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

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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

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 <=> Bandwith > 500 MHz   (between 1 and 10 GHz)

- Strict power limitations: -41.3 dBm/MHz

- Various possible modulations

- First Products: Wireless USB

Ultra Wide Band
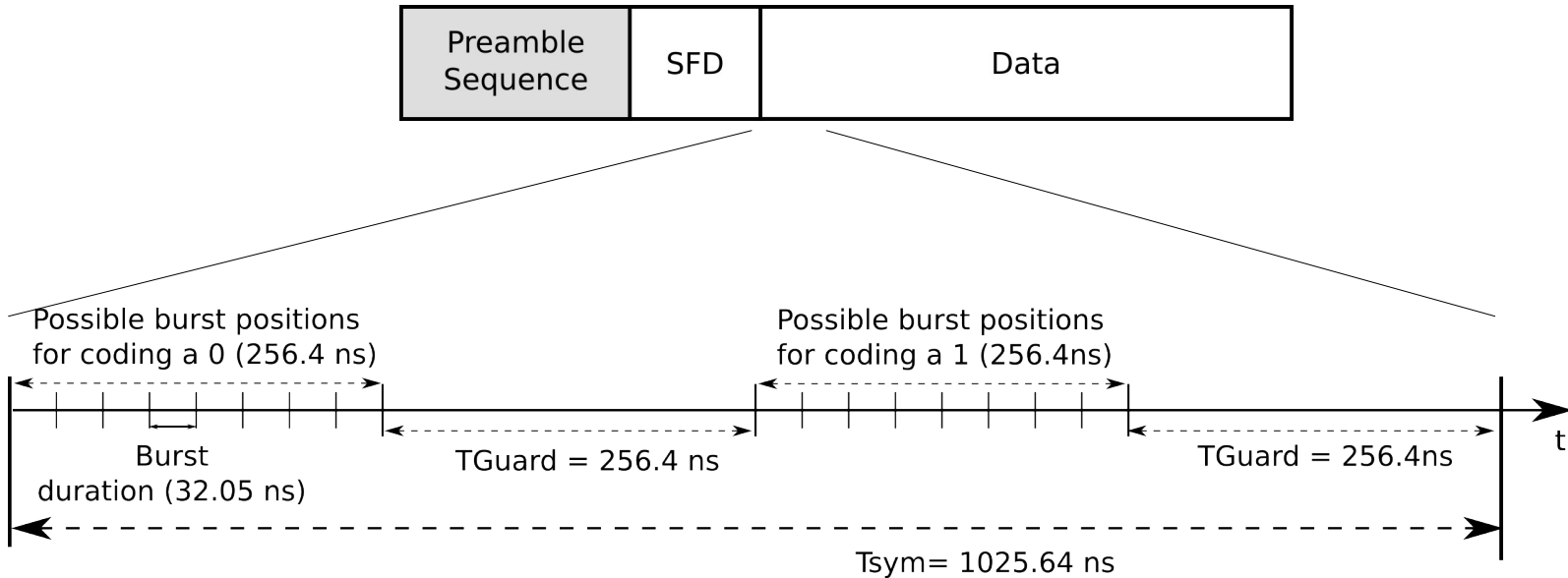
UWB <=> Bandwith > 500 MHz   (or Bandwidth > 0.2 fc)

- Strict power limitations: -41.3 dBm/MHz

- Various possible modulations

- First Products: Wireless USB

	MB-OFDM UWB	UWB-IR	FM-UWB
Transceiver Complexity	High	Medium	Low
Power Consumption	High	Low Tx, High Rx	Low
Data rates	High	Low, Medium	Low
Robustness	Low	Medium	High

IEEE 802.15.4A

Preamble Sequence	SFD	Data

IEEE 802.15.4A

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Preamble Sequence	SFD	Data

Possible burst positions for coding a 0 (256.4 ns)

Possible burst positions for coding a 1 (256.4ns)

Burst duration (32.05 ns)

