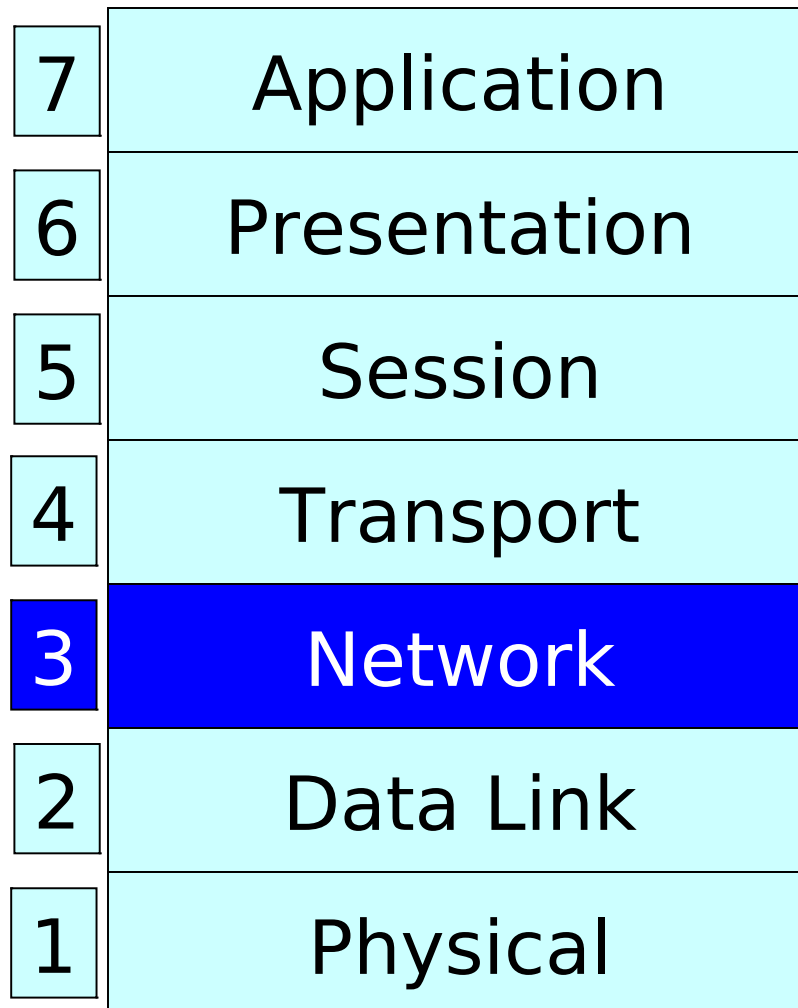


# The Network Layer



Gihan Dias

# Network Layer



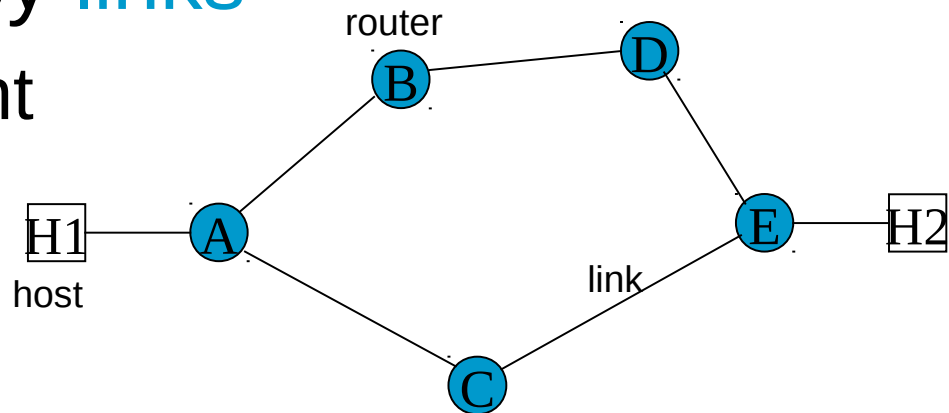


# Functions of Network Layer

- Establishing,
- Maintaining &
- Terminating connections
- Isolating upper layers
  - from data transmission technologies
- Addressing
- Routing

