A Survey of Mobility Models for Ad Hoc Network Research

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T-79.300 Postgraduate Course in Theoretical Computer Science

Outline

- Overview
- Entity Mobility Models
- Group Mobility Models
- Mobility Models and Performance Evaluation
- Conclusions

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The Goal

The *Performance Evaluation* of any particular Ad Hoc network protocol should be tested under:

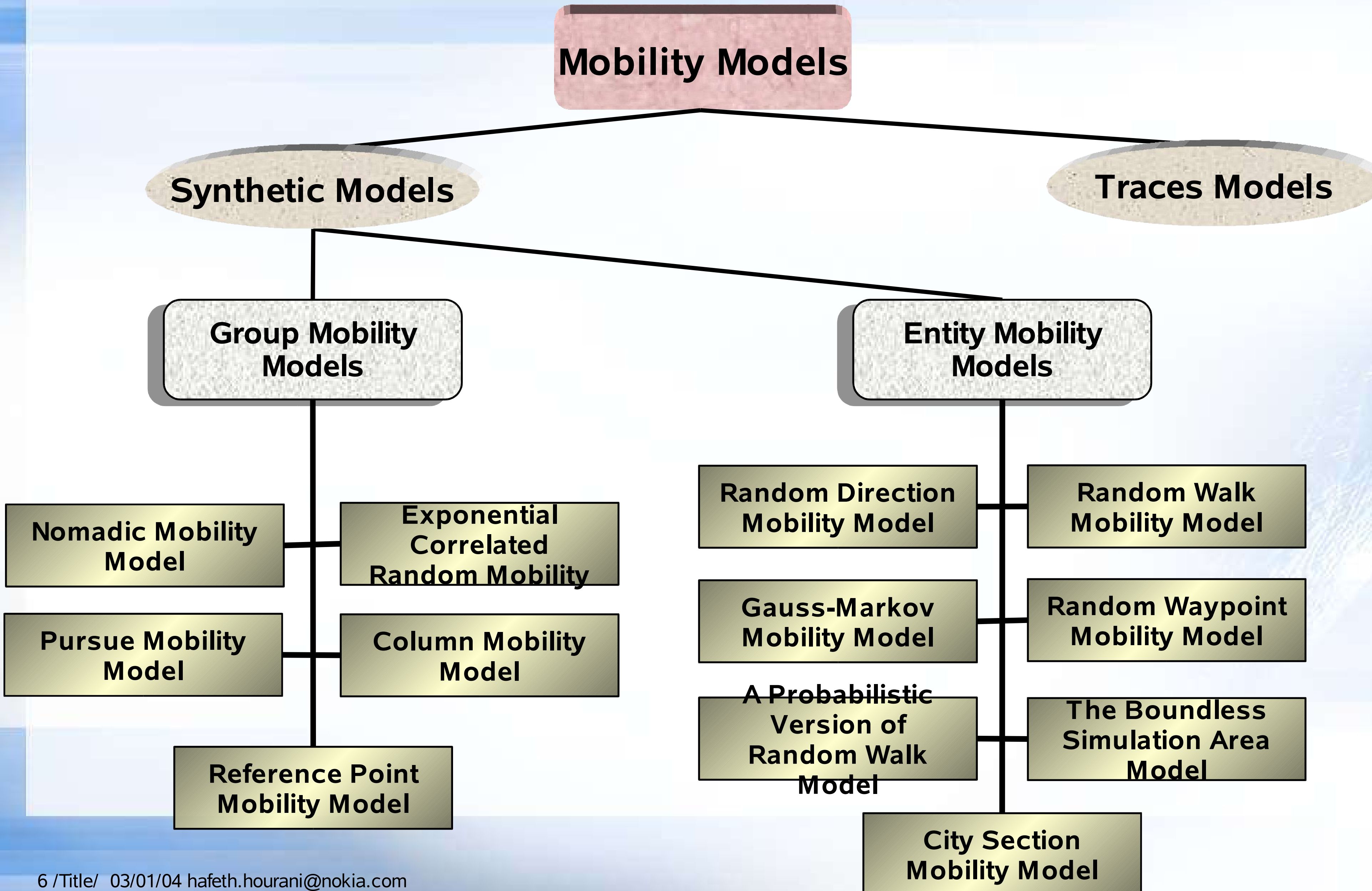
- Sensible transmission range
- Limited buffer space for the messages
- Realistic data traffic model
- Realistic **Mobility Model**

- *The target is to show how does the performance evaluation of a particular protocol changes drastically as the selected Mobility Model changes*

Traces vs. Synthetic Models

- Mobility models are used when simulating a certain Ad Hoc network protocol
- There are two types of mobility models used in Ad Hoc network simulations
  - Traces Models
    - Those models that are observed in the real life systems
    - They provide accurate information
  - Synthetic Models
    - Useful when simulating the new network environments (such as Ad Hoc)
    - The synthetic models attempts to represent the MN behavior
- In this presentation, only the Synthetic Models are considered

Mobility Models Overview



Entity vs. Group Mobility Models

- Entity
  - Multiple MNs whose actions are completely independent
- Group
  - Multiple MNs move together (e.g., group of soldiers)
  - Group mobility has a cooperative characteristics

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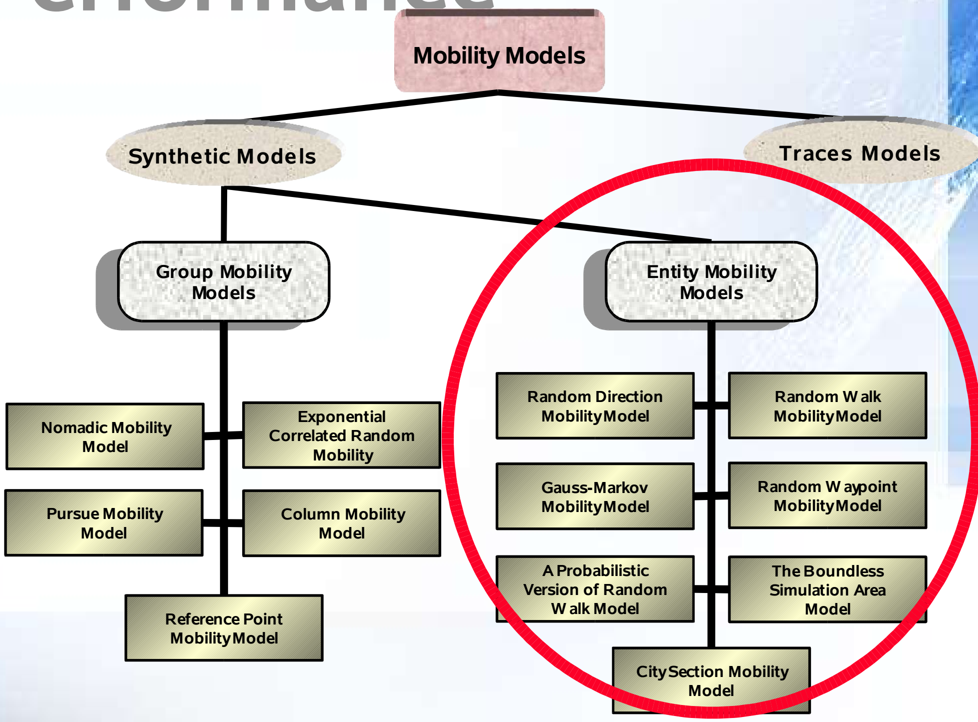
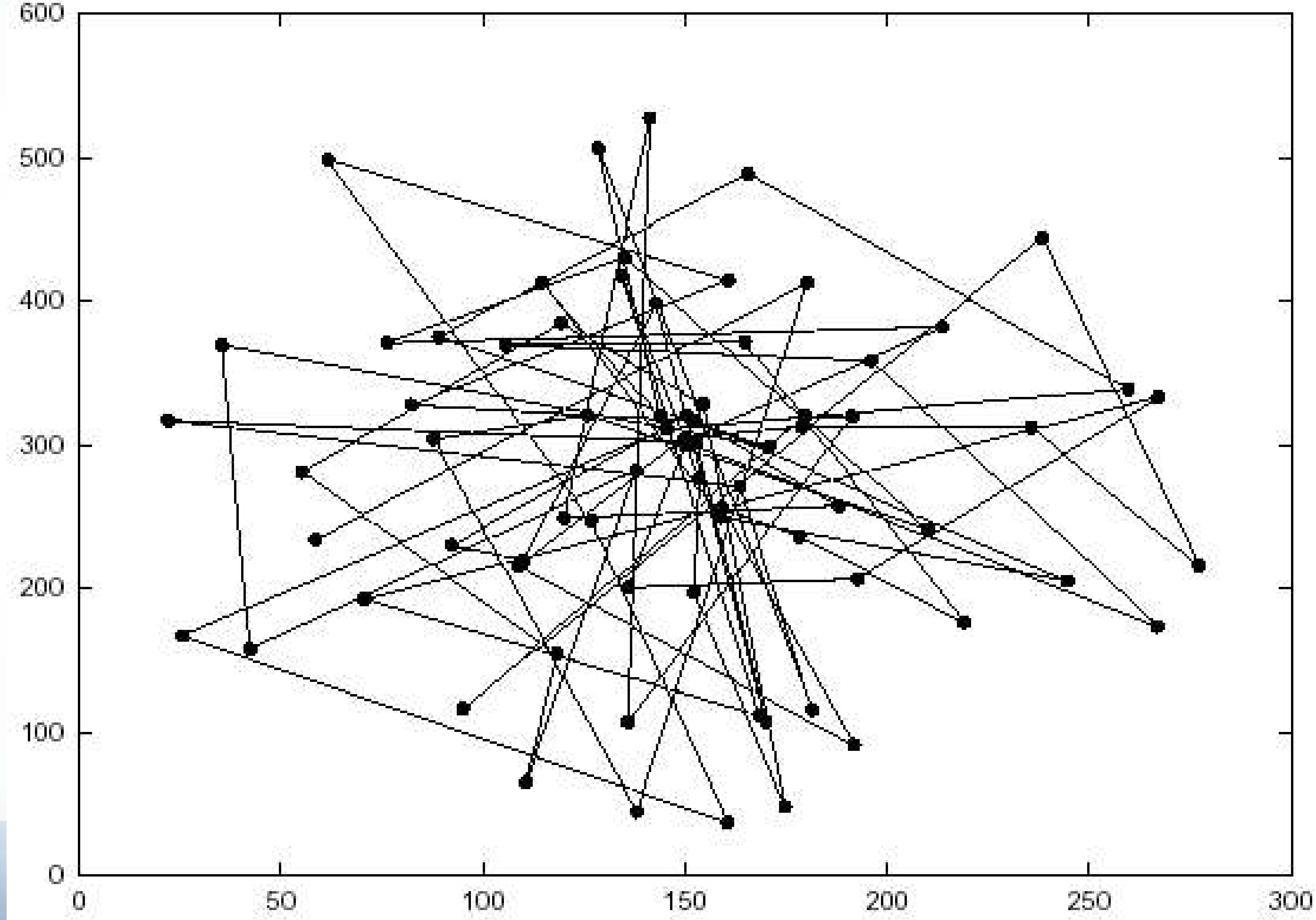


