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shaping tomorrow with you

An approach to 5G

Thailand-Japan joint workshop on
5th Generation Mobile Communication System
Bangkok, Thailand
Feb. 20, 2018

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Market demands and Mobile Communication systems

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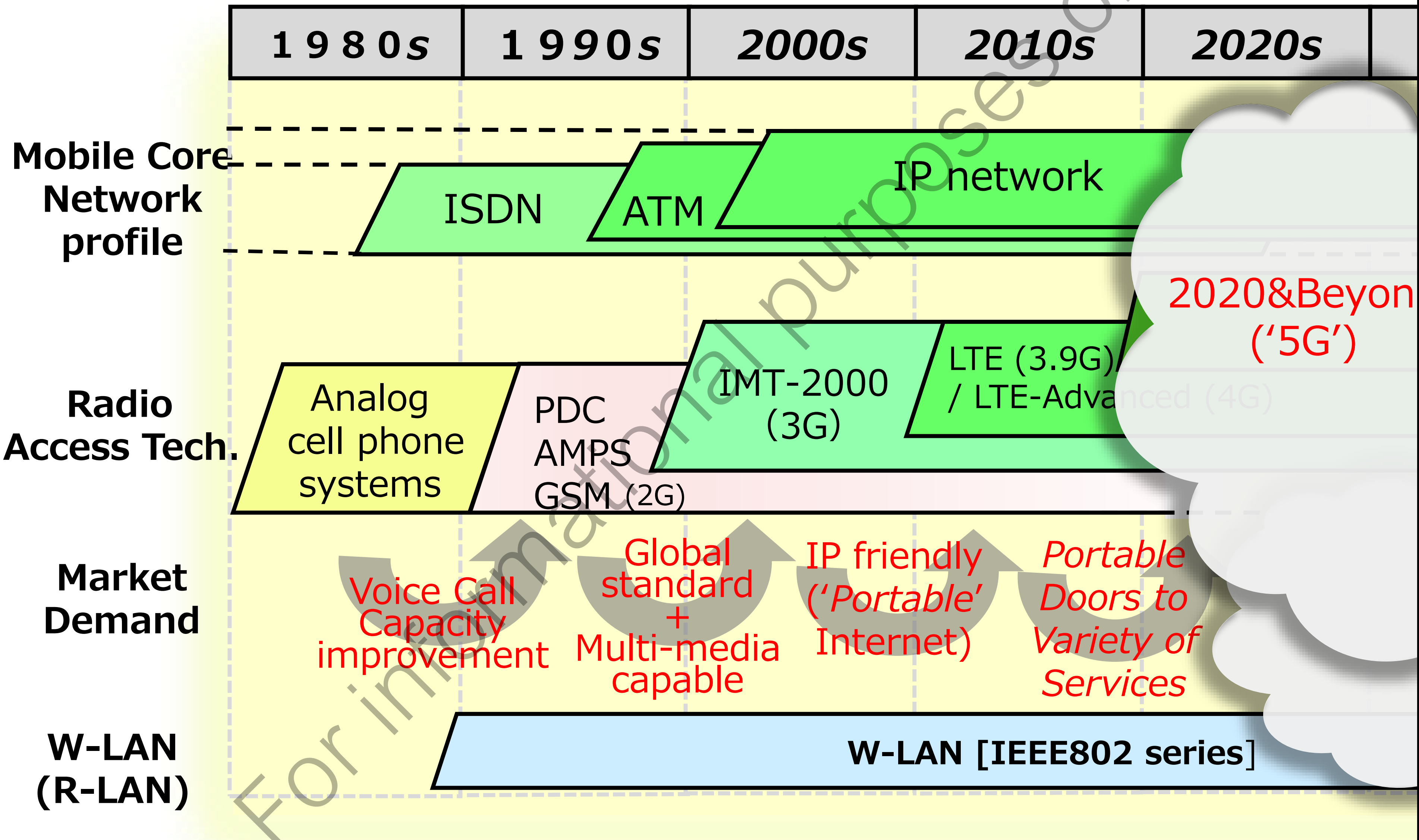

‘5G’ role: Bridging Digital World and Physical World

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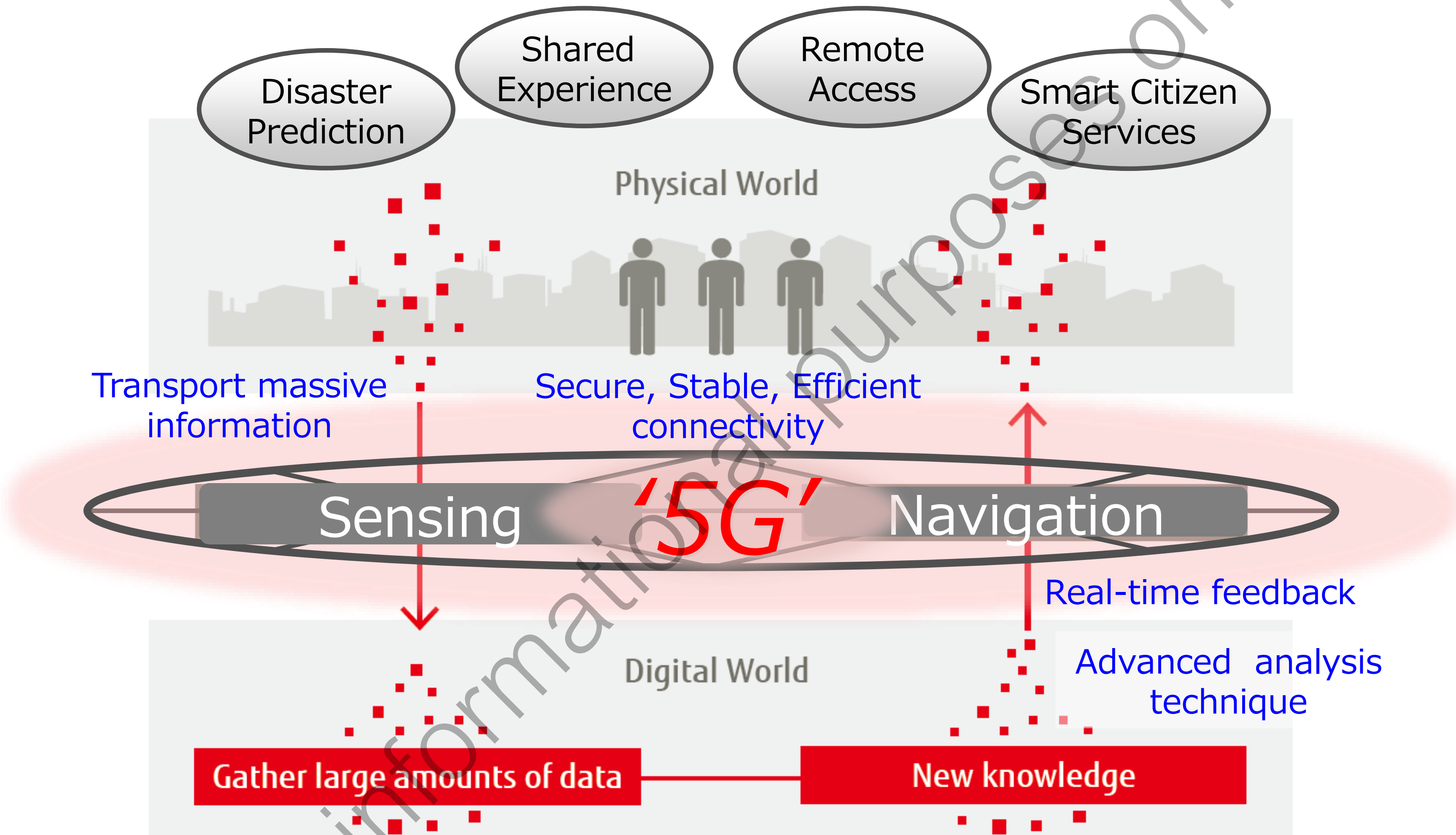

5G ICT creates new knowledge and supports activity of humans and machines in real time, by analyzing large amounts of data in physical world.

Requirements for 5G NR(New Radio)

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Use-case	Key performance indicator	New Radio		LTE-Advanced		LTE (Rel-8)	
		DL	UL	DL	UL	DL	UL
eMBB	Peak data rate	20 Gbps	10 Gbps	1 Gbps	500 Mbps	100 Mbps	50 Mbps
	Peak spectral efficiency	30 bps/Hz	15 bps/Hz	30 bps/Hz	15 bps/Hz	3~4 × HSDPA (Rel-6)	2~3 × HSUPA (Rel-6)
	C-plane latency	10 ms		Less than 50 ms		Less than 100 ms	
	U-plane latency	4 ms		reduced U-plane latency compared to Rel-8		Less than 5 ms	
	Celll/TRxP spectral efficiency [bit/s/Hz/TRxP]	3 times higher than IMT-A※ ※ ITU-R Rep. M. 2134		-		-	
	Area traffic capacity [bit/s/m²]			-		-	
	User experienced data rate [bit/s]			-		-	
	5% user spectrum efficiency [bit/s/Hz/user]			Cell edge user throughput [bit/s/Hz/cell/user]		User throughput	
				0. 12 (2×2 ANT)	0. 04 (1×2 ANT)	2~3 × HSDPA (Rel-6)	2~3 × HSUPA (Rel-6)
	Target mobility speed (URLLC, mMTCも関連)	500 km/h		350 km/h		350 km/h	
	Mobility interruption time (URLLC, mMTCも関連)	0 ms		-		-	
URLLC	U-plane latency	0. 5 ms		-		-	
	Reliability	10^{-5} for 32 Bytes with U-plane latency of 1 ms		-		-	
mMTC	Coverage	Max coupling loss 164 dB		Max coupling loss 164 dB (NB1)		-	
	UE battery life	Beyond 10 years		Up to 10 years		-	
	Connection density	1,000,000 devices/km²		60,680 devices/km²		-	

Ref: "Report of the Next Generation Mobile Communications system committee," MIC (Sep. 2017).
(Derived from original information in 3GPP TR 38.913, "Study on scenarios and requirements for next generation access technologies," (Aug. 2017))

3GPP NR (New Radio) specifications

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TS 38.101-1	NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone
TS 38.101-2	NR; User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone
TS 38.101-3	NR; User Equipment (UE) radio transmission and reception; Part 3: Range 1 and Range 2 Interworking operation with other radios
TS 38.101-4	NR; User Equipment (UE) radio transmission and reception; Part 4: Performance requirements
TS 38.104	NR; Base Station (BS) radio transmission and reception
TS 38.113	NR; Base Station (BS) and repeater ElectroMagnetic Compatibility (EMC)
TS 38.124	NR; Electromagnetic compatibility (EMC) requirements for mobile terminals and ancillary equipment
TS 38.133	NR; Requirements for support of radio resource management
TS 38.141	NR; Base Station (BS) conformance testing
TS 38.141-1	NR; Base Station (BS) conformance testing Part 1: Conducted conformance testing
TS 38.141-2	NR; Base Station (BS) conformance testing Part 2: Radiated conformance testing
TS 38.201	NR; Physical layer; General description
TS 38.202	NR; Services provided by the physical layer
TS 38.211	NR; Physical channels and modulation
TS 38.212	NR; Multiplexing and channel coding
TS 38.213	NR; Physical layer procedures for control
TS 38.214	NR; Physical layer procedures for data
TS 38.215	NR; Physical layer measurements
TS 38.300	NR; Overall description; Stage-2
TS 38.304	NR; User Equipment (UE) procedures in idle mode and in RRC Inactive state
TS 38.305	NG Radio Access Network (NG-RAN); Stage 2 functional specification of User Equipment (UE) positioning in NG-RAN
TS 38.306	NR; User Equipment (UE) radio access capabilities
TS 38.307	NR; Requirements on User Equipments (UEs) supporting a release-independent frequency band
TS 38.321	NR; Medium Access Control (MAC) protocol specification
TS 38.322	NR; Radio Link Control (RLC) protocol specification
TS 38.323	NR; Packet Data Convergence Protocol (PDCP) specification
TS 38.331	NR; Radio Resource Control (RRC); Protocol specification