TGuard = 256.4 ns

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T_{sym} = 1025.64 ns

t

Tx
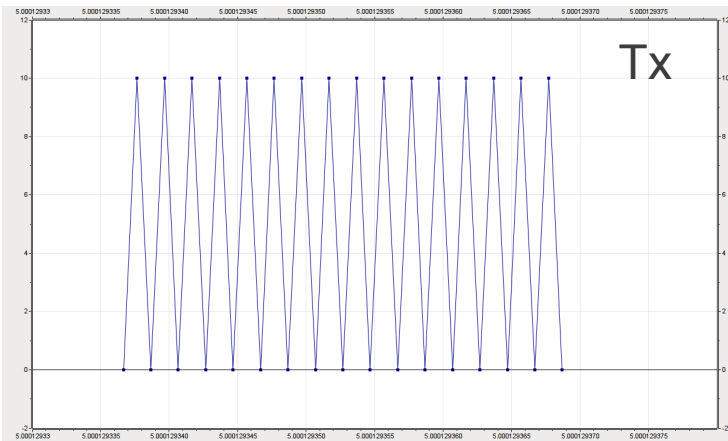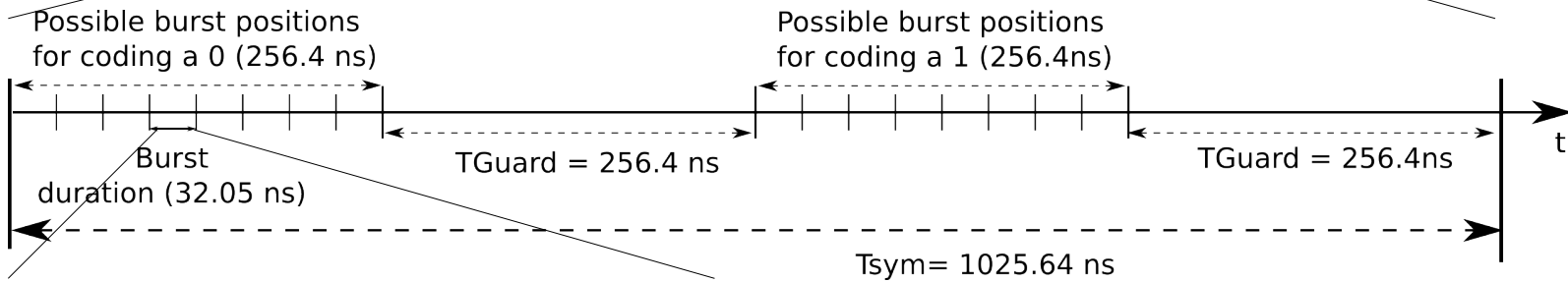