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TRAFFIC MODELING IN UAV/RPAS COMMUNICATION CHANNEL

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Abstract

This study is devoted to obtaining the traffic characteristics of communication channel between the Remotely Piloted Air System (RPAS) and the Base Station, the model of which was created in professional software NetCracker. The dependencies of dropped packets, message Travel Time (TT) and HUB Average Utilization on the Transaction Size (TS), the link bandwidth and the Bit Error Rate (BER) for different distribution laws of Time Between Transactions (TBT) were analyzed. It was observed that for smaller TBT the lower transaction size can be transmitted, which is true for all distributions. But the lowest percentage of packet loss is observed for the LogNormal distribution. Additionally, it was observed that the TT does not depend on the value of the TBT parameter with the Exponential or LogNormal distribution laws, which is not true for the Const law. Hub utilization does not exceed ≈ 20% for all distributions with 1 s TBT. Nevertheless, the maximal TS for LogNormal law is ten times bigger than for other laws. The transaction TT decreases with the transmission rate increase, and for T3 bandwidth it equals to 0.5 s approximately for all considered distributions. However, the smallest percentage of packet loss and HUB utilization is observed for the LogNormal law. The TT does not exceed 1 s for low BER values for all TBT distributions. Such numerical analysis allows us set up and change traffic parameters while observing the results under specified transmission modes.

Keywords: Remotely Piloted Air System (RPAS), communication channel, data traffic, drone, transaction size, time between transactions, travel time, Bit Error Rate, bandwidth, dropped packets, statistical distribution law.

1. Introduction

The Unmanned Aerial Vehicles (UAVs), Remotely Piloted Air Systems (RPASs) or drones are widely used by the civilian and military communities nowadays. The deployment of 5G mobile networks will require the solution of such crucial questions as navigation, control, reliable communication of drones with ground control stations and good interaction between drones in swarms. In this regard, Mobile Ad Hoc Networks (MANETs) and Vehicular Ad Hoc Networks (VANETs) are actively studied from point of view providing the necessary Quality of Service (QoS) for Air-to-Ground (A2G), Ground-to-Ground (G2G) and Air-to-Air (A2A) channels [1 – 3]. Channels' quality and reliability issues in the Space-Air-Ground Integrated Networks (SAGINs) are of particular relevance for the Beyond Line of Sight communications C2 (Command and Control) and C3 (Command, Control and Communications).

The concept of the RPAS as a key component of cellular networks is developed now and the cost-effectiveness of RPASs exploitation is coming currently to the fore. Ensuring reliable and efficient communication between RPAS devices in the line of sight and through the existing infrastructure plays an important role in achieving the necessary performance and security requirements. The use of RPASs together with a conventional network can help improve the cellular system, as well as reduce time and financial investments [4].

The modern environment of drones functioning is constantly becoming more complicated and the demands for reliable data transmission from and to RPAS are increasing. In this regard, significant efforts have recently been made to increase the performance of Radio Access Networks (RAN). Known channel modeling studies do not take into account data traffic features in RPAS communication channels and their impact on the packet loss, the message travel time and the channel utilization. However, messages delays are critical for command and control operations with drones. Knowledge of traffic parameters can effectively improve the use of network resources and increase QoS by choosing the optimal data transfer modes.

The Drone-Base Station (D2B) communication channel is usually ignored or idealized in many works. The D2B channel must be considered accurately, since it ensures the reliability of mobile communication networks. The problem of deploying the three-dimensional networks consisting of drones is affected not only by the user distributions, but also by the quality limitations of D2B channels. It is necessary to design and investigate models for the loss analysis on the air-ground path to maximize the throughput of communication channel. Since the RPAS's wireless communication channel is one of the main components, simulating its operation on models is vital for evaluating the performance of a digital mobile communications system. This study is devoted to obtaining the traffic characteristics of RPAS's communication channel with the Base Station.

2. Analysis of publications and problem statement

The review [1] is devoted to modeling of RPAS communication channels A2G, G2G, and A2A. Recommendations for links budget managing are also provided, taking into account line losses and channel attenuation effects. The improvements using spatial multiplexing of RPAS antennas are analyzed. The latest achievements and future trends in the field of modeling RPAS communication channels and air communication networks are considered in reviews [2 – 8].

An unmanned RAN architecture is proposed in the article [9], in which drones are used to transfer data between base stations and users. First, user coverage and features of D2B connections are analyzed, and then an algorithm for deploying a three-dimensional drone network is implemented to maximize user coverage while maintaining D2B communication quality. The possibility of using RPASs for fifth generation (5G) networks in areas requiring short-term coverage improvement is empirically evaluated in paper [10]. It has been shown that the potential for using ultra-low altitude unmanned aerial vehicles to provide 5G cellular services substantially depends on the quality of the D2B signal and the coverage of the cellular communication. The increased use of RPASs will occur with the introduction of 5G mobile communications, which will require more capacity and high data transfer speed, less latency and a more flexible scalable network.