Random Walk

- Many entities move in extremely unpredictable ways . . .
- The MN moves from its current location to a new location by
  - Randomly chosen direction ∈ *[0, 2π]*
  - Randomly chosen speed ∈ *[speed_min, speed_max]*
- Each movement occurs in either a
  - Constant time interval, or
  - Constant distance to travel
- This model is widely used, and sometimes referred to as Brownian Motion (when small distance and times are used)
- Random Walk is a memoryless model
  - It does not keep any knowledge about its past speed and location
- This model generates unrealistic movements
  - Sudden movements and sharp turns

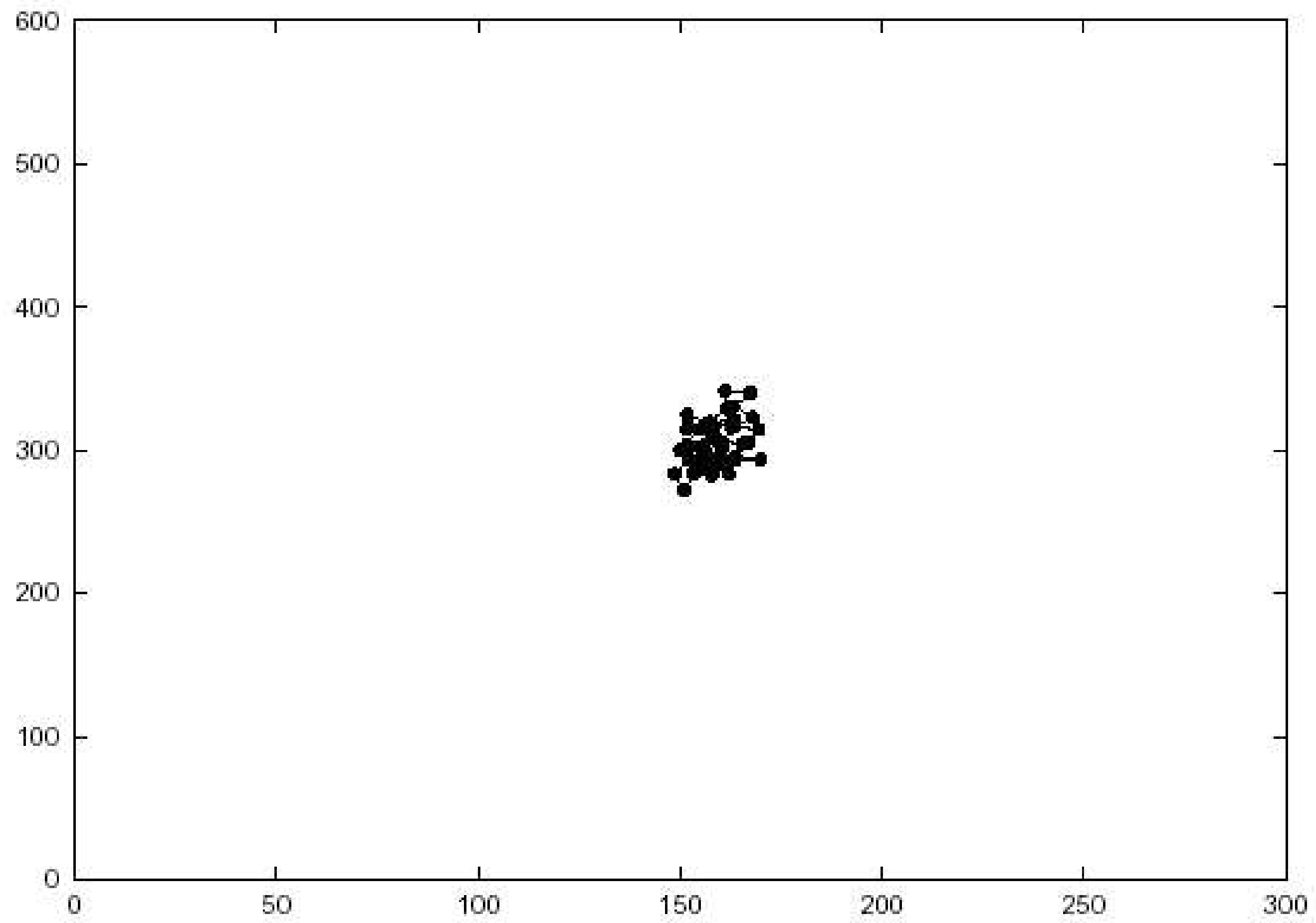
Random Walk: constant travel time

- The movement occurs in a constant time interval
- The MN is allowed to travel 60 sec before changing its direction and speed



Random Walk: constant travel distance

- The movement occurs in a constant distance
- The MN must change its speed and direction every 10 steps

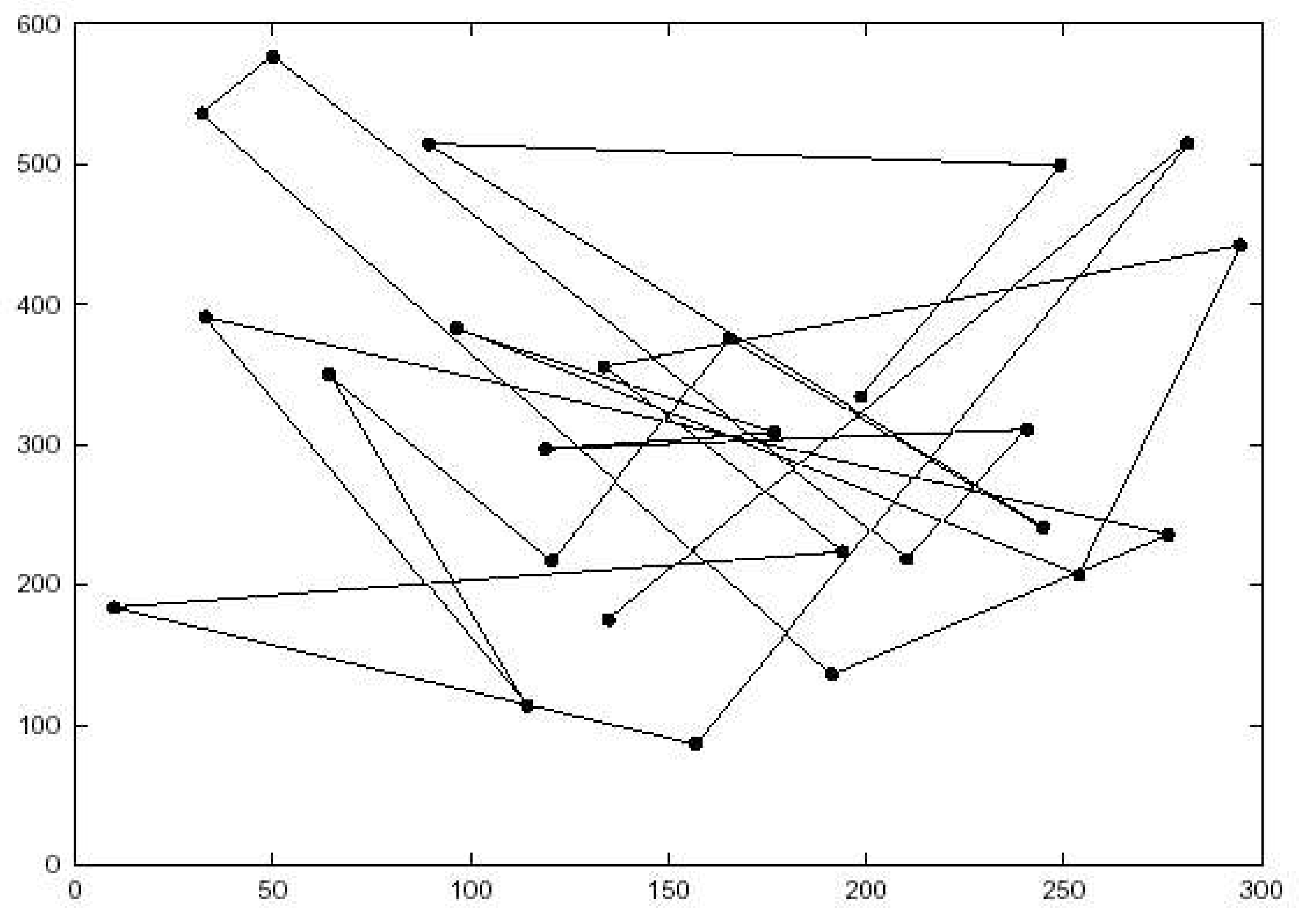


Random Waypoint

- Similar to the Random Walk model, but with a pause times between changes in direction and/or speed.
- The speed in this model is uniformly distributed ∈ *[min_speed, max_speed]*
- The Random Waypoint models gets to the Random Walk model if
  - The pause time is zero
  - The speed is chosen from [speed_min, speed_max] range without being uniformly distributed
- This model is widely used
- Compared to the Random Walk, the Random Waypoint generates more realistic movements.
- Once concern with this model is the straight movement pattern created by the MN.

