IEEE 802.15.4 STANDARD

Anuj Sehgal

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OUTLINE

- Introduction
- The IEEE 802.15.4 and 802.15.4a
  - Physical Layer Overview
  - Network Devices
  - Topologies
  - Access Strategies
  - Ranging Support
- Conclusion
IEEE 802.15.4
- Low Data Rate (LDR)
- Wireless Personal Area Network (WPAN)
- Direct Sequence Spread Spectrum (DSSS)

IEEE 802.15.4a
- Addresses ranging applications
- CSS and Impulse-Radio Ultra-wide Band (IR-UWB)
Physical Layers

- IEEE 802.15.4
  - Wideband DSSS physical layer
  - Three different frequency bands
  - Frequency Division Multiplexing (FDM)

<table>
<thead>
<tr>
<th>Channel(s)</th>
<th>Band</th>
<th>Bandwidth</th>
<th>Data Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>868 MHz</td>
<td>NA</td>
<td>20 kbps</td>
</tr>
<tr>
<td>1 - 10</td>
<td>915 MHz</td>
<td>2 MHz</td>
<td>40 kbps</td>
</tr>
<tr>
<td>11 - 26</td>
<td>2.4 GHz</td>
<td>5 MHz</td>
<td>250 kbps</td>
</tr>
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</table>
Physical Layers

- **IEEE 802.15.4a**
  - IR-UWB & CSS physical layers
  - Multiple communication bands
    - *Channels 0, 3 & 9 required*
  - Up to two networks within one channel
  - Bit rates between 100 Kbps to 26 Mbps

<table>
<thead>
<tr>
<th>Channel</th>
<th>Center frequency (MHz)</th>
<th>Bandwidth (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>499.2</td>
<td>499.2</td>
</tr>
<tr>
<td>1</td>
<td>3494.4</td>
<td>499.2</td>
</tr>
<tr>
<td>2</td>
<td>3993.6</td>
<td>499.2</td>
</tr>
<tr>
<td>3</td>
<td>4492.8</td>
<td>499.2</td>
</tr>
<tr>
<td>4</td>
<td>3993.6</td>
<td>1331.2</td>
</tr>
<tr>
<td>5</td>
<td>6489.6</td>
<td>499.2</td>
</tr>
<tr>
<td>6</td>
<td>6988.8</td>
<td>499.2</td>
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<tr>
<td>7</td>
<td>6489.6</td>
<td>1081.6</td>
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<tr>
<td>8</td>
<td>7488.0</td>
<td>499.2</td>
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<tr>
<td>9</td>
<td>7987.2</td>
<td>499.2</td>
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<td>8486.4</td>
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<td>499.2</td>
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<td>12</td>
<td>8985.6</td>
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<tr>
<td>13</td>
<td>9484.8</td>
<td>499.2</td>
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<tr>
<td>14</td>
<td>9984.0</td>
<td>499.2</td>
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<tr>
<td>15</td>
<td>9484.8</td>
<td>1355</td>
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</table>

- **CSS contains 14 Channels**
  - 5 MHz *bandwidth* (1 Mbps)
  - 2410 MHz to 2486 MHz

IR-UWB Sample Preamble (16, 64, 1024, 4096 symbols/burst)

IR-UWB Channelization Scheme
Network Devices

- Two types of devices
  - Full Function Devices (FFDs)
  - Reduced Function Devices (RFDs)

- RFDs & FFDs organize into a PAN

- Each PAN requires a coordinator
  - FFD assumes coordinator role

- RFDs communicate with PAN coordinators (but may directly do so with other devices too)
Both 802.15.4 and 802.15.4a only provide for the above two within the standard.
ACCESS STRATEGIES

- PAN coordinator controls the medium access.
- Two available strategies
  - Beacon-enabled
  - Nonbeacon-enabled
Beacon-Enabled

- Periodic beacon broadcast
  - Time period between each beacon divided into 16 slots
  - Contention Access Period (CAP) for data by random access
  - Guaranteed Time Slots (GTS) for low-latency applications

- Beacon contains PAN information
  - Identification
  - Synchronization
  - Superframe structure

- Slotted Carrier Sensing Multiple Access w/ Collision Avoidance (CSMA-CA) used to select free slots

- Only used for Star topology
SAMPLE SCENARIO

- Device to coordinator
  - Locate free slot using Slotted CSMA-CA
  - Transmit data
  - Receive acknowledgement within same slot

- Coordinator to device
  - Announce data availability in the beacon
  - Interested device picks slot using CSMA-CA
  - Transmit data request
  - Coordinator uses same method to transmit

- CSMA-CA
  - Wait to select slot for backoff delay
  - Backoff delay multiple of backoff time unit (or of the duration of a slot)
Nonbeacon-Enabled

- No synchronization information from PAN coordinator
- No superframe structure
  - No GTS slots available
- CSMA-CA used to select free slots randomly
  - Random backoff delay based on a backoff time unit
  - Clear Channel Assessment (CCA) performed
RANGING SUPPORT

- Based on Symmetrical Double-Sided Two-Way Time of Arrival (SDS TW-TOA)
- Data packet’s preamble ranging bit set high
- Processing delays taken into account
  - Crystal drifts accounted for as well
- Node A to B and B to A calculation results in same (or very similar) result
IEEE 802.15.4 standard family intended for LDR networks

Latest revision provides high accuracy ranging support

Star and P2P topologies defined in standard (but others can be implemented)

Based on IR-UWB/CSS/DSSS

CSMA-CA used to detect available communication slots

Adoption of a preamble enables multiple devices to work in same channel (IR-UWB only)
Thank you!