The Network Layer

Lecture given by Emmanuel Lochin

ISAE-SUPAERO

Original slides from A. Carzaniga (Univ. Lugano)
Extended/modified by E. Lochin (ISAE-SUPAERO) with author permission

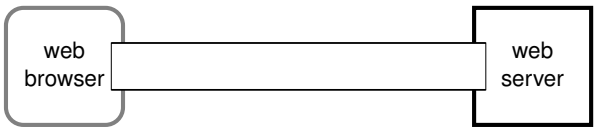
Textbook Chap. #4 Sections 4.1, 4.2.2, 4.3, 4.4.1

Outline

- Basic network-layer architecture of a datagram network
- Introduction to forwarding
- Introduction to routing
- General architecture of a router
- Switching fabric and queuing
- Internet network-layer protocol
- The Internet protocol (IP)
- Fragmentation

Application Level

Application Level



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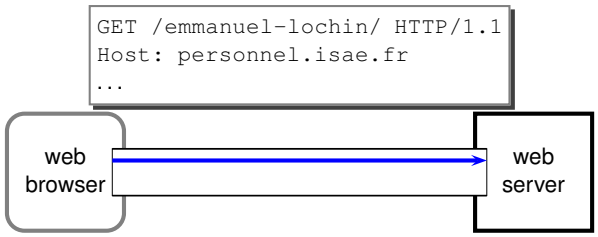

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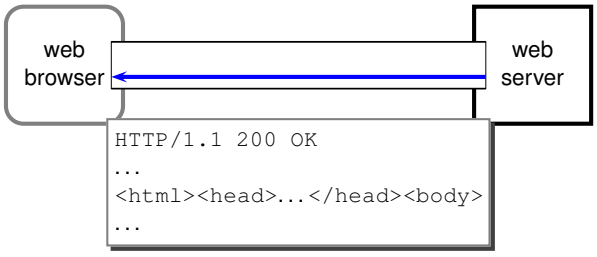

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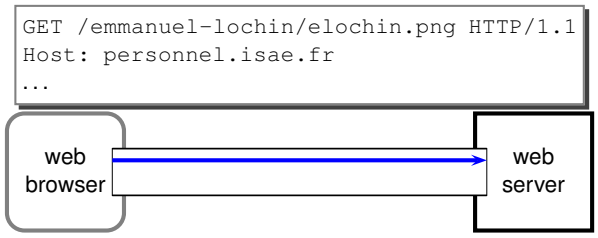

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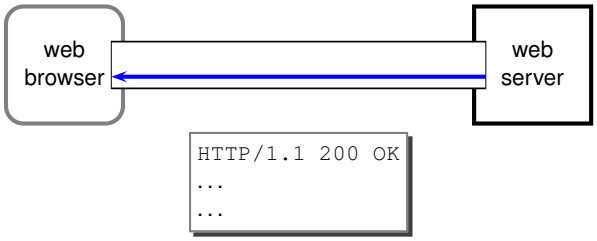
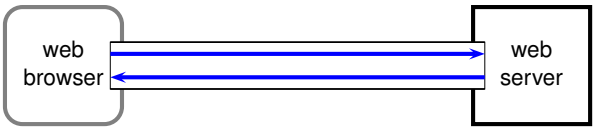


Transport Level



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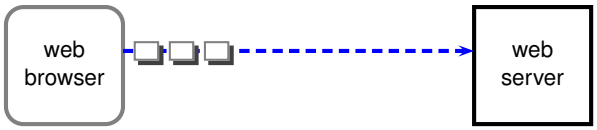

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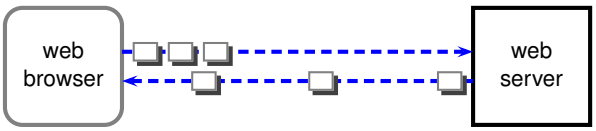

Network Layer

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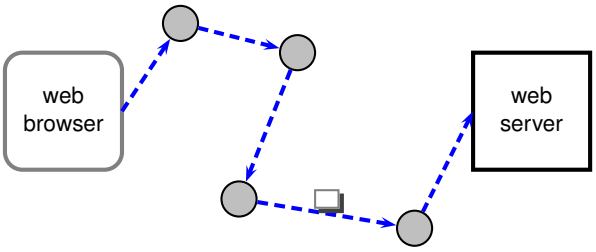

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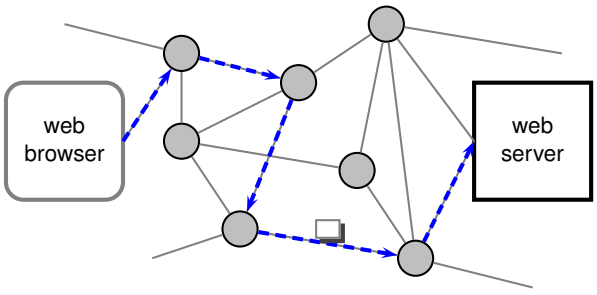
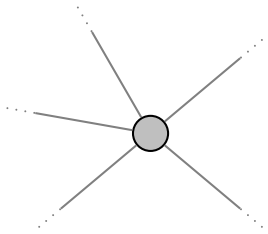
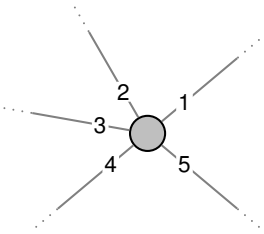


