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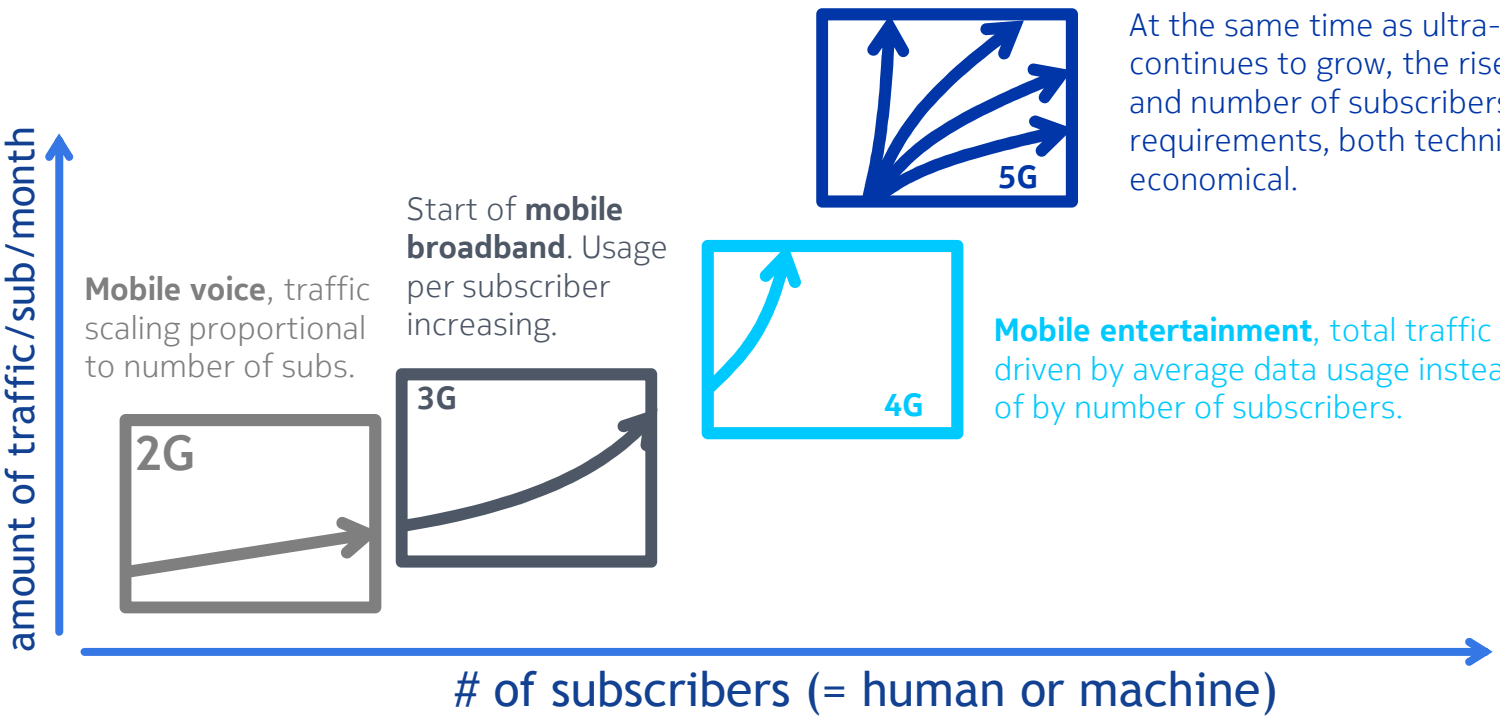
Research on 5G

Hans-Peter Mayer
Nokia Bell Labs

A broader range of applications



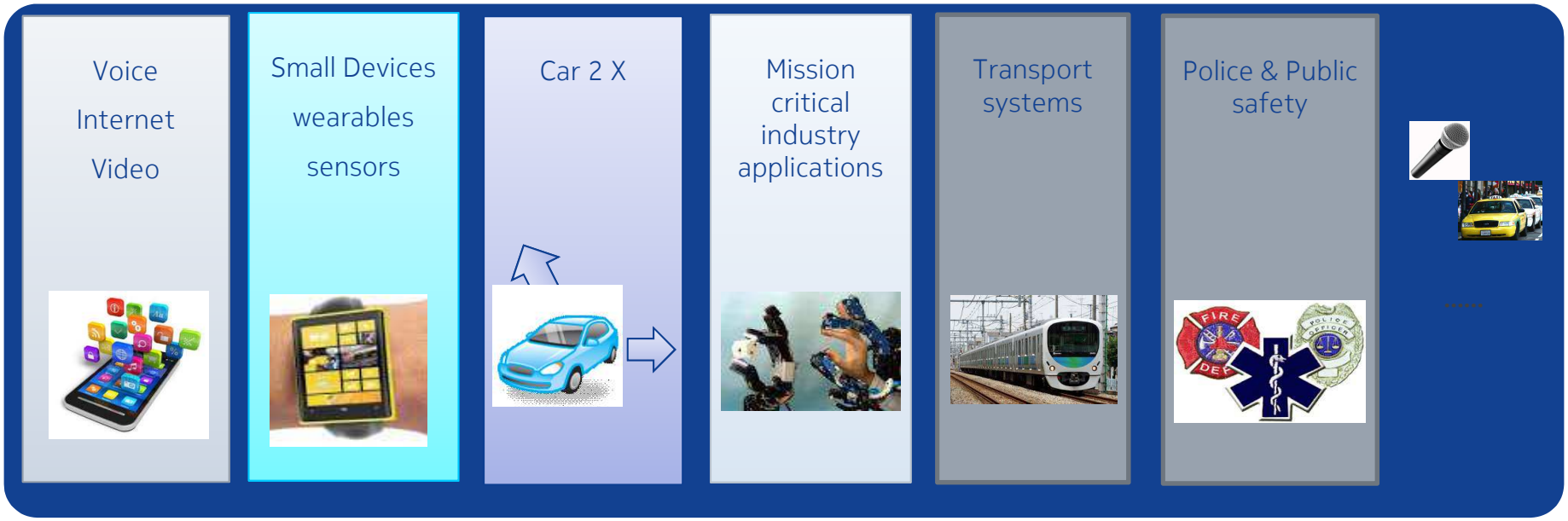
Mobile voice, traffic scaling proportional to number of subs.

Start of **mobile broadband**. Usage per subscriber increasing.

Mobile entertainment, total traffic driven by average data usage instead of by number of subscribers.

At the same time as ultra-broadband continues to grow, the rise of M2M traffic and number of subscribers causes diverging requirements, both technical and economical.

How Many Networks?



