Naming and Mobility

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Based on slides by
Ken Birman, Dan Duchamp, Paul Francis, Jochen Schiller

NAMING

Naming: layer of indirection

- Makes objects human readable
- Hides complexity and dynamics
- Allows searching

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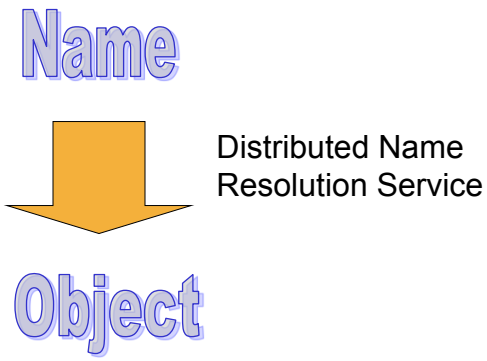
Names map to objects through a resolution service



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Identifiers and Locators

- Name is always an identifier
  - Persistent or non-persistent
  - globally unique
  - locally unique
  - non-unique
- If a name has structure that helps the resolution service, then the name is also a locator

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Naming in networks

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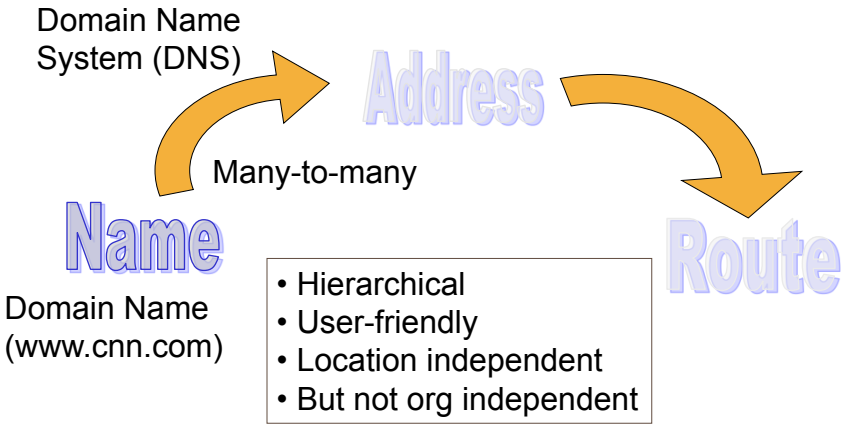
DNS names map into addresses



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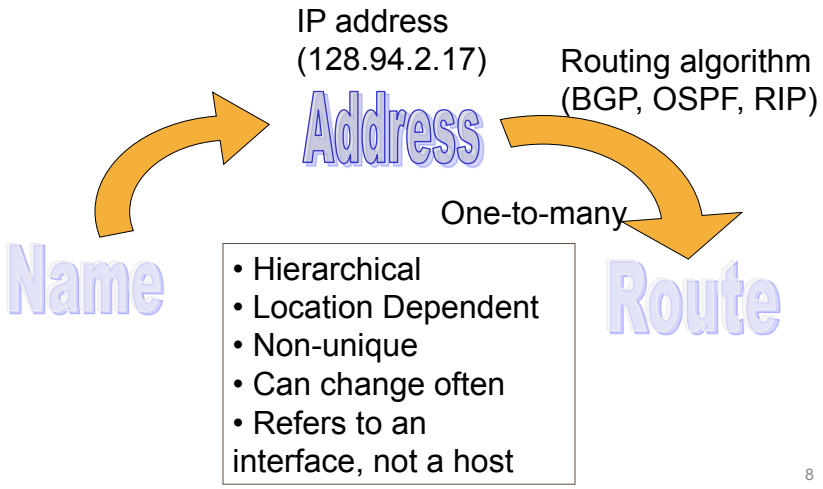
Addresses map into routes



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Routes get packets to interfaces

- A path
- Source dependent
- Can change often

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DNS names and IP addresses are identifiers and locators

- Both are typically non-persistent
- Private IP addresses identify only in the context of an IP realm
- Domain names are good identifiers
  - nexus.stevens.edu identifies a host
  - www.cnn.com identifies a service
- URLs are good identifiers
- See additional material: DNS

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MOBILE IP: ROUTING

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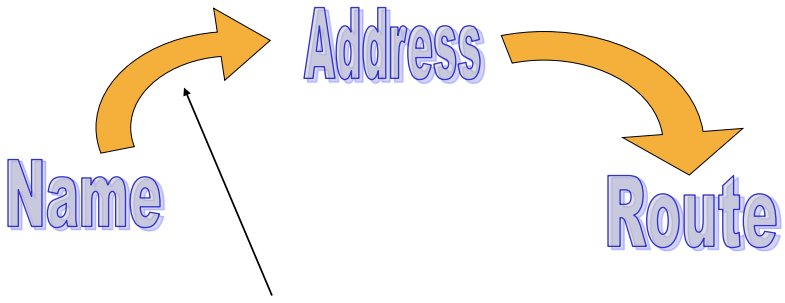
Mobility and Naming



Mobile Devices: This mapping is changing often

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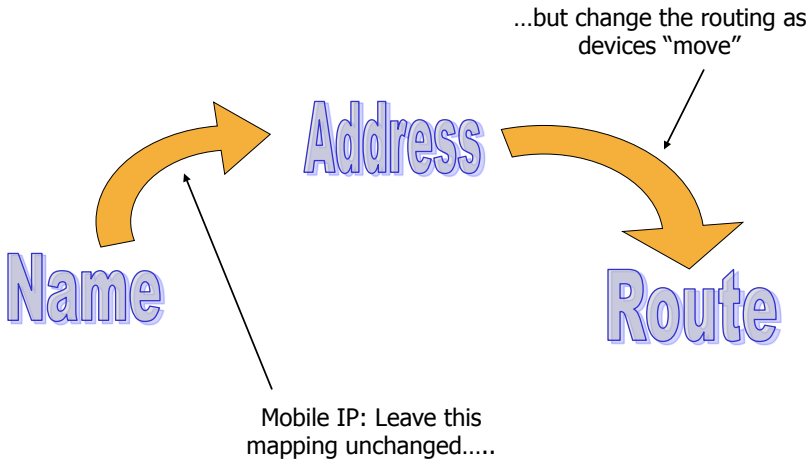
Mobile IP and Naming



