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ANALYSIS OF A MODEL FOR ESTIMATION OF DELAYS IN ACCESS NETWORKS

Abdujapparova Mubarak Baltabaevna
TUIT named after Muhammad al-Khwarizmi, Head of the Department of Telecommunication Engineering

Muradova Alevtina Aleksandrovna
TUIT named after Muhammad al-Khwarizmi, PhD, associate professor of the Department of Telecommunication Engineering
a.muradova1982@inbox.ru

Mirkhosilov Murodjon Muzaffarovich
TUIT named after Muhammad al-Khwarizmi, 2nd year master's student

ABSTRACT

The article presents an analysis of the model for assessing delays in access networks. A mathematical model for calculating the parameters of functioning of distributed data processing systems using wireless technologies with competing access is considered. Some methods used in the analysis of the model for assessing delays in subscriber access networks are presented, as well as an example of Maple 13 software for a numerical solution. The developed mathematical model helped to calculate the law of distribution of packet delivery time, to determine their parameters.

Keywords: *probability of collisions, decreases time delays, the limiting probabilities, graphs of the change in delivery, packet sending intensity.*

АНАЛИЗ МОДЕЛИ ОЦЕНКИ ЗАДЕРЖЕК В СЕТЯХ ДОСТУПА

АННОТАЦИЯ

В статье представлен анализ модели оценки задержек в сетях доступа. Рассмотрена математическая модель для расчета параметров функционирования систем распределенной обработки данных, использующих беспроводные технологии с конкурирующим доступом. Представлены не которые методы, используемые при анализе модели оценки задержек в сетях абонентского доступа, а также пример программного обеспечения Maple 13 для численного решения. Разработанная математическая модель помогла рассчитать закон распределения времени доставки пакетов, определять их параметры.

Ключевые слова: *вероятность коллизий, уменьшение временных задержек, предельные вероятности, графики изменения доставки, интенсивность отправки пакетов.*

INTRODUCTION

As technologies develop and improve, the quality of information transmission improves, noise immunity increases, and time delays in the network decrease. Mathematical modeling of information transmission processes also contributes to solving these problems.

When transmitting data in wireless Wi-Fi networks, a distributed coordination function DCF is used, which uses the carrier sense multiple access with collision avoidance (CSMA/CA) method together with the binary exponential backoff algorithm. This method is used to organize equal access to the data transmission medium in IEEE 802.11 standards and allows for the possibility of errors in information transmission. The transmitting side does not receive an ACK frame about successful reception if the transmission was unsuccessful (due to station collisions or interference), and then the size of the contention window for the transmitting node after each unsuccessful attempt almost doubles according to formula 2, where n = 5,…,10 (for 802.11a). The maximum window size is 1023, 1021 slots. Thus, as the number of collisions increases, the window size increases dynamically, which reduces the probability of collisions and decreases time delays. The sequence of information exchange (for the 802.11a standard) in the case of successful transmission of one packet (fragment) is shown in Figure 1, and in the case of unsuccessful information transmission on the first attempt, but successful on the second - in Figure 2.

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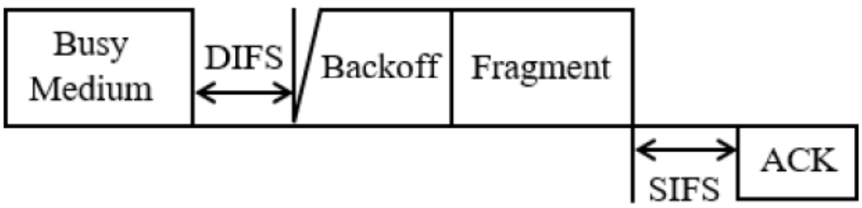

