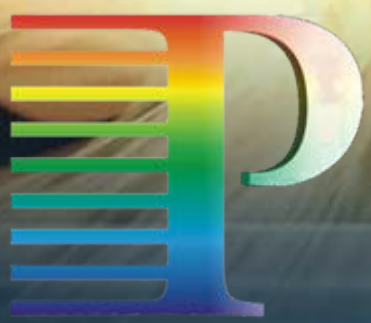

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G²MPLS in a nutshell

Nicola Ciulli, Gino Carrozzo

Nextworks

ASON/GMPLS as a promising starting point

- ASON/GMPLS is an interesting solution in support of dynamic circuit provisioning for advanced research high-end applications
  - Distributed (either in signalling or routing, or both)
  - Faster restoration
  - Scalable solution
  - Built on a lot of lesson learnt from tlc history, both in terms of protocols (e.g. MPLS RSVP, OSPF) and architectures (e.g. ATM P-NNI)
  - Strong standardization and industry support
    - Standardized UNI and E-NNI interfaces (as a result of OIF IAs)
  - Flexible enough to migrate to new architectures / protocols

Major limitations in the near future

- ASON is for SDH and G.709, whileas the optical new trends are WSONs and Ethernet switching services
- The OIF UNI is still a user-*network* to provider-network interface, not an application-to-network interface
- And it does not allow routing info (e.g. endpoints info) to flow across
- Applications have relationships beyond the single domain; the OIF E-NNI is just an *inter-vendor* i/f (not inter-carrier)
- No support for scheduled circuit reservations
- Point-to-multipoint e2e circuits are not clearly supported
- An application might want to interconnect remote endpoints between them, not just itself with some other endpoint
- Applications might want to specify endpoints not just in terms of network names/addresses

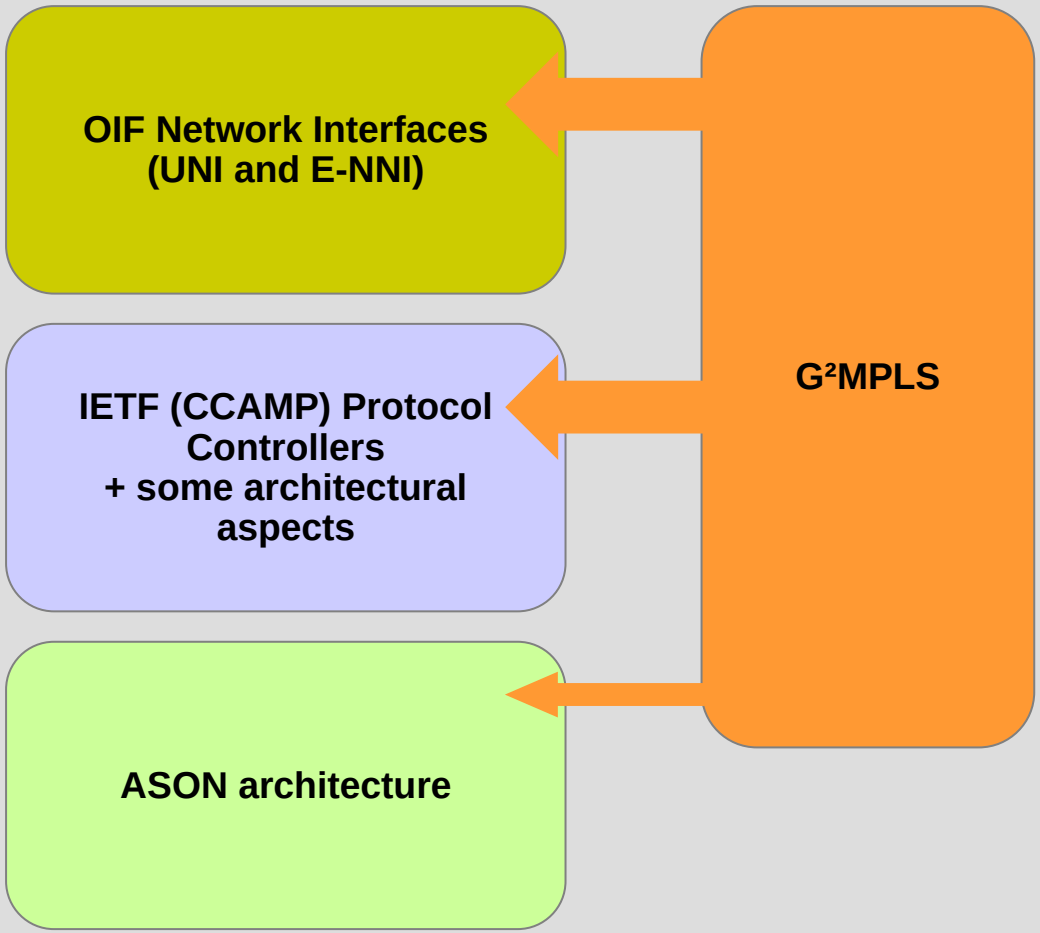
G²MPLS main features

- Lambda Switching Capable, with some WSON extensions
- G.UNI gateways to allow applications to “drive” its reference G.UNI-C and get dedicated dynamic circuits
- Support for application-specific information across the Control Plane
  - I-NNI, E-NNI and UNI routing extensions to distribute application node resources (grid)
  - I-NNI, E-NNI and UNI signalling extensions, for both Call and LSP signalling
- Support for advance reservations (in a distributed way)
- G.E-NNI as an inter-carrier i/f
  - Integration with AuthN/AuthZ frameworks
- Anycast circuits, i.e. “connect this local TNA with this amount of app (grid) resources”
- Indirect calls, i.e. “connect this TNA / amount of app (grid) resources (maybe elsewhere) to this TNA / amount of app (grid) resources (anywhere)”

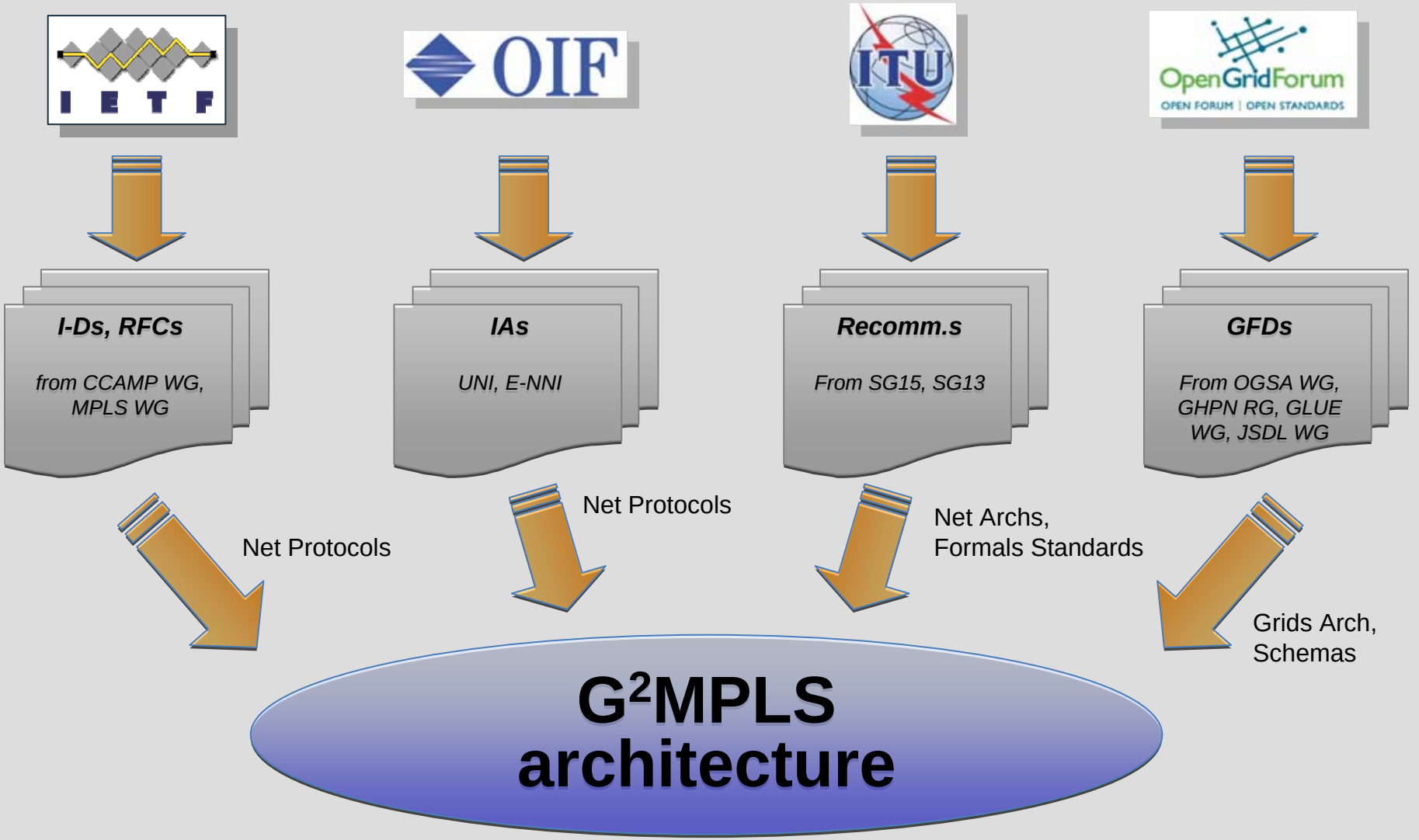
What is G²MPLS ?

- G²MPLS is …
  - a Network Control Plane **architecture** that implements the concept of **Grid Network Services**
    - *GNS is a service that allows the provisioning of network and Grid resources in a single-step, through a set of seamlessly integrated procedures.*
  - expected to expose **interfaces specific for Grid services**
  - made of a set of **extensions to the standard GMPLS protocols**
    - provide enhanced network and Grid services for “power” users / apps (the Grids)
  - Basically, a superset of ASON/GMPLS
  - A set of Controller prototypes developed in Phosphorus WP2
    - A preliminary prototype publicly delivered as XEN VM (http://www.ist-phosphorus.eu/deliverables.php, ref. D2.5)
    - Supports ADVA FSP300RE-II ROADM, Calient DiamondWave FiberConnect
    - Planned demonstrations at SC’08 and ICT-2008
    - Final prototype planned for public delivery Jan/Feb 2009
- G²MPLS is not …
  - an application-specific architecture; it aims to
    - support **any kind of end-user applications** by providing network transport services and procedures that can fall back to the standard GMPLS ones
    - provide automatic setup and resiliency of network connections for “standard” users

G²MPLS positioning w.r.t. standards [1]



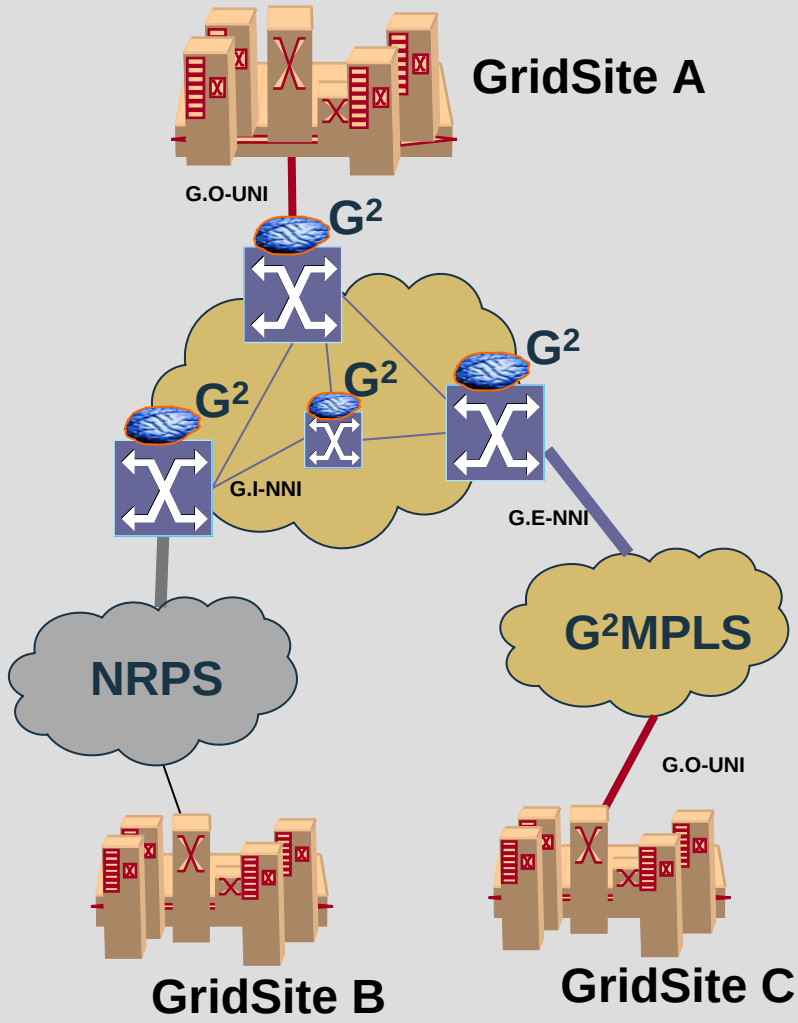
G²MPLS positioning w.r.t. standards [2]



Why G²MPLS ?

