The Network Layer

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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

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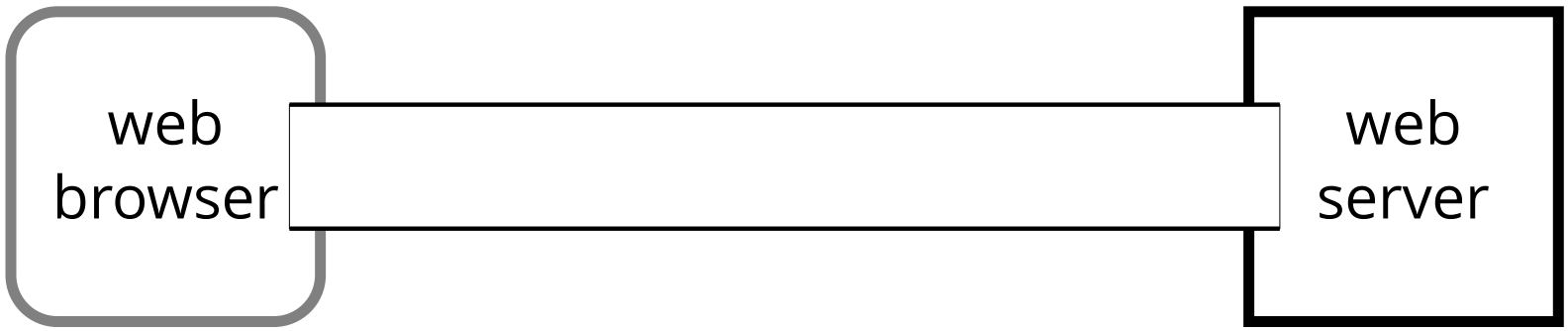

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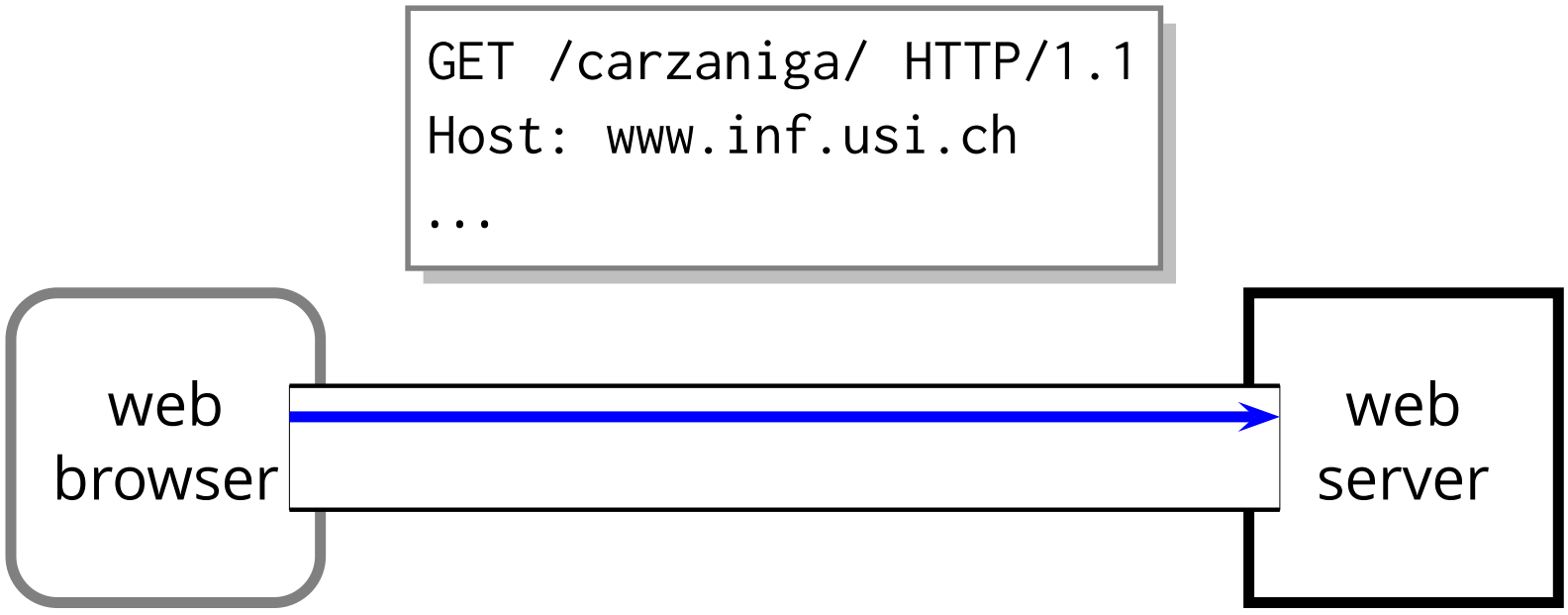

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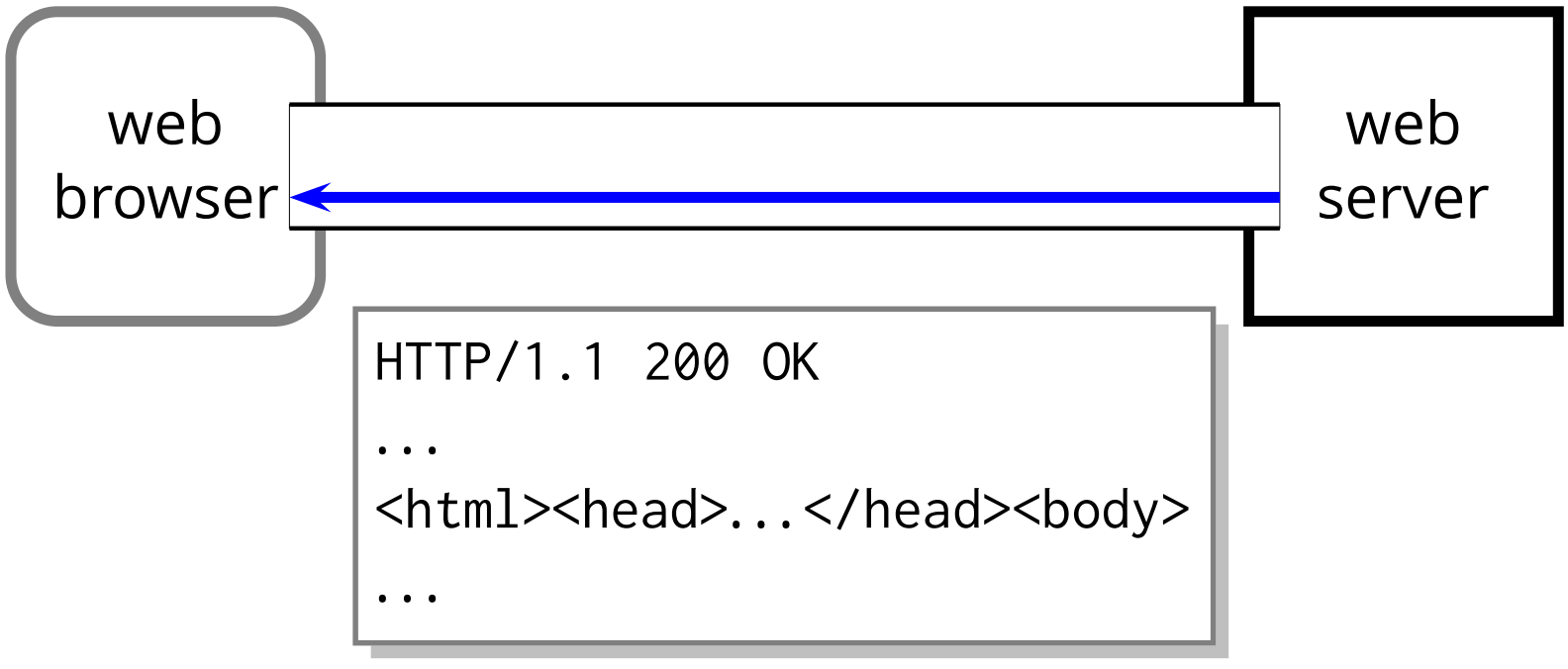

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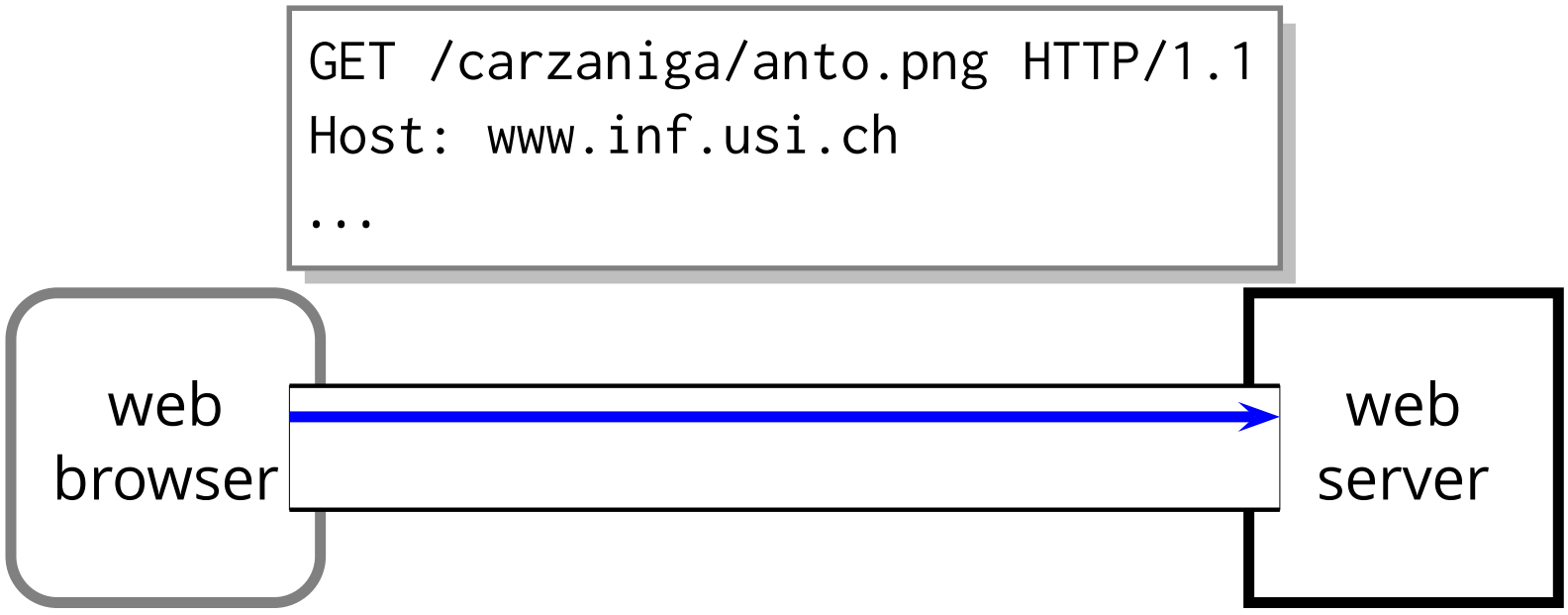

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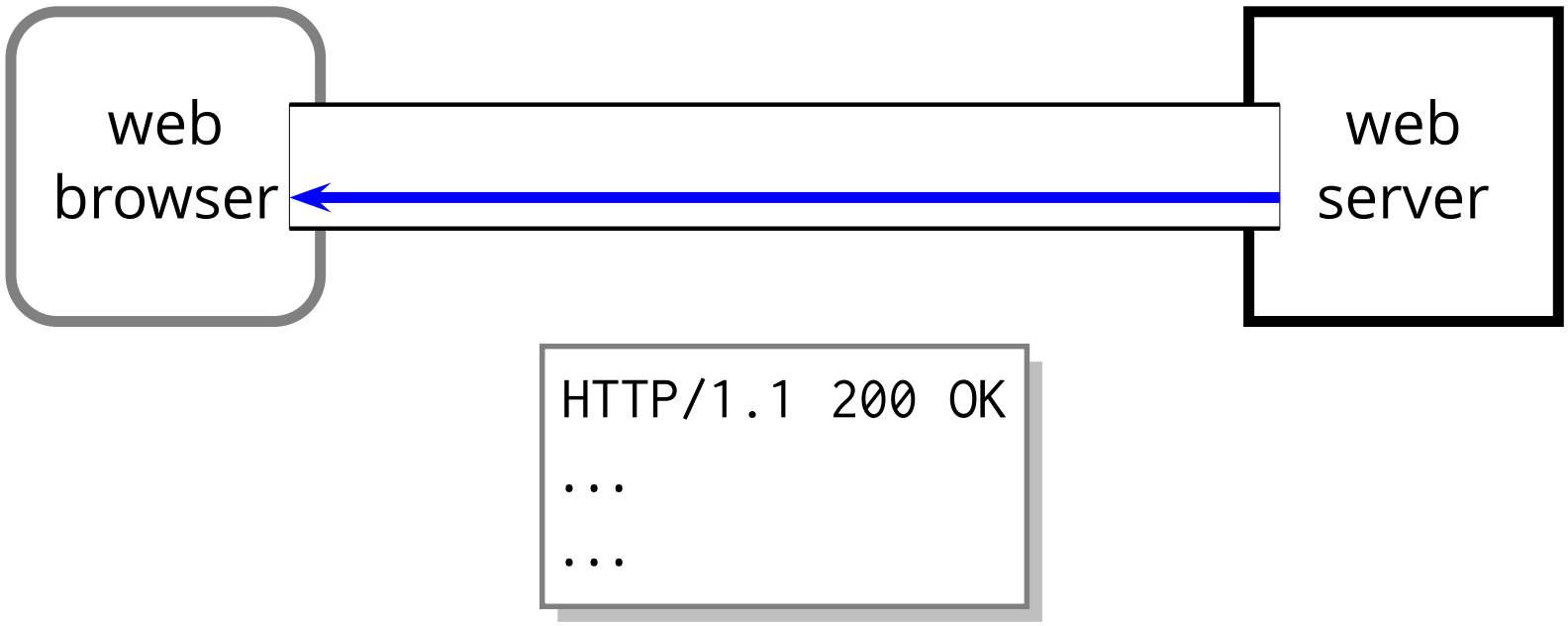

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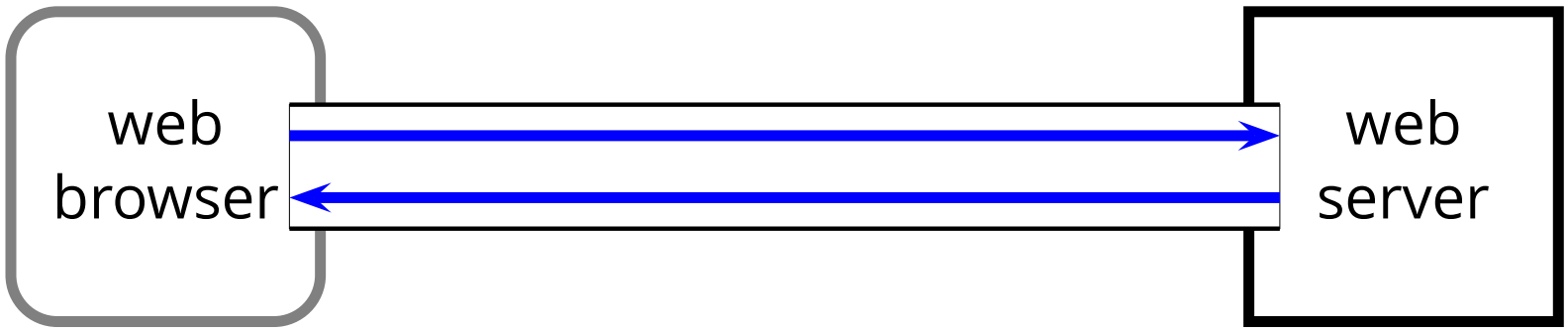

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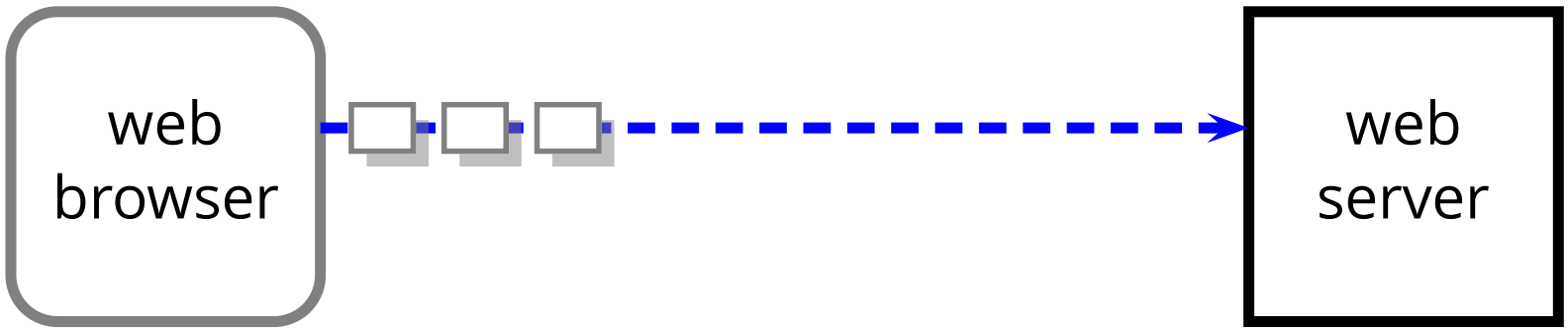

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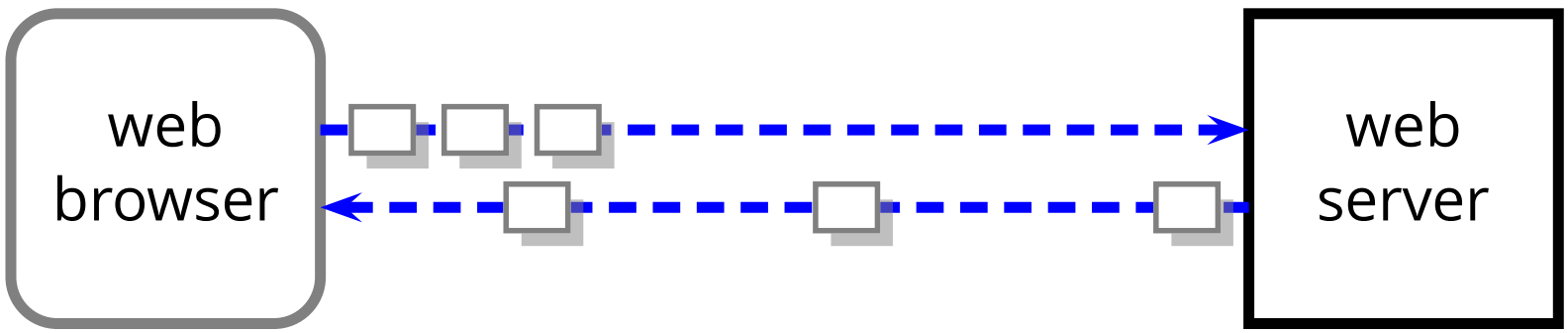
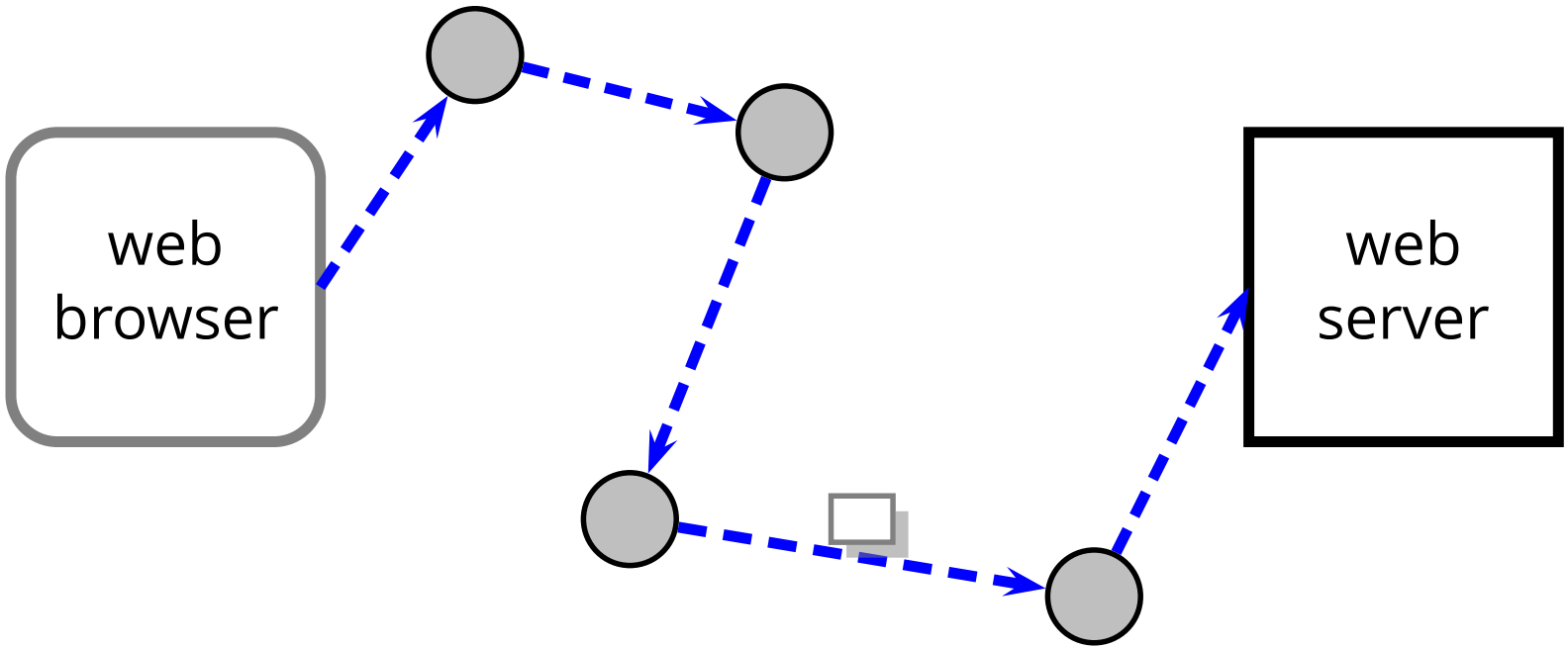
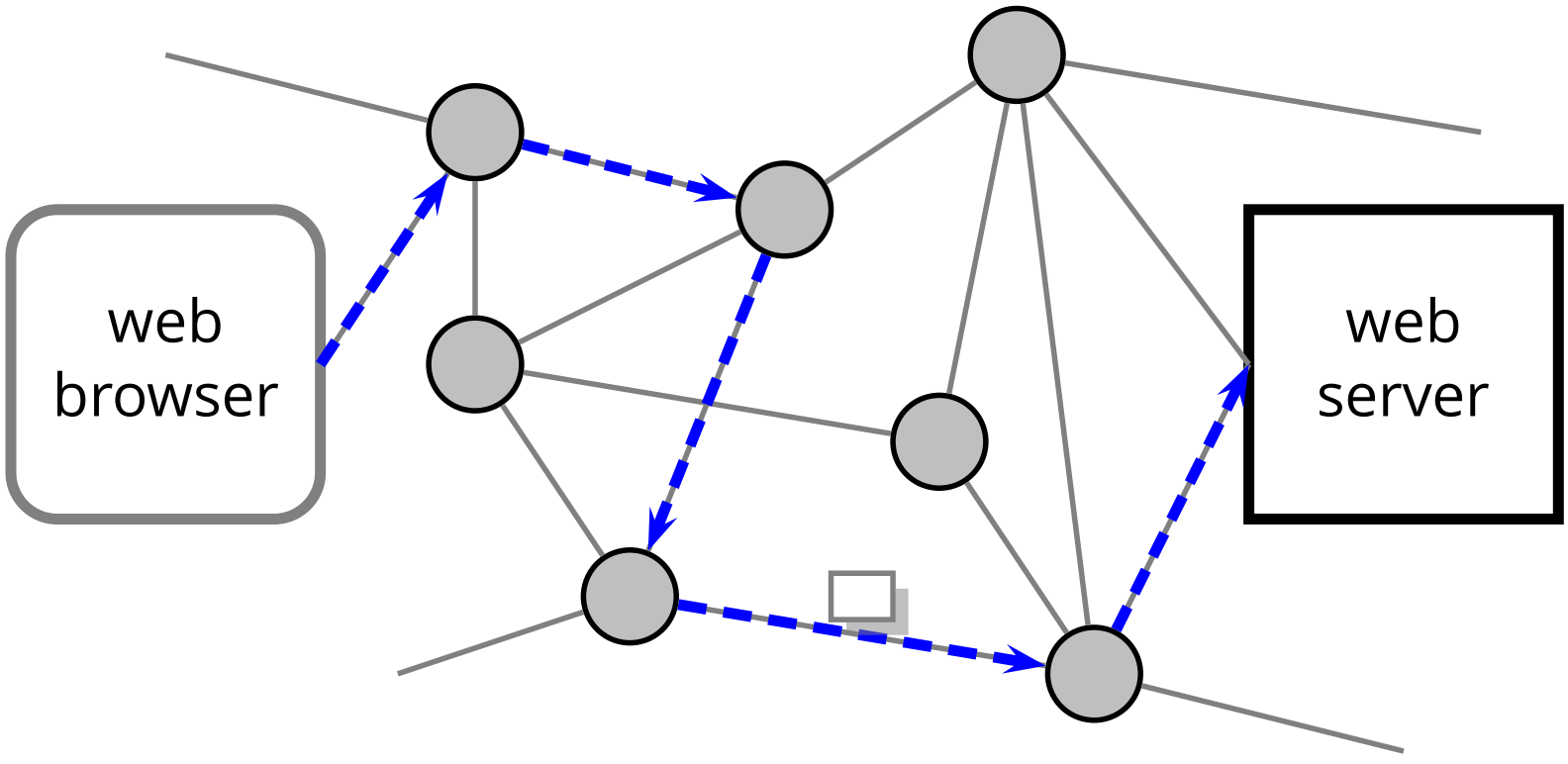



web
browser
web
server

Network Layer

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Router

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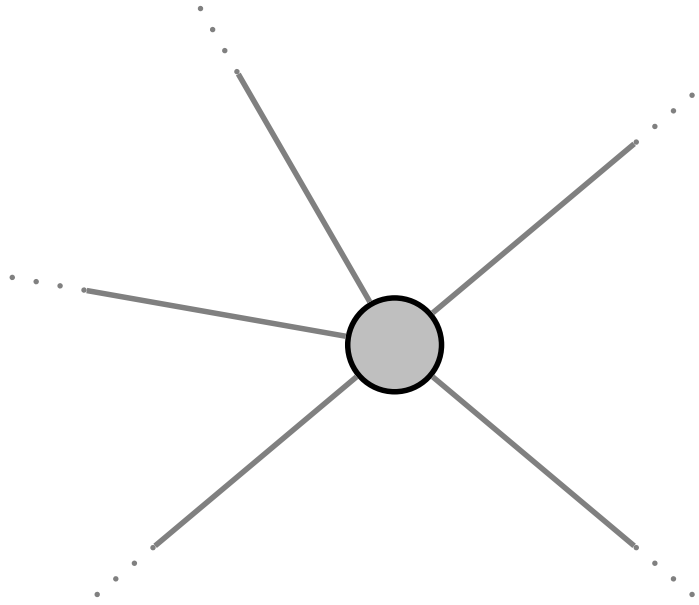

