MOBILITY MANAGEMENT FOR VOIP SERVICE: MOBILE IP VS. SIP

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Outline

- Introduction
- Network Layer Solution: Mobile IP
- Application Layer Approach: SIP
- Shadow Registration
- Delay / Disruption Analysis
- Conclusion

Introduction (1/4)

- Wireless technologies convergence
  - way to support seamless mobility to mobile nodes
- Emergence of VoIP service and growth
  - the amount of disruption time to process the handoff of an ongoing VoIP call (or session)

Introduction (2/4)

- Three types of mobility
  - Roaming — in absence of the Internet connectivity
  - Macromobility — from one administrative domain to another
  - Micromobility — inside a given domain
- Mobility management framework
- Two basic approaches to support mobility in VoIP services
  - Network layer — Mobile IP
  - Application layer — H.323 and SIP

Introduction (3/4)

- Authentication, Authorization, Accounting (AAA)
  - user moves into the visited network
  - user initiates Internet connectivity in the home network
- Problem: the mobile node should resolve the AAA issue whenever it hands off between different administration domains

Introduction (4/4)

- Minimize delay/disruption in dealing with macromobility and micromobility
  - noticeable disruption during a voice conversation make VoIP service users unhappy
- Shadow registration
  - Reduce the time to process interdomain handoff
  - Establish a registration status in the neighboring administrative domains a priori anticipating possible handoffs when the user registers in the given wireless/mobile network

Network layer solution: Mobile IP (1/3)

- Mobile IPv4 Overview
  - Home address
    - A mobile node (MN) is reachable by its invariant home address when it stays connected in its home network
  - Care-of-address (CoA)
    - Only valid for the time the MN stay connected to a foreign network
  - Two mobility agent
    - The foreign agent (FA) and the home agent (HA)
    - Registration: whenever the MN obtains the CoA from the FA, it must inform its HA of the obtained CoA
    - Tunneling: After registration, the HA can forward the packets to the FA

Network Layer Solution: Mobile IP (2/3)

- Basic working of Mobile IP
  - Packets from the correspondent node (CN) to the MN are first captured by the HA and tunneled to the MN, while the MN sends packets to the CN directly.
  - Optimization — Mobility binding
    - Allows the CN to encapsulate packets directly to the current CoA of the MN
    - CN maintains a binding cache to store the mobility bindings for one or more MNs
    - The *Binding Update* message is used for the HA to inform the CN that the MN has changed its CoA

Network Layer Solution: Mobile IP (3/3)

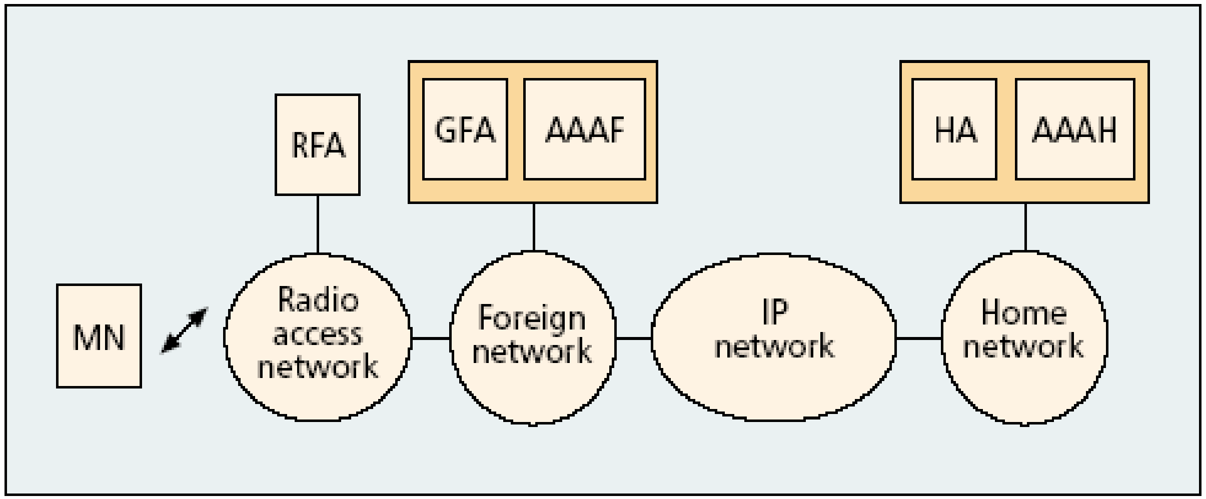
- Optimization－Mobility binding (cont.)
  - Binding Warning message: sent by FA to inform HA of the MN and retunnel the packet to the CoA in the cache entry when the FA receives a tunneled packet for an MN that is not in its visitor list.
  - If the FA has no binding cache entry for that MN?
    - The FA sends the packet to the home addr of the MN and the packet will be trapped by the HA -> current CoA of the MN.
  - *Smooth Handoff* : the old FA and the new FA exchange the *Binding Update/Acknowledgment* message when the MN obtains a new CoA.

