FUTURE GENERATION WIRELESS COMMUNICATION SYSTEMS

REQUIREMENTS AND OPEN ISSUES

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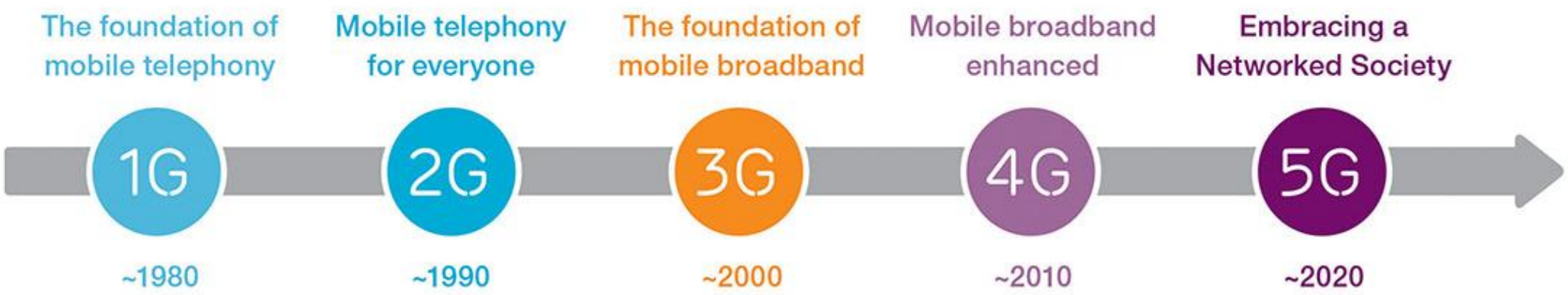
«OUTLINE»

- 5G key requirements and use cases
- Radio access technologies and control architectures for 5G
- Optical transport and WDM technologies for 5G
- Photonic integrated technologies enabling 5G optical transport

WIRELESS ACCESS GENERATIONS



Non-limiting access to information and sharing of data anywhere and anytime for anyone and anything

5G WIRELESS ACCESS

Much more than just enhanced mobile broadband

A wide range of requirements and capabilities

A flexible, scalable, and future-proof solution

- Very high traffic capacity
- High data rates everywhere
- Very low latency
- Massive number of devices
- Very low device cost
- Very low device energy consumption
- Ultra-high reliability and availability
- Machine-type communication (MTC)

Affordable and sustainable

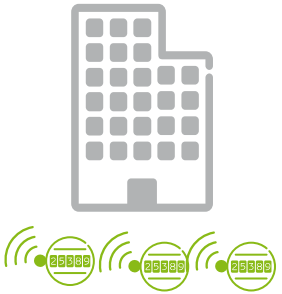
RANGE OF REQUIREMENTS

EXAMPLE: MACHINE TYPE COMMUNICATION

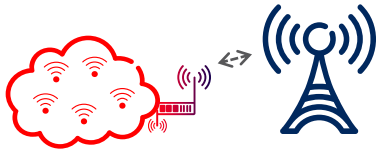
Massive MTC

Low cost
Low energy
Small data volumes
Massive numbers

- Ultra-long range for remote locations
- Low protocol overhead to reduce battery consumption
- Scalable Access connecting either many or few devices
- Capillary Networks & short-range radio



Sensors, actuators

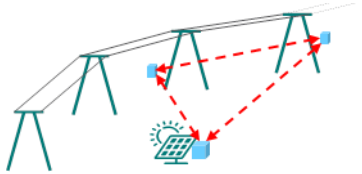


Capillary networks

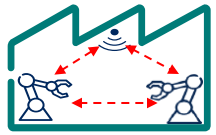
Critical MTC

Ultra reliable
Very low latency
Very high availability

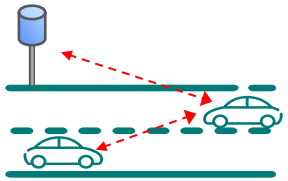
- ms-level latency
- Robust transmission
- Fast channel assignment
- High reliability



Smart grid



Industrial application



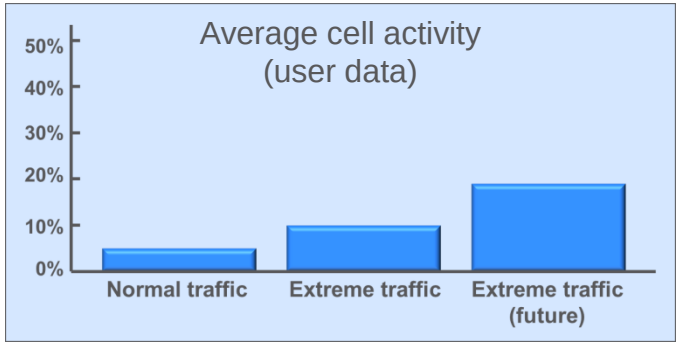
Traffic safety/control

“Tactile Internet”