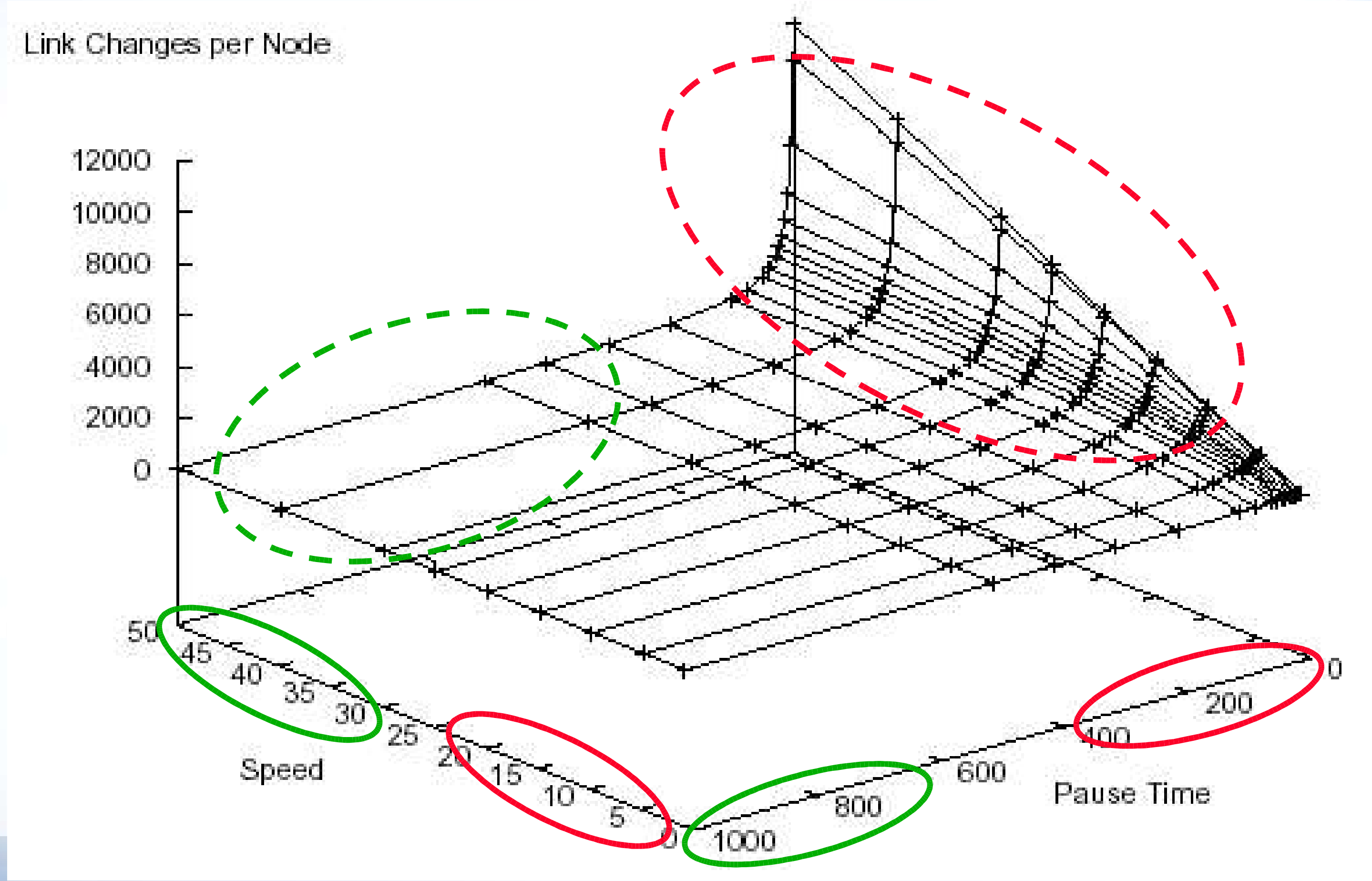
Random Waypoint Example

- The speed is uniformly chosen between 0 and 10 m/s



Random Waypoint: "speed" vs. "pause time"

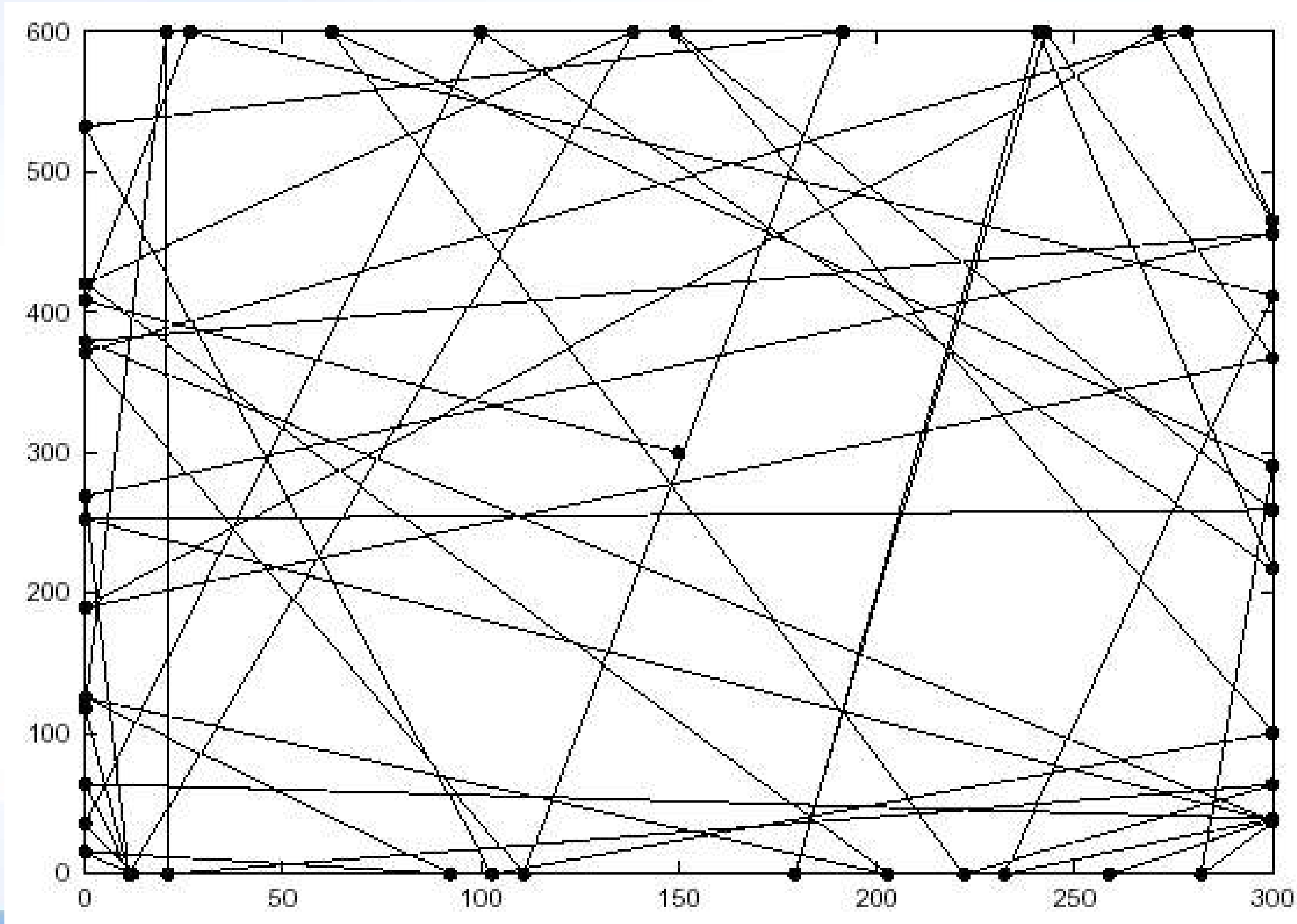
- There is a complex relationship between the speed and the pause time in this model.



Random Direction Model

- Random Direction mobility model was created to overcome the neighbors "density waves"
- Density Waves happens due to MN clustering in the center of simulation area
    - This happens in Random Walk and Random Waypoint models
- In this model, the MN chooses a random direction in which to travel
- When the simulation area boundary is reached, the node pauses for a time and then selects another direction to go
- The average hop count for data packets is higher in this model than other models
    - Since the MN travel to, and usually pause at the border of the simulation area
- Unrealistic model, because it is unlikely that people would spread themselves evenly through an area

Random Direction Model: Example



A Boundless Simulation Area Model

- This model handles the simulation area differently . . .
- In this model, there is a relationship between the previous location and velocity with its current direction and velocity
- The velocity vector $\bar{v} = (\nu, \theta)$ is used to describe an MN velocity ν as well as the direction θ
- Both the velocity and the position are updated according to:

$$\nu(t+\Delta t) = \min[\max(\nu(t)+\Delta\nu, 0), V_{max}]$$

$$\theta(t+\Delta t) = \theta(t) + \Delta\theta$$

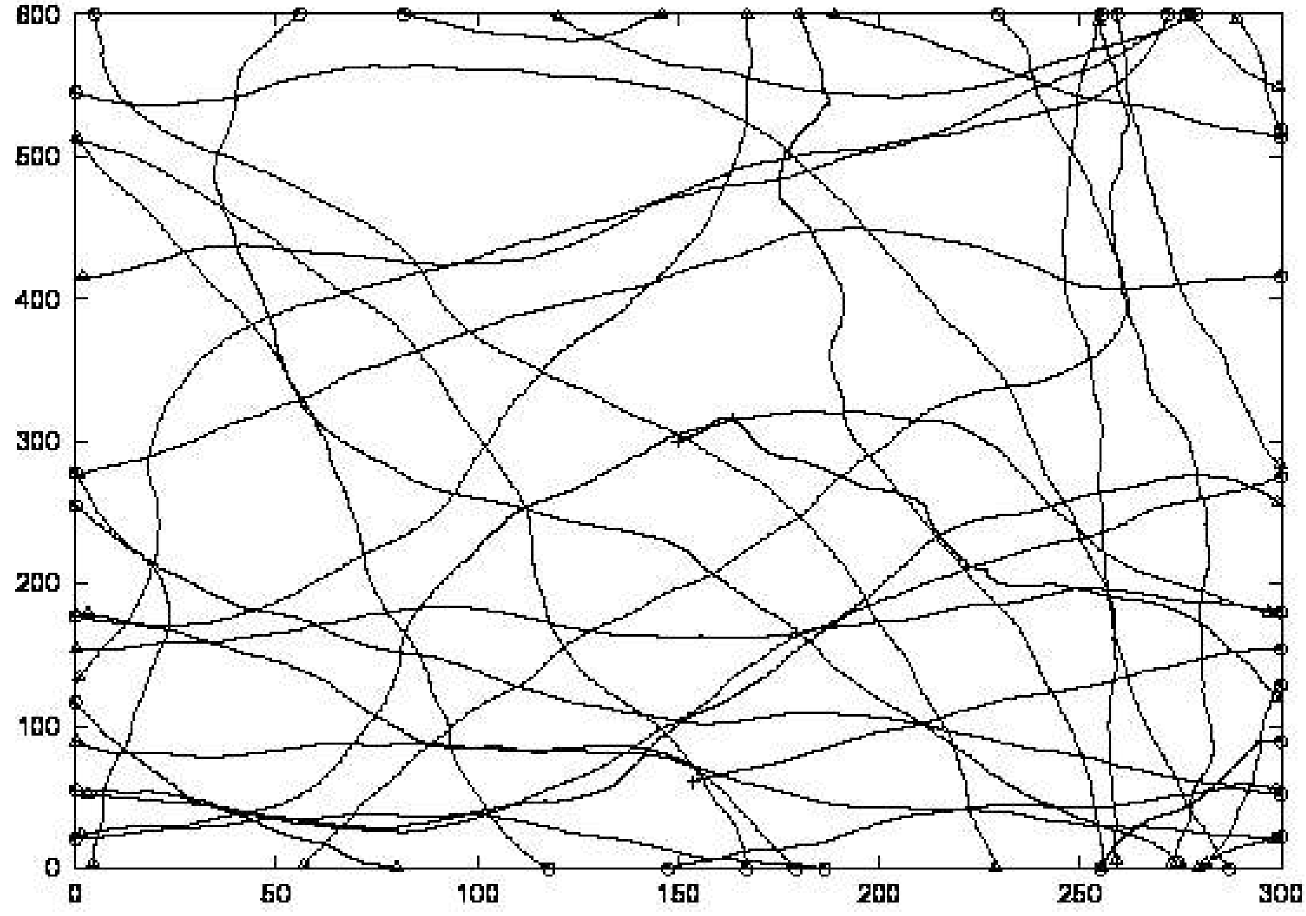
$$x(t+\Delta t) = x(t) + \nu(t)\cos\theta(t)$$

$$y(t+\Delta t) = y(t) + \nu(t)\sin\theta(t)$$

  - V_{max} is the maximum velocity defined in the simulation

Boundless Simulation Area: Example

- MNs that reach one side of the simulation area continue traveling and reappear on the opposite side of the area



Gauss-Markov Model

- This model was designed to adapt to different levels of randomness via one tuning parameter
- The value of seed and direction are calculated as the following:

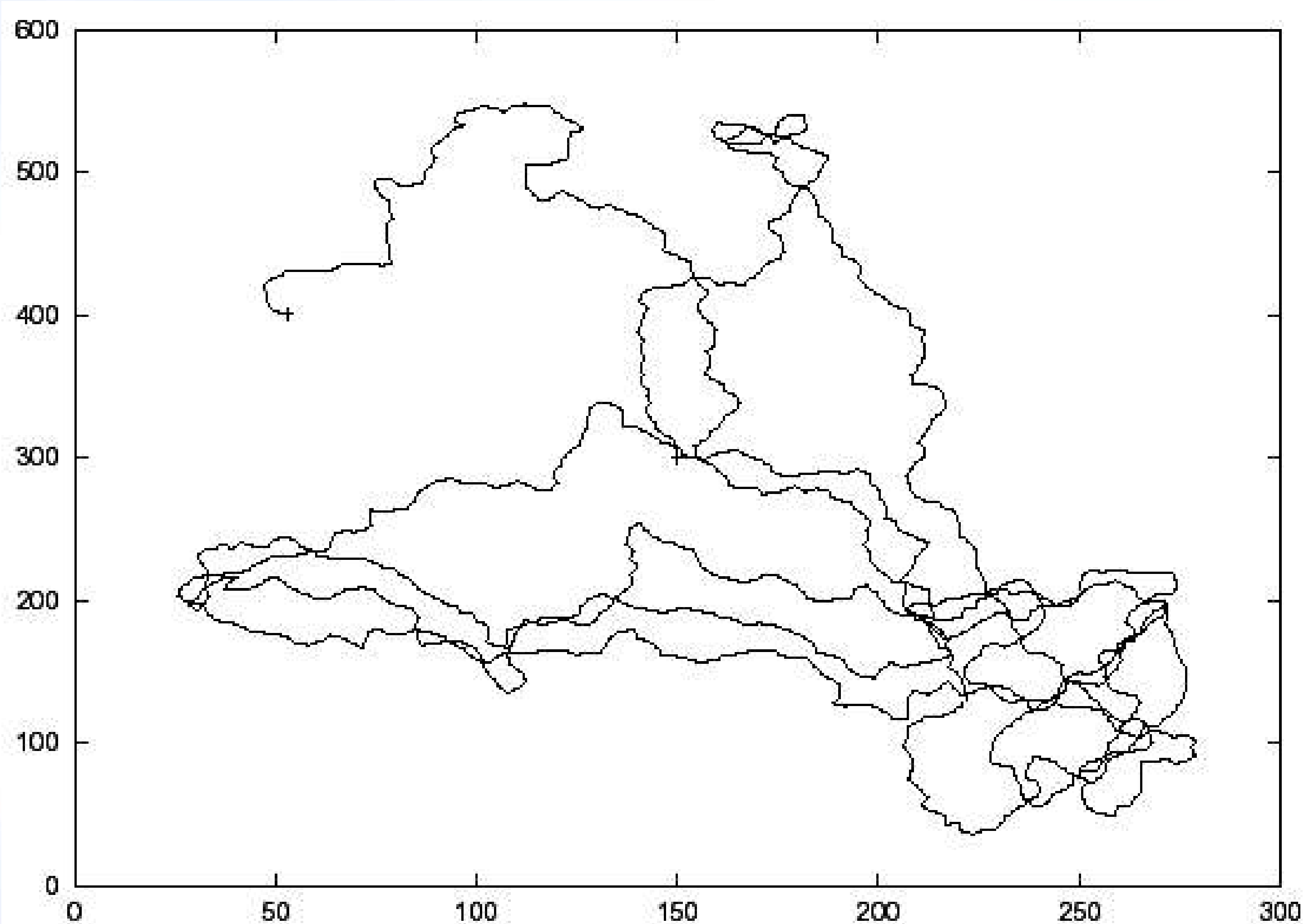
$$s_n = \alpha s_{n-1} + (1-\alpha)\bar{s} + \sqrt{(1-\alpha^2)}\, s_{x_{n-1}}$$

$$d_n = \alpha d_{n-1} + (1-\alpha)\bar{d} + \sqrt{(1-\alpha^2)}\, d_{x_{n-1}}$$

  - where α is the tuning parameter. $(0 \le \alpha \le 1)$

- Gauss-Markov model can eliminate the sudden stops and sharp terns reconnoitered in the previous models

