Simulation Model of Mobile Ad-hoc Network with UV-channel

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Abstract:
Analysis of mobile ad hoc networks as complex systems should be carried out using the simulation modelling method. Using the NS-3 discrete simulation modelling package, a simulation model of a mobile ad hoc network consisting of local groups of nodes interconnected by optical communication channels is developed. To study the characteristics of the mobile ad hoc network model, command shell scripts are proposed with the aim of its specialising in the model settings, and organizing the collection of statistical data. An example of using the developed model to assess the possibility of transmitting voice traffic between nodes of a mobile ad hoc network consisting of two local groups of nodes connected by an optical communication channel is given. It is shown that with certain settings of the model it is possible to obtain acceptable characteristics of voice traffic transmission.

Key words:
Ad hoc network, MANET, NS-3, shell scripts, simulation model, UV-channel.

1. INTRODUCTION

The successful development of methods and techniques for wireless information exchange provides broad opportunities for developers of mobile ad hoc networks (MANET) to choose technical means, protocols for medium access, routing and data delivery, and to use not only radio but also optical communication channels to organize exchanges between nodes (CC) within the range from infrared to ultraviolet wavelengths [1 - 4]. One of the important tasks in the MANET designing is to comply with consistent and sufficient requirements. An analysis of the technical requirements for the MANET shows that many requirements are incomplete and / or inconsistent at the stage of developing the technical specifications, in the absence of experience in the development and operation of such networks in the considered applications. The identification of such shortcomings usually occurs at the stage of integration and testing of the MANET components, i.e. at the end of the development work. In order to reduce the cost of developing the complex technical systems, nowadays they actively use various approaches: a model-based design [5], digital twins, mathematical simulation models [6], and semirealistic systems. The MANET complexity [7, 8] makes it difficult to develop its exact mathematical model. Field experiments with a MANET are actually a working system that has yet to be developed. Field studies of MANET fragments are not sufficient to characterize the whole system. The digital twin requires feedback from the operating system. The most expedient is the analysis of the MANET using its simulation model [6, 9]. As you can see, in most cases, it is not the MANET itself that is investigated, but its model. Therefore, the development of a MANET model with optical CCs for typical applications taking into account the specified environmental influences is an urgent task.

2. STRUCTURE OF THE STUDIED NETWORK

A modern MANET is a complex system consisting of many nodes and communication channels. In some cases, it is advisable to present a large volume MANET as a set of local groups of nodes connected by communication channels of border nodes.

In respect to the MANET, a local group of nodes is understood as a set of nodes located within a limited area and designed to perform joint tasks. It is assumed that traffic between nodes in a local group of nodes is significant compared to traffic destined for nodes in another local group of nodes. The local group of nodes will be designated as LNG (local node group).

We mean a border node by an LNG node, which in addition to the tasks of the LNG nodes provides traffic exchange with neighbouring LNGs. The border node can have different physical interfaces to create communication channels using different physical principles. There may be several border nodes at an LNG. We will denote a boundary node of an LNG as a BN (border node).

Integral functioning of the MANET involves the exchange of traffic between all nodes that are included in various LNGs. The use of optical methods for transferring information between LNGs is of particular

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importance in the conditions of the destructive influence of external factors. We will assume that optical communication channels (OCCs) are organized by means of border nodes of neighbouring LNGs using optical interfaces. The use of optical CC for organizing information exchange within LNG is not excluded.

Fig. 1 shows the structure of the investigated MANET, which consists of N LNGs interconnected by optical CC. Information exchange between nodes (designated as "n" - node) inside an LNG is carried out using radio channels. LNG's border nodes can operate both in the point-to-point mode, for example, with the formation of one optical CC OCC_{2N} between the border nodes LNG_2 and LNG_N of an LNG, and in the point-to-multipoint mode with the formation of several optical CCs from one border node, for example, channels OCC_{12} and OCC_{1N} between border nodes LNG_1, LNG_2 and LNG_1, LNG_N of the LNG, respectively. The number of LNG nodes, excluding border nodes, is k_j, where j=1,…, N.

