Transport Networks and Transport MPLS

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Agenda

1. Transport network basics
2. TMPLS rationale
3. TMPLS features
4. TMPLS standard status & perspectives
5. A multi-layer multi-technology transport network
6. Appendix: basics of GMPLS CP protocols
1 Transport network basics
"E2E" transport network

Service provider

Service

Client

Operator A

Node

Network

Service

Operator n

Client

Service “transparent” transport

"E2E" transport network
Transport service characteristics

<table>
<thead>
<tr>
<th>For the client</th>
<th>For the operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available (% UAT)</td>
<td>Resilient</td>
</tr>
<tr>
<td></td>
<td>By means of short term countermeasures against failures (50 msec ÷ ~sec)</td>
</tr>
<tr>
<td>Maintainable</td>
<td>By means of mid-long term countermeasures against failures (~h ÷ ~d)</td>
</tr>
<tr>
<td>Measurable</td>
<td>In terms of service quality, according to the different technology type</td>
</tr>
</tbody>
</table>
A simplified model for transport networks

**Client**, requiring transport service

**UNI**, interface between the client and the service provider

**Physical connection**, i.e. the physical transport medium

**NNI**, interface between two network nodes

**Logical connection**, related to the transport service and characterized by being **continuous** along the service path within the network (end-to-end)

**Connection matrix**, operating on logical connection and allowing for service grooming and routing

**More than one layer** is possible (and typically is used) at logical connection level. **Each layer**, is independently operated from the other ones
Transport service functional model

Client

Non intrusive monitoring:
- integrity check
- connectivity check
- quality check

Client-server adaptation
- forward defect indication

Termination:
Like non intr. mon. +
- backward integrity info.
- backward quality info.

Connection:
- forwarding
- grooming

Logical connection

Physical connections

Client-server adaptation
- forward defect indication

Termination:
Like non intr. mon. +
- backward integrity info.
- backward quality info.
## Simplified network model & basic OAM tools

<table>
<thead>
<tr>
<th>Protection</th>
<th>Integrity</th>
<th>Integrity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Connection</td>
<td>Connection</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Integrity</td>
<td>Integrity</td>
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<tr>
<td></td>
<td>Connection</td>
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<td>Quality</td>
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<tr>
<td>Quality measurement</td>
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<td>Integrity</td>
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<tr>
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<td>Connection</td>
<td>Connection</td>
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<td></td>
<td>Quality</td>
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<td>Integrity</td>
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<td>Connection</td>
<td>Connection</td>
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<tr>
<td></td>
<td>Quality</td>
<td>Quality</td>
</tr>
</tbody>
</table>
Service protection is typically based on physical line (because it is the one that breaks) and logical connection (because it is related to the end-to-end service within the network).
Service maintenance is typically based on physical line check and can be helped by logical connection and client signals inspection; in addition downstream alarm silencing is performed.
Quality of service is typically measured on the logical connection both at termination and non-intrusive monitoring points; possibly also at client non-intrusive monitoring points. Remote indications allow for bidirectional service monitoring making enquiries to a single system.
SDH according to simplified model

**Client:** e.g. PDH, Ethernet

**Physical connection:** STM-N
(from 155Mb/s to 10Gb/s)

**Logical connection:** VC12, VC3, VC4
(Virtual Container)

Connection matrices operate at VC4 and/or VC12, VC3 level
SDH (SONET) OAM - as an example

<table>
<thead>
<tr>
<th>Protection</th>
<th>Client spec B</th>
<th>AU (TU) SF</th>
<th>LOS, LOF</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>TT1d Mism.</td>
<td></td>
</tr>
<tr>
<td></td>
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<td>EXBER, DEG</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>MS-RDI</td>
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<tr>
<td></td>
<td></td>
<td>MS_REI</td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>Client spec C</td>
<td>AU (TU) SF</td>
<td>LOS, LOF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TT1d Mism.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>EXBER, DEG</td>
<td></td>
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<tr>
<td></td>
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<td>MS_REI</td>
<td></td>
</tr>
<tr>
<td>Quality measurement</td>
<td>Client spec C</td>
<td>AU (TU) SF</td>
<td>BIP-N</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TT1d Mism.</td>
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<tr>
<td></td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>RDI</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>REI</td>
<td></td>
</tr>
</tbody>
</table>