Converge: hardware platform
sites and backhaul
access to spectrum

Enablers: flexible air interface
virtualization

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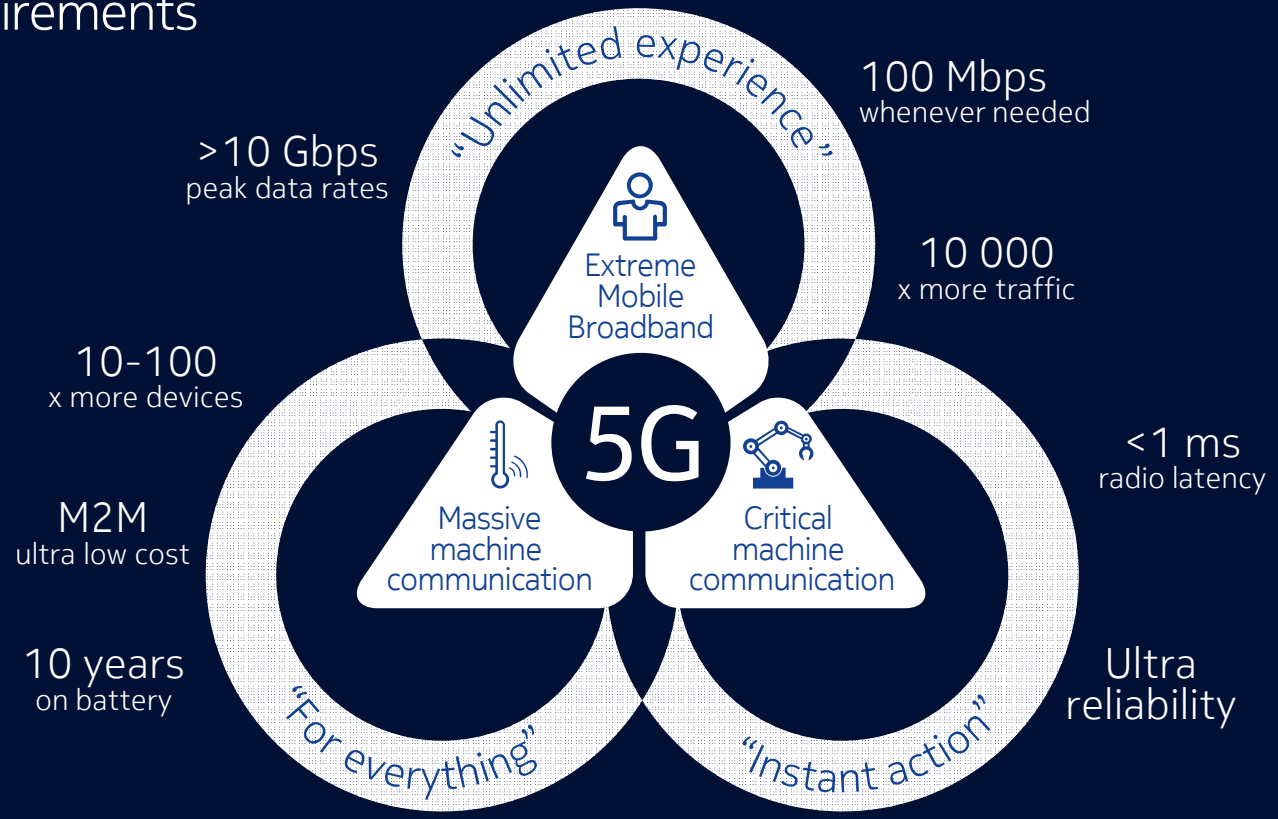
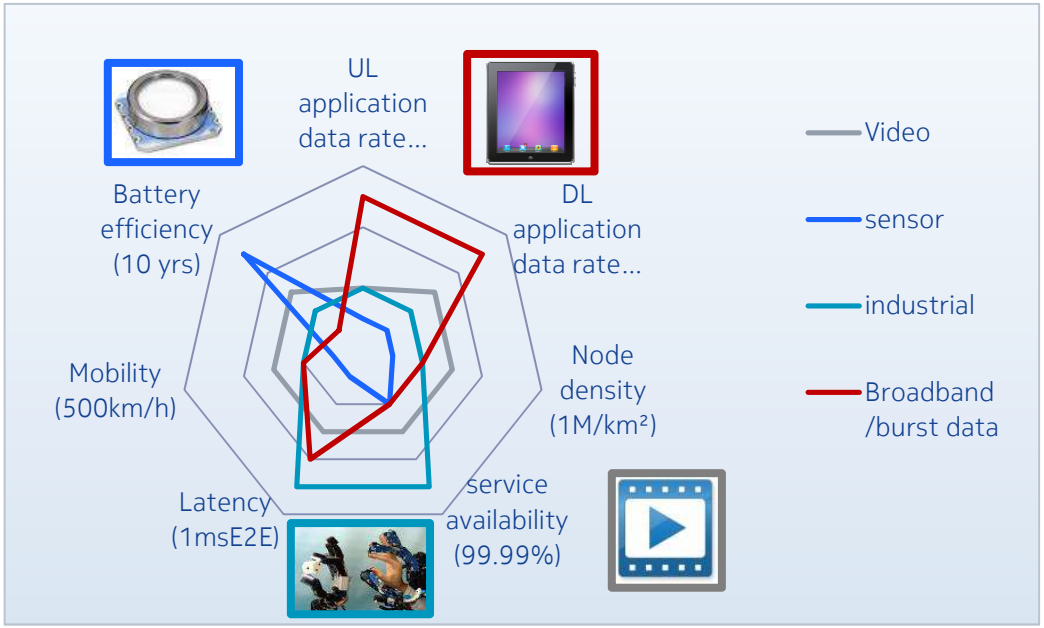
Heterogeneous use cases – diverse requirements



5G Services | Extremely diverse requirements



Efficient resource usage:

- Use Service profiles to configure the system End to End
- Avoid design compromises
- Service information depends on
  - device type and contract
  - user input
  - context
  - ...

Requirements differ by service and scenario
5G uses profiles to adapt

Forward compatibility

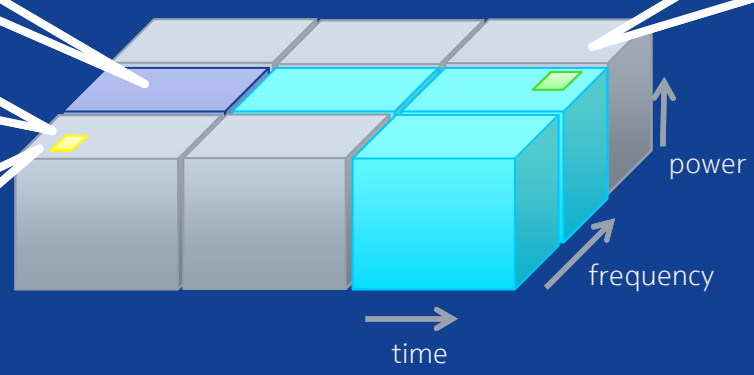
Allow all 5G mobiles to operate in any future 5G network

Keep transmissions confined in time and frequency

Confine pilot signals to the actual transmission

scalable support of MIMO antenna configurations

Control signals shall be user and service specific with a minimum common part



Allow addition of

-New device categories and services

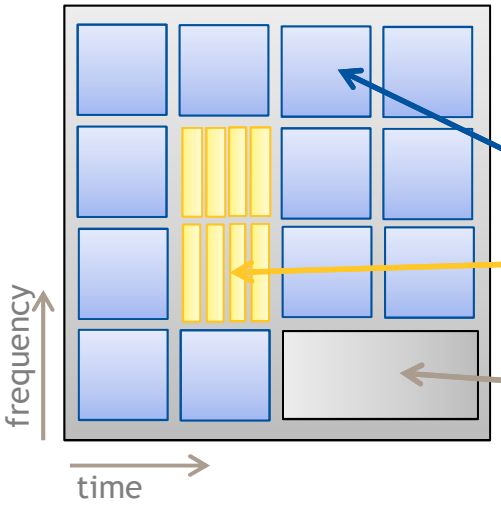
-New technologies

-New features and optimizations

Support innovations during the next 15 years

Configurable Air Interface | The Tiling Concept

- Different services combined on one carrier
- Tiling: Flexible modular design of the radio frame
- Different optimized signal configurations, avoiding a “one-fits all“ solution
- Scheduled- and random access
- minimal amount of must-be present signals



	TTI (ms)	Symbols per TTI	Sub-carrier spacing
Broad-band	1 ms	14	15 kHz
Low latency	0,125 ms	7	60 kHz
Long distance	2ms	7	3.75 kHz

Example parameter sets

A set of optimized configurations to push the service envelope
Arrangement of services side-by side on one carrier

