UAVs or drones as an alternative solution to providing high-quality Internet service in difficult terrain are environmentally friendly and do not consume electricity during the day as is the case with communication towers. But the developers of the network face difficulties in the drone communication system associated with the need to take into consideration unpredictable weather conditions and terrain, as well as the short life of the drone's batteries. Therefore, the object of this study is the process of managing UAV traffic through the use of gNB-IoT in 5G.

The possibility of using a mobile UAV repeater during traffic management using radio resources (RR), radio access network (RAN), the infrastructure with broadcasting tools and dynamic connection using MU-MIMO modulation is shown. The use of these tools makes it possible to connect the drone to the wired base network from the provider and then restore the radio frequency signal and broadcast to another coverage area where this subscriber does not have network coverage, use the channel quality indicator (CQI) representation as a QoE function.

Undoubtedly, traffic management is the process of obtaining information about traffic control from one endpoint to another, which confirms the reliability and management of data transmission. Meanwhile, drone traffic management can be used to reduce time delays and remove network interference by relying on Internet of Things programs that use NB-5G technology. The UAV's traffic management improvement process uses a proposed algorithm to generate dynamic flow data management to enhance traffic processing of flow control in the IoT

Keywords: traffic management, unmanned aerial vehicle, Internet of Things, 5G network, gNB-IoT

UDC 004.77
DOI: 10.15587/1729-4061.2022.260084

DEVISING A TRAFFIC CONTROL METHOD FOR UNMANNED AERIAL VEHICLES WITH THE USE OF GNB-IOT IN 5G

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Received date 12.04.2022
Accepted date 16.06.2022
Published date 30.06.2022

***How to Cite**: Qasim, N. H., Jawad Abu-Alshaeer, A. M., Jawad, H. M., Khlaponin, Y., Nikitchyn, O. (2022). Devising a traffic control method for unmanned aerial vehicles with the use of gNB-IOT in 5G. Eastern-European Journal of Enterprise Technologies, 3 (9 (117)), 53–59. doi: https://doi.org/10.15587/1729-4061.2022.260084*

1. Introduction

An important task is to provide high-quality Internet service in remote areas that do not have coverage towers, such as mountains, forests, and deserts, but in which there is such a need (firefighting, rescue operations, destruction of traditional communication networks, etc.). One way to solve this problem is to use unmanned aerial vehicles (UAVs or drones), the effectiveness of which is at the level of communication towers and covers larger areas. Developers face difficulties in the drone communication system associated with the need to take into consideration unpredictable weather conditions and terrain, as well as the short life of the drone's batteries.

The IoT strategy will depend on different traffic management scenarios for appropriate UAV mobility. UAVs provide NB-IoT applications with low data rates, a large number of connected devices, and a large coverage range.

The disadvantage of UAV applications is the imperfection of UAV traffic control in the context of the need to receive Internet service and 5G or 4G network coverage.

The evolution of telecommunication networks, which will lead the world to the fifth generation of mobile communications (5G), is characterized by profound changes in the infrastructure of the telecommunications network and the technologies used. 5G should support more users/devices that require an Internet connection, with different performance requirements and more applications and usage options. The Internet of Things (IoT) will cover an even greater number of connected devices aimed at collecting and sending data for different purposes and under different application scenarios such as smart city, smart factory, and smart agriculture.

Therefore, scientific research on this topic is important and relevant.

