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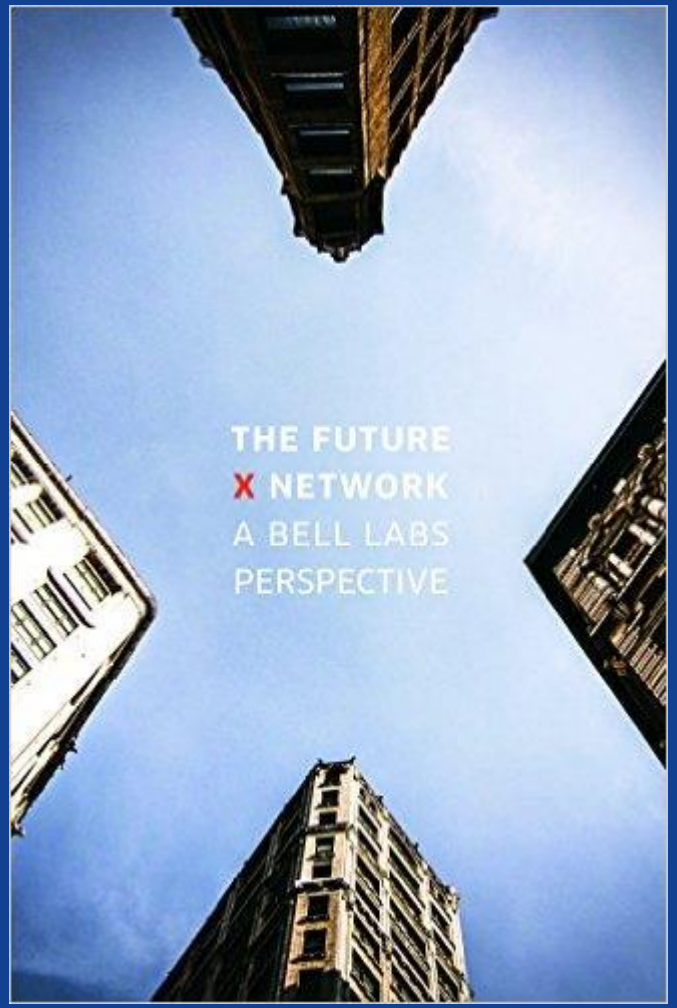
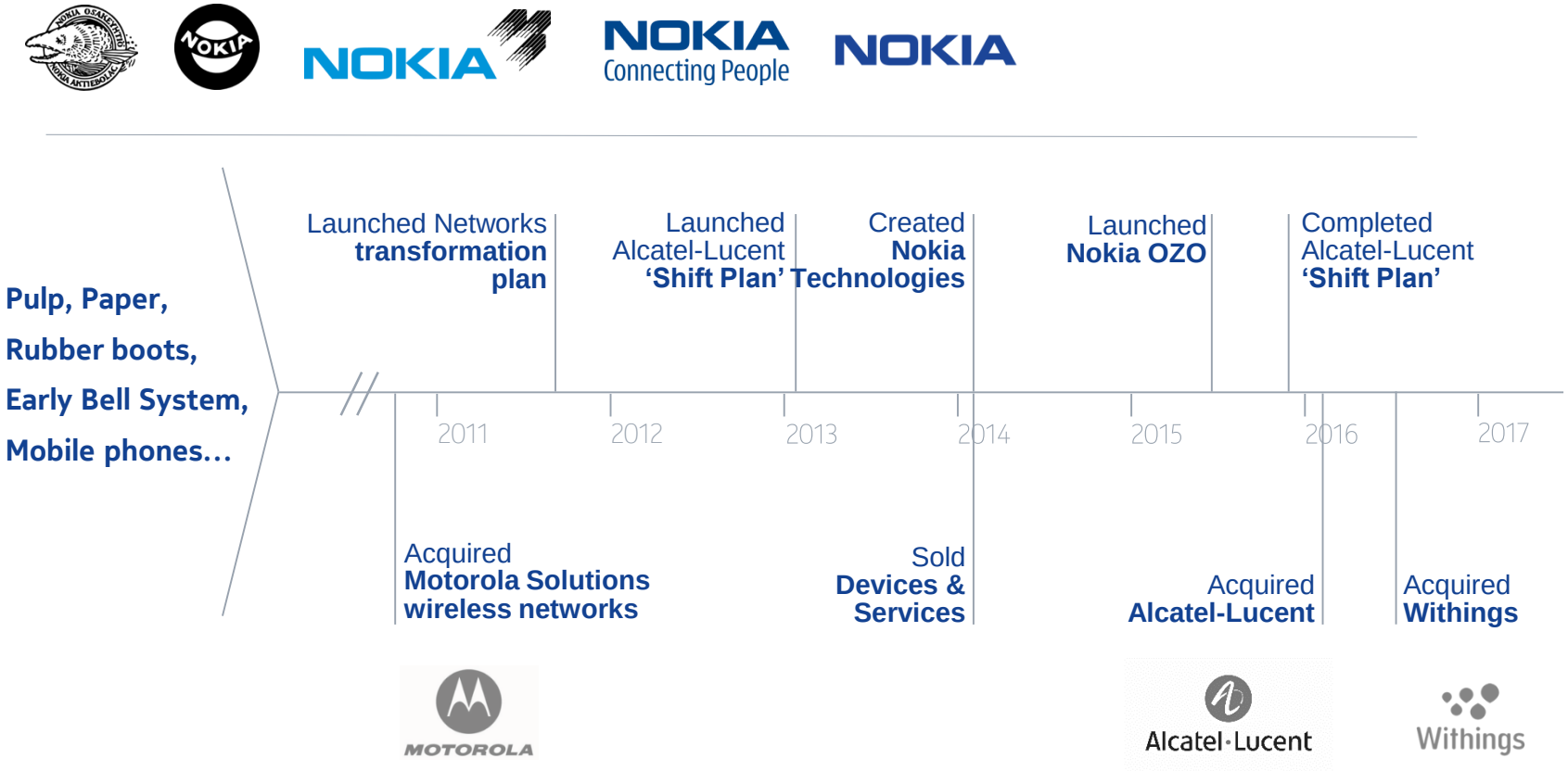
Future X Network
for 5G and IoT



