NOKIA

Future Network Architecture Vision

Vision for Future Communication Summit

October 23 and 24, 2017, Lisbon

Presented by Werner Mohr

The change: the future is very different from the past

	Past	Future
Solutions	**Technology-driven**	**Human/Business need driven**
Driver	**Consumer** (BW)	**Industry & Consumer** (Latency & SLA)
Architecture	**Heavily Centralized**	**Massively Distributed**
Partnership	**Monoliths w/Limited APIs**	**Modular w/Co-design & Open specs**
Standards	**Definitive**	**Iterative**
Investment	**Singular** (Operator only)	**Multiple & Cooperative** (Many contributors/new players)
Flexibility	**Limited** (Provisioned)	**Large** (Software definable)
Sharing	**Static and Limited** (HW VPNs)	**Dynamic and Infinite** (SW Slices)
Innovation Speed	**Per annum/decade** (new services)	**Per hour/day** (new apps)

Fundamental digital needs for new human & business value creation

seemingly infinite capacity

1 **Need:** 100x capacity growth in <10 years

imperceptible latency

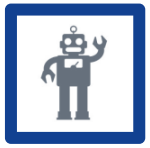
2 **Need:** Millisecond latency for networks & new ‘human’ services

terascale things

3 **Need:** Optimize TCO for a trillion things

global-local alliance

4 **Need:** Massive distribution of cloud infra with global federation



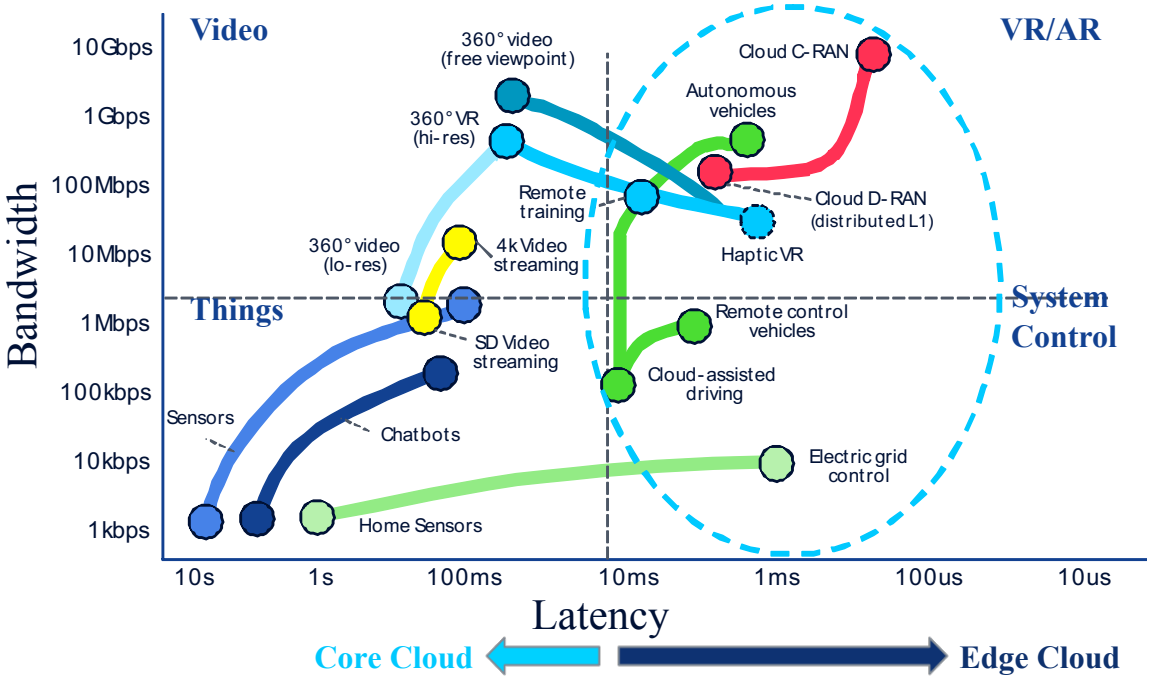
human cognitive operation

5 **Need:** Human assistance & task automation @ machine scale

personalized protection

6 **Need:** Enable dynamic, contextual security & trust @ terascale

Imperceptible latency – New applications redefine network requirements

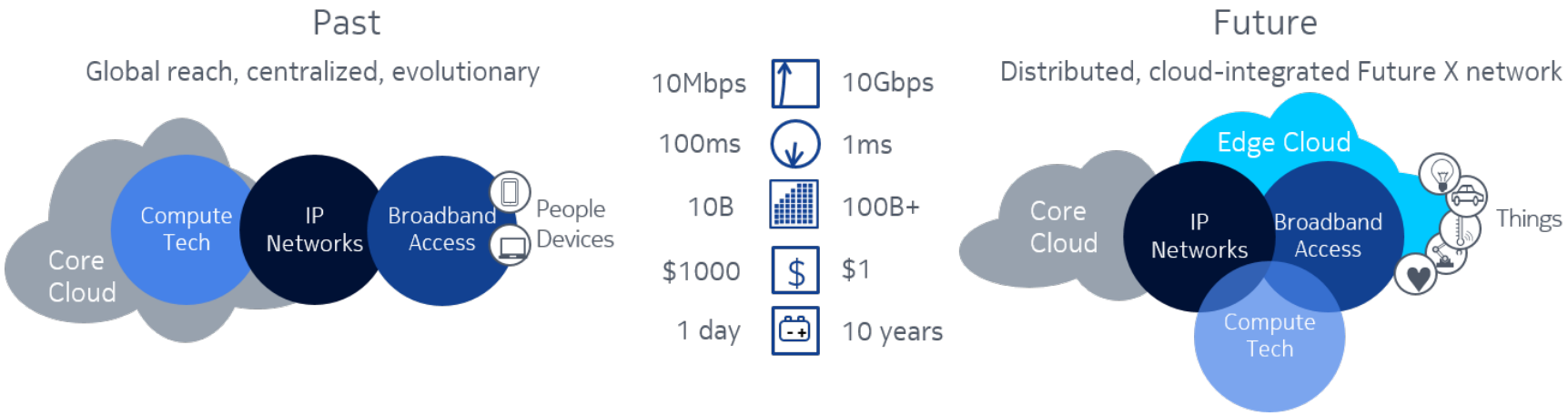


Low latency drivers

- 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

The future network is a new digital infrastructure for the "automation of everything"