Regional Registration

- Regional registration
  - When a MN first arrives at a visited domain, it performs a registration with its HA.
  - The home network of the MN generates a registration key and distributes it to the MN and visited domain.
  - The CoA will not change when the MN changes FA under the same GFA (gateway foreign agent)
  - Two new message types: *Regional Registration Request* and *Regional Registration Reply*

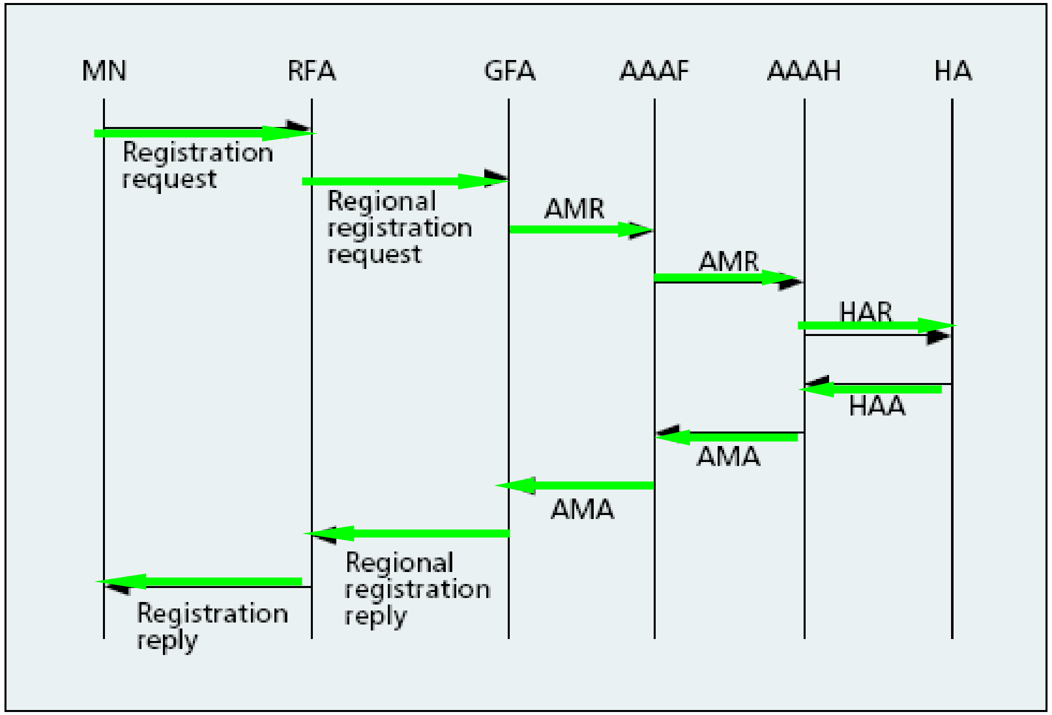
The entities of Mobile IP-based approach

- RFA (regional foreign agent): the local FA that accommodates the MN in the subnet
- AAAF (the AAA server in the foreign network)
- AAAH (the AAA server in the home network)



Message flow —initial registration

- Message flow for initial registration at a foreign network

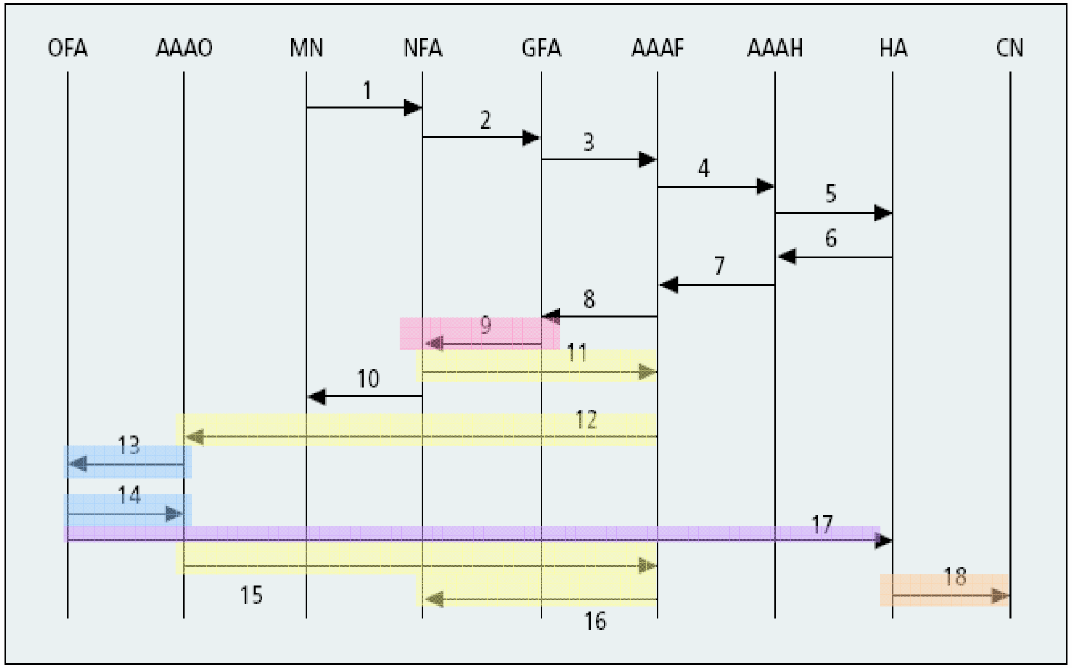


- MN: mobile node
- RFA: regional foreign agent
- GFA: gateway foreign agent
- AAAF: AAA server in foreign network
- AAAH: AAA server in home network
- HA: home agent
- AMR: AA-Mobile-Node-Request
- HAR: home agent request
- HAA: home agent answer
- AMA: AA-Mobile-Node-Answer

Message flow — intradomain handoff

- Message flow in the intradomain handoff
  - When the MN changes the point of attachment between FAs, it sends the *Registration Request* message to the new RFA (NFA)
  - When the NFA receives this message, it modifies the message into the *Regional Registration Request* message
  - The NFA sends the *Binding Update* message to the old RFA (OFA)
  - The OFA replies with *Binding Acknowledgment* message to confirm the update of binding cache entry on the MN
  - The *Binding Update* message to the CN is not necessary
    - The addr of GFA is registered in the HA of the MN

Message flow — interdomain handoff



MN is authenticated

Diameter-compliant messages that contains *Binding Update/Acknowledgment* information

