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An Architecture, Protocols, and Information Models for SDN in Flexi-Grid Optical Networks

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What Shall We Talk About?

- Flexi-grid
- Software Defined Networks
- Architectural overview
  - Application-Based Network Operation (ABNO)
  - Interacting with the Control Plane
- Key Components
  - Path Computation Element
  - Traffic Engineering Database
- Data models
  - What, why, how?

Flexible Optical Grid (flexi-grid)

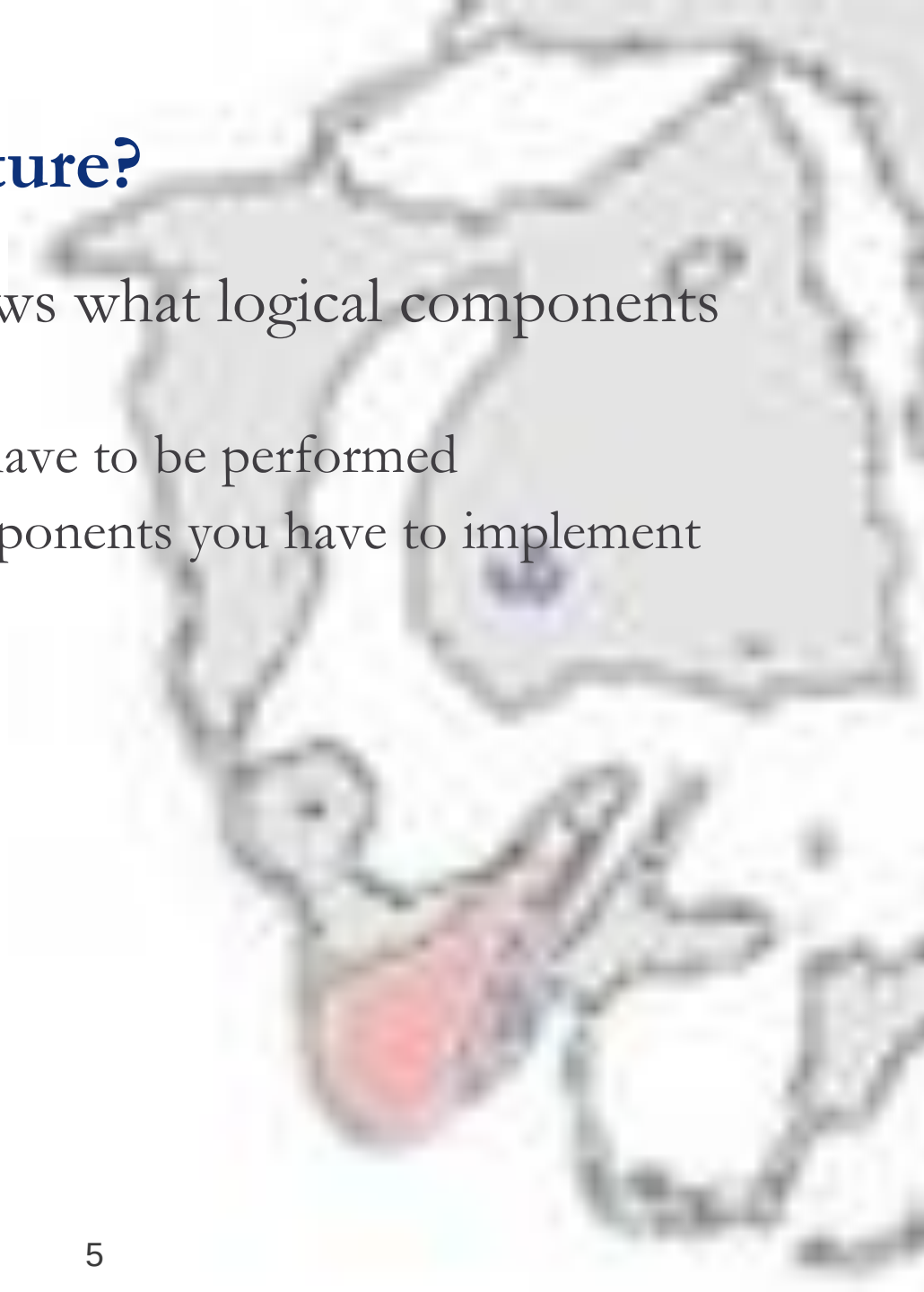
- Hope we know what this is all about!
- Extensions to ITU-T Recommendations
  - G.694.1 and G.872
- Target is to allow efficient allocation of optical spectral bandwidth for high bit-rate systems
  - Enables flexible, application-based tuning of bandwidth use
- Extensions include a new DWDM grid
  - Define a set of nominal central frequencies, channel spacings, and the concept of "frequency slot“
  - Data plane connections are switched based on allocated, variable-sized frequency ranges within the optical spectrum

