Evolution towards Integrated Routing

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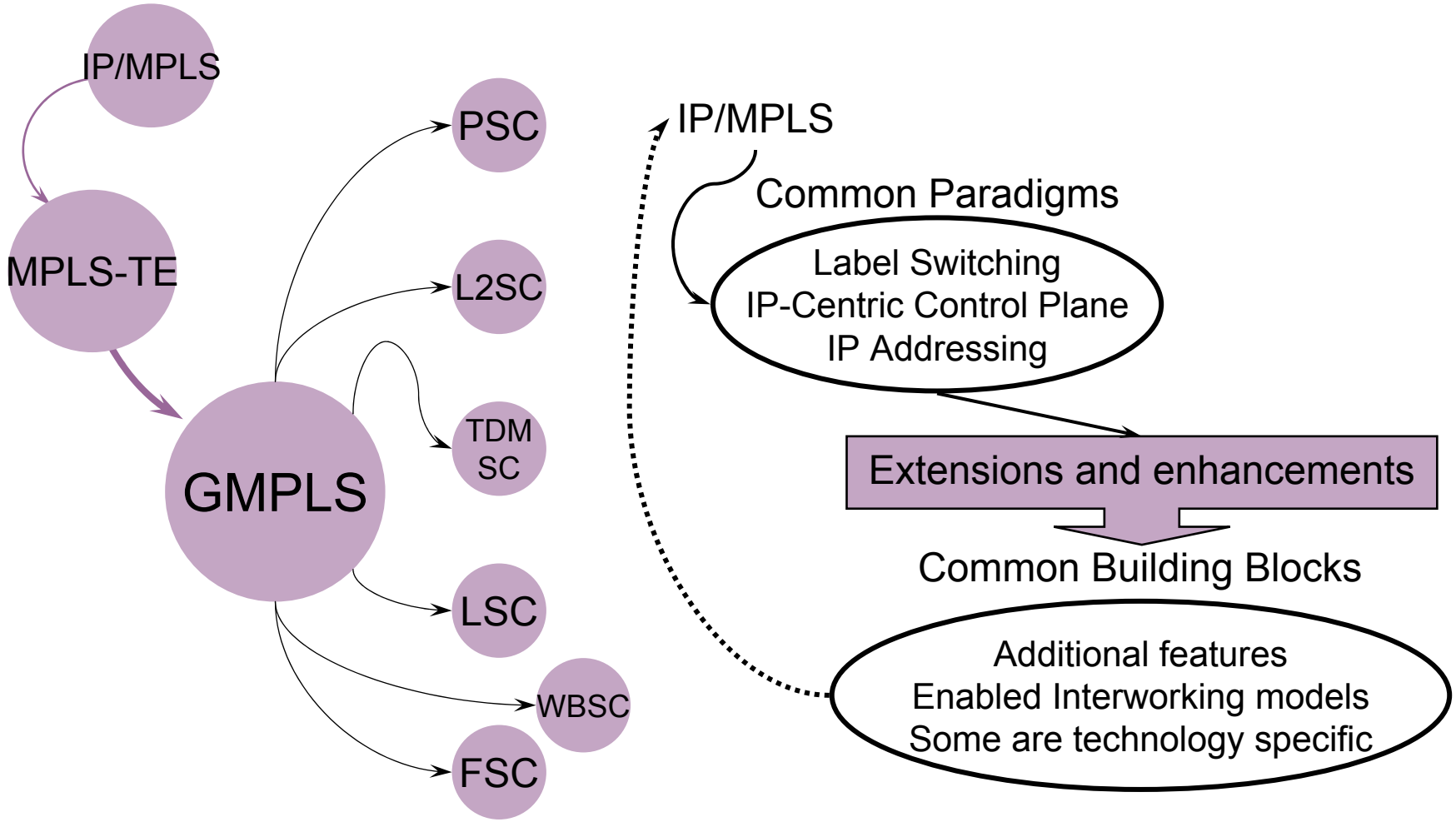
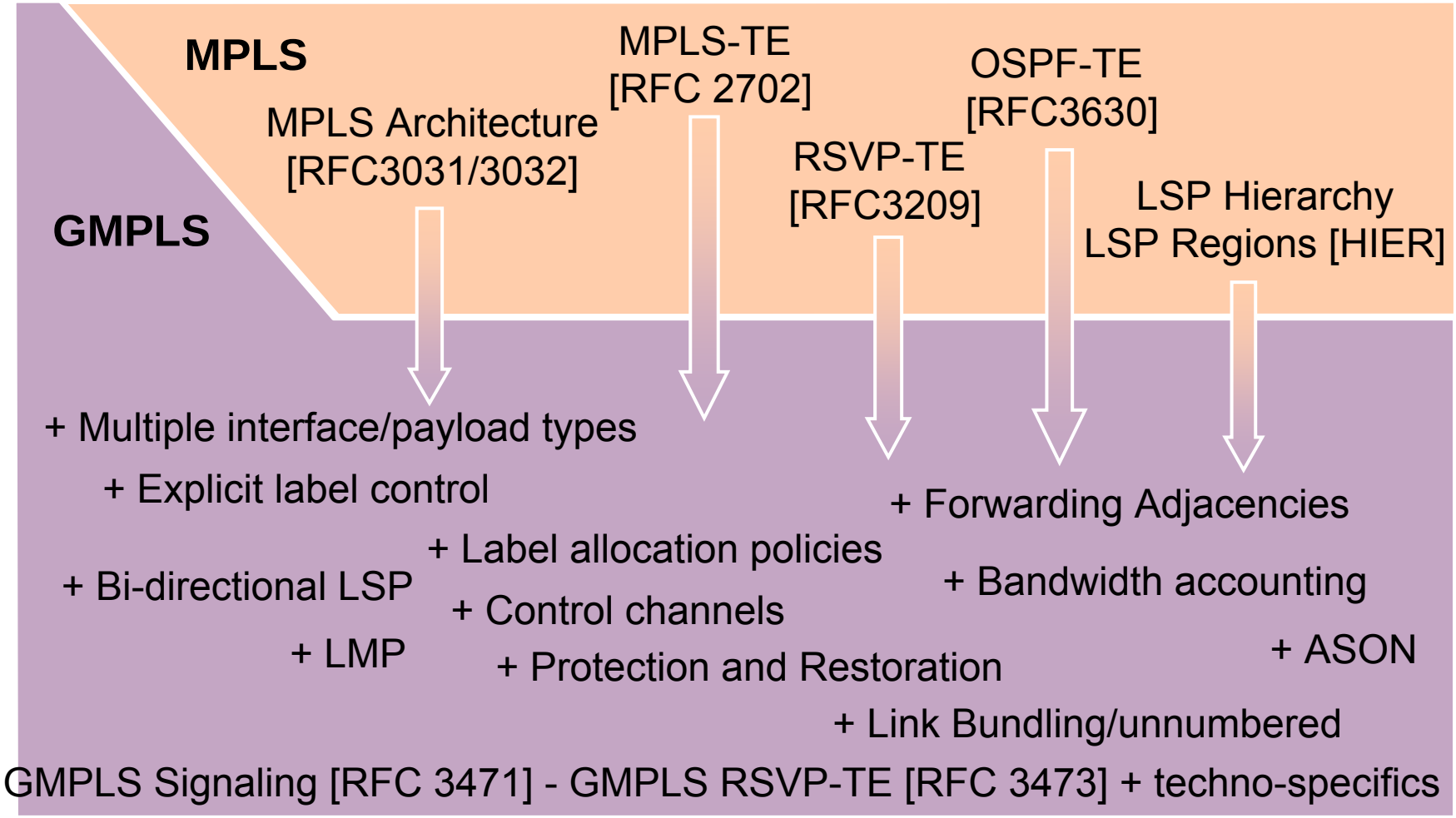
Introduction

