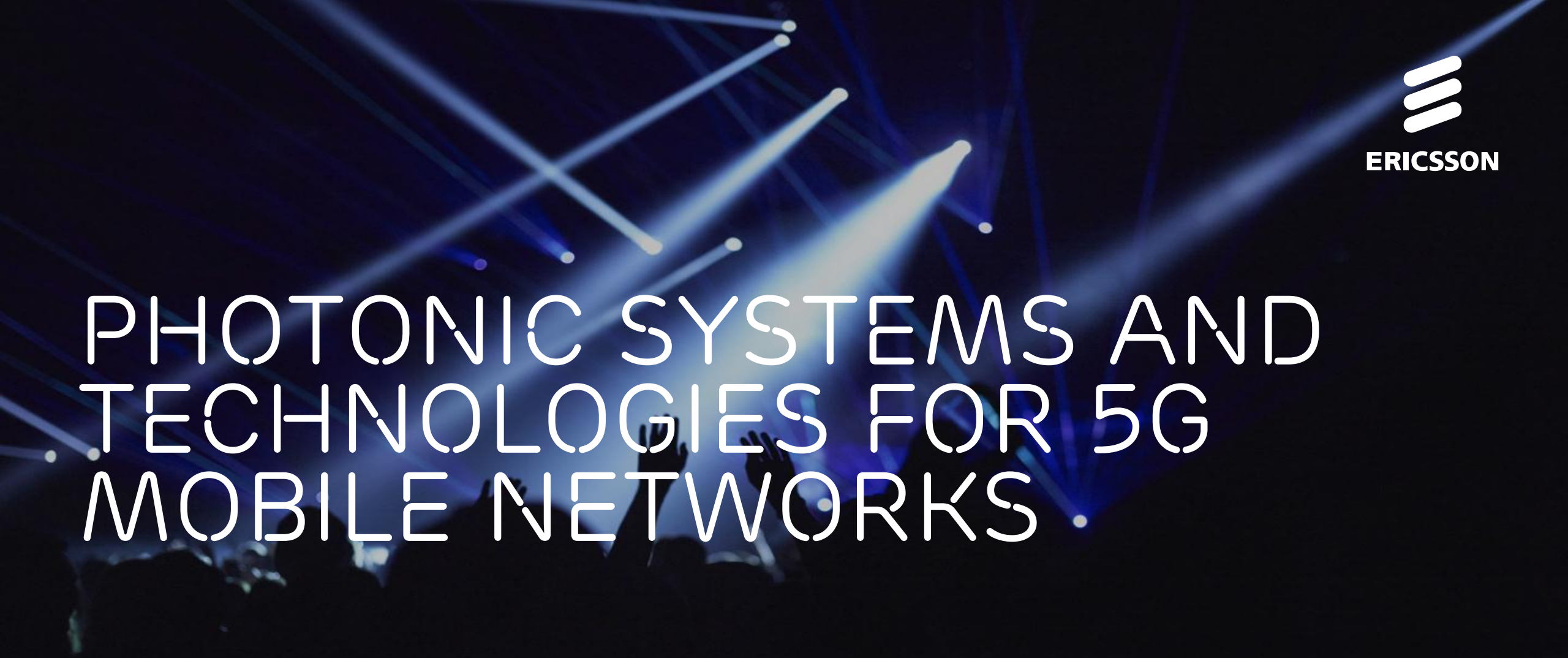


PHOTONIC SYSTEMS AND TECHNOLOGIES FOR 5G MOBILE NETWORKS

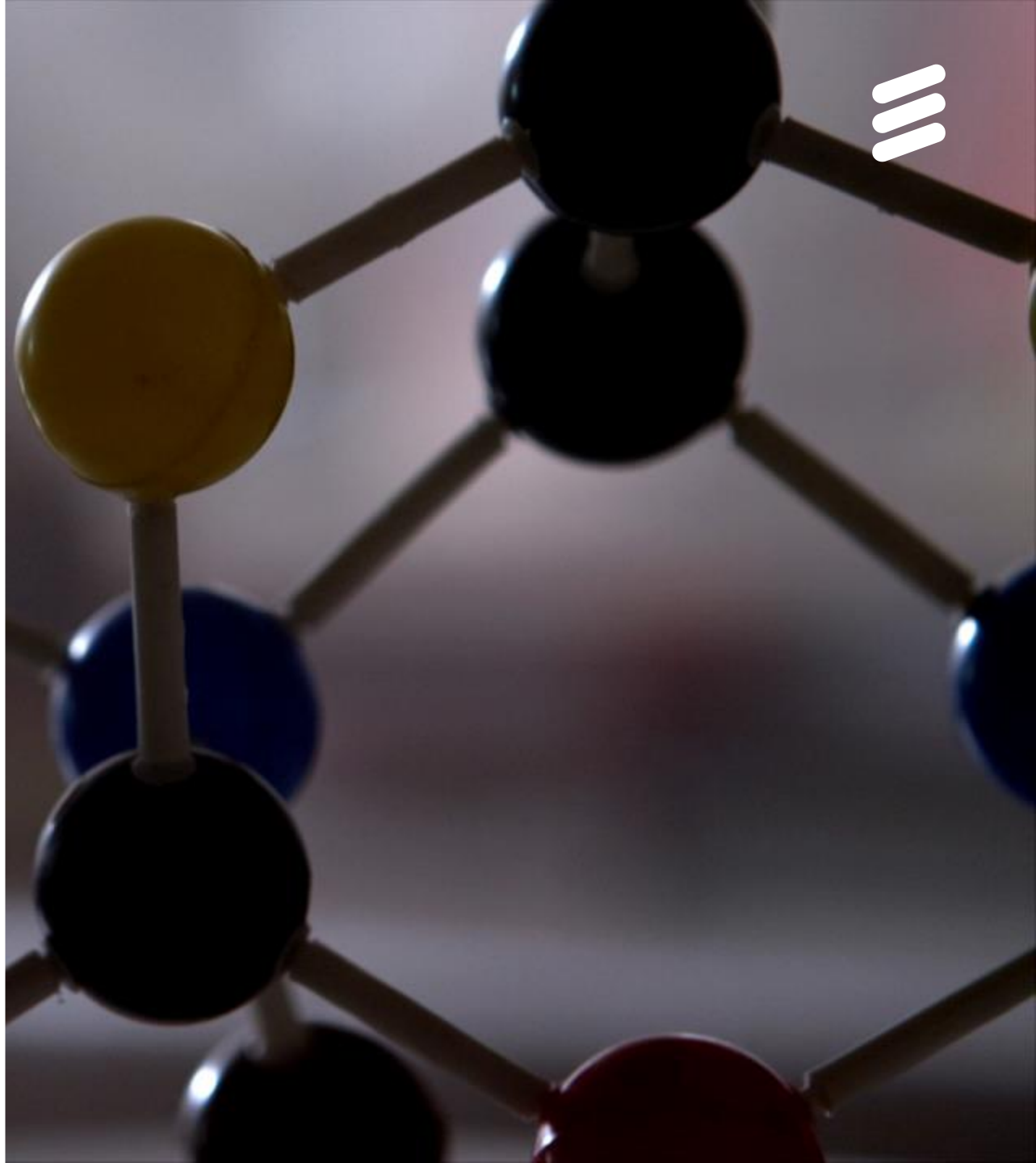
Dr Roberto Sabella, Dr Alberto Bianchi
Ericsson Research - Italy

