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User(s) Mobility Prediction in Mobile Networks to Enhance Location Based Services (LBS) Performance

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Agenda

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- Introduction
- Research question
- Proposed research plan
- Where my research is now?
- Summery

Introduction(1/3)

- Background:
  - Different type of information (history about user movement trajectories, BTSs location map, city map,…) could be used to estimate the next location of user(s).

- Motivation:
  - Information about the next location of user(s), could be applied to improve various performance metrics (e.g, handover latency, content retrieval, resource utilization,…), in the different applications.

- Application (in our research!):
  - LBS(Location Based Services)

Introduction(2/3)

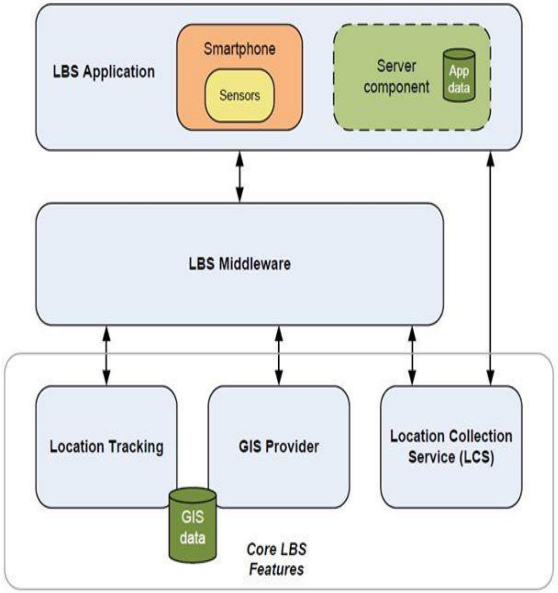
LBS

- Examples of LBS applications
  - Navigation assistances
  - Emergency location detection
  - Disaster aid
  - Finding friends in social networks

- Benefits of Location-Based Services
  - Traffic coordination and management.
  - Content delivery and advertising.
  - Tourist services.
  - Traveling related services.

Introduction(3/3)

➢ LBS Components



- LBS Application
  - Specific application such as “find my friends.”
  - Smartphone components and sensors.
  - Server component.
- LBS Middleware
  - Services to implement MUs coordination, information correlation and information dissemination.
- Core LBS Features
  - Location Tracking
  - GIS provider
  - Location Collection Service(LCS)

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Research Questions:

- How information about the next location of user(s) can be used to enhance the LBS-based applications performance?

  - Sub ques 1 : What are the possible and most related mobility prediction approaches?
  - Sub ques 2 : Which mobility prediction mechanism(s) are most fitted in our research area?
  - Sub ques 3 : How the selected mechanism(s) are feasible to implement in our research area? (possible inputs/ outputs/ doable!)
  - Sub ques 4 : How to evaluate and validate the solution ?

Proposed research plan

- Step 1- Preforming comprehensive literature review about the mobility prediction approaches--> to answer sub ques 1

- Step 2- Studying detail about the most fitted mechanisms in our research area and classify them based on pros and cons -> to answer sub ques 2

- Step 3- Investigating about the feasibility of selected mobility prediction approaches --> to answer sub ques 3

- Step 4- Finding possible way(s) for evaluation -> to answer sub ques 4

Where I am (my research is) now?

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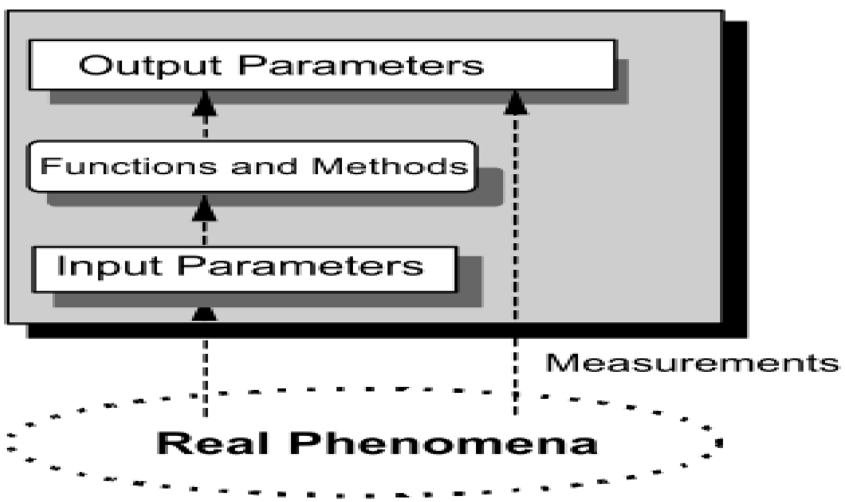
- Step 1
  - Started since first of February 2016
  - Partially (mostly) is done
  - One report is written
  - Still continue to have a complete overview!

