5G for people and things
Spectrum Opportunities and Challenges of 5G

Design and Verification Conference (DVCON) 2017
Munich, Germany, October 17, 2017

Outline

- Trends in mobile and wireless communications
- 5G overview
- Spectrum for 5G
- Licensing of 5G spectrum
- Conclusions

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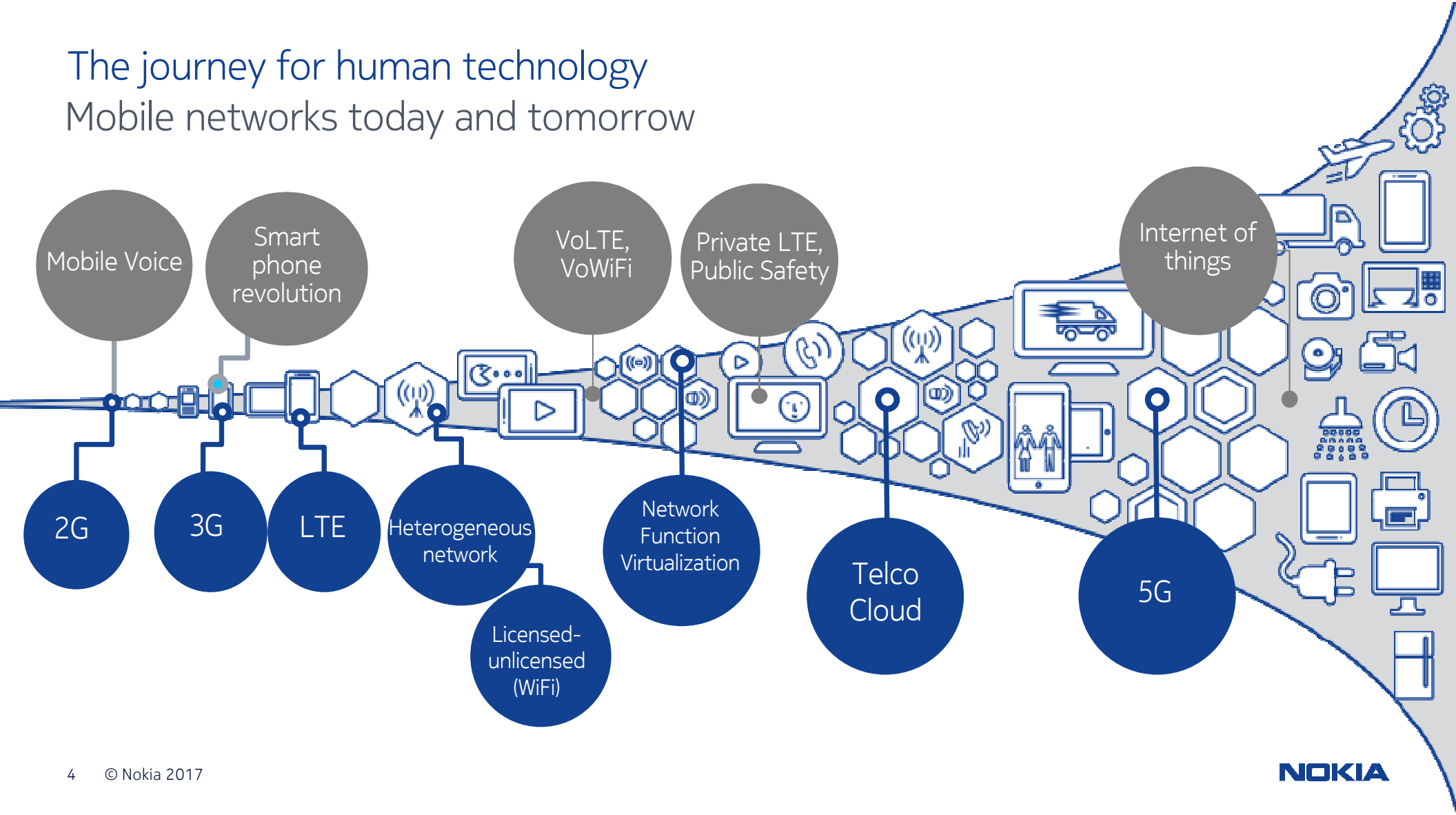
Trends in mobile and wireless communications