# Packet Switching

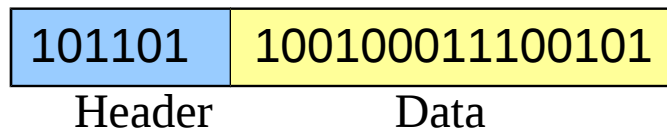
- Network comprises a set of *nodes* (switches or routers)
  - intermediate stations
- Connected by *links*
  - point to point
  - Multipoint



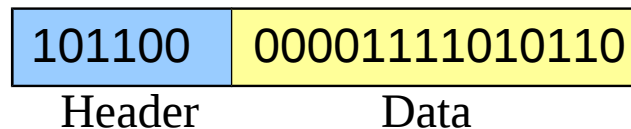
# Packet Switching (cont.)

- Data stream is divided into packets
- Each packet comprises data and a header

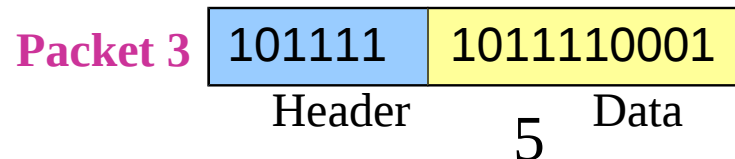
100100011100101000011110101101011110001      **Data Stream**



**Packet 1**



**Packet 2**

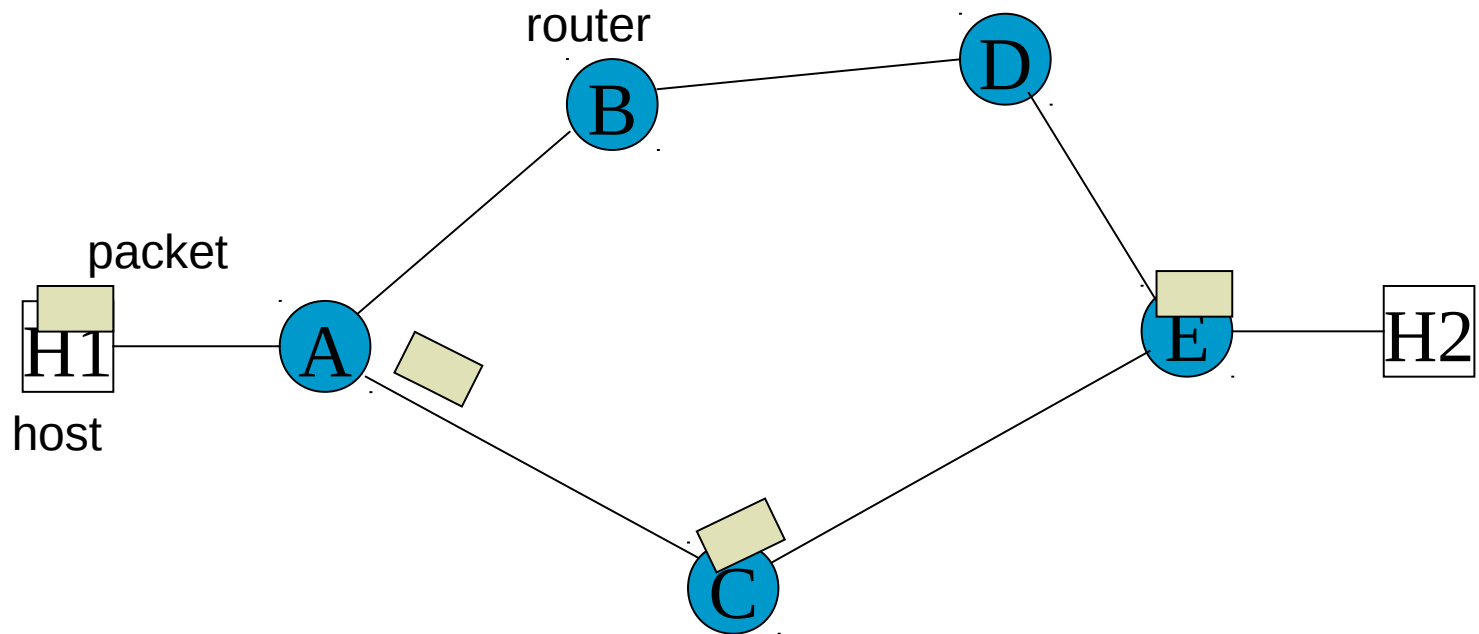




# Packet Switching (cont.)

- Data sent from one **host** to another
  - end stations
- Each node **switches** each incoming packet through a link to another node
- Packets make their way through the network from node to node and finally to their destination