- Step 2
  - Starting to have preliminary comparison about the mechanisms
  - Having some initial idea
  - Continuing the research!

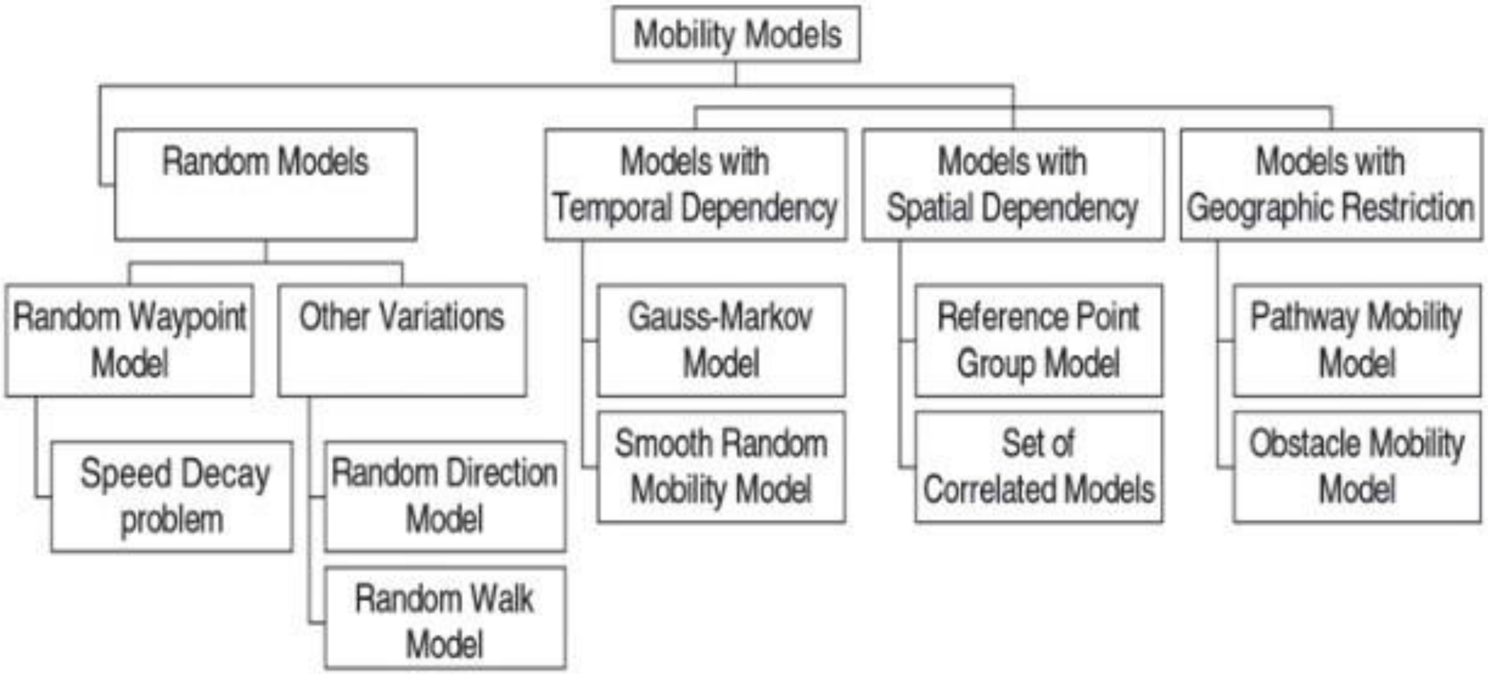
Step1

- Step1: Mobility and Prediction models
  - Mobility Models: Represent the movement of mobile users and how their location, velocity and acceleration change over time.
    - Input parameters.
    - Function and methods.
    - Output parameters.