Normal *Binding Update/Acknowledgment* messages

Binding Warning message

Binding Update message

AAAO: the AAA server of the old foreign network to which the OFA belongs

AAAF: the AAA server of the new foreign network to which the NFA belongs

Application Layer Approach: SIP(1/4)

- SIP overview
  - Establish and tear down multimedia sessions, both unicast and multicast
  - SIP user agent
    - Listen to incoming SIP messages
    - Send SIP messages
  - SIP redirect server
    - Return location of the host

Application Layer Approach: SIP(2/4)

- SIP overview
  - SIP proxy server
    - Use domain name to find a user
    - Hide the location of the user
    - Message exchange delay is shorter
    - Handle firewall and network address translation (NAT)

Application Layer Approach: SIP(3/4)

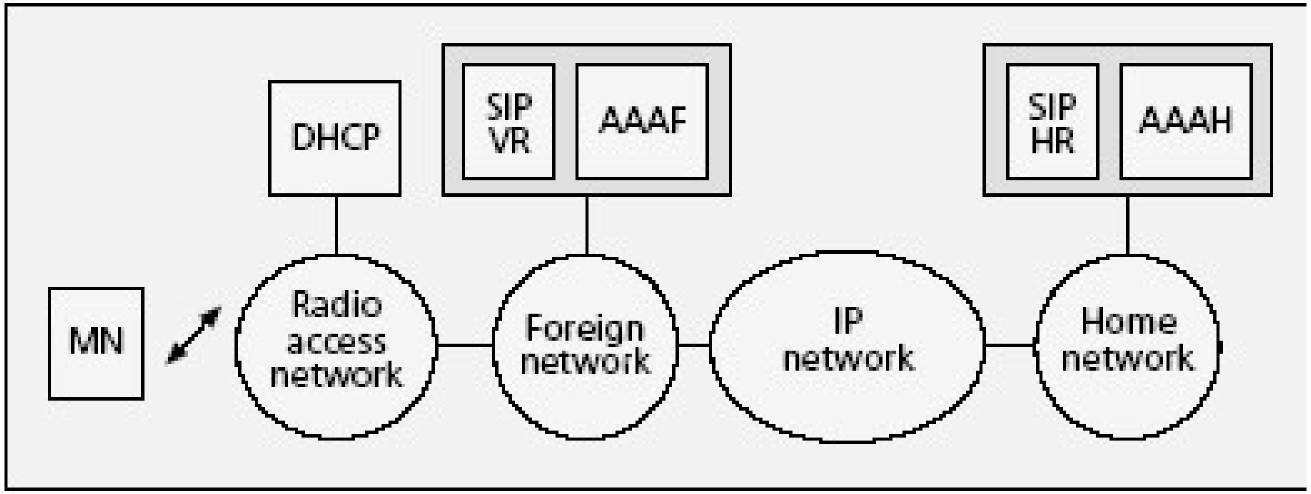


Figure 4. *SIP architecture.*

- SIP architecture
  - Visit registrar (VR)
  - Home registrar (HR)
  - MN : user agent client

Application Layer Approach: SIP(4/4)

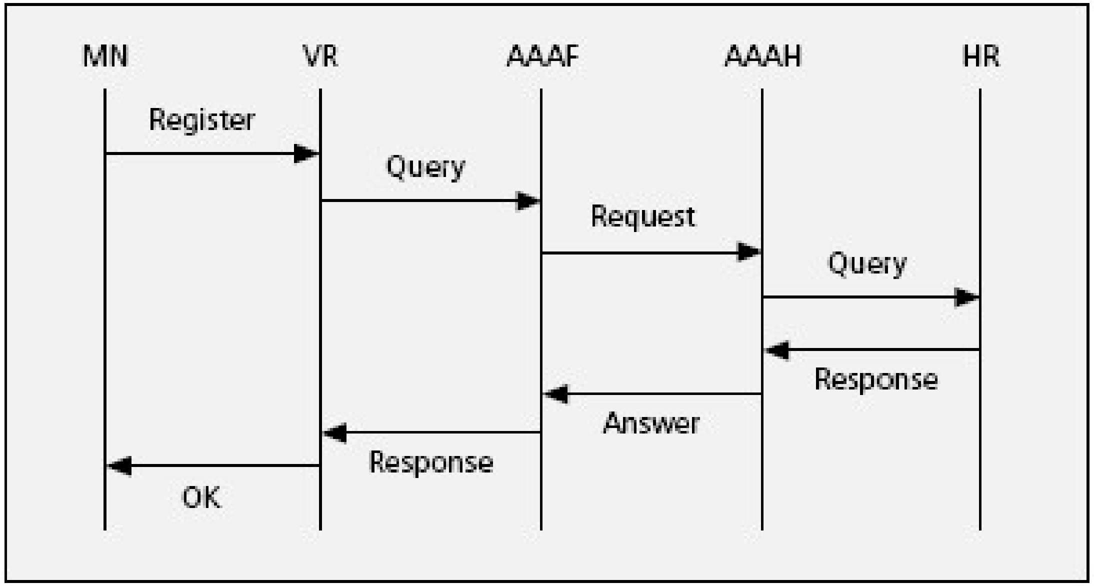
- Personal mobility
  - Maintain connectivity during SIP session
  - Fast handoff : RTP translator

SIP Message Flow(1/3)

- Acquire IP address:
  1. MN broadcasts DHCP_DISCOVER
  2. Several DHCP server offer IP address via DHCP_OFFER
  3. MN select one server DHCP_REQUEST
  4. DHCP server sends DHCP_ACK

SIP Message Flow(2/3)

- SIP registration :



