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MATHEMATICAL MODELS FOR ESTIMATING RADIO CHANNELS UTILIZATION WHEN TRANSMITTING REAL-TIME FLOWS IN MOBILE AD HOC NETWORK

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ABSTRACT

The wireless self-organized network functioning efficiency is considered from its radio channels utilization point of view. In order to increase the radio channels utilization it is offered to carry out flow smoothing of the arriving requests for audio-and video flow transfer due to their buffering. Definition of the radio channel utilization indicator is given. Mathematical models for radio channels utilization assessment by real-time flows transfer in the wireless self-organized network are presented. Estimated experiments results according to the average radio channel utilization productivity with and without buffering of the arriving inquiries are shown. It is proved that due to requests for real-time flows transfer buffering in the wireless self-organized network it is possible to increase the radio channels utilization indicator significantly.

Keywords: mobile ad hoc network, mathematical model, real-time flows, indicator of the radio channel utilization.

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1. INTRODUCTION

Performance of a specific tasks number requires ensuring information transfer under conditions of the high subscribers' mobility, intensive destructive influences, absence and expansion inexpediency of telecommunication networks with the fixed send-receive nodes. Such tasks can arise in the course of search and rescue operations, the prevention and elimination of emergency situations, work under conditions of the natural and technogenic character factors striking influence hazard, operations on ensuring law and order and counteraction to terrorism, protecting the important and dangerous territorially distributed objects (Konstantinov et al., 2016, Polschykov, 2012). At the same time there is a need for data transmission networks application having dynamic topology and capable of effectively carrying out transfer of speech messages and video flows, i.e. types of the traffic formed by real-time flows. Mobile Ad Hoc Networks (MANET) having the decentralized changeable structure has the specified potential (Basagni et al., 2004, Konstantinov et al., 2017). The main features of creating the MANET consist in realization of the network components decentralized management, lack of base stations (the fixed nodes), ability of each knot to perform the router functions. Advantages of the specified networks are rapid expansion, high survivability, ability to provide communication on dynamically changing topology (Polschykov, 2013).

Receiving requests for real-time flows transfer from subscribers of MANET changes in a random way (Polschykov et al., 2015). At reduction of these inquiries receipt intensity the network loading decreases, channels work in the underloaded mode, pauses in their use are observed (Rvachova et al., 2015). At essential increase of users activity in network temporary deficiency of channel resources is observed, MANET overload occurs. At such moments quality of audio-and video information transfer worsens (Polschykov et al., 2013). Accident, unevenness of requests receipt for real-time flows transfer in epy network leads to inefficient use of radio channels owing to transfer quality of audio and video messages decreasing. For the solution of this problem the RSVP protocol (Resource ReSerVation Protocol) provided reservation of channel resources for real-time flows transfer requests service (Awduche et al., 2001). This approach allows providing high-quality transfer of those messages for which the required part of channels capacity was reserved previously. However at the same time under conditions of high activity of subscribers and deficiency of channels it is not possible to reserve the necessary resources for many inquiries and the corresponding flows are not transferred. In order to avoid similar situations in MANET it is expedient to carry out flow smoothing of the arriving requests for audio-and video messages transfer due to their buffering. Besides, owing to unevenness of inquiries receipt the network channels are used insufficiently (Polschykov et al., 2010). The mathematical models presented in this article are developed for assessment of the radio channels utilization in MANET taking into account a possibility of requests buffering for real-time flows transfer.

2. THE RADIO CHANNEL UTILIZATION INDICATOR

High-quality transfer of various real-time flows on the network channel will be guaranteed if for these purposes the required the channel productivity is allocated (Konstantinov et al., 2015). It is known that the maximum the channel productivity corresponds to its capacity, i.e. the extreme volume of information which can be transferred on the channel for a certain period.

The channel utilization indicator U – is the value showing what part of this channel capacity was used for information transfer during the set time interval.

Value of an indicator U is numerically equal in the ratio of the channel productivity C, used for information transfer during the set time interval T, to value of capacity $C_{\max}$ of this channel:

$$U = \frac{C}{C_{\max}}. \quad (1)$$

It is possible to apply mathematical modeling to assessment of the channel utilization indicator and as a result of computing experiments to receive value C_A – the average channel productivity used. In this case assessment of the channel utilization indicator can be found according to a formula:

$$U^* = \frac{C_A}{C_{\max}}. \quad (2)$$

3. MATHEMATICAL MODELS FOR ASSESSING THE AVERAGE RADIO CHANNEL UTILIZATION PRODUCTIVITY

For calculating the value C_A it is possible to use the models applied within the theory of mass service to definition of the busy serving devices average (Baccelli et al., 2003). If buffering of the arriving requests for real-time flows transfer on a radio channel of MANET is not provided, then its average used productivity can be determined by expression:

$$C_{A1} = \frac{R\sum_{k=0}^{n}\frac{k}{k!}\left(\frac{\lambda}{\mu}\right)^{k}}{\sum_{k=0}^{n}\frac{1}{k!}\left(\frac{\lambda}{\mu}\right)^{k}}. \quad (3)$$

where R – the channel productivity demanded for high-quality transfer of one real-time flow; n – number of real-time flows which can be transferred at the same time on a radio channel with the required quality; λ – intensity of requests receipt for real-time flows transfer on a radio channel; μ – intensity of requests service for real-time flows transfer.