Hybrid terrestrial satellite networks and the role of RPASs are considered in paper [11]. Opportunities and interest in providing cellular communications in new ways were considered in [12], where it was shown that the use of RPASs in conjunction with a conventional cellular network can improve the cellular system, as well as reduce time and financial investment. The use of any air drone as an intermediate node between the user and the installed wireless network is considered in article [13]. Radio channel modeling for RPAS communication over cellular networks was studied in [14]. Network modeling in [15] included several airborne cellular base stations that are in constant motion. It has been found that constant movement increases throughput and reduces the number of drones needed.

RPASs will become an integral part of the next generation wireless networks, as their application in various communication applications will improve coverage and spectral efficiency compared to traditional ground-based solutions. The manuscript [16] provides a detailed review of research works in which machine learning (ML) methods were used to improve various design and functional aspects, such as RPAS channel modeling, resource management, positioning, and security.

Simulation of RPAS data transmission via satellites using MATLAB and NetCracker software was described in [17 – 21]. Satellite channel parameters based on IEEE 802.11a, 802.11 b, 802.16 and Long-Term Evolution (LTE) standards and RPAS satellite traffic characteristics were estimated. Simulation of network-connected UAV/RPAS communications with estimation of data loss is presented in [22].

The aim of this article is: 1) to create model of RPAS communication channel with the Base Station using NetCracker software; 2) to analyze the dependencies of the HUB dropped packets, the Travel Time (TT) and the HUB Average Utilization on the Transaction Size (TS) with different distribution laws for the Time Between Transactions (TBT); 3) to obtain the dependencies of the HUB dropped packets, the TT parameter and the HUB Average Utilization on the bandwidth for different distribution laws for the TBT parameter; 4) to investigate the dependencies of the TT parameter and the HUB Average Utilization on the Bit Error Rate (BER) for different distribution laws for the TBT parameter.

3. RPAS communication channel simulation

Communication channel model (Fig. 1) was designed using Professional NetCracker 4.1 software (https://www.netcracker.com/). The model contains the Base Station (BS), the HUB — Wireless Local Area Network (WLAN) station, and the RPAS. The BS contains an Ethernet server with 10 Mbps bandwidth and the Ethernet switch with 10 Mbps bandwidth too. The BS–HUB link is fiber optic cable and has T3 (44.736 Mbps) data rate, the Packet Latency of zero seconds and BER = 0. The HUB –

RPAS link has T3 data rate, the Packet Latency of zero and BER = 0. The RPAS is the usual WLAN equipment with a bandwidth of 10 Mbps.

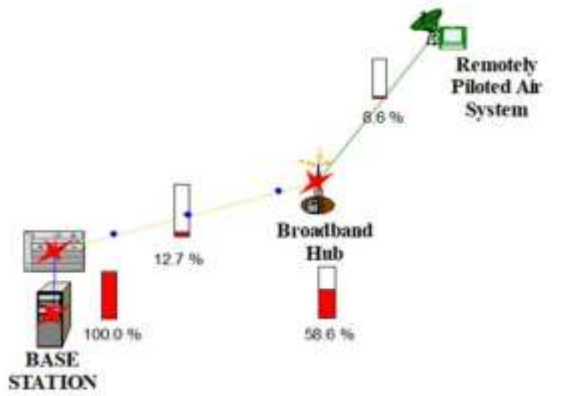
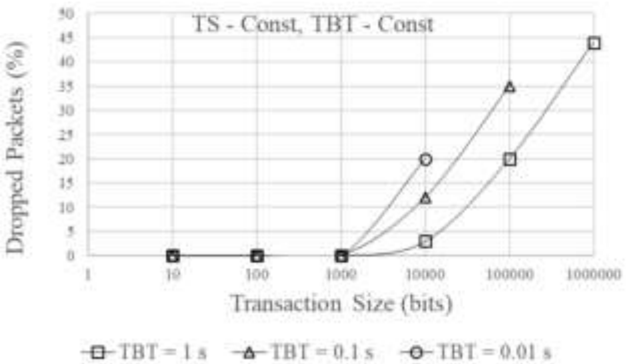


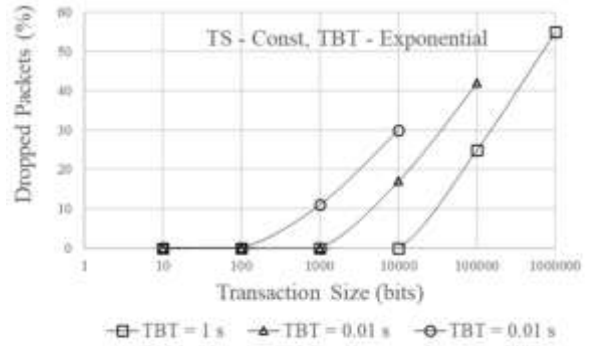
Fig. 1. BS – HUB – RPAS communication channel

Fig. 2 shows the dependencies of HUB dropped packets on the transaction size, the time between transactions, and the type of statistical distribution law. The general distribution law (Const) is selected for the TS parameter in Fig. (2a, 2b, 2c), and three different laws for the TBT parameter — Const (Fig. 2a), Exponential (Fig. 2b) and LogNormal (Fig. 2c).

