Mobile Ad Hoc Networks

Mobility (II)

11th Week

04.07.-06.07.2007

CoNe
Freiburg

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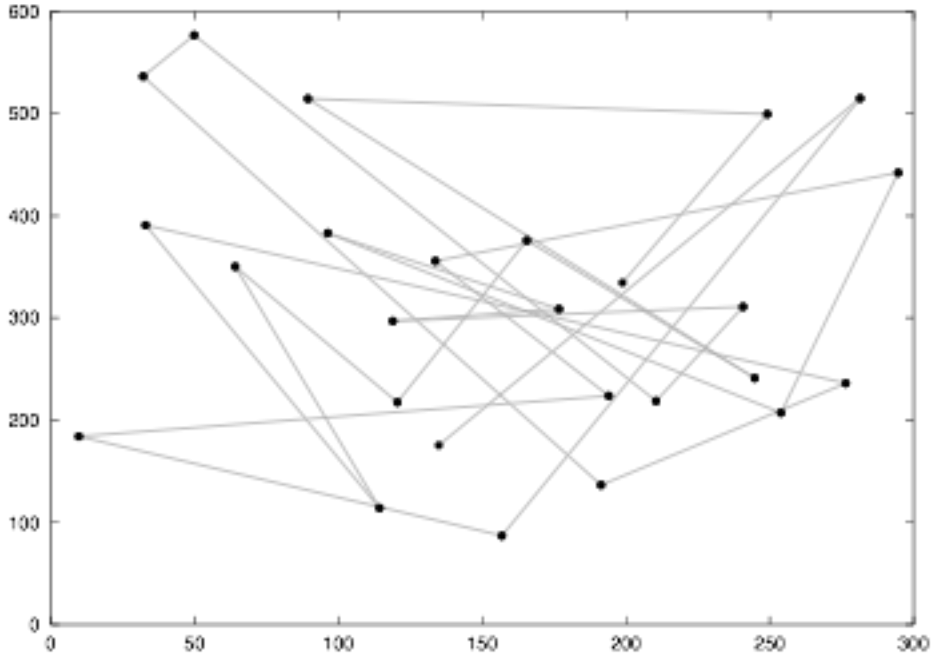
Models of Mobility Random Waypoint Mobility Model

[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

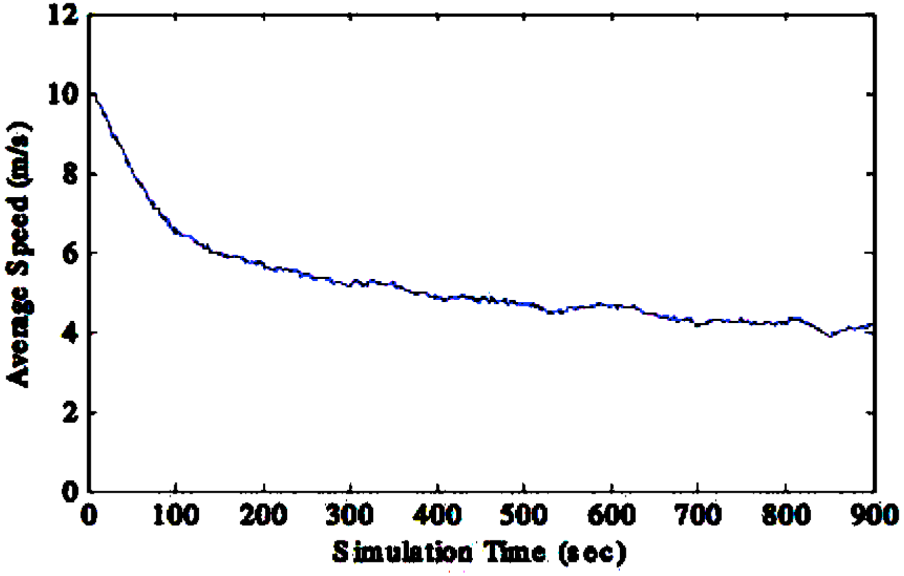


[Camp et al. 2002]

Random Waypoint Considered Harmful

[Yoon, Liu, Noble 2003]

- **move directly to a randomly chosen destination**
- **choose speed uniformly from** $[v_{\min}, v_{\max}]$
- **stay at the destination for a predefined pause time**
- **Problem:**
  - If v_{min}=0 then the average speed decays over the simulation time



Random Waypoint Considered Harmful

- **The Random Waypoint (V_{min},V_{max}, T_{wait})-Model**
  - All participants start with random position (x,y) in [0,1]x[0,1]
  - For all participants $i \in \{1,\ldots,n\}$ repeat forever:
    - Uniformly choose next position (x',y') in [0,1]x[0,1]
    - Uniformly choose speed v_i from (V_{min}, V_{max}]
    - Go from (x,y) to (x',y') with speed v_i
    - Wait at (x',y') for time T_{wait}.
    - $(x,y) \leftarrow (x',y')$
- **What one might expect**
  - The average speed is $(V_{min} + V_{max})/2$
  - Each point is visited with same probability
  - The system stabilizes very quickly
- **All these expectations are wrong!!!**