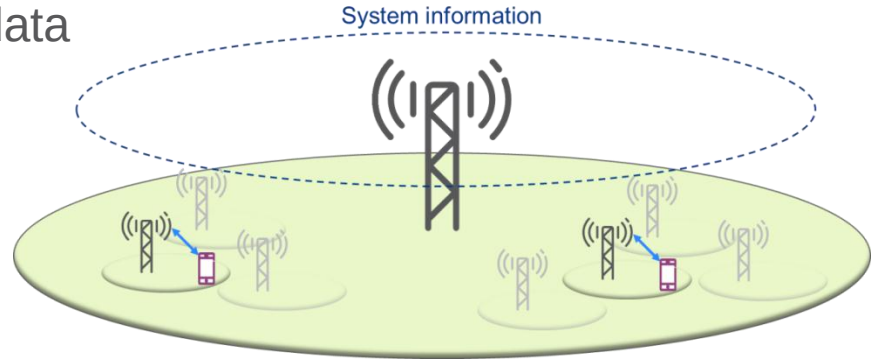
Balance Complexity, Cost, and Relevance

LEAN DESIGN AND DUPLEX FLEXIBILITY

- Networks lightly loaded on average
- Not expected to change dramatically in the future
  - Much more traffic but also much more network nodes
- Network transmissions not related to user data
  - Synchronization signals, certain reference signals, system information, …
  - Impact on network energy efficiency and achievable data rates

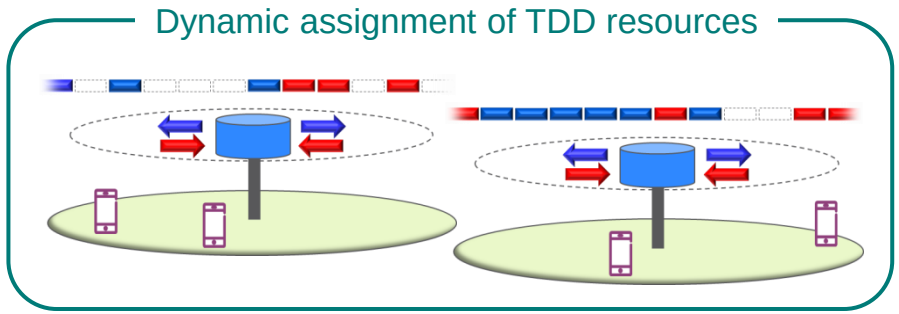


- **Lean design:** Minimize network transmissions not related to user data
- Minimize amount of broadcast system information
  - Main part of system information should be provided on a per-need basis
  - Separation of user data and system information
- System information provided wide-area by overlaid layer
  - Underlaid network nodes only active when user-data to convey



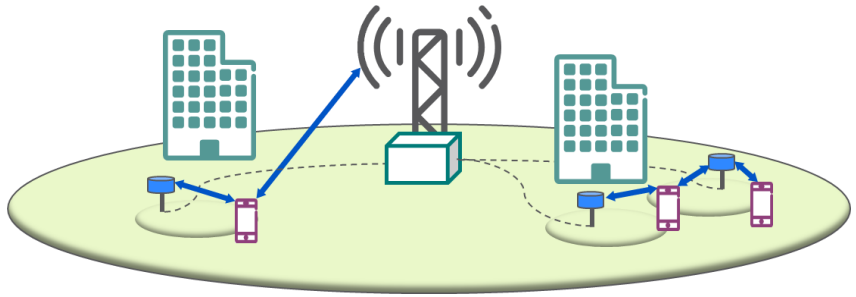
Flexible Duplex

- TDD more relevant for higher frequencies in dense deployments
  - More easy to find unpaired spectrum
  - More dynamic traffic variations



MULTI-SITE FUNCTIONALITY

- Multi-site transmission
  - Natural extension of multi-antenna transmission/reception
    - Use all antenna resources in the best possible way
  - Diversity and robustness
    - Rapid changes in propagation conditions
      - ➡ connectivity to multiple sites beneficial

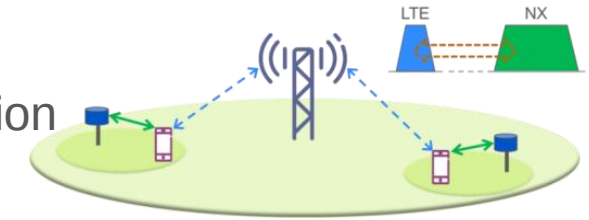


"Cell" concept becoming blurred!

