Neuro-Fuzzy Controller for Handover Operation in 5G Heterogeneous Networks

Olena Semenova
Dept. of Telecommunication Systems and Television
Vinnytsia National Technical University
Vinnytsia, Ukraine
Helene_S@ukr.net

Andriy Semenov
Dept. of Radio-Frequency Engineering
Vinnytsia National Technical University
Vinnytsia, Ukraine
https://orcid.org/0000-0001-9580-6602

Olha Voitsekhovska
Dept. of System Analysis, Computer Monitoring and Engineering Graphics
Vinnytsia National Technical University
Vinnytsia, Ukraine
olgav1085@gmail.com

***Abstract*—The paper suggests to apply a neuro-fuzzy controller in 5G heterogeneous networks in order to improve the handover process. The architecture of the controller as well as input and output variables have been elaborated. A rule base and mathematical models of the controller has been considered. The efficiency of the proposed handover neuro-fuzzy controller has been checked by performing the computer simulation.**

***Keywords*—heterogeneous, handover, ANFIS, 5G**

I. Introduction

Over the past few years we faced a fast development of telecommunications [1], [2]. The great efforts are directed towards researching, developing and deploying of the 5th generation mobile networks (5G). One of the main challenges in the 5G heterogeneous networks is Mobility management. Moreover, in heterogeneous networks handover is an important factor in providing the seamless mobility between various network environments [3]–[5].

Handover management maintains all active connections for user equipment (UE). Handover is the mechanism of transferring a connection between an UE and a correspondent terminal from one network attachment point to another. Handover decision determines the best access network and decides whether to perform handover or not. Vertical handover takes place between the different attachment points of the different networks and is implemented in heterogeneous networks.

The handover process has three steps: system discovery, handover decision, handover execution. Network selection can be initialized either by UE or can be based on measurements performed by the network. UE tends to join the best attachment point, and network selection can be regarded as a decision making problem. So, the handover problem is solved by the search of optimal solution.

The heterogeneous networks differ in terms of coverage, signal strength, data rate and loss rates. Therefore, there is a relevant scientific problem of developing an effective handover decision algorithm, which is able to adapt dynamically to varying conditions in the wireless environment.

Soft-computing techniques, such as neural net systems, fuzzy controllers, genetic programming and chaos theory [6]–[8] are used in automatic control engineering and are widely applied in telecommunication networks [9].

Employing soft-computing techniques in 5G network would give more capability in traffic handling. Furthermore, soft-computing techniques can be used to support decision making. Thus soft-computing 5G heterogeneous networks can satisfy expected needs and face new technical challenges [10].

Several solutions about soft-computing schemes for handover decision have been proposed in [11]–[17].

The authors have already proposed the handover neuro-fuzzy controller for mobile networks in [18]. This paper provides results of further investigations.

Therefore, the objective of this paper is a handover neuro-fuzzy controller for 5G heterogeneous networks.

II. Architecture of the Neuro-Fuzzy Controller

A common fuzzy controller consists of four blocks. The fuzzification block converts each crisp input value into a fuzzy one. The fuzzy rule base is a set of “if-then” rules involving linguistic variables The inference engine computes the fuzzy output taking into account fuzzy inputs and a rule base. The defuzzification block produces a crisp output action.

The problem of designing a fuzzy-controller for application in telecommunication networks being considered in [18]–[21], we propose an architecture of a neuro-fuzzy controller to be used in 5G heterogeneous networks. This neuro-fuzzy controller has three input linguistic variables which are a received signal strength indicator (RSSI), a distance (D) and a user’s speed (S), its output action is a handover indicator.

The RSSI is a measurement value of received carrier’s power in the system bandwidth. For defining the RSSI terms low (L), medium (M) and high (H) are used. The term set of the RSSI is:

T(RSSI)={Low, Medium, High}.

Fig. 1 shows membership functions for T(RSSI).

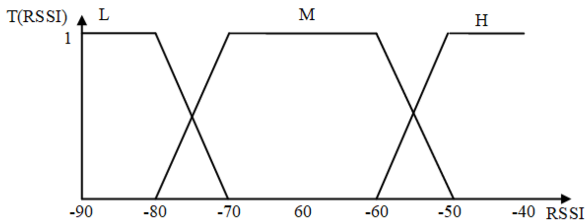

Fig. 1. Membership functions for the linguistic variable RSSI.

