รายงานผลการประชุมคณะทำงาน 5A ครั้งที่ ๑๔
ของภาควิทยุคมนาคม สหภาพโทรคมนาคมระหว่างประเทศ
ณ นครเจนีวา ประเทศสวิตเซอร์แลนด์

๒๗ ตุลาคม – ๖ พฤศจิกายน ๒๕๕๗

สายงานบริหารคลื่นความถี่และภูมิภาค
สำนักบริหารคลื่นความถี่
สำนักงานคณะกรรมการกิจการกระจายเสียง กิจการโทรทัศน์ และกิจการโทรคมนาคมแห่งชาติ
เลขที่ ๘๗ ถนนพหลโยธิน ซอย ๘ แขวงสามเสนใน เขตพญาไท กรุงเทพมหานคร ๑๐๔๐๐

รายงานผลการประชุมคณะทำงาน 5A ครั้งที่ ๑๔

ITU-R the 14th Meeting of Working Party 5A
(Land mobile service above 30 MHz (excluding IMT); wireless access in the fixed service; amateur and amateur satellite service)

๑. รายละเอียดการประชุม

การประชุมคณะทำงาน 5A ครั้งที่ ๑๔ ของภาควิทยุคมนาคม จัดขึ้นโดยสหภาพโทรคมนาคมระหว่างประเทศ ระหว่างวันที่ ๒๗ ตุลาคม – ๖ พฤศจิกายน ๒๕๕๗ ณ นครเจนีวา ประเทศสวิตเซอร์แลนด์ โดยมีหน้าที่รับผิดชอบครอบคลุม เรื่อง กิจการเคลื่อนที่ทางบกที่ใช้ความถี่วิทยุสูงกว่า ๓๐ MHz (ยกเว้น IMT) การเชื่อมต่อไร้สายในกิจการประจำที่ กิจการวิทยุสมัครเล่นและกิจการวิทยุสมัครเล่นผ่านดาวเทียม

๒. ผู้เข้าร่วมประชุม

ผู้เข้าร่วมประชุมประกอบด้วยผู้แทนจากรัฐสมาชิก (Member States) สมาชิกสมทบ (Associates) องค์การระหว่างประเทศและองค์กรภูมิภาค (Regional and Other International Organizations) ผู้ประกอบกิจการโทรคมนาคมที่เป็นที่รู้จัก (Recognized Operating Agencies) สหภาพโทรคมนาคมระหว่างประเทศInternational Telecommunication Union: ITU) และหน่วยงานด้านวิทยาศาสตร์หรืออุตสาหกรรม (Scientific or Industrial Organizations) รวมทั้งสิ้นจำนวน ๑๖๘ คน โดยมี Mr. Jose Costa จากประเทศแคนนาดา ทำหน้าที่ประธานที่ประชุม

๓. หน้าที่ความรับผิดชอบของคณะทำงานที่เกี่ยวข้องภายใต้กลุ่มศึกษาที่ ๕

๓.๑ กลุ่มศึกษาที่ ๕ (Study Group 5) ของภาควิทยุคมนาคม จัดตั้งขึ้นตามมติของที่ประชุมสมัชชาว่าด้วยการวิทยุคมนาคม ค.ศ. ๒๐๐๗ (Radio Assembly 2007: RA-07) ของสหภาพโทรคมนาคมระหว่างประเทศ โดยให้มีหน้าที่รับผิดชอบการศึกษาเกี่ยวกับระบบและโครงข่ายสำหรับกิจการประจำที่ กิจการเคลื่อนที่ กิจการวิทยุตรวจการณ์และตรวจค้นหา กิจการวิทยุสมัครเล่น และกิจการวิทยุสมัครเล่นผ่านดาวเทียม

๓.๒ เพื่อให้ครอบคลุมหน้าที่ความรับผิดชอบตามข้อ ๓.๑ กลุ่มศึกษาที่ ๕ จึงได้จัดตั้งคณะทำงานขึ้นอีก ๕ คณะทำงาน ประกอบด้วย

- ๓.๒.๑ <u>คณะทำงาน 5A (Working Party 5A)</u> มีหน้าที่ รับผิดชอบการจัดทำคู่มือ (Handbook) และข้อเสนอแนะต่างๆที่เกี่ยวข้องกับกิจการเคลื่อนที่ทางบกที่ใช้ความถี่วิทยุสูงกว่า ๓๐ MHz (ยกเว้น IMT) การเข้าถึงแบบไร้สายในกิจการประจำที่ กิจการวิทยุสมัครเล่นและกิจการวิทยุสมัครเล่นผ่านดาวเทียม
- ๓.๒.๒ <u>คณะทำงาน 5B (Working Party 5B)</u> มีหน้าที่ รับผิดชอบการจัดทำคู่มือ (Handbook) และข้อเสนอแนะต่างๆที่เกี่ยวข้องกับกิจการเคลื่อนที่ทางน้ำ รวมถึง GMDSS กิจการเคลื่อนที่ทางการบินและกิจการวิทยุตรวจการณ์และตรวจค้นหา
- ๓.๒.๓ <u>คณะทำงาน 5C (Working Party 5C)</u> มีหน้าที่ รับผิดชอบการจัดทำข้อเสนอแนะและรายงานเกี่ยวกับระบบเชื่อมโยงแบบไร้สาย ย่าน HF และระบบอื่นๆที่มีความถี่วิทยุต่ำกว่า ๓๐ MHz ในกิจการประจำที่และกิจการเคลื่อนที่ทางบก
- ๓.๒.๔ <u>คณะทำงาน 5D (Working Party 5D)</u> มีหน้าที่ รับผิดชอบการจัดทำข้อเสนอแนะและรายงานเกี่ยวกับระบบ IMT

๓.๒.๕ คณะทำงาน JTG 5-6 (Working Party JTG 4-5-6-7) มีหน้าที่ ศึกษาการใช้งานของ Mobile Applications และระบบอื่นๆ ในย่านความถี่วิทยุ ๗๙๐ – ๘๖๒ MHz

๓.๓ วัตถุประสงค์ของการจัดตั้งคณะทำงาน 5A (Working Party 5A) ตามข้อ ๓.๒.๑ เพื่อ

๓.๓.๑ สนับสนุน การเข้าถึงการใช้ความถี่วิทยุอย่างเท่าเทียมกัน เพื่อให้เกิดประโยชน์สูงสุด

๓.๓.๒ พัฒนาและสร้างมาตรฐานเทคโนโลยีให้กับกิจการเคลื่อนที่ทางบก

๓.๓.๓ ให้ความสำคัญลักษณะและเทคนิคของกิจการวิทยุสมัครเล่น และเพื่อเตรียมความพร้อมในประเด็นที่เกี่ยวข้องกับระเบียบวาระของ WRC

๓.๓.๔ เผยแพร่ความรู้ที่เกี่ยวข้องกับการวางแผนทางวิศวกรรมและการพัฒนากิจการเคลื่อนที่ทางบกในรูปแบบของ Handbook

และเพื่อให้ครอบคลุมหน้าที่ความรับผิดชอบของคณะทำงาน 5A ที่ประชุมคณะทำงาน 5A เห็นชอบให้กำหนดโครงสร้างของคณะทำงาน 5A ซึ่งแบ่งได้เป็น ๕ กลุ่มทำงานหลัก ดังนี้

Group	Chairman
WG 5A-1: *พิจารณาประเด็นต่างๆที่เกี่ยวข้องกับกิจการวิทยุสมัครเล่น*	Dale Hughes : ประเทศ ออสเตรเลีย
WG 5A-2 : *พิจารณาประเด็นต่างๆที่เกี่ยวข้องกับระบบและมาตรฐาน*	Lang Baozhen: ประเทศจีน
WG 5A-3 : *พิจารณาประเด็นต่างๆที่เกี่ยวข้องกับ PPDR*	Amy Sanders: ประเทศ สหรัฐอเมริกา
WG 5A-4 : *พิจารณาประเด็นต่างๆที่เกี่ยวข้องกับการใช้ความถี่วิทยุกันร่วมและการรบกวนความถี่วิทยุ*	Michael Kraemer: ประเทศ เยอรมัน
WG 5A-5 : *พิจารณาประเด็นต่างๆที่เกี่ยวข้องกับเทคโนโลยีใหม่*	Hitoshi Yoshino: ประเทศ ญี่ปุ่น

๓.๔ เป้าหมายของการประชุมคณะทำงาน 5A (Working Party 5A) แยกตามโครงสร้างของคณะทำงาน ในการประชุมครั้งนี้ มีดังนี้

๓.๔.๑ วิทยุสมัครเล่น และ วิทยุสมัครเล่นผ่านดาวเทียม (Agenda item 1.4)

- จัดทำร่าง CPM ในส่วนที่เกี่ยวข้องให้แล้วเสร็จ โดยพิจารณาจากข้อเสนอของประเทศสมาชิกต่างๆ และกลุ่มศึกษาอื่นที่เกี่ยวข้อง พร้อมทั้งเสนอให้ที่ประชุมกลุ่มศึกษา ๕ พิจารณาให้ความเห็นชอบ ต่อไป
- จัดทำร่างรายงานผลการศึกษาผลกระทบที่อาจจะเกิดขึ้นระหว่างกิจการวิทยุสมัครเล่นกับกิจการประจำที่ กิจการเคลื่อนที่ทางบก กิจการเคลื่อนที่ทางทะเล และกิจการวิทยุหาตำแหน่ง ในย่านความถี่ 5250 – 5450 kHz และกิจการเคลื่อนที่ทางการบิน ในย่านความถี่ข้างเคียง ตามข้อเสนอของประเทศสมาชิกต่างๆ และกลุ่มศึกษาอื่นที่เกี่ยวข้องให้แล้วเสร็จ พร้อมทั้งเสนอให้ที่ประชุมกลุ่มศึกษา ๕ พิจารณาให้ความเห็นชอบ ต่อไป

๓.๔.๒ ระบบและมารตรฐาน

- พิจารณาปรับปรุง ITU-R -R M.1076 ตามข้อเสนอของประเทศสมาชิก หรือ กลุ่มงานที่เกี่ยวข้อง

- พิจารณาปรับปรุง Operational guidelines for the deployment of broadband mobile systems for local coverage in the frequency bands below 6 GHz

๓.๔.๓ PPDR

- พิจารณาจัดทำร่าง CPM on review and revision of Resolution 646 ให้แล้วเสร็จ ตามข้อเสนอของประเทศสมาชิก
- พิจารณาขั้นตอนการดำเนินงานเกี่ยวกับการจัดทำ ร่างรายงาน Broadband public protection and disaster relief communications ฉบับใหม่ และการดำเนินการที่จำเป็นต่อระเบียบวาระที่ ๑.๓ ให้แล้วเสร็จ รวมถึงพิจารณาขอบเขตการดำเนินงานของ CG และรายละเอียดอื่นๆที่เกี่ยวข้อง

๓.๔.๔ ประเด็นที่เกี่ยวกับปัญหาการรบกวนจากการใช้ความถี่วิทยุและการใช้ความถี่วิทยุร่วม

- พิจารณาปรับปรุง ข้อเสนอแนะ ITU-R M.1824: System characteristics of television outside broadcast, electronic news gathering and electronic field production in the mobile service for use in sharing studies
- พิจารณาปรับปรุง ร่างข้อเสนอแนะ ITU-R M.[MS 14.5 – 15.35 CHAR] ซึ่งเกี่ยวข้องกับคุณสมบัติและมาตรการการป้องกันสำหรับกิจการเคลื่อนที่ในย่านความถี่วิทยุ 14.5 – 15.35 GHz
- พิจารณาปรับปรุง ข้อเสนอแนะ ITU-R M.1652 ตามข้อเสนอจากประเทศสมาชิกต่างๆ

๓.๔.๕ ประเด็นเทคโนโลยีใหม่

- ปรับปรุง Report (PDNR) M.[LMS.CRS2] ให้สอดคล้องกับ ITU-R 241-1/5 และ Resolution ITU-R 58 ตามข้อเสนอของประเทศสมาชิกต่างๆ โดยจะต้องแล้วเสร็จในการประชุมคณะทำงาน 5A ครั้งนี้ เพื่อเสนอให้ที่ประชุมกลุ่มศึกษาที่ ๕ พิจารณาให้ความเห็นชอบ ต่อไป
- ปรับปรุงร่าง Recommendation ITU-R M.[V2X] และรายงาน ITU-R M.2228 : Advanced ITS radiocommunication รวมถึง ร่างรายงาน ITU-R M.[ITS USAGE]
- พิจารณาผลการปรับปรุงร่างรายงาน ITU-R M.[AUTOMOTIVERADARS] ซึ่งพิจารณาเกี่ยวกับคุณสมบัติของระบบและผลการศึกษาความเข้ากันได้ของเรดาร์สำหรับรถยนต์ในย่านความถี่ 77.5 – 78 GHz ภายใต้การดำเนินงานของคณะทำงาน 5B ในระเบียบวาระที่ ๑.๑๘ (WRC-15)

๓.๔.๖ คู่มือกิจการเคลื่อนที่ทางบก

- ปรับปรุงคู่มือกิจากรเคลื่อนที่ทางบกที่ประกอบด้วย ๕ ประเด็นหลัก รวมถึงการเชื่อมต่อแบบไร้สาย (wireless access)

๓.๔.๗ <u>คำศัพท์</u>

- ปรับปรุงและพัฒนาคำศัพท์เกี่ยวกับกิจการเคลื่อนที่ทางบก (Annex 25 to Doc. 5A/79) เป็นร่างข้อเสนอแนะใหม่ หรือปรับปรุงจากข้อเสนอแนะที่มีอยู่เดิม ITU-R M.1797

๔. การดำเนินการประชุม แบ่งเป็น ๓ ส่วน ดังนี้

๔.๑ การประชุมเต็มคณะ (Plenary Session) เพื่อพิจารณารายงานความคืบหน้าในการศึกษาของแต่ละกลุ่มทำงาน พิจารณาให้ความเห็นชอบอย่างเป็นทางการ (consent) ต่อร่างข้อเสนอแนะใหม่และที่มีการแก้ไข รวมทั้งพิจารณาให้ความเห็นชอบเอกสารติดต่อประสานงาน (Liaison Statement) ที่ออกโดยคณะทำงาน 5A ไปยังหน่วยงานอื่นที่เกี่ยวข้อง

๔.๒ การประชุมกลุ่มทำงาน (Working Groups) จำนวน ๕ กลุ่ม (WG 5A-1, WG 5A-2, WG 5A-3,WG 5A-4 และ WG 5A-5) เพื่อพิจารณาความคืบหน้าของการศึกษาในหัวข้อต่าง ๆ ที่อยู่ในความรับผิดชอบ

๔.๓ การประชุมกลุ่มทำงานย่อย (Sub-Working Groups) เพื่อศึกษาหัวข้อต่างๆ ที่อยู่ในความรับผิดชอบ (CRS, ITS, WASN และ SDR) ของกลุ่มทำงานแต่ละกลุ่มตามข้อ ๔.๒

๕. ผลการประชุมกลุ่มทำงาน (Working Group)

คณะทำงาน 5A ได้ดำเนินการประชุมกลุ่มทำงาน ๕ กลุ่ม แบบควบคู่และขนานกัน ซึ่งในแต่ละกลุ่มทำงานมีหน้าที่ความรับผิดชอบที่แตกต่างกันไปในแต่ละกลุ่ม ดังมีรายละเอียด ดังนี้

๕.๑ <u>กลุ่มทำงาน 5A-1 (WG 5A-1)</u> : ระเบียบวาระที่เกี่ยวข้อง คือ ระเบียบวาระที่ ๑.๔ (WRC-15)

กลุ่มทำงาน 5A-1 มีหน้าที่รับผิดชอบในการพิจารณาประเด็นต่างๆที่เกี่ยวข้องกับกิจการวิทยุสมัครเล่น และกิจการวิทยุสมัครเล่นผ่านดาวเทียม โดยประเด็นหลักที่อยู่ในความรับผิดชอบของกลุ่มทำงานนี้ คือ การกำหนดความถี่วิทยุให้กับกิจการวิทยุสมัครเล่น เป็นกิจการรอง ในช่วงความถี่วิทยุ 5300 kHz ซึ่งถูกระบุไว้เป็นระเบียบวาระที่ ๑.๔ ของการประชุม WRC-15

ซึ่งในการประชุมครั้งนี้ มีข้อเสนอจากประเทศสมาชิกที่สนใจและกลุ่มทำงานอื่นๆภายใต้ ITU รวมทั้งสิ้น ๘ ข้อเสนอ โดยแบ่งการพิจารณาออกเป็น ๓ ประเด็นหลักๆ ดังนี้

๕.๑.๑ <u>ร่าง CPM ที่เกี่ยวข้องกับระเบียบวาระที่ ๑.๔ (WRC-15) เรื่อง การกำหนดความถี่วิทยุให้กับกิจการวิทยุสมัครเล่นเป็นกิจการรอง ในย่านความถี่วิทยุ 5250 - 5450 kHz</u>

ในการประชุมครั้งนี้ ที่ประชุมได้ร่วมกันพิจารณาร่าง CPM ที่เกี่ยวข้องกับ การกำหนดความถี่วิทยุให้กับกิจการวิทยุสมัครเล่นเป็นกิจการรอง ในย่านความถี่วิทยุ 5250 - 5450 kHz อย่างไรก็ตามในการประชุมครั้งนี้ไม่มีข้อเสนอแนะใดๆเพิ่มเติมในการปรับปรุงแก้ไขร่าง CPM เมื่อการประชุม 5A ครั้งที่ ๑๓ ที่ประชุมจึงมีมติเห็นชอบร่าง CPM ซึ่งได้กำหนดทางเลือก (Method) เพื่อเป็นแนวทางในการพิจารณาประเด็นนี้ โดยมีรายละเอียด ดังนี้

<u>Method A:</u> กำหนดกิจการวิทยุสมัครเล่นเป็นกิจการรอง ในย่านความถี่ 5275 – 5450 kHz โดยอาจกำหนดช่วงความถี่ใดความถี่หนึ่งหรือหลายช่วงความถี่ก็ได้ โดยสามารถแยกออกเป็น ๔ วิธีย่อย ดังนี้

Method A1: กำหนดกิจการวิทยุสมัครเล่นเป็นกิจการรอง ในย่านความถี่ 5275 – 5450 kHz
Method A2: กำหนดกิจการวิทยุสมัครเล่นเป็นกิจการรอง ในย่านความถี่ 5350 – 5450 kHz
Method A3: กำหนดกิจการวิทยุสมัครเล่นเป็นกิจการรอง จำนวน [xx] kHz ในย่านความถี่ 5270 – 5450 kHz
Method A4: กำหนดกิจการวิทยุสมัครเล่นเป็นกิจการรอง หลายๆช่องความถี่ ในย่านความถี่ 5270 – 5450 kHz

Method B: ไม่มีการแก้ไข ปรับปรุงตารางกำหนดคลื่นความถี่ในข้อบังคับวิทยุที่เกี่ยวข้องกับ ย่านความถี่ 5250 - 5450 kHz

และจากแนวทางดังกล่าวข้างต้น ที่ประชุมเห็นชอบให้ยกเลิกข้อมติที่ ๖๔๙ (WRC-12) เพิ่มเติมด้วย อนึ่ง รายละเอียดที่เกี่ยวข้องกับร่าง CPM ภายใต้ประเด็นดังกล่าวนี้ปรากฏตามเอกสารแนบ ๑ (Document 5A/543-E Annex 4)

๕.๑.๒ การพิจารณาทบทวน ปรับปรุง รายงาน “การศึกษาผลกระทบที่อาจจะเกิดขึ้นระหว่างกิจการวิทยุสมัครเล่นกับกิจการประจำที่ กิจการเคลื่อนที่ทางบก กิจการเคลื่อนที่ทางทะเล และกิจการวิทยุหาตำแหน่ง ในย่านความถี่ 5250 – 5450 kHz และความถี่ข้างเคียง ซึ่งใช้ในกิจการเคลื่อนที่ทางการบิน

ที่ประชุมได้พิจารณาข้อเสนอจากประเทศสมาชิก (IARU สหรัฐอเมริกา รัสเซีย สาธารณรัฐประชาชนจีน และแคนนาดา) ในเรื่องของการการศึกษาผลกระทบที่อาจจะเกิดขึ้นกับกิจการประจำที่ ในย่านความถี่ 5250 – 5450 kHz หากมีการใช้ความถี่สำหรับกิจการวิทยุสมัครเล่นในย่านความถี่เดียวกันนี้ (ซึ่งเป็นประเด็นที่อยู่ในความรับผิดชอบของกลุ่มทำงาน 5C ด้วย)

ทั้งนี้ ภาพรวมของรายงานฉบับนี้ แสดงให้เห็นว่า หากจะมีการกำหนดคลื่นความถี่ให้สำหรับกิจการวิทยุสมัครเล่นเป็นกิจการรองในย่านความถี่ 5250 – 5450 kHz จะต้องมีการกำหนดเงื่อนไขการใช้งานของกิจการวิทยุสมัครเล่นด้วย เนื่องจากอาจส่งผลกระทบกับกิจการประจำที่กับกิจการเคลื่อนที่ที่มีใช้งานอยู่ก่อนแล้วในกิจการหลัก

ในส่วนของผลกระทบที่อาจเกิดขึ้นกับกิจการวิทยุหาตำแหน่ง ในกรณีที่จะกำหนดคลื่นความถี่ให้สำหรับกิจการวิทยุสมัครเล่นเป็นกิจการรองในย่านความถี่ 5250 – 5275 kHz นั้น ที่ประชุมเห็นว่า ข้อเสนอแนะของ ITU-R ซึ่งเห็นชอบในการประชุม WRC-12 นั้นเคยให้ข้อเสนอแนะไว้แล้วว่า มีความเป็นไปได้ยาก

อย่างไรก็ตาม จากการพิจารณาข้อเสนอของประเทศสมาชิกต่างๆ ที่ประชุมได้ปรับปรุงแก้ไข และเห็นชอบร่วมกันภายหลังการปรับปรุงร่างรายงานฉบับดังกล่าว โดยมีรายละเอียดปรากฏตาม Document 5A/146-E ITU-R.M.[5 MHz COMPAT] และได้ร่วมกันกำหนดเป้าหมายของกลุ่มทำงาน 5A-1 ในการประชุมคณะทำงาน 5A ครั้งต่อไป (ครั้งที่ 15)

- จัดทำร่างข้อเสนอแนะ รายงาน หรือคู่มืออื่นๆที่เกี่ยวข้องกับกิจการวิทยุสมัครเล่น และ วิทยุสมัครเล่นผ่านดาวเทียม ตามความจำเป็น
- พิจารณาทบทวนข้อคำถามของ ITU-D รวมถึงข้อเสนอแนะ รายงาน และคู่มือต่างๆ ที่เกี่ยวข้องกับกิจการวิทยุสมัครเล่น และ วิทยุสมัครเล่นผ่านดาวเทียม รวมถึงจัดทำเอกสารประสานงานไปยังกลุ่มศึกษาอื่นๆที่เกี่ยวข้อง

๕.๒ กลุ่มทำงาน 5A-2 (WG 5A-2) :

กลุ่มทำงาน 5A-2 มีหน้าที่รับผิดชอบในการพิจารณาประเด็นที่เกี่ยวข้องกับ มาตรฐานและระบบ โดยในการประชุมครั้งนี้ มีข้อเสนอจากประเทศสมาชิก ๑๘ ข้อเสนอ ซึ่งที่ประชุมได้ร่วมกันพิจารณาในประเด็นต่างๆที่เกี่ยวข้อง และสามารถสรุปผลการพิจารณาออกเป็นประเด็นต่างๆ ดังนี้

๕.๒.๑ Local coverage aspects

ประเทศญี่ปุ่น เสนอให้มีการปรับปรุงข้อเสนอแนะที่เกี่ยวกับ Local Coverage ความถี่วิทยุย่าน 6 GHz ซึ่งภายหลังจากการพิจารณาในที่ประชุมร่วมกันแล้ว ที่ประชุมเห็นชอบให้มีการพิจารณาปรับปรุงร่าข้อเสนอแนะ Local Coverage ฉบับใหม่ โดยให้มีการพิจารณาอีกครั้งในที่ประชุม คณะทำงาน 5A ครั้งต่อไป ในขณะเดียวกัน เห็นควรส่งเอกสารประสานไปยังกลุ่มงานหรือหน่วยงานอื่นๆที่เกี่ยวข้อง เพื่อพิจารณาให้ข้อเสนอแนะ พร้อมทั้งนำเข้าสู่ที่ประชุมคณะทำงาน 5A ครั้งต่อไปในคราวเดียวกัน

ในขณะเดียวกันเพื่อให้สอดคล้องกับการดำเนินงานของคณะทำงาน ที่ประชุมจึงเห็นชอบให้มีการปรับปรุงแผนการดำเนินงานของคณะทำงานนี้ด้วย

๕.๒.๒ เป้าหมายของกลุ่มทำงาน 5A-2 ในการประชุมคณะทำงาน 5A ครั้งต่อไป (ครั้งที่ 15)

- พิจารณาปรับปรุง Operational guidelines for the deployment of broadband mobile systems for local coverage in the frequency bands below 6 GHz

๕.๓ กลุ่มทำงาน 5A-3 (WG 5A-3) : ระเบียบวาระที่เกี่ยวข้อง คือ ระเบียบวาระที่ ๑.๓(WRC-15)

กลุ่มทำงาน 5A-3 มีหน้าที่รับผิดชอบในการพิจารณาประเด็นที่เกี่ยวข้องกับการป้องกันและบรรเทาสาธารณภัย (Public Protection and Disaster relief: PPDR) ซึ่งสอดคล้องตามระเบียบวาระการประชุมที่ ๑.๓ และ ๑.๑๐ ของการประชุม WRC-15 โดยในการประชุมครั้งนี้ มีข้อเสนอจากประเทศสมาชิก ๒๐ ข้อเสนอ เพื่อเสนอความเห็นหลากหลายประเด็นที่เกี่ยวข้องกับ PPDR ซึ่งที่ประชุมได้ร่วมกันพิจารณาและให้ความเห็นชอบในประเด็นต่างๆ ดังนี้

๕.๓.๑ ที่ประชุมร่วมกันพิจารณาข้อเสนอของประเทศสมาชิก เพื่อจัดทำร่าง CPM สำหรับระเบียบวาระที่ ๑.๓ โดยรายละเอียดร่าง CPM ดังกล่าว จะประกอบด้วย ผลการศึกษาทางเทคนิคที่เกี่ยวข้อง ข้อเสนอแนะอ้างอิงจากหน่วยงานต่างๆที่เป็นสากล ตลอดจนการนำเสนอทางเลือก ผลดี ผลเสียต่อการพิจารณาแก้ไข Resolution 646 (Rev.WRC-12) (เพื่อเป็นข้อมูลพื้นฐานที่สำคัญต่อการพิจารณาให้ความเห็นของประเทศสมาชิกต่างๆ ในการประชุม WRC-15) ซึ่งที่ประชุมได้เห็นชอบร่วมกันในการแก้ไขร่าง CPM โดยสามารถแบ่งแนวทางการดำเนินการออกเป็น ๓ วิธี (Method) ดังนี้

<u>Method A</u> : ไม่มีการปรับปรุงในส่วนที่เป็นสาระสำคัญของข้อมมติ ๖๔๖ (Resolution 646(Rev.WRC-12)) โดยจะแก้ไขเฉพาะคำผิดในข้อมตินี้เท่านั้น และให้นำประเด็น Broadband PPDR ไปปรากฏในผลการศึกษาอื่นๆตามความเหมาะสม ต่อไป

ข้อดี: ๑. แนวทางตามวิธีนี้ ครอบคลุมตามวัตถุประสงค์ของข้อมมติ ๖๔๖ (Rev.WRC-12)

๒. แนวทางตามวิธีนี้ เพียงพอแล้วสำหรับความต้องการในการดำเนินการ Broadband PPDR ตามผลการศึกษาของ ITU-R

๓. แนวทางตามวิธีนี้ ใกล้เคียงกับข้อมติ 646 (Rev.WRC-12) (resolves part) ที่ให้มีการ harmonized ความถี่เข้าด้วยกันของแต่ละประเทศ/แต่ละภูมิภาค ในเรื่องของ การป้องกันและบรรเทาสาธารณภัย

ข้อเสีย: ๑. ไม่ครอบคลุมตามวัตถุประสงค์ความต้องการของข้อมมติ ๖๔๘ (Rev.WRC-12)

๒. แนวทางตามวิธีนี้ ไม่ได้ให้ข้อเสนอแนะต่อประเทศต่างๆรวมไปถึงบริษัทผู้ผลิต ในการสนับสนุนแต่ละประเทศ/ภูมิภาค ให้มีการ harmonized สำหรับ wide area mobile broadband PPDR

๓. แนวทางตามวิธีนี้ จะไม่สามารถเพิ่มเติมความถี่ที่มีการ harmonized สำหรับ Broadband PPDR ของแต่ละภูมิภาค (ภูมิภาคที่ ๑ และ ๓) ได้

<u>Method B</u> : ปรับปรุงสาระสำคัญของข้อมมติ ๖๔๖ (Resolution 646(Rev.WRC-12)) โดยสะท้อนให้เห็นถึงประเด็น Broadband PPDR ไว้ในข้อมตินี้ และให้สอดคล้องตามข้อมติ ๖๔๘

ข้อดี: ๑. แนวทางตามวิธีนี้ ครอบคลุมตามวัตถุประสงค์ของข้อมมติ ๖๔๘ (WRC-12) ที่ให้มีการปรับปรุง แก้ไขข้อมติ ๖๔๖ (Rev.WRC-12) สำหรับ Broadband PPDR

๒. แนวทางตามวิธีนี้ สามารถอำนวยความสะดวกให้แต่ละภูมิภาค มีการ harmonization ความถี่สำหรับ Broadband PPDR ได้อย่างเหมาะสม

๓. เนื่องจาก แนวทางตามวิธีนี้ จะช่วยให้มีการ harmonization ความถี่สำหรับ Broadband PPDR ได้อย่างเหมาะสมของแต่ละภูมิภาค ซึ่งจะส่งผลให้อุปกรณ์ เครื่องมือที่ใช้งานมีราคาที่ถูกลง ซึ่งเป็นไปตามความต้องการของกลุ่มประเทศกำลังพัฒนาที่มีความต้องการใช้ Broadband PPDR ซึ่งผลการศึกษาที่ผ่านมาแสดงให้เห็นว่า การใช้เทคโนโลยีที่เป็นแบบเดียวกันในแต่ละประเทศ หรือแต่ละภูมิภาค จะเป็นประโยชน์รอบด้านระหว่างภูมิภาคต่อภูมิภาค และระหว่างประเทศที่มีอาณาเขตติดกัน ซึ่งจะทำให้มีความปลอดภัยมากยิ่งขึ้นจากสาธารณภัยที่อาจเกิดขึ้นในอนาคต

ข้อเสีย: ๑. การปลี่ยนแปลงช่วงความถี่อาจสร้างความยุ่งยากให้กับการ harmonization สำหรับ Broadband PPDR

๒. แนวทางตามวิธีนี้ ประเทศที่อยู่ในภูมิภาคที่ ๑ ที่มีการใช้ความถี่สำหรับ mobile broadband ในย่านความถี่ 700 MHz อาจจะต้องมีการประสานงานกับประเทศที่มีการใช้ สถานีกระจายเสียงกำลังส่งสูงช่อง ๔๘ ในขณะเดียวกัน ปัจจุบันประเทศในกลุ่มภูมิภาคที่ ๒ ได้กำหนดแผนการใช้ความถี่สำหรับ Broadband PPDR สอดคล้องตามข้อมมติที่ ๖๔๖ (Rev.WRC-12) ซึ่งหากไม่มีการนำแนวทางตามวิธีนี้มาใช้ อาจส่งผลกระทบต่อกลุ่มประเทศที่มีอาณาเขตติดกับประเทศในเขตภูมิภาคที่ ๒

Method C : ปรับปรุงสาระสำคัญของข้อมมติ ๖๔๖ (Resolution 646(Rev.WRC-12)) โดยสะท้อนให้เห็นถึงประเด็น Broadband PPDR ไว้ในข้อมตินี้ และเสนอให้การพิจารณาเรื่องย่านความถี่วิทยุไปปรากฏอยู่ใน ข้อเสนอแนะ ITU-R M.2015
โดยให้แยกประเด็นเรื่องของความถี่วิทยุสำหรับ PPDR ไว้ใน ITU-R M.2015 ทั้งนี้ในส่วนของข้อกำหนดทางเทคนิคต่างๆที่เกี่ยวข้องกับ PPDR ทั้ง narrow-band , wide-band และ Broadband PPDR จะไปปรากฏอยู่ในร่างรายงานฉบับใหม่ ITU-R M.[PPDR] ตามข้อมติที่ ๖๔๘ (WRC-12)

ข้อดี: ๑. แนวทางตามวิธีนี้ ครอบคลุมตามวัตถุประสงค์ของข้อมมติ ๖๔๖ (Rev.WRC-12) และ ข้อมติ ๖๔๘ (WRC-12) ที่ให้มีการทบทวนและปรับปรุง ข้อมติ ๖๔๖ (Rev.WRC-12) ในเรื่องของ Broadband PPDR

๒. แนวทางตามวิธีนี้ สามารถอำนวยความสะดวกให้หน่วยงานกำกับดูแลของแต่ละประเทศ สามารถเลือกใช้ความถี่ เทคโนโลยีต่างๆ กระบวนการดำเนินงานที่เกี่ยวกับ Broadband PPDR ให้สามารถเข้ากันได้ (Harmonized) กับหน่วยงานกำกับดูแลของประเทศอื่นๆ

๓. หากในอนาคต มีการแก้ไขเกี่ยวกับระเบียบข้อบังคับ หรือ รายละเอียดทางเทคนิคที่เกี่ยวข้องกับ PPDR ก็สามารถปรับปรุงแก้ไขได้ตามความเหมาะสมในรูปแบบของ ข้อเสนอแนะ ITU-R หรือ รายงาน ITU-R

ข้อเสีย: ๑. การแยกประเด็นเรื่องความถี่ออกจากข้อมมติที่ ๖๔๖ (Rev.WRC-12) อาจเป็นปัญหาต่อผู้ผลิตอุปกรณ์ PPDR ผู้ให้บริการ และผู้ใช้งานที่มีอยู่เดิม เนื่องจากความไม่แน่นอนในการเลือกย่านความถี่ หรือ เทคโนโลยีที่จะใช้สำหรับ PPDR ซึ่งการนำประเด็นเรื่องความถี่ไประบุไว้ในข้อเสนอแนะที่สามารถเปลี่ยนแปลงได้ตลอดเวลานั้น จะไม่กระตุ้นให้เกิดการลงทุนเพื่อพัฒนาระบบหรือ อุปกรณ์เกี่ยวกับ PPDR ซึ่งไม่สอดคล้องตามวัตถุประสงค์ตามข้อมติ ๖๔๖ (Rev.WRC-12)

๒. ข้อมมติ ๖๔๘ (WRC-12) เสนอให้มีการปรับปรุงข้อมติ ๖๔๖ (Rev.WRC-12) เพื่อให้เกิด Broadband PPDR เท่านั้น แต่ไม่ได้เสนอให้มีการปรับปรุงเปลี่ยนแปลงย่านความถี่วิทยุสำหรับ PPDR ทั้ง Narrow Band และ Wide Band ซึ่งมีระบุไว้อยู่แล้วในข้อมมติ ๖๔๖ (Rev.WRC-12) ดังนั้น การแยกประเด็นเรื่องความถี่วิทยุดังกล่าว จึงอยู่นอกเหนือขอบเขตความรับผิดชอบของระเบียบวาระ ๑.๓ (WRC-15)

๓. แนวทางตามวิธีนี้ จะแยกแนวทาง/คำแนะนำว่าช่วงความถี่ใดเหมาะสมที่จะนำมาใช้ในการพัฒนา PPDR เพื่อให้เกิดการใช้ความถี่ที่สอดคล้องกัน (Harmonization) ซึ่งไม่สอดคล้องตามวัตถุประสงค์ตามข้อมติ ๖๔๖ (Rev.WRC-12)

๕.๓.๒ การพิจารณาปรับปรุงร่าง PDNR ITUR-M.[PPDR] Broadband public protection and disaster relief communications และยกเลิกรายงาน ITU-R M.2033: Radiocommunication objectives and requirements for public protection and disaster relief (2033)

ที่ประชุมร่วมกันปรับปรุงร่าง ITUR-M.[PPDR] ต่อจากการประชุมกลุ่มทำงาน 5A ครั้งที่ผ่านมา โดยมีข้อเสนอจากประเทศสมาชิกต่างๆรวม ๘ ข้อสเนอ ทั้งนี้ร่างรายงานฉบับนี้ประกอบด้วยเนื้อหาหลัก ๔ ส่วนที่สำคัญ ประกอบด้วย บททั่วไปเกี่ยวกับการติดต่อสื่อสารเพื่อใช้ในการป้องกันและบรรเทาสาธารณภัย ลักษณะการจัดช่องความถี่วิทยุแบบ Narrow band and wideband สำหรับการป้องกันและบรรเทาสาธารณภัย พื้นที่ครอบคลุมและเทคโนโลยีที่มีใช้อยู่ในปัจจุบัน ตลอดจนความต้อมการการใช้งาน PPDR จากกลุ่มประเทศกำลังพัฒนา อย่างไรก็ตามที่ประชุมคาดว่ารายงานฉบับดังกล่าวนี้จะแล้วเสร็จในการประชุม คณะทำงาน 5A ครั้งต่อไป (ครั้งที่ ๑๕) จึงขอความร่วมมือให้ประเทศสมาชิกต่างๆ พิจารณาจัดทำข้อเสนอแนะเพื่อนำเข้าที่ประชุมคณะทำงานเพื่อพิจารณาครั้งต่อไป

๕.๓.๓ การพิจารณาจัดทำร่างข้อเสนอแนะ ITU-R M.2009: Radio Interface standards for use by public protection and disaster relief operations in some parts of the UHF band accordance with Resolution 646 (WRC-03) และ ITU-R M.2015: Frequency arrangements for public protection and disaster relief radiocommunication systems in UHF bands in accordance with Resolution 646 (Rev.WRC-12)

ที่ประชุมร่วมกันพิจารณาปรับปรุงร่างข้อเสนอแนะทั้ง ๒ ฉบับดังกล่าว โดยมีข้อเสนอจากประเทศสมาชิกต่างๆรวม ๑๑ ข้อสเนอ ซึ่งที่ประชุมได้ปรับปรุงร่างข้อเสนอแนะทั้ง ๒ ฉบับ เรียบร้อยแล้ว โดยจะได้มีการเสนอให้กลุ่มศึกษาที่ ๕ พิจารณาให้ความเห็นชอบต่อไป ทั้งนี้รายละเอียดที่เกี่ยวข้องปรากฏตามเอกสารแนบ ๒ (Document/Temp/268R1-E) และ เอกสารแนบ ๓ Document 5A/Temp/271-E) ตามลำดับ

๕.๓.๔ เป้าหมายของกลุ่มทำงาน 5A-3 ในการประชุมคณะทำงาน 5A ครั้งต่อไป ประกอบด้วย

- พิจารณาขั้นตอนการดำเนินงานเกี่ยวกับการจัดทำ ร่างรายงาน Broadband public protection and disaster relief communications ฉบับใหม่ และการดำเนินการที่จำเป็นต่อระเบียบวาระที่ ๑.๓ ให้แล้วเสร็จ รวมถึงพิจารณาขอบเขตการดำเนินงานของ CG และรายละเอียดอื่นๆที่เกี่ยวข้อง เพื่อให้สอดคล้องตามข้อเสนอของประเทศสมาชิก
- พิจารณาองค์ประกอบต่างๆในอนาคตจากการปรับปรุงข้อเสนอแนะ ITU-R M.2015 (Annex 7 of the Chairman’s Report)

๕.๔ กลุ่มทำงาน 5A-4 (WG 5A-4) :

กลุ่มทำงาน 5A-4 มีหน้าที่รับผิดชอบในการพิจารณาประเด็นที่เกี่ยวข้องกับการใช้ความถี่วิทยุร่วมกันและการรบกวนความถี่วิทยุ โดยในการประชุมครั้งนี้ มีข้อเสนอจากประเทศสมาชิก ๓๕ ข้อเสนอ ซึ่งที่ประชุมได้ร่วมกันพิจารณาและให้ความเห็นชอบในประเด็นที่สำคัญๆ ดังนี้

๕.๔.๑ การพิจารณาปรับปรุงข้อเสนอแนะ ITU-R M.1824: System characteristics of television outside broadcast, electronic news gathering and electronic field production in the mobile service for use in sharing studies รายละเอียดปรากฏตามเอกสารแนบ ๔ (Document 5A/Temp/255-E (Rev1))

๕.๔.๒ การพิจารณาปรับปรุง ร่างรายงาน PDN Report ITU-R M.[RLAN MITIGATION] เพื่อเพิ่มเติมแนวทาง และการแก้ไขทางเทคนิคในการใช้ความถี่ร่วมกันระหว่าง RLAN และกิจการอื่นๆที่มีใช้อยู่เดิม

๕.๔.๓ แผนการดำเนินงานและเป้าหมายของการประชุม WG 5A-4 ในการประชุมครั้งต่อไป (ครั้งที่ ๑๕) ประกอบด้วย

- พิจารณาปรับปรุง ข้อเสนอแนะ ITU-R M.1824: System characteristics of television outside broadcast, electronic news gathering and electronic field production in the mobile service for use in sharing studies
- พิจารณาปรับปรุง ร่างรายงาน PDN Report ITU-R M.[RLAN MITIGATION] เพื่อเพิ่มเติมแนวทาง และการแก้ไขทางเทคนิคในการใช้ความถี่ร่วมกันระหว่าง RLAN และกิจการอื่นๆที่มีใช้อยู่เดิม
- พิจารณาปรับปรุง ข้อเสนอแนะ ITU-R M.1652 ตามข้อเสนอจากประเทศสมาชิกต่างๆ

๕.๕ กลุ่มทำงาน 5A-5 (WG 5A-5) :

กลุ่มทำงาน 5A-5 มีหน้าที่รับผิดชอบในการพิจารณาประเด็นต่างๆที่เกี่ยวข้องกับเทคโนโลยีใหม่ ซึ่งที่ประชุมกลุ่มทำงาน 5A-5 พิจารณาแล้ว เห็นควรมีการแบ่งกลุ่มการพิจารณา เพื่อให้ครอบคลุมหน้าที่ความรับผิดชอบของกลุ่มทำงาน 5A-5 ซึ่งประกอบด้วย Cognitive Radio Systems (CRS) , Intelligent Transport System (ITS), Wireless Access Sensor Network (WASN) และ Software Defined Radio (SDR) รวมถึงระเบียบวาระที่ ๑.๑๘ ซึ่งเกี่ยวข้องกับกลุ่มทำงาน 5A-5 ด้วย โดยในการประชุมครั้งนี้ มีข้อเสนอจากประเทศสมาชิกรวม ๑๖ ข้อเสนอ ซึ่งที่ประชุมได้ร่วมกันพิจารณาและให้ความเห็นชอบในประเด็นต่างๆ ดังนี้

๕.๕.๑ Cognitive Radio Systems (CRS)

ที่ประชุมร่วมกันปรับปรุงร่าง Report (PDNR) M.[LMS.CRS2] ต่อเนื่องจากการประชุมครั้งที่ผ่านมา โดยอยู่บนพื้นฐานของข้อเสนอของประเทศสมาชิกต่างๆ เพื่อให้สามารถครอบคลุมเป็นร่างรายงานฉบับเดียวกัน ซึ่งที่ประชุมได้ร่วมกันปรับปรุงร่างรายงานเรียบร้อยแล้ว โดยจะได้มีการเสนอให้ที่ประชุมคณะทำงาน 5A พิจารณาให้ความเห็นชอบ ต่อไป รายละเอียดที่เกี่ยวข้องปรากฏตาม Document/Temp/270R1-E

๕.๕.๒ Intelligent Transport System (ITS)

ที่ประชุมร่วมพิจารณาร่างข้อเสนอของประเทศสมาชิก จำนวน ๙ ข้อเสนอ ในการปรับปรุงร่าง Report/Recommendation ต่างๆที่เกี่ยวข้อง ตลอดจนประเด็นที่เกี่ยวกับระเบียบวาระที่ ๑.๑๘ (WRC-15) โดยมีรายละเอียดดังนี้

- ที่ประชุมร่วมกันปรับปรุงร่าง Recommendation ITU-R M.[V2X] และ แผนการดำเนินงานในการ กำหนดมาตรฐานวิทยุคมนาคมสำหรับ เครื่องยนต์-เครื่องยนต์ และ เครื่องยนต์-โครงสร้างพื้นฐานอื่นๆ สำหรับระบบ ITS โดยอยู่บนพื้นฐานของข้อเสนอของประเทศสมาชิกต่างๆ ทั้งนี้ ที่ประชุมเห็นชอบให้จัดทำเอกสารประสานงานไปยังกลุ่มงานต่างๆเพื่อขอความร่วมมือจัดทำข้อเสนอเข้าสู่ที่ประชุมครั้งต่อไป เพื่อให้ร่างฉบับดังกล่าวแล้วเสร็จภายในการประชุมคณะทำงาน 5A ครั้งที่ ๑๕ รายละเอียดร่างข้อเสนอแนะฉบับดังกล่าวปรากฏตามเอกสารแนบ ๕ (Document 5A/Temp/265-E)
- ในส่วนของร่าง รายงาน ITU-R M.2228 : Advanced ITS radiocommunication นั้น ที่ประชุมคณะทำงานครั้งนี้ ได้ร่วมกันจัดทำร่างข้อเสนอแนะแล้วเสร็จโดยมีรายละเอียดปรากฏตามเอกสารแนบ ๖ (Document 5A/Temp/266R1-E)
- ปรับปรุงร่างรายงาน ITU-R M.[ITS USAGE] intelligent transport systems โดยมีรายละเอียดปรากฏตามเอกสารแนบ ๗ (Document 5A/Temp/267R1-E)

๕.๕.๓ แผนการดำเนินงานและเป้าหมายของการประชุม WG 5A-5 ในการประชุมครั้งต่อไป (ครั้งที่ ๑๕) ประกอบด้วย

- ปรับปรุง Report (PDNR) M.[LMS.CRS2] ให้สอดคล้องตามข้อเสนอของประเทศสมาชิกต่างๆ เพื่อเสนอให้ที่ประชุมกลุ่มศึกษาที่ ๕ พิจารณาให้ความเห็นชอบ ต่อไป
- ปรับปรุงร่าง Recommendation ITU-R M.[V2X] และรายงาน ITU-R M.2228 : Advanced ITS radiocommunication รวมถึง ร่างรายงาน ITU-R M.[ITS USAGE] เพื่อเสนอให้ที่ประชุมกลุ่มศึกษาที่ ๕ พิจารณาให้ความเห็นชอบ ต่อไป
- ปรับปรุง Report (PDNR) M.[ITS USAGE] ให้สอดคล้องตามข้อเสนอของประเทศสมาชิกต่างๆ เพื่อเสนอให้ที่ประชุมกลุ่มศึกษาที่ ๕ พิจารณาให้ความเห็นชอบ ต่อไป
- ปรับปรุง Report (PDNR) M.[RAIL.LINK] ให้สอดคล้องตามข้อเสนอของประเทศสมาชิกต่างๆ เพื่อเสนอให้ที่ประชุมกลุ่มศึกษาที่ ๕ พิจารณาให้ความเห็นชอบ ต่อไป
- ปรับปรุงคู่มือ Intelligent Transport Systems of the Land Mobile Handbook (LMH) ให้เป็นปัจจุบัน

๖. การประชุมคณะทำงานครั้งต่อไป

กำหนดการประชุมของคณะทำงาน 5A ครั้งที่ ๑๕ จะจัดขึ้นที่ประเทศโรมาเนีย ระหว่างวันที่ ๖ – ๑๖ กรกฎาคม ๒๕๕๘ ในขณะที่การประชุมกลุ่มศึกษาที่ ๕ ครั้งที่ ๙ จะจัดขึ้นระหว่างวันที่ ๒๐ - ๒๑ กรกฎาคม ๒๕๕๘ ณ นครเจนีวา ประเทศสวิตเซอร์แลนด์

เอกสารแนบ ๑

DRAFT CPM text for WRC-15 Agenda item 1.4

Source: Document 5A/TEMP/234

Annex 4 to
Document 5A/543-E **(edited)**
13 June 2014
English only

Annex 4 to Working Party 5A Chairman's Report

DRAFT CPM TEXT FOR WRC-15 AGENDA ITEM 1.4
(as approved by WP 5A for submission to the Chapter Rapporteur)

CHAPTER 1

Mobile and Amateur issues

(Agenda items 1.1, 1.2, 1.3, 1.4)

AGENDA ITEM 1.4
(**WP 5A** / **WP 5B, WP 5C,** (WP 3L))

1.4 to consider possible new allocation to the amateur service on a secondary basis within the band 5 250-5 450 kHz in accordance with Resolution ***649 (WRC-12)****;*

Resolution **649 (WRC-12)**: *Possible allocation to the amateur service on a secondary basis at around 5 300 kHz*

1/1.4/1 Executive Summary

Two primary methods have been developed as a result of studies.

