A Comparative Study of Mobility Prediction Schemes for Grid Location Service (GLS)

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http://nile.usc.edu/~helmy/GLSPrediction/grp1.html

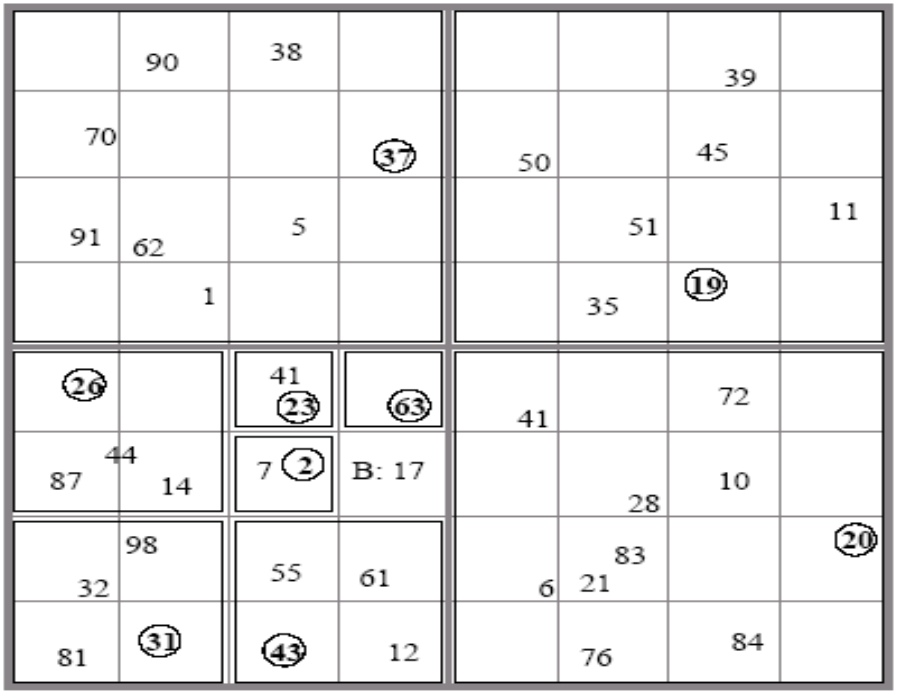
Grid Location Service (GLS)*

– Distributed based on geographic location information

–Grid-like structuring of the ad-hoc network (scalable)

–Each node updates its location servers

–Density of Location Servers reduces away from node



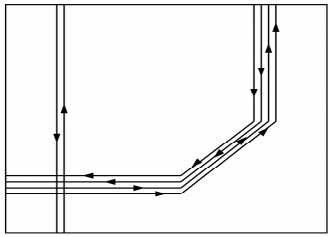
Problem and Approach

- Errors in location information with GLS
  - Low frequency of location update to higher order location servers
  - Query to a location server fails when a node moves far away from its previous location (mobility-induced errors)
- Need **more accurate location information**
- Prediction can help improve performance by reducing errors
  - Implemented in Location Servers
- Prediction of
  - Location Coordinates
  - Grid ID of the node's location

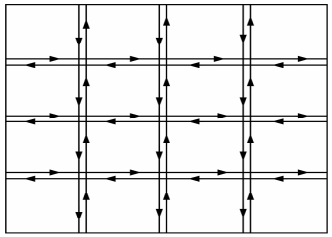
* J. Li, J. Jannotti, D. DeCouto, D. Karger, R. Morris, "A Scalable Location Service for Geographic Ad Hoc Routing, *ACM MOBICOM* 2000

