ouees-202306 topic 03:

Internet Protocol (IP) addresses

Routing in details

Network transports

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Lecture notes and reporting

- https://github.com/jj1bdx/oueees-202306-public/
- Check out the README.md file and the issues!
- Keyword at the end of the talk
- URL for submitting the report at the end of the talk

Internet Protocol (IP) addresses

Role of IP addresses

- Network numbers
- Interfaces: connected to the networks
- Host IDs in the numbered networks
- Global uniqueness
- Special addresses (private, broadcast, multicast, loopback, etc.)

IPv4 addresses: 32 bits

192.168.100.20

In hexadecimal notation: 0xC0A86414

- 4 x 0~255 numbers split with dots
- Relatively easy to remember, but already being used up

IPv4 address with netmask

192.168.100.20/24

- Network: 192.168.100.0/24
- Host: number 20 (0~255) (32-24=8)
- Host 0 = network itself
- Host 255 = broadcast

Address in another netmask

192.168.100.20/28

- Network: 192.168.100.16/28
- Host: number 4 (0~15) (32-28=4)
- Host 0 = network itself
- Host 15 = broadcast
- Different netmask = different address interpretation

Private addresses (RFC1918)

No global routing for these address blocks

- 10.0.0.0/8
- 172.16.0.0/12 (172.{16~31}.*.*)
- 192.168.0.0/16 (192.168.*.*)

Other special addresses (RFC6890)

- 0.0.0.0/8: "This" network
- 100.64.0.0/10: Shared address
- 127.0.0.0/8: Loopback
- 169.254.0.0/16: Link local
- 192.0.0.0/24: IANA specific
- 192.0.2.0/24, 198.51.100.0/24, 203.0.113.0/24: Documentation
- 192.88.99.0/24: 6to4 Relay Anycast
- 198.18.0.0/15: Benchmarking
- 240.0.0.0/4: Reserved
- 255.255.255.255/32: Limited broadcast

IPv6 addresses: 128 bits

2404:6800:4004:810::2004

= 2404:6800:400a:0810:0000:0000:0000:2004

- a www.google.com address, as of 14-JUN-2023 0117UTC
- :xxxx: = up to 4 hex digits
- :: = arbitrary number of 0, appearing only once in an address
- Your lookup results may vary

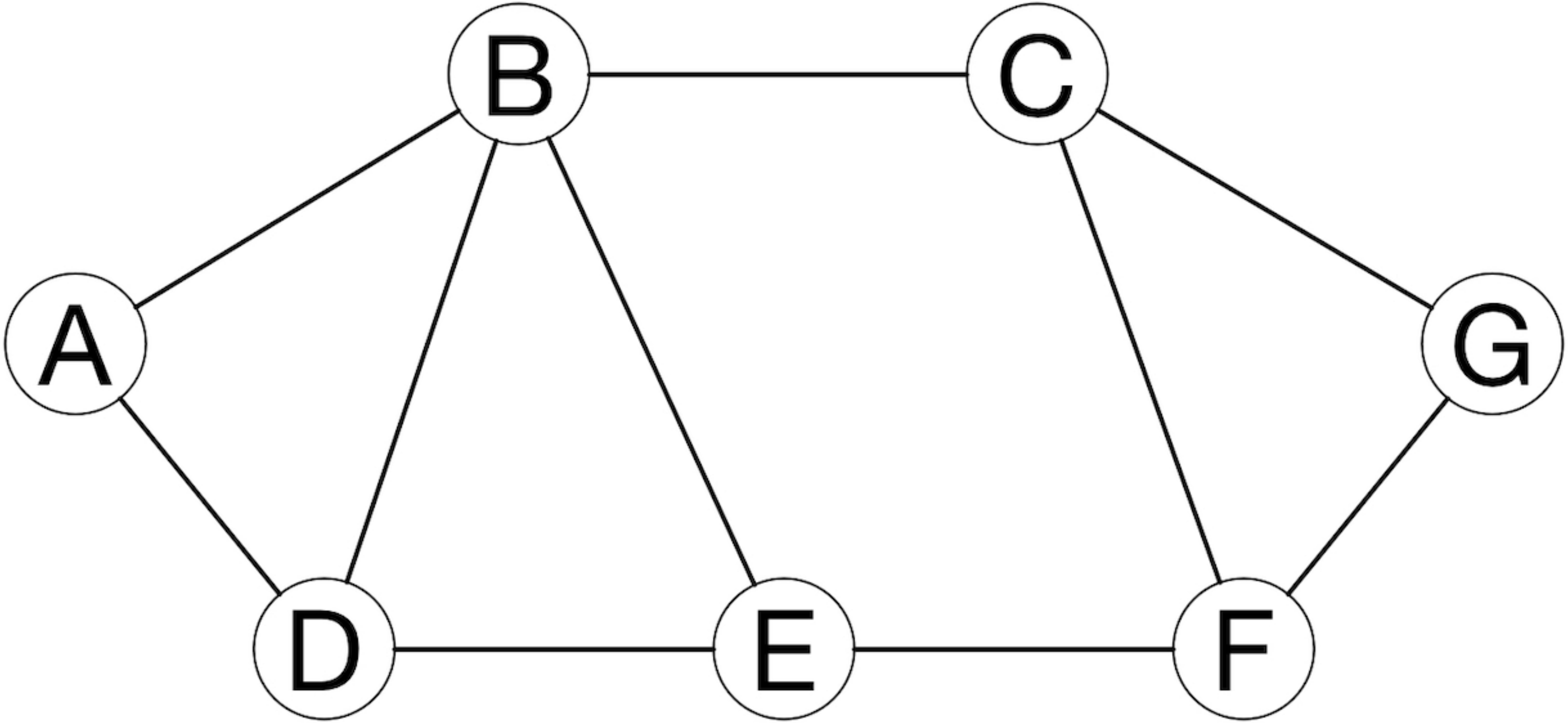
IPv6 addresses with netmask 2404:6800:400a:810::2004/64

- Network: 2404:6800:400a:810::/64
- Host number: 0x0000000000002004
- Host number: 64 bits (0: network)
- Broadcast -> multicast addresses
- ff02::1 = all hosts, ff02::2 = all routers, etc.

Why IPv4 to IPv6?