2. Literature review and problem statement

According to [1], it is possible to improve the efficiency of the receiver data transmission path on highways, which can improve the quality of communication between the aircraft, user equipment, and the base station. The approach specified in [1] can be used to improve the accuracy and efficiency of the transmitted data used in the Internet of Things. Although the cited paper aims to improve 5*g* radio signals, it lacks bandwidth data when changing the trajectory of the UAV receiver/transmitter. In [2, 3], the model implemented and processed self-driving traffic using the Pareto distribution function and took into consideration the time used in traffic management using M/M/1 and the Weibull distribution. The disadvantage in [2, 3] is the lack of information about the response of the channel quality indicator (CQI) in the frequency range exceeding the throughput intended for the equipment of the transmitter-receiver channel. Industrial traffic requires microsecond latency for IoT communication [4]. Such traffic consists of information about emergencies, traffic data management, and remote control traffic, which can be used in applications for high reliability UAV management [5]. Although information on calculating the probability of overlapping in [4, 5] as an intellectual dynamic structure of spectrum resource management is not enough.

IOT applications will be used to control the flow of data using 5G/LTE network traffic management for intelligent connections between base stations and new hardware (gNB, UAV, IoT application). The IoT strategy will depend on different traffic management scenarios for appropriate UAV mobility. Taking into consideration [6], UAVs provide NB-IoT applications with low data rates, a large number of connected devices, and a large coverage range. The cited paper examines the quality of service, delay, throughput, and energy consumption and does not take into consideration shadow zones with weak networks to determine the speed and height of UAVs on different metrics and paths. In [7], unique Network Management Solution (PNMS) operated one server for 5G networks to operate drones according to enterprise services. Study [7] contains general projects without presenting solutions that include management, implementation, a basic network, and a fifth-generation wireless access network that help improve and develop infrastructure.

The disadvantage of UAV application is the imperfection of UAV traffic management in the context of the need to receive Internet service and 5G or 4G coverage.

NB-IoT is a specification of the cellular communication standard, which is designed to service devices that generate a small amount of data. The technology is great for different meters, sensors, alarm systems, etc.

The new radio access technology is called "NR" and replaces "LTE", and the new base station is called gNB (or gNodeB) and replaces eNB (or eNodeB or developed node B).

Ultimately, solving the problem of defining network coverage areas and improving the data receiver, as well as the appropriate path through an intelligent dynamic spectrum resource, to improve and develop the infrastructure network, can be achieved using a UAV.

3. The aim and objectives of the study

The aim of this study is to develop a method for managing UAV traffic through the use of gNB-IoT in 5G. This will make it possible to provide high-quality Internet service in remote areas that do not have mobile coverage towers.

To accomplish the aim, the following tasks have been set:

– to show the possibility of using a mobile UAV repeater when managing traffic using gNB-IoT in 5G;

– to show the ability to connect the drone to the wired base network from the provider and restore the radio frequency signal and broadcast to another coverage area where this subscriber does not have network coverage;

– to propose to use real-time spectrum expansion to ensure high bandwidth for all UAV users;

– to propose a way to control the movement of UAV using the distribution algorithm in order to constantly transfer the direction of the antenna in the best position of the main gNB beam towards the UAV.

4. The study materials and methods

The object of this research is the process of managing UAV traffic through the use of gNB-IoT in 5G.

The main methods of our study are methods of mathematical analysis using graph theory, method of analysis of structural reliability, and mathematical modeling. To improve traffic algorithms, a different type of Simulink is proposed and an algorithm for supporting data transfer between V2X is suggested, which will create a path for data processing owing to gNB-IoT for a distribution strategy that integrates ultra-wide-flow networks. The algorithm will be built to broadcast the necessary data together with official data through data distributors/transmitters. Thus, it is possible to increase the coverage area for each gNB and platform (IoT). After all, IoT UAV Simulink can optimize time latency, transmission, and energy. This is needed to improve network coverage and support the development of the Internet of Things in the near term. This is a future in which user equipment (UE) and the founders of telecommunications companies will receive increased data traffic bandwidth and connected to the Internet of Things via gNB [8–11].

