Towards 5G

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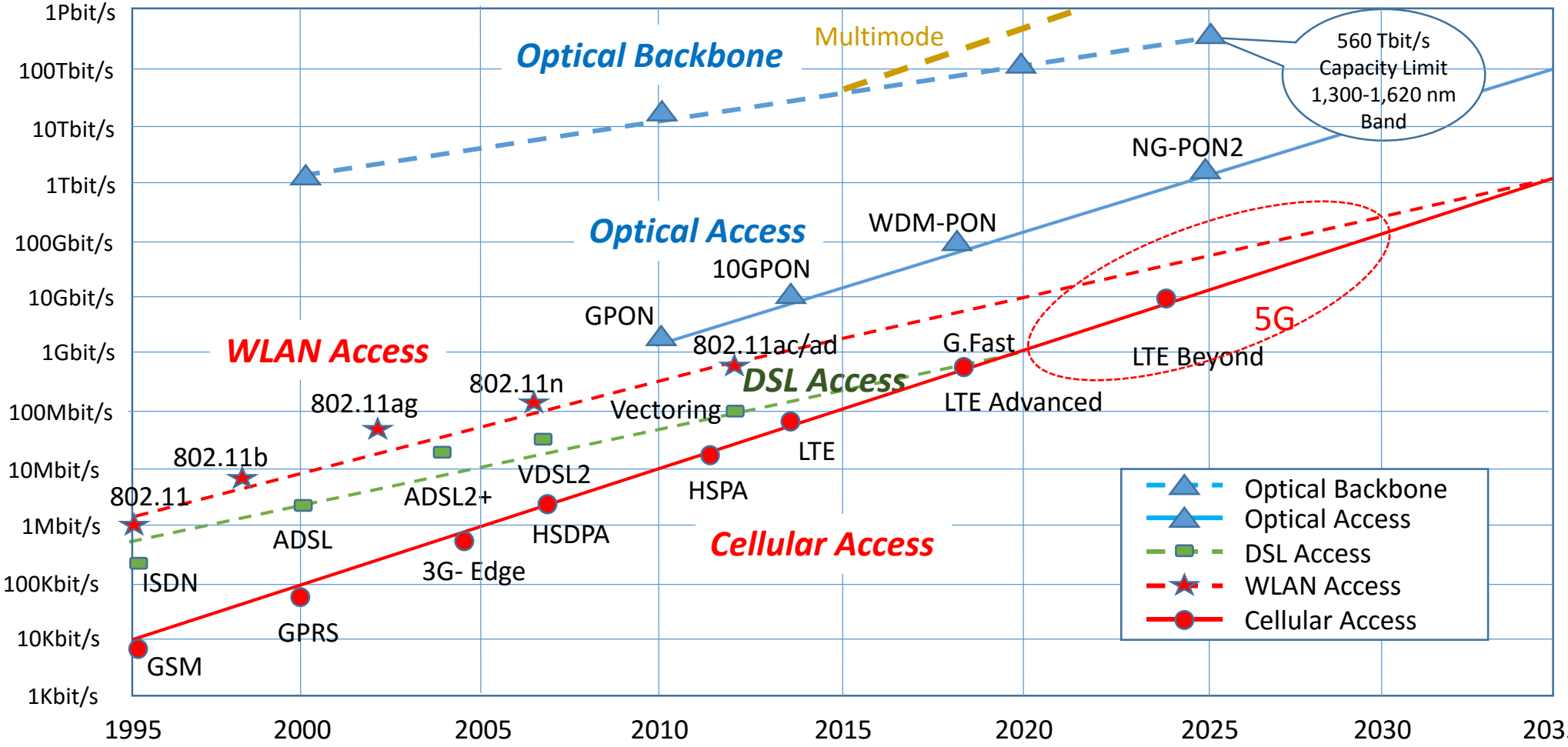
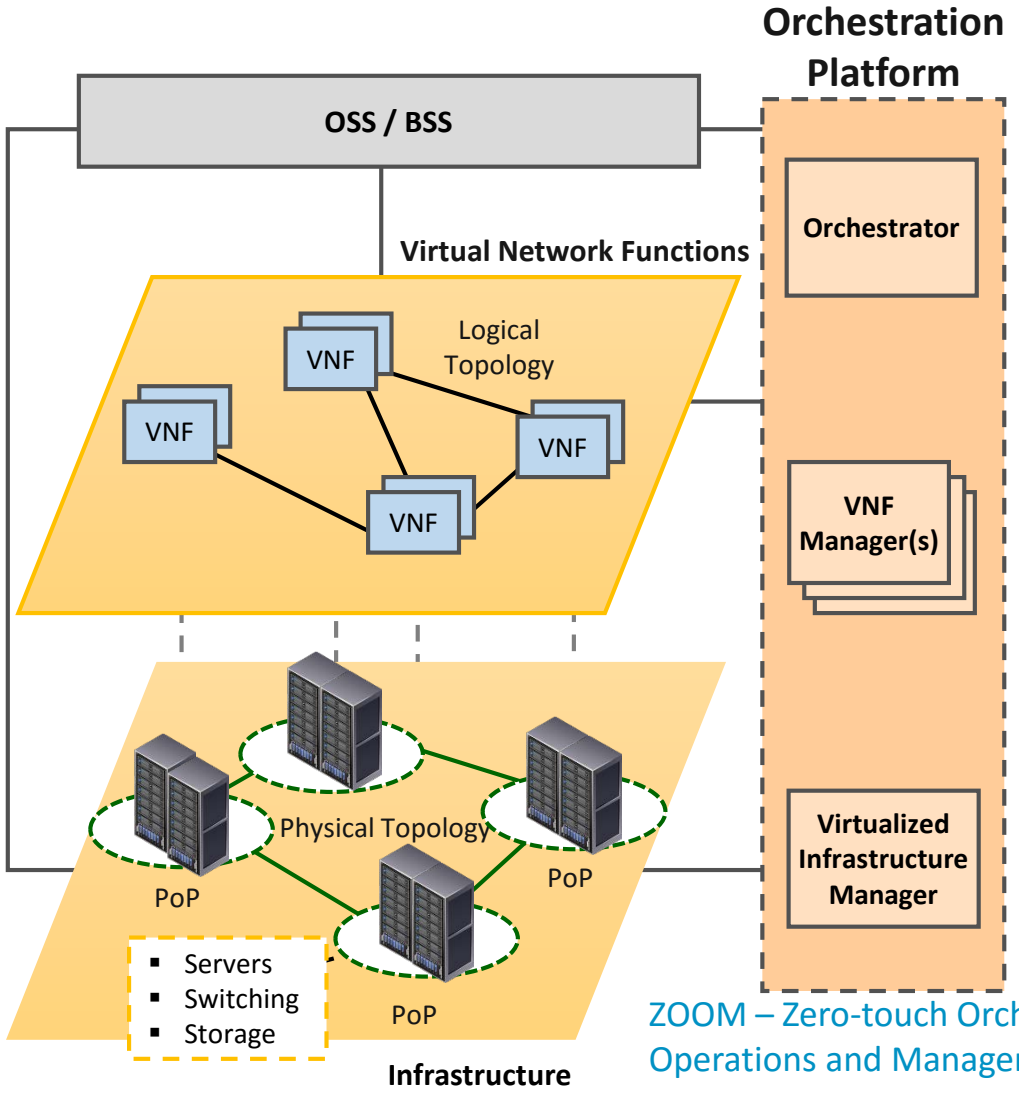
Market Entry Benchmark of Wired and Wireless Technologies with Projections



Source: M. Dècina, 2014, based on data by Bell Labs, G. Fettweis, and others

NFV Orchestration Architecture

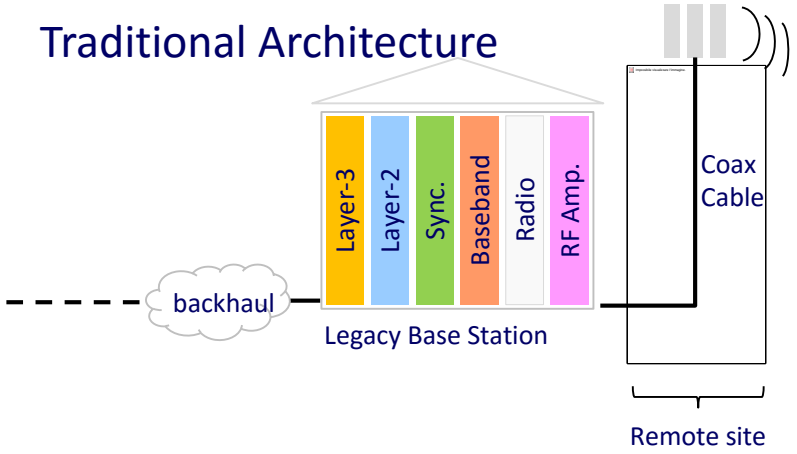


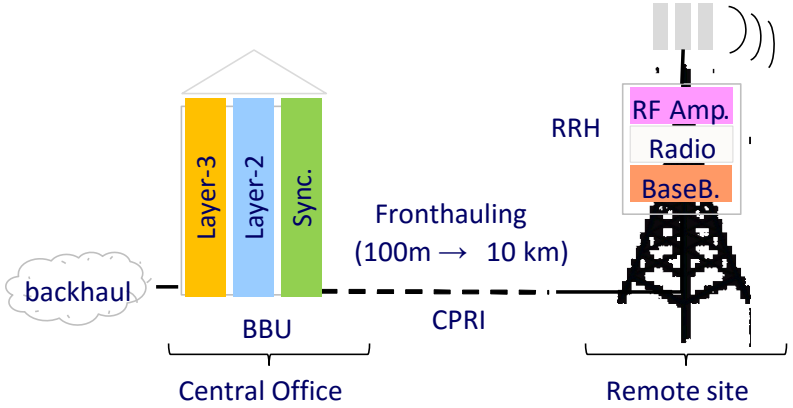
Source: ETSI, 2014

ZOOM – Zero-touch Orchestration, Operations and Management

- Orchestration Platform
  - Platform to mechanize management of the life cycle of Virtual Network Functions
  - It is composed by several modules, to be offered by different vendors
- Virtual Network Functions
  - Set of virtual machines implementing network functions and/or virtualized services
- Infrastructure
  - Geographically distributed domain
  - Includes physical and virtual resources made available by virtualization layer