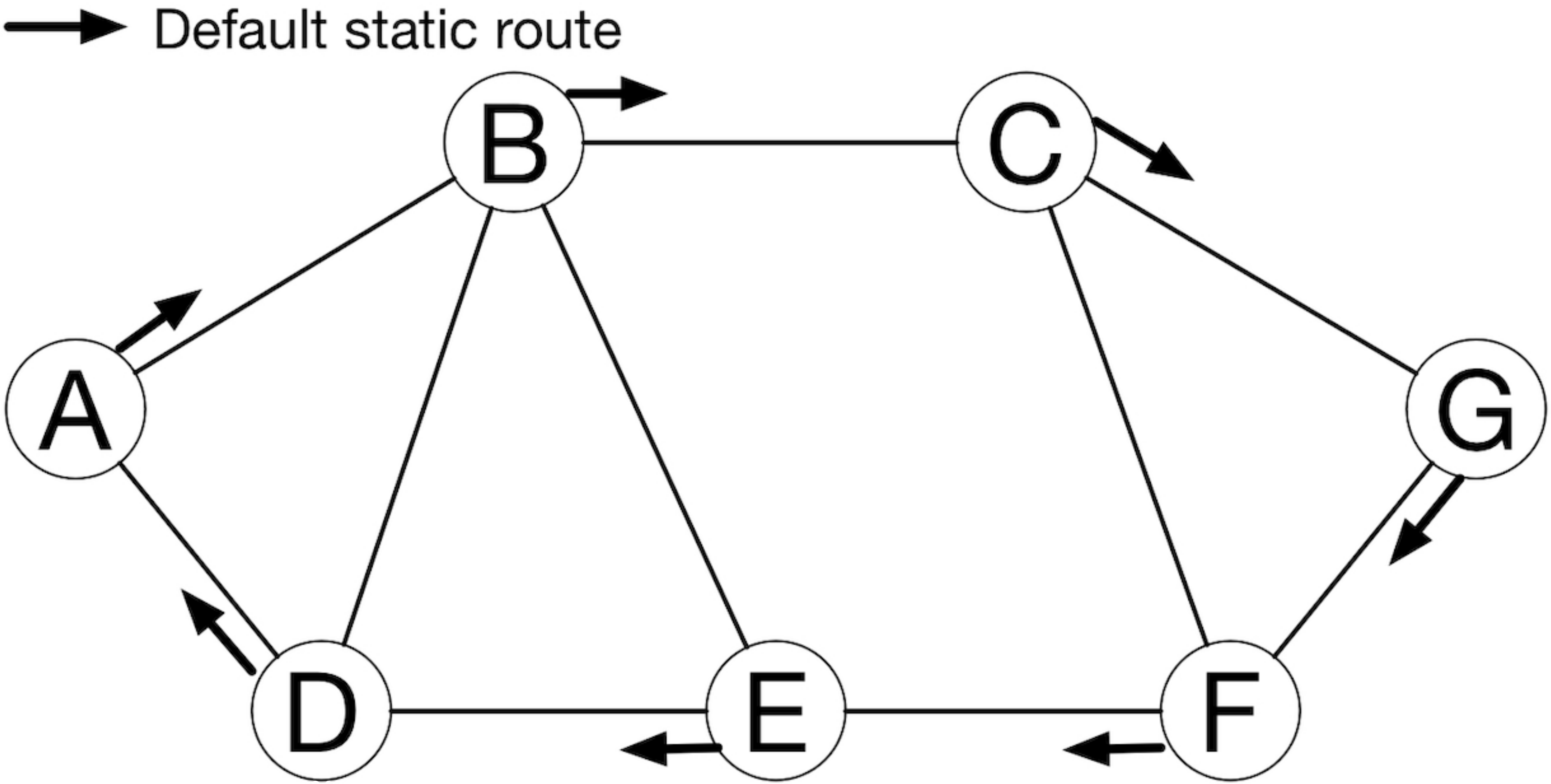
- Because we've used up the 32-bit IPv4 addresses already
- No more new address block for IPv4
- You need to buy unused blocks from other users
- Took ~20 years (1996-2016) for the transition from IPv4 to IPv6
- IPv6 has less users and nodes; plausibly faster

Routing in details


B
C
A
G
D
E
F

Static routing

- Set the default route for nodes which are not directly reachable
- Works well on simple networks or star networks
- Static routing may cause *ping-pong*