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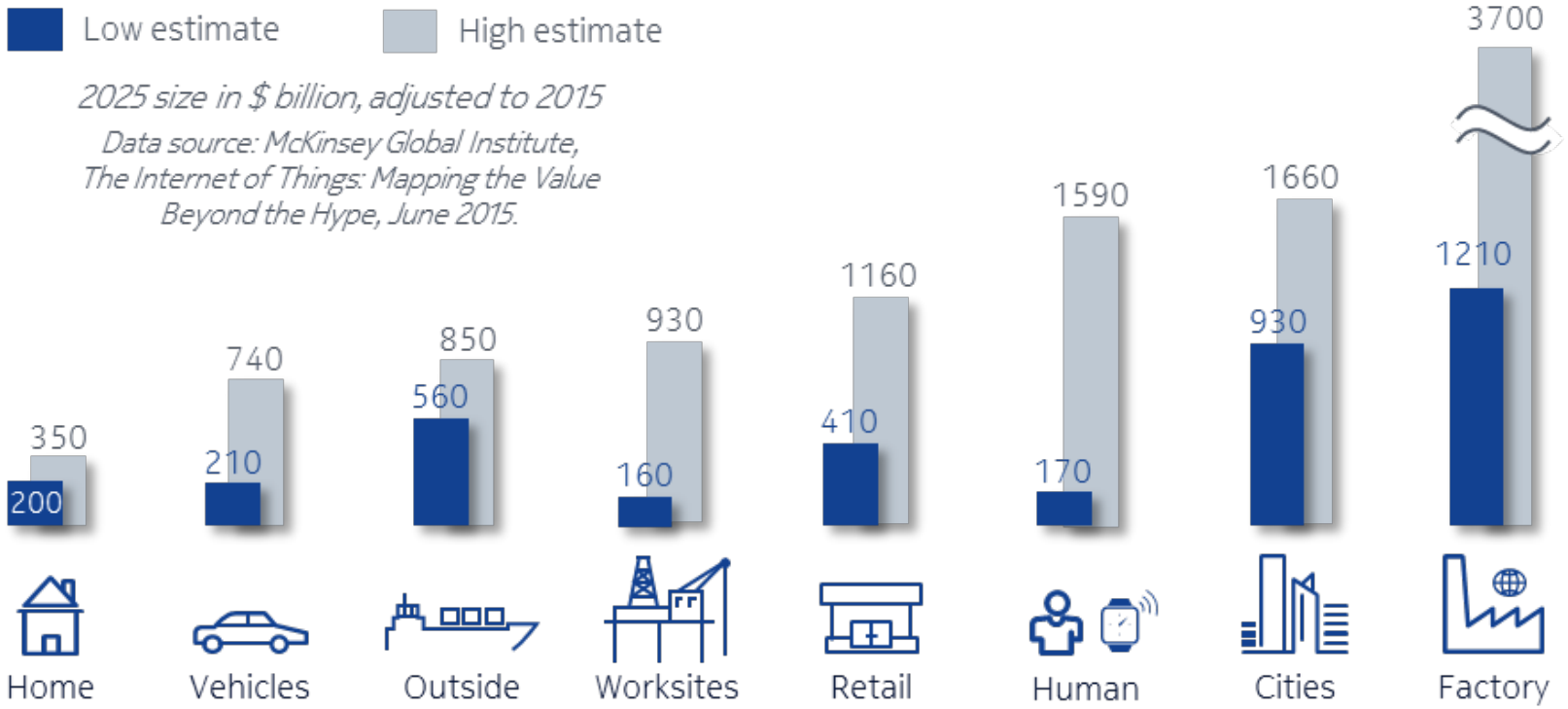
Estimated value creation potential by 2025
of the Internet of Things



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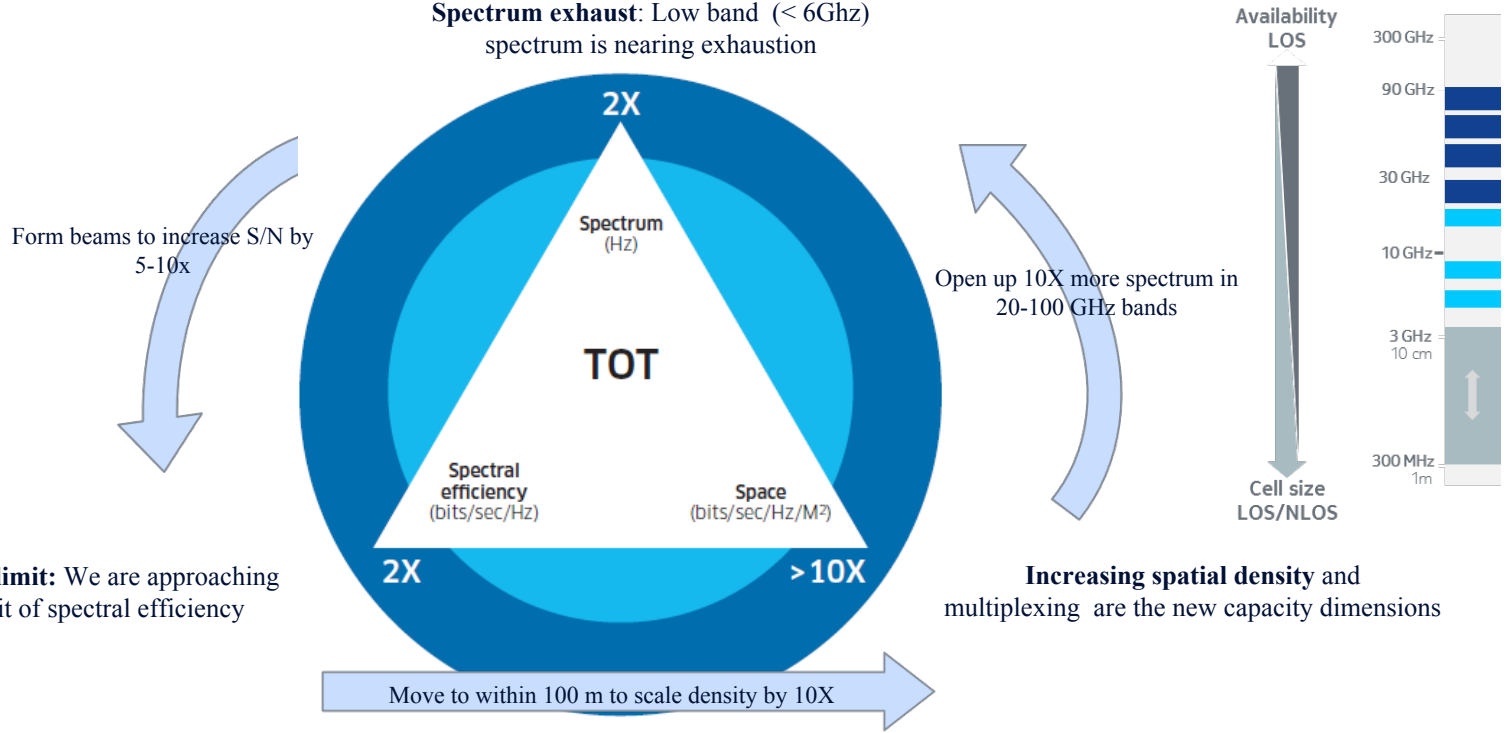
Seemingly infinite capacity - Networks are reaching physical limits

Spectrum exhaust: Low band (< 6Ghz) spectrum is nearing exhaustion



Shannon limit: We are approaching the limit of spectral efficiency

Increasing spatial density and multiplexing are the new capacity dimensions

Radical shift in network architecture needed to deliver required access capacity

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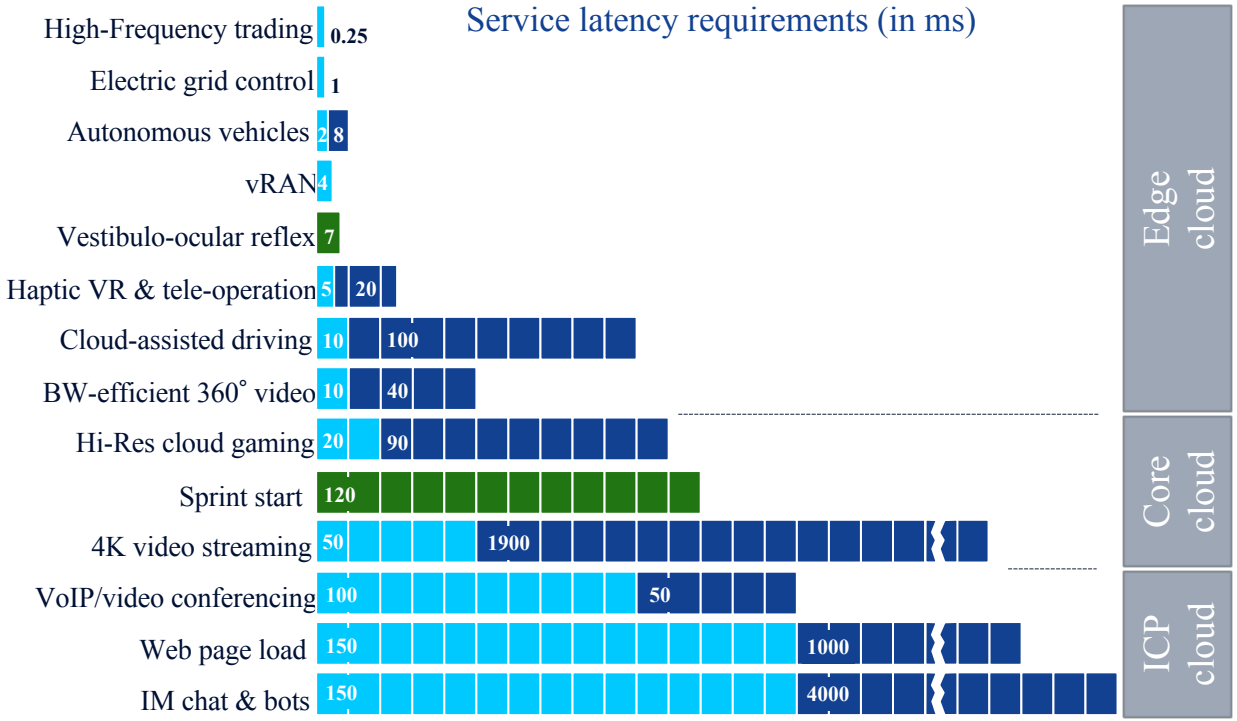
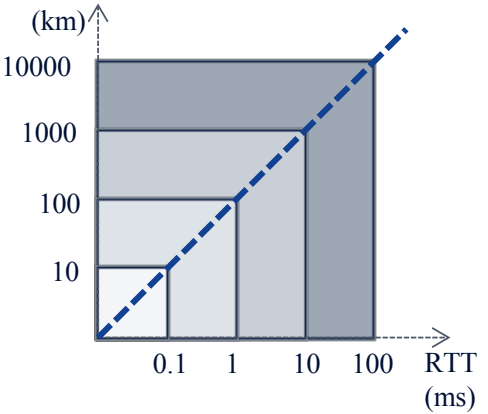
Imperceptible latency – Shift to ‘human’ control changes everything





