W7 (1b)

Computer Networks

Network Layer - Introduction

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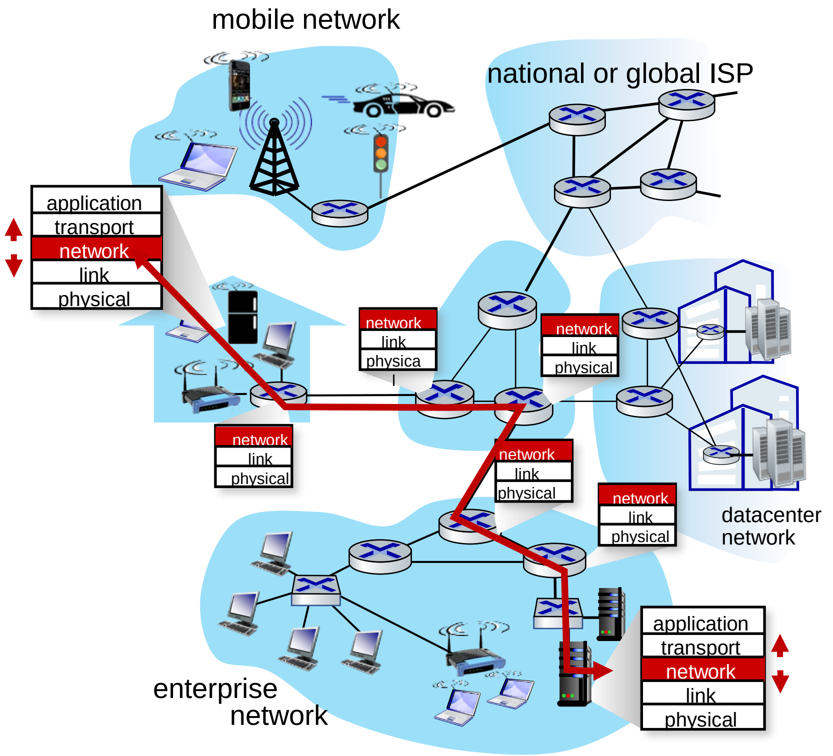
Network-layer services and protocols

- Transport segment from sending to receiving host
  - Sender: encapsulates segments into datagrams, passes to link layer
  - Receiver: delivers segments to transport layer protocol
- Network layer protocols in every Internet device: hosts, routers
- Routers:
  - examines header fields in all IP datagrams passing through it
  - moves datagrams from input ports to output ports to transfer datagrams along end-end path



Why do we need Network Layer?

We can build networks with switches, which can exchange messages in between the hosts

- Scalability
  - Routing table size will be huge
- Heterogeneity
  - Should work on Ethernet, 802.11, Token ring
- Traffic management
  - Routing flexibility, bandwidth management etc.

Two key network-layer functions

Network-layer functions:

- Forwarding: Move packets from a router's input link to appropriate router output link
- Routing: Determine route taken by packets from source to destination

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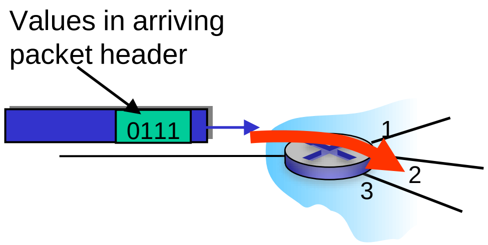
Network Layer: Data plane, Control plane

Data plane:

- Local, per-router function
- Determines how datagram arriving on router input port is forwarded to router output port



