Context Routing in Sensor Networks

Sensor Networks Seminar 2006 November

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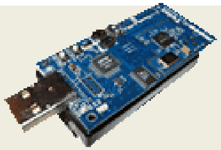
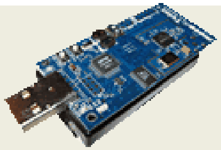


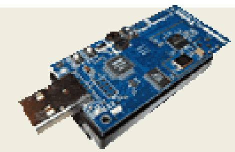
Outline

- Introduction
- Context Awareness
- Surge
  - Structure
  - Example
- TOSSIM
  - Introduction
  - Radio Model
- Radio Propagation Model (Matlab)
  - Analysis
- Results and Conclusions



Introduction

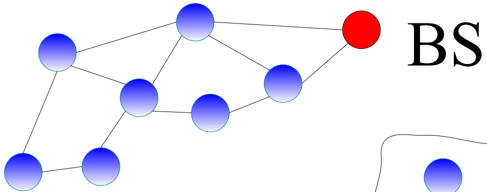
- Wireless Sensor Network (WSN) – large scale network of sensor nodes
- Purpose – monitoring, control, surveillance, security, civil and military applications, etc.
- Properties – ad-hoc node interconnection, distributed organization, variable density, mobility of nodes, source-sink structure
- Structure – application dependent
- Limitations – battery capacity, bandwidth, computing power. How? Routing
- Requirements – low power consumption, maximum network lifetime, low data rates, in-network stability, mobility tolerance. How? Context awareness

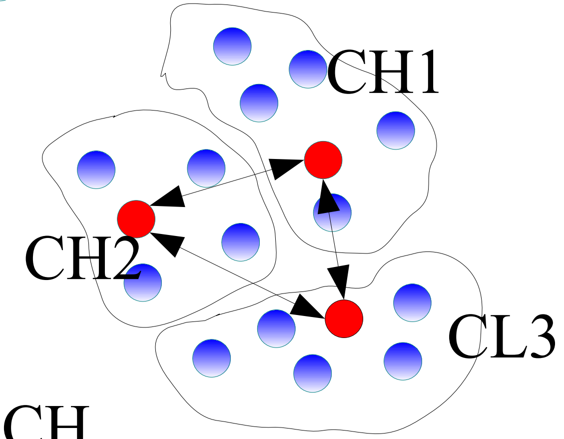


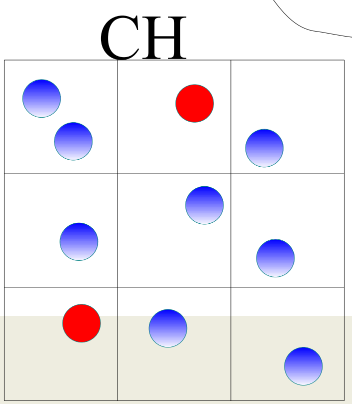
Routing Types in Sensor Networks

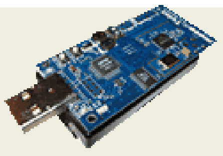
- Flat Networks Routing
  - Data-centralization (BS), multi-hop
- Hierarchical Networks Routing
  - Clustering
- Location-Based Networks Routing
  - Space division

- Routing – forwarding data over optimal path
  Optimization: Context awareness









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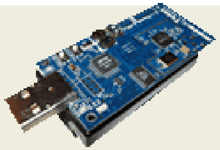
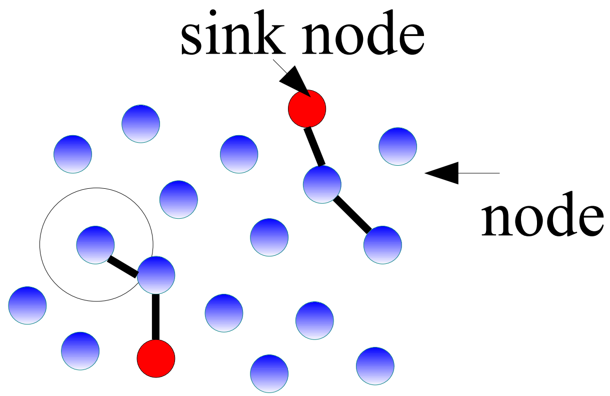


Context Awareness

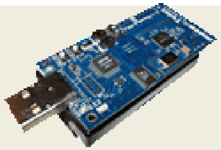
- Acquire information about the context of current environment
- Adapt the behavior of the node
  → efficient routing

- Infrastructure context
  - Infrastructure around the node
  - e.g. Bandwidth, reliability, signal strength
- Domain context
  - Relations between nodes
  - e.g. Information about next data sink



Context Awareness
Context types (attributes)

- Power/Energy
  - Battery level, bandwidth, transmission cost, connectivity
- Mobility
  - Relative mobility, collocation with sinks -> adaptive algorithms
- Information
  - Max. information gain, data aggregation, compression
- Privacy
  - Data encryption, cloaking, authentication, access rights
- Quality of Services
  - Energy reserve, delays, service rate

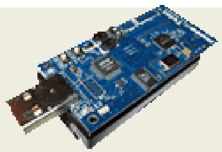


Context Awareness
Utilization function

- Significance-based evaluation of context-aware information
- Context information
  - Set of attributes $(X_1, X_2, \ldots, X_n)$
  - Delivery probability (Utilization) $U(x_1, x_2, \ldots, x_n)$
- Goal function (max. utilization)

$$Maximize\{f(U(x_i))\} = \sum_{i=1}^{n} w_i U(x_i)$$

- Problem. Fixed significance weights w_i (static analysis)
  → use adaptive prediction



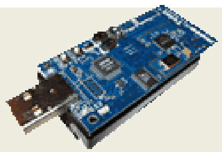
Context Awareness
Adaptive Routing

- Adaptive weights $a_i(x_i)$ related to the variation of the context

$$Maximize\{f(U(x_i))\} = \sum_{i=1}^{n} a_i(x_i)\, w_i\, U(x_i)$$

- Criticality of certain ranges of values, $a_{range_i}(x_i)$
- Predictability of context information, $a_{pred_i}(x_i)$
- Availability of context information, $a_{avail_i}(x_i)$
- also Autocorrelation of data, Kalman Filter prediction techniques

