The Usage of the Mobile Ad-Hoc Networks in the Construction Industry

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***Abstract*— This article defines the terms "remote under-construction facility" and "hazardous under-construction facility". The up-to-date sci-tech problem of provision for efficient communication at remote and hazardous construction facilities is stated. The suitability of usage of mobile ad hoc networks is proved in this article as well.**

Index Terms*— *remote and hazardous construction facilities, communication provision, mobile ad hoc networks, construction activity, emergency.

I. Introduction

The information exchange at the construction facilities is an issue of a great significance, especially from a perspective of the quality and safety management. The communication process at the construction facilities is based on the completion of the following tasks:

- operational cooperation assurance in the process of construction activity;
- monitoring and well-timed detecting of destructive factors of natural and anthropogenic origin leading to fire and explosion emergencies, destruction, flooding, impact of poisonous substances and radioactive radiation;
- efficient management and coordination of the personnel and resources in the process of emergency response and recovery at the construction facilities in order to minimize human losses and material damage [1].

All these tasks are complicated with a number of issues, which perplex the construction process especially when constructing the remote and hazardous facilities.

II. The Specific Nature of Remote and Hazardous Construction Facilities

A remote construction facility is a building constructed in the distant areas with poorly developed telecommunication infrastructure. Such geographically dispersed objects are being constructed, as a rule, at poorly acquired land areas such as mountains, industrial extracting companies, workers camps, research stations and camps, landing fields, spaceports.

A hazardous construction facility is a building constructed in conditions of destructive and adverse factors of both natural and anthropogenic origin such as fire and explosion emergencies, destruction, flooding, impact of poisonous substances and radioactive radiation. The following geographically dispersed objects could be aggregated to the class of hazardous construction facilities:

- buildings, constructed in the areas with a high level of probability of having an extreme impact of wind, earthquakes, flooding, landsliding and other natural extreme factors;
- tunnels, subway lines and other underground facilities being in the construction process;
- buildings and facilities constructed in the dangerous vicinity of industrial objects, where chemical, radioactive, flammable, toxic substances are produced, extracted, storage, transported and exterminated;
- objects being constructed in the vicinity of mining activity sites or mining excavations.

III. Benefits of the Mobile Ad Hoc Networks

In conditions of threats carried by destructive external impact and lack of the traditional telecommunication infrastructure the data transfer networks are of high demand. The system requirements of such networks are fast deployment, autonomous electricity supply for every component, high durability, capacity to transfer and receive messages in conditions of dynamically and rapidly changing topology (occasional processes of transferring, destruction, adding, turning-on and turning-off of the subassemblies). The characteristics mentioned above are incidental to the mobile ad hoc networks (MANET) [2–4]. The main benchmark feature of such networks is a randomly changing structure. The main peculiarities of MANET design are as follows:

- realization of decentralized network components control;
- lack of base stations (fixed subassemblies);
- every subassembly is designed to take on the router functional.

The MANET technology possesses great perspectives to be applied for communication provision at remote and hazardous construction facilities because of the benefits listed above. The usage of a self-organizing network is quite often a single opportunity to organize a decent informational exchange at construction facilities, as the deployment of the traditional cellular, wired or radio communication is estimated to be laborious and expensive process. More than that, fixed receive/transmit subassemblies being set up make the network insufficiently mobile and durable or, in other words, incapable of effectively functioning in conditions of occasional displacements and extreme external impacts.

IV. The Specifics of the Mobile Ad Hoc Networks Usage at the Remote and Hazardous Under-Construction Objects

The personnel at the remote and hazardous under-construction objects should use compact personal ad-hoc devices which must be provided with autonomous electricity supply elements (rechargeable batteries). The following elements might also be included into the set:

- wireless headset – for communication sessions being held without operator's hands involved;
- surveillance cameras – for video information of the construction process transmitting to the operation-dispatching posts;
- equipment for monitoring of the external conditions at the under-construction facilities: sensors of water, potentially explosive gases, radioactive radiation, poisonous substances, crevices and fractures, ditches and falling objects detecting; sensors for the human body functionality analyzing (pulse, temperature and breathing measuring);
- equipment for network nodes positioning – required in order to get the coordinates of the construction workers in need of help and rescue.

