Location Services for Ad-Hoc Networks

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Outline

- Introduction
- Problem
- Characteristics of Location Services
- Solution Space Review
- Overview of Selected Approaches
- Summary
- Questions

Introduction

- *Position-Based* routing protocols:
  - use physical location of destination node to turn global routing into a local decision.
    - Examples of progress based algorithms: Greedy, DIR, MFR [S2]
  - scale with increasing network size [LCN][C];
  - have reduced overhead in comparison to position-less protocols [C][SPHL];
  - can operate without memory;

Problem

- In order to route, the source node S needs accurate position of destination node D.
- This requires a *location service* beneath the routing layer that provides the following service primitives [SQ][SP]:
  - Node position registration;
  - Node position update;
  - Node position location;

Location Service Characteristics

- An effective location service:
  - must be scalable (hinges on position discovery and maintenance overhead [SPHL] [DPH][SP]);
  - must be robust to changes in network topology [DPH];
  - should itself operate using position based routing [DPH];

Solution Domain

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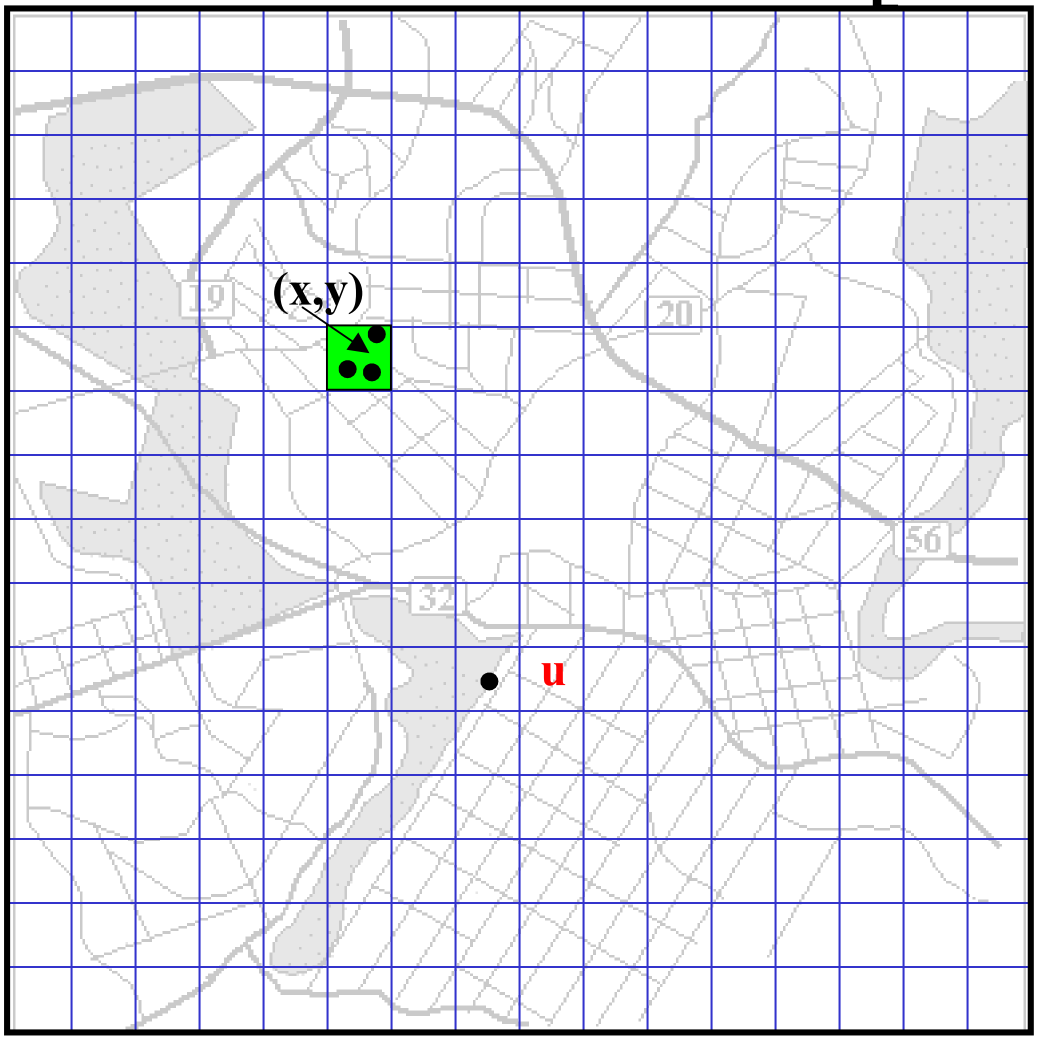
SLURP [WS]

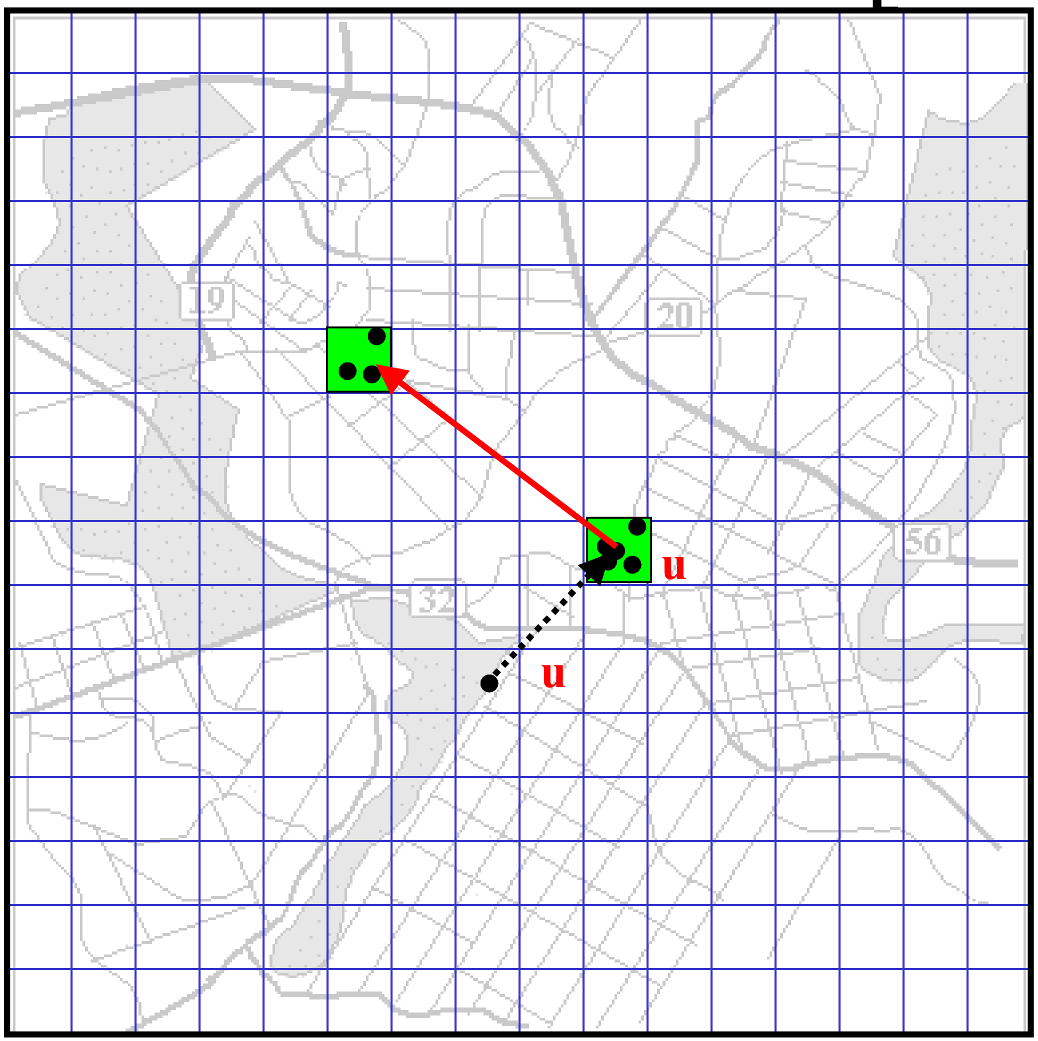
- **SLURP**: Scalable Location Update-Based Routing Protocol [WS].
- Simplest "home region" implementation [YLZ];
- Home Region (HR) for each node is derived by hashing Node IDs to (x,y) coordinates.
- One HR for the entire network.

SLURP [WS]



- Geographical area divided into "grid squares".
- Node **u**'s ID is hashed to produce (x,y) location.
- All nodes in square containing (x,y) are responsible for maintaining position location of **u**.

