Optical Routing and Related Interface Requirements

Monika Jäger
T-Systems Nova GmbH

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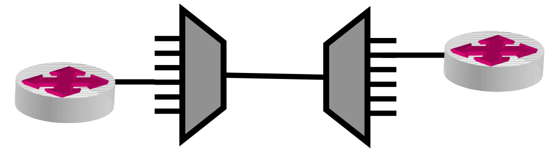
Outline

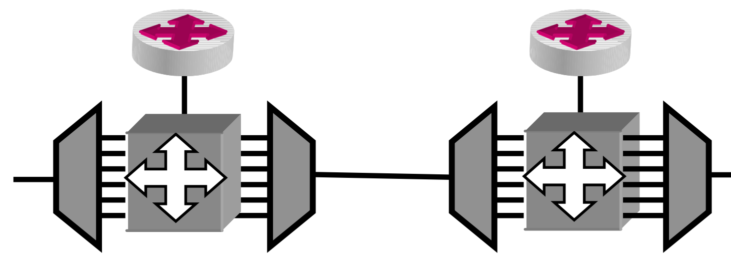
- **Optical Routing Motivation**
- **Transparent Routing and Interface Requirements**
- **Possible Solution Approaches**
  - All-Optical Sub-Networks
  - Analytical, Numerical Problem Description
  - Signal Measurements
  - Logical Abstraction of Physical Constraints
- **IETF Transparent Routing Activities**
- **Conclusions**

Motivation: Why Optical Routing?

- **Today: static WDM system connections**



- **Tomorrow: dynamic Optical Transport Network (OTN)**
  - availability of flexible OADMs and OXCs allows fast reconfiguration of optical layer
  - virtual topologies may be laid on top of optical layer
  - enables more flexibility in Transport Network (TN)



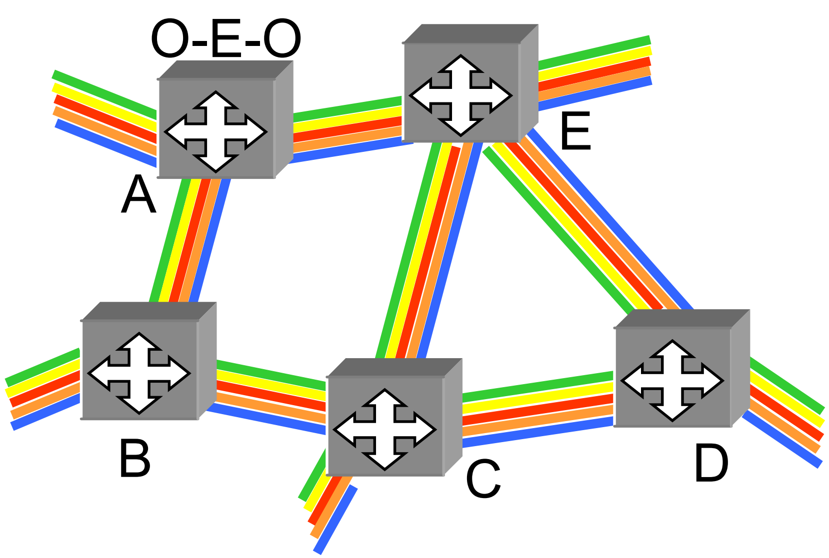
- **OTN control needs**
  - Optical Channel (OCh) based routing for optical layer configuration
  - today static TN configuration (centralized Network Management)

- **Automatic OTN configuration**
  - fast provisioning: new services
  - efficient rerouting in failure cases
  - automatic (distributed) routing for topology discovery, update and path calculation needed
  - signaling for connection management needed

Optical Routing Introduction
Opaque Routing

- **End-to-end connections based on Optical Channels (OCh)**
- **Routing concepts IP based**
- **Pre-standards available today**
  - ASTN, ASON, GMPLS, OIF NNI

Link State Database R. ID		
Link	Cost	Sequence
AB	1	A,3
CD	1	C,2
BD	1	D,4
...		



