Dynamic Graphs... when elements are moving

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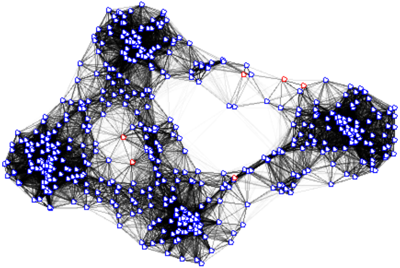
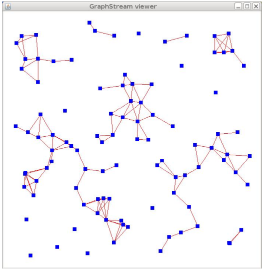
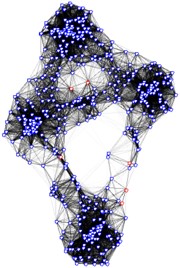
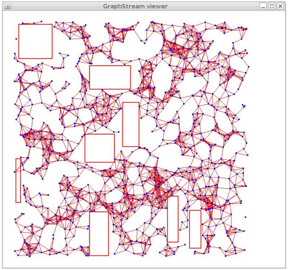


Mobile/Sensor Ad Hoc Networks



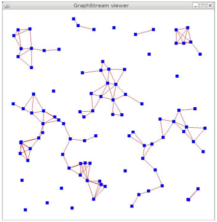




- An **ad hoc** network is a spontaneous network made or communicating devices.
- Such networks need neither infrastructure, nor control, nor supervision.
- If some elements are mobile they are called mobile ad hoc networks a.k.a. **MANETs**

- Within mobile/sensor ad hoc networks we can find: classical computers, smartphones, sensors.

Mobile/Sensor Ad Hoc Networks
From Real to Dynamic Graphs



- How can we simulate the movement? → **Mobility Model**

  this is of paramount importance since
  movement ⇒ topology
- Which kind of biais are produced by mobility models?
- How to broadcast efficiently the data? → the network might be never connected (∼ reachability of TN)

Human and Animal Societies

- Within human and/or animal societies we can find: living beings.

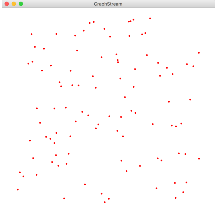
Human and Animal Societies
From Real to Dynamic Graphs

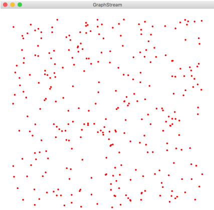
- What are the underlying mechanisms explaining the movements?
- Are the mechanisms identical for different species? (starlings, fishes, sheeps)
- Do there exist some communities?
- How to detect them?

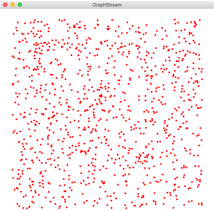
Mobile Ad Hoc Networks

Building a graph model

- initialy we may consider that stations are randomly distributed within the environment
- environment? A square ($L \times W$)
- density of stations?





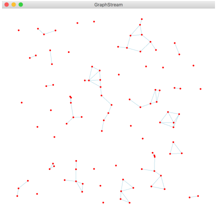


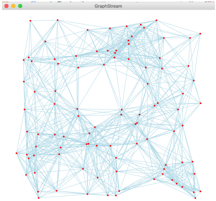
Mobile Ad Hoc Networks

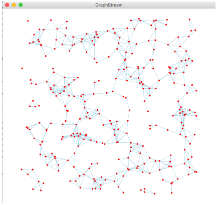
Building a graph model

- the nodes are connected to each other if their euclidean distance is lower than a chosen value

random euclidean graph







Algorithm

$L \leftarrow$ value
$W \leftarrow$ value
radius $\leftarrow$ proximity threshold
for $i \leftarrow 1$ to n **do**
    create the node
    randomly choose its position w.r.t. L and W
endFor
for each node v **do**
    for each node $u \neq v$ **do**
        if euclidean_distance(u, v) $\leq$ radius **then**
            if no edge between u and v **then** add the edge $\{u, v\}$
        endIf
    endFor
endFor

