BONE

Work-Packages and Joint-Activities

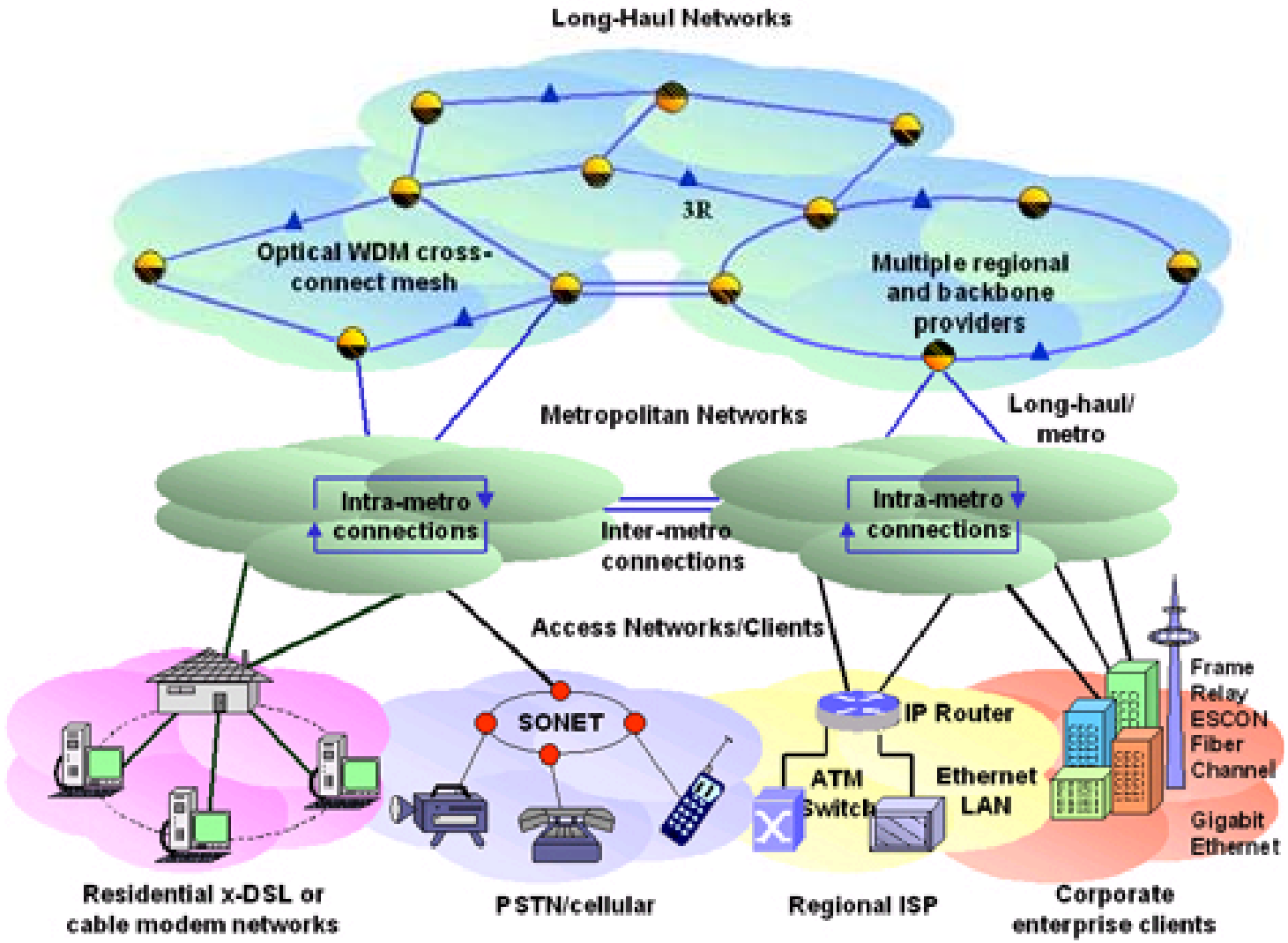
BONE VCE Work-Packages

General Tasks

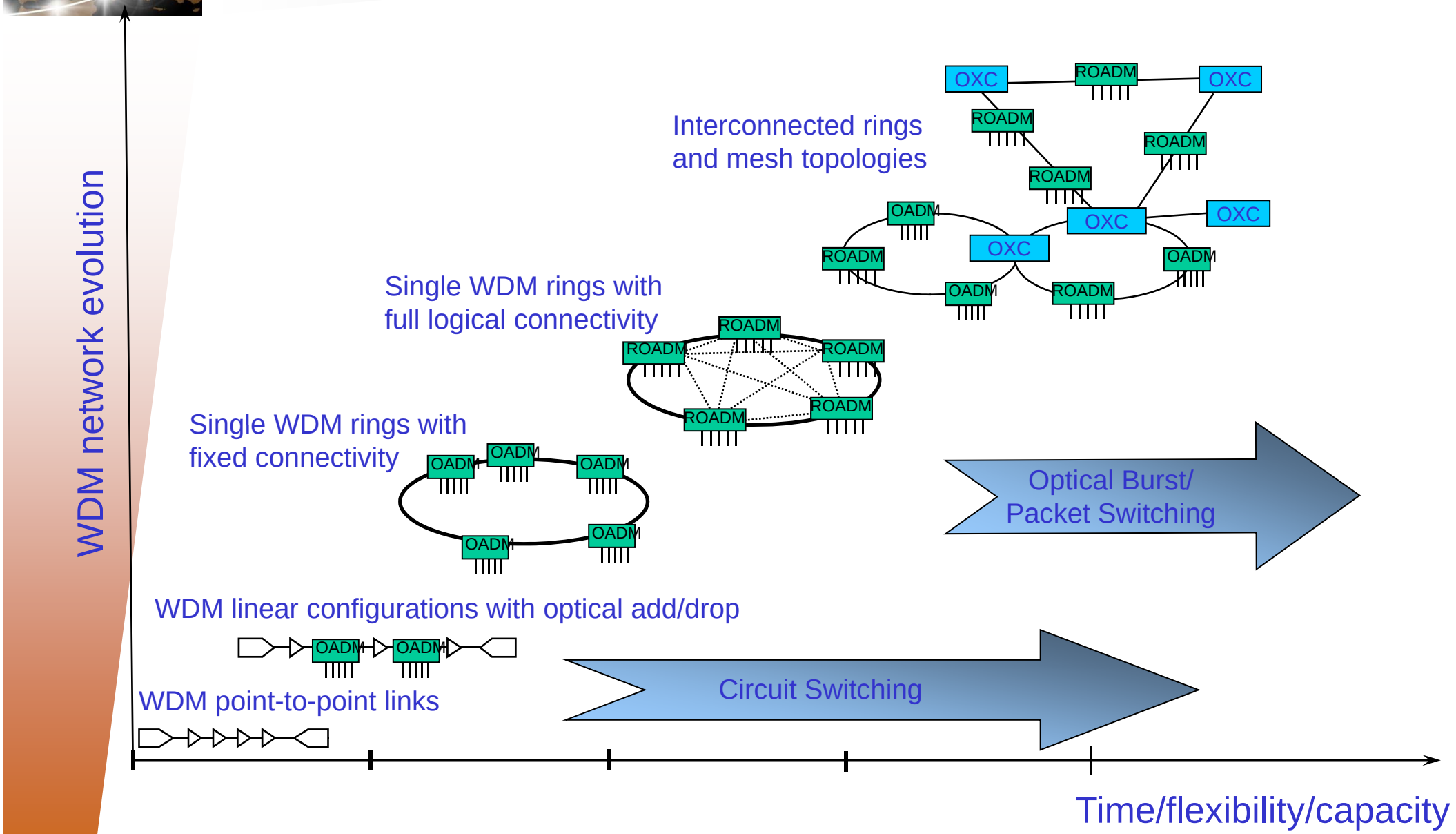
Virtual Centres of Excellence (VCE)

- WP11 Network Technologies and Engineering
- WP12 Services and Applications
- WP13 Access Networks
- WP14 Optical Switching Systems
- WP15 Transmission techniques
- WP16 In-building Networks
- WP21 Green Optical Networking
- WP22 MPLS, GMPLS and Routing
- WP23 TP on Optical communication networks in support of user mobility and Networks in Motion
- WP24 Edge-to-core adaptation for hybrid networks
- WP25 TP on Optical Interconnects
- WP26 Alternatives for multi-layer networking with cross-layer optimization
- WP27 Physical Impairments constrain based routing in packet switching networks

Network segmentation



Optical Networking Evolution

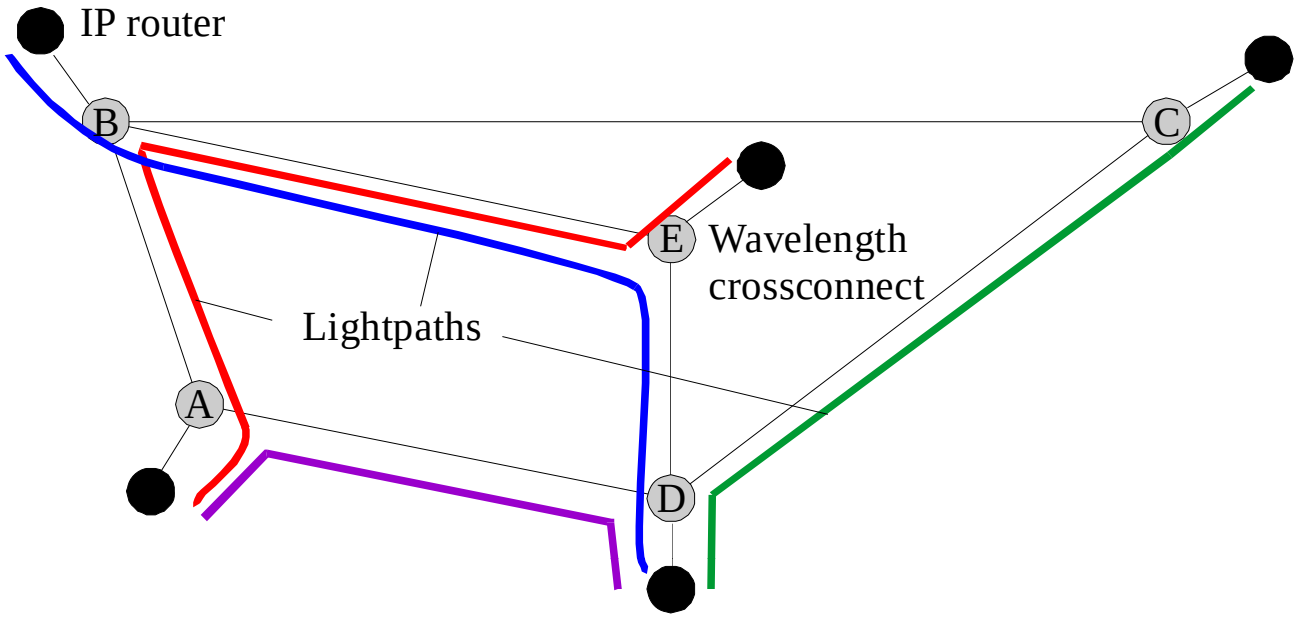


WP11 Virtual Centre of Excellence on Network Technologies and Engineering

Franco Callegati
DEIS University of Bologna - ITALY

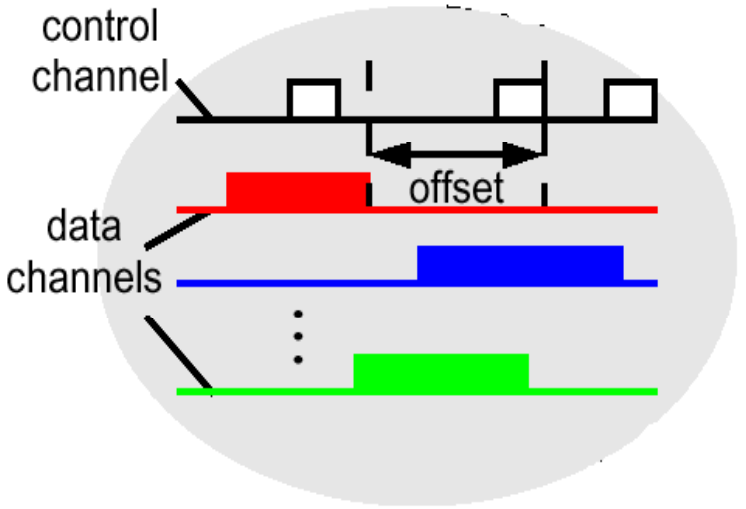
Participants:
CTTC, TID, UAM, UC3M, UPC, UPCT, FT, GET, AIT, FER, FUB, POLIMI, POLITO, SSSUP, DEIS-UNIBO, UNIMORE, UNIROMA1, TELENOR, AGH, KTH, UNIROMA3

- Establish high-speed optical layer connections (lightpaths)
- Wavelengths can be used for routing
- Lightpaths are established using optical cross-connects.



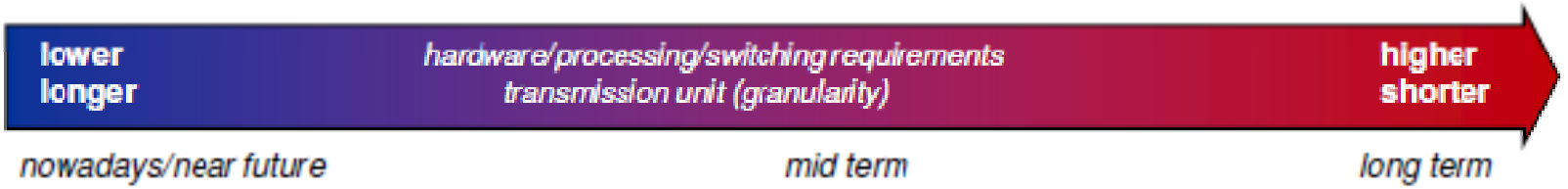
Optical Burst and Packet Switching

- OBS assumes burst aggregation at the edge of the network with burst lengths of 10s of kB
  - The control information is out of band and transmitted prior to the burst
  - The control packet processing is mostly in the electronic domain
  - Reduction or elimination of optical buffering
- OPS assumes a low degree of client layer packet assembly and packet size ranges from 100-1500 bytes
  - The control information can be in-band or out-of-band
  - Optical or electronic header processing
  - Buffering required



Evolution Scenario

	OCS optical circuit switching	C-OBS conventional optical burst switching	E-OBS offset time-emulated OBS	OPS optical packet switching
Signalling:	● out-of-band	● out-of-band	● out-of-band	● in-band
Offset time:		● offset in edge	● offset in core	● offset in core
Data unit:	● long-living optical circuits	● long bursts	● short bursts	● short packets
Complexity:	✓ low	✓ medium	✓ medium	× high
Flexibility:	× low	✓ high	✓ migh	✓ very high
Efficiency:	× low	✓ medium	✓ high	✓ very high
FDL buffering:	-	× impractical	✓ possible	✓ yes

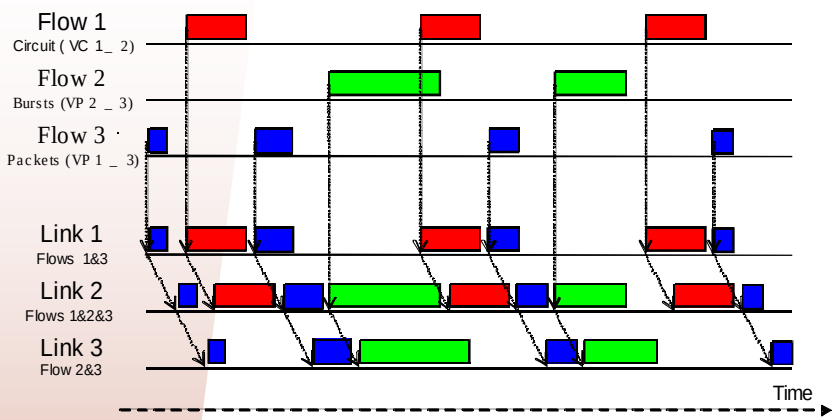


WP11 Network Technologies and Engineering - Focus

- Integration of research activities on technologies for all-optical networks in metro and core networks area
- *Common challenges addressed are*
  - Protection and restoration
  - Traffic engineering and congestion resolution
  - Control plane for fast resource allocation according to user needs

WP11 JA summary

1	Common Architecture/Hierarchy for integration of OCS, OBS, and OPS in a common transport plane	TUW, DTU, AGH, GET/ENST, TUB, Uessex
2	Comparative techno-economic network planning in OCS/OBS/OPS networks	UPCT, TID, UNIRM, FT, AGH
3	Experimental tests of Carrier Ethernet techniques	FUB, UNIROMA3, UNIROMA1, UNIBO, UNIMORE, KTH, CORITEL
	Carrier Ethernet Transport	DTU, TUW, FUB, CORITEL, TU-BERLIN, IBBT
4	Extension of the Flow-Aware Networking (FAN) architecture to the IP over WDM environment	GET/ENST, UaM, AGH
5	Network planning algorithms considering fault tolerance, security threats and periodic traffic patterns	FER, KTH, UPCT, IT, AIT
6	On exploring Admission Control Mechanisms for OBS networks	UaM, UC3M, UniMORE
7	PCE for Multi-domain Traffic Engineering	SSSUP, PoliMI
8	Resilience analysis of double rings with dual attachments	UaM, TID
9	Traffic engineering and topology design in metro networks	SSSUP, GET/ENST
10	Survey on OBS routing methods for OBS networks	UPC, IT
12	Optical Buffering Technologies Survey	FT, USWAN, TUW, UNIBO, UPC, KTH, Ericsson

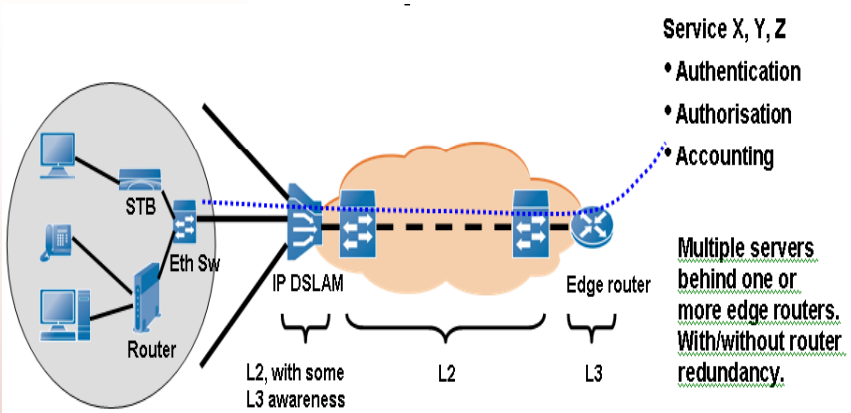


Common Architecture/Hierarchy for integration of OCS, OBS, and OPS in a common transport plane

- Outline migration/implementation/integration
- *Topics and areas addressed*
  - Transport Plane Architectures/Hierarchies
  - Control Plane adoption/extension demand/options
  - Performance Study (feasible utilization limits)
  - Integration alternatives/options

Comparative techno-economic network planning in OCS/OBS/OPS networks

- CAPEX-OPEX techno-economic comparison of networks with 3 switching paradigms: OCS/OBS/OPS
  - Network and traffic scenario (set of traffic matrixes)
  - Node architectures – related CAPEX/OPEX costs
  - Define measures of quality for networks (loss, end-to-end delays, etc) – dimension OPS and OBS
  - Dimension comparable OCS network



Experimental tests of Carrier Ethernet Technologies

- Experimental demonstration of core/metro network techniques
- Experimental and theoretical investigations on Carrier Ethernet techniques, such as VPLS, T-MPLS, PBB-TE
- Experimental investigations in different PON solutions (EPON, WDM-PON

Traffic Engineering and Topology Design in Metro Networks

- Apply network planning techniques to networks based on the slotted WDM rings implemented at TELECOM
  - Problem: optimal design (i.e., minimum cost) of a network of interconnected slotted WDM rings
  - Solution: optimal approach based on mixed integer linear programming (MILP) formulation

GMPLS-based control plane for optical packet-based technologies

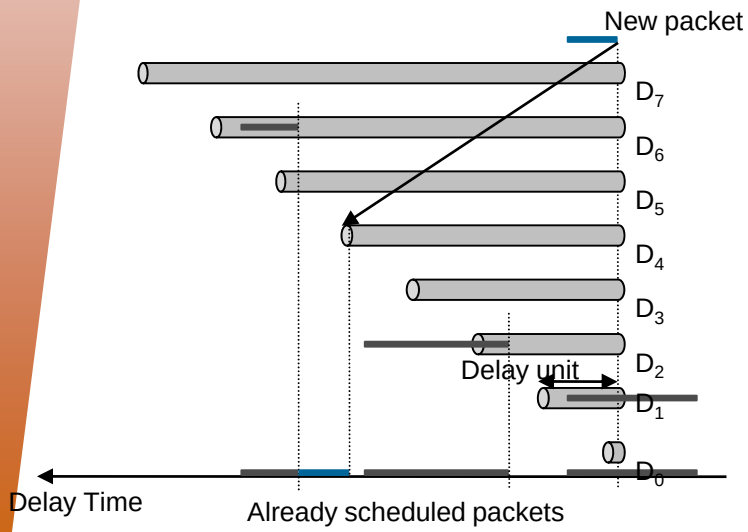
- Study the interoperability between GMPLS and OBS/OPS control layers
- Interoperate by maintaining GMPLS and OBS/OPS control components operating
  - at different timescales
  - in different (physical) networks

Network planning algorithms considering fault tolerance, security threats and periodic traffic patterns

- New network planning algorithms aimed at network robustness to cope with
  - security threats (deliberate attacks)
  - faults (component malfunctions)
- Formulate Attack-Aware RWA
  - study heuristic algorithms

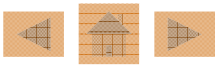
Survey on routing methods for OBS networks

- Put together a survey on routing methods for OBS networks
- Provide a detailed comparison of the selected strategies
  - Performance/complexity trade-offs
  - Optimization methods (linear, non-linear) used



Optical Buffering Technologies Survey

- Survey advanced optical buffering technologies
  - Potentially help the realisation of random access optical buffers in the future
- Establish a forecast on optical buffering technologies
- Identify the most promising technologies for optical buffering



WP12
VCE on SERVICES AND APPLICATIONS

Piero Castoldi and Luca Valcarenghi
WP-Leaders
Scuola Superiore Sant‘Anna
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Residential Services

TV Focused Services

20 Mbit/s
10
0

- High definition TV
- Picture in Browser
- Broadcast TV, VoD, Personal Video Recorder
- Interactive TV browser
- E-mail, Instant Messaging, Chat, Games, pictures/videos exchange

up to 2 Mbit/s peak

PC Focused Services

5 Mbit/s
0

Residential Customers

- High speed Internet access, server based e-mail
- Live TV on PC, VoD, interactive games
- Pictures/videos exchange

up to 2 Mbit/s peak

10 Mbit/s
0

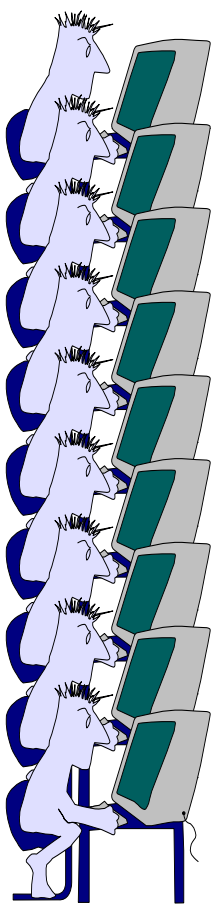
SMEs and SOHOs

- Virtual Private Network (VPN) access, LAN extension
- High speed Internet access, server based e-mail
- Video conferencing

up to 10 Mbit/s peak

Source: BONE Roadmap

Large Enterprise Services



Downstream / Upstream

Storage Area Networking (SAN), IP Storage
- Remote storage
- Data replication
- Disaster recovery

