Dynamically Adjusting the Request Zone in GeoAODV Protocol

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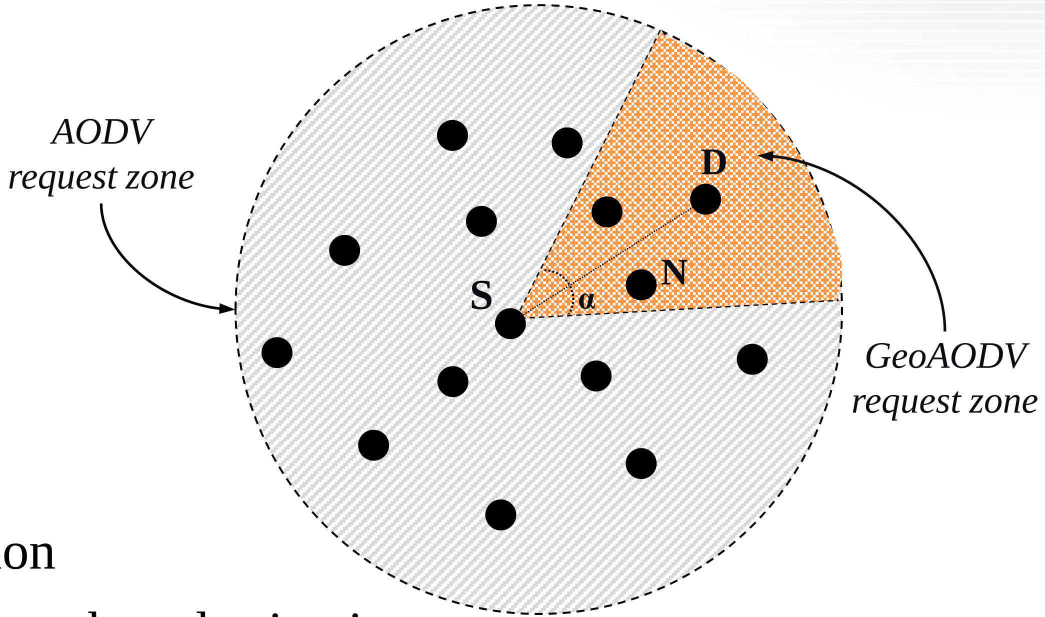
Introduction: AODV

- Ad-hoc on-demand distance vector (AODV) routing protocol
  - Reactive routing protocol for mobile ad-hoc networks (MANET)
  - Finds a route when there is data to transmit
  - Discovers routes using a flooding technique
    - Broadcasts a route request (RREQ) packet to its immediate neighbors
    - Neighboring nodes retransmit RREQ packet
    - Route reply packet (RREP) is unicast to the source node when a destination or a node that has a path to the destination is reached.
    - Process terminates when RREP arrives at the source
  - Generates too much control traffic (i.e., RREQ broadcast)
    - Expanding ring search:
      - TTL field limits the broadcast area
    - Location-aided routing
      - Only certain nodes participate in RREQ broadcast

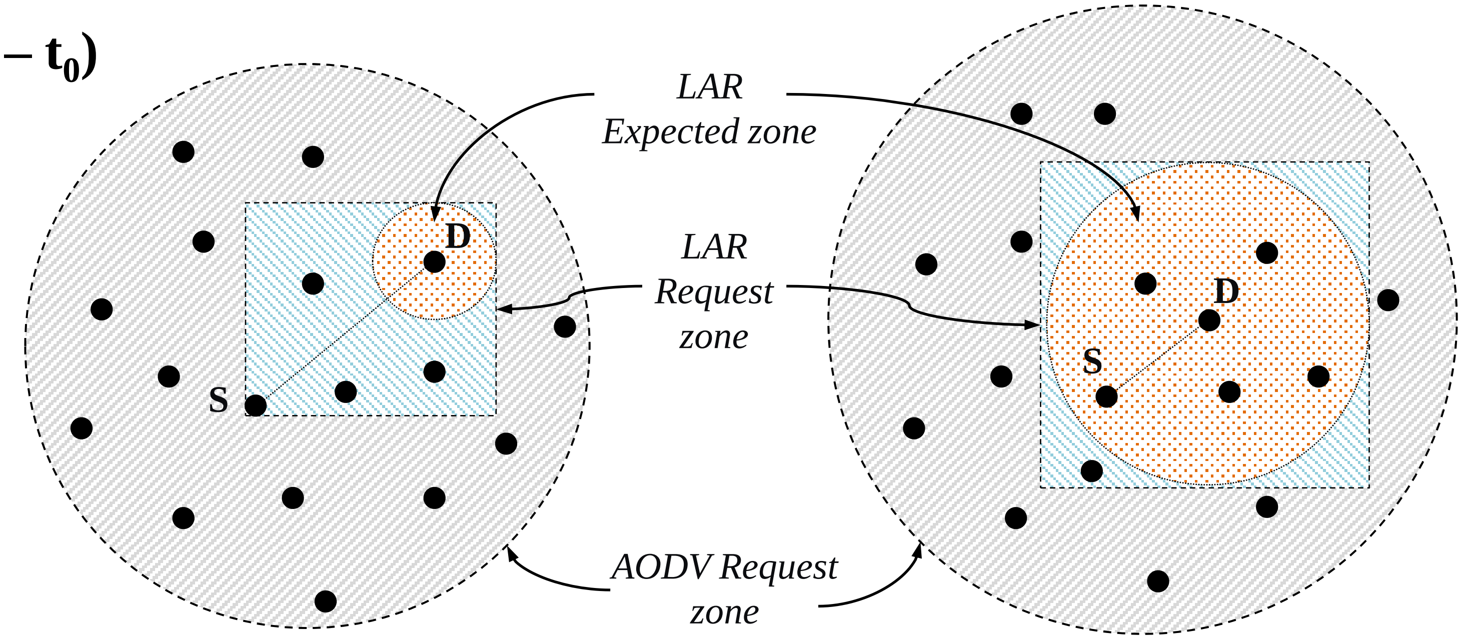
Introduction: Location-Aided Routing

- Idea of location-aided routing
  - Location information:
    - (x, y, z) coordinates
    - Traveling speed
    - Obtained via GPS
  - Request zone:
    - Based on location information
    - Area that likely contains the path to destination
    - Only nodes within request zone re-broadcast RREQs
- Advantages
  - Only nodes that likely on the path to destination participate in route discovery
  - Fewer nodes rebroadcast RREQs
  - Reduces the control traffic overhead