already done

Mobility Model

Choice

- non limited number of possibilities
- **brownian moves** (each node changes its position of a small value)
- **Random WayPoint** (RWP): widely studied mobility model
- **pattern** mobility: each station draws a pattern which parameters may vary (for instance moving along a circle, which radius may change from time to time)
- **Group** mobility: some groups of, usually, close stations are moving together
- **Constrained** mobility: in case we add obstacles in the environment
- ...

$\longrightarrow$ the choice mainly depend on the real network, some mobility might be more relevant than others

Mobility Model

Questions

- how should we consider the movement of the vertices?
- several strategies are possible, the two commons are:
- at random
  1. at each time step randomly choose a vertex,
  2. change its position
  3. update its neighborhood
  4. back to 1
- synchronously:
  1. at each time step choose a new position for all the vertices,
  2. change their position (simultaneously)
  3. update their neighborhood
  4. back to 1

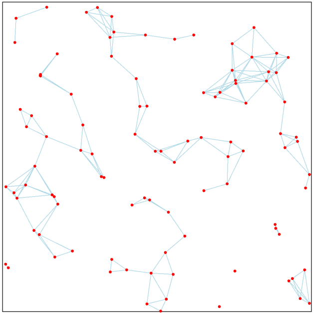
Mobility Model

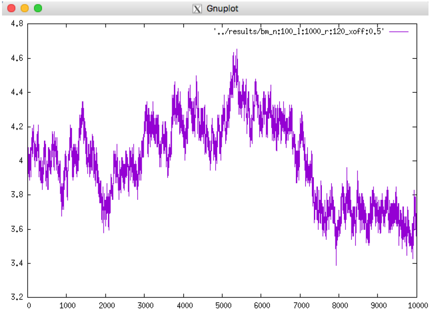
Analysis

- once the mobility model chosen, the dynamic graph can be produced and we can analyse it:
  - evolution of the average degree
  - evolution of other metrics
- analysis of dynamical processes operating on them: broadcast
- design and analysis of decentralized method for... building and maintaining a consensus, a spanning forest, another structure...

Brownian Motion

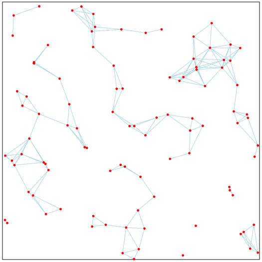
- each entity randomly changes its position and moves to a very close place
- we choose the synchronous approach for the movement (all together), that means that the neighborhood is updated only when each node has its new position

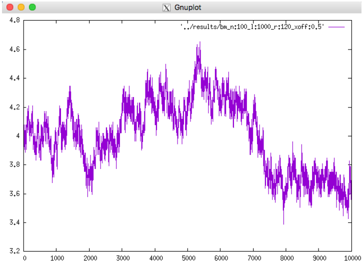




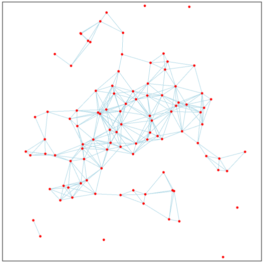
Random Waypoint Mobility Model

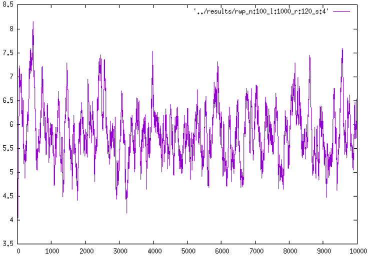
- known as **RWP**
- nodes are initially randomly distributed over the environment
- each node chooses a destination in the environment and moves to that direction following a straight line
- once arrived it can have a pause or choose another destination and goes toward it
- we choose the synchronous approach for the movement (all together), that means that the neighborhood is updated only when each node has its new position