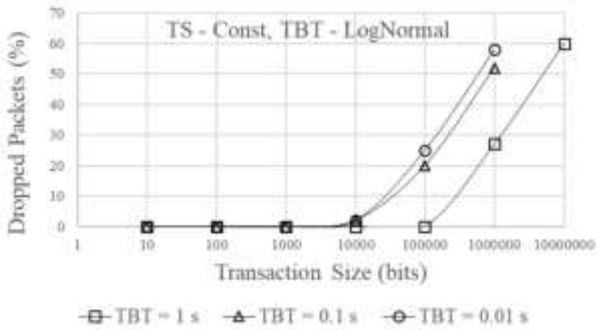
The value of the TS parameter varied from 10 bits to 1 Mbits, and the TBT parameter took values of 1 s, 0.1 s, and 0.01 s. These values are selected from the considerations that aircraft Automatic Dependent Surveillance - Broadcast (ADS-B) messages of 112 bits in size (Grekhov, 2019, p.277) are transmitted with an interval (0.2 - 1.0) s. Therefore, the values of the TBT parameter are selected to be 10 times different from each other, taking into account a wide range of transaction size changes. This allows simulating the change in channel utilization in real conditions and determine critical situations in terms of information loss during data transfer.



(a)



(b)

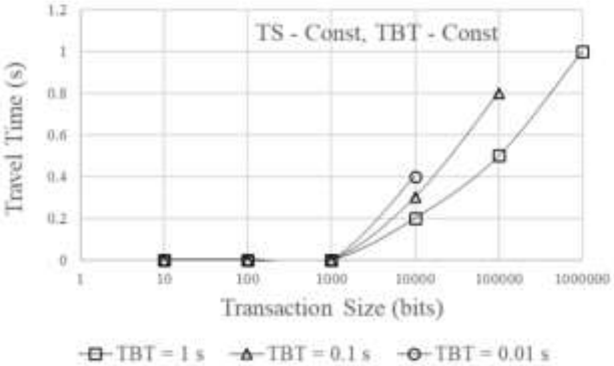


(c)

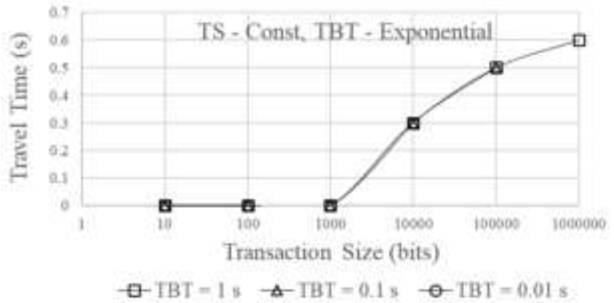
Fig. 2. Dependencies of HUB Dropped Packets on TS (RPAS link with T3 bandwidth)

Fig. (2a, 2b, 2c) show the maximum possible packet sizes for transmission under the specific conditions shown in the figures. The channel simply closes for larger TS values. For example, the largest possible transaction size with TBT = 0.01 s (Const law) is TS = 10 Kbits (Fig. 2a). Therefore, using the obtained data, it is possible to predict which modes of reliable transmission are permissible. The same will apply to dependencies given in Figs. 2b, 2c. Obtained results allow to identify the following patterns. The smaller the TBT parameter is, the lower the maximum value of the transaction that can be transmitted. This is true for all distributions. The transmission of the largest packets with TS = 10 Mbit is possible for the LogNormal law with TBT = 1 s (Fig. 2c). In a transaction with TS = 1 Mbits and TBT = 1 s, the number of lost packets reaches ≈ 44% for Const law (Fig. 2a), ≈ 55% for Exponential law (Fig. 2b) and ≈ 28% for LogNormal law (Fig. 2c). The lowest percentage of packet loss is observed for LogNormal distribution. For LogNormal law (Fig. 2c), unlike the other two distributions, the packet loss for TBT = 0.1 s and TBT = 0.01 s turn out to be close. This may be a favorable factor for transmitting sufficiently large packets at small time intervals.

Fig. 3 shows the dependence of messages travel time through the communication channel on the transactions size and the time interval between them for different statistical distributions. For the data in Fig. 3 (a, b, c) the general law (Const) is selected for the TS parameter.



