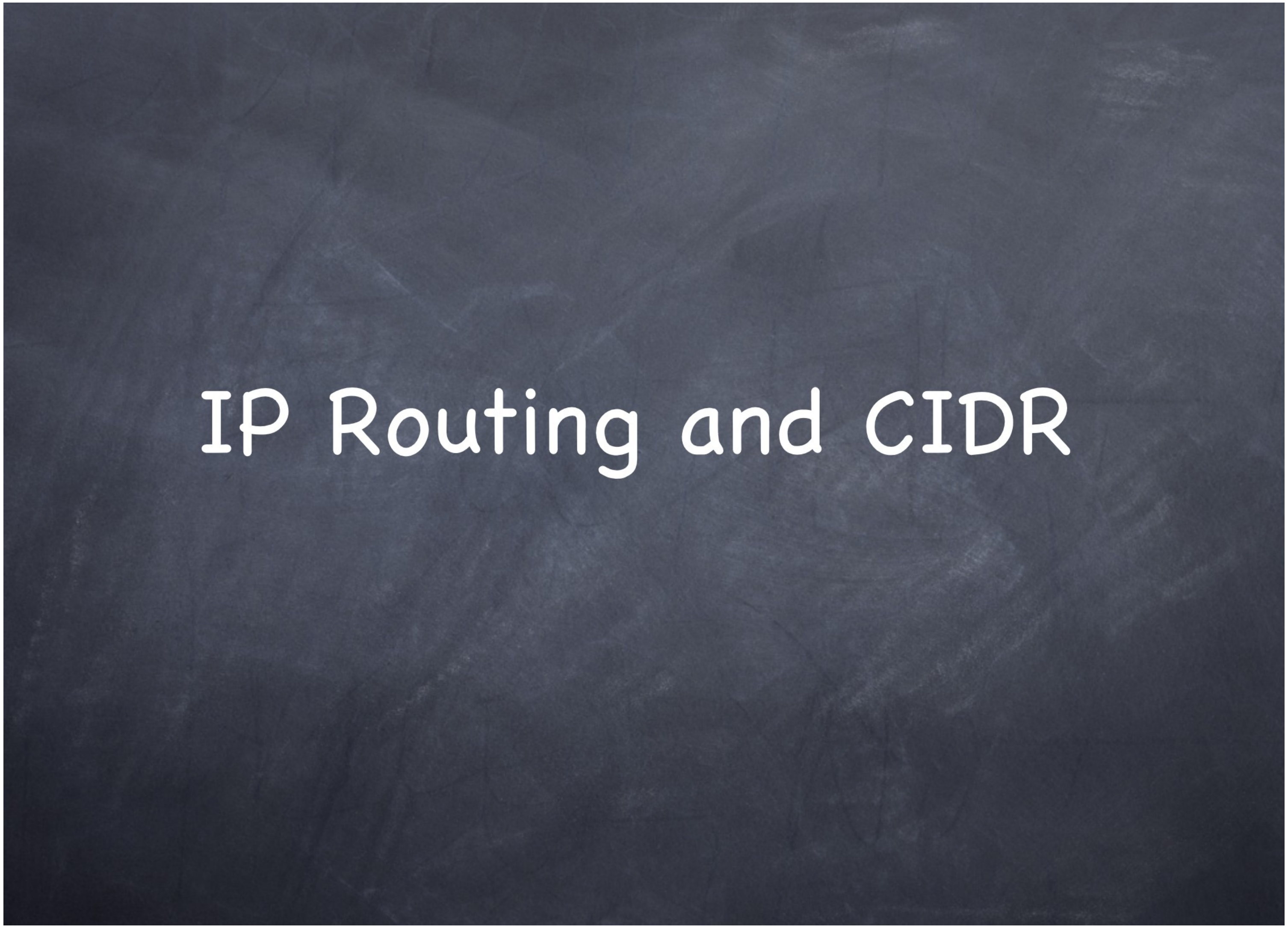
# IT 609
# Network and System Administration

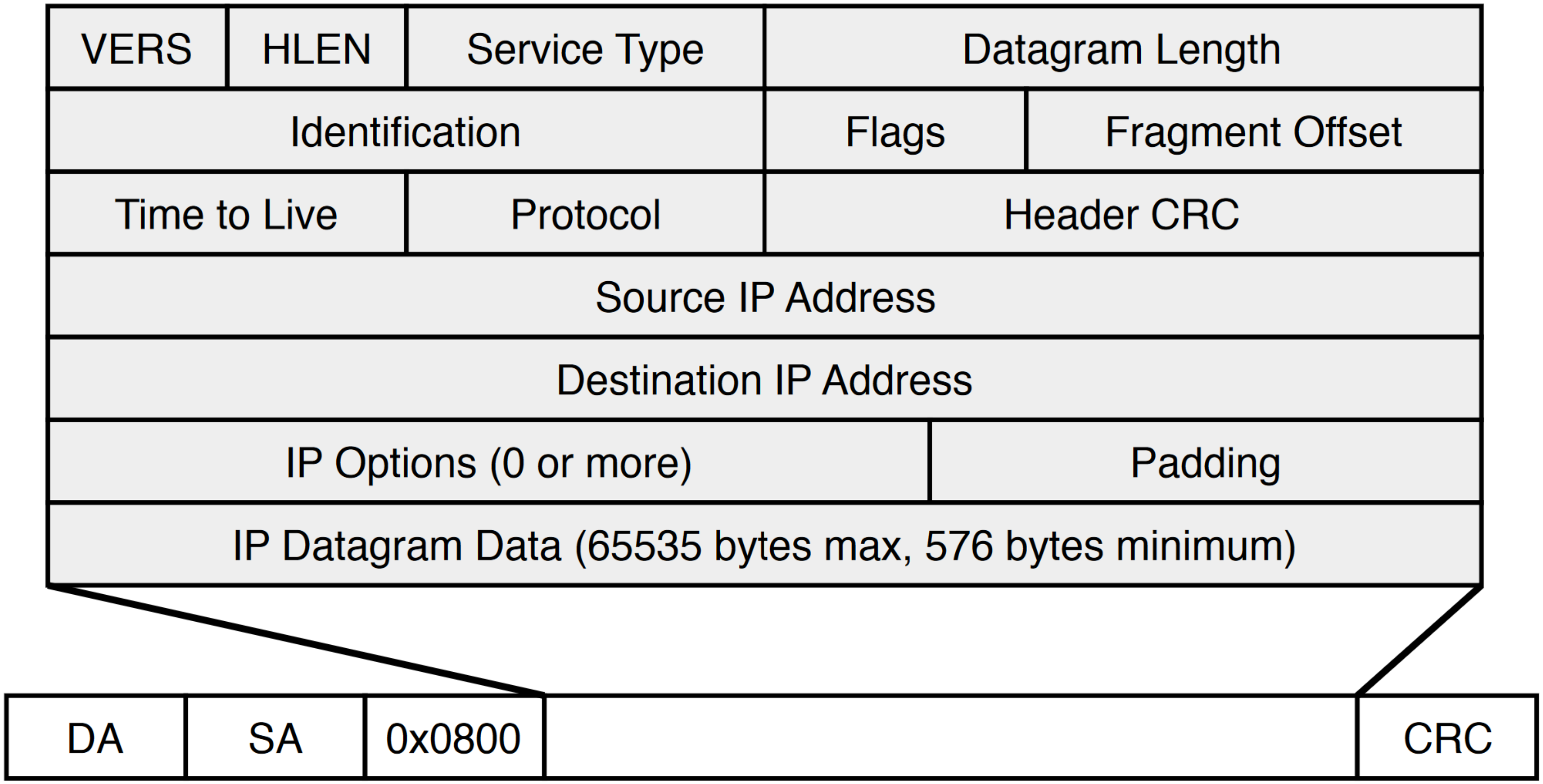
# IP Routing and CIDR

Tuesday November 02, 2021

# IP Routing and CIDR



# IP Packets




Just plain old data to Level 2

# Routers

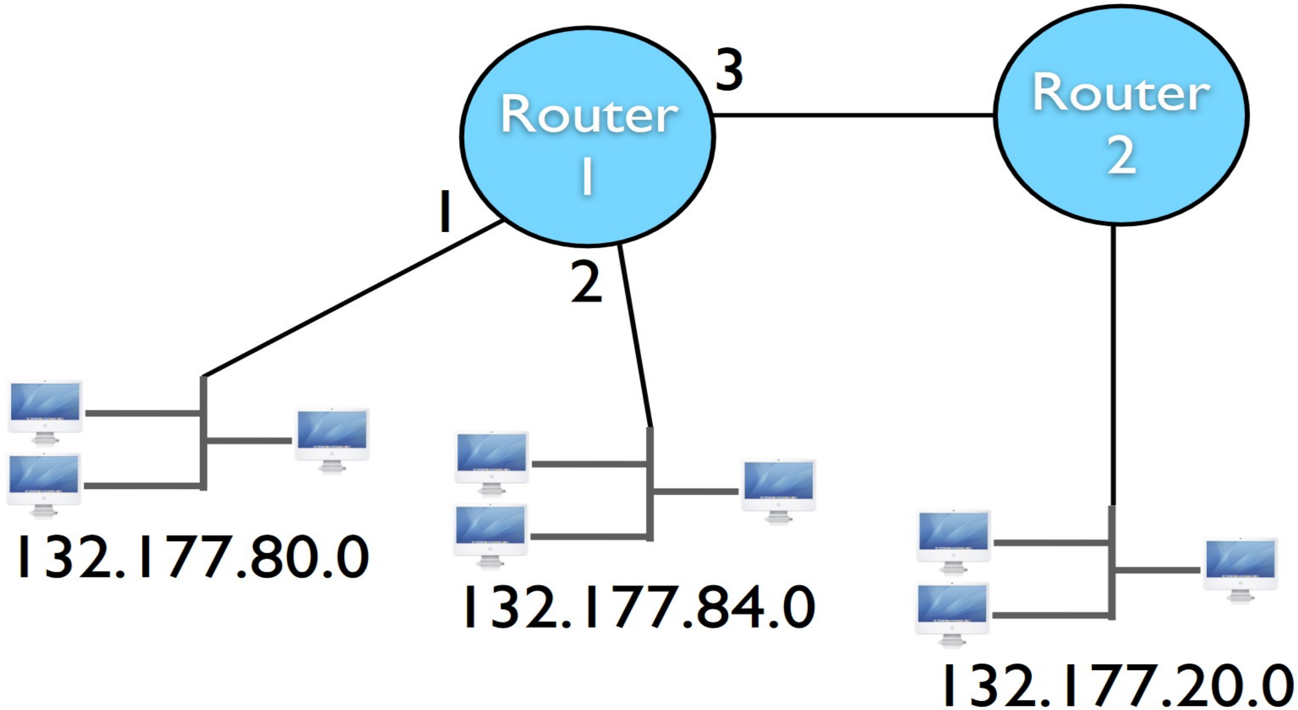
Routers are the devices that connect networks together and direct traffic from one network to the next

Routing Table - records kept in memory about which networks a router can reach

Routers can be either specialized devices or software that runs on an ordinary computer

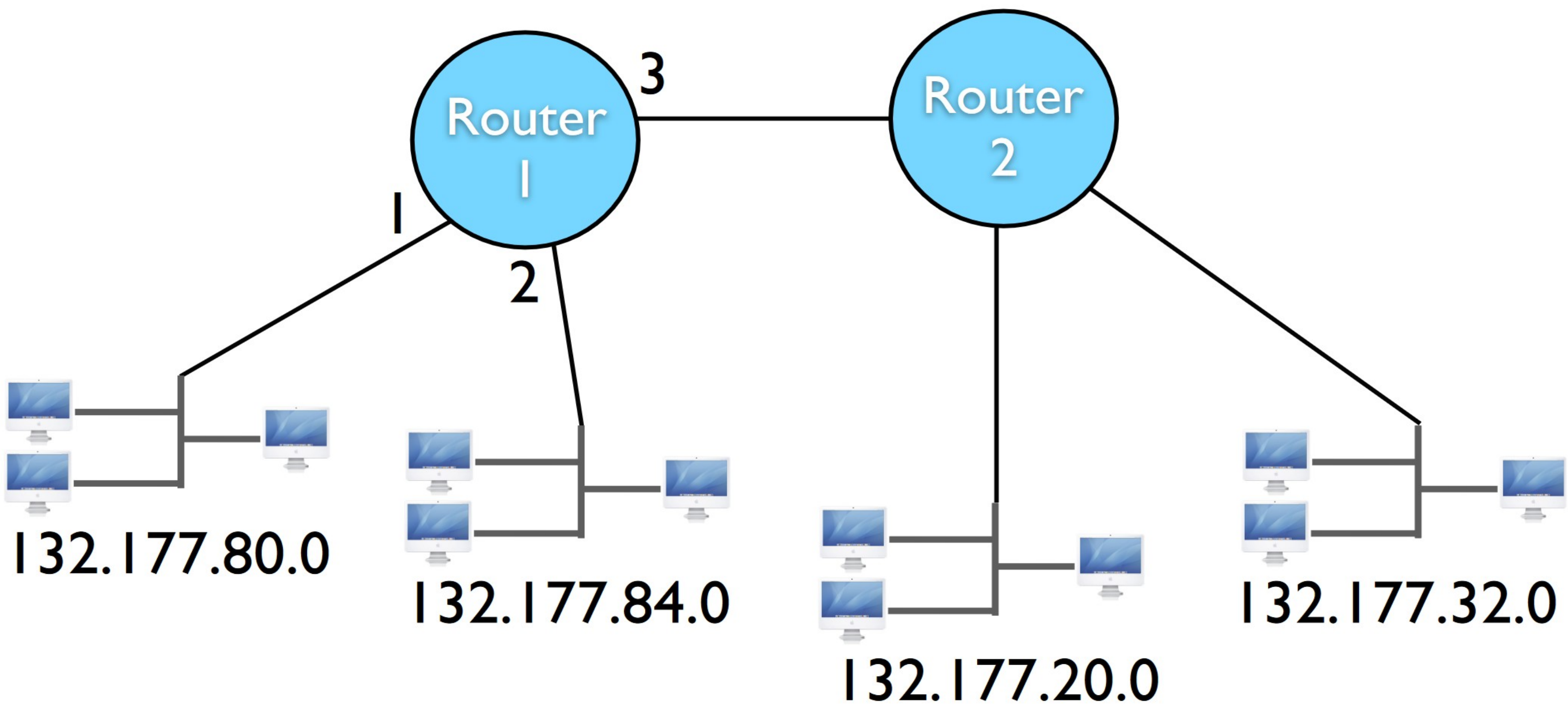
# Routing Table Example

| Routing Table | |
|---|---|
| Network | Interface |
| 132.177.80.0 | 1 |
| 132.177.84.0 | 2 |
| 132.177.20.0 | 3 |



