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ERICSSON'S 5G NETWORK RESEARCH

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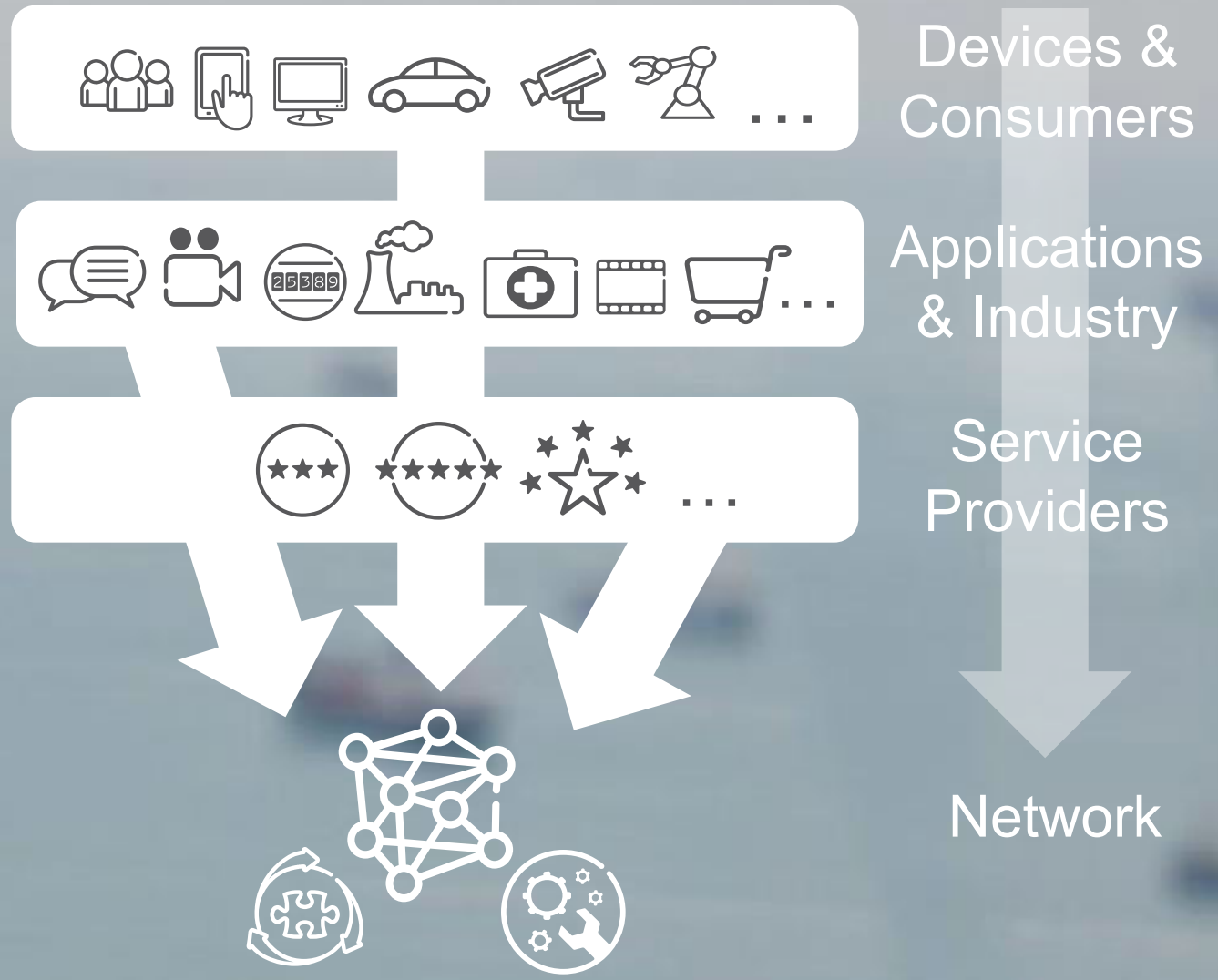
DEMAND 2020


25389
Devices & Consumers
Applications & Industry
Service Providers
Network

INDUSTRY TRANSFORMATION

Traditional Industries

Digitalize & Mobilize

Transformed Industries

5G USE CASES

SENSORS EVERYWHERE

BROADBAND AND MEDIA EVERYWHERE

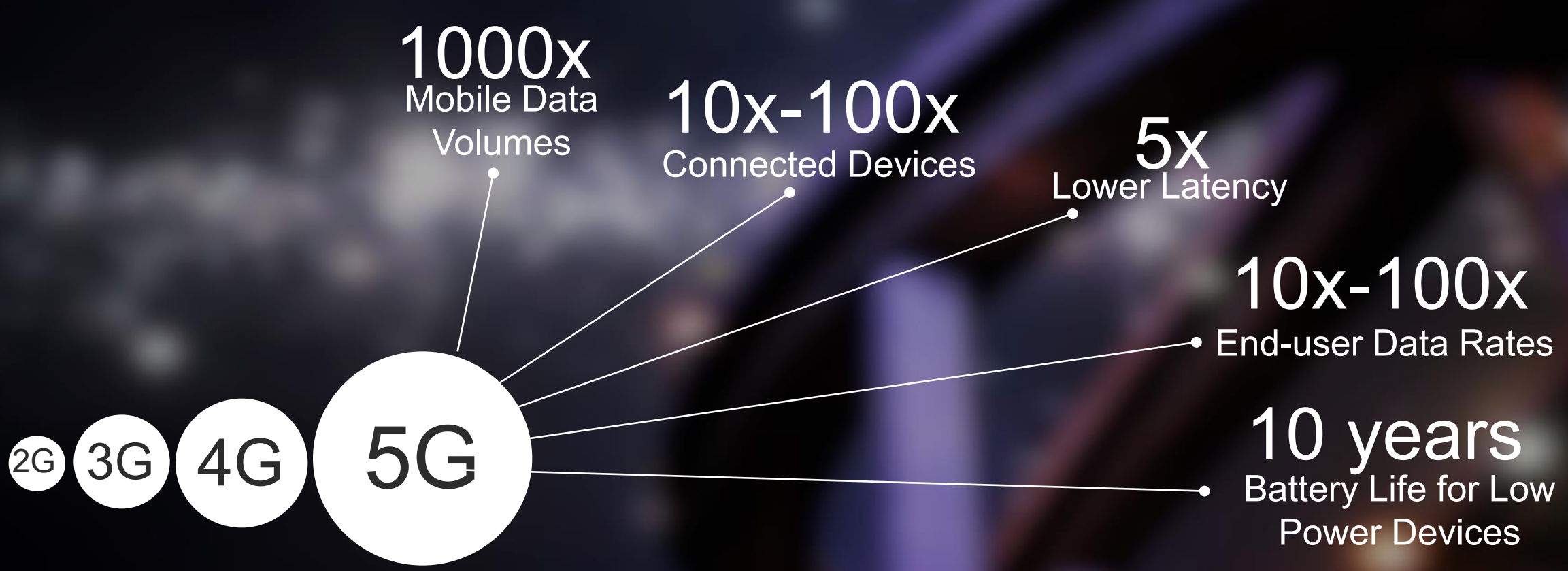
SMART VEHICLES, TRANSPORT

INFRASTRUCTURE, MONITOR AND CONTROL

CRITICAL CONTROL OF REMOTE DEVICES

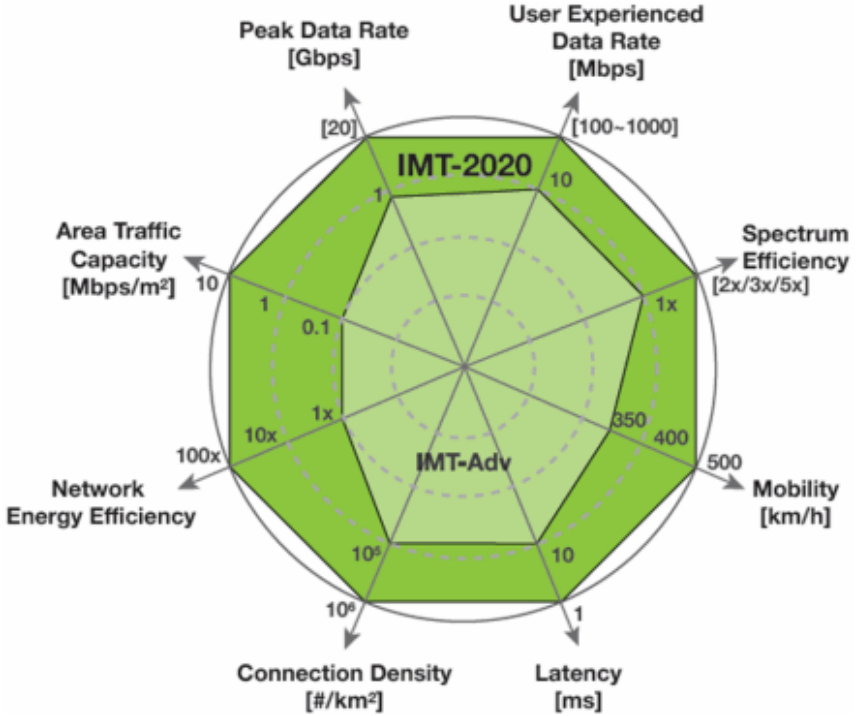
INTERACTION HUMAN-IOT

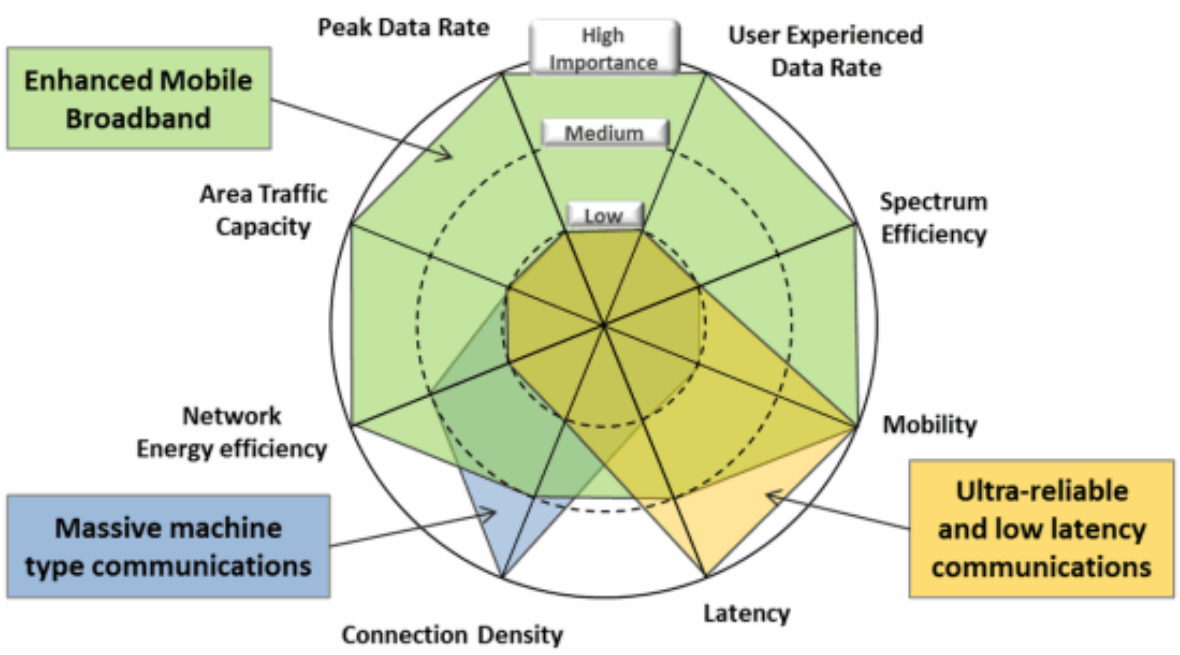
EVOLUTION TOWARDS 2020



Source: METIS, Ericsson AB

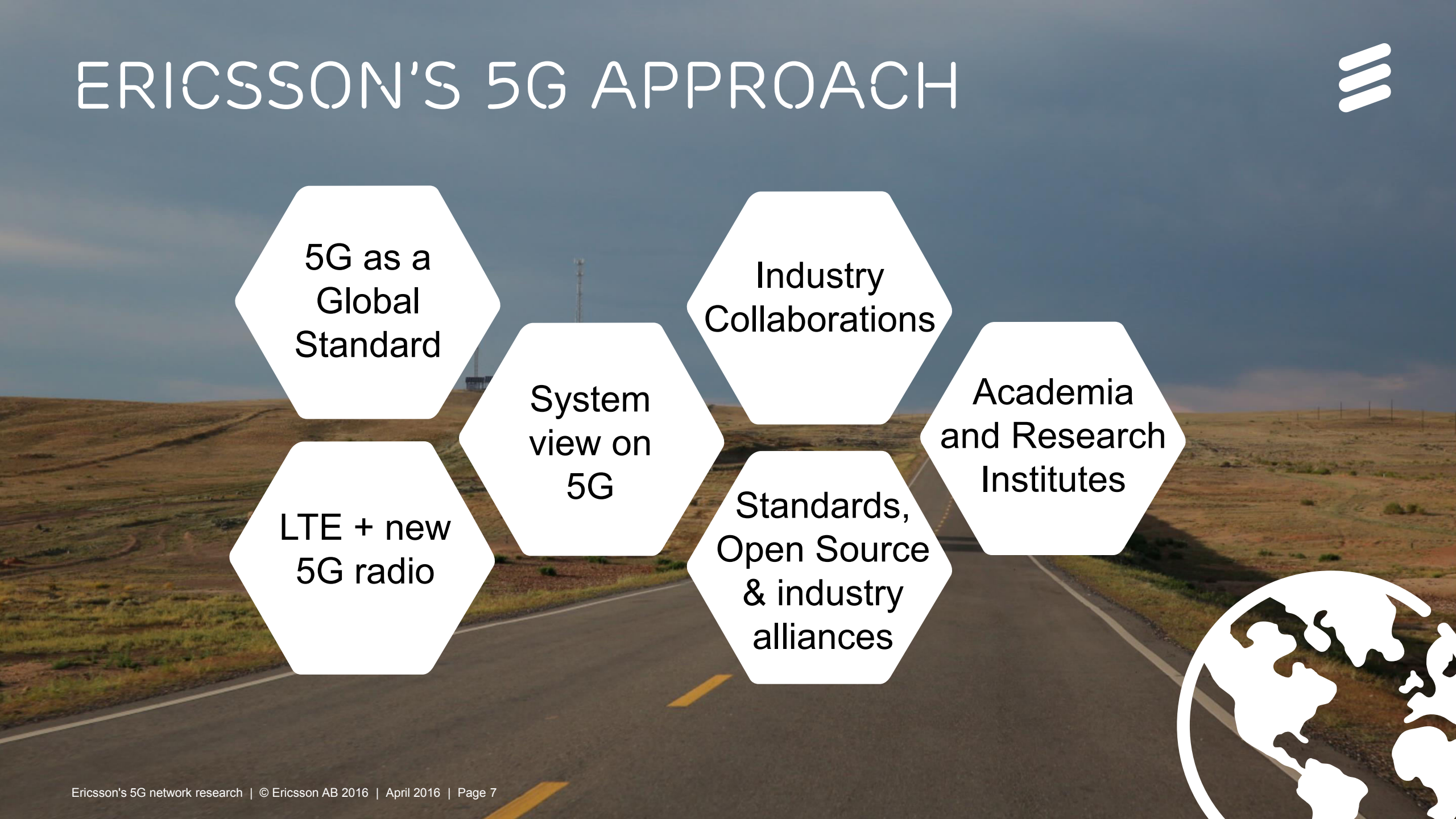
5G REQUIREMENTS





3GPP requirements expected in end-2016
IMT-2020 requirements expected finalized in mid-2017