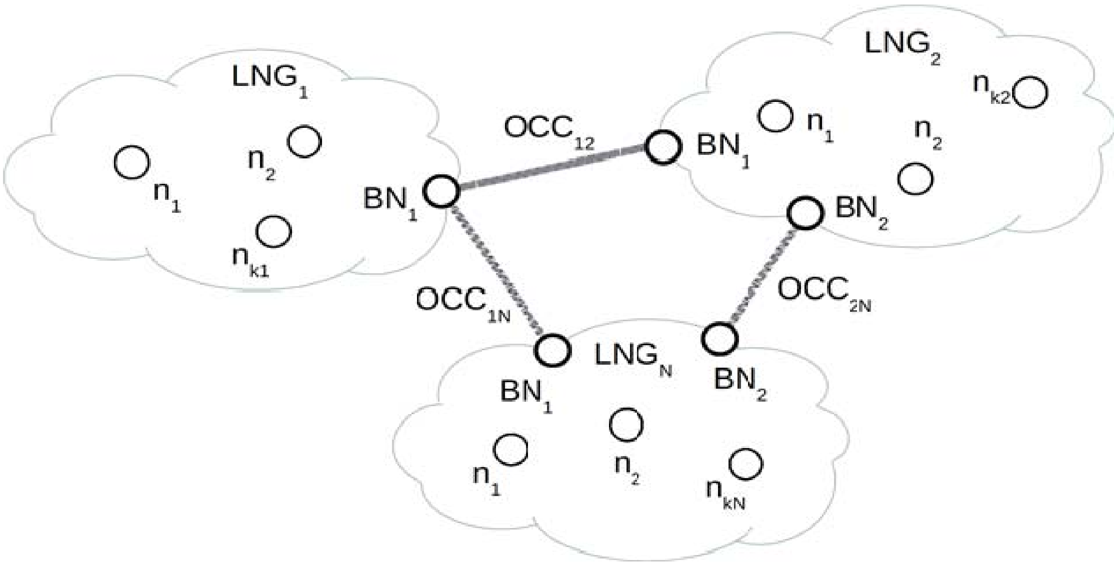

Figure 1. The structure of the investigated MANET

3. CONSTRAINTS AND REQUIREMENTS FOR THE MODEL

When developing a simulation model of MANET, we will consider the class of MANET with LNGs connected by optical CCs of border nodes.

We present the following requirements to the MANET simulation model:

1) support of modern methods for information processing and transmission on channel, network and transport levels of the open system interaction model;

2) support of operational characteristics of optical CCs with the specified bit errors and data transmission rates;

3) creation, delivery and consumption of a data stream representing voice traffic in real time;

4) controllability to create different MANET operation modes;

5) the availability of capabilities to assess the operational characteristics of the protocols used at the network and transport layers;

6) the accessibility of the study of the model for scientific and educational purposes.

4. METHODS AND MEANS OF SOLVING THE PROBLEM

To develop the MANET model, we will use the simulation modelling method representing the MANET elements with the corresponding models, which are affected by external conditions. It is advisable to use the available results for development of open software, i.e. the NS-3 discrete simulation modelling package as a means of constructing a simulation model of the MANET with optical CCs [10]. NS-3 is widely used for educational and research purposes; it is described in detail in the accompanying documentation and scientific publications, in part of which mobile ad hoc networks and networks with optical CCs are studied [11 - 15].

The capabilities of the NS-3 simulation modelling package ensure the fulfilment of the requirements for the model, and the availability of open source allows us to achieve the following goals:

1) Studying the correct implementation of the protocols and mechanisms of the modelling package which cannot be done using proprietary closed products;

2) Lack of license and hidden contributions;

3) Independence from the simulation modelling package supplier, and the creation of own branches of the simulation modelling package;

4) The ability to contribute to the development of the modelling package by publishing new models.

