Architecture and Performance of SIGMA: A Seamless Mobility Architecture for Data Networks

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Outline of Presentation

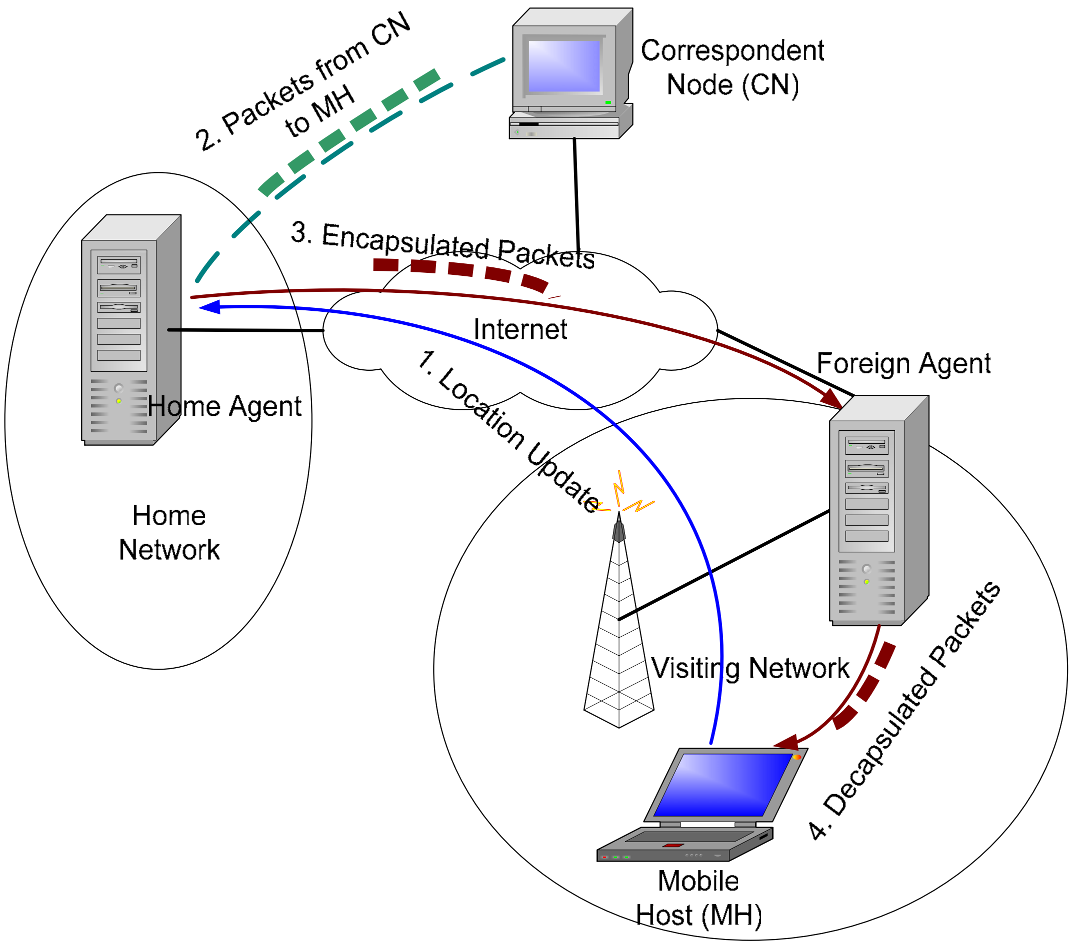
- Why IP mobility is needed?
- Mobile IP and its drawbacks
- Architecture of SIGMA
- Simulation topology
- Handover performance and network friendliness evaluation
- Conclusions

Why Introduce IP Mobility?

- In current Internet, IP addresses have duplex roles:
  - Identifying the end points in transport layer connections
  - Routing IP packets.
  - In wired networks, these two roles do not contradict.
- In Mobile Networks, we got a problem:
  - Internet enforces a hierarchical address structure. To maintain routing scalability of the Internet, mobile hosts (MH) have to change their IP addresses after change the point of attachment.
  - Popular transport layer protocols, like TCP, require the connection identifier unchanged during data transmission.

IETF Solution to IP Mobility: Mobile IP

- Mobile IP employs a pointer mechanism similar to the one used by the postal system.
- MH registers its location with HA after every subnet change.
- Packets from CN to MH are encapsulated then decapsulated and delivered to MH.



Major Drawbacks of Base Mobile IP

- Need modification to Internet infrastructure.
- High handoff latency and packet loss rate.
- Inefficient routing path.
- Home Agent must reside in MH's home network
  - hard to duplicate HA to various locations to increase survivability and manageability.
- All data traffic for MHs in a particular network must go through one HA
  - creates scalability issues.

Research Efforts and Proposed Scheme

- Enhancements on Mobile IP:
  - Low latency Handover for MIPv4.
  - Hierarchical IP, HAWAII and Cellular IP.
  - Optimized Smooth Handoff.
  - Mobile IPv6
  - FMIPv6, HMIPv6, FHMIPv6.
- Transport Layer Mobility:
  - MSOCKS
  - TCP Connection Migration

Our proposed scheme: Seamless IP diversity based Generalized Mobility Architecture (SIGMA)

Overview of HMIPv6

- Mobility Anchor Point *(MAP)*, is used to introduce hierarchy in mobility management.
  - When an MH roams between the subnets within the *region* covered by a MAP, it only sends location updates to the local MAP rather than the HA (that is typically further away and has a higher load).
- The HA is updated only when the MH moves out of the region.
- ***HMIPv6 can reduce the frequency and delay of location updates caused by MH's mobility***.

Overview of FMIPv6

- ***Reduce the handover latency***: resolve the new CoA address to be used before the MH enters into the coverage of the new AR.
- ***To reduce packet loss rate***: setup a temporary tunnel between Previous Access Router (PAR) and New Access Router (NAR) to forward packets to the new location.
- FMIPv6 depends on the wireless link layer triggers which inform the mobile node of an imminent handoff between the wireless access points attached to PAR and NAR.
- ***Performance of FMIPv6 greatly relies on the accuracy and timing of the link layer trigger***.

Overview of FHMIPv6

- HMIPv6 and FMIPv6 can be used together to further reduce signaling overhead and packet loss, we call it as *FHMIPv6*.
  - Natural way to integrate HMIPv6 and FMIPv6 is to place the MAP at an aggregation point above the NAR and PAR. However, forwarding of packets between PAR and NAR would be inefficient, since these data packets will traverse the MAP-PAR link twice before arriving at the NAR.

- ***Temporary tunnel is set up between MAP and NAR instead of between PAR and NAR***.

- FHMIPv6 also relies heavily on accurate link layer information. ***MH's high moving speed or irregular movement pattern may reduce the performance gain***.

Motivation of SIGMA

- Real-time traffic requires low-latency, low-loss rate mobility protocol support.
- Various *diversity* techniques have been used extensively in wireless communications at physical layer:
  - space (or antenna) diversity, polarization diversity, frequency diversity, time diversity, and code diversity.
- Many mobile hosts are equipped with multiple interfaces enabled by the improvements in wireless networking device.
  - Development of Software Radio technology will eventually integrate all interfaces into one card.
- Advances in transport layer protocols: built-in support for multihoming by Stream Controlled Transmission Protocol (SCTP).
- **A new kind of diversity is possible: *IP diversity*.**

Objective of SIGMA

- No new hardware or software component in the Internet infrastructure.
- Low handoff latency and packet loss rate.
- No tri-angular routing.
- Increased survivability, scalability and manageability.
- Suitable for satellite IP handoffs.