Max tolerable networking delay

Max application delay for processing

Human response times (for reference)

Radical shift in network architecture needed to deliver required latency

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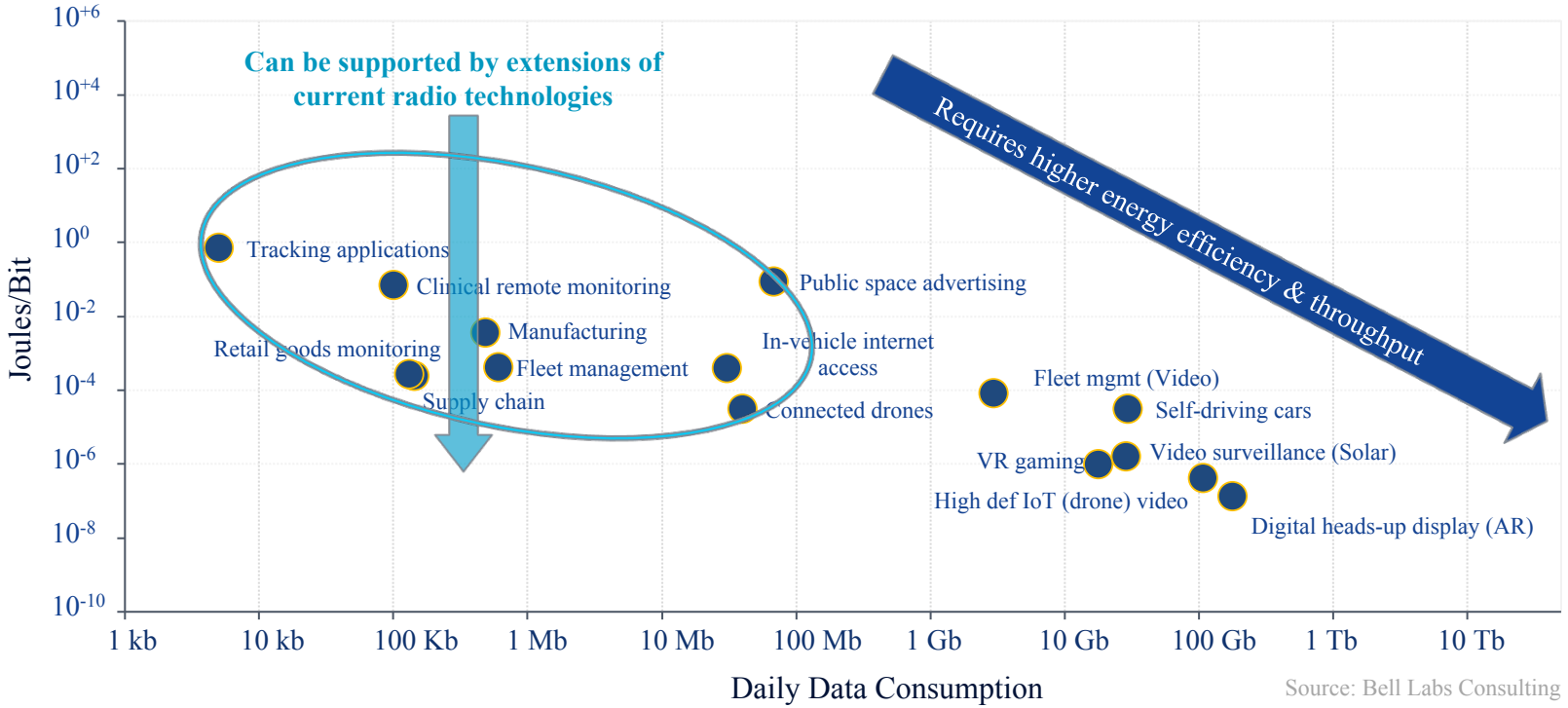
Terascale things – Expanding lifetime and throughput for IoT



Source: Bell Labs Consulting

New radio architecture required for terascale machine type communications

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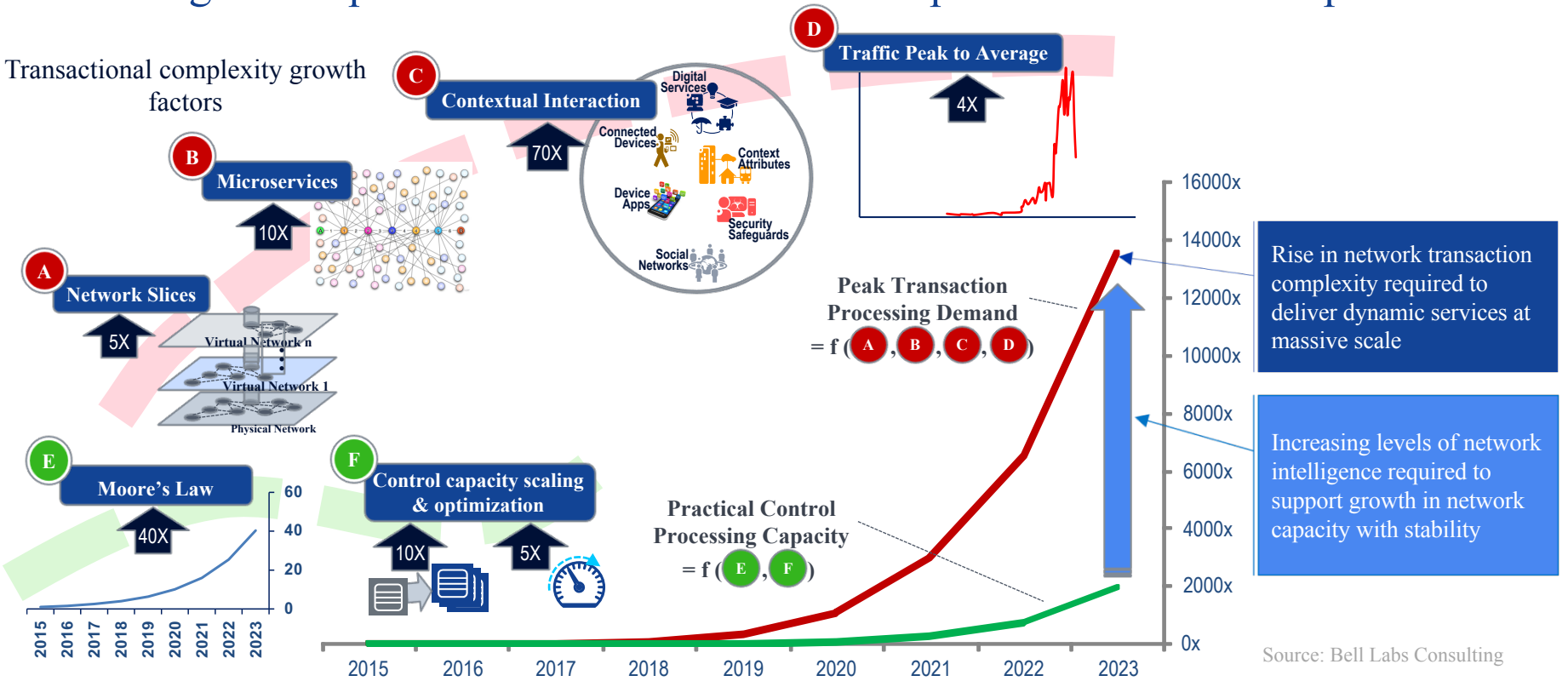
Human cognitive operation – Networks must anticipate & act at human speed



