A Method of Increasing the Reliability of Heterogeneous 5g/Iot Special Communication Networks when Using the Terahertz Wave Range

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Annotation

A method of increasing the reliability of heterogeneous 5G special communication networks when using the terahertz frequency range is proposed, which includes the process of establishing a connection of a mobile terminal equipped with several network interfaces to several access points in wireless networks, managing the location of special terminals, a special service transfer procedure (handover), which has three consecutive operations - collection of network information, decision-making and transfer of service, the following procedures are new in comparison with the known ones: when making a decision and transfer of service, the procedure of network selection and transition to a new network connection point is applied when blocked by dynamic obstacles to the connection of the line-of-sight channel based on the developed intelligent handover initialization algorithm, taking into account the signal strength in the coverage areas of the main and neighboring networks, network energy saving, distribution of users in the area of service of the main base station, the terminals of which are in standby mode, quality of service, distribution of bandwidth within the cell.

The algorithm for initializing the intelligent handover when the line-of-sight connection is blocked by moving obstacles during transmission in the terahertz wave range and the algorithm for monitoring the state of network devices for the technical implementation of the proposed method for collecting and retraining the corresponding neural networks are given.

Keywords[1]

terahertz frequency range, intelligent handover, line-of-sight connection blocking, network reliability, heterogeneous mobile network.

1. Introduction

Existing special communication networks are mainly deployed in the spectral range below 3 GHz. But one of the promising areas of development of 5G networks is the use of higher frequency ranges, such as millimeter and terahertz wave ranges (from 30 to 300 GHz) [1]. The peculiarity of the terahertz wavebands is that they provide much wider spectral bands, making it possible to significantly increase the bandwidth in the cell. Another advantage of terahertz waves is the much more compact size of transmitting and receiving antennas, which makes it possible to use more efficient spatial multiplexing schemes due to an increase in the number of antennas, both on the side of the base station and on the side of the subscriber device. However, the use of higher frequency ranges requires taking into account a number of problems that must be solved. It is necessary to develop new approaches to the organization of radio channels in the high-frequency range, which would make it possible to effectively use the advantages and, at the same time, eliminate the disadvantages of using waves in the terahertz range. In

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particular, significant attenuation of the signal power in the high frequency range can be compensated by a greater number of transmitting and receiving antennas and more complex spatial multiplexing algorithms, which would allow to increase the energy efficiency of communication channels.

Existing methods of diagramming in combination with spatial multiplexing and interference compensation algorithms can increase the energy and spectral efficiency of special communication networks when they are implemented in a higher spectral range.

In addition, significant attenuation of terahertz waves makes them promising for use in pico and femto cells, where it is necessary to provide significant bandwidth in limited areas. This will reduce the distance between co-channel cells and, accordingly, increase the efficiency of using radio frequency resources in heterogeneous networks.

2. Current state of the problem and ways to solve it

2.1. Analysis of the latest research and solutions

For the effective implementation of mobile communication networks in the spectral range of 30-300 GHz, it is also necessary to solve a number of problems related to terminal subscriber devices. Existing special communication terminals support many radio interfaces in different frequency bands. Currently, modern special devices are able to function efficiently in the range from 800 MHz to 2.7 GHz, however, the introduction of higher frequency ranges requires significant improvement of the hardware part of special communication terminals. In addition, it is necessary to improve the antenna systems for terminal subscriber devices in order to ensure their efficient operation in any frequency range from 800 MHz to 300 GHz.

Studies of waves in the terahertz range have shown [2] that due to shorter wavelengths, transmission at extremely high frequencies is subject to radio signal blocking by relatively small objects. This effect leads to a drop in the power level at the receiving end and thus makes the terahertz connections less reliable. Therefore, a solution in which compaction of the cellular infrastructure with statically small cells of the terahertz range is supplemented by special nodes of mobile communication is of interest, which leads to an increase in the reliability of establishing a connection [3].

To organize the operation of the terahertz network with increased reliability, it is also possible to use the simultaneous connection of the subscriber terminal (MT) (multi-connectivity), when it is connected to two or more cells at once [4].

2. 2. Setting objectives

It is important to remember that the blocking of a terahertz band connection is a random event that requires an immediate response from the communication system [5] to avoid breaking the active session. Therefore, it is necessary to manage the simultaneous connection of the subscriber terminal to two or more connections of the terahertz range in order to promptly redirect this session to another radio access point when the current connection is blocked. Such management is a new functionality of the access network and differs from known approaches related to the offloading of subscriber traffic to other radio access technologies. Therefore, one of the promising directions in the wireless network using the terahertz range is the development of intelligent handover decision algorithms to determine the time to perform service handover and ensure the optimal choice of access network technology among all available access networks for users equipped with a multi-mode special terminal.

