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SIMULATION OF TRAFFIC LOADING IN MESH NETWORKS

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Abstract

This paper analyzes the performance of reactive, proactive and hybrid routing protocols when used in a wireless mobile peer-to-peer network (MANET). An appropriate algorithm for evaluating the effectiveness of routing protocols is developed. The simulation tool was an OPNET network simulator (Optimized Network Engineering Tool) Modeler version 14.0. The modeling process was based on the fact that the performance of routing protocols in networks with increased scalability and mobility was studied. Two possible situations were considered: UDP traffic was used in the first one, packet delivery is not guaranteed, generating traffic was video conference traffic, in the second one TCP traffic was used, packet delivery is guaranteed, traffic generator was traffic from the FTP server. A simulation model of the video conference network was developed, with each of the nodes in the network configured to run the appropriate routing protocol. Several parameters were analyzed: the amount of lost information (bits/sec), delay (sec), network load (bit/sec), the ratio of the number of retransmitted packets to sent, the intensity of the input stream (bits/sec). Next, a multi-criteria selection of the routing protocol by the method of hierarchy analysis for the video conference was carried out. A matrix of pairwise comparisons was formed among the selected parameters for the second level of the hierarchy, which contains criteria that affect the General goal - the choice of the routing protocol. After the simulation, it was found that the least amount of information loss is characterized by the OLSR protocol, since the amount of information loss is minimized due to the fact that a subset of repeaters is used. The minimum delay we get for the TORA protocol, but this increases the load on the network, because the service information of the protocol is noticeably increased. Based on the scale of the relative importance of the criteria, as well as the results obtained on the basis of the method of analysis of hierarchies, it was found that in the analyzed model it is preferable to use the OLSR protocol as a routing protocol.

Keywords:

Computer network, traffic loading, protocol.

ACM Computing Classification System

Network protocols, Network algorithms, Network types

Introduction

This paper is devoted to the investigation of speed reactive, proactive and hybrid routing protocols in a wireless mobile peer-to-peer network (MANET), as well as the development of an algorithm for evaluating the effectiveness of routing protocols. MANET is a type of Ad-Hoc network that operates under 802.11 standard in a discrete and dispersed environment without a common control center.

The mobile peer-to-peer network (MPN) is rapidly evolving and is an important area of the wireless mobile network. MPN is combined in it wireless networks in which mobile nodes move and control the construction of routes.

In MPN network topology changes very quickly and unpredictably, each mobile node moves without a fixed access point. MPN nodes can transmit information using multiple retransmissions, and the number of intermediate nodes can vary. Nodes must support multiple routes. If the mobile nodes are within each other's radio access zone, the source node can send the message directly to the destination node, otherwise the transfer will take place through the intermediate nodes. Therefore, today, routing is an important role to ensure reliability and efficient operation in mobile wireless networks. Efficient routing management saves you the cost of building routes, which leads to improved network performance.

Mostly, the MPN is used in military communication between soldiers, aircraft, tanks, etc. in operations management in battles, emergency management teams to rescue people, in search operations of fire or police and to deploy fixed infrastructure in case of floods, fires, etc.

Mobile offices, taxis, sports stadiums, electronic payments from anywhere, voting systems, automotive computers, the education system, from the installation of virtual classrooms, conference rooms, file sharing between users, sharing game multiple gamers [1].

The main problem in MANET is to restore communication when it is lost and to build a route for the subscriber with the minimum amount of time delay for mobile nodes in chaotic motion.

The MPN will be an integral part of the next generation of networks because of its flexibility, infrastructure, ease of maintenance, automatic configuration and cost-effectiveness.

In mobile ad hoc networks, mobile nodes should communicate with each other in order to restore communications and organise dynamic topology mobility for rapid changes of the route and the restoration of relations in a wireless network.

1 Wireless network simulation based on OPNET simulation tool

As a means of simulation the network simulator OPNET (Optimized Network Engineering Tool) Modeler version 14.0 is used. It is the most widely used commercial simulator running under the Microsoft Windows operating system and includes realizaciju studied routing protocols.

This software product not only supports MANET routing, but also provides a parallel core to support increased stability and mobility in the network. Functions of intense analysis OPNET provide the best conditions for comparisons, calculations, and coordination of output.[1].