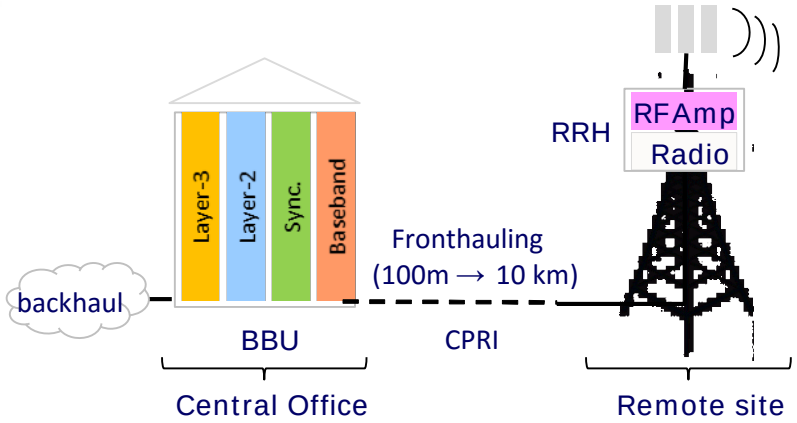
Cloud RAN Architecture: Fronthauling & Backhauling





CPRI (*Common Public Radio Interface*)

Distributed Architecture (partial centralization)

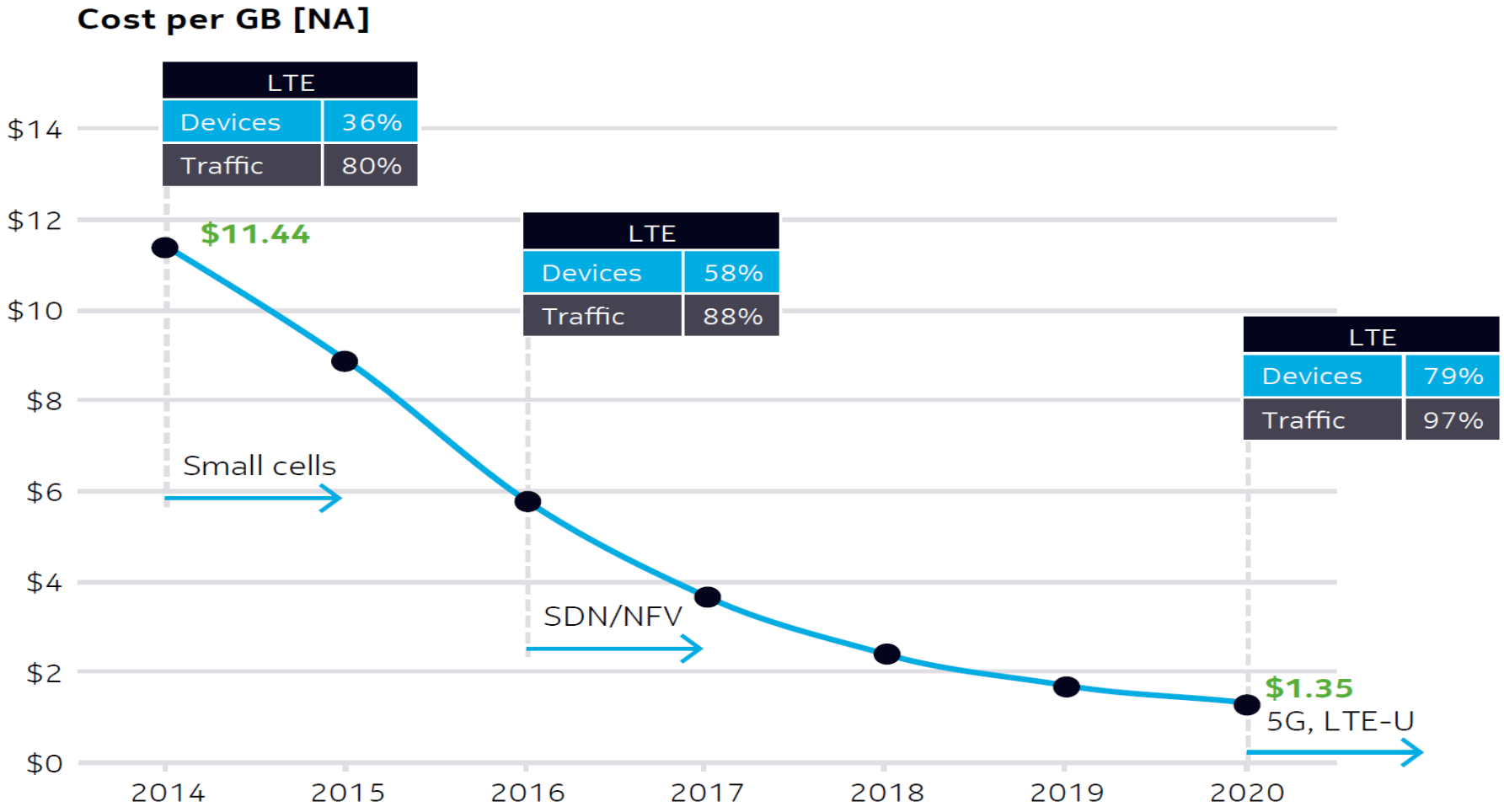


Distributed Architecture (full centralization)