The journey for human technology

Mobile networks today and tomorrow



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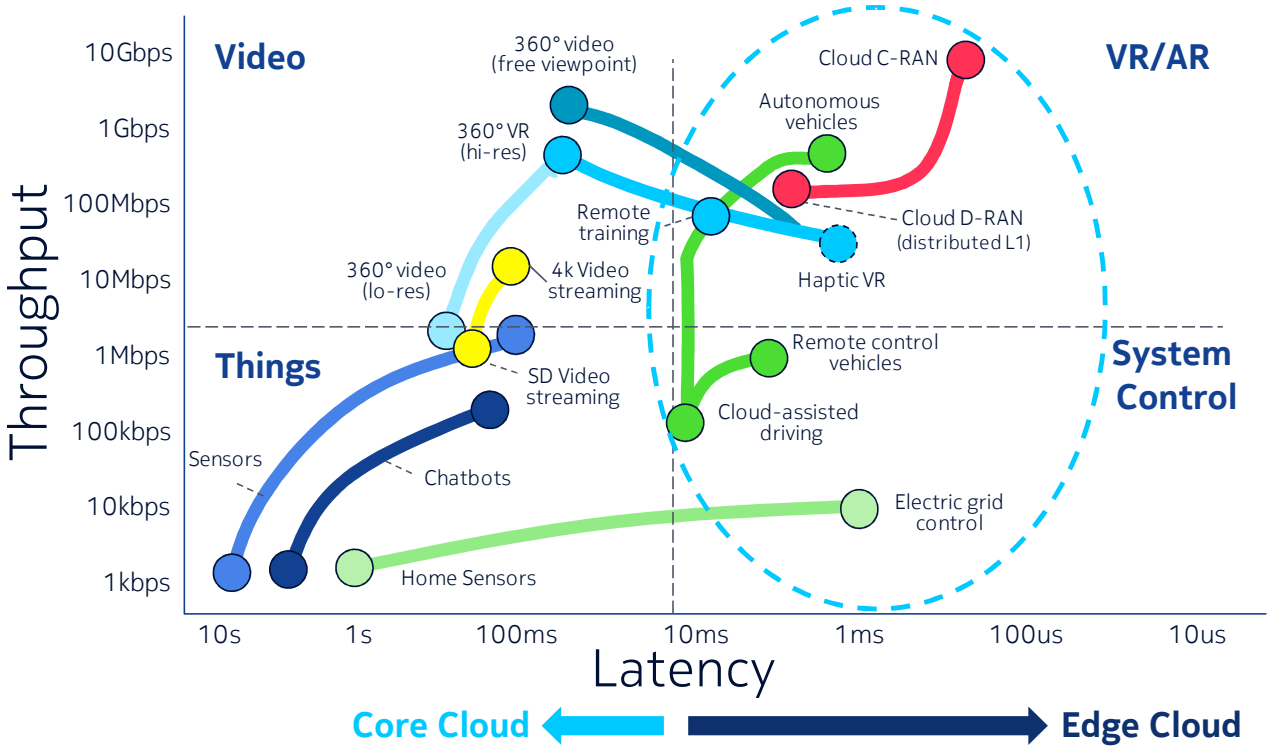
Imperceptible latency – New applications redefine network requirements



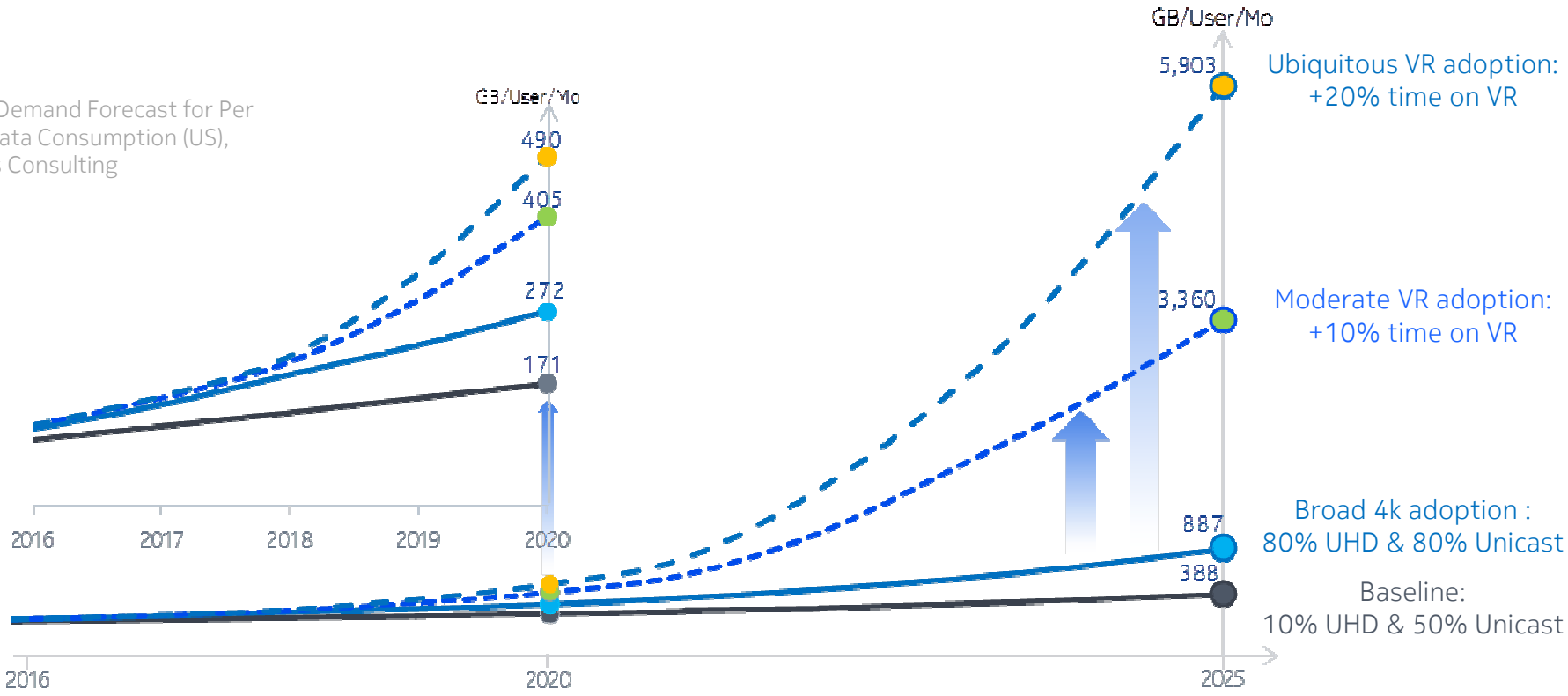
Low latency drivers

- Virtualized cloud access
- Interactively-intense AR/VR applications
  - virtual remote control
  - real time cloud rendering
  - haptic interaction
- Critical control systems
  - industrial/utility
  - vehicular automation

Shift to highly distributed cloud architecture required to realize new business value