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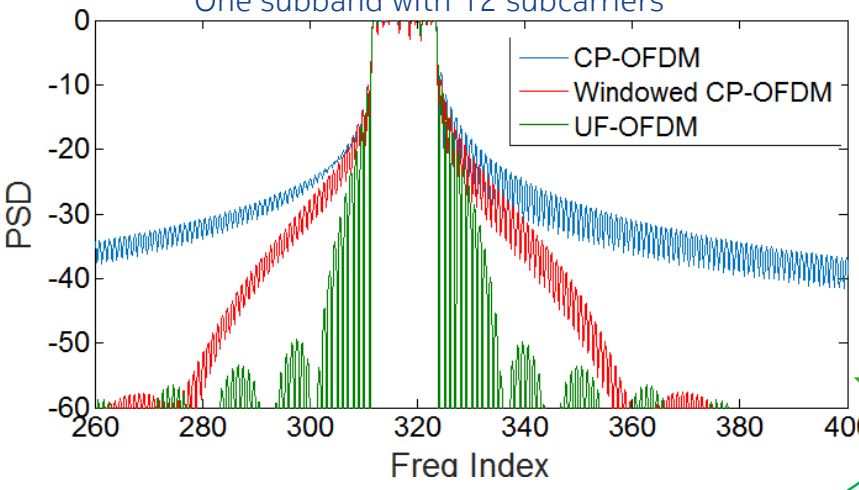
OFDM-family Waveform Candidate Technologies: UF-OFDM and CP-OFDM

Spectral advantages of UF-OFDM

- more robust against time-frequency misalignments
- better support of fragmented spectrum
- supports user-specific multi-carrier numerology

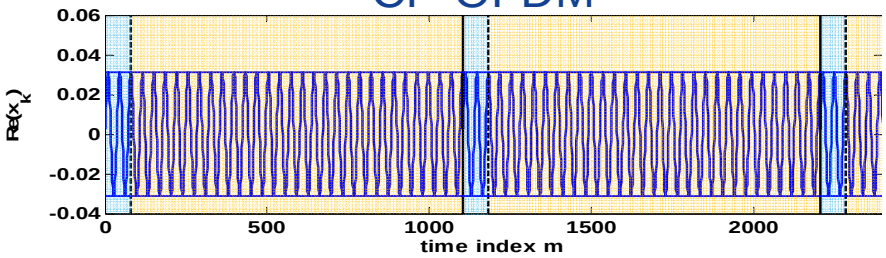
One subband with 12 subcarriers



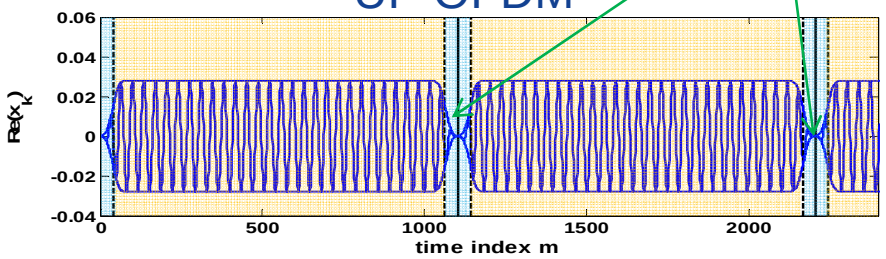
Several tens of dB improved out-of-subband radiation

Soft symbol transition

CP-OFDM

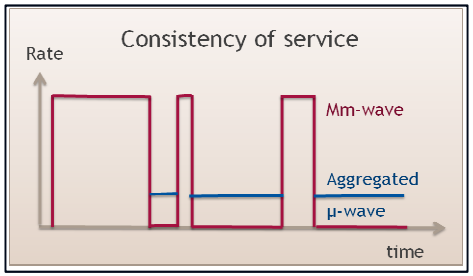


UF-OFDM

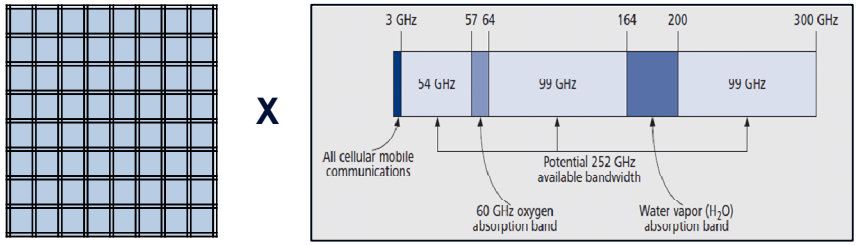


UF-OFDM improved spectral localization opens up new flexibility

5G Radio | Adding massive capacity



Array antennas x wide spectrum bands

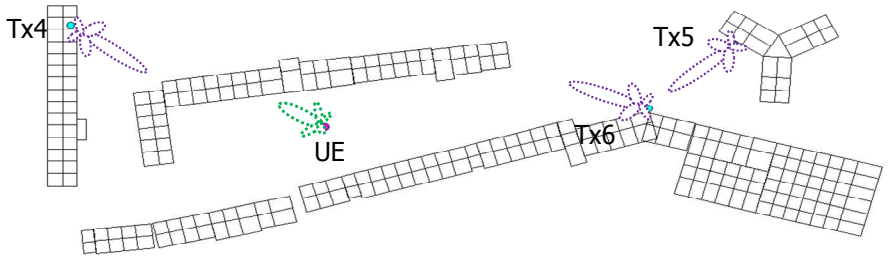


- "Low band" (<6 GHz, in cellular bands)
  Provides coverage, performance, long battery life
- "High band" (20-60 GHz, "mm-wave" bands)
  Provides massive capacity for users in dense urban areas
- "Low" and "high" band 5G work together

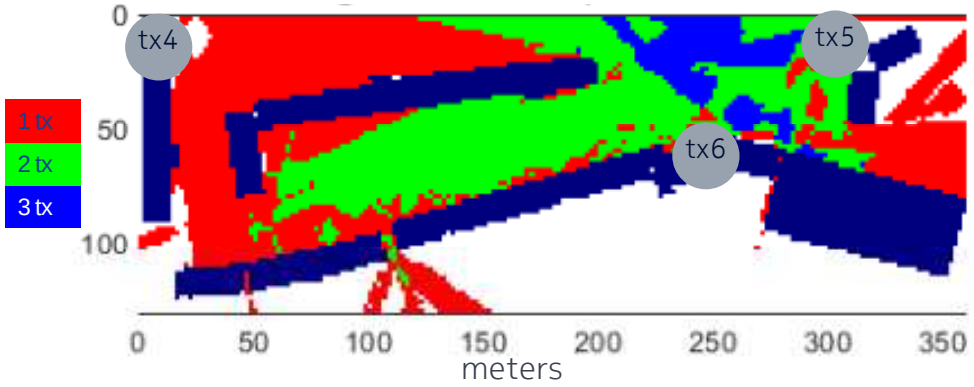
Multiple active mm-wave base stations
How many nodes for outdoor coverage? -- Ray tracing analysis

3 active BS (1 serving, 2 interfering) @ 28 GHz

- coverage by multiple BS (1, 2 or 3 tx)
- high gain beamforming needed to reduce interference



Model of campus



Coverage with overlap:
Most of the outdoor area is covered

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Slim Radio | Low cost & power for massive machine type communication

LTE-M for small, infrequent & low cost data transfer

Power saving

Longer sleeping cycles*

Less signaling for wakeup

Power Save Mode

Simplified modems

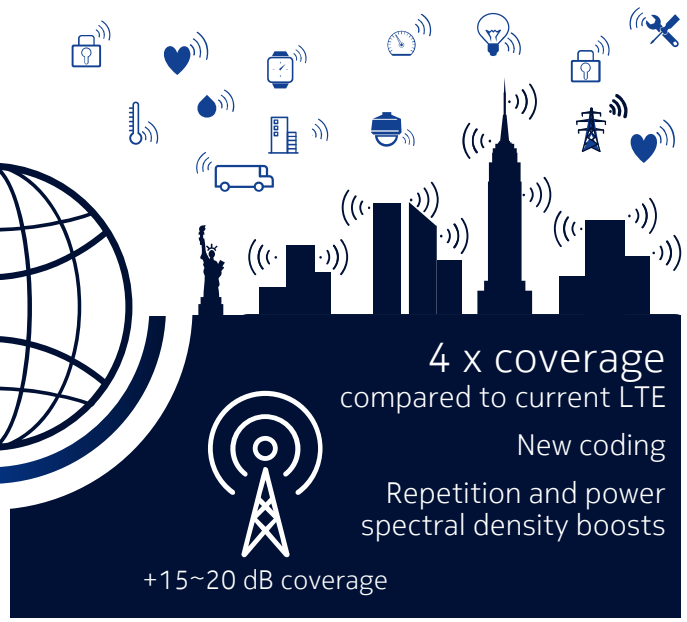
Narrowband transmission

Reduced transmit power

Limited downlink transmission modes

UE processing relaxations

...