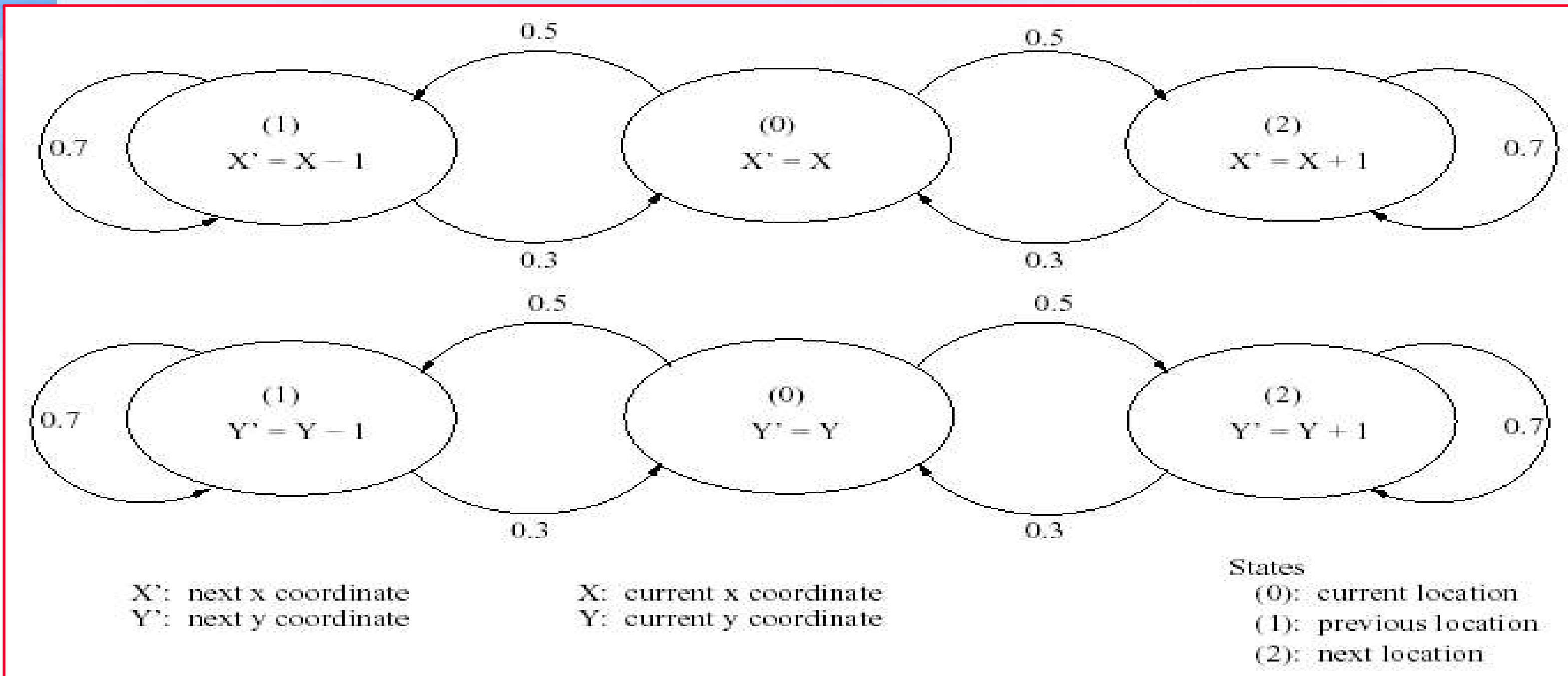
Gauss-Markov Model: Example

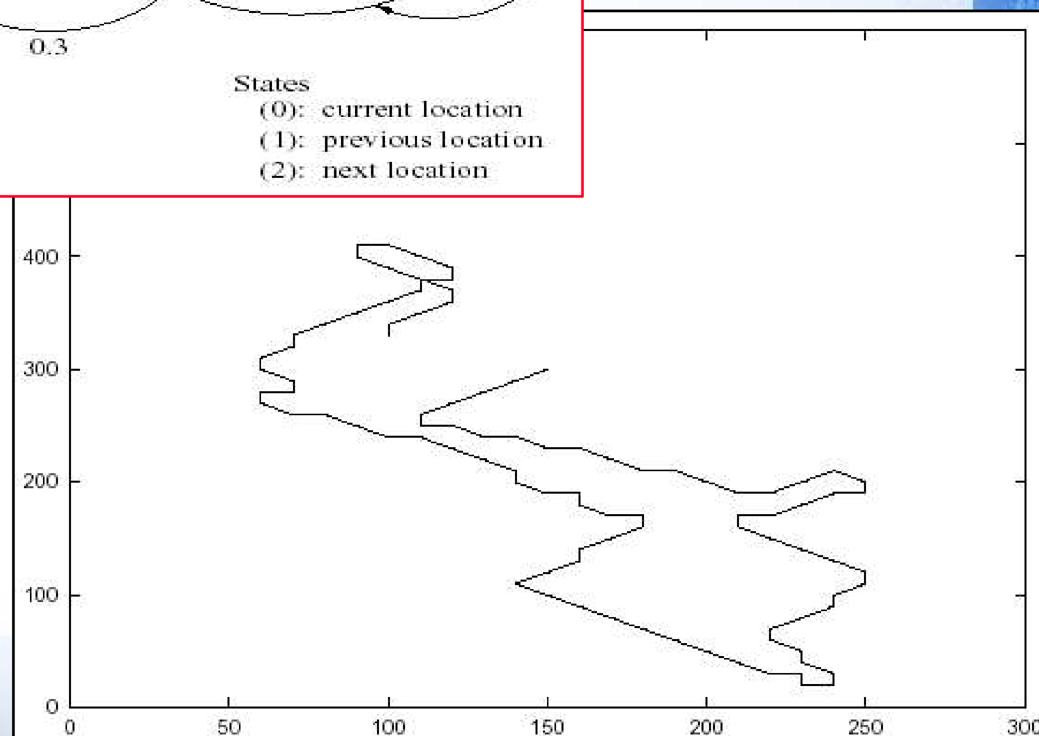


A Probabilistic Version of Random Walk

- This model utilizes a probability matrix to determine the position of a particular MN in the next time step.
- The probability matrix specifies a limited number of “next states” in each direction (x and y)
- In this model, the probability that of the MN to continue to follow the same direction is higher than purely random movements
  - This yields to more realistic behavior

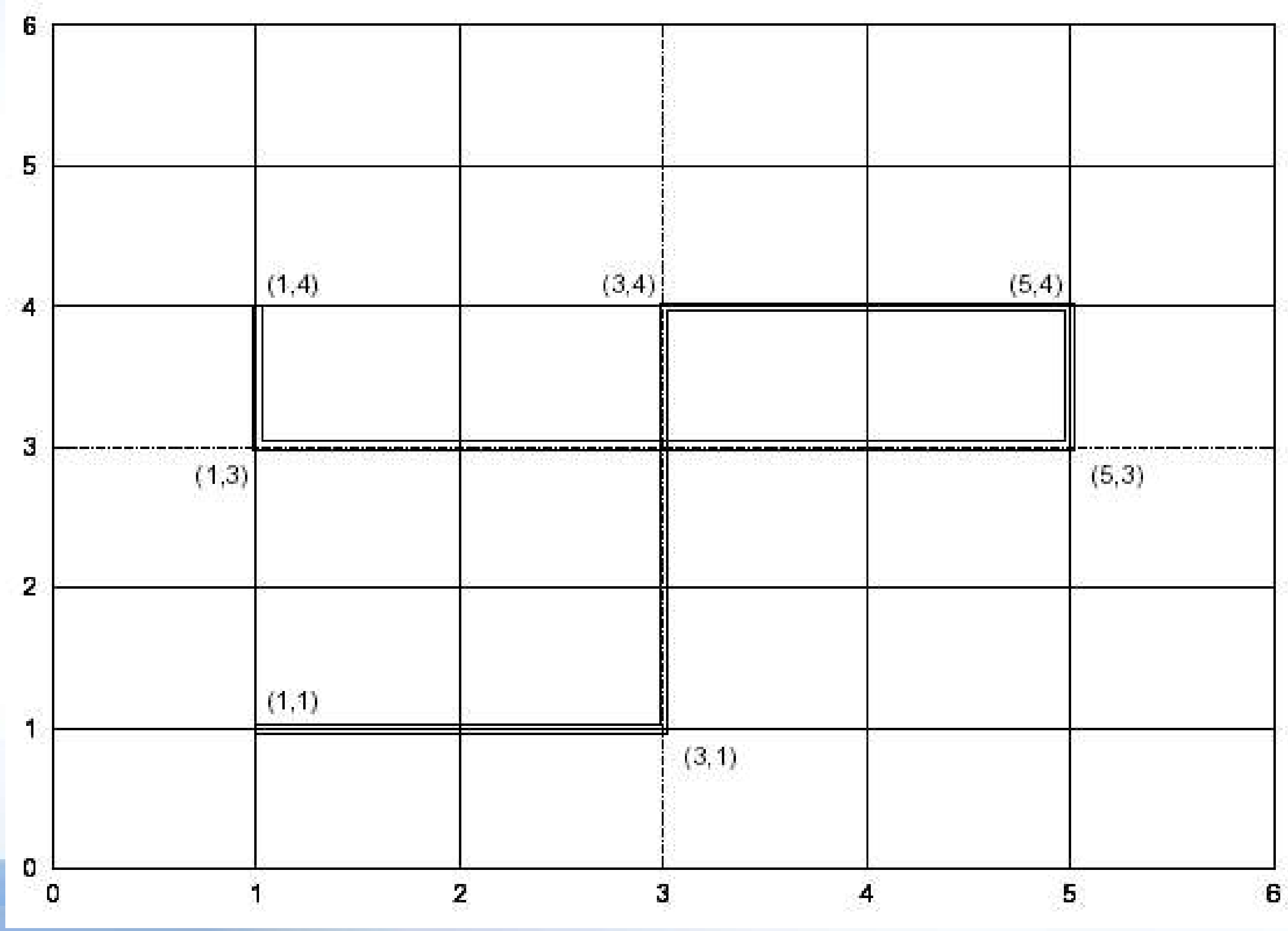
Probabilistic Random Walk: Example





City Section Mobility Model

- In this model, the simulation area is a street network that represents a section of a city.



