Mobile Ad Hoc Networks

Routing

10th Week

27.06.-29.06.2007

University of Freiburg
Computer Networks and Telematics
Prof. Christian Schindelhauer

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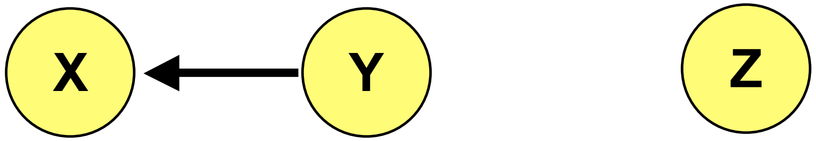
Destination-Sequenced Distance-Vector (DSDV) [Perkins94Sigcomm]

- **Each node maintains a routing table which stores**
  - next hop towards each destination
  - a cost metric for the path to each destination
  - a destination sequence number that is created by the destination itself
  - Sequence numbers used to avoid formation of loops

- **Each node periodically forwards the routing table to its neighbors**
  - Each node increments and appends its sequence number when sending its local routing table
  - This sequence number will be attached to route entries created for this node

Destination-Sequenced Distance-Vector (DSDV)

- **Assume that node X receives routing information from Y about a route to node Z**



- **Let S(X) and S(Y) denote the destination sequence number for node Z as stored at node X, and as sent by node Y with its routing table to node X, respectively**

Tutorial by Nitin Vaidya presented on INFOCOM 2006
Tutorial on Mobile Ad Hoc Networks: Routing, MAC and Transport Issues
http://www.crhc.uiuc.edu/wireless/talks/2006.Infocom.ppt

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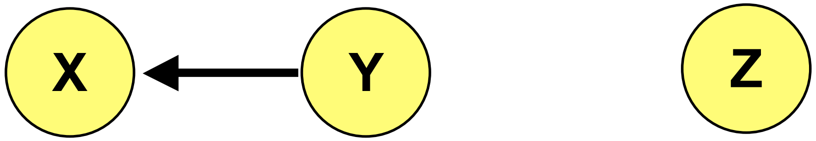
Destination-Sequenced Distance-Vector (DSDV)

- **Node X takes the following steps:**



  - If S(X) > S(Y), then X ignores the routing information received from Y
  - If S(X) = S(Y), and cost of going through Y is smaller than the route known to X, then X sets Y as the next hop to Z
  - If S(X) < S(Y), then X sets Y as the next hop to Z, and S(X) is updated to equal S(Y)

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Hybrid Protocols

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Zone Routing Protocol (ZRP) [Haas98]

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Zone routing protocol combines

- **Proactive protocol: which pro-actively updates network state and maintains route regardless of whether any data traffic exists or not**
- **Reactive protocol: which only determines route to a destination if there is some data to be sent to the destination**

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ZRP

- **All nodes within hop distance at most *d* from a node X are said to be in the routing zone of node X**

- **All nodes at hop distance exactly *d* are said to be peripheral nodes of node X's routing zone**

ZRP

- **Intra-zone routing: Pro-actively maintain state information for links within a short distance from any given node**
  - Routes to nodes within short distance are thus maintained proactively (using, say, link state or distance vector protocol)

- **Inter-zone routing: Use a route discovery protocol for determining routes to far away nodes. Route discovery is similar to DSR with the exception that route requests are propagated via peripheral nodes.**

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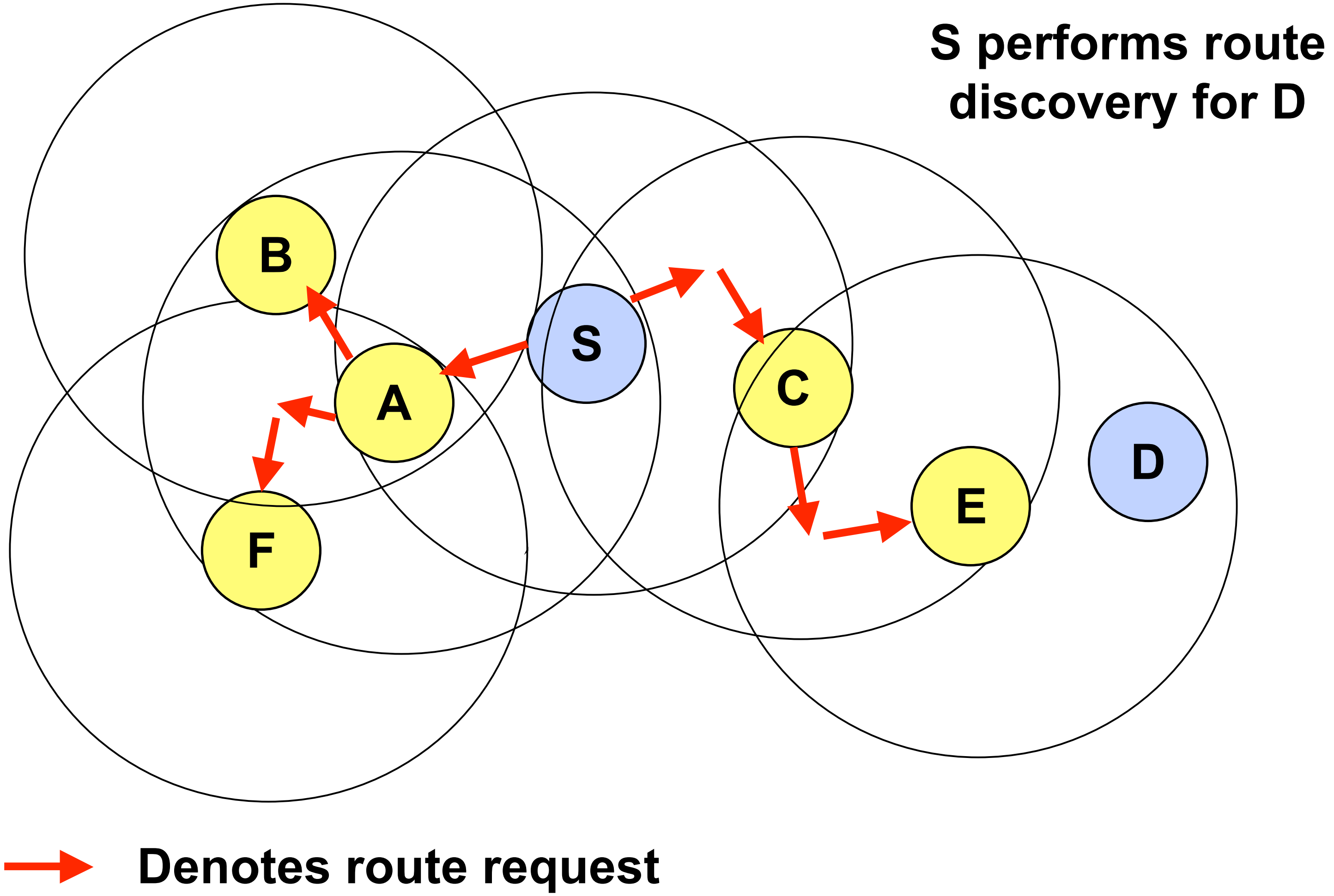
ZRP: Example with
Zone Radius = *d* = 2