- **uniform interface for the Grid-user** to trigger Grid & network resource actions
- **single-step provisioning** of Grid and network resources (w.r.t. the dual approach Grid brokers + NRPS-es)
- adoption of **well-established procedures** for traffic engineering, resiliency and crankback
- possible **integration of Grids in operational/commercial networks**, by overcoming the limitation of Grids operating on dedicated, stand-alone network infrastructures

Grid nodes can be modelled as network nodes with node-level grid resources to be advertised and configured (this is a native task for GMPLS CP)



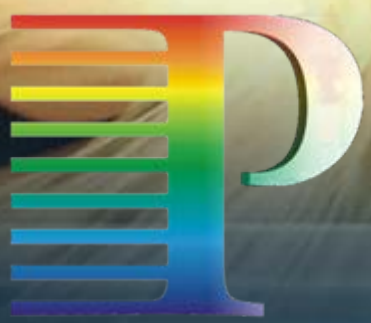
G²MPLS functional scope

- G²MPLS will provide part of the functionalities related to the **selection and co-allocation** of both Grid and network resources
- Co-allocation functionalities
  - **Discovery and Advertisement** of Grid + network capabilities and resources of the participating virtual sites (GridSites)
  - **Service setup / teardown**
    - **coordination** with local job scheduler in middleware
    - **configuration** of the involved network connections among the participating GridSites

      (The network end-point – TNA – might not be specified, if Grid resources are specified)
    - **resiliency** mgmt for the installed network connections and possible recovery escalation to the Grid MW for job recovery
    - **advanced reservations** of Grid and network resources
  - **Service monitoring**
    - retrieving the status of a job (*Grid transaction*) and of the related network connections

G²MPLS steps beyond state-of-the-art

- **w.r.t. ASON/GMPLS**
  - OTN extensions (in sig. and routing)
  - Grid extensions (in sig. and routing)
  - support for additional procedures (advanced reservation, anycasting, Grid + network coordinated recovery, “grid” crankback, etc.)
  - Grid-aware interfaces (G.OUNI, G.E-NNI)
- **w.r.t. NRPS-es (UCLP, DRAC, ARGON)**
  - native multi-domain and multi-tech support in a single CP
  - seamless escalation of recovery procedures, possilbly with the MW
  - uniformed user-to-network transactions (G.OUNI), not dependent on specific Grid MW
- **w.r.t. GN2 BoD system**
  - a control plane solution instead of a mgmt one for BoD services
  - support of “power” users (Grids) and one-step co-allocation of Grid and network
- **w.r.t. other projects in the GMPLS field (e.g. NSF-DRAGON, IST-MUPBED)**
  - GNS compliancy
  - direct interface with Grid MW and peering with NRPS/IDM
  - demonstration of seamless coexistence in a structured distributed test-bed



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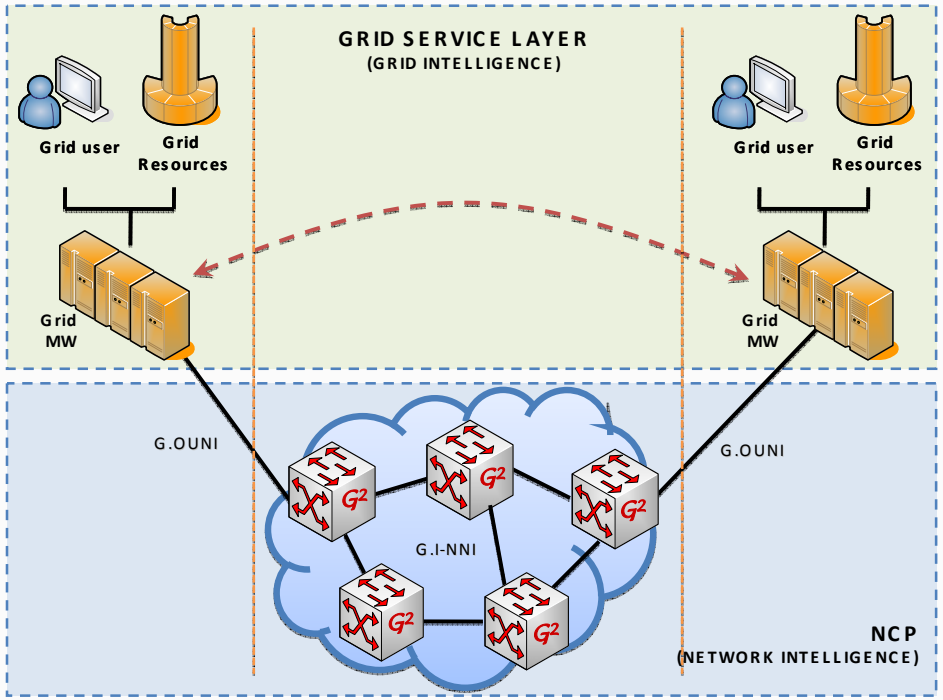
Architectural insight

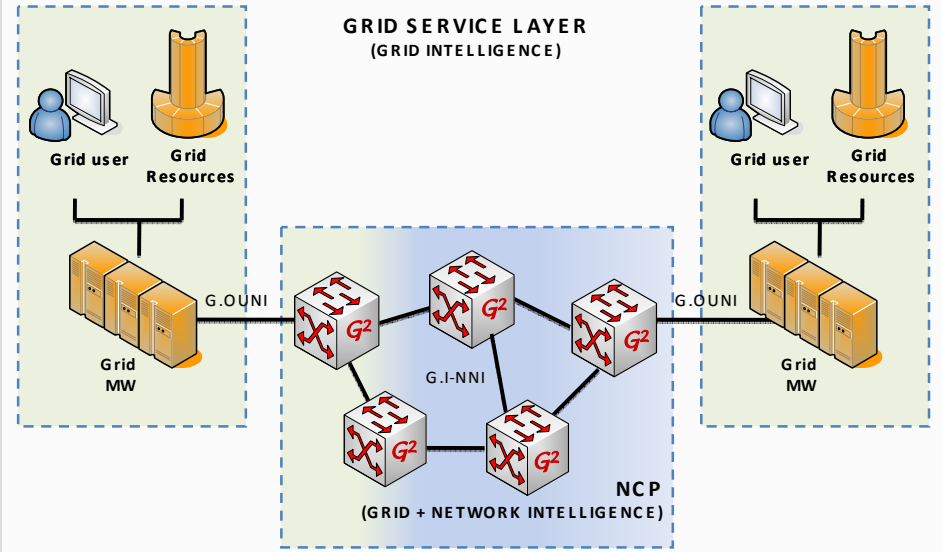
G²MPLS Control Plane models [1]

- Two models for the layering between Grid and Network resources

G²MPLS overlay model



G²MPLS integrated model

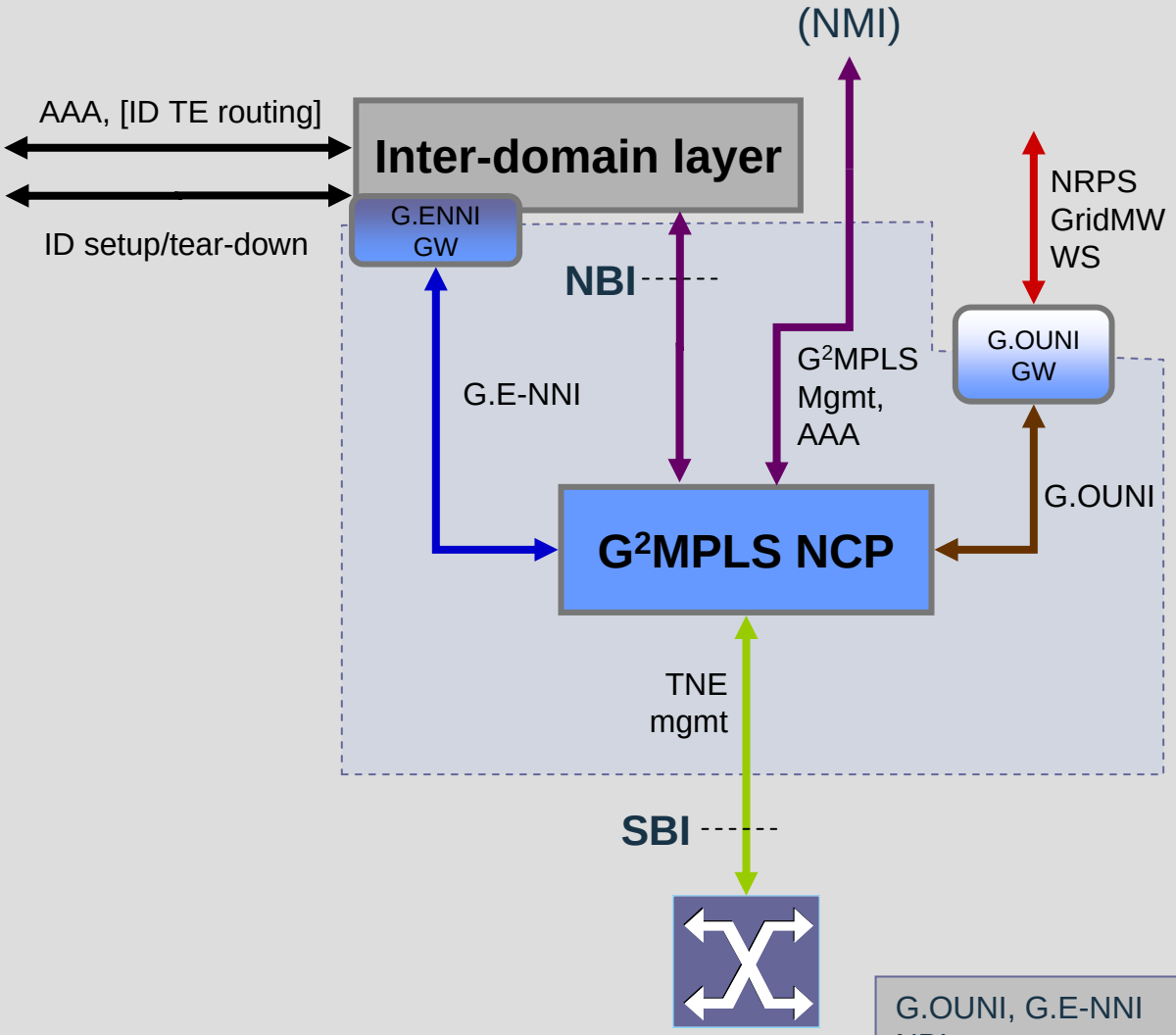


different scope with respect to the IETF GMPLS Overlay & Peer

G²MPLS Control Plane models [2]

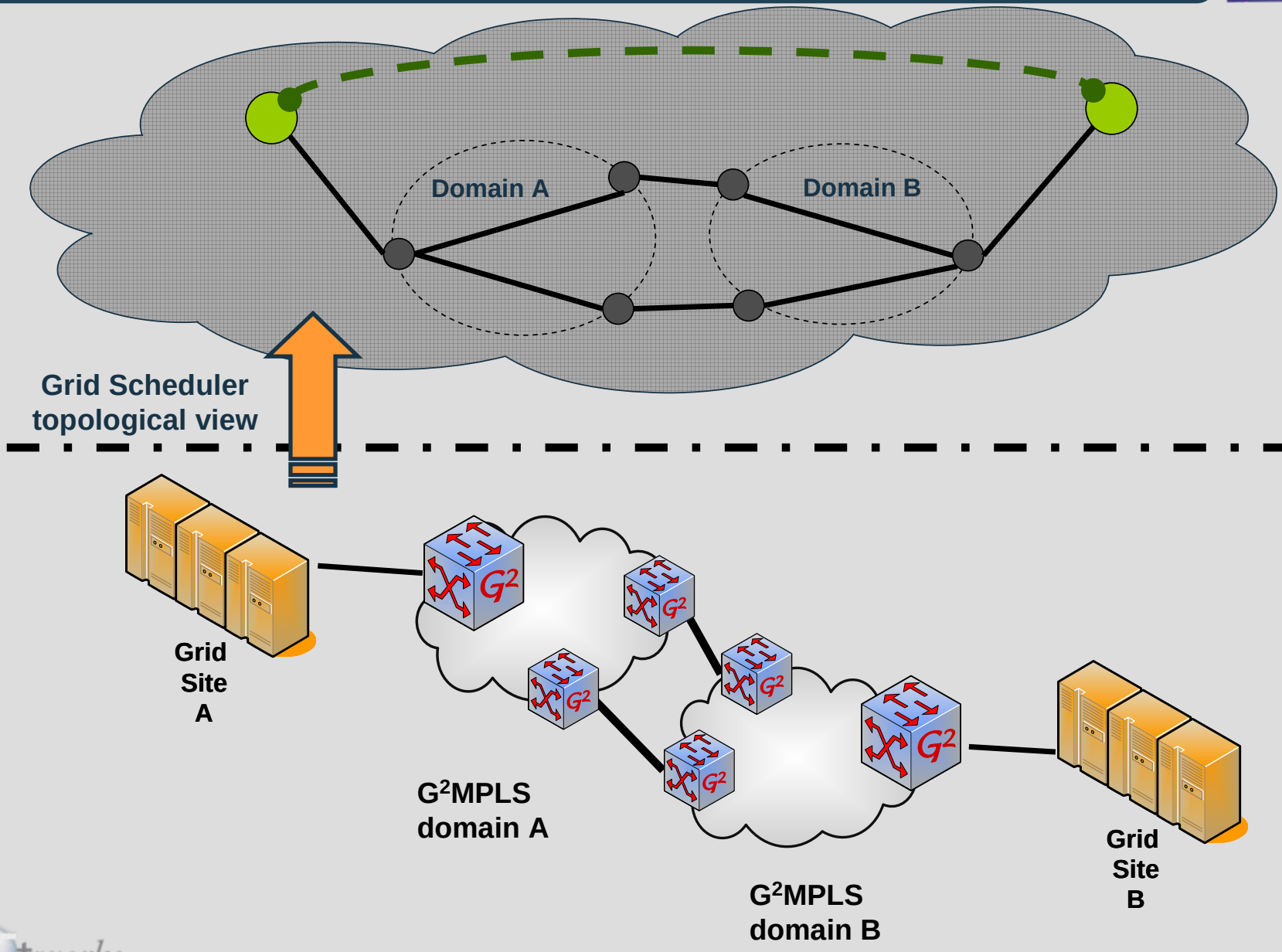
- **G²MPLS Overlay**
  - **Grid scheduler:**
    - traditional configuration / monitoring of Grid resource
    - configuration / monitoring of network resource
  - **G²MPLS**
    - e2e information bearer for network and Grid resources information
    - configuration of just network service
- **G²MPLS Integrated**
  - **G²MPLS**
    - e2e information bearer for network and Grid resources information
    - selection of the job segment providers (Grid and network)
    - co-allocation of Grid and network
  - **Grid scheduler:**
    - traditional workflow and information services