Increasing digital complexity requires cognitive control and automation

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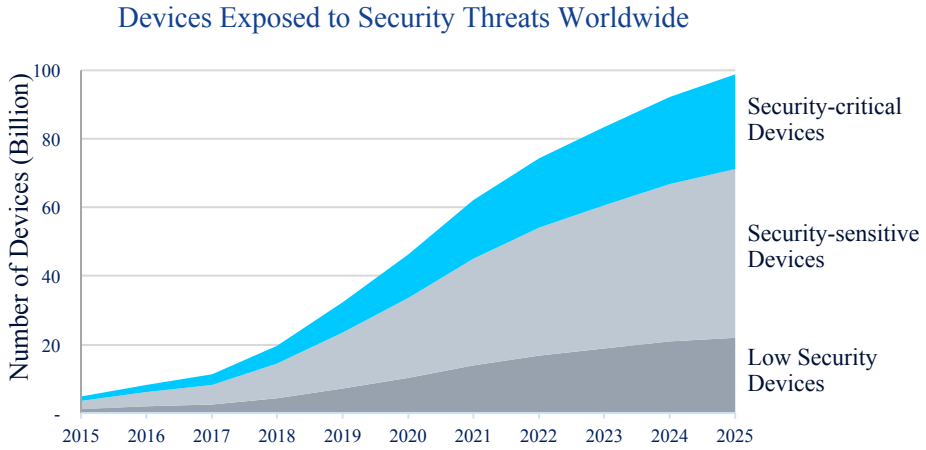
Personalized protection – Value of personal data vs. unsecured IoT world

Increasing number of data breaches triggered by the increasing value of digital data.

Low risk and high potential gain from ‘ransomware’ attacks.

Expanding threat surface due to a move from billions of smart devices to trillions of simple things that will be connected to the internet.

Future potential for disrupting industrial and infrastructure systems via network-based automation and cognitive operation systems.



Source:
Bell Labs Consulting

“Information is (only) secure when it costs more to get it than it’s worth.” *Kevin Poulsen (hacking pioneer, editor of Wired magazine)*

New approach required for scalable (trusted) data protection

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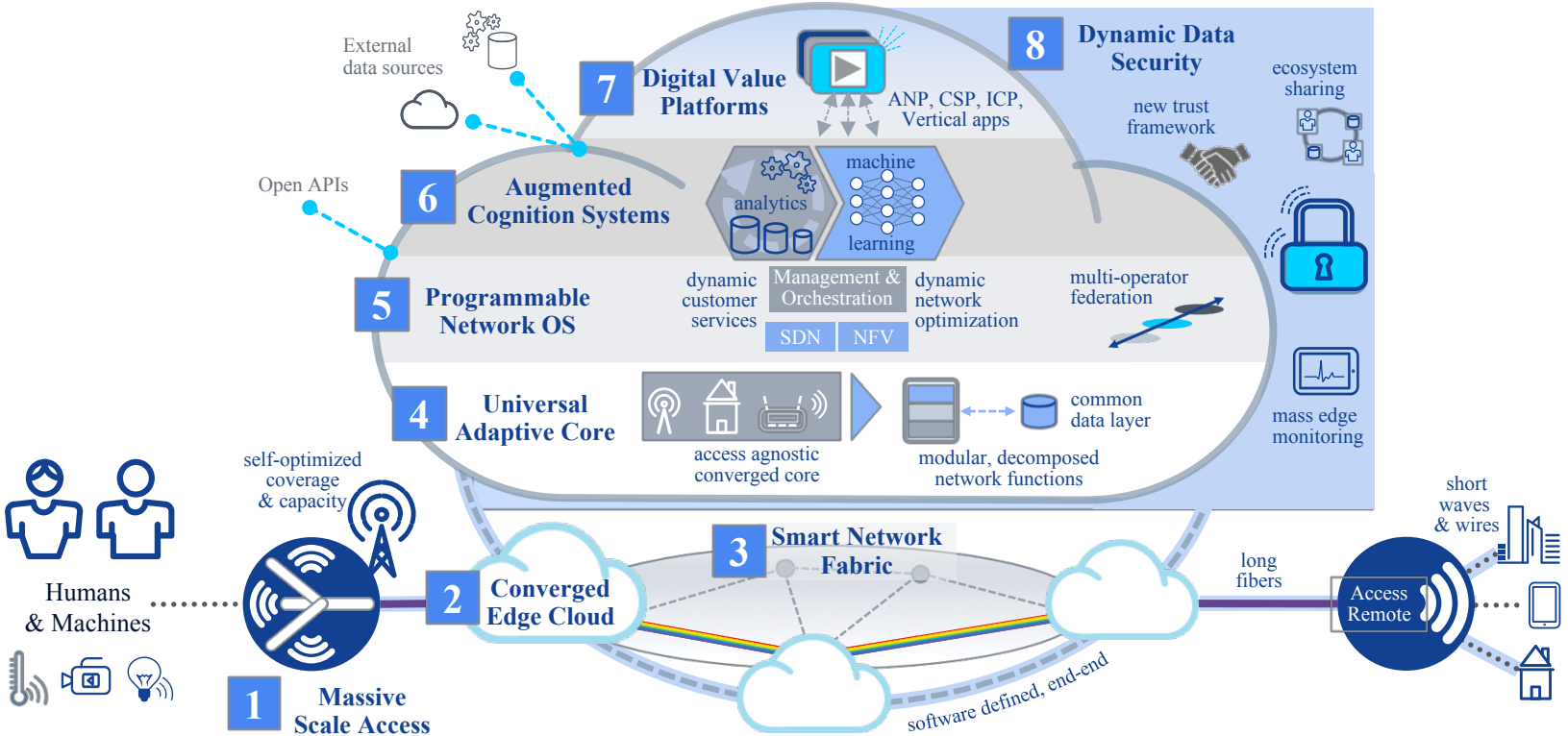
High level architecture: The Future Network Architecture



Future network: cognitive + converged + cloud-optimized network (r)evolution

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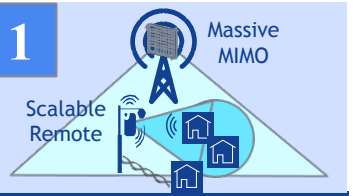
The 8 technology/architecture domains for a new digital reality

Massive Scale Access

1



The creation of ultra-small and ultra-close access nodes

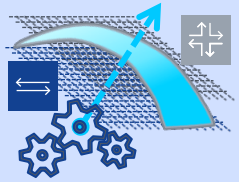
Converged Edge Cloud

The emergence of the edge cloud for low latency and high performance

2

Smart Network Fabric

3

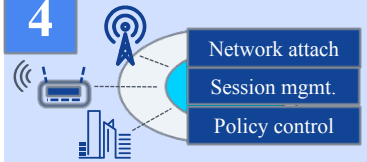


Creating dynamically reconfigurable IP + optical metro and core networks

Universal Adaptive Core

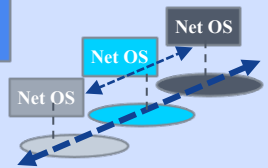
Access-agnostic core for seamless user experience

