# Management and Operations of Networks, Services, and Systems

## IP Addressing

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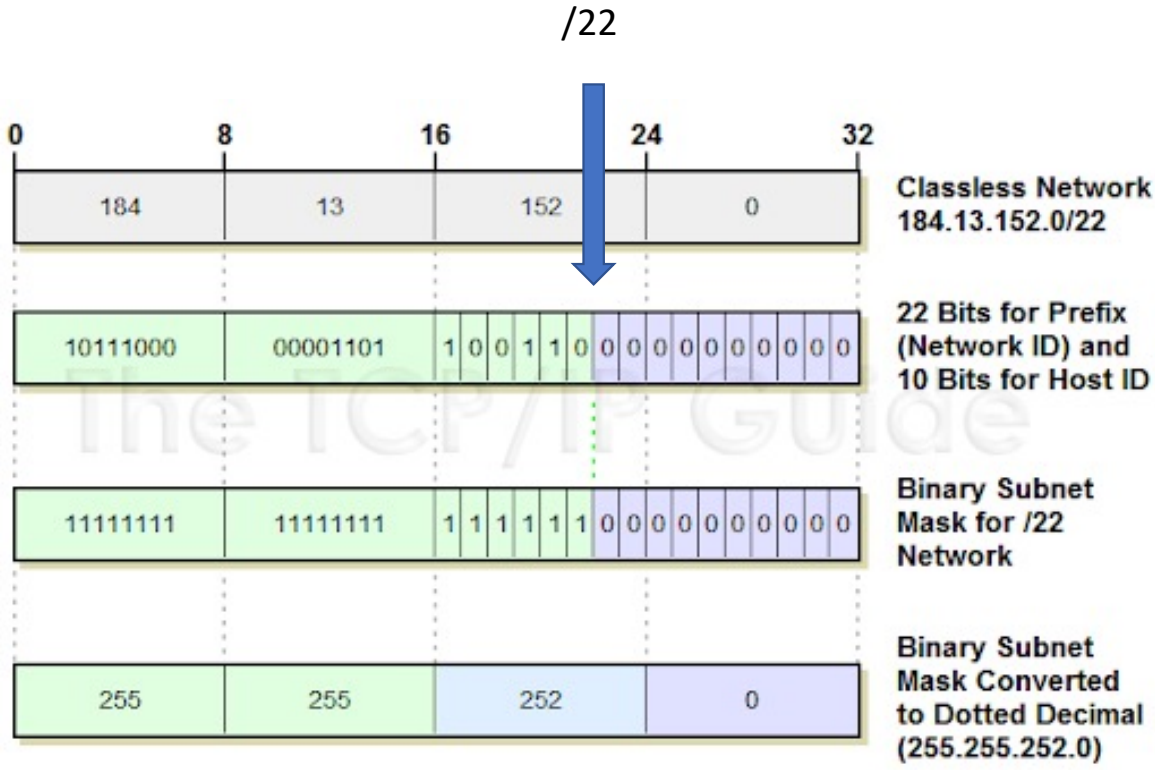
# Racionale for IP addresses

- Domain names, IP addresses, MAC addresses
  - Functional requirements (IP / location vs. MAC / factory)
  - Usage requirements (names - users, IP / MAC computers)
- Global routing vs. private
- Embedded in applications
- New addressing paradigms

# IP Address Formats

- 32 bits (IPv4) vs. 128 bit (IPv6)
- Split address bits in two parts : < Network id | Interface id >
- Classes (IPv4, A/B/C/D/E) vs. classless (CIDR)
  - A/B/C: only 3 network sizes
  - A: /8 , 2^24 addrs. ; B: /16 , 2^16 addrs. ; C: /24 , 2^8 addrs.
  - CIDR: can specify how many bits in network part, /n n bits in network part
- Ranges
  - Range of addresses in a network: interface id from all 0s to all 1s, network id fixed
  - Private, Multicast, Reserved (specific networks)
  - Subnetting, supernetting (split or group networks into larger/smaller nets)

