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Communication Device for Team Members Working in Extreme Environments

Master's thesis

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Ph. D

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Ekstreemsetes keskkondades tegutseva meeskonna liikmete sisekommunikatsiooni seade

Magistritöö

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Summary

Members of teams working in extreme environments (firefighters, rescuers, etc.) need reliable hands-free radio communication devices allowing them to be in contact with each other. The design of such a device sets requirements for both hardware and software to withstand the harsh environment and operation stability during mission critical tasks.

The main goal of the current thesis is to design and implement a radio communication protocol needed to maintain a connection between the members of teams working in extreme environments (firefighters, rescuers, etc.).

The work is based on a client project and uses an existing hardware device developed by the client. The main features of the device are the purpose-built casing for the use as a communication device in extreme environments and user interface components such as the OLED screen, notification LEDs, several buttons, two speakers and a microphone.

The initial phase of development involves defining the requirements for the communication protocol. Analysis of existing TETRA (Terrestrial Trunked Radio) and DMR (Digital Mobile Radio) protocols is also carried out and a general overview is provided. The results of the analysis led to a conclusion that under the current circumstances the development of a new dedicated protocol is more suitable.

The new protocol is developed in collaboration with the client and the result is a new set of requirements and general operation plan. The new protocol uses FDMA (frequency division multiple access) to allocate up to 16 different channels which can be used by team members in the same area to form a group and start communicating. Each channel is also further divided into frames and slots using TDMA (time division multiple access). Single frame contains two sync slots to synchronize the devices and transmit control data needed for group retention. Additionally, four data slots are used to transmit data or encoded voice packets.

The new protocol includes three device roles (master, repeater and slave) which are assigned automatically and define the tasks each device needs to carry out in the group. Protocol supports automatic connection establishment when two or more devices are in range of each other and up to four simultaneous speakers per group with automatic data slot allocation.

The current thesis gives an overview of the used tools and thorough description of the implemented components. It explains how radio states and events are handled, how the TDMA frame is synchronized, how timing is implemented and how radio transceiver control is realized. Additionally, overview of the different packet types and their contents is provided. The thesis also gives a detailed explanation of the connection process, role assignment and slot allocation as well as encountered problems along with their solutions. All of this is also depicted on state diagrams and flow charts to better explain the operation process.

The thesis also covers the preliminary testing methods and results obtained during the development process to confirm the functionality of the implemented components. These include range tests, connection establishment tests, handling of unknown or broken radio packets and audio transmission tests.

The result of this work is a working implementation of the radio communication protocol on the hardware platform provided by the client. After boot-up, the device configures its radio transceiver and starts searching for other devices on the same channel. When it detects a second device or an active group of other devices, the device is able to establish a connection with them. Devices perform a procedure to synchronize the TDMA frames and obtain the master, repeater or slave role before starting communication over the air. The devices can send voice or data packets during the data frames which are assigned to devices using the slot allocation. When any device is turned off or moves out of range, others are able to reassign the roles and keep the group active.