How Rail Transport Could Benefit from 5G

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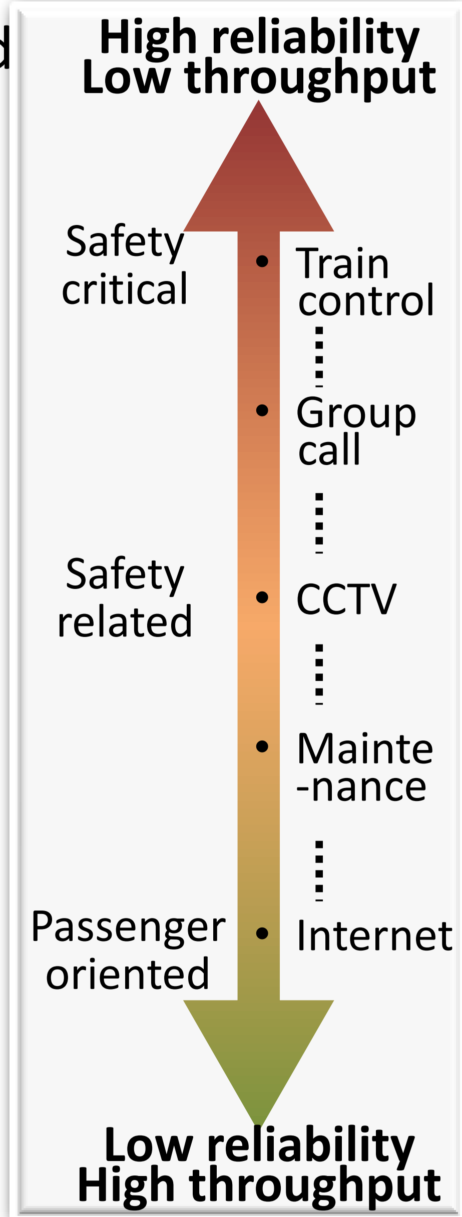
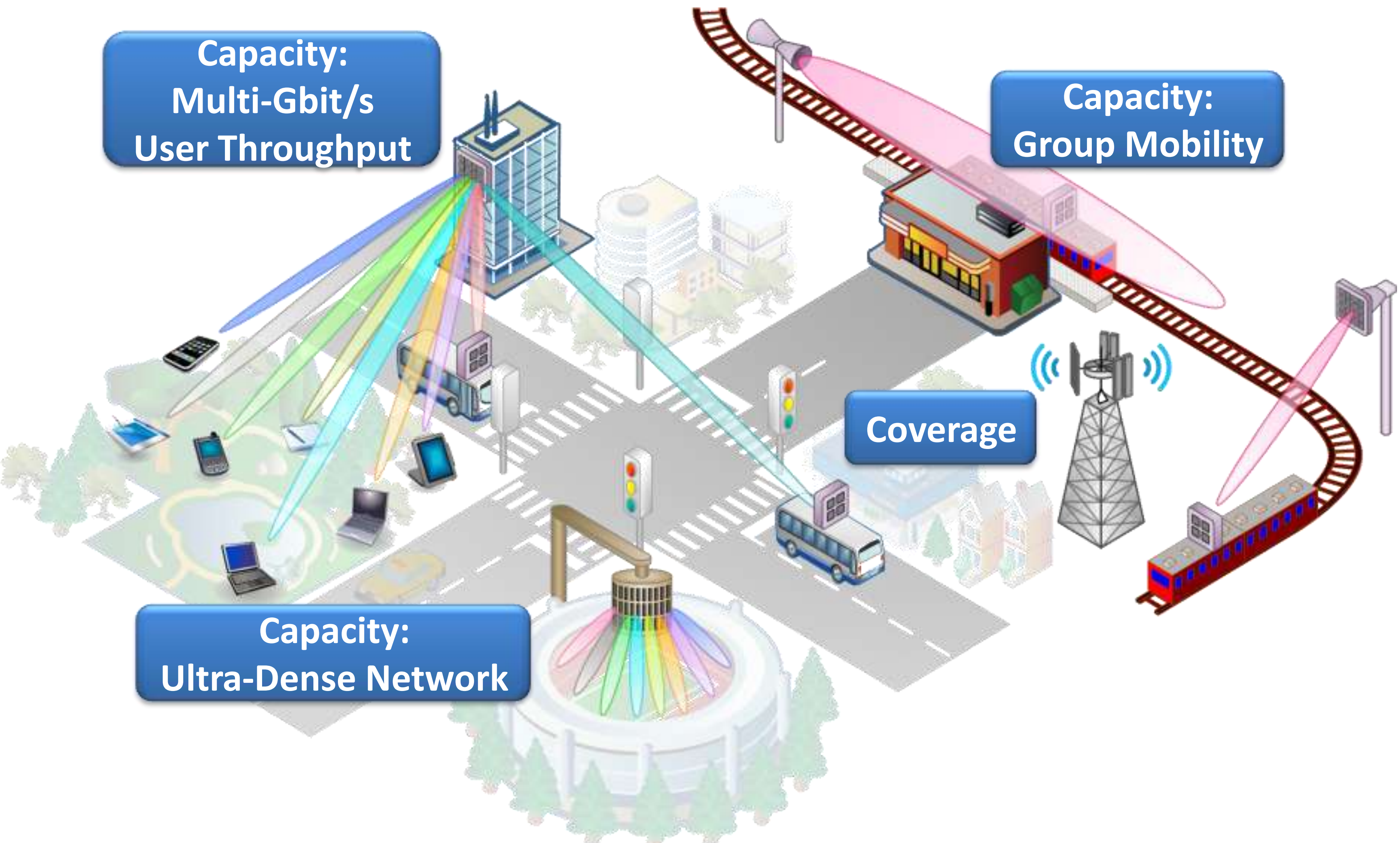
Trains and Radio

