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An Inter-domain Routing Protocol for Multi-homed Wireless Mesh Networks

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Motivation

- Wireless Mesh Networks are becoming an appealing way to extend wireless coverage.
- As the size of wireless mesh network increases, so will the number of Internet connected nodes.
- Internet connections are not necessarily on the same network.
- New protocols are needed to enable mobility and efficient use of hybrid wired-wireless environment.

Challenges

- Not changing the client
- Multi-homed mesh environment
  - Multiple Internet Gateways
  - Handoff between Internet Gateways
- Fast, lossless inter-domain handoff

Related Work

Handoff on Wireless Networks

- Mobile IP [C. Perkins, IP Mobility Support, RFC2002, 1996]
- MobileNAT [Buddhikot, Hari, Singh, Miller, MONET 2005]

Wireless Mesh Networks

- Metricom Ricochet, MIT Roofnet, Microsoft MCL, Rice TAPS, UCSB/Bell Labs MeshCluster, SUNY Stony Brook iMesh etc.

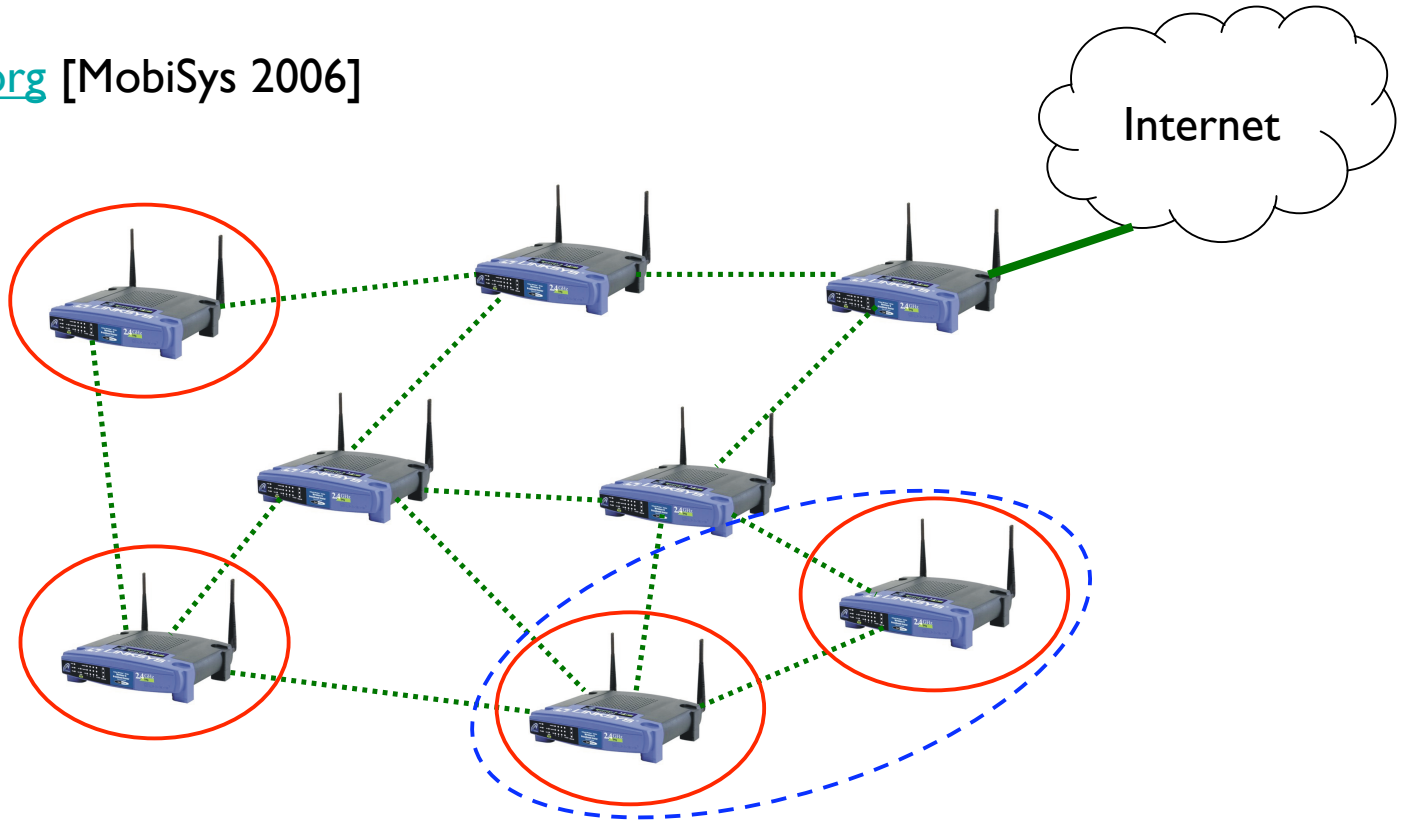
Overview

- The SMesh Architecture
- Multi-homed Wireless Mesh Network
  - Self-forming Overlay Network
  - Optimized routing
  - Inter-domain Handoff
- Experimental results

The **SMesh** Architecture

Intra-domain Handoff

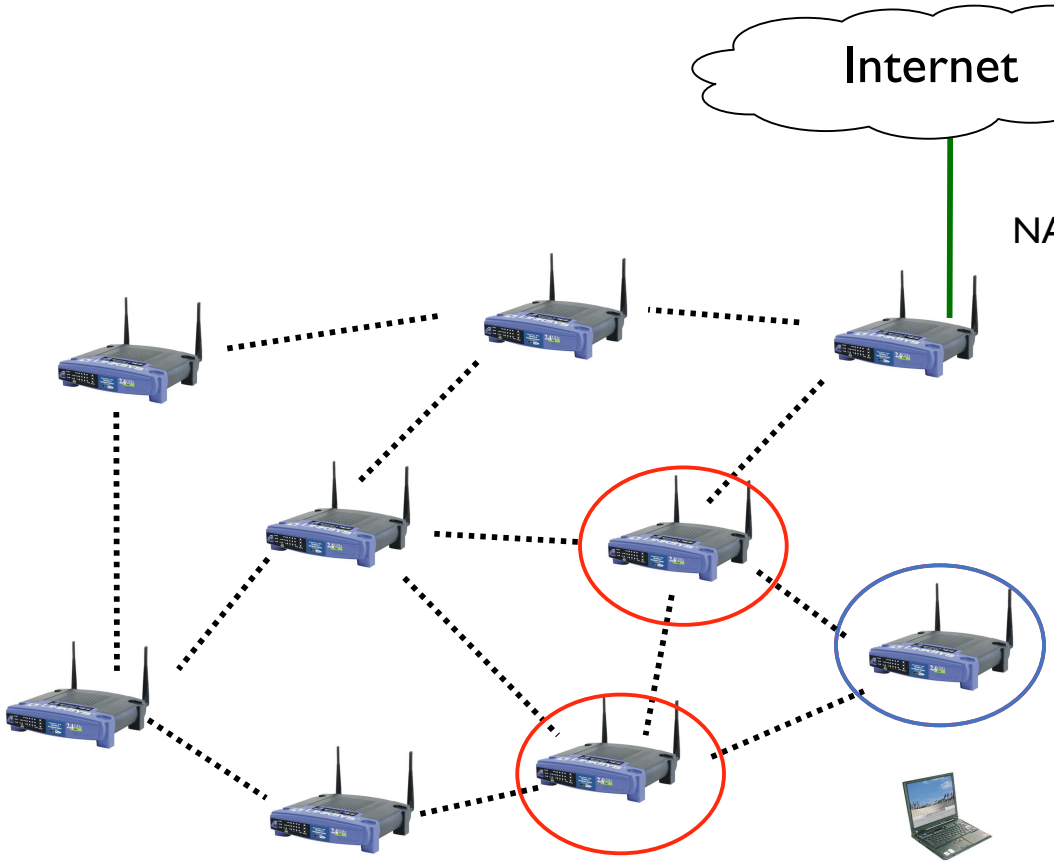
http://smesh.org [MobiSys 2006]



