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A Novel Approach of Optimum Multi-criteria Vertical Handoff Algorithm for Heterogeneous Wireless Networks

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***Abstract* — In this paper is proposed method of intellectual vertical handover that allows performing unloading of wireless heterogeneous access networks using multi-criteria network evaluation. An algorithm of handover functioning is further improved using fuzzy logic based on cloud technology. An imitation model is created for investigation of heterogeneous network with realization of proposed algorithm of initiation of vertical handover. A process of service provisioning by heterogeneous network is investigated based on created model. In the process of modeling it is shown that proposed algorithm allows choosing optimal cell for each individual user among available cells of different access systems.**

***Index Terms* —heterogeneous networks, triangular fuzzy number, vertical handoff, base station, cloud technology, access network, packet loss ratio**

I. INTRODUCTION

Today progressive development of telecommunications leads to creation of various radio access technologies and increasing of the number of multi-standard user terminals which in the nearest future will allow integration different technologies into a single network, i.e. to create heterogeneous wireless network [1]. This network will consist of segments of different technologies that have their coverage zones overlapping. This allows to increase networks throughput and extend is coverage area, and for the user to provide services with lower price and higher quality of service. In heterogeneous wireless networks of next generations, user with multi-standard terminal will be able to obtain access to networks of different operators/providers. In such conditions arises a necessity to support users' mobility that can be done by intellectual vertical handover – technique of handing over connections from one radio access network to another (see Fig. 1). Such switching can be based on different criteria (QoS (delay, jitter, losses, throughput), QoE, users priority, users movement speed, service class, signal level of each particular access network), which by combining and processing by different algorithms can affect on quality of service for end users and their satisfactory and also on distribution efficiency of network resources.

II. METHOD OF INTELLECTUAL VERTICAL HANDOVER BASED ON CLOUD COMPUTING

A. General Task Set Up

Increasing complexity of communication systems, increasing of mobile traffic volumes and development of coordination of communication networks (including protocols that determine networks collaboration) lead to arising of new tasks plurality. Such tasks include optimal selection of access system when system is overloaded. The goal of this work is increasing of QoS of mobile systems [2] by effective utilization of network and radio resources of heterogeneous network and optimal procedure of intellectual vertical handover based on fuzzy logic technique.

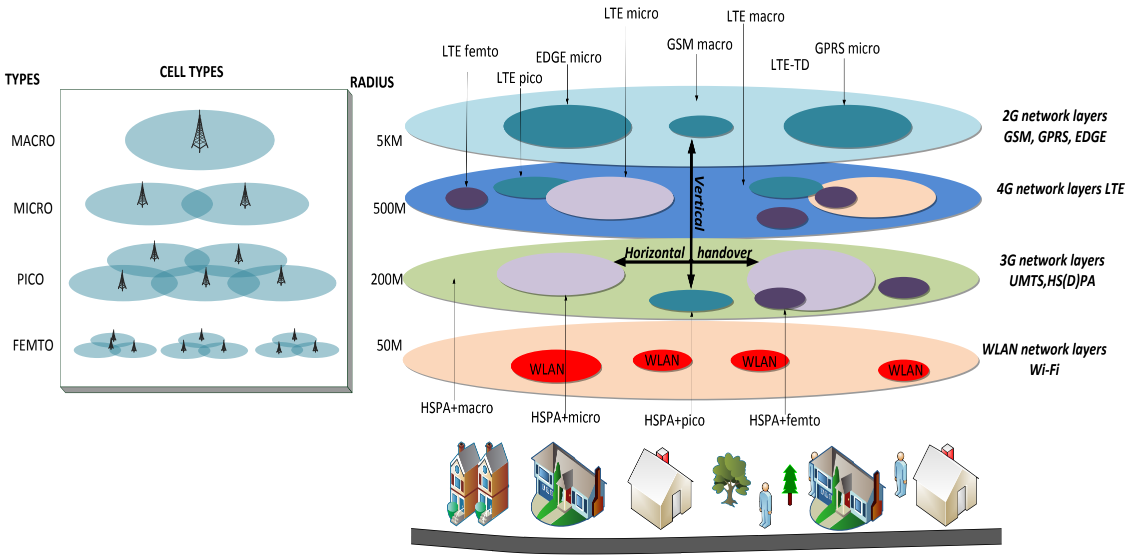

Fig. 1. Heterogeneous Wireless Networks

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Proposed approach in comparison with already existing [3], uses theory of fuzzy sets. This theory is a tool for solving tasks of aggregation double-meaning, subjective and unclear evaluative judgments about state of particular parameter or indicator of optimal network selection. Using classical theory of sets it is hard to connect all evaluation into one result or even sometimes in impossible. Moreover fuzzy sets can divide obtained data using linguistic terms for further decision making. Thus, if such approach is used to build a model, the latter becomes quantitative unlike existing subjective evaluations.

B. Using of Cloud Computing for IVHO

In order to solve the task of initiation and performing of handover, in this work is proposed a centralized method of handover management based on cloud technologies using fuzzy logic. For handover performing it is proposed to use parallel computation principles based on cluster of servers. Each operator can setup such cluster for individual purpose integrating it into his infrastructure. Another way for operator is to use service models of cloud systems, i.e. it can develop own software and use cloud infrastructure as a service for deploying this software.