To provide a solution to this problem of predicting the maximum range of the line-of-sight interval of the terahertz range, the authors developed a model based on artificial intelligence [6].

Theoretical research of cellular networks with the possibility of establishing connections of the millimeter range of frequencies is often carried out by methods of stochastic geometry. The approach in work [7] offers a mathematical model for the analysis of the SINR value and its derived characteristics of the communication system during both downlink and uplink transmission. At the same time, it is assumed that there are many evenly distributed on the plane of the base station (BS) and the main features of connections of the millimeter frequency range are taken into account, such as the possibility of blocking transmission by small objects and the use of antennas with a sharp directional pattern. To reduce the probability of lack of coverage in the millimeter frequency range and increase the possible data transfer rate, a two-step full-duplex scheme with retransmission, which is suitable for use in 5G networks, has also been developed [8].

Most of the available research in the field of millimeter frequency range communication converges on the conclusion that due to shorter wavelengths, transmission at extremely high frequencies is subject to radio signal blocking by relatively small objects. This effect leads to a drop in the power level on the side and, thereby, makes the connections of the millimeter frequency range less reliable [9; 10].

IN robots in direction research algorithms adoption initiation decisions transfer of service (handover) three publications can be distinguished. The first is based on multi-criteria decision -making algorithms regarding the initiation of intersystem handover, in whose different parameters are aggregated in functions cost [11]. The second provides processing incoming parameters by mathematical algorithms on basis Markov's processes adoption solutions concerning switching between networks, example, as in [12]. The third founded on use mechanisms unclear logic, examples solutions on basis unclear logic presented in [thirteen]. But in these robots criteria of choice network access have only been considered few parameters, which are not give be able to consider in process evaluations a significant set of criteria and adapt decision-making rules in a dynamic mode operation of wireless networks in the terahertz range. A well-known solution with the possibility of simultaneous connection was investigated in a software application to cloud radio access systems to improve the efficiency of servicing terminals located at the edge of the cell [14].

The disadvantage of the known solution is that the issues of network and personal data security still remain unsolved in the existing cloud computing models. Despite the fact that centralized cloud services are quite convenient for end subscribers, this paradigm raises critical concerns about the privacy of subscribers' data, given that large volumes of various data transmitted over special networks and the Internet of Things are stored and used in dynamic cloud environments. Thus, entrusting the protection of their data to a third party, users risk losing their privacy, and also bear the associated risks associated with the possible use of this data by attackers. There is a well-known solution for managing the service system of special users, which consists of the mobele operator's own infrastructure and leased service subsystems [15]. The authors proposed a set of methods for managing the quality of service of flows in a heterogeneous special environment. The disadvantage of this solution is that the issue of joint management of existing networks to ensure QoS using terahertz waveband technologies and improving the performance of a heterogeneous network has not been investigated.

There is another well-known way to organize the operation of the millimeter wave network with increased reliability [16] by using the simultaneous connection (multi-connectivity) of the subscriber terminal, that is, when it is connected to two or more cells at once. This solution is aimed at reducing the time when the subscriber terminal remains connected to the base station of the millimeter wave range, with which the connection is blocked. In case of transition of the connection of the millimeter wave range from the current BS to the blocked state, the terminal service is redirected to another (reserve) BS, which has a fairly low probability of blocking the connection in the current zone of the subscriber. Thus, this method of organizing the work of the millimeter wave network indirectly reduces the probability of session termination due to insufficient quality of the connection caused by its blocking. In order for this method to work, the subscriber terminal needs information about which of the potential BSs in the millimeter wave range will be least blocked for it in the current service area. The disadvantage of such a solution is that the complexity of its technical implementation on the existing centralized 5G special communication infrastructure leads to additional channel switching delays, since decisions are made remotely, and accordingly reduces the overall efficiency of the system. This is due to the fact that the existing centralized infrastructure architecture of special communication networks today is vulnerable from the point of view of overloading of computing resources and therefore it does not guarantee uninterrupted provision of IoT services in case of software failures in the main servers. In addition, the authors did not provide options for the implementation of technical solutions, and did not estimate the computational costs and time spent on decision-making according to the proposed method and its modified versions, which is important for ensuring the necessary quality indicator of the QoS network. The purpose of this work is to increase the energy saving and reliability of the functioning of decentralized 5G mobile communication networks in the case of dynamic blocking of the line-of-sight connection by moving obstacles during transmission in the terahertz range of wavelengths by improving the method of sharing time-frequency and energy resources using the blockchain and autonomous slicing infrastructure based on D2D mobile terminals in the terahertz range.