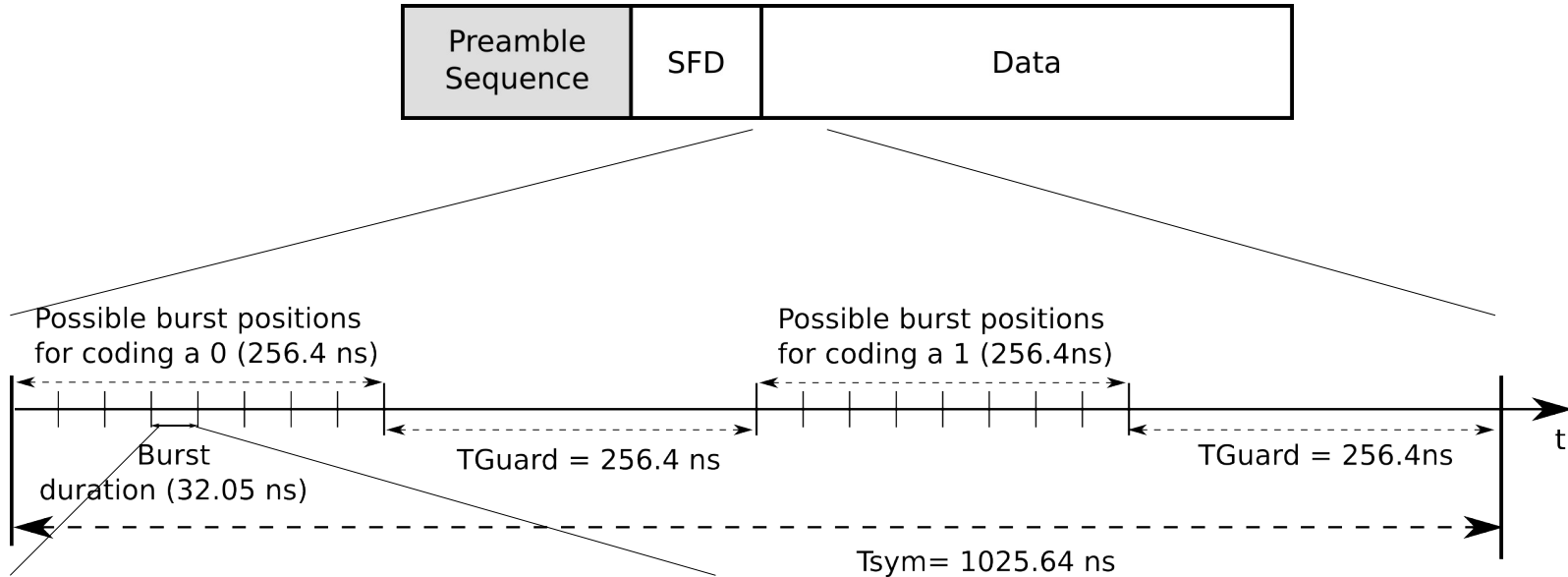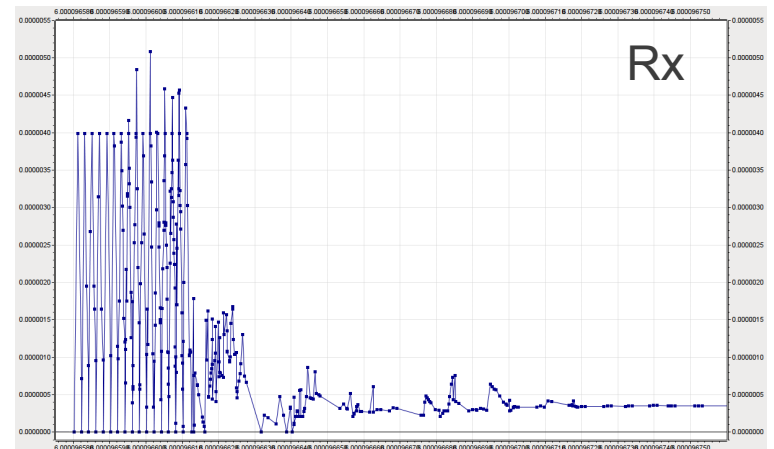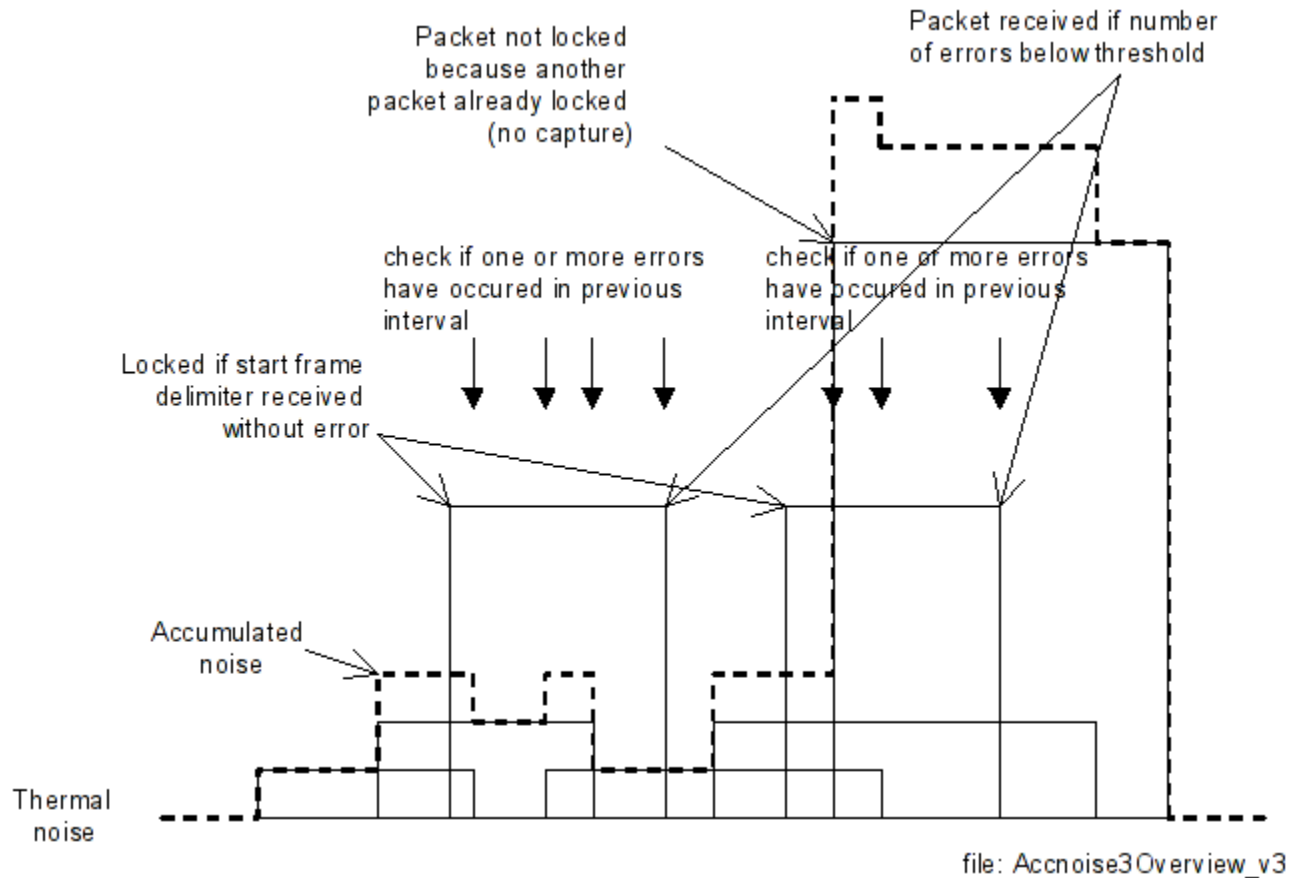
IEEE 802.15.4A
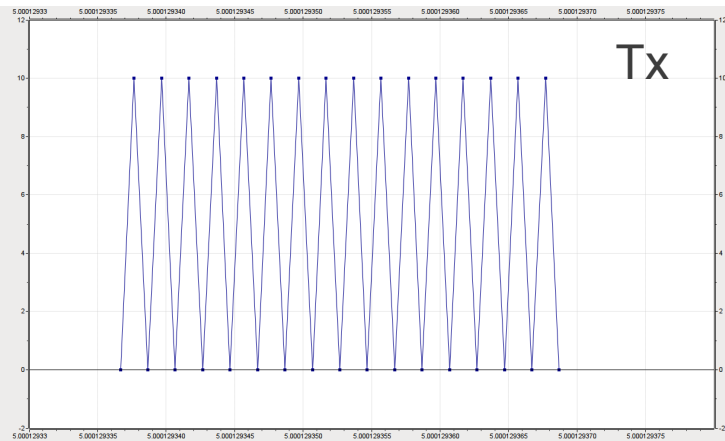
Narrow Band MAI: Accumulative Noise Model

