

## Part 2: Design Principles

### Goals:

- identify, study common architectural principles, protocol mechanisms
- *synthesis*: big picture

### Overview:

- Separation of data and control: signaling
- state management: hard vs. soft-state
- randomization
- indirection
- multiplexing
- virtualization
- design for scale

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## 7. Designs for Scale

How to deal with large numbers (millions) of entities in a system?

- IP devices in the internet (0.5 billion)
- Users in P2P network (millions)

Example: routing!

**scale:** with 200 million destinations:

- can't store all dest's in routing tables!
- routing table exchange would swamp links!

**administrative autonomy**

- internet = network of networks
- each network admin may want to control routing in its own network

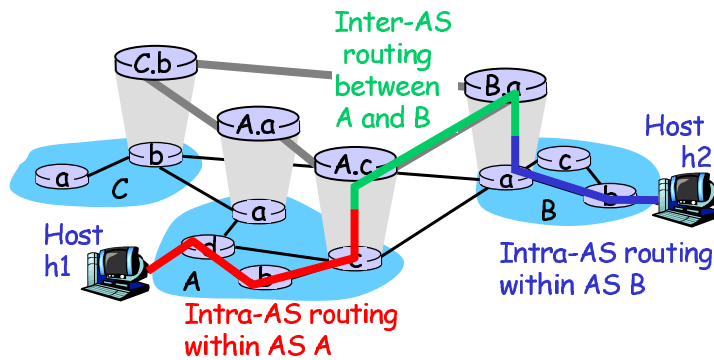
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## Hierarchical Routing

- aggregate routers into regions, "autonomous systems" (AS)
  - routers in same AS run same routing protocol
    - "intra-AS" routing protocol
    - routers in different AS can run different intra-AS routing protocol
- gateway routers
    - special routers in AS
    - run intra-AS routing protocol with all other routers in AS
    - also responsible for routing to destinations outside AS
      - run *inter-AS routing* protocol with other gateway routers

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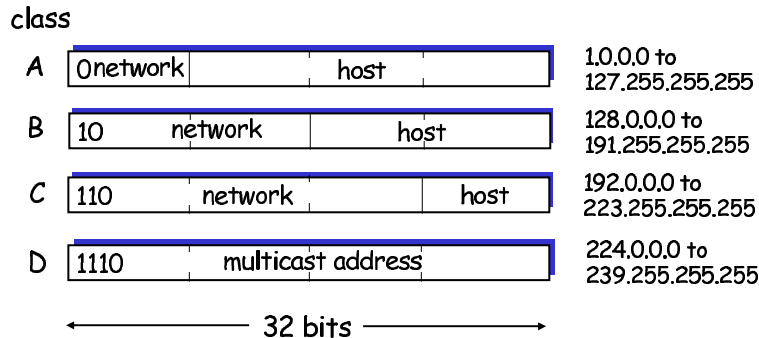
## Intra-AS and Inter-AS routing



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## Dealing with scale: addressing

Old-fashioned "class-full" addressing:



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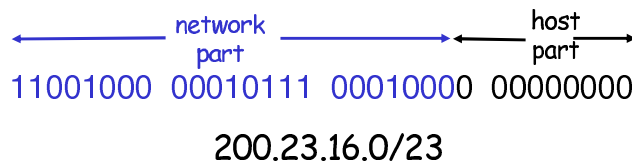
## IP addressing: CIDR

### □ Classful addressing:

- inefficient use of address space, address space exhaustion
- e.g., class B net allocated enough addresses for 65K hosts, even if only 2K hosts in that network

### □ CIDR: Classless InterDomain Routing

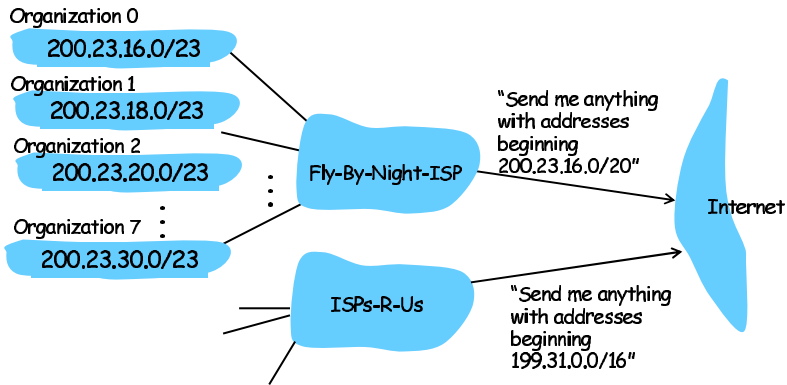
- network portion of address of arbitrary length
- address format: **a.b.c.d/x**, where x is # bits in network portion of address



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## Hierarchical addressing: route aggregation

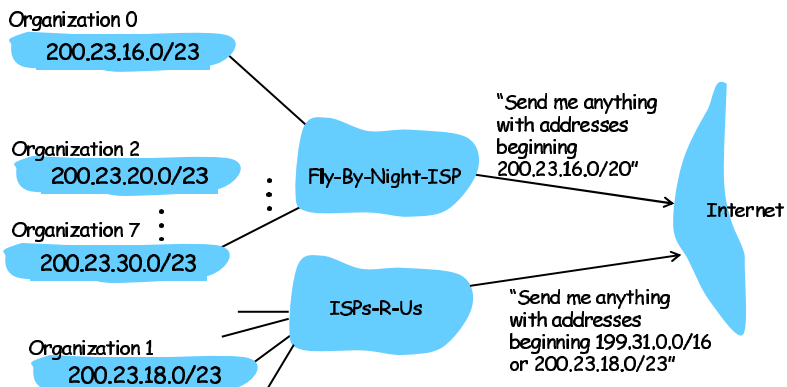
Hierarchical addressing allows efficient advertisement of routing information:



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## Hierarchical addressing: more specific routes

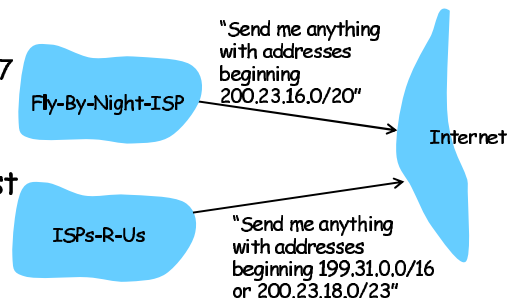
ISPs-R-Us has a more specific route to Organization 1



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## Hierarchical IP addressing: more specific routes

- Multiple advertised routes could hold destination  
200.23.16.0/20  
200.23.18.0/23  
both hold 200.23.18.7
- always route to *more specific* destination (longest prefix match)



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## Dealing with Scale: Other Examples

- Ethernet doesn't scale to very large numbers of users
- routing: fully-connected network only possible when small; use hierarchy to keep elements in same level fully connected (e.g., telephone network)
- p2p networks (like gnutella) scale using hierarchy
- DNS - use hierarchy to scale
- Use of multicast to scale 1-many communication: N-way 1-1 communication OK when small, move to 1-N as N gets large. What about reliability: explicit receiver-to-sender ACK/NAK OK when small, but implosion as N gets big. SRM - uses local recovery
- Human management doesn't scale: DHCP as auto-configuration. Autonomic computing - zero configure. Self-healing.

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## End of "Design Principles"!

### Goals

- ❑ review: different backgrounds
- ❑ framework for covering "advanced topics"
- ❑ material that is timely, timeless: hot now but also long shelf life
- ❑ synthesis: deeper understanding; "see the forest for the trees"

How did it work? ("Was it good for you?")