Positioning in Ad-Hoc Networks

- A Channel Model for Low Power Data Transmission

Jan Beutel
Computer Engineering and Networks Lab
Swiss Federal Institute of Technology (ETH) Zurich

June 15, 2001
Outline

• Sensor Networks
• Radio Channel
• Propagation Channel
• Simulation using ETH Raytracing Tool
• Some RSSI Sample Data
• First Positioning Results
Sensor Networks

- Ad-Hoc network of many sensors, monitors and actuators (>100 total)
- Vision of system on a chip
- No infrastructure
- Deployable in different environments
- Limited radio range
- Node clusters and depletion

Goal: Ultra Low Power
Radio Ranging Methods

TOA - time of arrival

TDOA - time distance of arrival

AOA - angle of arrival

Signal strength

Carrier phase
Radio Frontend Requirements

- Simple direct down-conversion frontend
- Emphasis on digital processing ($\mu$J vs. pJ per Bit)
- Mostly sleepy radio (receiver)
- Tx power scalable (Wolisz et al.)

- CMOS SOC’s -> 2.4 GHz / 5 GHz
- $P_{Tx} < 0$ dBm

- RSSI used in transceivers for carrier sensing
  -> available at no cost
- Possibly separation of multi-path and multi-access through advanced baseband processing (RAKE)
Propagation Channel in Mixed Environments

- Mechanism: Reflection, Diffraction, Scattering

- Transmission through a wall:
  - up to 6-10 dB at 2.5 GHz -> walls are not transparent
- Received signal strength for low power at $1/r^3$ to $1/r^4$. In commercial space, e.g., supermarkets, Lucent measured $1/r^{3.8}$ at 2.5 GHz. (Source G. Wright, Lucent)

- High impact of geometry on overall picture
- Local impact of material fluctuates statistically

- Models are highly specific or give average overview
Received Signal Strength

- Multi-path vs. LOS components
- Delay and AOA reflect geometry (large scale)
- Fading
- Amplitude influenced by dielectrics, angle of incidence and polarization

- Multiple access interference, depending on CD/TDMA scheme

- Around $\lambda/2$ spacing, signal strength variation may be as high as 30-40 dB (small scale fading)
Tools for Simulation: Raytracing

- Exact modeling of LOS path and reflections
- Differentiating
  - Order of reflections
  - Geometry
  - Material
  - Polarization
  - Delay and AOA
  - Amplitudes
  - Power Spectrum Densities

- Raytracing tool developed by J. Hansen
Power Density: Polarization

- Transmitter located at ceiling
- Arbitrary location receiver
Power Density: Windows

- Small window (0.7 x 0.8) in wall
- Windows behave like walls
Power Density: Room Size and Layout

- Transmitter fixed in middle of Z axis
- Guidance effect of very long room
Bluetooth RSSI Samples Free Space

Samples/Distance
Bluetooth RSSI Samples Office Space

![Graph showing Bluetooth RSSI Samples Office Space](image-url)
Wavelan 802.11b RSSI Samples
Wavelan 802.11b Indoor Environment
Redundant Triangulation

Iteration on 25 individual ranges with 50% each

Delaunay Mesh of 25 Networked Nodes

Solution on 25 Ranges and 50% Error

50 Solutions and Mean

Zoom on Error

1% error
Triangulation on Real Data

- Application to Wavelar RSSI data shows good average

Solution
- Iterative triangulation
- Overload systems
- Influence of geometric DOP
- Include environmental information

Yielding sub meter DOP
Literature