OUTLINE

5G: a Real Game Changer

Optical solutions for 5G

Conclusions



NEW BEHAVIORS

$13 million
crowdfunding

700,000
new internet users

$2,7 billion
e-commerce

EVERY DAY

2.7 billion likes
on Facebook

133 million hours
YouTube video
watched

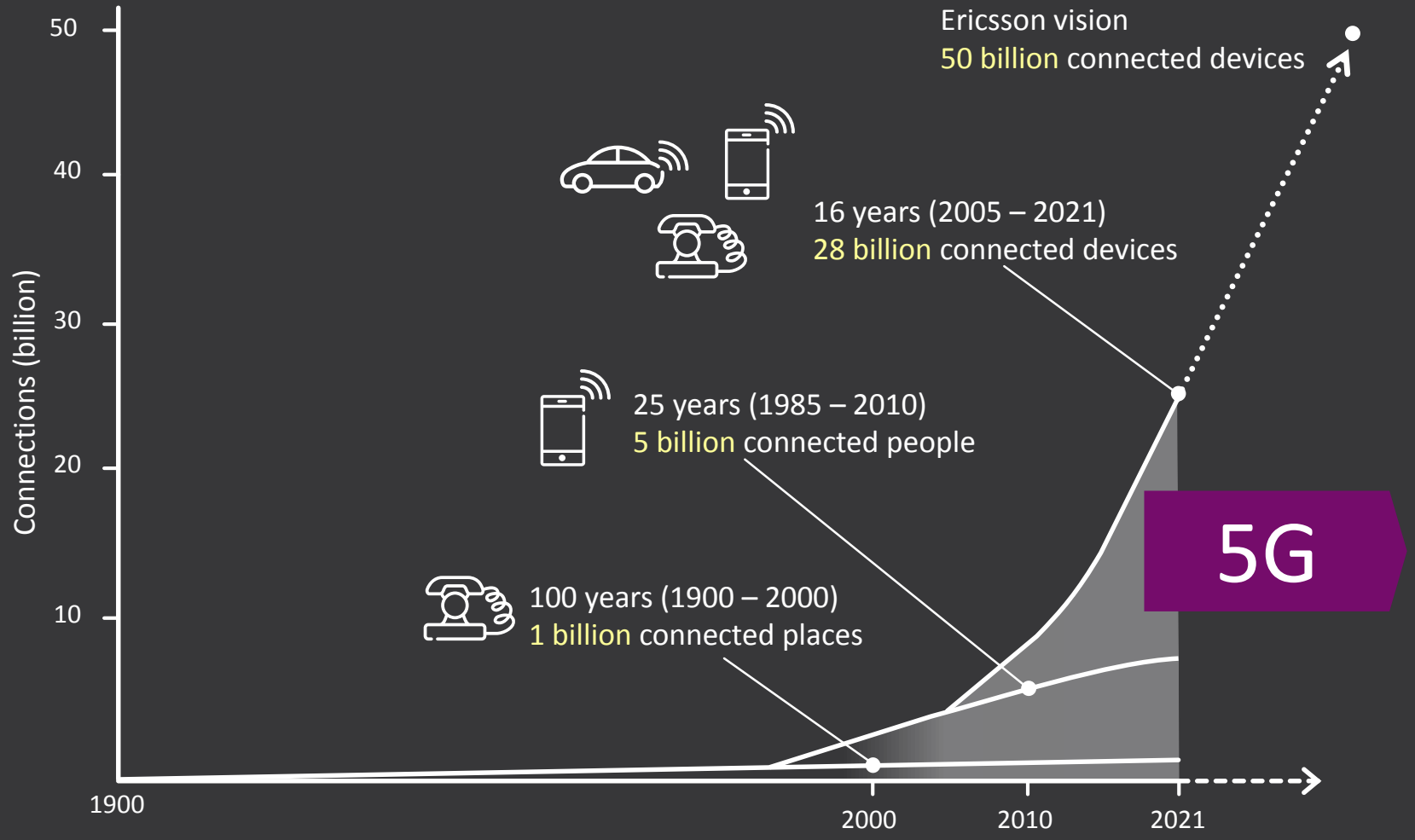
328 million
app downloads

2.7 billion
photos posted

THE PATH TOWARDS 5G

This chart highlights the phenomenal pace of change, which connected **5 billion of people** in only 25 years.

Ericsson forecast that there will **28 billion** connected devices by **2021**, well on the way to our vision of **50 billion** connected devices in total.