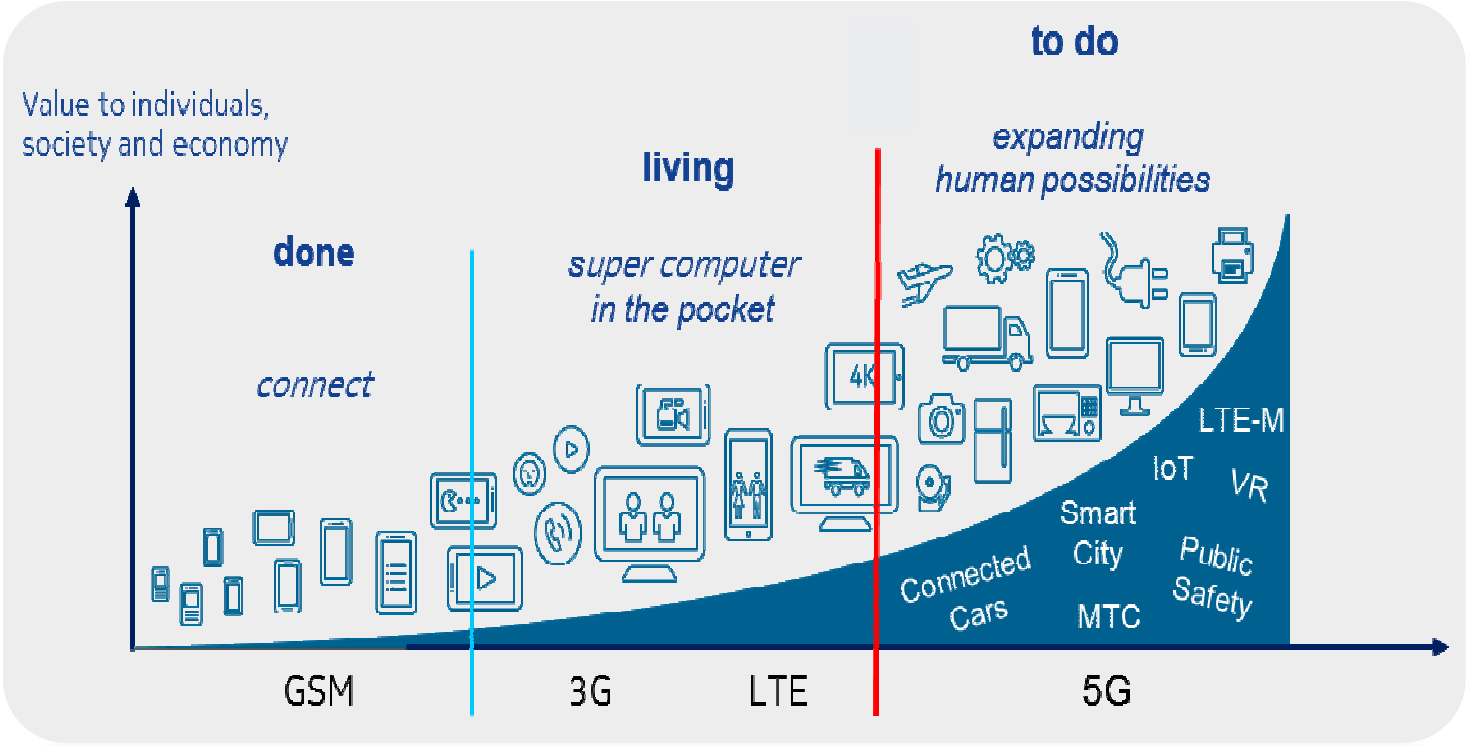
Seemingly infinite capacity - Exponential traffic growth drives massive capacity

Source: Demand Forecast for Per Capita Data Consumption (US), Bell Labs Consulting



~100x more capacity required in < 10 years

Telco industry – the world is opening up



Communication at a turning point

Beyond Connectivity

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Five major industry trends

Digitization driving **data explosion**

Demand for **enhanced security** and privacy rules

Convergence of technologies

Cloud adoption

Continued momentum for **industry consolidation**

Internet of Things – Next big thing & Opportunities

IoT requires thought leadership to build an “Optimized” IoT connectivity solution

Connectivity & service usage pattern vary across IoT verticals

- Connectivity
- Mobility
- Throughput
- Device Power
- Services Quality
- Latency

Smart City

Smart Citizen,
Smart Heath care,
Smart governance,
Smart education,
Smart energy,
Smart technology,
Smart infrastructure,
Smart traffic mobility,
Smart building

Smart Home

Home control,
Security solution,
Entertainment,
Energy Management,
Remote Service,
Smart Toys,
Online games,
Critical Communication,
Appliance & Electronics,
PC & Office Equipment,
Sports & Fitness

Connected Car

Mobility, Location,
Tracking, **fleet management**
Infotainment,
Entertainment,
Driver assistance,
Security / alerts,
Emergency Support,
Traffic Efficiency & Safety,
Vehicle Interaction

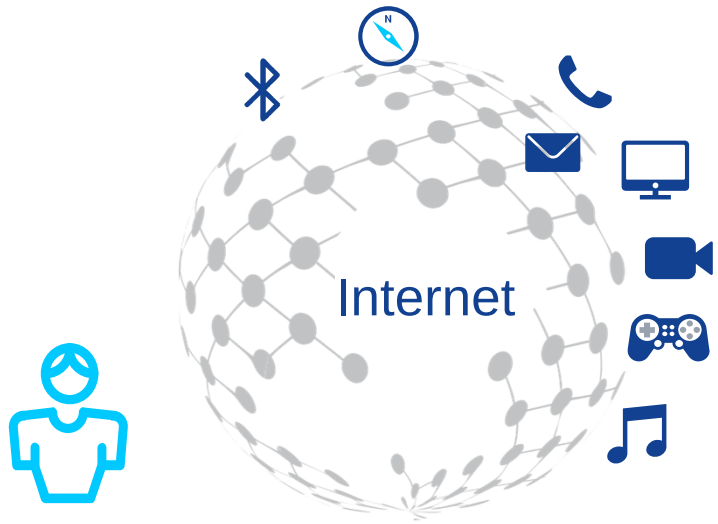
Industrial Production

Smart Grid,
Production,
Logistics and fleet tracking,
Smart meters,
Local sensors,
Smart Gateway,
Service value chain

