UWB Ranging in Dense Multipath Environments

Joon-Yong Lee
UWB Radio Laboratory
University of Southern California
Potentials for Ranging

- Multipath immunity
  - 100~1000 times finer time resolution than conventional narrowband

- Penetration capability
  - Low center frequency for a given bandwidth

- Potential applications
  - Communication+location, tracking RF tags, …
Fine Range Resolution

UWB ambiguity function of a single pulse
Fine Range Resolution

UWB ambiguity function of time-hopped pulses
Test Site (Basement, EEB, USC)
Measured Signals

[Diagram showing a floor plan with labeled points and graphs displaying signals over time (ns).]
Direct Path Detection Using GML Estimation

\[ r = \rho_d \cdot s_\delta + \sum_{k=1}^{M} \alpha_k s_{\beta_k} + n \]

\[ \hat{\delta} = \arg \max_{\delta} \left[ \max_{\rho_d, M, \alpha, \beta} f(r | \delta, \rho_d, M, \alpha, \beta) \right] \]
Direct Path Detection Using GML Estimation

\[ \theta^{\delta} \]

Time (ns)
Propagation Test for Statistical Modeling

- 622 samples of signals taken with a blocked LoS
Statistical Modeling of Critical Parameters – Marginal Densities

Exponential fit for $\delta$

Lognormal fit for $\rho$
Statistical Modeling of Critical Parameters – Joint Density

- Independence between $\delta$ and $\rho$ was tested using $\chi^2$ test.
Ranging Errors

- Direct path
- Early false alarm error
- Missed direct path error
- Excess propagation delay
ToA Estimation Errors

$P_{FA}$

$P_M$
Threshold Setting

\[ P_{FA} + P_{M} \text{ is minimized} \]

\( P_{FA} \) and \( P_{M} \) for different SNR values.
Test Result (Location 13)

Expected ToA assuming the presence of a clear LoS

Time (ns)
Range Estimation Errors

![Graph showing range estimation errors](graph.png)
UWB Ranging System
Two-Way Ranging Scheme

\[
\tau_{\text{prop}} \approx \frac{\tau_{\text{round}} - T_M/2 - \tau_{\text{off,1}} - \tau_{\text{off,2}}}{2}
\]
More Issues

- Detection of LoS blockage
- Estimation of the excess propagation delay in LoS blockage
- Clock synchronization
- Utilization of a reasonable channel model for the refinement of ranging algorithm