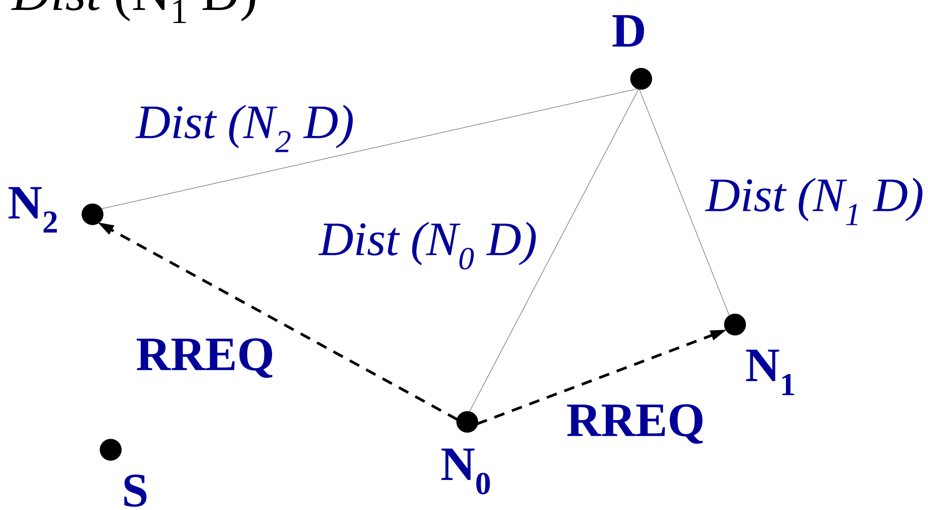
Location-Aided Routing: LAR zone

- All nodes know:
  - **d** - destination's location at time $\mathbf{t_0}$
  - **v** - destination's average speed
- Expected zone:
  - Area likely to contain destination at time $\mathbf{t_1}$
  - Circle centered in **d** with radius **r**
    - $\mathbf{r = v \times (t_1 - t_0)}$
- Request zone:
  - Rectangular area
  - Sides parallel to x and y axis
  - Sides tangent to expected zone
  - Contains source node and the expected zone



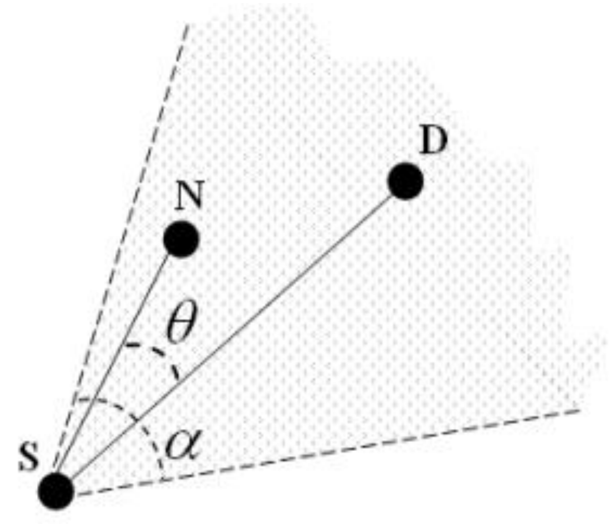
Location-Aided Routing: LAR distance

- Uses the distance between an intermediate node and destination to determine if an RREQ message will be rebroadcast or not
- Example:
  - RREQ for destination **D** arrives at node $\mathbf{N_1}$ from node $\mathbf{N_0}$
  - If distance between $\mathbf{N_1}$ and **D** is not larger than distance between $\mathbf{N_0}$ and **D** then RREQ re-broadcast, otherwise RREQ discarded
  - RREQ is forwarded if
    - $\alpha \times \mathit{Dist}\,(N_0\ D) + \beta \leq \mathit{Dist}\,(N_1\ D)$



Geographical AODV: Regular GeoAODV

- GeoAODV approach:
  - Request zone is a cone-shaped area controlled via a flooding angle
    - Source node is the apex of the cone
    - Flooding angle is evenly divided by line between source and destination
  - **N**, **S**, and **D** – denote intermediate, source, and destination nodes
  - RREQ carries last known coordinates of **S** and **D** nodes and flooding angle **α**
  - Compute angle **θ** formed between nodes **D**, **S**, and **N**:
    - $\theta = \cos^{-1}((SD \bullet SN) / (|SD| \times |SN|))$
  - If **θ < ½ × α** then RREQ is rebroadcast, otherwise RREQ is discarded