GRID Computing

up to 10 Gbit/s + symmetrical

Leased Lines, Virtual Private Networks (VPNs, IP based)
- LAN extension/interconnection
- WAN access

up to 10 Gbit/s + symmetrical

Other Services
- Fast Internet Access (web services, e-mail)
- Videoconferencing
- Voice

up to 1 Gbit/s asymmetrical

Direct Access to the MAN

Source: BONE Roadmap

General

- Scalability
- Strictly low cost
- Cost structure should allow for "pay as you grow"

Residential Customer

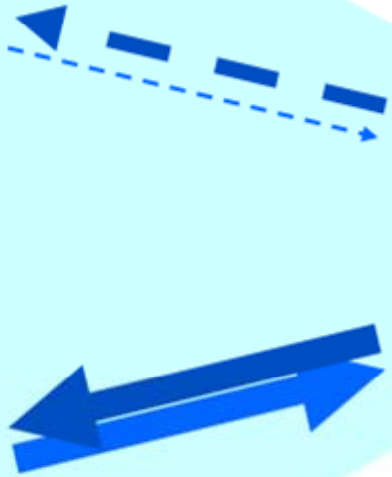
Bitrate Downstream:	≥ 20 Mbit/s peak
Bitrate Upstream:	≥ 2 Mbit/s peak
Quality of Services:	QoS differentiation
	≤ 50:1 overbooked

SOHOs, SMEs

Bitrate Downstream:	≥ 10 Mbit/s peak
Bitrate Upstream:	≥ 10 Mbit/s peak
Quality of Services:	QoS differentiation
	≤ 5:1 overbooked

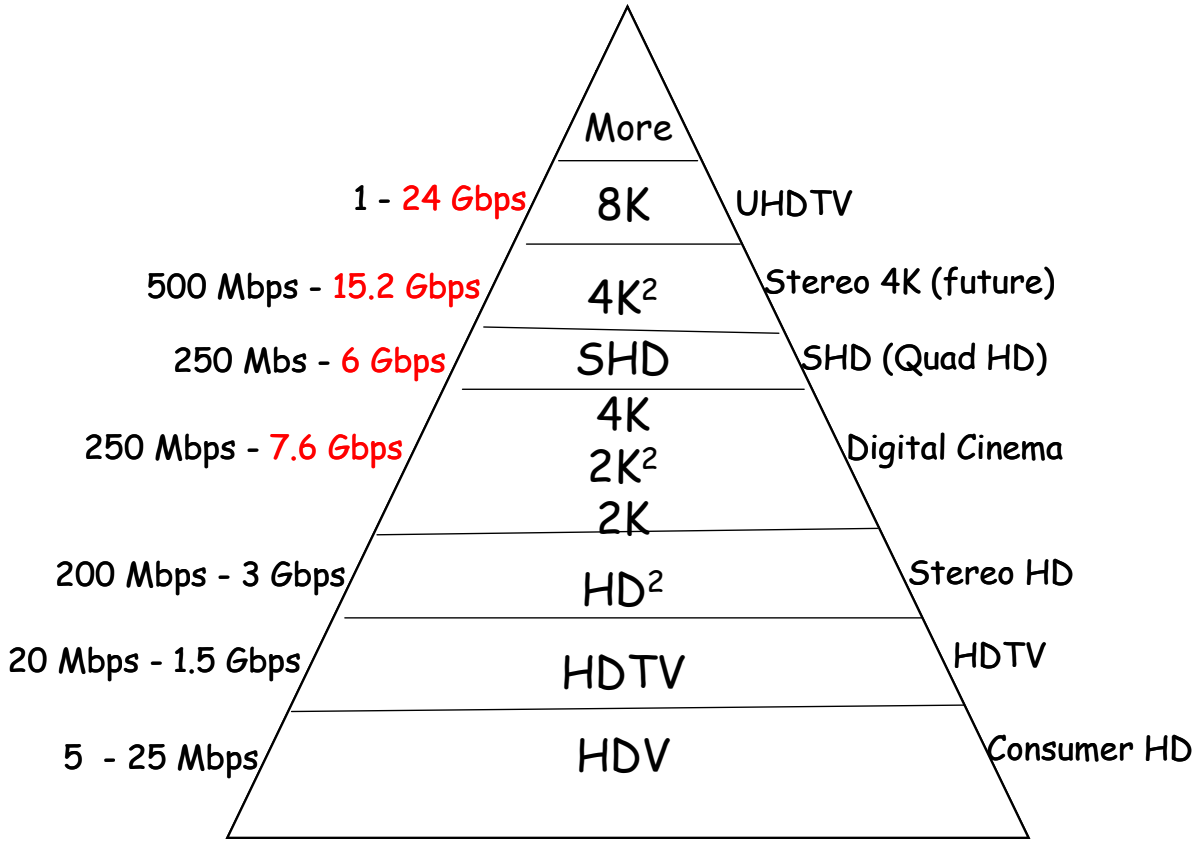
Large Enterprises/Campus

Bitrate Downstream:	≥ 10 Gbit/s peak
Bitrate Upstream:	≥ 10 Gbit/s peak
Quality of Services:	QoS differentiation
	no overbooking



Regional Metro Network

Source: BONE Roadmap



Source: BONE Roadmap – D. Simeonidou

New Digital Services

Virtual Immersive Reality applications
Medical and surgery applications
Remote manipulation of complex appliances
Cultural heritage museum
10 -40 Gbit/s symmetrical

Service-platform based services
Network services (e.g. lightpath on demand)
Service composition (non-network resource + network resource)
10 -40 Gbit/s symmetrical

New Digital Media Services
10 -40 Gbit/s symmetrical

Other Digital Services
Virtual Terminal (remote hard disk, CPU, etc)
Cloud Computing
Quadruple Play
E-science
1-10 Gbit/s asymmetrical

MAN\WAN

Source: BONE Roadmap

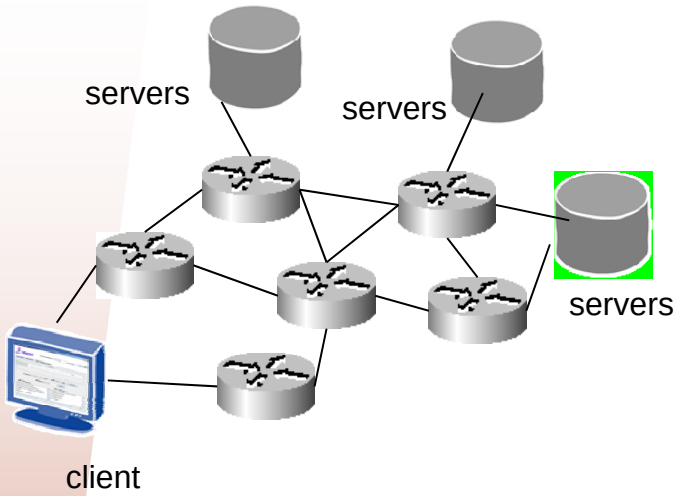
WP12: Services and Applications - focus and objectives

Services

- Service definition, architectures and implementation
  - Service definition and abstraction, service virtualization, service plane architectures, GMPL-based complex services, L1-L2-L3 Virtual Private Networks, multidomain services, service routing, signaling, resilience, autonomic network configuration, paradigms for end-to-end QoS

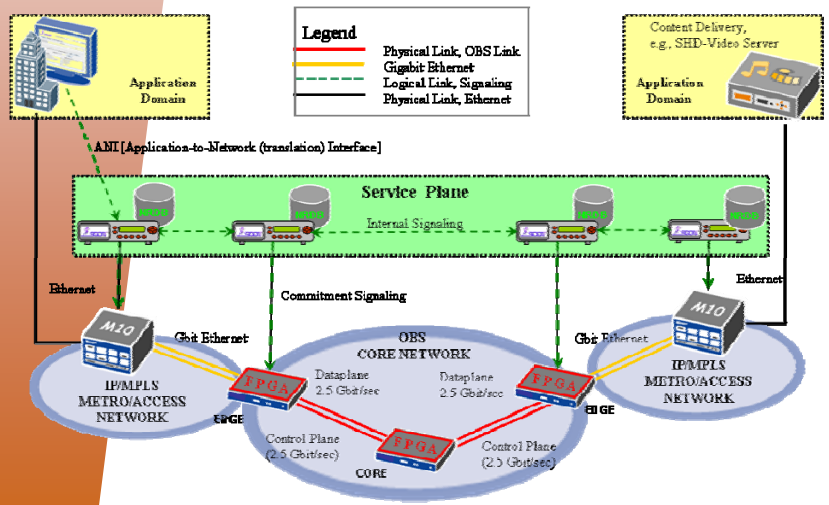
Applications

- Application definition architectures requirements
  - Voice over IP (VoIP), Grid over optical networks, peer-to-peer optical networks
- Services and application in an integrated view
  - ITU-T Next Generation Network, Service Control Fucntions, Resource and Admission control fucntions, service platforms, service composition, service plane-control plane interaction



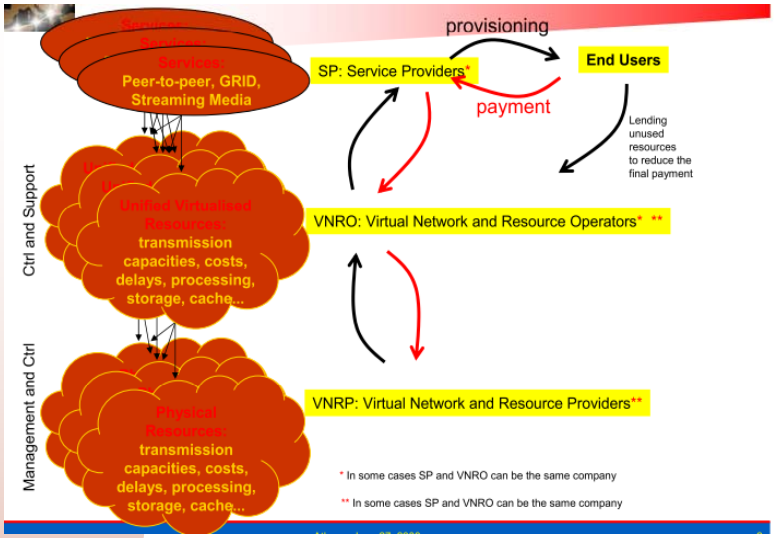
Service Interconnection Fault Tolerance

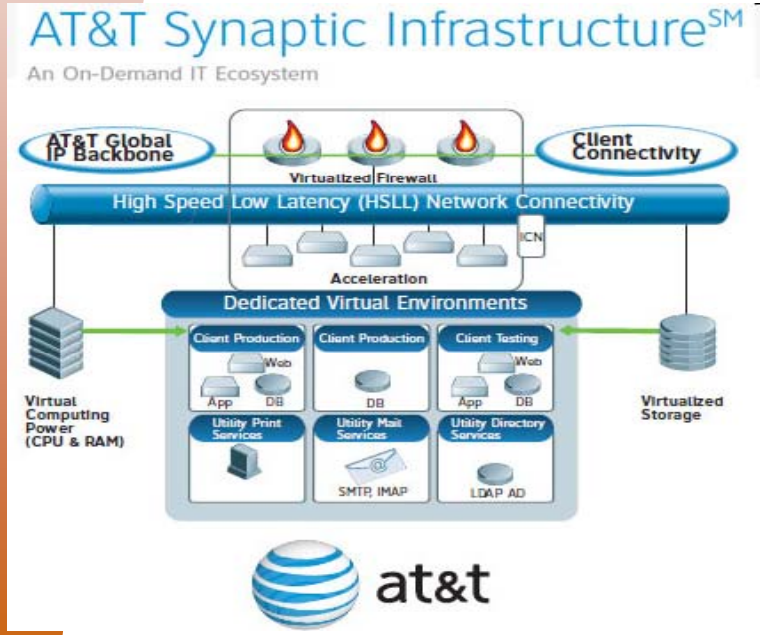
- Participants: SSSUP, IBBT, AGH, KTH
- Develop heuristics for QoS-aware choice of servers
  - High reliability
  - Guaranteed bandwidth
  - Static and nomadic clients with dynamic connections



Service Plane functionalities and demonstration

- Participants: SSSUP, FUB, UEssex, UniBO
- Realization of the application-to-network mapping in case of OBS network domain. The OBS network devices are configured to realize Dynamic Session Management with a real end-to-end provision and triggering of dynamic high-bandwidth connections and QoS-enabled reservation
- Definition of a SIP-DSE architecture for the provisioning of QoS-based connectivity service in transport networks based on the SIP protocol and the SOON prototype.





Joint Optimisation of Grid and Network Resources

- Participants: SSSUP, BME, PoliTO
- Optimise jointly computing resources (grid services) and network resources (grooming capble, two-layer network)
  - Least cost and least time
- Constraints: Resources, time, and cost

Cloud Computing

- Participants: UEssex, …
- As more facets of work and life move online and the Web expands beyond a communications network to become a platform for business and society
- Overview of cloud computing issues and solutions

WP13 Access Networks

WP leader: John Mitchell (UCL)
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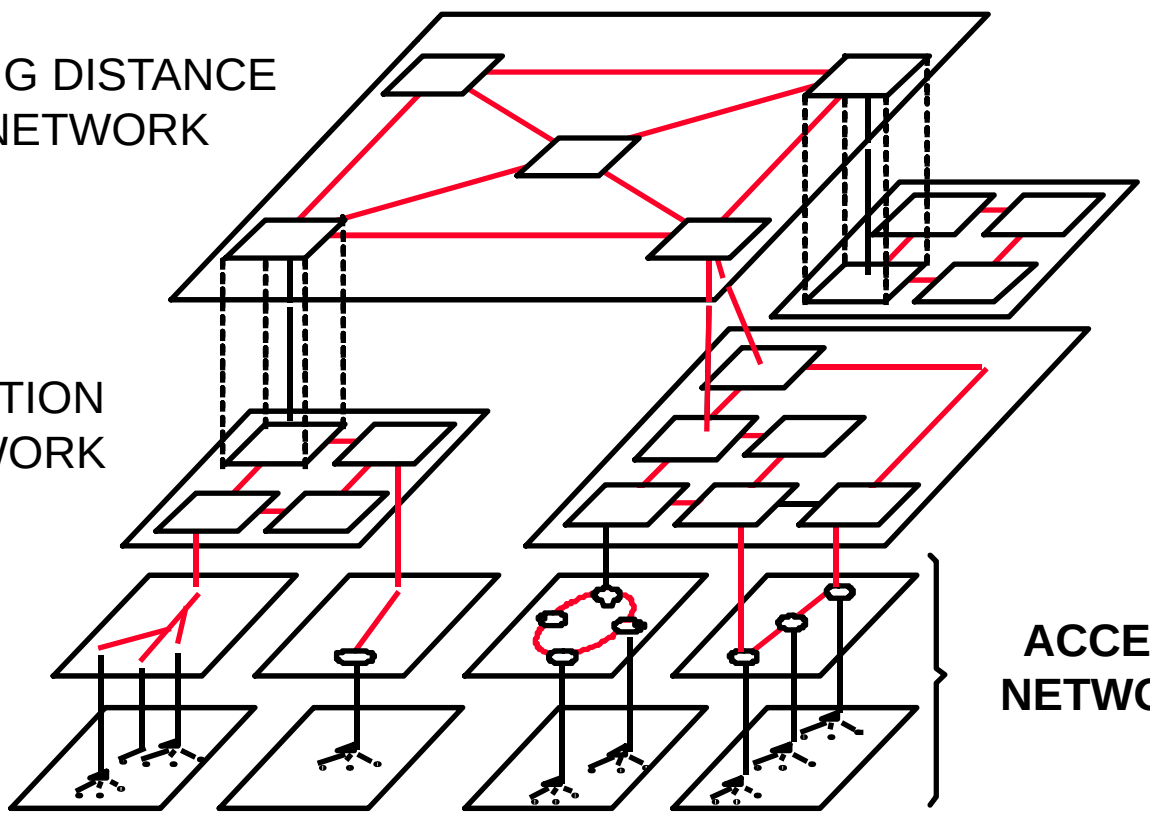
Partners Involved:

UCAM, IBBT, UESSEX, UPVLC, UCL, GET/ENST, Polimi, UC3M, FT, TUE, UoA, FUB, Coritel, UNIROMA3, ISCOM, IT, DTU, UoA, FUB, UNIROMA1, AGH, KTH, UniMORE, AIT, RDTL, Ericsson, UDE

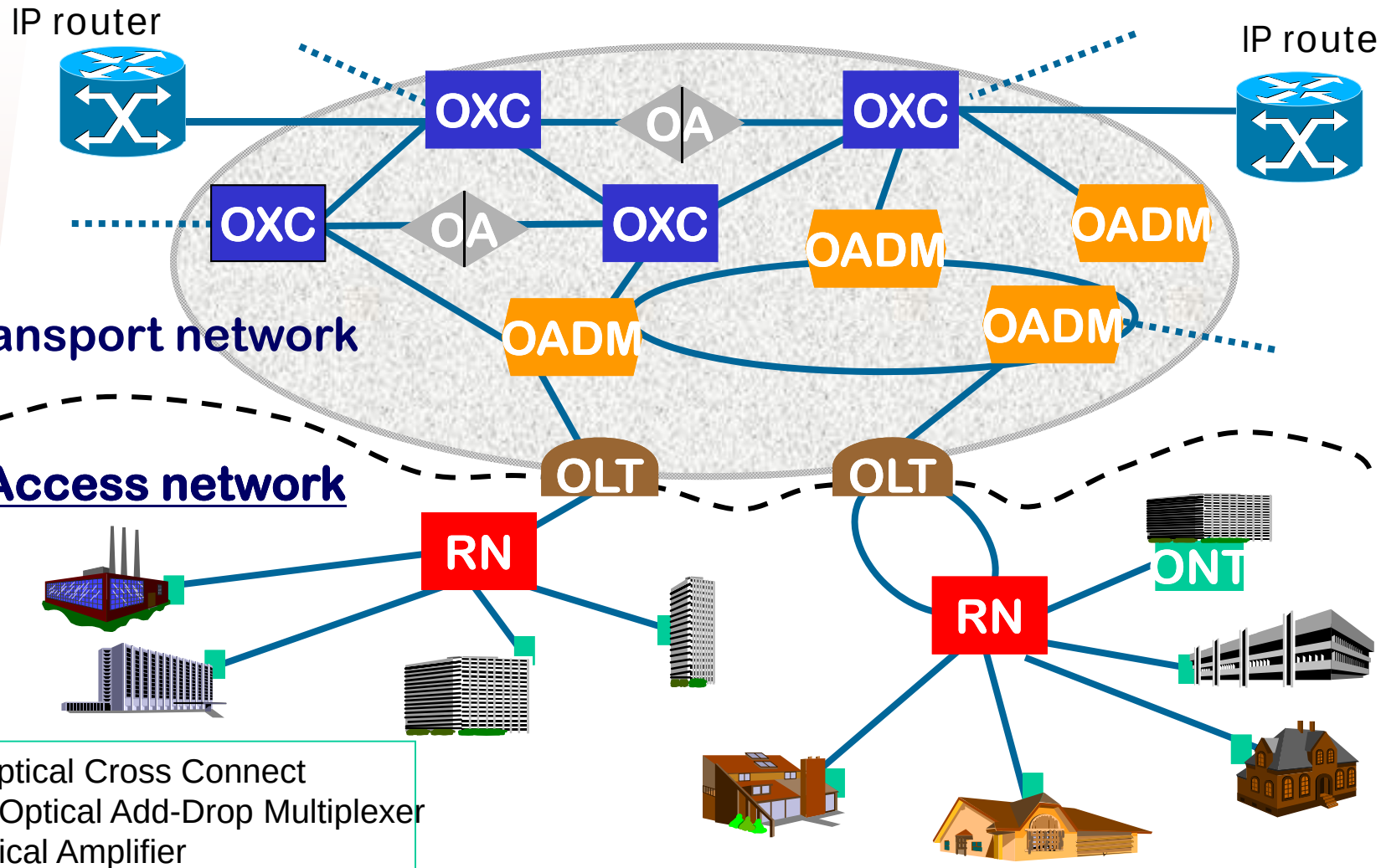
Telecommunication network structure

Traditional structure



Telecommunication network structure

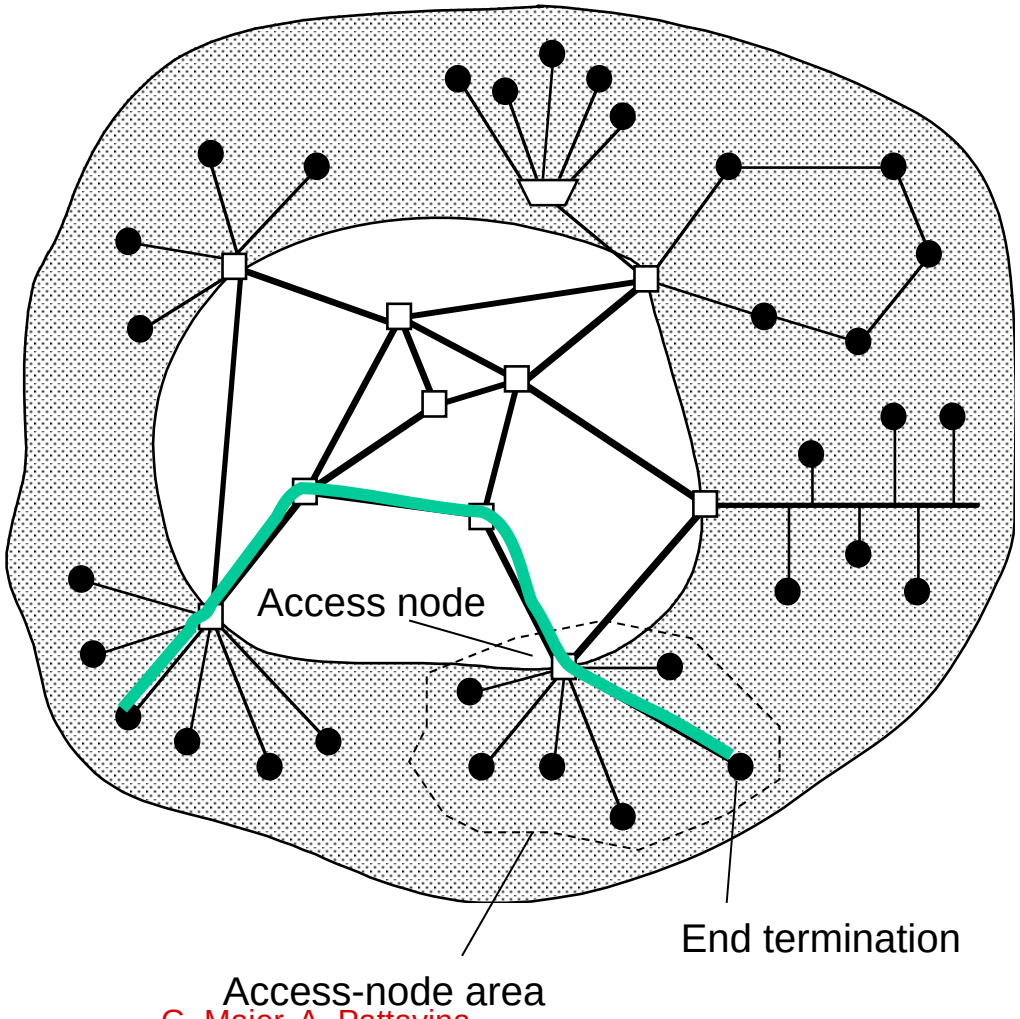
Modern structure



OXC = Optical Cross Connect
OADM = Optical Add-Drop Multiplexer
OA = Optical Amplifier
OLT, RN, ONT …. wait and see….

