Efficient End-to-End Mobility Support in IPv6

Christian Vogt, chvogt@tm.uka.de
Mark Doll, doll@tm.uka.de
Mobile IPv6 Basics

- Mobile node
- Home address @
- Home network
- Correspondent node
- Visited network
- Internet
Mobile IPv6 Basics (2)

binding
home address ↔ c/o address

home network

@ home address

@ c/o address

visited network

Internet

bidirectional tunneling

home agent

correspondent node
Mobile IPv6 Basics (3)

- **Home Agent**: Directs traffic to the correspondent node's current location.
- **Home Address** and **c/o (care of) Address**: Correspond to the node's home network and current network, respectively.
- **Home Network** and **Visited Network**: Environments where the node is registered.
- **Internet**: Medium for communication between networks.
- **Route Optimization**: Process to minimize traffic to the correspondent node.
- **Binding**: The association between the home address and the c/o address.
Caution!

Issue 1: Connection hi-jacking

- Attacker pretends to own victim's (home) address

Solution: Verify reachability at home address
Issue 2: Redirection-based flooding

- Attacker pretends to be at victim's (c/o) address

Solution: Verify reachability at c/o address
Conservative Mobile IPv6

Mobile Node

- Binding Update

Home Agent

- Binding Ack
- Home Test Init
- Care-of Test Init
- Home Test
- Care-of Test
- Binding Update

Correspondent Node

- Binding Ack

- include tokens

authenticated w/both tokens

link-layer handoff

return-routeability procedure
Conservative Mobile IPv6 (2)

Mobile Node: 3 RTT

- Bind registration
- Home Test Init
- Care-of Test Init
- Home Test
- Return routability procedure
- Binding Update

Home Agent: 4 RTT

- Bind registration
- Home Test Init
- Care-of Test Init
- Home Test
- Binding Ack

Correspondent Node: switch to new c/o address

2 link-layer handoff
Optimistic Mobile IPv6

- 2 RTT: Home registration
  - Binding Update
  - Binding Ack
  - Care-of Test Init
  - Home Test Init
  - Home Test
  - Care-of Test

- 3 RTT: Correspondent registration
  - Binding Update
  - Binding Ack

- Return-routability procedure and home registration simultaneously

- In parallel

- Switch to new c/o address
Reduce handoff latency

Early Binding Updates for Mobile IPv6
Credit-Based Authorization
Mobile IPv6 + Optimizations

- Home Test (Init) exchange prior to handoff
- Home and correspondent registration simultaneously
- Tentative registration without test of new c/o address
- Standard registration with test of new c/o address
- Test of c/o address in parallel with data exchange
Mobile IPv6 + Optimizations (2)

- **RTT switch to new c/o address**
  - ~ 0 RTT
    - Home Test Init
    - Home Test
    - Home Test
    - Binding Update
    - Early Binding Update
    - Care-of Test Init
    - Binding Ack
    - Early Binding Ack
    - Care-of Test
    - Binding Update
    - Binding Ack
    - switch to new c/o address

- **1 RTT**
  - Home Test Init
  - Home Test
  - Care-of Test
  - switch to new c/o address
Mobile IPv6 + Optimizations (3)

Correspondent node may send to incorrect c/o address.
While C/O Address is Unverified

Without protection
⇒ amplified redirection-based flooding

attacker

attacker's peer

victim

investment << ROI

Amplification
Credit-Based Authorization precludes amplification
⇒ redirection-based flooding unattractive

attacker

No amplification

attacker's peer

victim

investment

ROI

attacker

$\Rightarrow$
Credit-Based Authorization precludes amplification
⇒ redirection-based flooding unattractive

Correspondent node counts bytes recently received from mobile node

Sends no more bytes to unverified c/o address
Experimental Evaluation

- FreeBSD
- Kame-Shisa Mobile IPv6

extended to support optimistic Mobile IPv6, Early Binding Updates, Credit-Based Auth.
IP Telephony: Parameters

Application
- bidirectional
- 64 kbps payload
- 10ms chunks
- 164B per packet (IPv6, IPv6 extensions, UDP, RTP)

Round-trip times
- 200ms btw. home agent, routers, correspondent node

Mobile IPv6 versions
- conservative
- optimistic
- Early Binding Updates, Credit-Based Authorization

Confidence
- 500 handoffs per Mobile IPv6 version
Handoff Delay w/IP Telephony

\[ \text{RTT} = 200\text{ms} \]

- \( 1 \) RTT + \( \varepsilon \)
- \( 3 \) RTT + \( \varepsilon \)
- \( 4 \) RTT + \( \varepsilon \)
TCP File Downloads: Parameters

Application
- unidirectional download: correspondent node to mobile node
- 60s duration
- 1024 kbps bandwidth
- TCP Reno

Round-trip times
- 40ms to 200ms btw. home agent, routers, correspondent node

Mobile IPv6 versions
- conservative
- optimistic
- Early Binding Updates, Credit-Based Authorization

Confidence
- 20 experiments per round-trip time per Mobile IPv6 version
- 5 handoffs per experiment
Handoff Delay w/TCP File Transfers

- conserv
- optim
- ebu/cba

Handoff latency (s)

round-trip time (ms)

40  80  120  160  200
Throughput w/TCP File Transfers

Why does TCP benefit so much?
Why TCP Benefits So Much

1st timeout → new c/o address

1st timeout → old c/o address
2nd timeout → new c/o address

ebu/cba

conserv

sent and acknowledged sequence numbers (KiB)
Why TCP Benefits So Much (2)

After 1st timeout

- set cwnd = 1
- set ssthresh = flightsize
- do Slow Start until cwnd > ssthresh

After 2nd timeout

- set cwnd = 1
- set ssthresh = 2 (minimum)
- skip Slow Start, do Congestion Avoidance
Conclusions, Future Perspectives

- Handoff latencies are high in standard Mobile IPv6
  - 4 RTT in conservative Mobile IPv6
  - 3 RTT in optimistic Mobile IPv6
- Early Binding Updates, Credit-Based Authorization → 1 RTT
  - disadvantage: some additional signaling
- UDP, TCP applications benefit significantly
  - Handoff latencies down by ≤ 75% in UDP
  - 1 TCP retransmission timeout instead of 2
  - ⇒ Faster throughput ramp-up after handoff
- Efforts within IETF and IRTF
  - Adopted by Mobopts research group
  - Credit-Based Authorization adopted by Mipshop, HIP working groups
- Current work: Proactive registration before handoff
  - ⇒ Eliminate/reduce remaining 1 RTT handoff latency