Fast Handoff for Seamless Wireless Mesh Networks

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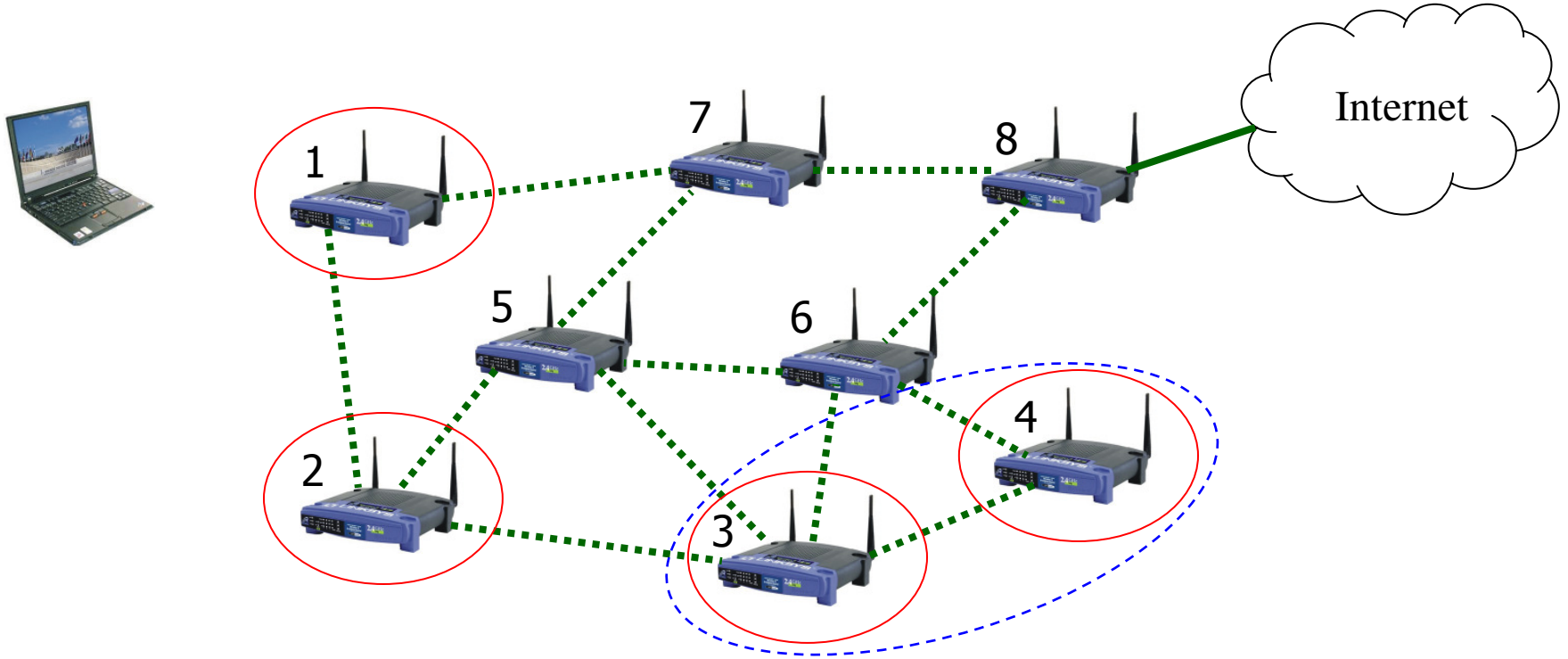
Motivation

- Over 200 million 802.11 chips sold
- Wireless becoming the Norm for Internet connectivity
- VoIP becoming popular
- Want a wireless infrastructure that allows unmodified clients to connect and roam freely with real-time fast handoff

Rethinking the Problem

- How will clients connect to the wireless infrastructure?
  - 802.11 BSS (Infrastructure) or IBSS (Ad-Hoc) Mode
- How should we route to and from the mobile client?
  - Should clients be part of the Routing Topology
  - What is the natural way of routing to the Internet Gateway
- How can we achieve fast handoff?
  - Does 802.11 handoff have to be Hard and Forward
  - Can the wireless infrastructure (not the mobile client) control the handoff
  - Can we reroute packets fast enough.

SMesh



Related Work

- Handoff on Wireless Networks
  - Handoff in Cellular Wireless Networks [Seshan, Balakrishnan and Katz, Kluwer Journal on Wireless Personal Communications, 1996]
  - Fast and Scalable Handoff [Caceres and Padmanabhan, MOBICOM, 1996]
  - An Empirical Analysis of 802.11 Handoff [Mishra, Shin and Arbaugh, SIGCOMM, 2003]
  - SyncScan [Ramani and Savage, INFOCOM, 2005]
- Wireless Mesh Networks
  - Metricom Ricochet, MIT Roofnet, Microsoft MCL, Rice TAPS, UCSB MeshNet, ...