Fig. 1. Successful transmission of one fragment on the first attempt

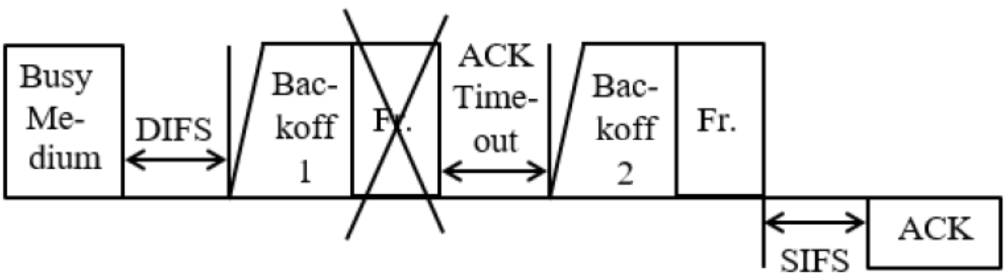

Fig. 2. Unsuccessful transmission of one fragment on the first attempt

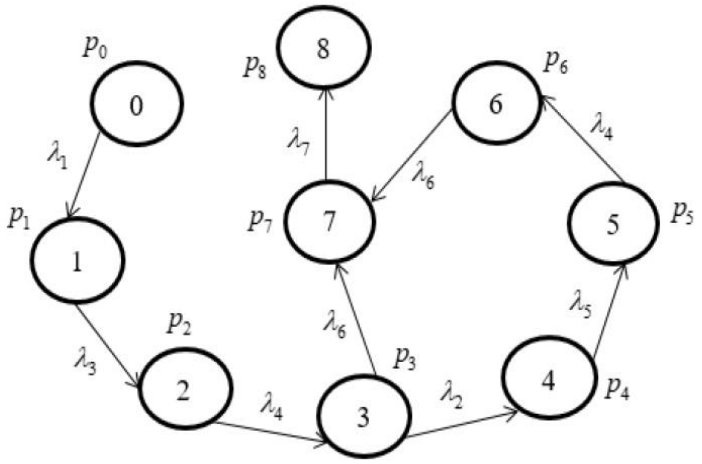

Fig. 3. State graph for possible unsuccessful transmission of one packet by one station with delay

Let us describe the states shown in Figure 3: p_0 is the initial state (there are no packets to send); p_1 is packet generation by the transmitting station; p_2 is pause 1 (the station waits for DIFS + Backoff Time_1); p_3 is the station sending a packet with a delay; p_4 is the station unsuccessfully transmitting some packets the first time; p_5 is pause 2 (the station waits for ACK-Timeout and Backoff Time-2); p_6 is successful transmission of “unsuccessful” packets, p_7 is the transmitting station waiting for SIFS; p_8 is the receiving station transmits an ACK acknowledgement packet with a delay [1,2]. Here λ_i is the information transmission intensity, λ_1 packets/s is the information transmission intensity by the transmitting station, *k* is the unsuccessful sending coefficient (percentage of sent packets). The delay time takes the values 50, 75,100,125 of the delay t [μs].

RESEARCH OBJECT AND METHODS

Solution method. To find the limiting probabilities of the system states and the law of distribution of the information transmission time, we construct a system of Kolmogorov equations corresponding to this graph:

$$\begin{cases} \frac{dp_0}{dt} = -\lambda_1 p_0, \\ \frac{dp_1}{dt} = \lambda_1 p_0 - \lambda_3 p_1, \\ \frac{dp_2}{dt} = \lambda_3 p_1 - \lambda_4 p_2, \\ \frac{dp_3}{dt} = \lambda_4 p_2 - \lambda_2 p_3 - \lambda_6 p_3, \\ \frac{dp_4}{dt} = \lambda_2 p_3 - \lambda_5 p_4, \\ \frac{dp_5}{dt} = \lambda_5 p_4 - \lambda_4 p_5, \\ \frac{dp_6}{dt} = \lambda_4 p_5 - \lambda_6 p_6, \\ \frac{dp_7}{dt} = \lambda_6 p_3 + \lambda_6 p_6 - \lambda_7 p_7, \\ \frac{dp_8}{dt} = \lambda_7 p_7 \end{cases}$$

with initial conditions:

$$\begin{cases} p_0(0)=1, \\ p_i(0)=0 \quad (i=1,\ldots,8). \end{cases}$$

For the numerical solution of system (1)-(2), the parameter values from the IEEE 802.11a standard were used: SLOT TIMER t = 16 μs, SIFS t = μs, DIFS SIFS SLOT TIMER t = 100 μs, ACK Timeout t = μs BACKOFF SLOT TIMER t_d (i_d is a random value of the Backoff Time timer, in this case 1_d = 31 , 2_d = 63), the ACK packet size is 14 bytes, the size of the transmitted FRAGMENT packet is 798 bytes (770 bytes plus 28 bytes of service information). Data transfer rate K is 100 Mbit/s. The solution to the system was found numerically on the segment [0;0.04] with the number of partition segments N = 2000 [3,4].

