Multi-Domain Routing Techniques in ASON Networks

Multi-Partner European Test Beds for Research Networking

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http://www.ist-mupbed.org/

Introduction to Inter-domain Routing

- In ASON/GMPLS routing is a distributed network-function
- In distributed routing:
  - Size of routing databases in the nodes
  - Running-time of routing algorithms
  - Overhead-traffic to carry routing signaling messages

All the above increase with the size of the network, leading to potential **scalability problems**

→ To ensure scalable routing over large and complex networks:
  - Divide the network into independent but interacting domains
  - Restrict the exchange of routing information between domains

Inter-domain communication

- Large amount of routing information exchanged between domains → disadvantages in terms of scalability and security
  - Complexity grows with network size
  - Administrators are reluctant to disclose too many details about their intra-domain network topology for commercial reasons
- Small amount of routing information exchanged between domains → disadvantages in terms of network performance
  - Walking around congested network elements may be impossible
  - Finding the minimum-cost path for a connection may be impossible

- This work investigates the complex trade-off between scalability and performance

Summary

- ASON routing architecture
- ASON routing policies
- Dynamic-traffic case-study: the Pan-European research network
- Conclusions

ASON routing architecture

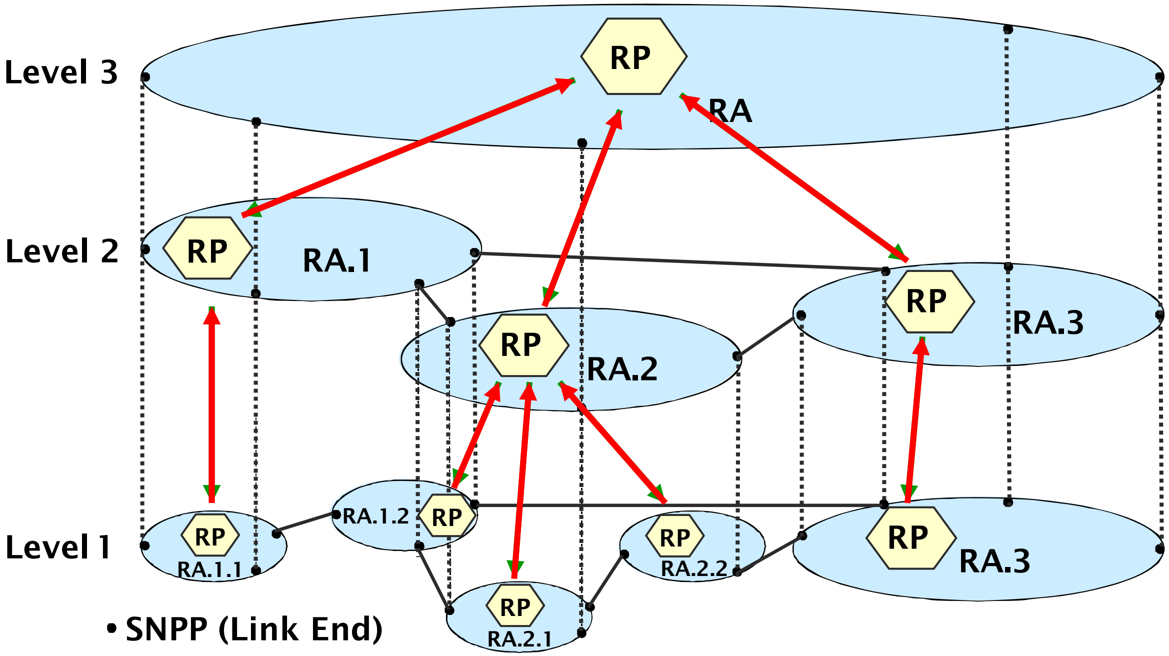
- Defined by ITU-T standards
  - Recommendations: G.8080/Y.1304; G.7715/Y.1706; G.7715.1/Y.1706.1
- Precise definition of abstract components and general procedures of the routing architecture
- Encompasses several routing approaches and info-propagation modes
  - Very flexible framework, many choices left to network operators
  - Is PROTOCOL INDEPENDENT