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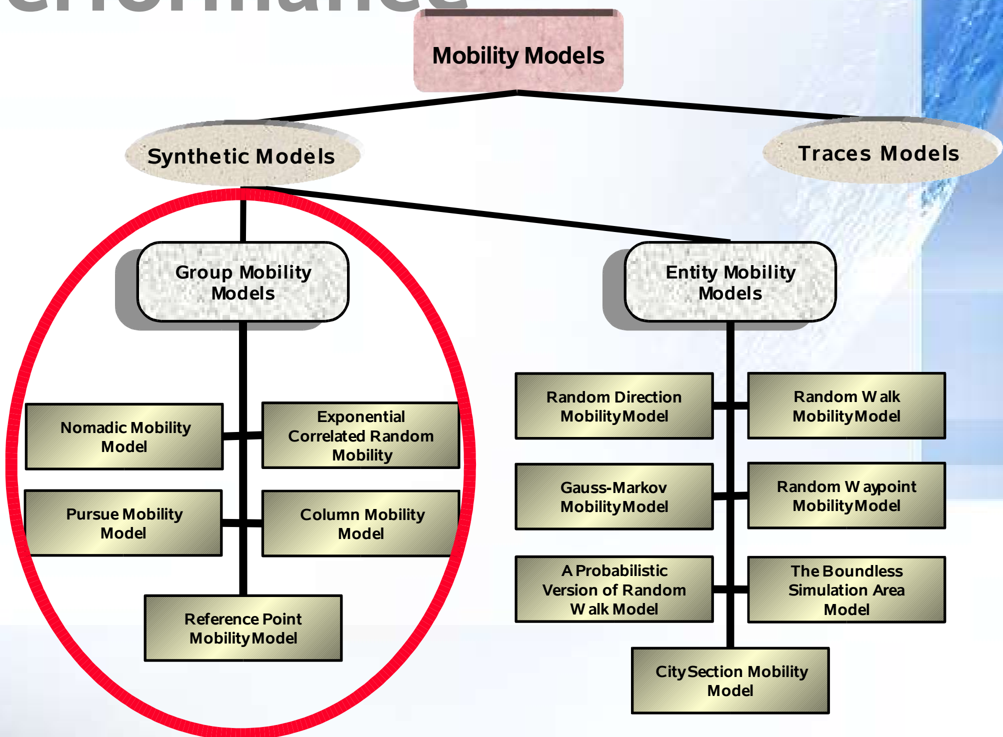
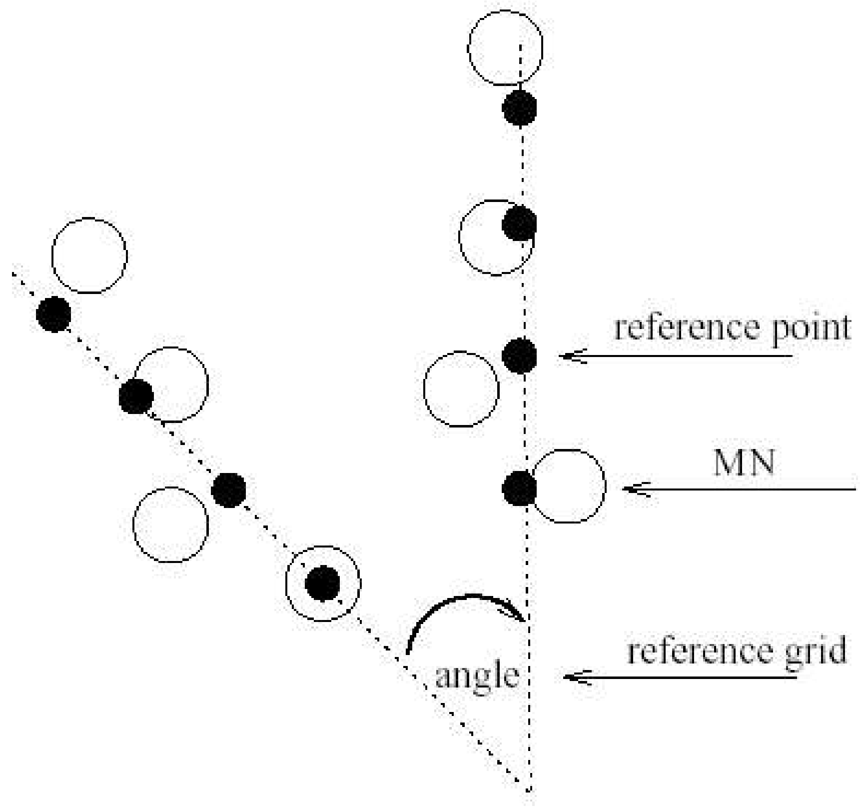
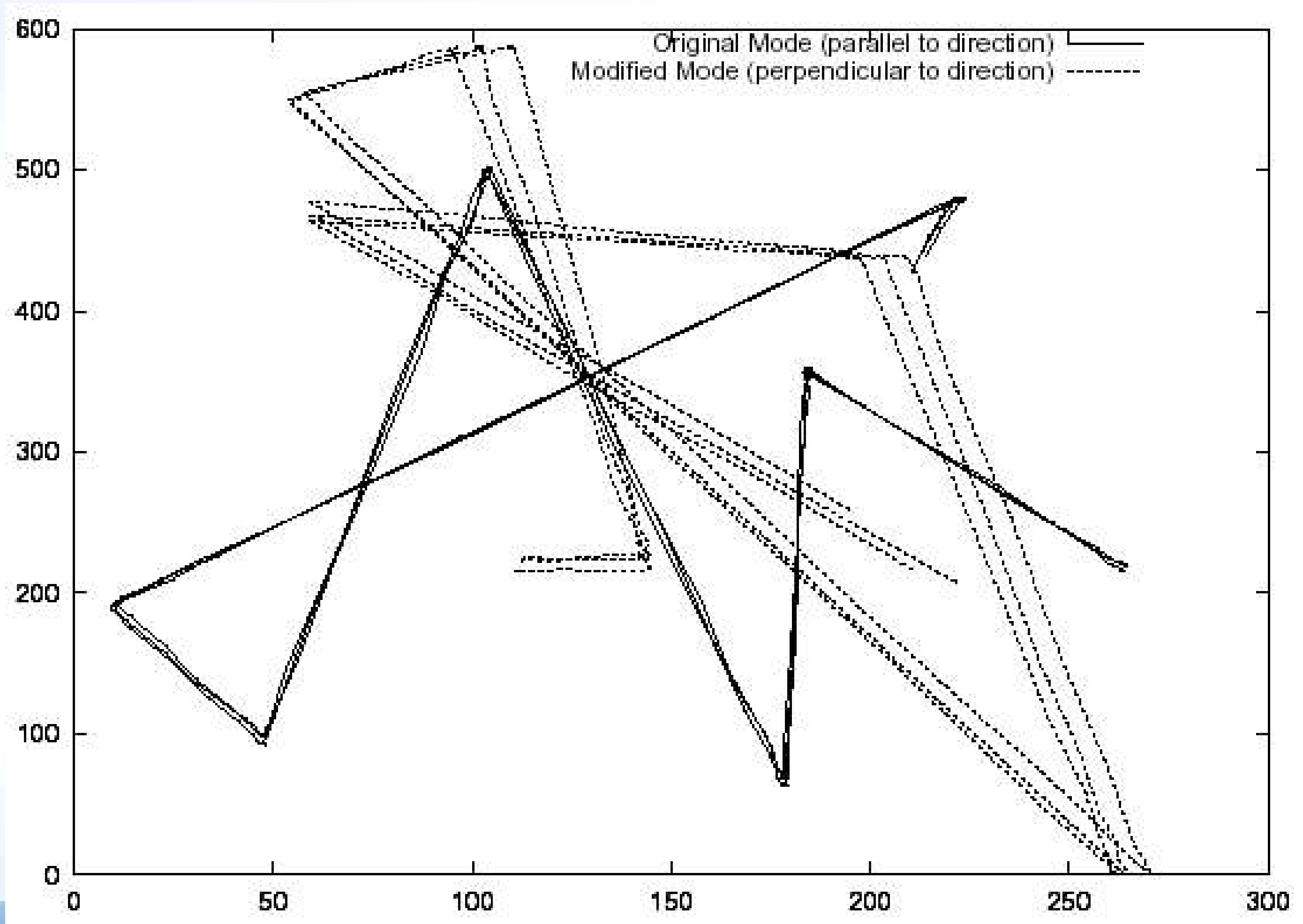


Column Mobility Model

- This model represents a set of MNs that move around a given line (or column), which is moving in forward direction
- In this model, the MNs are allowed to move randomly around its reference point via an entity model

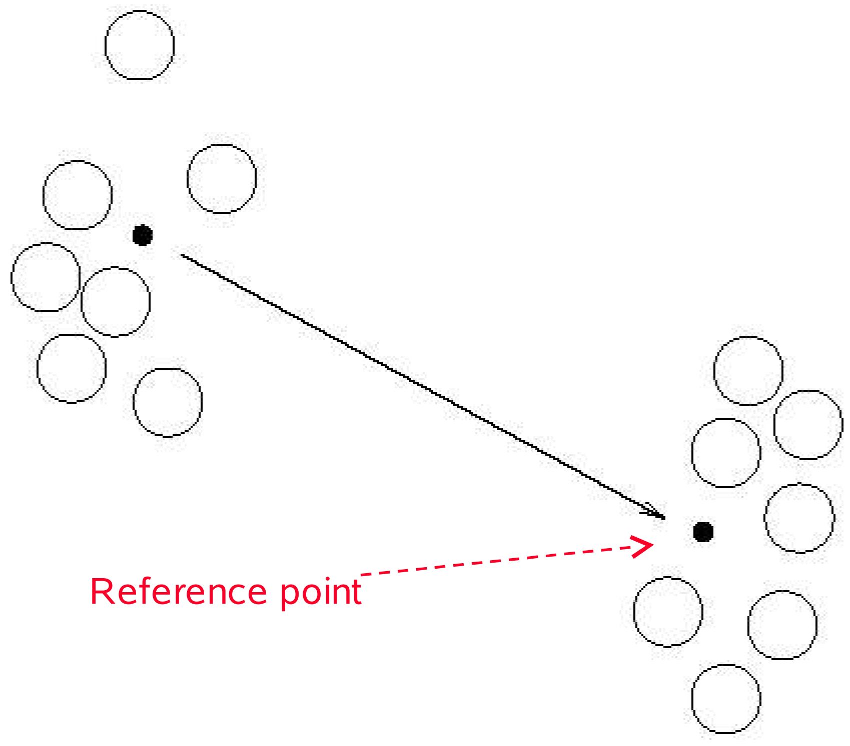


Column Mobility Model: Example



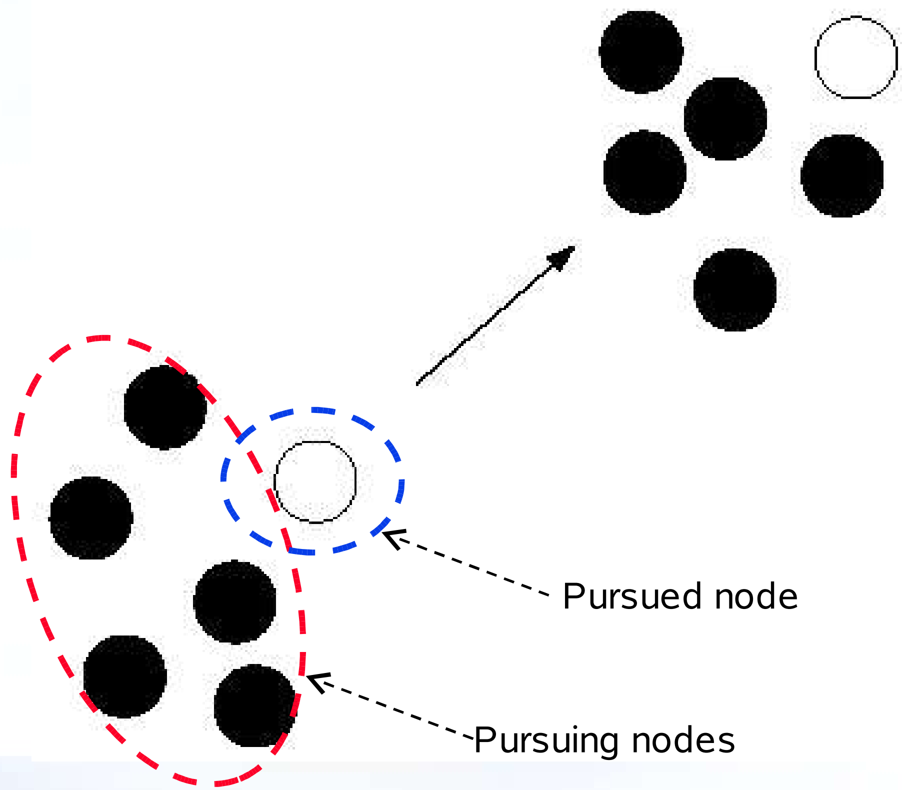
Nomadic Mobility Model

- Nomadic Mobility Models represents groups of MNs that collectively move from one point to another.
- Within each group, individual MNs use entity mobility model to roam around the reference point
- Unlike the Column Mobility Model, the MNs share a common reference point



