Cross Layer Research in GENI

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Optical substrate in GENI

- Optics will be a major part of the GENI physical infrastructure:
  - Core of GENI will have a high degree of photonic componentry
  - Current high-end optical networking equipment: High bandwidth WDM transmission, network elements, ROADMs, OXCs, etc.
  - But…Just inserting this equipment as "black-box" layer 1 will not be sufficient to enable GENI research agenda
- Develop GENI-ized optical layer that can address the full spectrum of GENI research
  - Will span depth of programmability access into optical substrate
  - Some slices of GENI will encompass near standard, highly robust equipment with minimal programmability, (OMIS favorite)
    - Ex. Provision optical λs, circuit, stable configuration
  - Isolated GENI slices with full programmability perhaps even at component level, (OMIS least favorite)
    - Ex. Multiple time-sensitive data communications patterns; security attacks; dynamic sub-λ bandwidth reallocation/balancing

Implications for optical substrate

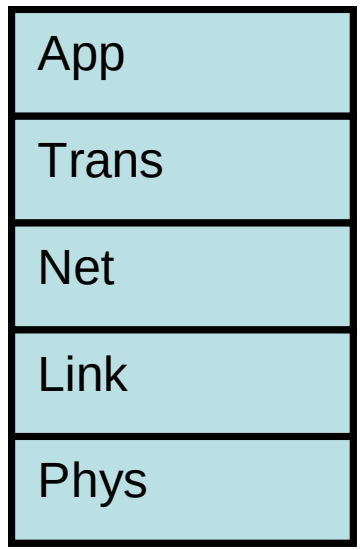
- GENI-izing the optical substrate:
  - What programmability functions are needed?
  - How should they get implemented? At what granularity?
  - Flexibility in bandwidth – open spectral bands
  - Control plane interface with GENI operations

- Rethinking and redesigning the core should take an *integrated approach:*
  - Network architecture co-designed with opportunities and challenges presented by advanced optical technologies
- We are NOT doing research on the optical substrate, not about transmitting higher data rates, more wavelengths, etc.

- Research is on how the intelligent (via programmable control plane) optical substrate is designed and implemented to enable ***required*** and ***transforming*** GENI experiments

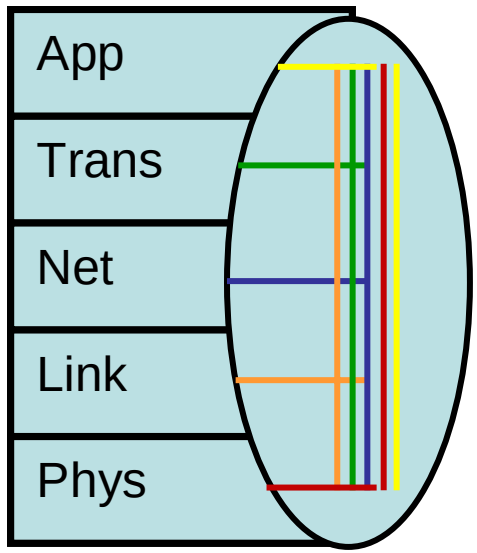
Cross-layer communications

- Today's Internet design based on (favorable) notion of **layering**:
  - Each layer is designed to provide barebones functionality that can be used by layers above
  - Barebones philosophy was generally good, enabled rapid independent development of the layers: protocols, applications, services
- Layering is also limiting:
  - Often, lower layers technology can perform additional *functionality* but cannot deliver to higher layers
  - Network layers can perform QoS but applications cannot invoke it and derive benefit



Cross-layer communications

- Bi-directional information exchange between layers
- Cross-layer designs improves broad range of network performance and applications
  - QoS, flow prioritization
  - Wireless security and authentication
- With cross-layer communications optical substrate can deliver **functionalities** (in addition to bandwidth) that enable GENI networking
- To achieve this requires integrated network architecture/optical substrate research agenda