Client

Logical connection

Physical connection

Fiber

Client logical connection Physical connection

Protection

Maintenance

Quality measurement

Client

Logical connection

Physical connection

Fiber

Client logical connection Physical connection

Protection

Maintenance

Quality measurement

Client
OTN according to simplified model

**Client**: e.g. SDH (STM16, STM64) or Ethernet (GE, 10GE)

**Physical connection**: OTM-x, (x \( \lambda \) WDM signal); **OTU-N** (N=1, 2, 3 for \( \lambda \) at 2.5Gb/s, 10Gb/s, 40Gb/s)

**Logical connection**: ODU-N (N=1, 2, 3 for \( \lambda \) at 2.5Gb/s, 10Gb/s, 40Gb/s)

Connection matrices operate at ODU1, ODU2, (ODU3) level
### OTN OAM - as an example

<table>
<thead>
<tr>
<th>Protection</th>
<th>Logical connection</th>
<th>Physical connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>OTU SF</td>
<td>OTU SF</td>
<td>OTU-BEI</td>
</tr>
<tr>
<td>ODU-TT Id Mis.</td>
<td>ODU-TT Id Mis.</td>
<td>OTU-BEI</td>
</tr>
<tr>
<td>DEG</td>
<td>EXBER, DEG</td>
<td>OTU-BEI</td>
</tr>
</tbody>
</table>

#### Maintenance

<table>
<thead>
<tr>
<th>Logical connection</th>
<th>Physical connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client AIS</td>
<td>OTU SF</td>
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<tr>
<td>ODU-TT Id Mis.</td>
<td>ODU-TT Id Mis.</td>
</tr>
<tr>
<td>DEG</td>
<td>EXBER, DEG</td>
</tr>
<tr>
<td>ODU-BDI</td>
<td>OTU-BEI</td>
</tr>
<tr>
<td>ODU-BEI meas.</td>
<td>OTU-BEI</td>
</tr>
</tbody>
</table>

#### Quality measurement

<table>
<thead>
<tr>
<th>Logical connection</th>
<th>Physical connection</th>
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<tbody>
<tr>
<td>Client spec f</td>
<td>OTU SF</td>
</tr>
<tr>
<td>ODU-TT Id Mis.</td>
<td>BER meas.</td>
</tr>
<tr>
<td>ODU-BDI</td>
<td>ODU-BEI meas.</td>
</tr>
<tr>
<td>Client spec b</td>
<td>BER meas.</td>
</tr>
<tr>
<td>ODU-BDI</td>
<td>ODU-BEI meas.</td>
</tr>
</tbody>
</table>

### Diagram

- Client
- Logical connection
- Physical connection
- Fiber

- Quality measurement
- Maintenance
- Protection
T-MPLS Rationale
Why a Packet Transport Network?

Mobile Service Operators  | Triple Play  | Business Services

Converging transport of radio acc., pt-to-pt mw, NGN services...  | Driving with HSI, video, voice  | Migrating to data-oriented leased lines, virtual private LANs

Service delivery through packet-based technologies

Packet/cell/frame based networking

Service Evolution Networking Requirements

TDM/WDM-based networking

Scalability and granularity

Packet Transport Networking

Reliability, availability, & flexibility

OAM in service delivery

Transport network evolution (min cost) with (max carrier-class & flexibility)
Packet Transport Network: Requirements

- Being **client-agnostic** (able to carry L3, L2, L1)
- Being strictly **connection-oriented**
- Implementing strong **OAM** capabilities, similar to those available in existing transport networks (e.g., SDH)
- Implementing both service and line **resilience mechanisms**, similar to those available in existing transport networks (e.g., SDH)
- Allowing for network provisioning either via a **centralized management** tool and/or a **distributed CP**
- Allowing for **homogeneous and/or unified management and control** of transport network when different layers are present at the same time

These requirements are the basis of ITU T-MPLS design.
Common multilayer operations, survivability, control and management paradigms for packets, circuits & photonics
3 T-MPLS features
Transport MPLS (T-MPLS) in Brief

Transport MPLS is a **connection-oriented** packet transport technology, based on MPLS frame formats.

