SAPIENZA
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Static Routing

Network Infrastructures course

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Routers

- Routers have an interface for each network they connect
- For each interface, they have a different IP address
- Each router, for each arriving IP packet, makes 3 steps:

1. Receive IP packet and read the **destination address**
2. Lookup in a **Routing Table** and decide which is the **next hop** (another router or the final node)
3. Send the packet on **right interface** or to the next hop

Anatomy of an IPv4 Packet

32 bits

<table>
<tr><td>Version</td><td>IHL</td><td>Type-of-Service</td><td colspan="2">Total Length</td></tr>
<tr><td colspan="3">Identification</td><td>Flags</td><td>Fragmentation offset</td></tr>
<tr><td colspan="2">Time-to-live</td><td>Protocol</td><td colspan="2">Header Checksum</td></tr>
<tr><td colspan="5">Source Address</td></tr>
<tr><td colspan="5">Destination Address</td></tr>
<tr><td colspan="5">Options (+ padding)</td></tr>
<tr><td colspan="5">Data (variable)</td></tr>
</table>

Routing Table

- Each router has its own routing table
- A Routing Table lists the routes to particular network destinations, and (in some cases) lists also the **metrics** (distances) associated with each route
- We have two types of routing

1. **Static Routing:** a router uses a manually-configured routing entry. So, each row of the routing table is manually-configured by the network administrator
2. **Dynamic Routing:** (also called **adaptive routing**) it provides optimal data routing, enables routers to select the optimal paths according to real-time logical network layout changes.

- In dynamic routing, the routing protocol operating on the router is responsible for the **creation**, **maintenance** and **updating** the <u>dynamic routing table</u>.
  In static routing, all these tasks are manually done by the system administrator.

Static Routing

Advantages

- Easy to implement in a small network.

- Very secure. No advertisements are sent, unlike with dynamic routing protocols.

- It is very predictable, as the route to the destination is always the same.

- No routing algorithm or update mechanisms are required. Therefore, extra resources (CPU and memory) are not required.

Disadvantages

- Suitable only for simple topologies or for special purposes such as a default static route.

- Configuration complexity increases dramatically as the network grows. Managing the static configurations in large networks can become time consuming.

- If a link fails, a static route cannot reroute traffic. Therefore, manual intervention is required to re-route traffic.

Dynamic Routing

Advantages

- Suitable in all topologies where multiple routers are required.
- Generally independent of the network size.
- Automatically adapts topology to reroute traffic if possible.

Disadvantages

- Can be more complex to initially implement.
- Less secure due to the broadcast and multicast routing updates.
- Additional configuration settings such as passive interfaces and routing protocol authentication are required to increase security.
- Route depends on the current topology.
- Requires additional resources such as CPU, memory, and link bandwidth.

How To Create A Routing Table

The proposed methodology includes the following steps:

1. Determining the list of IP networks in the topology
2. Determining the network type: **directly connec**ted network (**C** = Connected) or **remote network** (**S** = Static)
3. Defining the routing tree to each IP network identified in the previous steps
4. For each network, determining the **next hop** (in case of remote network) or the **router's interface** (in case of directly connected network) in order to reach the destination network

Routing Table

IP Routing Table

Network Destination	Netmask	Gateway	Interface	Metric
0.0.0.0	0.0.0.0	192.168.1.1	10	20
12.0.0.0	255.0.0.0	192.168.11.1	17	50
127.0.0.0	255.0.0.0	127.0.0.1	1	306
127.0.0.1	255.255.255.255	127.0.0.1	1	306
127.255.255.255	255.255.255.255	127.0.0.1	1	306
192.168.1.0	255.255.255.0	192.168.1.2	10	276
192.168.1.2	255.255.255.255	192.168.1.2	10	276
192.168.1.255	255.255.255.255	192.168.1.2	10	276
192.168.11.0	255.255.255.0	192.168.11.2	17	286
192.168.11.2	255.255.255.255	192.168.11.2	17	286
192.168.11.255	255.255.255.255	192.168.11.2	17	286
224.0.0.0	240.0.0.0	127.0.0.1	1	306
224.0.0.0	240.0.0.0	192.168.1.2	10	276
224.0.0.0	240.0.0.0	192.168.11.2	17	286
225.0.0.0	255.0.0.0	192.168.11.1	17	50
255.255.255.255	255.255.255.255	127.0.0.1	1	306
255.255.255.255	255.255.255.255	192.168.1.2	10	276
255.255.255.255	255.255.255.255	192.168.11.2	17	286