Opnet Modeler offers users a graphical environment for creating, executing, and analyzing event modeling of communication networks. This user-friendly software can be used for a large number of problems, such as typical creation and verification of communication protocol, analysis of rotocol interactions, network optimization and planning. It is also possible to carry out with the help of the package verification of the correctness of analytical models and description of the protocols [2].

Within the framework of the so-called project editor, palettes of network objects can be created, to which the user can assign various forms of connection of nodes and connections up to the puzzle-like ones. Automated generation of network topology-ring, star, random network, is also supported and reserved by utilities for imported network topologies in various formats.

Random traffic can be automatically generated from the algorithms specified by the user, as well as imported from the standard package of real line traffic formats. The results of the simulation can be analyzed, and the graphs and traffic animation will again be generated automatically. A new feature is the automatic conversion to html.

One of the advantages of creating a network model using the software is that the level of flexibility provided by the core of the simulation is the same as for the simulation, written from scratch, but the object the build environment allows the user much faster to do the development, improvement and to produce models for repeated use.

There are several editor environments - one for each object type. Organization of objects - hierarchical, network objects (models) are connected by a set of nodes and communication objects, while node objects are connected by a set of objects, such as priority modules, processor modules, transmitters and receivers. Version software for modeling the radio channel contains a model of the antenna of a radio transmitter, receiver antenna, moving objects node (including satellites).

The behavior logic of the processor and precedence constraints determines the model of the process that the user can create and modify within the process editor. In the process editor, the user can determine a process model using the combination of the algorithm of a finite state machine (finite-state machine - FSM), and operators of the programming language C/C++.

The invocation of a process model event during the simulation is controlled by the initiation of the interrupt, and each interrupt corresponds to an event that must be processed by the process model.

The basis of communication between processes is a data structure called a package. Package formats can be defined, that is, they define which fields can contain standard data types such as integers, floating-point numbers, and package pointers (this last ability allows you to encapsulate a package simulation).

Data structure, the caller information for the control interface (interface control information-ICI) can be divided between the two process models is another mechanism for interprocessor communication, it is very convenient for teams simulation and corresponds to the layered architecture of the Protocol.

A process can also dynamically spawn child processes that simplify the functional description of systems such as servers.

Several basic process models are included in the basic package, simulating popular network protocols and algorithms, such as the border gateway protocol (BGP), the Protocol of transmission control.

Internet Protocol (TCP/IP), frame relay (frame relay), Ethernet, asynchronous transfer mode (asynchronous transfer mode -ATM), and WFQ (weighted fair queuing). Basic models are useful for the rapid development of complex simulation models for common network architectures as well as for training to give an accurate functional description of the Protocol to students.

There is a possibility of support by companies and graphics (with hypertext support) of network, node or process models [3, 4].

In this paper, the simulation is based on the study of the performance of routing protocols in a network with increased scalability and mobility. Thus, two modeling scenarios were created. The first-with UDP traffic, where the delivery of packets is not guaranteed, as the generating traffic was video conference traffic, the second-with TCP traffic, where the delivery of packets is guaranteed, as a traffic generator used traffic from the ftp server [5, 6].

The simulation model of the video conference network consisted of 20 mobile units, randomly located on the territory of 1000m per 1000m. 10 nodes from which transmitted information, and 10 nodes are received.

Each node was moving randomly throughout the territory. The speed varied between 10 Mbps and 20 Mbps throughout the simulation.

The nodes were configured with the following parameters:

- Physical characteristics of 11 Mbps
- Transmitter power 0.005 W

Traffic for the model was specified explicitly, traffic from the video conference with the following parameters was used as traffic generation:

- number of frames per second: 15 fps;
- frame size: 128x240 pixels.

Each node in the network has been configured to run the appropriate routing Protocol for AODV, DSR, OLSR, TORA for each simulation. The simulation time was 600 seconds. Each node was randomly configured with a path to simulate network mobility in space throughout the simulation.

As a result of simulation for video conference traffic, we got the following numerical data (table 1).

The simulation model of the FTP server network consisted of 20 mobile nodes and one fixed node simulating the FTP server located randomly on the territory of 1000m by 1000m.