Edge Computing:
BTS Virtualization,
Hetnets, …

Cost of LTE GByte in North America

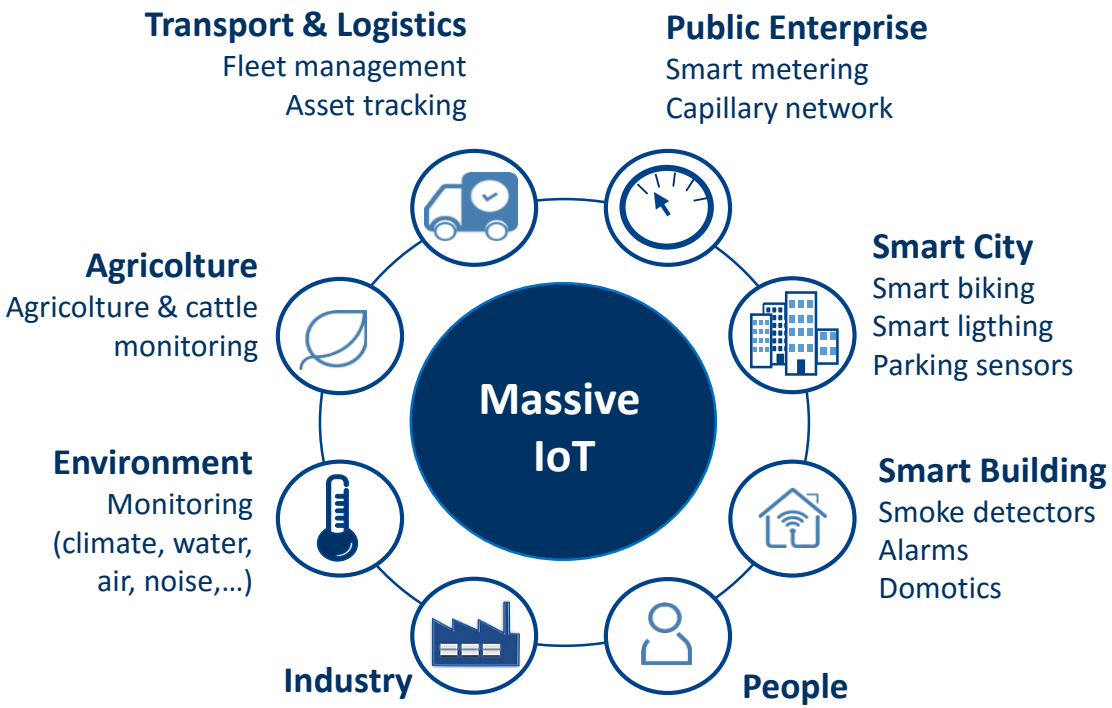
2014-2020

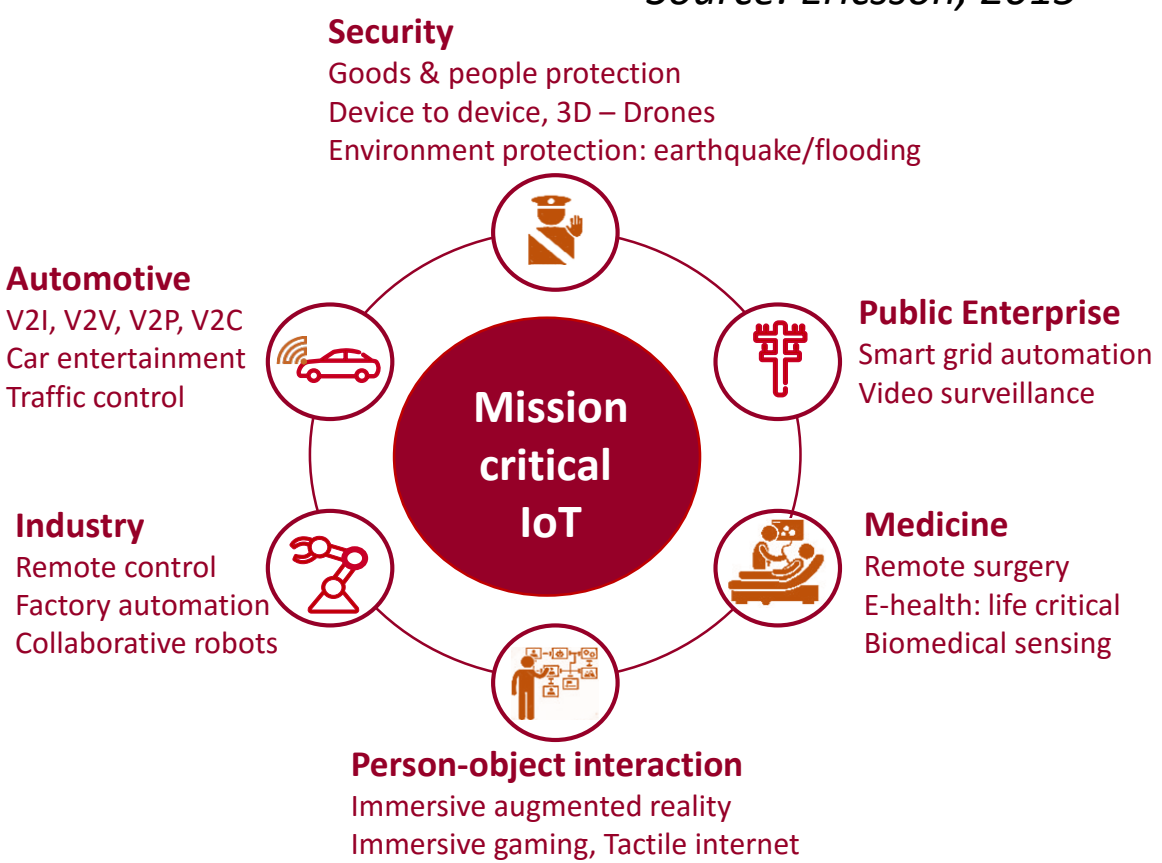


Source: Bell Labs, 2016

IoT Market Applications

Source: Ericsson, 2015





Low cost
Low power
Low capacity
High number of devices

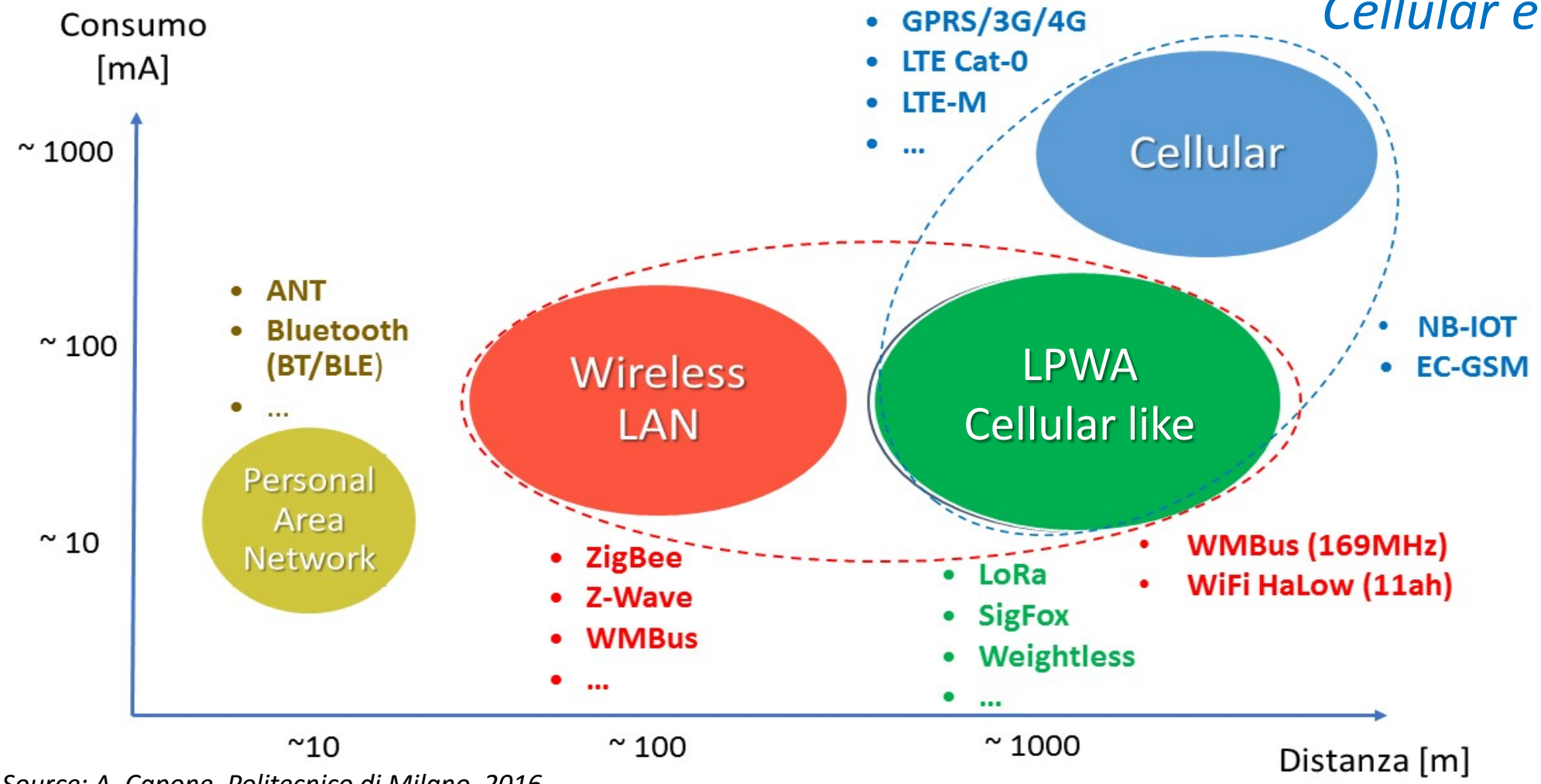
Low Power solutions

High-reliability, Low Latency solutions

High availability
High reliability
Low latency
High capacity

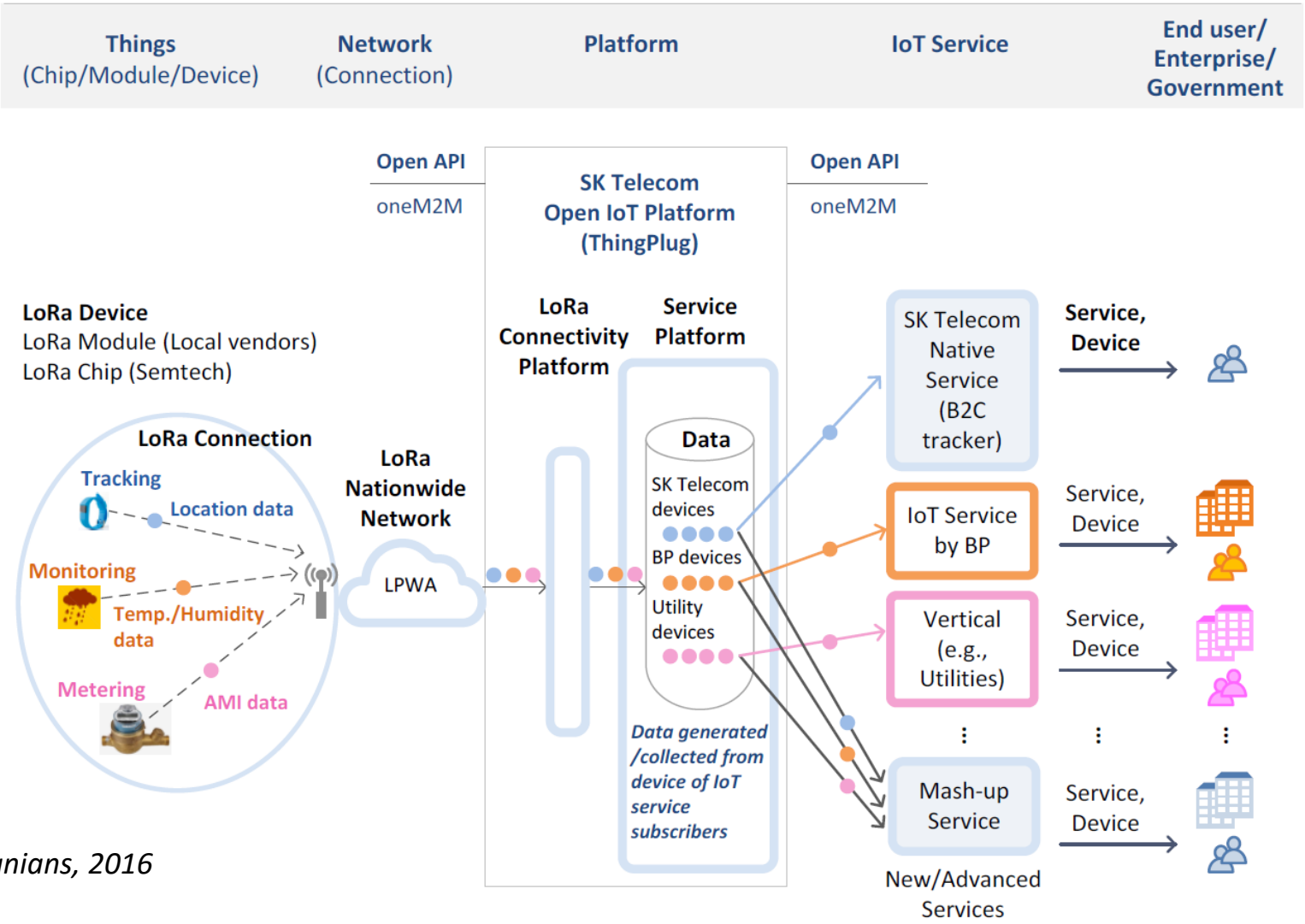
IoT Communications Protocols

Cellular eats IoT!



