DATA COMMUNICATOIN NETWORKING

Instructor: Ouldooz Baghban Karimi

Course Book & Slides: Computer Networking, A Top-Down Approach

By: Kurose, Ross

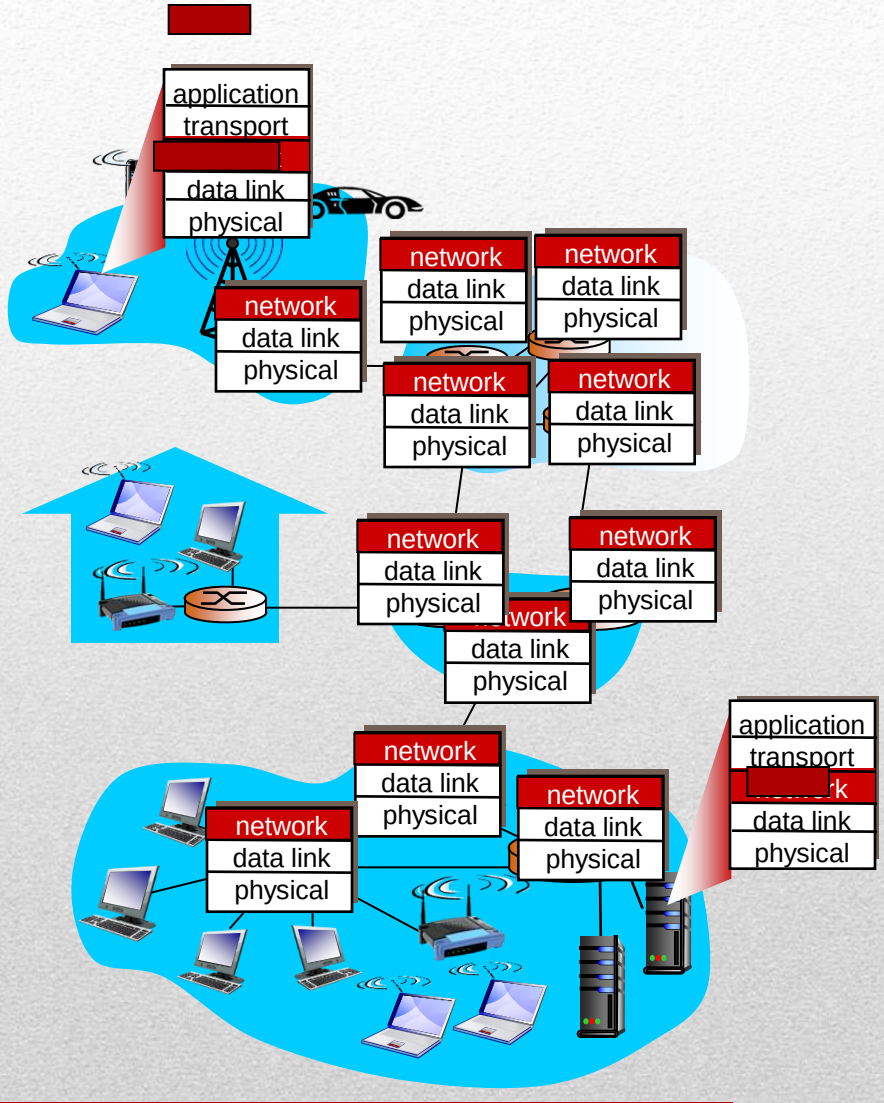
Course Overview

- **Basics of Computer Networks**
  - Internet & Protocol Stack
  - Application Layer
  - Transport Layer
  - Network Layer
  - Data Link Layer

- **Advanced Topics**
  - Case Studies of Computer Networks
  - Internet Applications
  - Network Management
  - Network Security