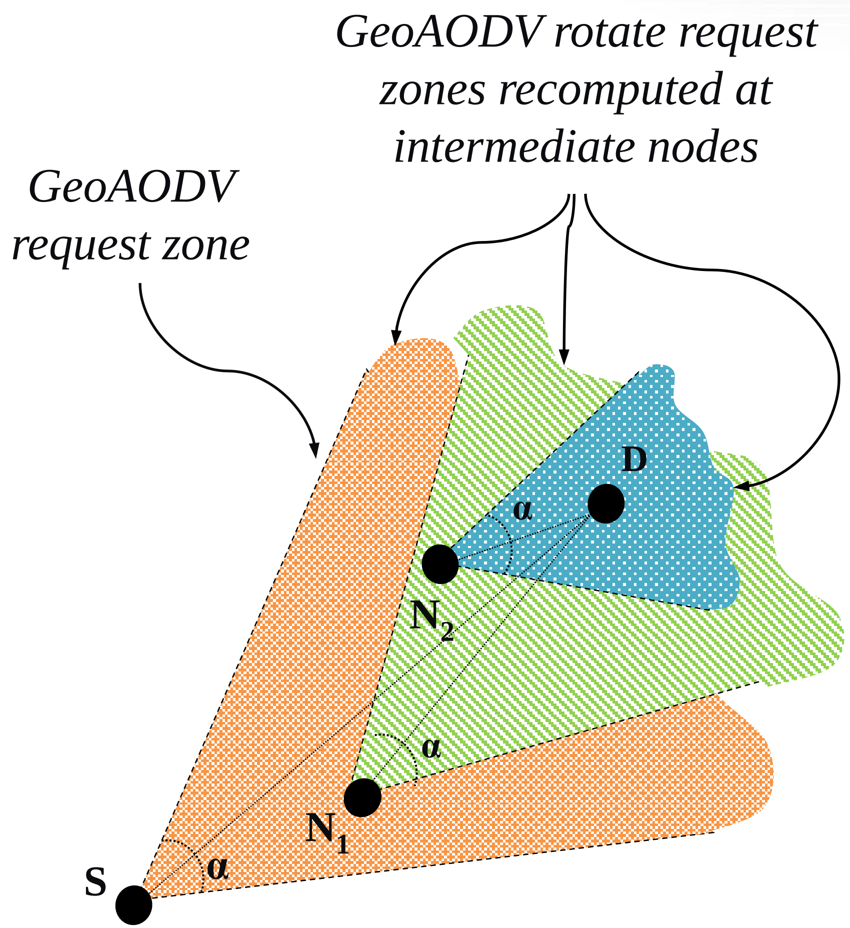


Geographical AODV: Regular GeoAODV

- GeoAODV supporting structures
  - Does not assume that node coordinates are known
  - Coordinates are distributed via control messages
  - Nodes maintain location tables with other node's coordinates, IP addresses, and freshness (i.e., a sequence number)
  - Stale location information is periodically purged
- If destination coordinates are unknown then flooding angle is 360°
  - GeoAODV operates the same way as regular AODV
- If route discovery fails to find a path then flooding angle increased and process repeated again until flooding angle becomes 360°
- GeoAODV requires initialization time to distributed node coordinates
  - Initially, GeoAODV is expected to perform similarly to AODV
  - GeoAODV performance is expected to improve once the node coordinates are available throughout the network.

Geographical AODV: GeoAODV Rotate

- GeoAODV Rotate
  - Operates the same way as Regular GeoAODV, but
  - Request zone is computed based on previous node's coordinates
    - Regular GeoAODV uses the source node coordinates
  - Request zone is re-oriented towards destination node at intermediate nodes
- Example
  - $\mathbf{N_1}$ computes the request zone using coordinates for **S** and **D**
  - $\mathbf{N_2}$ computes the request zone using coordinates for $\mathbf{N_1}$ and **D**



OPNET Implementation

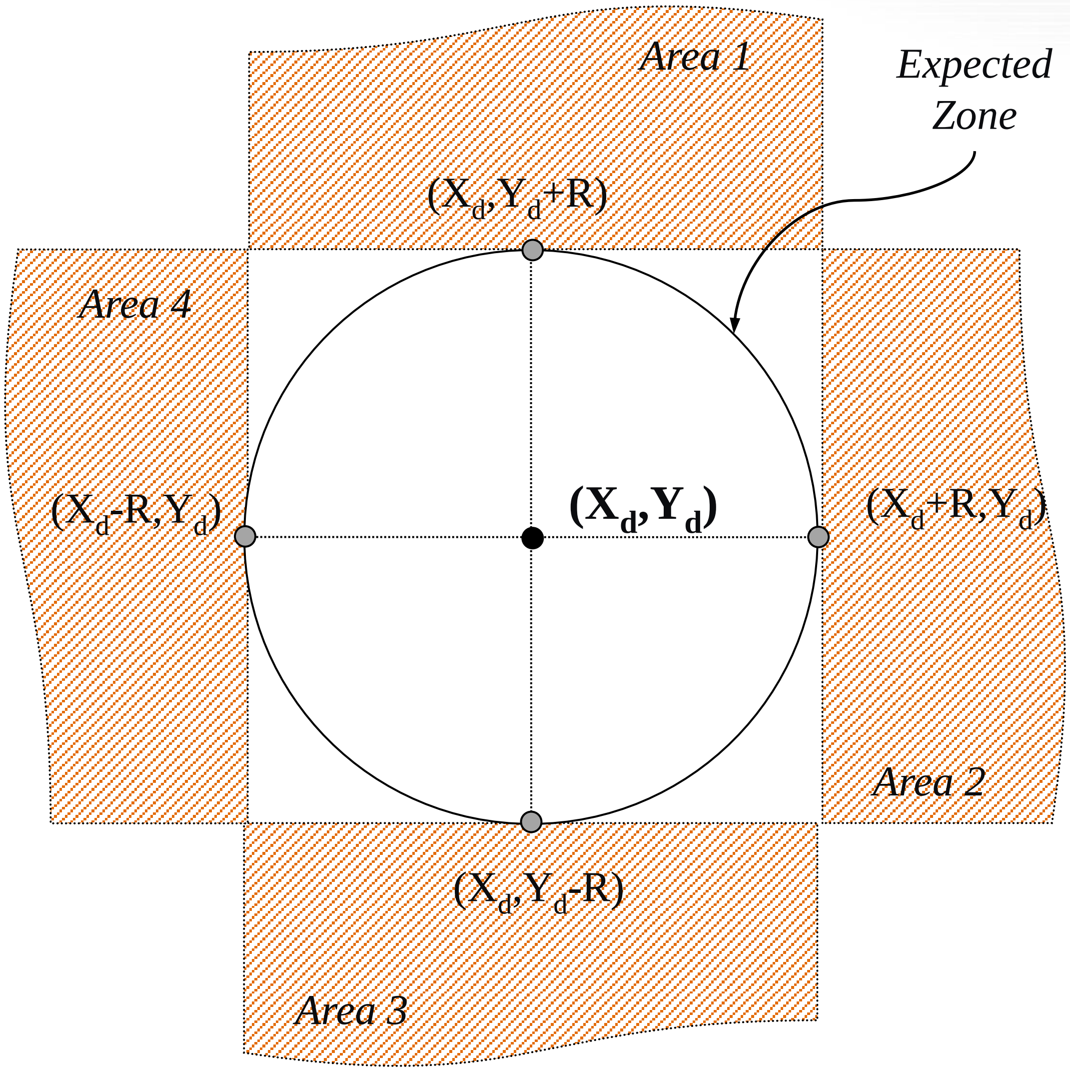
- Used OPNET Modeler 16.0
- Modified the code for
  - Standard AODV process model
  - Various supporting external files
  - RREQ and RREP packets structure files
- List of updated files:
  - *manet_mgr.pr.c*, *aodv_rte.pr.c*, *aodv_pk_support.exc.c*, *aodv_request_table.ex.c*
  - *aodv_ptypes.h*, *aodv_pkt_suport.h*, *aodv.h*, *manet_mgr.pr.m*
- Added few additional external files for LAR and GeoAODV implementation
- For LAR, node traveling speed and coordinates maintained using *oms_data_def* package
  - Add location information using *oms_data_def_entry_insert()* call
  - Retrieve location information using *oms_data_def_entry_access()* call