Pursue Mobility Models

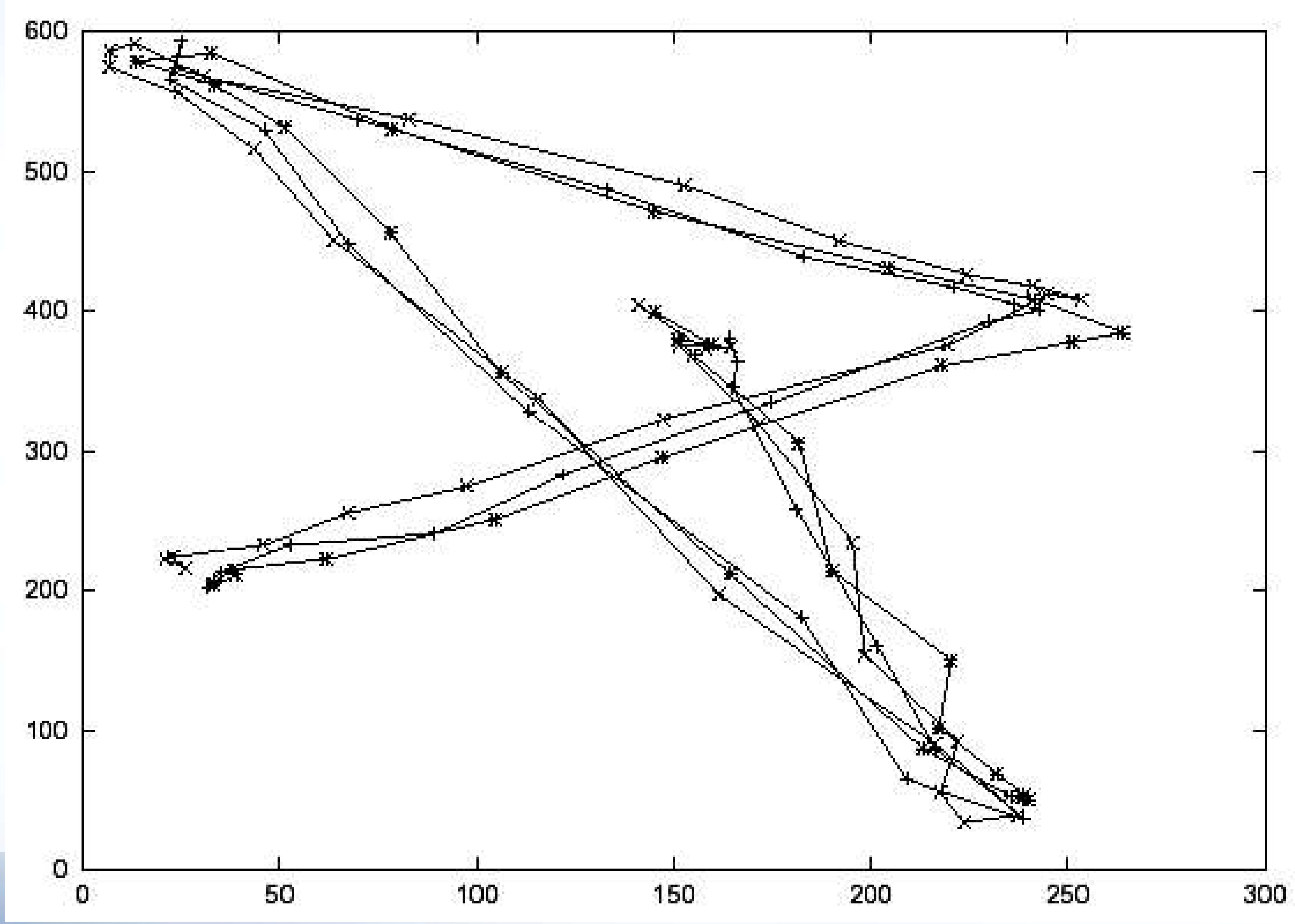
- This model attempts to represent MNs tracking a particular object



Reference Point Group Mobility Model

- The RPGM represents the random motion of group of MNs as well as the random motion of each individual MN within the group.
- Group movements are based upon the path traveled by a logical center of the group

RPGM: Example



Traveling pattern of one group (three MNs) using RPGM

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Simulation Goals

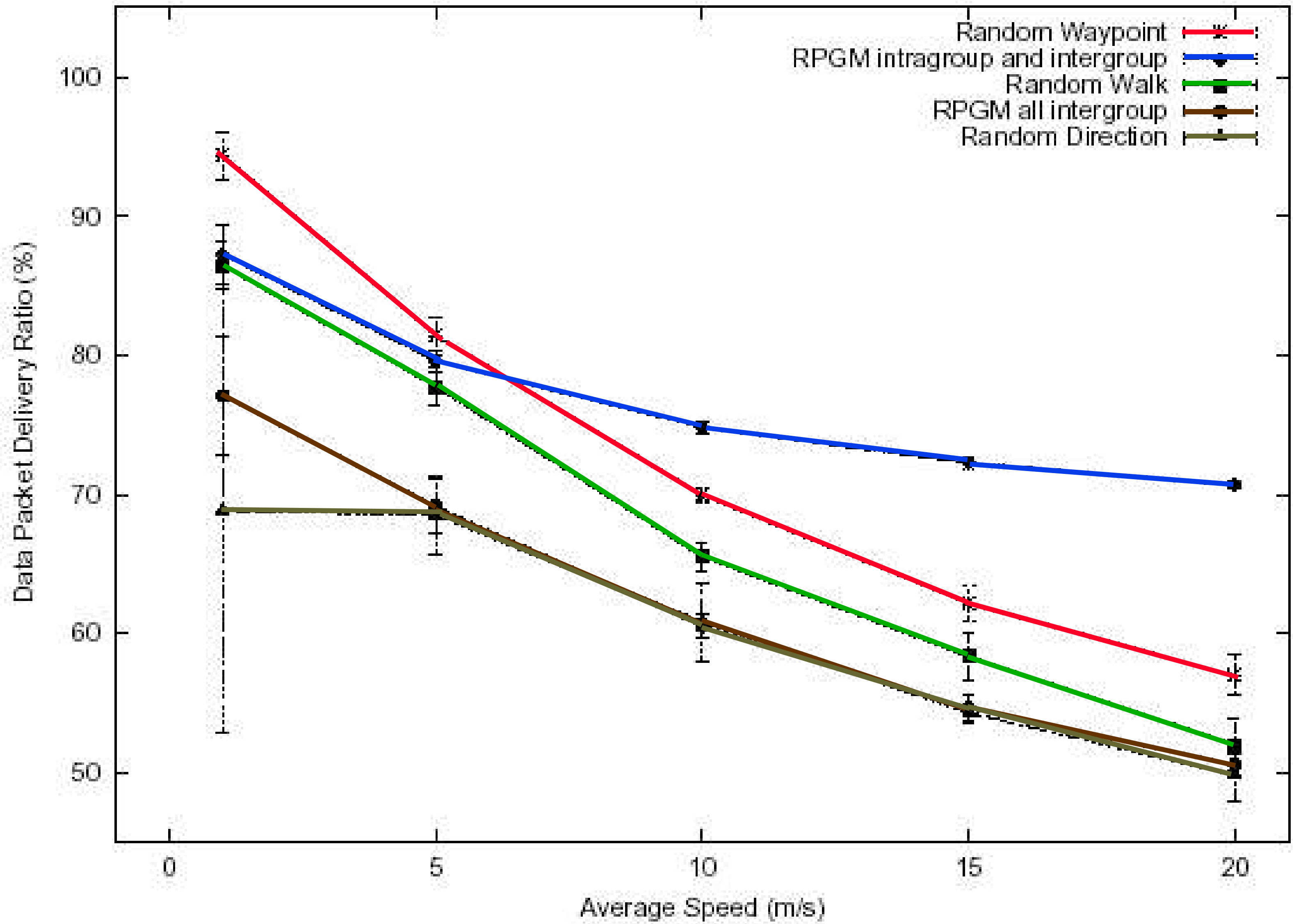
- To find out the effect of adopting a particular Mobility Model on the overall performance evaluation of a certain Ad Hoc Network Protocol

- The performance of Dynamic Source Routing (DSR) is studied with different Mobility Models:
  - Entity Models
    - Random Walk
    - Random Waypoint
    - Random Direction
  - Group Models
    - RPGM (inter-group communication)
    - RPGM (inter-group + intra-group communication)

