IP Routing Overview

Static-, Default-, Dynamic-Routing

Agenda

- **Routing Basics**
- **Static Routing**
- **Default Routing**
- **Dynamic Routing**

IP Routing 1

- **routing**
  - process of choosing a path over which to send IP datagram's
  - direct versus indirect delivery
    - depends on destination net-ID
      - net-ID equal to source net-ID -> direct delivery
      - net-ID unequal to source net-ID -> indirect delivery
  - IP hosts and routers take part in this process
    - IP hosts responsible for direct delivery of IP datagram's
    - IP hosts responsible for choosing a default router (“default gateway”) as next hop in case of indirect delivery of IP datagram's
    - routers responsible for selecting the best path in a meshed network in case of indirect delivery of IP datagram's

IP Routing 2

- **indirect routing of IP datagram's**
  - is done by routers based on routing tables
  - routing table
    - database of known destinations
  - database contains
    - next hop router (and next hop MAC address in case of LAN)
    - outgoing port
    - metric (information how far away is a certain destination network)
    - time reference (information about the age of the table entry)

    for every known (or specified) destination network
    - net-ID / subnet-mask

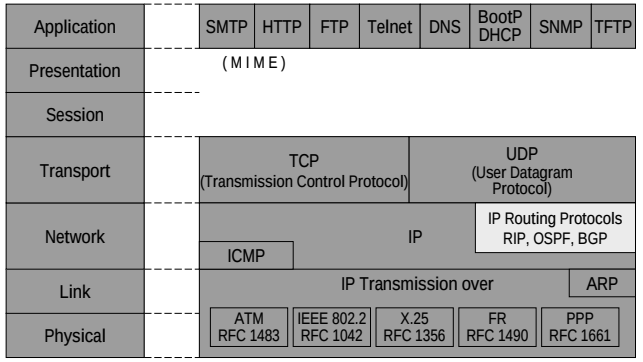
IP Routing 3

- **routing can be either**
  - static
    - routing tables are preconfigured by network administrator
    - non-responsive to topology changes
    - can be labor intensive to set up and modify in complex networks
    - no overhead concerning CPU time and traffic
  - or dynamic
    - routing tables are dynamically updated with information received from other routers
    - communication between routers is done by routing protocols
    - responsive to topology changes
    - low maintenance labor cost

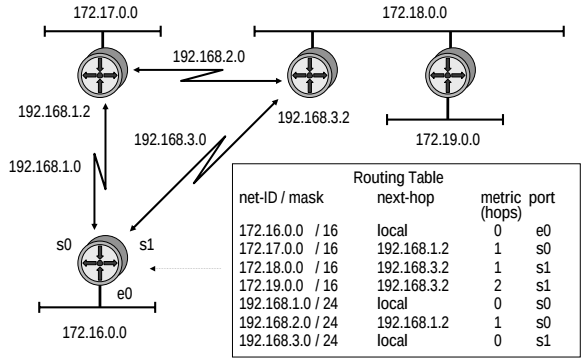
IP Routing 4

- **routing protocol**
  - discovers current network topology
  - determines the best path to every reachable network
    - best path is determined by the help of metric
  - stores information about best paths in the routing table
  - uses routing messages for communication
  - routing messages need a certain percentage of bandwidth
  - dynamic routing need a certain percentage of CPU time of the router
  - that means overhead

IP Routing Related Protocols



Routing Table Example



Routing Table

net-ID / mask	next-hop	metric (hops)	port
172.16.0.0 / 16	local	0	e0
172.17.0.0 / 16	192.168.1.2	1	s0
172.18.0.0 / 16	192.168.3.2	1	s1
172.19.0.0 / 16	192.168.3.2	2	s1
192.168.1.0 / 24	local	0	s0
192.168.2.0 / 24	192.168.1.2	1	s0
192.168.3.0 / 24	local	0	s1

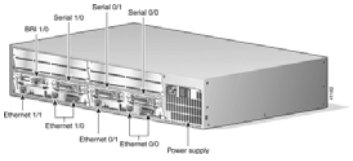
IP Routing Paradigm

- **Destination Based Routing**
  - source address is not taken into account for the forward decision
- **Hop by Hop Routing**
  - IP datagram's follow the path, which is pointed by the current state of the routing tables
- **Least Cost Routing**
  - normally only the best path is considered for forwarding of IP datagram's
  - alternate paths will not be used in order to reach a given destination
    - note:some methods allow load balancing if paths are equal

Router

- **Initially Unix workstations with several network interface cards**
- **Today specialized hardware**

Cisco 3600 Router



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- **Routing Basics**
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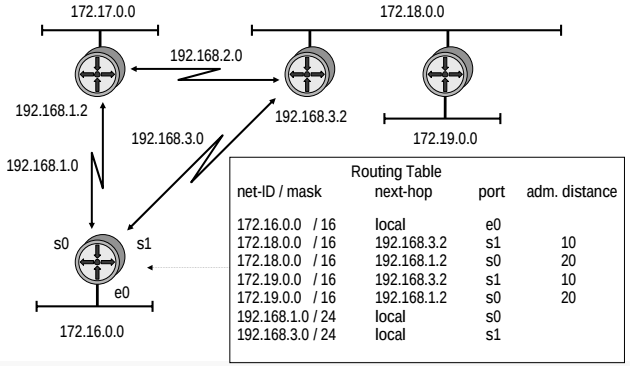
Static Routing 1