OPNET Implementation: LAR Special Cases

- We uncovered several special case for LAR
- Notation:
  - **(X_s, Y_s)** – source coordinates
  - **(X_d, Y_d)** – destination coordinates
  - **R** – expected zone radius
- LAR defines request zone as
  - *Rectangle that encompasses the expected zone and has its sides tangent to the expected zone circle and parallel to x and y coordinate axis*
- If source node is located in any of the areas specified below then the above definition of LAR request zone will not include portion of expected zone.
  - *Area 1:* X_s in $(X_d - R, X_d + R)$ and $Y_s > Y_d + R$
  - *Area 2:* $X_s > X_d + R$ and Y_s in $(Y_d - R, Y_d + R)$
  - *Area 3:* X_s in $(X_d - R, X_d + R)$ and $Y_s < Y_d - R$
  - *Area 4:* $X_s < X_d - R$ and Y_s in $(Y_d - R, Y_d + R)$

OPNET Implementation: LAR Special Cases

- *Area 1:*
  - X_s in $(X_d - R, X_d + R)$ and
  - $Y_s > Y_d + R$
- *Area 2:*
  - $X_s > X_d + R$ and
  - Y_s in $(Y_d - R, Y_d + R)$
- *Area 3:*
  - X_s in $(X_d - R, X_d + R)$ and
  - $Y_s < Y_d - R$
- *Area 4:*
  - $X_s < X_d - R$ and
  - Y_s in $(Y_d - R, Y_d + R)$



OPNET Implementation: LAR Special Cases

- To address the above issue by changing the definition of the corners in the request zone, as follows:
  - Lower-left corner: **$[Min(X_d - R, X_s), Min(Y_d - R, Y_s)]$**
  - Upper-right corner: **$[Max(X_d + R, X_s, Max(Y_d + R, Y_s)]$**

- Other observations:
  - LAR distance may fail to find a route to destination even if it exists; if a path to destination contains sections which require traveling in the direction away from destination
  - LAR distance does not provide any mechanism for identifying and dealing with the situations when the protocol fails to find the path to destination while the path exists.
  - The optimal values of α and β very much depend on the network topology
  - Determining proper values of α and β could be quite challenging.