G. Maier, A. Pattavina,
Optical Access and Metro Networks
Module 1. Introduction to metro and access networks
– E-PHPTON ONE

- Connects the transport network to the end-users
- Geographically covers the “last mile”, usually in urban areas
- Interfaces
  - access node, towards the transport network
  - end node (or end termination), towards the end user
- Segmentation and branching
  - Each access-node domain subnet an is independent system
  - Communications between different access areas is carried out via the transport network, not through access



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Module 1. Introduction to metro and access networks
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- End-users (alias "subscribers")
  - User type
    - Residential customers
    - Business customers
    - Small Office – Home Office (SOHO)
  - End users may be equipped by LANs
    - customer premises network (business)
    - home network (residential)
- End nodes (or terminations)
  - User to Network Interfaces (UNI)
  - Various type of simple devices
    - Set-top box
    - Computer communication cards
    - Telephone terminal
  - Usually owned by the customer or leased from the operator

- Operator
  - The same operator of the transport network (e.g. public access network)
  - Local operator
  - Service provider
- Access nodes
  - Interfacing the access subnets to the transport network (NNI)
  - Complex equipment
    - Central Office (CO) in the public access network
    - Local exchange
    - Server center
    - Hub
    - Point of Presence (POP) (IP, Ethernet)
  - Usually property of the operator
    - The operator can sometimes lease an access-node-site area from another operator to deploy its own equipment

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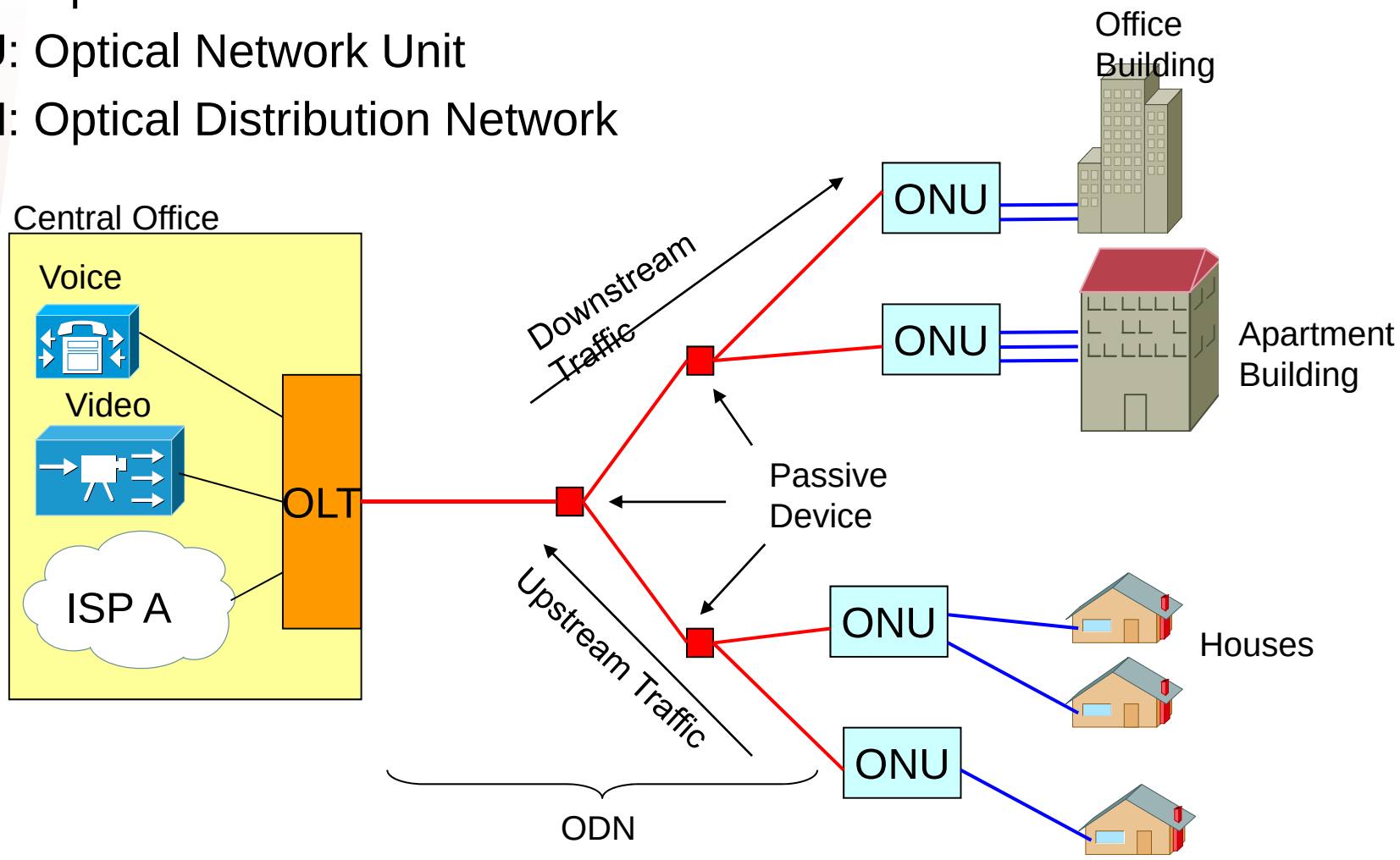
Module 1. Introduction to metro and access networks
– E-PHPTON ONE

OLT: Optical Line Terminator

ONU: Optical Network Unit

ODN: Optical Distribution Network



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Optical Access and Metro Networks
Module 4. xPONs access networks: e-PHOTON ONE

Aims of WP13 – Access Networks

- provide a forum for exchange and consolidation of the latest research and development on access systems that use optics to provide true-broadband connections to fixed and mobile users
- Different technologies like new TDM-PONs, WDM-PONs, Radio-over-Fibre, Free-Space-Optics or xDSL-over-fibre are being developed and are competing in diverse scenarios
- *With this aim, specific objectives of WP13 are*
  - Integrate the research efforts on broadband access in Europe
  - Establish benchmarking platform for different optical access technologies - provide a series of guidelines for deployment of most promising and effective access techniques for the different scenarios present in Europe
  - Provide insight into integration of access technologies to provide operators with cost-effective evolution paths for the introduction of new services
  - Document and make available to all test-bed and platforms
  - Contribute to standards in the area - within Europe and externally

Activities of WP13

- Architecture of Hybrid Optical/Wireless Networks
  - theoretical and practical research regarding a Hybrid Optical Wireless (HOW) network - integrating existing optical fibres (PON) and the rapidly developed wireless technology (WiMax / WLAN) at the access/home network - effectively combine the high date rates optical fibre offers and the mobility support of wireless technology
    - Investigation of possible interworking architectures with a QoS-aware MAC layer control protocol.
    - Evaluation of resource management mechanisms in HOW considering network characteristics, user mobility, and service types by simulation
- Techno-economic analysis of optical access networks
  - Research on techno-economic issues in optical access networks
  - Analyze standard and novel architectures on cost and network performance
  - Take into account reliability of power supply systems and its impact on performance

Activities of WP13

- Secure OCDMA-based PONs
  - Optical code division multiple access (OCDMA) is a challenging candidate for the next generation broadband multiple access networks with unique features of full asynchronous transmission, low latency access, soft capacity on demand, as well as optical layer security
  - Combining OCDMA with wavelength division multiplexing (WDM) can in prospective enable gigabit-symmetric fiber-to-the-home (FTTH) systems
  - Data confidentiality will be analyzed within a rigorous cryptanalysis framework investigating both computational and optical layer security issues

WP14 Optical Switching Systems

WP Co-leaders

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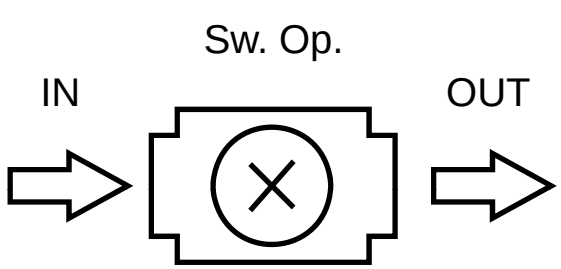
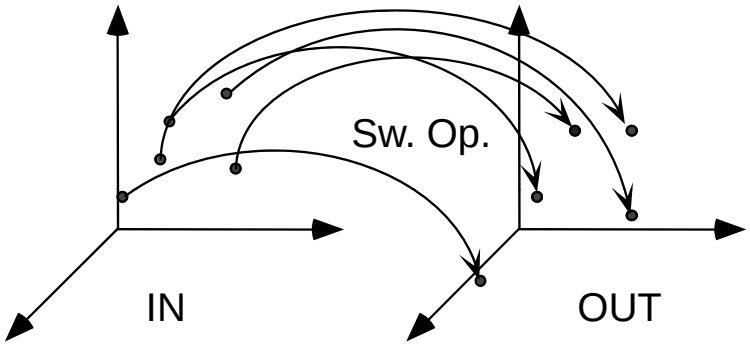


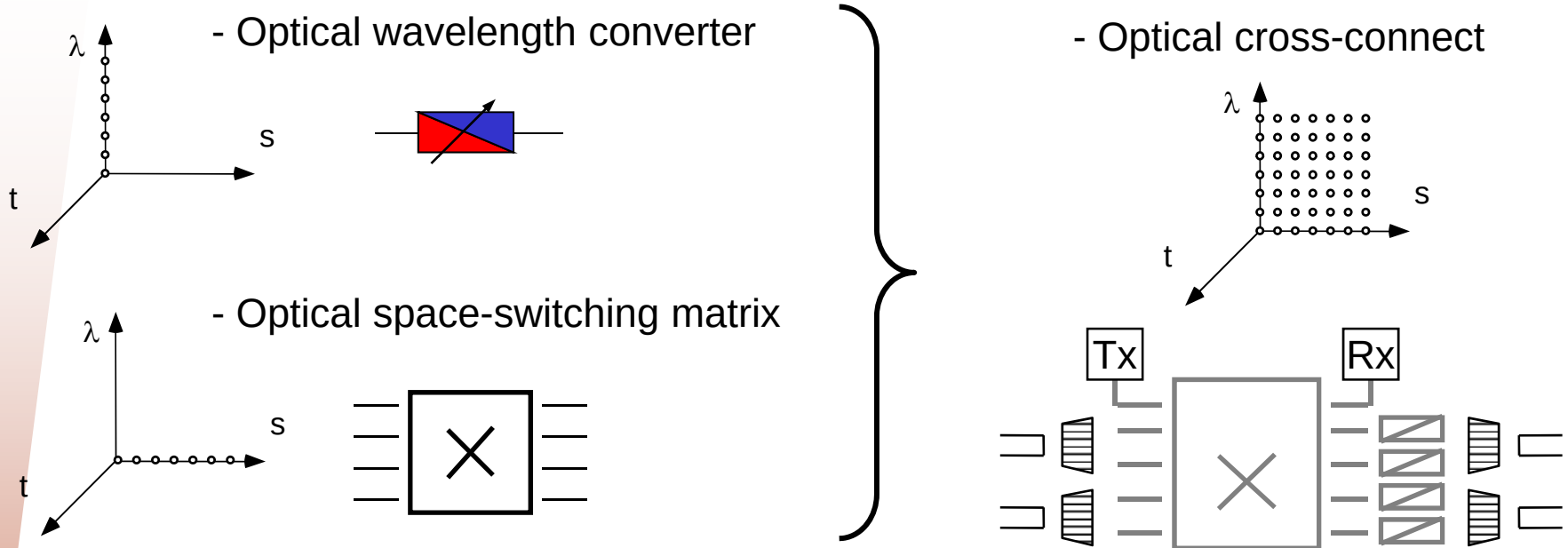


- Switching is a transformation operation performed over a given multiplexing domain
- A switch is a network element able to perform a switching transformation over a set of input signals leading to a set of output signals which are the inputs shifted in the multiplexing domain
  - Switching complexity increases with multiplexing-domain complexity (e.g. number of dimensions of the multiplexing-domain)

Authors: **Guido Maier, Achille Pattavina**

Optical switching

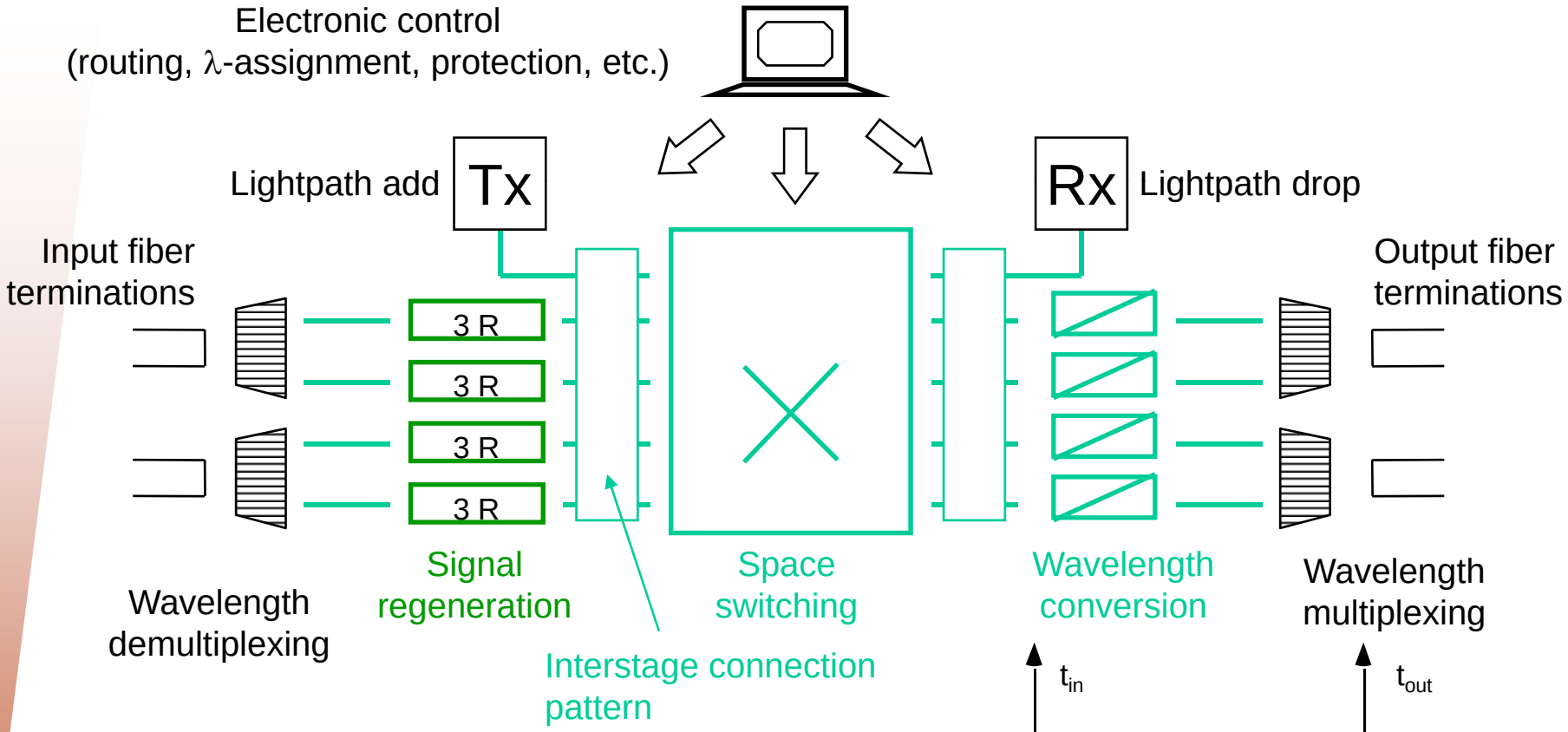
New domain: wavelength-division-multiplexing



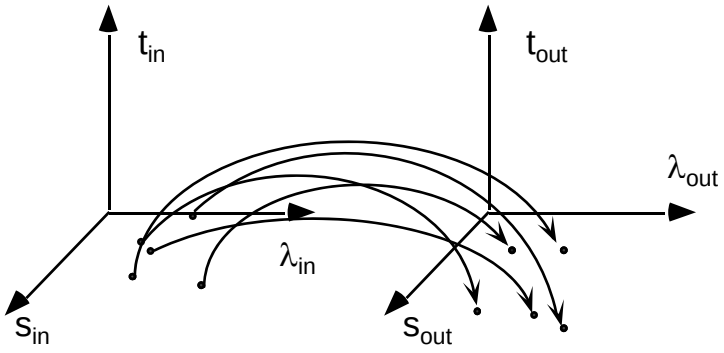
- The switch operating in the combined λ-s multiplexing domain is known as the Optical Cross-Connect (OXC)

Authors: **Guido Maier, Achille Pattavina**
Course: **Photonics in Switching**
Module: **Optical Cross Connects e-PHOTON - ONE**

WDM optical cross-connect (OXC)



- There is the need for the OXC …
- … but is it feasible with optical switching technology available today?



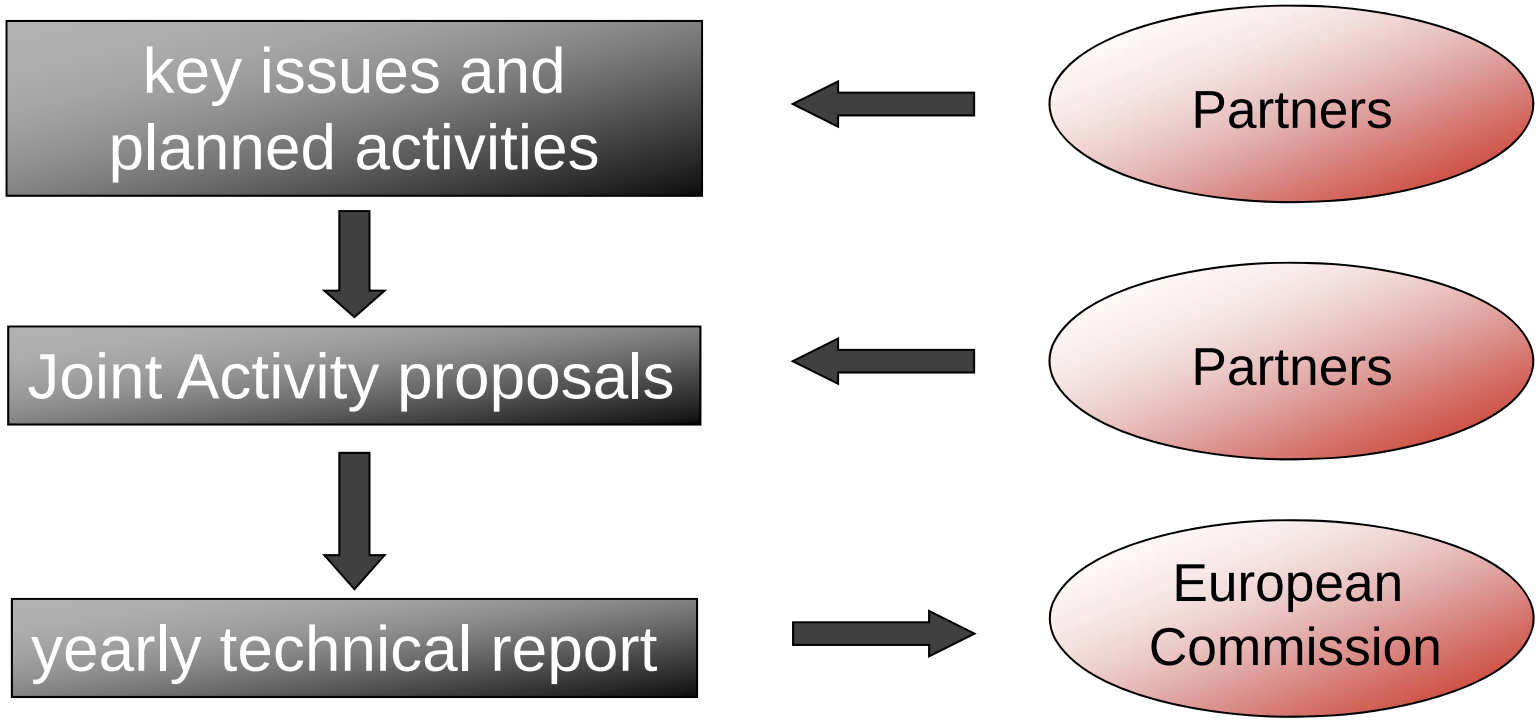
Authors: **Guido Maier, Achille Pattavina**
Course: **Photonics in Switching**
Module: **Optical Cross Connects e-PHOTON - ONE**

WP14 Optical Switching Systems – main tasks

- Foster deep and lasting research integration between the involved partners using mobility actions (exchange of researchers), joint publications and technical meetings as the main tools.
- Craft R&D directions and define the position of photonic switching in future optical networks.
- Study topics such as: provisioning, protection and restoration, switch fabrics, transparency, switching topologies and architectures, node design and buffering.