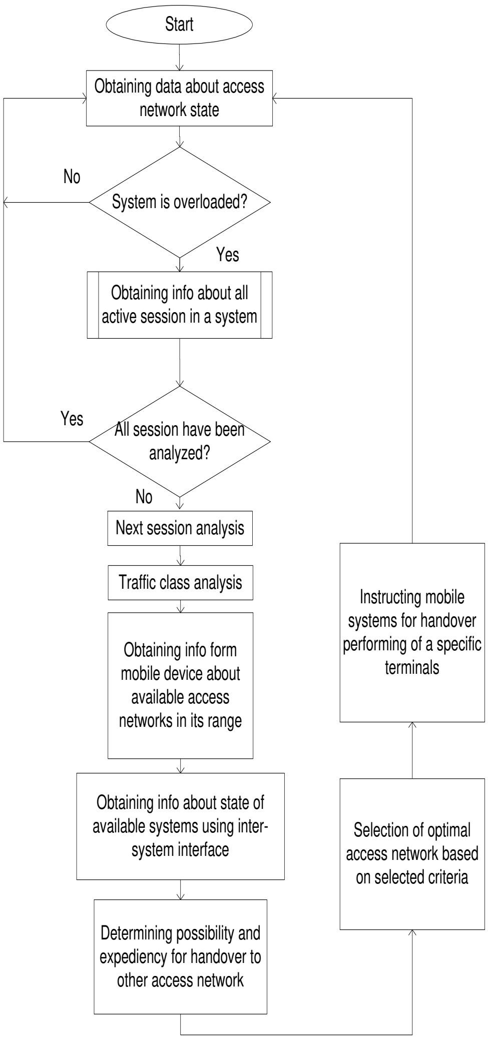

Fig. 2. Algorithm of initiation of intellectual vertical handover

It will allow him to significantly decrease capital expenses. Such approach is dictated by the fact that handover initiating decision and optimal access network selection algorithms require use of complex forecasting and processing methods which can take much time depending on hardware performance and software architecture. It is clear that mobility of users makes time as a critical factor of decision making as far as when user moves with high speed and has multimedia session established, long time of calculations for handover decision will lead to session interruption and possible problems when trying to reestablish it. Using abilities of cloud systems it is possible to conduct such calculations in a few milliseconds and ensure optimal selection of access system for handover [4]. That is why in this work is proposed algorithm of intellectual vertical handover conduction (Fig.2). For realization of such system on cluster of servers it is installed a special software that performs all necessary processes. Taking into account described conditions concerning software algorithm of intellectual vertical handover is shown on Fig.1.

III. MULTIPLE CRITERIA VERTICAL HANDOFF ALGORITHM

A. Traffic Classes and Handoff Metrics

Figure 3 describe different traffic classes and several handoff metrics that are used as inputs to the various vertical handoff algorithms [5]. These metrics are described below:

Received Signal Strength (RSS): This criterion is simple, direct, and widely used in both horizontal and vertical handoffs. This network metric is easy to measure and is directly relevant to the QoS of an application. Also, RSS readings are inversely proportional to the distance between the MS and the BS, and could result in excessive and/or unnecessary handoffs.

Available Bandwidth: Measured in bits/sec, available bandwidth is used to determine traffic-loading conditions of an AN, and is a good measure of available communication resources at the BS.

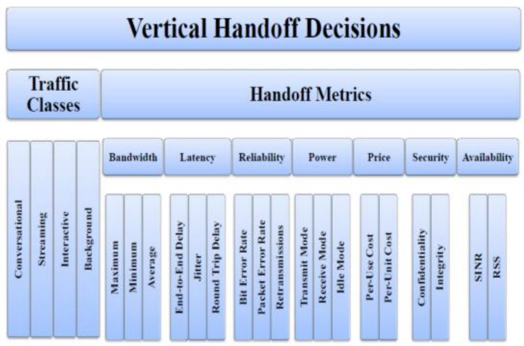

Fig. 3. Traffic classes and handoff metrics

***Network Connection Duration*:** This is the amount of time that the MS remains connected to a specific access network AN. This time duration depends on the location and velocity of the MS, which in turn affect its RSS. Due to different coverage areas in heterogeneous wireless networks, the

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evaluation of this criterion is very important to determine two factors: 1) the triggering conditions required for the handoff at the right time in order to maintain a satisfactory QoS while avoiding wastage of network resources and 2) to reduce the number of unnecessary handoffs. For example, a hasty handoff from an IEEE 802.11 WLAN to a 3G cellular network [6] would result in network resources being wasted. On the other hand, delaying the handoffs between these networks would result in handoff failures and subsequent call drops. Statistics, such as total time spent in an AN and arrival time of a new call in the network, can also be used as handoff criteria.

Monetary Cost: Different operators may operate heterogeneous wireless networks and may have varying costs associated with them. The network with the least cost should be a preferred target of handoff.

Handoff Latency: For an MS, handoff latency is defined as the elapsed time between the last packet received from the old AN, and the arrival of the first packet via the new AN after a successful handoff. This metric varies considerably between various heterogeneous wireless technologies

Security: Certain applications require that the confidentiality, and/or the integrity of the transferred data be preserved.

Power Consumption: Handoff process demands a fair amount of power consumption. If an MS were running low on battery power, it would be preferable to handoff to a target AN that would help extend the MS's battery life.

Velocity: Velocity is an important decision factor as it relates to the network-connection-duration metric and location of the MS. An MS travelling at a very high speed may result in excessive handoffs between wireless networks.

