Mobility Models

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Motivation

- Wireless network simulations often involve movements of entities
- Examples
  - Users are roaming on WLAN access points that are installed in buildings (infrastructure mode)
  - Cell phone users are walking a city
  - Cars use car-to-car communication
  - Ad hoc networks in emergency situations, e.g., earthquake or fire
- Mobility of entities plays an important role in such scenarios
- Results may vary significantly if the mobility pattern is changed

Categorization

- Traces and synthetic mobility models
  - **Traces**: Mobility patterns that are logged from real life situations
    - **Synthetic mobility models**: Generated by algorithms that specify virtual behavior of users and predict their movements
- Entity and group mobility models
  - **Entity models**: Movement of a single individual entity, e.g., a human being or an animal.
  - **Group models**: A group of individual entities, which is moving as a whole.

Categorization

- Human, animal, and vehicle mobility models
  - **Human**: Human beings in certain scenarios.
  - **Animal**: Herds or swarms
  - **Vehicle**: Restricted to traffic rules
- Normal situation and special situation mobility models
  - **Special**: earthquake

What is Mobile Network? Why is it called Ad Hoc?

- Mobile Ad Hoc Networks (MANET) is a network consisting of mobile nodes with wireless connection (Mobile) and without central control (Ad Hoc)
  - Self-Organized Network
- Each mobile node communicates with other nodes within its transmitting range
- Transmission may be interrupted by nodal movement or signal interference

It seems that something is watching

- Sensor Network is recently a hot topic
- Specified Application in MANET
- Nodes are equipped some observation devices (GPS, Temperature, Intruder Detection and so on)
- Nodes may move spontaneously or passively
- There are more restrictions in Sensor Networks
  - Power
  - Transmission Range
  - Limited Computation Power
  - Moving Speed (if does)

Realistic Mobility Model is better than Proposed Mobility Models

- Although MANET and Sensor Network are being researched for a while, there do not exist many realistic implementation
- To implement a real MANET or Sensor Network environment for emulation is difficult
  - Signal Interference
  - Boundary
- We will need to evaluate MANET by simulation
- To have useful simulation results is to control factors in simulation
  - Traffic Pattern
  - Bandwidth
  - Power Consumption
  - Signal Power (Transmission Range)
  - Mobility Pattern
  - And so on

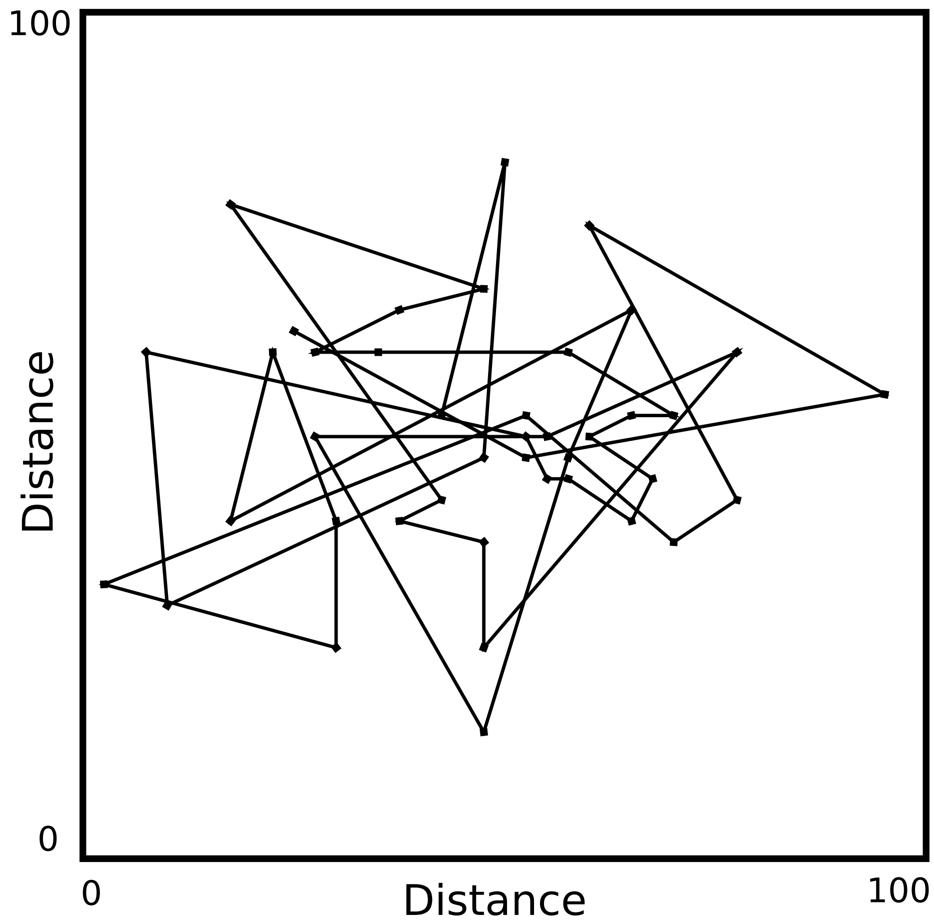
How Many Mobility Model are inspected?

- Entity Mobility Models
  - Random Walk Mobility Model
  - Random Waypoint Mobility Model
  - Random Direction Mobility Model
  - A Boundless Simulation Area Mobility Model
  - Gauss-Markov Mobility Model
  - A Probability Version of the Random Walk Mobility Model
  - City Section Mobility Model

- Group Mobility Models
  - Exponential Correlated Random Mobility Model
  - Column Mobility Model
  - Nomadic Community Mobility Model
  - Pursue Mobility Model
  - Reference Point Group Mobility Model

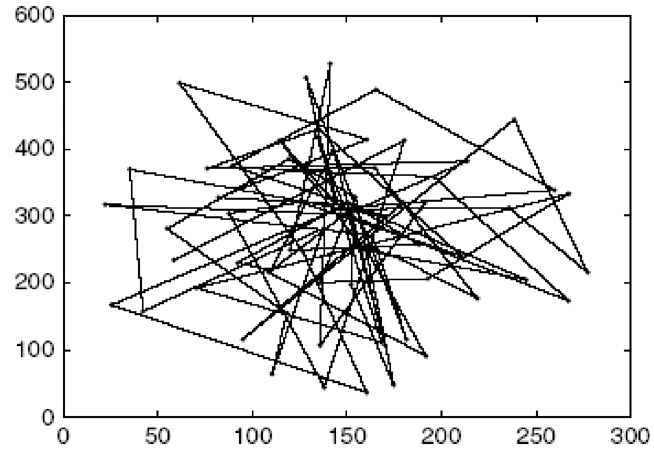
Random Walk model

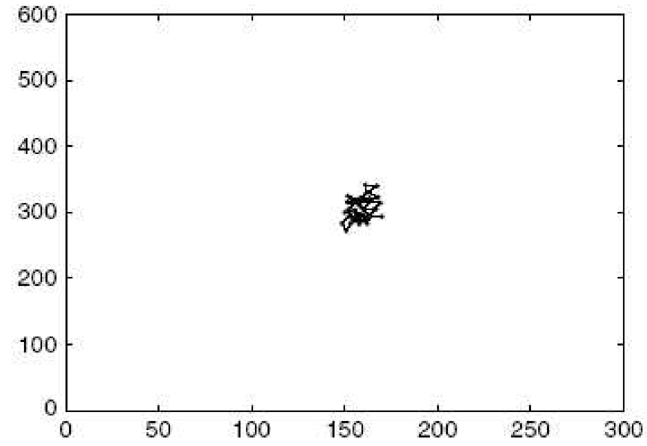
- Entities in nature move in unpredictable ways
- Entity moves from its current location to a following location by choosing randomly a new direction and speed
- Every movement is limited to a constant time interval