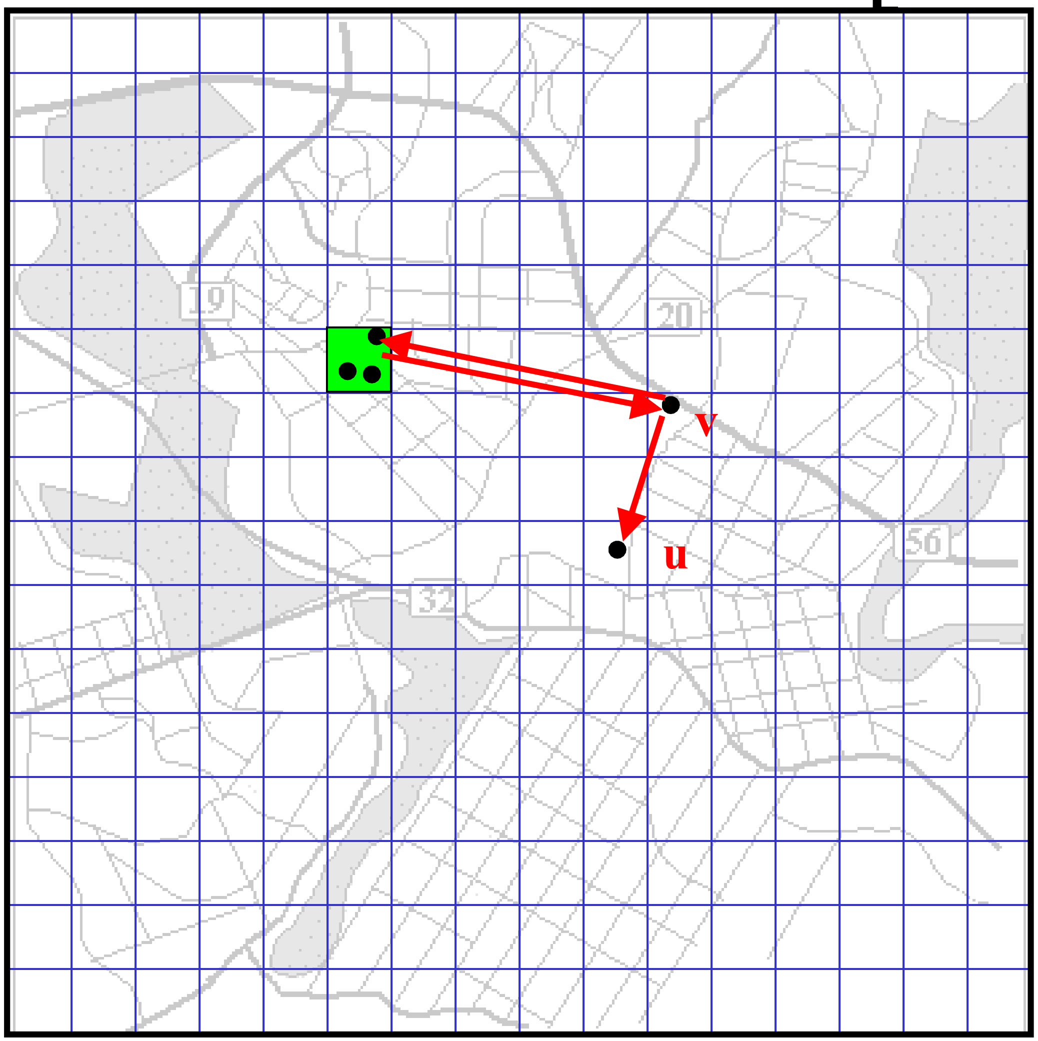
SLURP [WS]



Position Update:

- Node **u** moves.
- **u** sends position update packet.
- u queries all nodes in square to find out what nodes it must keep position info for.

SLURP [WS]



Position Location:

- Node **v** wishes to locate **u**.
- **v** determines HR from ID of **u** and hash and then unicasts location request.
- The first node in HR to receive unicast returns location.
- **v** unicasts towards **u**.

SLURP [WS]

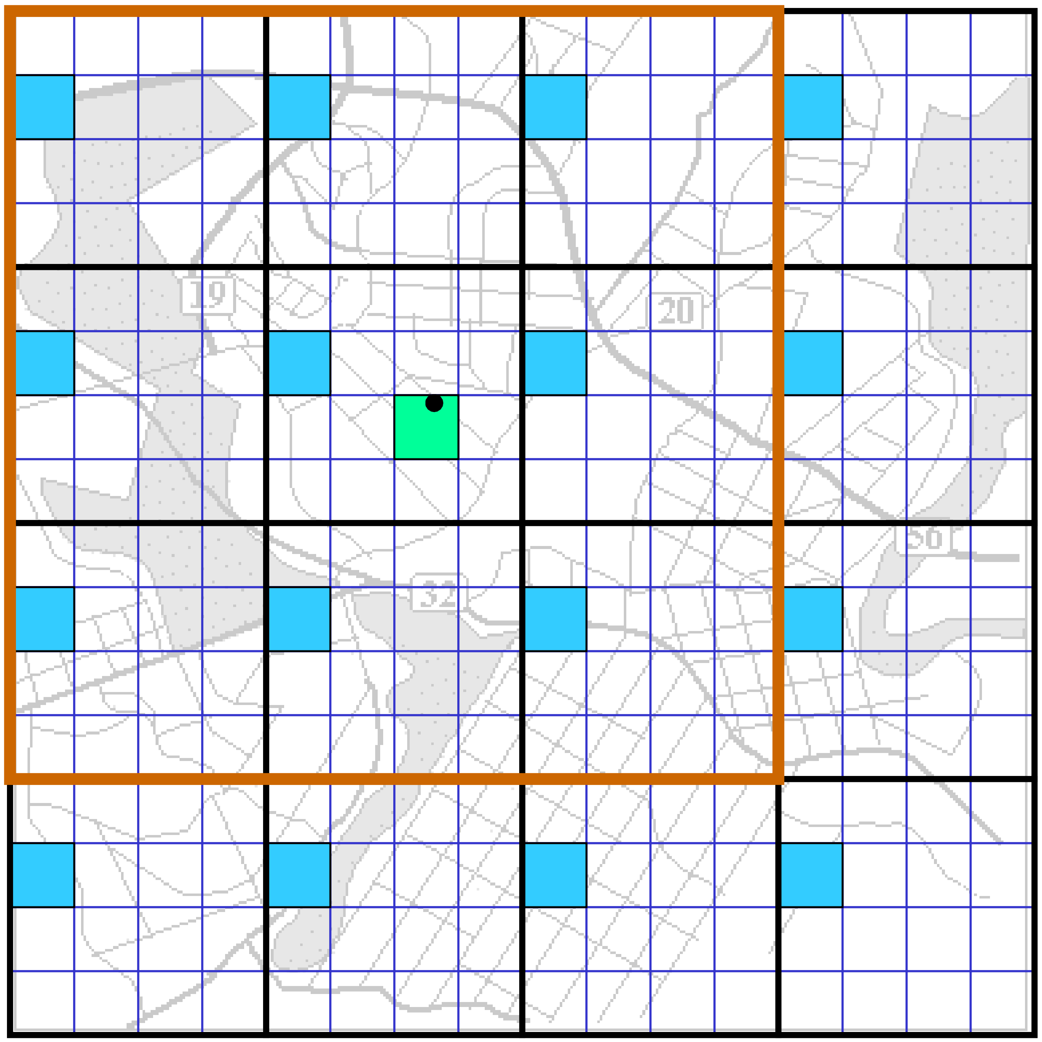
- Observations:
  - SLURP has low implementation complexity.
  - Slurp does not appear to be scalable [SPHL][YLZ]. Location requests may traverse long paths even if nodes are close.
  - Robustness could be problematic for non-uniformly distributed networks (empty HR, restricted zones).
- SLALoM seeks to improve scalability of SLURP by localizing updates.

SLALoM [CLPBZ]

- **SLALoM**: Scalable Ad-hoc Location Management [CLPBZ].
- Grid-based – physical location of network divided into “grid squares.”
- Home Regions (HR) for each node are derived by hashing Node IDs to (x,y) coordinates.
- SLALoM maintains multiple home regions – can be viewed as a hybrid between quorum and home zone approach.

SLALoM [CLPBZ]

A



Order1 square

Order2=K^2 Order1

<u>Home Region Assignment</u>

for each node n_i:

$HR(n_i)=F(n_i,Order2)$

next

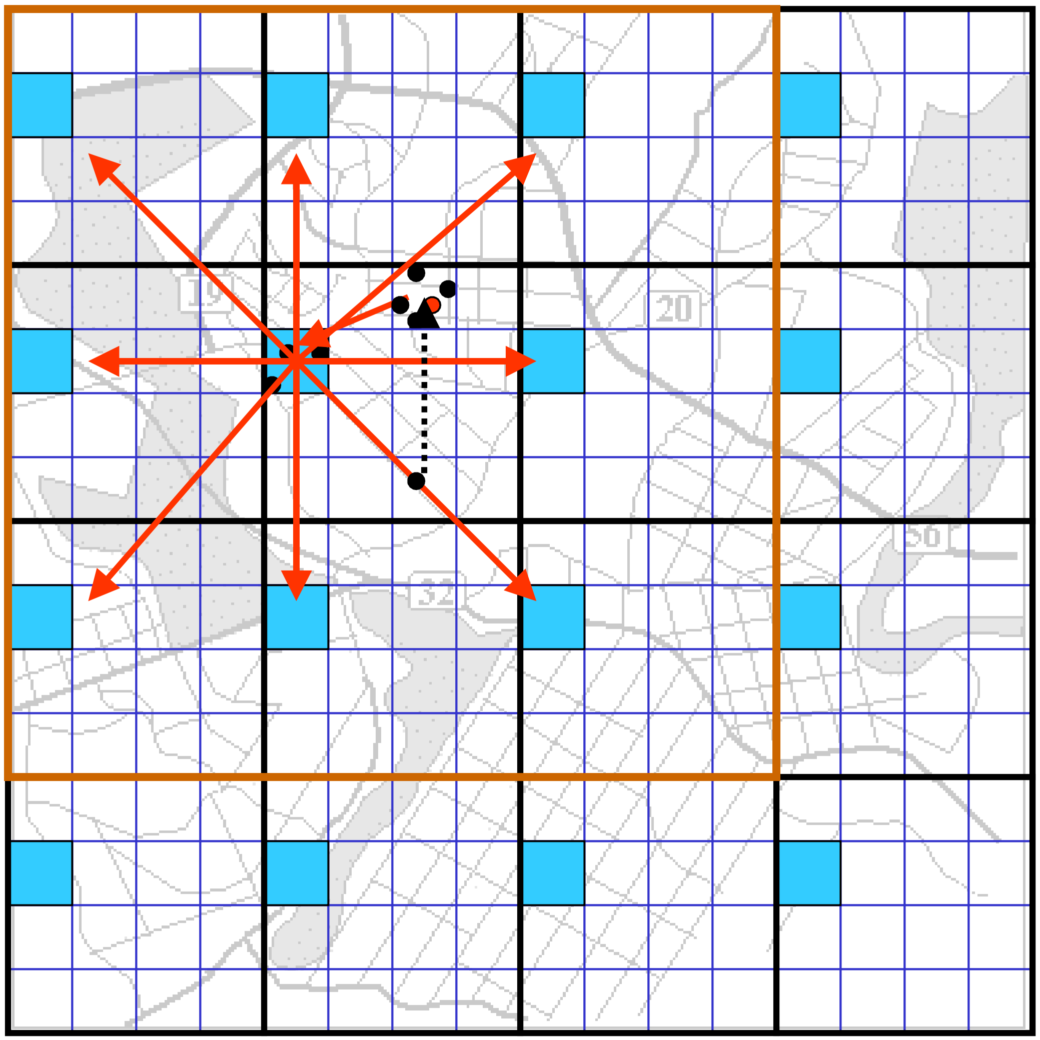
HR for node u in each Order2 square

Current Order1 square of u.

"Near" HRs for current location of u.

SLALoM [CLPBZ]

A

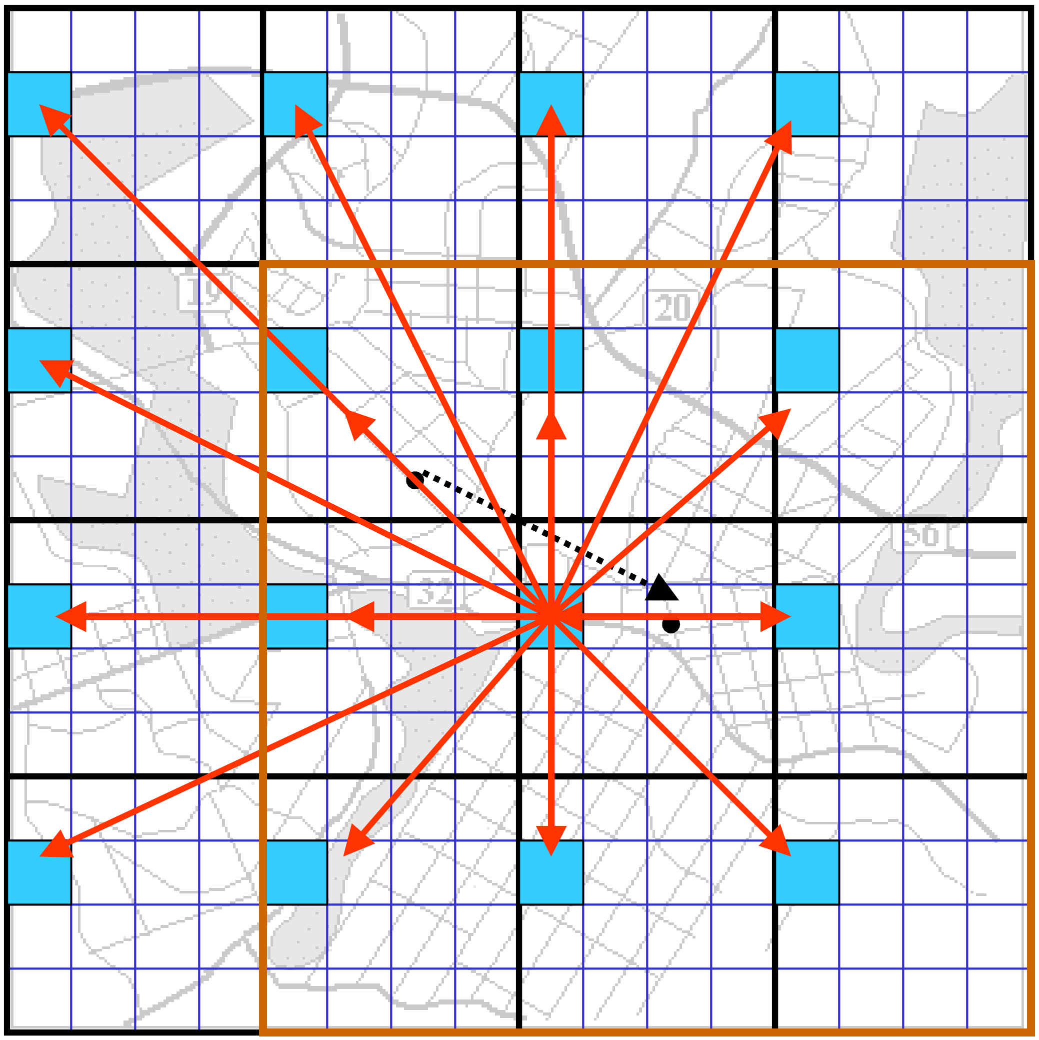


Location Update:

- u moves between Order1 squares.
- u informs current Order2 home region.
- Home region multi-casts update to "near" home regions using efficient multicast tree
- u determines from Order1 neighbors what location server info it must keep

SLALoM [CLPBZ]

A



<u>Location Update</u>:

- u moves <u>between</u> <u>Order2</u> squares.
- u informs current Order2 home region.
- “Near” home regions updated.
- All home regions updated using efficient multicast tree

SLALoM [CLPBZ]

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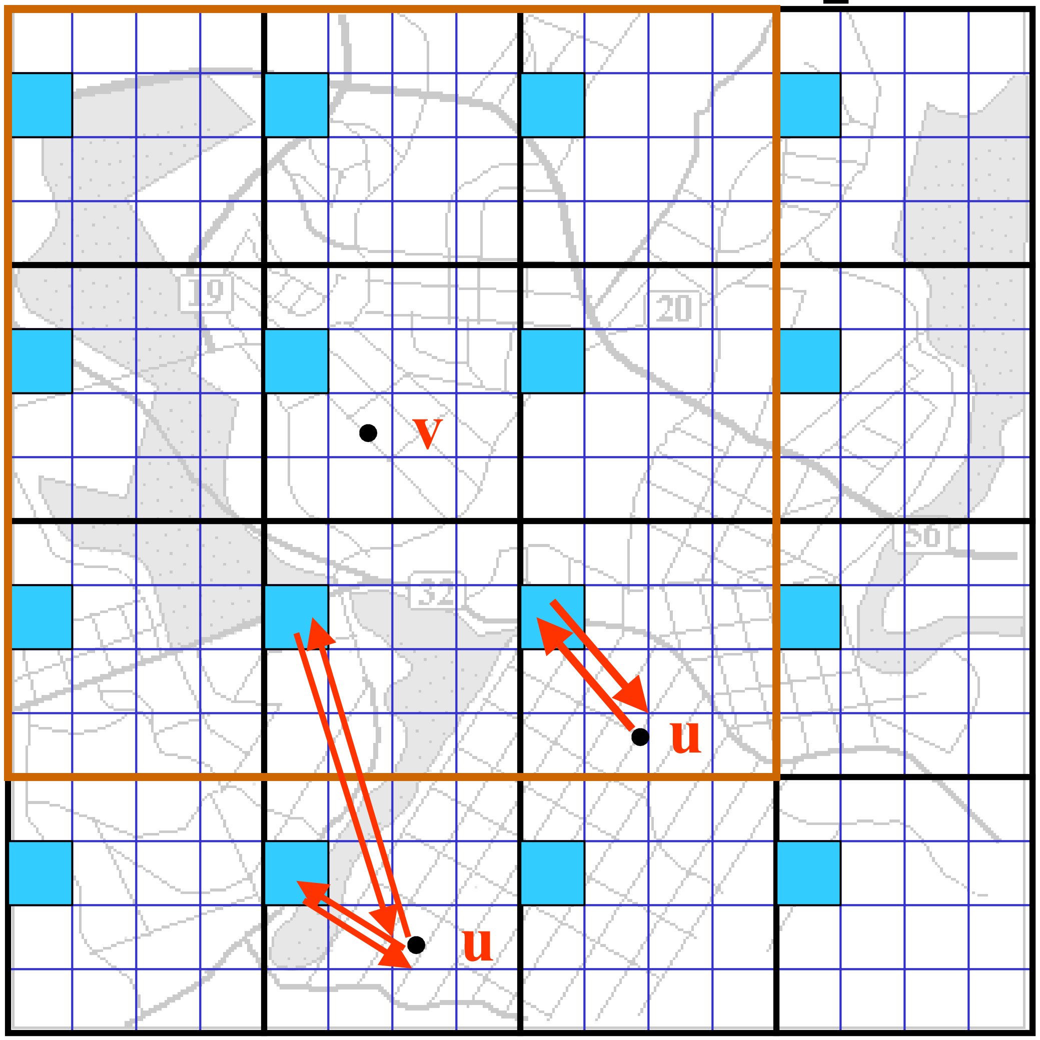


Location Discovery
(u wishes to find v):

Case 1: u is "near"

- u locates Order2 HR for v using F() and fwds loc query.
- HR returns Order1 (exact) location of v.