3. Statement of the task

3.1 Mathematical formalization of the problem

Initial conditions of the problem:

Let:

- a closed space θ *is given*;
- space θ consists of $\theta \rightarrow \theta_t$U θ_{nt}, θ_t- space covered by wireless technologies, θ_{nt}- uncovered space (dead zones and zones of unstable communication);

• a wireless heterogeneous network operates in space θ (or a heterogeneous network consisting of Qradio access networks and a set of connections n = 1,2,..., N , each of which consists of individual repeater stations, i.e. is a set of wireless communication stations connections with appropriate characteristics:

$$Q= \{Q_i\},\ i = 1 \dots n, \tag{1}$$

where Qis base stations or access points in a heterogeneous environment, i - the number of stations.

In the space θ there are many special devices (AT) that function in free mode (without load), or perform technological operations (or tasks) both separately - alone and together.

Let these devices be:

$$F = F_1 , F_2, \dots , F_u, \dots , F_c \tag{2}$$

where s is the number of special devices, u – the position of the special device, which is part of the special devices.

Each device $F\epsilon\ F_u$can be in three states:

$$Q\ (\ F_u) = Q^1, Q^2, Q^3, \tag{3}$$

where Q^1- does not function (not turned on, faulty), Q^2- functions in free mode, Q^3- works separately or together.

Certain requirements are imposed for the execution of JSC of each technological operation:

1) It is required to meet conditions on the part of the device or devices, that is, the selection of devices for performing work operations (for the assignment of technological operations of devices) requires the fulfillment of a number of conditions, restrictions, criteria.

We denote all these requirements through

$$P = \{P_1 , P_2, \dots P_i, \dots , P_r\}, \tag{4}$$

where r – the total number of requirements, i.e. a criterion whose value is determined by the task setter; P_i – a requirement determined by the producer.

A requirement or criteria $P_i$has such values (content, characteristics) as: signal level or wireless power. For trouble-free operation of the special device, its value should not be less than the specified value, which is determined on the basis of previous studies.

There are also other requirements, such as: failure/continuity not less than E , energy capacity not less than O , which must be known and specified based on previous studies.

2) There are a number of requirements for the quality of technological operations:

$$G = \{G_1, G_2, G_3 , G_w\} , \tag{5}$$

where w is the number of requirements and criteria for performance (supporting the performance process and the result of performance of technological operations), which is determined by the setter of tasks or tasks. G_i– requirements for the execution of a technological operation: efficiency, minimum energy consumption costs, etc. for the results of the execution of the technological operation, that is, for the quality of the output products; maximization (of bandwidth, QoS, transfer rate or a certain complex criterion), etc.

Now, let's formulate the general task of effective fail-safe communication with dynamic blocking of the line-of-sight connection by moving obstacles during transmission in the terahertz wavelength range:

Let the t_n state of the space environment θ *at the moment of time be as* follows, i.e., the decision-making situation in the case of dynamic blocking of the line-of-sight connection by moving obstacles during transmission in the terahertz wavelength range:

$$Q\ (\theta) = (\ T_d, F\ , P\ , G\ ), \tag{6}$$

T_d– base station or radio access point.

Then at the moment you $t_n$need to select such a base station or radio access point$T_d \in T$, which will satisfy the requirements of the objective function

$$A = L(G) = L\{G_1, G_2, \dots G_j\} \rightarrow opt \tag{7}$$

where $G = \{G_1, G_2, \dots G_j\}, j < w$

Next, we turn function A into an objective function of the form:

$$f(b_{ij}, c_{ij}, d_{ij}), \tag{8}$$

The objective function $f(b_{ij}, c_{ij}, d_{ij})$ is a criterion that must be maximized (a certain complex criterion **)** . Then the general algorithm for solving the above problem, i.e. the task of ensuring effective fail-safe communication in case of dynamic blocking of the line-of-sight connection by moving obstacles during transmission in the terahertz wavelength range, will have the following form:

$$\max\left(f(b_{ij}, c_{ij}, d_{ij})\right) \tag{9}$$

3.2 Technical implementation of the proposed method of 5G special communication with increased reliability

The task is solved by the fact that the 5G special communication method [16], which includes the process of establishing a connection of an MT equipped with several network interfaces to several access points in wireless networks, MT location management, a special service transfer procedure (handover), which has three consecutive operations - collection of network information, decision-making and service transfer, additionally includes:

- preliminary formation of a complex wireless network with the involvement of additional resources of neighboring base stations and an auxiliary cluster network based on MT, which are in standby mode, in the area of the current BS for user service;
- after establishing a connection of a MT equipped with several network interfaces to several access points in a complex wireless network, the quality of its operation is monitored: data collection and training of the neural network using the software controller of the BS network, the control and data storage node and the neural network infrastructure; neural network training; neural network training and optimization;
- when making a decision and performing a service transfer, the procedure for selecting a network and switching to a new network connection point is applied when the line-of-sight channel connection is blocked by dynamic obstacles based on the developed intelligent handover initialization algorithm, taking into account the signal strength in the coverage areas of the main and neighboring networks, network energy saving , distribution of users in the service area of the main base station, whose terminals are in standby mode, quality of service, distribution of bandwidth within the cell.

The essence of the development is explained by figures 1-3:

Figure 1 shows the implementation scheme of the proposed 5G special communication method with increased reliability when the line-of-sight connection is blocked by moving obstacles during transmission in the terahertz wave range. On him:

1 – The main base station of the network.

2 – The main communication channel of the subscriber's MT connection with the current base station.

3 – Backup communication channel connecting the MT of the subscriber with the current MT of the auxiliary cluster network.

4 – Backup communication channel connecting the MT of the subscriber with the base station of the neighboring service area.

5 – MT of the subscriber.

6 – The main MT of the auxiliary cluster network.

7 – Auxiliary cluster network.

8 - MT neural networks.

9 - Cloud storage of neural networks.

10 - Cloud storage of statistical technical parameters FE.
11 – Software controller of the current network base station.
12 – Node of control and data storage.
13 – Cluster formation block.
14 – Service area of the current base station of the network.
15 – Neural network of the software controller of the current network base station.

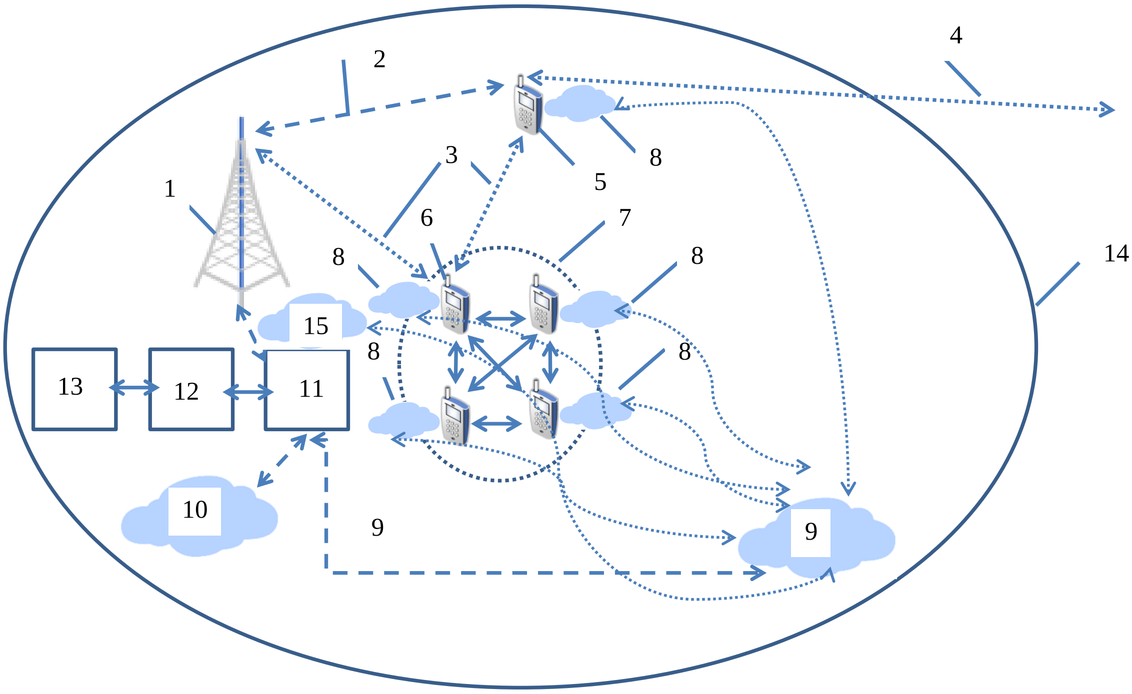

Figure 1. Implementation scheme of the proposed method of 5G special communication with increased reliability when the line-of-sight connection is blocked by moving obstacles during transmission in the terahertz wave range.