Source: A. Capone, Politecnico di Milano, 2016

SK Telcom IoST/LoRa Architecture

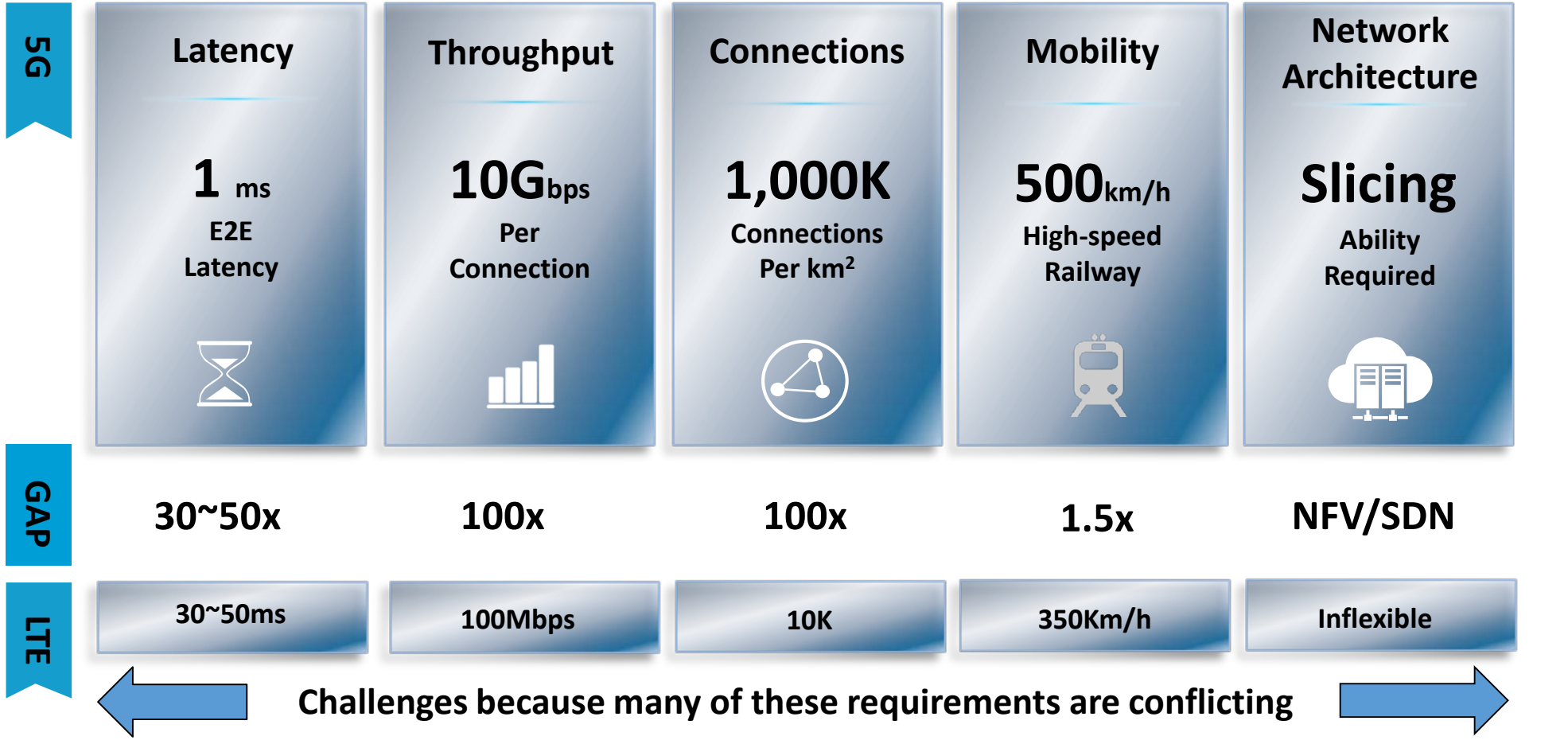


Source: Netmanians, 2016

SK Telecom IoST Volume Pricing 2016

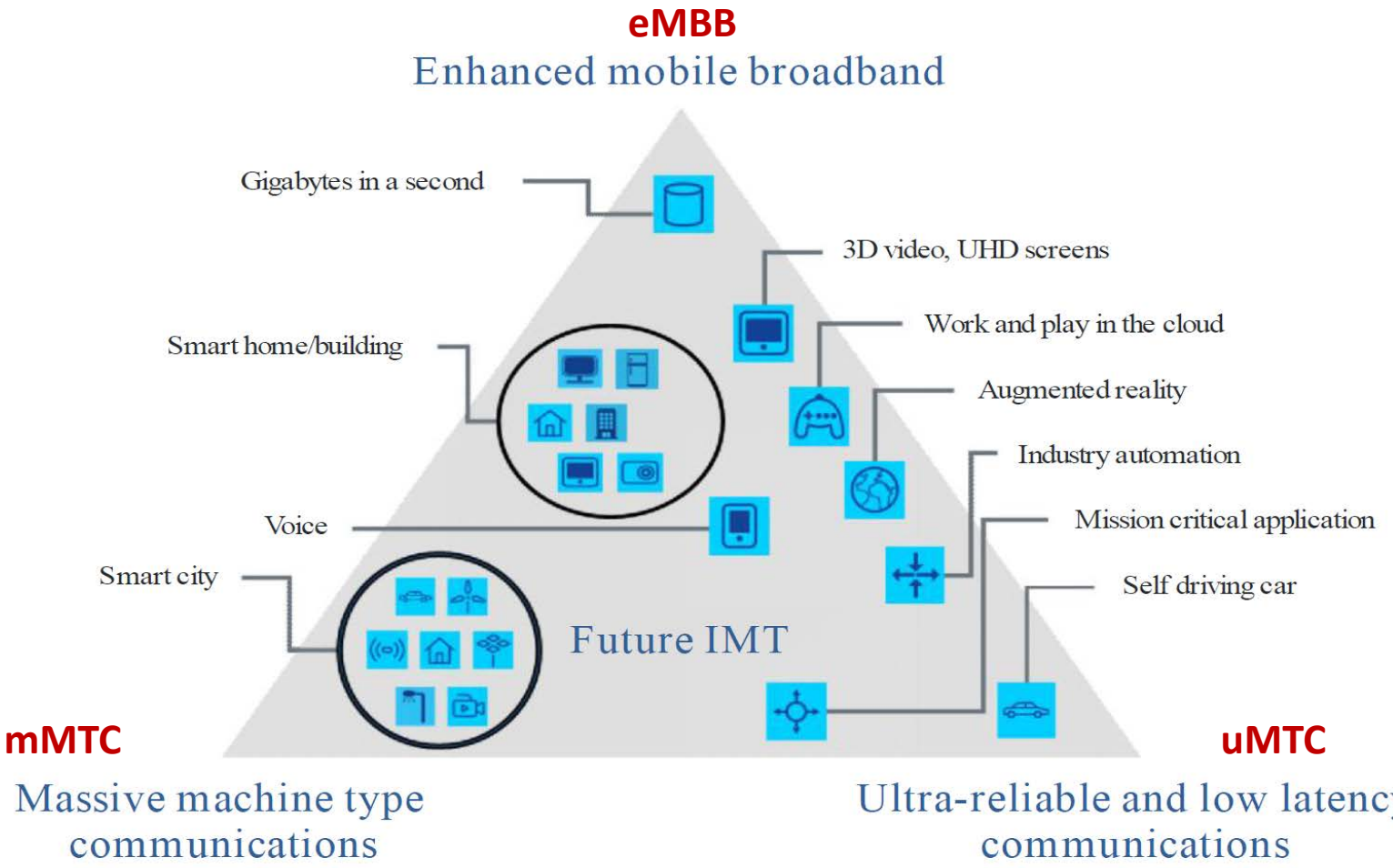
Price Plan	Data Allowance (Frequency of communication)	Monthly Flat Rate (VAT Excluded)	Examples of Services	Notes
Band IoT 35	100KB	KRW 350 23p	Metering and monitoring services (e.g. Advanced Metering Infrastructure (AMI), environmental monitoring, water leakage monitoring, etc.)	- Discount benefits for long-term contracts: Ranging from a 5% discount for two-year contracts to a 20% discount for 5 year-contracts - Multi-line discount: Ranging from a 2% discount for those using 500 lines to a 10% discount to those who use 10,000 lines
Band IoT 50	500KB	KRW 500 33p		
Band IoT 70	3MB	KRW 700 46p	Tracking services (e.g. locating tracking for people/things, asset management, etc.)	
Band IoT 100	10MB	KRW 1,000 66p		
Band IoT 150	50MB	KRW 1,500 £1.00	Control service (e.g. safety management, lighting control, shared parking, etc.)	
Band IoT 200	100MB	KRW 2,000 £1.32		

