CS6504

Mobile Computing

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Mobile IPv4

Outline

- Host Mobility problem and solutions
- IETF Mobile IPv4

Host Mobility Problem 1/2

An ***IP address*** reflects a host's point of attachment to the network
Example: TCP connection identified by a 4-tuple
< ***source IP address, source TCP port, destination IP address, destination TCP port*** >

if either host move, and acquire a new IP address, the **TCP connection breaks**

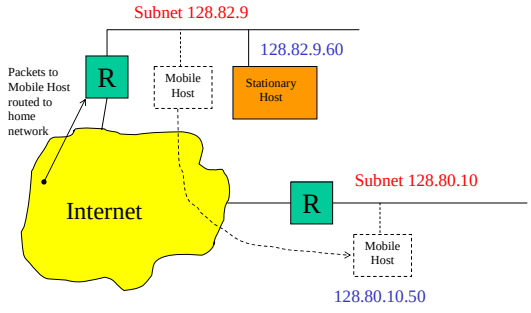
Fundamental Problem

an IP address serves dual purpose

Transport and application layer perspective: **end-point identifier**

Network Layer: **routing directive**

Host Mobility Problem 2/2



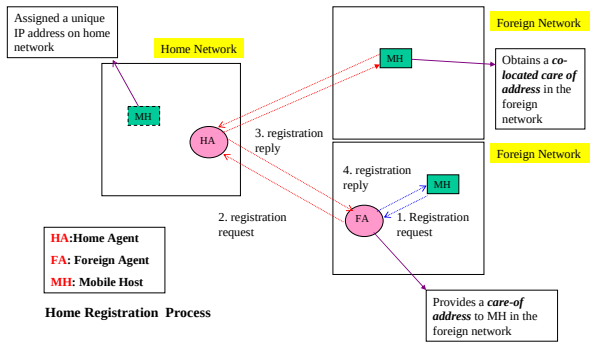
Host Mobility Problem Solutions

- **Network layer solutions**
  - -IETF Mobile IP (MIPv4 and MIPv6)
    - •uses "Mobility agents"
    - •hides a change of IP address, when a mobile host is moving between IP networks.
- **Application layer solutions**
  - -Mobility support using "Session Initiation Protocol"
    - •used for real-time mobile communications
    - •problem with TCP connections, suggests using mobile IP for TCP connections
- **End-to-End Host Mobility support**
  - •Relies on DNS secure dynamic updates
  - •TCP option for connection migration (suspend TCP connection and reactivate it from another IP address)

Network Layer Solutions Model

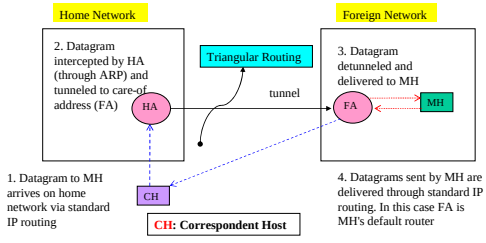
- •two-level addressing architecture
  - ➢home address & care-of address
- •key mechanisms
  - ➢address translation
    - ❑map home address to care-of address
  - ➢packet forwarding
    - ❑tunnel packets to care-of address
  - ➢location management
    - ❑update mobile host's location

IETF Mobile IPv4 1/4



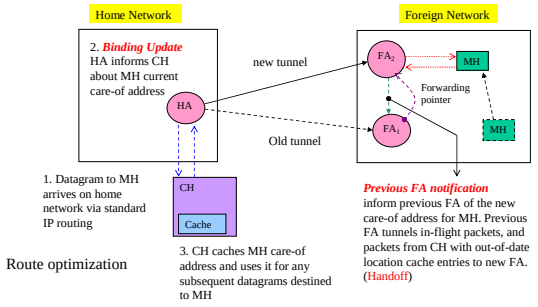
Home Registration Process

IETF Mobile IPv4 2/4



Unicast datagram routing to the MH's care-of address

IETF Mobile IPv4 3/4



Route optimization

IETF Mobile IPv4 4/4

Problems

- triangular routing (sub-optimal routing)
- tunneling overhead
- use of route optimization solves the triangular routing problem, BUT requires change in the IP stack of CH
- large signaling overhead (registration) , if movement within the same domain (local-area mobility). MH has to inform the HA whenever it changes its point of attachment.