# Packet Switching





# Types of Networks

- Connectionless
- Connection-oriented





# Connectionless Networks

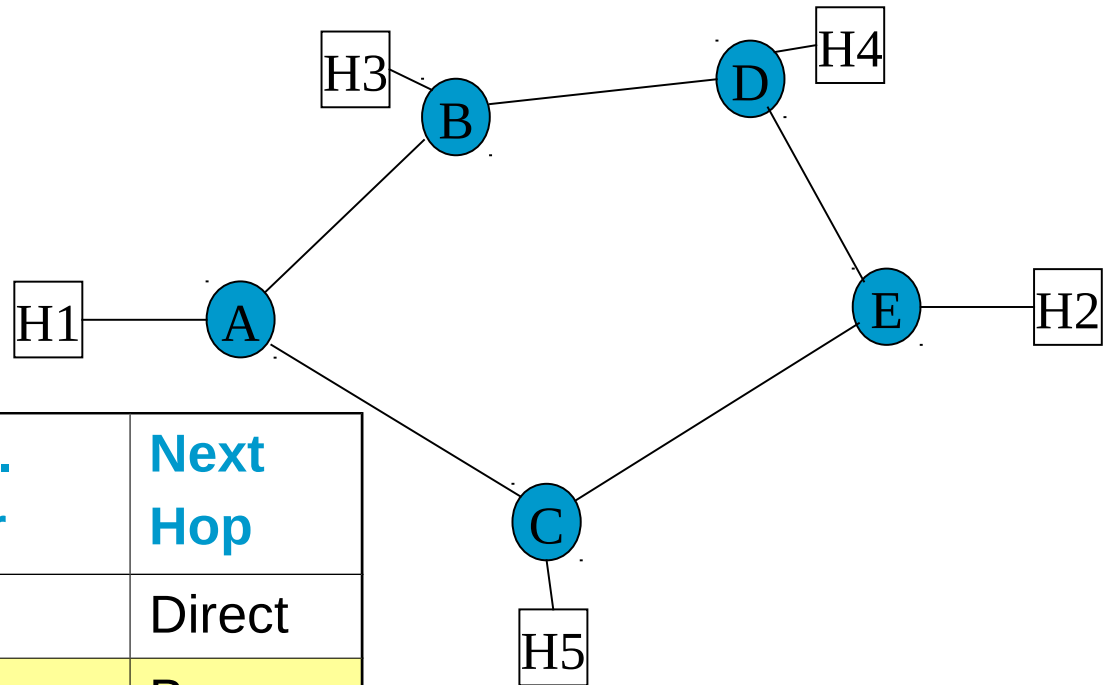
- Datagram service
- No need to establish connection
- Routing on a **per-packet** basis
- Generally no error control