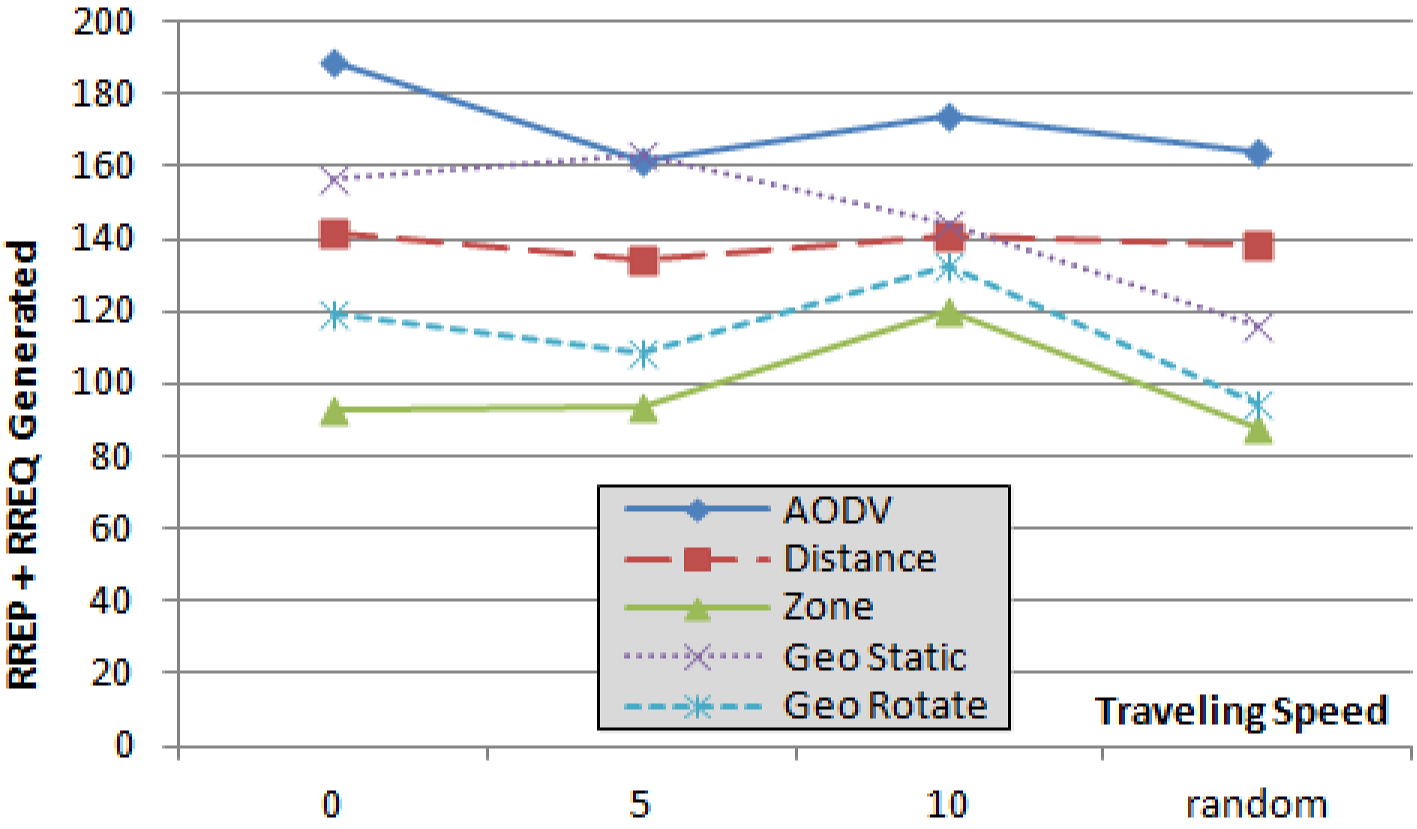
Simulation Study: Set-up

- Simulation set-up:
  - Area size: 1500 m x 1500 m
  - 50 randomly placed nodes
  - Number of communicating nodes: 2, 5, 10, 20, and 30
  - Communicating nodes and destinations selected randomly
  - Communication start time: 100 seconds
  - Random Waypoint node movement model
  - Pause time: exponential(10) seconds.
  - Node traveling speed: 0, 5, 10, and uniform(0,20) meters/second
  - Wireless LAN configuration: default OPNET Modeler values.
  - Duration of simulation: 300 seconds.
- Each scenario executed 6 times (different seed value)
- Total 600 simulation runs
- GeoAODV flooding angle: initial value 90°, with 90 ° increment

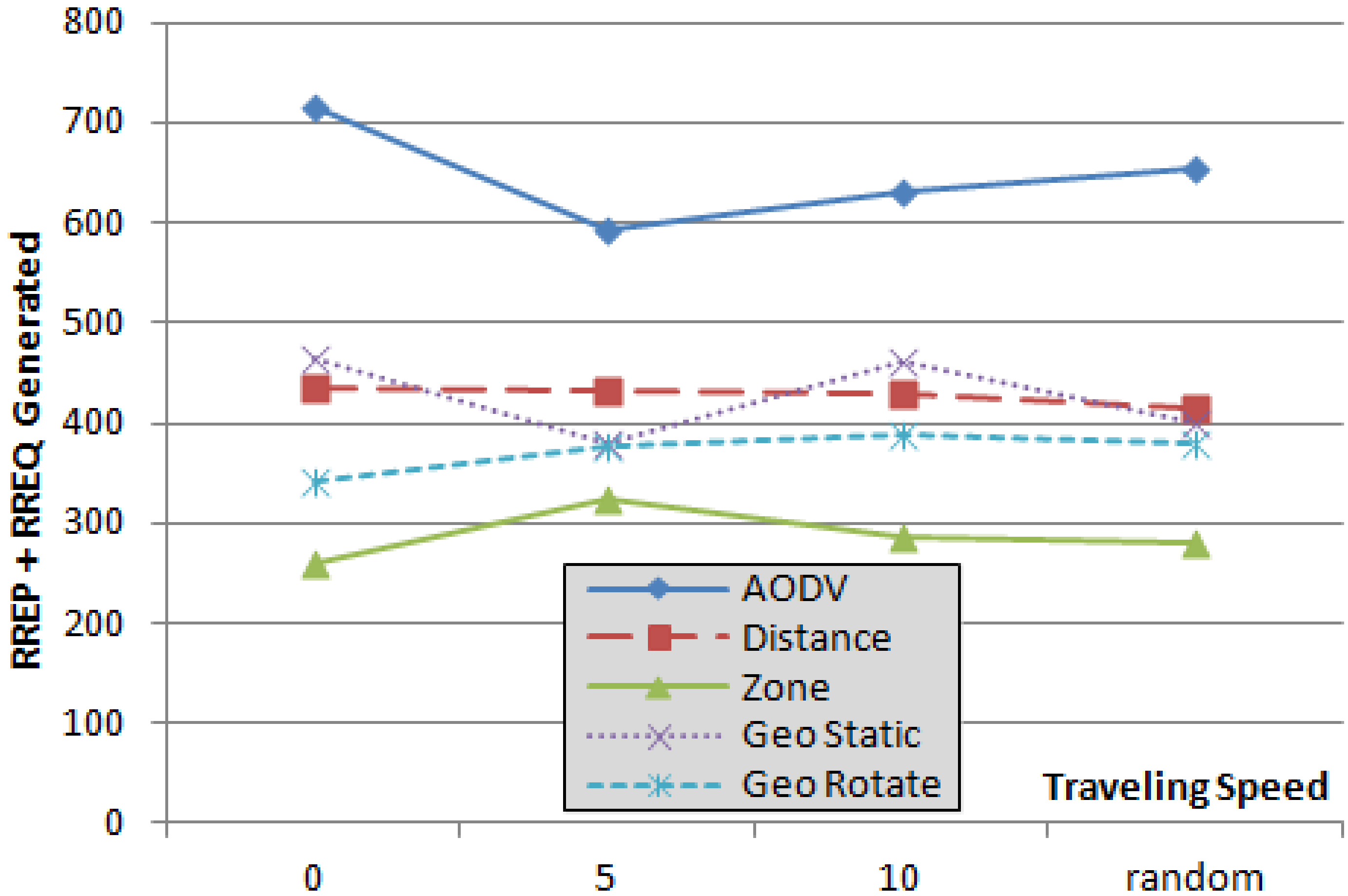
Simulation Study: Set-up

Configuration Parameter	Value
Channel Data Rate	*11 Mbps*
Transmit Power	*0.0005 Watts*
Packet Reception Power Threshold	*-95 dBm*
Start of data transmission	*normal (100, 5) seconds*
End of data transmission	*End of simulation*
Duration of Simulation	*300 seconds*
Packet inter-arrival time	*exponential (1) second*
Packet size	*exponential (1024) bytes*
Mobility model	*Random Waypoint*
Pause Time	*exponential(10)*
Destination	*Random*