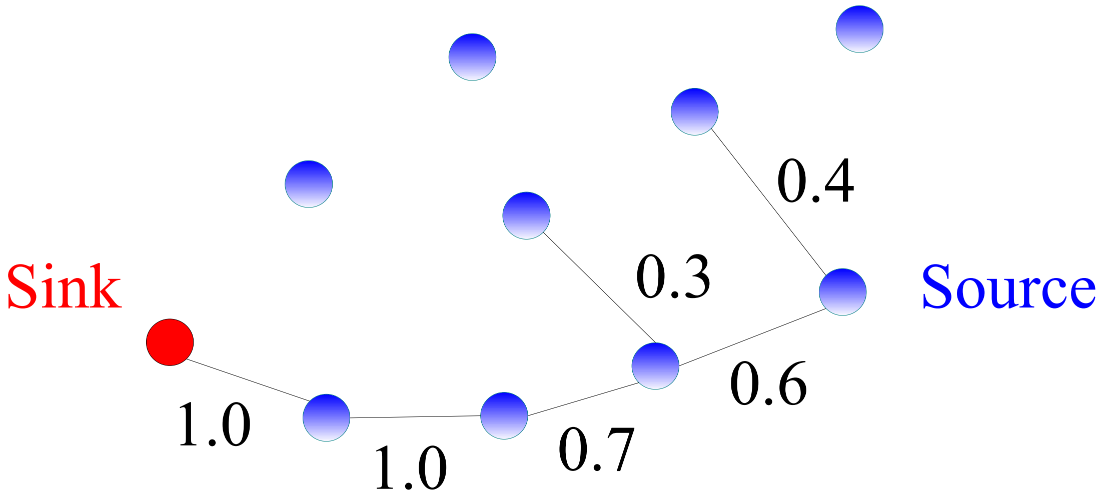
- e.g. If battery of candidate node is depleted faster, find another route



Context Awareness

Example. Predictive routing

- Local decision at each node (max. utilization)



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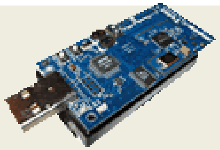
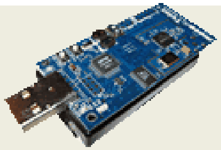


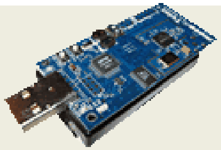
TinyOS
Basic Routing Algorithms

- TinyOS - event based operating environment designed for use with WSN
- Bcast - flooding protocol
  - BS floods "commands" to all the nodes, such as to sleep, wakeup, or set the interval for how often sensors are read
- MultiHopRouter – transfer packets from any sensor to the BS
  - Forms a spanning tree - path from any node to the BS must have the least number of hops over "reliable" links

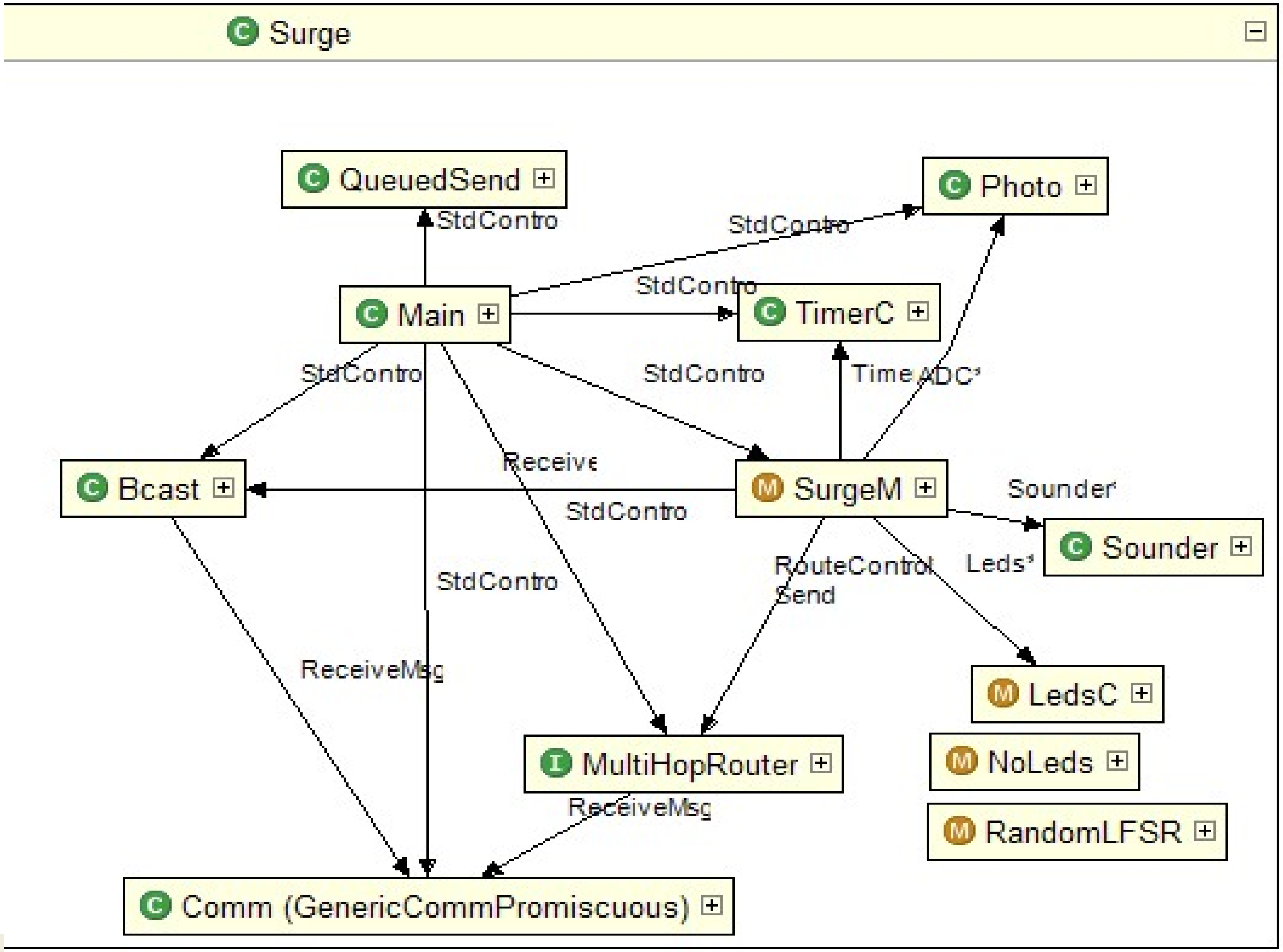


Routing
Surge

- Surge - Basic TinyOS application for multi-hop routing
- Detects the existence of all the motes in a wireless network
- Displays mote information, including the mote ID, the number of messages sent from each mote, etc.
- Displays the topology of network