Informational cooperation during the construction of the remote and hazardous objects based on the technology of the self-organizing network allows to conduct the following functions:

- monitoring the process of the construction works;
- remote management of the construction works;
- messages exchange for purposes of technical tasks solving;
- external conditions surveillance at the construction facilities in order to detect destructive factors in time and ensure the safety;
- distant control and coordination of the rescue and response process during the emergencies;
- informing the personnel and men in charge about the spots or coordinates of construction workers and their functional state;
- monitoring and control of the under-construction facilities and of their specific sections during the emergencies liquidation.

V. The Mobile Ad Hoc Networks Usage Issues

Despite the number of significant benefits, MANET has not gain widespread yet. The slowed down implementation tempo could be explained by the impact of the following factors which complicate the information delivery:

- shirt duration of connections as a result of a rapid network topology change and regrouping;
- high level of probability to distort the information due to radio noises waves;
- substantial packet transfer delays determined by the low radio channels' bandwidth;
- significant packets losses as a result of frequent network overloads, which occur due to the nonpermanent traffic [5].

The impact of the factors mentioned above turns up in decrease of the quantity of information and the increase of the information delivery time, which is unacceptable when constructing the remote and hazardous facilities. Plentiful and well-timed information is the basis of the constructors' life and health preserving, as well as the factor of construction damage reduction.

A simulation model was designed in MatLab + Simulink software environment to examine how the dynamic of ad hoc network topology affects information delivery characteristics. Its diagram is shown in the Fig. 1.

The model simulates controlled flow (CF) through ad hoc network channels. CF-packets are transmitted through the channels 1, 2, 3 and 4 which connect sending and receiving

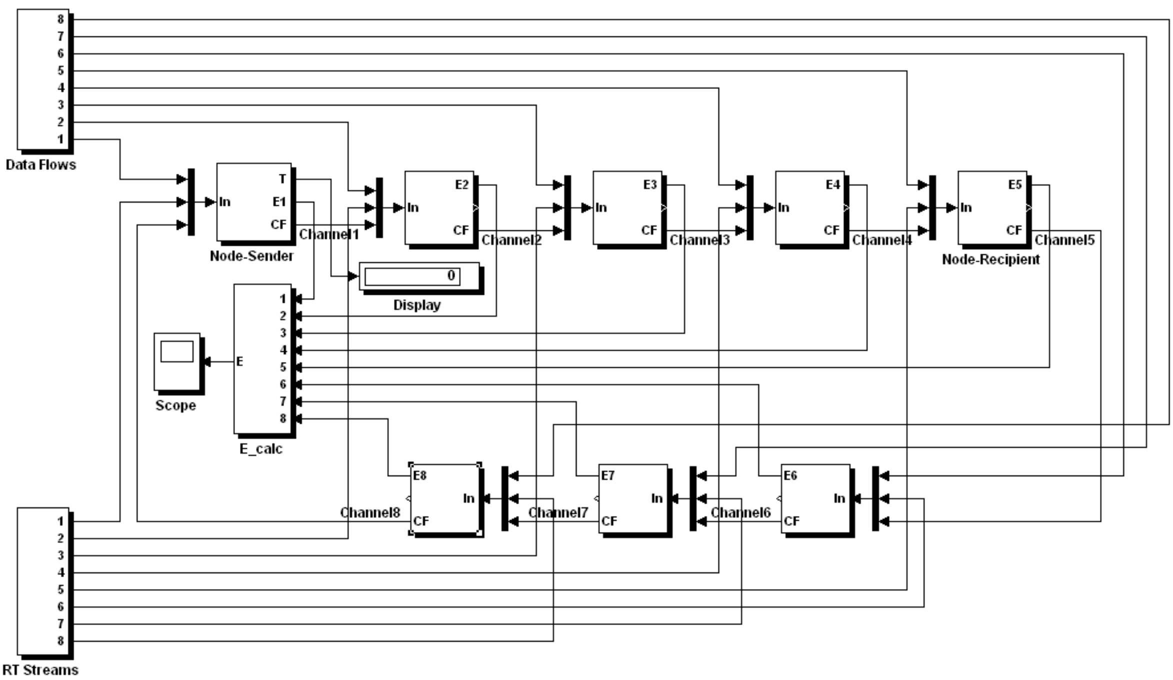

Fig. 1. Block diagram of a simulation model.

