Fragmentation / Reassembly at the MAC Layer

Presented by
Mark Demange
Motorola
Wireless Data Group

<table>
<thead>
<tr>
<th>Presentation</th>
<th>Slide 1</th>
<th>Mark Demange, Motorola</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Presentation</th>
<th>Slide 2</th>
<th>Mark Demange, Motorola</th>
</tr>
</thead>
</table>

Background

- Foundation MAC doesn't specify fragmentation capability
- Fragmentation enhances system performance
  - Improves performance in presence of microwave ovens
  - Improves performance with hidden stations within BSA
  - Allows optimal hopping FH PHYs
  - Reduces or Eliminates Variation in Start of Time Bounded Services Superframe
- Authors believe MAC without fragmentation is a broken MAC

<table>
<thead>
<tr>
<th>Presentation</th>
<th>Page 1</th>
<th>Mark Demange, Motorola</th>
</tr>
</thead>
</table>
Goals

- Include Fragmentation in MAC (issue 20.6)
- Adopt Proposal Given in doc: IEEE P802.11-94/37 as basis for inclusion in MAC

Outline Of Presentation

- Advantages of Fragmentation
- Cost of Fragmentation
- Fragmentation Proposal
- Conclusion
Advantages of Fragmentation -
Enhanced Performance in Presence of Microwave Oven Interference

- Characteristics Of Microwave Oven Interference
  - Pulse Amplitude Modulated Signal
  - 60 Hz Square Wave - 8.3 ms. ON, 8.3 ms. OFF
  - Typically Occupies 10 to 20 MHz of the band at any time
    - Rising and Falling Edges of Pulse “splatter” Across the Band
  - Center Frequency of Oven Drifts By Up to 10 MHz

- Impact of Oven Interference
  - Both DSS and FH Systems Effected
    - Systems Effected If Desired Signal Is Interfered
    - Signal Ratio Is Too Small
  - Any Frames Greater than 8.3 ms Guaranteed Not To Be Received Correctly (1100 Byte Ethernet Packet = 8.8 ms @ 1 Mbps)
Advantages of Fragmentation - Enhanced Performance in Presence of Microwave Oven Interference

<table>
<thead>
<tr>
<th>Frame per 1100 Byte Packet</th>
<th>% of packet received successfully during OFF time of oven</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - no fragmentation</td>
<td>0% - 100%</td>
</tr>
<tr>
<td>2</td>
<td>0% - 50%</td>
</tr>
<tr>
<td>3</td>
<td>50% - 80%</td>
</tr>
<tr>
<td>4</td>
<td>50% - 70%</td>
</tr>
</tbody>
</table>

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Advantage of Fragmentation – Better Performance With Hidden & Sleeping Stations

• DS and FH Systems Vulnerable to Interference From Hidden Stations
• RTS/CTS Helps IF Stations Are Awake To Hear RTS/CTS Transmissions
• Consider System With No RTS/CTS:

![Diagram showing stations A and B]

Station A and B are hidden from each other.
Station B is sleeping.
Station A transmits RTS to Access Point
Access Point transmits CTS to station A
Station A starts to transmit data frame
Station B wakes up and senses channel as CLEAR

F16: Station B transmits to AP and complete AP reception of data frame from station A
Station A's transmission completes AP reception of data frame from station B
Both stations required to retransmit

F17: Station B transmits to AP and is not acknowledged by AP
Station B required to retransmit
Advantage of Fragmentation – Removes Constraints On Dwell/Superframe Times

- ‘MAC Should Maximize Use Of Bandwidth In Each Hop Interval’ – January 1993 PHY Committee (Passed)
- Three Options To Achieve Above Goal – more details in submission
  - Fix Dwell/Superframe – No Fragmentation
    - Requires Long Dwell To Compensate For
      Wasted Bandwidth – Long Dwell Undesirable
      For Effective FH
  - Stretched Dwell/Superframe
    - High Retransmission Rate Due To
      Un synchronized Hopping
    - Does not meet PHY Motion January 1993 “The
      hop rate shall be configurable in the MAC but
      fixed within a given BSA. It does not have to
      adapt.” PASS 20-1-1
  - Fix Dwell/Superframe – With Fragmentation
    - Allows Short Dwell Without Lost Bandwidth
      Penalty
    - Eliminates Un synchronized Hopping And Its
      Drawbacks
    - Eliminates Variation In Start Time Of Time
      Bounded Services Superframe

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Advantage of Fragmentation – Removes Constraints On Dwell Times

- Fixed Dwell Duration with Fragmentation
  - Transmit Frames That Will Fit Within
    Current Dwell
  - Dynamically Adjust Frame Length To
    Fully Utilize End Of Dwell

<table>
<thead>
<tr>
<th>Frame size</th>
<th>Maximum wasted bandwidth in each hop interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20 ms. hop interval</td>
</tr>
<tr>
<td>1518 bytes - no fragmentation</td>
<td>80.7%</td>
</tr>
<tr>
<td>759 bytes</td>
<td>30.4%</td>
</tr>
<tr>
<td>506 bytes</td>
<td>20.2%</td>
</tr>
<tr>
<td>380 bytes</td>
<td>15.2%</td>
</tr>
<tr>
<td>Dynamic</td>
<td>approx. 0%</td>
</tr>
</tbody>
</table>
Cost Of Fragmentation

- Stations In Fringe Areas (No Interference or Hidden Stations)
  - 10% Of Stations In Outer 5% of Coverage Radius
  - Frame Error Rate (FER) approximated from BER (1 \times 10^{-5})
  - Expected Bytes Transmitted per 1100 Byte MSDU