Case 2: v is "far"

- u locates closest HR which fwds loc of closest "near" HR of v.
- u fwds request to closest "near" HR.
- HR returns exact position of v.

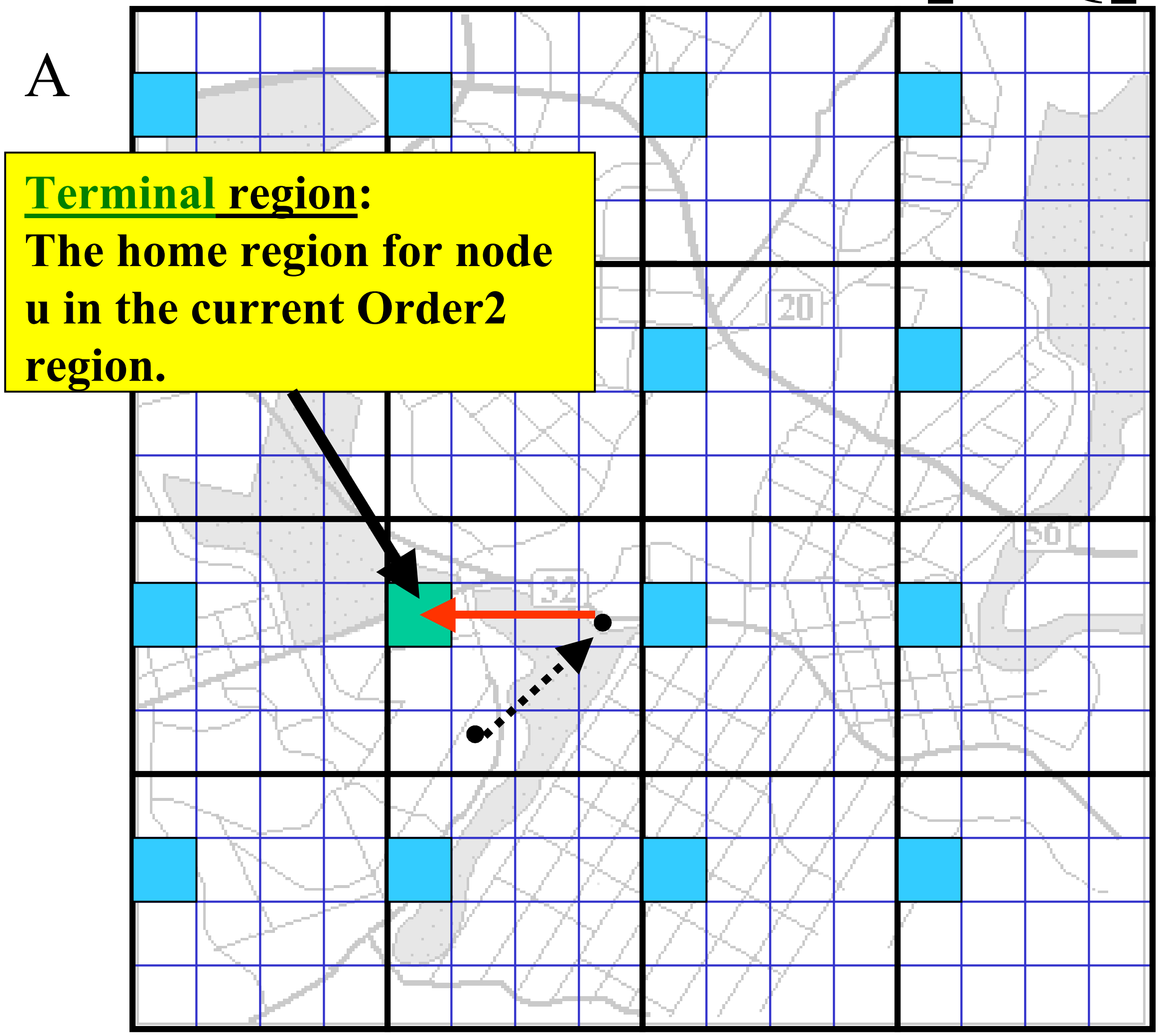
SLALoM [CLPBZ]

- Observations (from [CLPBZ]):
  - Compared to SLURP:
    - Average signalling delay of SLALoM remains relatively constant as network size grows (while SLURP increases).
      - Location updates and queries are localized in Order2 squares
    - For small to moderate sized networks, both have comparable signalling traffic.
      - SLALoM signalling can be reduced by increasing Order2 dimension at expense of signalling delay.
  - SLALoM is more robust to loss of nodes in HR.
  - ELF seeks to improve SLURP by introducing location forwarding concept from packet radio.

ELF [SQ]

- **ELF**: **E**fficient **L**ocation **F**orwarding
- Aim: to improve SLALoM by introducing location forwarding.
- Replace "near" and "far" home regions with *forwarding* and *terminal* home regions.

ELF [SQ]



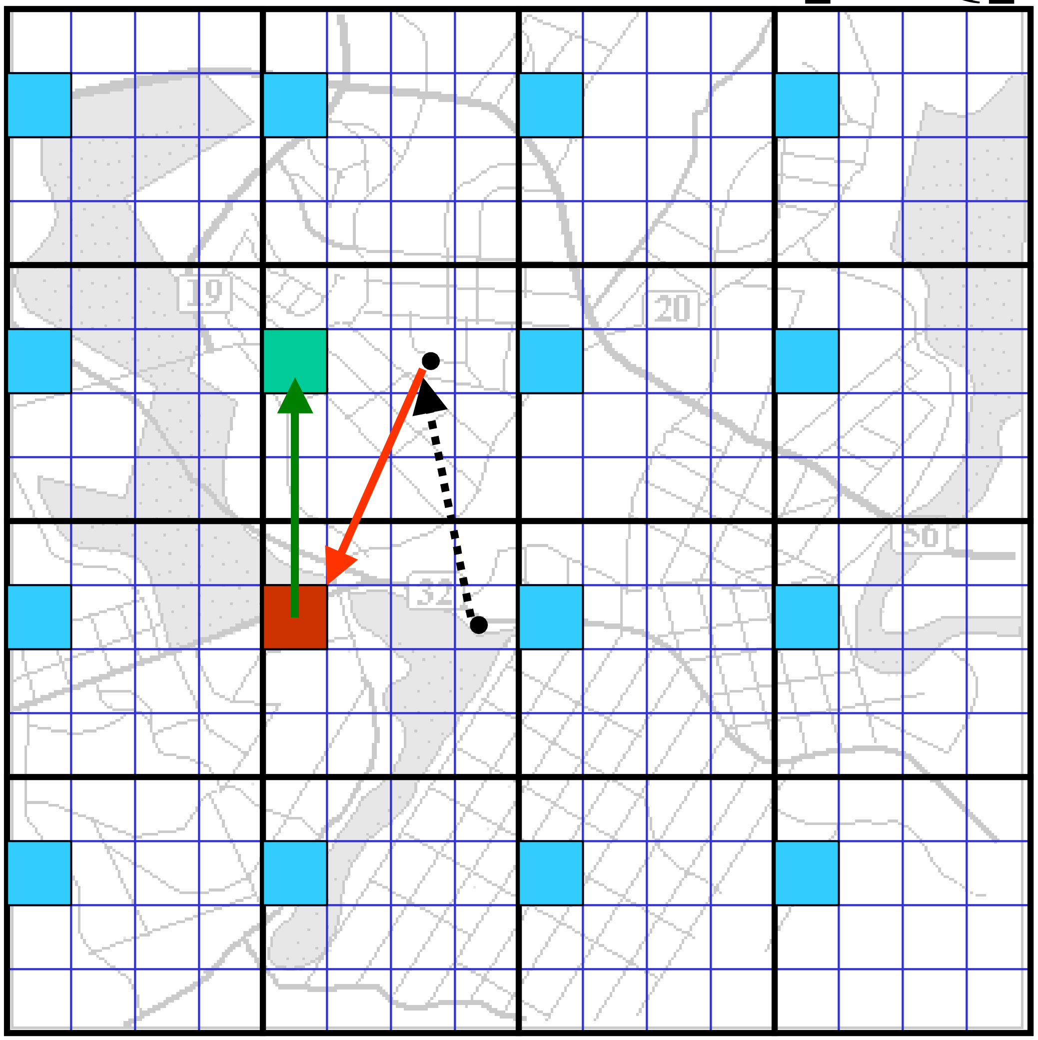
Location Update

Case 1:

- u moves within Order2 region.
- u updates terminal home region.