Diversified Challenges and Gaps to Reach 5G



Source: Huawei, 2016

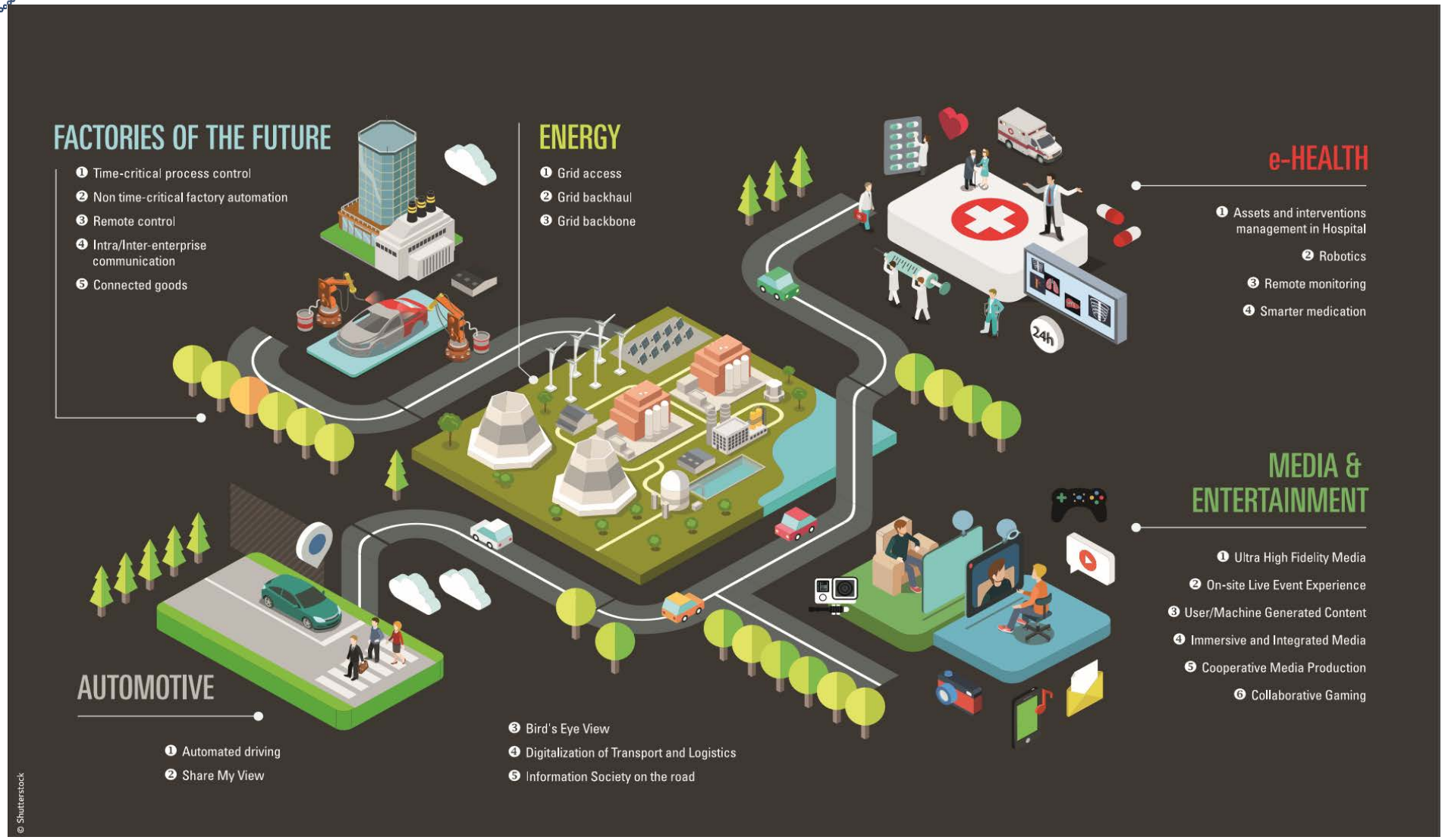
5G Application Clusters



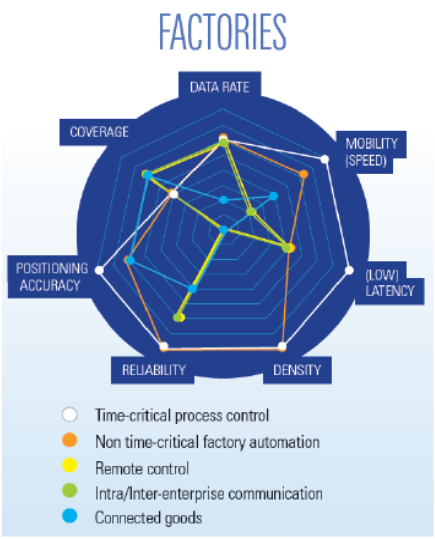
- Full Virtualization (SDN/NFV)
- Heterogeneous Networks
- Adaptive Radio Interface (multiple RATs)
- New Radio Spectrum (mmWave)