Software Defined Networking (SDN)

- Yesterday's buzz word
- Everyone has a different definition, but…
  - Centralized view of the network
  - Centralized planning and control
  - Use of software rather than manual intervention
    - More adaptive, flexible, rapid, co-ordinated
- Programming of the network by a variety of means
  - Direct to the network nodes
  - Interaction with a control plane
- Application awareness
  - What are the resources used for?
  - What are the future demands?

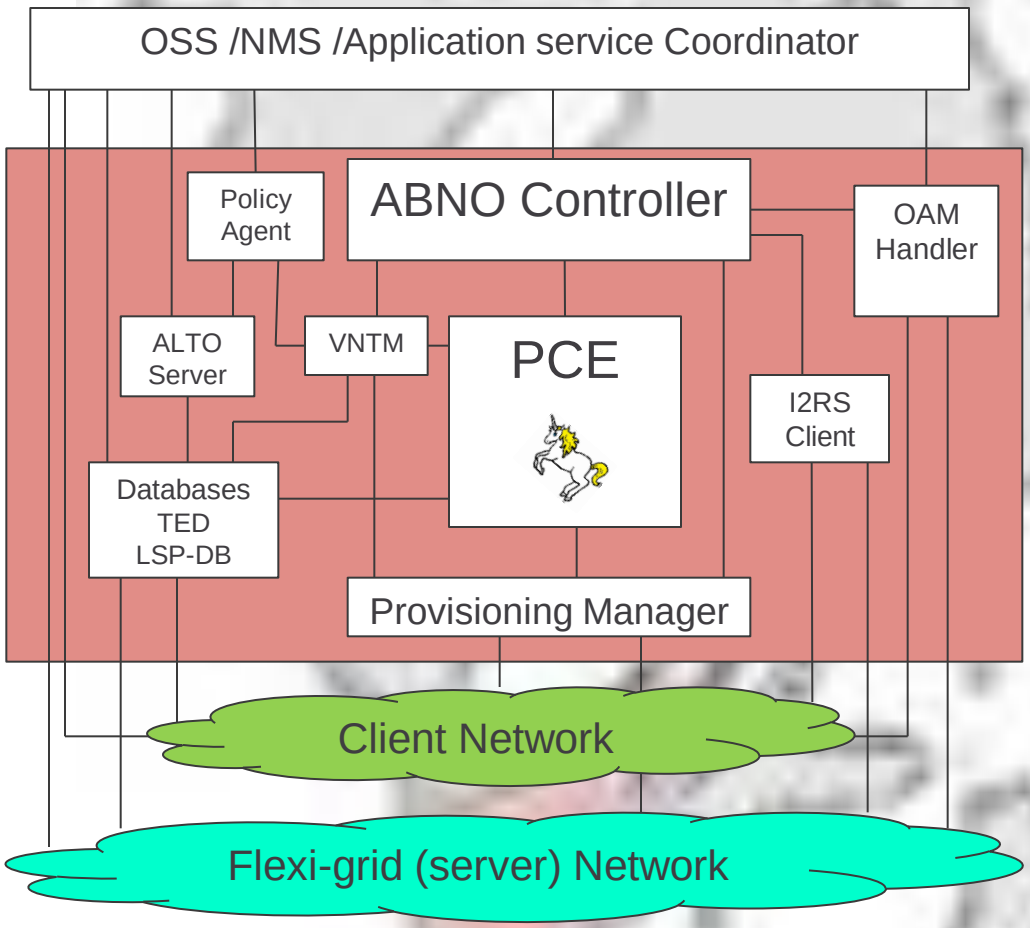
Why have an architecture?

