

Routing in the WAN (1/11)

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Selecting a path for forwarding a packet from sender to receiver via different networks in the WAN is called **routing**

Routers are packet switches in the WAN that forward data from one subnetwork to another along the path chosen

- Routing in the WAN is organized **source independently**:
 - Route of a packet depends solely on the destination and not on the previous path
- The principle of source independence makes the implementation of extremely efficient routing algorithms possible

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For a simple description of a WAN and to develop routing algorithms the WAN is described by a **graph**

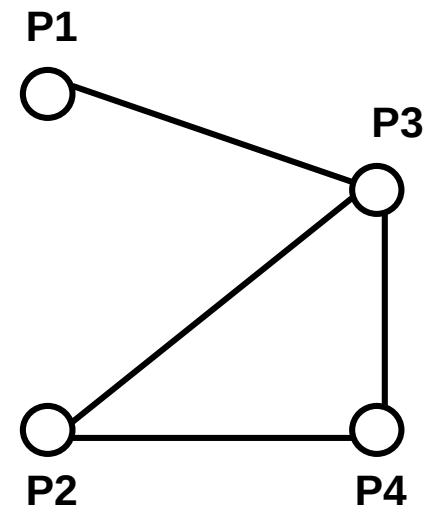
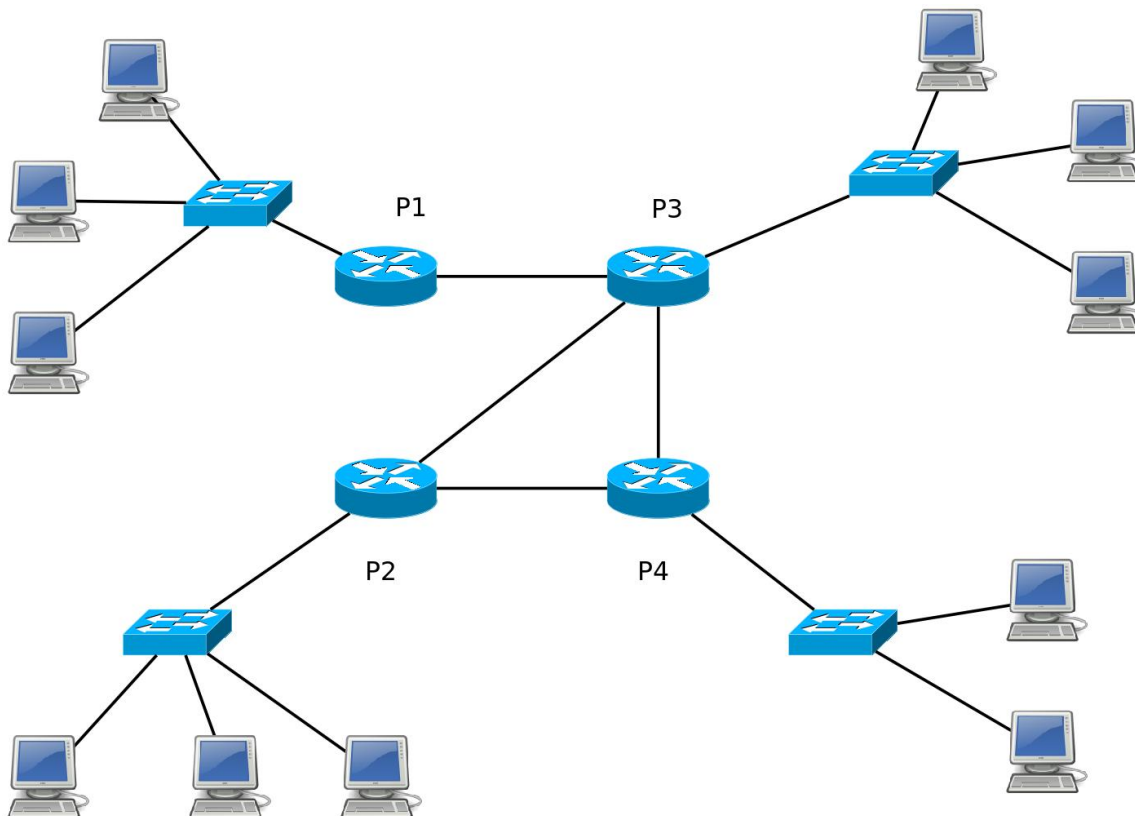
- Nodes represent routers
- Edges represent the direct connection between two routers

The graph description abstracts from the details of the connected end systems since these do not play any role in calculating the hops

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Example: WAN with a corresponding graph representation



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Routing tables are the central data structure for the routing algorithm in the WAN

Each packet switch maintains its own routing table

- Routing tables contain only information about the next station for each destination → **next hop**
- Routing tables must provide an entry for every potential destination → **universal routing**
- Routing tables must provide the optimal routes, i.e. the next hop must be on the best path to the destination

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Theoretical justification of the optimality principle:

Theorem:

- If B is on an optimal route from A to C , then there is also an optimal path from B to C on this route.

Proof:

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Inference from the optimality principle:

Theorem:

- If the optimal routes from all possible routers $A_1, \dots, A_n$ are connected with a destination Z , we get a rooted tree
→ **sink tree** (it is not uniquely determined!)