Default static route
B
C
A
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D
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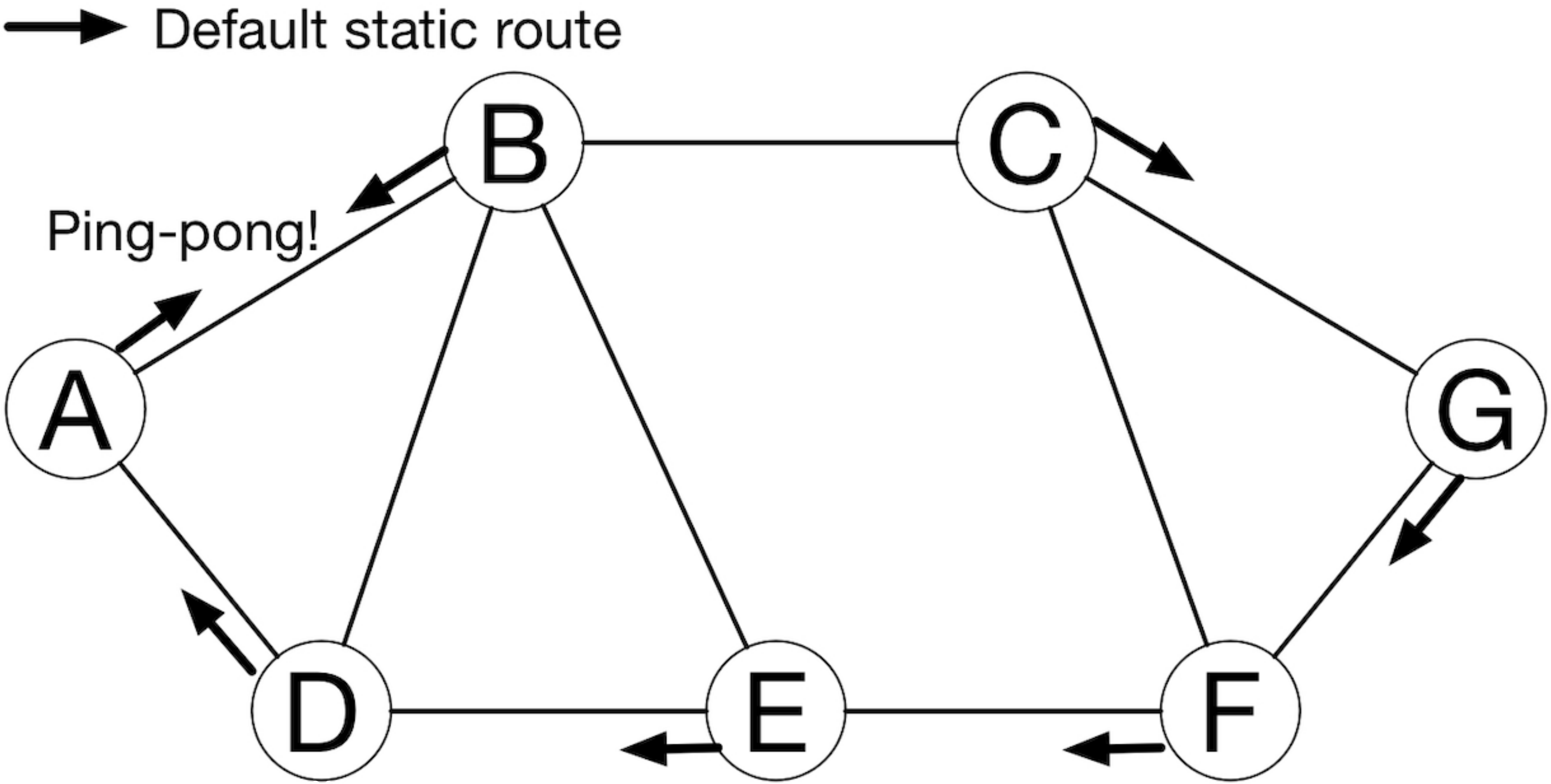
F

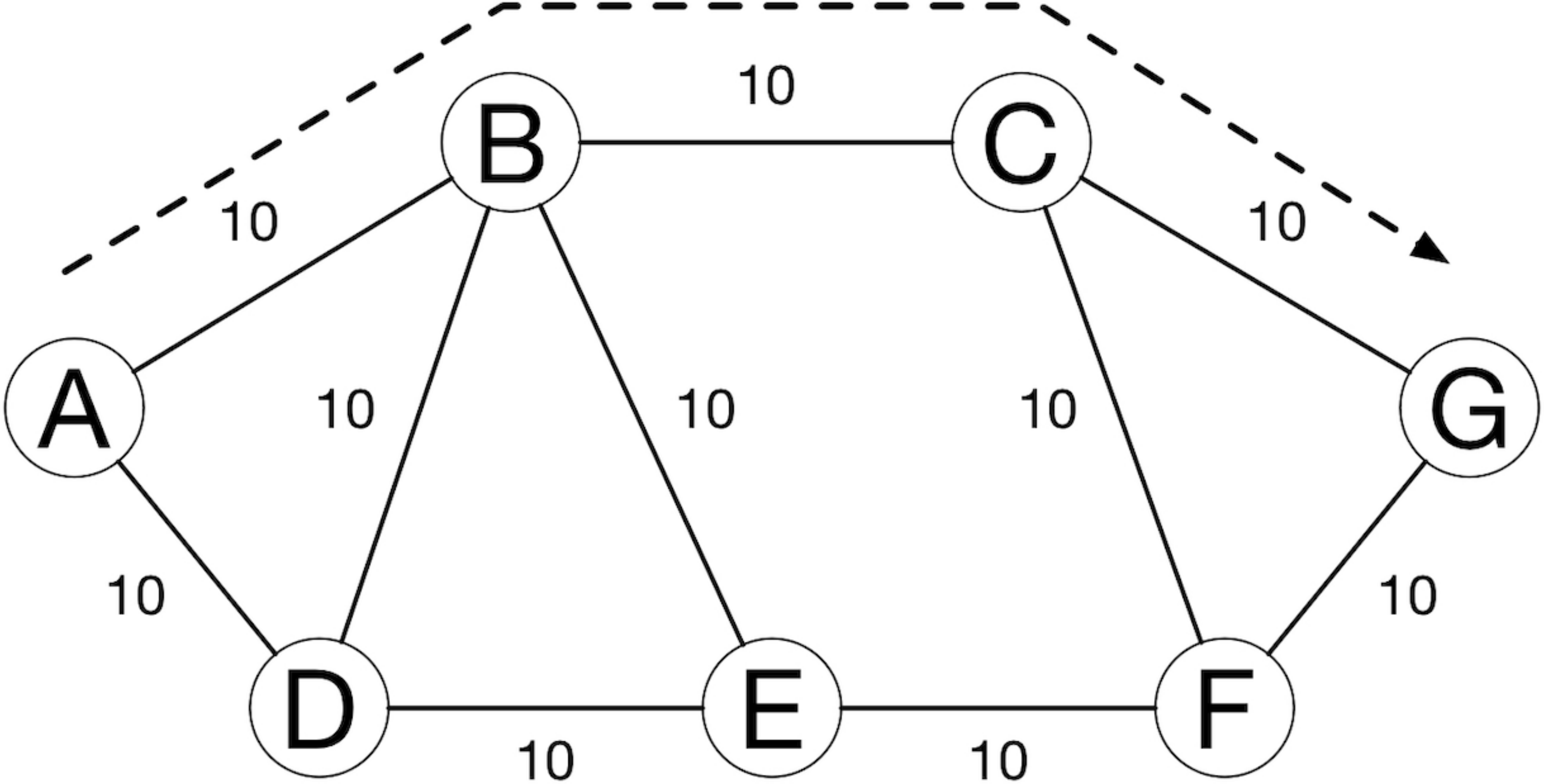

Default static route
A
B
C
D
E
F
G
Ping-pong!

