Sustainable Communication Networks
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Smart Communication Environment for Extraterrestrial Habitats

Prerequisites:	- Basic knowledge of networking protocols and technologies
Reccomended background:	- LoRa
Level:	This topic is appropriate for Master Students
Language:	German or English

Introduction

When planning long-term, sustainable extraterrestrial activities of humans, e.g. on Mars, several hard problems need to be solved: how to transport people to/from Mars; how to build a self-sustainable habitat for their living; how to communicate between Earth and the habitat; and last but not least, how to ensure the safety of the astronauts outside of the habitat, for example during exploration missions. This project targets the last of these challenges.
When executing activities outside of the habitat, astronauts face a harsh, unnatural for them environment. Health monitoring and continuous communication to their colleagues in the habitat become critical. Additionally, the habitat needs to know in real-time where the astronauts are exactly in case of an emergency. Before an exploration mission, astronauts also need precise environmental data to judge he risk of the mission.
This project aims to implement a localised communication infrastructure around the main habitat, which implements the following functionalities: continuous localisation of the astronauts, health monitoring and short voice messaging. The project consists of three sub-projects, described in further details below. It is also organised in two phases, which can be for example addressed in mini projects and master thesis assignments.

1 Communication infrastructure

The communication infrastructure should cover at least an area of 10x10 km with the habitat in the center. It should consist of LoRa-enabled base stations (BS), which relay packets from the astronauts to the habitat. On Earth, LoRa base stations are connected to the Internet via 4G/5G or WiFi, which is obviously not an alternative for Mars. Thus, the base stations need to form a multi-hop self-organised network, which autonomously and energy-efficiently relay data traffic to/from the habitat.
In the first phase of the sub-project, the following tasks need to be executed:

- Requirements analysis of data traffic, in cooperation with sub-projects 2 and 3.
- Requirements analysis in terms of expected signal propagation and possible interference and disturbance sources (atmospheric composition, expected weather conditions like dust storms, etc.). Calculation of best case and worst case transmission radius for BS-to-BS and BS-to-astronaut communication.
- Overall system design architecture, with number of needed base stations and their positions. The astronaut needs to be always connected to at least 3 base stations. You can assume power is continuously provided to all BS, e.g. by solar panels.

- Theoretical design of the astronaut-to-habitat-and-back communication protocol with pseudo code for the astronaut, BS and habitat. The number of base stations and their positions must be flexible and easily to be changed in run-time of the system.

In the second phase of this project, the implementation of the above described protocol must be conducted on real devices (to be discussed with the supervisors). A small testbed with at least 2 hops must be deployed to test the protocol together with the applications from sub-projects 2 and 3. For the purpose of the testbed, minimum transmission power can be used for the devices to scale down the size of the testbed.

2 Astronaut localisation service

The goal of this sub-project is to enable continuous and autonomous location tracking of the astronauts outside the habitat. The assumption is that each astronaut carries a dedicated device for localisation and communicates to the above described infrastructure. Localisation is typically performed with triangulation or trilateration algorithms, based on the received signal strength from several base stations.
In the first phase of the sub-project, the following tasks need to be executed:

- Study and comparison of trilateration and triangulation algorithms based on RSS (received signal strength) from the domain of wireless sensor networks. Special attention needs to be put on algorithms based on LoRa. The best suited algorithm must be identified.
- The expected effect of Mars atmosphere and weather conditions on the precision of the algorithm must be evaluated in best case and worst case theoretical scenarios.
- Training database with RSSI measurements and location information from a small testbed on Earth must be gathered, unless a similar database can be found readily available.
- A first offline implementation of the algorithm must be conducted and evaluated with the above described training database.

In the second phase of this project, the implementation of the algorithm must be transferred to the real-world. However, first the question must be answered: Can we efficiently implement the targeted algorithm locally on the astronauts' devices? If not, a distributed processing of the information must be designed, where processing is divided between the astronauts' devices, the BS and the habitat itself. The implemented algorithm must be implemented and tested in the communication infrastructure prototype of sub-project 1.

3 Health monitoring and short voice messaging services

This sub-project targets the design and implementation of two astronaut services: health monitoring and short voice messaging. The first one assumes that health monitoring is implemented as an event-based application on an astronaut-carried device (separate from his/her localisation device), which evaluates locally the health status and alarms the habitat only in case of a dangerous situation. For the purposes of this project, no real health data will be used, but "simulated" offline recorded ones. The short voice messaging service can be activated any time by an astronaut and is sent to all astronauts outdoors and to the habitat (sort of a multiple walkie-talkie). The habitat can also initiate a message.
In the first phase of the sub-project, the following tasks need to be executed:

- Design a health monitoring system with sensors, sensor data analysis and event reporting (in theory), tailored for astronauts.
- Create or find online health data to be used to test the above design. In case no real data is available, create realistic synthetic data, including critical events. In any case it is important that the created or generated data includes critical events to be reported.

- Implement the health monitoring application real devices and test the event reporting independently from the future communication infrastructure (e.g. forward to a local TTN base station or similar).

In the second phase of this project, the following tasks need to be executed:

- Test the above health monitoring system together with the communication infrastructure from sub-project 1.
- Design a networking protocol for the communication infrastructure from sub-project 1 for the walkie-talkie application.
- Implement and test the walkie-talkie application in the communication infrastructure of sub-project 1.

Contact

If you are interested in this work, please contact us via mail: projects@comnets.uni-bremen.de