(a)



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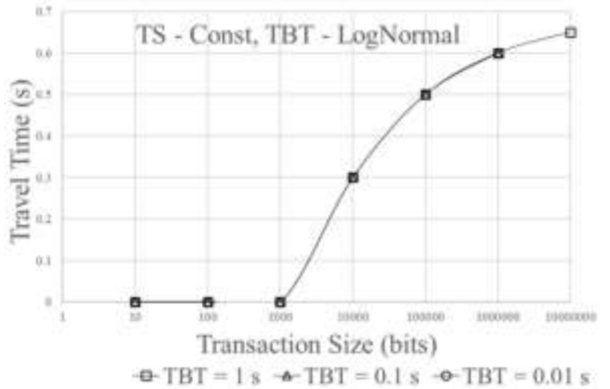


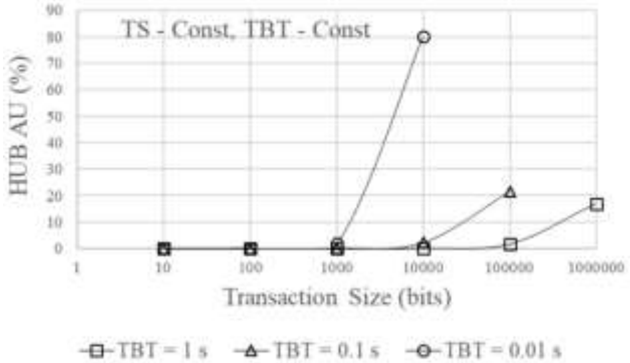
(c)

Fig. 3. Dependencies of transaction Travel Time on TS (RPAS link with T3 bandwidth)

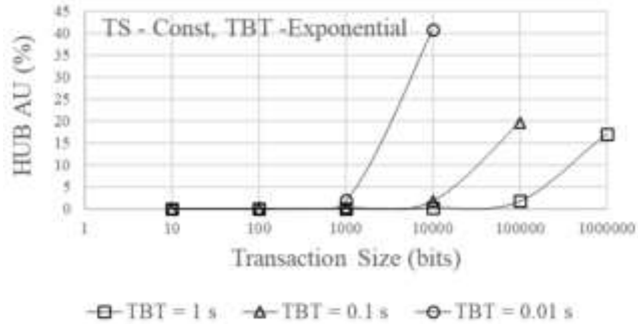
The following features are noteworthy. The nature of the TT parameter dependence on the TS for the TBT parameter with Const law (Fig. 3a) differs from the Exponential law (Fig. 3b) and the LogNormal law (Fig. 3c) in the following way: for two latter laws the travel time does not depend on the value of the TBT parameter, but for Const law in Fig. 3a the travel time differs significantly for values of 1 s, 0.1 s, and 0.01 s.

The travel time increases with the packet size increase and turns out to be ≈ 1.0 s for the Const law with TS = 1 Mbits and TBT = 1 s (Fig. 3a), ≈ 0.6 s for the Exponential law with TS = 1 Mbits and TBT = 1 s (Fig. 3b) and ≈ 0.65 s for LogNormal law with TS = 10 Mbits and TBT = 1 s (Fig. 3c).

The dependence of HUB utilization on the transactions size and time between them for different statistical distribution laws of the TBT parameter is presented in Fig. 4. The general law (Const) of TS parameter distribution is selected in Fig. 4. Here, as in Figs. 2 and 3, data for the maximum possible packet sizes are shown. The following features are observed.



(a)



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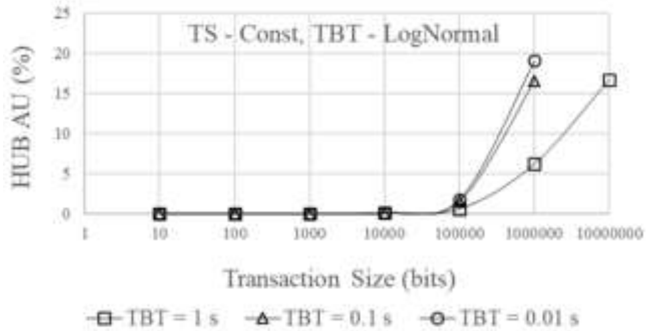


(c)

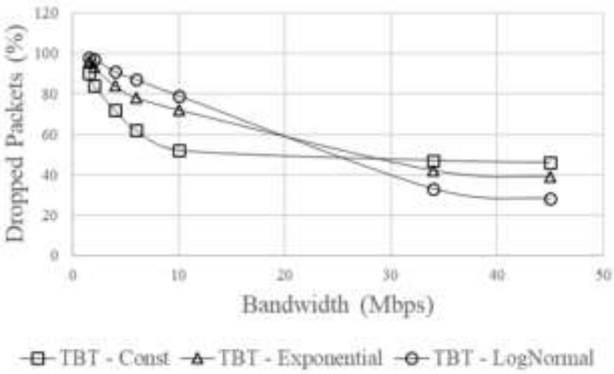
Fig. 4. Dependencies of HUB AU on TS (RPAS link with T3 bandwidth)

Hub utilization does not exceed ≈ 20% for all distributions with TBT = 1 s (Fig. 4 a, b, c). Nevertheless, the maximal transaction size for LogNormal law is ten times bigger than for Const and