WP14 has 34 partners

IBBT, TUW, TUB, DTU, UC3M, UPCT, UPVLC, UVIGO, GET, AIT, ICCSNTUA, RACTI, UOA, BME, CORITEL, POLIMI, POLIT, SSSUP, DEISUNIBO, UNIMORE, UNIROMA1, TELENOR, TUE, IT, PUT, HUAWEI, KTH, Bilkent, UNIROMA3, ORC, UCAM, UCL, UEssex, Ericsson.


key issues and planned activities
Joint Activity proposals
yearly technical report
Partners
Partners
European Commission

Hot key-issues

- Wavelength Converter Usage Reduction
- Switching for Network Recovery
- Quality of Service in switches
- New switching paradigms
- Optical Clock Recovery
- Wavelength conv. by nonlinear effects
- Optical Multicast Architecture
- Switching and network reliability
- Power Issues in Switching Systems
- OCDM encoders/decoders
- 2R Regeneration
- Optical packet switching
- Hybrid Switch Architectures
- GMPLS optical switch nodes
- Contention Resolution Schemes
- Optical Buffering
- OTDM time-slot switching
- Optical Cross Connects

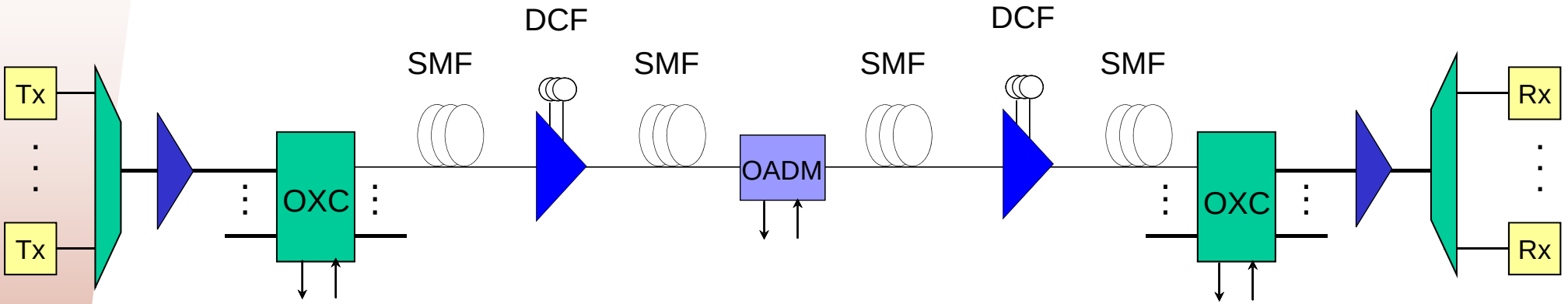
Summary

- 21 defined ***key issues*** relevant to the Optical Switching Systems WP
- 15 active Joint Activities is the result of the defined key issues

WP15 Virtual Centre of Excellence on Transmission Techniques

WP Leader: P. Petropoulos (ORC)

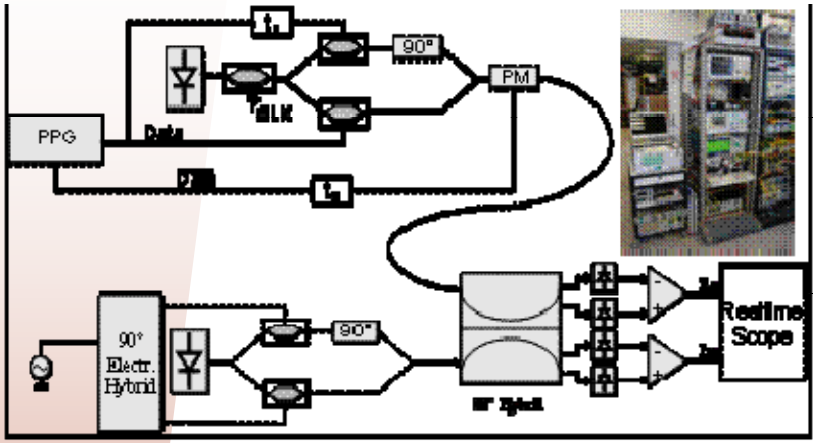
WDM optical communication system



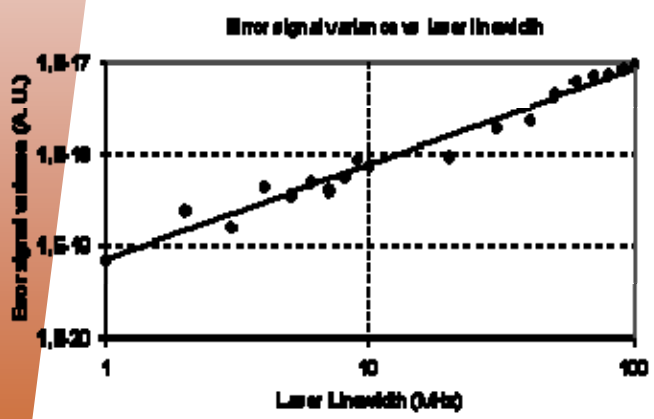
Tx: Transmitter OXC: Optical Cross-connect
Rx: Receiver OADM: Optical Add Drop Multiplexer
SMF: Single Mode Fibre DCF: Dispersion Compensating Fibre

Focus Groups

- New problems in transmission
  - Ultra-dense WDM
  - Resilient 100Gb/s transmission
  - Coherent detection techniques
  - Backward compatibility issues
- Regeneration
  - Fibre-based
  - SOA-based
- Burst amplification
- Authoring group: „Ultra broadband transmission in the networks of the future“
  - Publication of a book collecting the expertise of the participants of VCE-T



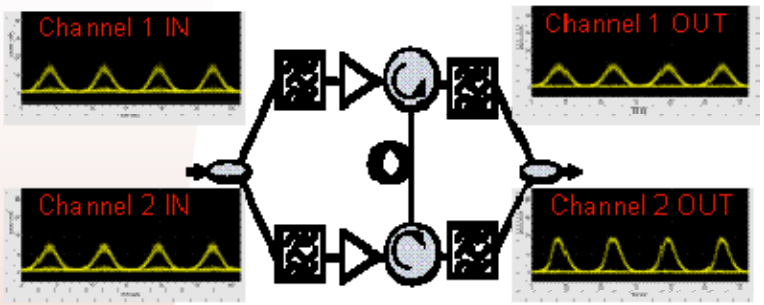
Preliminary experiment: 8-PSK RZ frequency tracking



Source: UPC/HHI

New problems in transmission

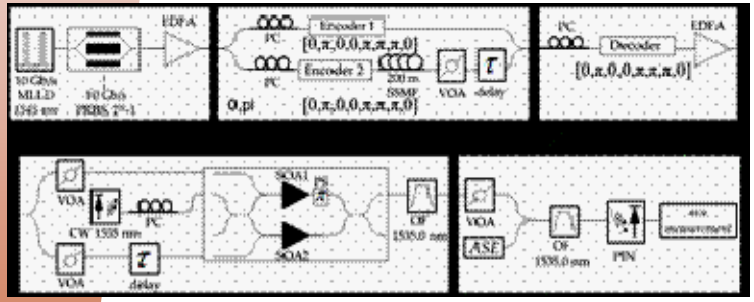
- Example of joint activity:
  - Comparison of L.O. + processing proposals
  - Loop design, simulations
    - Loop delay impact
    - Phase noise impact

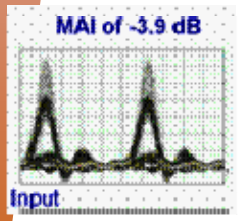


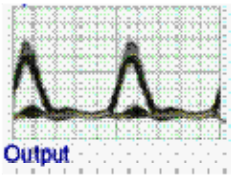
Source. ORC

Fibre-based regeneration

- Fibre-based techniques rely on ultra-fast nonlinear response of silica
  - Germanium doped HNLFs
- Simple architectures, very good performance
- Multi-wavelength & high bit-rate solutions possible



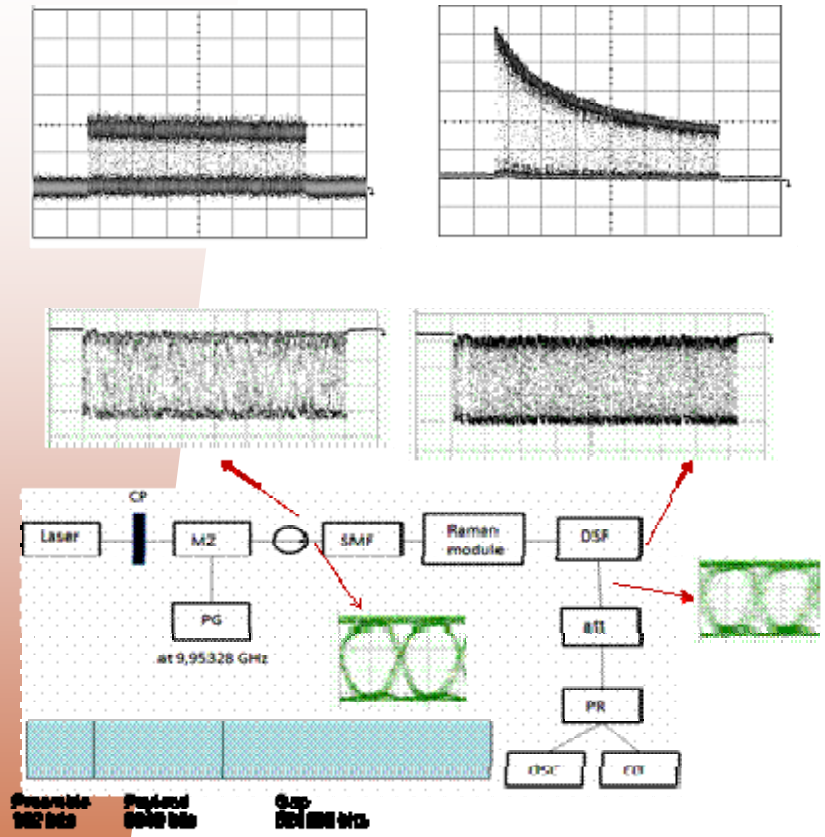




Source: IT/ISCOM

SOA-based signal regeneration

- different modes of operation can provide:
  - Nonlinear amplitude and noise behaviour
  - Linear amplitude and phase behaviour
- compact size → possible to integrate into complex structures
- can allow regeneration of amplitude, phase polarization or spectrum



Effects of burst mode in Raman amplification

Source: IT/ISCOM

Burst-mode amplification

- Bursty intensity-modulated signals cause dynamic transient of the envelope of packets when amplified by EDFAs due to the consumption of excited population of Er^{3+} ions in gain media
- The degree of transience might be cumulative and can seriously affect clock and data recovery
- Cheap and easy solutions to the problem are investigated

WP16 Virtual Centre of Excellence on Indoor Networks

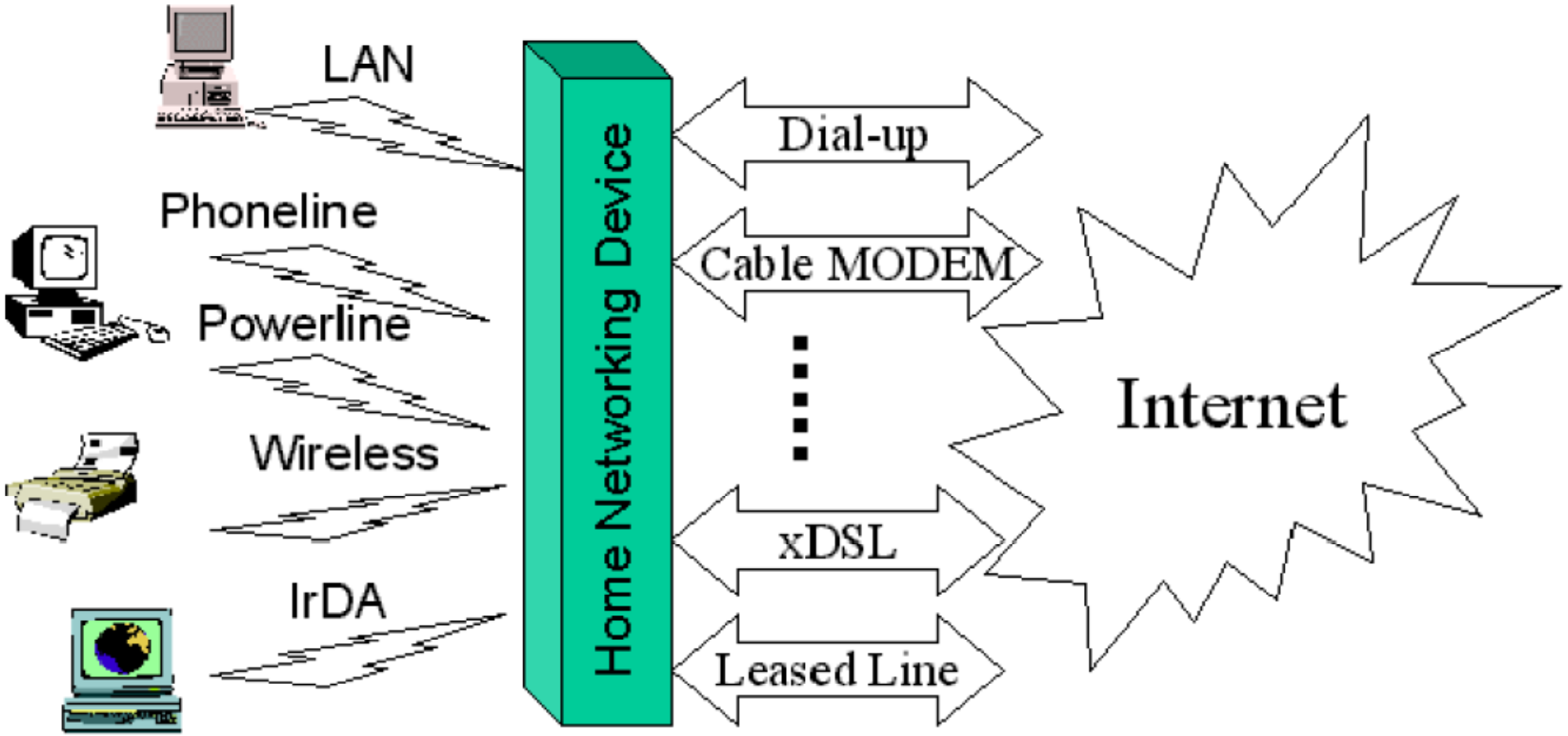
WP Leader: Ton Koonen (TUE)
A.M.J.Koonen@tue.nl

Partners Involved:

TUE, FT, Ericsson, Fraunhofer,

UDE, TUB, UOA, POLITO, UCL

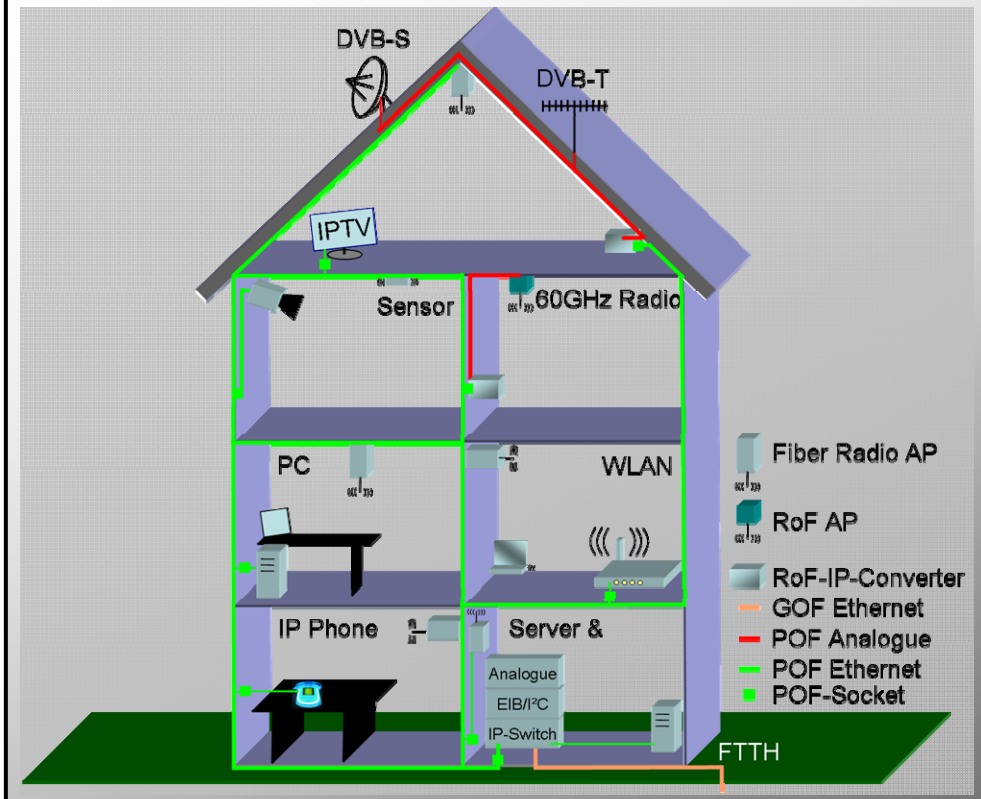
Home Networking Infrastructure



WP16 In-building Networks - Topics

- In-building Optical Network Architectures
- Hybrid (optical/copper/wireless) In-building Networks
- Management and Control of In-building Optical Networks
- Fault and Performance Monitoring
- Interface In-building Network with Access Network
- Wireless optical communication
- Techno-economic analysis
- Safety and health aspects

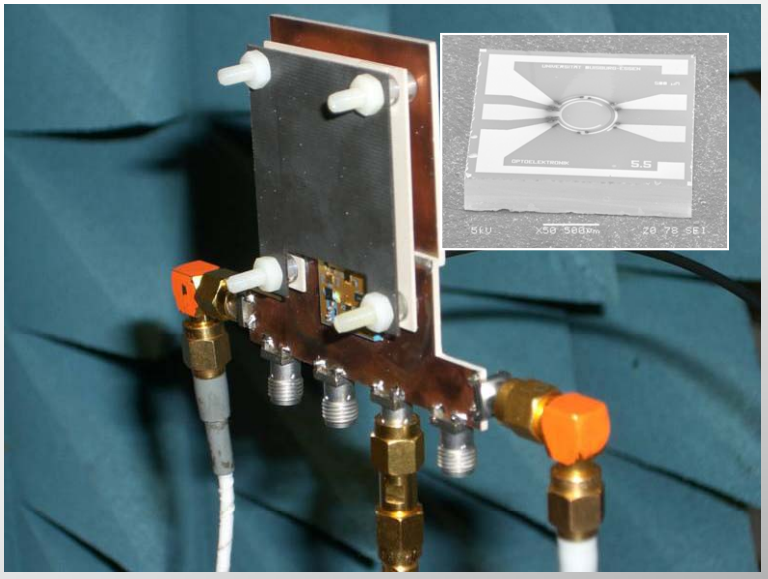
WP16 In-building Networks – Home Network Architecture



Home Network Scenario:

- Triple / Quadruple Play
- POF/MMF as backbone (IP based)
- Fiber-Radio Systems (GSM, WLAN up to 60GHz)
- Pico- / Femtocells
- Sensor Applications

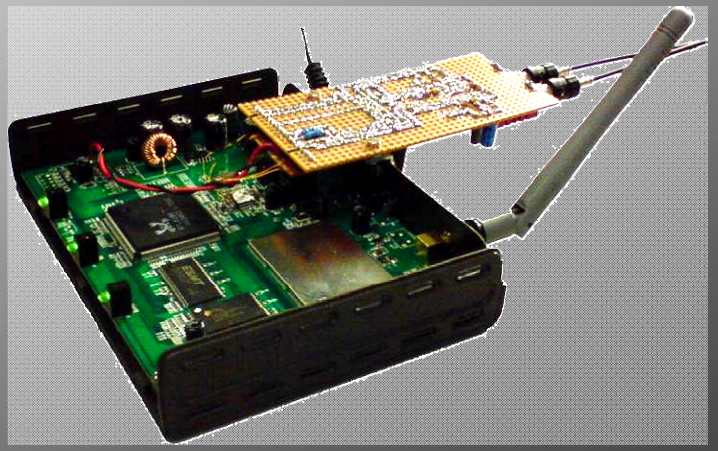
WP16 In-building Networks – Fiber-Radio-Systems



Radio over POF Base Station

based on
Vertical Electro Absorption Transceiver (VEAT)

WLAN-POF-Base Station



WP21 Green Optical Networking

Co Leaders
Dimitra Simeonidou (UESSEX)
Mario Pickavet (IBBT)

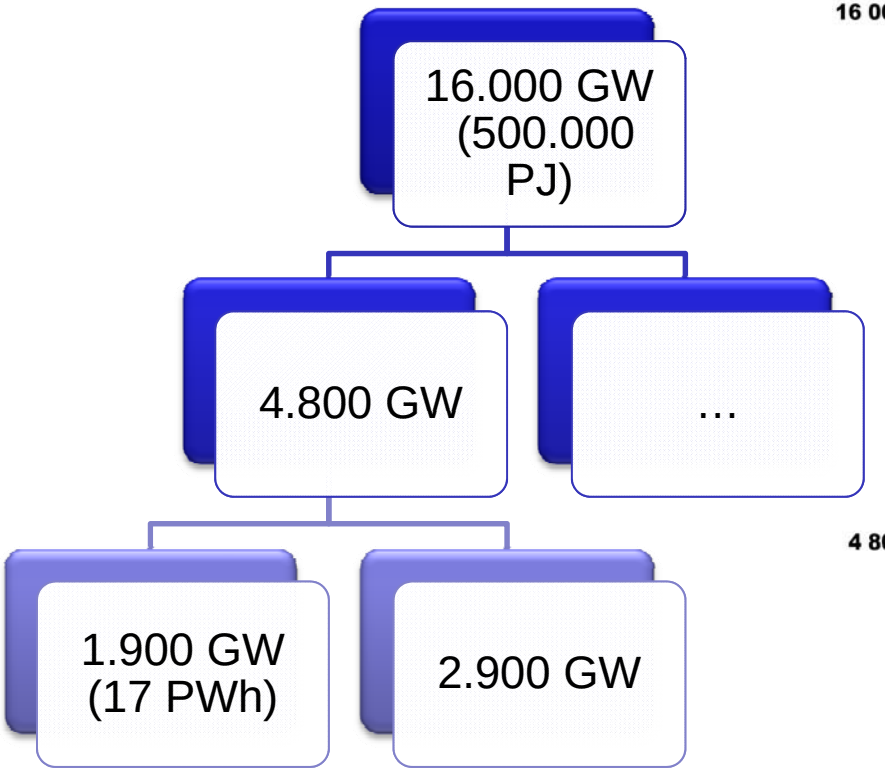
Partners
IBBT, GET, TUW, UPCT, BME, PoliTo, UNIMORE, UoP, USWAN, FUB, KTH, TUB, Telecom Bretagne, AIT, SSSUP

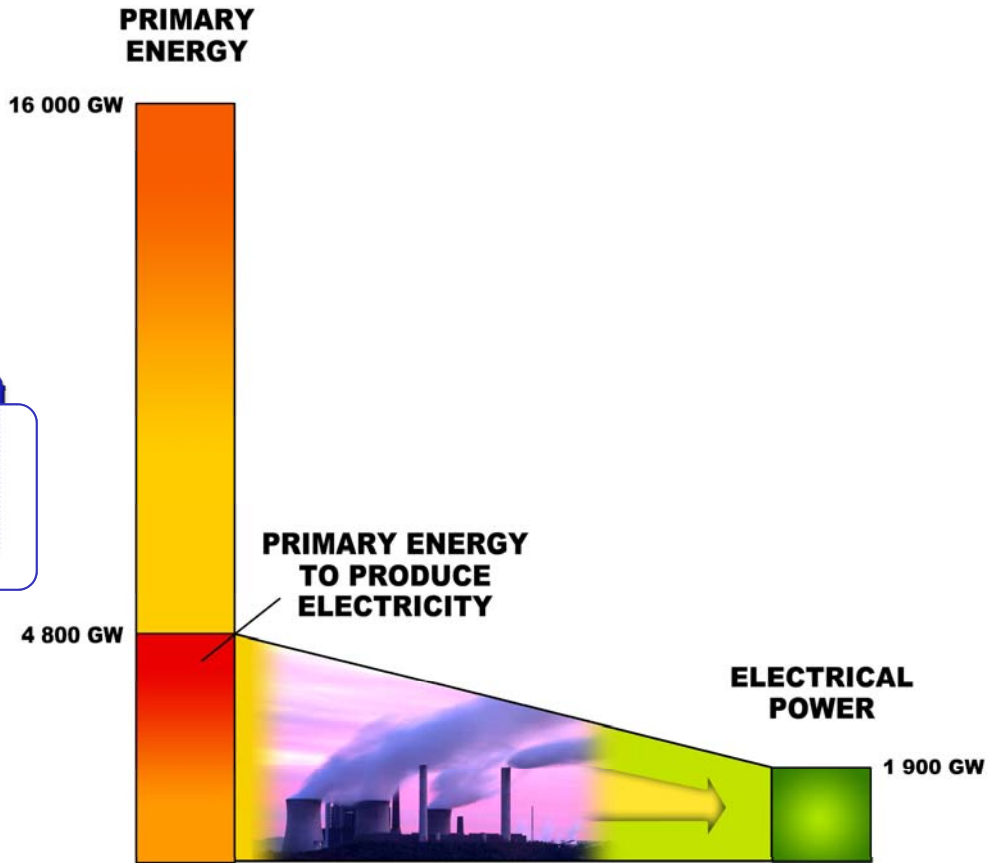
Motivation of WP21

- Global warming big threat to future society
- Need to reduce carbon footprint in ICT