Frame events
Signal Level → SNR History → BER History

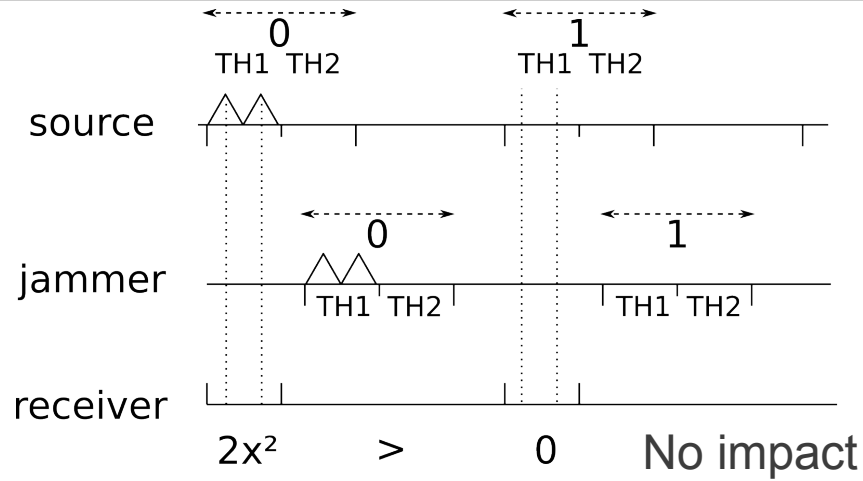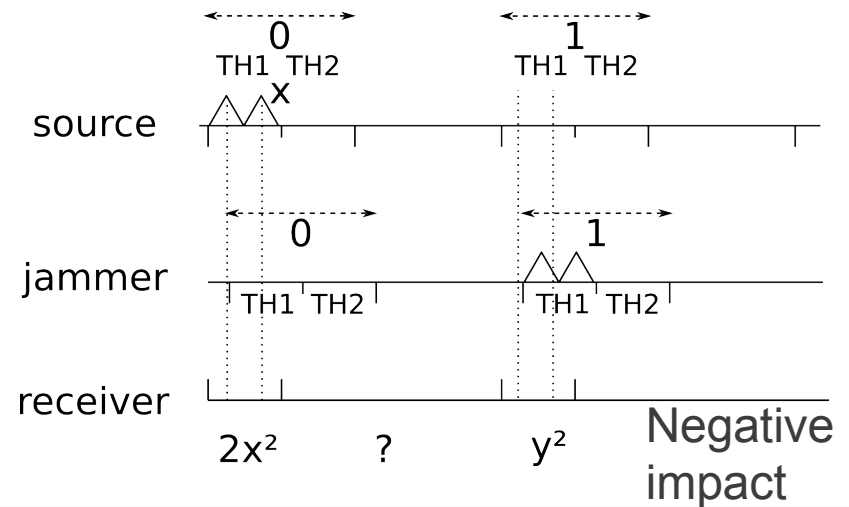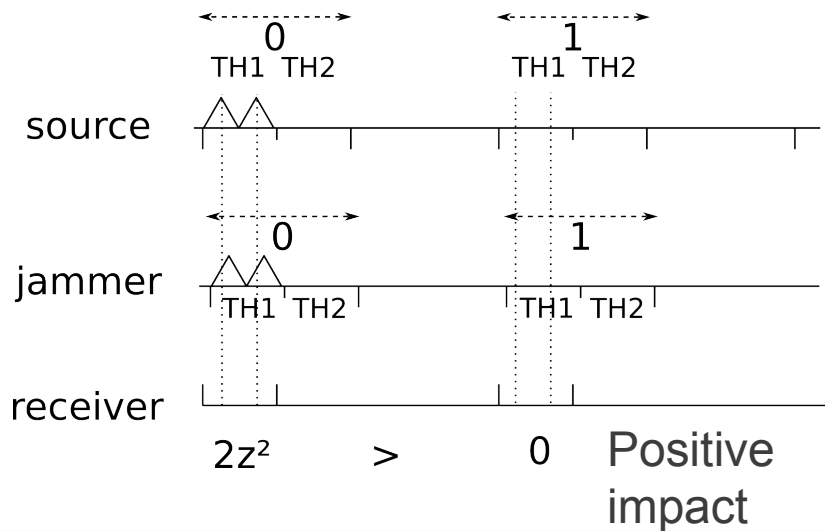# UWB-IR Multiple Access Interference