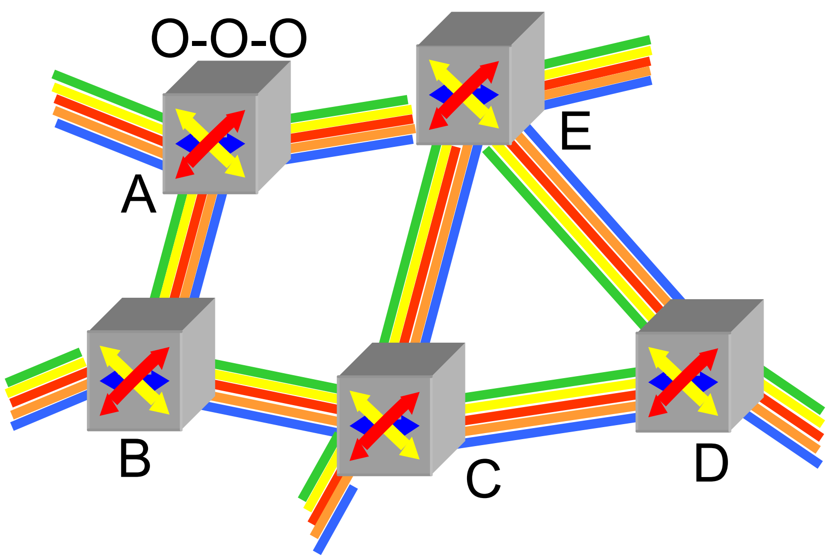
- **Resource information on links needed**
  - # of wavelengths on links

Optical Routing Introduction
Transparent Routing

- **No optical to electrical conversion (O-E-O) on routes**
- **Advantages**
  - “protocol“ and “transmission“ transparent
  - cost savings: less expensive transponders

Link State Database R. ID

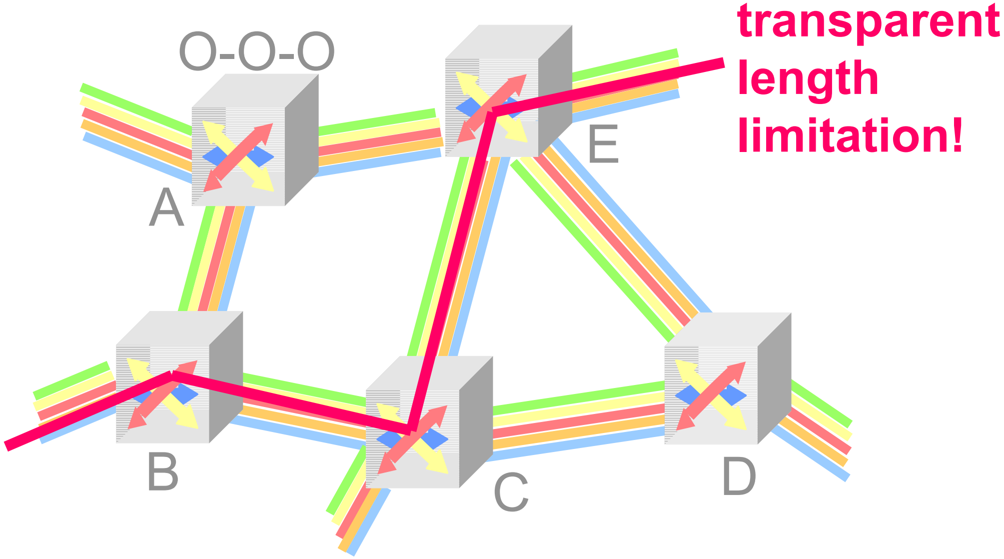
Link	λ	Cost	Sequence
AB	1	1	A,3
CD	2	1	C,2
BD	3	1	D,4
…			



- **Resource information on links needed**
  - specific wavelength availability

Optical Routing Introduction
Wavelength Continuity

- **No optical to electrical conversion (O-E-O) on routes**
- **Advantages**
  - "protocol" and "transmission" transparent
  - cost savings: less expensive transponders



Link State Database R. ID			
Link	λ	Cost	Sequence
AB	1	1	A,3
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…			

- **Wavelength Continuity**
  - resource information on links needed
  - specific wavelength availability