Random Walk

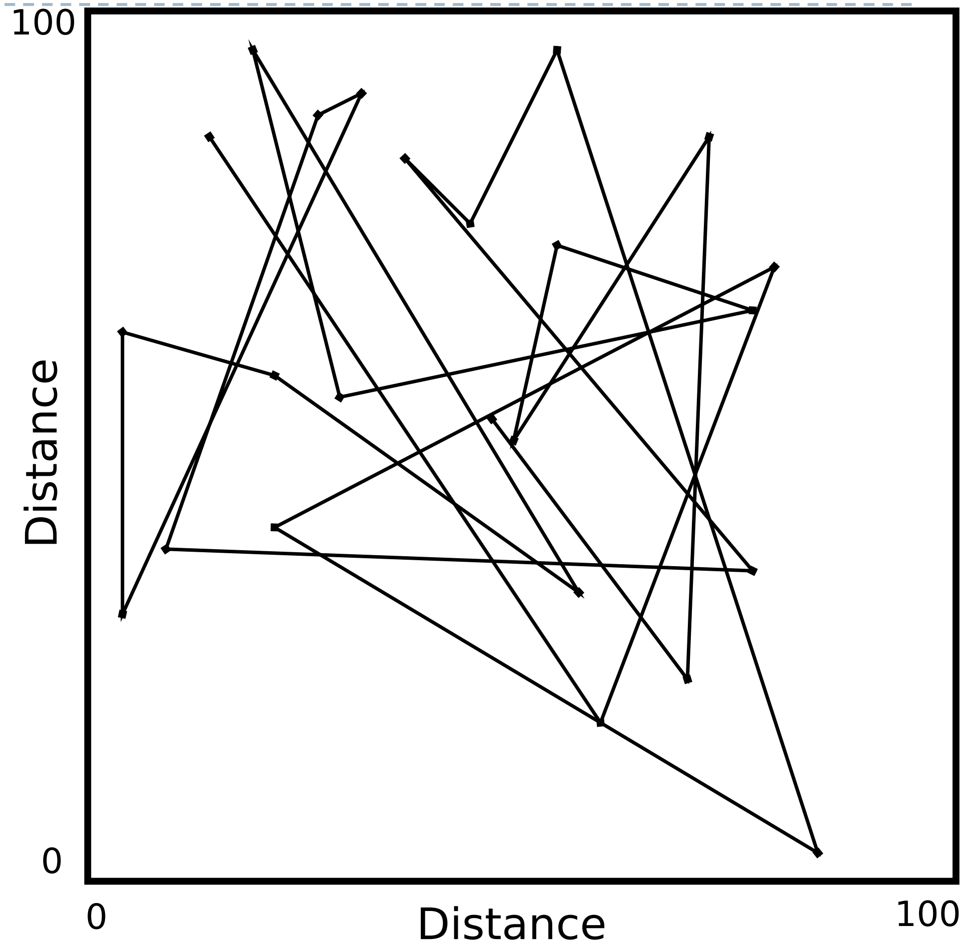
- Parameters:
  - Speed = [Speed_MIN,Speed_MAX]
  - Angle = [0,2π]
  - Traversal Time (t) or Traversal Distance (d)





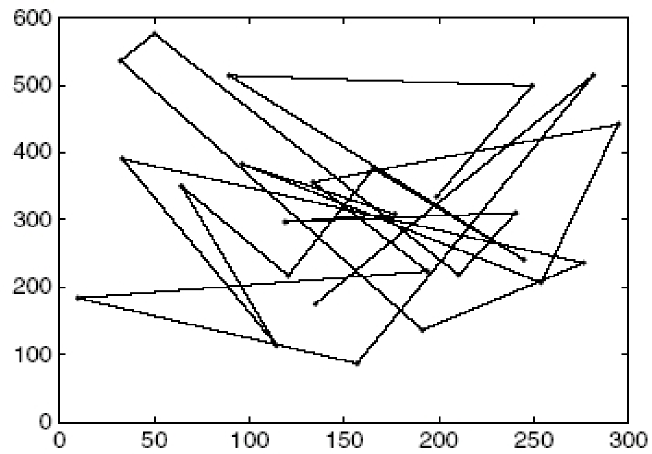
Random Waypoint Model

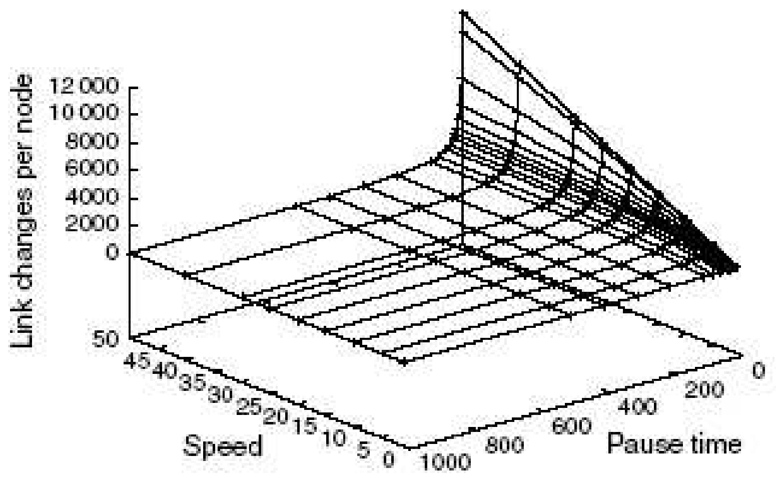
- The entity chooses a random destination coordinate
- Then it moves from its current location to the destination location
- After a pause, the new movement is calculated

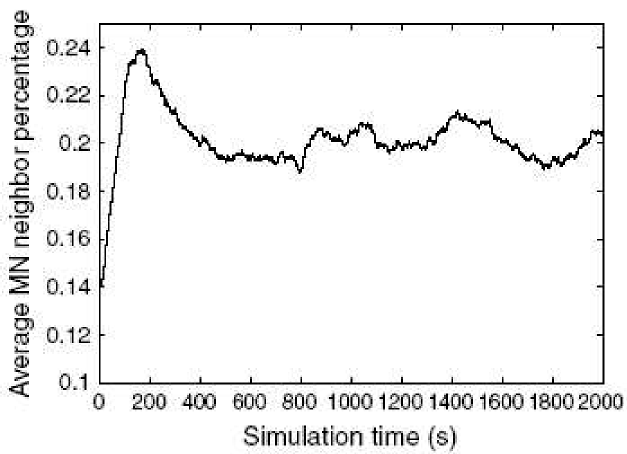


Random Waypoint

- Parameters
  - Speed = [Speed_MIN,Speed_MAX]
  - Destination = [Random_X,Random_Y]
  - Pause Time >= 0