Connected Health

Wearable with Smartphone,
Remote monitoring (with SIM),
Remote monitoring (with local gateway),
Smartphone Health applications,
Mobile diagnostics,
devices and applications management,
Health Data collection and Management,
Location & Analytics & Diagnoses

IoT Predictions



- < 5 Billion connected people
- Data meaningful in context
- From product…

Today

- > 50 Billion connected “things”
- Data disassociated from any source
- …to everything delivered as a Service

2025

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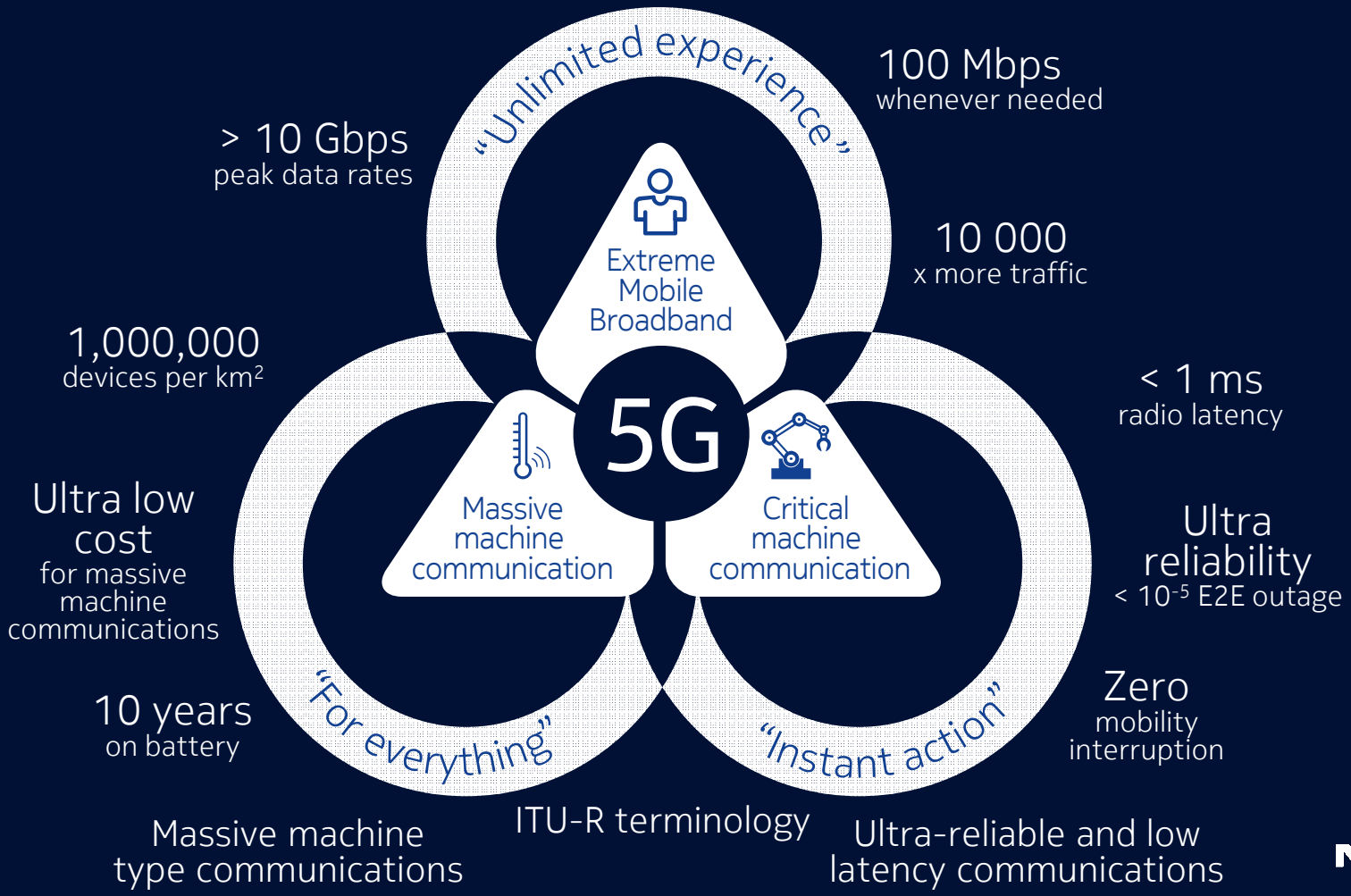
5G overview