Each of the 20 nodes contacted the server to download the file with the specified characteristics. The traffic for the model was also explicitly set on the FTP server side, the FTP traffic with the following characteristics was used as traffic generation:

- file size: 1.4 Gb;
- request time between packets : 3600 s.

Table 1 - Results of the network analysis using video conferencing

	Protocols			
	AODV	DSR	OLSR	TORA
Amount of lost information (bits / sec)	96 150 000	75 990 000	35 120 000	35 875 000
Delay (sec)	0.16800	0.19800	0.30000	0.14000
Network load (bit/sec)	19 300 000	16 900 000	17 800 000	23 000 000
The ratio of the number of packets relayed to sent	0.96	0.92	1.49	0.95
The intensity of the input stream (bits/sec)	40 000	110 000	12600	6 900 000

After a packet is requested, each packet is sent according to the Gaussian distribution law, i.e. each subsequent value is independent of the previous one and this value is characterized by a request time between packets of 3600 seconds.

Table 2 - Results for the network with the FTP server

	Protocols			
	AODV	DSR	OLSR	TORA
Amount of lost information (bits / sec)	30 200	52 500	21 900	34 500
Delay (sec)	0.015000	0.019500	0.008200	0.010100
Network load (bit/sec)	6 250 000	5 900 000	6 400 000	6 200 000
The ratio of the number of packets relayed to sent	0,359	0,351	0,255	0,550
The intensity of the input stream (bits/sec)	16 100	20 000	3 750	11 950

As with the first model in the second model, each node in the network was configured to perform the appropriate routing Protocol AODV, DSR, OLSR, TORA for each simulation.

The simulation time was 600 seconds, and nodes would access the server to download the file from the fifty-fifth second after the simulation started. Each node was randomly configured with a specific path path to simulate network mobility in space throughout the simulation.

And in the first and second cases, the simulation lasted for six hundred seconds.

For the model with FTP traffic generation we got the following results (Table 2).

2 Multi-criteria routing protocol selection by hierarchy analysis method for video conference

To make a decision based on the data obtained, we will use the method of hierarchy analysis [7, 8]. The General view of the hierarchy of the decision will be as follows (Figure 1), where Ki are particular selection criteria, Aj are possible alternatives.

A1-protocol AODV; A2 – protocol DSR; A3- protocol OLSR; A4- protocol TORA.

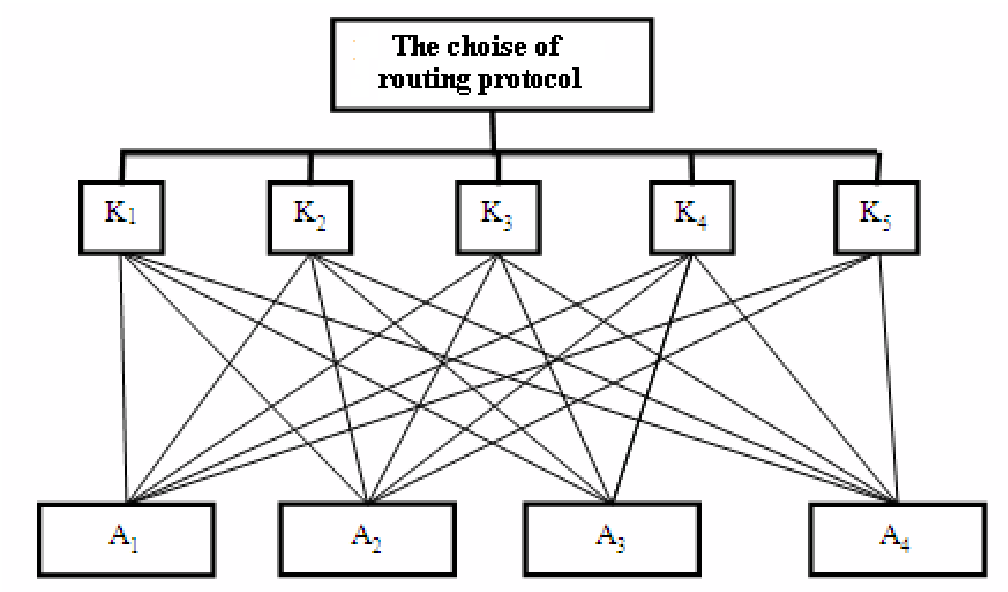

Fig.1. Hierarchy of the decision

Table 3 is a matrix of pairwise comparisons for the second level of the hierarchy, which contains the criteria that affect the overall goal - the choice of routing protocol.