ERICSSON'S 5G APPROACH



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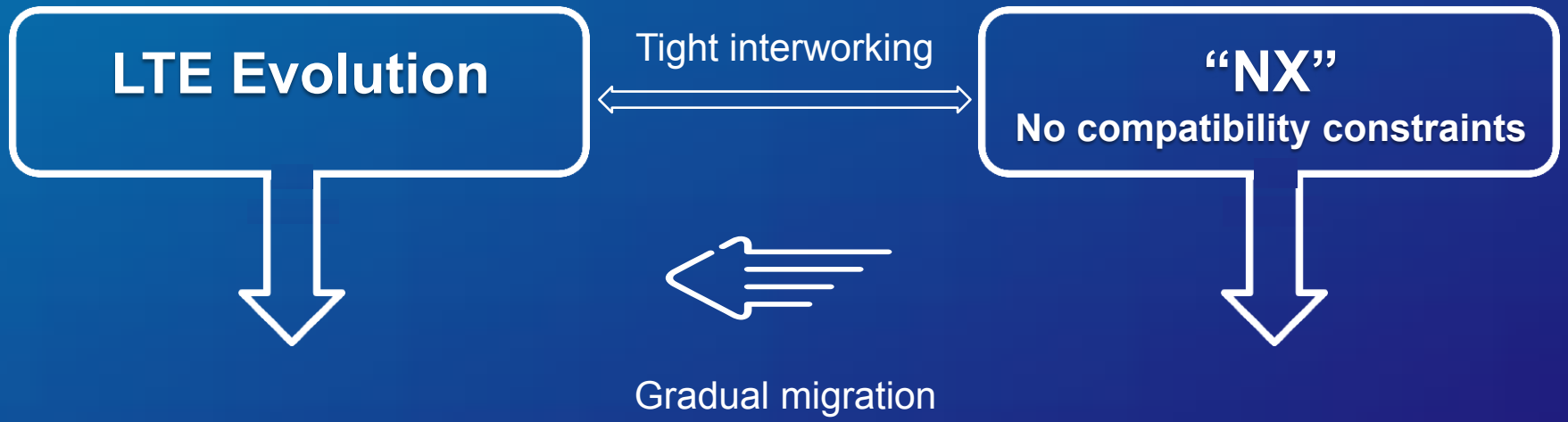
5G RADIO CONCEPT

5G RADIO ACCESS ~2020



"Existing" spectrum

Below 6 GHz

"New" spectrum

Above 6 GHz
New spectrum below 6 GHz

NX – KEY TECHNOLOGY FEATURES
MANY ALSO APPLY TO LTE EVOLUTION

Flexible, scalable and future-proof design

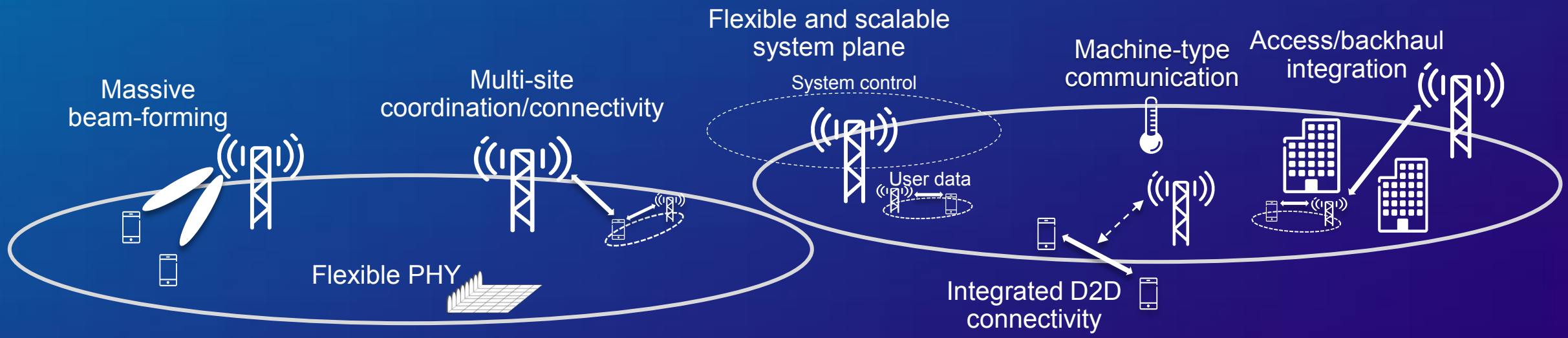
Spectrum

Deployment

Use cases

Ultra-lean design

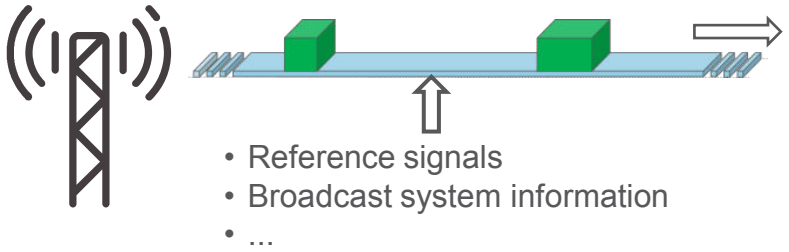
Energy efficient: minimize network transmissions not directly related to user data delivery



ULTRA-LEAN DESIGN

Minimize network transmissions not directly related to user-data delivery

Today



- Reference signals
- Broadcast system information
- ...

Ultra-lean

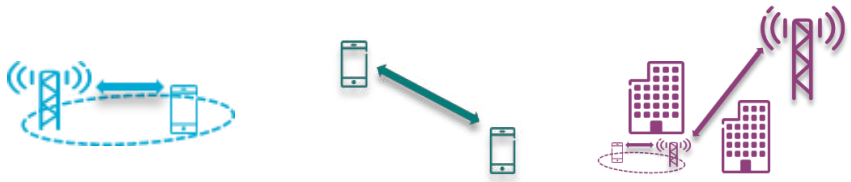
- No ”always-on” refeference signals
- Minimum amount of ”always-broadcast ”system information
- ...

- Higher achievable data rates
- Enhanced network energy performance
- Future-proof design

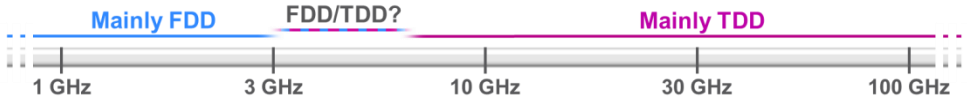
NX PHY DESIGN

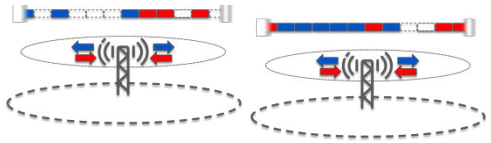
High degree of symmetry

- Low-power base stations similar to devices
- Integrated D2D and radio based backhaul



Access schemes

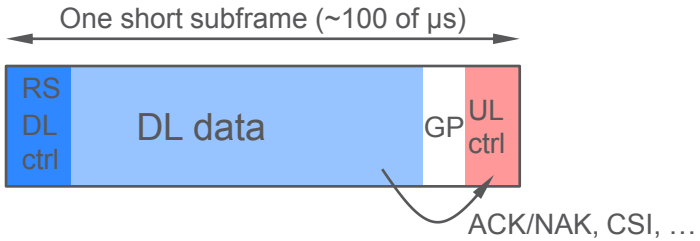




Time-domain structure

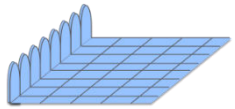
- Physical mapping enabling fast detection/decoding
- Self-contained subframes
- Avoid strict timing relations between subframes

Example: TDD

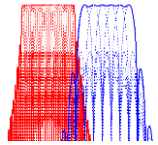


Waveform

- OFDM with flexible numerology



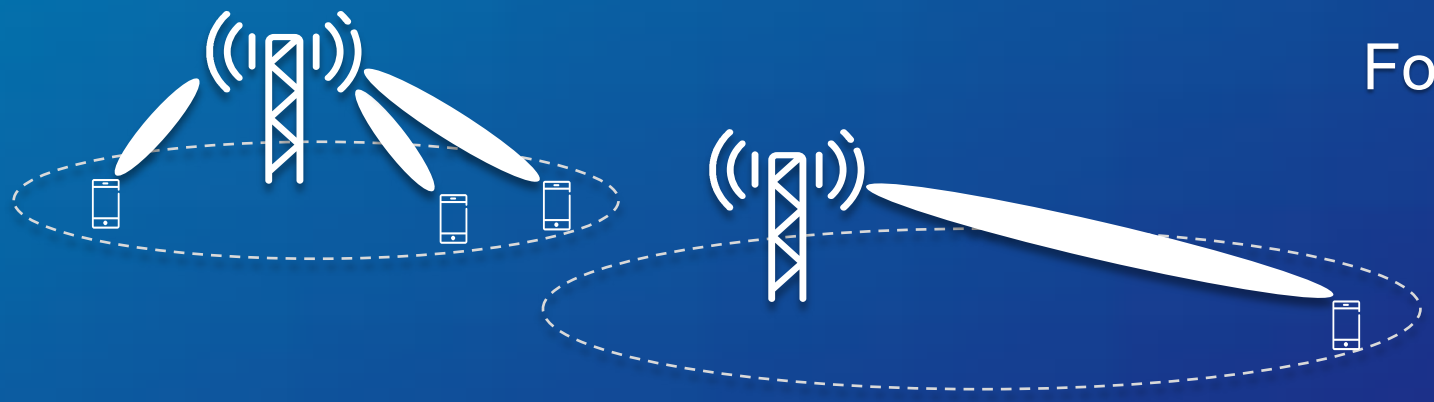
OFDM



Mixed numerology

BEAMFORMED TRANSMISSION

To enable the capacity, data rate, and coverage needed in the 5G era



For both high and low frequencies

For both NX and LTE

Beam-centric NX design

- Self-contained data transmissions
- “Beam mobility” – mobility between beams rather than nodes
- System plane matched to beam-formed user plane

ACCESS/BACKHAUL INTEGRATION

Today: Extensive use of radio backhaul

- Line-of-sight links to macro sites using dedicated technology in dedicated high-frequency spectrum

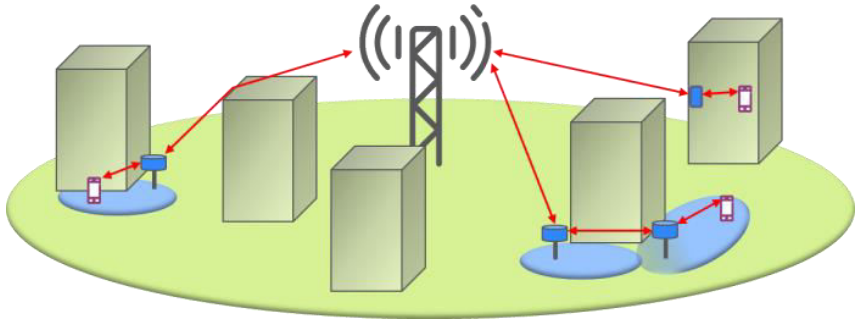
Tomorrow: Large number of low-power nodes

- Wireless backhaul must extend to non-LOS conditions
- Access link will extend to higher frequencies

Access and backhaul are becoming more similar

Access/Backhaul integration

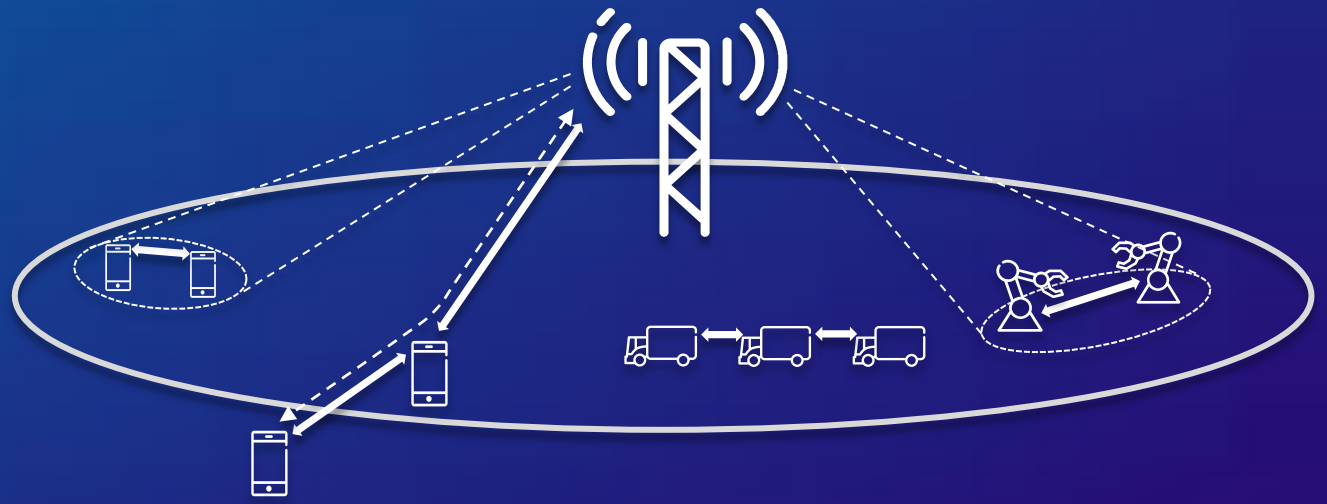
- Same technology for access and backhaul
- Joint spectrum pool for access and backhaul



- More efficient utilization of available spectrum
- Reduced operation and maintenance effort

DEVICE-TO-DEVICE CONNECTIVITY

- Device-to-device connectivity as a further step of extreme densification
- An integrated part of the overall radio-access network
- Under network control
- When beneficial from an efficiency or service-level point-of-view



HIGH FREQUENCY CHARACTERISTICS

Propagation

Diffraction

Outdoor-to-indoor penetration

Rain/atmospheric attenuation

(Less of an issue for small cells)