5. Results of studying the process of traffic management of unmanned aerial vehicles through the use of gNB-IOT in 5G

5. 1. Relaying and optimizing radio planning for unmanned aerial vehicles

It is proposed to use a UAV repeater when managing traffic using radio resources (RR), radio access network infrastructure (RAN) with broadcasting tools and dynamic connection using MU-MIMO modulation. In the relay of UAV, we propose to calculate the distance (radio) between the drone node B and the mobile station (MS) as the IoT application controller. After that, it is necessary to specify the basic specification for installation, for example, such as 3D position, speed, radius, coverage area, and direction of beam, optimizing radio planning with antenna phased grids [12].

In addition, it is necessary to increase the bandwidth of the channel using the bandwidth guaranteed by the use of UAVs. This will make it possible to find out the time-frequency interval and the balance of the delay, and then use QoS and QoE between UAV and gNB to improve the high speed of data transmission (Fig. 1).

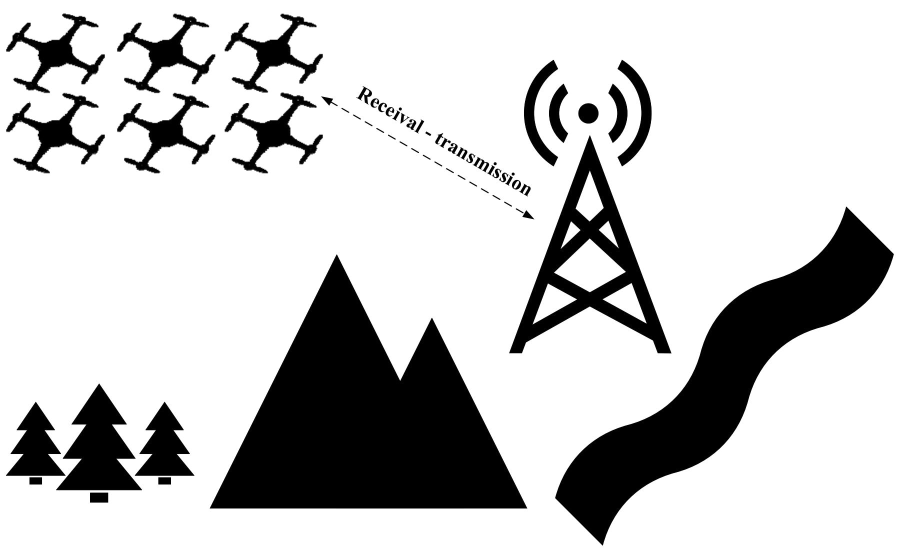

Fig. 1. Coverage with an unmanned aerial vehicle

The relay of the UAV method will depend on the interpreter's path, which needs to increase the signal spectrum and forward the radio frame using MU-MIMO, relying on the resource blocks displayed in the time and frequency grid in 5G NR [13].

That will improve frame transfer by using drones as receivers for critical edge coverage areas. On the other hand, QoE 5G will provide more flexibility for a higher degree of 3D beam formation to assess traffic control [14] and UAV-transmitted traffic data. The full LoS used to adapt custom equipment using a UAV to the nearest RAN and easy control to optimize the greater data traffic is shown in Fig. 2.

The shortest path to the receiver in the coverage area to RAN via UAV with a higher probability of connecting all MS and with greater UAV mobility is shown.

