Address Space Utilization

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Recap

- Hierarchical addressing based on classes (A,B,C) to handle scalability and different network sizes
  - IP address has a network part and a host part
  - Routers maintain entries corresponding to network portion
- What can potentially go wrong now?

Problem Statement

- Network part uniquely identifies a physical network

2 hosts

IP address – 32 bits

class B address → block of IP address

190.23.*.*

16 bits 2^{16}

- Network with just 2 hosts needs Class C address
  - Efficiency: 2/2^8 = 0.7%

8 bits 2^8

- Network with 256 hosts needs a Class B address

256 hosts

  - Efficiency: 256/2^16 = 0.4 %

2^{32} ~ 4 billion hosts

Problem Statement

- Class B addresses in high demand (keeping future needs in mind) 2^{24} hosts ~ very few
  - Host addresses ~ 4 billion (2^{32}) 150 hosts
  - Class B networks: 2^{14} (~16000)
  - Out of class B addresses, out of addresses to hand out
- Need to solve "Address assignment inefficiency"
  - Challenge: Within IP framework (using 32-bits)

“The gem cannot be polished without friction, nor man perfected without trials.”

---Chinese proverb

“You see a mousetrap; I see free cheese and a ******** challenge!”

---Scroobius Pip

Specific Scenario –1

- An organization has 30 different physical networks, each network has about 2000 hosts
- Current Allocation: Allocate 30 class B addresses
  - Efficiency = 2000/2^16 = 3%
- Will one class B address suffice?
  - Can support 2^{16} = 65536 hosts > 30*2000

Solution: Subnetting

- Introduce another level of hierarchy
  - Divide host part into subnet id and host id

Network Number	**Host Number**

Network Number	**Subnet ID**	**Host ID**

16 + 5 = 21

  - 16 host bits divided into 5 subnet bits (32 physical networks) and 11 host bits (2048 hosts)

- Address format: a.b.c.d/x, where x is # bits in net portion of address

  8(1's) 8(1's) 11111000

  - Example: 190.23.12.17, mask is 255.255.255.248.0 (/21)

    00001100 190.23.8.0 /21

- ifconfig eth0 190.23.12.17 netmask 255.255.255.~~240~~ 248

  190.23.00001000.000000

- The bit-wise end of the IP address and the subnet mask give the subnet number of the host

- All hosts on a given physical network have the same subnet number and mask

Class B Address: 10111110. 00010111. *. *; 190.23.0.0/16

$(2^{11}-2)$

32 Subnets

Subnet ID 5 bits	Subnet No 16 bits	Hosts 11 bits
00000	190.23.0.0	190.23.0.1 – 190.23.7.254
00001	190.23.8.0	190.23.8.1 – 190.23.15.254
…….		
11111	190.23.248.0	190.23.248.1 – 190.23.255.254

00000 ← all zero

all ones

broadcast

- All routers outside organization have one entry (190.23.0.0/16)
- Routers within organization have more detailed entries corresponding to different subnets

