Excellence Award 2013
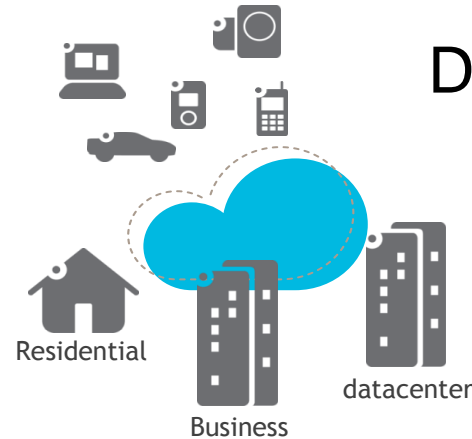
EO-Net: **E**lastic **O**ptical **Net**works

40.8PY and 5 countries:

France: Alcatel-Lucent Bell Labs, Ekinops, Orange,
Sweden: University of Chalmers, Proximion,
Denmark: Danish Technical University, NORDUnet,
Greece: Analogies, University of Patras,
Turkey: CTECH

Patricia Layec, Alcatel-Lucent Bell Labs

Elastic Optical Networks
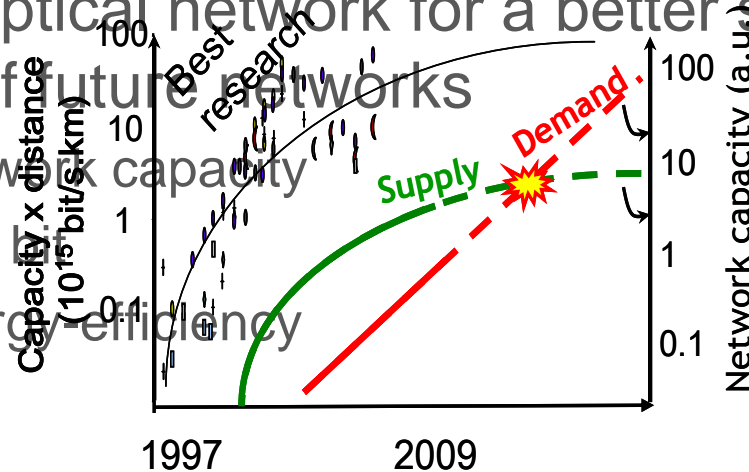
Data explosion

"Cloudification"

New usage

Residential

Business

datacenter

- Traditional (fixed) networks do not scale
- "Elasticity" of optical network for a better scalability and sustainability of future networks
  - → increased network capacity
  - → lower cost per bit
  - → improved energy efficiency

Best research

Supply

Demand

Capacity x distance $(10^{15}$ bit/s·km)

Network capacity (a.u.)