Method A proposes an allocation to the amateur service, on a secondary basis, for one or more segments of contiguous spectrum in the range 5 275 kHz to 5 450 kHz. Four sub-methods have been developed:

– Method A1 calling for an allocation to the amateur service, on a secondary basis in the frequency band, 5 275-5 450 kHz.

– Method A2 calling for an allocation to the amateur service, on a secondary basis in the range 5 350 to 5 450 kHz

– Method A3 calling for an allocation to the amateur service up to [xx] kHz, on a secondary basis, in the range 5 275 kHz to 5 450 kHz.

– Method A4 calling for an allocation to the amateur service at several specific channels, on a secondary basis, in the range 5 275 kHz to 5 450 kHz.

Method B is for No Change to the 5 250-5 450 kHz band.

For all of the proposed methods, suppression of Resolution **649 (WRC-12)** would be a consequential change.

1/1.4/2 Background

Based on the recommendation of the 1978 CCIR Special Preparatory Meeting, WARC-79 accepted the principle that, like other high-frequency radio services, the amateur service should have access to a family of frequency bands such that communications can be maintained as propagation conditions change. The amateur service has access to allocations in the vicinity of 3 500 and 7 000 kHz; however, there are frequent occasions when ionospheric conditions render either or both of these allocations unsatisfactory for communications over the distances which amateur radio operators are frequently requested to cover in the course of facilitating emergency and disaster relief operations. These distances might be relatively short (less than 1000 km) when providing direct support to first responders or relatively longer (greater than 1000 km) when exchanging information, for example, with international organizations.

The frequency range 5 250-5 450 kHz is allocated to fixed and mobile (except aeronautical mobile) services in all three Regions on a primary basis. Radiolocation services are also allocated in the range 5 250 to 5 275 kHz as a secondary service in Regions 1 and 3 and primary in Region 2.

The Master International Frequency Register (MIFR) shows 13314 frequency assignments to the fixed service, 2104 frequency assignments to base stations on land in the mobile service, 251 frequency assignments to transmitting coast stations in the mobile service and 14 frequency assignments to coast maritime receiving stations in the mobile service. Assignments in such numbers illustrate that it is often unfeasible to deploy traditional mobile communication networks and satellite communication stations in many sparsely populated, inaccessible and remote areas of the globe including those in the Arctic and Antarctic regions. These links are typically used for different purposes including disaster relief operations. The usage of these assignments is strongly dependent on link distances, time of day, month/season, level of solar activity and real-time propagation conditions. Technologies for automatic evaluation of propagation channels have resulted in new and different operational use of these HF frequencies.

The view of some administrations is that using the MIFR to determine the number of active stations in the band significantly overestimates the spectrum occupancy by incumbent services as listings of stations that become inactive are not routinely deleted.

Amateur service characteristics in the frequency range 5 250 to 5 450 kHz are similar to land mobile service with respect to antenna types, modulation, and transmission bandwidths. This range of spectrum provides propagation at times when the maximum usable frequency (MUF) is below 7 MHz and the lowest usable frequency (LUF) is above 4 MHz permitting reliable communication for radio amateurs at any time of the day.

Currently more than 50 countries e.g. Bahrain, Bangladesh, Canada, the Czech Republic, Cayman Islands, the Dominican Republic, Finland, Ireland, Norway, Sweden, the United Kingdom, the United States allow amateur use of this band, either in the full band or part of the band.

It should be noted that RR No. **1.56** specifies that *amateur service:* is *a radiocommunication service* for the purpose of self-training, intercommunication and technical investigations carried out by amateurs, that is, by duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest.

1/1.4/3 Summary of technical and operational studies, including a list of relevant ITU-R Recommendations and Reports

Relevant ITU Recommendations:

ITU-R P.533-12, ITU-R P.372-11, ITU-R P.368-9, ITU-R F.240-7, ITU-R F.339-8, ITU-R M.1677-1, ITU-R M.1732-1, ITU-R F.1761-0, ITU-R F.1762-0, ITU-R F.1821-0, ITU-R M.1874-1 and ITU-R SM.1541-5

Relevant ITU Reports:

ITU-R M.2080-0, ITU-R M.2234-0, ITU-R M.[PPDR] and ITU-R M.[5 MHz COMPAT]

1/1.4/3.1 Compatibility with stations in the fixed service

Studies conducted by several administrations have led to different conclusions about the impact of the proposed secondary allocation to the amateur service upon the existing primary users.

One administration analyzed the potential interference to a fixed-link operating over a 1 500 km path from an amateur link of a similar path length and determined that – notwithstanding the assumed amateur secondary status and practice of listen-before-transmit – operation of the amateur link on the same frequency as the fixed link was using was generally not practical. After taking account of the few remaining occasions when the amateur link might nonetheless operate co-channel with the fixed link, the incidence of potential interference should be infrequent and generally would not preclude continued operation of the fixed link and should be resolvable on a case-by-case basis.

However, a study conducted by another administration concluded that harmful interference caused by amateur transmissions could result in unacceptable interference which could lead to loss of FS link functionality and in degradation of wanted signal reception conditions unless separation distances of, e.g., 2 000 km for single-hop links and 6 500 km for double-hop links, were observed.

1/1.4/3.2 Compatibility with stations in the mobile service

The characteristics of stations in the mobile service are similar to the characteristics of stations in the fixed service, but the use of omnidirectional whip antennas on mobile units in the mobile service has two results:

1) otherwise identical circuits being less reliable in the mobile service than the fixed service; and

2) equal sensitivity of mobile units to both wanted and potentially interfering signals in all directions.

Studies on these two points are not complete.

Adjacent band analysis with stations in the aeronautical mobile service above 5 450 kHz indicates compatibility with potential amateur service stations in the 5 250-5 450 kHz frequency range.

1/1.4/4 Analysis of the results of studies

Views of the feasibility of sharing between incumbent services and the amateur service in the band 5 275 to 5 450 kHz vary.

Some administrations are of the view that compatibility of amateur stations with the fixed and mobile services systems is extremely difficult and may require operational constraints on the amateur stations.

Other administrations are of the view that compatibility is feasible. One of these administrations cites that there have been few cases of interference to incumbent services by amateur stations operating in the 5 MHz range under domestic authorizations consistent with No. **4.4** of the Radio Regulations. Interaction with the incumbent services, should it occur, generally does not preclude their continued operation and such instances are normally resolvable on a case-by-case basis.

Other of these administrations report that they are unaware of any such cases of interference by amateur stations operating under similar domestic authorizations.

In the case of the frequency range 5 250 to 5 275 kHz, allocated to radiolocation service for oceanographic applications, previous ITU-R studies have found sharing "seems to be difficult ...[1] For these reasons a secondary allocation to the amateur service within the frequency band 5 250-5 275 kHz authorized at WRC-12 should not be considered.

If necessary, to ensure compatibility of amateur stations with the fixed and mobile services, operational constraints on the amateur stations additional to those already incumbent on a secondary user might be required.

1/1.4/5 Methods to satisfy the agenda item

1/1.4/5.1 Method A

An allocation to the amateur service, on a secondary basis, for one or more blocks of spectrum (not necessarily contiguous) in the range 5 275 kHz to 5 450 kHz.

Advantages

– The requirement of the amateur service for access to frequencies in the vicinity of 5 300 kHz would be met.

– The secondary status imposes an obligation on amateur stations to avoid harmful interference to the incumbent primary user.

– A wide tuning range will allow amateurs to find a frequency that is not used by primary services.

Disadvantages

– Risk of decreased throughput for automated HF systems, as fewer channels may be available.

– Unacceptable interference may be caused to the links of the fixed and mobile services (excluding aeronautical mobile service) including operation links used in disaster situations and in relief operations.

[1] § 2/1.15/3 of the Report of the Conference Preparatory Meeting to the World Radiocommunication Conference 2012.

1/1.4/5.1.1 Method A1

An allocation to the amateur service, on a secondary basis in the frequency band, 5 275-5 450 kHz.

1/1.4/5.1.2 Method A2

An allocation to the amateur service, on a secondary basis in the range 5 350 to 5 450 kHz

1/1.4/5.1.3 Method A3

An allocation to the amateur service up to [xx] kHz, on a secondary basis, in the range 5 275 kHz to 5 450 kHz.

1/1.4/5.1.4 Method A4

An allocation to the amateur service at several specific channels, on a secondary basis, in the range 5 275 kHz to 5 450 kHz.

1/1.4/5.2 Method B

No changes to Frequency Allocation Table of Radio regulations in the frequency band 5 250-5 450 kHz

Advantages

– Unacceptable interference would not be caused to operation of fixed, land mobile, maritime mobile and radiolocation services.

Disadvantages

– Amateur service stations could operate in the frequency band 5 250-5 450 kHz only subject to RR No. **4.4** provisions.

1/1.4/6 Regulatory and procedural considerations

For all of the methods below, Suppression of Resolution **649 (WRC-12)** would be a consequential change.

1/1.4/6.1.1 Regulatory and procedural considerations for Method A1

ARTICLE 5

Frequency allocations

Section IV – Table of Frequency Allocations
(See No. **2.1**)

MOD

5 003-7 450 kHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
. . .		
5 250-5 275 FIXED MOBILE except aeronautical mobile Radiolocation 5.132A 5.133A	**5 250-5 275** FIXED MOBILE except aeronautical mobile RADIOLOCATION 5.132A	**5 250-5 275** FIXED MOBILE except aeronautical mobile Radiolocation 5.132A
5 275-5 450	FIXED MOBILE except aeronautical mobile Amateur	
. . .		

1/1.4/6.1.2 Regulatory and procedural considerations for Method A2

ARTICLE 5

Frequency allocations

Section IV – Table of Frequency Allocations
(See No. **2.1**)

MOD

5 003-7 450 kHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
. . .		
5 250-5 275 FIXED MOBILE except aeronautical mobile Radiolocation 5.132A 5.133A	**5 250-5 275** FIXED MOBILE except aeronautical mobile RADIOLOCATION 5.132A	**5 250-5 275** FIXED MOBILE except aeronautical mobile Radiolocation 5.132A
5 275-~~5 450~~5 350	FIXED MOBILE except aeronautical mobile	
~~5 275~~5 350-5 450	FIXED MOBILE except aeronautical mobile Amateur	
. . .		

1/1.4/6.1.3 Regulatory and procedural considerations for Method A3

ARTICLE 5

Frequency allocations

Section IV – Table of Frequency Allocations
(See No. **2.1**)

MOD

5 003-7 450 kHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
. . .		
5 275-~~5 450~~5 xxx	FIXED MOBILE except aeronautical mobile	
~~5 275-5 450~~5 xxx-5 yyy	FIXED MOBILE except aeronautical mobile Amateur ADD 5.A104	
~~5 275~~5 yyy-5 450	FIXED MOBILE except aeronautical mobile	
. . .		

ADD

5.A104 The maximum equivalent isotropically radiated power (e.i.r.p.) of stations in the amateur service using frequencies in the band 5 xxx-5 yyy kHz shall not exceed [xx] W. Stations in the amateur service shall not initiate transmissions before confirming the expected operating channel is not occupied by fixed or mobile services.

1/1.4/6.1.4 Regulatory and procedural considerations for Method A4

ARTICLE 5

Frequency allocations

Section IV – Table of Frequency Allocations
(See No. **2.1**)

MOD

5 003-7 450 kHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
...		
5 275-5 450	FIXED MOBILE except aeronautical mobile Amateur ADD 5.B104	
...		

ADD

5.B104 The amateur service can only operate on the frequencies 5 xxx kHz, 5yyy kHz, …, and 5 zzz kHz. The maximum equivalent isotropically radiated power (e.i.r.p.) of stations in the amateur service shall not exceed [xx] W. Stations in the amateur service shall not initiate transmissions before confirming the expected operating channel is not occupied by fixed or mobile services.

1/1.4/6.2 Regulatory and procedural considerations for Method B

ARTICLE 5

Frequency allocations

Section IV – Table of Frequency Allocations
(See No. **2.1**)

NOC

5 003-7 450 kHz

เอกสารแนบ ๒

[Preliminary] draft Revision of Recommendation ITU-R M.2009

Radiocommunication Study Groups

Source: Annex 13 to Document 5A/543, Documents 5A/590,5A/596, 5A/627	**Revision 1 to Document 5A/TEMP/268-E**
	5 November 2014
Subject: Recommendation ITU-R M.2009	**English only**

Working Party 5A

[PRELIMINARY] DRAFT REVISION OF RECOMMENDATION ITU-R M.2009

Radio interface standards for use by public protection and disaster relief operations in some parts of the UHF band in accordance with Resolution 646 (Rev. WRC-0312)

(2012, 201X)

Summary of the revision

The broadband radio interface standards LTE-Advanced, SCDMA and B-TrunC have been added as part of this Recommendation. Annex 3 has also been deleted and replaced with a reference to Report ITU-R M.2033 in the *noting*. Other editorial improvements have also been made, such as adding relevant ITU-R Recommendations to the list of references, amending the titles of some sections to better reflect the contents, and removing acronyms/abbreviations no longer in use or used only once.

1 Scope

This Recommendation identifies radio interface standards applicable for public protection and disaster relief (PPDR) operations in some parts of the UHF band. The broadband standards included in this Recommendation are capable of supporting users at broadband data rates, taking into account the ITU-R definitions of "wireless access" and "broadband wireless access" found in Recommendation ITU-R F.1399.

This Recommendation addresses the standards themselves and does not deal with the frequency arrangements for PPDR systems, for which a separate Recommendation exists: Recommendation ITU-R M.2015.

2 Introduction

This Recommendation addresses radio interface standards for use for public protection and disaster relief operations. These standards are based on common specifications developed by standards development organizations (SDOs). Using this Recommendation, regulators, manufacturers and PPDR operators should be able to determine the most suitable standards for their needs.

3 Relevant Recommendations and Reports

The existing Recommendations and Reports that are considered to be of importance in the development of this particular Recommendation are as follows:

– Recommendation ITU-R F.1399 – Vocabulary of terms for wireless access.

– Recommendation ITU-R M.1457 – Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2000 (IMT-2000).

– Recommendation ITU-R M.1801 – Radio interface standards for broadband wireless access systems, including mobile and nomadic applications, in the mobile service operating below 6 GHz.

– Recommendation ITU-R M.2012 – Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications Advanced (IMT-Advanced).

– Recommendation ITU-R M.2015 – Frequency arrangements for public protection and disaster relief radiocommunication systems in UHF bands in accordance with Resolution **646 (Rev. WRC-0312)**.

– Report ITU-R M.2014 – Digital land mobile systems for dispatch traffic.

– Report ITU-R M.2033 – Radiocommunication objectives and requirements for public protection and disaster relief.

– Report ITU-R M.2014 – Digital land mobile systems for dispatch traffic.

4 Considering

a) that administrations can determine which technologies to deploy for PPDR operations;

b) that inclusion of standards in this Recommendation does not preclude the use of other standards for PPDR operations;

5 Noting

The PPDR user requirements outlined in Report ITU-R M.2033 and the acronyms and abbreviations listed in Annex 3;

6 Recognizing

a) that Resolution **646 (Rev. WRC-0312)** encourages administrations to consider the following the frequency bands/ranges or parts thereof as identified in that Resolution when undertaking their national planning for the purposes of achieving regionally harmonized frequency bands/ranges for advanced public protection and disaster relief solutions:

– in Region 1: 380-470 MHz as the frequency range within which the band 380-385/390-395 MHz is a preferred core harmonized band for permanent public protection activities within certain countries of Region 1 which have given their agreement;

– in Region 2[1]: 746-806 MHz, 806-869 MHz, 4 940-4 990 MHz;

– in Region 3[2]: 406.1-430 MHz, 440-470 MHz, 806-824/851-869 MHz, 4 940-4 990 MHz and 5 850-5 925 MHz;

[1] Venezuela has identified the band 380-400 MHz for public protection and disaster relief applications.

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b) that Recommendation ITU-R M.2015 – Frequency arrangements for public protection and disaster relief radiocommunication systems in UHF bands in accordance with Resolution 646 (WRC-03)**646 (Rev. WRC-12)** provides guidance on frequency arrangements for public protection and disaster relief radiocommunications in certain regions in some of the bands below 1 GHz identified in Resolution 646.

7 Recommendation

The ITU Radiocommunication Assembly,

recommends

that for PPDR operations the radio interface standards as contained in Annexes 1 and 2 should be used.

Annex 1

Broadband radio interface standards for use by PPDR operations in accordance with Resolution 646 (WRC-03)646 (Rev. WRC-12)

This Annex provides information on broadband standards for use by PPDR operations. References are provided to ITU texts which contain more detailed descriptions of these standards and their capabilities. It is recognized that these standards may not fulfil all the user requirements described in Report ITU-R M.2033Annex 3, and that each administration and its PPDR organizations will have to analyse the information and determine which standard is most appropriate for their purposes.

1 IMT-2000 CDMA Multi-CarrierTechnology "A"

Technology "A" corresponding to tThe specifications for the radio interface standard IMT-2000 CDMA Multi-Carrier (IMT-2000 CDMA-MC) technology isare developed within 3GPP2 Generation Partnership Project 2). A full description is available in Annex 2 of Recommendation ITU-R M.1801. For additional information, see also § 5.2 of Recommendation ITU R M.1457.

2 IMT-2000 CDMA Direct SpreadTechnology "B"

The specifications for the radio interface standard IMT-2000 CDMA Direct Spread (Technology "B" corresponding to IMT-2000 CDMA-DS), specifically UTRA FDD, is are developed within 3GPP (3rd Generation Partnership Project). This radio interface standard also includes the FDD elements of the Evolved Universal Terrestrial Radio Access (E-UTRA) referred to as Long-Term Evolution (LTE). A full description is available in Annex 2 of Recommendation ITU-R M.1801. For additional information, see also § 5.1 of Recommendation ITU R M.1457.

[2] Some countries in Region 3 have also identified the bands 380-400 MHz and 746-806 MHz for public protection and disaster relief applications.

3 IMT-2000 OFDMA TDD WMANTechnology "C"

The radio interface standard IMT-2000chnology "C" corresponding to OFDMA TDD WMAN is developed within the IEEE. A full description is available in Annex 2 of Recommendation ITU-R M.1801. For additional information, see also § 5.6 of Recommendation ITU R M.1457.

4 IMT-2000 TDMA Single-CarrierTechnology "D"

The radio interface standard IMT-2000 TDMA Single-Carrier (chnology "D" corresponding to TDMA-SC) is developed by ATIS utilizing within 3GPP (3rd Generation Partnership Project)specifications. A full description is available in Annex 2 of Recommendation ITU-R M.1801. For additional information, see also § 5.4 of Recommendation ITU R M.1457.

5 IMT-2000 CDMA TDDTechnology "E"

The specifications for the radio interface standard chnology "E" corresponding toIMT-2000 CDMA TDD, specifically UTRA TDD, technology isare developed within 3GPP (3rd Generation Partnership Project). This radio interface is called the Universal Terrestrial Radio Access (UTRA) time division duplex (TDD), where three options, called 1.28 Mchip/s TDD, 3.84 Mchip/s TDD and 7.68 Mchip/s can be distinguished. This radio interface standard also includes the TDD elements of the Evolved Universal Terrestrial Radio Access (E-UTRA) referred to as Long-Term Evolution (LTE). A full description is available in Annex 2 of Recommendation ITU-R M.1801. For additional information, see also § 5.3 of Recommendation ITU-R M.1457.

6 LTE-Advanced

"The IMT-Advanced terrestrial radio interface specifications known as LTE-Advanced and based on LTE Release 10 and Beyond are developed by 3GPP. In 3GPP terminology, the term E-UTRA (Evolved-UTRA) is also used to indicate the LTE radio interface.

LTE-Advanced is a Set of RITs (Radio Interface Technologies) consisting of one FDD RIT and one TDD RIT designed for operation in paired and unpaired spectrum, respectively. The TDD RIT is also known as TD-LTE Release 10 and Beyond or TD-LTE-Advanced. The two RITs have been jointly developed, providing a high degree of commonality while, at the same time, allowing for optimization of each RIT with respect to its specific spectrum/duplex arrangement." [3]

A full description is available in Annex 3 of Recommendation ITU-R M.1801. Technology "F"

Technology "F" corresponding to E-UTRA (LTE) technology is developed within 3GPP (3rd Generation Partnership Project). This radio interface is called the Evolved Universal Terrestrial Radio Access (E-UTRA) also referred to as the Long-Term Evolution (LTE). LTE supports scalable carrier bandwidths, from 20 MHz down to 1.4 MHz, and supports both frequency division duplexing (FDD) and time division duplexing (TDD). For additional information, see Annex 1 of Recommendation ITU-R M.2012.For additional information, see §§ 5.1 and 5.3 of Recommendation ITU-R M.1457.

[3] See §1.1.1 of Recommendation ITU-R M.2012-1 – Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-Advanced (IMT-Advanced)

7 SCDMA

The radio interface standard SCDMA is developed within CCSA (China Communications Standards Association). The radio interface supports a channel bandwidth of a multiple of 1 MHz up to 5 MHz. Sub-channelization and code spread, specially defined inside each 1 MHz bandwidth, provides frequency diversity and interference observation capability for radio resource assignment with bandwidth granularity of 8 kbit/s. The channelization also allows coordinated dynamic channel allocations among cells to efficiently avoid mutual interference.

The system employs TDD to separate uplink and downlink transmission. For additional information, see Annex 7 of Recommendation ITU-R M.1801.

8 B-TrunC

The radio interface standard B-TrunC is developed by CCSA and published by Ministry of Industry and Information Technology of the People's Republic of China. B-TrunC supports scalable carrier bandwidths, from 20 MHz down to 1.4 MHz. Moreover, B-TrunC can support one-to-many voice call, one-to-many video call, and other PPDR applications by introducing new one-to-many transmission mechanism in radio interface. For additional information, see also YD/T 2741-2014.

Annex 2

Narrow-band radio interface standards for use by PPDR operations in accordance with Resolution ~~646 (WRC-03)~~646 (Rev. WRC-12)

This Annex provides information on narrow-band standards for use by PPDR operations. References are provided to ITU texts which contain more detailed descriptions of these standards and their capabilities. It is recognized that these standards may not fulfil all the user requirements described in Report ITU-R M.2033~~Annex 3~~, and that each administration and its PPDR organizations will have to analyse the information and determine which standard is most appropriate for their purposes.

1 ~~Technology "A"~~Project 25

~~Technology "A" corresponding to~~ Project 25 is developed by TIA ~~TR-8~~ with input from the Project 25 steering committee made up of representatives from the Association of Public Safety Communications Officials International (APCO), the National Association of State Technology Directors (NASTD), selected federal agencies and the National Communications System (NCS). Project 25 operates in 12.5 kHz or 25 kHz channels.

For additional information on the technical and operational characteristics of Project 25, see Report ITU-R M.2014 and Volume 3 of the Land Mobile Handbook.

2 Terrestrial Trunked Radio (TETRA)~~Technology "B"~~

Th~~echnology "B" corresponding to the~~ Terrestrial Trunked Radio (TETRA) system was developed in the European Telecommunications Standards Institute (ETSI) as ETSI Project TETRA (now known as ETSI Technical Committee (TC) TETRA) to deliver a digital trunked mobile radio set of standards, under a mandate from the European Commission, for a PMR communications system that could be deployed in Western Europe.

Besides meeting the needs of traditional PMR user organizations, the TETRA standard has also been developed to meet the needs of Public Access Mobile Radio (PAMR) operators.

For additional information on the technical and operational characteristics of TETRA, see Report ITU-R M.2014.

3 Digital Mobile Radio (DMR)~~Technology "C"~~

T~~echnology "C" corresponding to t~~he Digital Mobile Radio (DMR) system was developed by ETSI as a direct digital replacement for analogue PMR while imposing no fundamental changes in the architecture of either conventional or trunked systems.

DMR is a scalable system that can be used in unlicensed mode, and in licensed mode, subject to national frequency planning. It is developed in three "tiers":

- tier 1 is the low-cost, licence-exempt "digital PMR446".
- tier 2 is for the professional market offering peer-to-peer mode and repeater mode (licensed).
- tier 3 is for trunked operation (licensed).

DMR is a two slot Time-Division Multiple Access (TDMA) system offering digital voice and data solutions, and uses a 4FSK modulation scheme utilizing 6.25 kHz per channel. The standard is designed to operate within the existing 12.5 kHz channel spacing.

For additional information on the technical and operational characteristics of DMR, see ETSI Technical Report TR 102 398 that provides a useful introduction to DMR. Technical Specification TS 102 362 parts 1 to 3 covers DMR protocol conformance testing and test suites, and Technical Specification TS 102 490 defines the narrow-band or "digital PMR" protocol.

The System Reference Documents are ETSI Technical Report TR 102 335-1 (Tier 1 DMR) and TR 102 335-2 (licensed).

~~Annex 3~~

~~PPDR user requirements~~

~~PPDR is defined in Resolution 646 (WRC-03) through a combination of the terms "public protection radiocommunication" and "disaster relief radiocommunication". The first term refers to radiocommunications used by responsible agencies and organizations dealing with maintenance of law and order, protection of life and property and emergency situations, and the second term refers to radiocommunications used by agencies and organizations dealing with a serious disruption of the functioning of society, posing a significant widespread threat to human life, health, property or the environment, whether caused by accident, natural phenomena or human activity, and whether developing suddenly or as a result of complex, long-term processes.~~

~~In addition, Resolution 646 and Report ITU-R M.2033 describe a range of requirements for PPDR. It is recognized that there is a need for narrow-band, wideband and broadband applications, and Resolution 646 and Report ITU-R M.2033 provide general definitions of these terms applicable for PPDR. It is recognized, however, that other definitions of these terms exist in other ITU texts (such as Recommendation ITU-R F.1399) or in the rules of various individual administrations. As a result, the terms are defined in the Annexes to this Recommendation in a manner appropriate for how they are used within this Recommendation.~~

~~PPDR requirements from a user perspective are described in detail in Report ITU-R M.2033, specifically in § 3.2 of Annex 1. These user requirements include priority access, grade of service/quality of service, coverage, a variety of capabilities (including push-to-talk, fast call set-up, hardened equipment that is capable of operating in harsh environments, interconnection to the PSTN, one touch broadcasting/group call capabilities), secure communications, interoperability and regulatory compliance. It is noted that individual administrations or PPDR organizations may have their own requirements for PPDR that go beyond those described herein, and that each standard would need to be evaluated on a case-by-case basis against those requirements.~~

~~A Key capabilities of broadband systems relevant to PPDR organizations~~

~~– Advanced broadband data capabilities. Broadband data capability enables a broad range of applications. These basic capabilities allow end-users to retrieve information from databases, send information to central locations, such as control centres, and exchange information with other users in their own group or in other user groups. In addition, messaging services offered by SMS, EMS and MMS range from simple text messages~~

~~to multimedia including transmission of pictures and photos, which is very effective in property protection and recovery operations. With MMS, real-time video transmission also is possible. Real-time video can be an efficient way for public safety users to communicate between the scene of an accident and central locations such as control centres and hospitals.~~

- ~~Interoperability. Open standards-based technology allows any manufacturer to provide equipment interoperable with equipment from any other manufacturer.~~
- ~~Economies of scale. As standard-based technologies designed for carrier-class commercial deployment are also used, economies of scale can be achieved. In addition to commercial off-the-shelf equipment, specialized PPDR devices or features required by some PPDR entities can be accommodated with modifications to commercial products and designs.~~
- ~~IP-based services. Fully compatible with IP-based services.~~
- ~~Push-to-talk. This function allows predefined groups of users to communicate over a packet channel by pressing a special key.~~
- ~~Location-based services. Advanced technology solutions built into handsets and networks, and often utilizing satellite signals such as GPS, can enable public safety officials to accurately locate an emergency situation or track a secure shipment. Advanced methods of location measurements from both satellite constellations and the terrestrial infrastructure are capable of sending information that can compute a device's position and relay it back to a requesting entity.~~
- ~~Encryption. Encryption of voice and data can be provided in several ways, such as over the radio interface, which is standard in different network technologies, or between network equipment. End-to-end encryption of voice can be supported by special terminals or by carrying voice over an encrypted data channel.~~
- ~~Prioritization (in protocol level) of public safety services over commercial services in case of emergency.~~

~~B Key capabilities of narrow-band systems relevant to PPDR organizations~~

- ~~Effective, efficient, and reliable intra-agency and inter-agency communications so organizations can easily implement interoperable and seamless joint communication in both routine and emergency circumstances.~~
- ~~User-friendly equipment so users can take full advantage of their radios' lifesaving capabilities on the job – even under adverse conditions – with minimal training.~~
- ~~Radio spectrum efficiency so networks will have enough capacity to handle calls and allow room for growth, even in areas where the spectrum is crowded and it is difficult for agencies to obtain licenses for additional radio frequencies.~~
- ~~System designs that provide effective and efficient one-to-many half-duplex communications throughout a PPDR organization's coverage area, reconfiguration of dispatch talk groups, as well as specialized communications configurations at an incident scene when required.~~

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Annex 43

Acronyms and abbreviations

3GPP – 3rd Generation Partnership Project

~~3GPP2 – 3rd Generation Partnership Project 2~~

~~APCO – Association of Public Safety Communications Officials International~~

B-TrunC- Broadband Trunking Communication

CDMA TDD – Code division multiple access time division duplex

~~CDMA-DS – Code division multiple access – Direct spread~~

~~CDMA-MC – Code division multiple access – Multi-carrier~~

DMR – Digital mobile radio

~~EMS – Enhanced messaging service~~

ETSI – European Telecommunications Standards Institute

E-UTRA – Evolved Universal Terrestrial Radio Access

FDD – Frequency division duplex

FDMA – Frequency division multiple access

IEEE – Institute of Electrical and Electronics Engineers

LTE – Long-Term Evolution

~~MMS – Multimedia messaging service~~

~~NASTD – National Association of State Technology Directors~~

~~NCS – National Communications System~~

OFDMA TDD WMAN – Orthogonal Frequency Division Multiple Access Time Division Duplex Wireless Metropolitan Area Network

PAMR – Public access mobile radio

PMR – Private mobile radio

PPDR – Public protection and disaster relief

~~SDO – Standards Developing Organization~~

~~SMS – Short message service~~SCDMA – Synchronous Code Division Multiple Access

~~TDMA – SC – Time division multiple access – Single carrier~~

TETRA – Terrestrial trunked radio

~~TIA – Telecommunications Industry Association~~

TR – Technical report

UHF – Ultra high frequency

UTRA – Universal ~~t~~Terrestrial ~~r~~Radio ~~a~~Access

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[PRELIMINARY] DRAFT] REVISION OF RECOMMENDATION ITU-R M.2015

Radiocommunication Study Groups

Source: Docs. 5A/543 (Annex 5A/601, 5A/605, 5A/606 and 5A/610

Subject: Recommendation ITU-R M.2015

Document 5A/TEMP/271-E
4 November 2014
English only

Working Party 5A

WORKING DOCUMENT TOWARDS A [PRELIMINARY] DRAFT REVISION OF RECOMMENDATION ITU-R M.2015

Frequency arrangements for public protection and disaster relief radiocommunication systems in UHF bands in accordance with Resolution 646 (Rev.WRC-12)

(2012, 201X)

Summary of the revision

Frequency arrangements for the band 406.1-430 MHz have been added in Annex 4 and two additional frequency arrangements for the bands 806-824/851-869 MHz have been added in Annex 5 to reflect current deployments of PPDR networks. A number of additions and editorial changes have been made to the *considerings* and *notings*. *Recognising d)* has been added from Resolution **646 (Rev. WRC-12)** as well as a new footnote 4 that includes frequency ranges/bands used or considered for use in some administration that are not included in Resolution **646 (Rev. WRC-12)**.

Scope

This Recommendation provides guidance on frequency arrangements for public protection and disaster relief radiocommunications in certain regions in some of the bands below 1 GHz identified in Resolution **646 (Rev.WRC-12)**. Currently, the Recommendation addresses arrangements in the ranges 380-470 MHz in certain countries in Region 1, 746-806 MHz and 806-869 MHz in Region 2, 406.1-410 MHz, 410-430 MHz, and 806-824/851-869 MHz in some countries in Region 3 in accordance with Resolutions ITU-R 53, ITU-R 55 and WRC Resolutions **644 (Rev.WRC-1207)**, **646 (Rev.WRC-12)**, and **647 (Rev.WRC-0712)**.

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The ITU Radiocommunication Assembly,

considering

a) that growing telecommunication and radiocommunication needs of public protection and disaster relief (PPDR) agencies and organizations are vital to the maintenance of law and order, protection of life and property, disaster relief and emergency response;

b) that many administrations wish to facilitate interoperability and interworking between systems used for PPDR radiocommunication, both nationally and for cross-border operations in emergency situations and for disaster relief;

c) that a continuing requirement is envisaged for narrow-band applications (such as voice and various types of messaging), along with wideband and broadband applications in the futurethere will continue to be narrow-band, wideband and broadband requirements for future applications;

d) that continuing development of new technologies such as International Mobile Telecommunications (IMT) and Intelligent Transport Systems (ITS) may be able to serve, support or supplement advanced public protection and disaster relief applications;

e) that, over time, traditional narrow-band public protection and disaster relief applications, such as mission critical voice and low-data rate applications, may be provided by advanced broadband systems;

fe) that some administrations may have different operational needs and spectrum requirements from for their PPDR user organizations for PPDR applications depending on their operational needs, spectrum requirements, policy objectives and organizational structurescircumstances;

gf) that national spectrum planning for PPDR radiocommunication systems needs to have regard for cooperation and bilateral consultation with other concerned administrations, in order to facilitate greater levels of spectrum harmonization;

hg) that usage of the same frequencies of the same allocation will enable administrations to benefit from harmonization while continuing to meet national planning requirements,

noting

a) that the benefits of spectrum harmonization are:

– increased potential for interoperability between PPDR organizations within a particular administration, or between PPDR organizations in difference administrations;

– a broader manufacturing base and increased volume of equipment resulting in economies of scale and expanded equipment availability;

– improved spectrum management and planning;

– enhanced cross-border coordination and circulation of equipment.

b) that spectrum planning for PPDR radiocommunications is performed at the national level, taking into account the need for interoperability and benefits of neighbouring administrations using harmonized or common frequency bands;

c) the benefits of cooperation between countries for the provision of effective and appropriate humanitarian assistance during disasters;

d) the needs of countries, particularly the developing countries, for low-cost communication equipment;

e) that not all frequencies within an identified common frequency range will be available within each country of the relevant ITU Region;

f) that flexibility must be afforded to administrations:

– to determine, at the national level, how much spectrum to make available for PPDR from the band identified in Resolution **646 (Rev.WRC-12)** in order to meet their particular national requirements;

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– to have the ability for the bands identified in Resolution **646 (Rev.WRC-12)** to be used by all services having allocations according to the provisions of the Radio Regulations, taking into account the existing applications and their evolution; and

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– to determine the need and timing of availability, as well as the conditions of usage of the bands identified in Resolution **646 (Rev.WRC-12)** for PPDR in order to meet specific national policy objectives, operational priorities, organizational structures and operating environments;situations.

g) that information on technologies that may be appropriate for use in these frequency arrangements is provided in Recommendation ITU-R M.2009 - *Radio interface standards for use by public protection and disaster relief operations in some parts of the UHF band in accordance with Resolution* ***646 (WRC-12)*** sent for adoption/approval by correspondence (PSAA) in Administrative Circular CAR/329;

h) that Report ITU-R M.2291, *The use of International Mobile Telecommunications for broadband public protection and disaster relief applications*, describes the features and benefits that make LTE particularly suitable for PPDR applications;

ih) the relationship of between Resolution **646 (Rev.WRC-12)** on public protection and disaster relief, which invites the development of this Recommendation, withand Resolution **647 (Rev. WRC-0712)** on spectrum management guidelines for emergency and disaster relief rRadiocommunication and Resolution **644 (Rev.WRC-0127)** on radiocommunication resources for early warning, disaster mitigation and relief operations, which also address the need to coordinate activities under these Resolutions in order to prevent any possible overlap,

recognizing

a) Resolution **646 (Rev.WRC-12)** encourages administrations to consider the following identified frequency bands/ranges or parts thereof when undertaking their national planning for the purposes of achieving regionally harmonized frequency bands/ranges for advanced public protection and disaster relief solutions:

– in Region 1: 380-470 MHz as the frequency range within which the band 380-385/390-395 MHz is a preferred core harmonized band for permanent public protection activities within certain countries of Region 1 which have given their agreement;

– in Region 2[1]: 746-806 MHz, 806-869 MHz, 4 940-4 990 MHz;

– in Region 3[2]: 406.1-430 MHz, 440-470 MHz, 806-824/851-869 MHz, 4 940-4 990 MHz and 5 850-5 925 MHz;

[*b)* the urgent need for development of regionally harmonized frequency arrangements in the frequency range 380-470 MHz in Region 1, the range 746-806 MHz in Region 2, the frequency range 806-869 MHz in Region 2, and the frequency ranges 406.1-410 MHz, 410-430 MHz and 806-824/851-869 MHz in some countries in Region 3 for the purposes of implementing advanced PPDR solutions;]

c) that, in the context of Resolution **646 (Rev.WRC-12)**, the term "frequency range" means a range of frequencies over which relevanta radio equipment is envisaged to be capable of operating, but limited to specific frequency band(s) according to national conditions and requirements;

d) that currently some bands or parts thereof have been designated for existing public protection and disaster relief operations in some administrations, as is recognized in *recognizing g)* of Resolution **646 (WRC-12)**[3];

[1] Venezuela has identified the band 380-400 MHz for public protection and disaster relief applications.

[2] Some countries in Region 3 have also identified the bands 380-400 MHz and 746-806 MHz for public protection and disaster relief applications.

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ed) that the identification of these frequency bands/ranges or parts thereof for PPDR radiocommunications does not preclude the use of, nor establish priority over, any other frequencies for PPDR[4] in accordance with the Radio Regulations including the provisions of Resolution **646 (Rev.WRC-12)**, and does not preclude the use of these bands/frequencies by any application within the services to which these bands/frequencies are allocated;

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fe) that the frequency bands identified in Resolution **646 (Rev.WRC-12)** and covered by this Recommendation are allocated to a variety of services in accordance with the relevant provisions of the Radio Regulations;

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gf) that the frequency arrangements in the Annexes are provided for PPDR applications in the mobile service at the national level;

hg) that compatibility of stations using these frequency arrangements with other services operating in other countries is studied in the ITU at the service level and not at the application level;

ih) that Resolution ITU-R 53 instructs the Director of the Radiocommunication Bureau to assist Member States with their emergency radiocommunication preparedness activities, such as listing of currently available frequencies for use in emergency situations for inclusion in a database maintained by the Bureau;

j) that World Radiocommunication Conferences haveWRC-07 identified bands, including 450-470 MHz, and part or all of the bands 698-960 MHz in certain Regions and countries, for use by administrations wishing to implement IMT, as detailed in Nos. **5.286AA**, **5.317A**, **5.313A**, **5.316**, **5.316A** and **5.316B**, Resolution **224 (Rev.WRC-1207)** and Resolution **749 (Rev.WRC-0712)**;

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k) that the Regional Radiocommunication Conference (Geneva, 2006) established Regional Agreement relating to the planning of the digital terrestrial broadcasting service in Region 1 (parts of Region 1 *situated to the west of meridian 170° E and to the north of parallel 40° S*, except the territory of Mongolia) and in the Islamic Republic of Iran, in the frequency bands 174-230 MHz and 470-862 MHz (GE-06);

l) that commercial terrestrial wireless systems may effectively complement dedicated systems in support of PPDR, particularly where advantage can be taken of the availability, high-bit rate, and reliability features of these commercial systems. There may be a need for suitable upgrading of such commercial systems to meet the specific needs of PPDR agencies,

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[3] 3-30, 68-88, 138-144, 148-174, 380-400 MHz (including CEPT designation of 380-385/ 390-395 MHz), 400-430, 440-470, 764-776, 794-806 and 806-869 MHz (including CITEL designation of 821-824/866-869 MHz).

[4] These additional frequency bands are used or considered for use by some administrations for PPDR: 350-370 MHz (China), 703-713/758-768 MHz (United Arab Emirates and Jordan), 791-801/832-842 MHz (Qatar) and 806-824/851-869 MHz (Israel).

recommends

1 that administrations implementing the frequency arrangements in the Annexes should make all necessary efforts to ensure compatibility between PPDR and stations of other services in neighbouring countries;

2 that the frequency arrangements in the Annexes should be used by administrations as guidance when making spectrum available for PPDR applications in the frequency bands described in *recognizing b)*.

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Annex 1

Examples of frequency arrangements for the band 380-470 MHz in certain countries in Region 1 for narrow-band and wideband public protection and disaster relief operations

1 Region 1

The frequency range 380-470 MHz has been identified as a tuning range for PPDR in Region 1. The frequency band 380-385 MHz (uplink)/390-395 MHz (downlink) is the harmonized core band for permanent use for PPDR. For more information relating to countries within Europe, see ECC/DEC/(08)05 and ECC Report 102.

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Wideband PPDR applications use channels within available parts of the frequency range 380-470 MHz.

Additionally certain channels have been identified for DMO (Direct mode operation) and AGA (Air-ground-air operation) purposes.

1.1 DMO (Direct mode operation)

Simplex channels within the frequency bands 380-380.150 MHz and 390-390.150 MHz should be used as harmonized channels for DMO. For more information relating to countries within Europe see ERC/DEC/(01)19.

1.2 AGA (Air-ground-air operation)

Duplex channels within the frequency bands 384.800 MHz-385 MHz/394.800-395 MHz should be used as the core band for harmonized channels for AGA. Duplex channels within the frequency bands 384.750 MHz-384.800 MHz/394.750-394.800 MHz may be used as the preferred extension band for AGA when additional channels are required. For more information relating to countries within Europe, see ECC/DEC/(06)05.

1.3 Centre frequencies:

a) *For systems with a channel bandwidth of up to 150 kHz*

$$F_{CH} = \text{band edge} - (\text{channel bandwidth}/2) + n * \text{channel bandwidth}$$

where:

F_{CH} = centre frequency;

n = channel number (1, 2, 3, ...);

band edge: is lower edge of frequency band.

b) *For systems with a channel bandwidth of 200 kHz*

The centre frequencies should be selected according to the formula under *a)* with an option to offset these centre frequencies by 100 kHz.

c) *For systems with a channel bandwidth of 1.25 MHz*

The centre frequencies should be selected according to the formula under *a)* with an option to offset these centre frequencies by multiples of 12.5 kHz, in order to provide flexibility to locate the centre frequencies in the optimum position within the band.