■ Figure 5. *SIP registration.*

MN : mobile node   VR : visited registrar   HR : home registrar

AAAF: AAA server in foreign network

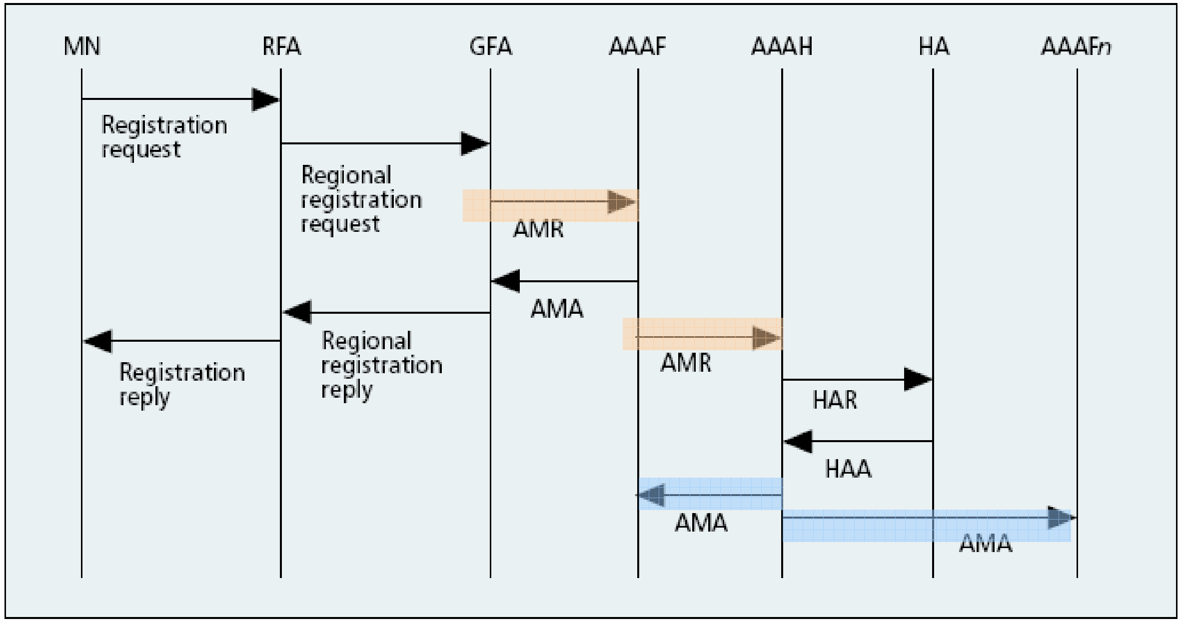
AAAH: AAA server in home network HR :

SIP Message Flow(3/3)

- Signaling message flow
  - Micromobility
    - No need to verify the user's credentials via AAA server
    - MN sends SIP-REGISTER message with new address
    - VR update its list
  - Macromobility
    - Same as SIP registration

Shadow Registration — Mobile IP case

Signaling message flows for the interdomain handoff in the presence of the Shadow Registration

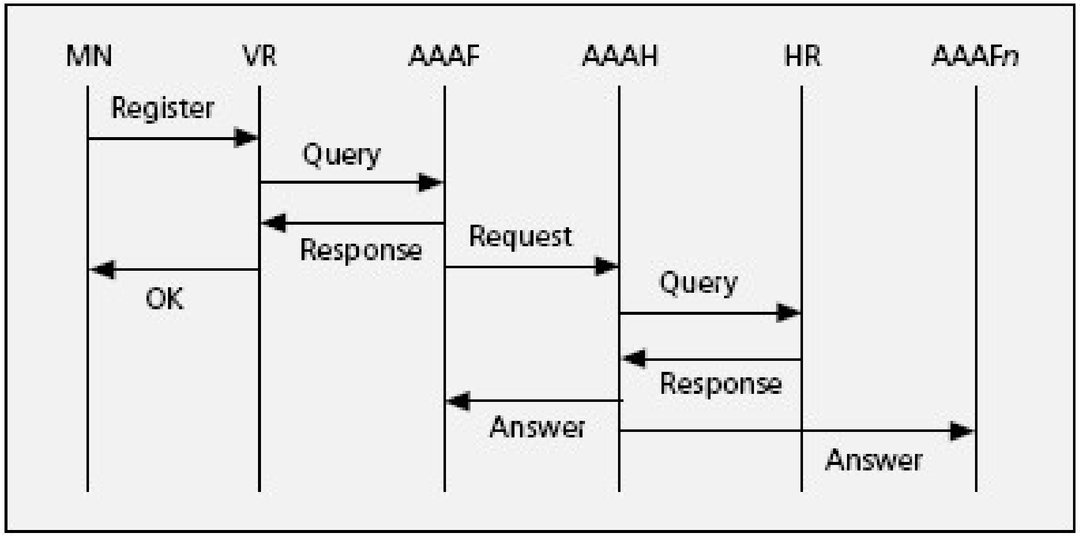


The AAAF appends the information about all of its neighboring AAA servers to the AMR message

AAAH checks out which neighboring AAA servers are available to the MN and sends the AMA message to those AAA servers for shadow Registration

Shadow Registration — SIP case

- SIP interdomain handoff with Shadow Registration :