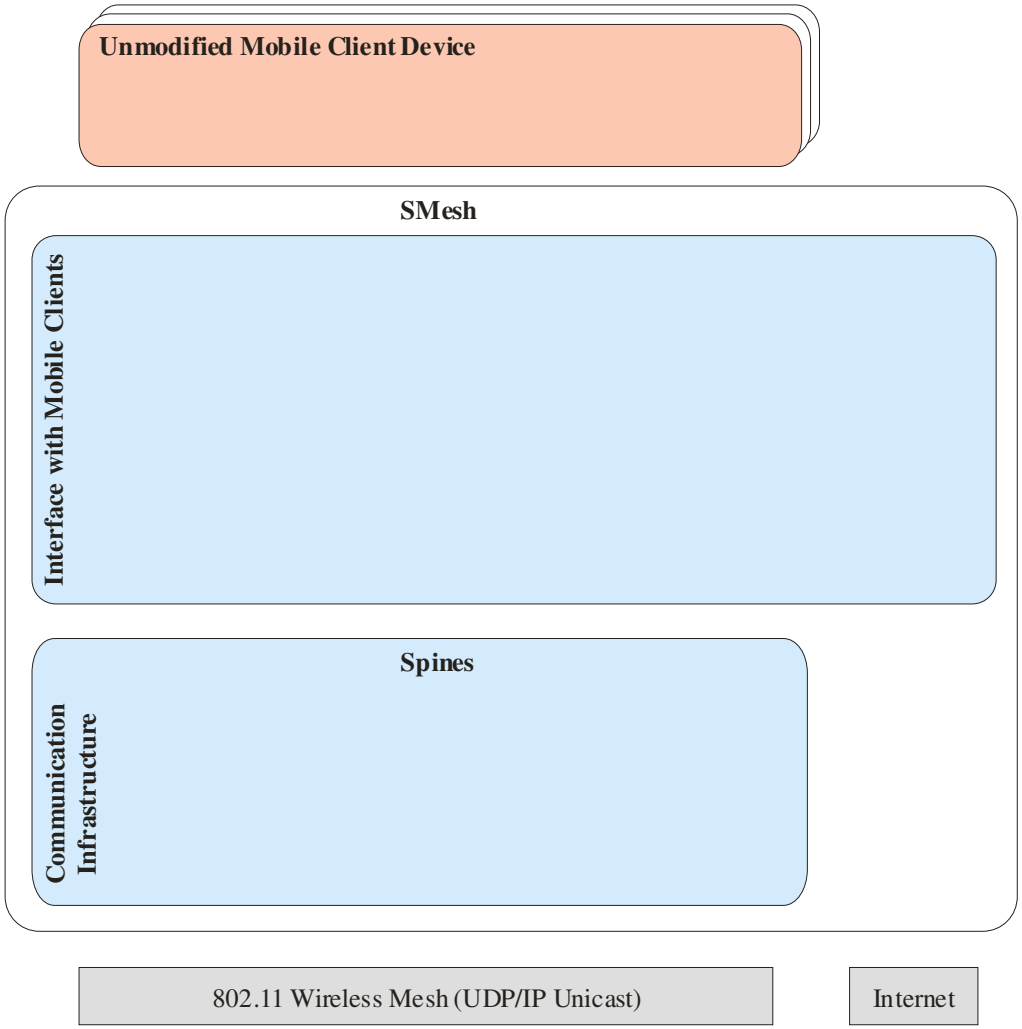
Outline

- Architecture
  - Overlay Communication Infrastructure
  - Client Seamless Access
  - Sending and Receiving packets
- Fast Handoff
  - Client Quality Metric
  - Client Mobility
- Experimental Results

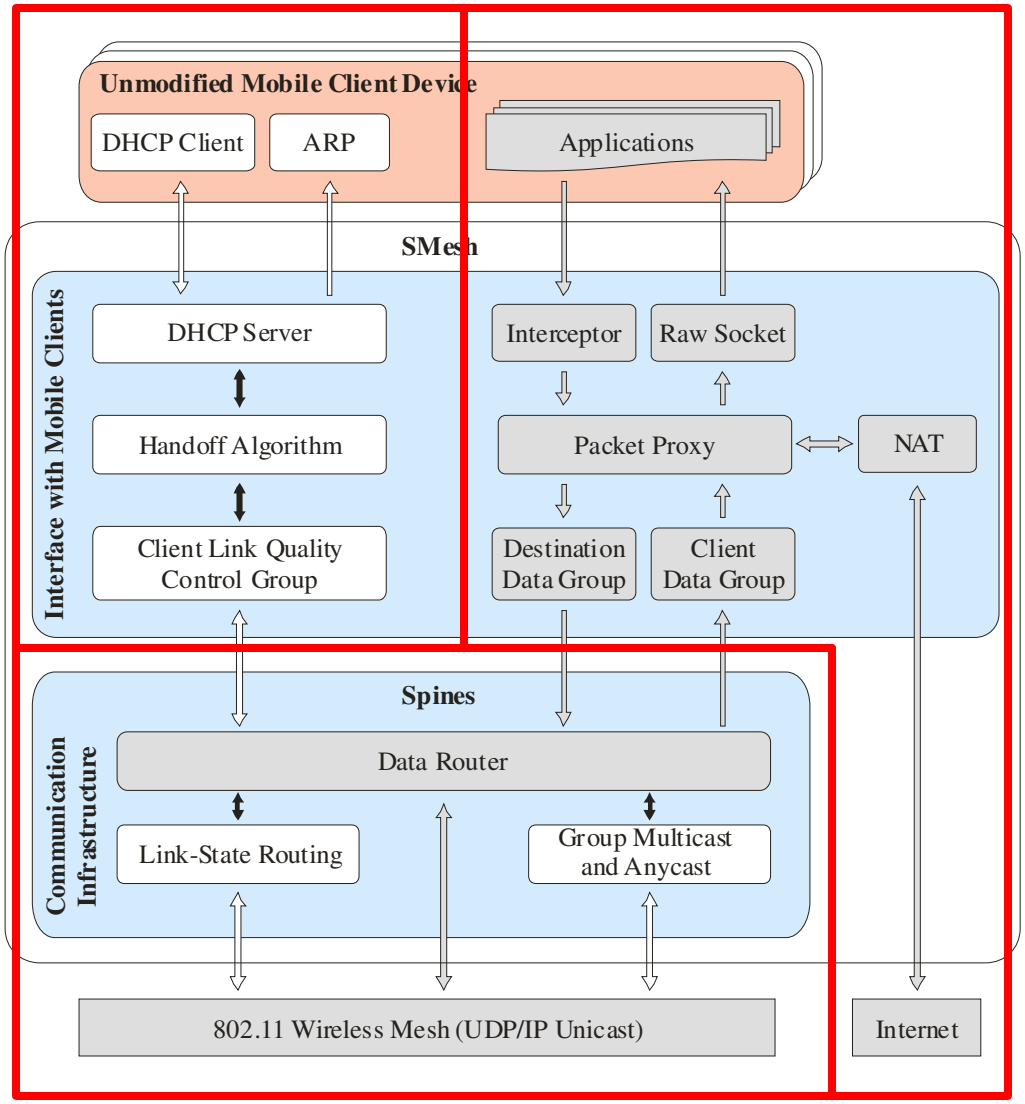
Architecture Overview

- Unmodified Mobile client
  - Connectivity
- Interface with Mobile Client
  - Handle client connectivity
  - Handoff Logic
  - Data Packet Proxy to handle client packets
- Communication Infrastructure
  - Topology Management
  - Multi-Hop Communication (Routing)
- Medium (Wireless Mesh and the Internet)

