Introduction to IP Routing

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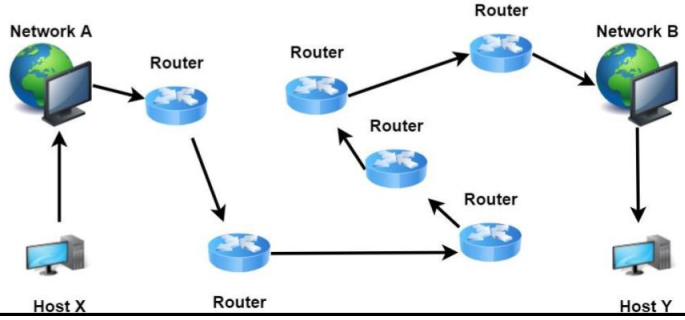
Routing Basics

- IP routing is the process of sending packets from a host on one network to another host on a different remote network
- This process is usually done by routers
- Routers use routing tables
- Routers don't really care about hosts—they care only about networks and the best path to each network



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Routing Basics

To be capable of routing packets, a router must know at least the following information:

- Destination network address
- Neighbor routers from which it can learn about remote networks
- Possible routes to all remote networks
- The best route to each remote network
- How to maintain and verify routing information

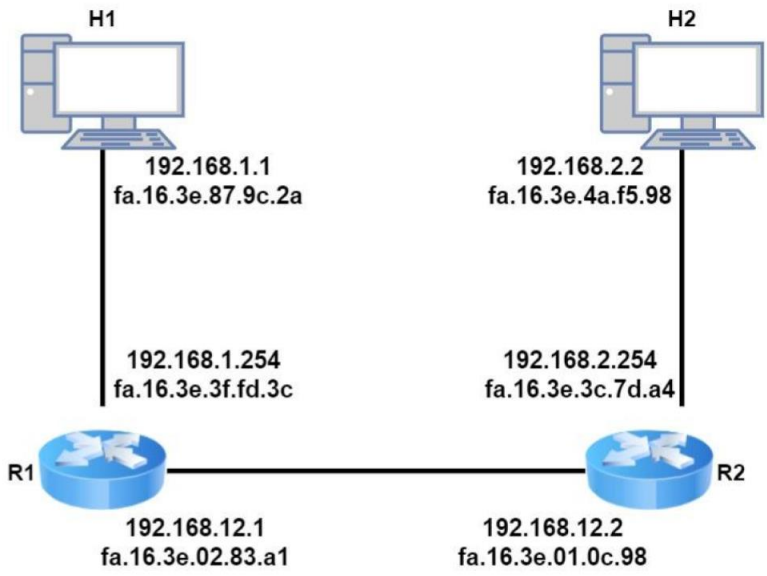
Routing Basics

- Each router maintains a routing table
- Routing table is used to determine the path to the destination network
- Each routing table consists of:
  - Network destination and subnet mask
  - Remote router – IP address of the router
  - Outgoing interface

```
[Comware] display ip routing-table
Routing Tables: Public
Destinations : 7 Routes : 7

Destination/Mask   Proto  Pre  Cost      NextHop         Interface
10.2.0.0/18        OSPF   10   110       10.1.1.5        Vlan3
10.2.64.0/18       OSPF   10   130       10.1.1.13       Vlan5
10.2.128.0/17      OSPF   10   30        10.1.1.5        Vlan3
10.2.192.0/17      OSPF   10   40        10.1.1.13       Vlan5
<-output omitted->
```

IP Routing Process



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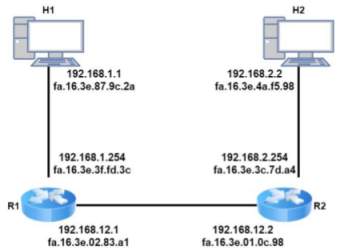
IP Routing Process

H1

IP Packet | Source: 192.168.1.1 | Destination: 192.168.2.2 | Data



Is the destination local or remote?