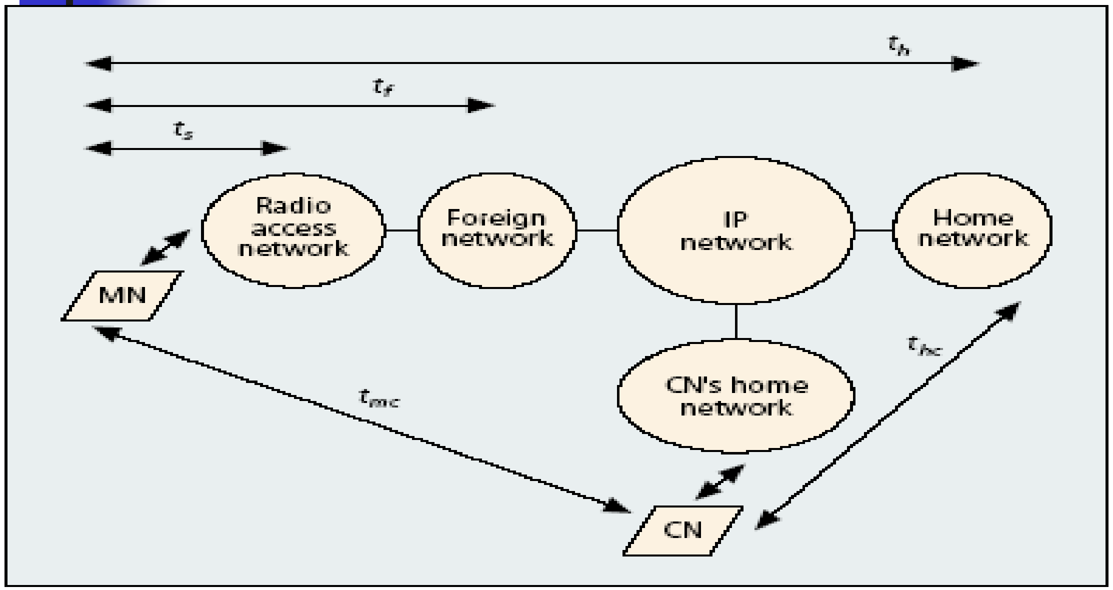


AAAFn :
relevant neighboring AAA servers

■ Figure 7. *SIP interdomain handoff with Shadow Registration.*

Add one more message :
ANSWER from AAAH to AAAFn for Shadow Registration

Delay/Disruption Analysis



t_s : time via wireless link

t_f : time to send message over foreign network

t_h : time to send message to home network

In general $t_s < t_f < t_h$

t_{mc} : delay between MN and CN

t_{hc} : delay between MN's home network and CN

Assumption:

- Simple VoIP application (SVA) with SIP operates on top of Mobile IP.
- Home address of CN is cached in MN's SVA.

  (SVA is mobility-unaware)

Initial Registration and Session Setup (Mobile IP)

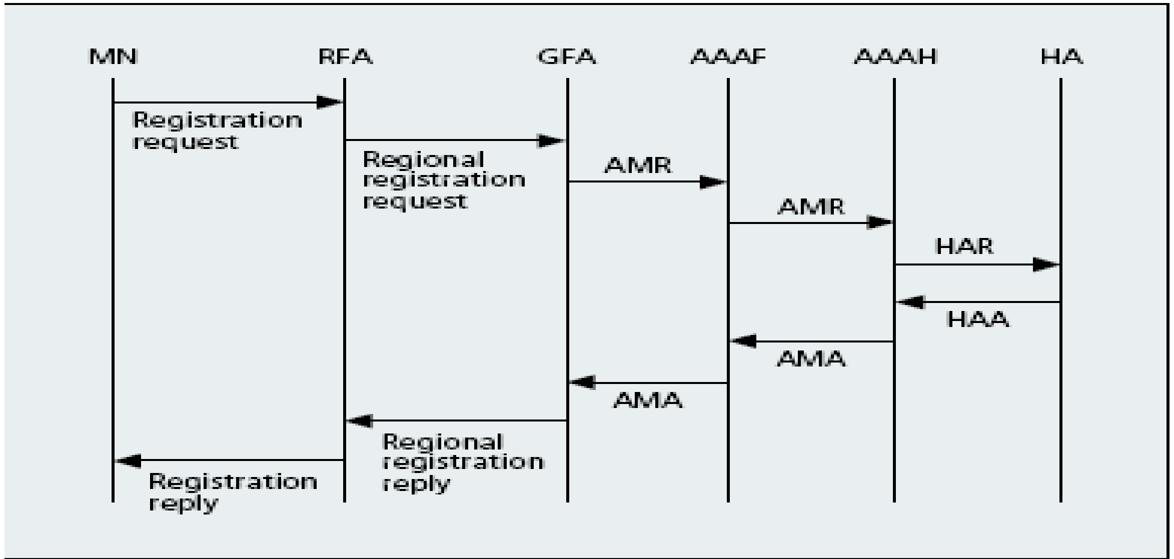


Figure 2. *Mobile IP registration.*

MN: mobile node

RFA: regional foereign agent

GFA: gateway foreign agent

AAAF: AAA of foreign network

AAAH: AAA of home network

HA: home agent

$$\text{initiation of Internet connection}: 2t_s$$

$$\text{registration to home network (HA)}: 2t_h$$

$$\text{SVA sends INVITE to CN}: 2t_{mc}$$

$$T_{mip\_init} = 2t_s + 2t_h + 2t_{mc}$$

Initial Registration and Session Setup (SIP)