ELF [SQ]

A



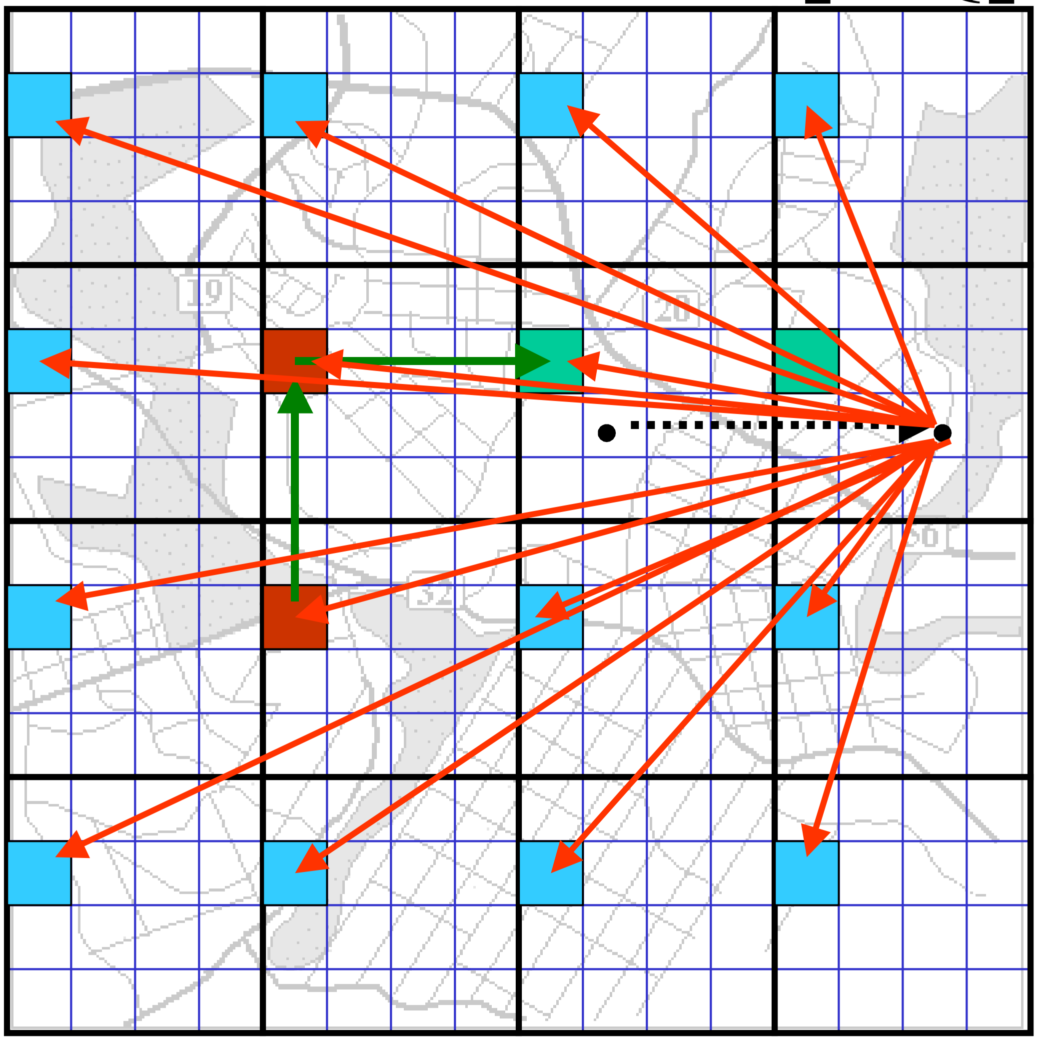
Location Update

Case 2:

- u moves between Order2 square AND C_{cross} < thresh.
- u instructs former terminal HR to set up pointer to new **terminal** HR. Former **terminal** HR becomes **forwarding** HR.

ELF [SQ]

A

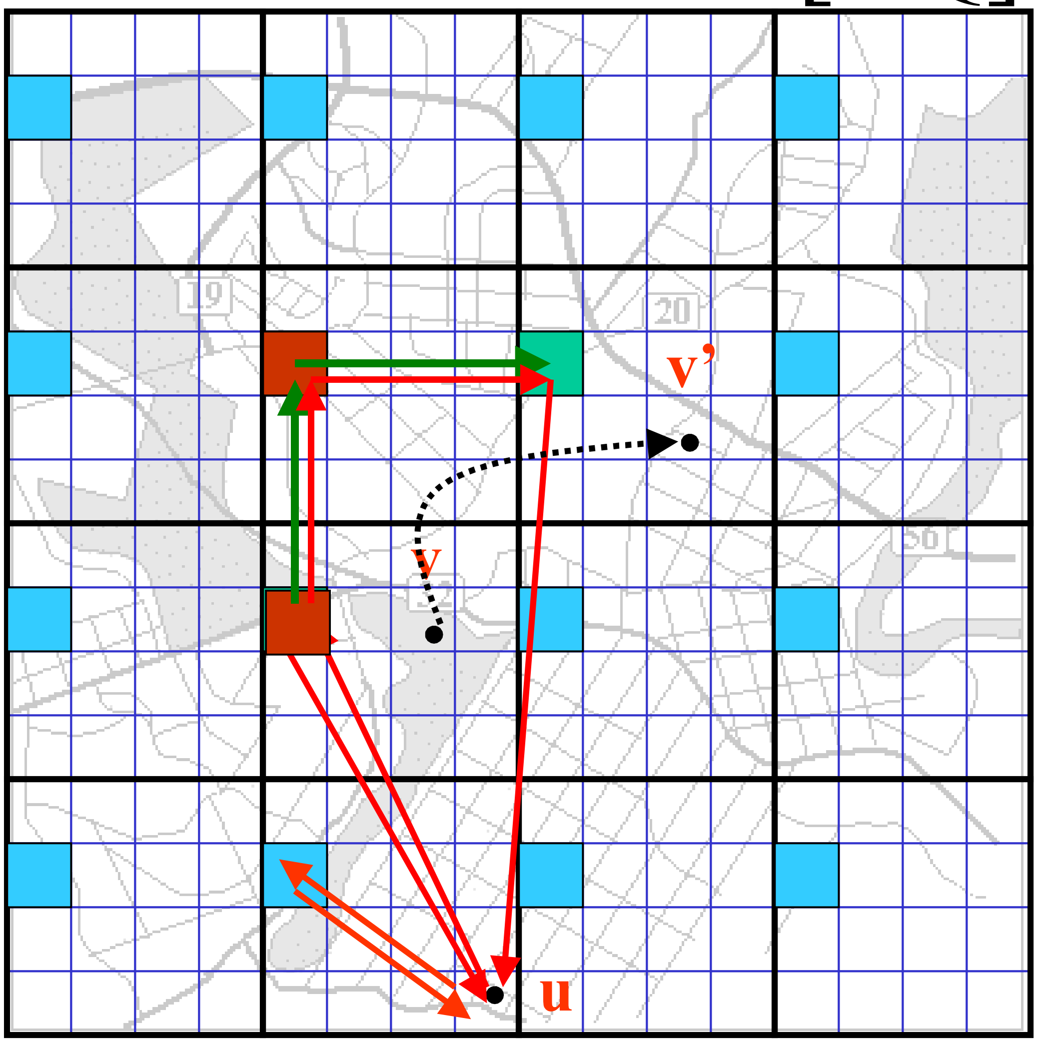


Location Update

Case 3:

- u moves between Order2 regions AND C_{cross} > thresh.
- u sets new terminal region and advises all other HR using multicast tree.
- u inquires into Order1 square about nodes for which it must maintain location information.

ELF [SQ]



<u>Location Discovery (u wishes to find v):</u>

- **u** computes **v**'s HR within Order2 square and requests **v**'s location.
- Local HR returns location of last known terminal HR.
- Case 1: <u>HR is terminal</u>. Location of v returned to u.
- Case 2: <u>HR is a fwding</u>. Location request is fwded along chain to terminal HR. Location of **v'** is returned to **u**.

ELF [SQ]

- Observations:
  - ELF outperforms SLALoM in *average* case scenarios and is no worse in worse case scenarios ([SQ]).
  - Use of forwarding chain enhances scalability by reducing the average signalling cost in comparison to SLALoM ([SQ]).