Step1

- Classification of mobility prediction models:



Step1

- Random Models:
  - Mobile nodes move randomly and freely without restriction.
  - Mobile nodes have independent destination, speed and direction.
- Models with temporal dependency:
  - Mobile nodes trajectories are constrained by acceleration, velocity , and direction.
  - Mobile nodes mobility patterns are affected by their movement history.
- Models with spatial dependency:
  - Mobile nodes mobility patterns are affected by mobility pattern of other neighbouring nodes.
  - Applicable in disaster relief and battlefield scenarios.
- Models with geographic restriction:
  - Mobile nodes' trajectories are subject to the environment and bounded by freeways, local streets…

Random Models

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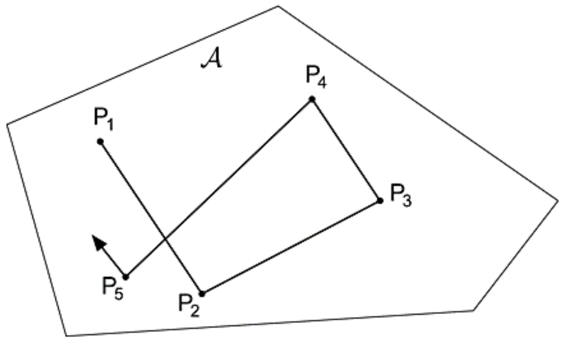
- Random Waypoint (RWP) model:

  - Synthetic model for mobility in Ad Hoc-like network.
  - Each node moves along a *zigzag* line from one waypoint *Pi* to the next *Pi+1.*
  - The waypoint are uniformly distributed over the given convex area.
  - At the start of each leg a random velocity is drawn from the velocity distribution.

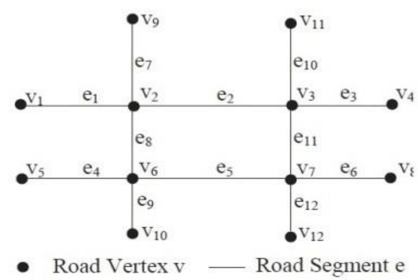


Models with temporal dependency

- The Gauss-Markov Mobility Model
  - Probability density function of node's location used for mobility prediction.
  - Input parametrs:
    - The mobile node's location and velocity updated report, which is inspected periodically by node.
    - The mobile node's velocity is correlated in time.
    - The probability density function of the mobile's location
  - Function and methods:
    - $R_v(\tau) = E[v(t)v(t+\tau)] = \sigma^2 e^{-\beta|\tau|}$
      - $-\sigma^2$: *The variance*
      - $-\beta \geq 0$: *The degree of the memory in the mobility pattern*
      - $-v_n = v(n\Delta t)$: *The discrete version of the mobile velocity*
      - $-\alpha = e^{-\beta\Delta t}$, $0 \leq \alpha \leq 1$
      - $-\Delta t$: *The clock − tick period*
  - Output parameters:
    - The future location of a mobile at time t

Models with temporal dependency cont.

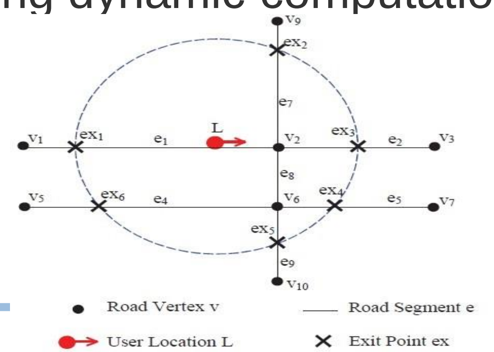
- Predictive Location Model (PLM):
  - Map-based location prediction model.
  - Comprises a database and error control mechanism to improve prediction accuracy.
  - Input parameters:
    - PLM data base
    - Road network
    - Historical trajectories
    - Probability matrix