Network Layer

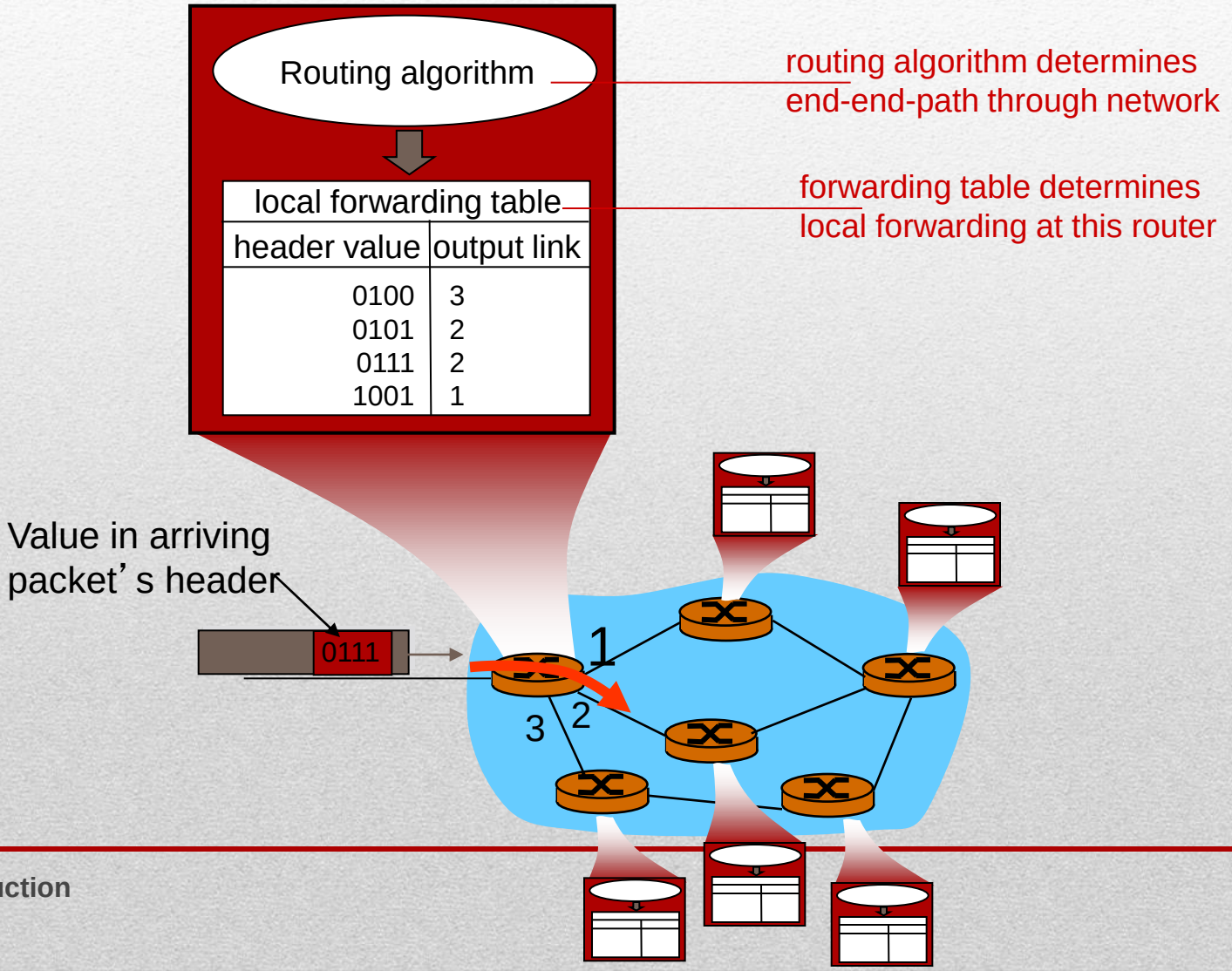
- **Transport segment**
  - From sending to receiving host
  - On sending side encapsulates segments into datagrams
  - On receiving side, delivers segments to transport layer
- **Network layer protocols in *every* host, router**
- **Router examines header fields in all IP datagrams passing through it**



Network Layer Functions

- **Forwarding**
  - Move packets from router's input to appropriate router output
  - Analogy
    - Process of getting through single interchange
- **Routing**
  - Determine route taken by packets from source to destination
  - Routing algorithms
  - Analogy
    - Process of planning trip from source to destination

Interlay between Routing & Forwarding



Connection Setup

- Before datagrams flow, two end hosts and intervening routers establish virtual connection

- **Connection Service**
  - Network Layer
    - Between two **hosts** (may also involve intervening routers in case of VCs)
  - Transport Layer
    - Between two **processes**

Network Service Model

Q: What service model for "channel" transporting datagrams from sender to receiver?