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ZRP: Example with *d = 2*

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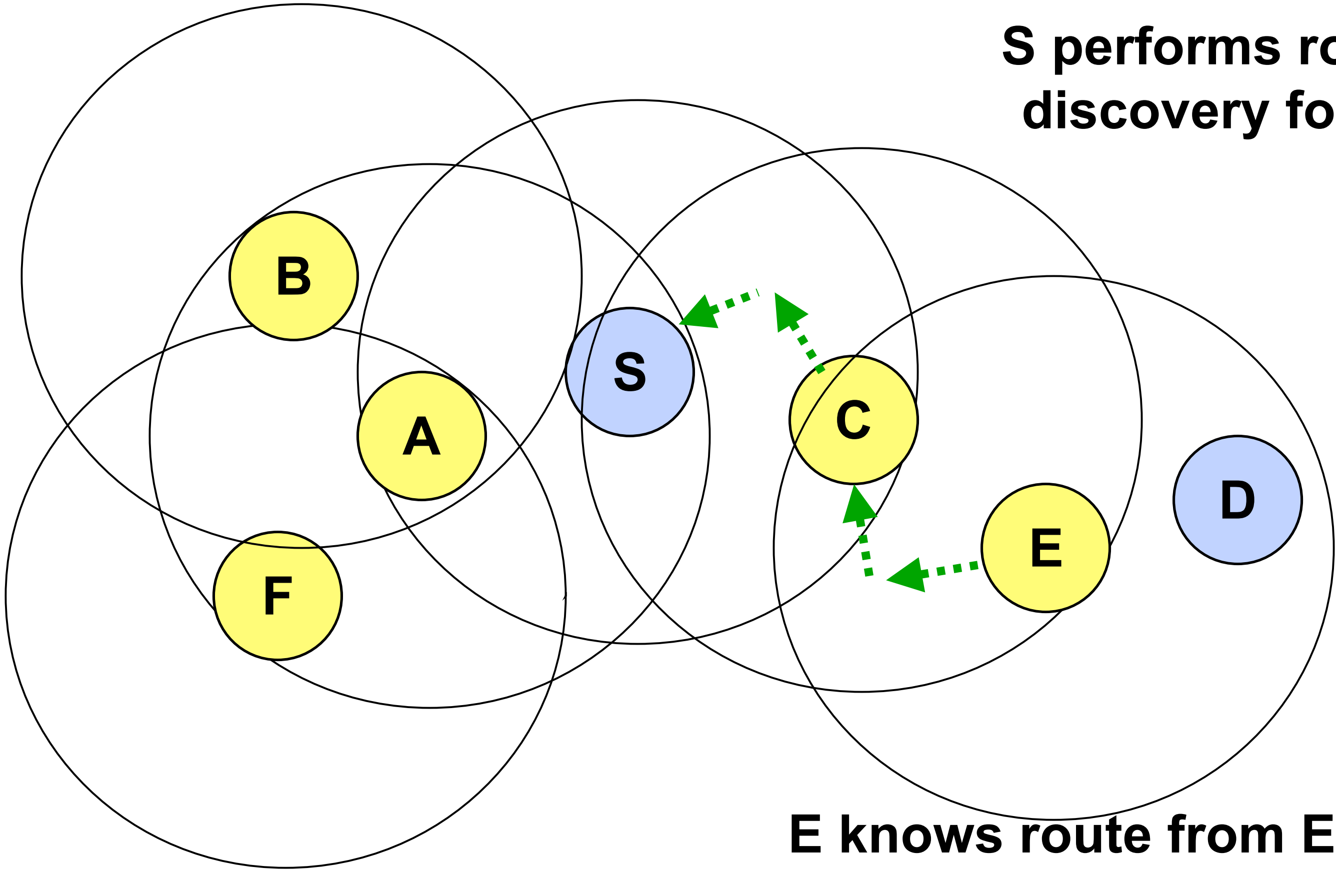

S performs route discovery for D

Denotes route reply

E knows route from E to D, so route request need not be forwarded to D from E

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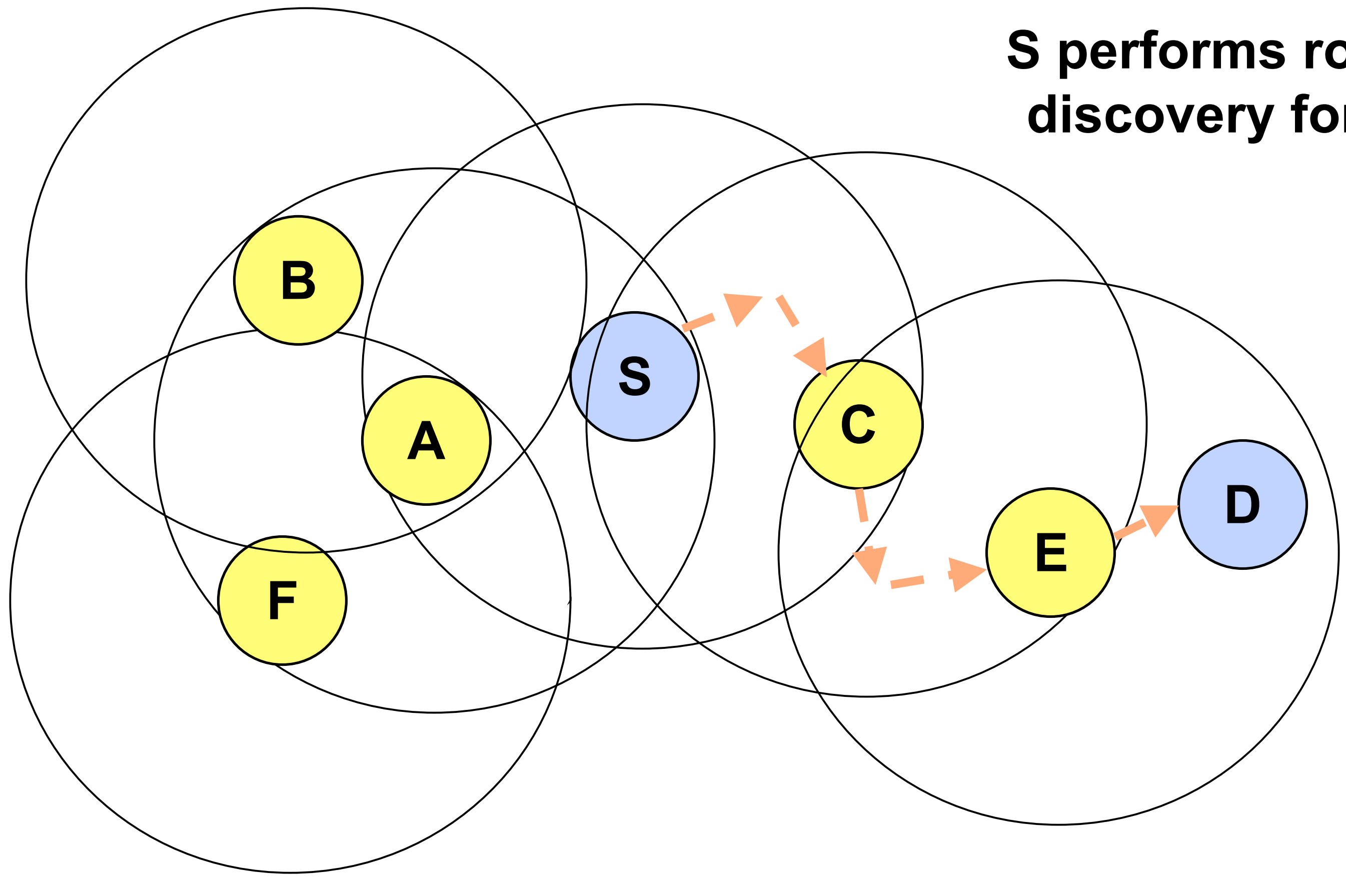
ZRP: Example with *d* = 2

S performs route discovery for D



Denotes route taken by Data

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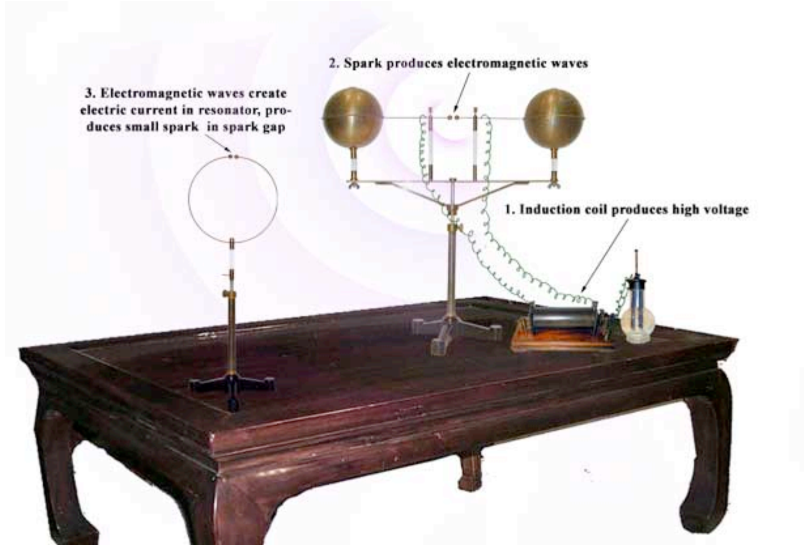
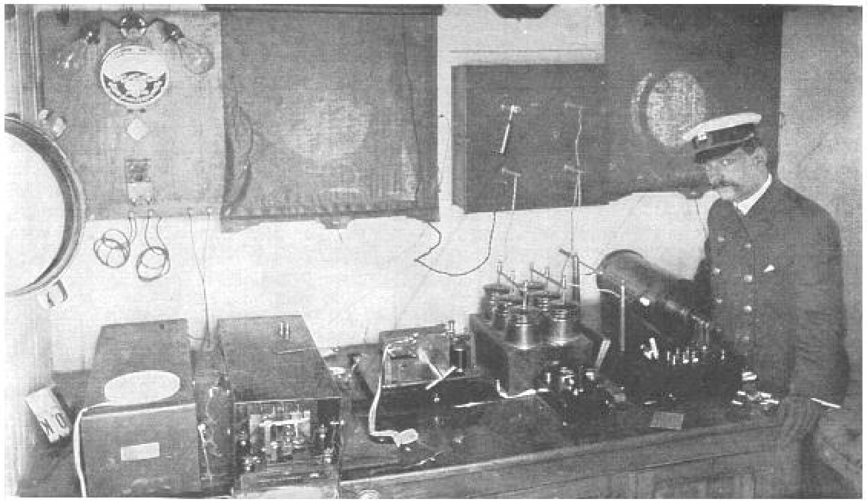
- Introduction
- **Wireless Networks in a Nutshelf**
  - Cellular Networks
  - Mobile Ad Hoc Networks
  - Sensor Networks
- **Mobility Patterns**
  - Pedestrian
  - Marine and Submarine
  - Earth bound Vehicles
  - Aerial
  - Medium Based
  - Outer Space
  - Robot Motion
  - Characterization of Mobility Patterns
  - Measuring Mobility Patterns
- **Models of Mobility**
  - Cellular
  - Random Trip
  - Group
  - Combined
  - Non-Recurrent
  - Particle based
  - Worst Case
- **Discussion**
  - Mobility is Helpful
  - Mobility Models and Reality

