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

Yair Amir, Claudiu Danilov, Raluca Musaloiu-E., Nilo Rivera

Distributed Systems and Networks Lab
The Johns Hopkins University

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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.
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

Client A
10.1.2.3

204.127.205.8.0 / 24
(Comcast)

206.46.230.0 / 24
(Verizon)
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

Client A
10.1.2.3

Client B
10.7.8.9
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

![Graph showing packet loss and duplicate packets between Client B and Client A.]

Lost: 84; Duplicate: 216;

Client B → Client A
84 / 15,000

![Graph showing packet loss and duplicate packets between Client A and Client B.]

Lost: 92; Duplicate: 276;

Client A → Client B
92 / 15,000
Non-Owner Internet Gateway Failover

TCP Stream
Conclusion

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