4



Programmable Network OS

5

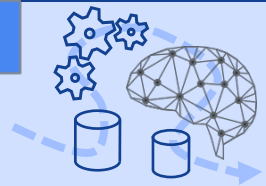


The emergence of the network OS to enable programmability and network federation

Augmented Cognition Systems

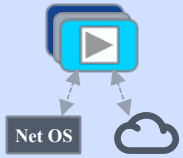
Pervasive cognitive capabilities for operating networks & systems

6



Digital Value Platforms

7



Digital value platforms augmented by advanced network capabilities

Dynamic Data Security

The emergence of new trust models & security architectures

8

Digital Trust

Adaptable Security

Future success defined by leadership in multiple domains

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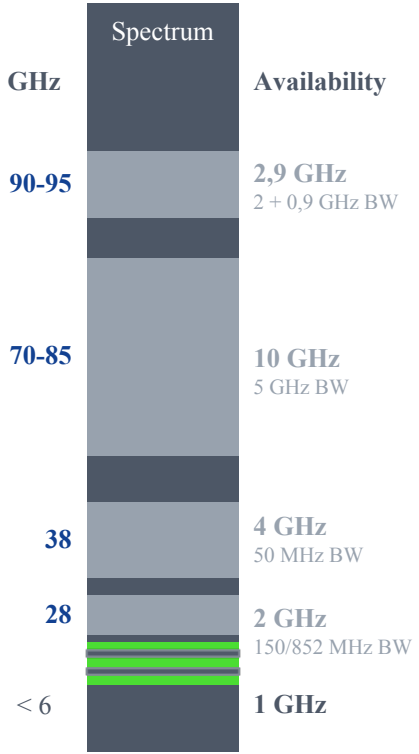
1 Massive scale access – Enabled by spatial multiplexing and new spectrum



Frequency → path loss ↑↑

Cells sizes → mmWave ↓ ✓

Dynamic TDD

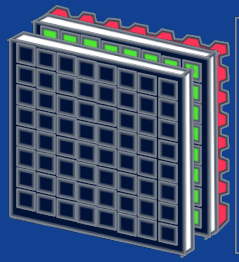
each slot usable for DL/UL/ backhaul

Latency

<1 ms

- Appropriate numerology
- Frame structure
- Variable scheduling interval << 1 ms

Massive antenna arrays to overcome propagation challenges



- ≥ 16 element arrays at base station
- Beamforming at RF
- Polarization → 2 stream MIMO
- Chip-scale array elements

High digital data rates

1-2 GHz	**20 Gbps**	**> 100 Mbps**
bandwidth	2x2 MIMO	cell edge rates

cm/mm-wave & massive antenna arrays essential enablers of ultra-capacity RAN

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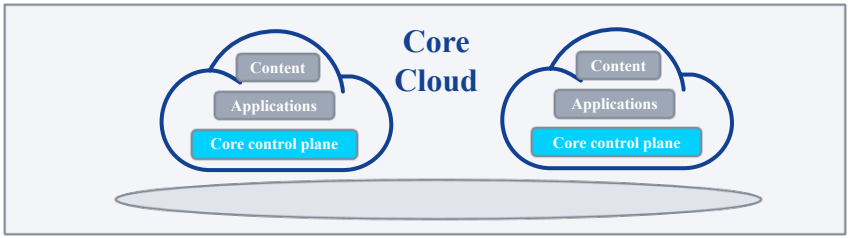
2 Converged edge cloud – driven by low latency and high performance

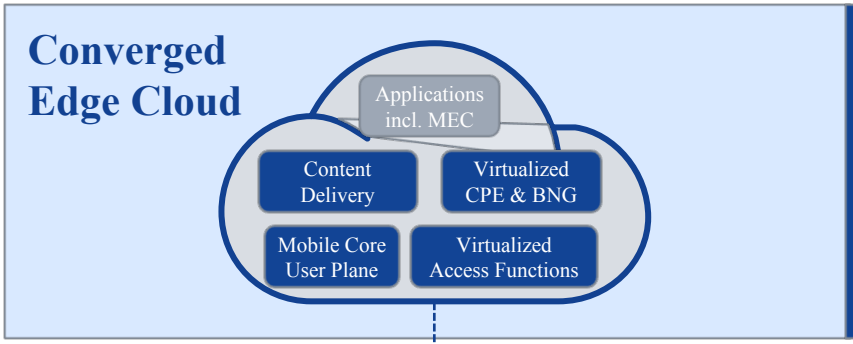
- Centralized data centers co-located with IP/optical PoPs
- 10 – 50ms latency



Unavoidable shifts in network architecture :

Distribution of key edge/core functions & applications to edge cloud to localize traffic and reduce latency

- Emerging metro data centers
- ~50k-250k subscribers (multiple/large metro)
- 1-5ms latency



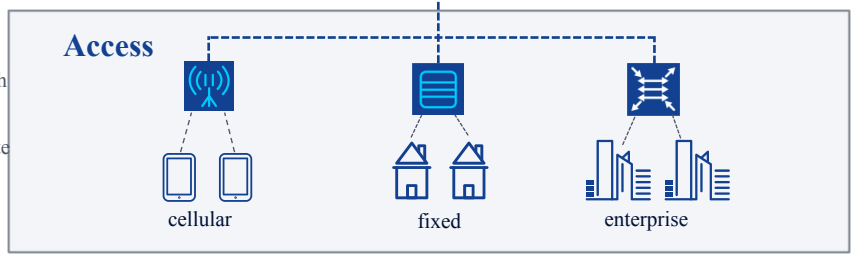
Low-latency applications

- applications and user plane functions close to the access

Massive network capacity

- scaling delivery for UHD video, VR/AR and personalized content consumption

- Ultra-capacity long-reach fiber access
- Highly distributed remote nodes



Virtualization of SW-defined access functions in edge cloud for better agility and reduced TCO

Distribution of ultra-small remote units to achieve higher data rates

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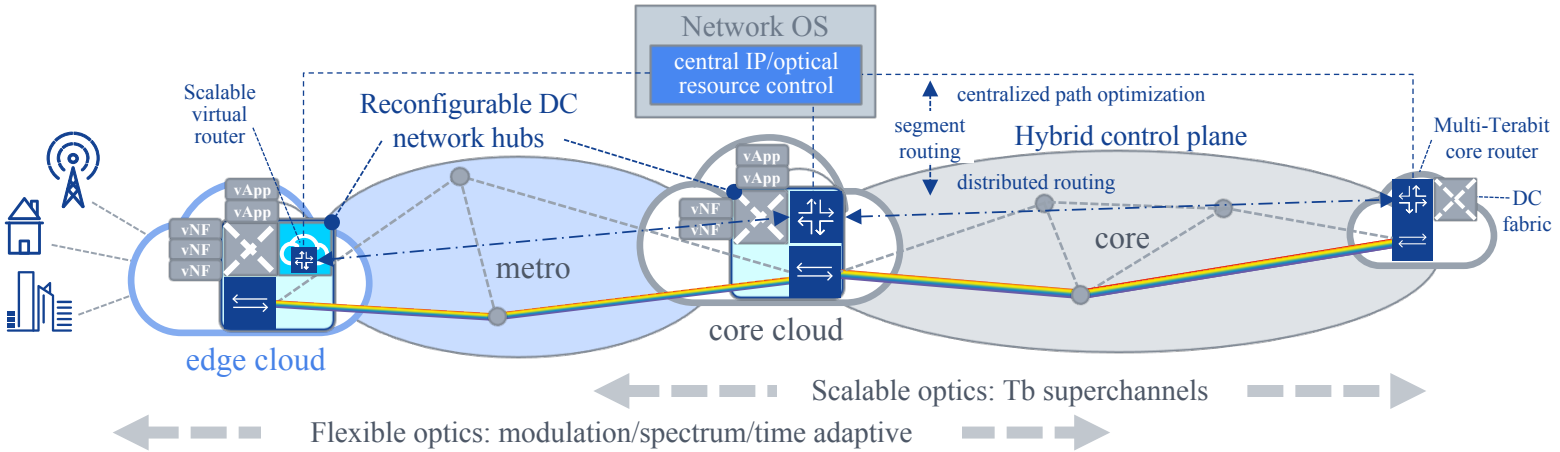
3 Smart network fabric - reconfigurable IP/optical fabric for dynamic digital delivery