A significant advantage of using the NS-3 open source software is the existence of a community of developers, which is able to conduct a professional analysis of the developed code in the shortest possible time, to identify inaccuracies and errors in the implementation of the model, and to give recommendations for optimizing and harmonizing a new model, which cannot be done in a narrow team, where "own thing will always look good."

The NS-3 Discrete Simulation Package provides the ability to execute scripts written in C ++ or Python. To develop the MANET model, the C ++ language was chosen as an object-oriented add-on for the C language being the system language of many operating systems, including possible subscriber devices of the MANET.

The use of object-oriented design and programming methodology makes it possible to represent objects of the studied subject area in the form of objects of a strictly defined hierarchy of classes, which, in turn, will make it possible to obtain a controllable MANET model with expected behaviour and strict boundaries.

The NS-3 discrete simulator package of version 3.30.1 was used under the control of the Linux Ubuntu operating system version 18.04 for the development of the MANET model. The literature accompanying discrete simulator NS-3 was used as its methodological support [16 - 20]. The development was carried out in the integrated environment Eclipse IDE for C / C ++ Developers [21].

5. MODEL DESCRIPTION

The MANET simulation model is developed according to the typical scenario proposed in the NS-3 user manual. The structural blocks of the model are shown in Fig. 2. The block “Input processing” is intended for parsing input parameters and generating correct values. The block “Topology Creation” is the main block of the model; it forms the structure of the MANET, and the CCs both inside the LNG, and the optical CCs between the LNG, and sets up the MANET nodes. The block "Mobility model" performs the initial setting of the node location and forms independent mobility models for nodes belonging to different LNGs. The block “Create Voice Traffic” creates voice traffic generation and consumption applications for the nodes defined in the input parameters. External influences on the MANET are formed in the form of delay and bit error rate in the optical CCs. The block “Download Output” writes XML format files containing a time-expanded process of the MANET operation for subsequent analysis by the NetAnim program [22]. Part of the functionality has been moved to structures and functions as a prototype for future object classes. The features of the MANET model implementation are:

1) LNGs, into which the original network can be divided;

2) Optical CCs represented by abstractions of the operational characteristics of communication lines: data transmission rate, channel delay, bit error rate;

3) Independent mobility models for various LNG.

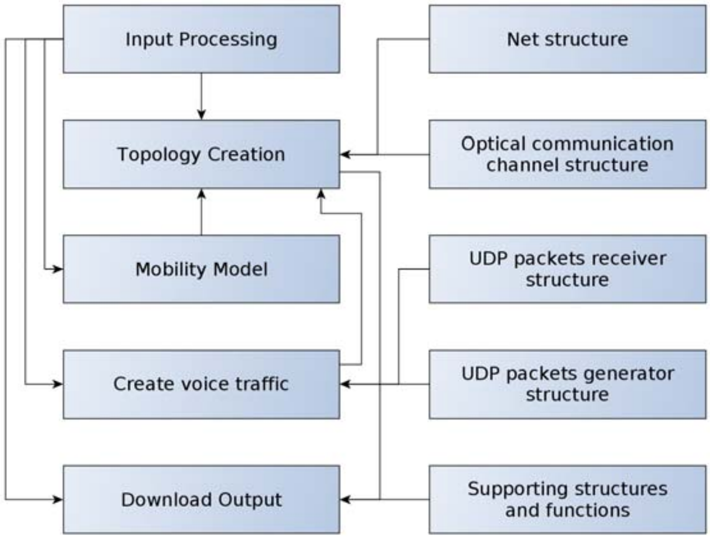

Figure 2. Structural blocks of the MANET simulation model

The input data of the MANET model are presented in table 1.