SCTP: A new Transport Protocol for Internet

What is SCTP?

- SCTP: “Stream Control Transmission Protocol”.
- Reliable transport protocol on top of IP, Standardized by IETF RFC 2960.
- Originally designed to support SS7 signaling messages over IP networks. Currently supports most of the features of TCP.

TCP and SCTP compared

- Both of them are reliable transport protocols;
- Similar Congestion Control algorithms (slow start, congestion avoidance);
- SCTP has two new important features:
  - Multihoming
  - Multistreaming

Upper layer applications

TCP, UDP, **SCTP**

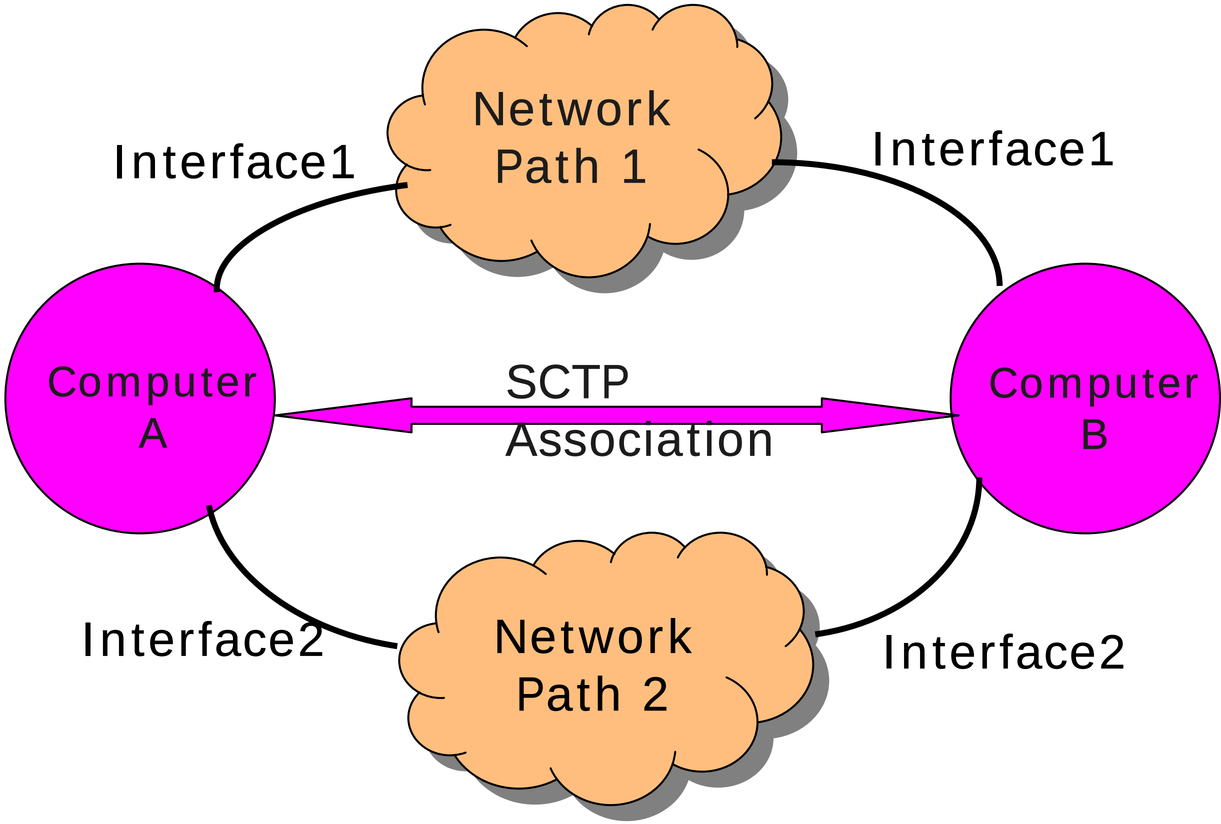
IP

Link Layer

Physical Layer

SCTP Multi-homing: Supporting Multiple IP Addresses in One Association.

- Each endpoint can have one or more IP addresses bound into the association.
- Address Dynamic Reconfiguration (ADR) option defines new chunk types: ASCONF and ASCONF_ACK, and new parameter types: ADD_IP, SET_PRIMARY, DELETE_IP.
- Using ADR option of SCTP, new IP addresses can be dynamically added into the association.