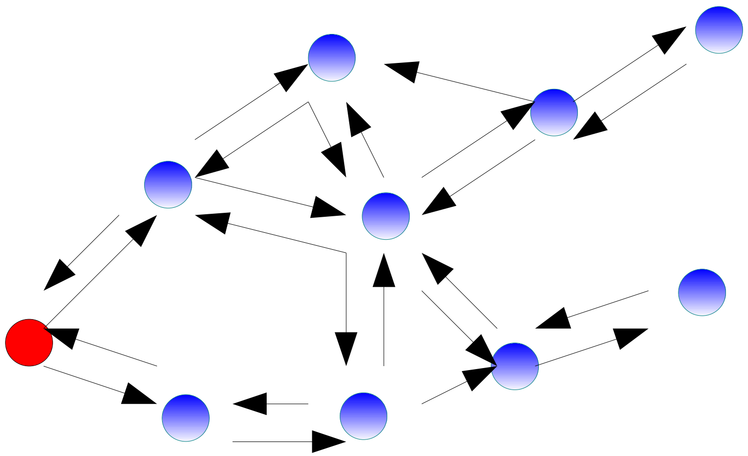
Surge Application Structure



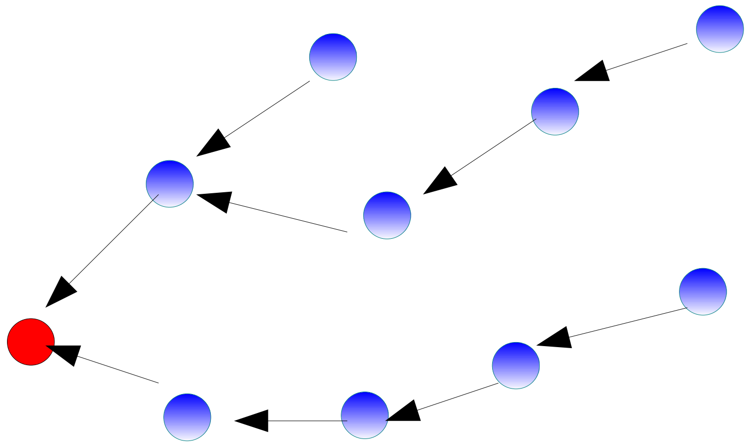
LFSR - linear feedback shift register

Example
Surge

BCast



Multi-hop Routing



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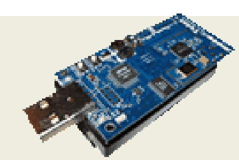
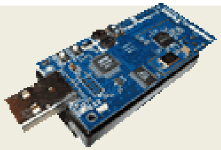


TOSSIM
Introduction

- TinyOS discrete-event simulator
- Key Requirements
  - Scalability, completeness, fidelity, bridging
- TinyViz – Java based, detailed visualization with GUI
- Implemented simulation methods:
  - Selective debugging
  - Radio model – Bit error rate (BER) tables
  - Loss Builder – can generate BER table
  - HW emulation – ADC, clock, Raw radio stack (beta)
  - User can add own plug-ins (e.g. BER table of real environment)

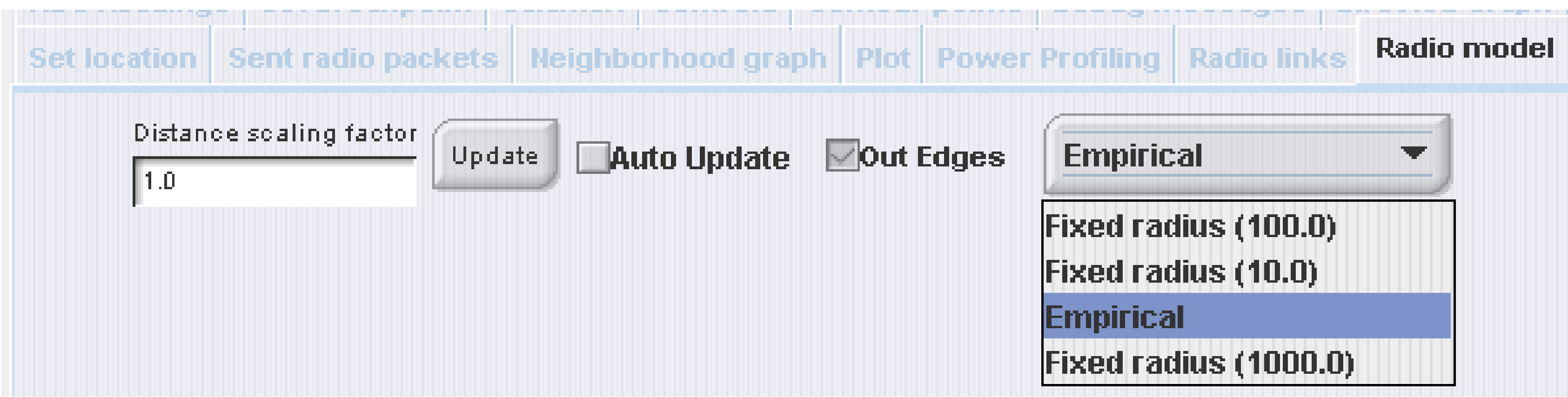
TOSSIM
Radio model

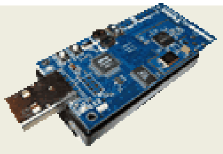
- TOSSIM provides empirical radio model
  - Abstraction of independent BER
  - BER simulated in a random way (scaling considered)
  - Environment is not exploited
  - Simulation of lossy mode allows BER data input



