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I. RUBAN, H. KUCHUK, A. KOVALENKO

REDISTRIBUTION OF BASE STATIONS LOAD IN MOBILE COMMUNICATION NETWORKS

The **subject** matter of the article is the processes of load distribution in mobile communication networks. The **object** of research is the handover. The goal is to develop a method for redistributing the load between neighboring areas for mobile nodes. The considered base stations are supposed to have the signal-to-noise ratios that are equal or close. The **methods t**hat are used: methods of system analysis, methods of digital signal processing. The following **results** are obtained. The method that allows mobile nodes, whose signal-to-noise ratios are equal or close, to switch to a less loaded base station. This method allows the base station to launch the handover process enabling more even distribution of the load from mobile nodes among neighboring base stations in wireless and mobile networks. In the suggested modification of the method, the function assessing the bandwidth of the uplink channel is added to the base stations, as well a threshold value for using its bandwidth. Thus, when the current value of bandwidth reaches the threshold, the base station starts sending out a message to all mobile nodes and verifies free neighboring areas for switching over mobile nodes. If there are adjacent areas with a lower load, the base station notifies all potential candidates about the necessity of their switching over. The handover process is launched when the available bandwidth of the base station decreases below a certain threshold. Therefore, it is possible to optimize the operation of the WiMAX network with respect to the criterion of the total bandwidth capacity of the base stations. Besides, the results of the comparative analysis of the handover process in networks based on the WiMAX technology that are obtained using the OpNet simulation environment are presented. **Conclusions.** The suggested approach can be used to improve the basic software of mobile communication networks. When moving a node from one area to another one in access servers, the node allocation tables are adjusted according to the developed method. Also, the suggested method enables improving and balancing the load of the base stations of mobile communication networks. The obtained results enables maintaining the required level of service quality in mobile communication networks.

Keywords: wireless network, mobile communication network, base station, access area, bandwidth capacity, balance, handover.

Introduction

The modern development of infocommunications is characterized, first of all, by the rapid development of wireless and mobile communication networks. The development of such networks requires the integration of mobile and traditional land-line telecommunication networks of diverse architecture.

The use of wireless environment for data transfer imposes additional conditions on the technologies that are used.

The main difference between these networks and wired ones is that the wireless networks are much more vulnerable in terms of interference and attacks. In addition, the mobility of a user makes the data transfer process more difficult, since the location of a subscriber can change while the data packet is delivered (passes through several transit nodes), that is, various problems connected with routing can happen [1].

One of the main tasks of management is developing an efficient data delivery mechanism, which becomes important and essential in mobile networks due to the constant movement of subscriber systems [2].

Thus, when there exists a data delivery mechanism, there is also a possibility of free movement of nodes and the continuity of their connections in such a move. When moving a node from one area to another area in access servers, the corresponding adjustment of the node allocation tables is carried out.

There are many factors that affect the quality of mobile networks, one of which is the handover process. The success and efficiency of such a process result not only in assessing the quality of services by a user, but also in the operability of the network in general [3].

Currently, a number of methods that support the mobility of a user are suggested, among them are: H-MPLS [4], MM-MPLS [5], as well as those described in the literary sources [6, 7].

Such methods enable rapid determining the address of the area for switching over, but they are unable to support the required level of service quality. For mobile networks, whose structure is constantly changing when nodes are moving, the minimum time of data transfer in the network should be ensured.

The **goal** of this article is to develop a method for redistributing the load among neighboring areas for mobile nodes.

Besides, the considered base stations are supposed to have the signal-to-noise ratios that are equal or close [8].

Theoretical part

Features of the handover process in wireless and mobile Features of the handover process in wireless and mobile networks.

Currently, there is a rapid qualitative and quantitative growth of multiple access of wireless media (including the Internet), allowing the mobile node to send and receive data regardless its location. In global networks, any device is identified by its IP address, which is also used for routing; in this way, the IP address is associated with a specific location in the network, which leads to the necessity in changing the IP address each time the node moves between networks in order to ensure the continuity of the connection. So far as the higher layers of the TCP / IP protocol stack use an IP address to identify the session, hence, the address adjustment should be transparent for such levels.