- **Generalized Multi-Protocol Label Switching (GMPLS)** with unified signaling & integrating routing approach for resources provisioning and recovery ⇒ control-plane optimization for **multiple switching layer networks**
- Targeted network architectures referred to as vertical interworking: nodes hosting multiple switching layers and controlled by a single instance of the control plane
- When such nodes are port of the same routing area the resulting network is referred to as a **Multi (LSP-)Region Network (MRN)** - note: an LSP Region defines the control plane representation of a switching layer
- This approach differs from horizontal integration related to interworking between partitions (routing areas, autonomous systems) of the network

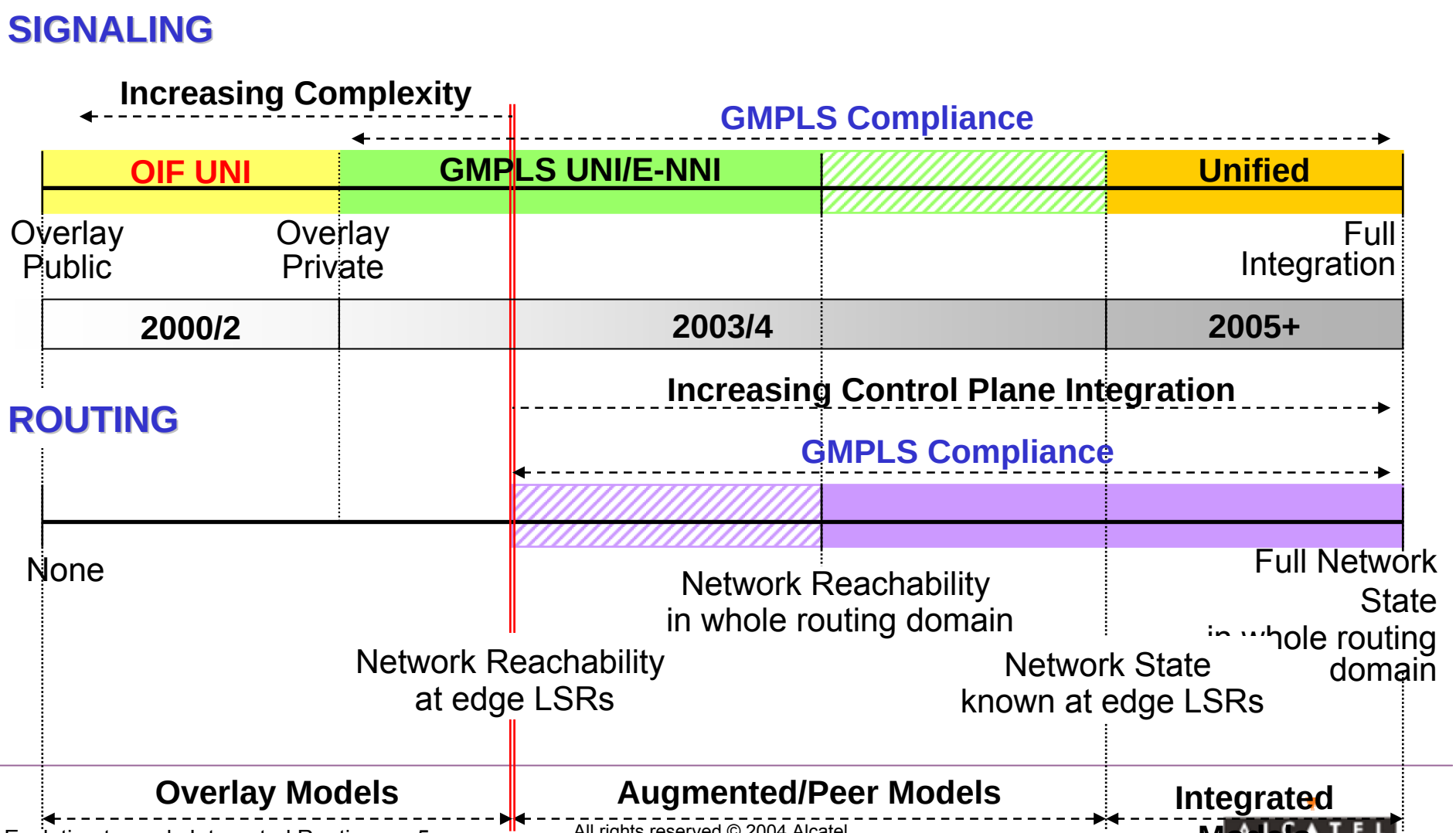
From MPLS towards GMPLS



Functional Panorama



GMPLS Evolution



Overlay Model Limitations (1)