The end-user can assign the relative importance of the first-level criteria. The order of preference for level-1 criteria, as utilized in our design, is given as: RSS, QoS, Velocity, Network Loading, Security, and Cost; where RSS and QoS are given equal importance as our goal is to maximize end-users' satisfaction. Nonetheless, our scheme is flexible and the end-users may change this preference order based on their requirements.

Table I. Parameters evaluation for handover initiation process with Likert scale

SCALE	1	2	3	4	5	The Min/Max Quantities
Load, [%]	70–100	50 –70	40 –50	30–40	0–30	0–100
Cost	1–2	2–3	3–4	4–8	8–10	1–10
Security	1–2	2–4	4–6	6–8	8–10	1–10
Ms-Velocity, [km/h]	<120	80–120	60–80	40–60	0–40	0–160
Delay,[ms]	<300	200–300	100–200	50–100	10–50	10–500
Jitter, [ms]	<30	20–30	10–20	5–10	1–5	10–30
Packet Loss Ratio (PLR), [%]	<8	6–8	4–6	3-4	1-3	1-8
Throughput, [Mbps]	<0/1	0.1-10	1-50	50-100	100-200	0/1-200
RSS, [dbm]	< -110	-100 – -110	-90 – -100	-75 – -90	-55 – -75	-110 –-55

The scheme of the weight calculation process for all four traffic classes is given as Fig. 4. Consequently, we proposed to split all the parametric criteria onto two groups: QoS-depended and radio interface depended. This was performed in the next section.

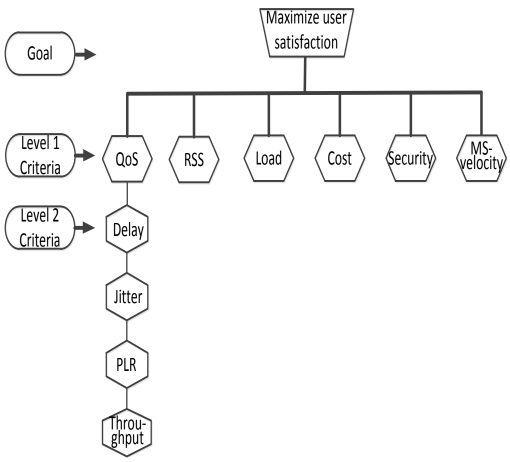

Fig. 4. Multi-criteria parameters for vertical handoff initiation

B. Model of Vertical Handoff Initiation Using Fuzzy Logic

A heterogeneous wireless network typically comprises of different types of wireless access technologies with dissimilar operating parameters and characteristics. In general, these dissimilar parameters are not directly comparable. Thus Fuzzy Logic [7] is utilized to normalize these parameters in the range of [0, 1].

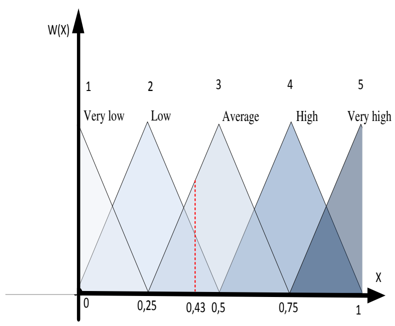

Fig. 5. Scale of grades and member functions of respective linguistic terms

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After preparing parameters for intellectual vertical handover performing, a scale of evaluation of importance of each criteria for handover initiation is introduced in accordance with Likert scale (1 – very inapplicable (0,0,0.25), 2- inapplicable (0,0.25,0.75), 3 – medium, (0.25, 0.5, 0.75), 4 – applicable (0.5,0.75,1), 5 – very applicable (0.75,0.75,1)) according to the Table I. A five-point scale of linguistic terms is also introduced for evaluation of correlation between state at the enterprise and criteria (1 – “very low”, 2 – “low”, 3 – “average”, 4 – “high”, 5 – “very high”), that is evaluation of parameter index level regarding to respective criterion in accordance with mention scale (Fig.5). In the considering heterogeneous network it is deployed seven services such as voice (A), and video conference (B), and IPTV (C), and Internet data (D), and interactive data (E), and media on demand (F), and Voice over IP (G)). Let’s form empiric coefficients of services importance regarding required quality of service for handover initiation using coefficients B_1, B_2, B_3 and B_4, that can be in a range from 1 to 3, where higher value means higher importance of specific quality of service parameter for a particular service category (see Table II).

Table II. Services and respective traffic parameters significance coefficient relative to others

P / S	PLR B_1	Delay B_2	Jitter B_3	Throughput B_4
Voice	2	3	3	1
Videoconference	2	3	3	2
IPTV	3	2	2	3
Internet data	3	1	1	1
Interactive data	2	2	1	1
VoD	2	2	2	3
VoIP	3	2	1	1

First, an influence of increasing load of each cell in all access network technologies on parameters that affect selection of access network when doing intellectual vertical handover is determined. Process of selection of optimal network will be performed in monitoring system of heterogeneous network using cloud technology calculation facilities and fuzzy logic. Let’s introduce parameter of node utilization capacity for particular wireless technology ρ_{mn} based on the node’s load parameter where m is a number of access system node located in space, and *n* – type of wireless access technology at the node *m*. Let’s assume that *n*=1 for LTE, *n*=2 for GSM. Respective coefficients of technological depended parameters’ importance for both technologies are given in the Table III.

