Algorithm for receiving the recommended bandwidth of a wireless self-organizing network channel

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ABSTRACT

The article presents the development and research results of a support decision-making algorithm forobtaining the recommended channel bandwidth to achieve the required probability values of satisfactory requests service for audio communication sessions inamobilead - hocnetwork. Therecommended channel bandwidth calculation is based on theservicemodelforrequestingaudio communication sessions in amobileadhoc network.The analytical dependenciesof the satisfactory service are probability values of voice streaming requests on channel characteristics anddynamism of the network topology which have taken into account when executing the algorithm.

The resultsof computationalexperimentsarepresented, which are confirming the correctness of the proposed algorithm.The implementation of the algorithm allows justifying the recommended bandwidth when designing a mobile ad hoc network.

Keywords: Mobile ad hoc network; channel bandwidth;voice streaming which requests servicing for audio communication sessions.

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1. Introduction

Mobile Ad Hoc Network (MANET) – network with random, dynamically changing topology, operating on the packet data transmission basis [1]. Application of MANET technology allows information exchange in the absence of base stations under intensive destructive influences and high mobility of network nodes [2–3]. The realization of audio communication sessions in a wireless self-organizing network based on voice information streams transmission with the required quality makes it possible to fulfill specific tasks related to search and rescue operations, law enforcement, emergency response and terrorism [4–9].

The need for high-quality transmission of streaming information in MANET led to the creation of some routing protocols [10–15], a traffic shaping mechanism for real-time applications based on the transfer of tokens during packet routing in MANET transit nodes [16], and a hybrid scheme for controlling the routing data update rate for streaming information in MANET [17]. However, the above approaches and algorithms do not significantly reduce packet loss and transmission delay and do not guarantee the achievement of the required quality of service requests for audio communication sessions in MANET.

The purpose of the article is to develop and study an algorithm for calculating the recommended channel bandwidth values, which allows support decision-making while designing a mobile ad hoc network to achieve the required probability values of the satisfactory requests service for audio communication sessions.

1.1. Formulation of the problem

To account for the dynamic nature of network topology, we introduce the concepts of primary and secondary voice streams as applied to a particular channel. The main voice streams will include many voice streams that would be transmitted through the channel if the network topology did not change over time. Due to changes in the network topology on this channel, in addition to the main ones, additional voice streams can be transmitted. Also, in a network with dynamic topology, some of the main voice streams on the channel may not be transmitted, and the transmission of certain main and additional voice streams may be stopped prematurely.

We will consider the requests servicing of audio communication sessions to be satisfactory if, within a certain time interval, no more than a specified percentage of the number of the received requests are denied.

The following values are specified:

P_{req} – the required probability of satisfactory requests service of audio communication sessions in a mobile ad hoc network;

K – the maximum number of network channels that can be used to transmit a voice stream during an audio communication session;

T – the time interval for estimating the number of requests for transmitting voice streams over a channel;

B – the percentage number of the unserved requests from the number of received, above which service requests for audio communication sessions are considered unsatisfactory;

λ_{base} – the intensity of the main voice streams transmission requests on the channel;

λ_{add} – the intensity of the additional voice streams transmission requests on the channel;

q_{base} – the requests absence probability for the main voice streams transmission over the channel due to a change in the network topology;

p_{prem} – the voice stream premature transmission termination probability over the channel due to a change in network topology;

τ_{req} – the average required duration of voice stream transmission over a network channel;

C_{prod} – the channel performance required for high-quality transmission of one voice stream;

m – the number that limits the request queue length for transmitting voice streams over a channel;

$C_{\min}..C_{\max}$ – the interval of available channel bandwidth values (value C).

It is necessary to develop an algorithm for obtaining the recommended values of the channel throughput, i.e. such smallest in the range from $C_{\min}$ to $C_{\max}$ values of C, that ensure the achievement of the required probability of satisfactory service of requests for audio communication sessions in a mobile ad hoc network.