- Actively participate in research to reduced global warming
- Investigate means through which the optical network can be developed to contribute to lower CO2 footprint
  - Idenify contributors to carbon footprint
  - Figure out the optical network energy saving potential
  - Discover energy efficient network planning and dimensioning means
  - Design energy efficient optical network

Indirect impacts of ICT: Power consumption



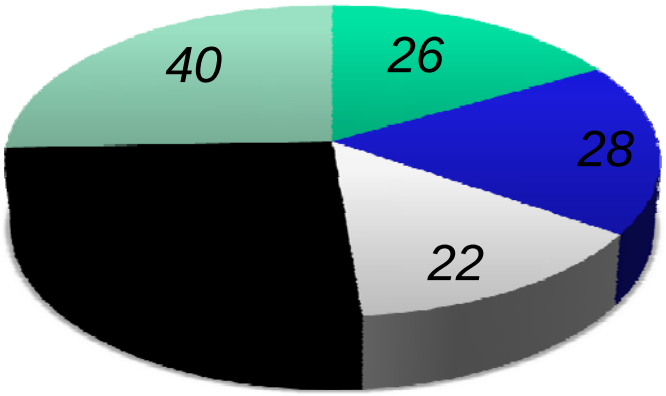


Worldwide

Equipment type	Power consumption during active mode (average load)
desktop PC with LCD display	100 W
desktop PC with CRT display	150 W
laptop PC	30 W
CRT TV	150 W (0.34 W per square inch)
LCD TV	190 W (0.29 W per square inch)
Plasma TV	330 W (0.34 W per square inch)
Gaming console	190 W
Volume server	220 W
Mid-range server	700 W
High-end server	10000 W
Core routers and switches	5 W per Gbit/s throughput
Access routers and switches	> 10 W per Gbit/s
Home gateway	7 W
GSM Base Station	700 W
WiMAX Base Station	400 W

Estimation:
Power consumption ICT Equipment Worldwide

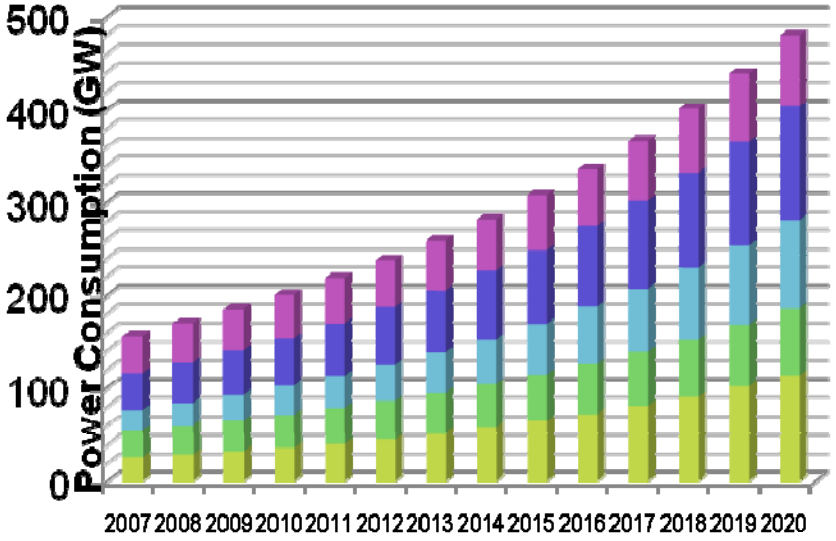
Power Consumption (GW)



Total = **156 GW** (1.400 TWh)

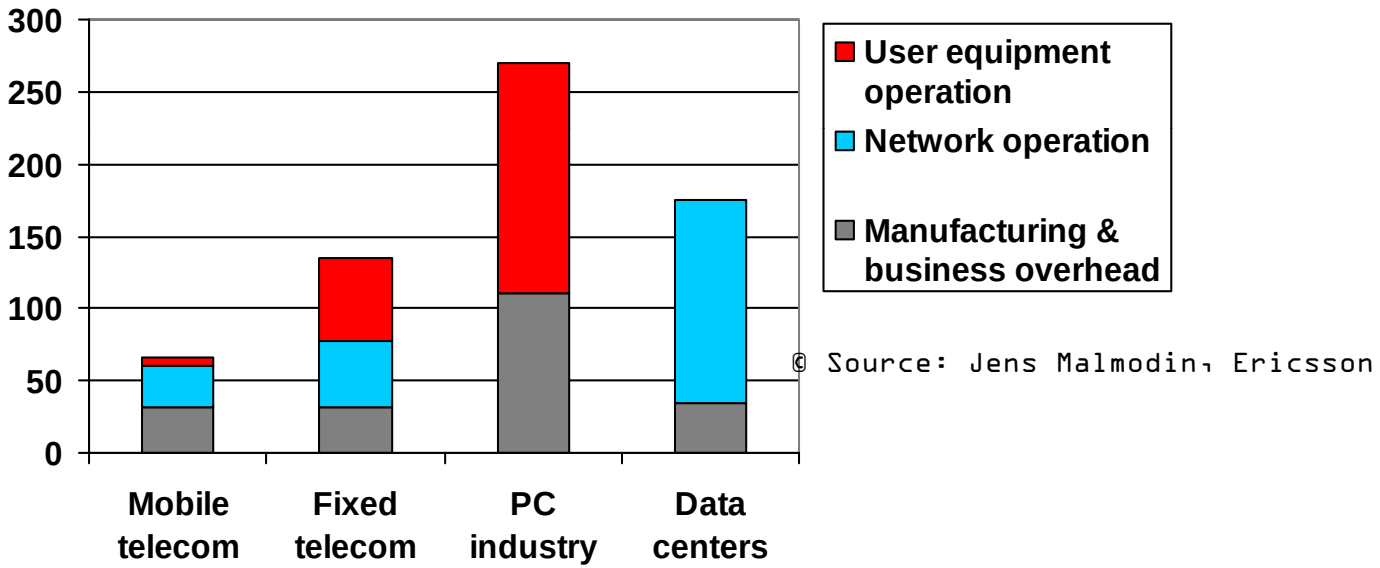
- Data centers
- PCs
- Network Equipment
- TVs
- Others

Yearly Power Consumption Forecast



- Data Center
- PCs
- Network Equipment
- TVs
- Other

CO_2 emissions from ICT in detail

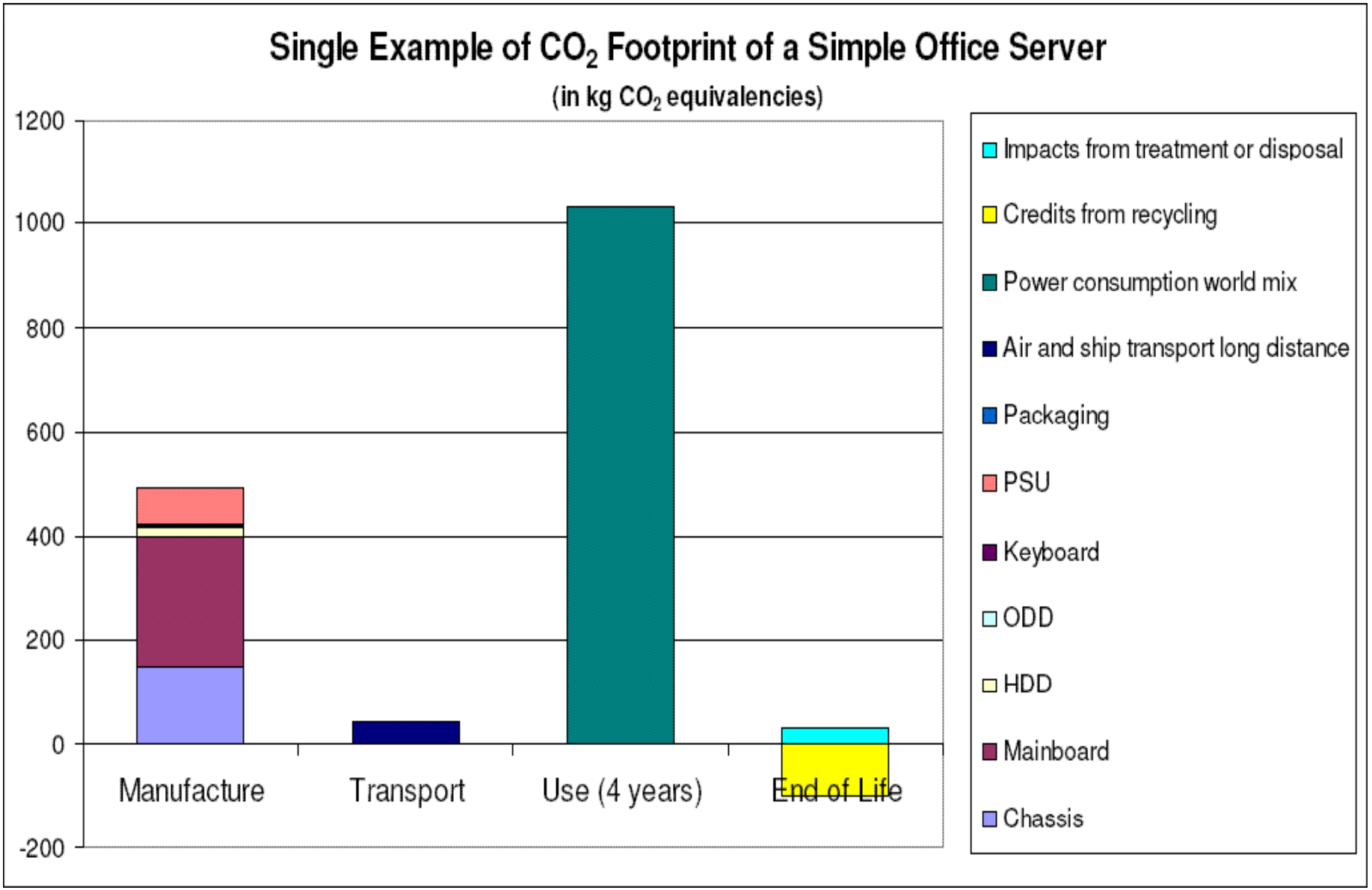


© Source: Jens Malmodin, Ericsson

Conclusions:

- Production vs. use: same order of magnitude
- Large differences depending on equipment type (e.g. mobile phone vs. server)

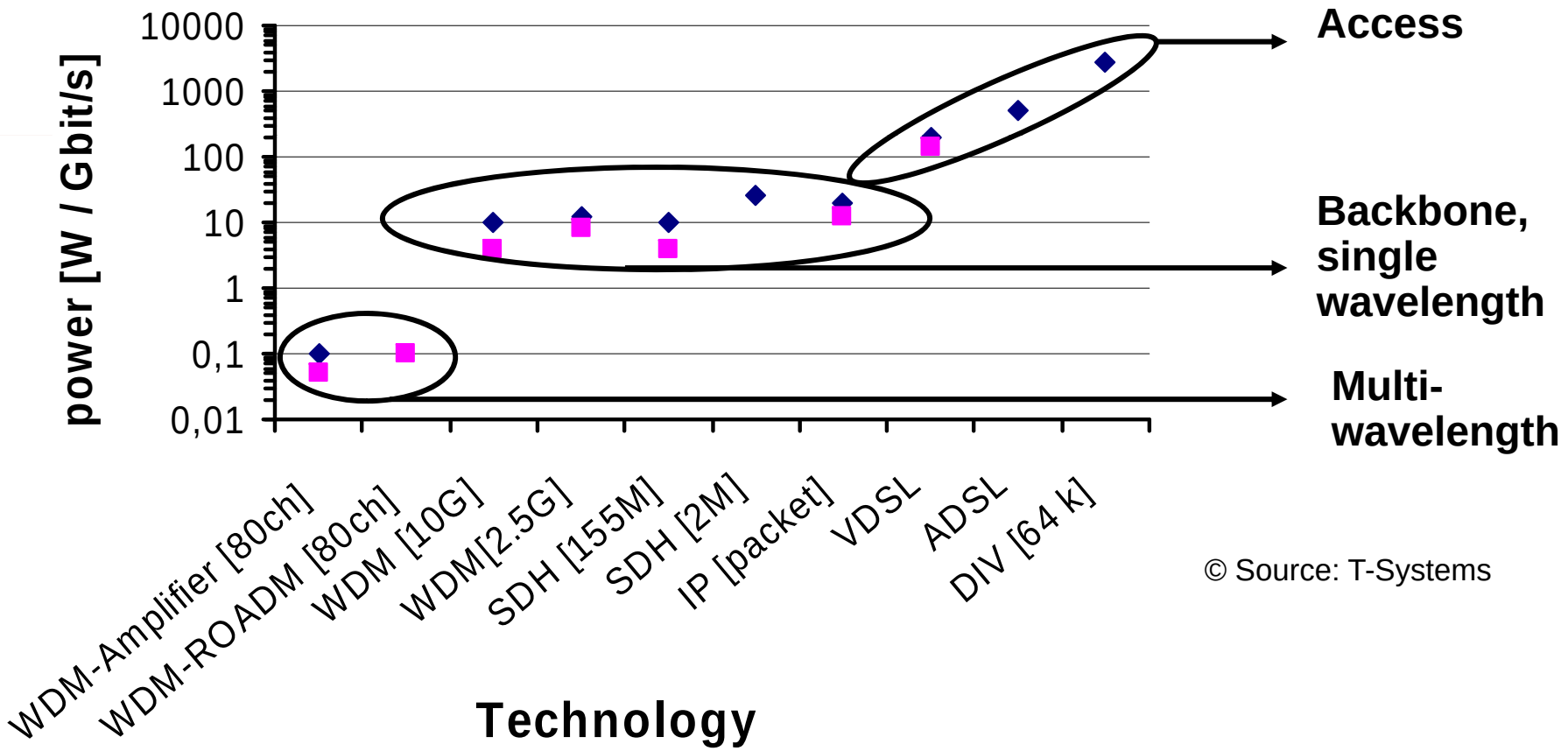
LCA: Life Cycle Assessment



Key conclusions on ICT footprint estimates

- Is ICT green ?
  - About 4% of primary energy today
  - About 8% of primary energy by 2020
- Is the situation hopeless ?
  - Much room for improvement
  - Research initiatives to be taken, also in field of optical networks
    → definition of new WP21
    - energy evaluation of different optical network solutions
    - new network paradigms (Future Internet)
  - Complex challenges: broad spectrum of environmental consequences:
    - Not only network equipment, also terminal equipment (e.g. FTTH vs. copper access)
    - Not only use phase, but full LCA (e.g. equipment replacement)
    - Not only energy or GHG emissions, also scarce materials, hazardous materials, landfills, …

Energy efficiency per platform

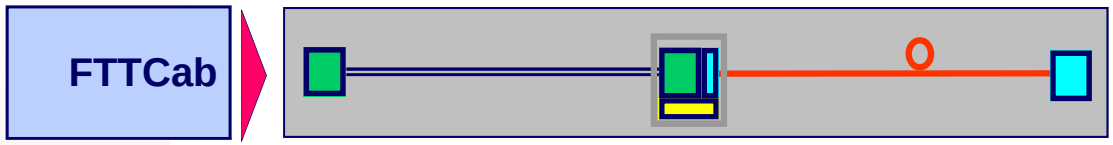


© Source: T-Systems

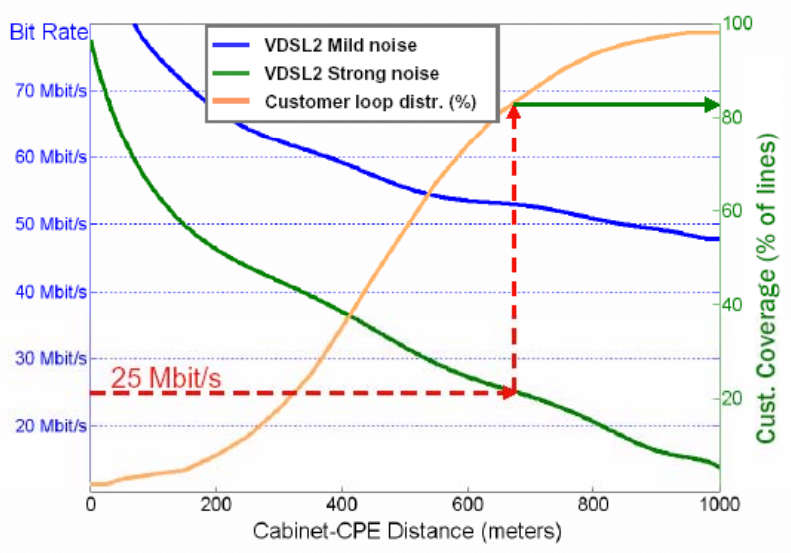
Energy efficiency is strongly correlated with aggregation level and physical medium

- **Optically transparent WDM technology is the most energy efficient technology**
- **Backbone equipment clearly more energy efficient than access equipment**

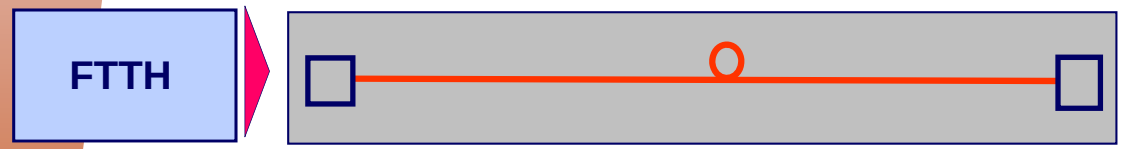
FTTH versus FTTCab



- Power supply and HVAC in outdoor cabinet required
- VDSL interface dominates the power consumption in the outdoor cabinet
- Key parameters for power consumption of VDSL are:
  - Characteristics of the line: Attenuation and Bandwidth
  - Signal processing
  - Power efficiency of current VDSL technology in the range of 100 W/Gbit/s



Source: C5 World Forum : Access alternatives for the Future Network Future Access Network: Telecom Italia view, Milano – 27th March 2007



- Optics provides a much higher power efficiency of 10 W / Gbit/s due to:
  - Lower attenuation
  - No intensive signal processing required

Estimating the Footprint of ICT and Identifying the Main Contributors

- Main objective:
  To estimate the optical networks impact w.r.t. the overall ICT impact
- Participants: IBBT, GET

Power Consumption & Supply of High-Performance Switching Elements

- Main objective:
  Establish database of power consumption for different architectures and technologies
- Participants: TUW, UPCT, BME, PoliTo, UniMore, UoP, USWAN, FUB

Energy Saving Potential by Selective Switch-off of Network Elements

- Main objective:
  Study and design energy conscious powering strategies for network devices and operation
- Participants: PoliTo, KTH, FUB, IBBT, TUB, GET, AIT, SSSUP

Green Routing Protocols

- Main objective:
  Study and design of energy-aware routing protocols and algorithms
- Participants: UESSEX, AIT, FUB, GET, KTH, SSSUP

Innovative Powering Strategies by Renewable Sources

- Main objectives:
  Identify green access network powering strategies
  Study its impact on performance and cost
- Participants: Telecom Bretagne, FUB, AIT

Energy Efficient Optical Network Design

- Main objective:
  Design cost and energy efficient optical networks
- Participants: AIT, KTH, UoP

WP22 MPLS, GMPLS and Routing

WP Co-Leaders

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- Inventory and resource management
  - Neighbor discovery: How do I know who is on the other end of a link?
  - Global topology dissemination, i.e. how do I know what equipment is in my network? (Links and switching nodes)
- Dynamic provisioning
  - Connection request, path calculation, connection establishment: how do I control (set up and tear down) lots of connections efficiently?

Previously manually configured!