Looks own IP Address and Subnet Mask

Network ID is 192.168.1
Destination is remote

```
C:\Users\H1>ipconfig
Windows IP Configuration
Ethernet adapter Ethernet 1:
   Connection-specific DNS Suffix  . : nwl.local
   Link-local IPv6 Address . . . . . : fe80::88fd:962a:44d6:3a1f%4
   IPv4 Address. . . . . . . . . . . : 192.168.1.1
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Default Gateway . . . . . . . . . : 192.168.1.254
```

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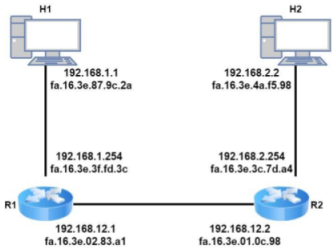
IP Routing Process

H1

The destination host is on another network, so I have to build an ethernet frame but do I know the destination MAC address of the default gateway?



Checks ARP Table

```
C:\Users\H1>arp -a
Interface: 192.168.1.1 --- 0x4
  Internet Address      Physical Address      Type
  192.168.1.254         fa-16-3e-3f-fd-3c     dynamic
  192.168.1.255         ff-ff-ff-ff-ff-ff     static
  224.0.0.22            01-00-5e-00-00-16     static
  224.0.0.251           01-00-5e-00-00-fb     static
  224.0.0.252           01-00-5e-00-00-fc     static
  239.255.255.250       01-00-5e-7f-ff-fa     static
```

Ethernet Frame

Source: FA16.3E87.9C2A	Destination: FA16.3E3F.FD3C	Source: 192.168.1.1	Destination: 192.168.2.2	Data

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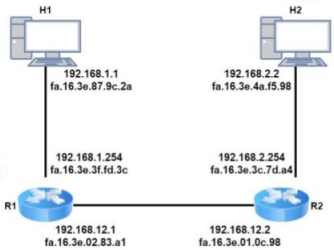
IP Routing Process

R1

I just received a frame. First, let's check if Frame Check Sequence (FCS) is correct or not.

FCS is wrong! → Drop the frame (No error recovery)

FCS is correct! → Process the frame



Preamble	SFD	Destination	Source	Type	IP Packet	FCS

Check destination MAC Address

The frame is addressed to me.
I need to de-encapsulate the IP packet.

Version	Header Length	Type of Service	Total Length	
Identification			IP Flags	Fragment Offset
Time to Live 255	Protocol		Header Checksum	
Source: 192.168.1.1				
Destination: 192.168.2.2				
IP Option				

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IP Routing Process

R1

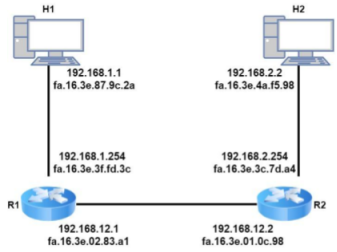
Version	Header Length	Type of Service	Total Length
Identification		IP Flags	Fragment Offset
Time to Live 255	Protocol	Header Checksum	
Source: 192.168.1.1			
Destination: 192.168.2.2			
IP Option			

Checksum is wrong!

Drop the IP packet (No error recovery)

Checksum is correct! **Look at destination address**

Version	Header Length	Type of Service	Total Length
Identification		IP Flags	Fragment Offset
Time to Live 255	Protocol	Header Checksum	
Source: 192.168.1.1			
Destination: 192.168.2.2			
IP Option			



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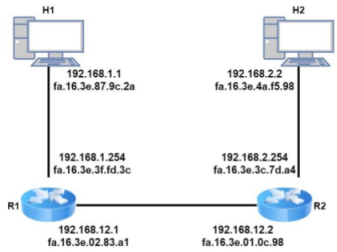
12

