Eidgenössische Technische Hochschule Zürich
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Distributed Computing Group

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Ad Hoc And Sensor Networks
Exercise 8

Assigned: November 17, 2008
Due: November 24, 2008

1 Localization using Sensor Nodes

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 32kHz and exhibit drift of up to 50ppm.

a) How accurate can the position of a whistling marmot be estimated if you assume all clocks to run at their nominal rate and to be 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 Tree-based Clock Synchronization

Common clock synchronization algorithms (e.g. TPSN, FTSP) rely on a spanning tree to perform clock synchronization. In the TPSN protocol sender-receiver synchronization is performed along the edges of the tree while FTSP is flooding synchronization messages along a tree rooted at the reference node. Finding a good spanning tree for clock synchronization is not trivial. Nodes which are neighbors in the network graph should also be close-by in the resulting tree. Show that in a grid of $n = m \times m$ nodes the stretch of the spanning tree is at least m. The stretch is defined as the hop distance in the tree divided by the distance in the grid.

3 Gradient Clock Synchronization

The A^{max} clock synchronization algorithm was introduced in the lecture. In this exercise, we use a slightly modified version of this algorithm. Instead of adjusting only the clock value of a node, we also set the rate of the logical clock to the maximum clock rate of any neighbor (if faster than the local clock rate). Can you see a problem that arises when this algorithm is used in a real-world sensor node deployment? (Hint: What happens to the logical clock rate when the environmental temperature is varying?)