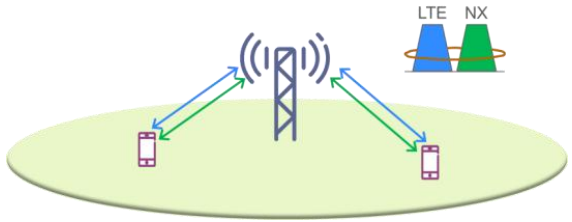
- Dual Connectivity between overlaid low-frequency layer for ubiquitous connectivity and underlaid high-frequency layer for high data rate in very dense deployments

⇨

- To provide robustness against spotty coverage at high frequency band
- To assist terminals in node detection

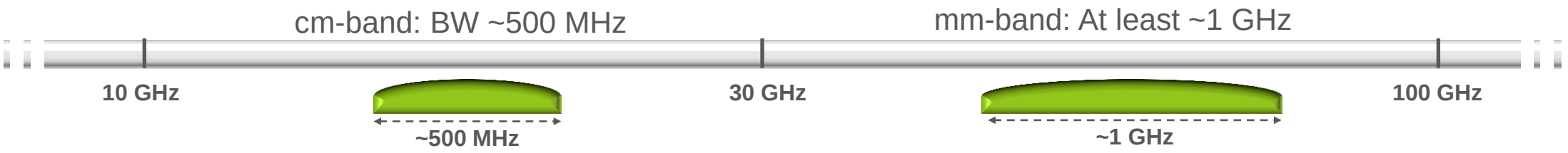


- User-plane aggregation
  - To increase the bandwidth

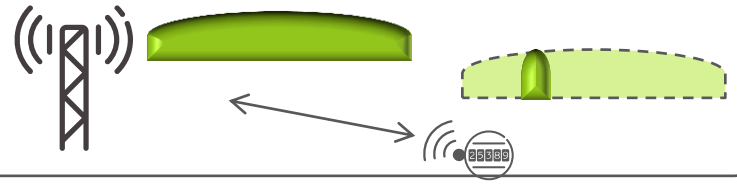


HIGHER BW AND BW FLEXIBILITY, MASSIVE BEAM FORMING

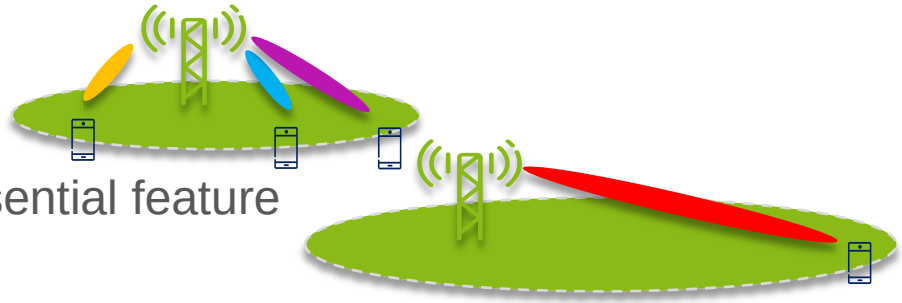
› Very wide transmission Bandwidth needed to enable extreme data rates



› Low-cost devices may require support for smaller bandwidths
  - Device transmit/receive on a fraction of the network bandwidth



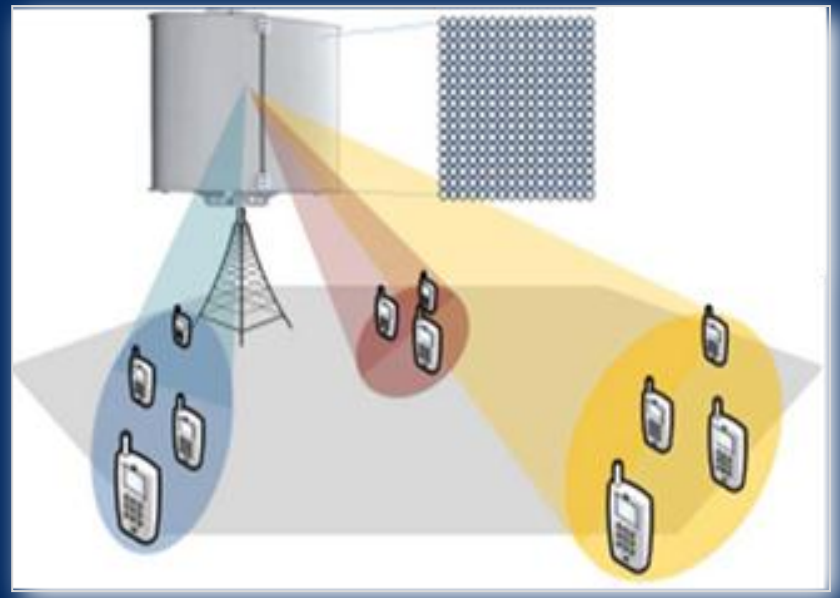
› Multi-antenna techniques is an important technology for coverage, capacity and data rate
  - › Higher frequency bands
  - › More challenging link budget
  - › Smaller wavelength more antenna elements possible