Forwarding at a Router

D = Destination IP Address

For each forwarding table entry

T = D & SubnetMask

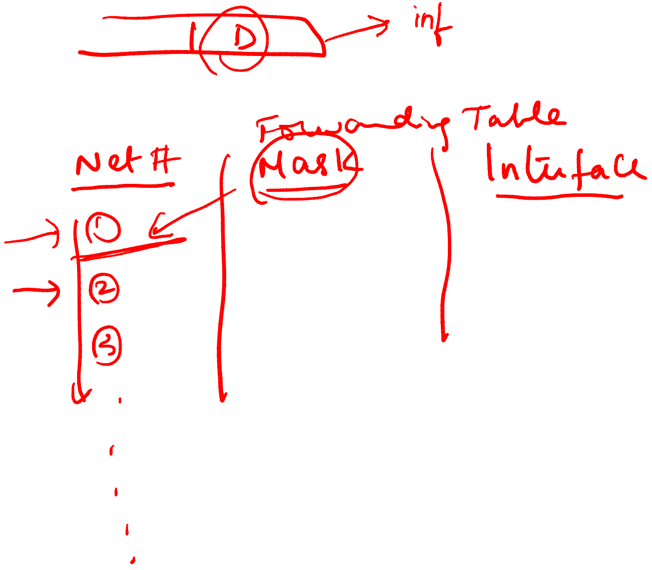
If T == SubnetNum

If Nexthop is an interface

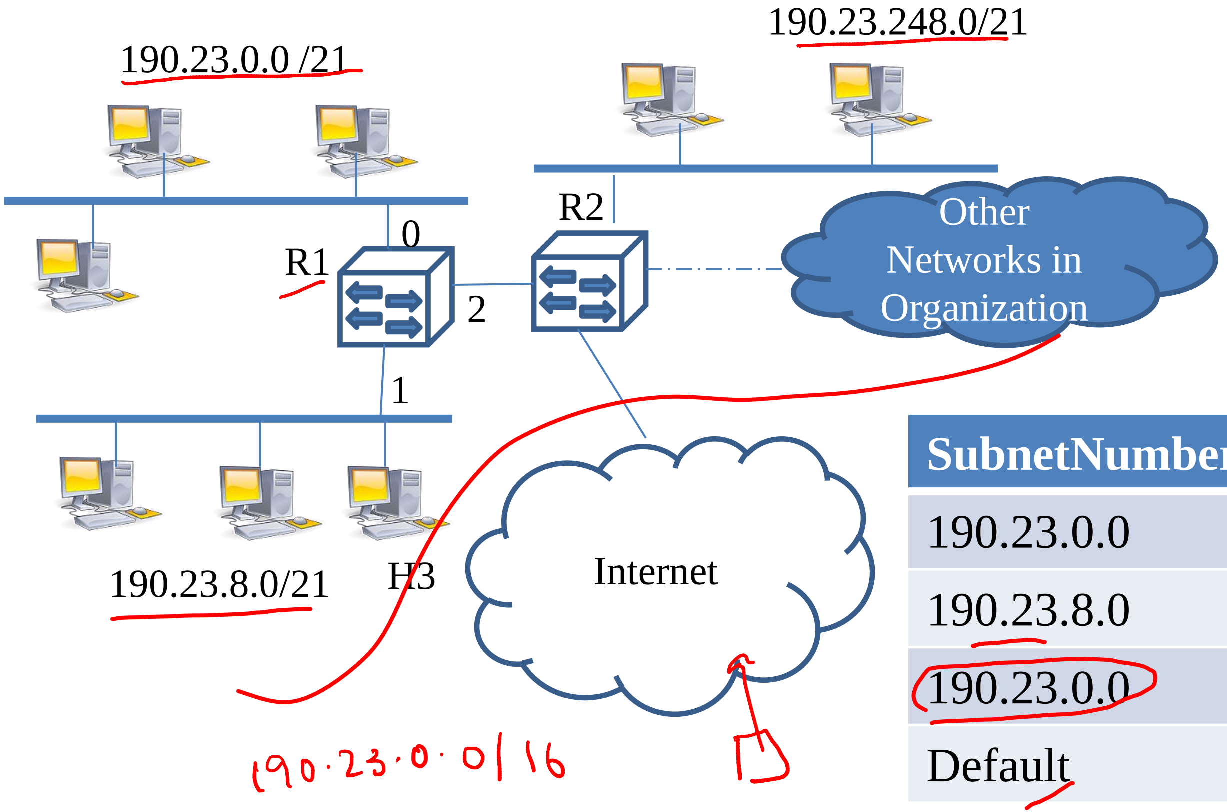
deliver datagram directly to destination

Else

deliver datagram to NextHop (router)



Example



Forwarding
~~Routing~~ Table at R1

SubnetNumber	Mask	Nexthop
190.23.0.0	255.255.248.0	Inf0
190.23.8.0	255.255.248.0	Inf1
190.23.0.0	255.255.0.0	R2
Default	0.0.0.0	R2

```
kameswari@asterix:~$ route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
10.129.0.0      *               255.255.0.0     U     1      0        0 eth0
link-local      *               255.255.0.0     U     1000   0        0 eth0
default         router.it.iitb. 0.0.0.0         UG    0      0        0 eth0
kameswari@asterix:~$
kameswari@asterix:~$
kameswari@asterix:~$ route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
10.129.0.0      0.0.0.0         255.255.0.0     U     1      0        0 eth0
169.254.0.0     0.0.0.0         255.255.0.0     U     1000   0        0 eth0
0.0.0.0         10.129.250.1    0.0.0.0         UG    0      0        0 eth0
kameswari@asterix:~$
```


INTERMISSION

Specific Scenario -- 2

- An organization has a physical network with 4000 hosts
- Current Solution: Give a class B address
  - Efficiency: $4000/2^{16} = 6\%$
- How about assigning multiple class C addresses?

  16 → 2^8 hosts
- Problem: 16 entries for same organization in the routing table

Solution--2

- Assign multiple contiguous class C addresses & aggregate
- 222.7.16.* through 222.7.31.*, top 20 bits in this range are the same (0001 bits, 20-bit network number)
- Advertise 222.7.16/20 as the organization’s network address
- Goes by the name supernetting

Conclusions

- Subnetting: One class address shared among many physical networks
- Supernetting: Multiple class addresses shared among one physical network (Autonomous system -- AS) → organization
- Network portion can take on any length

0 2 to 32

Classless Interdomain Routing (CIDR)

- Use a new notation to represent network numbers (also called IP prefixes)
- Address block represented as A/X, where A is the address prefix and X is the prefix length
  - X can range from 2 till 32
  - X is represented as a network mask as well

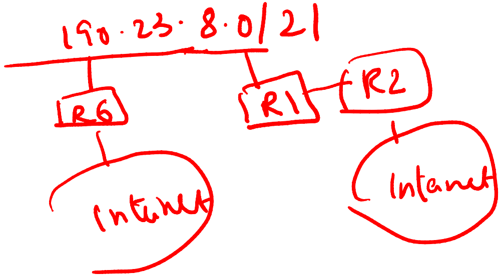
/21
255.255.248.0

entry → interna

- E.g. 222.7.16/20 (Mask 255.255.240.0) represents addresses in the range (222.7.16.0 to 222.7.31.255)

Longest Prefix Match

- Routers do a prefix match.
  - Does destination address fall in the range of addresses captured by prefix?
- Prefix match works if Internet topology is a tree
  - Shortest path between networks is unique
- Internet is a graph
  - Many networks multi-home
  - Many matching prefixes



Example

R6

- Two prefixes in a forwarding table190.23.8.0/21 and 190.23.0.0/16 → R2
  - Address 190.23.8.1 matches both
- Go with the longest prefix match (e.g 190.23.8.0/21)
- Challenge: Longest match between destination IP address and variable length prefixes in forwarding table
  - Lot of research in this space

Summary

- Class based addressing was found not to be scalable
- Subnetting: Share a single class address among multiple networks
- Supernetting: Share multiple class addresses on a single network
- Lead to CIDR (classless addressing) and Longest prefix match --- widely used now