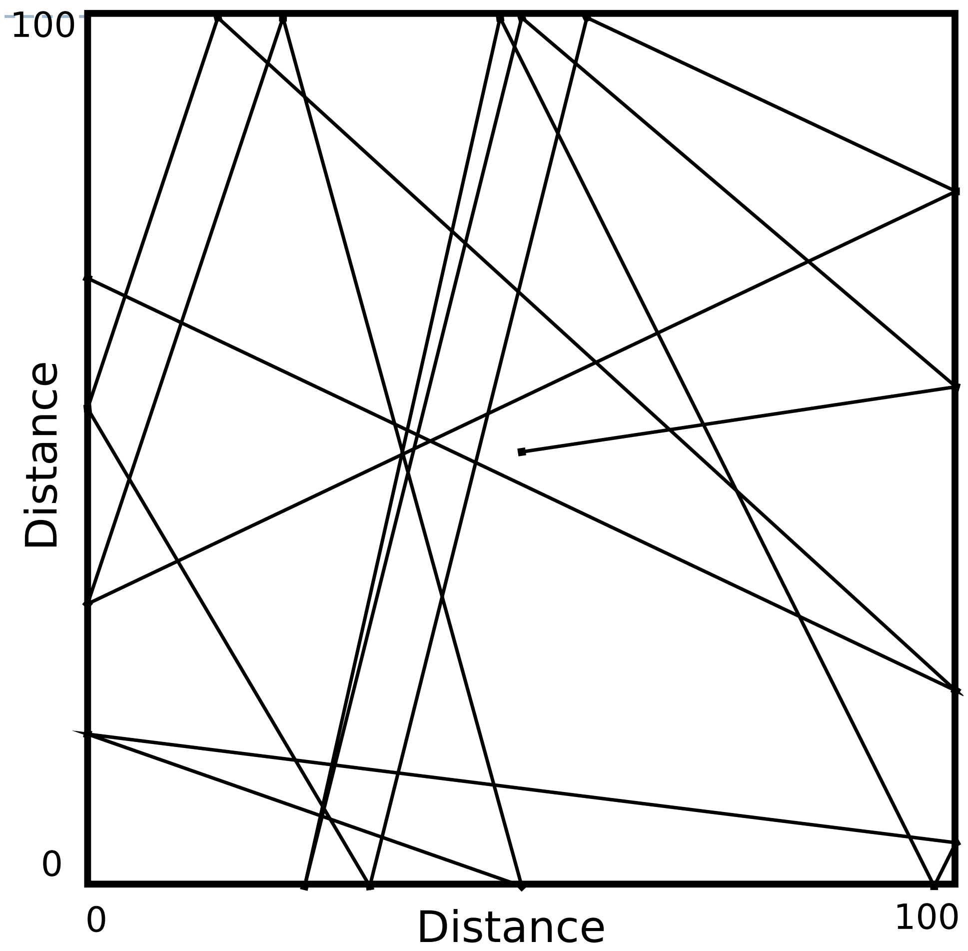






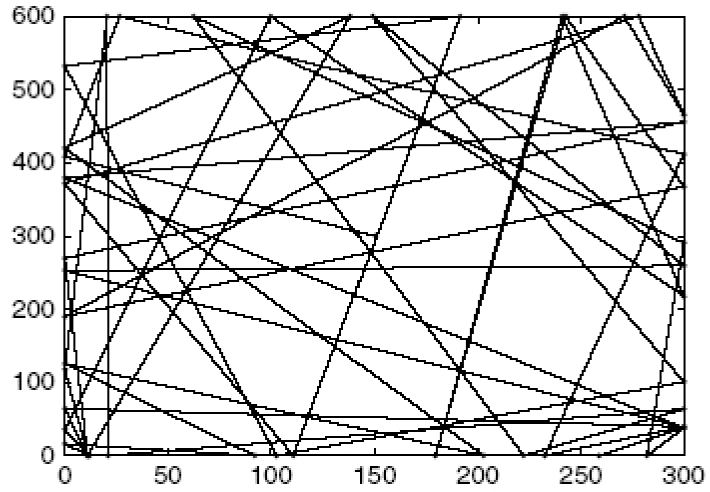
Random Direction Model

- The entity chooses a random direction and a random speed
- Entity moves towards the boundary of the simulation area
- After a pause, the new movement is calculated



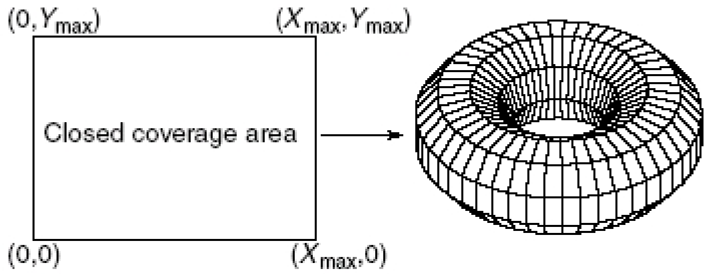
Random Direction

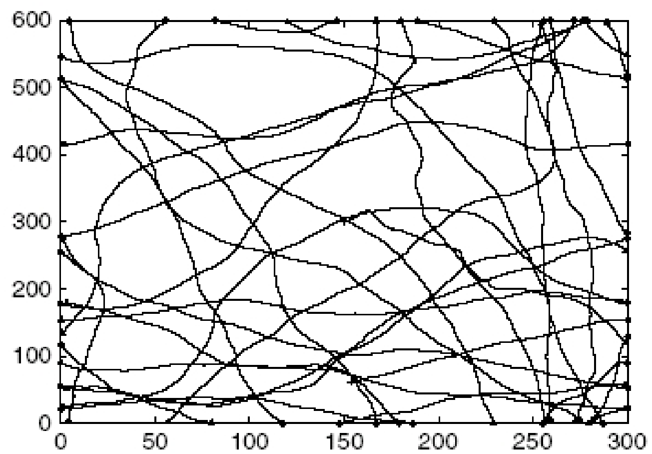
- Parameters:
  - Speed = [Speed_MIN,Speed_MAX]
  - Direction = [0,π] (Initial [0,2π])
  - Pause Time
- Go straight with selected direction until bump to the boundary then pause to select another direction