5G will change the world



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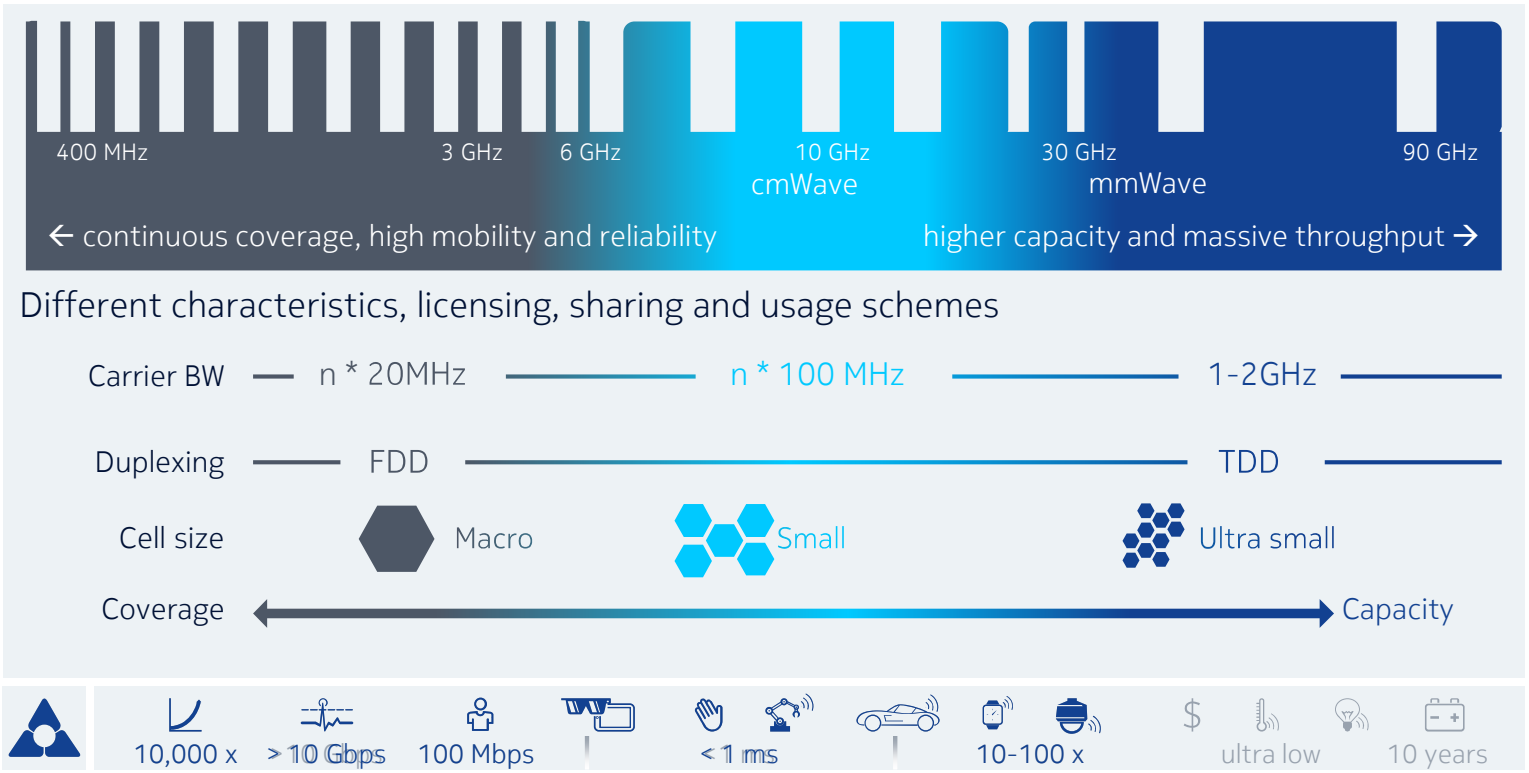
Unlocking new spectrum assets | Foundation for 5G

Leveraging all bands, ranging from ~400 MHz – 100 GHz



Nokia example activities

Leading METIS I & II spectrum work package

Pre-commercial
73 GHz system,
15 Gbps over 2 GHz

World's 1st trials
on shared spectrum access

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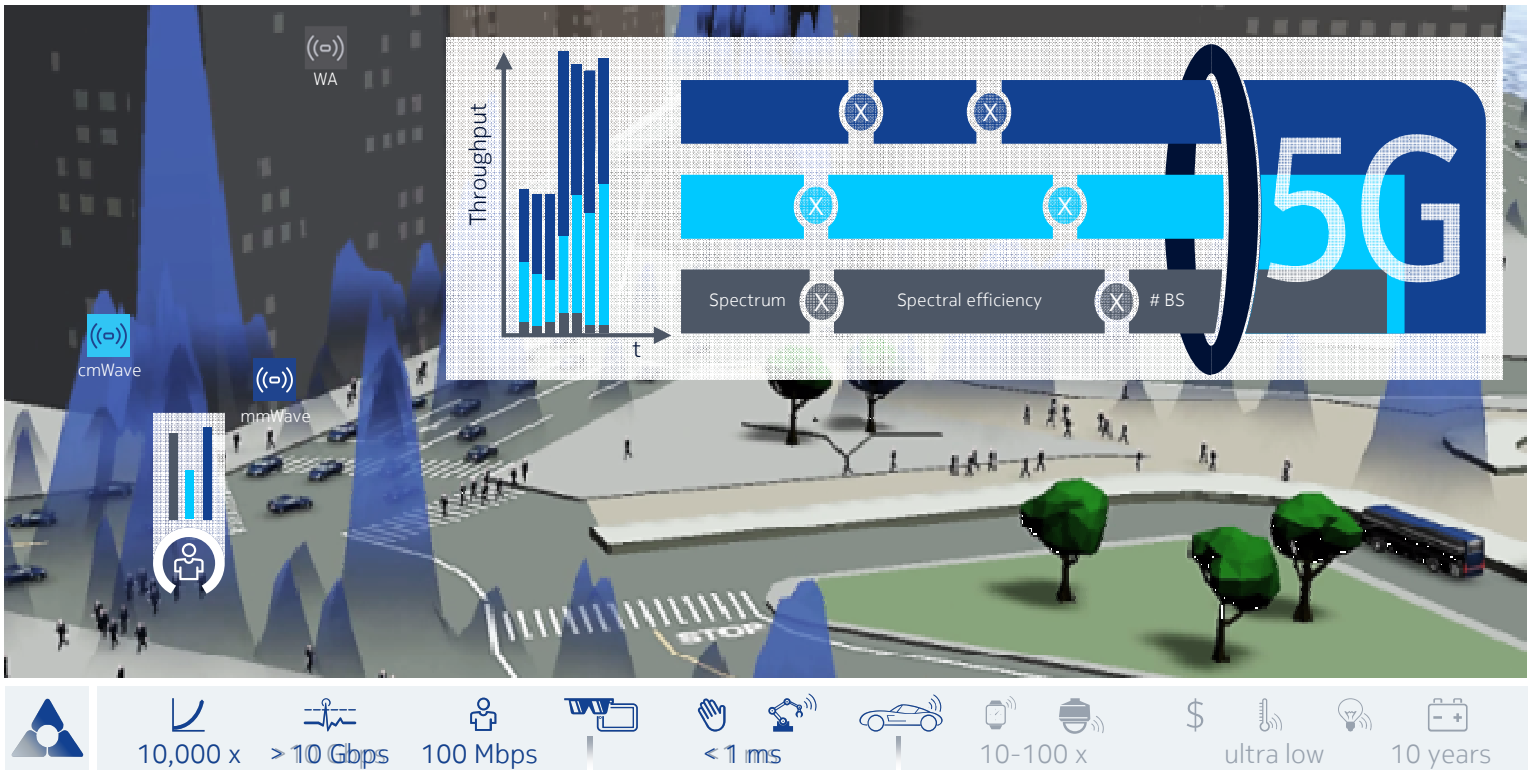
Multi-Connectivity | Perception of infinite capacity