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

>10 years
Battery life with two AA batteries

Very low device cost

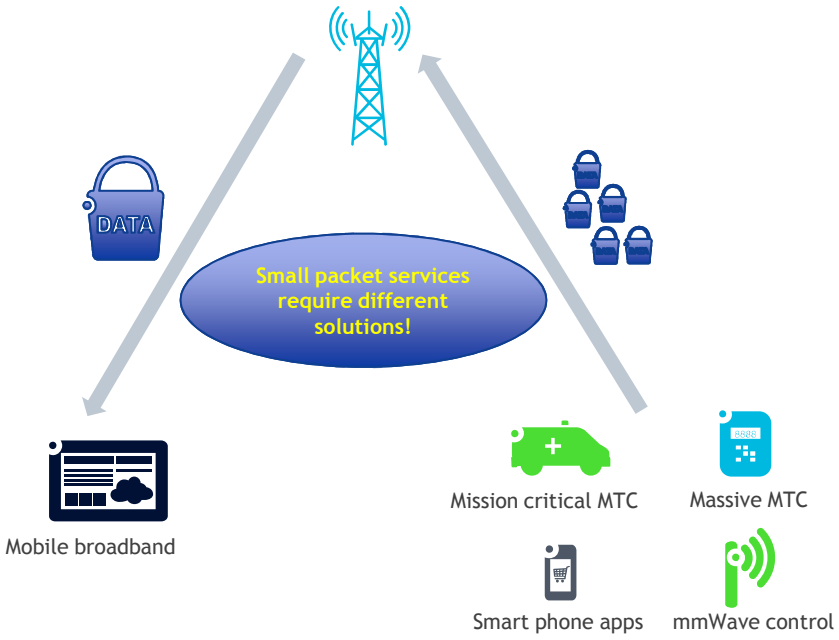
Live trial with KT

MWC 2015
First live demo
on commercial Nokia FlexiZone and core

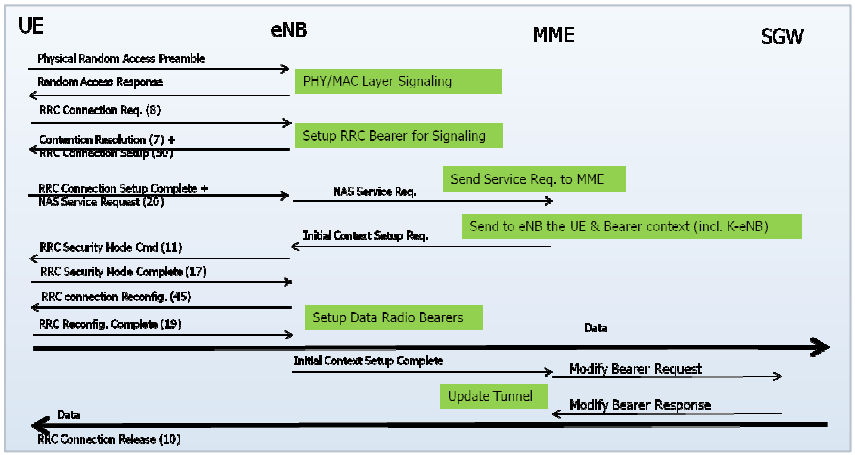
Driving for availability in 3GPP Rel.13, 2016

*) Extended Discontinuous Reception (DRX)

Motivation for small packet access protocols in 5G



- Target: Efficient transmission for sporadic small packet (~ 1000 bits) UL transmission
- Use cases: MTC, certain smart phone apps, control signaling, …



LTE: sending a small packet causes a signaling cascade

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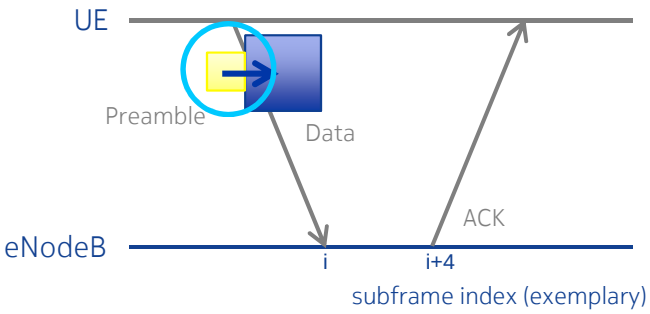
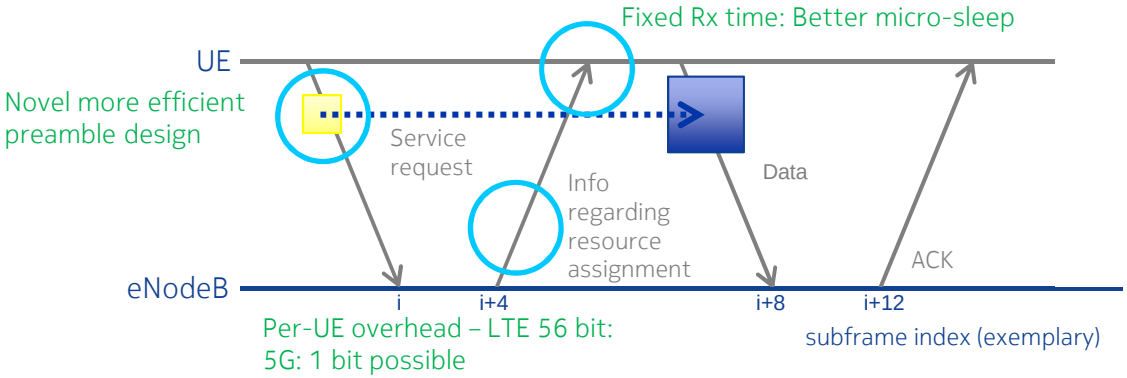
Small packet protocols: 1-stage vs. 2-stage

Principles in [R1-162892]





- Faster than 2-stage if successful
- ≈2x less DL feedback than 2-stage
- collision probability reduces throughput
- Good for very small packets and low traffic load

- Some (small) DL feedback required
- Reduced collision probability through service request over-provisioning
- Better for bigger packets and higher traffic load

Protocol solutions lead to >15x DL signaling overhead reduction and >2x battery lifetime