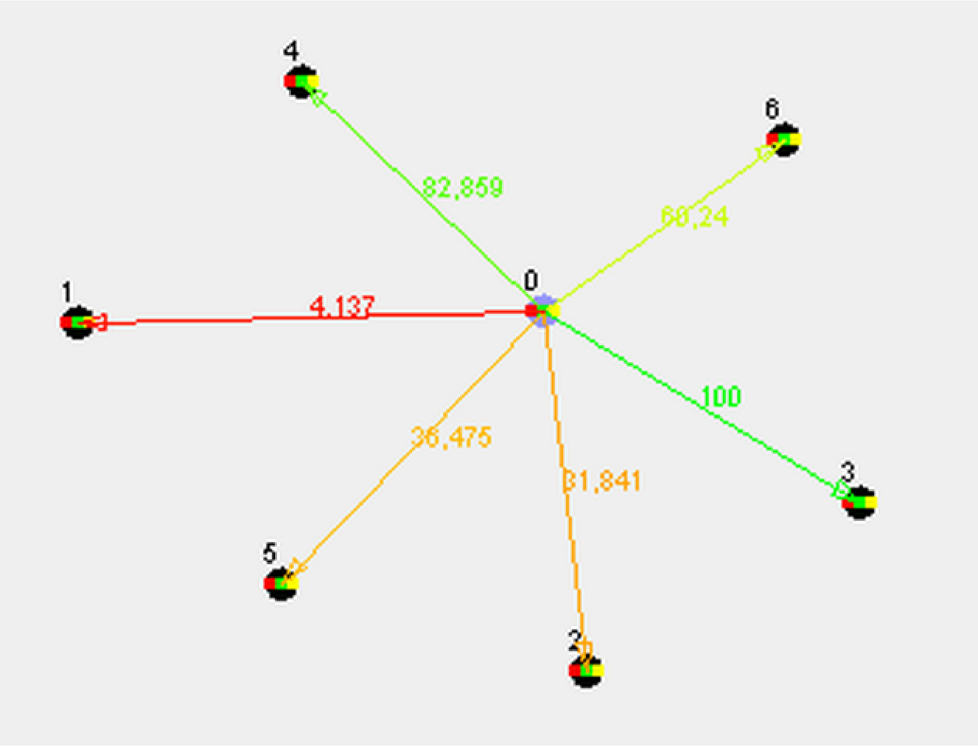
TOSSIM
Radio model (2)

- Simple model
  - All nodes can hear each other
- Lossy model
  - BER data provides information about pairs of nodes
  - Link BER are asymmetric



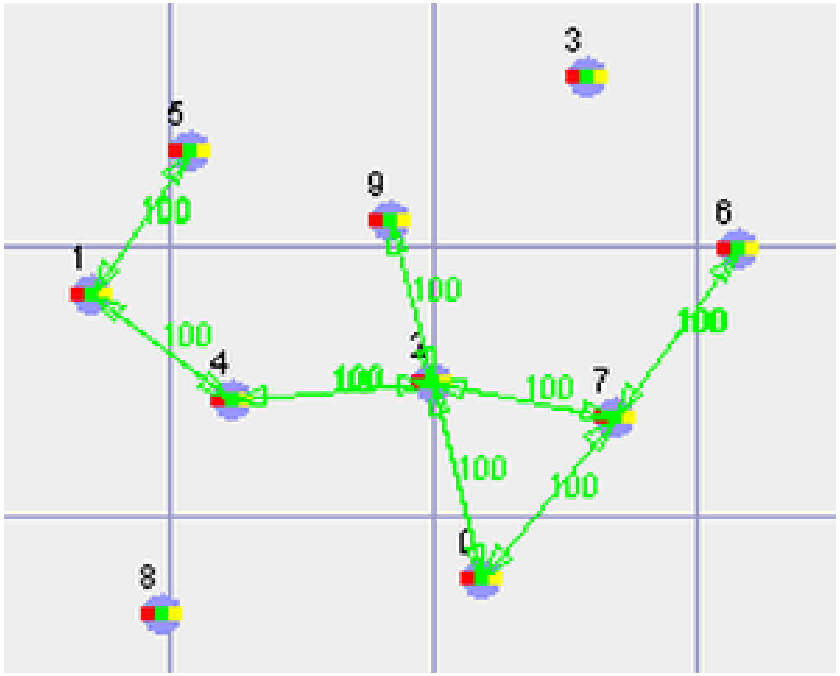


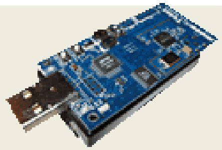
TOSSIM
Radio model (lossy, empirical)



TOSSIM

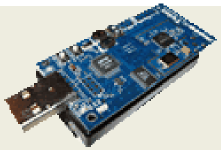
Radio model (lossy, fixed radius 10.0)





BER data file

- Simulation parameters
  - ./build/pc/main.exe **-r**=lossy 5
  - ./build/pc/main.exe **-rf**=mylossyfile.txt 5
- File contents
  - <mote ID>:<mote ID>:bit error rate
<mote ID>:<mote ID>:bit error rate
...
- Example
  - 0:1:0.087
0:2:0.341
1:0:0.092
...
- Mapping from desired radio model possible



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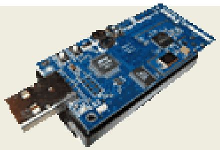


Radio propagation model

Introduction

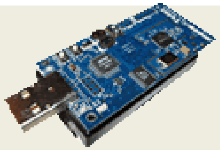
- Radio propagation model of real environment
  - Building plan for processing
  - Path loss and attenuation by walls to be considered
  - Generate input data for TOSSIM simulator

Source:
KLEPAL, M. , PECHAC, P. Prediction of Wide-Band Parameters of Engineering. He received Ms.C. degree in Radioelectronics Mobile Propagation Channel