# Example addresses, network mask



# Example addresses (2)

- Example address (network bits | interface bits)
  - IPv4: 01000100 1 | 0001000 00010000 00110100
    => 68.136.16.52 / 9 (decimal)
  - IPv6: 00100000 00000001 10100000 1011 | 0000 :: 00010001 00010001
    => 2001:A0B0::1010 / 28 (hexadecimal, :: means all zeros)
- Network ranges for the above addresses (all 0s to all 1s)
  - 01000100 1 | [0000000 00000000 00000000 to 111111 1111111 11111111]
    => from 68.128.0.0 to 68.255.255.255
  - 00100000 00000001 10100000 1011 | [all 0s -> to all 1s]
    => from 2001:A0B0:: to 2001:A0BF:FFFF:FFFF:FFFF:FFFF:FFFF:FFFF

# Special use addresses

- Host part all 0s : network address
- Host part all 1s : broadcast address
- 0.0.0.0/8 : This network, this host (0.0.0.0)
- 127.0.0.0/8 : Loopback
- 169.254.0.0/16, FE80:0:0:0:<Interface ID> : Link local
- 10.0.0.0/8, 172.16.0.0/12, 192.168.0.0/16 : Private, NAT
- 224.0.0.0/4, FF::/8 : Multicast
- FC00::/7 : unique local address (global id, subnet id, interface id)
- Others, look it up
  - https://datatracker.ietf.org/doc/html/rfc3330
  - https://datatracker.ietf.org/doc/html/rfc6890 (IPv6)

# Splitting and aggregating networks

- Break a network range into smaller networks
  - Keep consistency of the network parts
  - Keep all subnets inside original range
- Example: split 200.17.30.0/24 ($2^{32-24}=2^8=256$ addresses)
  - How many 32 address networks fit in this /24 network?
  - $32 = 2^5$ => 5 bit for subnet hosts (/27 network), leaves 8-5=3 bits for subnetting
  - 200.17.30.xxxyyyyy => x subnet, y host
  - xxx: 000 to 111, 8 subnets ; yyyyy: 00000 to 11111, 32 host addresses
    - 1st subnet, xxx=000: 200.17.30.0/27 => 200.17.30.0 to 200.17.30.31,
    - 2nd subnet, xxx=001: 200.17.30.32/27 => 200.17.30.32 to 200.17.30.63
    - 3rd subnet, xxx=010: 200.17.30.64/27 => 200.17.30.64 to 200.17.30.91
    - 5th subnet, xxx=100: 200.17.30.128/27 => 200.17.30.128 to 200.17.30.159
    - Last subnet, xxx=111: 200.17.30.224/27 => 200.17.30.224 to 200.17.30.255

