Part II: LAN Technologies and Internetworking

- **LAN Technologies**
  - **Switching**
  - **Ethernet**
  - **Token Ring and Fiber Channel**
- Multi Protocol Label Switching
  - Evolution
  - Architecture
  - Impacts on Network Management

LAN Technologies

- IEEE 802.3 Carrier Sense Multiple Access with Collision Detection (CSMA/CD), also known as the Ethernet*:*
  - 10 Mbit/s transmission speed and
  - Bus topology (shared medium).
- IEEE 802.5 Token Ring:
  - 4 Mbit/s and 16 Mbit/s versions and
  - Ring topology (shared medium).
- *Distributed* Medium Access Control Algorithm.
- Universal cabling systems with star topology are suitable for both LANs (unshielded and shielded twisted pair).

IEEE 802 LAN Standards

- 802.1: LAN/MAN Bridging & Management (.1p, .1q)
- 802.2 Logical Link Control*
- 802.3 CSMA/CD Access Method (.3z, .3ab)
- 802.4 Token-Passing Bus* Access Method
- 802.5 Token Ring Access Method*
- 802.6 DQDB Access Method*
- 802.7 Broadband*
- 802.8 Fiber Optic†
- 802.9 Integrated Services / Isochronous LAN*
- 802.10: LAN/MAN Security*
- 802.11: Wireless LAN
- 802.12: Demand Priority Access Method*
- 802.13 n/a (!)
- 802.14: Cable Modems†
- 802.15: Wireless Personal Area Networks
- 802.16: Broadband Wireless Access
- 802.17: Resilient Packet Rings (study group)

*: inactive; †:disbanded

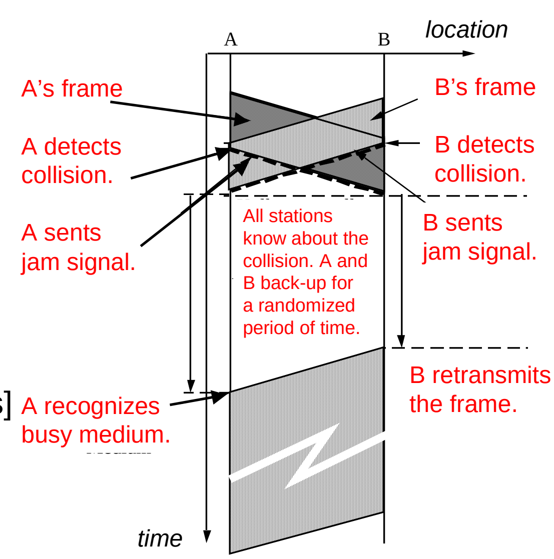
CSMA/CD Medium Access Algorithm

Maximum throughput is roughly indirectly proportional to β:

$$\beta = \tau / m = (\tau * C) / L$$

τ: Propagation delay [s]
m: Frame length [s]
L: Frame length [bit]
C: Transmission rate [bit/s]

For good performance, β should be <= 0.01.



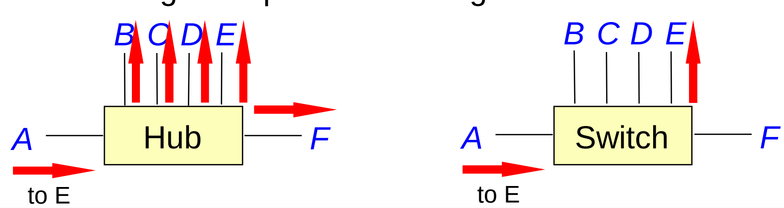
CSMA/CD Frame Format

7	1	2 (6)	2 (6)	2	0...1500	≤46	4	Byte
Preamble	SFD	DA	SA	Length	Payload	PAD	FCS	

Preamble:	Bit synchronization
SFD:	Byte synchronization
DA:	Destination address
SA:	Source address
Length:	Length of payload
Payload:	Upper layer frame
PAD:	To fill up a short frame
FCS:	32-Bit CRC for error detection

Switching (1)

- Hubs vs. Switches:
  - Similar locations in networks.
  - Hubs repeat all packets while switches examine all of them.
  - Switches require address examination and forwarding.
    - Store-and-forward: Analyze the entire packet.
    - Cut-through: Only examine destination and forward.
    - Blocking vs. non-blocking architectures.
    - Buffering: backpressure or large buffers.