The mobility of a node in a wireless network can cause the handover. Since the location of a node is directly related to its IP address, therefore, the fact of changing the IP address when the mobile node changes the access point

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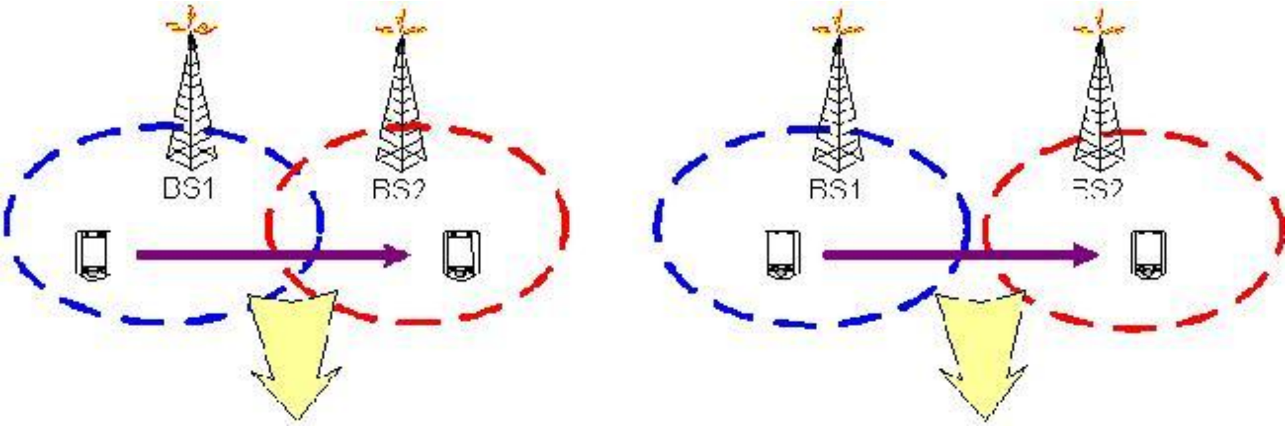
to the network requires notification. The handover is an event that can occur when a mobile node leaves the coverage area of access point due to its movement. Correct processing of such an event allows the mobile node to maintain the continuity of the connection during its movement and changing the access points to the network. In general, there are two types of the handover, each of which is determined by its ability to connect a node to a particular access point: the soft handover and the hard handover [9].

Possible scenarios illustrating such events are shown in fig. 1.



BHO – Soft Handover HHO – Hard Handover

Fig. 1. Probable scenarios of soft and hard handover

In case of the hard handover, the connection of a mobile node to the previous access point is broken before it is connected to a new access point, which results in packet loss. In case of the soft handover, the connection to the previous access point is broken only after establishing the connection with a next available one. Therefore, during the soft handover, a mobile node can simultaneously interact with both access points.

In case where a node moves to another access point that belongs to the same subnet, the handover of L2 link layer can take place. Such handover involves detecting a new access point and subsequent authenticating at the link layer.

If a mobile node moves between the subnets, the hangover of L3 network layer can take place which supplements the link layer handover and includes assigning a new IP address to a mobile node in a new subnet.

The content of the link and network layer handovers is shown in fig. 2. The handover type greatly influences both the speed and the quality of information transmission.

This is especially important when combining traffic of various types (for example, multimedia and data) with different requirements for service quality.