Outline

- A more detailed look to Mobile IPv4
  - Architectural Entities
  - Operation Outline
  - Agent Discovery
  - Registration
  - Datagram Routing
  - Reverse Tunneling
  - Replay Protection

Architectural Entities

- Mobile Node
  - A host or router that changes its point of attachment from one network or subnetwork to another

Home Agent

- A router on a mobile node's home network which tunnels datagrams for delivery to the mobile node when it is away from home
- maintains current location information for the mobile node

Foreign Agent

- A router on a mobile node's visited network which provides routing services to the mobile node while registered
- detunnels and delivers datagrams to the mobile node that were tunneled by the mobile node's home agent.

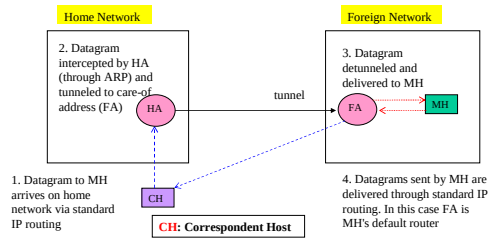
Operation Outline 1/3

- Mobility agents advertise presence via *Agent Advertisement messages*
- A mobile node may optionally solicit such message through an *Agent Solicitation message*
- A mobile node determines whether in a home or foreign network
- In home network → operates without mobility services
- If returning to its home network, the mobile node *deregisters* with its home agent
- In a foreign network, it obtains a *care-of address*
  - from a foreign agent's advertisements (a foreign agent care-of address)
  - by some external assignment mechanism such as DHCP (a co-located care-of address)

Operation Outline 2/3

- The mobile node operating away from home
  - registers its new care-of address with its home agent through exchange (possibly via a foreign agent)
- Datagrams sent to the mobile node's home address
  - intercepted by its home agent
  - tunneled by the home agent to the mobile node's care-of address
  - received at the tunnel endpoint, and finally delivered to the mobile node
- In the reverse direction, datagrams sent by the mobile node
  - are generally delivered to their destination using standard IP routing mechanisms

Operation Outline 3/3

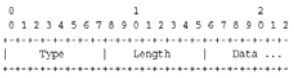


Unicast datagram routing to the MH's care-of address

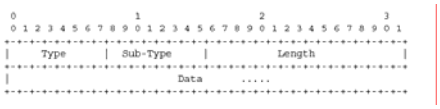
Message Format and Protocol Extensibility 1/2

- Mobile IP defines a set of new control messages, sent with UDP using well-known port number 434 (Registration request and reply)
- For Agent Discovery: use of the existing Router Advertisement and Router Solicitation messages defined for ICMP Router Discovery
- Mobile IP defines a *general Extension mechanism* to allow optional information to be carried by Mobile IP control messages or by ICMP Router Discovery messages
- Extensions format
  - Type-Length-Value Extension Format (Type-Length(8 bits)-Data)
  - Long Extension Format (Type–SubType– Length (16 bits)-Data)
  - Short Extension Format (Type-SubType-length(8 bits)-Data)

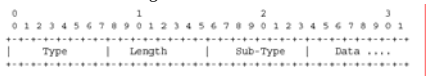
Message Format and Protocol Extensibility 2/2



Type-Length-Value Extension Format



Long Extension Format



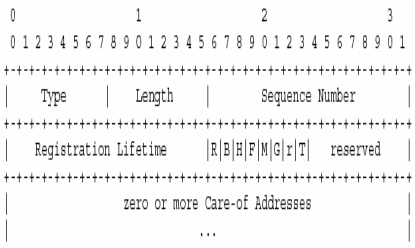
Short Extension Format

Agent Discovery 1/2

- An *Agent Advertisement* is formed by including a *Mobility Agent Advertisement Extension* in an ICMP Router Advertisement message
- An Agent Solicitation is identical to an ICMP Router Solicitation with the further restriction that the IP TTL Field MUST be set to 1
- IP Fields in ICMP router advertisement message (Mobile agents multicast group is 224.0.0.11)
  - TTL: set to 1
  - Destination address:
    - "all systems on this link" multicast address (224.0.0.1)
    - the "limited broadcast" address (255.255.255.255).
    - When unicast to a mobile node, the IP home address of the mobile node

