# Grid and Quality Monitoring

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# Agenda

1. Characteristics of today's optical networks vs. future
2. Physical layer Impairments
3. Challenges of large All-optical islands
4. Physical layer QoS
5. Networking choices and the Grid community

# Today's Optical Networks

Characteristics

- Small All-optical islands
- Relatively Low bit rates (less than 10Gig)
- Static wavelength configuration
- Over engineered to reflect a more homogeneous (from a physical layer QoS perspective) network – All routes have low BER
- More OADMs than photonic switches

# Future Optical Networks

- Characteristics
  - Large All-optical islands (no OEO regeneration) – end-to-end optical connections
  - Heterogeneous signals (modulation format, datarates, protocols)
  - Higher bitrates > 10 Gig
  - Dynamically reconfigurable at wavelength, and sub-wavelength levels
  - Multiple physical layer QoS levels

# Physical layer Impairments

- As datarates increase ( > 10 Gig), optical layer impairments play a more significant role in signal degradation.
  - Linear impairments:
    - ASE - Amplifier Spontaneous Emission
    - PMD - Polarized Mode Dispersion
    - CD - Chromatic Dispersion
  - Nonlinear impairments :
    - SPM - Self-phase modulation
    - XPM - Cross-phase modulation
    - FWM - Four-wave mixing
    - SRS - Stimulated Ramman scattering effects
    - SBS - Stimulated Brillion

# Challenges of large all-optical islands

- A goal of most optical switching technologies (lambda, packet, burst, etc.) is to increase the All-optical island (no OEO).
- Signals transmitted in the optical plane are modulation, protocol and datarate transparent to the network, however higher datarates will experience more signal degradation.
- Issue: the above concepts are at odds with each other :
  - Strong desire to increase all-optical island
  - While increasing the effects of optical layer impairments on signal degradation due to higher data rates - forcing carriers to OEO regenerate (thus reducing the all-optical island).

# Potential solution

- Increasing the all-optical island while providing high data rate channels:
  - Integrate quality monitoring information into dynamic routing algorithms
  - Provide different levels of physical layer QoS for end-to-end connections

- Benefits:
  - Low latency across the network (assuming application level latency and jitter requirements are handled at the edges)
  - No OEO (reduced NE costs)
  - Data format and protocol agnostic within the network

# Potential solution

- Today's optical networks use optical layer monitoring for determining the max # of hops, max length of spans, and max # of Amplifiers before regeneration in order to maintain low BER.
- Instead utilize optical monitors throughout the network and integrate quality monitoring information into the control plane (routing and forwarding).
  - The routing algorithm can incorporate link-based as well as channel-based quality monitoring information and provide the following benifits:
    - provide dynamic compensation per channel/link – as needed basis (research stage)
    - pre-determine end-to-end physical layer QoS (BER) of a route based on quality monitoring information on the links for that route
    - allow data to be maintained in the optical plane for longer distance than current practice

# Potential solution (cont'd)

- Allow networks to have different levels of physical layer QoS for different routes. Routes are chosen based on BER requirements of a requested connection.
  - Have best effort routes which may have high BER – for loss-insensitive
  - And have today's level of low BER routes - for loss-sensitive
  - May have more levels if not too complex
  - This will allow some connections to remain in the optical plane for longer distance if BER requirements could be met
- Grid users shall have a mechanism for querying a route's BER (source to destination) – network should provide choices
- Grid applications should be aware of their loss tolerance or requirements based on user controlled FEC mechanism and application's ability to re-transmit.

# Grid applications and BER requirements

- Most of today's application have not been tested for their BER requirements.

- Due to the potential high BER of a wireless networks, some applications are being analyzed for their loss tolerance.

- Best Effort optical routes may be used for loss-insensitive Grid applications (or streams within a Grid application).

# Choices for routing decisions

- Future networks will require optical layer monitoring:
  - Three possible strategies for integrating optical monitoring information with the control plane, Grid applications:
  - 1) Leave the routing decision to the network, i.e., making it transparent to the Grid users (homogeneous network – small all-optical islands).
  - 2) Grid users need to make routing decision, propose several ways to abstract the impairment constraints.
  - 3) Leave the routing decisions to the network, however provide a mechanism for the Grid user/application to request their required level of physical layer QoS (end-to-end BER).

# Important Optical Networking Choices
## Target Application Set

- Choices –
  - –Specific Research Communities (e.g., high energy physics)
    - •Relatively Small  Number Of Participating Locations
    - •Long-Lived Relationship (Years)
    - •Participants Have High Degree Of Trust
  - –Ad Hoc "Virtual Organizations" (as defined in Foster et al, "Anatomy Of The Grid")
    - • Participating Locations Determined By VO Needs – Unpredictable
    - •Number Of Simultaneous VO's Could Be Large
    - •Trust Levels, Longevitiy Of The Relationships, Etc. Will Vary By VO
- Draft "**Optical Network Infrastructure for Grid" Recommends The Latter.   Implications:**
  - – Networking Protocols Must Be Scalable, Robust, Not Assume Trust
  - –VO Optical Infrastructures Likely To Vary (Customer Owned, IRU, Leased)
  - –Multiple Optical Control Domains May Need To Cooperate To Support A Given VO

# Important Optical Networking Choices
## Network/Application Relationship

- Choices
  - –Peer Model: **Optical Network Control Is Shared Between User & Network**
  - –Overlay Model: **User Is Client Of Network**

- **Draft "Optical Network Infrastructure for Grid" Recommends The Former. Implications:**
  - –**Internal Network State Information Must Be Shared With User**
  - –**Network Security & Robustness Affected By User Software**
  - –**Participating Multi-User Optical Network Providers Will Require "Firewalls" To Keep Any User From Compromising Other Users Or Overall Network Performance/Robustness**
  - –**Commercial Protocol Development To Date Has Been Overwhelmingly Focused On Overlay – GGF Will Need To Work With IETF, OIF To Define Mutually Acceptable Form Of Peer Model (e.g., Some Sort Of "Optical Virtual Private Line" (OVPN))**

# Grid applications and network QoS

- Three orthogonal QoS categories per connection request:
  - Optical physical layer QoS – BER per route
  - Restoration level
  - Route priority and pre-emption