- **static routing**
  - preconfigured static routing tables
  - no overhead traffic
  - often sufficient in case of lack of any network redundancy
    - e.g. reaching stub networks
    - e.g. hub and spoke topology
  - but can be labor intensive to set up and modify in complex networks
    - overhead can be reduced by default route
  - sometimes only or preferred way in certain technologies
    - Dial on Demand Networks (e.g. X.25, ISDN, Frame Relay, ATM)
  - sometimes used for security reasons

Static Routing 2

- **static routing (cont.)**
  - topology changes can not automatically be handled
  - but in certain implementations exceptions are possible
- **example for such a behavior**
  - static routing with the possibility to specify an alternate (secondary) route
  - if primary route fails the system automatically switch over to the alternate route
  - e.g. Cisco “Administrative Distance” feature
    - allows to give a weight to an static route entry
    - the lower the weight the better

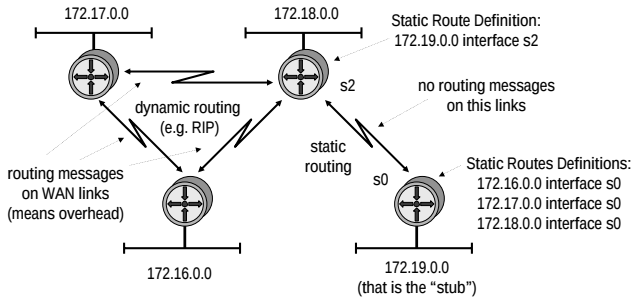
Static Routes - Administrative Distance



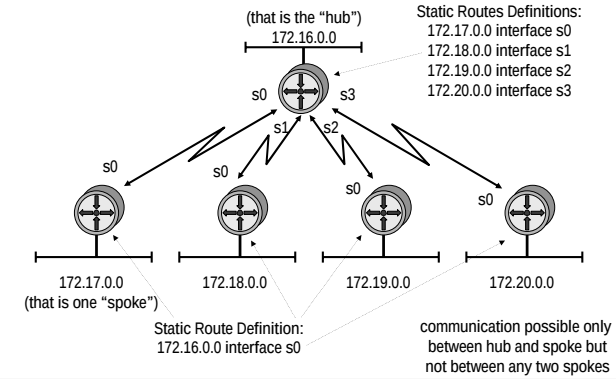
Routing Table

net-ID / mask	next-hop	port	adm. distance
172.16.0.0 / 16	local	e0	
172.18.0.0 / 16	192.168.3.2	s1	10
172.18.0.0 / 16	192.168.1.2	s0	20
172.19.0.0 / 16	192.168.3.2	s1	10
172.19.0.0 / 16	192.168.1.2	s0	20
192.168.1.0 / 24	local	s0	
192.168.3.0 / 24	local	s1	

Static Routes - Stub Network



Static Routes - Hub and Spoke



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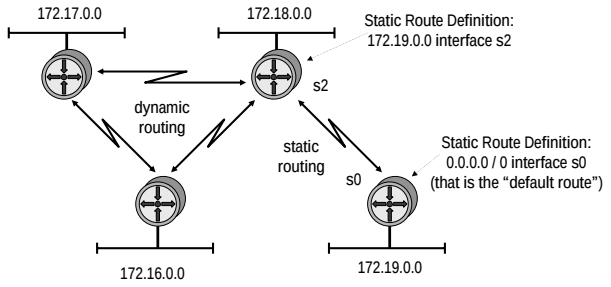
Default Route

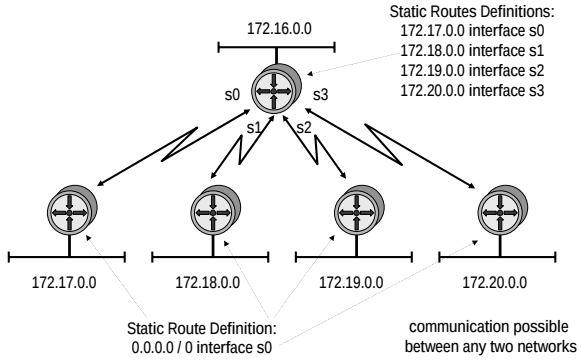
- **general routing principle**
  - traffic to destinations that are unknown to the router will be discarded by the router (ICMP message !!!)
  - behavior can be changed by default route
- **default routing principle**
  - traffic to destinations that are unknown to the router will be sent to a default route (default network)
  - implies that another router might know more networks
  - permits routers to carry less than full routing tables
  - default network marked with net-ID equal 0.0.0.0
    - in routing tables
    - in routing updates used by dynamic routing