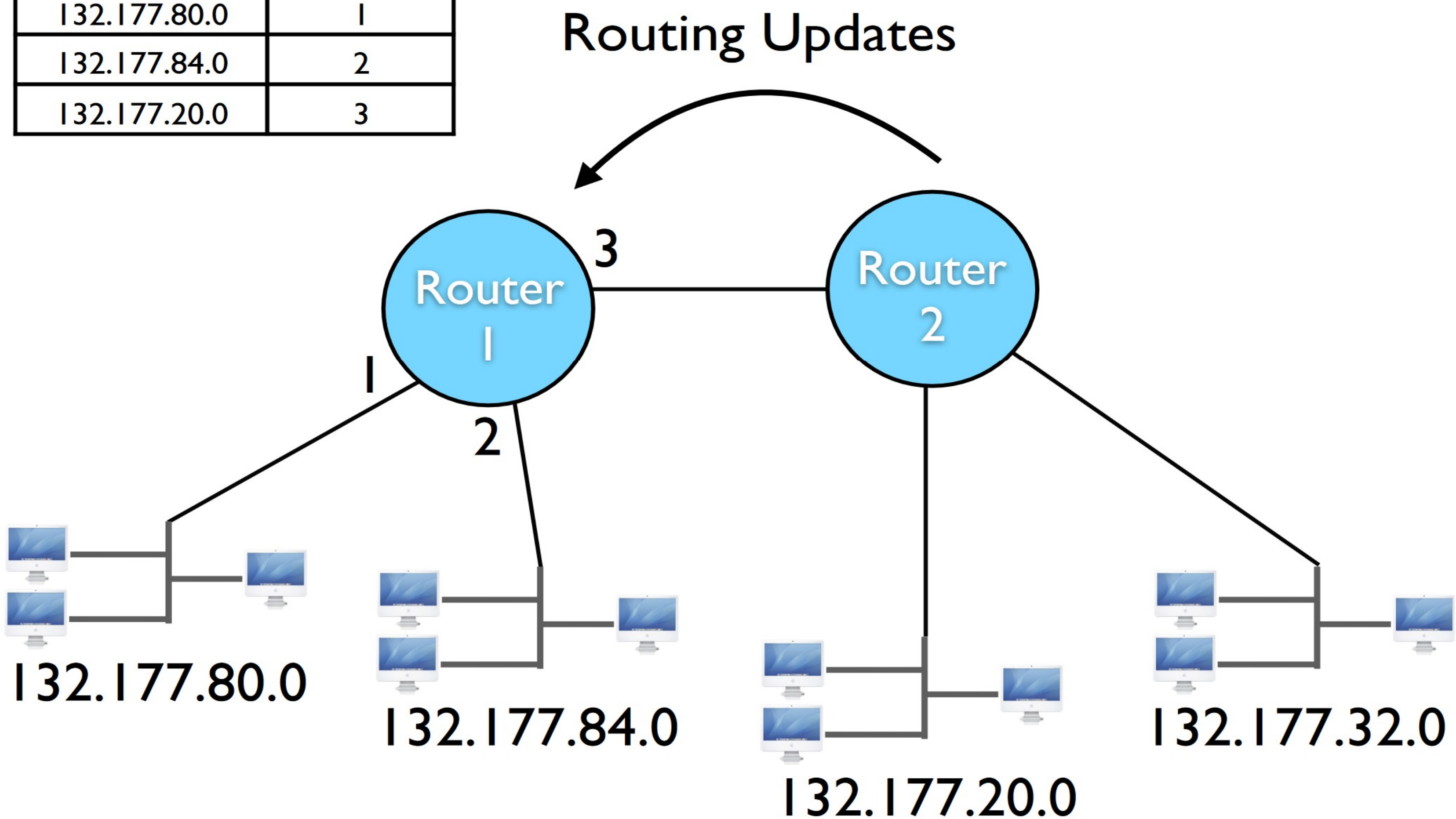
# Routing Table Example

| Routing Table | |
|---|---|
| Network | Interface |
| 132.177.80.0 | 1 |
| 132.177.84.0 | 2 |
| 132.177.20.0 | 3 |



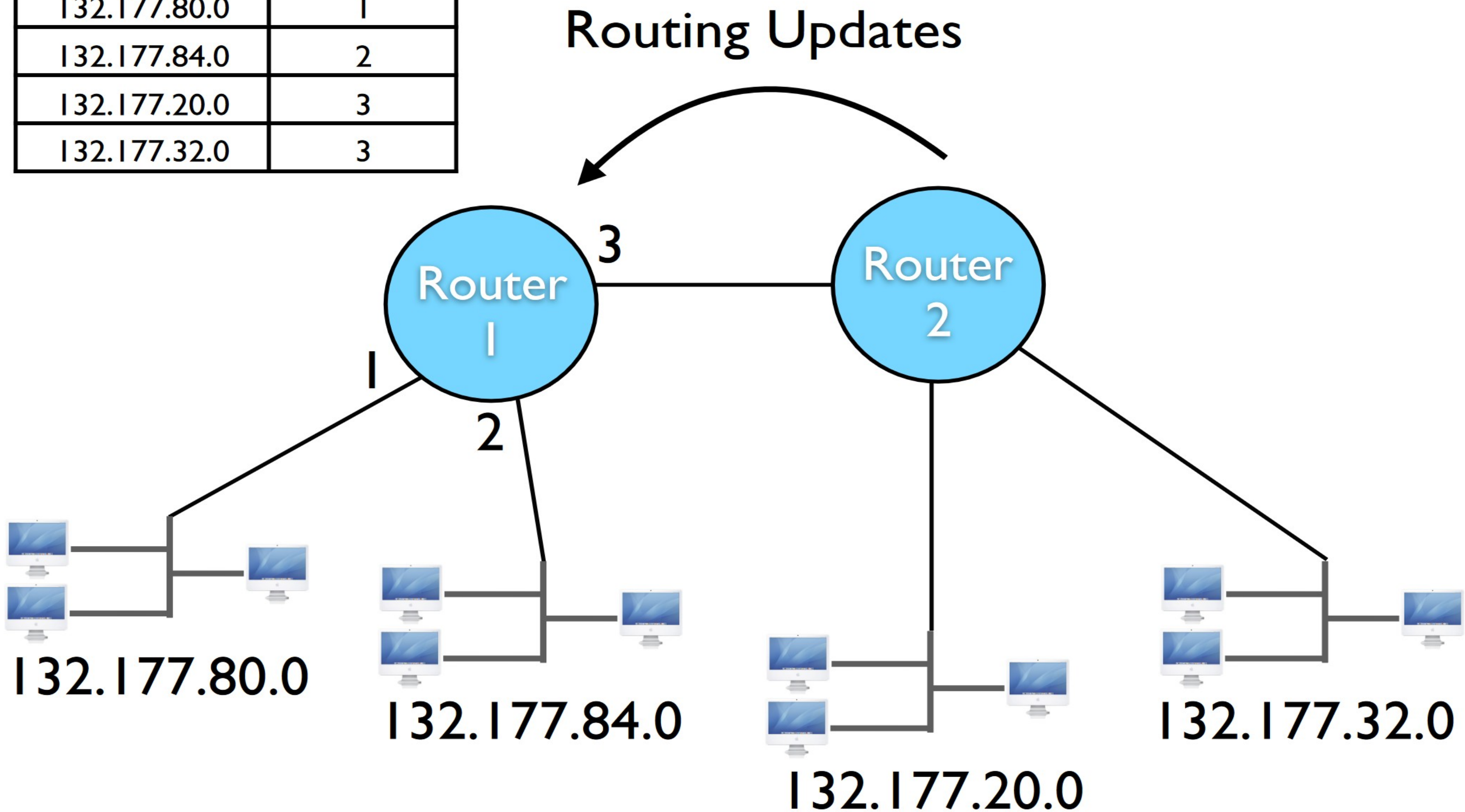
# Routing Table Example

| Routing Table | |
|---|---|
| Network | Interface |
| 132.177.80.0 | 1 |
| 132.177.84.0 | 2 |
| 132.177.20.0 | 3 |



# Routing Table Example

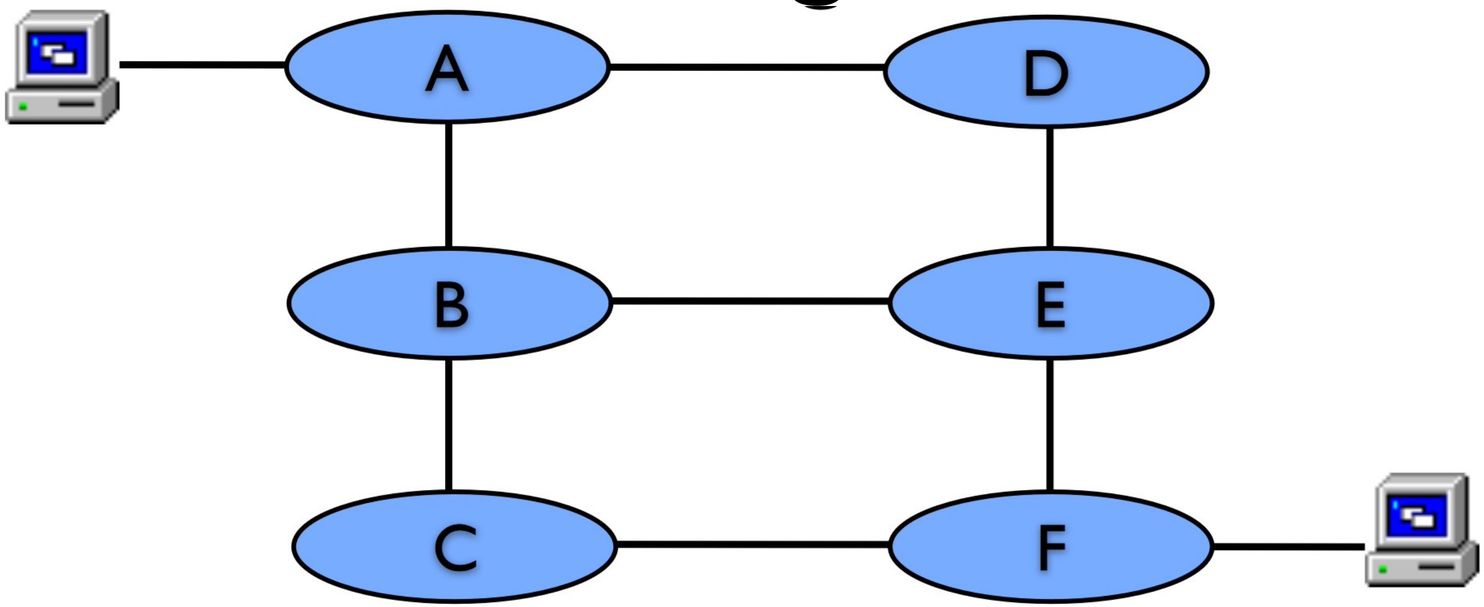
| Routing Table | |
|---|---|
| Network | Interface |
| 132.177.80.0 | 1 |
| 132.177.84.0 | 2 |
| 132.177.20.0 | 3 |
| 132.177.32.0 | 3 |



# Routing Protocols

- Routing protocols refer to how routers communicate with each other
- Routing protocols pair with routing algorithms - how the specific route is chosen
- Interior gateway routing
  - Internal to an autonomous system
  - RIP, OSPF are most common
- Exterior gateway routing
  - Connecting autonomous systems
  - BGPv4 - Internet's protocol

