CNCL: Contents

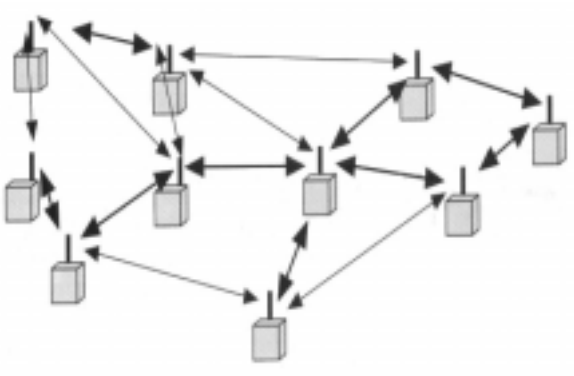
- CNCL – C++ library for supporting event driven simulations
- Learning CNCL by examples
- CNCL project work instructions

Setting the context…

- Context:
  - Ad hoc network with mobile nodes using a simple mobility model known as Random Waypoint
  - We are interested in connectivity properties of such a network assuming a simple node connectivity model (Boolean model)
    - Connectivity is related to network reliability (not to traffic performance)
- The assignment is about …
  - Creating a discrete event simulator for the above network
    - Requires handling of mobile movement but …
    - NO traffic needs to be simulated
  - Measuring connectivity requires sampling of the system state at fixed intervals

Ad hoc networks

- IETF working group: MANET (Mobile Ad Hoc Networks)
- Characteristics
  - Wireless meshed network where communication occurs over multihop paths
  - No centralized control (no base station)
  - Nodes communicate directly with other nodes that are within radio coverage
  - Nodes act as relays for the traffic from other nodes
  - Nodes can join and leave the network



- Applications
  - Conferences and meetings
  - Emergencies, disasters
  - Tactical military

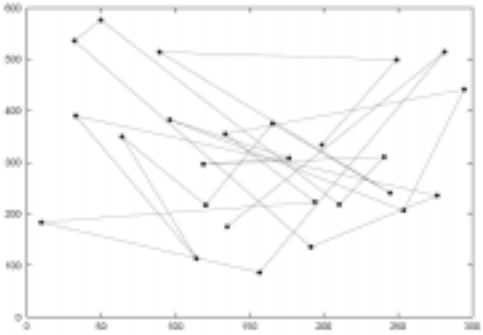
Mobility modeling (1)

- Much of ad hoc networking research based on simulations
- Mobility model is an important component in the simulations
- Two broad classes of mobility models
  - Simple, so called synthetic models
  - Realistic models
- Mobility affects many aspects in performance of networking mechanisms
  - Traffic load, routing, reliability…

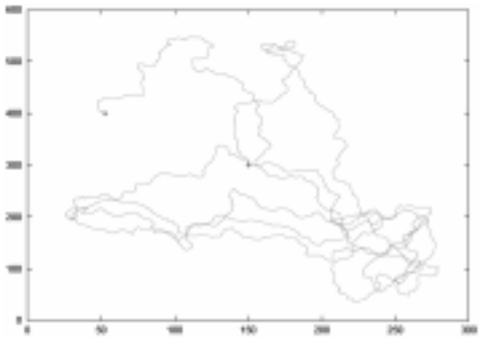
Mobility modeling (2)

- Realistic models
  - Often utilizes measurement based information
  - More complex to utilize
- Synthetic models
  - Do not aim at imitating human movement
  - Mobility is random and the movement rules are as simple as possible
  - Facilitates implementation but movement is still sufficient for evaluating the performance of a given protocol
  - Also, models that include topography info, group mobility…
- Properties of simple models can be analyzed analytically
  - Impact of mobility on performance may also be analyzed