Figure 2 shows the block diagram of the state tracking algorithm of the proposed 5G special communication method with increased reliability in the terahertz wave range based on artificial intelligence for collecting and retraining the corresponding neural networks. On him:

1 – Standard mode of operation of the device for the technical implementation of the proposed 5 G special communication method with increased reliability of the terahertz wave range.

2 – Monitoring of the state of MT operation of the auxiliary cluster network based on Forel and c - means clustering algorithms.

3 - Operation "Normal state of operation of the device for the technical implementation of the proposed method?".

4 - Operation "Known state of operation of the device for the technical implementation of the proposed method?".

4 - Operation "Known state of operation of the device for the technical implementation of the proposed method?".

5 – Data collection for training.

6 - Data aggregation and sending to the software controller of the current base station.

7 – Retraining of neural networks of the device for the technical implementation of the proposed method.

8 – Update of neural networks.

3.2.1 Algorithm for initializing the intelligent handover when the line-of-sight connection is blocked by moving obstacles during transmission

Figure 3 shows the block diagram of the intelligent handover initialization algorithm when the line-of-sight connection is blocked by moving obstacles during transmission in the terahertz wave range.

The general algorithm of operation of the proposed method of 5G special communication with increased reliability when the line-of-sight connection is blocked by moving obstacles during transmission in the terahertz wave range has four modes of operation: initial launch, formation of a complex wireless network with the involvement of additional resources of neighboring base stations and auxiliary cluster MT-based networks, mode of operation, network selection procedure and transition to a new network connection point when line of sight is blocked.

- In initial launch mode, the subscriber first establishes a connection with the current base station of the terahertz network and sends its own requests.
- In the mode of forming a complex wireless network with the involvement of additional resources of neighboring base stations and an auxiliary cluster network based on MT, the system first monitors the sector of the service area of the subscriber's location; operation of clustering MTs that are in standby mode in this sector; formation of a working group of 4-5 neighboring spatially dispersed MTs, which are in standby mode; search and finding of a free channel by the MT working group, determination of the group's main MT; formation of a cluster of neighboring BSs and determination of their priorities for relay transmission of communication when blocking the line-of-sight connection between the active MT and the current BS of the network.
- In the operating mode, the subscriber establishes a connection with the current BS of the network and the main MT of the auxiliary cluster network once. The operation of a complex wireless network in the terahertz range is monitored: data collection and neural network training using the BS network controller, data control and storage node, and neural network infrastructure; neural network training; neural network training and optimization.
- In the mode of network selection and transition to a new network connection point when the connection is blocked by moving line-of-sight channel obstacles, the developed algorithm for initializing intelligent relay transmission is used, taking into account the signal strength in the coverage areas of the main and neighboring networks, network energy saving, distribution of users in the service area of the current base station, the terminals of which are in standby mode, the quality of service, the distribution of bandwidth within the cell.

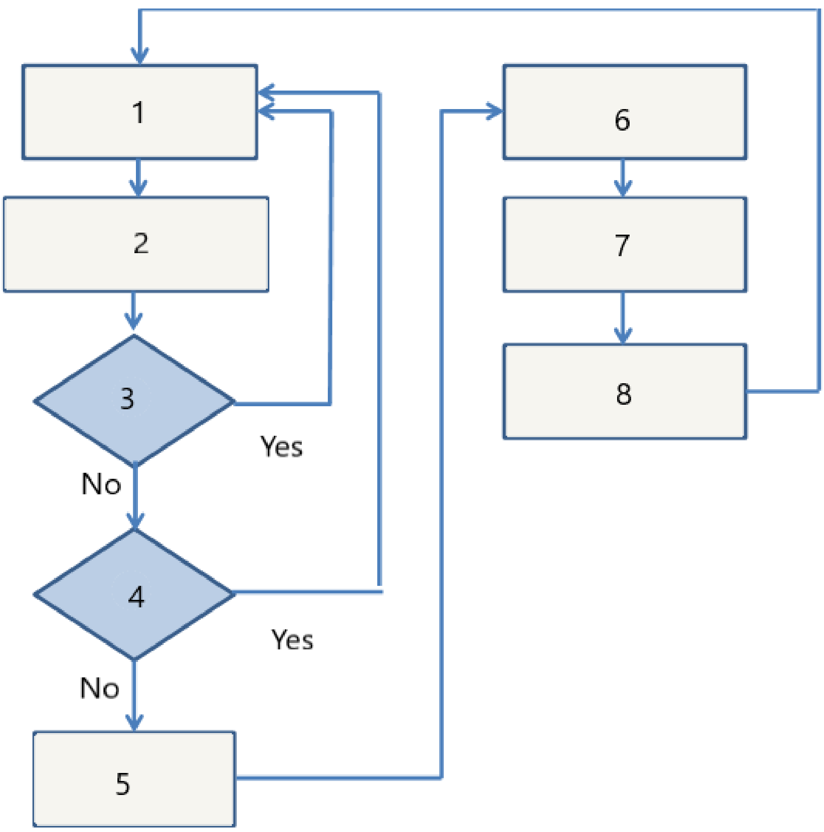

Figure 2. Block diagram of the algorithm for monitoring the state of network devices of the technical implementation of the proposed method for collecting and retraining relevant neural networks