Dr. (Bong Youl) Brian Cho, 趙奉烈
Head of Technology for APAC & Japan

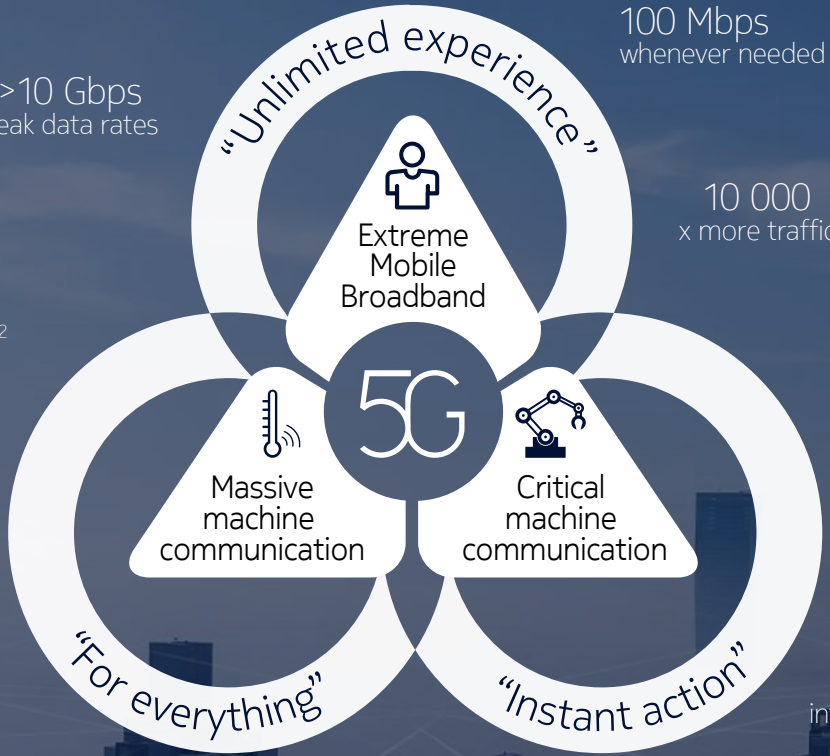
150 years of successful reinvention



Comprehensive portfolio and expertise

Mobile Networks	Fixed Networks	IP / Optical Networks	Applications & Analytics	Global Services	Nokia Technologies	Nokia Bell Labs

5G for eMBB, mMTC, URLLC, and more



Capacity

>10 Gbps
peak data rates

100 Mbps
whenever needed

10 000
x more traffic

Latency

<1 ms
radio latency

Connectivity

1,000,000
devices per km^2

Ultra low cost
for massive machine coms.