Routing areas

- Hierarchical decomposition of the network in Routing Areas (RAs)
  - A parent area can contain many child areas
  - As many hierarchy level as desired
- (Generalization of the OSPF-area concept)
- Each RA has an associated (abstract) Routing Performer (RP)
  - RP = a specific RC in centralized CP implementation
  - RP = the synchronized “ensamble” of RCs of the area in distributed CP implementation
- Each RP has a network vision comprising its area plus abstract and summarized topology outside its area

•Routing Controller (RC): local routing component invoked by the local Connection Controller (CC) during a connection setup
•Routing Information Database (RDB): loacally stores topology/state info

Routing areas



Routing policy
- Amount of information propagated between areas
- Degree of abstraction of topology information
- Type of information propagated

- Routing areas exchange routing information
  - Upward: each *N*-level area can propagate info on its internal topology (possibly in an abstract way) to its parent area
  - Downward: an (*N* + 1)-level area can propagate info to its children areas

G.7715/Y.1706_F06

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Degrees of freedom in ASON routing policies

- Path-selection can be carried out by two approaches
  - Step-by-step
    - Each RP independently selects the path to the next-hop routing domain
  - Source
    - The RP of the source domain selects the path from ingress node to destination
- Each network element can be represented in two formats
  - Reachability
    - Physical reachability, the simplest possible information
  - Link-state
    - Set of (variable-in-time) attributes: link weight, link capacity, link availability
- How many and which element to notify to other areas and in which format is part of an area routing-policy

ASON Multi-Domain Routing (MDR)

- Simplifying assumption
  - 2-level ASON routing-area-hierarchy
  - Level-1 (bottom) areas ≡ the administrative domains
- ASON-standard degrees of freedom allow each domain administrator to choose between many different routing policies
- We have defined an ASON-compliant “menu” of routing policies

ASON-compliant MDR policies

- **SBS-R1**: Step-by-step routing. Minimum quantity of routing information exchanged. Representation of topology elements by reachability relations
- **SBS-R2**: As SBS-R1 but enriched by inter-domain path information
- **SRC-L1**: Source-based routing. Link-state representation of the inter-domain links
- **SRC-L2**, **SRC-L3**: As SRC-L1 but enriched by link-state information concerning an increasing number of intra-domain links (forwarding adjacencies) externally propagated
- **SRC-LA**: Source-based routing. Full propagation of link-state information about all the inter-domain links and all the intra-domain links of each domain
- **SDM-LA**: The network is assumed to be a single domain (benchmark case)

Policy ID	Path selection	Reachabiliy / link-state ratio
SBS-R1	Step-by-step	
SBS-R2	Step-by-step	
SRC-L1	Source	
SRC-L2	Source	
SRC-L3	Source	
SRC-LA	Source	
SDM-LA	Source	

Scalability-evaluation parameter: TTE

- A novel problem: how to measure the complexity of MDR policies in order to evaluate scalability?
- We propose the new metric *Total number of Topology Elements (TTE)* estimating network-global memory occupation for routing info (sum of the sizes of all the Routing Information Database (RDBs)

$$\mathrm{TTE} = \sum_{\forall RP} \left(N_{RP} + 3 \cdot L_{RP} \right) RC_{RP}$$

  - *RP* = routing performer
  - N_{RP} = (number of nodes* + number of UNIs**) in the topology seen by *RP*
    - * a physical node, when directly seen within the topology, is a topological node
    - ** links connecting a UNI to a node and reachability links are not considered
  - L_{RP} = number of link-state links in the topology seen by *RP*
  - RC_{RP} = routing controllers comprised in the area of the *RP*. In our case:
    - RC_{RP} = # physical nodes $\in$ area *RP*, if *RP* is a level-1 area (each node is a RC)
    - RC_{RP} = # areas, if *RP* is the level-2 area (one RC per area)