G²MPLS and its neighbourhood

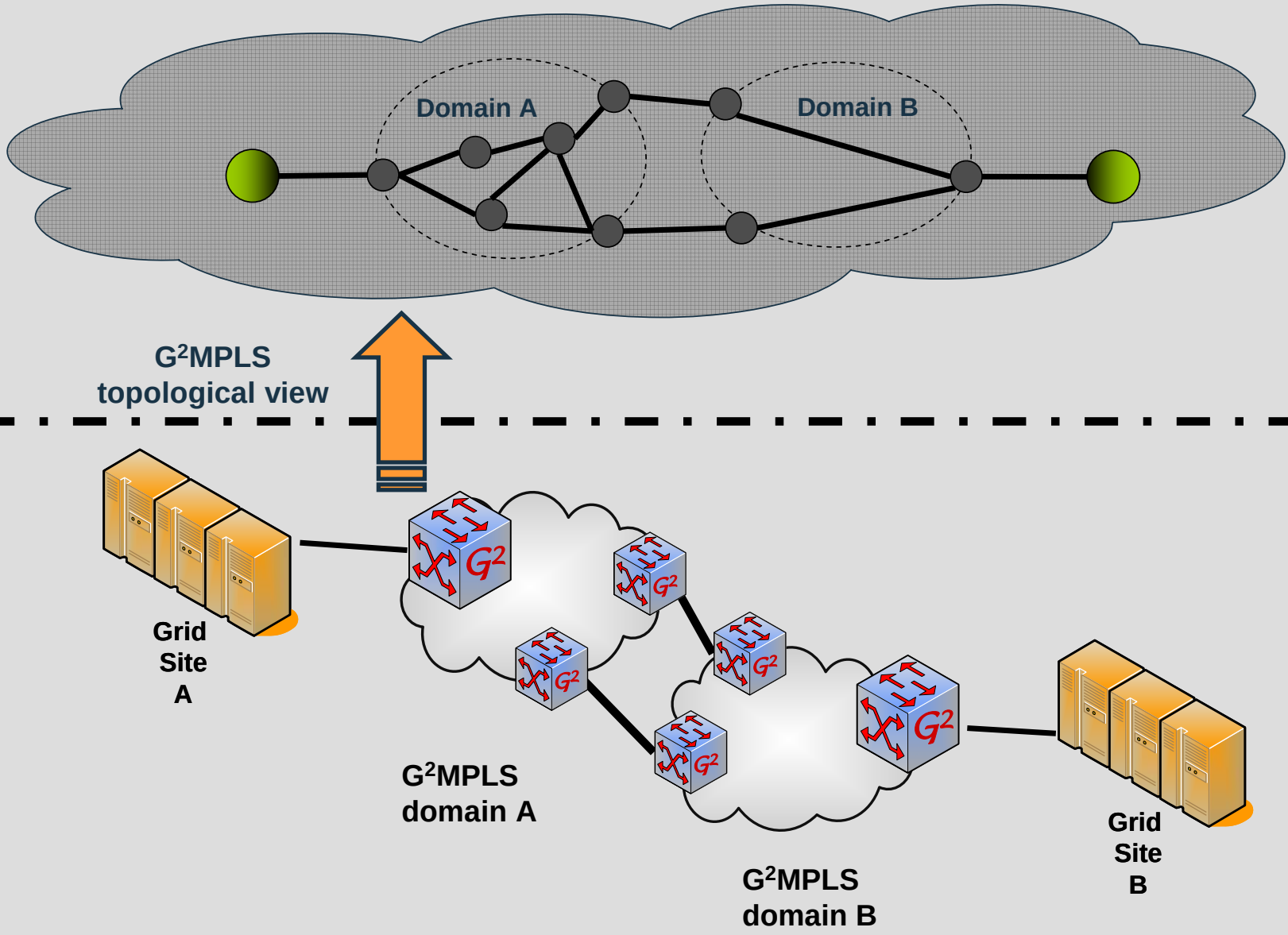


G.OUNI, G.E-NNI	East-westbound interfaces
NBI	Northbound Interface
SBI	Southbound Interface
NMI	Network Management Interface

G²MPLS Overlay: routing vision



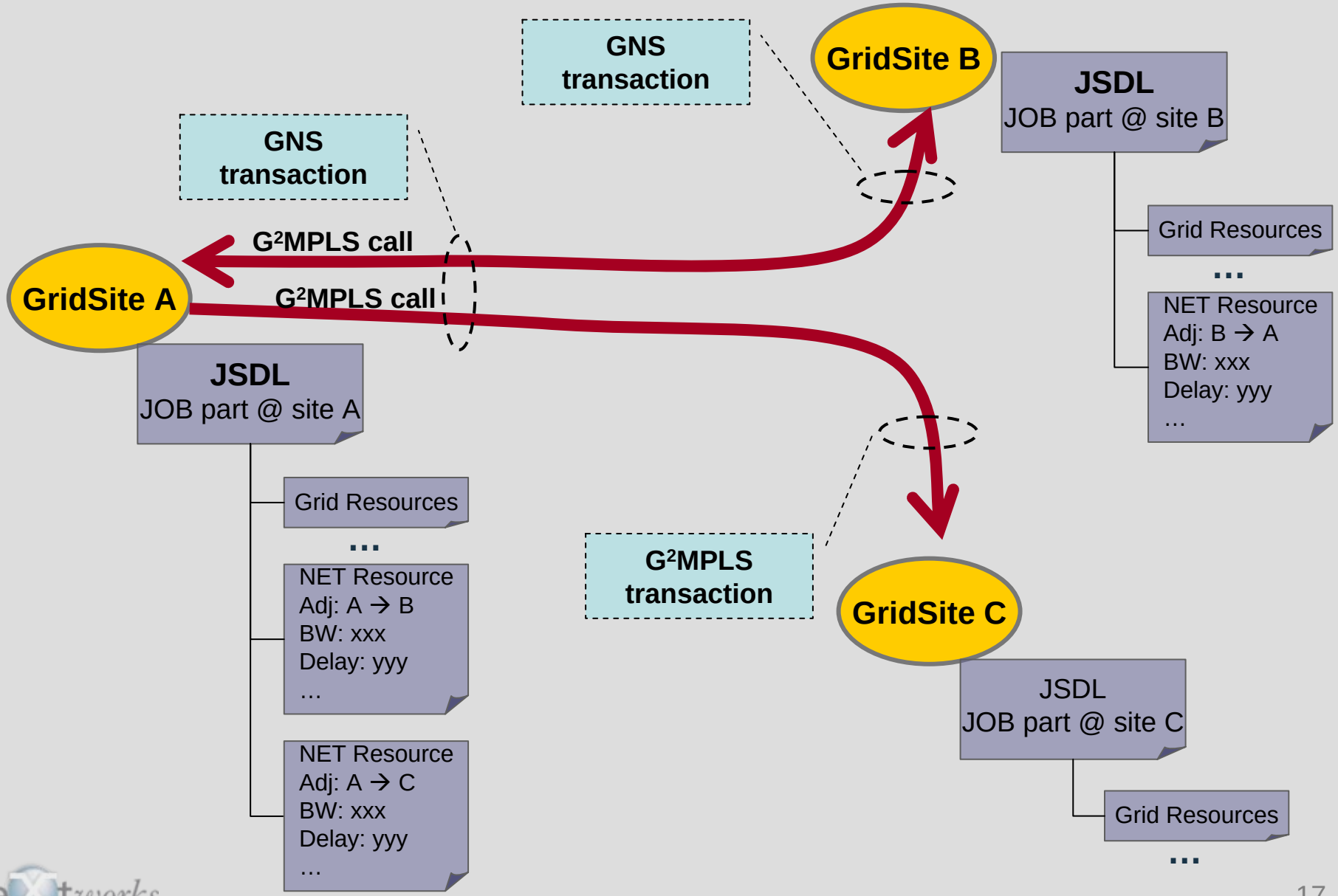
G²MPLS Integrated: routing vision



G²MPLS service concept: GNS transaction

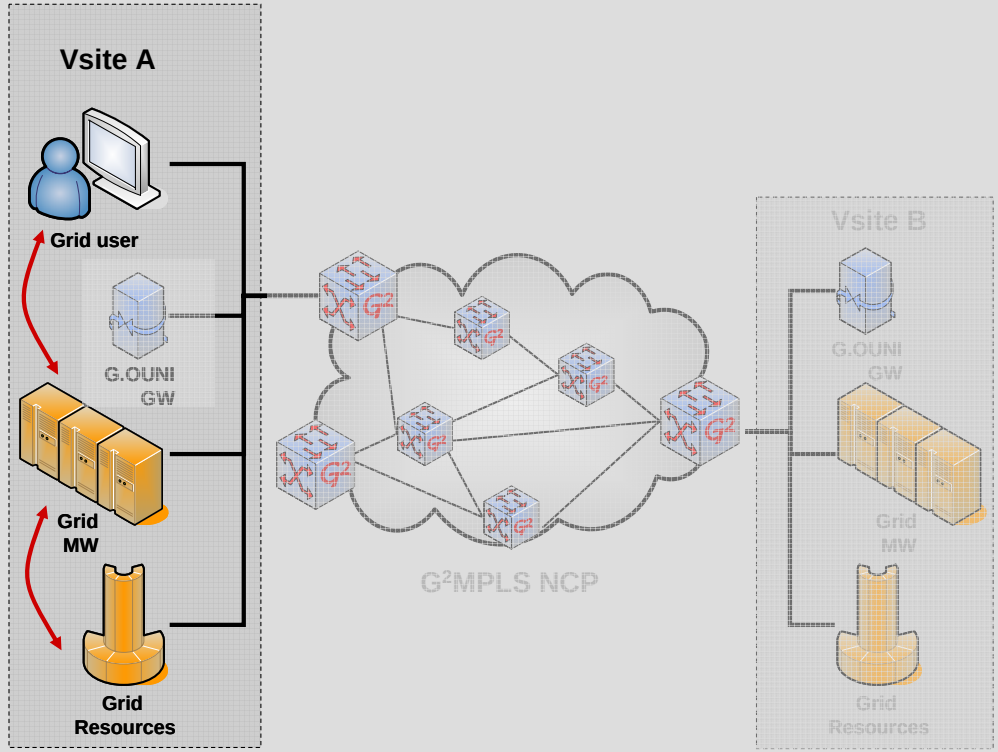
- **GNS transaction** is a set of network calls deriving from the same job specification.
  - related to the definition of a job [GFD.81], i.e. a manageable resource with endpoint references and managed by a job manager
  - needed to manage multiple calls between different end-points, requested for the execution of the unique job (e.g. refer to compute-store-visualize)
  - shareable in a distributed way in the NCP, in order to enable different invocation models
- **Network call** is an extension of the ASON call with further attributes such as temporal specifications

GNS transaction and destination end-points



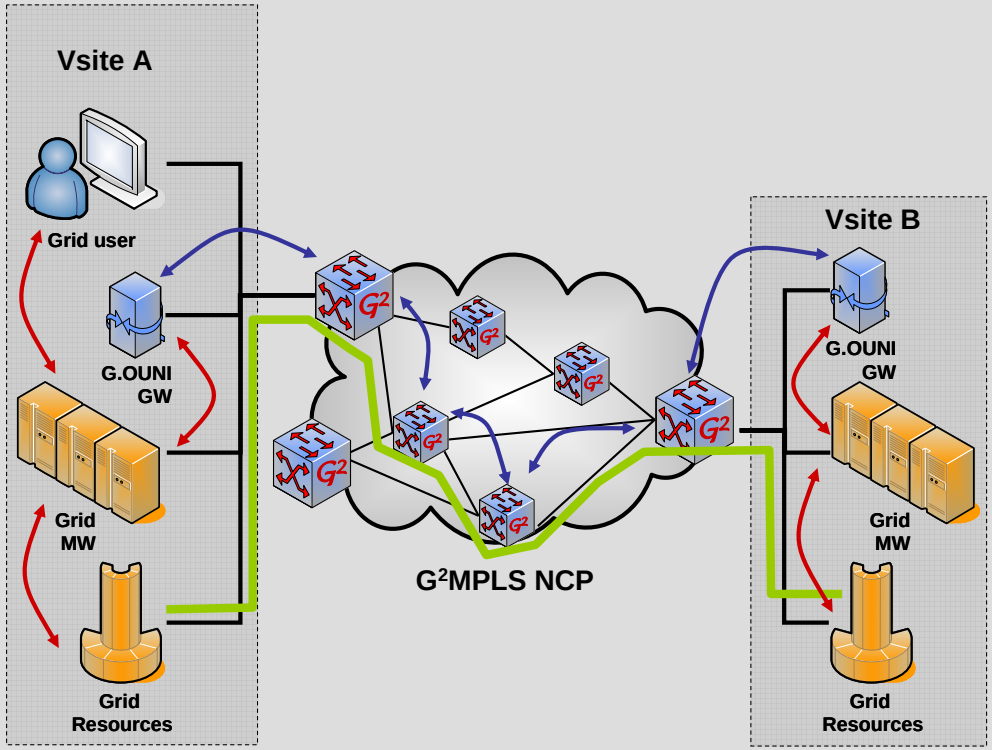
G²MPLS main use cases: Loopback GNS

Use case	
Number	UC#1
Name	Loopback GNS transaction
Goal	A Grid User configures and requests the execution of a job that involves Grid resources located only at his local GridSite
Actors	Grid User at GridSite A
System components	GridSite A o Client Application o Grid middleware o Local Grid resources
Preconditions	Grid Middleware (local Grid scheduler in particular) is aware of the types and amount of Grid resources located at its GridSite A.
Postconditions	Grid Middleware (local Grid scheduler in particular) advertise the new status/availability of the resources under their control.
Trigger	The Grid User defines the job in the Client Application and issues the request.



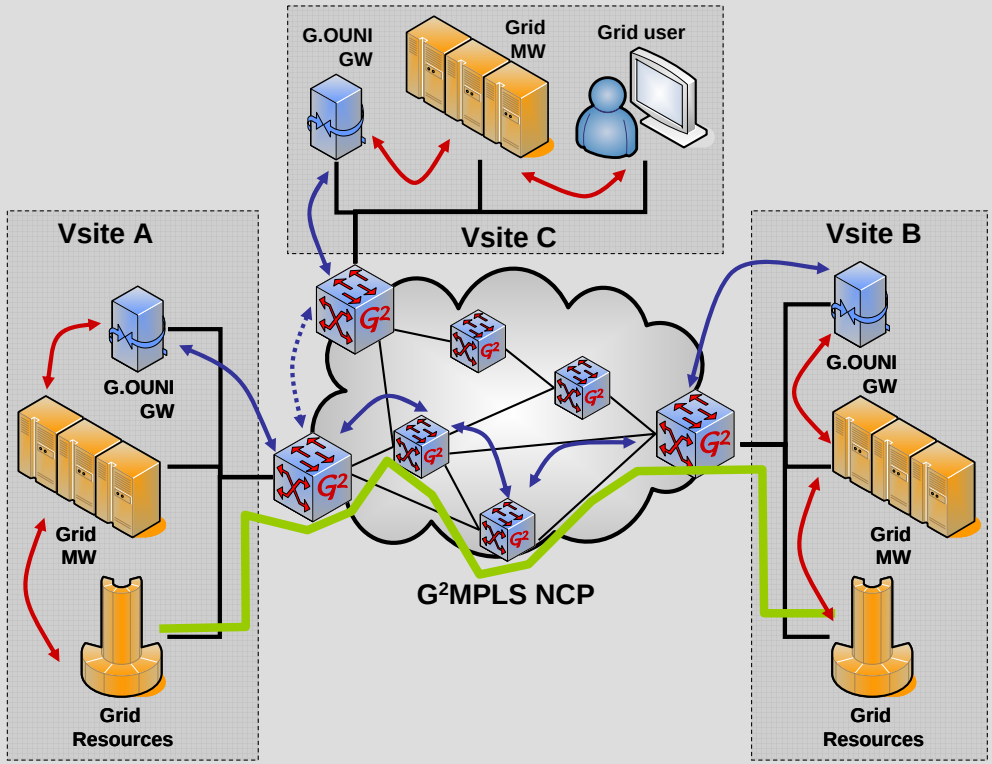
G²MPLS main use cases: GNS – direct invocation

Use case	
Number	UC#2
Name	GNS transaction – Direct Invocation
Goal	A Grid User configures and requests the execution of a job that involves Grid resources located at his local GridSite A and at GridSite B
Actors	Grid User at GridSite A
System components	GridSite A o Client Application o Grid middleware o Local Grid resources o G.OUNI gateway GridSite B o Grid middleware o Local Grid resources o G.OUNI gateway G²MPLS network control plane o G².LERs with G.OUNI-N functionality o G².LSRs
Preconditions	Grid Middlewares at GridSite A and GridSite B (local Grid scheduler in particular) are aware of the types and amount of Grid resources located at their own site (directly) and at remote sites (via G.OUNI service and resource discovery).
Postconditions	Grid Middlewares (local Grid scheduler in particular) advertise the new status/availability of the resources under their control.
Trigger	The Grid User defines the job in the Client Application and issues the request.