TS 38.508-1	5GS; User Equipment (UE) conformance specification; Part 1: Common test environment
TS 38.508-2	5GS; User Equipment (UE) conformance specification; Part 2: Common Implementation Conformance Statement (ICS) proforma
TS 38.509	5GS; Special conformance testing functions for User Equipment (UE)
TS 38.521-1	NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 1: Range 1 Standalone
TS 38.521-2	NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 2: Range 2 Standalone
TS 38.521-3	NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 3: NR interworking between NR range1 and NR range2; and between NR and LTE
TS 38.521-4	NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 4: Performance
TS 38.522	NR; User Equipment (UE) conformance specification; Applicability of RF and RRM test cases
TS 38.523-1	5GS; UE conformance specification; Part 1: Protocol conformance specification
TS 38.523-2	5GS; UE conformance specification; Part 2: Implementation Conformance Statement (ICS) proforma specification
TS 38.523-3	5GS; UE conformance specification; Part 3: Test Suites
TS 38.533	NR; User Equipment (UE) conformance specification; Radio Resource Management (RRM)

5G RAT and LTE Evolution (Fujitsu's view)

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■ 5G Phase-1 (To be deployed in 2020)
- New RAT (up to 30GHz)
  - Mainly for eMBB
  - Massive MTC, Ultra reliable MTC
- E2E latency reduction
- Flexible TDD
- Enhancements for UDN

Forward/ Backward compatibility

■ 5G Phase-2 (To be deployed in 2022~2023)
- Extension of BW using new spectrum above 6GHz (New RAT up to 100GHz, BF/MIMO)
- Support of full-duplex operation
- (mmWave) wireless back/fronthaul

Tight interworking

■ LTE Evolution
- eMBB
  - eLAA for 5GHz unlicensed
  - Flexible duplex (FDD)
  - WiGig aggregation
  - MUST
- Latency reduction, V2X, …

LTE Evolution continues

- Technologies for LTE evolution can also be used also for 5G new RAT. So, the above classification may not be strictly followed.

Ref: "R&D activities towards 5G in Fujitsu," Multimedia Promotion Forum, presentation #678, (Oct. 2015)

‘Expansion’ of data traffic

- Either in volume or in its behaviour -

New traffic types from possible new fields

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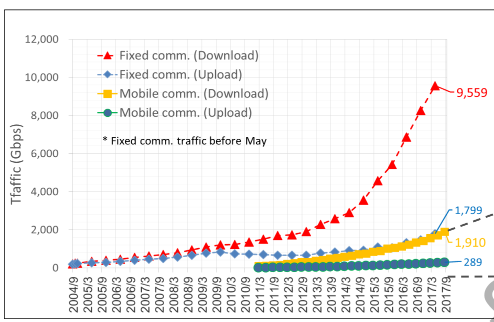
Urgent: Cope with enormously increasing traffic (on going story in '4G' systems)
Foreseen: Handling of genuine new type, genuine mobile specific traffic.

X 10 within 7 years!
X 100 within 14 years?
X 1000 in 21 years ???

Depending on
Cost vs. Value provided



Mobile specific traffic
(Mobile specific applications)

Genuine new Type Traffic

Replacement of fixed (wired) communications

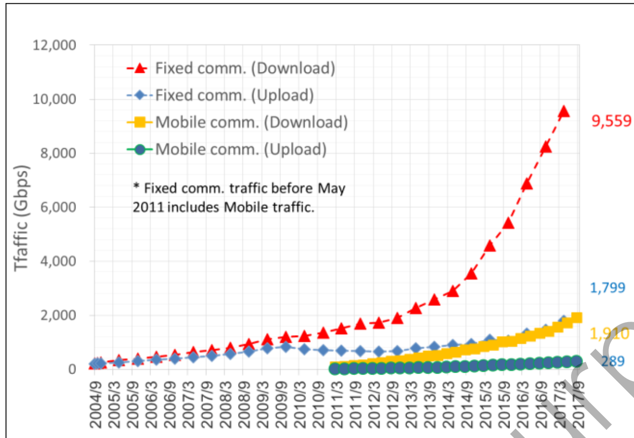
Wired comm. alike traffic

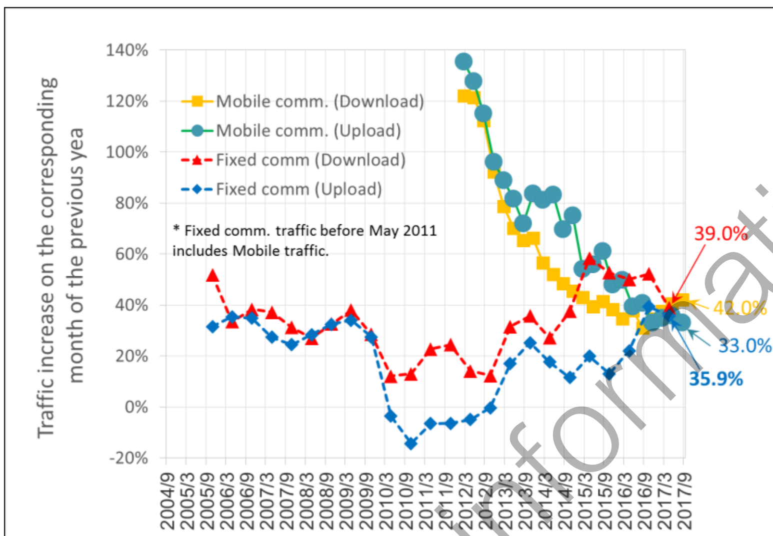
2017	202x
1910Gbps	1910Gbps

Refs:

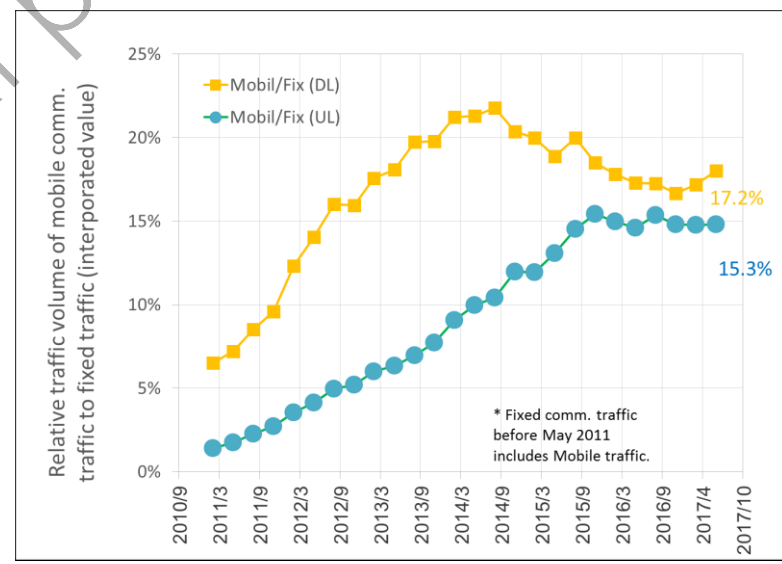
"Status of the mobile communications traffic of Japan (Sep. 2017)," Information and Communications Statistics Database, Ministry of Internal Affairs and Communications of Japan, Nov. 2017.
"Aggregation and Provisional Calculation of Internet Traffic in Japan (as of May 2017)," Ministry of Internal Affairs and Communications of Japan, Aug. 2017.

Profile of communication traffics





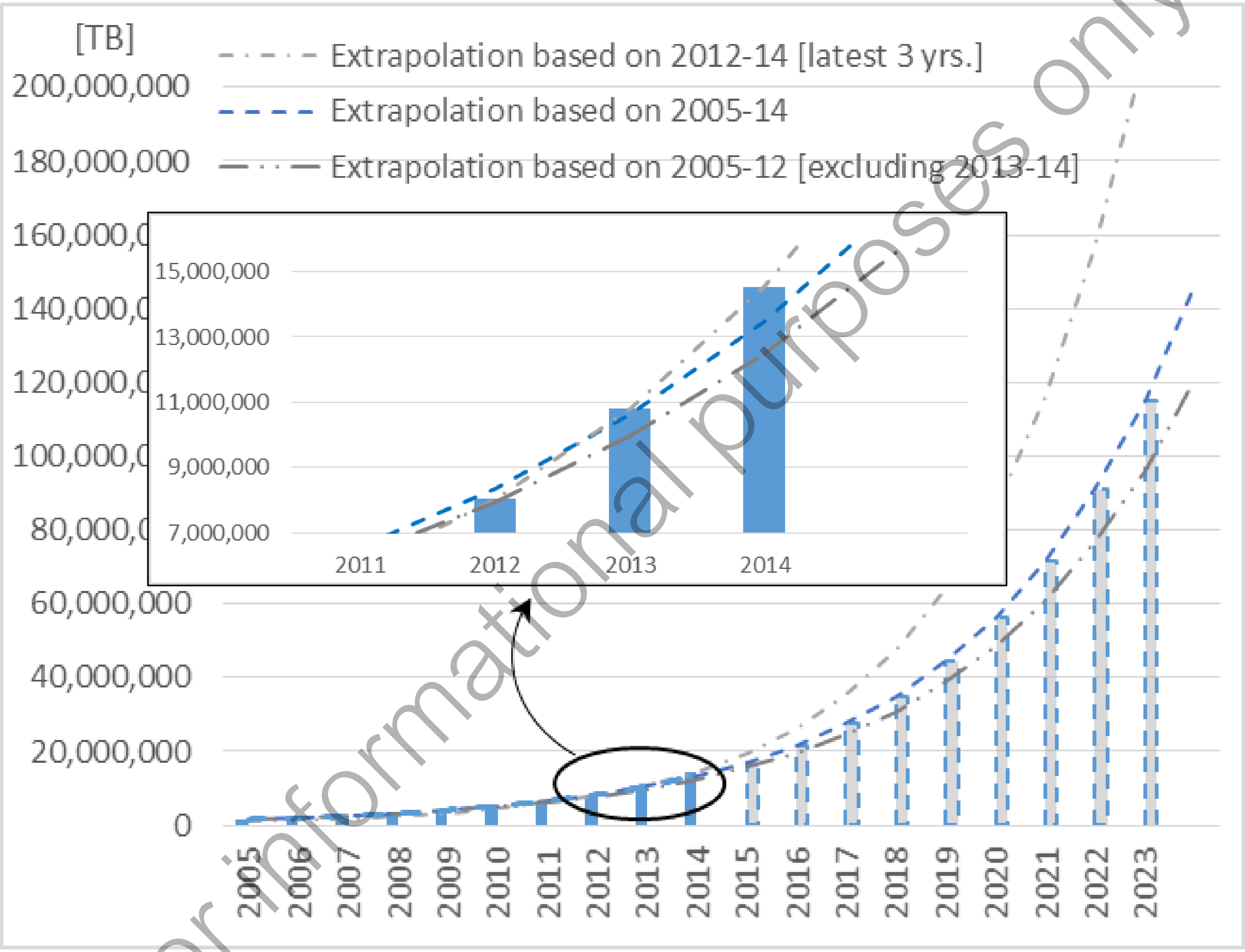
Annual growth ratio of communications traffic



Relative ratio of traffic volume (mobile / fixed)

Ref: "Status of the mobile communications traffic of Japan (Sep. 2017)," Information and Communications Statistics Database, Ministry of Internal Affairs and Communications of Japan, Nov. 2017.
Ref: "Aggregation and Provisional Calculation of Internet Traffic in Japan (as of May 2017)," Ministry of Internal Affairs and Communications of Japan, Aug. 2017.

Data traffic* and its extrapolations**



*Service industry, ICT, transport, real estate, money & securities, commercial services, utilities, construction and manufacturing
**: Extracted based on data up to year of 2014 in the reference below.

Ref:" "Traffic of big data flow estimation and investigations on usage of the big data," Ministry of Internal Affairs and Communications of Japan, 2015.