Introduction The history of Mobile Radio (I)

- 1880s: Discovery of Radio Waves by Heinrich Hertz
- 1900s: First radio communication on ocean vessels
- 1910: Radios requried on all ocean vessels





THE "MARCONI MAN" AND HIS INSTRUMENTS

Introduction The history of Mobile Radio (II)

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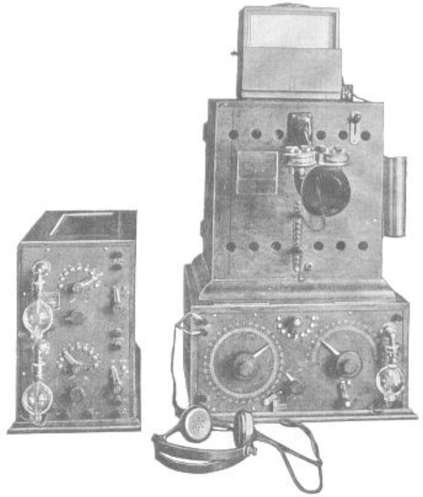
- 1914: Radiotelephony for railroads
- 1918: Radio Transceiver even in war air plane
- 1930s: Radio transceivers for pedestrians: “Walkie-Talkie”
- 1940s: Handheld radio transceivers: “Handie-Talkie”



RADIOTELEPHONY APPARATUS

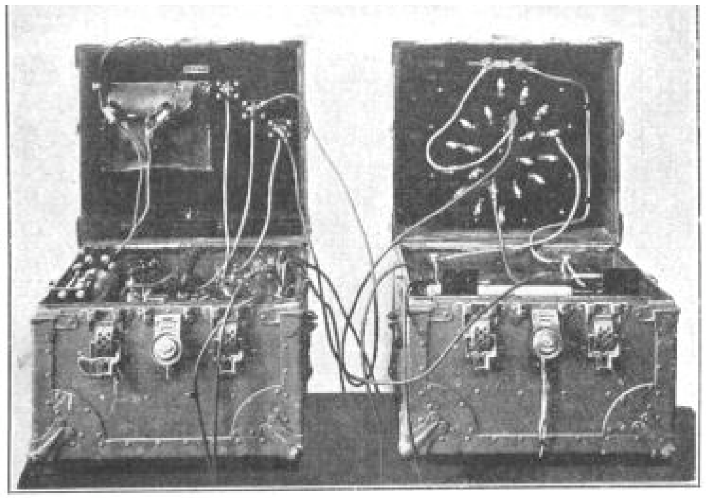


Fig. 108.—U. S. Signal Corps pack sets shown open and closed. Receiving apparatus on the left.

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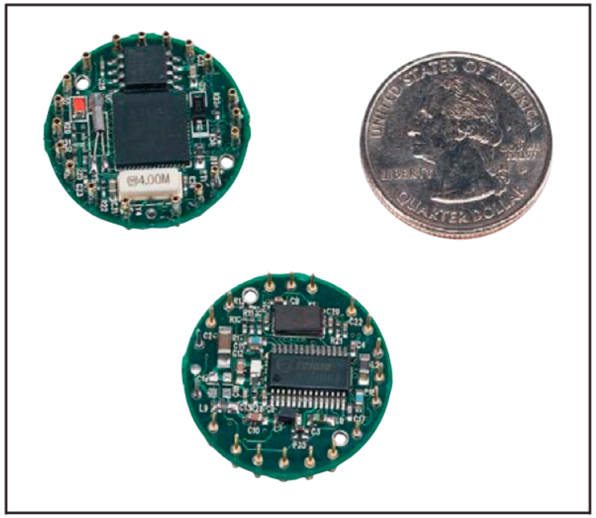
Introduction
The History of Mobile Radio (III)

- **1970s Vint Cerfs Stanford Research Institute (SRI) Van**
  - First mobile packet radio tranceivers
- **...**

- **2000s Wireless sensor coin sized sensor nodes Mica2dot from California based Crossbow company**



Wireless Networks in a Nutshelf
Cellular Networks

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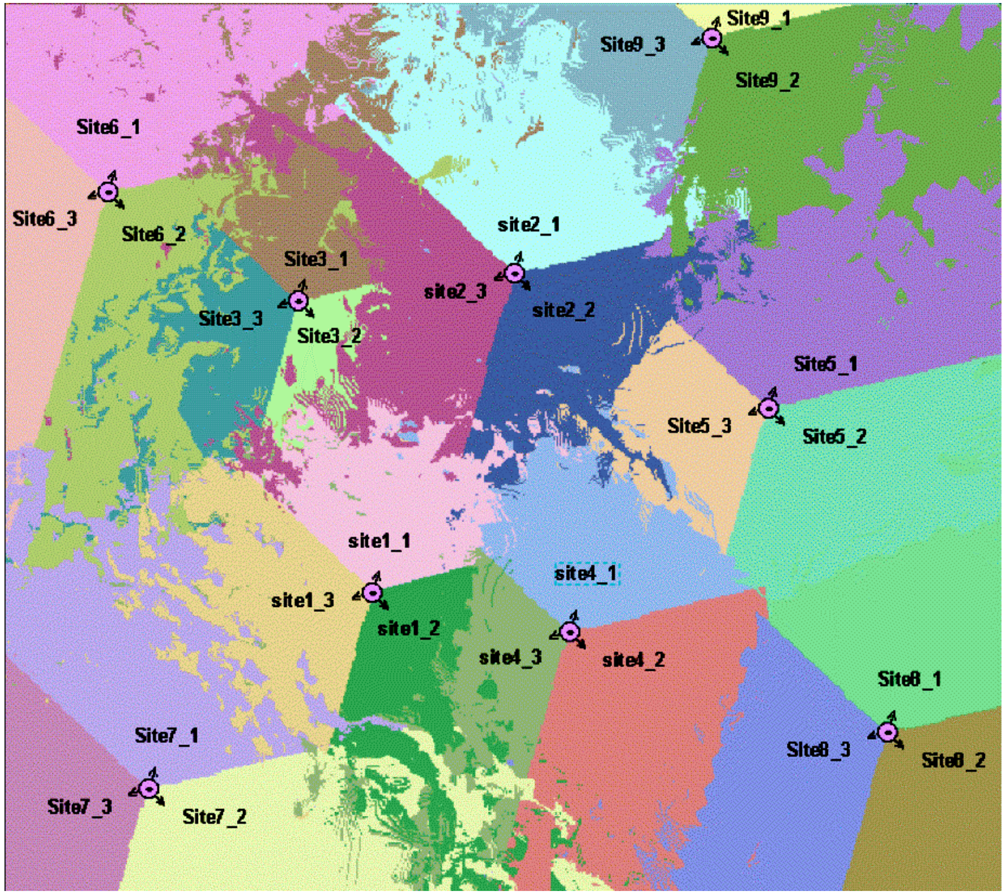
- **Static base stations**
  - devide the field into cells
- **All radio communication is only**
  - between base station and client
  - between base stations
    - usually hardwired
- **Mobility:**
  - movement into or out off a cell
  - sometimes cell sizes vary dynamically (depending on the number of clients - UMTS)
- **Main problems:**
  - Cellular Handoff
  - Location Service



Wireless Networks in a Nutshelf
Mobile Ad Hoc Networks

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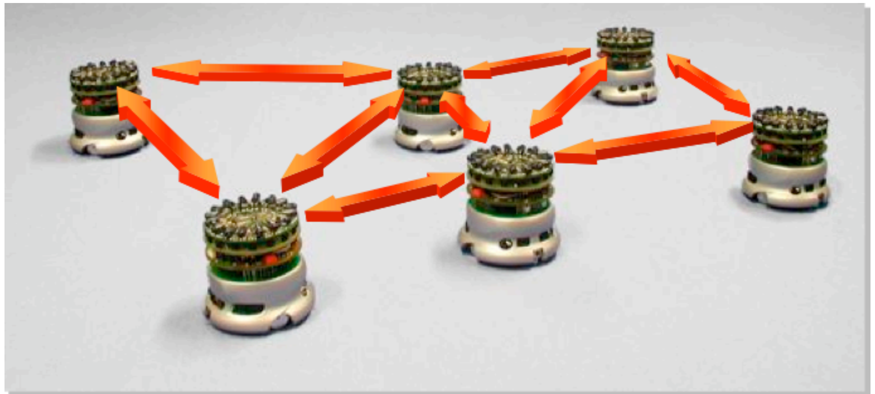
- **MANET:**
  - self-configuring network of mobile nodes
  - nodes are routers and clients
  - no static infrastructure
  - network adapts to changes induced by movement
- **Positions of clients**
  - in most applications not available
  - exceptions exist
- **Problems:**
  - Find a multi-hop route between message source and target
  - Multicast a message
  - Uphold the network routing tables