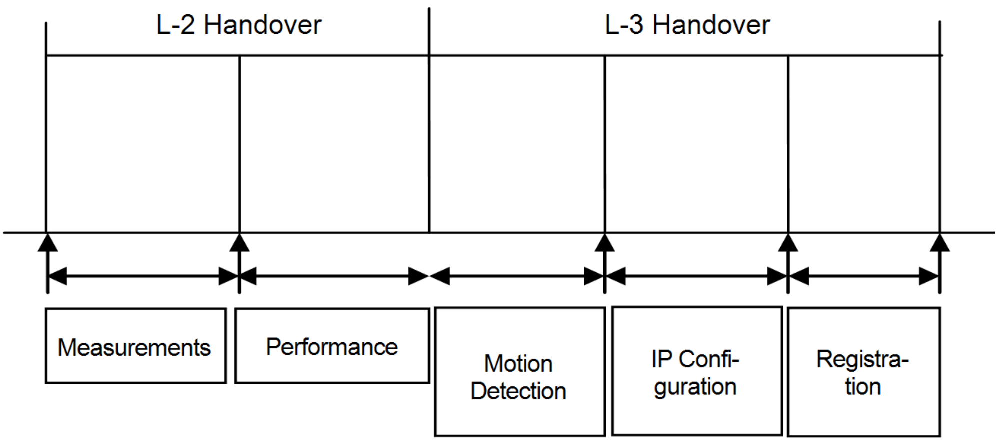


Fig. 2. Content of link (L-2) and network (L-3) handovers

The process of the handover includes 3 stages: detection, correction and registration [10].

The detection phase begins when a mobile node enters a new area.

After that, it receives a message from the nearest access point of such area.

The correction phase begins when a mobile node receives a message from a new access point and lasts until the network interface setting is completed in accordance with the new IP address.

The registration stage consists in the confirmation of the fact that a mobile node has received an IP address.

If T_d denotes the duration of the detection phase, T_c - the duration of the correction stage and T_r – the duration of registration stage, the total duration of handover T_h can be calculated in accordance with the following expression:

$$T_h = T_d + T_c + T_r \,.$$

Method of redistributing the load of base stations

Features of the handover in WiMAX networks. IEEE 802.16 (WiMAX) technology is a broadband wireless technology that supports both fixed and mobile access methods [11]. To meet the requirements of wireless technology support for different access methods, two WiMAX versions are defined.

The first one (Rev.D) is based on the IEEE 802.16-2004 standard and is desinged for using in both fixed and mobile networks.

The second version (Rev.E) is based on the IEEE 802.16e standard and differs from the first by the implementation of handover processing facilities.

The IEEE 802.16e (Rev.E) standard defines three methods for implementing the handover process: the hard handover, the soft handover, and macro diversity handover [12].

In WiMAX networks, the maximum and minimum handover time is calculated as follows [12]:

$$t_{\max} = t_n + t_s + t_i \,;$$

$$t_{\min} = t_i \,,$$

where $t_{\max}$ – is maximum handover time; $t_{\min}$ – is minimum handover time; t_n – is time of message exchange between two neighboring areas; t_s – is the length of the scanning interval for the mobile node of a new access point; t_i – is the time of delivery of the message about the handover to the access point.

To optimize the network operation under the handover, several methods are currently in use. The method suggested in [6] requires implementing a new control message, which, in turn, requires modifying the IEEE 802.16 standard.

Moreover, in this method, when the handover occurs, the process of selecting a new base station by a mobile node lasts for unacceptably long period of time.

The method suggested in [7] enables reducing the duration of the handover because a mobile node selects a new base station and synchronizes with it faster, provided that the neighboring base stations operate at the same frequencies (which is practically unattainable under real conditions).

Improving the method of load distribution. The handover process can be launched by both a mobile node and the base station, as a result of measuring the signal quality of nearby base stations and comparing it with a predetermined threshold value.

The base station considers mobile nodes, where the signal quality of nearby base stations is close to the threshold value, as potential candidates for launching the handover. In the suggested modification of the method, the function estimating the uplink channel bandwidth is added to the base stations, as well as the threshold value of its bandwidth use that is equal to 75% of the maximum threshold.

Thus, when the current value of the bandwidth reaches the threshold one, the base station starts sending out a message to all mobile nodes and verifies free neighboring areas for switching mobile nodes over. If there are adjacent areas with a lower load, the base station notifies all potential candidates about the necessity of switching them over.