Flexible frame structure (NR)

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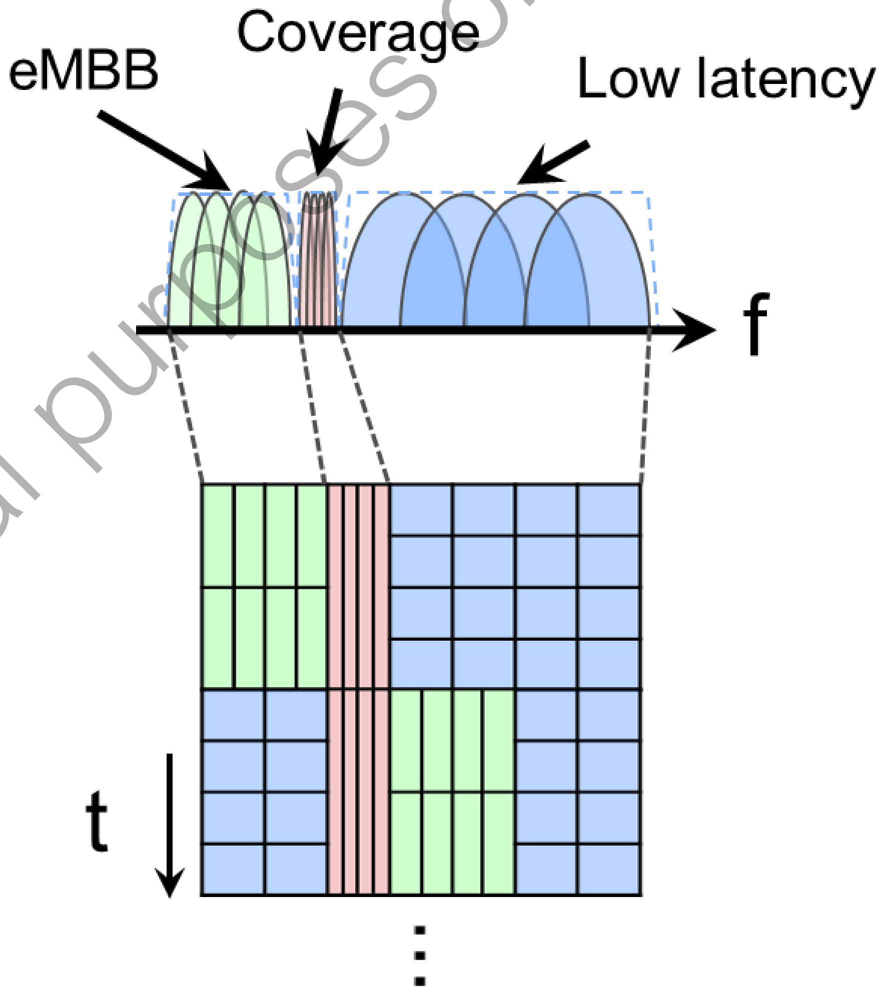
4.2 Numerologies

Multiple OFDM numerologies are supported as given by Table 4.2-1 where μ and the cyclic prefix for a carrier bandwidth part are given by the higher-layer parameters *DL-BWP-mu* and *DL-BWP-cp* for the downlink and *UL-BWP-mu* and *UL-BWP-cp* for the uplink.

Table 4.2-1: Supported transmission numerologies.

μ	$\Delta f = 2^{\mu} \cdot 15\,[\mathrm{kHz}]$	Cyclic prefix
0	15	Normal
1	30	Normal
2	60	Normal, Extended
3	120	Normal
4	240	Normal

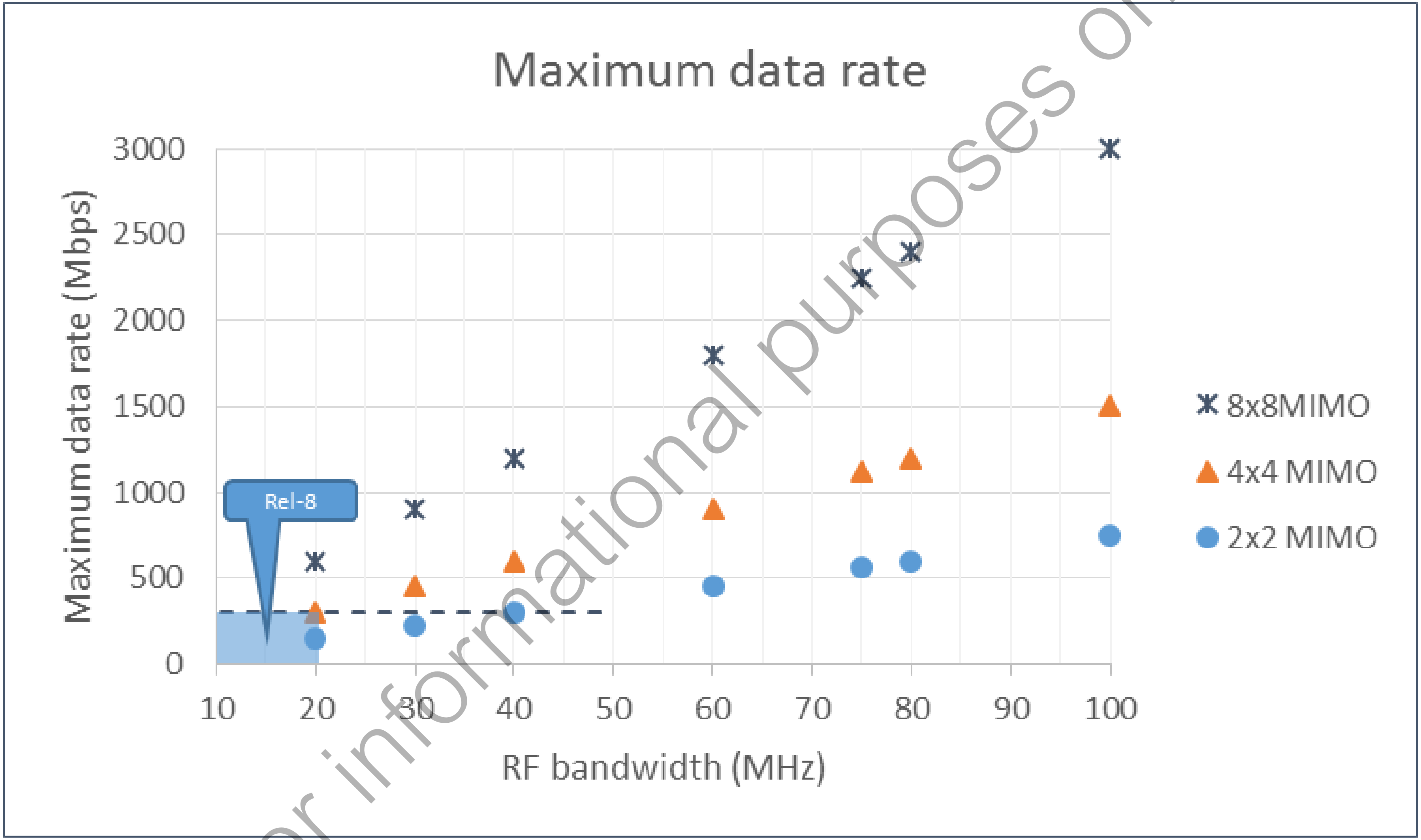
Ref: 3GPP TS38.211 "NR; Physical channels and modulation (V.15.0.0)." Dec. 2017



Higher data rate

- w.r.t. LTE/LTE-Advanced per 3GPP release -

Peak data rates in LTE FDD (DL)



Ref: “E-UTRAN UE radio access capabilities,” 3GPP TS36.306

Maximum data rates specified for LTE (per 3GPP release)

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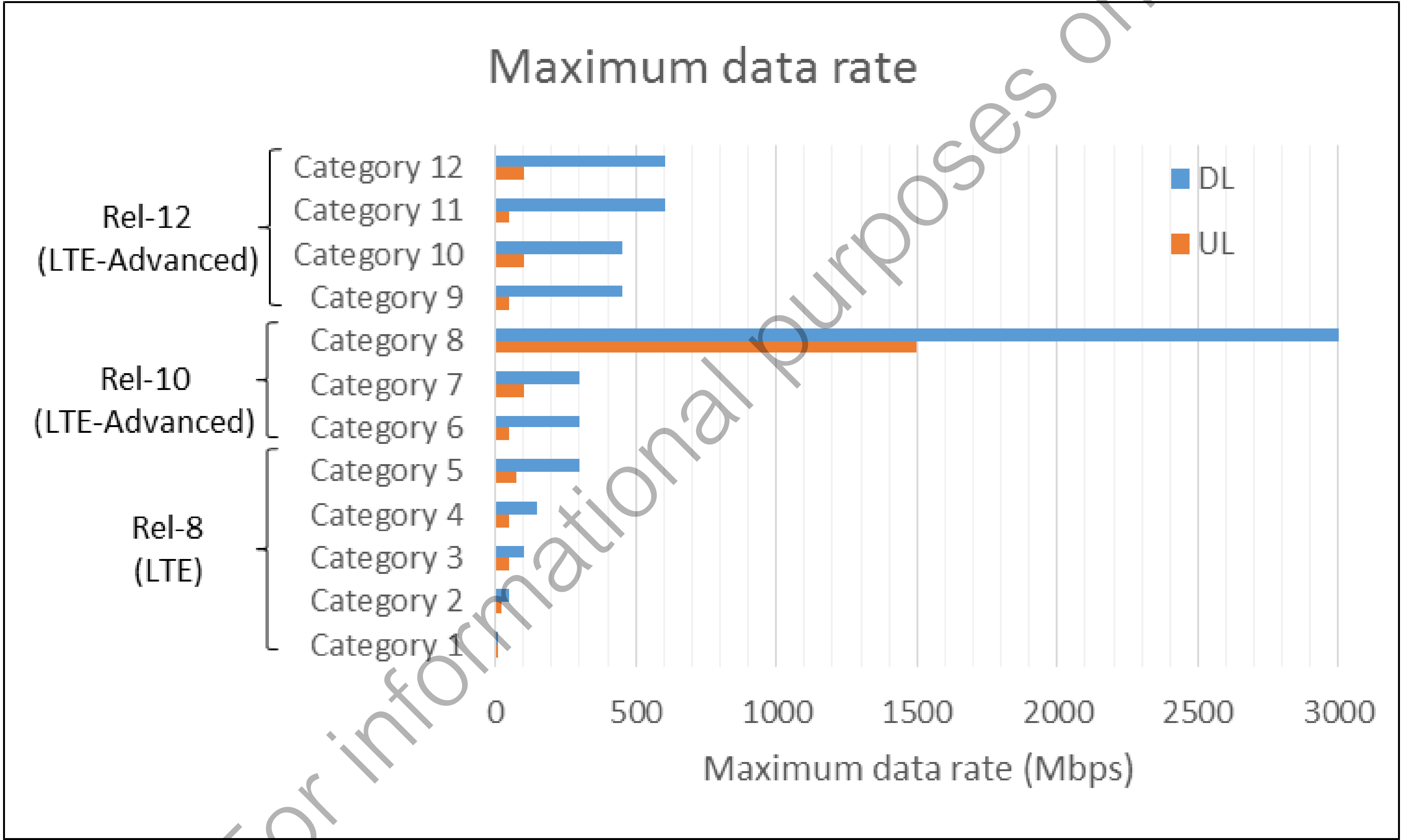
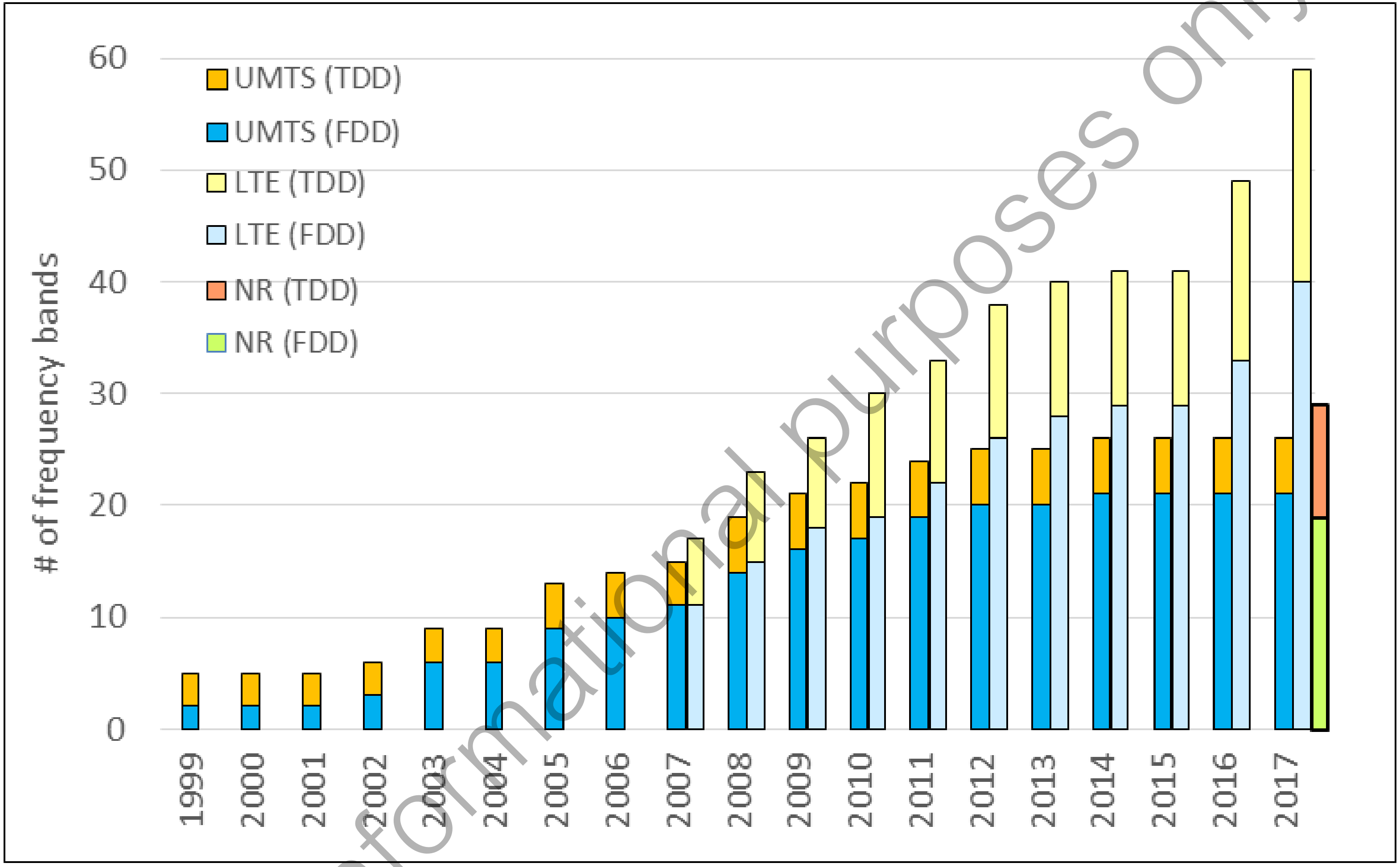