Body loss

Regulation

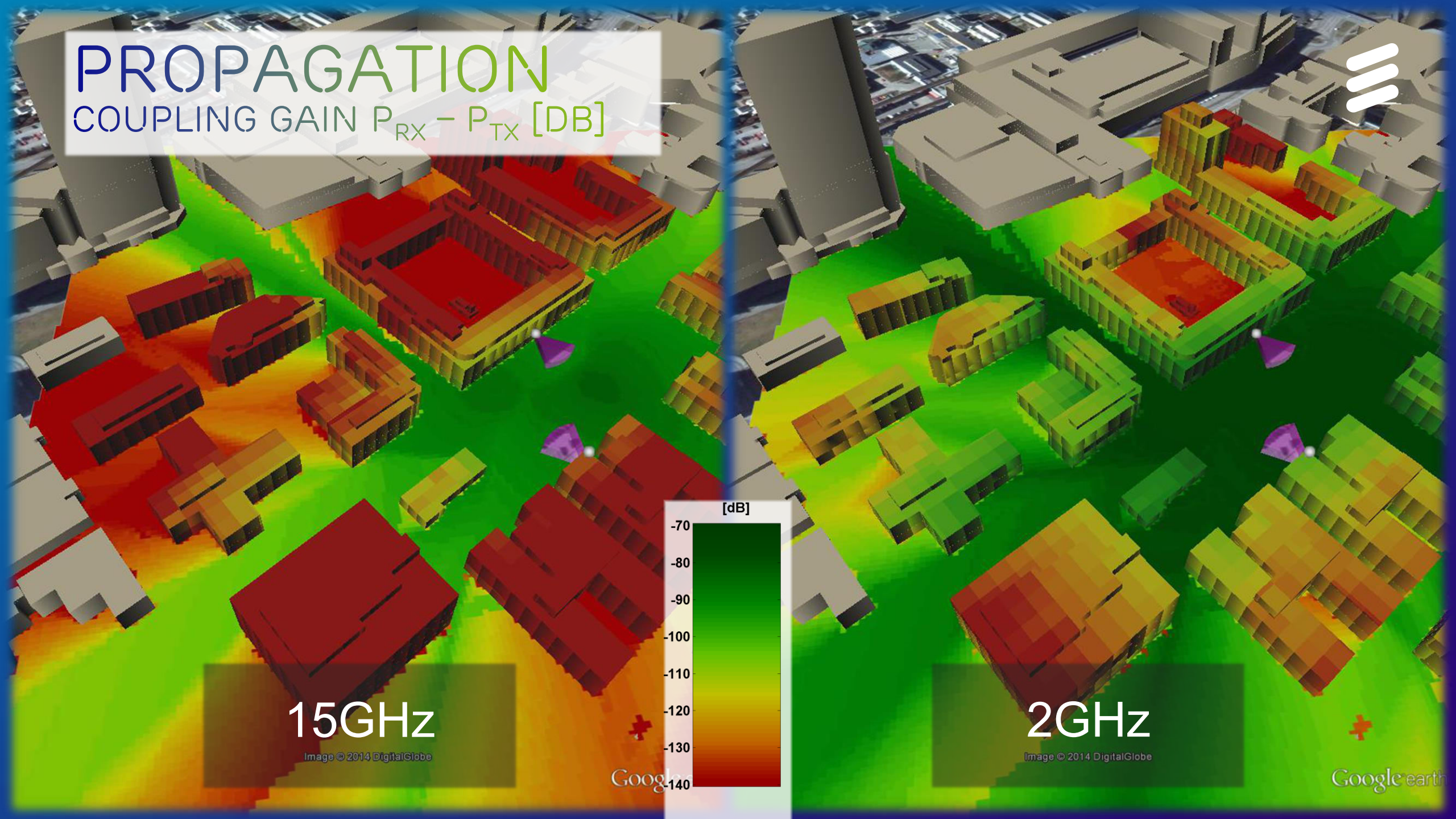
Tx power limitations above 6 GHz

Implementation

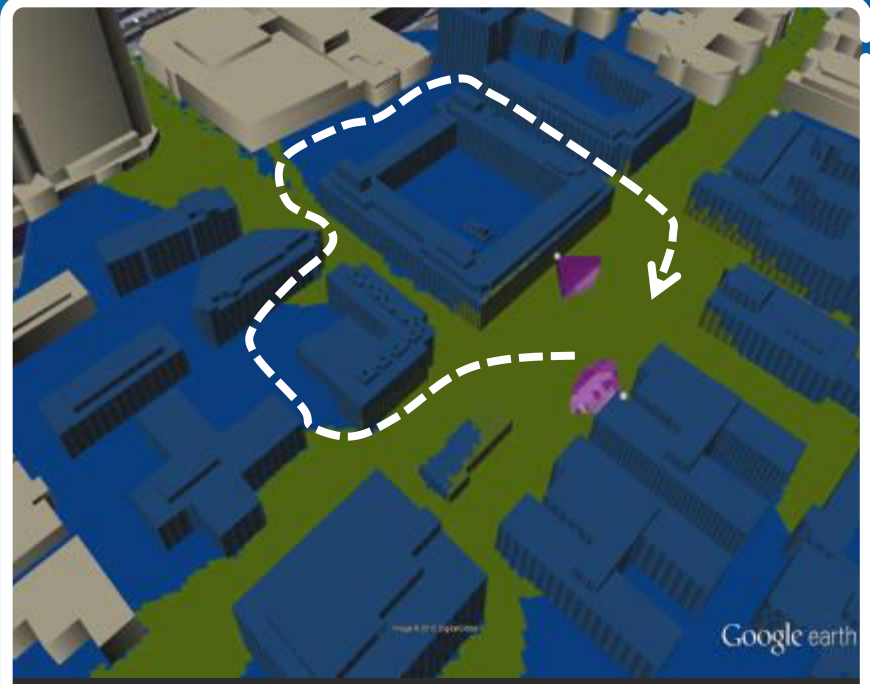
Efficiency, dynamic range, output power, antenna element size, …

PROPAGATION

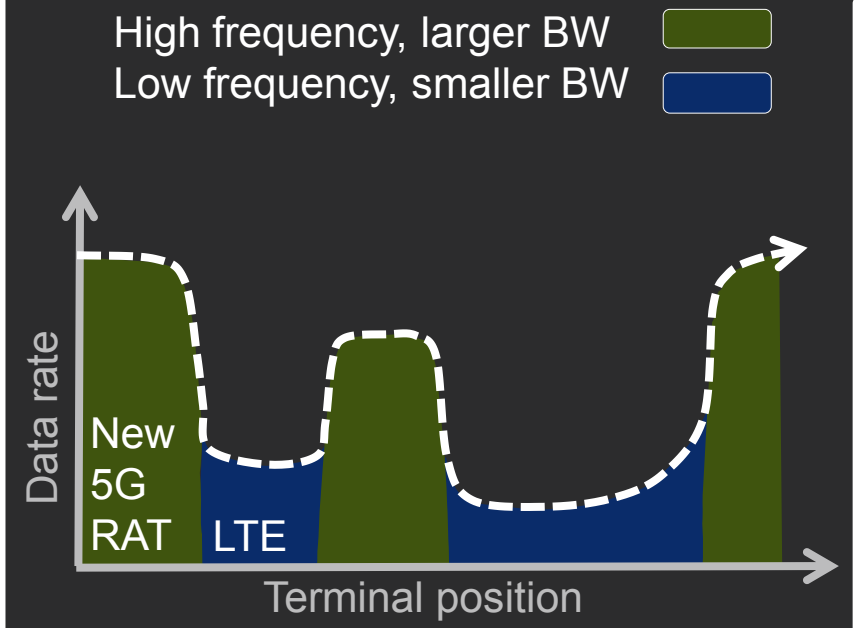
COUPLING GAIN $P_{RX} - P_{TX}$ [DB]



NX/LTE INTERWORKING



Example of possible RAT selection

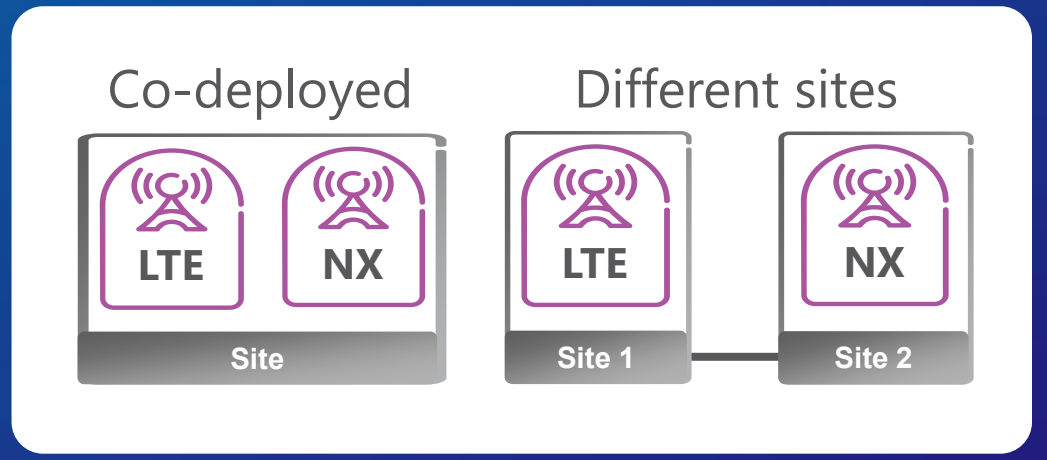


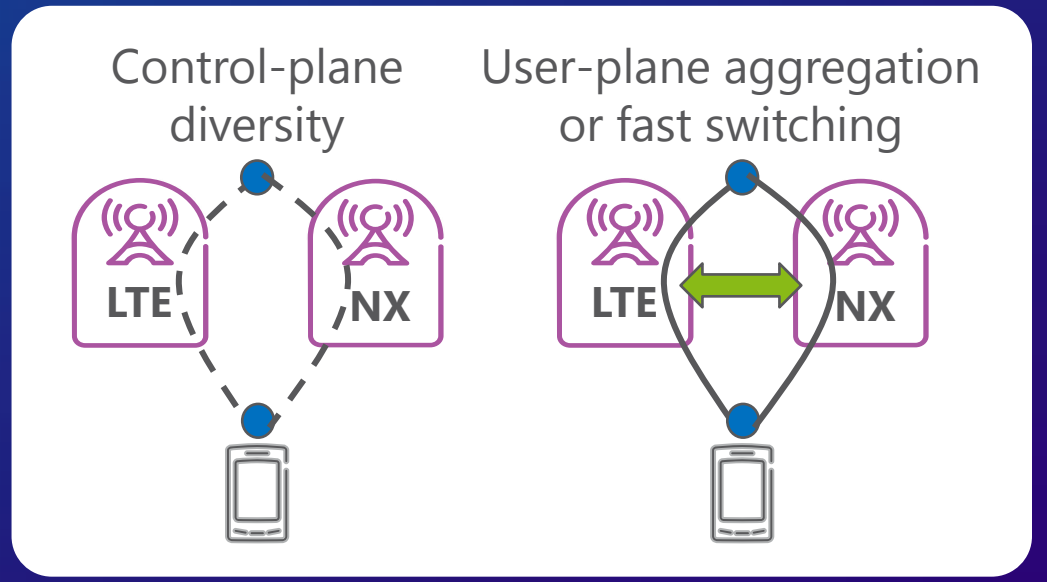
Combining low and high frequencies essential for end user experience

Tight interworking between LTE and NX is key to great end user experience

NX/LTE INTERWORKING

- Leverage LTE deployments when deploying NX on the higher frequency ranges
  - Coverage and performance reasons
- Support co-sited and non-co-sited deployments
- Supported using dual connectivity solutions
  - excellent mobility support using control-plane diversity
  - high user-plane throughput using user-plane aggregation or fast switching (depending on the scenario)