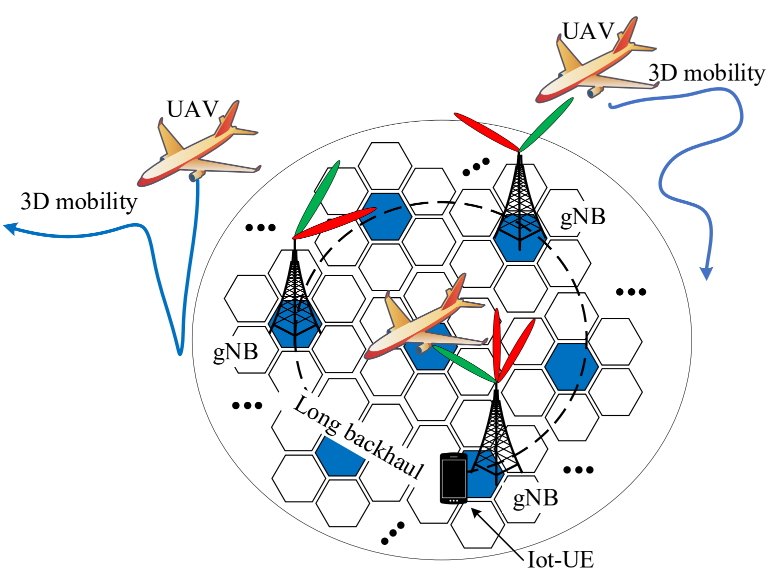

Fig. 2. 3D mobility of unmanned aerial vehicle with NB-IoT

5. 2. 3D beam direction of communication of V2X vehicles

Starting with version 16 [15], vehicle-to-vehicle communication (V2X) using these tools makes it possible to connect the drone to a wired base network from the provider. Then restore the radio frequency signal and broadcast to another coverage area where that subscriber does not have network coverage, use the Channel Quality Indicator (CQI) display as a QoE function.

In addition, it can increase the temporary coverage area, so the UAV will work as a gNB repeater to improve low latency with 3D beam formation and MU-MIMO with LoS among V2X. Next, the synchronization [16] and the configuration of the protocol for establishing a connection are performed, then the frame data are exchanged and all packages are re-transferred.

5. 3. Spectrum and radio frame as a technique to manage traffic

To improve UAV traffic management, real-time spectrum expansion has been used and will focus on data quality. To ensure high bandwidth for all UAV users, we shall use a higher frequency (FR) bandwidth with maximum bandwidth for the receiver tract. Therefore, the distribution of the data stream will cover even a zone that could not be achieved by frequency signals from gNB. In addition, UAVs with a 5G antenna will broadcast mm waves in all directions at the same time, use 3D beam formation, which prevents interference.

The formation of a 3D beam with a massive MIMO, which should increase throughput, depends on the efficiency of using the spectrum. Drones will provide coverage as the main technologies for traffic control, mobility, and data management, according to [17].

Fig. 3 shows the frequency range that can be used for UAVs:

– range 1: 410 MHz–7,125 GHz;
– range 2: 24,25 GHz–52,6 GHz;
– polarization +90°, -90°;
– the range of horizontal scanning of the beam formation -60° to 60°;
– vertical range of beam scanning –15° to 15°;
– antenna array 12 (horizontal) and 8 (vertical).

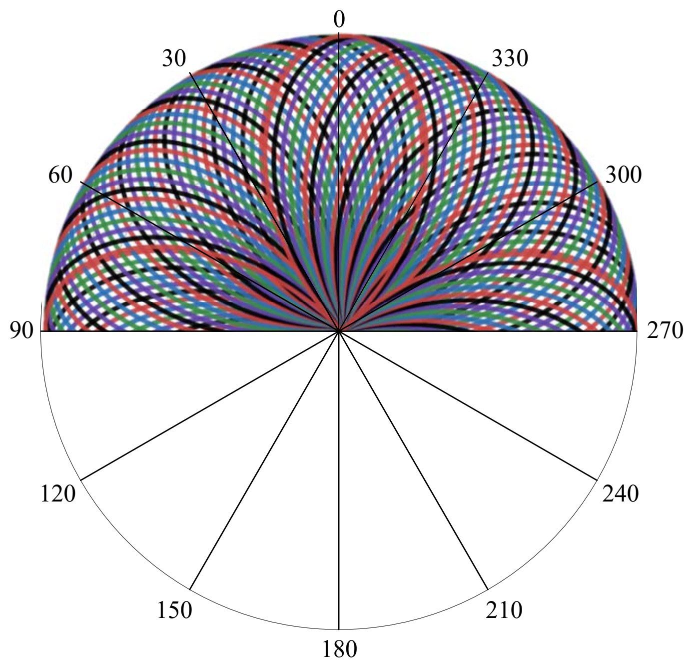

Fig. 3. The frequency range with polarization +90°, 90° for antenna phased array of unmanned aerial vehicle

In this project, the radio frame uses a high-frequency range with mm waves, which increases the bandwidth and distribution of radio resources for each transmitted information in the signal. The radio frame will be transmitted in CQI representation using OFDMA+CP [19] by the MIMO multiplayer antenna, the entire frequency range is based on the 3Gpp specification [18].