Ref: "E-UTRAN UE radio access capabilities," 3GPP TS36.306

Utilization of higher and wider spectrum

- implementation aspects -

Number of frequency bands in 3GPP



Refs:
3GPP TS25.101, "User Equipment (UE) radio transmission and reception (FDD)," (Dec. 1999-Dec. 2017).
3GPP TS25.102, "User Equipment (UE) radio transmission and reception (TDD)," (Dec. 1999- Dec. 2017).
3GPP TS 36.101, "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception", (Oct. 2010-Dec. 2017).
3GPP TS 38.101-1, "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone," (Dec. 2017).
3GPP TS 38.101-2, "NR; User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone," (Dec. 2017).

Number of combinations specified for LTE-Advanced

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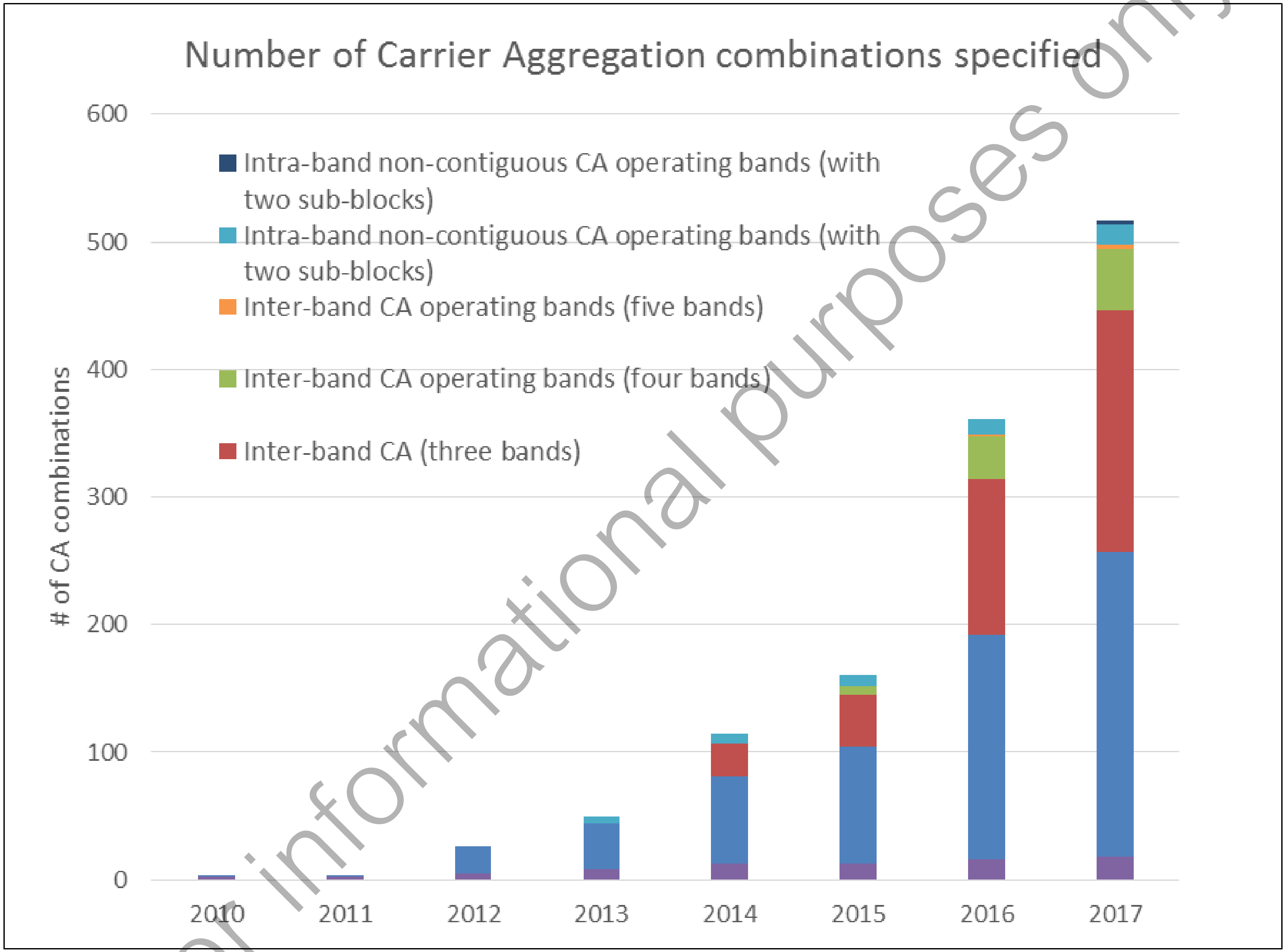
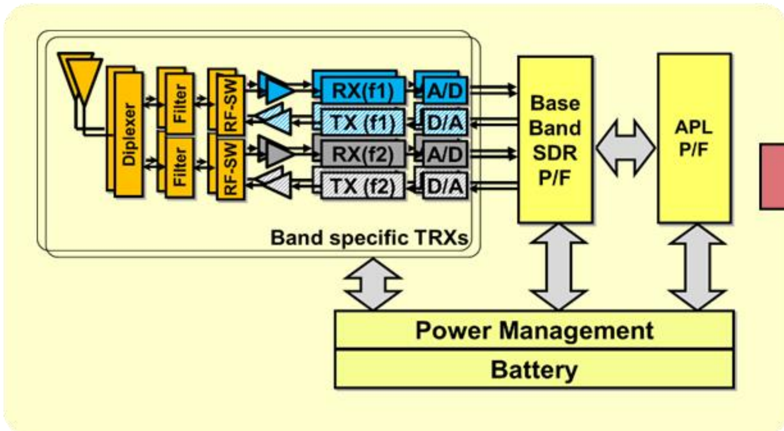
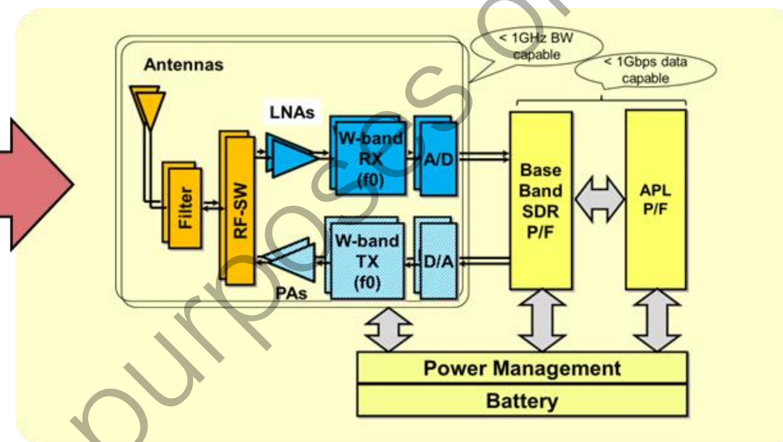
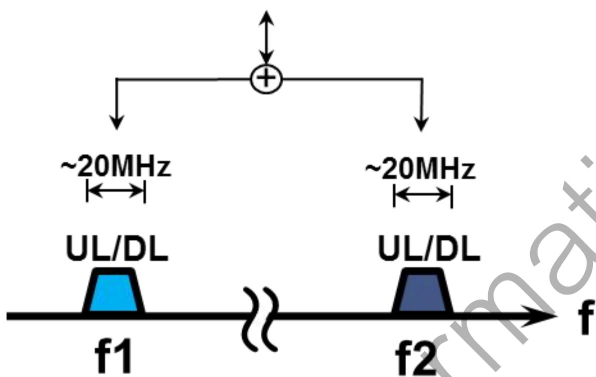


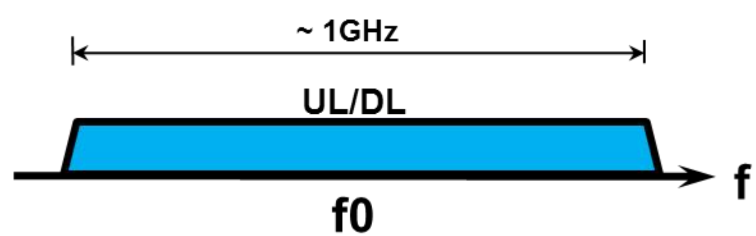
Ref: 3GPP TS 36.101, "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception", (Oct. 2010-Dec. 2017).