- It reuses the most widespread label swapping paradigm existing in telecom.
- It inherits all IETF definition activity in terms of server and client encapsulation rules.
- It profiles MPLS so that it avoids the complexity and need for IP routing capability.

Transport MPLS defines **powerful OAM capabilities** that enable status & performance reports, in such a way that they remain confined within the T-MPLS layer and do not require deeper packet inspection.

- It allows for guaranteed SLAs.
- It defines protection switching and restoration.
- It allows for efficient fault localization and multi-operator service offering.

A Transport MPLS layer network is operated with network management and/or by a control plane.

- **The control plane inside the T-MPLS network is GMPLS.**
Clients: in T-MPLS it can be any L2, using mapping options defined by IETF for PWE3: Ethernet, ATM, FR ... or IP/MPLS (so far only Ethernet formally defined in ITU)

Logical connection: in T-MPLS two networking layers are under definition: circuit (equivalent to IETF PWE3) and path (equivalent to IETF MPLS tunnel)

Physical connection: in T-MPLS it can be any L1 (Ethernet, SDH, OTN+WDM ...); moreover in T-MPLS an optional section layer is under definition, in order to support OAM if not otherwise available
Mp2mp and p2p adaptations may not be part, in strict sense, of the packet transport technology. As an example, in VPLS mp2mp adaptation is based on Ethernet.

Two true networking layers are (at least) typically needed for a transport solution. The first layer is the carrier devoted to a specific service, and thus allow for e2e OAM, performance monitoring and protection. It needs not to be associated end to end with the second layer, for network scalability purposes. It is the basic tool for SLA enforcement. The second layer allows mainly for aggregation and thus scalability. Restoration is possibly applied to this layer. Of course further aggregation layers can be recursively defined. In general, OAM and protection are data plane mechanisms, generally implemented in HW for fast and deterministic behavior.
Packet Transport Network Modeling & MPLS

Client services
- Any L1 (via CES), L2, L3 service

Network service layer(s)
- mp2mp adaptation
- p2p adaptation

Transport layer(s)
- Logical transport (1:1 with service)
- E2e & segment OAM
- SLA enforcement
- Logical transport (N:1 with service)
- Trunk OAM, protection & restoration (combined)
- Service aggregation

Recursive transport layer(s)
- L0-L1 networking

Physical layer
- Ethernet
- SDH, OTH

MPLS
- VPLS
- IP-VPN
- PW
- VCCV
- BFD, Ping, FRR
- MPLS PSN
- MS-PW (under standardization)

IETF MPLS:
- A complete toolset for L1/L2/L3 service management, with transport capabilities
- IP-centric and service optimized
- Coherence among MPLS Service and Transport Layers

Protocol suites:
- SDH, OTH
- Ethernet
- MS-PW (under standardization)
ITU-T T-MPLS:
- A packet technology optimized for transport purposes
- Carrier focused
- Coherence among packet and TDM/λ transport
- MPLS used as service layer only

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- E2e & segment protection
- Trunk OAM, protection & restoration (combined)
- Service aggregation

Recursive transport layer(s)
- L0-L1 networking

Centralized NM or ASON/GMPLS protocols suite as distributed control plane

ITU-T T-MPLS:
- Y.17tom G.8131 (linear protections)
- G.8132 (ring protection)

VPLS
IP-VPN

Logical transport
VPLS
IP-VPN

TMPLS circuit
Y.17tom G.8131 (linear protections)

TMPLS path
Y.17tom G.8131 (linear protections)
G.8132 (ring protection)

SDH
Ethernet
SDH
OTH
Eth. only

Any L1 (via CES), L2, L3 service

Any L2

Centralized NM or ASON/GMPLS protocols suite as distributed control plane

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VPLS
IP-VPN

Logical transport
VPLS
IP-VPN

TMPLS circuit
Y.17tom G.8131 (linear protections)

TMPLS path
Y.17tom G.8131 (linear protections)
G.8132 (ring protection)