Table III. Coefficients of technological depended parameters’ importance

P / S	GSM T_1	LTE T_2
Cost	1	2
Security	1	2
RSS	2	2
Load	2	1
MS-Velocity	1	2

After values of node parameters were estimated in the process of node evaluation based on collection of indexes that characterize QoS (PLR, delay, jitter, throughput) by default with all weights equal to 0.5. In case of weight decreasing while ρ_{mn} increasing, weight of parameter is calculated in accordance to Table IV by formula:

$$wp_{imn} = 0.5 + 0.5 \cdot \rho_{mn},\ i = 1..4. \quad (1)$$

Table IV. Services significance coefficient relative to others

	Load changes	Weight changes
Jitter	Increasing ρ ↑	Decreasing ↓
Cost	Increasing ρ ↑	Increasing ↑
Security	Increasing ρ ↑	Const ↔
Ms-Velocity,[km/h]	Increasing ρ ↑	Decreasing ↑
Delay,[ms]	Increasing ρ ↑	Increasing ↑
Packet Loss Ratio [%]	Increasing ρ ↑	Increasing ↑
Throughput,[Mbps]	Increasing ρ ↑	Decreasing ↓
RSS, [dbm]	Increasing ρ ↑	Const ↔

In case of weight decreasing while ρ_{mn} increasing, weight of parameter is calculated in accordance to Table IV by formula:

$$wp_{imn} = 0.5 - 0.5 \cdot \rho_{mn},\ i = 1..4, \quad (2)$$

where *i* is an index number of QoS-affecting parameter wp_{imn} by the order (see Table II) that is taken into account in the process of intellectual vertical handover (IVHO).

Finally, weights w_{imn} are obtained as a result of multiplying parameters’ weights (1-2) and coefficient of parameter importance regarding to requested service:

$$w_{imn} = wp_{imn} B_i,\ i = 1..4, \quad (3)$$

where B_i is coefficient of parameters importance regarding to service type requested by user (shown in Table II).

Thus normalization of w_{imn} is performed:

$$W_{imn} = w_{imn} \Big/ \sum_{i=1}^{4} w_{imn}, \quad (4)$$

Respectively, TFN evaluation of selected access node $\tilde{Q}_{mn}$ is calculated regarding to selected technology in accordance with parameters evaluation scaling listed in Table I, that immediately affect QoS for respective user serving:

$$\tilde{Q}_{mn} = (q_1, q_2, q_3)_{mn} = \sum_{i=1}^{4} \left(W_{imn} \times \tilde{L}_{imn} \right) \quad (5)$$

$$q_{j_{mn}} = \sum_{i=1}^{4} \left(W_{i_{mn}} \times l_{ij_{mn}} \right),\ \left(j = 1,2,3;\ m = 1,2,3;\ n = 1,2 \right), \quad (6)$$

where q_1, q_2, q_3 are bottom level of general evaluation $\tilde{Q}$, its basic value and top level respectively, $\tilde{L}_{imn} = (l_{i1}, l_{i2}, l_{i3})_{mn}$ - triangular fuzzy number that characterizes indicator of node parameter by *i-th* criteria for node of access system *m* based on *n-th* technology. Here l_{i1}, l_{i2}, l_{i3} - bottom level of linguistic variable, its basic value and top level respectively to

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TFN format (Triangular Fuzzy Number [3]), see scale Fig. 5. After determination of values of access node parameters in the process of node evaluation based on collection of indexes that characterize physical link to make an appropriate decision on handover procedure by air interface circumstances we operating with following parameters which by default assigned with all weights equal to 0.5. They are defined in Table III: RSS, Load, Security, Velocity, Cost. In case of increasing weight and increasing of ρ_{mn}, the weight of parameter is determined in accordance with Table IV and (1):

$$plp_{kmn} = 0.5 + 0.5 \cdot \rho_{mn} \quad (7)$$

In case of decreasing weight and increasing of ρ_{mn}, the weight of parameter is determined in accordance with table 3 and (2):

$$plp_{kmn} = 0.5 - 0.5 \cdot \rho_{mn}, \quad (8)$$

where k is an index number of physical radio interface parameter plp_{kmn} that is taken into consideration in the process of vertical handover (see Table III). Resulting weight pl_{kmn} is obtained as a result of multiplying parameters evaluations based on Table I and coefficients of parameter importance according to Table III for each technology:

$$pl_{kmn} = plp_{kmn} T_k, k = 1..5, \quad (9)$$

where k is a parameter that is taken into consideration in the process of vertical handover and T_k is an importance coefficient of parameters respectively to wireless access technology type (shown in Table III).

Then normalization of w_{kmn} is performed:

$$PL_{kmn} = pl_{kmn} \Big/ \sum_{i=1}^{5} pl_{kmn}, \quad (10)$$

Respectively the selected node evaluation $\tilde{P}_{mn}$ is calculated regarding to selected technology according to parameters evaluation that are obtained from Table I that immediately affect quality of radio interface:

$$\tilde{P}_{mn} = (p_1, p_2, p_3)_{mn} = \sum_{i=1}^{5} \left(PL_{kmn} \times \tilde{L}_{kmn}\right) \quad (11)$$

$$p_{j_{mn}} = \sum_{i=1}^{5} \left(PL_{k_{mn}} \times l_{kj_{mn}}\right), \quad (j = 1,2,3; m = 1,2,3; n = 1,2), \quad (12)$$

where p_1, p_2, p_3 are bottom level of general evaluation $\tilde{P}$, its basic value and top level respectively, $\tilde{L}_{kmn} = (l_{k1}, l_{k2}, l_{k3})_{mn}$ is triangular fuzzy number TFN that characterizes indicator of node parameter by *k-th* criteria for the node of m access system based on *n-th* technology. Here l_{k1}, l_{k2}, l_{k3} is bottom level of linguistic variable; its basic value and top level respectively to TFN format (see Fig.5). This way generalized evaluation of access node is determined as:

$$\tilde{R}_{mn} = (r_{1mn}, r_{2mn}, r_{3mn}) = \tfrac{1}{2} \times \left(\tilde{Q}_{mn} + \tilde{P}_{mn}\right) = \tfrac{1}{2} \times \left(q_{1mn} + p_{1mn}, q_{2mn} + p_{2mn}, q_{3mn} + p_{3mn}\right). \quad (13)$$