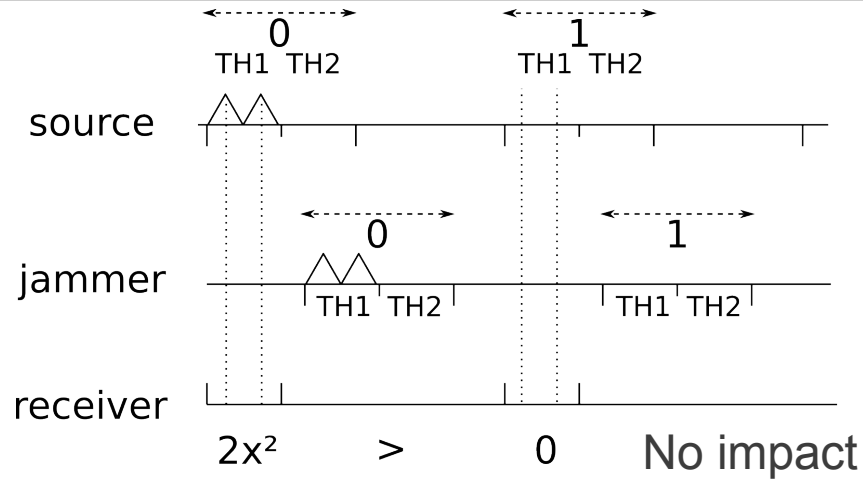
UWB-IR Multiple Access Interference
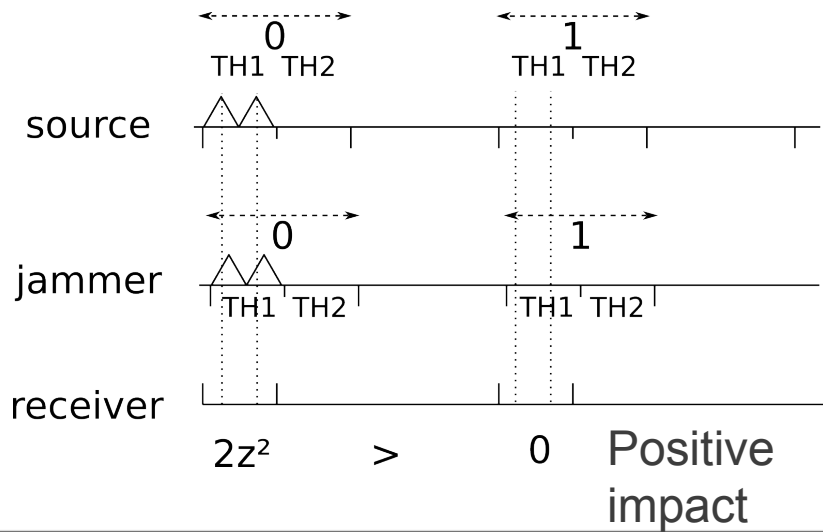
UWB-IR Multiple Access Interference
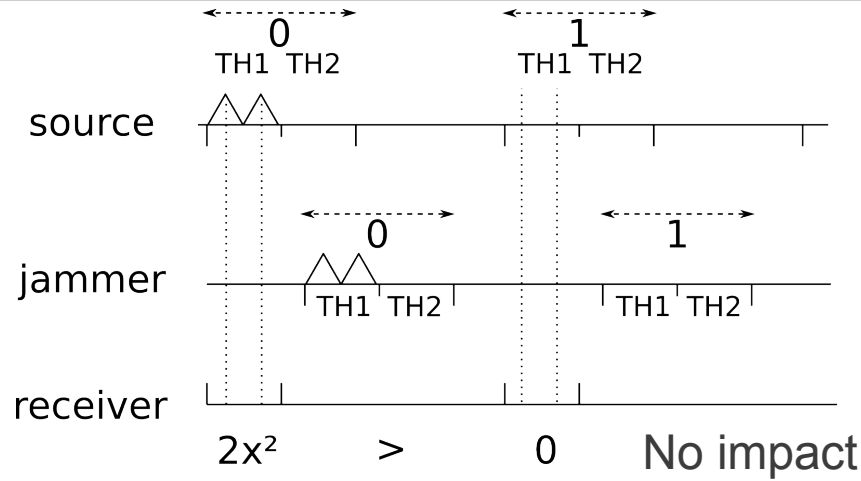
Existing Approaches to UWB-IR MAI