Radio propagation model
Procedure

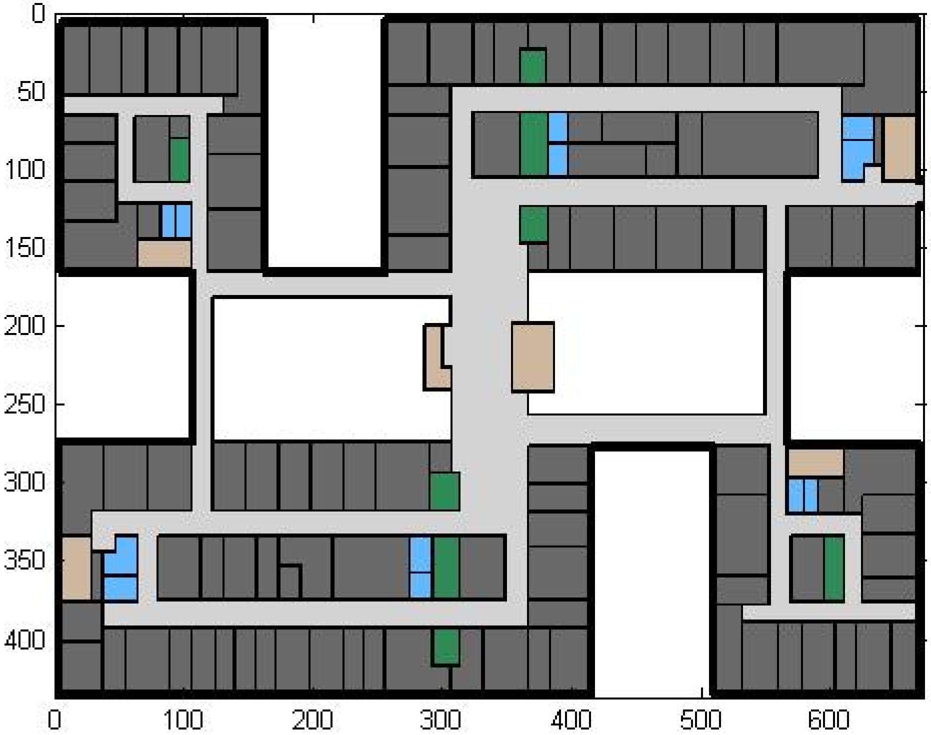
- Input data
  - Environment (building plan or manual setup)
  - Scaling
- Control data
  - Transceiver parameters (gains, power, frequency)
  - Wall attenuation

- Deployment of nodes
- Path Loss calculation
- RSSI calculation and BER mapping



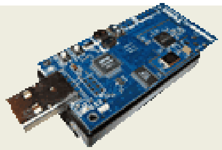
Radio propagation model
Input data

- NW1, 2^{nd} floor
  - Res: 673x437
  - Scale = 7.03



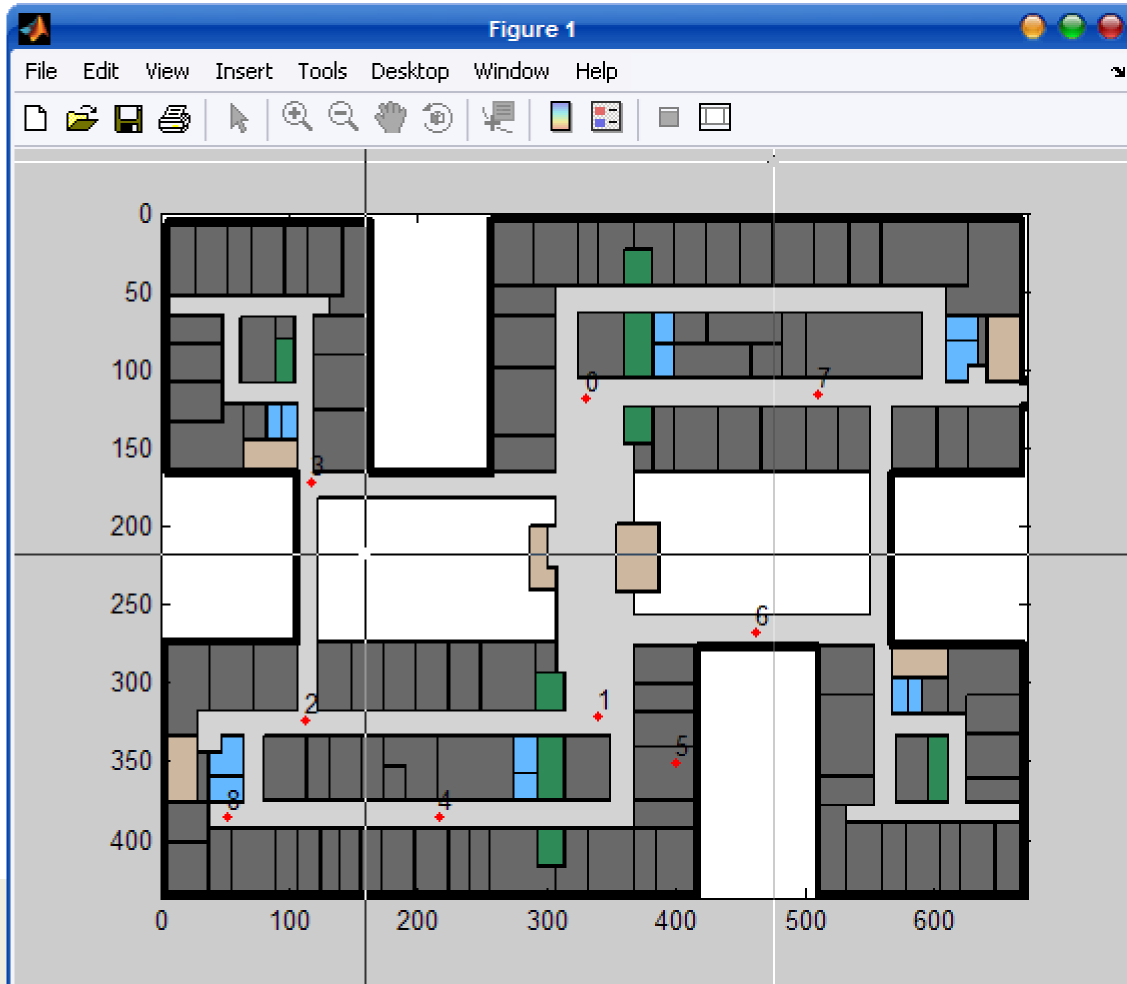
Radio propagation model
Control data

- Transceiver parameters (example)
  - TX power $P_{Tx}=0\,dBm$
  - Frequency $f=2.4\,GHz$
  - TX Gain (spreading) $G_{Tx}=9\,dB$
  - RX Gain (despreading) $G_{Rx}=9\,dB$
  - Receiver sensitivity $S_{Rx}=-95\,dBm$
  - Cable losses, antenna gain, etc.
- Wall attenuation
  - Depends on type of material, thickness, angle
  - Considered thickness only
  - 1x wall element attenuation (internal wall 2x, main 4x) $L_w=3.0\,dB$



