Deutsche Telekom Corporate R&D
Evaluation of Next Generation Network Architectures and Further Steps for a Clean Slate Networking Approach

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Motivation

Change of (technical) paradigms
- Services converge to packet-based solutions (VoIP, IPTV) at the customer edge
- Transport becomes ever more cost-efficient
- Optics in the access – broadband everywhere

Analysis & implications
- Implementation of converged networks offering seamless services
- Investigation of the trade-off between packet- and circuit-based solutions
  - How scalable are different network architectures?
  - Which role do transport solutions in future core networks?

Objectives
- Investigation of 3 typical architectures with respect to node throughput, link and tunnel size for a DT related network architecture
  - Extend technical discussion to further aspects ...
  - Some contributions to the ‘Clean Slate’ discussion regarding future network research direction

Embedding of Architectural and Traffic Demand Scenarios Considering Future Competitive and Regulatory Impact
Topological Scenario

**DT IP network topology**
- 75-node (3 inner core, 9 outer core, 63 regional nodes)
- Inner/outer core triangles
- 7 regio networks connected to each outer core location

**Abstracted topology**
- Traffic demand: 1 – 100 Tbit/s

Important Combinations of Architectural & Technological Alternatives

**ACCESS**
- Here: Focus on core/metro
- Multiple options possible for access (FTTX)

**METRO**
- Conventional Metro
-Collapsed residential aggregation network

**CORE**
- IP/static OTN
- IP/SDH/WDM
- IP/dynamic OTN (GMPLS)
- IP/Ether/static OTN
- IP/all optical

IP = IP/MPLS
Brief Description of Three Considered Architectural Scenarios

- **IP/MPLS**
  - IP/MPLS routers in the metro and backbone area interconnected by fixed OTH systems
  - Common management of IP and OTH

- **GMPLS**
  - IP/MPLS routers with fixed OTH systems in the metro, and reconfigurable OTH systems in the backbone
  - Common control and management (GMPLS)

- **Ethernet**
  - IP/MPLS routers and/or L2 switches in the metro and backbone interconnected by fixed OTH systems
  - Interconnection of routers / switches via L2 or L3 possible – the functional separation needs further investigation
  - Managed by common or separate IP and Ethernet control planes

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**Scenario I: All IP/MPLS**

- Efficient traffic grooming and cost effective transport of coarse granular traffic streams in backbone
- Offers IP/L3 services and emulates L1 and L2 services
- Increased data plane complexity
- Scalability of integrated multilayer control may be limited
- Acceptable migration path from MPLS to GMPLS
Scenario II: IP/MPLS – GMPLS

- Efficient traffic grooming and cost effective transport of coarse granular traffic streams in backbone
- Offers IP/L3 services and emulates L1 and L2 services
- Increased data plane complexity
- Scalability of integrated multilayer control may be limited
- Acceptable migration path from MPLS to GMPLS

Scenario III: Dominant Ethernet

- Leased line brutal bandwidth high because LLs’ low filling factor (20%): migration of LL to Ether production offers high packet gains
- Offers IP/L3 and L2 services and emulates L1 services
- Simplified data plane but continuing cost advantage of Ethernet switching over IP/MPLS routing unclear
- Currently high complexity of Ethernet configuration, fault and performance management
- Unresolved tension between view of Ethernet as a low-cost fabric versus the rich fabric for tomorrow’s services
## Assessment of Nodal Throughput, Link Load and Tunnel Bandwidth

<table>
<thead>
<tr>
<th>Nodes</th>
<th>IP/MPLS</th>
<th>GMPLS</th>
<th>Ethernet</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP/MPLS routers reach a maximum &gt; 10 TBit/s throughput</td>
<td>A) ODU begins at region: Router throughput max. 3 TBit/s ODU switch max. 30 TBit/s B) ODU begins at outer core: Router throughput max. 20 TBit/s ODU switch max. 30 TBit/s</td>
<td></td>
<td>IP routers process data in region (and outer core) with maximum of 3 TBit/s (20 TBit/s)</td>
</tr>
<tr>
<td>Achievable today</td>
<td>Data processing in inner- and outer core ODU based with reduced cost</td>
<td>Trade-off: reduced packet gain due to lower filling degree in inner- and outer core, leading to increased ODU brutto load</td>
<td>Ethernet switches in outer core and inner core reduce costs, but, a number of unresolved issues exist for Ethernet technology</td>
</tr>
<tr>
<td>But, highest transport cost</td>
<td></td>
<td>But, high transport cost</td>
<td>Achievable today</td>
</tr>
</tbody>
</table>

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<tr>
<th>Links</th>
<th>Requires inevitably link bundling on IP level for all load scenarios</th>
<th>Aggravates the problem identified for IP/MPLS scenario</th>
<th>Requires inevitably link bundling on IP level for all regarded load scenarios</th>
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<tr>
<td>Multiple channels per link required</td>
<td></td>
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<table>
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<tr>
<th>Tunnels</th>
<th>Full mesh outer core: higher than 10 GBit/s on all channels Full mesh region: mostly below 10 GBit/s per channel</th>
</tr>
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</table>

The choice of transport or packet technology depends on the incremental cost, the meshing and the resulting tunnel bandwidth.

## Critical Issues Identified … Leading to a more Thorough Investigation of Future Issues

- Link loads expected to exceed the capacity of a single physical channel (multiwavelength interface operated as one single logical interface)
- Load balancing is a basic requirement

- Paket vs transport efficiency
- ODU vs. transport

- First versions of multiwavelength interfaces are still in the process of being standardized, but not implemented yet
- Business customers might have different requirements

- Limited due to technical constraints of limited sharing capabilities
- Power consumption and heat dissipation in single shelf devices will be the most severe limitation factors
- Logical scaling limitations?
The entire industry undergoes both commercially and technically a deep transformation – a change even more profound than during the bubble years and completely changing the face of the industry.

Academia undertakes a rigorous evaluation of the existing network architectures and protocols – and prepares for a radical redefinition of architectures, protocols, and technologies which are truly suited for a knowledge-based society.

Long-term impact on architectures & technologies, value chains & business relationships

Architectural Implications

- IP and the optical core
- Topologies and routed networks
- Router development and IP architectures
- Issues in routing architectures
- Future applications
- The role of Ethernet