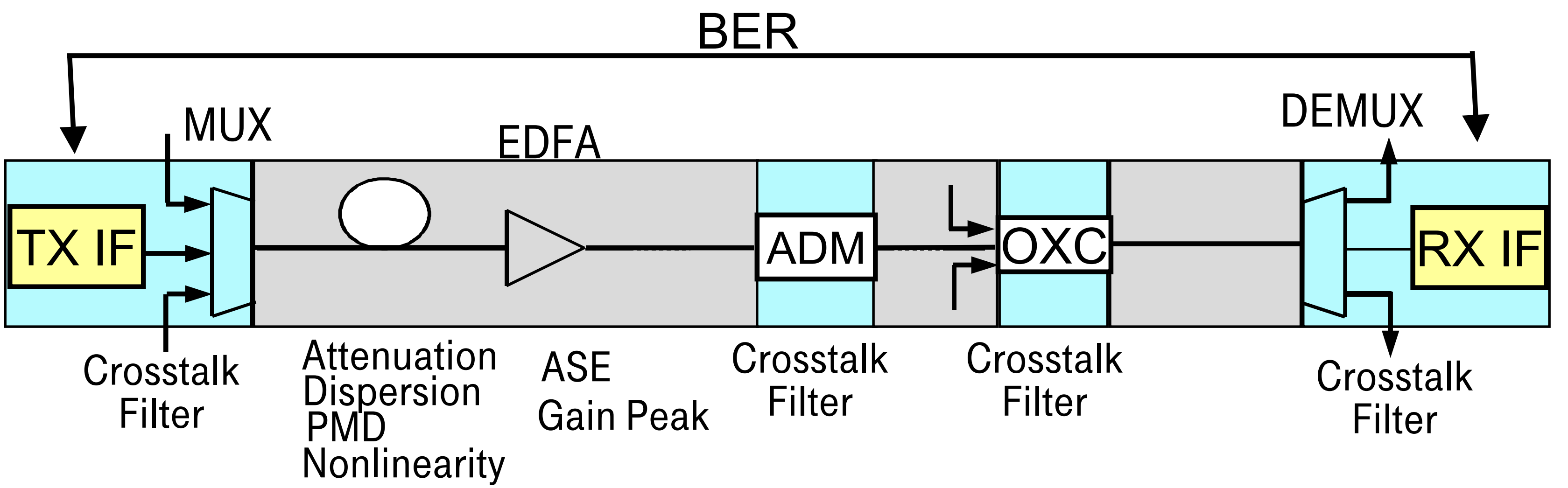
Transparent Routing Challenges
Transparent Length Limitations

- **Maximum transparency length depends on**
  - fibre distance length
  - type of fibre and design of links, e.g. dispersion compensation
  - # of Optical Amplifiers
  - signal bitrate (2.5 Gbps, 10 Gbps, 40 Gbps...)
  - # of wavelengths on WDM system
  - # and type of switching elements (OADM, OXC)

- **Analogue signal transmission impairments**
  - Polarization Mode Dispersion (PMD)
  - Amplifier Spontaneous Emission (ASE)
  - Cross-Talk...
  - non-linear effects
    - 4-wave mixing
    - Self-Phase Modulation, Cross-Phase Modulation...
- **Noise, dispersion**
  - signal degradation -> regeneration needed

Interface and Control Requirements

- Interfaces "detect signal quality" on routes
- Control functions get knowledge of signals and requirements
- Control functions choose "appropriate routes"
- Interfaces send with "appropriate signal quality"



There is nothing like this in today's interfaces and control protocols!

