Naming and Addressing

Protocol Design – S-38.3157

Identifying Communication Partners

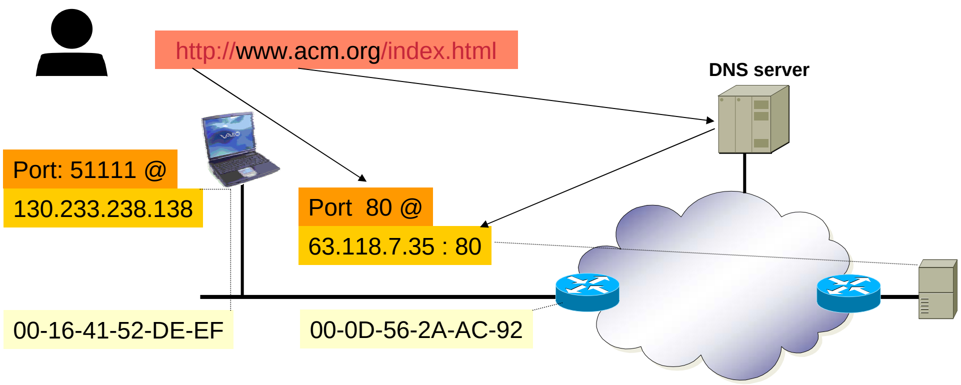
- Names
  - Human readable identifiers that can be remembered!
    (e.g., DNS name, URI, URN)
- Identifiers and addresses
  - Machine-processable identifier (e.g., Host Identity, HI)
  - Protocol-level identifier (e.g., IP address)
- Locators
  - Information about the location of a partner in the network topology
- Different levels: interfaces vs. machines vs. applications vs. users
- Need to be managed (unique assignment)
  - Or chosen randomly (and defended) in ad-hoc environments (‹birthday paradox)
- One needs to resolved into the other
  - Address books, (distributed) data bases (e.g., DNS, DHTs), protocol exchanges, caching, (manual) configuration, …

Some Examples

- 130.233.238.133
- fe80::20f:eaff:fe57:efe3
- 00-20-E0-74-22-53
- Port 80
- mail.ieee.org

- tel:+358-9-451-1234
- jo@netlab.tkk.fi
- http://www.acm.org/
- sip:alice@example.com
- ftp://ftp.ietf.org/

Typical Usage Example (1)



Typical Usage Example (2)

- Application layer: URI
  - Access protocol identifier
  - DNS name of the server
  - Resource name
- Transport layer: Type and port number
  - Obtained from access protocol identifier by static convention
  - Obtained dynamically via DNS service or NAPTR lookup
  - Local identifier typically chosen dynamically
- Network layer: IP addresses
  - Obtained from the DNS name via DNS A/AAAA record lookups (or /etc/hosts)
  - Local identifier obtained via DHCP or zeroconf or statically configured
- Link layer: MAC addresses
  - Obtained via broadcast using ARP (cached)
  - Local identifier from the network interface card

Typical Usage Example (3): Functions

- URI
  - Modestly user readable abstraction of lower layer identifiers
- DNS name
  - Indirection mechanism
  - Independent of IPv4 or IPv6 address
  - Support for load balancing, redundancy, …
- Port number
  - Transport layer demultiplexing
- IP address
  - Locates the node (host part) in a specific network (network part): routing
  - Identifies the endpoint for the transport layer (e.g., TCP)
- MAC address
  - Local relevance only

Name Spaces

- Needed for all kinds of things
  - Host names
  - IP address
  - The Web
  - Protocol identifiers
  - Protocol field names and possibly values
- Structure
  - Structured: DNS names, URIs, URNs
  - Semi-structured: IP addresses
  - Unstructured: port numbers, cryptographic host identifiers
  - Tuple spaces: collections of attributes
- Available addresses
  - Finite: IP addresses (v4 & v6), port numbers, cryptographic host identifiers
  - Infinite: DNS names, URIs, URNs
- Scope
  - Local scope: link local addresses, private address spaces, source routes
  - Global scope: public IP address, most DNS names, etc.
- Validity: “permanent” vs. ephemeral

Semantics (*casting)

- Purpose of an address
  - “Addressing” / referring to one or more entities
- For nodes: to identify
  - A single entity (unicasting)
  - All entities in a group (multicasting)
  - All entities (broadcasting)
  - Any (e.g., the closest) entities serving a certain purpose (anycasting)
    - Closely related to service location
- May be encoded into the address structure
  - IP and 802 layer multicast addresses
- May become visible only when resolving the address
  - Mail or SIP URI, tuple spaces