	v_1	v_2	v_3	v_4	v_5	v_6	v_7	v_8	v_9	v_{10}	v_{11}	v_{12}
v_1	0	e_1	0	0	0	0	0	0	0	0	0	0
v_2	e_1	0	e_2	0	0	e_8	0	0	e_7	0	0	0
v_3	0	e_2	0	e_3	0	0	e_{11}	0	0	0	e_{10}	0
v_4	0	0	e_3	0	0	0	0	0	0	0	0	0
v_5	0	0	0	0	0	e_4	0	0	0	0	0	0
v_6	0	e_8	0	0	e_4	0	e_5	0	0	e_9	0	0
v_7	0	0	e_{11}	0	0	e_5	0	e_6	0	0	0	e_{12}
v_8	0	0	0	0	0	0	e_6	0	0	0	0	0
v_9	0	e_7	0	0	0	0	0	0	0	0	0	0
v_{10}	0	0	0	0	0	e_9	0	0	0	0	0	0
v_{11}	0	0	e_{10}	0	0	0	0	0	0	0	0	0
v_{12}	0	0	0	0	0	0	e_{12}	0	0	0	0	0

  - Function and methods:
    - Information retrieval method, using dynamic computational window.
  - Output parameters:
    - Detect all candidate trajectories

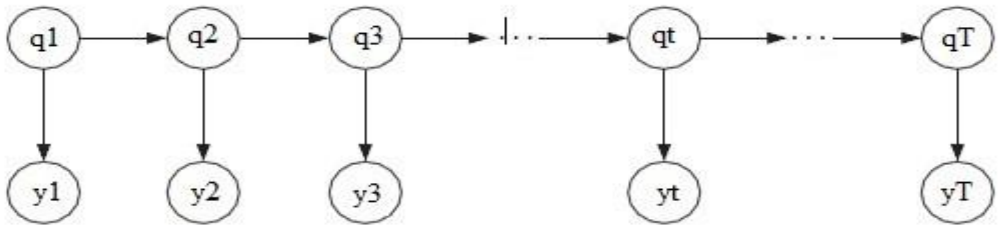
    And rank them.



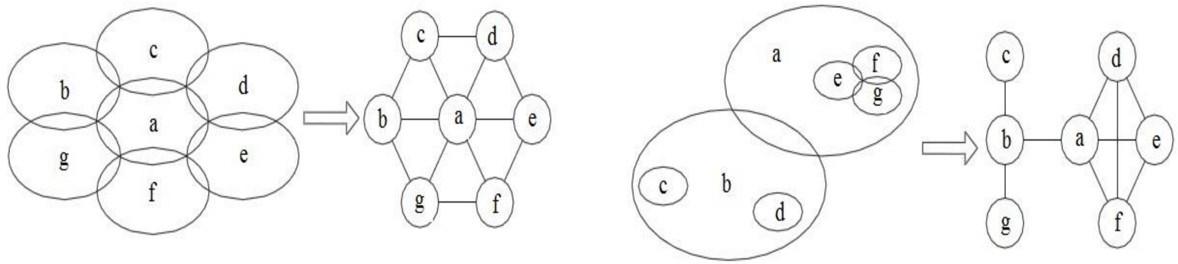
	v_1	v_2	v_3	v_5	v_6	v_7	v_9	v_{10}
v_1	0	e_1	0	0	0	0	0	0
v_2	e_1	0	e_2	0	e_8	0	e_7	0
v_3	0	e_2	0	0	0	0	0	0
v_5	0	0	0	0	e_4	0	0	0
v_6	0	e_8	0	e_4	0	e_5	0	e_9
v_7	0	0	0	0	e_5	0	0	0
v_9	0	e_7	0	0	0	0	0	0
v_{10}	0	0	0	0	e_9	0	0	0

Models with temporal dependency cont.

- Hidden Markov Model:
  - Two kind of stochastic variables (Hidden&Observable).



  - Transfer Matrix which is distributed and managed by BSC.