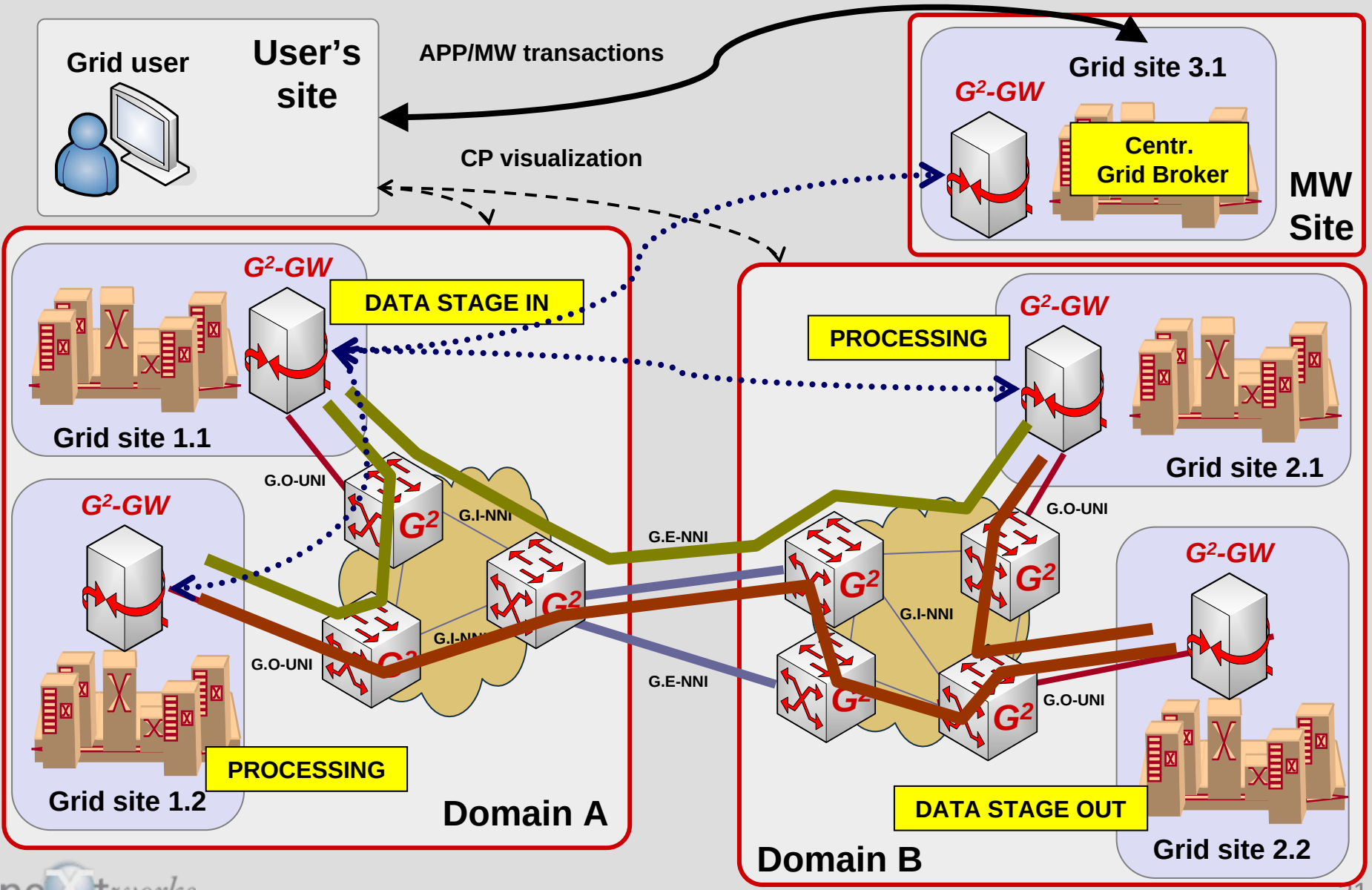


G²MPLS main use cases: GNS – indirect invocation

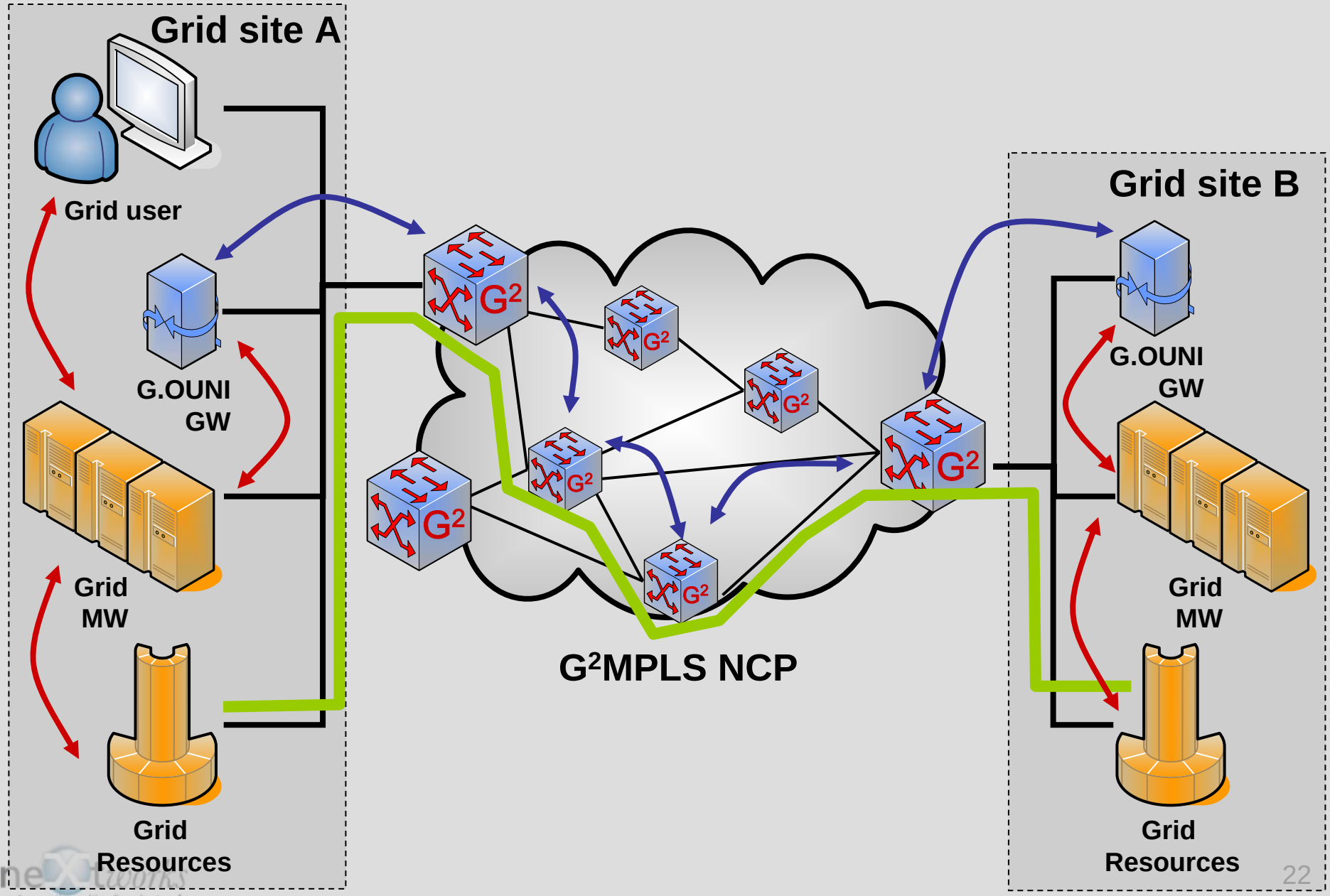
Use case	
Number	UC#3
Name	GNS transaction – Indirect Invocation
Goal	A Grid User at GridSite C configures and requests the execution of a job that involves Grid resources located remotely at GridSite A and GridSite B
Actors	Grid User at GridSite C
System components	GridSite A, GridSiteB o Grid middleware o Local Grid resources o G.OUNI gateway GridSite C o Client Application o Grid middleware o G.OUNI gateway G²MPLS network control plane o G².LERs with G.OUNI-N functionality o G².LSRs
Preconditions	Grid Middlewares at GridSite A, GridSite B and GridSite C (local Grid scheduler in particular) are aware of the types and amount of Grid resources located at their own site (directly) and at remote sites (via G.OUNI service and resource discovery).
Postconditions	Grid Middlewares (local Grid scheduler in particular) advertise the new status/availability of the resources under their control.
Trigger	The Grid User defines the job in the Client Application and issues the request.



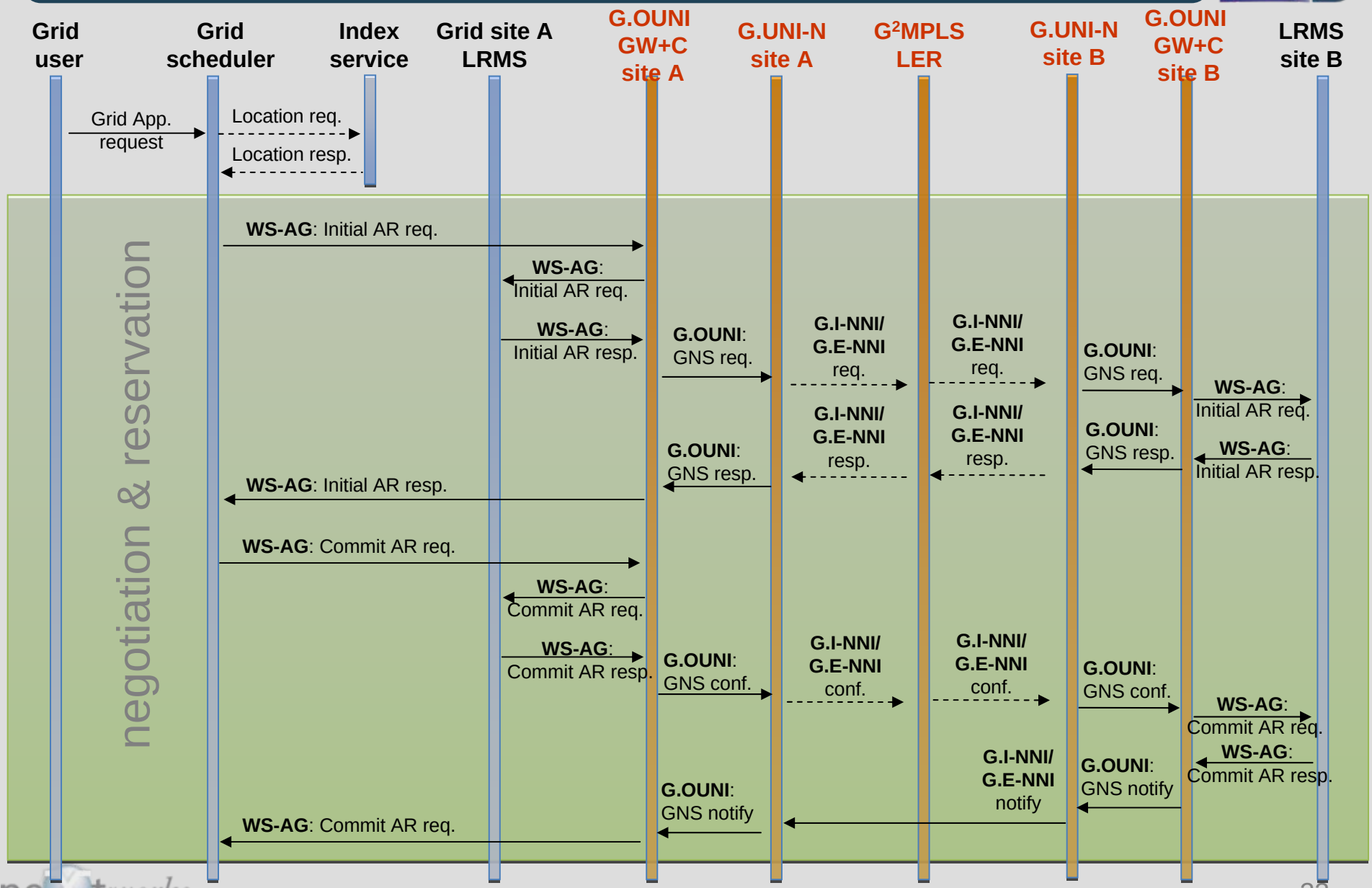
G²MPLS anycast service



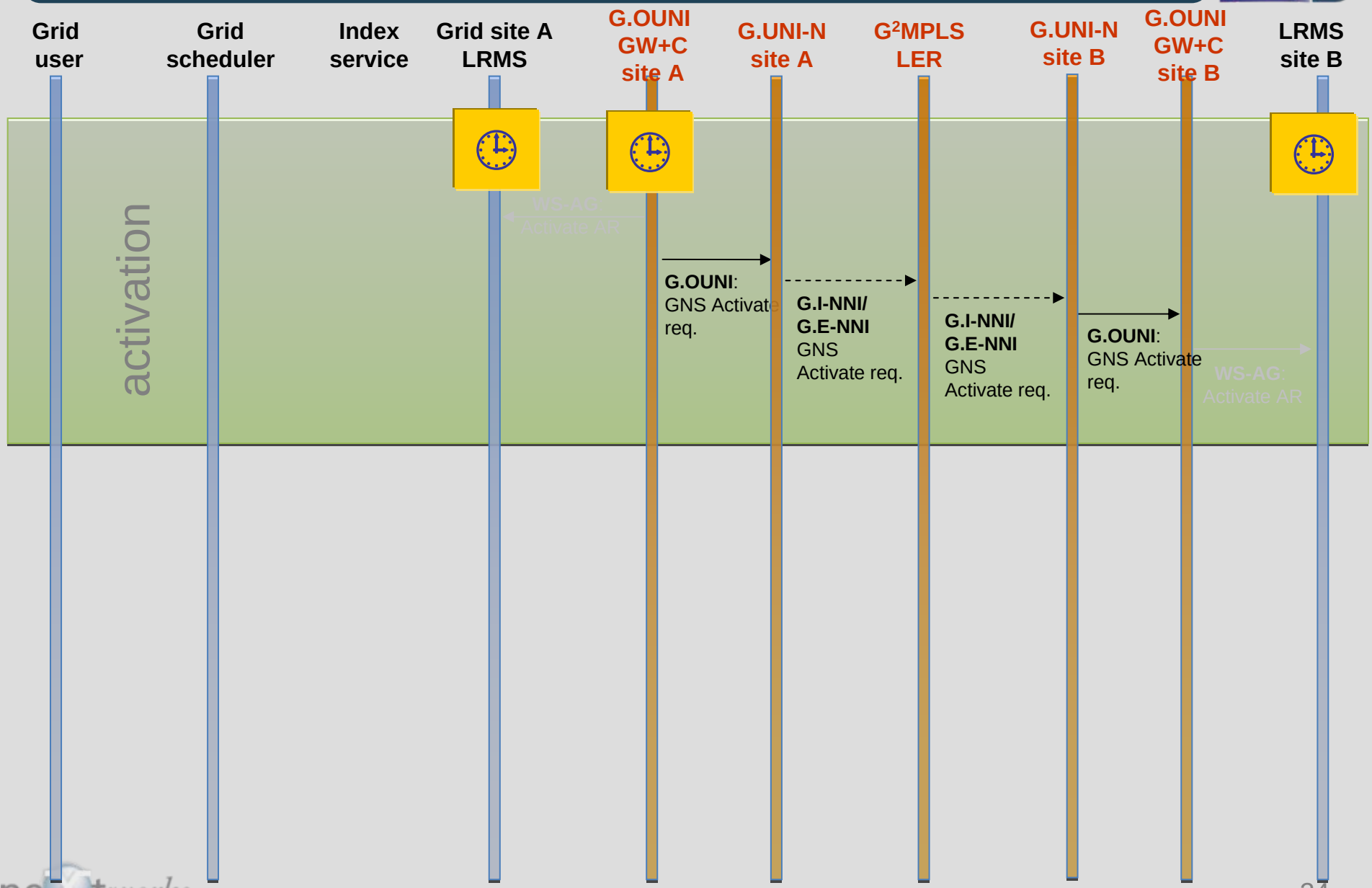
Example of direct invocation [1]