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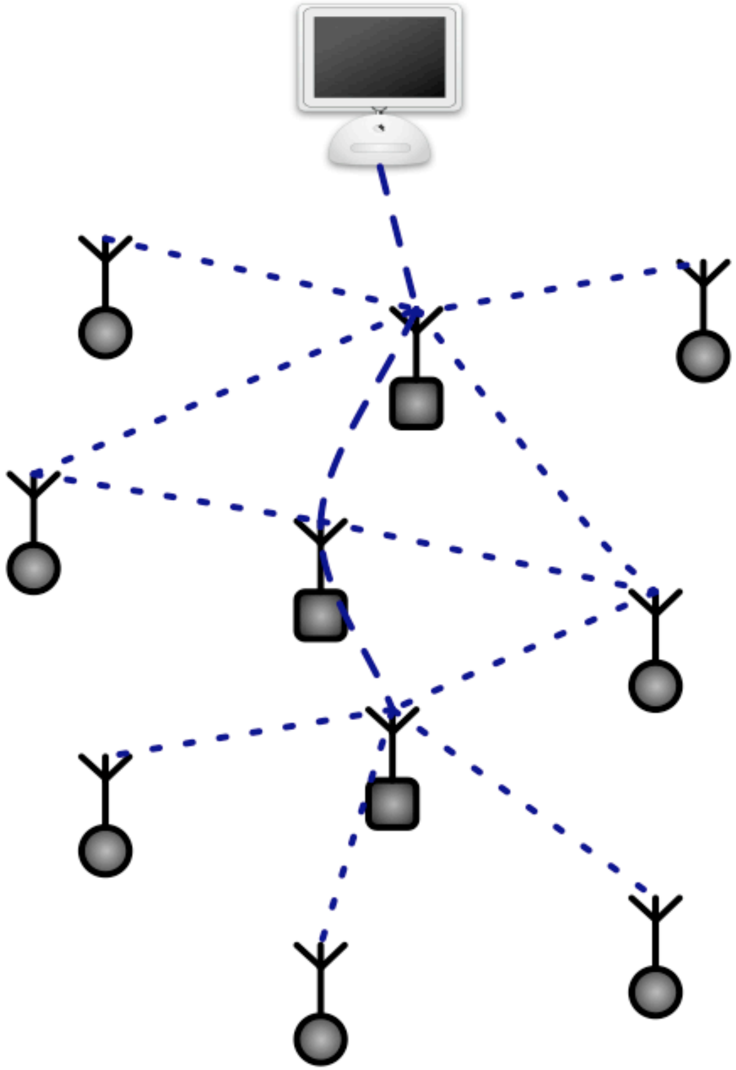
Wireless Networks in a Nutshelf
Wireless Sensor Networks

- **Sensor nodes**
  - spacially distributed
  - equipped with sensors for
    - temperature, vibration, pressure, sound, motion, ...
- **Base stations**
  - for collecting the information and control
  - possibly connected by ad-hoc-network
- **Main task**
  - Read out the sensor information from the field
- **Main problem**
  - Energy consumption
    - nodes are sleeping most of the time



Mobility Patterns: Pedestrian

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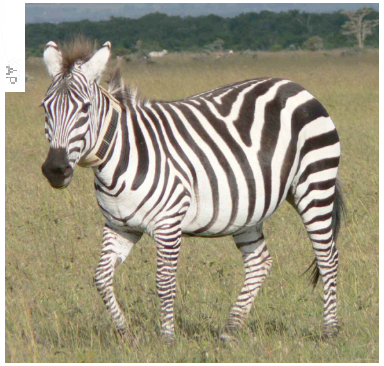
- **Characteristics:**
  - Slow velocity
  - Dynamics from obstacles obstructing the signal
    - signal change a matter of meters
  - Applies for people or animals
  - Complete use of two-dimensional plane
  - Chaotic structure
  - Possible group behavior
  - Limited energy ressources
- **Examples**
  - Pedestrians on the street or the mall
  - Wild life monitoring of animals
  - Radio devices for pets



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Mobility Patterns: Marine and Submarine

- **Characteristics**
  - Speed is limited due to friction
  - Two-dimensional motion
    - submarine: nearly three-dimensional
  - Usually no group mobility
    - except conoys, fleets, regattas, fish swarms
- **Radio communication**
  - On the water: nearly optimal
  - Under the water: terrible
    - solution: long frequencies or sound

Mobility Patterns: Earth bound vehicles

- **Mobility by wheels**
  - Cars, railways, bicycles, motor bikes etc.
- **Features**
  - More speed than pedestrians
  - Nearly 1-dimensional mobility
    - because of collisions
  - Extreme group behavior
    - e.g. passengers in trains
- **Radio communication**
  - Reflections of environment reduce the signal strengths dramatically
    - even of vehicles heading towards the same direction

Mobility Patterns: Aerial Mobility

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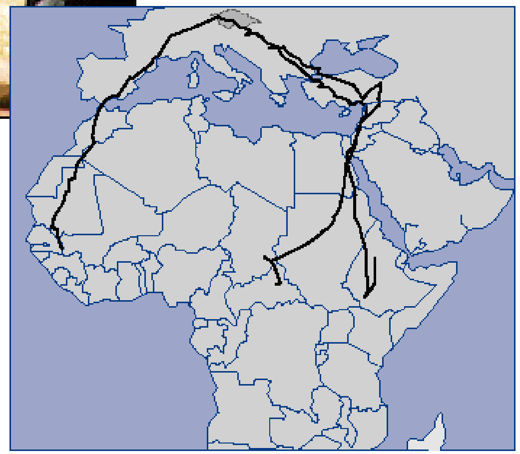
- **Examples:**
  - Flying patterns of migratory birds
  - Air planes
- **Characteristics**
  - High speeds
  - Long distance travel
    - problem: signal fading
  - No group mobility
    - except bird swarms
  - Movement two-dimensional
    - except air combat
- **Application**
  - Collision avoidance
  - Air traffic control
  - Bird tracking



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Mobility Patterns: Medium Based

- **Examples:**
  - Dropwindsondes in tornadoes/hurricanes
  - Drifting buoyes
- **Chararcteristics of mobility**
  - Determined by the medium
  - Modelled by Navier-Stokes-equations
  - Medium can be 1,2,3-dimensional
  - Group mobility may occur
    - is unwanted, because no information
  - Location information is always available
    - this is the main purpose

Mobility Patterns: Outer Space

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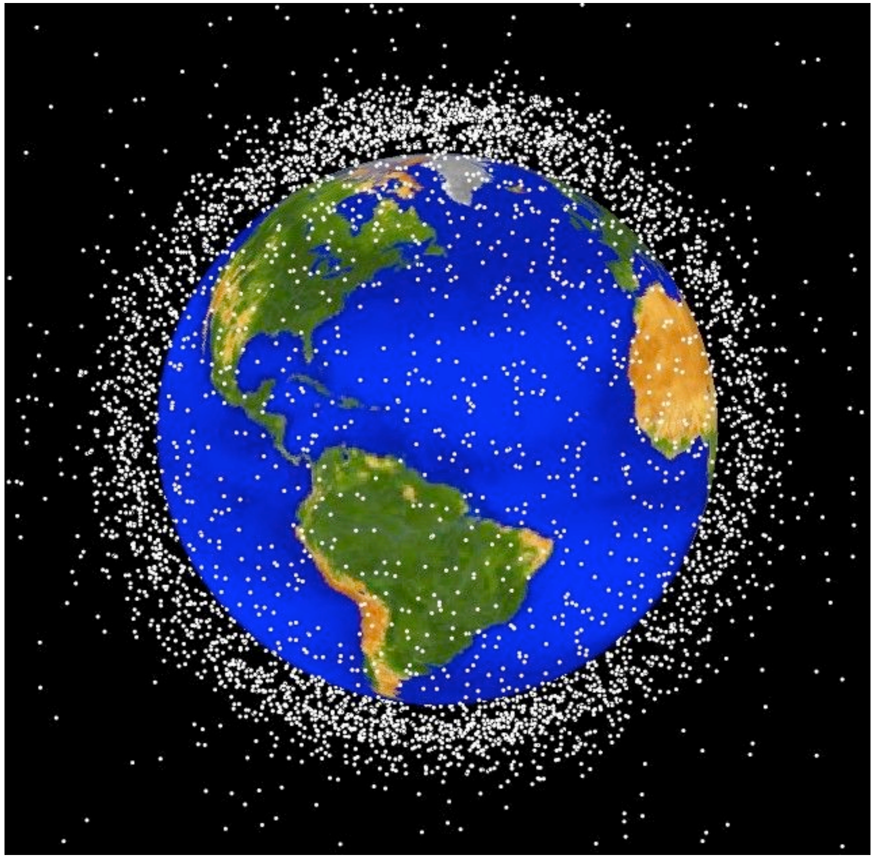
- **Characterization**
  - Acceleration is the main restriction
  - Fuel is limited
  - Space vehicles drift through space most of the time
  - Non-circular orbits possible
  - Mobility in two-planet system is chaotic
  - Group behavior in future systems
- **Radio communication**
  - Perfect signal transmission
  - Energy supply usually no problem (solar paddles)