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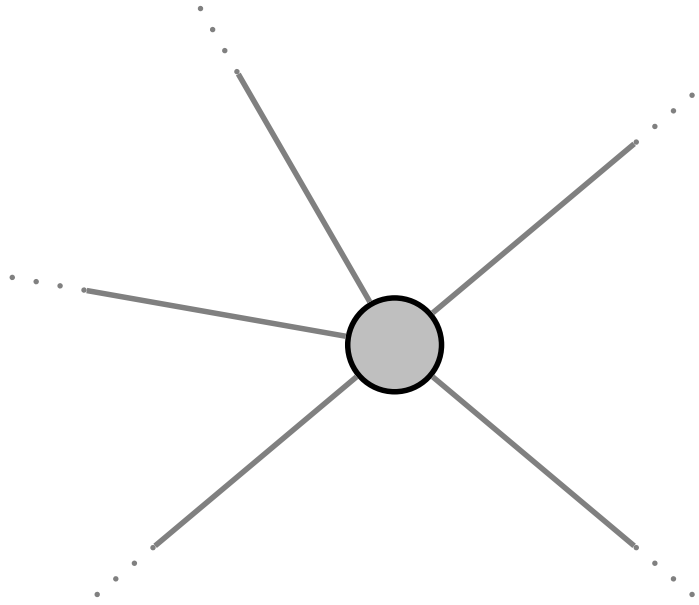

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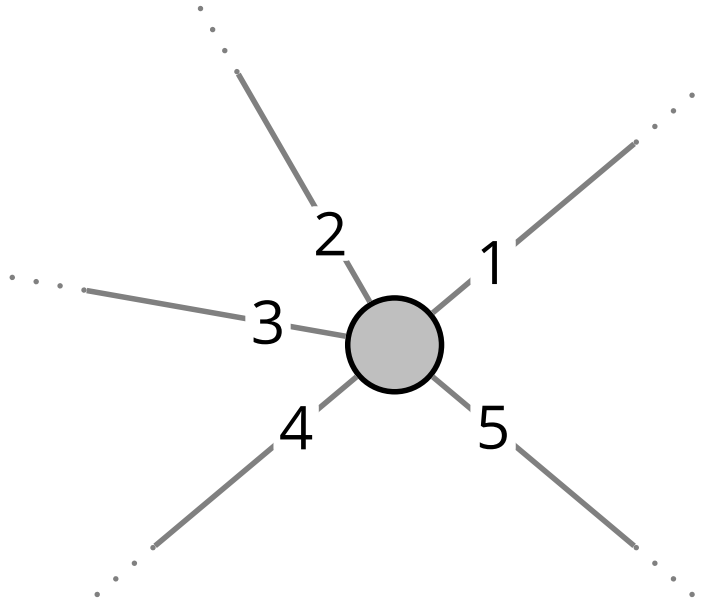

- Fundamental component of the network layer
- A *node in a graph*
- A finite set of input/output (physical) connections
  - a.k.a., ***interfaces*** or ***ports***

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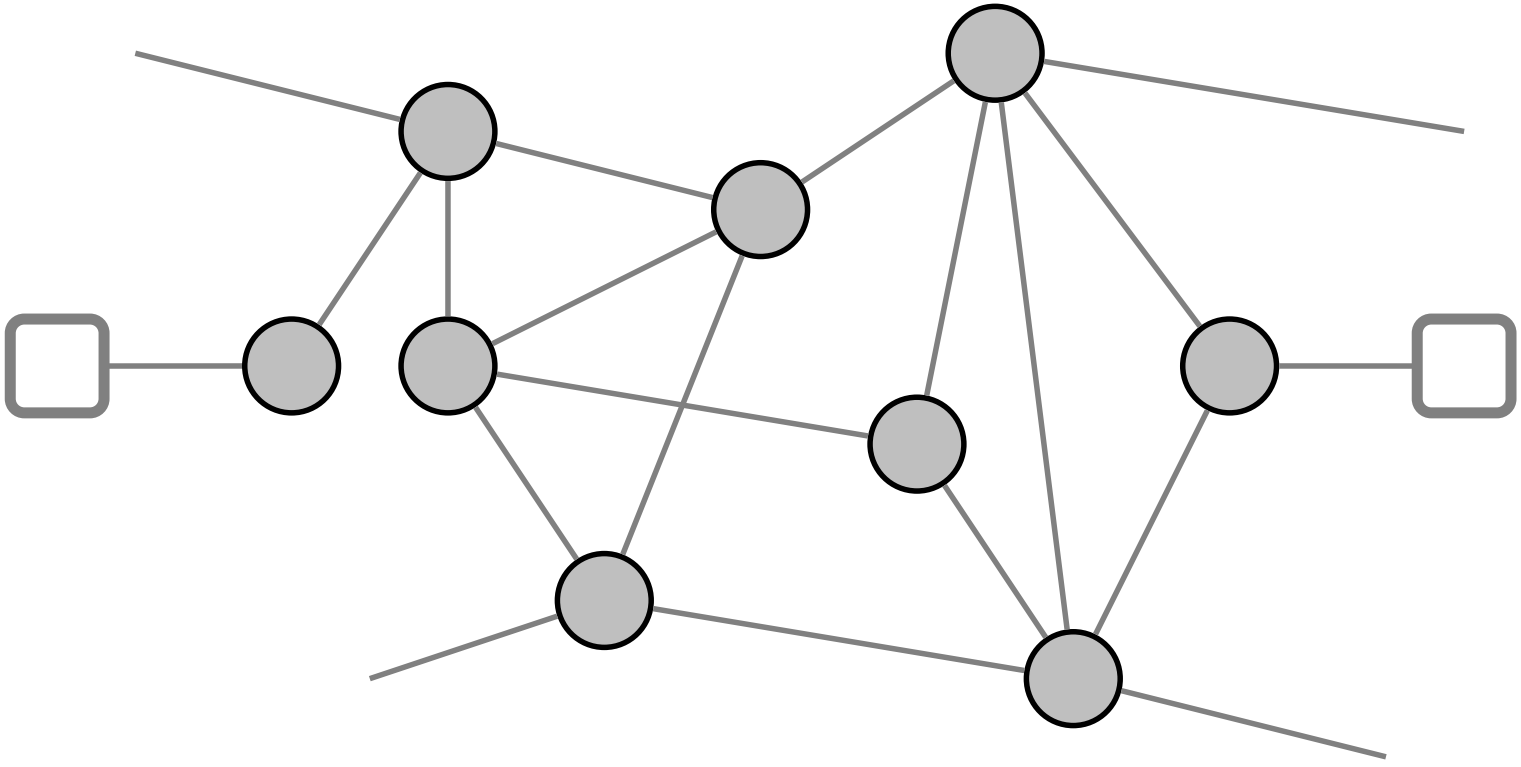
Datagram Network



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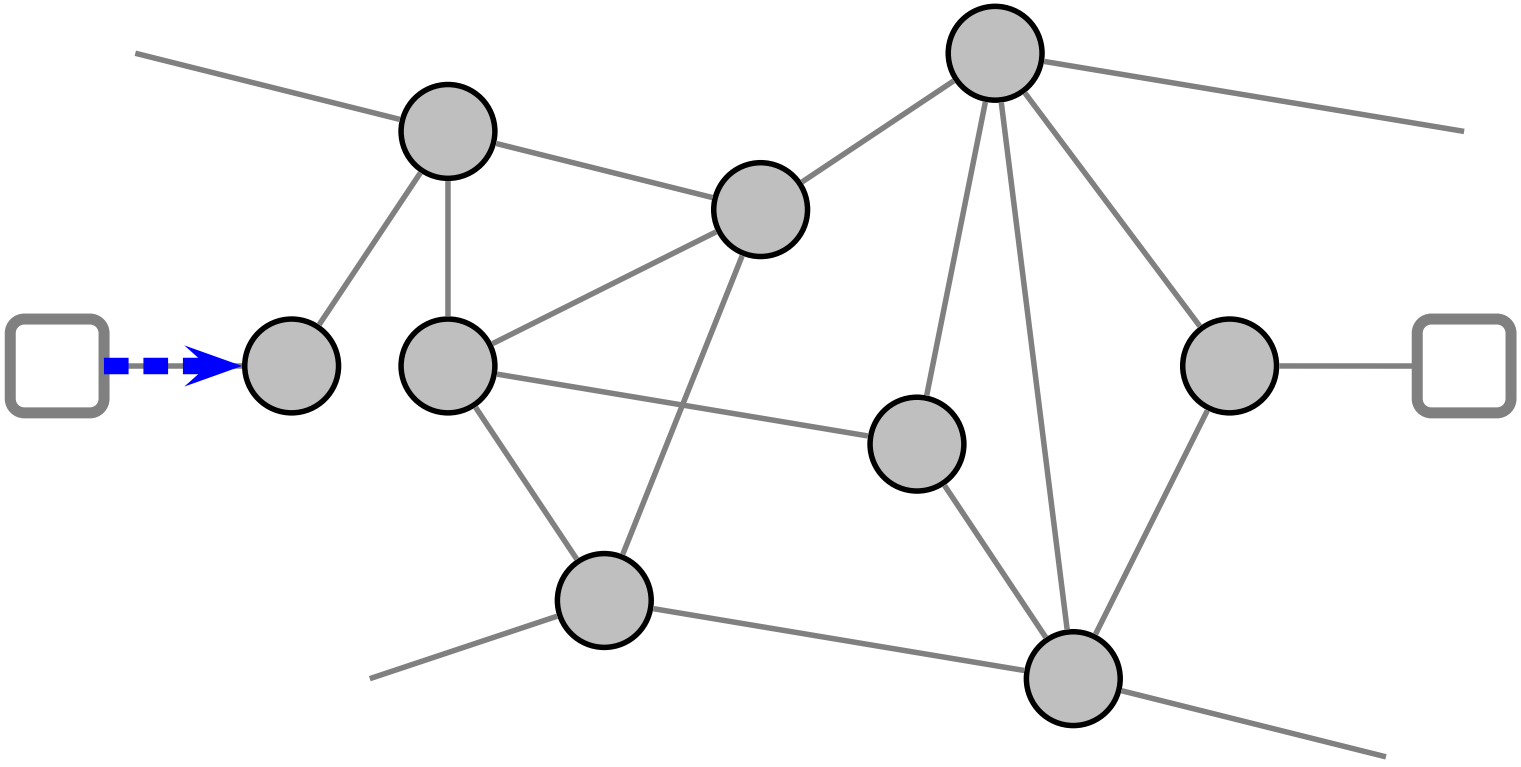

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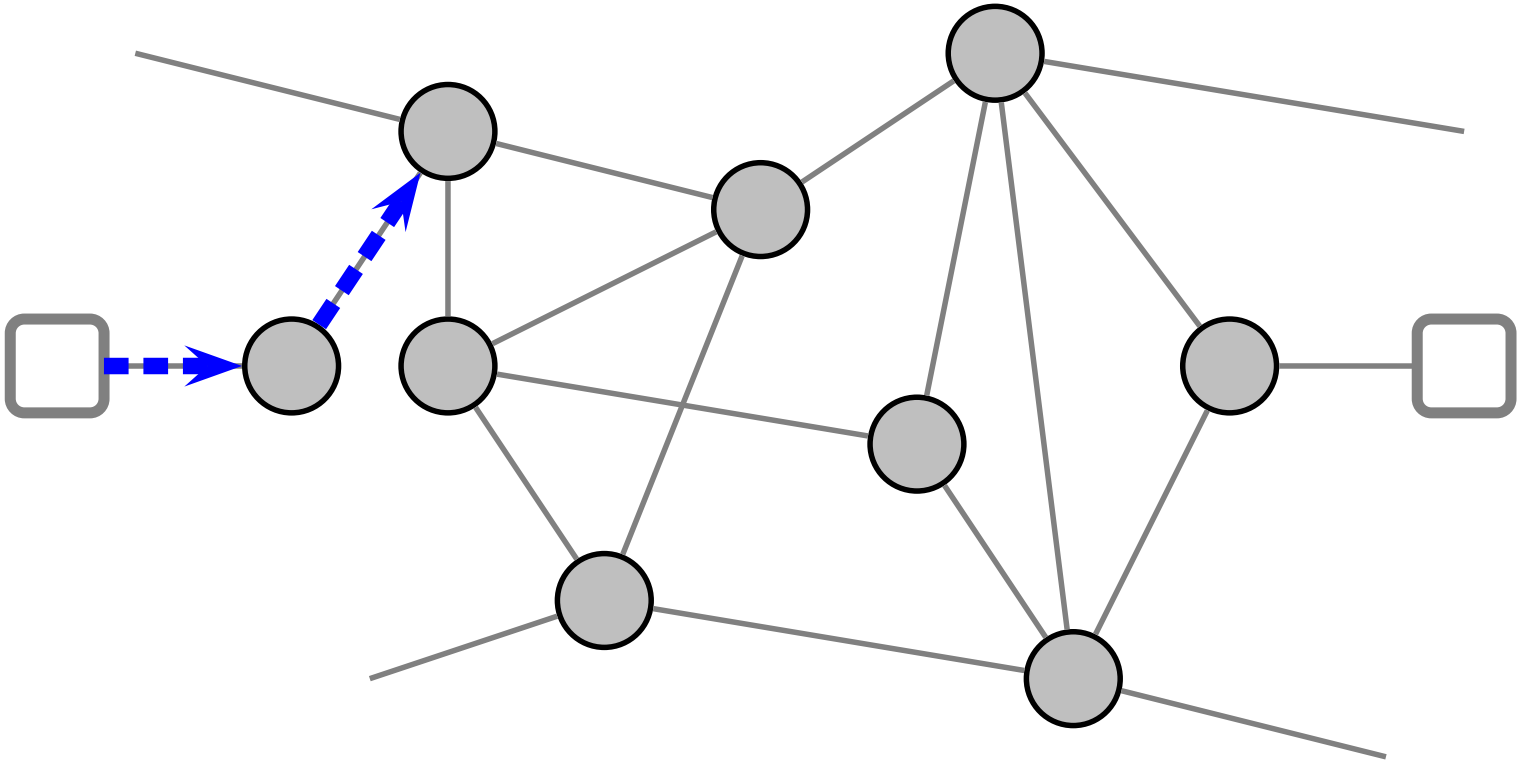

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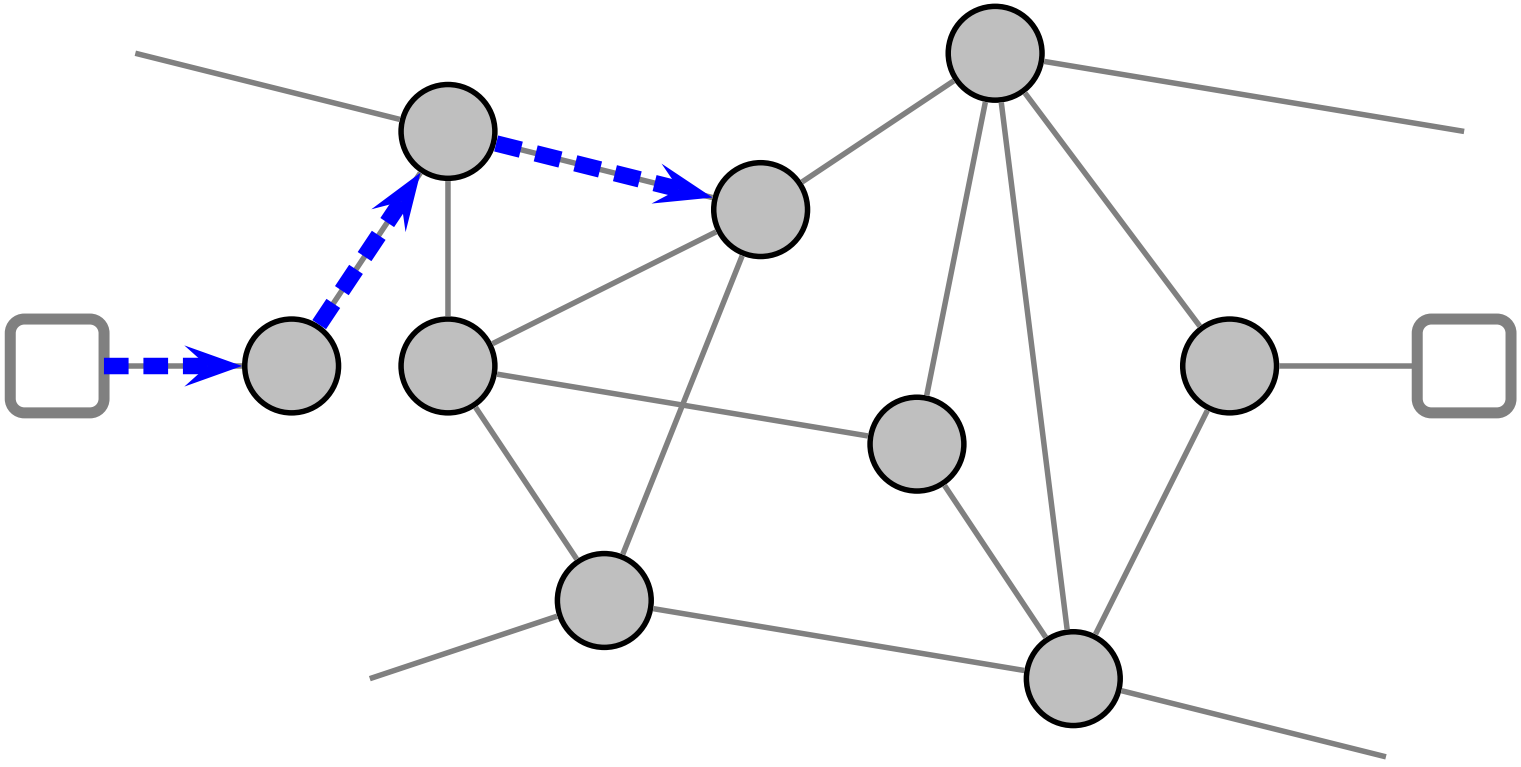

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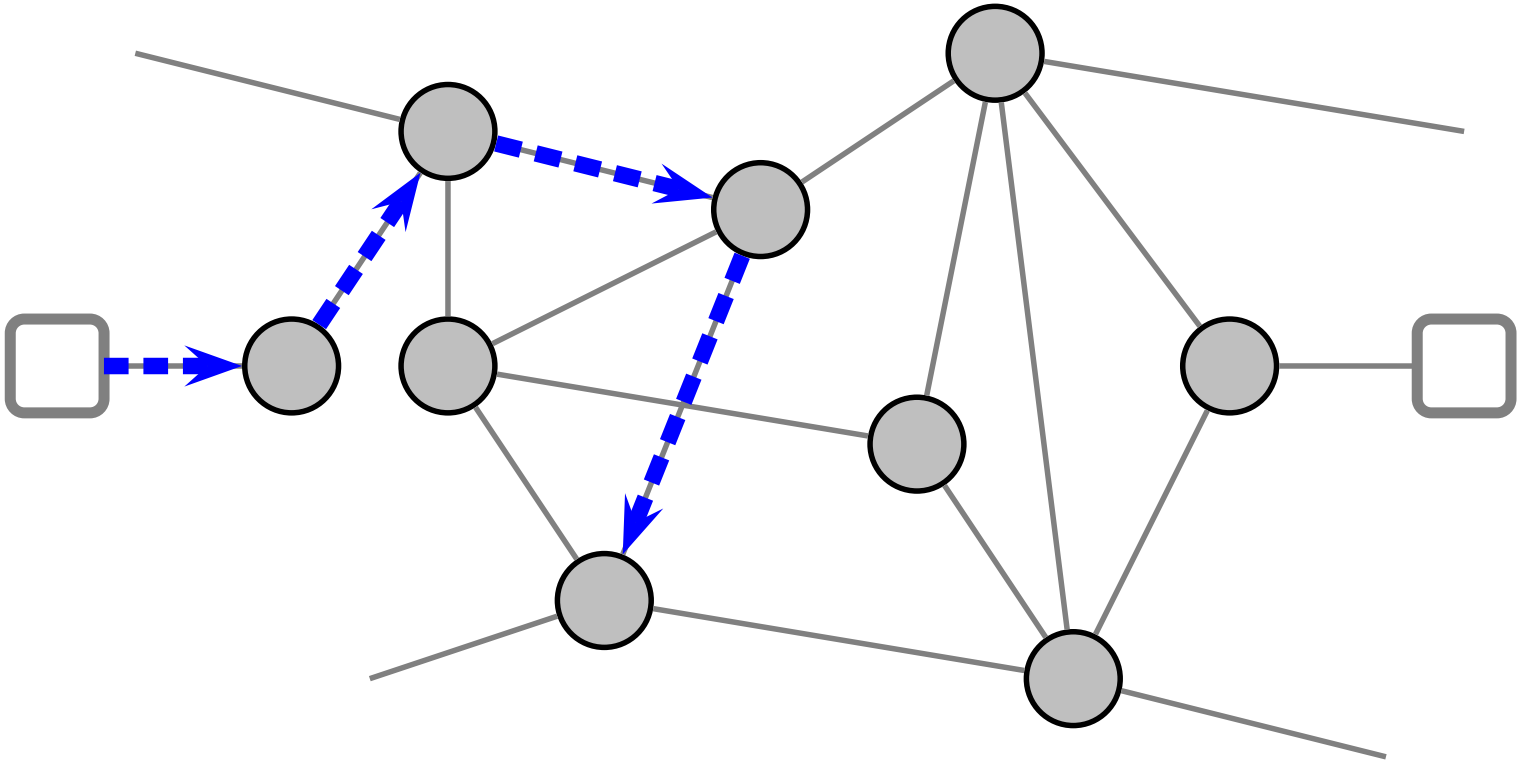

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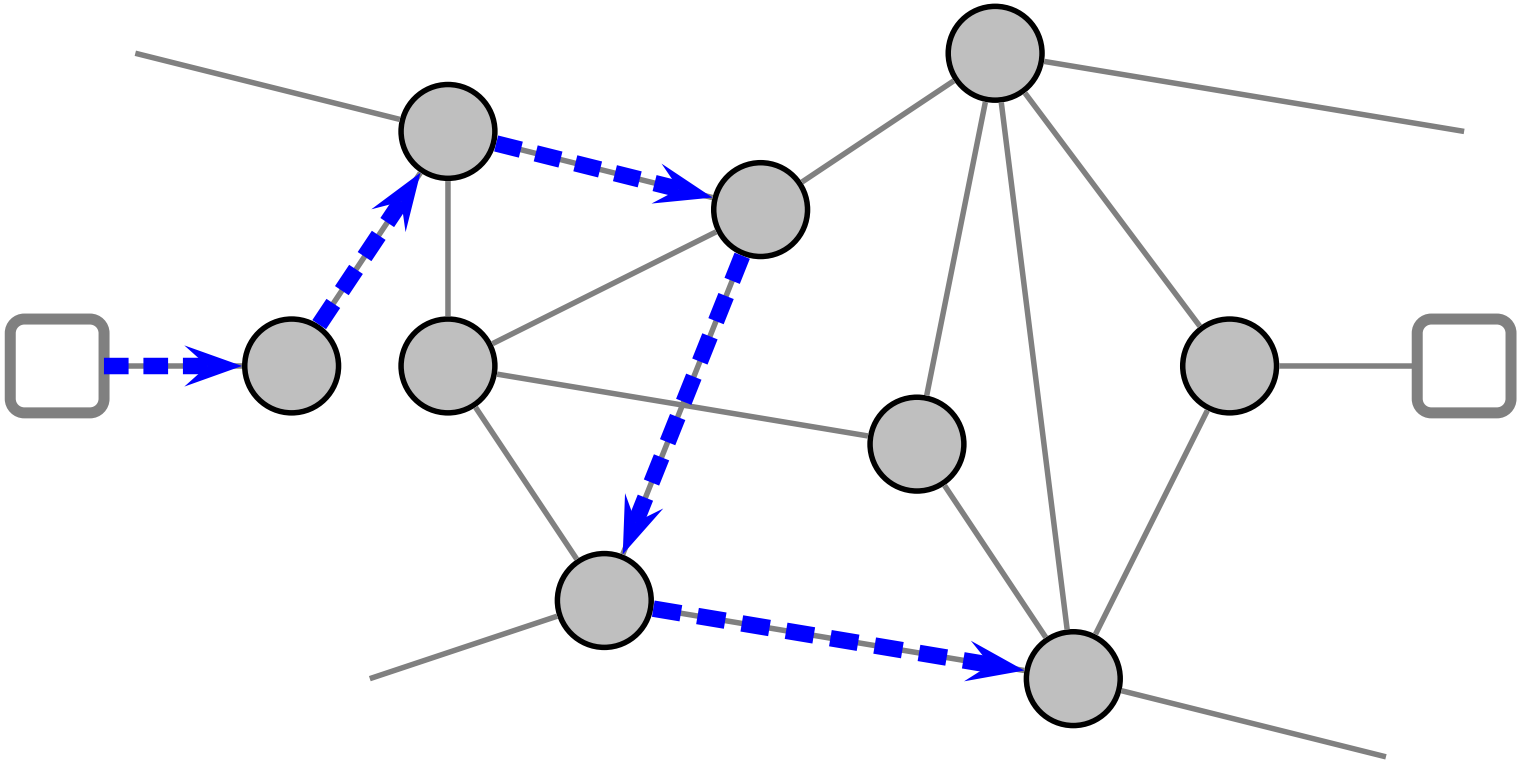

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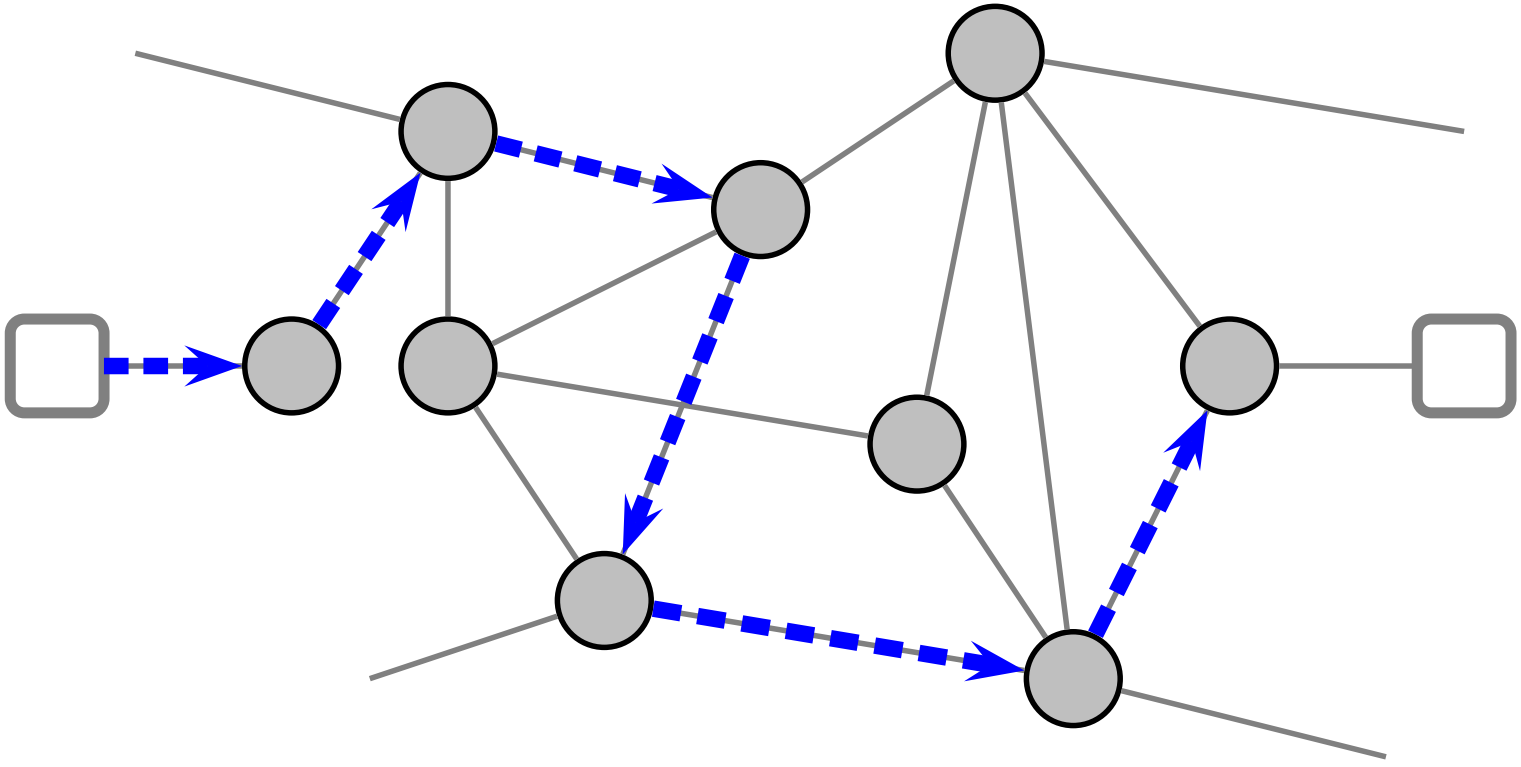