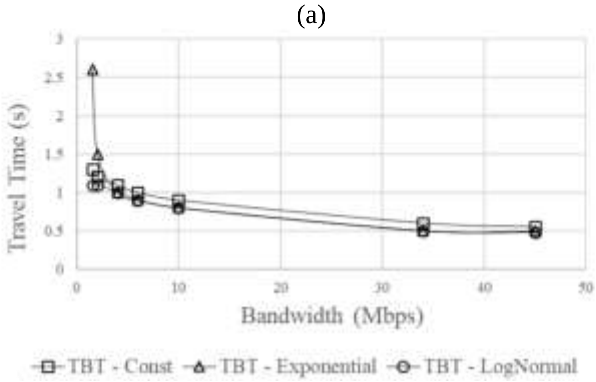
Exponential laws (Fig. 4c). The HUB utilization increases (Fig. 4a, b, c) with the TBT parameter decreasing and the maximal packet size decreases. The TBT parameter is critical for the Const and Exponential laws (Fig. 4a, b) with its decrease. This means that if for TBT = 1 s and TBT = 0.1 s the value of the AU parameter is almost the same, but for TBT = 0.01 s the HUB utilization is doubled for the Exponential law (Fig. 4b) and reaches ≈ 40%, and for the Const law it reaches ≈ 80%.

At the same time, a completely different behavior is observed for the LogNormal law (Fig. 4c), where the HUB utilization is ≈ (17-20) % for all three TBT intervals. Values of the maximal packet size at the same time are significantly larger: 10 Mbits for LogNormal law compared to 1 Mbits for Const and Exponential laws.

Of particular relevance is understanding of packet loss (Fig. 5a), transaction travel times (Fig. 5b) and HUB utilization (Fig. 5c) dependencies on the data rate. The transaction with TS = 500 Kbits and TBT = 1 s with various statistical distribution laws was studied as an example when obtaining the presented dependencies, for which the following features were established.



(a)



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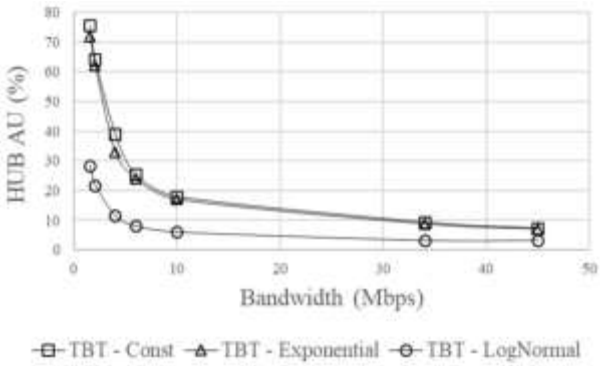


(c)

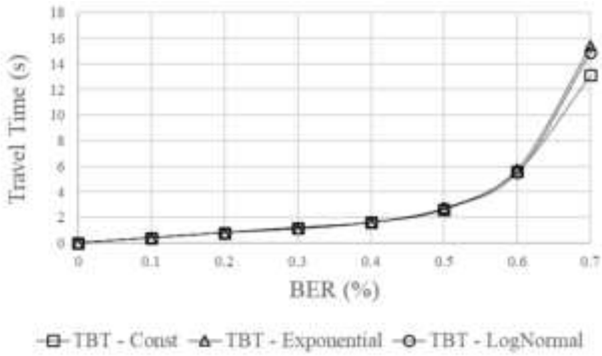
Fig. 5. Dependencies on HUB-RPAS bandwidth (TS=500 Kbits - Const, TBT=1 s)

A channel with a data rate of less than 10 Mbps results in the loss of more than half of all transmitted packets (Fig. 5a). The smallest percentage of packet loss is observed for the LogNormal law with E3 = 34.368 Mbps and T3 = 44.736 Mbps bandwidth (Fig. 5a). The transaction travel time decreases with the transmission rate increase and turns out to be almost the same (TT ≈ 0.5 s) for all distributions at T3 bandwidth (Fig. 5b).

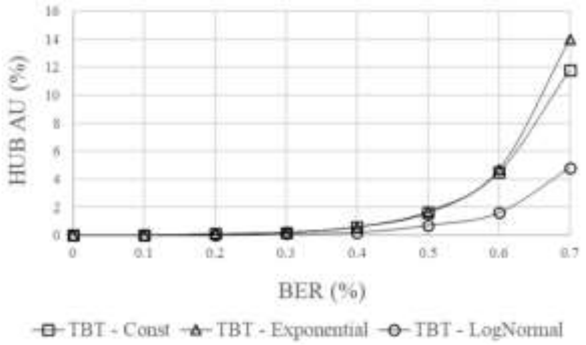
For the date rate E1 = 2.048 Mbps the TT parameter increases and can reach values ≈ (1.0 - 1.5) s. HUB utilization is less than 10% for E3 and T3 bandwidths for all distributions, but it is the smallest for the LogNormal law (Fig. 5c). For T1 bandwidth HUB utilization can reach ≈ (70-75) % for Const and Exponential laws, but it is less than ≈ 30% for LogNormal law.