GENI network research

- Examine GENI network research challenges, identify critical necessary roles and functionalities for substrate
  - **Optical layer aware and enabled networking**
- Virtualization of general, flexible, global network resources:
  - No longer assume single packet format
  - Virtualized network connections, dynamically sliced into shares for different users and applications
  - One format for information dissemination, another for real-time communications, another for bulk data transfers, video distribution, multicast, etc.
- **For the optical substrate this means dynamically programmable, simultaneous operation of optical circuits, optical packets with vast ranges in data flow granularities:**
- **(AST) application specific topology**
  - This is not trivial for optical substrate
  - Can do as overlay in software, but will not drive realistic requirements for future Internet
  - Goal to drive (not develop) technology toward GENI-ized substrate

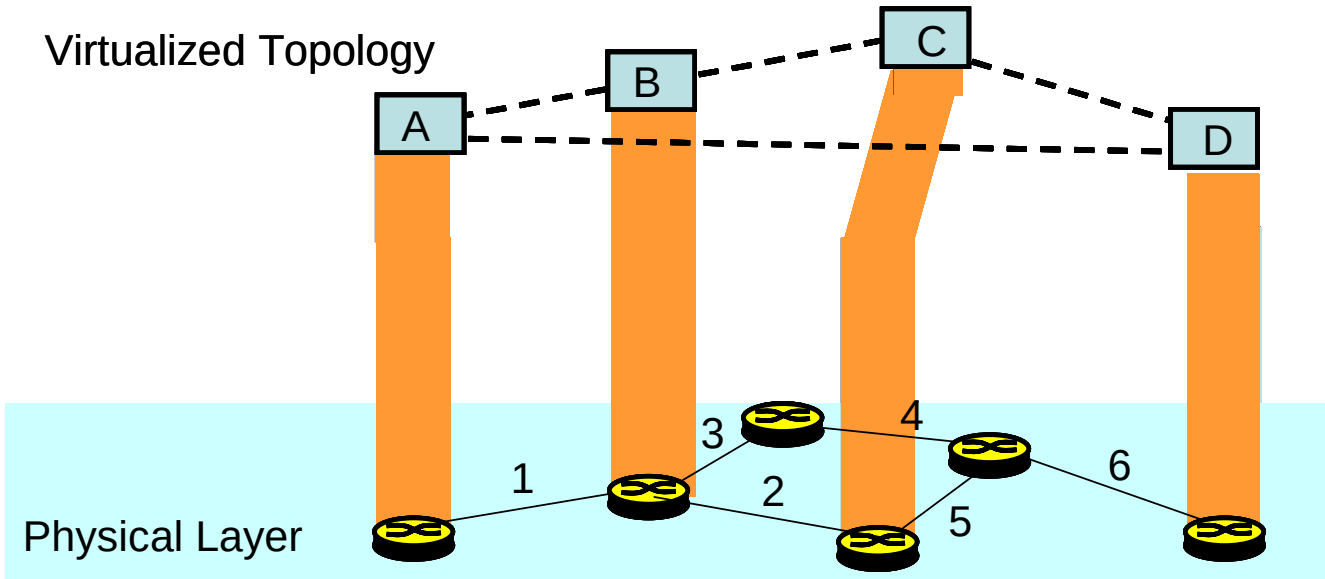
GENI network research

- Global network for multiple communications patterns of information dissemination
  - Point-to-point, one-to-many, range of transport
- Architecture that supports multiple traffic time sensitivities
  - Real-time with bounded delay
  - Delay tolerate traffic
- **These critical research challenges for GENI clearly require cross-layer communications capabilities**
  - Programmable interaction with optical substrate, provide upper layers dynamic access to full bandwidth at any granularity
  - Optical switching and routing that can be configured to process diverse traffic – with multiple time sensitivities
  - Not about developing new photonic devices, but deriving functionalities from optical substrate, programmable access via control plane, cross-layer communications