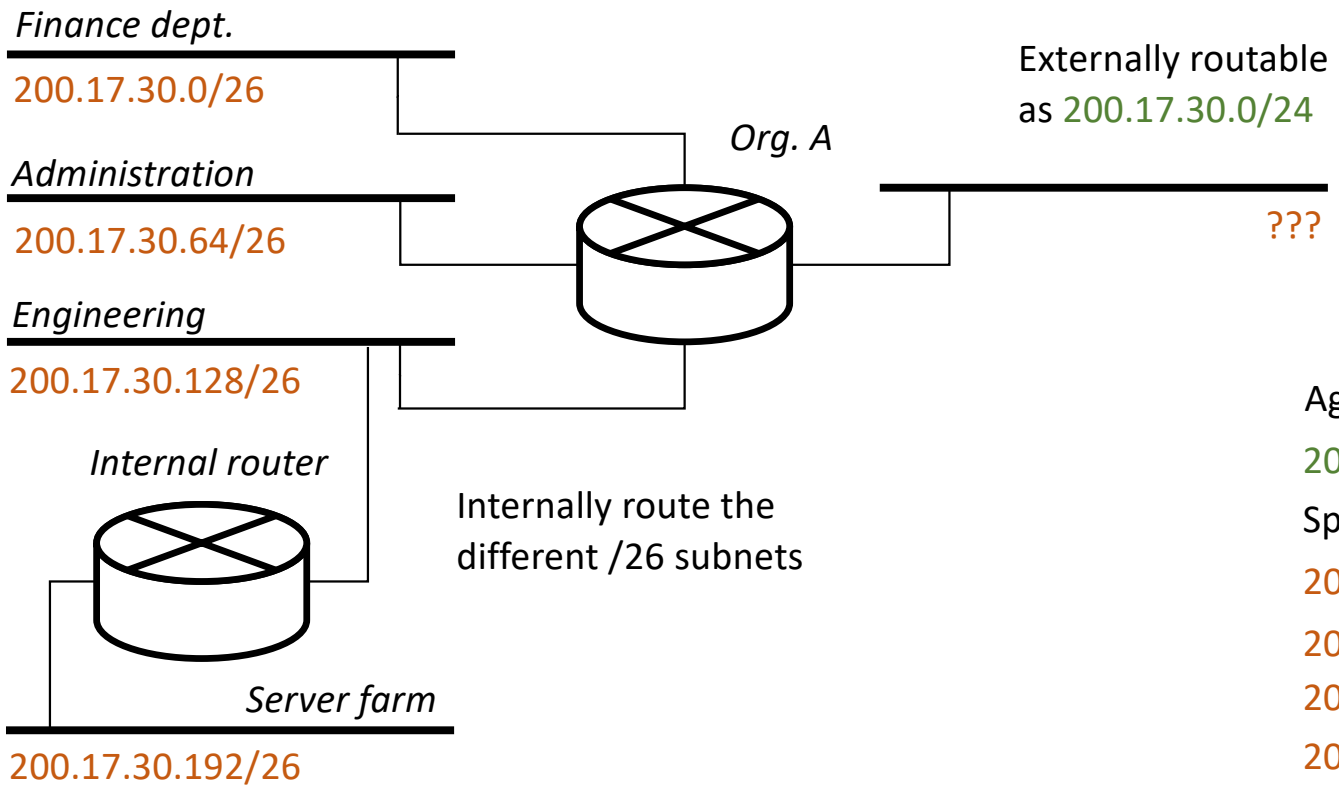
# Splitting and aggregating networks (2)

- Build from previous example
- Aggregate four /27 subnets in two /26 subnets
- Can we use just any pair of /27 subnets?
  - E.g. the 2nd and 3rd /27 subnets?
    - 2nd: 200.17.30.32 to 200.17.30.63
    - 3rd: 200.17.30.64 to 200.17.30.91
  - No; although the range is continuous, the network id bits are different
    - 200.17.30. 00|1yyyyy for 2nd /27 subnet
    - 200.17.30. 01|0yyyyy for 3rd /27 subnet
- How to do it then?
  - 64 = $2^6$ => 6 bits for host, leaves 8-6 = 2 bits for aggregating /27 subnets into /26 subnets
  - 200.17.30.ww|zyyyyy with 2 bits (ww) for identifying /26 subnets, 6 bits (zyyyyy) for host id
- Aggregated networks must be contiguous
  - No missing addresses between first and last address
  - All addresses in same network must have same network id bits