- Safety-critical train operation: an evolution required
  - GSM-R predicted obsolescence by 2030
  - Next generation needed by 2025 (5 years migration)
  - A COTS solution being operated on a **dedicated spectrum** is the preferred option by railway operators
- Additionally, a large set of safety-related services identified for railway operations
- Passengers comfort: a revolution expected
  - Poor cellular QoS inside trains so far
  - Dedicated deployment using **cellular spectrum** along railway tracks in slow progress
  - … whereas 5G is coming soon around the train

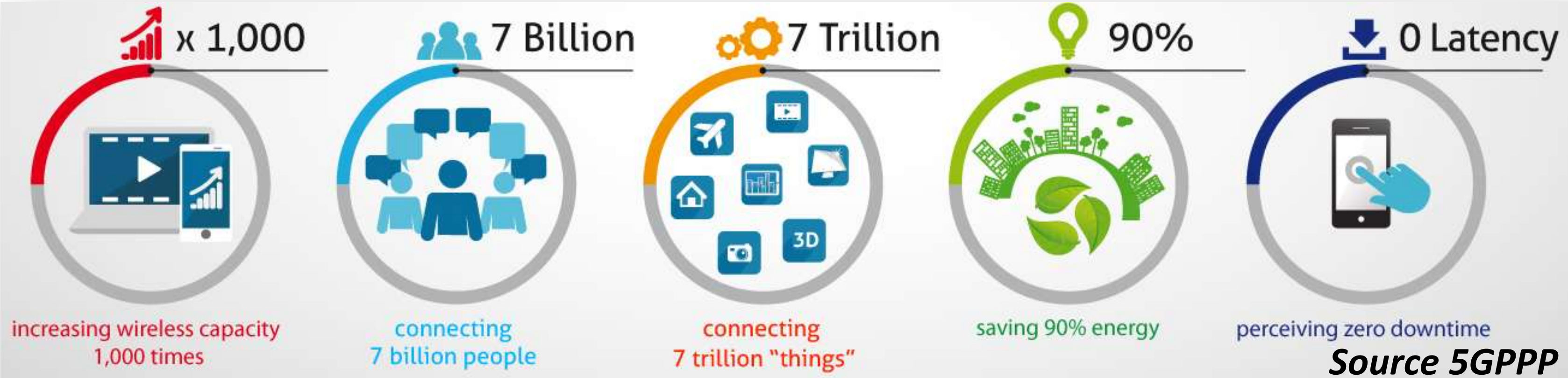


How to make the most of future access network infrastructures ?