- Separate routing instances between technology domains implies
  - no reachability information ($\Leftrightarrow$ address allocation/resolution)
  - no a priori routing adjacencies (b/w source and destination client)

  $\Rightarrow$ need for an out-of-band mechanism to bootstrap the system
- Per layer Traffic Engineering
  - path computation performed per layer using separate TE Database
  - only allows for manual triggered connection creation/modification $\Rightarrow$ default operational model is provisioned
  - state of the client connection is unknown within the network (no distinction b/w a protecting versus protected connection $\Rightarrow$ no restoration)
- Strict separation of the signalling domains, in turn requires split of (end-to-end) sessions for a single end-to-end connection

$\Rightarrow$ This leads to limitations in using overlay models (in turn this limits the gain from using GMPLS-based control plane)

Overlay Model Limitations (2)

- Client routing adjacencies are “unknown” ⇒ precludes dynamic connection triggering (or requires out-of-band messaging b/w edges) ⇒ only suitable in the context of a (server layer) provisioned model
  - ⇒ Bandwidth on demand limitation to sub-channels (logical or physical)
- Server layer unaware of client-initiated connection status
  - ⇒ usually part of client layer control plane topology (thus client control plane performance are strongly correlated to the data plane performance)
  - ⇒ Impossible to provide soft-reservation of network capacity (thus precluding client control-plane driven shared recovery mechanism
- Network address allocation (network to client) does not allow for dynamic client learning of reachable end-points
  - ⇒ requires address resolution mechanisms (logical to physical) for switched connections or (physical to logical) for soft-permanent connections (in turn this precludes best exit point selection for multi-homed clients)
- Other issues: multi-homing, session split, recovery timing efficiency

GMPLS Signaling Models

Signaling Model	Public UNI (OIF)	GMPLS UNI	GMPLS E-NNI	Unified Signaling
Service Invocation	Direct and Indirect	Direct	Direct	Direct
Symmetry/ scope	Asymmetrical/ Local (Client/ Server)	Asymmetrical/ End-to-end (Peer)	Symmetrical/ End-to-end (Peer)	Symmetrical/ End-to-end (Peer)
Routing protocol	None	Optional	Mandatory	Link state preferred
Routing information	None	Optionally end-point reachability information (filtering and summarization)	At least end-point reachability information (filtering and summarization)	End-point and internal Reachability information and TE attributes
Address space	Must be distinct	May be common	May be common	Common
Discovery	Optional and only local	Optional and may be network-wide	Optional and may be network-wide	Through routing and network-wide
Security	No trust	Limited trust	Limited trust	High trust
	Signaling must be domain specific (a separate signaling protocol instance must be running in the network)	End-to-end signaling that may be domain specific (a separate signaling protocol instance may be running in the network)	End-to-end signaling that may be domain specific (a separate signaling protocol instance may be running in the network)	Inherently multi-layer so is also referred to as end-to-end integrated signaling

Note: Unified signaling supports GMPLS UNI/E-NNI capabilities, and GMPLS UNI/E-NNI supports Public UNI capabilities

Standpoint on the GMPLS front (1)

- The GMPLS architecture covers the protocol building blocks required to build a carrier grade control plane for multiple switching layers
- GMPLS supports an overlay model, an augmented/peer model and an integrated model
- However, interactions between control planes are mainly seen as interactions between systems hosting a single switching layer and limited to signaling aspects (limited coupling from routing information exchange):
  - With different flavors of edge/core nodes relationship [GMPLS UNI]
  - Between areas/levels and/or autonomous systems [INTER-REGION]
- This does not cover current “real life” configurations…

Standpoint on the GMPLS front (2)