Table 3 - matrix of pairwise comparisons of criteria

CRITERIA	Amount of information lost (K_1)	Delay (K_2)	Network load (K_3)	Ratio of the number of packets relayed to sent (K_4)	Intensity of the input stream (K_5)
Amount of information lost (K_1)	1	9	7	7	9
Delay (K_2)	1/9	1	1/7	1/3	3
Network load (K_3)	1/7	7	1	5	3
Ratio of the number of packets relayed to sent (K_4)	1/7	3	1/5	1	3
Intensity of the input stream (K_5)	1/9	1/3	1/3	1/3	1

Based on the results obtained in the simulation of the network with video conference traffic (table 1) and using the method of hierarchy analysis, we construct a matrix for each of the criteria.

For the criterion "The amount of lost information (K_1)»:

Table 4 - Evaluation of the importance of alternatives for the criterion of the amount of lost information (K_1)

	AODV	DSR	OLSR	TORA	Normalized estimates of priority vectors
AODV	1	0.790327613	0.365262611	0.373114925	0.130154
DSR	1.265298066	1	0.462166074	0.472101592	0.164684
OLSR	2.737756264	2.163724374	1	1.021497722	0.356331
TORA	2.680139373	2.118188153	0.978954704	1	0.348831
Sum	7.6832	6.0722	2.8064	2.8667	

For the criterion " Delay (K_2)»:

Table 5 - Assessment of the importance of alternatives for the Delay criterion (K_2)

	AODV	DSR	OLSR	TORA	Normalized estimates of priority vectors
AODV	1	1.178571429	1.785714286	0.833333333	0.277125
DSR	0.848484848	1	1.515151515	0.707070707	0.235136
OLSR	0.56	0.66	1	0.466666667	0.155190
TORA	1.2	1.414285714	2.142857143	1	0.332550
Sum	3.6085	4.2529	6.4437	3.0071	

For the criterion «Network Load (K_3) »:

Table 6 - assessment of the importance of alternatives for the network Load criterion (K_3)

	AODV	DSR	OLSR	TORA	Normalized estimates of priority vectors
AODV	1	0.875647668	0.922279793	1.191709845	0.245978
DSR	1.142011834	1	1.053254438	1.360946746	0.280909
OLSR	1.084269663	0.949438202	1	1.292134831	0.266706
TORA	0.839130435	0.734782609	0.773913043	1	0.206407
Sum	4.0654	3.5599	3.7494	4.8448	

For the criterion «Ratio of the number of retransmitted alternatives to sent alternatives (K_4)»:

Table 7 - evaluation of the importance of alternatives for the criterion of the Ratio of the number of relayed to sent alternatives (K_4)

	AODV	DSR	OLSR	TORA	Normalized estimates of priority vectors
AODV	1	0.958333333	1.552083333	0.989583333	0.270395
DSR	1.043478261	1	1.619565217	1.032608696	0.282151
OLSR	0.644295302	0.617449664	1	0.637583893	0.174214
TORA	1.010526316	0.968421053	1.568421053	1	0.273241
Sum	3.6983	3.5442	5.7401	3.6598	

For the criterion «Intensity of the input flow (K5)»:

Table 8 - Evaluation of the importance of alternatives for the input flow Rate criterion (K_5)

	AODV	DSR	OLSR	TORA	Normalized estimates of priority vectors
AODV	1	2.75	0.315	172.5	0.220069
DSR	0.363636364	1	0.114545455	62.72727273	0.080025
OLSR	3.174603175	8.73015873	1	547.6190476	0.698631
TORA	0.005797101	0.015942029	0.001826087	1	0.001276
Sum	4.5440	12.4961	1.4314	783.8463	

As a result, we obtain the values of global priorities of alternatives AODV (A_1), DSR (A_2), OLSR (A_3), TORA (A_4):

According to the obtained values, you should choose an alternative with a maximum global priority value equal to 0,324954, which corresponds to the OLSR protocol.