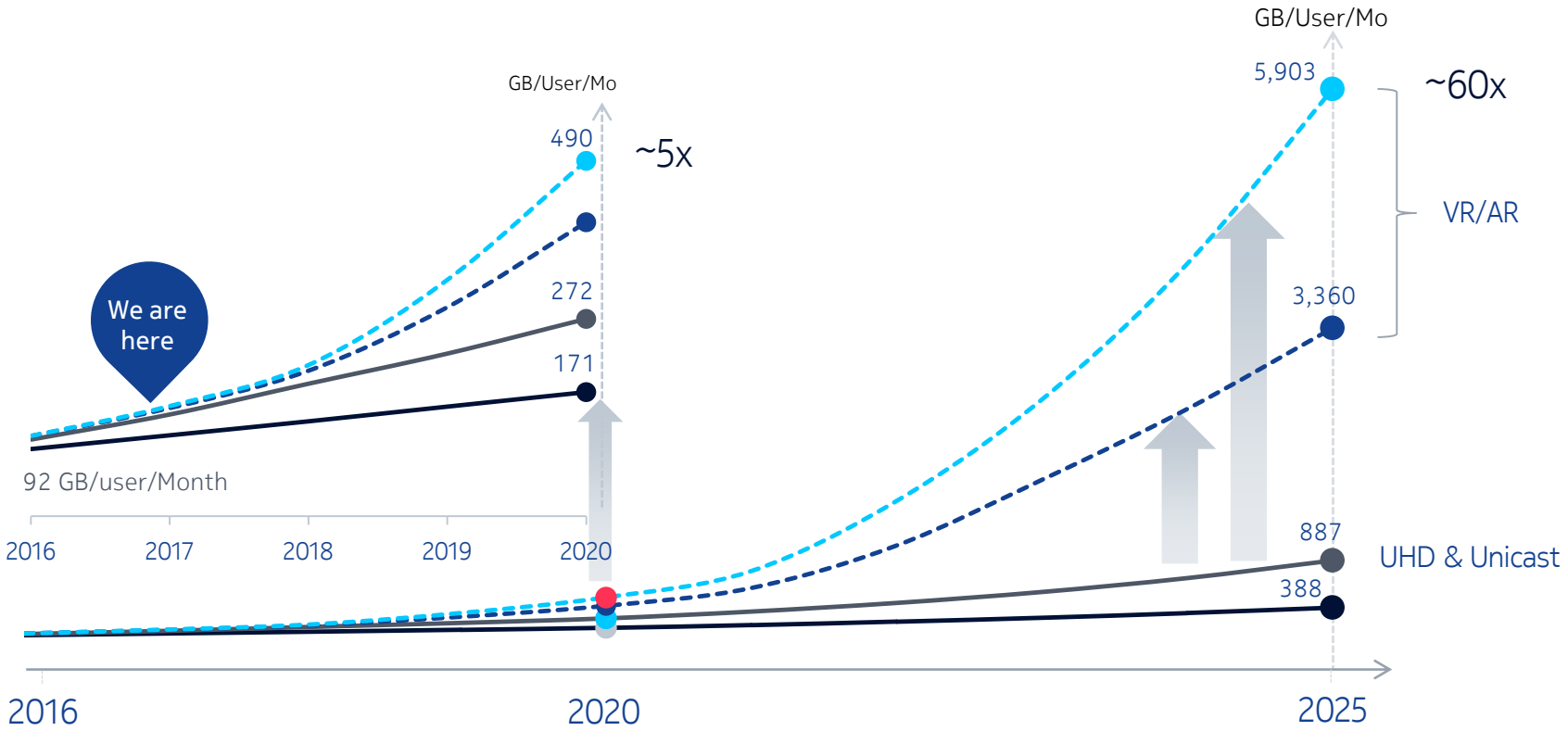
10 years
on battery

Reliability

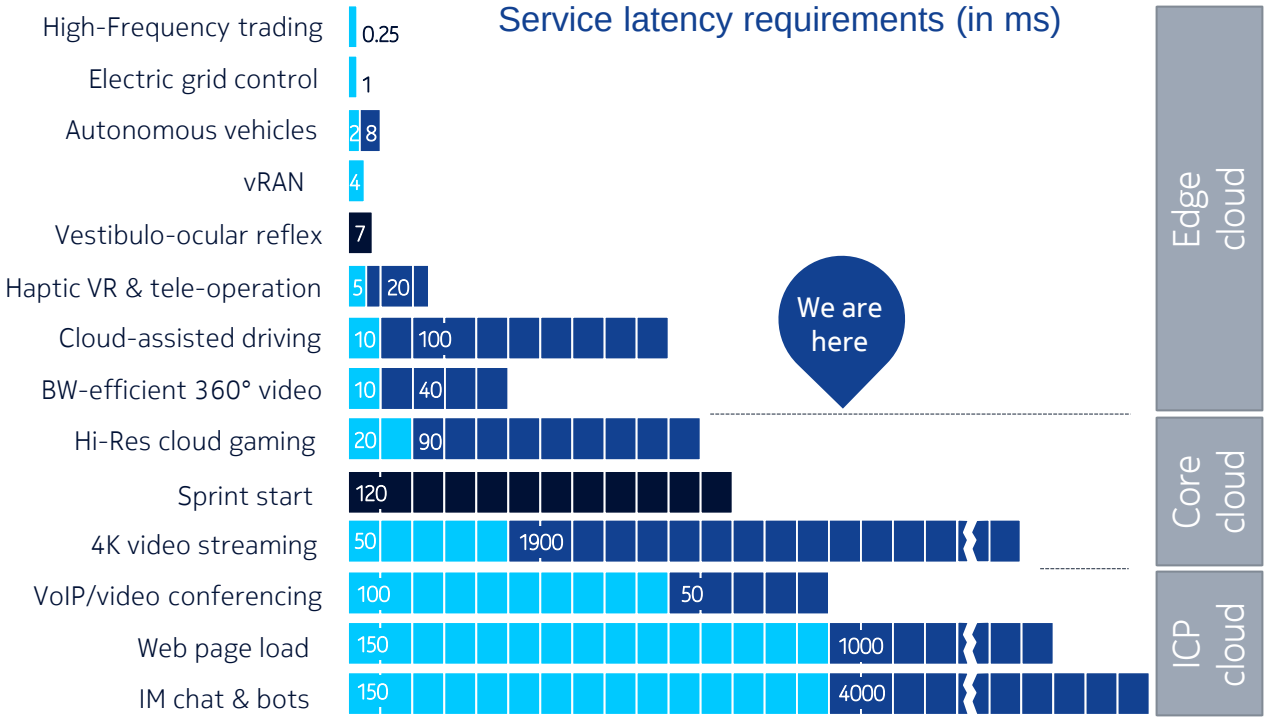
Ultra reliability
< 10^{-5} E2E outage

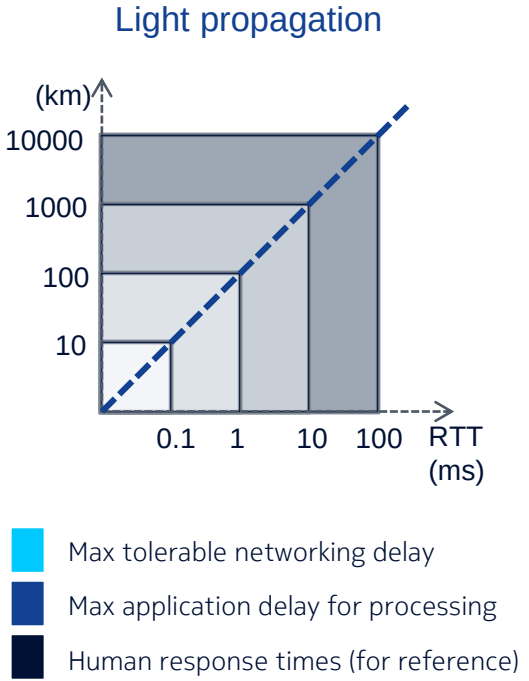
Zero
mobility interruption

Bandwidth matters …

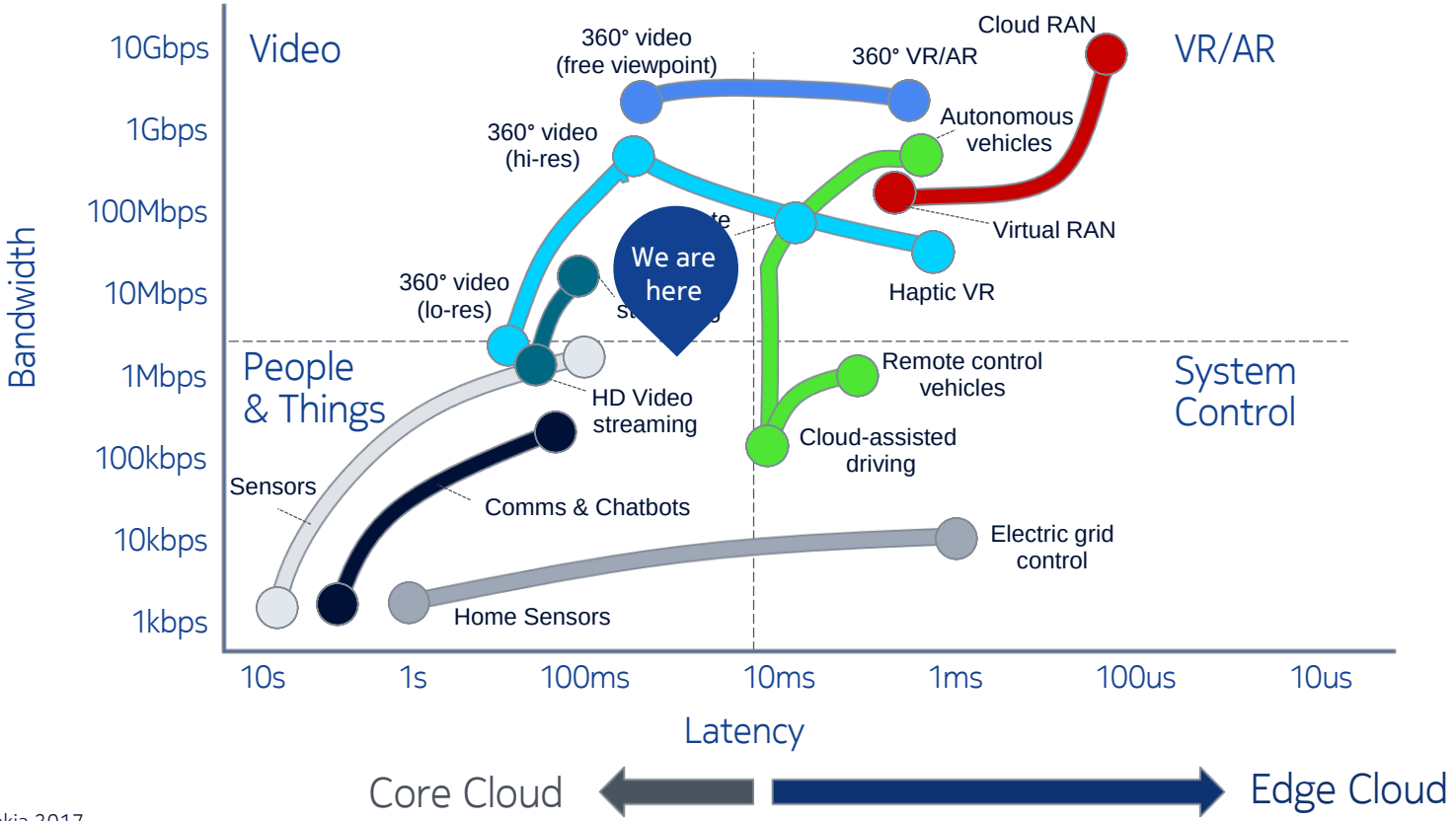


Latency matters …





Bandwidth & Latency matter …

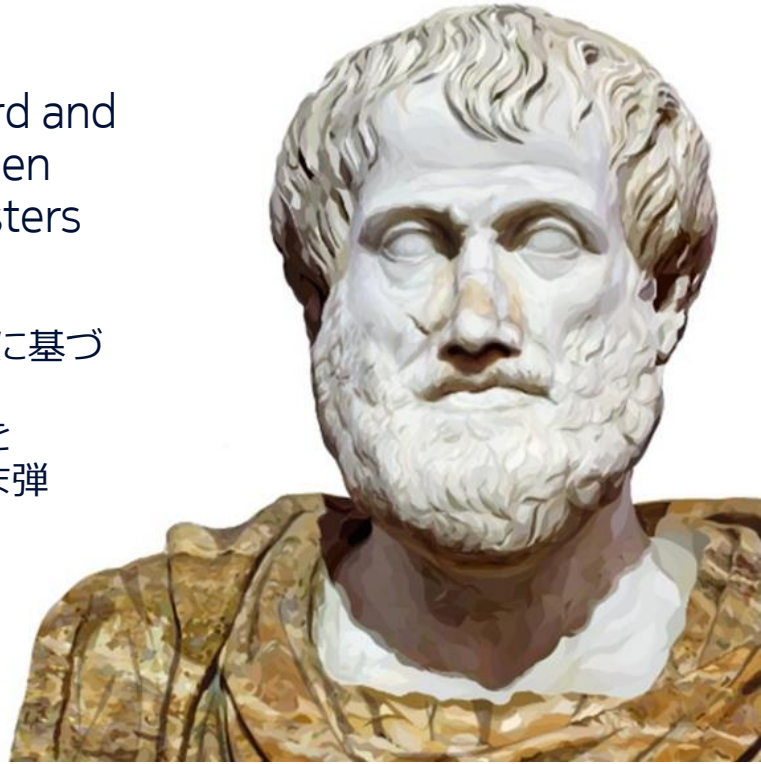


IoT (Internet of Things) – Humanity's long standing dream…

"Suppose every instrument could by command or anticipation of need, execute its function on its own; suppose that spindles[1] could weave of their own accord and plectra[2] strike the strings of zithers[3] by themselves; then craftsmen would have no need of hand-work and masters have no need of slaves."

"想像してみよう。あらゆる道具が、必要性から来る指示や予測に基づいて自身の機能を実行することが 出来たなら。
想像してみよう。はたおり軸がひとりでに動いて、美しい織物を織ったなら。チター（弦楽器）の弦をピックが自分の意思でつま弾いたなら。もはや職人が手作業でものを作る必要はなく、
主人に奴隷は無用のものとなるであろう。"

Aristotle (384 - 322 BC)



[1] a rod used in hand spinning to twist and wind thread from a mass of wool.
[2] thin flat pieces of material to pluck the strings of a musical instrument.
[3] a musical instrument consisting of a flat wooden sound box with numerous strings stretched across it, placed horizontally and played with the fingers and a plectrum.