# Connectionless switching

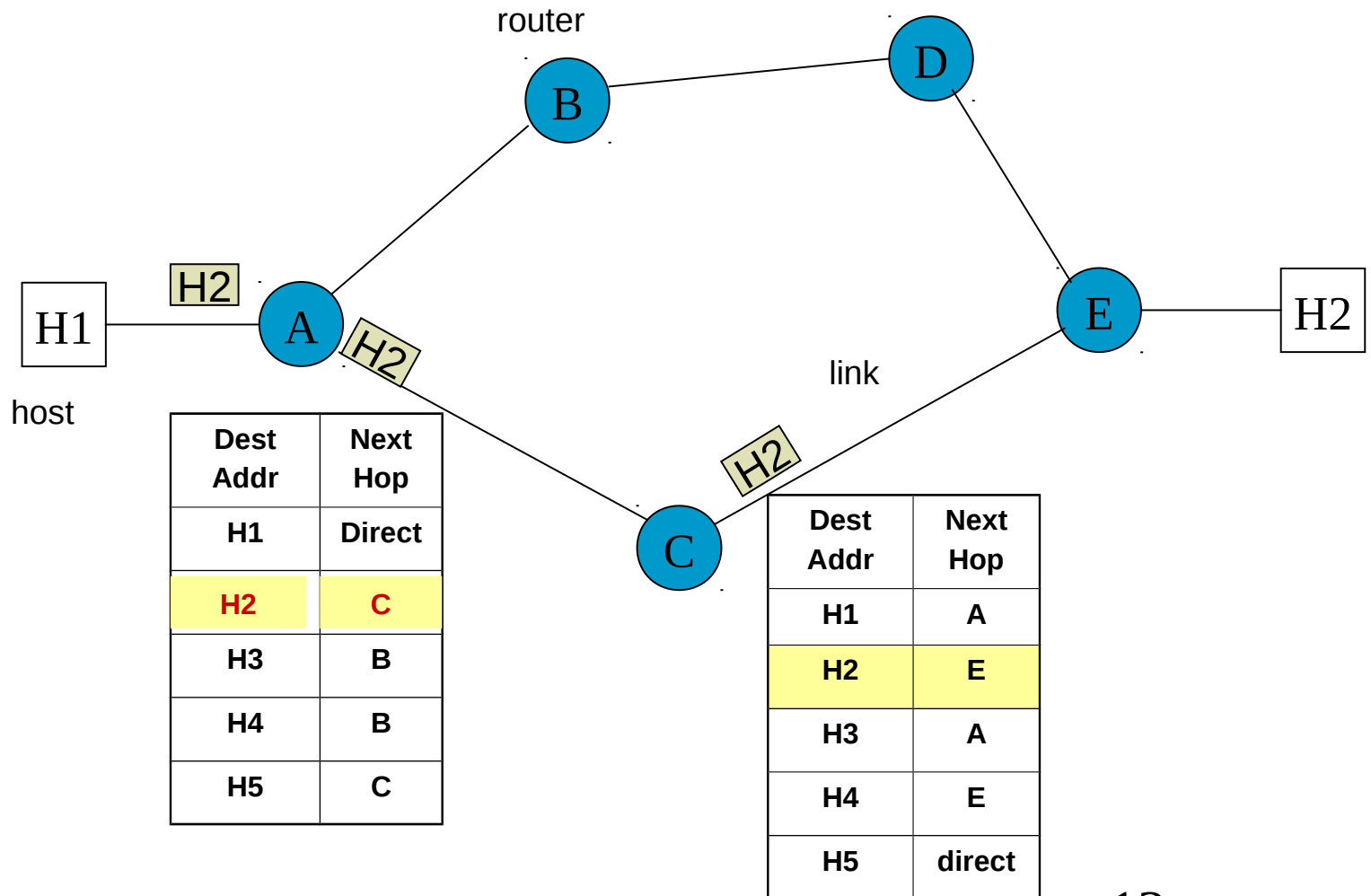
- Each packet contains the **destination address**
- Each node contains a **forwarding table** giving the **next hop** for each destination address

