Ultra Wideband
Towards Large-Scale, High-Density Indoor Geolocation Systems

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Summary

1. UWB - Driver

2. Ranging

3. Localization & Challenge
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3. Localization & Challenge
Ultra wideband (UWB)

- Use of very short RF pulses (some picoseconds)
- Bandwidth larger than 500 MHz
- Low power spectral density

Advantages:
- Very good temporal accuracy.
- Works well in multipath environments.
Contiki OS
Radio driver in Contiki

Zolertia Z1
16 bits, 8 MHz
Contiki OS at 8MHz

DWM1000
UWB transceiver
SPI up to 20 MHz

SPI at 4 MHz
Decawave DW1000

Configuration

- IEEE 802.15.4 MAC format (payload up to 1024 bytes)
- Bitrate
  110, 850 or 6800 kbps
- 6 frequency bands
  from 3.5 GHz to 6.5 GHz
- Preamble length
  from 64 μs to 4 ms
- Multiple preamble codes
- PRF - Pulse repetition frequency
  16 or 64 MHz (two setups can work independently using different PRF)

⇒ Study of parameters
Contiki OS
Radio driver in Contiki

```
struct radio_driver {
    int (* init)(void);
    int (* prepare)(const void *payload,
                     unsigned short payload_len);
    int (* transmit)(unsigned short transmit_len);
    int (* send)(const void *payload,
                 unsigned short payload_len);
    int (* read)(void *buf,
                 unsigned short buf_len);
    int (* channel_clear)(void);
    int (* receiving_packet)(void);
    int (* pending_packet)(void);
    int (* on)(void);
    int (* off)(void);
};
```

Structure « radio_driver » defined in « /core/dev/radio.h »
Contiki OS

Radio driver in Contiki

```c
struct radio_driver {
    int (* init)(void);
    int (* prepare)(const void *payload,
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    int (* transmit)(unsigned short transmit_len);
    int (* send)(const void *payload,
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Structure « radio_driver » defined in « /core/dev/radio.h »

⇒ CCA not feasible in UWB
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Propagation time measurement

Multiple protocols:

- **Time of Arrival**
- Time Difference of Arrival
- Two Way Ranging (TWR):
  - Single-Sided TWR
  - Double-Sided TWR

Same time base for all transceivers.

\[
T_{\text{prop}} = T_{\text{receive}} - T_{\text{send}}
\]
Propagation time measurement

Multiple protocols:
- Time of Arrival
- **Time Difference of Arrival**
- Two Way Ranging (TWR):
  - Single-Sided TWR
  - Double-Sided TWR

Same time base for all receivers.

Resolution of hyperbolic systems of equations to locate the mobile node followed by Euclidean distance.
Propagation time measurement

Multiple protocols:
- Time of Arrival
- Time Difference of Arrival
- Two Way Ranging (TWR):
  - Single-Sided TWR
  - Double-Sided TWR

\[ T_{prop} = \frac{RX_a - TX_a - T_{reply}}{2} \]
Propagation time measurement

Multiple protocols:
- Time of Arrival
- Time Difference of Arrival
- Two Way Ranging (TWR):
  - Single-Sided TWR
  - Double-Sided TWR

\[ T_{\text{prop}} = \frac{T_{\text{prop}A} + T_{\text{prop}B}}{2} \]
Ranging accuracy
Double-Sided TWR

12000 ranging samples
error $\leq 3\text{cm}$ for 50% of samples
error $\leq 5\text{cm}$ for 90% of samples

From 2 to 10 meters.
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Localization

Overview

- **GPS**
  - Does not work indoors

- **WiFi/Bluetooth**
  - Accuracy in decimeters
  - Ranging based on signal strength

- **Ultra wideband (UWB)**
  + Accuracy in centimeters
Localization

TDOA - Prototype

2D localization
most errors $\leq 5$ cm
Long-term objectives

- Increased **coverage** by factor 100
  from $O(100 \ m^2)$ to $O(10000 \ m^2)$
- Larger **number of anchors** by factor 10
  from $O(10)$ to $O(100)$
- Larger **number of mobile** nodes by factor 100
  from $O(10)$ to $O(1000)$
- **Higher** ranging / positioning **rate** by factor 10
  from $O(10/s)$ to $O(100/s)$
Large scale

Area of interests: large museums, warehouses, factories...
Large scale

Problem: coordination of anchors.
Large scale

- How to choose the correct anchors sub-group?
- How to optimize the selection to allow multiple localizations at the same time?
High density
High density
Problem:

- How to schedule transmissions to reduce congestion and collisions?

⇒ Channel access scheduling
  (e.g. time-division multiplexing)
High density

Problem:
- What is the highest achievable localization rate?

⇒ Non-ranging based techniques:
  - Time Difference of Arrival (TDoA)
  - Angle of Arrival (AoA)
  - Hybrid methods, ...
High density

Problem:

- What is the impact on the battery life?
  ⇒ Sensor fusion:
  - Mobile node’s accelerometer / compass
  - Received signal strength
  - Angle of Arrival (AoA)
Thank you for your attention.

Feel free to ask your questions now or by email at Maximilien.Charlier@umons.ac.be