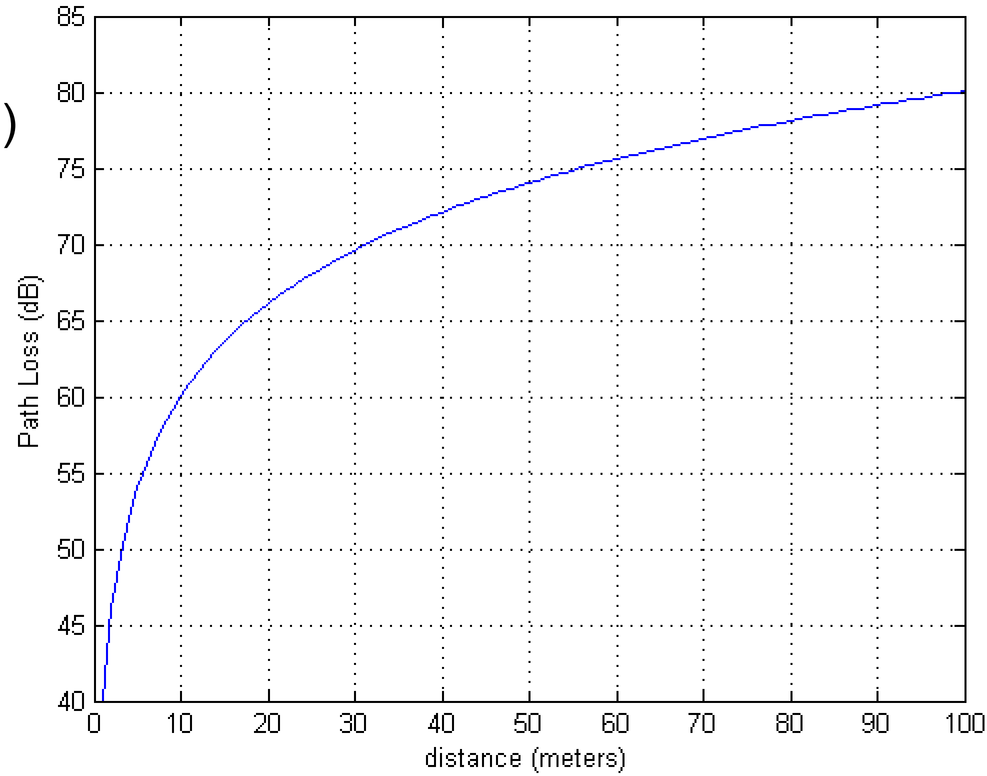
Radio propagation model
Node deployment

- Simply select points with mouse
- Generate deployment file
- File can be imported by TOSSIM
  - Mote locations



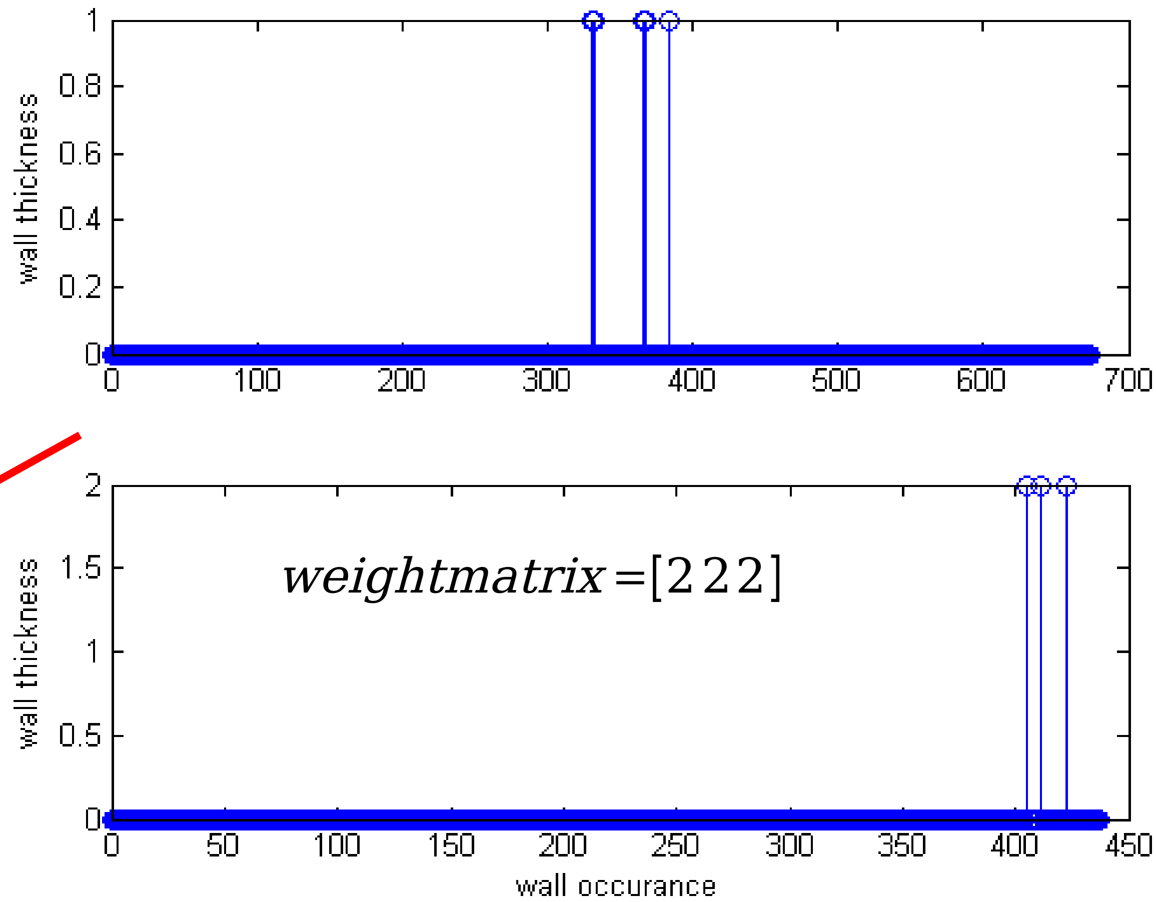
Radio propagation model
Path loss

- Radio signal decreases with distance
- Path loss $L(d) = L_0 + 10n \cdot \log(d) + \sum_{i=1}^{N} k_{wi} \cdot L_{wi}$
  - Free space, wall part
  - L_0 Reference loss of 1m (dB)
  - n Power decay factor
  - k_w Number of walls of type i
  - L_w Wall attenuation (dB)
  - d Distance (m)