Seamless Client Access

- Standard DHCP protocol
- Client always gets the same IP address
  - Assign IP based on MAC address (10.x.y.z)
- Client routes all packets through a Virtual Default Gateway
- Client gets Gratuitous ARP to associate Default Gateway IP address with the currently serving access point.

Routing Approach



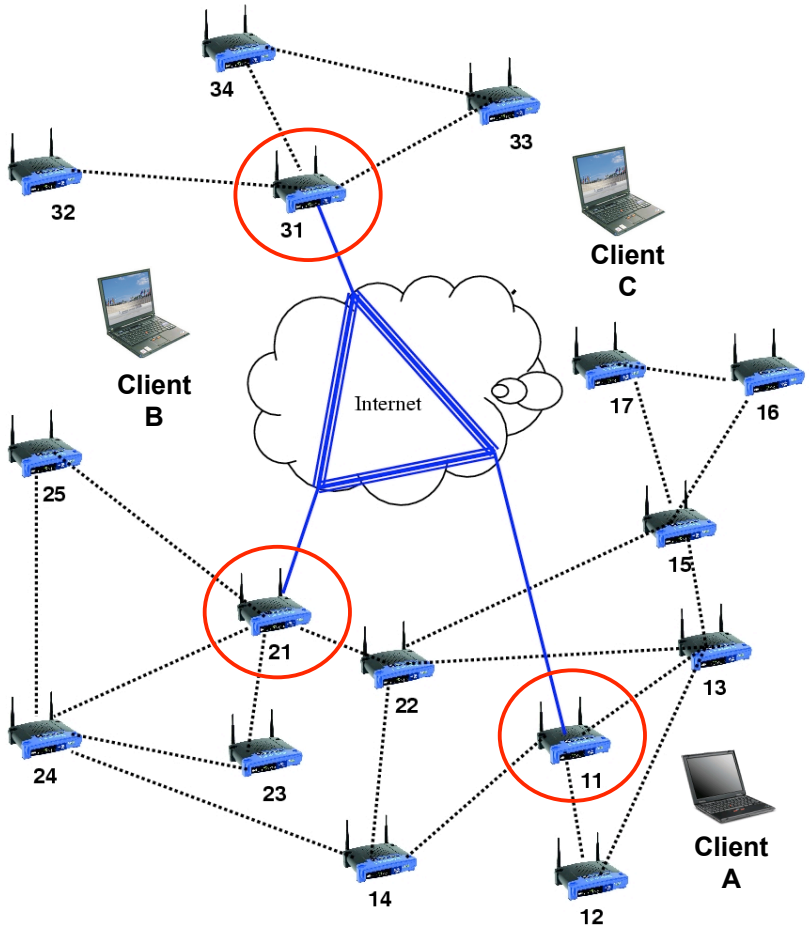
Multicast Control Group
224.1.2.3

Multicast Data Group
225.1.2.3

Multi-homed Environment

Multi-homed Environment

- Wireless Auto-discovery defines wireless topology.
- Internet Gateways need to be pre-configured to form an initial connected graph.
- Internet Gateways advertise their existence on gateways multicast group.
- All Internet Gateways eventually form a fully connected graph.



Inter-domain Handoff

SMesh runs in a private address space

- NAT Identifier: (Source IP, Source Port, Dest. IP, Dest. Port)

"Connection Oriented" protocols expect packets to come from the same source:

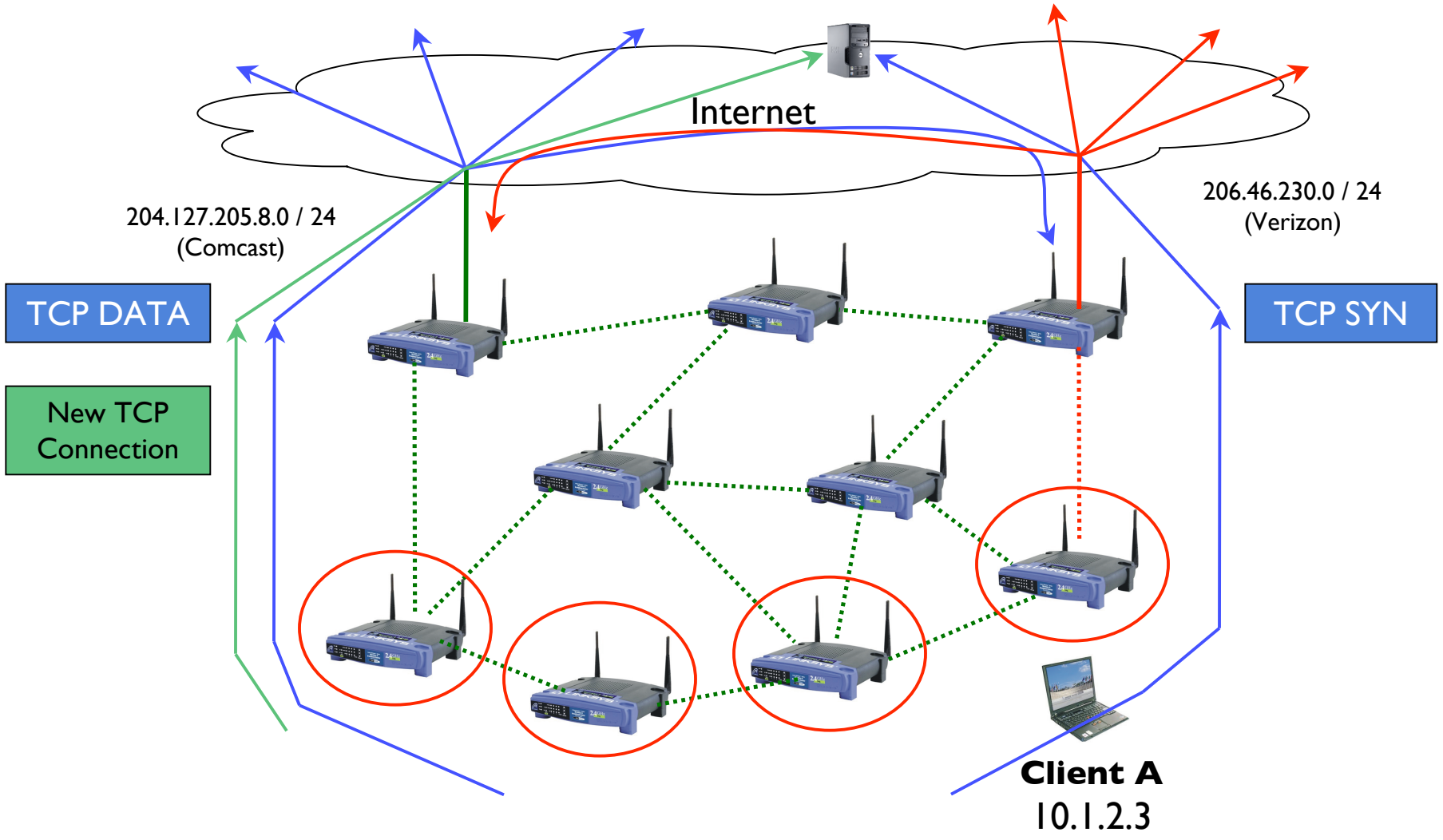
- TCP: If host address is different, connection breaks.
- UDP: Some protocols require the same host IP address or else they discard the packet.