The distance is an interval between a UE and a candidate attachment point. For defining the distance terms low, medium, and high are used. The term set of D is:

T(D)={Low, Medium, High}.

Fig. 2 shows membership functions for T(D).

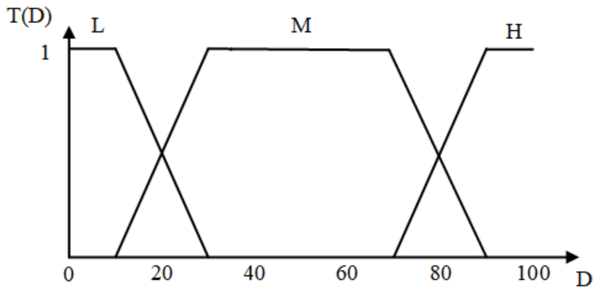

Fig. 2. Membership functions for the linguistic variable D.

The user's speed is a rate at which a mobile user changes its position during the communication. For defining the speed terms low, medium, and high are used. The term set of S is:

T(S)={Low, Medium, High}.

Fig. 3 shows membership functions for T(S).

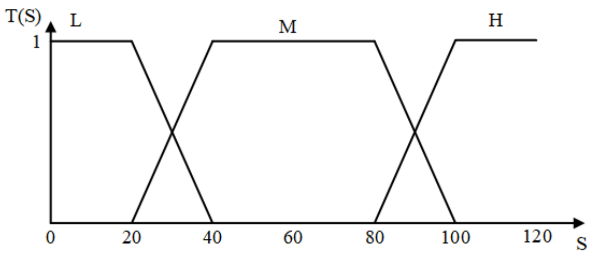

Fig. 3. Membership functions for the linguistic variable S.

For defining the handover indicator (HI) terms very low (VL), low (L), medium (M), high (H) and very high (VH) are used. The term set of HI is:

T(HI)={Very Low, Low,

Medium, High, Very High}.

Fig. 4 shows membership functions for T(HI).

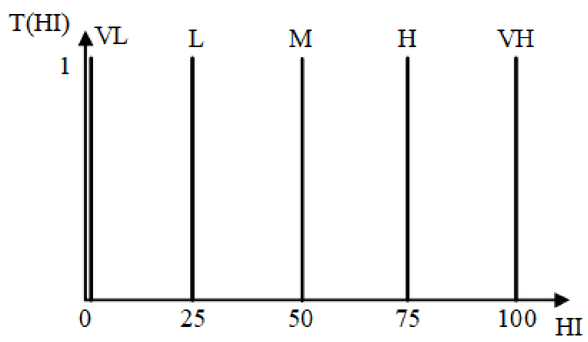

Fig. 4. Membership functions for the linguistic variable HI.

III. Operation of the Neuro-Fuzzy Controller

The rule base of the proposed handover neuro-fuzzy controller is:

1. RSSI=L ∧ D=L ∧ S=L → HI=L;
2. RSSI=L ∧ D=L ∧ S=M → HI=L;
3. RSSI=L ∧ D=L ∧ S=H → HI=L;
4. RSSI=L ∧ D=M ∧ S=L → HI=L;
5. RSSI=L ∧ D=M ∧ S=M → HI=VL;
6. RSSI=L ∧ D=M ∧ S=H → HI=VL;
7. RSSI=L ∧ D=H ∧ S=L → HI=L;
8. RSSI=L ∧ D=H ∧ S=M → HI=VL;
9. RSSI=L ∧ D=H ∧ S=H → HI=VL;
10. RSSI=M ∧ D=L ∧ S=L → HI=H;
11. RSSI=M ∧ D=L ∧ S=M → HI=M;
12. RSSI=M ∧ D=L ∧ S=H → HI=M;
13. RSSI=M ∧ D=M ∧ S=L → HI=M;
14. RSSI=M ∧ D=M ∧ S=M → HI=H;
15. RSSI=M ∧ D=M ∧ S=H → HI=M;
16. RSSI=M ∧ D=H ∧ S=L → HI=M;
17. RSSI=M ∧ D=H ∧ S=M → HI=M;
18. RSSI=M ∧ D=H ∧ S=H → HI=H;
19. RSSI=H ∧ D=L ∧ S=L → HI=VH;
20. RSSI=H ∧ D=L ∧ S=M → HI=VH;
21. RSSI=H ∧ D=L ∧ S=H → HI=H;
22. RSSI=H ∧ D=M ∧ S=L → HI=VH;
23. RSSI=H ∧ D=M ∧ S=M → HI=VH;
24. RSSI=H ∧ D=M ∧ S=H → HI=H;
25. RSSI=H ∧ D=H ∧ S=L → HI=H;
26. RSSI=H ∧ D=H ∧ S=M → HI=H;
27. RSSI=H ∧ D=H ∧ S=H → HI=H.