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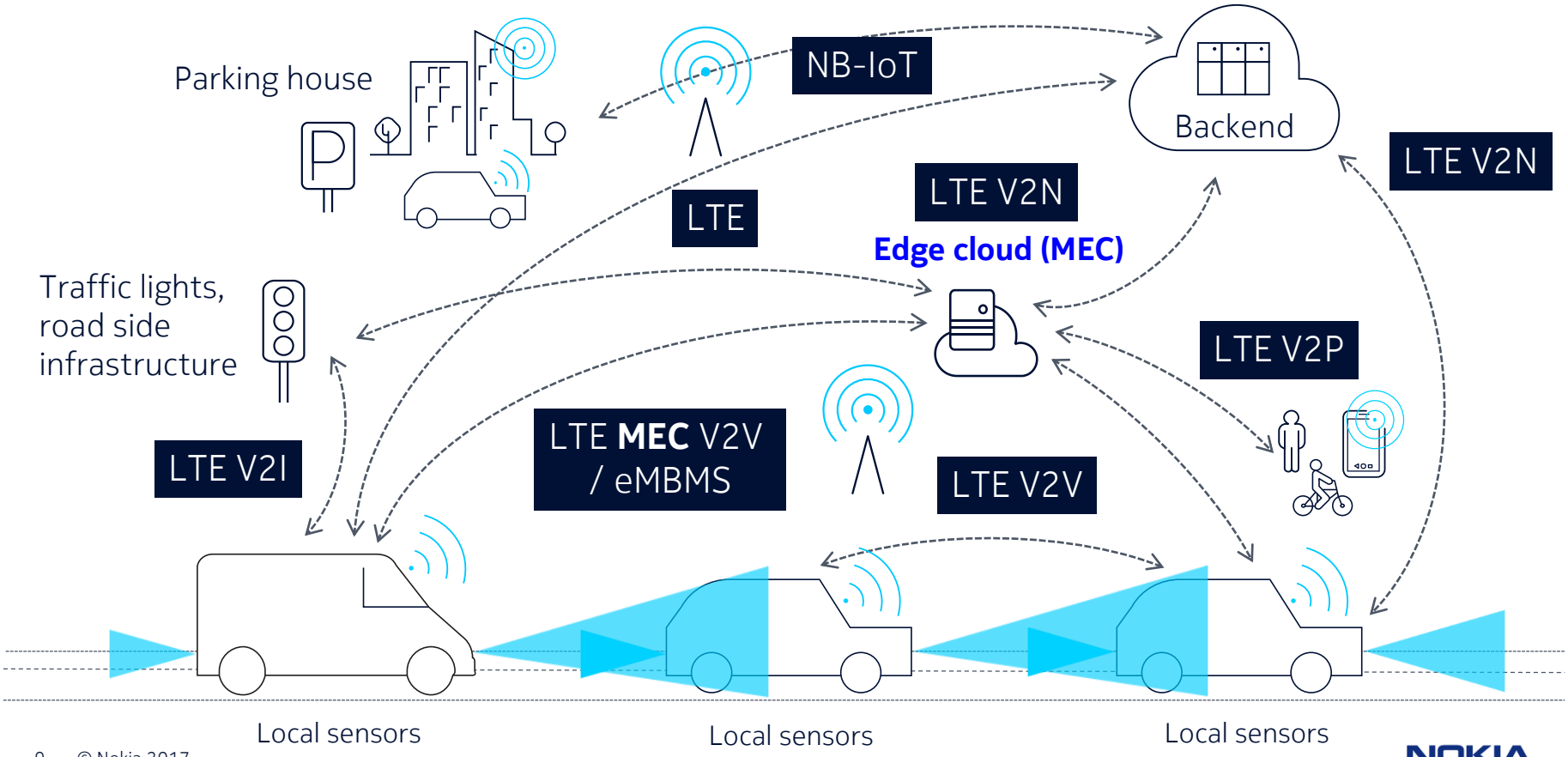
Connectivity: leveraging **LTE** for robust V2X communications – on the way to **5G**



Quick Technical Comparison

	C-V2X: PC5	802.11p	C-V2X: PC5 Advantage
Synchronization	Synchronous	Asynchronous	Spectral Efficiency. Synchronization enables time division multiplexing (TDM) and lowers channel access overhead.
Resource Multiplexing Across Vehicles	FDM and Time Division Multiplexing (TDM) Possible	TDM Only	Frequency Division Multiplexing allows for larger link budget and therefore longer range – or more reliable performance at the same range.
Channel Coding	Turbo	Convolutional	Coding gain from turbo codes leads to longer range – or more reliable performance at the same range.
Retransmission	Hybrid Automatic Repeat Request (HARQ)	No HARQ	Leads to longer range – or more reliable performance at the same range.
Waveform	SC-FDM	OFDM	Allows for more transmit power with the same power amplifier. Leads to longer range – or more reliable performance at the same range.
Resource Selection	Semi-persistent transmission with relative energy-based selection.	Carrier Sense Multiple Access with Collision Avoidance (CSMA-CA)	Optimizes resource selection with selection of close to 'best' resource with no contention overheads. By contrast 802.11p protocol selects the first "good enough" resource and requires contention overhead.

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V2X use case demonstrations in Germany and China

Cross industry

- Nokia Multi-Access Edge Computing installed in LTE networks
- Robust latency below 20ms

Nov. 2015

Fraunhofer ESK

Continental

Use cases

- Cooperative passing assistant
- Electronic brake lights

June 2016

BOSCH

Use cases

- Intersection assistant
- Electronic brake light

Nov. 2016

Fraunhofer ESK

Continental

Use cases

- Cooperative passing assistant
- Electronic brake lights

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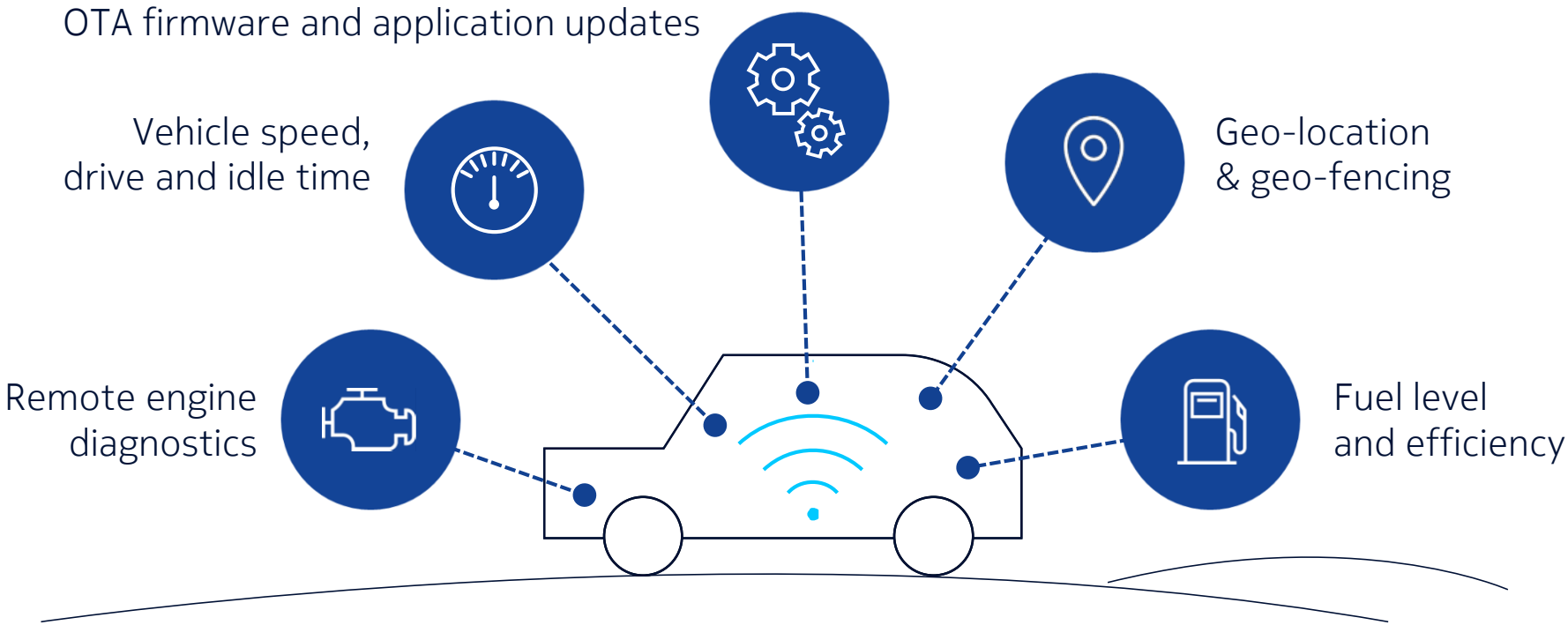
Software & Sensors: riding the **IoT** wave for predictive maintenance, fleet management, and driver monitoring applications