Boundless Simulation Area

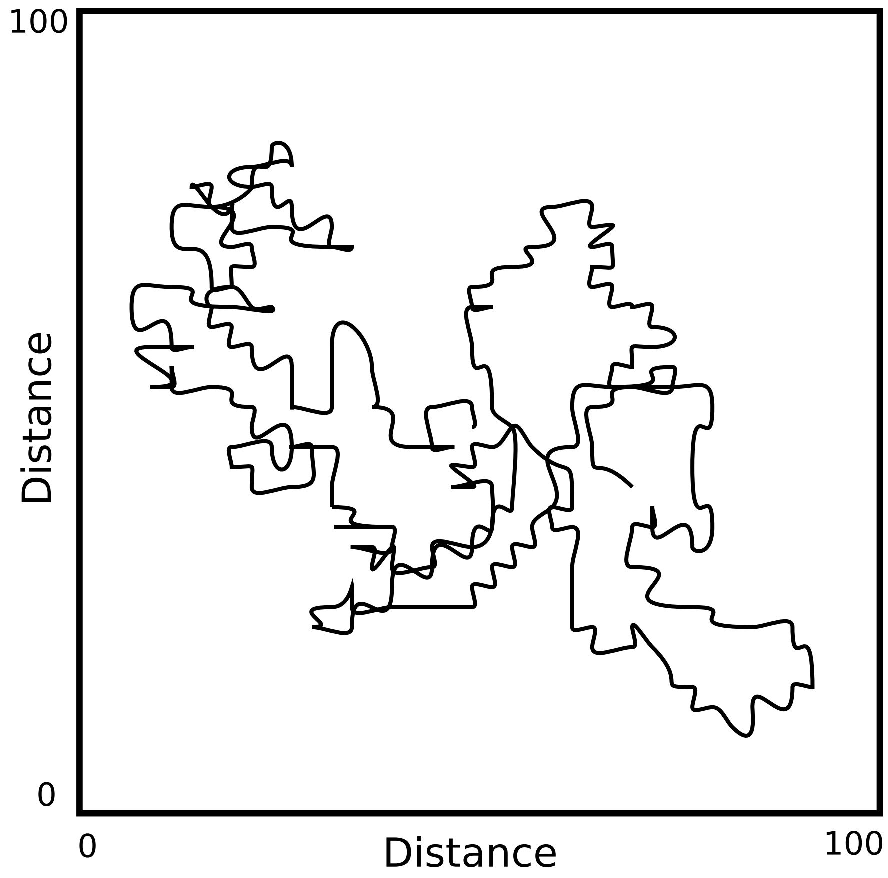
- Parameters:
  - $v(t+\triangle t) = \min\{\max[v(t)+\triangle v,0],V_{max}\}$
  - $\theta(t+\triangle t) = \theta(t) + \triangle\theta$
  - $x(t+\triangle t) = x(t) + v(t) * \cos\theta(t)$
  - $y(t+\triangle t) = y(t) + v(t) * \cos\theta(t)$
  - $\triangle v = [-A_{max} * \triangle t , A_{max} * \triangle t]$
  - $\triangle\theta = [-\alpha * \triangle t , \alpha * \triangle t]$





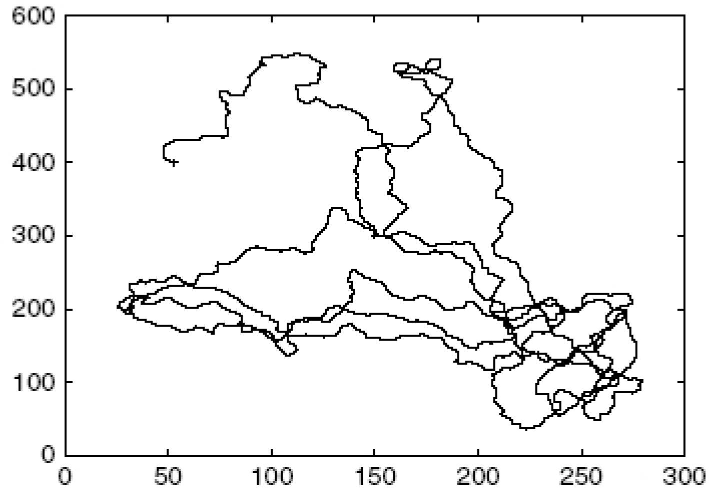
Gauss-Markov Model

- The entity gets initially assigned a speed and a direction
- At fixed intervals of time, an update of direction and speed is applied
- This model enables movements that are depending on previous movements



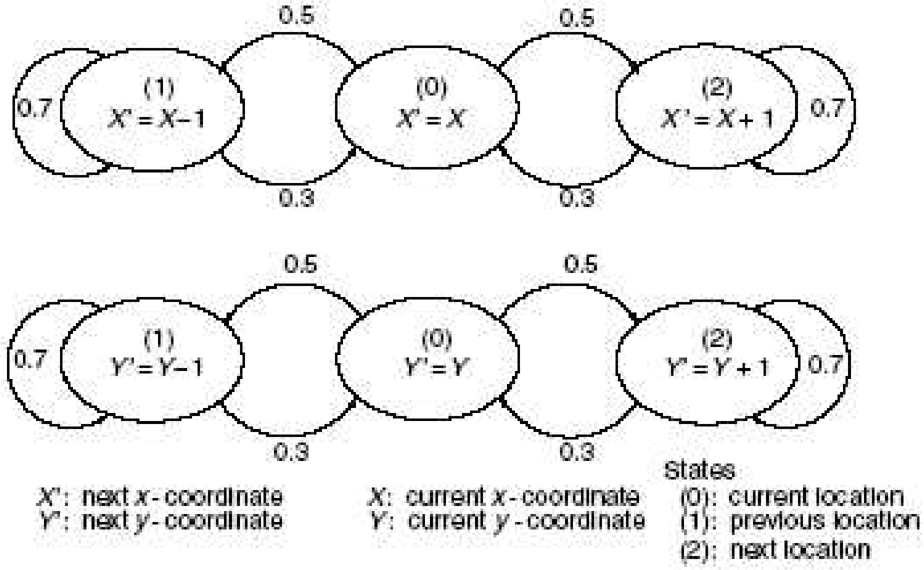
Gauss-Markov

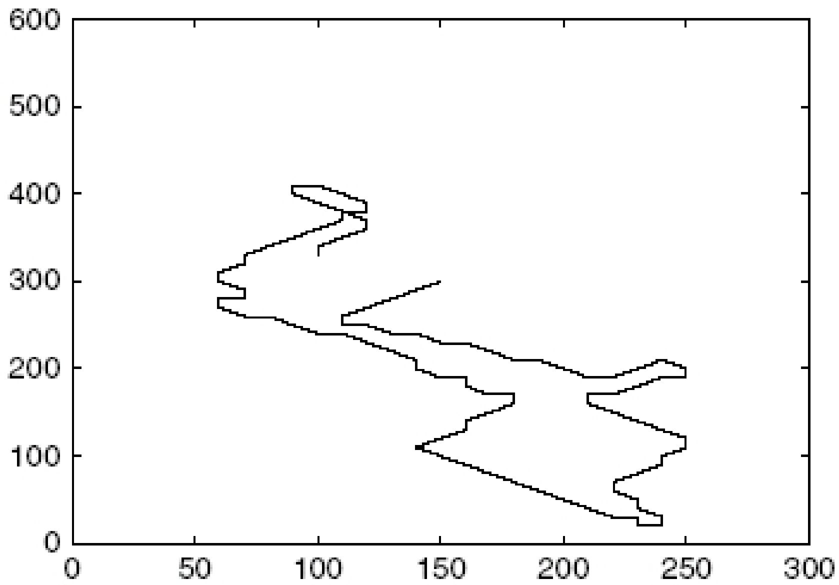
- Parameters:
  - $s_n = \alpha s_{n-1} + (1-\alpha)\bar{s} + \sqrt{(1-\alpha^2)s_{n-1}}$
  - $d_n = \alpha d_{n-1} + (1-\alpha)\bar{d} + \sqrt{(1-\alpha^2)d_{n-1}}$
- When approach the edge, d value will change to prevent the node stocking at the edge