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Annex 2

Examples of frequency arrangements within the bands 763 to 776 MHz and 793 to 806 MHz in certain countries in Region 2 for narrow-band, wideband and broadband public protection and disaster relief operations

1 Region 2

The frequency range 764-776 MHz and 794-806 MHz has been identified for PPDR in the CITEL PCC.II/REC. 18 (VII-06). Within this frequency range, administrations could consider a number of possible frequency arrangements examples as indicated below.

1.1 Example frequency arrangement "A"[5]

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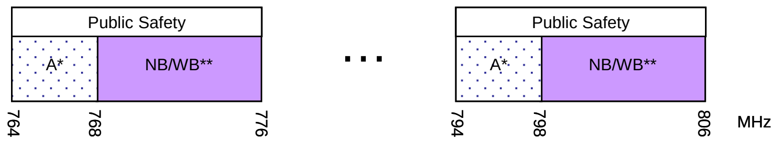
Base station transmit (MHz)	Mobile station transmit (MHz)	Frequency block
764-768	794-798	PPDR 1
768-776	798-806	PPDR 2



* Block A will be subject to a future consultation.

** The amount of narrowband (NB) and wideband (WB) spectrum will be set out in the relevant standard

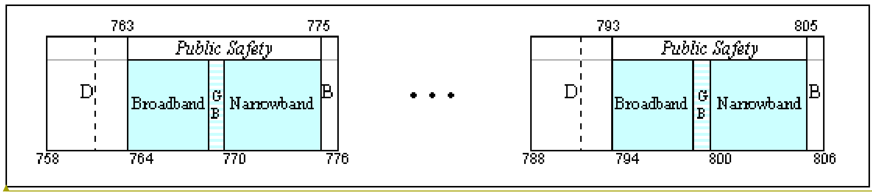
5 This frequency arrangement is from the Canadian rules. For more details, see Industry Canada's Gazette Notice No. DGTP-007-09 – Narrowband and Wideband Public Safety Radiocommunication Systems in the bands 768-776 MHz and 798-806 MHz (http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09553.html).

1.2 Example frequency arrangement "B"[6]

Base station transmit (MHz)	Mobile station transmit (MHz)	Frequency block
758~~63~~-768	788~~93~~-798	PPDR 1[1]
769-775	799-805	PPDR 2[2]
768-769	798-799	PPDR internal guardband
~~758-763~~	~~788-793~~	~~D (public/private partnership) with PPDR priority access during emergencies~~

NOTE 1 – This frequency block is used for broadband PPDR applications[7]. Broadband PPDR applications include web browsing, tactical video, surveillance video, high resolution imaging, database access, and virtual private networks.

NOTE 2 – This frequency block is used for PPDR applications that provide narrow-band voice and low-speed data services. In the context of PPDR, narrow-band is defined in Resolution **646 (Rev.WRC-12)** as "supporting voice and low data-rate applications, typically in channel bandwidths of 25 kHz or less". Narrowband channels may also be consolidated into wideband channels (50 to 150 kHz) if approval by the licensing administration is obtained through a limited waiver process.



[6] This band plan is from the United States' FCC Rules. For more details, see Part 90 of the FCC Rules at http://wireless.fcc.gov/index.htm?job=rules_and_regulations.

[7] The use of the term "broadband" in this Annex means indicative data rates in the order of 1-100 Mbit/s with channel bandwidths dependent on the use of spectrally efficient technologies (from Resolution 646 (Rev.WRC-12) and Report ITU-R M.2033). It is recognized that other definitions of these terms exist in other ITU texts (such as Recommendation ITU-R F.1399) or in the rules of various individual administrations.

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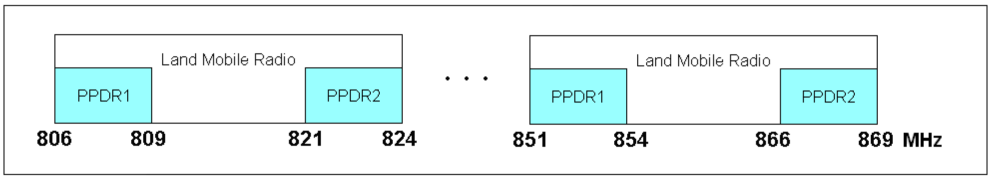
Annex 3

Examples of frequency arrangements for the band 806 to 869 MHz in certain countries in Region 2 for narrow-band public protection and disaster relief operations

1 Region 2

1.1 General band plan – 806-824/851-869 MHz

In a number of countries in the Region 2, the band 806-824/851-869 MHz is allocated to the mobile service, and designated for Land Mobile Radio (LMR) applications. The duplex spacing is 45 MHz, with the base stations transmitting in the 851-869 MHz, and the mobile stations in the 806-824 MHz range. PPDR channels may be assigned throughout this band and specific blocks may be designated exclusively for PPDR applications. (See § 1.1) Radio equipment is capable of tuning to all channels in the band ensuring interoperability. To simplify cross-border coordination and to ensure that public safety agencies have access to a stable and predictable pool of radio frequency channels, neighbouring administrations could implement complementary frequency arrangements, an example being shown in the figure below.



1.1 Example frequency arrangement

1.1.1 Designation of frequency blocks

Mobile station/Control station transmit (MHz)	Base station transmit (MHz)	Frequency block
806-809	851-854	PPDR1[8]
821-824	866-869	PPDR2[9]

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[8] This frequency arrangement is from the United States' FCC Rules. For more details, see Part 90 of the FCC Rules at http://wireless.fcc.gov/index.htm?job=rules_and_regulations.

[9] This frequency arrangement is from the Canadian rules. For more details, see Standard Radio System Plan 502 at http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf00050.html.

1.1.2 Channelization

The frequencies corresponding to the centre frequency of the channel number are defined by the following formulas, where *n* is the channel number:

Channel number	Mobile station transmit Channel centre frequency (MHz)	Base station transmit Channel centre frequency (MHz)	Channel bandwidth (kHz)
n = 1 to 600	$f_n = 806.0125 + (0.025) \times (n - 1)$	$f_n = 851.0125 + (0.025) \times (n\text{-}1)$	25
n = 602 to 790 except 639, 677, 715, 753	$f_n = 821.0375 + 0.0125 \times (n - 602) + 0.025 \times \text{floor}[(n - 601) / 38]$	$f_n = 866.0375 + 0.0125 \times (n - 602) + 0.025 \times \text{floor}[(n - 601) / 38]$	12.5
n = 601, 639, 677, 715, 753	$f_n = 821.0125 + 0.5 \times \text{floor}[(n - 601) / 38]$	$f_n = 866.0125 + 0.5 \times \text{floor}[(n - 601) / 38]$	25
n = 791 to 830	$f_n = 823.5 + (0.0125) \times (n - 791)$	$f_n = 868.5 + (0.0125) \times (n - 791)$	25~~12.5~~

Annex 4

Examples of frequency arrangements for the range 406.1-430 MHz in certain countries in Region 3 for narrowband public protection and disaster relief operations

1 Region 3

1.1 Example frequency arrangement - 406.1-410 MHz

Parts of the band 406.1-410 MHz are used in certain Region 3 countries to accommodate trunked land mobile systems. Frequency arrangements for this spectrum are shown below.

Simplex services are accommodated within a 12.5 kHz channel raster on the following centre frequencies (MHz):

Fn = 406.01250 + ((N-1) * 0.0125) N = 1, 2, 3,…

1.2 Example frequency arrangement for digital PPDR within 410-430 MHz

The band 410-430 MHz is used in certain Region 3 countries to accommodate digital trunked land mobile systems.

The frequency band 410 to 430 MHz provides a total bandwidth of 20MHz for Digital Trunked Radio Systems. The 12.5/25 kHz channelling plan is the standard channelling plan for this band giving a total of 800 physical radio channels (or equivalent TRS analogue traffic channel of 1600 noting possibility of two time slots per physical channel). Although the standard channel spacing is 12.5/25 kHz, it provides flexibility to operate two or more contiguous channels (i.e. 50 kHz or 100 kHz) if needed. Administrations normally assign one or more channel based on channel spacing 12.5 kHz or 25 kHz.

The channelling plan based on a raster of 12.5 kHz and 25 kHz is shown below:

1.2.1 Frequency arrangements for 25 kHz channel spacing

Centre frequencies of the base station transmitting channel are (MHz):

Fn = 420.0125 +(N-1)*0.025 N = 1, 2, 3,… 400

The centre frequencies of the base station receiving channel is (MHz):

Fn = 410.0125 +(N-1)*0.025 N = 1, 2, 3,… 400

1.2.2 Frequency arrangements for 12.5 kHz channel spacing

Centre frequencies of the base station transmitting channel are (MHz):

Fn = 420.00625 +(N-1)*0.0125 N = 1, 2, 3,… 800

The centre frequencies of the base station receiving channel is (MHz):

Fn = 410.00625 +(N-1)*0.0125 N = 1, 2, 3,… 800

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1.2.3 Channel allotment plan

The channel arrangements are divided into 4 pairs of frequency blocks (blocks A/A', blocks B/B', blocks C/C', and blocks D/D') with transmit/receive separation of 10 MHz. The channel allotment plan is designed to minimize inter-modulation and frequency interference problems by assigning co-sited channels that are 250 kHz apart. The frequency blocks A, B, C and D, which contain 200 channels each, are divided into ten (10) channel groups (i.e. A01-A10, B01-B10, C01-C10 and D01-D10) respectively.

The numbers of channels/channel groups assigned are based on the service requirement of the user agency based among others on the area covered, grade of service (GOS), capacity and services provided.

Block	**A**	**B**	**C**	**D**
Group Nos. 01 to 10	X= 1 to 10 A= 1 to 10	X= 1 to 10 B= 1 to 10	X= 1 to 10 C= 1 to 10	X= 1 to 10 D= 1 to 10
Channel Number N=	2*A-1+20*(X-1) and 2*A+20*(X-1)	2*B+199+20*(X-1) and 2*B+200+20*(X-1)	2*C+399+20*(X-1) and 2*C+400+20*(X-1)	2*D+599+20*(X-1) and 2*D+600+20*(X-1)

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Annex ~~4~~5

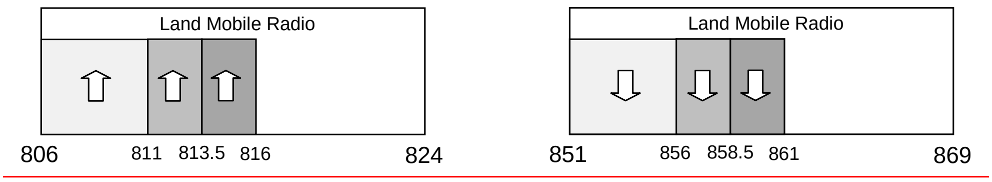
Examples of frequency arrangements for the bands 806 to 824 MHz and 851 to 869 MHz in ~~some~~ certain countries in Region 3 for narrowband and broadband public protection and disaster relief operations

1 Region 3

1.1 Example narrowband plan – 806-824/851-869 MHz

~~This example frequency arrangement is provided for information.~~

The entire band ~~may normally~~ could be used ~~with~~ for channel bandwidths of 25 kHz for digital trunked radio systems. However some administrations may want to use different channel bandwidths according to their policy. This ~~Annex~~ sub-section provides ~~the~~ examples ~~case~~ of ~~channelling. T~~three channelling schemes ~~can be considered in this band~~. In the sub-band of 806-811/851-856 MHz the channel bandwidth is 25 kHz, in the sub-band of 811-813.5/856-858.5 MHz the channel bandwidth is 12.5 kHz and in sub-band 813.5-816/858-861 MHz the channel bandwidth is 6.25 kHz. The lower block 806-824 MHz is used for mobile station transmitters (uplink) and the upper block is used for base station transmitters (downlink).



Formulas to calculate the centre frequency ~~centre~~ of each channel are as follows:

– In sub-band of 806-811/851-856 MHz:

The band is divided into 25 kHz channels.

Centre frequency of N-th base station transmitting channel (MHz):

$F_N = 851.0125 + (N - 1) \times 0.025 \qquad N = 1, 2, 3, \ldots, 200$

Centre frequency of N-th base station receiving channel (MHz):

$F_N' = 806.0125 + (N - 1) \times 0.025 \qquad N = 1, 2, 3, \ldots, 200$

– In sub-band of 811-813.5/856-858.5 MHz:

This sub-band is divided into 12.5 kHz channels.

Centre frequency of N-th base station transmitting channel (MHz):

$F_N = 856.00625 + (N - 1) \times 0.0125 \qquad N = 1, 2, 3, \ldots, 200$

Centre frequency of N-th base station receiving channel (MHz):

$FN' = 811.00625 + (N - 1) \times 0.0125 \qquad N = 1, 2, 3, \ldots, 200$

– In sub-band of 813.5-816/858.5-861 MHz:

This sub-band is divided into 6.25 kHz channels.

Centre frequency of N-th base station transmitting channel (MHz):

FN = 858.503125 + (N − 1) × 0.00625 N = 1, 2, 3, …, 400

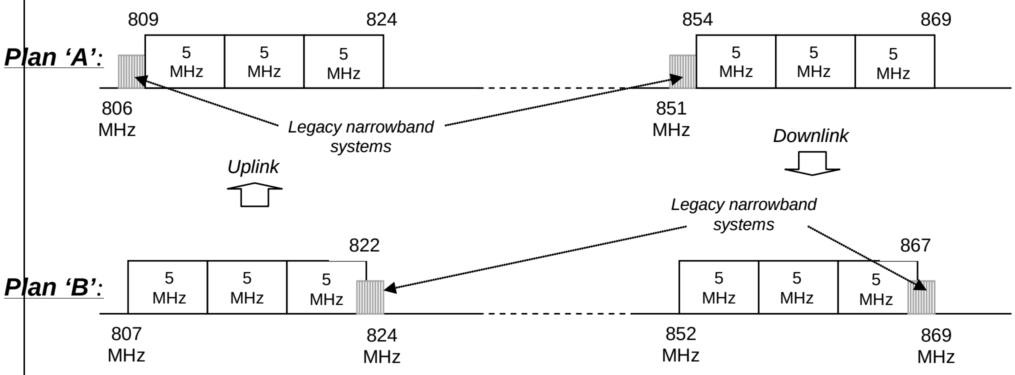
Centre frequency of N-th base station receiving channel (MHz):

F_N' = 813.503125 + (N − 1) × 0.00625 N = 1, 2, 3, …, 400.

1.2 Example broadband plan – 806-824/851-869 MHz

The broadband channel plan is based on paired frequencies with mobile station transmitters used in the frequency band 806-824 MHz (uplink) and base station transmitters used in the frequency band 851-869 MHz (downlink).

To allow for possible co-existence with legacy narrowband systems and adjacent broadband channel arrangements, administrations could consider the examples below:



The raster for the wideband channels is 100 kHz, which means that the channel center frequencies are an integer multiple of 100 kHz. The broadband channel bandwidth is an integer multiple of 5 MHz. This provides flexibility for administrations to implement appropriate channel arrangements in accordance with the above Plans 'A' or 'B', or some subset thereof, to suit specific national circumstances. Some administrations may want to use different amounts of broadband and narrowband spectrum than the examples in Plan 'A' or 'B' to allow for transition.

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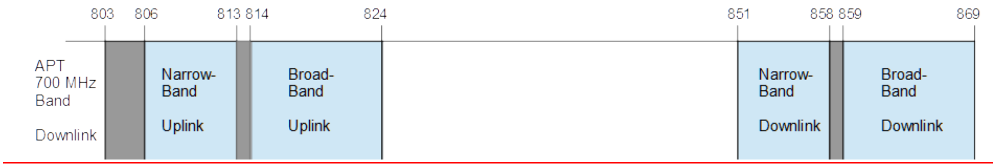
1.3 Example narrowband and broadband in 806-824/851-869 MHz

In Region 3 some countries, in accordance with Resolution **646 (WRC-12)**, have identified the band 806-824/ 851-869 MHz for PPDR in their national plans. With the regional adoption of the APT 700 MHz band plan, these countries wish to deploy broadband PPDR within the band 806-824/ 851-869 MHz and at same time a) provide the necessary spectrum for narrow band PPDR and b) ensure that the downlink of the APT 700 MHz band is protected from adjacent band interference from the uplink transmission of broadband systems operating in the band 806-824/851-869 MHz, particularly in cases where channel sizes of 10+10 or higher band width are use in the APT 700 MHz band.

This example shows how narrowband and broadband systems can be deployed in the band 806-824/851-869 MHz while ensuring the necessary protection of the APT 700 MHz band from adjacent band interference. The sub-band 806-813/ 851-858 MHz is used for narrowband systems with a channel bandwidth of 25 kHz; the sub-band 814-824/ 859-869 MHz is used for broadband (LTE) systems using carrier bandwidths of 5 to 10 MHz. The sub-band 813-814/ 858-859 MHz acts as guard band between narrowband and broadband systems.

1.3.1 Example of frequency arrangement for narrowband and broadband systems



Mobile station/Control station transmit (MHz)	**Base station transmit (MHz)**	**Frequency block**
806-813	851-858	Narrowband PPDR
813-814	858-859	Guard band
814-824	859-869	Broadband PPDR

1.3.2 Example channelisation for narrowband

The channeling plan for the sub-band 806-813/ 851-858 MHz is based on the channel spacing of 25 kHz.

The centre frequency (f_N) of the Nth channel is given by:

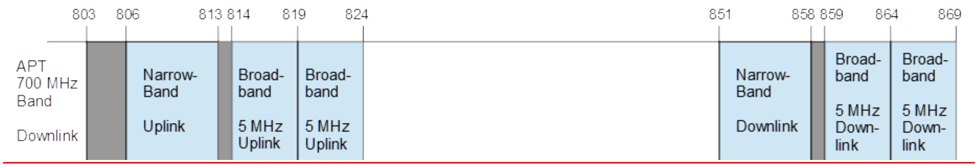
Channel number	**Mobile station transmit Channel centre frequency (MHz)**	**Base station transmit Channel centre frequency (MHz)**	**Channel bandwidth (kHz)**
N = 1 to 280	$f_N = 806.0125 + (0.025) \times (N - 1)$	$f_N = 851.0125 + (0.025) \times (N-1)$	25

1.3.3 Example channelisation for broadband

The channeling plan for broadband is based on a channel bandwidth of 5 MHz or 10 MHz as shown below:

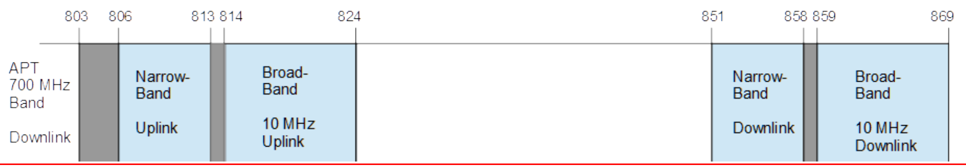
The centre frequency (f_N) of the Nth channel for two 5 MHz channels is given by:

Channel number	**Mobile station transmit Channel centre frequency (MHz)**	**Base station transmit Channel centre frequency (MHz)**	**Channel bandwidth (MHz)**
N = 1 to 2	$f_N = 816.5 + (5) \times (N - 1)$	$f_N = 861.5 + (5) \times (N\text{-}1)$	5



The centre frequency (f_N) of the Nth channel for one 10 MHz channels is given by:

Channel number	**Mobile station transmit Channel centre frequency (MHz)**	**Base station transmit Channel centre frequency (MHz)**	**Channel**
N = 1	f_N = 819	f_N = 864	1



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[PRELIMINARY] DRAFT REVISION OF RECOMMENDATION ITU-R M.1824

Radiocommunication Study Groups

International Telecommunication Union

Source: Annex 17 to Document 5A/543, Doc. 5A/593, Doc. 5A/617

Subject: Resolution ITU-R 59

Revision 1 to
Document 5A/TEMP/255-E
30 October 2014
English only

Working Party 5A
(WG 5A-4)

[PRELIMINARY] DRAFT REVISION OF RECOMMENDATION ITU-R M.1824

System characteristics of television outside broadcast, electronic news gathering and electronic field production in the mobile service for use in sharing studies

(Questions ITU-R 1/58 and ITU-R 7/58)

Summary of the revision

– Editorial updates in the light of the results of RA-12 and WRC-12.

– Added information on operational and technical characteristics that should be used for sharing studies between mobile broadband networks used for ENG applications in the mobile service and other services.

Scope

This Recommendation, dealing with system characteristics of television outside broadcast (TVOB), electronic news gathering (ENG) and electronic field production (EFP) in the mobile service to assist sharing studies, contains the typical operational and technical characteristics of broadcast auxiliary services (BAS)[1], which are required for sharing studies both between the BAS in the mobile service and other radiocommunication services and between mobile broadband networks used for ENG applications in the mobile service and other radiocommunication services.

Keywords

ENG, BAS, SAB, Mobile broadband.

[1] The term "BAS", also known as services ancillary to broadcasting (SAB), is defined in Report ITU-R BT.2069.

The ITU Radiocommunication Assembly,

considering

a) that some administrations operate extensive terrestrial broadcast auxiliary services (BAS) under mobile service allocations;

b) that some administrations are migrating from analogue to digital terrestrial BAS under mobile allocations;

c) that many administrations are likely to operate BAS including both terrestrial analogue and digital electronic news gathering (ENG) and television outside broadcast (TVOB) equipment in the mobile allocations for a reasonable amount of time;

d) that the frequency bands used for these BAS including TVOB, ENG and electronic field production (EFP) are, in many cases, shared by the mobile service and other services;

e) that the technical and operational characteristics of terrestrial BAS deployed under the mobile service are different from those systems deployed under the fixed service;

f) that several types of antennas are used by the BAS operated in various vehicles, and those antennas are controlled in elevation and azimuth during their operation to establish reliable links to the studio;

g) that it is desirable to identify the system parameters and operational characteristics to facilitate sharing with other services,;

h) that ENG applications require low latency and high Quality of Service (QoS) transmission of high-definition video and audio streams for live programs;

i) that ENG applications require reliable connectivity even in the event of a disaster,

recognizing noting

a) that Recommendation ITU-R F.1777 provides dealing with system characteristics of television outside broadcast (TVOB), electronic news gathering (ENG) and electronic field production (EFP) in the fixed service for use in sharing studies;

b) that Report ITU-R BT.2069 addresses –Sspectrum usage and operational characteristics of terrestrial electronic news gathering (ENG), television outside broadcast (TVOB) and electronic field production (EFP) systems;

c) that Resolution ITU-R 59 (2012) resolves to carry out studies on availability of frequency bands and/or tuning ranges for worldwide and/or regional harmonization and conditions for their use by terrestrial electronic news gathering systems"that the World Radiocommunication Conference in 2003 adopted Recommendation 723 recommending the ITU-R study, as a matte of urgency, the technical, operational and frequency issues of ENG on a global basis,

noting

a) that mobile broadband networks can be used for ENG applications when it is advantageous to do so;

b) that Report ITU-R BT.2299 "Broadcasting for public warning, disaster mitigation and relief" provides a compilation of supporting evidence that terrestrial broadcasting plays a critically important role in disseminating information to the public in times of emergencies, *recommends*

1 that the operational and technical characteristicsparameters described in the Annex 1 should be used for sharing studies between BAS deployed in the mobile service in certain bands and other services.;

2 that the operational and technical characteristics provided in Annex 2 should be used for sharing studies between mobile broadband networks used for ENG applications in the mobile service and other services.

ANNEX 1

Operational and technical characteristics of BAS systems deployed in the mobile service

1 Operational characteristics of BAS systems in the mobile service

Broadcasters use several frequency bands and several types of antennas depending on the situation where terrestrial crews send and receive live images. Figures 1 and 2 are examples of link situations. These systems are used for reporting the events of national disasters, contents production outside studio, etc. noting that the timing and location of national disaster events cannot be predicted.

Moreover, since broadcasters need to send the live video of national disasters and the contents which are needed in programme production; the geographical relation between the ENG equipments and collecting station or relay station installed on the helicopter or vehicular cannot be predicted. As a consequence, the antennas of ENG equipment need to point to any azimuth and elevation angle.

Figure 1 shows the example operation for transmitting live video to the collecting station, in order to broadcast the events which occur at the suburban area. In this case, the terrestrial video engineer who controls the microwave equipment points the antenna to the relay station installed on helicopter to avoid terrestrial obstacles. The relay station on the helicopter relays the live video to the collecting station which sends it to the broadcasting studio. The return link is also necessary to allow the terrestrial video engineers to collect information from the broadcasting studio.

Figure 2 shows the example of operation for transmitting live video to the collecting station, in order to broadcast the events which occur at the urban area. In this case, there are several ways to make a microwave link to the collecting station. The camera crew riding on the motorcycle takes the live video, and transmits it to the relay station installed on the vehicle which is also running in front of the motorcycle. In some cases, the relay station installed on the helicopter picks up the video which is transmitted by the camera crew riding on the motorcycle. A low gain antenna is usually used in these cases. The relay station installed on the vehicle also transmits live video to the helicopter which relays it to the collecting station, or directly transmits it to the collecting station by using a high gain antenna.

Broadcasters choose the antenna and frequency band depending on circumstances where the microwave links are to be established.

FIGURE 1

Example of operation for transmitting video to the collecting stations via helicopter

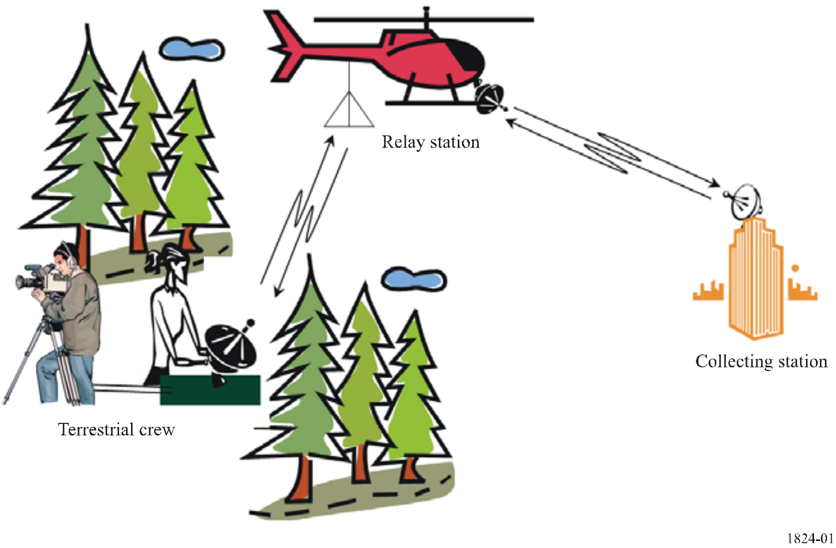
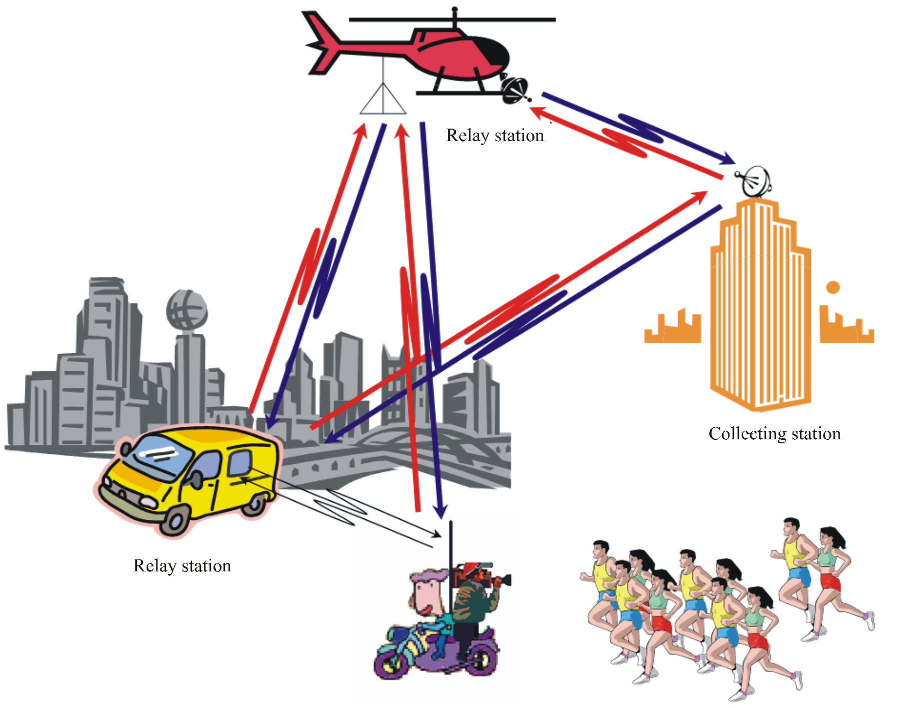


FIGURE 2

Example of operation for transmitting live video to the collecting stations via vehicles



2 Technical characteristics of BAS systems deployed in the mobile service[2]

Table 1 summarizes the technical parameters of BAS video link systems.

Table 2 summarizes the technical parameters of BAS talkback and walkie-talkie[3] systems.

Table 3 summarizes the technical parameters of BAS audio link systems[4].

[2] The radio microphone systems, which are currently operated in the bands 40.68 MHz to 47.27 MHz and 779.125 MHz to 805.875 MHz on a licensed basis in Japan, are not included in this Recommendation.

[3] These systems are used as the BAS audio link application in absence of alternative measures to establish the audio link.

[4] The terminologies of video link, talkback and audio link systems are defined in the Report ITU-R BT.2069.

TABLE 1

Parameters of BAS video link systems operated in the mobile service

Frequency allocation[1]	**770-806 MHz (r2, R3, 5.293)** **790-862 MHz (5.314, 5.316)**	**1 240-1 300 MHz (5.330)** **2 330-2 370 MHz (R1, R2, R3)**		**5 850-5 925 MHz (R1, R2, R3)** **6 425-6 570 MHz (R1, R2, R3)** **6 870-7 125 MHz (R1, R2, R3)**		**10.25-10.45 GHz (R1, R3, 5.480)** **10.55-10.68 GHz (R1, R2, R3)** **12.95-13.25 GHz (R1, R2, R3)**		**41.55-41.95 GHz (r1, r2, r3, 5.551F)**		**Note**
Antenna type and gain	Helix (10-13 dBi)	Helix (10-13 dBi)		Parabolic (22-35 dBi) Helix (10-13 dBi)				Parabolic (38-41 dBi)		H, V or circular polarization
	YAGI (12-19 dBi)	YAGI (12-19 dBi)		Horn (5-20 dBi)				N/A		Circular polarization
	Co-linear (5-6 dBi) Non-directional (2 dBi)	Co-linear (5-6 dBi) Non-directional (2 dBi)		Horn (15-20 dBi) Non-directional (2 dBi)				Horn (19 dBi)		H and V polarization
Tracking method	Automatic or Manual									
Modulation	QPSK-OFDM 16-QAM-OFDM 32-QAM-OFDM	BPSK-OFDM QPSK-OFDM 8PSK-OFDM 16-QAM-OFDM 32-QAM-OFDM 64-QAM-OFDM		QPSK-OFDM 16-QAM-OFDM 32-QAM-OFDM 64-QAM-OFDM				N/A		16-QAM-OFDM is normally adopted
	FM			FM				FM		
Maximum capacity (Mbit/s)	16	30	60	30	60	30	60	N/A	N/A	
Channel spacing (MHz)	9	9	18	9	18	9	18	N/A	N/A	For the digital system
	9	N/A	N/A	N/A	18	N/A	18	33	100	For the FM system
Feeder/multiplexer loss (typical) (dB)	1	1		1	1	1	1	1	1	For both transmitter and receiver

Frequency allocation[(1)]	**770-806 MHz (r2, R3, 5.293)** **790-862 MHz (5.314, 5.316)**	**1 240-1 300 MHz (5.330)** **2 330-2 370 MHz** (R1, R2, R3)				**5 850-5 925 MHz (R1, R2, R3)** **6 425-6 570 MHz (R1, R2, R3)** **6 870-7 125 MHz (R1, R2, R3)**		**10.25-10.45 GHz (R1, R3, 5.480)** **10.55-10.68 GHz (R1, R2, R3)** **12.95-13.25 GHz (R1, R2, R3)**		**41.55-41.95 GHz (r1, r2, r3, 5.551F)**		**Note**
Maximum antenna input power (dBW)	7	11*** 13****		14*** 16****		4	7	4*	7**	0	0	* –6 dBW in 10.60-10.68 GHz by the transmitter power. ** –3 dBW in 10.60-10.68 GHz by the transmitter power. *** 1 240-1 300 MHz **** 2 330-2 370 MHz
e.i.r.p. (maximum) (dBW)	25	29*** 31****		32*** 34****		38	41	38*	41**	40	40	* 29 dBW in 10.60-10.68 GHz. ** 32 dBW in 10.60-10.68 GHz. *** 1 240-1 300 MHz **** 2 330-2 370 MHz
Receiver IF bandwidth (MHz)	9	9		18		9	18	9	18	27	80	
Receiver noise figure (dB)	4	4		4		4	4	4	4	6	6	
Receiver thermal noise (dBW)	–130.5	–130.5		–127.4		–130.5	–127.4	–130.5	–127.4	–123.7	–119.0	
Normal Rx input level (dBW)	–88	SISO –93*	MIMO -103**	SISO –97***	MIMO –100**	–88	–85	–88	–85	–82	–77	* 64-QAM(3/4) ** 16-QAM-MIMO *** 16-QAM(2/3)
Rx input level for 1 × 10^{-3} BER (dBW)	- –120 - –113 –110.7 –	-122.8* -119.6* -115.0* -113.0* -110.0* -107.2*	-123.0* -121.5* -115.5* -111.5* - -	-119.7* -116.5* -111.9* -109.9* -106.9* -104.1*	-119.9* -118.4* -112.4* -108.4* - -	- –120 - –113 –110.7 –108.2	- –116.9 - –109.9 –107.6 –105.1	- –120 - –113 –110.7 –108.2	- –116.9 - –109.9 –107.6 –105.1	N/A	N/A	BPSK-OFDM QPSK-OFDM 8PSK-OFDM 16-QAM-OFDM 32-QAM-OFDM 64-QAM-OFDM *Rx input level for 1 × 10^{-4} BER

TABLE 1 (*end*)

Parameters of BAS video link systems operated in the mobile service

Frequency allocation[1]	**770-806 MHz (r2, R3, 5.293)** **790-862 MHz (5.314, 5.316)**	**1 240-1 300 MHz (5.330)** **2 330-2 370 MHz** (R1, R2, R3)		**5 850-5 925 MHz (R1, R2, R3)** **6 425-6 570 MHz (R1, R2, R3)** **6 870-7 125 MHz (R1, R2, R3)**		**10.25-10.45 GHz (R1, R3, 5.480)** **10.55-10.68 GHz (R1, R2, R3)** **12.95-13.25 GHz (R1, R2, R3)**		**41.55-41.95 GHz (r1, r2, r3, 5.551F)**		**Note**
Rx input level for CNR = 27 (dB)	–103.5	N/A	N/A	N/A	–100.4	N/A	–100.4	–96.7	–92.0	For FM system
Nominal long term interference (dBW)	–140.5	–140.5	–137.4	–140.5	–137.4	–140.5	–137.4	–133.7	–129.0	
Spectral density (dB(W/MHz))	–150.0	–150.0	–150.0	–150.0	–150.0	–150.0	–150.0	–148	–148	

[1] Each table contains the letters “R1”, “R2” and “R3”, “r1”, “r2”, “r3”, and the reference to footnote 5.xxx. The letters “R1”, “R2” and “R3” stand for the ITU-R Region which has a primary mobile allocation to the specified frequency band, the letters “r1”, “r2” and “r3” stand for the ITU-R Region which has a secondary mobile allocation to the specified frequency band, and the reference to footnote 5.xxx refers to the country footnote in the table of frequency allocations.

TABLE 2

Parameters of BAS talkback/walkie-talkie* systems operated in the mobile service

Frequency allocation(1)	**26.574 MHz (R1, R2, R3)**	**143-144 MHz (5.211, 5.212, R2, R3) 146-148 MHz (R1, 5.217, R3) 148-149.9 MHz (R1, R2, R3) 149.9-150.05 MHz (5.223) 150-156.7625 MHz (R1, R2, R3) 156.8375-174 MHz (R1, R2, R3)**	**166.5-166.9 MHz (R1, R2, R3) 168.5-168.9 MHz (R1, R2, R3)**	**459.5125-460 MHz (R1, R2, R3) 469.5-470 MHz (R1, R2, R3)**
Antenna type and gain	Co-linear, 8 dBi for base station (BS), non-directional, 2 dBi for mobile station (MS)			
Modulation	SSB	FM	RZ-SSB	FM
Channel spacing (kHz)		20	6.25	25
Feeder/multiplexer loss (typical) (dB)	Tx: 1.5 (BS), 0 (MS) Rx: 1.5 (BS), 1 (MS)	Tx: 1 (BS), 0 (MS) Rx: 1	Tx: 4 (BS), 0 (MS) Rx: 1	Tx: 1 (BS), 0 (MS) Rx: 1
Maximum antenna input power (dBW)	17 (BS), 14 (MS)	17	17	13
e.i.r.p. (maximum) (dBW)	17.5 (BS), 16 (MS)	24 (BS), 19 (MS)	21(BS), 19 (MS)	20 (BS), 15 (MS)
Receiver IF bandwidth (kHz)	3	12/ 16	3.4 /5.8	12/16
Receiver noise figure (dB)	4	4	4	4
Receiver thermal noise (dBW)	–165.0	–159.0/–157.7	–164.5/–162.2	–159.0/–157.7
Minimum Rx input level (dBW)	–147	–147.1/–145.9	–146.5/–144.2	–147.1/–145.9
Nominal long term interference (dBW)	–175.0	–169.0/–167.8	–174.5/–172.2	–169.0/–167.8
Spectral density (dB(W/kHz))	–179.8	–179.8	–179.8	–179.8
Audio frequency range	300 Hz-3 000 Hz	300 Hz-3 400 Hz	300 Hz-3 400 Hz	300 Hz-3 400 Hz

* These systems are used as the BAS audio link application in absence of alternative measures to establish the audio link.

Each table contains the letters "R1", "R2" and "R3", "r1", "r2", "r3", and the reference to footnote 5.xxx. The letters "R1", "R2" and "R3" stand for the ITU-R Region which has a primary mobile allocation to the specified frequency band, the letters "r1", "r2" and "r3" stand for the ITU-R Region which has a secondary mobile allocation to the specified frequency band, and the reference to footnote 5.xxx refers to the country footnote in the table of frequency allocations.

NOTE 1 – Antenna height and altitude above sea level of base stations will be required for sharing studies. For example, the antenna height more than 20 m and the altitude above sea level more than 1 000 m are used in some cases.

TABLE 3

Parameters of BAS audio link systems operated in the mobile service

Frequency allocation[(1)]	**38.96 MHz (R1, R2, R3)**	**164-167 MHz (R1, R2, R3)**	**462-465 MHz (R1, R2, R3)**	**3 405-3 423 MHz (r1, r2, r3, 5.432)**
Antenna type and gain	Non-directional (2 dBi)	Yagi (13 dBi) Non-directional (2 dBi)	Yagi (13 dBi) Non-directional (2 dBi)	Parabolic (22-26 dBi)
Modulation	FM AM	FM		
Channel spacing (kHz)	–	240	240	1 000
Feeder/multiplexer loss (typical) (dB)	Tx: 0 Rx: 1	Tx: 0 Rx: 1	Tx: 0 Rx: 1	Tx: 1 Rx: 1
Maximum antenna input power (dBW)	17	17	13	0
e.i.r.p. (maximum) (dBW)	19	30	26	25
Receiver IF bandwidth (kHz)	16/30	100	100	400
Receiver noise figure (dB)	4	4	4	4
Receiver thermal noise (dBW)	–157.8/–155.1	–149.8	–149.8	–139.8
Minimum Rx input level (dBW)	–125.7/–123	–123	–123	–95
Nominal long term interference (dBW)	–167.8/–165.1	–159.8	–159.8	–149.8
Spectral density (dB(W/kHz))	–179.9	–179.9	–179.9	–179.9
Audio frequency range	7 kHz	10 kHz	10 kHz	17 kHz

(1) Each table contains the letters “R1”, “R2” and “R3”, “r1”, “r2”, “r3”, and the reference to footnote 5.xxx. The letters “R1”, “R2” and “R3” stand for the ITU-R Region which has a primary mobile allocation to the specified frequency band, the letters “r1”, “r2” and “r3” stand for the ITU-R Region which has a secondary mobile allocation to the specified frequency band, and the reference to footnote 5.xxx refers to the country footnote in the table of frequency allocations.

NOTE 1 – Antenna height and altitude above sea level of collecting radio stations will be required for sharing studies. For example, the antenna height more than 20 m and the altitude above sea level more than 1 000 m are used in some case.

ANNEX 2

Operational and technical characteristics of mobile broadband networks for ENG applications

1 Operational characteristics of mobile broadband networks used for ENG applications in the mobile service

Until recently, ENG applications used specialized systems. However, with recent advances in technology, commercial systems have evolved and now are able to fulfill the requirements of ENG in some cases. Therefore, they can be used when it is advantageous to do so. It has already been demonstrated in a number of instances.[5]

In addition to meeting the demands of media consumers, mobile broadband networks can also support wireless feeds for news gathering applications for program development in the domain of Electronic News Gathering/Outside Broadcasting services (ENG/OB). This mobile broadband application provides real time feeds for broadcasting; the users could be professionals (e.g., camera people on a motorcycle following an event and transmitting the feed using LTE) or the general public (e.g., people with mobile broadband devices sending videos to newspapers and broadcasters). Suitably configured LTE networks enable the transmission of high-definition (HD) video streams from live cameras with the low latency and high quality required for studio feeds.

Compared to using alternative dedicated/transportable links for ENG/OB, such ENG/OB feeds over LTE networks can be more readily setup with less overhead. The LTE quality of service framework can ensure priority for the ENG/OB services above other types of traffic in the LTE network, thereby providing carrier-grade performance.

It should be noted that commercial communication networks would need to meet the quality of service requirements of ENG, including guaranteed throughput and latency in case of traffic congestion.

The applicable Recommendation for mobile broadband standards is Recommendation ITU-R M.1801, "Radio interface standards for broadband wireless access systems, including mobile and nomadic applications, in the mobile service operating below 6 GHz".

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[5] This has been demonstrated in several events, including:

- the Swedish Crown Princess Royal Wedding in 2010, where Swedish TV companies broadcasted live from the celebrations in Stockholm, as well as the video feeds being available live from the official website of the wedding;
- YouTube streamed the entire wedding event of Prince William and the Duchess of Cambridge live from The Royal Channel, which was built specifically for this event. BBC provided full streaming of the event on its own BBC News' dedicated wedding site. It was possible to watch the entire event live on a smartphone or other Internet devices, such as tablets.

2 Technical characteristics of mobile broadband networks used for ENG applications in the mobile service

The technical characteristics to be used in sharing studies are found in Report ITU-R M.2116 "Characteristics of broadband wireless access systems operating in the land mobile service for use in sharing studies."

This Report provides characteristics for a number of terrestrial broadband wireless access (BWA)[6] systems, including mobile and nomadic applications, operating, in the mobile service for use in sharing studies between these terrestrial BWA systems and other fixed or mobile systems. It contains technical and operational characteristics of mobile BWA[7] systems to be used for sharing studies for both mobile stations and base stations.

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6 "Wireless access" and "BWA" are defined in Recommendation ITU-R F.1399.

7 BWA radio interface standards can be found in Recommendation ITU-R M.1801 – Radio interface standards for broadband wireless access systems, including mobile and nomadic operations, in the mobile service operating below 6 GHz.

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Working document toward a preliminary draft new recommendation ITU-R M.[V2X]

Radiocommunication Study Groups

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Working Party 5A
(Sub-Working Group 5A5-1)

[PRELIMINARY] DRAFT NEW REPORT ITU-R M.[LMS.CRS2]

Cognitive radio systems (CRSs) in the land mobile service

(Question ITU-R 241-2/5)

TABLE OF CONTENTS

Page

1 Scope

This Report addresses cognitive radio systems (CRSs) in the land mobile service (LMS) above 30 MHz (excluding IMT). This Report presents the existing, emerging and potential applications employing CRS capabilities and the related enabling technologies, including the impacts of CRS technology on the use of spectrum from a technical perspective. The description of such technologies, operational elements and their challenges are also presented. Furthermore this Report provides high level characteristics, operational and technical requirements related to CRS technology, their performances and potential benefits. Finally, factors related to the introduction of CRS technologies and corresponding migration issues are discussed.

2 Introduction

Cognitive radio systems (CRSs) are expected to be a driver of innovation and development of future wireless systems. CRSs would be one of the foreseen technical solutions to address the growing traffic demand in the future. CRSs could allow more efficient use of radio resources including limited spectrum resources, compared with conventional radiocommunication systems.

Report ITU-R M.2225 gives an introduction to CRSs in the land mobile service addressing technical features and capabilities, potential benefits and challenges. A description of deployment scenarios for CRSs was also introduced. The key technical features and capabilities of a CRS as identified in Report ITU-R M.2225 and Report ITU-R SM.2152 are:

– the capability to obtain knowledge of its radio operational and geographical environment, its internal state and established policies, as well as to monitor usage patterns and users' preferences;

– the capability to dynamically and autonomously adjust its operational parameters and protocols according to the knowledge in order to achieve predefined objectives; and

– the capability to learn from the results of its actions to further improve its performance.

Due to rapidly increasing wireless traffic and the need for a larger amount of spectrum, studies in LMS have identified important aspects related to the use of CRS technologies. CRS technologies could be an enabler for spectrum sharing and radio resource management on a more dynamic basis, thus providing increased spectral efficiency and mitigating the problem of congestion, e.g., through enhancing capacity.