Dynamic routing

- Hop count: count the hops between nodes
- Link cost: determined by the speed and quality
- Administrative policies

Simple hop counting

- Assume every link costs the same with each other


A
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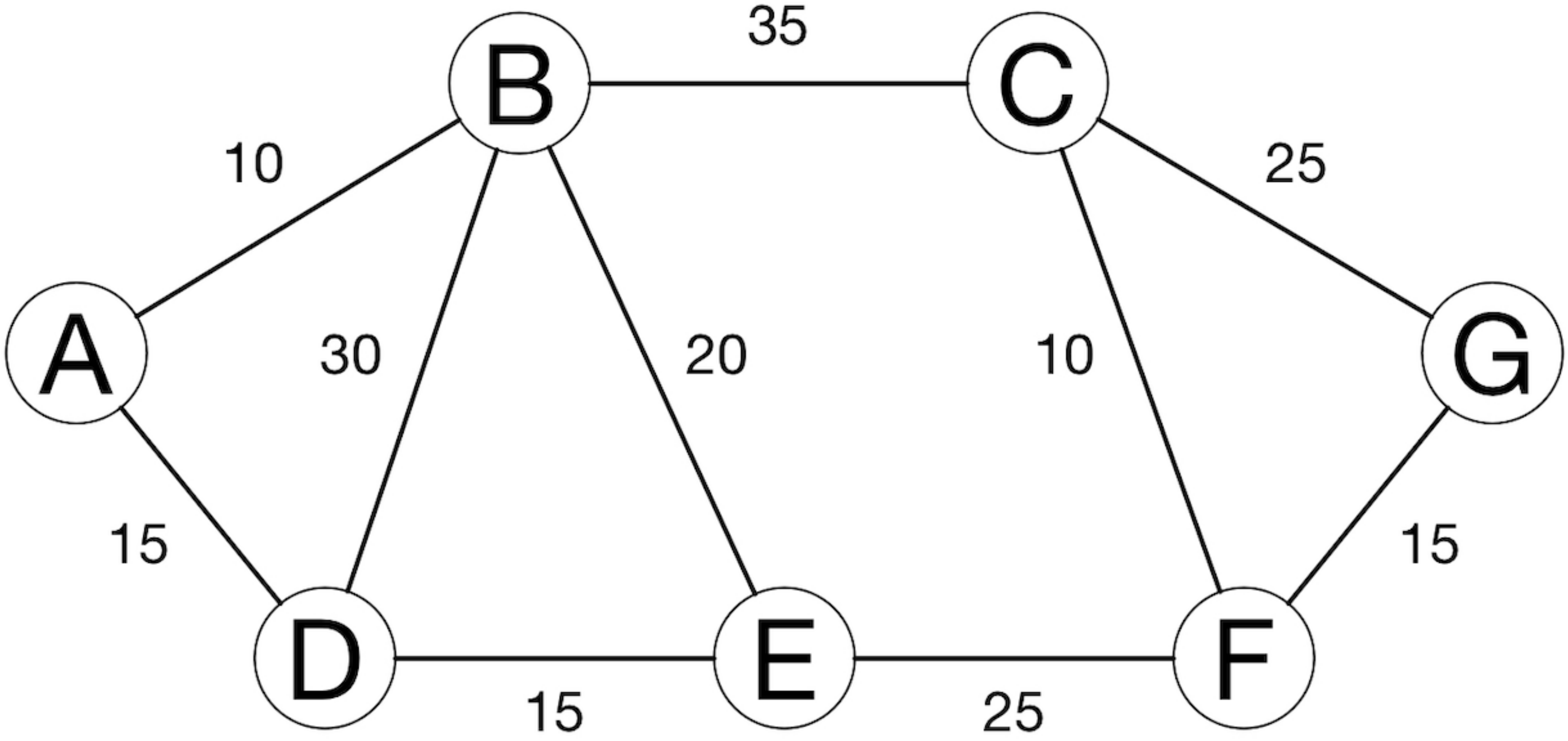
10

Evaluating link cost

- What if the cost of each link varies?
- If two or more paths have the equal cost, all of the links will be utilized for load balancing