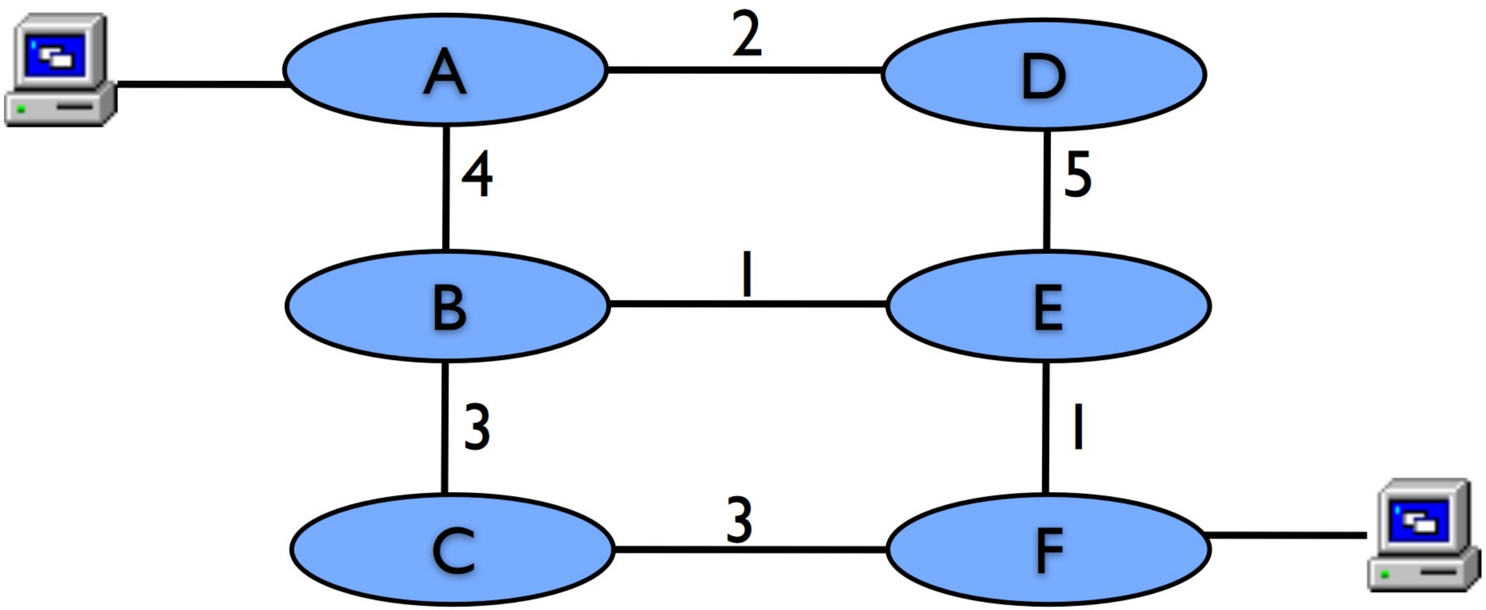
# IP Routing - RIP




Router A's Routing Table

| A | B | C | D | E | F |
|---|---|---|---|---|---|
| 0 | 1 | 2 (B) | 1 | 2 (B) | 3 (D) |
| | | 4 (D) | | 2 (D) | 3 (B) |
| | | | | | |

# IP Routing - OSPF

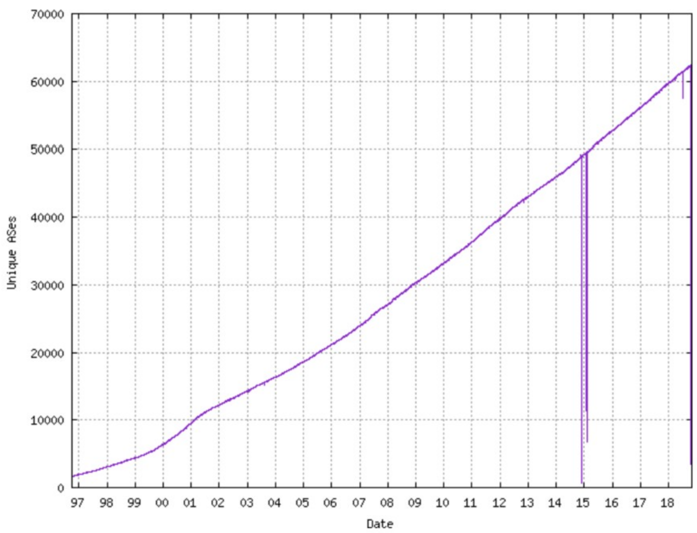



Generalized Routing Table

| A | B | C | D | E | F |
|---|---|---|---|---|---|
| B - 4 | A - 4 | B - 3 | A - 2 | B - 1 | C - 3 |
| D - 2 | C - 3 | F - 3 | E - 5 | D - 5 | E - 1 |
| | E - 1 | | | F - 1 | |

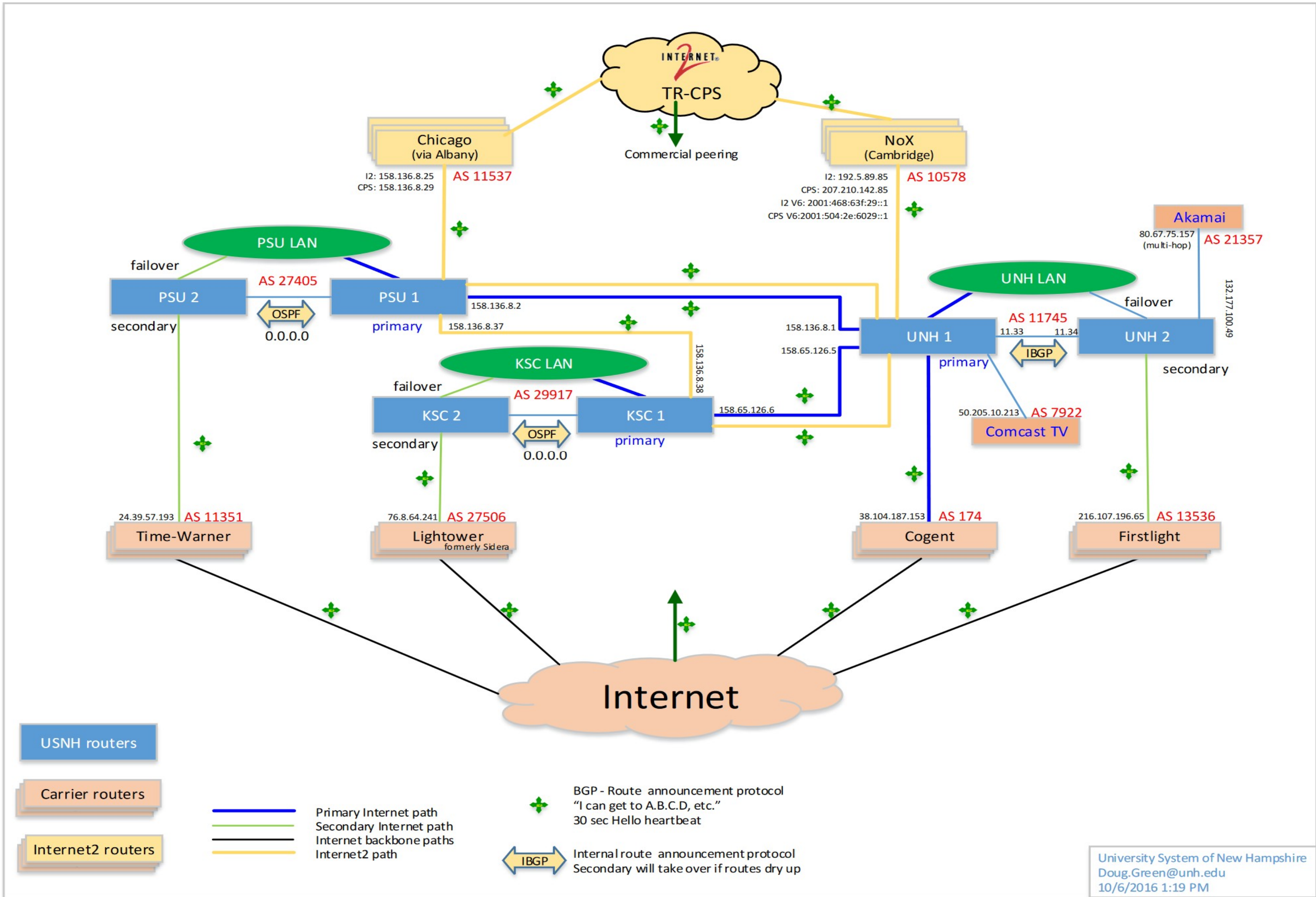
# ASN

- Autonomous System Numbers
  - Unique numbers assigned to each AS within the Internet routing structure
  - 32 bits long
- Assigned by IANA
- Currently 55,000+
- UNH = AS11745
- http://bgp.he.net/AS11745




http://www.cidr-report.org, 2018-10-30

# ASN



TR-CPS
Commercial peering
Chicago
(via Albany)
I2: 158.136.8.25
CPS: 158.136.8.29
AS 11537
NoX
(Cambridge)
I2: 192.5.89.85
CPS: 207.210.142.85
I2 V6: 2001:468:63f:29::1
CPS V6:2001:504:2e:6029::1
AS 10578
Akamai
80.67.75.157
(multi-hop)
AS 21357
PSU LAN
failover
AS 27405
PSU 2
PSU 1
OSPF
0.0.0.0
secondary
primary
158.136.8.2
158.136.8.37
UNH LAN
failover
AS 11745
UNH 1
UNH 2
11.33
11.34
IBGP
primary
secondary
158.136.8.1
158.65.126.5
132.177.100.49
KSC LAN
failover
AS 29917
KSC 2
KSC 1
OSPF
0.0.0.0
secondary
primary
158.136.8.38
158.65.126.6
50.205.10.213
AS 7922
Comcast TV
24.39.57.193
AS 11351
Time-Warner
76.8.64.241
AS 27506
Lightower
formerly Sidera
38.104.187.153
AS 174
Cogent
216.107.196.65
AS 13536
Firstlight
Internet
USNH routers
Carrier routers
Internet2 routers
Primary Internet path
Secondary Internet path
Internet backbone paths
Internet2 path
BGP - Route announcement protocol
"I can get to A.B.C.D, etc."
30 sec Hello heartbeat
IBGP
Internal route announcement protocol
Secondary will take over if routes dry up
University System of New Hampshire
Doug.Green@unh.edu
10/6/2016 1:19 PM

# IP Routing - BGP

Border Gateway Protocol

Vector path protocol

Routers update their neighbors with ASNs that they can reach

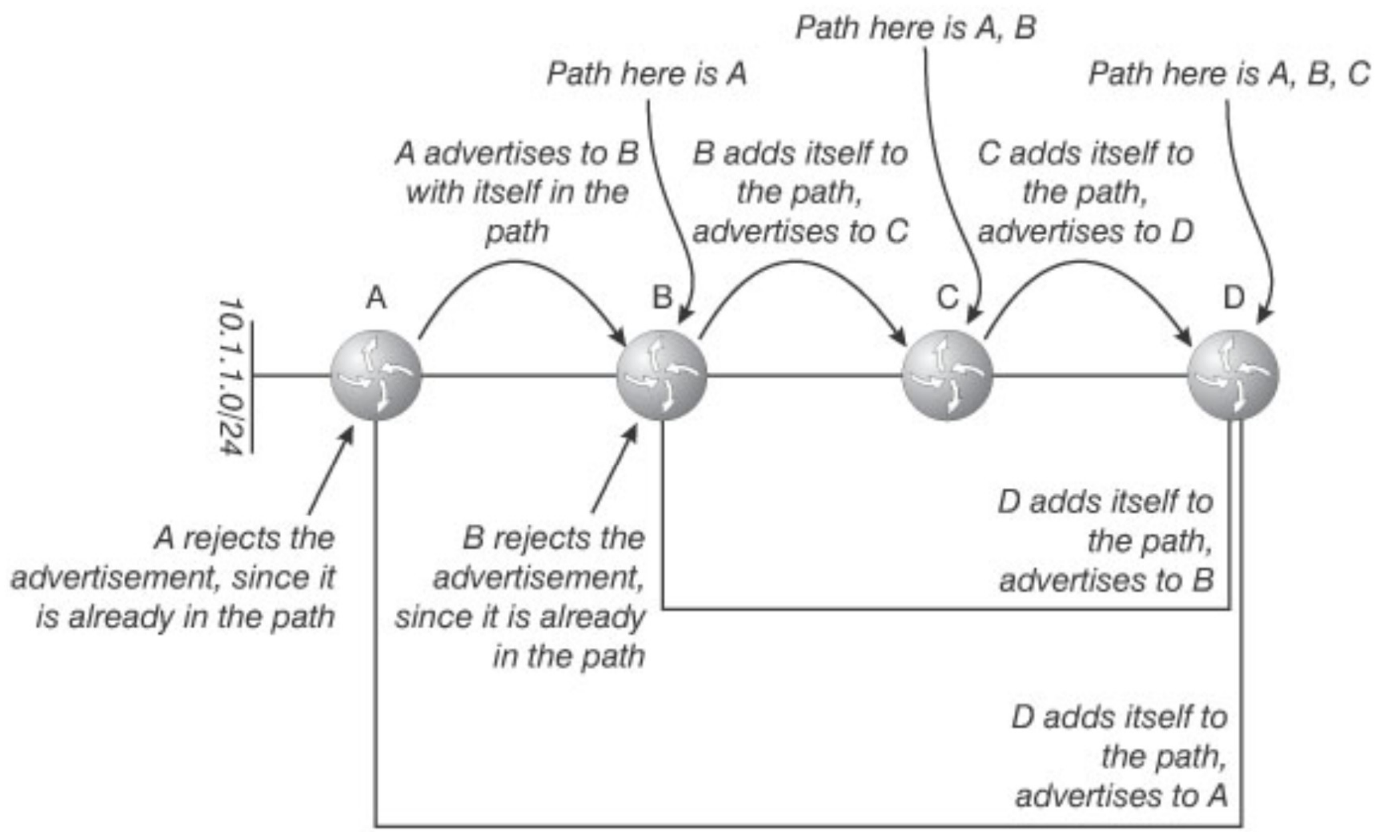
Information propagates slowly

Routers ignore routes that contain themselves to prevent loops

Only relevant if you have multiple routes!