Switching (2)

- Handle packets at wire speed.
- Layer-2-Switching:
  - cf. before
- Layer-3-Switching:
  - Combination of switching speed and router functionality.
  - Similar terminology: Routing switches or IP switches.
  - Identification for common traffic flows on layer 3 and switch these flows on the hardware level for speed. Other traffic will be routed as usual.
- Layer-4-Switching:
  - Includes application-level control by applying filters, e.g., security, and QoS-control on specific application flows.

Fast Ethernet

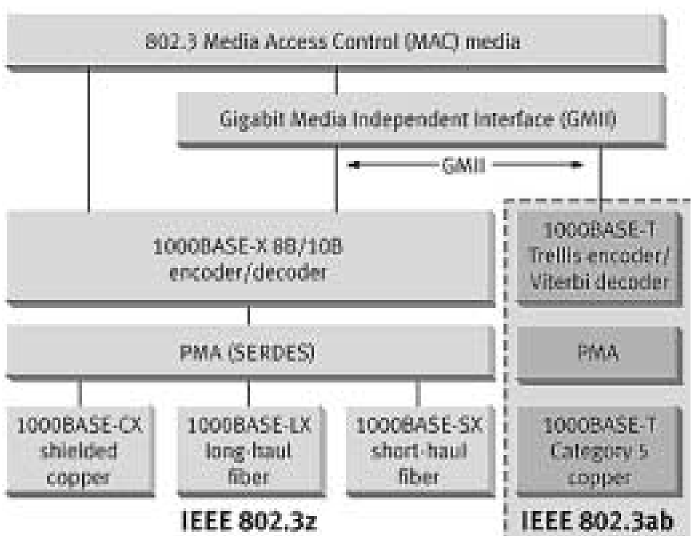
- 100 Mbit/s version of Ethernet, using CSMA/CD algorithm (recent addition to IEEE 802.3).
  - 10 times faster than “normal” Ethernet, and 10 times smaller (max. app. 200 m between stations).
  - Easy upgrade path from Ethernet, simply replace Ethernet hubs, adapters, and driver software!
  - Autosensing of physical media.
- Works with several physical media:

Physical Layer	Media Types
100BASE-TX	2 pairs category 5 balanced cable, or 2 pairs 150 ohm shielded balanced cable as defined by ISO/IEC 11801
100BASE-FX	2 multi-mode fiber as defined by ISO 9314
100BASE-T4	4 pairs of category 3, 4 or 5 balanced cable as defined by ISO/IEC 11801

Gigabit Ethernet

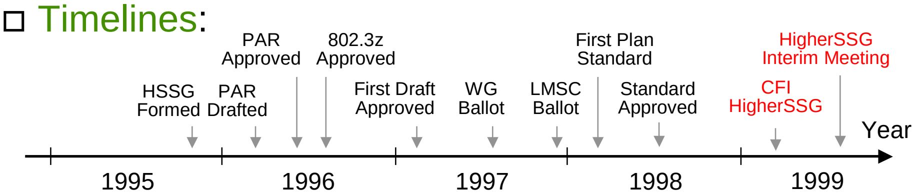
- Marketing aspect:
  - Term *Ethernet* used to hint at easy and cheap upgrade, reliability.
- Theory is different:
  - If CSMA/CD is used on a shared medium, the allowable size of a Gigabit Ethernet segment will be rather small (roughly 20 m).
  - If CSMA/CD is *not* used, it's *not* Ethernet.
- Realistically, a Gigabit/s LAN need not be a CSMA/CD-based LAN to grant compatibility.
  - Important are cost, compatibility with existing cabling and systems, and availability of good drivers for popular operating systems.