Example of direct invocation [2]

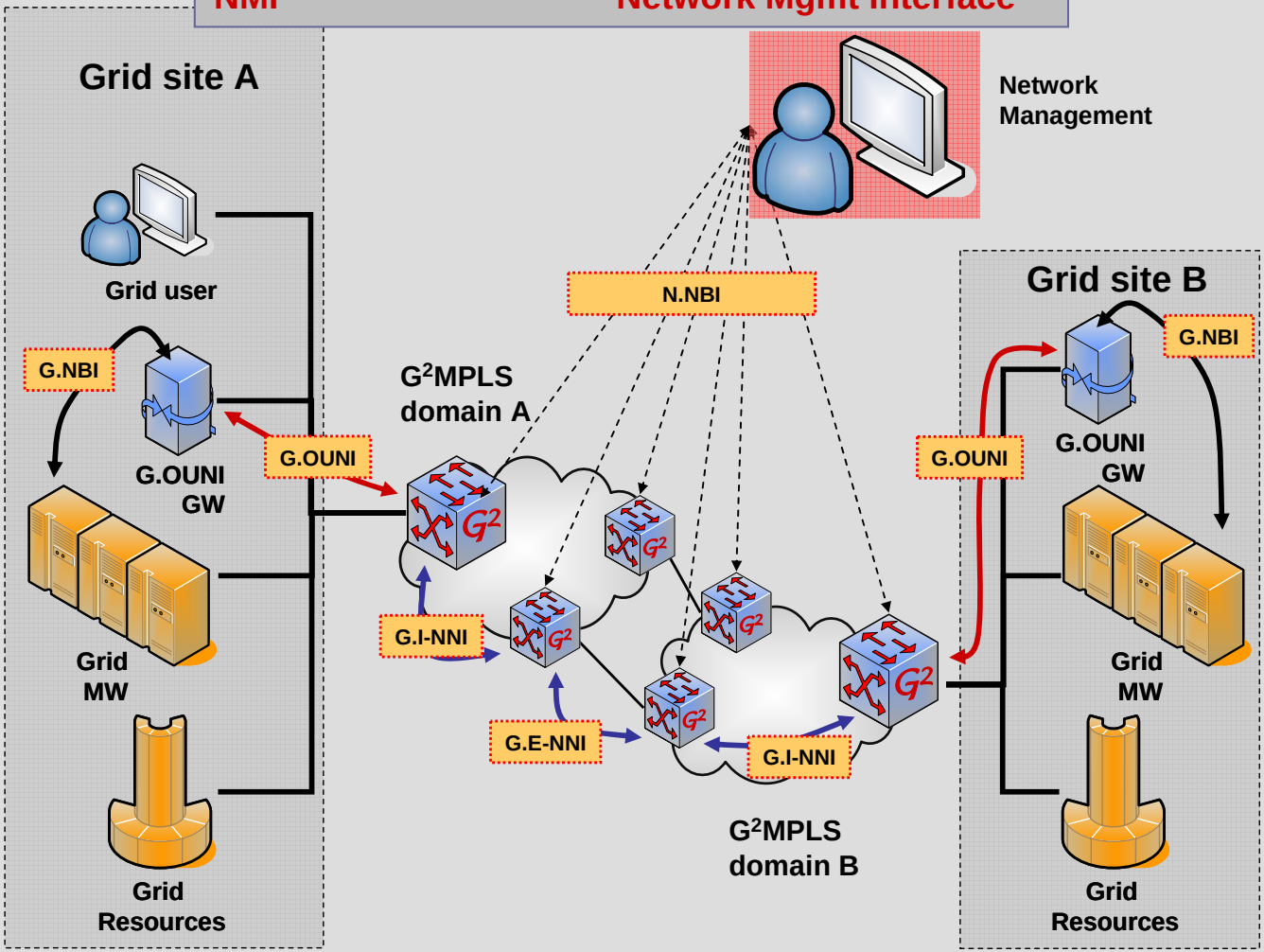


Example of direct invocation [3]



G²MPLS reference points

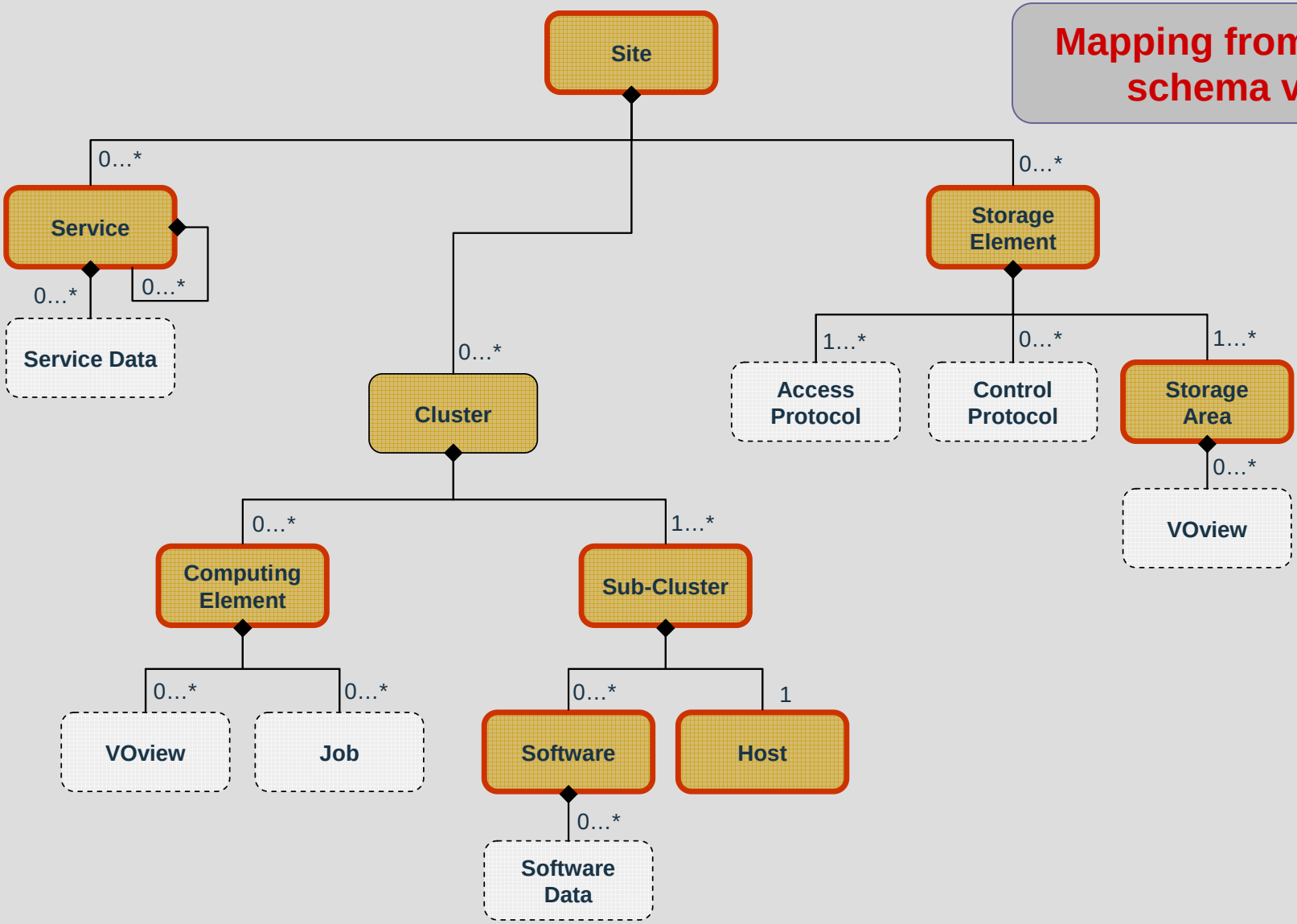
G.OUNI, G.E-NNI	East-West interfaces
NBI	North Interface
SBI	South Interface
NMI	Network Mgmt Interface



G²MPLS extensions to GMPLS

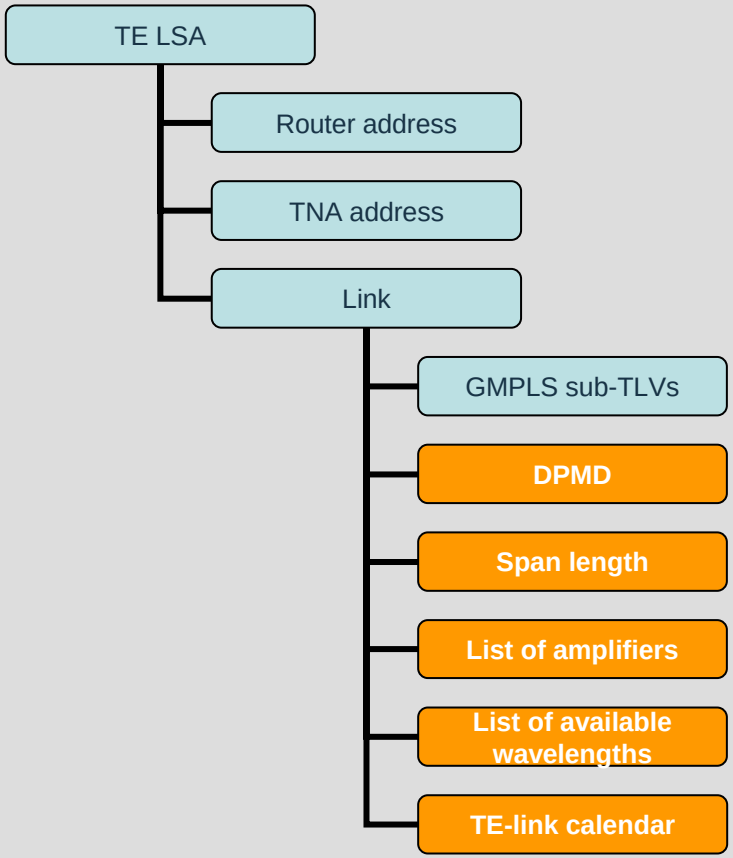
	Services at reference point		ASON / GMPLS	G²MPLS Overlay	G²MPLS Integrated
G.I-NNI	*Routing*	(TE) topology resource publication and discovery	✓	✓	✓
		Opaque piggybacking of discovered Grid resources		✓	✓
	Signalling	Connection (LSP) setup/tear-down/crankback	✓	✓	✓
		Connection (LSP) status inquire/notification	✓	✓	✓
		Opaque piggybacking of Grid job (JSDL) data		✓	✓
		Handling of Grid job (JSDL) data (anycast GNS)			✓
G.OUNI	*Routing*	Grid resources publication and discovery		✓	✓
	Signalling	NS (call) setup/tear-down	✓	✓	✓
		NS (call) status inquire/notification	✓	✓	✓
		Transparent handling of Grid job (JSDL) data		✓	✓
		(Advance) GNS setup/tear-down			✓
		(Advance) GNS status inquire/notification			✓
G.E-NNI	*Routing*	Network (TE) inter-domain resources publication and discovery	✓	✓	✓
		Inter-domain TE information feed-up/feed-down	✓	✓	✓
		Grid inter-domain resources publication and discovery		✓	✓
		Inter-domain Grid information feed-up/feed-down		✓	✓
	Signalling	NS (call) setup/tear-down	✓	✓	✓
		NS (call) status inquire/notification	✓	✓	✓
		Handling of Grid job (JSDL) data (anycast GNS)		✓	✓
		(Advance) GNS setup/tear-down			✓
		(Advance) GNS status inquire/notification			✓

Grid resource modelling in G²MPLS routing

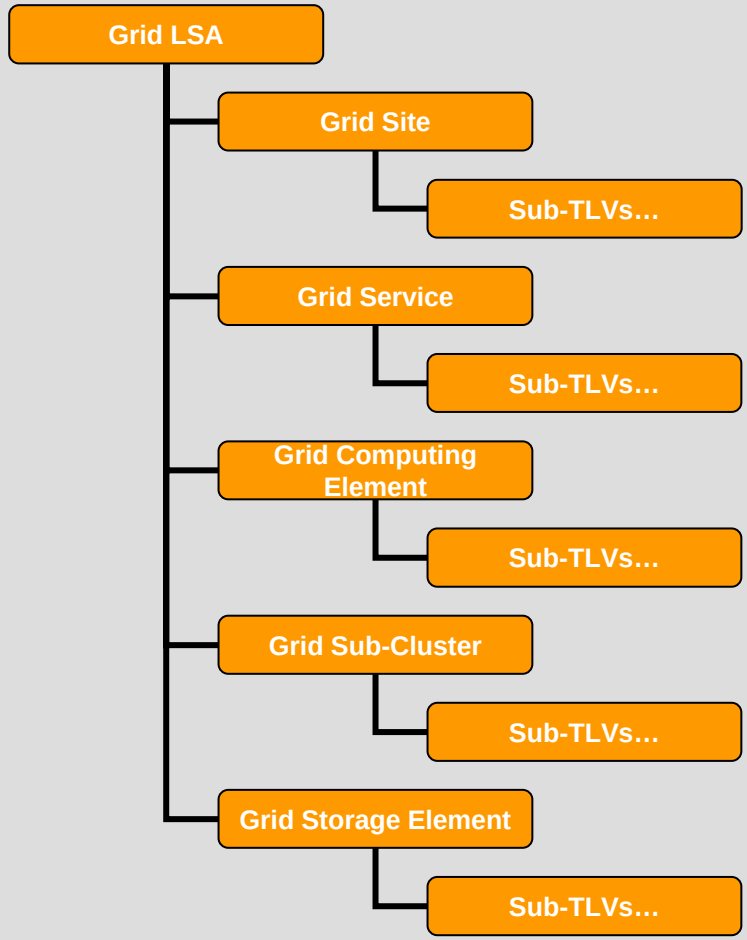


G² extensions to OSPF @ G.I-NNI & G.UNI

- Network-related extensions
  - new sub-TLVs for optical constraints in Link TLV in the TE LSA