node. In the opposite direction, CF-confirmations are transmitted through the channels 5, 6, 7 and 8. The set of channels through which CF-packets and CF-confirmations are transmitted forms a closed cycle of CF-circuit flow.

Besides CF-packets and CF-confirmations, packets of other basic data and real time streams are transmitted. Due to the ad hoc network dynamic topology besides main streams, additional data and real-time streams are transmitted through CF-circuit channels. The presence of additional streams reduces channels bandwidth available for the transmission of CF.

The elements represented in the figure simulate the following processes. "Data Flows" – generating packets of basic and additional data flows; "RT Streams" – generating packets of main and additional real-time streams; "Node-Sender" – CF-Packets formation in the sending node, CF-packets arrival for transmission through the channel 1, arrival of main and additional data and real-time streams for transmission through the channel 1, CF-confirmations reception by sending node, buffering and discarding in the sending node; "Channel 1" – "Channel 4" – CF-packets transmission through CF-circuit channels; "Node-Recipient" is reception of CF-packets by receiving node, CF-confirmation formation in the receiving node, CF-confirmations arrival for transmissions through the channel 5, arrival of main and additional data and real-time packets for transmissions through the channel 5, buffering and discarding in the receiving node; "Channel 5" – "Channel 8" – CF-confirmations transmission through CF-circuit channels; "E_calc" is calculation of the current CF-circuit bandwidth available for the controlled flow transmission.

The element "Display" is used to display CF transmission time. Virtual receptionist "Scope" is designed to display the current values of the CF-circuit bandwidth available for transmission of the controlled flow.

On the basis of the represented model a series of simulation experiments was made in which various scenarios of applying ad hoc network for communication on dangerous construction sites were simulated. The original data contained in the TABLE I was used.

The simulation result revealed that due to the influence of nodes mobility and the destructive factors, time of the controlled flow transmission in an ad hoc network is 25.8% higher than the values of this magnitude in a fixed network topology. This is connected to a decrease of 19.2 % of the available network bandwidth channels with dynamic topology. Represented studies show that the application of ad hoc network messaging significantly reduces the efficiency of messaging in the process of information exchange on remote and dangerous construction sites.

TABLE I. INITIAL DATA FOR SIMULATION EXPERIMENTS

Parameter	Value
Channel bandwidth	1 Mbit/s
Probability of a bit error in a channel	0.00005
Bandwidth required to transmit video	256 Kbit/s
Bandwidth required to transmit voice	128 Kbit/s
Volume of messages transmitted by data flow	1 MB
Number of packets in the data flow	800
Packet sending duration	10 ms
Packet bit length	10 Kbit
Capacity of the channel queue buffer memory	80 KB

Having regard to the above, it can be affirmed, that the efficient communication at the remote and hazardous construction facilities is an up-dated task. Theoretical apparatus must be researched and developed, as well as perfection of the packet information transfer technology used in the conditions of the dynamically changing network topology.

VI. CONCLUSIONS

Currently the problem of establishing an efficient communication network at remote and hazardous construction facilities is of pressing need. The authors' point of view is that the solution to this issue is the usage of wireless self-organizing networks. Further researches must have the main aim to develop and perfect the packet transfer methods and algorithms, which allow to advance the operativity of the information delivery in the random topology network.

The research has been carried out with the financial support of the Ministry of Education and Science of the Russian Federation (the unique identifier of the project is RFMEFI57815X0138).

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