35
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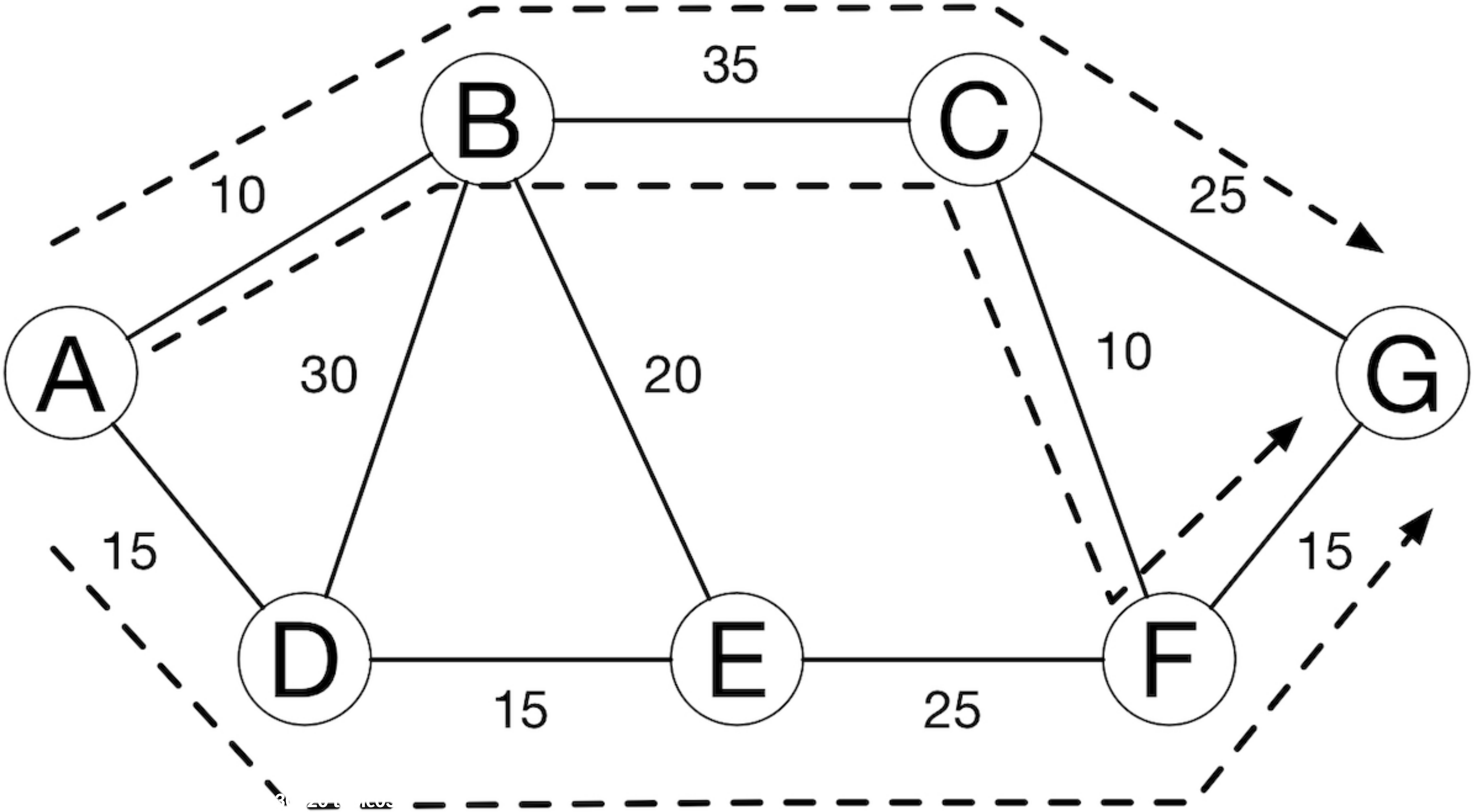
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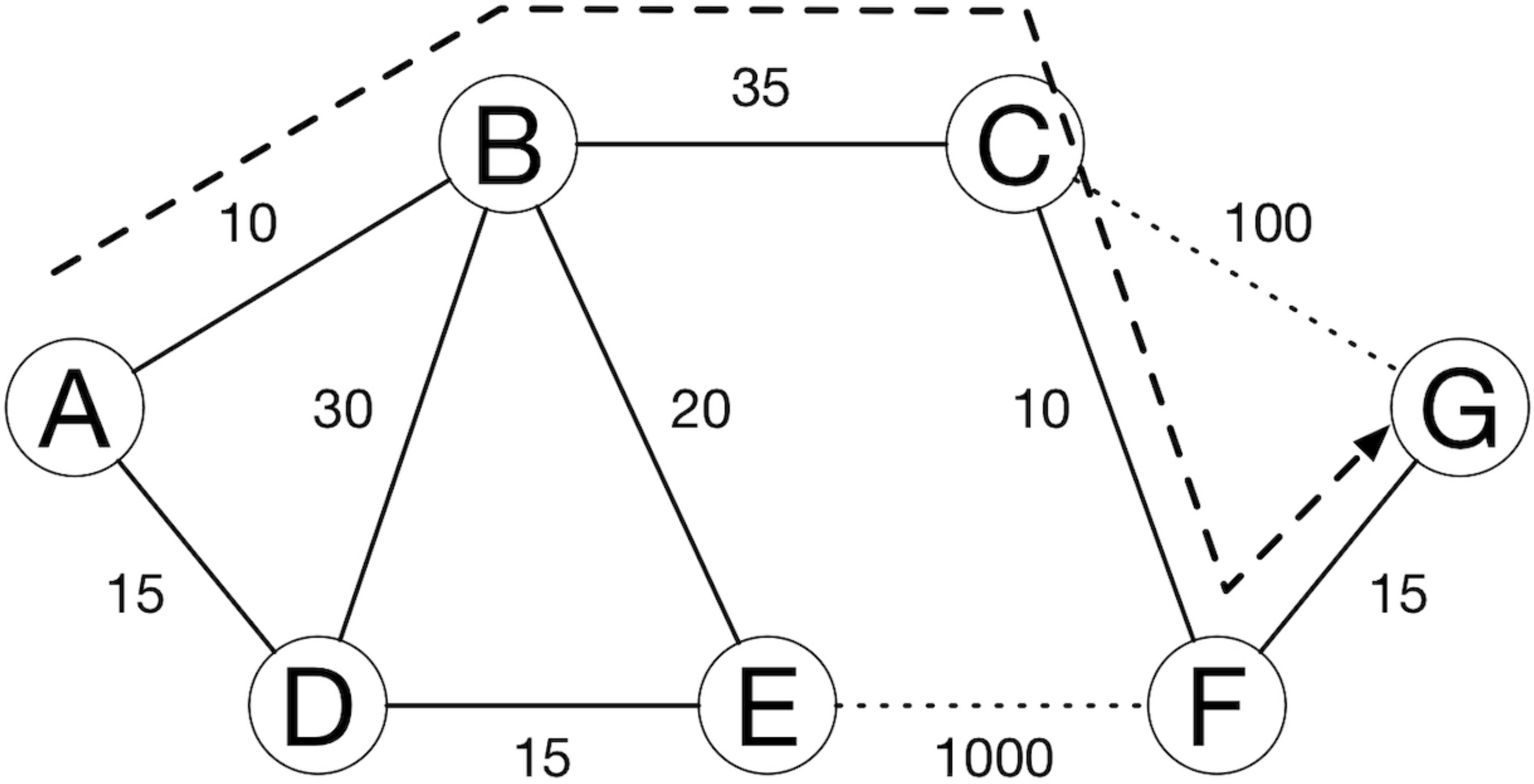
Simulating link failures

- What if the link suddenly degrades or is disconnected?
- Largely increasing the cost of degraded or disconnected links will give an easy solution