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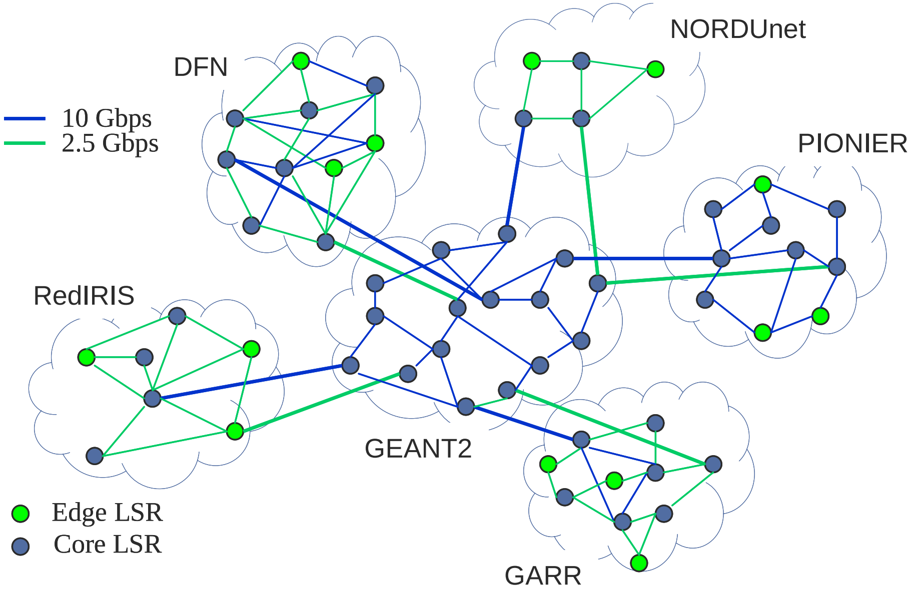
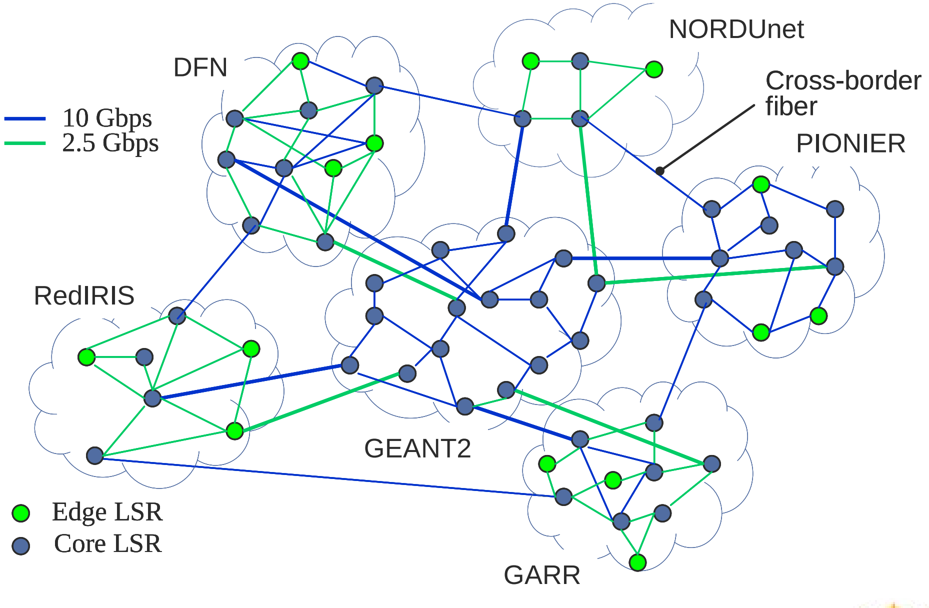
Case-study multi-domain network

- Complex topology obtained by interconnecting the five NRENs involved in MUPBED through GEANT2 and assuming ALL domain being ASON
  - A realistic possible projection of the future pan-European research network