100

10

1

0.1

100

10

1

0.1

1997

2009

Main Focus and Challenges

Direct Detection
Legacy 10G

Coherent detection
Today's 100G

Coherent detection + ELASTIC DSP
EO-Net

1 bit/symbol
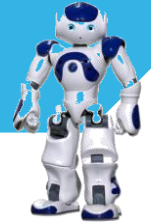
2 bit/symbol

Multi-bit/symbol

- At project start, very little work was performed
  - EO-Net work on the following building blocks, from (1) to (5)
  - Transponder (1) was made adaptive based on 100G product – coherent detection + DSP functions were key
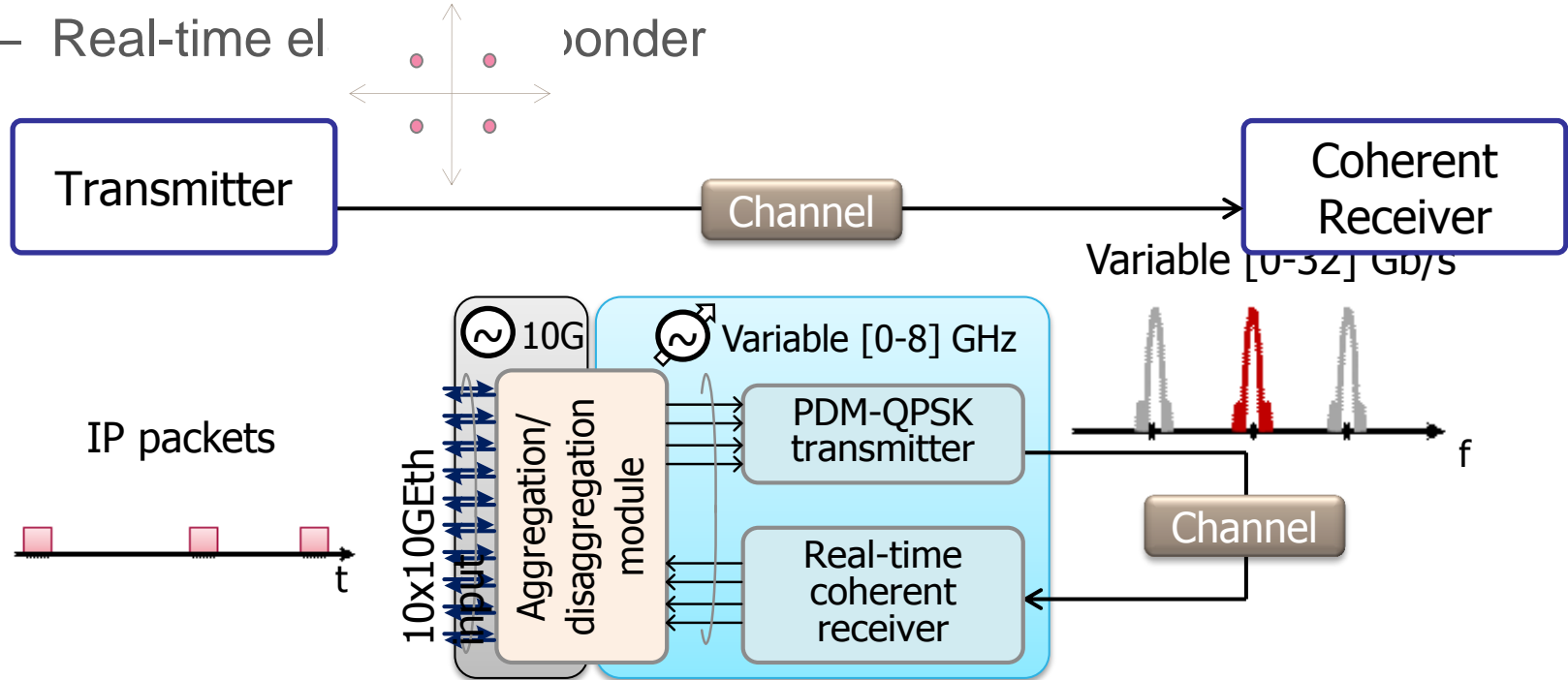 - Various parts of the optical network may also be adapted

(5) Control plane

Core routers

(2) Interface between transponders and routers

(3) Network architecture → new resource allocation algorithms

(1) Flexible transponder (TSP)

B

A   C

E   D

Optical cross-connect (OXC)