Utilization of single contiguous wide bandwidth spectrum









Carrier Aggregation (LTE-Advanced)
(Combining multiple component carriers)

Single contiguous wide bandwidth carrier

(Ref) Radio propagation properties in EHF and SHF band

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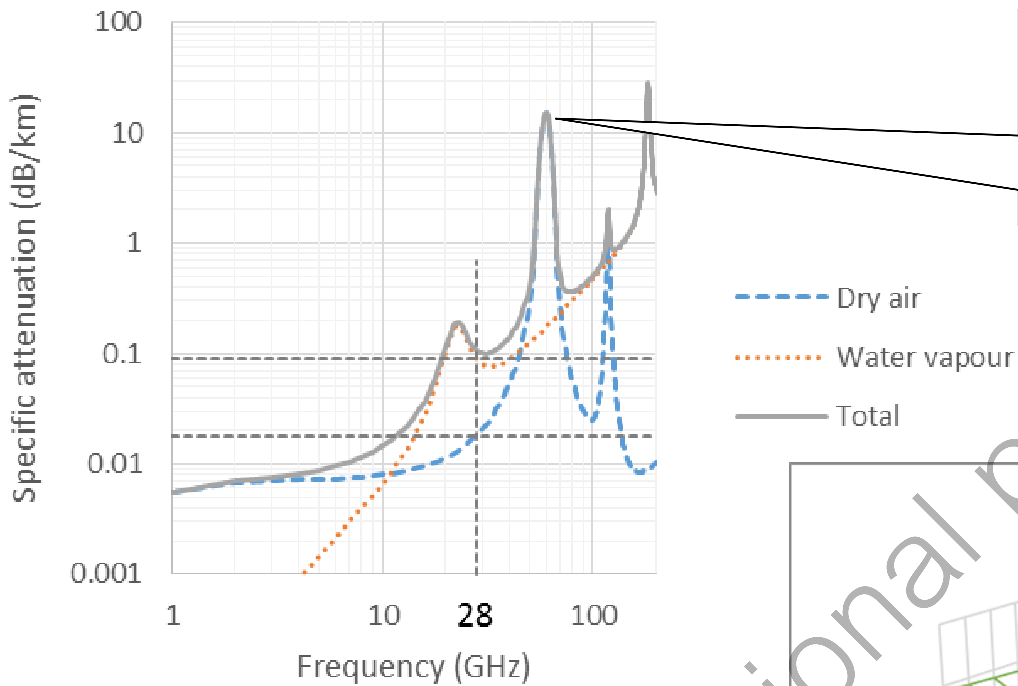
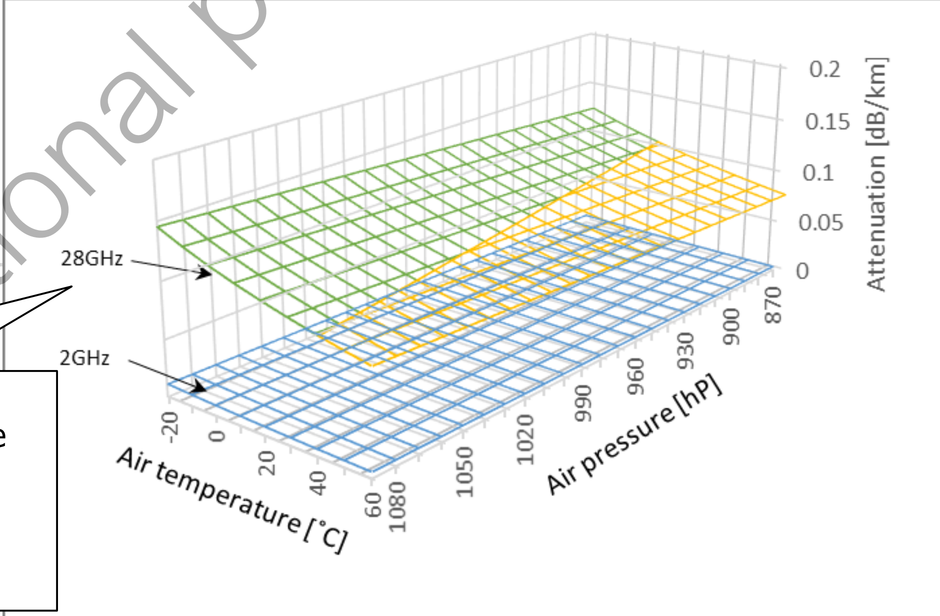


Several peak attenuation points, caused by water vapor etc., are observed as 60GHz as an example. These bands may suffer additional attenuation in some conditions such as rain or snow.

Attenuation due to atmospheric gasses



Compared to UHF(eg. 2GHz), relatively large but marginal dependency to air temperature as well as humidity is observed.
(Note: The chart does not capture …)

Attenuation due to atmospheric gasses (vs. air pressure and temperature)

Ref: "Attenuation by atmospheric gasses," Recommendation ITU-R P.676-10, pp.13-16, Sep. 2013, ITU-R.

Carrier frequency vs. bandwidth specified for LTE/LTE-Advanced

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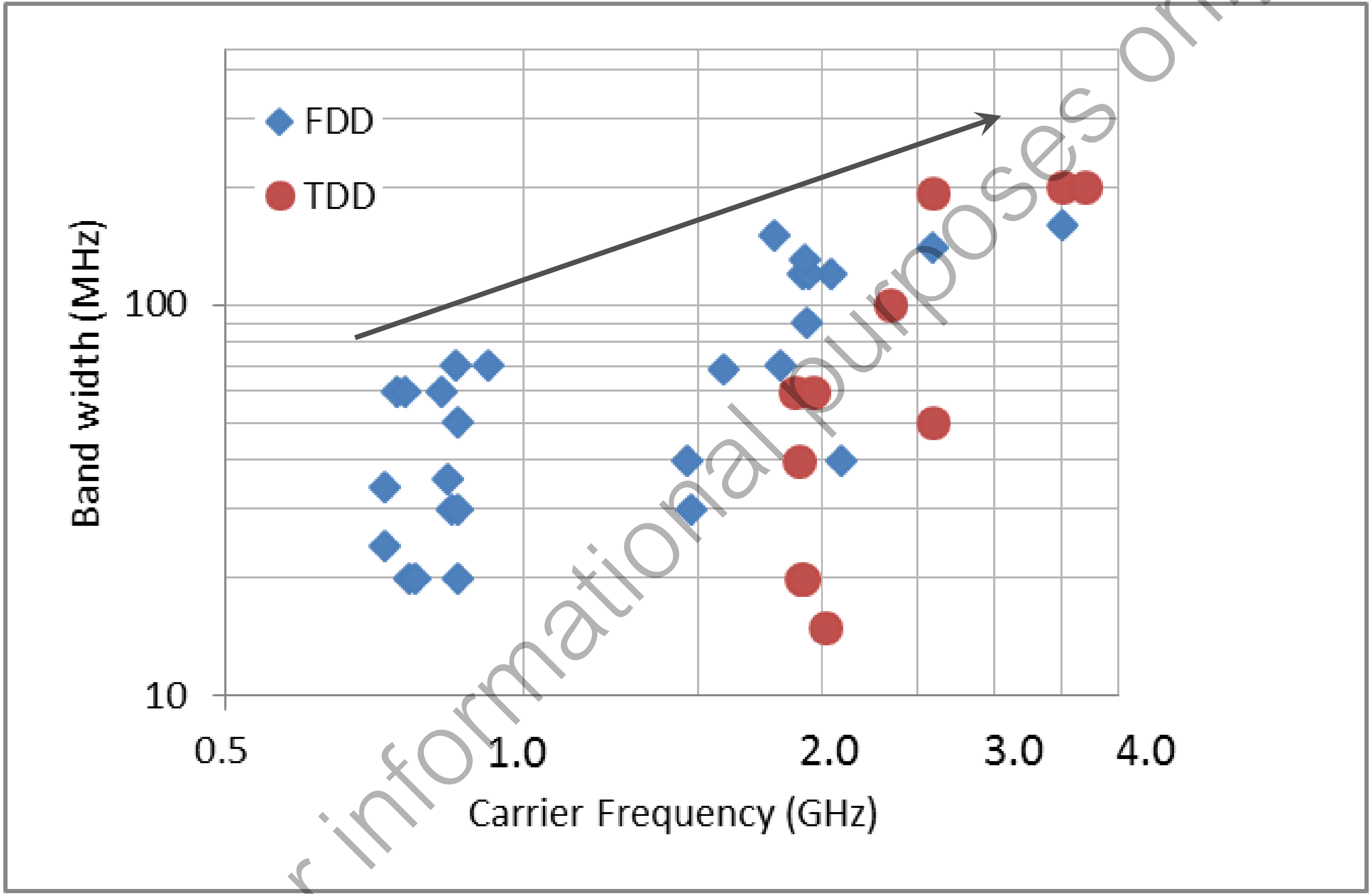

Ref: "Mobile Communications Systems for 2020 and beyond", ARIB 2020 and Beyond Ad Hoc Group White Paper, Oct. 2014.
(Derived from original information in 3GPP TS36.101 "E-UTRA UE radio transmission and reception,")

Fractional bandwidth of 3GPP bands vs. Reference sensitivity

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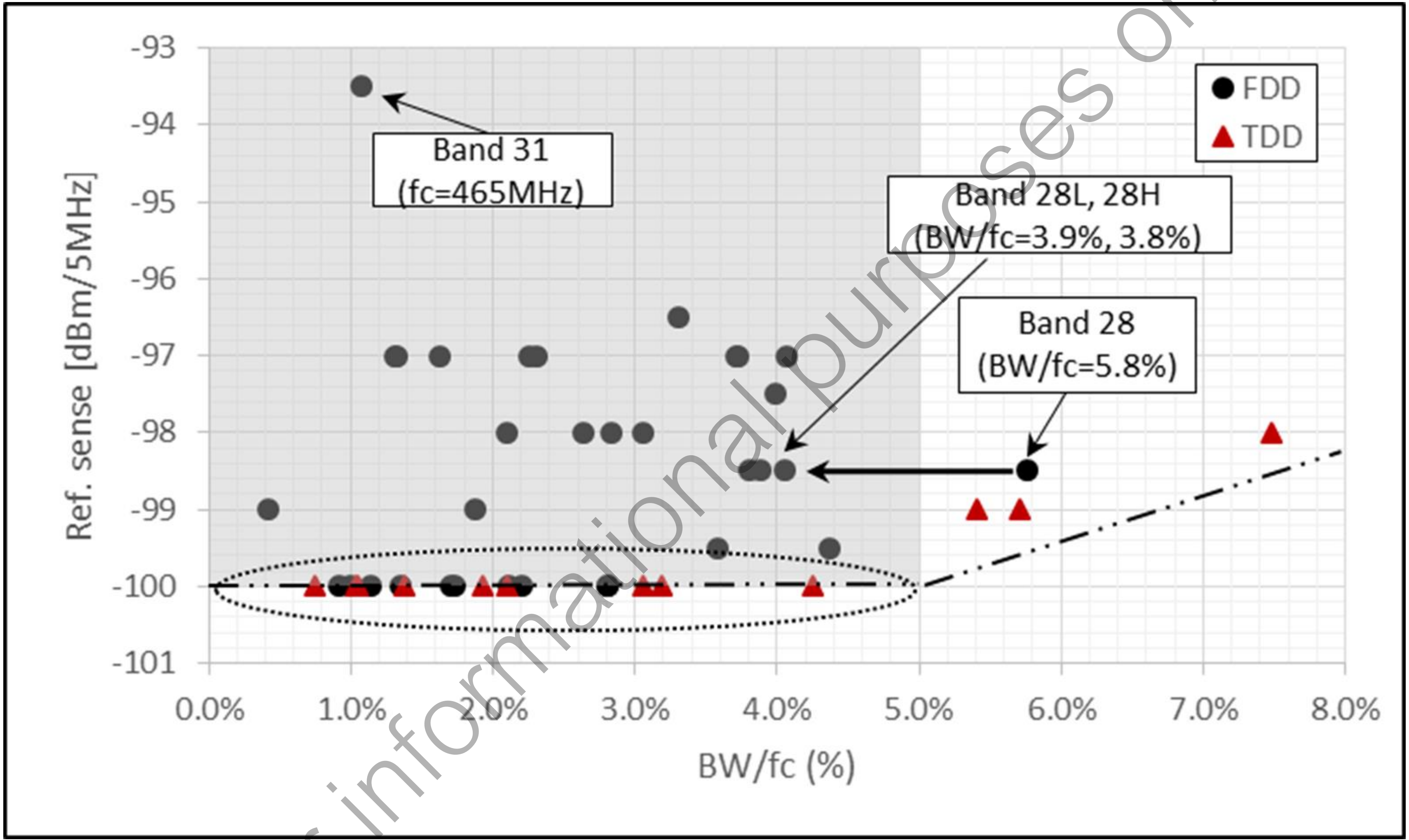

Ref: “Research Progress of the Fifth Generation Mobile Communications Promotion Forum,” IEEE VTS APWCS2016, Aug. 2016. (Derived from original information in 3GPP TS36.101 “E-UTRA UE radio transmission and reception,”)