# Forwarding Table for Router A



Dest. Addr	Next Hop
H1	Direct
H2	B
H3	B
H4	B
H5	C

# Packet Forwarding (connectionless)





# Connection-oriented Networks

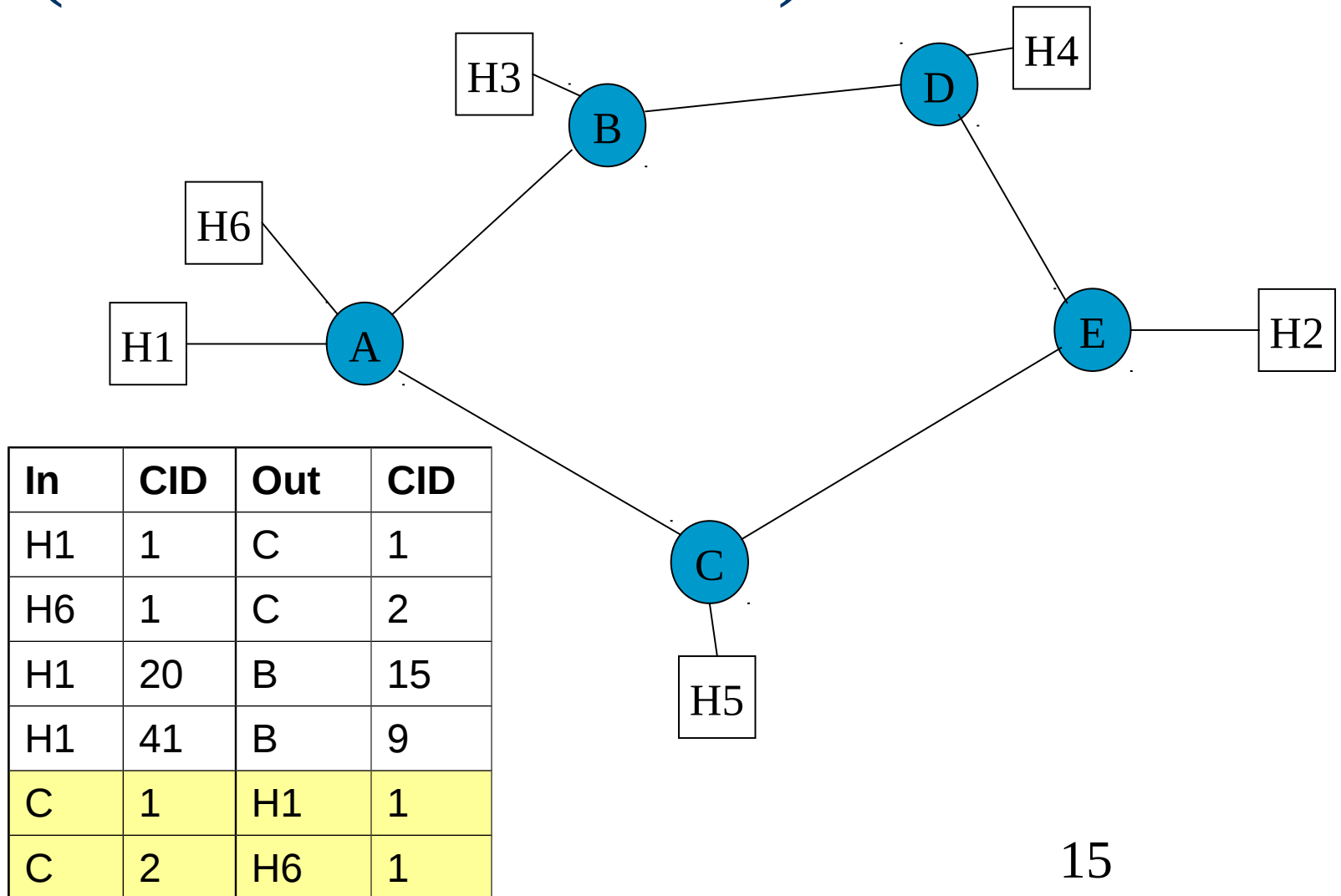
- Connection set up between end stations before data is transferred
- End stations exchange sequenced packet streams
- Routing on **per-connection** basis
- Network generally provides error control