Probability Version of Random Walk

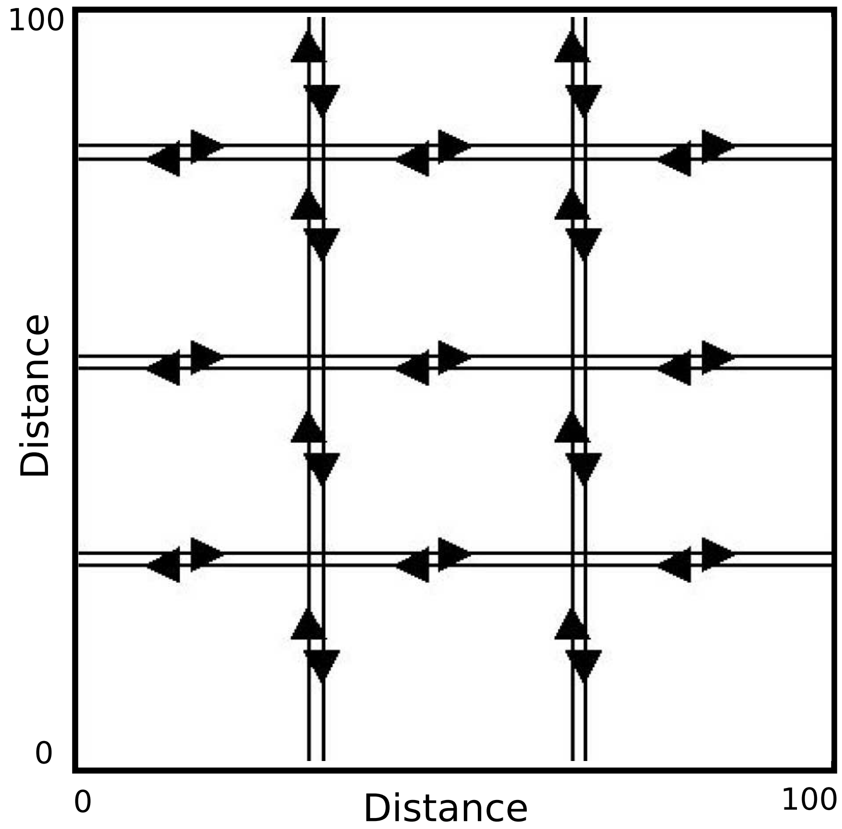
$$P = \begin{bmatrix} P(0,0) & P(0,1) & P(0,2) \\ P(1,0) & P(1,1) & P(1,2) \\ P(2,0) & P(2,1) & P(2,2) \end{bmatrix}$$



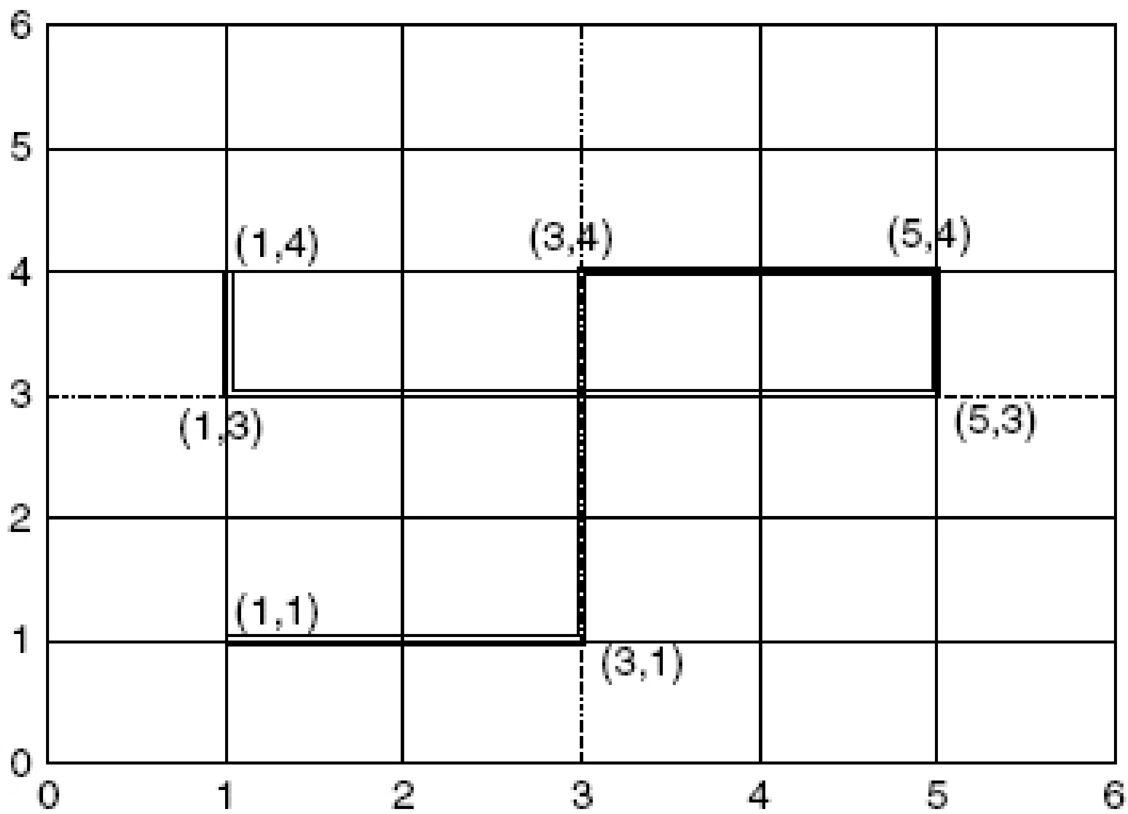


Manhattan Model

- Entities are bound to streets or highways
- Map with streets and crossings is defined
- Safety distance between entities
- Street changes at crossings happen according to a probability