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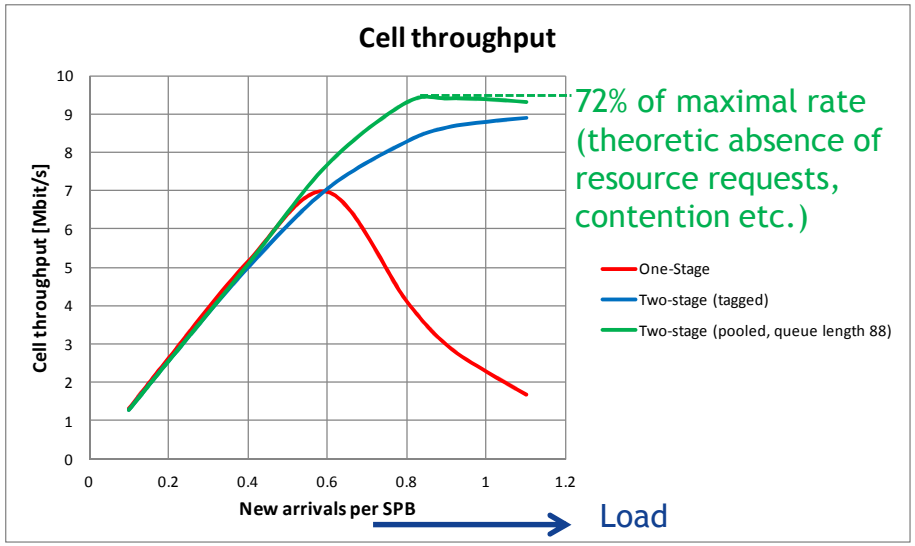
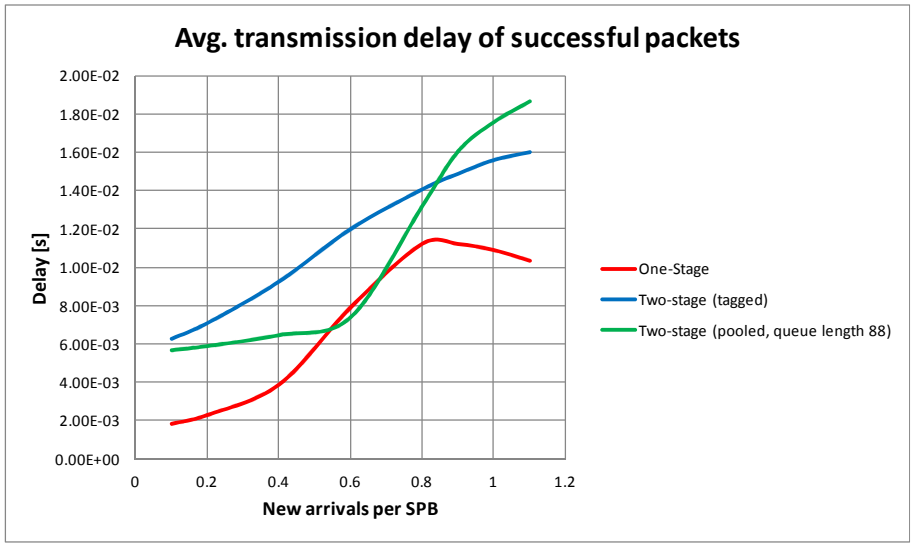
System simulation with perfect detection

One-stage vs. two-stage configurations





Two-stage protocol achieves higher throughput in spite of additional overhead due to over-provisioning of service requests. One-stage protocol is much faster at low traffic load

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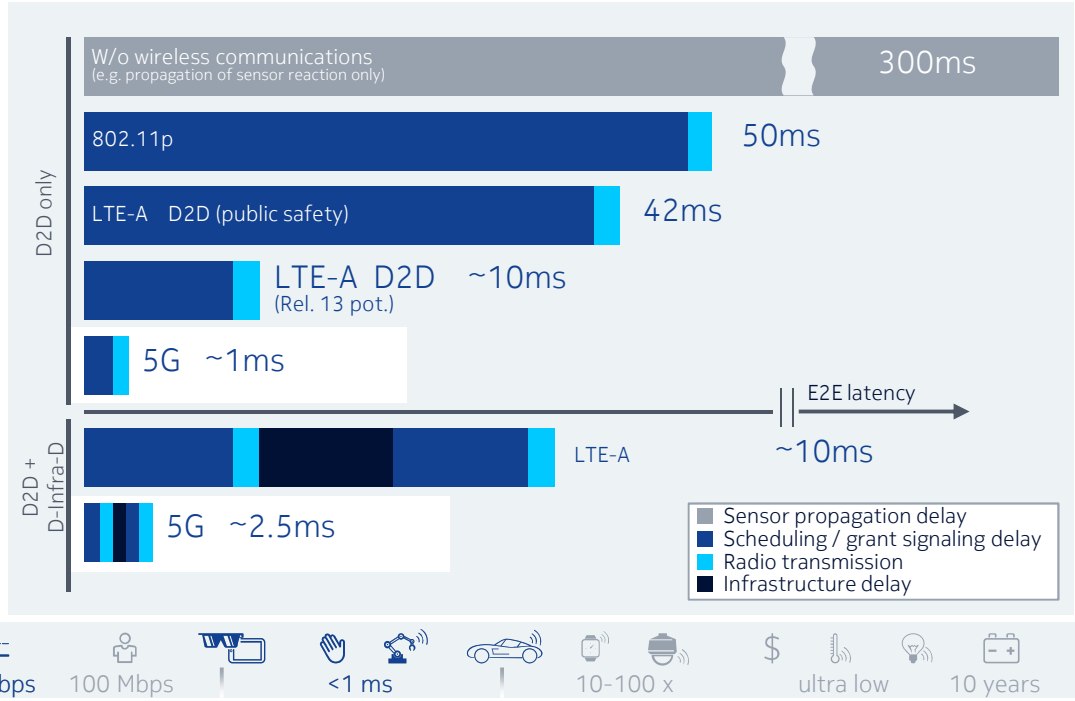
1ms Radio | Enabling a new generation of latency critical services
E2E latency aware scheduler

Latency optimized frame structure

Dynamic uplink-downlink

Pipeline processing



Autonomous driving and production

Tactile internet services

mmWave demo
with NTT DoCoMo

DMRS = Demodulation Reference Signal; GP = Guard Period

  Public

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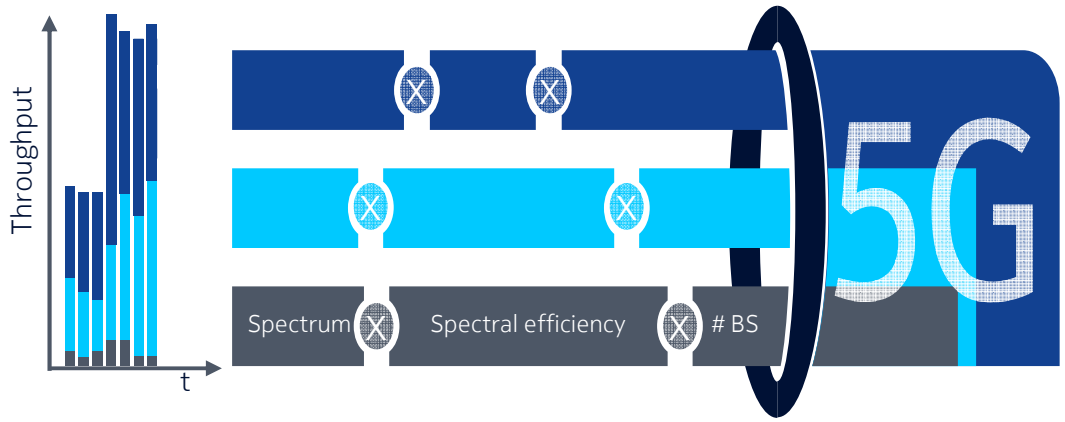
Multi-Connectivity | Perception of infinite capacity
Multiple radio technologies collaborating as one system



Extreme mobility robustness and ultra reliability

>100 Mbps anywhere

~ 3 x burst throughput*

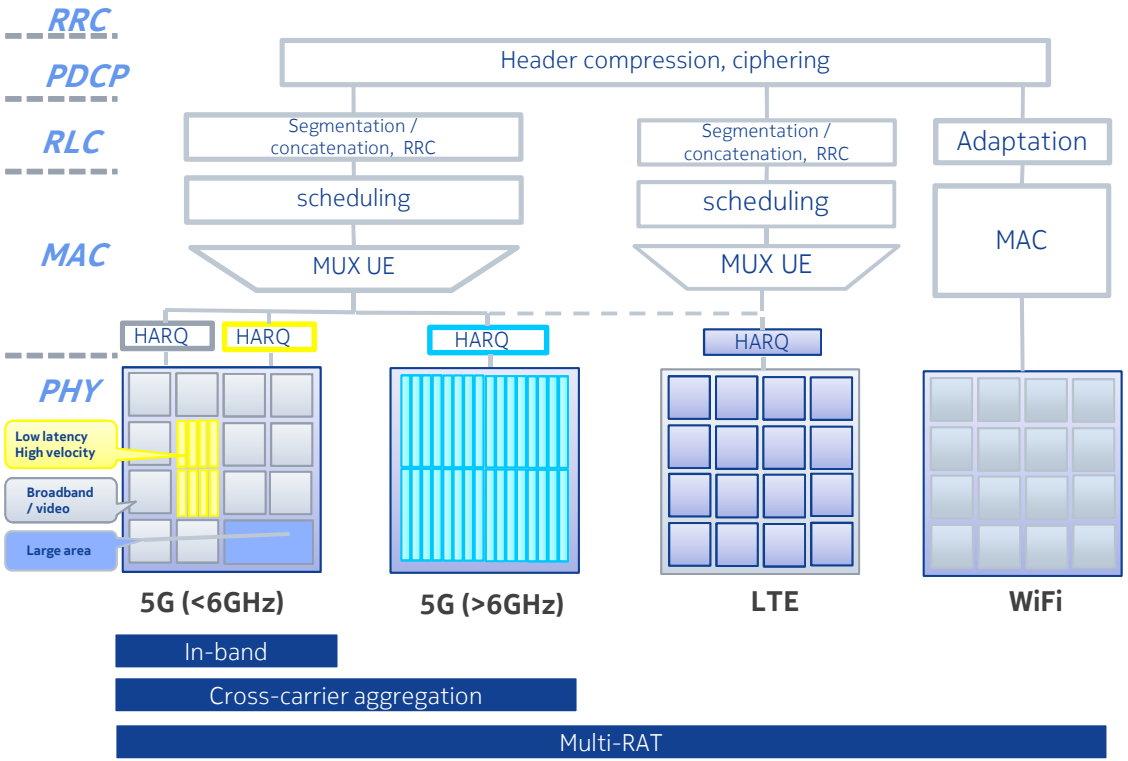
4G/5G real-time radio resource management know how built on demonstrator