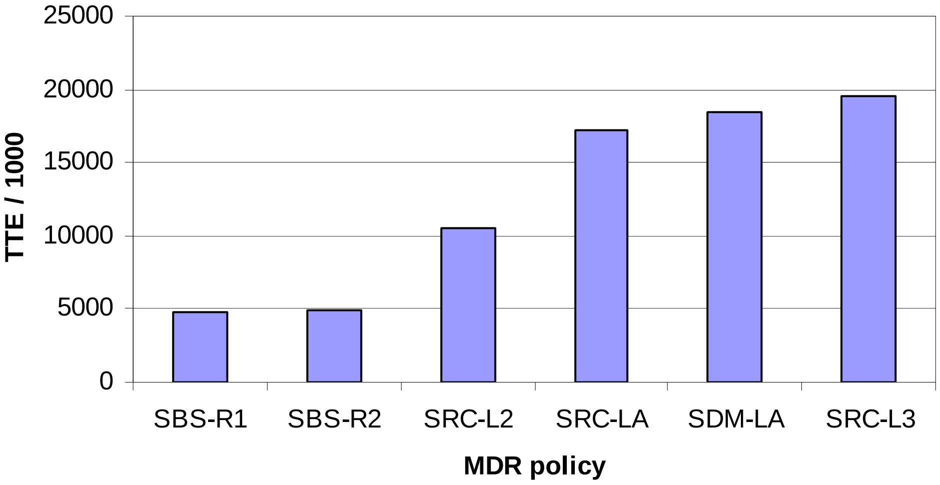


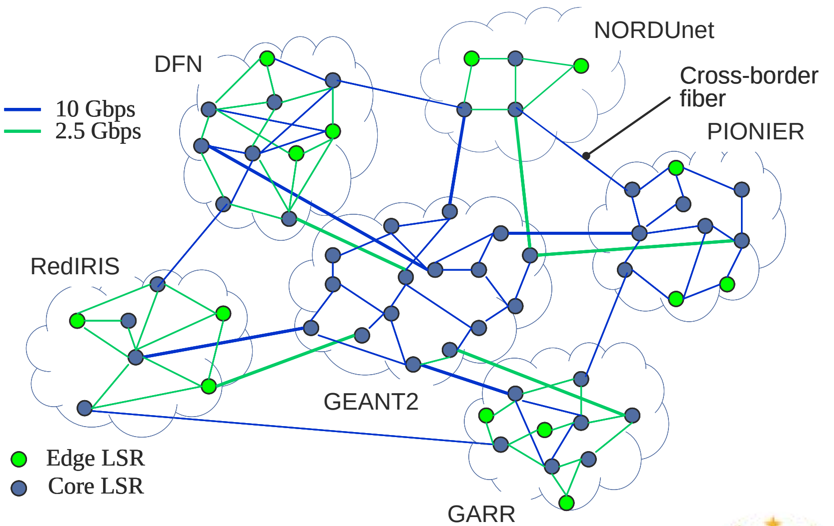
Case-study multi-domain network

- Complex topology obtained by interconnecting the five NRENs involved in MUPBED through GEANT2 and assuming ALL domain being ASON
  - A realistic possible projection of the future pan-European research network
  - “Cross-border” fiber links are added to transform the inter-domain star into a more-interesting inter-domain mesh