IP Routing Process

R1

Version	Header Length	Type of Service	Total Length
Identification		IP Flags	Fragment Offset
Time to Live 255	Protocol	Header Checksum	
Source: 192.168.1.1			
Destination: 192.168.2.2			
IP Option			



Check routing table if destination address matches any

```
R1#show ip route

Gateway of last resort is not set

      192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.1.0/24 is directly connected, GigabitEthernet0/1
L        192.168.1.254/32 is directly connected, GigabitEthernet0/1
S     192.168.2.0/24 [1/0] via 192.168.12.2
      192.168.12.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.12.0/24 is directly connected, GigabitEthernet0/2
L        192.168.12.1/32 is directly connected, GigabitEthernet0/2
```

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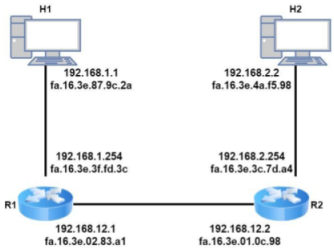
IP Routing Process

R1

Version	Header Length	Type of Service	Total Length
Identification		IP Flags	Fragment Offset
Time to Live 254	Protocol	Header Checksum	
Source: 192.168.1.1			
Destination: 192.168.2.2			
IP Option			

Decrease TTL by 1



Check ARP table if destination address (192.168.12.2) matches any

```
R1#show ip arp
Protocol  Address          Age (min)  Hardware Addr   Type   Interface
Internet  192.168.1.1             58   fa16.3e87.9c2a  ARPA   GigabitEthernet0/1
Internet  192.168.1.254            -   fa16.3e3f.fd3c  ARPA   GigabitEthernet0/1
Internet  192.168.12.1             -   fa16.3e02.83a1  ARPA   GigabitEthernet0/2
Internet  192.168.12.2            95   fa16.3e01.0c98  ARPA   GigabitEthernet0/2
```

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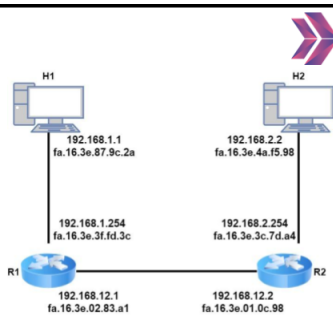
IP Routing Process

R1

- Build a new frame and send to R2

Source: FA16.3E02.83A1	Destination: FA16.3E01.0C98	Source: 192.168.1.1	Destination: 192.168.2.2	Data



R2

- Check the FCS of the Ethernet frame
- De-encapsulate the IP packet, discard the frame
- Check the IP header checksum
- Check the destination IP address

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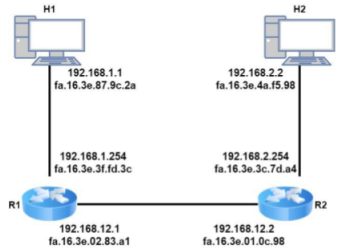
IP Routing Process

R2 Check its routing table for destination IP address

Source: FA16.3E87.9C2A	Destination: FA16.3E01.0C98	Source: 192.168.1.1	Destination: 192.168.2.2	Data




```
R2#show ip arp
S       192.168.1.0/24 [1/0] via 192.168.12.1
        192.168.2.0/24 is variably subnetted, 2 subnets, 2 masks
C          192.168.2.0/24 is directly connected, GigabitEthernet0/1
L          192.168.2.254/32 is directly connected, GigabitEthernet0/1
        192.168.12.0/24 is variably subnetted, 2 subnets, 2 masks
C          192.168.12.0/24 is directly connected, GigabitEthernet0/2
L          192.168.12.2/32 is directly connected, GigabitEthernet0/2
```