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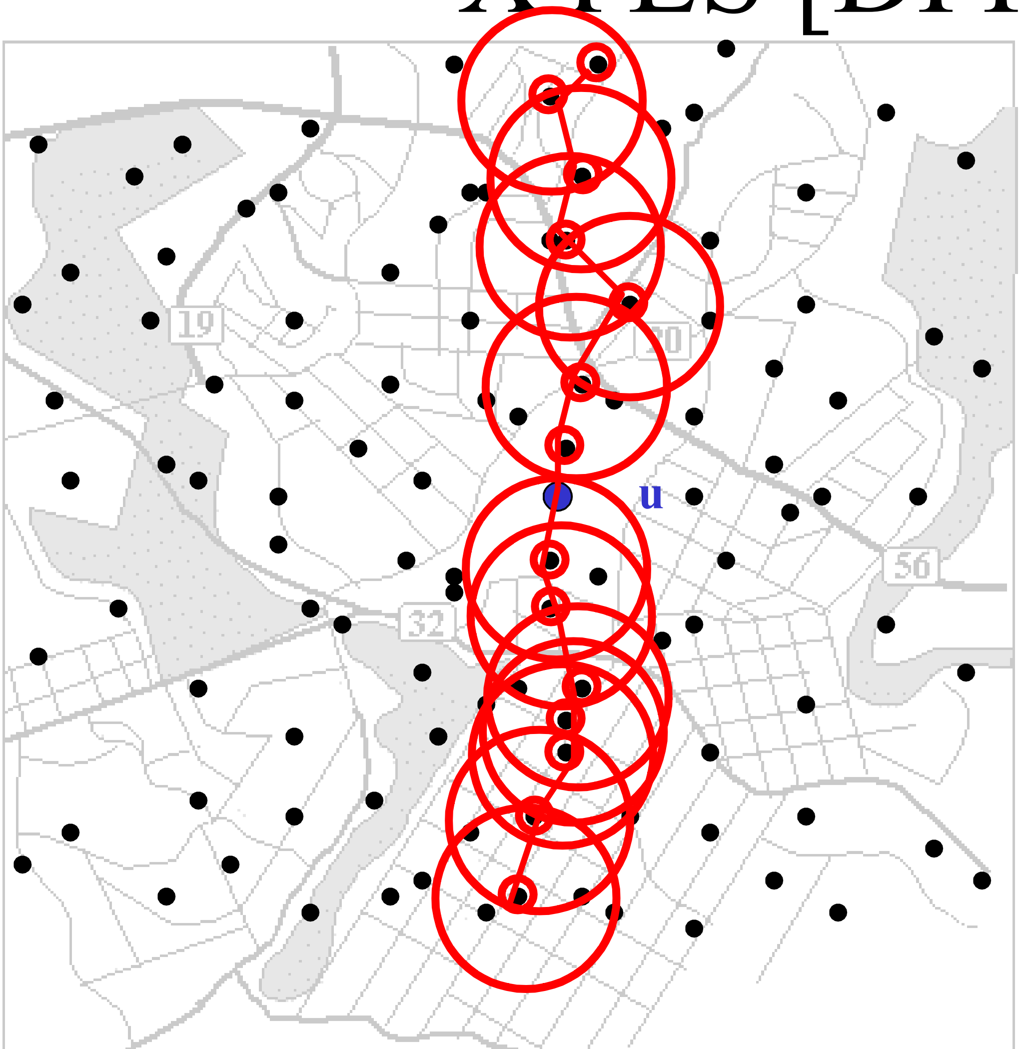
XYLS [DPH]

- A node updates position by storing to a “write” quorum.
- A node queries a location by making destination request from “read” quorum.
- Challenge is to ensure that read/write quorums intersect sufficiently to maximize P(query success) ([C])
- XYLS – a row/column quorum method based on [SP1]

XYLS [DPH]

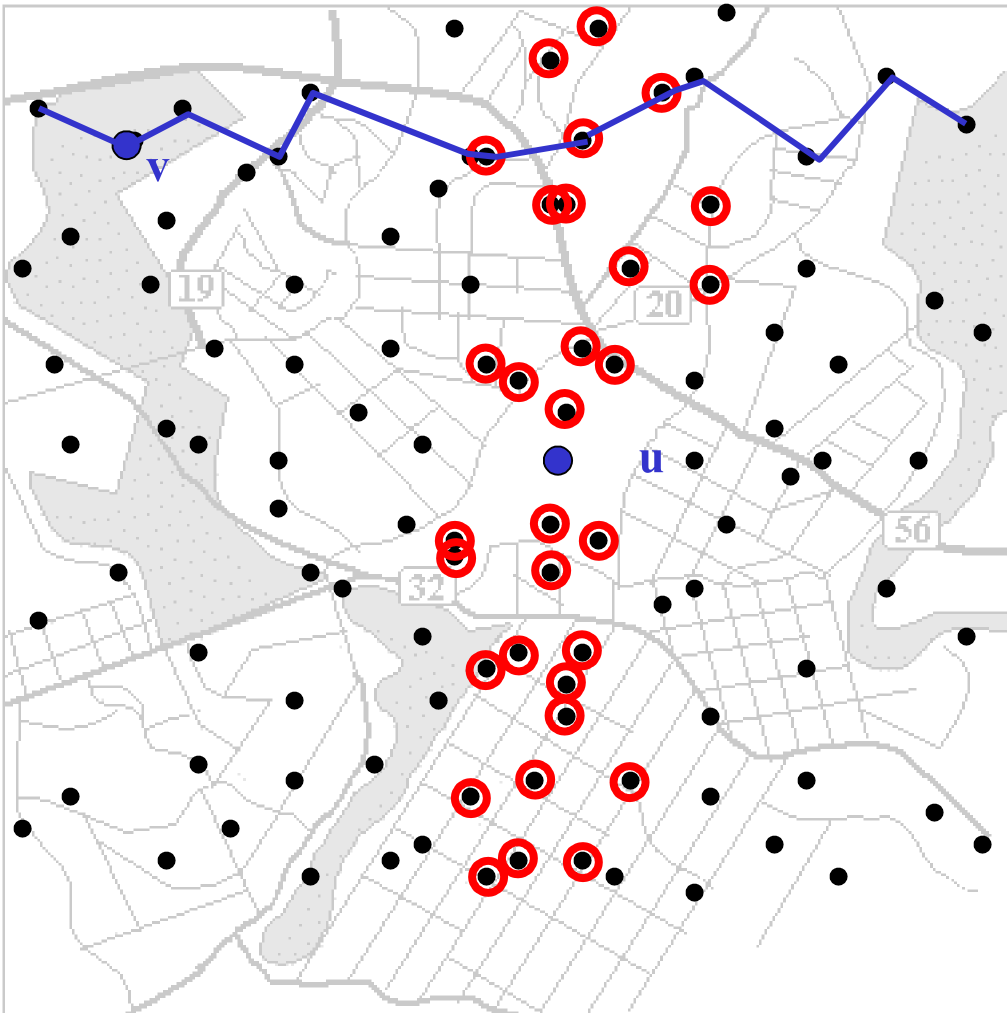


Location Registration/Update

- **u** updates after moving distance d.
- Update Quorum for **u** is all nodes located in geographic north-south direction.

- To increase column thick-ness, each update quorum node broadcasts to one-hop neighbour.
- Node update has validity period t determined using node mobility prediction data.

XYLS [DPH]



Location Query

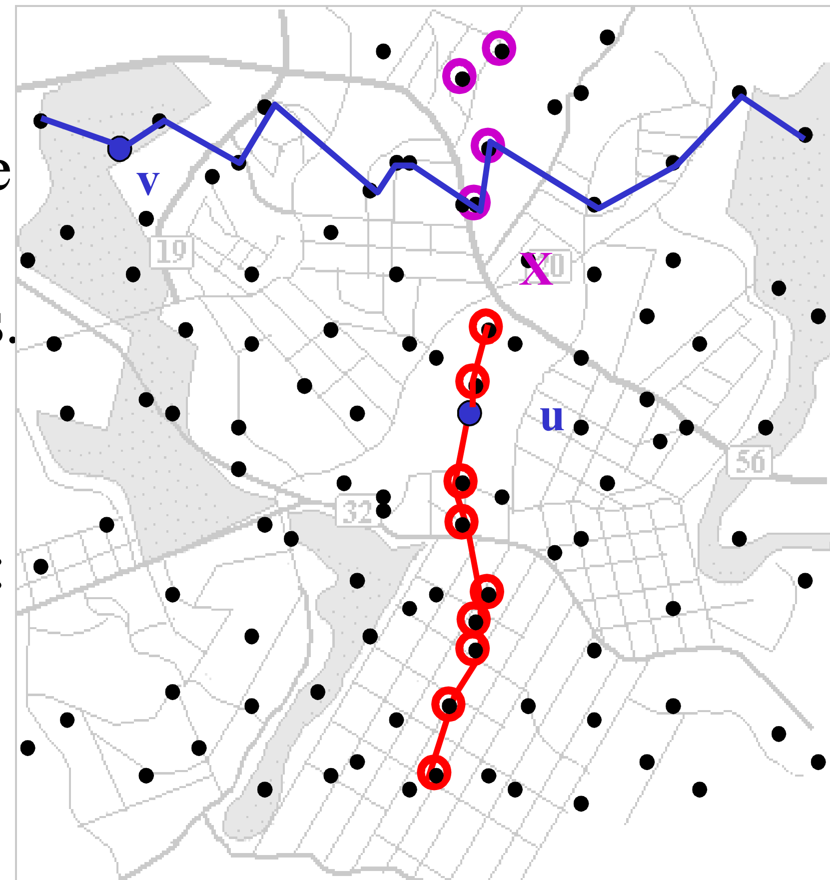
- **v** queries location of **u** by propagating loc request in east-west direction (query quorum).
- Loc request includes time-stamped last known position of **u**. Reply packets are sent with more recent loc only.