Gigabit Ethernet Layering and Standards



Gigabit Ethernet – Objectives

- IEEE 802.3 commitee's key objectives:
  - Half- and full-duplex operation at 1000 Mbit/s.
  - Complying with IEEE 802.3 Ethernet frame format.
  - Applying CSMA/CD access method.
  - Allowing one repeater per physical collision domain.
  - Providing address compatibility with Ethernet and Fast Ethernet technologies.
- Timelines:



CFI: Call for Interest, PAR: Project Authorization Request, WG: Working Group, HSST: High-Speed Study Group

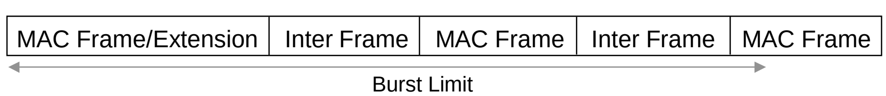
Gigabit Ethernet – Frames

- Frames compatible with Ethernet classic.
- Preamble: 101010 … 10.
- Start Delimiter: 10101011.
- Padding: Even # of Bytes.
- Extension used to safely detect collisions.
- Bursts: Concatenation of max. 65536 Byte.

Transmission ↓

Preamble	7 Byte
Start Frame Delimiter	1 Byte
Destination Address	6 Byte
Source Address	6 Byte
Length/Type	6 Byte
Data	1518 Byte
Padding	0/1 Byte
Frame Check Sequence	4 Byte
Extension	

bit 0 … bit 7



Gigabit Ethernet – Physical Layer

- Symbols are used to code MAC data (802.3z):
  - 8B/10B coding scheme (8 bit user data/10 bit phy. data)
  - Code-inherent clock regeneration.
  - Always min 4 and max 7 state changes per symbol.
  - 1250 Mbaud.
  - Code group symbols (always different to data symbols):
    - Carrier Extension,
    - Idle,
    - Start-of-Packet,
    - End-of-Packet,
    - Configuration Marks, and
    - Violations.

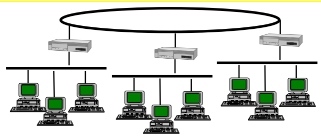
Gigabit Ethernet – Physical Media

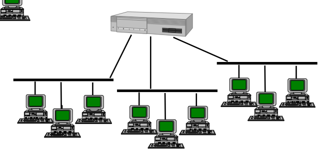
- Standard for UTP cabling accepted in June 1999 (802.3ab, 1000BASE-T)
- Smaller distances for fiber cabling compared to Fast Ethernet and FDDI due to dispersion.

Type	Cabling		Waves	Distance	Plugs
1000BASE-SX	62,5 µm Fiber	Multimode	830 nm	2 – 260 m	Duplex SC
1000BASE-SX	50,0 µm Fiber	Multimode	830 nm	2 – 550 m	Duplex SC
1000BASE-LX	62,5 µm Fiber	Multimode	1270 nm	2 – 550 m	Duplex SC
1000BASE-LX	50,0 µm Fiber	Multimode	1270 nm	2 – 550 m	Duplex SC
1000BASE-LX	10,0 µm Fiber	Monomode	1270 nm	2 – 3000 m	Duplex SC
1000BASE-CX	STP	Twinax		25 m	DB9 (Style 1)
1000BASE-CX	IEC 61076	Twinax		25 m	IEC (Style 2)
1000BASE-T		UTP, Cat 5		100m	RJ-45

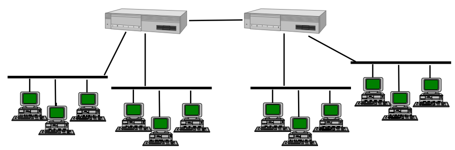
Network Design (1)

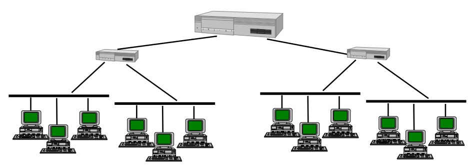
- ☐ Backbone





- ☐ Backbone Switching (collapsed backbone)
- ☐ Multiswitch Backbone

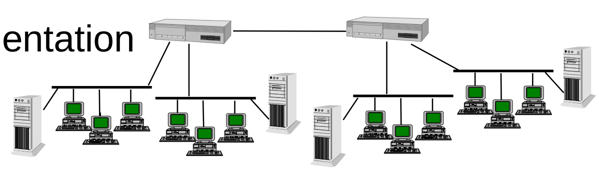




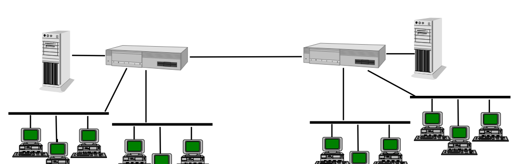
- ☐ N-tiered Switch (N=2)