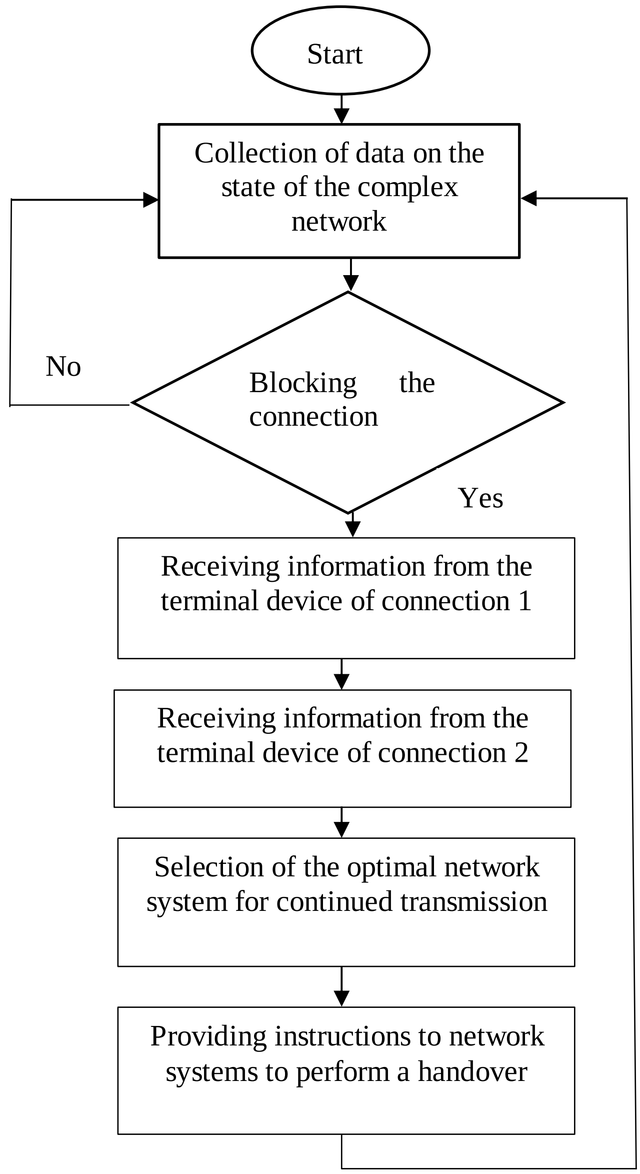

Figure 3. Block diagram of the intelligent handover initialization algorithm when the line-of-sight connection is blocked by moving obstacles during transmission in the terahertz wave range

5G special communication method with increased reliability in the terahertz range (see Fig. 1) has a software controller BS 11, which has a connection with a control and data storage node 12, a cloud 9 storage of neural networks, cloud 11 storage of FE statistical technical parameters (Features Engineering). To create an auxiliary cluster network based on MTs that are in standby mode in the area of the current BS for user service, an improved method of convergence of a heterogeneous network of the terahertz range using the technology of inter-terminal interaction and cluster analysis is used.

It assumes that only a limited number of special terminals will communicate directly with the base station. These terminals are called Direct Connect Devices (DDPs). Other devices connect to the PPP as access points and are called devices with indirect connection (PDP).

The main difference between this approach and existing cognitive radio solutions lies in the principles of radio interface implementation. Modern cognitive networks use an unlicensed frequency range of Wi - Fi technologies for communication between terminals. However, this is not enough for new special networks with high bandwidth due to the limited frequency range of waves. Therefore, we apply the joint use of the frequency range for inter-terminal exchange and communication between the PPP and BS based on the use of the terahertz range.

This solution provides for the conversion of carrier frequencies in PPP, in order to separate the frequency spectrum of transmission of terahertz signals from the base station to PPP, from the frequency range used in the inter-terminal network. At the same time, the PPP subscriber uses only a part of the information flow for his communication session. The rest of the information is relayed through the PPP to all POPs, using other spectral resources. This makes it possible to avoid interference, improve immunity and ensure the appropriate level of quality of service perception.