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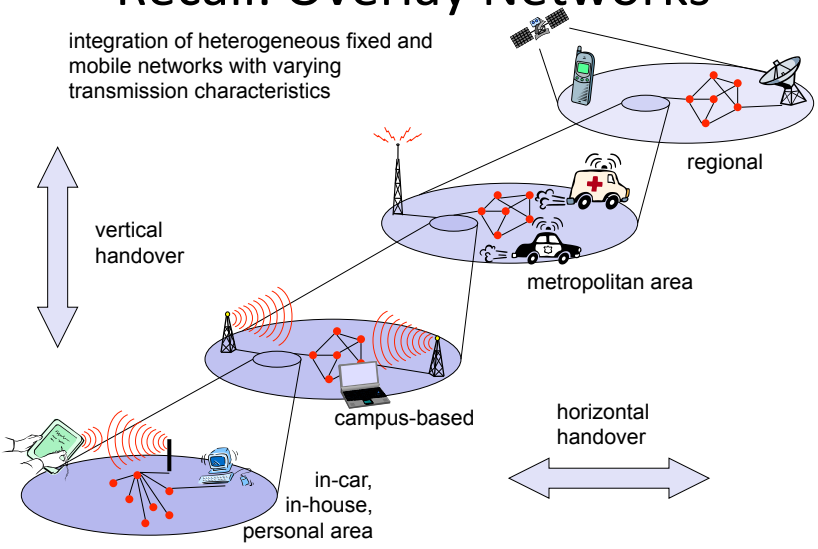
Recall: Overlay Networks



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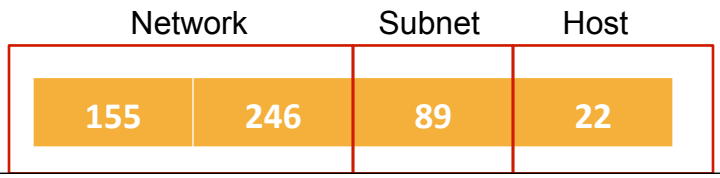
Motivation for Mobile IP

- Mobile devices
  - Suppose devices move across networks
  - Addressed by IP address
- IP Routing
  - Routing tables do not address every machine
  - IP addresses are hierarchical



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Motivation for Mobile IP

- Mobile devices
  - Suppose devices move across networks
  - Addressed by IP address
- IP Routing
  - based on IP destination address, network prefix (e.g. 155.246.89) determines physical subnet
  - change of physical subnet implies
    - change of IP address (standard IP) or
    - special entries in the routing tables

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Motivation for Mobile IP

- Specific routes to end-systems?
  - Change routing table entries to forward packets
  - does not scale
  - security problems
- Changing the IP-address?
  - adjust host IP address depending on current location
  - almost impossible to find a mobile device
    - DNS updates take too long
  - TCP connections break, security problems

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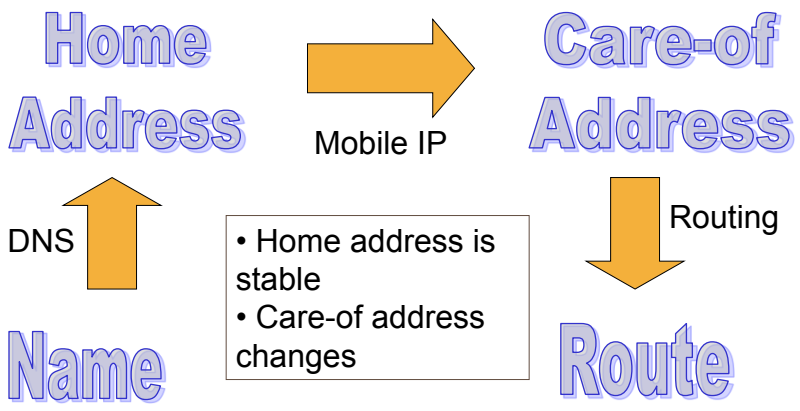
Mobile IP adds a layer of indirection



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Requirements for Mobile IPv4

- Transparency
  - mobile end-systems keep their IP address
  - continuation of communication after interruption
- Compatibility
  - support of the same layer 2 protocols as IP
  - no changes to end-systems and routers
- Security
  - authentication of registration messages
- Efficiency and scalability

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Terminology



- Mobile Node (MN)
- Home Agent (HA)
  - home network of the MN, typically a router
  - registers location of the MN, tunnels IP datagrams to COA
- Foreign Agent (FA)
  - current foreign network of the MN, typically a router
  - forwards the tunneled datagrams to the MN
- Care-of Address (COA)
  - address of current tunnel end-point for the MN
  - actual IP location of the MN e.g. DHCP
- Correspondent Node (CN)

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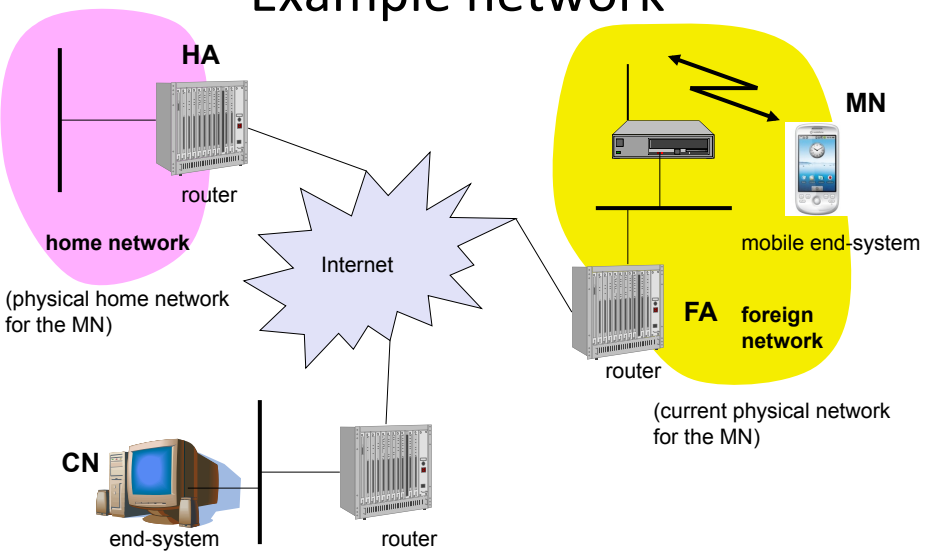
Example network