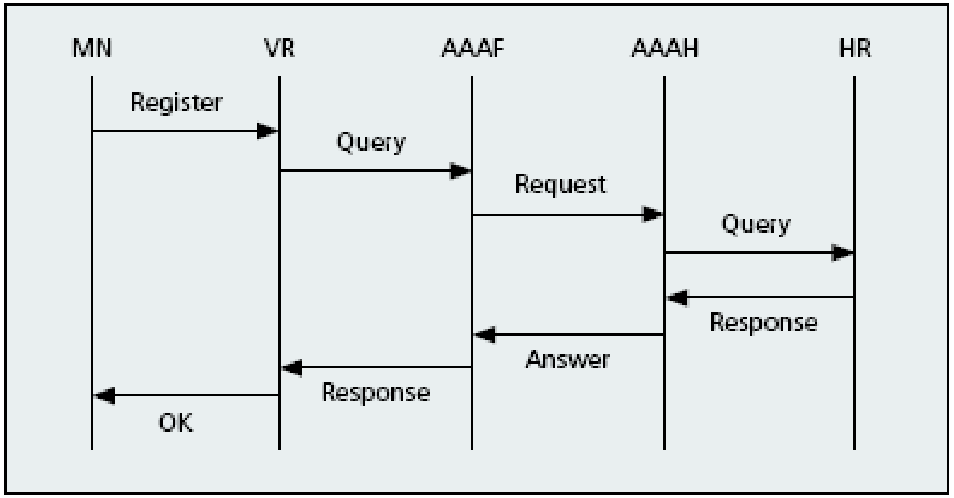


Figure 5. *SIP registration.*

MN: mobile node

VR: visited registrar

AAAF: AAA of foreign network

AAAH: AAA of home network

HR: home registrar

DHCP message interaction : $4t_s$

ARP detects duplicate addresses : t_{arp}

SIP REGISTER to MN's home network (HR) : $2t_h$

SIP call establishment with CN : $2t_{mc}$

$$T_{sip\_init} = 4t_s + t_{arp} + 2t_h + 2t_{mc}$$

Intradomain Handoff

Mobile IP :

initiation of Internet connection : $2t_s$

registration in intradomain handoff : $2t_f$

$$T_{mip\_intra} = 2t_s + 2t_f$$

SIP :

DHCP interaction : $4t_s$

ARP detects duplicate addresses : t_{arp}

MN sends REGISTER to VR : $2t_f$

$$T_{sip\_intra} = 4t_s + t_{arp} + 2t_f$$

Interdomain Handoff (Mobile IP)

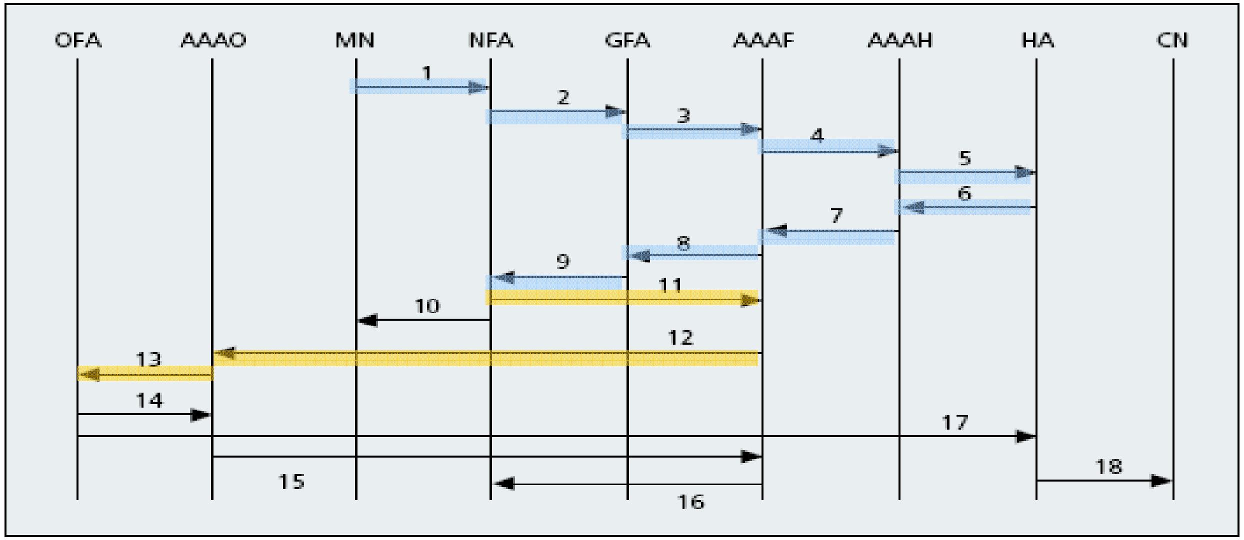


Figure 3. *Interdomain handoff in Mobile IP.*

MN: mobile node

NFA: new RFA

OFA: old RFA

GFA: gateway foreign agent

AAAF: AAA of foreign network

AAAH: AAA of home network

AAAO: AAA of old foreign network

HA: home agent

CN: correspondent node

- Two signaling flow (almost parallel):
  - Smooth handoff
  - Route optimization

initiation of Internet connection : $2t_s$

NFA catches msg from HA : $2t_h - t_s$

NFA sends msg to OFA : t_{no}

t_{no} : time between NFA and OFA

Interdomain Handoff (Mobile IP)

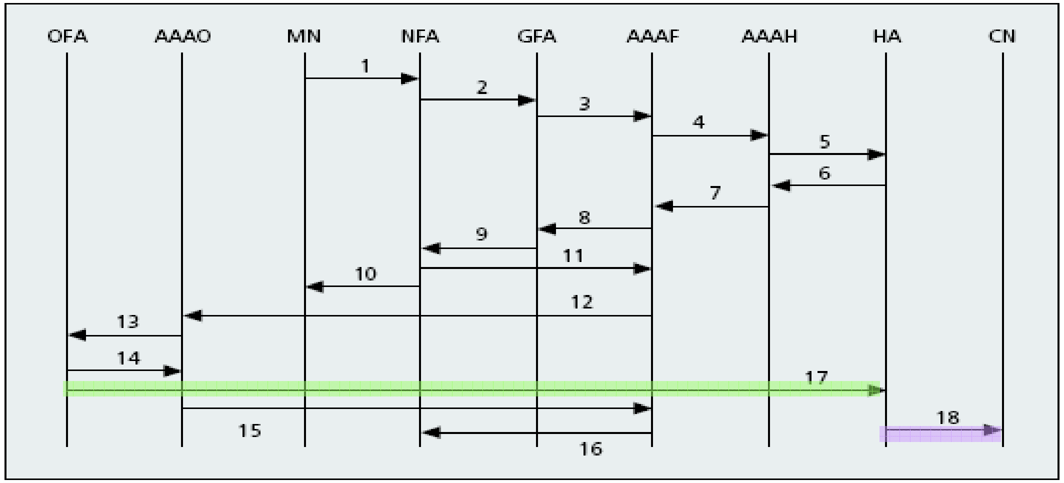


Figure 3. *Interdomain handoff in Mobile IP.*

MN: mobile node

NFA: new RFA

OFA: old RFA

GFA: gateway foreign agent

AAAF: AAA of foreign network

AAAH: AAA of home network

AAAO: AAA of old foreign network

HA: home agent

CN: correspondent node

Smooth Handoff

OFA forwards packets to MN : $t_s + t_{no}$

$$T_{smooth} = 2t_s + (2t_h - t_s) + t_{no} + (t_s + t_{no})$$
$$= 2t_s + 2t_h + 2t_{no}$$