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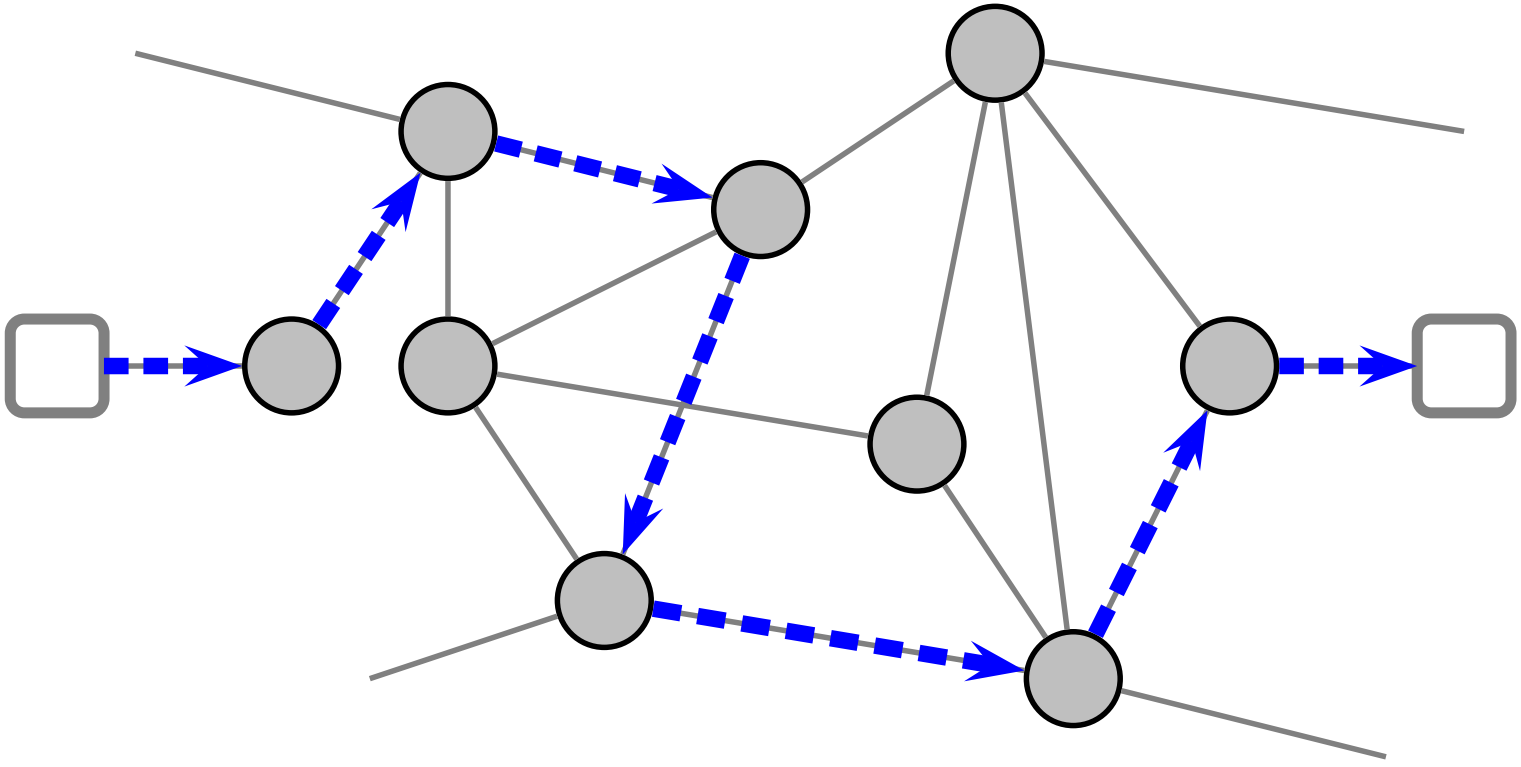

- Potentially *multiple paths* for the same source/destination

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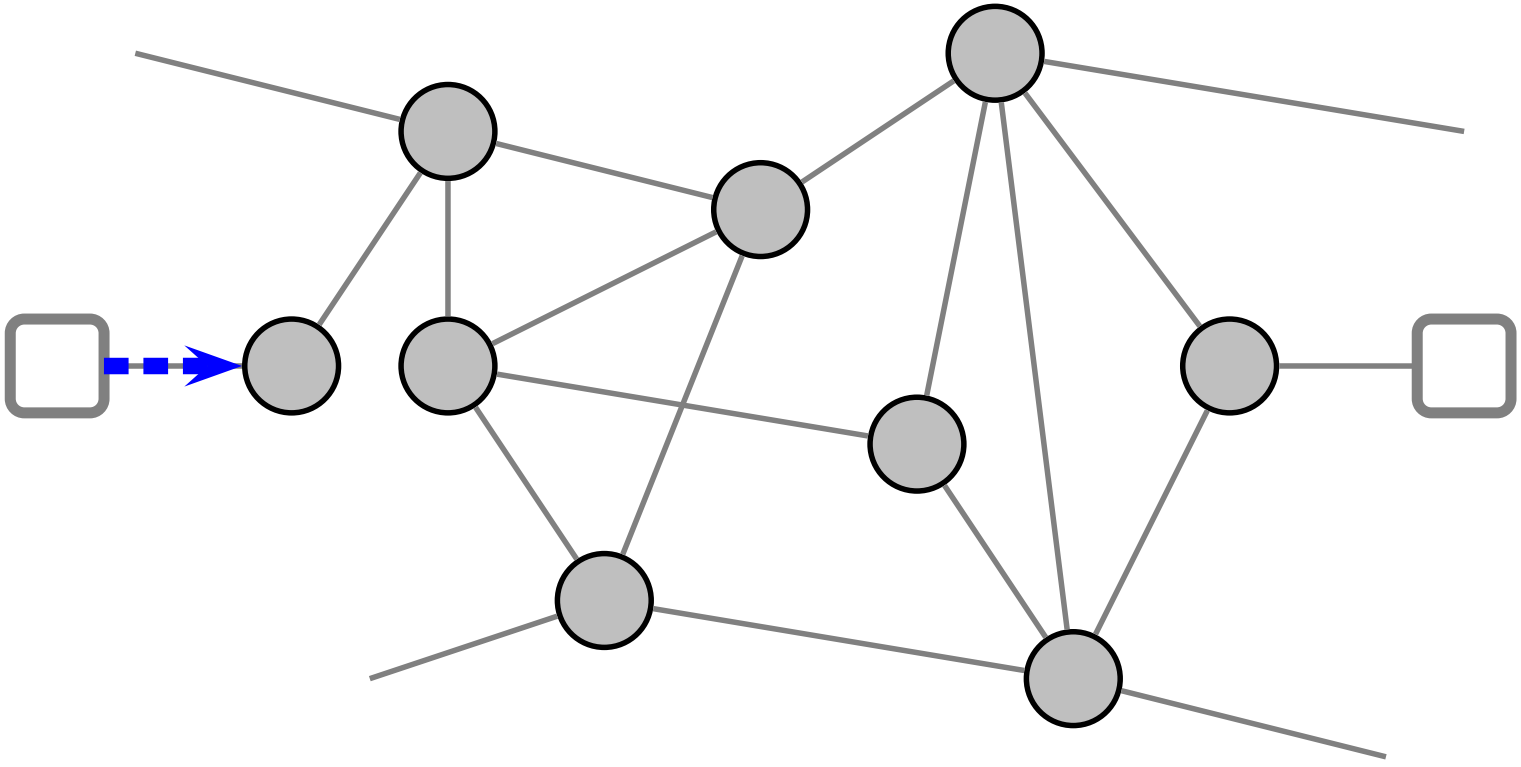

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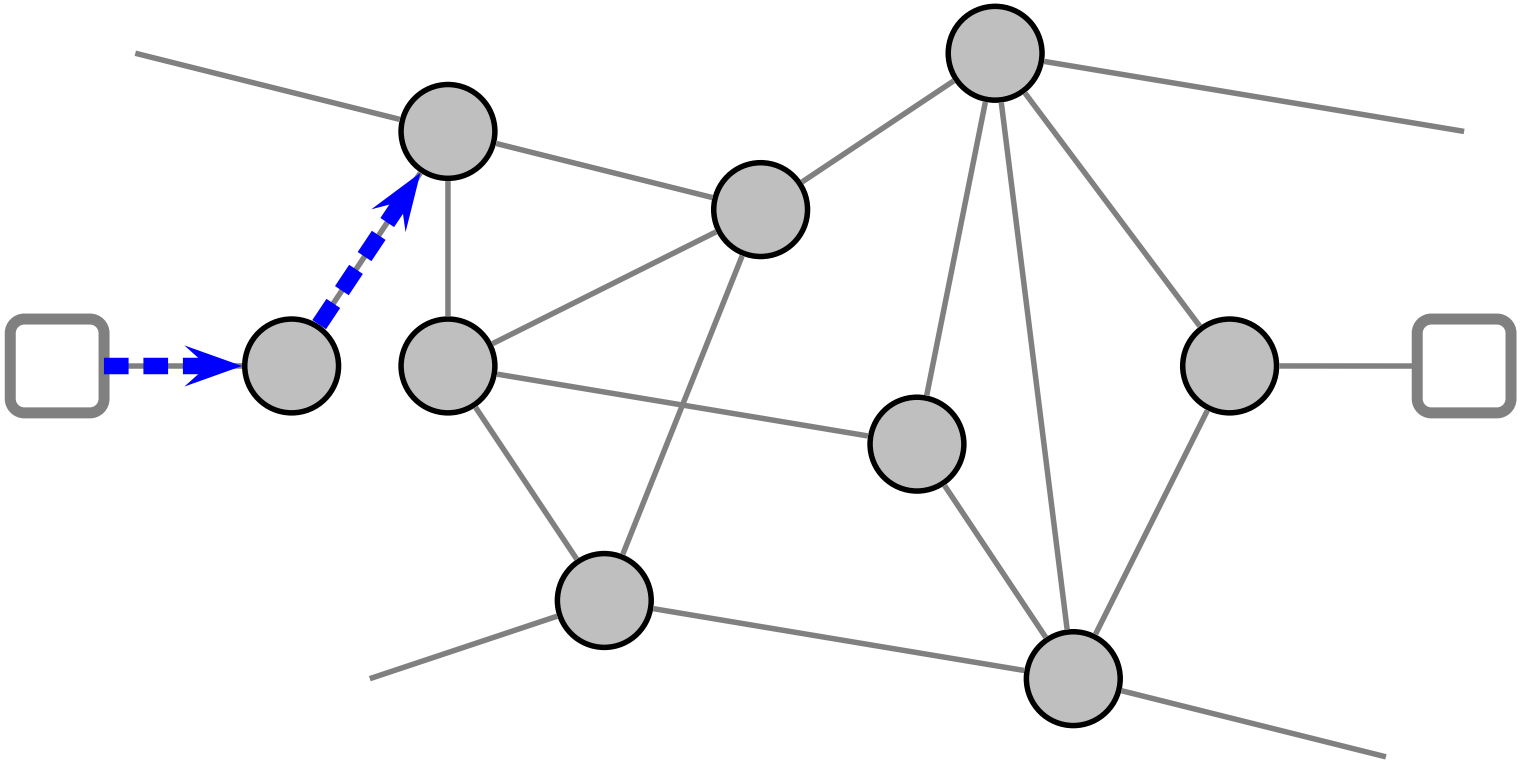

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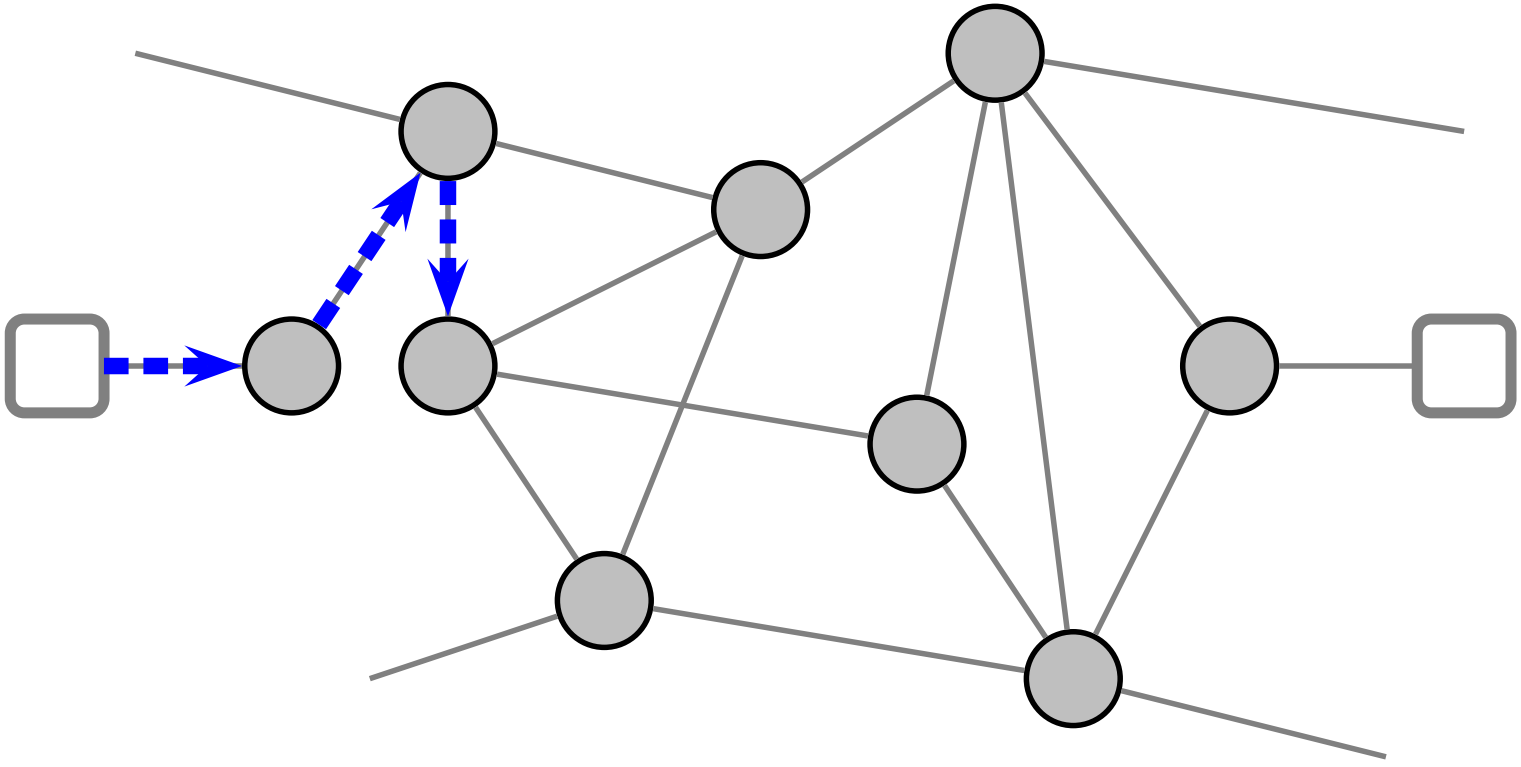

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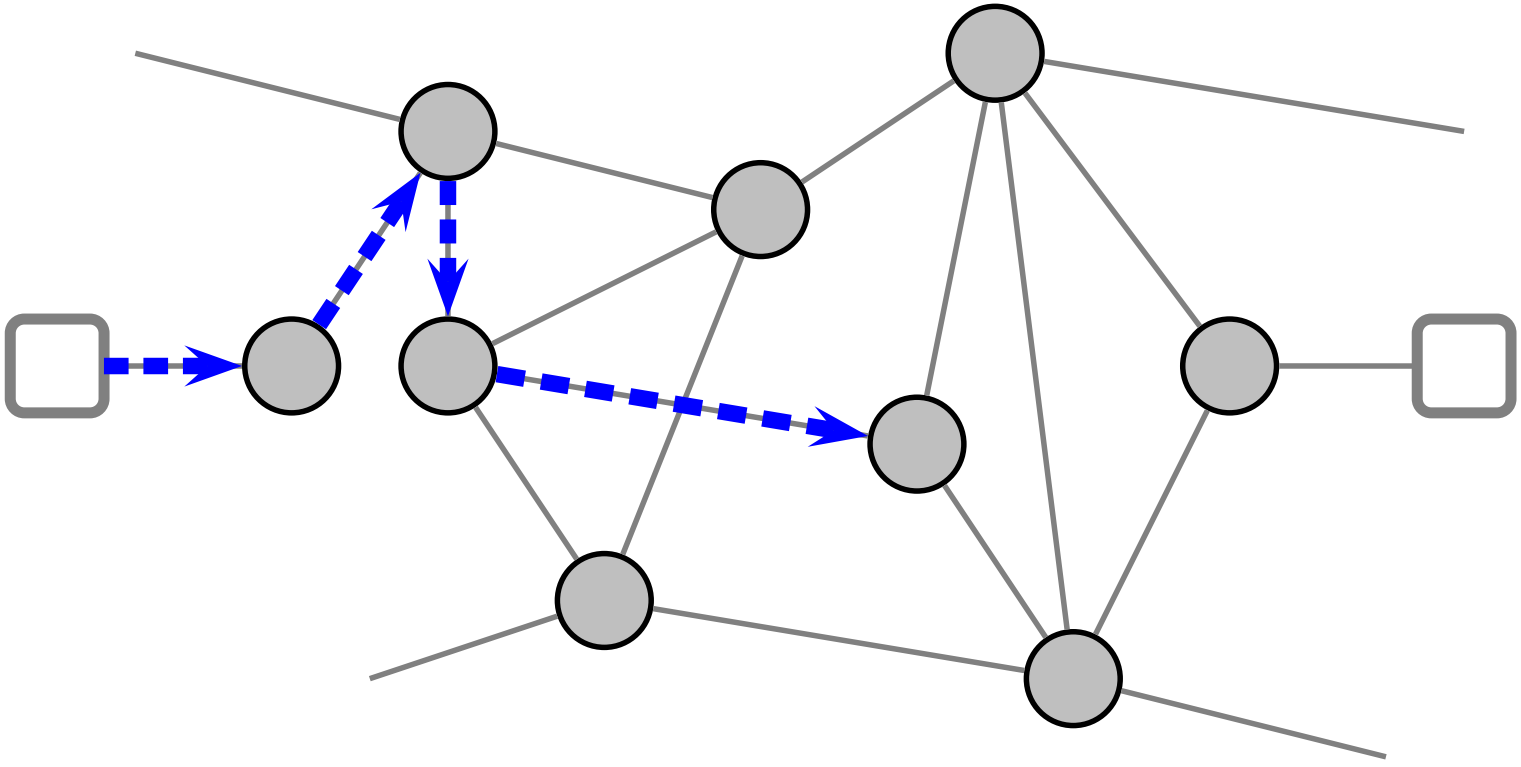

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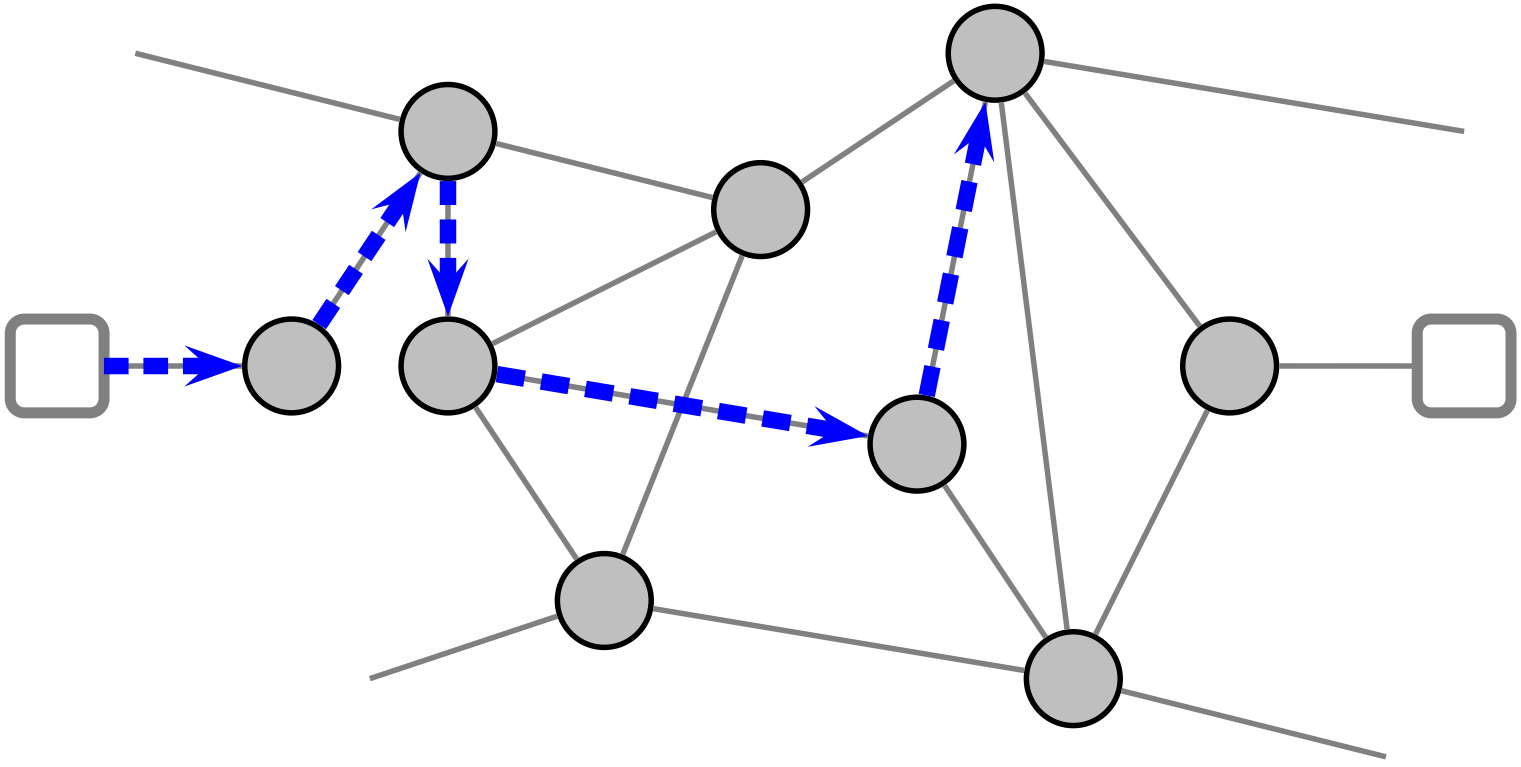

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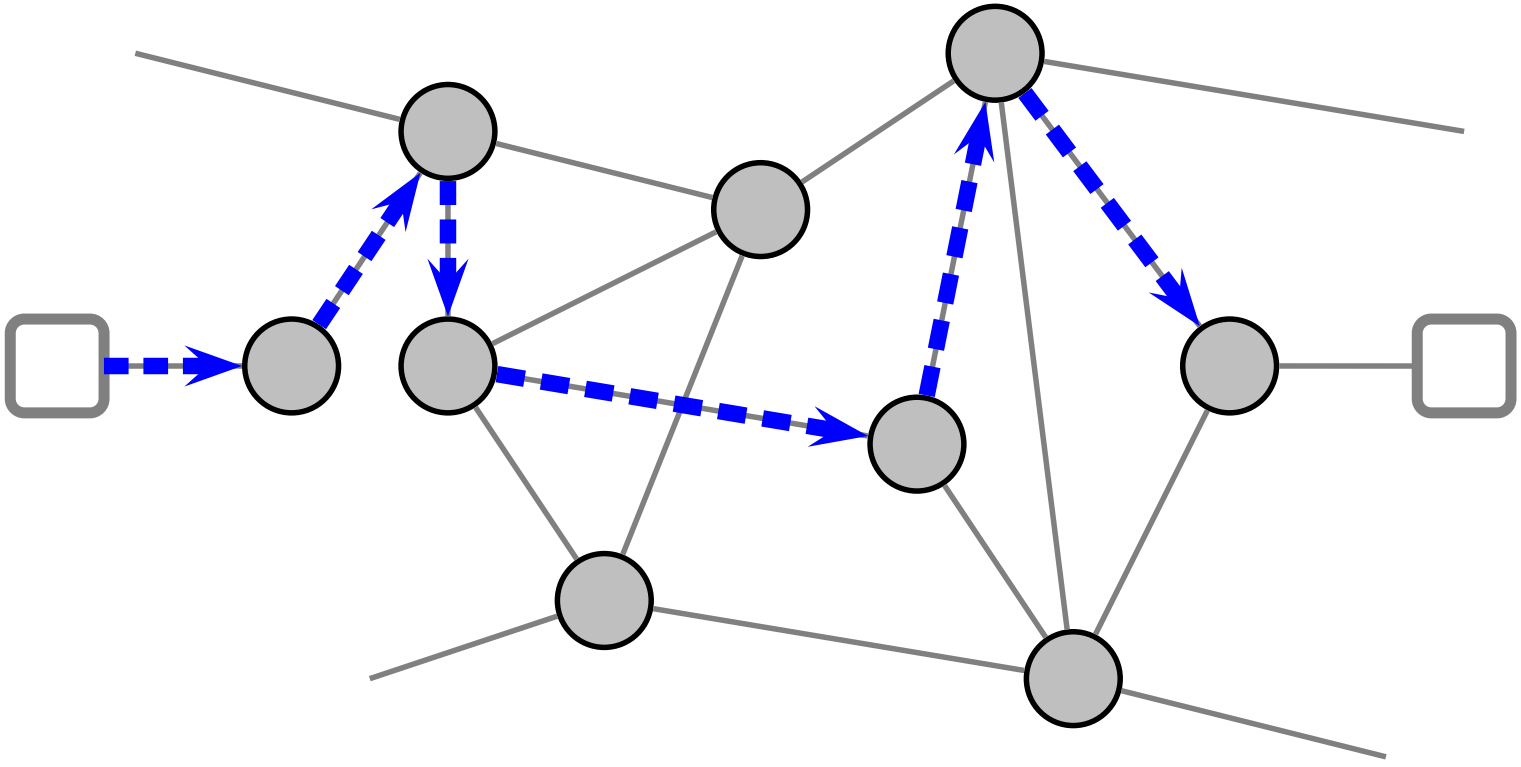

