WiMedia Media Access Control (MAC)

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Agenda

• Key Messages
• Relationship of Certified Wireless USB and other WiMedia Specifications
• WiMedia MAC 1.0 specification overview
  • Details frame formats
  • Details on the use of MAC device address and EUI-48 addresses
  • Details on beacons and synchronization
  • Details on dynamic reservation protocol (DRP)
  • Details on the Use of private reservations
  • Overview on security and the use of encryption offset
• Summary
• Q & A
Key Messages

• This session will teach vendors & manufacturers what they need to know to implement WiMedia MAC features into their product
  • Focus on information that developers of Certified Wireless USB hosts, devices, and dual role devices need to understand
  • Provide detailed examination of key features of the finalized WiMedia MAC 1.0 specification (also now ECMA-368)
High Level Overview of MAC Capabilities

• Mobility
  • Allows devices maintain connectivity as they move across network boundaries in which networks merge and split

• Simultaneous Operating Piconets (SOP) Performance
  • Allows independent Piconet to have distributed coordination to remove the problem of devices in different Piconets interfering with each other

• Support for isochronous and asynchronous data
  • Prioritized access for both types
• Decentralized PAN Operations
  • Every device beacons during the beacon period at the begin of the superframe (65ms) and access control is decided by each device
  • Rest of the superframe is for data transfers
  • Beacon slot occupancy info in each beacon to detect hidden node problem
  • Distributed Reservations ensures Quality of Service (QoS) Support
• Combination of Carrier Sense Multiple Access (CSMA) and Time Division Multiple Access (TDMA)
  • Distributed Reservation Protocol (DRP) is used to reserve the medium for isochronous or other traffic and provides the TDMA access
    • Reservations are announced in the beacons
  • For CSMA access Prioritized Contention Access (PCA) based on Enhanced Distributed Channel Access (EDCA), with mapping of 802.1d user priorities to MAC access priorities
    • Uses Ready to Send (RTS) and Clear to Send (CTS)
WiMedia MAC Header

- **PLCP Preamble**
  - PHY Header
  - Tail Bits
  - MAC Header
  - HCS
  - Tail Bits
  - Pad Bits

- **Frame Control**
  - Delivery ID/Frame Subtype
  - Frame Type
  - Sequence Ctrl

- **Duration/Access Method**
  - Ack Policy
  - Secure
  - Protocol Version

- **Frame Payload**
  - Variable Length: 0 - 4095 bytes

- **FCS**
  - Tail Bits
  - Pad Bits

Data Rates:
- 53.3, 80, 106.7, 160, 200, 320, 400, 480 Mb/s

PLCP Header: 39.4 Mb/s
Non-Secure and Secure Frames

- Secure frames provide encryption and integrity checks
- Non-Secure frames are clear text with no integrity checks
• Media Access Slot (MAS) is 256 us
• 256 MAS per Superframe
Beaconing Period (BP)

Superframe

Resv Beacon Expansion Time

DBP

Dynamic Beaconing Period

Signaling Slot

Beacon Slot #

Reserved Beacon Expansion Time
Allows Beacon to dynamically grow and shrink

Dynamic Beaconing Period Length
Beaconing

• How it works:
  • First, the device scans channels for beacons
    • If no beacons are received…
    • Then creates its own BP and sends the first beacon
  • If another beacon is received
    • Looks for Extended Window Slots
    • Once a slot is chosen, the beacon use the same slot until the BP can be compressed or unless a collision is detected
  • All devices, which are not sleeping, send beacons
Superframe Synchronization

Device a: Slower

Ta

Ta

Ta

Ta

dT = Ta - Tb

Device b: Faster

Tb + dT

Tb + dT

Tb + dT

Tb + dT

dT = 0

dT = Ta - Tb

dT = Ta - Tb

dT = Ta - Tb

• Clock Synchronization done using expected Beacon arrive time
DRPs

- Reserve the medium for isochronous or other traffic
- Provides QoS Support
DRPs (Cont.)