Route Optimization

OFA sends msg to HA : $t_h - t_s$

HA sends msg to CN : t_{hc}

CN sends packets to MN via NFA : t_{mc}

$$T_{route} = 2t_s + (2t_h - t_s) + t_{no} + (t_h - t_s) + t_{hc} + t_{mc}$$
$$= t_{no} + 3t_h + t_{hc} + t_{mc}$$

$$T_{mip\_inter} = t_{no} + 3t_h + t_{hc} + t_{mc}$$

Interdomain Handoff (SIP)

DHCP interaction : $4t_s$

ARP detects duplicate addresses : t_{arp}

MN sends REGISTER to HR : $2t_h$

MN reinvites CN by sending INVITE : $2t_{mc}$

$$T_{sip\_inter} = 4t_s + t_{arp} + 2t_h + 2t_{mc}$$

Numerical Results

- Assumption:
  - Delay in the wired foreign network is relatively short in comparison with wireless link.
  - MN, CN are connected to the Internet via wireless link.
  - Processing time in each entity is negligible.
  - t_{arp} is negligible.
- Three cases:
  - MN in it's home network; distance between MN and CN varies.
  - MN and CN are close; distance MN and it's home network varies.
  - Wireless link delay varies.

Case 1

►MN in it's home network; distance between MN and CN varies. (t_{mc} varies.)

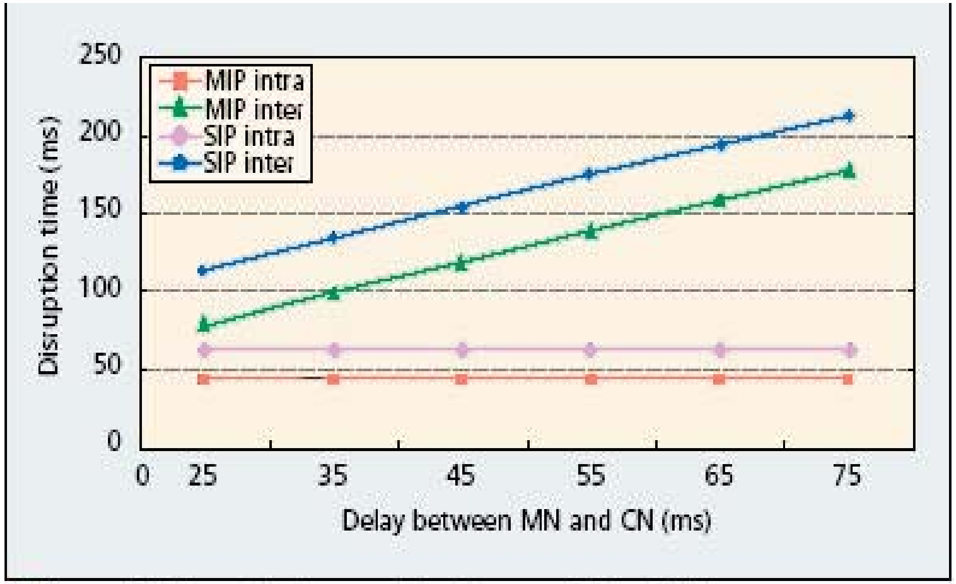


Figure 9. *Disruption time vs. delay between MN and CN.*

$$T_{mip\_intra} = 2t_s + 2t_f$$

$$T_{sip\_intra} = 4t_s + 2t_f$$

$$T_{mip\_inter} = t_{no} + 3t_h + t_{hc} + t_{mc}$$

$$T_{sip\_inter} = 4t_s + 2t_h + 2t_{mc}$$

- In MIP interdomain handoff, the forwarding of data between OFA to MN via NFA (smooth handoff) can make better performance than that in SIP interdomain handoff case.

Case 2

- MN and CN are close; distance MN and it's home network varies. (t_h varies.)