IV. The ANFIS Structure

The proposed fuzzy handover technique can be optimized using Adaptive Network Fuzzy Inference System (ANFIS) that incorporates a training element into the fuzzy handover technique. Fig. 5 shows the handover ANFIS block diagram.

Nine neurons in the first layer provide fuzzification of crisp inputs. Second layer's neurons correspond to fuzzy rules. Third layer's neurons provide the value normalization. The fourth layer has twenty-seven neurons and is a defuzzification one. The neuron in fifth layer represents an output of the ANFIS.

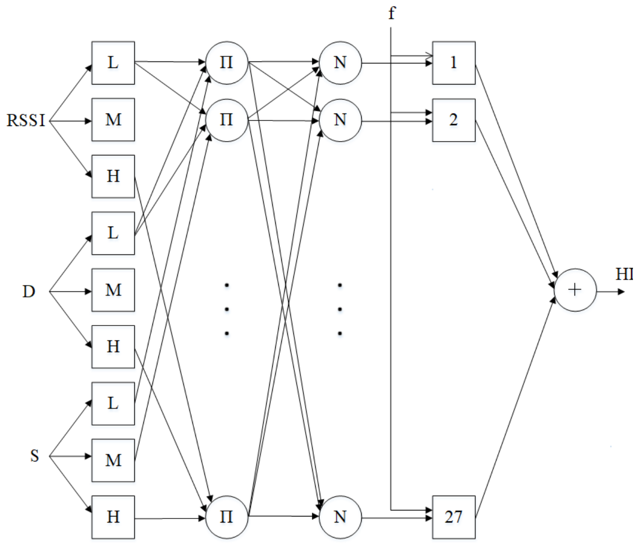

Fig. 5. Handover ANFIS block diagram.

The handover ANFIS has 27 if-then rules:

$$\text{If } x_1=A_a \text{ and } x_2=B_b \text{ and } x_3=C_c \text{ then } y=f(x_1, x_2, x_3)$$

$$a=1\ldots3;\ b=1\ldots3;\ c=1\ldots3.$$

In layer 1 every node produces a membership grade of the linguistic label:

$$z_{1i}=\mu_{Ai}(x_1) \text{ for } i=1, 2, 3;$$

$$z_{1i}=\mu_{Bi-3}(x_2) \text{ for } i=4, 5, 6;$$

$$z_{1i}=\mu_{Ci-6}(x_3) \text{ for } i=7, 8, 9.$$

In layer 2 weights of each membership function are checked:

$$z_{2i}=w_j=\mu_{Ai}(x_1)\cdot\mu_{Bi}(x_2)\cdot\mu_{Ci}(x_3),$$

$$i=1\ldots27.$$

In layer 3 each node's output of is the normalized firing strength:

$$z_{3i}=n_i=w_i/(w_1+\ldots+w_{27}).$$

In layer 4 each node's output is multiplication of the normalized output with a node function:

$$z_{4i}=n_i y_i.$$

In layer 5 the overall output is computed by adding the incoming signals :

$$z_5=n_1y_1+n_2y_2+\ldots+n_{27}y_{27}.$$

V. Simulation

Operability and availability of the proposed handover ANFIS can be confirmed by using the Matlab software. Fig. 7 shows the fuzzy controller interface. To evaluate the operability of the fuzzy controller the input values are assigned and the simulation is run in order to obtain the output value.