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

*in example area, 50% load

Multi-Connectivity | Perception of infinite capacity

In-band integration , carrier aggregation, multi-link integration



Diversity of radio path

High service availability even when moving

Bundling of resources

Aggregated user data rate (peak and average)

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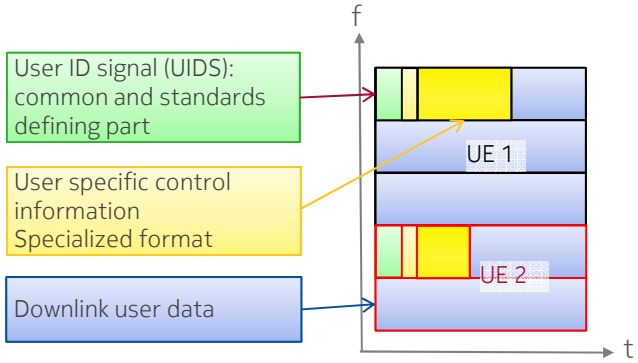
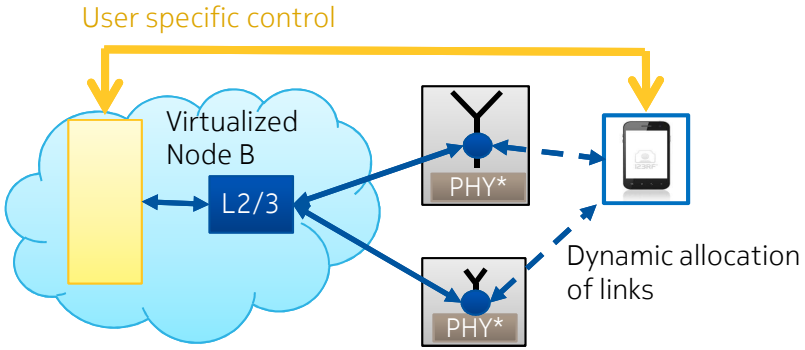
5G Control Channel





Simple, stand-alone, hierarchical control channel, maximizing forward compatibility

Supports separation of control and data

User specific- with minimum standard-defining parts: User ID signal and initial access

Adapts to service, deployment and device

Exploits gains from link adaptation, beamforming

Feasibility of basic design was shown by simulation

Discussed in pre-standards fora

Enables user-centric radio access and forward compatibility

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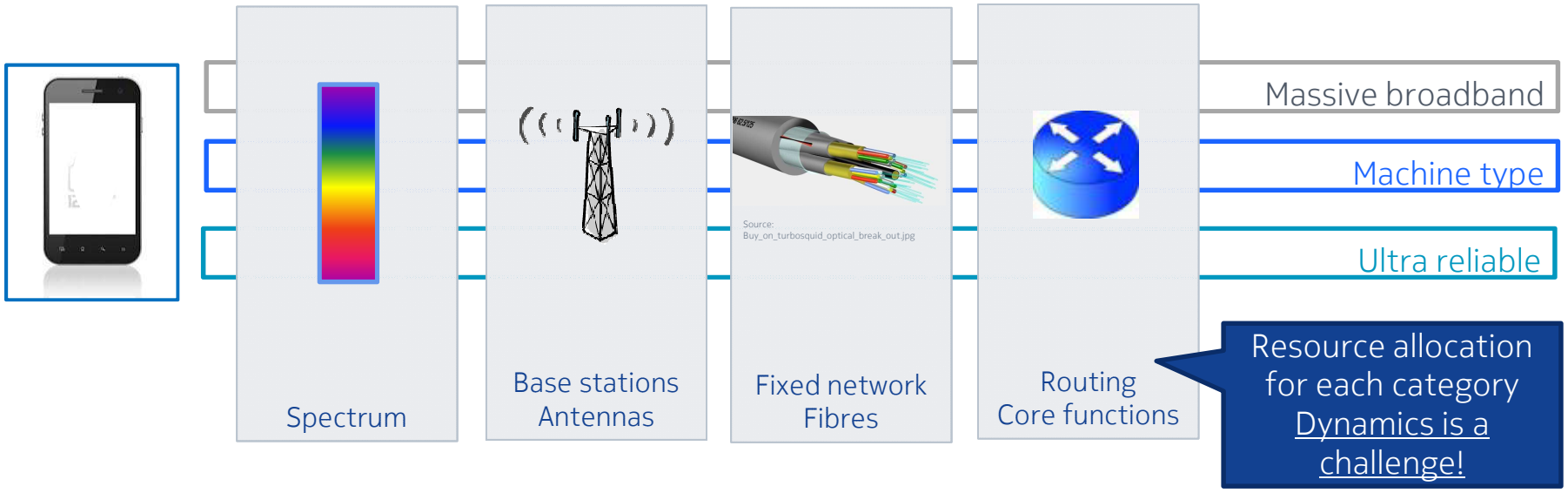
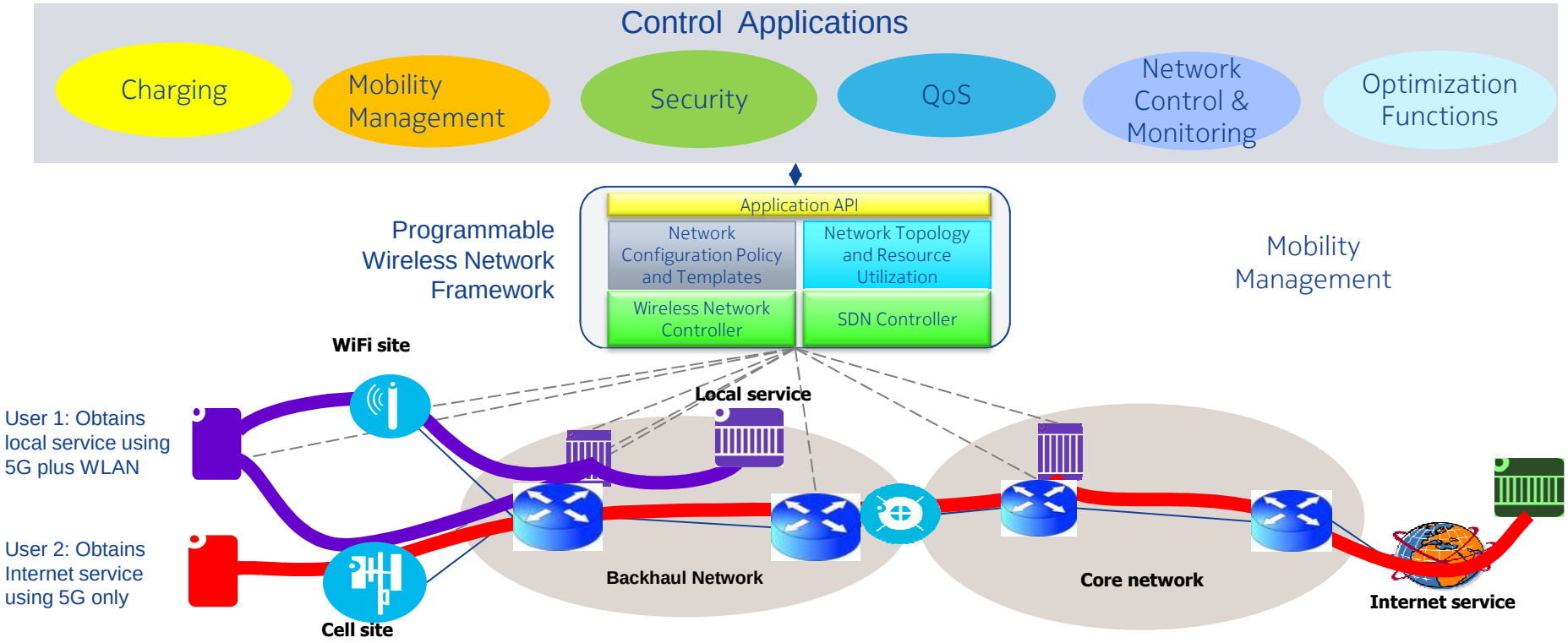
Network slicing | A way of sharing resources