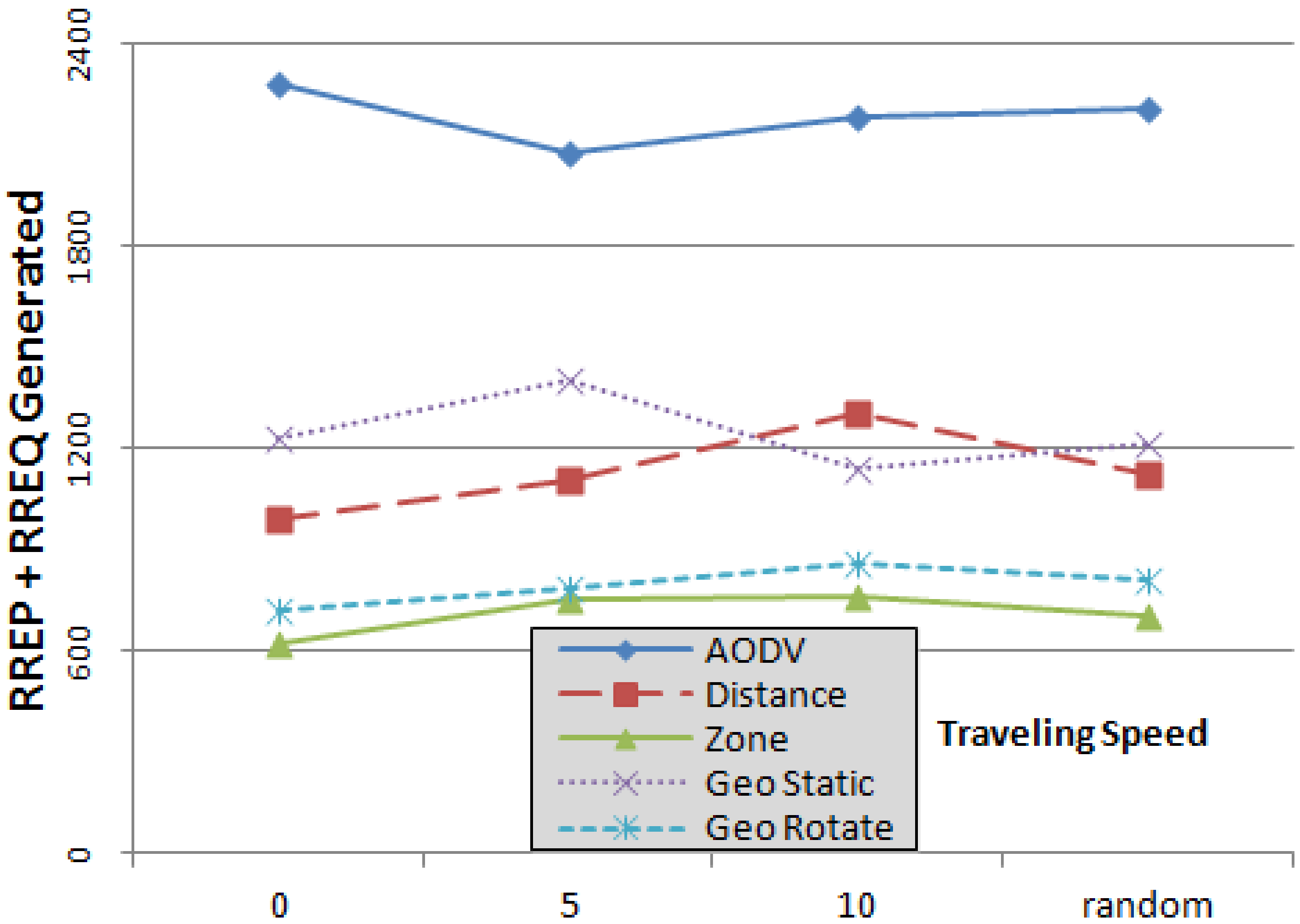
Simulation Results: 2 communicating nodes