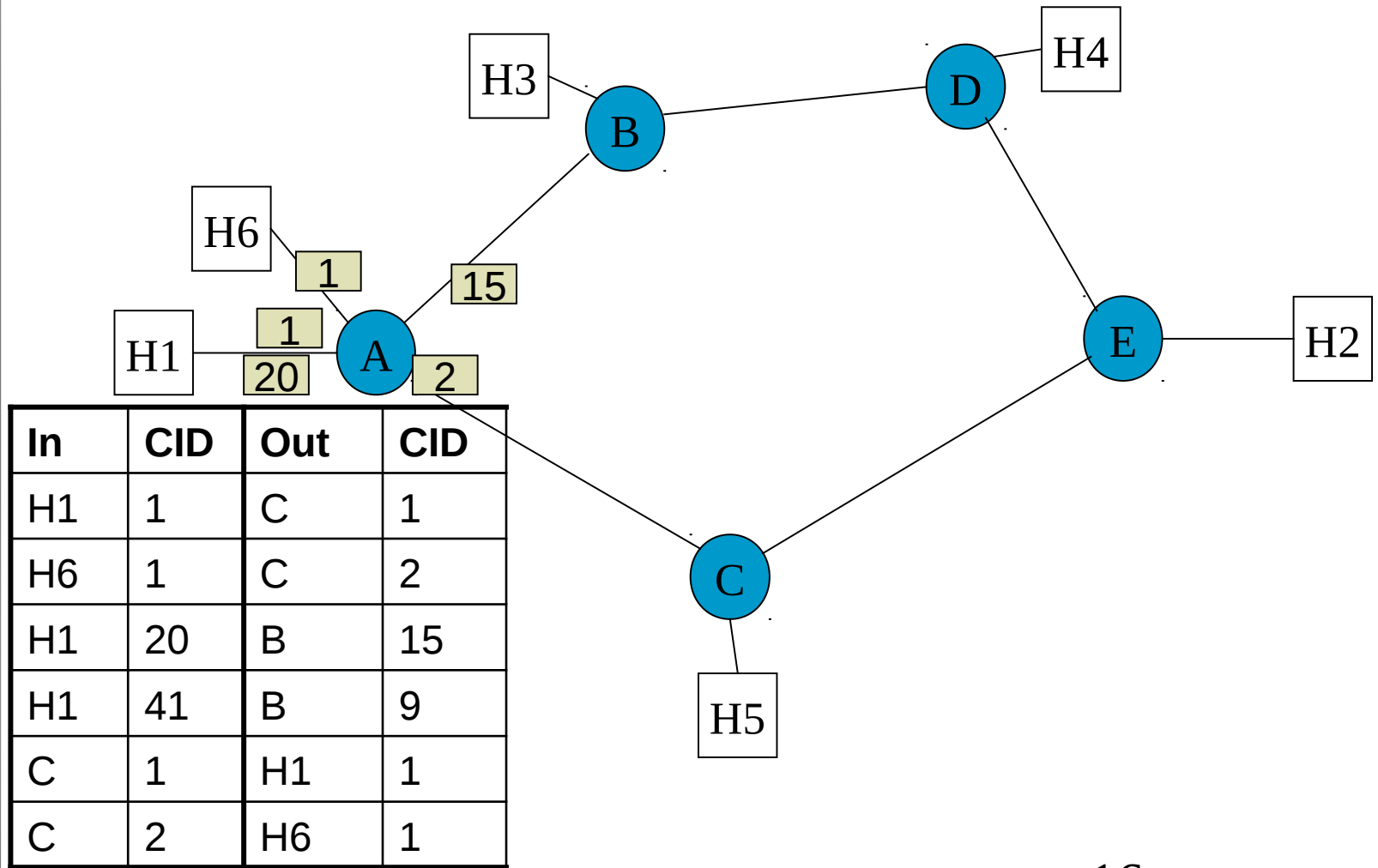
# Connection-Oriented Switching

- Each incoming virtual circuit on a switch has a **connection identifier**
  - unique for each link
- Each outgoing virtual circuit on a switch has a **connection identifier**
  - unique for each link
- Each switch has a **forwarding table** relating incoming and outgoing CIs

# Forwarding Table for A (connection-oriented)



# Packet Forwarding (CO)







# Comparison of CO and CL Networks

Issue	Connectionless	Conn-oriented
Setup	Not needed	Needed
Addressing in packet	Destination address	Connection ID
State	No state in routers	State in routers
Routing	Per-packet	Per-connection
Failures	Minimal	VCs are terminated
Quality of Service	Difficult	Possible
Congestion control	Difficult	Possible



# Addressing

- Function of addressing
  - to identify end stations

e.g.

- Names
- NIC Numbers / Registration Nos.
- Postal Addresses
- Telephone Numbers



# Types of addressing

- Flat
- Hierarchical
- Addressing is done in several layers
  - physical
  - data-link
  - network
  - application



# Flat Addressing

## ■ Personal Names

- Gihan Dias
- Shantha Fernando
- Gihan Fernando

## ■ Ethernet Addresses

- 54b37630e050
- 549395b2a750



# Hierarchical Addressing

## ■ Postal Address

V. C. Silva  
Dept. of Computer Sci. & Eng.  
University of Moratuwa  
Moratuwa  
Sri Lanka

## ■ Telephone No

country code      operator code  
94 11 2 640382  
                         area code      telephone no  
   21



# Routing

## ■ Function

- to set up a connection or route a packet from source to destination

## ■ End systems

- do not relay traffic

## ■ Intermediate systems

- route traffic from one subnet to another
- phys & DL conn between ES-IS & IS-IS



# Forwarding and Routing

## ■ Forwarding

- done by a router on arrival of each packet
- switches a packet from an input line to an output line
- based on a forwarding table