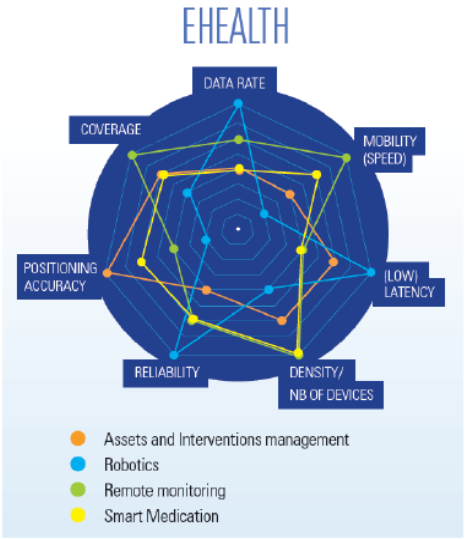
Source: ITU, 2015

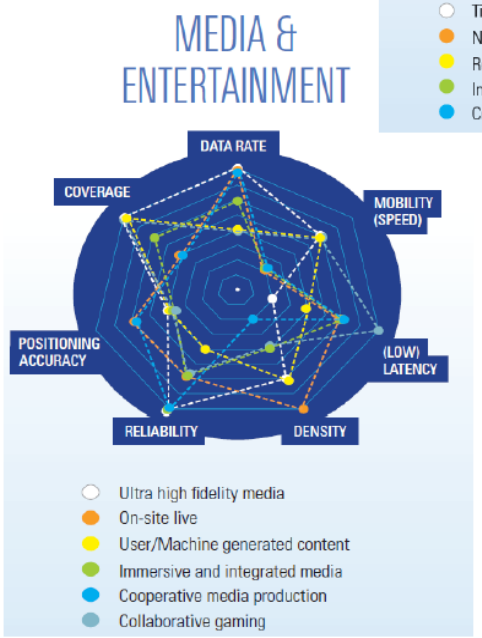
5G Application Verticals

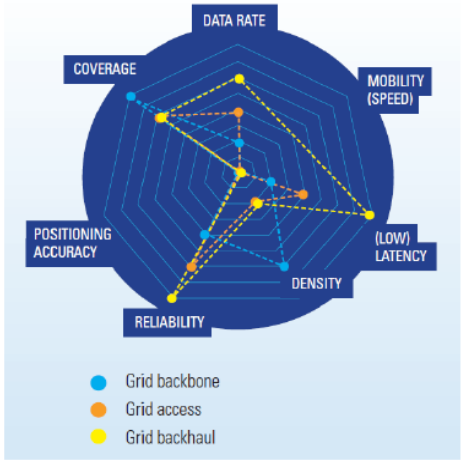


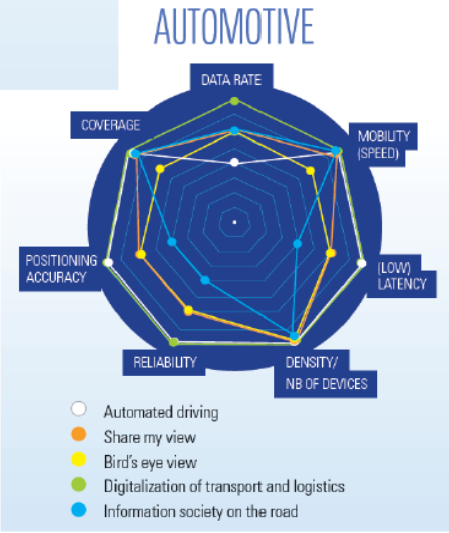
5G Vertical Sectors Requirements





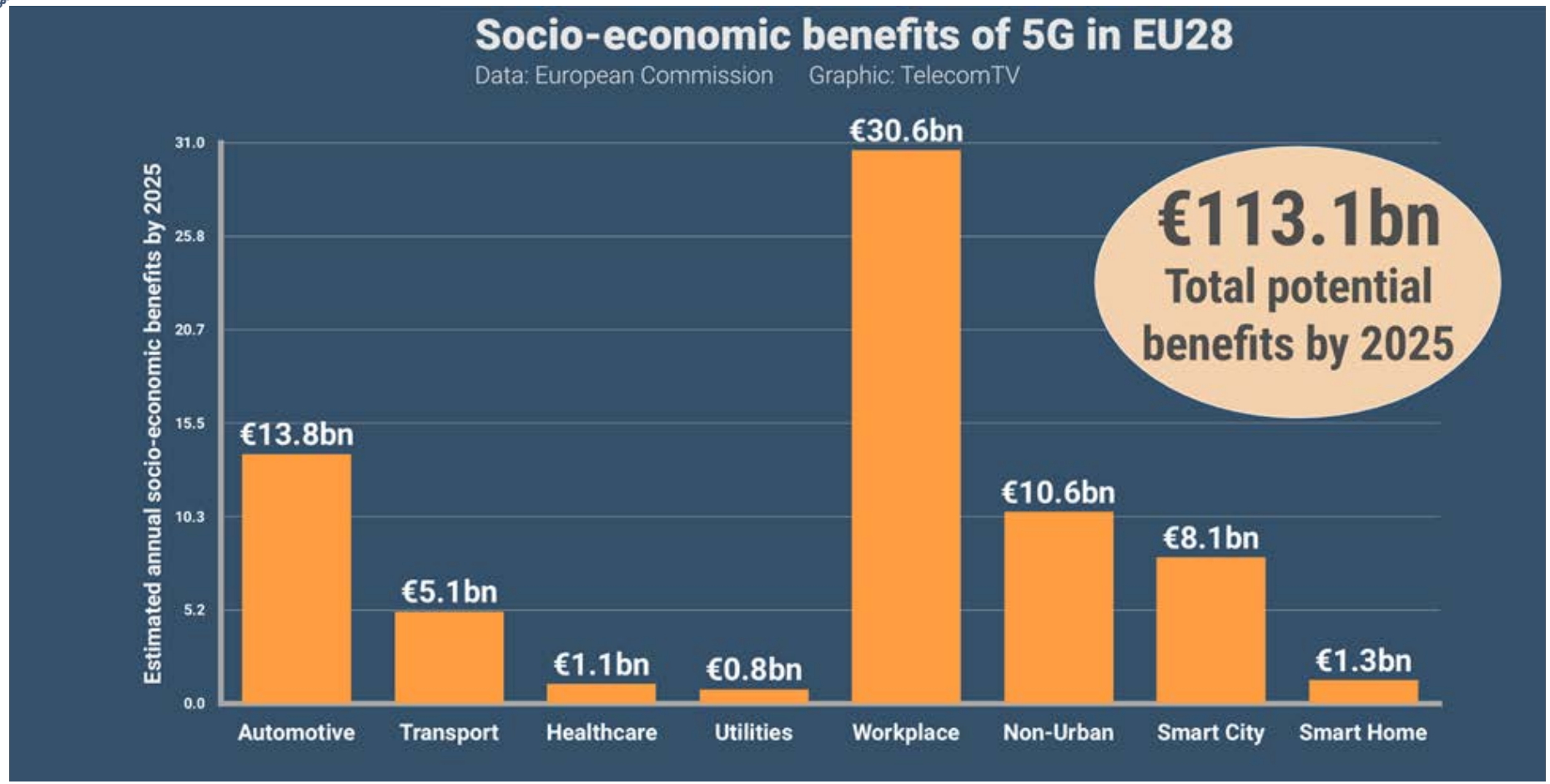






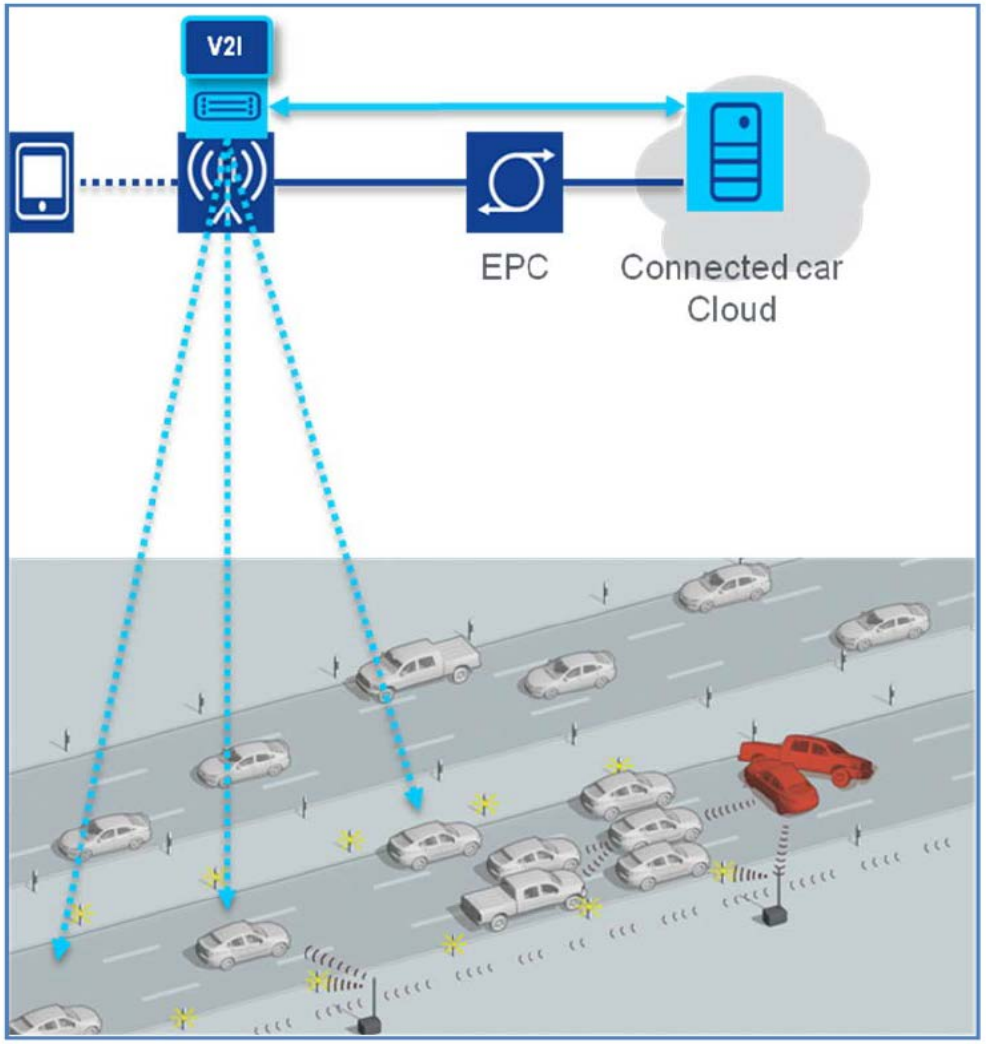
Source: 5G Infrastructure Association: Vision White Paper, February 2016.

Socio-economic benefits of 5G in EU28



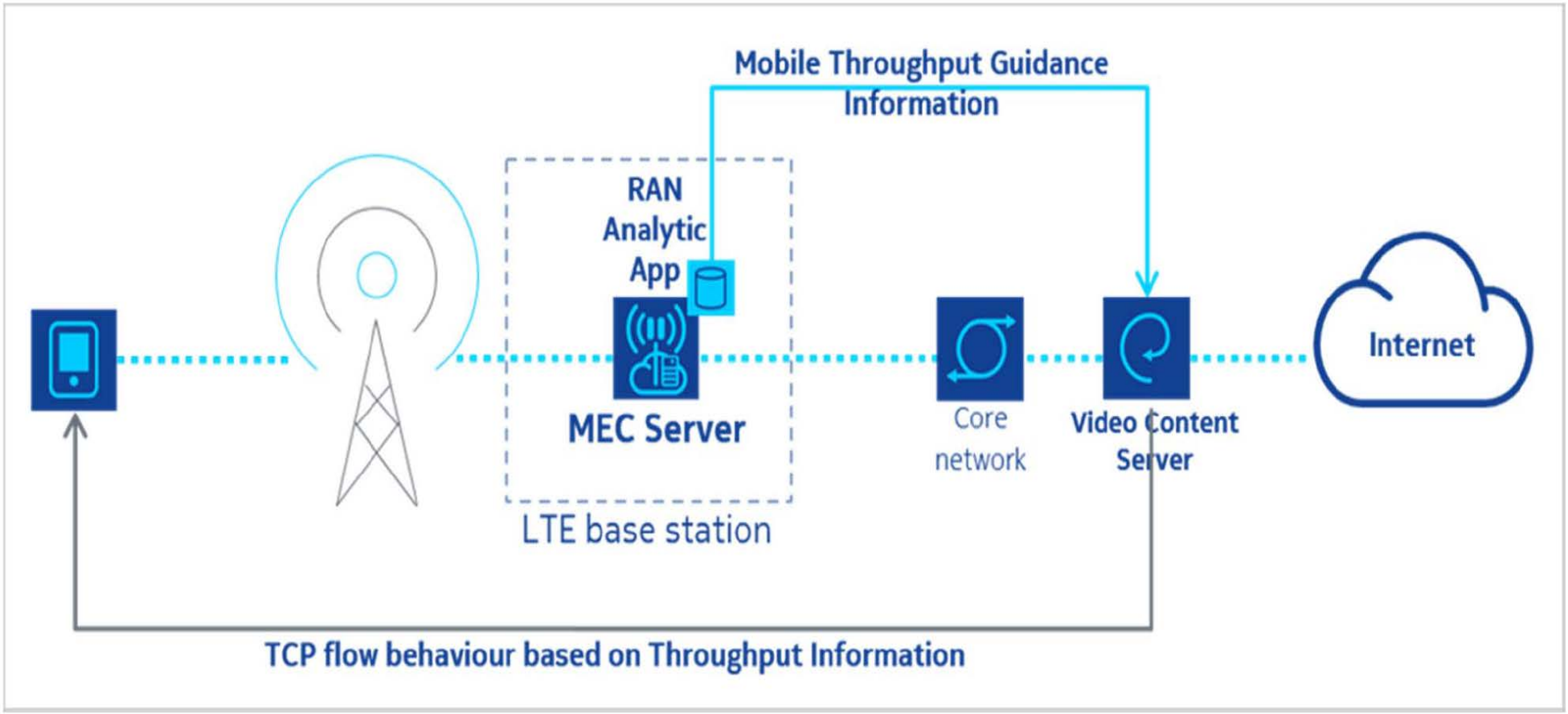
€56bn Total cost of 5G in EU28 by 2020
5G could lead to the creation of 2.4 million jobs in EU28 by 2025