Operation of New RAT above 6GHz

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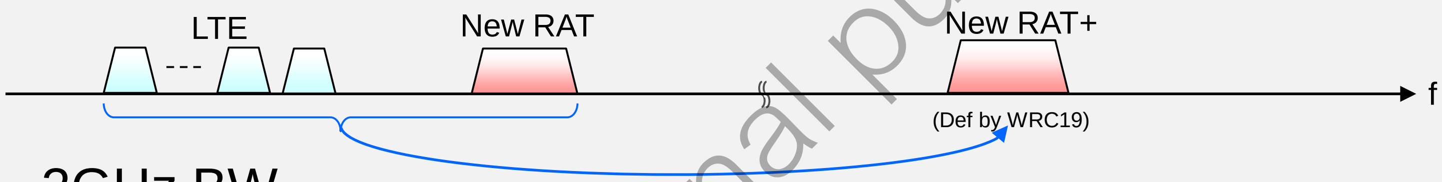
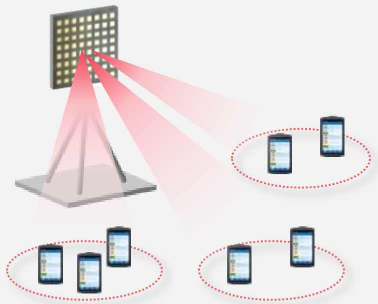
- **Channel susceptible to shadowing, large penetration loss**
- **Beamforming gain and diversity to compensate the large path loss**
  - **→ Potentially high device cost/complexity and power consumption**
  - **→ Limited mobility and cell/beam discovery/tracking**

- **Features for above 6GHz (up to 100GHz)**
  - Dual connectivity SCell (First priority)
  - Standalone operation should also be supported



  - ~2GHz BW
  - Support of multiple radio interface parameters for future proofing and optimization for different scenarios (e.g. Indoor/outdoor, frequency bands, fronthaul/backhaul applications)
- **Beam-space multiplexing of multiple TX signals**
  - Analog/digital hybrid beamforming
    - Low power consumption & cost
    - One analog beam serves multiple UEs
- **Beam-space + site diversity to compensate shadowing**

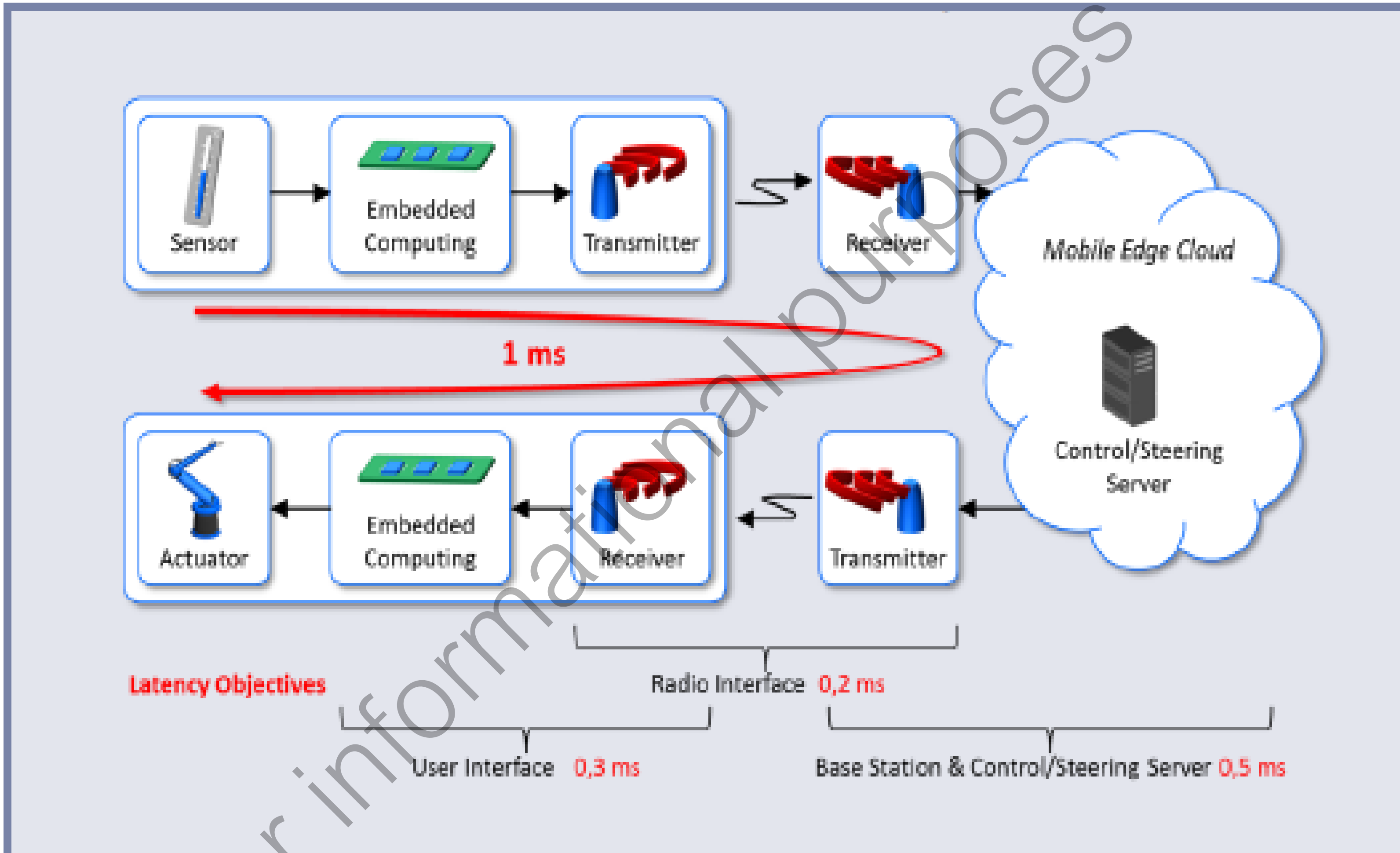


Ultra low latency data transmisson

\- You can't go beyond the speed of light -

[Ref] The Tactile Internet

Exemplary latency budget of a system of the Tactile Internet [16]



[16] The Tactile Internet, ITU-T Technology Watch Report, Aug. 2014

Lower bound of propagation delay vs. distance

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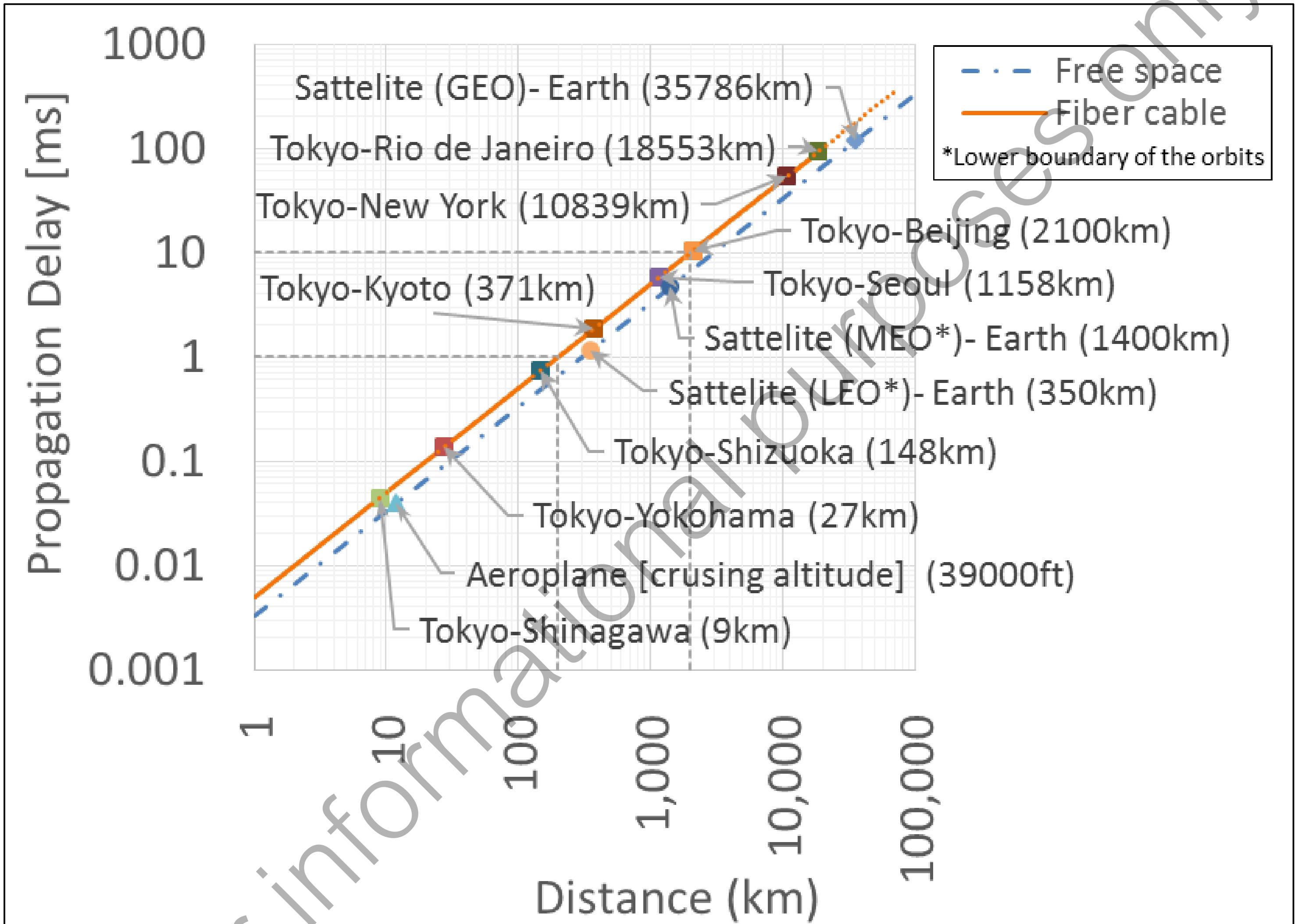
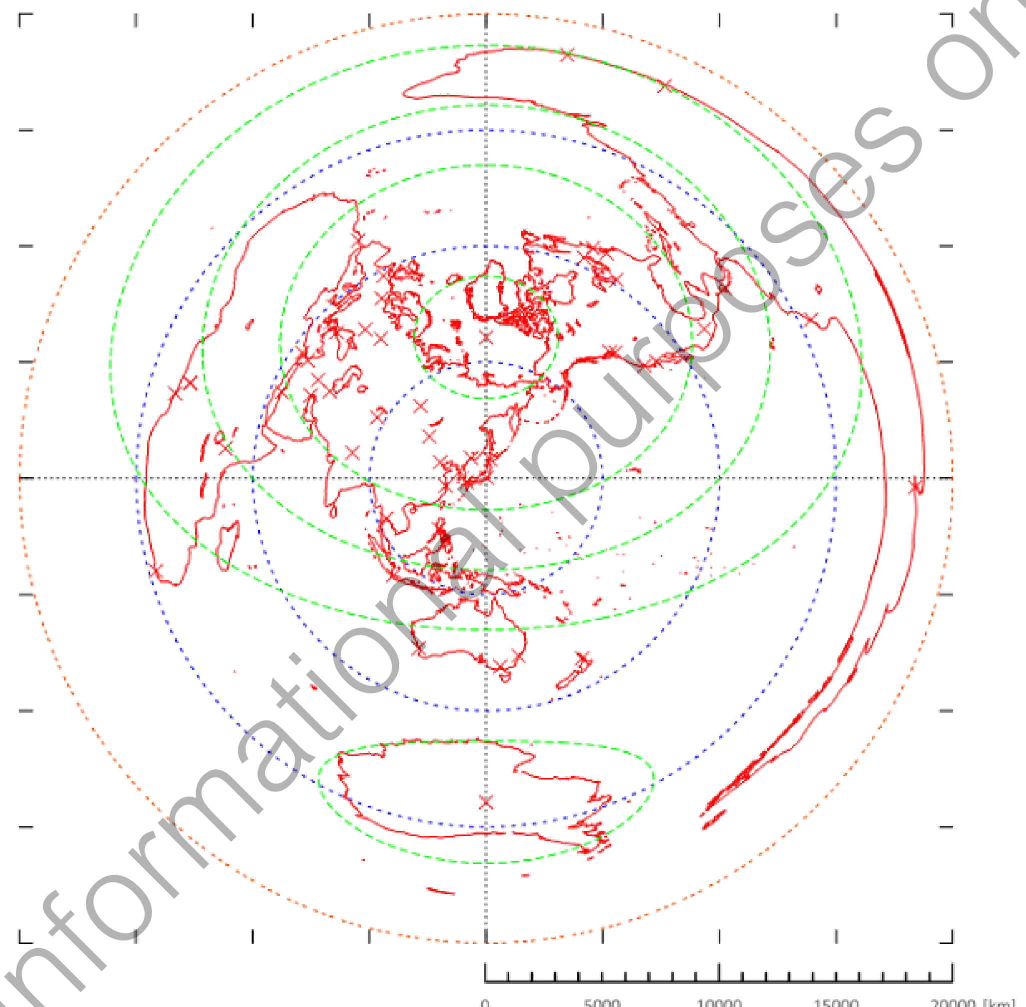


Propagation delay at speed of light [6]

[6] "Embarking on Mobile Communications systems for 2020 and beyond," Proc. 2016 IEICE General Conference, TK-3-4, SSS-9, Mar. 2016 (in Japanese).)

