SURF and transport beyond 100G

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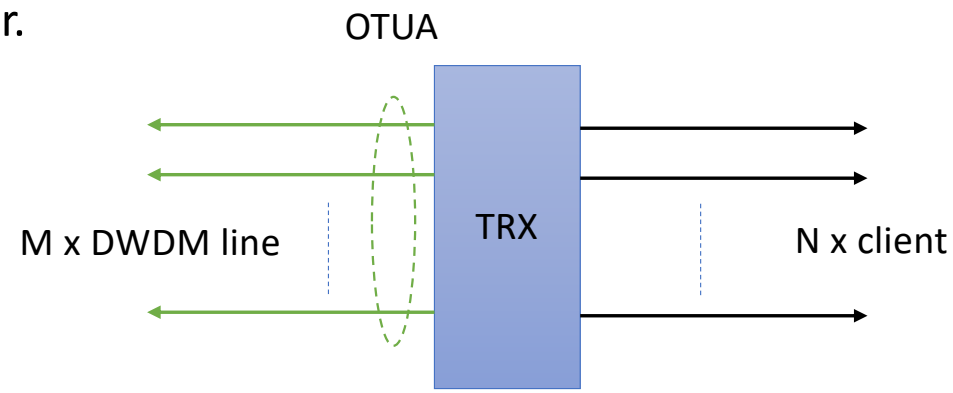
Network Technology and Security

Introduction

- Succesful transport beyond 100G requires improvement of:
  - Architecture and design of transport layer.
  - DWDM optical line system
  - Transponder capabilites
    - Line side
    - Client side
  - Connector handling
  - Knowledge at engineering level



- A different look at optical resources will help make decissions
  - No longer a day-0 network that can be fully loaded
  - Flexibility more valueable and required to guarantee needed transport forecasts

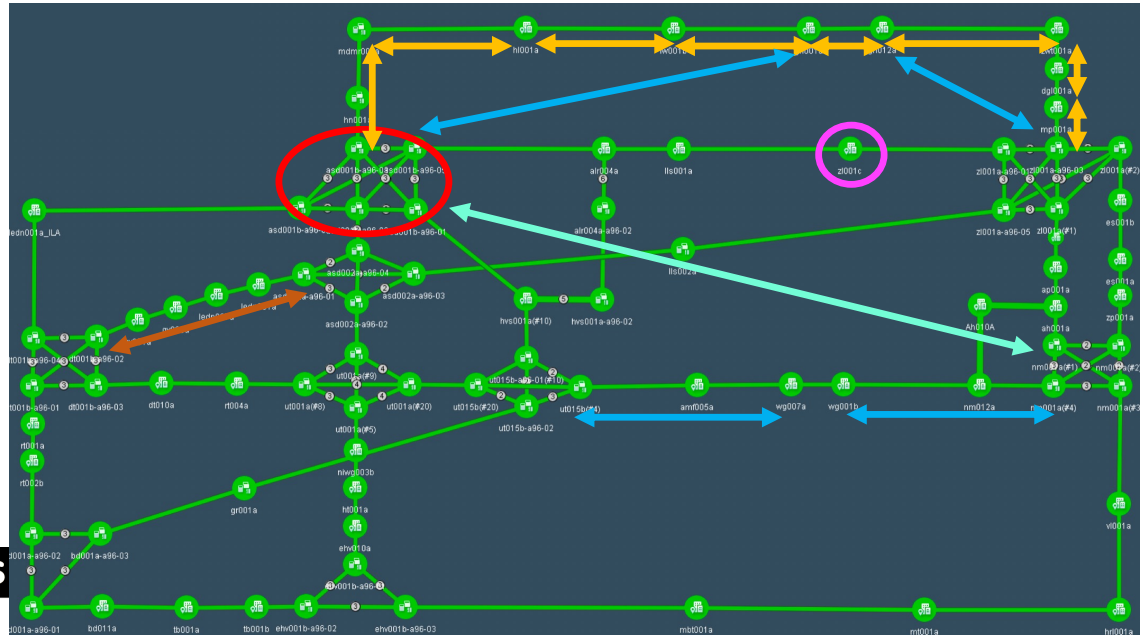
SN8 vs. SN7 different use of bandwidth

- SN7 was a static network based on static tunnels and limited flexibility on the optical transport layer:
  - **Limited multiplexing gain**
  - A lot of tickets in case of changes and trouble
  - No IP awareness
  - No restoration / single failure protection
  - Frequent regeneration of 10GbE waves
  - Complex EMS & NMS

- SN8 in combination with a A&O platform proofed to be the solution by implementing a dynamic network and improve future utilization of the 100GbE DWDM links.

SURF & > 100G Optical Transport

- Meshed national production network:
  - Comes from a dispersion compensated 10GbE DM/DD technology.
  - Daisy-chained links between sites on branches remain at 100G for some time.
  - Core nodes (Nodal Degree = 2) connect directly to Express nodes (Nodal Degree >2), thus by passing other core nodes remain at 100G.
  - Express links between Express nodes migrate to 200G.
  - Off-load Express nodes directly to Amsterdam (where most traffic terminates).
- Conclusion no immediate need for 400G in national core!



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- Different line-system architectures supported by a single vendor is key!
  - Typical ROADM based wavelength routable network
  - DCI type of line system
  - Space Division Multiplexed.

