CNCL: Contents

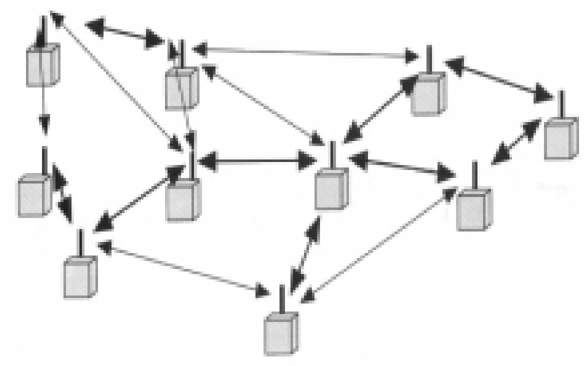
- CNCL – C++ library for supporting event driven simulations
- Learning CNCL by examples
- CNCL project work instructions

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 (Booloean 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 immediately 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

Connectivity (1)

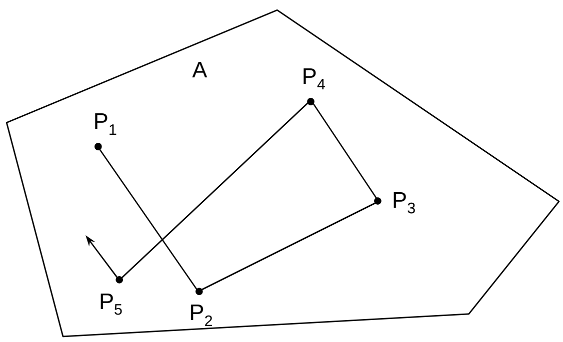
- Boolean network model
  - Two nodes are connected if distance between them is greater than the transmission range of a node
  - Additionally we assume that all nodes have the same transmission range
  - Only takes into account signal attenuation as a function of distance (ignores interference effects)
- 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 disconected) for random periods of time
  - In this exercise, we are only interested in the **mean** length of the connectivity periods

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 square



Analysis of RWP (1)

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

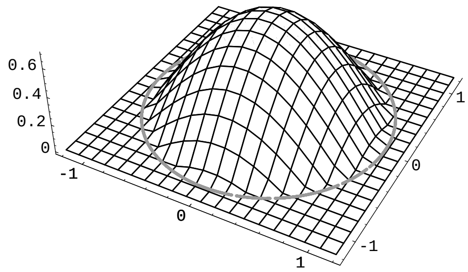
$$f(r) = \frac{2\left(1-r^2\right)}{\bar{\ell}\,\pi^2}\int_0^{\pi}\sqrt{1-r^2\,\mathrm{Cos}^2\,\phi}\;d\phi$$

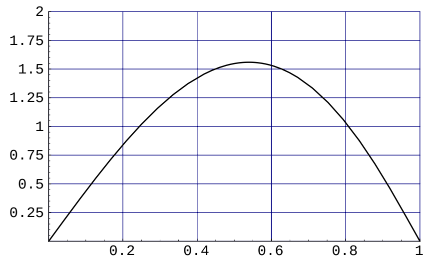
  - mean length of a leg

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

  - pdf for distance from center, *R*

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





S-38.148 Simulation of data networks / CNCL

Analysis of RWP (2)

- In this exercise the movement area is a unit square
  - drawing waypoints is very easy: X ~ U(0,1) and Y~U(0,1)
- Pdf of node location can be numerically computed from the general form

$$f(\mathbf{r}) = \frac{1}{\bar{\ell}}\int_0^{\pi} a_1 a_2\left(a_1 + a_2\right) d\varphi$$

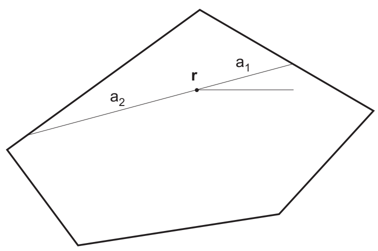
  - a_1 is the distance to border in direction ϕ and a_2 the same in direction $\phi+\pi$
- By normalization we get

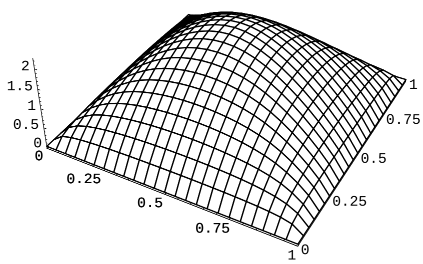
$$\int_{\mathbf{r}\in A} f(\mathbf{r}) = 1 \quad\Rightarrow\quad \bar{\ell} \approx 0.521$$

- Mean distance from origin

$$\mathrm{E}[R] = \int_{\mathbf{r}\in A} |\mathbf{r}|\; f(\mathbf{r}) \approx 0.745$$

- Tip: use knowledge of $\bar{\ell}$ and E[*R*] to verify that your RWP implementation works!





CNCL assignment

- You are given an example skeleton code for a simulation model of RWP
  - Makefile, cncl_sim.c
- Your task is to
  - implement the RWP mobility model
  - implement the statistics collection
  - implement the main method