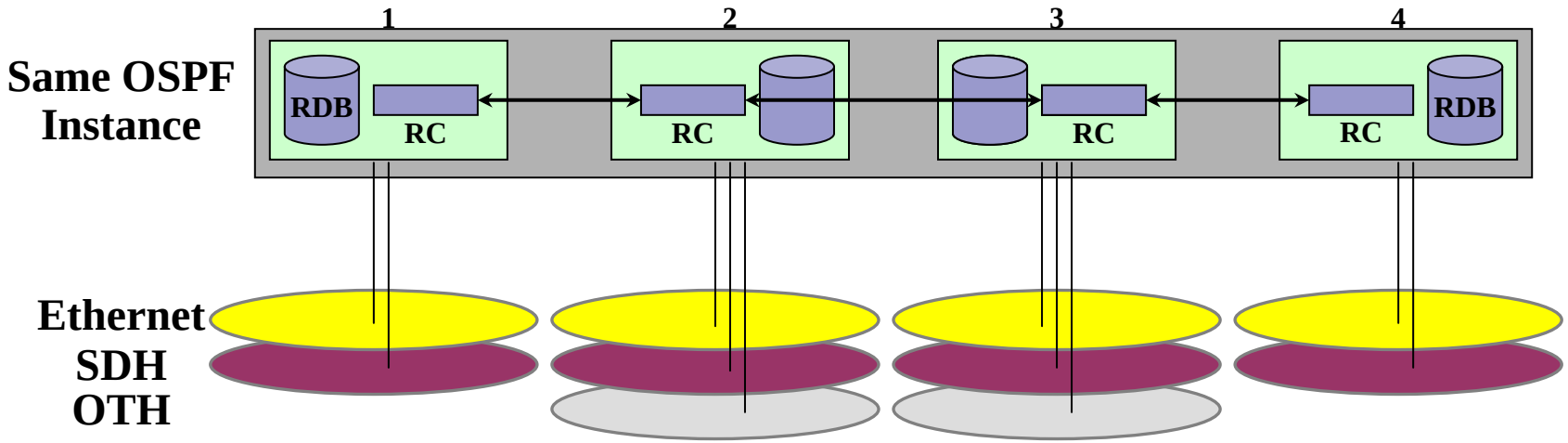
- Within the peer model, no restriction implying exact matching of LSP regions and routing systems resulting from network partitioning (horizontal integration)
- Transport networks evolution towards delivery of multi-service over a multi-switching capable network (e.g., SDH, ETH)
- Therefore GMPLS models should cover the vertical integration case dealing with multiple switching capable nodes resulting in multi-region networks (MRN)
- Examples of multiple combinations that already exist today or may appear are:
  - PSC+LSC (e.g. IP/MPLS + Lambda), L2SC+TDM (e.g. ETH + SDH), etc.
  - PSC+L2SC+TDM, L2SC+TDM+LSC, etc.

Integrated Routing Approach - Overview

- Considering one administrative authority (e.g., a single carrier) driving a network including multiple switching capability (MSC) systems, GMPLS should provide an effective solution avoiding multiplication of control plane instances per node
- Corresponding to the data plane integration, GMPLS is the unique credible candidate which is able to target this function
- The MRN approach squeezes the most out of GMPLS [MRN]
  - Reducing addressing complexity (single addressing space)
  - Reducing the complexity of interactions (single control plane instance)
  - Allowing best usage of the LSP hierarchy (i.e., Forwarding Adjacencies)
  - Consistent Traffic Engineering (TE) within the scope of a single policy to improve resource optimization (using a coordinated routing approach)

Integrated Routing Definition

- Scope: 1:N (control plane instance:data plane switching layers)
- Single GMPLS (routing) controller (single RC / RDB) that processes and maintains all routing information (TE link topology/attributes) for all data links whose switching capabilities are hosted



Integrated Routing Perspectives…

- System/network architecture (multi-granularity and multi-service)
- New dynamic resource provisioning policies (multi-region routing, virtual topology engineering)
- New control plane driven protection/re-routing schemes (policies)
- New optimization and TE capabilities (metrics consolidation through layers)
- Control and Management simplification (common resource identification, addressing)
- Export and generalization of same concepts at least for MAN and WAN