brownian motion



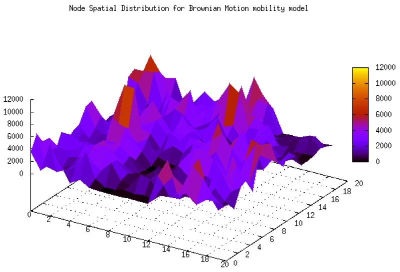


random waypoint mobility model

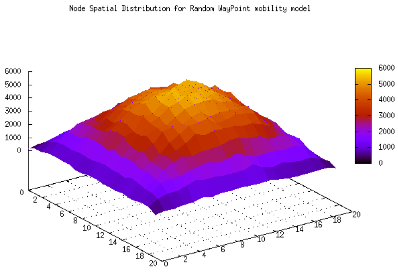
Why?

- it seems that station's **spatial distribution** is not uniform
- let us test, by meshing the environment and recording the number of stations in each cell along the lifetime of the network
- choose the size of the mesh, typical paramters set:

  mesh cell size 50, environment dimensions $L = W = 1000$, number of vertices $n = 100$ and distance threshold $r = 120$.



brownian motion



random waypoint mobility

Analytical Results (2002)

The Spatial Node Distribution of the Random Waypoint Mobility Model

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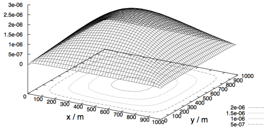
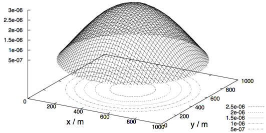
Abstract: The random waypoint model is a frequently used mobility model for simulation–based studies of wireless ad hoc networks. This paper investigates the spatial node distribution that results from using this model. We show and interpret simulation results on a square and circular system area, derive an analytical expression of the expected node distribution in one dimension, and give an approximation for the two–dimensional case. Finally, the concept of attraction areas and a modified random waypoint model, the random borderpoint model, is analyzed by simulation.



a. Square simulation area



b. Circular simulation area (disc)

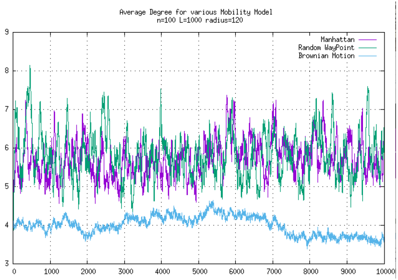
Figure 1: Spatial node distribution resulting from the random waypoint mobility model: Simulation results

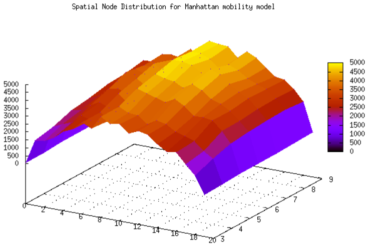
Patterns Mobility Models

Manhattan

- the **Manhattan Mobility Model** constrains the nodes to move according to the x axis or to the y axis.
- the vertex chooses a target, located either on its x axis or on its y axis
- we may consider two versions of this mobility model:
  - the set of ”streets” is restricted and nodes can only use these streets (thus the number of possible x and y is limited
  - there is no such limitation (version implemented as for now)

Manhattan Mobility Models





Patterns Mobility Models

Circular

- the **Circular Mobility Model** constrains the nodes to move according to a circle
- the vertex chooses a center, and then turns around it (the radius is implicitely given by the choice of the center), at any moment or when the vertex hits a border, a new center is chosen and the vertex moves again