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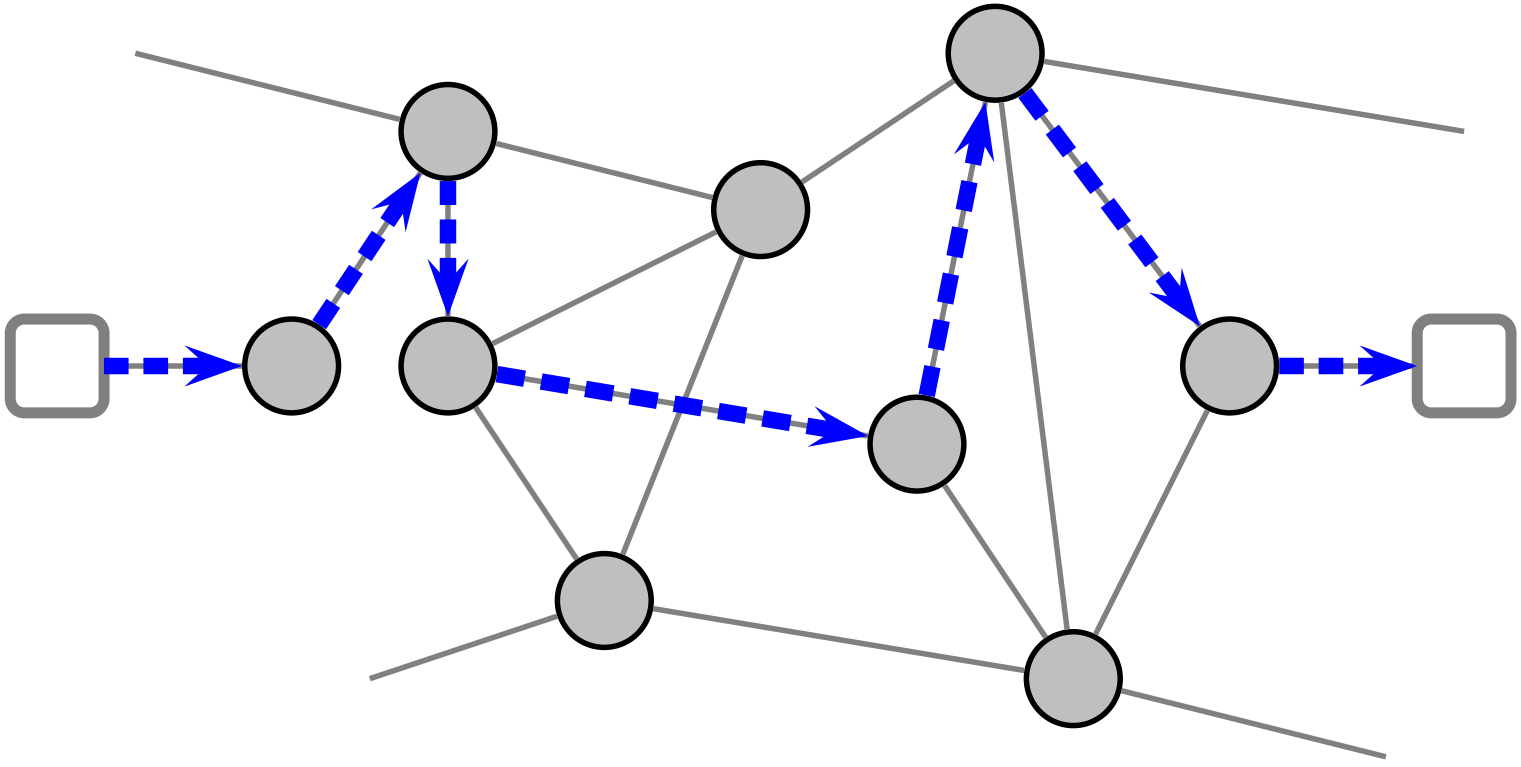

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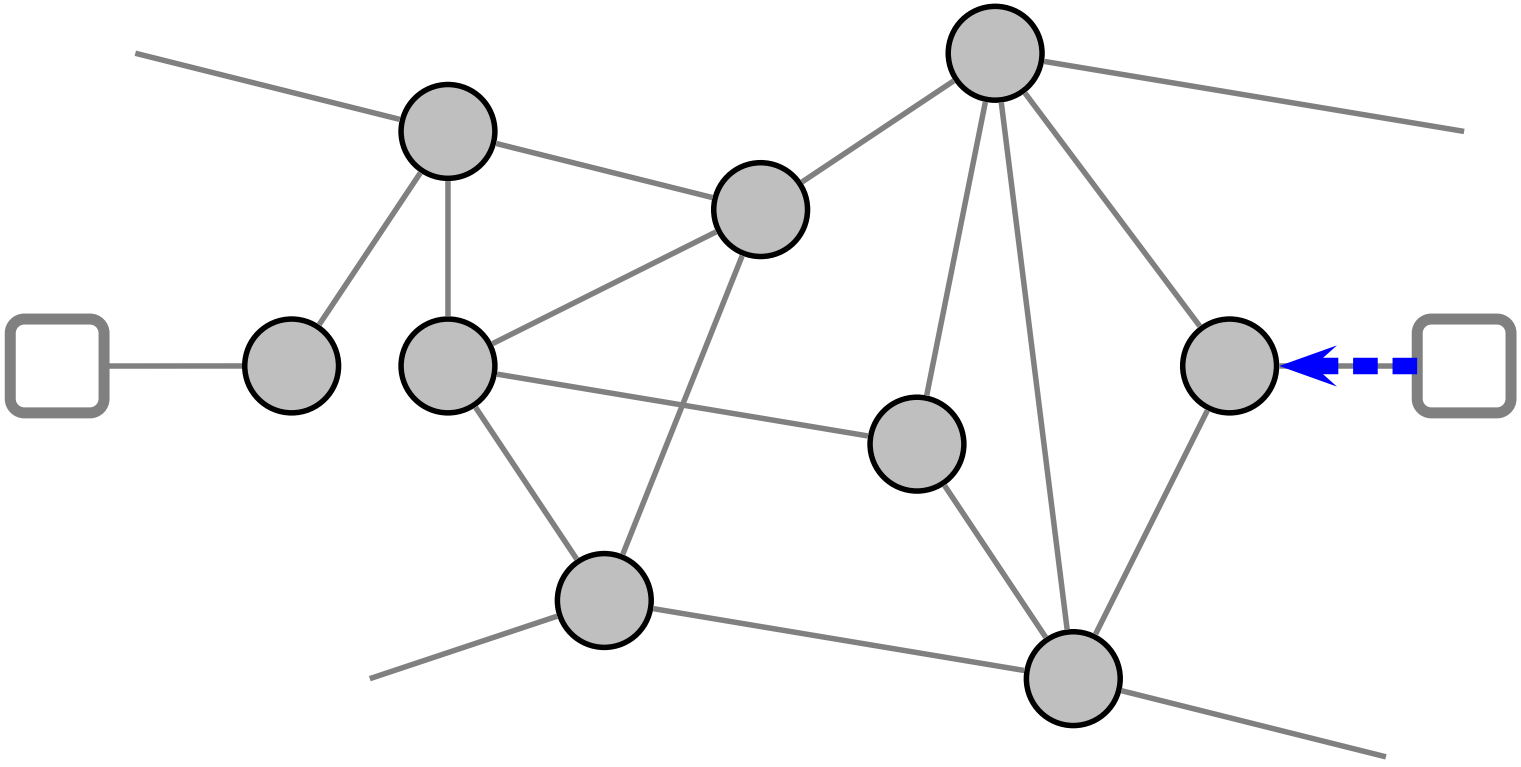

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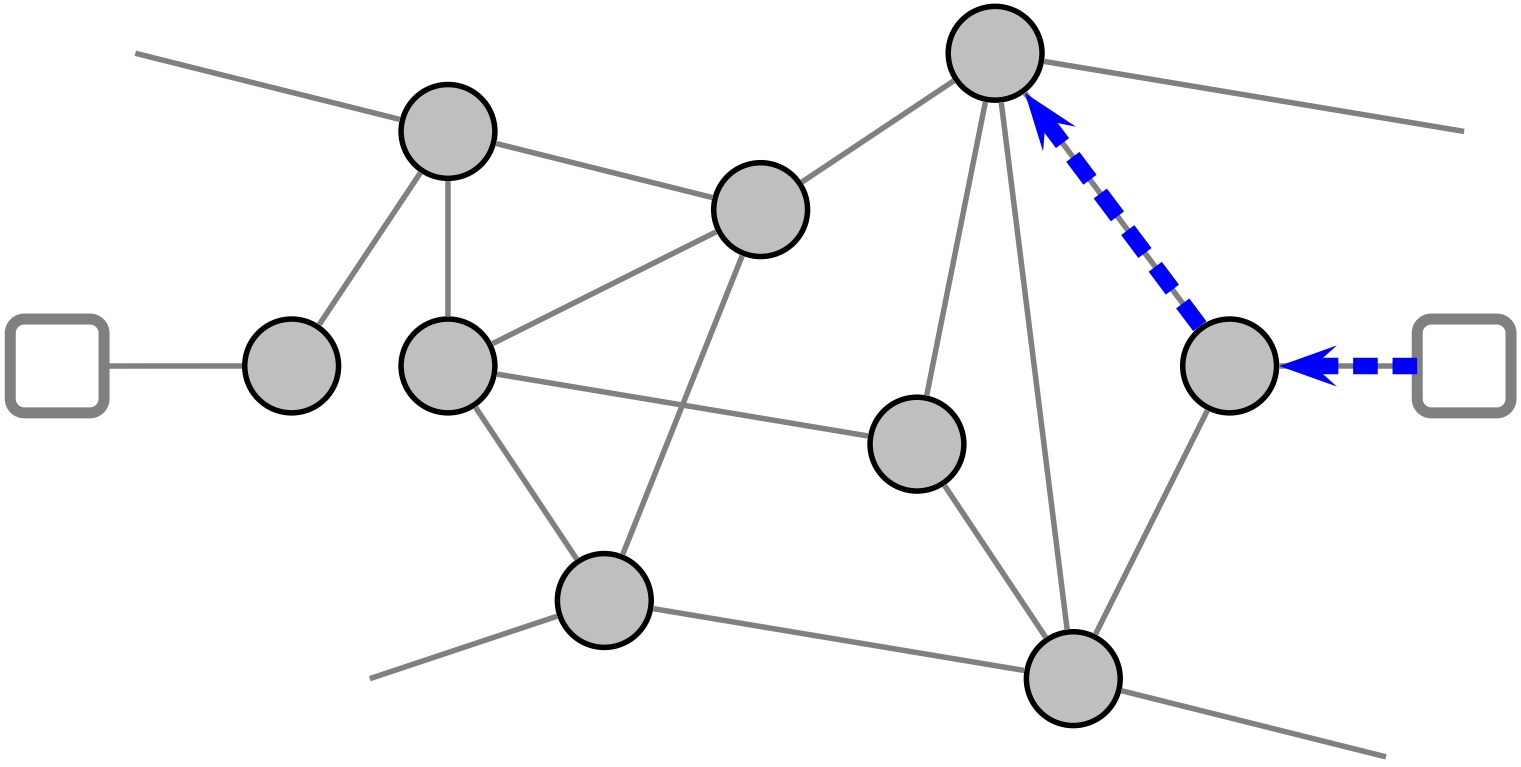

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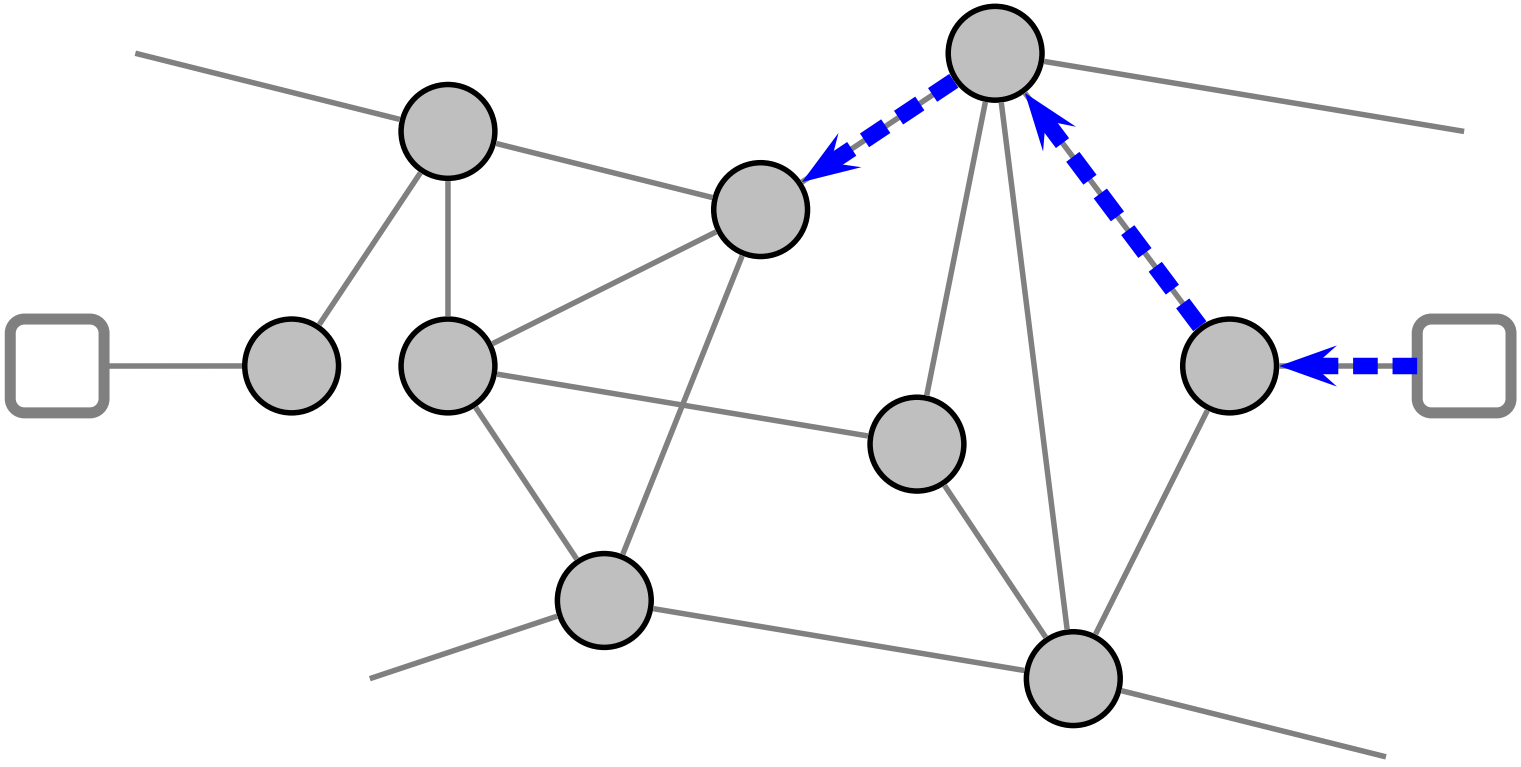

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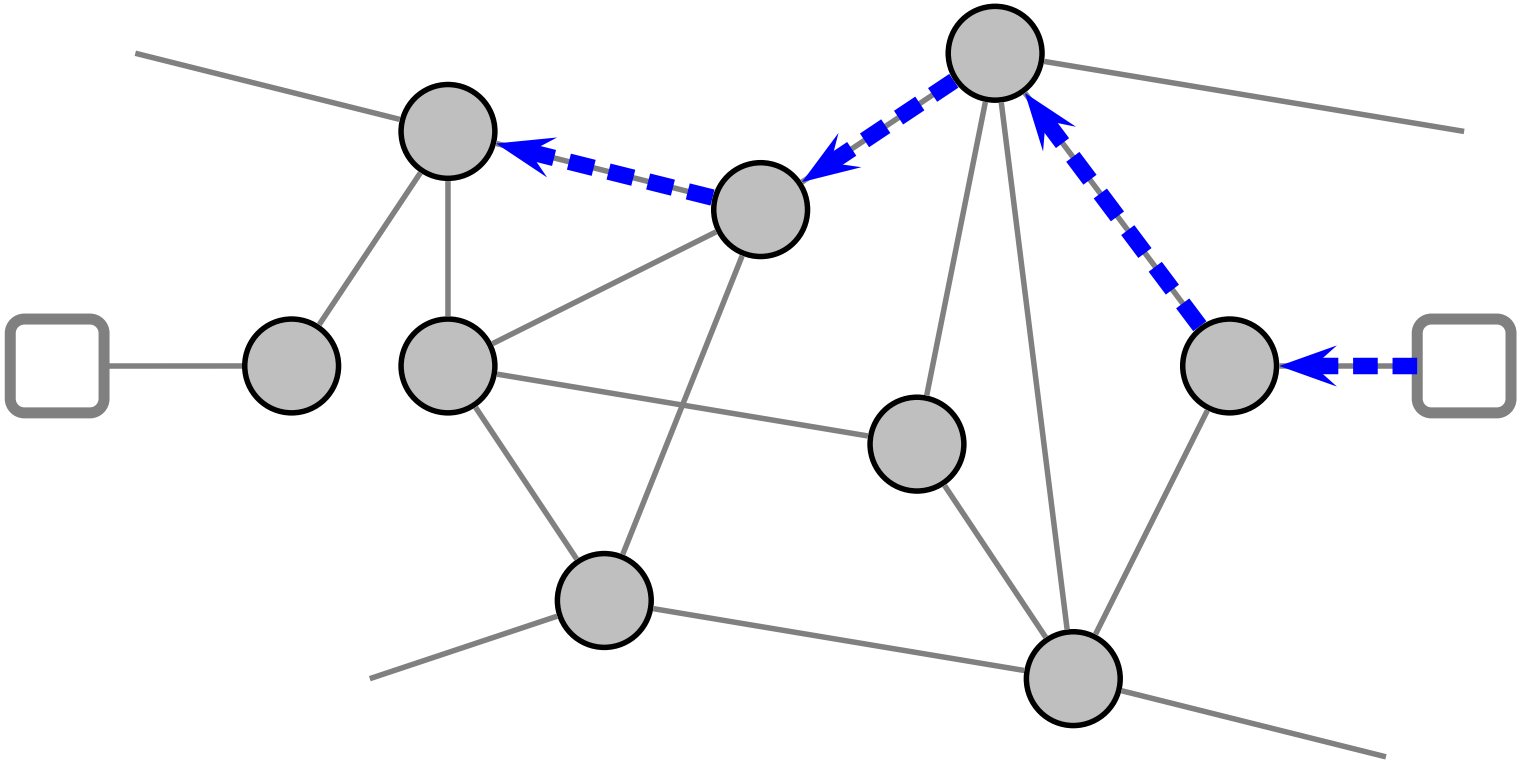

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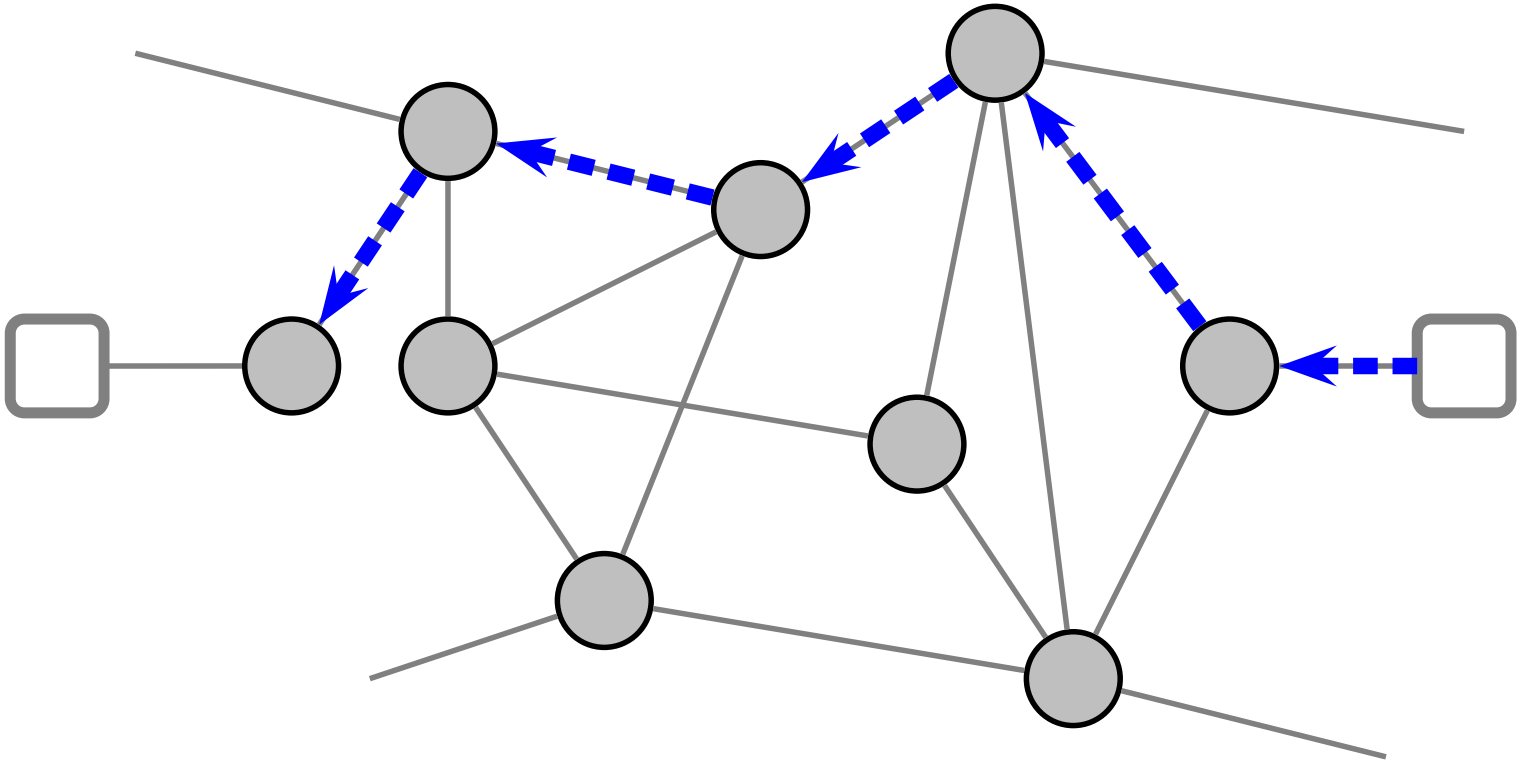

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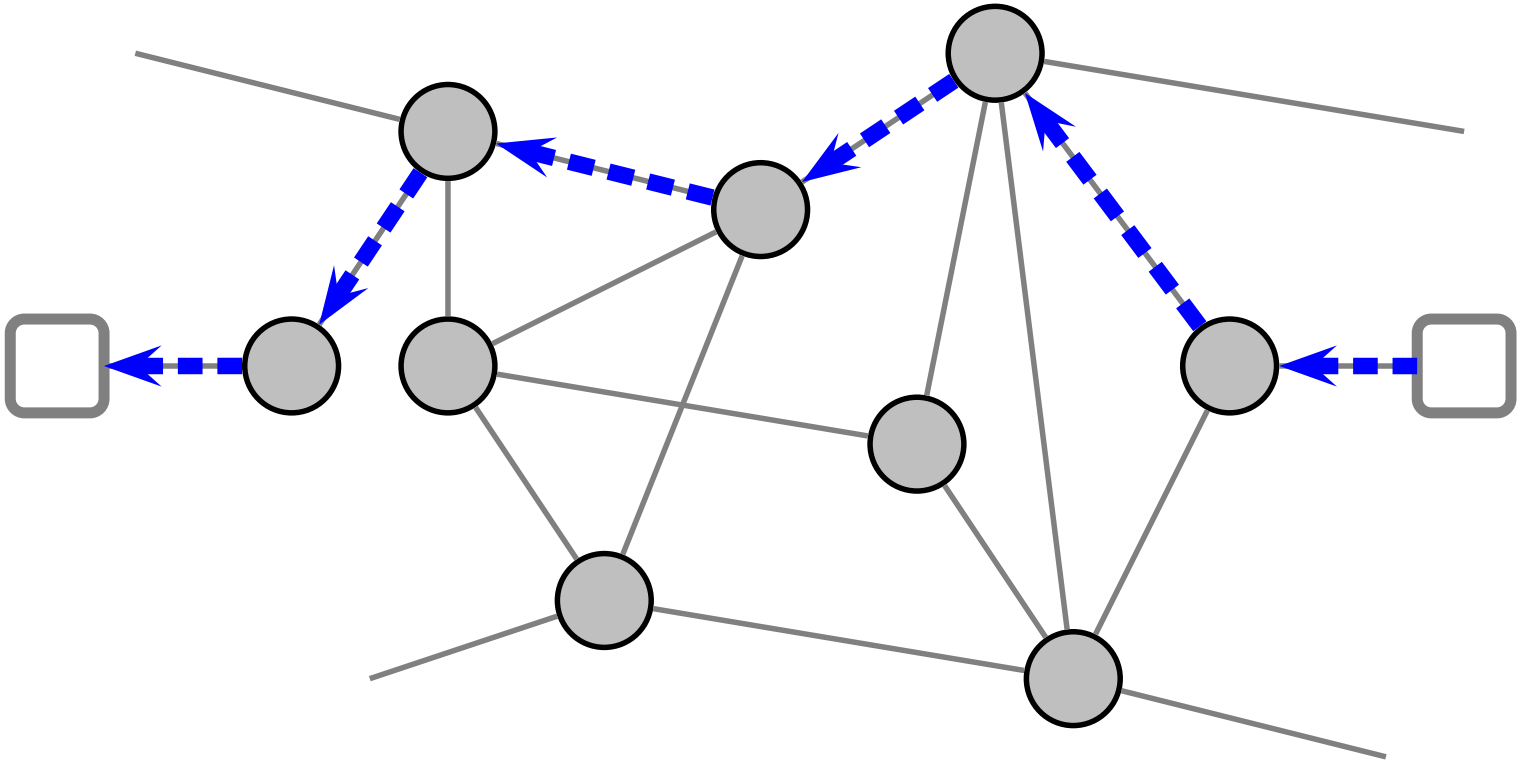