	Receiver Type	Channel	Modulations
Gaussian Approximation	Correlation	AWGN, multipath	PPM,PSK
Characteristic Function	Correlation	AWGN, multipath	PPM,PAM
Pulse Collision Model	Correlation, rake	AWGN	PPM
Large Deviations	Correlation, rake	arbitrary	PSK
Cumulative Noise	Correlation	AWGN	PSK

- 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

Simulator	Advantages	Inconvenients
NS-2	Well-known, large user base	No prior experience Difficulty to implement our solution
JiST	Java	No user base, no models
Glomosim	Legacy	abandonware
Omnet++	Clean design, user community, Model libraries	Not as famous as NS-2 Framework selection

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| Framework	Strengths	Weaknesses
MF-2	Well-known, stable	Design issues
MiXiM	Suitable for detailed PHY modeling	In Development

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

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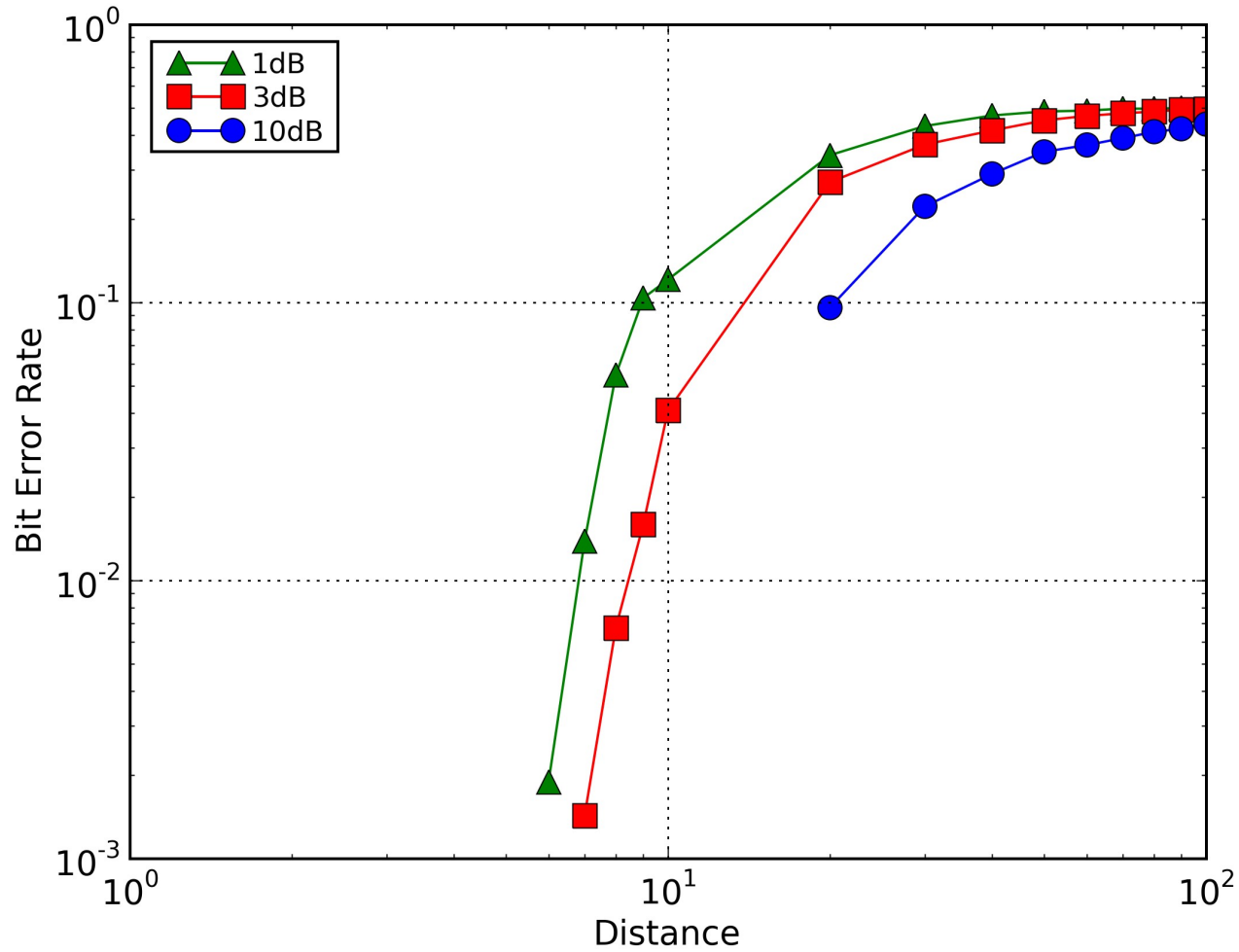et de microtechnique