It is a parallel network devoted to the transport of routing and signalling messages (e.g. adjacencies information exchange)

- Each data plane element has a control plane controller

Functional tasks:

- Automatic Neighbor Discovery
  - Allows a node to determine the identity of each neighboring node and the set of links that connect them.
- Topology and resource status dissemination
  - Allows every node to automatically discover the complete network topology and resources
- Signaling for Connection Provisioning
  - Allows the establishment and teardown of a path from one end of the connection

Control Plane technology standards
Standard Bodies and Organizations

Charter: Global Telecom Architecture and Standards

Member Organizations:
- Global Service Providers
- PTTs, ILECs, IXCs
- Telecom equipment vendors
- Governments

Charter: Evolution of the Internet (IP) Architecture

Active Participants:
- ISPs
- Service Provider IP Divisions
- IP/Ethernet Vendors

Charter: Network Management

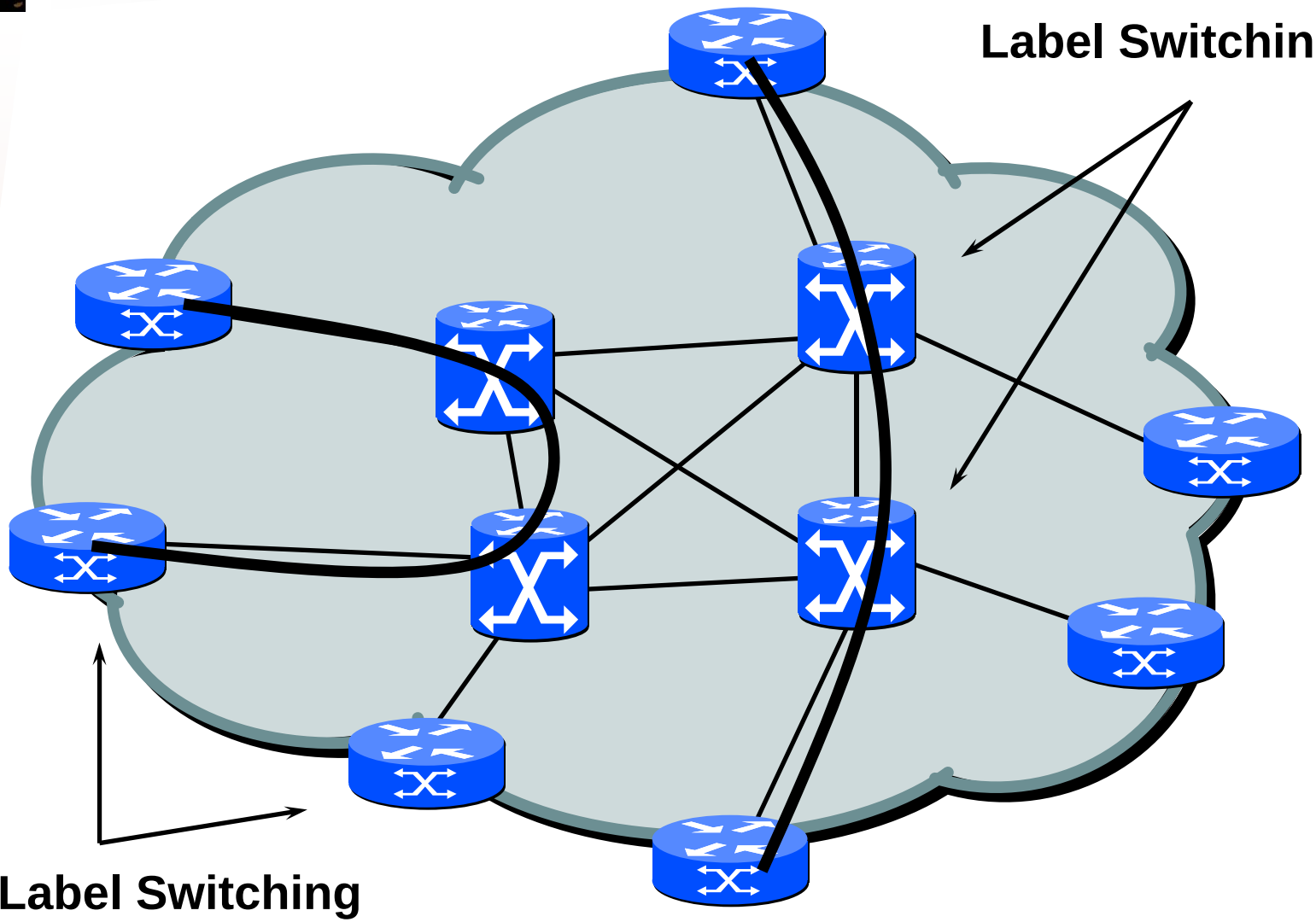
Over 350 members including
- Service providers
- Equipment vendors
- Software vendors

Charter: Development of Optical Networking Products and Services

Member Organizations:
- PTTs, ISPs, ILECs, IXCs
- Optical Networking Vendors

Authors: **Piero Castoldi**
Course: **Optical Core Networks – e-PHOTON**
Module: **ASON-ASTN-GMPLS basics**

MPLS Network



Authors: **Piero Castoldi**
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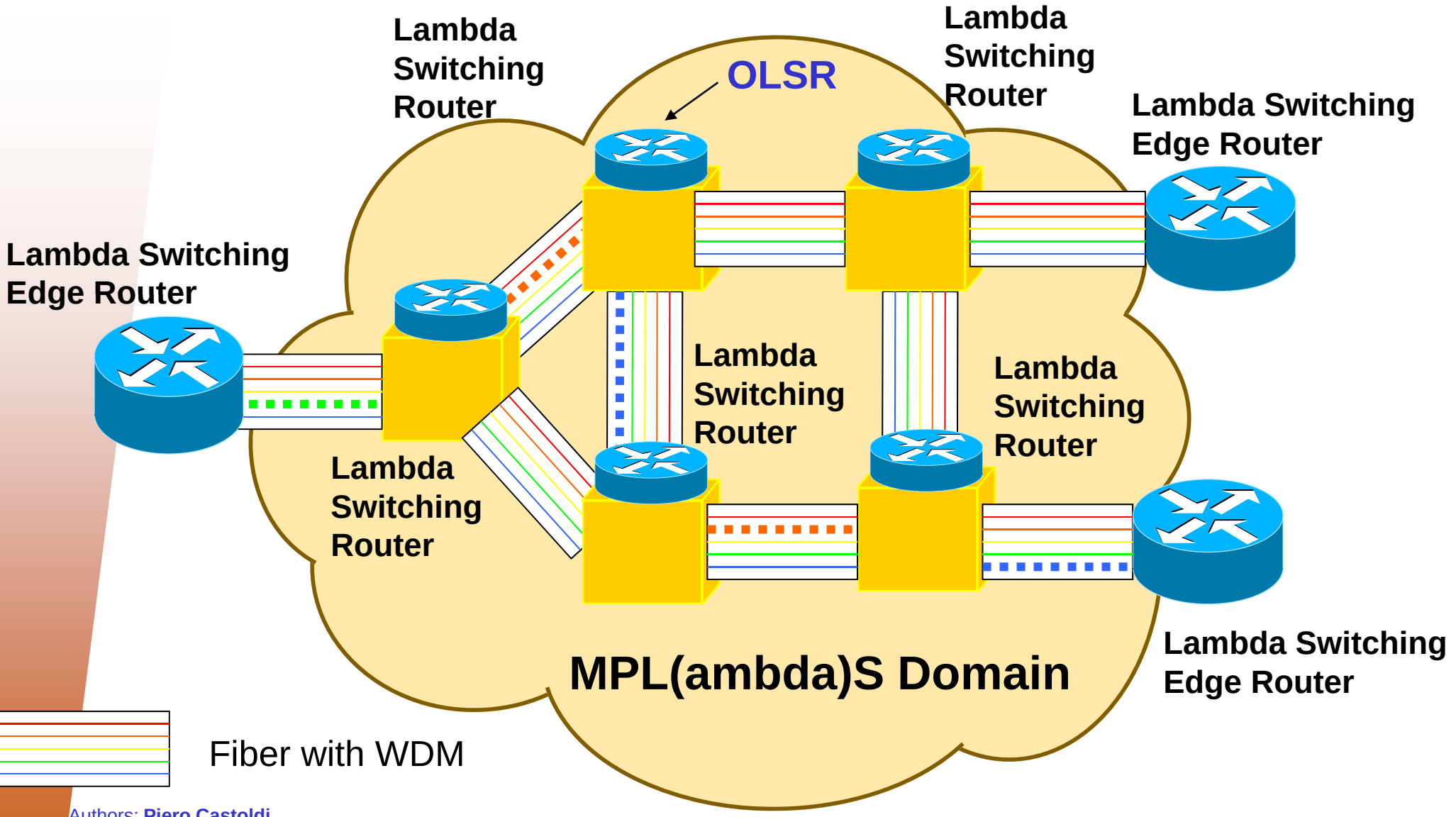
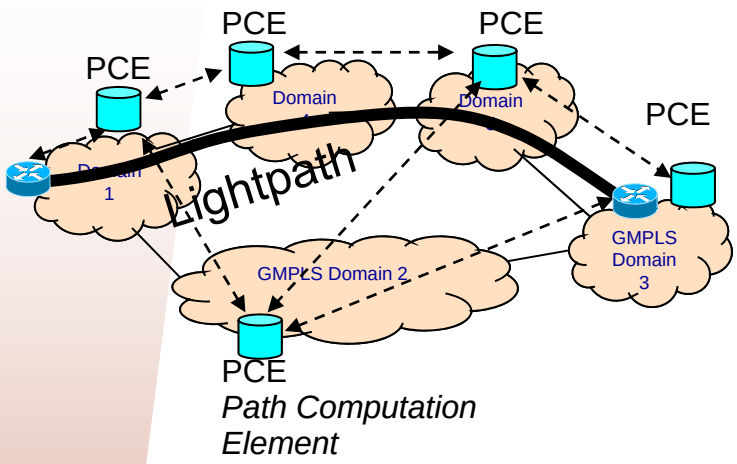
GMPLS Network



Authors: **Piero Castoldi**
Course: **Optical Core Networks – e-PHOTON**
Module: **ASON-ASTN-GMPLS basics**

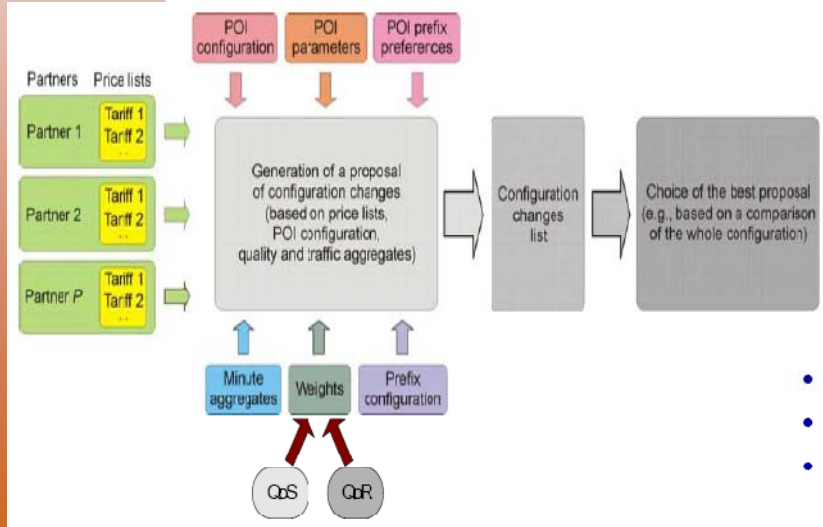
WP22 MPLS, GMPLS and Routing

- Scalability of Path Computation Elements
- BGP extensions for interdomain TE in optical transport networks
- Enhancing GMPLS Signaling Protocol for Encompassing Quality of Transmission (QoT)
- MPLS-ASON/GMPLS Interconnection
- Scalability issues in G/MPLS-based VPLS network design
- GMPLS-based RWA algorithms for optical protection/restoration
- Resilience Issues in the GMPLS-enabled Control Plane
- Carrier Ethernet Transport



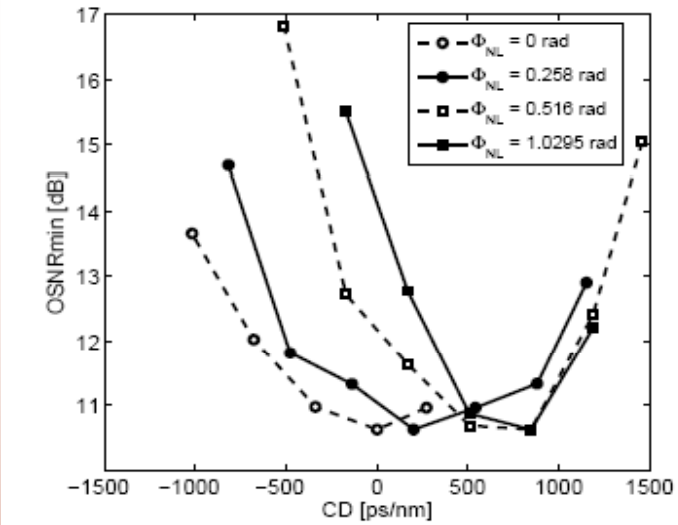
JA on Scalability of PCEs

- Develop heuristics and algorithms for path computation and wavelength assignment, carry out simulation-based and real validation evaluation of PCE prototypes in search of keys for scalability and performance.



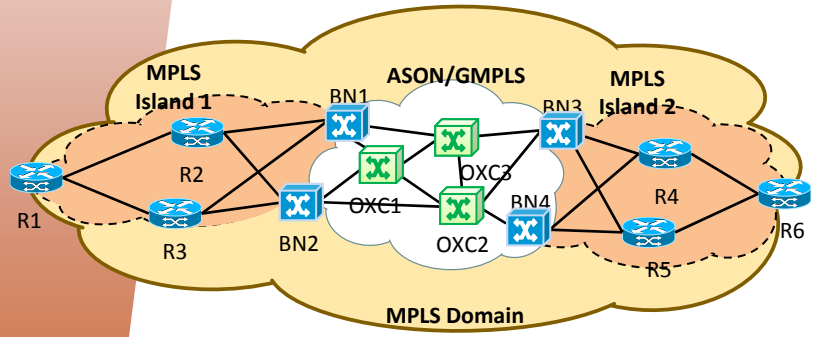
JA on BGP extensions for interdomain TE in optical transport networks

- Support:
  - TE resource dissemination
  - Protection/restoration support
  - Policy exchange mechanism
  - Cooperation with other frameworks for multi-domain TE such as PCE
- Can the inherent BGP drawbacks be avoided?



JA on Enhancing GMPLS Signaling Protocol for Encompassing Quality of Transmission (QoT)

- To perform theoretical and experimental analysis on the signaling approach to encompass physical impairment parameters within the GMPLS protocol suite
  - SAP, SAP-HR, SAP-HRA, SAL, SAL-A, …

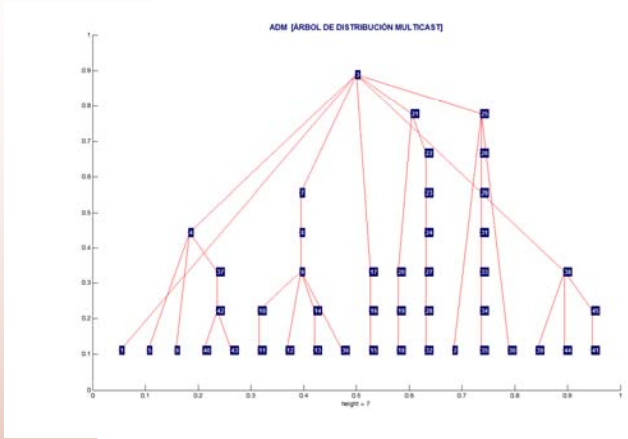


MPLS and ASON/GMPLS networks are managed by different operators.

Multi-domain scenario.

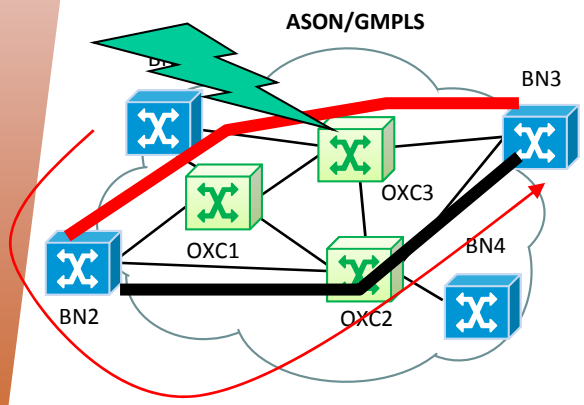
JA on MPLS-ASON/GMPLS Interconnection

- Key signaling mechanisms and interconnection framework for GMPLS-MPLS
  - Basic scenario: connection of two or more MPLS islands belonging to the same MPLS domain through one ASON/GMPLS domain managed by the same or by different operators.



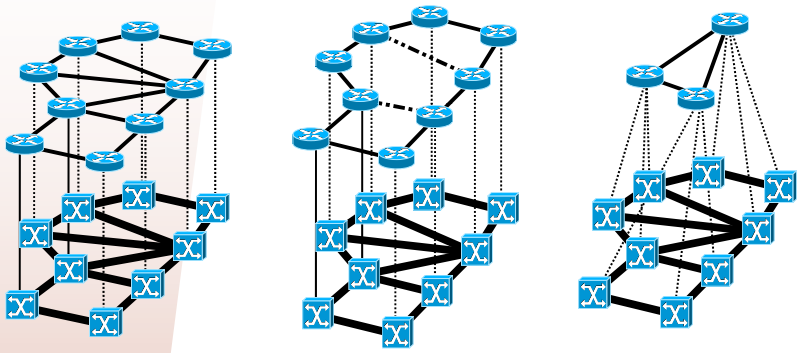
JA on Scalability issues in G/MPLS-based VPLS network design

- Evolution of the VPLS (Virtual Private LAN Service) from a MPLS-based implementation to an eventual all optical GMPLS
- Solve scalability problem due to connection-oriented nature of this technology.
- Provide the LAN's broadcast emulation in an efficient way via traffic engineering and grooming.



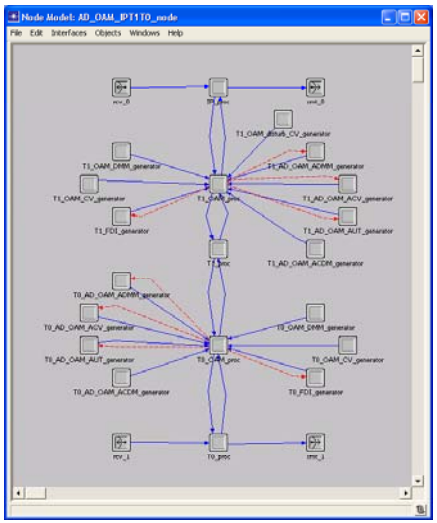
JA on GMPLS-based RWA algorithms for optical protection/restoration

- Research on routing and wavelength assignment (RWA) algorithms along with the required extensions to the current GMPLS protocols to efficiently encompass Protection and Restoration schemes in Wavelength-Routed Networks (WRN) with Wavelength Continuity Constraint (WCC)



JA on Resilience Issues in the GMPLS-enabled Control Plane

- The control plane plays a crucial role in next-generation optical networks
  - Different topologies for CP can be assumed
    - in-fiber" vs. "out-of-fiber" implementation
  - Signaling information
  - Routing information updates
  - Resource discovery and management information



JA on Carrier Ethernet Transport

- For PBT and T-MPLS, a dynamic control plane (e.g. GMPLS) is a key area for future development.
  - To develop dynamic a carrier Ethernet control plane, compatibility with the ETSI TISPAN RACS and ITU RACF specifications will provide a roadmap for NGN compliance.
  - Key issues: QoS mapping, resilience, OAM, etc

WP23 TP on Optical communication networks in support of user mobility and Networks in Motion

WP Leader: Ioannis Tomkos
itom@ait.edu.gr
Athens Information Technology (AIT)

TP on Optical communication networks in support of user mobility and Networks in Motion

- combines partners from various research fields in an effort to develop a common knowledge portfolio that will examine both technological and networking issues related with future networks in motion.
- The purpose is to benefit from the partners' expertise and create a spherical view of the challenges in this area from which:
  - the technology providers will identify operating characteristics of the system
  - the network layer designers will identify networking requirements to be addressed for protocols and algorithms
- The consortium will define the technology and networking challenges for the creation of networks in motion and will provide solutions from which the European industry and operators interested in this new market will benefit

TP on Optical communication networks in support of user mobility and Networks in Motion

Collaborative research towards three directions:

- Intelligent technologies and design challenges for wireless access
  - Provide rapid handover and high BW connectivity
  - RoF, FSO or conventional wireless solutions
- Switching characteristics for the aggregation/core network
  - Fast reconfigurable switching needed
  - Ethernet-based solutions or advanced schemes like OBS/OPS
- Control plane / signaling and networking algorithms and protocols
  - Dynamic registering of mobile users
  - Seamless end-to-end connectivity
  - MAC / network layer approaches with QoS guarantees

JA1 Hardware implications issues for Networks in motion

Objectives:

- In this JA **the reliability of components and hardware implications** issues for **network in motion** and sensor applications will be investigated.

Target outcome:

- **Improved design and reliability of hardware** for networks in motion is the main outcome of this JA

(Ericsson, Universität Duisburg-Essen)

JA2 State of the art definition for components supporting FSO networks in motion

Objectives:

- **Free space optic** is one of the options for **high-bandwidth (and cost effective**) means of support for networks in motion. In this JA, existing techniques and component features will be collected and the performance of different techniques will be benchmarked/compared

Target outcomes:

- **A comprehensive survey on the state-of-the-art technologies for FSO-based network in motion**

(Instituto de Telecomunicacoes, Superior Institute of Communication and Information Technologies, Athens Information Technology)

JA3 Converged MAC algorithms for unified optical wireless functionality

Description:

- A unique control layer (for SLA and service differentiation provisioning) is required to implement dynamic resource allocation based on conventional NRZ over PONs.
- To enable efficient integration, an effective mapping mechanism is required between PON priority queue for equivalent QoS.

Objectives and target outcomes:

- Unified MAC protocol for legacy PON and wireless networks
- Hardware implementation of the underlying network architecture

(University of Hertfordshire, University College London, AIT)

JA4 UWB Radio-over-fiber transmission in indoor environments using different media

Objectives:

- RoF transmission of both OFDM and IR UWB signals for in-building applications, (e.g. offices or home)
- Testing different media such as standard single mode fiber (SSMF), multimode fiber (MMF), plastic optical fiber (POF)

Target outcomes:

- Performance evaluation of UWB signals in RoF transmission for in-building applications (QoS, bit rate, spectral efficiency, maximum reach, etc.)

(UPVLC, AIT)

JA5 Optimizing service delivery in a converged hybrid optical-wireless network

Objectives:

- Optimization of service delivery and resource usage under user mobility.
- Study of re-configurability in various networking layers and dynamic mechanisms for quick network adaptation to accommodate broadband mobile networking.

Target outcomes:

- Key solutions in various networking layers (architecture, protocols, tools)
- Verification and benchmarking of the realized innovations with respect to the existing solutions

(UAM, AIT, TUE)

JA6 All-optical Routing Architecture of Radio Signals using Label Processing Technique for In-building Optical Networks

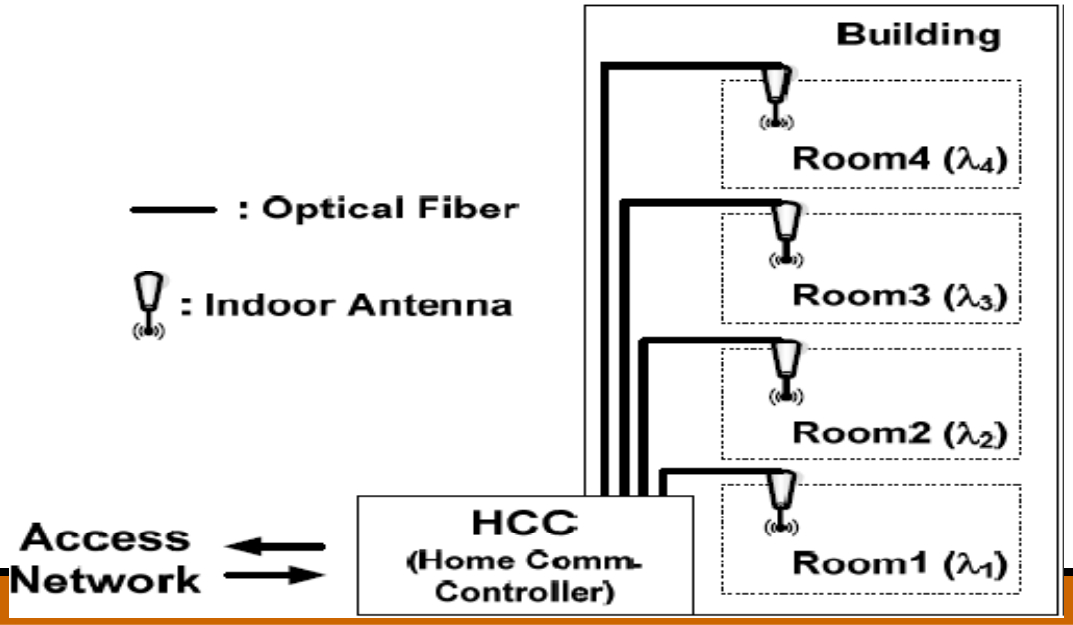
Objectives:

- Optical routing performed in a home communication controller (HCC), which arranges communications between rooms and routes signals to the proper rooms.
- Investigation of a new all-optical HCC architecture that forwards the radio signals to the specific rooms based on the label information.