Case-study network: TTE evaluation

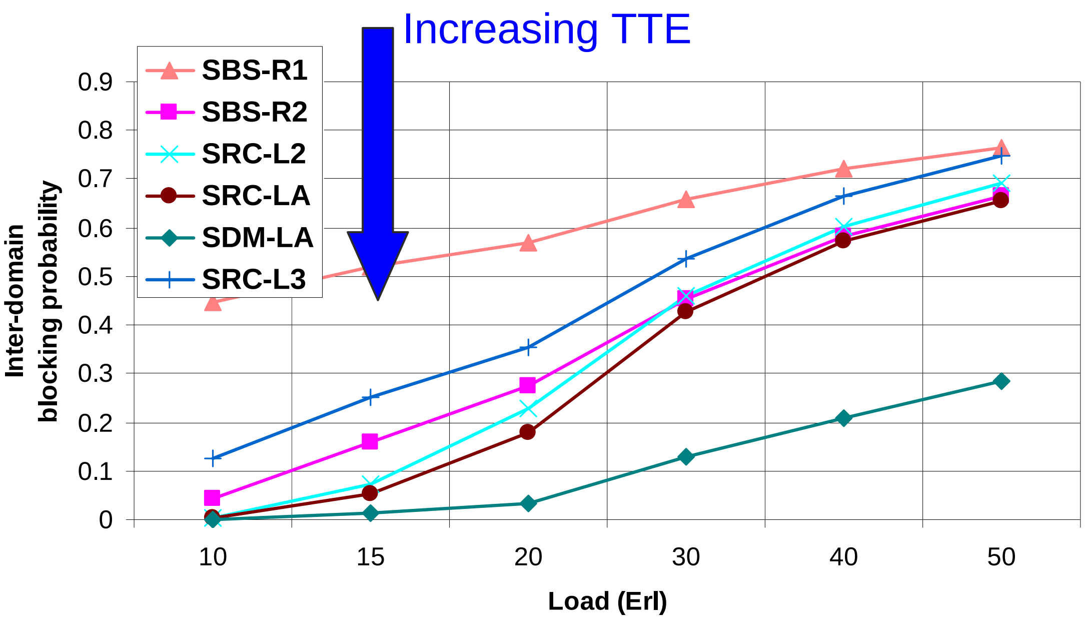




- TTE follows the expected MDR-policy complexity
  - (Except some exceptions
    - Distribution of UNIs and border nodes among the domains is very relevant
    - More “faithful” behavior in a regular multi-domain network

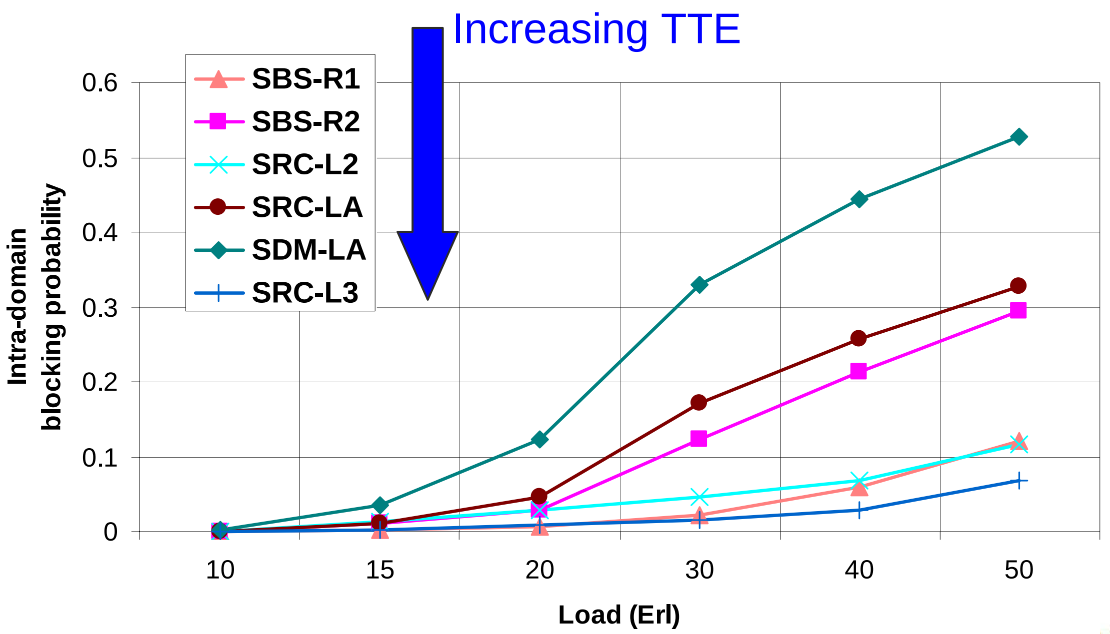
Performance evaluation: inter-domain blocking

- Performance is computed in terms of blocking probability of the inter-domain connections as a function of the traffic load
- The different routing approaches can be compared by comparing the corresponding curves
- Inter-domain blocking performance are in accordance with the TTE complexity
  - Large TTE → small block. prob.