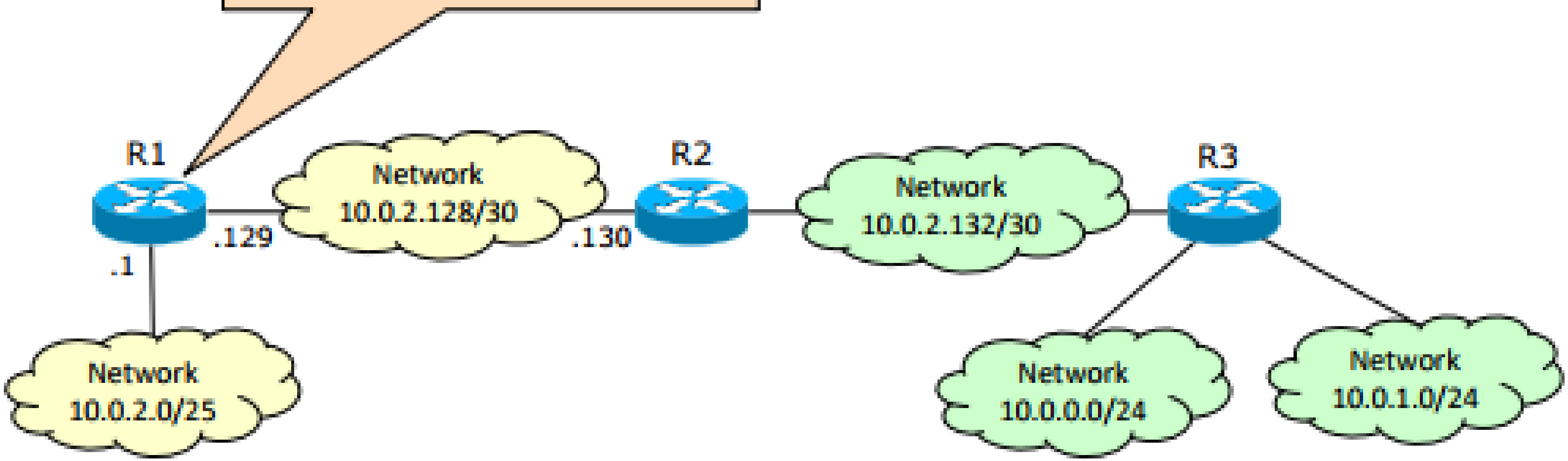
Next Hop

- We can consider *Hops* as the routers along a packet's path during its travel from a source to a destination.
- Whenever a packet passes a router, the hop count increases by one.
- In a network, the **next hop** is the next possible destination for a packet.
- Next hop is an IP address (an entry in a routing table belonging to a router), which specifies the next closest/most optimal router in its routing path.
- Every single router maintains its routing table with a next hop address for each network destination.