Target outcomes:

- Investigation (experimentally) of a new all-optical HCC architecture for routing of RoF signals with label processing techniques

(UAM, TUE, AIT)



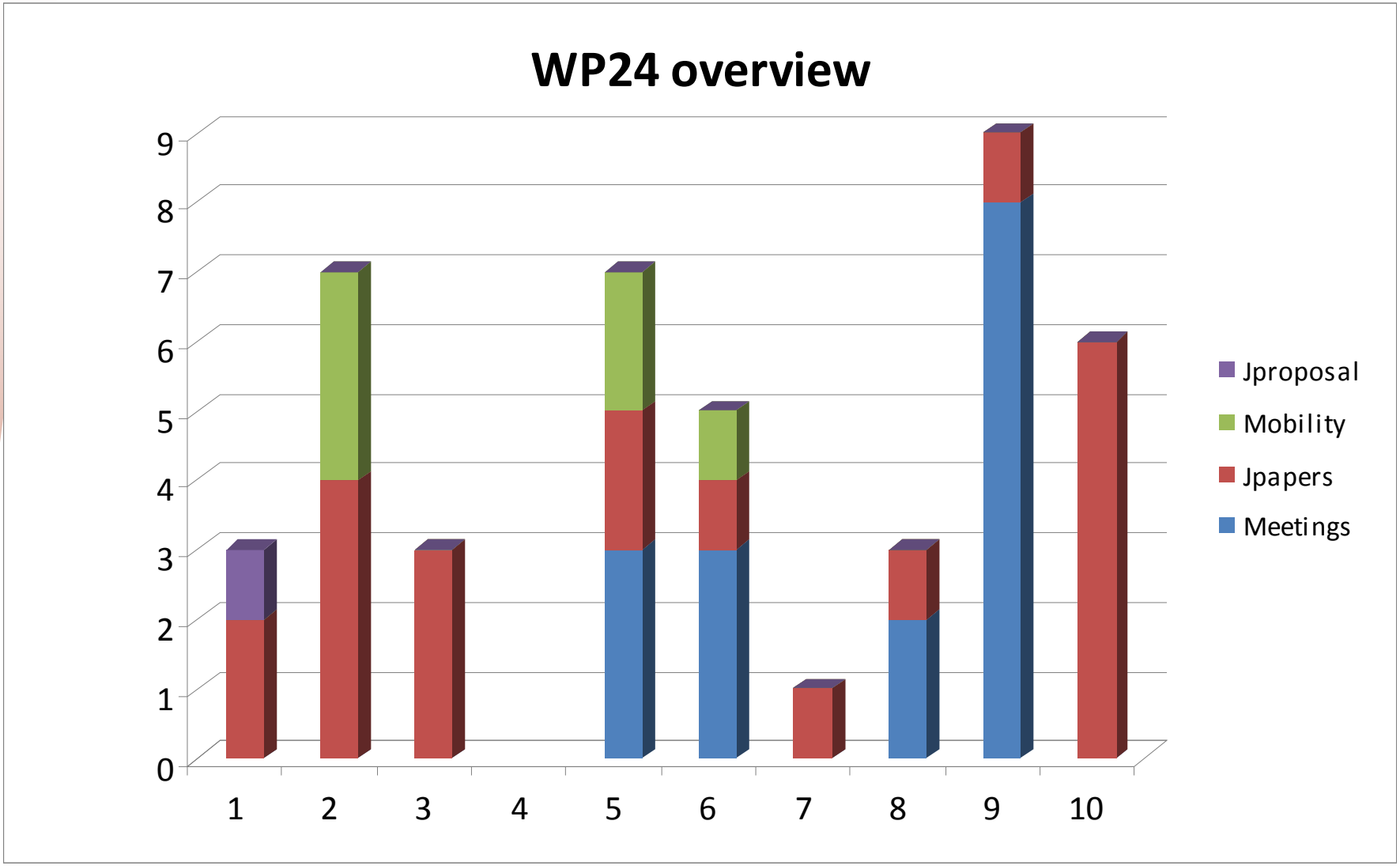
WP24

Edge-to-core adaptation for hybrid networks

WP Co-Leaders
Javier Aracil (UAM)
Victor Lopez (UAM)
Reza Nejabati (UEssex)

Shared research focus

- Assembly techniques:
  - **Evaluation of video transmission over OBS networks for different assembly schemes**
  - **Dynamic Multi-Queue Burst Assembly schemes for TCP performance enhancement**
  - **New assembly schemes taking into account the number of flows and their flow window size.**
- Synchronous traffic/Video:
  - **Design and evaluation of a periodic OBS burst reordering model for TCP throughput estimation**
  - **Synchronous traffic and OBS**
  - **Evaluation of video transmission over OBS networks for different assembly schemes**
- Qos and traffic
  - **Traffic conditioning and congestion control in OBS/OPS networks**
  - **Survey on QoS differentiation Mechanisms for OBS**
- Other
  - **The OTDM Add-Drop technique to overcome granularity problems in optical networks**
  - **Advanced optical amplifier for OBS/OPS transmission**


WP24 overview
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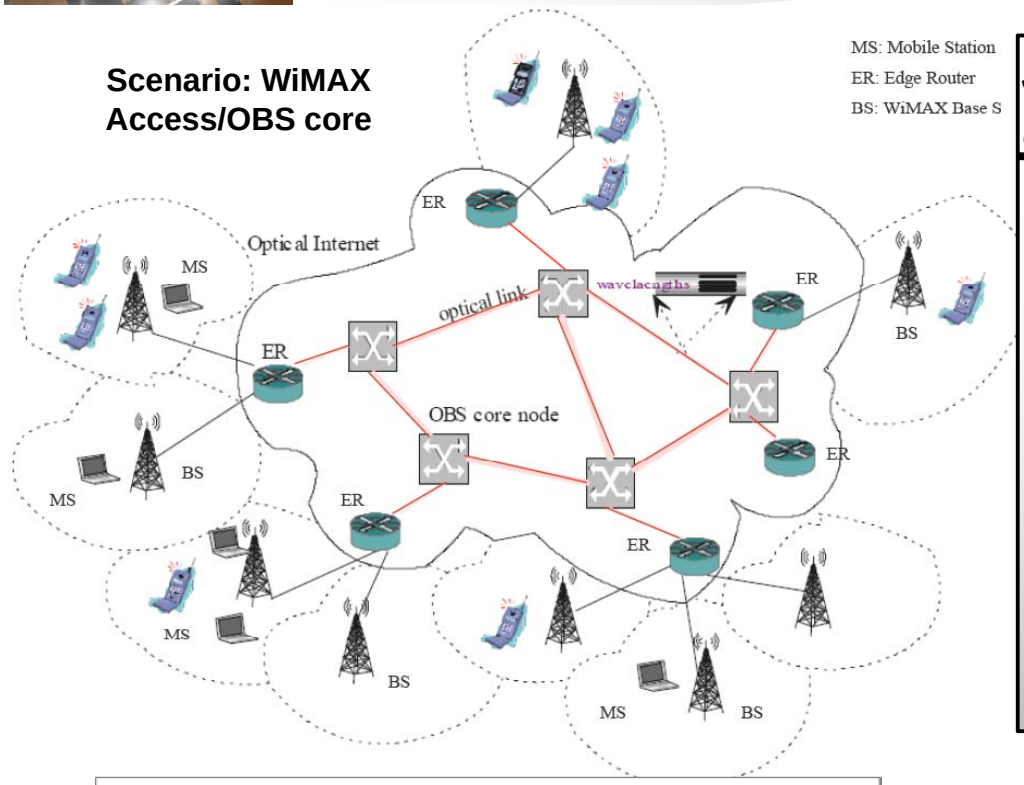
Jproposal
Mobility
Jpapers
Meetings

Main Objectives

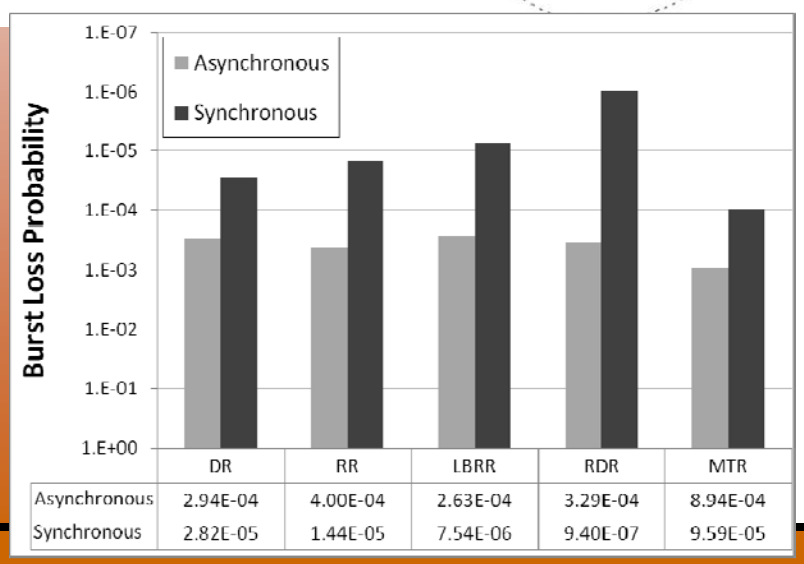
- To pursue research in the area of edge-to-node adaptation in hybrid optical network supporting next generation Internet applications.
- Define edge node functionality, role and architecture in polymorphic networks: Optical Burst/Packet Switching and Optical Circuit Switching.
- Propose burstification algorithms beyond the current time-size based algorithms.
- Study adaptation of adequate interplay between TCP and the optical network.
- And more: QoS, resilience, capacity planning, etc in OBS/OPS

Scenario: WiMAX Access/OBS core

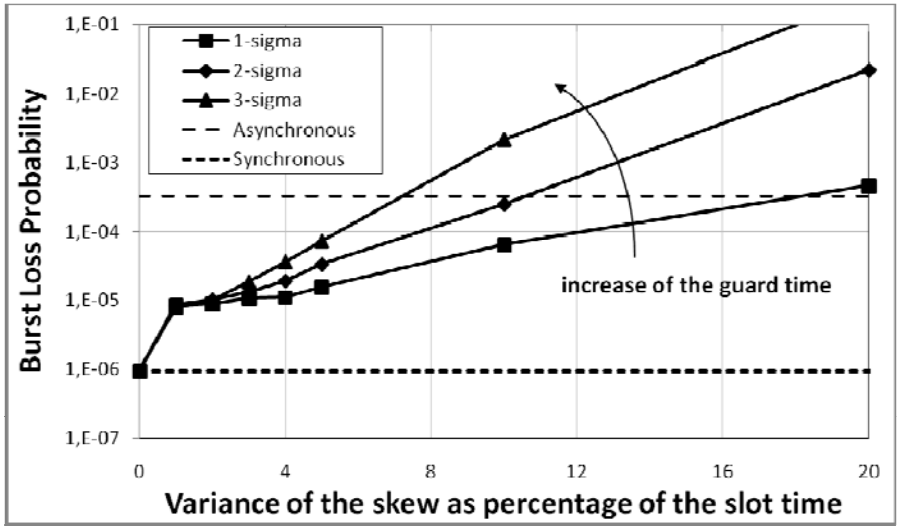


JA1 OBS routing algorithms for resilient and dynamic network scenarios

- Backhauling Wireless broadband traffic over OBS (AIT, UEssex)
- Performance of Deflection Routing algorithms (UPC-EPFL)
- Quasi-synchronous OBS network operation (UPC-EPFL)

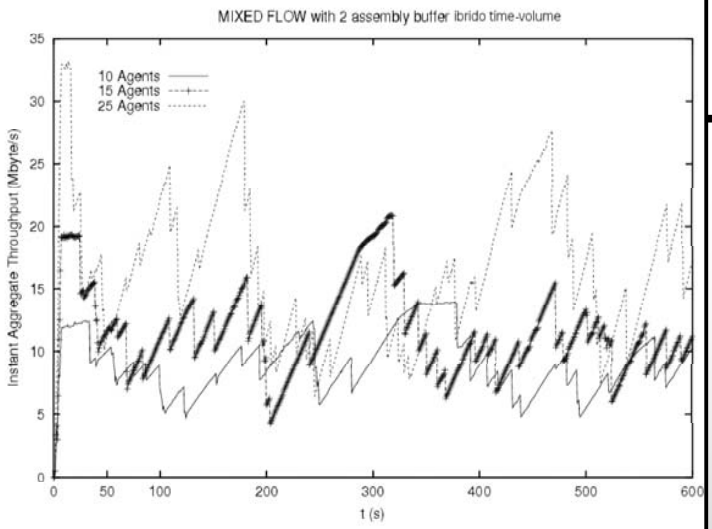


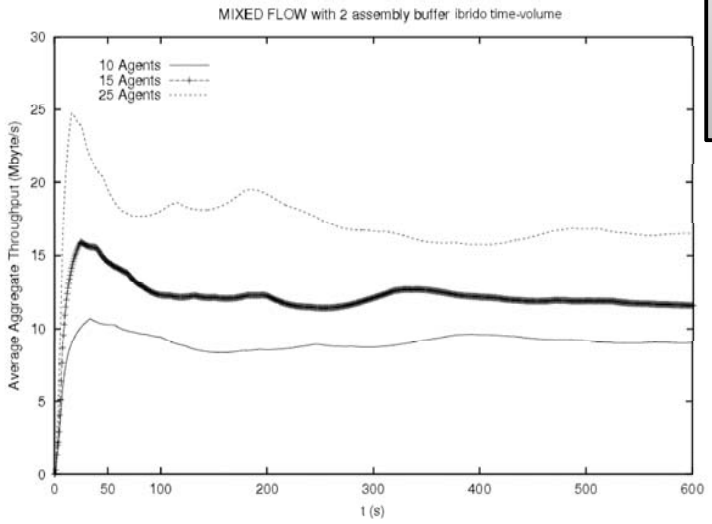
	DR	RR	LBRR	RDR	MTR
Asynchronous	2.94E-04	4.00E-04	2.63E-04	3.29E-04	8.94E-04
Synchronous	2.82E-05	1.44E-05	7.54E-06	9.40E-07	9.59E-05



JA2 Evaluation of video transmission over OBS networks for different assembly schemes

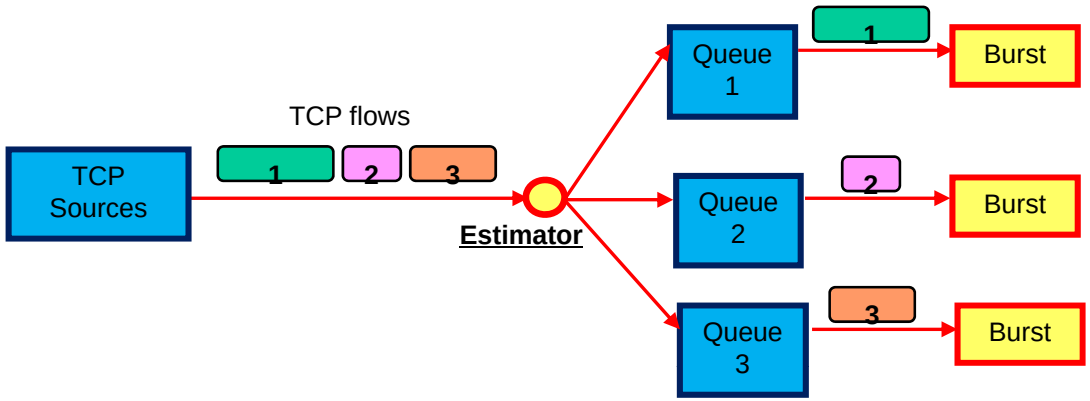
- The main objective the evaluation of digital video transmissions over OBS networks for different assembly schemes.
  - **RACTI/UPatras** provide expertise in the OBS ns-2 simulator, and in implementation of different assembly strategies.
  - **UPVLC** provide expertise in objective and subjective video evaluation, knowledge in video codification standards, and providing the necessary video traces files.
  - **UEssex** provide a video streaming capable OBS test-bed than will be used to test and evaluate performance of the video transmissions over OBS networks with different burst assembly schemes.

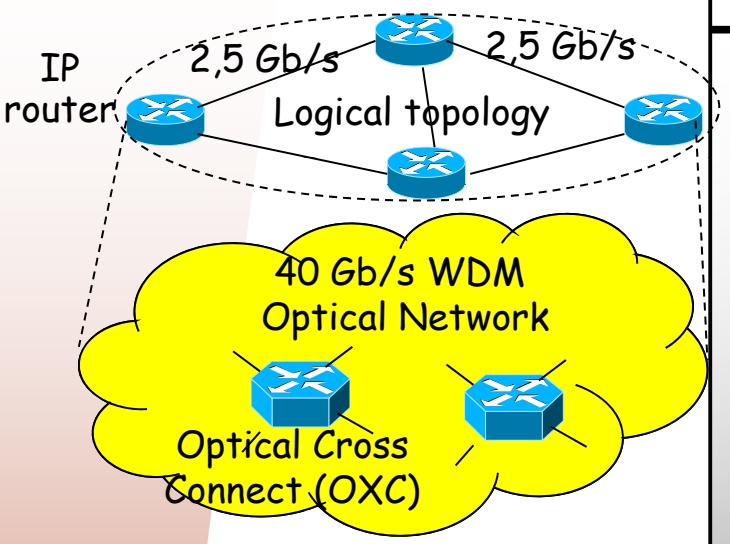




JA3 Dynamic Multi-Queue Burst Assembly schemes for TCP performance enhancement

- Investigation of multi-queue assembly scheme, where TCP flows are assigned to flows dynamically, according to TCP window (UNIBO/RACTI)
- Study of TCP flow synchronization phenomenon in OBS networks, which leads multiple TCP flows simultaneously increasing/decreasing their windows. (UNIBO/RACTI)
- Investigation of the synchronazation phenomen for TCP flows with mixed flow hybrid time-volume based assembly algorithms (UNIMORE)
- Investigation of mixed flow multi-queue hybrid assembly algorithms working on the current estimated value of the congestion window UNIMORE)

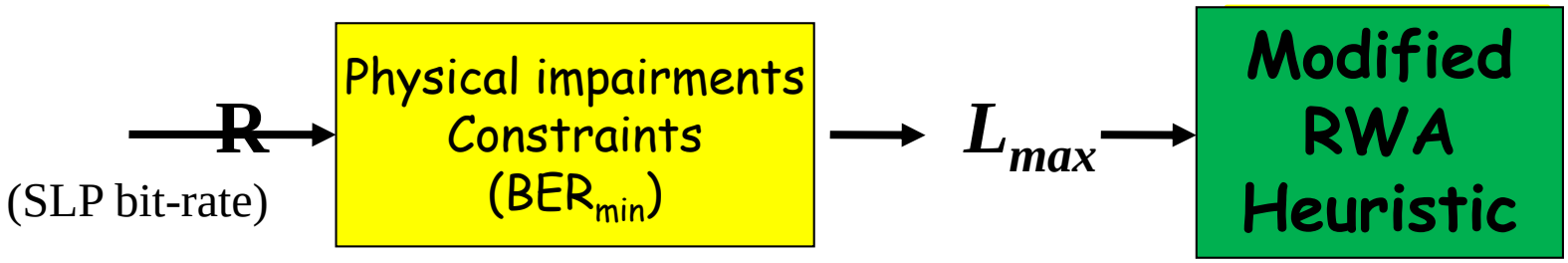




JA5 The OTDM add-drop technique to solve granularity problems in optical networks

- To evaluate the technological and economic aspects of Optical Time Division Multiplexing/Wavelength Time Wavelength (OTDM/WDM) solutions solving the granularity problems in optical networks
  - Routing and Wavelength Assignment (RWA) in OTDM/WDM networks
  - Physical Impairments in OTDM/WDM networks

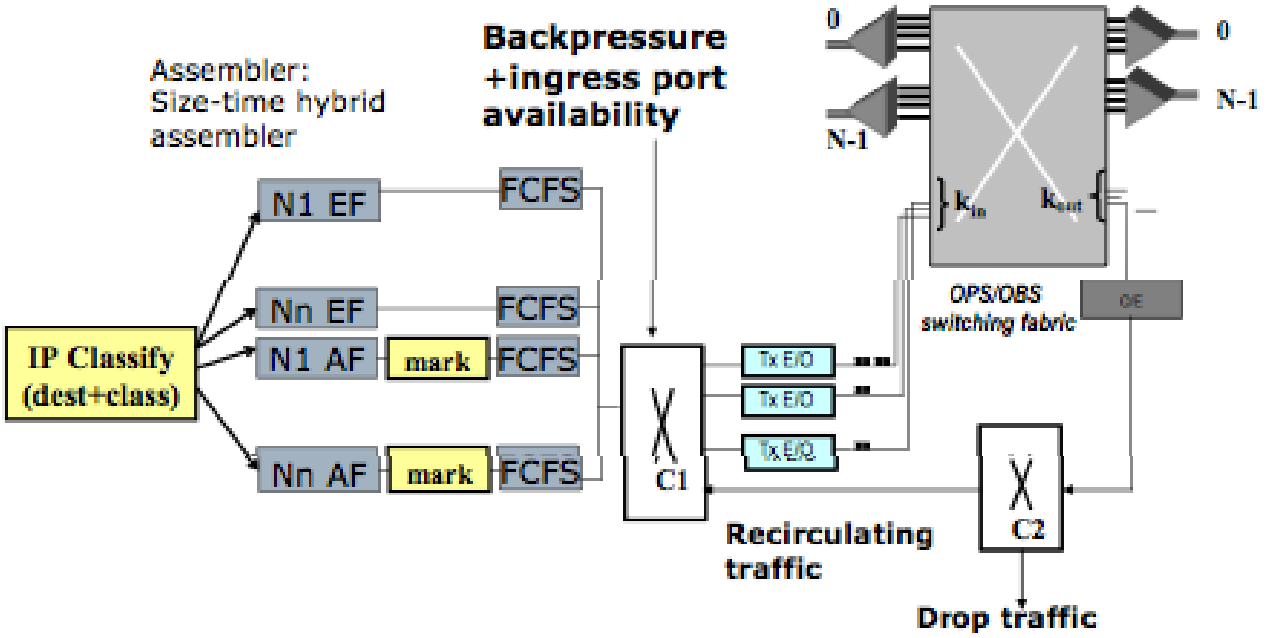
Sapienza-Università di Roma, Fondazione Ugo Bordoni, Co.Ri.Tel.