Network Design (2)

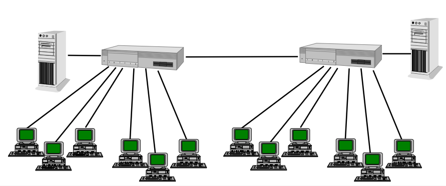
- ☐ Workgroup Segmentation (decentralized)



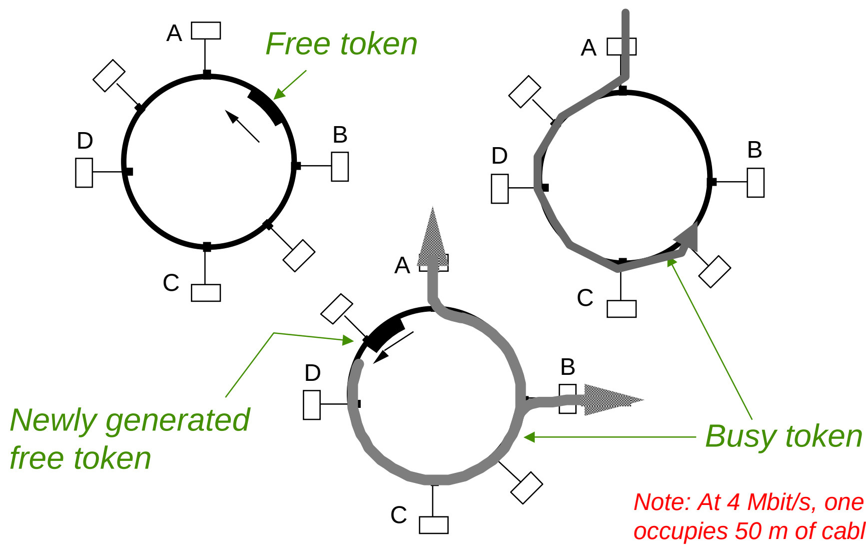
- ☐ Workgroup Segmentation (centralized)



- ☐ Micro Segmentation



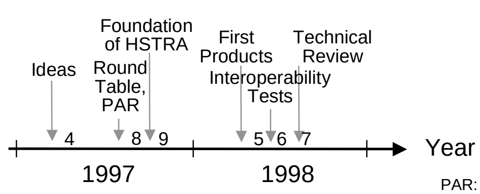
Token Ring Medium Access Algorithm



Note: At 4 Mbit/s, one bit occupies 50 m of cable!

High Speed Token Ring (HSTR) – Objectives

- IEEE 802.5 commitee's key objectives:
  - Support large Token Ring frames sizes (up to 18.2 kByte).
  - Full source routing support (RI field up to 14 hops).
  - Eight levels of priority.
  - Availability and robustness as with 4/16 Mbit/s versions.
  - Scaling from 100 Mbit/s up to 1 Gbit/s.
  - Upwards compatibility with 802.1q (multiple VLANs)
- Timelines:



PAR: Project Authorization Request
HSTRA: High Speed Token Ring Alliance

HSTR – Members, Goals

- High Speed Token Ring Alliance (HSTRA):
  - 3Com
  - Bay Networks
  - IBM
  - Madge Networks
  - Olicom
  - University of New Hampshire – Interoperability Lab
  - Xylan
- Goals:
  - Minimize cost of acquisition and ownership.
  - Maximize throughput and utilization.

Press Coverage (1)

InternetWeek
August 29, 1998

With its high-speed network interface cards and uplinks, Olicom next week will become the first vendor to ship 100-megabit-per second token-ring devices. Olicom's RapidFire 3530 HSTR 100 peripheral component interconnect adapter and CrossFire 8650 HSTR uplink are part of what the company is calling a "renaissance" in token ring, said Jorgen Hog, vice president of product management. He said there's still a huge base of token-ring users that like its stability and can't afford to switch to technologies such as gigabit Ethernet

Press Coverage (2)

Just A Token Presence?
By David Wilby

Network Week
November 18, 1998

(...)
In one recent study, the Tolly Group concluded through testing of Olicom's CrossFire 8650 HSTR uplink and HSTR server adaptor, that the technology consistently delivered higher throughput and better use of CPU ratings than Fast Ethernet. Joergen Hoeg, vice-president, product marketing of Olicom duly asserted: These tests prove... that it [Token Ring] is a more efficient and robust networking technology than Ethernet.

