Location-Based Routing

An overview and possible directions for GeoCRON

Kyle E. Benson

Department of Computer Science
University of California, Irvine
Irvine, California 92697

kebenson@uci.edu

May 15, 2013

Introduction

- Traditional routing
  - Unique address: IP, MAC, Peer ID, etc.
  - Source routing: next hop address, neighbor index
  - Local routing: distance-vector, link state, label-switching

Introduction

- Traditional routing
  - Unique address: IP, MAC, Peer ID, etc.
  - Source routing: next hop address, neighbor index
  - Local routing: distance-vector, link state, label-switching
- Why location information?
  - Geocast: message all (or some) nodes in target region
  - Latency: request from closer server, route locally when possible
  - Congestion: confine route requests to smaller regions (MANETs)
  - Energy: closer nodes need less radio power to reach
  - Sensors: regional event detection, spatial querying
  - Planning: paths (robots), surveillance cameras (focus on area target will appear next)
  - Recovery: avoid problematic areas of the network

Introduction

- Traditional routing
  - Unique address: IP, MAC, Peer ID, etc.
  - Source routing: next hop address, neighbor index
  - Local routing: distance-vector, link state, label-switching
- Why location information?
  - Geocast: message all (or some) nodes in target region
  - Latency: request from closer server, route locally when possible
  - Congestion: confine route requests to smaller regions (MANETs)
  - Energy: closer nodes need less radio power to reach
  - Sensors: regional event detection, spatial querying
  - Planning: paths (robots), surveillance cameras (focus on area target will appear next)
  - Recovery: avoid problematic areas of the network
    - our primary interest!

Roadmap

Roadmap

Location Service

- Nodes have GPS
- But how to look up destination's location?
- Maintain global information

Location Service

- Nodes have GPS
- But how to look up destination's location?
- Maintain global information
  easily outdated/inefficient

Location Service

- Nodes have GPS
- But how to look up destination's location?
- Maintain global information
  easily outdated/inefficient
- Distribute load
  - In Jinyang Li et al. (2000), node updates *location servers* (LS) throughout network
  - Divide network into hierarchical grid
  - LS's in 3 external grids at each level
  - Lookup distance $<$ square LS co-resides in

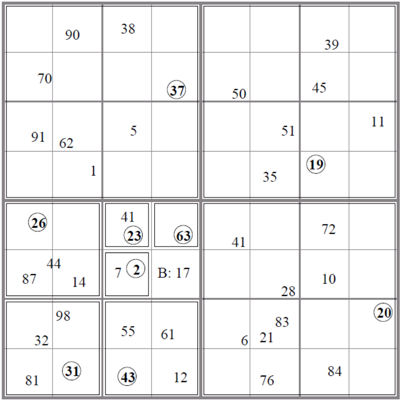

Figure: Hierarchical grid with 4 order-i squares in order-i+1 square.

Location Service for GeoCRON

- Grid $\Leftrightarrow$ CSN's *geocells*
- Location servers $\rightarrow$ sensor's overlay contacts
- Natural geographic diversity $\rightarrow$ more robust!
- Location servers hold address, NOT just location!
- Region ID $\leftarrow$ quad tree path
  - *ex: B* at 203 (count like Cartesian plane)
- Region similarity $\rightarrow$ prefix match region ID

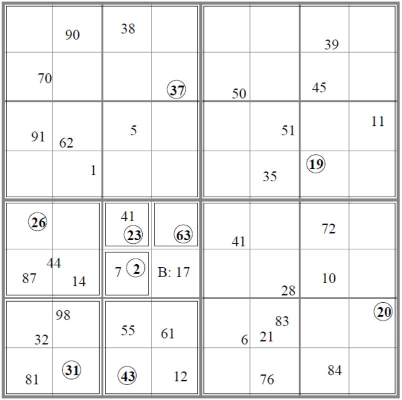

Figure: Hierarchical grid closely resembles CSN's *geocells*

Roadmap

Greedy Forwarding

- Forward to next closest hop to destination
- What if no such neighbor?
  - Reached local minimum
  - *Voids* in network
  - Solution: temporarily forward to farther hop
  - Used by Ko et al. (1998); Young-bae Ko et al. (1999) with parameter δ
  - Forward if next hop distance $\leq$ previous distance $+ \delta$