Let's conduct defuzzification of obtained fuzzy number (13) in accordance with [3]:

$$R_{mn} = \tfrac{1}{3} \times \sum_{t=1}^{3} r_{tmn}. \quad (14)$$

IV. INVESTIGATION OF HETEROGENEOUS NETWORKS USING PROPOSED IVHO WITH IMITATION MODEL

A. Development of Imitation Model of Heterogeneous Network

Imitation modeling of serving process always required for developer of imitation model as well as testing of adequacy of created model to processes that are performed in a real system. The simplest way of determining characteristics of service system lies in obtaining of experimental data regarding to serving process. Data analysis allows determining what parameters of service system must be changed in order to increase quality of service, i.e. optimize the process. Existing service systems contain wide variety of components where each component is a complex system that has its parameters and characteristics. In general all components individually affect quality of service of the whole system. That is why for creating adequate model and performing adequate evaluation of modeling results it is necessary to take into account all components that take part in service process. Big number of users, applications and sessions that are generated by these applications and their variety have significant impact on characteristics of traffic that arrives at service system. Thus, in order to model such traffic it is necessary to apply mathematical apparatus that will allow describing characteristics of such traffic more precisely. In is understood that the most effective way of modeling in such situation is development of specialized software. By virtue to software realization of imitation model it is possible to realize not only all necessary functions of model but also ensure control over its work. Software allows using graphical user interface dynamically change model parameters and by that evaluate systems behavior in specific situation that can occur in a real service system. Besides that, software using GUI allows in a real time all parameters of the model, what can be done using graphics, diagrams, lists and tables. For investigation of mobile network functioning with high mobility if users it is necessary to develop imitation model using big number of parameters and characteristics that allow describing existing networks using mathematical, prognostic and optimization models. Thus, in this paper a model of heterogeneous mobile network is developed. It structure is shown on Fig.6.

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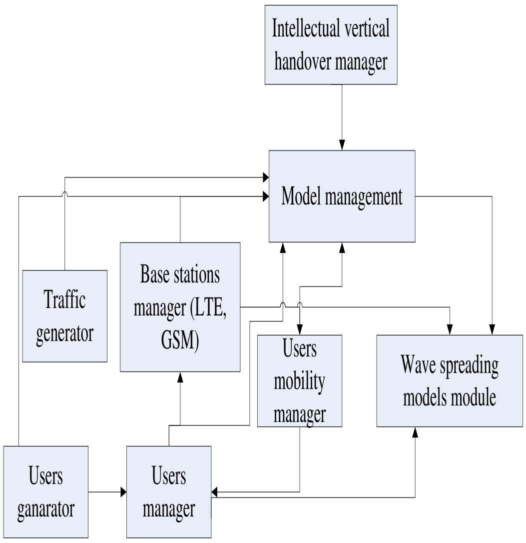

Fig. 6. Structural scheme of imitation model

Imitation model contains block of users' behavior modeling which includes traffic generation. Generated users are passed to "user's manager". If users is only registered in the network and doesn't have active connections that he is marked in the model as grey bold point. If user has active connection with network than it is marked with colored point depending on what system it is connected to: GSM – green color, LTE – blue color. User in such model is represented as an object with a set of parameters such as: activity duration, movement vector, movement speed, current location, and distance to base stations, signal level from each base station of LTE and GSM and other extra parameters necessary for model operation. User movement speed is determined by the formula:

$$V_{SPEED} = \frac{\sqrt{(x_i - x_{i-1})^2 + (y_i - y_{i-1})^2}}{\Delta\tau}, \quad (15)$$

In this paper it is proposed to conduct classification of users speed in order to record change of base station signal level during observation time and to conduct forecasting of handover necessity into another cell with respect on forecasting of users movement direction probability. Original software is developed in this paper which allows setting arbitrary distribution law of user's movement with different speeds. Coordinates and parameters of users are stored into monitoring system and represented by arrays of data. The main arrays are: coordinated (x, y), movement speed (V_{SPEED}, m/s), signal level RSS from neighbor base stations (n = 1, 2, 3). Data to this array is written every second. Users' manager represents an array that stores user objects and conducts monitoring of activities of each user registered in a system. If duration of storing user object in array is higher than the average duration of call that was set by generator when user object was created, than it is considered that user has finished the call and his object is removed from the array. Another important element of the model is block that is responsible for realization of mathematical model of radio waves spreading. Block can encapsulate any model and thus is universal, i.e. allows conduct modeling for different systems with different radio interfaces and under different circumstances. Algorithm of this block monitors location of users and their movements, based on which it calculates signal attenuation form all base stations. In turn base station which is also described as an object has its own parameters such as: location height, signal radiation power, working frequency, number of antennas etc. Signal spreading and respectively its attenuation is described by Okumura-Hata model for city conditions where effect of multi-wave propagation is manifested the most. Hence, calculation of attenuation in the model for city conditions is conducted by formula:

$$L_{[dbm]} = 69,55 + 26,16 \bullet \lg(f) - 13,82 \bullet \lg\left(h_{N[m]}\right) - a\left(h_0\right) + \quad (16)$$
$$+ \left(\left[49,9 - 6,55 \bullet \lg\left(h_{N[m]}\right)\right]\right) \bullet \lg\left(d_{[\kappa m]}\right)$$