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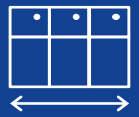
Nokia End-to-End IoT portfolio from a helicopter view

Applications

IMPACT applications for selected use cases

Ecosystem

IoT Community and strategic partners



Platform

IMPACT platform
- Application enablement
- Data collection & analytics
- Device management
- Connectivity management

Connectivity

Cellular radio: NB-IoT, LTE-M, EC-GSM
Unlicensed & home: LoRa, Wi-Fi, Zigbee, Z-wave
Optimized IoT core, leveraging SDN/NFV
MEC, Backhaul & FTTx

CPE and devices

Home hub (ONT) & enterprise gateway
Partner devices & device certification services
Withings digital health products

Security

Netguard Endpoint Security, Deepfield

Analytics & Deep Knowledge

Connect, Experience, Market, Automate

Services

Planning, readiness, design, integration

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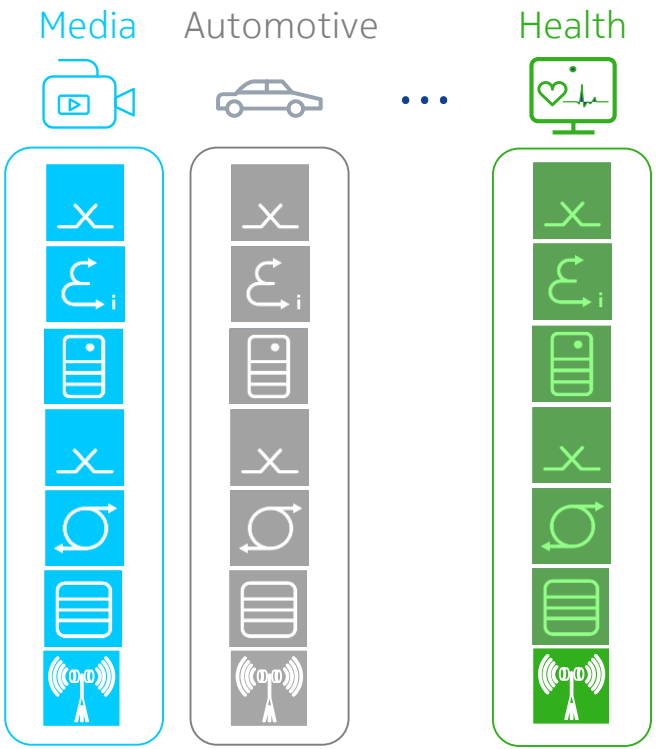
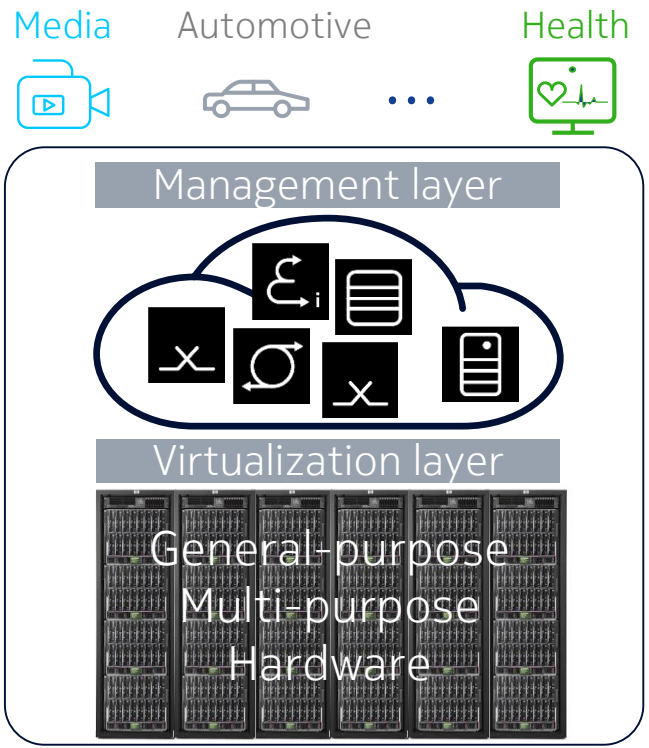
Network Operator's TCO challenge – to be overcome by Cloudification