Table 1. Parameters of the MANET model

Parameter	Purpose and value range [default values]
v	Output of debugging information.
routeProtocol	Routing protocol. olsr aodv dsdv dsr [olsr]
nodesCount	Number of nodes in each group, 2..6 [5]
clientNode	Source node number (client), 1..nodesCount [2]
serverNode	Receiver node number (server), 1..nodesCount [2]
mtu	The maximum transmission unit, bytes [1400]
packetSize	UDP packet size, bytes [256]
packetInterval	The interval between UDP packets, µs [2500]
dataRate	Data transmission rate of the optical communication channel, Mbit / s [10]
ber	Bit error rate of optical communication channel [1e-05]
simulationTime	The duration of the simulation time, s [120]
speedMax	Maximum speed of nodes, m / s [20]
filePrefix	Output files prefix [udp-check]
delayBinWidth	Bin width of UDP packet delay, ms [1]
jitterBinWidth	Jitter bin width of UDP packet, ms [0.2]

The MANET model was specialized (Fig. 2) in order to study the characteristics of the MANET model: route bridging of UDP packets in the network, searching for routes to packet recipients, time of initial configuration of network routes, time of reconfiguring network routes. This was performed by developing Bash scripts with a smaller list of input parameters than for the MANET model (see table 1). In Bash scripts, the input parameters are processed in order to form the input parameters of the MANET model for the case under study, and a cycle of statistical processing of the output data of the MANET model is organized.

The scheme for studying the characteristics of the MANET model using Bash scripts is shown in Fig. 3.

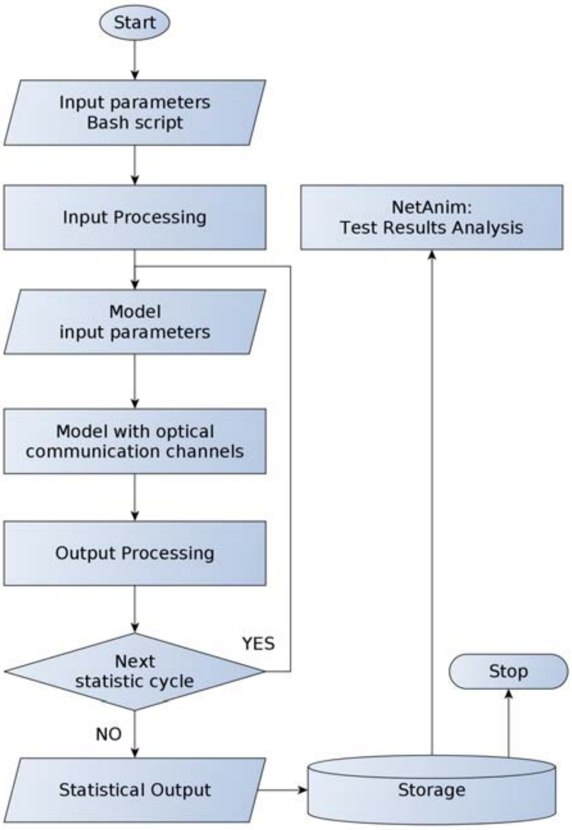

Figure 3. Scheme of studies of the MANET model characteristics

The list of Bash scripts, their purpose and input parameters are given in table 2.

Table 2. Bash Scripts for the Specializing of Model Properties

Name	Purpose	Parameters
udpCheck	Checking the route bridging of UDP packets in the network	--routeProtocol --mode=0 --tx --rx --packetSize

		--packetInterval --checkCount --outputFile
findRoute	Checking the route finding to package recipients	--routeProtocol --mode=1 --outputFile
findInitialRoutes	Estimation of the initial configuration time for finding network routes	--routeProtocol --mode=2 --checkCount --outputFile
dynamicReconfig	Estimation of time to reconfigure network routes	--routeProtocol --mode=3 --checkCount --outputFile
Where --routeProtocol – dynamic routing protocol; --mode – the case under study; --tx - number of UDP packet transmitter node; --rx - number of UDP packets receiver node; --packetSize - UDP packet size; --packetInterval - interval between UDP packets; --checkCount - the number of check counts; --outputFile - the name of the output file.		

