Distributed Positioning in Ad-hoc Networks

Jan Beutel – Computer Engineering and Networks Lab, ETH Zurich

**Distributed Positioning – The Problem**

Mobile ad-hoc networks made up of many nodes have many attractive applications for distributed positioning ranging from ubiquitous context-aware applications to location-aware protocols [KWZ2002] for routing and network management.

Connectivity
- Local Connectivity Information: Next Neighbor Graph

Relative Positioning
- Exchanging Connectivity Information: Topology Graph
- Range Estimates: Weighted Topology Graph
- Distributed Triangulation: Relative Position Information

Absolute Positioning
- Reference Positions: Absolute Position Information
- Map Databases: Absolute Position Context

Convergence issues in distributed positioning are twofold:

**Initial Startup Convergence**
- Initialization requirements:
  - Graph degree, high connectivity, topology
  - Range error
  - Mobility

**Update Accuracy Convergence**
- Amount and duty cycle of data transfers
- Local storage size and computation requirements
- Network connectivity and MAC layer issues


**TERRAIN: A Cooperative Ranging Algorithm for Positioning in Multihop Ad-Hoc Networks**

The TERRAIN algorithm has been proposed [SBR2001] to support absolute positioning in a multihop environment with sparsely located anchor nodes.

Cooperative Ranging exploits the high connectivity of ad-hoc networks. Triangulation solutions are formulated as a set of linear equations

\[
(X_i - U_x)^2 + (Y_i - U_y)^2 + (Z_i - U_z)^2 = R_i^2
\]

and each solved as a MMSE problem.

- A number of distributed local optimization problems converge to a global solution by interaction
- Integrates nicely with routing
- Distributed load on limited resource nodes
- Enabler for geographic routing [KWZ2002]


Range Estimate Quantization – Range estimates are known to be inaccurate and highly variable.

- How good can we get without dedicated hardware?
- Bounding to \( R_i \leq R_{\text{max}} \)
- Limit on quantization steps

Overdetermined Sets of Linear Equations – Ad-hoc networks generally exhibit high local connectivity.

- Exploit connectivity to do better than cell based systems, like GSM.
  - Enforcing more connections than routes
  - Strongly overdetermined MMSE
  - Heuristics and filters

Geometric Dilution of Precision – Situations like the ones shown on the right have poor GDOP resulting in very large errors.

- Selection of triangulation partners:
  - Equal length, equally distributed anchors
  - Variable radio ranges

Network Topology – Highly populated networks can establish different network topologies.

- Corner, edge, center area detection
- Use different weighting metrics in computation

Open issues:
- How to detect and treat obstacles?
- Mobility
- Convergence bounds

**NetSim: A MANET Simulation Framework for Large Distributed Topologies**

The existing approaches for network simulation are based on low level event driven models of networking and physical layer functions [NS-2, GloMoSim, Opnet, Matlab] and target the detailed statistical analysis of very specific functions. They are quite insufficient when it comes to large network extents and topologies such as envisioned for wireless sensor networks.

- Designed to cope with very large multihop networks
- Every node is implemented as single instance
- Different communication mechanisms
- Support for mobility
- Detailed analysis and logging capability