SDH
Ethernet
SDH
OTH
Eth. only

Any L1 (via CES), L2, L3 service

Any L2

Centralized NM or ASON/GMPLS protocols suite as distributed control plane

ITU-T T-MPLS:
- A packet technology optimized for transport purposes
- Carrier focused
- Coherence among packet and TDM/λ transport
- MPLS used as service layer only
TMPLS service architecture is inherited by MPLS. TMPLS enhances MPLS thanks to its transport capabilities, in line with and operationally similar to SDH and OTH. GMPLS CP common to packets, TDM and lambdas opens the possibility of multi-layer network optimizations. Identical data plane subset and encapsulation rules allow very efficient MPLS-TMPLS inter-working schemes. ITU “tandem connection” concept ideally complements IETF OAM capabilities.
T-MPLS Survivability

Protection (data plane)
- <50 ms with automatic protection switch (APS) protocols on data plane OAM channels
- 1+1, 1:1, N:1 (no extra traffic)
- Unidirectional, bidirectional
- Section, path, circuit
- Subnetwork connection (SNCP)
- Ring
- Dual node interconnect (DNI)

Restoration (control/management plane)
- Distributed \(\rightarrow\) control plane (ASON/GMPLS)
- Full LSP rerouting restoration
- Pre-planned LSP rerouting restoration
- Any topology (mesh)
- GMPLS-based restoration in synergy with other transport network technologies (SDH, OTN, WDM)
## T-MPLS OAM

<table>
<thead>
<tr>
<th>OAM primitives</th>
<th>T-MPLS Y.1711 - Y.17tom</th>
<th>Continuous</th>
<th>On demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrity</td>
<td>FFD, CV</td>
<td></td>
<td><strong>Loopback</strong></td>
</tr>
<tr>
<td>Connectivity</td>
<td>FFD</td>
<td></td>
<td><strong>Link Trace</strong> (ffs)</td>
</tr>
<tr>
<td>Quality</td>
<td><strong>PM (carried by FFD)</strong></td>
<td><strong>Frame Loss, Frame Delay, FDV</strong></td>
<td></td>
</tr>
<tr>
<td>Remote integrity</td>
<td>BDI</td>
<td></td>
<td><strong>Loopback</strong></td>
</tr>
<tr>
<td>Silencing</td>
<td>FDI</td>
<td></td>
<td>Not applicable</td>
</tr>
</tbody>
</table>

**Standardized**

**Ongoing**
T-MPLS OAM
(according to ITU-T Y.1711, Y.17tom)

T-MPLS OAM according to ITU is contained in MPLS frames associated to the connection by the relevant LSP (outer) label and characterized by an (inner) label 14. OAM information is contained within the MPLS payload.

<table>
<thead>
<tr>
<th>Protection</th>
<th>( \lambda_i )</th>
<th>FFD</th>
<th>Server specific</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>FFD (via TTSId)</td>
<td>Server specific</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PM</td>
<td>Server specific</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BDI</td>
<td>Server specific</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maintenance</th>
<th>( \lambda_i )</th>
<th>CV, FFD</th>
<th>Server specific</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client specific</td>
<td></td>
<td>Link Trace</td>
<td>Server specific</td>
</tr>
<tr>
<td>Client specific</td>
<td></td>
<td>PM</td>
<td>Server specific</td>
</tr>
<tr>
<td>Client specific</td>
<td></td>
<td>Silencing</td>
<td>Server specific</td>
</tr>
<tr>
<td>Client specific</td>
<td></td>
<td>CV, FFD</td>
<td>Server specific</td>
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<tr>
<td>Client specific</td>
<td></td>
<td>CV, FFD, FDI</td>
<td>Server specific</td>
</tr>
<tr>
<td>Client specific</td>
<td></td>
<td>PM</td>
<td>Server specific</td>
</tr>
<tr>
<td>Client specific</td>
<td></td>
<td>BDI</td>
<td>Server specific</td>
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</table>

<table>
<thead>
<tr>
<th>Quality Measurement</th>
<th>( \lambda_i )</th>
<th>CV, FFD</th>
<th>Server specific</th>
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<tbody>
<tr>
<td>Client specific</td>
<td></td>
<td>CV, FFD</td>
<td>Server specific</td>
</tr>
<tr>
<td>Client specific</td>
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<td>CV, FFD</td>
<td>Server specific</td>
</tr>
<tr>
<td>Client specific</td>
<td></td>
<td>PM</td>
<td>Server specific</td>
</tr>
</tbody>
</table>

Remote quality

Silencing

CV, FFD

PM

BDI

Remote quality
T-MPLS Control Plane (ASON/GMPLS)