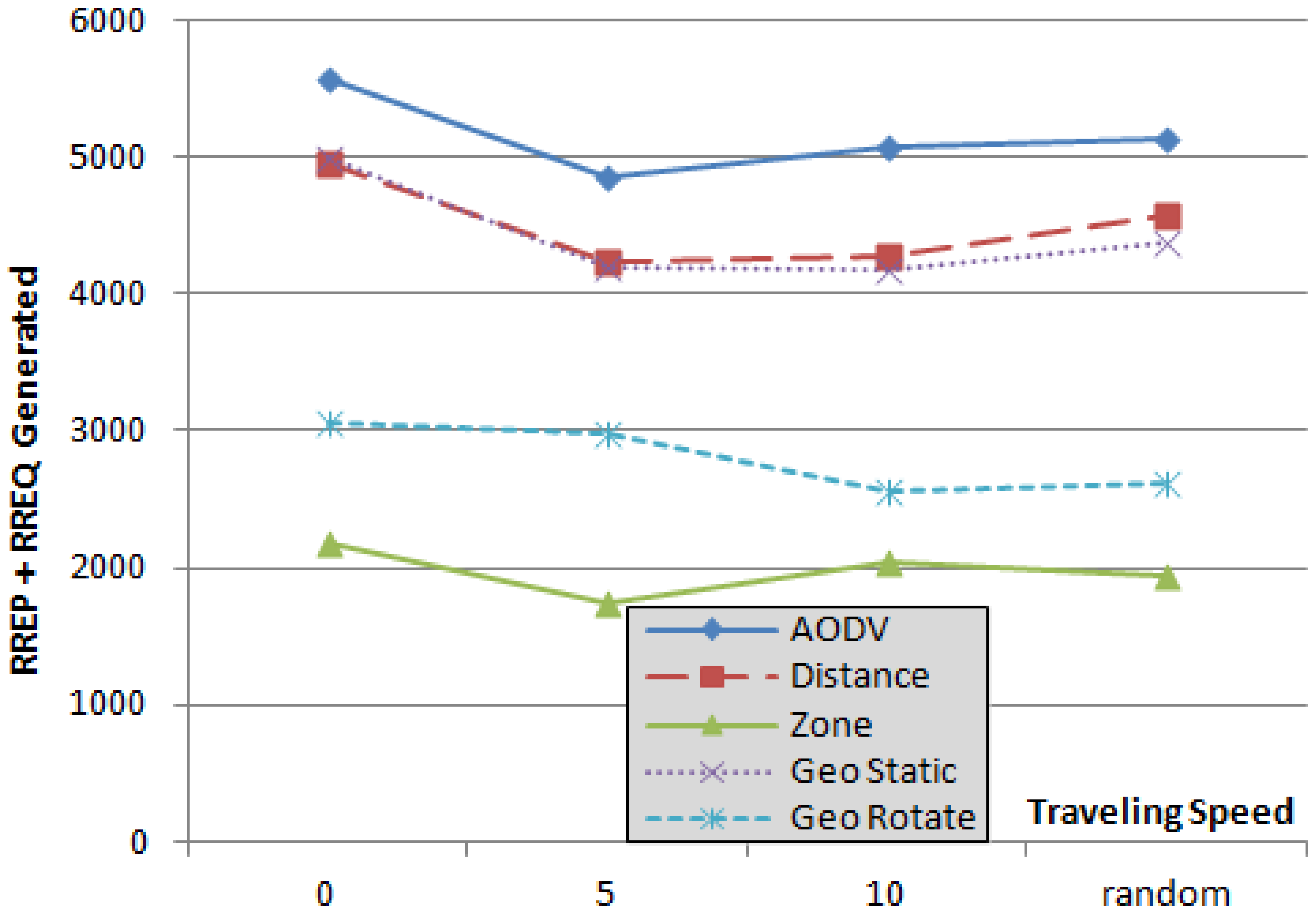
Simulation Results: 5 communicating nodes



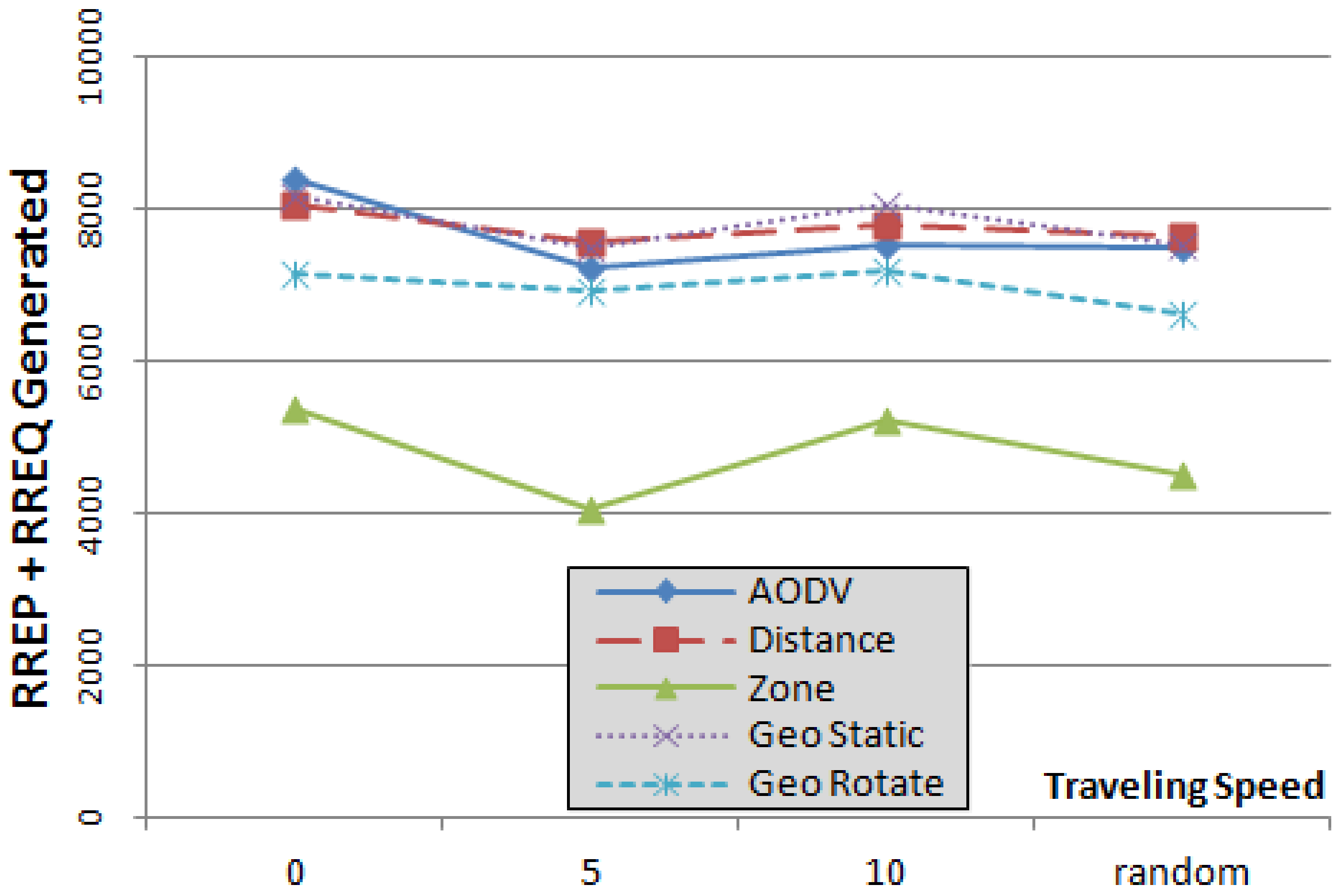
Simulation Results: 10 communicating nodes