BGP "looking glass" systems allow you to see what the Internet knows about your network

# IP Routing - BGP



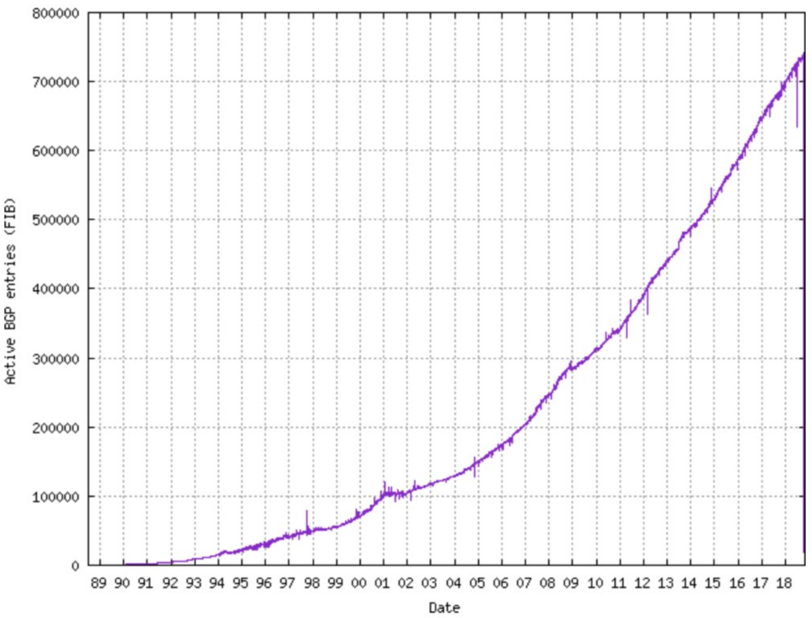

http://www.informit.com/articles/article.aspx?p=331613&seqNum=2

# BGP Routing Tables

As the Internet has grown, so as the BGP table

The larger the table, the harder for routers to do their job

And it would have been a lot worse…




http://www.cidr-report.org, 2018-10-30

# Subnetting

Allows local admins to divide an IP range into more networks with fewer hosts

Cuts down the scope of IP broadcasts

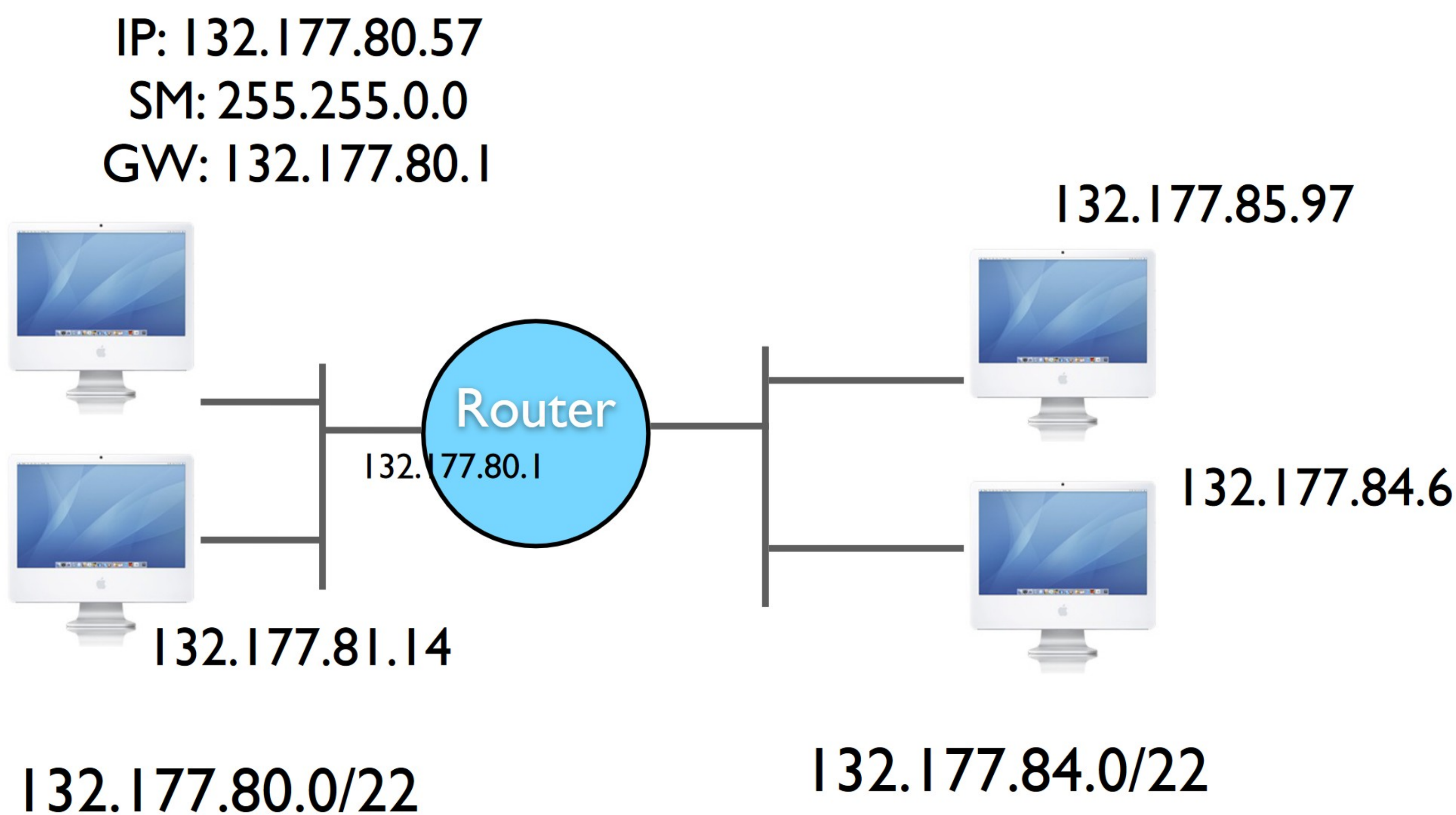
Allows for security restrictions

More efficient use of IP address space

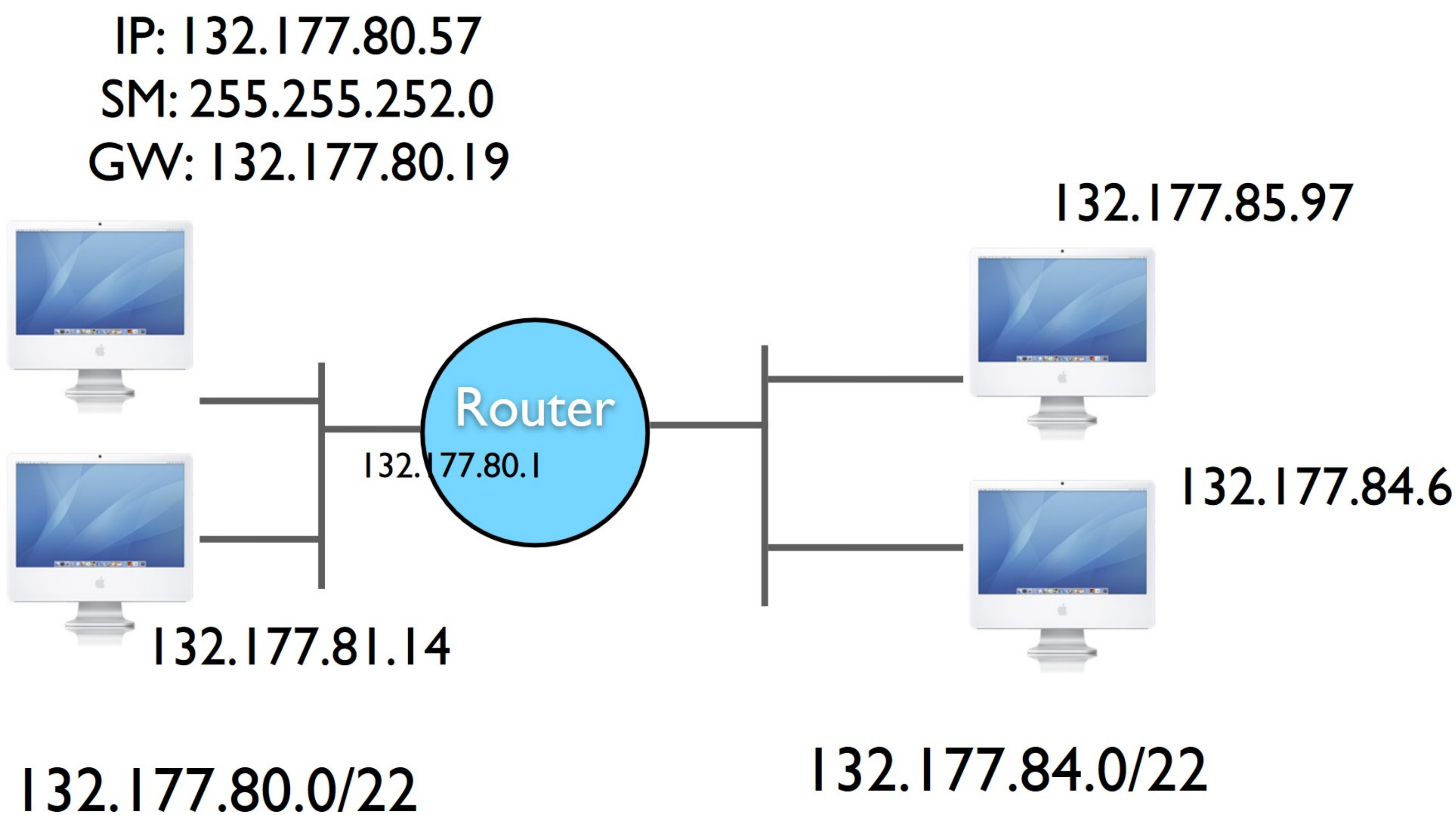
**<u>Must</u>** match the physical (or VLAN) network

- Impossible to have 65000 (Class B) hosts on one Ethernet segment
- All devices within an IP subnet must be in the same broadcast domain or APR won't work

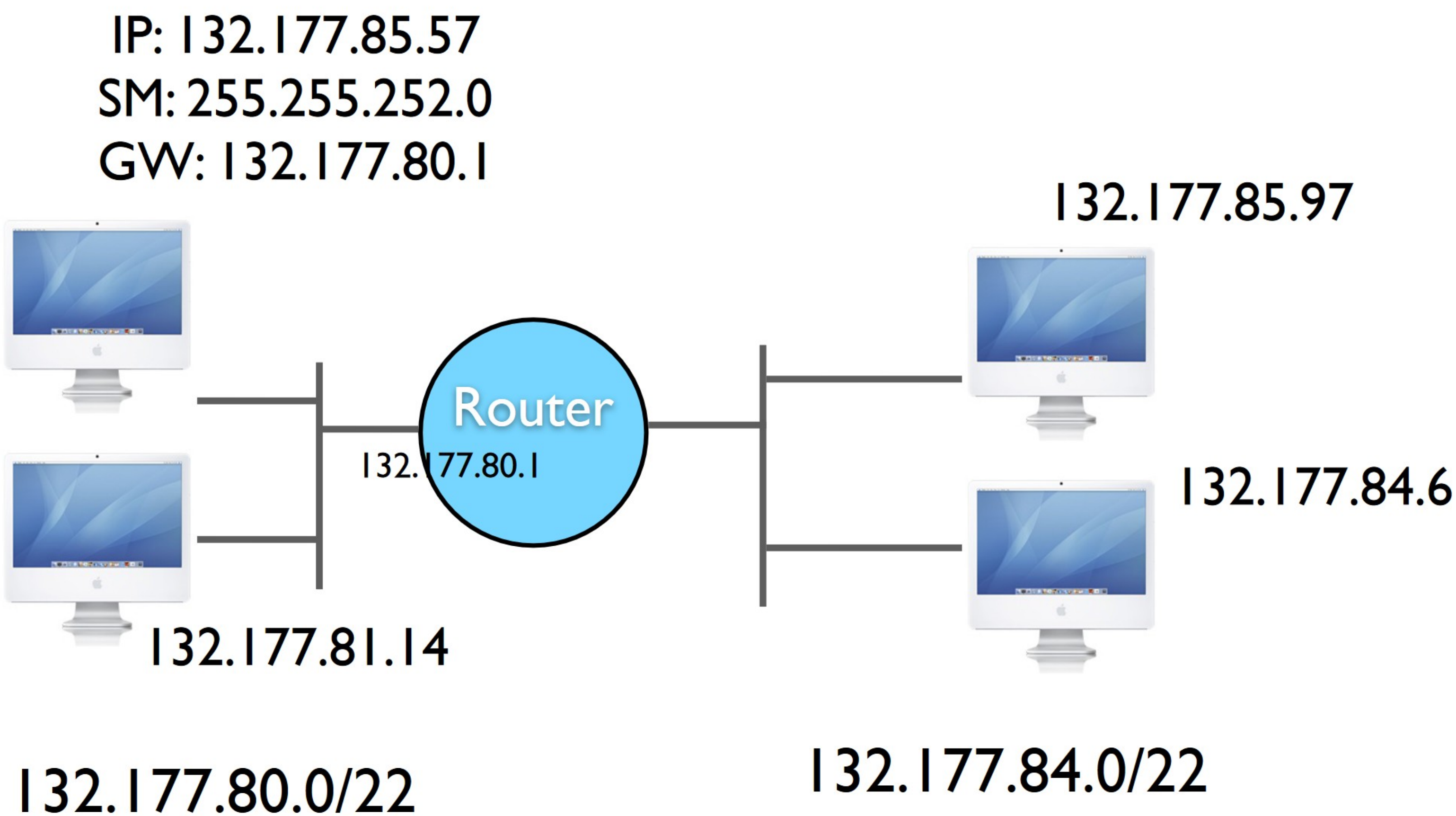
# Wrong Subnet Mask



# Wrong Gateway



# IP from Wrong Subnet



# Subnetting Examples

UNH - 132.177.0.0/16

Standard mask - 255.255.0.0

1 Network

65534 Hosts

UNH - 132.177.0.0/22

Subnetted mask - 255.255.252.0

64 Networks

1022 Hosts

# Special Addresses in a Subnet

Lowest address = the address of the subnet itself

Highest address = broadcast to all devices in that subnet

For example, in 132.177.80.0/22

- 132.177.80.0 is the subnet address
- 132.177.83.255 is the broadcast address

This means for any size subnet, you have two addresses that cannot be assigned to devices