Decrease TTL to 253 and check the ARP table if destination address (192.168.2.2) matches any

```
R2#show ip arp
Protocol  Address          Age (min)  Hardware Addr   Type   Interface
Internet  192.168.2.2            121  fa16.3e4a.f598  ARPA   GigabitEthernet0/1
Internet  192.168.2.254            -  fa16.3e3c.7da4  ARPA   GigabitEthernet0/1
Internet  192.168.12.1           111  fa16.3e02.83a1  ARPA   GigabitEthernet0/2
Internet  192.168.12.2             -  fa16.3e01.0c98  ARPA   GigabitEthernet0/2
```

C

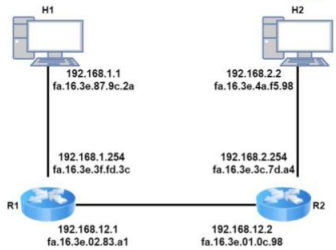
16

IP Routing Process

R2

- Build a new frame and send to H2

Source: FA16.3E3C.7DA4	Destination: FA16.3E4A.F598	Source: 192.168.1.1	Destination: 192.168.2.2	Data



H2

- Checks the FCS
- Finds its own MAC address as the destination MAC address
- De-encapsulates the IP packet from the frame
- Finds its own IP address as the destination in the IP packet

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17

IP Routing Process

The host has a simple decision to make:

- Is the destination on the local network?
  - Check ARP table for **destination** IP address, if empty, send an ARP request.
- Is the destination on a remote network?
  - Check ARP table for **default gateway** IP address, if empty, send an ARP request.

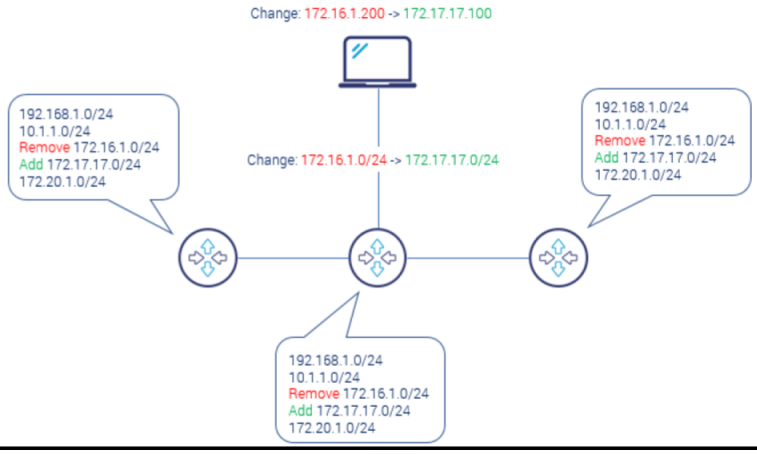
IP Routing Process

The router has to perform a number of tasks:

- When it receives an Ethernet frame, checks if the FCS is correct. If not, drops the frame
- Checks if the destination address of the frame is:
  - destined to router's MAC address
  - destined to a broadcast address of the network router's interface is in
  - destined to a multicast address that the router listens to
- De-encapsulates the IP packet from the frame, discard the Ethernet frame
- Looks for a match in the routing table for the destination IP address, figures out what the outgoing interface and optionally, the next hop IP address is
- Decreases the TTL field in the IP header, recalculates the header checksum
- Encapsulates the IP packet in a **new Ethernet frame**
- Checks the ARP table for the destination IP address or next hop IP address
- Transmits the frame

Static and Dynamic Routing

- How routers know the IP destinations?
- In static routing (or non-adaptive) routing, tables created and updated manually



Static and Dynamic Routing

- In dynamic routing (or adaptive) routing, tables created and updated automatically using **routing protocols**
- Dynamic routing is used in larger networks
- Finds the optimal route (shortest path)
- Reacts to topology changes and failures, recalculates optimal path

Static and Dynamic Routing

Static	Dynamic
Routes are user defined	Routes are updated according to the topology
Does not use complex routing algorithms	Uses complex routing algorithms
Provides high or more security	Provides less security
Manual	Automated
Implemented in small networks	Implemented in large networks
Additional resources are not required	Additional resources are required