Name and Address Assignment

- Static allocation
  - Obtain an address from an organization (IEEE, IANA, …)
  - Past: your static IP subnet or address assignment
  - Protocol registries (e.g., IANA)
- Hierarchical assignment delegation
  - Allocate base addresses and delegate sub-address allocation
  - DNS names, IEEE 802 MAC address, IP subnet addresses
- Dynamic assignment
  - Obtaining an address upon request (e.g., DHCP, SIP GRUUs)
  - Administering entity needed (DHCP server, kernel for dynamic port numbers)
- Self-assignment
  - Derive from other address and/or properties: UUIDs, IPv6 addresses
  - Generate and defend addresses (zeroconf)
  - Choose based upon unlikely collisions: cryptographically generated identifiers

Resolution or Mapping

- Names and addresses need to be converted into (other) names and addresses
- Mechanisms
  - Built-in resolution (mapping)
    - By convention (“well known”): you “know” that port 80 is HTTP, IPv4 all routers is 224.0.0.2
    - By algorithm: how to construct an 802 multicast address from an IPv4 multicast address
  - “Centralized” resolution (possibly multiple “central nodes”)
    - Need one or more rendezvous points (centralized/locatable per domain)
    - Examples: SIP, Mobile IP
  - Hierarchical resolution
    - DNS
  - Broadcast-/multicast-based (distributed) resolution
    - ARP, service location protocols
  - Distributed resolution
    - Overlays (e.g., DHTs)
- Responsibility for mapping/resolving
  - Single entity: message originator, proxy (deferred resolution)
  - Some (or multiple) entities “on the way”: late binding
- Helpful: if responsibilities for administration and resolution of addresses match

Location and Forwarding

- Need to find the way towards an addressed entity
- From an address to the locator: another resolution step
  - One-stop: given the address, obtain the locator
    - IP address = locator (exception: mobile IP)
    - DNS name to IP address conversion
  - Incremental: step-by-step resolution along with forwarding
    - Routing: routing tables in each router show the next hop towards the destination
- Locators and forwarding
  - (Hierarchical) locator structure enables routing aggregation
    - Downside: locators change with point of network attachment
    - Example: IP address structure of (network, host)
  - Special case: source-routing
- Location-free addresses (no locators)
  - Downside: lots of routing/forwarding information data to store

Mobility and Multicasting

- Name to identifier/address to locator binding
  - Mobility changes the identifier to locator binding
  - Multicasting impacts the name to identifier/address binding
    - and leads to multiple (many) locations
  - Anycasting impacts the name to id/addr or the id/addr to locator bindings
- Changes need to be reflected in resolution/mapping and/or location/forwarding
  - In a single node: e.g., mobile IP Home Agent, SIP registrar, current peer(s)
  - In the network: e.g., multicast state in routers, anycast nodes
    - Global network mobility example: Connexion by Boeing (BGP routing tables)
- Issues with update frequency, overhead, consistency, …

Tradeoffs

- Name to id/address to locator bindings require mappings
  - Convenience (user)
  - Flexibility, redundancy, efficiency (system)
- Finding the way to an entity requires locating/forwarding
- Naming and addressing conventions (structure, etc.) define where you push the effort to
  - Examples
  - Indirections increase flexibility but add infrastrutcture and latency
  - Structure helps with routing but creates (e.g., topological) dependencies
  - Flat name spaces can help mobility but may increase cost

Example: IP Address Functions

- Node location for routing
  - Structure: (network, host) pair
  - Locates the node (host part) in a specific network (network part)
- Node identification
  - Identifies the endpoint for the transport layer (e.g., TCP)
  - Identifier the node for a security association (e.g., security context, certificate)
- Communication type identification
  - Unicast vs. broadcast vs. multicast addresses
  - Anycasting support in cooperation with routers
- May limit the propagation
  - Administratively scoped multicast addresses

Issues with IP Addresses

- Dual nature: Locator and Identifier
  - An IP address refers to an interface (not a node!)
- Some issues
  - Mobility
    - A node with a change in the point of attachment, changes its IP address
    - (one suboptimal remedy: mobile IP)
  - Multi-attachment
    - Failover between different interface does not work transparently to the transport protocol
  - Network address translators (NATs)
    - Identifiers do not refer to the endpoint
    - Identifiers may change (e.g., for NATs with multiple external IP addresses)
  - Identifiers depend on the IP version used