Mobile Edge Computing: Connected Car Scenario



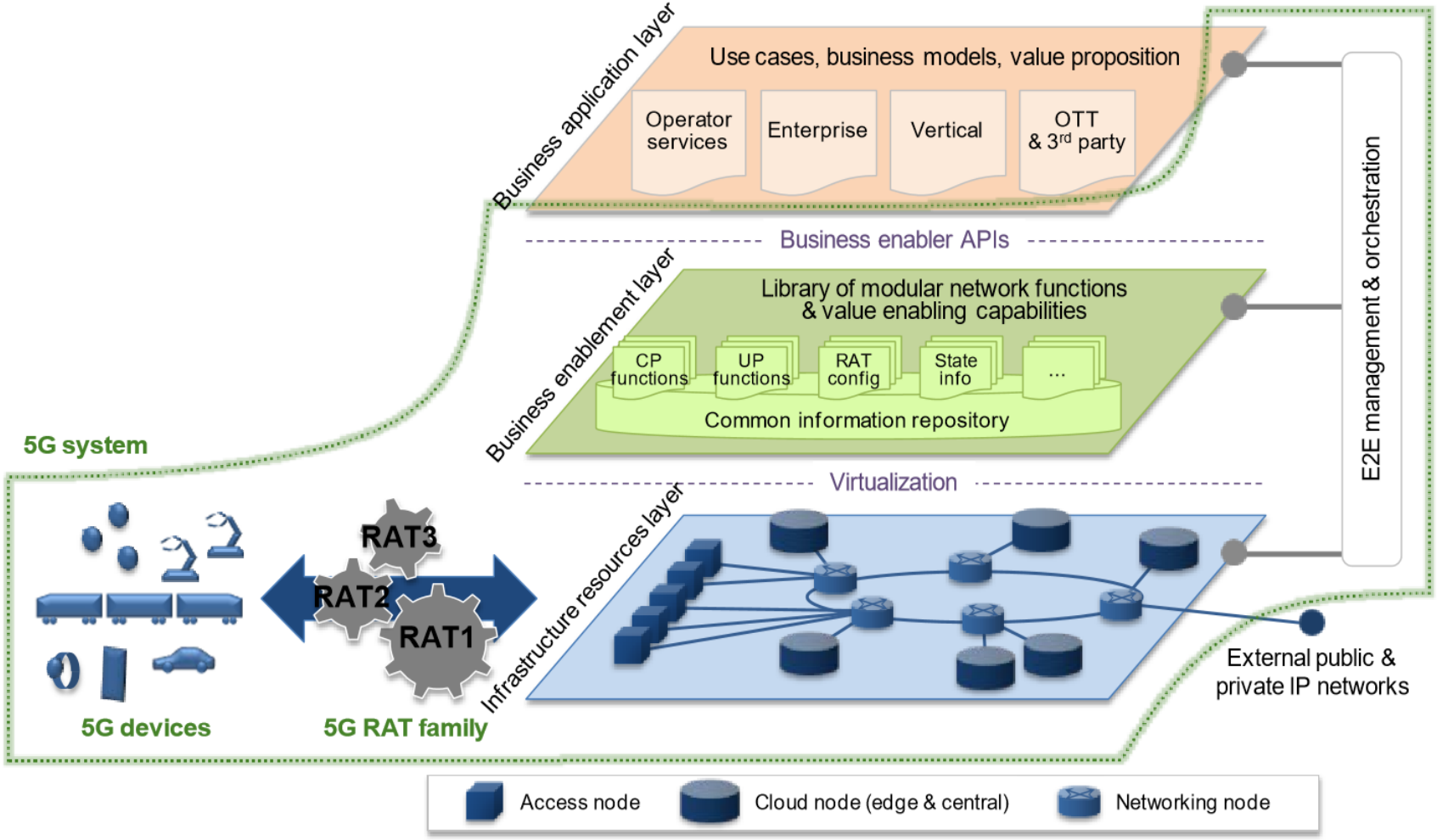
Source: ETSI, 2016

Mobile Edge Computing: Video Acceleration



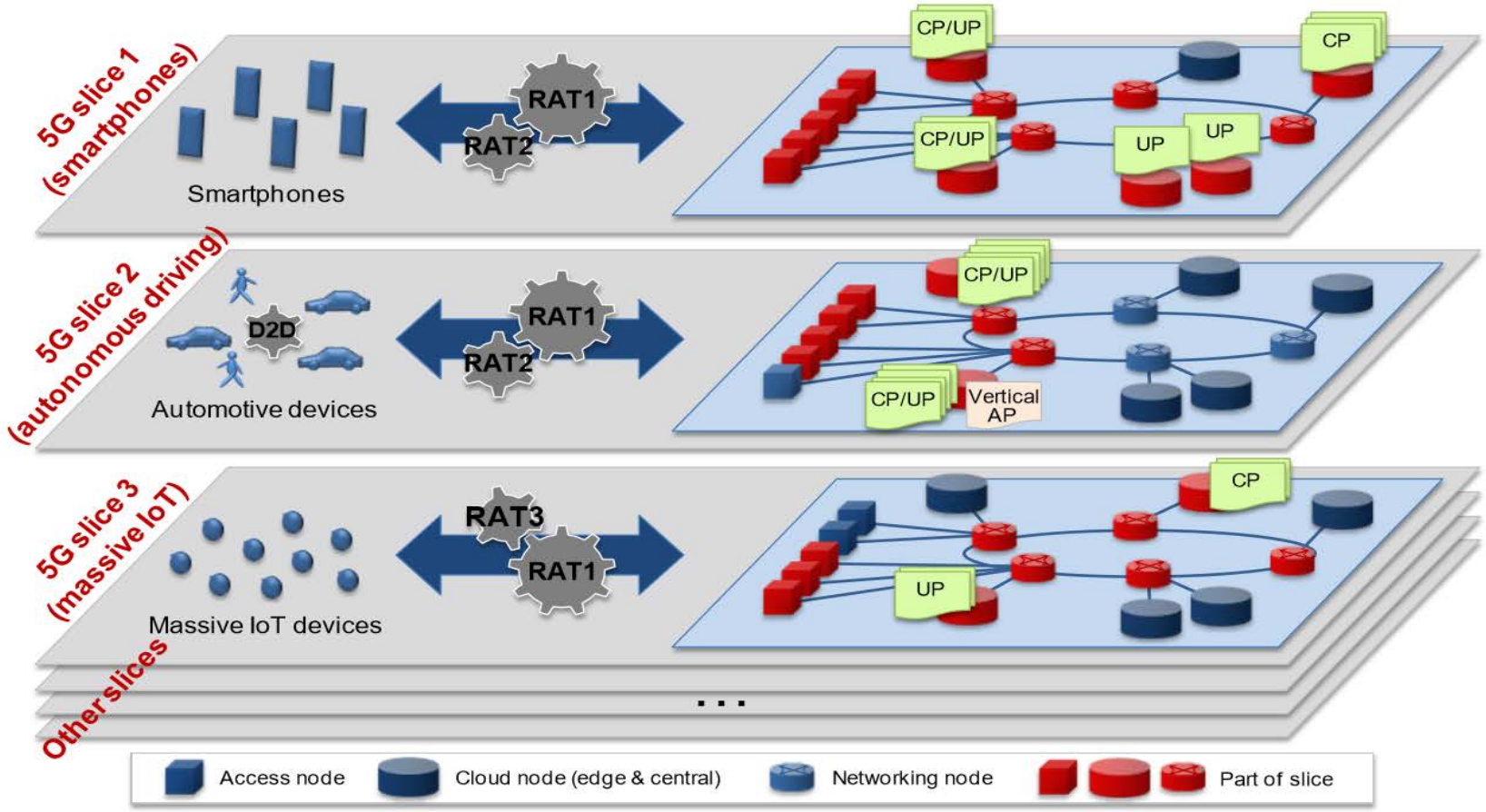
Source: ETSI, 2016

5G Network Architecture



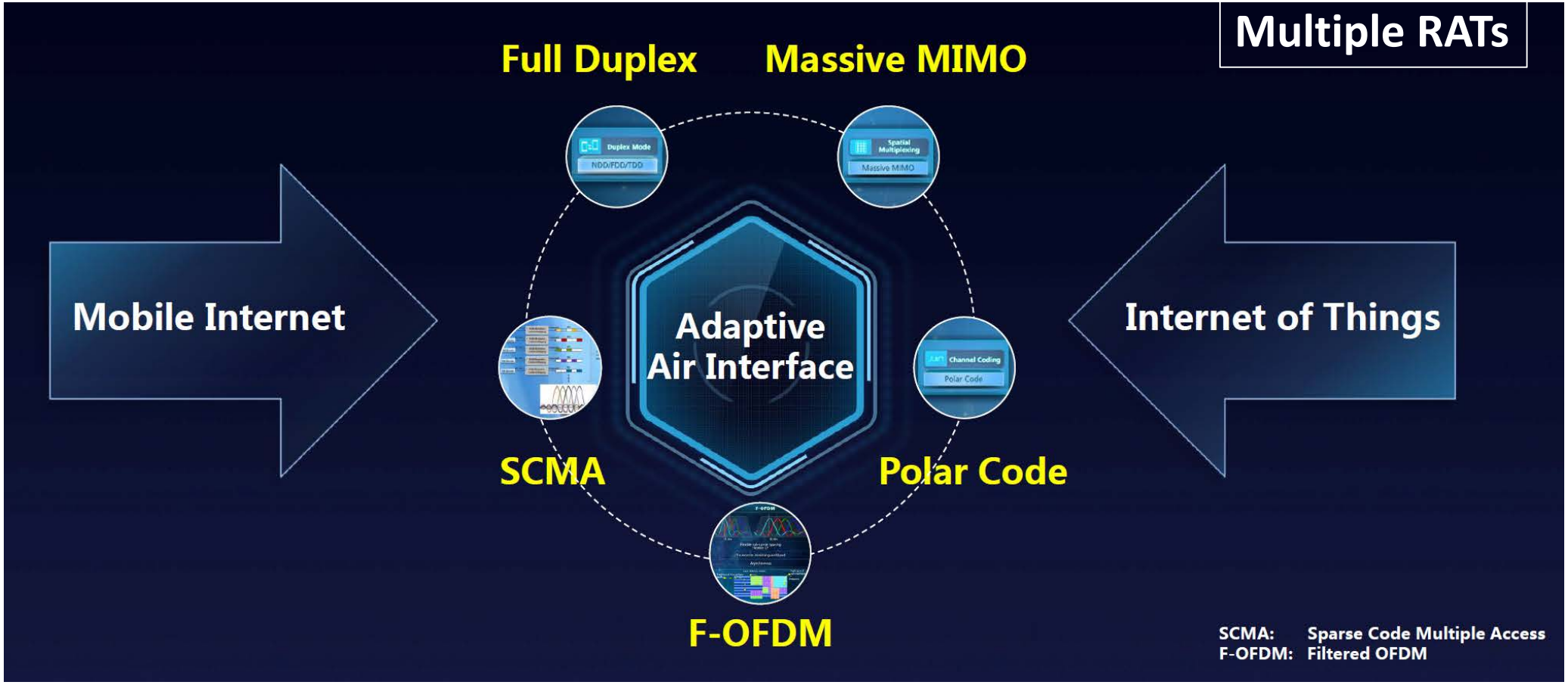
Source: NGMN 5G White Paper, 2015

5G Network Slicing



Source: NGMN 5G White Paper, 2015

Adaptive (Software Defined) Radio Interface

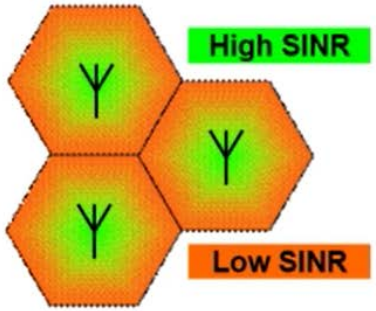


Source: Huawei, 2016

Beam Forming & Massive MIMO

More antennas than user equipment in a single cell? - 64 antennas to start up, than grow to hundreds

Co-location and Massive MIMO



- Omni Directional Antenna cells tend to have high SINR at the center of the cell and low SINR at the edges of the cell
- Beam steering can be used to improve SINR at cell edges
- Colocation places several independent cells together
- Massive MIMO coordinates the cells using beam forming

