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ANALYSIS OF THE CHARACTERISTICS OF ROUTING PROTOCOLS IN AD-HOC NETWORK

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ДОСЛІДЖЕННЯ ХАРАКТЕРИСТИК ПРОТОКОЛІВ МАРШРУТИЗАЦІЇ В AD-HOC МЕРЕЖІ

Adhoc мережі набувають значного поширення останнім часом. Впровадження 5G є одним із чинників які прискорюють цей процес. Але стрімкий зріст окрім переваг має і ряд обмежуючих чинників. Одним із таких чинників є велика кількість існуючих протоколів маршрутизації і відсутність стандартизації вже цьому питанні. Тому ця робота присвячена дослідженню ефективності протоколів маршрутизації в adhoc мережах при різних зовнішніх параметрах, таких як рівень навантаження чи мобільність користувачів. Результати дослідження дозволяють обрати найкращий алгоритм маршрутизації в залежності від заданих умов.

Researching the characteristics of routing protocols in ad-hoc networks is a highly relevant task in telecommunications, as wireless ad-hoc networks are becoming increasingly prevalent in remote regions, even in extreme conditions, military operations, and scenarios where establishing infrastructure networks is not feasible. Routing protocols are essential for ad-hoc networks to ensure efficient and reliable data exchange between network nodes. However, due to such networks' dynamic and unpredictable nature, selecting the optimal routing protocol becomes challenging. Current research in this area is necessary to optimize the operation of ad-hoc networks and ensure their best functioning.

Analyzing the characteristics of different protocols enables telecommunications engineers to understand their advantages and limitations, thereby facilitating the development of optimal solutions to enhance the functionality and efficiency of ad-hoc networks in various application scenarios. Current challenges include high variability in packet loss, network instability when users' movement speed changes, and insufficient efficiency of routing protocols in ad-hoc networks.

This work aims to analyze the dependency of packet loss on network uptime, study the impact of users' movement speed on network efficiency, and investigate the effectiveness of different routing protocols in network operation. To achieve this goal, simulations were conducted to collect and analyze relevant information regarding network dynamics, users' movement speeds, and the selected routing protocol. We commenced the research by choosing the optimal moment for simulation to ensure the stability of the metrics. We considered various user movement patterns to identify robust metrics. The research results are presented in a graph, enabling the selection of the best time for further analysis. To thoroughly study packet behavior over different periods, we plan to conduct eight simulations ranging from 70 to 50,000 seconds. These data will be the basis for developing

optimization strategies and network management to improve productivity and efficiency (Figure 1).

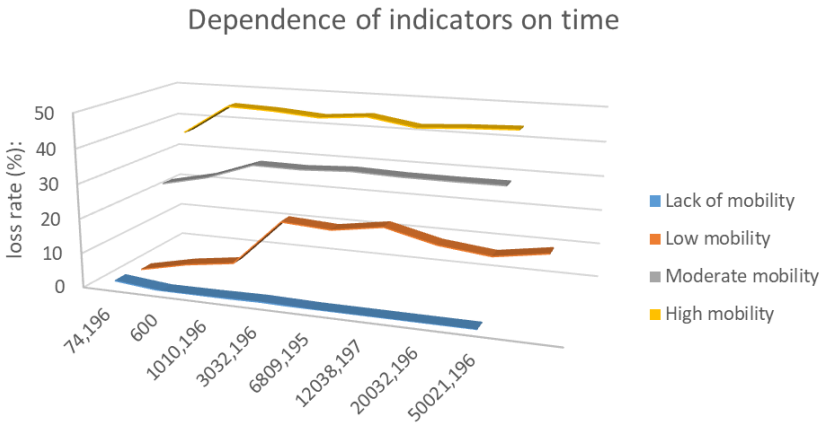

Fig. 1. Dependence of indicators on time.

During the initial stages of network operation, there is a notable exponential growth in traffic, leading to system instability. Conducting research on network parameters during such periods becomes impractical due to the need for more stability to ensure reliable results.

Therefore, waiting for the network to enter a stable operational mode for the load to stabilize and reach its maximum values before embarking on scientific research and network analysis is advisable.

Accordingly, the optimal time interval for conducting research is 20,000 seconds or more. Only under such conditions can sufficient stability and reliability of the obtained data be ensured for further analysis and practical application.

In the subsequent stage of the study, the impact of user mobility on the efficiency of ad-hoc networks using the AODV protocol was analyzed (see Table 1). Notably, for this study, two fixed communication nodes were established, interacting with mobile nodes of varying velocities.

Table 1. Analyzing the impact of user speed on network efficiency.

Speed	**loss rate (%):**	**round-trip avg (ms):**	**stddev (ms):**
Lack of mobility	0,00297965	1.91593	0,101542
Low mobility	16.0342	177,603	857,769
Moderate mobility	30,7564	460,749	1255,67
Fast mobility	43,6678	787,03	1521,98

From the perspective of a telecommunications engineer, the research findings indicate that as the user speed in an ad-hoc network using the AODV protocol increases, data loss increases, as does the average connection setup time and its standard deviation.

In cases where user movement speed is low or mobility is absent, the network efficiency is relatively high, as evidenced by minimal data loss and low average connection setup time. Such conditions may be typical for stationary or low-mobility objects, such as sensors in monitoring systems.

However, in cases where user movement speed is high (moderate to high mobility), network efficiency significantly deteriorates, leading to significant data loss and increased connection setup time. Such conditions may arise, for example, in mobile applications or scenarios where users move quickly.

Thus, an ad-hoc network using the AODV protocol may be effective when a fast and reliable connection between nodes is required in cases of low or zero mobility. However,

issues with network stability and efficiency may arise in cases of high mobility, necessitating additional optimization measures or the selection of a different network type.

In the final stage of the study, an evaluation of network performance using different routing protocols, including AODV, DSDV, and GPSR, was conducted (see Table 2). The results provided important information regarding the performance of each protocol under different network conditions. Specifically, the AODV and GPSR protocols demonstrated low levels of data loss and small average delay times, highlighting their high efficiency in route establishment and data exchange in the network. On the other hand, the DSDV protocol showed significant data loss and ample average delay time, indicating its lesser efficiency than other protocols.

Table 2.Investigation of network performance under different routing protocols.

Протокол	**loss rate (%):**	**round-trip avg (ms):**	**sent**
AODV-1	0.00595752	3.15598	33571
AODV-M	0.00596303	4.81104	33540
DSDV	7,99487	13,9246	33559
GPSR-M	0,152103	14,2624	33530
GPSR-M	0,149134	14,2303	33527

Conclusion. The conducted research confirms the relevance of analyzing routing protocol characteristics in ad-hoc networks, especially considering their prevalence in remote regions and conditions where establishing infrastructure networks is not feasible.

The research results underscore the importance of selecting the optimal routing protocol depending on specific application conditions, such as user mobility and network stability. High user mobility rates may lead to significant data losses and network efficiency degradation, necessitating careful protocol selection and potential optimization strategies.

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