Random Waypoint Considered Harmful

- **What one might expect**
  - The average speed is $(V_{min} + V_{max})/2$
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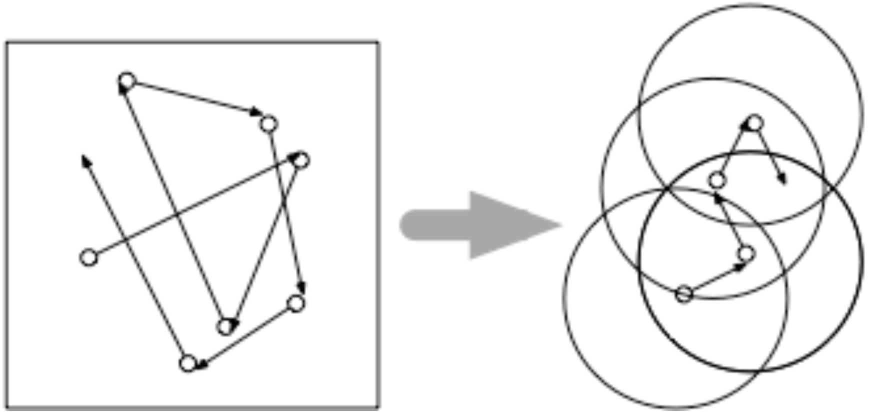
- **All these expectations are wrong!!!**

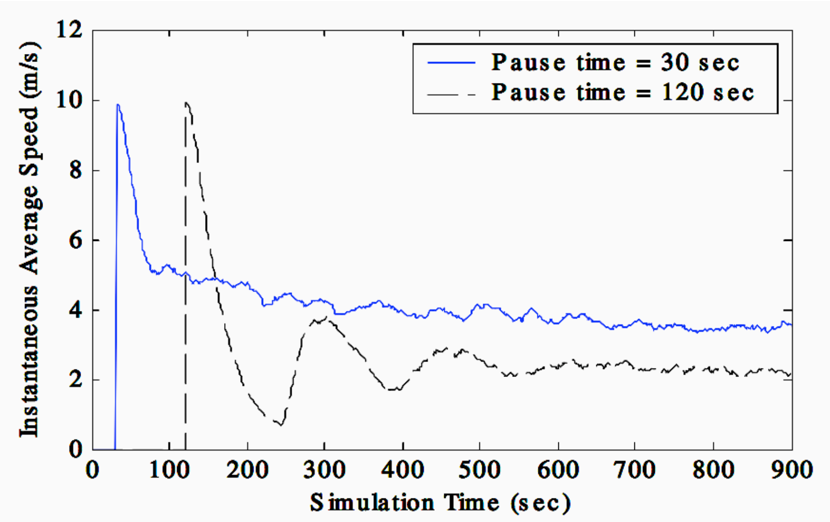
- **Reality**
  - The average speed is much smaller
    - Average speed tends to 0 for $V_{min} = 0$
  - The location probability distribution is highly skewed
  - The system stabilizes very slow
    - For $V_{min} = 0$ it never stabilizes
- **Why?**

Random Waypoint Considered Harmful
The average speed is much smaller

- **Assumption to simplify the analysis:**

1. **Assumption:**
    - Replace the rectangular area by an unbounded plane
    - Choose the next position uniformly within a disk of radius R_{max} with the current position as center
2. **Assumption:**
    - Set the pause time to 0: $T_{wait} = 0$
    - This increases the average speed
        - supports our argument





Random Waypoint Considered Harmful
The average speed is much smaller

- **The probability density function of speed of each node is then for**

$$V_{\min} \leq v \leq V_{\max}$$

- **given by**

$$f_V(v) = \frac{1}{V_{\max} - V_{\min}}$$

- **since $f_V(v)$ is constant and**

$$\int_{v=V_{\min}}^{V_{\max}} f_V(v)\ dv = 1$$

Random Waypoint Considered Harmful
The average speed is much smaller

- **The Probability Density Function (pdf) of travel distance R:**

$$f_R(r) = \frac{2r}{R_{\max}^2} \qquad \text{for } 0 \leq r \leq R_{\max}$$

- **The Probability Density Function (pdf) of travel time:**

$$f_S(s) = \begin{cases} \frac{2s}{3R_{\max}^2}(V_{\max}^2 + V_{\min}^2 + V_{\max}V_{\min}) \ , & 0 \leq s \leq \frac{R_{\max}}{V_{\max}} \\ \frac{2R_{\max}}{3(V_{\max} - V_{\min})}\frac{1}{s^2} - \frac{2V_{\min}^3}{3R_{\max}^2(V_{\max} - V_{\min})}s \ , & \frac{R_{\max}}{V_{\max}} \leq s \leq \frac{R_{\max}}{V_{\min}} \\ 0 & s \geq \frac{R_{\max}}{V_{\min}} \ . \end{cases}$$