Agent Discovery 2/2

- Mobility Agent Advertisement Extension



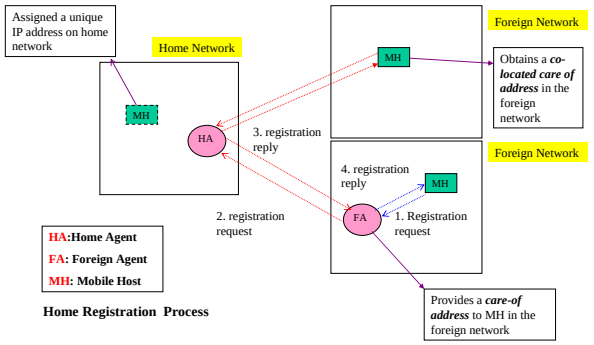
R Registration required
B Busy
H Home Agent
F Foreign Agent
M Minimal Encapsulation
G GRE Encapsulation
r sent as Zero
T Reverse tunneling

- Length is 6 + 4 * number of care-of addresses
- Sequence number is the count of Agent Advertisement messages sent since the agent was initialized. Initially 0. Upon rollover, start from 256 (why?)

Registration 1/2

- request forwarding services when visiting a foreign network
- inform home agent of current care-of address
- *renew* a registration which is due to expire
- *deregister* when they return home
- Optionally
  - maintain *multiple simultaneous registrations*, so that a copy of each datagram will be tunneled to each active care-of address
  - deregister specific care-of addresses while retaining other mobility bindings
  - discover the address of a home agent, if not already configured with such information

Registration 2/2



Home Registration Process

Registration Authentication

•Each mobile node, foreign agent, and home agent MUST be able to support a *mobility security association* for mobile entities, indexed by their SPI and IP address. In the case of the mobile node, this must be its Home Address

•Mobility Security Association (MSA)

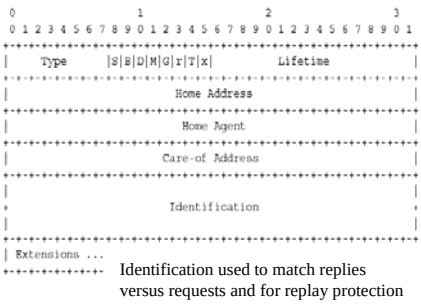
A collection of mobile IP security contexts, between a pair of nodes. Each context indicates an authentication algorithm and mode, a secret (a shared key, or appropriate public/private key pair), and a style of replay protection

•Security Parameter Index (SPI)

An index identifying a security context between a pair of nodes among the contexts available in the MSA.

Registration Request

Mobile IP Fields in registration request



Identification used to match replies versus requests and for replay protection

S Simultaneous binding

B Broadcast datagrams

D Decapsulation by MH

M Minimal Encapsulation

G GRE Encapsulation

r sent as Zero

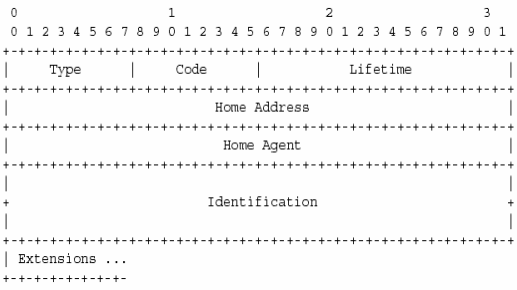
T Reverse tunneling

x sent as Zero

A value of zero in lifetime indicates request for deregistration

Registration Reply

Mobile IP Fields in registration reply



Registration extensions

Computing authentication extension values

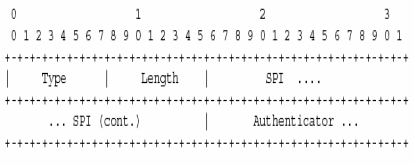
•The default authentication algorithm compute a 128-bit "message digest" of the registration message

•The data over which the digest is computed is defined as

- ➢the UDP payload (Registration Request or Registration Reply data)
- ➢all prior Extensions in their entirety
- ➢the Type, Length, and SPI of this Extension

Mobile-Home Authentication Extension

Must be present in registration requests and in registration replies generated by HA



The same format is used for *Mobile-Foreign* and *Foreign-Home* authentication extensions

Extensions order 1/2

The following order must be adhered to in registration requests

- ➢The IP header, followed by the UDP header, followed by the fixed-length portion of the Registration Request
- ➢If present, any non-authentication Extensions expected to be used by the home agent (which may or may not also be useful to the foreign agent)
- ➢An authorization-enabling extension
- ➢If present, any non-authentication Extensions used only by the foreign agent
- ➢The Mobile-Foreign Authentication Extension, if present.