RESEARCH RESULTS AND THEIR DISCUSSION

For the numerical solution, the Maple 13 software package and the Runge-Kutta Felberg method of 4-5 orders were used. The constructed mathematical model allows calculating the law of delivery time distribution and determining its parameters. For the coefficient of unsuccessful sending k = 0.1%, the influence of different values of the delay time t (50, 75,100,125) of the delay t on the information delivery time was estimated for different values of the packet sending intensity λ_1 (λ_1 varies from 200 to 10000 packets/s). Figure 4 shows the graphs of the change in delivery time for different values of λ_1 with changing values of the delay t. The nature of the curves is close to linear, and the curves are parallel. With increasing intensity, the delivery time decreases, and the higher the intensity, the closer the graphs are to each other [5,6].

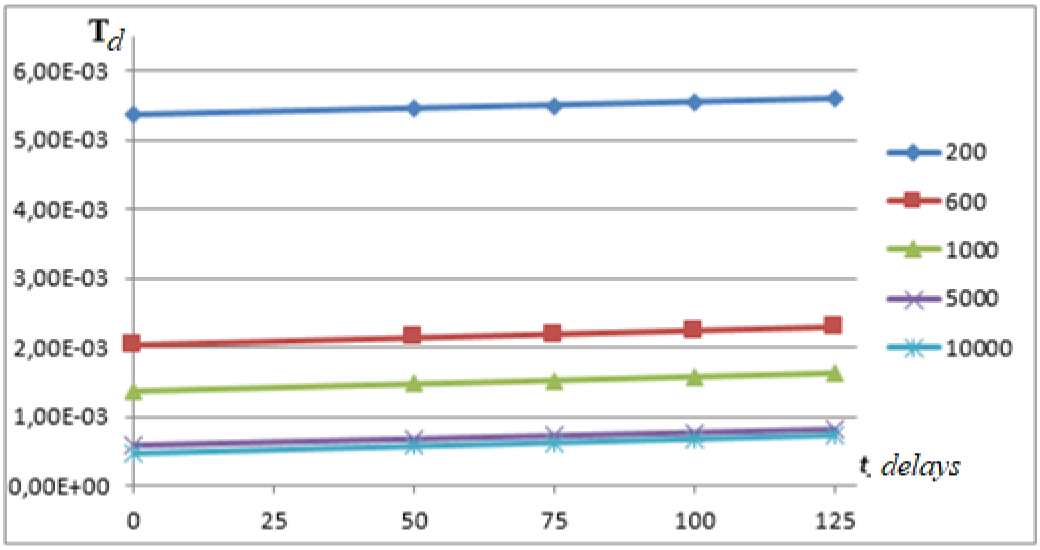

Fig. 4. Change in delivery time for different values of λ_1 with changing values of delay t

Figure 5 shows graphs of change in delivery time for a fixed value of delay t for changing values of λ_1, and shows an exponential decrease in delivery time with an increase in the intensity of sending packets, and for small values of λ_1 the time values are very close, and for large values they differ slightly, increasing with an increase in delay t.