- Collored Optics in Service Platforms
  - SN7 network already gave experience with JDSU tunable XFPs and Menare OTN framing XFPs (ca. +6dB OSNR budget)
  - Skipped CFP2-DCO/ACO because of low port density on routers
  - First candidate: 400GBASE-ZR(+)
  - Only implemented if we can avoid vendor-lock
    - License free
    - Device management interoperability standardised and proven.

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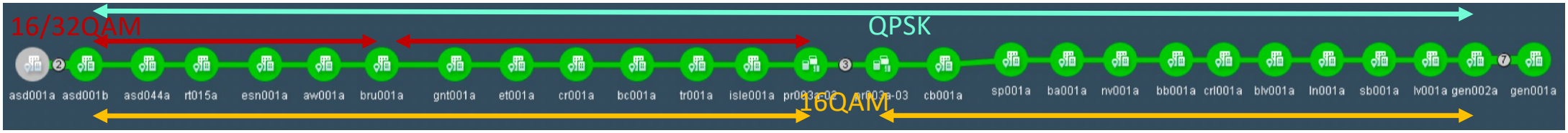
- Cross-border fiber Amsterdam - Geneva:
  - Most fiber still on G.655
    - Introduction of Hybrid-Raman amplifiers
    - Mode Field Diameter adaptation between G.655 line and G.652 patch fiber (ca. 0.35dB OSNR gain)
- Transponders on a symbol rate as high as possible
  - Symbol rate scales better than modulation complexity
  - “Blue” waves with a higher modulation complexity for shorter distances
  - “Red” waves with a low modulation complexity for long distance
- At present ca. 1dB OSNR short for 400G on single wavelength (SE=3)
  - At present 2x 200G QPSK wave for one 400GbE client. (SE=2)
  - Ambition: 16x 400GbE service in 100GHz spectrum on Amsterdam Geneva.



SURF

SURF & > 100G Optical Transport

- Cross-border fiber: Amsterdam – Hamburg
  - 200G at 16QAM in 50GHz with 3dB margin. (SE=4)

- Cross-border fiber: Amsterdam – London
  - Ended operation in 2021. Now spectrum lease from GEANT (direct route) and NORDUnet (route via Brussels).
  - Current: 2x 100G waves, redundant
  - Future:
    - 2x 400G, 16QAM, 100GHz direct route (SE=4)
    - 8x 100G, QPSK, 50GHz via brussels (SE=2) (present 50GHz line system)

Client Optics (I)

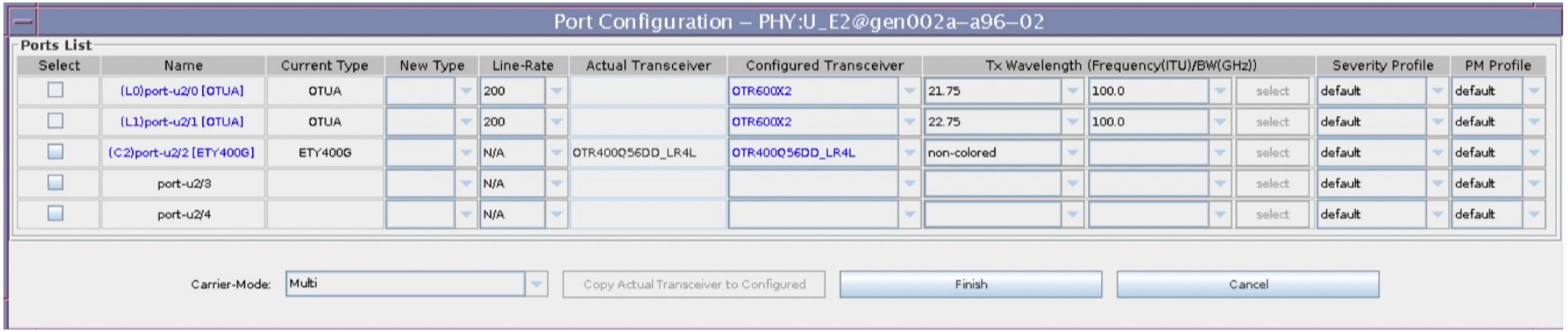
- 100GBASE-LR4
  - Available in almost all form factors!
  - Used to connect older CFP-DCO based transponders (CFP2) to Juniper MX service platforms (QSFP28).
- 100GBASE-CWDM4
  - Used to connect more modern CFP2-DCO (both 100G/200G) based transponders (QSFP28) to Juniper MX service platforms (QSFP28)
- 400GBASE-LR4L/FR4+ and 400GBASE-FR4
  - Used to connect most recent hi-symbol rate transponders to Juniper platforms and directly to customers. (all QSFP-DD)

Client Optics (II)

- Avoid as much as possible client optics with e.g. MPO connectors.
  - Keep everything as much as possible on duplex SMF.
- 100GBASE-LR1 candidate successor of 100GBASE-CWDM4
- 400GBASE-ZR candidate successor of 400GBASE-LR in case more distance is needed. (featuring tuneability)
- 800GBASE-XX or ASIC/on-board integrated optics?

Engineering

- DWDM side:
  - Need more expertise from network engineer as there is a non-explicit OTU convergence layer between the OTS and ODU to combine the different DWDM waves into a single resource.



Client optics:

- 100G client optics already showed increased sensitivity to dirt and damage
- 400G client optics shows extreme sensitivity to dirt and damage
  - Inspection is key!

Questions?