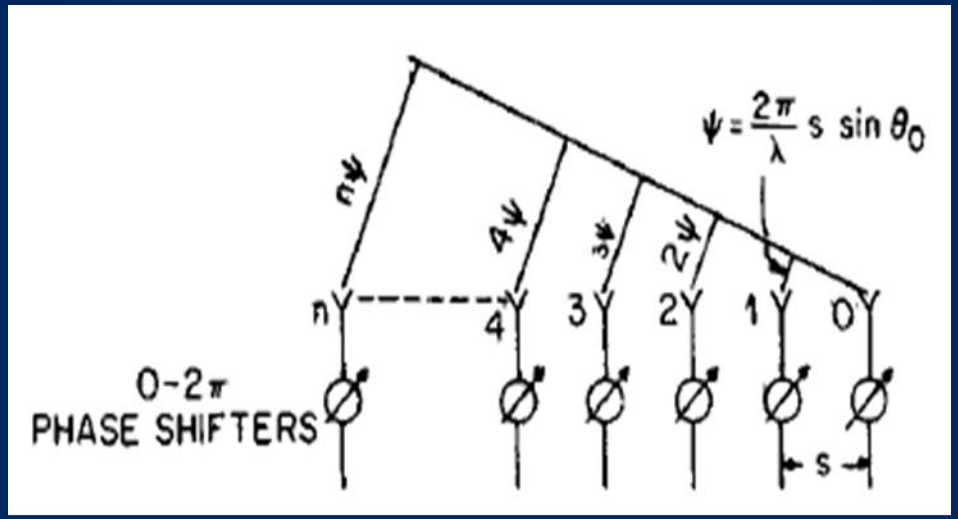
› Support for Massive MIMO and Beam Forming will be an essential feature of 5G
  - › To provide coverage and capacity
  - › May relax RF requirements (imperfections “average out”)

OPTICAL BEAMFORMING FOR 5G

- Beamforming is a technique for controlling electronically transmission directionality thanks to an array of smalls antennas.
- Electronic implementation is challenging due to high frequency and wideband required by 5G systems
- A superior performance can be achieved with photonic implementation in terms of VCO phase noise and phase shift resolution.
- The areas under investigation:
  - photonic RF generators to reduce phase noise
  - optical phase and delay shifting for accurate beam pointing



Optical beam forming prototype (in cooperation with Scuola S. Anna/CNIT) based on phase shifting