(4) Performance prediction
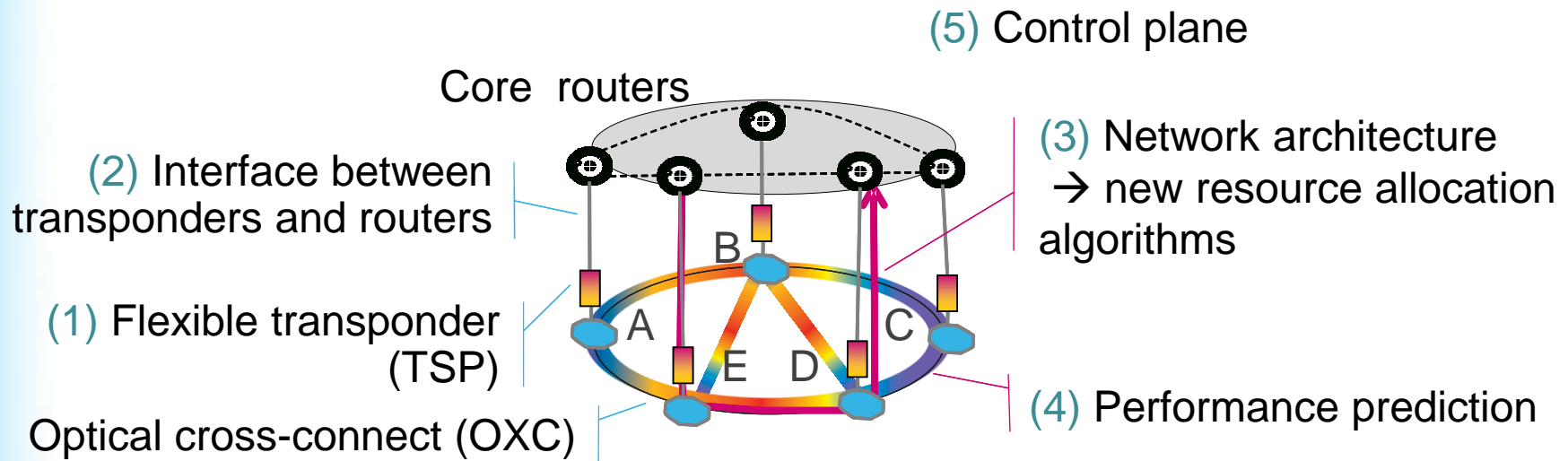
Hardware-oriented

Software-oriented

- First prototypes developed to demonstrate the feasibility of the concept
  - A (burst-mode) elastic transmitter up to 100Gbps
  - Real-time el   onder

Hardware-oriented

→ enables a power consumption proportional to the actual traffic

Achievements

- First prototypes developed to demonstrate the feasibility of the concept
  - A (burst-mode) elastic transmitter up to 100Gbps
  - Real-time elastic muxponder
- Key ideas of an adaptive code rate for LDPC convolutional codes patented and a proof-of-concept was developed
- Studies on coded modulations as alternative to QPSK, 8QAM
  - → Next ALU chipset may include it (under discussion)

- New performance estimation models for (elastic) optical networks → very accurate (<0.5dB accuracy) and fast (<ms → 1000x speed-up!), Based on disruptive assumption of nonlinearities as a Gaussian noise
- Novel routing and resource allocation algorithms developed
- A wide range of Techno-Economic studies

Example: Ability to **upgrade their data rate** to follow capacity growth
→ no need to uninstall and replace the low-rate devices.
→ Elastic devices are **cost-efficient by -18%** (CAPEX only)

Business Impact

- Concrete business transfers
  - Alcatel-Lucent (ALU) 1830 PSS
    - Multi-format PSE 400G chip
    - Accurate and fast performance estimators, up to 40% extended reach

- Some of the next improved products (within 2-3 years)
  - Analogies next generation FEC is developing a high-speed prototype
  - Ekinops to introduce "elasticity" in its product line
  - CTECH will leverage on EO-Net to improve 3 radar/satellite products

- Estimated Return over Investment ~10x

- EO-Net also permits:
    - 3 new permanent employees hired
    - Huge growth within ALU on this subject (internal growth)
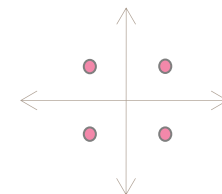
- Other major impacts
  - 2 patents filed
  - 46 scientific contributions including 14 journal papers
  - 3 workshop participations and co-organization
  - 1 tutorial at a major conference
  - Follow-up research activities on elastic and software-defined optical networks in CELTIC+ SASER

- Estimated value of impact
  - Enhancement of expertise of this disruptive concept
  - Collaboration between academics and industry contributing to the motivation of young and talented researchers