WIDE RANGE OF REQUIREMENTS

MASSIVE MTC

SMART BUILDING

LOGISTICS, TRACKING AND FLEET MANAGEMENT

SMART METER

SMART AGRICULTURE

CAPILLARY NETWORKS

CRITICAL MTC

REMOTE HEALTH CARE

TRAFFIC SAFETY & CONTROL

INDUSTRIAL APPLICATION & CONTROL

REMOTE MANUFACTURING, TRAINING, SURGERY

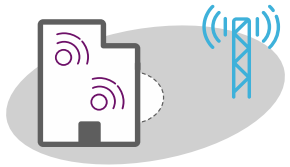
LOW COST, LOW ENERGY
SMALL DATA VOLUMES
MASSIVE NUMBERS

ULTRA RELIABLE
VERY LOW LATENCY
VERY HIGH AVAILABILITY

SOLUTIONS FOR CELLULAR IOT

GSM-EC

Global solution for Cellular IoT



Supported on legacy GSM equipment

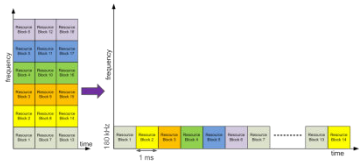
Leverage existing module eco-system

NB-IoT

Scalable ultra low-end Cellular IoT solution

Ultra-low bit rates & extreme coverage

Native narrowband LTE solution



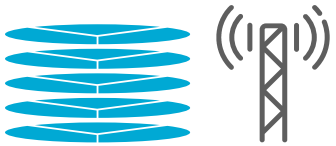
Part of LTE evolution to 5G

LTE CAT-M

Broadest range of Cellular IoT capabilities

Wide range of bit rates enabling advanced applications

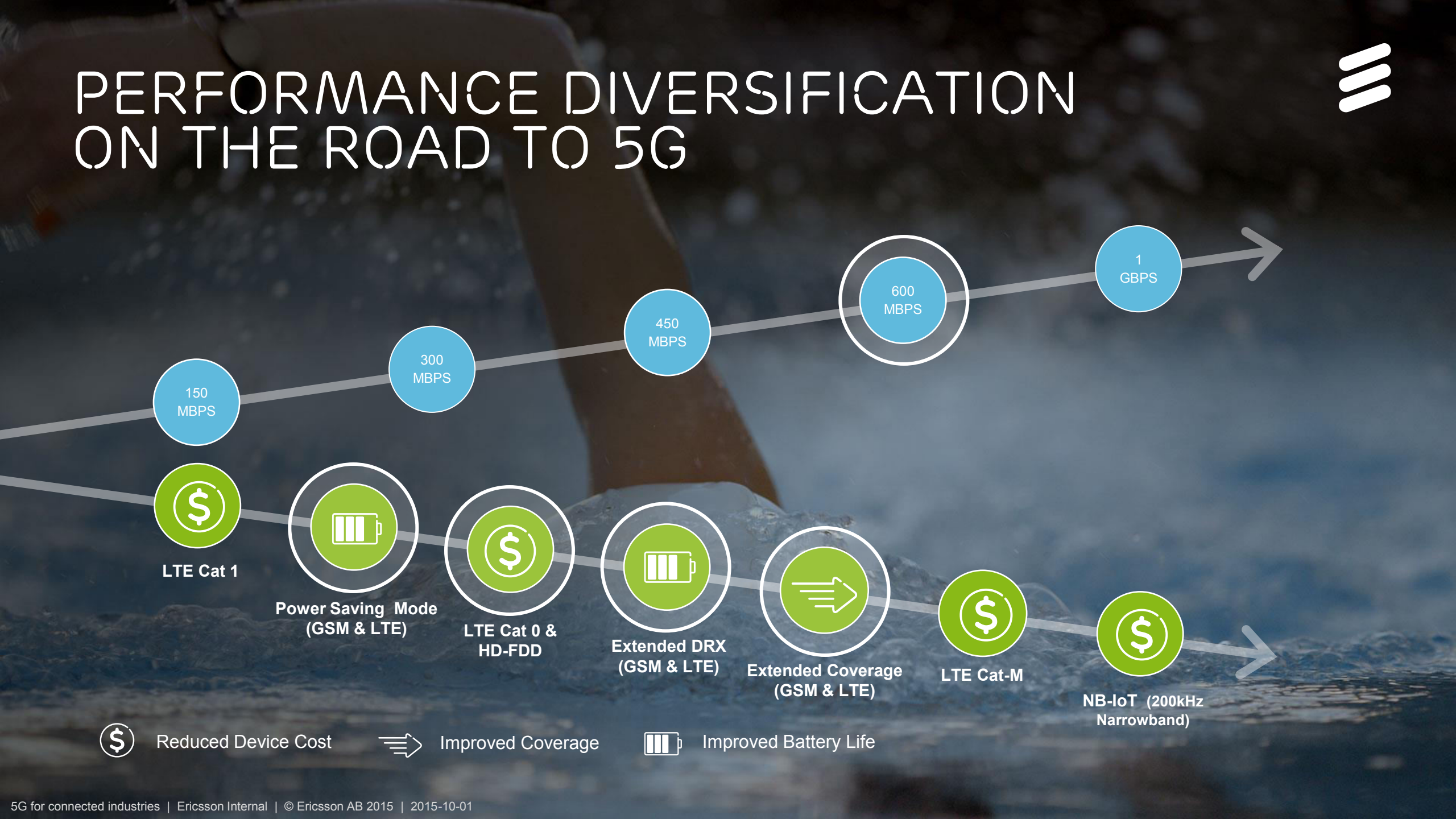
Efficient co-existence with MBB traffic



- Reduced Device Cost
- Improved Coverage
- Improved Battery Life

OPERATE AS ONE NETWORK

PERFORMANCE DIVERSIFICATION ON THE ROAD TO 5G

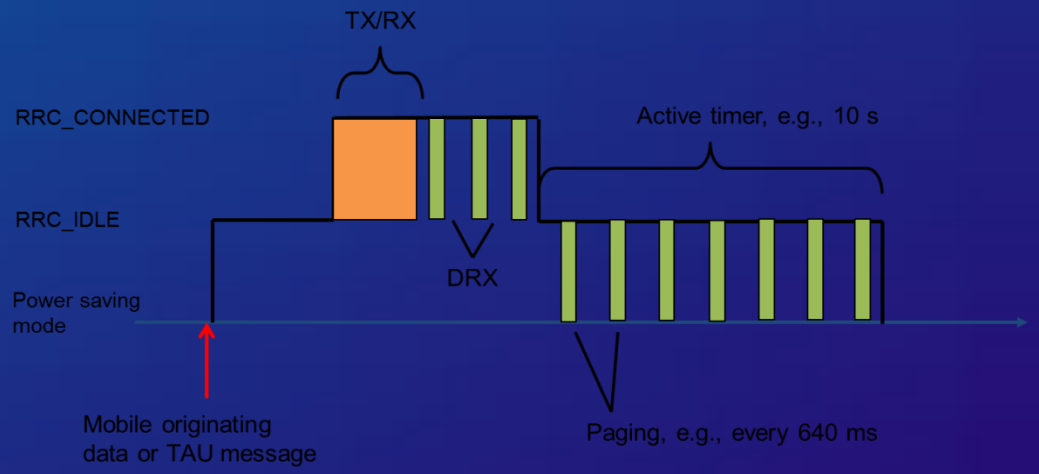


DEVICE ENERGY EFFICIENCY

- Example: LTE Rel-12 power-saving mode
  - UE performs periodic tracking area update (TAU) after which it stays reachable for paging during a configurable time
  - Otherwise the UE stays in a power-off like mode, not reachable, but still registered

Reachability (TAU cycle)	UL data inter-arrival time		
	15 min	1 hour	3 hour
15 min	9.2 years	10.0 years	10.2 years
1 hour	9.2 years	16.1 years	16.7 years
3 hour	9.2 years	16.1 years	19.4 years

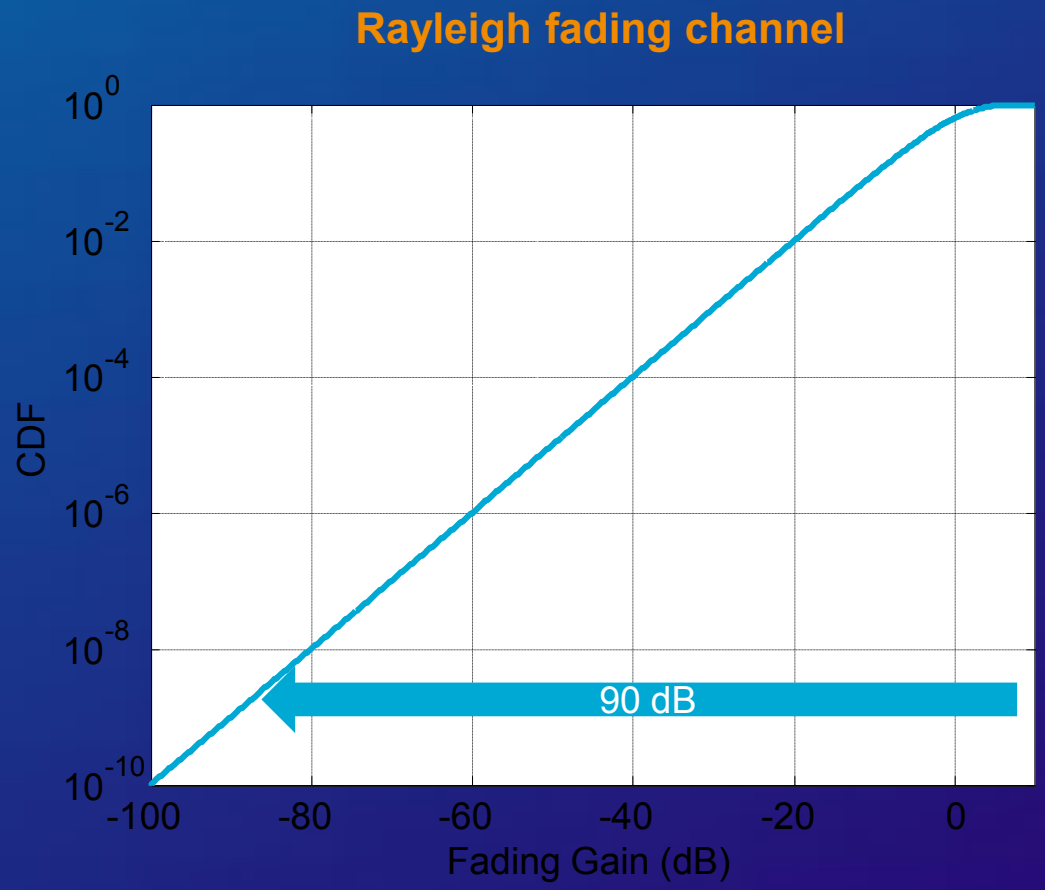
Cell edge, 64/84 kb/s UL/DL, 2xAA with 4% self-discharge



- (Rel-8 LTE can achieve 1.1 years with max DRX cycle 2.56 s)

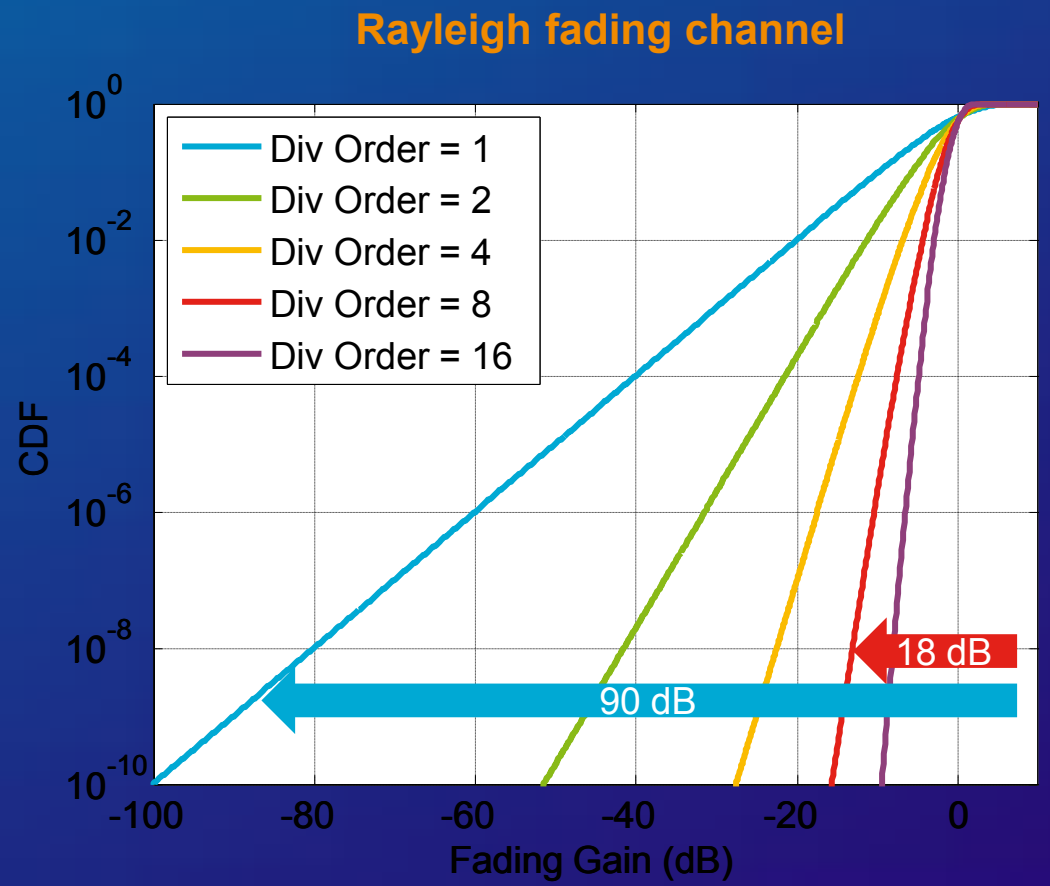
COST OF GUARANTEEING HIGH RELIABILITY

- High reliability (e.g. 10^{-5} – 10^{-9})
  - 50-90 dB fading margin



REDUNDANCY THROUGH DIVERSITY

- Diversity may be obtained through
  - spatial diversity, and
  - frequency diversity
- Time diversity difficult due to latency constraint
- Coding needed to fully exploit frequency and transmit diversity



Diversity is key for ultra-reliable communications

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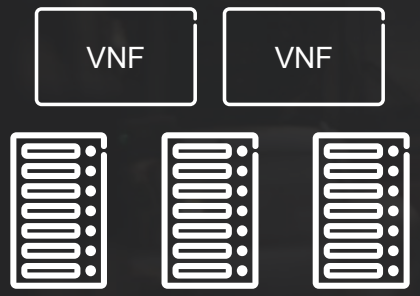
NETWORK ARCHITECTURE

5G READY CORE NETWORK COMPONENTS

Management & Orchestration, Analytics & Exposure

Virtualization

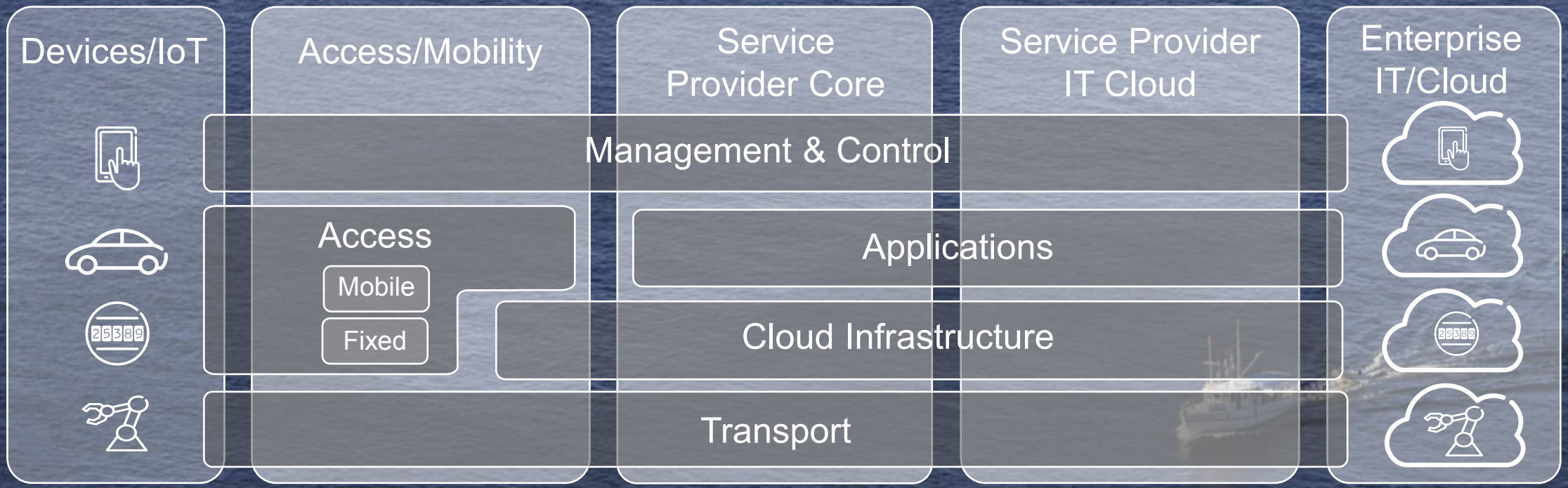


Software Defined Networking (SDN)