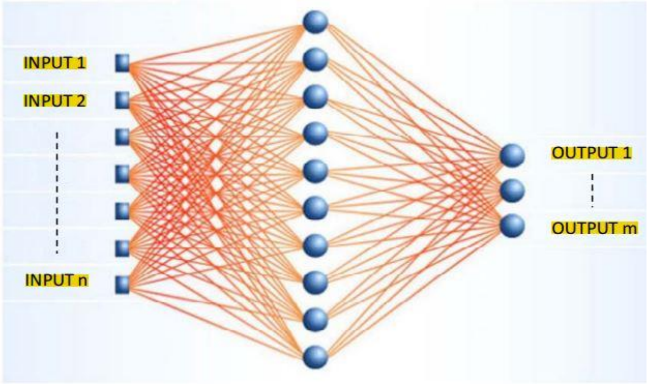


Models with temporal dependency cont.

- Hidden Markov Model (HMM)
  - Input parameters:
    - History of mobile nodes trajectories.
    - Learning parameters acquired as long as user steps into new cell.
    - Graph model of cellular network.
  - Functions and methods:
    - A hybrid technique-Bayesian Neural Network.
  - Output parameters:
    - Prediction of mobile user's location

Models with temporal dependency cont.

- Multilayer Neural Network (MNN)
  - Predict the future location of Mus based on the past predicted information.
  - Single or multiple mobile target can be predicted.
    - Input parameters
      - Moving direction
      - Moving distance (Number of cells)
    - Function and methods
      - A hybrid technique with other methods: Bayesian Network, Hidden Markov Model.
    - Output parameters
      - Next direction and distance travelled.



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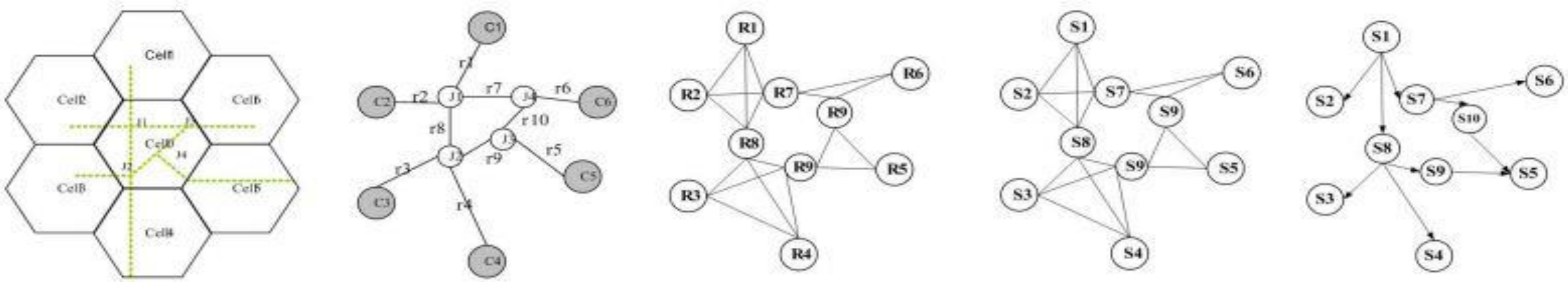
Models with temporal dependency cont.

- Bayesian Network Model
  - Resolve location prediction with multiple restricting factors.



(a) cell environment (b) CRT (C) RST (d) PDN (e) BNM

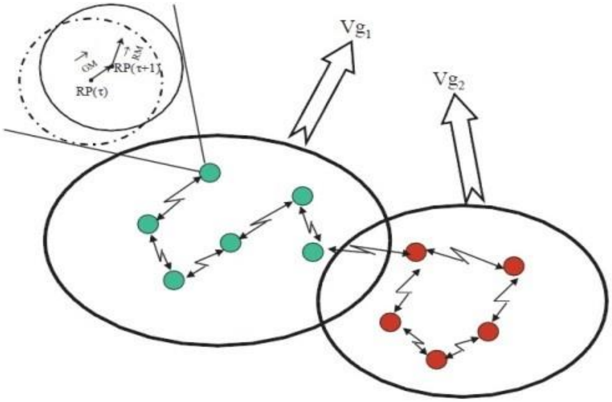
- Input parameters
  - Environment factors (Cell ID, Road length, Intersection Location)
  - Movement factors (Position Information, Current Velocity, Acceleration, Angular velocity)
- Function and methods

$$P(\text{new data} \mid \text{data}) = \int_{\text{parameters}} P(\text{new data} \mid \text{parameters})\, P(\text{parameters} \mid \text{data})$$

- Output parameters
  - Prediction of MUs next location

Models with spatial dependencies

- Reference Point Group Mobility Model (RPGM)
  - Mobile nodes are organized in different groups.
  - Mobile node could be assigned into several groups.

