Using Multi-hop Sensor Networks on the Surface of Solar System Bodies

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There are several solutions to discover and continuously investigate a selected area on a surface of a Solar System body, which are based on expensive devices and sometimes on human monitoring. Instead of complex and expensive robots, we propose to deploy high number of cheap mobile sensor devices on the orbital planet surface to make the exploration more effective. These sensors form a multi-hop network and communicate with each other offering many challenges from communications point of view. The sensor network can be used on surface of distant planet for different measurement and exploration. In this work, we examined a possible sensor network in area of Mars, including some surface factors (sandstorm, craters, dunes), which have influencing effect on positioning and energy management of network elements. Sensors are able to perform different measurements (e.g., radiation detection, atmospheric measurement, magnetic field measurement), visual recording. In addition, there are some higher power sensor, which can communicate with control center on the Earth and forward the common data.

Sensor devices were already used to explore and analyze the bottom of oceans or even active volcanos [1], but utilizing mass of sensor devices for distant planet exploration can be also very promising. In most of the cases the accurate position of the sensors is also needed. Several localization scheme exist based on triangulation (AOA) or trilateration (TOA, TDOA, RSS) [2], however, all the positioning systems assume that reference points exist is the network with precisely known coordinates. Recursive positioning [3], [4] is an alternative solution that can increase system coverage iteratively, as nodes with newly estimated positions join the reference set.

In most space missions, the localization of each node is essential in order to know where each measurement has been made. But without energy, no communications nor positioning is possible. In case of recursive positioning the number stalled sensors reduces the overall positioning accuracy. In this work, our goal was to show how an energy efficient analyses of a sensor network can be performed in a space-based environment and what types of key questions should be identified and answered. We developed a C++ program for simulation, which models the behavior of a sensor network, its recursive positioning method on the area of Mars and energy consumption efficiency. For this reason, the state diagram of the energy consumption of sensors was defined. The movement, communication, measurements and measurement processing entail energy loss, however these activities will be performed only if the energy level of given sensor is high enough. In order to ensure that the sensors are useable in a long term interval, external resources are needed, which are able to reload the accumulators. In case of sensors with solar cell, this external resource is the Sun.

In the simulated environment every sensor starts its movement from a common start point and they have to reach a predefined endpoint or target point. These analyses were made in the function of accumulator capacity. We examined how much time is necessary to reach the target point of the

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simulation, if lower capacity accumulators are used. As a result, we got an upper estimate for accumulator capacity, but we were interested in the minimal value as well. Thus, the change of positioning error value in function of accumulator capacity was also analyzed.

We utilized the concept of a sensor network which consists of large number of simple sensors moving on the surface of a distant solar system body. A complex framework was developed to analyze the movement, positioning and communication in such a network.

Keywords: sensor networks, space communications, energy efficiency

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