Daily Tour

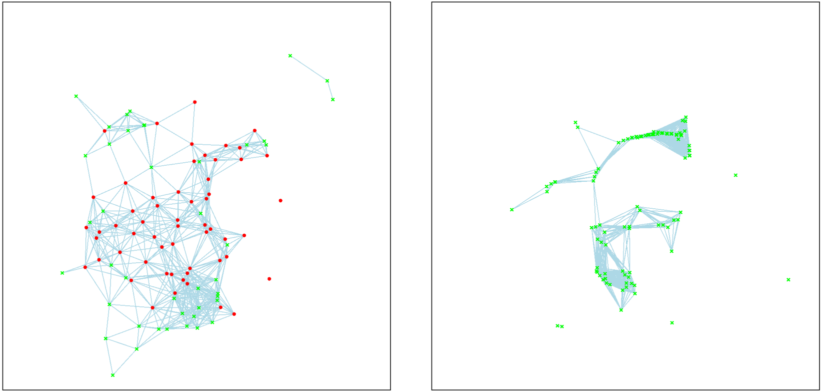
- the **Daily Tour Mobility Model** constrains the nodes to move according to a set of initially randomly chosen destinations
- the movement is thus periodical
- this mobility is closely related to what most of people are doing everyday, visiting a limited number of places
- this mobility model can be improved by imposing that the set of destinations all belong to a restricted region of the environment (→ region-based mobility model)

Group-based Mobility Models

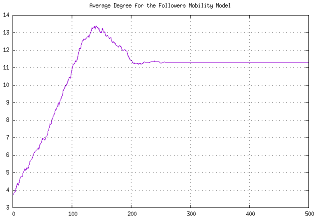
1. follower mobility
2. leaders-followers mobility
3. region-based mobility
4. swarm mobility

Followers Mobility Models

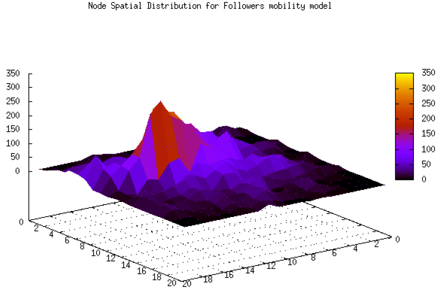
follower mobility: each node chooses a target among the set of nodes, when the target is reached (proximity less than a given threshold, it stops)



Followers Mobility Models



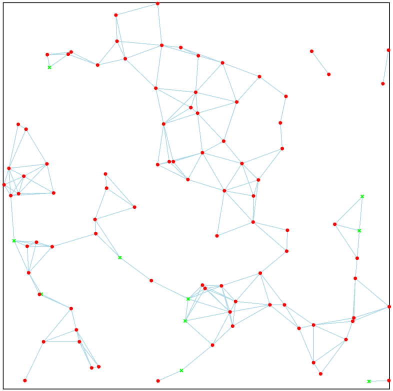
follower mobility model (end)

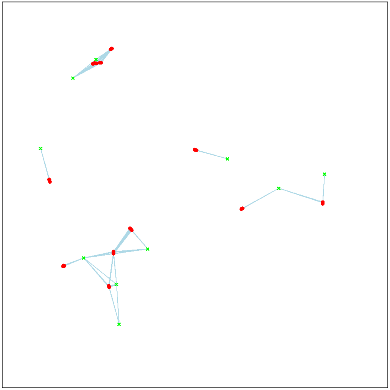


spatial distribution

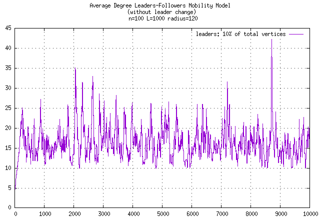
Leaders-Followers Mobility Models

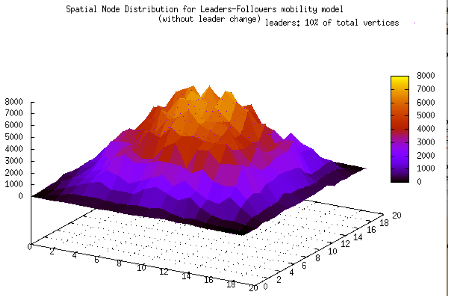
leaders-followers mobility: some nodes are chosen as leaders, they move according to the RWP mobility model. Each other node chooses one leader as a target and moves towards its direction. When the distance between the follower and the leader is lower than a given threshold, the follower may choose another leader as target,



