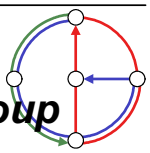
ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Distributed Computing Group



HS 2009 Prof. Dr. Roger Wattenhofer, Philipp Sommer, Johannes Schneider

Ad Hoc And Sensor Networks
Exercise 10

Assigned: November 23, 2009
Due: November 30, 2009

1 Accoustic Positioning

A single-hop sensor network is deployed in a natural park to monitor the location of marmots (= "Murmeltier"). Each sensor node is equipped with a highly sensitive microphone to detect the whistle noises when a marmot warns its fellows of potential natural enemies or humans. If a sensor node detects a whistle noise, it reads the current timestamp and forwards it to the base station. The base station employs the time of arrival information at the different sensor nodes to estimate the position of the marmot. The TPSN clock synchronization protocol is used to synchronize the clocks of the sensor nodes with the base station every 30 seconds. The clocks used on the sensor nodes are running at a nominal rate of 32 kHz and exhibit drift of up to 50 ppm.

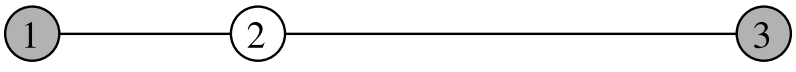
a) How accurate can the position of a whistling marmot be estimated if you assume that all clocks run at their nominal rate and are perfectly synchronized?

b) Frequent re-synchronization is necessary since the clocks are drifting apart due to clock drift. Give a bound for the worst-case localization error when synchronizing the clocks using the TPSN protocol every 30 seconds. You can assume that the protocol implementation uses MAC layer timestamping to eliminate variances in the message transmission delay.

c) You are asked to improve the localization accuracy of the existing system. In order to keep the energy consumption low you are not allowed to send synchronization messages more frequently. What possible solutions (hardware/software) can be employed to achieve better localization accuracy?

2 Spring Embedding

Let's assume a simple network topology consisting of three nodes as depicted below. Communication links exist between nodes 1 and 2 and nodes 2 and 3, respectively. The exact positions of nodes 1 and 3 are assumed to be known. Their coordinates are (0,0) and (0,2), respectively. Furthermore, the measured distances $d(1,2)$ and $d(2,3)$ are both 1. We want to embed this graph with a simple spring embedder. Nodes 1 and 3 are thereby anchor points and the initial placement of node 2 is set according to the figure below at (0,0.6).



a) As seen in the lecture, the force at node i is given by $F_i = \sum_{\forall j} F_{ij}$. The spring embedder moves node i in the direction of the superposition of all forces by $\rho * F_i$, where ρ is the attenuation factor. What happens if ρ is set equals to 1?

b) How many iterations does it take node 2 to move to its actual position—which is obviously (0,1)—if ρ is set to 0.9? What is the ideal attenuation factor for this example?