Ultra-Scale Flexible Optics

- Spectral & spatial superchannels
- Spectrum-adaptive networking & fully flexible wavelength routing
- Dynamically adaptive optical-Ethernet switching

Cloud-Optimized IP Routing

- From tiny virtual routing endpoints to massive multi-Tb core routers
- Scalable hybrid control plane
- Segment routed data plane with centralized traffic engineering

Cloud-Centric Network Fabric

- Network built around new edge/ core data center hubs
- All network resources organized as programmable pools of capacity
- Network OS composition/control

Scale, flexibility, and programmability for new distributed cloud driven delivery

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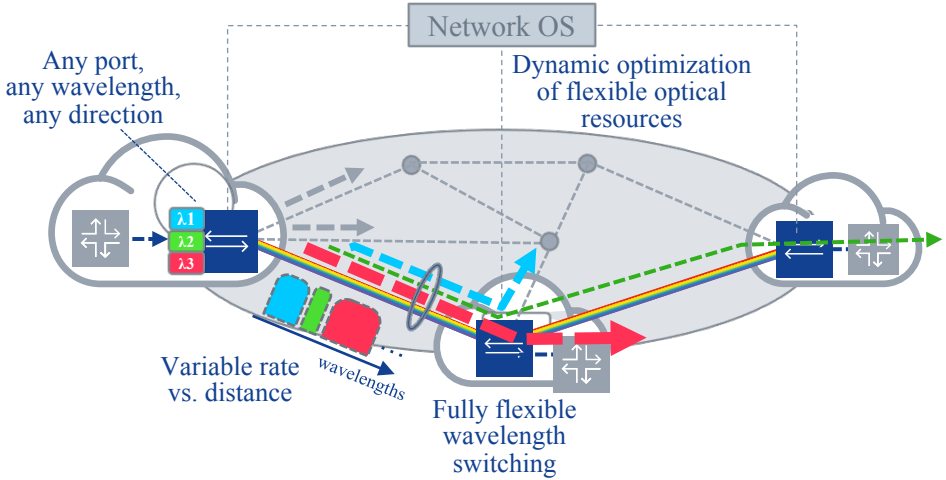
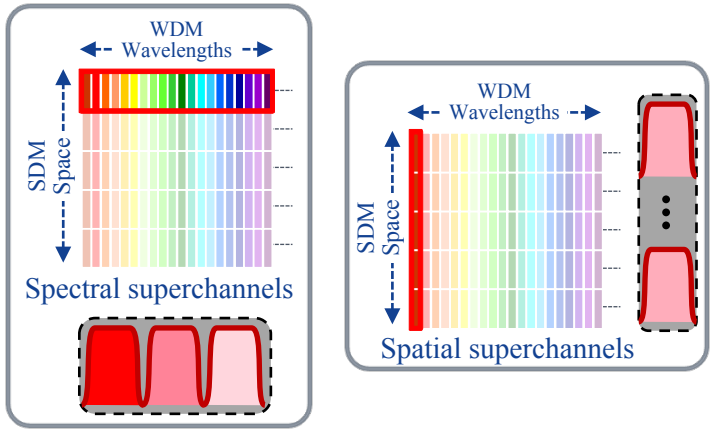
3 Smart network fabric – underpinned by flexible ultra-scale optical capacity





Superchannels aggregate spectrum for efficient very high rate interface rates

Flexible Optics Empower Programmability

- Assignable pools of optical interfaces and spectrum
- Adjust capacity vs. distance (via symbol rate, modulation order, or spectrum width), optimized at network level

Superchannels Essential to Advancing Scale

- Spectral superchannels enable Tb+ interface rates
- Spatial superchannels and component integration required for future orders of magnitude scaling

Advanced optical networking technologies fundamental to efficiently scaling the network

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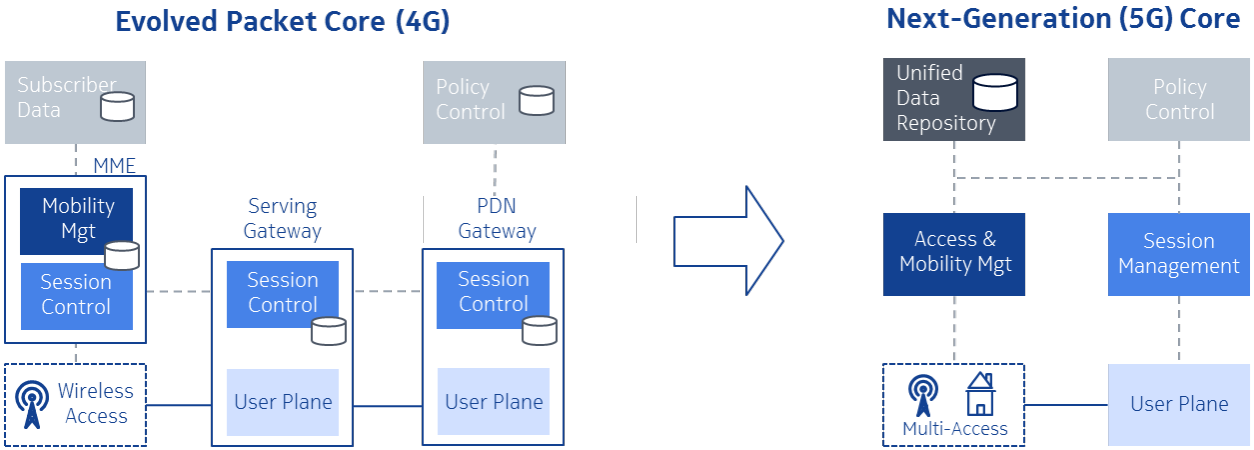
4 Universal adaptive core

Extended packet core versus future network architecture



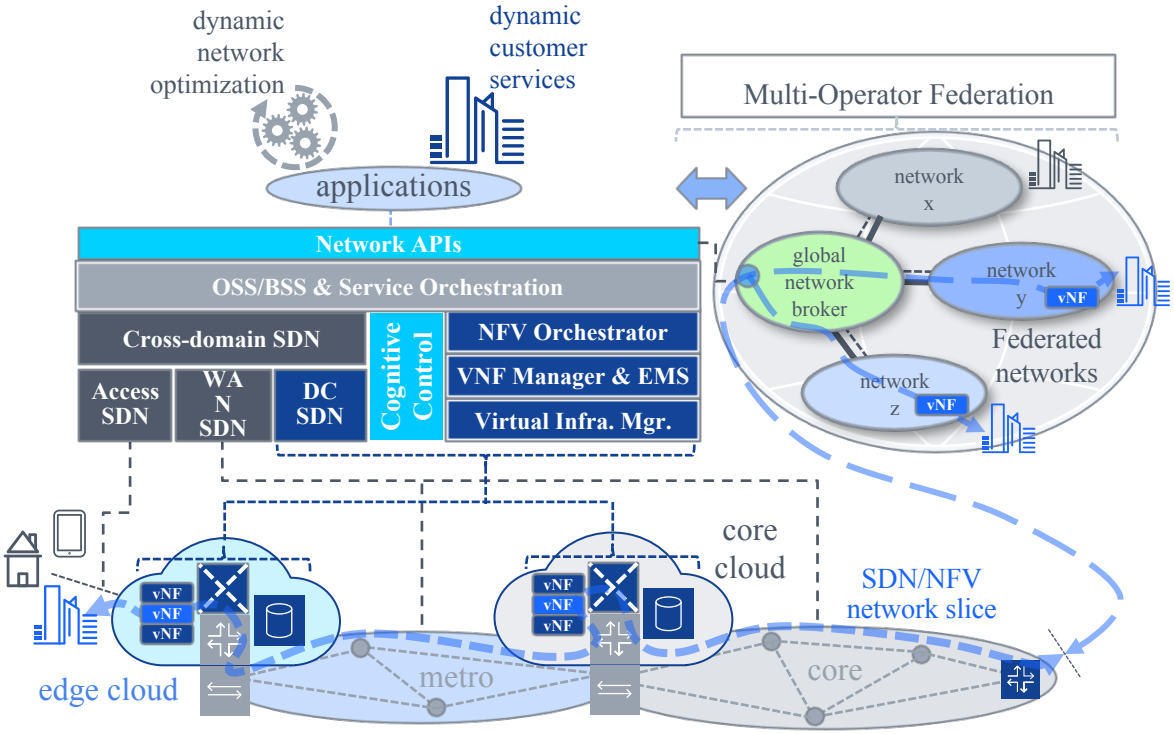
- *Radical simplification* by separating orthogonal functions — session management, access/mobility management and user plane are independent network functions to enable distributed user plane deployments for latency-critical applications hosted in edge clouds