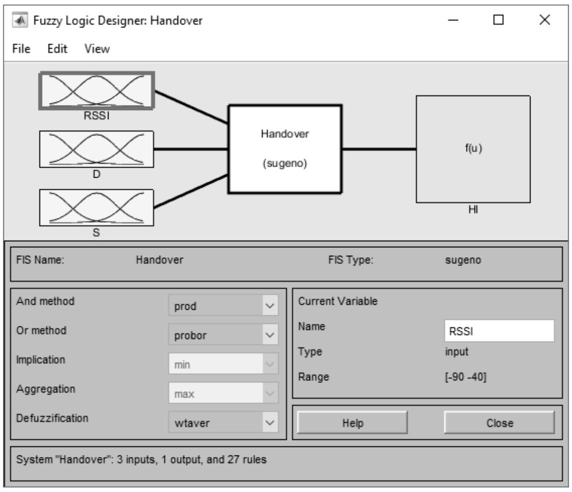

Fig. 6. Fuzzy-controller in Matlab.

The rule base in the Matlab interface is shown in fig.7.

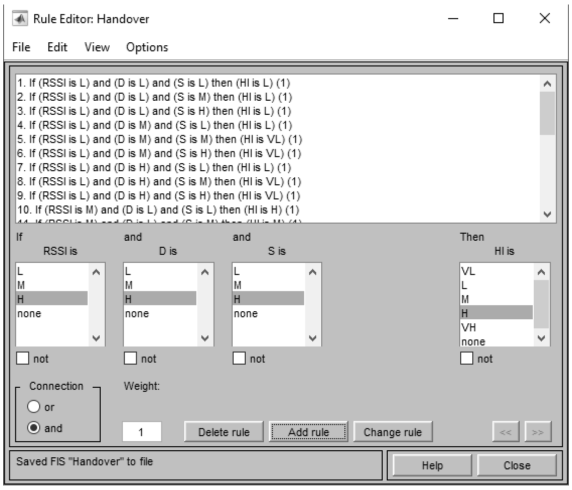

Fig. 7. The rule base.

Let the received signal strength indicator RSSI=-75dBm, the distance D=90 m, and the user's speed S=50 km/h. According to Fig. 8, we get the handover indicator HI=25%.

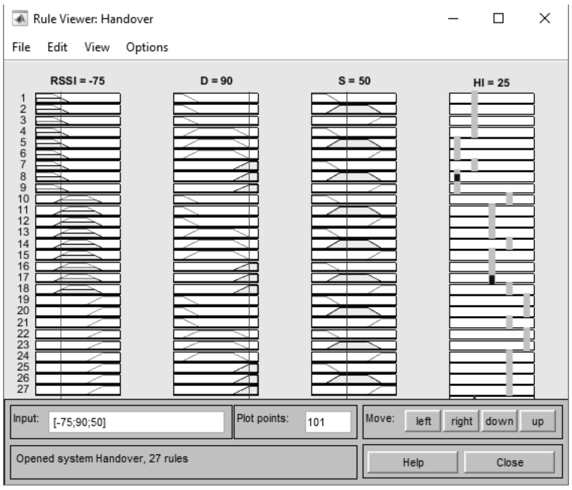

Fig. 8. Simulation result.

Let the received signal strength indicator RSSI = –55dBm, the distance D = 35 m, and the user's speed S = 110 km/h. According to fig. 9, we get the handover indicator HI = 62.5%.

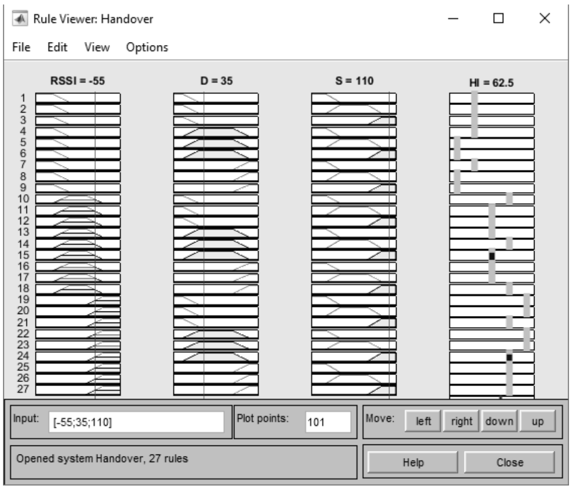

Fig. 9. Simulation result.

Fig. 10 illustrates the training data. Desired output values as well as corresponding input values were presented as an array. Fig. 11 illustrates the error after training process.

