Performance Analysis of Hand-over Mechanisms, Part II: Experimental Analysis

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Review: Mobility types

Assumption here: Infrastructure networks (only first hop wireless)

Different Levels of Mobility:
• Pico (e.g. within same radio cell)
• Micro (e.g. within same subnet)
• Macro (e.g. across subnets but within same administrative domain)
• Global (e.g. across different administrative domains)

'Alternative' classification:
• vertical mobility: changing access technology

Considered here: Micro/Macro, vertical/horizontal
Motivation to investigate vertical HO: heterogeneous access networks

1. Background
   • Mobility & Handover Types

2. Scenarios and Mobility Support Schemes
   • Migrating IP address
   • Mobile IPv4
   • (Mobile) SCTP

3. Measurement Methodology
   • Approach
   • Parameter definitions

4. Results and Discussion
   • Migrating IP address
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   • Mobile SCTP
   • Comparison of schemes

5. TCP and Mobility
**Background II: Handover & more mobility types**

Hand-over classification:
- *Mobile initiated* or *network-initiated*
- *Backward* or *forward*
- *mobile controlled* or *network controlled*
- *Mobile-assisted* or *network assisted* or *unassisted*
- *Proactive* or *reactive*
- *Make-before-break* or *break-before make*
- *Soft* or *hard*
  - *fast* (without 'noticeable' delay)
  - *smooth* (no loss of data)

  *seamless = fast + smooth*

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**Migrating IP address (I): setup**

- Hand-over only within same subnet
- Transparent to transport layer
- Hand-over script based on Linux standard bash script commands
**Migrating IP address (II): Gratuitous ARP**

Gratuitous ARP Request
- Protocol Type: Request
- Target Protocol Address: 10.10.1.42
- Sender Protocol Address: 10.10.1.42
- Sender Hardware Address: 00-E0-2D-59-4A-7C

ARP cache (Layer 2)
- IP address: 10.10.1.80
- MAC address: 00-E0-2D-59-3D-7B

ARP Request (Layer 2)
- IP address: 10.10.1.42
- MAC address: 00-E0-2D-59-4A-7A

**Mobile IP (I): Tunneling & Triangle Routing**

1. CN sends packets to the MN using its Home Address IP
2. HA tunnels them to FA, using CoA, FA forwards them to MN
3. MN sends packets back to the CN using IP (without any tunneling)
   - Home Agent needs to contain mapping of care-of address to home address (location register)

Source: Mobile IPv4 Illustrated
**Streaming Control Transmission Protocol (SCTP)**

- Defined in RFC2960 (see also RFC 3257, 3286)
- Purpose initially: Signalling Transport
- Features
  - Reliable, full-duplex unicast transport (performs retransmissions)
  - TCP-friendly flow control (+ many other features of TCP)
  - Multi-streaming, in sequence delivery within streams
    → Avoid head of line blocking (performance issue)
  - Multi-homing: hosts with multiple IP addresses, path monitoring (heart-beat mechanism), transparent failover to secondary paths
    - Useful for provisioning of network reliability
Transport Layer Handover in SCTP

1. MN communicates with CN via established SCTP association (From IP1 to IP CN)
2. When MN comes in Range of AP B
   - MN obtains new IP address IP2
   - MN adds IP2 to the existing SCTP association
     Address configuration Change (ASCONF) Chunk
3. When connection should be transferred to new AP B
   - MN sets primary address to IP2
   - MN deletes old IP1 from SCTP association (ASCONF chunk)

SCTP Mobility support: Discussion

- SCTP Handover transparent for network
  - No additional network infrastructure needed
  - Possible use-case: switch to peer-to-peer mode without network support (CNTK)
- Avoids tunneling and tri-angular routing
- Endpoints need to support SCTP (with dynamic control of IP addresses)
- Signalling to every correspondent node necessary (for every established SCTP association)
  - for high number of parallel connections, large signalling volume over air interface
- Dynamic Naming Service for connection set-up from CN required (to establish the initial SCTP association)
  - Dynamic DNS
  - Other location mechanisms (e.g. based on SIP URLs)
- Only usable for traffic without real-time requirements (due to SCTP flow/congestion control)
  - but similar approaches, e.g. for RTP, possible
- Simultaneous Handover (Mobile Node and Correspondent Node) can lead to loss of connection
**SCTP (III): setup**

- SCTPlib (from sctp.de)
  - Partial support for Mobile extension
  - no dynamic modification of IP addresses of association in current implementation
- Mobile node
  - Handover script for forcing handover

**Measurement Methodology: Packet streamers**

- Handover determined from packet stream
  - With deterministic inter packet time
  - UDP and SCTP packet streamer
- Packet stream captured on mobile node (Ethereal)

SCTP Packet Streamer:
- Client/Server application
  - Maintain association
- Reliable transport protocol
  - Flow control mechanisms!