Advantages

Reduced complexity

Power efficient respect to electronics

No need of RF filters after PD

Photonics can be integrated

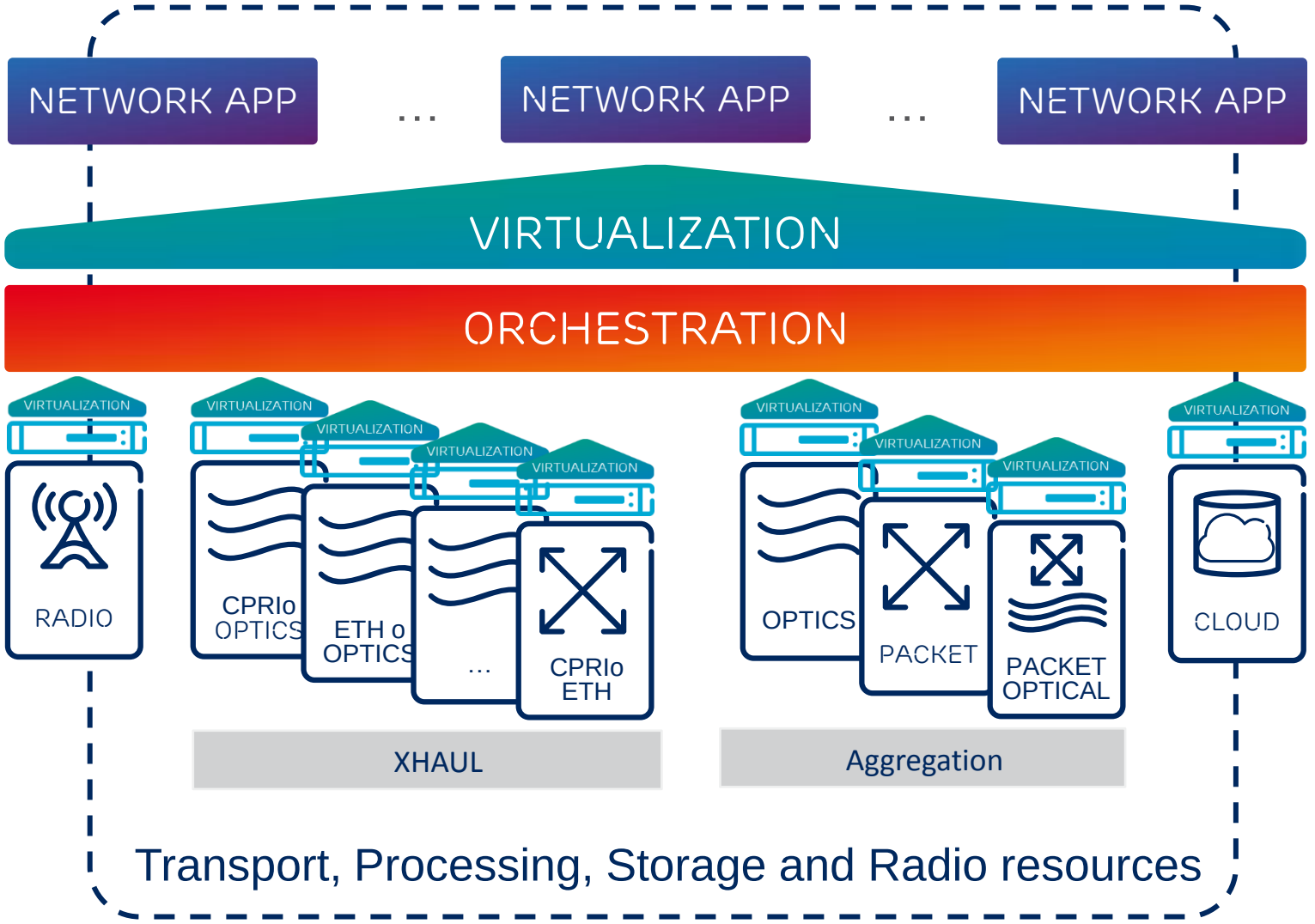
5G TRANSPORT CONTROL ARCHITECTURE

Orchestration Layer

- Aggregation of Heterogeneous Resources into a Unified Resource Representation
- Abstraction and Virtualization of Aggregated Resources
- Multi-Domain Resource Management & Mapping from High-Level Resource Requests to Individual Domains

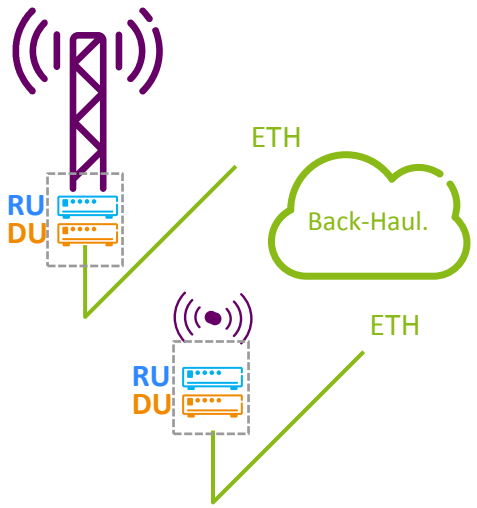
Domain Controllers

- Domain-Specific Resource Management
- Resource Abstraction and Virtualization within Individual Domains