5G: A REAL GAME CHANGER

Remotely Operate Robots

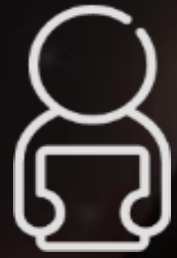
Stop a self-driving car faster

Fixed wireless broadband

Drone Control & Communication

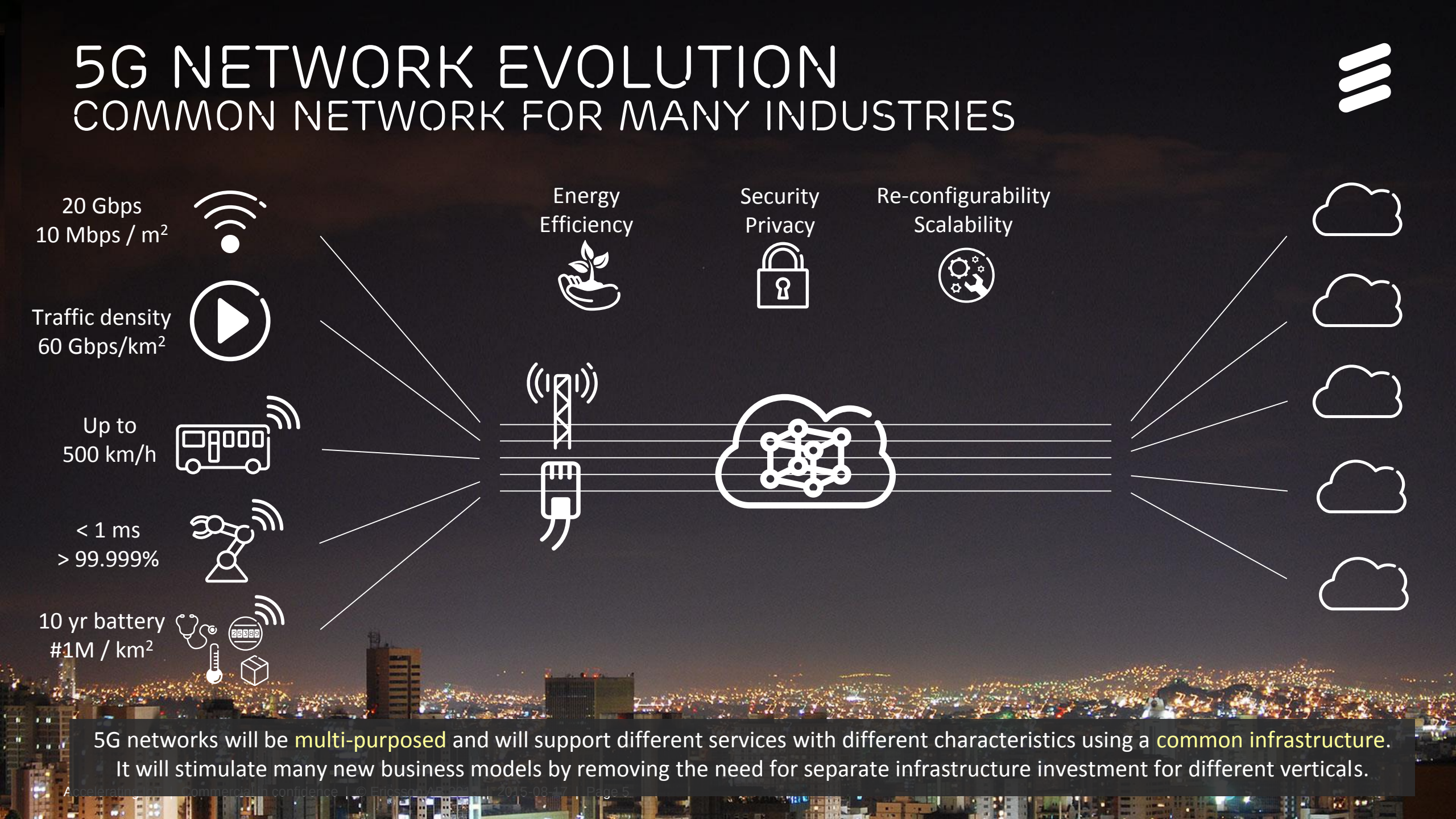
10 Year Battery Life for Remote Sensors

Virtual Reality / Hologram



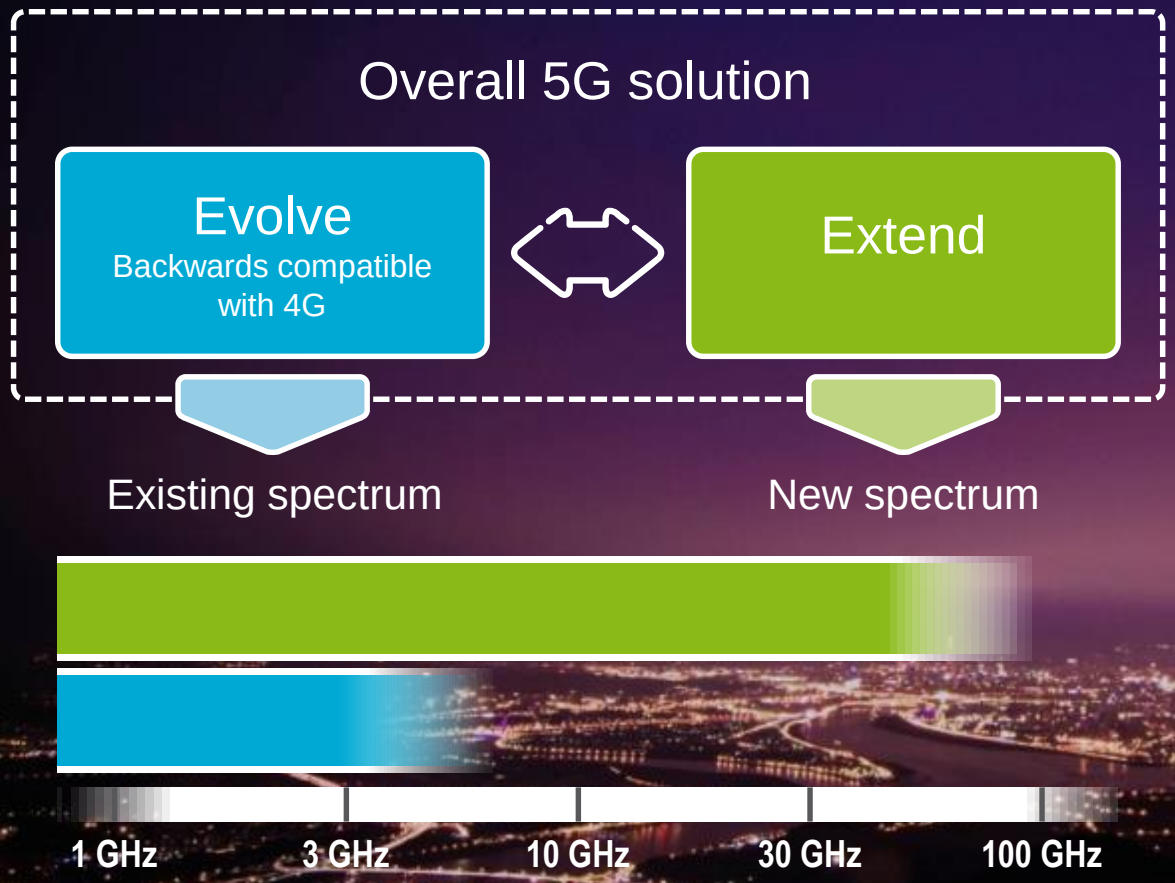
Full-length HD movie in seconds

5G NETWORK EVOLUTION
COMMON NETWORK FOR MANY INDUSTRIES



5G networks will be multi-purposed and will support different services with different characteristics using a common infrastructure.
It will stimulate many new business models by removing the need for separate infrastructure investment for different verticals.

5G: EVOLVE AND EXTEND



- The 5G radio consists of an LTE evolution that is backwards compatible and a new radio component.
- The LTE evolution will primarily operate in existing spectrum.
- The new radio component will be a clean-slate design, optimized for performance.

5G WIRELESS ACCESS

Much more than just enhanced mobile broadband

- A wide range of requirements and capabilities
- Multiple use-cases supported by a common network platform

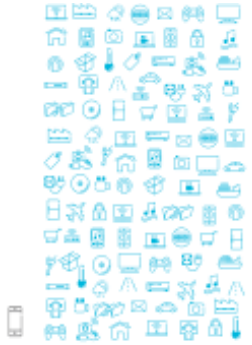
- Very high traffic capacity
- High data rates everywhere
- Very low latency
- Massive number of devices
- Very low device cost
- Very low device energy consumption
- Ultra-high reliability and availability
- Machine-type communication (MTC)

Affordable and sustainable

5G – KEY REQUIREMENTS

PERFORMANCE

1000x
higher mobile
data volumes



10x - 100x
higher number of
connected devices

10x - 100x
typical end-user
data rates

5x
lower latency

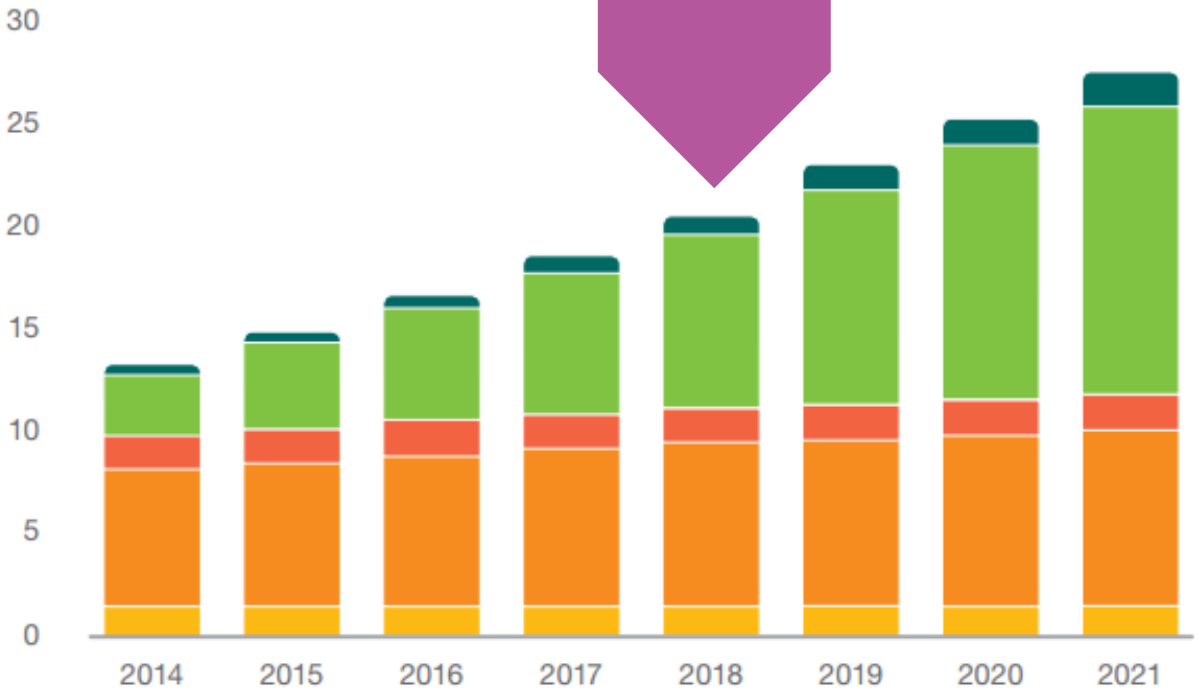
10x
longer battery life
for low-power devices

FLEXIBILITY

- Network programmability
- Agile service development
- Affordable and sustainable

2018, IOT WILL SURPASS PHONES

IoT connected devices are expected to surpass mobile phones in 2018



	15 billion	28 billion	Growth 2015–2021
Cellular IoT	0.4	1.5	27%
Non-cellular IoT	4.2	14.2	22%
PC/laptop/tablet	1.7	1.8	1%
Mobile phones	7.1	8.6	3%
Fixed phones	1.3	1.4	0%
	2015	2021	

Things

People

Growth in the number of connected devices is driven by emerging applications and business models, and supported by **falling device costs**