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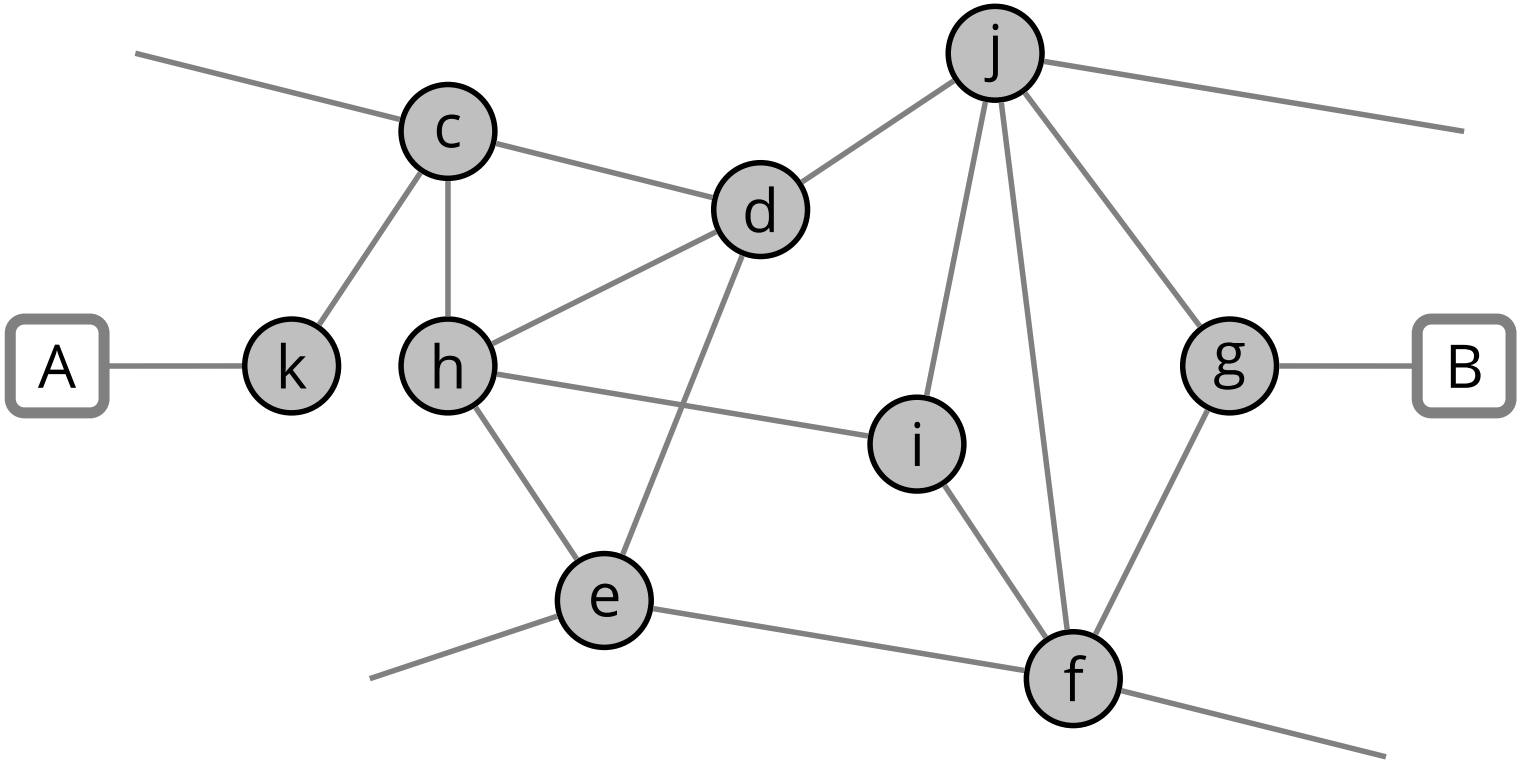

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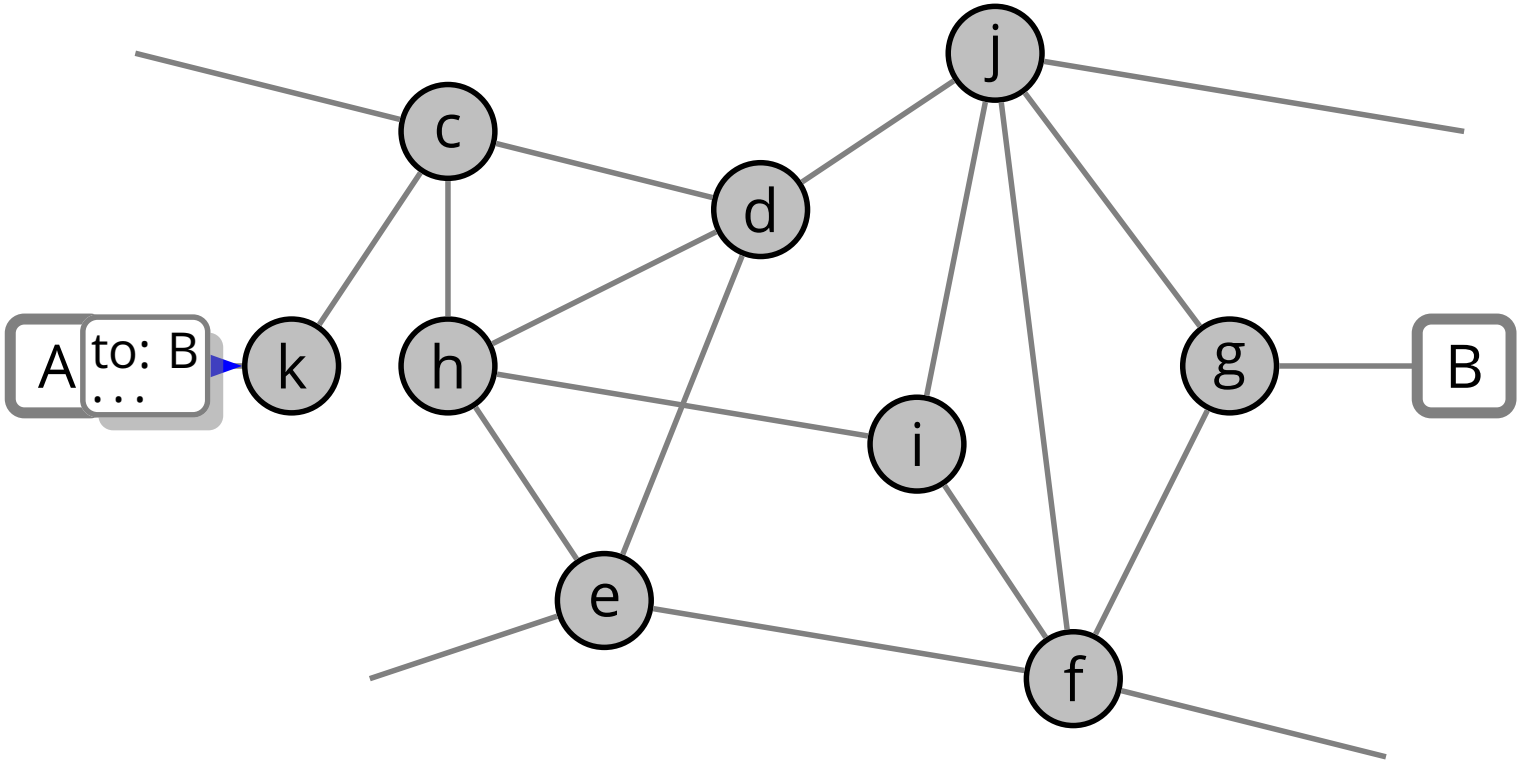

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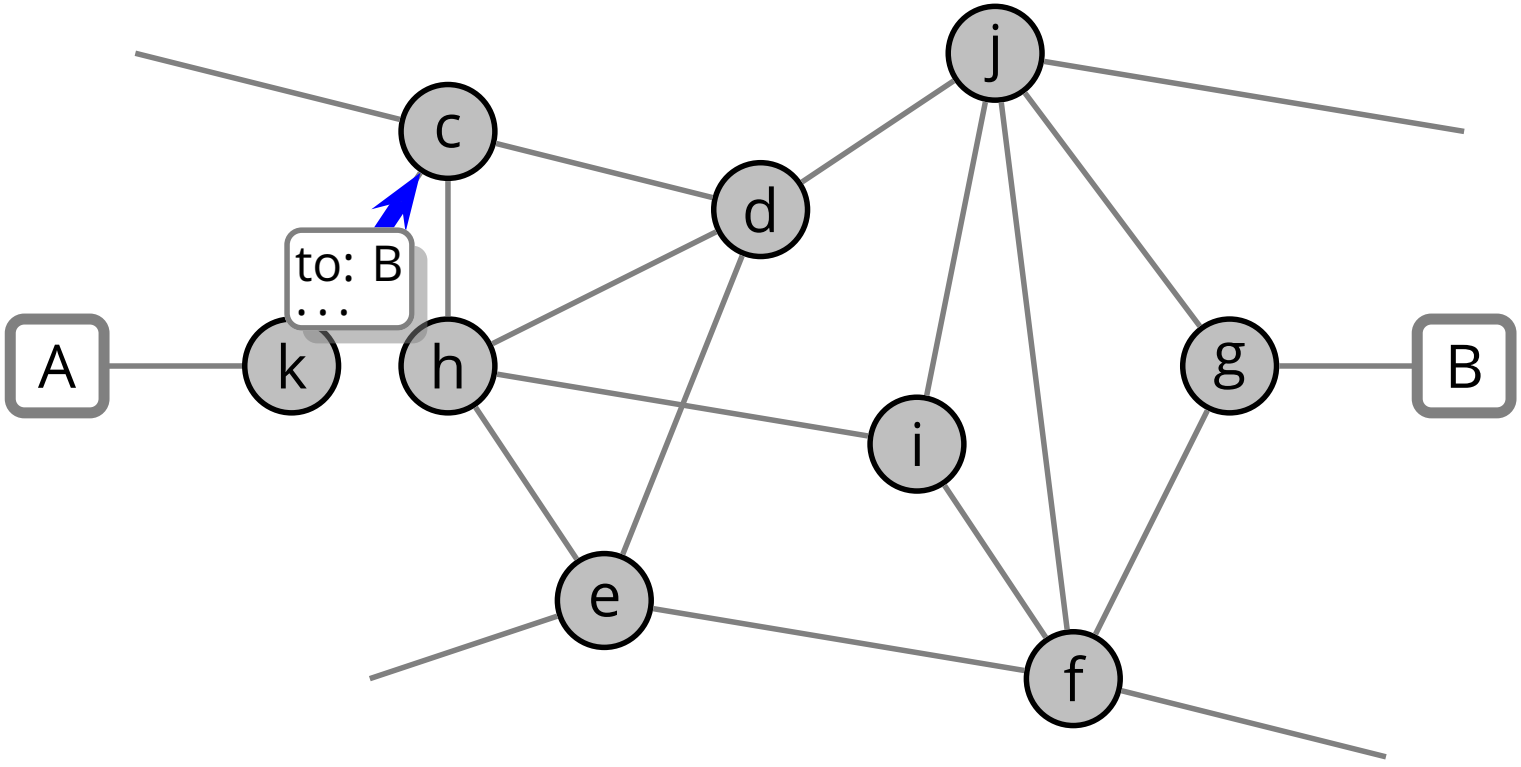

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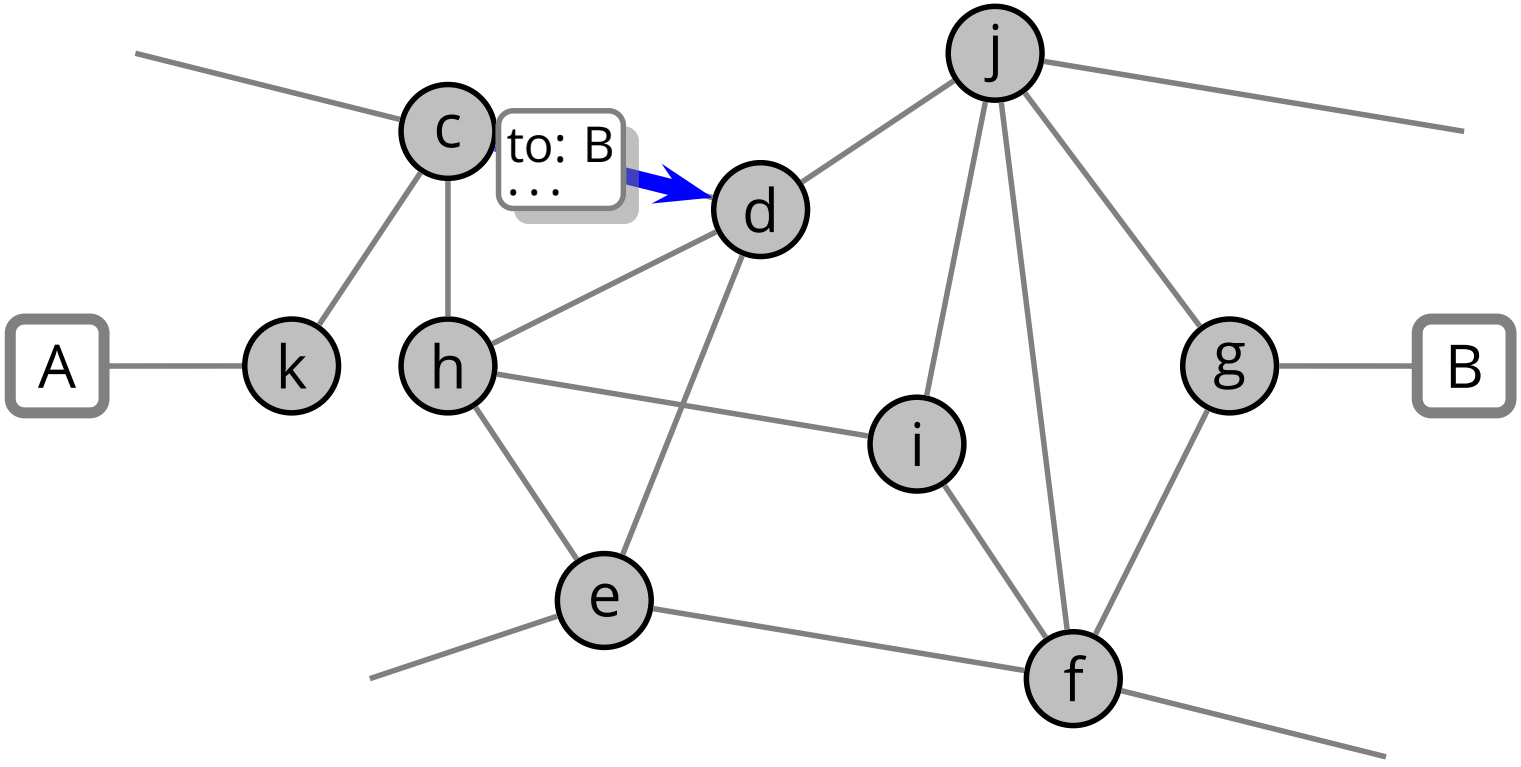

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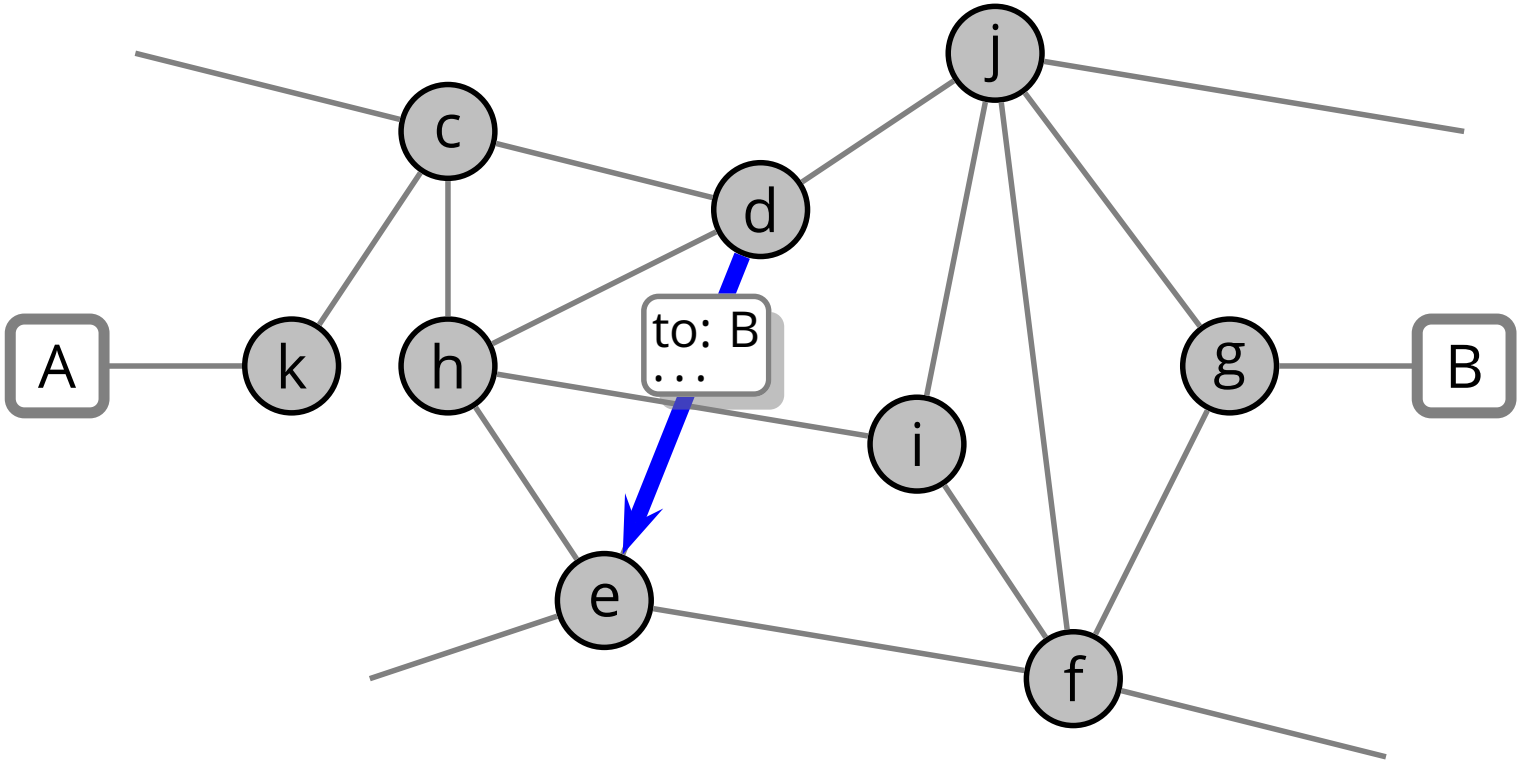

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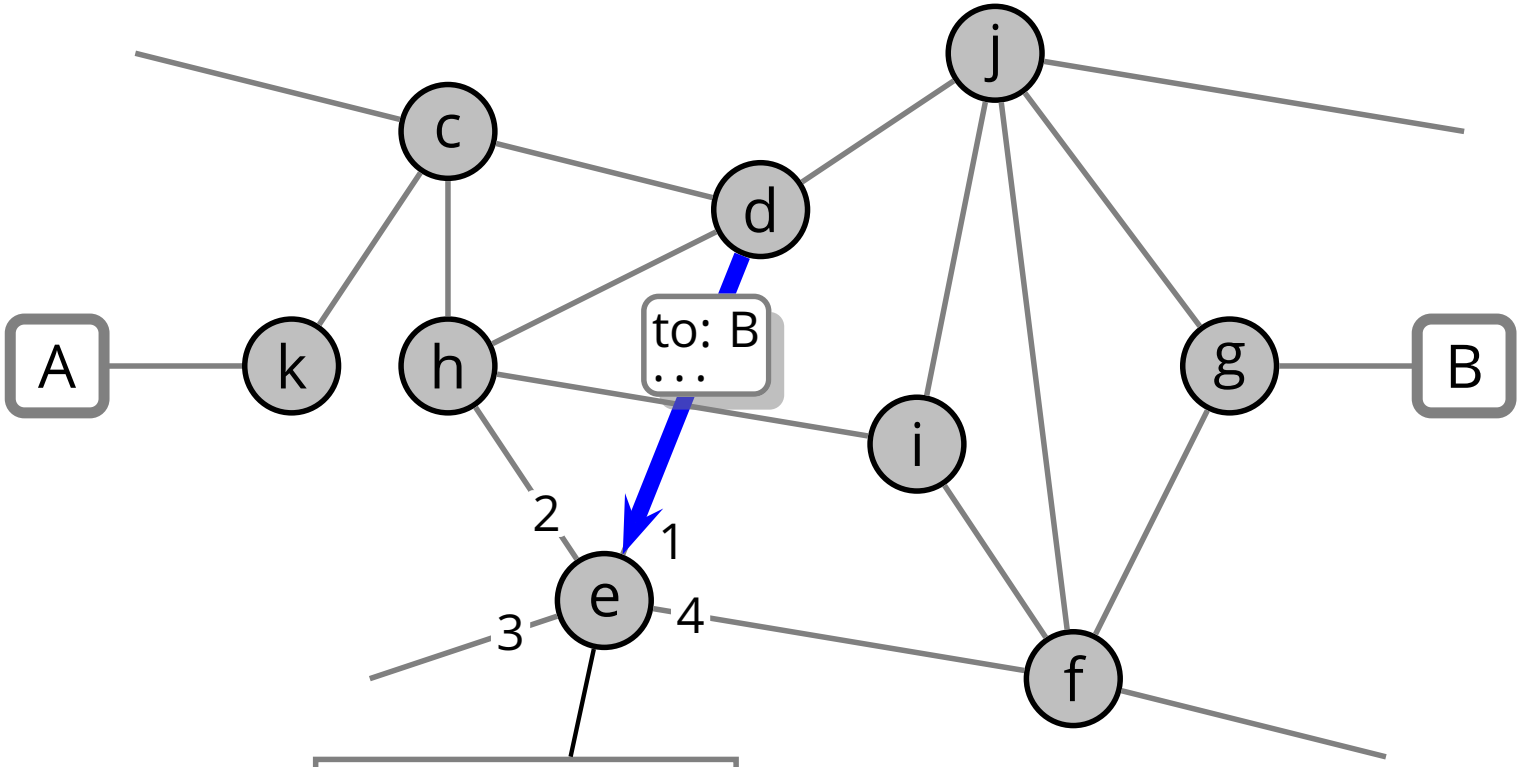

forwarding table

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

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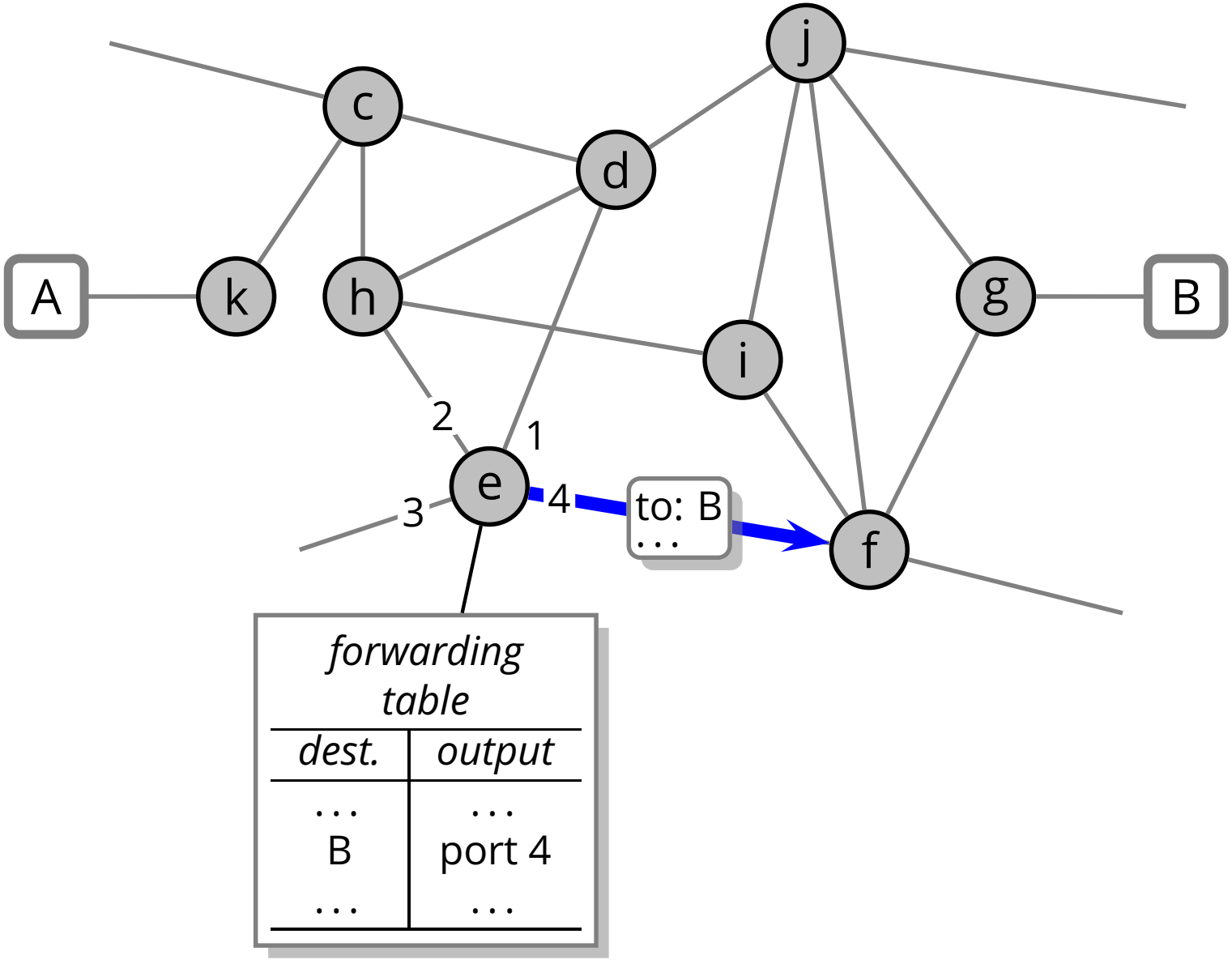

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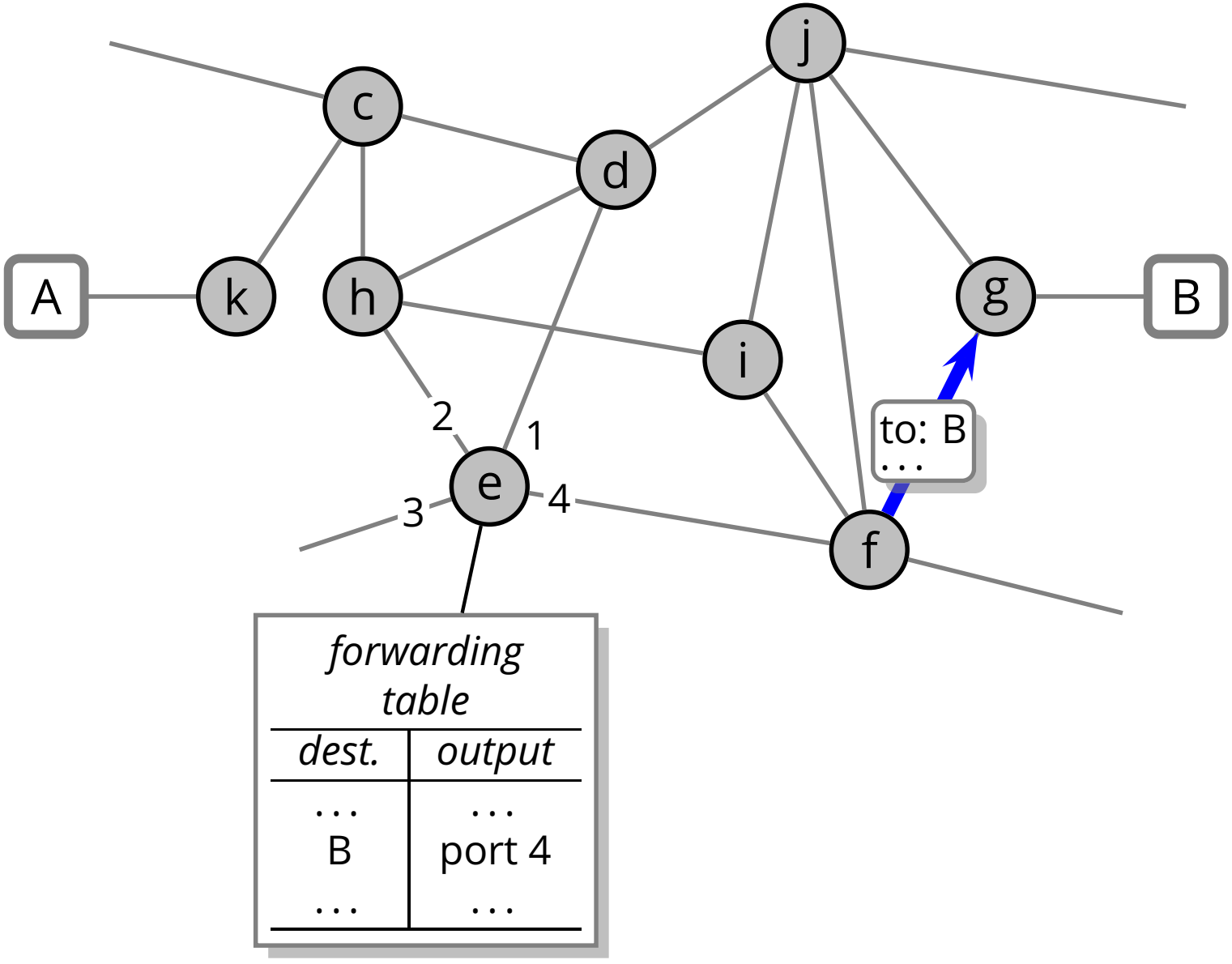