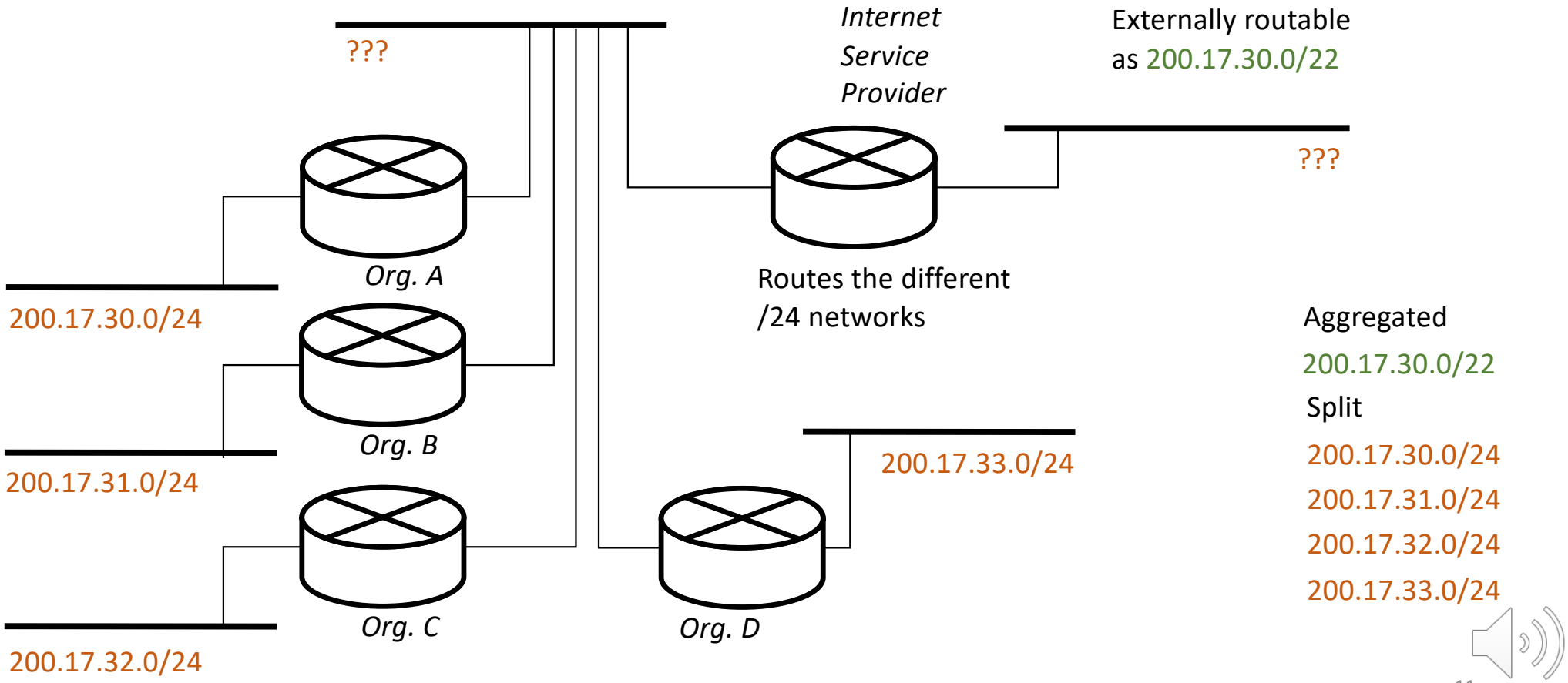
# Subnetting and Supernetting

- Subnetting
  - Have a network range with a large number of addresses
  - Need many networks with fewer addresses in each network
  - Can split the network range accordingly
- Supernetting
  - Have consitituents with different network ranges
  - Need to identify the whole of your constituents with a single range
  - Can aggregate ranges into a unique, continuous range
- Some addresses may be left unused

# Example – subnetting, networks in same organization



# Example – supernetting, ISP, route announcements



# Example addressing problem

- Assign subnetwork addresses from a given network address range to the different networks in a given network topology
- Use the subnetting and supernetting topologies in the previous slides
  - Assume each network requires different number of interfaces
  - Include router addresses, don’t worry about the external network
  - Don’t forget to account for network and broadcast addresses in each network
  - Find out the minimum range of the aggregated network

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