GLS Query Loss Analysis

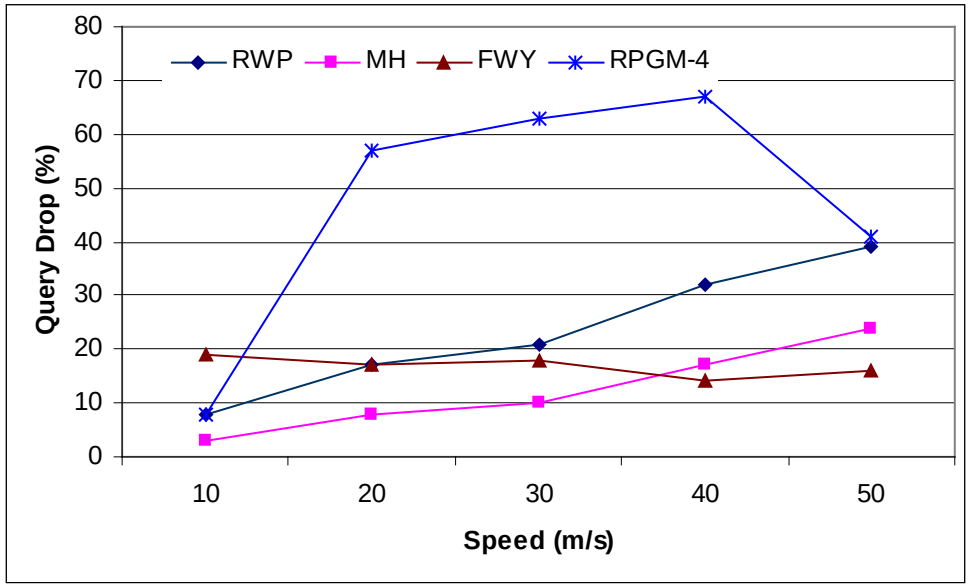
- Mobility Models (IMPORTANT Mobility Tool*)
  - Freeway (FWY) - Manhattan (MH)
  - Random Way Point (RWP)
  - Ref Point Group Mobility (RPGM) - 4Grps
  - Trace-based Mobility Pattern (in progress)
- Simulation Parameters
  - Nodes: 100, Node speed (10m/s – 50m/s)
  - Simulation Area (1000m x 1000m)



(a) Freeway Model



(b) Manhattan Model

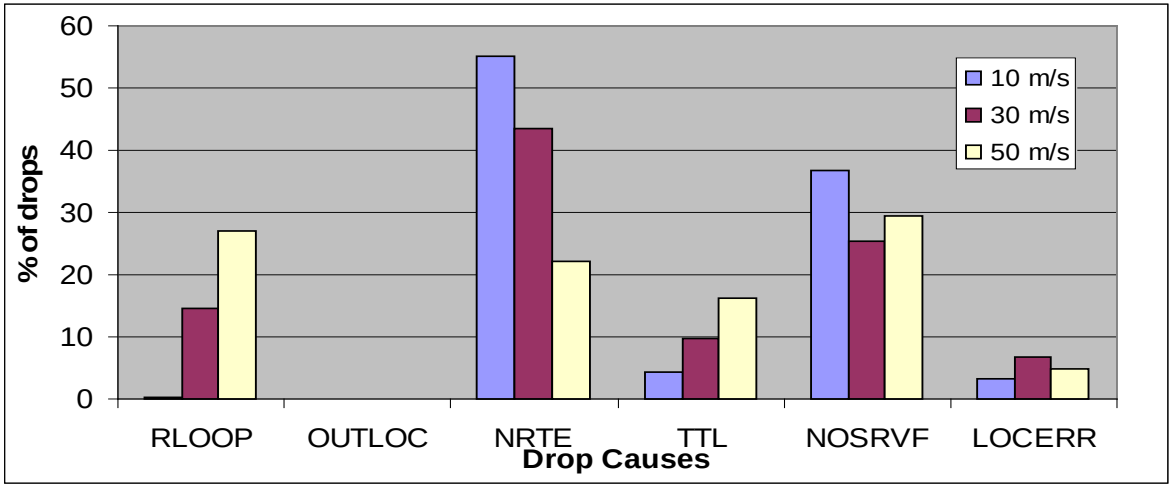


Analysis

- Query drop varies widely with mobility pattern
- Observed up to ~20% drop (10m/s) and ~70% drop (at 40m/s)
- Main causes of query drop
  - RWP: mobility-induced location errors
  - RPGM: clustering of groups and network partitioning
  - FWY: non-grid-like map
  - Many drops due to voids