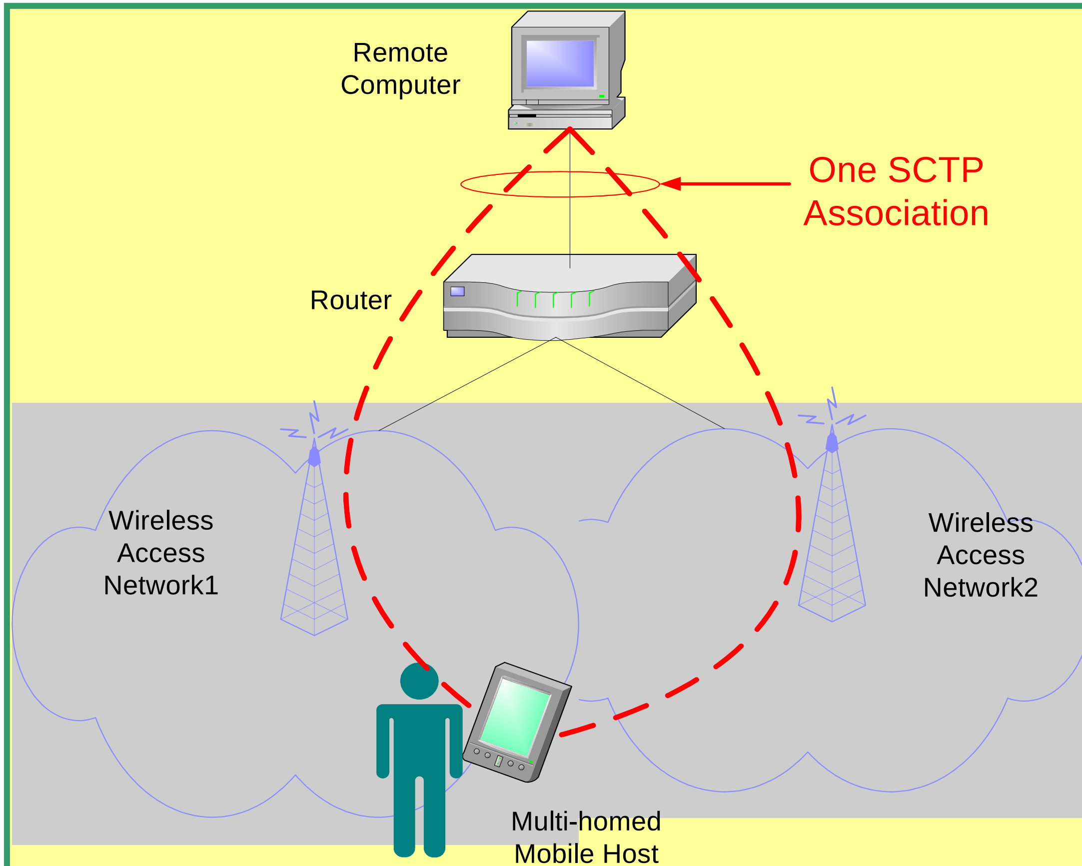


Basic concept of SIGMA: Seamless Mobile Handover based on IP Diversity

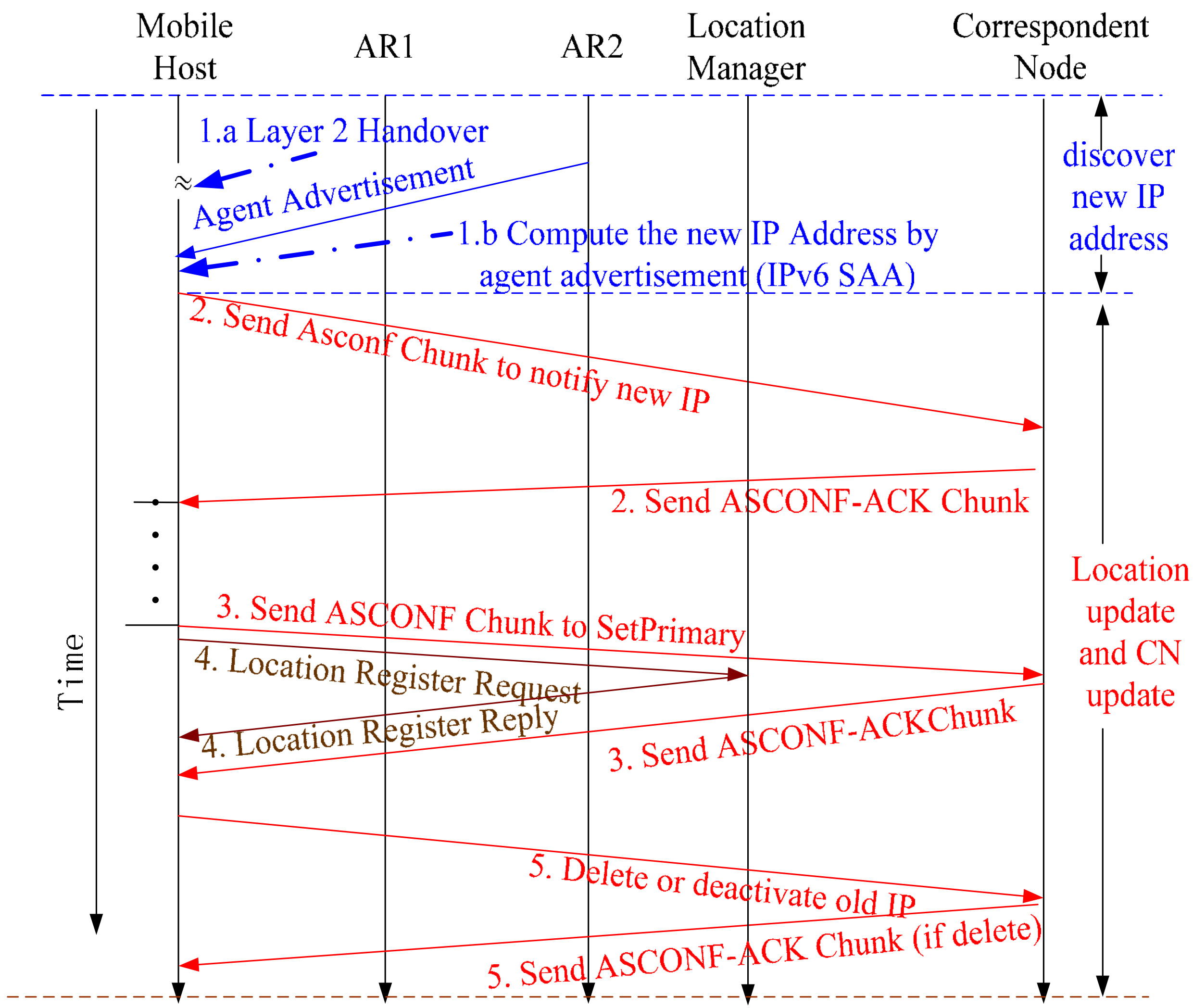
Basic idea: setup a new path to communicate with CN while maintaining the old path.

Handover process:

- STEP 1: Layer 2 handover and obtain new IP address
- STEP 2: Add IP addresses into the association
- STEP 3: Redirect data packets to new IP address
- STEP 4: Update location manager (LM)
- STEP 5: Delete or deactivate obsolete IP address



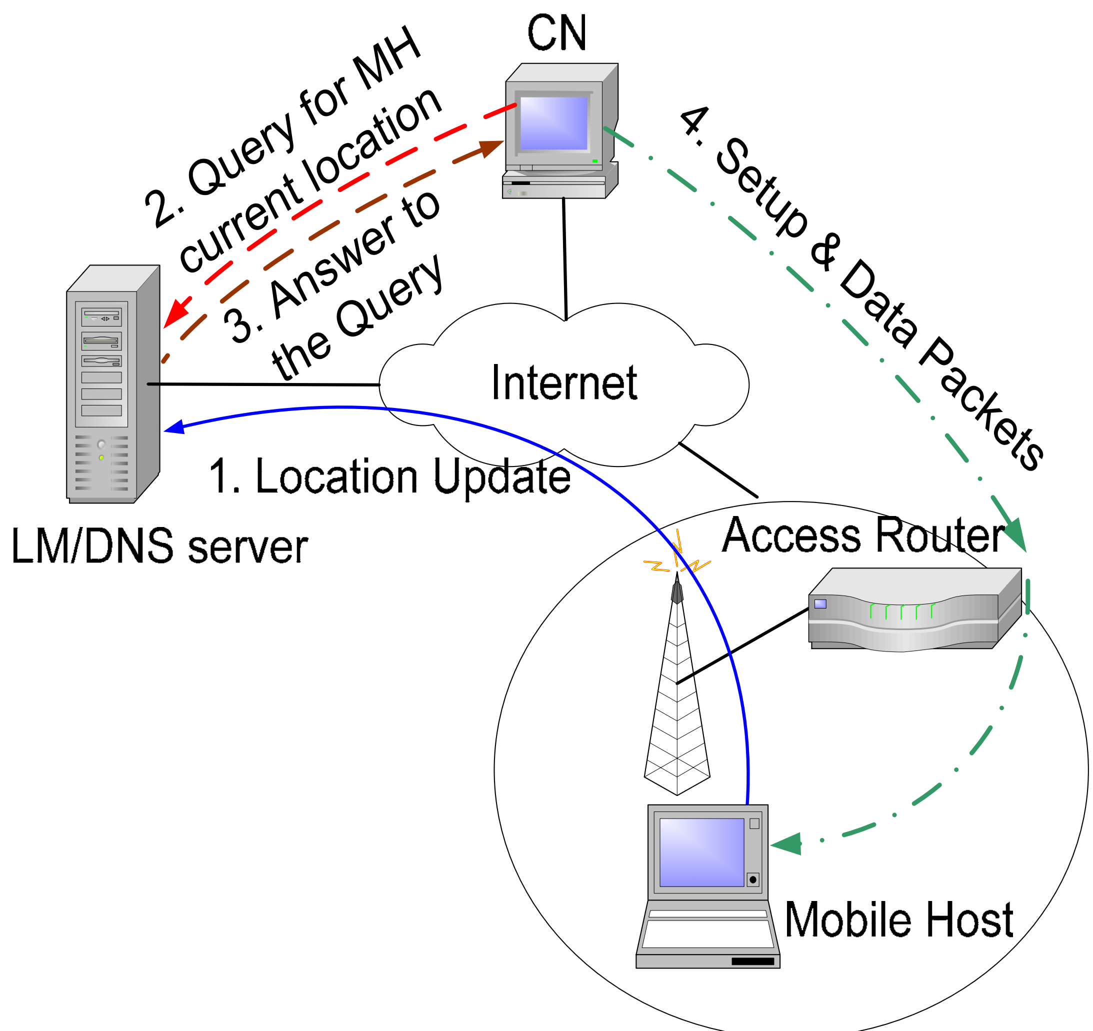
Time Line of SIGMA



Location Management of SIGMA

Advantages:

- Transparency to existing network applications.
- Decoupling of location management from data forwarding functions.
- Significant reduction in system complexity and operating cost.
- Enhanced system survivability and manageability.