5G Consumer Scenarios: Coverage & Capacity



5G Key Radio Access Technologies



Source 5GPPP

x10 spectrum efficiency

- Use very narrow antenna beams for spatial user multiplexing: Massive MIMO

x10 network density

- Reduce deployment footprint: RF/Baseband functional split (RRH/BBU)
- Optimize mobility: Control plane/User plane separation

x10 spectrum

- Aggregate bands including millimeter wave bands (up to 100 GHz)
- Reserve low bands for coverage and use millimeter wave bands for capacity

1 ms latency

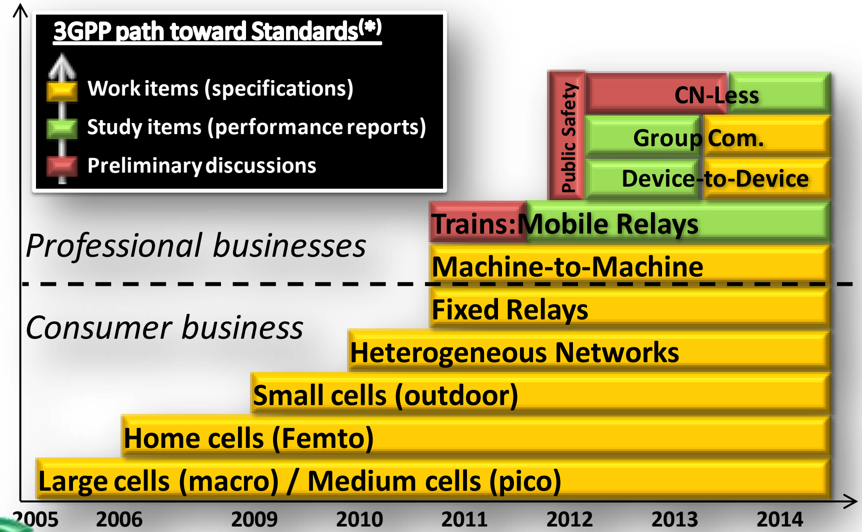
- Reduce the minimum slot duration: mini-slot, shorter symbols
- Distribute network intelligence close to the base stations: Edge computing

3GPP Evolutions Towards Verticals

From a set of **add-on** in 4G

LTE → LTE Advanced → LTE Advanced Pro

- Mainly driven by public safety (adoption in US in 2012)
- LTE-Pro released in Mar. 2016 (Rel.13)



