<table>
<thead>
<tr>
<th>Title</th>
<th>Advanced internet (I2) : key projects and technologies</th>
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<tbody>
<tr>
<td>Author(s)</td>
<td>Conklin, Bill</td>
</tr>
<tr>
<td>Date</td>
<td>1999</td>
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<td>URL</td>
<td><a href="http://hdl.handle.net/10220/1411">http://hdl.handle.net/10220/1411</a></td>
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<td>Rights</td>
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Advanced Internet (I2)

Key Projects & Technologies
A collaborative effort by more than 140 U.S. universities, working with partners in industry and government, to develop advanced Internet technologies and applications to support the research and education missions of higher education. Internet2 is a project of the University Corporation for Advanced Internet Development (UCAID).

A research effort complimentary to the Next Generation Internet (NGI) Initiative .....a multi-agency Federal research and development program that is developing advanced networking technologies, revolutionary applications that require advanced networking, and demonstrating these capabilities on testbeds that are 100 to 1,000 times faster end-to-end than today's Internet.
What is the Internet?

- Major Change in Internet Applications and Networks
  - Applications: Audio, Video/Visualization, Data/Transactions
  - Technologies: Streaming, Real-time, Immersive
  - Network: Quality of Service, Application Intelligence
  - Scaling: Bandwidth, Distributed Memory, Servers, Transactions
  - Telephony: Usage pattern change, not just cheap delivery
  - Dispersed distributed computing and storage, metacomputing

- Already $8B Experimental Market, $90B by 2003
  - Video: Servers, clients, conferencing
  - Audio: Music, voice
  - Servers: Solutions, bundles
  - Network: Hardware, software, services
  - Services: Creative, professional, integration, hosting
<table>
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<tr>
<th>Goals</th>
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<tbody>
<tr>
<td>✓ Enhance researchers' ability to collaborate and conduct experiments</td>
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<tr>
<td>✓ Support development and adoption of advanced applications</td>
</tr>
<tr>
<td>✓ Demonstrate enhanced delivery of education and other services</td>
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<tr>
<td>✓ Ensure end-to-end quality of service and interoperability</td>
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<tr>
<td>✓ Catalyze partnerships with governmental and private sector organizations</td>
</tr>
<tr>
<td>✓ Encourage transfer of technology from Internet2 to the rest of the Internet</td>
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</table>
Strategic Initiatives

- The Internet2 Digital Video Network (I2-DVN) will establish a National Higher Education Video Network service to provide capabilities to support scalable and easy-to-use applications to deliver live or stored streaming and interactive high-quality digital video.

- Led by Northwestern University/International Center for Advanced Internet Research (iCAIR).

- IBM is the premier partner (SP Processor, Videocharger, Technical Resources)

- Will also develop archive and research capabilities for Video Libraries.
Strategic Initiatives

- The Internet2 Distributed Storage Infrastructure (I2-DSI) Initiative supports researchers in exploring the most effective way to deliver high bandwidth content, like full-motion video, over public networks like the Internet. Will determine the most efficient mix of networking and storage to ensure quality of services.

  - Led by University of Tennessee/Innovative Computing Lab
  
  - IBM Web Cache Managers used in initial deployment
    = Six TeraBytes

  - University of Tennessee, University of North Carolina, Indiana University, U.S. Geological Survey's EROS Center at University of Hawaii.
Strategic Initiatives

- The Internet2 QBone Interoperability Group (QIG) is exploring implementation of Quality of Service (QoS) to enable advanced applications

  - Establishing an Interdomain Testbed for Differentiated Services.

  - Participants represent 14 Regional Research Networks/GigaPops/Application Development groups.

  - International Center for Advanced Internet Research (iCAIR) leads the QBone International Consortium.
IBM and Internet

- Foundation for Future e-business Applications

- New Services and Applications Space
  - Entertainment
  - Education
  - Business
  "More Natural Way for People to Interact"

- IBM Technologies/Skills/Resources Committed
IBM I2 Work In Progress...

QBone - Interdomain Testbed for Differentiated Services

➢ NHD DiffServ product testing with:
  - NCNI and NCSU
  - DANTE Consortium (Europe)
  - University of Twente (Netherlands)
  - University of Pennsylvania

➢ Traffic Characterization Study
  - NCNI, DUKE, UNC
  - I2 Measurement Workgroup

IBM NHD Additional Activities with NCSU

➢ Connected via NC GigaPoP
➢ Multimedia Lab - Video Collaboration over ATM
➢ Product Testing
  - ATM with MSS
  - Ethernet Switch Product Testing
Significant subset of the Internet implements well-defined notions of QoS and is regarded by users as infrastructure.

Testbed

Interdomain DiffServ testbed being built by R&E networks

Infrastructure only a graduate student could love

Initiative

Internet2 initiative that includes QBone testbed (QIG)

Quality of Service

What is "the QBone"?
Test Description

Router Policy
- Loaded via LDAP Client from LDAP server

Experiment
- One Sender, Multiple Receivers
- MGEN for UDP flows (and measure delay in AF & BE)
  - 28 Byte UDP Payload
- NETPERF for TCP flows
  - MTU = \{500, 1000, 1500\}
- One Flow per DS Class

Very Short UDP Packets Competing With Large TCP Packets
- So, worst case type test

Quality of Service
Testbed & Experiment

Quality of Service

2 Mbps PPP
NHD DiffServ Offering

Diff Serv enables reservation of b/w ...