Router



- Fundamental component of the network layer
- A **node in a graph**
- A finite set of input/output (physical) connections
  - a.k.a., interfaces or ports

Router



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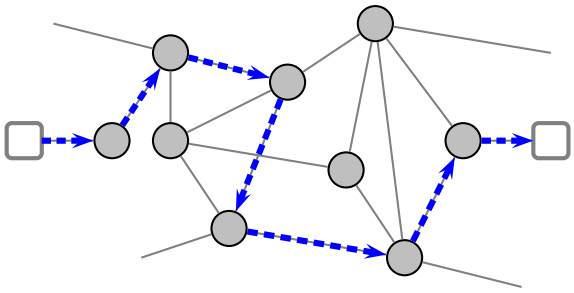
Focus : “Datagram” Networks

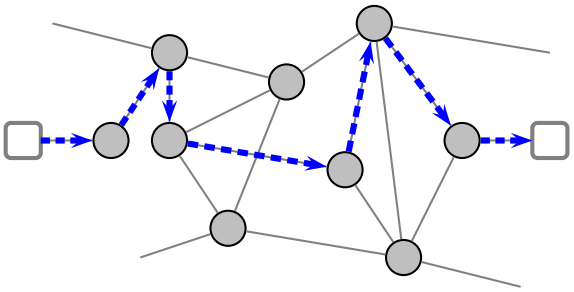
- **Packet-switched network**
  - information is transmitted in discrete units called datagrams
- **Connectionless service**
  - a datagram is a self-contained message
  - treated independently by the network
  - no connection setup/tear-down phase
- **“Best-effort” service**
  - delivery guarantee : none
  - maximum latency guarantee : none
  - bandwidth guarantee : none
  - in-order delivery guarantee : none
  - congestion indication : none

Datagram Network



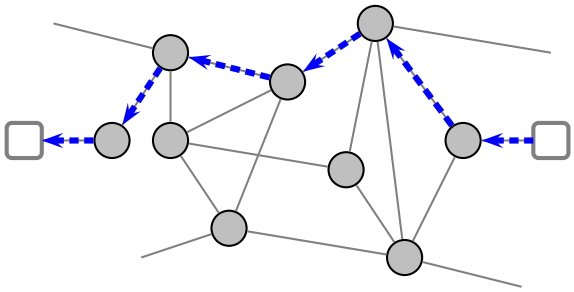
- Potentially **multiple paths** for the same source/destination

Datagram Network



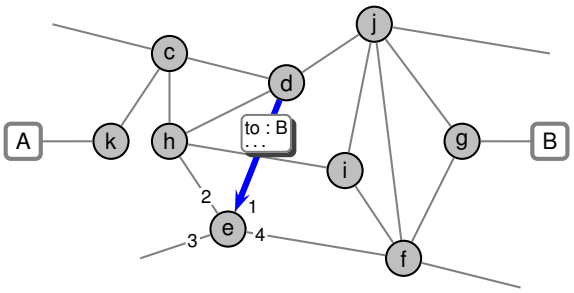
- Potentially **multiple paths** for the same source/destination

Datagram Network



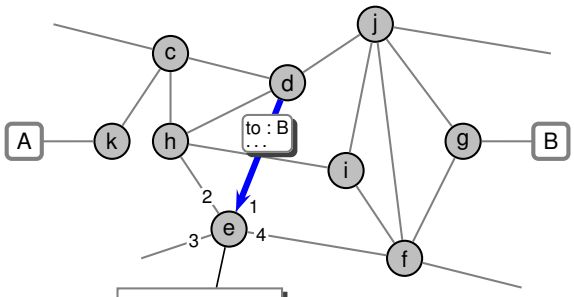
- Potentially **multiple paths** for the same source/destination
- Potentially **asymmetric paths**

Forwarding



- *A* sends a datagram to *B*
- The datagram is forwarded towards *B*

Forwarding



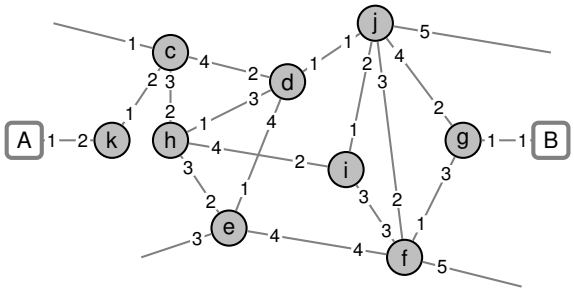
forwarding table

dest.	output
...	...
B	port 4
...	...

Forwarding

- **Input :** datagram destination
- **Output :** output port
- Simple design : “forwarding table”
- Issues
  - how big is the forwarding table ?
  - how fast does the router have to forward datagrams ?
  - how does the router build and maintain the forwarding table ?