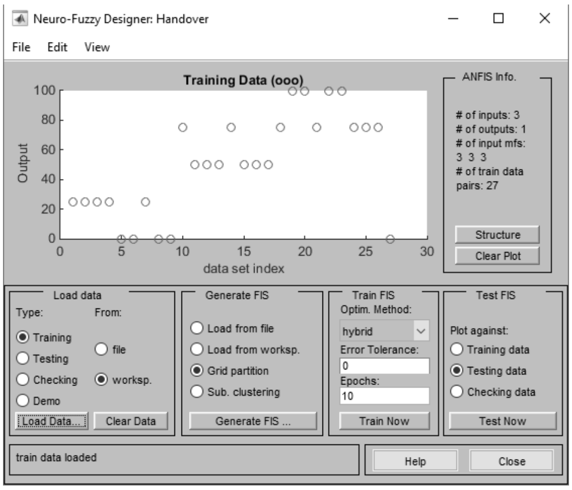

Fig. 10. ANFIS training data.

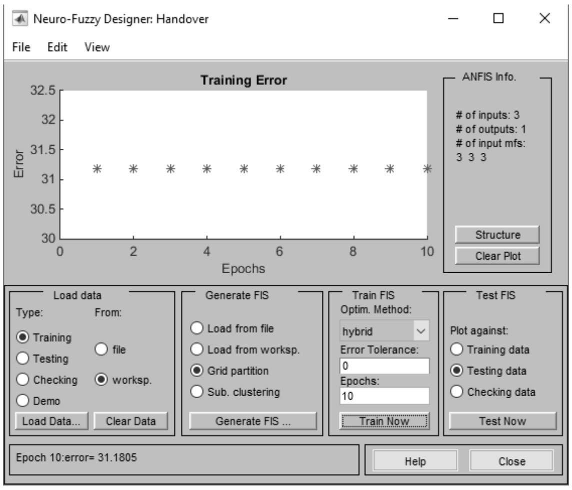

Fig. 11. Training error.

Fig. 12 illustrates the received signal strength indicator input linguistic variable updated after the process of training. Fig. 13 shows the distance input linguistic variable updated after the training. Fig. 14 shows the user's speed input linguistic variable updated after the training.

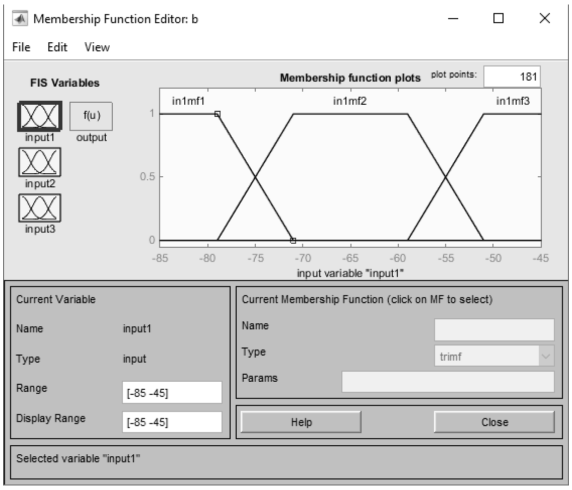

Fig. 12. The first input after training.

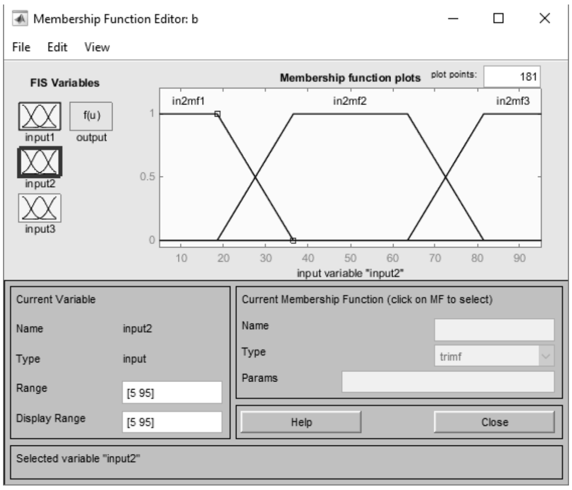

Fig. 13. The second input after training.