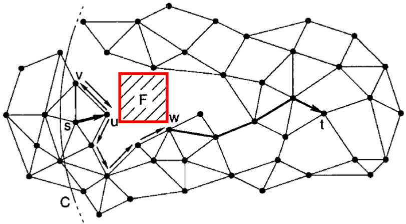

Figure: A void in a network (roughly centered at F, outlined in red) may disrupt greedy forwarding

Greedy Forwarding in confined region

- In Young-bae Ko et al. (1999), source defines a *multicast region* and *forwarding zone*
  - Message delivered to all nodes in multicast region
  - Defined as a rectangle, coordinates inside message
  - Includes source, destination, plus error
  - Message flooded within forwarding zone until target reached

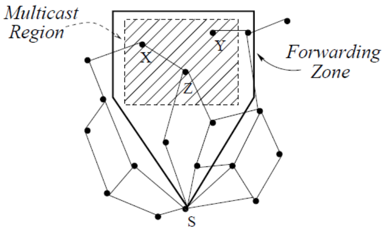

Figure: Depiction of multicast region and forwarding zone

Greedy Forwarding further enhancements

- Adapt forwarding region at each hop Young-bae Ko et al. (1999)
  - Intermediate (closer) nodes know topology better
  - Change region shape
- Adaptive technique may help GeoCRON
  - Failure assumed close to sensors
  - Message farther away → less chance of failures → routing region shrinks

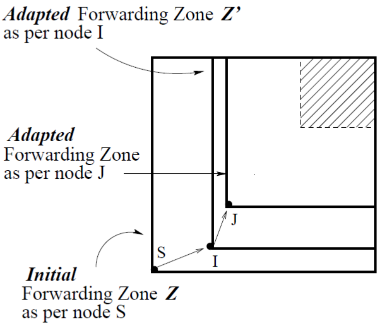

Figure: Depiction of adaptive multicast region and forwarding zone

Roadmap

1. Location Service
2. Greedy Forwarding
3. Trajectory Routing
4. Geometric Routing
5. Clustering
6. Hybrid
7. Wired Overlay Routing

Trajectory Routing

- Introduced in Niculescu and Nath (2003, 2004), implemented in Yuksel et al. (2006)
- Message follows a curve
- Hybrid greedy/source routing
- Forward to neighbor furthest along curve
- Routes around voids, obstacles, etc.
- GeoCRON: identify failed regions → route around

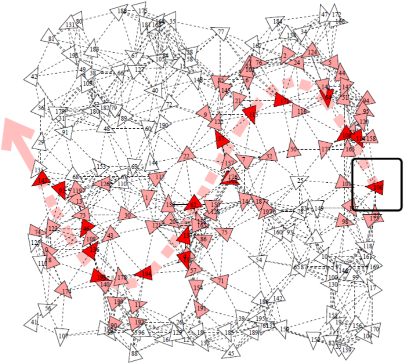

Figure: Forwarding along a trajectory

Roadmap

Geometric Routing

- Network topology $\rightarrow$ graph
  - Vertices = nodes
  - Edges = direct communication

Geometric Routing

- Network topology $\rightarrow$ graph
  - Vertices = nodes
  - Edges = direct communication
- Graph geometry $\rightarrow$ forwarding

Geometric Routing

- Network topology → graph
  - Vertices = nodes
  - Edges = direct communication
- Graph geometry → forwarding
- *Compass routing* proposed Kranakis et al. (1999)
  - *Right-hand rule*
  - Also called *face routing*
  - Also used in Kuhn et al. (2003); Kim et al. (2005)

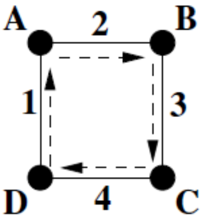

Figure: The right-hand rule: forward packet along next counter-clockwise edge. Analogous to following the right hand wall in a maze.

Geometric Routing in GeoCRON

- Overlay network → planar graph
- Faces large enough to avoid routing back to failed regions
- Intermediary makes routing decision, NOT source

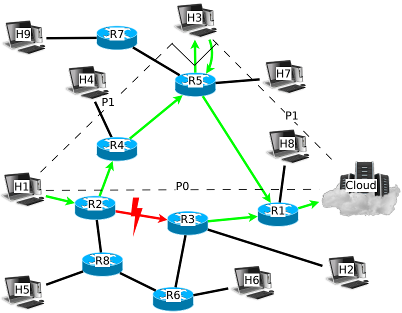

Figure: Apply right-hand rule to overlay paths. Similar to Orthogonal Path Heuristic.