![Diagram of network topology and packet streamer setup](image-url)
**Definition of handover delay**

- **Handover initiated**
- **Handover started**
- **Last packet on NIC 1**
- **First packet on NIC 2**
- **Handover ended**

Total handover delay
(Hard handover)

**Migrating IP address: Results**

- **Precision**
  - Inter-packet time 5ms

- **Results (w. 95% conf. interv.)**
  - Bluetooth→WLAN
    - $18.8 \text{ms} \pm 3.2$ (Soft)
    - $31.5 \text{ms} \pm 2.8$ (Hard)

  - WLAN→Bluetooth
    - $25.9 \text{ms} \pm 3.2$ (Soft)
    - $60.4 \text{ms} \pm 2.1$ (Hard)
### MIP: handover delay distribution

- Home BT → Foreign WLAN, MN decapsulation
- Problems with packet forwarding FA→MN cause long delays in many measurements

### SCTP: handover delay distribution

- BT→WLAN in different subnets
- Problem with long total handover delay (>3s), but not for WLAN→BT handover
  - Possibly due to ‘inter-working’ problems between SCTP library and WLAN device driver
Content

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TCP performance: 802.11b Handovers

Legend:
- Router
- Switch
- WLAN Access Point
- Fixed Host
- Mobile Host
TCP Performance: Results

- Long HO delays due to DHCP configuration!
  (standard Windows 2000)

TCP Proxy

- Home Agent uses TCP proxy as gateway
  - Reverse Tunneling forced to intercept packets from MN to CN
- TCP Proxy uses MIP messages to determine MN connectivity
- CN is frozen by automatically sending a Zero Window Advertisement
- TCP Proxy starts sending data after receiving a MIP response and recovers CN by sending a non-zero Window Advertisement

Result:
- The TCP Proxy was successfully enhanced with the new routing feature in upstream
- MIP messages are decoded and „inform“ the TCP connection
## TCP Performance: HO times in second setup

<table>
<thead>
<tr>
<th>Run</th>
<th>Mobile IP HO time (s)</th>
<th>TCP HO time (s)</th>
<th>degradation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.79</td>
<td>8.07</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>6.61</td>
<td>8.22</td>
<td>24</td>
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<tr>
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<tr>
<td>10</td>
<td>6.61</td>
<td>8.20</td>
<td>24</td>
</tr>
</tbody>
</table>

Average: Mobile IP HO time: 5.80 s, TCP HO time: 8.19 s, degradation: 39%

| Std.Dev | 3.19 s | 5.35 s | 24% |

### Table 1: Handover times of TCP and its degradation compared to Mobile IP Handover time

Using SW Routers (Linux based) and Intel 802.11 Aps

No use of proxy here!

## TCP: Improvements using Proxy
Summary

- Measurement of hand-over delays (hard, soft) between WLAN and BT for
  - IP address migration
  - MIPv4
  - Mobile SCTP
- Results strongly implementation dependent (HW, OS, interface drivers, MIP implementation, etc.)
  - Long HO delays for MIP in certain scenarios: problems with packet forwarding FA→MN
  - Long total (hard) HO delay for SCTP for BT→WLAN scenarios: suspected inter-working problems
  - Otherwise HO delays below 0.5sec
- Long HO delays of Windows based MIP client due to DHCP behavior
  - TCP degradation due to exponential increase of time-out interval
  - Proposed TCP proxy removes additional TCP delays

References

- IETF Working groups (see also for RFCs and drafts):
  - Others: nemo, mipv6, dhcp, seamoby
- Seok Joo Koh, 'mSCTP: Use of SCTP for IP Mobility Support', Presentation, IT Forum, Korea, 2003