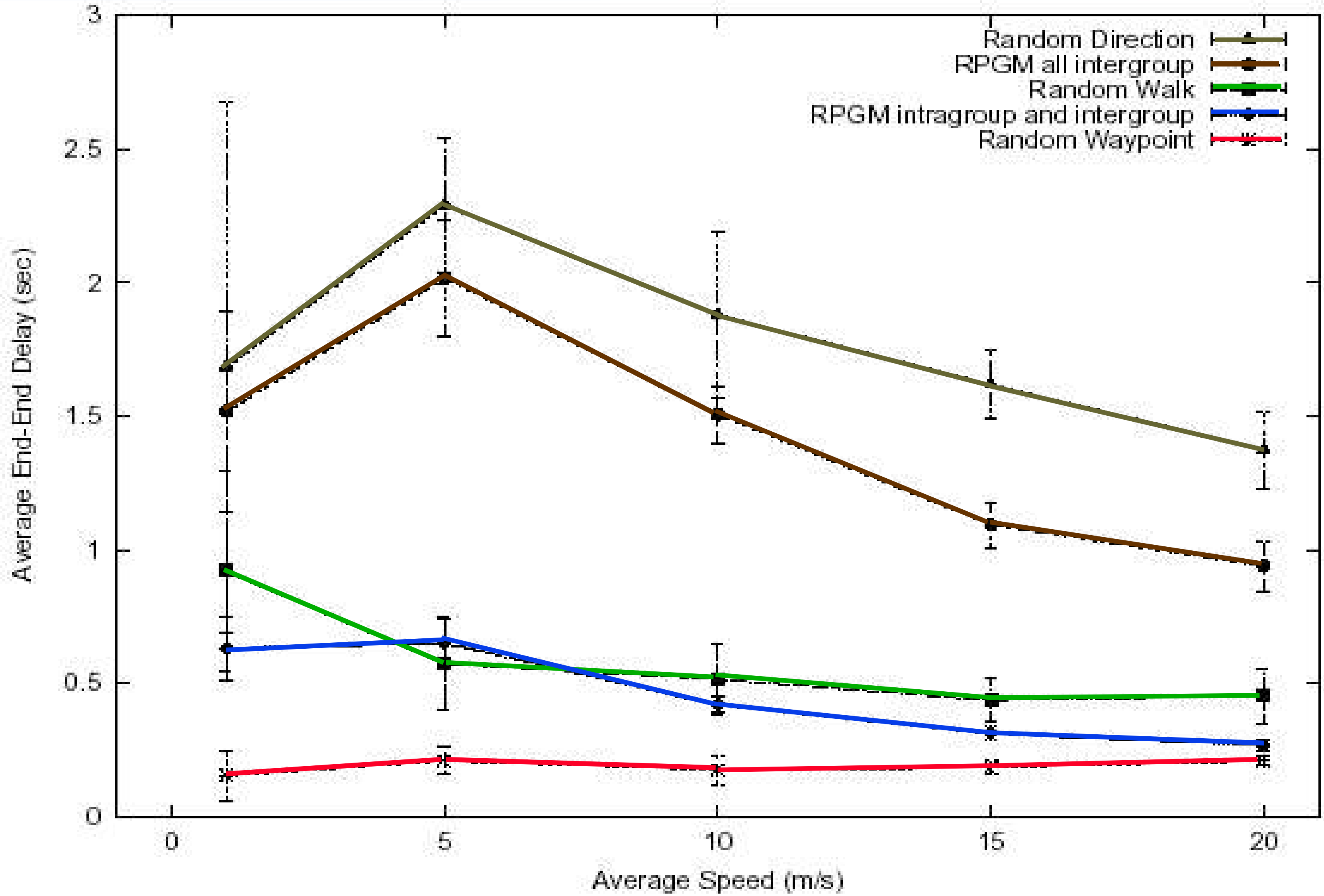
Simulation Setup

- NS-2 was used to carry out the simulation
- 50 MNs were used
- MN transmission range = 100 m
- Dynamic Source Routing Protocol (DSR)
- Performance metrics:
  - Data packet delivery ration
  - End-to-end delay
  - Average hop-count
  - Protocol overhead

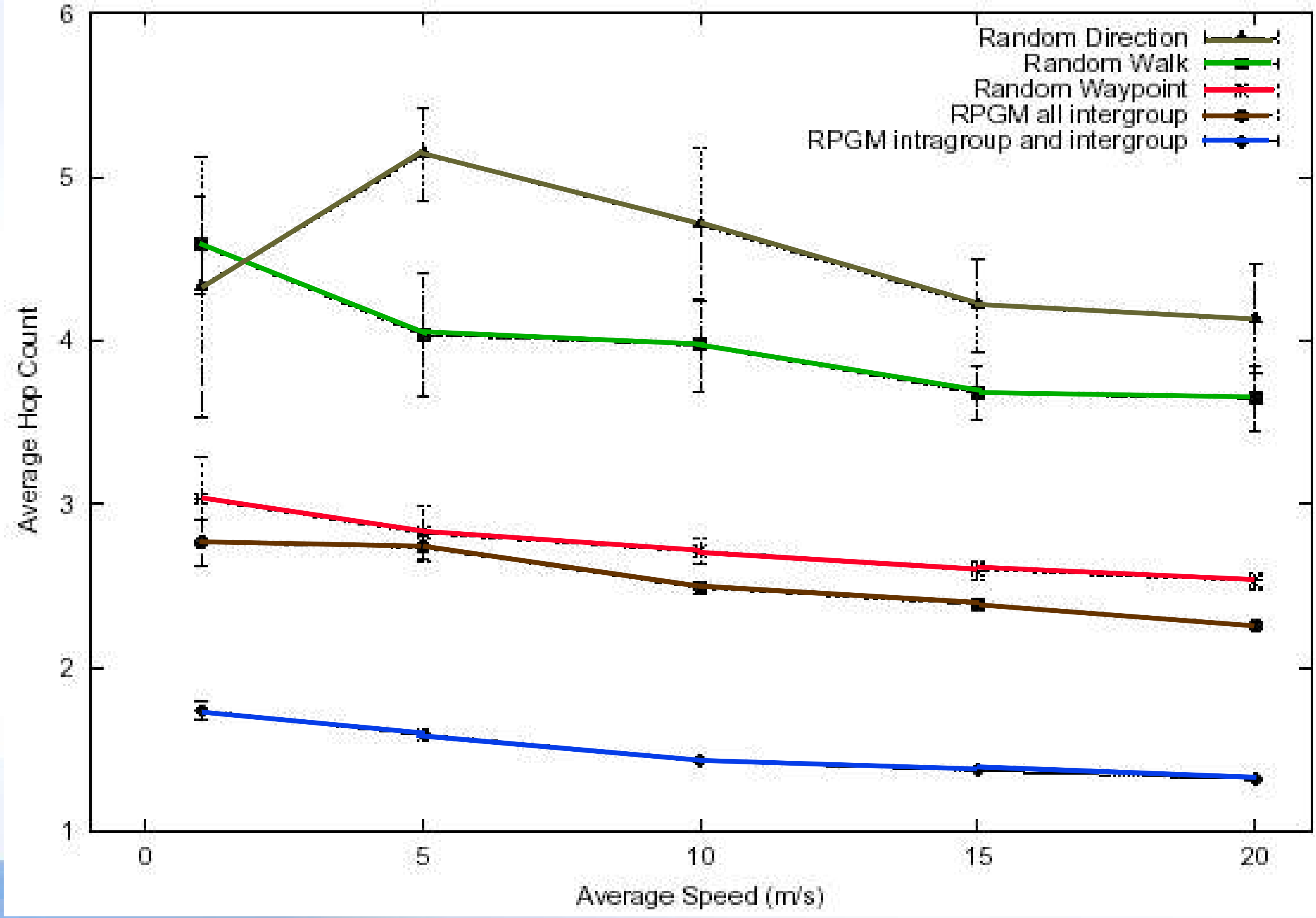
Results: Packet Delivery Ratio



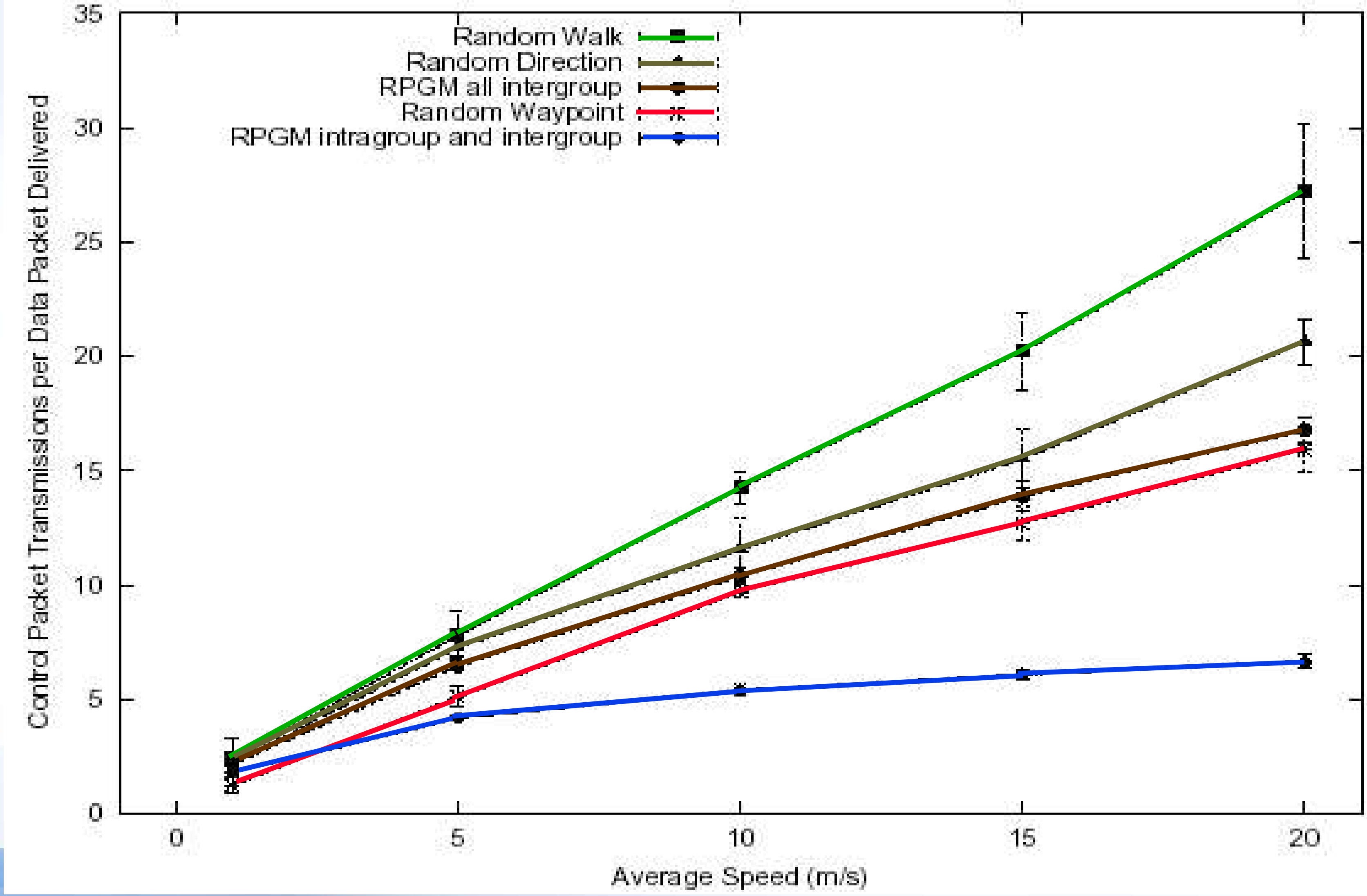
Results: End-to-End Delay



Results: Average Hop Count



Results: Protocol Overhead



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Conclusions

- The performance of an ad hoc network protocol can vary significantly due to the selected mobility model
- The performance should be evaluated with the mobility model that most closely matches the expected real-world scenarios
- For the DSR protocol, the Random Waypoint model has the highest data packet delivery ratio, the lowest end-to-end delay, and the lowest average hop count.

References

- Tracy Camp, et. al.: *A Survey of Mobility Models for Ad Hoc Network Research*

Thank You !