Important for conducting of researches that are described in this paper is block that is responsible for spreading users. It uses interface of users' manager and in accordance with Brownian motion distribution law performs change of user coordinates with different interval and count of steps, hence ensuring modeling of users' motion [8]. Thus, block of wave spreading on each new step calculates signal attenuation for the user at new location. It worth to mention that there are such users that don't move. For developing such software in this paper is used programming language C++ based on development environment Borland Builder C++ 6.0. The main window of the program that realizes modeling according to created imitation model is shown on Fig.44. Interface contains a component for displaying of utilization of three base stations of GSM type and three base stations of LTE type. For each base station there is a graph in application interface that displays registered and active users. In order to compare system performance without IVHO and with it, a possibility to turn off algorithm of IVHO is added to the program.

B. Experimental Results

Based on proposed solution using imitation modeling the next results were obtained (see details on Figs. 7-13 and in the Table V). The most optimal result for IVHO performance at the modelled circumstances was obtained for BS2 (LTE) node (it is shown on the Fig. 13). Result for BS1 (LTE) is not so high, but still belongs to the same member function with linguistic term "High". So, fuzzy sets show us the quantitative difference between qualitatively equal solutions.

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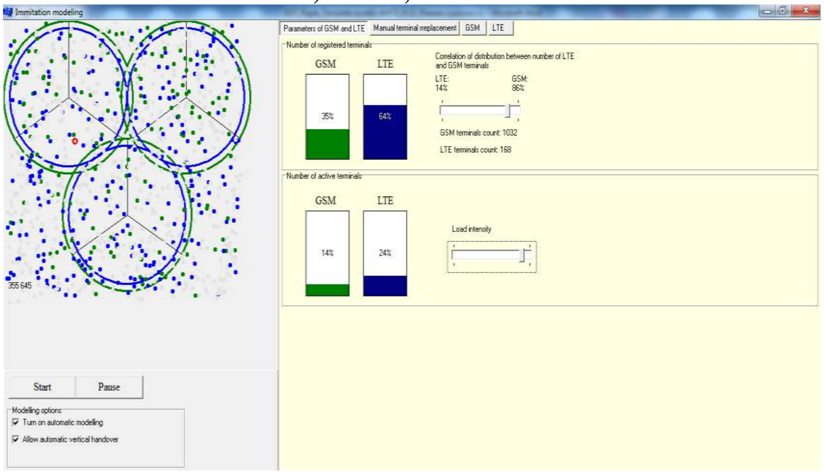

Fig. 7. Interface of imitation model of heterogeneous network with ability to change incoming load intensity at LTE and GSM when systems are highly loaded

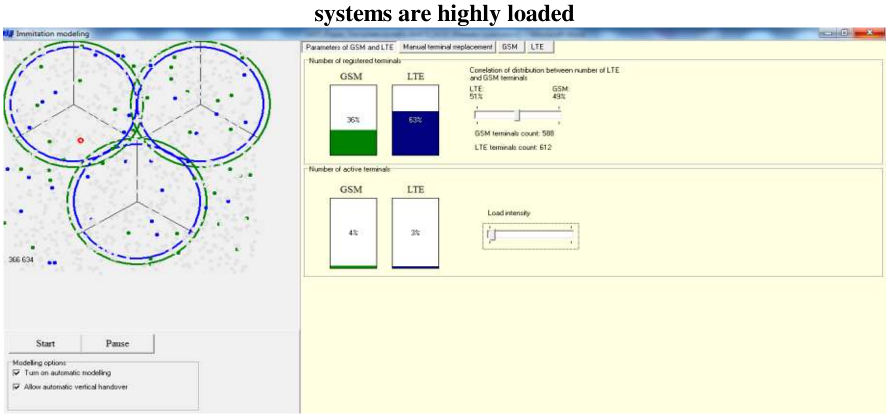

Fig. 8. Interface of imitation model of heterogeneous network with ability to change incoming load intensity at LTE and GSM when systems are unloaded

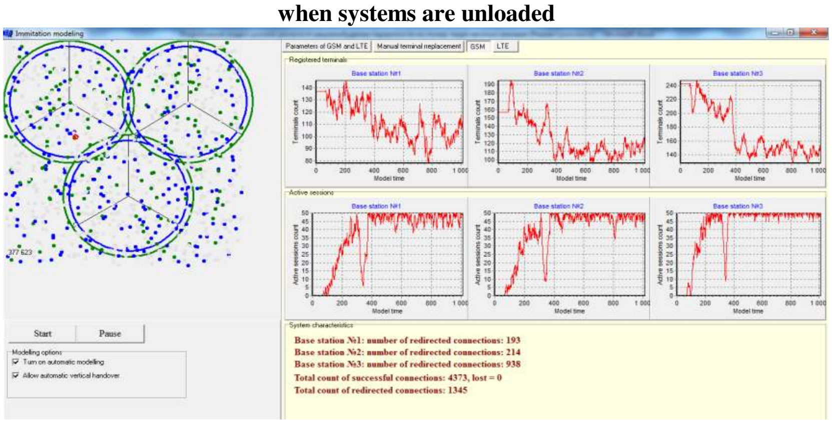

Fig. 9. Interface of imitation model of heterogeneous network with monitoring of registered and redirected active users in GSM cells