Default Route - Stub Network

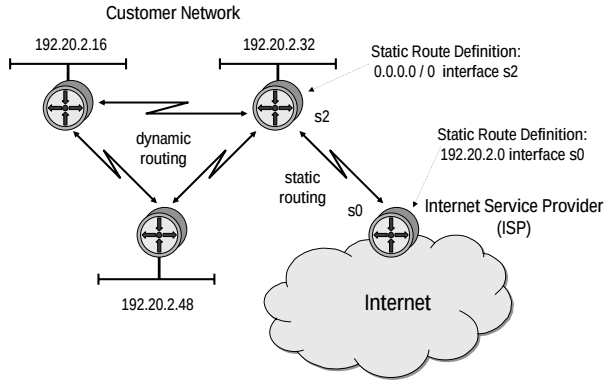


Questions: What happens to traffic generated in network 172.19.0.0 with an unknown destination address? What does this mean for the WAN link?

Default Route - Any to Any



Default Route - Internet Access



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Dynamic Routing

- **dynamic routing**
  - routing tables are dynamically updated with information from other routers done by routing protocols
  - routing protocol
    - discovers current network topology
    - determines the best path to every reachable network
    - stores information about best paths in the routing table
  - metric information is necessary for best path decision
    - in most cases summarization along the a given path of static preconfigured values
      - hops, interface cost, interface bandwidth, interface delay, etc.
  - two basic technologies
    - distance vector, link state

Distance Vector Protocols 1

- **routing table is sent periodically to all immediately-neighboring routers (IP limited broadcast)**
  - after power-up routing table contains information about local attached networks only
- **incoming updates are checked for changes**
  - new networks, metric change of already known networks, etc.
- **own routing table is adapted accordingly**
  - changes announced by next periodic routing update

Distance Vector Protocols 2

- **metric information based on hops (distance between hops)**
- **limited view of topology**
  - routers view is based on its routing table only
    - exact view how to reach local neighbors
    - but topology behind neighbors is hidden
  - based on signpost principle only
- **several procedures necessary**
  - to solve problems caused by limited view
    - e.g. count to infinity, routing loops
  - to reduce convergence time
    - time to reach consistent routing tables after topology change

Distance Vector Protocols 3

- **some usual procedures to solve inherent problems**
  - maximum hop count
  - split horizon, poison reverse
  - triggered update
  - hold down, route poisoning
- **distance vector protocols examples**
  - RIP, RIPv2 (Routing Information Protocol)
  - IGRP (Cisco, Interior Gateway Routing Protocol)
  - IPX RIP (Novell)
  - AppleTalk RTMP (Routing Table Maintenance Protocol)

Link State Protocols 1

- **routers have a global view of network topology**
  - exact knowledge about all routers, links and their costs (metric) of a network stored in topology database (“roadmap”)
  - roadmap principle
- **routing table entries are based**
  - on computation of own router-resident topology database
- **SPF computation**
  - **S**hortest-**P**ath-**F**irst (Dijkstra) algorithm to find lowest cost path to every destination network
  - lowest cost path is stored in routing table

Link State Protocols 2

- **topology changes (link up or down, link state)**
  - are recognized by routers responsible for supervising those links
  - are flooded by responsible routers to the whole network (**L**ink **S**tate **A**dvertisements, LSAs)
- **flooding**
  - is a controlled multicast procedure to guarantee that every router gets corresponding LSA information as fast as possible
  - is used to update network topology database and hence may lead to change of routing table

Link State Protocols 3

- **with the lack of topology changes**
  - local hello messages are used to supervise local links (to test reachability of immediate-neighboring routers)
  - therefore less routing overhead concerning link bandwidth than periodic updates of distance vector protocols
- **but more network load is caused by such a routing protocol**
  - during connection of former separate parts of the network
  - topology database synchronization

Link State Protocols 4

- **in large networks**
  - two level hierarchy is used to decrease
    - CPU time for SPF calculations
    - memory requirement for storing topology database
  - one backbone area
  - several non-backbone areas
    - non-backbone area can be connected by area border router to backbone area only
  - summarization possible at area border routers
    - route aggregation to reduce size of routing tables
    - summarization means that some net-IDs can be summarized in one net-ID only

Link State Protocols 5

- **link state protocols examples**
  - OSPF (Open Shortest Path First)
  - Integrated IS-IS (IP world)
    - note: Integrated IS-IS takes another approach to handle large networks (topic outside the scope of this course)
  - IS-IS (OSI world)
  - PNNI (in the ATM world)
  - APPN (IBM world),
  - NLSP (Novell world)

Routing Protocol Comparison

Routing Protocol	Complexity	Max. Size	Convergence Time	Reliability	Protocol Traffic
RIP	very simple	16 Hops	High (minutes)	Not absolutely loop-safe	High
RIPv2	very simple	16 Hops	High (minutes)	Not absolutely loop-safe	High
IGRP	simple	x	High (minutes)	Medium	High
EIGRP	complex	x	Fast (seconds)	High	Medium
OSPF	very complex	Thousands of Routers	Fast (seconds)	High	Low
IS-IS	complex	Thousands of Routers	Fast (seconds)	High	Low
BGP-4	very complex	more than 100,000 networks	Middle	Very High	Low