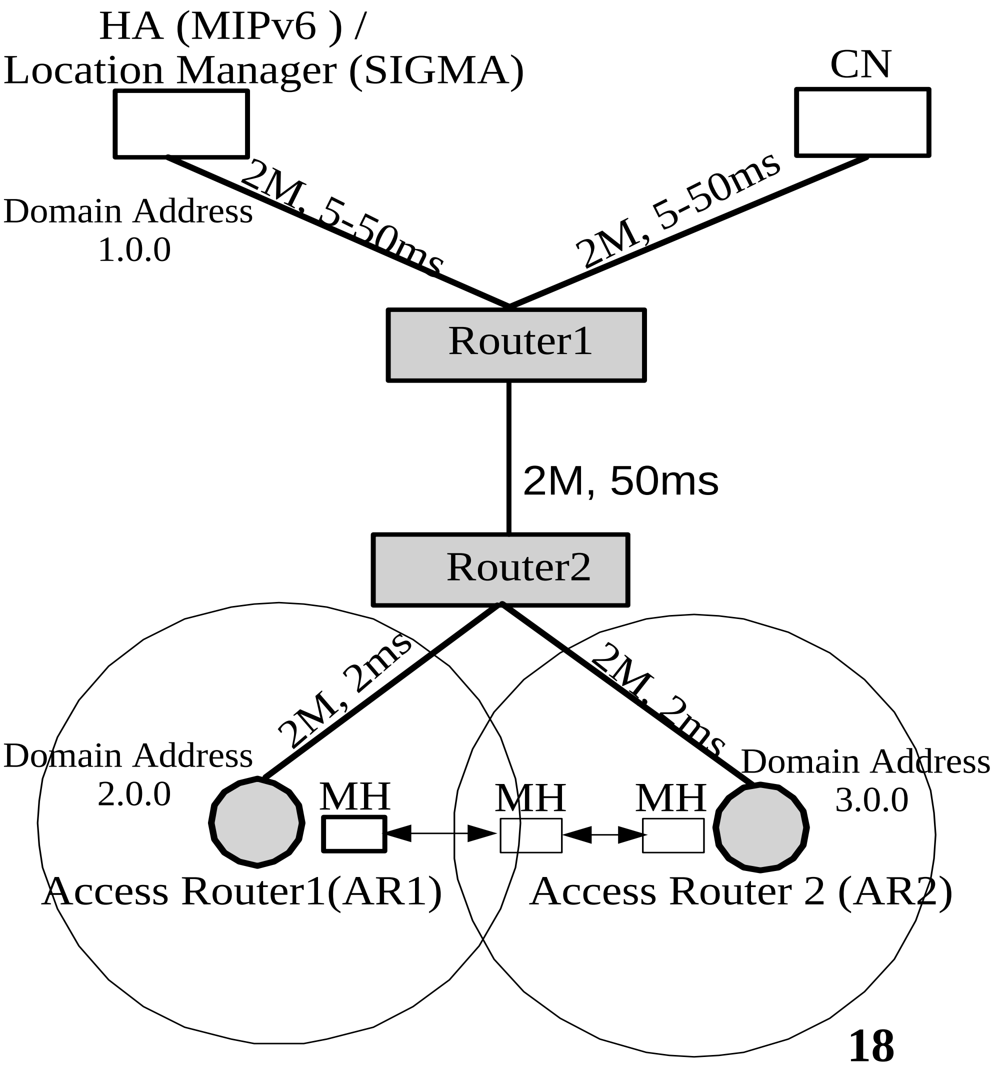


SIGMA Performance Evaluation

- Uses *ns-2* simulator that supports SCTP as the transport protocol.
- Implemented SIGMA in *ns-2* simulator package.
- Incorporated FMIPv6, HMIPv6, FHMIPv6, route optimization implementations.

Simulation Topology

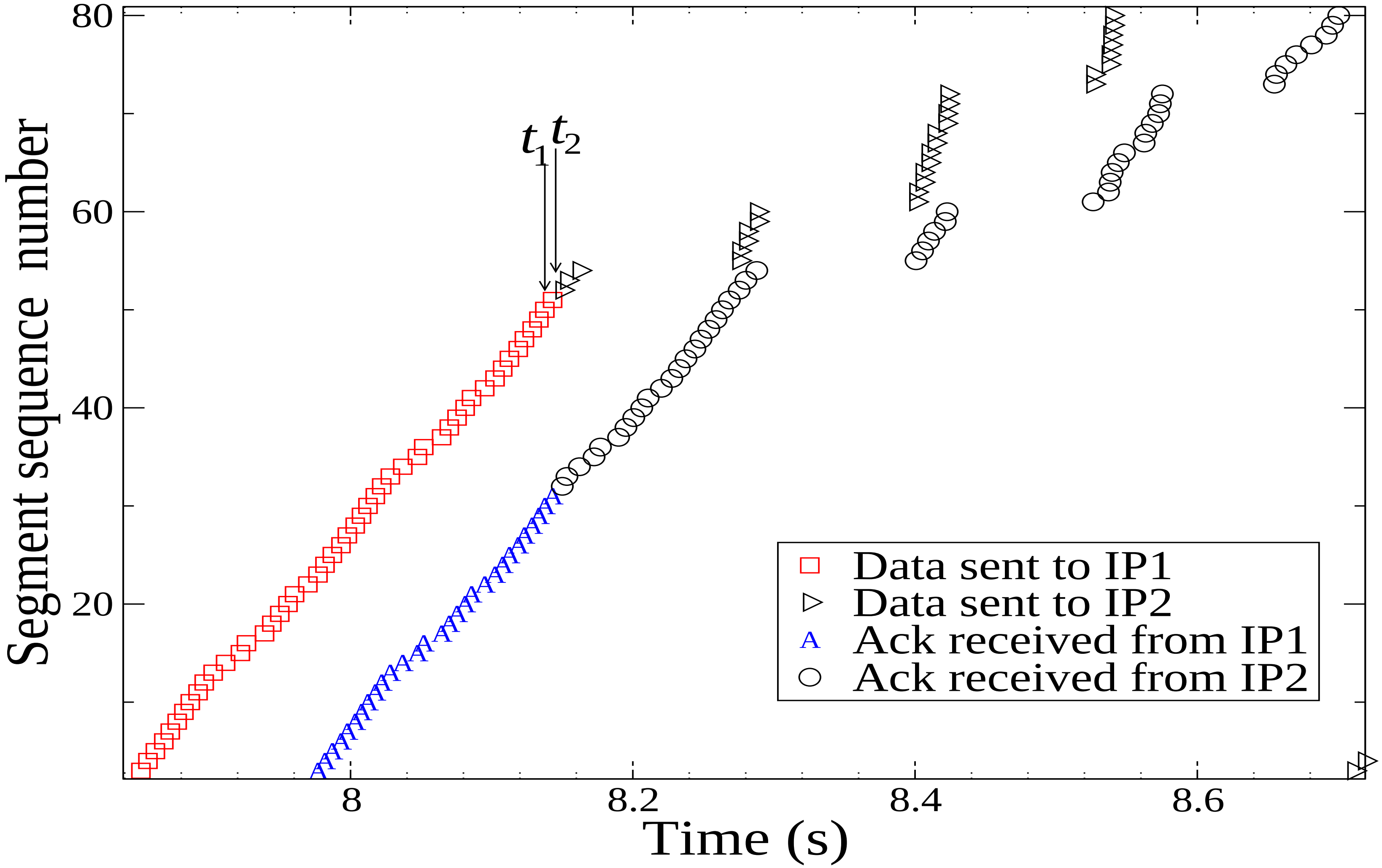
- FTP traffic used to transfer bulk data from CN to MH.
- Router2 acts as MAP for HMIPv6 and FHMIPv6, while as normal router for FMIPv6 and SIGMA.
- Standard SCTP protocol used as the transport layer protocol for MIPv6 enhancements to ensure fair comparison.