GMPLS is a single, generalized distributed control plane that can be used in common for multiple networking technologies, including packets, TDM and photonics

GMPLS defines:
- UNI concept (thus easing overlay dynamic approach)
- I(nternal)-NNI concept (the only supported in MPLS CP)
- E(xternal)-NNI concept (thus allowing for interworking among different vendors/operators)
- Bidirectional paths

GMPLS allows for separation of data plane and control plane
- Only control interfaces are used to flood control information

GMPLS allows for “horizontal” scalability in routing domains (thanks to separation of data plane and control plane and recursive topology)

GMPLS allows for “vertical” scalability (same control plane across different layers)

GMPLS is the ideal control plane for multilayered networks
4 T-MPLS Standard Status & Perspectives
T-MPLS Standards Framework

MPLS Architecture/Protocols (IETF)
Carrier-grade packet forwarding best from IETF

GMPLS Protocols Control Plane & Restoration (IETF)
Carrier-grade control plane best from IETF

TMPLS Framework

T-MPLS Interfaces G.8112
T-MPLS Equipment Functional Blocks G.8121
Architecture of T-MPLS Layer Network G.8110.1
ASON Architecture G.8080
Best from ITU

Contribute

Protection G.8131
OAM Y.17tom

Best from ITU
## Transport Network Standard Overview

<table>
<thead>
<tr>
<th></th>
<th>Connection Oriented (G.805)</th>
<th>Generic</th>
<th>T-MPLS standard status</th>
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<tbody>
<tr>
<td><strong>SDH</strong></td>
<td>G.803</td>
<td>G.8110.1</td>
<td>Version 1 approved</td>
</tr>
<tr>
<td><strong>OTH</strong></td>
<td>G.872</td>
<td>G.8112 (G.motnmi)</td>
<td>Version 1 approved, Amend. 1 (p2mp, extended OAM) to be consented Mar-Jun07</td>
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<tr>
<td><strong>T-MPLS</strong></td>
<td></td>
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<td>G.805</td>
<td>Version 1 approved, Amend. 1 (p2mp, extended OAM) to be consented Mar-Jun07</td>
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<td><strong>Network Architecture</strong></td>
<td>G.803</td>
<td>C.L.</td>
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<td>C.O. + C.L.</td>
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<td></td>
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<td>G.uftan</td>
<td>Version 1 approved, Amend. 1 (p2mp, extended OAM) to be consented Mar-Jun07</td>
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<tr>
<td><strong>UNI &amp; NNI Interface</strong></td>
<td>G.707</td>
<td>G.8121 (G.mplseq)</td>
<td>Version 1 approved, Amend. 1 (p2mp, extended OAM) to be consented Mar-Jun07</td>
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<tr>
<td></td>
<td>G.709</td>
<td>G.813 (Y.1711)</td>
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<td><strong>OAM [frame format]</strong></td>
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<td>C.O.</td>
<td>Version 1 approved, Amend. 1 (p2mp, extended OAM) to be consented Mar-Jun07</td>
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<td></td>
<td>G.806</td>
<td>Version 1 approved, Amend. 1 (p2mp, extended OAM) to be consented Mar-Jun07</td>
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<tr>
<td><strong>Equipment</strong></td>
<td>G.783</td>
<td>G.8121 (G.mplseq)</td>
<td>Version 1 approved, Amend. 1 (p2mp, extended OAM) to be consented Mar-Jun07</td>
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<td></td>
<td>G.798</td>
<td>G.808 (G.808.1)</td>
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<td><strong>Linear Protection</strong></td>
<td>G.841</td>
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<td>Version 1 approved, Amend. 1 (p2mp, extended OAM) to be consented Mar-Jun07</td>
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<td>G.873.1</td>
<td>G.808.2 (G.808.2)</td>
<td>Version 1 approved, Amend. 1 (p2mp, extended OAM) to be consented Mar-Jun07</td>
</tr>
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<td><strong>Ring Protection</strong></td>
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<td>G.8132</td>
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5 A multi-layer multi-technology transport network
Key transport networking needs