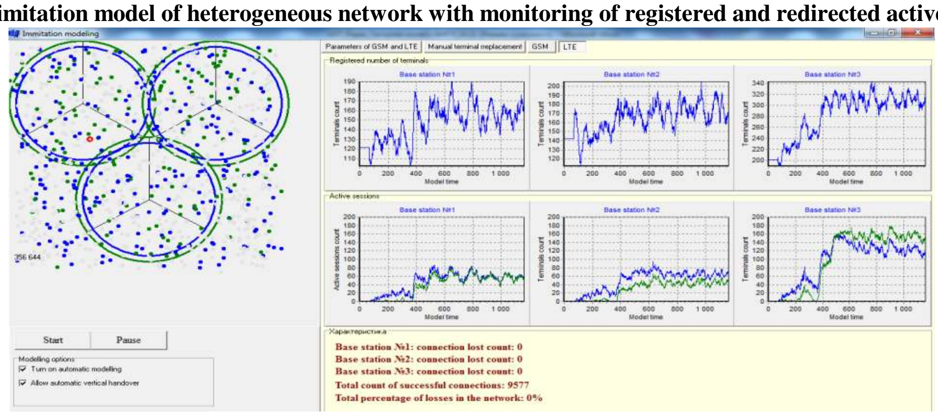

Fig. 10. Interface of imitation model of heterogeneous network with monitoring of registered and redirected active users in LTE cells

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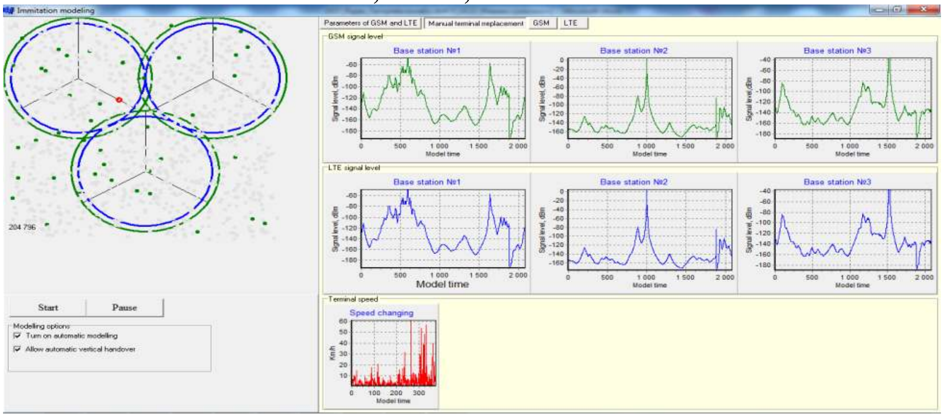

Fig. 11. Interface of imitation model of heterogeneous network with monitoring of speed of user motion <red point>, change of signal attenuation from base station during observation time in networks cells and performing forecasting of IHVO

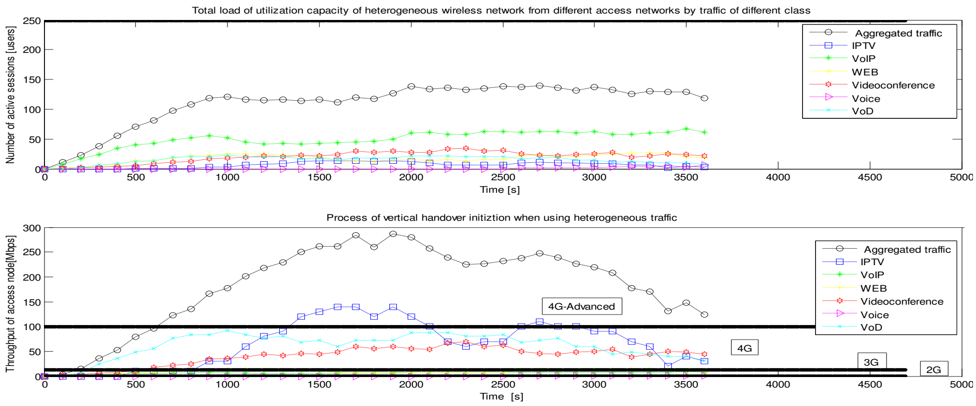

Fig. 12. Total load on heterogeneous network form different access networks and threshold of initiation of IVHO