Security and robustness

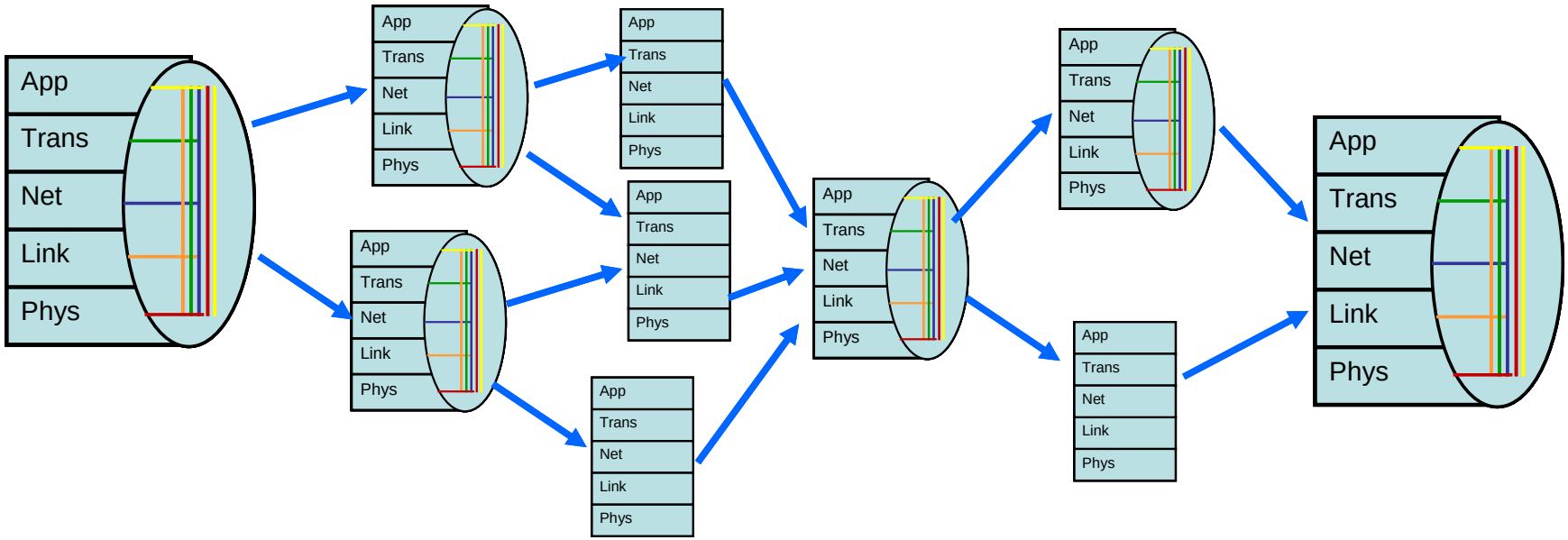
- GENI requirements:
  - Any set of well behaved hosts can communicate reliably, malicious or corrupted nodes should not
  - Security and robustness must extend across layers, need entire chain secure: phy+net+app
- **Optics cross-layer traffic engineering:**
  - **Optical substrate monitoring inherent part of network management and operation via bi-directional cross-layer communications**
  - **Network configuration using operator automated tools relies on sound optical substrate**
  - **Security information exchange via control plane**

Survivability via path diversity



- Network resilience through additional path provisioning in case of primary link failure
- Path diversity viewed by application from node A to D is false because at least 2 of links are shared
- Cross-layer communications can expose optical physical layer and relate information directly to application

Example: Multipath Routing



- Nodes with cross-layer communications functionality can realize multipath routing with significantly better performance
  - Knowledge of physical true path diversity
  - Security requirements – which nodes can be addressed
  - QoS requirements – query the physical layer
  - Routing, switching -- is packet reordering permitted?
  - Time sensitivity
- Nodes without CL functionality simply route unicast to the next hop

Cross-layer research

- Optical substrate: no longer a static black box
- Intelligent, dynamic, programmable, network and applications aware:
  - Not just high-bandwidth
  - Provides functionality
- GENI network research agenda clearly demands new functionalities from the optical substrate
- These functionalities will NOT be available with standard commercial optical system technology
- Research is required on network architectures in synergy with the optical substrate that can lead to integrated GENI-ized solutions
  - Drive (not develop) optical systems technology in concert with architecture to enable GENI experiments and applications.