XYLS [DPH]

- Observations:
  - Authors of [MWH] conclude:
    - Algorithm for selecting row/column nodes can impact overhead.
    - Robustness of Quorum-Based location services can be affected by node failure.
  - Authors of [DPH] conclude XYLS is scalable in comparison to other protocols (GLS, GHLS).

XYLS [DPH]

- Observations:
  - Read/Write quorums can be a challenge to define and manage in mobile networks.
    - Position based
    - Virtual backbone
  - Commonly identified issue: Locally northernmost problem.



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DREAM [BCS]

- DREAM: **D**istance **R**outing **E**ffect **A**lgorithm for **M**obility.
- Dream represents class of proactive, flooding based protocols.
- Based on two observations:
  - Distance Effect: "the greater the distance separating two nodes, the slower they appear to be moving with respect to each other."[BCS]
  - Node updates are related to node mobility rate.

DREAM []

- Distance Effect

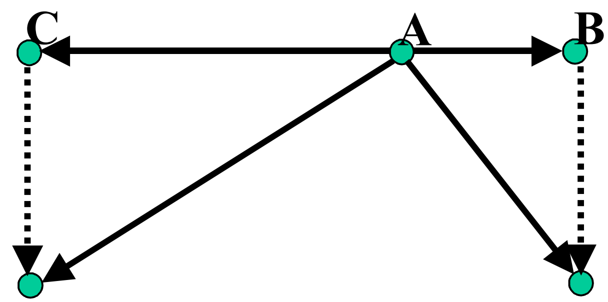
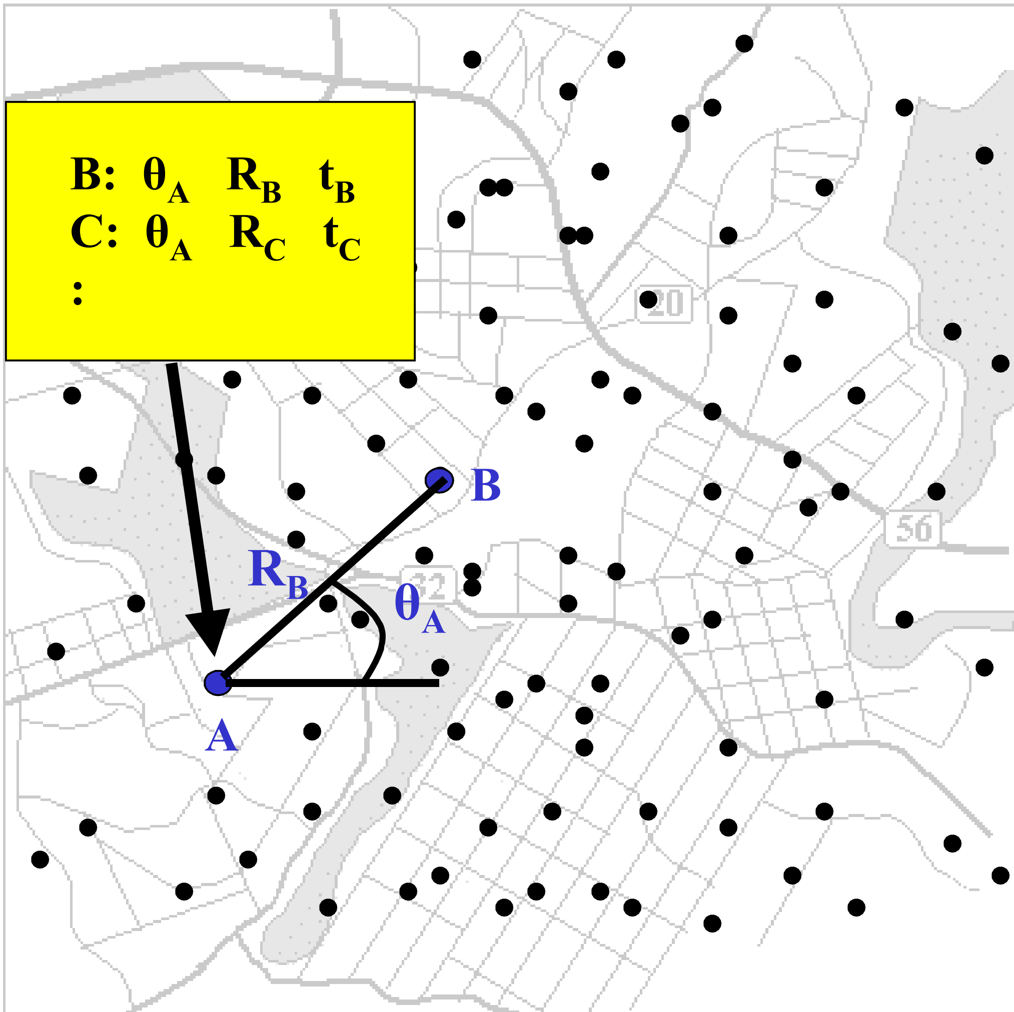


Figure 2 from [Mauve]

- Nodes transmit *update packets* with fixed lifetime:
  - Most are "short lived" and don't travel far.
  - Some are "long lived" and reach outer edges.
- Frequency of update packets related to speed.

DREAM [BCS]



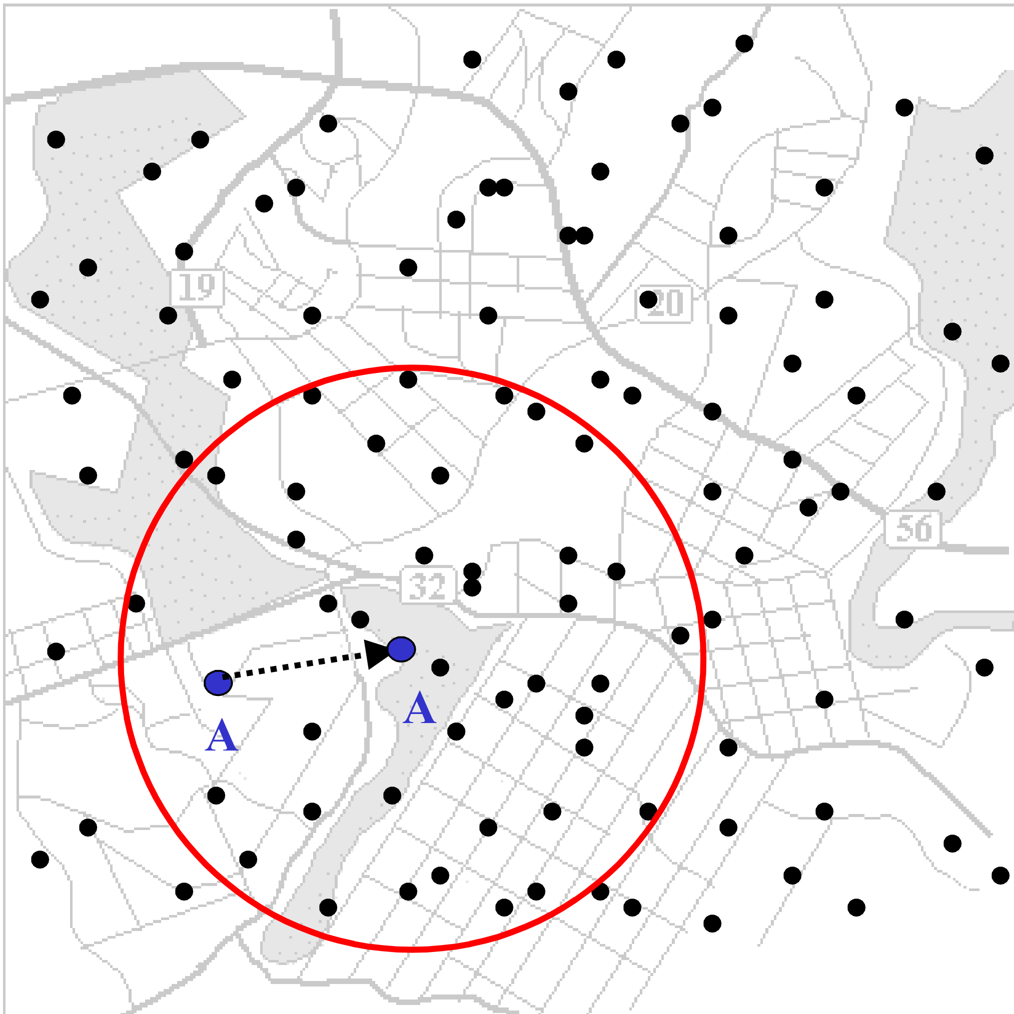
Location Registration

- All nodes broadcast to fill location table (LT) for all other nodes in network.

- LT has direction **θ** and distance **R** to each other node in the network. Each entry is time stamped.