Consideration: Geological localized network services



Azimuthal equidistant projection

Ref: Nakamura. T, “Radio Access Network Technologies for ‘5G’”,IEICE Soc. conf. 2015 (Sep. 2015),
P. Wessel, W. Smith, “A global self-consistent, hierarchical, high-resolution shoreline database”, Journal of geophysical research, Vol. 101, No. B4, pp.8741-8743 (Apr. 1996)

対数等距離・正方位図(東京中心)による距離圏表示

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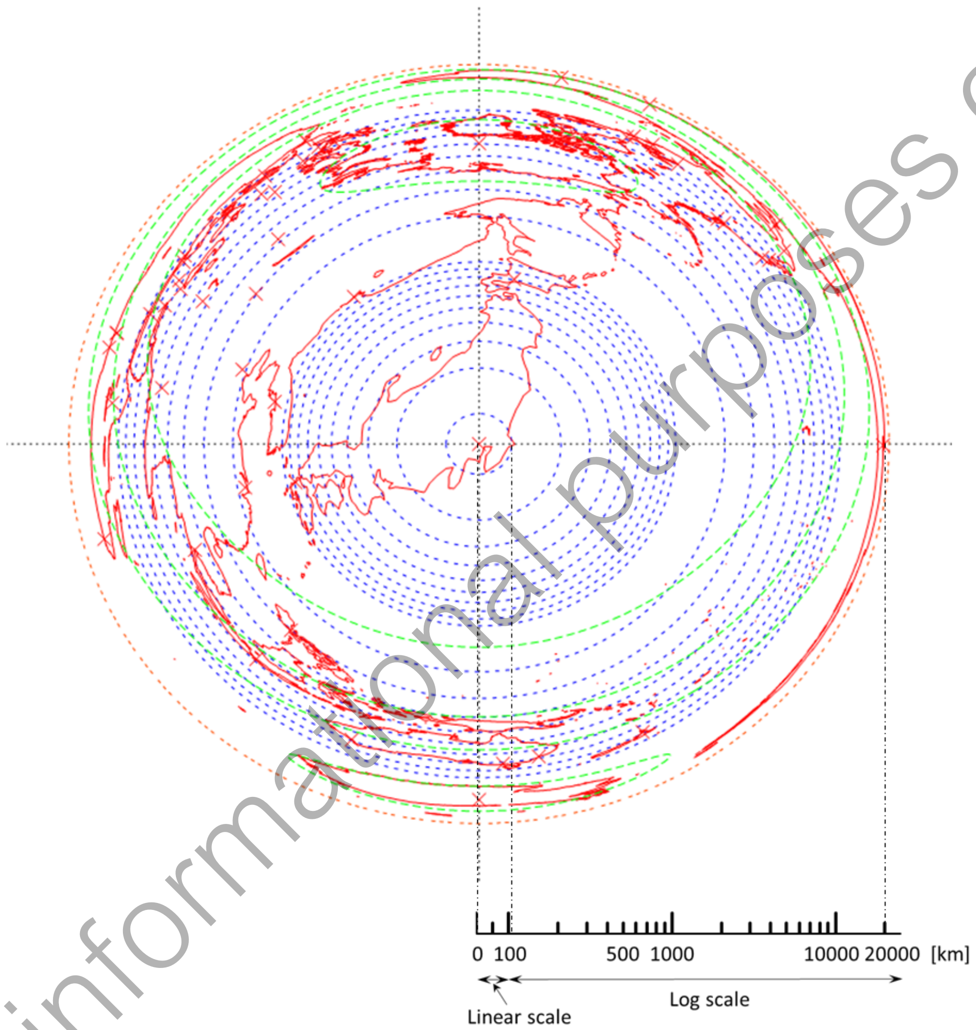

Azimuthal equidistant map (Tokyo centered) [6][17]

[6] "Embarking on Mobile Communications systems for 2020 and beyond," Proc. 2016 IEICE General Conference, TK-3-4, SSS-9, Mar. 2016 (in Japanese).)
[17] P. Wessel, W. Smith, “A global self-consistent, hierarchical, high-resolution shoreline database”, Journal of geophysical research, Vol. 101, No. B4, pp.8741-8743 (Apr. 1996)

An enabling technology

Ultra High-Density Distributed Smart Antenna Systems

Ways to improve system capacity

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1. Improved spectral efficiency:
   - Peak spectral efficiency: 30bps/Hz (UL), 15bps/Hz(DL)
2. Wider spectrum
   - Utilization of SHF or EHF (up to bandwidth of several hundreds MHz)
3. Smaller cells
   - Area traffic capacity (bps/m^2) should be 3 times higher than IMT-Advanced (ITU-R Rep. M.2134)

Ultra High-Density Distributed Smart Antenna Systems

Ultra High-Density Distributed Smart Antenna Systems

- BS-BS distance < 100m

  (Outdoor: ～several 10m,
  Indoor: ～ Several meters)

Propagation characteristics

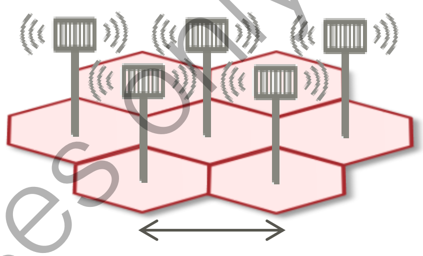
- Line of sight propagations

  ⇒ Stable and high quality communications
- **Higher inter-cell interference**

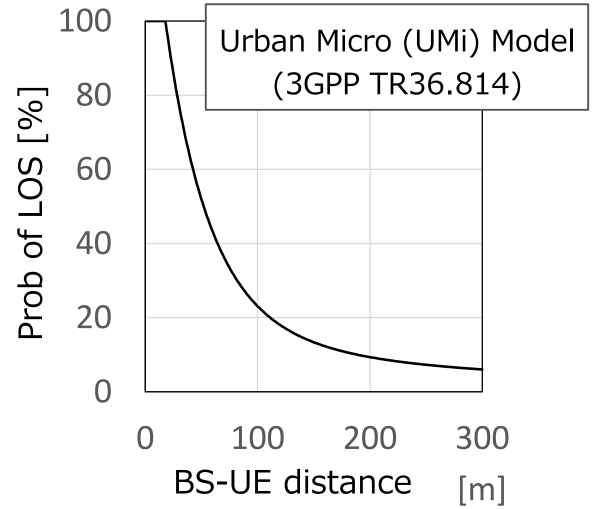
  Utilizing inter BS **coordinated transmission at cell edge areas**

Enabling technologies

- Inter cell coordinated beam forming
- Combination of distributed and concentrated antenna deployment



Inter BS distance [m]	# of BSs [BSs/km^2]
500	5
200	29
100	116
50	462
35	943



Prob. of LOS vs. ISD (Inter Site Dist.)

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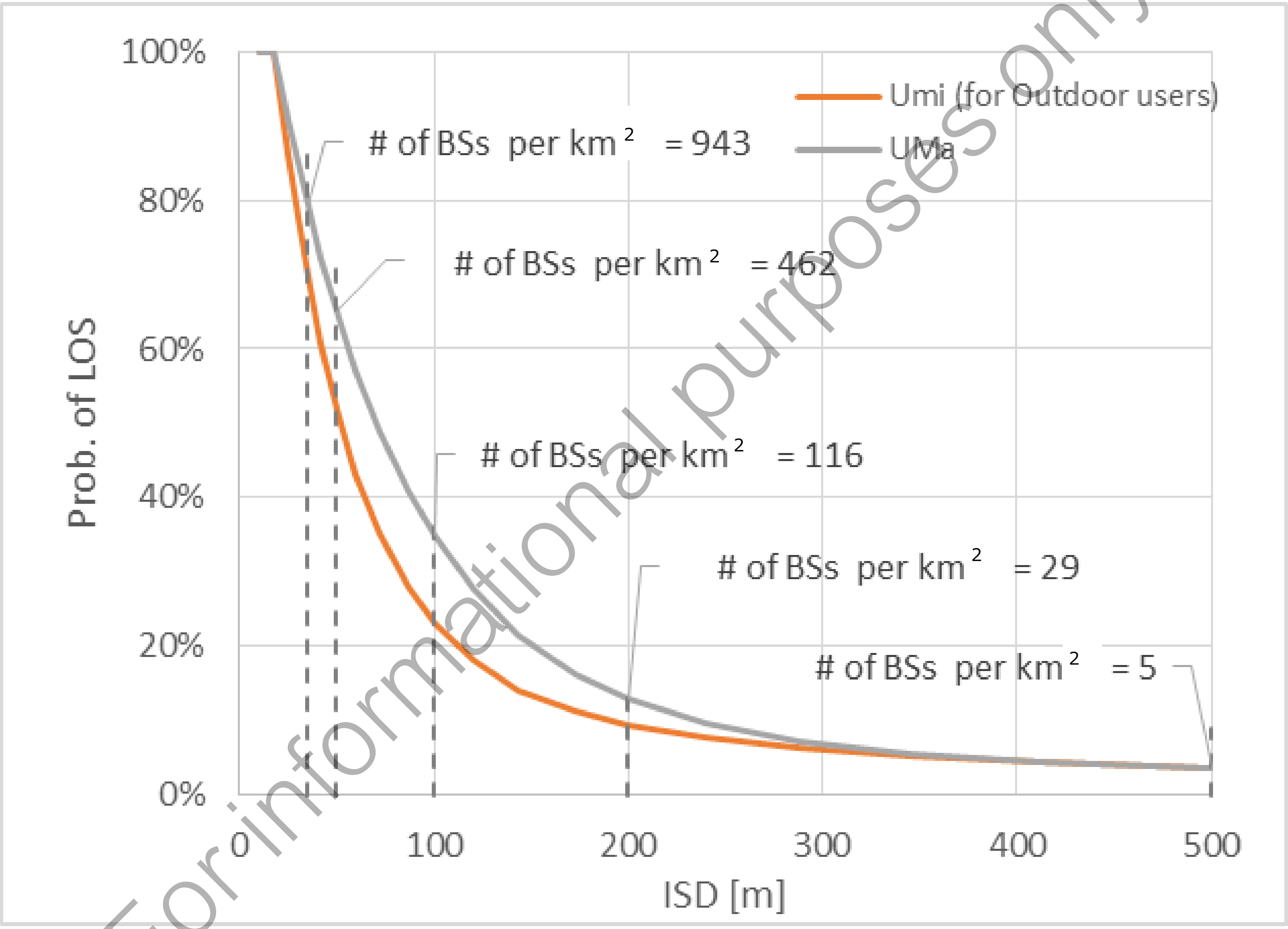

(Ref: 3GPP TR36.814 (V.9.2.0) for 2-6HGz spectrum)

Ultra Dense Network (UDN)

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Dense deployment of small cells improves bps/Hz/m²