## ■ Routing

- builds forwarding tables
- based on a number of factors



# Properties Desirable in a Routing Algorithm

- correctness
- simplicity
- robustness
- stability
- fairness
- optimality





# Types of Routing

- Static (non-adaptive)
  - routing tables are pre-defined
  - address-based (hierarchical)
- Dynamic (adaptive)
  - Network runs a *routing protocol* to compute routes
  - centralised
  - distributed



# Types of Routing (contd.)

- Source routing
  - source station specifies route



# Static (non-adaptive) Routing

- Each intermediate station contains a routing table containing the next hop for each address
  - Most tables include a *default route*
- Suitable for small networks
- Not resilient
- Labour consuming



# Hierarchical routing

- use a **prefix** of the destination address (most significant part)
- If prefix is in routing table route accordingly
- else use **default route**
- Simplifies the routing table



# Dynamic (adaptive) Routing

- Intermediate Stations exchange routing information periodically
- Each station computes best path to each destination
- Based on
  - link speed    - delay
  - congestion    - error rate
  - cost        - policy



# Distance

In routing, distance may be defined by

- no. of hops
- physical distance
- delay
- bandwidth (inverse)
- communication cost
- etc.



# Routing Mechanisms

- Shortest Path Routing
  - calculates the shortest path between pairs of nodes
- Flooding
  - packets are sent on all unused links
- Distance Vector Routing
  - each router has table of distances to each destination



# Routing Mechanisms (cont.)

- Link State Routing
  - keeps track of the state of each link
- Broadcast Routing
  - sends packet to **all** nodes in a network

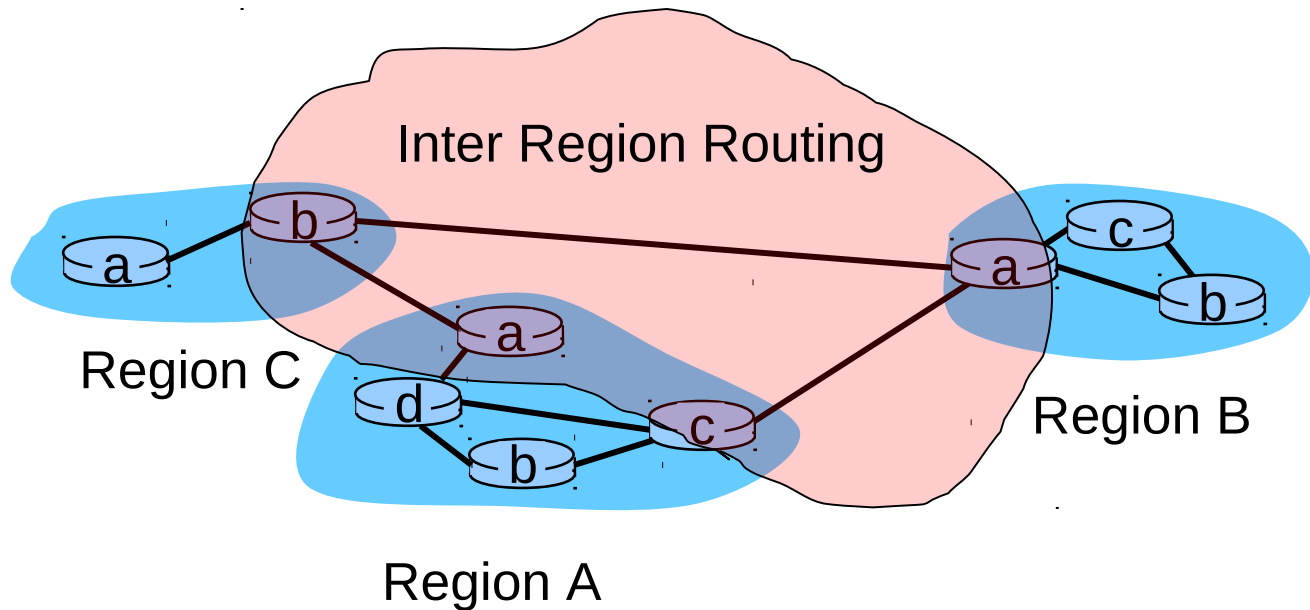




# Hierarchical Routing

- In a large network, it is infeasible to keep track of all nodes
  - over 100,000 networks on the Internet
- routers are grouped into regions
  - each region handles internal routing
- gateways handle routing between regions
- may need more than two levels