5. 4. Expanding the coverage area with unmanned aerial vehicles

The ability of energy to re-transmit data over large areas outside of network coverage is important for analyzing the characteristics of mobile cellular networks and providers. 3D channel models, massive MIMO antenna diagrams, and 5G beam 3D formation are needed. At the same time, the use of UAV measurements opens up new opportunities for more efficient networks, especially now that UAVs are becoming more accessible and commercialized. Currently, researchers who use UAVs to increase mobile network coverage rely on manual drone control and data flow. Drones will help increase throughput, increase the angular range and signaling phase with a phased array.

Fig. 4 shows the algorithm of the technique of UAV motion control.

The algorithm that is shown in Fig. 4, is the basis of the method of UAV motion control:

1) enter the initial parameter – the total number of UE in UAV networks;

2) choose the type of modulation:

– calculate subframe numbers when transmitting traffic data to a single subframe. In NR-5G technology, the number of subframes depends on resource blocks in time/frequency slots: 69, 138, 275, etc.;

– choose the type of massive MIMO to improve energy efficiency and spectral efficiency, which can provide the bandwidth of UAV networks;

3) LoS calculation: LoS distribution is used to determine the channel correlation between UAV networks and user equipment to generate high traffic, which improves QoS performance;

4) QoS Identification "3D Beamforming": 3D Beamforming: Using 3D beamforming with massive MIMO and mm Wave-UAV. Using antenna arrays in higher FR 5G, transceivers can perform a flexible beam direction to compensate for LoS signals for greater propagation and compensate for interference common in UAV networks;

5) if the coverage distance exceeds 100 m, the modulation will be changed to another type of modulation, for example, from 4×4 MIMO to 2×2 MIMO, and/or resource blocks for OFDM characters will be reduced to improve the data traffic controller. The rest will be extended to the next step;

6) transmission data traffic: depends on the required bandwidth between the UAV and UE;

7) optimization traffic controller: improves encoding speed when using encoding for each UE signal and bit load from UAV characters. Then the amount of UE from UAV data traffic can improve for each sub-frame with a separate frequency spectrum.