Silos of multiple heterogeneous networks

One unified/**cloudified** network

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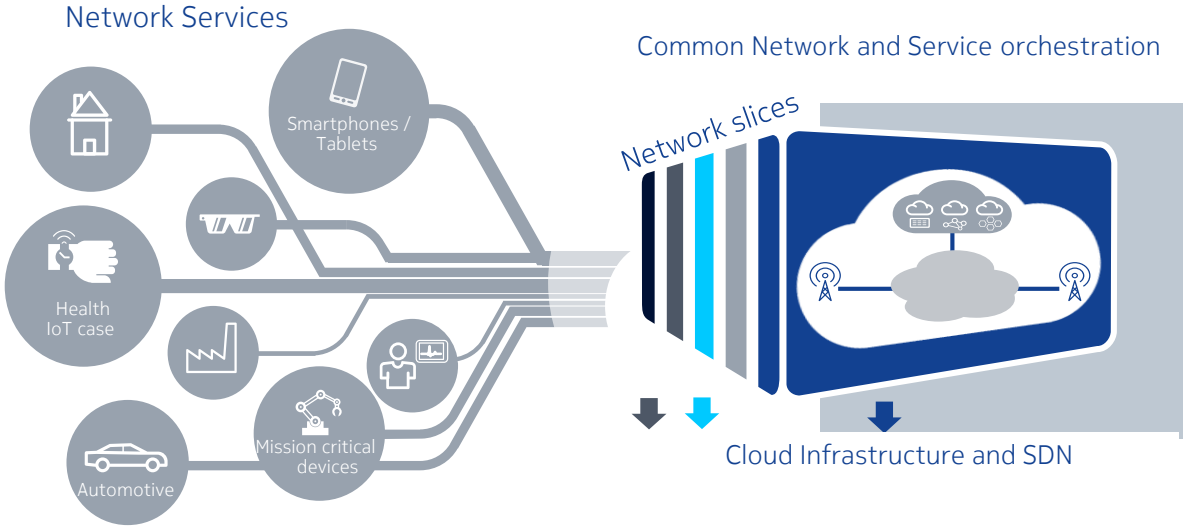
Network Slicing | Optimized service delivery for heterogeneous use cases
Multiple independent instances on one physical network



"The target of Network Slicing is to provide dedicated logical networks with **customer specific functionality**, without losing the **economies of scale of a common infrastructure**"

- Deutsche Telekom AG, White Paper

Network slicing provides optimized software-defined network functions for specific use cases, governing capacity, scalability, security, connectivity, quality and mobility per 'slice'.