Random Waypoint Considered Harmful
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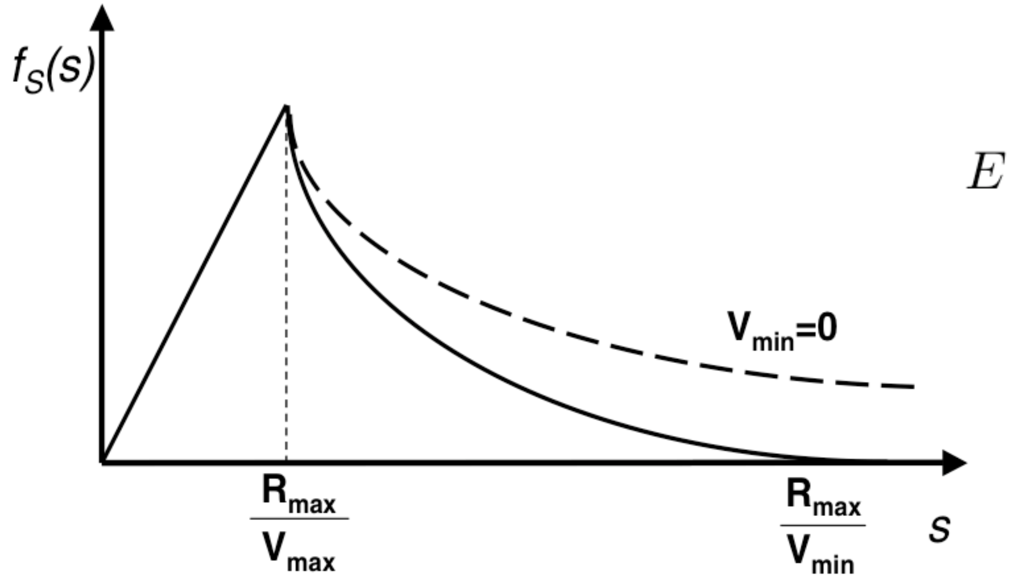


$$E[S] = \frac{2R_{\max}}{3(V_{\max}-V_{\min})}\ln\left(\frac{V_{\max}}{V_{\min}}\right)$$

Random Waypoint Considered Harmful
The average speed is much smaller

- **The average speed of a single node:**

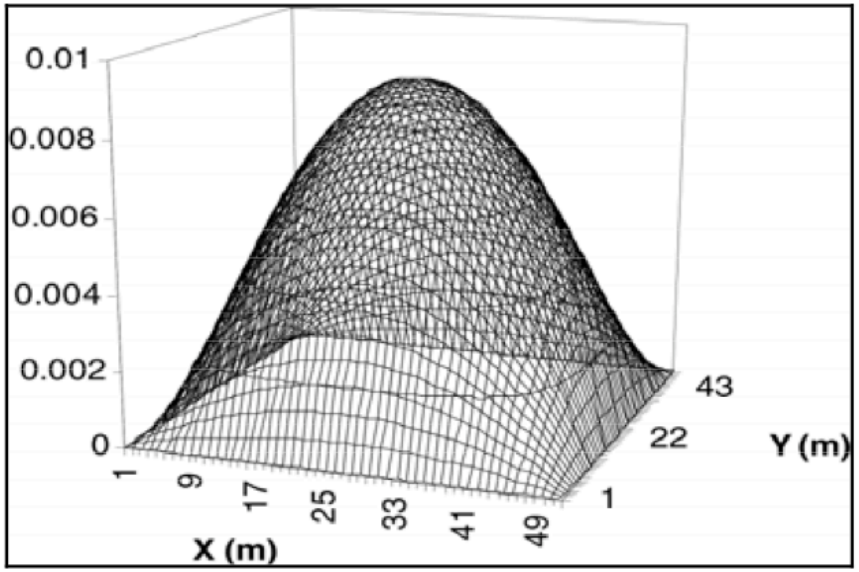
$$\begin{aligned}
\bar{V} &= \lim_{T \longrightarrow \infty} \frac{1}{T} \int_0^T v(t) dt \\
&= \lim_{T \longrightarrow \infty} \frac{\sum_{k=1}^{K(T)} r_k}{\sum_{k=1}^{K(T)} s_k} \\
&= \lim_{T \longrightarrow \infty} \frac{\frac{1}{K(T)} \sum_{k=1}^{K(T)} r_k}{\frac{1}{K(T)} \sum_{k=1}^{K(T)} s_k} \\
&= \frac{E[R]}{E[S]} = \frac{V_{max} - V_{min}}{\ln\left(\frac{V_{max}}{V_{min}}\right)}.
\end{aligned}$$

Models of Mobility
Problems of Random Waypoint

- **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



[Liang, Haas 1999]

Models of Mobility Gauss-Markov Mobility Model

- **adjustable degree of randomness**
- **velocity:**
- **direction:**

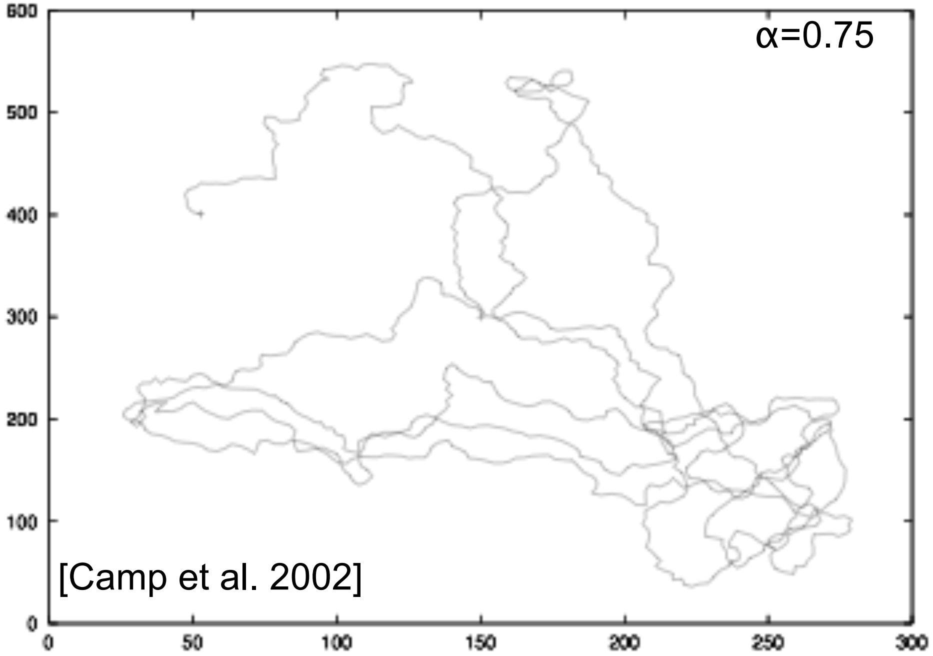
$$v_n = \alpha v_{n-1} + (1-\alpha)\bar{v} + \sqrt{1-\alpha^2}\, v_{x_{n-1}}$$