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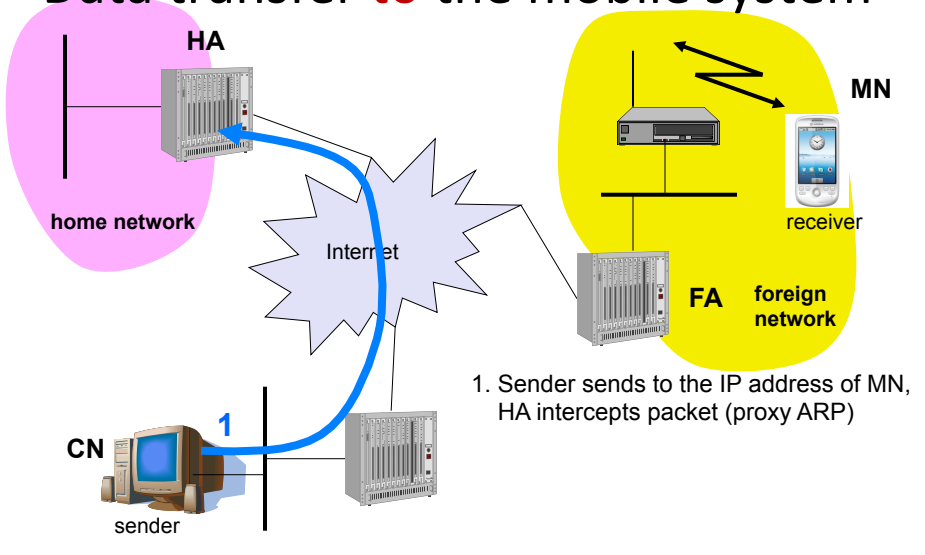
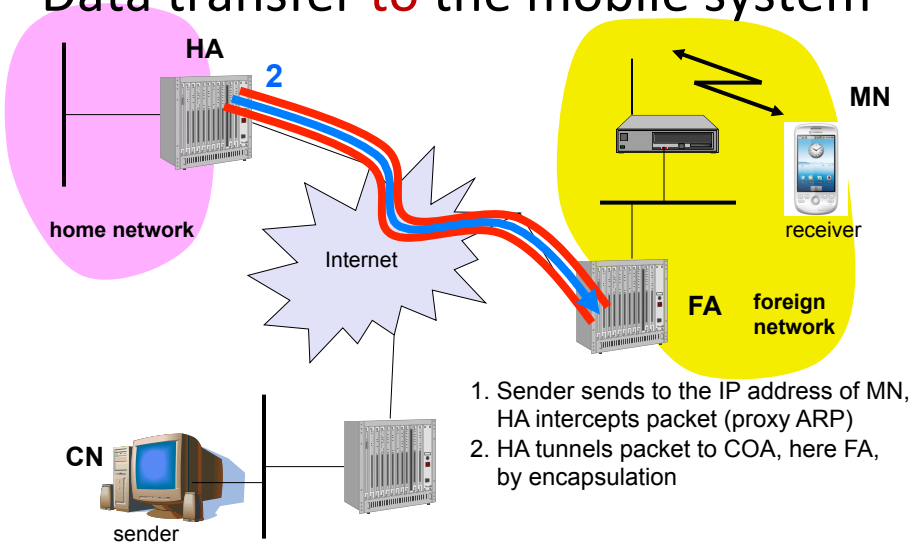
Data transfer to the mobile system



1. Sender sends to the IP address of MN, HA intercepts packet (proxy ARP)

22

Data transfer to the mobile system



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2. HA tunnels packet to COA, here FA, by encapsulation

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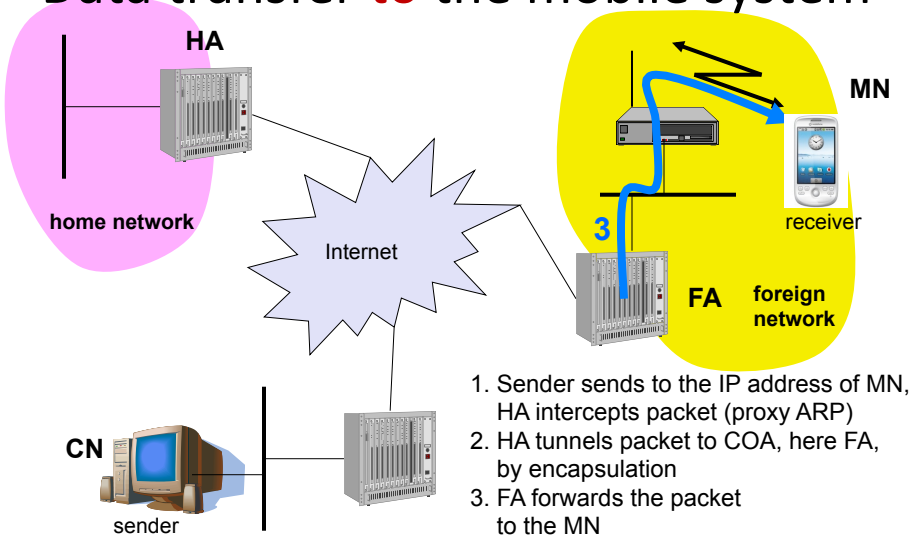

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2. HA tunnels packet to COA, here FA, by encapsulation
3. FA forwards the packet to the MN

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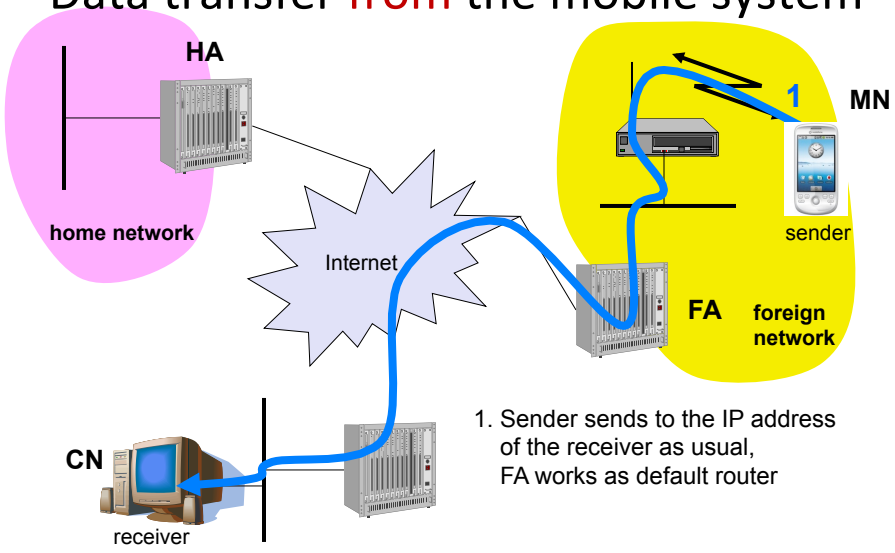
Data transfer from the mobile system