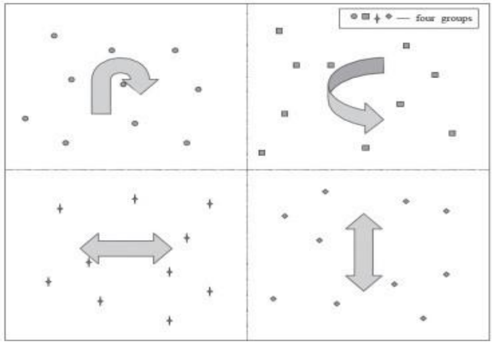


- Input parameters
  - Logical relationship among groups' membe
  - Place and motion of target for each teams
- Function and methods
  - Reference Point Group Mobility (RPGM) based on the relationship among mobile nodes.
- Output parameters
  - Prediction of users group location

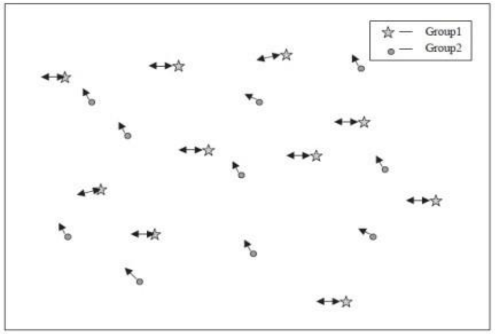
Based on RPGM model we can define following models:

Models with spatial dependencies cont.

- In-place Mobility Model
  - Dividing the serving area to several adjacent region.

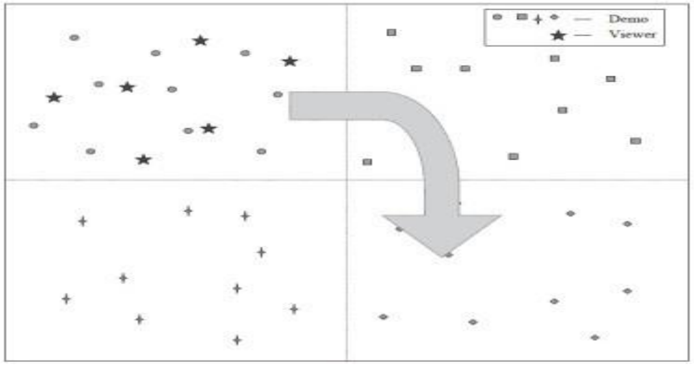


- Overlap Mobility Model
  - Various groups, different tasks, different mobility pattern in a geographical area.

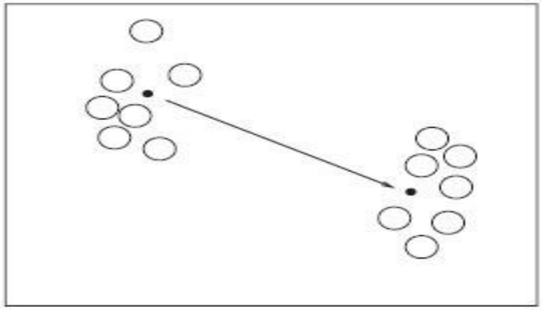


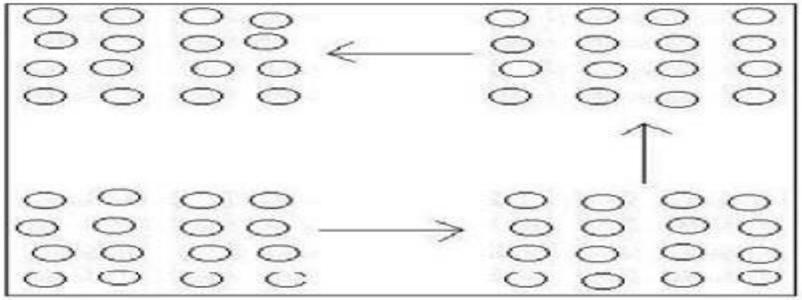
Models with spatial dependencies cont.