2. Algorithm development

Recommended channel bandwidth values of a mobile ad hoc network can be obtained using the model for audio communication sessions requests servicing in MANET [18]. Following this model, the probability of requests satisfactory service for audio communication sessions can be calculated by the formulas:

$$P_{SS} = \left[p^{\alpha} + \sum_{x=1}^{\beta} k_{\alpha,x} p^{\alpha-x} (1-p)^{x} \right]^{K}, \qquad (1)$$

$$k_{\alpha,x}\begin{cases}0, & x \ge \alpha;\\ \alpha, & x = 1 \text{ or } x = \alpha - 1;\\ k_{\alpha-1,x-1} + k_{\alpha-1,x}, & 1 < x < \alpha - 1.\end{cases} \quad (2)$$

where p is the probability of servicing a request for transmitting a voice stream over a channel;

α – the number of requests for the voice streams transmission on the channel received within a given time interval;

β – the limit of unserviceable requests, exceeding which service requests is considered unsatisfactory.

To obtain a value p uses an expression to calculate the servicing probability of a request in a multi-channel system in which the length of the request queue is limited by the value m [19]:

$$p = 1 - \frac{\frac{(\lambda\tau)^n}{n!}\left(\frac{\lambda\tau}{n}\right)^m}{\sum_{k=0}^{n}\left[\frac{(\lambda\tau)^k}{k!}\right] + \frac{(\lambda\tau)^n}{n!}\sum_{u=1}^{m}\left(\frac{\lambda\tau}{n}\right)^u}, \quad (3)$$

where λ – the requests receipt rate for the transmission of voice streams on the channel;

τ – the average voice stream transmission duration over a channel;

n – the number of voice streams that can be simultaneously transmitted over the channel with the required quality.

The value α can be calculated by the formula:

$$\alpha = T\lambda, \quad (4)$$

and the value β according to the formula:

$$\beta = \frac{B\alpha}{100}. \quad (5)$$

The requests receipt value for the voice streams transmission on the channel can be calculated by the formula:

$$\lambda = (1 - q_{base})\lambda_{base} + \lambda_{add}. \quad (6)$$

The average voice channel transmission duration over a channel can be calculated using the expression:

$$\tau = \tau_{req}(1 - p_{prem}). \quad (7)$$

The expression can be used to calculate the n:

$$n = \frac{C}{C_{prod}}. \quad (8)$$

The value α can be calculated by the formula with expression (5):

$$\alpha = \lfloor T[(1 - q_{base})\lambda_{base} + \lambda_{add}]\rfloor, \quad (9)$$

and the value β can be found using the:

$$\beta = \left\lfloor \frac{BT[(1 - q_{base})\lambda_{base} + \lambda_{add}]}{100} \right\rfloor. \quad (10)$$

The algorithm scheme for obtaining the recommended values of a wireless self- organizing network channel bandwidth is shown in Figure 1.

The algorithm prescribes the implementation of the 10 steps below :

Step 1. Initialization is performed (initial data and quantities initial values input): the values P_{req}, K, T, B, C_{prod}, m, λ_{base}, λ_{add}, q_{base}, $C_{\min}$, $C_{\max}$ are set and the quantity initial value is set $C = C_{\min}$.

Step 2. The values of α, β, λ and τ and are calculated by formulas (10), (11), (7) and (8), respectively.

Step 3. A condition check is performed:

$$C > C_{\max}. \tag{11}$$

If this condition is met, go to step 4; otherwise, go to step 10.

Step 4. The value n is calculated by the formula (9).

Step 5. The value p is calculated by the formula (4).

Step 6. The value P_{SS} is calculated by the formulas (1) – (3).

Step 7. A condition check is performed:

$$P_{SS} > P_{req}. \tag{12}$$

If this condition is met, go to step 8, otherwise, go to step 9.