- A *functional architecture* shows what logical components exist
  - What discrete functions have to be performed
  - NOT what software components you have to implement



Application-Based Network Operations

- Functions
  - Service-oriented orchestration
  - Policy and fault management
  - Databases…
    - Topology (TED)
    - Inventory
    - Services (LSP-DB)
  - Path Computation Element (PCE)
    - Path computation and planning
    - Stateful & Stateless
    - Online & Offline
  - Multi-layer Coordination
    - Virtual Network Topology Manager
- Interfaces and protocols
  - Requesting services
    - NETCONF/YANG
  - Programming the Network
    - OpenFlow
    - PCEP
    - Interface to the Routing System (I2RS)
    - NETCONF/YANG
- Control plane
  - Discussed in two slides time



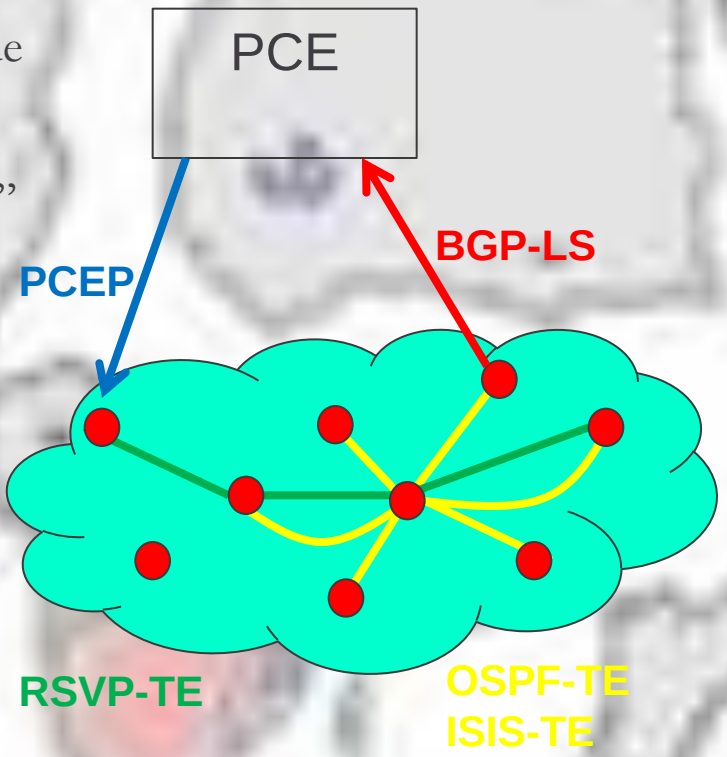
RFC 7491 ABNO Architecture

Path Computation Element (PCE)

- The Madjick at the heart of SDN
- Computes paths through the network
  - P2P, P2MP, MP2P, MP2MP
- Uses knowledge of the network
  - Topology
  - TE capabilities
  - Resources in use and available
  - Paths (LSPs) already set up
  - Scheduled resource usage
- Issues instructions to program the network
  - Create new LSPs
  - Re-organise existing LSPs

