Implementation and evaluation of TSCH over UWB

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Ultra Wideband (UWB)
Ultra Wideband (UWB) is a wireless technology that uses very short pulses (a few picoseconds long) to transmit data. These pulses allow very accurate measurement of the propagation time. UWB is thus a promising technology for ranging and localization applications.

Pro
- Multiple bit rates (from 110 kbps up to 27 Mbps)
- First path detection
- Ranging & localization
- Low power spectral density

Con
- Power consumption up to 10 times higher than 2.4 GHz transceivers
- Clear Channel Assessment (CCA) not available

Time Slotted Channel Hopping (TSCH)
Time Slotted Channel Hopping (TSCH) is a medium access mechanism specified by IEEE 802.15.4e. TSCH relies on two different principles:

1. **Time synchronization** and **time division multiplexing** allow for deterministic medium access and low-power operation
2. **Channel hopping** enables more robust operation in presence of noise and interferences

The RxGuard is used to compensate the clock drift between two transmissions and hardware clock imprecisions.

Slot
Slots are used to allow time synchronization. A slot is itself subdivided into 3 parts: the CCA, the data and the ACK transmission.

<table>
<thead>
<tr>
<th>Source</th>
<th>MaxTx</th>
<th>CCA</th>
<th>Preamble</th>
<th>SFD</th>
<th>DATA</th>
<th>AckGuard</th>
<th>AckGuard</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCAOffset</td>
<td>TxOffset</td>
<td>TShr</td>
<td>TShr</td>
<td>RxWait</td>
<td>RxGuard</td>
<td>TxAck Delay</td>
<td>AckWait</td>
</tr>
<tr>
<td>RxGuard</td>
<td>RxGuard</td>
<td>TShr</td>
<td>TShr</td>
<td>MaxAck</td>
<td>Preamble</td>
<td>SFD</td>
<td>ACK</td>
</tr>
</tbody>
</table>

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Channel Interferences & Concurrent communications
Interferences may occur if we transmit simultaneously on two adjacent channels. The following figure shows the PSD of 3 adjacent channels. Channel 2 interferes with channels 1 and 3.

<table>
<thead>
<tr>
<th>Channel 1</th>
<th>Channel 2</th>
<th>Channel 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>3494</td>
<td>3494</td>
<td>3494</td>
</tr>
<tr>
<td>3994</td>
<td>3994</td>
<td>3994</td>
</tr>
<tr>
<td>4493</td>
<td>4493</td>
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<tr>
<td>4994</td>
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<tr>
<td>5494</td>
<td>5494</td>
<td>5494</td>
</tr>
</tbody>
</table>

Result & Future Works

Results:
- Working time synchronization
- Bitrate-dependent timeslot
  - 25 ms at 110 kbps
  - 2 ms at 6.8 Mbps
- 6 TSCH channels (on 3 different UWB channels)

Future works:
- Concurrent transmissions
- Dedicated ranging slots
- Scheduling schemes

UWB-TSCH implementation
Our implementation runs over Contiki OS using a 32-bit ARM platform and an off-the-shelf UWB transceiver.

- Zolertia FIREFLY
  - 32-bit ARM Cortex-M3
  - 512 KB flash and 32 KB RAM
  - Running at 16 MHz
- Decawave DWM1000 module
  - IEEE 802.15.4-UWB transceiver
- MCU ↔ transceiver through SPI bus
- DMA transfers for the frame payload