15-441 Computer Networking
Lecture 10 – Routers and Routing

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Outline

- ICMP
- How do Routers Works?
- Routing
- Distance vector

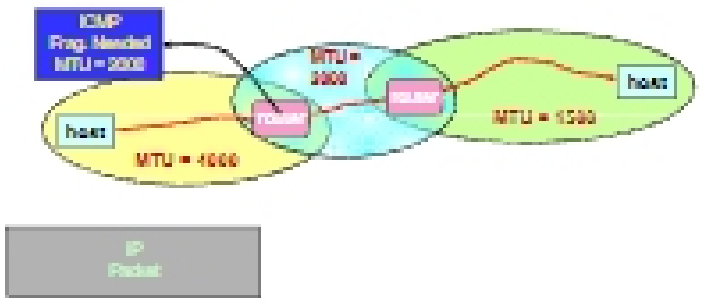
Internet Control Message Protocol (ICMP)

- Short messages used to send error & other control information
- Examples
  - Ping request / response
    - Can use to check whether remote host reachable
  - Destination unreachable
    - Indicates how packet got & why couldn't go further
  - Flow control
    - Slow down packet delivery rate
  - Redirect
    - Suggest alternate routing path for future messages
  - Router solicitation / advertisement
    - Helps newly connected host discover local router
  - Timeout
    - Packet exceeded maximum hop limit

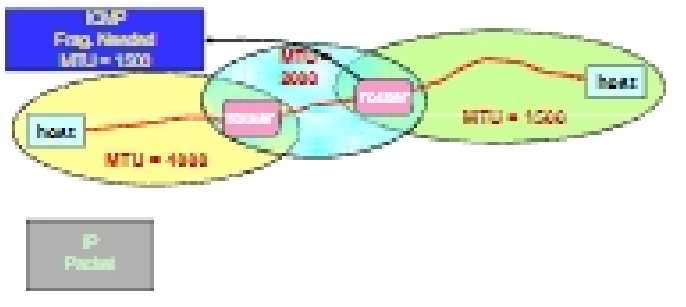
IP MTU Discovery with ICMP

- Typically send series of packets from one host to another
- Typically, all will follow same route
  - Routes remain stable for minutes at a time
- Makes sense to determine path MTU before sending real packets
- Operation
  - Send max-sized packet with "do not fragment" flag set
  - If encounters problem, ICMP message will be returned
    - "Destination unreachable: Fragmentation needed"
    - Usually indicates MTU encountered

IP MTU Discovery with ICMP



IP MTU Discovery with ICMP



IP MTU Discovery with ICMP

- When successful, no reply at IP level
  - "No news is good news"
- Higher level protocol might have some form of acknowledgement

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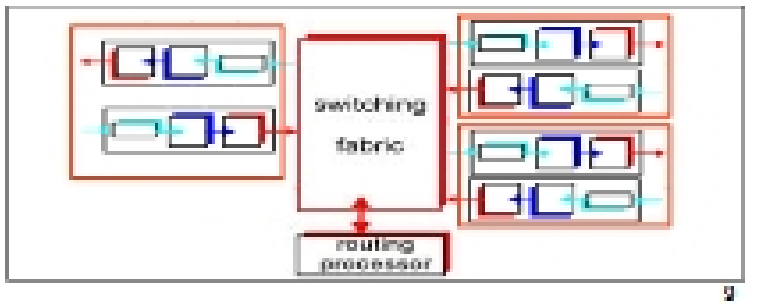
Router Architecture: Key Functions

- Run routing algorithms/protocol (RIP, OSPF, BGP)
  - Done by routing processor
- *Switching* datagrams from incoming to outgoing link
  - Common case handled by line cards