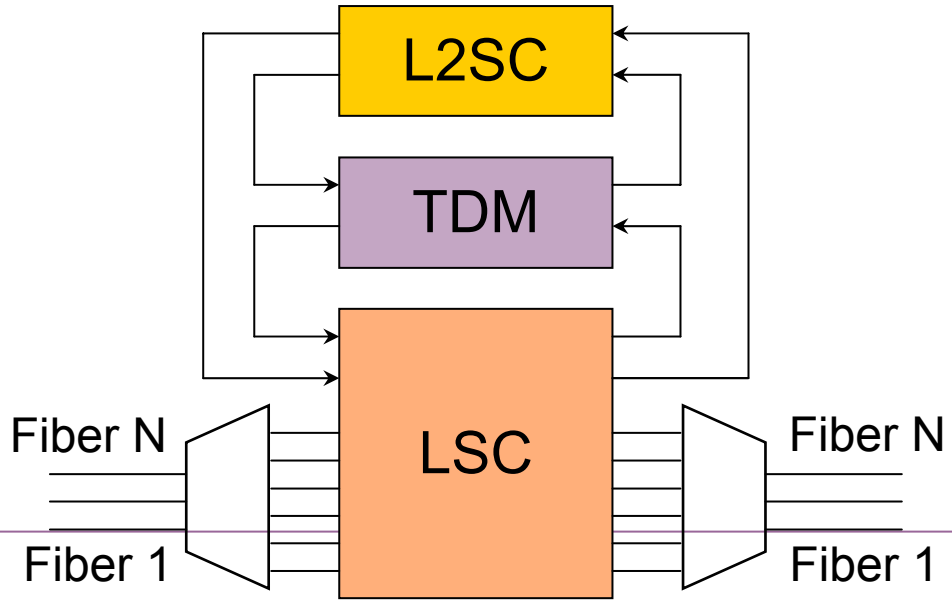
What is Missing from GMPLS ?

- A profile of existing GMPLS building blocks
  - Routing over Forwarding Adjacencies (FA) with TE metric inheritance policies to avoid undesirable effects (e.g. full mesh)
    - TE attributes related to packet and circuit constraints may be orthogonal (e.g. TE metric)
    - consideration for LSP region specifics and multi LSP-region advertisement of resources (one FA TE link built from two FA-LSPs)
- Extensions for cross-region considerations
  - By definition MSC devices are not able to process all the transit traffic at each switching capability
  - This results in potential contention for use (terminate a LSP for example) of a given SC (interface capability is not sufficient)

  ⇒ Introduction of interface adaptation capability descriptor (IACD)

Interface Adaptation Capability Descriptor (IACD)

- The Interface Switching Capability descriptor alone does not allow remote LSR to deduce intermediate termination capabilities of the MSC systems
- IACD may complete sub TLVs of the TE link TLV of the TE opaque LSA (defined in [RFC3630] and extended in [GMPLS-OSPF])
- Termination issues (ambiguous/blocking case):



Application Scope

- Many combinations of switching capabilities and encoding generate ambiguous or blocking situations where IACD should be necessary
- Advanced utilization of such information may also be useful for:
  - Grooming strategies implying cross-region at intermediate nodes
  - Use of regeneration capability in Hybrid Photonic Networks
  - Any situation where one may want to access a region within a MSC system with blocking states

Conclusion

- As GMPLS is experiencing its first deployment, the unified signaling with integrated routing may also apply for “real life” models based on devices supporting multiple switching capabilities
- Starting with a mono-carrier (single administrative authority) framework, few protocol extensions (Interface Adaptation Capability Descriptor) are required to support multi-region networks
- MRN is one enabler for optimized networking (TE, protection and rerouting, reduced complexity,…) and packet/transport integration
- Further developments may also cover more sophisticated features such as (re-)grooming or Hybrid Photonic Networks

Thanks for your attention...

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