When considering whether the handover can be launched for a particular node, the following conditions are taken into account:

– the difference in the signal-to-noise ratio (decibel) in the coverage area of the base station should be no greater than 5 decibel ($\Delta S \le 5$):

$$\Delta S = S_n - S_{n-1},$$

$$S_n = \frac{P_{s_n}}{P_{n_n}},$$

$$S_{n-1} = \frac{P_{s_{n-1}}}{P_{n_{n-1}}},$$

where S_n – is a signal-to-noise ratio for the area which mobile node is moving into; S_{n-1} – is a signal-to-noise ratio in the current area; P_s – is the average signal power; P_n – is the average noise power;

- the area which the mobile node is moving into should have at least 25% of free bandwidth of the uplink channel.

The handover process is launched after assessing the signal quality for all mobile nodes and selecting suitable nodes to switch over.

Fig. 3 shows the handover processing diagram according to the suggested modification of the method, which shows the message transfer process (DSA-REQ, MOB_BSHO-RSP, MOB_BSHO-RSP, MOB_HO-IND) among mobile nodes and base stations according to WiMAX technology.

Results of simulation modeling

The results of the comparative analysis of the handover process in the networks based on WiMAX technology that are obtained using the OpNet simulation environment are presented below [13]. Three possible WiMAX service areas were considered, as well as the location of mobile nodes and base stations. In the first area there are seven mobile nodes, and in the second and the third ones there are four nodes. All mobile nodes simultaneously send voice traffic to the server. The nodes of the first area are fixed, and the other two areas move towards the first area.

The process of the handover occurs when nodes from the second and third areas move towards the first one.

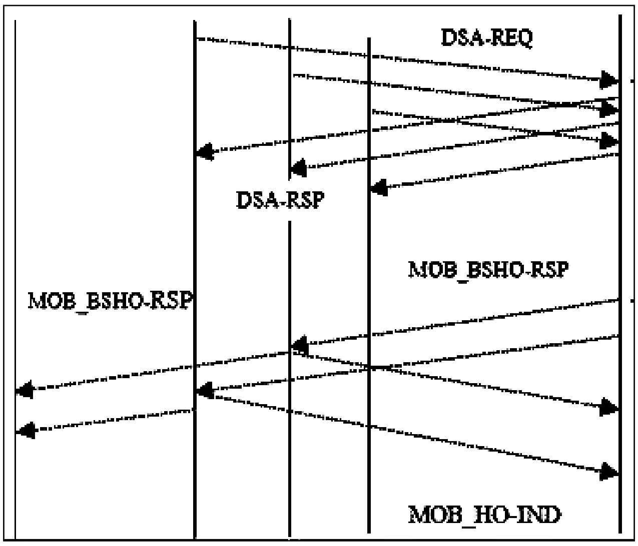


Fig. 3. The handover diagram

When the simulation process starts, the movement starts at the110th second of simulation time. All mobile nodes enter the first area within the period from the 115th to the120th seconds (fig. 4 and fig. 5).

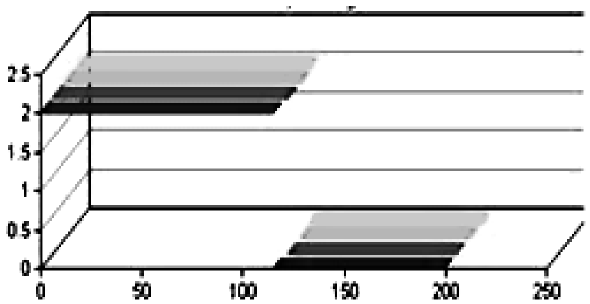


Fig. 4. Time dependence of assigning mobile nodes to the service area when they move from the third area to the first one

When nodes move into the first area, a part of the bandwidth of its uplink channel is assigned to newly appeared mobile nodes. As a result, the bandwidth of the uplink channel of the first area decreases, while the load increases. In the remaining two areas (the second and third areas), after the mobile nodes have left, the bandwidth of the channel increases, which is shown in fig. 6.

The analysis carried out for the uplink channel showed that for the second and third areas the bandwidth increases when the number of mobile nodes serviced in them decreases.