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

tuning factor

mean

random variable
gaussian distribution

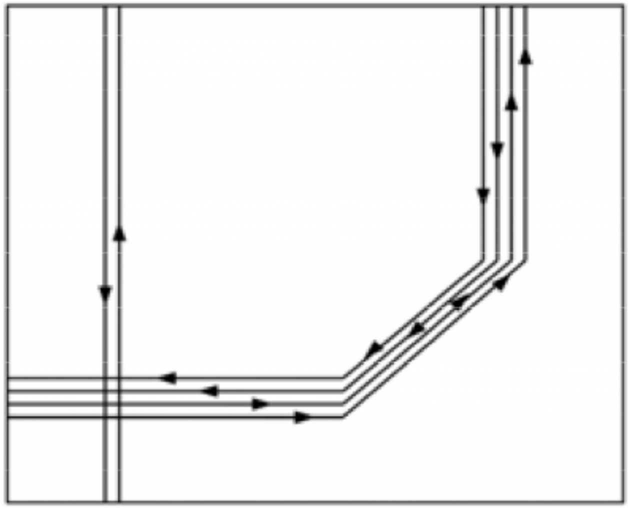


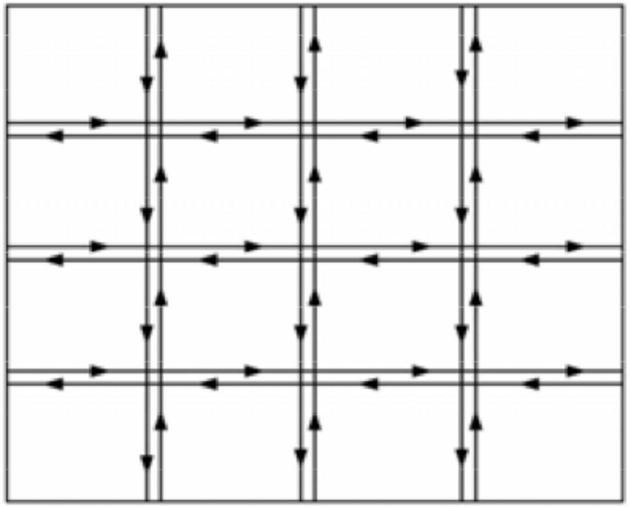
α=0.75

[Camp et al. 2002]

Models of Mobility
City Section and Pathway

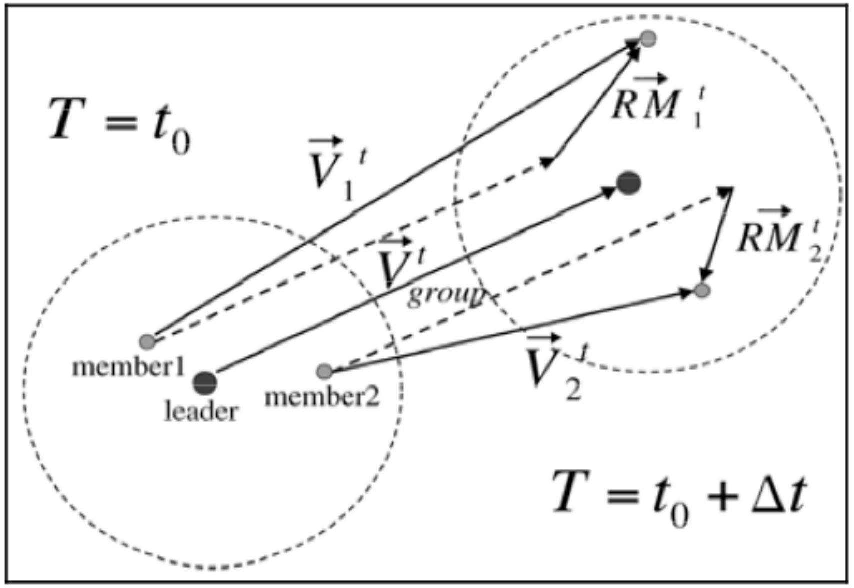
- **Mobility is restricted to pathways**
  - Highways
  - Streets
- **Combined with other mobility models like**
  - Random walk
  - Random waypoint
  - Trace based
- **The path is determined by the shortest path between the nearest source and target**