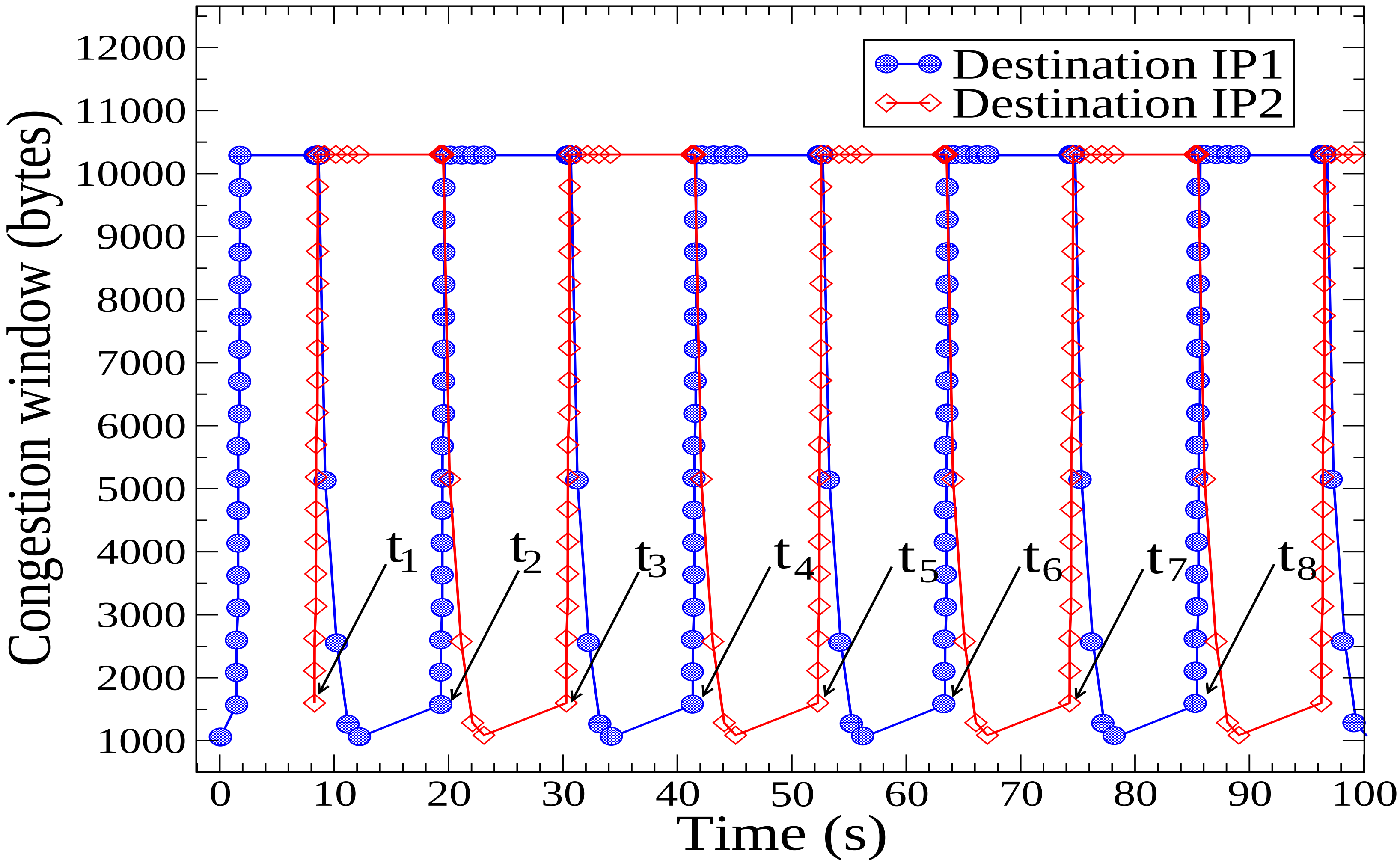
Performance Measures

- ***Handover Latency***: time interval between the last data segment received through the old path and the first data segment received through the new path from CN to MH.
- ***Packet loss rate:*** number of lost packets due to handover divided by the total number of packets sent by CN.
- ***Throughput***: total useful bits that can be delivered to MH's upper layer application divided by the simulation time,

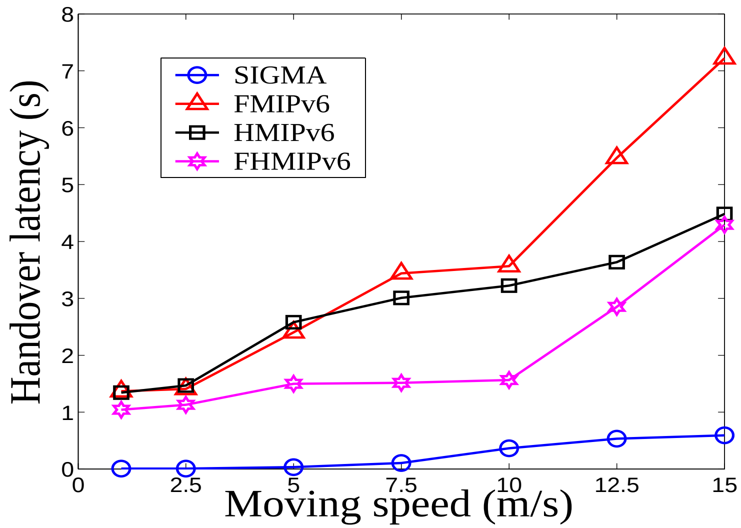
Simulation Results - Packet Trace of SIGMA