<table>
<thead>
<tr>
<th>Cost Of Fragmentation</th>
<th>BLE per frame</th>
<th>Average Bytes TX per frame</th>
<th>Total Bytes TX per packet</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8%</td>
<td>1.37</td>
<td>607</td>
<td>1215</td>
</tr>
<tr>
<td>4.5%</td>
<td>4.07</td>
<td>409</td>
<td>1228</td>
</tr>
<tr>
<td>3.1%</td>
<td>3.13</td>
<td>513</td>
<td>1250</td>
</tr>
</tbody>
</table>

Cost Of Fragmentation

- Stations Not In Fringe Areas (No Interference or Hidden Stations)
  - BER of PHY Better Than 1 \times 10^{-5} Yields
    FER < 1%
  - Expected Throughput Typical Stations

<table>
<thead>
<tr>
<th>Cost Of Fragmentation</th>
<th>BLE per frame</th>
<th>Maximum Throughput at 1 Mbps</th>
<th>Maximum Throughput at 3 Mbps</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - no fragmentation</td>
<td>547 Kbps</td>
<td>900 Kbps</td>
<td>2700 Kbps</td>
</tr>
<tr>
<td>2 - (250 + 300) bytes</td>
<td>540 Kbps</td>
<td>786 Kbps</td>
<td>2358 Kbps</td>
</tr>
<tr>
<td>3 - (280 + 300) bytes</td>
<td>520 Kbps</td>
<td>776 Kbps</td>
<td>2328 Kbps</td>
</tr>
<tr>
<td>4 - (275 + 300) bytes</td>
<td>524 Kbps</td>
<td>772 Kbps</td>
<td>2324 Kbps</td>
</tr>
</tbody>
</table>

Fragmentation yields less than 5% degradation in performance.
Fragmentation yields less than 4% degradation in performance.
Fragmentation Proposal

- Control Of Channel
  - Fragmentation Protocol Must Ensure Control Of the Channel is Maintained
  - Current Foundation MAC Provides A Mechanism To Provide Channel Control
  - Channel Control With Windowing

Fragmentation Proposal

- Fragmentation Rules
  - Payload Of A Packet Shall Typically Be Some Fixed Number Of Bytes: (max_payload) (except when near the end of a dwell)
  - The Payload Of A Packet Shall Typically Be Greater Than Some Fixed Number Of Bytes: (min_payload) (except when fewer than min_payload bytes are remaining in the packet)
  - The Number Of Bytes In A Payload Can Be Reduced From max_payload To Allow More EfficientUsage Of The Time Near The End Of A Dwell.
  - When A Data Packet Needs To Be Transmitted, The Number Of Bytes In The Payload Of A New Fragment Is Determined By:
    - The Time Remaining In The Current Dwell.
    - The Number Of Bytes In The Packet That Have Not Yet Been Transmitted For The First Time.
Fragmentation Proposal

- Fragmentation Rules (continued)
  - Once the payload of a fragment has been established, that fragment will remain fixed until the fragment is successfully delivered to the immediate destination.
  - An access point relaying a packet will be allowed to re-fragment the packet.
  - Devices must transmit only if there is enough time remaining in the dwell to allow the transmission plus the acknowledgment if one is due.
  - If a fragment requires retransmission near the end of a dwell and there is not enough time left for the fragment plus the Ack, the device must defer until the next dwell.

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**Presentation Slide 17**

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**Presentation Slide 18**

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Fragmentation Proposal

- Fragmentation Rules (continued)
  - Fragmentation near dwell boundary:

![Diagram]

Maximum frame size = 200 bytes, minimum frame size = 35 bytes
Fragmentation Proposal

- Fragmentation Rules (continued)
  - Fragmentation Near Dwell Boundary:
    (another example)

Maximum Frame Size = 200 Bytes, Minimum Frame Size = 25 Bytes, 1

- Retransmission of Window Due To Lost Acknowledgment

Not enough time in dwell to transmit Fragment 2. Order Fragment 2 until next dwell.
Fragmentation Proposal

• Packet Reassembly
  - Each Data Frame Requires Sufficient Information To Allow Reassembly At Receiving Station
    • Frame Type (data, acknowledgment, etc.)
    • Source Address
    • Destination Address
    • Packet Sequence Number
    • Fragment ID Number – fragments of MSDU sequentially numbered
    • End-Of-Packet Indicator – Indicates current fragment ID number corresponds to total frame in MSDU

• Frame Formats
  - Data Frame
    • 1 additional element required

<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Frame Type</td>
</tr>
<tr>
<td>Source Address</td>
</tr>
<tr>
<td>Destination Address</td>
</tr>
<tr>
<td>Packet Sequence</td>
</tr>
<tr>
<td>Fragment ID Number</td>
</tr>
<tr>
<td>End-Of-Packet</td>
</tr>
</tbody>
</table>

Fragment ID # is a binary field – not bit-mapped

• Acknowledgment Frame
  • Bitmap Field Of Fragments Received Is Required
Conclusion

- Fragmentation enhances system performance
  - Improves performance in presence of microwave ovens
  - Improves performance with hidden stations
  - Allows optimal hopping FH PHYs
  - Reduces or Eliminate Variation in Start of Time Bounded Services Superframe

- Benefits Of Fragmentation Offsets Minimal Overhead
  - 1 Element Per Frame of OH
  - Frame Windowing Minimizes Additional Acknowledgments

- Fragmentation Proposal Easily Integrated Into Foundation MAC
  - Mechanism To Control Channel Already Exists
  - Data Frames and Acknowledgment Frames Altered Slightly

Conclusion

- Goals:
  - Close issue 20.6 "Is there a need for fragmentation/reassembly at the MAC layer?" – YES
  - Motion: Use the proposal given in this submission as a basis for Implementation in the draft standard? – YES