Roadmap

- GRID Liao et al. (2001) divides network into squares
    - Gateway chosen for each square
    - Zone-based version of AODV to route
    - Route requests confined to geographic region
- In Joa-Ng and Lu (1999), an inter-zone clustering protocol periodically run
    - Updated with inter-zone links
    - Destination's exact location within zone unknown $\rightarrow$ packet gets close enough

Clustering - LABAR

- LABAR Zaruba et al. (2003)
    - GPS-enabled nodes → backbone G-nodes
    - Nodes near G-nodes belong to a *zone*
    - G-nodes give sender vector towards intermediary zones

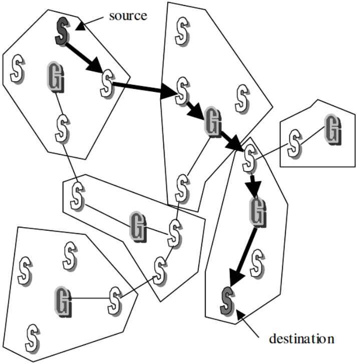

Figure: Routing in LABAR

Clustering in GeoCRON

- Sensors clustered by region (city, geocell, etc.)
- More reliable node (or first to reach server) $\rightarrow$ clusterhead
- Sensors report to clusterhead
- Clusterhead forwards aggregate packets
  - Data compression
  - Paths overlap anyway $\rightarrow$ reduce local congestion
  - Cluster aware of failures

Clustering in GeoCRON

- Sensors clustered by region (city, geocell, etc.)
- More reliable node (or first to reach server) $\rightarrow$ clusterhead
- Sensors report to clusterhead
- Clusterhead forwards aggregate packets
  - Data compression
  - Paths overlap anyway $\rightarrow$ reduce local congestion
  - Cluster aware of failures
  - Problem: increased latency if > 1 overlay hop

Clustering in GeoCRON

- Sensors clustered by region (city, geocell, etc.)
- More reliable node (or first to reach server) $\rightarrow$ clusterhead
- Sensors report to clusterhead
- Clusterhead forwards aggregate packets
    - Data compression
    - Paths overlap anyway $\rightarrow$ reduce local congestion
    - Cluster aware of failures
    - Problem: increased latency if > 1 overlay hop
    - Problem: what if clusterhead fails?

Roadmap

Hybrid

- In Kuhn et al. (2003); Huang et al. (2005); Karp and Kung (2000), greedy forwarding until *void* reached
  - *Face routing* within a bounded region
  - Enlarge bounded region if destination unreachable
  - FAR Huang et al. (2005) introduced *mobicast*: mobile geocast
    - Application: mobile regional sensing
    - *Just in time* forwarding: packet arrives right before mobicast region
    - Decreases *lag time* (how long nodes hold data before mobicast region arrives)
- Such hybrid approaches necessary in GeoCRON
  - Adaptability $\rightarrow$ resilience
  - One technique may work well for some failures, not for others
  - e.g. earthquake $\neq$ hurricane

Roadmap

Wired Overlay Routing - path choices

- Little work done in this context
- In Kim and Venkatasubramanian (2010) overlay-based data dissemination is considered
- Overlay neighbors chosen to minimize distance between routers on path
- Intuition: geo-correlated failures affect nodes in proximity
- Improve path diversity

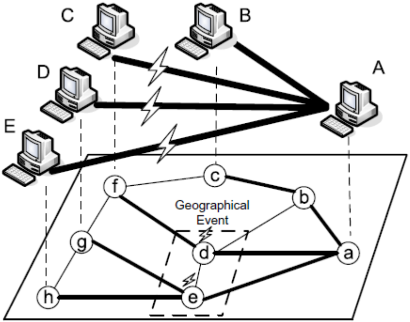

Figure: Different overlay links may share the same underlay links/nodes

Wired Overlay Routing - regional trees

- Concept of *responsible region tree (RRTree)* used in Kim et al. (2012)
- Similarly to GRID, regions organized hierarchically
- RRTree nodes' region = childrens'
- Each has emphregion hopping table to contact non-adjacent regions
- Route tree in O(logn)
- Conjugate regions → geographically diverse → maintain external communication