A sink tree has

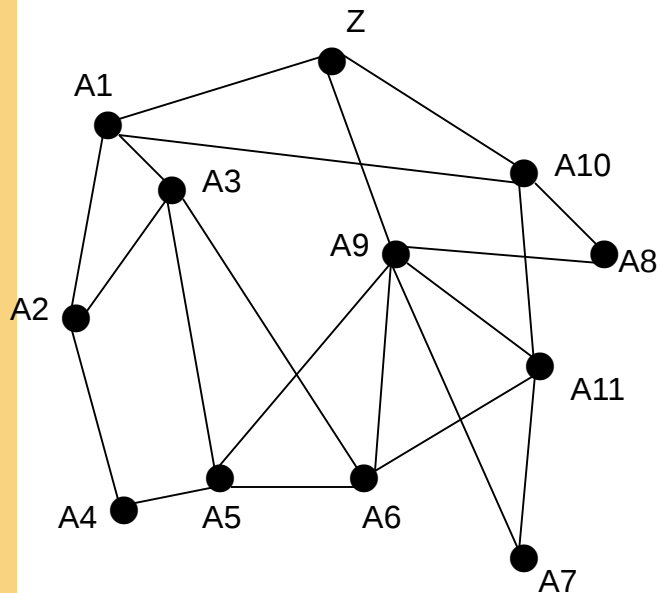
- a natural metric – number of hops
- no loops, i.e., packets reach their goal after a finite number of steps

Goal of the different routing algorithms is the construction of a sink tree for determining the optimal route and the corresponding entries in the routing table

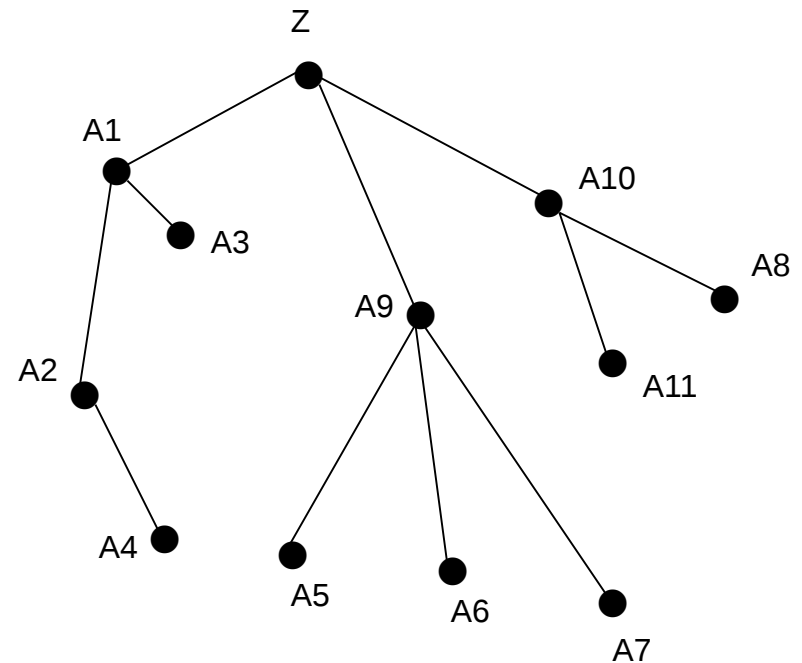
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Network with Sink Tree:



Network



Sink tree for router Z

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Optimization of a Routing Table:

Basic structure:

- For each destination there is an entry in the field: *Next Hop*

Optimization ideas:

- **Destination information:**

- Computers at the same packet switch have the same first address component, therefore the name of the second component is sufficient for every computer in the subnetwork. The first component is required for all other subnetworks

- **Default routing:**

- The next hop is the same for many destination – therefore a **default hop** is set and all targets that run via the default hop are deleted from the routing table

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Calculation of a Routing Table (1/3):

- Manual calculation only makes sense in the case of small WANs – otherwise routing algorithms are implemented

Routing algorithms are

- **static** (or non-adaptive), or
- **dynamic** (or adaptive)

Static routing algorithms calculate routing tables with the help of fixed routing metrics on router start-up

- Calculation is very easy
- Use is however limited as it cannot react to changes in the WAN

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Calculation of a Routing Table (2/3):

Dynamic routing algorithms can be adapted to changes in the network with regular or as-needed new calculations of the routing table

- Basis of adaption are again suitable router metrics
- The methods differ in
 - the timing of the new calculation and in
 - the new calculation of the information and criteria they are based on
- Application of dynamic routing algorithms allow automatic reaction to network problems or changing traffic situations

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Calculation of a Routing Table (3/3):

Dynamic routing algorithms are

- **centralized** or **decentralized**

With **centralized routing algorithms** routing tables are calculated by a central instance

- Relatively long waiting times
- Failure/resource bottleneck of the central instance endangers network operation

With **decentralized routing algorithms** every router calculates the routing table based on its own knowledge of the network situation

- Relatively long adaption process to a changed network situation
E.g. isolated routing, distance-vector method, link-state algorithm,