Optical Networks: status and trends

Bart Van Caenegem
University of Gent
Department of Information Technology
INTEC
Outline

• Service and network capacity
• Optical Transport networks
  • today
  • in the future
• Access network evolution
• Datacom and telecom: Network architecture evolution
• Conclusion
Predominant growth of data traffic

reason for WDM; challenge for IP
User and Service Requirements

Information content (bits)

Response time (ms)

64kb/s 100kb/s 1Mb/s 10 Mb/s 100Mb/s 1Gb/s

A. POTS
B. Videoconferencing (low quality)
C. Videoconferencing (high quality)
D. Teleworking
E. Telelearning
F. Information exchange and retrieval
G. Entertainment

Source: Heinrich Hertz Institute

(including Internet)
Expected Growth in Network Capacity in Europe

Increase in:

- OFDM=WDM
- FDM
- SDM
- OSDM
- TDM
- OTDM

\[ \text{Line Capacity (Gbit/s)} \]

- 35% increase
- 60% increase

\[ \text{number of users} + \text{bandwidth demand} + \text{usage of the services} \]
Evolution of Transport Technology

The diagram illustrates the evolution of transport technology with respect to switch granularity and link capacity. The y-axis represents different transport technologies: Teleph, PDH, SDH, and WDM. The x-axis represents bit rates in Mbit/s, ranging from 0.01 to 1,000,000. The stars indicate the progression of technology with arrows pointing upwards, indicating an increase in both switch granularity and link capacity.
Evolution of Transport Equipment

- Capacity increase at 60% rate per year

- Volume of installed PDH equipment
- Volume of installed SDH equipment
- Volume of installed WDM equipment
- Next generation photonic equipment
Exploitation of the inherent fiber capacity by the introduction of Wavelength Division Multiplexing

WDM: the capacity unlocker

- Evolution to steeper and narrower filter technology
- New amplifier technologies will allow more bandwidth
WDM: the capacity unlocker

Wider transmission band and decreased channel spacing.

Drastic cost reductions (factor 10 over last 4 years)
Evolution of Optical Channels

Commerically or announced by Ciena, Pirelli, Lucent, Nortel, Alcatel, Siemens
WDM + TDM: challenging the limits

- Wavelength multiplexing
- Time multiplexing

- Agregate Capacity (Gbit/s)
- Single Channel Bitrate (Gb/s)

- The Terabit Region

Electronical Limits?
WDM in today’s networks

Most telecom operators are using WDM in bottleneck links:

- first in the US (95-96), now also in Europe (‘98-)
- international and long-haul carriers: MCI-Worldcom, Sprint
- GTS carrier services (*)

research networks:

DFN, CA-net2-3, SURFnet, OXYGEN (*), etc.
Start in 2001
phase 1 till 2003

170 000 km undersea fibre cable using SDH and DWDM
32 x 10 Gb/s

Phase 1-A1
Phase 1-A2
Phase 1-B
Phase 1-C
Phase 1-D

Http://www.projectoxygen.com
Optical Network Elements

Add and Drop Multiplexer

- tributary add/drop ports
- aggregate cable port

Optical Cross Connect

- tributary ports
- aggregate cable ports
Photonic Networking Evolution Scenario

- **WDM transmission**
  - 1996
- **WDM rings with node addressing**
  - 1998
- **WDM rings with full connectivity**
  - 2000
- **Interconnected rings and mesh topologies**
  - 2002

Technology evolution timeline:
- 1996: WDM transmission
- 1998: WDM rings with node addressing
- 2000: WDM rings with full connectivity
- 2002: Interconnected rings and mesh topologies
Achievements of ACTS - projects

Field trials of WDM networks
OPEN, PHOTON and METON
managed WDM networks
MOON, MEPHISTO and METON
PHOTON and OPEN

OPEN field trials
- G652 and G653 transmission
- 4 x 2.5 Gb/s crossconnection with wavelength conversion protection and restoration cascadeability experiments

PHOTON field trial
- 8 x 2.5 Gb/s and 10 Gb/s two different channel plans crossconnection leased wavelength service

Results of the OPEN field trial:
- Transmission over 1700 km through 4 WT-crossconnects
Network issues

