Precise localization using Ultra wideband technology

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Localization applications

- **Safety**
  - Crossing of lines
  - Dangerous devices or objects

[Image: bordersystem.be [1]]
Localization applications

- Safety
  - Crossing of lines
  - Dangerous devices or objects
- Manufacturing process
  - Objects tracking
  - Quality assessment

Amazon Warehouse [2]
Localization applications

- **Safety**
  - Crossing of lines
  - Dangerous devices or objects

- **Manufacturing process**
  - Objects tracking
  - Quality assessment

- **Entertainment**
  - Interactive tour
  - Audio guide

Musée[3]
Context

Indoor localization

- Sub-meter accuracy
- Large scale → warehouse
- High density → thousand of nodes
- Low complexity & Low cost

Museum example [3]
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Localization technology

Overview

- **GNSS** (GPS/Galileo/GLONASS...)
  - Low accuracy (4 m [4])
  - Doesn’t work indoors
Localization technology

Overview

- **GNSS** (GPS/Galileo/GLONASS...)
  - Low accuracy (4 m [4])
  - Doesn’t work indoors

- **WiFi/Bluetooth**
  - Low accuracy (few meters [5])
Localization technology
Overview

- **GNSS** (GPS/Galileo/GLONASS...)
  - Low accuracy (4 m [4])
  - Doesn’t work indoors

- **WiFi/Bluetooth**
  - Low accuracy (few meters [5])

- **Ultra wideband (UWB)**
  + High accuracy (few centimeters [6])
Ultra Wideband

- Wireless communication technology
- Pulse radio
- Frequency band $\geq 500$ MHz

Very short pulse ($<\text{ns}$) $\Rightarrow$ Wide frequency band

Figure: Pulse waveform

Source: wlan62d [7]
Ultra Wideband

Low power spectral density

The power spectral density is spread over the spectrum of UWB, therefore it is much lower than narrow band technology.

This figure is not to scale.
Two Way Ranging technique

Based on the propagation time

\[
\text{Distance} = T_{prop} \times c
\]

with \(c = 299\,792\,458 \,\text{m/s}\)

1 meter traveled in 3.3 ns
Two Way Ranging technique

Based on the propagation time

$$\text{Distance} = T_{\text{prop}} \times c$$

with $$c = 299,792,458\ \text{m/s}$$

1 meter traveled in 3.3 ns

$$T_{\text{prop}} = \frac{RX - TX - T_{\text{reply}} A}{2}$$
Two Way Ranging technique

Ranging
most errors ≤ 10cm
Two Way Ranging technique

Ranging
most errors $\leq 10$cm

2D localization
most errors $\leq 5$cm
Application to large scale scenario
Application to large scale scenario
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Medium Access Control

1. Transmit as soon as possible
   - Low channel occupancy
   - Low power efficiency (overhearing)

ALLOHA
Medium Access Control

1. Transmit as soon as possible
   - Low channel occupancy
   - Low power efficiency (overhearing)

2. Listen before transmit
   - Reduce collision
   - No Clear Channel Assessment in UWB (PSD too low)

ALOHA

Carrier-Sense Multiple Access (CSMA)
Medium Access Control

1. Transmit as soon as possible
   - Low channel occupancy
   - Low power efficiency (overhearing)

2. Listen before transmit
   - Reduce collision
   - No Clear Channel Assessment in UWB (PSD too low)

3. Transmit according a scheduling
   - Minimization of the power consumption
   - Channel occupancy improvement

Our proposal:
⇒ Increase of channel occupancy by adapting TSCH to UWB.
Medium Access Control

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   - Low channel occupancy
   - Low power efficiency (overhearing)

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Our proposal:

⇒ Increase of channel occupancy by adapting TSCH to UWB.
Time Slotted Channel Hopping

A IEEE 802.15.4 MAC protocol originally for Narrow Band.

Example of scheduling
Time Slotted Channel Hopping

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Example of scheduling
Time Slotted Channel Hopping

A IEEE 802.15.4 MAC protocol originally for Narrow Band.
TSCH - Time slot

**Sender:**

```
Synchronization  DATA
```

**Receiver:**
TSCH - Time slot

Sender:

| Synchronization | DATA |

Receiver:

| DATA |
TSCH - Time slot

Sender:

Receiver:

Synchronization

DATA

RxGuard

RxGuard
TSCH - Time slot

**Sender:**

- Synchronization
- DATA

**Receiver:**

- RxGuard
- RxGuard
- $T_{x\text{Ack}}$
- Delay
- Sync
- ACK
TSCH - Time slot

Sender:

Receiver:

RxGuard

Sync

ACK

Delay
TSCH - Time slot

**Sender:**

**Receiver:**

RxGuard  |  RxGuard  |  TxAck Delay  
---|---|---
Sync  |  DATA  |  ACK
Network synchronization

Global synchronization error in $\mu$s

Frequency (%)

Guard time
N2
N3
N4
N5

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Conclusion

Achievements
- Working TWR and 3D localization (master thesis)
- TSCH-inspired UWB medium access control
- Working prototype based on off-the-shelf transceiver

Future work
- Definition of a Two-Way Ranging slot (ongoing)
- Scheduling of concurrent localization
- Large scale testbed validation
Thank you for your attention,
Any questions?
Bibliography I

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Bibliography II