JA6 Traffic conditioning and congestion control in OBS/OPS networks

- This JA studies the problem of traffic conditioning, traffic pacing in the egress side of OBS/OPS networks

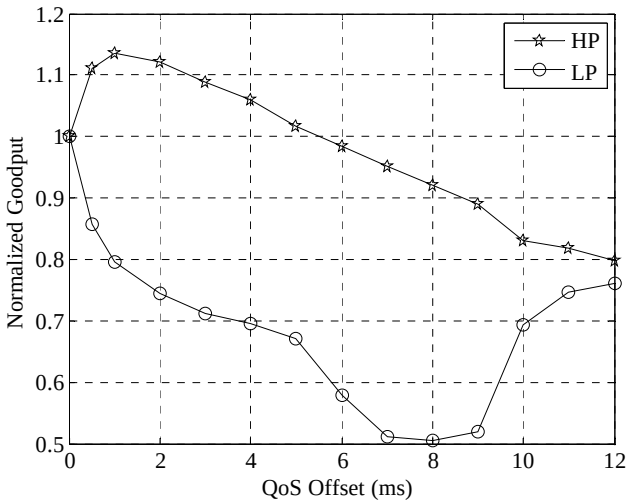
UPCT, AIT, TUB

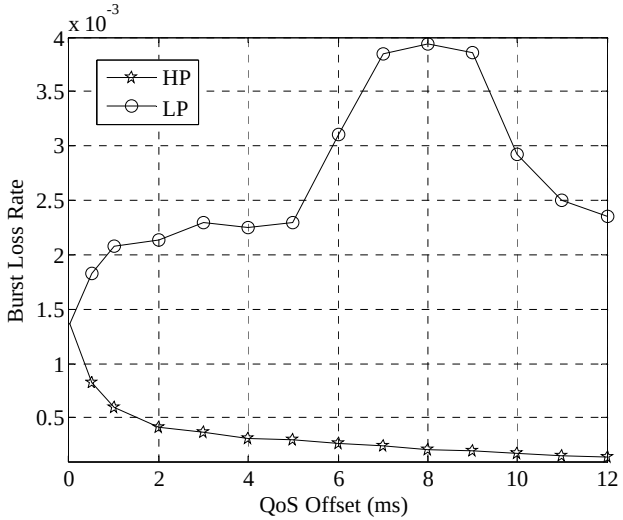


JA7 Traffic conditioning and congestion control in OBS/OPS networks

- Survey on QoS Differentiation Mechanisms for OBS

UPC, RACTI, BILKENT

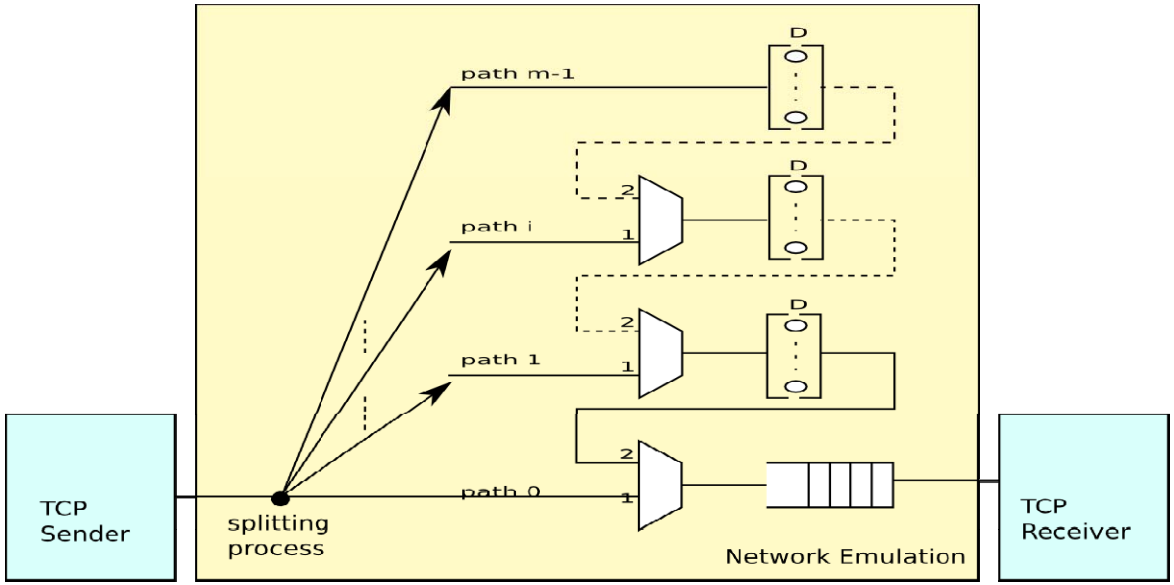




JA8 Design and evaluation of periodic OBS burst reordering model for TCP throughput estimation

- Optical burst reordering results of contention resolution schemes
- Design of an analytic TCP throughput model for periodic burst reordering
- Includes multi-layer analysis on optical burst reordering and the TCP over OBS periodic loss model OBS

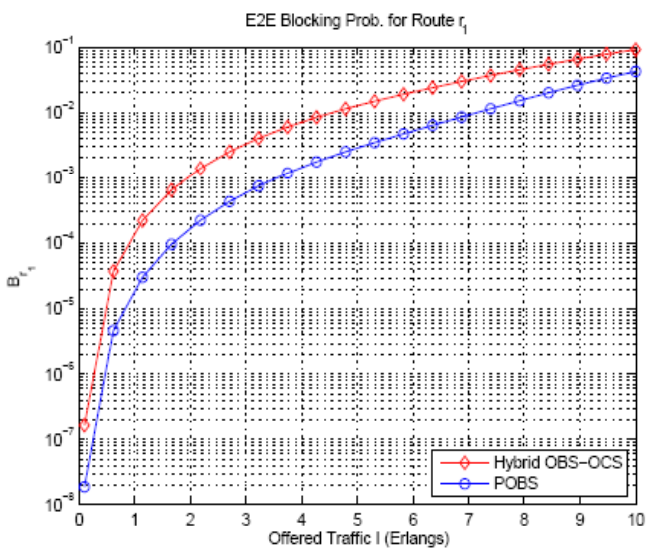
TID, UST-IKR



JA9 *Synchronous traffic and OBS*

- This JA intends to study different aspects of the paradigm “hybrid burst-switched circuit-switched exploitation of the OBS network”.
- Compare several approaches: parallel hybrid OBS-OCS, POBS (Qiao), hybrid opto-electronic switching, …
- Analyse performance on packet-switched traffic.
- Propose new schemes for hybrid burst-switched circuit-switched exploitation of the OBS network.

(U. Autónoma de Madrid, U. Carlos III de Madrid)



ig. 6. B_{r_1} for POBS (circles) and OCS-OBS (diamonds) in the IPTV cenario.

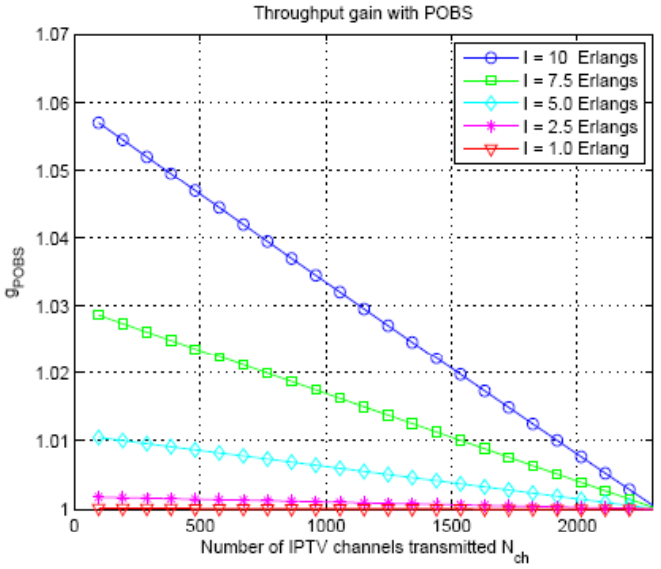


Fig. 7. Throughput gain with variable number of transmitted TV channels

JA10 Advanced optical amplifier for OBS/OPS transmission

- Bring together expertise in OBS/OPS transmission and advance optical amplification.
- Investigate and minimize amplification impairments in OBS/OPS transmission.
- Performance evaluation of WDM burst traffic amplification.
- Design aspects of effective all-optical amplification stabilization for burst transmission.
- Burst transmission statistics and model of WDM burst traffic real data.
- Assessment of effective amplification performance with real burst data and critical cases (BER and power fluctuation measurements).

(UPC, UAM, USWAN)

WP25 TP on Optical Interconnects

WP-Leader
Achille Pattavina (PoliMI)
achille.pattavina

TP on Optical Interconnects

- will pursue integration by coordinating the work of partners of different natures and with different expertise's around a common work-plan with the final goal of designing a scalable and efficient optical backbone for next-generation switches and routers
- Integration of expertise will be important not only for the final result but also for other more limited but not less-important “by-product” topics (e.g. short-reach optical transmission systems operating at 100 Gbit/s or above) that will be explored in the course of the TP activity

Schedule: M13-M36 (Jan. 2009 – Dec. 2010)

WP26 Alternatives for multi-layer networking with cross-layer optimization

WP Leader: Ioannis Tomkos
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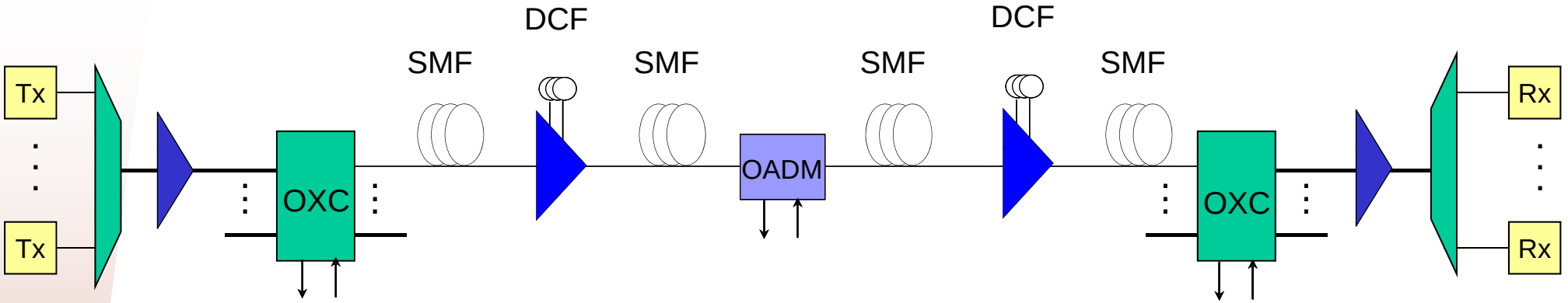
Athens Information Technology (AIT)



- Fiber transmission and networking impairments degrade the system performance
- Sufficient signal quality cannot be assumed for all possible lightpaths
- Cross-layer optimization is required

Tx: Transmitter OXC: Optical Cross-connect
Rx: Receiver OADM: Optical Add Drop Multiplexer
SMF: Single Mode Fibre DCF: Dispersion Compensating Fibre

Alternatives for multi-layer networking with cross-layer optimization

- Objectives:
  - **Multi-layer approaches (architectures, protocols and network characteristics) for future Internet Protocol (or Ethernet) convergence over optical network solutions**
  - **Cross-layer optimization approaches that take into consideration the physical layer, transport/data link layer and network layer characteristics.**
- Duration: **M01-M24 (Jan. 2008 – Dec. 2009)**
- Activity Type: RTD
- Total PM: 13 PM
- Number of involved partners: 16

JA1: Multi-layer algorithm using Bayesian decision theory

- Main objective: Definition of a multi-layer algorithm which uses the IP routers deployed in the network till they can not provide the user desired QoS. Once this QoS is not achieved, optical by-pass are created to solve such situation.

Achievements:

  - Definition and testing of algorithm for multi-hop scenarios.

- Participants: UAM-TID

JA2:RWA (Routing and Wavelength Assignment) and regenerator placement (RP) in transparent/translucent optical networks

- Main objective: Develop a IA-RWA (Impairment Aware Routing and Wavelength Assignment) mechanism able to deal with RWA and taking into account the inaccuracy in the physical impairment parameters.

Achievements:

- Novel offline IA-RWA algorithms
- Novel offline IA-RWA algorithms with path protection capabilities
- Novel online IA-RWA algorithm based on predictive analysis in order to alleviate the QoT inaccuracy
- Validation and evaluation of IRWA algorithms for GMPLS-enabled translucent networks
  - Definition and implementation of the IA-RWA algorithm and the required translucent GMPLS protocol extensions within the CTTC ADRENALINE testbed.
  - Initial study of regenerator allocation schemes in translucent networks.
  - Novel online IA-RWA algorithm that incorporate the QoT inaccuracy within the algorithm decision.
  - First results on performance comparison of deterministic IA-RWA algorithms with different regenerator placement strategies.
  - Proposal of an algorithm aiming at minimizing the global number of regenerators and the number of regeneration sites.

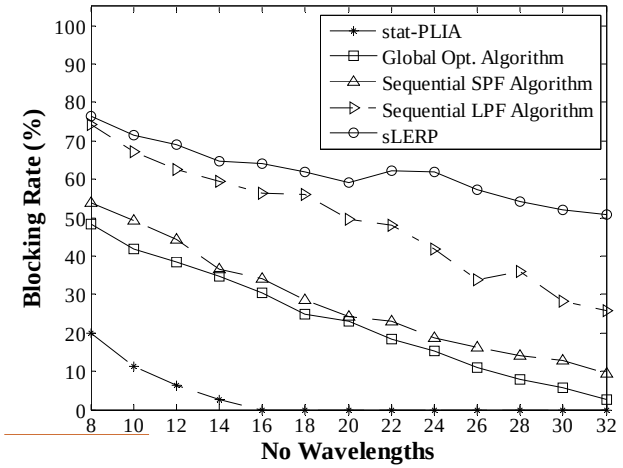
Participants: UPC, AIT, TUW, POLIMI, IT, UPCT

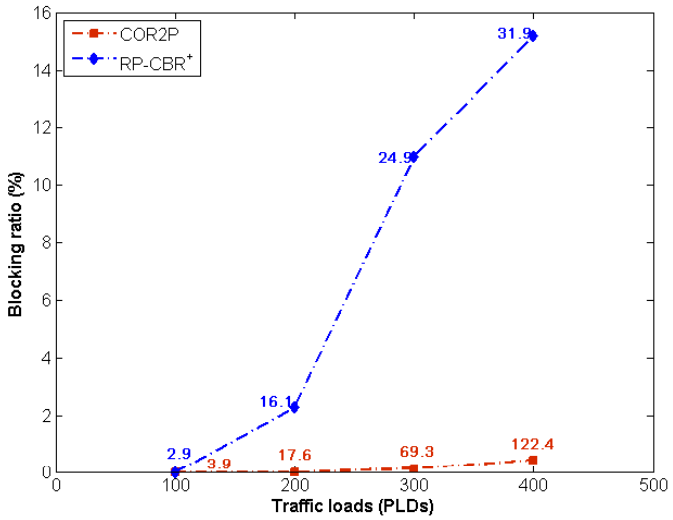
JA3: Algorithm for multilayer Optimization with ICBR Constraints

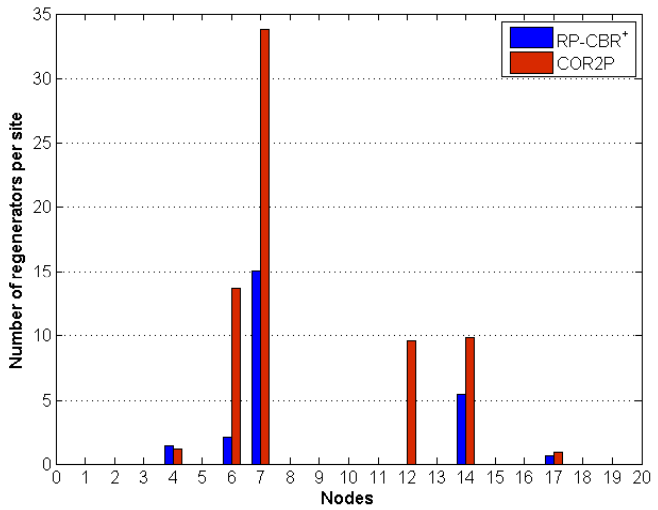
- Design and comparison of static IA-RWA algorithms, combining heuristics and MILP formulations.
- Solution of the plain RWA problem and deal with it considering the physical impairments, using Genetic Algorithms in both Static and Dynamic cases.

- Participants:

  UPCT, TID, AIT, RACTI, BME, , UAM, CCTC, UPC, BILKENT

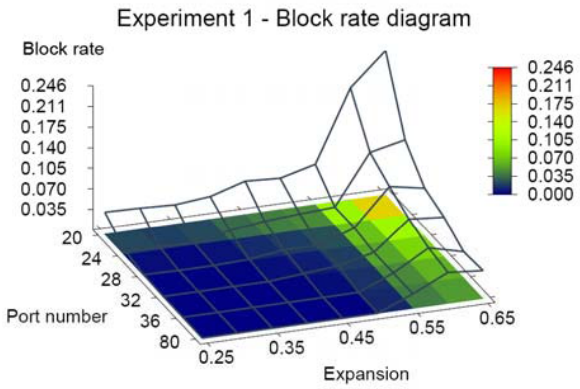


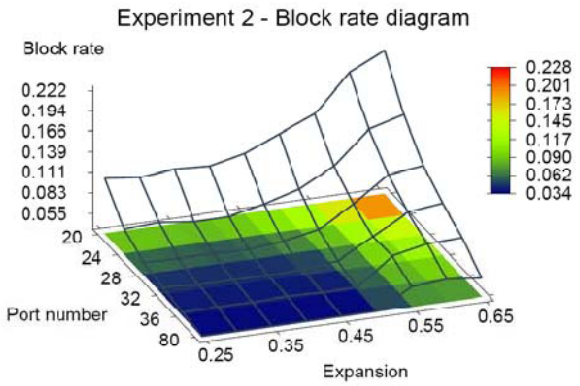


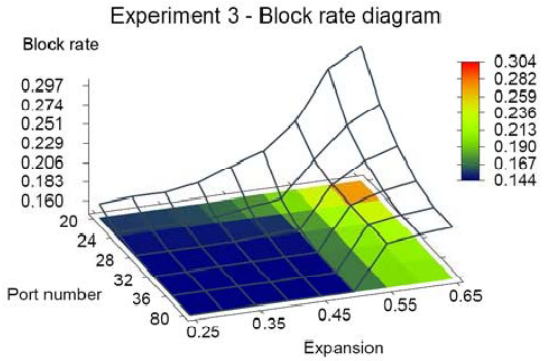


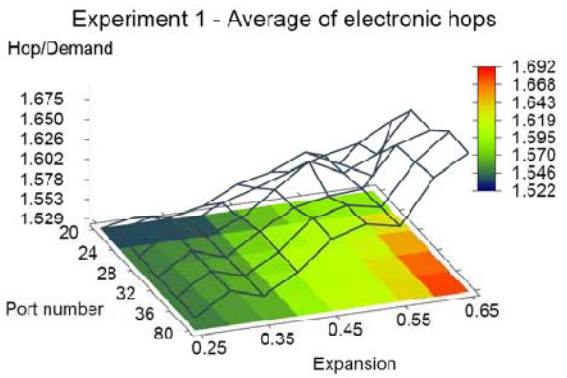
JA4:ICBR algorithm taking into account traffic grooming

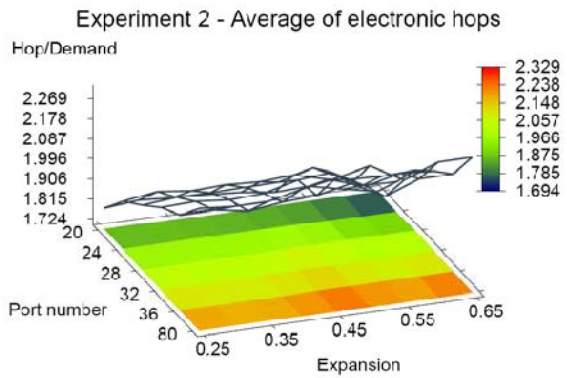
- Main objective: Impairment Constraint-based Routing (ICBR) algorithms considering various physical layer impairments and all kind of grooming.
- Participants: BME, AIT

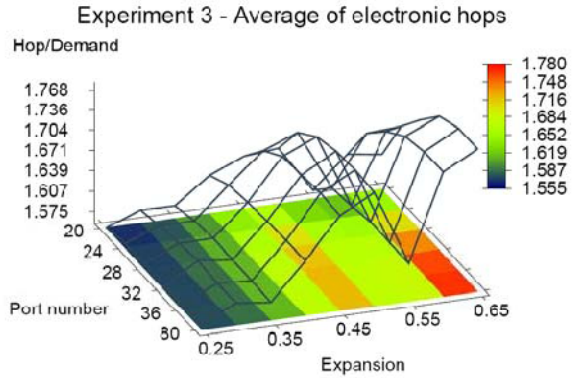






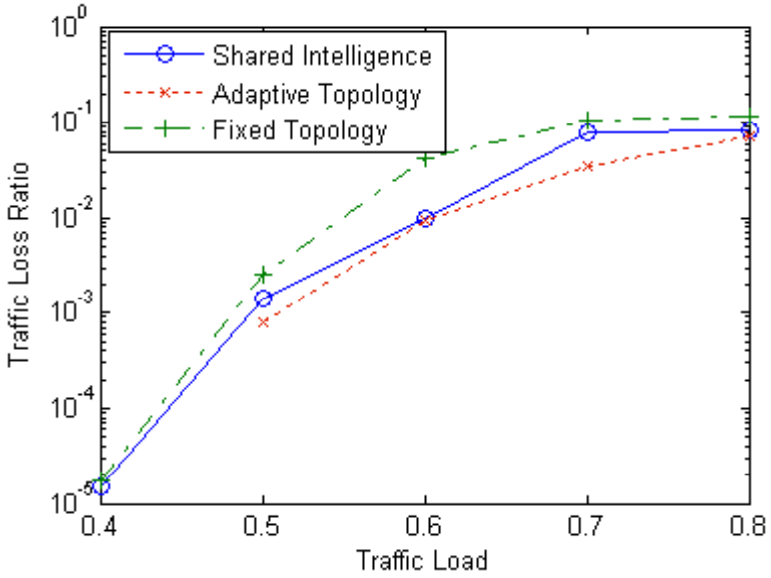


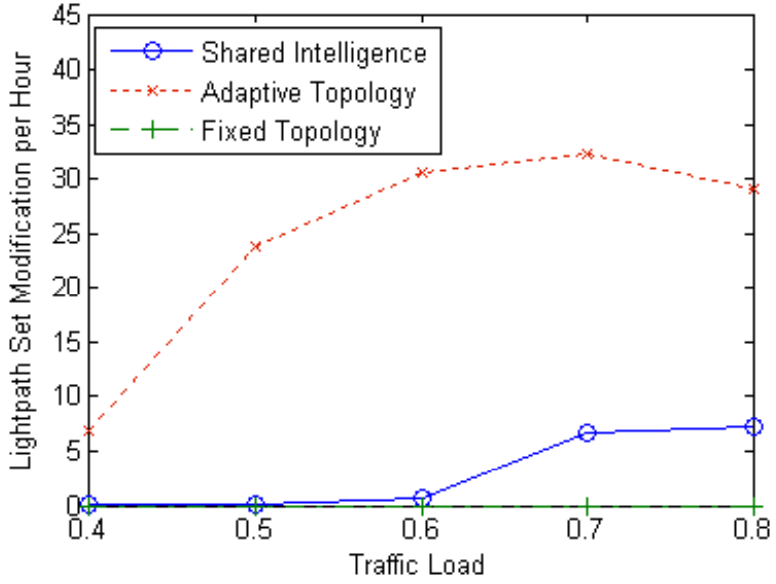




JA5:Traffic Engineering in Integrated and Interconnected Control Plane Models in the Presence of Physical Impairments

- Main objective: Traffic Engineering (TE) mechanisms with physical impairment constraints, for different control plane models
- Perfromed Activities:
  - TE mechanisms based on three approaches are implemented on a common simulation platform
  - Adaptive Topology and Fixed Topology approaches are comparatively evaluated by simulations
- Participants: Bilkent, BME





WP27 Physical Impairments constrain based routing in packet switching networks

WP Leader
Antonio Teixeira (IT)
teixeira@ua.pt

TP on physical impairments constrain based routing in packet switching networks

- will gather a group of specialist in the field of ICBR and all-optical processing of packets
- Since optical packet switching is seen as a promising however still far viewing technique the links will surely endure and stimulate the spin off of several smaller projects or ideas

Schedule: M13-M36 (Jan. 2009 – Dec. 2010)