- Reservations are negotiated for multiple Superframes until they are removed

- Hard Reservations
  - Reservations must be explicitly released by Unused DRP Announcement/Unused DRP Response (UDA / UDR)

- Private Reservations
  - Used by Certified Wireless USB
  - Reservations must be explicitly released by Unused DRP Announcement/Unused DRP Response (UDA / UDR)
• Soft Reservations
  • Accessed by PCA method
  • Owner of reservation has Highest priority
  • If they are not used can be reclaimed by neighbors

• PCA Reservations
  • Accessed by normal PCA method
  • If they are not used can be reclaimed by others
The Physical Layer communications channel is a sequence of symbols in a frequency band.
The WiMedia MAC defines a repeating superframe over the PHY channel.

Reservations can be established in the WiMedia MAC channel.
Certified Wireless USB Channel

- Certified Wireless USB MAC defines a monotonically increasing channel time
- Linked list of MMCs occupy the Certified Wireless USB channel
• WUSB channel can be mapped onto a set of WiMedia MAC reservations on the same WiMedia PHY channel

• Certified Wireless USB logo/certification will enforce the mapping
WiMedia MAC Policies
Meet Joe User

Joe runs a graphics art business out of his home office

PC monitor resolution is critical
More Bandwidth Required Than Available at Joe’s House

A = Too Close
B = Too Close

Joe always wants his monitor to get maximum resolution. How does Joe get what Joe wants?
Meet Jane User

Jane is a videophile that cares passionately about HDTV resolution
More Bandwidth Required Than Available at Jane’s House

A = Too Close
B = Too Close

Request 3/4X

Fail

Jane always wants her HDTV to be operating at maximum resolution. How does Jane get what she wants?
Multiple Users

A = Too Close
B = Too Close

Joe’s Apartment

Jane’s Apartment

Request 3/4X

Fail

Request 3/4X

Now what? Only fair outcome is ½ each?
WiMedia MAC Allocation Limits Policy

- A device can take any available reservation at any time
- A device can not maintain more than approximately half the MAS (112) on a channel under contention
- Devices should be able to provide some level of functionality with approximately half the bandwidth on the channel
- Policy is designed to allow at least two high bandwidth links to operate on the same channel in most circumstances
- Addressing how bandwidth should be shared between multiple pairs of the same user’s devices is outside the scope of WiMedia policy
Device Reservation Types

- Low Latency devices prefer or need MAS that are evenly spaced throughout the superframe.
- Power Conscious devices prefer a small number of groups of contiguous MAS.
- There are devices that have both power and latency concerns.
- How do all these devices coexist on the same channel?
Start of Beacon Period

Allocation Zone 0

0 ... 15 16 ... 31 32 ... 47 48 ... 63 64 ... 79 80 ... 95 96 ... 111 112 ... 127 128 ... 143 144 ... ... ... 255

1 MAS
256 Microseconds

1d view of Superframe is difficult to use in describing full bandwidth allocation strategies
Superframe – 2d View

<table>
<thead>
<tr>
<th>Allocation Zones</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15</td>
</tr>
<tr>
<td>0 0 16 32 48 64 80 96 112 128 144 160 176 192 208 224 240</td>
</tr>
<tr>
<td>1 1 17 33 49 65 81 97 113 129 145 161 177 193 209 225 241</td>
</tr>
<tr>
<td>2 2 18 34 50 66 82 98 114 130 146 162 178 194 210 226 242</td>
</tr>
<tr>
<td>3 3 19 35 51 67 83 99 115 131 147 163 179 195 211 227 243</td>
</tr>
<tr>
<td>4 4 20 36 52 68 84 100 116 132 148 164 180 196 212 228 244</td>
</tr>
<tr>
<td>5 5 21 37 53 69 85 101 117 133 149 165 181 197 213 229 245</td>
</tr>
<tr>
<td>6 6 22 38 54 70 86 102 118 134 150 166 182 198 214 230 246</td>
</tr>
<tr>
<td>7 7 23 39 55 71 87 103 119 135 151 167 183 199 215 231 247</td>
</tr>
<tr>
<td>8 8 24 40 56 72 88 104 120 136 152 168 184 200 216 232 248</td>
</tr>
<tr>
<td>9 9 25 41 57 73 89 105 121 137 153 169 185 201 217 233 249</td>
</tr>
<tr>
<td>10 10 26 42 58 74 90 106 122 138 154 170 186 202 218 234 250</td>
</tr>
<tr>
<td>11 11 27 43 59 75 91 107 123 139 155 171 187 203 219 235 251</td>
</tr>
<tr>
<td>12 12 28 44 60 76 92 108 124 140 156 172 188 204 220 236 252</td>
</tr>
<tr>
<td>13 13 29 45 61 77 93 109 125 141 157 173 189 205 221 237 253</td>
</tr>
<tr>
<td>14 14 30 46 62 78 94 110 126 142 158 174 190 206 222 238 254</td>
</tr>
<tr>
<td>15 15 31 47 63 79 95 111 127 143 159 175 191 207 223 239 255</td>
</tr>
</tbody>
</table>

