

Developing a national R&E optical networking capability in the United States

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INTERNET. Primary motivations and a caveat

Emerging requirements may not met by a high-performance, yet best-effort IP network

- DWDM: 10-Gbps channels now; 40-Gbps hard, but coming
- Computational science grids
 - Applications with deterministic network requirements
- Infrastructure for basic and applied network research

Period of unprecedented contrarian economic opportunity

- Distressed fiber assets available on national scale
- Optronics industry severely impacted by carrier woes

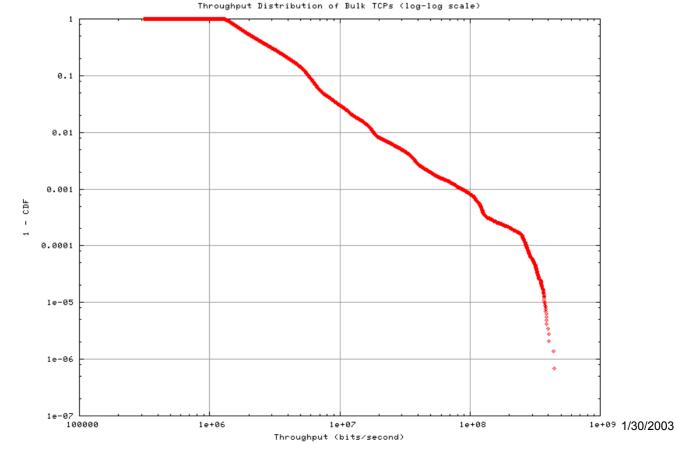
However, optical networking alone does not solve the end-to-end performance problem

- Host configuration (Web100)
- Local networking capability (DAST, Internet2 E2EPI) ^{1/30/2003}



Bulk TCP flows (payloads > 10 MBytes)

Median flow rate over Abilene: 2.1 Mbps



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INTERNET. Optical network project differentiation

	Distance scale (km)	Examples	Equipment	
Metro	< 60	UW(SEA), USC/ISI(LA)	Dark fiber & end terminals	
State/		I-WIRE (IL),	Add OO	
Regional	< 500	I-LIGHT (IN),	amplifiers	
		CENIC ONI		
Extended		TeraGrid	Add OEO	
Regional/	> 500	NG Abilene,	regenerators	
National		Light Rail	& O&M \$'s	

INTERNET. Unique optical requirements in Higher Education Community (HEC)

10-Gbps: 10 Gigabit Ethernet preferred over OC-192c SONET

HPC could need 40-Gbps λ 's prior to the carriers

Integrated view of network management

- Transport & IP enginering/operational approaches are not intrinsically different
- SNMP preferable for network polling

HEC can provide experimental environment for development of 'rational', customerfocused optical switching

- Switching tightly integrated with optical transport
- Capacity for IP backbone expansion and p2p λ 's

INTERNET. U.S. optical networking initiatives

Three current projects

- Fiberco
- USA Waves
- National Light Rail

Common factors

- National fiber footprint represents a strategic asset for HEC
- All leverage the much lower *incremental* cost of λ's in an existing DWDM system (vs. the cost of the first λ)

Differentiating factors

- Scope
- Buy vs. build
- Production vs. research capabilities
- Participation cost



National fiber assets

• CENIC: \$5M minimum commitment for Level 3 fiber

Fiberco as fiber holding company

- Can hold national/regional fiber assets with capability to assign to other organizations
 - Intent is for CENIC and UCAID to assign fiber here
 - Can support national initiatives such as National Light Rail
 - Unlit national fiber is a strategic asset for HEC
 - Can support regional fiber acquisition outside NLR
 - Not an operational entity (i.e., cannot light the fiber)

Limited scope simplifies governance issues

- UCAID assumed responsibility for LLC formation
 Destroyers: CENIC, Desifie Northwest, Virginia Tech
 - Partners: CENIC, Pacific Northwest, Virginia Tech
- Level 3 has been very supportive of the concept

INTERNET® USA Waves

SURA initiative

- Outgrowth of SURA National Buyers Consortium
- UCAID and many U.S. Gigapops are collaborators

Proposed cooperative agreement with AT&T

- Ability for HEC to provision 2.5 and 10 Gbps λ IRUs at carrier's *incremental cost*
 - Anywhere on existing DWDM deployment and on future DWDM network
- Dark fiber & network equipment donation
 - Fiber available for network research
- Ability for HEC to procure additional dark fiber

Organization

- Non-profit, cooperative membership approach
- No entry fee for participation
- Very much in early stages of development

INTERNET. National Light Rail

National facilities-based approach for optical networking and network research

- 15,000+ miles of fiber footprint
- HEC owned/managed fiber and optronics for p2p $\lambda \dot{}s$
- Shared experimental services: IP and GigE

Enabling innovative network research is key goal

Leadership: CENIC, Pacific Northwest Gigapop

- Outgrowth of CENIC ONI regional project
- UCAID and multiple research universities collaborating

Corporate partners: Cisco, Level 3

Economics

- 5-year cost for national footprint: \$83M (for 4 10-Gbps λ 's)
- Significant participation fee: \$5M over 5 years

NLR Footprint and Layer 1 Topology



15808 Terminal, Regen or OADM site (OpAmp sites not shown) Fiber route

NLR networking research use vs. production (including science research) use

Infrastructure Use	Research based on measurements of real user Internet traffic (and not just univ-to-univ traffic) and visibility into Internet BGP for the first time since NSFnet	Production use for higher ed and K-12 \AUP-free commodity Internet access and inter-GigaPoP transit backup	Research needing its own L2 links with the capability to do complex topologies but where speed is not the primary focus and 1GE or lower ports are sufficient, e.g., multicast routing	Production use for cases where shared IP service is not acceptable but also dedicated 10G waves not needed either, e.g., remote instrument control	Research needing its own L1 links and/or dedicated 10G bandwidth, e.g., very large MTU performance, XTP implementation	Production use of dedicated (multiple) 10G bandwidth, e.g., DTF/ETF cluster supercomputers "backplane" interconnect, federal agency mission use, international connections transit	Research needing its own dark fiber full spectrum and/or deployment of breakable L1 gear, e.g., optical packet switching, IP-optics unified control plane, 100GE optics	
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ucture	Production IP service (Cisco COTS routers) - 10GE and 1GE ports		Experimental or breakable L3 gearProduction L3 gearProduction Ethernet service (Cisco COTS switches) - 1GE ports		Experimental or breakable L2-3 gear	Production L2- 3 gear	Experimental or breakable L1-3 gear	
Infrastructure	Production p							
			Production fiber (2nd pair)					
	NLR operated NLR or its production customer or researcher operated							
		Research use	Production use					



- 3 significant national optical networking initiatives underway in the U.S.
 - Fiberco, USA Waves, National Light Rail
- Higher education community will continue to acquire dark fiber assets on the national and regional scales in 2003
- Regional optical networks will be deployed
- Whether a national optical networking capability will be 'built or bought' is an open issue
 - Possibility of hybrid approach
- In either case, expanding requirements of the computational science and network research communities must be addressed