Outline

- Motivation of workshop
- Introduction of MUSE
- Why optical access networks?
- Access network technologies: TDM-PON, WDM-PON, AON, Long reach PON
- Conclusions
Motivation

• The workshop on Optical Access Networks aims at informative education of
  – students
  – professionals short on experience in this field
  – interested colleagues

• Framework is the European R&D-project Multi Service Access Everywhere – MUSE

• Presentation slides are available soon at http://www.ist-muse.org/presentations
Agenda

• Overview on optical access networks
  Klaus-Dieter Langer, Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, Berlin, Germany

• Techno-economics
  Thomas Monath, T-Systems International, Berlin, Germany

• Single-fibre bidirectional transmission
  Matthias Seimetz, Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, Berlin, Germany

• PONs using reflective optical network units
  Cristina Arellano, Universitat Politècnica Catalunya, Barcelona, Spain

• WDM in optical access networks
  Joachim Vathke, Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, Berlin, Germany

• Optical extension of xDSL
  Jason Lepley, University of Essex, UK
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MUSE Overall Objective

Multi service access network that provides secure connectivity between end-user terminals and edge nodes in an open, multi-provider environment at a low cost for every European citizen.
MUSE is a European consortium funded by EC as part of 6\textsuperscript{th} Framework Programme IST

- Strategic objective: “Broadband for All”

Co-operative research of operators, vendors and academia

- Studies are driven by requirements from European operators
- Addresses medium and long term commercialisation

Output

- Research reports
- Proof of concept in lab prototypes
- Standards contributions
Who is in MUSE?

Phase I: 2004-2005
Phase II: 2006-2007
34 partners - 110 PY/year

System vendors

Operators

Research Inst. & Universities
IMEC
Inria
Budapest University (BUTE)
ICCS/NTUA
HHI
Lund Institute of Technology (LTH)
TU Eindhoven
ACR E O
Univ. Carlos III de Madrid
University of Essex

Component vendors

SME
Aarhus BB society
Robotiker

www.ist-muse.org
Project Organisation

Overall **network architectural studies** (Subproject A)

**Subprojects**: End-to-end scenarios and demos

- **SP B Migration scenarios** from legacy to Ethernet/IP network
  - *Phase II*: also *Multimedia service enablers*
- **SP C Non-legacy scenarios** optimised for native Ethernet and IPv6
  - *Phase II*: also *Fixed mobile convergence*
- **SP D FTTx - High bandwidth scenarios** integrating new concepts for optical access, VDSL, and feeders for wireless access
  - *Phase II*: also *decentralised architectures and GRID application*

**Task forces**: Consensus and pre-standardisation work per technical area across Subprojects
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The present situation

• Rapidly progressing digitalisation of consumer electronics
• Growing presence of PCs and LANs, CPNs (Fast Ethernet, GbE, Firewire)
• Internet is part of our life, non-use causes job-related, private and social disadvantages
• Continuously growing Internet traffic
• General trend towards IP-based transport
• Growing demand for bandwidth (success of DSL), but ...
Bottleneck access network and the need for speed

- Services become greedy for bandwidth
- Equipment offers high-speed interfaces
- Metro & long-haul networks offer high speeds and huge capacities
- Access network bit rates fall far short

Example: transmission time for digital miniature film (64 MB)

<table>
<thead>
<tr>
<th>Service</th>
<th>Transmission Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISDN (64 kbit/s)</td>
<td>2.5 h</td>
</tr>
<tr>
<td>TDSL upstream</td>
<td>1 h</td>
</tr>
<tr>
<td>TDSL downstream</td>
<td>11 min</td>
</tr>
<tr>
<td>Ethernet 10 Mbit/s</td>
<td>50 sek</td>
</tr>
<tr>
<td>Ethernet 100 Mbit/s</td>
<td>5 sek</td>
</tr>
</tbody>
</table>
How much bandwidth is needed?