Multiple radio technologies collaborating as one system



Extreme mobility robustness and ultra reliability

>100 Mbps anywhere

>30 Gbps throughput *

Massive Capacity combining any kind of mobile and fixed access

* Combining any access

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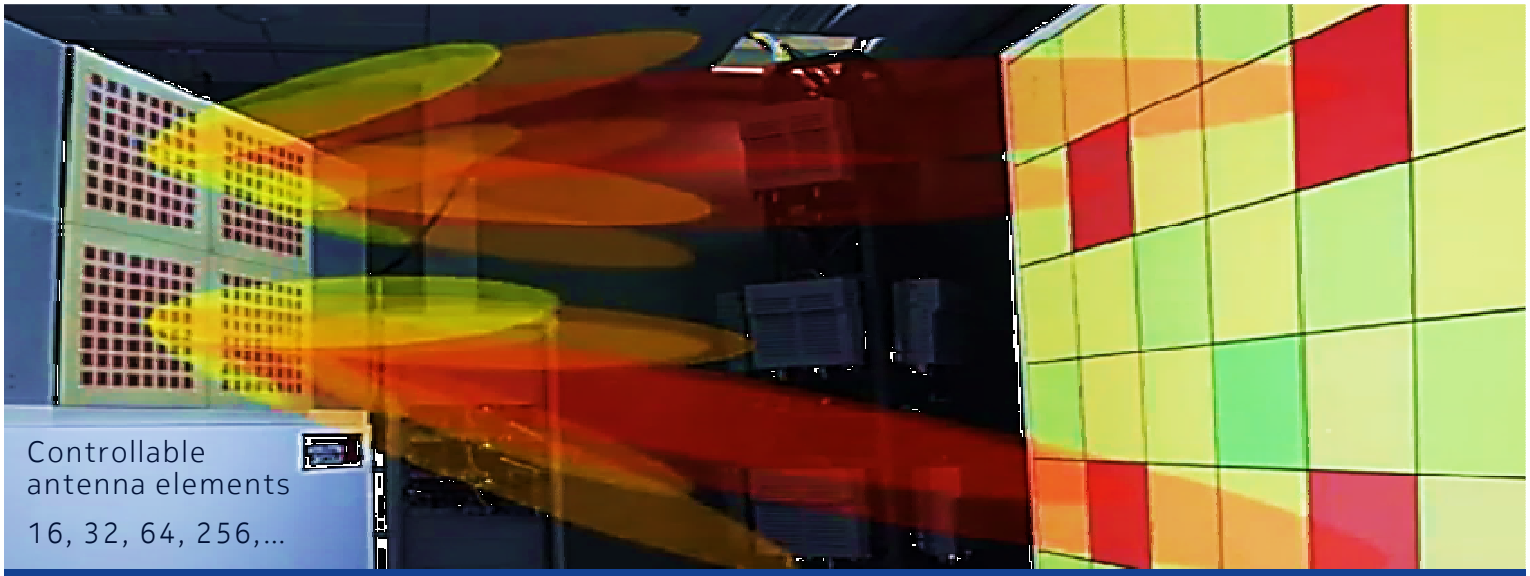
Improving spectrum efficiency in 5G: native massive MIMO

Chip-scale antennas, high beamforming & multiplexing gain



Exploiting high frequency bands with chip scale antenna array research
→ Compensating path loss with high antenna gain

10,000 x | > 10 Gbps | 100 Mbps | <1 ms | 10-100 x | ultra low | 10 years

700 %
Cell edge gain

+80 %
Spectral efficiency

Cooperation with top notch industry and university partners

mmWave trials
with DOCOMO

> 20 Gbps
at 8x8 MIMO with SKT

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Configurability | One versatile and self-configurable radio for everything

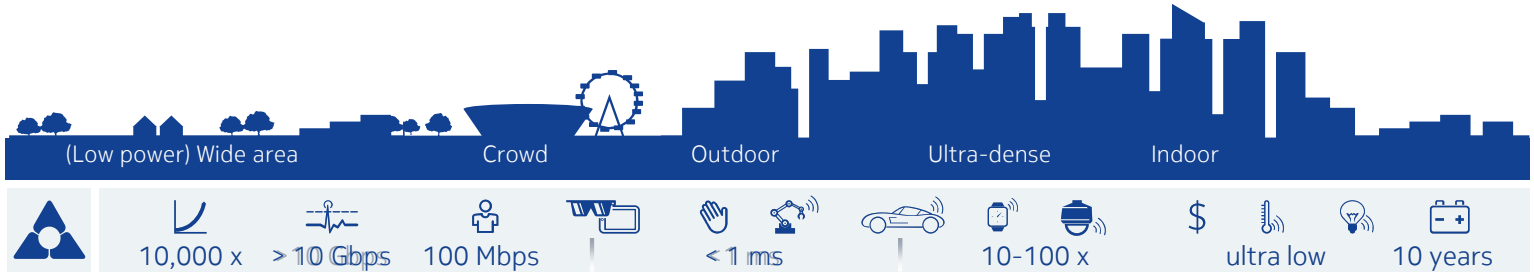
Flexible radio parameter setting for tailored QoE

One versatile radio

Diverse use cases

Diverse deployments

OFDMA-based waveform	Same for uplink & downlink
Scalable carrier bandwidth	5 MHz ↠ 2 GHz
Sub frame lengths	Adjusted to latency requirements



For all use cases

E.g. different sub-frame lengths for different latency requirements

For all deployment scenarios

Different frequency bands, macro and small cells, ...