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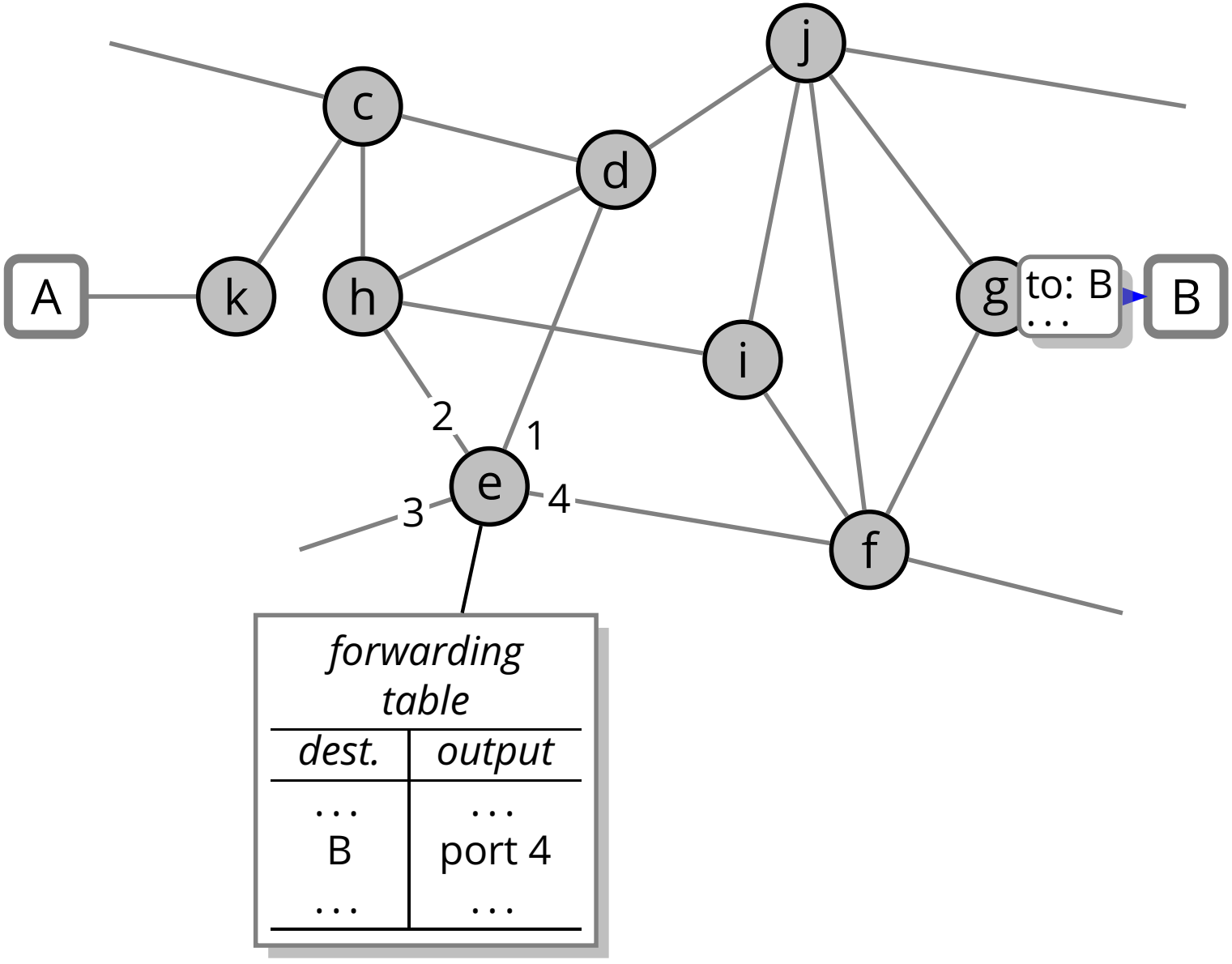

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  - how does the router build and maintain the forwarding table?

Routing

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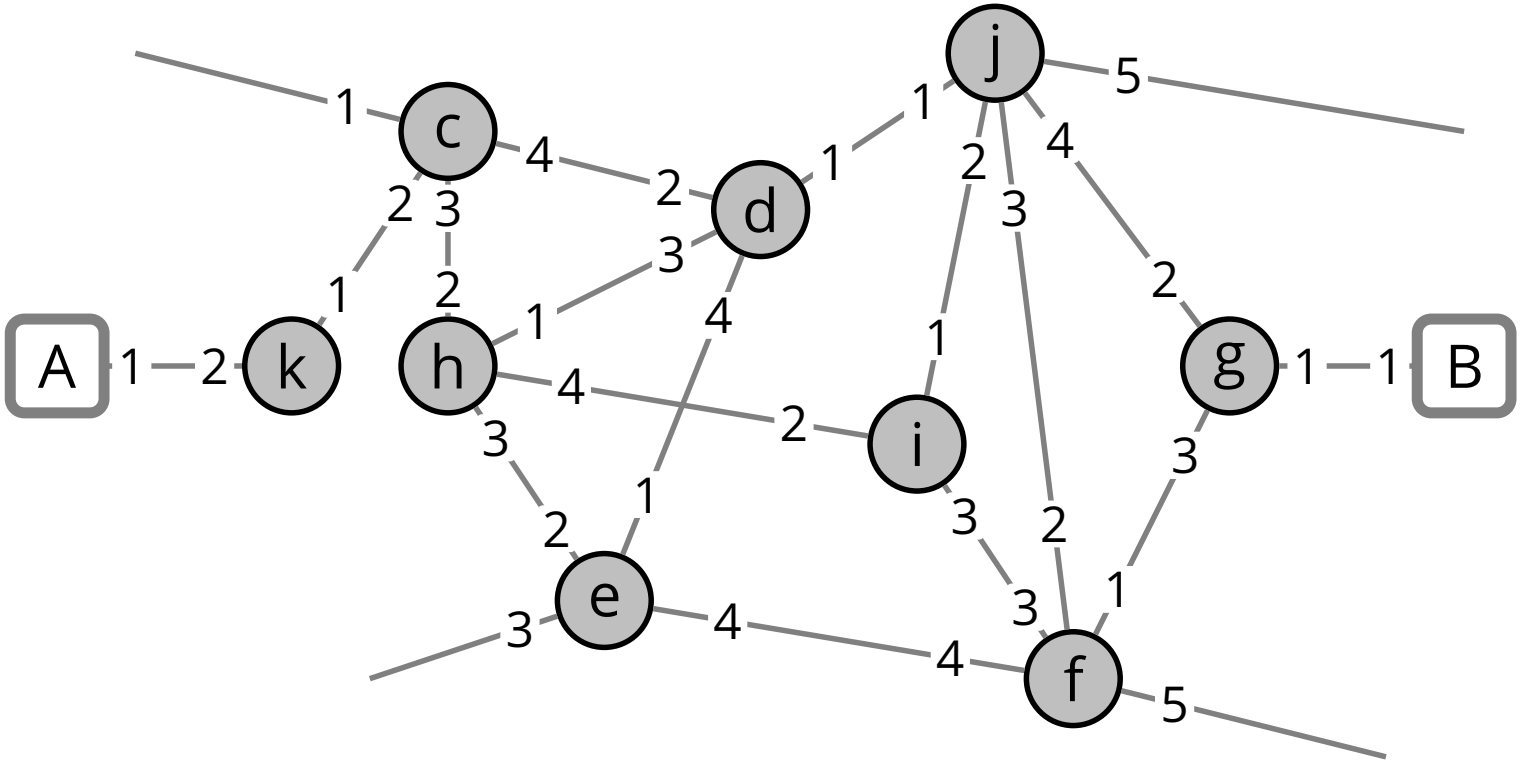

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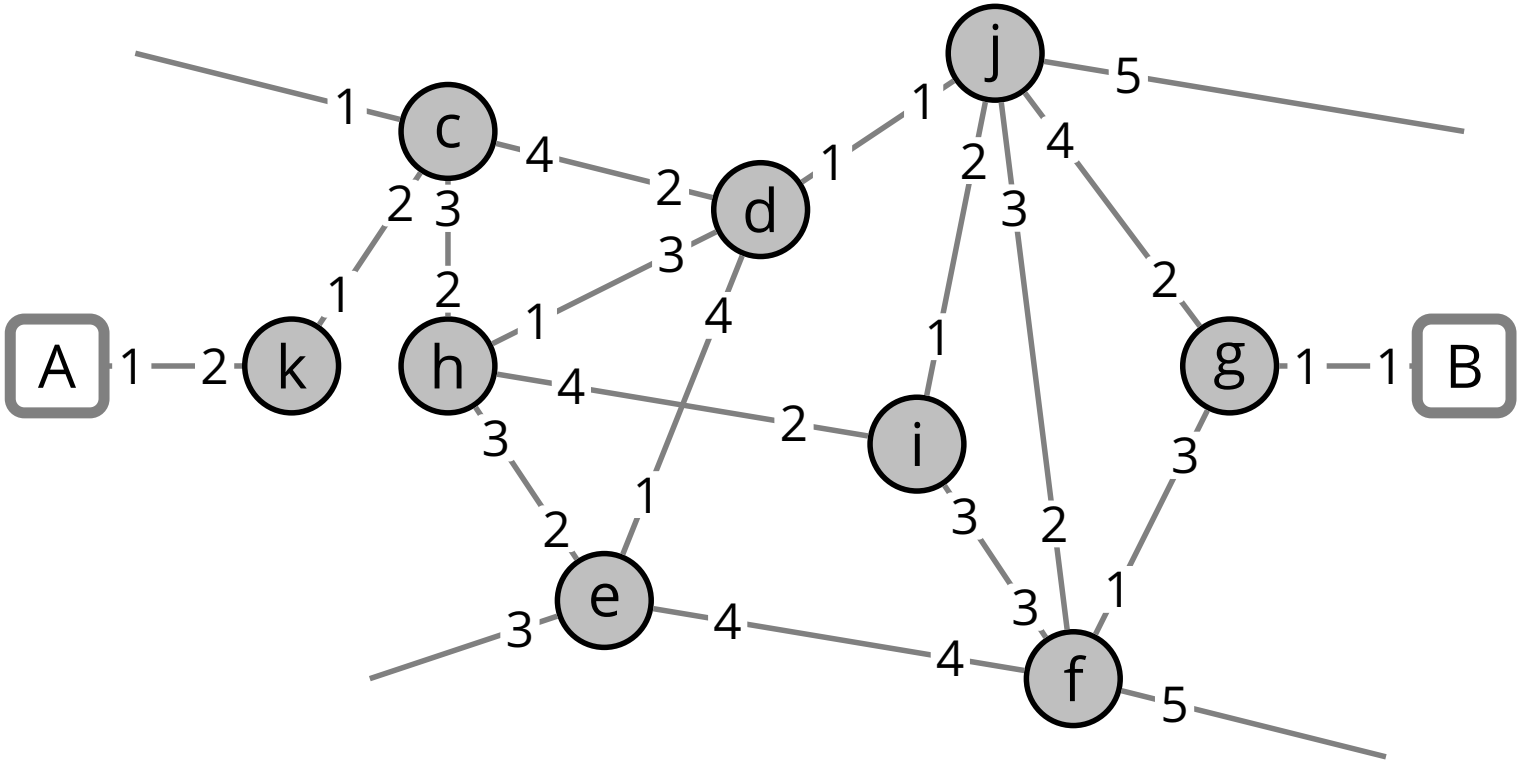

router k	
A	2
B	1

...

Router Functions

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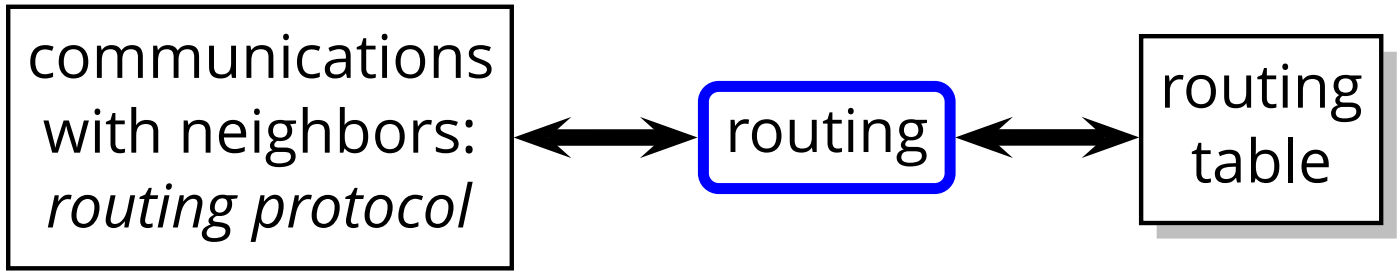

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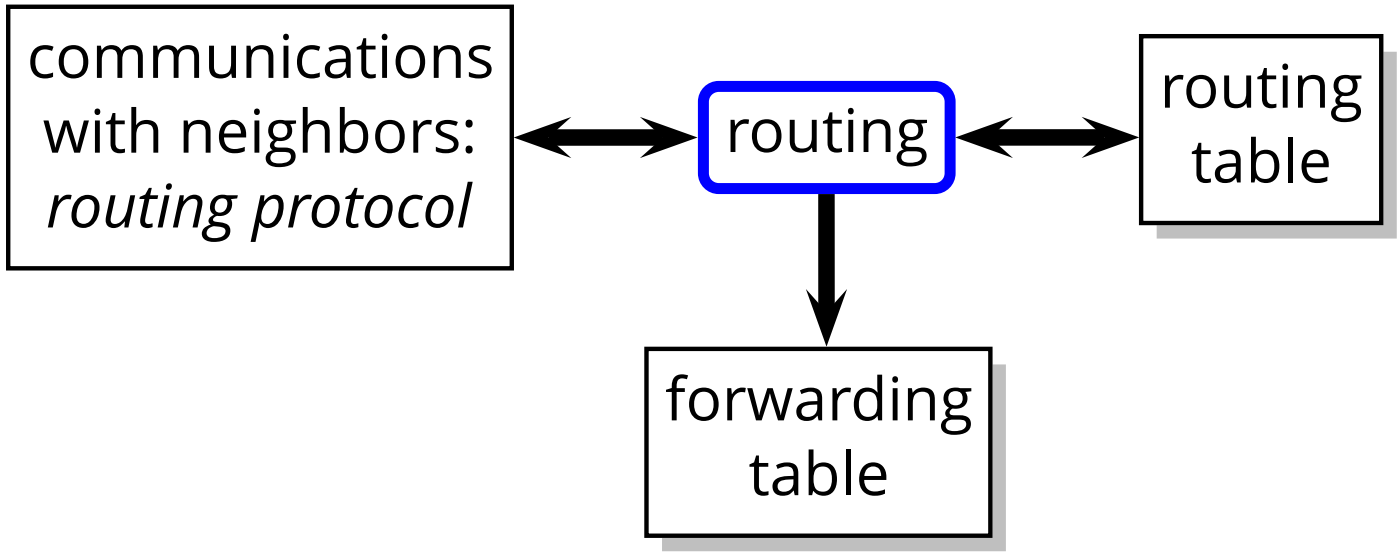

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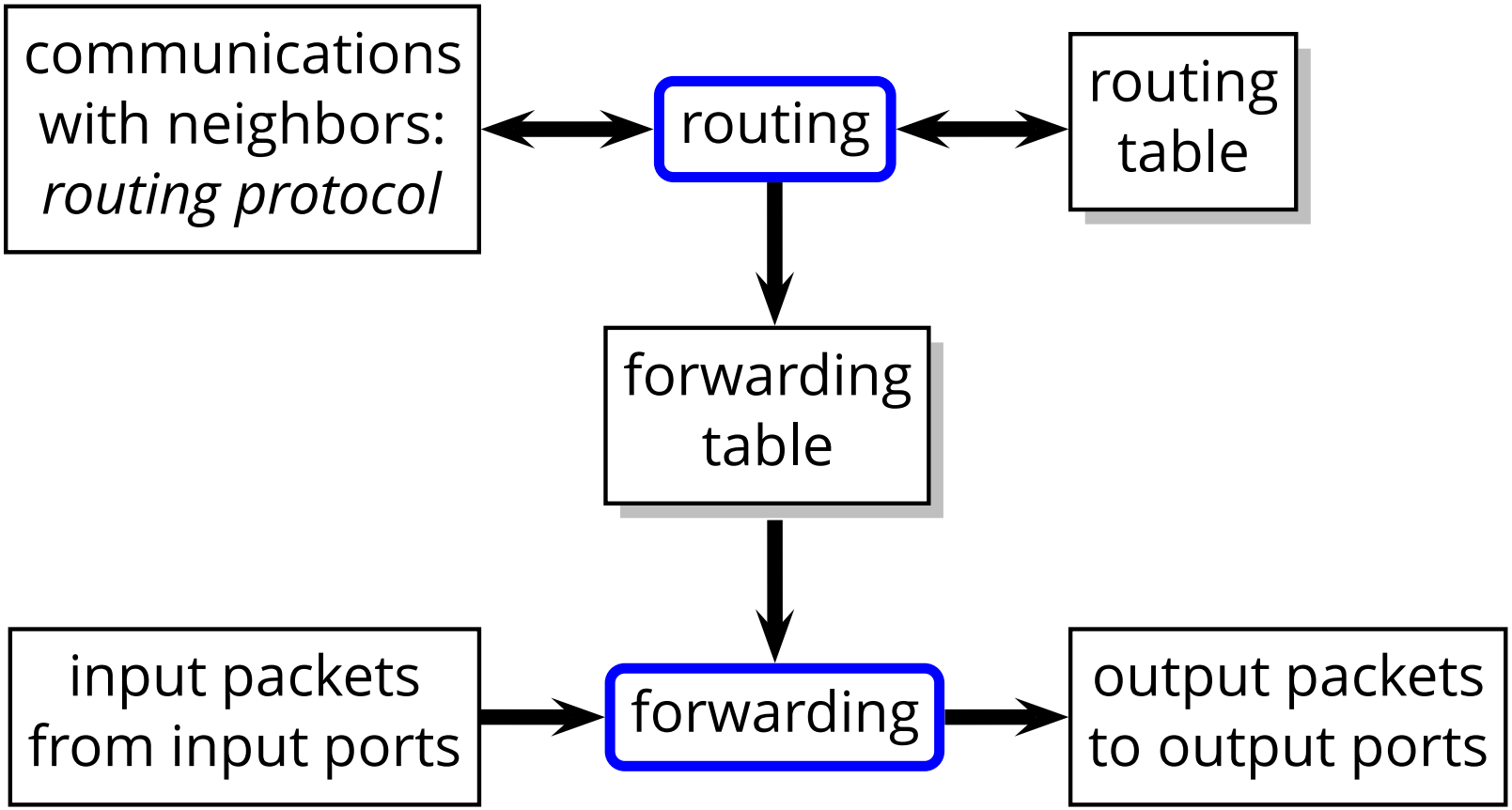

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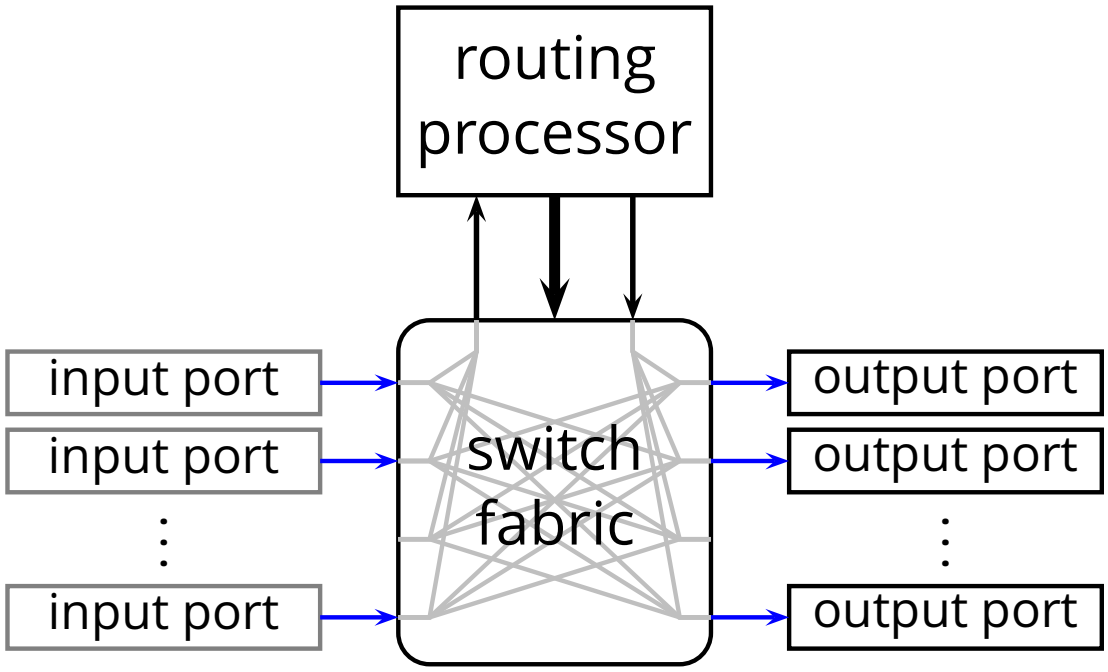

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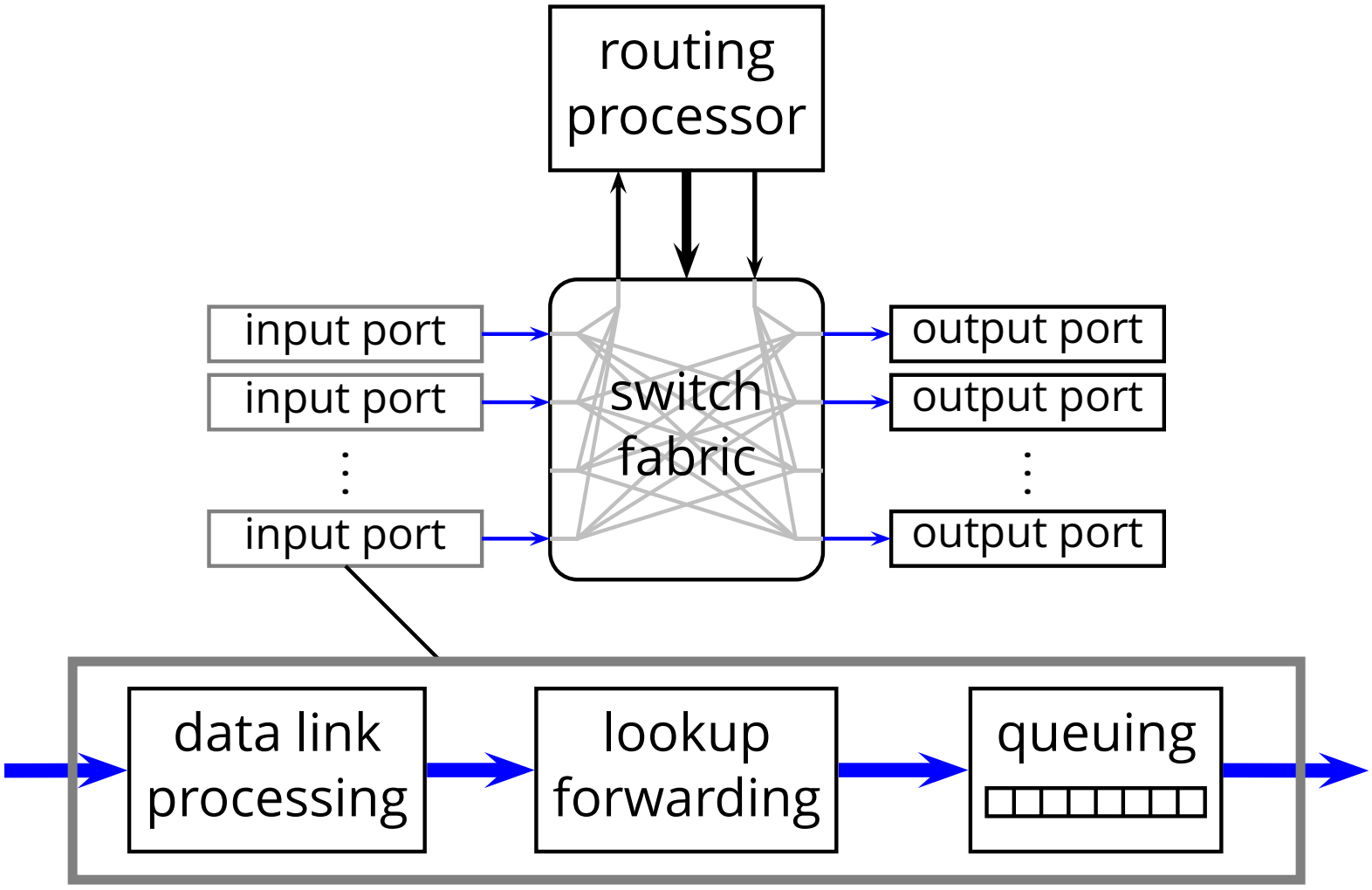

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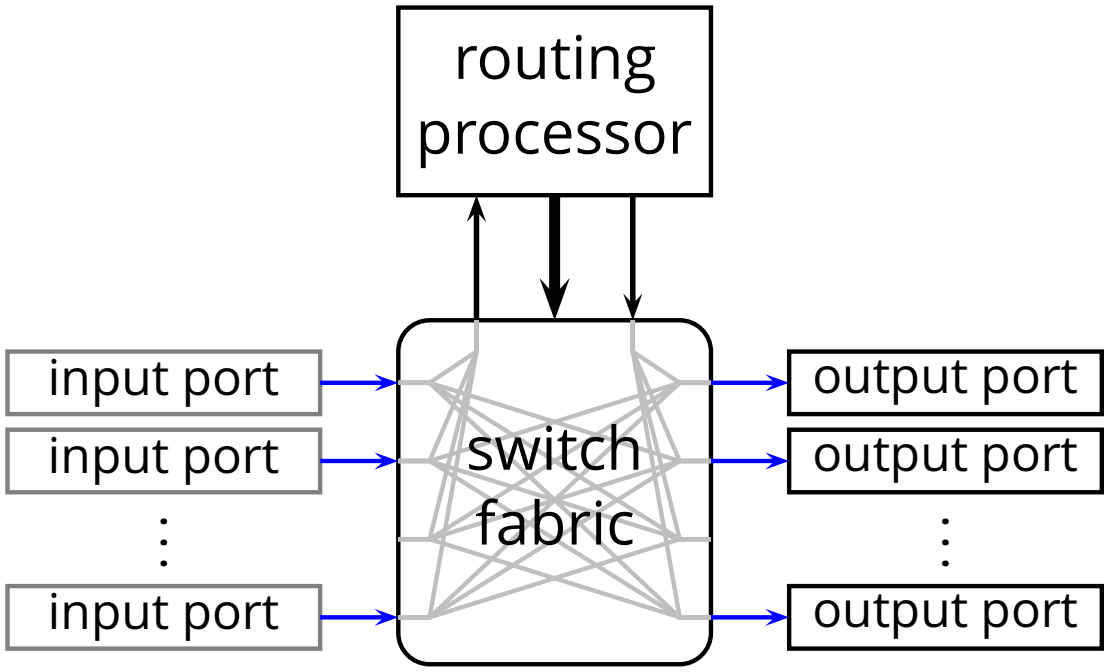