RAN EVOLUTION
FROM TRADITIONAL RBS TO XHAUL

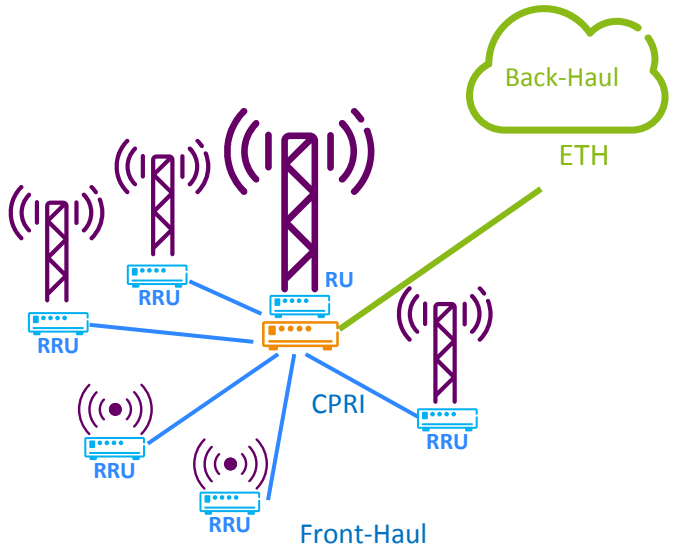
1



Traditional RBS

Network, BB and radio features in the same unit

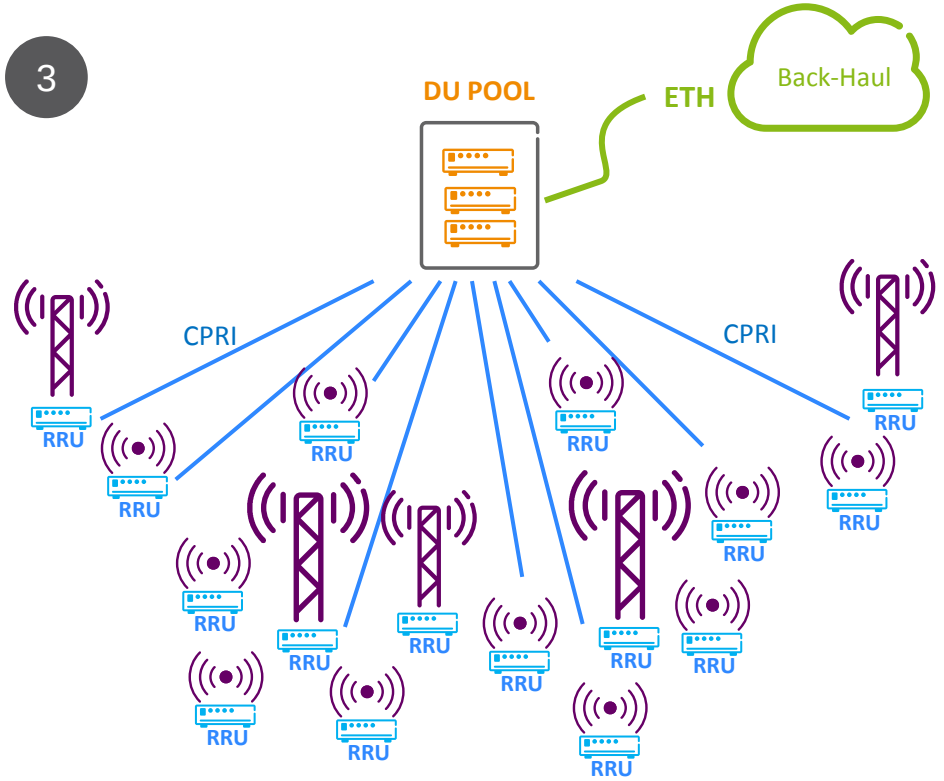
2



Main Remote System

Radio unit are remotized from the BB processing units

3



CRAN

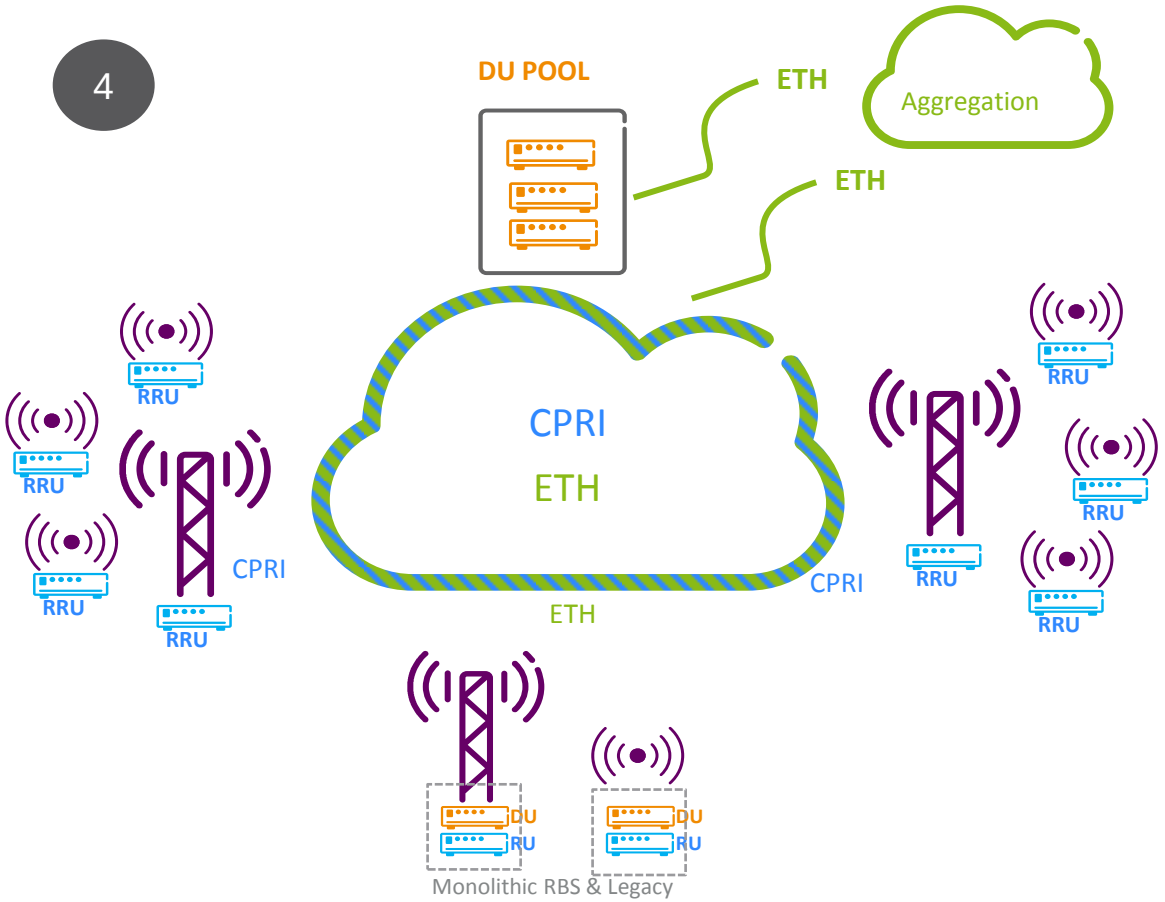
CPRI transported over P2P links towards a centralized BB processing

Macro RBS

Small cell

RAN SCENARIOS
FROM TRADITIONAL RBS TO XHAUL

4



Optical Transport layer