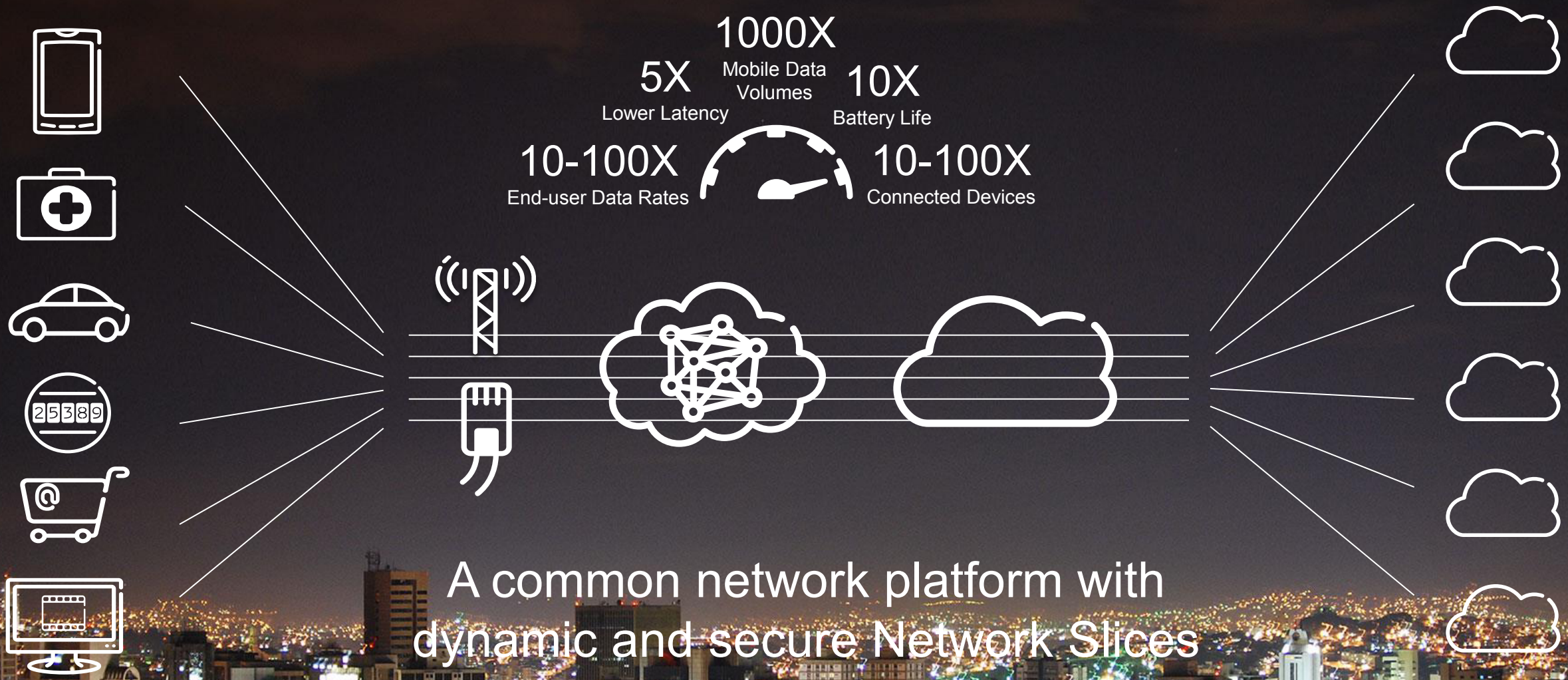
Distributed Cloud

Network Slicing

EVOLUTION OF THE CONVERGED NETWORK

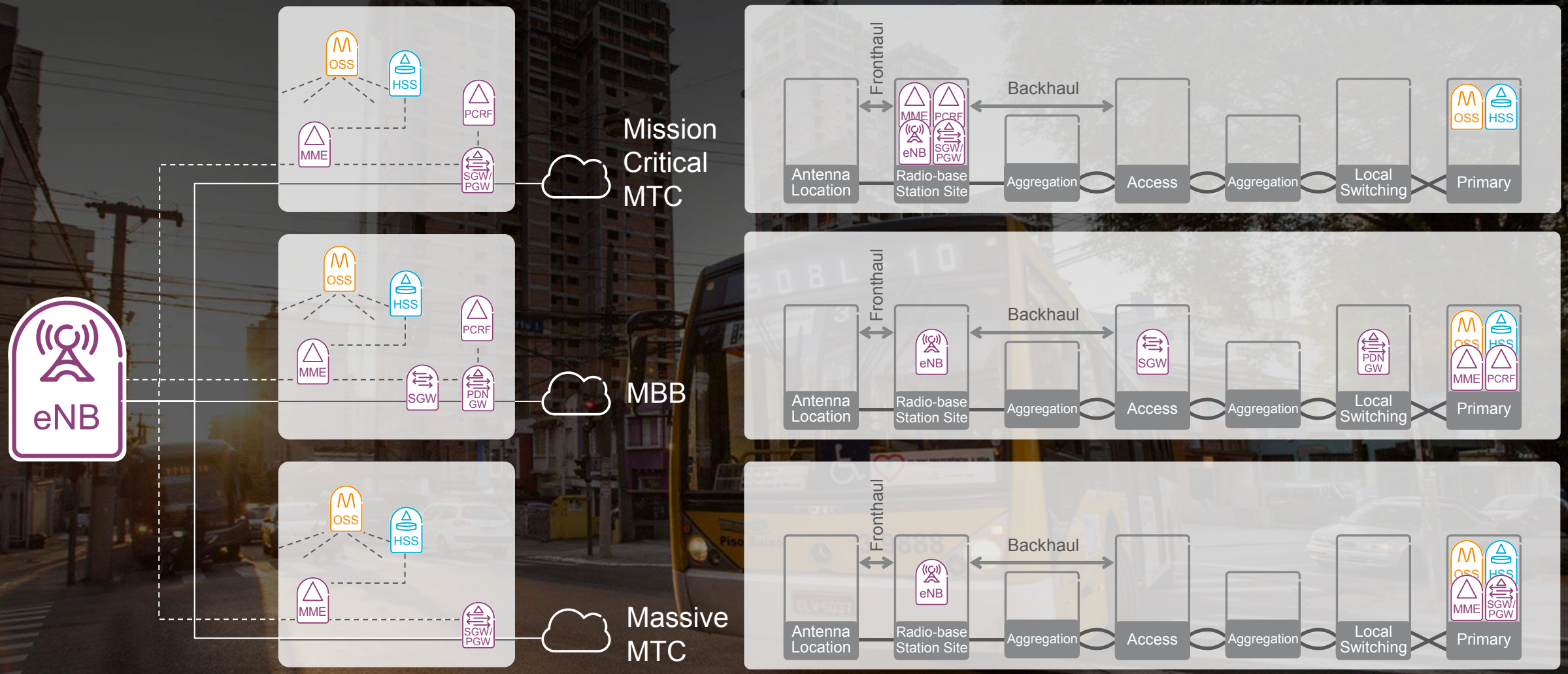


NETWORK SLICING



A common network platform with dynamic and secure Network Slices

NETWORK SLICING



ORCHESTRATION

Network Slice Blueprints:

- Mobile Broadband
- Industry Automation
- Media
- Enterprise Communication
- Massive Sensors/Actuator
- ....

Retail Customer

Whole Sale Customer

Network Slice Resources

- Access
- Nw Function
- Transport
- Cloud
- OSS/BSS

Service n

Health

Robotic communication

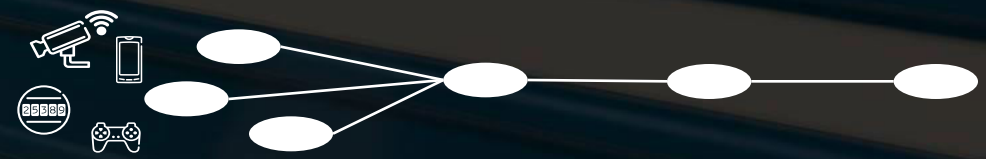
Premium Communication

Media

MBB Basic

Network Slices

Physical Resources



WHAT IS IN THE SLICE? - PRINCIPLES

- The architecture shall be flexible
  - It shall not mandate certain combination and/or location of functions
    - Today we have to co-locate all functions of a node
    - Any change must go through 3GPP
    - Look, what it led to in case of LIPA or SIPTO
  - It shall not mandate the existence or lack of any function
    - Should be easy to add/remove functions
      - E.g., no mobility support for this device
  - It shall be able to utilize distributed cloud (easy deployment of VMs)
  - It shall enable programmatic composition
    - Even on a per-flow basis

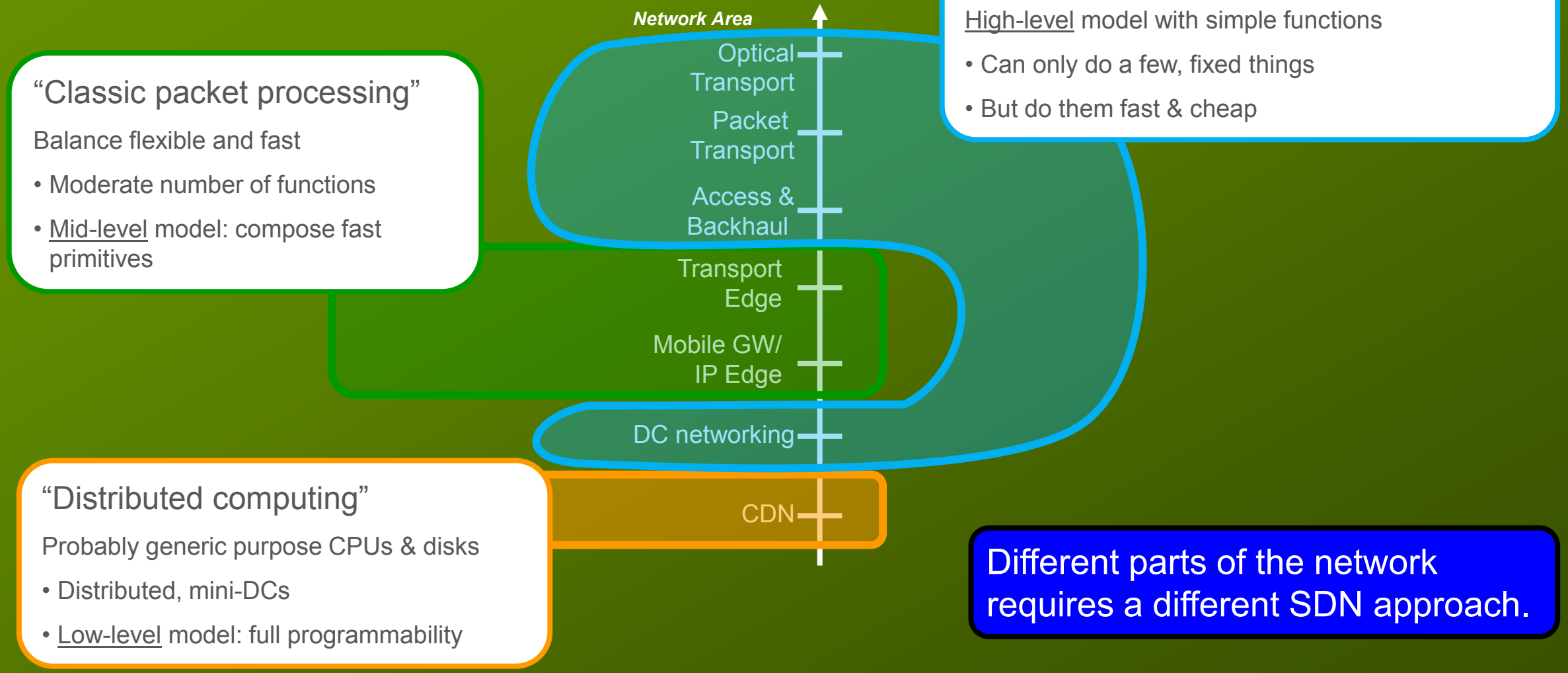
(BRIEF SDN ASIDE) DATA PLANE MODEL

- The *Data Plane Model* is what the CP sees from the DP
  - The DP presents itself as an abstract machine
  - The CP issues commands to this abstract machine
- Selection of the right DP Model is key for SDN
  - Much more important than the protocol
  - Needs to be somehow standardized/specified for multi-vendor SDN
- Example: OF 1.0
  - The DP is capable of matching 15 fields and based on the result either forward or drop the packet or send it to the controller
  - OF also specifies a protocol
- Example: Forces
  - No DP Model is specified (in forces called a Library of primitives)
  - Only a protocol is specified leaving the Library free

DP MODEL GRANULARITY

- High-level models
  - A few customizable (but perhaps complex) functions
  - Example: OpenFlow 1.x, Ethernet chips
  - Not very flexible, but probably enables high performance implementation
- Mid-level models
  - Small pieces of functionality composed by the Control Plane
    - E.g., IPv4 longest prefix match lookup, IPv4 header sanity check
  - Example: Forces, Some OF 2.0 proposals
  - Quite flexible, but still abstract, probably can utilize network processors, as well
- Low-level models
  - Fully programmable data plane
    - The Control Plane can download code
    - Need to address many low-level issues
      - Memory layout, NPU specific instructions or properties (e.g., 64-bit?)
  - Example: assembly, P4
  - Absolutely requires network processors

DP MODEL APPLICABILITY



"Cheap silicon"

High-level model with simple functions

- Can only do a few, fixed things
- But do them fast & cheap

"Classic packet processing"

Balance flexible and fast

- Moderate number of functions
- Mid-level model: compose fast primitives

"Distributed computing"

Probably generic purpose CPUs & disks

- Distributed, mini-DCs
- Low-level model: full programmability

Different parts of the network requires a different SDN approach.

(BACK TO ARCHITECTURE) PRINCIPLES

› Functionality in two conceptual layers

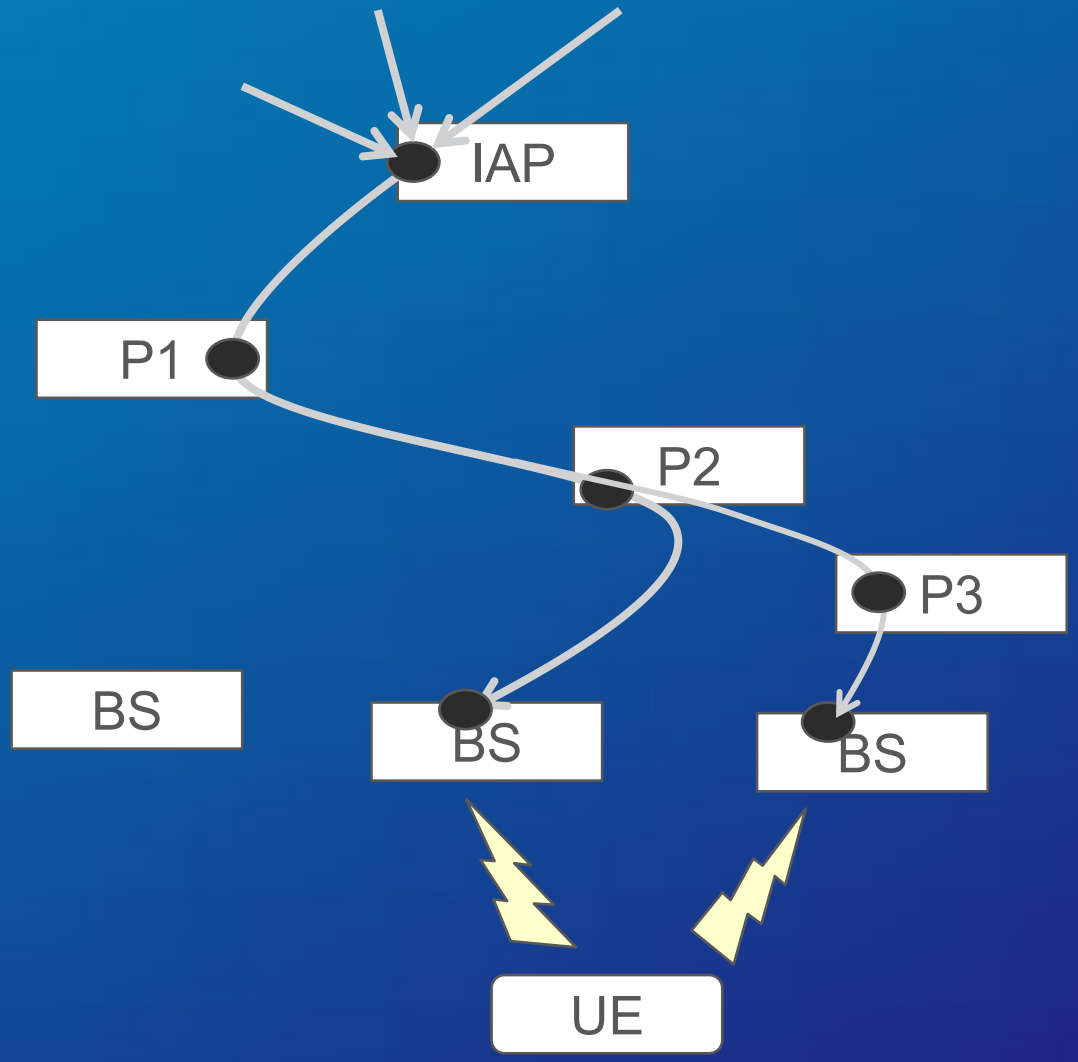
Actual functions

(policing, QoS marking, DPI, charging, encryption (PDCP), mobility, parental control, cache, idle mode buffering, virus filter, etc..)