SMesh Architecture



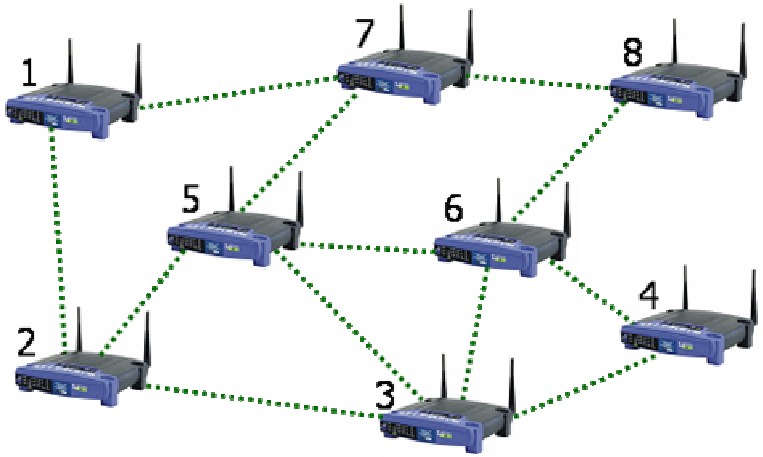
SMesh Architecture



Generic Overlay Network

Spines Messaging System

[DSN 2003], [NOSSDAV 2005]



- Hello Protocol
- Routing Metrics
- Multicast / Anycast
- Transparent API

Client Seamless Access

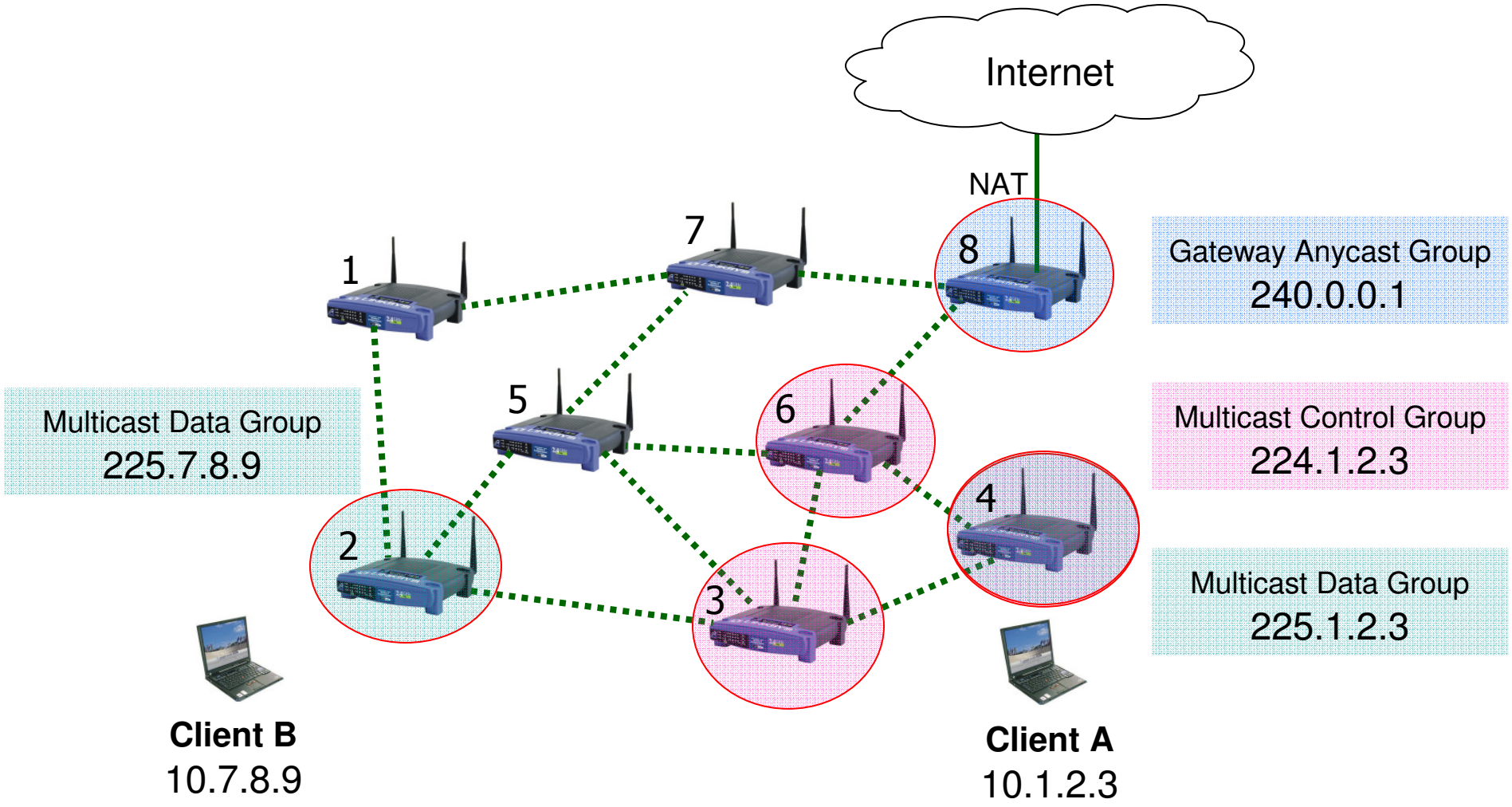
- Use Standard DHCP Protocol

- Ensure client always gets the same IP address
  - Assign IP based on MAC address

- Make client route all packets through a Virtual Default Gateway
  - Default Internet Gateway: 10.20.30.40
  - Netmask: 255.255.255.254

- Send Gratuitous ARP to associate Default Gateway IP with the Access Point

Routing Groups



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Client Quality Metric

- Make client Broadcast a DHCP request every 2 seconds
  - DHCP T1 and T2 Timers
- Measure Loss Rate on Broadcast DHCP Packets
  - Broadcast Packets are Not Retransmitted

Client Quality Metric

$$M_{NEW} = M_{OLD} * Df + Const * Received * (1 - Df) \qquad 0 < Df < 1$$

M = Link Quality Measure
Df = Decay Factor
Received = DHCP Packets Received on Window
Const = 30 (Granularity + Integer Mapping)

Fast Lossless Handoff

- Nearby Access Points share metric on Client Control Group periodically
- Best of them joins Client Data Group, and Unicast **Gratuitous ARP**
- **We need to guarantee that, at all times, there is at least one member in the Data Group**
  - When not best and in Data Group, send Leave Requests
  - Leave Request ACK can only be sent by members of the DATA Group not currently sending a Leave Request.
  - Disagreement is allowed
  - A Tie between members resolved by IP address