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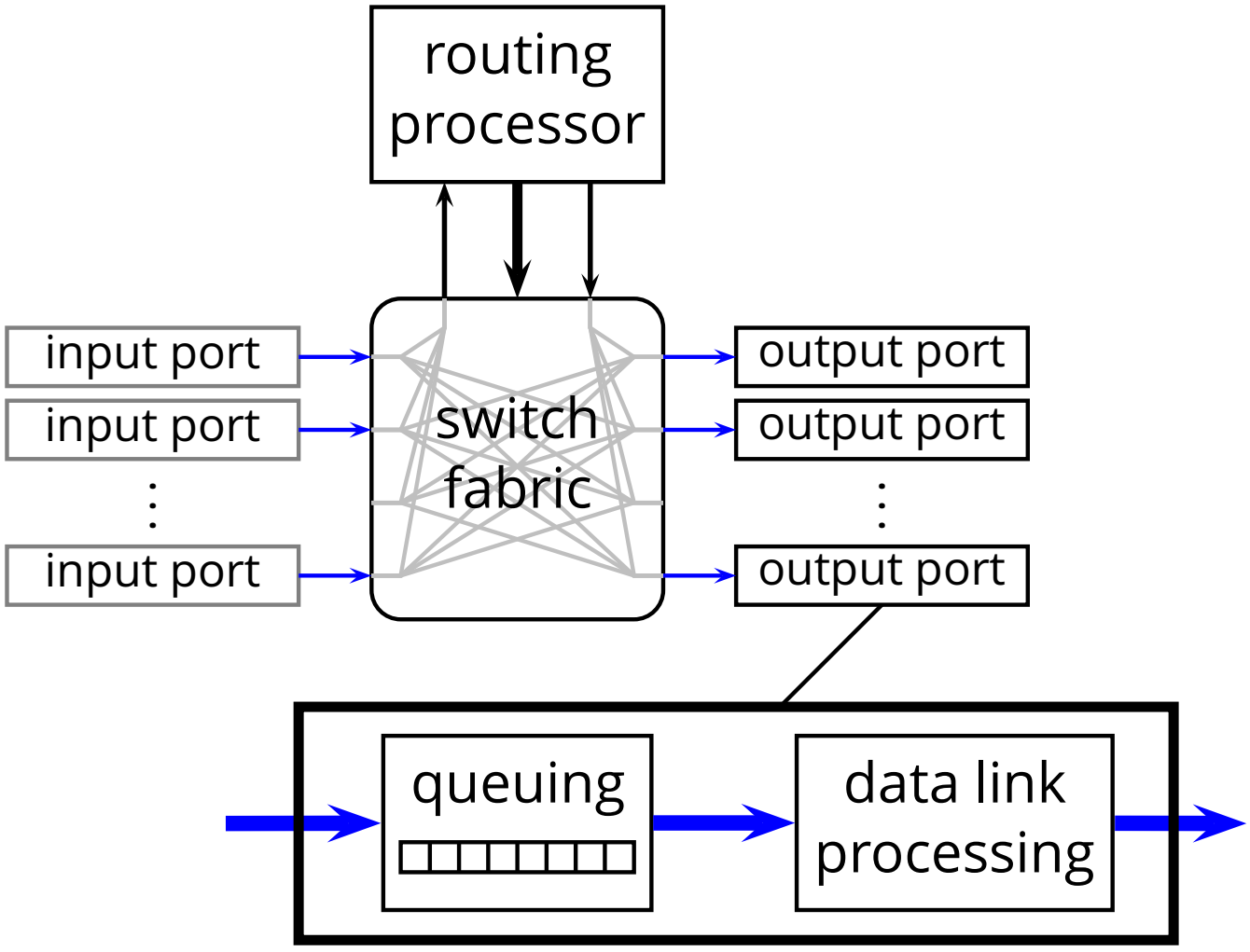

Queuing

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  - queuing may occur here because of the limited throughput of the output link. I.e., $R_{out} < \min(R_S, nR_{in})$

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  - *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

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IPv4 Datagram Format

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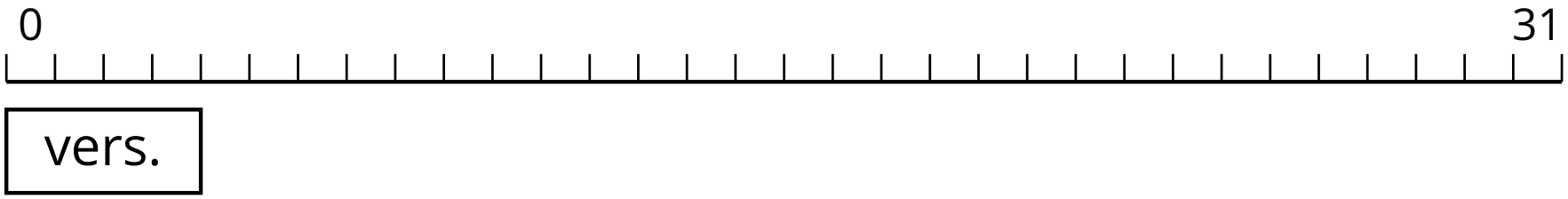

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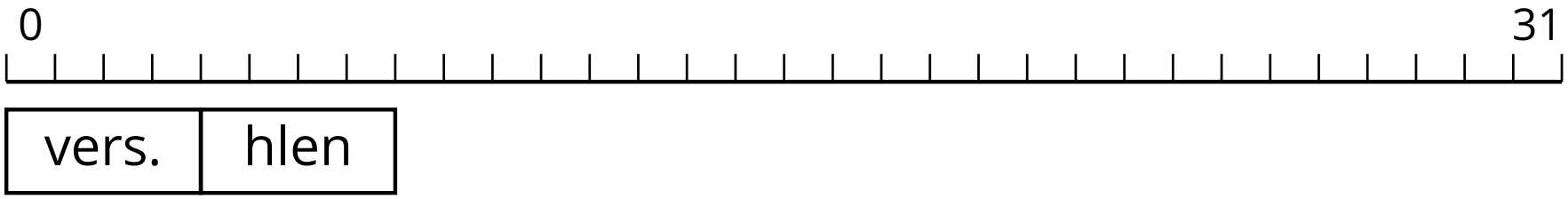

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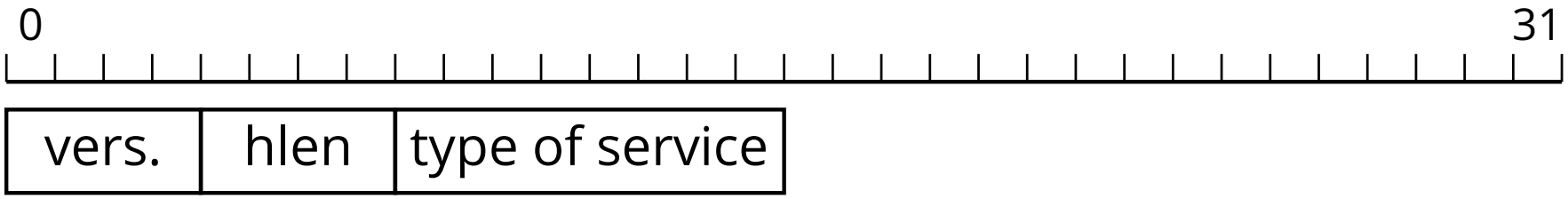

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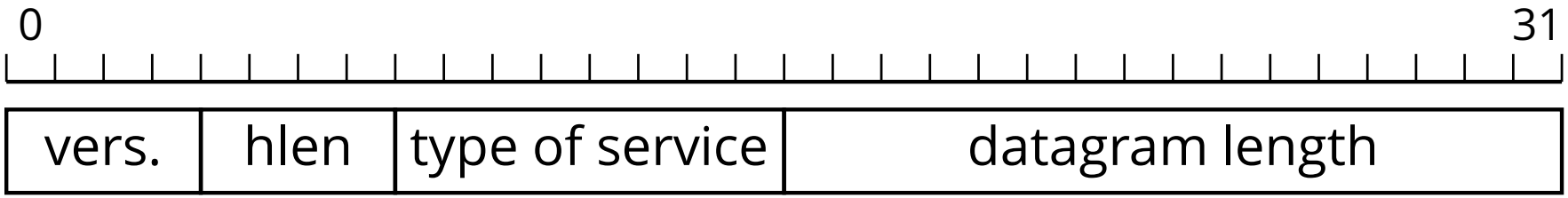

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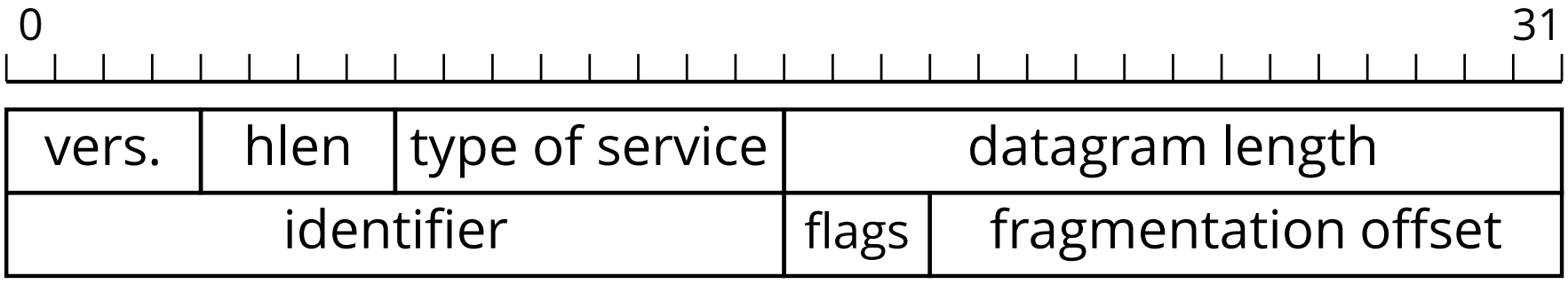

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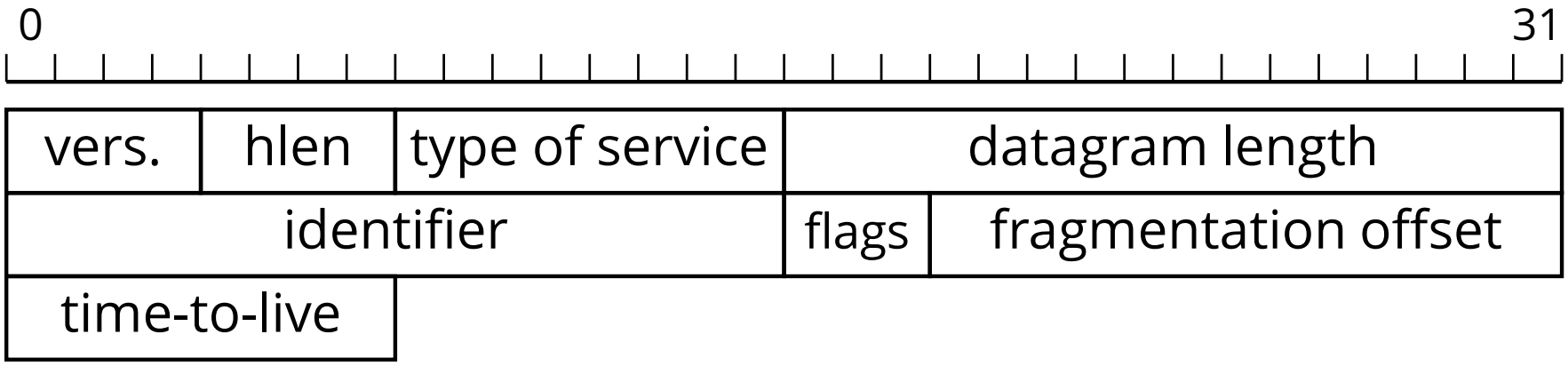

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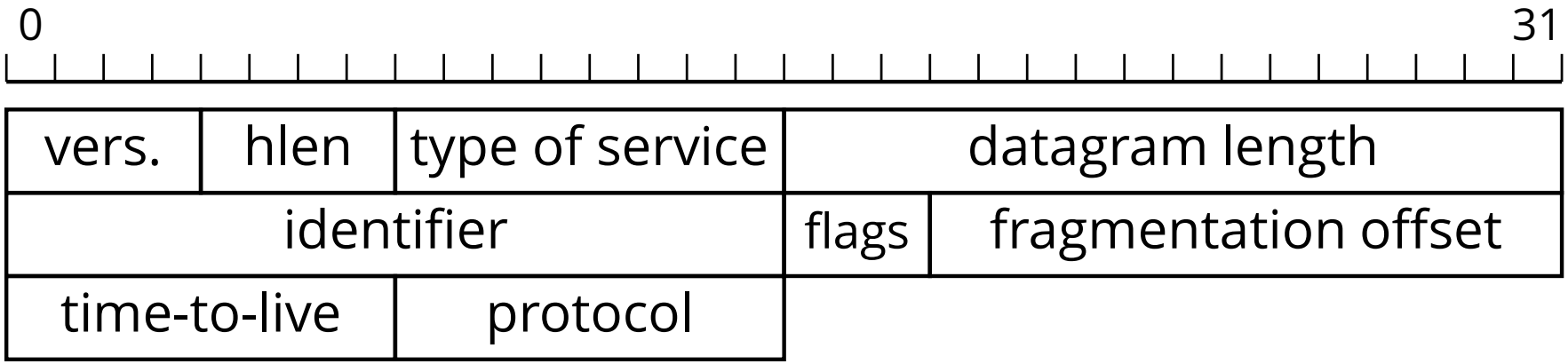

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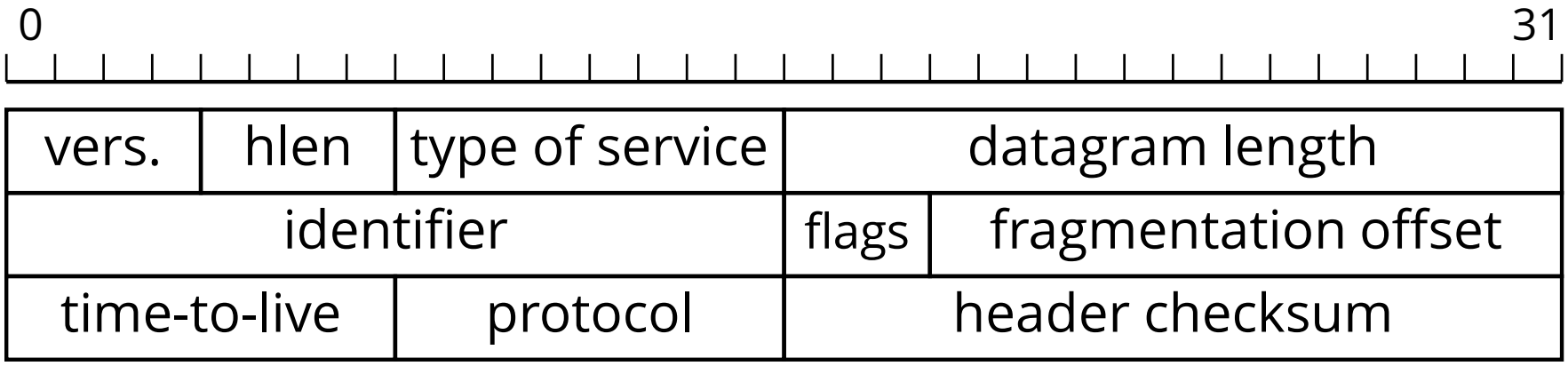

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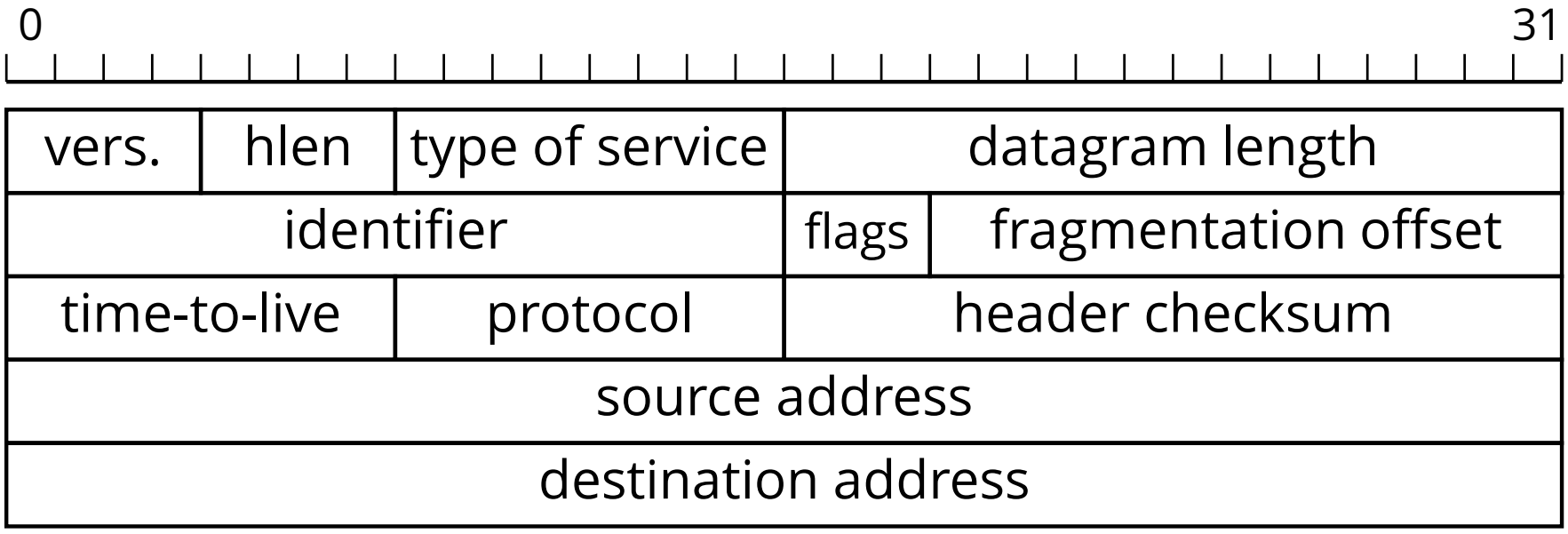

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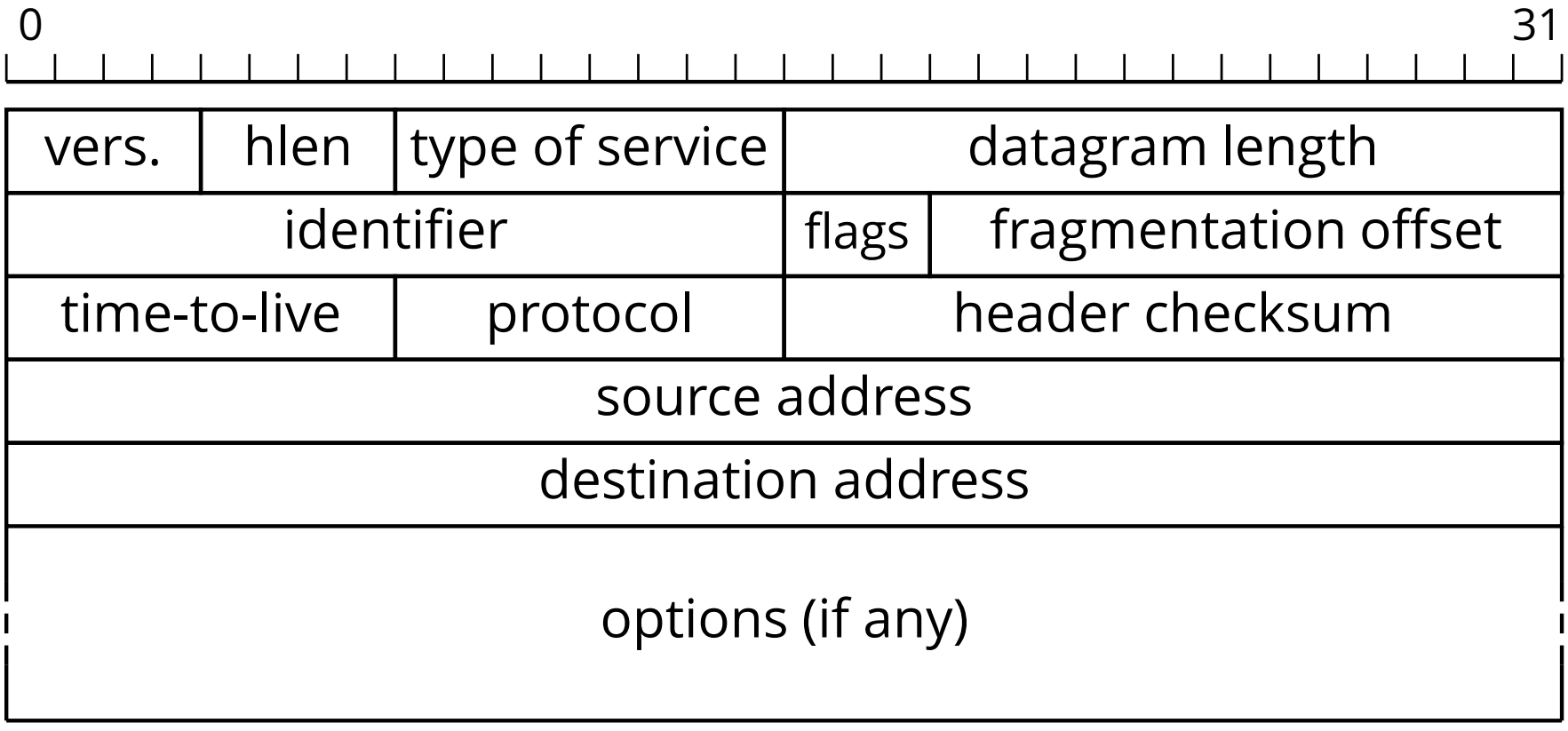

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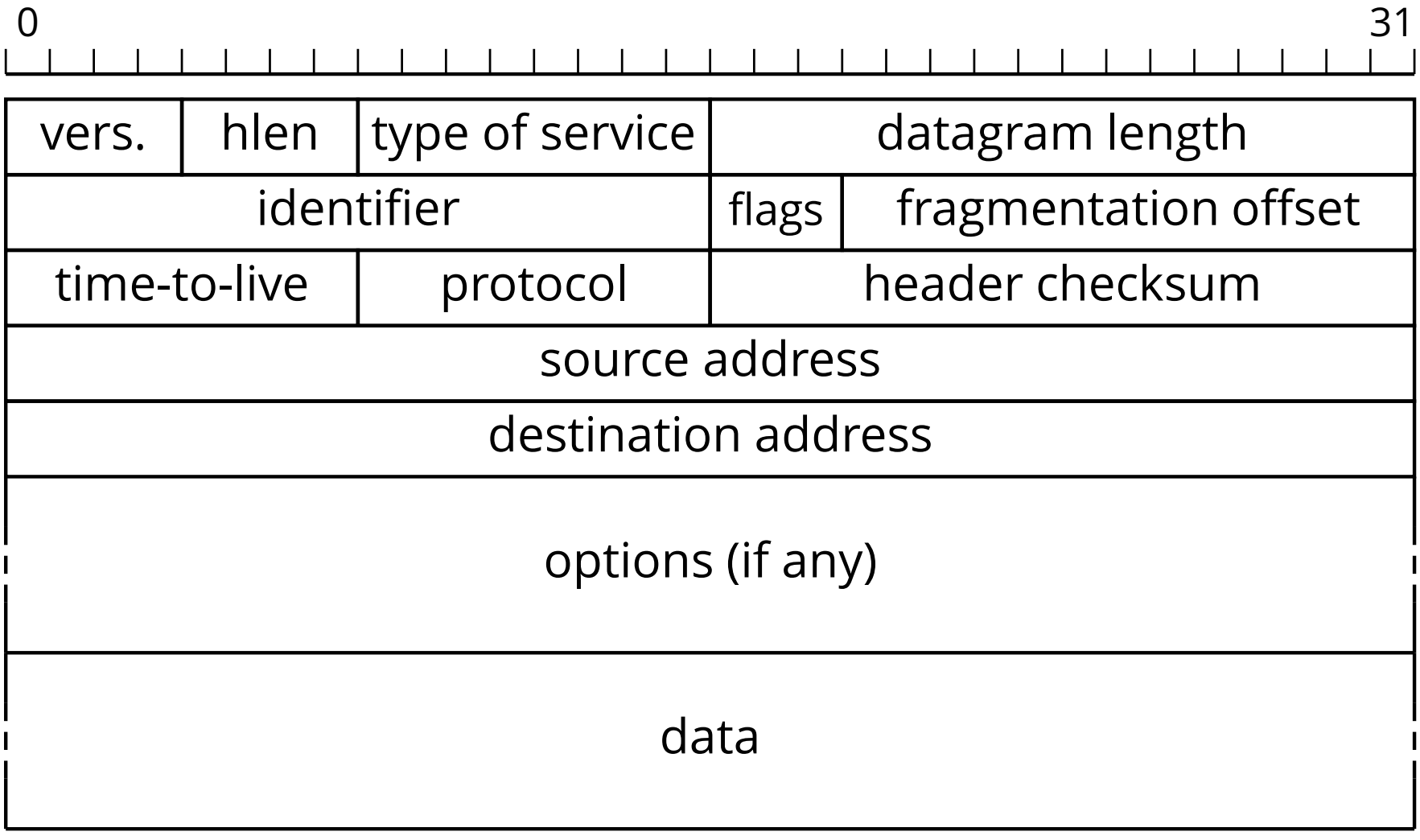

Fragmentation

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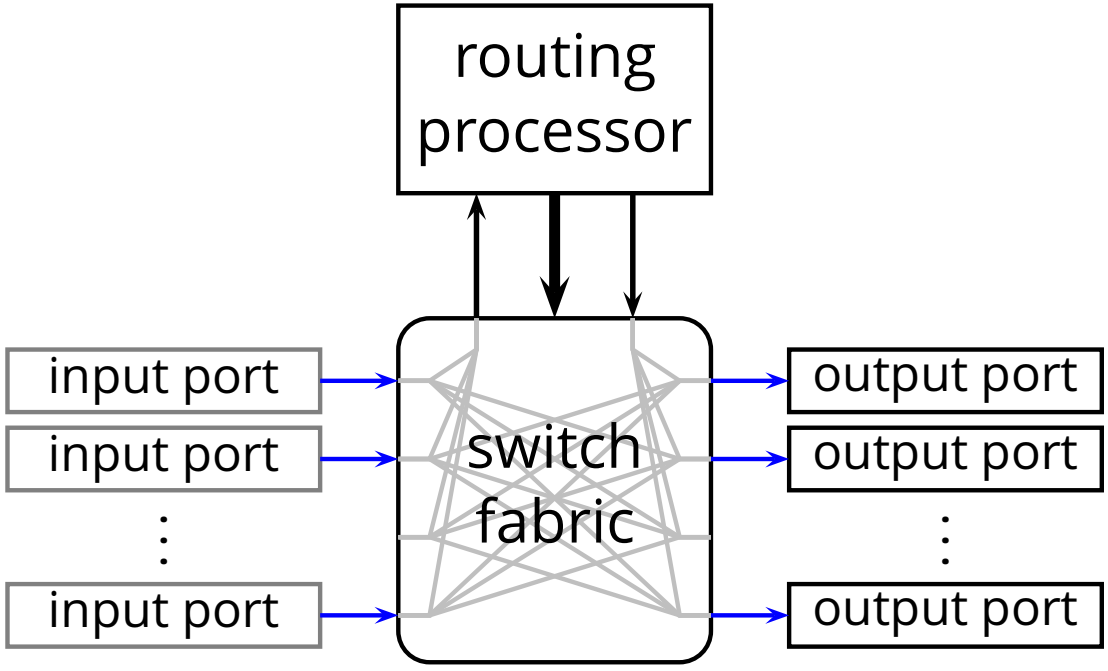