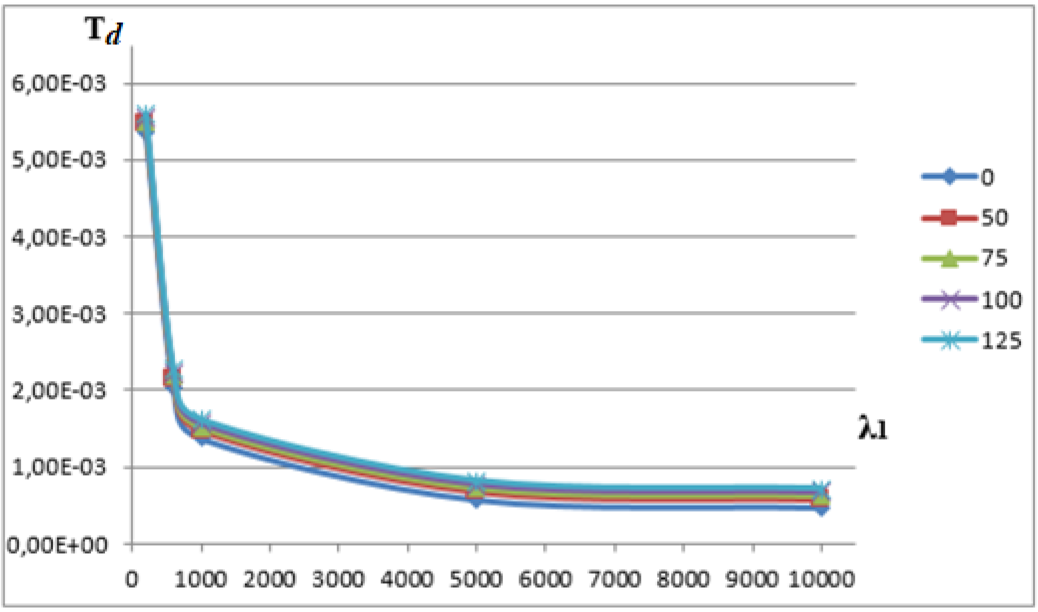

Fig. 5. Change in delivery time at a fixed delay value t for changing values of λ_1

Figure 6 shows graphs of changes in delivery time differences at fixed values of differences t=delay–0 for changing values of λ_1. The nature of the curves is practically constant. With an increase in the values of differences t=delay–0, the difference in delivery times increases.

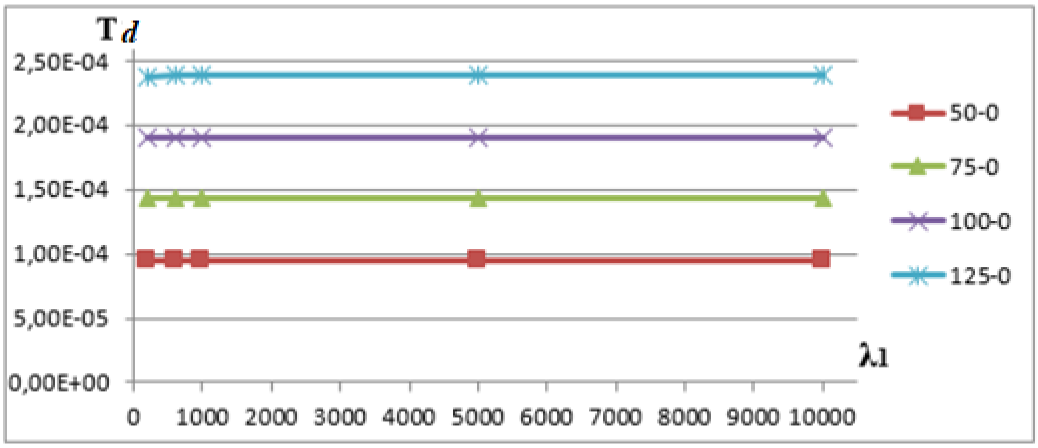

Fig. 6. Change in delivery time differences at fixed values of t=delay–0 differences for changing values of λ_1

SCIENTIFIC RESEARCH RESULTS AND CONCLUSION

Figure 7 shows graphs of change in delivery time differences for different values of λ_1 at changing differences of 50, 75, 100, 125 delay values t = 0. The graphs practically merge with each other, and with an increase in the differences t=delay–0, the difference in delivery times increases linearly [7,8].