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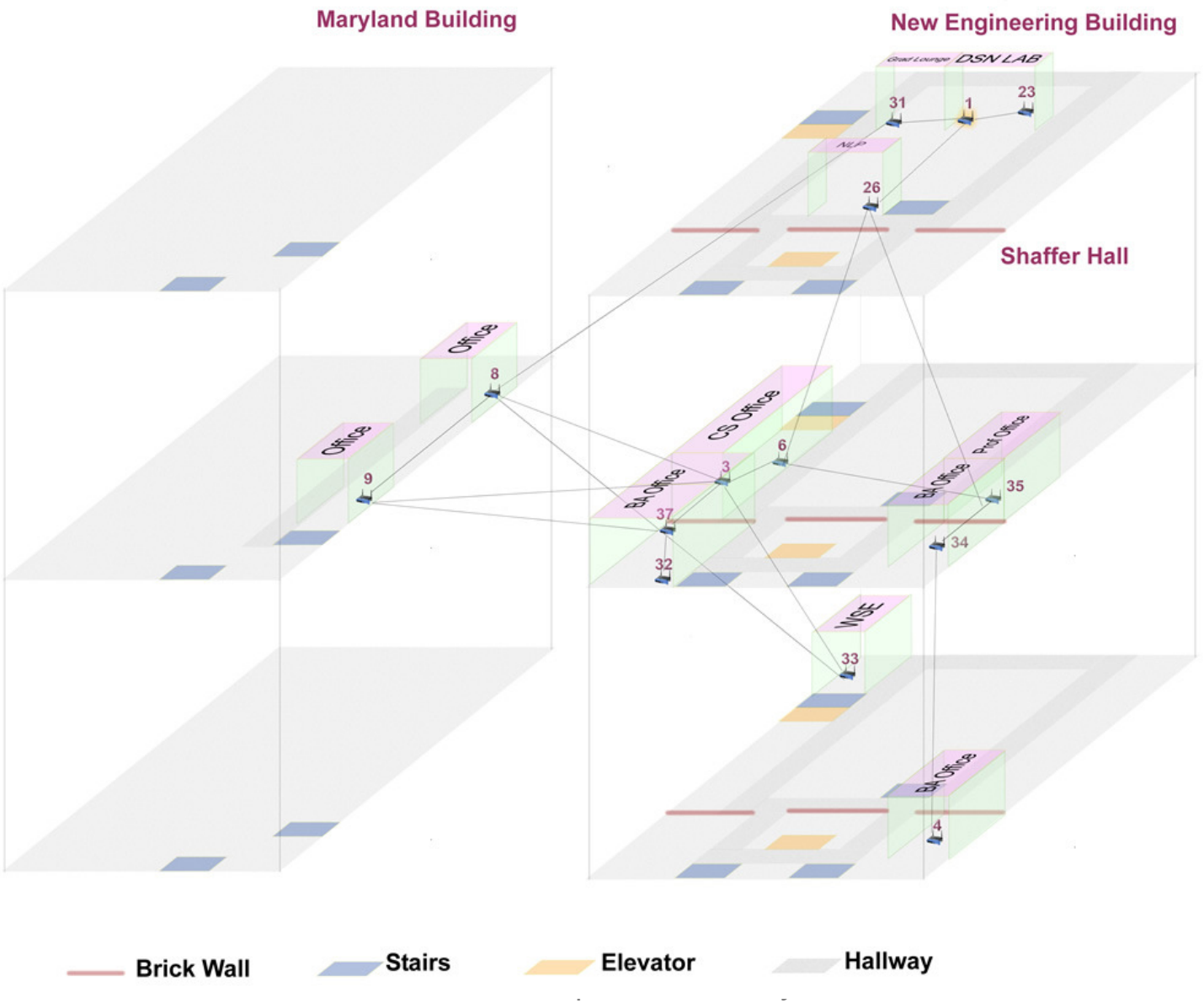
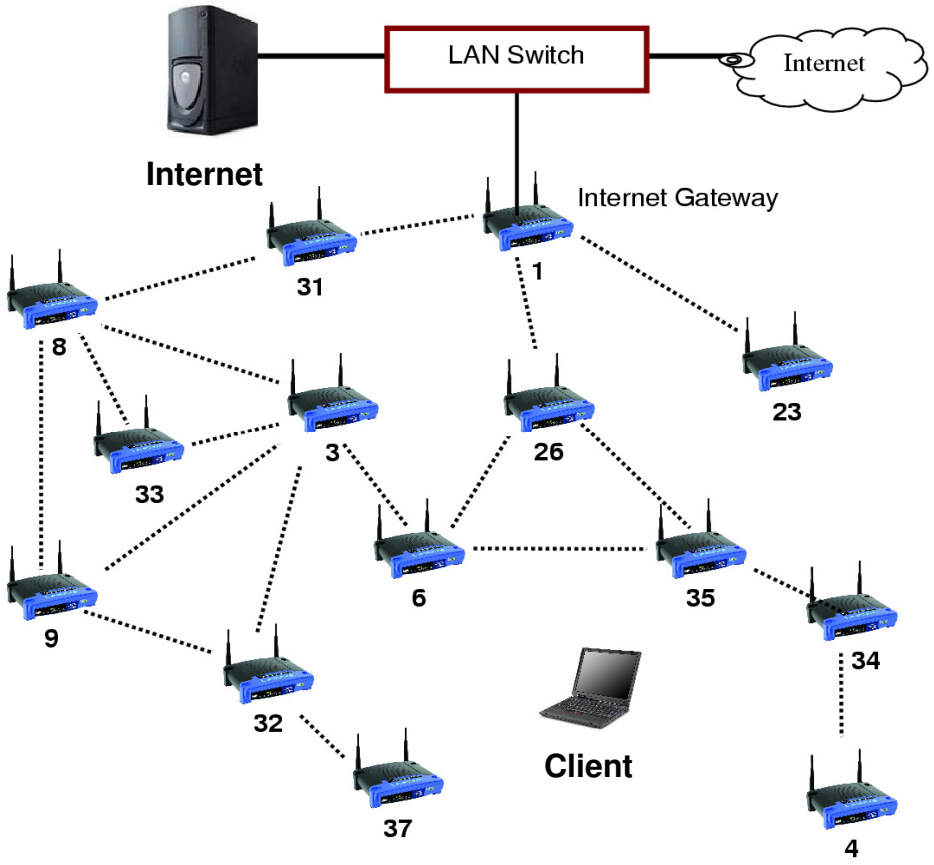
SMesh Wireless Testbed
(Dec 9 2005)