- Teleworking
- Telelearning
- Information exchange, retrieval
- Videoconf.
- Interactive entertainment

**Data volume (bit)**

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

**Required response time (ms)**

- 10^0
- 10^1
- 10^2
- 10^3
- 10^4
- 10^5
- 10^6
- 10^7
- 10^8
- 10^9

K.-D. Langer, October 14, 2005
Content of 1.25 MByte to be presented within 0.2 s

Data volume (bit) 10^0 10^1 10^2 10^3 10^4 10^5 10^6 10^7 10^8 10^9

Required response time (ms) 10^0 10^1 10^2 10^3

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

Need of 100 Mb/s single-user peak bit rate widely accepted

Interactive entertainment

Transmission @100 Mb/s: 100 ms

Provision (server access), presentation, etc.: 100 ms

K.-D. Langer, October 14, 2005

Fraunhofer Heinrich-Hertz-Institut
Expectations from access networks

- Private clients: > 10 Mb/s, peak bit rate 100 Mb/s
- Professional clients: ≫ 100 Mb/s, peak bit rate \( n \) Gb/s
- Peak bit rates needed for short times only
- High peak bit rates more important than high average
- Symmetrical capacity for all subscribers (increasing importance of data exchange)
- Range of data rates covers 3 orders of magnitude !!!

→ Various solutions for network access
→ Fibre-based technology essential
Performance of xDSL options

- VDSL
- ADSL 2+
- ADSL

Max. transmission capacity (Mb/s)
Reach (km)

Example of 10 Mb/s down & upstream

Fraction of lines throughout Europe
- 75%
- 17%
- 8%

K.-D. Langer, October 14, 2005
Conclusions on xDSL

- Total bit rates up to 26 ... 52 Mb/s (according to up-/downstream share)
- Max. bit rate depends mainly on loop length, cable quality and utilisation
- If we define “broadband” as e.g. >10 Mb/s in both downstream and upstream, >50% of European citizens redlined from broadband
  - mainly in rural areas and suburbia → Digital divide
  - Remedy is fibre → FTTx
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Access network segments

- **Technical option 1**: fibre based network
- **Technical option 2**: remote node (cabinet), central office, building node

**Option 2**
- also supply of radio base stations (e.g. GSM)
- xDSL
- FTTH
- fixed wireless
- WiMax

**Segments**
- **Metro/WAN**: distribution segment
- **Inhouse network**
- **Central office**, **feeder segment**, **remote node (cabinet)**

**Active or passive hardware**
- also supply of radio base stations (e.g. GSM)

**Network Technologies**
- xDSL
- FTTH
- fixed wireless
- WiMax
Point-to-point options (P2P)

- Dual fibre or **single fibre transmission**
- FTTB, FTTP: e.g. Ethernet in the First Mile (EFM) standard
- FTTCab: e.g. **fibre optical extender for DSL (+ media converter)** or Switched Ethernet (→ active optical network, AON)
P2P FTTB / FTTP: Pros & Cons

• Pro
  – Simple & clear topology
  – Passive outside plant
  – Uniform & simplest transceivers
  – Power budget, robustness
  – Lowest complexity (fibre terminals and customer owned ONUs possible)
  – Highest privacy
  – Minimum maintenance in the field
  – Low briefing effort for installation
  – Individual upgrade and migration
  – Future-proof

• Con
  – Installation effort (fibre handling, # of splices)
  – Footprint & fibre count in central office

K.-D. Langer, October 14, 2005
Power splitting passive optical networks (PON)

- Dual fibre or single fibre (WDM) transmission
- TDM (Downstream) / TDMA (Upstream)
- Point-to-multipoint communication (P2MP)
- BPON-, GPON-, EPON-Standards
Power splitting PONs: Pros & Cons

• **Pro**
  - Sharing-Factor up to 64 (128)
  - Single transceiver in central office
  - Passive outside plant
  - Uniform transceivers in ONUs

