Support for IEEE 802.15.4 Ultra Wideband Communications in the Contiki Operating System

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1 Principles and benefits of UWB

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Ultra Wideband principles

UWB uses a bandwidth larger than 500 MHz while Narrowband uses a bandwidth limited to a few MHz.

- The Power Spectral Density of Zigbee is limited to 10 dBm/MHz.
Ultra Wideband benefits

- Larger bandwidth $\rightarrow$ Higher bit rate $\rightarrow$ Higher node density
- Performs well in environments with high level of multipath fading
- Cohabits with Narrowband technology
- Unlicensed spectrum
- Supports Time of Flight (ToF) and Time Difference of Arrival (TDoA)
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IEEE 802.15.4 UWB

- IEEE 802.15.4a-2007 includes a UWB PHY.
- High bit rates: from 110 Kbps to 27 Mbps
- MAC layer unchanged (same frame format).
- One-way/two-way ranging protocol.

Figure: P-/M-PDU formats.
Contiki OS

- Operating System for Internet of Things
- Low cost and low power micro-controller
- Cooperative scheduling

Objectives

- Send/receive 6LoWPAN datagrams over UWB
  - Proof of concept in this paper
  - Determine achievable performance

Figure: Zolertia Z1.

Figure: Decawave DW1000 UWB transceiver.
## IoT network stack

<table>
<thead>
<tr>
<th>Layer</th>
<th>Protocols</th>
</tr>
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<tbody>
<tr>
<td>Application</td>
<td>CoAP, ...</td>
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<tr>
<td>Transport</td>
<td>UDP, TCP</td>
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<tr>
<td>Network, Routing</td>
<td>IPv4, IPv6, RPL, AODV...</td>
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<tr>
<td>Adaptation</td>
<td>6LoWPAN</td>
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<tr>
<td>MAC</td>
<td>CSMA</td>
</tr>
<tr>
<td>RDC</td>
<td>X-MAC, ContikiMAC, LPL, ...</td>
</tr>
<tr>
<td>Radio Driver</td>
<td>CC2420, Decawave DW1000,...</td>
</tr>
</tbody>
</table>
Contiki OS Driver Architecture

**Figure:** Block diagram of the radio driver.
Contiki OS Driver Architecture

**Figure:** Block diagram of the radio driver.

- **Above stack layers**
  - outbound frame
  - inbound frame

- **DW1000 driver**
  - hardware dependent
  - SPI read / write
  - ISR

- **Decawave DW1000 transceiver**
  - SPI
  - INTerrupt

**Software part, run on embedded system**

**Transceiver part**
Contiki OS Driver Architecture

Figure: Block diagram of the radio driver.
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How long does it take to send a frame?

**Figure:** Measurement of transmission time and overhead.
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Figure: Measurement of transmission time and overhead.
How long does it take to send a frame?

![Graph showing measurement of transmission time and overhead.](image)

**Figure:** Measurement of transmission time and overhead.
What bit/packet rates can be achieved?

![Graph showing achievable bit and packet rates at 6.8 Mbps](image)

**Figure**: Achievable bit and packet rates at 6.8 Mbps
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Discussion and Further work

- Working support for IEEE 802.15.4-UWB
  - Implementation of a radio driver
  - Validated through several transmissions
  - Impact of SPI transfers

- Further work
  - Evaluate on additional platforms (e.g. CC2538)
  - Support for Radio Duty-cycling
    - CCA primitive used in many protocols (e.g. ContikiMAC, X-MAC)
    - Issue: UWB PHY CCA always report channel clear
    - Adapt existing protocols? Develop new approaches?
  - Support for Ranging
    - Indoor geolocation
    - Measured distance as a routing metric
Any questions?
Acknowledgments

We thank H. Derhamy and K. Albertsson for sharing their initial DW1000 driver for the Mulle platform (Kinetis K60). We also acknowledge DecaWave Ltd for their support.