SMesh Testbed



Test

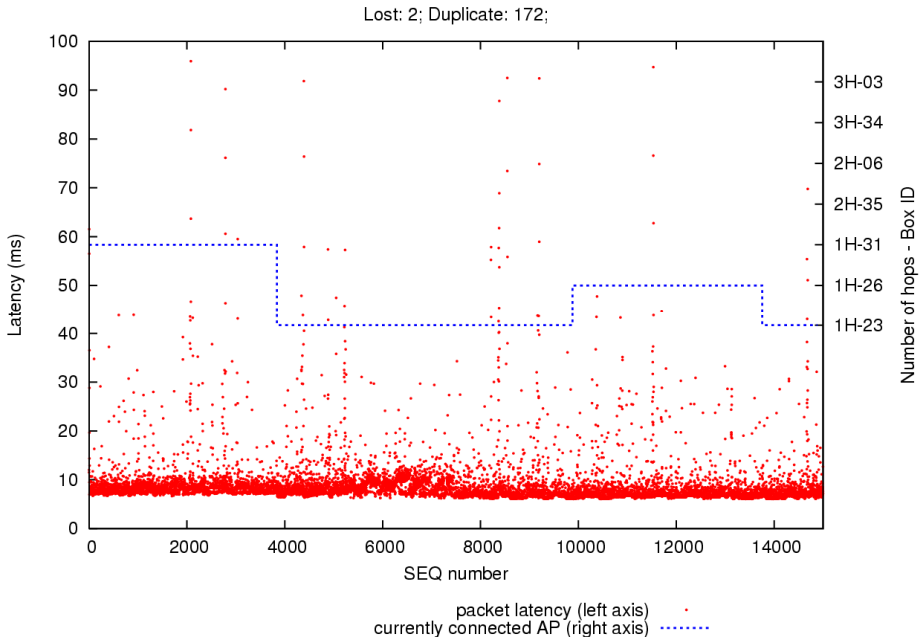
Full Duplex VoIP
Internet <==> Client

Each Stream

G.711
64 Kbps
160 bytes / 20 ms

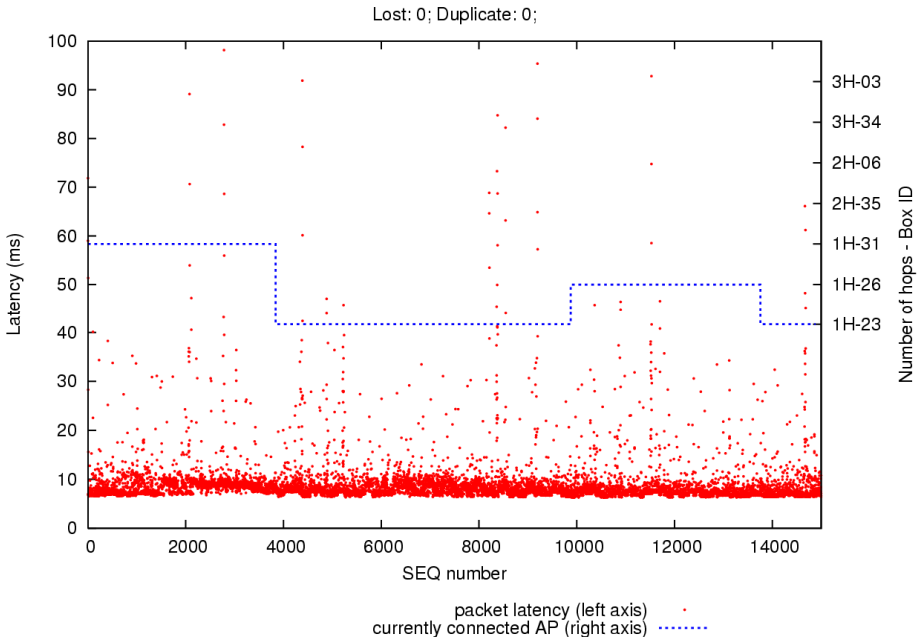
Stationary Client: Latency

Internet -> Mobile Client



Packets delayed over 100ms
9 packets

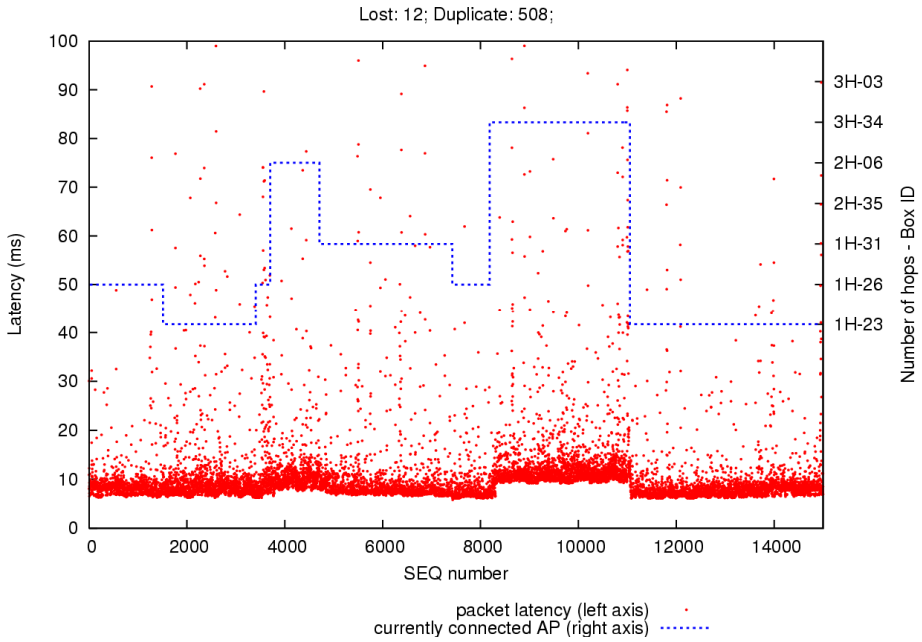
Mobile Client -> Internet



Packets delayed over 100ms
16 packets