Case Study: Host Identity Protocol (HIP)

Starting Point

- Current naming in the Internet world
  - Domain names
    - Used to name a limited number of hosts, typically well-known hosts
    - Many hosts do not have names associated with them
  - URLs
    - Application-specific extensions to DNS
  - IP addresses: two functions for interfaces
    - Topological locators for network attachment points (used in routing)
    - Naming of interfaces (used by higher layer transport protocols)
    - Issues with address changes impact transport and application layer protocols
  - A naming scheme supporting all hosts does not exist today
- HIP: Add a new name space for identifying computing platforms
  decouple network aspects from transport and applications

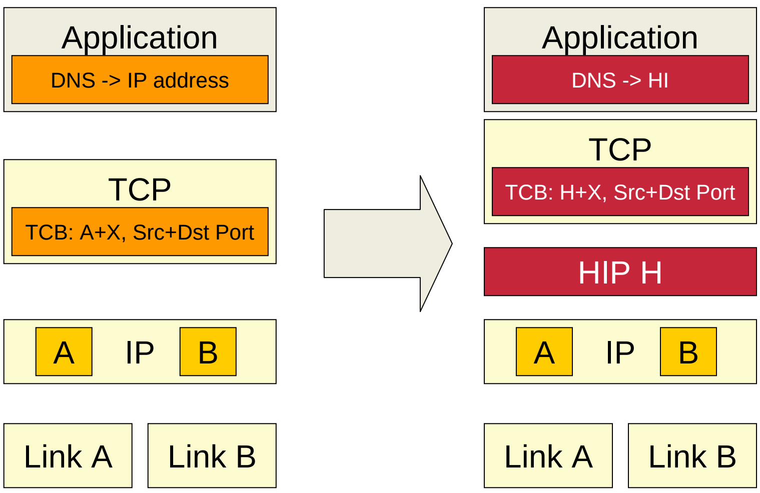
Requirements for a New Namespace

- Applied to the "IP kernel" – across network interfaces
- Decouple higher layers from internetworking
- Do not mandate administrative infrastructure
  - (enable pairwise deployment)
- Names should have a fixed length representation
- Acceptable packet size for use in other protocols
- Names should be statistically globally unique
- Names should have a localized abstraction for use in APIs and existing protocols
- Possibility to create names locally (➔anonymity)
- Names should be long-lived but still replaceable at any time

Host Identity Namespace

- Provides identifiers for computing platforms across interfaces
- Host Identifiers (HI)
  - The Public Key of a Public-Private key pair
  - Allows for decoupling + provides authentication
  - Self-asserted identities + third party authentication (e.g. X.509 certificates)
  - May be stored in DNS, other PKI
- Host Identity Tag (HIT)
  - 128 bit representation of HI
    - Regular hosts: prefix (01) + lower 126 bits of SHA-1 digest of normalized HI
    - Well known hosts: prefix (10) + authority assigned value + lower 64 bits of SHA-1 digest
- Local Scope Identifier (LSI)
  - 32 bit locally generated (and mutually agreed upon) identifier
  - Looks like drawn from the IPv4 1.0.0.0/8 address space
  - Used in local APIs

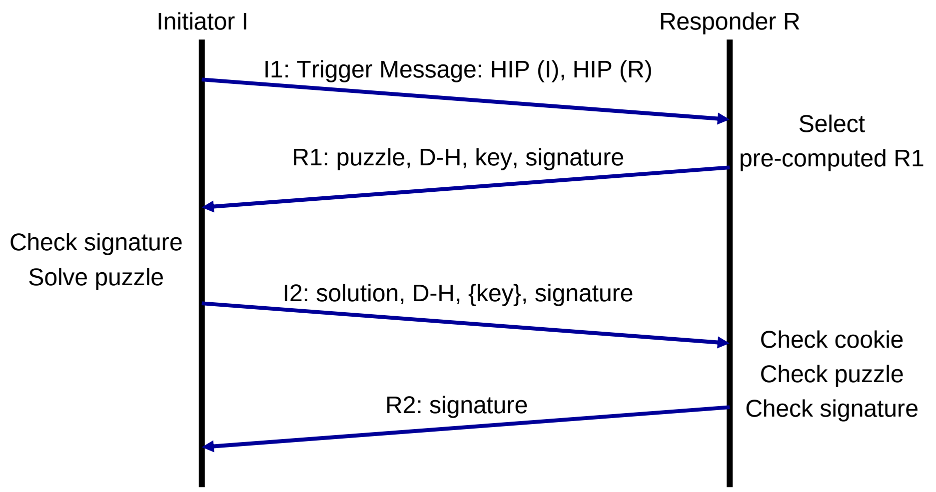
Internet Protocol Stack Positioning



Host Identity Protocol (HIP)