1. Sender sends to the IP address of the receiver as usual, FA works as default router

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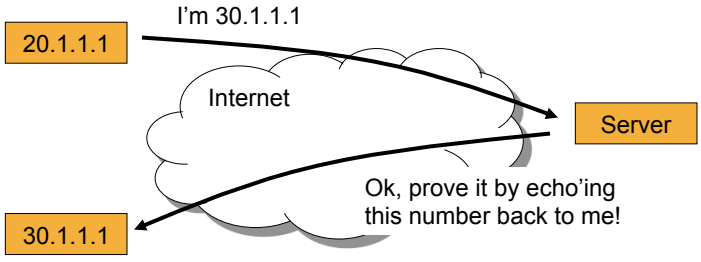
Reverse routability to prevent DoS



Since challenge doesn't go back to 20.1.1.1 (i.e. is not reverse routable), 20.1.1.1 cannot spoof 30.1.1.1

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Mobile IP with reverse tunneling

- Problem: Routers often only accept "topological correct" addresses (firewall!)
- Reverse Tunneling: tunnel replies back to HA
  - a packet from the MN encapsulated by the FA is now topological correct
  - furthermore multicast and TTL problems solved (TTL in the home network correct, but MN is too far away from the receiver)

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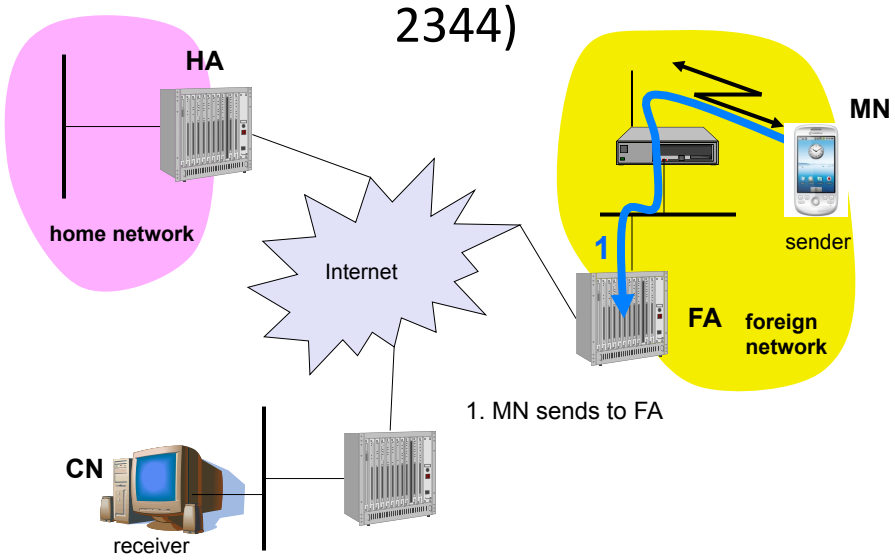
Reverse tunneling (RFC 3024, was: 2344)



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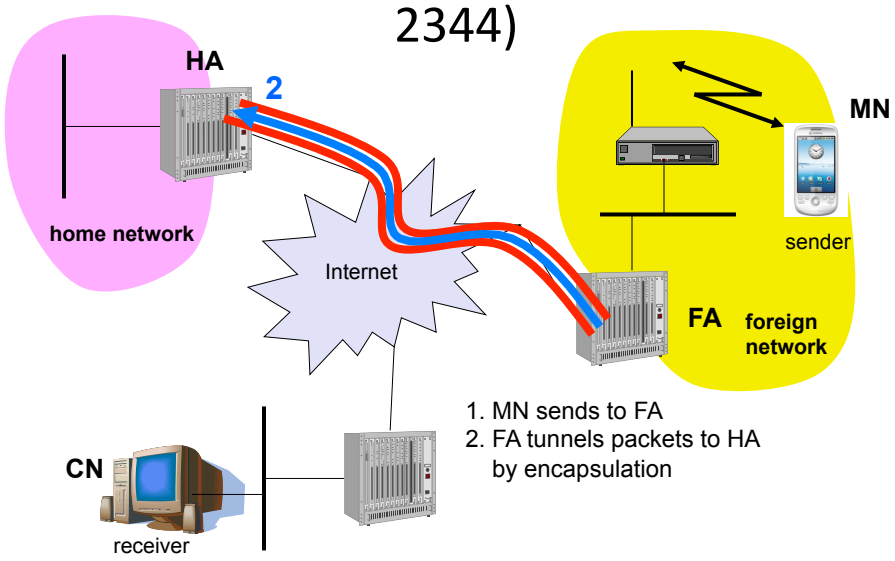

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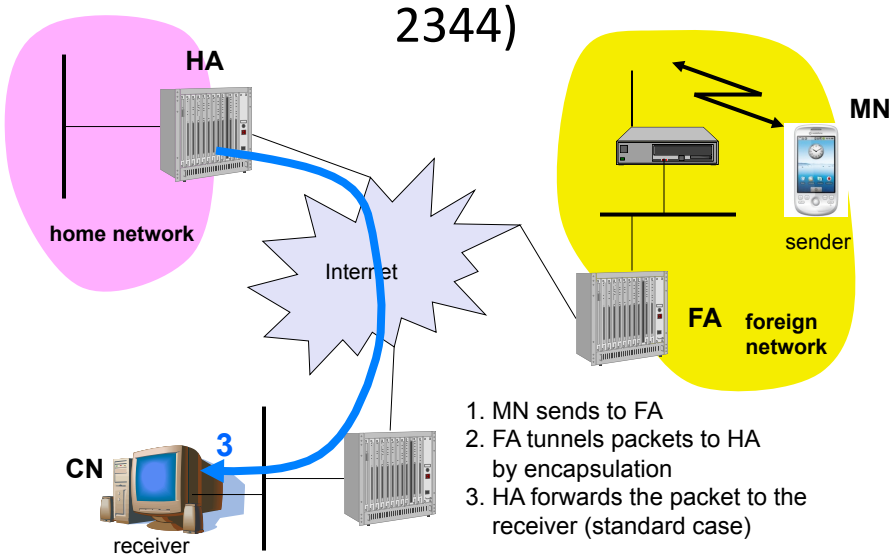