As described in Report ITU-R M.2225, CRSs may provide several benefits to both system operators and end users, however, the extent of the benefits and suitability of CRS technologies depends on the deployment scenarios and use cases for these systems as well as the technical conditions of CRS operation.

In principle, the introduction and deployment of CRS can take place without the need for any changes to the Radio Regulations. In addition to that, as stated in Report ITU-R M.2225, it should be noted that any system of a radiocommunication service that uses CRS technology in a given frequency band will operate in accordance with the provisions of the Radio Regulations governing the use of that band. A CRS is not a radiocommunication service, but a set of technologies that in the future may be implemented in a wide range of applications in the LMS. However the deployment of CRSs in the LMS may require identification of unique and detailed characteristics such as security mechanisms to ensure appropriate operation which can be achieved by future studies and further technical analysis.

This Report focuses on the applications of CRSs in the land mobile service. It provides a detailed description of CRS capabilities and enabling technologies as well as the relationship between them. It describes also the key technical features related to these technologies as enablers for enhanced sharing and coexistence as well as more efficient use of resources. It also discusses the impact of CRSs on the use of spectrum from a technical perspective. The report describes the high level characteristics, operational and technical requirements of a CRS. As well general performance criteria and metrics are presented in this report to help the performance evaluation of LMS radio system employing CRS technology. In this report the initial set of potential benefits introduced in Report ITU-R M.2225, are further expanded. Furthermore, factors related to the introduction of CRS technologies are discussed in addition to related migration issues.

3 Related documents

3.1 ITU-R Recommendations

ITU-R F.1110 Adaptive radio systems for frequencies below about 30 MHz.

ITU-R F.1337 Frequency management of adaptive HF radio systems and networks using FMCW oblique-incidence sounding.

ITU-R F.1611 Prediction methods for adaptive HF system planning and operation.

ITU-R F.1778 Channel access requirements for HF adaptive systems in the fixed service.

ITU-R M.1652 Dynamic frequency selection (DFS) in wireless access systems including radio local area networks for the purpose of protecting the radiodetermination service in the 5 GHz band.

ITU-R M.1739 Protection criteria for wireless access systems, including radio local area networks, operating in the mobile service in accordance with Resolution **229 (WRC-03)** in the bands 5 150-5 250 MHz, 5 250-5 350 MHz and 5 470-5 725 MHz.

ITU-R SM.1266 Adaptive MF/HF systems.

3.2 ITU-R Reports

ITU-R M.2034 Impact of radar detection requirements of dynamic frequency selection on 5 GHz wireless access system receivers.

ITU-R M.2117 Software-defined radio in the land mobile, amateur and amateur satellite services.

ITU-R M.2225 Introduction to cognitive radio systems in the land mobile service.

ITU-R M.2242 Cognitive radio systems specific for IMT systems.

ITU-R SM.2152 Definitions of software-defined radio (SDR) and cognitive radio system (CRS).

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4 Definitions and terminology

The following definition and terms are used in the Report.

4.1 Definitions

Cognitive radio system (CRS): A radio system employing technology that allows the system to obtain knowledge of its operational and geographical environment, established policies and its internal state; to dynamically and autonomously adjust its operational parameters and protocols according to its obtained knowledge in order to achieve predefined objectives; and to learn from the results obtained. (See Report ITU-R SM.2152.)

Software-defined radio (SDR)

A radio transmitter and/or receiver employing a technology that allows the RF operating parameters including, but not limited to, frequency range, modulation type, or output power to be set or altered by software, excluding changes to operating parameters which occur during the normal pre-installed and predetermined operation of a radio according to a system specification or standard. (See Report ITU-R SM.2152.)

Further information on SDR can also be found in Report ITU-R M.2117. The conceptual relationship between SDR and CRS is described in Annex A.

4.2 Terminology

For the purpose of this report, the following terms have the meanings given below.
However, these terms do not necessarily apply for other purposes.

Coexistence

Coexistence refers to the situation where two or more radio systems operate in adjacent frequency bands.

Node

Node refers to a generic network element (e.g. a base station, an access points, radio terminals, core network element) that is involved in the related network operations. (See Report ITU-R M.2225.)

Policy

a) A set of rules governing the behavior of a system,

b) A machine interpretable instantiation of policy as defined in (a).

NOTE 1 – Policies may originate from regulators, manufacturers, network and system operators. A policy may define, for example, waveforms, radio resource control, and power levels.

System users may also be able to define preferences as long as they are consistent with the operator and regulatory policies.

NOTE 2 – Policies are normally applied post manufacturing of the radio as a configuration to a specific service application.

NOTE 3 – b) recognizes that in some contexts the term "policy" is assumed to refer to machine-understandable policies. (See Report ITU-R M.2225.)

Spectrum Sharing

Spectrum sharing refers to the situation where two or more radio systems use the same frequency band.

TV White space

A portion of spectrum in a band allocated to the broadcasting service and used for television broadcasting that is identified by an administration as available for wireless communication at a given time in a given geographical area on a non-interfering and non-protected basis with regard to other services with a higher priority on a national basis. (See Report ITU-R M.2225.)

5 Applications

The CRS capabilities encompass a number of techniques that can be applied to different wireless systems. A CRS can offer several benefits to system operators and end users, such as improved efficiency of spectrum use, additional flexibility, self-correction and potential for new mobile communication applications as discussed in Report ITU-R M.2225.

Actually, there are already existing applications (i.e. radio local area networks (RLANs) using Dynamic Frequency Selection (DFS)) or planned applications (i.e. radio systems using TV White Space) that employ some of the CRS capabilities in order to obtain knowledge of their radio environment. Based on the obtained knowledge they are able to select parameters such as their frequencies and/or adjust their transmit power to enhance coexistence and sharing with the aim of avoiding harmful interference being caused.

CRSs may share spectrum with other radio systems that are not necessarily CRSs, as well as with other CRSs. In this context, pertaining only to sharing involving CRSs, sharing as referenced in section 4.2 can be described as follows:

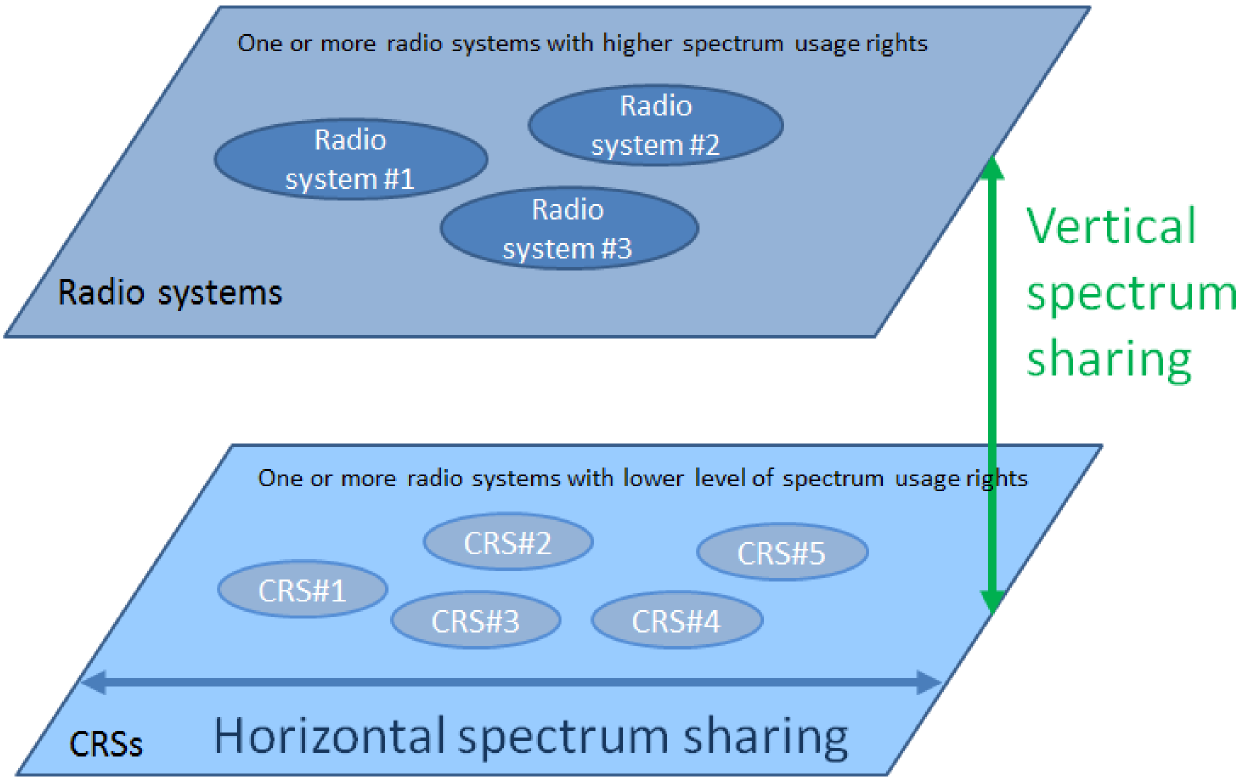
– vertical spectrum sharing: The case where one or more radio systems with CRS capabilities share the band of another radio system that does not necessarily have CRS capabilities. The radio systems with CRS capabilities are only allowed to utilise frequencies within the band as long as the other radio system is not affected by harmful interference from the CRSs;

– horizontal spectrum sharing: The case where multiple radio systems with CRS capabilities are accessing the same shared spectrum band.

A graphical illustration of vertical and horizontal spectrum sharing is given in Figure 1. In this illustration, vertical sharing refers to situation where CRS(s) with lower level of spectrum usage rights share spectrum band with radio systems having higher spectrum usage rights. One example of this kind of sharing is the use of TV white spaces as discussed in section 5.1.2. It should be noted that radio systems with higher spectrum usage rights may also possess CRS capabilities. As well, the figure illustrates the horizontal sharing that could also take place between radio systems with/without CRS capabilities at the same level of spectrum usage rights.

FIGURE 1

Vertical and horizontal spectrum sharing involving CRSs



Vertical and horizontal spectrum sharing are not mutually exclusive and both of them are present in the examples of applications employing CRS capabilities that will be given in this section. Vertical and horizontal spectrum sharing can also exist separately.

Coexistence essentially refers to the interference issues that a CRS operating in a certain band may imply on another radio system (that is not necessarily a CRS) that operates in the adjacent bands.

The technical description of sharing and coexistence may find specific applications according to the deployment scenarios described in Report ITU-R M.2225. Each application may have different implications on sharing and coexistence aspects.

In this section, existing and emerging applications as well as potential applications for the future are reviewed.

5.1 Existing and emerging applications employing CRS capabilities

There are already examples of existing or emerging applications employing CRS capabilities, such as obtaining knowledge with spectrum sensing and geo-location with access to database. These example applications can also make decisions and adjust their operational parameters based on the obtained knowledge.

Both examples that are introduced in this section represent opportunistic access of spectrum as defined in ITU-R Report M.2225: an existing example is the RLAN using 5 GHz band and the emerging application is the TV White Space usage.

5.1.1 5 GHz RLANs utilizing dynamic frequency selection (DFS)

RLANs can operate in the 5 250-5 350 MHz and 5 470-5 725 MHz bands on a co-primary basis with radiolocation systems and radars. RLANs operate within the mobile service allocation and radars in the radiolocation service allocation, both having a co-primary status. In this band, Radio Regulations have been adopted by the ITU (cf. Resolution **229 (WRC-03)**) to facilitate sharing between the two systems with the aid of a DFS protocol (cf. Recommendation ITU-R M.1652). This protocol specifies the sensing/detection and operational techniques to be used by the RLANs to avoid interference to the radar systems. Recommendation ITU-R M.1739 provides the protection criteria. Prior to operation, RLANs are required to use DFS to ensure that radiolocation systems are not operating in the same channel they intend to use. The mobile systems must also vacate channels when new radiolocation systems come into operation.

5.1.2 Use of TV white space

Due to various reasons some channels have had to be left unused by TV applications to provide guard bands between the active broadcast channels. The guard bands have been needed to accommodate TV receiver characteristics for strong or weak signals and adjacent channel performance. Some channels have also been left unused as there has been limited TV service deployment in some geographic areas.

Recently, some administrations have allowed or are considering to allow license-exempt devices to operate on a non-interfering basis within these TV white spaces. To facilitate spectrum sharing and to protect incumbent services from interference, a variety of technical approaches for the operation in these bands have been considered. These approaches include:

– geo-location capability with access to a database;

– sensing capability.

With respect to the capabilities of a CRS to obtain knowledge of its environment, in the case of TV white spaces the key capability is geo-location coupled with access to a database which in this application is referred to as the TV white space database approach. One administration adopted rules in April 2012 in [1] to allow license-exempt devices employing the TV white space database approach to access available channels in the UHF television bands. That administration has selected several private-sector database managers and announced in the first half of 2012 the public availability of several databases, which were coordinated with local stakeholders. TV white space database functionality for TV white space usage is now available nationwide. The TV white space databases identify channels available for transmission of radio signals from license-exempt devices, register radio transmitting facilities entitled to protection, and provide protection to authorized services and registered facilities as required by that administration, see [2]. Additionally, in late 2012, that administration launched a nationwide registration system for unlicensed wireless microphones. That registration system enables qualifying entities across the nation to register with the TV white space database managers so that the wireless microphones will be protected at specified times from other license-exempt devices operating on unused broadcast TV channels.

Other administrations are also considering defining requirements for the operation of the devices using TV White Spaces. One such administration has developed an approach for license-exempt TV white space access, again, based on the database approach (see [3], as well as links referred to therein), and at the time of writing is undertaking a pilot test of license-exempt devices under these rules [4]. Moreover, this approach has been adopted by ETSI into a European Harmonised Standard (HS), aiming to converge to common approach for TV white space access on a European level [5]. Further details related to this HS can be found in Annex B.

One key difference between this approach and another approach developed in [1] by another non-European administration is that there is a more flexible approach to the transmit power limit of license-exempt devices based on the actual interference caused at the edge to the primary coverage area. This is a different approach to using a fixed transmit power limit irrespective of distance/loss to the edge of primary coverage.

5.2 Potential applications

The following subsections address the potential applications of CRSs. Each of them uses either one or combinations of the deployment scenarios identified in Report ITU-R M.2225.

5.2.1 Cognitive networks exploiting reconfigurable nodes

Cognitive networks are networks in which CRS capabilities are implemented at the infrastructure level. This includes, for example, network elements such as O&M (Operation & Maintenance) and base stations. In particular, a cognitive network is a network that could dynamically adapt its parameters, functions and resources on the basis of the knowledge of its environment.

The potential application of cognitive networks described in this section refers to the scenario outlined in section 5.2 of Report ITU-R M.2225.

In the context of this section, cognitive networks are intended to be deployed using reconfigurable nodes. In principle, the application of such cognitive networks includes the following functionalities and entities (see Figure 2):

− cognitive network management;

− reconfigurable base stations;

− reconfigurable terminals.

The cognitive network management functionality spans different radio access technologies (RATs), managing and controlling the nodes inside the network, with the goal of self-adapting towards an optimal mix of supported RATs and frequency bands. This functionality could act on the basis of some input parameters, for example the available resources, the traffic demand, the capabilities of the mobiles within the network (supported RATs, frequency bands, etc.), the requested bearer services (bandwidth, quality of service (QoS), etc.), etc. In addition, this functionality could exploit a collaborative cognitive radio resource management scheme, where the decision making functions are shared among different network nodes.

In this approach, the reconfigurable base stations (RBSs) are the nodes establishing the cognitive network. The hardware resources of a reconfigurable base station could be dynamically reconfigured in order to be used with different RATs, frequencies, channels, etc., and they could support multi-RAT operation with dynamic load-management.

The reconfigurable terminals are the nodes connecting to the base station in the cognitive network. The software and hardware of a terminal could be reconfigured dynamically. Thus it could support operating on different RATs, frequencies, resource utilization modes, etc. Therefore, the reconfigurable terminals could facilitate the flexible and efficient adaptation of the cognitive network to the dynamic environment. For example, they could support multi-RAT operation, such as joint admission control and vertical handovers to balance the load of different RATs more efficiently.

In addition, cognitive networks enable the introduction of the CRS concepts and technologies in a multi-RAT environment.

The availability of reconfigurable base stations in conjunction with cognitive network management functionalities could give the network operators the means for managing the radio and hardware resource pool with better overall efficiency. This enables the adaption of the network to dynamic variations of network traffic.

The main features of cognitive networks can be summarized as follows:

– the dynamic self-adaptation of the network configuration towards an optimal mix of supported RATs and frequency bands can be achieved by the exploitation of the reconfigurable nodes and the application of cognitive network management functionalities;

– the dynamic self-adaptation (e.g. network configuration) can be based on the traffic patterns variations in time and space for the different deployed RATs;

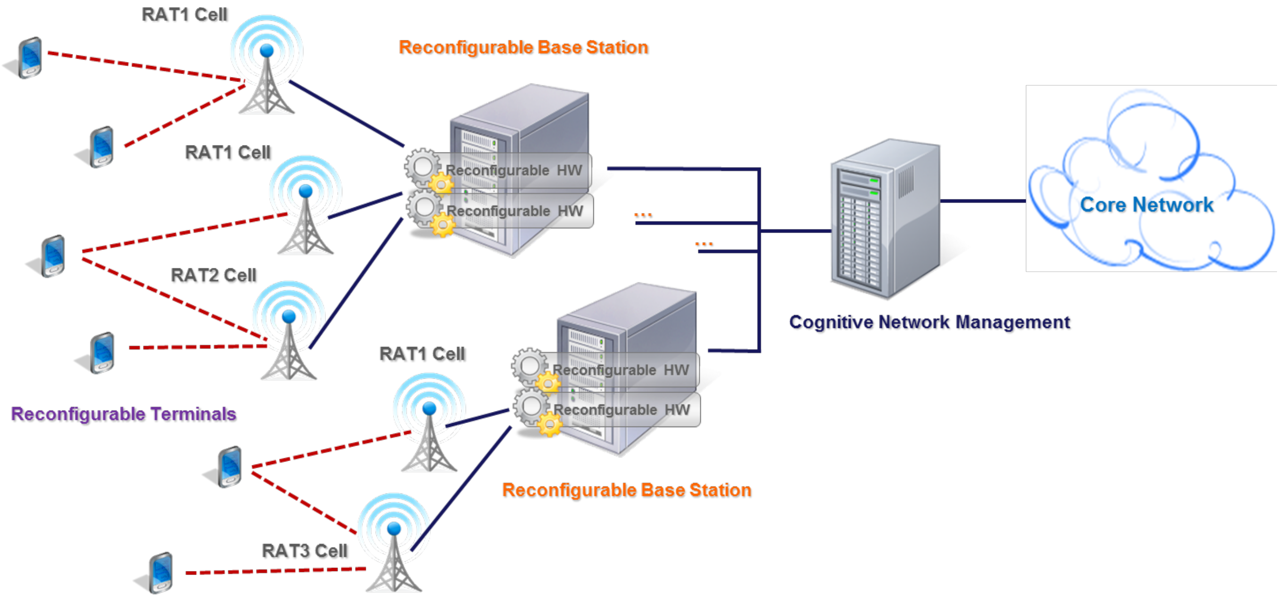
– ability to provide sufficient information to the terminals for initiating a communication session appropriately in a dynamic context (e.g. wireless control channels).

An example of cognitive network application could be the enhancement of spectrum efficiency and high data rate provision based on GSM system frequency reuse. For cellular systems like GSM, in order to ensure that the mutual interference among cells remains below a defined threshold, adjacent cells use different frequencies. However in cells that are separated by a certain distance, frequencies can be reused. On this basis, a cognitive network management could efficiently reuse appropriate GSM frequencies to activate micro cells within the coverage area of a GSM macro cells by using a low transmission power in order to avoid harmful interference to the GSM system. Such micro cells can be deployed using a different radio access technology to provide high date rate transmission [6].

Other examples of higher efficiency of spectrum usage enabled by cognitive networks are reported in Annex C.

FIGURE 2

Cognitive networks functionalities and entities

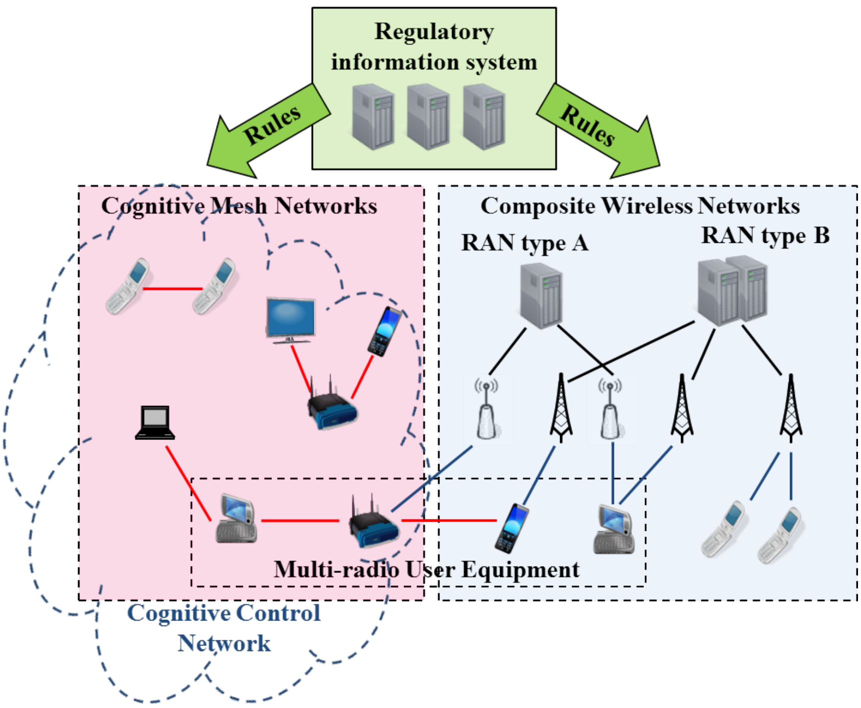


5.2.2 Cognitive mesh networks

In addition to the centralized concept described in the section 5.2.1, decentralized CRS concept may also be considered as illustrated in the left part of Figure 3 [7].

FIGURE 3

Centralized and decentralized CRS concepts



In Figure 3, Multi-radio User Equipment (MUE) represents a user device with reconfigurable radio capabilities and ability to have connections to multiple radio networks at the same time. Such radio networks can be identified as i) Composite Wireless Network (CWN) representing a set of radio networks operated by a network operator using a common network management system that may also have cognitive capability (see section 6.2.1), and ii) Cognitive Mesh Networks (CMNs).
In general, mesh networks can be seen as a group of nodes which all communicate with each other creating a mesh typically using short-range radios. Every node can send and receive messages, but the nodes may also function as routers. CMNs introduce the possibility to use opportunistic spectrum access in collaborative manner so that different CMNs active in the same geographical area can coordinate their use of radio frequencies. Interworking between CMNs may be arranged in a decentralized manner by using logically separate Cognitive Control Network (CCN) to exchange information between CMNs. CCN may be implemented with the Cognitive Control Channel (CCC) which is described in section 6.1.1.1.

It should be noted that a MUE could be simultaneously connected to both CMN and CWN, however, the CMN domain is separated by the CWN domain, in terms of used radio frequencies and RATs. Inside CMN domain, MUEs do not act as relay entities towards CWN for others MUEs, while each of them may connect directly to CWN by the appropriate RAT [7].

5.2.3 Heterogeneous system operation using CRS capabilities

In a heterogeneous network environment, CRS capabilities provide users with the optimal wireless access that best suits the users' needs as well as operators' objectives towards efficient use of radio resource and spectrum. CRS capabilities can be utilized for handover across different RATs and across different systems. In the following, the use of the CRS capabilities to enhance the handover operations within an operator's networks is considered first, followed by a multi-operator situation.

5.2.3.1 Intra-system inter-RAT handover

Intra-system handover is considered within heterogeneous radio environment, where multiple RATs are deployed by a single operator on one or different frequency bands assigned to it, for example an operator deploys two different radio interface technologies within a single Radio Access Network (RAN) of a cellular system. In order to implement such intra-system handover functionality, the capabilities of a CRS and its enabling technologies described in section 6 could be exploited by the system.

When a terminal in connected mode moves close to the cell edge of a RAT, it needs to handover to another cell. The candidate cell to handover may be the same type of RAT, or may also be different types of RATs. Therefore, the intra-system handover functionality may consist of RAT discovery, RAT selection, and terminal reconfiguration. For example, a terminal discovers available RATs and selects an optimal RAT among them by obtaining knowledge of its operational and geographical environment, its internal state and the established policies provided by the network operator.
After an optimal RAT is selected, the terminal adjusts its parameters and protocols dynamically and autonomously according to its obtained knowledge and the network policies by reconfiguration procedure and executes the handover to the selected RAT. There may be cooperation between terminals and wireless networks for the universal access functionality to find an optimal wireless access.

A possible functional architecture for the intra-system handover based on IEEE P1900.4 [8] and IEEE802.21 [9] is reported in Figure 4. Entities described IEEE P1900.4, for example Network Resource Manager (NRM), Terminal Resource Manager (TRM) and Cognitive Base Station (CBS), are applied for the optimization of radio resource management and an entity from IEEE802.21, i.e. entity which has Media Independent Handover Function (MIHF), is used as a toolbox for handover between heterogeneous radio access networks. A terminal may have various kinds of RATs through software-defined radio (SDR) technology and it reconfigures its parameters in order to access an optimal RAT determined by the universal access functionality. Context information of the core network is transferred to terminals through cognitive pilot channels (CPC), which are used for RAT discovery and selection procedures whenever terminals require context information of access networks as described in more detail in section 6.1.1.2.

Another example of intra-system handover application is shown in Figure 5, where one operator deploys multiple radios systems on different frequency bands. These systems have different coverage areas from small to large cell. The resource manager collects the radio operational environment information from the base stations and user terminals on the geo-location basis, which is one of CRS capabilities (i.e. obtaining knowledge). The radio environment information may include the information of signal strength, throughput, and transmission delay. The resource manager provides the information to the control equipment. Based on this information, the control equipment selects the appropriate connectivity for the user terminal, which is another CRS capability (decision and adjustment).

FIGURE 4

Functional architecture for Inter-RAT handover

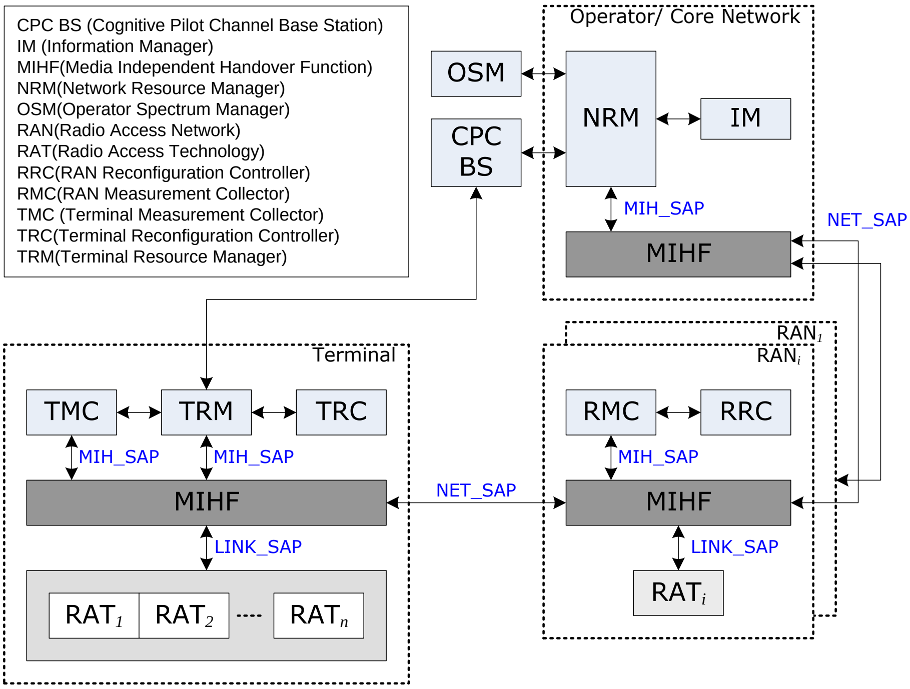
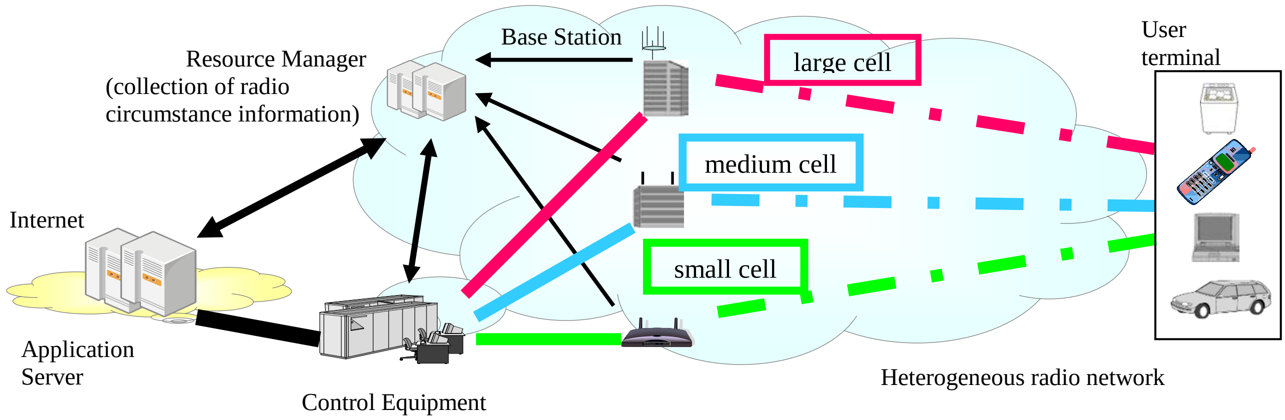


FIGURE 5

Network configuration consisting of multiple RATs



5.2.3.2 Inter-system handover

Inter-system handover is considered within heterogeneous radio environment, where multiple operators operate multiple RATs on different frequency bands assigned to them, for example one operator operates a radio interface technology in a single RAN, i.e. a cellular system while another operator operates an RLAN technology as a public RLAN system. There are many ways to utilize CRS capabilities for inter-system handover, e.g. implementing the capabilities to terminals, base stations, and core networks.

5.2.3.2.1 Inter-system handover using cognitive radio terminals

An example of inter-system handover using cognitive radio terminals is shown in Figure 6 [10] [11] [12]. Some terminals may also have reconfiguration capability. The terminals in this application have capability to support several simultaneous connections with different radio access networks. The solid lines show the data paths and the dotted lines show the signalling. In this example reconfigurable terminal performs an inter-system handover.

The terminal utilizes multiple wireless networks concurrently so that communication bandwidth for applications becomes large. Following terminal movement and/or change of radio environment, suitable wireless link(s) are adaptively and actively utilized in order to keep stability.

Another example is shown in Figure 7 [13]. In this example reconfigurable terminal performs inter-system handover. Decision making is being supported by selecting the appropriate parameters. A common signalling channel between ubiquitous networking server and the terminal, drawn in orange solid line in the figure, is used in order to obtain knowledge in addition to the sensing performed by the terminal. On the other hand, Figure 8 [14] shows the same potential application with different implementation of CRS features. The example implements a dedicated radio system as the common signalling channel shown in an arrow, named Basic Access Network (BAN) in [14], between BAN-BS and BAN-component. Terminals exchange information with management entity on network, named Signaling Home Agent (SHA), for adjusting its parameter and selection of RANs.

FIGURE 6

Inter-system handover using cognitive radio terminals

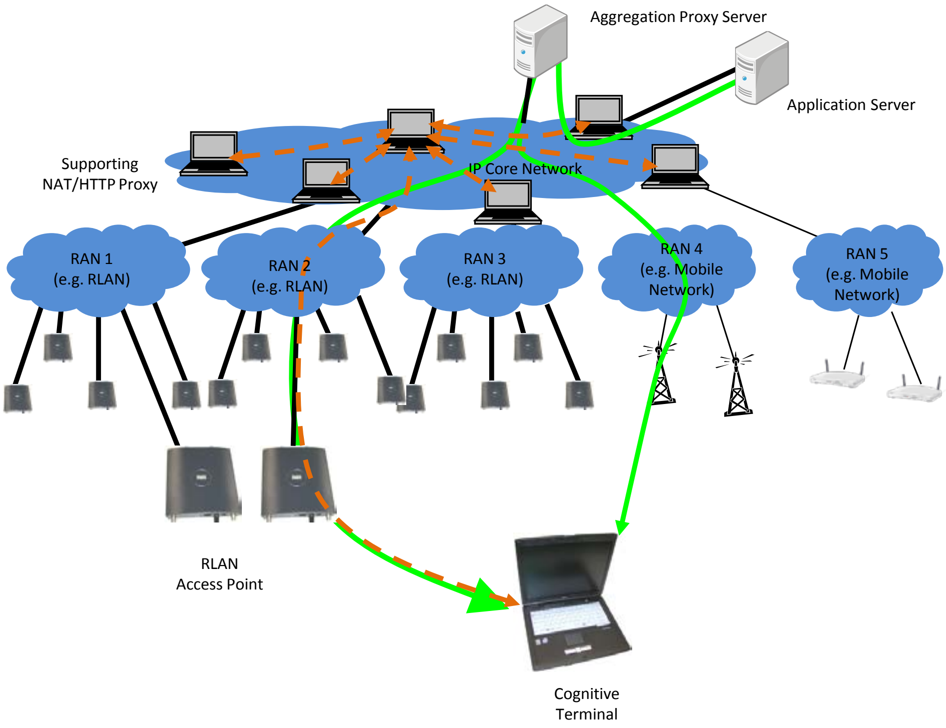


FIGURE 7

Inter-system handover using in-band signaling

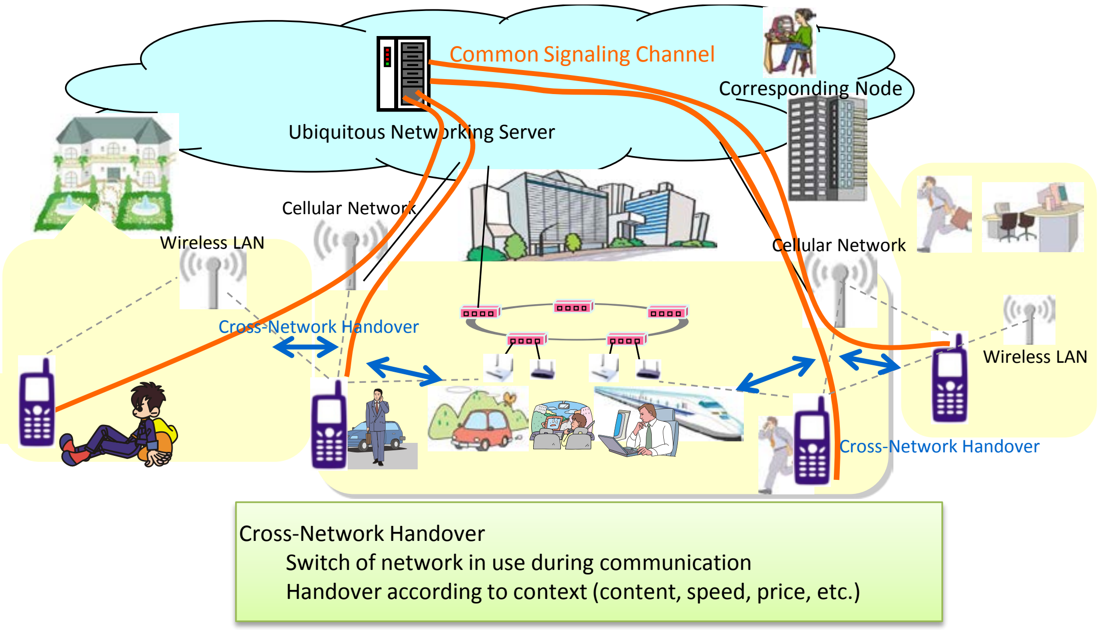
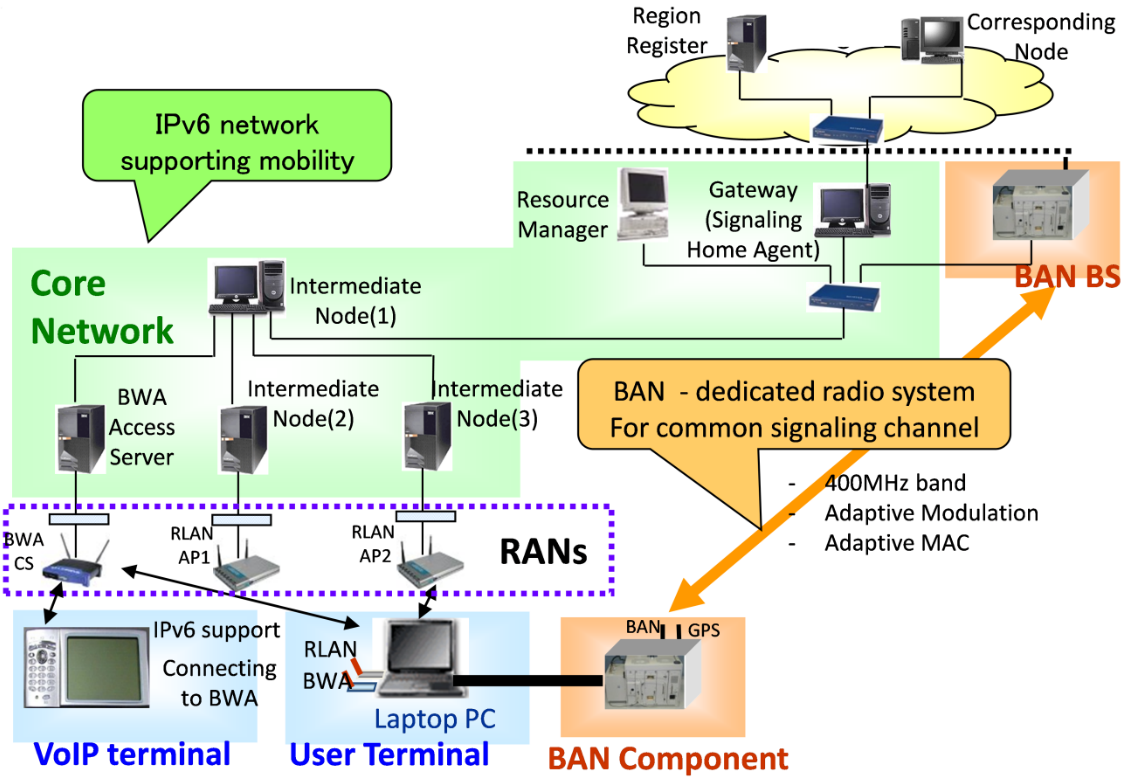


FIGURE 8

Dedicated radio system for signalling



5.2.3.2.2 Inter-system handover using CRS supporting network entities

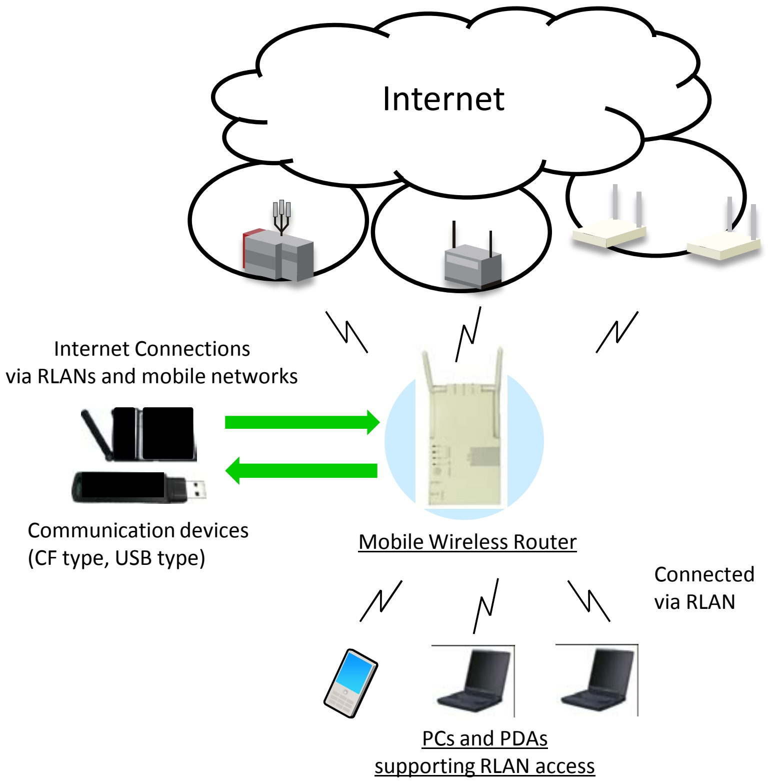
Compared to potential applications in the previous subsection, the applications in this subsection can address terminals without cognitive capabilities. Instead of using CRS supporting terminals, the CRS capabilities are provided by CRS supporting network entities, e.g. mobile wireless router (MWR) which has CRS capability itself and resource manager which realizes CRS capabilities with existing base stations.

An example of MWR application is shown in Figure 9 [15] [16] [17]. In this example MWR reconfigures itself to provide the best suitable service application for its terminals. A mobile wireless router serves as a bridge between multiple radio systems and terminals. Such MWR is required to have a CRS capability to obtain knowledge which RANs (and mobile networks) are available at its location, and also to adjust its operational parameters and/or switch the attaching radio access systems. The thresholds are configured by the obtained users' preferences and they are used for RAN's selection.

The MWR conducts Network Address Translation (NAT) routing between the Internet and local wireless network to which terminals are connected. When the MWR is turned on, the best frequency channel is selected, e.g. based on the lowest interference level. Then the MWR selects and conducts the various RAN authentication procedures according to the selected RAN.

FIGURE 9

Mobile wireless router



5.2.4 Coordinated spectrum access in heterogeneous radio environment

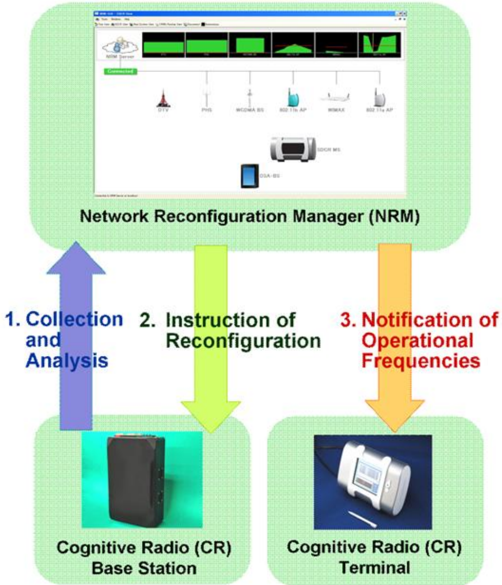
In this section, coordinated spectrum access is considered within a heterogeneous radio environment, where particular frequency band(s) can be shared by several radio systems in order to optimize spectrum usage. Improvement in spectrum usage is based on the fact that different radio systems in the same geographic area at some time intervals may have different levels of spectrum usage.

One possibility in this scenario is that one radio system is not a CRS while another radio system is a CRS. Another possibility is that both radio systems are CRSs.

One example of coordinated spectrum access is shown in Figure 10 [16] [17] based on the example 2 of use case of “Use of CRS technology as an enabler for opportunistic spectrum access in bands shared with other systems and services” described in section 6.4 in Report ITU-R M.2225 combined with “centralized decision making” described in section 6.2.1.1 of the current report. In this example base station and terminals with CRS capabilities of obtaining knowledge can sense the spectrum usage at their location. The sensing information of base station and terminals are gathered to Network Reconfiguration Manager (NRM) [8], which has a CRS capability of decision making. The NRM analyzes the measurements and detects temporary vacant frequency bands. Then, the NRM instructs the base station to reconfigure correspondingly. After the base station reconfigures itself to use these vacant frequency bands and starts its operation, NRM notifies the terminals of the operation frequencies of the base stations.

FIGURE 10

Coordinated spectrum access in heterogeneous radio environment



5.2.5 Vertical and horizontal spectrum sharing enabled by CRS technologies

Potential applications of the vertical and horizontal spectrum sharing are currently under study by several administrations. Such access to shared spectrum is foreseen to be facilitated by CRS technologies and their capabilities. In general, vertical and horizontal sharing application would then allow additional users to access spectrum with existing incumbent usage.

One administration is currently studying the application of vertical and horizontal sharing [18]. Specifically, one application in the 3.5GHz band is intended to make spectrum, when not used by incumbent systems, available for the operations of other radio systems while ensuring the protection of incumbent radio systems from interference using vertical sharing. In this application radio systems with QoS needs (e.g. mobile broadband systems) could be granted exclusive access with respect to other non-incumbent radio systems. Furthermore, the application under study would allow the use of selected portion(s) of the 3.5GHz band by radio systems employing CRSs technology on an opportunistic and non-protected basis, where and when this spectrum is otherwise not in use. In this case, spectrum sharing would be accomplished using horizontal and vertical sharing methods.

In Europe, there is currently an on-going standardization activity to define a solution for vertical sharing in the 2.3-2.4 GHz band [19] between mobile broadband systems and one or more incumbent systems already existing in that spectrum band. The mobile broadband systems are allowed to use the band on a time period or geographical area that it is not being used by the incumbent. This band offers a first possibility to implement a solution that provides both the incumbent and mobile broadband systems a certain QoS by guaranteeing them an exclusive access for a spectrum resource at a given place and at a given time [20]. However, the incumbent maintains higher level of spectrum usage rights and the mobile broadband system needs to evacuate spectrum band if so requested by the incumbent. Thus, unlike the sharing proposal described in the previous paragraph, only two levels of spectrum usage rights are considered and both incumbent and mobile broadband systems are protected from harmful interference.