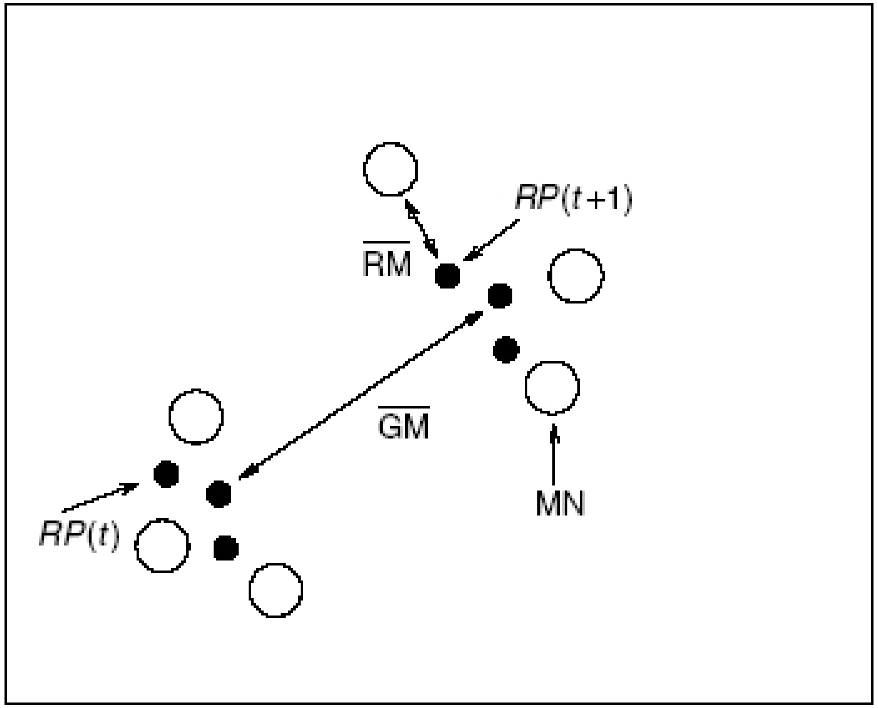
City Section



Group Mobility

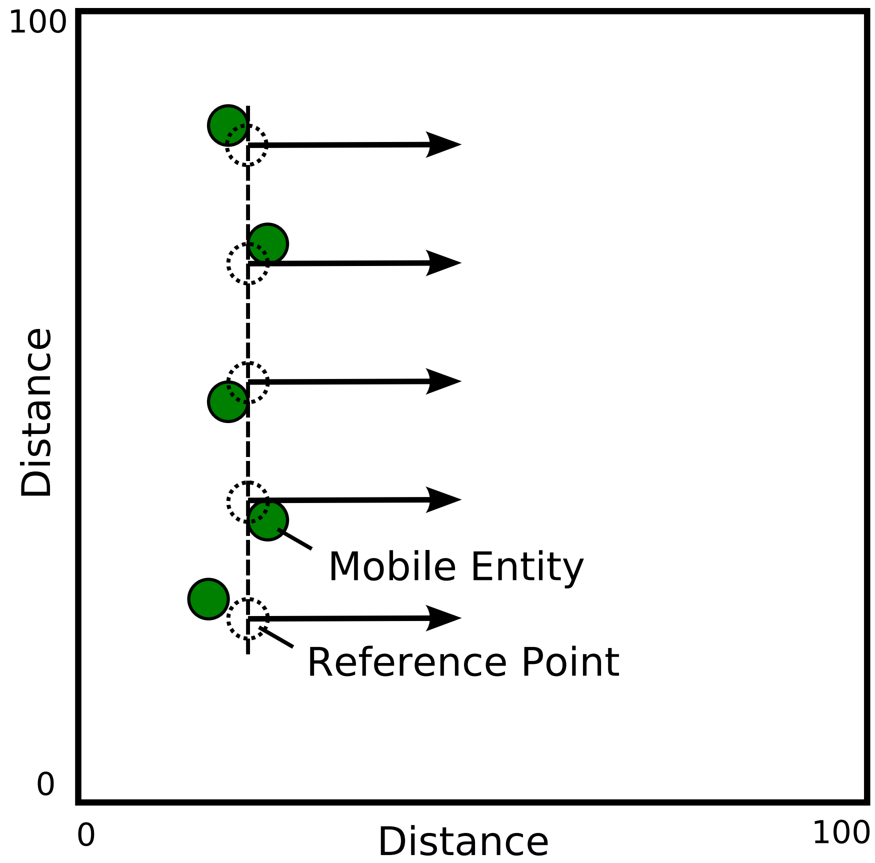
- Exponential Correlated Random Mobility Model
  - $$b(t+1) = b(t)e^{-\frac{1}{\tau}} + \left(\sigma\sqrt{1-\left(e^{-\frac{1}{\tau}}\right)^2}\right) r$$
- Column Mobility Model
  - Given a reference grid, each node has a reference point on the reference grid
  - Each node can move freely around its reference point (Ex: Random Walk)
- Nomadic Community Mobility Model
  - Similar to Column Mobility Model, but all nodes of a group share a reference point
- Pursue Mobility Model
  - new_pos = old_pos + acceleration(target-old_pos) + random_vector

- Reference Point Group Mobility Model
  - Group movements are based on the path traveled by a logical center for the group
  - GM: Group Motion Vector
  - RM: Random Motion Vector
  - Random motion of individual node is implemented by Random Waypoint without Pause



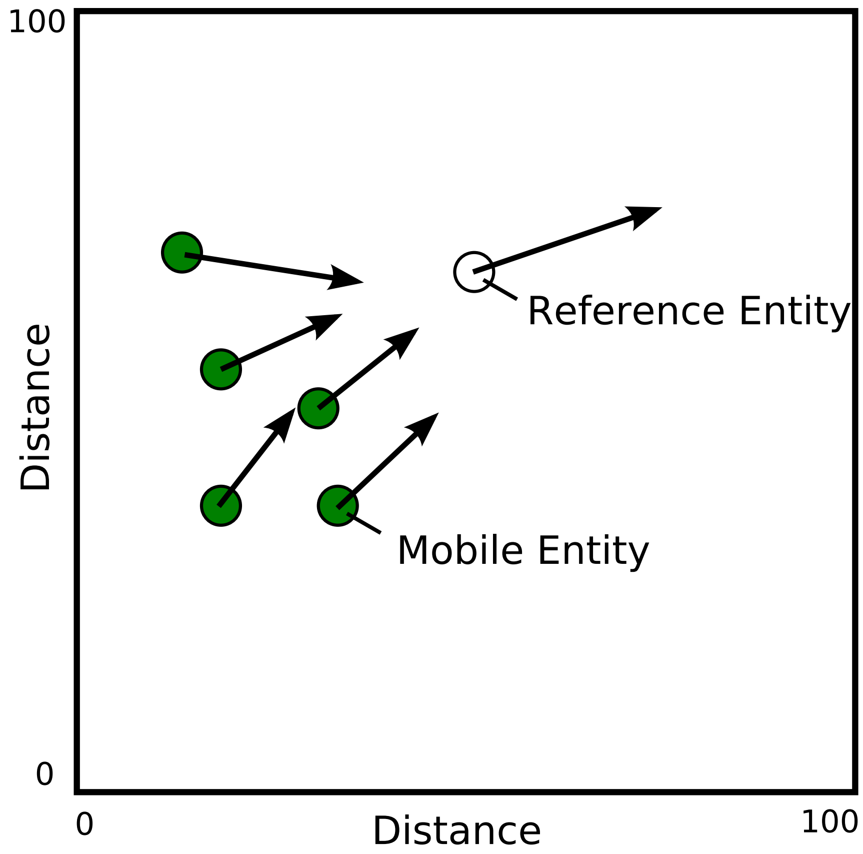
Column Model

- Group mobility model in which each entity follows a *reference point*
- Reference points are arranged in a line
- The line is moving
- Entities are choosing random point near the reference point to move to
- Example: tanks