- MAS numbers increase with time from 0 to 255
- Columns contain 16 consecutive MAS (Allocation Zone)
- Rows contain 16 evenly spaced MAS in superframe (Coordinated MAS Set)
MAS Allocation Policy

Principle #1

• Most available reservations may be made at any time. There are a variety of rules that indicate when a portion of a reservation must be moved or dropped under contention

• Example
  • On an empty channel a hard drive backup must be able to utilize the entire channel for optimal performance until there is contention
MAS Allocation Policy
Principle #2

• A device must have a deterministic way to know when it may obtain MAS from another device through contention
### Relinquish Requests

<table>
<thead>
<tr>
<th>octets: 1</th>
<th>1</th>
<th>2</th>
<th>2</th>
<th>4</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element ID</td>
<td>Length ((=4+4 \times N))</td>
<td>Relinquish Request Control</td>
<td>Target DevAddr</td>
<td>Allocation 1</td>
<td>Allocation N</td>
</tr>
</tbody>
</table>

- Request to release reserved MAS
- Allocations use same format as DRP IE
- Basic MAC mechanism to allow devices to take optimal (any) reservation on an empty channel but still have a policy structure that balances the needs of different reservation types
Unsafe Reservations – DRP Control Field

<table>
<thead>
<tr>
<th>bits: b15-b13</th>
<th>b12</th>
<th>b11</th>
<th>b10</th>
<th>b9</th>
<th>b8-b6</th>
<th>b5-b3</th>
<th>b2-b0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reserved</td>
<td>Unsafe</td>
<td>Conflict Tie-breaker</td>
<td>Owner</td>
<td>Reservation Status</td>
<td>Reason Code</td>
<td>Stream Index</td>
<td>Reservation Type</td>
</tr>
</tbody>
</table>

Reservations Must Be Marked Unsafe If They Are Subject To Preemption

Relinquish Requests Are Only Sent To Devices With DRP IEs Marked Unsafe
• Latency
  • Smallest application needs submitted to MAC committee were 4-5 milliseconds (game controllers)
  • Rules are designed offer availability for 4.096 millisecond latency reservations until superframe becomes fairly crowded (A row in the 2 dimensional superframe view)

• Contiguous Reservation Blocks
  • PCA has large efficiency gains up to block sizes of 4 contiguous MAS
  • Rules are designed to offer availability for reservations with contiguous block sizes of at least 4 MAS until the superframe becomes very crowded
Conclusions

• WiMedia MAC policy allows for multiple devices interact
  • The policy deal with aspects of device behavior that can adversely affect the performance and/or ability to function for other devices

• WiMedia MAC Provides the following key Personal Area Networking features
  • Mobility, Support for isochronous and asynchronous data, Decentralized PAN Operations

• WiMedia MAC Specification 1.2 expected to be completed by end of Q3 2006
  • Adds MAC support for Detect and Avoid (DAA)
Additional Information

• Join WiMedia for additional information on the MAC Specification and the workgroup
Acronyms

- PCA  – Prioritized Contention Access
- EDCA  – Enhanced Distributed Channel Access
- TDMA  – Time Division Multiple Access
- CSMA  – Carrier Sense Multiple Access
- DRP  – Distributed Reservation Protocol
- BP  – Beacon Period
- MAS  – Media Access Slot
- TIM  – Traffic Indication Map
- IE  – Informational Element
Backup
Purpose of Beacons