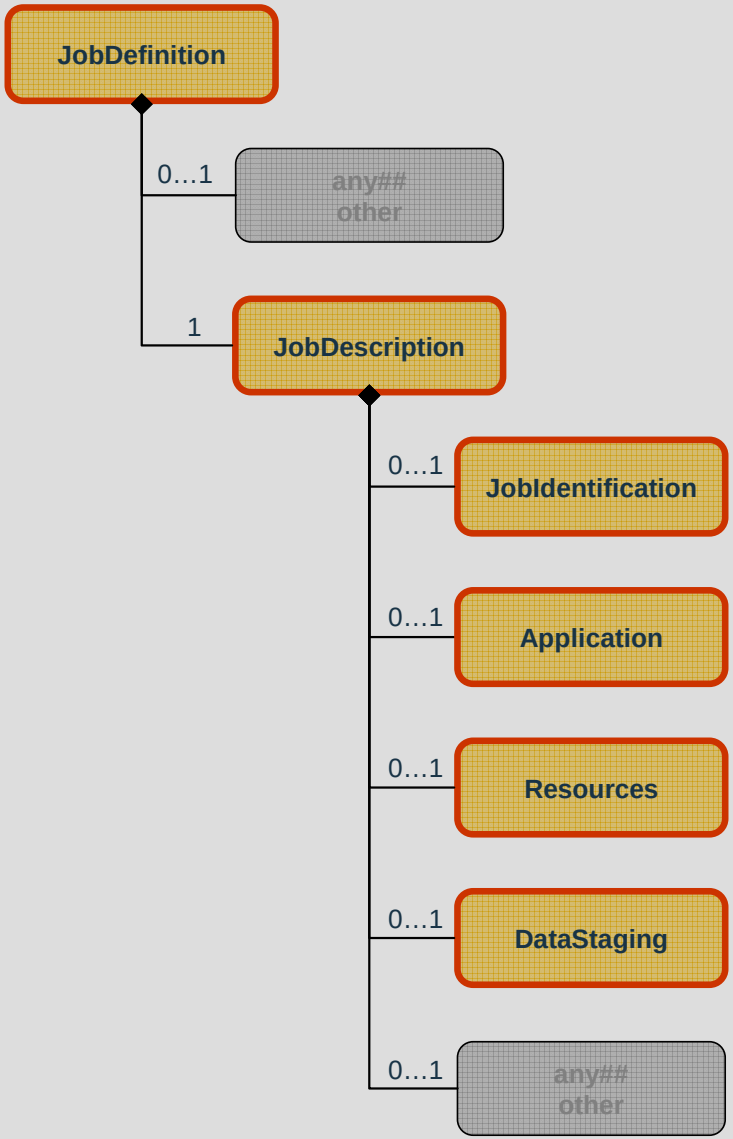
- Grid-related extensions
  - new opaque LSA: **Grid LSA**
  - + top-level TLVs in it
  - + sub-TLVs in each of them



G²MPLS routing extensions: G.E-NNI considerations

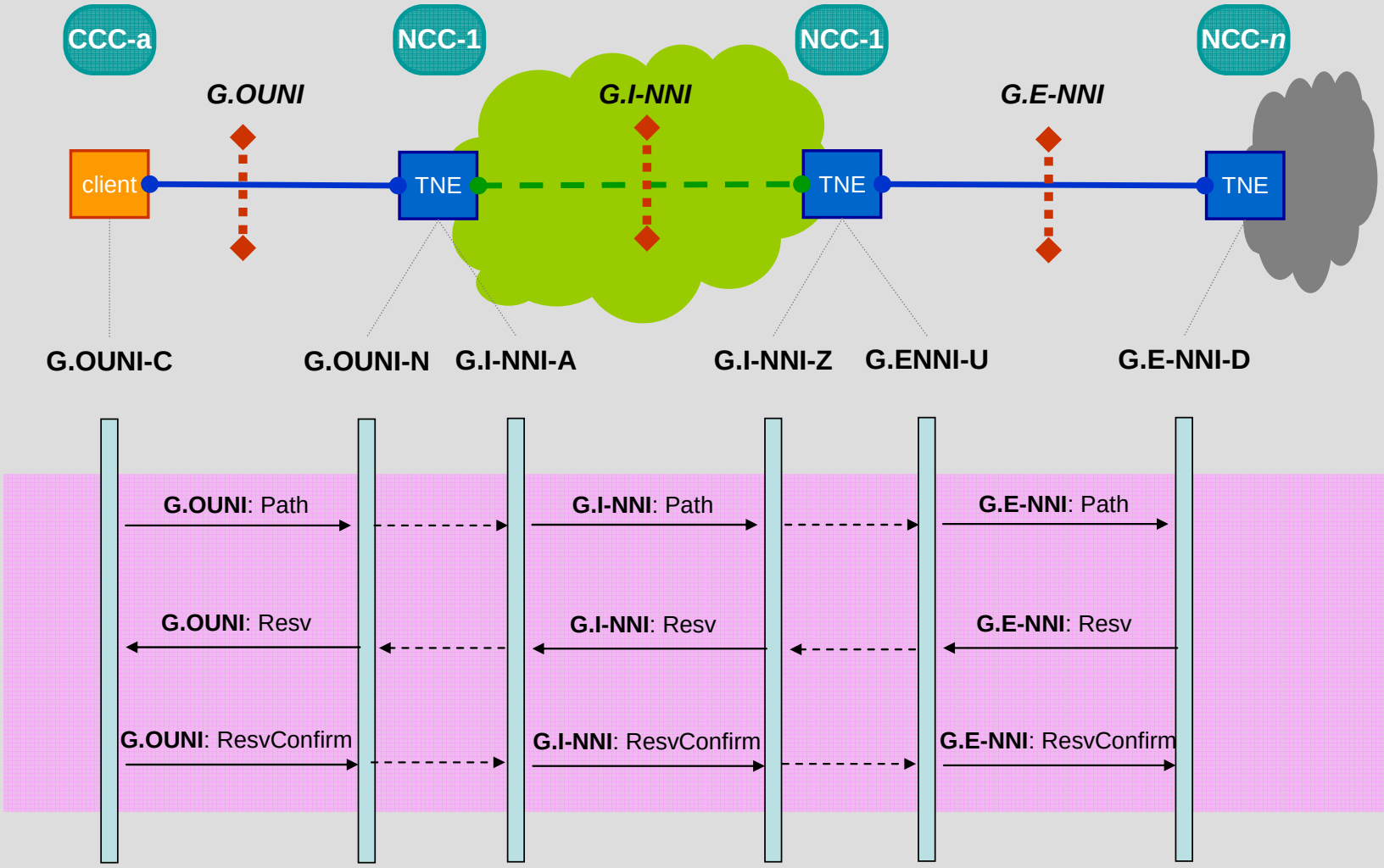
- based on the standard OIF E-NNI OSPF extensions + G².OSPF-TE extensions
- G²MPLS extensions for TE-link top-level TLV → optional parameters for both inter-domain and intra-domain TE links
- Grid Site TLV may be filtered (site ID is contained in other top-level TLVs)
- Grid Sub-Cluster and Storage Element TLVs natively summarize information related to the Grid site
  - to publish a minimum homogeneous bundled set is a configuration policy (
- Grid Service and Computing Element TLVs could/should be summarized during the feed-up at RCs
  - Strategy: bundle homogeneous mandatory information (e.g. LRMS Info for Computing Element, Service Info for Service TLVs)