Virtualization: 5G can host different end to end networks on one platform

WHAT WILL 5G LOOK LIKE?

5G will use policy control to adapt the network to the user



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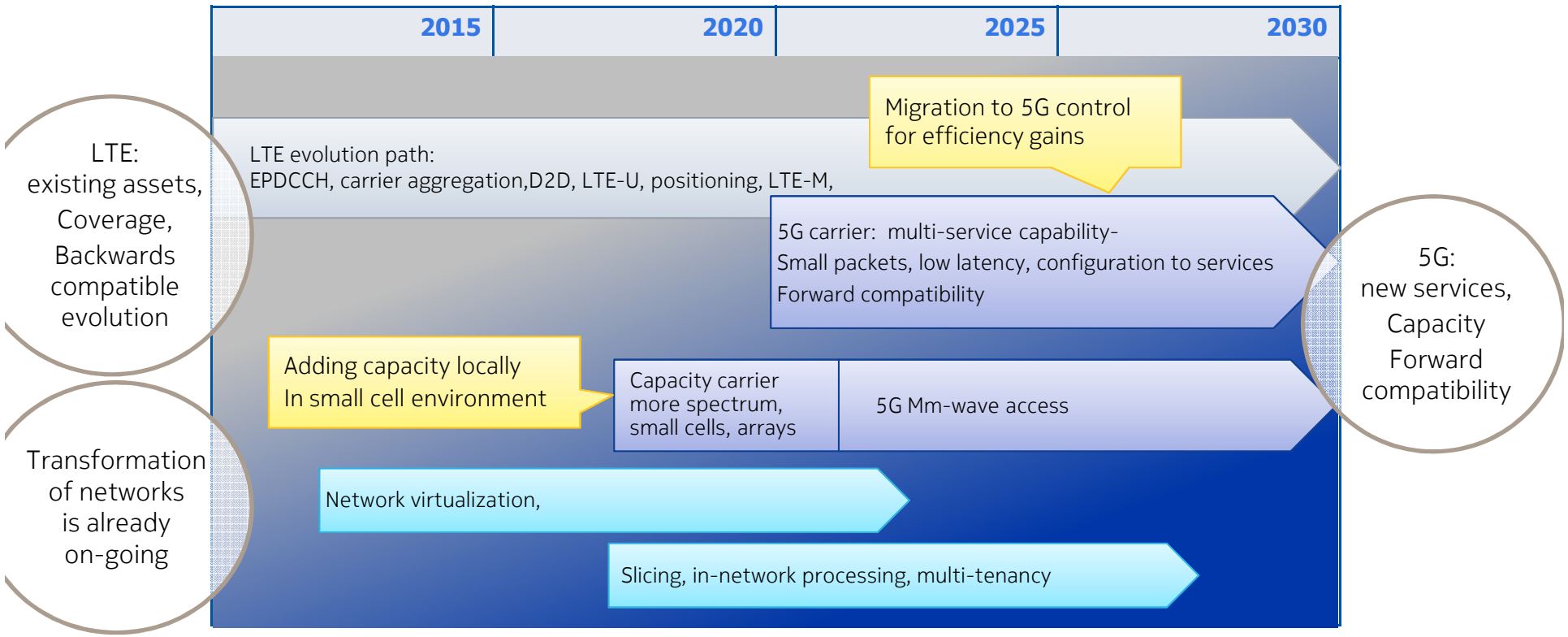
Transformation of the networks



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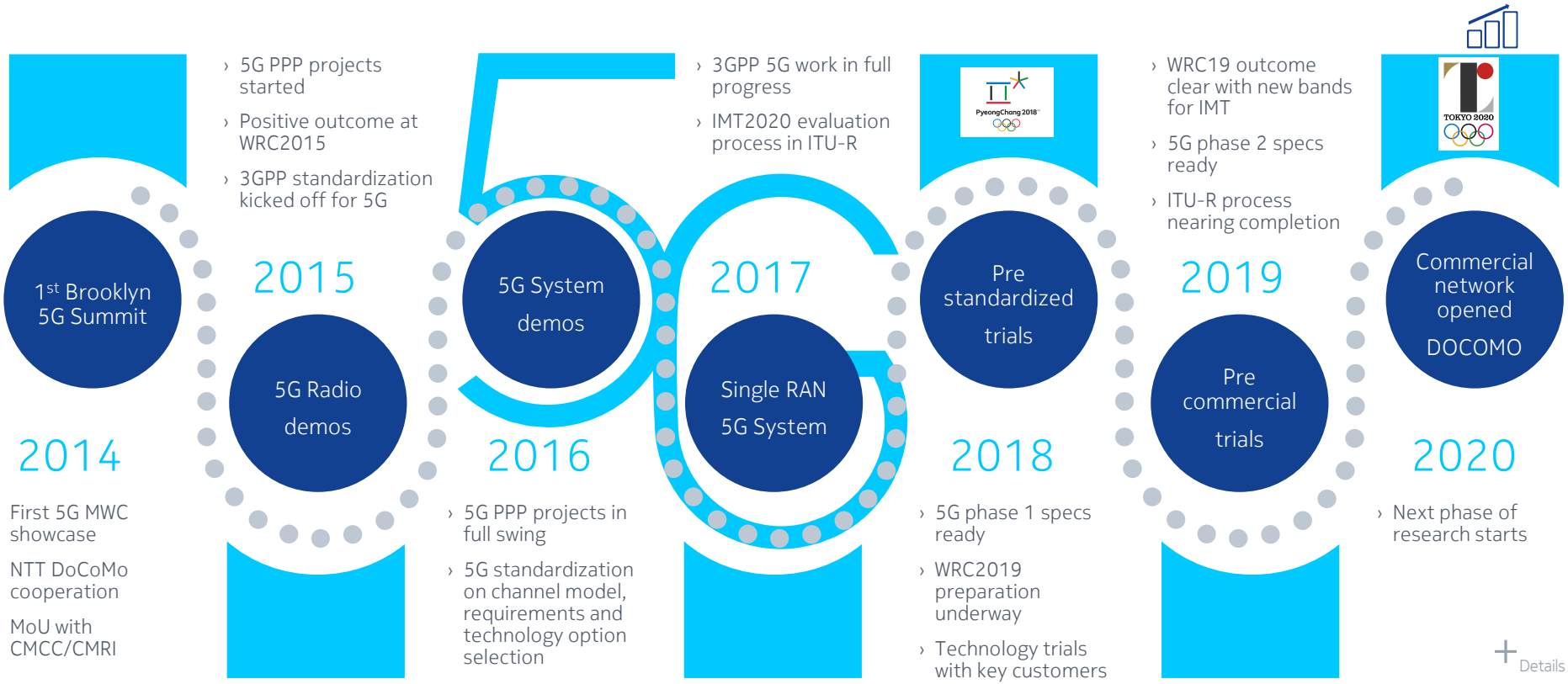
Key milestones on the road to 5G