- Specific protocol exchange defined for association setup
  - 4-way handshake
    - Authenticates peers
    - Establishes IPsec security association + Diffie-Hellman based keys
    - Protects against DoS attacks
  - Subsequent data exchange uses IPsec ESP for tunneling packets
- Dynamic rekeying during the exchange
  - Update exchange for keying material
- Support for multi-homing and mobility
  - Update and validate peer addresses
  - Dynamics supported by rendezvous server
- Initial contact via DNS
  - Resolve to IP address of the target system or its rendezvous server

Basic HIP Operation



Updating Peer Addresses

- IP addresses are no longer needed for identifying endpoints
- Their routing function still is
- IP addresses may need updating
  - as interfaces come up and go down
  - as an interface address changes due to mobility

- Send REA parameter (remote address) to peer
- Wait for new security parameter index (SPI) from peer
- Then transmit data using new SPI

- Second and third step used for target address validation
  - Protection against e.g. DoS

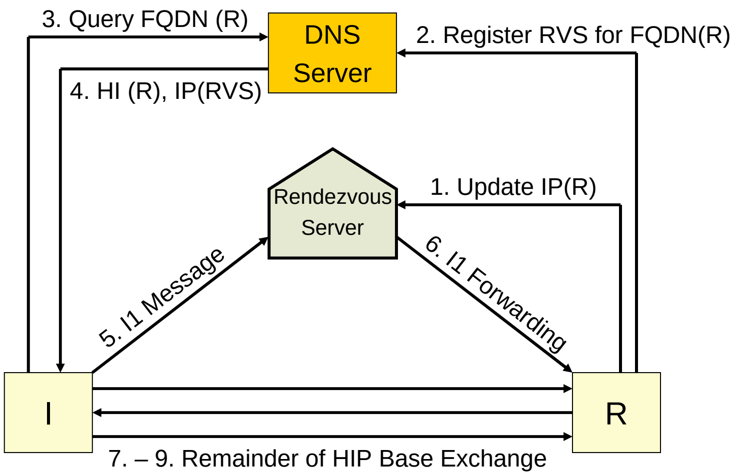
HI Resolution

- Initial use of DNS
  - Map DNS name to IP address
  - Map DNS name to HI
    - No mapping from HI to IP address provided (DNS hierarchy unsuitable)
  - Send IP packet (I1) to target, negotiate bindings
  - Provide remote address updates during operation as necessary

- Issues
  - Dynamic changes of IP address
    - Difficult to update timely with DNS (overhead, authentication, caching, ...)
  - Not all hosts have visible IP addresses

- Indirection mechanism: Rendezvous Server
- (other mechanisms such as Distributed Hash Tables conceivable)

Sample Rendezvous Server Operation



Concluding Remarks on HIP

- Rendezvous server may also help interworking with non-HIP systems
  - Provide fixed point of contact (despite sub-optimal routing)
  - Perform packet forwarding
  - May provide protocol / address translation as necessary
- HIP provides third namespace in addition to IP address and DNS
- Allows IP address inpendent naming of computation platforms
  - Supports multi-homing, mobility
  - Identifiers works across NATs and other middleboxes
  - Provides security for all exchanges
- Issue: quite some effort towards deployment

Some Discussion

- The Purpose of HIP
  - "Lowest layer name that does not have a location property."
- What are the short-term motivator for HIP deployment?
  - Why should Microsoft, Sun, Apple, etc. put this into their OSes?
- Prospective uses
  - HIP to allow for anonymity (self-generated HIs and HITs)
  - HIP to support security (enabler for secure communications, IPsec)
    - Secure storage of permanent HIs?
    - Enable secure communication without PKI after initial contact
  - HIP to enable mobility (instead of mobile IP?)
  - HIP as enabler for middlebox traversal?
    - But at what cost?
- How user friendly is HIP / must HIP be?
  - Configuration and management of HIs
  - Transparent re-use of existing application?
    - With / without API modifications