Radio propagation model

Wall count and thickness



Radio propagation model
RSSI and BER

- RSSI – Received Signal Strength Indication

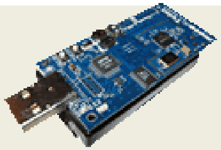
$$RSSI = P_{Tx} + G_{Tx} + G_{Rx} - L(d)$$

- Bit Error Rate (BER)

$$P_b = \frac{1}{2} \cdot erfc\left(\sqrt{\frac{RSSI}{N}}\right)$$

- Total loss limits coverage

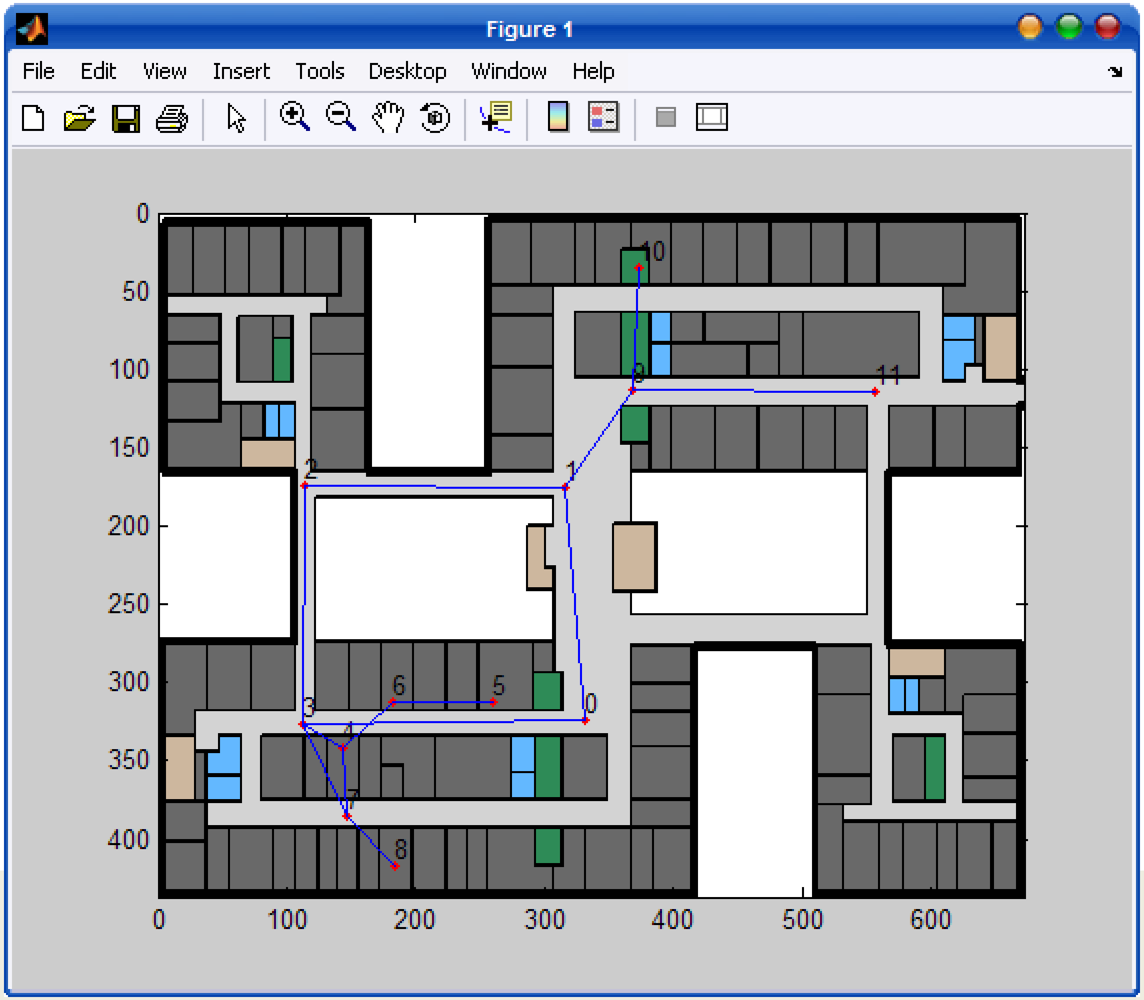
$$\forall\, RSSI < S_{Rx} \rightarrow P_b = 1.0$$