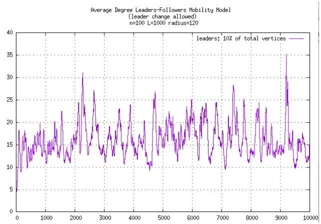


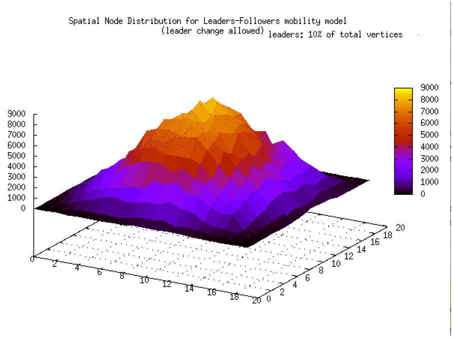
Leaders-Followers Mobility Models (without leader change)





Leaders-Followers Mobility Models (with leader change)





Other Group-based Mobility Models

Region-Base Mobility Models

region-based mobility: some regions are defined as regions of interest, and nodes move towards these regions. When a node reaches one position located in the target region, it stops for a while and then choose another region

Swarm Mobility Models

swarm mobility: each node tries to move at a position close to similar nodes, not too close and not too far away, it align its movement on the one of its nearest neighbors, this corresponds to a boids-like mobility model

Constrained Mobility Model

1. What can we say in presence of obstacles?

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Mean Degree of Ad Hoc networks in Environments with Obstacles

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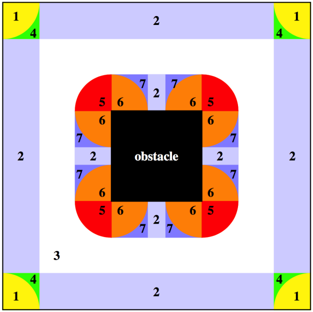
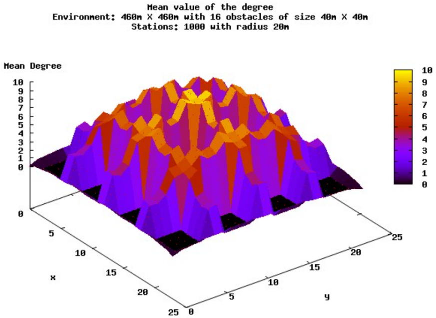
Constrained Mobility Model





Specific Metrics for Dynamic Graphs

1. time-series of classical metrics: order, density, average degree, centralities, clustering coefficient, etc.
2. **DynamicScore** (https://arxiv.org/abs/2309.05320) for vertices and/or edges

DynamicScore

Definition

V-DynamicScore:

Given a dynamic graph G, such that at time t $G_t = (V_t, E_t)$. We call **V-DynamicScore** at time t and denoted by $\mathcal{D}_t^v$, the ratio:

$$\mathcal{D}_t^v = \frac{|V_{t+1} \triangle V_t|}{|V_{t+1} \cup V_t|}$$

where $|A|$ denotes the number of elements present in set A. The $\triangle$ operator for all set A and B, referred to as $A \triangle B$, is defined as $A \cup B - A \cap B$.

DynamicScore

Similarly, for a given dynamic graph the definition of its edges DynamicScore is defined as follow:

Definition

E-DynamicScore:

Given a dynamic graph G, such that at time t $G_t = (V_t, E_t)$. We call **E-DynamicScore** at time t and denoted by $\mathcal{D}_t^e$, the ratio:

$$\mathcal{D}_t^e = \frac{|E_{t+1} \triangle E_t|}{|E_{t+1} \cup E_t|}$$