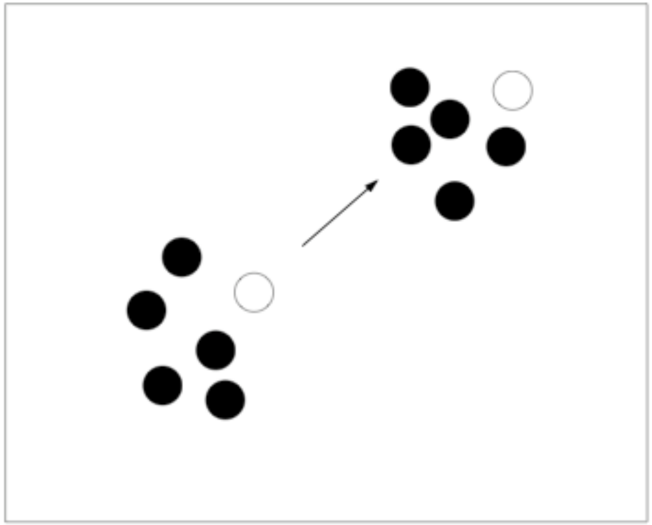




Models of Mobility: Group-Mobility Models

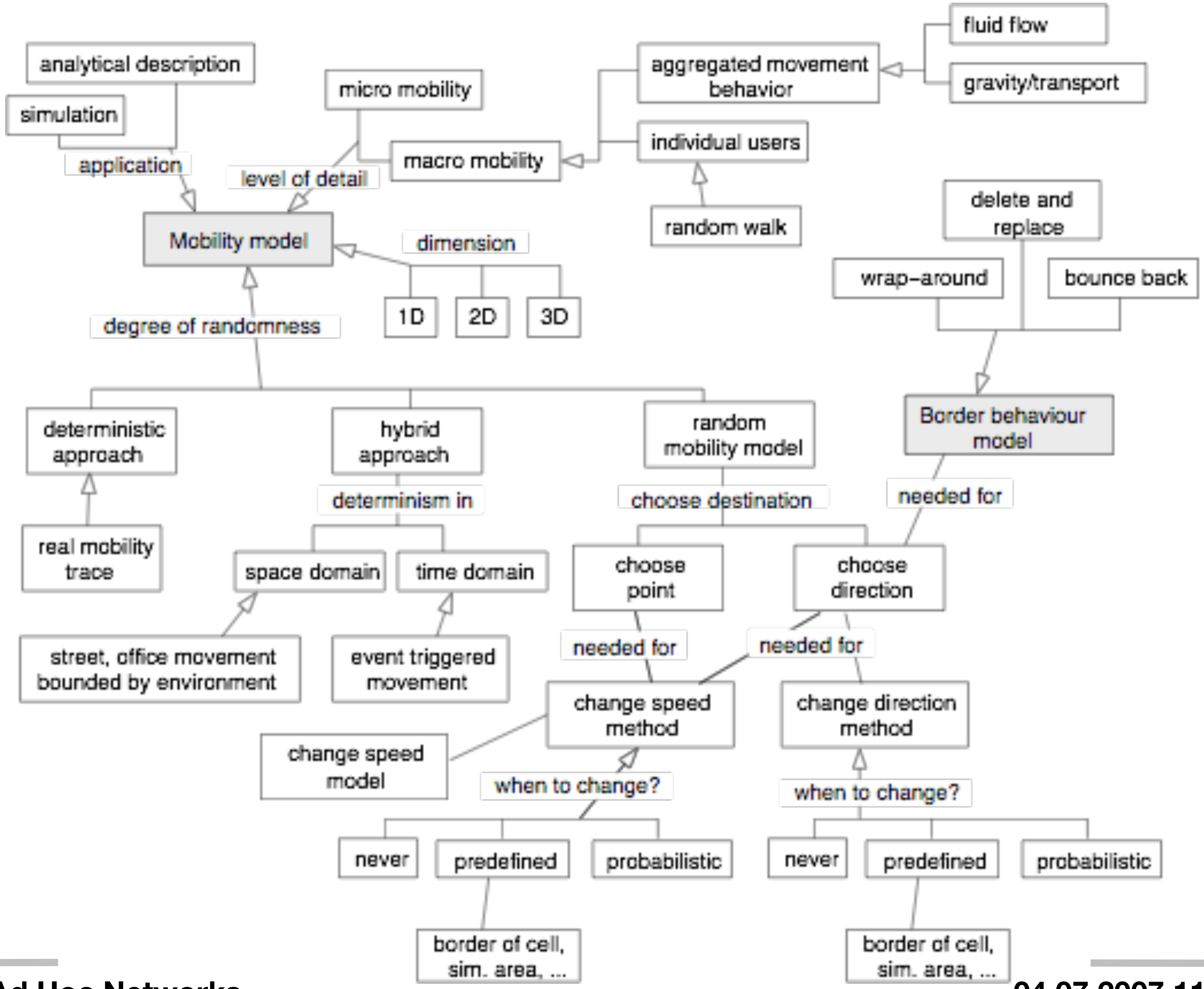
- **Exponential Correlated Random**
  - Motion function with random deviation creates group behavior
- **Column Mobility**
  - Group advances in a column
    - e.g. mine searching
- **Reference Point Group**
  - Nomadic Community Mobility
    - reference point of each node is determined based on the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





Models of Mobility
Combined Mobility Models

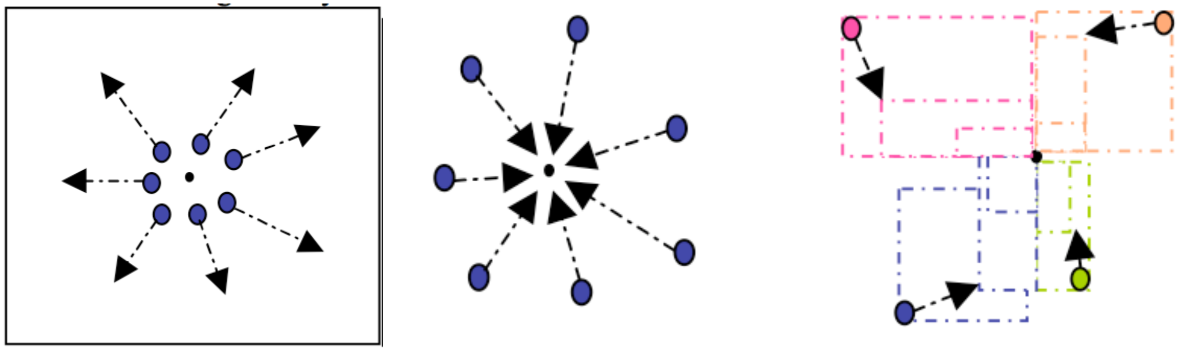
[Bettstetter 2001]