Radio propagation model

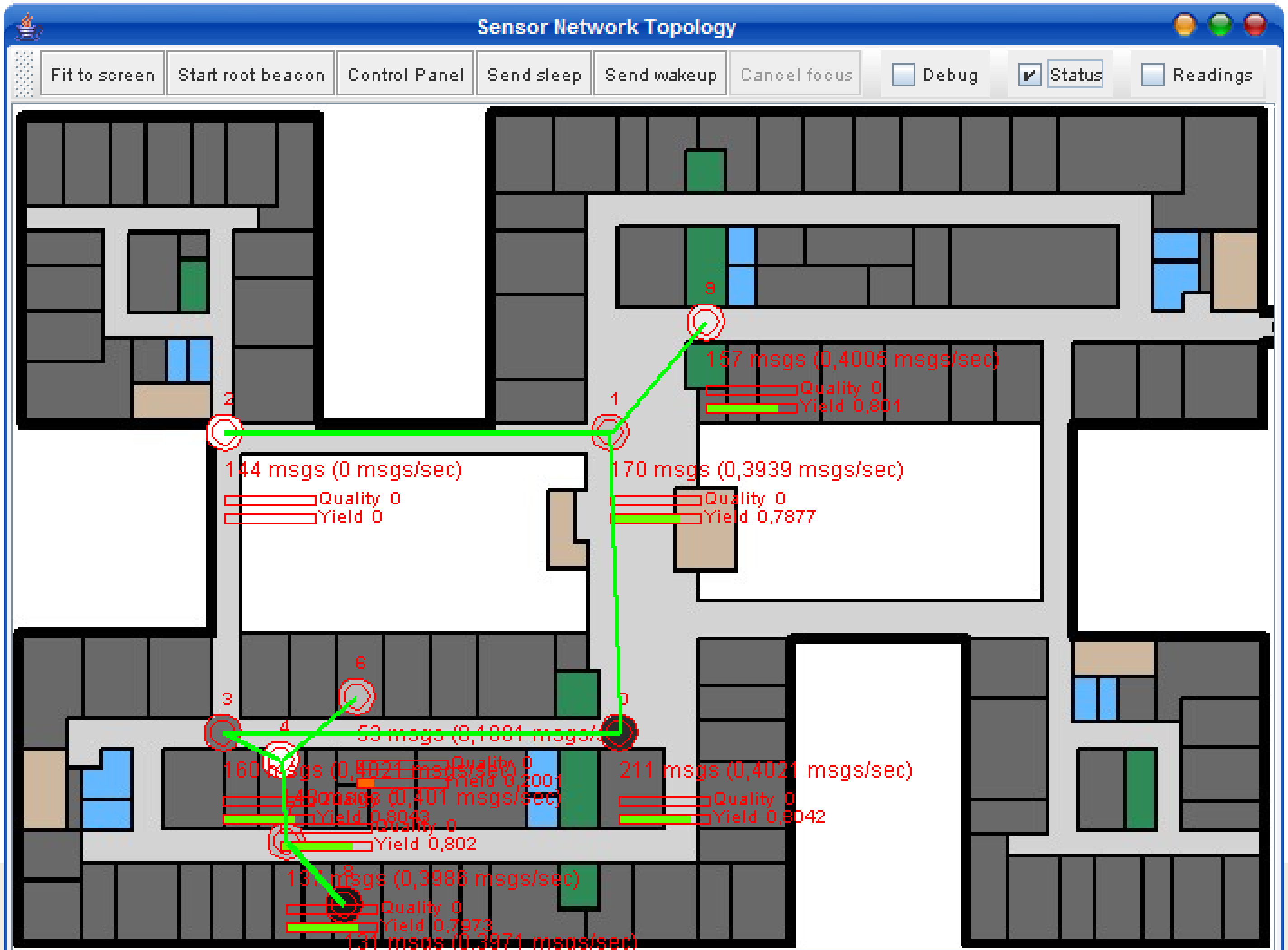
Final Topology. Matlab

- Resultant topology
- Threshold BER = 0.25

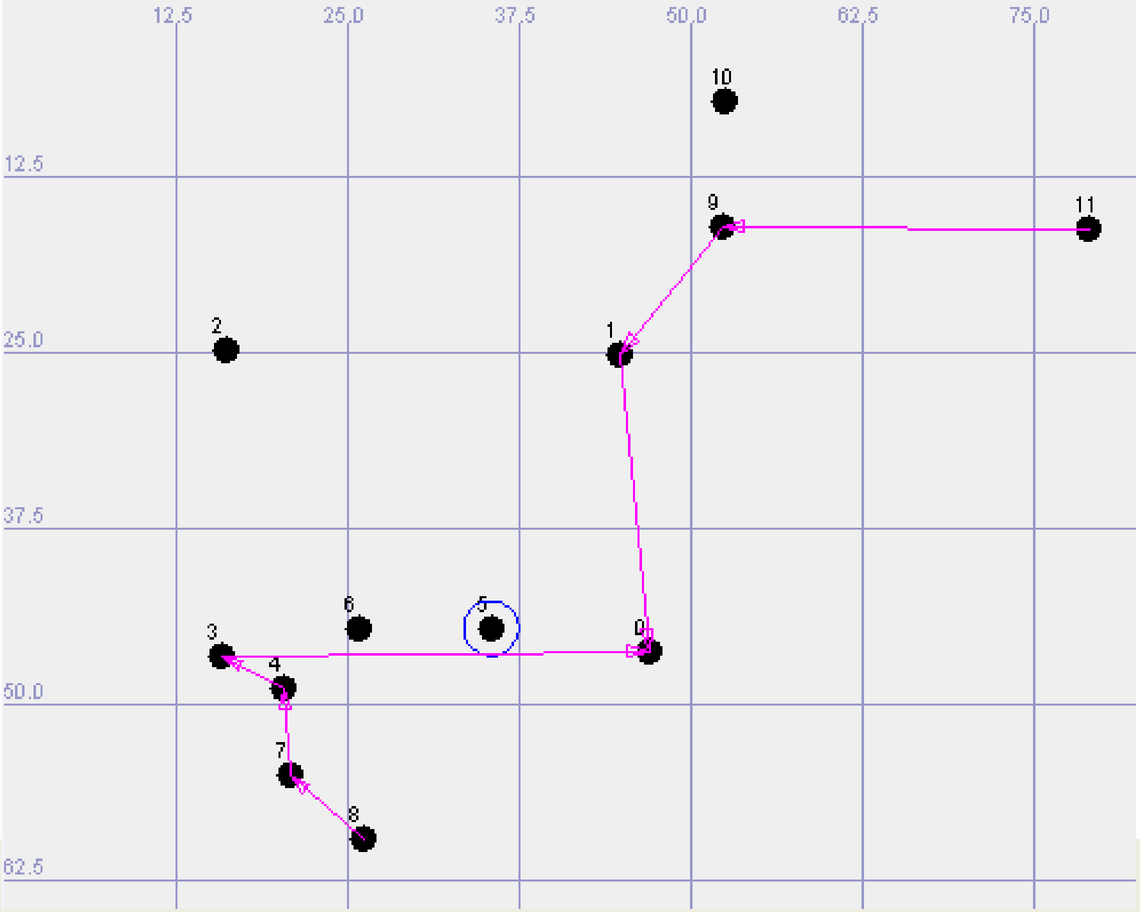


Radio propagation model

Final Topology. Surge



Radio propagation model
Final Topology. TOSSIM (TinyViz)



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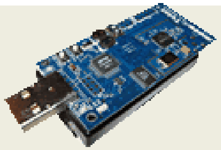
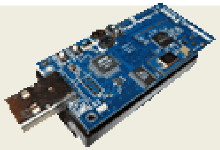


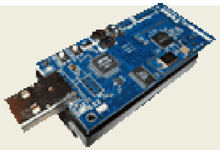
Results and Conclusions

- Radio propagation model output results are comparable to TOSSIM simulation
  - Model approximation enough for TOSSIM
- Environmental data includes information only about wall structure
  - Detailed building plans are necessary
- We exploit infrastructure context information
  - Power awareness (signal strength)



Results and Conclusions (2)

- Simulation is static
  - Dynamic models are complicated. Adaptive are more complex when more context attributes must be considered
- Model could be used for radio planning
  - Analysis of possible mote deployment



Thank You! Questions?