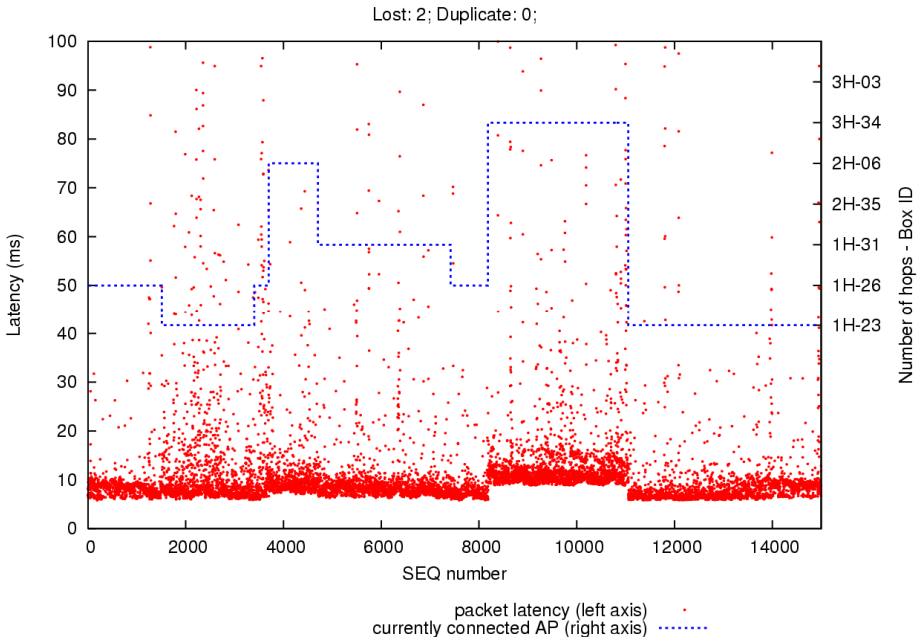
Moving Client: Latency

Internet -> Mobile Client



Packets delayed over 100ms
55 packets

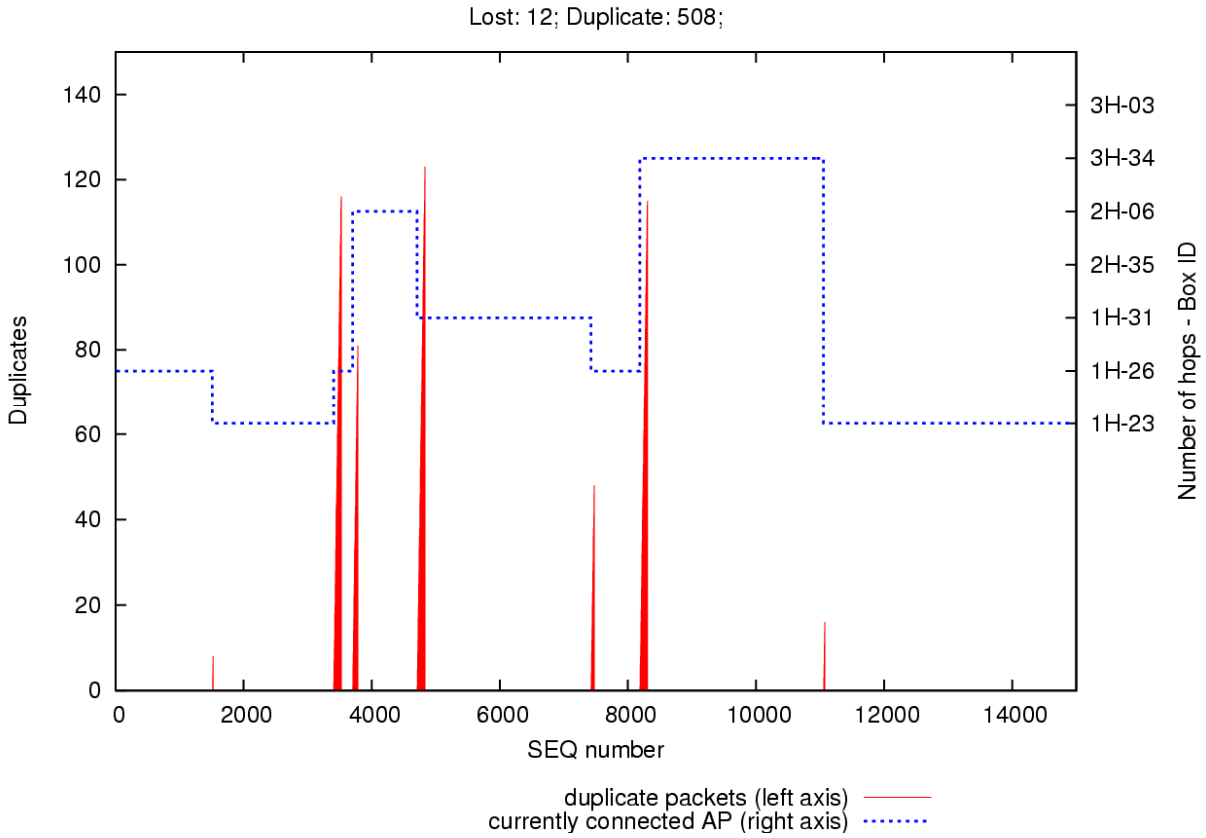
Mobile Client -> Internet



Packets delayed over 100ms
56 packets

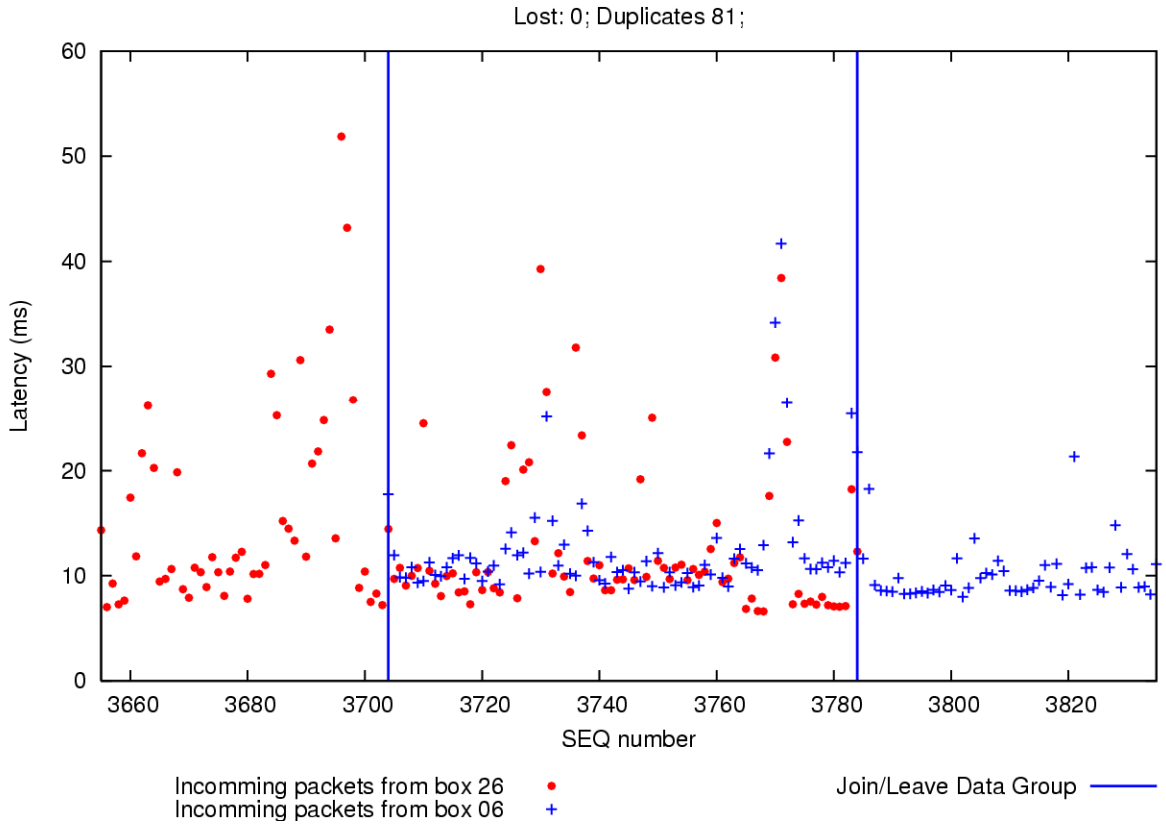
Moving Client: Duplicates

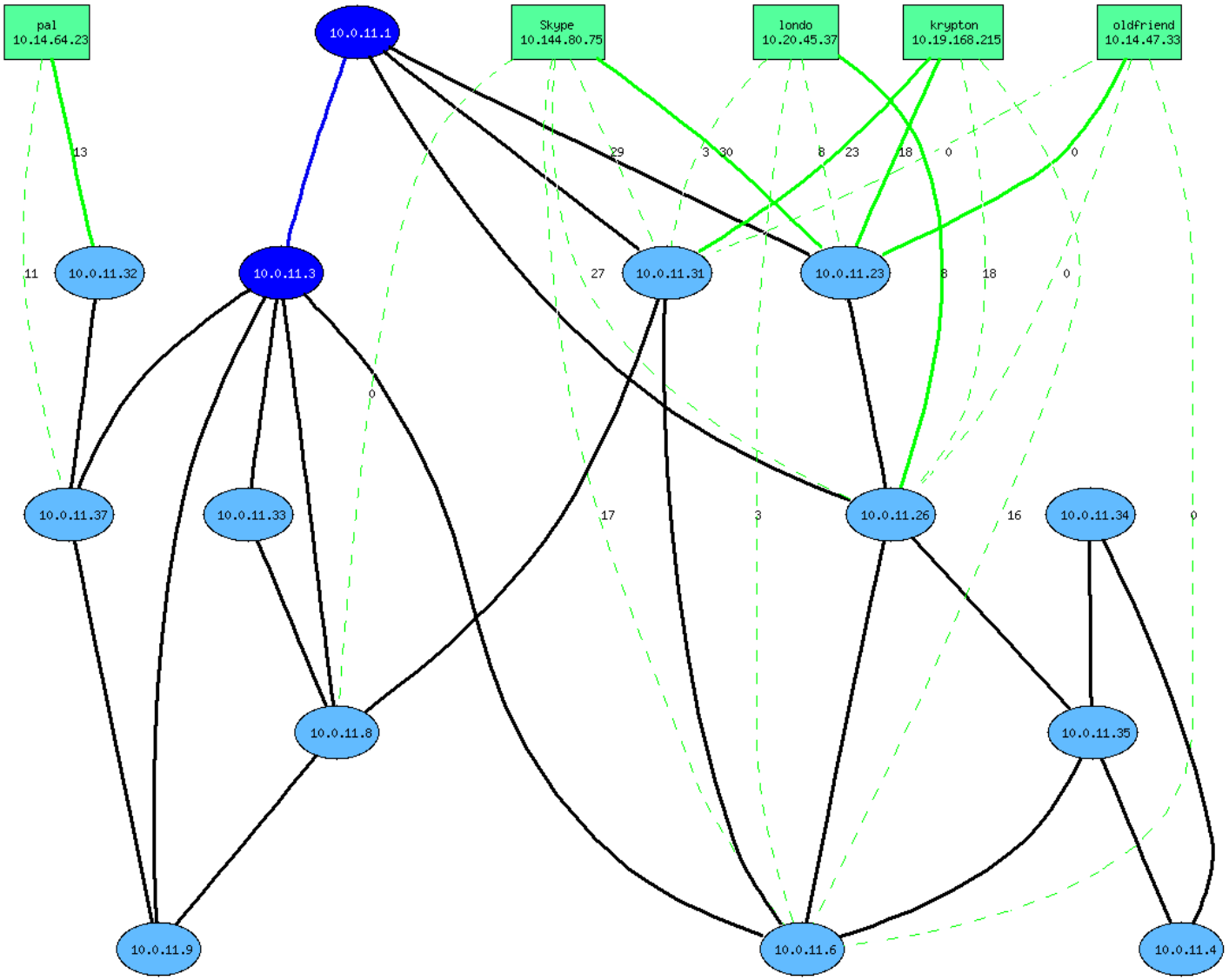
Internet -> Mobile Client



Moving Client: Handoff Zoom

Internet -> Mobile Client




pal
10.14.64.23
10.0.11.1
Skype
10.144.80.75
londo
10.20.45.37
krypton
10.19.168.215
oldfriend
10.14.47.33
13
29
3
30
8
23
18
0
0
11
10.0.11.32
10.0.11.3
27
10.0.11.31
10.0.11.23
8
18
0
0
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10.0.11.33
17
3
10.0.11.26
16
10.0.11.34
0
10.0.11.8
10.0.11.35
10.0.11.9
10.0.11.6
10.0.11.4