Models of Mobility: Non-Recurrent Models

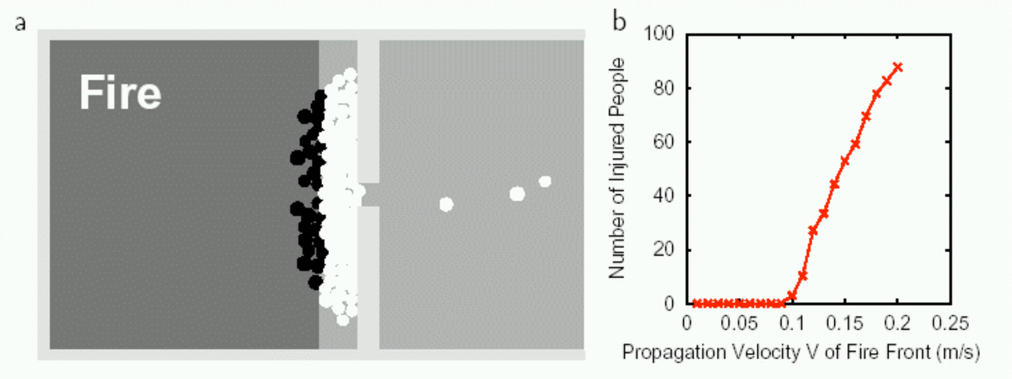
- **Kinetic data structures (KDS)**
  - framework for analyzing algorithms on mobile objects
  - mobility of objects is described by pseudo-algebraic functions of time.
  - analysis of a KDS is done by counting the combinatorial changes of the geometric structure
- **Usually the underlying trajectories of the points are described by polynomials**
  - In the limit points leave the scenario
- **Other models [Lu, Lin, Gu, Helmy 2004]**
  - Contraction models
  - Expansion models
  - Circling models

This room is for rent.



Models of Mobility: Particle Based Mobility

- **Motivated by research on mass behavior in emergency situations**
  - Why do people die in mass panics?
- **Approach of [Helbing et al. 2000]**
  - Persons are models as particles in a force model
  - Distinguishes different motivations and different behavior
    - Normal and panic



Models of Mobility: Particle Based Mobility: Pedestrians

- **Speed:**
  - f: sum of all forces
  - ξ: individual fluctuations

$$v_i(t) := \frac{dx_i(t)}{dt}$$

$$m_i \cdot \frac{dv_i(t)}{dt} = f_i(t) + \xi_i(t) \ ,$$

- **Target force:**
  - Wanted speed v⁰ and direction e⁰

$$\frac{v_i^0 e_i^0 - v_i(t)}{\tau_i}$$

- **Social territorial force**
- **Attraction force (shoe store)**

$$f_{ij}^{soc}(t) = A_i \quad e^{\frac{r_{ij}-d_{ij}}{B_i}} \quad n_{ij} \quad \left(\lambda_i + (1-\lambda_i)\frac{1+\cos(\phi_{ij})}{2}\right)$$

- **Pedestrian force (overall):**

$$f_{ij}^{att}(t) = -C_i \quad n_{ij}$$

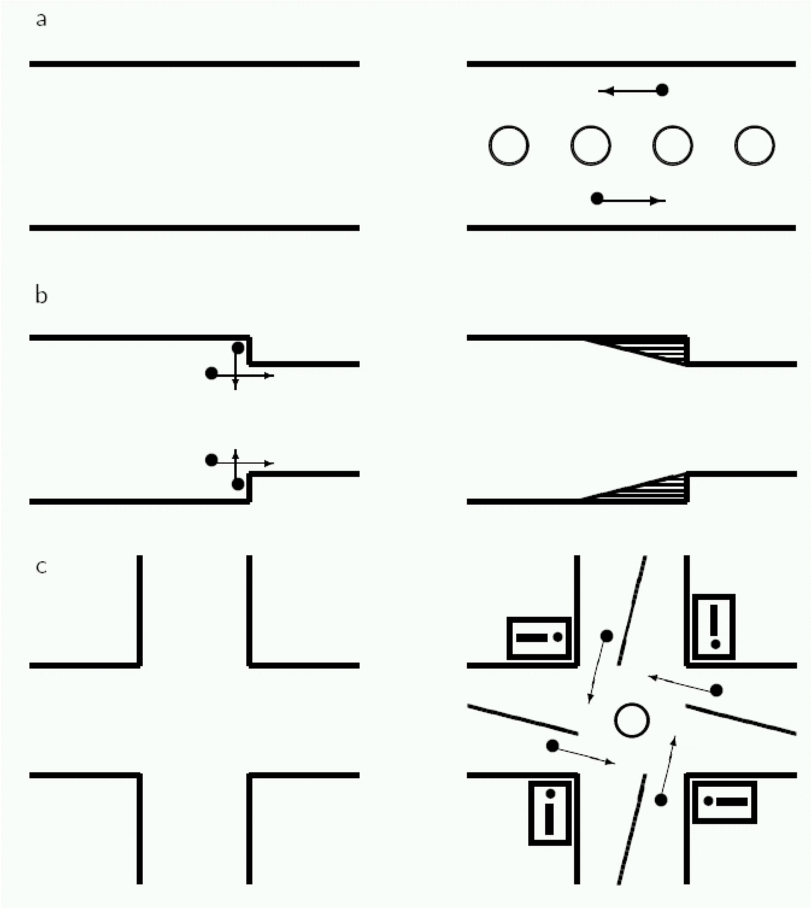
$$n_{ij}(t) = \frac{x_i(t) - x_j(t)}{d_{ij}(t)}$$