MASSIVE AND CRITICAL IOT

MASSIVE

SMART BUILDING

LOGISTICS, TRACKING AND FLEET MANAGEMENT

SMART METER

SMART AGRICULTURE

CAPILLARY NETWORKS

CRITICAL

REMOTE HEALTH CARE

TRAFFIC SAFETY & CONTROL

INDUSTRIAL APPLICATION & CONTROL

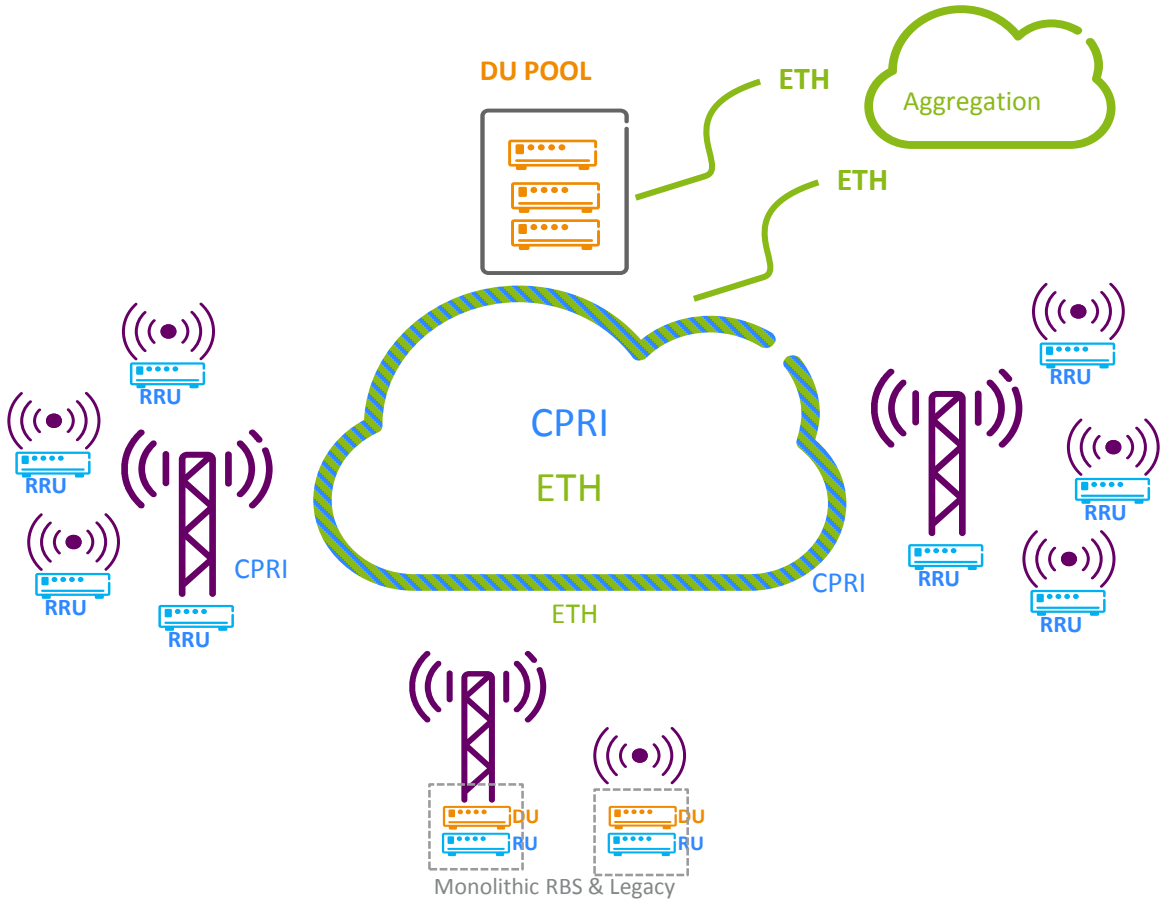
REMOTE MANUFACTURING, TRAINING, SURGERY

LOW COST, LOW ENERGY
SMALL DATA VOLUMES
MASSIVE NUMBERS

ULTRA RELIABLE
VERY LOW LATENCY
VERY HIGH AVAILABILITY

OPTICAL NETWORKING SOLUTIONS FOR 5G TRANSPORT: THE XHAUL CONCEPT

RAN SCENARIOS
FROM TRADITIONAL RBS TO XHAUL



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"

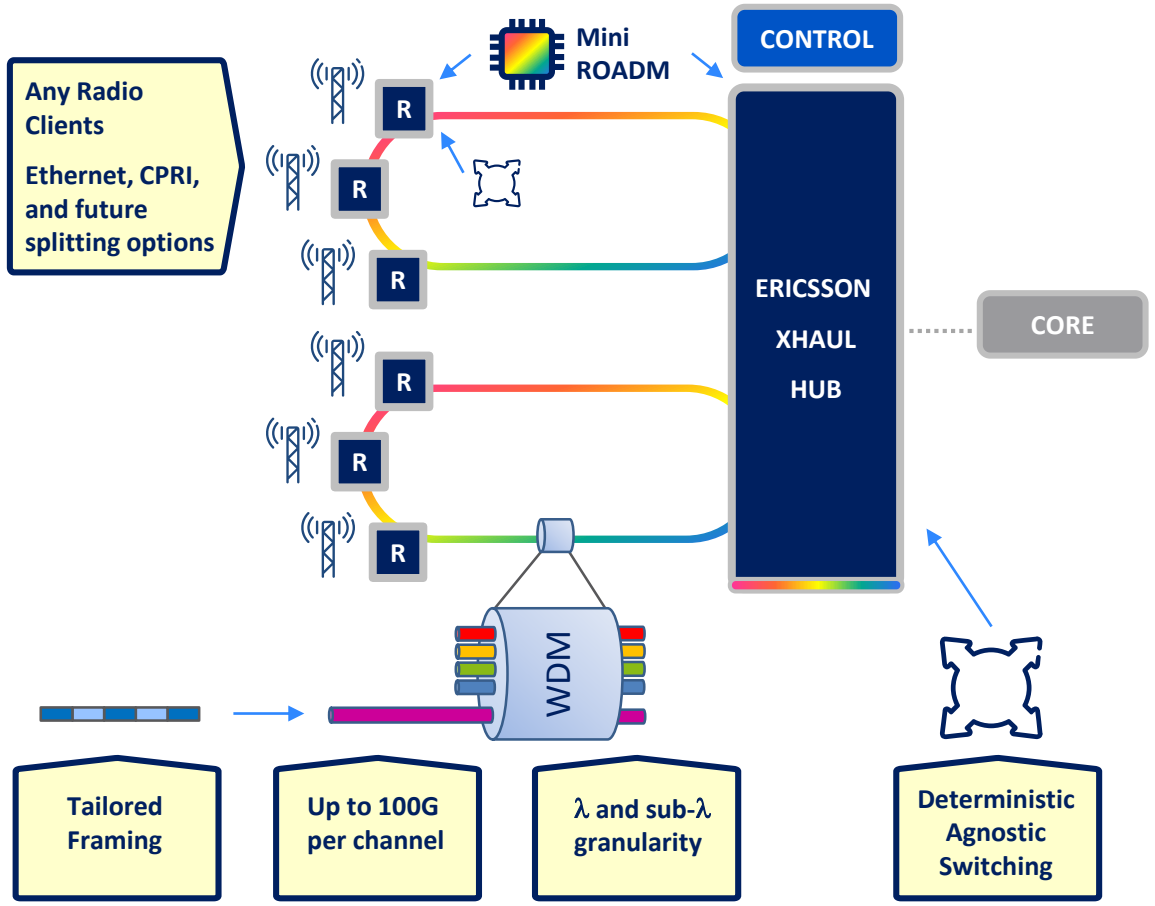
› …"be ready for the unexpected"

XHAUL AT GLANCE

Xhaul is a novel network concept which provides agnostic transport of any client types for the different protocol split supported by 5G systems, satisfying tight requirements of latency, jitter and synchronization.

Key elements

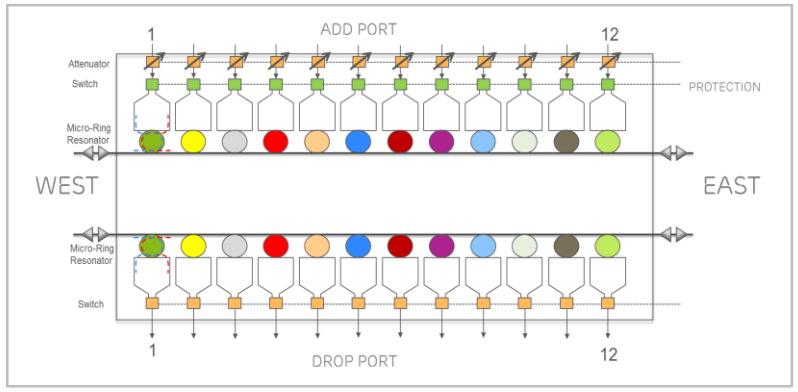
- Hub & Spoke architecture eliminates processing nodes between radio and baseband units, minimizing latency.
- Combining deterministic switching with statistical multiplexing for agnostic transport.
- Patented agnostic framing for any type of traffic mix.
- WDM for increased capacity and fiber optimization.
- Dynamic control to follow traffic changes in the day/week from residential to business areas.