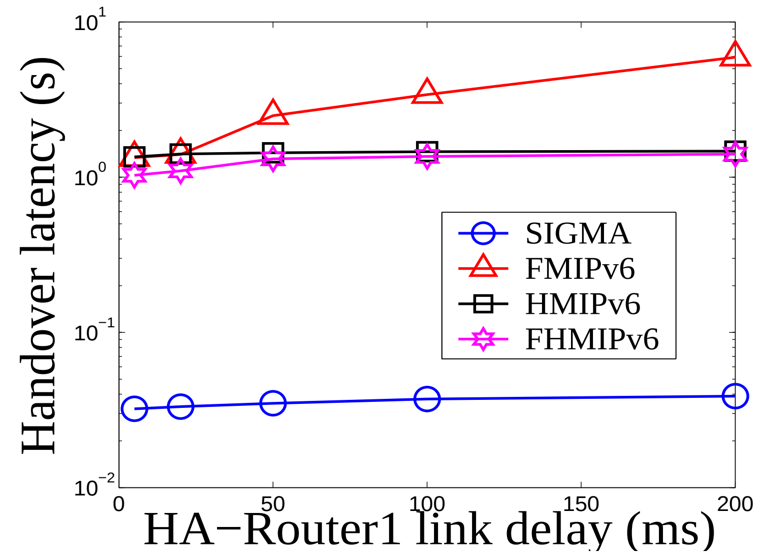


Results : Congestion Window Evolution of SIGMA

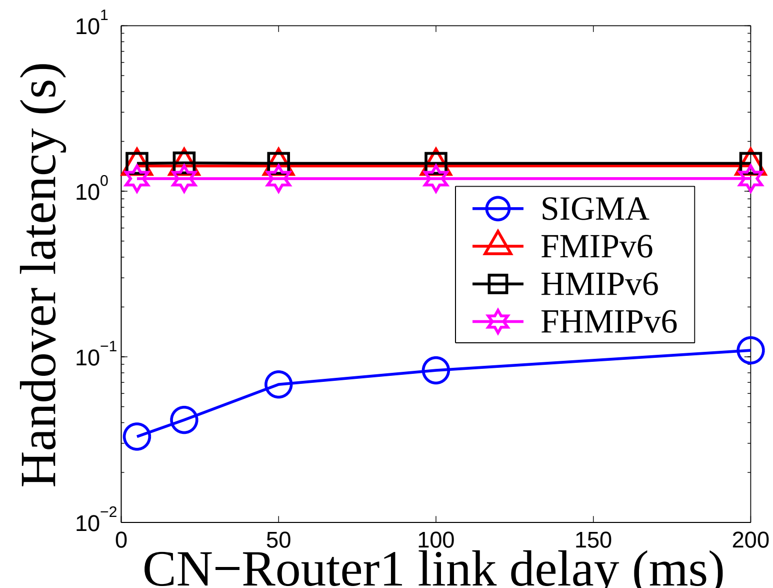


Results: Handover latency comparison

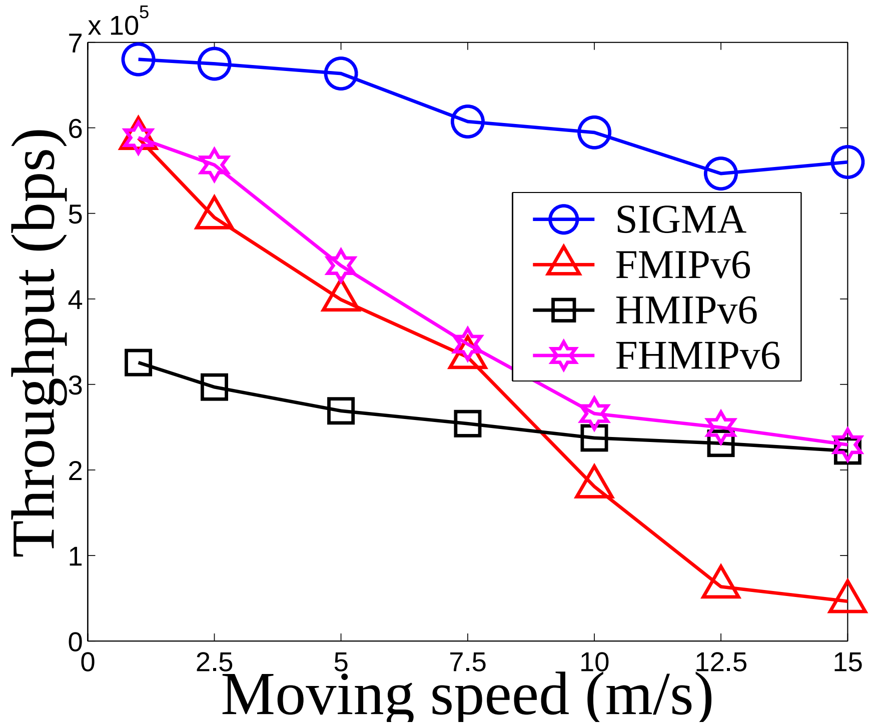


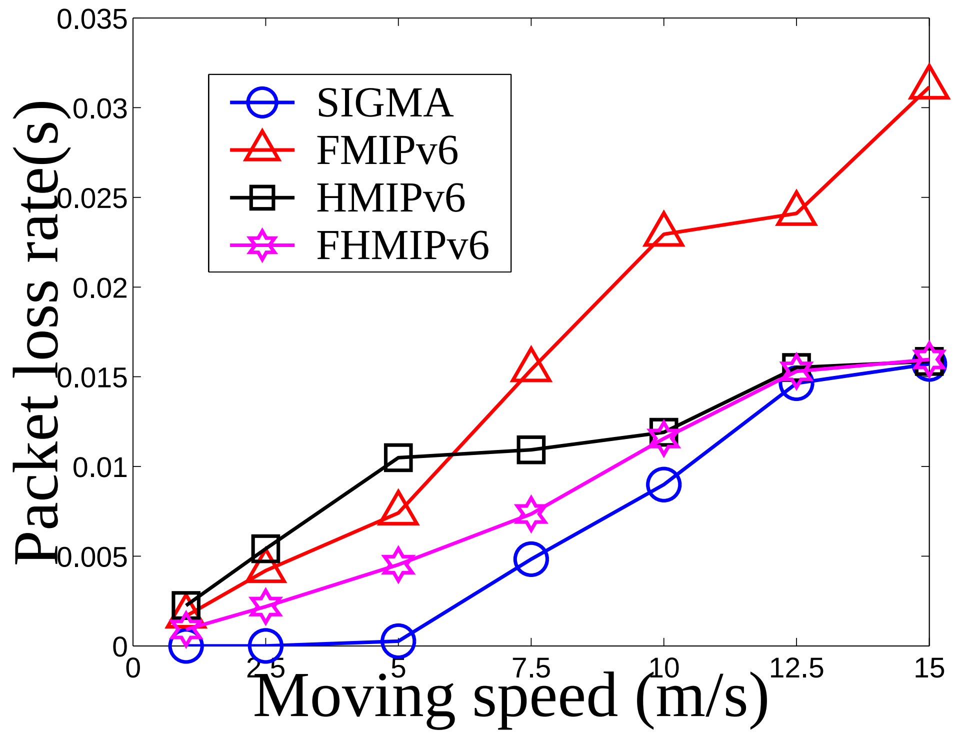


- SIGMA can achieve a lower handover latency than MIPv6 enhancements.
- Moving speed has most significant impact on FMIPv6.
- SIGMA is insensitive to HA-Router1 delay, but sensitive to CN-Router1 delay.