Mobile Service Chaining

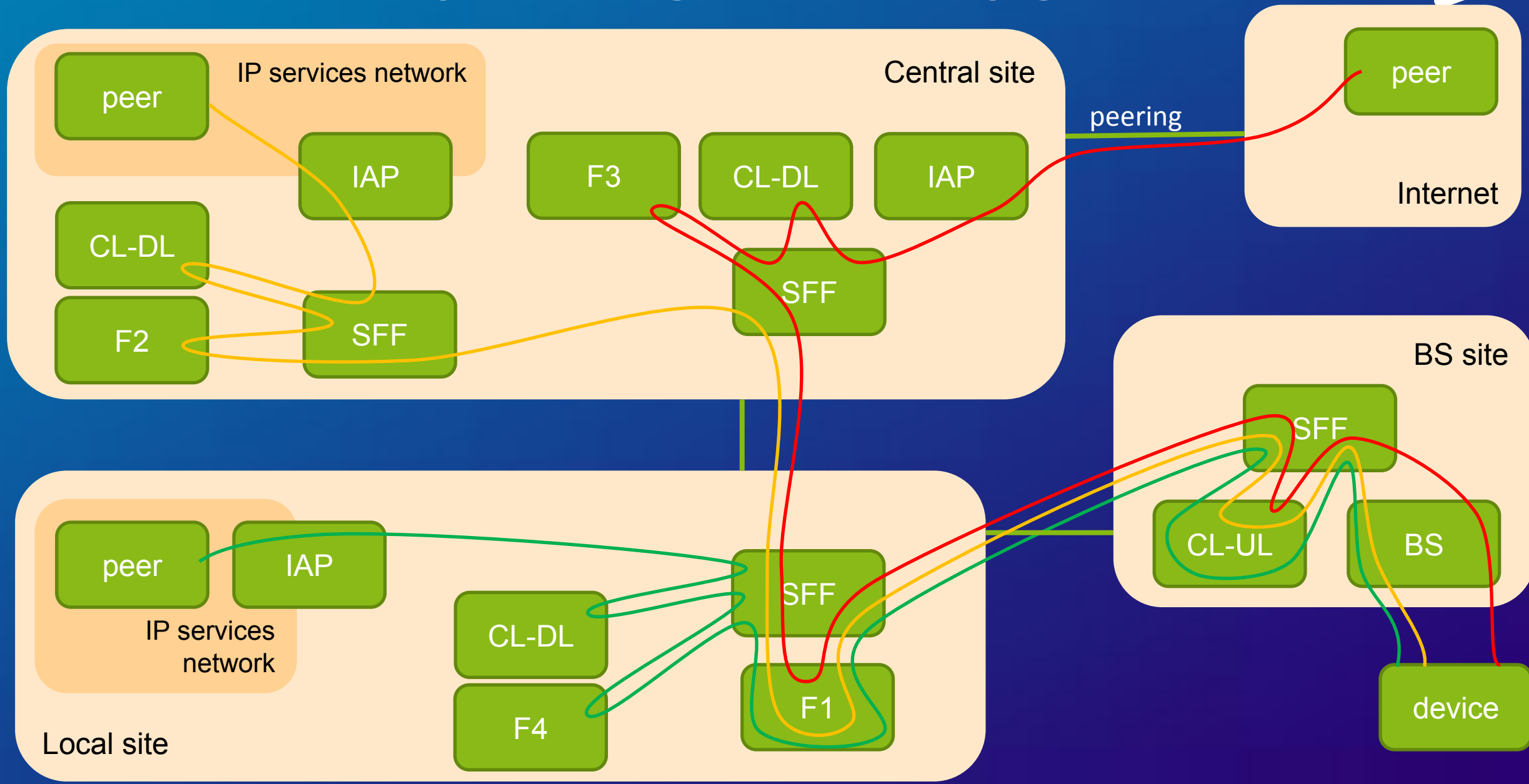
(Functionality to chain these functions, execution optimization when co-located, support for context transfer at mobility)

10K FEET VIEW



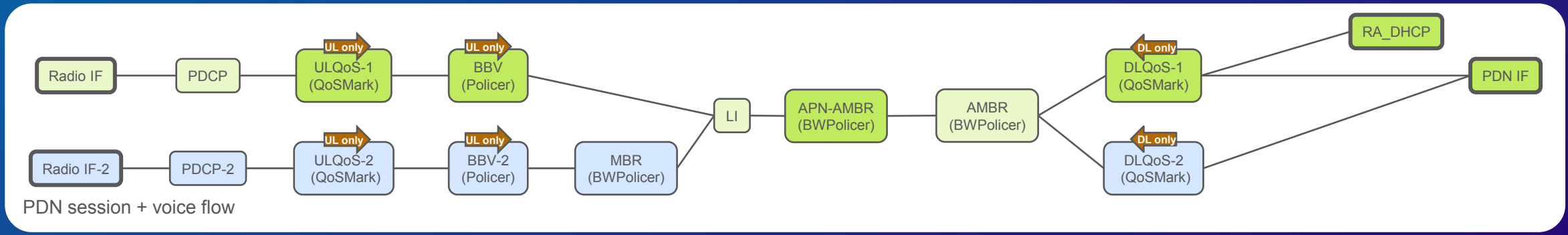
- There are small processing functions chained together
  - Typically smaller than a VM/container
  - One VM/container processes many users
  - Co-located functions execute in an optimized way (zero copy)
- Collectively they implement core functions and more
  - Some service network stuff (e.g., parental control)
  - Some radio stuff (e.g., PDCP termination)
- A logically centralized control plane
  - Maps a user to a pre-established VM/container running the given function
  - Configures that function for the user
  - Controls chain forwarding
  - Requests scale-in/out

EXAMPLE CHAINS FOR A USER

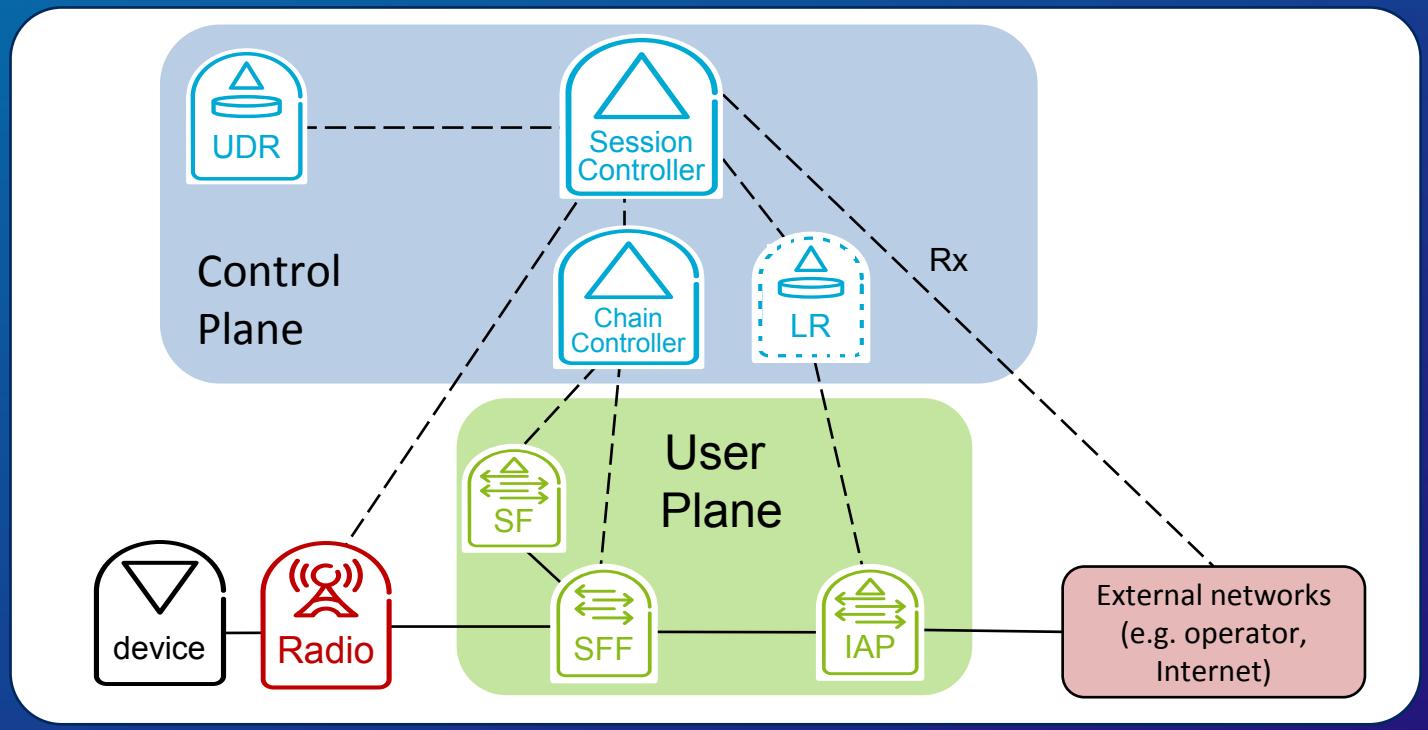


BEYOND SERVICE CHAINING USER GRAPHS

- Every user has (potentially) a unique graph
- This graph needs to be expressed
- The graph may change depending on events (e.g. adding an additional PDN connection)
- A fairly wide range of function size



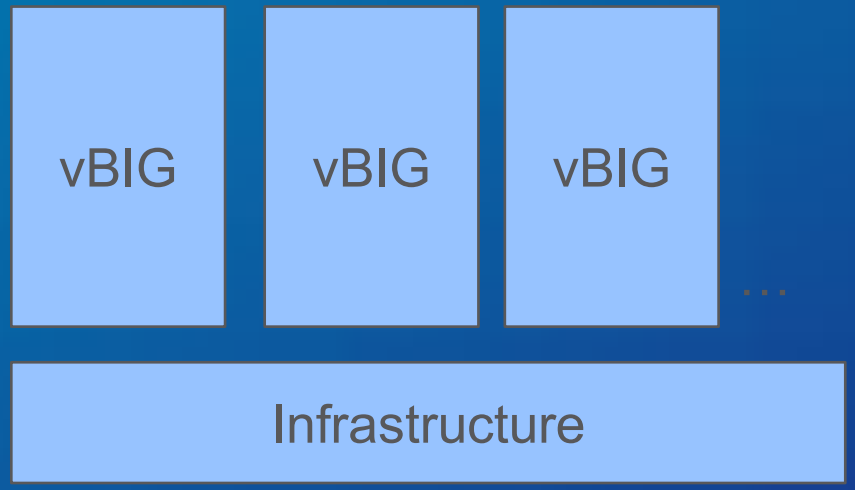
RESEARCH CONCEPT FOR CORE NETWORK



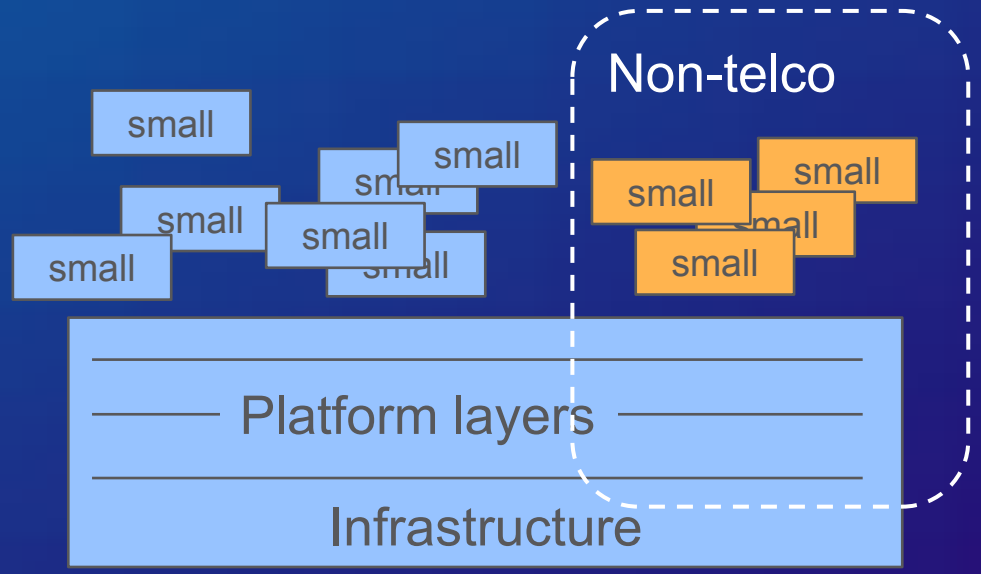
THE NEW NETWORK

SOFTWARE PRINCIPLES

Classic NFV



Decomposition

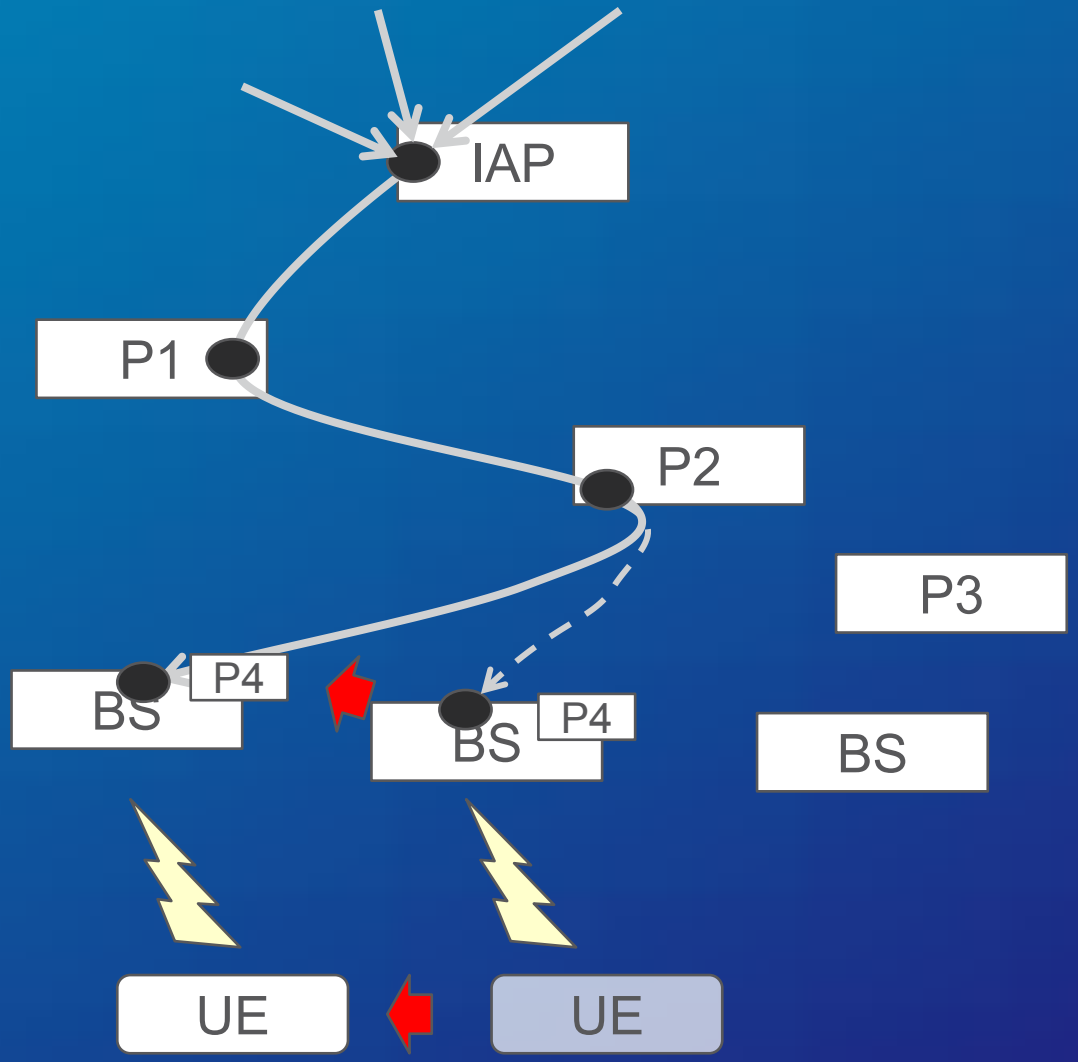


Decomposing

- Data Plane
- Control Plane
- Analytics
- Applications
- Orchestration

"Same concept as microservices, but different realization"