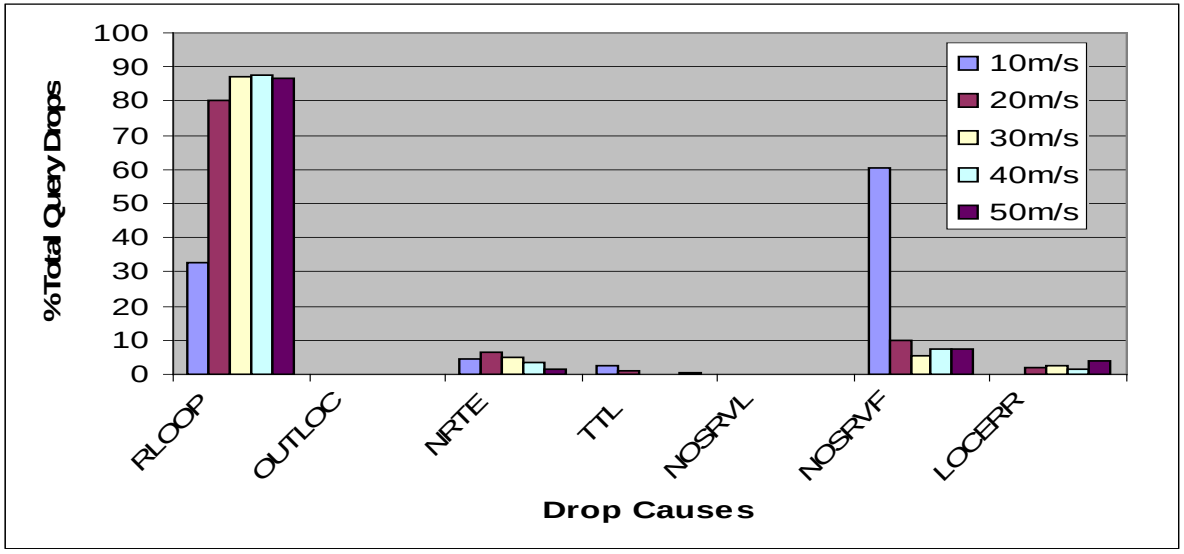
* F. Bai, N. Sadagopan, A. Helmy, "The *IMPORTANT* Framework for Analyzing the Impact of Mobility on Performance of Routing for Ad Hoc Networks", IEEE Infocom 2003 (*nile.usc.edu/important*)

GLS Query Failure Analysis



Random Way-Point

Query drops rise from 8% at 10m/s to to 40% at 50 m/s. Main reasons for drop are the mobility-induced RLOOP and TTL drops.