35
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G
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20
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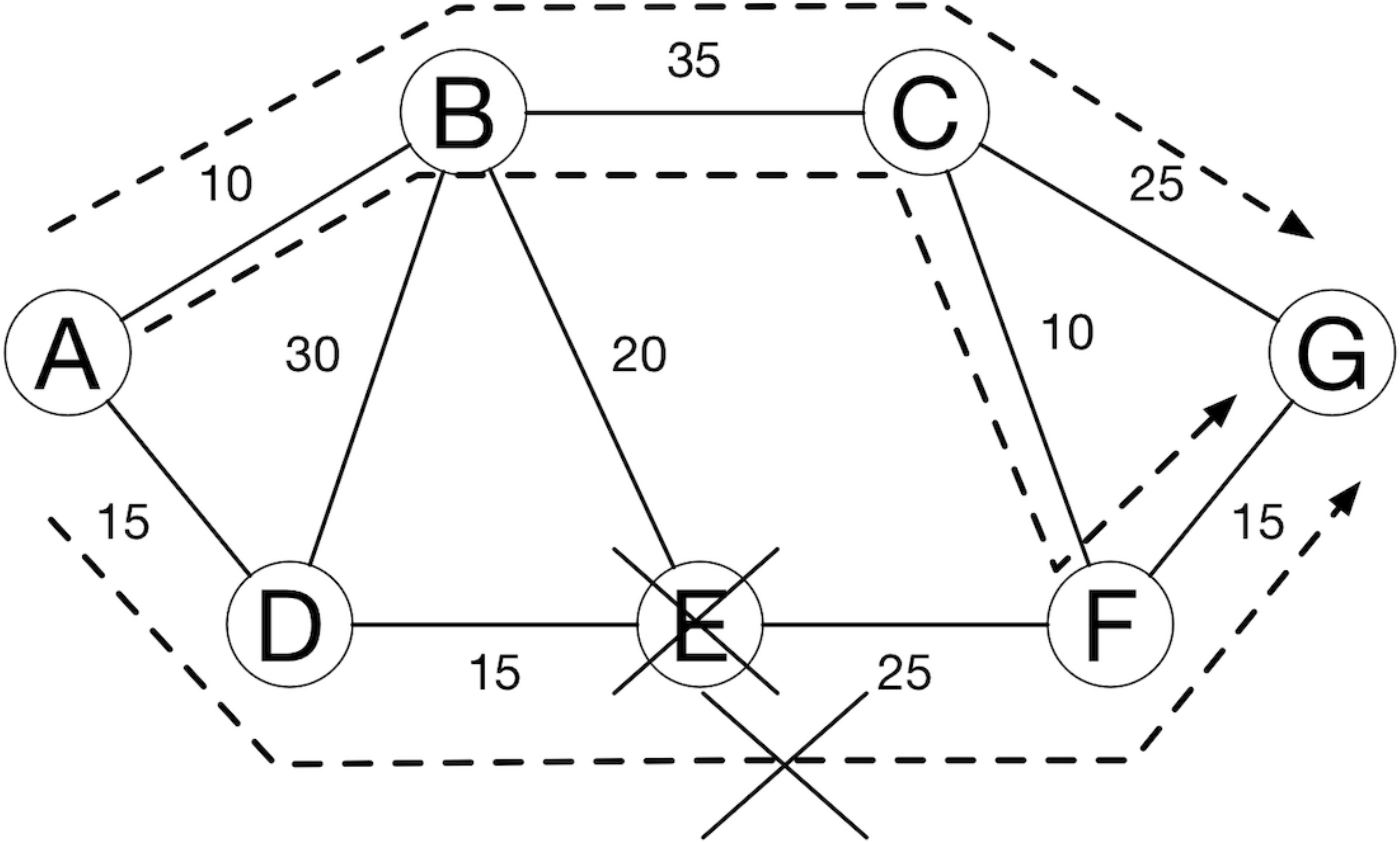
15
15
D
E
F
15
1000

Administrative policies

- For many reasons, you don't want to accept packets from some nodes, depending on the relay paths
- For example: passing C is OK, but passing E is not: A-B-C-G and A-B-C-F-G are OK, but A-D-E-F-G is blocked
- Common among interconnection of the autonomous systems (internet service providers and organizations)


35
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25

Routing information dissemination protocols

- Link-state protocol: flooding link cost information of each node throughout the network
- Path vector protocol: exchanging path of nodes for each network instead of the link costs
- Highly vulnerable to external attacks

Routing aggregation

- The following four networks
  - 192.168.100.0/24
  - 192.168.101.0/24
  - 192.168.102.0/24
  - 192.168.103.0/24
- -> aggregated as 192.168.100.0/22
- 4 networks together as one aggregated network

Network transports

IP address and the port number

- Each service has a 16-bit port number
- HTTPS = 443, DNS = 53, SSH = 22, etc.
- A pair of IP address and port number defines an endpoint of communication