The growth of traffic inevitably leads to an increase in the number of bit errors, messages travel time and HUB utilization respectively.

Fig. 6 demonstrates these processes using example of transferring a transaction with TS = 1 Kbits (Const law) and TBT = 1 s for all considered earlier statistical distributions. The BER value for channels without additional error protection is 10-4–10-6, and for fiber – 10-9. The value of the BER parameter 0.1 % corresponds to a value of 10-3, which indicates a high intensity of bit errors. Nevertheless, the BER value varied from zero to 0.7 % for analysis during modeling.



(a)



(b)

Fig. 6. Dependencies on HUB-RPAS BER (TS=1 Kbits - Const, TBT=1 s, RPAS link with T3 bandwidth)

The dependencies character (Fig. 6a) of the TT parameter on the BER is almost the same for all statistical distributions up to BER = 0.6 %. Moreover, the travel time does not exceed 1 s for values up to BEP = 0.3 %. This allows to conclude that bit errors do not critically affect the travel time for messages with the selected parameters.

As can be seen from Fig. 6b, HUB utilization also practically does not increase when transmitting selected test messages up to BER = 0.3 %. The value of BER = 0.7 % corresponds to a large number of bit errors, which is observed for hard traffic. HUB utilization increases and can reach ≈ 12 % for the Const law, ≈ 14 % for Exponential law and ≈ 5 % for the LogNormal distribution law (Fig. 6b).

4. Conclusions

The Line of Sight data transmission model of the BS-HUB-RPAS channel was designed using NetCracker Professional 4.1, which is a powerful analytical simulator for the structural-logical design and performance prediction of computer and communication networks. The quantitative characteristics of the RPAS data traffic were obtained for the first time. Such data are currently not available in the literature.

First, the dependencies of the HUB dropped packets (Fig. 2), the messages Travel Time (Fig. 3) and the HUB Average Utilization (Fig. 4) on the Transaction Size with different distribution laws for the Time Between Transactions were analyzed. For the data transmission under the specific studied conditions it was observed that the largest possible transaction size for the TBT = 0.01 s with the Const and Exponential distribution laws was 10 Kbits, while for the LogNormal distribution it was significantly higher – 1 Mbit. The channel simply closed for larger TS values. In general, the smaller the TBT parameter was, the lower transaction size could be transmitted, which was valid for all distributions. However, for the LogNormal distribution the percentage of packet loss was the lowest, and in contrast to the other two distributions, packet loss for TBT = 0.1 s and TBT = 0.01 s turned out to be very close (Fig. 2c). This could be a favorable factor for transmitting sufficiently large packets at small time intervals. The nature of the TT parameter dependence on the TS for the TBT parameter with Const law (Fig. 3a) differs from the Exponential law (Fig. 3b) and the LogNormal law (Fig. 3c) in the following way: for two latter laws the travel time does not depend on the value of the TBT parameter, but for Const law in Fig. 3a the travel time differs significantly for values of 1 s, 0.1 s, and 0.01 s. The TBT parameter has appeared to be critical for the Exponential and Const distribution laws with its decrease in terms of HUB utilization (Fig. 4a, b), which reaches ≈ 40% and 80% for the Exponential and Const laws correspondently. At the same time, for the LogNormal law (Fig. 4c) the HUB utilization did not exceed 20 % for all three TBT intervals.

Next, the dependencies of the HUB dropped packets (Fig. 5a), the Travel Time (Fig. 5b) and the HUB Average Utilization (Fig. 5c) on the bandwidth for different distribution laws for the Time Between Transactions were obtained, where again the LogNormal distribution law showed better performance in comparison with two others.

In addition, the dependencies of the Travel Time (Fig. 6a) and the HUB Average Utilization (Fig. 6b) on the Bit Error Rate for different distribution laws for the Time Between Transactions were investigated. It was discovered that low Bit Error Rates do not critically affect the travel time for all TBT distribution laws. However, for the hard traffic, with BER ≥ 40 % use of LogNormal distribution law is preferable, because it gives less percentage of HUB average utilization.

The importance of such numerical analysis lies in the ability to set traffic parameters and observe the resulting throughput, packet loss, the number of bit errors and QoS in the channel under certain transmission modes. This allows one to identify critical cases when communication becomes unreliable or is completely interrupted.