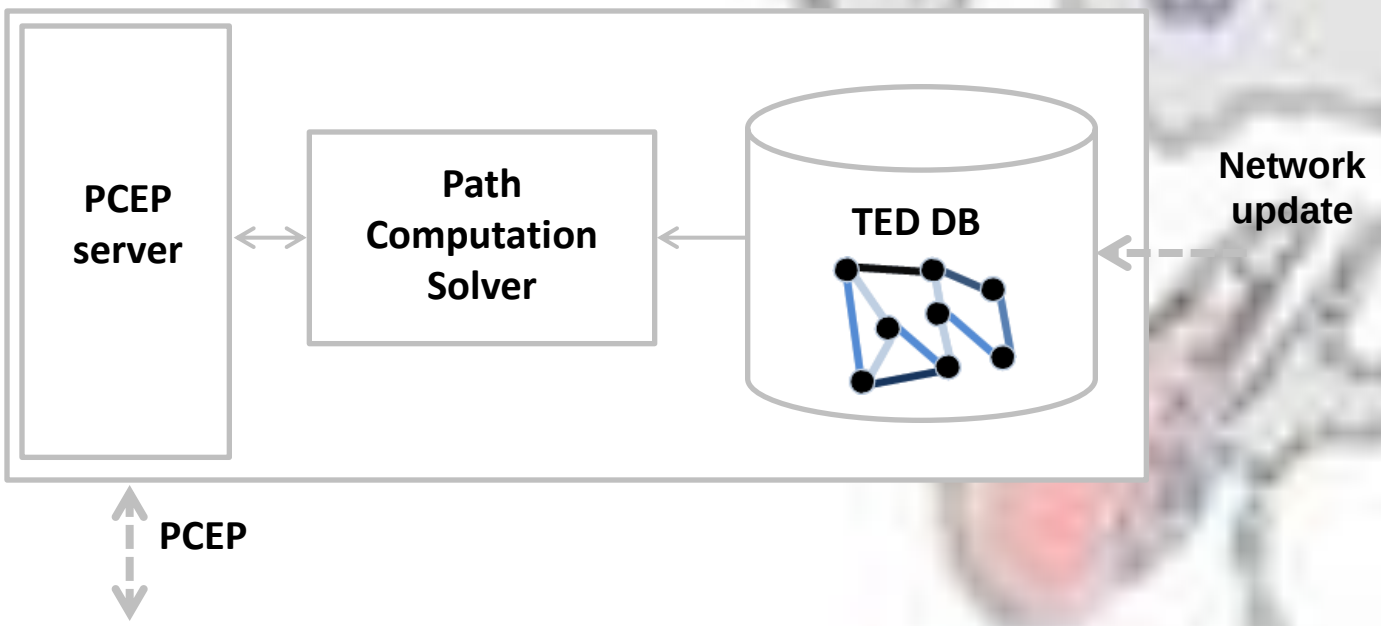
SDN with a Control Plane

- A common misunderstanding
  - "SDN implies node-by-node programming of the network"
- SDN is about centralised view and control
  - How to convert into network state is an open issue
- One option is node-by-node programming
  - Such as OpenFlow or ForCES from a "controller"
- We choose a hybrid approach
  - Central control leveraging an active control plane
  - Keeps autonomy and smarts in the network
  - Adds central, programmable control
  - Allows migration to SDN
    - Supports existing deployment models
- Key component is the TED



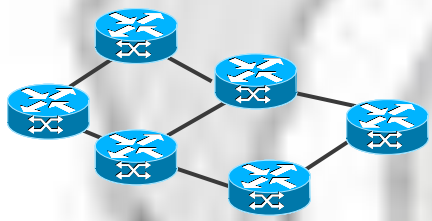
The Traffic Engineering Database

- Traffic Engineering Database (TED) is essential internal component of a PCE
  - Provides the updated snapshot of the controlled network and its resources
  - PCE algorithms resort to TED as primary information source input

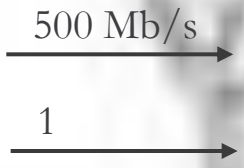


What does the TED store?

- The topology of the controlled network
  - Nodes
  - Links
  - Nodes/Links connectivity



- The *available* resources and attributes
  - Available Link Bandwidth
  - Link Metrics (e.g., costs)



- Availability facilitates
  - Reservation for other purposes
  - Partitioning of network resources
  - Network virtualization

Topology and TE Information Distribution OSPF-TE or IS-IS-TE

- Usual link-states IGPs with traffic engineering extensions
  - the standard IP routing protocols (OSPF and IS-IS)…
  - … extended to provide TE and GMPLS information distribution
- States of links in the area
  - metrics, Shared Risk Link Groups, admin. groups/resource classes
  - reserveable bandwidth, unreserved bandwidth
  - Optical switching capability (packet, L2, TDM, lambda, slice, fiber)
  - unnumbered links (Node ID + port ID) may be used
- Optionally some node information
  - TE router ID
  - TE capabilities
- Optionally some inter-domain TE-links connected to the area
  - no IGP adjacency
  - area-scoped flooding of configured parameters

Building the TED from the Network

- Different mechanisms may be used
  - The functional architecture doesn't care how the TED is built
- Information can come from different sources
  - From the network
  - From management
  - Through policy
- Getting information from the network
  - Passive peering with OSPF-TE or IS-IS-TE
  - Through Link State BGP (BGP-LS)
  - Reading from the network devices (e.g., SNMP or YANG)
  - PCEP Notifications

