Overview of IEEE802.11s
- Wireless Aware L2 Mesh Networks

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Mesh Related IEEE802 Organization

IEEE802
- IEEE802.11
- IEEE802.15
- IEEE802.16

IEEE802.11s
- IEEE802.11s
- IEEE802.15.3
- IEEE802.15.4
- IEEE802.15.5

Working Group
- Task Group

WiFi
- WiMedia
- ZigBee
- Wimax
IEEE802.11 WLAN Network Configurations

(a) Infrastructure
(b) Adhoc (iBSS)
(c) Mesh Networks

Major Usage Scenarios

(1) Residential

(2) Office

(3) Campus/ Community / Public Access Network

Source: IEEE P802.11-04/662
Backgrounds and Motivations

- Core building block for ubiquitous communications society
- Mesh NWs provide:
  - Higher throughput (short distance) / low-power consumption
  - NW robustness enhancement
  - Increased NW capacity (frequency spatial reuse)
  - Flexible NW deployment (coverage, timing)
- Prevailing/maturing WiFi Technologies (AP, PC, CE, HH)
- Progresses of research
  - MANET: solid Layer-3 routing research outcomes

WiFi based practical, interoperable and extensible mesh networks

Why L2 Mesh Networks?

(High-level Requirements)
- Device power consumption and cost reduction
- High speed and small latency
- Usability with current applications (e.g. little effects on upper layer)
- Effective use of radio resources

(Detailed Technical Requirements)
- L2 wireless technology parameter optimization (e.g. L2 flow control for buffer-overflow in multi-hops)
- Multi-channel Interface operation (e.g. mixture of single and dual)
- Frequency resource allocation in varying environments (e.g. traffic pattern, STA vs. Infra.)
- Practical QoS-aware power consumption reduction (APSD: advanced power save delivery)
**Layer-2 Mesh Basic Frame Formats**

**Data frame format**

<table>
<thead>
<tr>
<th>Octets: 2</th>
<th>2</th>
<th>6</th>
<th>6</th>
<th>6</th>
<th>2</th>
<th>6</th>
<th>2</th>
<th>3</th>
<th>0-2312</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame Control</td>
<td>Dur</td>
<td>Address 1</td>
<td>Address 2</td>
<td>Address 3</td>
<td>Seq Control</td>
<td>Address 4</td>
<td>QoS Control</td>
<td>Mesh Forwarding Control</td>
<td>Body</td>
<td>FCS</td>
</tr>
</tbody>
</table>

**Management frame format**

<table>
<thead>
<tr>
<th>Octets: 2</th>
<th>2</th>
<th>6</th>
<th>6</th>
<th>2</th>
<th>0-2312</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame Control</td>
<td>Duration</td>
<td>DA</td>
<td>SA</td>
<td>BSSID</td>
<td>Seq Control</td>
<td>Frame Body</td>
</tr>
</tbody>
</table>

Source: IEEE 11-05-0562-00-000s-802-11-tgs-simple-efficient-extensible-mesh-seemesh-proposal.doc

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**WLAN Mesh Capability Element Formats**

"WLAN Mesh Capability" element (in MP beacons/probe-responses to notify active path selection protocol, active path metric)

<table>
<thead>
<tr>
<th>Octets: 1</th>
<th>1</th>
<th>1</th>
<th>4</th>
<th>4</th>
<th>2</th>
<th>1</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
<td>Length</td>
<td>Version</td>
<td>Active Protocol ID</td>
<td>Active Metric ID</td>
<td>Peer Capacity</td>
<td>Power Save capability</td>
<td>Channel Precedence</td>
</tr>
</tbody>
</table>

**Protocol identifier format**

<table>
<thead>
<tr>
<th>Octets: 3</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>OUI</td>
<td>Protocol Identifier</td>
</tr>
</tbody>
</table>

**Protocol Identifier Values**

<table>
<thead>
<tr>
<th>OUI</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>00-0F-AC</td>
<td>0</td>
<td>Radio Metric AODV (default path selection protocol)</td>
</tr>
<tr>
<td>00-0F-AC</td>
<td>1</td>
<td>Radio Aware OLSR (optional path selection protocol)</td>
</tr>
<tr>
<td>00-0F-AC</td>
<td>2-254</td>
<td>Reserved for future use</td>
</tr>
<tr>
<td>00-0F-AC</td>
<td>255</td>
<td>Null protocol</td>
</tr>
<tr>
<td>Vendor OUI</td>
<td>Other</td>
<td>Vendor specific</td>
</tr>
</tbody>
</table>

Source: IEEE 11-05-0562-00-000s-802-11-tgs-simple-efficient-extensible-mesh-seemesh-proposal.doc

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Expected 802.11s Functional Component Architecture