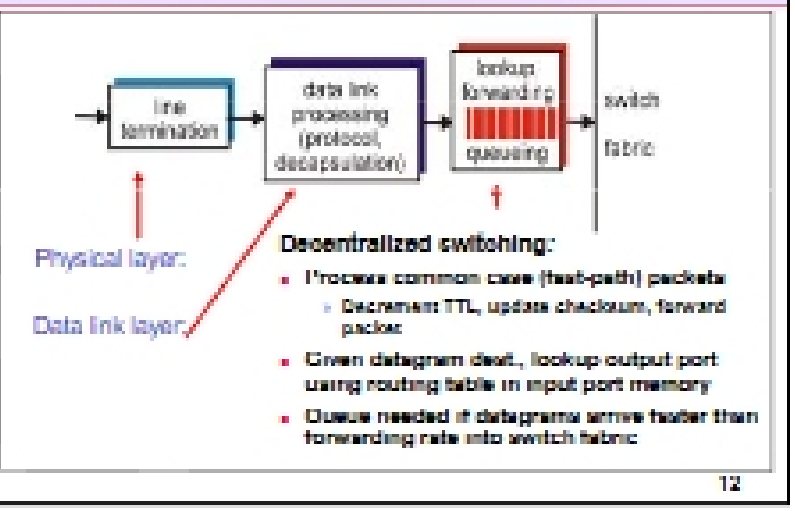


Router Physical Layout

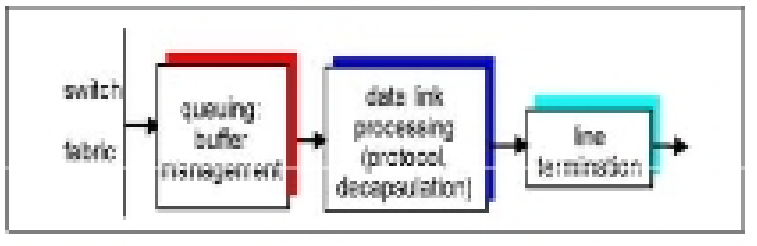
Line Cards

- Often uses special purpose hardware (e.g. ASICs)
- Network interface cards
- Fast path (common-case) processing
  - Decrement TTL
  - Recompute checksum
  - Forward to next hop line card
    - forwarding engine

Line Card: Input Port



Line Card: Output Port

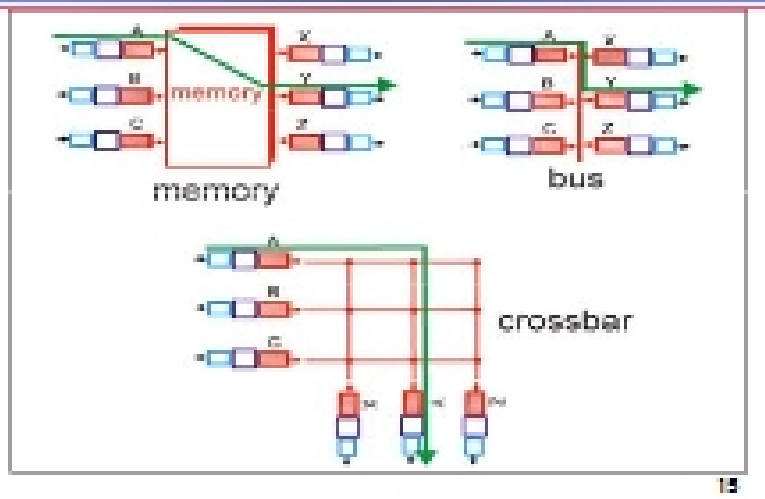


- Queuing required when datagrams arrive from fabric faster than the line transmission rate

Router Processor

- Runs routing protocol and downloads forwarding table to forwarding engines
- Performs "slow" path processing
  - ICMP error messages
  - IP option processing
  - Fragmentation
  - Packets destined to router

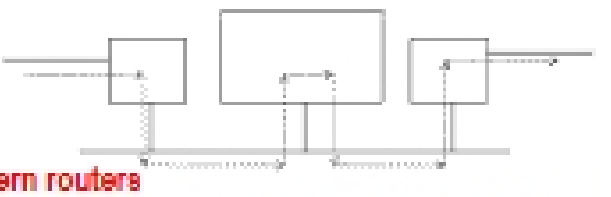
Three Types of Switching Fabrics



Switching Via a Memory

First generation routers → looked like PCs

- Packet copied by system's (single) CPU
- Speed limited by memory bandwidth (2 bus crossings per datagram)

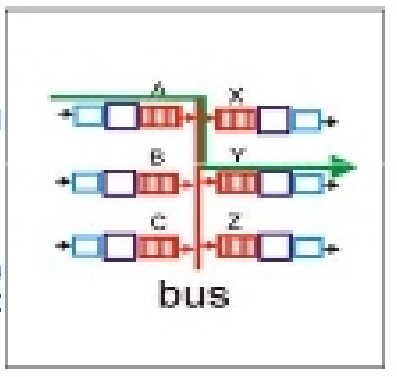


Modern routers

- Input port processor performs lookup, copy into memory
- Cisco Catalyst 8500

Switching Via a Bus

- Datagram from input port memory to output port memory via a shared bus
- Bus contention: switching speed limited by bus bandwidth
- 1 Gbps bus, Cisco 1900: sufficient speed for access and enterprise routers (not regional or backbone)



Switching Via an Interconnection Network

- Overcome bus bandwidth limitations
- Crossbar provides full NxN interconnect
  - Expensive
- Banyan networks & other interconnection nets initially developed to connect processors in multiprocessor
  - Typically less capable than complete crossbar
- Cisco 12000: switches Gbps through the interconnection network