Updates to Existing Protocols for Flexi-Grid

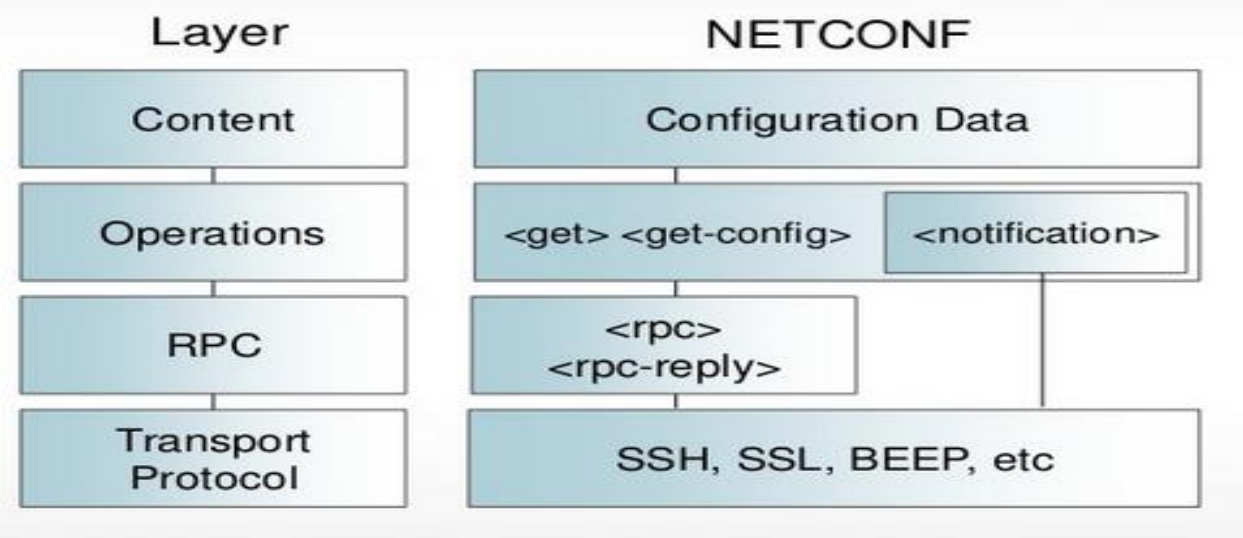
- Flexi-grid is essentially the same as many previous switching technologies
  - Physical network resources are switched at each router
  - Labels explicitly represent bandwidth and physical resources
- Protocol changes are minor
  - Different granularity of resource availability
    - Extra information in the IGPs and in BGP-LS
    - New ways of expressing bandwidth in RSVP-TE and PCEP
  - Need more precision in identifying physical resources
    - New GMPLS label format for use in RSVP-TE and PCEP

Why Build a Standard Topology Data Model?

- Data models let us represent information in a well-known way
- Useful for moving it between implementations
  - Export from the network
    - From a single network node talking about its local resources
    - From a network node that collects and aggregates it from the network
  - Share between servers
    - Exchange between PCEs that synchronize state
  - Store, test, and experiment
    - Archive the network at a point in time
    - Conduct offline tests and experiments on stored topologies
    - Debug networks and software
    - Share topologies between researchers or with suppliers

NETCONF & YANG

- NETCONF is the configuration protocol and YANG is able to model configuration data, state data, operations, and notifications
  - NETCONF will get RESTful support as RESTCONF
- YANG definitions directly map to XML content