If you need to communicate outside of the subnet, you also need a gateway router address

- Often the lowest usable IP address is the router
- Ex. 132.177.80.1

# Useful Subnet Masks

| Prefix | Subnet Mask | Useable Host Addresses |
|---|---|---|
| /16 | 255.255.0.0 | 2^16 - 2 = 65534 |
| /17 | 255.255.128.0 | 2^15 - 2 = 32766 |
| /18 | 255.255.192.0 | 2^14 - 2 = 16382 |
| /19 | 255.255.224.0 | 2^13 - 2 = 8190 |
| /20 | 255.255.240.0 | 2^12 - 2 = 4094 |
| /21 | 255.255.248.0 | 2^11 - 2 = 2046 |
| /22 | 255.255.252.0 | 2^10 - 2 = 1022 |
| /23 | 255.255.254.0 | 2^9 - 2 = 510 |
| /24 | 255.255.255.0 | 2^8 - 2 = 254 |
| /25 | 255.255.255.128 | 2^7 - 2 = 126 |
| /26 | 255.255.255.192 | 2^6 - 2 = 62 |
| /27 | 255.255.255.224 | 2^5 - 2 = 30 |
| /28 | 255.255.255.240 | 2^4 - 2 = 14 |
| /29 | 255.255.255.248 | 2^3 - 2 = 6 |
| /30 | 255.255.255.252 | 2^2 - 2 = 2 |

# Internet Routing Today

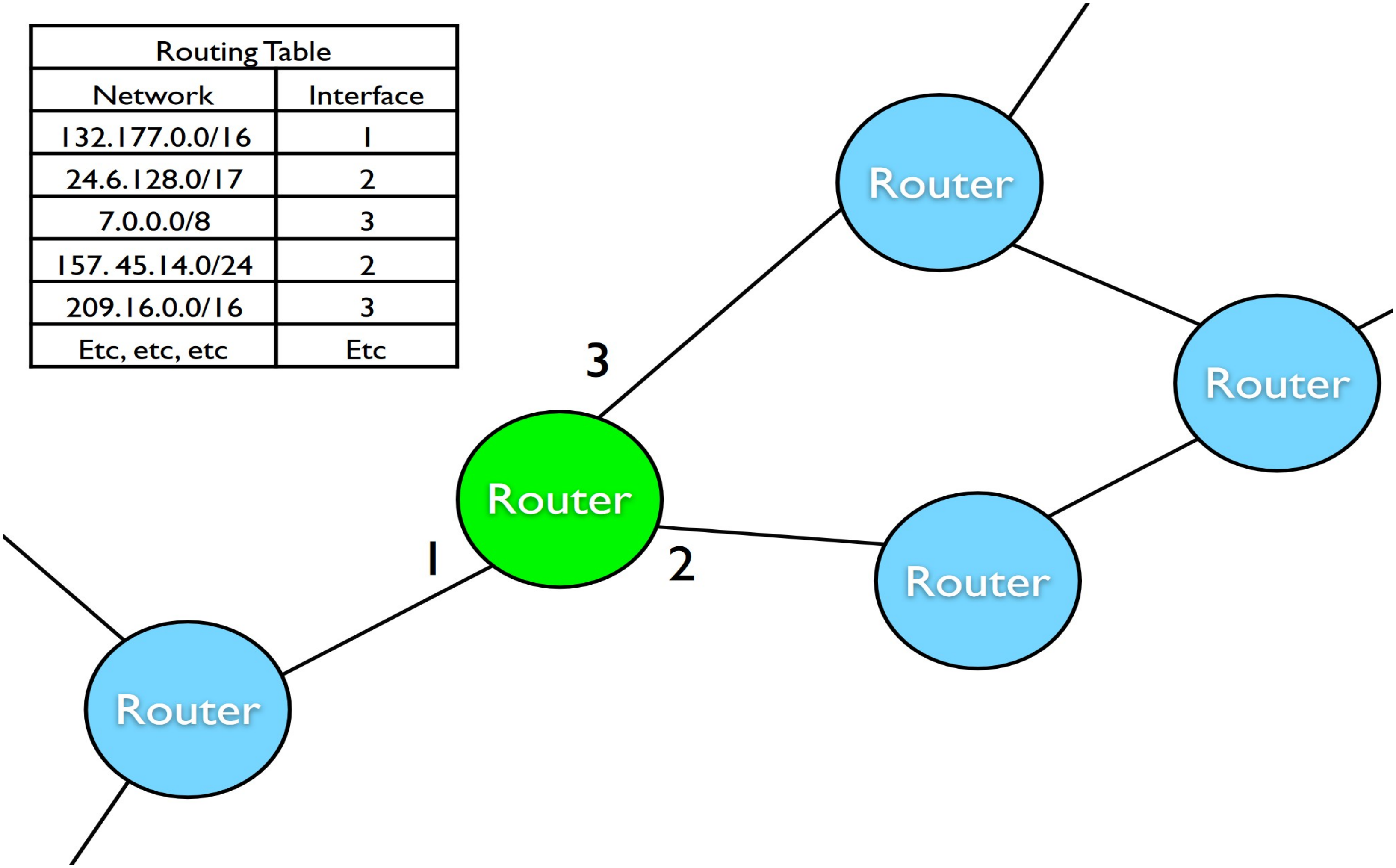
- Class-based determination of network addresses is no longer used
  - Too limiting
  - Inefficient in use of address space
  - Routing tables would be huge!
- CIDR - Classless Internet Domain Routing
  - Routers advertise what networks they serve
  - Done using a network address and prefix
  - E.g. UNH's ISP advertises 132.177.0.0/16
  - Provides for flexible movement between ISP's without re-numbering your network

# Supernetting And Route Aggregation

- Supernetting is the opposite of subnetting–it combines several networks together as one
  - 209.16.0.0/16
    - Should be 256 separate Class C networks
    - Treated as 1 network - given to 1 ISP
    - Can be subdivided by the ISP
- Route Aggregation
  - An advantage of CIDR
  - Supernetted address ranges get 1 entry in Internet routing tables

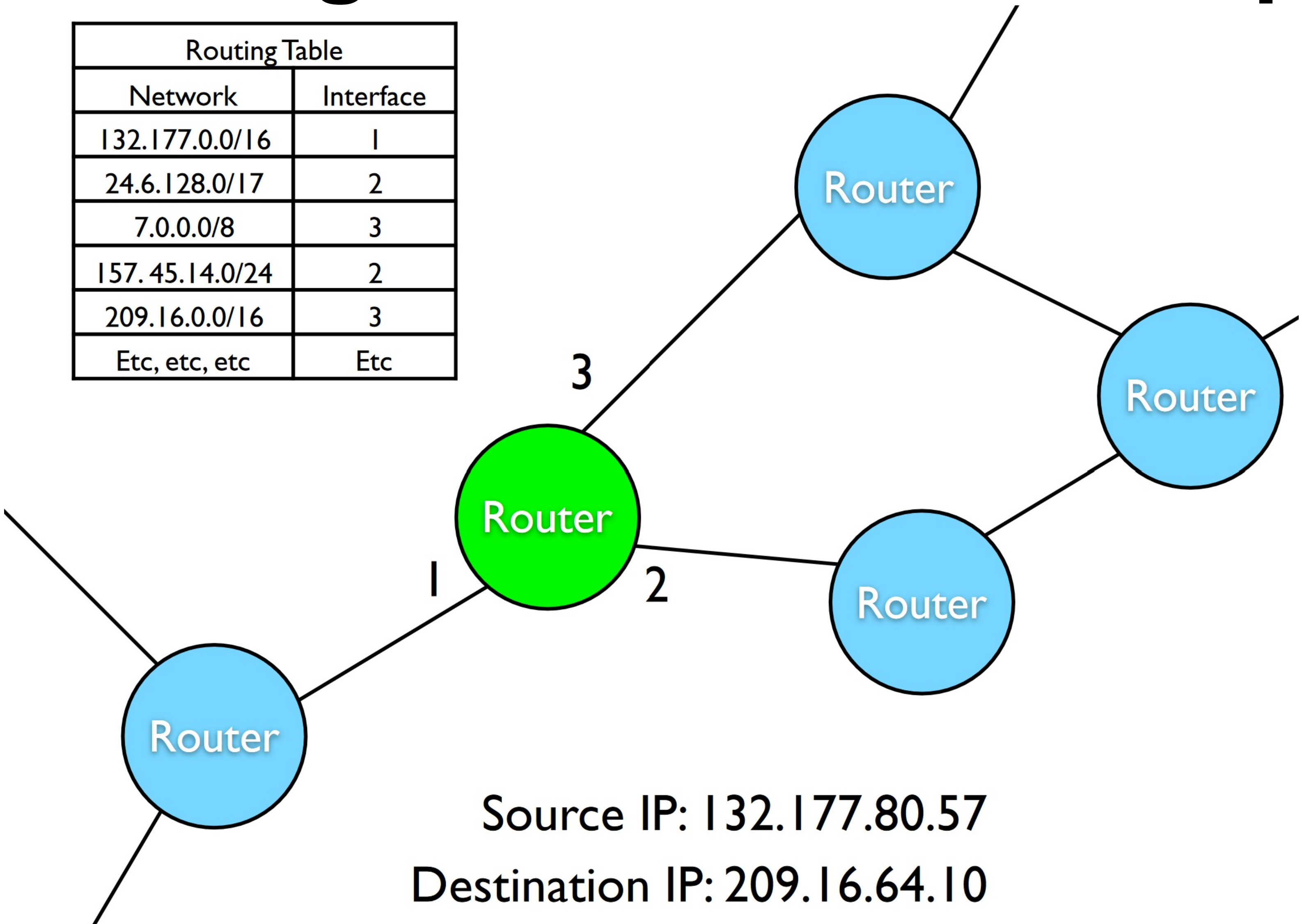
# Routing Table - CIDR Example

| Routing Table | |
|---|---|
| Network | Interface |
| 132.177.0.0/16 | 1 |
| 24.6.128.0/17 | 2 |
| 7.0.0.0/8 | 3 |
| 157.45.14.0/24 | 2 |
| 209.16.0.0/16 | 3 |
| Etc, etc, etc | Etc |



# Routing Table - CIDR Example

| Routing Table | |
|---|---|
| Network | Interface |
| 132.177.0.0/16 | 1 |
| 24.6.128.0/17 | 2 |
| 7.0.0.0/8 | 3 |
| 157.45.14.0/24 | 2 |
| 209.16.0.0/16 | 3 |
| Etc, etc, etc | Etc |

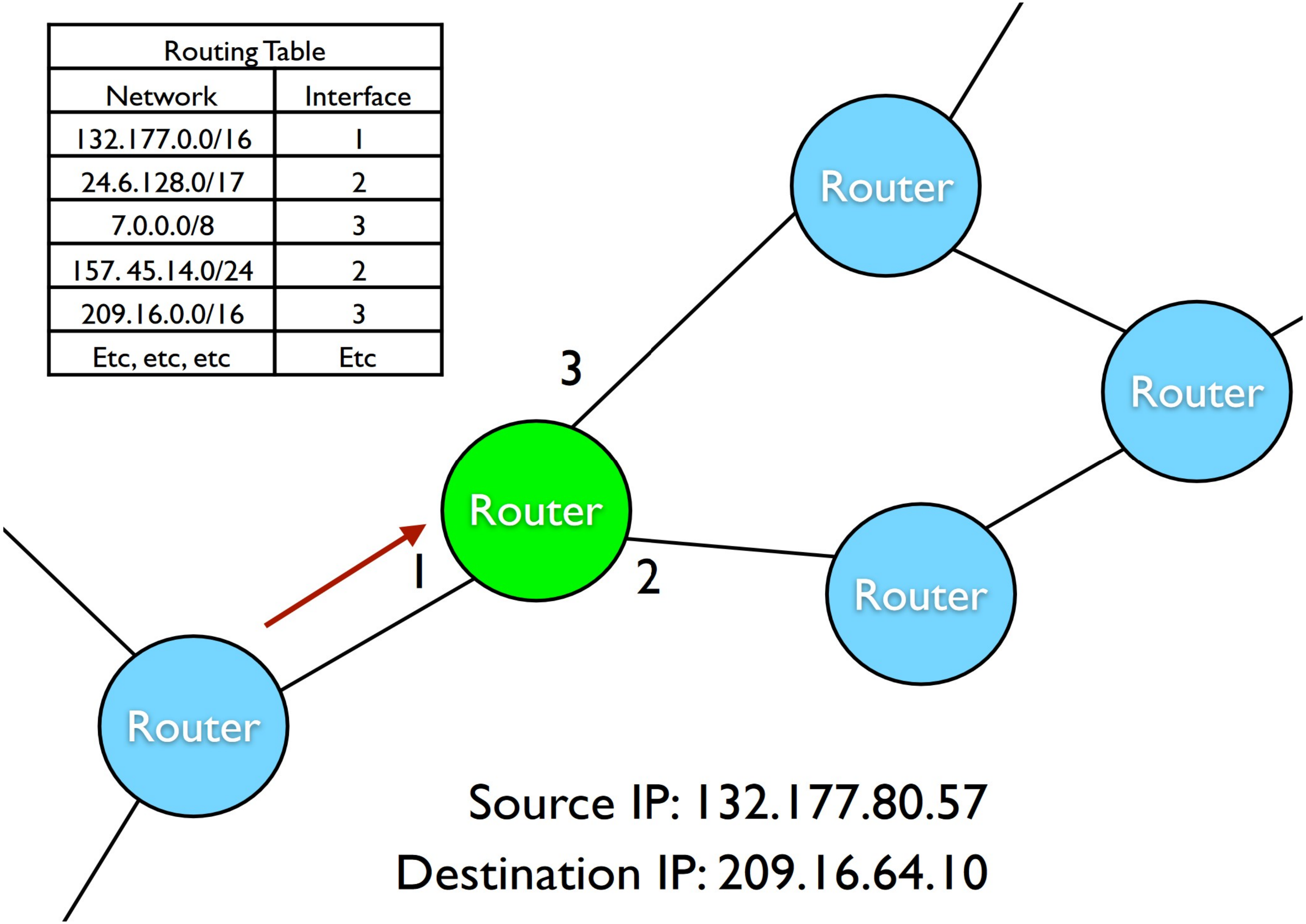



Source IP: 132.177.80.57

Destination IP: 209.16.64.10

# Routing Table - CIDR Example

| Routing Table | |
|---|---|
| Network | Interface |
| 132.177.0.0/16 | 1 |
| 24.6.128.0/17 | 2 |
| 7.0.0.0/8 | 3 |
| 157.45.14.0/24 | 2 |
| 209.16.0.0/16 | 3 |
| Etc, etc, etc | Etc |