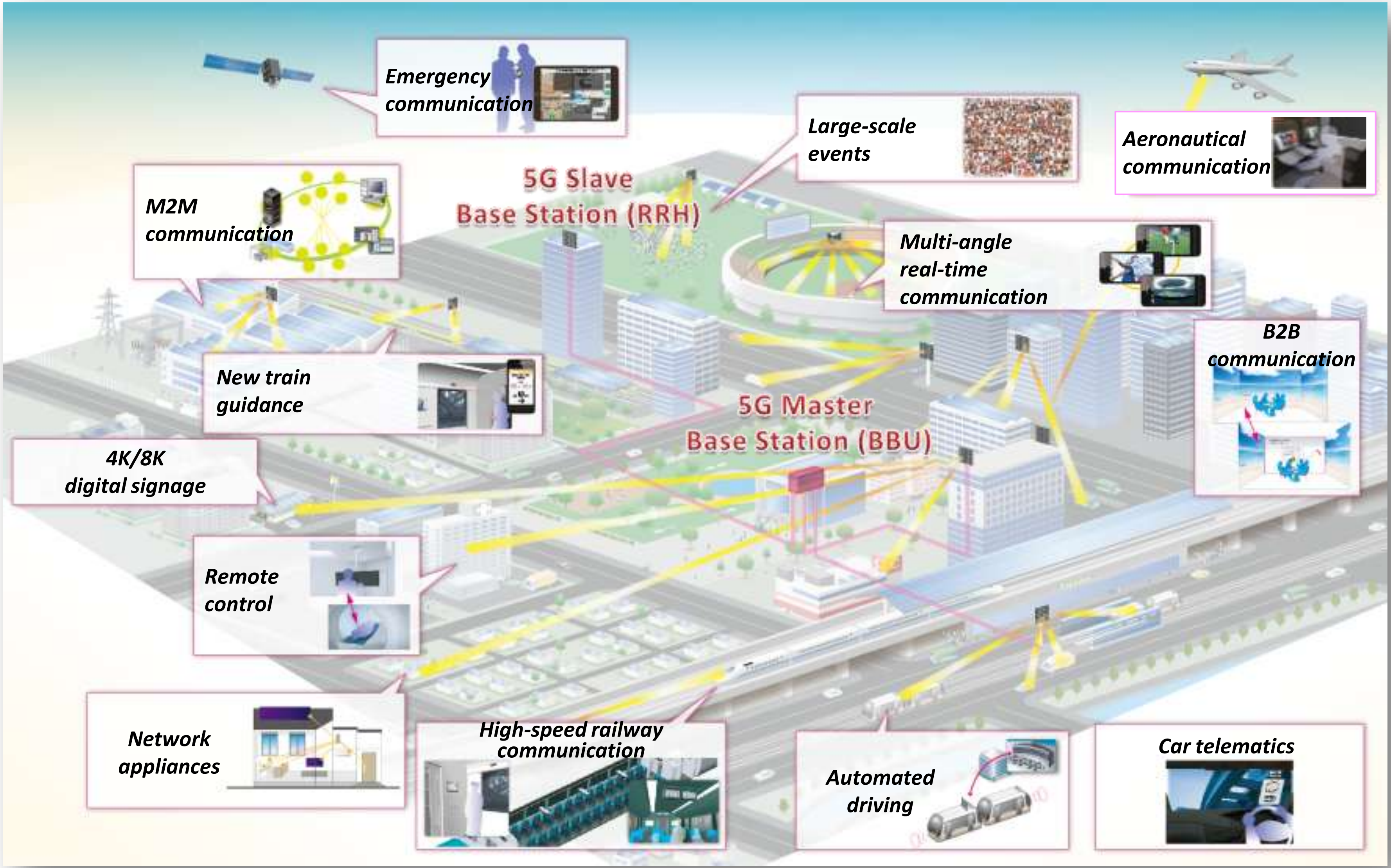
… to **native requirements** in 5G

- Mar. 2015: SA study on 5G use cases (FS_SMARTER)
  - Including critical communications
- Dec. 2015: EU Commission liaison with 3GPP to consider use cases from verticals as drivers of 5G basic requirements (phase 1)
- Mar. 2017: SA study on 5G Communication for Automation in Vertical Domains (FS_CAV)
  - Including rail-based mass transit, surveying other SDOs' work

Source 3GPP, Mar.2017

RAN: Radio Access Network **SA**: Service & system Aspects **SDO**: Standards Development Organization