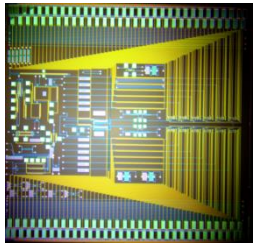


KEY ENABLING TECHNOLOGIES

Mini-ROADM on a Chip

Add/Drop, multiplexing, switching

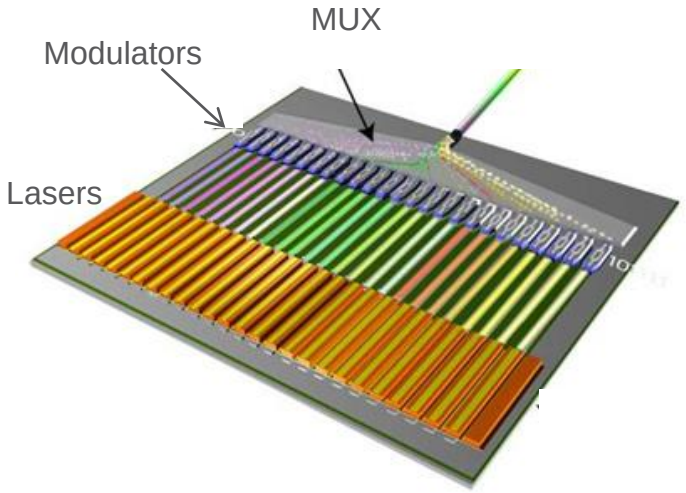




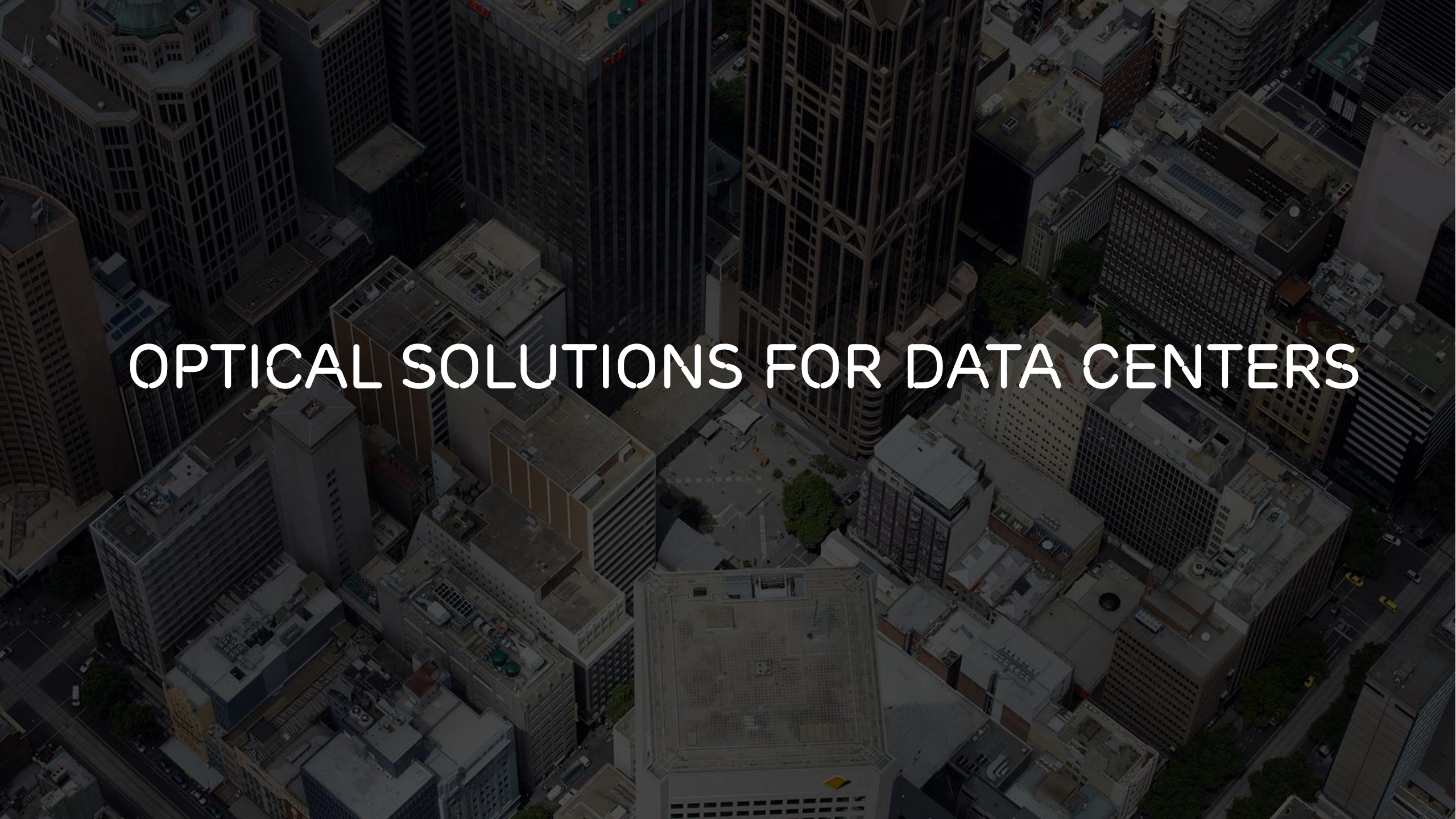
A complete switching system with one hundred optical processing functions monolithically integrated in a single silicon photonics chip. The Mini-ROADM includes an high number of optical circuits implemented in a single chip of silicon and many optical networking functions like add and drop of up to 12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

Multi-wavelength Laser Source

WDM Transmission



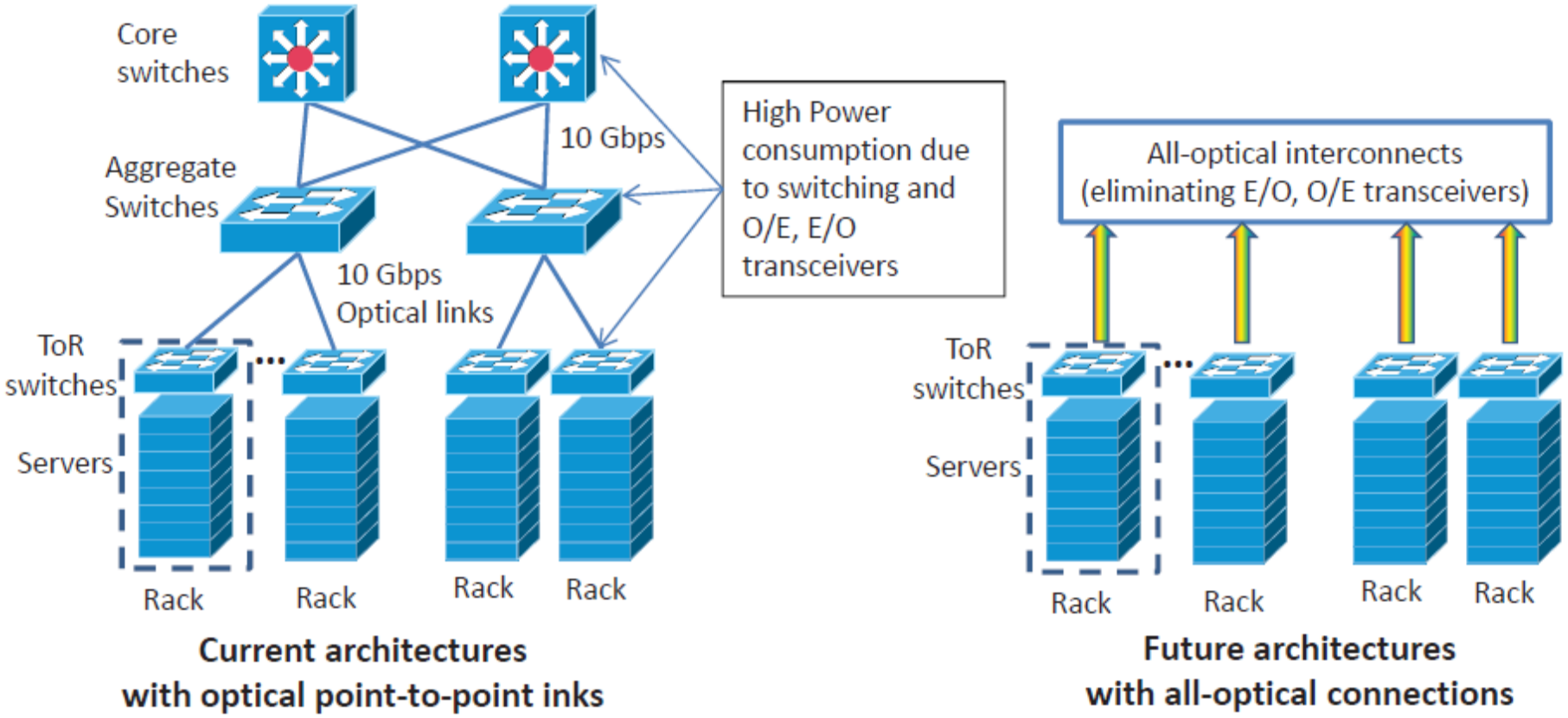
Low cost, photonic integrated multi-wavelength transceivers. Two technologies are under investigation: InP monolithic integrated (in an advanced stage of development) and silicon photonics hybrid integrated (in an initial development stage)


OPTICAL SOLUTIONS FOR DATA CENTERS

WHY OPTICAL SWITCHING IN DC

- Data center networks shall sustain the huge increase of network traffic, i.e. high bandwidth, low latency, scalable and green.
- A hybrid packet-optical switching solution will be the best approach:
  - Optical → transparency and high bandwidth features of well proven optical circuit switching technologies
  - Electrical → advantages of the CMOS scalable technology used for electrical packet switching able to ensure an ever increasing processing capacity
- Optical switching enable the offload of packet switching for long lasting big flows to increase throughput and energy performance
  - high throughput, low latency, low energy consumption

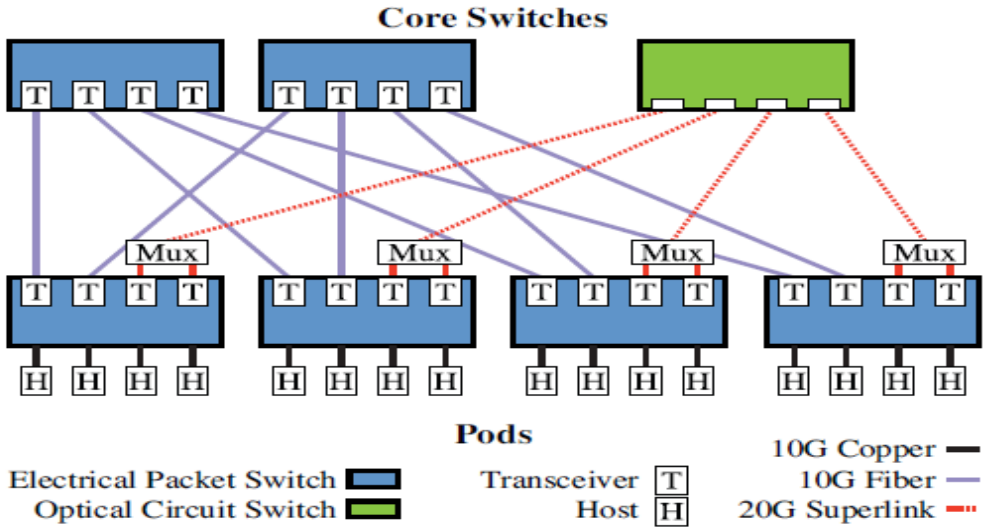
OPTICAL INTERCONNECTS FOR DC



Source: Kachris, Bergman, Tomkos, “Optical interconnects for future data center networks”, Elservier publication