• management (MIB ; TMN, SNMP)
• fault detection
• signalling
• network availability
• survivability (protection / restoration)
• transmission performance
• mesh and ring network design
Remaining technological issues

3R-regeneration, wavelength conversion, large optical switches

today: via the electrical domain

work ongoing and breakthroughs in research labs
Access Networks: Influence of Legacy Networks

LEX

POTS
twisted pair

CATV
HE
coax

Mobile
BTS

Satellite

Evolution in Access Networks

feeder section scenario’s

active star

passive optical network

ring

FTTx / xDSL
hybrid fibre / coax
wireless
distribution section scenario’s

optical fibre

RN: Remote Node
NIU: Network Interface Units
Corporate Optical Backbone Network (COBNET)

Corporate networks: investigate the use of Optical add-drop ring networks (OADR) as part of the backbone network.

- SDM + WDM rings
- one HE access node + several LE access nodes
- SDM: 12 space channels, 1300 nm
- WDM: 12 wavelengths, 1500 nm, 1.6 nm channel spacing
- approx 180 km distance
Towards Broadband Access Systems for CATV Optical Networks (TOBASCO)

- Upgrade of fiber-coax CATV networks with ATM/IP based Broadband Interactive Services with on average ~ 2 Mbit/s per subscribing Living Unit (LU)
- To develop a fiber-coax system using HDWDM and ATM-PON optical technology and S-CDMA cable modem technology
Evolution in Layering

- IP
- ATM
- SDH

Open Optical Interface

- SDH
- ATM
- IP
- Other

WDM
Network Evolution Options

Direct optical access (SDH, ATM, WDM, IP, other)

ACCESS

open optical interface

Copper + ADSL

IP:ATM
SDH

WDM
32 x 10 Gb/s

SDH: ADM

Radio/ Mobile

VDSL
FTTH

PON (ATM) (Super)

(10 Mb/s)

(50 Mb/s)

(100 Mb/s)

TRANSPORT

Copper + ADSL

SDH: ADM

WDM
32 x 10 Gb/s

PON (ATM)

Packet OADM

Packet OXC

OADM

WDM

OXC

1 Tb/s WDM

Photonic Transport Layer

Packet OADM

Packet OXC

SDH: DXC

SDH: ADM

Direct optical access (SDH, ATM, WDM, IP, other)

open optical interface

Copper + ADSL

IP:ATM
SDH

WDM
32 x 10 Gb/s

SDH: ADM

Radio/ Mobile

VDSL
FTTH

PON (ATM) (Super)

(10 Mb/s)

(50 Mb/s)

(100 Mb/s)

HORIZON Project - ACTS

Dec 1998

HORIZON Project - ACTS

Dec 1998
New trends in optical research

- higher number of wavelengths (200+)
- higher bitrates with OTDM (160 Gb/s +)
- further exploration of the fibre bandwidth
- tunable lasers, faster switches, …
- optical packet switching
- simpler and more cost-effective node and network architectures
Keys to Optical Packet Switching (KEOPS)

Analysis and demonstration of Optical Packet Switching providing transparency to the payload bit rate in an all-optical network architecture.

**InterWorking Unit:**
- data rate adaptation,
- packetisation,
- time multiplexing.

**Edge interface:**
- wavelength multiplexing

**Core Optical switch**

**Edge interface:**
- wavelength reallocation
KEOPS Packet Switch

No random access optical memory! (fibre delay lines)

Technology for optical IP routers!
IP-WDM

- New architectures for access and transport networks
- Data optimised architectures
- Shared resources (superPON, etc.)
- Simple and cost-effective
- Gigabit Ethernet; Dynamic Packet Transport ring

Challenge for IP

IP routers with 20-100 interfaces at 2.5 - 10 Gb/s? Scalability of IP routers?
Concluding remark

IT industry: top down from the applications down to the network at ever higher speed and more functionality

Telco industry: bottom up from the transport/access network towards the services

- mergers and take-overs
- collaborative projects (IST-programme)
4th framework (ACTS) project: HORIZON
webpage: http://www.intec.rug.ac.be/horizon

follow-up horizontal project in 5th framework (IST):
OPTIMIST

bart.vancaenegem@intec.rug.ac.be