Mobility Patterns Outer Space: Chaotic Mobility

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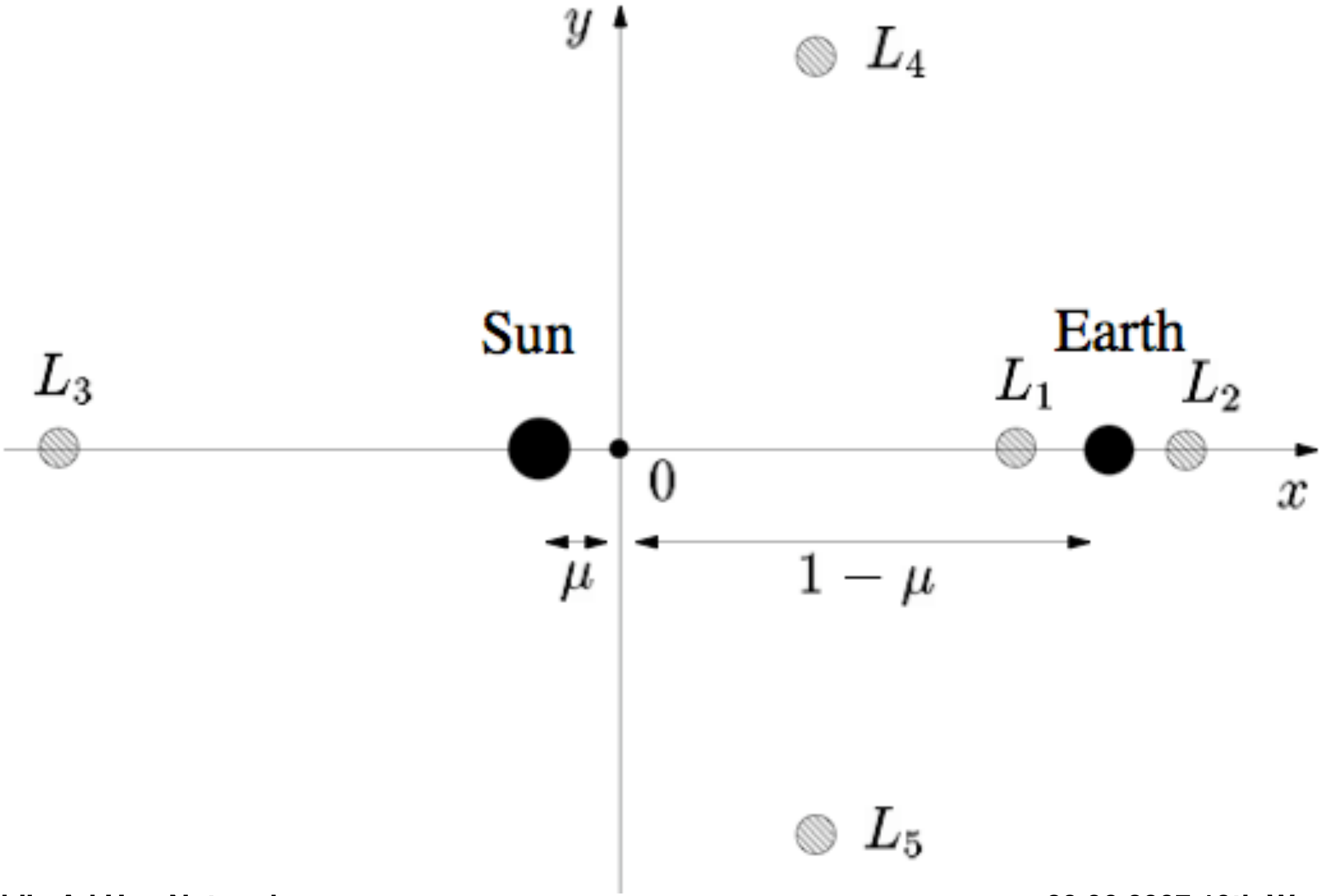

Mobility Patterns
Outer Space: Chaotic Mobility
[Junge et al. 2002]

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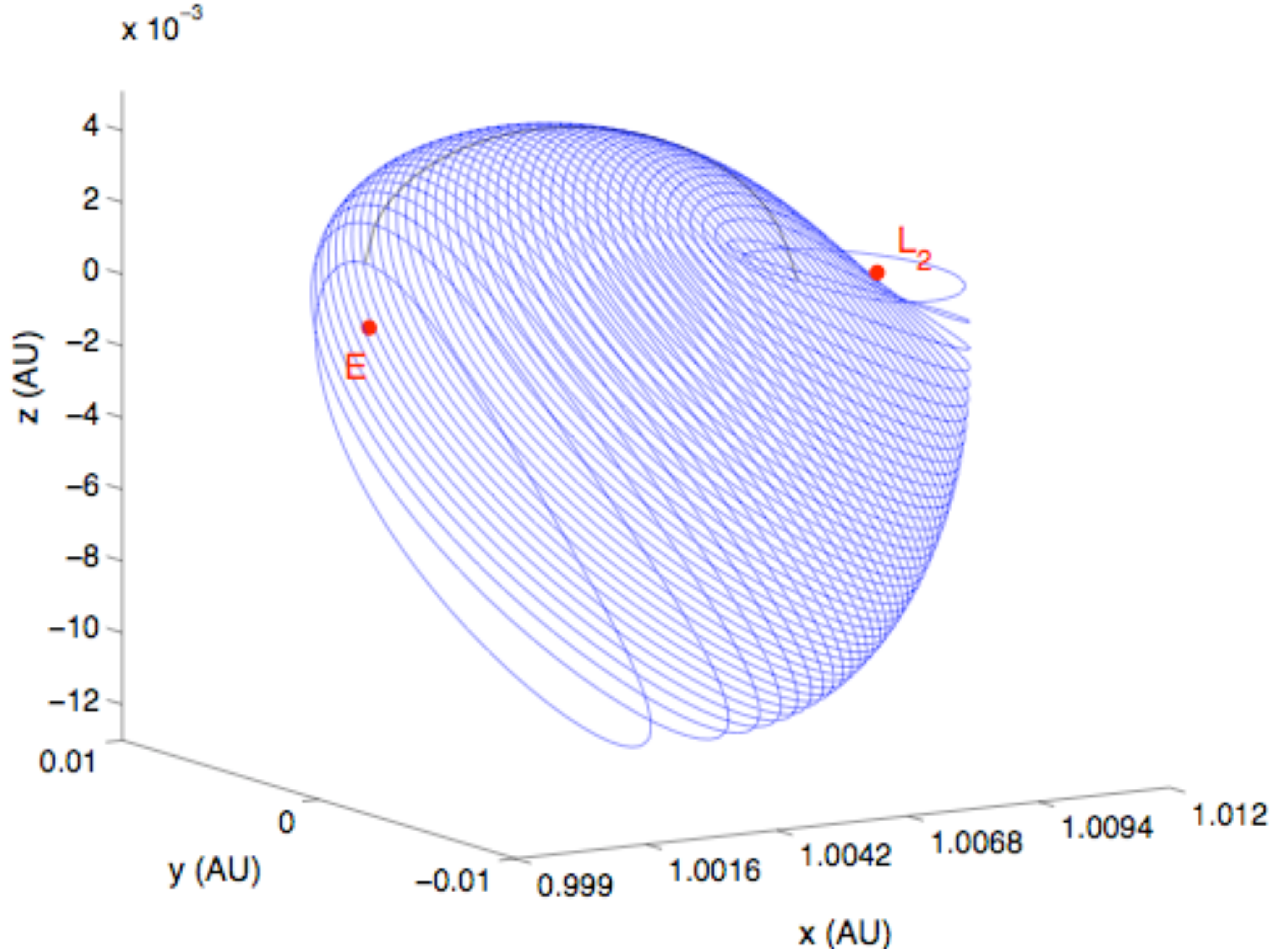