Simulation Results

- Channel Models

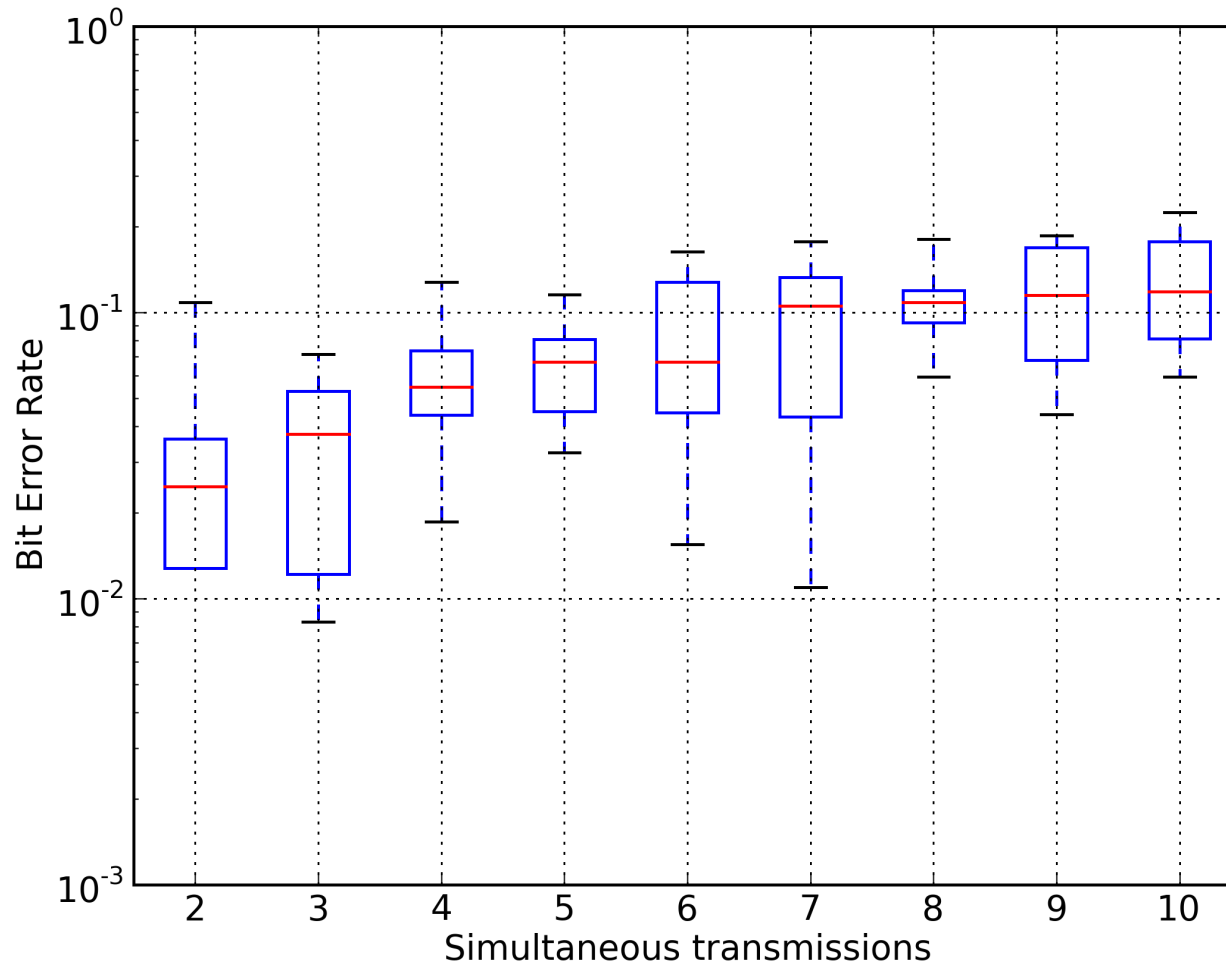- Receiver Sensitivity

- Multiple Access Interference

- Performance