5G Professional Scenarios: Reliability

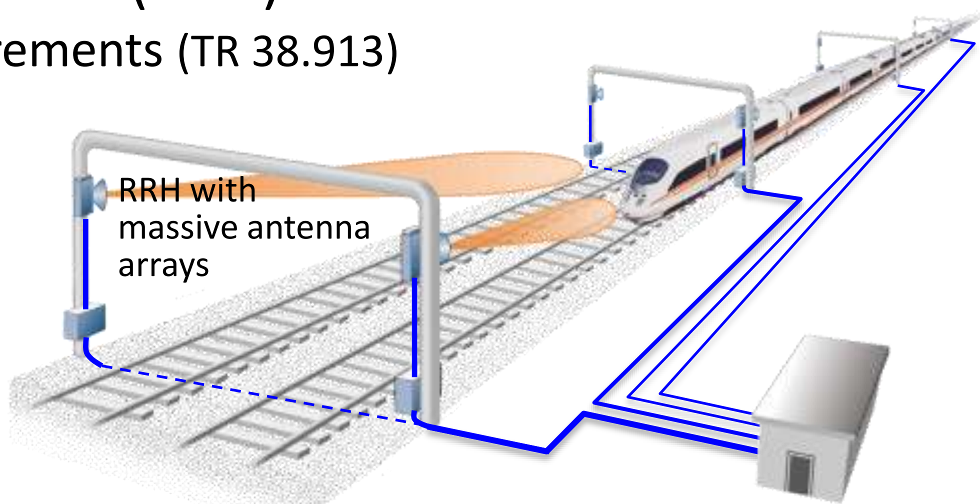


Train-Specific Requirements in 5G

- Train-specific service and architecture requirements (SA)
  - ✔ Study on Future Railway Mobile Communication System (TR 22.989)
    - 8 categories of use cases (basic, critical, business,…) listed: completed in Mar. 2017
  - Work on Mobile Communication System for Railways (MONASTERY, TS 22.289)
    - In which existing specifications the FRMCS requirements can be included
    - New TS for requirements highly specific to railways: to be completed in June 2017
  - Study on Architecture to fulfill FRMCS requirements (TR 23.790)
    - Gap analysis with current specifications: to be completed in Dec. 2017
- Train-specific deployment scenarios (RAN)
  - ✔ Study on 5G Scenarios and Requirements (TR 38.913)
    - Critical train communications included in high speed scenario

Carrier frequency (GHz)	4	30
System bandwidth (MHz)	200	1000
RRH inter-site distance (km)	1.7	0.6
Max. mobility speed (km/h)	500	