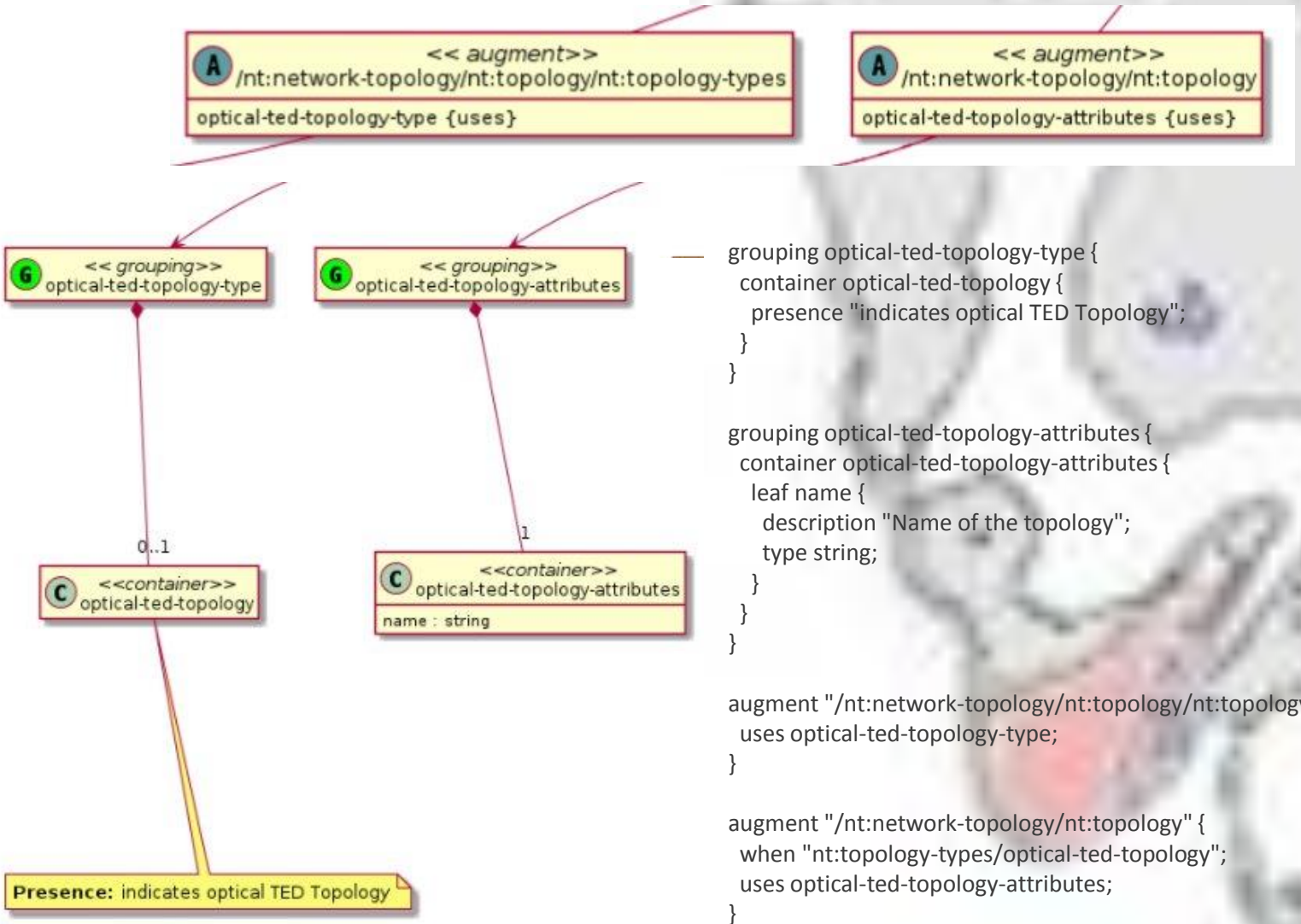
NETCONF & YANG Design Goals

- The design goals for NETCONF, included:
  - Distinction between configuration and state data
  - Multiple configuration data stores:
  - Candidate, running, startup
  - Configuration change validations
  - Configuration change transactions
  - Selective data retrieval with filtering
  - Extensible Remote Procedure Call (RPC) mechanism
- Key YANG Capabilities
  - Human readable, easy to learn representation
  - Hierarchical configuration data models
  - Reusable types and groupings (structured types)
  - Extensibility through augmentation mechanisms
  - Supports the definition of operations (RPCs)
  - Formal constraints for configuration validation
  - Data modularity through modules and sub-modules
  - Versioning rules and development support

