Wireless Mesh Networks: Current Experience and Future Experimental Needs

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What I was Missing

• The Access Point paradigm is great
  – Until I move away from mine
    • East Coast schools have massive walls …

• So:
  – Put more access points
    • Connect them all to the Internet

• However:
  – As I move between access points
    • Some interruption in connectivity, potential loss of sessions.
  – Connecting only few of the access points to the Internet could be useful:
    • First responders, lack of infrastructure, etc.

• In parallel: VoIP is becoming popular.
  – Skype.
  – Cell phones with 802.11.
The Mesh Paradigm

• Two classes of participants
  – Mesh nodes and clients
    • Some of the mesh nodes, the Internet Gateways, are connected to the Internet.
    • Other mesh nodes forward packets over multiple wireless hops.
  – Clients are mobile
  – Mesh nodes are relatively stationary

• In between the Access Point and the Ad-hoc paradigms
  – Different optimization considerations
Challenges

• Not changing the client
  – No special software or hardware
  – The client should feel as if there is one omni-present access point

• Fast, lossless handoff
  – Handoff between access points fast enough for VoIP and video
  – The responsibility of the mesh and not the client

• Multi-homed mesh environment
  – Multiple Internet gateways
    • Potentially on different networks
    • How to utilize to our advantage
  – Handoff between Internet gateways
    • How to keep connectivity alive on different networks
Introducing SMesh

www.smesh.org [Mobisys 2006]
Related Work

• Handoff on Wireless Networks
  – 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/Bell labs MeshCluster, SUNY Stony Brook iMesh, UIUC Net-X, ...
Outline

• Motivation
• Related work
• A bit on SMesh
  – Architecture
• Intra-domain Environment (2005)
  – A bit on how it works
  – Intra-domain Testbed
• Inter-domain Environment (2006)
  – A bit on how it works
  – Inter-domain Testbed
• What’s next (2007)
  – Neighborhood → Metropolitan?
The SMesh Architecture

- **Unmodified Mobile Client Device**
  - DHCP Client
  - ARP
  - Applications

- **SMesh**
  - DHCP Server
  - Handoff Algorithm
  - Client Link Quality Control Group
  - Interceptor
  - Raw Socket
  - Packet Proxy
  - Destination Data Group
  - Client Data Group
  - NAT

- **Spines**
  - Data Router
  - Link-State Routing
  - Group Multicast and Anycast

- **Communication Infrastructure**
  - 802.11 Wireless Mesh (UDP/IP Unicast)
  - Internet
The Spines Messaging System

- Daemons create an overlay network on the fly
- Clients are identified by the IP address of their daemon and a port ID
- Clients feel they are working with UDP and TCP using their IP and port identifiers
- Efficient support for unicast, multicast and anycast

[DSN03, NOSSDAV05, TOM06]
A Routing Approach for Lossless Handoff

Client A
10.1.2.3

Internet

Gateway Anycast Group
240.0.0.1

Multicast Control Group
225.1.2.3

Multicast Data Group
226.1.2.3

Client B
10.7.8.9

NAT

Multicast Data Group
226.7.8.9

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First (Intra-domain) Testbed (2005)

Test

Full Duplex VoIP
Internet <=> Client

Each Stream

G.711
64 Kbps
160 bytes / 20 ms
Moving Client Latency

Internet -> Mobile Client

Lost: 12; Duplicate: 508;

55 packets delayed over 100ms

Mobile Client -> Internet

Lost: 2; Duplicate: 0;

56 packets delayed over 100ms

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Moving Client Loss

Internet -> Mobile Client

Lost: 12; Duplicate: 508;

SEQ number

Loss

Number of hops - Box ID

0 2000 4000 6000 8000 10000 12000 14000

0 2 4 6 8 10

lost packets (left axis), currently connected AP (right axis)
Moving Client Duplicates

Internet -> Mobile Client

Lost: 12; Duplicate: 508;

duplicate packets (left axis)
currently connected AP (right axis)
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Inter-domain Environment

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

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Inter-Domain Handoff

[WoWMoM 2007]
By Product: Optimized Peer 2 Peer Routing

[Diagram showing a network with routers and clients connected through dotted lines, labeled with IP addresses 10.7.8.9 (Client B) and 10.1.2.3 (Client A).]
Second (Inter-domain) Testbed (2006)

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Inter-domain Handoff Performance

Mobile Client -> Internet

Duplicates

Loss

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Non-Owner Internet Gateway Failover

TCP Stream

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Real-Time Monitoring
What’s Next

• Neighborhood → Metropolitan scale
Observations

- Mesh environments become increasingly complex
  - A few access points with a single Internet connection
  - Inter-domain environments with a few networks and tens of access points
  - Neighborhoods to metropolitan areas with a few tens of networks and hundreds to thousands of access points

- Change is rapid and appetite is growing…

- What’s needed with respect to testbeds?
  - Testbed environments that can quickly scale with needs
  - Pay attention to latency considerations (reservation vs sharing)
  - Built-in monitoring
  - How to allow developer control but also realistic user load and movement?