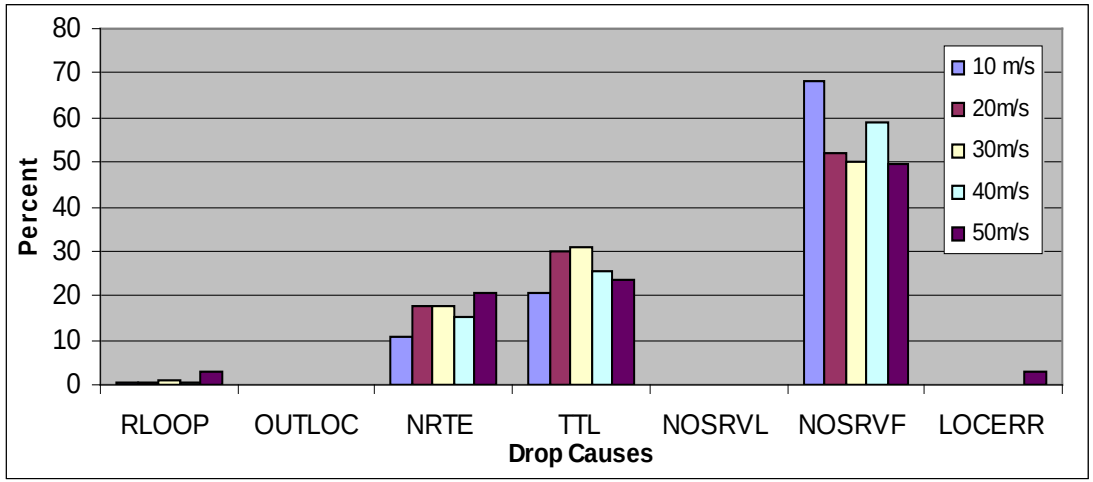


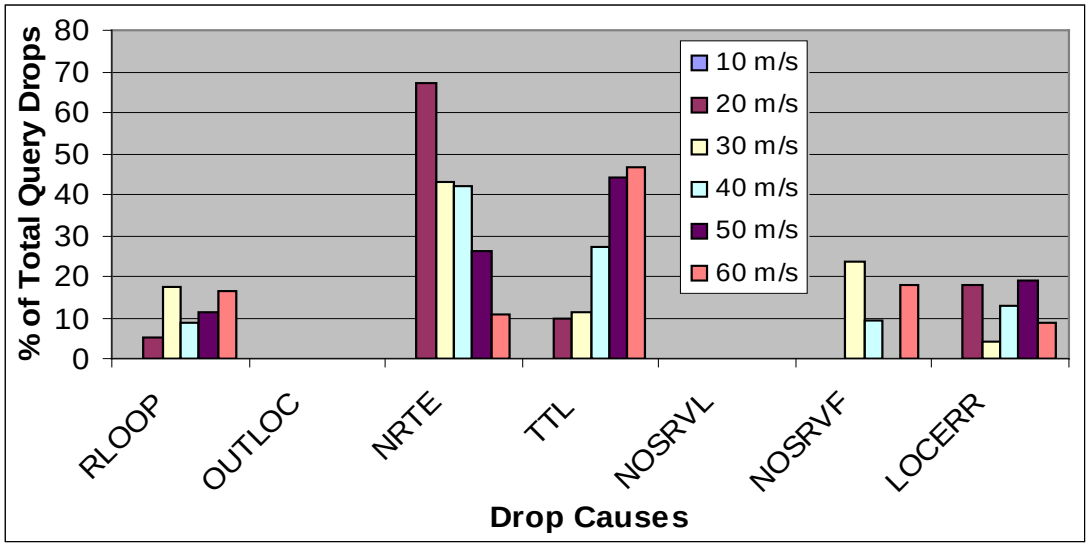
Manhattan

Query drops rise from 3% at 10m/s to to 25 % at 50 m/s. At higher speeds (above 20m/s), more than 85% of drops occur due to RLOOP. Other drop reasons stay relatively constant.

- RLOOP - Routing Loop detected, NRTE – No Route due to voids, TTL - Time-to-Live expired
- NOSRVF – No Location Server, OUTLOC - Outdated destination location
- LOCERR - Outdated location of location-server

GLS Query Failure Analysis





Freeway

- Key feature is geographic restrictions, more severe than the Manhattan model.
- Query failure rate stays between 15-20% across the speed range. Inability to find a location server is the major reason for query failures.

RPGM - 4 Groups

- At higher speeds (above 20m/s), query failure rates of about 60% are observed, mainly due to TTL drops.
- Communication pattern (inter group or intra group) has major impact on query failure rate; a query to find a target node in the same group is more likely to be successful than a query for a node in a different group.

Mobility Predictions Schemes

Velocity Based Prediction

- Linear Velocity Prediction (LVP)
  - Speed Estimation
    - $S_x=(X_k - X_{k-1}) / (t_k - t_{k-1})$,
    - $S_y=(Y_k - Y_{k-1}) / (t_k - t_{k-1})$
  - Location Estimation
    - $X_{est}=X_k + S_x \times (t_{k+1} - t_k)$
    - $Y_{est}=Y_k + S_y \times (t_{k+1} - t_k)$
- Weighted Velocity prediction (WVP)
  - $S_{x\_ave} = \alpha S_{x\_ave} + (1- \alpha) S_x$
- Intelligent Map Based*