Results: Impact of moving speed

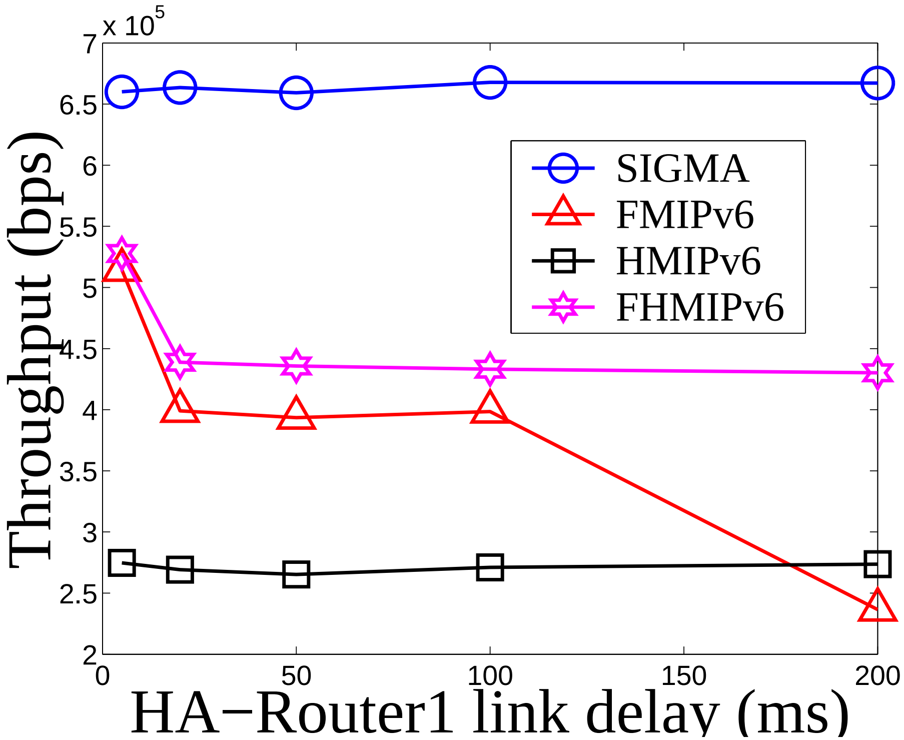


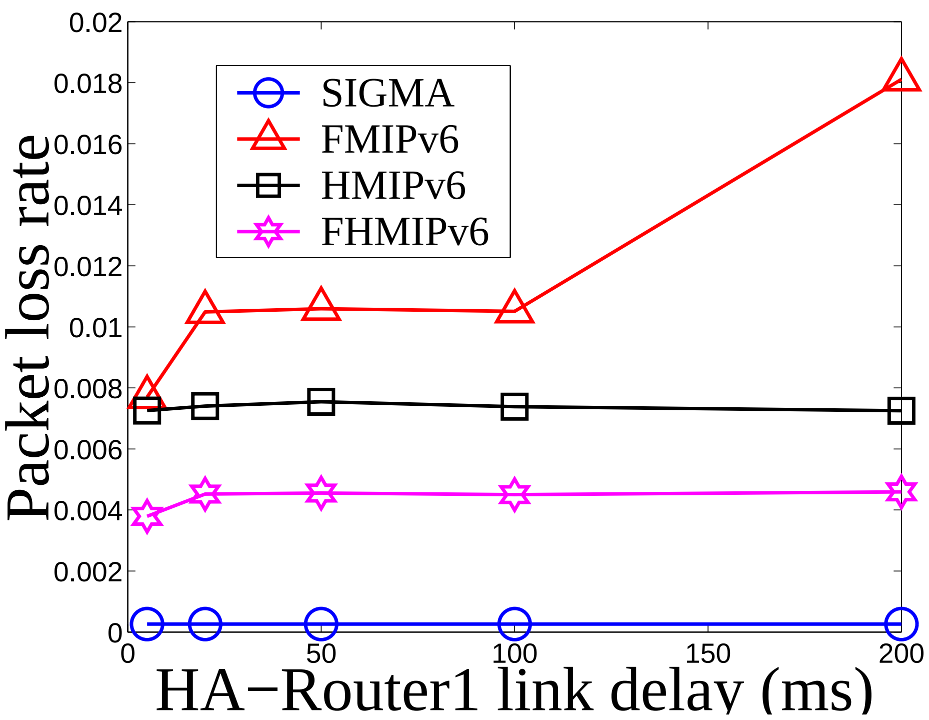


Analysis: Impact of moving speed

- When MH moves faster:
  - all MIPv6 enhancements and SIGMA will experience a higher packet loss rate and decreased throughput.
  - Possibility of packets being forwarded to the outdated path increases.
- Increase of speed has the most significant effect on FMIPv6.
  - FMIPv6 relies on the assumption that detection of the new agent is well in advance of the actual handover
    - may not hold when MH moves fast.

Results: Impact of LM (HA) - Router1 link delay

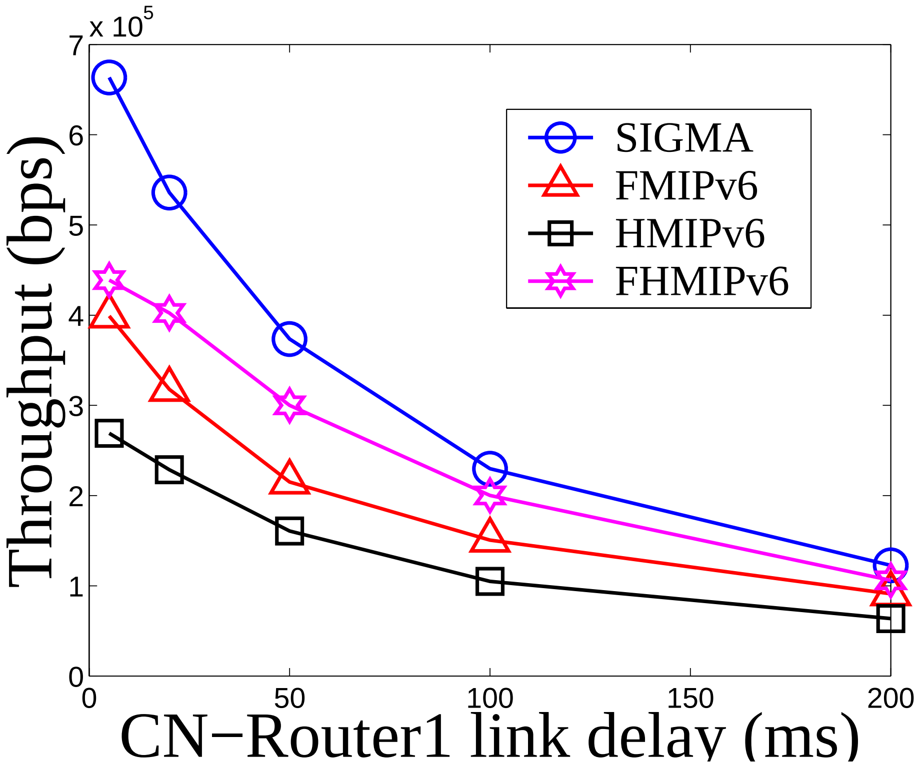




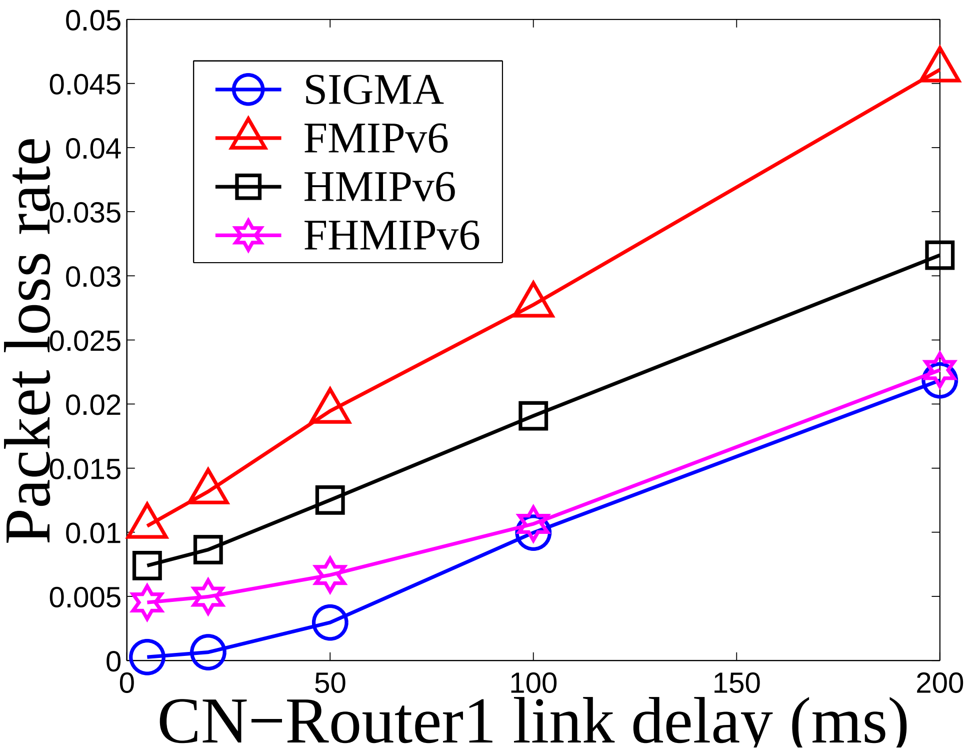
Analysis:
Impact of LM (HA) - Router1 link delay