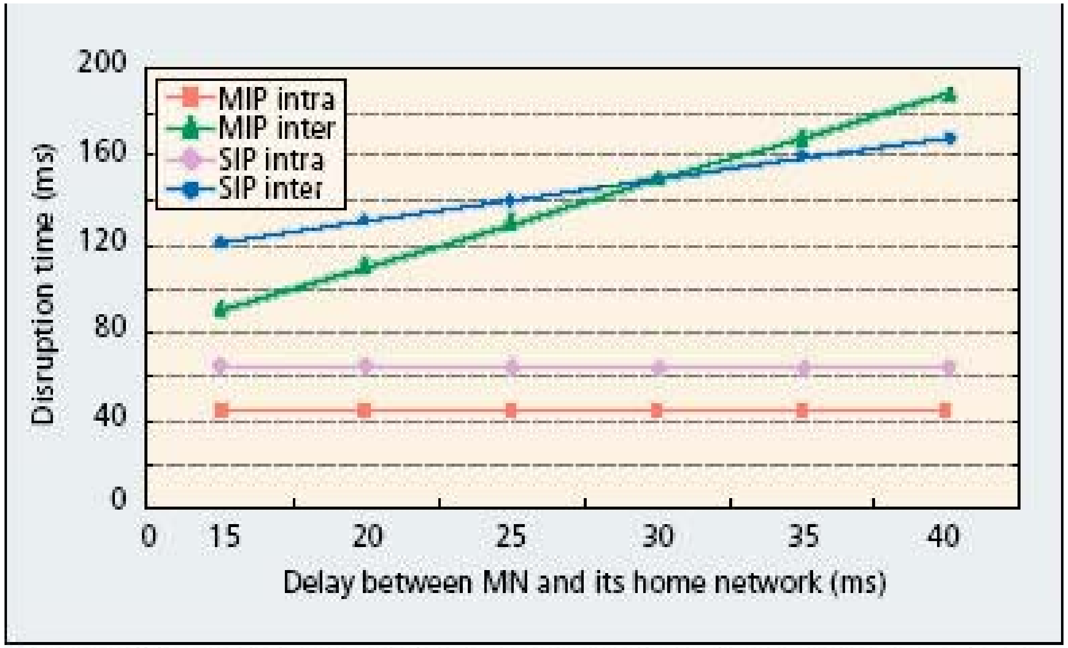


Figure 10. *Disruption time vs. delay between the MN and its home network.*

$$T_{mip\_intra} = 2t_s + 2t_f$$

$$T_{sip\_intra} = 4t_s + 2t_f$$

$$T_{mip\_inter} = t_{no} + 3t_h + t_{hc} + t_{mc}$$

$$T_{sip\_inter} = 4t_s + 2t_h + 2t_{mc}$$

Case 3

- Wireless link delay varies. (t_s, t_{mc} varies.)

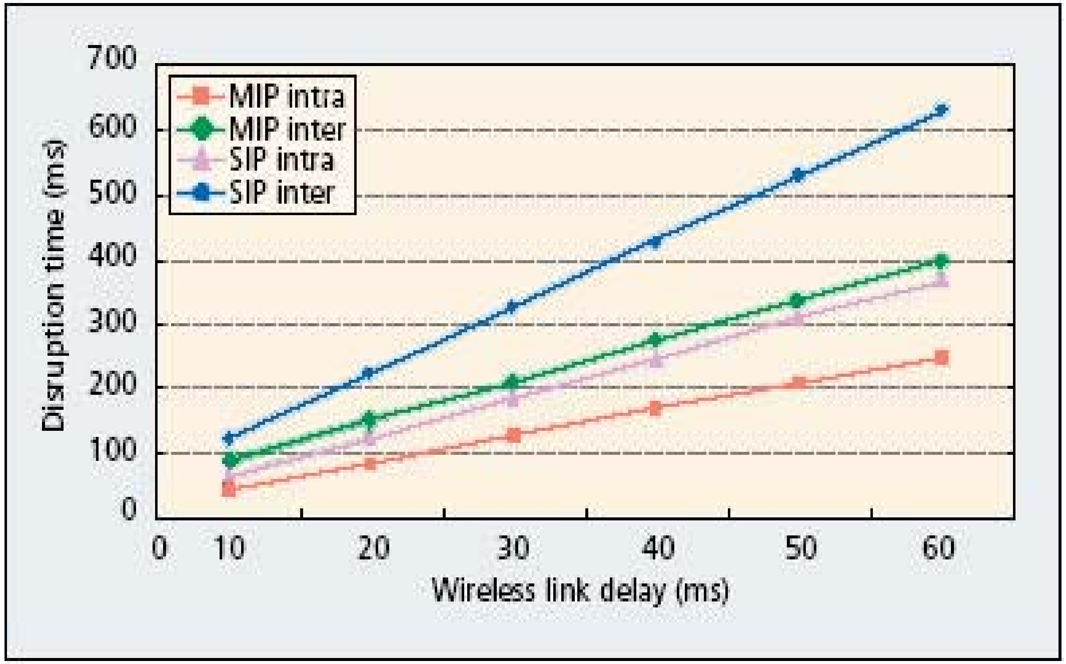


Figure 11. *Disruption time vs. wireless link delay.*

$$T_{mip\_intra} = 2t_s + 2t_f$$

$$T_{sip\_intra} = 4t_s + 2t_f$$

$$T_{mip\_inter} = t_{no} + 3t_h + t_{hc} + t_{mc}$$

$$T_{sip\_inter} = 4t_s + 2t_h + 2t_{mc}$$

Disruption with Shadow Registration

Mobile IP

initiation of Internet connection : $2t_s$

MN's registration msg is handled in current FA : $2t_f - t_s$

route optimization : $t_{no} + (t_h - t_s) + t_{hc} + t_{mc}$

$$T_{mip\_inter\_shadow} = 2t_s + (2t_f - t_s) + (t_{no} + (t_h - t_s) + t_{hc} + t_{mc})$$

$$= 2t_f + t_{no} + t_h + t_{hc} + t_{mc}$$

SIP

DHCP and ARP : $4t_s + t_{arp}$

REGISTER msg is processed in the local AAAF and VR : $2t_f$

MN reinvites CN by sending INVITE msg : $2t_{mc}$

$$T_{sip\_inter\_shadow} = 4t_s + t_{arp} + 2t_f + 2t_{mc}$$

The Effect of Shadow Registration

Without Shadow Registration

$$T_{mip\_inter} = 3t_h + t_{no} + t_{hc} + t_{mc}$$

$$T_{sip\_inter} = 4t_s + t_{arp} + 2t_h + 2t_{mc}$$

With Shadow registration

$$T_{mip\_inter\_shadow} = 2t_f + t_{no} + t_{hc} + t_{mc}$$

$$T_{sip\_inter} = 4t_s + t_{arp} + 2t_f + 2t_{mc}$$