Extensions order 2/2

The following order must be adhered to in registration replies

- ➢The IP header, followed by the UDP header, followed by the fixed-length portion of the Registration
- ➢If present, any non-authentication Extensions used by the mobile node (which may or may not also be used by the foreign agent)
- ➢The Mobile-Home Authentication Extension
- ➢If present, any non-authentication Extensions used only by the foreign agent
- ➢The Foreign-Home Authentication Extension, if present.

Data Structures at HA and FA

Mobility binding entry at HA

- the mobile node's home address
- the mobile node's care-of address
- the Identification field from the Registration Reply
- the remaining Lifetime of the registration

Visitor list entry at FA (for each pending or current registration)

- the link-layer source address of the mobile node
- the IP Source Address
- the IP Destination Address (FA IP address might be unknown to MH)
- the UDP Source Port
- the Home Agent address
- the Identification field
- the requested registration Lifetime
- the remaining Lifetime of the pending or current registration.

Datagram routing 1/5

- Broadcast datagrams
  - ➢ MH must have requested forwarding of broadcast datagrams
  - ➢ Tunnel to co-located care-of address
  - ➢ If FA care-of address, encapsulate into unicast datagram destined to MH home address, then encapsulate into a unicast datagram to FA address (MH must be able to decapsulate received datagram)
- Multicast datagram routing
  - ➢ To receive
    - ❑ Join via a local multicast router in foreign network
    - ❑ Join via a bi-directionnal tunnel to its HA (assuming HA is a multicast router)
  - ➢ To send
    - ❑ Send directly on visited network (must use a co-located care-of addr)
    - ❑ Send via a tunnel to its home agent (use home IP address)

Datagram routing 2/5

- A *Proxy ARP* is an ARP Reply sent by one node on behalf of another node which is
  - ➢ unable or,
  - ➢ unwilling to answer its own ARP Requests (provide link-layer address)
  - ➢ The node receiving the Reply will then associate this link-layer address with the IP address of the original target node
  - ➢ Will transmit future datagrams for this target node to the node with that link-layer address
- A *Gratuitous ARP* is an ARP packet sent by a node in order to spontaneously cause other nodes to update an entry in their ARP cache

Datagram routing 3/5

- While a mobile node is registered on a foreign network
  - ➢ its home agent uses proxy ARP to reply to ARP Requests it receives that seek the mobile node's link-layer address
  - ➢ provide its own link-layer address
- When a mobile node leaves its home network and registers a binding on a foreign network
  - ➢ its home agent uses *gratuitous ARP* to update the ARP caches of nodes on the home network
  - ➢ such nodes will associate the link-layer address of the home agent with the mobile node's home (IP) address

Datagram routing 4/5

•ARP Processing rules when MH leaves home network

- ➢The mobile node disables its own future processing of any ARP Requests relating to its home address (unless request is by FA)
- ➢When the mobile node's home agent receives and accepts the Registration Request
  - ✓performs a *gratuitous ARP* on behalf of the mobile node, and
  - ✓begins using *proxy ARP* to reply to ARP Requests that it receives requesting the mobile node's link- layer address

Datagram routing 5/5

•ARP Processing rules when MH returns to home network

- ➢Before transmitting the Registration Request, the MH re-enables its own future processing of any ARP Requests relating to its home address
- ➢The MH performs a gratuitous ARP for itself
- ➢When the mobile node's HA receives and accepts the Registration Request
  - ➢it stops using proxy ARP to reply to ARP Requests, and
  - ➢then performs a gratuitous ARP on behalf of the mobile node

Reverse Tunneling 1/5

•MIP uses tunneling from the home agent to the mobile node's care-of address, but rarely in the *reverse direction*

•Usually, a mobile node sends its packets through a router on the foreign network, and assumes that routing is independent of source address