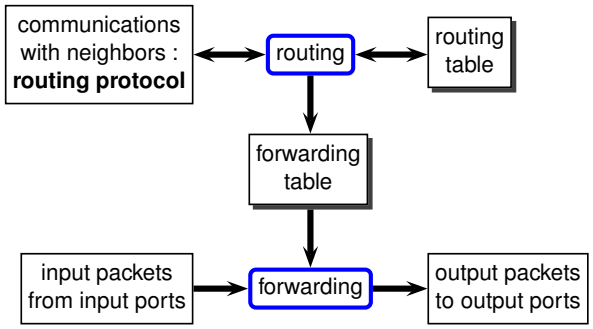
Routing



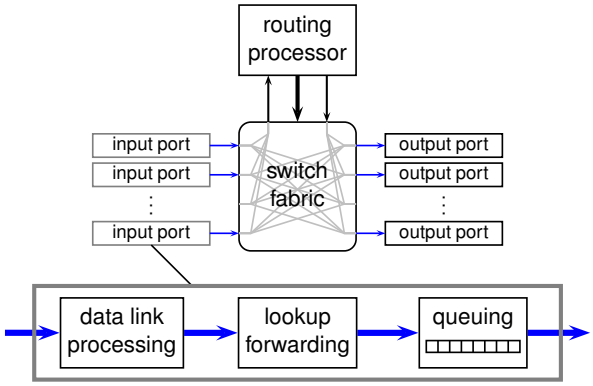
router k

A	2
B	1
...	

Router Functions



Anatomy of a Router



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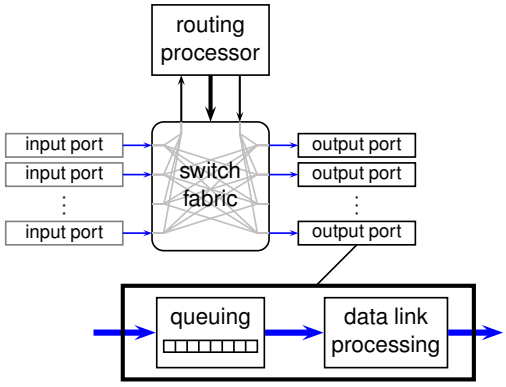


Queuing

- Where does queuing occur ?
- Input ports
  - queuing may occur here if the switching fabric is slower than the aggregate speed of all the input lines. I.e., $R_S < nR_{in}$
- Output ports
  - queuing may occur here because of the limited throughput of the output link. I.e., $R_{out} < \min(R_S, nR_{in})$

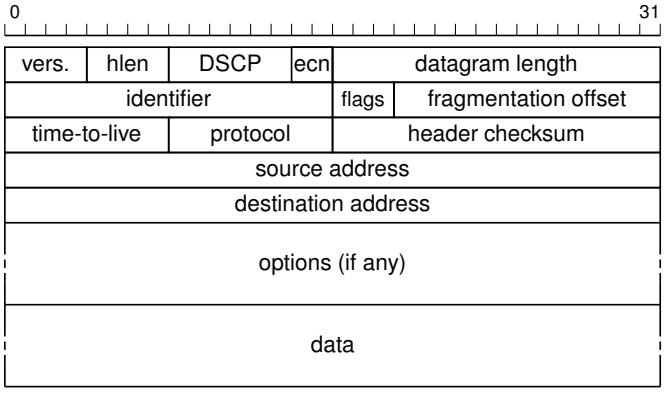
Queuing

- What happens when packets queue up in a router ?
- **Scheduling :** deciding which packets to process
  - **first-come-first-served**
  - **weighted fair queuing :** the router tries to be balance traffic evenly among the different end-to-end connections. Essential to implement **quality-of-service guarantees**
- Deciding when to drop packets, and which packets to drop
  - **drop tail :** drop arriving packets when queues are full
  - **active queue management :** a set of policies and algorithms to decide when and how to drop or mark packets in the attempt to prevent congestion

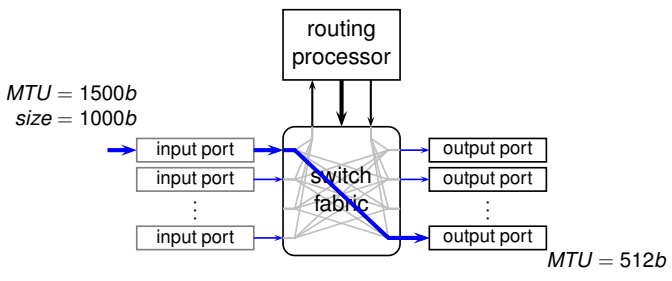
Internet Network Layer

- **Routing :** defining paths and compiling forwarding tables
  - RIP
  - OSPF
  - BGP
- IP
  - addressing
  - datagram format
  - fragmentation and packet handling
- ICMP
  - error reporting
  - signaling

IPv4 Datagram Format



Fragmentation



- How does the router handle cases where the size of an input datagram exceeds the maximum transmission unit (MTU) of the output link ?
- The datagram is fragmented
  - Today, fragmentation rarely occurs