Conclusion

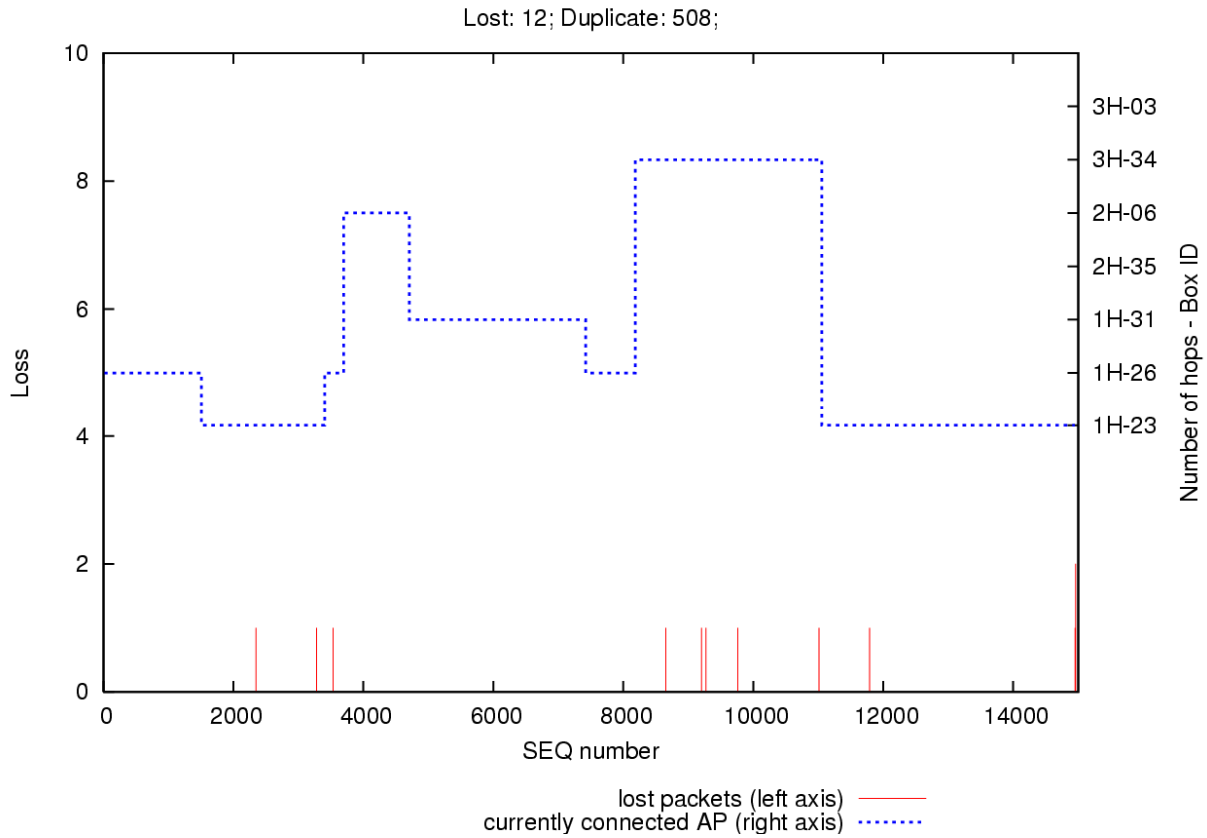
- Seamless Wireless Mesh Network with Fast Handoff
- Uses only common Internet and 802.11 protocols
- System Demonstrated on Practical Deployment

SMESH

www.smesh.org

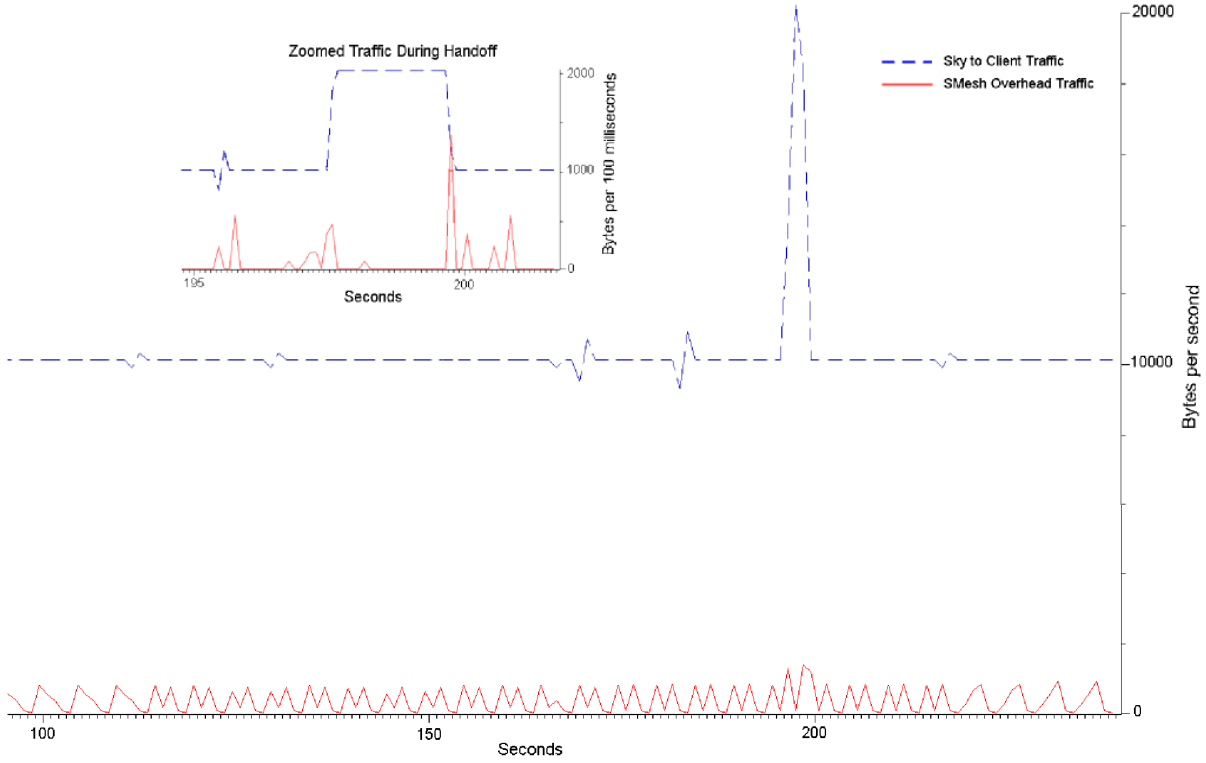
Moving Client: Loss

Internet -> Mobile Client



Overhead

Internet -> Mobile Client



Failover

Mobile Client -> Internet