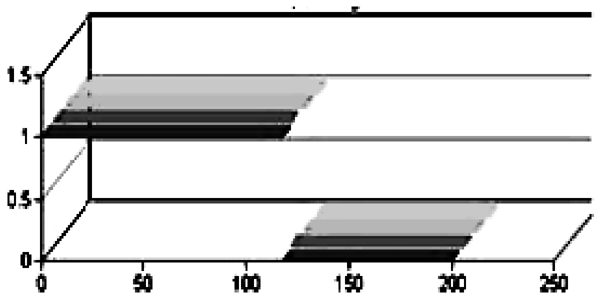


Fig. 5. Time dependence of assigning mobile nodes to the service area when they move from the second area to the first one

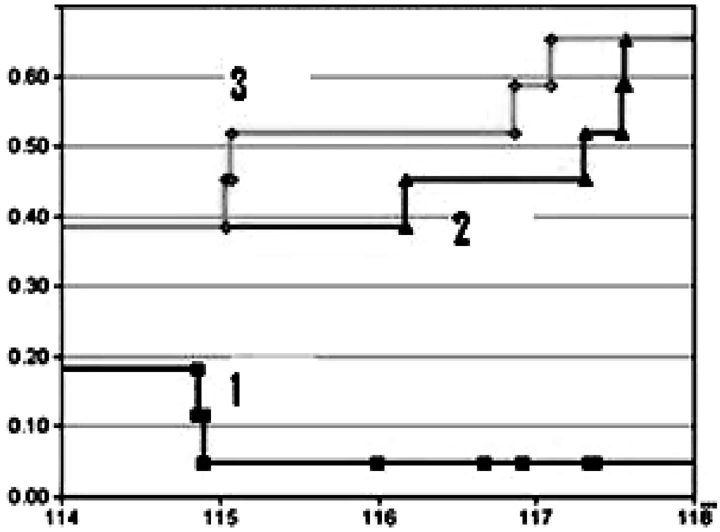


Fig. 6. Change in the bandwidth of the uplink channel of each area during the handover

Discussion of results

According to fig. 7, in the first area the handover has negative effect on the bandwidth of the channel, which periodically decreases.

This is due to the interference caused by the mobile nodes of the second and third areas, when they approach the boundary of the first area, and then move into it. After moving, the load on the first area increases and, if it exceeds the threshold value, the base station of the first area begins selecting and switching mobile nodes that meet the criterion to other areas (fig. 8).