1. MN sends to FA
2. FA tunnels packets to HA by encapsulation
3. HA forwards the packet to the receiver (standard case)

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MOBILE IP: REGISTRATION

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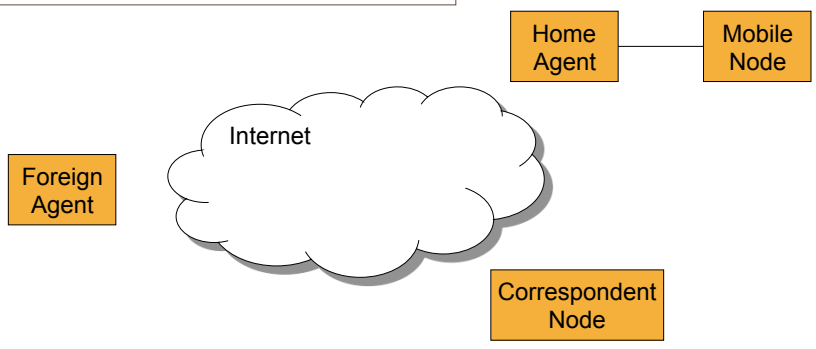
Agent Advertisement

Mobile Node has a stable home address at its home network



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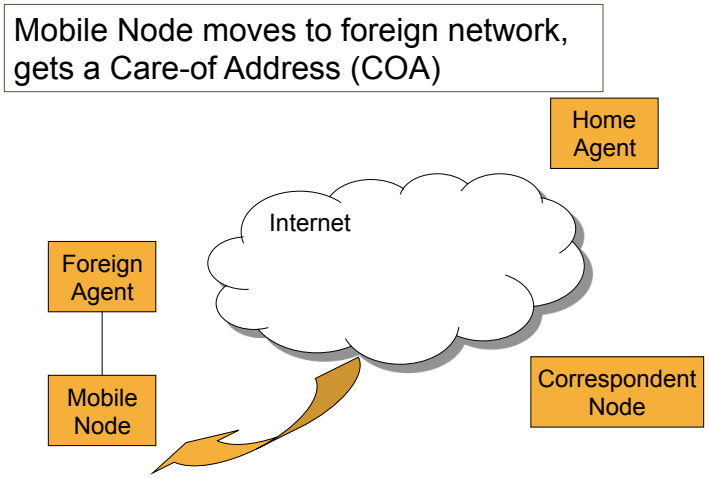
Agent Advertisement



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Agent Advertisement

- How does mobile node learn its HA/FA?
  - HA and FA periodically send **advertisement** messages into their physical subnets
  - MN listens to these messages, and detects if it is in the home or a foreign network
  - MN reads a COA from the FA advertisement messages

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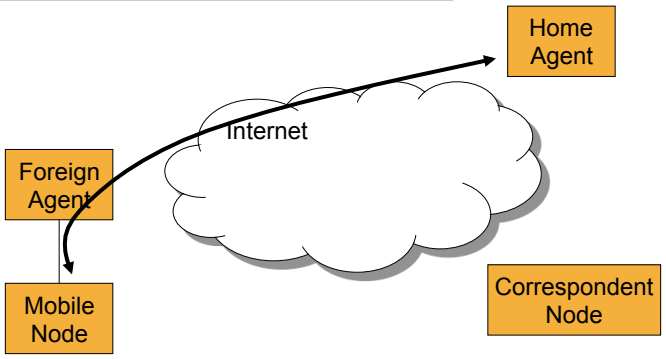
Registration

Mobile Node registers with Home Agent, creates IP tunnel



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Registration

- Registration (always limited lifetime!)
  - MN signals COA to the HA via the FA
  - HA acknowledges via FA to MN
  - these actions have to be secured by authentication

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Mobile Node Advertisement

- How do other hosts learn of MN address?
  - HA advertises the IP address of the MN (proxy ARP)
  - routers adjust their entries (HA association long-lived)
  - packets to the MN are sent to the HA
  - independent of changes in COA/FA

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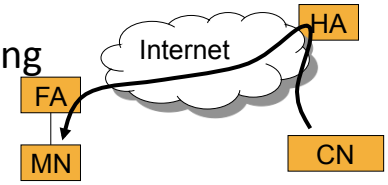
Optimization of packet forwarding

- Problem: Triangular Routing
  - sender sends all packets via HA to MN
  - higher latency and network load



- "Solutions"
  - sender learns the current location of MN
  - direct tunneling to this location
  - HA informs a sender about the location of MN
  - big security problems!

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Change of Foreign Agent

- Packets on-the-fly during the change can be lost
- New FA informs old FA to avoid packet loss
- Old FA now forwards remaining packets to new FA
- This information also enables the old FA to release resources for the MN

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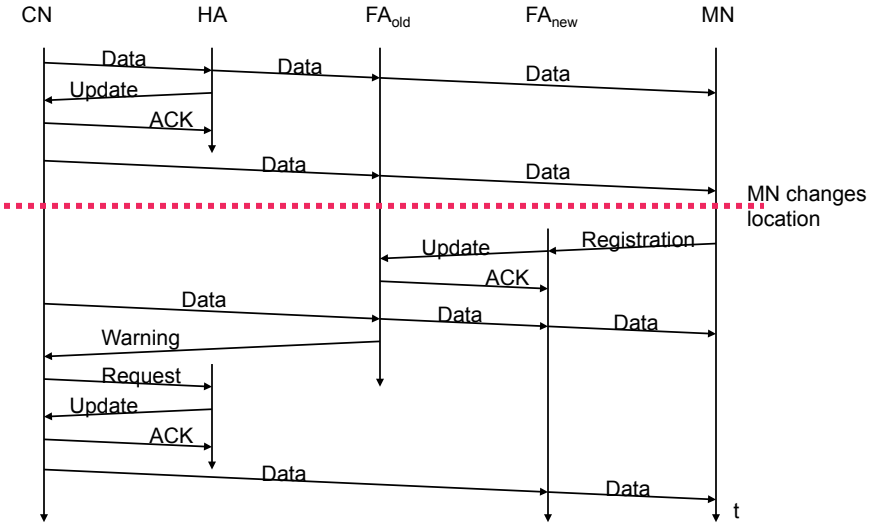
Change of Foreign Agent



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MOBILE IP: PROSPECTS

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Mobile IP and IPv6 (RFC 3775)