Inter-domain Handoff

Solution:

- Route each stream through the Internet gateway used during connection establishment
- New NAT table field: Owner Internet Gateway

TCP Inter-domain Handoff



UDP Inter-domain Handoff

Problem:

- No SYN Packet to identify "connection" establishment.

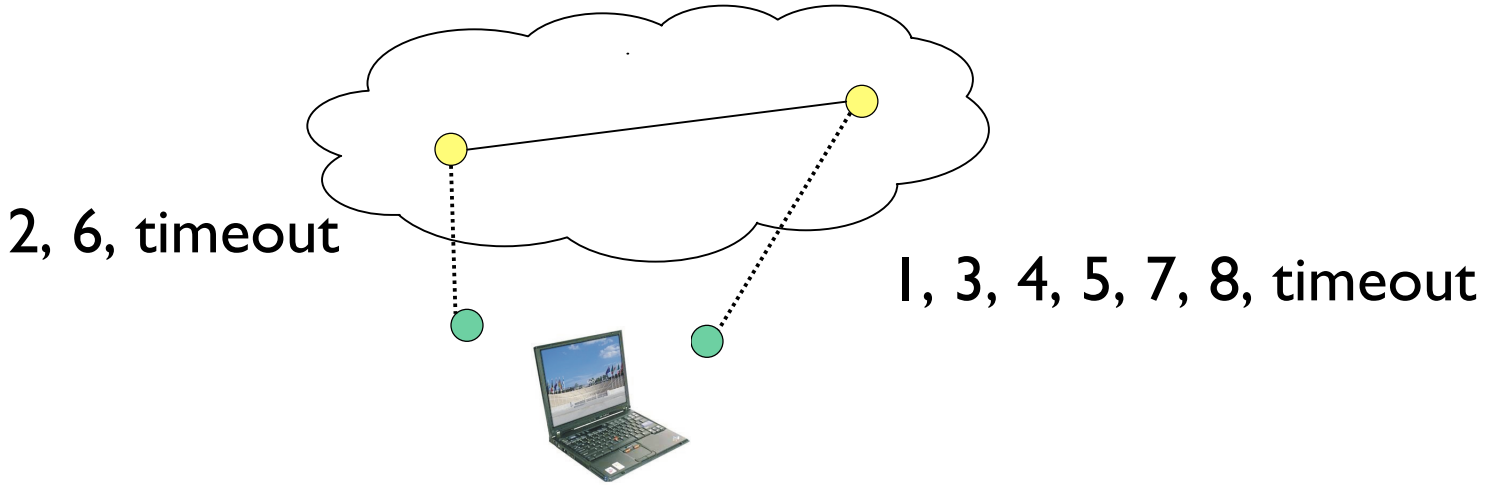
Solution:

- Route packets with unknown owner to both destination and gateways multicast group.
- If no owner announcement, claim ownership after a timeout (i.e. 200ms).

UDP Inter-domain Handoff

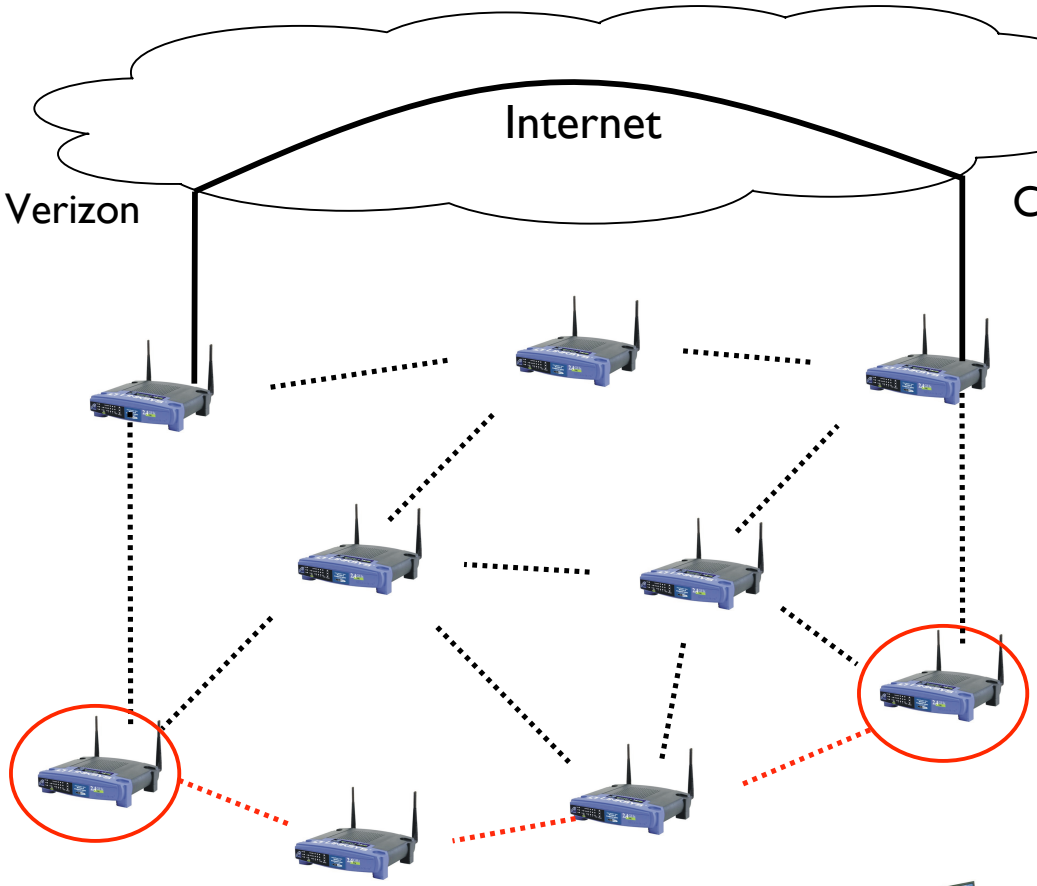
Caveat:

- Have to deal with multiple nodes claiming ownership.