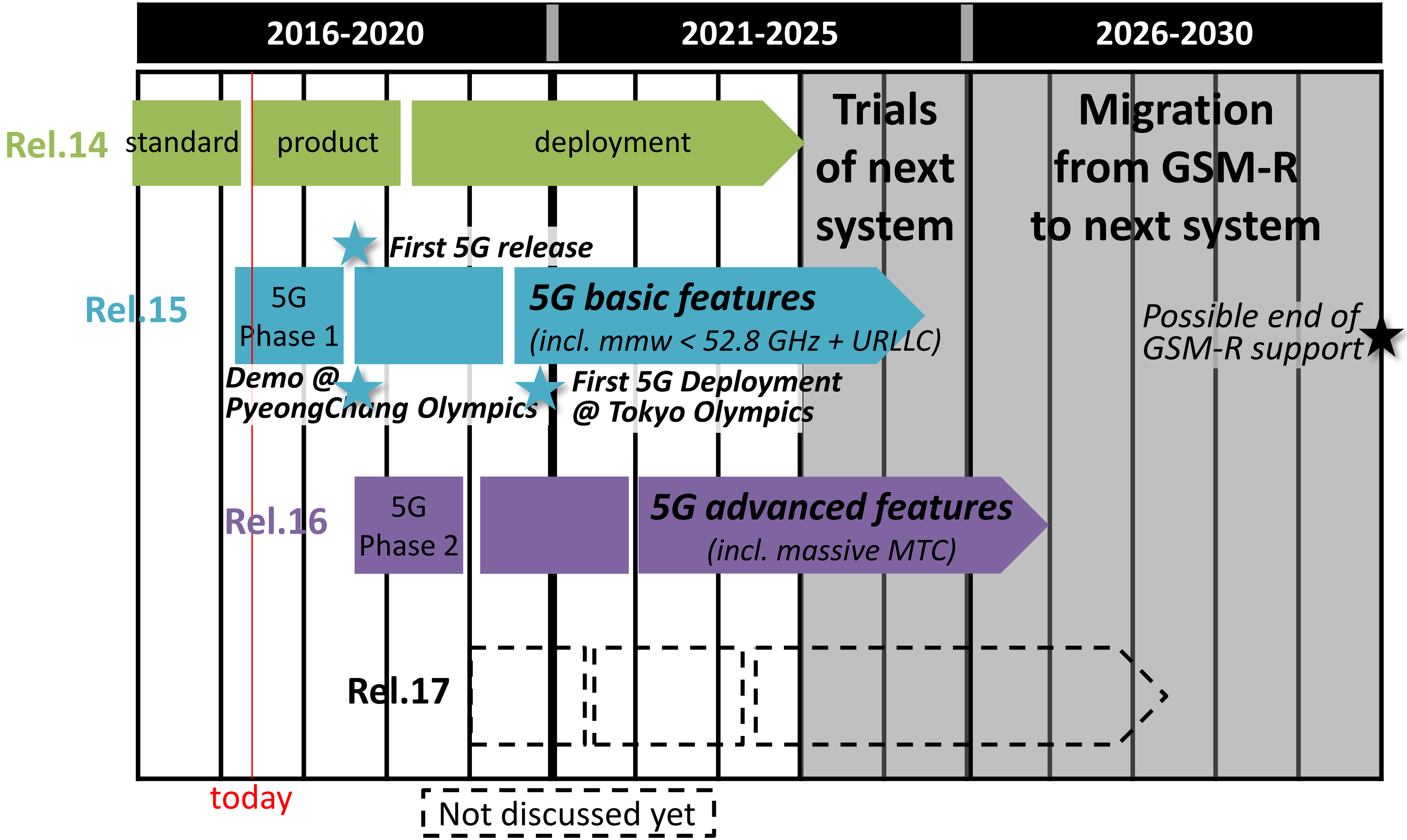
Typical radio parameters



    - Completed in Mar. 2017, to be sent to ITU-R WP5D

BBU: Base Band Unit **RAN**: Radio Access Network **RRH**: Remote Radio Head **TR**: Technical Report **TS**: Technical Specification **SA**: Service & system Aspects

Tentative Roadmap of 5G Deployments



mmw: milli-meter wave **MTC**: Machine-Type Communications **URLLC**: Ultra Reliable Low-Latency Communications

Dimensioning of Next Train Radio Access

- Many applications with different requirements
  - Throughput, reliability, service areas, train velocity
  - Ex: Platform CCTV (only close to station, at medium/low velocity)