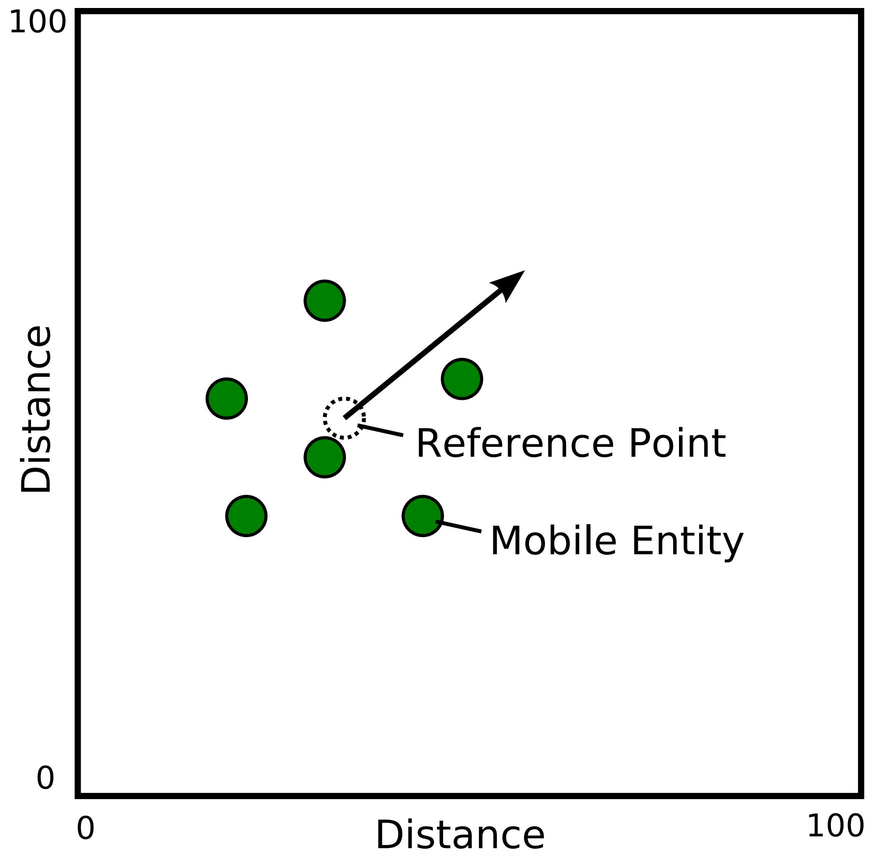
Persue Model

- Group of mobile entities are pursuing single *reference entity*
- The reference entity is using an entity mobility model
- Group entities are pursuing the reference entity while adding small deviations
- Example: Tourists following guide



Nomadic Community Model

- Group of entities are following a single *reference point*
- All entities are sharing the same reference point
- Each entity is randomly moving around the reference point
- Example: Nomads moving from one place to another



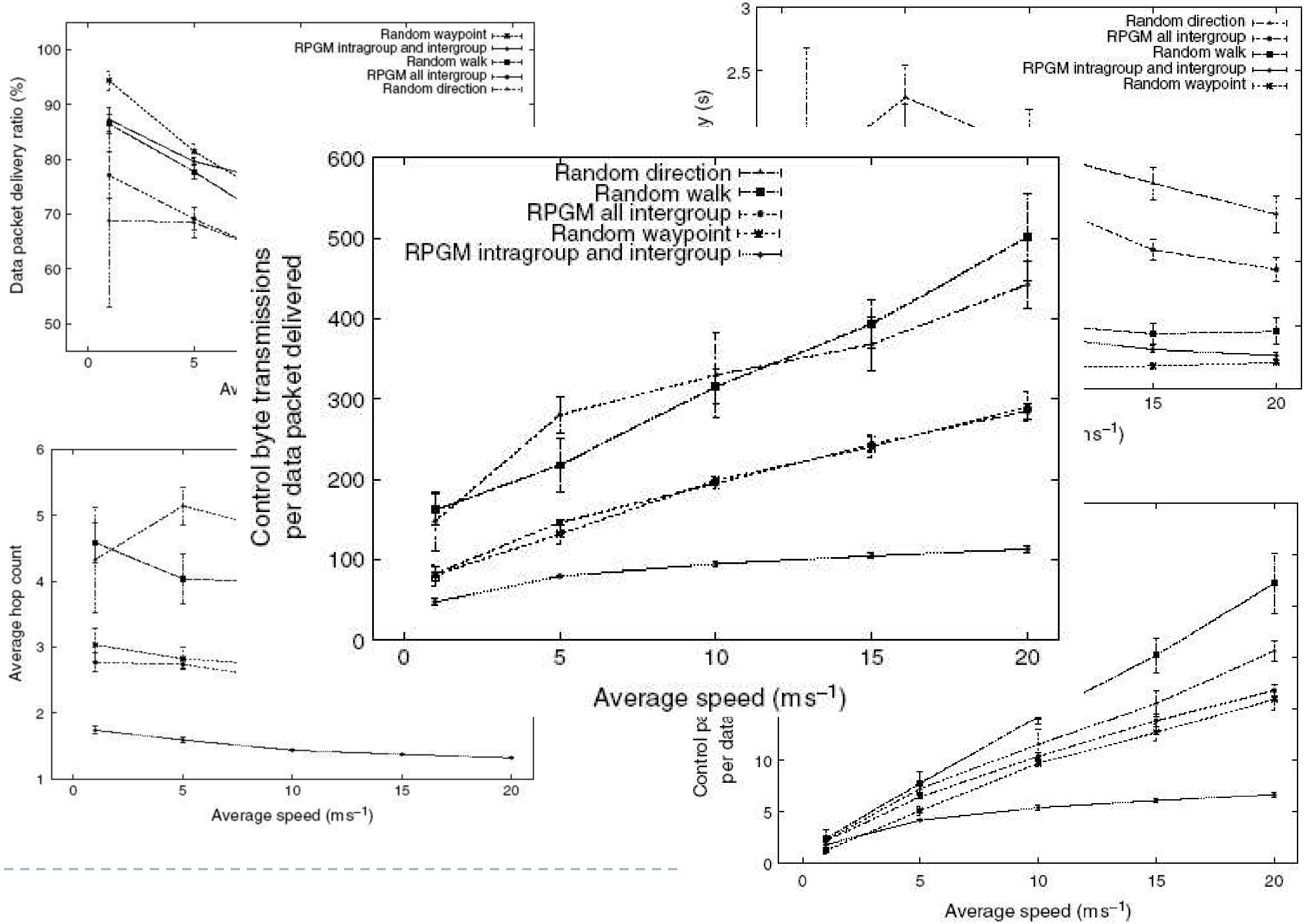
Selection of Models

- Trade-off between accuracy and costs of the model
  - Detailed models fit into real-life scenarios
  - Realistic models impose high complexity
    - Implementation efforts
    - Performance of calculation
- Simple models are easy to implement and can be calculated fast
- Finding the right model
  - Review available models of the area
  - Start with a simple model that fits best
  - Improve it to the specified scenario
- Alternatively: Use the same model as it is used in related research → comparable results

Simulation Parameters

- Simulation Package: ns-2
- 50 Mobile Nodes
- 100m Transmission Range
- Simulation Time from 0s ~ 2010s
  - Results is collected from 1010s
- Routing Protocol: Dynamic Source Routing (DSR)
- Each mobility model has 10 different runs and show with 95% confidence interval
- Simulated Model
  - Random Walk
  - Random Waypoint
  - Random Direction
  - RPGM
    - 100% Intergroup communication
    - 50% Intergroup communication, 50% Intragroup communication

What results do different mobility models bring?