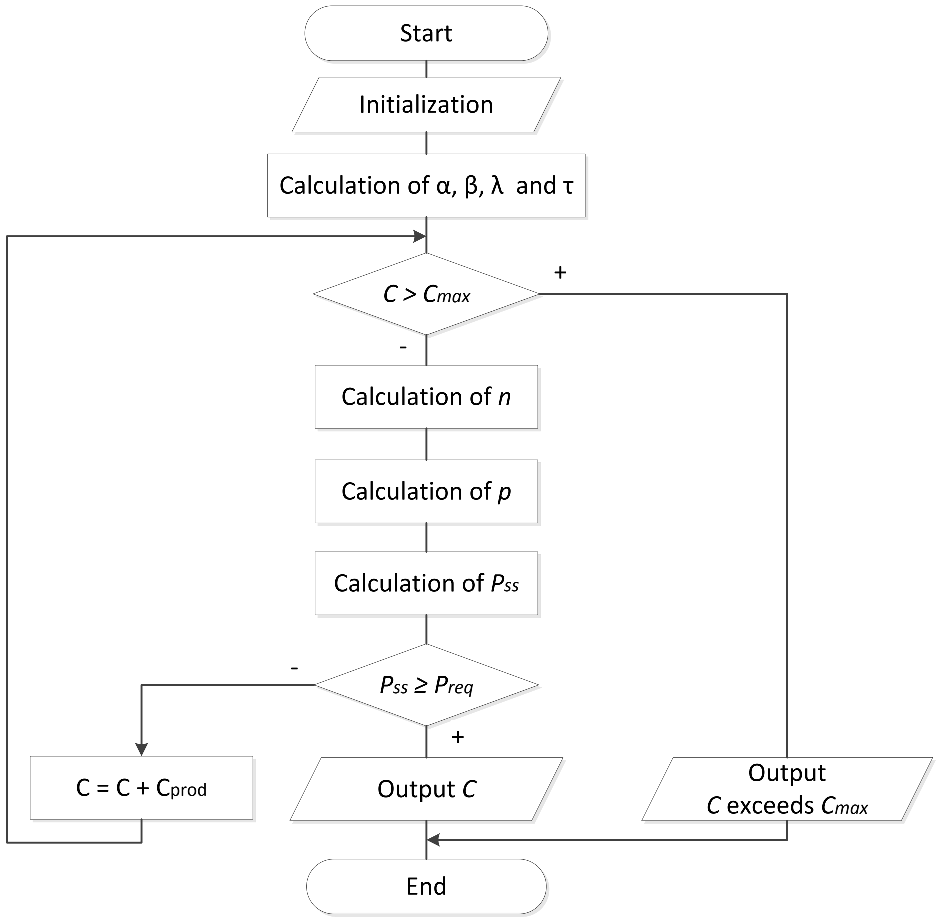

Figure 1. The algorithm scheme

Step 8. The output of C – the recommended channel bandwidth value of the mobile ad hoc network.

Step 9. The current value of C increases by a value C_{prod} and go to step 3.

Step 10. The output of $C_{\max}$ – the recommended channel bandwidth value of the mobile ad hoc network. The recommended channel bandwidth value of the mobile ad hoc network is presented as a result of the algorithm execution.

3. Computational experiments

The presented algorithm was used in computational experiments to obtain the recommended channel bandwidth of a mobile ad hoc network. The results of one of these experiments are presented below as an example.

The source data for the algorithm execution is presented in table 1.

Table 1. The source data for the computational experiment

Quantities	Values
P_{req}	0,95
K	12
T	0,2 hour
B	10 %
λ_{base}	480 hour^{-1}
λ_{add}	120 hour^{-1}
q_{base}	0,1
p_{prem}	0,1
τ_{req}	0,025 hour
C_{prod}	64 Kbps
m	2
$C_{\min}$	64 Kbps
$C_{\max}$	2 048 Kbps

The value of C_{prod} is selected using the standard bit rate of the main digital channel, which allows high-quality transmission of voice information streams [20].

The results of the developed algorithm executing, are presented in table 2.

Table 2. The results of the computational experiment

Quantities	Values
λ	552 hour^{-1}
τ	0,0225 hour
α	110
β	11
n	16
p	0,961
P_{SS}	0,985
C	1 024 Kbps

As a result of the proposed algorithm implementation with given initial parameters, the experimental data shows that the recommended channel bandwidth of the mobile ad hoc network is 1024 Kbps.
Carrying out computational experiments with another initial data corresponding to the actual operating conditions of a mobile ad hoc network showed that the recommended channel bandwidth values obtained as a result of the developed algorithm are in the range from 832 Kbps to 1,280 Kbps. The performed studies confirm the correctness of the algorithm and indicate the feasibility of its application in practice in the design process of a mobile ad hoc network.

4. Conclusion

An algorithm to obtain the recommended channel bandwidth of a mobile ad hoc network has been developed. The calculation of this value is based on a mathematical model that reflects the dependence of the satisfactory service probability values of voice streaming requests on channel characteristics, taking into account the dynamism of the network topology.
Results of computational experiments confirmed the correctness of the proposed algorithm since the initial data used and the obtained simulation results correspond to the actual characteristics of the functioning of a packet network with a dynamic topology in the process of servicing requests for audio communication sessions. The algorithm application makes it possible to substantiate the recommended bandwidth in the design of a mobile ad hoc network.
The direction of further research will be the development of software for the practical implementation of the proposed algorithm.

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