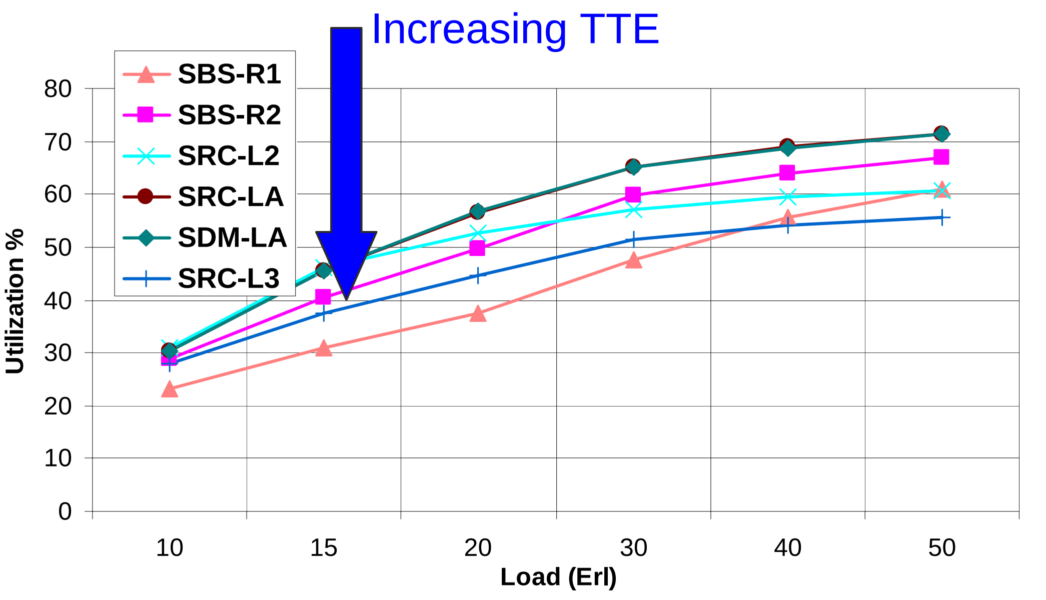
Performance evaluation: intra-domain blocking

- Routing policies guaranteeing good inter-domain routing performance on the other hand indirectly induce higher loss on intra-domain traffic (finite-resource sharing)
- MDR is a complex problem potentially leading to conflicts of interest
  - A domain administrator may not be happy to reduce intra-domain capacity in favor of transit traffic



Performance: overall network utilization

- Routing policies guaranteeing good inter-domain routing performance also improve the utilization of the overall multi-domain network
  - An important performance parameter in the point of view of a *super-partes* administrative entity (e.g. the EU Commission in our example), though not important for the single domains



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Conclusions – future work

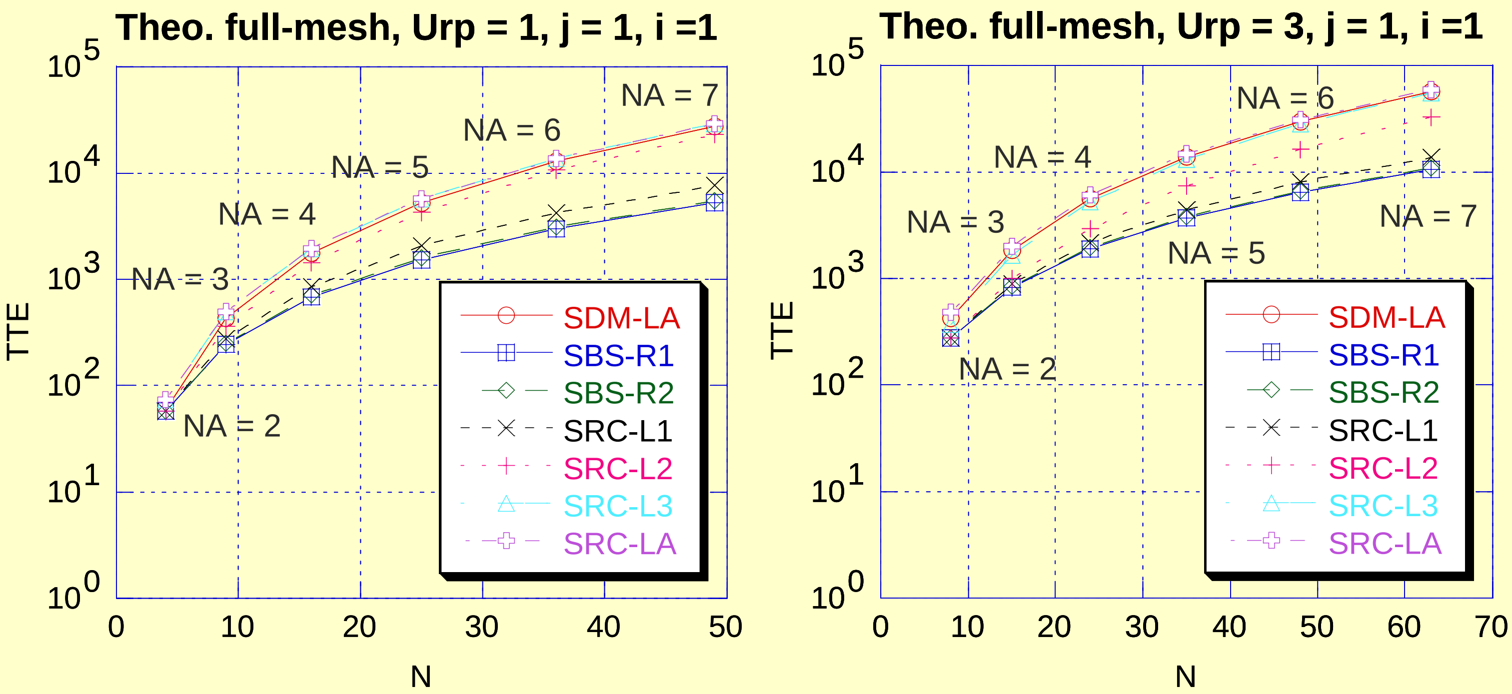
- Scalability of MDR policies is very sensitive to the particular network topology and distribution of UNI among domains
- There is the possibility of "overshooting" in routing information distribution: some better scalable policies may also be better performing than others
- Inter-domain routing is a complex issue in which the optimization of inter-domain connections is in conflict with the optimization of intra-domain traffic