Dissemination of Flexi-Grid Network Information

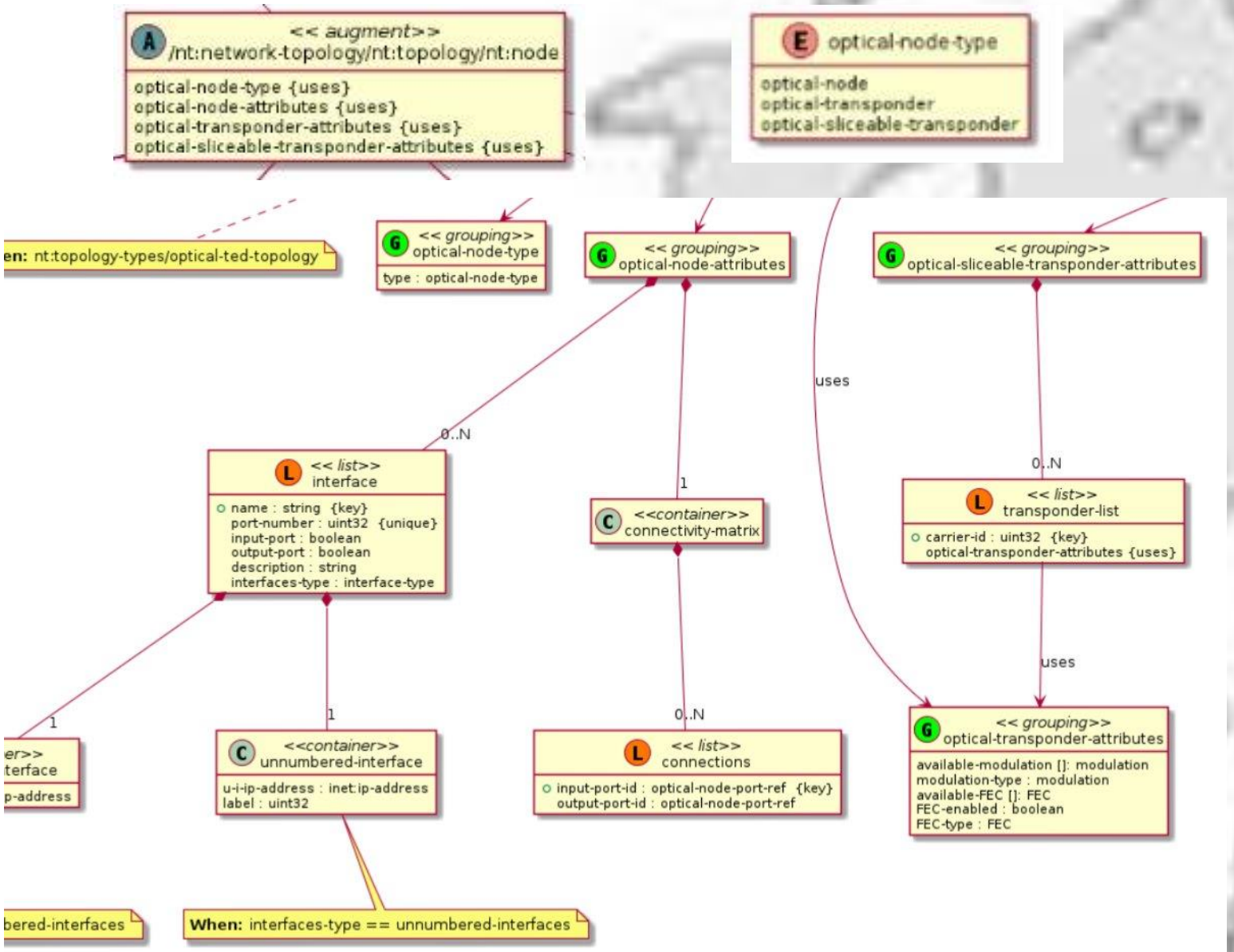
- The YANG model we propose is spilt into two modules:
  - Optical TED
    - Includes: optical-node, optical-transponder and optical-link; optical-sliceable-transponders
    - Each element is defined as a container and includes a set of attributes. The module also includes the data types for the type of modulation, the optical technology such as Forward Error Correction (FEC).
  - Media Channel (two types)
    - An (effective) frequency slot supported by a concatenation of media elements (fibers, amplifiers, filters, switching matrices.)
    - Network Media Channel: is a media channel that transports an Optical Tributary Signal.