- IPv6 simplifies the protocols
  - security is integrated
  - COA assigned via auto-configuration e.g. DHCPv6
  - all routers perform advertisement (no need for FA)
  - MN can signal a sender directly the COA, sending via HA not needed in this case (automatic path optimization)
  - "soft" hand-over, i.e. without packet loss, between two subnets is supported
    - MN sends the new COA to its old router
    - old router forwards packets to the new COA
    - authentication is always granted

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Problems with Mobile IP

- Security
  - authentication with FA problematic (typically belongs to another organization)
  - no standard protocol for key management and key distribution
  - patent and export restrictions
- Firewalls
  - Typically cannot be used with firewalls (reverse tunneling)
- QoS
  - tunneling makes it hard to ensure QoS

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Mobile IP in Telephone Networks

- In long term, carriers moving to IP
  - Bandwidth/cost efficiency of packet-based service
  - IP is standard packet technology
- Hierarchical approach to mobility:
  - Hardware/link based mechanism for tower-to-tower handover
  - Mobile IP for region-to-region handover
  - "Stacked" Mobile IP sessions for internetworking

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CDMA2000

- Uses Mobile IP within a single network
- Three levels of support station, all within one CDMA2000 network
  - Cell base station (BS)
  - FA (called "Packet Data Serving Node," PDSN)
  - HA
  - Each FA connects to several BSs

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CDMA2000

- MN initiates **two** sessions:
  - PPP session with FA
  - Mobile IP session with HA
- Mobile IP traffic travels over PPP
- Move between BSs attached to same FA: no changes
- Move between BSs attached to different FAs: Mobile IP style handover + teardown/ establish PPP sessions

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CDMA2000

- Move between CDMA2000 network and another network: use second, "stacked" Mobile IP session
- Mobile IP session #1: remains, for mobility within CDMA2000 network
- Mobile IP session #2: for mobility between CDMA2000 network & other network
  - CDMA2000's HA can act as cross-network Mobile IP HA
  - CDMA2000's HA can act as cross-network FA
  - Identity of HA depends on MN-HA trust relationship

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The Future

- Cross-network mobility likely to be "vertical" rather than "horizontal"
  - Vertical ⇒ between local high speed (e.g., 802.11) and wide area low speed carrier
  - Horizontal ⇒ between wide area low speed carriers
- Carriers have spent 10s of billions to acquire licenses & build out
- Each wants its customers on ITS network 100% of the time

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MOBILITY IN NAMING

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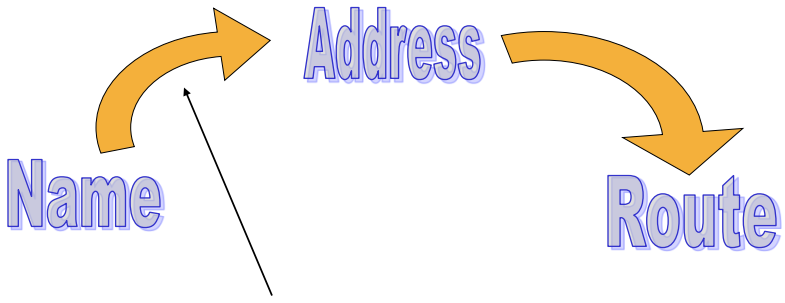
Mobility and Naming



Mobile Devices: This mapping is changing often

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When do we need Mobile IP?

- Most mobile systems are clients
  - Servers are rarely mobile
- Clients need to:
  - Send/receive email
  - Send/receive instant messages
  - VOIP (Voice over IP)
- Key Insight: Clients initiate connections

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Application specific registration as a mobility solution

- To receive email, client connects to an email server
- To do instant messaging, client registers with an IM server
- To do VoIP, client registers with a SIP server
- Handles many of the problems

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Discovery

- Discovery: How do we find a service?
  - URL
  - URN: Uniform Resource Name
  - More general approach: a discovery service
    - Search UDDI database
    - WSDL provides interface for service

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Example: Why discovery is tricky

- Client has opinions
  - "I want current map data for Disneyland showing line-lengths for the rides right now"
- Service has opinions
  - Amazon.com would like requests from Hoboken to go to the NJ-3 datacenter, and if possible, to the same server instance within each clustered service
- DNS has opinions
  - Many systems play with name → IP bindings
- Internet has opinions (routing)

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How we do it now

- Client queries directory to find the service
- Server has several options:
  - Web pages with dynamically created URLs
    - Content hosting companies remap URLs on the fly. E.g. http://www.akamai.com/www.cnn.com
  - Server can control mapping from host to IP addr.
    - Must use short-lived DNS records; overheads are very high!
- Mechanisms are non-standard and costly
- See additional material: CDNs and Akamai

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Based on slides by Hari Balakrishnan, Karthik Lakshminarayanan, Sylvia Ratnasamy, Scott Shenker, Ion Stoica, Michael Walfish

LAYERED NAMING

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Architectural Brittleness in Internet Naming

- Hosts are tied to IP addresses
  - Mobility and multi-homing pose problems
- Services are tied to hosts
  - A service is more than just one host: replication, migration, composition
- Packets might require processing at intermediaries before reaching destination
  - "Middleboxes" (NATs, firewalls, …)

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The Trouble with Host-Centric Names

- Host-centric names are *fragile*
  - If a name is based on mutable properties of its referent, it is fragile
  - Example: If Joe's Web page www.berkeley.edu/~hippie moves to www.wallstreetstiffs.com/~yuppie, Web links to his page break
- Fragile names constrain movement
  - IP addresses are not stable host names
  - DNS URLs are not stable data names

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Name Services and Hosts Separately

- *Service identifiers* (*SIDs*) are host-independent **data names**
- *End-point identifiers* (*EIDs*) are location-independent **host names**
- Protocols bind to names, and resolve them
  - Apps should use SIDs as data handles
  - Transport connections should bind to EIDs

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Name Services and Hosts Separately

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Binding principle: Names should bind protocols only to relevant aspects of underlying structure

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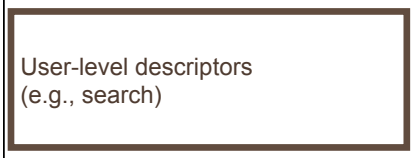
The Naming Layers



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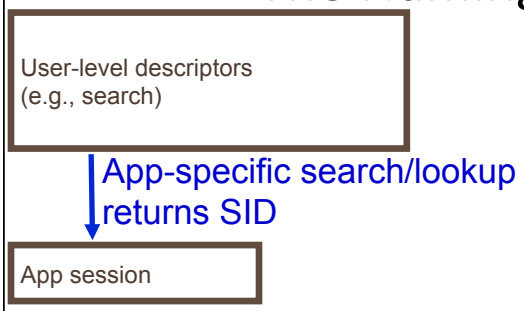