- **Individual datagrams**
  - Guaranteed delivery
    - Guaranteed delivery with less than 40 msec delay
- **Flow of datagrams**
  - In-order datagram delivery
  - Guaranteed minimum bandwidth to flow
  - Restrictions on changes in inter-packet spacing

Network Service Model

Network Architecture	Service Model	Guarantees ?				Congestion feedback
		Bandwidth	Loss	Order	Timing	
Internet	best effort	none	no	no	no	no (inferred via loss)
ATM	CBR	constant rate	yes	yes	yes	no congestion
ATM	VBR	guaranteed rate	yes	yes	yes	no congestion
ATM	ABR	guaranteed minimum	no	yes	no	yes
ATM	UBR	none	no	yes	no	no

Network Service Model

Q: What service model for "channel" transporting datagrams from sender to receiver?

- **Individual datagrams**
  - Guaranteed delivery
    - Guaranteed delivery with less than 40 msec delay
- **Flow of datagrams**
  - In-order datagram delivery
  - Guaranteed minimum bandwidth to flow
  - Restrictions on changes in inter-packet spacing

Connection & Connection-less Service

- **Datagram network**
  - Network-layer connectionless service
- **Virtual-circuit network**
  - Network-layer connection service
- Analogous to TCP/UDP connection-oriented / connectionless transport-layer services, but:
  - Service: host-to-host
  - No choice: network provides one or the other
  - Implementation: in network core

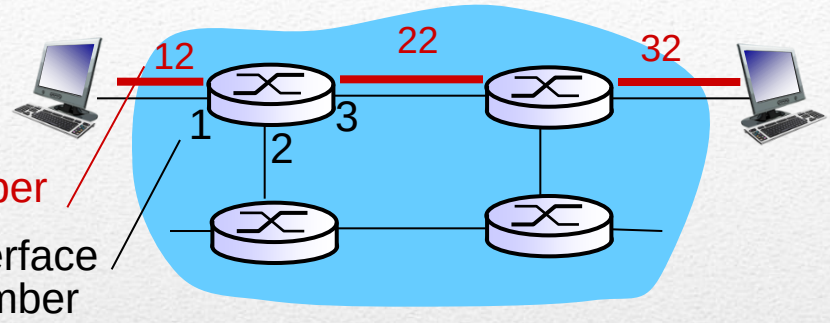
Virtual Circuits

- Call setup, teardown for each call before data can flow
- Each packet carries **VC identifier**
  - NOT destination host address
- Every router on source-destination path maintains "state" for each passing connection
- Link, router resources (bandwidth, buffers) may be allocated to VC (dedicated resources = predictable service)

VC Implementation

- **A VC consists of**
  - path from source to destination
  - VC numbers, one number for each link along path
  - entries in forwarding tables in routers along path
- **Packet belonging to VC carries VC number**
  - rather than destination address
- **VC number can be changed on each link**
  - new VC number comes from forwarding table

VC Forwarding Table



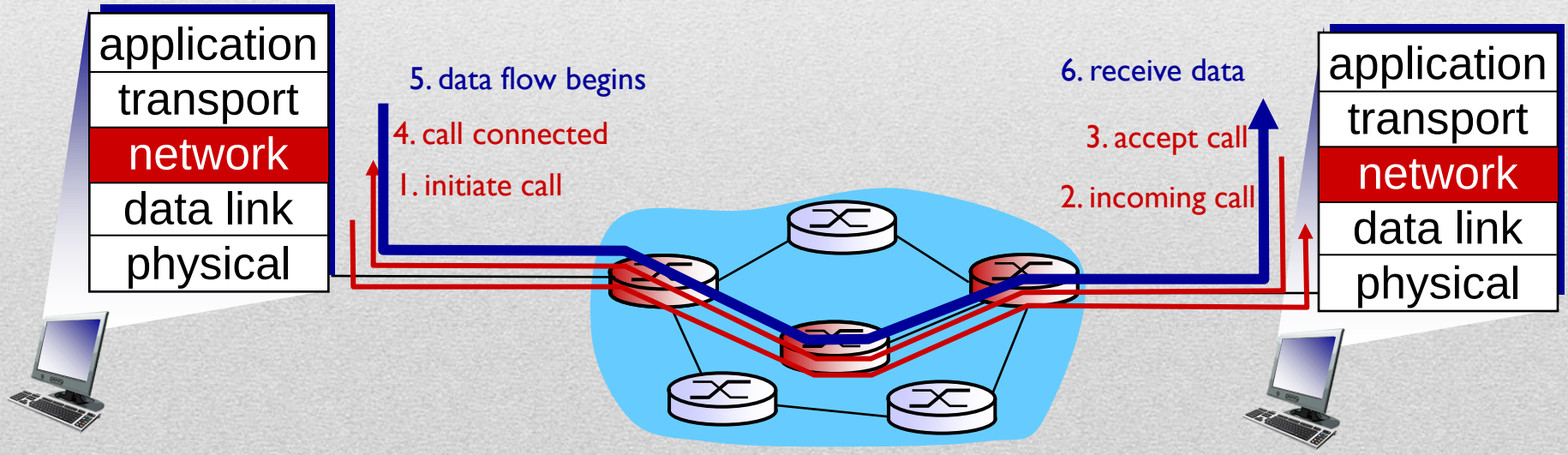
Forwarding table in northwest router:

Incoming interface	Incoming VC #	Outgoing interface	Outgoing VC #
1	12	3	22
2	63	1	18
3	7	2	17
1	97	3	87
…	…	…	…

VC routers maintain connection state information!

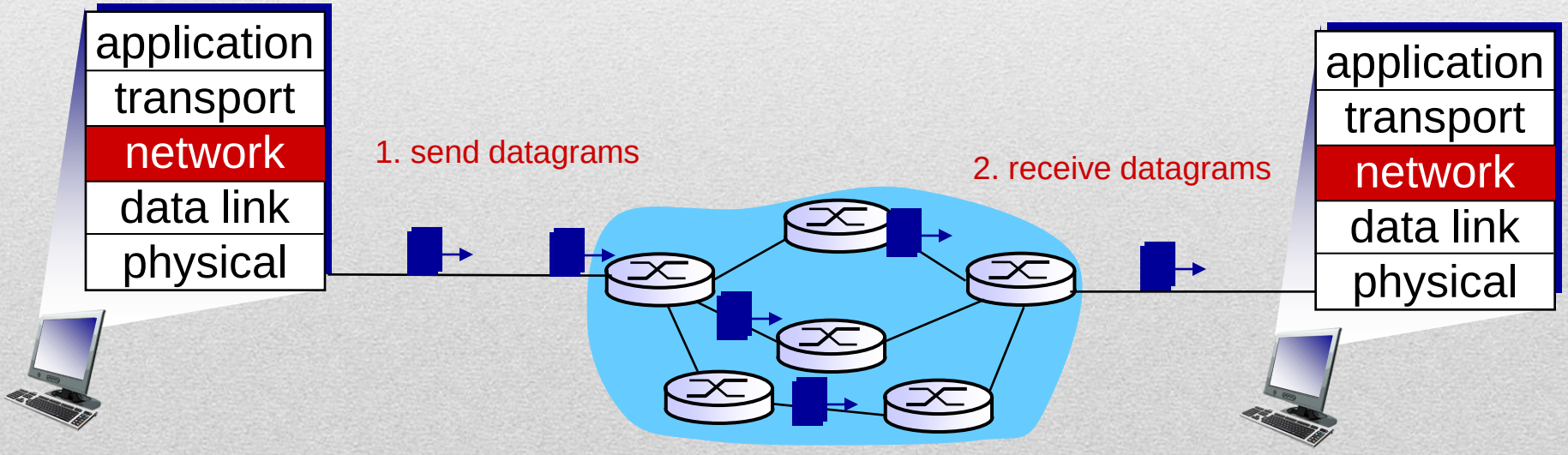
VC: Signaling Protocol

- To setup, maintain teardown VC
- Used in ATM, frame-relay, X.25
- Not used in today's Internet

