Research Overview
: Past, Current, and Future

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Outline

- Energy efficient MAC design
- Performance Evaluation of QoS-aware Mobile Ad Hoc Network
- Enhanced Positioning Probability System for Wireless Ad Hoc Networks
- Personal Information Based IP Autoconfiguration in Tactical Mobile Ad Hoc Network
- Multi-Channel Wireless Mesh Network Platform
- Interworking through Multiple Mesh Portals
Energy Efficient MAC Design

• Research goals
  – Propose a mechanism to enhance the performance of IEEE802.11 MAC PSM in ad hoc network

<table>
<thead>
<tr>
<th>Phase</th>
<th>Current(mA)</th>
<th>Power(mW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmit</td>
<td>270.83</td>
<td>1,304.476</td>
</tr>
<tr>
<td>Receive</td>
<td>198.17</td>
<td>954.507</td>
</tr>
<tr>
<td>Idle</td>
<td>164.12</td>
<td>790.47</td>
</tr>
<tr>
<td>Sleep</td>
<td>35.07</td>
<td>168.91</td>
</tr>
<tr>
<td>Warm-up</td>
<td>105.75</td>
<td>509.35</td>
</tr>
</tbody>
</table>

• Results
Rate Adaptive Relaying MAC Protocol for Wireless Mesh Networks

Voluntary Relaying MAC Protocol

- Neighbor node helps voluntarily the low rate nodes through relaying procedure.
- Every awake node quickly enters doze mode by cooperatively helping transmit data packet at higher rate.

- Power conservation: 40~50%
- Aggregate throughput improvement: 30~50%

• Results
  - "Multi-rate Adaption", Book Chapter 7 of Medium Access Control in Wireless Networks, Nova Science Publisher USA, 2007
Performance Evaluation of QoS-aware Mobile Ad Hoc Network

- **Research goals**
  - Analysis the performances of real time traffics in multi-hop ad hoc network and design a prototype system

- **Results**
  - A prototype system implementation
Enhanced Positioning Probability System for Wireless Ad Hoc Networks

- **Research goals**
  - Find a position of mobile nodes which are not equipped GPS receiver or in defective environment of trilateration location system.

- **Results**
Personal Information Based IP Autoconfiguration In Tactical Mobile Ad-Hoc Network

• Research goals
  – Design a mechanism to have following functionalities in tactical mobile ad hoc network: (1) Self-configuration capability (Network configuration, Naming and IP Addressing), (2) Self-healing capability

• Results

<table>
<thead>
<tr>
<th></th>
<th>IBA</th>
<th>RBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duplicate Possibility</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>State Maintenance</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Critical Node</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Periodic Message</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Communication Overhead</td>
<td>$O(r \times h \times N)$</td>
<td>$O(r \times h \times N)$</td>
</tr>
<tr>
<td>Address Latency</td>
<td>$O(r \times D \times t)$</td>
<td>$O(r \times h \times t)$</td>
</tr>
</tbody>
</table>
Overview of Wireless Mesh Networks
What are the Mesh Networks?

- Mesh Portal
- Mesh AP
- Mesh Point
- Ethernet
- IEEE802.11abg
- Infrastructure Mode Station
- Internet
Mesh Network Characteristics

- Multi-hop wireless network
  - Extend coverage with lower transmission power
  - Provide non-line-of-sight (NLOS) connectivity
- Ad hoc network with self-forming, self-healing, and self-organization capability
  - Low upfront investment
  - Easy deployment
  - Fault tolerance
- Minimal mobility
  - Mesh routers (AP, Point, Portal) have minimal mobility
  - Mesh clients can be stationary or mobile
- Wireless internetwork
  - Internetwork of heterogeneous wireless networks (e.g., Wi-Fi networks, WiMax networks, cellular networks, Zig-Bee networks etc.)
- Traffic pattern
  - Most traffic is user-to-gateway or gateway-to-user
  - In ad hoc networks, most traffic is user-to-user
- Not an energy-limited network
  - Mesh routers are usually AC-powered
  - Energy efficiency is not an issue in protocol design
IEEE 802.11s : Timeline

- January 04: Formation of 802.11 Mesh Study Group
- July 04: First 802.11 TGs Meeting
- January 05: Call for Proposals Issued
- July 05: Mandatory Proposal Presentations
- March 06: First 802.11s Draft Spec Adopted
Major Functional Components

Mesh Interworking

Mesh Configuration and Management

Mesh Topology Learning, Path Selection and Forwarding

Mesh Network Measurement

Mesh Medium Access Coordination (including QoS)

Mesh Security

802.11 Medium Access (11e/n)

*See 11-06/337 for overall functional requirements and scope coverage
Usage Models

* IEEE P802.11-04/662r16

Residential / Consumer Electronics

Campus/Community/Public Access

Military

Public Safety
Mesh Network Advantages

• Very low installation and maintenance cost
  – No wiring
  – Wiring is always expensive: labor intensive, time consuming, inflexible

• Easy to provide coverage in outdoors and hard-to-wire areas
  – Ubiquitous access

• Rapid deployment

• Self-healing, resilient, extensible
Multi-Channel Wireless Mesh Network Platform

- **Research goals**
  - Develop a flexible common platform to design, test, and evaluate new protocols for multi-channel wireless mesh network

- **Results**
  - Support multiple wireless transceivers: up to 4
  - A multi-hop network using RF attenuator on the table
  - Dynamically use 802.11a 12 non-overlapping channels
  - 1msec channel switching
  - Support legacy 802.11 access
  - Applications: Internet Access, VoIP, Video transmission
  - Topology monitoring and node management
Interworking through Multiple Mesh Portals

• Propose mesh domain scheme for support multiple Mesh Portals in wireless mesh network
  – Two solution: Multi-domain mesh network / Single-domain mesh network
• Propose load balanced multi-hop grouping scheme
  – Overhead: Average 30% decrement more than proactive method
  – Periodic Load balance (*PLBI): Average 4/10 times smaller than reactive method, Average 7/10 times smaller than proactive method
Broadcast Loops/Storms

Reasons

- Frame Format
- Single-hop Broadcast Environment
- Bridge Functions

Broadcast Frame (ARP, DHCP request)
Destination outside
Source inside

Mesh Portal 1
Mesh Portal 2
Gateway

Mesh Portal Point
Mesh Point/Mesh AP
STAs

Frame Control (2 bytes)
Our Address (6 bytes)
Address2 (6 bytes)
Address3 (6 bytes)
Sequence Control (2 bytes)
QoS Control (2 bytes)
Mesh Forwarding Control (3 bytes)
Body (6-2312 bytes)
Frame Check Sequence (4 bytes)
Further Issues

• How many?
• Where?
• How to resolve bottleneck?
• How to guarantee the fairness?