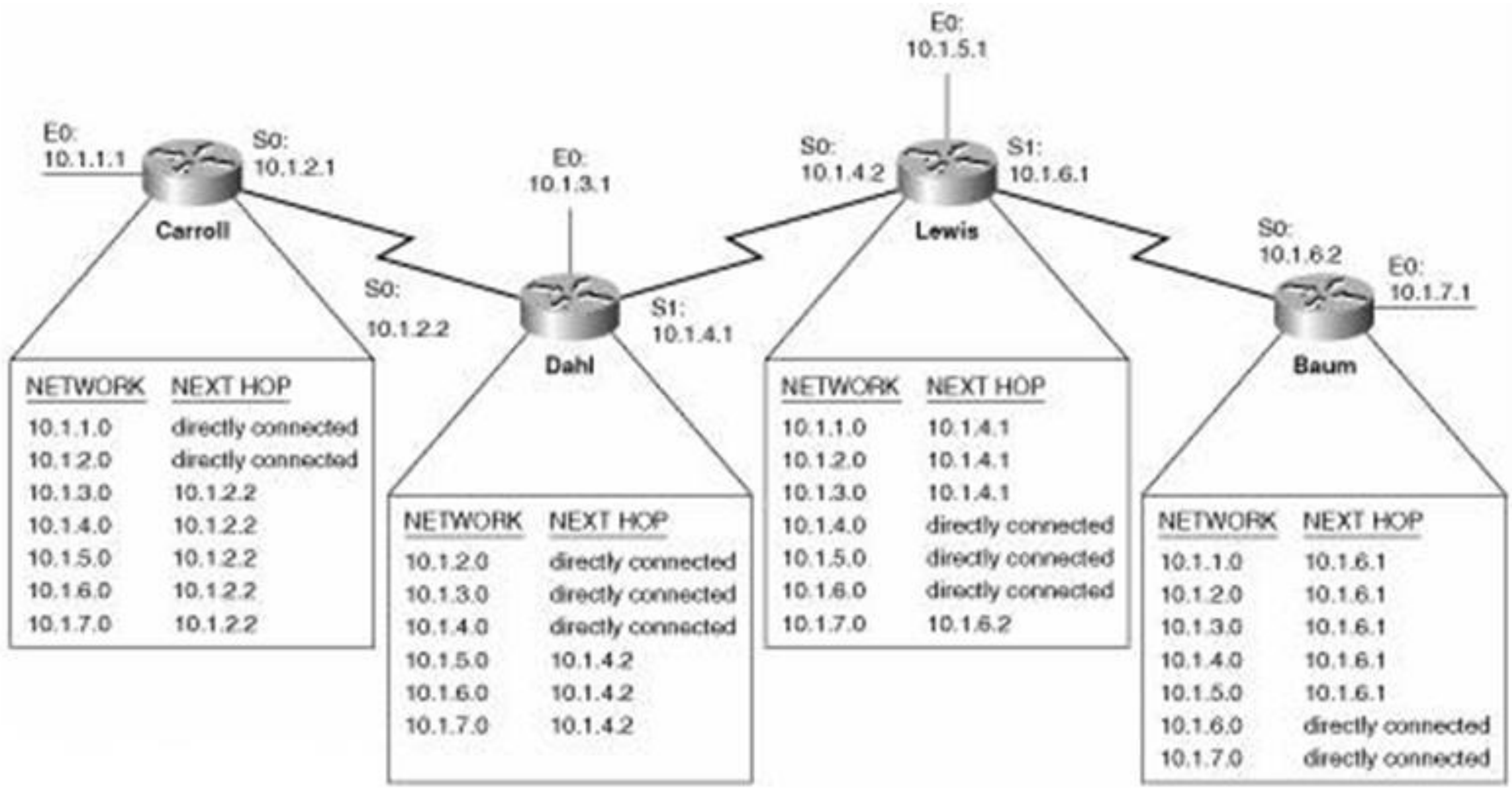
Routing Table

Routing table

Type	Network	NextHop	Cost
C	10.0.2.0/25	10.0.2.1	0
C	10.0.2.128/30	10.0.2.129	0
S	10.0.2.132/30	10.0.2.130	1
S	10.0.0.0/24	10.0.2.130	2
S	10.0.1.0/24	10.0.2.130	2



Routing Table



Router behavior

1. When a packet arrives at Router A, this router consults its routing table in order to find the best path towards the packet destination
2. Router A forwards the message to the interface specified by the routing table (best metric)
3. When the packet arrives a router directly connected to the destination network, its routing table indicates that the destination network is directly connected, so the router modifies the packet with the destination host MAC address and delivers the frame to the host