* DLS [] also maintains speed as provided by node

DREAM []



Location Update

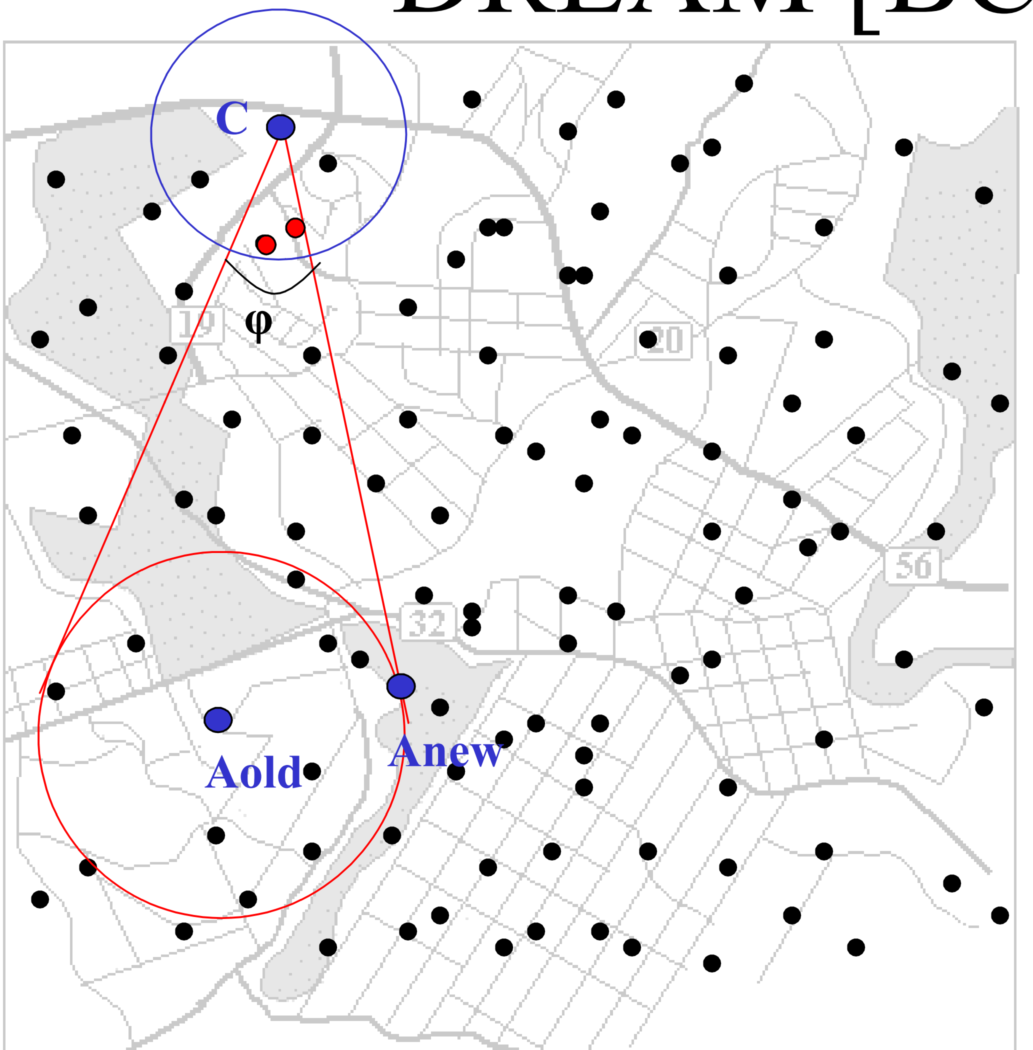
Case 1:

- **A** has moved some threshold distance.
- **A** transmits a short update.

Case 2:

- **A** transmits long update after it has moved some threshold distance or every **t** time units.

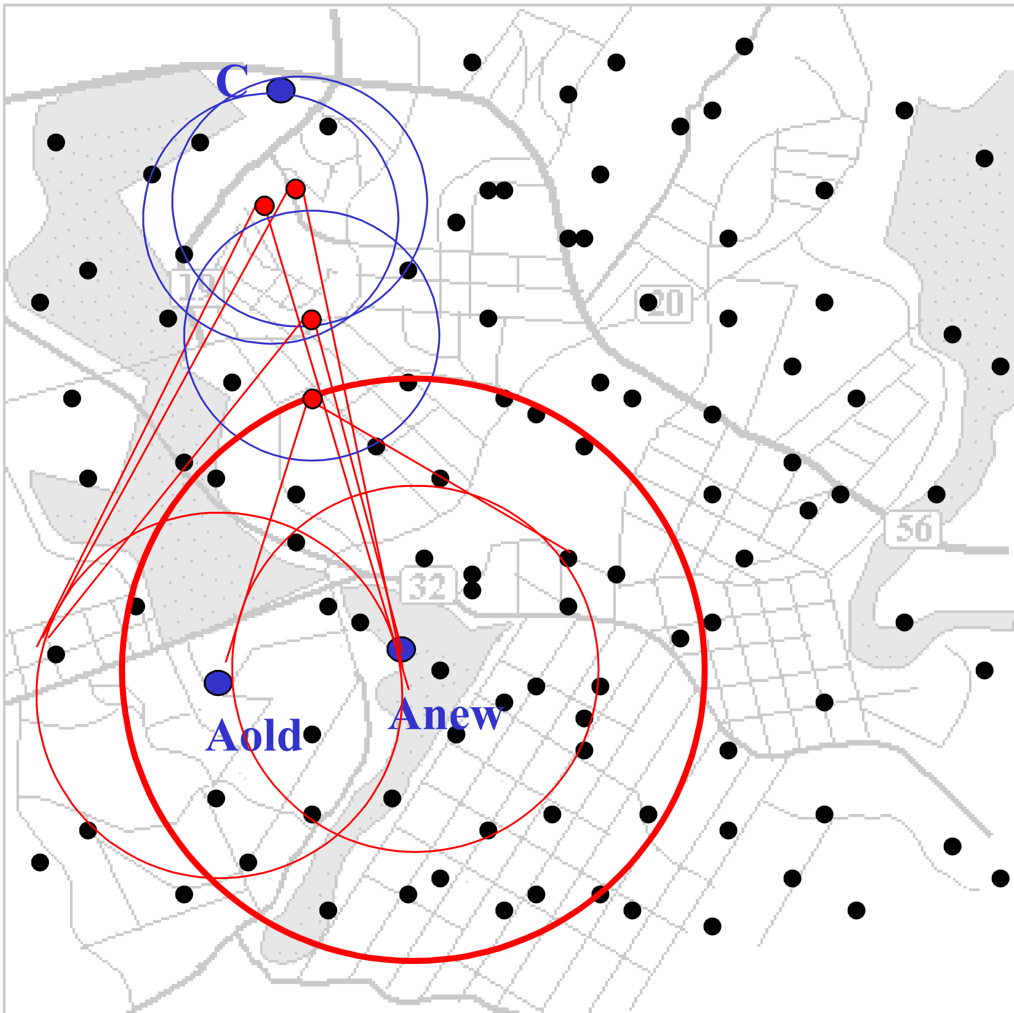
DREAM [BCS]



Location Query

- **C** wishes to communicate with **A**. **C** refers to **A**'s LT.
- **C** computes angle φ based on *estimate* of node **A** radial speed s.t. **A** is within radius **R** of last known position.
- **C** transmits *loc query* to all nodes within one-hop distance within subtended angle.

DREAM [BCS]



Location Query

- One-hop neighbours re-transmit to their one-hop neighbours using their LT info for **A**.
- In this case, a node within short update range redirects the update request direction.

DREAM [BCS]

- Observations:
  - Authors of DREAM contend loop free but [S2] indicates that this is not the case;
  - Authors of [MWH] conclude:
    - DREAM is very robust (messages can take multiple, independent routes and all nodes contain info on all other nodes).
    - Implementation complexity is low;
    - BUT not scalable (for large networks) due to update communication complexity (flooding).

DREAM [BCS]

- Observations:
  - In event that node has no LT entry or entry is stale, a recovery mechanism (flooding) is needed.
  - Authors of [BCS] found that messages are delivered 80% of time with moderate mobility rate.
  - Authors of [CBW] found:
    - Location requests are almost always answered;
    - Location information <u>accuracy</u> is affected by speed;

Summary

- Use of position information for routing has generated need for *location services*.
- Location services need to provide position registration, update, and query in efficient, robust, scalable manner.
- Some examples – SLURP, SLALoM, DREAM.

Questions for Exam

1. During the course, a number of position-based routing protocols (eg SLURP, SLALOM) were examined. What difficult problem must be solved in order for these algorithms to be effective?

A. Each node must be able to obtain and share position information in a scalable, robust, and bandwidth efficient manner.

2. Position-based routing depends on a location service to provide three basic tasks in relation to position information. What are these?

A. Position registration, position update, and position query.

3. The Distance Routing Effect Algorithm for Mobility (DREAM) is a location service for position-based routing. Explain the "Distance Effect" that it is based on.

A. The Distance Effect makes nodes that are further away appear to move less. This is used by DREAM to limit location updates to the local area.

Questions

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