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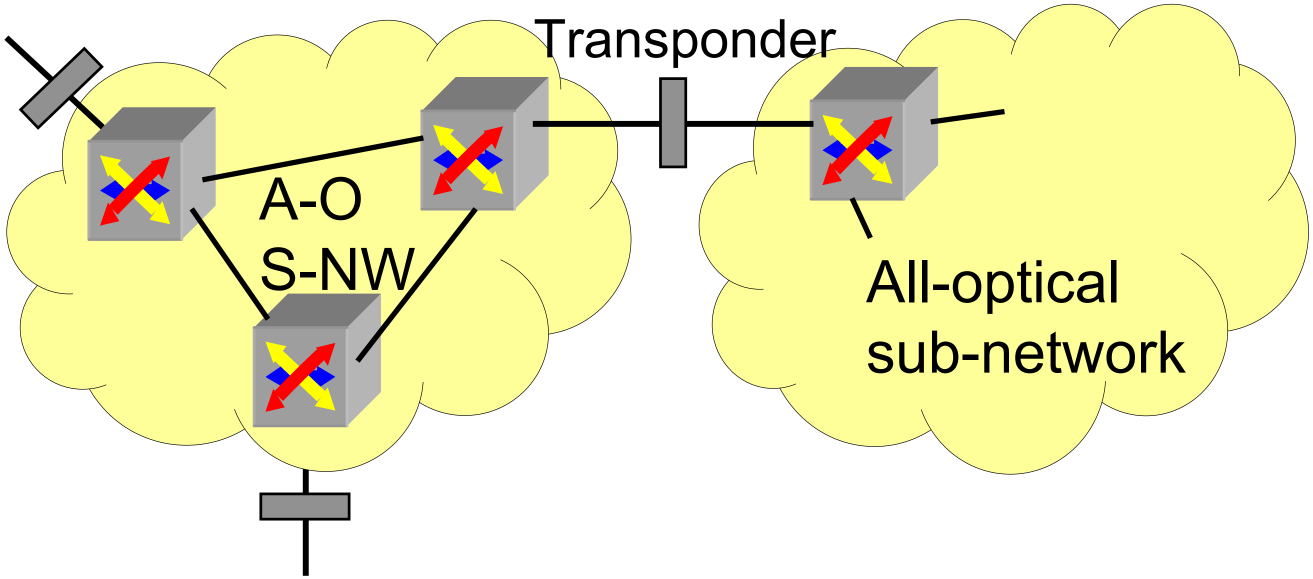
  - Analytical, Numerical Problem Description
  - Signal Measurements
  - Logical Abstraction of Physical Constraints
- **IETF Transparent Routing Activities**
- **Conclusions**

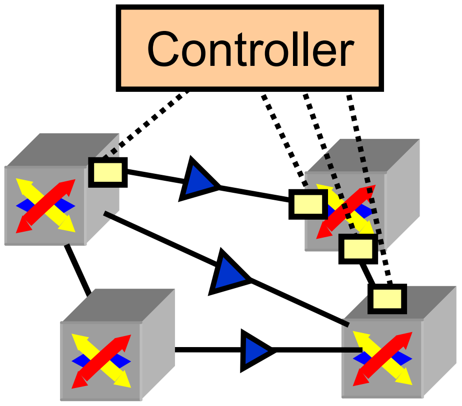
Possible Solution I
All-Optical Sub-Networks



- **Problem avoidance**
  - design sub-networks so that **any** route is usable
  - equip interfaces at borders of sub-networks with transponders
- **Evaluation**
  - simple and straight-forward
  - usable for static and dynamic OTNs!
  - *but*, static, sub-optimal design of all-optical sub-networks

Possible Solution II
Analytical, Numerical Problem Description

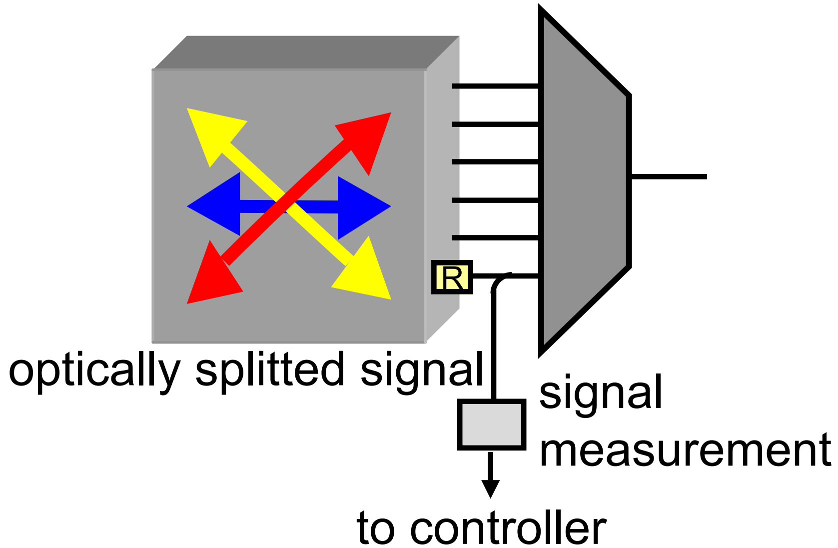
- (Central) control has detailed information on physical infrastructure
- For each path signal degradation (BER) is calculated from input IF to output IF
  - analytically
  - numerically