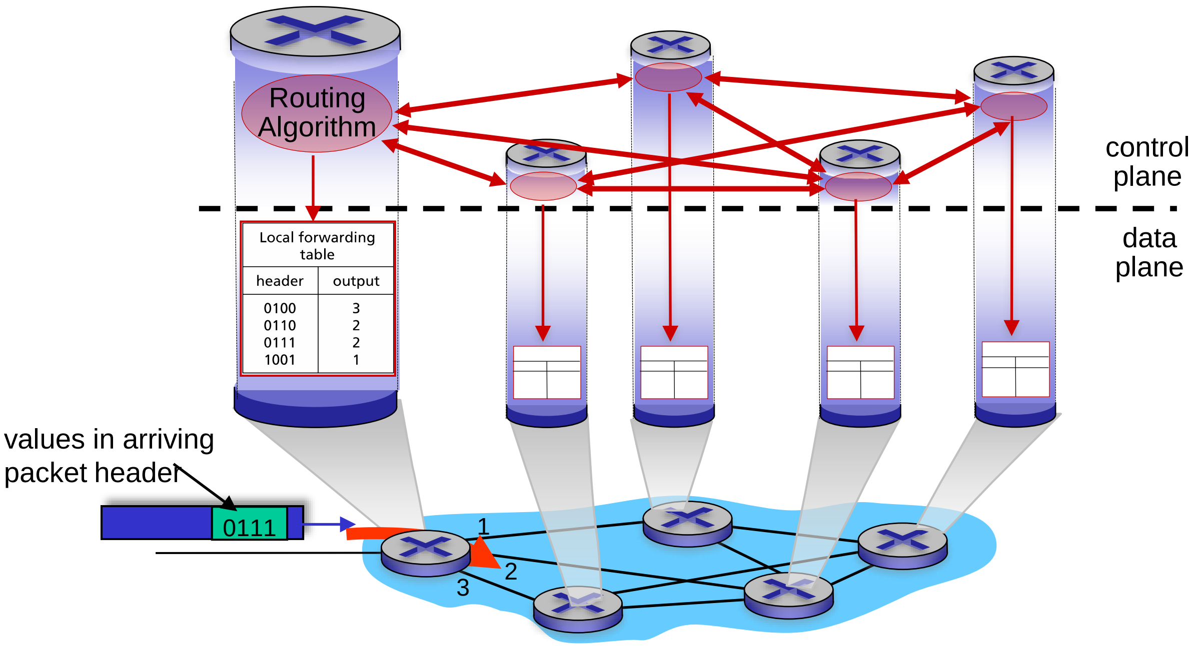
Control plane

- Network-wide logic
- Determines how datagram is routed among routers along end-end path from source host to destination host

- Two control-plane approaches:
  - Traditional routing algorithms: implemented in routers
  - Software-defined networking (SDN): implemented in (remote) servers