But surely it is now irrelevant for the majority of managers with purchasing power whether or not TR has any technical benefits over Ethernet? **Determined HSTR vendors must now fight for the remaining TR sites,** ***that have decided to stick with the devil they know*****, and save on the expense of ripping out their TR infrastructures and flood-wiring with Ethernet technologies.**
(...)

Press Coverage (3)

Bell Tolls For High-Speed Token Ring Alliance
By Marc Songini
Network World
July 26, 1999

Roughly two years after it started, High-Speed Token Ring Alliance (HSTR) has accomplished its goals of establishing a specification and seeing some members ship 100M bit/sec token-ring products.
The question is, does all of this activity matter? Has the HSTRA arrived just in time for its own funeral? Founded to give token-ring customers an upgrade alternative to 100M bit/sec Ethernet, the HSTRA's roster initially was a who's who of network players, including Cisco, 3Com, Texas Instruments, Compaq, Cabletron, Xylan, the former Bay Networks and IBM. Now after two years, the membership list has been whittled down, by defections or acquisitions, to the three leading token-ring players: IBM, Madge and Olicom. (…)

Note: In September 1999, Olicom sold their TR business to Madge.

Press Coverage (4)

Raleigh, NC
September 27, 1999

FROM:
Scott D. Smith
Vice President, Worldwide Sales and Marketing IBM Networking Hardware Division
TO:
All IBM Token Ring business partners and customers

In light of our recent announcement of an alliance with Cisco, and the concurrent announcement of the purchase of Olicom's Token-Ring business by Madge, I am writing to clarify our position and answer any questions you may have regarding IBM's commitment to providing you with Token-Ring products, solutions and support.

Our new relationship with Cisco pertains only to our routing products and ATM and Ethernet switching offerings. It has no impact on our continuing development, enhancement and support of Token-Ring products. You will still be able to purchase all the IBM Token-Ring adapters, hubs and workgroup switches that you have in the past. We also will continue to enhance our Token-Ring portfolio as the market demands, with a significant product announcement planned for early next year. (…)

Fibre Channel: Goals

- Performance 266 Mbit/s - 4 Gbit/s
- Support for distances up to 10 km
- High-bandwidth utilization with distance insensitivity
- Broad availability (i.e., standard components)
- Support for multiple cost/performance levels, from small systems to supercomputers
- Ability to carry multiple existing interface command sets, including Internet Protocol (IP), SCSI, HIPPI-FP, and audio/video.

Fibre Channel Technology (1)

- High speed serial links for processor-to-processor or processor-to-mass storage interconnectivity.
  - Point-to-point: High speed, “zero” latency, limited.
  - Switching fabrics: Virtual point-to-point links, connections must be set up through switch, 10µs latency.
  - Arbitrated loops: Shared capacity of one Fiber Channel between all nodes, low latency.
- Fiber Channel layering:
  - FC-0: Physical issues: links, speed, cabling, distances.
  - FC-1: Block encoding method (8B/10B).
  - FC-2: Framing, service classes, fragmenting.
  - FC-3: Set of common services for higher-layer protocols.
  - FC-4: Mapping of higher-layer protocols onto FC services.

Summary of High-speed Technologies

Fast Ethernet

- Inexpensive, emerging technology.
- A 100 Mbit/s solution that integrates well into many installed Ethernet bridged and routed networks.
- Use of existing expertise – familiarity with Ethernet should enable customers to incorporate this new technology easily into their existing networks.

Gigabit Ethernet

- Technology now stable.
- Compatibility with UTP cabling.
- Uses Ethernet frame formats.
- Easy integration in an existing Ethernet switching infrastructure.
- Attractive backbone technology.
- „Ethernet“ label mainly a marketing asset.