This feature and the possibility of establishing direct connections between terminal devices are used in the proposed solution to organize an auxiliary cluster network based on MT, which are in standby mode in the area of the current BS for user service.

For this purpose, the process of clustering MTs, which are in standby mode in the user service area of the current BS relative to the location of the subscriber planned to be served by the network, is first carried out. A spatially dispersed group of 4-5 neighboring MTs is formed relative to the location of the subscriber's MT. In order to ensure the quality of user switching, regardless of their location, a new approach to distributing bandwidth evenly within a given cell is proposed. In this case, to search for a free channel between multiple MTs, an auxiliary cluster network is formed, in which one of the MTs acts as the main MT. This MT is selected according to the criterion of the quality of the communication channel and the maximum number of neighboring spatially dispersed MTs. This model differs from the classic heterogeneous network in that small cells are dynamic and access points in them are one or several MTs. POPs are connected to the PPP or to other POPs according to the criterion of the maximum signal-to-noise ratio. The MT (VOP) of the cluster group that first finds a free channel automatically becomes the main one and reserves it for other MTs of the group, which will be able to block connection of line-of-sight channel obstacles of the subscriber's MT (subscriber's MT (PPP) - current BS of the network) to transmit its data in the following frames using the new communication channel formed: subscriber's MT (PPP) - main MT (PPP) of the group - current BS network.

The advantage of this approach is that the majority of MTs of this group in the network do not directly participate in the search process for access to the channel, which makes it possible to use a much smaller time window and, accordingly, a sufficiently low probability of collisions during relay transmission in the event that the line-of-sight channel is blocked by obstacles MT of the subscriber. It is clear that the choice of the number of groups and their size depends on balancing the bandwidth and the probability of collisions. In addition, the size of groups also depends on the proximity of spatially dispersed MTs that are in standby mode. As the distance of inter-terminal connections increases, MT may be physically located in different coverage areas, this method does not guarantee effective functioning when obstacles block the direct line of sight channel of the subscriber's MT. In this case, taking into account the network energy saving indicator, a new channel is formed with the involvement of additional resources of neighboring base stations: MT (PPP) of the subscriber of the current BS network - BS of the neighboring network.

3.2.2 Algorithm for monitoring the state of network devices of the technical implementation of the proposed method for collecting and retraining relevant neural networks

5G special communication method with increased reliability in the terahertz range, a cluster approach using ML (Machine Learning) of the Forel and c-means algorithms [17]. This approach allows you to determine the necessary states of the proposed device or the appearance of new states based on a certain time interval, take into account the dynamics of subscriber movement, a greater number of functional technical parameters with minimal software changes, and makes it possible to distinguish MT working groups by connectivity, by distance from the center, by MT density in the service area of the current BS. In addition, it allows you to take into account the requirements for the quality of service (throughput) for MT that are clustered and ensure an increase in the efficiency of the use of network resources. The authors of this solution proposed the use of intelligent algorithms based on trained artificial intelligence models for monitoring the quality of a complex wireless network with the involvement of additional resources of neighboring base stations and an auxiliary cluster network based on MT and ensuring decision-making on the relay transfer of services when the line-of-sight connection is blocked by moving obstacles line-of-sight channel.

The work of these algorithms is focused on managing the use of spatially dispersed channels of the established MT connection to several access points in wireless networks and, as a result, optimizing the use of time-frequency resources. For this, such algorithms must have an appropriate infrastructure for data collection, training, testing and updating of the corresponding trained models.

Its components are: the module of ML algorithms on the software controller of the BS network; neural network monitoring and training module; neural network training and optimization module; module of algorithms using a neural network, communication channels for updating neural networks.

The functional metrics of the developed system for evaluating the performance of an overtrained neural network should be the usual functional parameters of this solution: signal strength in the coverage areas of the main and neighboring networks, the network energy saving parameter, bandwidth allocation data within the cell and users in the service area of the current base station, whose terminals are located in standby mode. If an overtrained model for a certain algorithm led to deterioration of functional parameters, then this model should be returned for retraining or should be removed from the data storage module. In order for intelligent control algorithms to produce the correct result, it is necessary to collect a sufficient set of data. A sufficient set of data means the optimal amount of data at which model training is considered complete and the so-called overfitting process is not observed.

G special communication method with increased reliability in the terahertz range.

Each block of the proposed system (blocks 5, 6, 7, 11, see Fig. 1) is a source of information for ML algorithms. The main data processing before training neural networks 11 is carried out on the software controller BS 11 of the network. All collected functional parameters, which are necessary for training neural networks, are stored in the FE 9 cloud. Only intelligent algorithms on the software controller BS 11 of the network have access to these parameters.