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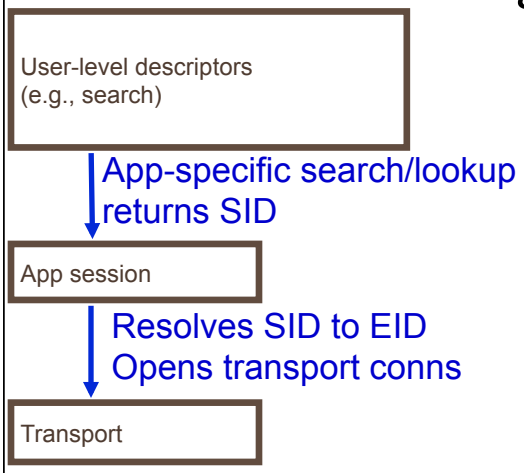

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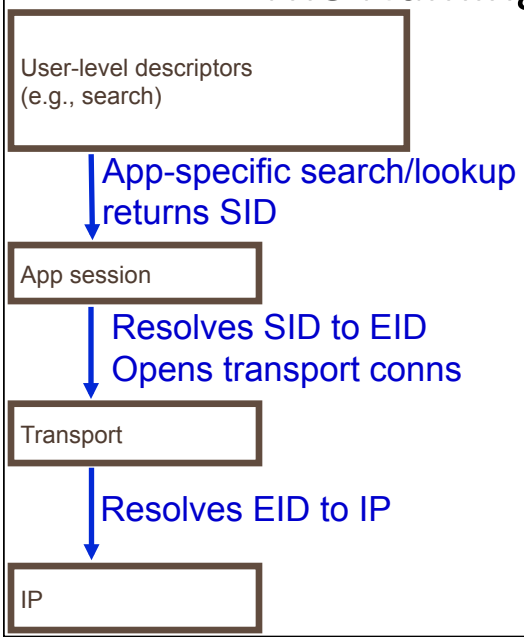

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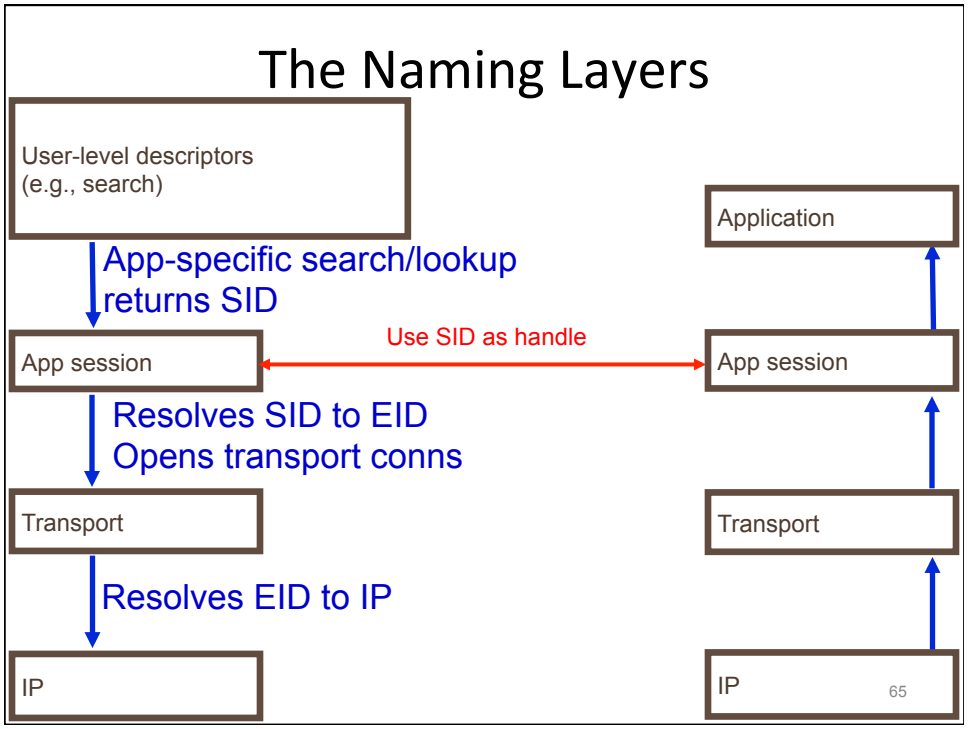
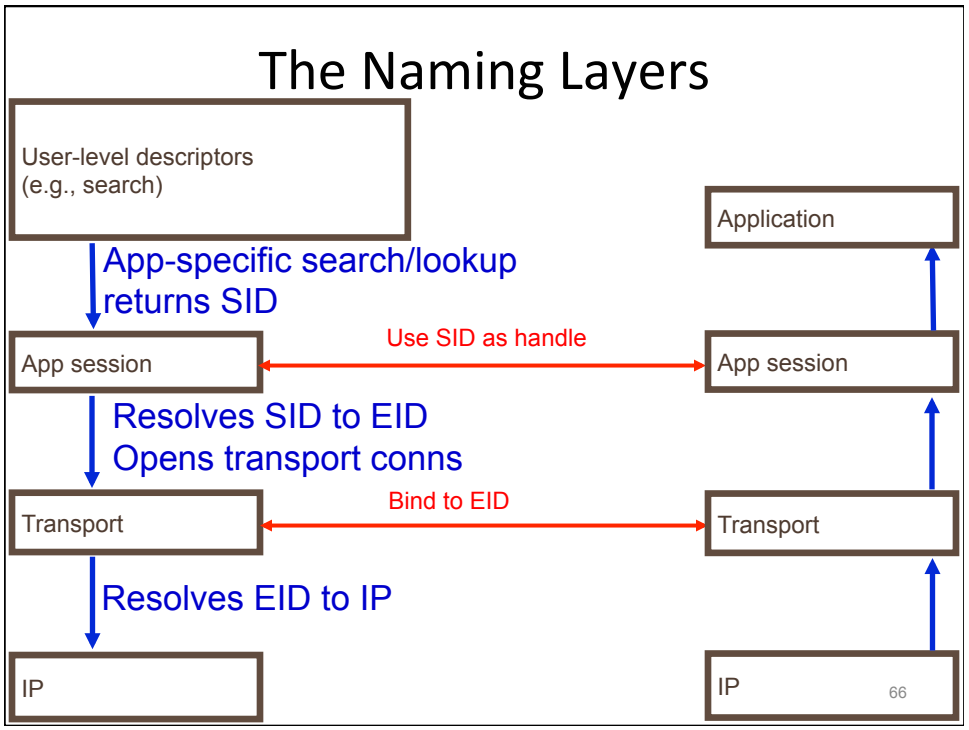