The formula (3) is fair in case time interval between inquiries receipt, as well as duration of flows transfer on a radio channel are distributed under the exponential law. Then value μ can be found as value, inversely proportional the average duration of a real-time flow transfer on a radio channel:

$$\mu_A = \frac{1}{\tau_A}. \quad (4)$$

If $\frac{\lambda}{\mu} < n$, that the average radio channel utilization productivity with buffering of the arriving requests for real-time flows transfer can be calculated according to a formula:

$$C_{A2} = R\left[n - p_0\sum_{k=0}^{n-1}\frac{n-k}{k!}\left(\frac{\lambda}{\mu}\right)^{k}\right]. \quad (5)$$

where p_0 – probability that any flow of real time will not be transferred to any moment on a radio channel.

For value calculation p_0 it is necessary to use expression:

$$p_0 = \frac{1}{\sum_{k=0}^{n-1}\frac{1}{k!}\left(\frac{\lambda}{\mu}\right)^{k} + \frac{1}{n!\left(1-\frac{\lambda}{n\mu}\right)}\left(\frac{\lambda}{\mu}\right)^{n}\left[1-\left(\frac{\lambda}{n\mu}\right)^{m+1}\right]}. \quad (6)$$

where m – limit number of the buffered requests for real-time flows transfer on a radio channel.

4. ESTIMATED EXPERIMENTS RESULTS

For the basic data presented in table 1 on the basis of application of expressions (3) - (5) calculations of the average values for radio channel utilization productivity with and without buffering requests for real-time flows transfer are executed.

Table 1. Basic data for estimated experiments

Parameter	Value
R	100 Kbps
n	10
m	8
λ	0 ... 99 min^{-1}
τ_A	6 min
$C_{\max}$	1 Mbps

As a result of estimated experiments the curves presented in figure 1 are received. Functions $C_{A1}(\lambda)$ correspond to the dashed line, and functions $C_{A2}(\lambda)$ – to the continuous line.

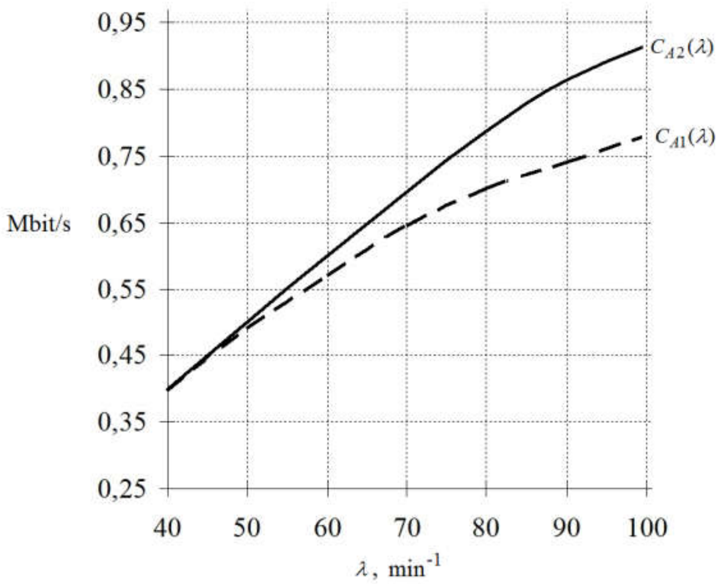

Fig.1. Curves of the average radio channel utilization productivity with and without buffering inquiries

The analysis of figure 1 shows that with increase in intensity of requests receipt for real-time flows transfer the average radio channel utilization productivity with buffering is significantly more, than without buffering.

Researches showed that the radio channel utilization rises with increase in limit number of inquiries which can be buffered for expectation of the corresponding real time flow transfer. The value of relative increase in the radio channels utilization indicator due to buffering of inquiries was calculated according to a formula:

$$\Delta U^* = \frac{(C_{A2} - C_{A1}) \cdot 100\%}{C_{\max}}. \quad (7)$$

In table 2 results of calculating the value ΔU^* where λ=95 min^{-1} and m=0, 2, …, 16 are presented.

Table 2. Calculations results for value ΔU^*

m	0	2	4	6	8	10	12	14	16
ΔU^*, %	0	6.1	9.3	11.4	12.8	13.8	14.5	15.1	15.5

The data analysis in table 2 shows that requests buffering for real-time flows transfer allows to increase MANET radio channel utilization by the value exceeding 15%.

5. DISCUSSION AND CONCLUSION

Increase in radio channels utilization in the course of real-time flows transfer is an important criterion for MANET functioning efficiency. Researches of various options for reservation of the channel resources demanded for implementation of high-quality real-time flows transfer showed that due to buffering of the corresponding inquiries in MANET it is possible to increase the radio channels utilization indicator significantly.

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