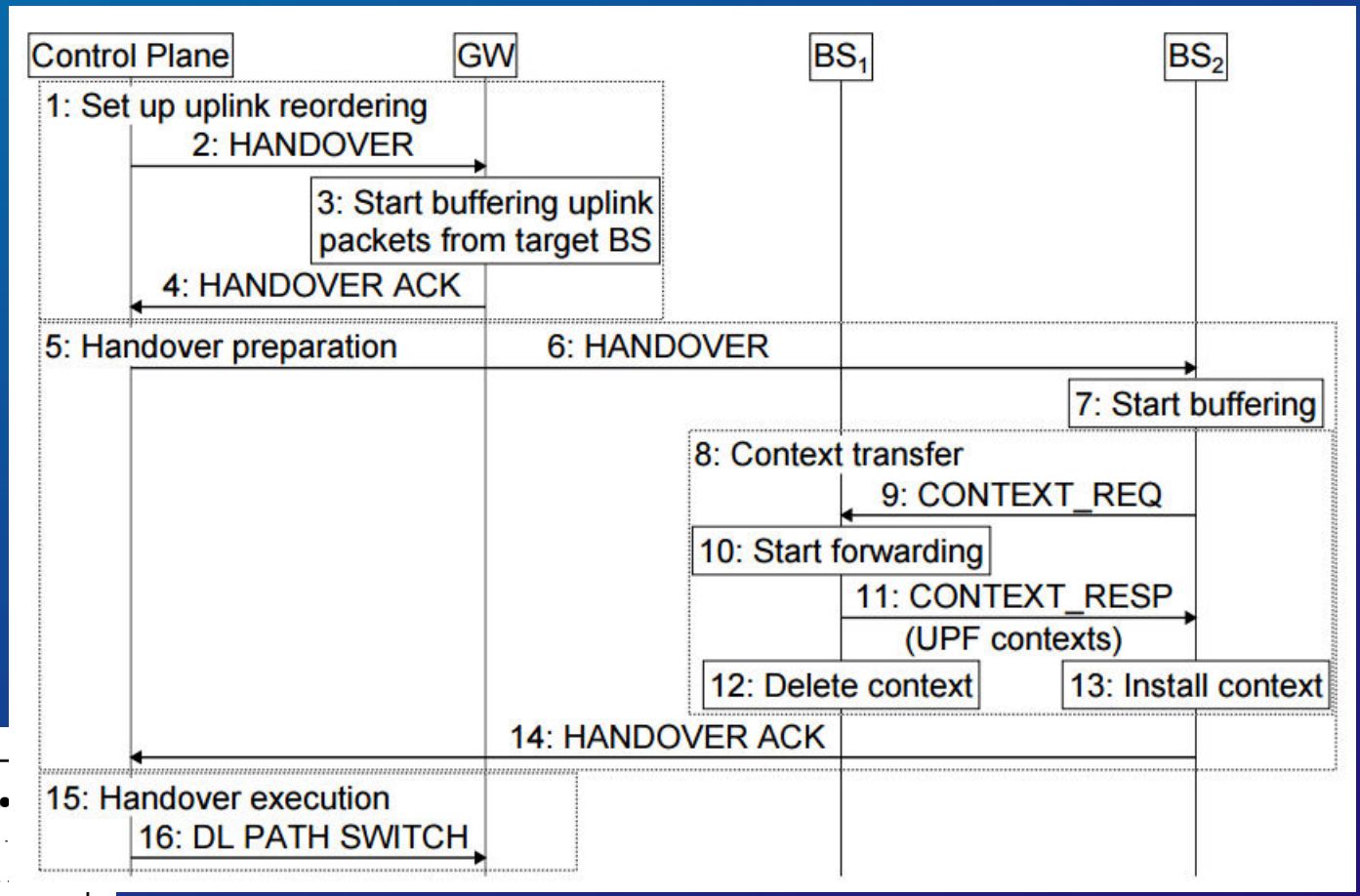
HANDOVER WITH CTX TRANSFER

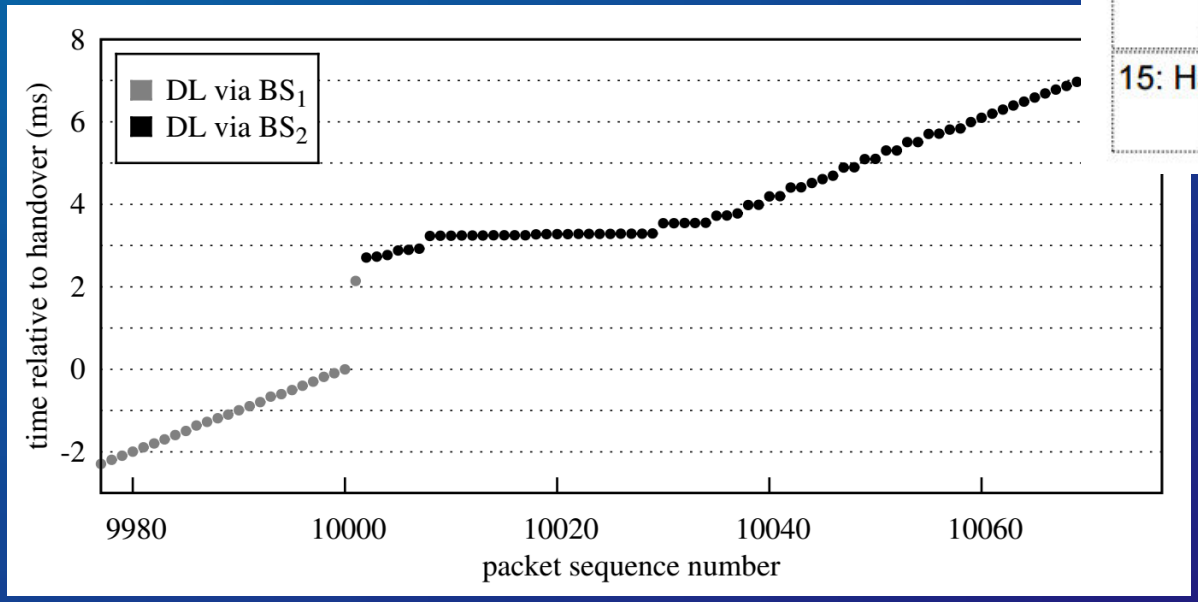


- Functions support context extraction/insertion
- Controller can move contexts
  - Buffer for lossless handovers
  - Buffer more for lossess and reordering free handovers
- Many levels potentially
- Other uses of live state migration
  - Rearrange centralized/distributed
  - Load balancing
  - Code upgrade
  - Scheduled maintenance

PROCEDURE

- Implemented in Click
- How much intelligence at the DP node?
- What to expose on the CP/UP interface?





Balázs Pinczel, Dániel Géhberger, **Zoltán Turányi,** Bence Formanek Towards High Performance Packet Processing for 5G,' *IEEE Conference on Network Function Virtualization & Software Defined Networks (IEEE NFV-SDN),* November 18, 2015, Los Angeles, USA

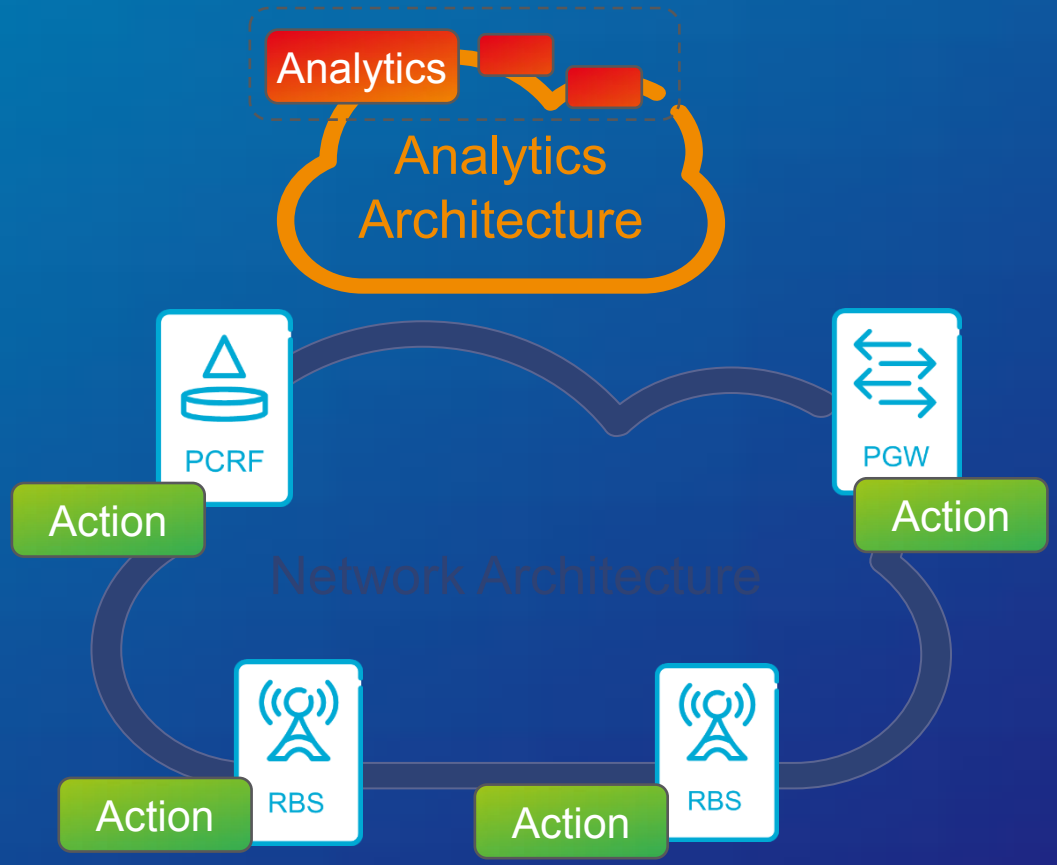
ANALYTICS

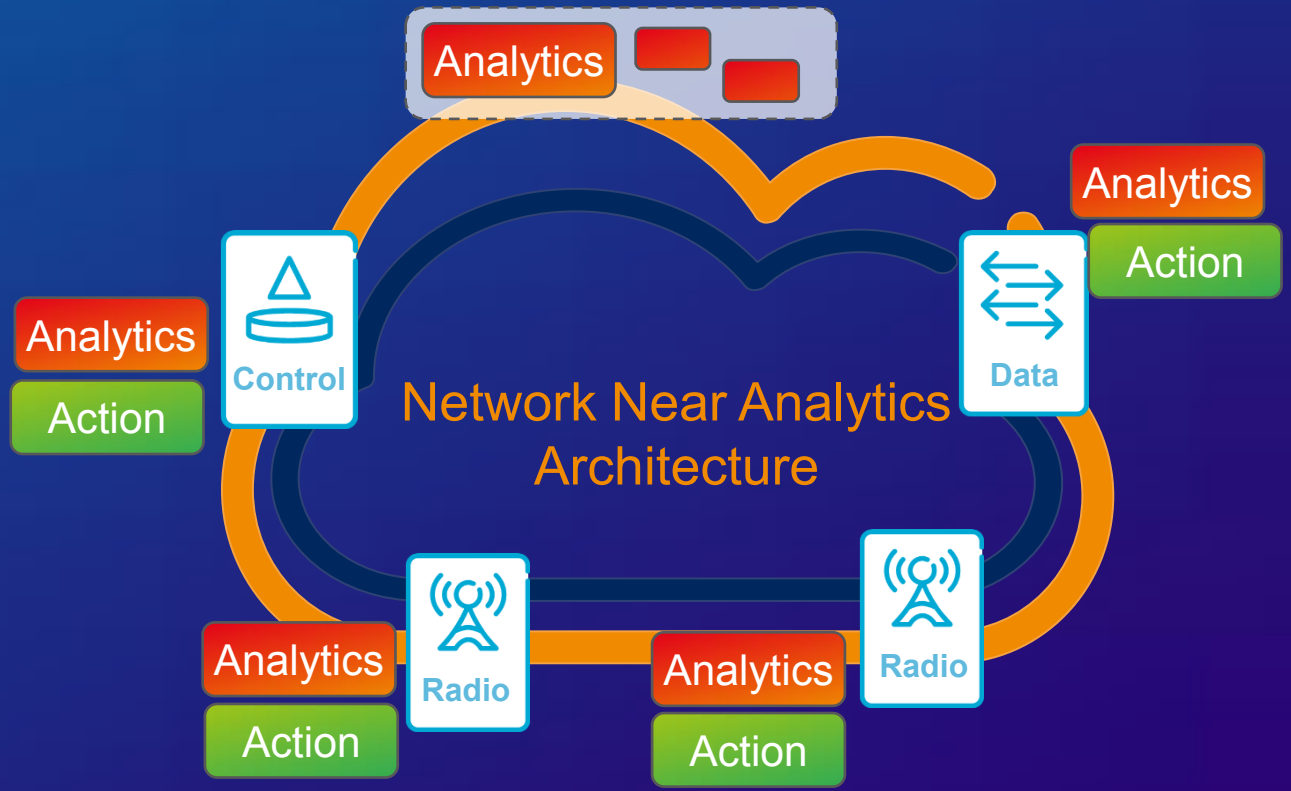
- Collection and evaluation of data for the purpose of gaining insight
- A network is ideal target
  - Generates a lot of data
  - Correlation is required to really know what is going on
  - Insight is actually useful
- Recent advances in analytics enable real-time KPI calculation
  - E.g., correlate all events of a subscriber with momentary bandwidth to a “satisfaction index”
  - ~100ms timescale