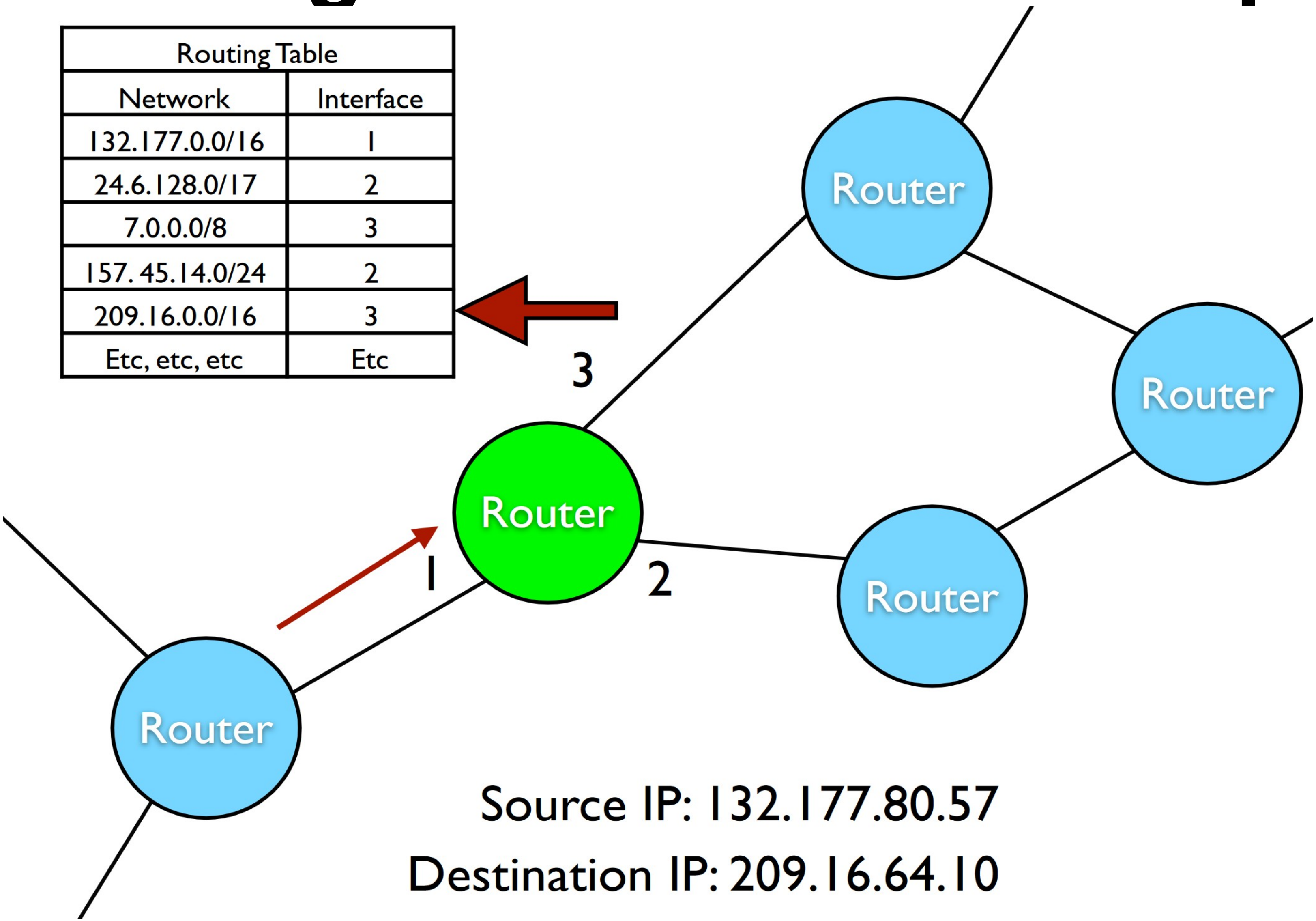



Source IP: 132.177.80.57

Destination IP: 209.16.64.10

# Routing Table - CIDR Example

| Routing Table | |
|---|---|
| **Network** | **Interface** |
| 132.177.0.0/16 | 1 |
| 24.6.128.0/17 | 2 |
| 7.0.0.0/8 | 3 |
| 157.45.14.0/24 | 2 |
| 209.16.0.0/16 | 3 |
| Etc, etc, etc | Etc |

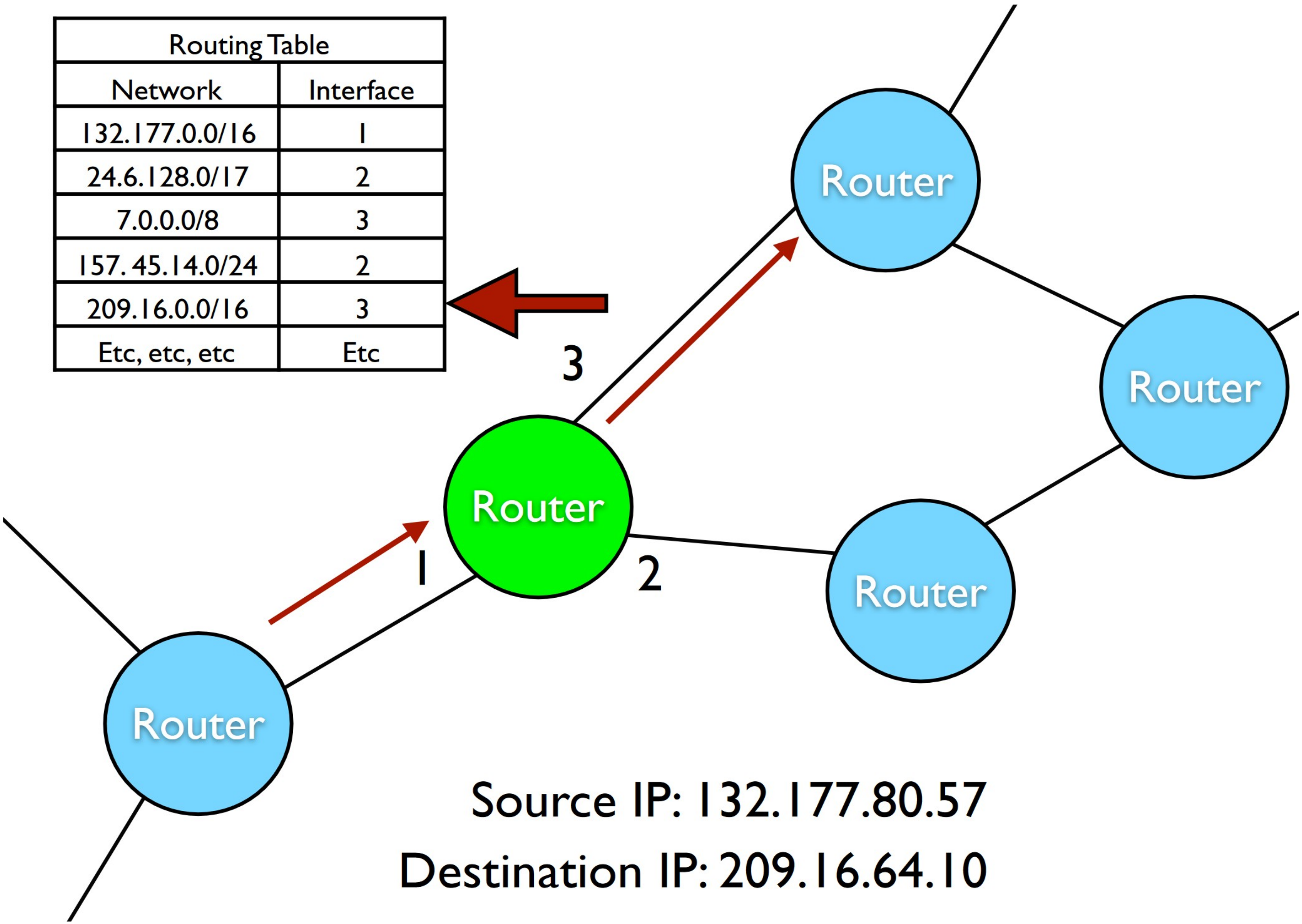



Source IP: 132.177.80.57

Destination IP: 209.16.64.10

# Routing Table - CIDR Example

| Routing Table | |
|---|---|
| Network | Interface |
| 132.177.0.0/16 | 1 |
| 24.6.128.0/17 | 2 |
| 7.0.0.0/8 | 3 |
| 157.45.14.0/24 | 2 |
| 209.16.0.0/16 | 3 |
| Etc, etc, etc | Etc |




Source IP: 132.177.80.57

Destination IP: 209.16.64.10

# CIDR Example

ISP is issued 209.16.0.0/16

- One network of 2^16 - 2 hosts (65534)

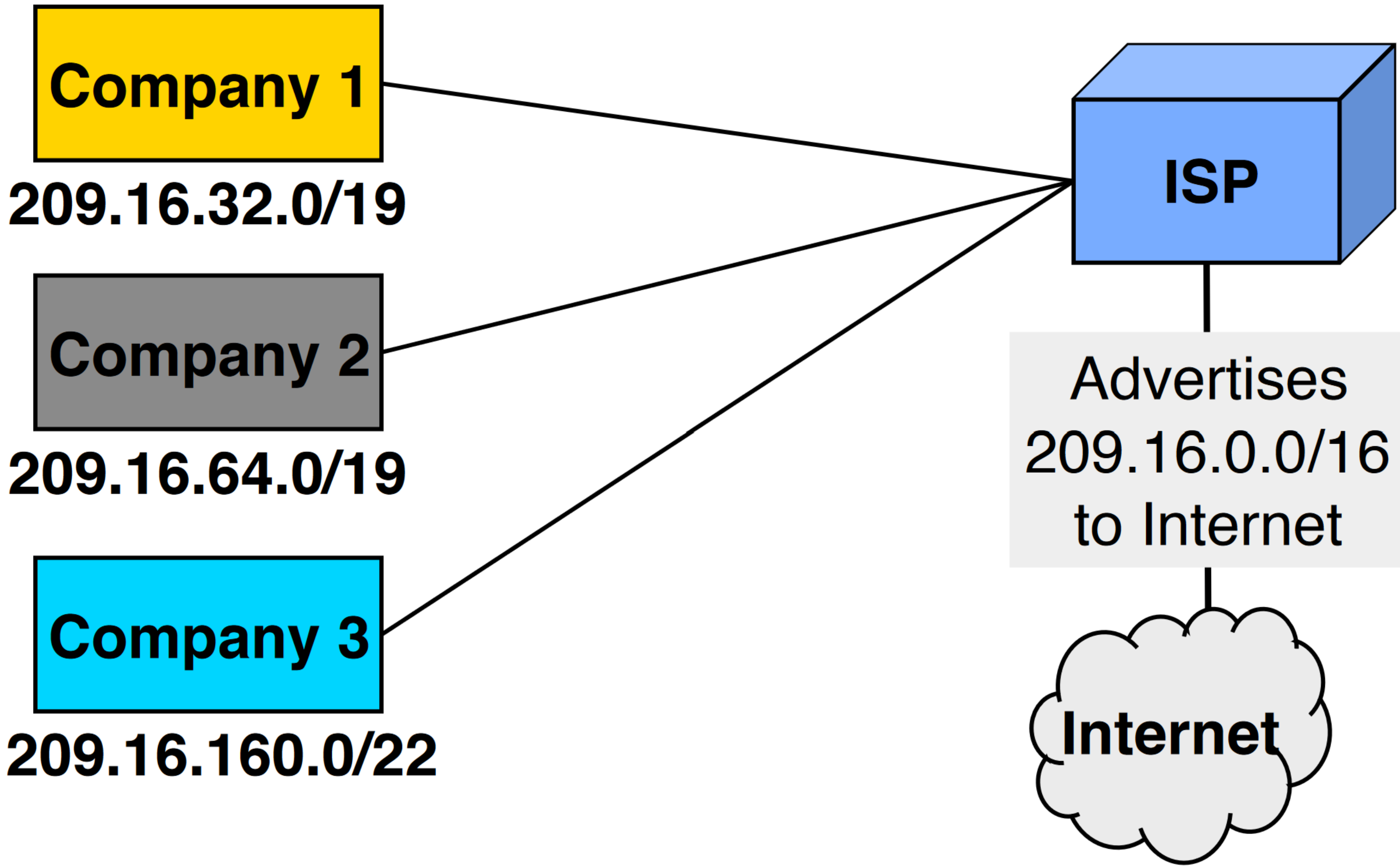
ISP decides to first subdivide the addresses into 8 blocks