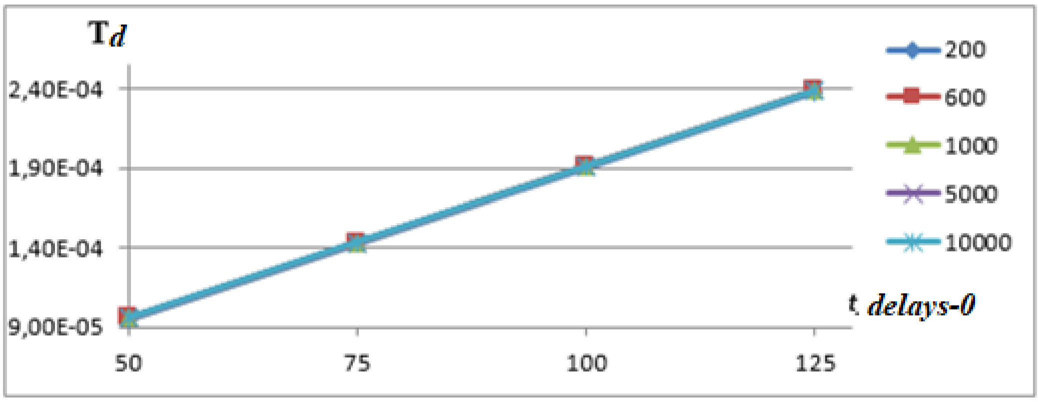

Fig. 7. Change in the differences in delivery times for different values of λ_1 with changing differences in the values of t delay = 0

FINAL CONCLUSION

The constructed mathematical model provides for the possibility of an error occurring during the information transfer process on the first attempt and allows analyzing the operating modes of the Wi-Fi network when changing various parameters: packet generation intensity, data transfer rate, unsuccessful sending rate, delay time. This model can be useful both in designing wireless sections of a distributed information processing network and in their modernization. The model allows estimating and investigating the delivery time of one packet by one station depending on various parameters: delay time, unsuccessful sending rate, packet sending intensity, data transfer rate, etc. The packet exchange process is considered to be homogeneous Markov with discrete states and continuous time. To find the marginal probabilities of the system states and the law of distribution of the information transfer time, a marked state graph and the corresponding system of Kolmogorov equations are constructed. The results of calculating the change in the packet delivery time depending on various parameters are presented. This model can be useful both in designing wireless sections of a distributed information processing network and in upgrading them. Keywords: Wi-Fi, CSMA/CA, WLAN, MAC, data transmission modeling, delay, interference, throughput, medium access protocol.

REFERENCES

1. Ahmetshin, D.A. (2019). Setting the mathematical problem of organizing a seamless wireless network using WiFi technology with content filtering. *Modern knowledge intensive technologies.* № 11. P. 15-23.

2. Fineman, Jeremy T. (2016). Contention Resolution on Multiple Channels with Collision Detection. P*roceedings of the 2016 ACM Symposium on Principles of Distributed Computing*, July, P. 175-184.

3. Fineman, Jeremy T. (2016). Contention Resolution on a Fading Channel. *Proceedings of the 2016 ACM Symposium on Principles of Distributed Computing*, July, P. 155-164.

4. Bender, Michael A. (2016). How to Scale Exponential Backoff: Constant Throughput, Polylog Access Attempts, and Robustness. *Proceedings of the 2016 Annual ACM-SIAM Symposium on Discrete Algorithms*, January, P. 636-654.

5. Bender, Michael A. (2016). Contention resolution with log-logstar channel accesses. *Proceedings of the 48 annual ACM symposium on Theory of Computing*, June, P. 499-508.

6. Glushakov, V. E. (2018). Study of approaches to modeling data transmission in wireless networks. *Scientific journal "Globus": XXX International Scientific and Practical Conference "Achievements and Problems of Modern Science*, Sankt-Peterburg, Part 1. pp. 48-55.

7. Glushakov, V. E. (2020). Research on the dependence of information delivery time on the number of fragments. *Information technologies of modeling and control. International Scientific and Technical Journal*. № 2 (120). P. 130-138.

8. Glushakov, V. E. (2020). Study of the model of unsuccessful transmission of information. *Modern science: problems, ideas, trends: materials of the International Scientific and Practical Conference*. June 23, pp. 46-53.