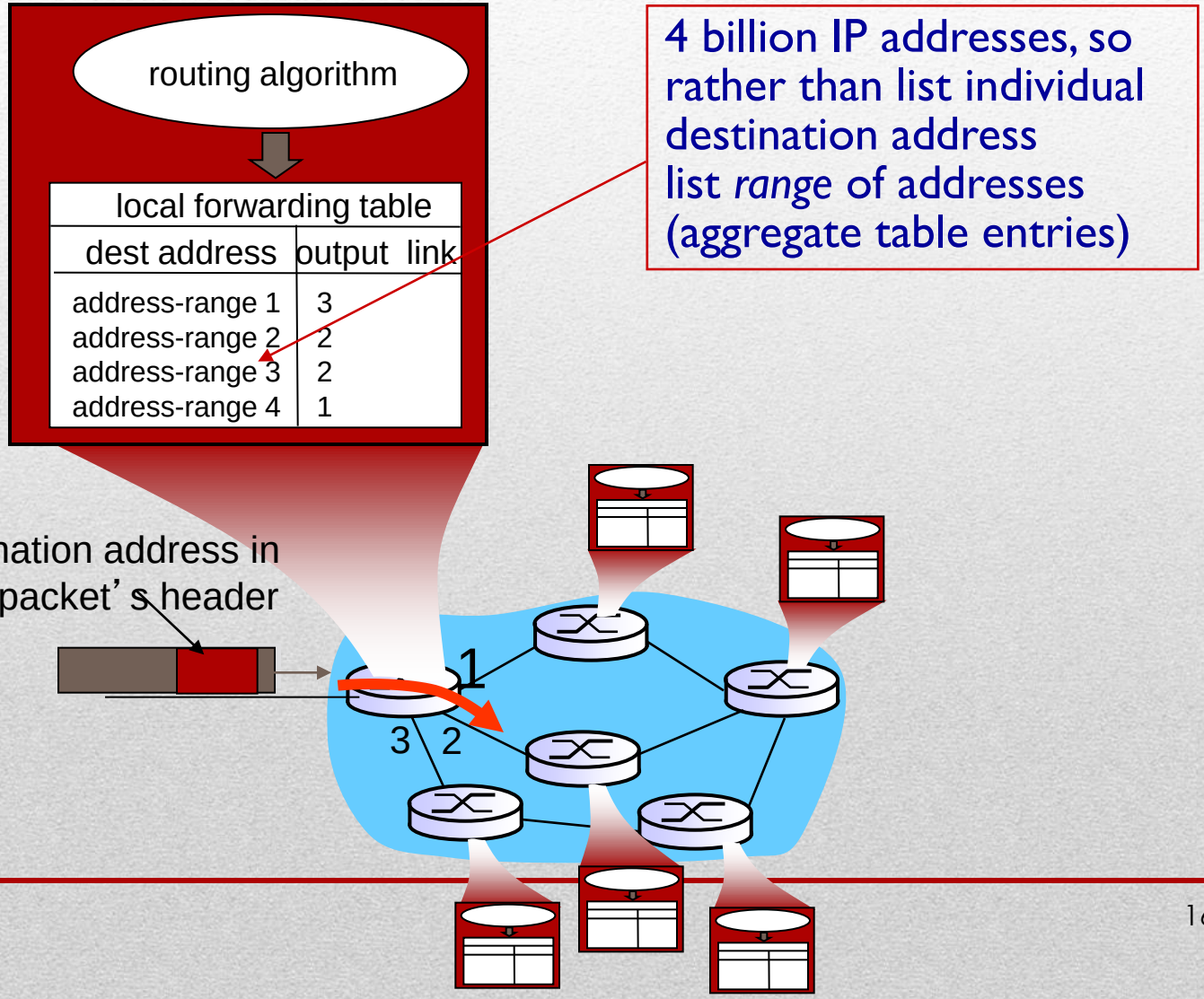


Datagram Networks

- No call setup at network layer
- Routers: no state about end-to-end connections
  - No network-level concept of "connection"
- Packets forwarded using destination host address



Datagram Forwarding Table



Datagram Forwarding Table

Destination Address Range	Link Interface
11001000 00010111 00010000 00000000 through 11001000 00010111 00010111 11111111	0
11001000 00010111 00011000 00000000 through 11001000 00010111 00011000 11111111	1
11001000 00010111 00011001 00000000 through 11001000 00010111 00011111 11111111	2
otherwise	3

Q: But what happens if ranges don't divide up so nicely?

Longest Prefix Matching

Longest prefix matching

When looking for forwarding table entry for given destination address, use *longest* address prefix that matches destination address.

Destination Address Range	Link interface
11001000 00010111 00010*** *********	0
11001000 00010111 00011000 *********	1
11001000 00010111 00011*** *********	2
otherwise	3

Datagram or VC: Why?

Internet (datagram)

- Data exchange among computers
  - "elastic" service, no strict timing req.
- Many link types
  - Different characteristics
  - Uniform service difficult
- "smart" end systems (computers)
  - Can adapt, perform control, error recovery
  - **Simple inside network, complexity at "edge"**

ATM (VC)

- Evolved from telephony
- Human conversation:
  - Strict timing, reliability requirements
  - Need for guaranteed service
- "dumb" end systems
  - Telephones
  - **Complexity inside network**