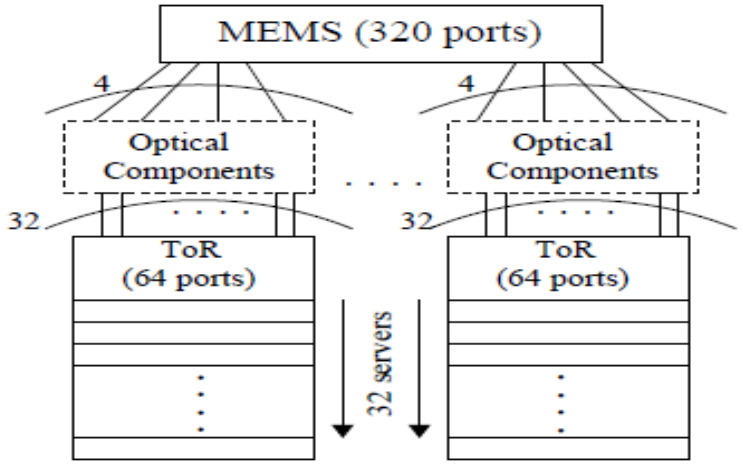
FLAT ARCHITECTURE WITH OPTICAL SWITCHING
TWO EXAMPLES

HELIOS PROJECT (UCSD)



To Enable a dynamic bypass / fast path
To provide additional network service options for High Availability, Performance, and Capacity Expansion.
Software Defined Technology can choose path to configure service

PROTEUS PROJECT



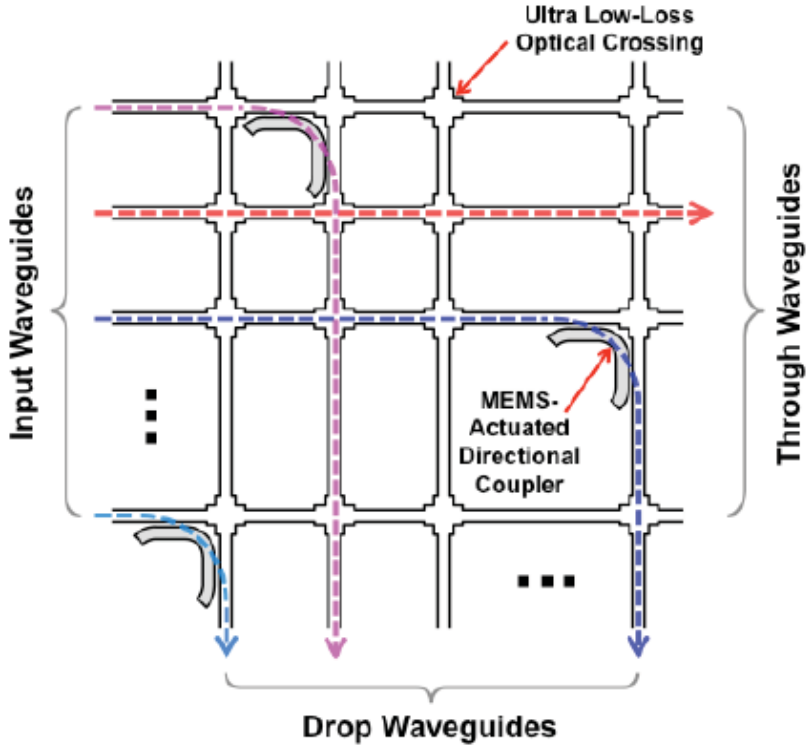
Based on optical WDM multiplexing and wavelength/space switch technology to add the flexibility and re-configurability according to traffic demand

Other projects: c-through architecture (Rice U, CM, Intel), OSMOSIS (IBM, Corning), DOS architecture, Petabit architecture, Space-WL, E-Rapid, IRIS, Bdirectional

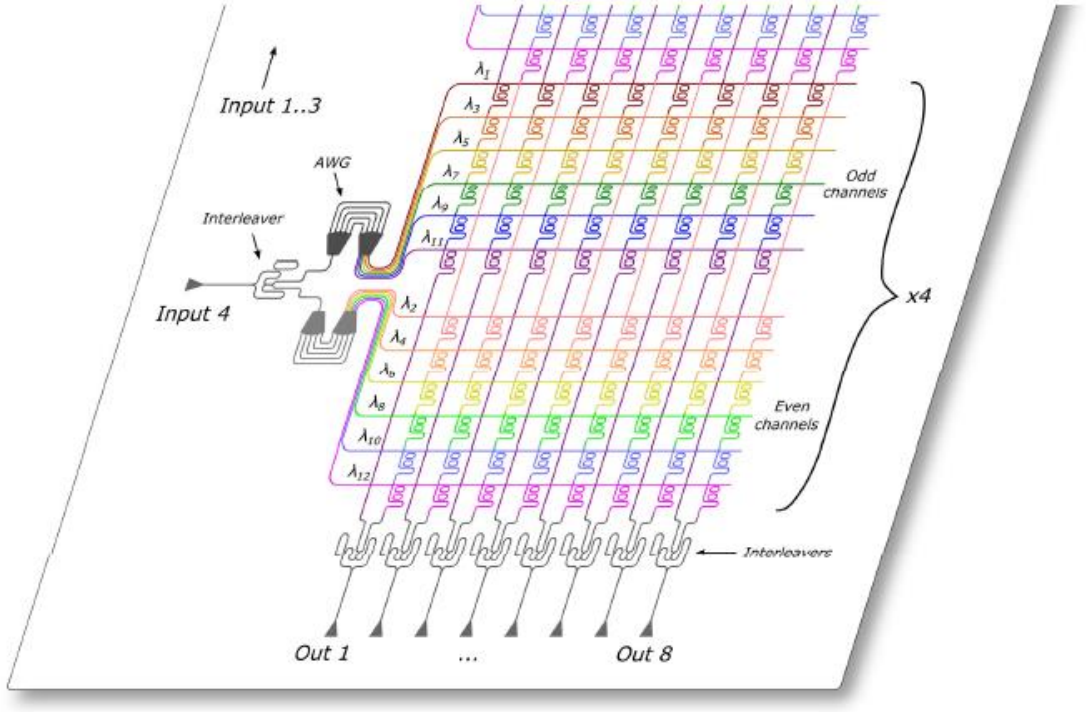
SILICON PHOTONICS HIGH SCALE INTEGRATED SWITCHES

Cost potentially 2 order of magnitude less than commercial optical switches
Low power consumption, low footprint (7mmx7mm), response time in us range.
Loss > 10 dB but with SOA integration it is possible to achive 0-loss
Prototypes under development.

64x64 grey optics broadband switch
Univ. California, Berkeley



IRIS Switch: 48 channels Wavelength selective switch




PHOTONICS FOR
CHIP-TO-CHIP INTERCONNECT

ELECTRICAL VS OPTICAL INTERCONNECT

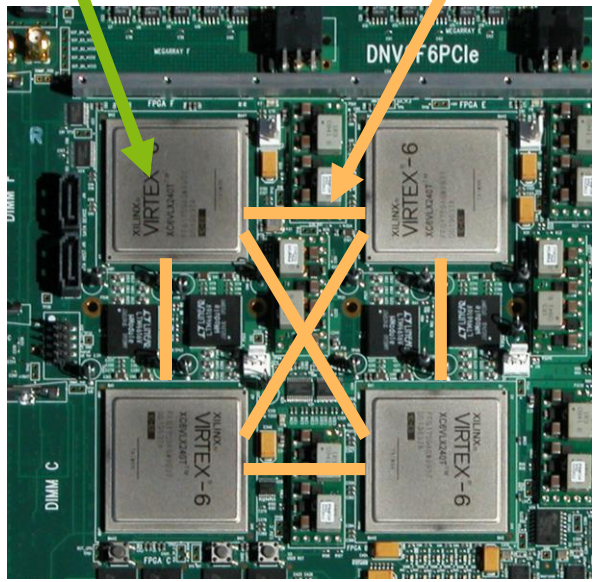
ELECTRICAL

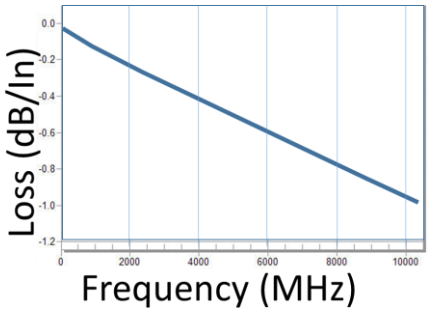
Moore's Law

Processing Capacity: 1T, 500G, 100G

I/O Pads and packages do not scale enough!!