Source: IEEE P802.11-04/1474

Upper Layers

Mesh Internetworking

Mesh Configuration and Management

802.11s WLAN Mesh (L2)

Mesh Topology Learning and L2 Routing/Forwarding

Mesh Network Measurement

Mesh Medium Access Coordination (including QoS)

Mesh Security

Lower MAC enhancement for Mesh (11e/n+)

IEEE802.11 PHY IEEE802.11 a/b/g/j/n

Hidden/Exposed Nodes


STA1 STA2 STA3 STA4

Case (a)

STA1 STA2 STA3 STA4

Case (b)

STA1 STA2 STA3 STA4

Case (c)

STA1 STA2 STA3 STA4

Case (d)

STA1 STA2 STA3 STA4

Case (a)

STA1 STA2 STA3 STA4

Case (b)

STA1 STA2 STA3 STA4

Case (c)

STA1 STA2 STA3 STA4

Case (d)

Normalized Total Throughput (%)

30

25

20

15

10

5

0

STA4 to STA1

STA1 to STA4

(a) (b) (c) (d)
**MAC Level Flow Controls**

Actual Scheduling Result when load=700kb/s

- 674k
- 449k
- 355k
- 235k
- 347k
- 450k
- 697k
- 238k
- 1020k
- 899k
- 1056k
- 235k
- 674k
- 687k
- 702k
- 685k
- 697k

Rx: 238k 1020k 899k 1056k 235k
Tx: 674k 687k 702k 685k 697k

e2e throughput

Congested nodes

Wasted TX

Ideal Scheduling, when the network is overloaded

- 430k
- 430k
- 430k
- 430k
- 430k
- 430k
- 430k
- 430k
- 430k
- 430k
- 430k

Rx: 430k 860k 860k 860k 860k
Tx: 430k 860k 860k 860k 430k

e2e throughput

**Layer-2 Mesh Routing Protocol**

- Table Driven → Conformance with Legacy LAN
- Reactive →
  - Implementation for various devices (mandatory for interoperability)
  - Quick/flexible response to changing radio/traffic environments
  - Extensibility for multi-radio I/F operation

<table>
<thead>
<tr>
<th>Routing Protocol</th>
<th>Route Maintenance</th>
<th>Forwarding Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>AODV</td>
<td>Reactive</td>
<td>Table driven</td>
</tr>
<tr>
<td>DSR</td>
<td>Reactive</td>
<td>Source routing</td>
</tr>
<tr>
<td>OLSR</td>
<td>Proactive</td>
<td>Table driven</td>
</tr>
<tr>
<td>TBRPF</td>
<td>Proactive</td>
<td>Table driven</td>
</tr>
</tbody>
</table>
Recommended Basic Radio Metric “Air Time”

\[
c_a = \left[ O_{ca} + O_p + \frac{B_t}{r} \right] \frac{1}{1 - e^{pt}}
\]

Rate dependent on local implementation of rate adaptation
Frame error rate for test frame size \(Bt\)

Airtime Cost Constants

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value (802.11a)</th>
<th>Value (802.11b)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(O_{ca})</td>
<td>75ms</td>
<td>335ms</td>
<td>Channel access overhead</td>
</tr>
<tr>
<td>(O_p)</td>
<td>110ms</td>
<td>364ms</td>
<td>Protocol overhead</td>
</tr>
<tr>
<td>(B_t)</td>
<td>8224</td>
<td>8224</td>
<td>Number of bits in test frame</td>
</tr>
</tbody>
</table>

Source: IEEE 11-05-0562-00-000s-802-11-1gs-simple-efficient-extensible-mesh-seemesh-proposal.doc

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Radio Metric AODV with Multi-radio Interfaces

Nodes with different single/multiple I/Fs
Avoid “high” QoS node
Non-radio-aware AODV

When costs equal, chose first-arrival path

x: Radio metric

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**Experimental Results**

![Graph showing experimental results](image)

**Interworking**

(Requirement)
- Interworking with Layer 2 networks (LAN networking with broadcasting)

(Approach)
- Conformance with IEEE802.1D bridge
- Loop avoidance with Spanning Tree (between MPs)
Basic Security Model Example

- Group key for broadcast communications
- Pair-wise keys for unicast communications
- Authentication server could be distributed or centralized

Source: IEEE P802.11-04/1115r2

Summary

- Mesh WLAN (IEEE802.11s) improves robustness, coverage, and capacity for multiple streams
- Get ready for mesh networking
  - Get involved in the standards organizations
  - Design compatible products
- IEEE802.11s Schedule
  - (submission deadline: June 15 2005)
  - Presentation of proposals: July 2005
  - Technical Specification Ratification: June 2008
- For more information
  - IEEE802.11
    - http://grouper.ieee.org/groups/802/
  - IETF MANET
    - http://www.ietf.org/