6. EXAMPLE OF THE MODEL APPLICATION

Approbation of the developed MANET model with optical CCs was carried out on the basis of the following initial data:

1. The total number of network nodes - 10;

2. The number of LNGs - 2;

3. The number of transmitted UDP packets - 1000;

4. Dynamic routing protocol - OLSR;

5. The number of optical CCs - 1;

6. Border nodes are linked by the optical CC;

7. Border nodes are immobile.

The rest of the model parameters were selected by default (see Table 1). The choice of the bit error rate value was made on the basis of the results represented in [23].

Fig. 4 shows the structure of the studied MANET, which shows two LNGs: LNG_1 and LNG_2, 4 nodes each. Each LNG is located within a square with a side of 1 km. Border nodes BN5 and BN6 are connected by optical CC, or OCC_{12} with a length of d = 1 km.

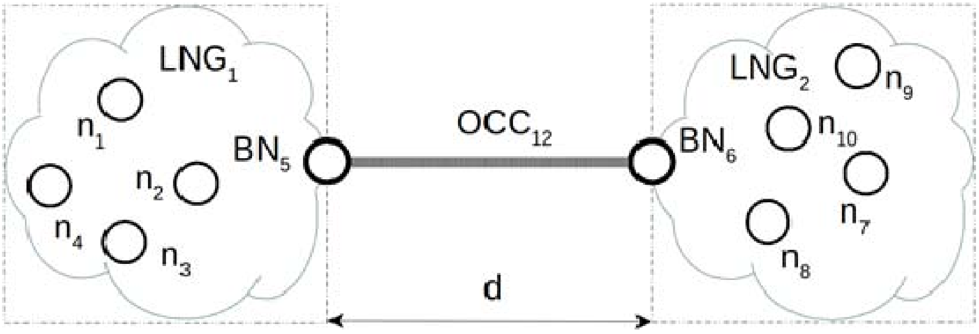

Figure 4. MANET structure with one optical CC between LNGs

Fig. 5 shows a fragment of the MANET initial work. After starting the simulation, the route detection process follows. The figure shows how node n_2 of LNG_1 sends out OLSR packets for route finding. The routing tables at the MANET nodes are updated after changing the location of the nodes. An example route detection scheme for a node from LNG_1 is given in Table. 3.

Figure 5. Route detection in the investigated MANET (displaying in the NetAnim program)

Table 3. Route detection scheme for the node n_1 from LNG $_1$

Route detection, s	LNG $_1$	BN_5	BN_6	LNG_2
3	+	-	-	-
5	+	+	-	-
6	+	+	+	-
11	+	+	+	+

After the initial setting of the MANET routes, the MANET characteristics for voice traffic transmission were evaluated. For this purpose, voice traffic was generated at node n_4 (T_x) in the form of UDP packets; voice traffic was transferred from LNG_1 to LNG_2 through the optical communication channel OCC_{12}, and voice traffic was consumed at node n_9 (R_x), while nodes LNG_1 and LNG_2 moved inside their local areas.

A fragment of the process of delivering UDP packets from their source in the node n_4 (T_x) to the receiver in the node n_9 (R_x) is shown in Fig. 6. It can be seen that there is no direct delivery channel from the border node BN_6 to the receiver node n_9 (Rx), therefore UDP packets were routed and relayed at intermediate nodes of LNG_2.