**Access**
- **Ethernet demarcation** at (business) user-network interface
- **Circuit emulation** capabilities in order to cross pure packet based access areas with legacy, TDM based, services
- **Multi-service encapsulation** capability, for converging different types of L2 services (ATM, FR, Ethernet ...) on a common packet infra-structure in view of coherent end-to-end service management
- **Optical access solutions** for FTTx, either point-to-point or WDM PON based

**Metro**
- **Multi-service aggregation** capability, for converging new business and residential packet based with legacy ones along with 2G and 3G mobile backhauling
- **Strong OAM capabilities, and efficient (linear & ring) protections** to manage and maintain the growing-in-size aggregation network, while optimizing OPEX
- Capability of **mixing optical and electronic** aggregation capabilities, according to the real needs, in order to optimize CAPEX
- **QoS management** for business services and for residential beyond Internet access

**Core**
- **Multi-service transport** capability, for converging IP/MPLS traffic coming from edge/outer core routers with clear channel (carrier’s carrier) type services, evolving to very fat pipes (10Gb/s ⇒ 40Gb/s ⇒ 100Gb/s)
- **OAM capabilities** in line with traditional transport services over geographical distances
- **Distributed restoration**, in order to fully exploit the meshed nature of core networks
- “**Coarse** QoS, traffic and granularity management” according to the nature of aggregated streams in core network
Key transport networking needs:

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- **OAM capabilities** in line with traditional transport services over geographical distances

- **Distributed restoration**, in order to fully exploit the meshed nature of core networks

- **“Coarse” QoS, traffic and granularity management** according to the nature of aggregated streams in core network

**TMPLS** allows for a convergent packet platform for any L2 protocol, thanks to the PWE3 concept defined by IETF. On top of this, **TMPLS** adds transport specific OAM tools, linear and ring protection schemes along with the possibility of GMPLS distributed control plane, that is in common with other, TDM and \( \lambda \) based, transport technologies. Multicast capabilities are as well under definition.
Key transport networking needs: core

**TMPLS** is an ideal packet platform for edge router interconnection, leveraging on MPLS pipes as natural “channels” of the router interfaces, to be used in order to classify traffic and forward it through a TMPLS tunnel to its due destination. Besides common with other transport layers OAM and protection like in metro, GMPLS control plane adds the possibility of path setup and restoration jointly at packet/TDM/\(\lambda\) level. The conceptual, and then physical, distinction between “service” (IP/MPLS) and “transport” (TMPLS) allows for the design of systems the complexity (and cost) of which is correctly tailored to transport needs.

<table>
<thead>
<tr>
<th>Aggregation tier 2</th>
<th>Outer Core</th>
<th>Inner Core</th>
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<tbody>
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*Transport MPLS Rationale and Features* | February 2007

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# Network vision: aggregation networks layers usage

## TMPLS network (stat.mux.) layer
- **Clients**: E1, ATM, FR ...
- **Transparency**: Packets, frames
- **Networking**: TMPLS
- **Resiliency**: TMPLS prot.

## SDH network layer
- **Clients**: PDH, SDH, "Any"
- **Transparency**: VCx, bit stream
- **Networking**: VCx, VCx-nc
- **Resiliency**: SDH prot.

## ODU adaptation (OAM) layer
- **Clients**: STM-N
- **Transparency**: STM-N
- **Networking**: NA
- **Resiliency**: NA

## Och network layer
- **Clients**: OTU1, OTU2
- **Transparency**: OTU1, OTU2
- **Networking**: Och
- **Resiliency**: Och prot.

---

**TMPLS for statistical multiplexing, SDH for transparent transport, λ for optical bypass**
Network vision: core networks layers usage

**TMPLS network (stat.mux.) layer**
- **Clients**: POS, Eth (Martini)
- **Transparency**: Packets, frames
- **Networking**: TMPLS
- **Resiliency**: TMPLS restor.

**SDH network layer**
- **Clients**: STM-N, Ethernet
- **Transparency**: VC4, frames
- **Networking**: VC4, VC4-nc
- **Resiliency**: VC4 restor.

**ODU network layer**
- **Clients**: STM-N, Ethernet
- **Transparency**: STM-N, PHY
- **Networking**: ODU
- **Resiliency**: ODU restor.