- A *service-based architecture* allows for rapid creation of new services. Network functions will expose their capabilities as 'services' that can be consumed by any other network or application function, enabling flexible per-service software deployment.

5 Programmable Network OS – enabling multi-operator federation

Multi-Operator Federation

- Common service composition & APIs spanning multiple networks
- Unified network state & policy framework
- Enables global dynamic connectivity and network slicing services
- Via federated brokers and/or consortiums



Federation of network OS drives E2E network programmability in new global-local paradigm

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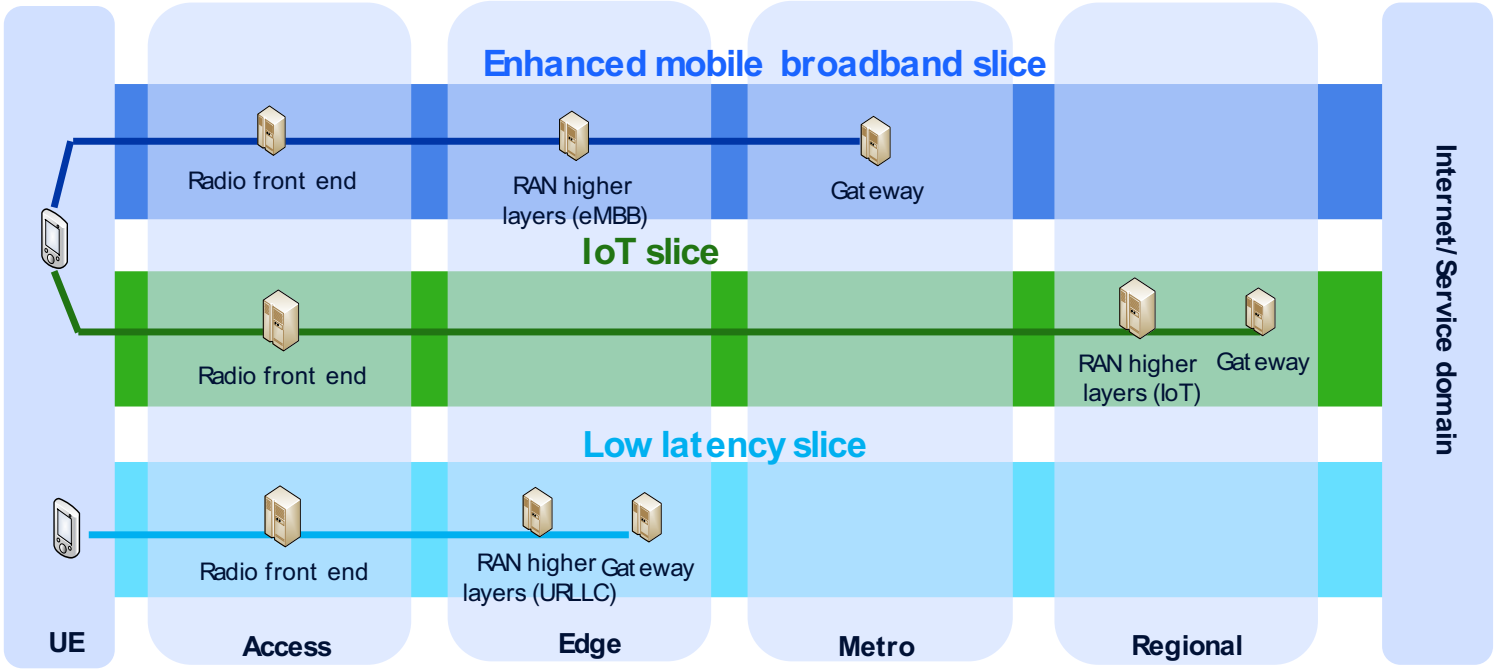
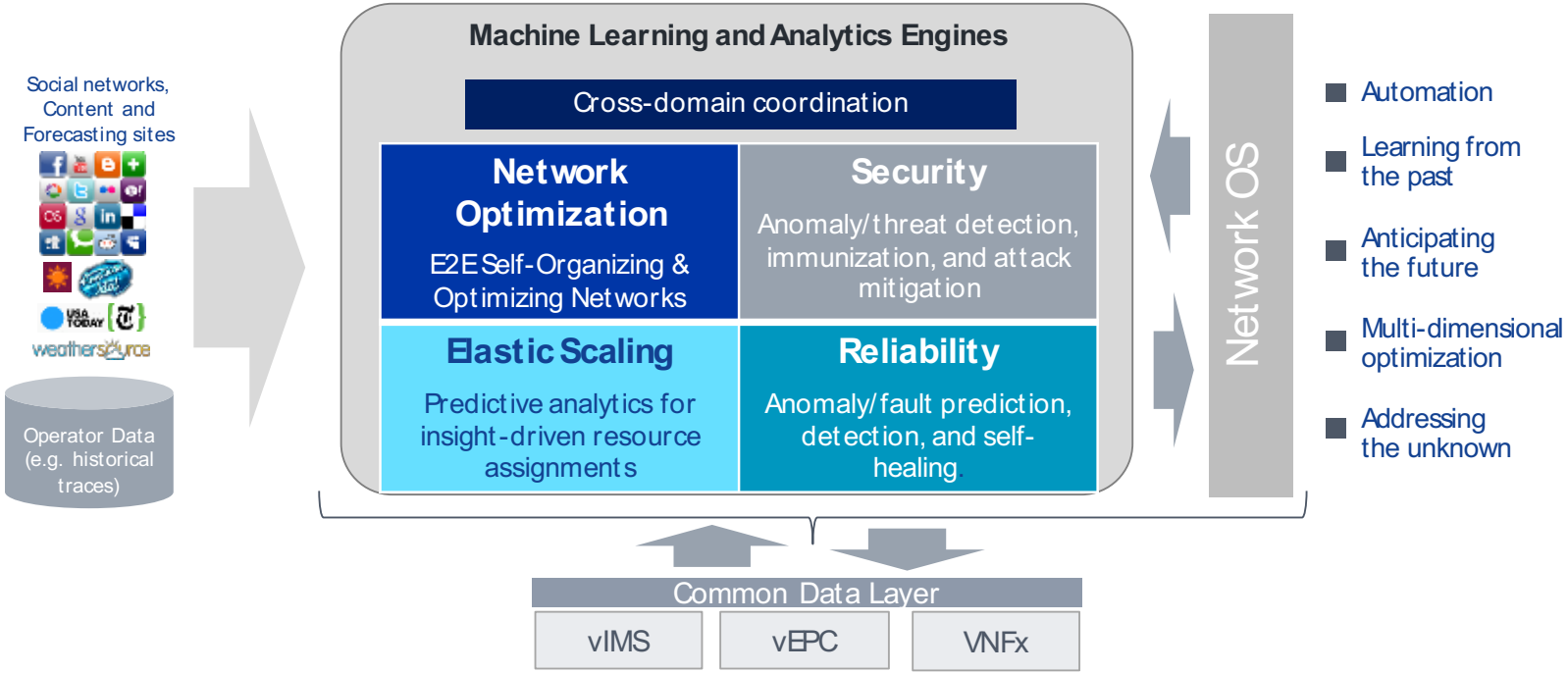
5 Network slicing