UDP and TCP

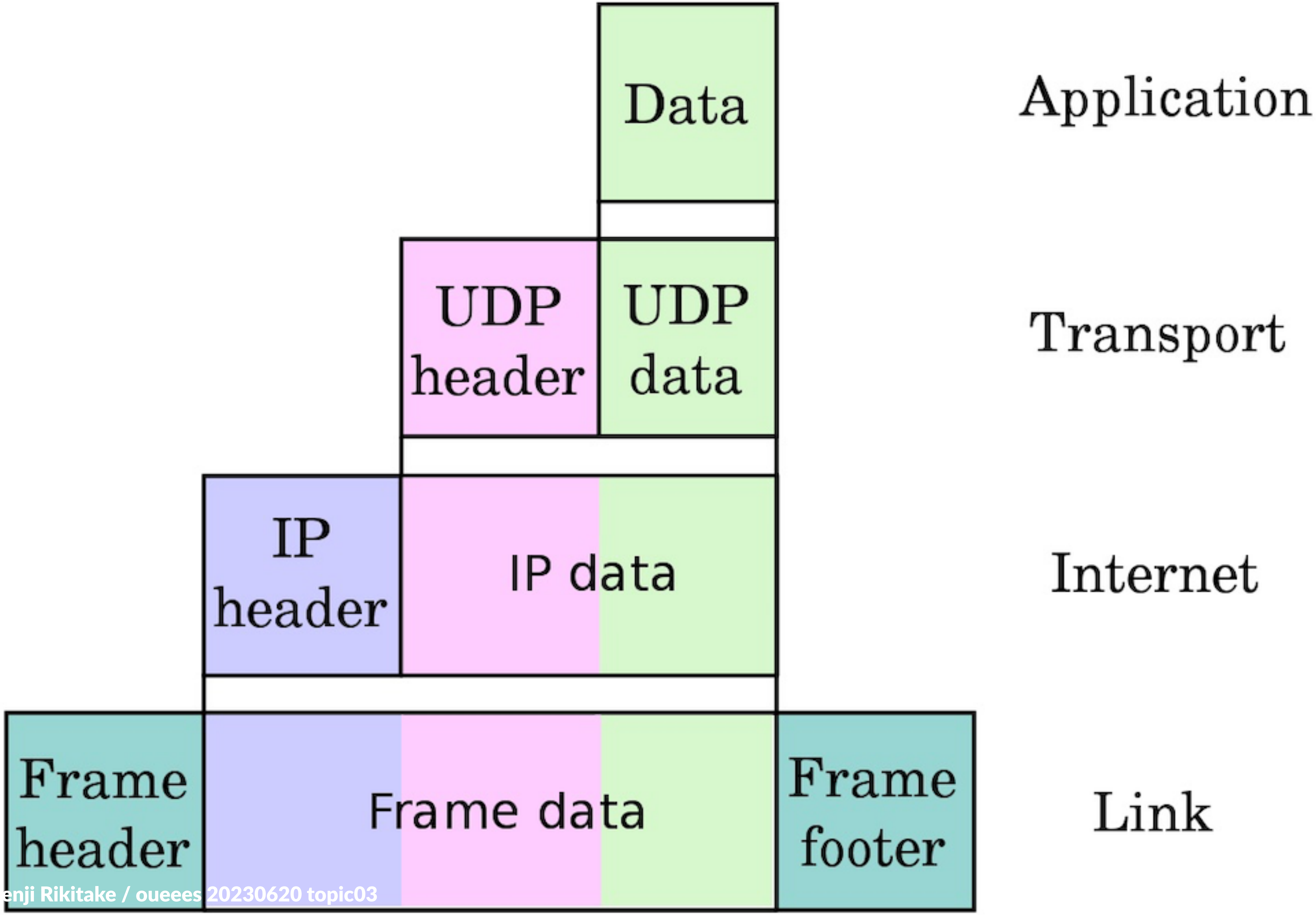
- Two major transport protocols on the internet
- User Datagram Protocol (UDP, RFC 768): connection-less
- Transport Control Protocol (TCP, RFC 9293): connection-oriented
  - Obsoleted RFCs: 793, 879, 2873, 6093, 6429, 6528, 6691
- See https://www.rfc-editor.org for all the internet RFCs
- RFC: Request for Comment

Packet exchange limitation

- Packets are not always delivered
- Sending sequence is not preserved
- The same packet may be received multiple times
- The content of the packet may get altered or damaged
- Packet size has the limitation

What UDP does

- Add a header with the port number
- Send it in an IP packet
- ... and that's it

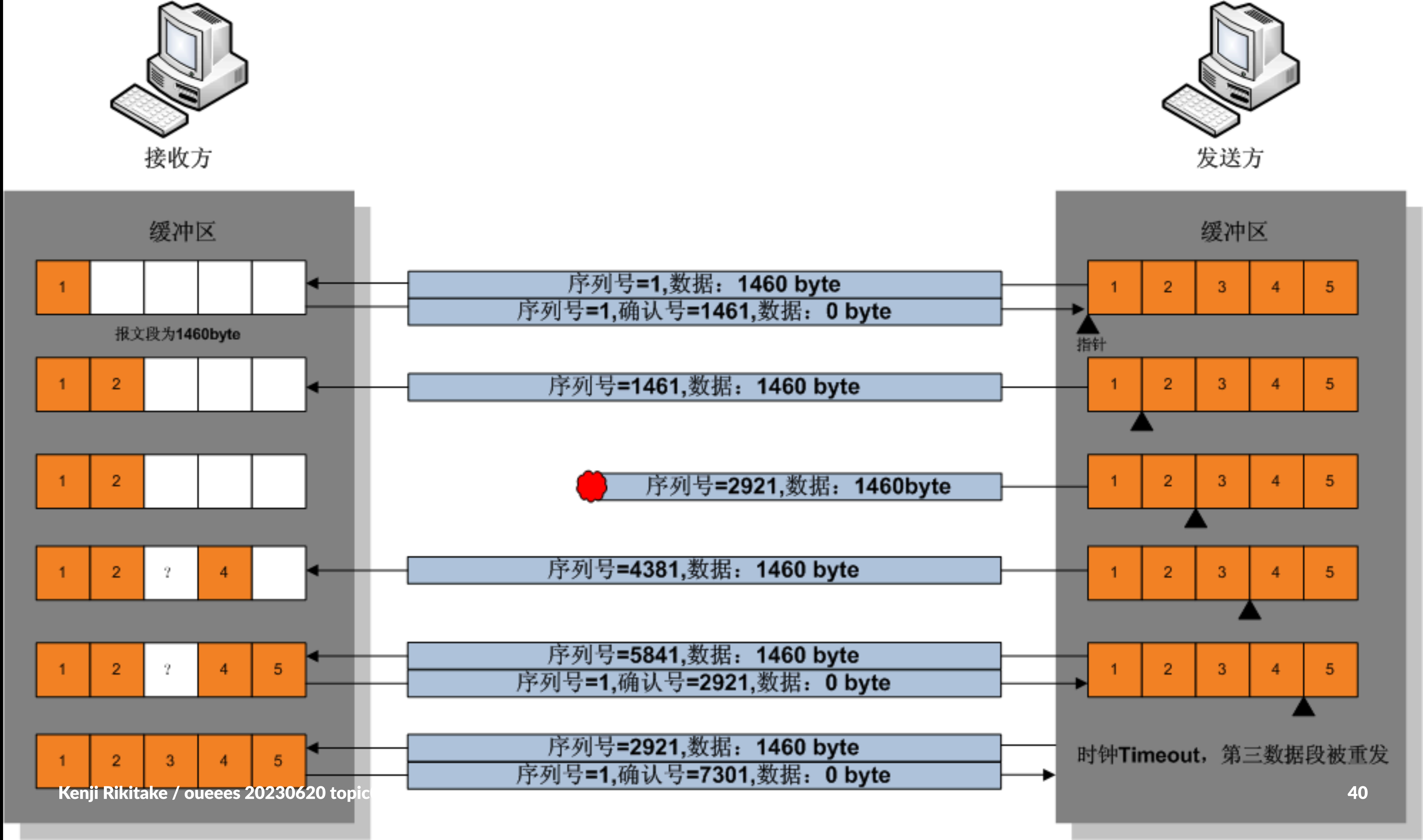

Data
Application
UDP header
UDP data
Transport
IP header
IP data
Internet
Frame header
Frame data
Frame footer
Link