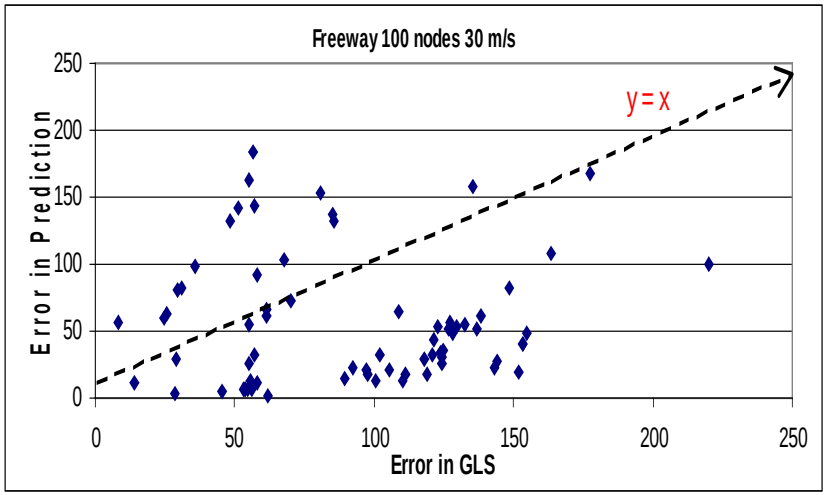
History Based Prediction

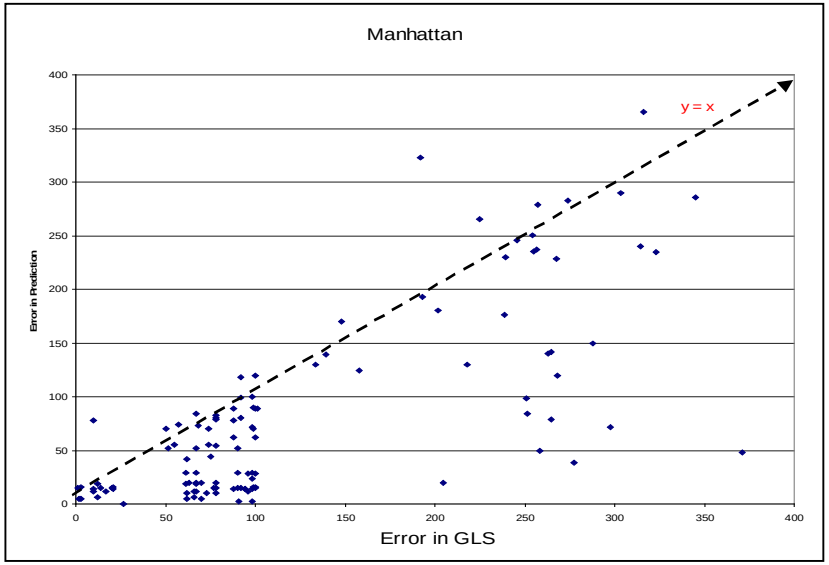
- O(1) Markov Recent History Based
- O(2) Markov Recent History Based*

- RLOOP and OUTLOC can be reduced with prediction
- TTL and NRTE can be reduced using face routing