Example of network slices for different services



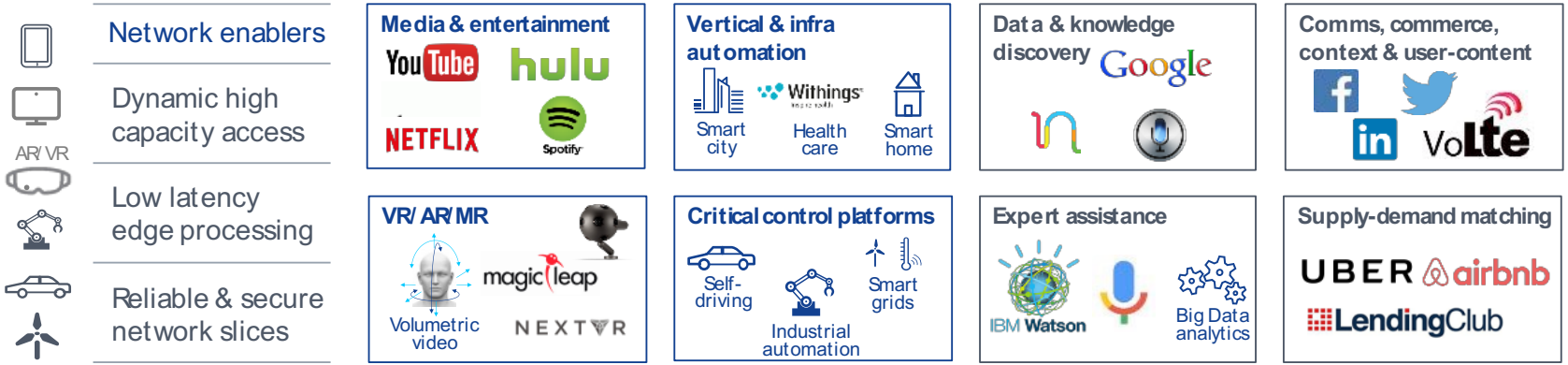
6 Augmented cognition systems

Cognitive cloud as analytics- and machine-learning-based autonomics engine



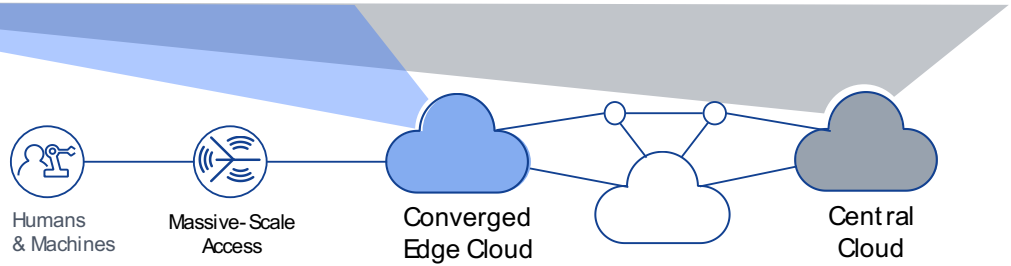
7 Digital value platforms

Types of existing and future digital value platforms



Combining local delivery with global reach

- Service performance with local customization
- Innovative and disruptive business models
- New players in global-local value networks



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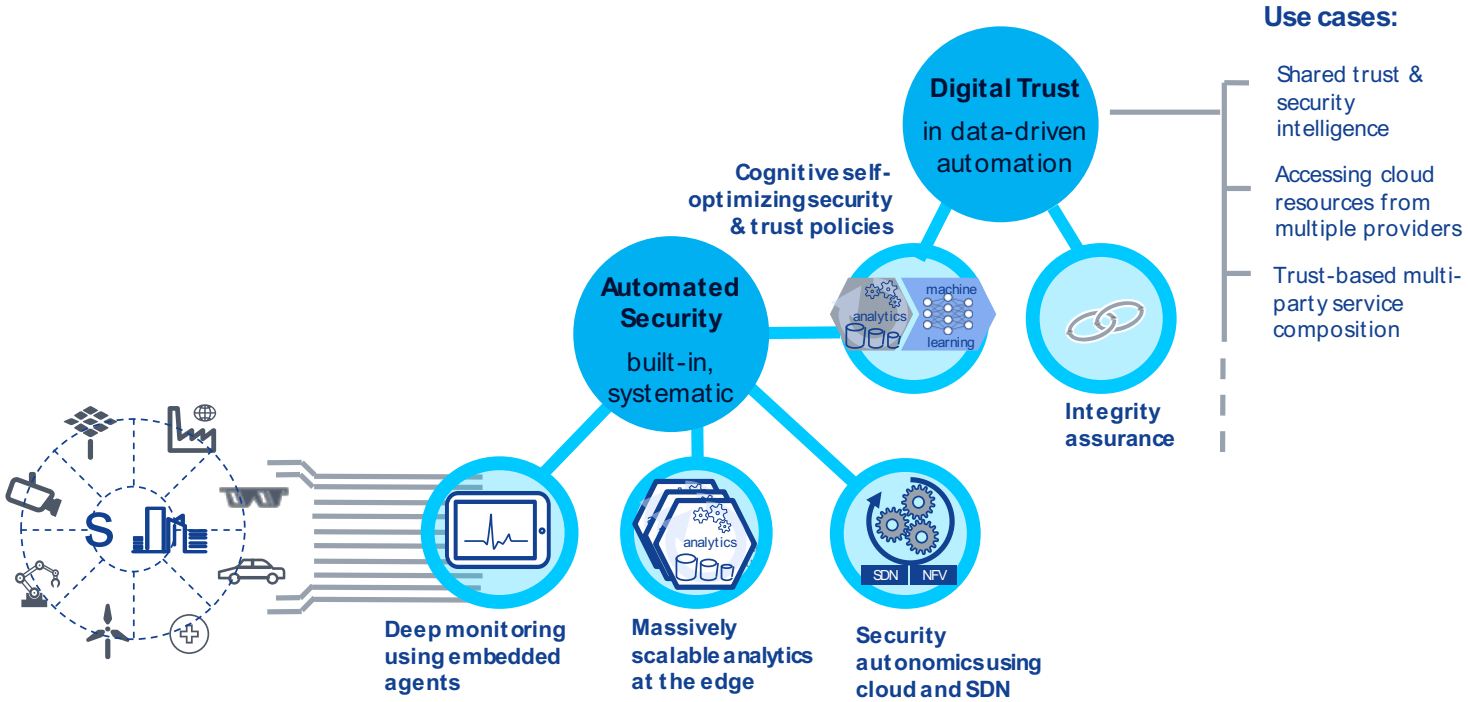
8 Dynamic data security

Dynamic data security based on digital trust and automated security



Major research challenges

- Exploration and exploitation of centimeter and millimeter wave frequency bands
- Massive antenna arrays and use of carrier aggregation techniques across available frequency bands
- Means for spectrum sharing and co-existence

- Low latency requires: New network architecture with edge clouds close to the end user and centralised clouds with flexible function split, optimisation of radio interface, RAN and core processing
- Use of network analytics, big data and artificial intelligence/machine-learning, neural networks and quantum computing to enable complex network management and automation
- Optimisation of network protocols beyond the today's Internet protocol to meet new requirements

- New security mechanisms as part of the overall system design from the start

- Software technology for efficient and secure implementation

- Optical communication:
  - Scalability and programmable flexibility of optical links
  - Tunable wavelength
  - Variable modulation schemes
  - Approaching limits in optical transmission by exploiting all dimensions amplitude, phase, polarisation of light, frequency and space

- Energy efficient devices, systems and protocols

- Chip architecture design and implementation for high processing power