- RTT between MH and LM (HA)
- SIGMA decouples location management from critical handover process
  - link delay does not have impact on the packet loss rate and throughput of SIGMA.
- HMIPv6 and FHMIPv6
  - MH only needs to register with the MAP node (Router2)
    - Link delay between HA and Router1 does not have significant impact
- FMIPv6
  - Location update has to go through this link
    - a higher delay in this link will result in higher packet loss rate and lower throughput.

Results: Impact of CN - Router1 link delay



Throughput comparison

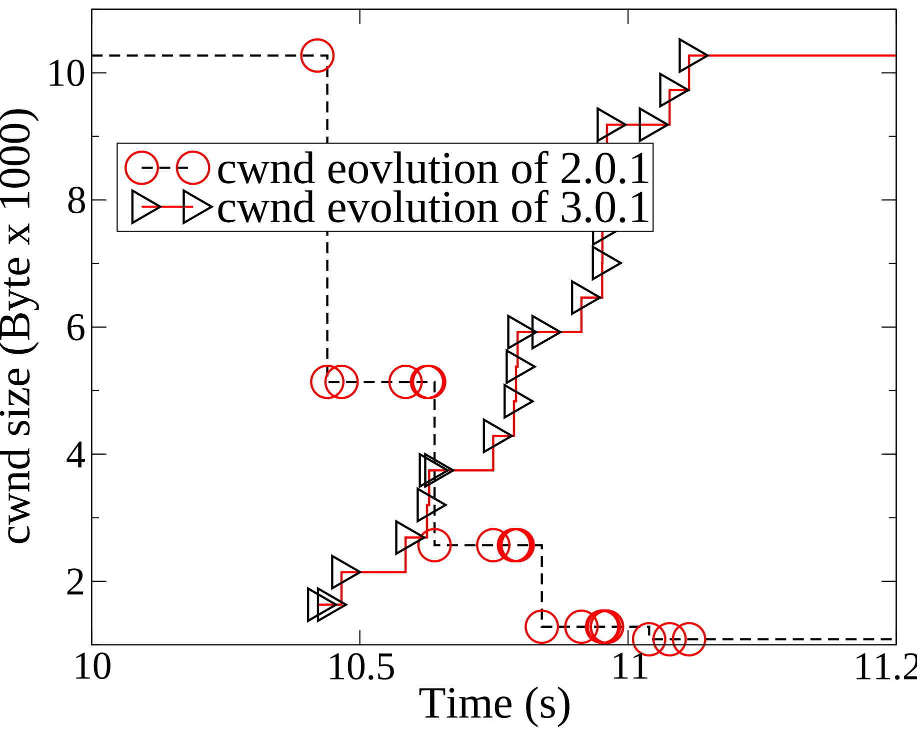


Packet loss rate comparison

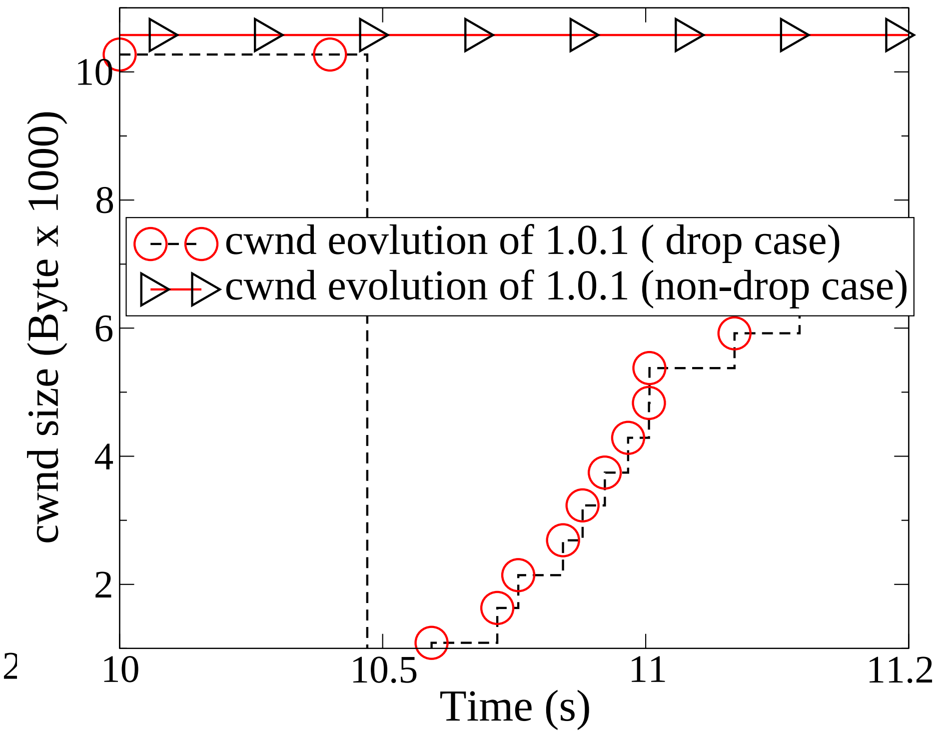
Analysis: Impact of CN - Router1 link delay

- This delay decides the RTT between MH and CN since the other link delays (Router1-Router2, Router2-ARs, ARs-MH) are fixed.
- For SIGMA, as this link delay increases, it has a negative effect on both packet loss (due to non-timely CN update) and throughput (longer RTT), so the packet loss rate increases relatively fast.
- Link delay between CN and Router1 does not have much impact on the ***total number of packet losses*** in MIPv6 enhancements. However, due to throughput is less with longer RTT, resulted ***packet loss rate*** will increase.

Results: Friendliness Comparison



Mobile IP



SIGMA

Analysis: Friendliness Comparison

- Network friendly mobility protocol:
  - When an MH enters a new domain, CN should probe for the new domain's network condition.
- MIP
  - Transport layer in unaware of handover
    - CN can not probe the network condition after handover
    - This network unfriendliness can help MIP achieve better throughput
      - Not preferable from the perspective of network performance.
- SIGMA
  - CN always probes the new network path after a handover, regardless of segment drops.
    - Better network friendliness

Conclusions

- SIGMA can utilize IP diversity to achieve seamless mobile handover.
- Requires no change in Internet infrastructure.
- For typical network configuration and parameters, SIGMA has a lower *handover latency*, *lower packet loss rate* and *higher throughput* than MIPv6 enhancements.
- SIGMA is more *network friendly* than MIP due to probing of the new network path following every handover.

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http://www.cs.ou.edu/~netlab

Thank You