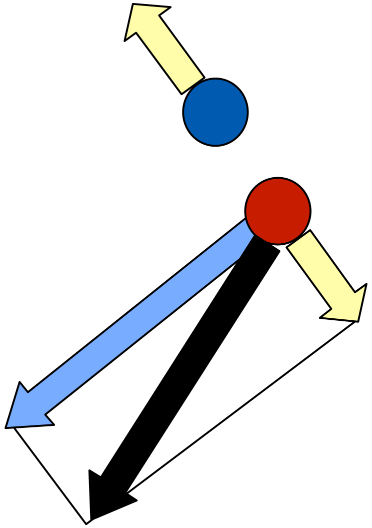
$$f_i(t) = \frac{v_i^0(t)e_i^0(t) - v_i(t)}{\tau_i} + \sum_{j \neq i} f_{ij}^{soc}(t) + \sum_{j \neq i} f_{ij}^{att}(t) + \sum_{k} f_{ij}^{att}(t) + \sum_{b} f_{ib}^{obst}(t)$$

Models of Mobility: Particle Based Mobility: Pedestrians

- **This particle based approach predicts the reality very well**
  - Can be used do design panic-safe areas

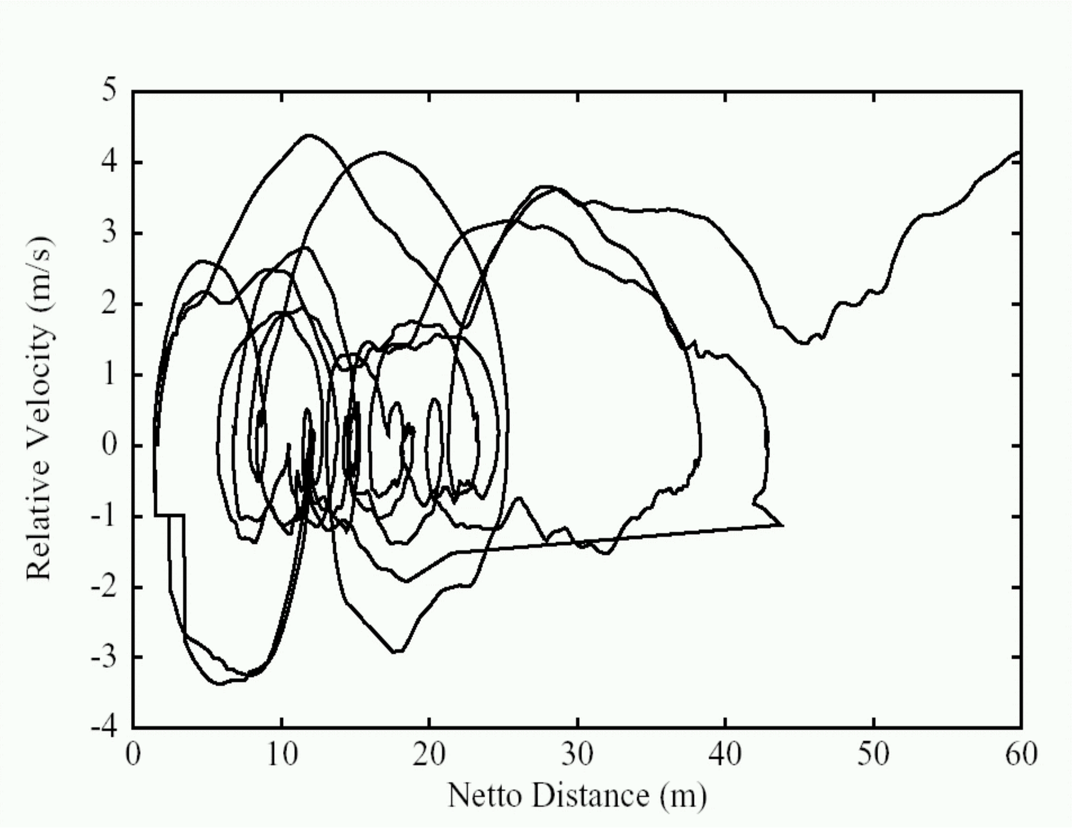
- **Bottom line:**
  - All persons behave like mindless particles





Models of Mobility Particle Based Mobility: Vehicles

- **Vehicles use 1-dimensional space**
- **Given**
  - relative distance to the predecessor
  - relative speed to the predecessor
- **Determine**
  - Change of speed



Models of Mobility: Particle Based Mobility: Pedestrians

- **Similar as in the pedestrian model**

$$\frac{dv_i(t)}{dt} = f_i^0(t) + \sum_{j \neq i} f_{ij}(x_i(t), v_i(t), x_j(t), v_j(t)) + \xi_i(t)$$