Mobility Patterns: Robot Motion

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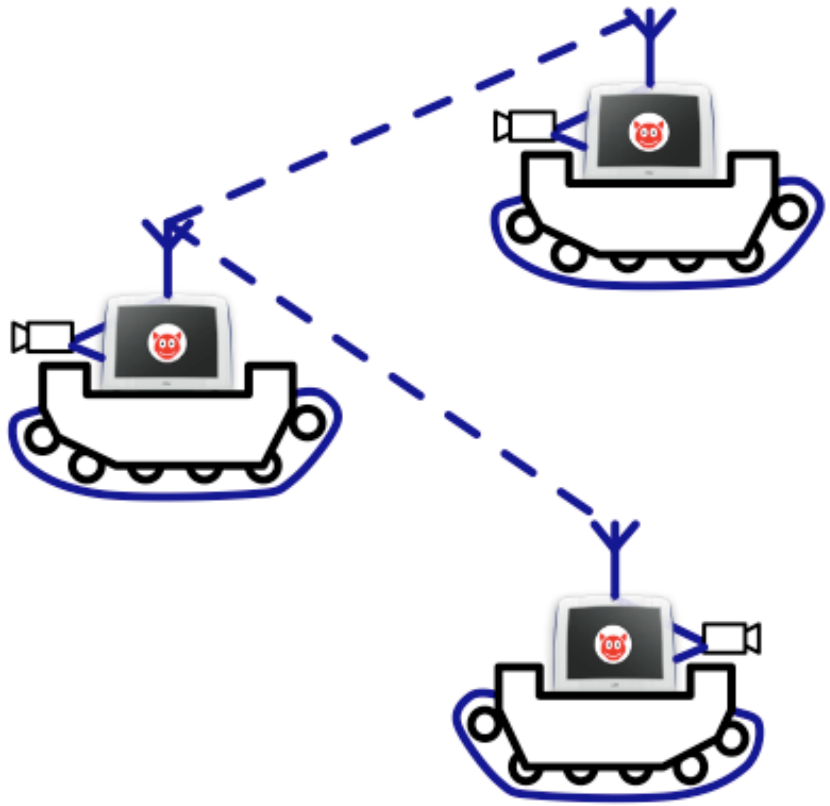
- **Scenario**
  - any above
- **Main difference**
  - Mobility behavior given by the programmer
- **Predictability?**
  - depends on programmer and environment
- **Problem**
  - Robot motion designer don’t care about communication
  - Robot goals and wireless communication may conflict
- **Solution**
  - Find a compromise
  - “Smart Team Project”



Mobility Patterns: Characterization

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- **Group behavior**
  - Can be exploited for radio communication
- **Limitations**
  - Speed
  - Acceleration
- **Dimensions**
  - 1, 1 1/2, 2, 2 1/2, 3
- **Predictability**
  - Simulation model
  - Completely erratic
  - Described by random process
  - Deterministic (selfish) behavior

Mobility Patterns: Measuring Mobility

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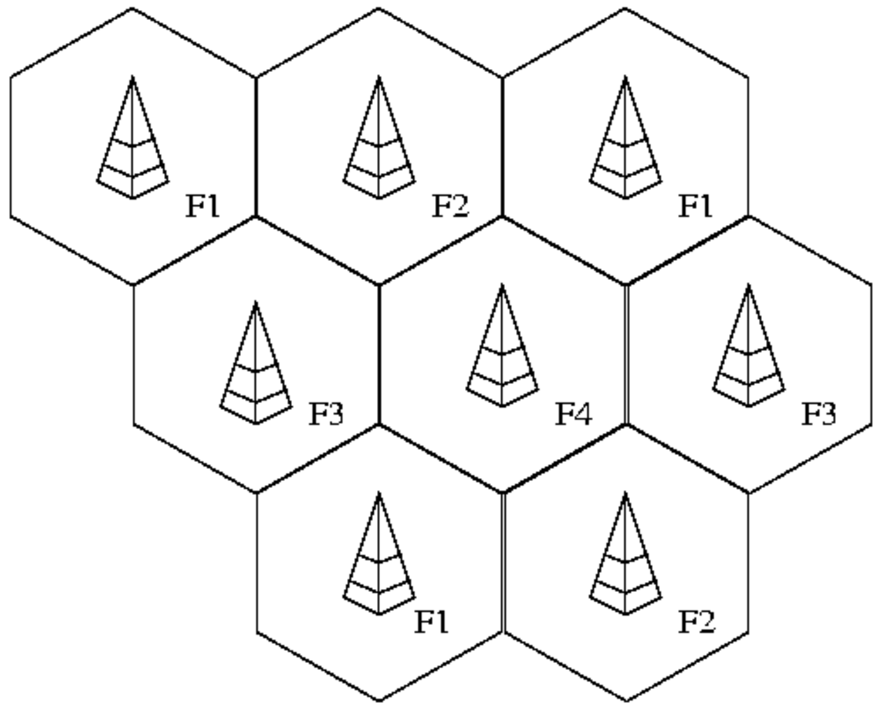
- **How to measure mobility?**
  - Use a wireless sensor network!
- **Localization in wireless networks**
  - Signal strength
  - Time of arrival
  - Time difference of arrival
  - Angle of arrival
  - Hop count based techniques
  - Cell information
- **Global Positioning System (GPS)**
  - (predecessor of Galileo)
  - Works very well on the planet's surface
    - Perfect for cars, trucks, trains, bikes, pets, cows, zebras,...
    - Not in offices, shopping malls, subway systems, tunnels,underwater
  - Not always available
    - Energy consumption, cost, distances too short

Models of Mobility
Cellular Mobility

- **Random Walk**
  - A node stays in a cell or changes to a neighbored cell with a given probability
  - Memoryless model for handoff
- **Trace Based**
  - Large records of real mobility patterns of users
  - Simulate handoff
- **Fluid Flow**
  - Macroscopic level
  - Mobility is modeled like a fluid/gas in a pipe
  - works very well for highways
  - insufficient for individual movements including stopping and starting



Models of Mobility
Random Trip Mobility

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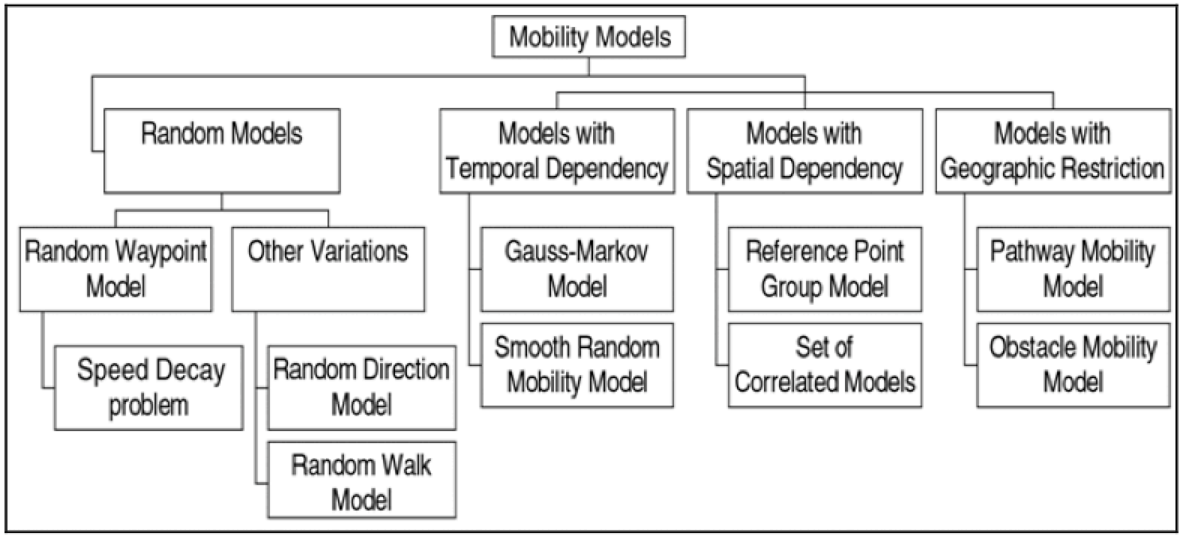
- **Random Walk**
- **Random Waypoint**
- **Random Direction**
- **Boundless Simulation Area**
- **Gauss-Markov**
- **Probabilistic Version of the Random Walk Mobility**
- **City Section Mobility Model**