Use reverse traffic from destination and lowest IP address to break such ties.

P2P Hybrid Routing



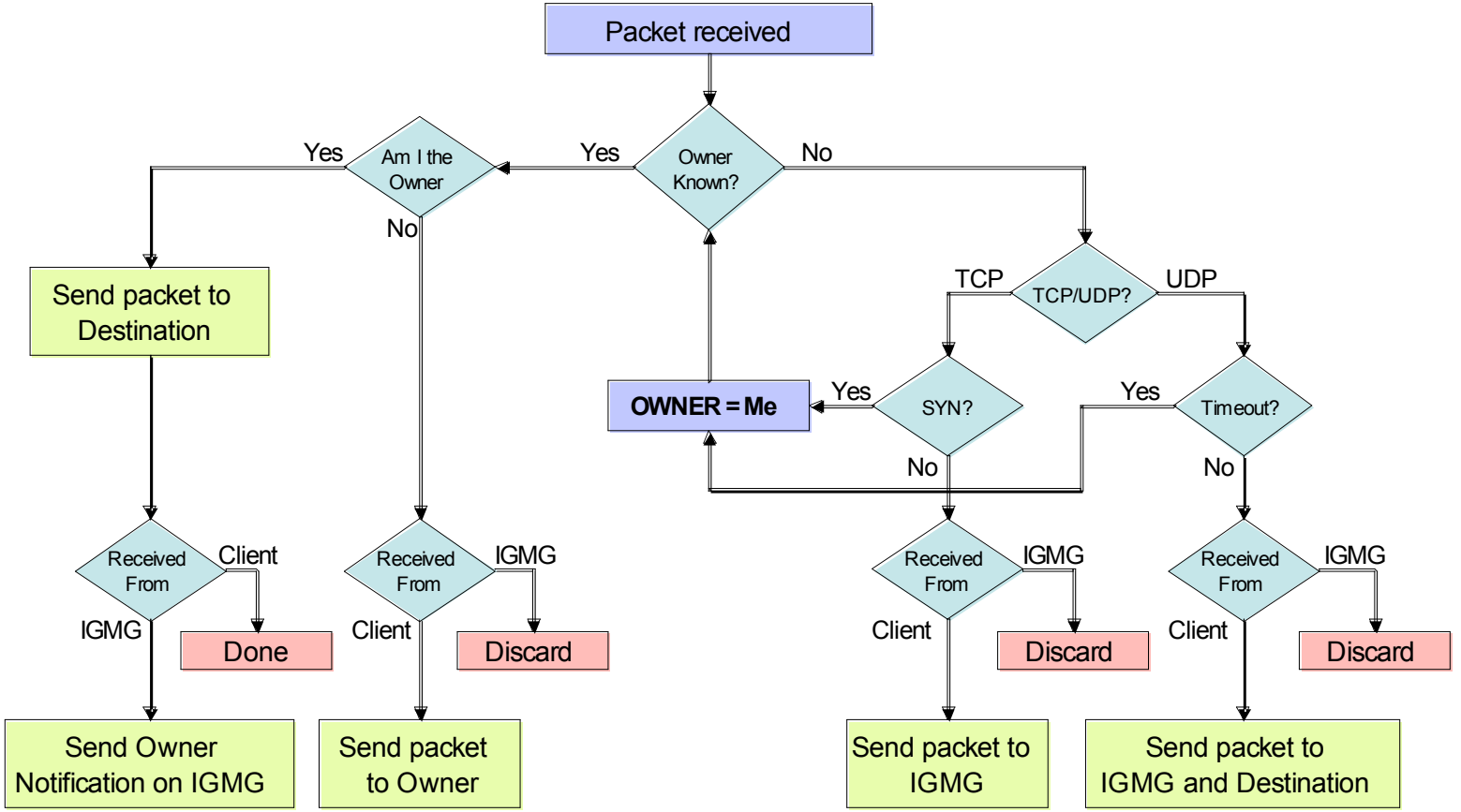
Use hybrid wired-wireless routes

Give priority to wired links

RoutingCost = ActualCost (M + 1)

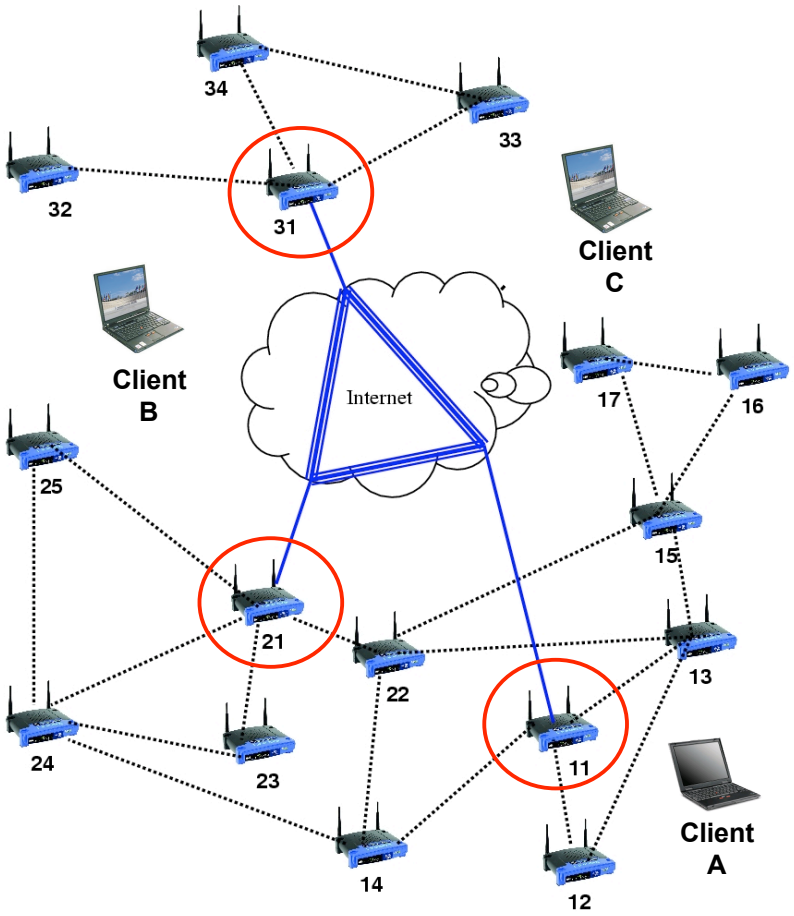
M = max cost for a wired path

Inter-domain Handoff Flow Chart



Experimental **Results**

Multi-homed Testbed



Experiment:

Full Duplex VoIP

Internet ⟷ Client

Client ⟷ Client

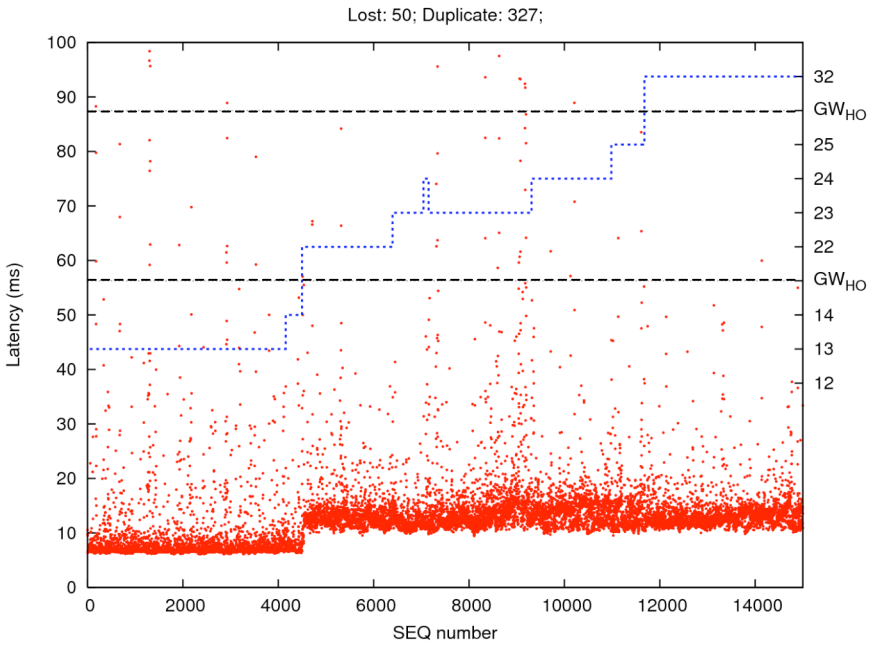
Each stream:

G.711

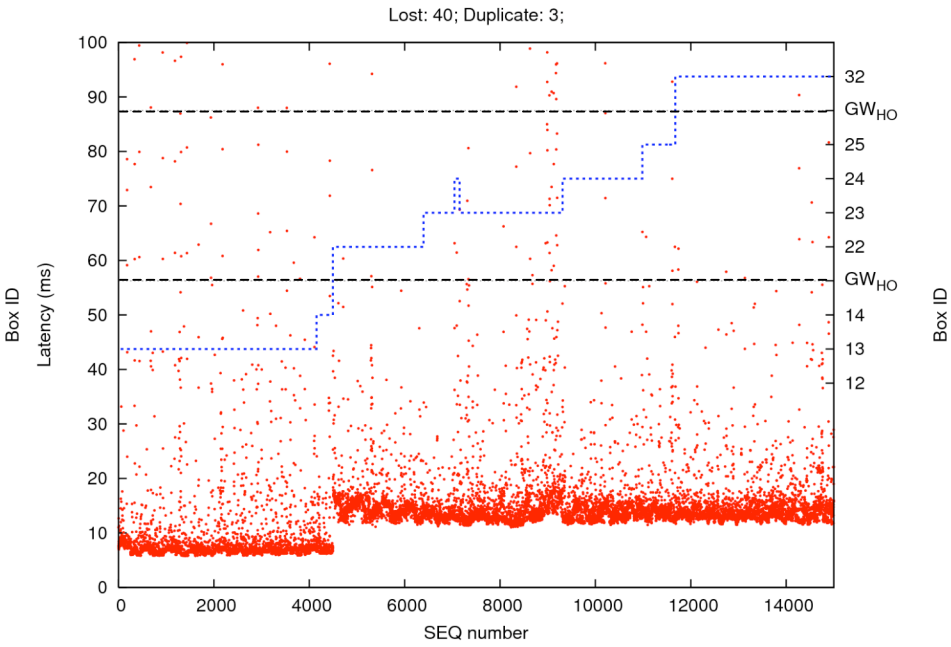
64 Kbps

160 bytes / 20 ms

Client-Internet: Latency

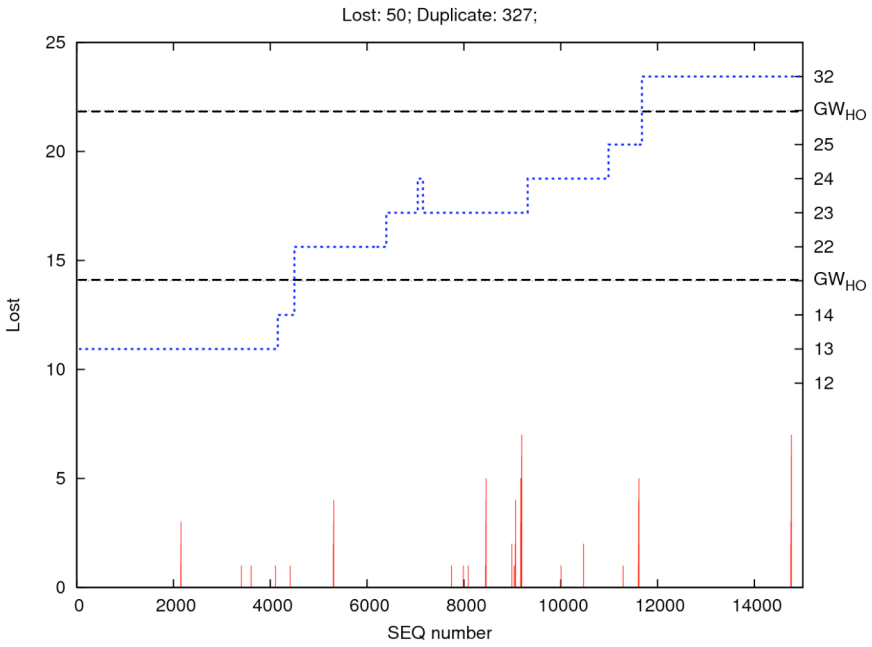


Internet ⟶ Client

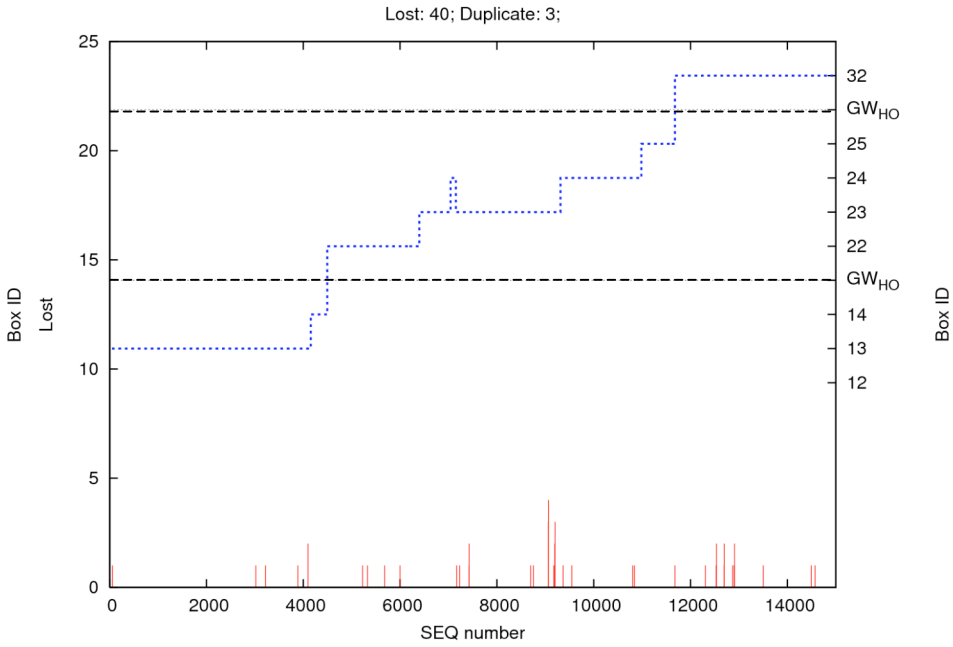


Client ⟶ Internet

Client-Internet: Lost Packets

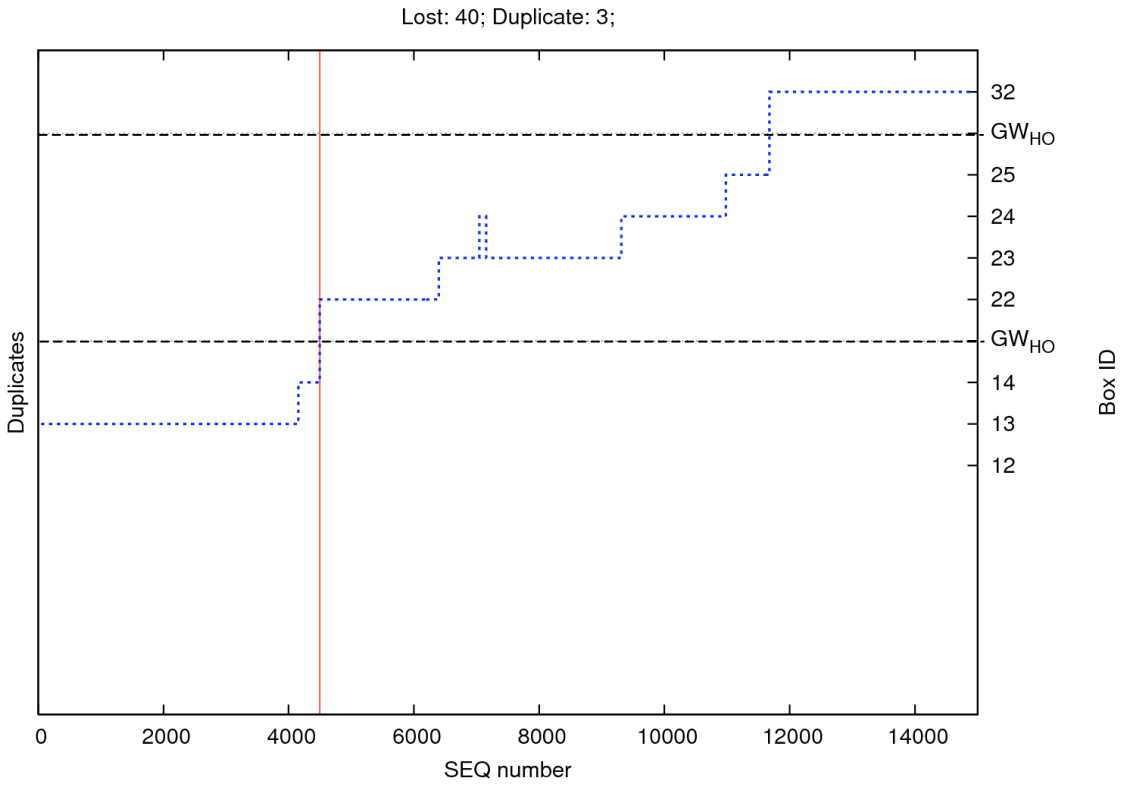


Internet ⟶ Client
50 / 15,000



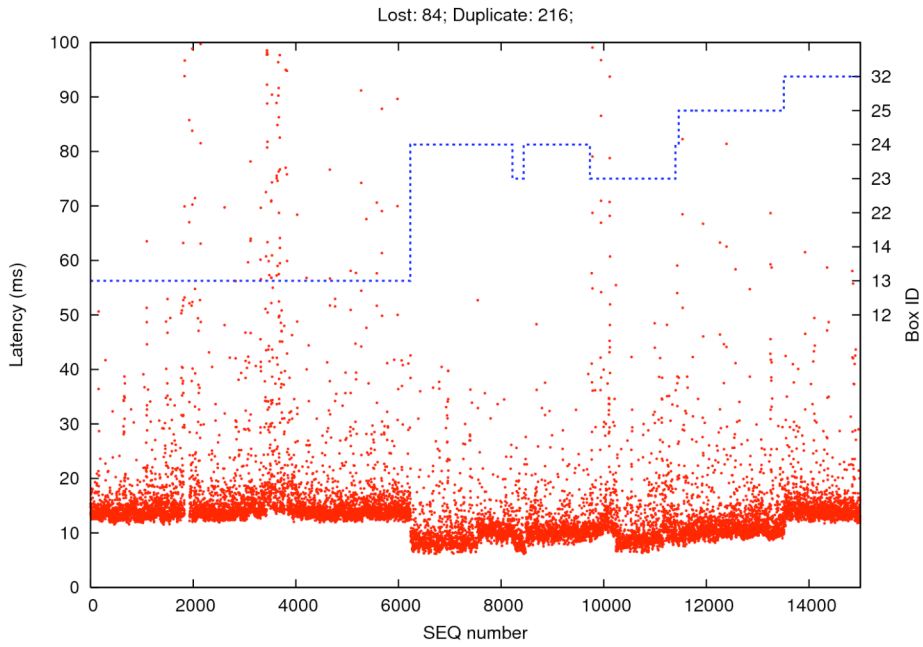
Client ⟶ Internet
40 / 15,000