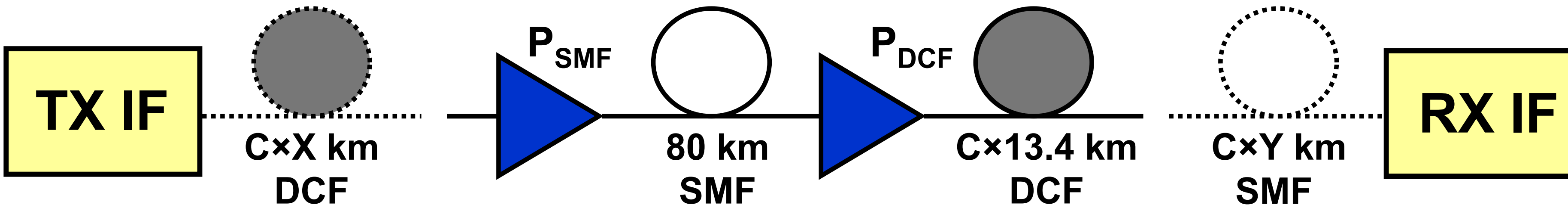
- **Evaluation**
  - most exact method
  - ”most optimized“ network configuration possible
  - most complex
  - feasible for on-line network configuration?
  - suitable centralized network control

Possible Solution III
Signal Measurements

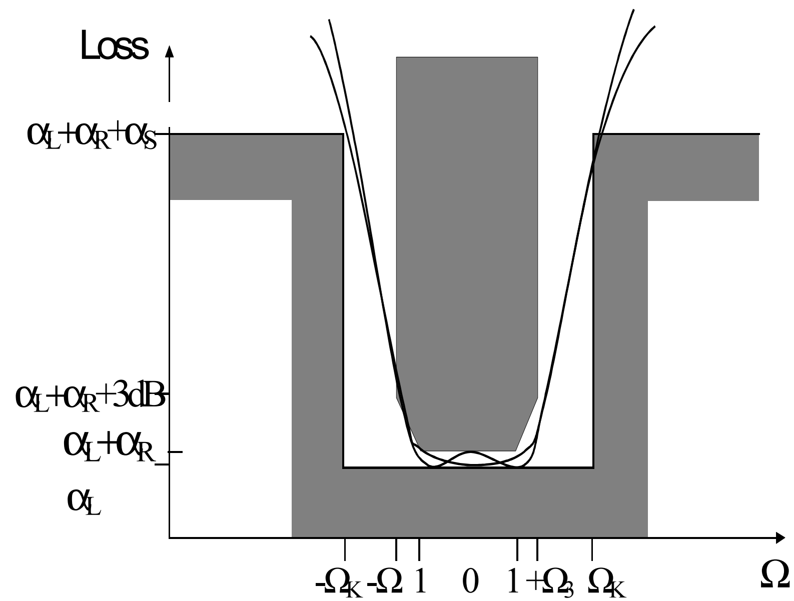
- **End-to-end quality of potential paths is evaluated by measurements**
  - on single links, Σ of link values
  - on end-to-end paths
- **Measures of signal quality**
  - Eye opening penalty
  - Bit Error Rate (BER)
  - Q-Factor
  - Optical Signal to Noise Ratio (OSNR)
  - Histogram
- **Evaluation**
  - exact method
  - not useful for on-line routing