5G ready AirScale radio access

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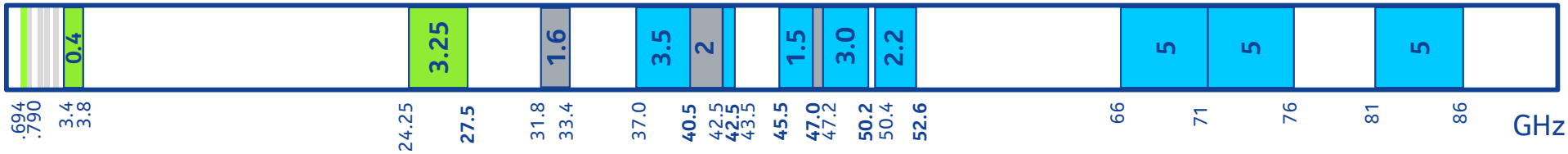
Spectrum for 5G

5G Pioneer Bands in Europe: 700 MHz, 3.4-3.8 GHz, 24.25-27.5 GHz

5G needs spectrum below 1 GHz, in between 1 and 6 GHz, and above 6 GHz



694-790 MHz Wide area coverage for mMTC* and URLLC*	700 MHz band targeted to become available latest 2020 in Europe Re-use of existing 900/800 MHz grids allows for timely coverage Pre-condition for new services like connected cars, smart sensors etc.
3.4-3.8 GHz Urban coverage for initial eMBB*	C-band is sparsely used in most parts of Europe Re-use of existing 1800/2100/2600 MHz grids Carrier bandwidths of 100 MHz + allow for single Gbps data rates
24.25-27.5 GHz Initially hot spots of true eMBB*	Common tuning range with 28 GHz range (US, Korea) is expected to allow for common economies of scale. Carrier bandwidths of several 100 MHz allow double digit Gbps data rates

* mMTC: massive machine type communication, URLLC: ultra reliable low latency communication, eMBB: enhanced mobile broadband

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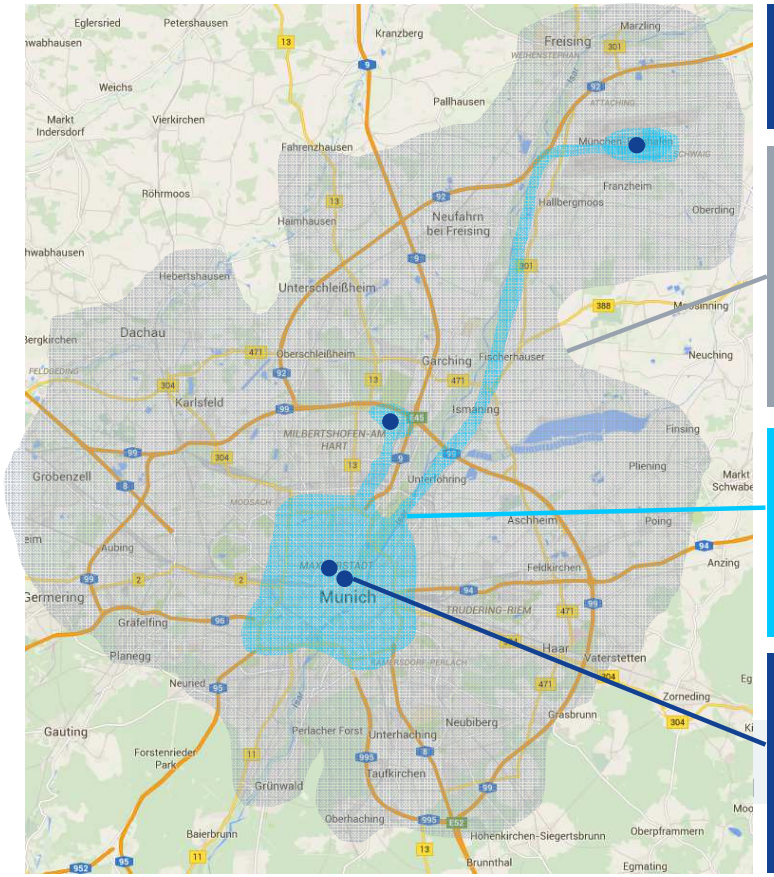
Unlocking new spectrum assets in European Football Championship 2020 cities

Leveraging 5G pioneer bands 700 MHz, 3.4-3.8 GHz, 26 GHz



Vision on commercial 5G deployments in 2020, e.g. in Munich

700 MHz layer with 1 ms latency

- large area coverage with outdoor-to-indoor penetration
- Supports massive machine type communication (mMTC)
- Supports ultra-reliable – low latency communication (URLLC)
- Moderate invest on existing 800/900 MHz grids

3.4-3.8 GHz layer with ~1 Gbps and 1 ms latency

- Dense urban coverage + airport + stadium + public transport
- Supports initial enhanced Mobile Broadband (eMBB)
- Moderate invest on existing 1800/2100/2600 MHz grids

26 GHz layer with ~10 Gbps and 1 ms latency

- Coverage in selected hot spots (airport, stadium, press center)
- Supports full enhanced Mobile Broadband (eMBB)
- Moderate invest in selected areas

Possible early bands for 5G (before year 2020)

GHz				Assumed time of availability
600 MHz	LTE/5G	US, Can		2017/18
700 MHz	LTE/5G	Europe	APAC, MEA, LatAm	Market demand
3.3 - 3.4	LTE/5G	China		?
3.4 - 3.6	LTE/5G	Europe, Korea, China		2018
3.55 - 4.2	LTE/5G	US		?
3.6 - 3.8	5G	Europe, Kor (upto 3.7), JPN		2018
4.5	5G	Japan	China?	?
26	5G	Europe		2020
28	5G	US, Korea, Japan		2018
39	5G	US		?
24.25 - 27.5	5G	Europe	(China?) WRC-19 band	2018/19
~30,~45,~70	5G	WRC-19 bands		?