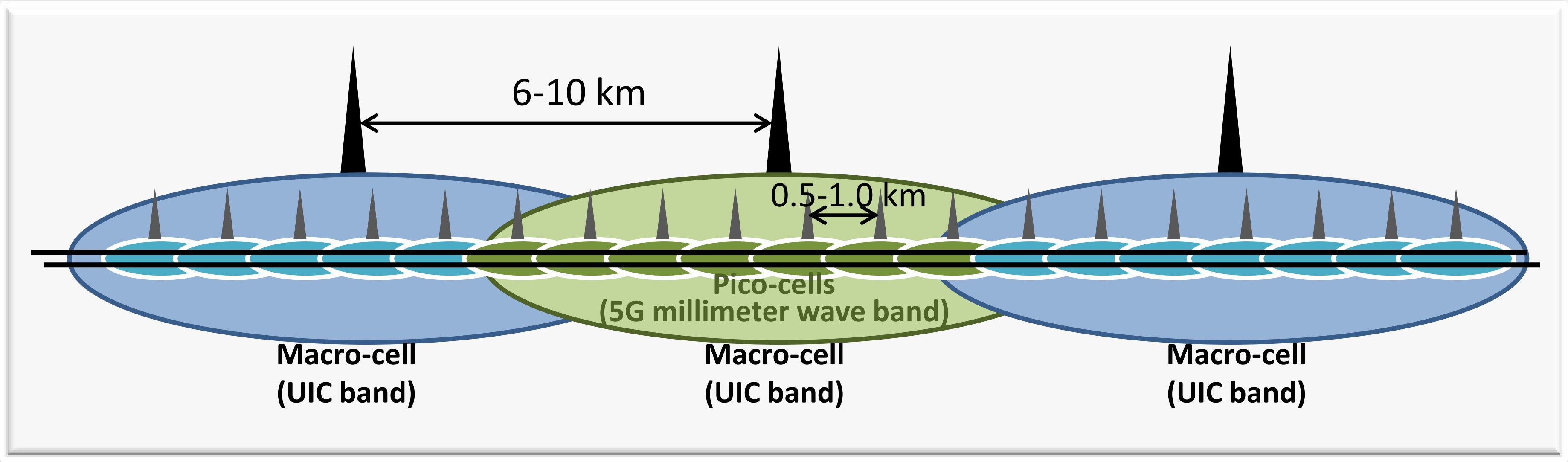
Client services	Link		Safety Communications	Application priority	Data rate per link	Number of links per line		Cumulative data rate (in kbps)	
	train	ground				nominal	maximum	nominal	maximum
Train Control System									
	Car Controler	Zone controler	Yes	High	10 kbps	40 trains	100 trains	400	1000
	Car Controler	Central controler	Yes	High	20 kbps	40 trains	100 trains	800	20000
Maintenance Management System									
	Train Information	Central	No	Low	0.5 kbps	40 trains	100 trains	20	50
	Car Controler	Central	No	Low	0.5 kbps	40 trains	100 trains	20	50
Video Transmission									
	Train Video	Central Controler	No	Low	2000 kbps	2 video flows	4 video flows	4000	8000
Audio Transmission									
	Audio in Train	Central Controler	No	Low	64 kbps	20 calls	200 calls	1280	12800
Passager Information System									
	Train Information	Central Controler	No	Low	10 kbps	40 trains	100 trains	400	10000
Other									
	Train	Central Controler	No	Low	10 kbps	40 trains	100 trains	400	10000

Example of train radio access dimensioning (urban rail requirements, Source ETSI TR 103111)

- Dedicated spectrum probably not enough to handle all applications
  - Reserve dedicated spectrum for high priority operational applications
  - Use shared/public spectrum for lower priority applications

How 5G may impact next generation train radio infrastructures

- Towards an heterogeneous infrastructure for FRMCS
  1. For the basic set of **high-priority applications**: Dedicated macro-cell layer reusing existing GSM-R masts on UIC frequency bands
  2. For **new FRMCS applications**: Shared pico-cell layer taking benefit of future passenger-oriented deployment by telcos along railways tracks
     – Additional antennas on millimeter wave bands offering enough capacity



Conclusion

- Requirements of vertical sectors considered natively in 5G
  - Insertion of railway scenario and radio requirements in progress
- 5G stable products below and above 6 GHz may be available by the time of migration from GSM-R to the next standard radio system
- 3GPP is fully engaged on 5G ultra-fast development with first deployment planned from 2020
  - E.g., RAN1: ~600 delegates, 9 meetings/year, >2000 contributions/meeting
  - Making sure 5G technologies are validated for railway scenarios requires a significant effort by railway stakeholders
- The limited UIC dedicated spectrum may imply using two radio access network infrastructures with a phased deployment

1. A soft-migration of the current infrastructure (same sites & spectrum)

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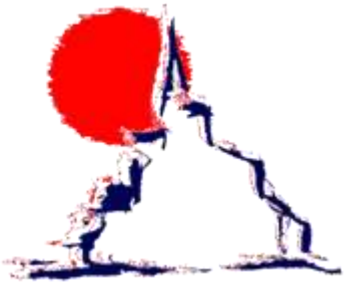
2. A new complementary capacity-oriented infrastructure after validation of 5G high-frequency technologies in railway environments

Thank you for your attention



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