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

$2,7 billion
e-commerce

700,000
new internet users

2.7 billion likes
on Facebook

2.7 billion likes
on Facebook

328 million
app downloads

2.7 billion likes
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700,000
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133 million hours
YouTube video watched

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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

- 5G: Remotely Operate Robots
- 4G: Stop a self-driving car faster
- 5G: Fixed wireless broadband
- Drone Control & Communication
- Virtual Reality / Hologram
- 10 Year Battery Life for Remote Sensors
- Full-length HD movie in seconds
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.
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

- 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

- A wide range of requirements and capabilities
- Multiple use-cases supported by a common network platform
5G – KEY REQUIREMENTS

PERFORMANCE

1. 1000x higher mobile data volumes
2. 10x - 100x higher number of connected devices
3. 10x - 100x typical end-user data rates
4. 5x lower latency
5. 10x longer battery life for low-power devices

FLEXIBILITY

- Network programmability
- Agile service development
- Affordable and sustainable
2018, IOT WILL SURPASS PHONES

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
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 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.
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.

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

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, Birectional
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 achieve 0-loss
Prototypes under development.

64x64 grey optics broadband switch
Univ. California, Berkeley
PHOTONICS FOR CHIP-TO-CHIP INTERCONNECT
Electrical interconnect has become a bottleneck due to frequency dependent loss.

Optical interconnect loss is almost bitrate and length independent.
H2020 TERABOARD PROJECT

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
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
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.