Possible Solution IV
Logical Abstraction of Physical Constraints



- **Define ”Normalized Sections“ of fibre regarding dispersion, fibre nonlinearity, noise with specific in out power level**
- **Network design: cascades of identical transmission sections**
- **Element Transfer Mask**
  - cross-talk and filter effects
  - phase & amplitude tolerance
  - Σ transfer masks of overall path
  - elements add penalty to the # of NS



Optical NW element transfer function characteristic

Possible Solution IV
“Normalized Section” Routing

- **Normalized Section information is exchanged e.g. with OSPF LSAs**
- **Path selection according to**
  - minimal cost
  - complying to “# of Normalized Sections limit“ constraint

- **Approach evaluation**
  - simple and straight-forward
  - easy to integrate into routing protocols
  - good interoperability
  - *but*, appropriate network design is a pre-requisite

Transparent Routing
State of Work at IETF

- **Varying number of drafts**
  - draft-banerjee-routing-impairments-00.txt (expired)
  - draft-parent-obgp-01.txt (expired)
  - draft-ietf-ipo-optical-inter-domain-01.txt (February 2002)
  - draft-hayata-ipo-carrier-needs-00.txt (expired)
  - draft-many-carrier-framework-uni-01.txt (expired)
  - draft-papadimitriou-ipo-non-linear-routing-impairm-01.txt (expired)
  - draft-ietf-ipo-impairments-02.txt (February 2002)

- **draft-ietf-ccamp-oli-reqts-00.txt (February 2002)**
  - fault detection of Photonic Cross Connect (PXC)
  - discovery of link characteristics
  - requirements for the Optical Link Interface (OLI) between optical line system and client
    - protocol for fast failure detection and notification to PXC
    - focus on SONET/SDH clients
    - no physical interface specification

draft-ietf-ipo-impairments-02.txt
Description

- **Physical impairment classification**
  - linear
  - non-linear
- **Analytical formulae as routing constraints for <u>linear</u> impairments**
  - PMD, ASE, OSNR, # of switching elements, chromatic dispersion, cross-talk, ...
- **Non-linear impairments: unlikely to be dealt with explicetly in routing algorithms**
  - design equipment sub-optimal, but „less aggressive“ with respect to non-linearities
- **Maximum distance constraint recommendations**
  - Appropriate network design
    - use low-PMD fibres, PMD compensation
    - fixed fibre distance for each span
  - Limit maximum distance
    - transparent network elements are converted inot equivalent length of fibre
  - Pre-qualification of all optical paths
  - “Static“ physical layer parameter database for all components

Evaluation State of IETF Progress

- Problem descriptions available
- General recommendations only
- No physical paramters or interface specifications available yet
- Little progress recently, time frame unclear

Conclusions

Transparent OTNs pose many new requirements on client and network element interfaces and network control due to analogue signal transmission impairments -> transparent path length limitation constraint

- **Centralized control**
  - needed for analytical/numerical descriptions (solution III) due to highly complex processing
- **Distributed control plane**
  - possible in all-optical sub-network concepts (solution I)
  - might be feasible in abstraction approach like “Normalized Section Routing” (solution IV)
- **Static OTNs**
  - for static network design all solutions are possible
- **Dynamic OTNs**
  - signal measurements (solution II) do not seem feasible for on-line calculation
- **Path length limitations may require (expensive) electrical regeneration**

-> Today, there is no easy solution!
Cost savings <-> complexity!

References

- "Impairments and Other Constraints On Optical Layer Routing", IETF draft, draft-ietf-ipo-impairments-02.txt, Feb. 2002.
- "Optical Link Interface Requirments", IETF draft, draft-ietf-ccamp-oli-reqts-00.txt, Feb. 2002.
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- "IP Control of All-Optical Networks", J. Yates et al., NFC2000.
- "Network Optimization with Transmission Impairments-Based Routing", M. Ali et al., ECOC2001.
- "Geschaltete optische Netze mit bedingter Vermittlung aufgrund physikalischer Degradationseffekte", J. Kissling et al., ITG-Fachtagung, April 2002, Leipzig, Germany.