Signal Bitrate: 50G, 25G, 10G, 2.5G

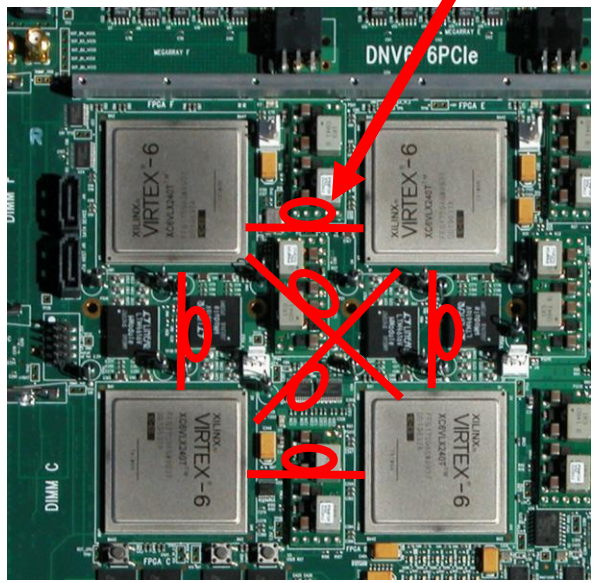


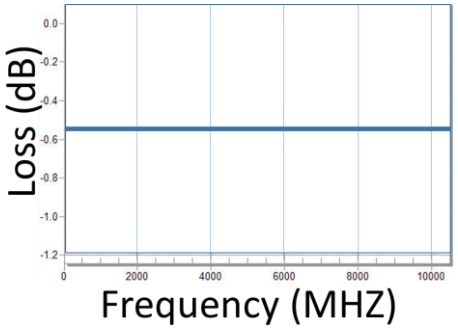


Electrical Interconnect has become a bottleneck due to frequency dependent loss

OPTICAL

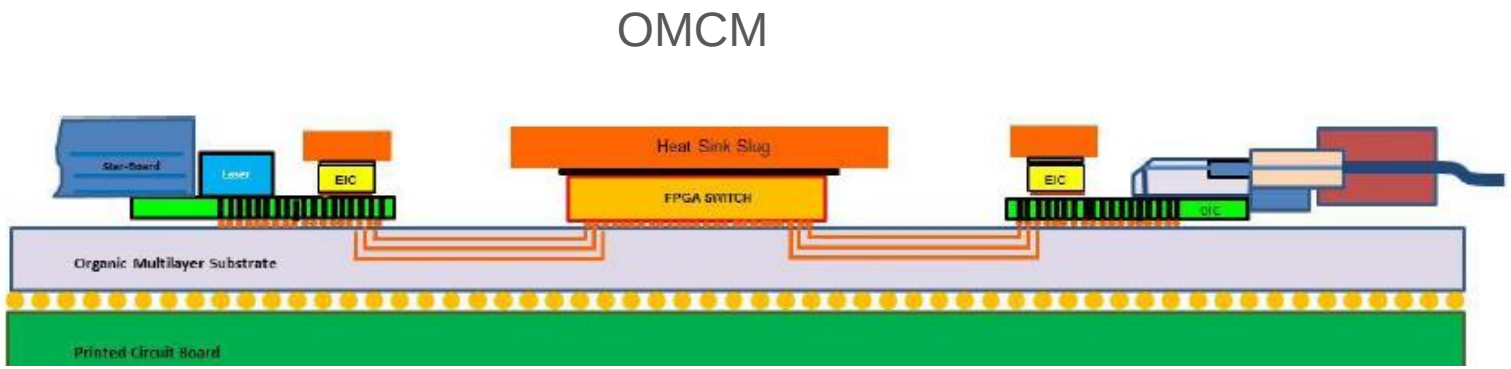
Signal Bitrate: 400G, 100G, 50G, 25G, 10G



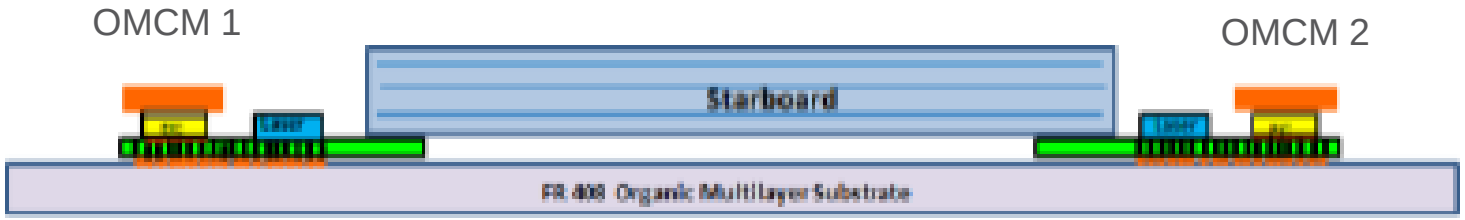


Optical interconnect loss almost bitrate and length independent

H2020 TERABOARD PROJECT



Intra-module communication

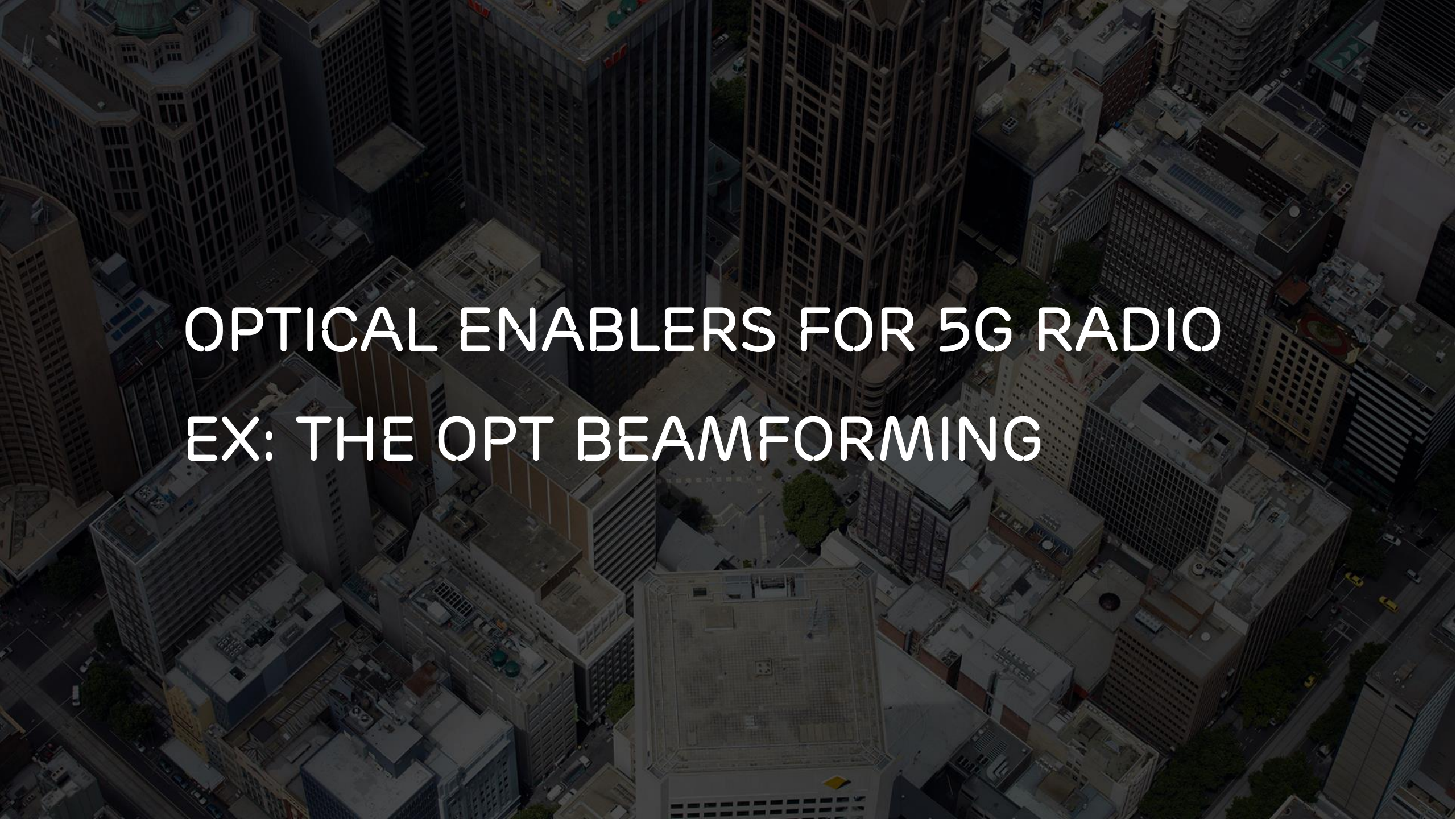


Inter-module communication

Objectives

To sustain the Data Center and Cloud traffic growth with 2020 target requirement for line cards of:

- some Tb/s of aggregated traffic scalable to tens and to hundreds of Tb/s per board
- a power consumption strategy so that the overall Data Center power consumption (mainly driven by internal links) can be reduced at least a factor of 10x;
- to interconnect several ASICs (more then 8) up to 40 cm far apart on the same board; with a cost below 0.1 $/Gb/s



OPTICAL ENABLERS FOR 5G RADIO

EX: THE OPT BEAMFORMING

OPTICAL BEAMFORMING FOR 5G

Beamforming is a technique for controlling electronically transmission directionality thanks to an array of smalls antennas exploiting signal interference. Electronics is severely impacted by wideband and microwave spectrum needed by 5G.