Augmented Topology

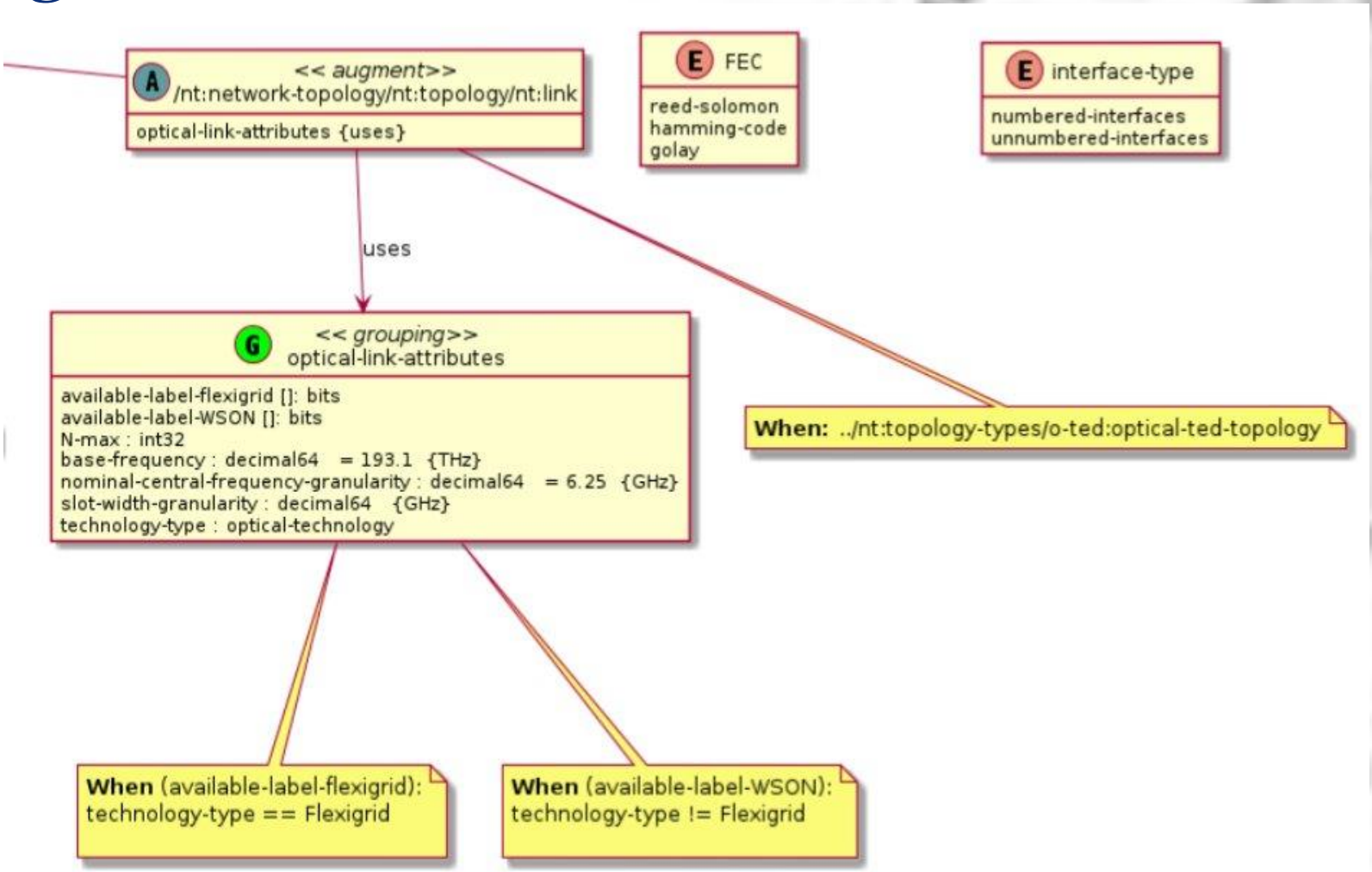



```
grouping optical-ted-topology-type {
  container optical-ted-topology {
    presence "indicates optical TED Topology";
  }
}

grouping optical-ted-topology-attributes {
  container optical-ted-topology-attributes {
    leaf name {
      description "Name of the topology";
      type string;
    }
  }
}

augment "/nt:network-topology/nt:topology/nt:topology-types" {
  uses optical-ted-topology-type;
}

augment "/nt:network-topology/nt:topology" {
  when "nt:topology-types/optical-ted-topology";
  uses optical-ted-topology-attributes;
}
```

Augmented Nodes



Augmented Links




```
augment "/nt:network-topology/nt:topology/nt:link" {
  when "../nt:topology-types/o-ted:optical-ted-topology";
  uses optical-link-attributes;
}
```

Impact on Standardisation

- A key output of YANG model development effort for Elastic Optical Networks has been a contribution to the IETF, in the form of an Internet-Draft within the "Common Control and Measurement Plane" (CCAMP) working group
  - "A YANG data model for WSON and Flexi-Grid Optical Networks"
  - The CCAMP working group is responsible for standardizing a common control plane and a separate common measurement plane for technologies found in the Internet.
- Most recently (December, 2014) the IETF created a new working group entitled "Traffic Engineering Architecture and Signaling" (TEAS).
  - This new working group is responsible for defining MPLS and GMPLS traffic engineering architecture, standardizing the signaling protocol, and identifying required related control-protocol functions, i.e., routing and path computation element functions and developing YANG models for network topologies and technology specific network attributes.
- Our objective will be to progress the YANG model defined and discussed in this paper within the new TEAS working group, and eventually publish our proposal as the IETF Internet RFC Standard YANG model to model Flexi-Grid nodes, transponders, links, and available media channels.

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Questions?

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