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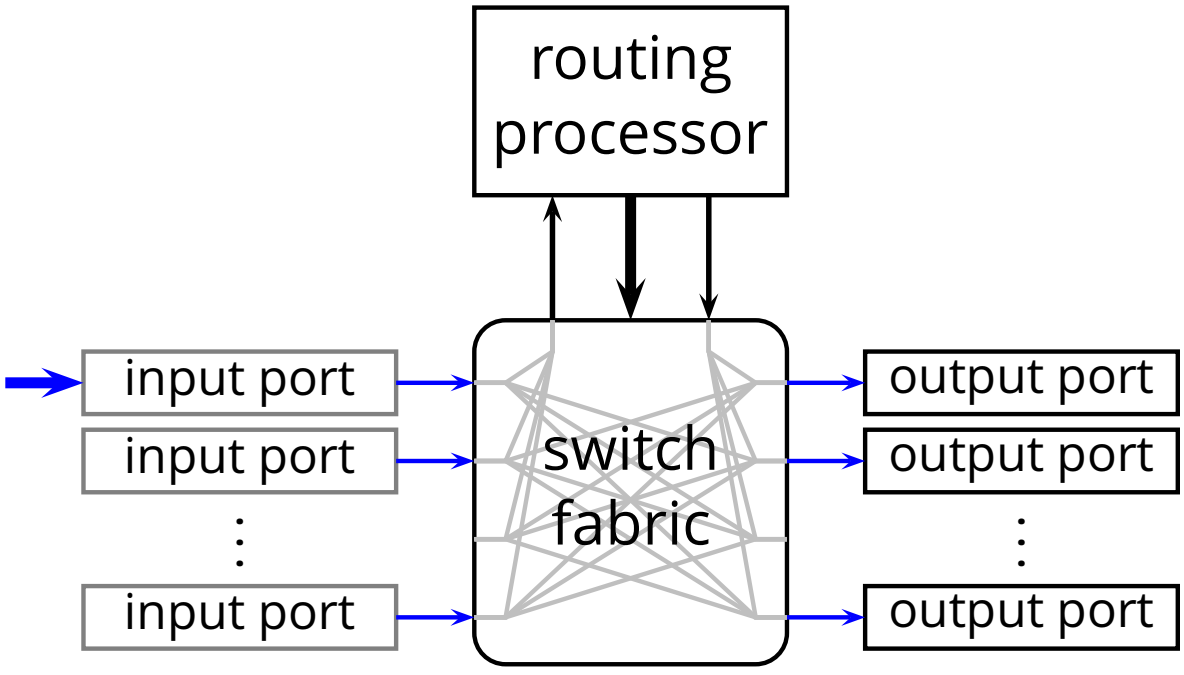

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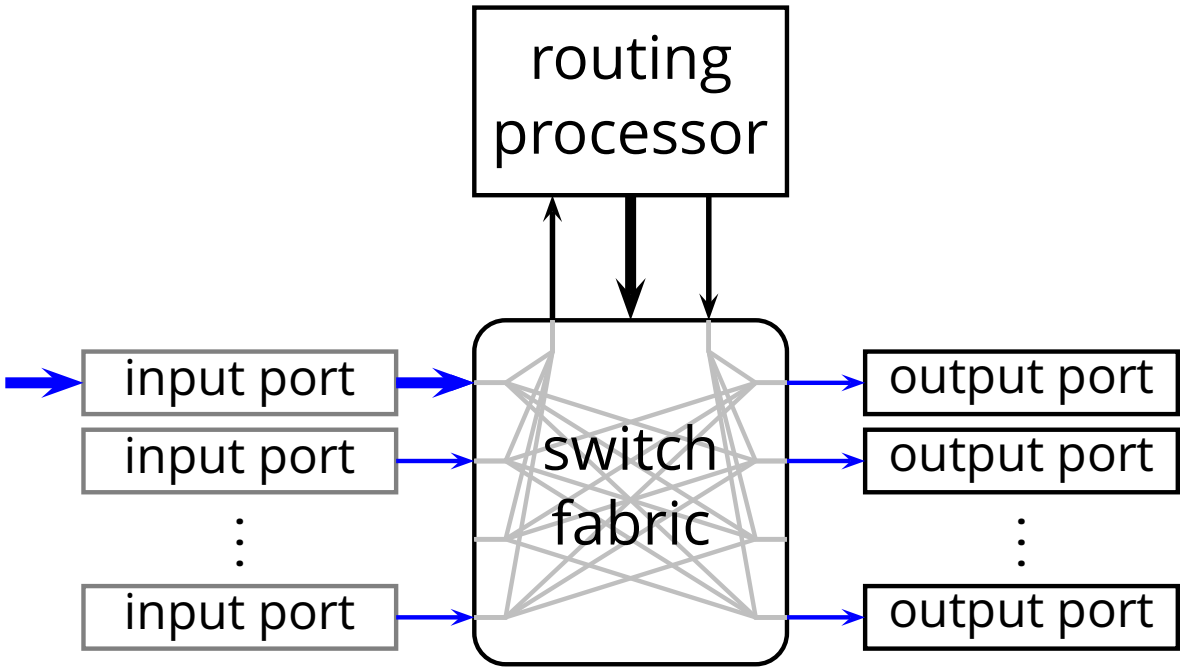

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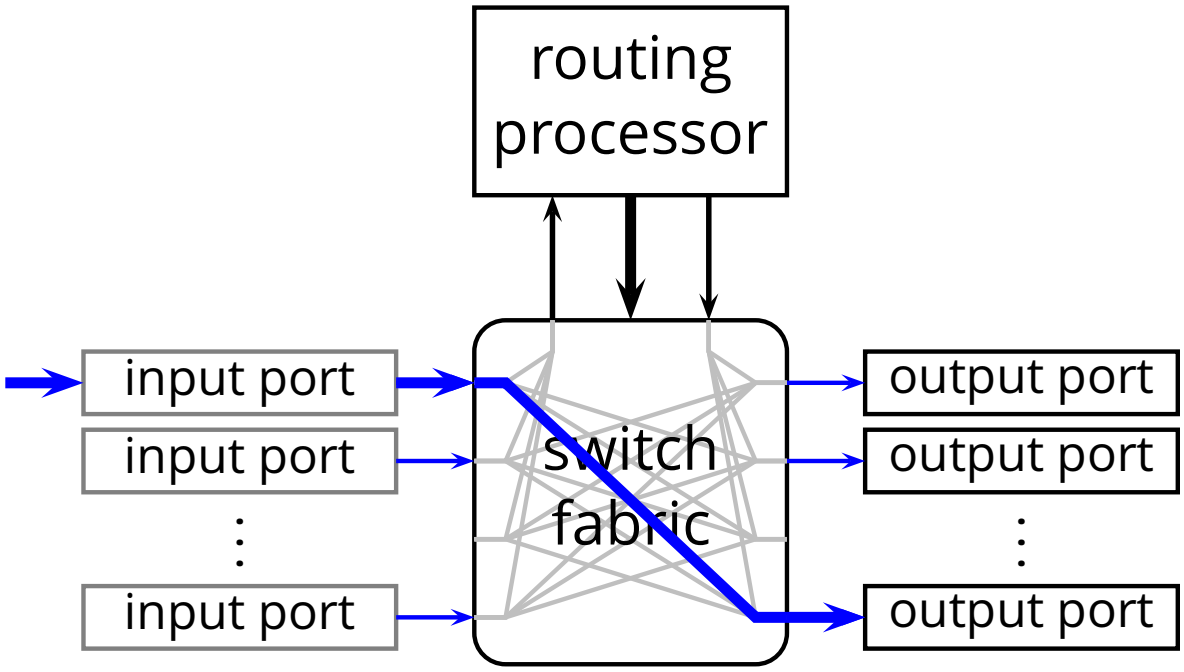
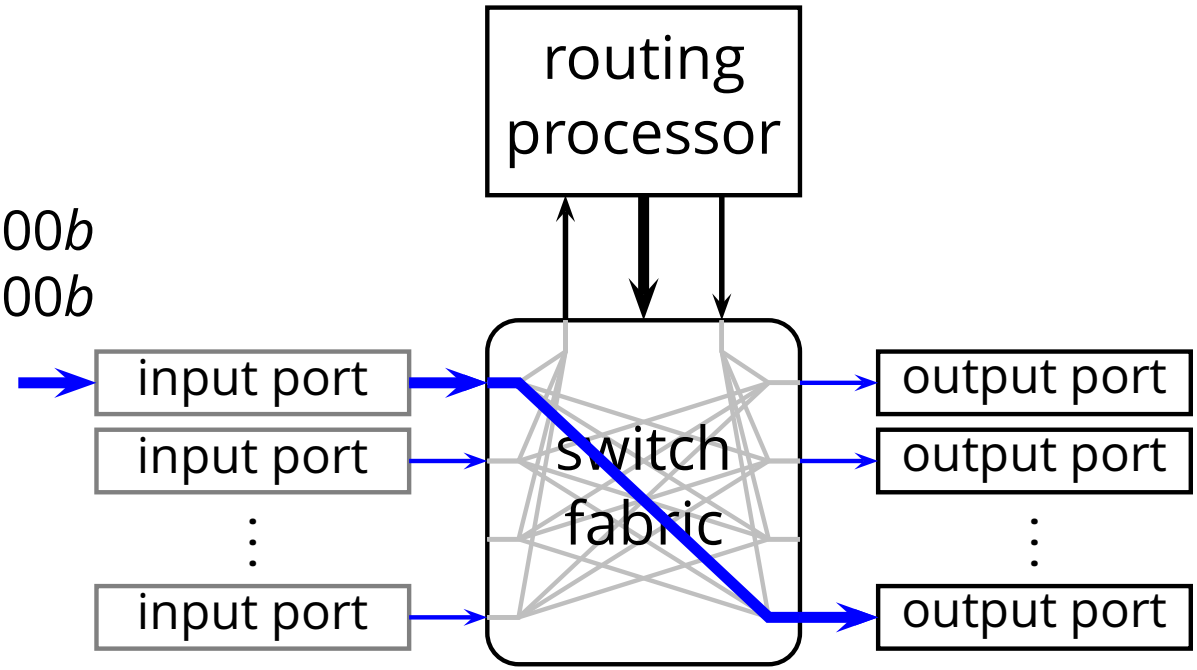


Fragmentation

$MTU = 1500b$
$size = 1000b$



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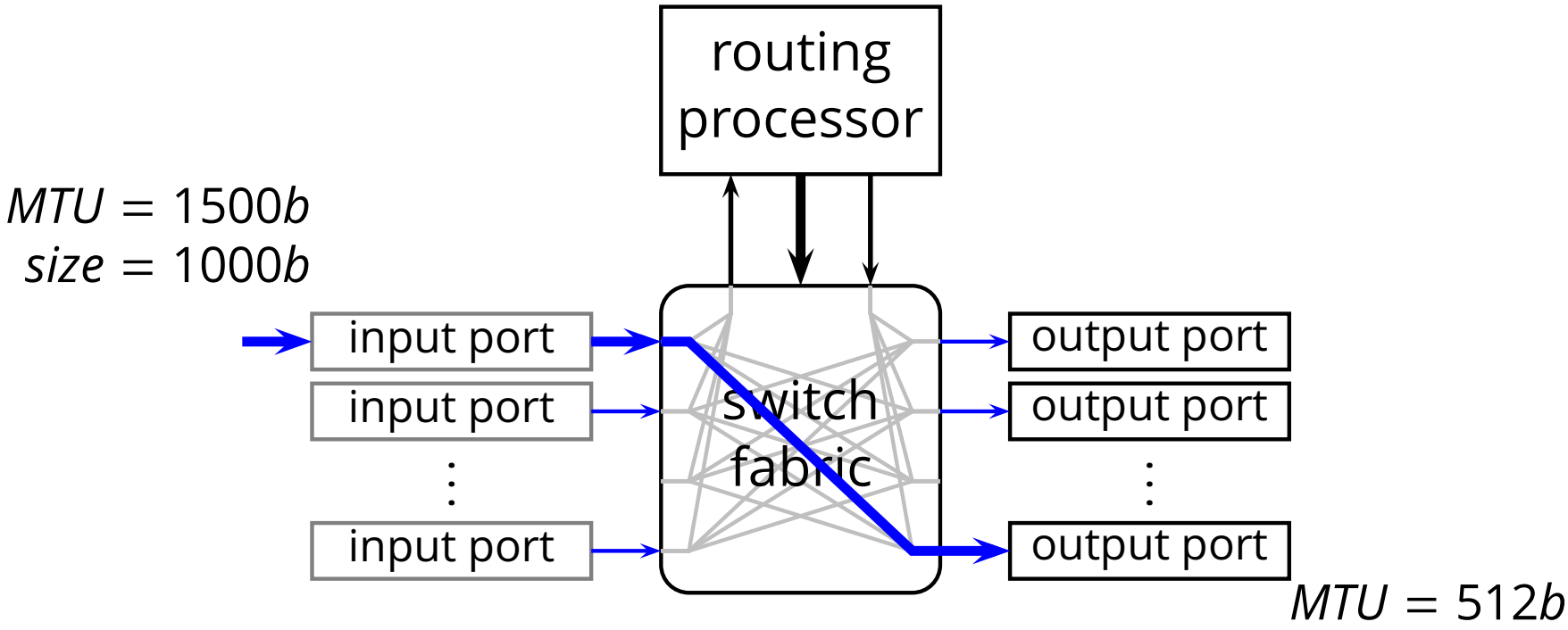

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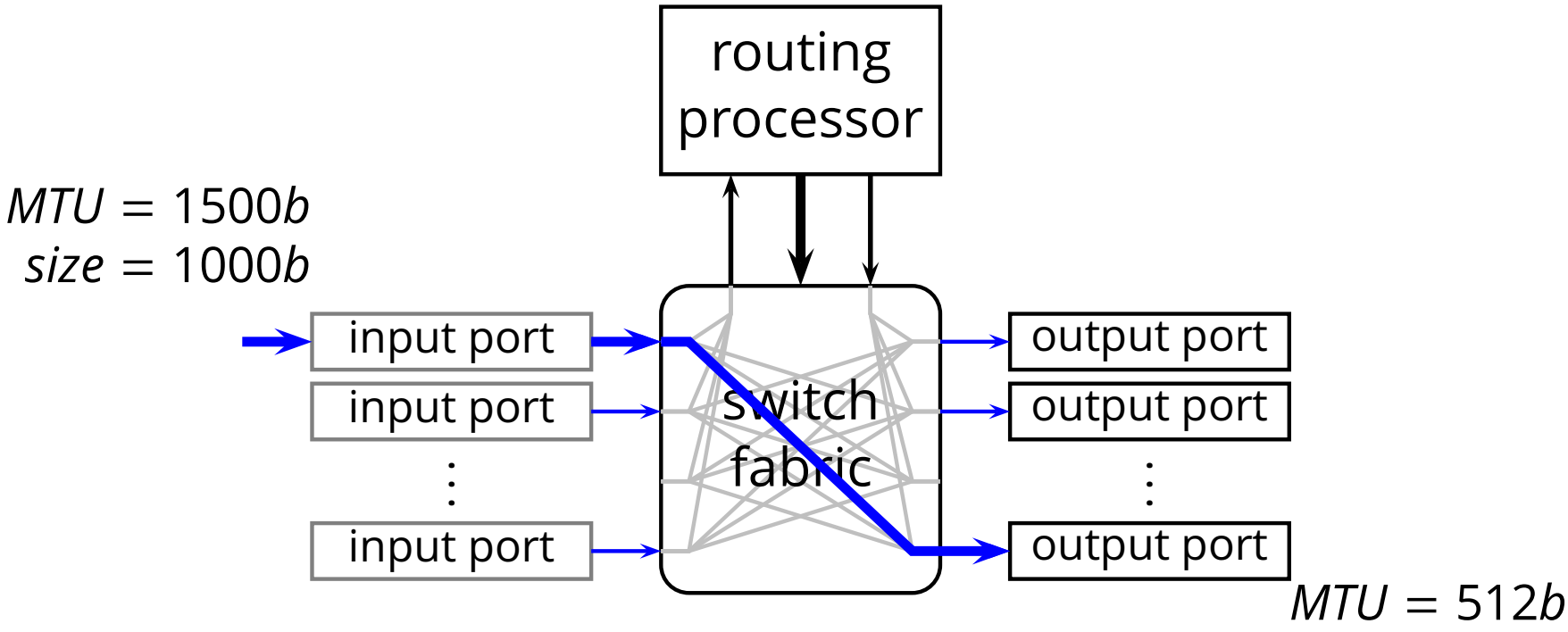

- How does the router handle cases where the size of an input datagram exceeds the maximum transmission unit (MTU) of the output link?

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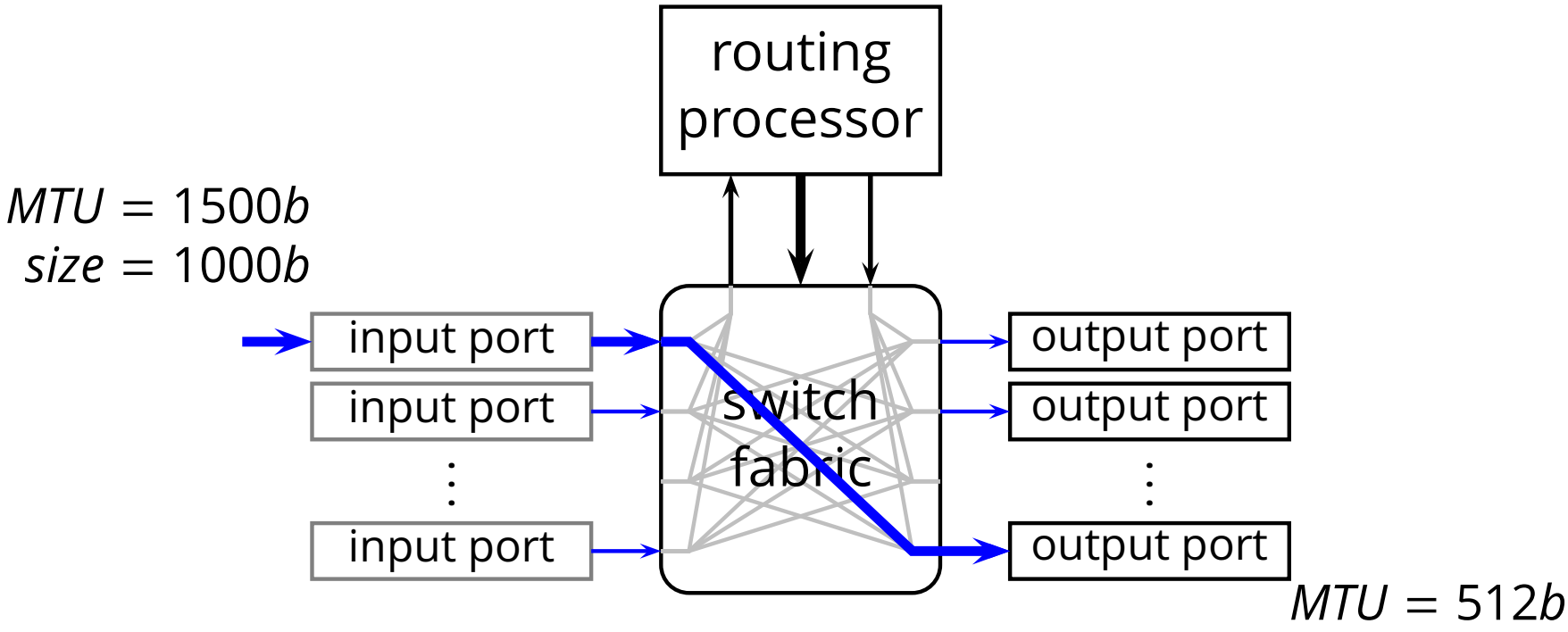

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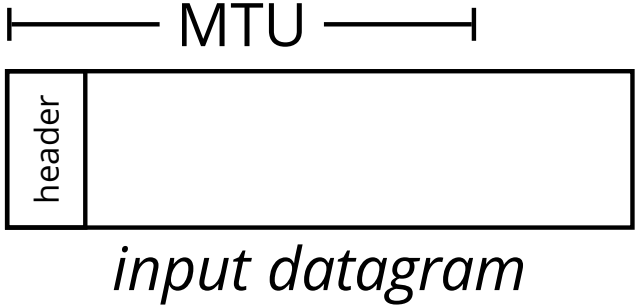
- The datagram is ***fragmented***

Fragmentation

input datagram

Fragmentation



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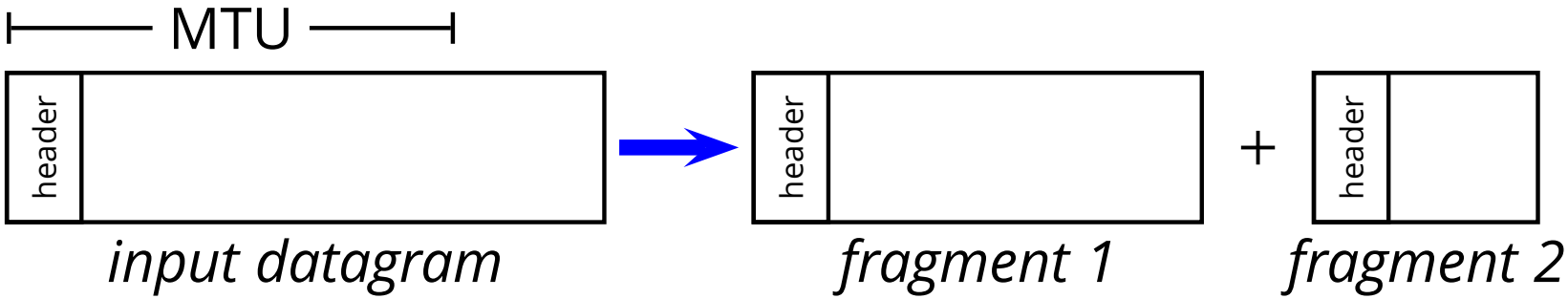

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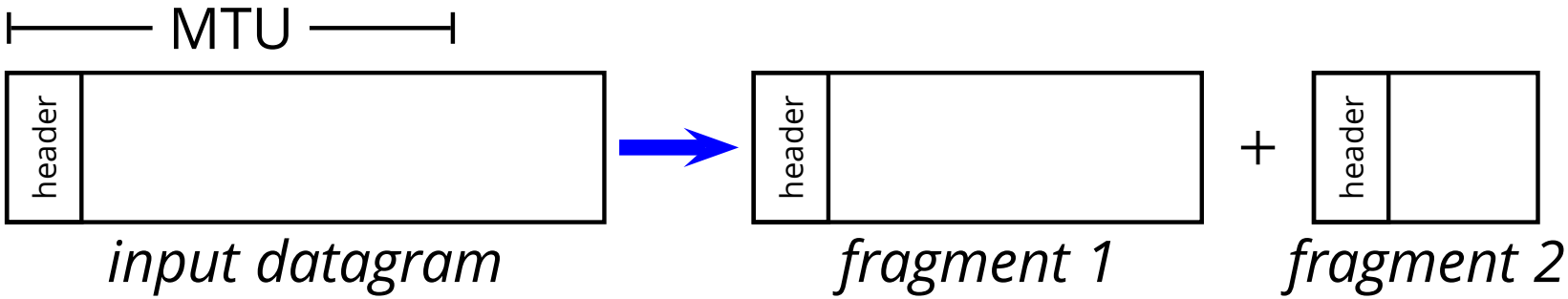

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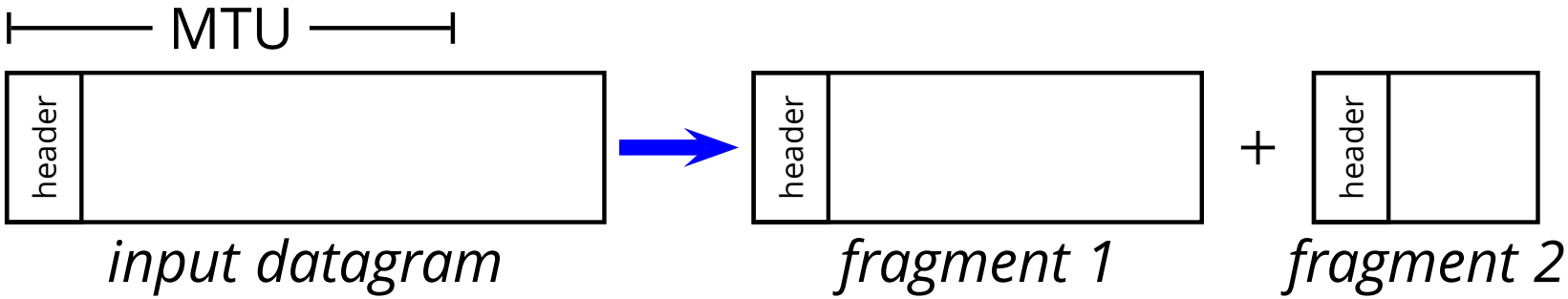

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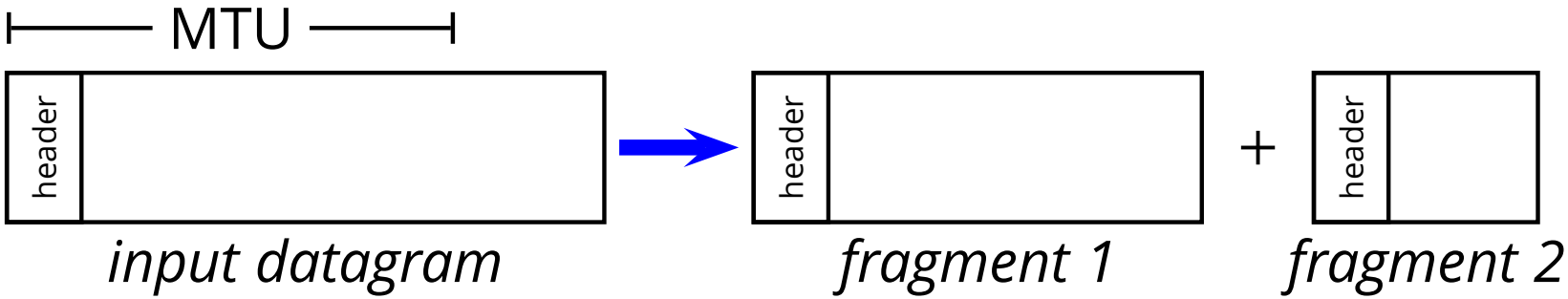

- The *destination* reassembles fragmented datagrams
  - push complexity out of the network
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- Requirements
  - destination must recognize two fragments of the same original datagram
  - destination must see if and when all the fragments have been received
  - intermediate routers must be able to fragment a datagram to whatever level necessary

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identifier	*fragment offset*	*more fragments*	*header length*	*total length*
789	0	0	20	1020

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789	61	1	20	508

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789	0	1	20	508

identifier	*fragment offset*	*more fragments*	*header length*	*total length*
789	61	1	20	508

identifier	*fragment offset*	*more fragments*	*header length*	*total length*
789	122	0	20	44