Optical transport for 5G will need to:

› be “programmable” to support increasingly diverse service requirements for the wide range of applications envisioned in 5G

› support higher capacities and an increasing number of cell sites

› facilitate radio interference coordination between sites, by connecting RRUs with DUs with severe latency constraints

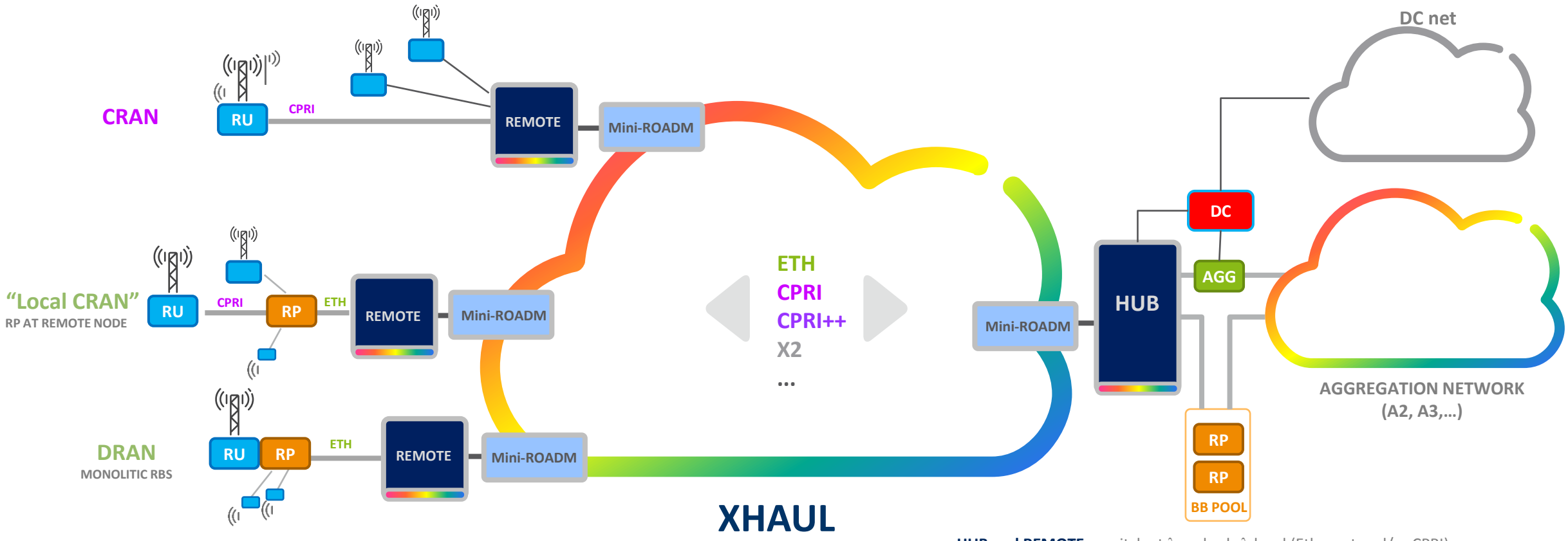
› address cost and energy constraints by exploiting emerging optical components/devices enabled by integrated photonics