• **Con**
  - Splitters to be installed: footprint, splices/ connectors
  - Reduced power budget due to splitter
  - All transceivers for high-speed burst mode operation
  - Bandwidth management needed
  - Privacy, interference sensitive
  - Limited upgrade (high aggregate bit rate)

OLTs w. 64 BPONs for 622 / 155 Mb/s (Alcatel)
## PON and Ethernet-in-the-first-mile (EFM) standards

<table>
<thead>
<tr>
<th>Acronym</th>
<th>BPON</th>
<th>GPON</th>
<th>EPON (EFM)</th>
<th>EFM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>ITU-T G.983.x</td>
<td>ITU-T G.984.x</td>
<td>IEEE 802.3ah</td>
<td>IEEE 802.3ah</td>
</tr>
<tr>
<td>Downstream data rate (Gb/s)</td>
<td>0.155 – 1.244</td>
<td>0.622 – 2.5</td>
<td>1.25</td>
<td>0.125 ; 1.25</td>
</tr>
<tr>
<td>Upstream data rate (Gb/s)</td>
<td>0.155 – 0.622</td>
<td>0.155 – 1.25</td>
<td>1.25</td>
<td>0.125 ; 1.25</td>
</tr>
<tr>
<td>Down/ upstream division</td>
<td>Single fibre (WDM 1.5 / 1.3 µm)</td>
<td>Dual fibre (SDM 1.3 / 1.3 µm)</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Reach</td>
<td>≤ 20 km</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum supported split ratio</td>
<td>32</td>
<td>64 (128 in future)</td>
<td>16 (32 with FEC)</td>
<td>---</td>
</tr>
<tr>
<td>Access scheme</td>
<td>TDMA</td>
<td>TDMA, others</td>
<td>direct</td>
<td></td>
</tr>
</tbody>
</table>
Video transmission in BPON and GPON

- Triple Play: data, voice (POTS), video
- Voice & data → inband
- Video
  - Broadcast
  - On demand
    - unidirectional
    - bidirectional

Band allocation

RF spectrum analog, digital
IP (baseband)

WDM overlay

IP

Inband (data channel)

Upstream

Future band

Downstream

CATV

Future band

1200 1300 1400 1500 1600 nm
Active optical networks (AON)

- **Pro**
  - High sharing factor in feeder area
  - Driven by # of options in distribution area
  - Network utilisation, protection switching, security etc. supported by node meshing

- **Con**
  - Active hardware in the field, power supply
  - Footprint and maintenance required
  - Distributed objects of value
  - Network management complex
  - Upgrade needs to touch equipment in the field
SuperPON

- Motivation
  - Reduction of central offices
  - Statistical MUX gain (low simultaneity)

Example: 10 Gb/s SuperPON
WDM-PON

- P2P links with fibre sharing in feeder area
  - Multiplexing of links
  - Multiplexing of services, unbundling of operators
- Beneficial exploitation of wavelength resources
- Use in various configurations (e.g. reflective ONUs)
- Support of PONs & AONs
- Use in various network topologies
WDM-PONs: Pros & Cons

• Pro
  – High sharing-factor (fibres)
  – Passive outside plant
  – Individual operation of p2p-channels
  – Upgrade of channels on demand with zero touched fibres

• Con
  – Footprint & transceiver count in central office
  – Mux/ Demux to be installed: footprint, splices/ connectors
  – Reduced power budget due to Mux/ Demux
  – Wavelength specific “coloured” ONUs
  – Up to now expensive technology
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- Peak bit rate per subscriber > 100 Mb/s
- FTTB / H/ P are ultimate solutions for stationary use
- Today mainly deployment of power splitting PONs, P2P, AONs
- WDM-PONs show promising options
- Fibre deployment dominates cost
  - particularly if cables are buried
  - air cabling promotes introduction in USA and Far East
- Introduction in dense urban areas first (temporary VDSL satisfactory)
- On the way towards FTTB / H/ P, a lot of different solutions will take root, perhaps permanently
Thank you for your attention!

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