More specifically, the potential applications depicted above are foreseen to be based on solutions that would include appropriate geo-location and controller functions to enable spectrum sharing between the various radio systems. For example, such solutions would take dynamic inputs from incumbent systems regarding their spectrum usage and protection criteria requirements. Based on such inputs and other factors, the spectrum availability (e.g. described in terms of band, geographical and time constraints) and operational parameters are communicated to the radio systems accessing the shared spectrum.

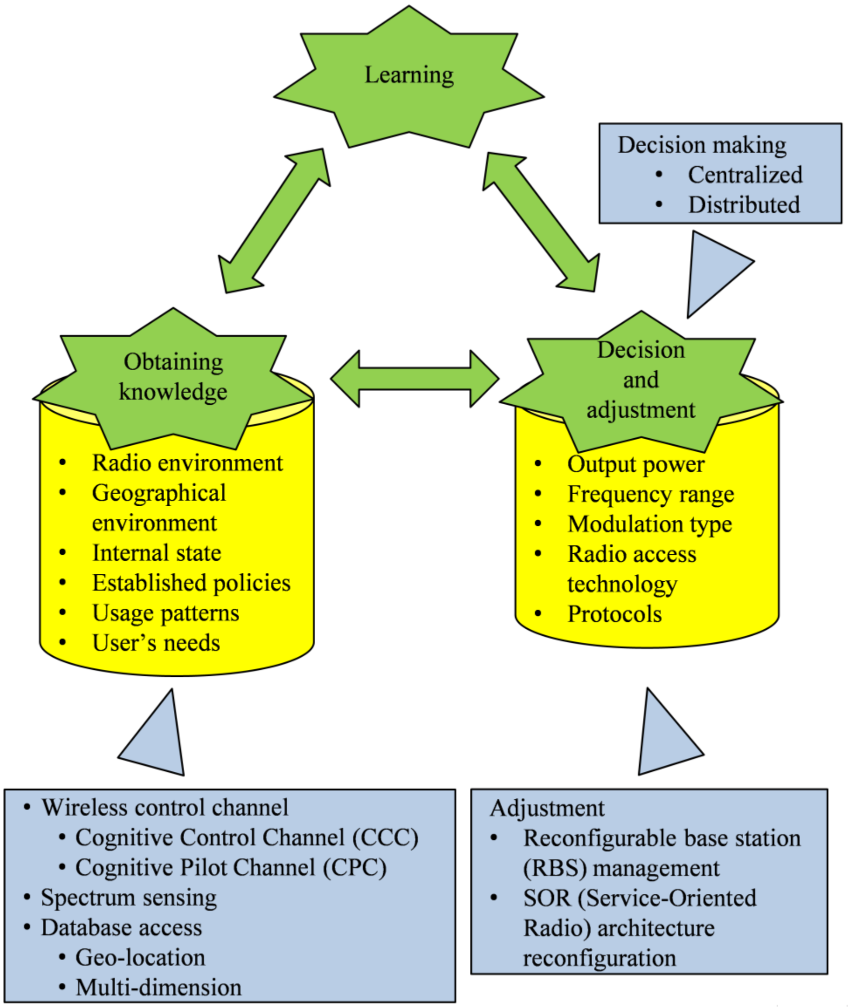
The applications described above have the potential to maximize the efficiency of the overall use of the band, while providing appropriate protection for incumbent systems and other radio systems that could have exclusive access.

6 CRS capabilities and enabling technologies

This section describes examples of enabling technologies, which are part of the CRS capabilities of obtaining knowledge, decision and adjustment, and learning. The deployment scenarios described in Report ITU-R M.2225 as well as the specific applications described in the section 5 of this report, rely on these capabilities. The relationship between these technologies and the CRS capabilities are illustrated in Figure 11. The section further identifies and describes technical features related to these technologies.

FIGURE 11

Example of enabling technologies for CRS capabilities



6.1 Obtaining knowledge

The first key capability of a CRS node is to obtain knowledge of its operational and geographical environment, established policies and its internal state.

Three most commonly suggested methods for obtaining knowledge in a CRS are listening to wireless control channels, spectrum sensing and access to databases. They are covered in detail in the following sections. Also combinations of the methods can be considered.

6.1.1 Listening to a wireless control channel

Control channels could be used for transmitting control information between two or more entities belonging to the systems which use the same spectrum resources. They facilitate more efficient CRS operation, spectrum use and coexistence of different radio systems. One of the key challenges with control channels is to decide how much and what control information should be exchanged to find the balance between the increased overhead and the gain achieved from exchanging that information. There also needs to be a way to ensure the reliability and accuracy of the control information sent on the channel. Following we have two examples of such control channels including Cognitive Control Channels (CCC), and Cognitive Pilot Channels (CPC).

CCCs may enable different CRSs to exchange information related to the local spectrum between each other. The CRS can use the CPC to obtain knowledge of radio operational environment and by doing this the CPC facilitates the efficient operation and spectrum use. It may be possible to use or extend control channels already defined for the existing radio systems operation for cognitive control information exchange.

The purpose of CCC is to enable distributed information exchange directly between the CRS entities which have operation in the same area, whereas CPC conveys elements of the necessary information to let the mobile terminal know e.g. operators, policies, and access technologies and their associated assigned frequencies in a given region to enable efficient RAT discovery and selection. CPC covers the geographical areas using a cellular approach. The focus of CCC is on enhancing coexistence between secondary systems which are using the same available spectrum resources, i.e. the networks operating in the same area and frequency band.

6.1.1.1 Cognitive Control Channel (CCC)

The Cognitive Control Channel (CCC) is a suggested approach for a real time communication channel between different distributed CRS nodes in a specific geographical area. The CCC has been introduced and studied in EU FP7 Project E3 as the Cognitive Control Radio (CCR).
In deliverables [21] and [22] the CCR concept and its functions as an awareness signalling mechanism are described, while analysis and comparison to other awareness signalling mechanisms are reported in [23], [24], and [25]. The CCC is based on the CCR definitions and it is further considered as a coexistence solution in IEEE P802.19.1 [26] and ETSI RRS [27].

The CCC is primarily targeted for enhancing the coordination of the CRS devices. The CCC enables different CRS entities to exchange information related to the sharing and coexistence, spectrum usage rules or policies and/or specific capabilities and needs of different entities.
The CCC may be used for:

– sharing and coexistence – Exchanging the information on the network capabilities and characteristics, network's spectrum need and use, and agreeing spectrum use with other networks in the geographic area;

– cooperative sensing – Agreeing on the common quiet periods for sensing the signal from other radio nodes which are not connected to the CCC, and exchanging spectrum sensing outcomes between the other networks in the area;

– network access – Discovering the networks or devices to connect to, their capabilities and provided services;

– access local policy and etiquette information, e.g. sharing rules for accessing specific bands and local availability of the bands.

These functionalities of CCC are further elaborated in Annex D.

The CCC may be implemented with a physical or a logical channel approach [25]:

– in the physical channel implementation approach a specific physical radio channel targeted for CCC operation is included in the entities exchanging cognitive control information. This enables direct communication between any entities within range on the used physical radio channel;

– in the logical channel implementation approach the CCC operates over any physical radio channel using a transport networking protocol such as Internet Protocol. If the entities, which need to exchange cognitive control information, do not support the same physical radio channel, direct communication between the entities is not possible. Thus, the communication is routed through the other entities, e.g. through internet servers or wireless router nodes. As an example IEEE 802.19.1 assumes logical channel implementation approach for coexistence communication [26].

The CCC can be applied e.g. in a context of heterogeneous networks, consisting of centralized and decentralized CRS concepts, operating in the same area [27]. The CCC enables the networks to share and exchange various information directly with each other to enhance simultaneous operation.

The operational procedure is discussed in more detail in Annex D.

The information which a network may exchange on the CCC can be collected by a combination of means, e.g.:

– querying a local database for spectrum availability;

– spectrum sensing, e.g. estimating spectrum availability or recognizing other spectrum users by evaluating the detected radio waves;

– information received from other CRS entities e.g. over CCC or CPC.

6.1.1.2 Cognitive Pilot Channel (CPC)

The CPC is a pilot channel (physical or logical) that broadcasts radio environment information intended to aid the decision processes of a cognitive terminal in a dynamic and flexible heterogeneous environment including broadcast platforms, as also described in [7], [28], [29], [30], [31], [32], [33], [34], [35] and [36]. The radio environment information includes information with regard to operators, frequency bands, available RATs, services, and load situation etc.

This information can be used to aid a variety of different usage including:

– initial camping[1];

– network association;

– policy distribution;

– simplify inter-system handovers;

– spectrum brokering;

---

[1] Initial camping identifies the procedure followed by a terminal at the start-up in order to select an appropriate network cell.

– pre-emptive access;
– real-time adaptations;
– migration to new standards.

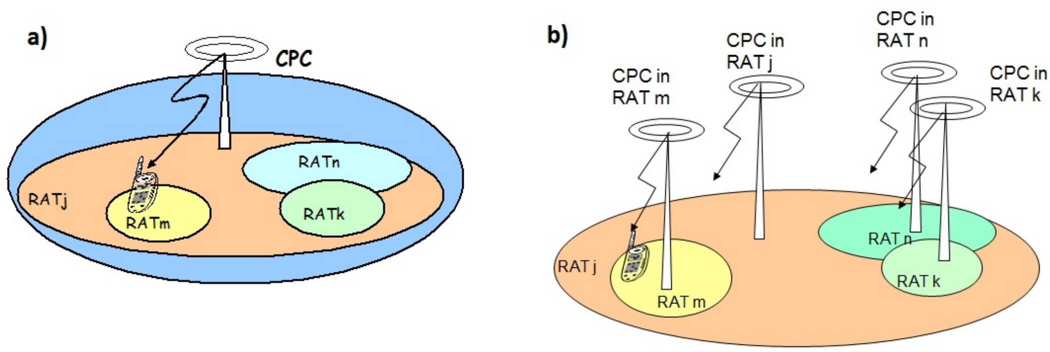
In some proposed radio environment, the CRS capability of the terminal (or possibly, base station) appears to be a crucial point to enable optimisation of radio resource usage.

Indeed, in order to obtain knowledge of its radio environment, a CRS may need to obtain information of the parts of the spectrum within the considered operable frequency range of its radio hardware: it is important that this action is reliable and would be carried out within an acceptable time and with acceptable power-consuming performance. On this basis, the CPC concept consists of conveying the necessary information to let the terminal or base station know the status of radio channel occupancy through a kind of common pilot channel.

In addition, the CPC is anticipated to be conveyed by two approaches: the “out-band” CPC and the “in-band” CPC. The first one, out-band CPC, considers that a channel outside the bands assigned to component RATs provides CPC service. The second one, in-band CPC, uses a transmission mechanism (e.g. a logical channel) within the technologies of the heterogeneous radio environment to provide CPC services. Figure 12 depicts the out-band and in-band CPC deployments while the related characteristics are summarized in Annex E.5. An example implementation using broadcast platforms is reported in Annex E.4.

FIGURE 12

Out-band and in-band CPC deployments



Out-band and in-band CPC approaches are considered to be used jointly by broadcasting the general information over out-band CPC and detailed information over in-band CPC. In principle, the CPC covers the geographical areas using a cellular approach for out-band deployment. While for in-band deployment case, CPC is carried in system resource, e.g. as an extended system information message on broadcast channel of RATs or other resource partition part. With CPC, information related to the spectrum status in the cell's area is broadcast, such as:

– indication on bands currently assigned to cellular-like and wireless systems; additionally, pilot/broadcast channel details for different cellular-like and wireless systems could be provided;
– indication on current status of specific bands of spectrum (e.g. used or unused).

By considering such a CPC, the following advantages are pointed out:

– simplifying the RAT selection procedure;

– avoiding a large band scanning, therefore simplifying the terminal implementation (physical layer) for manufacturers;

– the CPC concept seems particularly relevant for the implementation of DSA/FSM;

– the CPC concept as a download channel could be useful to the operator and user where it is necessary to download a new protocol stack to connect to the network.

Taking into account the description of spectrum use database as described in section 6.1.3, used to store information of spectrum use indicating vacant or occupied frequencies and the rules related to the use of the frequencies in certain locations, the CPC may be used for providing such information to CRS nodes.

Further details related to CPC are reported in Annex E. In particular, CPC operation procedure is described in Annex E.1, its main functionalities in Annex E.2, the geography based implementation of CPC in Annex E.3.

6.1.1.3 Challenges of CCC and CPC

Some challenges arise when considering listening to a wireless control channel for obtaining knowledge of the operational environment.

Various sources in literature have proposed the use of a predetermined common coordination channel for spectrum etiquette, network establishment and adaptation to changing interference environments, see [37] [21] [38]. Local coordination and exchange of information provides low delay and accurate sharing limited to the involved networks.

The CCC usage may increase the power consumption of the devices. The power consumption should be considered carefully and particularly if the nodes are mobile. In such case the challenges related to the power consumption are to limit the signalling overhead and to enable efficient power save mode which still enables low latency information exchange. Thus, it is important to find the optimal amount of exchanged information and the latency for the information exchange.
In addition, in the case the nodes have to connect over the internet, the appropriate network access to be used should be selected.

Further challenges of CCC such as the synchronization between the involved nodes, the contention resolution mechanisms when accessing the spectrum band, and the reliability of the exchanged information should be investigated.

According to [39], the CPC concept could provide the necessary support for obtaining knowledge of the spectrum occupancy. However, also the use of CPC would require further investigations on some technical challenges before being considered as a mature approach, such as: the CPC delivery should strictly satisfy the timing requirements coming from the opportunistic spectrum use;
the CPC content should be updated in a proper timeframe, according to the one related to opportunistic spectrum use.

Arising from the above consideration, it can be concluded that further research and development in order to improve the maturity of both CCC and CPC are needed e.g. in ETSI RRS and IEEE 802.19.1. For this purpose a feasibility study on different approaches and implementation options of control channels for CRSs has been carried out in the scope of [40].

6.1.2 Spectrum sensing

Spectrum sensing is a capability to detect other signals around the CRS node and is one method to determine unused spectrum bands. Spectrum sensing is usable in particular in cases where the level of the detected signal is sufficiently strong, and/or the signal type/form is known beforehand.

Considerable research is focused on sensing techniques, which has resulted in a number of sensing methods, which are described in the following sections.

6.1.2.1 Sensing methods

Currently different spectrum sensing methods are considered for CRSs. These methods include energy detection, matched filtering, cyclostationary feature detection and waveform based detection etc. These existing sensing methods differ in their sensing capabilities, requirements for a priori information, and also their computational complexities. The choice of a particular sensing method can be made depending on sensing requirements, available resource such as power, computational resource and application/signal to be sensed. These sensing methods can also be used in a cooperative way where several CRS nodes do sensing and reporting.

Performance indicators which are related to the impact of different spectrum sensing techniques to other users of the spectrum include e.g. the following:

– Detection threshold for the signals of the existing system

  The minimum signal-to-noise ratio (SNR) which is needed by a spectrum sensing method to achieve a certain probability of detection.

– Pre-determined detected signal intensity

  The minimum detected signal intensity which is needed by a spectrum sensing method to achieve a certain probability of detection.

– Detection time for the signals of the existing system

  The duration which is used by each spectrum sensing method to detect the signals of existing system.

– Detection probability

  Probability that the signal is correctly detected when it is present.

– False alarm probability

  Probability that the signal is detected when it is not present.

– Time between failures in detection

  Average time period between failures in signal detection (i.e. signal is not detected when it is present).

– The lost spectrum opportunity ratio

  The expected fraction of the OFF state (i.e., idle time) undetected by CRS nodes.

– The interference ratio

– The expected fraction of the ON state (i.e., the transmission time of the networks of the existing systems) interrupted by the transmission of CRS nodes.

In Annex F, the description of different sensing methods can be found.

6.1.2.2 Implementation of sensing methods

Currently several implementations of sensing methods are studied. Besides incorporating the sensor directly into the user device, the following implementations are under consideration:

– Dedicated listening devices: A dedicated listening device could be used to detect incumbent systems at a distance if mounted outside such as on a tower or rooftop. CRSs communicate with the dedicated listening device to follow its instructions when the listening device detects the channels that incumbent systems are using. A dedicated listening device could also be used in conjunction with a database as well.

– Community sensor networks: A network of sensors may be used either alone or in conjunction with a database to identify and communicate the presence of incumbent transmissions and the availability of particular frequencies to end-user devices.

6.1.2.3 Challenges of spectrum sensing

Some challenges arise when considering spectrum sensing for obtaining knowledge of the operational environment. One of them is the hidden node problem. The hidden node problem occurs when a CRS node cannot sense another node transmitting (for example, due to radio propagation conditions) or not sense the presence of a receive only node and therefore incorrectly assumes that the frequency channel is not in use (Report ITU-R M.2225).

Furthermore, spectrum sensing requires high sensitivity, sampling rate, resolution, analogue to digital (A/D) converters with large dynamic range, and high speed signal processors. When wideband sensing is considered terminals are required to capture and analyse a wide band, which imposes additional requirements on the radio frequency (RF) components. Wideband sensing also means that a wide range of signals with different characteristics needs to be detected which adds to the complexity of sensing since it needs to adapt to e.g. different energy levels or cyclostationary features of the primary signal [41].

Therefore it might be useful to utilize sensing technologies in a limited frequency range in which the range of technologies used by the other existing systems in the band is limited [42]. Moreover, considering the constrained energy and limited processing capacity of some CRS nodes, the power consumption and complexity of spectrum sensing algorithms should also be considered. For example, the order of channels to be sensed, sensing interval, and complexity should be optimized while maintaining sensing accuracy.

An important issue that has to be considered is the reliability of sensing, that is how reliable is the information obtained through sensing the spectrum band. Indeed, in the case of unreliable information, there could be consequences for the primary system (and even for the secondary system). Several recent studies and statements as the ones reported in [43], [44], [45], [46], [47] and [48], show that the reliability of the information obtained through sensing is one of the most critical challenge to spectrum sensing.

Reference [39] reports a study focused on the reliability of a spectrum sensing technique as a way to obtain the knowledge of the 2G system spectrum occupancy. As a result of the study, it is possible to conclude that the considered spectrum sensing techniques may suffer due to a very low reliability in the evaluation of the spectrum occupancy and this aspect could be really critical in an opportunistic spectrum use context as decisions should be made in a strict timeframe. Similar results are also reported in [44], where it is concluded that the dependence of the perceived spectral activity with the user location along with the presence of external noise sources (e.g. man-made noise sources like AC power systems, electric motors, etc.) altering the observed spectrum occupancy suggest the need for sophisticated spectrum sensing methods as well as some additional techniques in order to guarantee an accurate spectrum occupancy detection.

Thus, it does appear clear that the implementation of opportunistic spectrum access mechanisms could not rely simply on the spectrum sensing techniques, in particular in case of terminal-side only approaches. Indeed, when exploiting spectrum sensing in case of failure to obtain knowledge or in case of unreliable information of radio environment, a CRS using spectrum sensing approach needs to have alternative methods to cope with the situation.

In [47] it is stated that sensing is not a preferred solution to protect the broadcast service in the UHF TV bands and that the potential benefit of using sensing in addition to the geo-location database needs to be further considered. When sensing is implemented, testing procedures would need to be developed by standardization bodies to assess the efficiency and the reliability of the sensing process/device. In addition, to protect emerging systems of the broadcast service, sensing algorithm would require continuous developments, which may raise legacy issues. Research on sensing [49] has shown that PMSE[2] services can be very difficult to detect under realistic conditions, even by cooperative sensing.

When spectrum is used opportunistically, the primary system has the priority to use its frequency bands anytime. Therefore, CRSs should be able to identify the presence of primary user and vacate the band as required within a certain time depending on the requirements of the specific primary user. For example if the CRS is exploiting opportunities at the public safety band, there may be a sudden need for more spectrum by the primary use, the tolerance time will be very small and if the opportunistic spectrum use is based on sensing, it needs to be done frequently. Also the temporal characteristics of the primary user affect how frequently the sensing should be done. For example the presence of a TV station does not usually change frequently in a geographical area, but the use of wireless microphones may change rapidly [38].

It can occur that the primary user receiver is in the transmission range of the CRS but the primary user transmitter is not. This could be the case e.g. with wireless microphones. There are also receive-only users, such as passive radio astronomy services which cannot be detected by sensing [41] [42].

In addition to the challenges reported above, in general, also the following ones should be addressed while investigating the sensing approach:

– algorithm complexity may be related with power and processing consumptions;

– the complexity of each spectrum sensing method (in terms of power and processing consumptions) related to the observed bandwidth;

– sensing signalling cost (e.g. including cost in sensing measurement and sensing reporting);

– for cooperative sensing, the cost of aggregating and processing the sensing reports as well as synchronization issues.

Based on the current studies that have been referred, the sensing techniques are not mature enough and further research effort is needed on spectrum sensing in order to understand how such a technique can be implemented and what would be the sensing requirements in each band and with relevant primary services.

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[2] Programme Making and Special Events (PMSE) is a term that denotes equipment that is used to support broadcasting, news gathering, theatrical productions and special events, such as culture events, concerts, sport events, conferences and trade fairs. PMSE devices use low power.

6.1.3 Databases

6.1.3.1 Geolocation and access to databases

The objective of databases is to provide information about the locally usable frequencies and thus to provide protection to incumbent services from harmful interference. The database can protect a wide range of radio services, including passive services which cannot be covered by sensing.

Databases can deliver information of vacant spectrum bands and the rules related to the use of those frequencies in certain locations, such as information on the allowed maximum transmit power. By knowing the locations and having access to the database, the CRS nodes can check available frequencies from the database to be used for their own transmissions. The information on the database can be obtained either by the CRS itself or the information can be provided by another system. The CRS nodes can access the database in several ways and for example CPC could be used for providing the information contained in the database to CRS nodes.

Database approach is especially useful to protect primary usage where the locations of the stations are known and remain stable and spectrum use does not change frequently [42].

Several approaches to databases can be possible. The approach can vary e.g. on the time frame on which the information on the spectrum band is gathered.

In UHF TV bands, as stated in [48], the geo-location and database access method provides adequate and reliable protection for broadcast services, so that spectrum sensing is not necessary.

Furthermore, in one country industry has set up a voluntary database for recording RLAN systems operating in the 5 470-5 725 MHz band outdoors if they are within 35 km of a Terminal Doppler Weather Radar (TDWR) that is operating in the 5 600-5 650 MHz band. In other bands the geolocation databases may become a key tool of enabling other forms of vertical as well as horizontal spectrum sharing.

Additionally, in the sharing approach currently considered in Europe for 2.3-2.4 GHz band described in section 5.2.5, the access to spectrum is based on a use of a geolocation database. This database is able to store as well as exchange information dynamically between entities involved in this spectrum sharing framework [50].

Any database could contain and utilize information on all services the administrations want to protect in the bands to be accessed by the CRS nodes. This could include information on protected receive sites or operational areas of those protected services, as well as on any registered devices.

The operation of the database can also be organized in different ways, and there are several proposed architectures. [47]

It is possible to have one or more databases and they could be provided by the regulator or third parties authorized by the Regulator. If there are multiple databases they all need to provide the same minimum information about the available frequencies to the cognitive device.

– Single open database: One option is to have a single database for the entire country or for a region. All CRS nodes consult this database using a pre-defined and standardized message format. The database would be open to all users. In practice a regional database may not be practical due to differences in national approaches.

– Multiple open databases: A second option is to have multiple databases. In this case, CRS nodes could select their preferred database but there would be no difference between them in the information related to the allowed frequencies. One benefit could be an improved availability as a result of the redundancy of databases. In addition, if some of the databases are operated by third parties, they could offer also other information and value-added services to the CRS nodes, in addition to the mandatory interference protection related information.

– Proprietary closed databases: A third option is to have “closed” databases corresponding to different types of devices. For example, a manufacturer of CRS nodes might also establish a database for those devices it had made. Multiple manufacturers might work together to share a single closed database or one manufacturer might “open up” its protocols and database for others to use if they wish.

– “Clearinghouse” model: The “clearing house” model partitions the process of providing information on available channels to CRS nodes, in order to facilitate the development of multiple database service providers. The key element is the clearing house, which aggregates and hosts the raw data needed to perform database calculations.

  Since there would be only one of these per country or region, it would need to be carefully regulated to ensure equitable access conditions as well as integrity of data handling and distribution.

Open interfaces and protocols should be defined between the devices and the database so that different types of CRS nodes can access a database-based on those interfaces and protocols.

Geolocation is an important part of the database access approach as the location of the CRS node needs to be known to retrieve correct information from the database for the specific location. There are several ways to implement the geo-location. Fixed CRS devices such as access points can be professionally installed and their location then programmed into the device. Personal computers and other portable devices can use geo-location technologies such as GPS chips. Also triangulation using radio towers or any other location determination method provided those methods provide sufficient accuracy to determine the location of devices at a given point and time. Once the device determines its location, or it is determined by the access point acting as a master device, it can be communicated to the database to determine the frequencies available for use in its area [47].

6.1.3.2 Multi-dimension cognitive database

An important characteristic of a CRS is its capability of making decisions and adapting based on past experience, on current operational conditions, and also possibly on future behavior predictions. An underlying aspect of this concept is that CRS must efficiently represent, store and manage environmental and operational information.

Cognitive database [51] is a promising module in CRS architecture by storing and managing cognitive information to support the CRS. This database is a logical entity which can be organized flexibly in both centralized and distributed manner.

The cognitive information in cognitive radio systems is comprehensive, including information of space, time, frequency, user, network and different layers of system. The cognitive database should be divided into several dimensions in terms of its nature, and the cognitive information in which should be managed based on the dimension division, such as:

– Radio dimension
  • Parameters of radio transmission characteristics
– Network dimension
  • Information reflecting the network status
– User dimension
  • Information related to users or concerned by users
– Policy dimension

- Guideline of radio resource management, spectrum policies, operator policies.

6.1.3.3 Challenges of geo-location/database

CRS nodes may need to be capable of knowing their locations and accessing the database. Using databases to present fast varying spectrum use is challenging as the information stored in the database can become outdated fast.

Furthermore, database approach may not be suitable in cases where the location of the protected stations is not known or they cannot be registered in the database.

The management of database includes also security and privacy aspects that need to be considered.

The sensitivity of the information stored in the database could be very high, and should be carefully managed in the network, in order to avoid any unauthorized or unexpected access to the data. As a basic principle for addressing the security of the information, two categories of information could be introduced: a first category related to non-sensitive information, and a second category related to sensitive information. Any information related to the available RATs and related frequency bands in a certain area should be included in the first category, since this kind of information needs to be sent freely to any mobile device. On the other side, any information related to some specific actions, decisions and operations in the networks should be included in the second category.

The information that the database provides to the devices may depend on the regulation and the database implementation. The CRS may be able to operate in various countries and frequency bands, and thus it may need to access to various databases. For providing global interoperability for CRSs, a unified and flexible interface, which enables access to various databases globally, should be defined. An example of such an interface is defined in IETF PAWS[3].

6.2 Decision making and adjustment of operational parameters and protocols

The design of future CRSs will face new challenges as compared to traditional wireless systems. Future CRSs need take into account the underlying policies in the different spectrum bands that determine the rules for using the bands and transform the policies into adjustment actions. The operational environment will be heterogeneous consisting of several RATs with diverse sets of terminals to support a wide range of services.

In addition, the operational environment will be more dynamic as the number of users and the applications they are requesting vary in time leading to changing requirements for resource management. As a result the resource management in a dynamic and complex environment becomes a multivariable optimisation problem with conflicting requirements where optimal solutions are difficult to find.

The decision making in CRSs including e.g. the resource allocations among the CRS nodes such as frequency channels, output power levels, RAT, transmission timing and modulation types, can be done with mathematical or heuristic methods. Mathematical algorithms have good performance and reliability, but they can be complex and their applicability depends on the characteristics of the target system. In dynamic environment mathematical models may not be suitable for the target problem leading to performance degradations. Heuristic methods could be based on mathematical understanding and statistical knowledge, human-kind thinking or artificial intelligence (AI) applied to problem to solve. Techniques like rule-based expert systems, fuzzy logic, neural networks,

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[3] There is standardization effort by Internet Engineering Task Force (IETF) to standardize a Protocol to Access White Space databases (PAWS).

genetic algorithms, or combinations of them may be attractive to tackle problems that hinder using mathematical algorithms. With heuristic methods the decision making system can be designed to handle such unusual, or even unpredictable, cases that are difficult to implement using mathematical methods.

For decision making in CRSs, the nodes may use various parameters, which can be categorized into radio link quality and network quality parameters. Radio link quality parameters include metrics such as received signal strength and signal to interference-plus-noise ratio (SINR). Network quality parameters include traffic load, delay, jitter, packet loss, and connection drop/block statistics. This two-level information covering both physical level and network level can be used for the decision making. For instance, network congestion cannot be observed at the physical layer, while its effects will be shown on network level monitoring as decreased throughput and/or increased delays and packet losses. Another example is that if packet losses start to increase, they might be caused by low or alternating signal strength, which will be shown immediately at the physical layer. Then again, high overall SINR combined with packet losses is an indication that there could be sporadic shot noise interference, problems with link layer delivery, or problems somewhere behind the radio link. All this information, taken together, can contribute to the decision making process of the CRS.

6.2.1 Decision making methods

Centralized and distributed decision making methods are hereafter described. In general, their specific application depends on the considered scenario and the trade-off between the two methods should be studied case by case. Sometimes hybrid solution may bridge the gap between the two extremes [52].

6.2.1.1 Centralized decision making

A simple architecture to support the dynamic adaptation of the operational parameters in a CRS is to have a centralized entity for decision making, which could coordinate the operational parameters and resources and consequently realize and issue decisions for utilizing the spectrum resources or channels.

The central entity obtains the knowledge of its radio operational and geographical environment, its internal state and the established policies, and monitors spectrum usage patterns and users' needs, for instance, by sensing the spectrum use, using a database and/ or receiving control and management information through listening to a wireless control channel. Based on all obtained information, the central entity makes a decision on the adaptations of its operational parameters including e.g. spectrum resources to CRS nodes in the area it manages.

The centralized architecture is simple and easy to control from the operator's view. However, when the amount of components increases greatly, a single centralized entity would not be able to cope with the coordination, decisions making and management for a large number of CRS nodes' resources. This will not only lead to scalability issues, but will also introduce significant delays in the resource management decisions being conveyed. Besides, the centralized entity may not be easy to collect dynamic information from all involved network entities and make fast decision.

6.2.1.2 Distributed decision making

A distributed approach is based on localized decisions of distributed CRS nodes. Distributed decision making approach could be used when a set of ad hoc CRS nodes operates in the same area, and in the same frequency band using dynamic access. In this case, each CRS node would have to gather, exchange, and process the information about the wireless environment independently. The decisions on the actions would be carried autonomously based on the available information.

The delay is substantially shorter to facilitate dynamic change of situations when compared with centralized approach. However, there may be an issue with stability (especially when entities act independently without coordination) as it is difficult to prove that the proposed solution will always behave in a predictable manner. Distributed decision making can be useful in networks employing relay transmission schemes which help to avoid interference by selecting appropriate transmission power levels and paths.

There is a wide range of techniques for distributed decision making including e.g. game theory, metaheuristics (e.g. genetic and search algorithms), Bayesian networks and neural networks. Different decision making techniques are more suitable depending on the operational environment, network conditions and the use of coordinated or non-coordinated mechanisms. The main aspects of the coordinated and non-coordinated mechanisms are reported in the following.

In general, in the coordinated mechanisms a CRS nodes will make a decision on e.g. spectrum access to achieve the best overall performance of the network whereas in the non-coordinated mechanisms CRS nodes will make a decision only to maximize its own benefits. In both mechanisms CRS nodes have to collect information such as information on RATs, operating parameters, capabilities and measurement results to make the decision.

In the non-coordinated mechanisms such information are gathered and processed locally by each of the CRS nodes that can make the decision independently by choosing the actions that optimize their own performance while fulfilling the given constraints arising e.g. from policies. If the nodes decide independently e.g. their channel and power allocations, the overall performance of the network in terms of e.g. throughput may not be good. Examples of non-coordinated mechanisms are, CSMA, frequency hopping, and adapting transmission power based on interference level.

In the coordinated mechanisms, the actions can be optimized to obtain better overall network performance. The CRS nodes can collaborate using e.g. control channels or databases to optimize the operation of the network based on policies to ensure fairness and effectiveness taking into account the different CRS nodes characteristics and other aspects e.g. load balance between CRSs.

6.2.1.3 Examples of possible criteria to be used for decision making

6.2.1.3.1 Frequency channel selection based on channel usage

The CRS may be able to recognize the utilization probability of different frequency channels, the state transition probability from idle to busy of different channels, the usage model of different channels from periodically-collected statistical information though out-of-band and in-band spectrum sensing. In order to select most suitable channel that improves the utilization of available spectrum, the CRS needs to identify the opportunity utilization quality of the different channels by integrally considering the information obtained by the CRSs. The considered information could include e.g. the following aspects:

1) utilization of channel probability;
2) state transition probability from idle to busy of channels;
3) the usage model of different channels;
4) traffic pattern in different channels;
5) bandwidth as well as traffic requirements of the cognitive radio users;
6) channel collision problem for the scenario of multi-cognitive radio users.

6.2.1.3.2 Frequency channel handover

Frequency channel handover occurs when a CRS user changes frequency e.g. in case the frequency is reclaimed or, due to the channel conditions, the communication cannot be maintained. Frequency channel handover may cause delay and packet loss to the CRS user. Frequency channel handover strategy is trying i) to maintain the seamless connectivity of CRS users and ii) to guarantee the QoS requirements of the CRS user.

The considered information may include e.g. the following aspects:

1) usage model of different channels;

2) predicted vacant time of channels;

3) quality of channels, such as SNR and path loss;

4) bandwidth as well as traffic requirements of the cognitive radio users;

5) handover delay.

6.2.2 Adjustment methods

A CRS node could dynamically and autonomously adjust its operational parameters, protocols, and configurations according to the obtained knowledge and past experience based on appropriate decision methods. This section reports an example of cognitive network management.

6.2.2.1 Cognitive network management

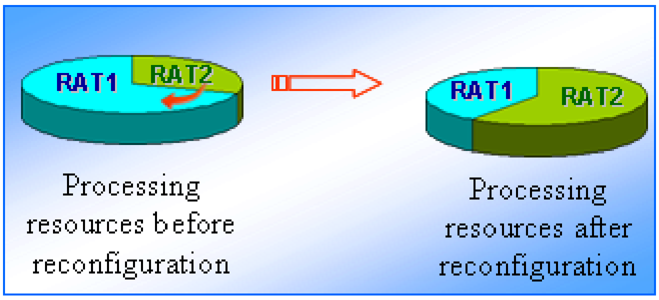
Based on the knowledge of its environment, a cognitive network (as described in section 5.2.1) can dynamically adjust its parameters, functions and resources by means of appropriate methods. To accomplish such tasks, appropriate management functions need to be identified.

The availability of reconfigurable nodes in the networks (i.e. nodes whose hardware and processing resources can be reconfigured in order to be used with different RATs, frequencies, channels, etc.), coupled with appropriate cognitive network management functions, will give the network operators the means for managing in a globally efficient way the radio and processing resource pool, with the aim to adapt the network itself to the dynamic variations of the traffic offered to the deployed RATs and to the different portions of the area. In some cases cognitive network management could be used for energy saving purposes.

As an example of self-adaptation on the basis of traffic load, it could be considered to deploy RAT1 and RAT2 systems in a geographical area with a network built with reconfigurable base stations, thus having reconfigurable hardware shared between RAT1 and RAT2 functionalities. During the daily life of the network, it could be needed, for instance due to different traffic loads on the two RATs, to increase the percentage of processing resources devoted to the over-loaded system while decreasing the resources given to the other (supposed under-loaded). In Figure 13, a reconfiguration example increasing RAT2 resources is depicted.

FIGURE 13

Reconfiguration example



As another example, sometimes the traffic loads of a RAT could be low so that such RAT could be switched into dormant mode for energy saving. The dormant mode operation saves power by allowing the CRS to power down part of the reconfigurable hardware shared between the two RATs, while all residual resources are allocated to the active system.

As anticipated before, in order to perform such network reconfigurations, an appropriate cognitive network management function need to be introduced. Such function is devoted to:

– monitor periodically the current activity status of the cells (for each supported RAT) in terms of measurement of the number of the requests and rejects (if any) from the different systems;
– execute a reconfiguration algorithm that decides which base station(s) are to be reconfigured, e.g. with the aim to adapt the percentages of processing resources devoted to each supported RAT and to dynamically shape the active radio resources to the behaviour of the traffic;
– control the network reconfiguration by sending appropriate reconfiguration commands to the reconfigurable base stations in order to perform the appropriate actions (e.g. to activate/deactivate processing resources and/or radio resources – such as frequency carriers – for each supported RAT).

It is worth noting that the cognitive network management function can reside in any radio network control node, a core network or O&M node as well as inside each reconfigurable node (e.g. in case of flat-architecture) supposing that it can opportunely interact with the other network management functions e.g. Radio Resource Management (RRM) and the reconfigurable node entities. Distributed solutions of the cognitive network management function are also possible.

6.3 Learning

Learning can enable performance improvement for the CRS by using stored information both of its own actions and the results of these actions and the actions of other users to aid the decision making process. The learning process creates and maintains knowledge base where the data is stored.

Learning techniques can be classified into three major learning schemes such as supervised learning, unsupervised learning, and reinforcement learning. Supervised learning is a technique which uses pairs of input signals and known outputs as training data so that a function that maps inputs to desired outputs can be generated. Case-based reasoning is an example of supervised learning technique where the knowledge base contains cases that are representations of past experiences and their outcomes. Reinforcement learning uses observations from the environment in learning. Every action has an impact in the environment and this feedback is used in guiding the learning algorithm. Q-learning is an example of this class. Unsupervised learning techniques aim at determining how the data are organized. Clustering is an example of unsupervised learning technique [53]. Also aspects of “game theory” and “policy engines” are among the techniques under investigation for CRS management [54].

Major learning schemes can include several specific learning techniques such as genetic algorithms, neural networks, pattern recognition, and feature extraction. Neural networks provide a powerful tool for building classifiers. Pattern recognition and classification can be seen as crucial parts of an intelligent system that aims at observing its operating environment and acting based on observations. Feature extraction and classification are complementary functions. A very important task is to find good distinguishing features to make classifier perform efficiently.

Learning makes the operation of CRSs more efficient compared to the case where only information available at the design time is possible. For example, learning enables use of traffic pattern recognition. A CRS can learn the traffic patterns in different channels over time and use this information to predict idle times in the future. This helps to find channels offering long idle times for secondary use, increasing throughput for secondary users and simultaneously decreasing collisions with primary users. Moreover, a CRS could also be able to recognize the type of the application generating the traffic by looking at the statistical features of the traffic. This would help the management of the network since different applications have different QoS requirements, e.g., VoIP and media downloading.

Learning helps also in fault tolerance since patterns of faults can be identified as logical sets that can be interconnected as a constraint network or a reactive pattern matching algorithm. This approach can enable a more efficient fault isolation technique as it identifies multiple potential causes concurrently and then chooses the most likely based on precedence and weighting factors.

A major challenge in learning is the maintenance of knowledge base which is a key requirement for efficient learning and reasoning. The knowledge base should be able to adapt to the possible changes in the environment to offer relevant information to the decision making. The size of the knowledge base is not allowed to grow uncontrollably. Rather the size should remain at the reasonable level. Thus, a management element might be needed in the system to take care of these tasks. All the unnecessary information should be taken away from the database on a regular basis. Management element might be also needed to restrict the amount of changes in the knowledge base to avoid chaotic situations. Moreover, the knowledge base could be tailored to operate efficiently with the specific learning techniques used in the system [55] [56].

6.4 Implementation and use of CRS technologies

The implementation and use of CRS technologies in the different applications in LMS would depend on the particular application and the band where certain radiocommunication services are used and the particular CRS technologies for obtaining knowledge such as sensing and access to database that are required.

As described in section 5, applications that are employing CRS technologies would have an implication on sharing and coexistence issues.

In the following some examples are given of how the use of CRS technologies could enhance sharing and coexistence, specifically when the existing radio systems undergo technical upgrades and technology evolution. These and other technical solutions for sharing and coexistence are subject to study before they can be implemented. It should be noted that sensing and database are examples of CRS technologies with potential for technical suitability in the applications of a CRS as addressed in section 5. However, this does not preclude that other CRS technologies can also be applicable.

Use of sensing allows the CRS nodes to detect changes of the existing radio systems around them and to act accordingly, based on the appropriate policy. The changes can usually be related to change of frequencies used by the existing radio system around the CRS nodes. But also technical changes of the signals to be detected may be handled as the sensing method may be sufficiently flexible or broad to cover a range of signals or technical changes in the signals of the existing radio systems. More fundamental technical changes of the radio systems, due to technology evolution and technology upgrades, can be handled through reconfiguration of the CRS nodes. It should be noticed, that also policy updates can be delivered to the CRS nodes.

Use of access to database by CRS nodes can ensure no harmful interference to the existing radio system practically under any changes and evolution of the radio systems. CRS nodes are following the updated orders from the database, where the changed protection requirements have been taken into account. Thus dealing with evolution of the existing radio system is more straightforward when the database approach is in use. The valid policies are implemented in this case by the database and the CRS nodes just continue to follow the orders, even if they are changed.

Therefore, particular sets of CRS capabilities and related technical solutions may be needed to allow spectrum sharing and radio resource management on more dynamic basis, depending on particular bands and applications.

In addition, there is a need to utilize appropriate policies and condition under which CRSs could operate. For example, in the case where CRSs would share spectrum bands with other radio systems (in particular for the vertical sharing approach presented in section 5), such policies and conditions could be set under a framework defined by the rights of spectrum usage. The framework should describe the condition of use and provide possible mechanisms for sharing.

In the horizontal spectrum sharing arrangement where several CRSs share the same spectrum band, there is a need to define some rules of accessing the shared spectrum band such that all CRSs have an equal chance to access the spectrum band, i.e. the CRS capabilities are used to ensure fair access to the spectrum.

In order to exploit the opportunities of CRS technologies in the LMS to their fullest harmonized technical solutions could be beneficial. However, it should be noted that CRS technologies can be applied to the various systems for the various applications. Harmonised technical solutions would be useful to address possible CRS applications in various bands.

6.4.1 Dimensions of flexibility

The CRS technology may offer flexibility in following dimensions: time, space, frequency and other operational parameters. Each of them is discussed in the following:

6.4.1.1 Time

– A CRS can receive guidance about the time validity of the available frequencies from the database or from some other source. If sensing is used, it may also provide some information about the instantaneous changes in the environment around the CRS nodes.

– Another approach may be that the CRS operates according to policies that define the timing of the transmit/receive signals.

The CRS itself can be able to make the timely changes rapidly.

6.4.1.2 Space

– CRS operation may be location specific. For example if geo-location database is used, it can instruct the CRS in a manner that facilitates flexibility in the space domain. Thus the CRS may operate differently in different locations.

– The spectrum occupancy and the resulting spectrum availability can vary significantly depending on the location indicating that different frequency channels can be available in different locations. A CRS can exploit the spatial variations in the spectrum availability by adapting its operations according to the local situation.

6.4.1.3 Frequency

– A CRS can obtain knowledge of the available frequencies based on its own observations, through sensing, or by receiving the information from other sources, such as geo-location database. It can then change its operation to available frequencies.

6.4.1.4 Other operational parameters

– The CRS nodes may need to adjust various other operational parameters, like the transmit power (TPC), modulation, coding, used RAT, protocols, etc. Especially if the CRS is implemented using SDR, the CRS node characteristics can be changed flexibly.

– Ability to change the operational parameters improves the ability of a CRS to ensure avoidance of harmful interference and can improve its operational capabilities.

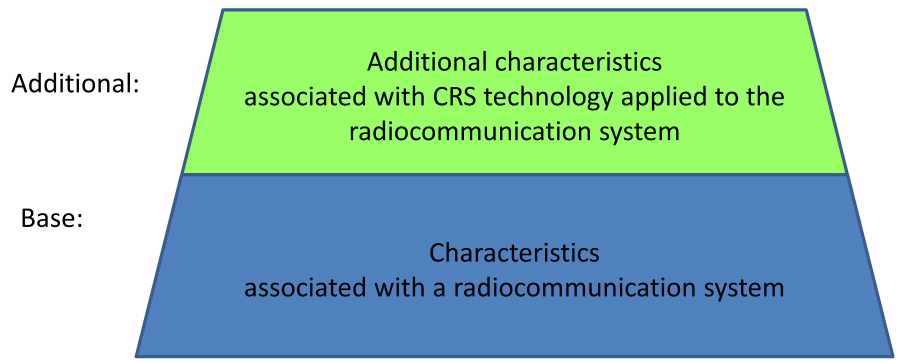
7 High level characteristics and operational and technical requirements

7.1 High level characteristics

LMS radio systems are characterized by physical characteristics as discussed in ITU reports (e.g. in Report ITU-R M.2116-1 on wireless broadband access) as well as other system characteristics. The characteristics of an LMS radio system that includes CRS technology consists of the characteristics associated with a land mobile radio system and additional characteristics associated with CRS technology which are applied to it as shown in Figure 14.

FIGURE 14

The characteristics of an LMS radio system and its CRS technology



The characteristics of a conventional LMS radio system are represented by operating and technical parameters such as frequency band, modulation type, data rate, access method, channelization, transmit power, transmit spectrum mask, spurious emission, antenna gain, receiver sensitivity and others.

CRSs have not yet reached the maturity for discussing in detail additional characteristics related to LMS radio systems employing CRS technology. Therefore, in this document CRS characteristics are discussed at a high level based on the features that characterize a CRS listed in Report ITU-R M.2225. CRS characteristics that could be added on top of the characteristics of conventional mobile radio systems are:

A) flexible spectrum management in temporal, frequency and geographical domains to improve spectrum efficiency, and

B) dynamic coordination among radiocommunication systems to facilitate spectrum sharing and co-existence,

which arise from the CRS capabilities:

1) to obtain the knowledge of the established policies;

2) to autonomously adjust its operational parameters and protocols;

3) to learn from the results of its actions.