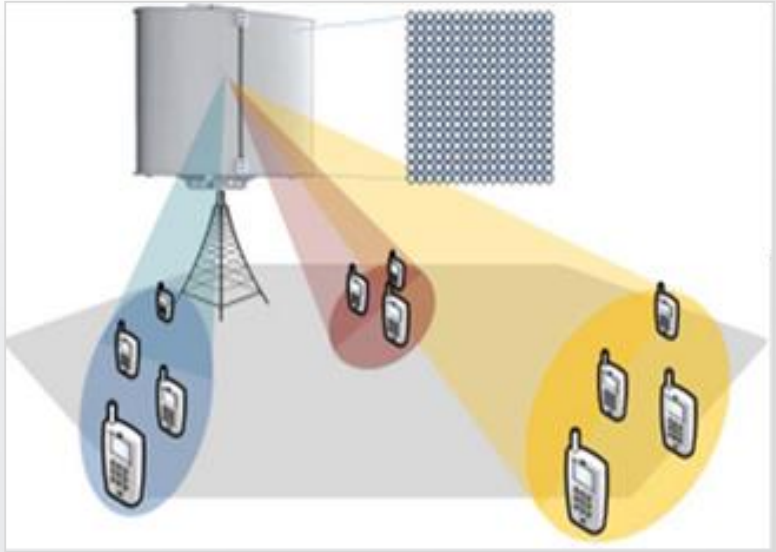
A superior performance can be achieved replacing electronics with photonic devices.

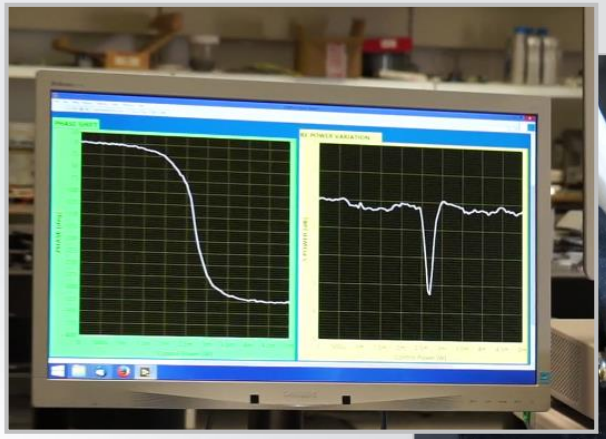
The areas under investigation cover photonic RF generators to reduce phase noise , optical phase and delay shifting for accurate beam pointing and photonic DAC/ADC.

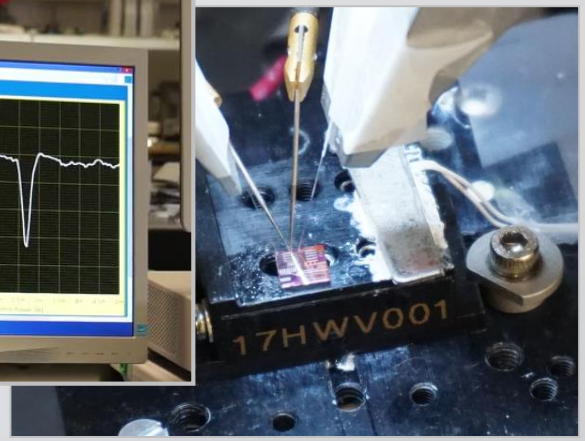
Several optical beamforming architectures were studied most of them exploiting integrated photonics.

A first photonic RF optical generator was tested with excellent results.

A first beamforming transmitting element was successfully experimented using integrated optical phase shifting





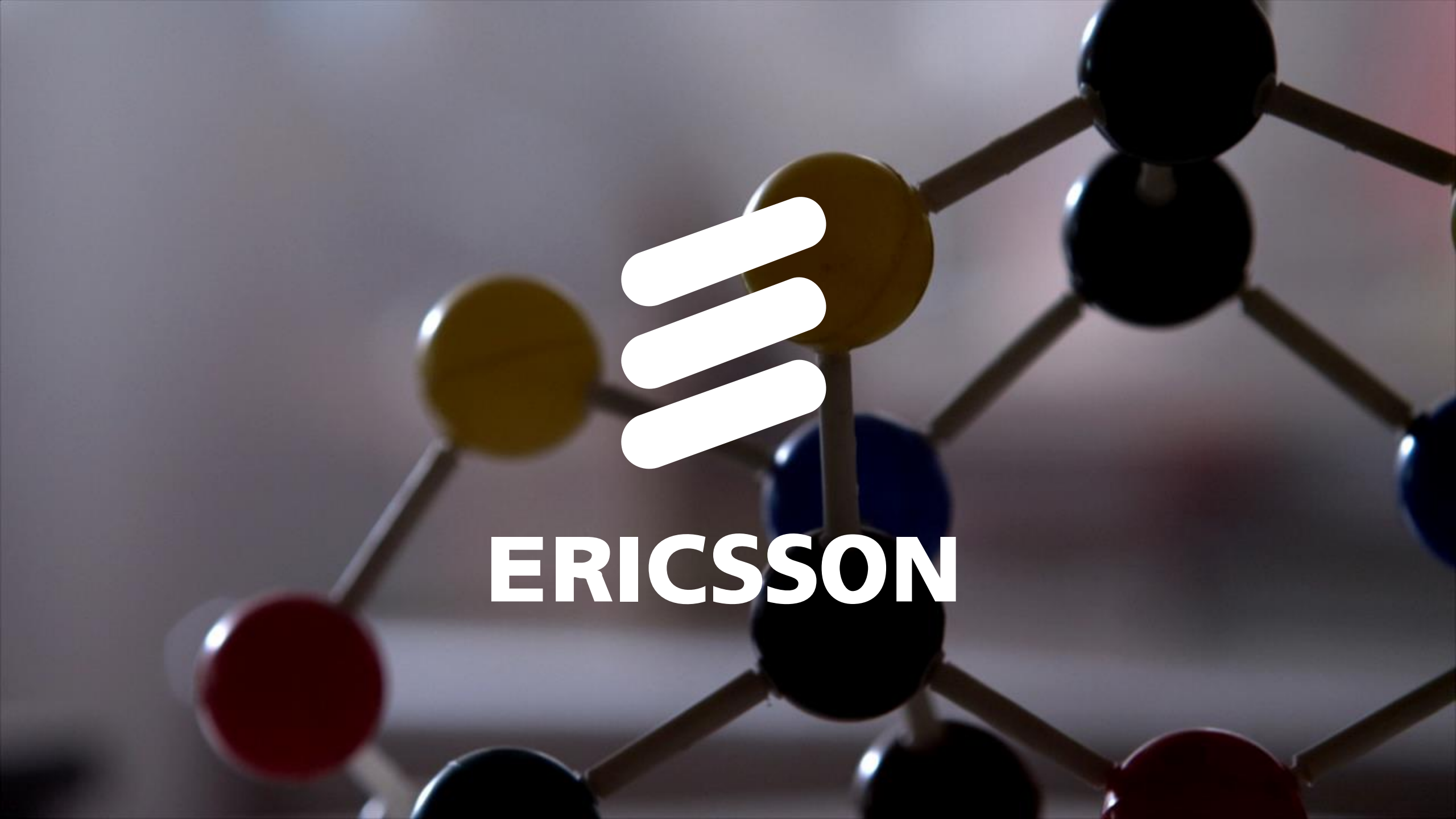


CONCLUSIONS: PHOTONICS IS KEY FOR 5G

In the future, all devices that could benefit from an internet connection will be connected. In this Networked Society, every person and every industry will be empowered to reach their full potential.

The capabilities of 5G wireless access will extend far beyond previous generations of mobile communication in all aspects: tremendous flexibility, lower energy requirements, greater capacity, bandwidth, security, reliability and data rates, as well as lower latency and device costs.

1. Enabler of suitable transport solutions in new network segments
   - Fronthaul: high-capacity interconnects are needed (low-latency and high flexible network solutions)
   - Xhaul networks: to simultaneously support fronthaul and backhaul in the last 10-20 Km segment
   - Optical offload in aggregation (backhaul) networks characterized by high capacity and low-costs
2. Solutions for data centers
   - Massive use of optical interconnects
   - Use of optical transmission and switching to boost performance of packet-based modules, simplify the architecture, and lower costs and power consumption
3. Photonics is key to scale up capacity of HW platforms
   - Increase the capacity while dramatically lower power consumption, costs, footprint
4. Optical enablers for 5G radio
   - Realize key subsystems leveraging on optical properties.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