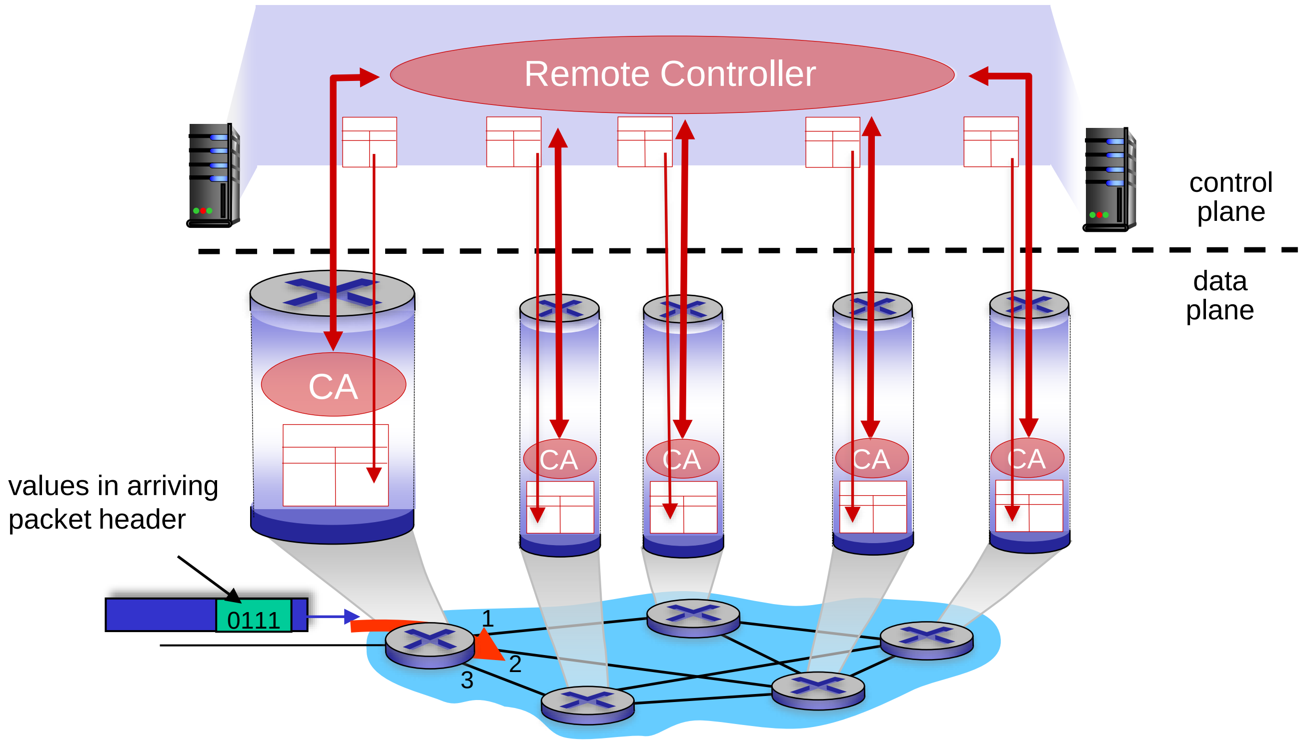
Traditional per-router control plane

Individual routing algorithm components in each and every router interact in the control plane



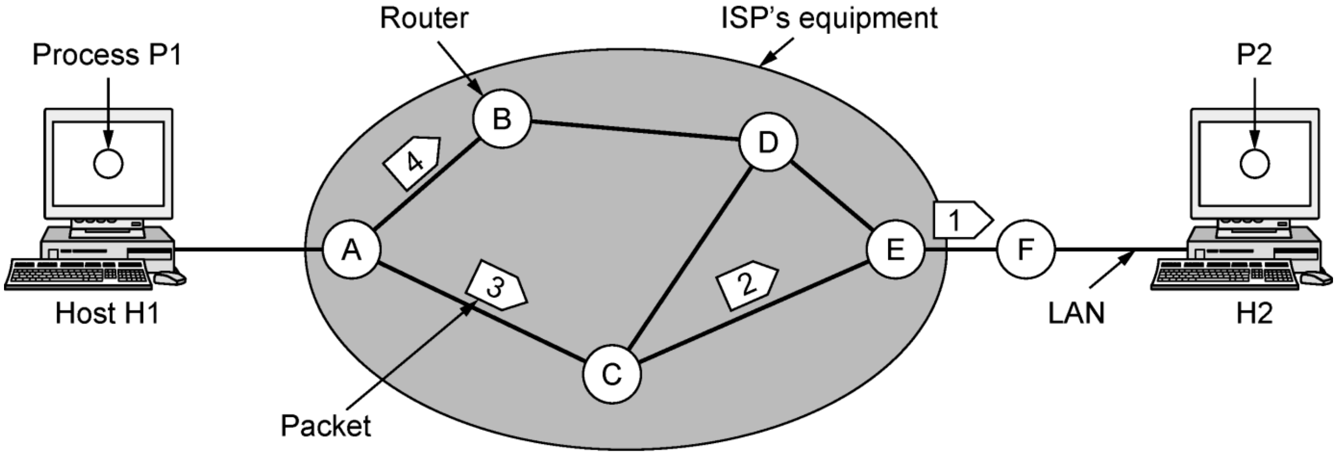
Software-Defined Networking Control Plane