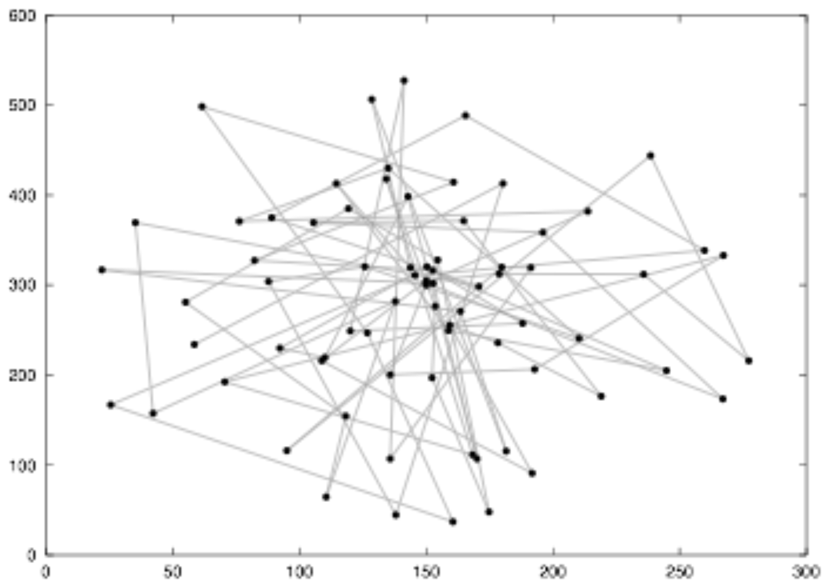


[Bai and Helmy in Wireless Ad Hoc Networks 2003]

Models of Mobility Brownian Motion, Random Walk

- **Brownian Motion (microscopic view)**
  - speed and direction are chosen randomly in each time step (uniformly from $[v_{\min}, v_{\max}]$ and $[0, \pi]$)

- **Random Walk**
  - macroscopic view
  - memoryless
  - e.g., for cellular networks
  - movement from cell to cell
  - choose the next cell randomly
  - residual probability

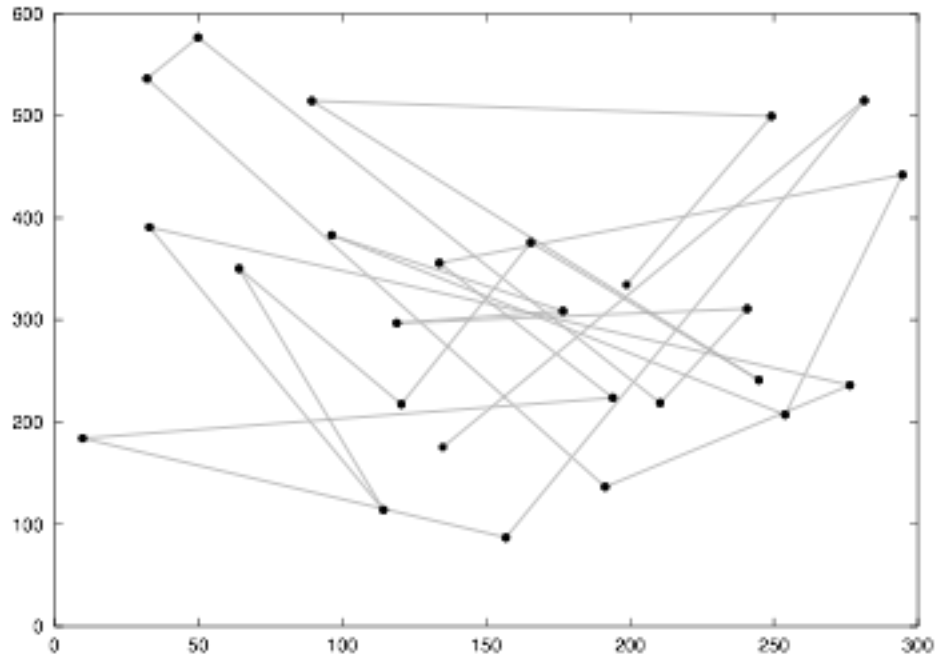


[Camp et al. 2002]

Models of Mobility Random Waypoint Mobility Model

[Johnson, Maltz 1996]

- move directly to a randomly chosen destination
- choose speed uniformly from $[v_{\min}, v_{\max}]$
- stay at the destination for a predefined pause time



[Camp et al. 2002]

Models of Mobility Problems of Random Waypoint

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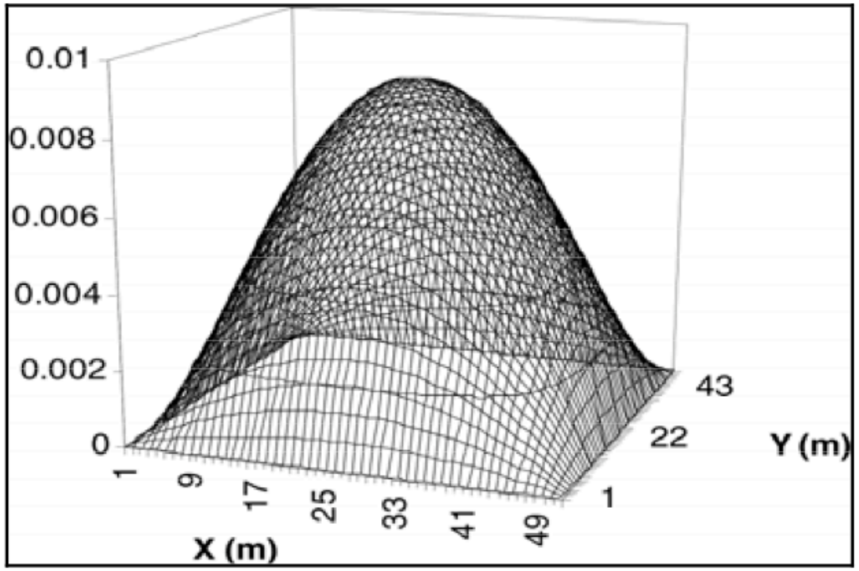
- **In the limit not all positions occur with the same probability**
- **If the start positions are uniformly at random**
  - then the transient nature of the probability space changes the simulation results
- **Solution:**
  - Start according the final spatial probability distribution



Models of Mobility Gauss-Markov Mobility Model

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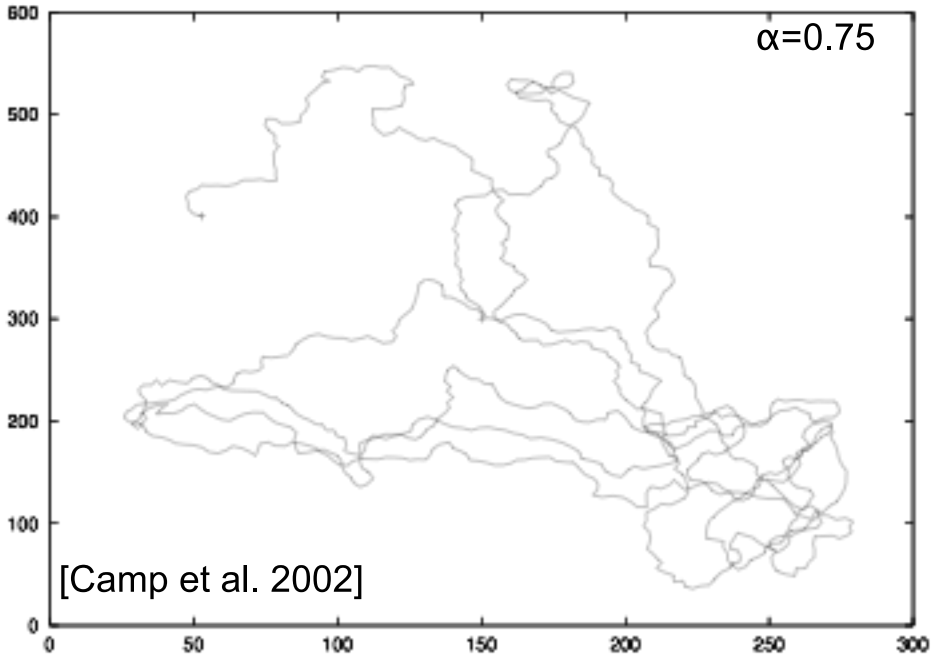
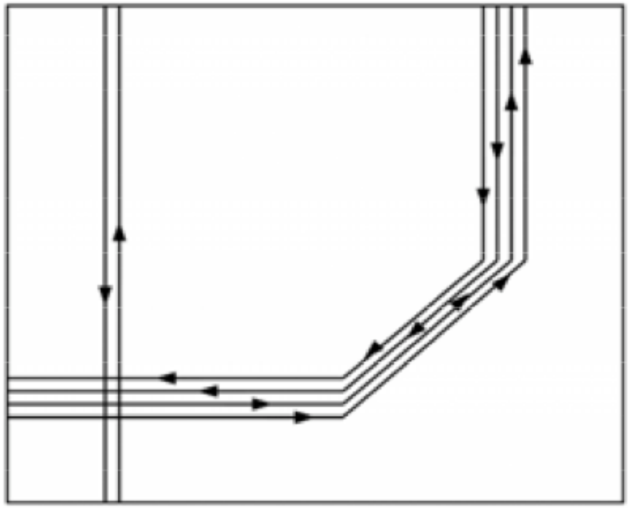
- **adjustable degree of randomness**
- **velocity:** $v_n = \alpha v_{n-1} + (1-\alpha)\overline{v} + \sqrt{1-\alpha^2}\, v_{X_{n-1}}$
- **direction:** $d_n = \alpha d_{n-1} + (1-\alpha)\overline{d} + \sqrt{1-\alpha^2}\, d_{X_{n-1}}$

