March 1994 Doc: IEEE P802.11-94/

Fragmentation / Reassembly at the MAC Layer

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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 Eliminate Variation in Start of Time Bounded Services Superframe
- Authors believe MAC without fragmentation is a broken MAC

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

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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 DS and FH Systems Effected
    - Systems Effected If Desired Signal to 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)

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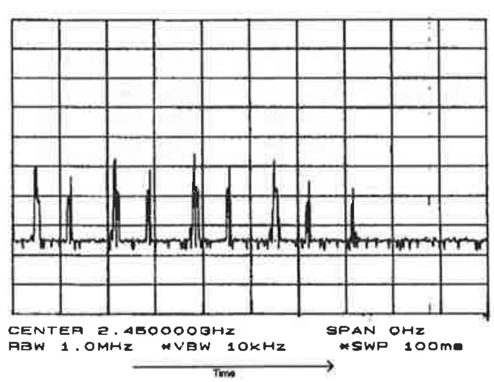
Advantages of Fragmentation - Enhanced Performance in Presence of Microwave Oven Interference



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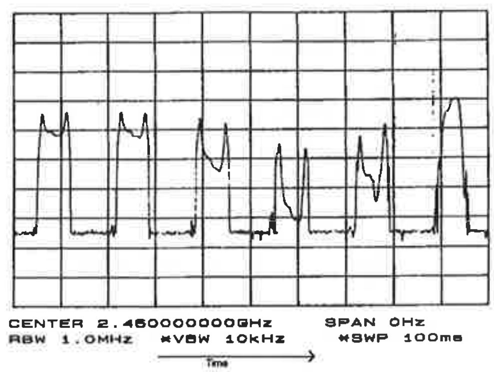
Advantages of Fragmentation - Enhanced Performance in Presence of Microwave Oven Interference



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Advantages of Fragmentation - Enhanced Performance in Presence of Microwave Oven Interference

Frames per 1100 Byte Packet	% of packet received successfully during OFF time of oven	
	1 Mbps Data Rate	2 Mbps Data Rate
1 - no fragmentation	0%	0% to 100%
2	0 % - 50%	50% - 100%
3	33% - 66%	66% - 100%
4	50% - 75%	75% - 100%

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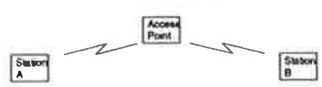
Advantage of Fragmentation – Better Performance With Hidden & Sleeping Stations

- 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:

Station A and B are hidden from each other and are both AWAKE
Station A starts to transmit data frame to Access Point
Station B senses channel as CLEAR (station A is hidden)
FH:
Station B transmits to AP and corrupts AP reception of data frame from station A
Station A's transmission corrupts AP reception of data frame from station B
Both stations required to retransmit
DS:
Station B transmits to AP and is not acknowledged by AP
Station B required to retransmit

Advantage of Fragmentation – Better Performance With Hidden & Sleeping Stations

- Consider System With RTS/CTS:



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
FH:
Station B transmits to AP and corrupts AP reception of data frame from station A
Station A's transmission corrupts AP reception of data frame from station B
Both stations required to retransmit
DS:
Station B transmits to AP and is not acknowledged by AP
Station B required to retransmit

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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 Dwells To Compensate For Wasted Bandwidth – Long Dwells Undesirable For Effective FH
  - Stretched Dwell/Superframe
    - High Retransmission Rate Due To Unsynchronized 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 Dwells Without Lost Bandwidth Penalty
    - Eliminates Unsynchronized Hopping And Its Drawbacks
    - Eliminates Variation In Start Time Of Time Bounded Services Supperframe

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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

Frame size	Maximum wasted bandwidth in each hop interval		
	20 ms. hop interval	50 ms. hop interval	100 ms. hop interval
1518 bytes - no fragmentation	60.7%	24.3 %	12.1%
759 bytes	30.4%	12.1%	6.1%
506 bytes	20.2%	8.1%	4.0%
380 bytes	15.2%	6.1%	3.0%
Dynamic	approx. 0%	approx. 0%	approx. 0%

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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 * 10^{-5})
    - Expected Bytes Transmitted per 1100 Byte MSDU

nes per 1100 byte MSDU	FER per frame (30 bytes overhead per frame)	Average Bytes TX'd per frame	Total Bytes TX per packet
fragmentation	8.6%	1237	1237
;0 + 30 OH) bytes	4.5%	607	1215
;7 + 30 OH) bytes	3.1%	409	1228
'5 + 30 OH) bytes	2.4%	313	1250

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Cost Of Fragmentation

- Stations Not In Fringe Areas (No Interference or Hidden Stations)
  - BER of PHY Better Than 1 * 10^{-6} Yields FER < 1%
  - Expected Throughput Typical Stations
    - Table Assumes Network Level Request-Reply protocol with 1100 byte packets, 100 byte acknowledgments, client response time of 3 ms., server response time of 3 ms., and MAC level windowing of frames. Table does not include effects of interference.

Frames per 1100 Byte Packet	Maximum Throughput at 1 Mbps	Maximum Throughput at 2 Mbps
1 - no fragmentation	547 Kbps	800 Kbps
2 – (550 + 30 OH) bytes	540 Kbps	786 Kbps
3 – (367 + 30 OH) bytes	533 Kbps	779 Kbps
4 – (275 + 30 OH) bytes	524 Kbps	772 Kbps

Fragmentation yields less than 5 % degradation in performance
Fragmentation yields less than 4% degradation in performance :

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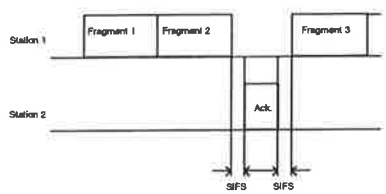
Fragmentation Proposal

- 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 Efficient Usage 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.

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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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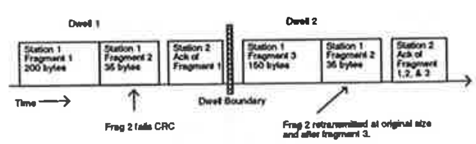
Fragmentation Proposal

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



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

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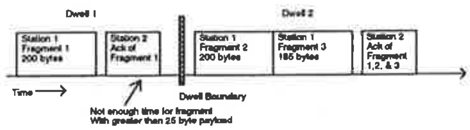
Fragmentation Proposal

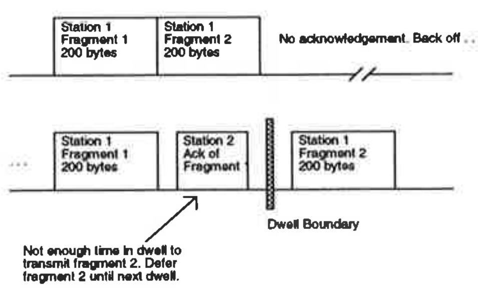
- **Fragmentation Rules (continued)**
  - **Fragmentation Near Dwell Boundary: (another example)**



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

Fragmentation Proposal

- **Fragmentation Rules (continued)**
  - **Retransmission of Window Due To Lost Acknowledgment**



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 frames in MSDU

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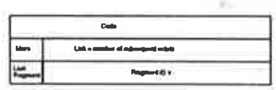
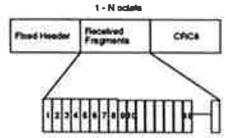
Fragmentation Proposal

- **Frame Formats**
  - **Data Frame**
    - 1 additional element required



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