RWP

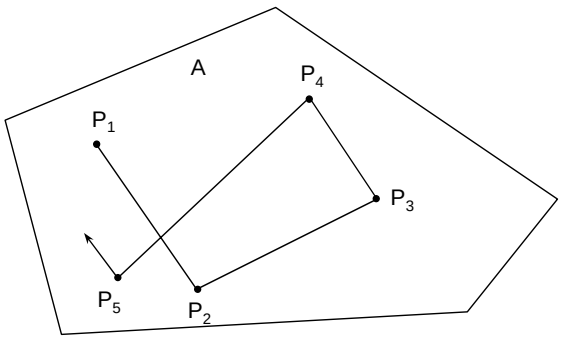


Gauss-Markov model



Random waypoint mobility model

- Node moves within an area A along a zig-zag path
- Each turning point called way point
- Path from waypoint to another called a leg
- At each way point node selects a new destination way point from a uniform distribution over A
- Node moves to the new location at constant speed
- Speed can also be chosen from a given distribution independently of everything else ($v_{min} > 0$)
- In case of a network of nodes, each node moves independently
- In this exercise we consider
  - n nodes
  - movement area is the unit disk



Analysis of RWP

- General results: node location distribution, *f*(*r*), and mean length of a leg, $\bar{\ell}$
- Example: unit disk
  - pdf of node location distribution

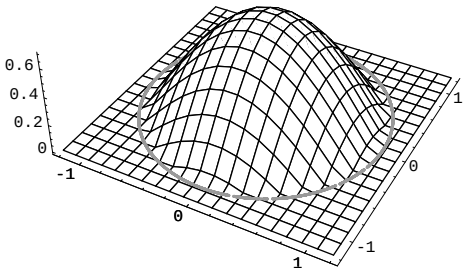
$$f(r) = \frac{2\left(1-r^2\right)}{\bar{\ell}\,\pi^2} \int_0^{\pi} \sqrt{1-r^2\,\mathrm{Cos}^2\,\phi}\; d\phi$$

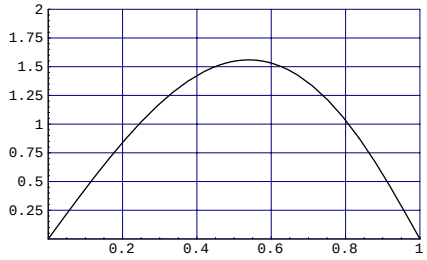
  - mean length of a leg

$$\int_{r=0}^{1} 2\pi r\; f(r) = 1 \quad \Rightarrow \quad \bar{\ell} = \frac{128}{45\pi} = 0.905$$

  - pdf for distance from center, *R*

$$g(r) = 2\pi r\; f(r) \quad \Rightarrow \quad \mathrm{E}[R] \approx 0.516$$





Connectivity (1)

- We consider a network of n nodes moving according to RWP
- Boolean network model
  - Two nodes are connected if distance between them is greater than the transmission range of a node
  - Additionally we assume that all nodes have the same transmission range
  - Only takes into account signal attenuation as a function of distance (ignores interference effects)
- Definition: For a given graph,
  - 1-connectivity: there exists a path from all nodes to all other nodes
    - sufficient to check if from one node all other nodes can be reached
  - k-connectivity: there exists k node disjoint paths from all nodes to all other nodes
    - implies that any k-1 nodes can fail and the network is still connected
- Here we are only interested in properties related to 1-connectivity, and we use just the word connectivity to refer to 1-connectivity

Connectivity (2)

- We are interested in
  - probability of connectivity, and
  - mean length of the connectivity periods
- Probability of connectivity:
  - Probability that the network is connected at an arbitrary point of time
  - By definition, it gives also the fraction of time the network is connected
- Mean length of 1-connectivity periods
  - observing the system state over time, the network is connected (and disconnected) for random periods of time
  - In this exercise, we are only interested in the **mean** length of the connectivity periods

CNCL assignment

- You are given an example skeleton code for a simulation model of RWP
  - Makefile, cncl_sim.c
- Your task is to
  - Part 1: implement the RWP mobility model and verify it works (by Thu, 15.11.)
  - Part 2: study the connectivity properties and write report (by Mon, 26.11.)