Table 9 - Global priorities of alternatives AODV (A_1), DSR (A_2), OLSR (A_3), TORA (A_4):

Alternatives	Criteria					Global priorities
	The amount of lost infor-mation	Delay	The network Load	The ratio of the number of packets relayed to sent	Intensity of the input stream	
	Numerical value of the priority vector					
AODV	0.130154	0.277125	0.245978	0.270395	0.220069	0.177248
DSR	0.164684	0.235136	0.280909	0.282151	0.080025	0.199034
OLSR	0.356331	0.155190	0.266706	0.174214	0.698631	0.324954
TORA	0.348831	0.332550	0.206407	0.273241	0.001276	0.298763

In the model under study, based on the results, it can be seen that the smallest amount of information loss is observed when using the OLSR protocol as a routing protocol (table 9). This is because the OLSR Protocol minimizes information loss by using a specific subset of nodes in the network, called preferred relays.

The minimum delay is achieved when using the TORA Protocol as the routing protocol (table 9), but the load on the network has increased due to a significant increase in the service information of the protocol itself.

Routing protocols AODV and DSR showed similar results. This is because both protocols are reactive routing protocols and both build on-demand route tables based on the distance vector. Their difference lies in the fact that the protocol uses DSR for routing, the routing table of the source, not the intermediate nodes.

Based on the scale of relative importance of the criteria (table 3) and the results obtained by the method of hierarchy analysis, in our model it is preferable to use the OLSR protocol as a routing protocol.

3 Multi-criteria selection of the routing protocol method of analysis of hierarchies for the FTP server

Based on the results obtained in the simulation of the network with video conference traffic (table 4) and using the method of hierarchy analysis, we construct a matrix for each of the criteria.

For the criterion «The amount of lost information (K_1)»:

Table 10 - Evaluation of the importance of alternatives for the criterion of the amount of lost information (K_1)

	AODV	DSR	OLSR	TORA	Normalized estimates of priority vectors
AODV	1	1.738410596	0.725165563	1.142384106	0.261124
DSR	0.575238095	1	0.417142857	0.657142857	0.150209
OLSR	1.378995434	2.397260274	1	1.575342466	0.360089
TORA	0.875362319	1.52173913	0.634782609	1	0.228578
Sum	3.8296	6.6574	2.7771	4.3749	

For the criterion " Delay (K_2)»:

Table 11 - Assessment of the importance of alternatives for the Delay criterion (K_2)

	AODV	DSR	OLSR	TORA	Normalized estimates of priority vectors
AODV	1	1.3	0.546666667	0.673333333	0.196709
DSR	0.769230769	1	0.420512821	0.517948718	0.151315
OLSR	1.829268293	2.37804878	1	1.231707317	0.359834
TORA	1.485148515	1.930693069	0.811881188	1	0.292142
Sum	5.0836	6.6087	2.7791	3.4230	

For the criterion «Network Load (K3) »:

Table 12 - Assessment of the importance of alternatives for the network Load criterion (K3)

	AODV	DSR	OLSR	TORA	Normalized estimates of priority vectors
AODV	1	0.944	1.024	0.992	0.247283
DSR	1.059322034	1	1.084745763	1.050847458	0.261952
OLSR	0.9765625	0.921875	1	0.96875	0.241487
TORA	1.008064516	0.951612903	1.032258065	1	0.249277
Sum	4.0439	3.8175	4.1410	4.0116	

For the criterion «Ratio Of the number of retransmitted alternatives to sent alternatives (K_4)»:

Table 13 - Evaluation of the importance of alternatives for the criterion of the Ratio of the number of relayed to sent alternatives (K_4)

	AODV	DSR	OLSR	TORA	Normalized estimates of priority vectors
AODV	1	0.977715877	0.710306407	1.532033426	0.244896
DSR	1.022792023	1	0.726495726	1.566951567	0.250478
OLSR	1.407843137	1.376470588	1	2.156862745	0.344775
TORA	0.652727273	0.638181818	0.463636364	1	0.159850
Sum	4.0834	3.9924	2.9004	6.2558	

For the criterion «Intensity of the input flow (K5)»:

Table 14 - Evaluation of the importance of alternatives for the input flow Rate criterion (K_5)