Grid job modelling in G²MPLS signalling

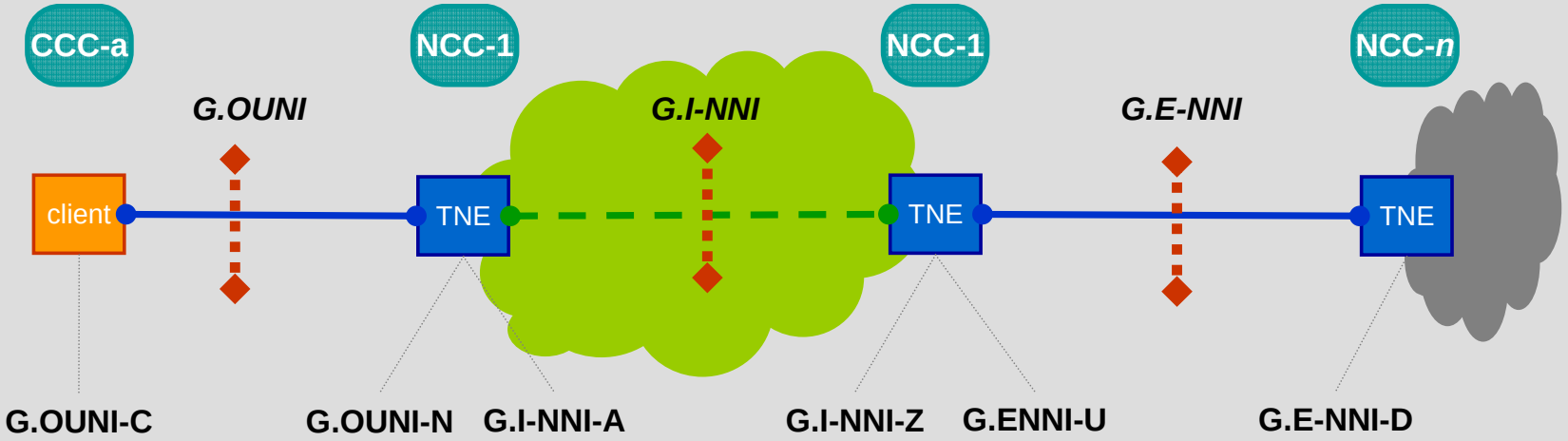


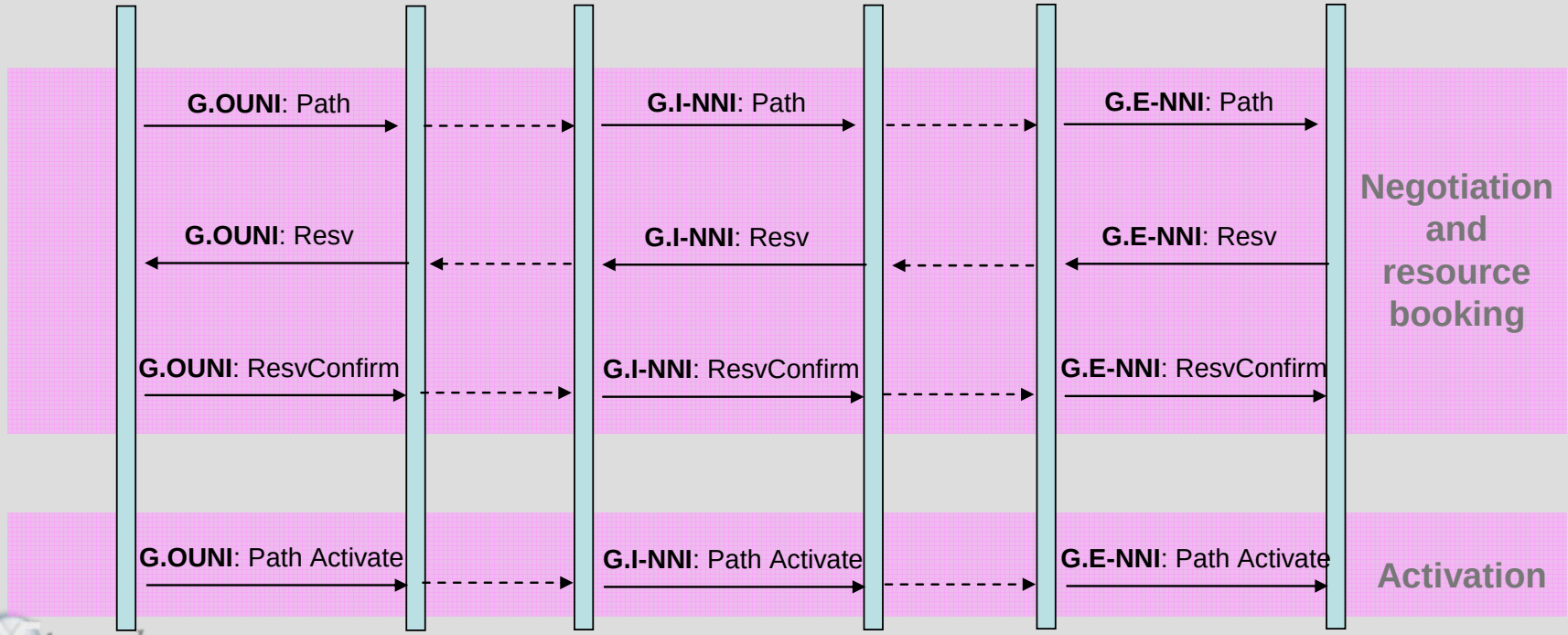
Mapping from JSDL schema v1.3

Immediate GNS transaction setup

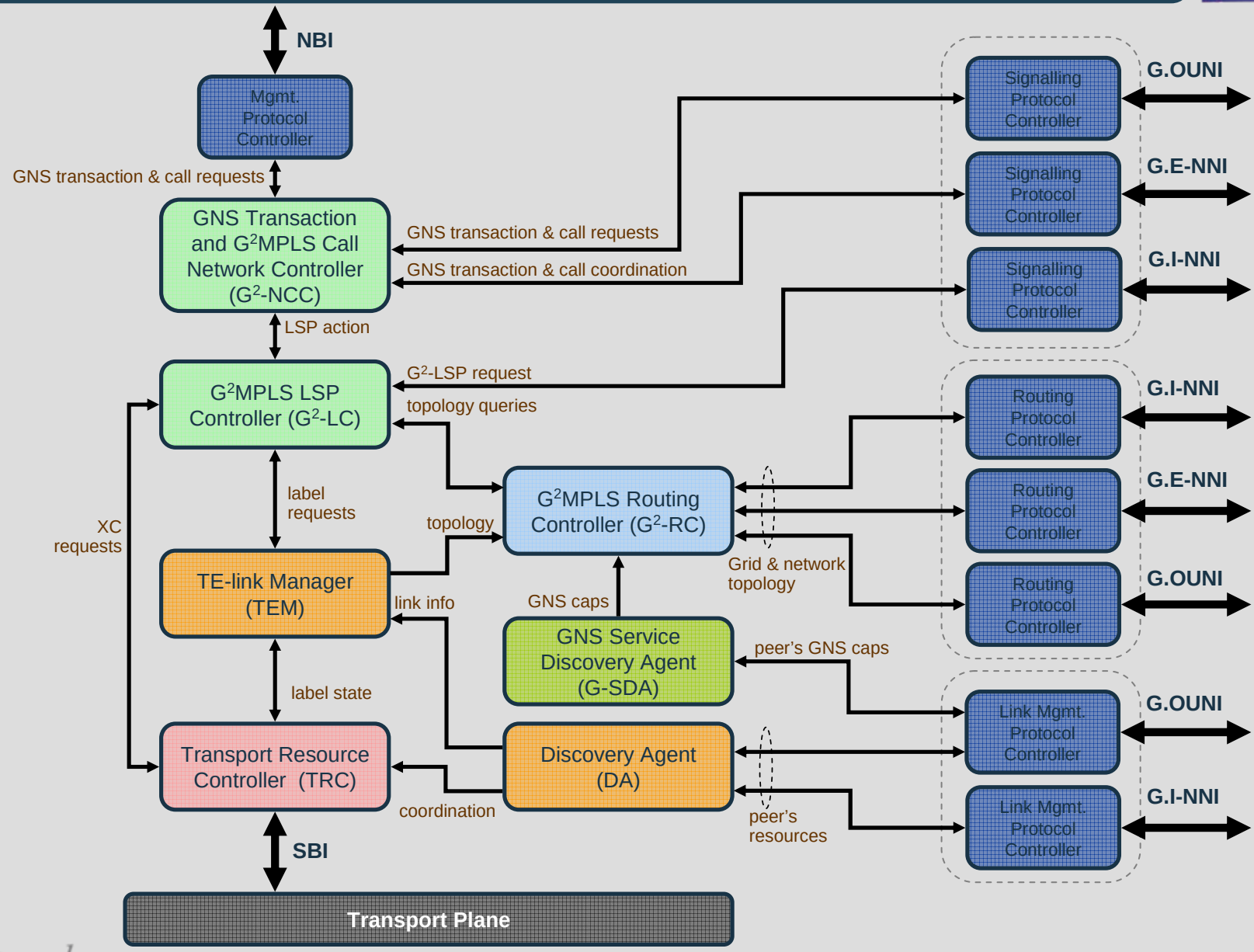


Advance reservation of GNS transaction





G²MPLS controller functional decomposition



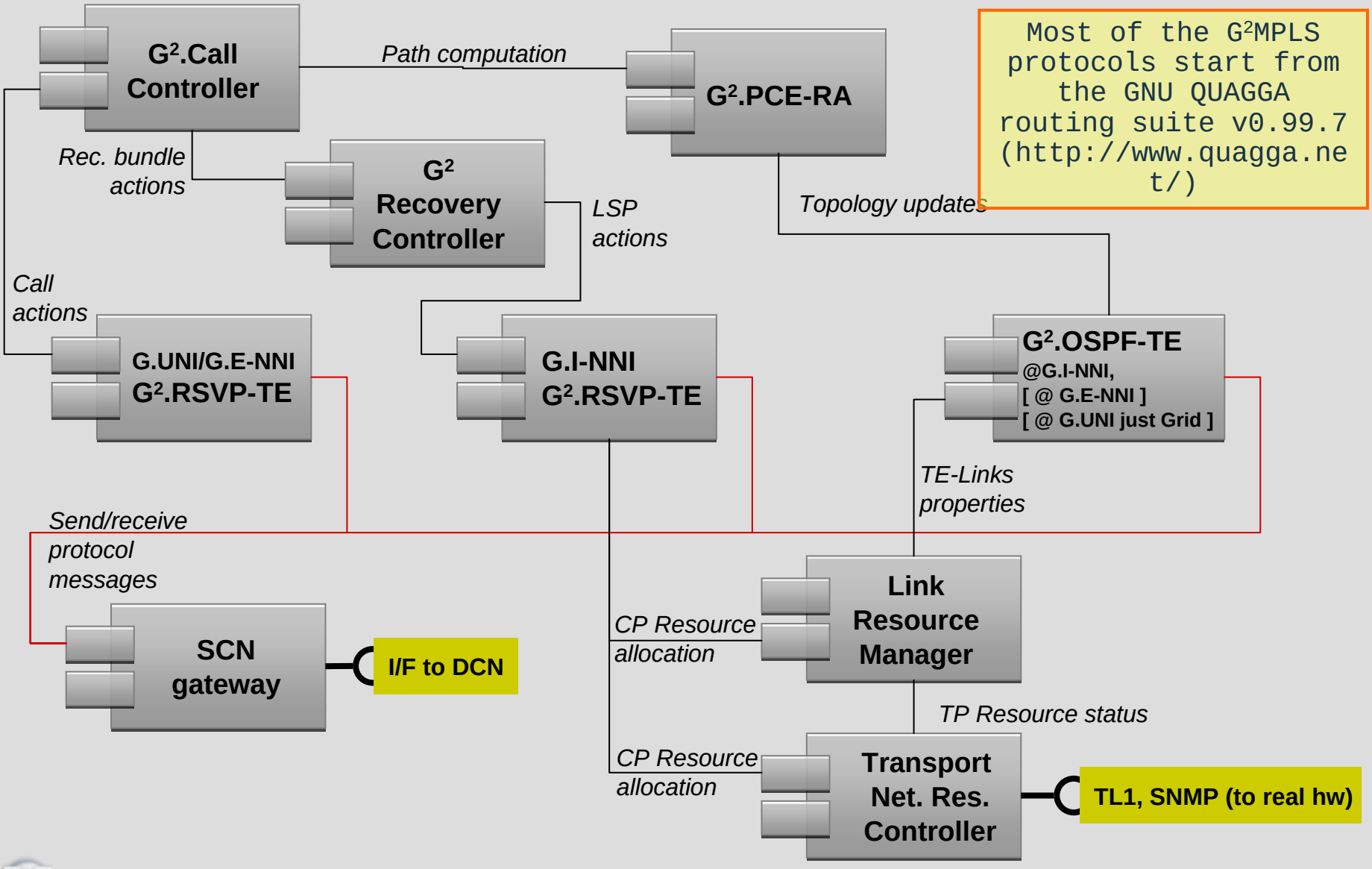
G²MPLS functional components [1]

- GNS Transaction and G2MPLS Call Controller (**G²-CC**)
  - control and management of both GNS Transactions and the related G²MPLS Calls
  - 2 types: calling/called party G²-CC (**G²-CCC**), network G²-CC (**G²-NCC**)
- G²MPLS LSP Controller (**G²-LC**)
  - management of each Label Switched Path (LSP) that is part of a G²MPLS call
- G²MPLS Routing Controller (**G²-RC**)
  - stores an updated topology view of Grid and network resource
  - uses the topology for the computation of paths upon a request from G²-LC
- TE-link Manager (**TEM**)
  - selection and allocation/de-allocation of resources (<Data-link, label>) in TE-link for signalling purposes
  - management of the TE-link status and bundling information for topology purposes

G²MPLS functional components [2]

- GNS Service Discovery Agent (**G-SDA**)
  - discovers Grid and network capabilities between a GridSite attached to the G.OUNI (client side) and the G²MPLS NCP (network side)
- Discovery Agent (**DA**)
  - discovers network resources (i.e. by correlation and verification) in the G²MPLS NCP
- Transport Resource Controller (**TRC**)
  - abstracting the technology specific details of the switching resources for NCP
- Protocol Controllers (**PC**)
  - maps the contents and actions of the interfaces into objects and messages of the G²MPLS protocol instances
  - 3 types
    - Signalling (**SPC**) → G².RSVP-TE
    - Routing (**RPC**) → G².OSPF-TE
    - Link management (**LPC**) → LMP (G.LMP?)

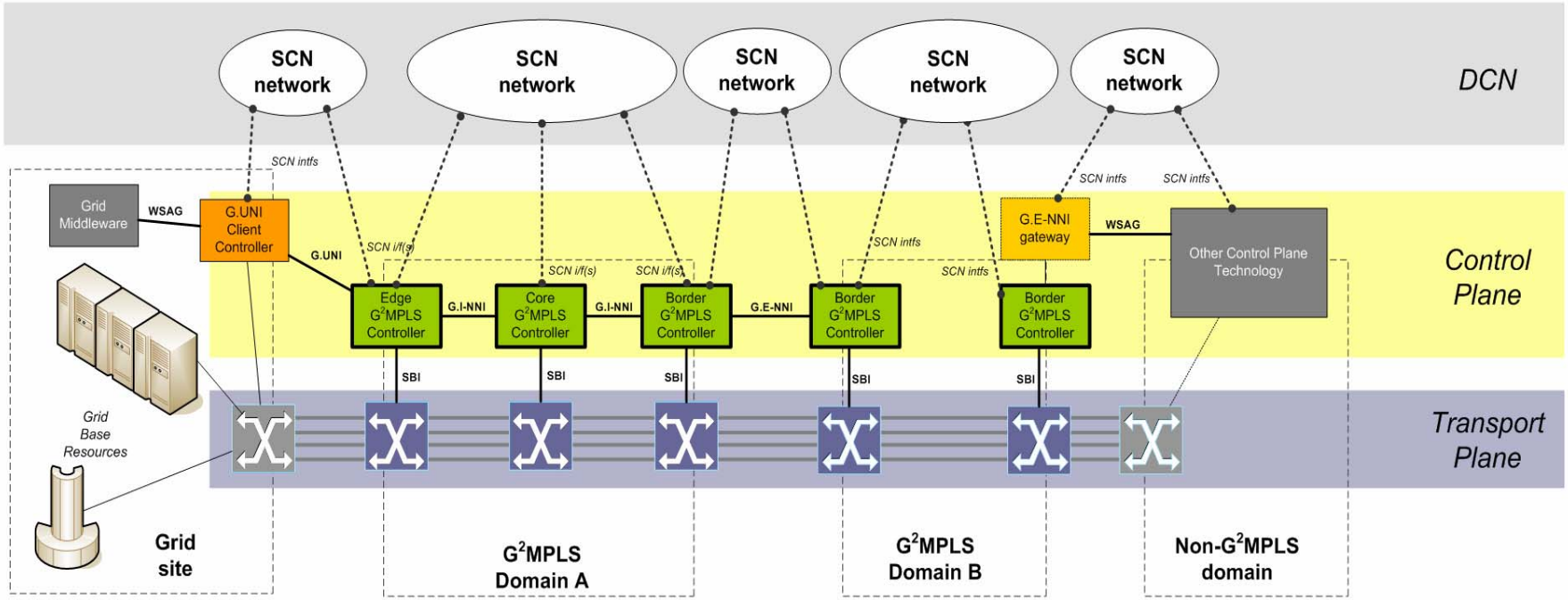
G²MPLS main software modules



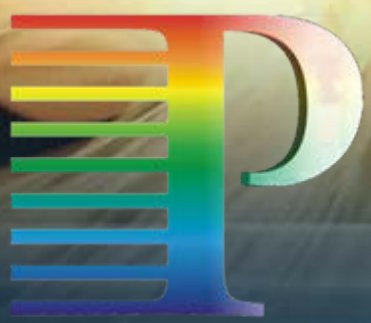
Some info about developments

- **Based on Quagga stack**
  - with some non-Quagga protocols
  - Internal CORBA (omniORB) middleware
- **Migration of QUAGGA to GMPLS**
  - **“Skeleton” GMPLS stack components**
    - Link Resource Manager (per ASON: a manager of TE links, data links and labels)
    - SCN Gateway client/server (to support the decoupling of TN and SCN)
    - cross-protocol utilities identified and implemented
    - a tool for the automated code generation for Finite State Machines
  - **Migration of QUAGGA protocols to GMPLS**
    - GMPLS extensions to the QUAGGA OSPFv2 daemon
    - From-scratch implementation of a GMPLS RSVP-TE integrated in QUAGGA
- **Grid extensions to GMPLS routing and signalling protocols**
  - Grid extensions to QUAGGA GMPLS OSPFv2 daemon
  - Grid extensions to the Phosphorus GMPLS RSVP-TE
- **Grid Optical User Network Interface (G.OUNI) implementation**
  - G.OUNI (both –N and –C) version of the Phosphorus GMPLS RSVP-TE
  - Interfacing to middleware
- **Call Controller and Recovery Controller**

G²MPLS controllers



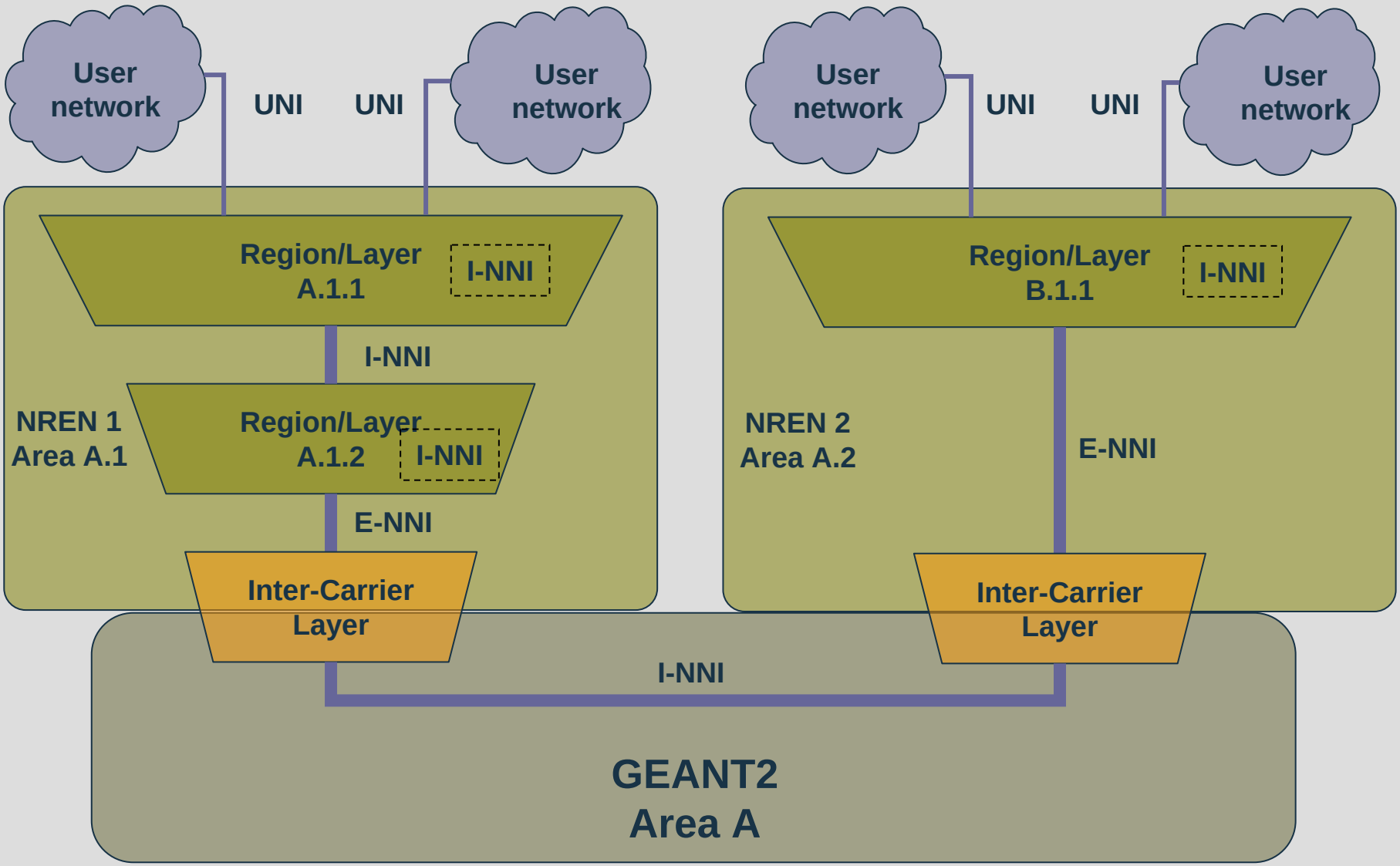
- A preliminary prototype publicly delivered as XEN VM (http://www.ist-phosphorus.eu/deliverables.php, ref. D2.5)
  - Supports ADVA FSP300RE-II ROADM, Calient DiamondWave FiberConnect
- Demonstrated at SC'08 and ICT-2008
- Final prototype scheduled for public delivery Jan 2009