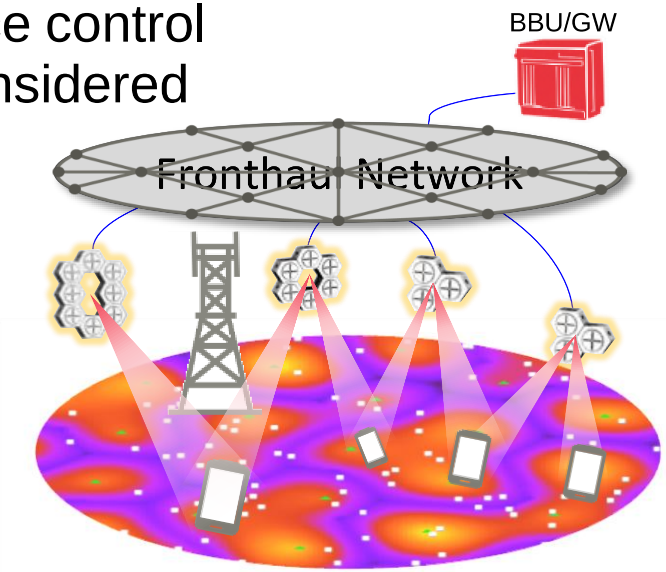
- Increased inter-cell interference limits the area throughput
- Increased requirements (bandwidth, scalability, cost) for backhaul/fronthaul networks

Dynamic virtual cell configuration based on traffic distribution

- UE-centric virtual cell configuration via large scale cooperation among distributed small cells for interference control
- Excessive lean carrier design should be considered

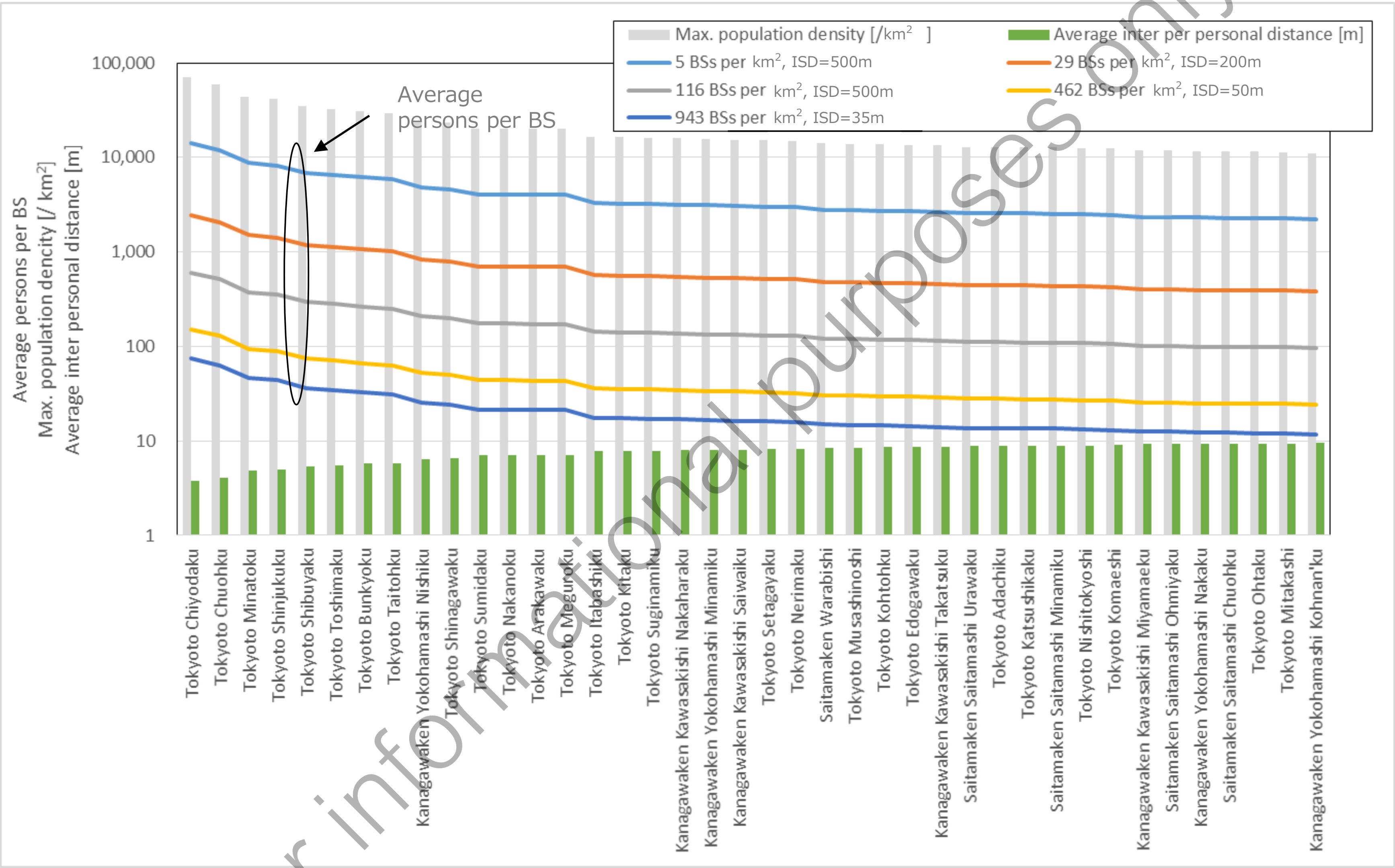
Flexible backhaul/fronthaul network

- Reconfigurable MP-to-MP, Packet-based
  - Architectural design and functional splitting
  - Heterogeneous transmission links (Optical, wireless, DSL)
- Study RAN specification impacts



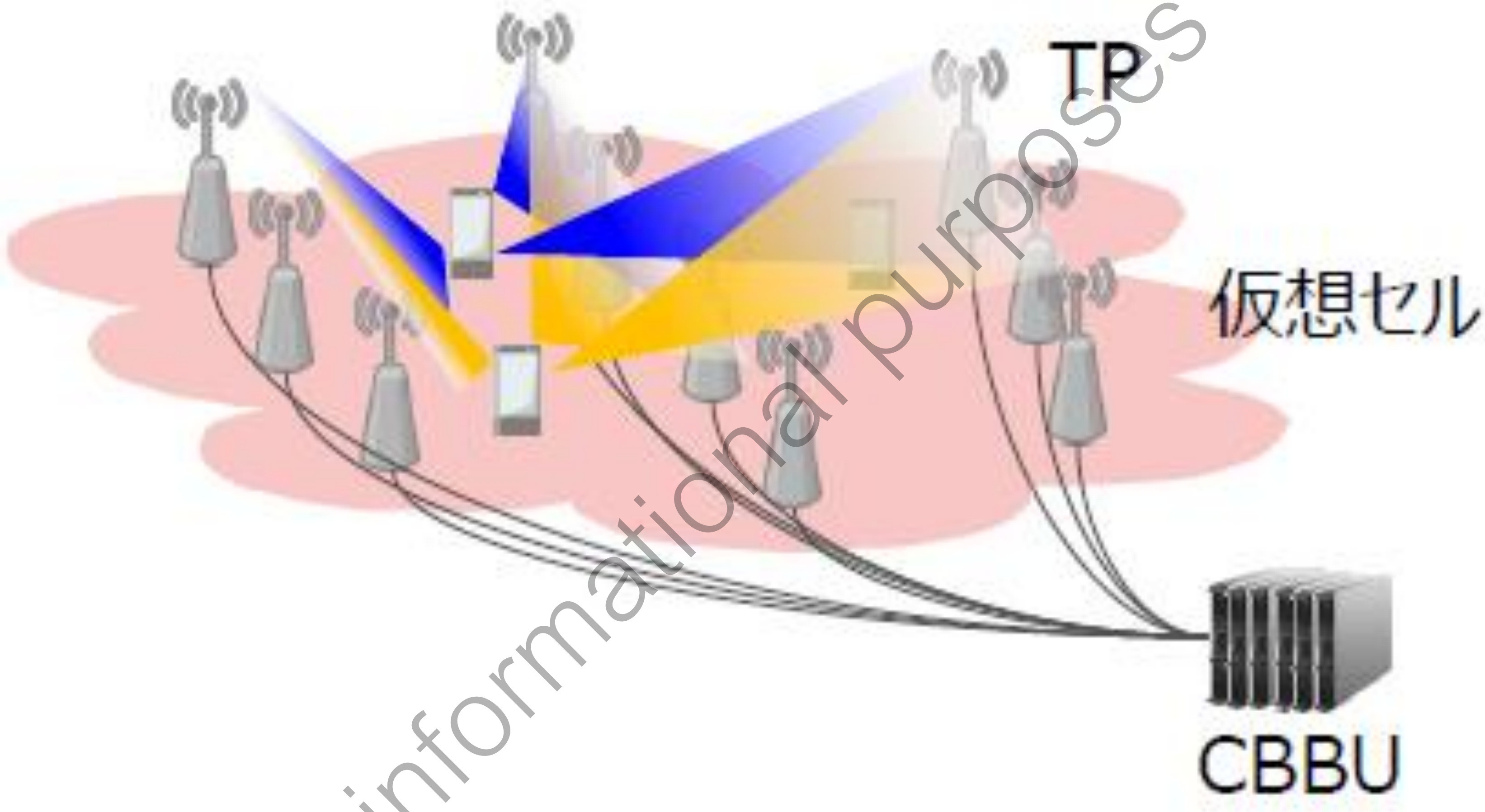
Dynamic virtual cell configuration

Population density vs. Transmission Point (TP) density, subscribers per TP



Ref: Derived from "5GMF White Paper (5G Mobile Communications Systems for 2020 and beyond) Ver.1.01," The Fifth Generation Mobile Communications Systems Forum, Jul.2016. Original in "Population based on place of working or schooling (Daytime population), Population based on place of usual residence (Nighttime population), Rate of daytime population to Nighttime population - Shi, Ku, Machi and Mura (2010)," Statistics Bureau of Japan, 2010-2015 (In Japanese) (URL: http://www.stat.go.jp/data/kokusei/2010/kihon4/zuhyou/syuyou.xls), Area of Shi, Ku, Machi and Mura in each Ken," Geospatial Information Authority of Japan.

Ultra Dense Network (2/2)



Field Trial of Ultra High-Density Distributed Antenna Systems for 5G

Fujitsu Launches Field Trial of Ultra High-Density Distributed Antenna Systems for 5G

Fujitsu establishes a 5G testing site at one of its network business locations, conducts trials of the simultaneous, high-speed transmission of high resolution video

Fujitsu Limited, Fujitsu Laboratories Ltd.

Tokyo and Kawasaki, Japan, November 07, 2017

Fujitsu Limited and Fujitsu Laboratories Ltd. have today commenced field trials of an ultra high-density distributed antenna[(1)], a technology aimed at increasing capacity for fifth generation mobile communications, or 5G. The trials, conducted jointly with NTT DOCOMO, Inc., are being conducted at a testing site established to trial 5G, located at the Fujitsu Shin-Kawasaki Technology Square, a central base for Fujitsu's network business.

This trial will utilize a testing system designed for the newly developed ultra high-density distributed antenna technology. In addition to testing that technology, trials will also be conducted on the simultaneous transmission of high resolution video using the distributed antennas. Fujitsu will evaluate application behavior on this testing system, verifying the effectiveness of this 5G technology for a variety of use cases, such as live video transmission in stadiums. Fujitsu and Fujitsu Laboratories will be conducting this trial jointly with DOCOMO, with the goal of commercializing 5G technology from 2020.

Fujitsu Shin-Kawasaki Technology Square (lobby)

Ref: "Fujitsu Launches Field Trial of Ultra High-Density Distributed Antenna Systems for 5G," Press release of Fujitsu, (Nov. 2017) [http://www.fujitsu.com/global/about/resources/news/press-releases/2017/1107-01.html]

Conclusion

Conclusion

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1. **Role of '5G', demanded features to the system**
   Bridging Digital World and Physical World
   in secure, stable and efficient manner

2. **Phased approach and candidate features**
   Phase 1: Flexible radio interface specification
   - May meet a sub set of 5G requirements
   - Forwards compatibility to Phase 2 and beyond

   Phase 2: Extended frequency bands above 6GHz
   - Has to meet all ITU-R IMT-2020 requirements
   - Backwards compatibility to Phase 1

3. **Enabling technology**(ies)
   - Ultra High-Density Distributed Smart Antenna Systems
   - mmWave beamforming
   - Space-division full duplex（SDFD）

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