A High-Precision Ultra Wideband Impulse Radio Physical Layer Model for Network Simulation
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A High-Precision UWB-IR PHY Layer Model for Network Simulation

Overview

- Research Problem and Context
- Ultra Wide Band
  - MB-OFDM UWB, FM-UWB, UWB-IR
  - IEEE 802.15.4A
- Modeling Multiple Access Interference in UWB
  - State of the Art
  - Our approach
- Implementation in Omnet++
- Simulation Results
- Conclusion
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Context

- Research Problem
  - Evaluate UWB-IR potential for Sensor Networks
- Context
  - Without commercial hardware
  - Without support in network simulators
  - Without access to Matlab simulation models
Ultra Wide Band

UWB $\Leftrightarrow$ Bandwidth $> 500$ MHz (between 1 and 10 GHz)

- Strict power limitations: -41.3 dBm/MHz
- Various possible modulations
- First Products: Wireless USB
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Ultra Wide Band

UWB $\iff$ Bandwidth $> 500$ MHz \quad \text{(or Bandwidth} $> 0.2$ fc)

- Strict power limitations: -41.3 dBm/MHz
- Various possible modulations
- First Products: Wireless USB

<table>
<thead>
<tr>
<th></th>
<th>MB-OFDM UWB</th>
<th>UWB-IR</th>
<th>FM-UWB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transceiver Complexity</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>High</td>
<td>Low Tx, High Rx</td>
<td>Low</td>
</tr>
<tr>
<td>Data rates</td>
<td>High</td>
<td>Low, Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Robustness</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
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</table>
IEEE 802.15.4A

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![Diagram](image)
A High-Precision UWB-IR PHY Layer Model for Network Simulation

IEEE 802.15.4A

Diagram:
- Preamble Sequence
- SFD
- Data
- Possible burst positions for coding a 0 (256.4 ns)
- Burst duration (32.05 ns)
- Possible burst positions for coding a 1 (256.4 ns)
- TGuard = 256.4 ns
- TGuard = 256.4 ns
- Tsym = 1025.64 ns

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IEEE 802.15.4A

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IEEE 802.15.4A

Possible burst positions for coding a 0 (256.4 ns)

Possible burst positions for coding a 1 (256.4 ns)

Burst duration (32.05 ns)

TGuard = 256.4 ns

Tsym = 1025.64 ns

Tx

Rx

Channel
Narrow Band MAI: Accumulative Noise Model

Frame events

Signal Level

SNR History

BER History
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**UWB-IR Multiple Access Interference**

![Graphical representation of UWB-IR Multiple Access Interference]

- Source
- Jammer
- Receiver

2x^2 > 0, No impact
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UWB-IR Multiple Access Interference

source

jammer

receiver

2x^2 > 0 No impact

2z^2 > 0 Positive impact
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**UWB-IR Multiple Access Interference**

Source

Jammer

Receiver

No impact

Positive impact

Negative impact
### Existing Approaches to UWB-IR MAI

<table>
<thead>
<tr>
<th>Receiver Type</th>
<th>Channel</th>
<th>Modulations</th>
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<tbody>
<tr>
<td>Gaussian Approximation</td>
<td>Correlation</td>
<td>AWGN, multipath</td>
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<td>Characteristic Function</td>
<td>Correlation</td>
<td>AWGN, multipath</td>
</tr>
<tr>
<td>Pulse Collision Model</td>
<td>Correlation, rake</td>
<td>AWGN</td>
</tr>
<tr>
<td>Large Deviations</td>
<td>Correlation, rake</td>
<td>arbitrary</td>
</tr>
<tr>
<td>Cumulative Noise</td>
<td>Correlation</td>
<td>AWGN</td>
</tr>
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</table>

- Complex Models
- Difficult to evaluate and to adapt
Our Approach to Modeling UWB-IR MAI

- **Objective**
  - Realistic UWB-IR PHY model for network simulation (especially MAI)

- **Approach**
  - Symbol-level simulation

- **Assumptions**
  - Channel coherence time > Packet duration
  - Triangular pulses
  - Synchronization requires jam-free signal
  - Random bit values
  - Energy detection
  - No clock drift
  - No interference from other systems
# Tools Selection

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<tr>
<th>Simulator</th>
<th>Advantages</th>
<th>Inconvenients</th>
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<td>NS-2</td>
<td>Well-known, large user base</td>
<td>No prior experience</td>
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<tr>
<th>Framework</th>
<th>Strengths</th>
<th>Weaknesses</th>
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<tr>
<td>MF-2</td>
<td>Well-known, stable</td>
<td>Design issues</td>
</tr>
<tr>
<td>MiXiM</td>
<td>Suitable for detailed PHY modeling</td>
<td>In Development</td>
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Implementation of our Approach in Omnet++

- Various Channel Models
  - Ghassemzadeh
  - Modified Saleh-Valenzuela (IEEE 802.15.4A channel models)
- Energy-Detection Receiver
- New radio state: SYNC
- Simple TimeMapping Signal object
Simulation Results

- Channel Models
- Receiver Sensitivity
- Multiple Access Interference
- Performance
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Channels, BER (Distance)
Receiver Sensitivity
Multiple Access Interference
Conclusions

- First UWB-IR Network Simulator
- Easy to adapt to other
  - Modulations
  - Receivers
  - Channels
- Offers speed <-> precision trade-off
- Made possible thanks to MiXiM's design (Signal and Mapping objects)
- Accelerated data analysis with Omnet++ 4 visualisation features
- Accelerated development thanks to the Eclipse-based editor
- Bazaar version control to track our code and resynchronize with MiXiM svn
Thank you for your attention.