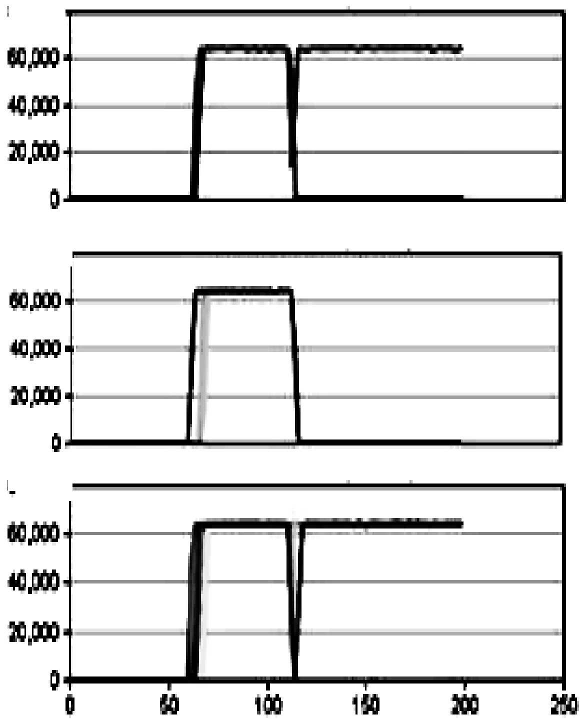


Fig. 7. Channel bandwidth dependence on the handover time

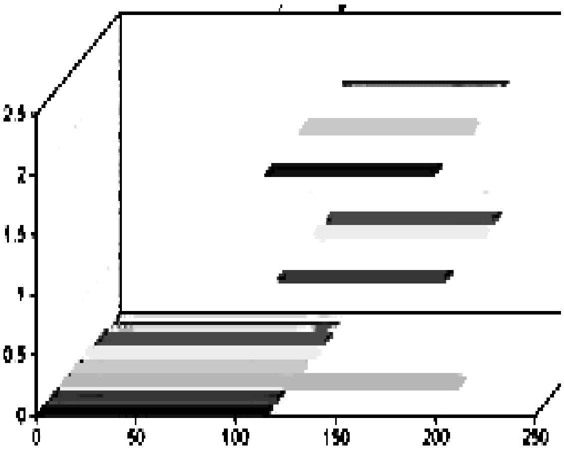


Fig. 8. Time dependence of assigning mobile units to the coverage area

Changes in the bandwidth of the uplink channel in these three areas are considered below. As it is shown in fig. 9, the bandwidth of the uplink channel of the first area decreases to 140 Kb / s at the 115th second, while in the third area the corresponding value increases.

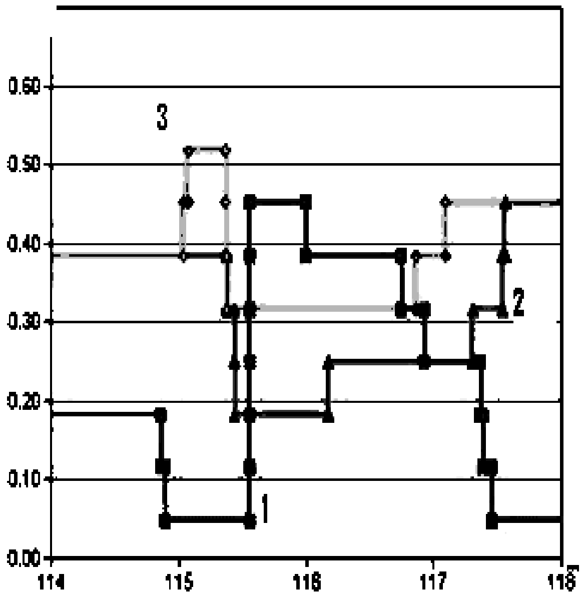


Fig. 9. Dependence of the uplink channel bandwidth on the handover time in the context of the suggested method

This is due to switching two mobile nodes from the third area to the first one, while the bandwidth of the uplink channel of the first area falls below a predetermined threshold value.

In this case, according to the suggested method, the base station in the first area assesses the state of all mobile nodes in this area (at the 115.75th second) and then launches the handover for the respective mobile nodes.

As a result, according to the suggested method, there are nine mobile nodes in the first area, while three ones switches to the second and third areas.

As a result, the bandwidth of the channel increases, as shown in fig. 10.

In the considered examples, fixed values of the signal-to-noise ratio, imposed constraints, and the univariant distribution case are used.

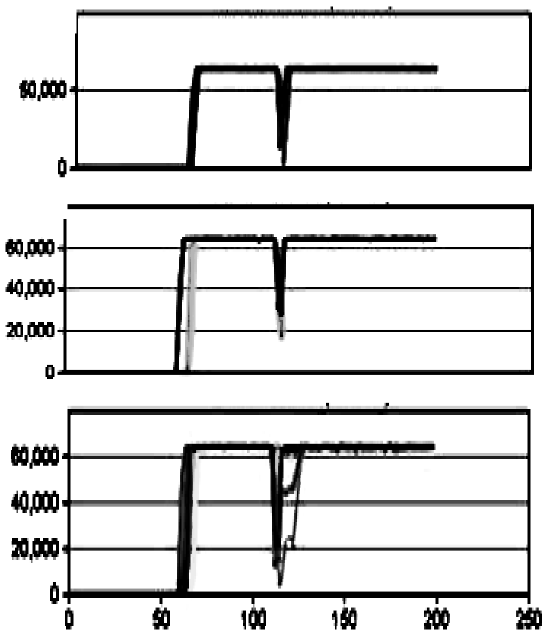


Fig. 10. Channel bandwidth dependence on the handover time

Conclusions

The method that allows mobile nodes, whose signal-to-noise ratio is equal or close, switch to a less loaded base station is suggested.