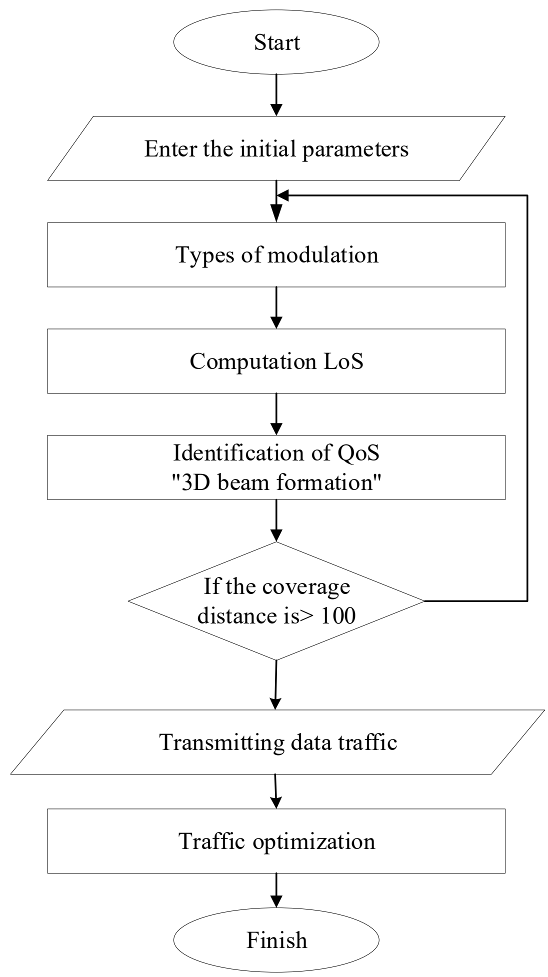

Fig. 4. UAV motion control algorithm

Determining the position of UAV using the distribution algorithm makes it possible to constantly transfer the direction of the antenna towards the UAV and hold it in the best position of the main gNB beam and thus maintain communication with high amplification.

We can say that the quality of the transceiver provides the best chance of UAVs sending/receiving signals constantly. As data traffic management and power in compatibility systems increase with increased data, traffic power can be found from Fries equation (1)

$$P_R = \frac{P_T G_T G_R \lambda^2}{(4\pi R)^2}, \quad (1)$$

where P_R is the resulting power, P_T is the power of the transmitter on the UAV, G_T and G_R is the amplification of the transmitting antenna on the UAV and receiving antenna on the gNB.

λ is the wavelength, R is the distance between the UAV and gNB in meters.

To calculate free space, use (2).

$$PL_{free\ space} = (4\pi R f)^2 / c, \quad (2)$$

$PL_{free\ space}$ is the power line for free loss space, f – carrier frequency in GHz, c=299792458 m/s – speed of light. In decibels (3):

$$PL_{free\ space,\ dB} = 32.45 + 20\log_{10}(f) + 20log_{10}(R). \quad (3)$$

Calculate the maximum range between UAV and gNB by equation:

$$R_{max} = \sqrt{\frac{P_T G_T G_R \lambda^2}{(4\pi)^2 K_B T_s Bw}}, \quad (4)$$

K_B is the Boltzmann constant, T_S – system temperature and B – receiver throughput.

Even the blind can see that the location of UAV is unlimited in frequency range, which is associated with the speed of connection of the UAV due to the speed of returning the UAV to the best position after a break of wireless communication with gNB.

The signal sent to the anchor channel can be recorded as follows:

$$S_{ref} = |S| e^{j\,\phi ref}, \quad (5)$$

where $|S|$ is the amplitude of the received signal, and ϕ_{ref} is the phase of the received signal through the support channel.

To calculate the distance between UAV and UE for NB-IoT, one needs to know the terms Advance (TA), where T_A (0, 1, 2 ... 1282) s is indexed, which are a time shift for the N_{TA} _×0001_ radio frame receiver path and for each time interval we used (6):

$$N_{TA} = 16\ T_A\ T_{slot}, \quad (6)$$

where T_{slot}=1/(2048·15000)=1/30720000 s.

Then the maximum propagation distance in meters of three-dimensional beam (d) will be:

$$d = (3\cdot 10^8 N_{TA})/2. \quad (7)$$

Calculate the maximum bandwidth of the 5G network in V2X [20]. The approximate speed of transmission of UAV data in 5G can be calculated from the formula:

$$Throughput(Mbps)_{UAV} = 10^{-6}\sum_{j=1}^{J}\left[v_{layers}^{j} Q_m^j f^j R_{max} \frac{12 N_{PRX}^{BW(j)\mu}}{T_s^{\mu}}\left(1 - OH^j\right)\right]. \quad (8)$$

Example for the project:

– J – the number of aggregate component carriers, J=1;

– ×0001_v_{layers}^j – the maximum number of MIMO layers, ×0001_$v_{layers}^j = 8$;

– Q_m^j – modulation order, $Q_m^j = 8$, the modulation type will be 256 QAM for the receiver path;

f^j – scaling factor=1;

$R_{\max}$ – for the LDPC code, the maximum number is 948/1024=0,92578125;

$BW(j)$ – bandwidth in MHz, BW: 50 MHz for FR1;

μ – distance between carriers, μ: 30 kHz;

$T_S^{\mu} = (10^{-3})/(14 * 2^{\mu})$ – the average duration of the OFDM symbol in the subframe for the value μ(j);

OH^j – overhead for control channels, OH^j=0,14.