Client-Internet: Duplicate Packets

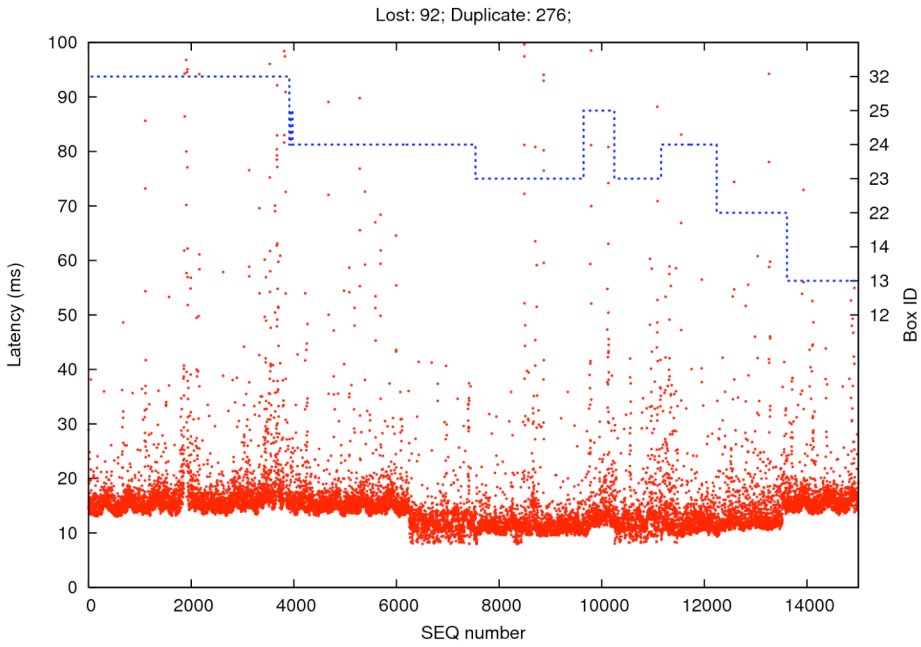


Client ⟶ Internet

P2P: Latency

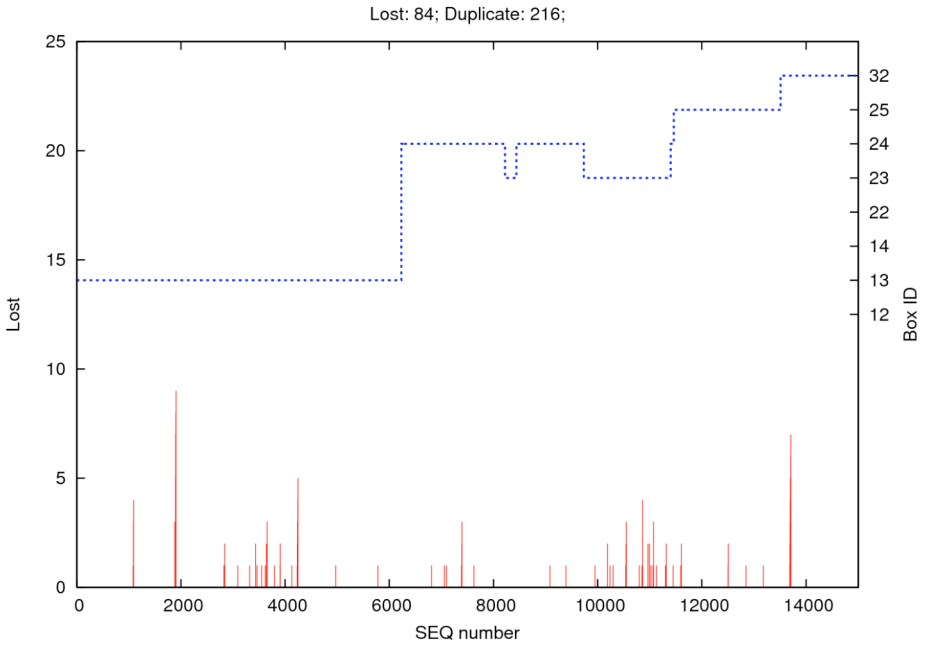


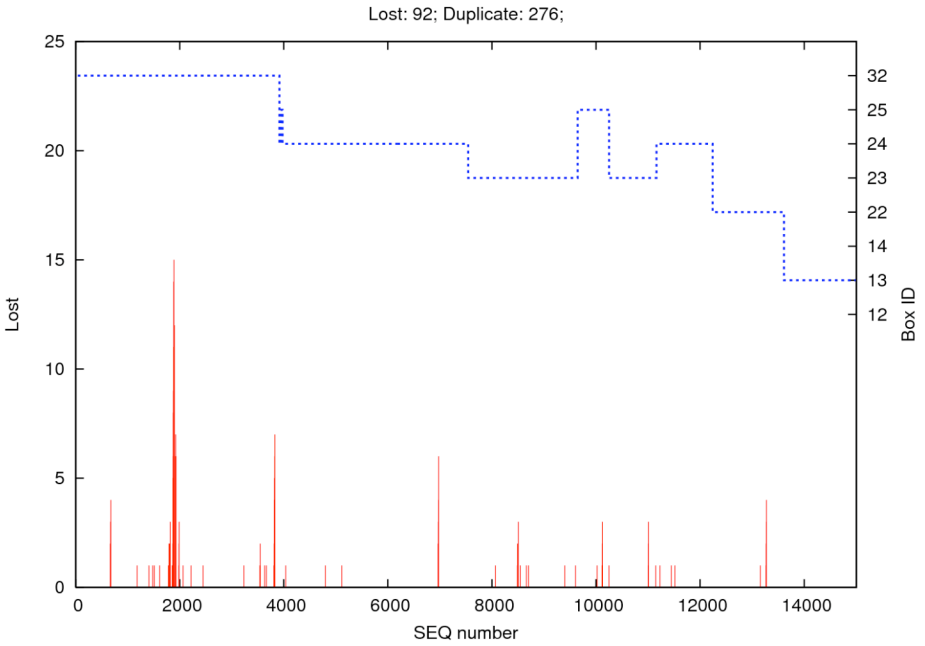
Client B ⟶ Client A



Client A ⟶ Client B

P2P: Lost Packets

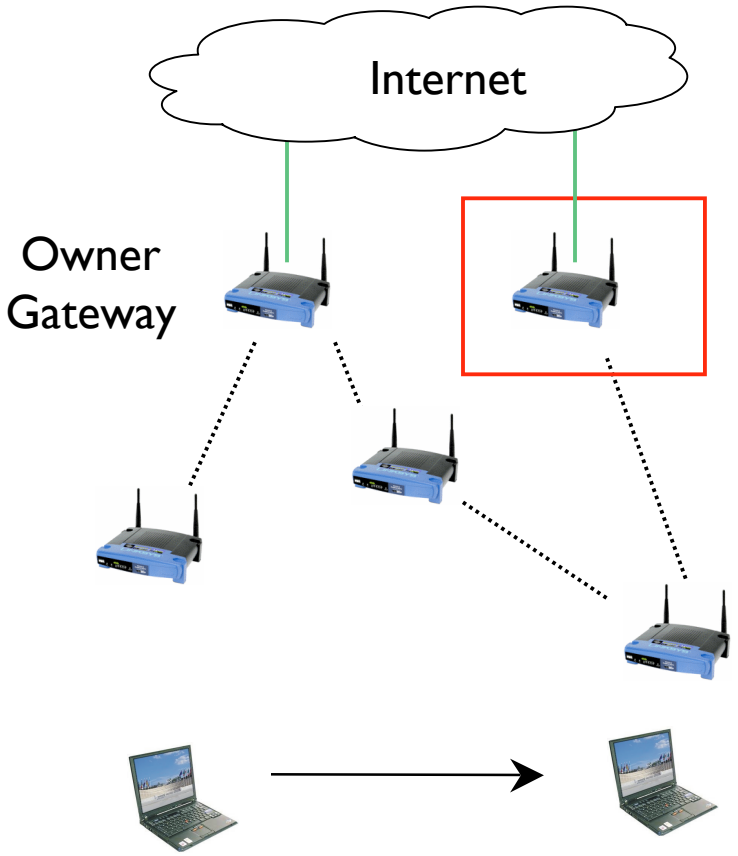


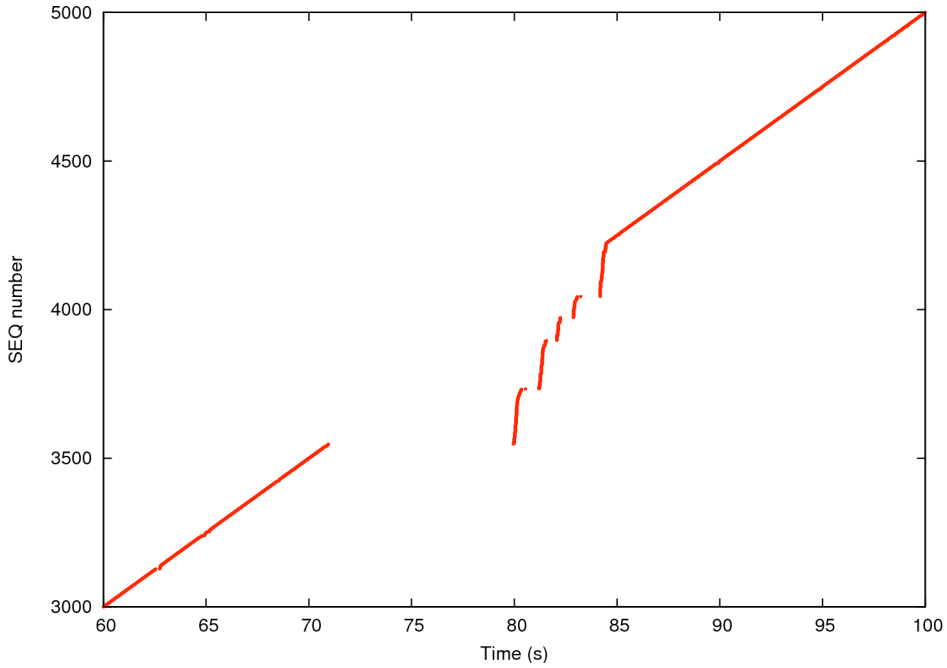


Client B ⟶ Client A
84 / 15,000