References

[1] Yan, C., Fu, L., Zhang, J., & Wang, J. (2019). A Comprehensive Survey on UAV Communication Channel Modeling. IEEE Access, 7, pp. 107769–107792. https://doi.org/10.1109/ACCESS.2019.2933173

[2] Khuwaja, A. A., Chen, Y., Zhao, N., Alouini, M. S., & Dobbins, P. (2018). A survey of channel modeling for uav communications. IEEE Communications Surveys and Tutorials, 20(4), pp 2804–2821. https://doi.org/10.1109/COMST.2018.2856587

[3] Khawaja, W., Guvenc, I., Matolak, D. W., Fiebig, U., & Schneckenburger, N. (2019). A Survey of Air-to-Ground Propagation Channel Modeling for Unmanned Aerial Vehicles. IEEE Communications Surveys & Tutorials, 21(3), pp. 2361–2391. https://doi.org/10.1109/COMST.2019.2915069

[4] Cao, X., Yang, P., Alzenad, M., Xi, X., Wu, D., & Yanikomeroglu, H. (2018). Airborne communication networks: A survey. In IEEE Journal on Selected Areas in Communications (Vol. 36, Issue 9, pp. 1907–1926). https://doi.org/10.1109/JSAC.2018.2864423

[5] Li, B., Fei, Z., & Zhang, Y. (2019). UAV Communications for 5G and Beyond: Recent Advances and Future Trends. IEEE Internet of Things Journal, 6(2), pp. 2241–2263. https://doi.org/10.1109/JIOT.2018.2887086

[6] Mozaffari, M., Saad, W., Bennis, M., Nam, Y. H., & Debbah, M. (2019). A Tutorial on UAVs for Wireless Networks: Applications, Challenges, and Open Problems. IEEE Communications Surveys and Tutorials, 21(3), pp. 2334–2360. https://doi.org/10.1109/COMST.2019.2902862

[7] Vinogradov, E., Sallouha, H., De Bast, S., Azari, M. M., & Pollin, S. (2018). Tutorial on UAVs: A blue sky view on wireless communication. In Journal of Mobile Multimedia (Vol. 14, Issue 4, pp. 395–468). https://doi.org/10.13052/jmm1550-4646.1443

[8] Sharma, V. (2019). Advances in Drone Communications, State-of-the-Art and Architectures. Drones, 3(1), 21 p. https://doi.org/10.3390/drones3010021

[9] Shi, W., Li, J., Xu, W., Zhou, H., Zhang, N., Zhang, S., & Shen, X. (2018). Multiple drone-cell deployment analyses and optimization in drone assisted radio access networks. IEEE Access, 6, pp. 12518–12529. https://doi.org/10.1109/ACCESS.2018.2803788

[10] Catherwood, P. A., Black, B., Mohamed, E. B., Cheema, A. A., Rafferty, J., & McLaughlin, J. A. D. (2019). Radio channel characterization of mid-band 5G service delivery for ultra-low altitude aerial base stations. IEEE Access, 7, pp. 8283–8299. https://doi.org/10.1109/ACCESS.2018.2885594

[11] Marchese, M., Moheddine, A., & Patrone, F. (2019). IoT and UAV integration in 5G hybrid terrestrial-satellite networks. Sensors (Switzerland), 19(17), 3704 p. https://doi.org/10.3390/s19173704

[12] Naqvi, S. A. R., Hassan, S. A., Pervaiz, H., & Ni, Q. (2018). Drone-Aided Communication as a Key Enabler for 5G and Resilient Public Safety Networks. IEEE Communications Magazine, 56(1), pp. 36–42. https://doi.org/10.1109/MCOM.2017.1700451

[13] Al-Hourani, A., & Gomez, K. (2018). Modeling Cellular-to-UAV Path-Loss for Suburban Environments. IEEE Wireless Communications Letters, 7(1), pp. 82–85. https://doi.org/10.1109/LWC.2017.2755643

[14] Amorim, R., Nguyen, H., Mogensen, P., Kovács, I. Z., Wigard, J., & Sørensen, T. B. (2017). Radio Channel Modeling for UAV Communication over Cellular Networks. IEEE Wireless Communications Letters, 6(4), pp. 514–517. https://doi.org/10.1109/LWC.2017.2710045

[15] Fotouhi, A., Ding, M., & Hassan, M. (2018). Flying Drone Base Stations for Macro Hotspots. IEEE Access, 6, pp. 19530–19539. https://doi.org/10.1109/ACCESS.2018.2817799

[16] Bithas, P. S., Michailidis, E. T., Nomikos, N., Vouyioukas, D., & Kanatas, A. G. (2019). A survey on machine-learning techniques for UAV-based communications. In Sensors (Switzerland) (Vol. 19, Issue 23, p. 5170). Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/s19235170

[17] Kharchenko, V., Wang, B., Grekhov, A., & Leschenko, A. (2016). Modelling the satellite communication links with orthogonal frequency-division multiplexing. Transport, 31(1), pp. 22–28. https://doi.org/10.3846/16484142.2014.1003599

[18] Grekhov, A. M. (2019). Recent Advances in Satellite Aeronautical Communications Modeling.