Channels, BER (Distance)
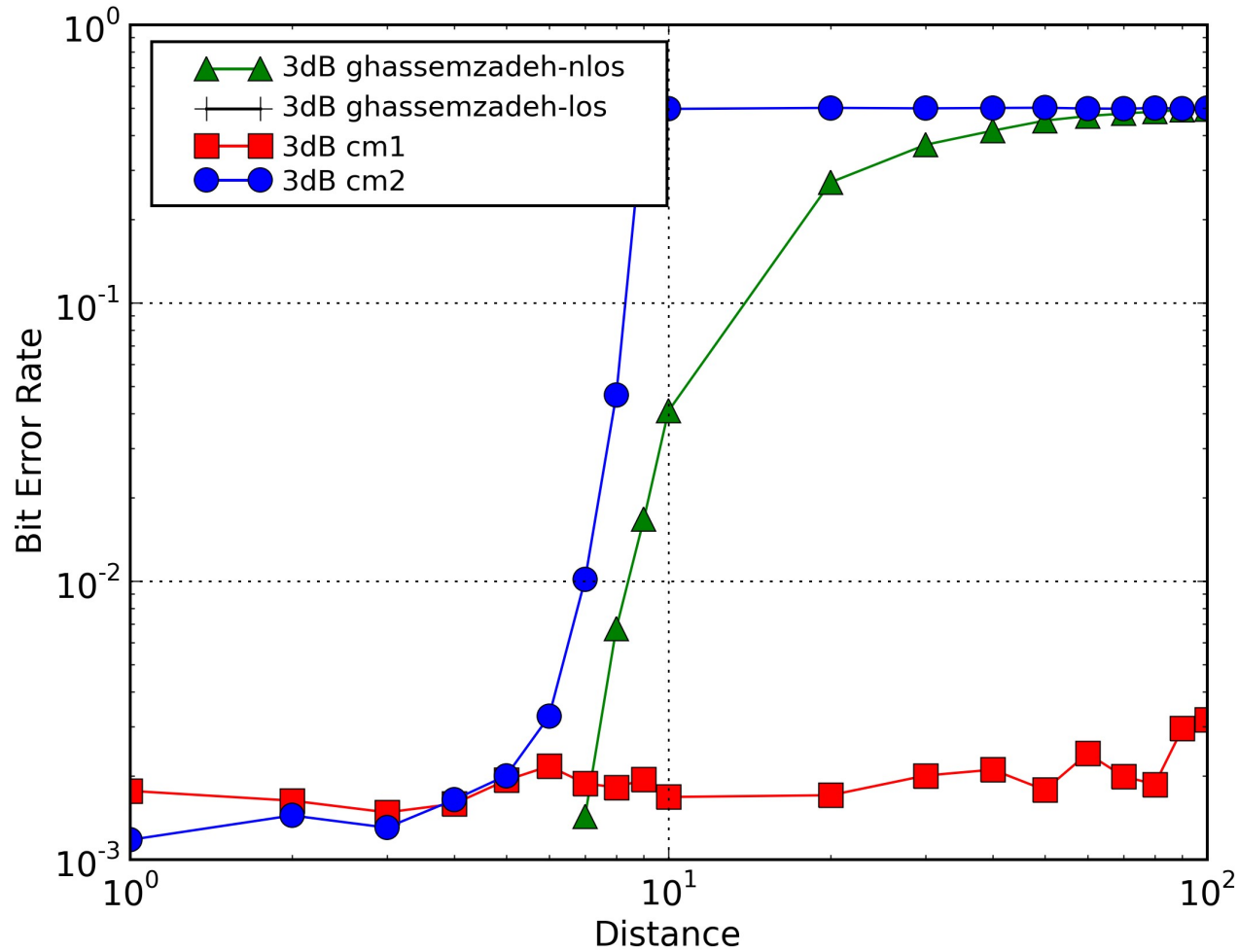
Receiver Sensitivity

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.