› facilitate resource sharing among different network “actors”

› …”be ready for the unexpected”

OPTICAL XHAUL ARCHITECTURE

Same infrastructure for backhaul and fronthaul



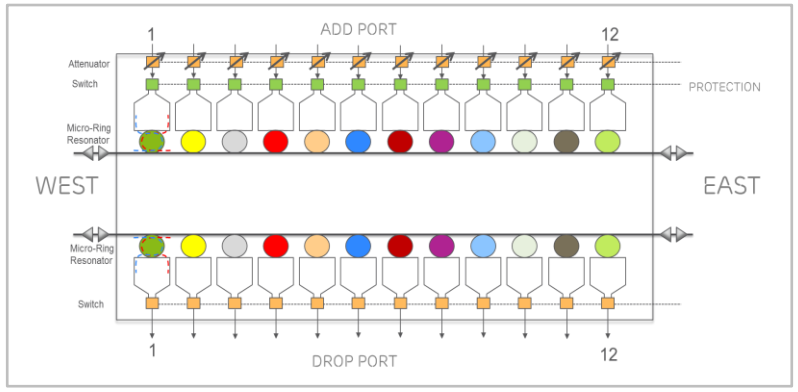
HUB and REMOTE = switch at λ and sub-λ level (Ethernet and/or CPRI)
AGG = aggregation node with L2/L3 capability.
RP = Radio Processing. It is equivalent to DU in case of CRAN. In case of different splitting options, part of radio processing is done at antenna side and some at hub side.
DC = Data Center
Mini-ROADM = Mini-Reconfigurable optical add and drop multiplexer

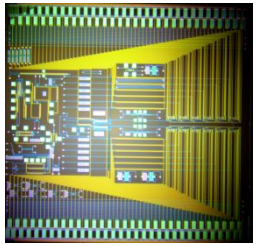
Sponsored in part by the project H2020-ICT-2014-2 "Xhaul: The 5G Integrated fronthaul/backhaul" (671598).

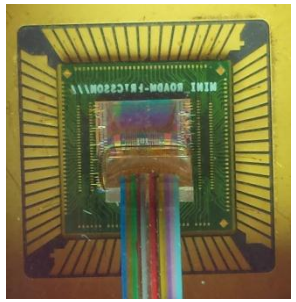
KEY ENABLING TECHNOLOGIES

Mini-ROADM on a Chip

Add/Drop, multiplexing, switching



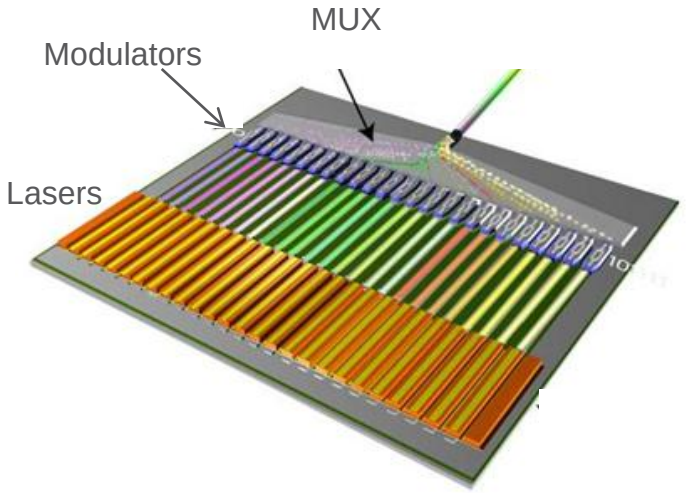




A complete switching system with one hundred optical processing functions monolithically integrated in a single silicon photonics chip. The Mini-ROADM includes an high number of optical circuits implemented in a single chip of silicon and many optical networking functions like add and drop of up to 12 wavelength channels, optical power regulation and monitoring, transmission direction selection for path protection

Multi-wavelength Laser Source

WDM Transmission



Low cost, photonic integrated multi-wavelength transceivers. Two technologies are under investigation: InP monolithic integrated (in an advanced stage of development) and silicon photonics hybrid integrated (in an initial development stage)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