UDP's pros and cons

- UDP datagrams are still not always delivered and may get lost
- Sequence is not preserved
- The same datagram may be received multiple times and may cause duplicate delivery
- The errors in the contents of UDP datagrams are detectable
- UDP datagram has the size limit: suitable for relatively small messages
- Very small additional latency

Transport control protocol (TCP)

- Detect packet loss by timeout
- Split stream into segments
- Put sequence numbers to the segments
- Reassemble segments to the stream
- Perform congestion control


接收方
发送方
缓冲区
缓冲区
1
报文段为1460byte
序列号=1,数据：1460 byte
序列号=1,确认号=1461,数据：0 byte
1 2 3 4 5
指针
1 2
序列号=1461,数据：1460 byte
1 2 3 4 5
1 2
序列号=2921,数据：1460byte
1 2 3 4 5
1 2 ? 4
序列号=4381,数据：1460 byte
1 2 3 4 5
1 2 ? 4 5
序列号=5841,数据：1460 byte
序列号=1,确认号=2921,数据：0 byte
1 2 3 4 5
1 2 3 4 5
序列号=2921,数据：1460 byte
序列号=1,确认号=7301,数据：0 byte
时钟Timeout，第三数据段被重发

TCP's pros and cons

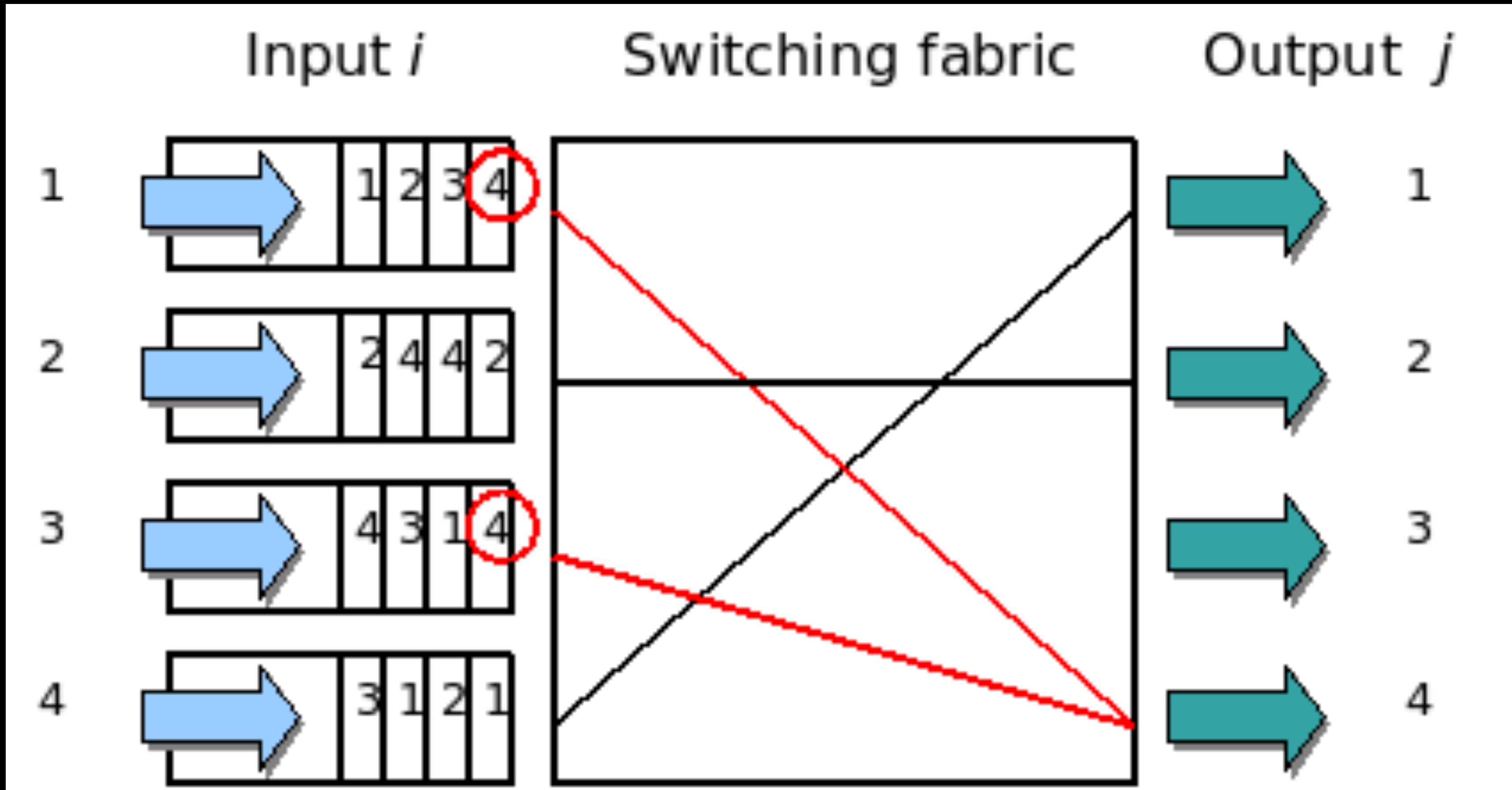
- Loss is detected and recovered so long as the connection is alive
- Sequence is preserved
- No content repetition
- Errors are detected and fixed by retransmission
- The stream will accept data so long as the connection is alive
- Data delivery may delay if retransmission occurs

Web: HTTP/3: HTTP2 over QUIC

- People wants *speed* and *smaller latency*
- HTTP/2 (RFC 7540): TCP-bound, stream aggregation and content compression
- QUIC (RFC 9000): UDP-based, tightly integrated to HTTP/2 and specific congestion control
- HTTP/2 had *head-of-line blocking problem* by TCP
- HTTP/3 (RFC 9114): HTTP/2 over QUIC (supported by most browsers already)

Buffering and head-of-line (HOL) blocking

- Buffering causes only the oldest packets to be forwarded
- Newer packets could be forwarded without HOL blocking
- In this example, moving buffers to output ports will avoid the delay for Output 3 at Input 1, blocked by the contention of Output 4



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