• WiMedia Device Discovery
• Superframe Time synchronization
• Creating, Sharing and Honoring Reservations
• Traffic Indications Map (TIM) Information
• Interference Mitigation
IE in Beacon

- Distributed Reservation Protocol IE
- Beaconing Period Occupancy Information Element
- Traffic Indication Map (TIM) IE

<table>
<thead>
<tr>
<th>Li</th>
<th>Lm</th>
<th>Ln</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beacon Parameters</td>
<td>Information Element-1</td>
<td>Information Element-2</td>
<td>...</td>
</tr>
</tbody>
</table>

Beacon Frame Body
MAC Synchronization and MMC

- MAC Synchronization must be done at end of the superframe
- In the Last MMC, the Next MMC field must be adjusted
### Beaconing Period Occupancy Information Element (BPOIE)

- **BPOIE** allows other devices to determine the set of neighbors for a device.
- The host can use this information to determine if the device is required to perform directed beaconing.

<table>
<thead>
<tr>
<th>octets: 1</th>
<th>1</th>
<th>1</th>
<th>K</th>
<th>2</th>
<th>…</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element ID</td>
<td><strong>Length</strong> (=1+K+2^N)</td>
<td>BP Length</td>
<td>Beacon Slot Bitmap</td>
<td>DevAddr 1</td>
<td>…</td>
<td>DevAddr N</td>
</tr>
</tbody>
</table>

**Table:**

- **Element ID:**
  - **Length:** \(=1+K+2^N\) octets
  - **BP Length:**
  - **Beacon Slot Bitmap:**
  - **DevAddr 1:**
  - …
  - **DevAddr N:**
Medium Access Methods

- Distributed Reservation Period (DRP)
  - Beacon Period (BP) Reservations
  - Hard Reservations
  - Private Reservations
  - Soft Reservations
  - PCA Reservations
- Prioritized Contention Access (PCA)
Low Latency Devices

- Some power conscious devices prefer large contiguous reservations.
- Large contiguous reservations can make a sparsely occupied channel unusable for devices with small service interval requirements.
Power Conscious Devices

- Some devices prefer large contiguous reservation blocks for power or transfer efficiency reasons.
- Small service interval reservations limit the availability of contiguous blocks of MAS for reservations.
Device B is power conscious and prefers to reserve the last 2 contiguous MAS in superframe.

- Device B takes 2 MAS to power on from deep sleep state.
- Other positions in superframe require powering on/off twice.
- Power conscious devices must be able to choose the optimal reservation if there is no contention.
Reservation Components

• **Row Component** — A portion of a reservation that includes an equal number of MASs at the same offset(s) within every zone, optionally excluding zone zero

• **Column Component** — The portion of a reservation that is not a row component
Limits on Size of Blocks ($Y$) in Column Components

- If block fits entirely in top half of superframe block size is not further constrained
- Otherwise, block size is limited to 4
- All policies generally favor Column components in the top half and row components in the bottom half
Safe vs. Unsafe Reservations

• A device shall not make reservations with more than 112 MAS in DRP IEs that are marked safe

• A device shall not mark more than Y contiguous MAS in a column component reservation block safe

• Devices with DRP IEs marked unsafe must give up requested MAS or become safe if they receive a relinquish request
Column Component Location Policy Summary

- If column component can fit entirely in top half of superframe it must and
  - Minimize highest used zone index

- Else
  - Column component must minimize how far down in the superframe it is located
  - Minimizing highest used zone index is a tiebreaker
• A row component must move lower in the superframe if possible
Rebalancing – Column Components

- A block in an column component most move up in its zone if possible
Though applications using column reservations prefer contiguous MAS they may also care to some extent about service interval.

A single column component reservation may prevent lower service intervals for all other reservations.
Zone Priorities

- Zone columns have numbers from 0 to 3
- Contiguous reservations in each column are treated individually
- If the same size contiguous reservation is available in a lower priority column the column must be moved if this can be done without breaking service interval requirements for the column component
Unrestricted Zone Priority – Example 1

Not Allowed

Allowed
Rebalancing – Row Components

Allocation Zones

Coordinated MAS Sets

Beacon Zone

Not Movable
Row Components K = 2
Allowed Examples

Only Allowed If Service Interval Requires