4.8-4.99, 4.4-4.5, China, grey
4.4-4.9 Japan, green

"Pioneer" bands for Europe

Early 5G bands

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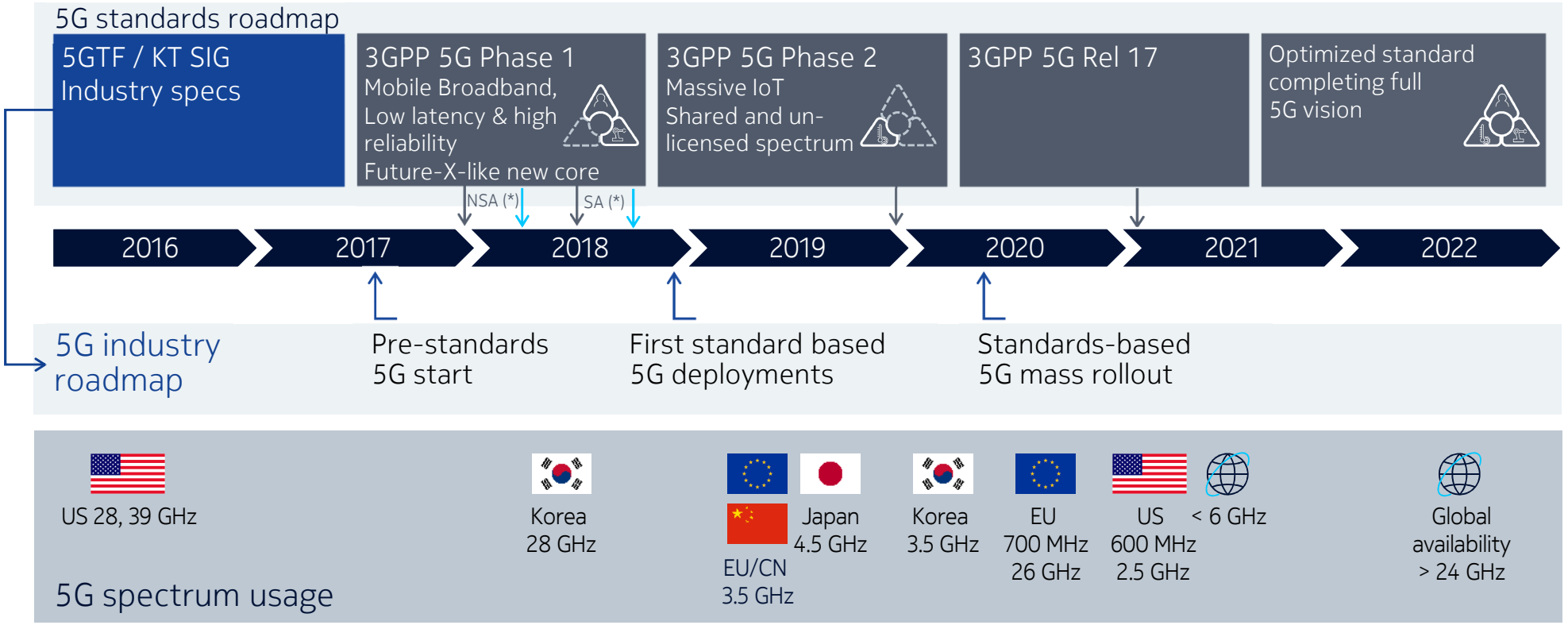
Nokia active in 3GPP standardization and supporting early adopters

5G spectrum – Nokia engaged in all relevant 5G frequency bands



*) NSA: Non standalone; SA: Standalone ... functional freeze ...protocol (ASN.1) freeze

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Licensing of 5G spectrum

Spectrum usage models: “horses for courses”

Need to cater for harmonization and global standards for economies of scale

Mainstream approach, auctions of cleared spectrum

Exclusive use
ensures
Quality of Service

7/8/900, 18/21/2600, 3.5 GHz (EU), 26 GHz …

Complementary license model e.g. Licensed Shared Access

Exclusive shared use
exclusive use on a *shared* and *binary* basis in time, location, and/or frequency with incumbent (government, defense etc.) predictable Quality of Service

2.3 GHz (EU), 3.5 GHz (US), …

Shared approach unlicensed (Wi-Fi, LTE-U, …)

Shared use
unpredictable
Quality of Service

2.4, 5 GHz, …

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Conclusions

Conclusion

- Mobile and wireless communications improves efficiency and user experience of huge number of use cases in society and economy with different requirements (e.g. latency, throughput)
- IoT is enabler for vertical sectors with significantly increasing number of connected devices
- Exponential traffic growth mainly driven by video and virtual reality applications
- 5G is next major step in research, standardization and development of communication technology for commercial deployment around 2020
- Sufficient suitable frequency spectrum for support of new use cases and traffic growth
- Exploration and investigation of different additional frequency bands in ITU-R and WRC
- Pioneer bands in Europe: 700 MHz, 3.6 GHz and 26 GHz range, to be assigned by 2018/19
- WRC 2019 will discuss and agree additional frequency bands
- Good chance for globally harmonized frequency bands around European pioneer bands
- New frequency bands will allow
  - for design of devices for global usage around European pioneer bands with wider tuning ranges
  - for early availability of devices and systems for first standards-based system deployments end of 2018 beginning of 2019 for first trials and commercial use.

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