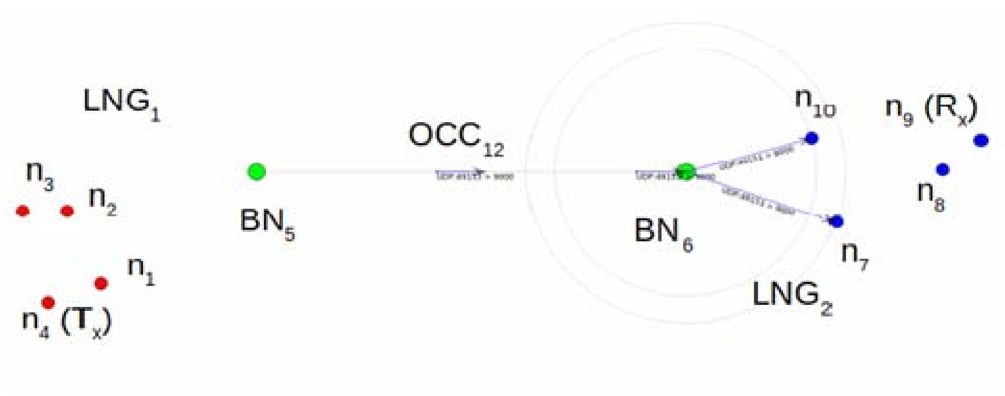

Figure 6. A fragment of the UDP packet delivering process (displaying in NetAnim)

The results of modelling the process of voice traffic transmission are shown in Fig. 7 and 8, which presents histograms of the delivery delay time and phase jitter of UDP packets, respectively.

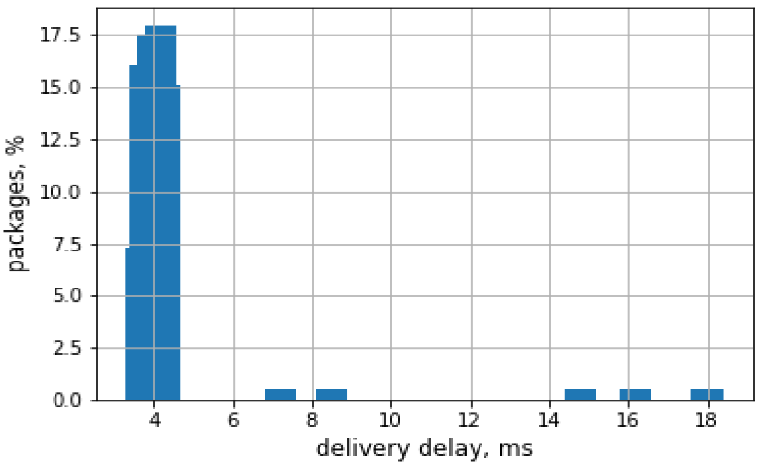

Figure 7. Histogram of UDP packet delivery delay time

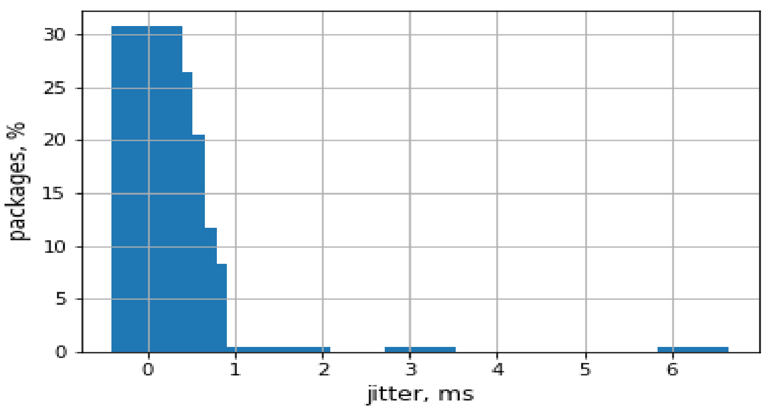

Figure 8. Histogram of UDP packet jitter

Analysis of the presented data shows that with certain settings of the MANET model it is possible to achieve the transmission of UDP packets with characteristics acceptable for the exchange of voice traffic. Lost UDP packets were 2.2 - 2.4%.

7. CONCLUSION

Thus, the developed simulation model of the MANET with optical CCs between the LNG boundary nodes allows us to evaluate the characteristics that are essential for the transmission of voice traffic.

Taking into account the possibility of obtaining unexpected results when modelling, it is planned to continue work on improving the simulation model of the MANET in the direction of determining the permissible boundaries and optimal values of the model parameters.

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