- **Each driver watches only the car in front of him**
- **No fluctuation**

$$\frac{dv_i(t)}{dt} = f_i^0(t) + f_{i,i-1}(x_i(t), v_i(t), x_{i-1}(t), v_{i-1}(t))$$

- **$s(v_i) = d_i + T_i v_i$, d_i is minimal car distance, T_i is security distance**
- **$h(x) = x$, if $x>0$ and 0 else, R_i is break factor**
- **$s_i(t) = (x_i(t)-x_{i-1}(t))$ - vehicle length**
- **$\Delta v_i = v_i - v_{i-1}$**

- **where**

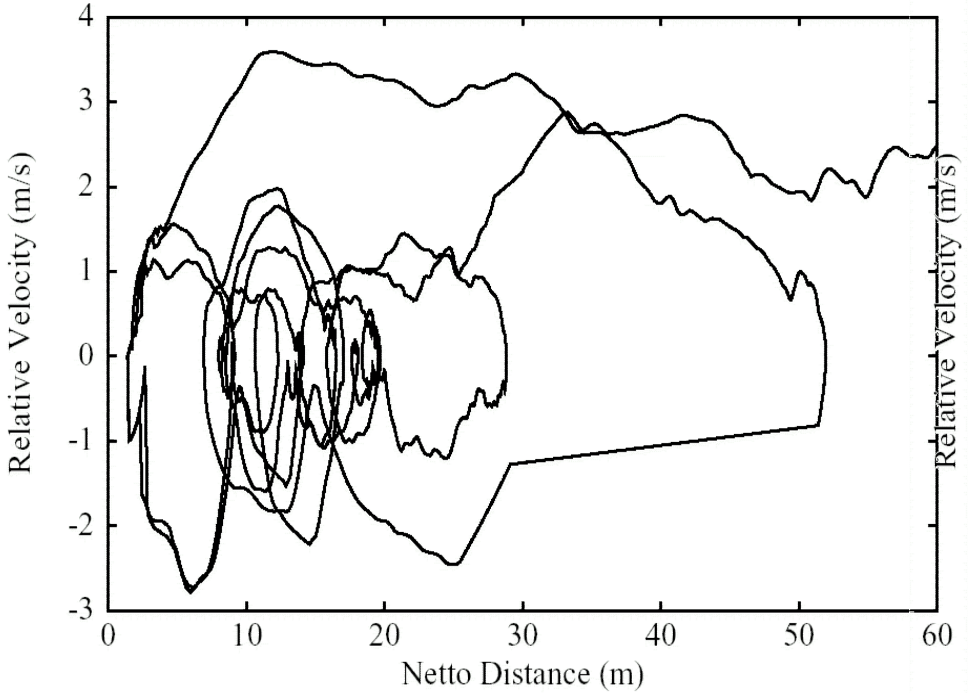
$$f_{i,i-1} = \frac{V_i(t) - v_i^0}{\tau_i} - \frac{\Delta v_i h(\Delta v_i)}{\tau_i'} e^{\frac{s_i(t)-s(v_i)}{R_i'}}$$

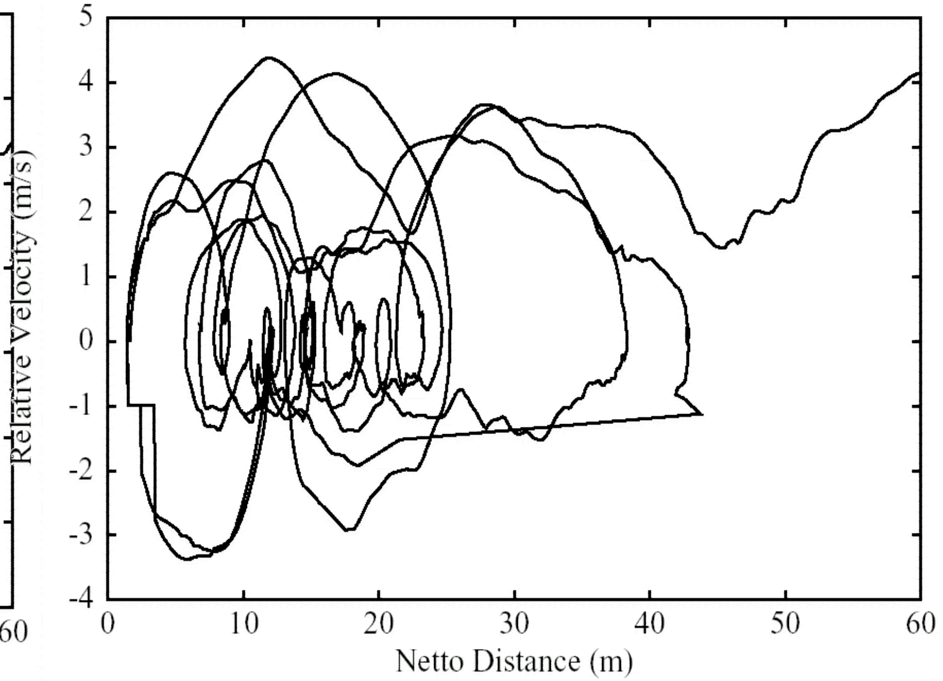
$$V_i(t) = v_i^0 \left((1 - e^{-\frac{s_i(t)-s(v_i(t))}{R_i}} \right)$$

Models of Mobility Particle Based Mobility: Vehicles

Reality

Simulation with GFM





Thank you!

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