Fibre Channel

- High speed interconnect
- Processor to processor
- Processor to mass storage
- Point-to-point links
- All IEEE 802.1 service classes
  - connectionless
  - connection-oriented
  - request-response
- Transports IP, SCSI

Comparison

	Fibre Channel	Gigabit Ethernet	ATM
Technology application	Storage, network, video, clusters	Network	Network, video
Topologies	point-to-point loop hub, switched	Point-to-point hub, switched	Switched
Baud rate	1.06 Gbps	1.25 Gbps	622 Mbps
Scalability to higher data rates	2.12 Gbps, 4.24 Gbps	Not defined	1.24 Gbps
Guaranteed delivery	Yes	No	No
Congestion data loss	None	Yes	Yes
Frame size	Variable, 0-2KB	Variable, 0-1.5KB	Fixed, 53B
Flow control	Credit Based	Rate Based	Rate Based
Physical media	Copper and Fiber	Copper and Fiber	Copper and Fiber
Protocols supported	Network, SCSI, Video	Network	Network, video

Taken from http://www.fibrechannel.com/technology/technology.htm

References

- Tutorial materials on: *ATM, VG AnyLAN, Ethernet, Fast Ethernet, Fiber Channel, Gigabit Ethernet*; http://www.iol.unh.edu/training/index.html
- C. Spurgeon: *Quick Reference Guide to 100 Mbps Ethernet;* http://wwwhost.ots.utexas.edu/ethernet/descript-100quickref.html
- IEEE Standards Library: http://standards.ieee.org/catalog/olis/index.html
- Gigabit Ethernet Comes Of Age *(A 3Com* White Paper); http://www.3com.com/technology/tech_net/white_papers/503003.html

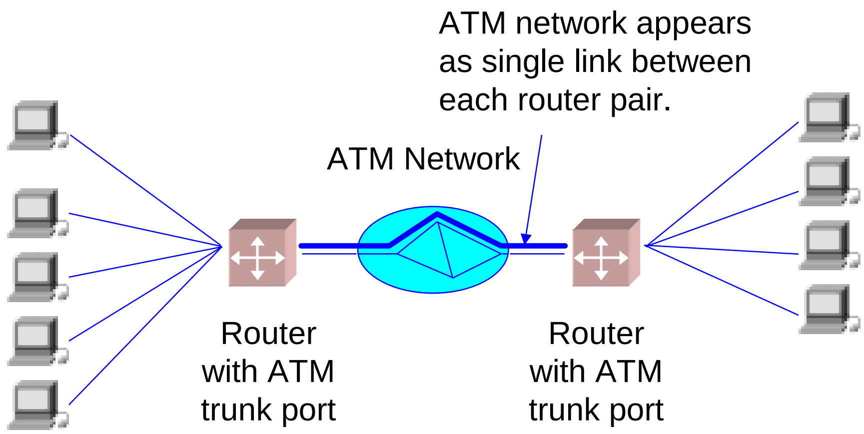
Part II: LAN Technologies and Internetworking

- LAN Technologies
  - Switching
  - Ethernet
  - Token Ring and Fiber Channel
- **Multi Protocol Label Switching**
  - **Evolution**
  - **Architecture**
  - **Impacts on Network Management**

IP Datagram based Backbones

- Efficient longest prefix matching requires complex algorithms. Simple implementations are too slow for large backbones.
- Each router maps IP packets to a “Forwarding Equivalence Class”. This requires large filter databases in every backbone router.
- The IP routing paradigm does not provide adequate traffic control mechanims (load balancing, multi-path routing, ...).

Overlay Network Model

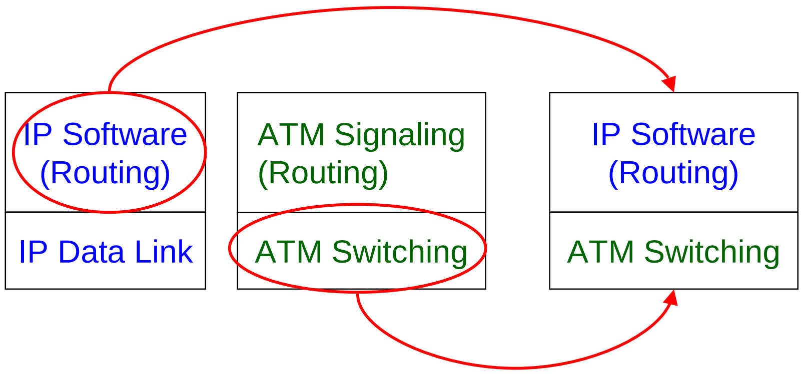


(Router solution initially used by SWITCH between Universities)

Assessment of the Overlay Model

- Data forwarding in the backbone is very efficient.
- VPCs allow for an explicit control of traffic flows.
- VPCs require manual configuration.
- For n peering routers, n^2 VPCs or SVCs are needed. This limits the scalability of the approach.
- If SVCs are used, routing is done in both the IP and the ATM layer.
- Two independent networks have to be operated, managed and maintained.

