Indoor UWB localization in high density and large scale

Maximilien Charlier

Computer Science Department
University of Mons, Belgium

January 31, 2019
Table of contents

1. Introduction to UWB
2. Channel occupancy
3. Localization
4. Scheduling
Ultra Wideband

- Wireless technology
- Very short pulse (<ns)
- Initially used for military radar and stealth/undetectable transmission
- Performs well in environments with high level of multipath fading

Figure: First path detection on the receiver side

UWB PHY added in the IEEE 802.15.4 Low power standard in 2007.
Ultra Wideband

Spectrum

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

Power Spectral Density (dBm/MHz)

-41

10

IEEE 802.15.4
ZigBee
Bluetooth
IEEE 802.11b

WLAN IEEE 802.11a

UWB Spectrum

CCA floor

Noise floor

Frequency (GHz)
UWB TSCH

No CCA $\Rightarrow$ no CSMA $\Rightarrow$ Aloha $\Rightarrow$ bad channel occupancy.

Our proposal: adapt an existing TDMA protocol: TSCH

- **Time Slotted**
  - Global synchronization
  - Minimize the power consumption
  - Improve channel occupancy
  - Challenge: new PHY parameters (preamble, bit-rate).

- **Channel Hopping**
  - Initially, for improve resilience to interference
  - Here, maximize the bandwidth (concurrent communications)
  - Up to 8 simultaneous communications
Table of contents

1 Introduction to UWB
2 Channel occupancy
3 Localization
4 Scheduling
Single Sided Two Way Ranging

1. Measure the propagation time
\[ T_{prop} = \frac{RX - TX - T_{reply}}{2} \]

2. Convert to distance based on speed of light

3. True range multilateration based on at least 3 ranging measurement to compute the position

Figure: SS-TWR
Scheduling

Localization: 4 successive slots needed per mobile (10 ms).

Figure: Example of localization order
Scheduling

The slotframe (schedule) is local for each node.

Figure: Resulting slotframe for M
UWB based indoor localization

- **Large scale**: building, warehouse
- **High density**: thousands people/objects
- **High accuracy**: less than 20 cm
- **Low power**: year autonomy
- **Low cost**: less than 50€
Scheduling: Large scale

Multi cell network with concurrent communications.

Figure: Localization at large scale
Scheduling: Large scale

Multi cell network with concurrent communications.

Figure: Localization at large scale
Scheduling: Large scale

Multi cell network with concurrent communications.

Figure: Localization at large scale
Any questions?

TSCH: Slot

- Synchronization ⇒ CCA
- Slot specified according to the PHY parameters
- Clock drift ⇒ Guard time
  - $RX_{Guard} = \max(\text{clock drift}) + \max(\text{clock imprecision})$
  - $Ack_{Guard} = \max(\text{clock imprecision})$

Sender:

```
MaxTx
Preamble SFD PHR DATA
```

$T_{Head}$

$Tx_{Offset}$

Receiver:

```
RxWait
```

$Rx_{Offset}$

$Rx_{Guard}$

$T_{xAckDelay}$

```
MaxAck
Preamble SFD SHR ACK
```

$Rx_{Guard}$

$Rx_{Wait}$

$Rx_{Guard}$

$RxAckDelay$
Platform

- Operating system
  - Currently Contiki OS may be Open WSN in the future.
- 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

Figure: Firefly (Left), DWM1000 (Right)
**UWB Data Slot**

- Example at 6.8 Mbps
- Slot duration: 2.5 ms
- Wakeup duration: 2.5 ms

![Data Slot Diagram]

**Figure:** Data slot, A send to B
UWB Data Slot

- Check the real temporal implementation

**Figure**: Logical analyzer connected to multiple nodes
Channel Hopping

IEEE 802.15.4 specifies 16 channels for the UWB PHY ranging from 249.6 MHz up to 10.16 GHz.

Figure: Subset of the UWB channels defined by IEEE 802.15.4 [2].
Channel Hopping

8 simultaneous communications based on 4 separate channels and 2 Pulse Repetition Frequency (PRF)

Figure: Subset of the UWB channels defined by IEEE 802.15.4 [2].
IoT network stack

- **Application**
  - CoAP, ...

- **Transport**
  - UDP, TCP

- **Network, Routing**
  - IPv4, IPv6, RPL, AODV...
  - 6LoWPAN
  - 6TiSCH Operation Sublayer (6top)

- **Adaptation**
  - TSCH, X-MAC, ContikiMAC, ...

- **MAC**
  - CC2420, Decawave DW1000,...
Double Sided Two Way Ranging

Compute the propagation time on each side and use the mean

⇒ Cancel the clock drift error
Testbed

Composition :
- 27 fixed nodes
- 13 mobiles nodes
- USB architecture
  - Centralized
  - Raspberry Pi

Experimentation :
- Localization
- Concurrent localization
- Scheduling
- Synchronization
Testbed