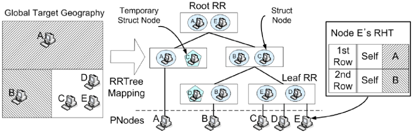

Figure: Depiction of GSFord's RRTree, RHT, and target geography

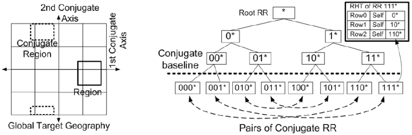

Figure: Depiction of GSFord's conjugate regions

References I

Huang, Q., Bhattacharya, S., Lu, C., and Roman, G.-C. (2005). FAR. *ACM Transactions on Sensor Networks*, 1(2):240–271.

Jinyang Li, J. J., Li, J., Jannotti, J., De Couto, D. S. J., Karger, D. R., and Morris, R. (2000). A Scalable Location Service for Geographic Ad Hoc Routing. *Proceedings of the 6th annual international conference on Mobile computing and networking*, pages 120–130.

Joa-Ng, M. and Lu, I.-T. (1999). A peer-to-peer zone-based two-level link state routing for mobile ad hoc networks.

Karp, B. and Kung, H. T. (2000). GPSR. In *Proceedings of the 6th annual international conference on Mobile computing and networking - MobiCom '00*, pages 243–254, New York, New York, USA. ACM Press.

References II

Kim, K. and Venkatasubramanian, N. (2010). Assessing the Impact of Geographically Correlated Failures on Overlay-Based Data Dissemination. In *2010 IEEE Global Telecommunications Conference GLOBECOM 2010*, pages 1–5. IEEE.

Kim, K., Zhao, Y., and Venkatasubramanian, N. (2012). Gsford: Towards a reliable geo-social notification system. In *Reliable Distributed Systems (SRDS), 2012 IEEE 31st Symposium on*, pages 267–272.

Kim, Y.-J., Govindan, R., Karp, B., and Shenker, S. (2005). Geographic routing made practical. *Proceedings of the 2nd conference on Symposium on Networked Systems Design & Implementation - Volume 2*, pages 217–230.

References III

Ko, Y.-b., Vaidya, N. H., and Young-bae Ko, N. H. V. (1998). Location-Aided Routing (LAR) in mobile ad hoc networks. *in: International Conference on Mobile Computing and Networking (MobiCom98*.

Kranakis, E., Singh, H., Urrutia, J., and Evangelos Kranakis, H. S. (1999). Compass Routing on Geometric Networks. In *IN PROC. 11 TH CANADIAN CONFERENCE ON COMPUTATIONAL GEOMETRY*, pages 51–54.

Kuhn, F., Wattenhofer, R., Zhang, Y., and Zollinger, A. (2003). Geometric ad-hoc routing. In *Proceedings of the twenty-second annual symposium on Principles of distributed computing - PODC '03*, pages 63–72, New York, New York, USA. ACM Press.

References IV

Liao, W.-H., Tseng, Y.-C., Sheu, J.-P., and Wen-Hwa Liao, Y.-C. T. (2001). GRID: A Fully Location-Aware Routing Protocol for Mobile Ad Hoc Networks.

Niculescu, D. and Nath, B. (2003). Trajectory based forwarding and its applications. In *Proceedings of the 9th annual international conference on Mobile computing and networking - MobiCom '03*, page 260, New York, New York, USA. ACM Press.

Niculescu, D. and Nath, B. (2004). Routing on a curve. pages 129–151.

Young-bae Ko, N. V., Ko, Y.-B., and Vaidya, N. F. (1999). Geocasting in Mobile Ad Hoc Networks: Location-Based Multicast Algorithms. *Mobile Computing Systems and Applications, 1999. Proceedings. WMCSA '99. Second IEEE Workshop on*, pages 101–110.

References V

Yuksel, M., Pradhan, R., and Kalyanaraman, S. (2006). An implementation framework for trajectory-based routing in ad hoc networks. *Ad Hoc Networks*, 4(1):125–137.

Zaruba, G., Chaluvadi, V., and Suleman, A. (2003). LABAR: location area based ad hoc routing for GPS-scarce wide-area ad hoc networks. In *Proceedings of the First IEEE International Conference on Pervasive Computing and Communications, 2003. (PerCom 2003).*, pages 509–513. IEEE Comput. Soc.