Forwarding decision

- When a packet arrives a router interface, its IP destination address is not a **network_id**, but a **host_id**
- In a routing table we have only the network_id, not the host_id of ALL HOSTS of ALL NETWORKS!!!
- We just need to find out what is the network_ID starting by an IP address and by the netmask

3 STEPS:

1. Convert both IP Address and Netmask into the equivalent binary
2. Make the logical AND operator between the IP Address and the Netmask
3. Convert the result into decimal -> We find the Network_ID

Forwarding decision – an example

- We have these networks:
  - 133.45.0.0/20
  - 133.45.4.0/22
  - 133.45.12.0/22
  - 133.45.16.0/20
  - 133.45.16.12/30

What is the network_ID of a packet having the IP destination address **133.45.16.5**?

Forwarding decision – an example

We convert both the netmask and the IP address 133.45.16.5 into binary:

- ✓ IP address: 10000101.00101101.00010000.00000101
- ✓ Netmask

/20: 255.255.240.0 = 11111111.11111111.11110000.00000000

/22: 255.255.252.0 = 11111111.11111111.11111100.00000000

/30: 255.255.255.252 = 11111111.11111111.11111111.11111100

Forwarding decision – an example

AND operator between IP address and each netmask

1. /20

10000101.00101101.00010000.00000101 AND
11111111.11111111.11110000.00000000 =
10000101.00101101.00010000.00000000 = 133.45.16.0

2. /22

10000101.00101101.00010000.00000101 AND
11111111.11111111.11111100.00000000 =
10000101.00101101.00010000.00000000 = 133.45.16.0

3. /30

10000101.00101101.00010000.00000101 AND
11111111.11111111.11111111.11111100=
10000101.00101101.00010000.00000100 = 133.45.16.4

Forwarding decision – an example

- Consider the network addresses **133.45.16.0** and **133.45.16.4,** are they among the following rows?
- IP Address -> 10000101.00101101.00010000.00000101
  - 133.45.0.0/20 -> **10000101.00101101.0000**0000.00000000
  - 133.45.4.0/22 -> **10000101.00101101.000001**00.00000000
  - 133.45.12.0/22-> **10000101.00101101.000011**00.00000000
  - **133.45.16.0**/20-> **10000101.00101101.0001**0000.00000000
  - 133.45.16.12/30-> **10000101.00101101.00010000.000011**00

If we have another row having the **133.45.16.0/24** as Network_ID, two entries will be verified!!!!! What happens???

Longest prefix match

Entry with the longer netmask wins!

Forwarding decision – an example

- Consider the network addresses **133.45.16.0** and **133.45.16.4,** are they among the following rows?
- IP Address -> 10000101.00101101.00010000.00000101

▪ 133.45.0.0/20 -> **10000101.00101101.0000**0000.00000000

▪ 133.45.4.0/22 -> **10000101.00101101.000001**00.00000000

▪ 133.45.12.0/22-> **10000101.00101101.000011**00.00000000

▪ **133.45.16.0**/20-> **10000101.00101101.0001**0000.00000000

▪ 133.45.16.4/30-> **10000101.00101101.00010000.000001**00

Exercise

- A router has the following routing table

Net_ID	PortNumber
151.64.0.0/10	Eth0
151.96.0.0/11	Eth1
151.0.0.0/8	Eth2
151.140.25.0/28	Eth3
151.100.25.0/28	Eth4

- What is the interface for the destination IP address **151.96.25.63**?

Exercise

- IP Address: 151.96.25.63 -> 10010111.01100000.00011001.00111111

- Routing Table
- 151.64.0.0/10 -> **10010111.01**000000.00000000.00000000
- **151.96.0.0/11** -> **10010111.011**00000.00000000.00000000
- 151.0.0.0/8 -> **10010111**.00000000.00000000.00000000
- 151.140.25.0/28-> **10010111.10001100.00011001.0000**0000

151.100.25.0/28 -> **10010111.01100100.00011001.0000**0000

Answer: Eth1!!