Simulation Results: 20 communicating nodes



Simulation Results: 30 communicating nodes



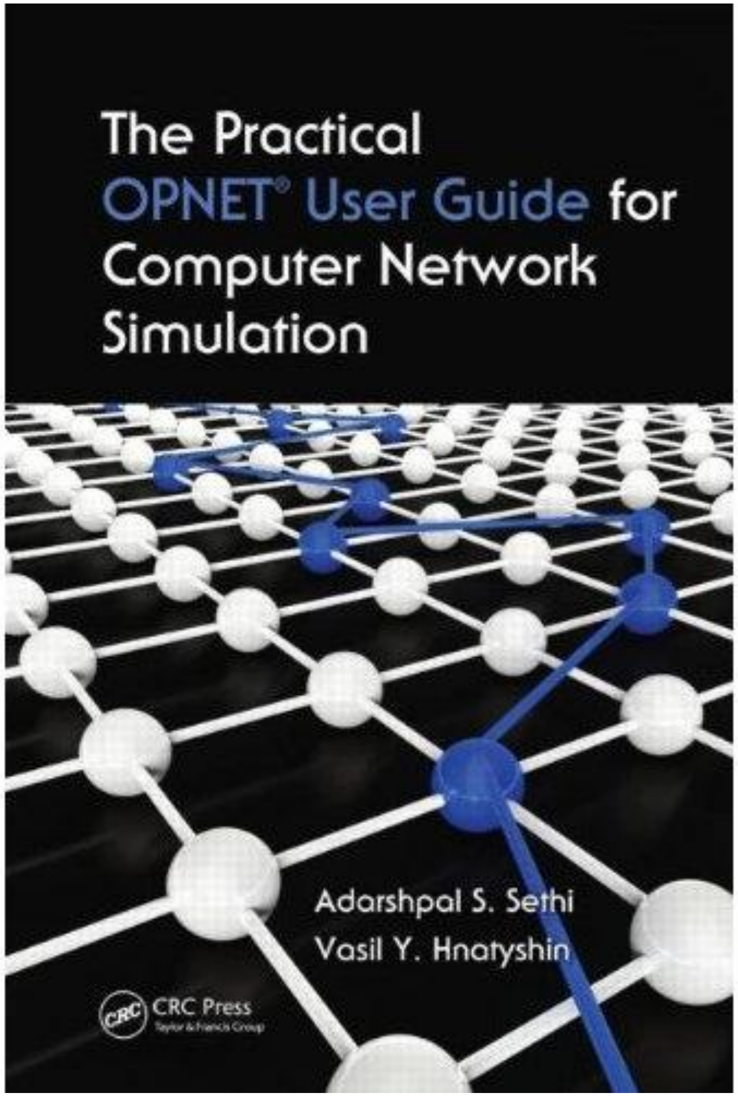
Simulation Study: Conclusions

- The protocols that employ location information generate less control traffic than regular AODV.
- LAR Zone is outperforms all other protocols
  - Assumes that node coordinates and traveling velocity are known
- GeoAODV Rotate is consistently the second best option
  - Dynamically distributes node coordinates
    - Requires initialization time
  - Does not employ the knowledge of node velocities

Future Work

- We currently investigating:
  - Performance of GeoAODV Rotate in different environmental settings
  - Developing mechanisms to more accurately increment the value of flooding angle after failures
- We plan to:
  - Create a mechanism for determining more accurate flooding angle values (initial and increment)
  - Re-run the simulation study with a larger number of repetition (each with a different seed value),
  - Further analyze the collected results
  - Examine the performance of the GeoAODV Rotate during the pre- and post-convergence periods
  - Study how fast GeoAODV Rotate converges to a stable state
  - Examine the accuracy of node locations distributed via GeoAODV Rotate
  - Investigate how the accuracy of node locations influences the performance of GeoAODV Rotate
  - Compare GeoAODV Rotate with other location-based routing protocols

The Practical OPNET® User Guide for Computer Network Simulation



The Practical OPNET® User Guide for Computer Network Simulation

- **Adarshpal S. Sethi**
- **Vasil Y. Hnatyshin**

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The Practical OPNET® User Guide for Computer Network Simulation

- The Practical OPNET® User Guide for Computer Network Simulation
  - One of the first books to provide a comprehensive description of OPNET® IT Guru and Modeler software
  - Explains how to use this software for simulating and modeling computer networks.
  - The included laboratory projects help readers learn different aspects of the software in a hands-on way.
- Quickly Locate Instructions for Performing a Task
  - The book begins with a systematic introduction to the basic features of PNET, which are necessary for performing any network simulation.
  - The remainder of the text describes how to work with various protocol layers using a top-down approach.
  - Every chapter explains the relevant OPNET features and includes step-by-step instructions on how to use the features during a network simulation.

The Practical OPNET® User Guide for Computer Network Simulation

- Gain a Better Understanding of the "Whats" and "Whys" of the Simulations
  - Each laboratory project in the back of the book presents a complete simulation and reflects the same progression of topics found in the main text.
  - The projects describe the overall goals of the experiment, discuss the general network topology, and give a high-level description of the system configuration required to complete the simulation.
- Discover the Complex Functionality Available in OPNET
  - By providing an in-depth look at the rich features of OPNET software, this guide is an invaluable reference for IT professionals and researchers who need to create simulation models.
  - The book also helps newcomers understand OPNET by organizing the material in a logical manner that corresponds to the protocol layers in a network.

The Practical OPNET® User Guide for Computer Network Simulation

- Features
  - Provides detailed descriptions of the most commonly used OPNET software features
  - Illustrates how to develop and configure models for every layer of the TCP/IP reference model
  - Contains extensive examples that show how to set up and configure many nontrivial features of OPNET software
  - Presents detailed answers to commonly asked “how-to” questions
  - Includes laboratory assignments that cover all layers of the TCP/IP reference model and enable readers to experiment with various software features described in the text