It is foreseen that these additional characteristics could be especially relevant to the horizontal and vertical sharing which could require better awareness of the environment outside the CRS such as other radio systems and the resulting interference situations. Thus the knowledge of the characteristics of other radio systems operating in the same or adjacent bands could be of interest for LMS with CRS capabilities for more efficient spectrum sharing. More accurate knowledge of the other systems and the resulting interference situations, could enable the CRS to share the spectrum more efficiently.

These characteristics define the CRS's ability to avoid harmful interference to other radio communication systems with or without CRS technology and therefore give additional interference margin thanks to *dynamic* interference management and/or radio resource management, being compared with conventional *fixed or predefined* interference criteria for sharing and/or coexistence.

The CRS specific characteristics are represented by some additional operating and technical parameters which can be quantified as metrics. The detailed CRS specific metrics are discussed in section 8.1.1. The same parameters may be used to characterize CRSs across LMS radio systems employing CRS technology. The values of the parameters, however, vary depending on the radiocommunication system themselves and the system(s) that they share or coexist with.

7.2 High level operational and technical requirements

This section introduces some high level operational and technical requirements for a CRS. In general, requirements can be categorized into two main sets: i) requirements that focus on the CRS operations itself in order to guarantee a certain level of performances in its operations, and ii) requirements related to the interaction with the other systems that operate in the same band and/or in the adjacent bands. The requirements are strictly related to the different scenarios and applications of a CRS. In addition, CRS operations may rely e.g. on the technical features and functionalities such as the ones described in section 6 of this Report that may impact the requirements.

Some high level operational and technical requirements related to the CRS operations only are as follows:

– Scalability and insensitivity to network topology changes [58]: the CRS should react in an appropriate manner to the changes in network topology (e.g. some nodes may go out-of-service). The connectivity between the CRS nodes should be maintained in a robust manner, and advanced protocols are required to reconnect nodes via different channels.

– Power efficiency [58]: some CRS operations may require high power consumptions. Such consumptions should be optimized in each CRS node, taking into account the new functions that the nodes need to perform such as sensing, coordinated and non-coordinated approaches in the decision making mechanism, etc.

– Network discovery [58]: the protocols and procedures of a CRS should be designed in such a way that the network discovery from the user perspective meet specific delays restrictions (e.g. defined through network policies).

– Robust control plane [58]: the control planes both within a single CRS as well as between different CRSs should be robust and able to continue to provide connectivity in the context of different radio environments that change dynamically during time.

– Reconfigurability of the radio nodes [58]: the radio part of CRS nodes should be capable of adjusting to different radio frequency environments. This kind of dynamic adaptability means that the transmission parameters and resource allocation can be easily adjusted to the needs of the system operator and/or the user, or the interference environment in a particular band.

– Context, policies and information provisioning support [58]: for the purpose of supporting CRS nodes in their selection of radio technology and frequency band as well as radio link configuration, context provision needs to provide the radio context information such as e.g. available frequencies and radio technology selection constraints (policies) in the appropriate manner.
– Efficient use of spectrum: The CRS should support functionalities that improve the efficiency of overall spectrum use. This could be assessed by using for example spectrum occupancy metric, see section 8.1.4.
– Support for designated method(s) to obtain knowledge: The CRS should support method(s) to obtaining knowledge on e.g. spectrum availability information.
– Location knowledge: The CRS should support geo-location functions to be aware of its location to the level and accuracy required by its capabilities e.g. to obtain knowledge.
– Security and privacy: The CRS should ensure the security of its interfaces and data transmission, as well as data privacy.

The requirements reported above are related to some of the CRS applications depicted in this Report. For example, the requirements on reconfigurability of the radio nodes and on context, policies and information provisioning support, are both valid for the cognitive network application [59].

The following are three examples of high level requirements related to the interaction with the other systems which are very important in the context of applications that involve horizontal and vertical sharing as well as coexistence issues with other radio systems:

– Harmful interference and QoS degradation avoidance: a CRS should support specific technical features and functionalities to avoid any harmful interference and QoS degradation to the other radio systems with equal or higher levels of spectrum usage rights operating in the same band and/or in the adjacent bands.
– Sharing and coexistence: The CRS should support functionalities that facilitate sharing and coexistence with other CRSs as well as other radiocommunication systems according to the operating environment.
– Spectrum coordination: The CRS should be able to release a spectrum band on demand e.g. in the case of appearance of another, radio system (or another CRS) with higher level of spectrum usage rights. In order to provide continuous service to its user (if required), the CRS should support changing its operating channel.

8 CRS performances and potential benefits

8.1 Aspects related to the performance of the CRS radio operations

In this section, general performance criteria and metrics are presented to help the performance evaluation of LMS radio systems employing CRS technology.

A metric is a quantitative value to be used to evaluate performance(s). In the case of a CRS, since some metrics may be interdependent, distinguishing their basic attribute may not be straightforward. Appropriate metrics should be selected for specific applications depicted in section 5.

CRS technology introduces additional dynamic radio operations and functionalities whose performances may require the introduction of new metrics. For example, metrics for the CRS to respond to dynamic availability of spectrum in time domain in addition to geographical domain. The impact of learning as one of the key characteristics of a CRS is not straight forward to quantify with metrics used for conventional radio systems. In fact, LMS radio systems employing the CRS technology can function in a more dynamic radio operational environment and adjust their operations accordingly, which calls for new metrics to measure this dynamic behaviour.

Section 8.1.1 reports some radio performance metrics for CRS operations. Spectrum related performance metrics are captured in section 8.1.2.

8.1.1 Radio performance metrics for CRS operations

For CRS radio operations, performance metrics can be categorized into two levels: radio link level and radio access network level. Radio link level quality would give an indication and measure of physical characteristics and performances of CRS transmissions, whereas radio access network level quality could be used to provide a quantified measure and indication of the overall CRSs system performance.

The following metrics could be used to evaluate radio link level quality:

– Received signal strength indicator (RSSI).

  The received power, including thermal noise and noise generated in the receiver, within the bandwidth defined by the receiver pulse shaping filter[4].

– Signal-to-interference plus noise ratio (SINR).

  The ratio of the power of the wanted signal to the total power of interfering signals and noise, evaluated in specified conditions at a specified point of a transmission channel[5].

– Error ratios (e.g. bit error ratio (BER), frame error ratio (FER)).

  The ratio of the number of errored bits/frames received to the total number of bits/frames received over a given time interval[6].

Additional radio link level metrics can be defined according to different CRS applications.

In the case of horizontal and/or vertical spectrum sharing, the LMS employing CRS capabilities might experience interference from other radio systems. The interference term in the SINR metric would consist of both LMS internal and external system interferences. It may be useful to differentiate these interferences as the LMS system has different level of control over them to take actions accordingly using the CRS capabilities.

In addition to the SINR, the interference only can be also used as a metric by comparing its value with defined thresholds instead of using the transmitted signal as a reference. More in general, which metrics to consider and how such metrics are used depends on the different applications.

Radio access network level metrics can be divided into system performance metrics and users related performance metrics. System performance metrics refer to overall operation of the radio network, while user performance metrics refer to the Quality of Service (QoS) and Quality of Experience (QoE) of the end user.

The radio access network level system performance metrics include, but are not limited to:

– Accuracy of obtained knowledge (e.g. radio environment)

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[4]In line with the RSSI term from 3GPP TS 25.225.

[5]In line with the signal to interference (SIR) term from Recommendation ITU-R V.573-5.

[6]In line with the BER term in Recommendation ITU-R V.662-3.

It refers to the accuracy of information that CRS systems obtain to use for decision making and adjustment of operational parameters and/or protocols. This mainly impacts on interference management.

Accuracy of the knowledge obtained by the CRS may be affected e.g. by the following metrics or a combination of them;

Propagation channel measurement error which is a metric of difference between actual radio propagation channel state information values and their estimated values.

Geographical position error which is a metric which is a displacement of recognised position from a real position.

Other metrics related to specific CRS technologies for obtaining knowledge can be found in section 6.1.

– Base station reconfiguration time

It refers to the duration from the time when a reconfigurable base station receives a particular reconfiguration command to the time when it starts to operate again with the new configuration.

– Time-scales related to CRS specific characteristics

It refers to delays introduced by the CRS capabilities operations. As an example, these metrics could include *decision delay* and *control delay*.

Decision delay is the time required to take decisions. Such metric may be relevant because information that was collected at the past instance may no longer be appropriate or out of date due to the dynamic nature of land mobile radio systems. Control delay is the required time to adjust radio parameters after the decision of adjustment.

– System capacity

It refers to the peak aggregate throughput that can be achieved over a communications system under certain conditions.

– Aggregate average throughput

Aggregate average throughput is throughput in a cell summed from all users over the time divided by the number of users.

– Peak spectral efficiency (Report ITU-R M.2134)

The peak spectral efficiency is the highest theoretical data rate (normalized by bandwidth), which is the received data bits assuming error-free conditions assignable to a single mobile station, when all available radio resources for the corresponding link direction are utilized.

– System spectral efficiency (Report ITU-R M.2134)

System spectral efficiency is defined as the aggregate throughput of all users divided by the channel bandwidth. The system spectral efficiency is measured in bit/s/Hz.

– Successful communication establishment probability

It refers to the probability of successfully establishing communications links.

– Frequency channel handover time

It refers to the time for a CRS device to handover from current frequency channel to another frequency channel.

Radio network level's users related performance metrics include:

– Delay and Jitter

Communications delay and delay variation of the end user traffic.

– Connection reliability

Connection reliability measures the probability that the user session will be maintained during a session.

– Percentage of users with low quality

Defines the percentage of network user's whose selected user performance metric(s) have remained below a certain threshold(s) for a predetermined duration of time.

8.1.2 Metrics for evaluation of spectrum use

The CRS aims at enabling more efficient use of spectrum. This may be evaluated e.g. in terms of:

– Spectrum occupancy

The utilization rate of the frequency channel, thus, the fraction of time that the power in a frequency channel exceeds a certain threshold. Measurements of the spectrum occupancy enable monitoring on how efficiently the current spectrum allocations are being used in reality. Measurements are influenced by detection method, measurement channel bandwidth, number of channels, observation time per channel, revisit time and duration of monitoring. Spectrum occupancy can be given in three different levels (Report ITU-R SM.2256):

– Frequency channel occupancy: A frequency channel is occupied as long as the measured level is above the threshold.

– Frequency band occupancy: The occupancy of a whole frequency band counts every measured frequency and calculates a total figure in percent for the whole band, regardless of the usual channel spacing.

– Spectrum resource occupancy: The ratio of the number of channels in use to the total number of channels in a whole frequency band.

– Spectrum utilization efficiency (SUE)

SUE is a measure of spectrum efficiency given as the ratio between the useful effect obtained by the radio systems through the utilization of the spectrum and the spectrum utilization factor (Recommendation ITU-R SM.1046). Considering a CRS that operates at a particular frequency, at a given location, and at a particular time, the spectrum utilization factor is defined as the product of the bandwidth, the geographic space, and the time. The useful effect for CRSs (and mobile systems in general) increases with the amount of information that can be transferred.

The first metric describes how efficiently a spectrum band is used in the course of time by all radiocommunication systems that are allowed to use it. The second metric describes the spectral efficiency of a CRS but it may not be valid for all applications. It may be used to study and compare the efficiency of different CRSs providing the same service or a CRS with another system providing the same radiocommunication service.

8.1.2.1 Metrics for performance evaluation in the context of spectrum sharing and coexistence

Performance metrics in the context of spectrum sharing refer to the situation between a LMS employing CRS capabilities and other systems operating in co-channel frequency bands. Sharing considerations are particularly important as the protection of the existing radio systems in co-channel bands may influence the performances of the CRS.

Performance in the context of spectrum sharing may be evaluated e.g. in terms of:

– SINR degradation

Reduction in SINR in the radio systems involved in sharing.

– Co-channel interference

The interference between different radio systems utilizing the same frequency bands.

– Sharing delay

Set of delays due to the sharing and coordination mechanisms. It may include the delays related to the channel access, channel evacuation and others. Metrics to evaluate the net transmission time that may occur during the channel evacuation procedure can be defined for interference remark purposes.

Performance metrics in the context of coexistence refer to the situation between a LMS employing CRS capabilities and other systems operating in adjacent frequency bands. Coexistence considerations are particularly important as the protection of the existing radio systems in adjacent bands may influence the performances of the CRS.

Performance in the context of coexistence may be evaluated e.g. in terms of:

– SINR degradation

Reduction in the SINR in the coexisting radio systems.

– Adjacent channel interference

The interference between different radio systems utilizing adjacent frequency bands.

8.2 Benefits of CRSs

In Report ITU-R M.2225 an initial set of CRS benefits have been identified. This section further expands and develops on the potential benefits.

Cognitive radio systems are expected to increase the efficiency of the overall radio resources (e.g. including spectrum) usage by offering new and enriched radio resource management mechanisms and also to provide more flexibility to applications as a result of their ability to adapt their operations e.g. to external and internal factors. CRSs are enablers for technological evolution of wireless technologies and are likely to become a key means for future innovation of LMS radio systems.

8.2.1 Benefits related to vertical and horizontal spectrum sharing

CRS could be an enabler for vertical and horizontal spectrum sharing to allow more flexible access to spectrum. The benefits associated with vertical and horizontal spectrum sharing include:

– Interference minimization: for example when utilizing CRS capability of obtain knowledge like database, the CRSs will get information on the current protection requirements thus adapting the radio systems to operate in accordance within the given rules and policies.

– Efficient spectrum use: enabling radio systems to share spectrum with each other leads to increased efficiency of spectrum use. Additional spectrum can be made available by allowing radio systems to share spectrum with other radio systems (vertical sharing) on a geographical or time basis. This can lead to capacity enhancements for the system employing CRS technologies.

– Flexible operations: in sharing and coexistence situation CRS system would have advantages over conventional radiocommunication systems. As CRS technology is flexible and could operate over various system configurations and with its advance capabilities in obtaining knowledge and adapting dynamically to policies, information shared between the involved CRS nodes would ensure that the relevant nodes have the most accurate information of available spectrum in a timely manner.

8.2.2 Optimization of the system operator network

In general, the main challenge from system operator perspective is to answer user needs in a timely and adapted manner satisfying the requirements in terms of capacity and QoS. A CRS having the potential to obtain knowledge from and analyse the radio operational environment, can make the system operator's network react accordingly by optimizing the choice of radio access technologies and associated radio resources. Some of the potential benefits that a CRS may introduce are the following [58]:

– Dynamic spectrum reconfiguration: a particular situation is that of spectrum reconfiguration in the context of technology evolution and periodical emergence of new families of standards. This implies their progressive introduction/coexistence in the legacy "bands" rather than a simple and quick switchover which is not appropriate due to the large amount of legacy equipment and the corresponding investments. A CRS may allow a smooth spectrum transition period in this case taking into account the traffic constraints and user requirements.

– Radio Resource optimization: considering a cell set in a certain area, the traffic of different services on a specified RAT may change from one sub-area to another according to the day period. Moreover, in case of deployment of different RATs in the same area, the offered traffic of different services may vary depending on the RAT in both time and space domains. In such contexts, a CRS may provide to the network operator the means for managing in an efficient and dynamic way the radio resources (e.g. reducing of radio access blocking percentages, redistributing resources among different RATs and/or minimizing system interference problems, energy saving purposes, etc.).

– Enabler for dynamic device context provision: considering a heterogeneous or multi-RAT context managed by an operator in which radio resource management mechanisms could be performed dynamically in time (e.g. spectrum refarming, radio resource optimization, etc.), solutions to provide appropriate information for the mobile devices operations are needed. In this context, a CRS may provide the tools to achieve such objective in an efficient manner e.g. through the utilization of an in-band control channel.

9 Factors related to the introduction of CRS technologies and migration aspects

In this section, factors related to the introduction of CRS technologies are discussed followed by related migration issues. Some the factors being introduced are currently under practice in today’s LMS networks, i.e., pre-cognitive features already exist in current practice. On the other hand some other factors are not yet introduced and still subject to further study and investigations.

9.1 Introduction of CRS technologies to current radiocommunication systems

In Report ITU-R M.2225, four different deployment scenarios for a CRS were identified. Each of these four scenarios is summarized below for which there will be different factors related to the introduction of CRS in the LMS. In the following, these factors are discussed.

Scenario 1: Reconfiguration of connections between terminals and radio systems.

Multiple radio systems employing different radio access technologies (RATs) are deployed on different frequency bands to provide wireless access. For this scenario factors would include but are not limited to e.g. terminals should be reconfigurable, able to obtain knowledge and able to adjust operational parameters and protocols dynamically and automatically. Also the terminals may be equipped with learning capability. Other enabling factors to improve the performance of the CRS in scenario 1 include radio interface enhancements and network architectural changes to enable radio systems to assist terminals in obtaining knowledge and guide terminals in their reconfiguration decisions.

Scenario 2: An operator of a radiocommunication system improving the management of its spectrum.

A network operator managing two or more RATs can dynamically and jointly manage the resources of the deployed RATs. For this scenario operator benefits from techniques such as traffic pattern recognition and prediction, load balancing algorithms between RATs and RAT reforming. These techniques are currently under discussion in standardization bodies, and some deployments of techniques are foreseen in the near future.

Scenario 3: An enabler of cooperative spectrum access.

Utilizing parts of the spectrum remaining unused due to variations in the spectrum occupancy using CRS technology. Enabling factors for the scenario include:

– exchange of spectrum use information among systems;
– identification of spectrum occupancy variations;
– sharing mechanisms between a CRS and non-CRS or between CRSs.

Scenario 4: An enabler for opportunistic spectrum access.

The CRS accesses parts of unused spectrum in bands shared with other radio systems and services without causing harmful interference. Enabling factors for the scenario include:

– methods to obtain knowledge;
– sharing mechanisms between a CRS and non-CRS or between CRSs.

9.2 Migration aspects

Traditionally in the development of LMSs, backwards compatibility has been an important design criterion and continues to be important along with the introduction of CRS technology. It is likely that intelligence by using the CRS technology will be added to the systems in a step-by-step fashion by gradually enhancing conventional systems with new features of CRS technology.

The introduction of CRS technology into a radio system will differ depending on the considered scenarios and related applications and will require specific CRS capabilities and enabling technologies to be implemented. In addition, some applications may require the introduction of CRS technology on the network side only, others on the mobile devices only, and others may require on both sides.

The introduction of CRS technology on the network side may take the advantages of having low power and size restrictions while, on the contrary, such aspects may have bigger impacts on the mobile devices side. Despite that, the introduction of CRS technology on the network side or mobile devices (or either) will depend on the specific application. In both cases, the operations compatibility with other radio system (i.e. network and mobile devices) not employing CRS technologies should be anyway guaranteed. Taking into consideration such aspects, it is anyway quite straight forward that the introduction of the CRS technology on both network and devices side would have the merit to exploit the CRS capabilities in a more efficient way. For example, related to the obtaining knowledge capability, the system would get information on radio environments both from the network and mobile devices side so that decision making, adjustment of the operational parameters and learning capabilities could then take advantage of it.

The obtaining knowledge capability implies information exchange between different nodes and its introduction into a radio system is foreseen most impacting when considering spectrum sharing applications. In fact, in such contexts, mechanisms for the exchange of protection requirements information between systems (e.g. by using database) and technical solutions to avoid harmful interference, QoS degradation and to guarantee an overall efficient spectrum use are needed.

This inter-system information exchange could be realized at different hierarchy levels which call for different level of changes to the system architecture and interfaces for information exchange. The evolution path could be envisaged to move from information exchange between databases, between network controllers or between the radio access networks themselves. The information exchange between databases could be implemented with additional functionalities on top of existing LMS systems whereas the cooperation between radio access networks would require standardized interfaces and more substantial changes to current systems.

10 Conclusion

This Report has addressed the cognitive radio systems (CRSs) within the land mobile service (LMS) continuing the work of Report ITU-R M.2225 that provided an introduction of CRSs in the LMS. The focus has been on providing an in-depth analysis of the application areas and technical features of CRSs in the LMS excluding IMT but many of the findings may also be applicable to IMT systems.

This Report has presented several applications of the CRS capabilities that consist of obtaining knowledge, decision making and adjustment and learning. Existing, emerging and potential future applications of the CRS capabilities have been presented to show that there already exist CRS applications within the LMS and there is potential for new application areas.

This Report has also presented a detailed description of the CRS capabilities and related enabling technologies. Particular sets of CRS capabilities and technical solutions may be needed to enhance spectrum sharing, coexistence and radio resource management on more dynamic basis, depending on particular bands and applications. The introduction of the CRS capabilities into the LMS would have the potential to offer considerable benefits across a broad range of improvements in the system performance and increased flexibility to respond to the operational environment. For example, the CRS capabilities may facilitate vertical and horizontal spectrum sharing, coexistence and radio resource management on more dynamic basis. For these purposes radio systems employing CRS techniques may operate with other radio systems that are not necessarily employing CRS technologies, as well as with other radio systems employing CRS technologies.

CRSs are expected to increase the efficiency of the overall radio resources (e.g. including spectrum) usage by offering new and enriched radio resource management mechanisms and also to provide more flexibility to applications as a result of their ability to dynamically adapt their operations e.g. to external and internal factors. Thus CRSs are enablers for technological evolution of the future wireless technologies and are likely to become a key means for future innovation of land mobile radio systems.

Abbreviations

A/D	Analogue to Digital
AC	Alternating Current
AI	Artificial Intelligence
ASM	Advanced Spectrum Management
BAN	Basic Access Network
BS	Base Station
BWA	Broadband Wireless Access
CBS	Cognitive Base Station
CCC	Cognitive Control Channel
CCN	Cognitive Control Network
CDMA	Code Division Multiple Access
CMN	Cognitive Mesh Network
CPC	Cognitive Pilot Channel
CR	Cognitive Radio
CRS	Cognitive Radio System
CSMA	Carrier Sense Multiple Access
CWN	Composite Wireless Network
CPU	Central Processing Unit
D/A	Digital to Analogue
DAB	Digital Audio Broadcasting
DFS	Dynamic Frequency Selection
DNP	Dynamic Network Planning
DRM	Digital Radio Mondiale
DVB-H	Digital Video Broadcasting – Handheld
ETSI	European Telecommunications Standards Institute
EUTRA	Evolved UMTS Terrestrial Radio Access
FFT	Fast Fourier Transform
FH	Frequency Hopping
FSM	Flexible Spectrum Management
FSU	Flexible Spectrum Use
GPS	Global Positioning System
GSM	Global System for Mobile Communications
HS	Harmonized Standard
HTTP	Hypertext Transfer Protocol
HW	Hardware
IEEE	The Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IMT	International Mobile Telecommunications

IM	Information Manager
IPv6	Internet Protocol version 6
JRRM	Joint Radio Resource Management
LAN	Local Area Network
LMS	Land Mobile Service
LTE	Long Term Evolution
MAC	Medium Access Control
MBMS	Multimedia Broadcast/Multicast Service
MIHF	Media Independent Handover Function
MT	Mobile terminal
MUE	Multi-radio User Equipment
MWR	Mobile Wireless Router
NAT	Network Address Translation
NRM	Network Reconfiguration Manager
O&M	Operation & Maintenance
OSM	Operator Spectrum Management
PAWS	Protocol to Access White Space databases
PDA	Personal Digital Assistant
PMSE	Programme Making and Special Events
PSD	Power Spectrum Density
QoS	Quality of Service
RAN	Radio Access Network
RAT	Radio Access Technology
RBS	Reconfigurable Base Station
RF	Radio Frequency
RLAN	Radio Local Area Network
RMC	RAN Measurement Collector
RRC	RAN Reconfiguration Controller
RRM	Radio Resource Management
RRS	Reconfigurable Radio Systems
SDR	Software-Defined Radio
SHA	Signalling Home Agent
SINR	Signal to Interference and Noise Ratio
SNR	Signal to Noise Radio
SOR	Service-Oriented Radio
SUE	Spectrum Utilization Efficiency
T-DMB	Terrestrial - Digital Multimedia Broadcasting
TMC	Terminal Measurement Collector
TPC	Transmit Power Control

TRC	Terminal Reconfiguration Controller
TRM	Terminal Resource Manager
TV	Television
UHF	Ultra High Frequency
UMTS	Universal Mobile Telecommunications System
USB	Universal Serial Bus
VHF	Very High Frequency
VoIP	Voice over IP
WiMAX	Worldwide Interoperability for Microwave Access
WRAN	Wireless Regional Area Network
WSD	White Space Device
WSDB	White Space Database

ANNEX A

Conceptual relationship between SDRs and CRSs

Software-defined radio (SDR) is recognized as an enabling technology for the CRSs. SDRs do not require CRS technologies for operation. One can be deployed/implemented without the other.

In addition, SDRs and CRSs are at different phases of development, i.e., radiocommunication systems using SDR applications have been already utilized and CRSs are now being researched and applications are under study and trial.

Furthermore, SDRs and CRSs are not radiocommunication services but are technologies that can be implemented in systems of any radiocommunication service. Moreover, it is seen that SDRs and CRSs are two technologies which can be combined.

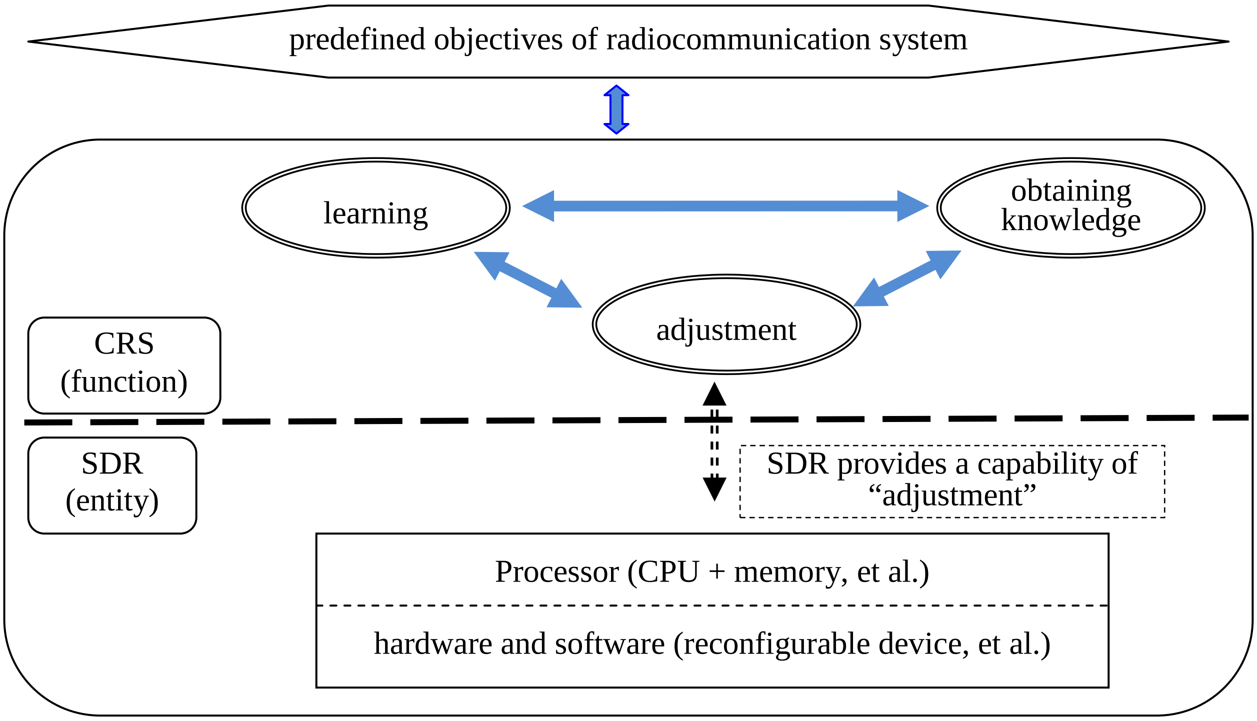
From the viewpoint of the progression in the development of SDRs, the signal processing technology has played major role, because it enhanced the digitalization of the communication equipment. Therefore, several kinds of signal processing become to be possible, which are not attainable by the analogue devices. At the initial stage of the SDR development, analogue devices are replaced to signal processor and A/D and D/A converters. Then, signal processing can be controlled by the CPU (Central Processing Unit) with intelligence.

Considering these development steps, SDRs may be the basis of a CRS, although it is also said that the SDRs and CRSs are not dependent with each other. SDRs are one of the tools for realization of the reconfiguration functions.

One example of conceptual relationship is depicted in Figure A.1. SDR is the composite entity of the hardware, software and processing capability, which provide the capability of adjustment for the CRS to achieve the predefined objectives. For such objectives the CRS will obtain knowledge regarding the operational and geographical environment, learn from the results obtained, and furthermore adjust its operational parameters and protocols, e.g. modulation scheme.

FIGURE A.1

Example of conceptual relationship between CRSs and SDRs



ANNEX B

An example of geolocation database controlled equipment

B.1 Introduction

ETSI has developed EN 301 598 the harmonized standard (HS) for white space devices (WSDs) operating in the UHF TV band (470-790 MHz). This harmonized standard is the key element in the regulation of WSDs in Europe. This section explains the framework under which ETSI compliant WSDs will operate, and provides an overview of the requirements in the HS.

B.2 Background

The European regulatory regime for the use of wireless devices was designed with the aim of removing the need for national type approval of devices. In this regime, manufacturers are required to self-declare conformance to the "essential requirements" of the Radio and Telecommunications Terminal Equipment Directive (R&TTE Directive) via a number of possible routes. The primary route is through compliance with a HS developed by European Standards Organizations. HSs that address the requirements of Article 3.2 of the Directive (effective use of the spectrum to avoid harmful interference) are normally produced at ETSI. These typically include RF requirements, such as transmitter power and unwanted emissions.

Once the ETSI Standard has completed the approval process and is cited in the Official Journal (OJ), equipment manufacturers could use it to show compliance with the requirements of the R&TTE Directive. Devices compliant with the requirements of the Directive can be put into the European market – although actual use will be subject to the authorisation regimes of each member state.

In practice, citation in the OJ means that manufacturers have a well-defined set of technical requirements that TV WS equipment needs to comply with. This facilitates the development process and greatly reduces the risk that different member states come up with different requirements.

EN 301 598 differs from past ETSI HSs, in the sense that it targets the interactions between a WSD and a white space database (WSDB) in addition to the usual specification of RF limits. This is because the European framework for access to TV white spaces stipulates that the limits on the radiated frequency and power of a WSD shall not be fixed, but dynamically calculated by a WSDB on the basis of the WSD's location, technical characteristics and requirements for protection of the incumbent users. The novel features detailed in this standard set the precedents that could be used in future standards.

B.3 Framework for operation in the TV White Spaces

EN 301 598 is based on a framework for access to TVWSs which involves the following four entities:

1) WSDBs provide operational parameters that allow WSDs to transmit without causing undue interference to primary users.
2) WSDB regulatory listing identifies the WSDBs that are authorized by a national regulatory authority (NRA) to provide service in the relevant jurisdiction.
3) Master WSDs are geolocated devices capable of communicating with a WSDB and of accessing the regulatory list.
4) Slave WSDs are devices that do not communicate directly with a WSDB, but instead operate under the control of a master WSD.

WSDBs and master WSDs exchange information to determine the parameters of the radio transmissions, EN 301 598 specifies three datasets for this:

– **Device parameters (DPs)** are the parameters that WSDs will communicate to a WSDB in order to provide the WSDB with relevant information about the device. These parameters include the technical characteristics of the device and its location.

– **Operational parameters (OPs)** are generated by a WSDB and communicated to WSDs. They specify the radio resources (frequencies and powers) and other instructions which WSDs must comply with. There are two types of operational parameters:

  • Specific operational parameters. The WSDB derives these for a particular WSD, on the basis of the WSD’s specific device parameters.

  • Generic operational parameters. The WSDB derives these for all slave WSDs operating in the coverage area of a master WSD. These are derived from the characteristics of the master WSD, and assumed default (cautious) slave device parameters.

– **Channel usage parameters**– These are reported back by a WSD to a WSDB to inform of the *actual* radio resources that it will use.

The framework assumes a typical sequence of events in the interactions between the four entities. This is described below and illustrated in Figure B.1.

1) **Database identification**. The master WSD must obtain the list of the WSDBs approved to operate in the regulatory domain. The list is hosted by the relevant NRA (as is the case of the UK) or by a trusted party, and accessible over the internet. The master WSD selects a WSDB from the list for its operations.

2) **Specific operational parameters for a master WSD**. The master WSD communicates its device parameters – which include its location – to the chosen WSDB. The WSDB will generate the operational parameters on the basis of the information provided by the master WSD, and the information that it holds about the primary users. The operational parameters will include a range of channels and powers. The master device must select which of those it will use, and report its choice to the WSDB by means of the channel usage parameters. The device can then start transmissions.

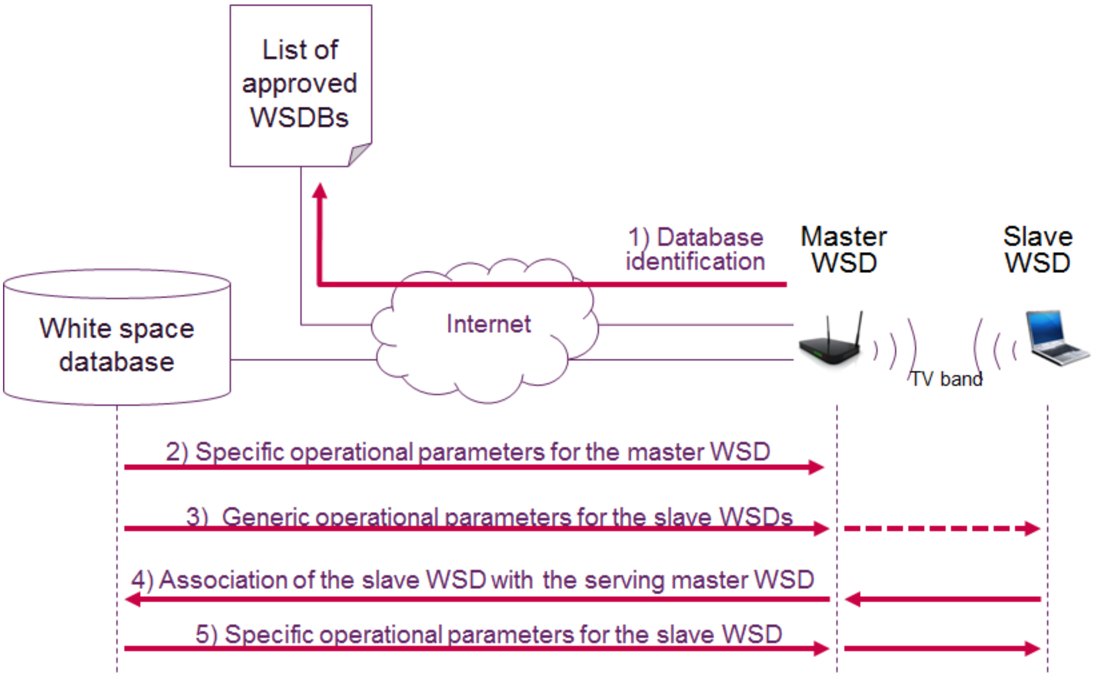
3) **Generic operational parameters for slave WSDs.** These parameters identify the resources that any slave WSD in the coverage area of master WSD can use. The master WSD will make a request for these parameters to the WSDB, which will use the information about the master WSD to calculate the master’s coverage area. The WSDB will then calculate the generic operational parameters by assuming a) that slaves may be at any location within the master’s coverage area, and b) default conservative values for the DPs of the slaves. At this stage the WSDB does not know anything about the slave WSDs that could be using these parameters. The WSDB will then send the generic operational parameters to the master WSD, and the master WSD will broadcast them to its coverage area.

4) **Association of a slave WSD with a serving master WSD.** When switched on, a slave WSD will listen for a master’s broadcasts. It will then use the channels and powers identified in the generic operational parameters to associate with the master WSD. This means that it will communicate its unique device identifier, or the full set of its device parameters. The slave WSD may now continue to use the radio resources identified in the generic operational parameters for data transmissions, or alternatively it may request specific operational parameters.

5) **Specific operational parameters for a slave WSD.** The radio resources allowed by the generic operational parameters will be limited because they are based on conservative assumption. A slave WSD whose device parameters are better than these assumptions, in particular a device that can accurately locate itself, may provide its parameters to the WSDB to gain access to more resources. For this, a process similar to obtaining specific operational parameters for a master WSD will be followed.

FIGURE B.1

Framework for operation in the TV whites spaces and typical sequence of operation



B.4 Device requirements in EN 301 598

EN 301 598 includes several requirements. It first defines that devices can be of two types – A and B, next specifies a number of RF requirements which are not unlike those of traditional harmonised standards, and finally it includes several non-RF requirements to deal with the fact that the radio parameters are communicated by a database. This section summarises these requirements.

B.4.1 Device types

EN 301 598 defines two types of WSDs:

– A Type A WSD is a device that is intended for fixed use only. This type of equipment can have integral, dedicated or external antennas.

– A Type B WSD is a device that is not intended for fixed use and which has an integral antenna or a dedicated antenna.

The key differentiator between the two classes is the type of antenna that the device supports. In this context, an integral antenna is designed as a fixed part of the equipment and that cannot be disconnected. An external antenna is removable antenna which is designed for use with a broad range of radio equipment, i.e. it has not been designed for use with a specific product. And a dedicated antenna is removable antenna supplied and assessed with the equipment, designed as an indispensable part of the equipment.

The classification also corresponds to the applications that have so far have been identified. Professional installations, such as a base station serving rural broadband customers, will most likely be Type A devices. Type B WSDs correspond to mobile/portable equipment such as handsets, dongles, or access points which do not require installation and can be mass market. EN 301 598 requires these devices to have non-detachable antennas, to mitigate the risk of the end user tampering with the antenna.

B.4.2 RF requirements

As with past standards, the RF requirements in EN 301 598 address the prevention of harmful interference by ensuring that the wanted radiated power, and the unwanted radiated power (inside and outside the band) do not exceed specific limits.

The specifications of limits outside the UHF TV band are relatively straightforward, and are defined in the same manner as existing HSs, and include limits on transmitter/receiver spurious emissions and transmitter inter-modulation. On the other hand, the limits inside the UHF TV band are more complex. This is fundamentally because a WSD may operate in a single digital terrestrial television (DTT) channel, or simultaneously in a group of contiguous DTT channels, or in multiple non-contiguous DTT channels, or a mixture of contiguous and non-contiguous DTT channels. The key RF requirements are the following.

B.4.2.1 Nominal Channel

A Nominal Channel is defined as one or more contiguous DTT channels that are used by a WSD for its wanted transmissions. Its lower and upper edge frequencies must coincide with the European harmonized DTT channel raster. The EN requirements are:

- The Nominal Channel Bandwidth used by a WSD shall not exceed the Maximum Nominal Channel Bandwidth specified by the WSDB.
- The Total Nominal Channel Bandwidth, which is the sum of the bandwidth in all Nominal Channels, shall not exceed the Maximum Total Nominal Channel Bandwidth specified by the WSDB.

B.4.2.2 In-block power and power spectral density

The WSDB will communicate to the WSD the following two power limits for each DTT channel where operation is possible:

- P_0 (dBm / 100 kHz) Maximum in-block RF e.i.r.p. spectral density for each DTT channel edge frequency pair.
- P_1 (dBm) Maximum in-block RF e.i.r.p. for each DTT channel edge frequency pair.

The requirement of EN 301 598 is that the device must not exceed the levels communicated by the WSDB. In particular, the RF power spectral density in any 100 kHz bandwidth within a DTT channel shall not exceed the level P_0 specified by the WSDB for that channel.

B.4.2.3 Unwanted emissions inside the band

The out-of-block e.i.r.p. spectral density, P_{OOB}, of a WSD shall satisfy the following requirement:

$$P_{OOB} \text{ (dBm / (100 kHz))} \leq \max\{ P_{IB} \text{ (dBm / (8 MHz))} - \text{ACLR (dB)}, -84 \text{ (dBm / (100 kHz))} \}$$

where P_{IB} is the in-block e.i.r.p. spectral density over 8 MHz, and adjacent channel leakage ratio (ACLR) is outlined in the Table I below for different device emission classes. Each out-of-block e.i.r.p. spectral density is examined in relation to P_{IB} in the nearest (in frequency) DTT channel used by the WSD.

The device class is part of the device parameters communicated to the WSDB, which will use the information in calculating operation parameters. Class 1 devices have the most stringent emission mask and will benefit from increased TVWS availability.

Table B.1 ACLR for different device emission classes.

Where P_{OOB} falls within the nth adjacent DTT channel (based on 8 MHz wide channels)	**ACLR (dB)**				
	Class 1	**Class 2**	**Class 3**	**Class 4**	**Class 5**
n = ±1	74	74	64	54	43
n = ±2	79	74	74	64	53
n ≥ +3 or n ≤ -3	84	74	84	74	64

The absolute threshold of -84 dBm/(100 kHz) is to take into account the difficulty in maintaining a high leakage ratio at very low in-block e.i.r.p.s.

B.4.3 Data communication requirements

The objective of EN 301 598 is that the WSDs only communicate with approved WSDBs, and then provide the necessary device parameters to the WSDB and operate in accordance with the information received from the database.

EN 301 598 defines the contents of the operational parameters, the device parameters and the channel usage parameters, but their detailed specification (such as the format and size of the data) is left to the protocols that devices and WSDBs will use to communicate (such as Internet Engineering Task Force Protocol to Access White Spaces (IETF PAWS)).

B.4.3.1 Database identification

Database identification is the process by which a master WSD consults the list of WSDBs that have been approved by the relevant NRA for the provision of services at the geographical location of the master WSD.

At start up, and before initiating any transmissions, a master WSD must locate and consult the list. EN 301 598 further specifies that the master WSD must not transmit if it cannot consult the list, and that it must not request parameters from a WSDB that is not on the list. In addition, the master WSD must re-consult the list with a frequency that is specified in the list itself, and that would normally be in the order of one or several days.

The internet address for the lists for the various regulatory domains is provided in ETSI TR 103 231.

B.4.3.2 Data exchange and compliance with parameters

The dynamic nature of frequency and power allocations to WSDs led ETSI to specify precise requirements for the exchange of parameters between WSDBs and WSDs and subsequent compliance with OPs. However, EN 301 598 is not prescriptive about the sequence, or about the name and format of the parameters. Instead, the requirements are about what parameters a device is allowed to use, and what parameters it must communicate to other entities. These requirements can be summarised as follows:

– A WSD shall only transmit in accordance with operational parameters that it has received from a WSDB.

– A master or a slave WSD that require specific operational parameters from a WSDB must report their device parameters to the WSDB. A slave WSD that intends to use the generic operational parameters broadcasted by a master must report its unique device identifier (although it may report the rest of the device parameters if it wishes to).
– A master WSD must communicate its channel usage parameters to the WSDB prior to transmission, and slave device must do the same to the serving master WSD.
– A master WSD must relay the parameters between the WSDB and slave WSDs that it serves.

B.4.3.3 Master and slave WSD update

NRAs have stated that it should be possible to switch off a device within a short time for interference management purposes. For this, EN 301 598 requires a master WSD to support an update function, through which a WSDB can inform that the OPs of the master WSD and its served slave WSDs are no longer valid.

In addition, there are requirements to automatically stop transmissions when the connection between the master WSD and the WSDB is lost, and where the slave WSD stops receiving the signal of the serving master WSD.

B.4.4 Other requirements

Accurate location of devices is an important element of operation under the framework. Also, special attention must be given to avoid the end user tampering with the elements of the device that are used in determining the operational parameters. The EN 301 598 includes specific requirements in these areas.

B.4.4.1 Geolocation requirements

A key element in the operation of WSDs is the ability of the WSDB to provide OPs on the basis of the location of the WSD. Not all WSDs are required to geolocate, though. The broad location of slave WSDs can be derived from an estimate of the coverage area of the serving master WSD, and hence slave WSDs are not required to have this capability. On the other hand, the location of the master WSDs must be known by the WSDB in order to calculate operational parameters for it and generic operational parameters for the slave devices that it serves. Therefore, EN 301 598 requires master WSDs to have this capability.

In addition, WSDs which geolocate must check its location at least every 60 seconds and renew the parameters if they move away from the location originally reported to the WSDB.

B.4.4.2 User access restrictions and security measures

An important concern from the perspective of interference to incumbent primary services is the risk of users tampering with the WSDs. If a WSD user is capable of bypassing the process of receiving parameters from a WSDB, or is capable of inputting bogus device parameters into the WSD, then serious interference could result. For this reason, EN 301 598 contains strict requirements to avoid the users gaining access to the configuration of the WSD, and to ensure that communications with a WSDB are secured and authenticated.

ANNEX C

Examples of improved spectrum usage efficiency enabled by cognitive networks

This Annex provides examples to illustrate the importance of the CRS technology employed by the operators to improve spectrum utilization and traffic load distribution.

An operator today must manage a heterogenic radio environment due to its multiple services, different network architectures, various multiple access techniques and multiple frequency bands. Intra-operator spectrum pooling enabled by a CRS is becoming essential in order to balance the load of the different networks that represent different technologies and different generations. Spectrum pooling also can increase the utilization of the scarce resources available.

The continuing growth of mobile radio systems is driving demand for more efficient use of spectrum. Spectrum pooling is a novel approach to radio resource management enabled by a CRS. A simple example to show the benefits of spectrum pooling enabled by a CRS is shown below.

In this calculation the resource needed for each call is assumed to be one channel. It is assumed that there are two different groups of spectrums available. Each spectrum group has 18 channels. It is also assumed that the performance criterion is not to exceed 1% probability of blocking.