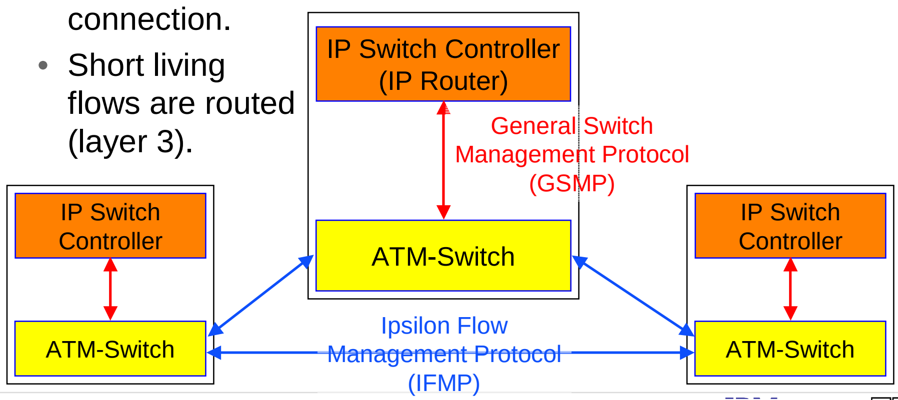
IP Switching: Ipsilon’s Solution



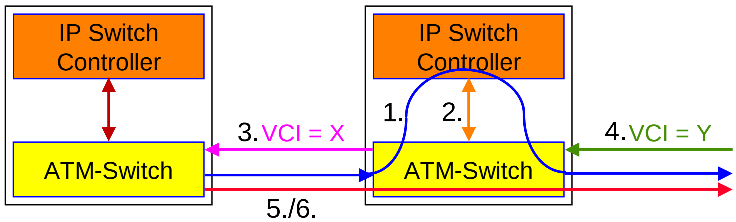
“The best of two worlds”

IP Switching Architecture

- Ipsilon’s IP Switch Architecture:
  - Flows = IP packets with similar source and destination address.
  - Long living flows are supported by setting up an ATM connection.
  - Short living flows are routed (layer 3).



Setup of an ATM Connection for Flows



1. Arrival of IP packet and forwarding via IP switch controller.
2. Switch controller decides on setup of an ATM connection.
3. Send re-configuration to upstream switch to use separate VPI/VCI.
4. Re-configuration message arrives at downstream switch.
5. Cut-through link is connected.
6. Cut-through link is disconnected, if configuration messages are missing.

Assessment of Ipsilon's IP Switching

- Data forwarding in the backbone is very efficient.
- Architecture is homogeneous and fairly simple.
- GSMP and IFMP are published as informational RFC 2297 and RFC 1953, respectively.
- Scalability is limited due to a potentially large number of traffic flows.
- Since path is only set up after a number of packets have been processed, a high latency results.
- Requires high performance packet classifiers.
- Only applicable to ATM networks.
- Ipsilon has vanished from the market.