•When this assumption is not true, it is convenient to establish a topologically correct reverse tunnel from the care-of address to the home agent

•*Use of MH's home address makes the reverse tunnel topologically incorrect*

Reverse Tunneling 2/5

•Two packet delivery styles from MH to FA

- ➢Direct Delivery Style
  - ✓the mobile node designates the foreign agent as its default router
  - ✓proceeds to send packets directly to the foreign agent, that is, without encapsulation
  - ✓The foreign agent intercepts them, and tunnels them to the home agent
- ➢Encapsulating Delivery Style
  - ✓the mobile node encapsulates all its outgoing packets to the foreign agent
  - ✓The foreign agent decapsulates and re-tunnels them to the home agent, using the foreign agent's care-of address as the entry-point of this new tunnel

Reverse Tunneling 3/5

Direct Delivery Style (MH must designate FA as default router)

- *Packet format received by the foreign agent*
  - IP fields
    - Source Address = mobile node's home address
    - Destination Address = correspondent host's address
- *Packet format forwarded by the FA*
  - IP fields (encapsulating header)
    - Source Address = foreign agent's care-of address
    - Destination Address = home agent's address
    - Protocol field: 4 (IP in IP)
  - IP fields (original header)
    - Source Address = mobile node's home address
    - Destination Address = correspondent host's address

Reverse Tunneling 4/5

Encapsulating Delivery Style (MH must perform encapsulation)

- *Packet format received by the foreign agent (Encapsulating Delivery Style)*
  - IP fields (encapsulating header)
    - Source Address = mobile node's home address
    - Destination Address = foreign agent's address
    - Protocol field: 4 (IP in IP)
  - IP fields (original header)
    - Source Address = mobile node's home address
    - Destination Address = correspondent host's address

Reverse Tunneling 5/5

Encapsulating Delivery Style (MH must perform encapsulation)

- *Packet format forwarded by the foreign agent*
  - IP fields (encapsulating header)
    - Source Address = foreign agent's care-of address
    - Destination Address = home agent's address
    - Protocol field: 4 (IP in IP)
  - IP fields (original header)
    - Source Address = mobile node's home address
    - Destination Address = correspondent host's address

Replay Protection 1/4

- The *Identification* field is used to let the HA verify that a registration message has been freshly generated by the mobile node
- Style of replay protection part of MSA
  - ➢ Timestamp-based replay protection
  - ➢ Nonce-based replay protection
- In either approach, low-order 32 bits of the *Identification* MUST be copied unchanged from the Registration Request to the Reply
  - ➢ The FA uses those bits (and the mobile node's home address) to match Registration Requests with corresponding replies
  - ➢ The mobile node MUST verify that the low-order 32 bits of any Registration Reply are identical to the bits it sent in the Registration Request.

Replay Protection 2/4

Timestamp-based replay protection

•The node generating a message inserts the current time of day, and the node receiving the message checks that this timestamp is sufficiently close to its own time of day (Implication?)

•A timestamp is valid if it is close to HA time and greater than all previously accepted timestamps

•If the timestamp is valid, the HA copies the entire Identification field into the Registration Reply

•If the timestamp is not valid, the HA copies only the low-order 32 bits into the Registration Reply, and supplies the high-order 32 bits from its own time of day

Replay Protection 3/4

Nonce-based replay protection

•The basic principle of nonce replay protection is that

- ➢node A includes a new random number in every message to node B, and checks that node B returns that same number in its next message to node A.
- ➢Both messages use an authentication code to protect against alteration by an attacker.
- ➢At the same time node B can send its own nonces in all messages to node A (to be echoed by node A), so that it too can verify that it is receiving fresh messages.

Replay Protection 4/4

Nonce-based replay protection

•The HA inserts a new nonce as the high-order 32 bits of the identification field of every Registration Reply.

•The HA copies the low-order 32 bits of the Identification from the Registration Request message into the low-order 32 bits of the Identification in the Registration Reply.

•When the mobile node receives an authenticated Registration Reply from the home agent, it saves the high-order 32 bits of the identification for use as the high-order 32 bits of its next Registration Request.

•If a registration message is rejected because of an invalid nonce, the Reply always provides the mobile node with a new nonce to be used in the next registration.