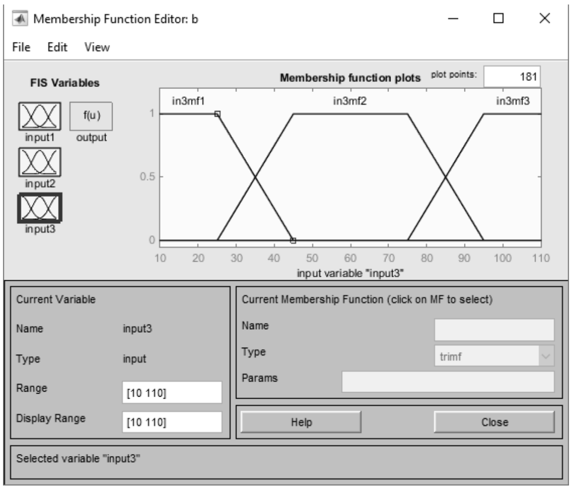

Fig. 14. The third input after training.

VI. CONCLUSION

This paper has proposed a handover mechanism based on fuzzy logic and a neural network for heterogeneous networks. The neuro-fuzzy system is to decide whether a candidate network is suitable for the handover operation. However, performing the handover decision in mobile networks may be quite complicated because of criteria, which must be considered.

In this paper the fuzzy-controller for heterogeneous 5G networks with several criteria has been developed in order to improve the handover decision operation.

The handover ANFIS has been developed by introducing the training process into the obtained fuzzy controller.

Using the adaptive network based fuzzy inference system reduces the rate of handover failure in 5G heterogeneous networks. Since the quality of service depends on the rate of handover failure, it means that the quality of service is enhanced. The simulation results have proved the feasibility of the obtained handover ANFIS application in heterogeneous networks.

Moreover, the simulation results have shown the feasibility of the proposed handover ANFIS to adapt membership function graphs. Application of the fuzzy controller reduces the quantity of superfluous handovers. Application of the neural network trains the system to select the best network among available ones. Therefore, the application of the handover ANFIS provides improving of the attachment point selection process and avoiding of unnecessary handovers.

Furthermore, consideration of other parameters of the heterogeneous 5G networks can enhance the proposed handover neuro-fuzzy controller. Also, handover mechanism can be optimized by combining the fuzzy logic and neural network methods with genetic algorithm technique that provides computation according to the features of mobile devices and networks.

REFERENCES

[1] Globa Larisa, Skulysh Mariia and Reverchuk Andriy, "Control strategy of the input stream on the online charging system in peak load moments," in *Proc. 2014 24th International Crimean Conference Microwave & Telecommunication Technology*, pp. 312–313. DOI: 10.1109/CRMICO.2014.6959409

[2] Skulysh Mariia and Romanov Oleksandr, "The structure of a mobile provider network with network functions virtualization," in *Proc. 2018 14th International Conference on Advanced Trends in Radioelecrtronics, Telecommunications and Computer Engineering (TCSET)*, pp. 1032–1034. DOI: 10.1109/TCSET.2018.8336370

[3] Atefeh Hajijamali Arani, Mohammad Javad Omidi, Abolfazl Mehbodniya, and Fumiyuki Adachi "A Handoff Algorithm Based on Estimated Load for Dense Green 5G Networks," in *Proc.2015 IEEE Global Communications Conference (GLOBECOM)*, San Diego, USA, 6-10 Dec. 2015, pp. 1–7. DOI: 10.1109/GLOCOM.2015.7417634

[4] Valente Klaine, P., Imran, M. A., Onireti, O. and Souza, R. D. (2017) A survey of machine learning techniques applied to self organizing cellular networks. *IEEE Communications Surveys and Tutorials*, (doi:10.1109/COMST.2017.2727878)

[5] F. Bouali, K. Moessner, and M. Fitch "A Context-Aware User-Driven Framework for Network Selection in 5G Multi-RAT Environments," in *Proc. 2016 IEEE 84th Vehicular Technology Conference (VTC-Fall)*, Montreal, QC, Canada, 18-21 Sept. 2016, pp. 1–7. DOI: 10.1109/VTCFall.2016.7880848

[6] Robert Fullér, "On fuzzy reasoning schemes," in *The State of the Art of Information Systems Applications in 2007*, Turku Centre for Computer Science, Åbo, 1999.

[7] Robert Fullér, "Fuzzy logic and neural nets in intelligent systems" in *Information Systems Day*, vol. 17, Turku Centre for Computer Science, Åbo, 1999, pp. 74–94.