THE GAP – ANALYTICS AND NETWORKING

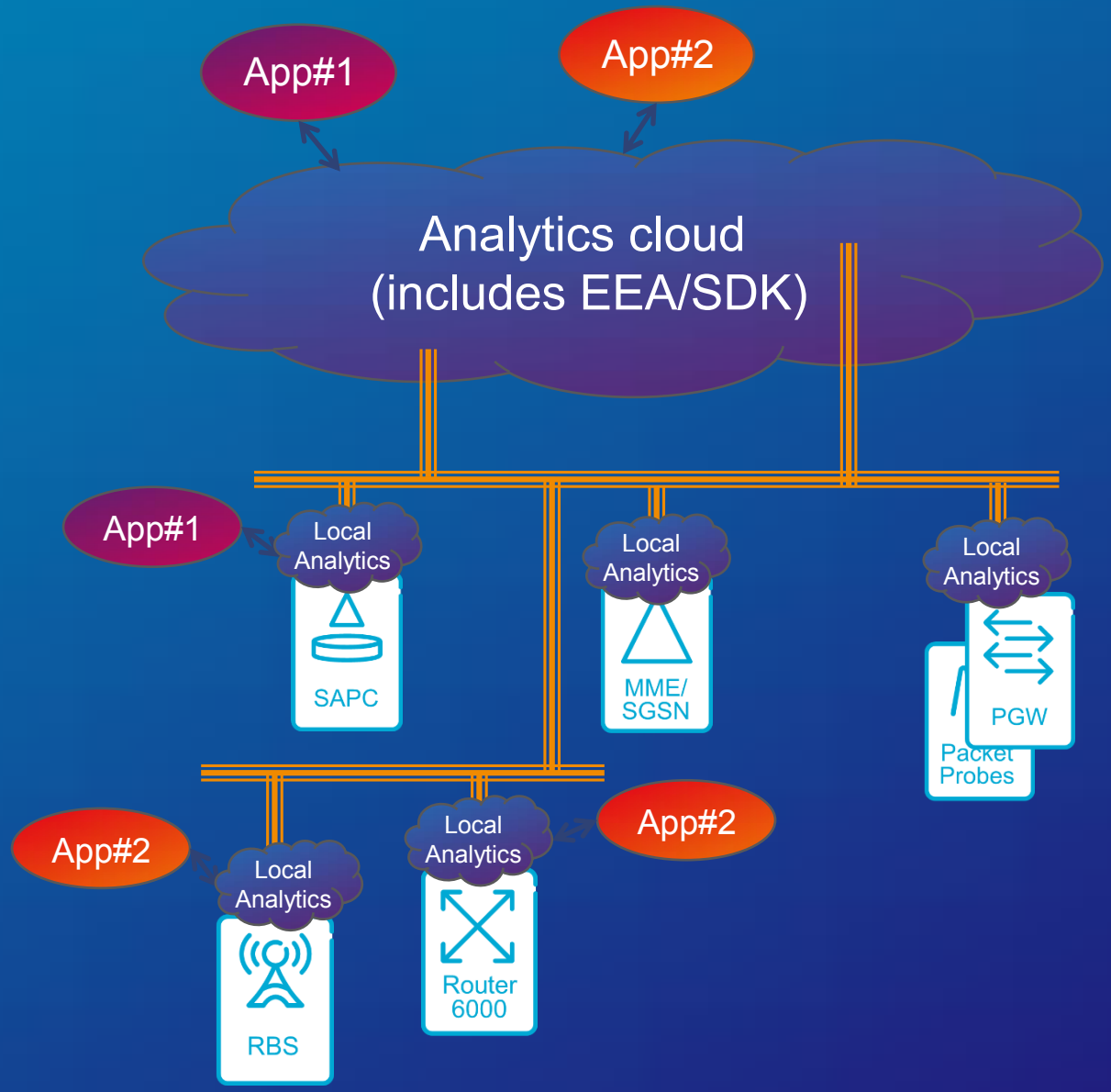
Separated location of data and action
lack of analytics & business information in network actions

Moving data near to the action
analytics driven, programmable network behavior



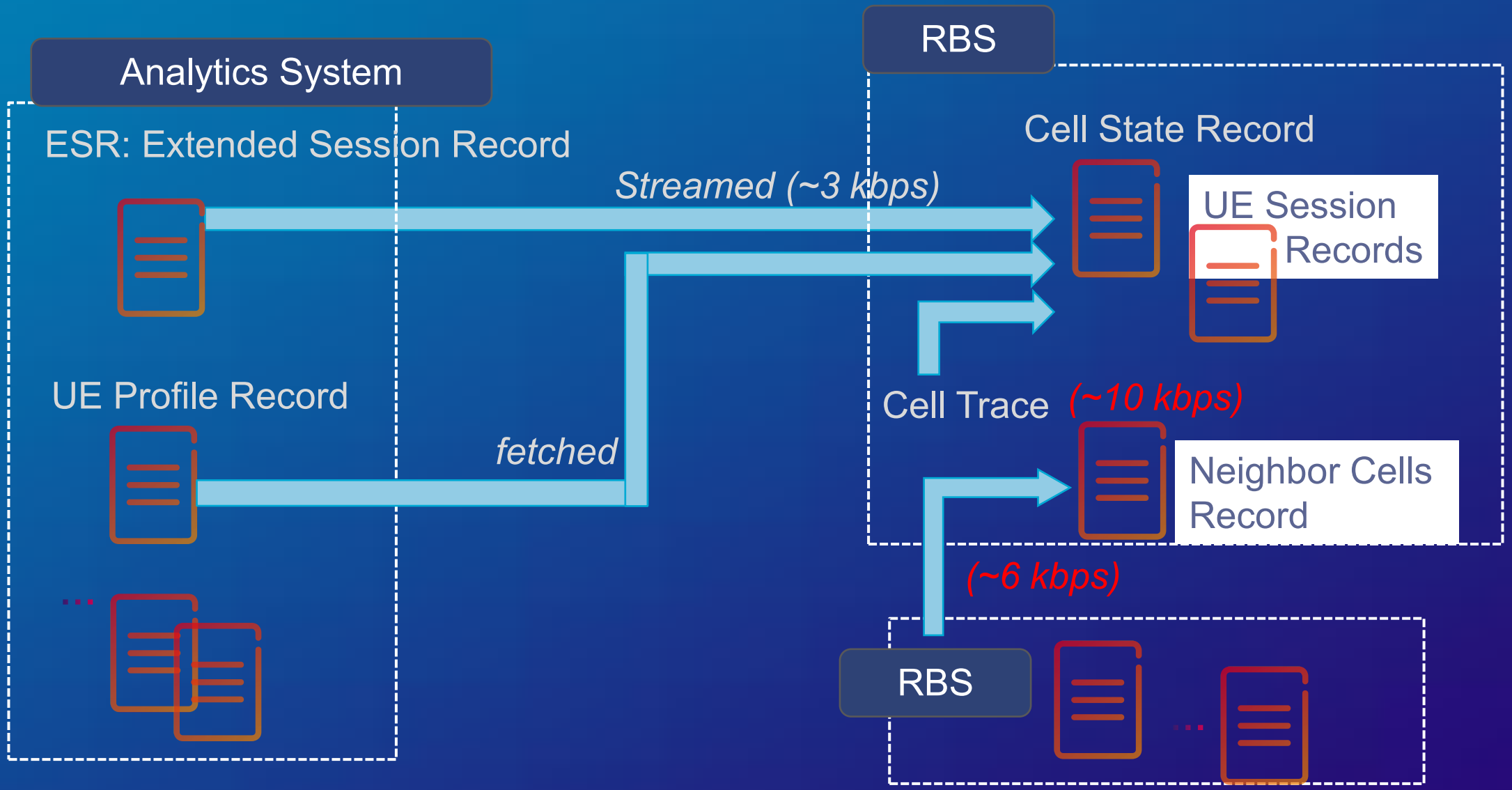


DESIRED ARCHITECTURE



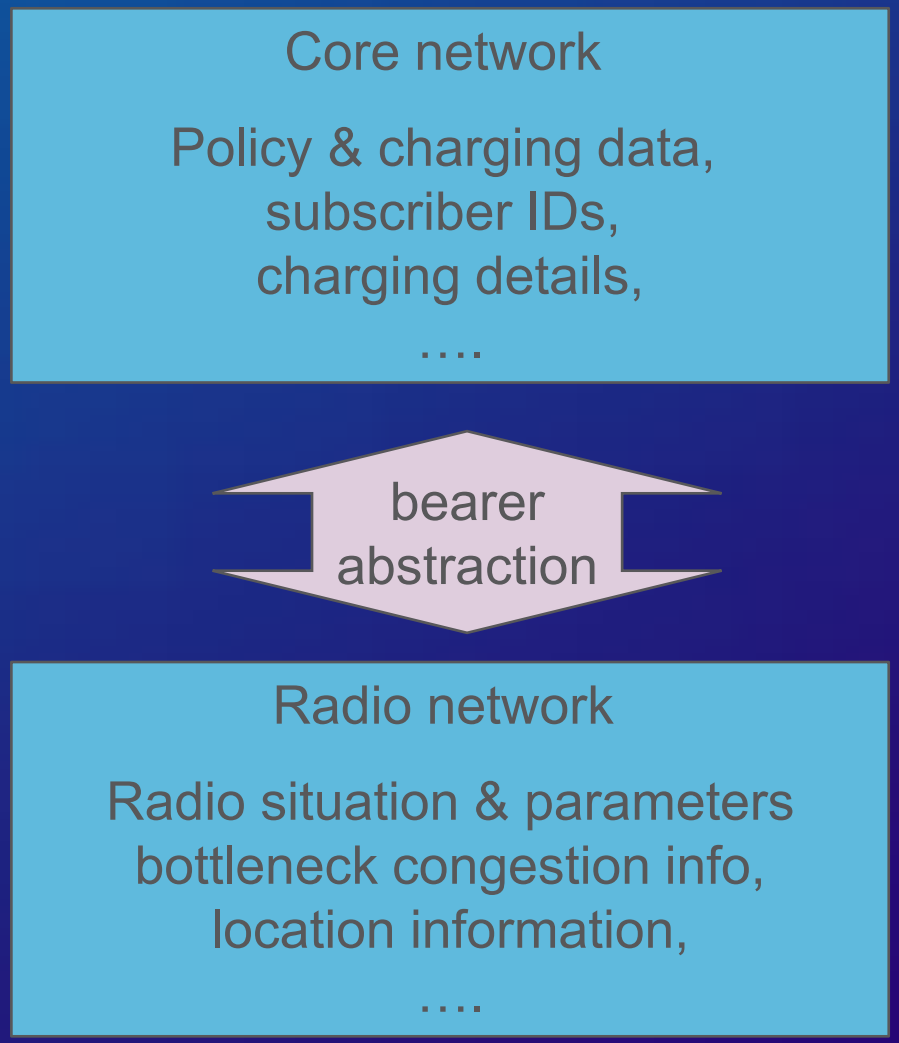
- Top level analytics extended with node local components
- Flexible environment to deploy analytics applications anywhere
- Enables closed loop use cases with actions on network level

EXAMPLE DATA FLOW

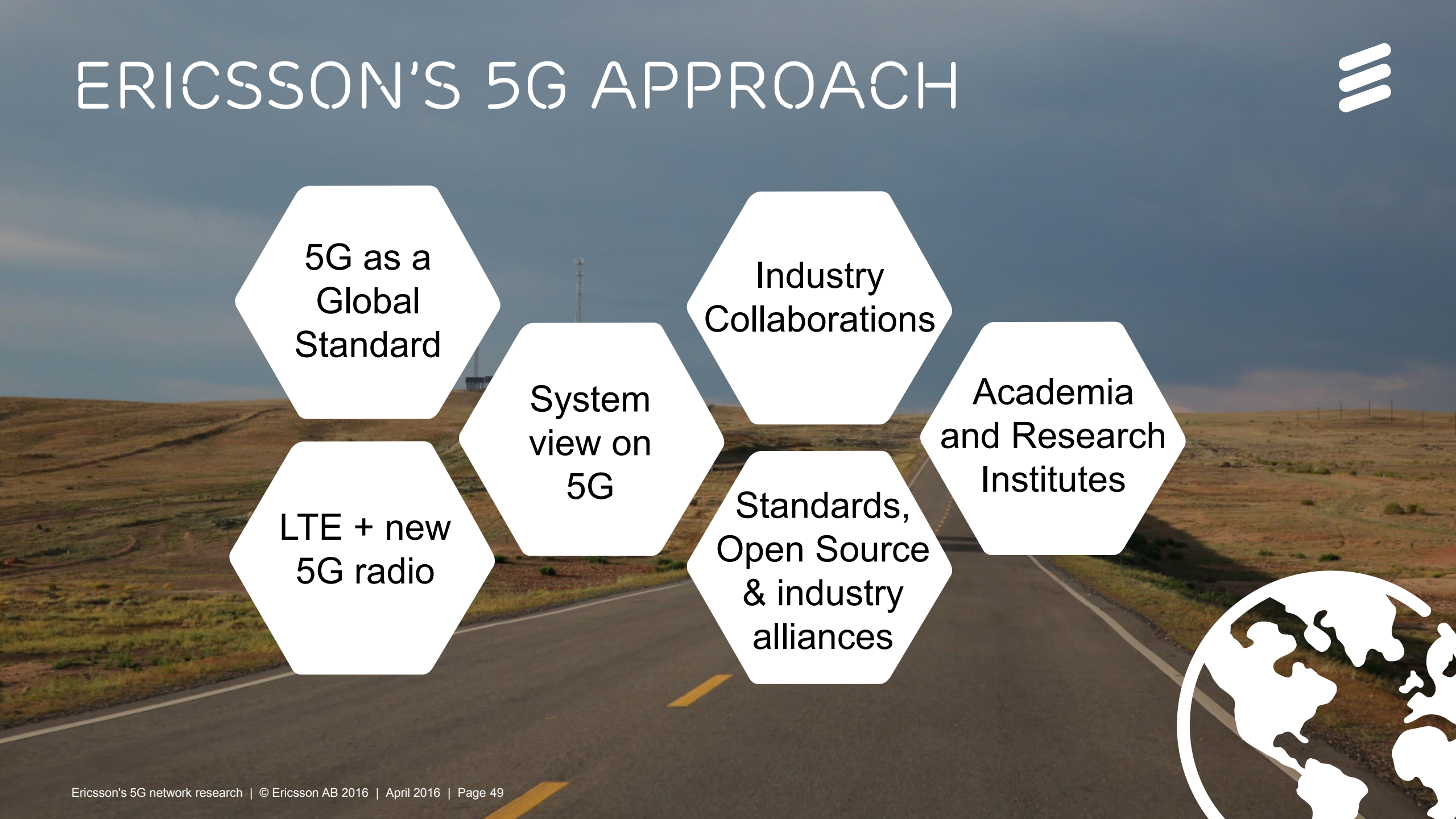


ARCHITECTURE IMPACT

- Analytics data as first class citizen in network nodes
  - Base decisions on readily available KPIs
  - Not as an afterthought
  - Not 15 mins later
- Remove current information barriers
  - Currently data is distributed in the system
  - Certain parts not allowed to know parts
  - Legacy limitation due to performance
  - No need, we can do better now



ERICSSON'S 5G APPROACH



ERICSSON