As a result, from above, the maximum result of V2X bandwidth will be, for a downstream channel, 15,614 Mbps, and for an upward channel, 4,176 Mbps if TDD is used, and there will be a downstream channel of 18,216 Mbps for the FDD, and 19,488 Mbps for the upward channel.

Another example: if BW is used: 400 MHz FR2, μ: 120 kHz, then for the downline 118208 Mbps and ascending 32436 Mbps, if TDD is used, and for FDD there will be a downline of 137910 Mbps, and for an ascending 151364 Mbps.

It is also possible to calculate spectral efficiency for UAVs from examples of the results using (9):

$$\text{spectral efficiency}_{UAV} = \frac{\text{Throughput}(\text{Mbps})}{Bw}. \quad (9)$$

Spectral efficiency is an important factor for 5G-NR radio stations, which is used to determine how much information fits into a given passing band channel for UAVs. This shows how efficiently the spectrum is used to transmit information and provides useful bandwidth in the frequency range.

6. Discussion of results of the study

The advantages of the proposed solutions are ensured by relaying and optimizing radio planning for unmanned aerial vehicles. Unlike existing solutions, this is achieved through dynamic connection using MU-MIMO modulation (Fig. 2). The UAV will work as a gNB repeater to improve low latency with 3D beam formation and MU-MIMO with LoS among V2X.

To ensure the high throughput of all UAV users, a higher frequency (FR) range with maximum bandwidth for the receiver tract is used (Fig. 3). Therefore, unlike existing methods, the distribution of data flow will cover even a zone that could not be achieved by frequency signals from gNB. Calculations of the maximum range between the UAV and gNB and the maximum bandwidth of the 5G network in V2X are carried out according to formulas (4) and (8), respectively.

Our genuine mathematical modeling makes it possible to assert that expert expectations from the implementation of the proposed method of UAV motion control will improve the throughput by 15 %. But the proposed solutions will need to be tested experimentally, so the limitations of this study are the need to have UAVs and the necessary equipment to conduct such an experiment.

In general, the ultimate solution was a reliable combination of 5G and IoT technologies to manage UAV traffic through the use of gNB-IoT in 5G, which fully meets the needs of hard-to-reach areas in coverage and acts as a vital link in the effective management of traffic flow data.

5G-based UAVs and broadband cellular networks are modern solutions for improving data coverage traffic management in conjunction with IoT applications. Such applications are used for many types of IoT sensors and UE coverage area and can significantly reduce gNB costs, increasing cross-country traffic management efficiency. IoT-enabled drones are at the forefront of this exciting new technological era.

7. Conclusion

1. The use of a mobile UAV repeater during traffic management using radio resources (RR), radio access network infrastructure (RAN) with broadcasting and dynamic connection using MU-MIMO modulation is proposed.

2. After implementing the procedure for connecting the drone to the wired base network from the provider, it becomes possible to restore the radio frequency signal and broadcast it to another coverage area where this subscriber does not have network coverage, analyzing the display of the channel quality indicator (CQI) as a QoE function.

3. To improve traffic management, UAVs are encouraged to use real-time spectrum expansion to ensure high bandwidth for all UAV users. Expert expectations for improving bandwidth are at 15 %.

4. A technique for controlling the movement of UAV using the distribution algorithm is proposed in order to constantly transfer the direction of the antenna in the best position of the main gNB beam towards the UAV and thus maintain communication with high amplification. This is dictated by the need to ensure high speed of connection of the UAV with the base station and return the UAV to the best position after a break of wireless communication with gNB.

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