PHOSPHORUS

Deployment of GMPLS at NRENs

A proposal for GMPLS deployment in NRENs



Deployment of G²MPLS in NRENs

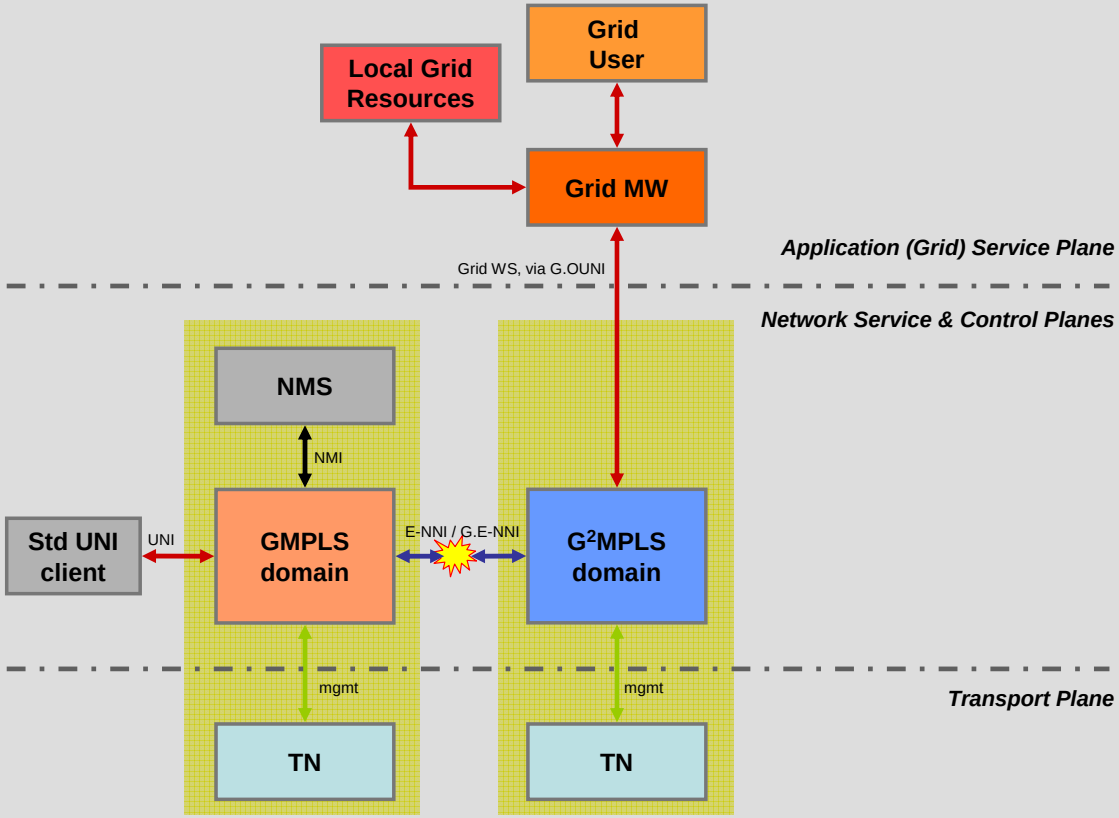
- Some add-ons to the required GMPLS feature list
  - **Advance reservations**
  - Co-existence with adjacent NRPS
  - **Clear resource partitioning and virtualization**
  - Path computation for **lambda networks (optical impairments)** + management of advance reservation
- Grid+network specific desiderata
  - **Integration of Grids with NRENs** infrastructures (a.k.a. add a CP to Grids)
    - No more a “ships-in-the-night” style but reciprocal awareness and seamless one-step configuration
  - Identification of the reference points and CP models
  - Integration and escalation of **recovery** procedures
  - Integration with existing **AAA AuthZ** mechanisms for Grids
  - Integration with existing NMS

Coexistence of GMPLS and G²MPLS [1]

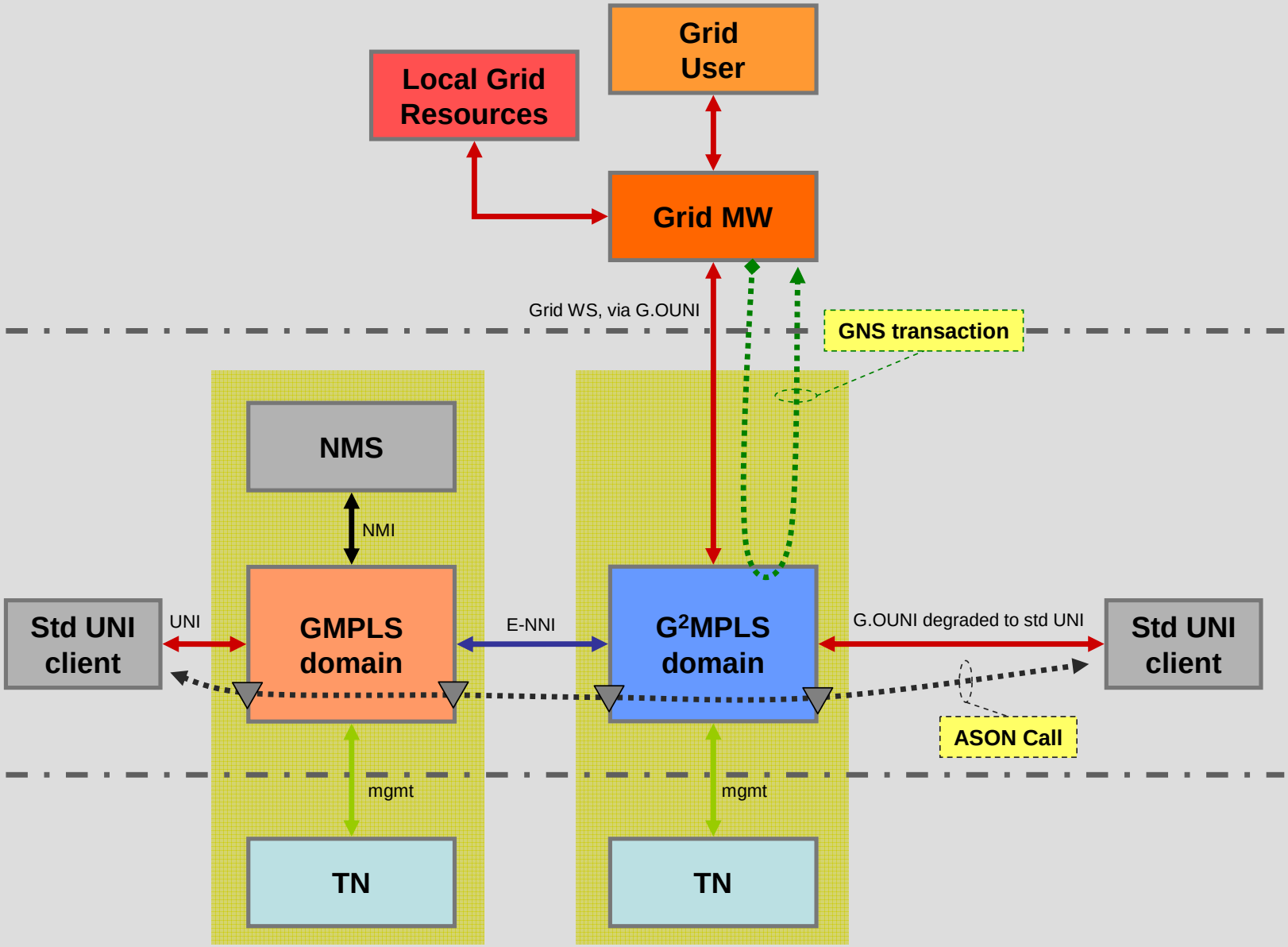
- Mainly an inter-domain problem
  - G²MPLS nodes dispersed in GMPLS domains act as std-GMPLS nodes (routing, signalling)
  - GMPLS nodes merged in G²MPLS domains CANNOT act as G²MPLS nodes
- The most convincing future scenario for intra-domain coexistence seems to be a multi-region domain
  - Phosphorus G²MPLS used to provide CP capabilities to equipments currently lacking in it (e.g. carrier Ethernet switches or similar)
  - Off-the-shelf GMPLS used to control SDH or WDM technologies

Coexistence of GMPLS and G²MPLS [2]

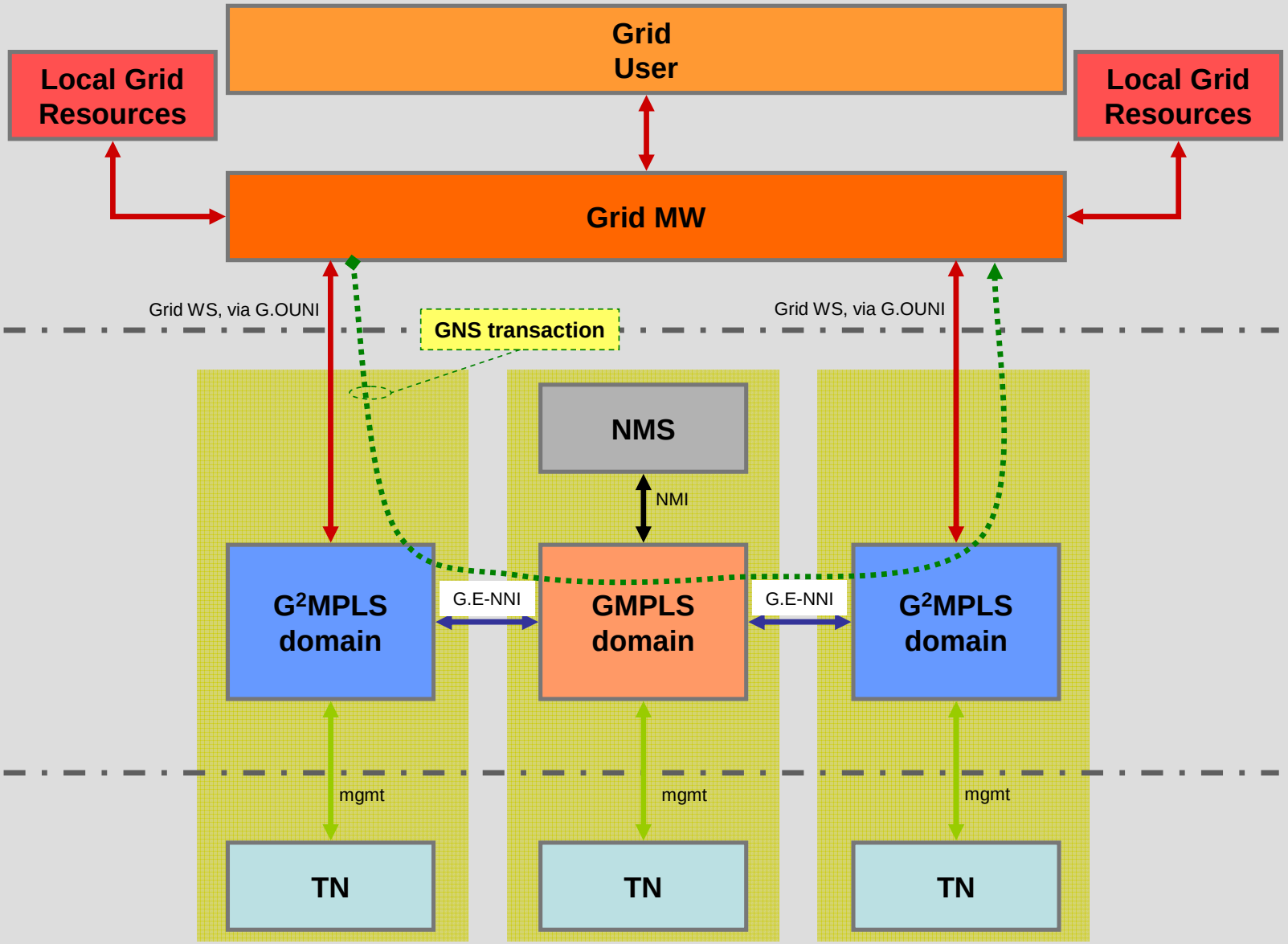
- … but in the inter-domain context
  - G²MPLS domains handle both Grid and network resources
  - ASON/GMPLS domains control only network resources
- This implies a reduction of the information set carried out through the G.E-NNI, both for routing purposes and, above all, for signalling



GMPLS/G²MPLS: 2-parties scenario



GMPLS/G²MPLS: 3-parties scenario



Support to this analysis [1]

- public questionnaires to NRENs and HPCs
- Goals
  - To collect requirements,
  - To stimulate interest towards our solutions,
  - To identify trends and plans for GMPLS/G^{2}MPLS deployment and/or Grid &network integration
- Questionnaire for NRENs
  - Answers (CESNET2, PIONER, FCCN, DFN, GARR, HEAnet)
- Questionnaire for HPCs
  - Answers (Barcelona Supercomp. Center, CINECA)

Support to this analysis [2]

- Positive positioning mainly by NRENs who are currently missing an automatic control/management system for network and Grid resources or just have test-beds for that
  - Internal to the project (PIONER, CESNET2)
  - External (GARR, DFN)
- “Conditional & polite” consensus by NRENs and HPC external to this consortium probably due to the lack of running and public demonstrations of the Phosphorus concepts
- Main drivers towards consensus
  - capability of Phosphorus GMPLS/G^{2}MPLS to control efficiently the optical infrastructures integrated with the switched Ethernet
  - smooth integration of Phosphorus GMPLS/G^{2}MPLS with the GN2 BoD
  - Support and maintenance of the produced software
  - The wide dissemination of Phosphorus concept