- 2^16 ÷ 8 - 2 = 2^16 ÷ 2^3 - 2 =
  2^13 - 2 hosts (8190)
- If 13 bits represent the hosts, then 32-13=19 represent the network portion. Prefix is /19.
- 209.16.0.0/19, 209.16.32.0/19, 209.16.64.0/19, 209.16.96.0/19, 209.16.128.0/19, 209.16.160.0/19, 209.16.192.0/19, 209.16.224.0/19
- Keeps one for itself, two go to current customers, and one is kept in reserve

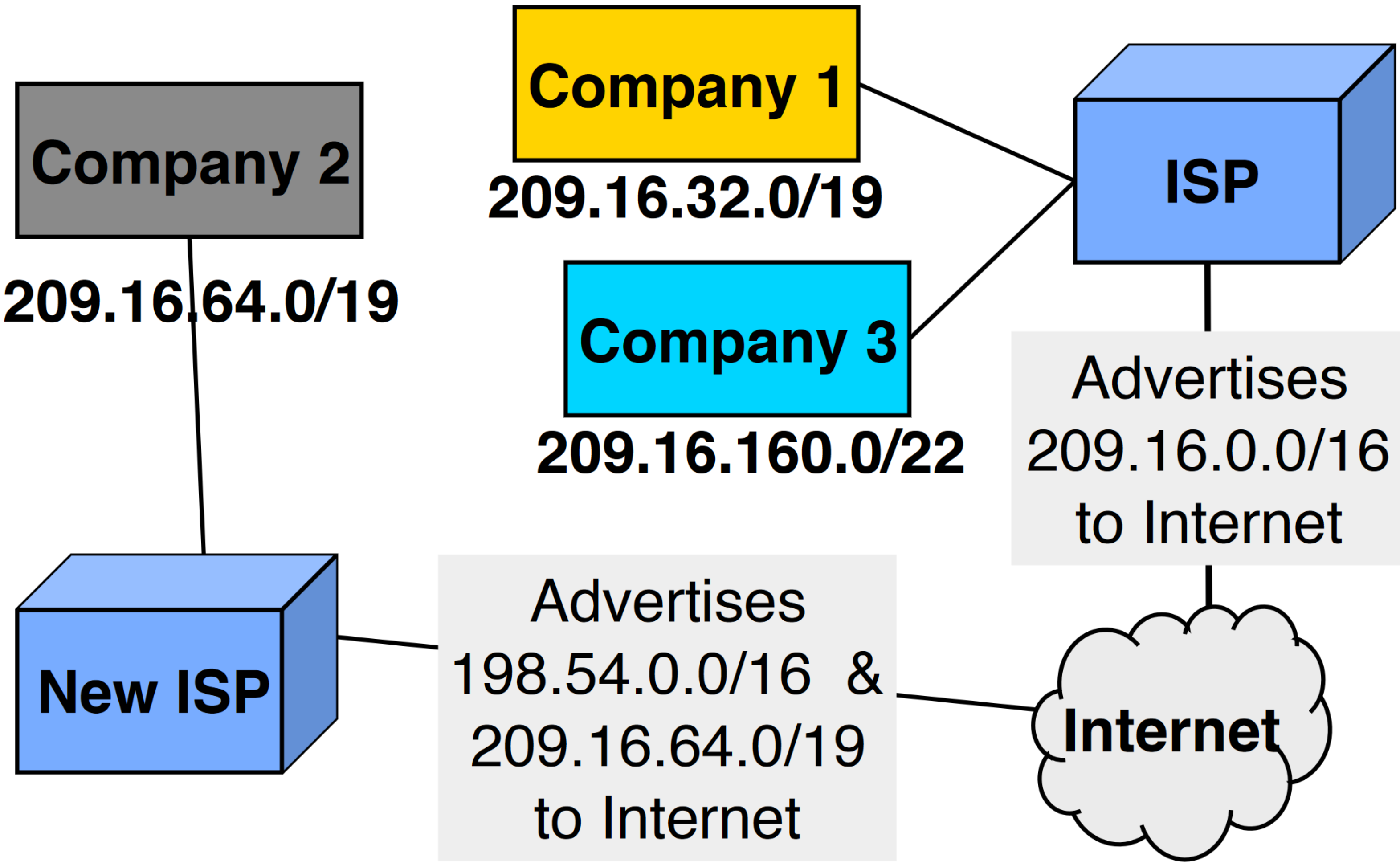
# CIDR Example

- 4 blocks remain
  - 209.16.128.0/19, 209.16.160.0/19, 209.16.192.0/19, 209.16.224.0/19
- These can be further sub-divided
  - 2046 hosts (2^11 - 2)
    - 209.16.128.0/21, 209.16.136.0/21, 209.16.144.0/21, 209.16.152.0/21
  - 1022 hosts (2^10 - 2)
    - 209.16.160.0/22, 209.16.164.0/22, etc.
  - 510 hosts (2^9 - 2)
    - 209.16.192.0/23, 209.16.194.0/23, etc.
  - Etc

# CIDR Example

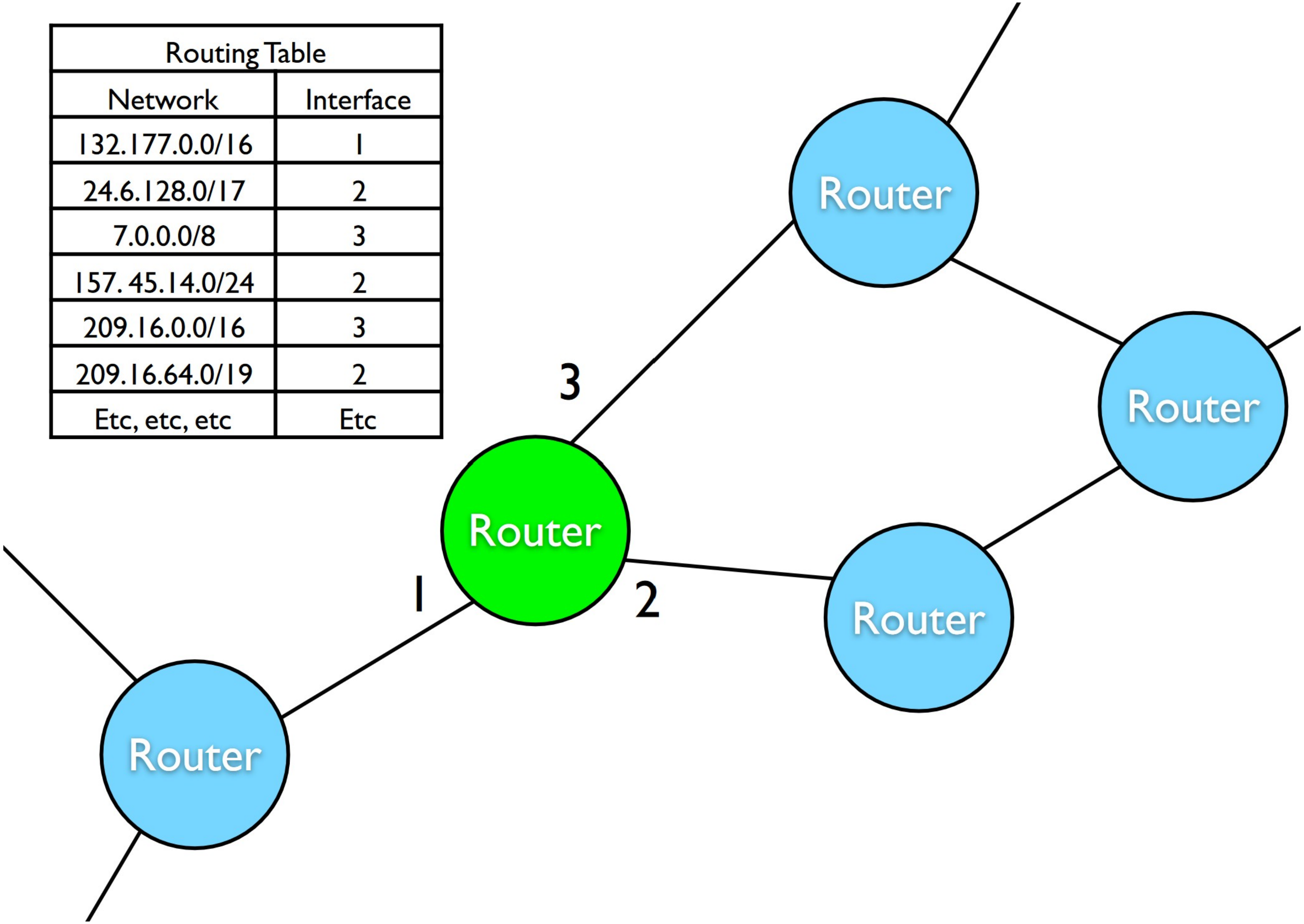


# CIDR Example



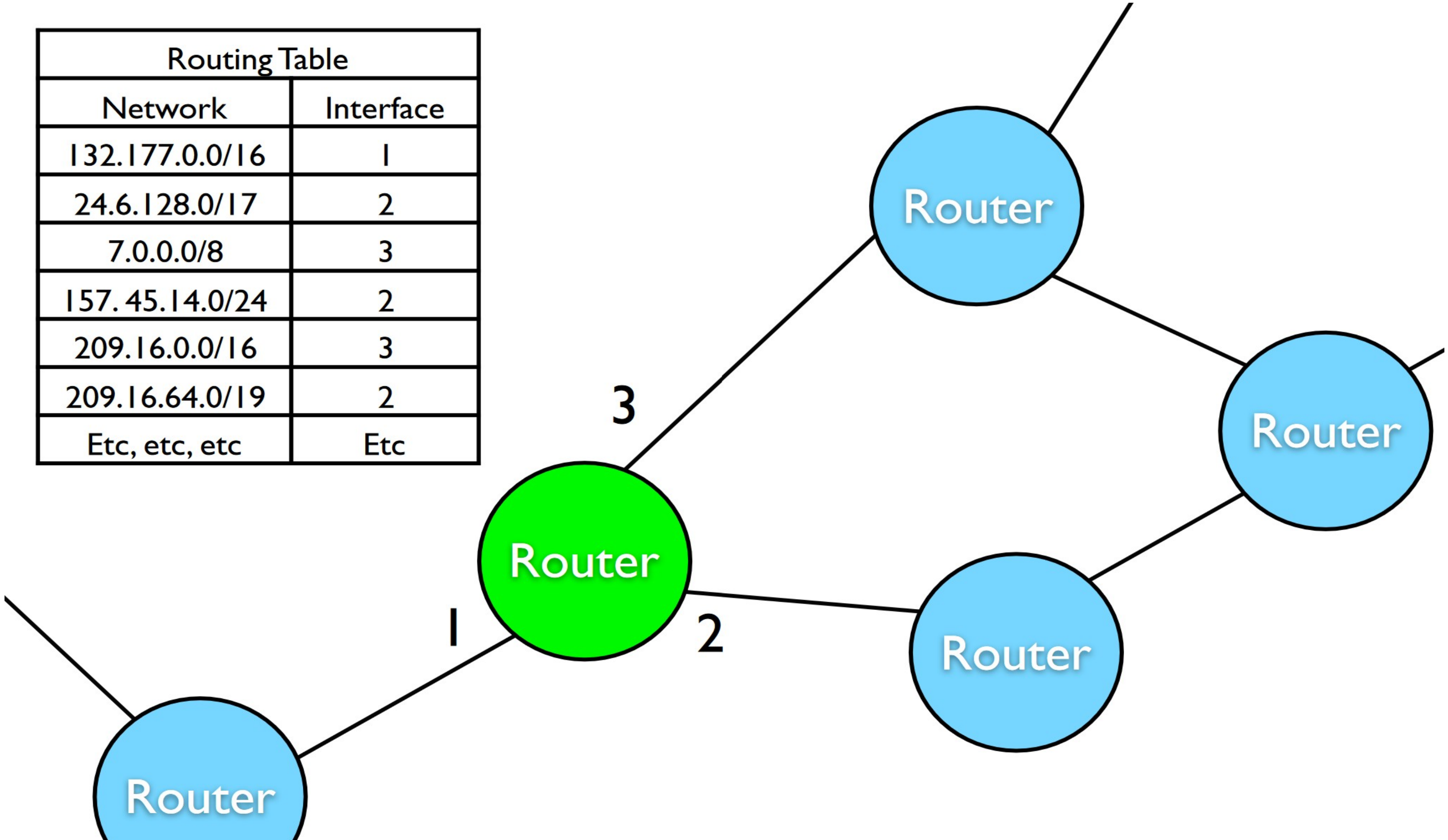
# CIDR Example

| Routing Table | |
|---|---|
| Network | Interface |
| 132.177.0.0/16 | 1 |
| 24.6.128.0/17 | 2 |
| 7.0.0.0/8 | 3 |
| 157.45.14.0/24 | 2 |
| 209.16.0.0/16 | 3 |
| 209.16.64.0/19 | 2 |
| Etc, etc, etc | Etc |