Co-location

Massive MIMO

Massive MIMO at mmWave Frequencies?

Beamforming Resolves mmWave Issues

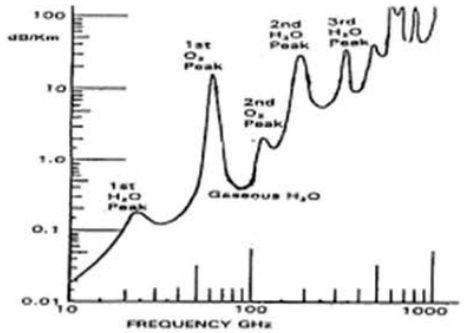
Large available bandwidth at mmWave

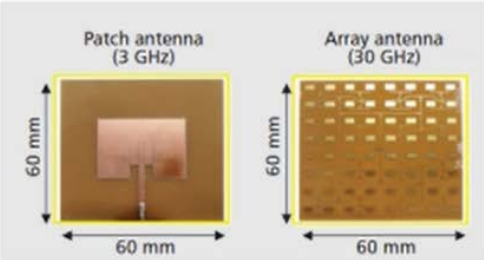
Frequency range	6-20 GHz	20-40 GHz	40-60 GHz	60-100 GHz
Specific bands identified	**10 GHz band** 10.125-10.225 GHz 10.475–10.575 GHz	**32 GHz band** 31.8-33.4 GHz	**40 GHz band** 40.5-43.5 GHz **'45 GHz' band** 45.5-48.9 GHz	**66 GHz band** 66-71 GHz
Potential bandwidth	2 x 100 MHz	1.6 GHz	5.8 GHz total	5 GHz

Source: Ofcom, Apr 2015

Path loss can be mitigated by high gain directional antennas

High path loss due to antenna aperture size and atmospheric absorption

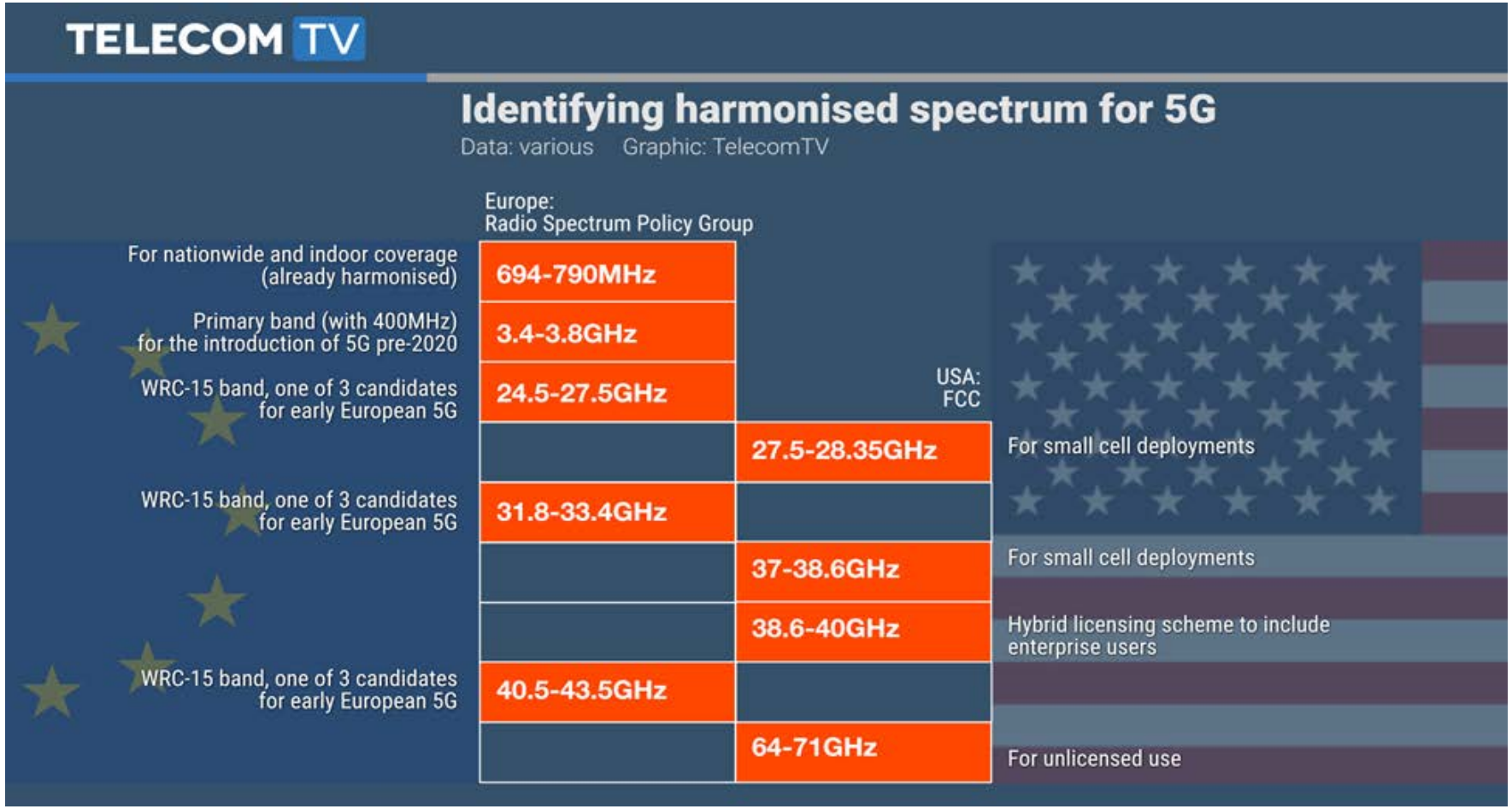




mmWave geometry allows for very small, high gain antennas

Source: Keysight Technologies, 2016

Harmonized Spectrum for 5G: US vs. EU



Source: Telecom TV, 2016

5G Trial Spectrum