* Future Work

Comparison of Location Errors



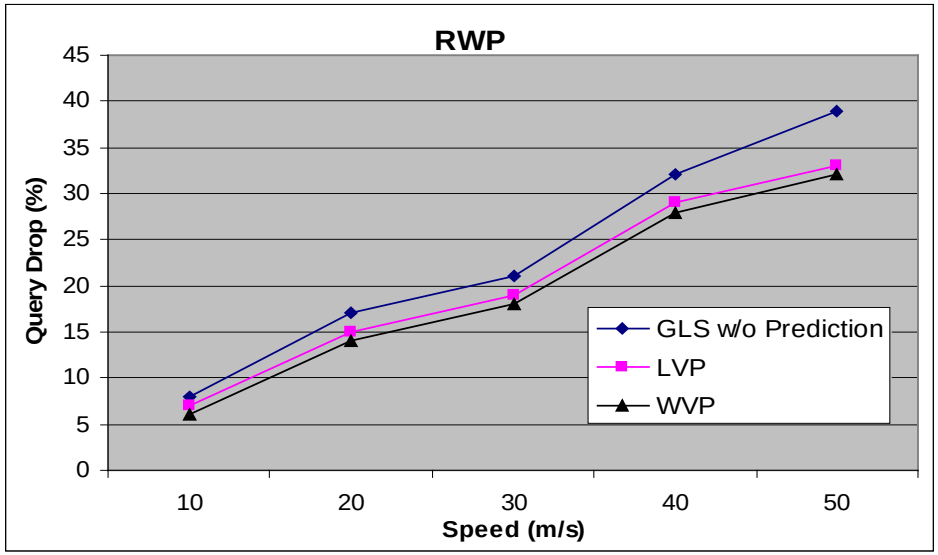


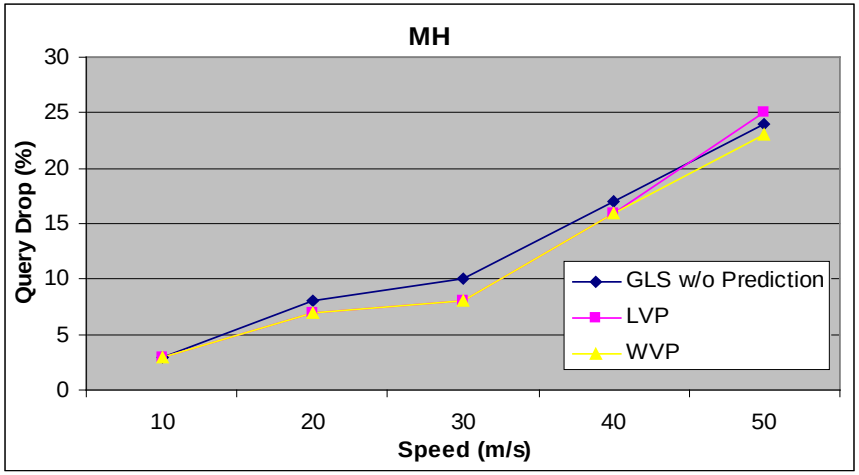
- Graphs show errors in GLS vs predicted location values using LVP
  - The x and y-axes the errors in location returned by GLS and the linear velocity-based (LVP) predictor, relative to the ns GOD object.
  - Points below the y=x line signify predicted value being better than the GLS location value.

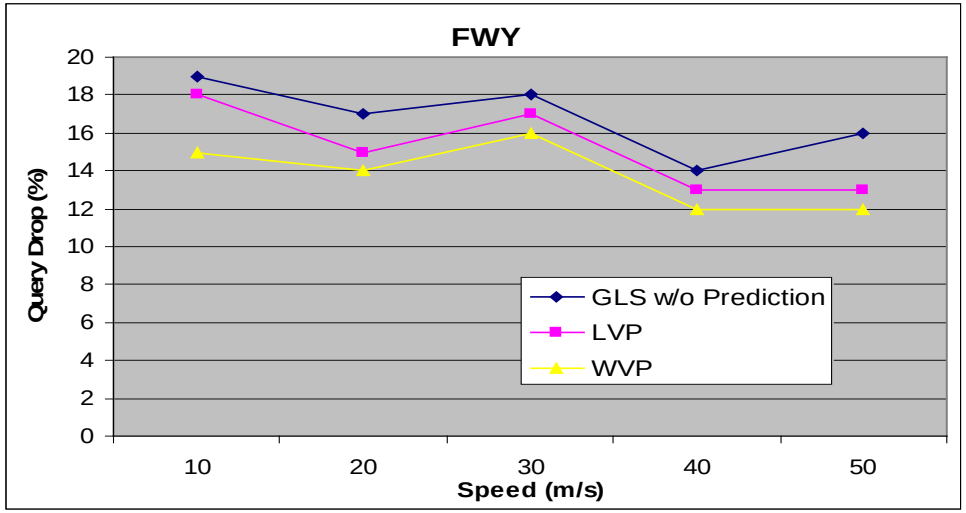
	RWP	MH	FWY
Scenarios Improved	64-70%	57-59%	68-72%

Prediction can improve location accuracy. But does this lead to improved query success rate?

Comparison of Query Errors







- WVP performs better than the LVP and GLS without prediction
  - LVP is affected by transient changes
  - WVP uses smoothed estimates to dampen effects of transients and dynamics in velocity
- Max improvement less than 10% even for high speeds
- Main problems occur due to greedy forwarding (cannot be corrected using prediction at the location servers)
- Manhattan and Freeway models geographically restrict mobility. Knowledge of map, streets, may help improve location accuracy even further. (under investigation)
- O(1) Markov recent history-based Grid prediction shows minimal improvement due to coarse granularity

Work in Progress

- Map based velocity prediction
  - Use geographic restriction information to validate predicted locations
- O(2) Markov Model
  - Use recent history for string/pattern search.
  - Expected to provide better matching and improves performance for recurring mobility patterns.
- Improvement in granularity of grids using sub-grids
  - Break down the GLS grid into smaller sub-grids and store patterns for those in order to provide a better granularity for prediction using history based schemes.