This method allows the base station to launch the handover process that enables more even distributing the load from mobile nodes among neighboring base stations in wireless and mobile networks.

The handover process is launched when the available bandwidth of the base station decreases below a certain threshold. Consequently, the operation of the WiMAX network can be optimized according to the criterion of the total bandwidth capacity of the base stations.

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Відомості про авторів / Сведения об авторах / About the Authors

Рубан Ігор Вікторович – доктор технічних наук, професор, Харківський національний університет радіоелектроніки, проректор з науково-методичної роботи, м. Харків, Україна; e-mail: ihor.ruban@nure.ua, ORCID: 0000-0002-4738-3286.

Рубан Игорь Викторович – доктор технических наук, профессор, Харьковский национальный университет радиоэлектроники, проректор по научно-методической работе, г. Харьков, Украина; e-mail: ihor.ruban@nure.ua, ORCID:0000-0002-4738-3286.

Ruban Igor – Doctor of Sciences (Engineering), Professor, Kharkiv National University of Radioelectronics, Vice-Rector for Scientific and Methodological Work, Kharkiv, Ukraine; e-mail: ihor.ruban@nure.ua, ORCID: 0000-0002-4738-3286.

Кучук Георгій Анатольович – доктор технічних наук, професор, Національний технічний університет "Харківський політехнічний інститут", професор кафедри обчислювальної техніки та програмування, м. Харків, Україна; e-mail: kuchuk56@ukr.net, ORCID: 0000-0002-2862-438X.

Кучук Георгий Анатольевич – доктор технических наук, профессор, Национальный технический университет "Харьковский политехнический институт", профессор кафедры вычислительной техники и программирования, г. Харьков, Украина; e-mail: kuchuk56@ukr.net, ORCID: 000-0002-2862-438X.

Kuchuk Heorhii – Doctor of Sciences (Engineering), Professor, National Technical University Kharkiv Polytechnic Institute", Professor at the Department of computer engineering and programming, Kharkiv, Ukraine; e-mail: kuchuk56@ukr.net, ORCID: 0000-0002-2862-438X.

Коваленко Андрій Анатолійович – кандидат технічних наук, доцент, Харківський національний університет радіоелектроніки, доцент кафедри Електронно-обчислювальних машин, м. Харків, Україна; e-mail: andriy_kovalenko@yahoo.com, ORCID: 0000-0002-2817-9036.

Коваленко Андрей Анатольевич – кандидат технических наук, доцент, Харьковский национальный университет радиоэлектроники, доцент кафедры электронно-вычислительных машин, г. Харьков, Украина; e-mail: andriy_kovalenko@yahoo.com, ORCID: 0000-0002-2817-9036.

Kovalenko Andrey – PhD (Engineering Sciences), Associate Professor, Kharkiv National University of Radioelectronics, Assistant Professor of the Department of Electronic computing machines, Kharkiv, Ukraine; e-mail: andriy_kovalenko@yahoo.com, ORCID: 0000-0002-2817-9036.

