What do railroads and high speed networks have in common?

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High speed networks are built with fiber optics
Fiber

• A fiber-optic connection is faster than wireless by many orders of magnitude. A single optical fiber can carry about 3 trillion bits per second (bps). The fastest wireless service (fixed wireless access) approaches 2 million bps. So, fiber optics can be more than a million times faster.

• Dense wave division multiplexing (DWDM) is the process of putting many colors of light-each carrying its own data stream-onto a single strand of fiber-optics cable and sorting out the data streams at the other end. The extremely clever scheme enables a single strand of fiber-optics cable to carry up to 3 trillion bits of information per second.
  – Currently, each lightwave (lambda) can carry 10Gbps
  – Future, each lightwave (lambda) will carry 40-100Gbps
Level 3 Communications And Union Pacific Railroad Sign Fiber Optic Right Of Way Agreement

- Agreement Will Provide Level 3 With Key Routes in Western U.S. To Build Its National Fiber Network

OMAHA, NE, April 2, 1998

- Granting Level 3 the use of approximately 7,800 miles of rights of way along Union Pacific's rail routes, primarily West of the Mississippi. The agreement, the terms of which were not disclosed, will initially allow Level 3 to construct, operate and maintain its advanced fiber network facilities along rights of way initially connecting 25 cities. Level 3 expects to begin construction of its advanced fiber optic network during the third quarter of 1998.
BNSF Employees inspect fiber-optic cabling in one of the bungalows along the Seattle-Tacoma railroad line that stretches 45 miles.
The graph reflects 926,201 IP addresses and 2,000,796 IP links (immediately adjacent addresses in a traceroute-like path) of topology data gathered from 22 monitors probing approximately 865,000 destinations spread across 77,678 (50% of the total) globally routable network prefixes.
National LambdaRail and Abilene
TeraGrid is a facility that integrates computational, information, and analysis resources at the San Diego Supercomputer Center, the Texas Advanced Computing Center, the University of Chicago / Argonne National Laboratory, the National Center for Supercomputing Applications, Purdue University, Indiana University, Oak Ridge National Laboratory, the Pittsburgh Supercomputing Center, and the National Center for Atmospheric Research.
NCAR-TG: Phase 1
10 Gbps Network Design

- NCAR Cisco 6509 Switch
- Boulder TCOM Movaz
- Denver Level3 Movaz
- Teragrid Denver Router
- Teragrid LA Router
- Teragrid Chicago Router
- Teragrid

Connections:
- 10Gbps from NCAR to Boulder TCOM Movaz
- 10Gbps from Boulder TCOM Movaz to Denver Level3 Movaz
- 10Gbps from Denver Level3 Movaz to Teragrid
- 10Gbps from NCAR to Denver Level3 Movaz
A. Lightweight users, browsing, mailing, home use
   Need full Internet routing, one to many

B. Business applications, multicast, streaming, VPN’s, mostly LAN
   Need VPN services and full Internet routing, several to several + uplink

C. Special scientific applications, computing, data grids, virtual-presence
   Need very fat pipes, limited multiple Virtual Organizations, few to few

BW requirements

- ADSL
- GigE

<=5Mbps (millions of users) 10-1000 Mbps (thousands of users) 10,000,000 Mbps (10Gbps) (hundreds of users)
Network Applications

- Downloading music and movies;-)
- Telemedicine
- Live interactive music master classes
- Genomics
- Real time weather and climate data for forecasts (hurricanes, Unidata, tornadoes)
- Sensor data (satellites, radars, buoys, GPS systems)
Using LDM software for **instant data relaying**, ~160 institutions cooperate to acquire a wide range of real-time, global, atmospheric & oceanic observations, model outputs, remotely sensed images..., in a coordinated **community effort**. There is no data center in the system.
NEXRAD Doppler Radar Network
The Benefits – University Research

KFWS Radar Observations

ARPS 3 km Forecast
With Radar Data

ARPS 3 km Forecast
Without Radar Data
Questions?