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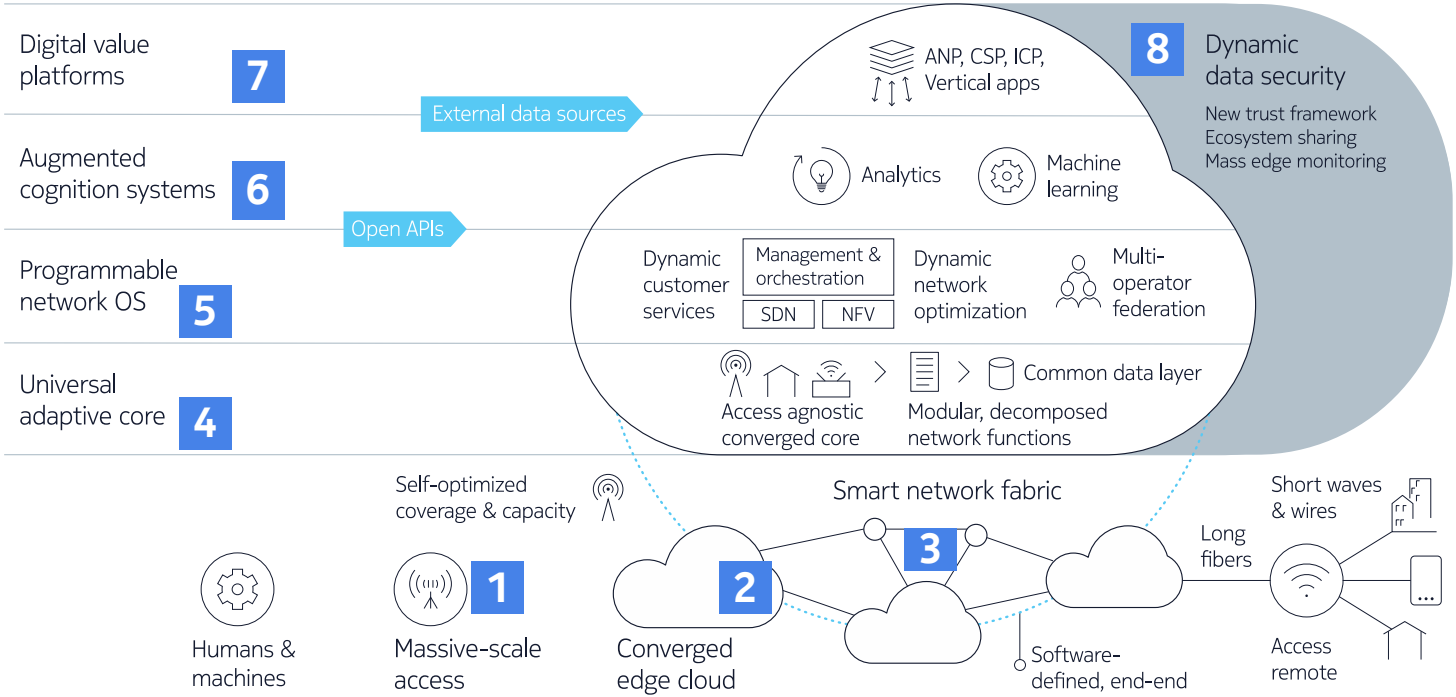
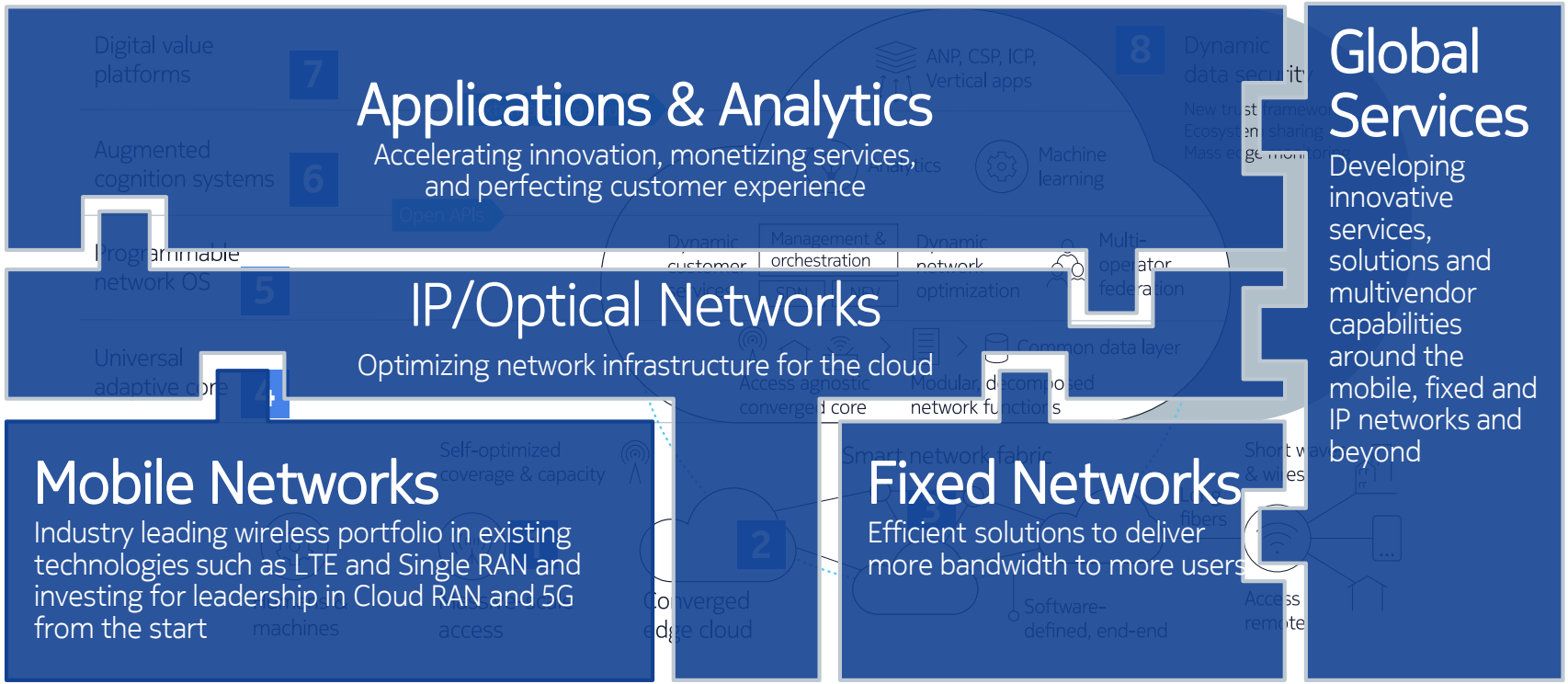
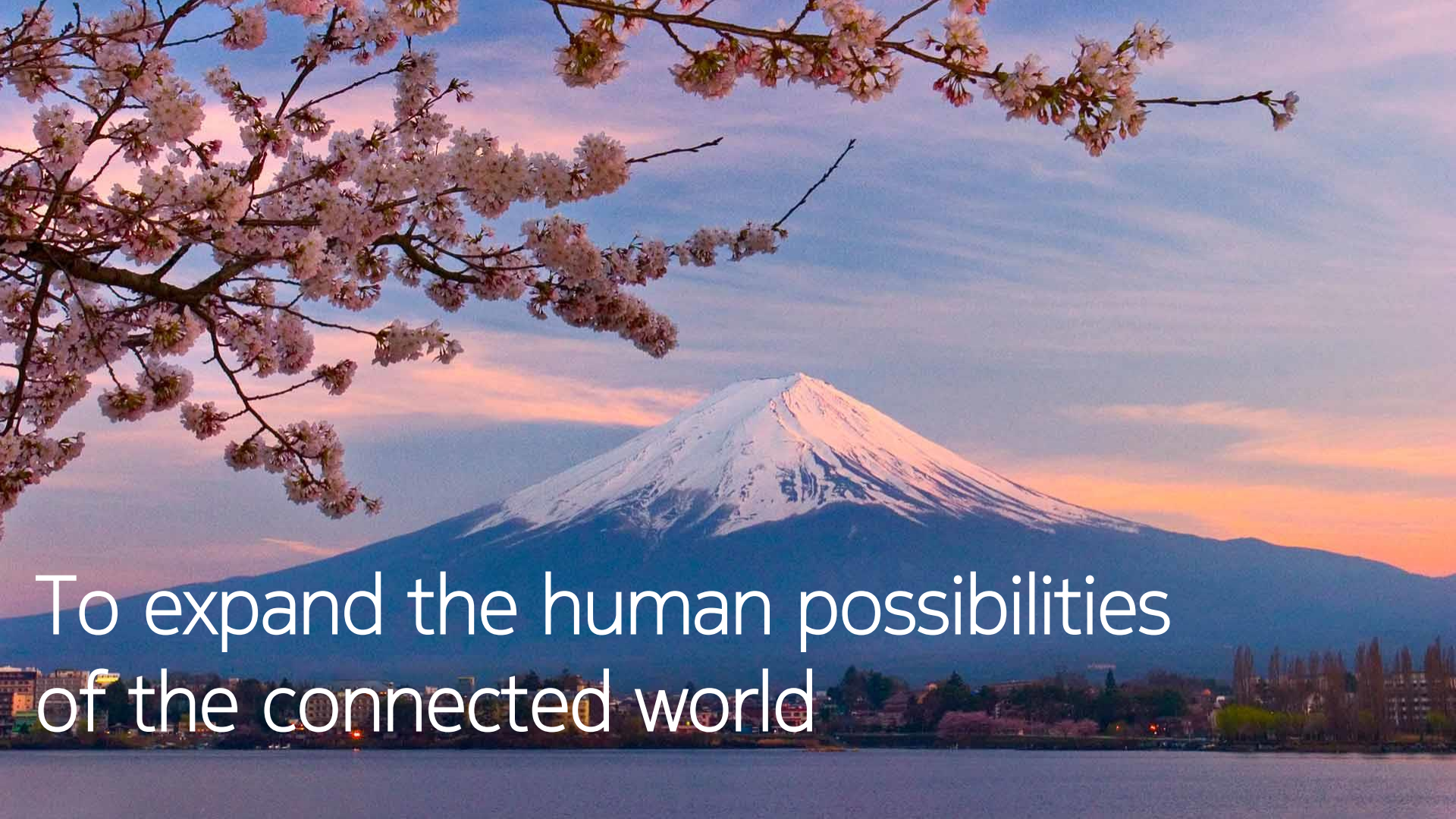
Nokia Future X Network – a cloud based digital fabric



Nokia Future X Network – a cloud based digital fabric




To expand the human possibilities
of the connected world