ПЕРЕРОЗПОДІЛ НАВАНТАЖЕННЯ БАЗОВИХ СТАНЦІЙ В МОБІЛЬНИХ МЕРЕЖАХ ЗВ'ЯЗКУ

Предметом вивчення в статті є процеси розподілу навантаження в мобільних мережах зв'язку. **Об'єкт дослідження** – хендовер. **Мета** – розробка методу перерозподілу навантаження між сусідніми зонами для рухливих вузлів. При цьому передбачається, що у розглянутих базових станцій співвідношення сигнал-шум рівні або близькі. Використовуваними **методами** є: методи системного аналізу, методи цифрової обробки сигналів. Отримані такі **результати**. Запропоновано метод, що дозволяє рухомим вузлам з рівним або близьким співвідношенням сигнал-шум перемикатися на менш завантажену базову станцію. Такий метод дозволяє базовій станції ініціювати процес хендовера, що дозволяє більш рівномірно розподіляти навантаження від рухливих вузлів між сусідніми базовими станціями в бездротових і мобільних мережах. У запропонованій модифікації методу до базової станції додається функція, яка оцінює значення пропускної здатності висхідного каналу, а також додається порогове значення використання його пропускної здатності. Таким чином, коли значення поточної пропускної здатності досягає порогового, базова станція починає розсилати повідомлення всім рухомим вузлам і перевіряє наявність більш вільних сусідніх зон для перемикання рухомих вузлів. При наявності сусідніх зон з меншим завантаженням, базова станція повідомляє всіх потенційних кандидатів про необхідність їх перемикання. Процес хендовера ініціюється при зниженні доступної величини пропускної здатності базової станції нижче певного порогу. Отже, існує можливість оптимізації роботи мережі WiMAX за критерієм сумарної пропускної спроможності базових станцій. Також представлені результати порівняльного аналізу процесу хендовера в мережах, заснованих на технології WiMAX, які отримані за допомогою середовища моделювання OpNet. **Висновки.** Запропонований підхід можна використовувати при вдосконаленні базового програмного забезпечення мобільних мереж зв'язку. При переміщенні вузла з однієї зони в іншу зону в серверах доступу здійснюється коригування таблиць розміщення вузлів відповідно до розробленого методу. Також запропонований метод дозволяє істотно поліпшити збалансованість завантаження базових станцій мобільних мереж зв'язку. Отримані результати дозволяють підтримувати необхідний рівень якості обслуговування в мобільних мережах зв'язку.

Ключові слова: бездротова мережа, мобільна мережа зв'язку, базова станція, зона доступу, пропускна здатність, баланс, хендовер.

ПЕРЕРАСПРЕДЕЛЕНИЕ НАГРУЗКИ БАЗОВЫХ СТАНЦИЙ В МОБИЛЬНЫХ СЕТЯХ СВЯЗИ

Предметом изучения в статье являются процессы распределения нагрузки в мобильных сетях связи. Объект исследования – хэндовер. **Цель** – разработка метода перераспределения нагрузки между соседними зонами для подвижных узлов. При этом предполагается, что у рассматриваемых базовых станций соотношения сигнал-шум равны или близки. Используемыми **методами** являются: методы системного анализа, методы цифровой обработки сигналов. Получены следующие **результаты.** Предложен метод, позволяющий подвижным узлам с равным или близким соотношением сигнал-шум переключаться на менее загруженную базовую станцию. Такой метод позволяет базовой станции инициировать процесс хэндовера, позволяющий более равномерно распределять нагрузку от подвижных узлов между соседними базовыми станциями в беспроводных и мобильных сетях. В предлагаемой модификации метода в базовые станции добавляется функция, оценивающая значение пропускной способности восходящего канала, а также добавлено пороговое значение использования его пропускной способности. Таким образом, когда значение текущей пропускной способности достигает порогового, базовая станция начинает рассылать сообщение всем подвижным узлам и проверяет наличие более свободных соседних зон для переключения подвижных узлов. При наличии соседних зон с меньшей загрузкой, базовая станция уведомляет всех потенциальных кандидатов о необходимости их переключения. Процесс хэндовера инициируется при снижении доступной величины пропускной способности базовой станции ниже определенного порога. Следовательно, имеется возможность оптимизация работы сети WiMAX по критерию суммарной пропускной способности базовых станций. Также представлены результаты сравнительного анализа процесса хэндовера в сетях, основанных на технологии WiMAX, которые получены с помощью среды моделирования OpNet. **Выводы.** Предложенный подход можно использовать при совершенствовании базового программного обеспечения мобильных сетей связи. При перемещении узла из одной зоны в другую зону в серверах доступа осуществляется корректировка таблиц размещения узлов в соответствии с разработанным методом. Также предложенный метод позволяет существенно улучшить сбалансированность загрузки базовых станций мобильных сетей связи. Полученные результаты позволяют поддерживать требуемый уровень качества обслуживания в мобильных сетях связи.

Ключевые слова: беспроводная сеть, мобильная сеть связи, базовая станция, зона доступа, пропускная способность, баланс, хэндовер.

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