- OIF recent E-NNI implementation agreement suggests intra-domain abstraction by regular topologies (mesh, star, node) → what is the impact on performance?
- What happens if each domain is free to chose a different MDR policy? → challenging multi-objective optimization problem involving independent rational decision-taking entities

Backup slides

TTE-metric validation on a regular network

- Scalability comparison between the routing policies using a theoretical full-mesh multi-domain network
  - Full-mesh inter-domain connection of domains with full-mesh intra-domain topology
  - N = # nodes; NA = # domains; Urp = # UNI per domain; j = # non-UNI internal nodes; i = inter-domain link multiplicity

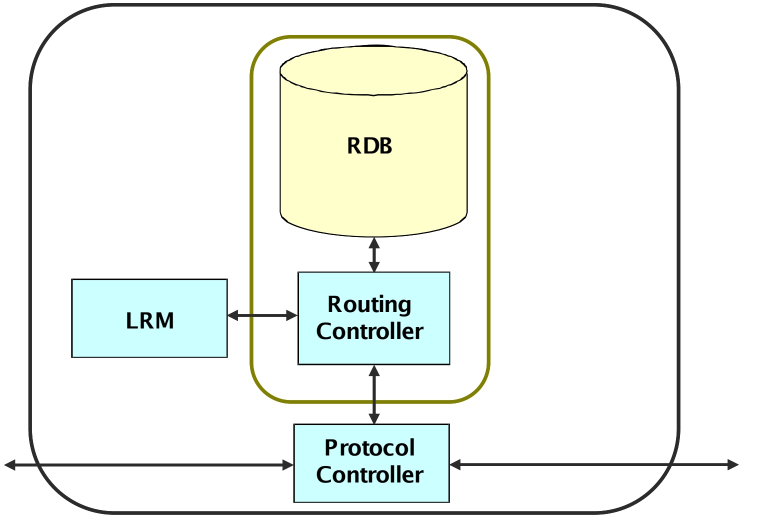


Dynamic-traffic simulation: assumptions

- Single-layer transport plane (i.e. common switching technology, no traffic grooming)
  - SDH network with VC-4 switching granularity
  - {WDM network with wavelength-channel switching granularity – only if there is time or as an alternative to SDH}
- Point-to-point connections all requesting a single bandwidth quantum (e.g. VC-4)
  - This constraint wil be removed in a next round of simulations (perhaps for a next deliverable)
  - In a next development, too, peer-to-peer traffic will be considered
    - P2p-traffic connection: set of simultaneous point-to-point connections from the same source to different destinations
- Dynamic traffic generation according to Poisson model
- Unprotected traffic