Expedited, 4 Assured and Best Effort

Guaranteed % of Total B/W

Quality of Service
IBM & MPLS

Pioneering Contributions

IBM Technical Contributions

- One of the MPLS Original Inventors
- ARIS
- Label Distribution Protocol
  - Co-author draft-ietf-mpls-ldp-03.txt
  - Ordered Label Binding
  - Label Hierarchy
  - Loop Detection
- Constraint-Based Routing via LDP
Test Results: EF, AF1-4, & BE flows

DS Class (Traffic Type) Policy Configured % of Link

Policy configuration (%)  Router measurements (%)  Host payload throughput (%)  Policy + expected share (%)
Why Integrate Routing & Switching?

- Growth Exceeds L3 Capacity of Routers
- Utilize Hardware Switching to Improve L3 Routing Price/Performance
- Need for a Rich Multi-Service Network
  - Work with Existing Frame Relay/ATM Infrastructures
  - L3 per-Packet Classification & Processing at Network Edge
  - Scalability like IP
  - Flexible & Easy Administration
  - Traffic Engineering, with QoS

MPLS Benefits

- Intelligence of Routing
- Performance of Switching
- Simpler & Faster Forwarding Paradigm
  - Layer 2 Label Swapping vs. Layer 3 per-Packet Processing
  - Single Forwarding Algorithm Across Multiple Functions
Label Swapping

- Routing (or flow) information is mapped to labels
  - Switch's label-swap tables are updated with the new labels
- Forwarding reduced to label lookup, label swap and output port selection
  - Done in hardware
  - Does not require longest address match on routing table

MPLS

Operation, Examples
MPLS Operation

1. Control protocol (LDP) distributes route-to-label mappings to LSRs along routed path
2. Classify, label and forward at network ingress
3. Label swap over layer-2 path to network egress
4. Remove label and forward at the egress

MPLS Example #1

Aggregation - One LSP Aggregates Flows for Multiple Destinations
MPLS Example #2

Explicit Routing - Net D traffic passed through (A,1,2,3,3,B)

MPLS Example #3

Possible VPN Support
- Add VPN ID# to MPLS access link
- MPLS nodes advertise FEC/label mappings to only those ingress routers that have matching VPN ID#
- Ingress router can only receive labels to egress router with the same VPN ID#
- Uses VC approach rather than tunnels to separate VPN traffic flows
Application Example: H.323

- High Quality Audio/Video Streaming
  - Video Conferencing for Distance Learning
  - Beyond ISDN
- Intelligent Integration
  - ISDN/ATM/IP
- Quality of Service, Multicast
- DiffServ Over MPLS
- H.323 Annex C

Comparison

<table>
<thead>
<tr>
<th></th>
<th>MPLS</th>
<th>Layer-3 Switches</th>
<th>Gigabit Routers</th>
<th>MPOA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast IP Forwarding</td>
<td>Yes, via label swapping</td>
<td>Yes, via ASICS</td>
<td>Yes, via ASICS</td>
<td>Yes, via ATM</td>
</tr>
<tr>
<td>Full IP Routing</td>
<td>Yes</td>
<td>Partial</td>
<td>Yes</td>
<td>Yes, on route server</td>
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<tr>
<td>IP Multicast</td>
<td>Yes</td>
<td>Partial/No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Environment</td>
<td>WAN, Internet</td>
<td>Campus</td>
<td>WAN, Internet</td>
<td>Campus, WAN</td>
</tr>
<tr>
<td>Network Layer Independence</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>QoS</td>
<td>Yes, via DiffServ, RSVP, ATM</td>
<td>No</td>
<td>No</td>
<td>Yes, via ATM</td>
</tr>
<tr>
<td>Interfaces</td>
<td>Edge Dependent</td>
<td>Ethernet</td>
<td>High Speed</td>
<td>Edge Dependent</td>
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<tr>
<td>Traffic Engineering</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Value Added Services</td>
<td>QoS, ATM, Traffic Engineering</td>
<td>None</td>
<td>None</td>
<td>QoS, ATM</td>
</tr>
</tbody>
</table>
IBM Differentiators

- Constraint-Based Routing
- Aggregation
  - Vital for Efficient Scalability
- VC Merge Hardware
- VC Merge & Non-Merge Interoperability
  - Vital for Smooth Migration & Deployment
- Multiprotocol Switched Services (MSS)
  - True Integrated Switch Router
- ARIS: Proven Code Base

IBM.
IBM Internet2 Commitment

- Position IBM as a technology and services leader focused on advanced, high bandwidth applications that require differentiated quality of service levels

- Establish IBM as an industry partner in the deployment of advanced technologies and services that focus on high bandwidth applications

- Provide comprehensive solutions leadership for advanced internet applications through alliances, technologies, and services
2nd Regional Symposium on "New Media & Learning Technologies in Asia"

September 8-10, 1999
Singapore

DAY TWO

9 September 1999