Example 1

Two groups of spectrum that are completely partitioned. Each spectrum group is assumed to support 10 identical calls at 1% probability of blocking:

Spectrum are not shared: each group is fully utilized			**Spectrum are pooled**
Group 1	Group 2	Group 1 + Group 2	Group 1 + Group 2
10 calls	10 calls	20 calls	25 calls
18 channels	18 channels	36 channels	36 channels
Utilization = 55%	Utilization= 55%	Utilization = 55%	Utilization = 69%

Example 2

Two groups of spectrum that are completely partitioned. It is assumed that the first group is not fully utilized, where the number of calls serviced is = 2 calls; and group 2 is overloaded (more than 10 calls) which resulted in unacceptable probability of blocking (higher than 1%)

Each group is assumed to support 10 identical calls at 1% probability of blocking.

Resources are not shared: group 1 is not fully utilized			**Resources are pooled**
Group 1	Group 2	Group 1 + Group 2	Group 1 + Group 2
2 calls	10 calls	12 calls	Can support up to 25 calls (2 calls from group 1 and 23 calls from the overloaded group 2)
18 channels	18 channels	36 channels	36 channels
Utilization = 11%	Utilization = 55%	Utilization = 33%	Utilization = 69%

ANNEX D

Further details on CCC

This Annex contains additional information on main functionalities and operation procedure of CCC which was introduced in section 6.1.1.1.

D.1 Main functionalities of the CCC

In terms of functionality, the CCC may:

1) enable information exchange between independent and/or heterogeneous CRSs which operate in the same area;

2) provide support for sharing and coexistence of the CRSs by enabling networks to exchange information of the network capabilities and characteristics, and spectrum use and;

3) provide support for efficient spectrum use by enabling CRSs to exchange information about spectrum use, and to share policies, etiquettes, and spectrum sensing outcomes;

4) enable collaborative spectrum sensing. The networks operating in the same area may agree on a common quite period when they can sense the interferences e.g. from primary spectrum users or other CRSs which are not connected to the CCC. Exchanging the sensing outcomes enables a network to gain more, and more reliable, information on the radio environment;

5) provide support for self-configuring networks by enabling CRSs to exchange and access information about radio environment, use the information to identify optimal spectrum resources, and agree on the spectrum sharing with other networks;

6) provide support for efficient discovery of networks or devices to connect to.

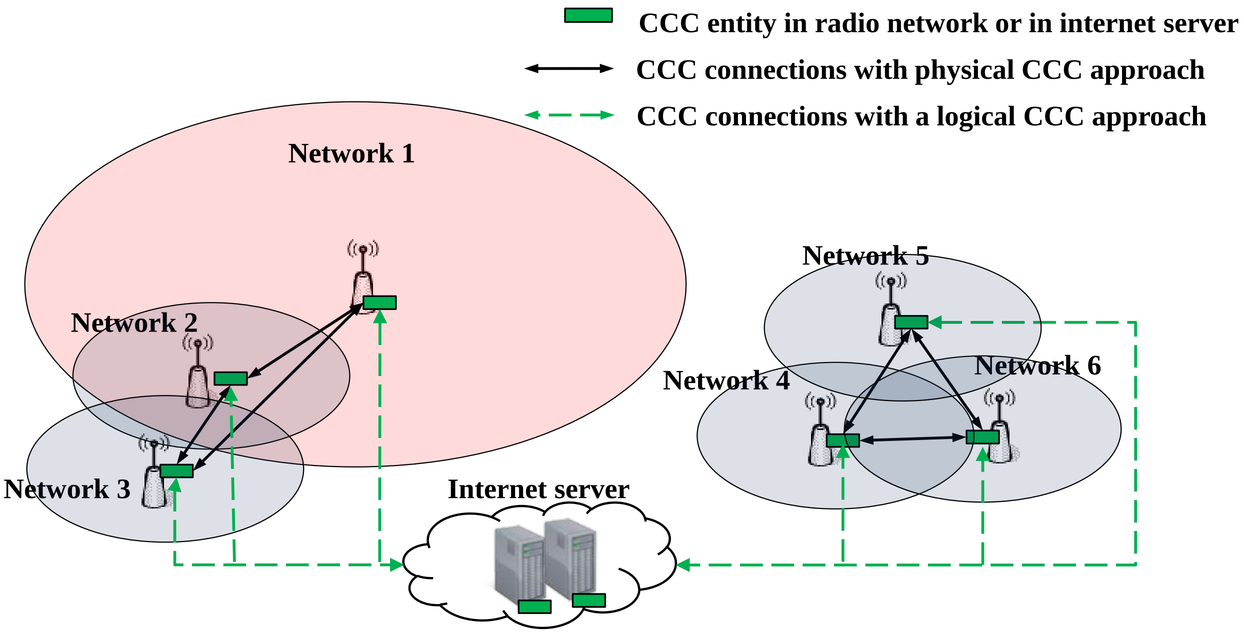
The messages and the protocols to discover other independent and/or heterogeneous networks in the area and to exchange the information with them should be defined.

D.2 CCC operation procedure

Typical applications of the CCC in an environment of independent and/or heterogeneous networks are illustrated in Figure D.1. The nodes exchange cognitive control information to each other over the illustrated CCC physical or logical connections. In the physical implementation option, direct CCC connections may be formed over low power local connectivity technology between the networks. In the logical channel implementation option of the CCC, internet servers supporting the logical CCC communication facilitate the connections between the nodes operating in the same geo-location area.

FIGURE D.1

Cognitive control channel used for enhancing coexistence between heterogeneous networks



Based on [26] and [27], which introduce requirements and information flows for sharing and coexistence communication, the CCC operations can be organized in four phases:

– initiate CCC;

– discover other nodes;

– connect to the relevant nodes;

– exchange and receive information with the relevant nodes.

The decision in each of the different phases depends on whether the physical or logical implementation option is used for CCC.

In the "Initiate CCC" phase the CCC entity in the CRS node starts the CCC operations. In the physical implementation option it switches on the physical radio channel which is used for CCC. In the logical implementation option, the CCC entity in the network registers to the CCC entity in the internet server. The geo-location area of the network is provided to the CCC entity in the registration.

In the "Discover other nodes" phase the CCC entity acquires information of other nodes in the area. The CCC entity may regularly enter the "Discover other nodes" phase to discover for example if new nodes have started operation in the same geo-location area. If the physical implementation option is used, the CCC entity scans or broadcasts messages from/to other CCC entities. This phase includes evaluation of the signal strength and content of the broadcast messages which are received from other CCC entities. In the logical implementation option, the CCC entity requests discovery information from the CCC entity in the internet server that provides a list of the nodes which are registered to operate in the same geo-location area. The list contains also information on how to connect to the CCC entities of those nodes, e.g. internet protocol address, or address specific to CCC system. The discovery mechanisms with different approaches are evaluated in [22].

In "Connect to the relevant nodes" phase the CCC entity determines with which nodes to exchange cognitive control information, and creates connection to the CCC entities of those networks.
In physical implementation option, the CCC entity responds to the broadcast messages to request

connection, and performs the required authentication procedures. Alternatively, the option to broadcast the cognitive control information may be used. This option does not require separate connection creation. In logical implementation option, the CCC entity connects to the CCC entities of the relevant nodes using the addressing information provided by CCC entity in the internet server in the “Discover other nodes” phase.

In the “Exchange and receive information with the relevant nodes” phase the CCC entity exchanges cognitive control information over the connections which were created in the “Connect to the relevant nodes” phase. The connections remain until they are terminated. A CCC entity may actively terminate the connection to another CCC entity. The connection may also be terminated passively if no messages have been exchanged before a pre-defined connection timeout.

ANNEX E

Further details on CPC

As described in section 6.1.1.2, the CPC is a pilot channel that broadcasts radio environment information in a CRS to facilitate the efficient operation and spectrum use. To implement CPC, the radio environment information is organized and delivered according to the geography area. Moreover, to achieve the operational efficiency, the main steps of the overall CPC operation procedure have been taken into account.

E.1 CPC operation procedure

When turned on, a mobile terminal or base station may not be aware of which is the most appropriate RAT in that geographic area where it is located, or which frequency ranges the RATs existing in that specific geographic area exploit. Indeed, in the case where Flexible Spectrum Management (FSM) schemes are applied[7], the mobile terminal or base station will have to initiate a communication in a spectrum context which may be completely unknown.

In this case, if information about the service areas of deployed RATs within the considered frequency range communicable from a radio terminal is unavailable, it would be necessary to scan the whole frequency range in order to know the spectrum constellation. This may be a power- and time-consuming effort and sometimes the search may not even be effective, as for example in the "hidden-node" case.

In this context, a CPC should provide sufficient information to components of the CRS, including a mobile terminal, so that it can initiate a communication session optimised to time, situation and location. The CPC broadcasts relevant information with regard to frequency bands, RATs, load situation etc. in the terminal location.

The envisaged CPC operation procedure is organized into two main phases, namely the "start-up" phase and the "ongoing" phase:

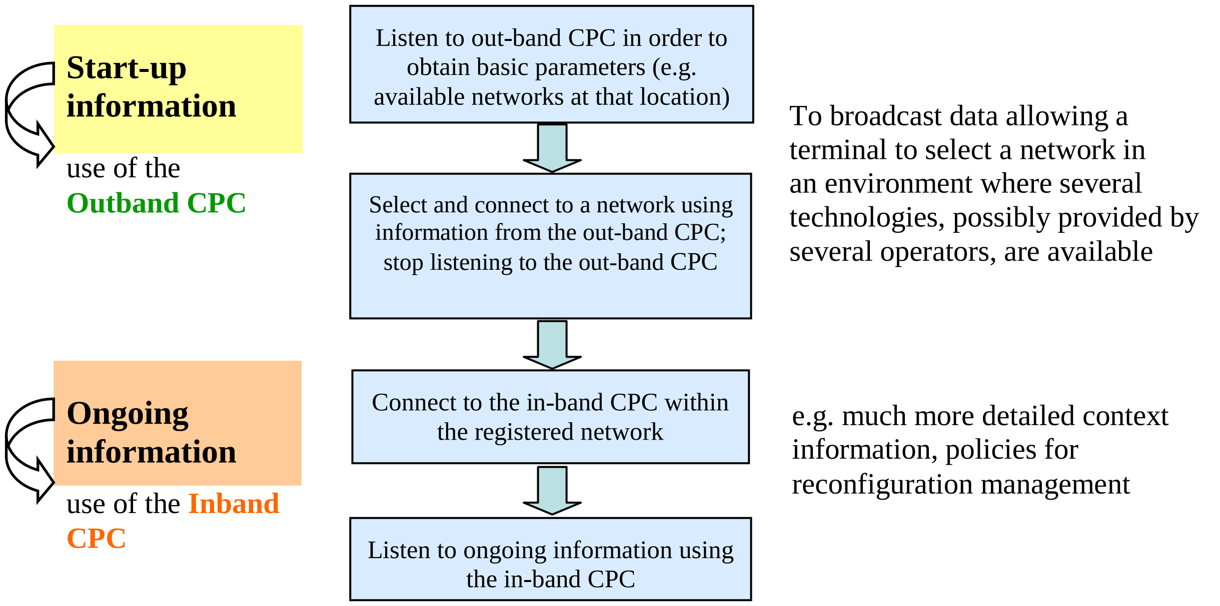
– For the "start-up" phase: after switching on, the node of the CRS (e.g. terminal) detects the CPC and optionally could determine its geographical information by making use of some positioning system. The CPC detection will depend on the specific CPC implementation in terms of the physical resources being used. After detecting and synchronizing with the CPC, the node of the CRS (e.g. terminal) retrieves the CPC information corresponding to the area where it is located, which completes the procedure. Information retrieved by the node of the CRS (e.g. terminal) is sufficient to initiate a communication session optimised to time, situation and location. In this phase, the CPC broadcasts relevant information with regard to operators, frequency bands, and RATs in this geographical location (e.g. terminal location).
– For the "ongoing" phase: once the terminal is connected to a network or CRS base station is on operation, a periodic check of the information forwarded by the CPC may be useful to rapidly detect changes in the environment due to either variations of the mobile position or network reconfigurations. In this phase, the CPC broadcasts the same information of the "ongoing" phase and additional data, such as services, load situation, etc.

[7] In this case, there is no core band for the network operation.

Figure E.1 presents the two main phases in the CPC operation taking into account the main steps of the overall CPC operation procedure described above. Both out-band CPC and in-band CPC are jointly used (see [28], [29], [35] and [36]).

FIGURE E.1

CPC operation procedure



E.2 Main functionalities of the CPC

In terms of functionality, the CPC:

1) enables the nodes of a CRS (e.g. mobile terminal) to properly select network depending on the specific conditions like for example RATs' operating frequency bands, established policies, desired services, RAT availability, interference conditions, etc. This provides support to Joint Radio Resource Management (JRRM), enabling a more efficient use of the radio resources;

2) provides support for an efficient use of the radio resource by forwarding radio resource usage policies from the network to the terminals;

3) provides support to reconfigurability by allowing the terminal to identify the most convenient RAT to operate with and to download software modules to reconfigure the terminal capabilities if necessary;

4) provides support to context awareness by helping the terminal identify the specific frequencies, operators and access technologies in a given region without the need to perform long time and energy consuming spectrum scanning procedures;

5) provides support to the network provider to facilitate dynamic changes in the network deployment by informing the terminals about the availability of new RATs/frequencies, thus providing support to dynamic network planning (DNP) and advanced spectrum management (ASM) strategies, providing information of the current status of specific spectrum bands (e.g. used or unused).

The deployment of CPC may require information also from the existing technology. The format of the frequency usage information as well as the spectrum band for the CPC needs to be realised in a way that CRSs are able to access it and understand the information.

E.3 Geography-based implementations of the CPC

There is a need to organize the information delivered over the CPC according to the geographical area where this information applies. A difference can be made between two options differing on how they provide geographical related information.

E.3.1. Coverage area approach

The CPC content for a given geographical area is organised considering the region, under-laying CPC umbrella, where such information has to be considered valid.

For instance, in case the CPC information is related to availability of operator/RAT/frequency the CPC information will be organised e.g. per coverage area of each RAT.

Knowing the position of the mobile terminal is not a strict requirement for the CPC operation using this approach, but a capability that enables higher efficiency in obtaining knowledge:

- in case positioning is not available, as long as the mobile terminal is able to receive the CPC information, the information about the different regions in that area are available;
- in case positioning is available, a subset of the information at the actual position could be identified. The mobile terminal could then use that information.

The structure of the CPC message includes at least the following fields:

- *Operator information*: operator identifier. This information is repeated for each operator to be advertised by the CPC.
- *RAT list*: for each operator, provide information on available RATs. This information is repeated for each RAT of *i*-th operator.
- *RAT type*: could be for instance “GSM”, “UMTS”, “CDMA2000”, “WiMAX”, “LTE”, etc.
- *Frequency information*: provide the list of frequencies used by the RAT, i.e. the operating band(s).

The information above is assumed to be valid wherever the CPC is received. Nevertheless, optionally additional information related to the local geographical deployment could be provided.

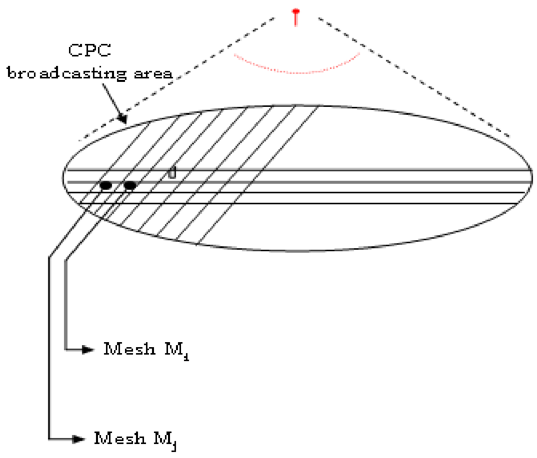
In the case of CPC In-band solution, other fields could be added to the reported ones. Such fields could include e.g. Policies, Context Information, etc.

E.3.2 Mesh-based approach

The CPC operates in a certain geographical area that could be imagined as subdivided into meshes, as shown in Figure E.2. A mesh is defined as a region where certain radio electrical commonalities can be identified (e.g. a certain frequency that is detected with power above a certain level in all the points of the mesh etc.). The mesh is uniquely defined by its geographic coordinates, and its adequate size would depend on the minimum spatial resolution where the above mentioned commonalities can be identified [57].

FIGURE E.2

Geographical area of the CPC divided into meshes



The coverage area of the heterogeneous networks could be divided into several meshes in geographical area. Each mesh can have different operational state, such as RATs, traffic load and etc. CPC could deliver information based on mesh-division. In the mesh division-based approach, there are mainly three CPC information delivering approaches: broadcast CPC, on-demand CPC and multicast CPC mode.

The multicast CPC mode is an evolution of on-demand CPC delivery mode, which adopts point-to-multipoint information delivery approach. In this mode, the network should wait the requests of users from the same mesh for a period time before sending the request of this mesh into the scheduling system which would arrange the requests.

The multicast CPC utilizes the scheduling system to manage the information delivering. The multicast CPC functionality would send the information to the scheduling system first, and then the scheduling system would deliver the information to the terminals according to certain scheduling policies.

The out-band CPC-cells can be divided as meshes to improve the accuracy and efficiency of the information delivered via CPC. And the mesh division scheme provide guidelines for how to divide meshes appropriately, in which the factors that are related to the mesh division size and have significant effects on the accuracy and efficiency of the information delivered via CPC should be considered, such as user density, information representation in multi-RATs overlapped meshes, dynamic mesh division size in multi-RATs overlapped deployment. Furthermore, the transmission delay of information delivery via CPC and the efficiency of overall procedure of CPC should also be considered.

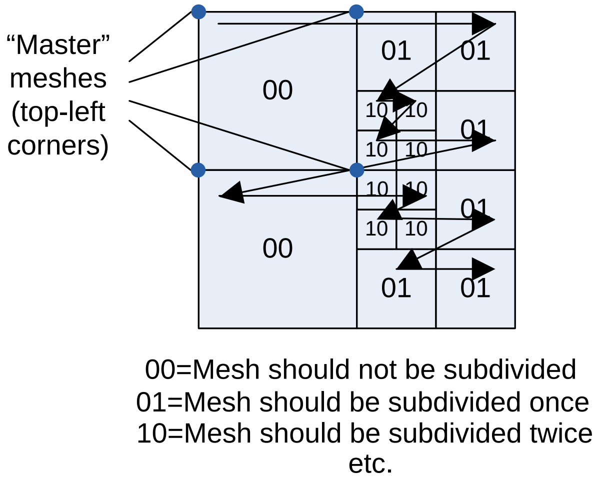
E.3.2.1 Link with subdivision of meshes

The coverage area approach might be achieved through dedicated transmissions each associated with a reference point (e.g., coordinate) and specification of the coverage area with respect to that reference point, or alternatively might be incorporated into the mesh-based approach. If such a capability were incorporated into the mesh-based approach, the information load (e.g., in order to specify each coordinate reference point and associated relative coverage area) could be significant.

One alternative solution could be to develop a scheme for sub-division of meshes, whereby a small number of bits could indicate at the start of a mesh whether it is subdivided or not, thereby allowing for a very large base mesh size (hence, a small information load for the CPC), while also allowing for the subdivision of that in locations where the information is varying more densely such as urban areas. Figure E.3 depicts one such possible scheme for the subdivision of meshes, where 2 bits are used in each mesh to indicate whether it is subdivided or not. This Figure also shows the order in which the information on the CPC would be transmitted under such a scheme (black arrows).

FIGURE E.3

An approach to the subdivision of CPC meshes



E.4 Implementation example of CPC using broadcast platforms

An example of CPC implementation is to realize a coverage-area CPC as a logical channel within some of the existing broadcast digital platforms. There are several properties that would determine how desirable a particular broadcast technology is for this purpose. It must satisfy the driving requirements of the CPC conceptual scheme, the main goal of which is the enabling of the transfer to mobile terminals (MTs) of available knowledge of the operational and geographical wireless environment, and the established policies.

The benefit of existing broadcast platforms is the possibility for the CPC to achieve a very high level of coverage of a given area. Ideally, coverage should at least match that offered by the RATs (e.g. mobile cellular systems) available in the area. Reception should be available indoors as well as outdoors. Technical characteristics will need to address QoS issues to ensure geographical coverage and mobility of MTs.

The out-of-band broadcast CPC will require a CPC receiver subsystem to be integrated into the MT. However for some broadcast platforms, the MTs will already have relevant receiver subsystems – to receive their other main broadcast services (e.g. video and audio broadcast) – so the extraction of the CPC channel information will largely be a software application addition to the subsystem. Where a receiver subsystem must be integrated, it should have minimal size, minimal power consumption requirements, and hardware manufacturing and integration costs, all so as not to adversely affect MT size, stored energy requirements, and manufacturing cost.

There are several seemingly suitable broadcast technologies to consider, such as the Digital Audio Broadcasting (DAB), the Terrestrial - Digital Multimedia Broadcasting (T-DMB), the Digital Radio Mondiale (DRM), the Multimedia Broadcast/Multicast Service (MBMS), and the Digital Video Broadcasting – Handheld (DVB-H).

In [60], the design and implementation of a three-layer 'CPC over DVB-H' system architecture is presented and evaluated by means of a hybrid software/hardware testbed, with specific emphasis on the CPC service layer and service descriptions.

Another promising alternative is to use the DAB standard, which since 2001 has become popular in several countries particularly in the UK and Europe, or the T-DMB standard, which is based on DAB with an additional Reed-Solomon (RS) forward error correction (FEC) module to improve communication performance in wireless channels. With the increased number of mobile phones supporting the T-DMB, the latter is seen as an attractive, early adopter, carrier technology candidate for CPC. In [61], the design and implementation of a 'CPC over T-DMB' system architecture are presented along with the concept validation through a testbed prototype platform implementation, and performance evaluation results.

E.5 Out-band and in-band characteristics

The characteristics of out-band and in-band parts of the CPC are summarized in the following Table E.1 (see also [29]).

TABLE E.1

Characteristics of out-band and in-band parts of the CPC

Characteristics	Outband CPC	Inband CPC
Information conveyed	Start-up information, e.g. context information on available networks at that location	Ongoing information, e.g. much more detailed context information, policies for reconfiguration management, etc.
Channel bit rate requirements	Initial requirements evaluations seem to conclude that relatively low bit rate is required in case of coverage area approach, while mesh-based approach could require a very high amount of bandwidth.	
Data direction	Downlink. Optionally uplink	Downlink and Uplink
Bearer	Most likely a harmonized frequency band, wide-area coverage. Might be a novel RAT, legacy mobile (e.g. GSM) or broadcasting technology (e.g. DVB-H and T-DMB) of appropriate characteristics	A bearer in a operator's network (e.g. a logical channel mapped on a 3G bearer)

ANNEX F

Sensing methods

This Annex provides a non-exhaustive list of different sensing methods that are actually under study.

Matched filter detection

The optimal detector in stationary Gaussian noise is the matched filter since it maximizes the received SNR. The main advantage of matched filtering is the short convergence time to achieve a certain probability of misdetection or false alarm. However, the problem with this approach is that the perfect prior information of the signal to be detected (modulation type, order, pulse shape and packet format, etc.) is needed. Radio networks with pilot, preambles and synchronization words and spreading codes can use this matched filter detection. Since the CRS needs receivers for several different signal types, the implementation complexity of sensing unit is impractically large and various receiver algorithms also lead to large power consumption. The matched filter is also not suitable for spectrum sensing in very low SNR regions since synchronization is difficult to achieve [41].

Energy detection

If there is no information of the primary user signals to be detected, the optimal detection is an energy detector. Its generic nature as well as low computational and implementation complexity are attractive features for this case. The energy detector simply measures the energy of the received signals and compares it to a threshold which depends on the noise floor. However, the problem with the energy detection is that the noise floor might be unknown to the detector, thus, finding a proper threshold is challenging though training can be done with pilot signals. Because the energy detector is unable to distinguish between noise and interference from primary user false detection might be triggered by unintended signals. The energy detector does not perform well in low SNR regions or in detecting spread spectrum signals [41]. One method for using information from the energy detector is noise floor based method where the receiver measures the cumulative RF energy from multiple transmissions over a particular frequency spectrum and set a maximum cap on their aggregate level. As long as a CRS node does not exceed this limit by their transmissions, it can use that frequency spectrum.

Cyclostationary feature detection

This type of detector operates based on the cyclostationary feature of the signals. Cyclostationary features are caused by the periodicity in the signal or in its statistics like mean and autocorrelation or they can be intentionally induced to assist spectrum sensing. Cyclostationary feature detector can differentiate between noise and primary users signal because noise has no correlation. It can also classify different types of transmission and primary users [41]. It performs better than the energy detection in terms of probability of detection particularly in low SNR region. However, the computation complexity is relatively high and it also requires longer sensing time than energy detector [62].

Self-correlation detection

In self-correlation detection, the decision statistic for the binary hypothesis is derived from signal autocorrelation sequence instead of the received signal itself. The correlation lag/delay is chosen in accordance with the maximum bandwidth of the signal involved. The decision statistic is obtained after converting the correlation sequence to frequency domain through FFT. The scheme improves the probability of detection compared to the energy detection in the presence of noise power uncertainty with less complexity compared to cyclostationary property detection. However, if multiple primary users are present, unwanted signal due to the non-linearity of the correlation operation arises. This would affect the performance especially if the primary users are many and have weak signals.

Waveform based detection

Known patterns, for example, preambles, mid-ambles, regularly transmitted pilot pattern, spreading sequences, are usually operated in wireless systems to assist synchronization or for other purposes. In the presence of a known pattern, waveform based detection can be performed by correlating the received signal with a known copy of itself. Compared with energy detection, this method requires shorter measurements time and outperforms in reliability. Furthermore, the performance of the sensing algorithm increases as the length of the known signal pattern increases [41].

Distributed sensing

Distributed sensing systems have been employed in the past for both commercial and military services. Due to multiple factors like noise and interference, shadowing, fading and limitation of the sensing method, it may be very difficult to use a single standalone sensor to obtain high quality of sensing. In this case, distributed sensing can be used where each individual sensor can either be located inside or outside the CRS node. As the name implies, the distributed spectrum sensing is executed using multiple sensors distributed spatially. These distributed sensors may have the ability to exchange sensing information, making decisions and relay the sensing information to the CRS nodes. The sensing information could include sensing outcome, accuracy of results, location of sensors, etc. The sensing information is supplied to the CRS node in a cooperative manner where the data from all sensors is aggregated to obtain the final sensing information. Such implementation method can dramatically improve the sensing quality of the CRS. This would relax the sensing requirements and choice of the sensing method at each sensor. Note, however, that relaying the sensing information requires a channel free from primary users.

Edge detection for wideband spectrum sensing

In some cases, a CRS may identify used spectrum over wide frequency bands. For spectrum sensing over wideband channels, the edge detection approach offers advantages in terms of both implementation cost and flexibility in adapting to the dynamic spectrum, as opposed to the conventional use of multiple narrow-band bandpass filters. The edge detection techniques [63] can be used to effectively detect the channel borders in power spectrum density (PSD). Therefore, the edge detection techniques for wideband spectrum sensing can effectively scan over a wide bandwidth to simultaneously identify all subbands, without prior knowledge on the number of subbands within the frequency range of interest.

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Preliminary draft REVISION of report ITU-R M.2228

Source: Annex 19 to Document 5A/543, Documents 5A/562, 5A/602, 5A/619

Subject: Question ITU-R 205-5/5

Document 5A/TEMP/265-E
3 November 2014
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Working Party 5A
(WG 5A-5)

WORKING DOCUMENT TOWARD A PRELIMINARY DRAFT NEW RECOMMENDATION ITU-R M.[V2X]

Radio interface standards of vehicle-to-vehicle and vehicle-to-infrastructure communications for intelligent transport systems applications

(Question ITU-R 205-5/5)

Scope

This Recommendation identifies specific radio interface standards of vehicle-to-vehicle and vehicle-to-infrastructure communications for ITS applications. The technical and operational characteristics described in this Recommendation are based on current and existing frequency bands already identified for ITS and the applications in the mobile service.

Keywords

ITS, vehicle-to-vehicle communications, vehicle-to-infrastructure communications

Acronyms and abbreviations

ARIB	Association of Radio Industries and Businesses
BPSK	Binary phase shift keying
CSMA/CA	Carrier sense multiple access/collision avoidance
DSRC	Dedicated short range communications
ETSI	European Telecommunications Standards Institute
FEC	Forward error correction
IEEE	Institute of Electrical and Electronics Engineers
ITS	Intelligent transport systems
OFDM	Orthogonal frequency-division multiplexing
QAM	Quadrature amplitude modulation
QPSK	Quadrature phase shift keying
TTA	Telecommunications Technology Association

V2I Vehicle-to-infrastructure

V2V Vehicle-to-vehicle

Related ITU Recommendations

Recommendation ITU-R M.1453	Intelligent Transport Systems – dedicated short-range communications at 5.8 GHz
Recommendation ITU-R M.1890	Intelligent Transport Systems – Guidelines and Objectives

The ITU Radiocommunication Assembly,

considering

a) that standards development organizations (SDOs) are developing specific standards for vehicle-to-vehicle and vehicle-to-infrastructure communication in the intelligent transport system (ITS) service;

b) that using the ITU-R Recommendation identifying these standards, manufacturers and operators should be able to determine the most suitable standards for their needs,

noting

Recommendation ITU-R M.1453, which recommends dedicated short-range communications (DSRC) operating at 5.8 GHz,

recommends

that the radio interface standards in Annexes 1 to 4 should be used for vehicle-to-vehicle and vehicle-to-infrastructure communication.

ANNEX 1

ETSI standards

ETSI Standards developed for the access and media layer are based on features such as:

– 5,9 GHz spectrum usage;

– multichannel operation;

– decentralized congestion control (DCC);

– coexistence of ITS and EFC (CEN DSRC) services in the 5.8 GHz and 5.9 GHz bands.

TABLE 1

Base standards for the access and media layer

Standard title	Standard number
Intelligent transport systems (ITS); Radiocommunication equipment operating in the 5 855 MHz to 5 925 MHz frequency band; Harmonized EN covering the essential requirements of Article 3.2 of the R&TTE Directive	ETSI EN 302 571
Intelligent transport systems (ITS); Access layer specification for intelligent transport systems operating in the 5 GHz frequency band	ETSI EN 302 663
Intelligent transport systems (ITS); Decentralized congestion control mechanisms for intelligent transport systems operating in the 5 GHz range; Access layer part	ETSI TS 102 687
Intelligent transport systems (ITS); Mitigation techniques to avoid interference between European CEN dedicated short-range communication (CEN DSRC) equipment and intelligent transport systems (ITS) operating in the 5 GHz frequency range	ETSI TS 102 792
Intelligent transport systems (ITS); Harmonized channel specifications for intelligent transport systems (ITS) operating in the 5 GHz frequency band	ETSI TS 102 724

TABLE 2

Testing standards for the access and media layer

Testing Standard title	Standard number
Intelligent transport systems (ITS); Test specifications for the channel congestion control algorithms operating in the 5.9 GHz range; Part 1: Protocol implementation conformance statement (PICS)	ETSI TS 102 917-1
Intelligent transport systems (ITS); Test specifications for the channel congestion control algorithms operating in the 5.9 GHz range; Part 2: Test suite structure and test purposes (TSS & TP)	ETSI TS 102 917-2
Intelligent transport systems (ITS); Test specifications for the channel congestion control algorithms operating in the 5.9 GHz range; Part 3: Abstract test suite (ATS) and partial protocol implementation eXtra information for testing (PIXIT)	ETSI TS 102 917-3
Intelligent transport systems (ITS); Test specifications for the methods to ensure coexistence of cooperative ITS G5 with RTTT DSRC; Part 1: Protocol implementation conformance statement (PICS)	ETSI TS 102 916-1
Intelligent transport systems (ITS); Test specifications for the methods to ensure coexistence of cooperative ITS G5 with RTTT DSRC; Part 2: Test suite structure and test purposes (TSS&TP)	ETSI TS 102 916-2
Intelligent transport systems (ITS); Test specifications for the methods to ensure coexistence of cooperative ITS G5 with RTTT DSRC; Part 3: Abstract test suite (ATS) and partial protocol implementation eXtra information for testing (PIXIT)	ETSI TS 102 916-3

ANNEX 2

IEEE standards

[*Editor's Note: Administrations, Sector Members or IEEE may wish to contribute to the November 2013 meeting, similar to the IEEE specifications provided in Document 5A/262*.]

ANNEX 3

ARIB standard

In Japan, for the use of the safe driving support systems, a part of the 700 MHz band (755.5-764.5 MHz) has been assigned in new spectrum allocation on a primary basis in the digital dividend band. The technical characteristics of vehicle-to-vehicle and vehicle-to-infrastructure communications for safe driving support systems are shown in Table 3.

TABLE 3

Characteristics of the transmission scheme

Item	Technical characteristic
Operating frequency range	755.5–764.5 MHz (Single channel)
Occupied bandwidth	Less than 9 MHz
Modulation scheme	BPSK OFDM. QPSK OFDM, 16QAM OFDM
Forward error correction	Convolutional coding, rate = 1/2, 3/4
Data transmission rate	3 Mbit/s, 4.5 Mbit/s, 6 Mbit/s, 9 Mbit/s, 12 Mbit/s, 18 Mbit/s
Media access control	CSMA/CA

Table 3 shows basic specifications of ARIB standard; ARIB STD-T109[1], 700 MHz band intelligent transport systems (ITS) which have been developed in February 2012.

A 9 MHz channel width in the 700 MHz radio frequency band will be used for the safe driving support systems.

Data transmission rate is variable based on the selection of Modulation scheme and coding rate (R) as follows:

– 3 Mbit/s (BPSK OFDM, R = 1/2), 4.5 Mbit/s (BPSK OFDM, R = 3/4);
– 6 Mbit/s (QPSK OFDM/, R = 1/2), 9 Mbit/s (QPSK OFDM, R = 3/4);
– 12 Mbit/s (16QAM OFDM, R = 1/2), 18 Mbit/s (16QAM OFDM, R = 3/4).

The single channel accommodates both vehicle-to-vehicle and vehicle-to-infrastructure communications based on CSMA/CA media access control.

[1] ARIB standard; ARIB STD-T109, 700MHz band intelligent transport systems (http://www.arib.or.jp/english/html/overview/doc/5-STD-T109v1_2-E1.pdf).

ANNEX 4

TTA standards

1 Technical characteristics

The advanced ITS radiocommunications system has to consider the described V2V/V2I communications and its service requirements and WAVE standards for international harmonization. In V2V applications, it is required to consider the low packet latency because the life-saving time of safety message is useful in the span of 100 m/s. Also it requires a highly activated radio channel when many vehicles try to activate radio channel simultaneously. In V2I applications, it needs to adopt the long packet transmission which includes a short message, map information and image information to be order of 2 Kbytes in a packet size in high mobility condition.

Thus the advanced ITS radiocommunication system has the following features as shown in Table 4.

TABLE 4

Technical characteristics

Item	Technical characteristic
RF frequency	5855 ~ 5925 MHz[(experimental)]
RF channel bandwidth	10 MHz
RF Transmit power	23 dBm
Modulation type	OFDM(BPSK, QPSK, 16QAM, Option : 64QAM)
Data rate	3, 4.5, 6, 9, 12, 18 Mbit/s, Option : 24, 27 Mbit/s
MAC	CSMA/CA, Option : Time Slot based CSMA/CA
Networking	IPv4/IPv6, VMP(WSMP compatible)
Multi-hop	Location information based routing

2 TTA Standards related to advanced ITS radiocommunications

In the Republic of Korea, Telecommunication Technology Association (TTA) established four standards for advanced ITS radiocommunications. The detailed information of these standards is shown in Table 5.

TABLE 5

Base standards related to advanced ITS radiocommunications

Standard title	Standard number
Vehicle communication system Stage 1: Requirements	TTAK.KO-06.0175/R1
Vehicle communication system Stage 2: Architecture	TTAK.KO-06.0193/R1
Vehicle communication system Stage 3: PHY/MAC	TTAK.KO-06.0216/R1
Vehicle communication system State 3: Networking	TTAK.KO-06.0234/R1

ANNEX 5

Technical characteristics of standards

Technical characteristics of each standard are shown in Table 6.

TABLE 6

Technical characteristics

Parameter	ETSI (Annex 1)	IEEE (Annex 2)	ARIB (Annex 3)	TTA (Annex 4)
Operating frequency range	5855 – 5925 MHz		755.5–764.5 MHz (Single channel)	5855 – 5925 MHz [(experimental)]
RF channel bandwidth	10 MHz		Less than 9 MHz	Less than 10 MHz
RF Transmit Power/EIRP	Max 33dBm EIRP			23 dBm
Modulation scheme	BPSK OFDM, QPSK OFDM, 16QAM OFDM, 64QAM OFDM		BPSK OFDM, QPSK OFDM, 16QAM OFDM	BPSK OFDM, QPSK OFDM, 16QAM OFDM, Option: 64QAM
Forward error correction	Convolutional coding, rate = 1/2, 3/4, 2/3		Convolutional coding, rate = 1/2, 3/4	Convolutional coding, rate = 1/2, 3/4
Data transmission rate	3 Mbit/s, 4.5 Mbit/s, 6 Mbit/s, 9 Mbit/s, 12 Mbit/s, 18 Mbit/s, 24Mbit/s, 27Mbit/s		3 Mbit/s, 4.5 Mbit/s, 6 Mbit/s, 9 Mbit/s, 12 Mbit/s, 18 Mbit/s	3, 4.5, 6, 9, 12, 18 Mbit/s, Option: 24, 27 Mbit/s
Media access control	CSMA/CA		CSMA/CA	CSMA/CA, Option: Time Slot based CSMA/CA
Duplex method	TDD		TDD	TDD
Packet Error Ratio				10%

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Working document toward a preliminary new report ITU-R M.[ITS usage]

Radiocommunication Study Groups

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Revision 1to
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5 November 2014
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Working Party 5A
(WG 5A-5)

PRELIMINARY DRAFT REVISION OF REPORT ITU-R M.2228

Advanced intelligent transport systems (ITS) radiocommunications

(Question ITU-R 205-5/5)

Summary of the revision

In this revision, update information on status of advanced ITS radiocommunications is introduced in Section 4.1.2 to reflect recent standardization activities in Japan.

[Editor's note: Further updates in the revision are expected to reflect recent activities in each region.]

 15.05.15

TABLE OF CONTENTS

1 Background

Intelligent transport systems (ITS) are applied to services such as the provision of road traffic information and electronic toll collection, and deployed in many countries by using dedicated short-range communications (DSRC) or cellular phone systems. ITS have now become an important social infrastructure.

Several ITS relevant ITU-R Recommendations exist as listed below:

– ITU-R M.1890: Intelligent transport systems – Guidelines and objectives

– ITU-R M.1452: Millimetre wave radiocommunication systems for Intelligent Transport Systems applications

– ITU-R M.1453: Intelligent Transport Systems – dedicated short-range communications at 5.8 GHz.

– ITU-R M.[V2X] Radio interface standards of vehicle to vehicle and vehicle to infrastructure communications for intelligent transport systems applications.

Recommendation ITU-R M.1453 – DSRC at 5.8 GHz, which supports a maximum data transmission rate of 4 Mbit/s, was limited to DSRC operations in the ISM band.

To extend beyond the existing ITS applications and to achieve traffic safety and reduce the environmental impact by the transportation sector, both R&D in and standardization of advanced ITS radiocommunications are expected, including not only roadside-to-vehicle communications but also vehicle-to-vehicle direct communications with a few hundred milliseconds or lower latency and with a few hundred metres or longer communication distance. To accommodate hundreds of vehicles in the communication range and to exchange their information in such a short latency, higher data rate wireless access technology is required for advanced ITS radiocommunications.

Studies and feasibility tests on advanced ITS radiocommunications have been actively conducted towards the realization of traffic safety and a reduction of the environmental impact.

As a result, recently, major progress has been made in R&D activities on advanced ITS radiocommunications in several regions including North America, Europe and Asia-Pacific Region. Therefore, it would be beneficial to share the information obtained for future harmonization and standardization.

Regarding standardization and information exchange, relevant discussions have been started in global standards collaboration (GSC) meeting. At the GSC-16 meeting, ITU-T, ETSI, TIA, TTA and ARIB presented their relevant activities. Furthermore, in the Asia-Pacific Region, issues relating to advanced ITS radiocommunications were discussed in a Task Group on ITS at the 11th meeting of APT Wireless Group (AWG-11).

2 Characteristics of advanced ITS radiocommunications

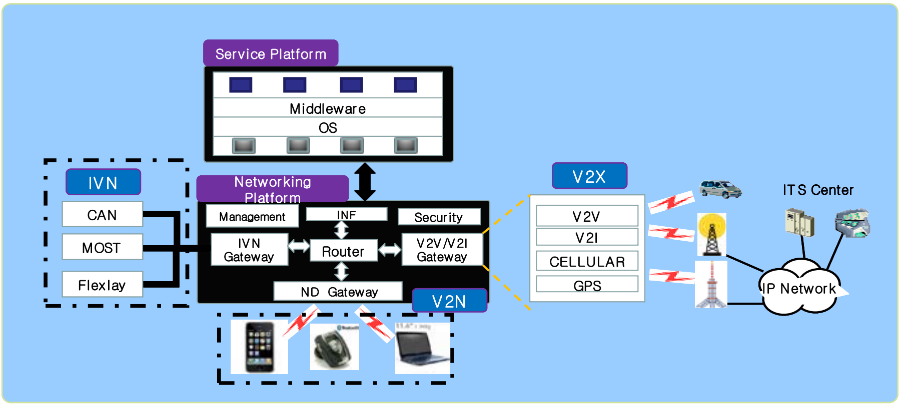
2.1 Terms and definitions

Advanced ITS have enhanced vehicular networking functionality to provide vehicle-to-vehicle communication (V2V), vehicle-to-infrastructure communication (V2I), in-vehicle network (IVN) and vehicle-to- nomadic devices (V2N). Enhanced vehicular networking functionality of advanced ITS also includes accurate location information with ID authentication and data encryption in the vehicle terminal. The vehicular networking is the basic requirement on the vehicle terminal for vehicle safety and new ITS applications. V2N allows hand-held devices to be used in vehicular environment as they are used in home and office environment.

Regarding radiocommunication aspects, advanced ITS radiocommunications support both V2V and V2I communications with improved performance in terms of radio coverage, packet data rate, packet size and latency.

FIGURE 1

Advanced ITS concept



2.2 Acronyms and abbreviations

ARIB	Association of Radio Industries and Businesses
ATIS	Alliance for Telecommunications Industry Solutions
BPSK	Binary phase shift keying
CCTV	Closed-circuit television
CSMA/CA	Carrier sense multiple access/collision avoidance
ECC	Electronic Communications Committee
ETSI	European Telecommunications Standards Institute
BAS	Broadcast Auxiliary Service
FEC	Forward error correction
GPS	Global positioning system
IEEE	Institute of Electrical and Electronics Engineers
ISE	Intersection safety equipment
ITS	Intelligent transport systems
IVN	In-vehicle network
LAN	Local area network
OFDM	Orthogonal frequency-division multiplexing
QAM	Quadrature amplitude modulation
OBD-II	On-board diagnostic system-II

QPSK Quadrature phase shift keying

RF Radio frequency

RSE Roadside equipment

TIA Telecommunications Industry Association

TTA Telecommunication Technology Association

V2V Vehicle-to-vehicle communication

V2I Vehicle-to-infrastructure communication

V2N Vehicle-to-nomadic device communication

2.3 Technical characteristics

Technical characteristics of current and advanced ITS are described in the following table, respectively.

TABLE 1

Technical characteristics of ITS

Items	Current ITS	Advanced ITS
Vehicular networking	V2I	V2I, V2V, V2N
Radio performance	Radio coverage: Max. 100 m Data rate: ~ 4 Mbps Packet size: ~100 bytes	Radio coverage: Max. 1 000 m Data rate: Max. 27 Mbps Packet size: Max. 2 kbytes Latency: within 100 m/s

3 Requirements for advanced ITS radiocommunications

3.1 General system requirements

No.	Contents
1	Each vehicle must be individually identifiable.
2	Warning message related to vehicle safety such as vehicle crash, accident, etc. should be deliverable.
3	Vehicle location information could be available.
4	The event occurrence time information of an accident should be able to transmit (broadcast) and receive.
5	Vehicle inter-communication should provide the functionality of transmitting and receiving messages in point-to-point communication as well as point-to-multi-point communication.
6	When needed, vehicle should be able to retransmit the received message to the nearby vehicles (multi-hop).
7	Vehicle should be able to collect the nearby vehicles’ information when there is a request by driver or passengers.
8	Terminal should provide the ability to display the information (voice, message, video, etc.) to driver or passengers.
9	Terminal should provide the user interfaces (voice, keyboard, mouse, etc.) for various services.
10	Terminal should have external interfaces (USB, IDB1394, Bluetooth, etc.) for updating software and information.

3.2 Service requirements

3.2.1 Safety services

3.2.1.1 Incident alert

A service that broadcasts monitoring messages of unexpected circumstances in front vehicles by means of vehicle-to-vehicle communications.

3.2.1.2 Emergency vehicle entry warning

A service that broadcasts information about emergency vehicles such as their location, velocity, traffic lane in which they are moving, direction and destination by means of vehicle-to-vehicle communications in order to free their path for quicker response.

No.	Contents
1	Emergency vehicles should be able to transmit vehicle's moving direction information.
2	Vehicle should be able to collect the Vehicle Status Information (ex. location, velocity, acceleration direction, brake information, etc.).
3	The authentication methods for messages of unexpected incident information should be prepared.
4	The messages of unexpected incidents information should have priority.
5	Emergency vehicles should be able to broadcast the alarm message about their moving direction.
6	Emergency vehicles should be able to transmit the destination information.
7	When needed, vehicle should be able to broadcast the received alarm message to the nearby vehicles (multi-hop).
8	When needed, vehicle should be able to collect the information on road conditions and unforeseen circumstances.