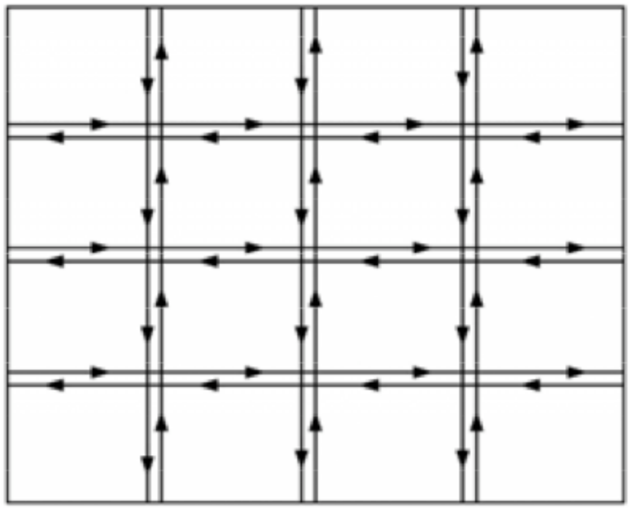
tuning factor (α) — mean ($\overline{v}$, $\overline{d}$) — random variable gaussian distribution ($v_{X_{n-1}}$, $d_{X_{n-1}}$)



Models of Mobility
City Section and Pathway

- **Mobility is restricted to pathways**
  - Highways
  - Streets
- **Combined with other mobility models like**
  - Random walk
  - Random waypoint
  - Trace based
- **The path is determined by the shortest path between the nearest source and target**





Models of Mobility: Group-Mobility Models

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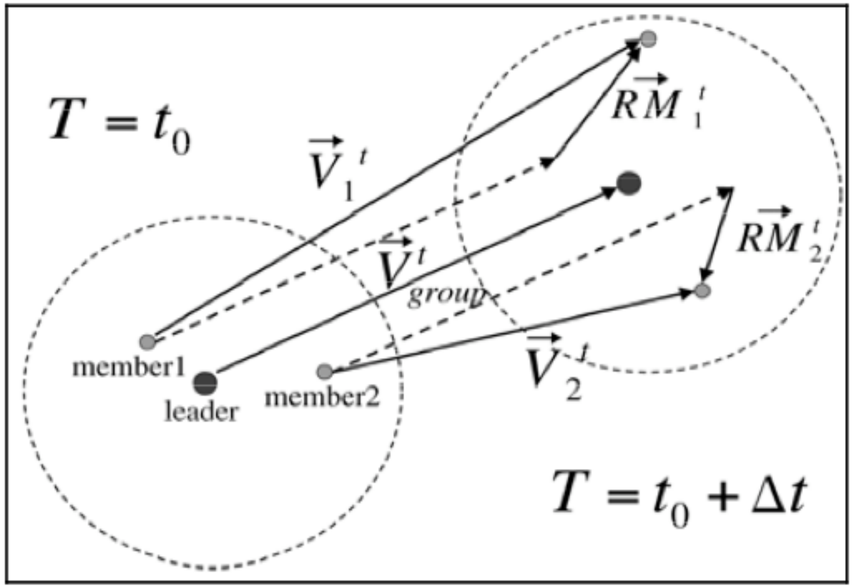
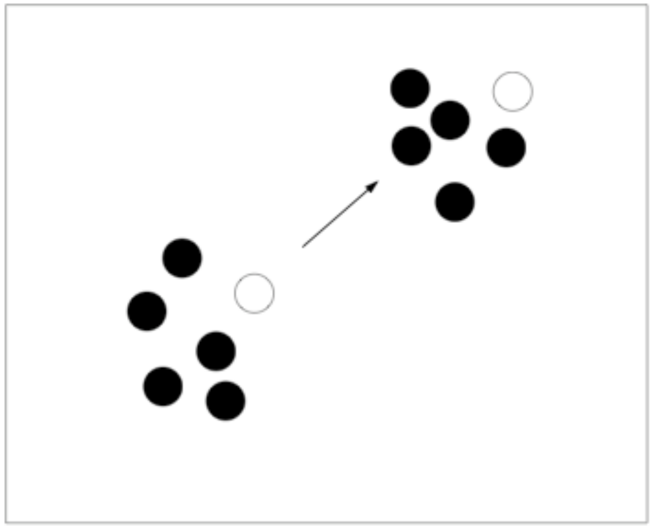
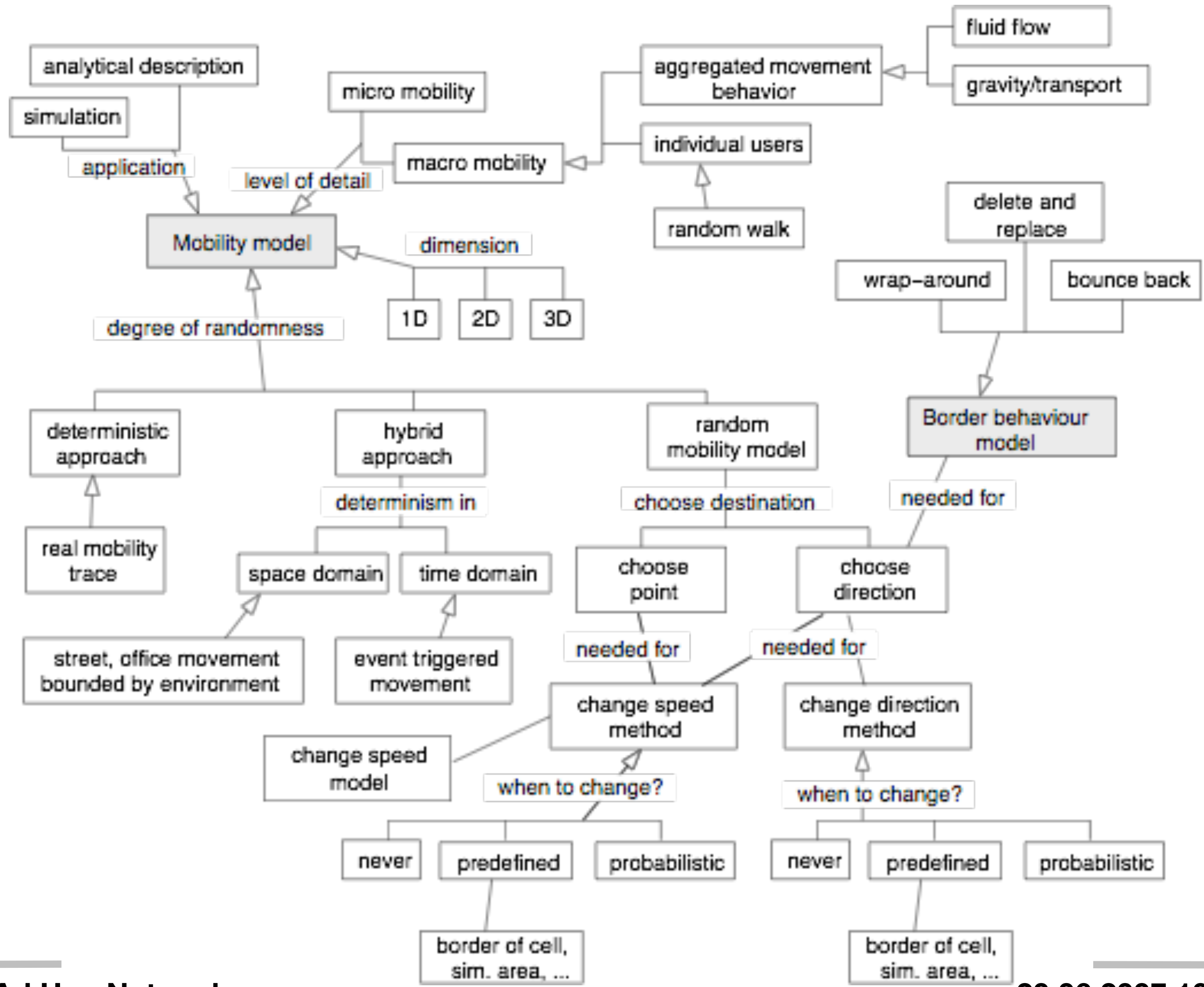
- **Exponential Correlated Random**
  - Motion function with random deviation creates group behavior
- **Column Mobility**
  - Group advances in a column
    - e.g. mine searching
- **Reference Point Group**
  - Nomadic Community Mobility
    - reference point of each node is determined based on the general movement of this group with some offset
  - Pursue Mobility
    - group follows a leader with some offset





Models of Mobility
Combined Mobility Models
[Bettstetter 2001]



Thank you!

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