	AODV	DSR	OLSR	TORA	Normalized estimates of priority vectors
AODV	1	1.242236025	0.232919255	0.742236025	0.134307
DSR	0.805	1	0.1875	0.5975	0.108117
OLSR	4.293333333	5.333333333	1	3.186666667	0.576626
TORA	1.347280335	1.673640167	0.313807531	1	0.180950
Sum	7.4456	9.2492	1.7342	5.5264	

Table 15 - As a result, we obtain the values of global priorities
of alternatives AODV (A_1), DSR (A_2), OLSR (A_3), TORA (A_4):

Alternatives	Criteria					Global priorities
	The amount of lost information	Delay	The network Load	The ratio of the number of packets relayed to sent	Intensity of the input stream	
	Numerical value of the priority vector					
AODV	0.261124	0.196709	0.247283	0.244896	0.134307	0.248582
DSR	0.150209	0.151315	0.261952	0.250478	0.108117	0.180216
OLSR	0.360089	0.359834	0.241487	0.344775	0.576626	0.343204
TORA	0.228578	0.292142	0.249277	0.159850	0.180950	0.227999

In the second case, when studying the model with the generation of ftp traffic, the smallest value of the amount of lost information is obtained when using the OLSR Protocol as a routing Protocol.

When using the OLSR Protocol, we got the lowest latency in the network, the ratio of relayed packets to sent packets, and the smaller value of the service information of the Protocol itself, but the value of the "network load" was the highest.

The largest value of the amount of lost information is obtained by using the DSR protocol. Despite the similarity of DSR with AODV, the value of this criterion is much lower when using AODV. This is due to the fact that during the generation of ftp traffic, tcp packets prevail, in which the sequence of sent data and their loss plays an important role. In the model of the network under study, high mobility of nodes prevails, which leads to intensive updating of route tables of each node. However, unlike AODV, which maintains a route table on each node, DSR is based on the source route table, which leads to an inevitable increase in the amount of information lost.

When using the TORA protocol as a routing protocol, we have similar results as with other protocols. However, the value of the ratio of the number of retransmitted packets to sent packets exceeds the values of other protocols. This is due to the hybrid nature of the protocol and the high mobility of the network under study. Since the network had high mobility and a large amount of generated traffic, the protocol had to save and use routes between all source – receiver pairs constantly, but not all routes were relevant.

As in the first model of mobile network with video conference traffic generation, in the second model it is also preferable to use OLSR protocol as a routing protocol.

Conclusion

In this paper, the problem of choosing a routing Protocol for a mobile wireless network with a cellular topology with different types of traffic is solved. Two models of wireless network were studied, one with udp traffic, where packet delivery is not guaranteed, as generating traffic was video conference traffic, the second - with tcp traffic, where packet delivery is guaranteed, as a traffic generator was used traffic from the ftp server. Four routing protocols AODV, DSR, OLSR, TORA, characterized by a number of indicators that affect the network characteristics in different ways, and the degree of influence was also different. The problem of choosing the best Protocol was related to the problem of multi-criteria selection. As a result, it was decided to use the method of hierarchy analysis as a method of selecting a suitable Protocol.

A matrix of criteria importance was compiled (table 3). The main and the most important common criterion for all protocols was the amount of user information lost, and the important criteria were the network delay and the intensity of the input stream.

The results show that the use of THE Tora hybrid Protocol in a network with traffic generated by a video conference allows to minimize the amount of lost information in conditions with an optional guarantee of package delivery. This allows it to deliver data much faster and more efficiently for applications that require high bandwidth or require little time to deliver data. However, this generates more service information for the Protocol itself.

Reactive protocols AODV and DSR showed similar results. However, under the conditions of packet delivery guarantee and high mobility, AODV Protocol is clearly superior to DSR Protocol, it has less delays and less sent service information, which leads to a reduction in the amount of lost information.

Based on the analysis of the simulation results and the use of the hierarchy analysis method to solve the multi-criteria problem of route selection in a wireless network, it can be concluded that for the considered networks the optimal choice is the OLSR routing Protocol. This Protocol belongs to the proactive protocols. It actively determines the level of network status by regularly exchanging packets between nodes in the network. The OLSR Protocol minimizes the amount of overhead by using a specific subset of nodes in the network, called repeaters, to relay control messages. This explains the low load on the network using this Protocol (table 4), which is especially effective in the transmission of information on the network, sensitive to delays.

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