Take away

- Beyond smartphone: Many new “devices” will be connected: cars, machines, healthcare, personal devices
- Gb/s broadband: mm-wave links are seamlessly integrated
- Open design:
  New applications can be added over the next 15 years
- The entire system adapts to the service
- Nokia has the aspiration and capabilities to be the leading vendor in 5G

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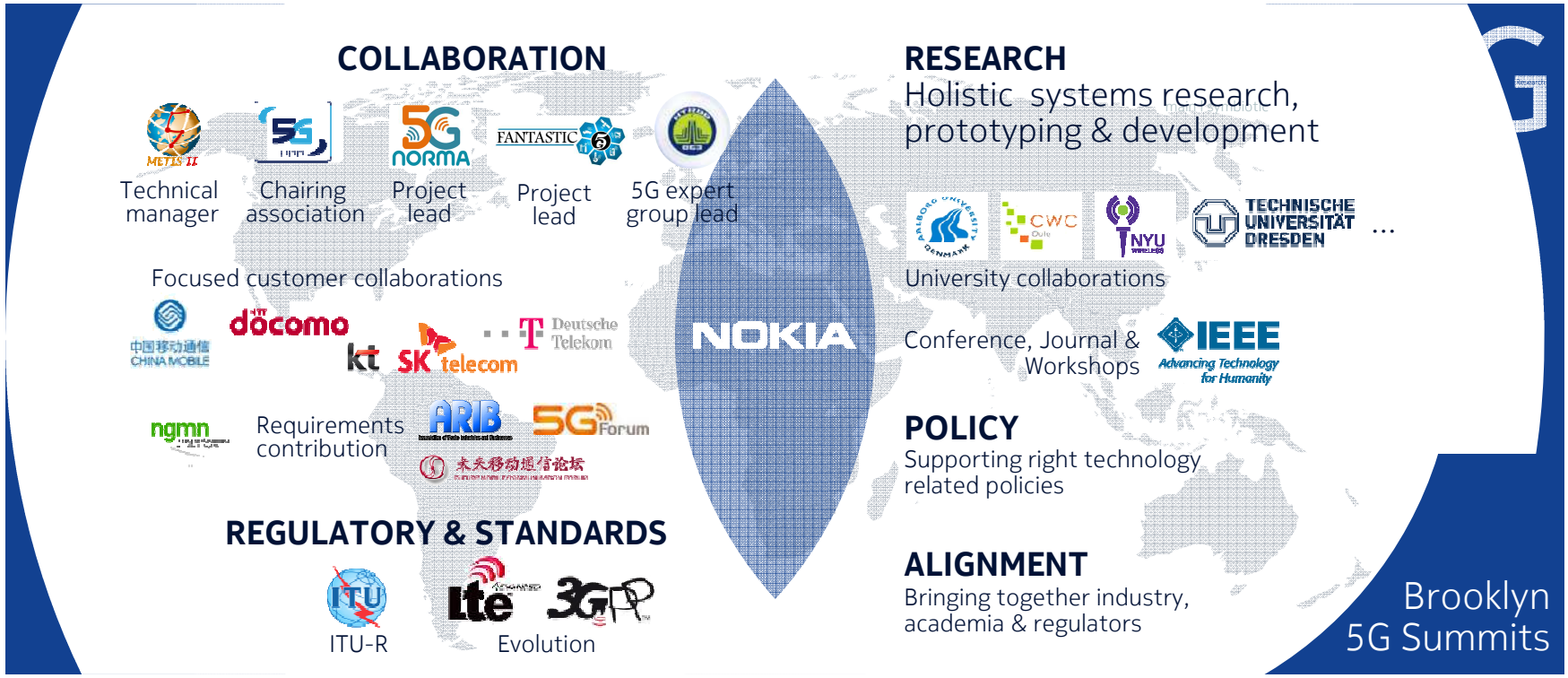
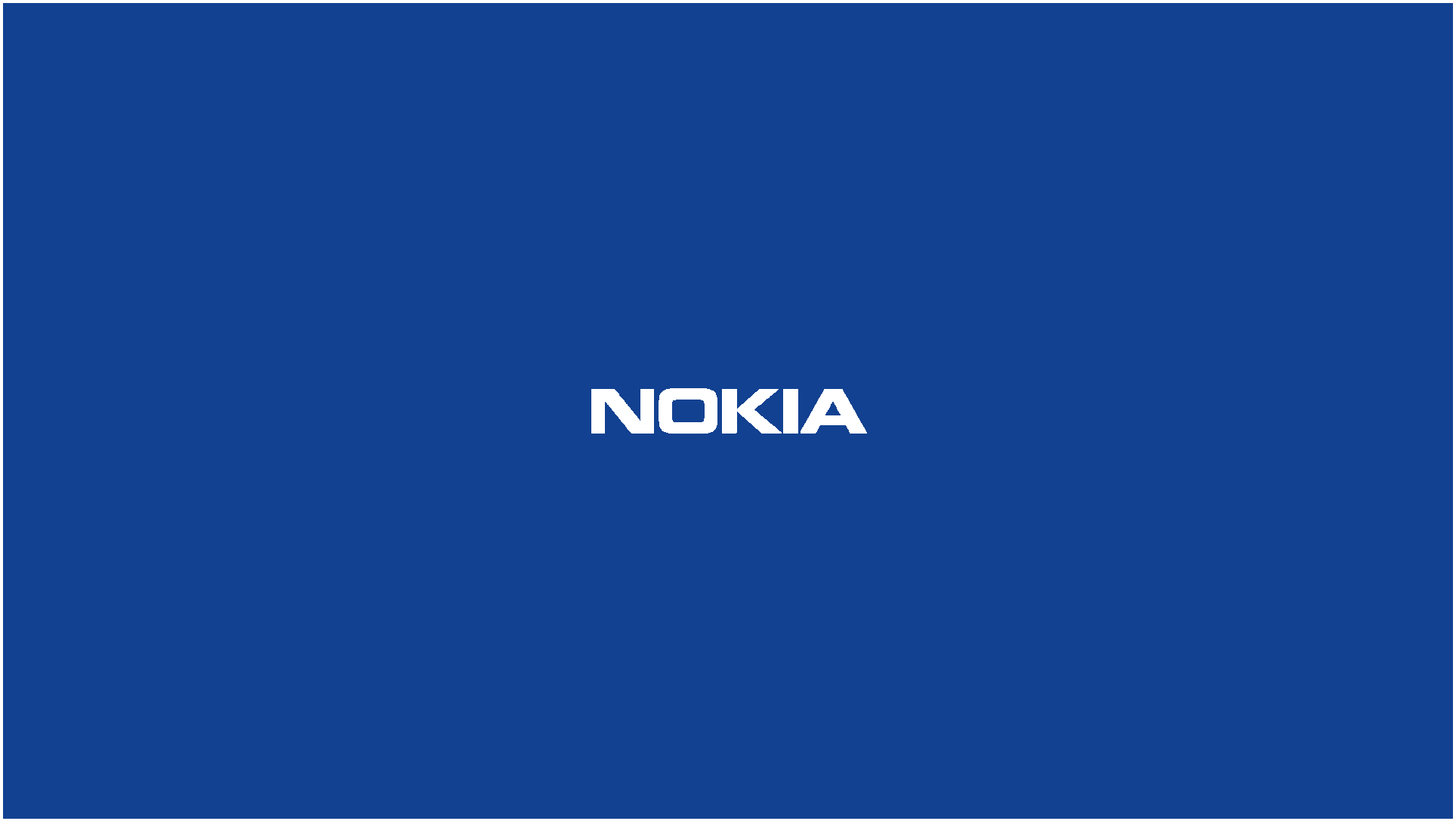
Active in shaping and aligning the global 5G end-to-end ecosystem

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