Table V. Fuzzy numerical evaluation for access nodes and its defuzzification

	BS1 (GSM) $\frac{1}{2}\times(\tilde{Q}_{mn}+\tilde{P}_{mn})$ ($\tilde{R}_{mn}$)	BS2 (GSM) $\frac{1}{2}\times(\tilde{Q}_{mn}+\tilde{P}_{mn})$ ($\tilde{R}_{mn}$)	BS3 (GSM) $\frac{1}{2}\times(\tilde{Q}_{mn}+\tilde{P}_{mn})$ ($\tilde{R}_{mn}$)	BS1 (LTE) $\frac{1}{2}\times(\tilde{Q}_{mn}+\tilde{P}_{mn})$ ($\tilde{R}_{mn}$)	BS2 (LTE) $\frac{1}{2}\times(\tilde{Q}_{mn}+\tilde{P}_{mn})$ ($\tilde{R}_{mn}$)	BS3 (LTE) $\frac{1}{2}\times(\tilde{Q}_{mn}+\tilde{P}_{mn})$ ($\tilde{R}_{mn}$)
Jitter	(0,2; 0,005; 0,005)	(0,2; 0,005; 0,005)	(0,105;0,005; 0,005)	(0,2; 0,005; 0,005	(0,15; 0,005; 0,005)	(0,105; 0,005; 0,005)
Packet Loss Ratio	(0,04; 0,053; 0,03)	(0,04; 0,053; 0,03)	(0,008; 0,053; 0,003)	(0,04; 0,053; 0,03)	(0,04; 0,053; 0,023)	(0,04; 0,053; 0,008)
Throughput	(0,15; 0,095; 0,075)	(0,1; 0,0095; 0,06)	(0,01075;0,0057; 0,1750)	(0,25; 0,195; 0,175)	(0,25; 0,0095; 0,175)	(0,01; 0,005; 0,175)
Delay	(0,105; 0,04)	(0,05; 0,105; 0,04)	(0,1; 0,105; 0,0055)	(0,1; 0,105; 0,04	(0,1; 0,105; 0,0055)	(0,1; 0,105; 0,0055)
Cost	(0,0025; 0,0125; 0,01)	(0,0025; 0,0125; 0,01)	(0,006; 0,011; 0,001)	(0,0051; 0,0225; 0,01)	(0,006; 0,0225; 0,001)	(0,006; 0,006; 0,001)
Security	(0,0225; 0,0525; 0,15)	(0,0225; 0,0525; 0,07)	(0,00375;0,05375; 0,15375)	(0,0325; 0,0525; 0,25)	(0,0325; 0,075; 0,15)	(0,0375; 0,0525; 0,15)
Ms-Velocity	(0,032; 0,017; 0,12	(0,032; 0,017; 0,02)	(0,0052; 0,012; 0,12)	(0,032; 0,017; 0,12)	(0,032; 0,012; 0,12)	(0,032; 0,012; 0,12)
RSS	(0,0125; 0,0875; 0,125)	(0,0625; 0,0375;0,052)	(0,125;0,00475; 0,0475)	(0,125; 0,2375; 0,225)	(0,1025; 0,2375; 0,225)	(0,125; 0,2375; 0,225)
Load	(0,00525;0,00525; 0,00525)	(0,00525;0,00525; 0,00525)	(0,00525;0,00525;0,00525)	(0,00525;0,00525; 0,00525)	(0,00525;0,00525; 0,00525)	(0,00525;0,00525; 0,00525)
$\tilde{R}_{mn}$	(0,51475;0,43275; 0,56025)	(0,51475;0,29725; 0,29275)	(0,36895;0,2555; 0,516)	(0,78985;0,69275; 0,86025)	(0,71825;0,52475; 0,70975)	(0,46075;0,48125; 0,69475)
R_{mn}	**0,502583333**	**0,36825**	**0,38015**	**0,78095**	**0,6509166**	**0,545583333**

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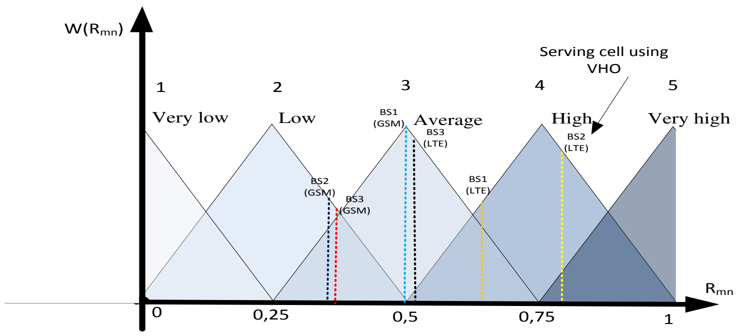

Fig. 13. Optimal cell determination by using Likert scale

V. CONCLUSION

In this paper has been increased quality of service in mobile systems based on efficient network and radio utilization of resources of heterogeneous network and optimal procedure of intellectual vertical handover based on cloud technology and fuzzy logic. In order to solve task of initiation and performing handover a central method of handover management has been proposed. Developed approach in comparison to existing ones uses theory of fuzzy sets. This theory was chosen as a tool for solving tasks of aggregation of double-meaning, subjective and fuzzy evaluative judgments about state of particular parameter of indicator of optimal cell selection. Thus, if the model is build according to such approach then it becomes quantitative unlike existing subjective evaluations. For investigation of functioning of real heterogeneous wireless network under conditions of high user mobility the imitation model has been developed. This imitation model includes wide number of different wireless access network parameters and uses mathematical and prospectively prognostic models. As was shown in the simulation results, the most appropriate network node could be easily selected within optimal access mode considering weighted criteria were corrected depending on overall cell loading index. The process of service provisioning to users of heterogeneous network based on developed model has been investigated when providing service of video-conference. The optimal cell of heterogeneous network has been determined based on evaluation of access node characteristics using fuzzy logic. It was shown that LTE node should be selected to satisfy user request for this service type. In the ambivalent situation, when the user is located on the mutual border of the spatial cell there is helpful solution to improve the quality of decision making.

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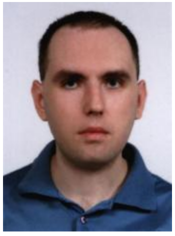

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