- Conventional Mobility Model
  - Models the interaction between exhibitors and viewers.



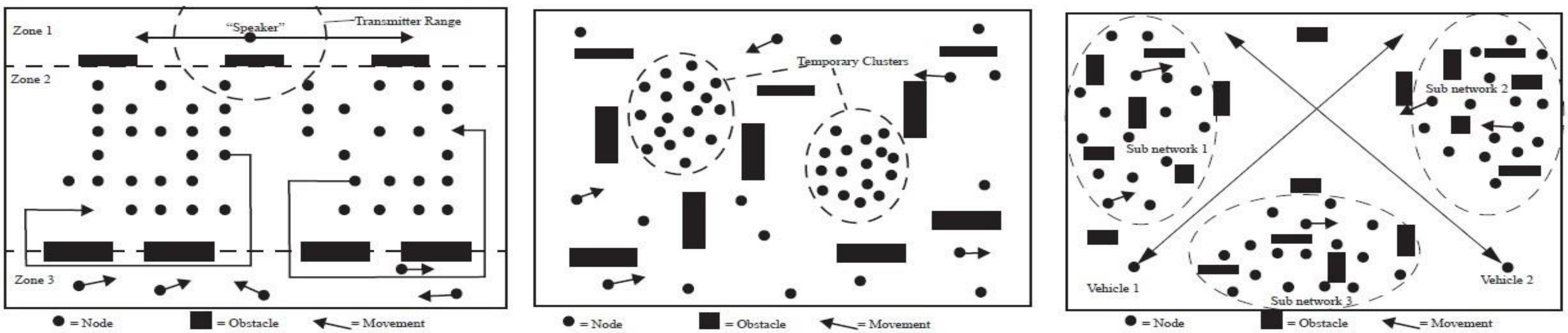
- Nomadic Community Mobility Model
  - Mobile nodes have a common reference point, and they move jointly from on point to another.





Models with geographic restriction

- Obstacle Mobility Model
  - Allows users to define the position of obstacles, so the mobile node
  - changes its trajectories accordingly.



(a) Conference scenario (b) Event coverage scenario (c) Disaster area scenarios

- Input parameters
  - Information about the place and position of obstacles
- Function and methods
  - Obstacle mobility model based on information about obstacles
- Output parameters
  - Prediction of mobile node trajectories

Step 2

Prediction Techniques	Advantages	Shortcomings
Random Waypoint Model	• Simple memoryless equations	• Lower prediction accuracy • Nodes walk randomly around the origin, never so far. • Disruptive in path turns.
Gauss-Markov Model	• More realistic than Random Waypoint Model	• More parameters to learn and tune.
Predictive Location Model	• Determine a user location as a point • Reduced number of predicted routes	• GPS will be needed • Costly prediction mechanism • Appropriate for outdoor • Inaccurate data on narrow roads
Hidden Markov Model	• Good prediction percentage	• Long training phase before prediction • Service area is too large • Slow reaction to users behaviors
Reference Point Group Mobility Model	• Low complexity • Group prediction	• Lower accuracy in cellular networks
Obstacle Mobility Model	• Easy to implement and work • Low complexity and easy equations	• Not realistic. • Low accuracy.
Dynamic Bayesian Network	• Higher accuracy in prediction • Easy for implementation • Only based on user trajectory trace data	• Requires training phase for prediction • Require quit enough users trace data as input
Multilayer Neural Network	• Higher accuracy in prediction	• The choice of model parameters is essentially arbitrary • Single weight vector

Summary

- The prediction methods are not optimum
- Performance and prediction accuracy depends on scenario and input parameters.
- It seems to be better to have a Hybrid prediction mechanism.

Thanks for Your Attention!