[8] Christer Carlsson and Robert Fuller, "Fuzzy Reasoning in Decision Making and Optimization," in *Studies in Fuzziness and Soft Computing Series*, Vol. 82, Springer-Verlag, Berlin/Heildelberg, 2014.

[9] A.A. Atayero and M.K. Luka, "Applications of Soft Computing in Mobile and Wireless Communications," *International Journal of Computer Applications*, vol. 45, No 22, pp. 48–54, May 2012, doi 10.5120/7085-9842

[10] M. Al-Maitah, O.O. Semenova, A.O. Semenov, P.I. Kulakov, and V.S. Kucheruk, "A hybrid approach to call admission control in 5G networks," *Advances in Fuzzy Systems*, vol. 2018, Article ID 2535127, https://doi.org/10.1155/2018/2535127

[11] Joanne Mun-Yee Lim and Chee-Onn Chow, "Smart Handover Based on Fuzzy Logic Trend in IEEE802.11 Mobile IPV6 Networks," *International Journal of Wireless & Mobile Networks*, vol. 4, no. 2, pp. 217–234, April 2012.

[12] Manoj Sharma and R.K.Khola, "Fuzzy logic based handover decision system," *International Journal of Adhoc, Sensor & Ubiquitous Computing*, vol. 3, no. 4. pp. 21–29, 2012.

[13] Manish Sachdeva and Pankaj Kumar, "A Survey of Handoff Strategy and Fuzzy Logic with Desired Quality of Service," *International Journal of Innovative Science, Engineering & Technology*, vol. 2, issue 10, pp. 316-319, oct. 2015.

[14] Dilpreet Kaur Bedi, Nirmal Singh Grewal, and Talwinder Singh Bedi, "Handoff Decision Using Fuzzy Logic," *International Journal of Electronics Communication and Computer Technology*, vol. 4, issue 6 pp. 777-783, nov. 2014.

[15] Kh. Playtoni Meetei, Govind R. Kadambi, B. N. Shobha, and Abraham George, "Design and Development of a Handoff Management System in LTE Networks using Predictive Modelling," *SASTECH Journal*, vol. 8, issue 2, pp. 71–78, sept. 2009.

[16] Kumar Gaurav Bachlas and Prabhjot Kaur, "Neural Network Based Handoff Status in Cellular Mobile Network," *International Journal of Engineering Sciences & Research Technology*, vol. 3(6), pp. 280–282, June, 2014.

[17] Saeed H. Alsamhi and N. D. Rajput, "Neural Network in Intelligent Handoff for QoS in HAP and Terrestrial Systems," *International Journal of Materials Science and Engineering*, vol. 2, no. 2, pp. 141–146, Dec. 2014.

[18] Olena Semenova and Andriy Semenov, "The neuro-fuzzy controller for handover operation in mobile networks," in *Proc. 2017 IEEE First Ukraine Conference on Electrical and Computer Engineering (UKRCON)*, Kiev, Ukraine, 29 May-2 June 2017, pp. 806–812. DOI: 10.1109/UKRCON.2017.8100362

[19] Olena Semenova, Andriy Semenov, Oleksandr Voznyak, Dmytro Mostoviy, and Igor Dudatyev, "The fuzzy-controller for WiMAX networks," in *Proc. 2015 International Siberian Conference on Control and Communications (SIBCON)*, Omsk, Russia, 21-23 May 2015, pp. 1–4. DOI: 10.1109/SIBCON.2015.7147214

[20] Andriy A. Semenov, Olena O. Semenova, Oleksandr M. Voznyak, Oleksandr M. Vasilevskyi, and Maksym Yu. Yakovlev, "Routing in telecommunication networks using fuzzy logic," in *Proc. 2016 17th International Conference of Young Specialists on Micro/Nanotechnologies and Electron Devices (EDM)*, Erlagol, Russia, 30 June-4 July 2016, pp. 173–177. DOI: 10.1109/EDM.2016.7538719

[21] O. Semenova, A. Semenov, K Koval, A. Rudyk, and V. Chuhov, "Access fuzzy controller for CDMA networks," in *Proc. 2013 International Siberian Conference on Control and Communications (SIBCON)*, Krasnoyarsk, Russia, 12-13 Sept. 2013, pp. 1–2. DOI: 10.1109/SIBCON.2013.6693644