# Hierarchical Routing



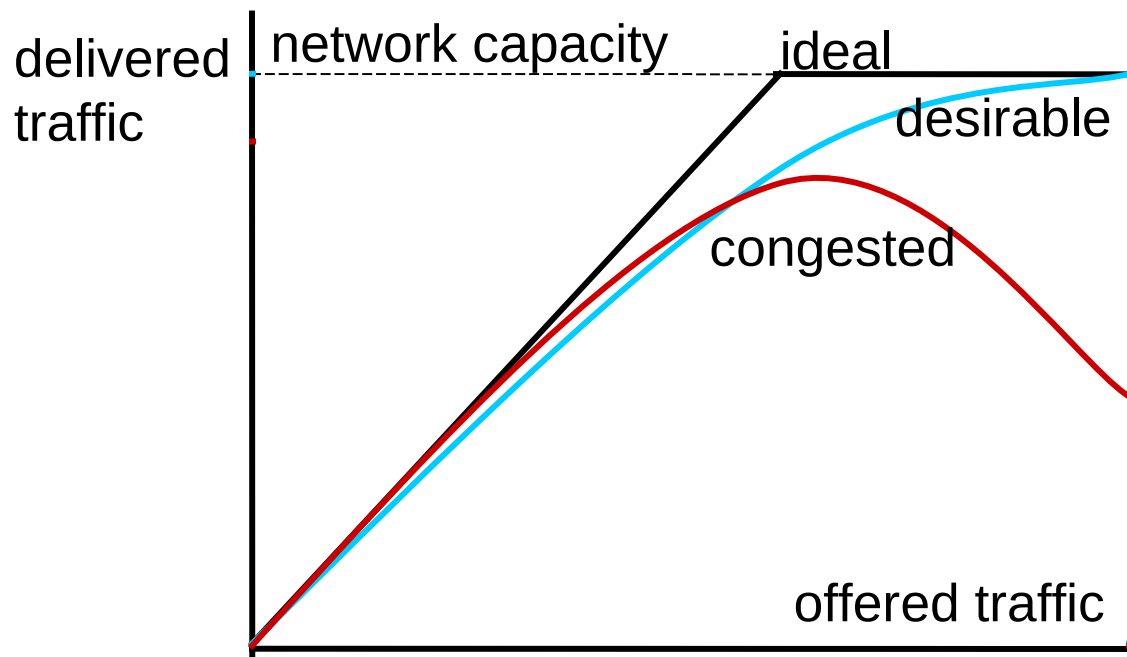


# Multicast Routing

- Sending a packet to a subset of hosts
- May have a number of multicast groups
- At each router, packet may be forwarded to zero or more links
- Router must keep track of which groups are accessible via each link

# Congestion

- A network is congested when the offered traffic approaches its capacity





# Congestion Control

- Open-loop
  - attempts to avoid congestion
- Closed loop
  - takes action when congestion is about to occur
    - monitor system
    - pass information to appropriate place
    - take action

# Quality of Service

## ■ Applications have differing requirements

Application	Reliability	Delay	Jitter	Bandwidth
e-mail	high	not critical	don't care	low
File Transfer	high	not critical	don't care	medium
Web	high	< 2s	don't care	medium
Remote login	high	<2s	not critical	low
Audio streamng	low	not critical	significant	medium
Video streaming	low	not critical	significant	high
Telephony	low	<0.2s	critical	low
Video conf	low	<0.2s	critical	High



# QoS Techniques

- Over provisioning
- Buffering
- Traffic Shaping



# QoS Technologies

## ■ Integrated Services

- e.g. RSVP
- ensure a quality of service for each flow

## ■ Differentiated Services

- divide traffic in to classes
- provide different services (bandwidth, priority, delay) for each class





# Internetworking

- Networks differ from each other
- Issues in interconnection
  - service offered
  - protocols
  - addressing
  - packet size
  - quality of service
  - security
  - etc.



# Interconnection Methods

- Physical Layer
  - repeaters and hubs
- Data Link Layer
  - bridges and switches
- Network Layer
  - routers
- Transport Layer
  - transport gateways
- Application Layer
  - application gateways