The Naming Layers
User-level descriptors
(e.g., search)
App-specific search/lookup
returns SID
App session
Use SID as handle
Resolves SID to EID
Opens transport conns
Transport
Resolves EID to IP
IP
Application
App session
Transport
IP
65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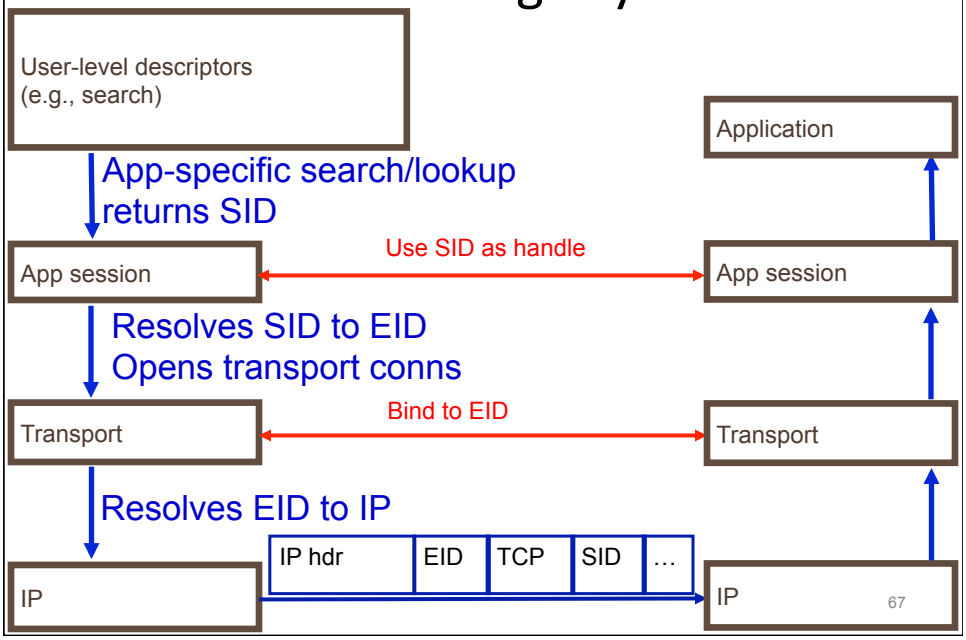
The Naming Layers



SIDs and EIDs should be Flat
0xf436f0ab527bac9e8b100afeff394300

- Flat names impose no structure on entities
  - Structured names stable only if name structure matches natural structure of entities
  - Can be resolved scalably using DHTs (e.g. i3)
- Flat names can be used to name anything
  - Once you have a large flat namespace, you never need other global "handles"

Stable-name principle: A stable name should not impose restrictions on the entity it names

Delegation

- Names usually resolve to "location" of entity
- Packets might require processing at intermediaries before reaching destination
- Such processing today violates layering
  - Only element identified by packet's IP destination should inspect higher layers

Delegation principle: A network entity should be able to direct resolutions of its name not only to its own location, but also to chosen delegates

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Conclusions

- Names: Identifiers, may also be locators
- Internet: Name $\Rightarrow^{DNS}$ address $\Rightarrow^{IP}$ route
- Mobile IP: Name $\Rightarrow^{DNS}$ home address $\Rightarrow^{MobileIP}$ COA $\Rightarrow^{IP}$ route
- Layered Names: Name $\Rightarrow^{Search}$ SID $\Rightarrow^{DHT}$ EID $\Rightarrow^{DHT}$ address $\Rightarrow^{IP}$ route

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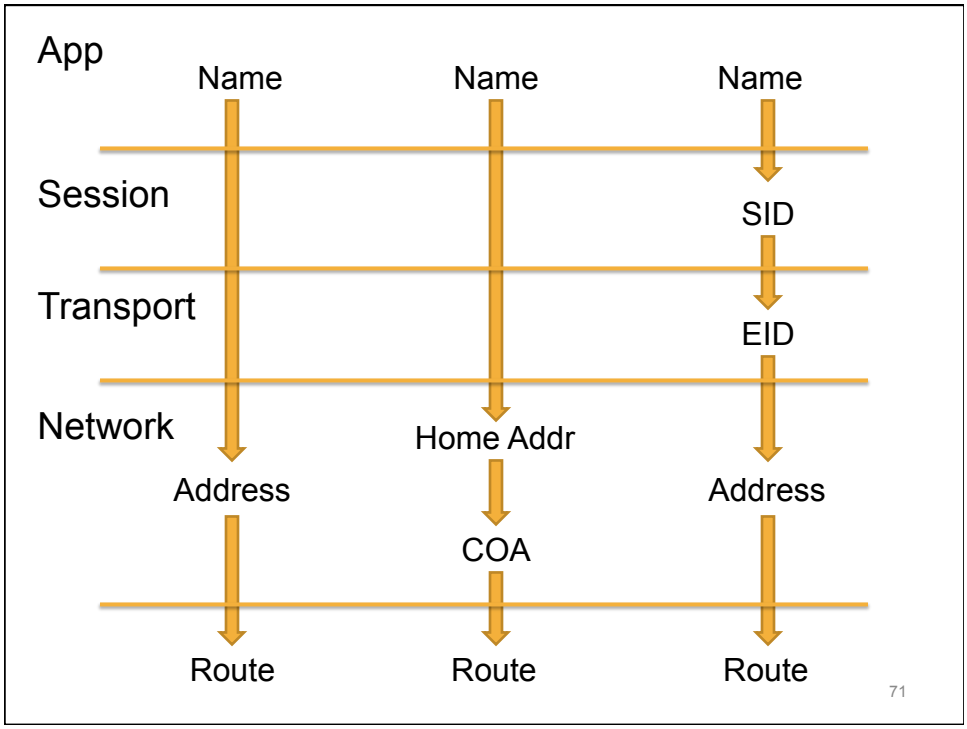
App
Name
Name
Name
Session
SID
Transport
EID
Network
Home Addr
Address
Address
COA
Route
Route
Route
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