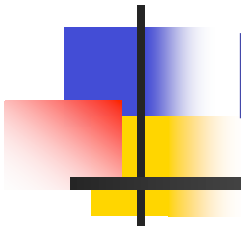


Intelligent High-Capacity Networks

Internet Innovations Workshop

June 20, 2007

Working Group Charter

Many emerging applications require that geographically-distributed devices be connected by

high-bandwidth pipes (with quickly-reconfigurable capacities).

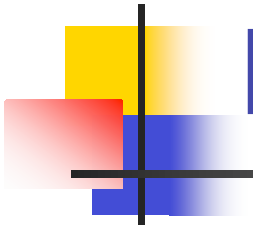
Optical fibers, which support enormous transmission capacity, are deeply imbedded in our network infrastructures; however, the design of the corresponding intelligent, efficient, and robust switching systems and network architectures are important and challenging problems for the future Internet. The objective of this track is to determine the future R&D needs and opportunities in high-capacity (optical) networking with special emphasis on

application-driven architectures

and holistic design involving

broadband access.

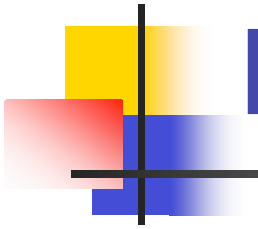
This track will address important research challenges, both fundamental and technological, which are likely to be at the forefront of intelligent high-capacity networks for many years to come.



Framing Questions

- What will the future Internet architecture look like considering the emerging high-capacity (optical) switching and networking technologies?
- How can emerging broadband access technologies influence the future Internet architecture?
- How can high-bandwidth applications (some of which are yet to be developed and are unanticipated) influence the design of intelligent high-capacity networks?
- How do we migrate from existing network architecture to the new one?

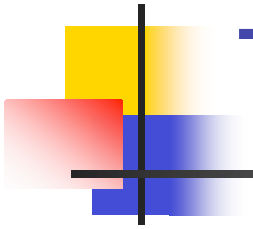
Fill in the following slide and send it by email to mukherjee@cs.ucdavis.edu prior to 6/20. Approximately 4~8 will be chosen for presentation during the breakout session.



Participation Template

- Grand Challenge:
  - Describe your grand challenge in one sentence.
- Experiments Required:
  - Provide a list of experiments that must be conducted in order to explore solutions to your grand challenge.
- Industry/Academic Relationship:
  - Describe interactions between industry and academia that will lead to better solutions that can be deployed more quickly.

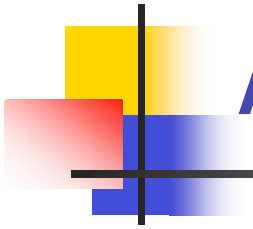
Michael Kounavis, Senior Research Scientist, Intel Corporation



Traveling Without Moving

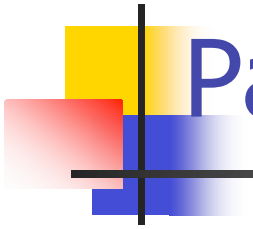
- Grand Challenge:
  - The capability of the communications infrastructure to transport the audio-visual representation of a physical world to some remote location where participants can emerge into this world via virtual and augmented reality tools and also be seen or communicate with the actual inhabitants of the physical world as virtual visitors
- Experiments Required:
  - Sensor network infrastructure experiments, graphics and media representation experiments, new network architecture with security and QoS guarantees experiments
- Industry/Academic Relationship:
  - Broad vision. Several schools work on different seemingly disjoint areas (sensor networks/graphics-multimedia/security/networking). This vision brings all these independent research efforts together

Glen Kramer, Chief Scientist, Teknovus



Access Network Architecture

- Grand Challenge:
  - Develop an access network architecture that would support existing bandwidth-intensive services (multiple HDTV streams in both directions) as well as accommodate new and unanticipated services, while allowing smooth upgrade and evolution one user at a time.
- Experiments Required:
  - Developing traffic models and test benches reflecting empirical traffic evolution
    - YouTube: 100M videos watched daily, = 10% of network traffic
  - Super-stressing existing/deployed systems or emerging NG architectures
- Industry/Academic Relationship:
  - Industry has accumulated deep knowledge of user and network behavior. This knowledge is generally not available to academic researchers; without it academic work often becomes less applicable to real world conditions.



Participation in High Capacity Nets

- Grand Challenge:
  - What are the right internet architectures to bridge high capacity wired networks with lower capacity wireless networks?
  - For example, distributed beamforming across cellular base stations, WiFi access points and 60GHz distributed antennas requires extremely tight synchronization over the optical backhaul (within picoseconds or less). Is this feasible?
- Experiments Required:
  - Examine the switching delays between optical and electrical/wireless networks in greater detail
  - Examine signaling overheads versus faster speeds over optical – do PHY/MAC/NET overheads kill the raw bit rate advantage?
- Industry/Academic Relationship:
  - Wireless cellular/infrastructure service providers must engage more with academia and provide information on their backhaul architectures and challenges

Yinghua Ye, Nokia

Wireless-Optical Broadband Access

- Grand Challenge:
  - How to seamlessly bridge optical backbone with various broadband access technologies?
- Experiments Required:
  - Understand the impact of real-time applications (such IPTV, mobile TV) on architecture
  - How to perform end-to-end resource allocation in terms of GENI?
  - How much intelligence do we need for optical network?
- Industry/Academic Relationship:
  - NSF (such as GENI, GOALI)
  - Industry Sponsored Projects

Optical layer flexibility at multiple time-scales

- Design level: building an optical layer that is less sensitive to technology changes – tighter use of spectrum, works for 10G→100G and beyond w/o infrastructure change
- Network planning level: how to build a network that can support unknown traffic patterns? (IP approach viz transport approach), e.g., where to regenerate
- Connection setup level: Solidify GMPLS for the WDM layer; Dealing w impairments in more flexible ways (e.g., tunable dispersion); Hitless re-optimization
- Client layer interconnect into optical layer: driving connections from a client and making use of it efficiently. E.g., routers can set up a connection, but how can they do so w/o re-converging every time?

IP-Optical Seamless Integration

- Grand Challenge
  - IP and Optical Network seamless Integration
- Experiments
  - Network Management Experiments
  - IP- Optical Reconfigruation Experiments
  - Heterogeneous Networking
- Industry/Academic Relationship
  - GENI-TF Forums
  - Joint Experiments

Other Thoughts…

- Applications Needs
  - Consumer products vs. business-critical needs
  - CBR with dynamism vs. packets with QoS
  - Measurements and visibility into the network for optimal operation of apps.
  - (Near) synchronous vs. asynchronous
  - What are some low-latency, low-jitter, high-capacity apps.?
- Access
  - FTTx testbed through network operators (GENI-enabled access)
- Some Technology Issues
  - Agile optical nets… stay optical as far as possible
  - Exploit dynamism over (static) lambdas

What Is An Optical Network?

- It is **NOT NECESSARILY** all optical
  " " " " packet switched
- **Characteristics of an optical network**
  - **Transmission: optical**
  - **Switching:** could be optical, could be electronic, could be hybrid
    could be circuit, could be packet, could be burst
- **Most Promising Approach Today**
  - Electronic circuit switching with sub-lambda granularity (STS-1, STS-3, …)
- **Example Utility for IP Networking**
  - Connect any two IP routers (geographically far apart) with a direct ("virtual") bandwidth pipe… of whatever capacity (STS-1, … , STS-192)
  - Increase (or decrease or delete) the capacity on demand
  - Dynamically control the "topology" connecting the IP routers
  - Create a "separated control network" (of whatever bandwidth)
  - …