3.2.2 Data communication services

3.2.2.1 Vehicle inter-communication service

A vehicle intercommunication service is that a data is transmitted and received by a point-to-point transmission among surrounding vehicles.

3.2.2.2 Group communication service

A group communication service is that a data is transmitted and received by a group transmission method among vehicles within a group.

No.	Contents
1	Link authentication should be supported for an individual communication.
2	Group ID and authentication should be supported for group communication.

4 Status of advanced ITS radiocommunications

4.1 Japan

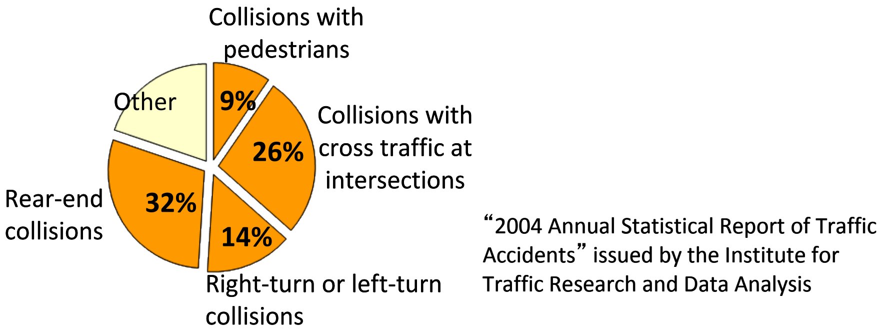
4.1.1 Applications

In Japan, realization of safe driving support systems has been studied extensively to reduce the number of traffic accidents. The 700 MHz radio-frequency band will be used for the safe driving support systems, since this frequency band is known for its good propagation characteristics in non-line-of-sight conditions such as behind buildings or large vehicles.

According to the “2004 annual statistical Report of traffic accidents” issued by the Institute for Traffic Research and Data Analysis in Japan, 80% of all traffic accidents fall into four accident types: rear-end collisions (32%), intersection collisions (26%), right-turn or left-turn collisions (14%), and collisions with pedestrians (9%).

FIGURE 2

Breakdown of traffic accidents by accident type



As much as the human factor behind traffic accidents is a concern, the Report reveals that “Failure to recognize a hazard in time,” accounts for 70% of the total and, is the single leading cause compared to other causes such as “Errors in judgment” and “Errors in operation.” Therefore, reduction of this “Failure to recognize a hazard in time” should lead to a substantial reduction in traffic accidents. Safe driving support systems to prevent “Failure to recognize a hazard in time” are expected to be realized.

FIGURE 3

Breakdown of traffic accidents by human factor

To improve drivers’ recognition of potential hazardous situations, the safe driving support systems are supposed to consist of two types of systems: vehicle-to-vehicle communication systems that support safe driving by inter-vehicular radiocommunications at intersections with poor visibility, and roadside-to-vehicle communication systems that support safe driving by sending information (signal and regulatory information, etc.) from roadside units of traffic infrastructure to vehicles through radiocommunications.

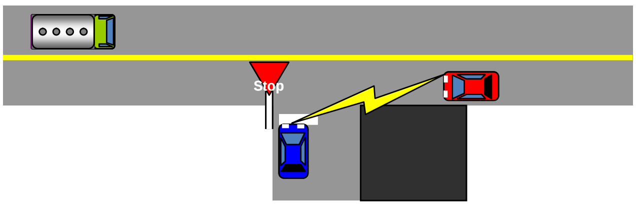
As the prioritized applications of safe driving support systems, such use cases as intersection collision avoidance, rear-end collision avoidance, right-turn/left-turn collision avoidance, emergency vehicle notification, provision of traffic signal information and regulatory information are considered and supported by using vehicle-to-vehicle and/or roadside-to-vehicle communications.

Examples of use cases are shown in the following three figures.

Figure 4 shows a scene of intersection collision avoidance by vehicle-to-vehicle communications.

FIGURE 4

Intersection collision avoidance using vehicle-to-vehicle communications



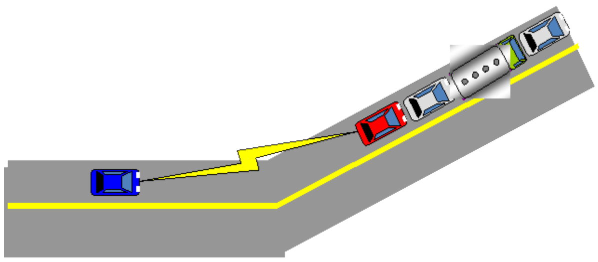
In Fig~~.~~ure 4, two vehicles, not visible to each other at the intersection, exchange information on their location, speed through vehicle-to-vehicle communications.

Thus, the drivers can receive alert messages in case of a hazardous situation.

Figure 5 corresponds to another use case and shows a scene of rear-end collision avoidance using vehicle-to-vehicle communications.

FIGURE 5

Rear-end collision avoidance using vehicle-to-vehicle communications

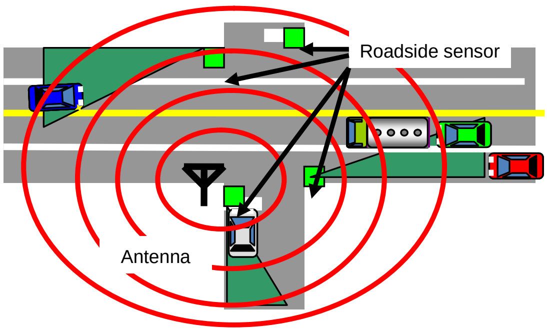


In Fig.ure 5, a vehicle approaching the tail end of a traffic jam, obtains information on the location, speed of vehicles ahead using vehicle-to-vehicle communications. Thus the driver can anticipate a traffic jam in advance.

Figure 6 shows a scene of intersection collision avoidance using roadside-to-vehicle communications.

FIGURE 6

Intersection collision avoidance using roadside-to-vehicle communications



In Fig.ure 6, roadside sensors at an intersection detect vehicles that cross or turn at the intersection and share this information amongst the vehicles approaching the intersection using roadside-to-vehicle communications.

4.1.2 Technical characteristics

This section provides examples of technical characteristic for the advanced ITS radiocommunications.

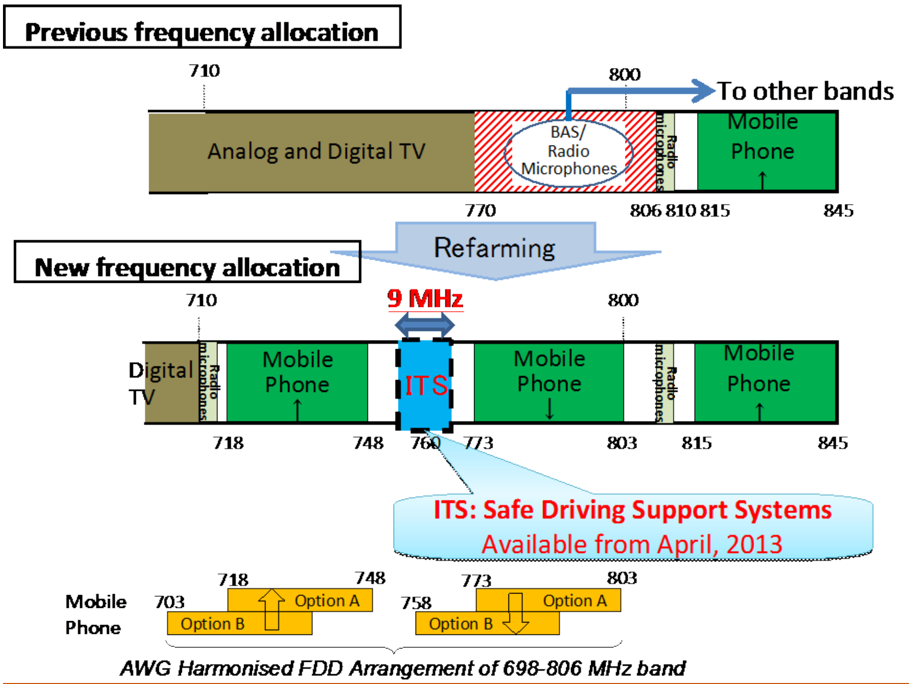
In Japan, for the use of the safe driving support systems, a part of the 700 MHz band (755.5-764.5 MHz) has been assigned in new spectrum allocation on a primary basis in the digital dividend band as shown in Figure 7. This figure also shows the AWG (APT Wireless Group) Harmonised FDD Arrangement of 698-806 MHz band[1]. Japan adopted “Option A” as shown in the figure.

[1] APT-AWF-REP-14 (http://www.aptsec.org/sites/default/files/APT-AWF-REP-14_APT_Report_Harmonized_Freq_Arrangement.doc)

Field Code Changed

FIGURE 7

700 MHz band frequency allocation for ITS in Japan



BAS: Broadcast Auxiliary Service

The technical characteristic of vehicle-to-vehicle and roadside-to-vehicle communications for safe driving support systems are shown in Table 2.

TABLE 2

Characteristics of the transmission scheme

Item	Technical characteristic
Operating frequency range	755.5–764.5 MHz ~~700 MHz band~~ (Single channel)
~~Channel spacing~~	~~10 MHz~~
Occupied bandwidth	Less than 9 MHz
Modulation scheme	BPSK OFDM/ QPSK OFDM/ 16QAM OFDM
Error correction	Convolution FEC R = 1/2, 3/4~~¾~~
Data transmission rate	3 Mbit/s, 4.5 Mbit/s, 6 Mbit/s, 9 Mbit/s, 12 Mbit/s, 18 Mbit/s
Media access control	CSMA/CA

Table 2 shows basic specifications of ARIB standard; ARIB STD-T109[2], 700 MHz band Intelligent Transport System(ITS) which has been developed in February 2012, is based on "ITS Forum RC-006"[3] which was issued by the ITS Info-communications Forum as an experimental guideline for feasibility tests in Japan.

A 109 MHz channel width in the 700 MHz radio frequency band will be used for the safe driving support systems.

Data transmission rate is variable based on the selection of Modulation scheme and coding rate (R) as follows:

– 3 Mbit/s (BPSK OFDM, R = 1/2), 4.5 Mbit/s (BPSK OFDM, R = 3/4);

– 6 Mbit/s (QPSK OFDM/, R = 1/2), 9 Mbit/s (QPSK OFDM, R = 3/4);

– 12 Mbit/s (16QAM OFDM, R = 1/2), 18 Mbit/s (16QAM OFDM, R = 3/4).

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The single channel accommodates both vehicle-to-vehicle and roadside-to-vehicle communications based on CSMA/CA media access control.

A 700 MHz radio frequency band will be used for the safe driving support systems. In particular, this frequency band is considered appropriate for communications in the use case of intersection collisions avoidance as shown in Fig.ure 78.

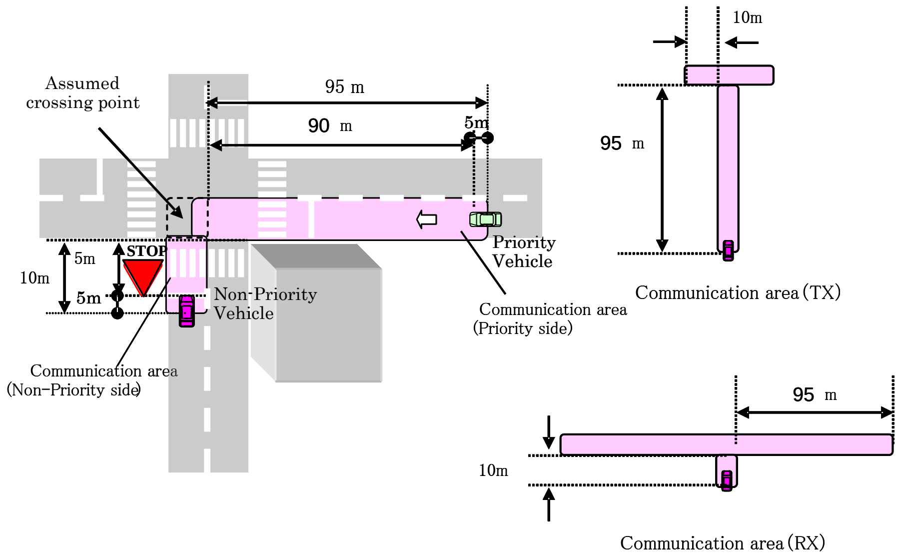
2 ARIB standard; ARIB STD-T109, 700MHz band Intelligent Transport Systems (http://www.arib.or.jp/english/html/overview/doc/5-STD-T109v1_0-E1.pdf).

Field Code Changed

3 Experimental Guideline for Vehicle Communications System using 700 MHz-Band (http://www.itsforum.gr.jp/Public/J7Database/p35/ITSFORUMRC006engV1_0.pdf).

FIGURE ~~7~~8

Communication areas for intersection collision avoidance using vehicle-to-vehicle communications (V2V)

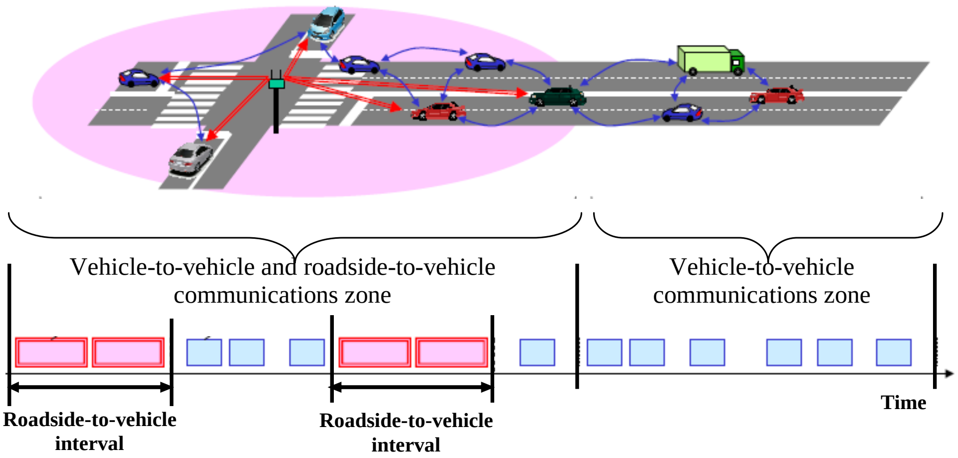


In some safety applications, information from roadside units is considered more reliable than on-board information, therefore, roadside-to-vehicle communications shall be allocated an appropriate time-slot to ensure the communication band using roadside-to-vehicle interval shown in Fig~~.~~ure ~~8~~9.

The time division mechanism is studied in ITS Info-communications Forum and ITS Radio System Committee in the Telecommunications Council in Japan.

FIGURE 89

Vehicle-to-vehicle and roadside-to-vehicle time division access



4.2 Korea (Republic of)

4.2.1 Applications

Advanced ITS radiocommunications system will provides new V2I and V2V vehicle communication based applications. Radar systems also provide traffic information for safety applications. Some of these services are used or will be available soon in real situation.

Vehicle information service provides vehicle diagnosis and traffic information by using V2I and IVN interworking. The ECU information can be monitored by connecting OBD-II interface equipment and processed in vehicle terminal. Vehicle terminal will store the vehicle data such as vehicle speed, time, direction, acceleration or de-acceleration, CO_2 emission, etc. Vehicle information is transmitted to the server via V2I communication. Server will generate real time traffic information from the raw vehicle data. Figure 910 shows vehicle information based service concept.

FIGURE 910

Vehicle information service

IP Video streaming service will provide CCTV image or streaming data to vehicle terminal. CCTV is installed on roadside and its video streaming data is sent to the server to monitor road situation. The CCTV information will be sent to the vehicle terminal on driver's request. CCTV data will provide information to the driver on road and traffic conditions in the driving direction. Figure ~~10~~11 shows IP Video streaming service.

FIGURE ~~10~~11

IP video streaming service

Intersection safety service will provide intersection road situation to the driver. Intersection situation information is attained by using CCTV, radar sensor, traffic signal to reduce traffic accidents at the intersection. The intersection situation information will be processed on the intersection safety equipment (ISE) which is connected to IP cameras and traffic signal. ISE will have intersection image, traffic signal and pedestrians, which will be transmitted to vehicle terminal through RSE. Figure ~~11~~12 shows intersection safety service.

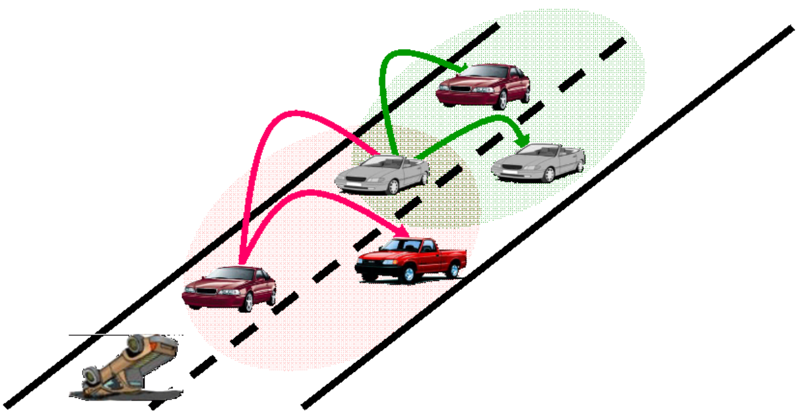
FIGURE ~~11~~12

Intersection safety service

Unexpected situation warning service will inform the driver about car accident, road construction and dangerous situation. Unexpected situation can be reported as warning packet in periodic broadcasting. For example, warning packet can be generated by pushing the emergency switch. It can be also automatically generated in the vehicle terminal in case of sudden stop by pressing on the brake. This warning packet would help preventing traffic accident. Figure ~~12~~13 shows unexpected situation broadcasting service.

FIGURE ~~12~~13

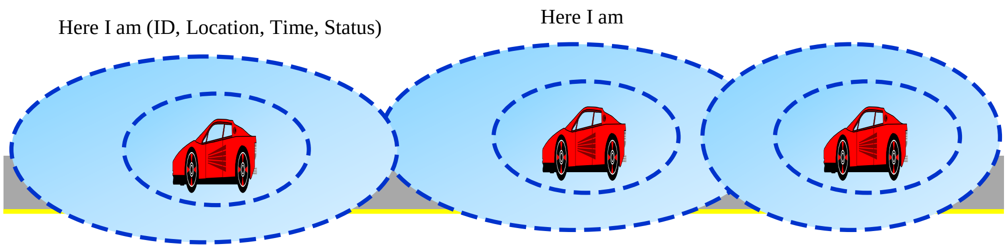
Unexpected situation broadcasting service



Vehicle anti-collision service provides pre-crash protection by broadcasting vehicle's information to the adjacent vehicle, the message is called "Here I am" message. Vehicle information includes its identification, location and driving status. This service needs accurate location information, signal signature and data encryption. Figure ~~13~~14 shows vehicle anti-collision service.

FIGURE ~~13~~14

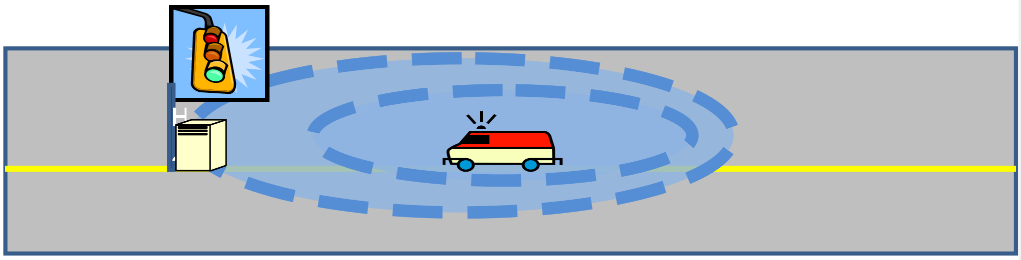
Anti-collision warning service



Emergency vehicle signal pre-emption service provides signal priority to ambulance and fire truck when they enter an intersection area. The emergency vehicle flickers emergency light and broadcasts packet message to inform other vehicles that it is approaching. RSE receives the packet and turns the traffic lights in order for the emergency vehicle to pass through the intersection without stopping. Figure ~~14~~ 15 shows emergency vehicle signal pre-emption service.

FIGURE ~~14~~15

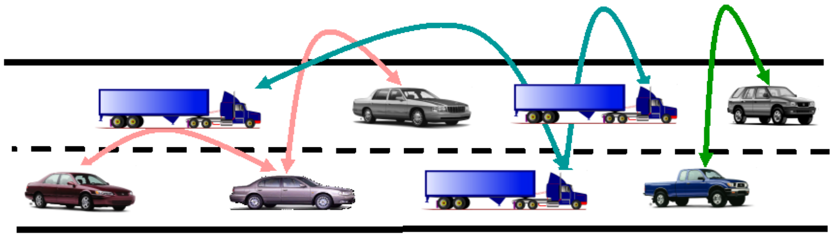
Emergency vehicle signal pre-emption service



Group communication service provides multi-hop communication among vehicles. Each vehicle has its own ID and supports group communication by unicasting. Group communication uses IP communication protocol and includes message, voice and image information. Thus it can be used for police, fire station, emergency and military applications. Figure ~~15~~16 shows group communication service.

FIGURE ~~15~~16

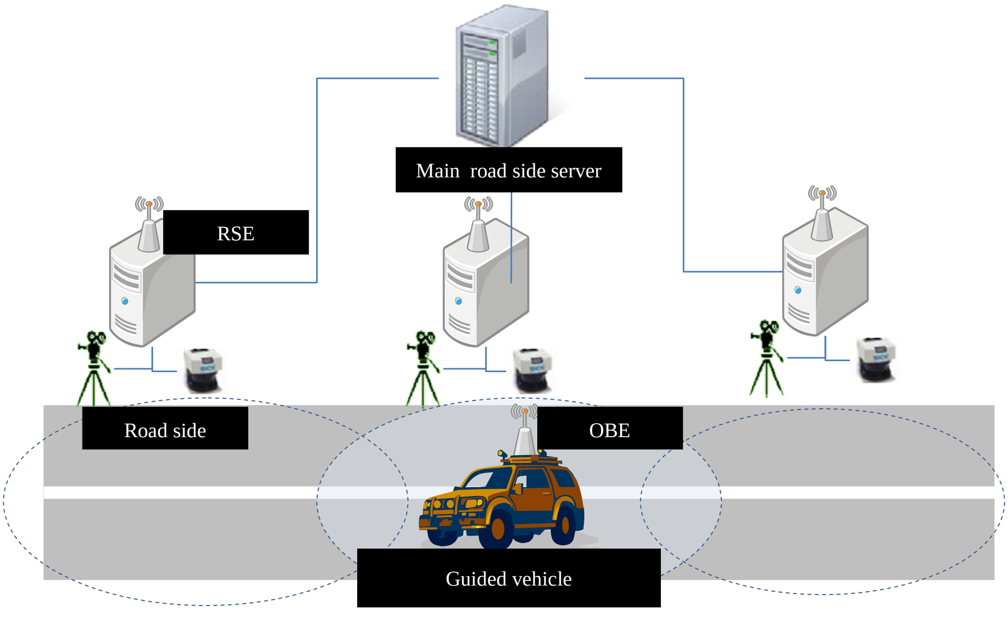
Group communication service



~~**Infra-based automatic vehicle guidance service** enables the guided vehicles to drive automatically without human intervention. The guided vehicle can be controlled by distant roadside servers via a highly reliable and low latency wireless communication link with. Roadside servers are equipped with sensing devices, cameras, laser scanners and etc., detect static/dynamic obstacles and guided vehicles in their service area. The servers provide the driving path information for the vehicles. The vehicles cooperating with the roadside servers follow the driving path. This service reduces the UGV's (Unmanned Ground Vehicle) sensors cost. That is because most high-cost sensors are installed on roadside and a vehicle has a few low-cost sensors. Furthermore, it is possible to extend vehicle's sensing area by using roadside sensors and vehicular communication.~~

~~FIGURE 16~~

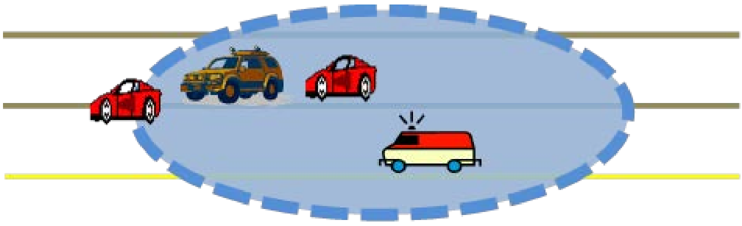
~~**Infra-based automatic vehicle guidance service**~~



Emergency vehicle approach warning service provides alarm to vehicles to clear front road for ambulance and fire truck when they approaching those vehicles. The emergency vehicle flickers emergency light and broadcasts packet message to inform other vehicles that it is approaching. The vehicles receiving the information change the lane to pass emergency vehicle without blocking. Figure 167 shows emergency vehicle approach warning service.

FIGURE 167

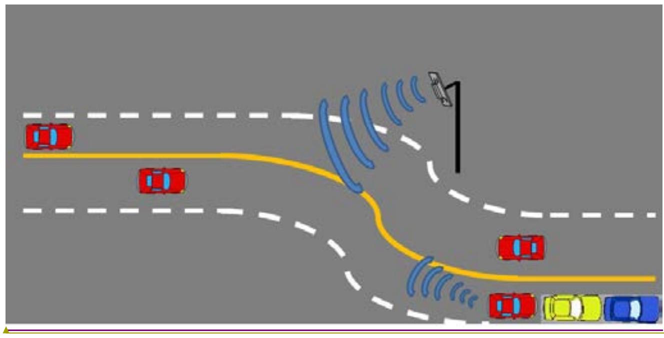
Emergency vehicle approaching warning service



Congestion/Curve warning service enables drivers in the approaching vehicles to receive congestion or road works information in advance, then it assists drivers to decrease the speed for safe driving roadside equipment or a vehicle to other vehicles to deliver the warning or alert information at the hard curve, entering/outgoing point of tunnel or accident occurred places. part in the predetermined area. And it also. drive cautiously the tail end of a traffic jam, obtains information on the location, speed of vehicles ahead using vehicle-to-vehicle communications. Thus the driver can anticipate a traffic jam in advance. Figure 178 shows safe driving assistant service.

FIGURE 178

Congestion warning service



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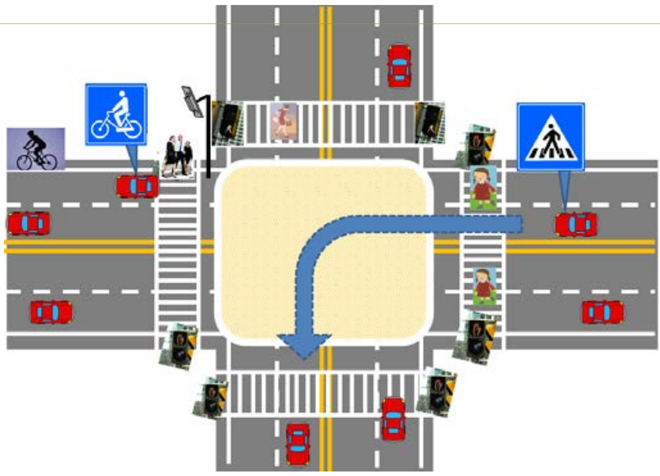
Pedestrian/bicyclist warning service enables drivers to receive warning messages the detected pedestrians or bicyclists in the vicinity from radar or video sensors in the vehicle. This service would be served at the intersection with or without the traffic signal. If pedestrians or bicyclers have equipped communication modules or wearable devices, they could be alerted approaching vehicles for safe walking or crossing. It would be bidirectional communications. Vehicle will warn automatically to pedestrians or bicyclers without human intervention. Figure 189 shows pedestrian warning service.

FIGURE 189

Pedestrian warning service



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Smart tolling service enables non-stop passing without the tollbooth. This service provides high speed electronic toll collection services in multiple lanes. Vehicles installed tolling system can pass tolling area at the same speed without stops and delay to pay the toll fee. Figure 1920 shows smart tolling service.

FIGURE 1920

Smart tolling service

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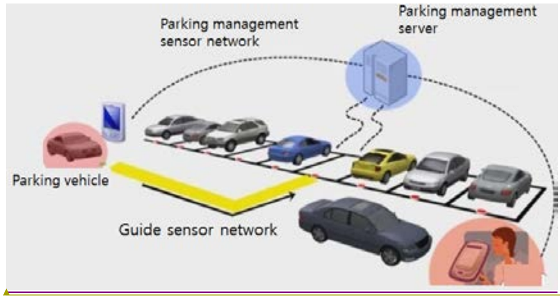
Auto valet parking service enables unmanned vehicle to park in the predetermined area. Parking management server, which manages the parking space with database of parking space, guides the parking vehicle to available parking space. Parking vehicle has parked automatically through guided sensor networks. Figure 201 shows auto valet parking service.

FIGURE 201

Auto valet parking



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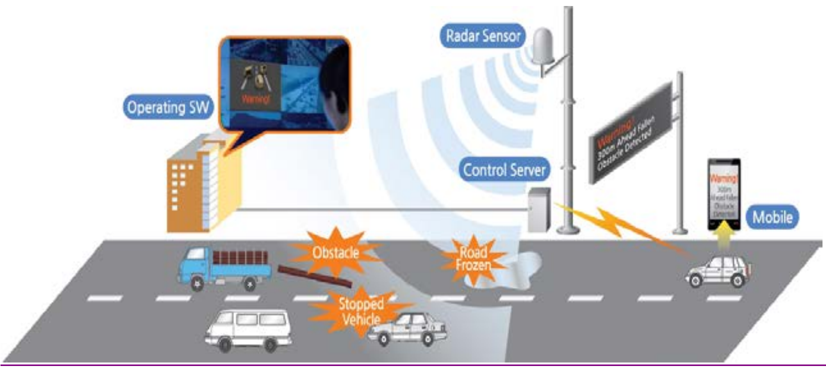
Incident detection service enables drivers in vehicles to receive real-time information for unexpected road situation (obstacle, stopped and wrong way vehicle, frozen-road etc.) through road detecting system to prevent unexpected accidents. It also provides traffic information within 1km from radar sensor road. It supports unexperienced driver in heavy rains and foggy weather to receive real–time information by road monitoring and detecting system. Figure 212 shows incident detection service.

FIGURE 212

Incident detection service



4.2.2 Technical characteristics

The advanced ITS radiocommunications system has to consider the described V2V/V2I communication and its service requirements and WAVE standard for international harmonization. In V2V application, it is required to consider the low packet latency because the life time of safety message is useful in the order of 100 m/s. Also it requires highly activated radio channel when many vehicles activate radio channel simultaneously. In V2I applications, it needs to adopt the long packet transmission which includes short message, map information and image information to be order of 2 kbytes in packet size in high mobility condition. Thus the advanced ITS radiocommunication system has the following features as shown in Table 3.

TABLE 3

Technical characteristics

Item	Technical characteristic
RF frequency	~~5.835~~5.855 ~ ~~5.855~~5.925 GHz (experimental)
RF channel bandwidth	10 MHz
RF Transmit power	23 dBm
Modulation type	OFDM(BPSK, QPSK, 16QAM, Option : 64QAM)
Data rate	3, 4.5, 6, 9, 12, 18 Mbit/s, Option : 24, 27 ~~Mbps~~Mbit/s
MAC	CSMA/CA, Option : Time Slot based CSMA/CA~~, EDCA~~
Networking	IPv4/IPv6, ~~WSMP~~VMP(~~IEEE 1609.3/4~~WSMP compatible)
Multi-hop	Location information based routing

TABLE 4

Technical characteristics for low power wireless device (2)

Technology regulation on the specific low power wireless devices for road detection radar are as follows:

Item	Technical characteristic
RF frequency	34.275~34.875 GHz
Bandwidth	600 MHz
RF transmit power	8 dBm/MHz

4.2.3 TTA Standards related to advanced ITS radiocommunications

In the Republic of Korea, Telecommunication Technology Association (TTA) established five standards for advanced ITS radiocommunications. The detailed information of these standards is shown in Table ~~4~~5.

TABLE ~~4~~5

TTA standards related to advanced ITS radiocommunications

Standard No.	Standard title	Summary	Issued date
~~TTAS~~TTAK.KO-06.0175/R1	Vehicle~~-to-vehicle~~ communication system Stage 1: Requirements	The standard describes mainly some services are supported by the multi-hop vehicle~~-to-vehicle~~ communications such as the warning service and group communication service. And it also describes general requirements and performance requirements of vehicle~~-to-vehicle~~ communication systems for information service and the group communications service, etc.	~~2008.06~~2013.12
~~TTAS~~TTAK.KO-06.0193/R1	Vehicle~~-to-vehicle~~ communication system Stage 2: Architecture	The standard describes mainly architecture and components of vehicle~~V2V~~ communications system which supports vehicle~~-to-vehicle~~ communication services such as the warning service and group communication service. As to the main contents, this standard defines the structure of the inter-vehicle communication system describing the hierarchical layers comprised the system architecture. And it also describes general architecture with the of vehicle-to-infrastructure communication systems for information service, etc.	2013.12~~2008.12~~
~~TTAS~~TTAK.KO-06.0216/R1	Vehicle~~-to-vehicle~~ communication system Stage 3: PHY/MAC	The standard describes specifications of physical (PHY) and medium access control layer (MAC) for vehicle-to-vehicle communication systems. This standard is based on IEEE P802.11p™ which modifies IEEE P802.11™ -2007 standard. The detailed description of IEEE P802.11p™ is not specified in this standard. This document only deals with new technologies for vehicle-to-vehicle communication systems which are not covered in IEEE 802.11p™. The other technical contents which are not specified in this standard follow IEEE 802.11p™.	2013.12~~2009.12~~
~~TTAS~~TTAK.KO-06.0234/R1	Vehicle~~-to-Vehicle~~ Communication System State 3: Networking	The standard describes specifications of networking layer for ~~vehicle-to-vehicle~~ multi-hop vehicle communication systems. This standard is based on IEEE P1609™ (WAVE) and IEEE P802.11p™ standards. The detailed description of IEEE P1609.3™ is not specified in this standard. This document only deals with new technologies for vehicle-to-vehicle multi-hop communication systems which are not covered in IEEE P1609.3™. The other technical contents which are not specified in this standard follow IEEE P1609.3™.	2013.12~~2010.09~~

~~TABLE 4 (*END*)~~

Standard No.	Standard title	Summary	Issued date
TTAK.KO-06.0242/R1	Vehicle~~-to-Vehicle~~ Communication System Stage 3: Application Protocol Interface	This standard is to specify the application protocol interface for vehicle~~V2V~~ communication system and to support its network layer. Also, it describes the authentication and registration procedures in application layer to interoperate between IEEE 802.11p WAVE and vehicle~~V2V~~ communication system.	2013.12~~2010.12~~

4.3 Europe

4.3.1 Standardization

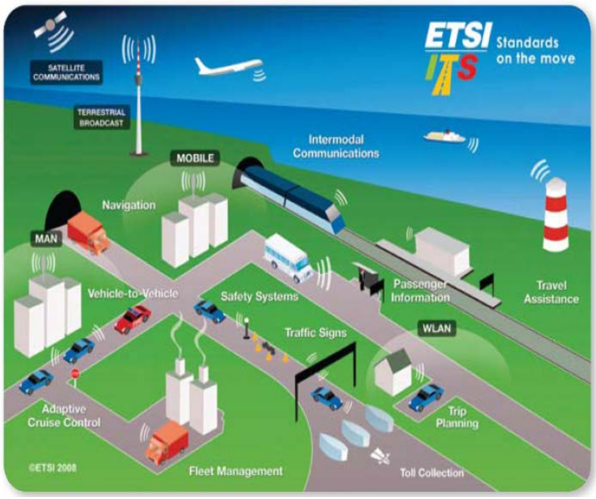
With regard to cooperative systems that include car-to-car, car-to-infrastructure, infrastructure-to car and infrastructure-to-infrastructure communications it has been necessary to identify a new frequency band that is able to cope with the requirements of the envisaged safety critical applications implying low latency and time-critical capabilities.

The ECC Decision of 14 March 2008 (ECC/DEC/(08)01) on the harmonized use of the 5 875-5 925 MHz frequency band for ITS stimulated an initiative to further develop ITS in Europe. Hereby the radio spectrum in the 5 875-5 905 MHz frequency is reserved for safety-related applications of ITS in Europe. Relevant parameters for the use of this band are covered by the European Commission Decision 2008/671/EC.

The European Commission (EC) issued the Mandate M/453 and invited the European standardization organizations to prepare a coherent set of standards.

FIGURE ~~17~~~~18~~23

Overview of ITS in ETSI



The European standardization organizations CEN and ETSI have accepted the mandate and they agreed to jointly develop a list of minimum set of standards for interoperability and other identified standards and technical specifications to support cooperative ITS services.

The standardization activities focus on:

– Basic set of applications (ETSI TR 102 638), e.g.:
  - Cooperative Awareness (ETSI TS 102 637-2)
  - Decentralized Environmental Notification (ETSI TS 102 637-3)
– Geonetworking (multi-hop communications, ETSI TS 102 636)
– Secure and Privacy-Preserving Vehicular Communication (ETSI TS 102 731)
– European profile standard based on IEEE 802.11p (ETSI ES 202 663)

– Congestion Control and Harmonized Channel Specifications (ETSI TS 102687, ETSI TS 102 724).

Furthermore the work of the Car-to-Car Communication Consortium and ISO/CALM is considered as well as the outcome of public funded projects (e.g. COMeSafety2, DRIVE C2X).

The status of the standardization is regularly reported, e.g. at the 3rd ETSI TC ITS Workshop in Venice 9-11 February 2011 (http://www.etsi.org).

4.3.2 Applications

The ITS standardization in Europe defines a system that is able to support a variety of applications. Therefore a basic set of applications has been specified in ETSI TR 102 638[4] and the standardization takes into account their requirements.

TABLE ~~5~~6

Basic set of applications definition

Applications class	Application	Use case
Active road safety	Driving assistance – Cooperative awareness	Emergency vehicle warning
		Slow vehicle indication
		Intersection collision warning
		Motorcycle approaching indication
	Driving assistance – Road Hazard ewarning	Emergency electronic brake lights
		Wrong way driving warning
		Stationary vehicle – accident
		Stationary vehicle – vehicle problem
		Traffic condition warning
		Signal violation warning
		Roadwork warning
		Collision risk warning
		Decentralized floating car data – Hazardous location
		Decentralized floating car data – Precipitations
		Decentralized floating car data – Road adhesion
		Decentralized floating car data – Visibility
		Decentralized floating car data – Wind
Cooperative traffic efficiency	Speed management	Regulatory/contextual speed limits notification
		Traffic light optimal speed advisory
	Cooperative navigation	Traffic information and recommended itinerary
		Enhanced route guidance and navigation
		Limited access warning and detour notification
		In-vehicle signage
Cooperative local services	Location based services	Point of interest notification
		Automatic access control and parking management
		ITS local electronic commerce
		Media downloading
Global internet services	Communities services	Insurance and financial services
		Fleet management
		Loading zone management
	ITS station life cycle management	Vehicle software/data provisioning and update
		Vehicle and RSU data calibration.

4 The description of this chapter is mainly taken from ETSI TR 102 638 v1.1.1 (2009-06).

The applications are divided into three classes:

– **Cooperative road safety**

The primary objective of applications in the active road safety class is the improvement of road safety. However, it is recognized that in improving road safety they may offer secondary benefits which are not directly associated with road safety.

– **Cooperative traffic efficiency**

The primary objective of applications in the traffic management class is the improvement of traffic fluidity. However it is recognized that in improving traffic management they may offer secondary benefits not directly associated with traffic management.

– **Cooperative local services and global internet services**

Applications in the cooperative local services and global internet services classes advertise and provide on-demand information to passing vehicles on either a commercial or non-commercial basis. These services may include Infotainment, comfort and vehicle or service life cycle management. Cooperative local services are provided from within the ITS network infrastructure. Global internet services are acquired from providers in the wider internet.

The following scenarios are examples (from ETSI TR 102 638):

FIGURE 181924

The motorcycle warning use case scenario has been demonstrated at the CAR 2 CAR Communication Consortium (C2C‐CC) Forum from 22-23 October, 2008 in Dudenhofen, Germany

FIGURE 192025

Road work warning (Cooperative road safety)

FIGURE 202126

Traffic light optimal speed advisory use case scenario (cooperative traffic efficiency)

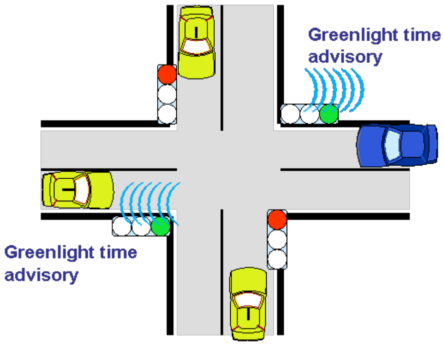
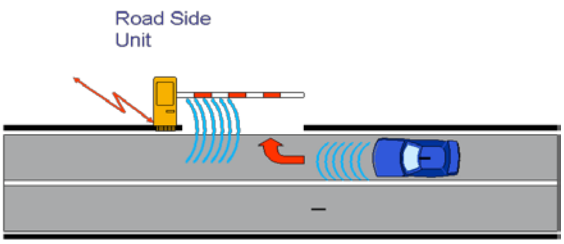


FIGURE 212227

Automatic access control/parking access use case scenario (cooperative local service)



4.3.3 Technical characteristics

ITS in Europe is based on the European profile standard based for IEEE 802.11p as described in ETSI ES 202 663. The set of protocols and parameters that are defined in that document are called ITS-G5 operating in the frequency ranges:

– ITS-G5A: 5 875 GHz to 5 905 GHz dedicated to ITS for safety related applications.

– ITS-G5B: 5 855 GHz to 5 875 GHz dedicated to ITS non- safety applications.

– ITS-G5C: 5 470 GHz to 5 725 GHz.

The technical characteristics for ITS-G5A and ITS-G5B are summarized in Table ~~6~~7.

TABLE ~~6~~7

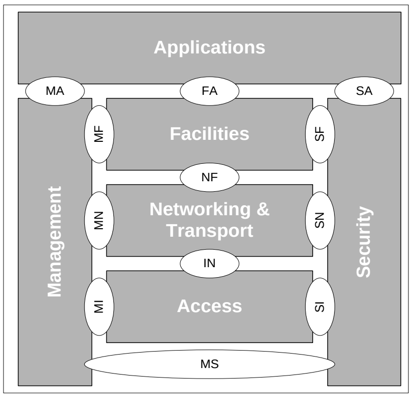
Characteristics of the transmission scheme

Channels		**Centre frequency**	**Name**	**Tx power limit (EIRP)**	**Default data rate**
	ITS-G5A	5 900 MHz	G5CC – control channel	33 dBm	6 Mbit/s
		5 890 MHz	G5SC2 – service channel 2	23 dBm	12 Mbit/s
		5 880 MHz	G5SC1 – service channel 1	33 dBm	6 Mbit/s
	ITS-G5B	5 870 MHz	G5SC3 – service channel 3	23 dBm	6 Mbit/s
		5 860 MHz	G5SC4 – service channel 4	0 dBm	6 Mbit/s
Channel bandwidth	10 MHz				
Modulation scheme	OFDM with channel access CSMA/CA (see IEEE 802.11p)				
Available data rates	3/4.5/6/9/12/18/24/27 Mbit/s				

The communications architecture is shown in Fig~~.~~ure ~~22~~~~23~~28.

FIGURE ~~22~~~~23~~28

ITS station reference architecture (from ETSI EN 302 665)



The main features of the ITS stations using ITS-G5 are:

– **Access layer**

Based on IEEE 802.11p, supplemented with a powerful "Decentralized Congestion Control" (DCC) as described in ETSI TS 102 687. The DCC uses channel load measurements to restrict transmissions such that the overall channel load is below a given threshold.

ITS stations are forced to always listen to the control channel it not transmitting. Consequently for using a service channel a second transceiver (dual channel concept) or a multi-channel receiver is needed.

– **Networking & transport**

Besides standard functionalities for unicast and broadcast transmission, this layer includes geocast functionalities, i.e. a geographic area (circle, ellipse, rectangle) can be addressed that exceeds the usual communication range. In that cast multihop communications are used.

– **Facilities**

Support of the applications by providing commonly used functions. The "Cooperative Awareness" basic service (ETSI TS 102 637-2) establishes the so-called vehicular ad-hoc network (VANET) by quasi-periodical transmissions of Cooperative Awareness Messages (CAM) on the control channel. Event messages like hazard warnings are wrapped into "Decentralized Environmental Notification" (DEN) messages (ETSI TS 102 637-3).

– **Security**

Security in VANETs care for secure and privacy preserving communication in ITS environments. It describes facilities for credential and identity management, privacy and anonymity, integrity protection, authentication and authorization (ETSI TS 102 731).

– **Management**

Management functionalities for configuration and cross layer issues.

– **Applications**

Cooperative road safety, Traffic efficiency and cooperative local services and global internet services.

NOTE – The ITS station communications architecture also describes how the ITS stations are integrated into the internet using other media like standard RLAN (e.g. operating in ITS-G5C) or mobile communications (e.g. UMTS). This is used for connecting to "central ITS stations".

5 References

[1] APT/AWG/REP-18, APT Report on "Usage of Intelligent Transportation Systems in APT Countries", 2011.03.

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[6] TTAK.KO-06.0242/R1, Vehicle-to-Vehicle Communication System Stage 3: Application Protocol Interface, 20102013.12.

[7] IEEE Std P802.11p-2010, Telecommunications and information exchange between systems-Local and Metropolitan networks-Specific requirements-Part II: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications-Wireless Access in Vehicular Environments, 2010.

[8] IEEE 1609, Family of Standards for Wireless Access in Vehicular Environments (WAVE).