**Och network layer**
- **Clients**: (OTU1), OTU2
- **Transparency**: (OTU1), OTU2
- **Networking**: λ
- **Resiliency**: λ restor. (tba)

**TMPLS** for statistical multiplexing, SDH and OTH (seen as ODU + λ) for transparent transport
Core transport network: target vision

**TMPLS network (stat.mux.) layer**
- Clients: POS, Eth(Martini)
- Transparency: Packets, frames
- Networking: TMPLS
- Restoration: TMPLS/GMPLS

**ODU network layer**
- Clients: STM-N, Ethernet
- Transparency: STM-N, PHY
- Networking: ODU
- Restoration: λ+ODU/GMPLS

**Och network layer**
- Clients: (OTU1), OTU2
- Transparency: (OTU1), OTU2
- Networking: λ
- Restoration: λ+ODU/GMPLS

**OTH progressively replacing SDH, integrated packet/ODU/λ networking**
Network vision is based on **multi-service node** concept, able to support both residential (wireline/wireless) and business services, in which **TMPLS** technology is chosen as a converged packet network able to support any service type (Ethernet, IP/MPLS, FR, ATM, TDM via CES, …) along with **GMPLS** distributed control plane, common also for TDM and λ layers.
Appendix: basics of GMPLS CP protocol
GMPLS versus MPLS: key points

UNI
- GMPLS defines
  - A UNI concept (thus easing overlay dynamic approach)
  - A I(ternal)-NNI concept
  - A E(xternal)-NNI concept (thus allowing for inter-working among different operators)
- MPLS implies the concept of (internal) NNI only
  - Note that hierarchical OSPF is not defined today neither for MPLS nor for GMPLS
- GMPLS defines a link protocol
  - LMP: it discovers which (user or network) interfaces are connected to a link and allows for detecting which type of service (TDM, packet, \( \lambda \)) is available at a UNI

Control plane and data plane
- GMPLS allows for a separation of data plane and control plane
  - Only control interfaces are used to flood LSAs
- In MPLS every data interface has to be also a control interface
  - And thus flood LSAs

Path concept
- Unidirectional in MPLS, packet only
- Bi-directional in GMPLS, multi-layer
GMPLS versus MPLS: OSPF flavours

**OSPF in general**
- OSPF is a link state routing protocols
- OSPF advertises to all the node of the network its adjacencies via LSA (Link State Advertisements)
- Every node builds up the entire network topology and evaluates the shortest path for each destination

**OSPF for IP**
- Data plane = control plane
- LSA refers to all interfaces
- One topology dB is built up

**OSPF for MPLS**
- Data plane ≠ control plane (in terms of routes, not of topology)
- Data plane can be constrained
- OSPF builds the control topology dB
- Opaque LSA are used to advertise data plane ports but are not managed by OSPF
- CSPF builds up the data top. dB

**OSPF for GMPLS**
- Same as MPLS, with extensions in order to:
  - Describe non packet i/fs
  - Managing **TE link bundling** for scalability (N p2p i/fs are advertised as 1)
  - Transmitting **several** opaque LSAs in 1 IP (OSPF) packet
GMPLS versus MPLS: RSVP-TE

RSVP-TE
- Defines a finite state machine for each path that is set-up
- The “Path” signal contains the route (ERO: Explicit Routing Object)
- The “ResV” signal allocates the resources and distributes the labels
- Path and ResV signals are output periodically to maintain the path (soft state)

RSVP-TE for MPLS
- Defines unidirectional paths
- The IP packet containing RSVP signaling has the path terminal node as DA (i.e. has to follow the path)
- In signaling N paths between A and B a compression can be done using one single IP message for all the relevant information (saving the header overhead)

RSVP-TE for GMPLS
- Defines bidirectional paths (so the signaling traffic and the number of state machines is ½ of MPLS)
- The IP packet containing RSVP signaling has the next path hop as DA (i.e. can follow a different route wrt a data packet to reach the node)
- In signaling N paths between A and B a compression can be done putting in a single IP message only the path identifiers (and not the paths characteristics that are already known)
The MPLS engine uses the [server technology] connection established by GMPLS as forwarding adjacency. The GMPLS engine asks a “loose source routed” [server technology] connection from A to D through B and C. Reachability information between A and D has to be known “a priori”. Connection between B and C is routed based on topology information exchanged among GMPLS NNI’s.