If there is a change in the state of the network devices of the proposed 5G special communication method, which requires retraining of the corresponding models, then the corresponding algorithms carry out the procedure of retraining them on the basis of new FE parameters. After that, the corresponding trained models are replaced in the cloud. When a new version of the model has appeared for blocks 5, 6, 7, 11, they download the corresponding updated version of the model.

An important component of intelligent control algorithms is the direct collection of data for training. One of the features of the use of these algorithms in telecommunication radio networks of the terahertz range is the variability of the states of network devices in a complex wireless network, as well as the appearance of new and disappearance of current states, which requires additional data collection and retraining of neural networks.

The developed data collection algorithm (see Fig. 2) involves monitoring the state of the blocks of the proposed device for rational data collection using the change in values of both Euclidean distance metrics and functional technical parameters metrics in relation to the number of clusters.

The novelty of this approach lies in the difference from the classical implementation in that the metrics of the signal/noise ratio of the signal strength in the coverage areas of the main and neighboring networks, the network energy saving parameter, data on the distribution of bandwidth within the cell and users in the service area of the main base station whose terminals are located are introduced in standby mode, instead of the Euclidean distance metric, which makes it possible to take into account the spatial and temporal characteristics of signal propagation in the terahertz wave range in the process of self-optimization of functioning when the line-of-sight connection is blocked by moving obstacles.

Seamless handovers, with low latency and minimal packet loss, are critical factors for special users who want uninterrupted and reliable services Handover execution requires the actual transmission of data packets over a new wireless link in order to redirect the connection path mobile device to a new access point. In traditional handovers that occur in homogeneous networks, only information obtained from the radio channel, such as received signal (RSS) and channel availability, are used in the handover decision process. In contrast to this solution, in addition to RSS, such parameters as signal strength in the coverage areas of the current and neighboring networks, network energy saving, distribution of users in the service area of the main base station whose terminals are in standby mode, quality of service, distribution of bandwidth within the cell, in the proposed solution are used in the process of acceptance of service transfer when the line-of-sight connection is blocked by moving obstacles. This makes the entire handover process more complex and ambiguous, as various factors must be considered to make a successful handover decision.

The block diagram of the initialization algorithm of intelligent relay transmission when the line-of-sight communication channel connection is blocked by moving obstacles during transmission in the terahertz wave range is shown in Figure 3. It can be implemented using protocols such as Mobile IP and flow control protocol. To implement the proposed solution, standard and proprietary designs of nodes and components of receiving-transmitting systems (modules) in the terahertz frequency range [18-21], which are built using photonics and microwave electronics technologies, can be used, which also makes it possible to propose new circuit-technological creating solutions in the terahertz range. In addition, to monitor the spatial and energy data of the network cluster structure, you can use a software application developed in the Mathlab software environment [22] using the 5 G package Toolbox (program example « NR Positioning Using PRS ").

3.2.3 Further perspective of using the innovative solution

The further perspective of using this decision is seen in the following. The proposed author's development allows solving a number of scientific and technical problems for the creation of new methods and algorithms of a complex heterogeneous 5 G network with simultaneous user connection to several nodes of the network infrastructure in conditions of their dense placement, which takes into account the blocking of the line-of-sight communication channel connection by moving obstacles when transmitting in the terahertz wave range , applicable to improve service quality parameters. Among the scientific and practical tasks that need to be solved for this, the main ones are the following:

• study of the operation of a complex wireless network with the involvement of additional resources of neighboring base stations and an auxiliary cluster network based on mobile terminals of the service area of the current base station based on a simulation model of the movement of subscribers to predict the choice of effective algorithms for initializing intelligent relay transmission when blocking the connection of a communication channel line of sight to moving obstacles during transmission.

• development and research of a simulation model of the processes of dynamic distribution of resources in a complex wireless network with the involvement of additional resources of neighboring base stations and an auxiliary cluster network based on mobile terminals in the service area of the current base station when the connection of the line-of-sight communication channel is blocked by moving obstacles during transmission.

• development of a structural diagram of the stages of optimization of an innovative solution, which makes it possible to increase the efficiency of the functioning of heterogeneous mobile communication networks when using the terahertz wave range.

4. Conclusions

1. A method of increasing the reliability of heterogeneous 5G/IoT special communication networks when the line-of-sight connection is blocked by moving obstacles during transmission in the terahertz wave range is proposed.

2. The developed algorithm for initializing the intelligent handover when the line-of-sight connection is blocked by moving obstacles during transmission in the terahertz wave range is presented.

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