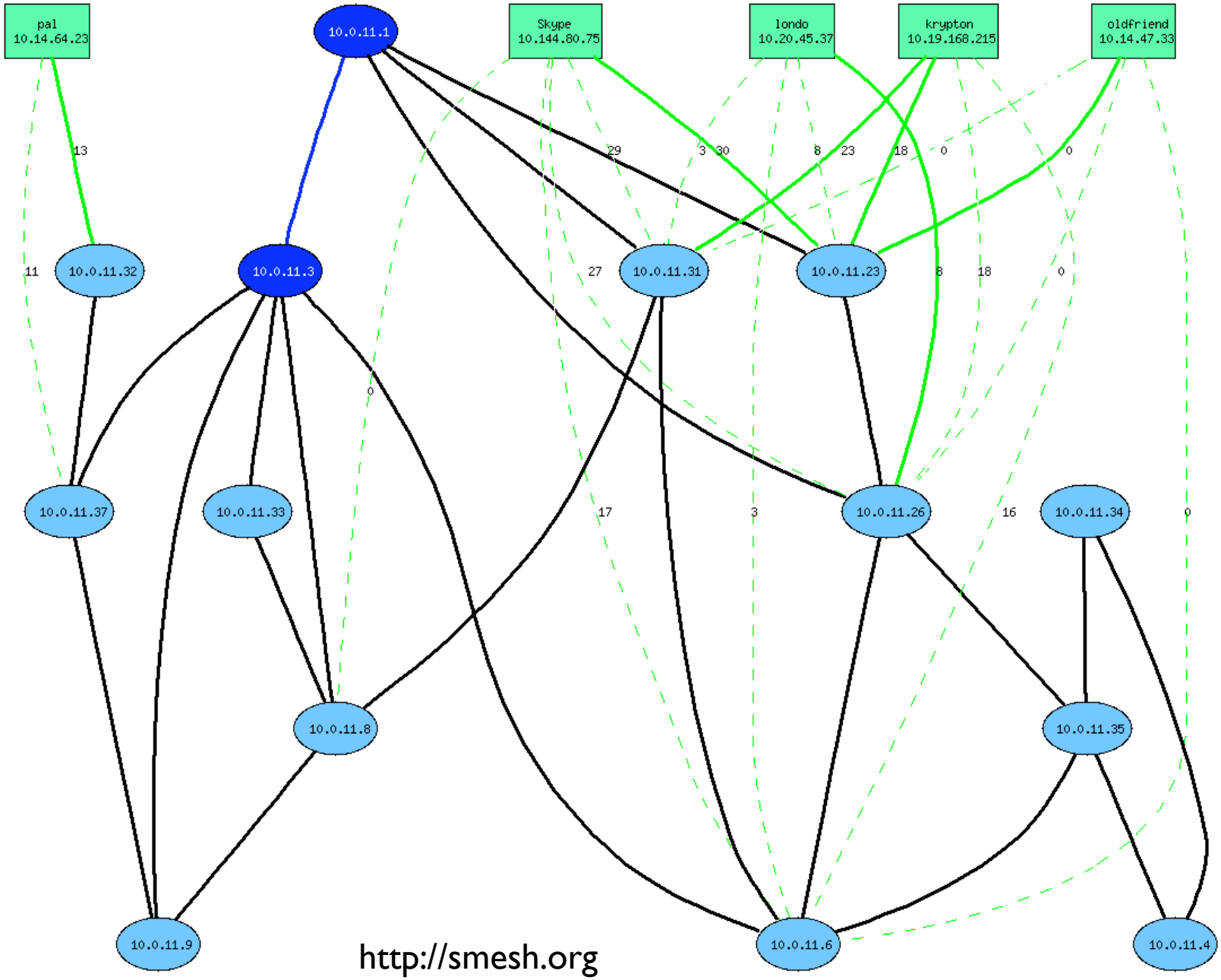
Client A ⟶ Client B
92 / 15,000

Non-Owner Internet Gateway Failover





TCP Stream


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
10.0.11.37
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
http://smesh.org

Conclusion

- Support for multi-homed wireless mesh networks
- Fast, seamless inter-domain handoff
- Optimized hybrid, wired-wireless routing

Questions?