IGI Global. https://doi.org/10.4018/978-1-5225-8214-4

[19] Grekhov, Andriy, Kondratiuk, V., Ilnytska, S., Vyshnyakova, Y., Kondratiuk, M., & Trykoz, V. (2019). Satellite Traffic Simulation for RPAS Swarms. 2019 IEEE 5th International Conference Actual Problems of Unmanned Aerial Vehicles Developments, APUAVD 2019 - Proceedings, pp. 265–269. https://doi.org/10.1109/APUAVD47061.2019.8943881

[20] Grekhov, Andrii, Kondratiuk, V., & Ilnitska, S. (2020). RPAS Satellite Communication Channel Based on Long-Term Evolution (LTE) Standard. Transport and Aerospace Engineering, 8(1), pp. 1–14. https://doi.org/10.2478/tae-2020-0001

[21] A. Grekhov, V. Kondratiuk, S. Ilnytska. “RPAS Communication Channels Based on WCDMA 3GPP Standard”. Aviation, vol. 24, no. 1 (May 2020), pp. 42-49, doi:https://doi.org/10.3846/aviation.2020.12166.

[22] S. I. Ilnytska, F. Li, A. Grekhov and V. Kondratiuk. (2020). "Loss Estimation for Network-Connected UAV/RPAS Communications," in IEEE Access, vol. 8, pp. 137702-137710, 2020, doi: 10.1109/ACCESS.2020.3011956.

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Моделювання трафіку в каналі зв'язку дистанційно пілотованої повітряної системи

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Дане дослідження присвячене отриманню характеристик трафіку каналу зв'язку між дистанційно пілотованих літальних апаратом і базовою станцією, модель якого створена в професійному програмному забезпеченні NetCracker. Були проаналізовані залежності втрачених пакетів, часу проходження повідомлення і середнього використання каналу в залежності від розміру транзакції, пропускної здатності каналу і частоти помилок по бітам для різних законів розподілу часу між транзакціями. Було відмічено, що при меншому часі між транзакціями може передаватися менший розмір транзакції, що вірно для усіх розподілів. Але найнижчий відсоток втрати пакетів спостерігається для логнормального розподілу. Крім того, було відмічено, що час передачі повідомлення не залежить від значення параметра «час між транзакціями» з експоненціальним або логарифмічним законами розподілу, що не є правдою для константного закону. Завантаження хаба не перевищує ≈ 20% для всіх типів розподілу з часом між передачею транзакціями в 1 с. Проте, максимальний розмір транзакції для логнормального закону в десять разів більше, ніж для інших законів. Час передачі транзакції зменшується зі збільшенням швидкості передачі і для смуги пропускання Т3 складає приблизно 0,5 с для всіх розглянутих типів розподілів. Однак найменший відсоток втрати пакетів і використання каналу спостерігається для логнормального закону. Час передачі повідомлення не перевищує 1 с для низьких значень частоти помилок по бітам для всіх розподілів часу між транзакціями. Такий чисельний аналіз дозволяє нам налаштовувати і змінювати параметри трафіку, спостерігаючи за результатами при заданих режимах передачі.

Ключові слова: дистанційно пілотована повітряна система, канал зв'язку, трафік даних, дрон, розмір транзакції, час між транзакціями, час передачі, частота бітових помилок, пропускна здатність, відкинуті пакети, закон статистичного розподілу

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Моделирование трафика в канале связи дистанционно пилотируемой воздушной системы

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Данное исследование посвящено получению характеристик трафика канала связи между дистанционно пилотируемым летательным аппаратом и базовой станцией, модель которого создана в профессиональном программном обеспечении NetCracker. Были проанализированы зависимости утраченных пакетов, времени прохождения сообщения и среднего использования канала в зависимости от размера транзакции, пропускной способности канала и частоты ошибок по битам для различных законов распределения времени между транзакциями. Было замечено, что при меньшем времени между транзакциями может передаваться меньший размер транзакции, что верно для всех распределений. Но самый низкий процент потери пакетов наблюдается для Логнормального распределения. Кроме того, было замечено, что время передачи сообщения не зависит от значения параметра «время между транзакциями» с экспоненциальным или логарифмическим законами распределения, что не является правдой для константного закона. Загрузка хаба не превышает ≈ 20% для всех типов распределения со временем между передачей транзакциями в 1 с. Тем не менее, максимальный размер транзакции для Логнормального закона в десять раз больше, чем для других законов. Время передачи транзакции уменьшается с увеличением скорости передачи и для полосы пропускания T3 составляет примерно 0,5 с для всех рассмотренных типов распределений. Однако наименьший процент потери пакетов и использования канала наблюдается для Логнормального закона. Время передачи сообщения не превышает 1 с для низких значений частоты ошибок по битам для всех распределений времени между транзакциями. Такой численный анализ позволяет нам настраивать и изменять параметры трафика, наблюдая за результатами при заданных режимах передачи.

Ключевые слова: дистанционно пилотируемая воздушная система, канал связи, трафик данных, дрон, размер транзакции, время между транзакциями, время передачи, частота битовых ошибок, пропускная способность, отброшенные пакеты, закон статистического распределения

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