# CIDR Example

| Routing Table | |
|---|---|
| Network | Interface |
| 132.177.0.0/16 | 1 |
| 24.6.128.0/17 | 2 |
| 7.0.0.0/8 | 3 |
| 157.45.14.0/24 | 2 |
| 209.16.0.0/16 | 3 |
| 209.16.64.0/19 | 2 |
| Etc, etc, etc | Etc |

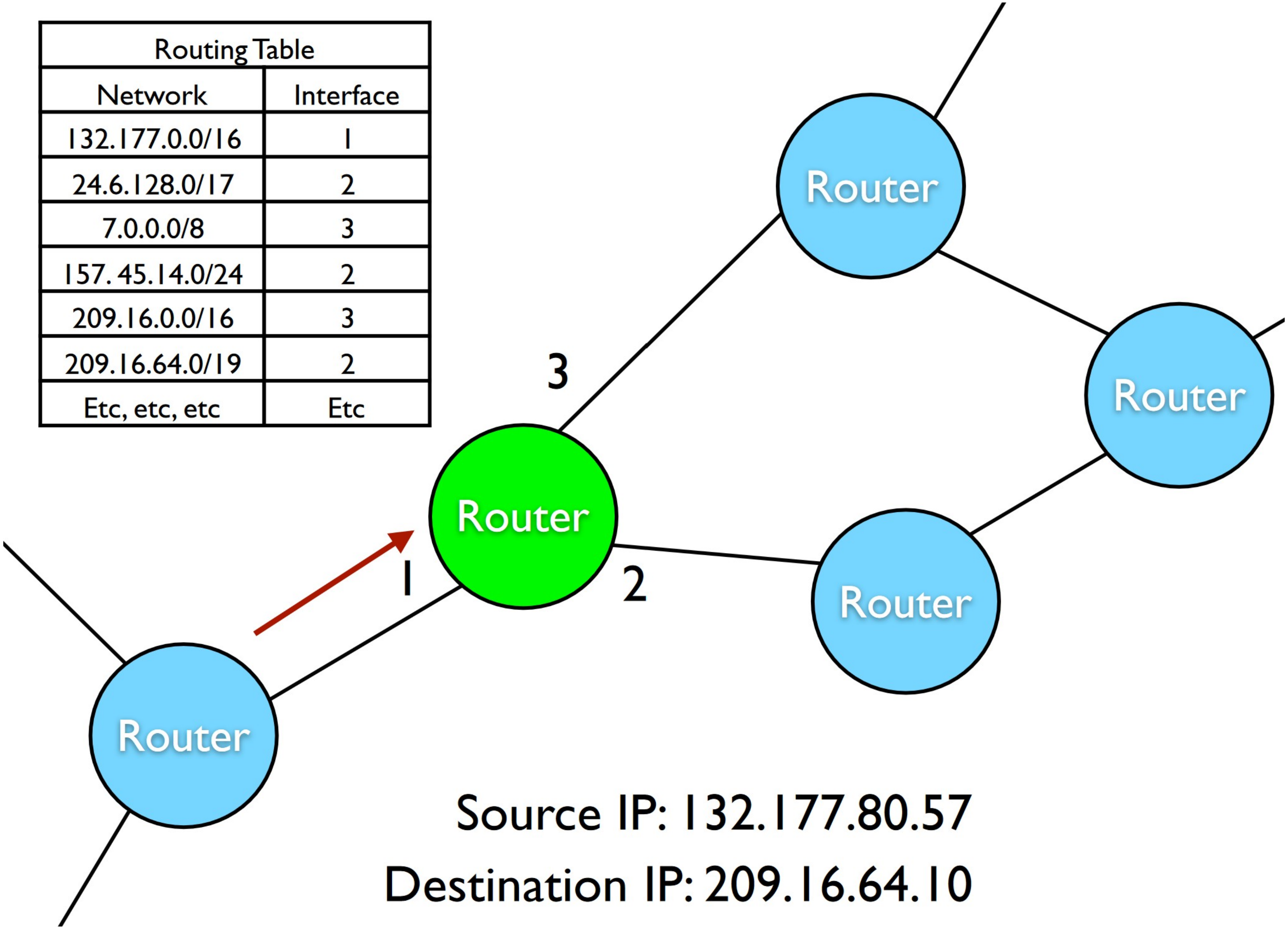



Source IP: 132.177.80.57

Destination IP: 209.16.64.10

# CIDR Example

| Routing Table | |
|---|---|
| Network | Interface |
| 132.177.0.0/16 | 1 |
| 24.6.128.0/17 | 2 |
| 7.0.0.0/8 | 3 |
| 157. 45.14.0/24 | 2 |
| 209.16.0.0/16 | 3 |
| 209.16.64.0/19 | 2 |
| Etc, etc, etc | Etc |

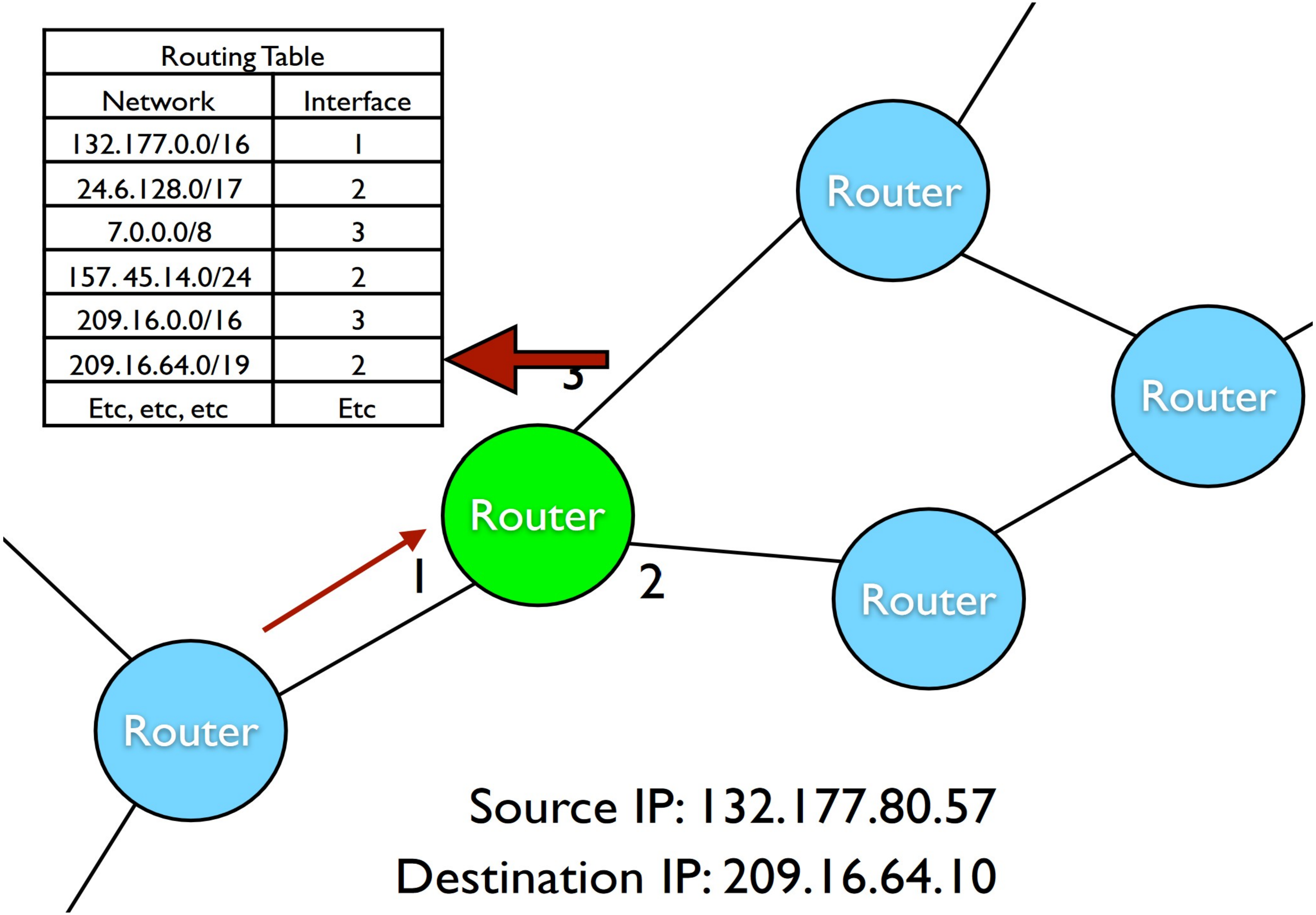



Source IP: 132.177.80.57

Destination IP: 209.16.64.10

# CIDR Example

| Routing Table | |
|---|---|
| Network | Interface |
| 132.177.0.0/16 | 1 |
| 24.6.128.0/17 | 2 |
| 7.0.0.0/8 | 3 |
| 157.45.14.0/24 | 2 |
| 209.16.0.0/16 | 3 |
| 209.16.64.0/19 | 2 |
| Etc, etc, etc | Etc |

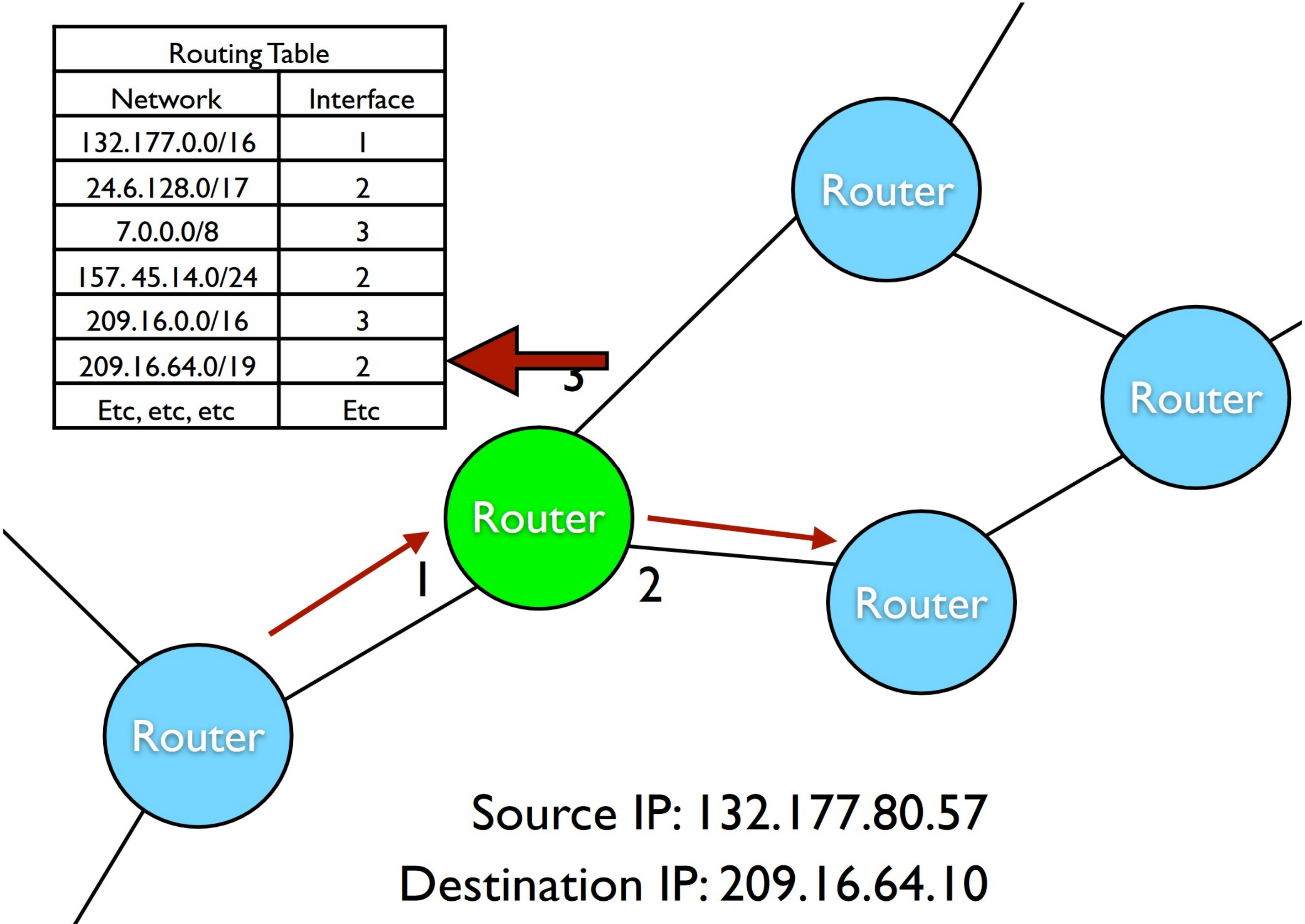



Source IP: 132.177.80.57

Destination IP: 209.16.64.10

# CIDR Example

| Routing Table | |
|---|---|
| Network | Interface |
| 132.177.0.0/16 | 1 |
| 24.6.128.0/17 | 2 |
| 7.0.0.0/8 | 3 |
| 157.45.14.0/24 | 2 |
| 209.16.0.0/16 | 3 |
| 209.16.64.0/19 | 2 |
| Etc, etc, etc | Etc |




Source IP: 132.177.80.57

Destination IP: 209.16.64.10