Performance Evaluation of Mobile IP

Investigating the Concept of Hierarchical Foreign Agents

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Outline

• Mobile IP with Hierarchical Foreign Agents
  – Main Idea and Advantages
• Goals of Experimental Investigations
• Testbed Setup
  – System and Workload Parameters, Factors, Metrics
• Results of Performance Evaluation
• Conclusions
MIP w/ HFA: Main Idea

- Foreign agents (FAs) arranged in a hierarchy
- Handover: FA in same hierarchy branch as both old and new FA becomes Switching FA (SFA)
- Handover messages relayed only up to SFA but not to Home Agent (HA)
Advantages of MIP w/ HFA

• Use of hierarchical Foreign Agents reduces
  – Handover latency
  – Packet loss during handovers
  – Signaling load
Goals of Experimental Investigations

• Evaluation of mobility-related performance parameters
• Comparison of Mobile IP w/ HFA with standard Mobile IP
• Impact of handover on transport layer performance
• Evaluation of strategies to shorten the handover trigger latency
• Identification of bottlenecks & potential areas for improvement
Testbed Setup I

- Wireless link replaced by standard Ethernet to emulate a "good" wireless channel
- Handover is controlled by manageable hub (SNMP)
Testbed Setup II

- **Software components**
  - OS: Linux 2.2.18 on base stations, routers, and end systems
  - Dynamics Mobile IP w/ HFA implementation version 0.6
  - WAN emulation: *softlink* (TKN, TU Berlin)
  - Measurement: *netperf, tcpdump, tcptrace*

- **Hardware components**
  - Standard desktop PCs (Pentium x)
  - Networking: 10BaseT, Ethernet hub (manageable)
# System and Workload Parameters

<table>
<thead>
<tr>
<th>Input parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offered Load</td>
<td>UDP: 1024Byte/10ms=1MBps</td>
</tr>
<tr>
<td>Socket buffer size</td>
<td>32kByte</td>
</tr>
<tr>
<td>Handover model</td>
<td>Exponentially distributed cell-dwell time (CDT)</td>
</tr>
<tr>
<td>Mean value for CDT</td>
<td>10sec, offset 5sec</td>
</tr>
<tr>
<td>Overlap of cells</td>
<td>-1, 0, 1sec</td>
</tr>
<tr>
<td>Latency (WAN emulation) [ms]</td>
<td>0, 200, 400</td>
</tr>
<tr>
<td>Advertisement frequency [N/sec]</td>
<td>10</td>
</tr>
<tr>
<td>Handover trigger policies</td>
<td>3 x Advertisement interval</td>
</tr>
<tr>
<td>Tunnel lifetime</td>
<td>600sec</td>
</tr>
<tr>
<td>Tunneling Type</td>
<td>Reverse Tunneling</td>
</tr>
<tr>
<td>Test length</td>
<td>3600sec</td>
</tr>
</tbody>
</table>
Experimental Factors and Metrics

- Factors
  - Number of hierarchies
  - Traffic type
  - Direction of data flow
  - Delay

- Metrics
  - Handover latency
  - Throughput
  - Signaling overhead
Results of Performance Evaluation

- Handover latency
- Mean throughput for UDP and TCP traffic
- Signaling overhead
Results: PDF of Handover Latency
MIP w/ HFA Uplink vs. Downlink

- FA-HA delay = 100ms,
- Mean Cell-dwell time $\lambda=10s + 5s$ offset
- Handover initiation policy: 3 x Adv. interval

Uplink traffic
Mean=328  StdDev=88

Downlink traffic
Mean=325, StdDev=84
Results: Handover Latency
MIP w/ HFA vs. Standard MIP

- FA-HA delay = 100ms,
- Mean cell-dwell time $\lambda=10s + 5s$ offset
- Handover initiation policy: 3 x Adv. interval

- W/ HFA
  Mean=328 StdDev=88

- Standard Mobile IP
  Mean=562, StdDev=73
Performance Evaluation of MIP

Results: Mean UDP Throughput
MIP w/ HFA, Uplink vs. Downlink

- Downlink UDP bulk transfer 1kB/10ms
- Loss ~ Service Interruption

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Results: Mean TCP Throughput
MIP w/ HFA, Uplink vs. Downlink

- Downlink TCP bulk transfer
- Mean Throughput [%]
- Delay varied ~0ms, 100ms, 400ms
Results: Mean UDP Throughput
MIP w/ HFA vs. Standard MIP

- Similar throughput for Mobile IP w/ HFA and standard Mobile IP
Results: Mean TCP Throughput
MIP w/ HFA vs. Standard MIP

- For high delays between FA and HA Mobile IP w/ HFA improves throughput
Impact of Handover on TCP Performance

- Scenario: Mobile IP w/ HFA
- Latency=100+100ms
- Snapshots of 10sec for typical TCP measures
  - Throughput
  - Round trip time (RTT)
  - Sequence numbers
  - Congestion window
Impact of Handover on TCP Performance

Throughput Graph

thruput (bytes/sec)

192.168.60.1:1047 ==> 192.168.70.40:1034 (throughput)

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Impact of Handover on TCP Performance

RTT Graph

19.168.60.1:1047 --> 192.168.70.40:1034 (rtt samples)
Impact of Handover on TCP Performance

Time Sequence Graph

sequence offset

192.168.60.1:1047 ==> 192.168.70.40:1034 (time sequence graph)
Impact of Handover on TCP Performance
Congestion Window Graph

Outstanding Data (bytes)

192.168.60.1:1047 --> 192.168.70.40:1034 (outstanding data)

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Utilization of Handover Initiation Policies

- Time to detect the need for handover is major part of the overall handover latency
- Increasing the advertisement frequency reduces latency, but signaling overhead grows
- Policies:
  - Reduced aging interval for FA advertisements
    - Handover is initiated after 2 x advertisement interval
  - Newest Foreign Agent
    - Foreign Agent with newest advertisement is used
  - Usage of link-layer trigger
Results:
Signaling Overhead (w/o Advertisements)

Mobile Host – Foreign Agent

w/o hierarchy

- 91 bytes (MN → FA)
- + 92 bytes (FA → MN)
- 183 bytes total per handover

w/ hierarchy

- 91 bytes (MN → FA)
- + 20 bytes (FA → MN)
- 111 bytes total per handover

Highest Foreign Agent – Home Agent

w/o hierarchy

- 165 bytes (new FA → HA)
- + 31 bytes (HA → old FA)
- + 199 bytes (HA → new FA)
- 395 bytes total per handover

w/ hierarchy

- ~0 bytes

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Conclusions

• Mobile IP w/ HFA reduces the signaling delay as part of the overall handover latency

• Time to detect the need for handover is major part of the overall handover latency in ALL scenarios

• To reduce handover latency considerably, the time to detect the need for handover must be also reduced

• Mobile IP w/ HFA does not supersedes TCP-enhancing approaches
Outlook

- Common handover trigger mechanisms for interfaces of different technology
- Comparison of Multicast-based handover (MOMBASA) and MIP w/ HFA
- Performance-enhancing proxies for TCP (ReSoA) required to improve TCP performance