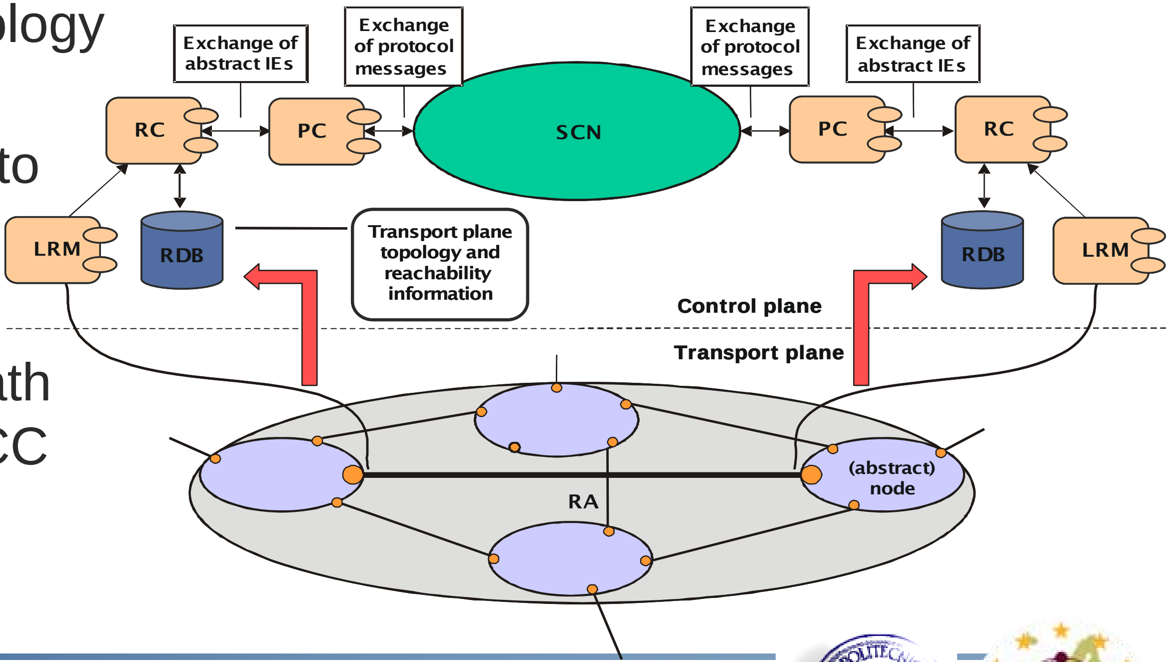
ASON routing components

- The Routing Controller (RC) is the component invoked by the Connection Controller (CC) during a connection setup
- Topology/state info is stored into a Routing Information Database (RDB)
- Local info provided by Link Resource Manager (LRM)
- Remote info provided by RC-RC communication
- Any inter-component info transaction is via a Protocol Controller (PC) [ITU-T G.7715 – Sec. 8.2]



ASON routing function

- Routing is a basic function of the ASON architecture
- Needed during the connection setup (part of the call setup [ITU-T G.8080 - Sec. 7.3.5.3])
- Routing steps
  - Network state / topology info dissemination
  - Query from the CC to the RC
  - Path selection
  - Return of output (path description) to the CC



ITU-T ASON main recommendations about routing

- Recommendation G.8080 “Architecture for the Automatic Switched Optical Network”.
  - It defines the general architecture of ASON, defining the functional elements of the ASON control plane and the general path-selection approaches to be used in ASON routing.
- Recommendation G.7714 “Generalized Automatic Discovery Techniques”.
  - It deals with the Automatic Neighbour discovery function.
- Recommendation G.7714.1 “Protocol for automatic discovery in SDH and OTN networks”.
  - It specifies automatic neighbour discovery details for SDH and OTN layers.
- Recommendation G.7715 “Architecture and requirements for routing in ASON”
  - It deals with the routing process, introducing the ASON routing hierarchy and specifying the basic information exchanges between the routing areas.
- Recommendation G.7715.1 “ASON routing architecture and requirements for link state protocols”.
  - It completes ASON routing adding several details, comprising e.g. addressing, and deals with topology representation and link-state attributes.