Multi-Protocol Label Switching

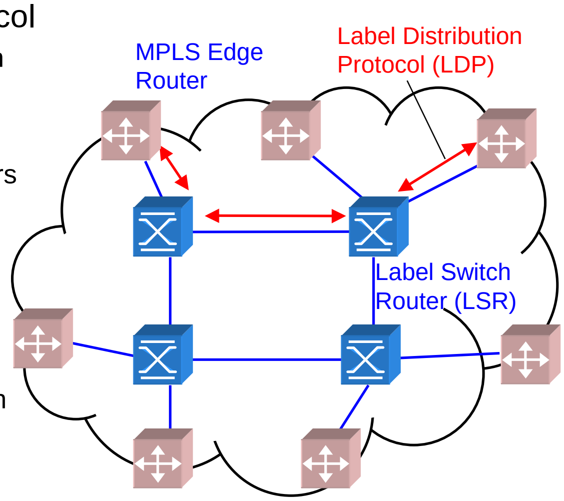
- Ipsilon's basic idea has triggered follow-up solutions:
  - Tag Switching [Cisco]
  - Cell Switch Router [Toshiba]
  - Aggregate Route Based IP Switch ARIS [IBM]
  - IPSOFACTO [NEC]
- Standard is now being developed by the IETF.
- Initial products are available. (see, e.g., http://www.dataconnection.com/mpls/mplsidx.htm)

MPLS overview

- MPLS consists of two components:
  - Network independent forwarding component
  - Control component
- Forwarding based on simple, fixed-sized labels
  - VPI/VCI for ATM
  - Small "shim" label header for native IPv4 networks
  - IPv6 flow label
- Control component creates bindings between labels and routes using combinations of:
  - Layer-3 destination prefix, forwarding equivalence class (FEC)
  - IP "Class of Service" bits
  - Application flows
  - Explicit routing (configured by network manager)

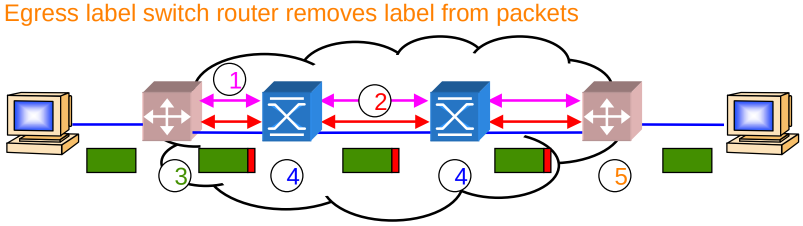
MPLS Architecture Overview

- Label Distribution Protocol
  - Distributes labels between devices
- MPLS Edge Routers
  - Full-function layer-3 routers
  - Apply labels to packets
  - Run the Label Distribution Protocol and standard routing protocols
- Label Switch Router
  - Forward packets based on labels
  - Run the Label Distribution Protocol and standard routing protocols



MPLS Operation

1) Standard Routing Protocol (OSPF, BGP, ...) used to establish routes in Edge Routers and Switches
2) Label Distribution Protocol builds up label bindings
3) Ingress label switch router "labels" packets
4) Label switches switch packets based on the label (no network layer needed)
5) Egress label switch router removes label from packets

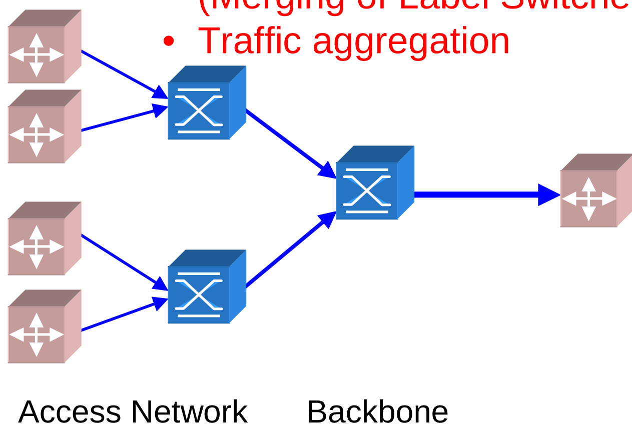


Example label bindings

In label	Address Prefix	Out Interface	Out label
1 2	129.132 171.56	1 2	4 8

Why Does MPLS Scale?

- Multi-point to Point Tree
  (Merging of Label Switched Paths)
- Traffic aggregation



Summary MPLS

- ☐ Allows for high performance backbones with multi-gigabit/s links.
- ☐ Suitable for large backbones due to multipoint-to-point trees and topology driven approach.
- ☐ Offers a wide range of traffic control mechanism (topology-, request- or traffic driven, configured).
- ☐ Can be used on different layer 2 network technologies (not just ATM).
- ☐ MPLS Switching may soon be an IETF standard.
- ☐ High flexibility may limit interoperability (motivation for interoperability tests/labs)
- ☐ Per flow QoS is not feasible in MPLS.