Remote controller computes, installs forwarding tables in routers



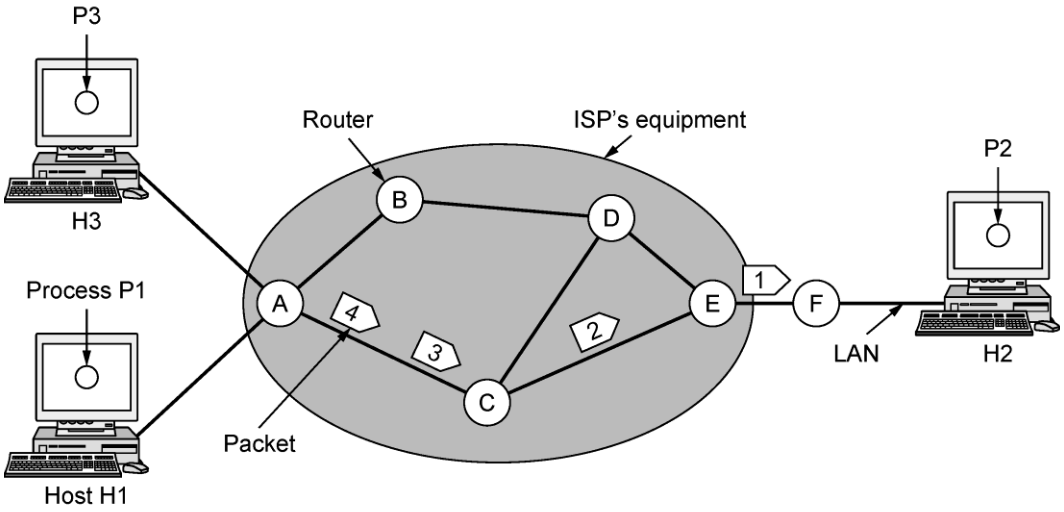
Network services

- Store-and-Forward Packet Switching
- Connectionless Service – Datagrams
  - Packets are forwarded using the destination address
  - Different packets take different paths
  - Example: Internet protocol (IP)



Network services

- Store-and-Forward Packet Switching
- Connection-Oriented – Virtual Circuits
  - Packet is forwarded along a virtual circuit using tag
  - Virtual circuit is set up ahead of time
  - Example: ATM, frame relay, MPLS



Comparison of Datagrams and VC

Issue	**Datagram network**	**Virtual-circuit network**
Circuit setup	Not needed	Required
Addressing	Each packet contains the full source & destination address	Each packet contains a short VC number
Routing	Each packet is routed independently	Route chosen when VC is set up; all packets follow it
Effect of router failures	Less severe, except for packets lost during the crash	More severe, all VCs that passed through the failed router are terminated
Quality of service	Difficult	Easy if enough resources can be allocated in advance for each VC

Internet Protocol (IP) service model

Network Architecture	Service Model	Quality of Service (QoS) Guarantees ?			
		Bandwidth	Loss	Order	Timing
Internet Protocol (IP)	best effort	none	no	no	no

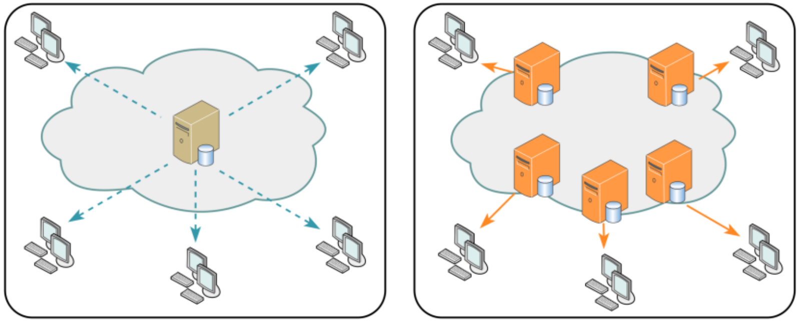
IP "best effort" service model

No guarantees on:

1. successful datagram delivery to destination
2. timing or order of delivery
3. bandwidth available to end-end flow

Why best-effort service?

- Simplicity of mechanism has allowed Internet to be widely deployed adopted
- Sufficient provisioning of bandwidth allows performance of real-time applications (e.g., interactive voice, video) to be “good enough” for “most of the time”
- Replicated, application-layer distributed services (datacenters, content distribution networks) connecting close to clients’ networks, allow services to be provided from multiple locations
- Reliability and congestion control may be implemented by the upper layers



Src: https://commons.wikimedia.org/wiki/File:NCDN_-_CDN.svg

Summary

- Network layer services and functions:
  - Forwarding vs Routing
  - Data plane vs Control plane
  - Network services
    - Connectionless Service – Datagrams
    - Connection-Oriented – Virtual Circuits