Observation of Different Mobility Models

- The performance of an ad hoc network protocol can vary significantly with different mobility models
- The performance of an ad hoc network protocol can vary significantly when the same mobility model is used with different parameters
- Data traffic pattern will affect the simulation results
- Selecting the most suitable mobility model fitting to the proposed protocol

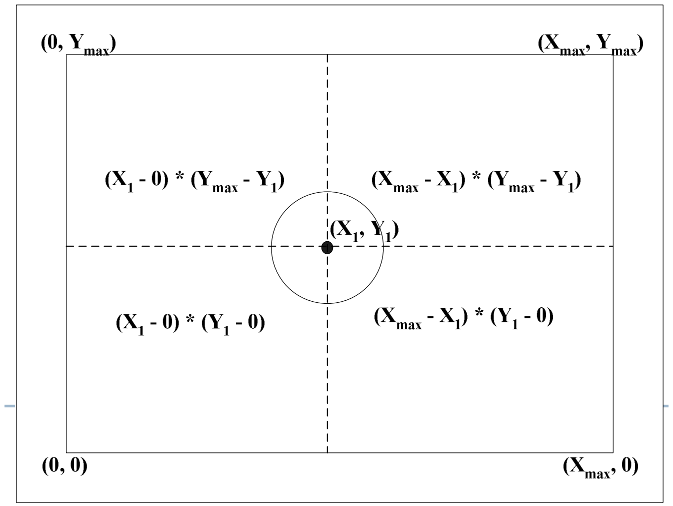
Considerations when Applying Each Mobility Model

- Random Walk
  - Small input parameter: Stable and static networks
  - Large input parameter: Similar to Random Waypoint
- Random Waypoint
  - Scenarios such as conference or museum
- Random Direction
  - Unrealistic model
  - Pause time before reaching the edge ➔ Similar to Random Walk
- Boundless Simulation
  - Although moving without boundary, the radio propagation and neighboring condition are unrealistic
- Gauss-Markov
  - Most realistic mobility model
- Probabilistic Random Walk
  - Choosing appropriate parameters to fit real world is difficult
- City Section
  - For some protocol designed for city walk

- Exponential Correlated Random Mobility Model
  - Theoretically describe all other mobility models, but selecting appropriate parameter is impossible
- Column, Nomadic Community, Pursue Mobility Models
  - Above three mobility models can be modeled by RPGM with different parameters
- RPGM Model
  - Generic method for group mobility
  - Assigned an entity mobility model to handle groups and individual node

Random Waypoint Considered Harmful

- Yoon has published a paper indicating that network average speed of RWP will decay to zero in simulation
  - Setting the minimum speed larger than zero
- Besides speed decaying, the nodes with RWP tend to cross the center of the area



$$First : \frac{(X_{max} - X_1)\cdot(Y_{max} - Y_1)}{X_{max} \cdot Y_{max}}$$

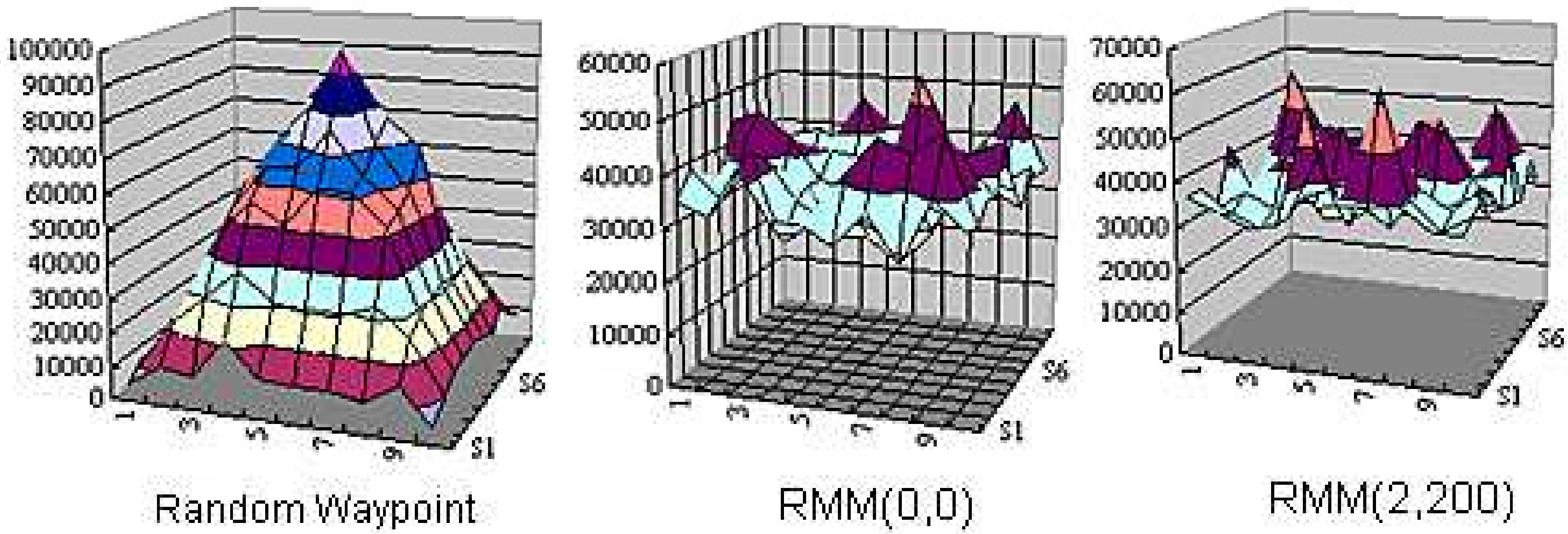
$$Second : \frac{(X_1 - 0)\cdot(Y_{max} - Y_1)}{X_{max} \cdot Y_{max}}$$

$$Third : \frac{(X_1 - 0)\cdot(Y_1 - 0)}{X_{max} \cdot Y_{max}}$$

$$Fourth : \frac{(X_{max} - X_1)\cdot(Y_1 - 0)}{X_{max} \cdot Y_{max}}$$

Spatial Distribution Comparisons

- Cumulate the nodal appearance in the square of 100mx100m (Moving area is 1000mx1000m)



Conclusions

- The defects in RWP are explored by some research and solutions are also proposed
  - Decaying Average Speed
  - Unfair Moving Pattern
- Most proposed solutions target to one of the defects but not both
- To generate different moving pattern within the same speed range is a reasonable requirement but it has not been brought up

Reference

- Tracy Camp, Jeff Boleng, and Vanessa Davies, "A Survey of Mobility Models for Ad Hoc Network Research", Wireless Communication and Mobile Computing (WCMC) 2002
- Guolong Lin, Guevara Noubir, and Rajmohan Raharaman, "Mobility Models for Ad Hoc Network Simulation", INFOCOM 2004