Network Selection Heuristics Evaluation in Vertical Handover Procedure

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Abstract – **Network selection heuristics are essential components of the heterogeneous wireless networks architecture deployment. Following the principles of heterogeneous networking, a mobile user may choose among multiple available connectivity alternatives based on the criteria related to networks performances, users preferences and services requirements. This paper seeks to provide a framework for network selection heuristics evaluation. Some perspective network selection heuristics, based on cost function, artificial neural networks, multi criteria decision making and fuzzy logic systems are systematically presented and analyzed in terms of efficiency and implementation complexity.**

Keywords – **Heterogeneous wireless networks, Mobility, network selection, QoS, Vertical handover.**

I. INTRODUCTION

Heterogeneous wireless networks inherits the vital complementary characteristics of both infrastructure and ad-hoc architectures, and thus has the potential of attaining the level of performance and efficiency required by the future ubiquitous wireless communications [1]. Following the principles of heterogeneous networking, users will be able to choose among multiple available connectivity alternatives based on the criteria related to networks performances, users preferences and services requirements. This process makes an important element in the complex vertical handover procedure. The need for a handover in the traditional wireless networks usually occurs when the terminal, due to the movement of the users, leaves the Point of Attachment (PoA) coverage area. In a heterogeneous environment, handover is more frequently used in order to improve communication and rider in order to maintain connections [2].

Major challenges in heterogeneous handover management are seamlessness and automation aspects in network switching. It is a strategic goal to define important advancements that happen and are predicted in technologies, networks, user terminals, services, and future business models that include all this issues while realizing and exploiting new wireless networks. On the other hand, because users could be always connected through the optimal Radio Access Network (RAN), it is necessary to develop an adequate mechanism for its selection.

ITU's concept of Optimally Connected, Anywhere, Anytime proposed in M.1645 [3] states that future wireless networks could be realized through the coalition of different RANs. According such a scenario, the heterogeneity of access networks, services and terminals should be fully exploited to enable higher utilization of radio resources. The main objective is to improve overall networks performances and perceived QoS.

Third Generation Partnership Project (3GPP) is defining an Access Network Discovery and Selection Function (ANDSF) [4] to assist mobile terminals in vertical handover between 3GPP and non-3GPP networks, covering both automated and manual selection as well as operator and user management.

IEEE 802.21 is developing standards to enable handover and interoperability between heterogeneous link layers [5]. This standard defines the tools required to exchange information, events and commands to facilitate handover initiation and preparation. IEEE 802.21 standard does not attempt to standardize the actual handover execution mechanism. Therefore, the Media Independent Handover framework is equally applicable to systems that employ mobile IP at the network layer as well as systems that use Session Initiation Protocol (SIP) at the application layer.

A great number of heuristics related to the handover initiation and optimal access network selection are proposed in the open literature. The suggested solutions are using different criteria and mathematical tools for solving the above mentioned problems. Unfortunately, currently proposed solutions do not meet all the requirements in terms of functionality and efficiency.

II. OPTIMAL NETWORK SELECTION FRAMEWORK

Network selection in heterogeneous environment is essentially a resource allocation problem and is typically addressed as user-centric, network-centric or a hybrid approach. In the network selection scenario users are always trying to seamlessly access high-quality wireless service at any speed, any location, and any time through selecting the optimal RAN. Therefore, ensuring a specific QoS is one of the main goals in the process of network selection.

There are four groups that are often analyzed as the criteria in the network selection, and those groups are related to the entities - the participants in handover decision:

- Network-oriented metrics (coverage, link quality, bandwidth, etc.),
- Service-oriented metrics (QoS level, security level, etc.),
- User-oriented metrics (user's preferences, perceived QoS, etc).
- Terminal-oriented metrics (velocity, energy consumption, etc.).

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Received Signal Strength (RSS) is the most widely used criterion because of its measure simplicity and close correlation to the link quality. There is a close relationship between RSS readings and the distance from the mobile terminal to its PoA. Traditional horizontal handover techniques are basically analyzing metrics through the variants of comparing RSS of the current PoA and candidate network PoA. In combination with threshold and hysteresis, RSS metrics represent a satisfying solution for a homogeneous network environment. In a heterogeneous environment RSS metric is not sufficient criterion for initiating a handover, but in combination with other metrics it could be applied as an ultimate condition.

Available bandwidth represents important indicator of RAN traffic performances and transparent parameter for users of the multimedia services. This is the measure for per user bandwidth allotted by the network operator which is dynamically changeable according the utilization of the network. The maximum theoretical bandwidth is closely related to the channel capacity. Transition to a network with better conditions and performances would usually provide improved perceived QoS.

The QoS level can be defined through the metric values of delay, jitter, package loss, etc. and it can be declared by the service provider on the basis of ITU recommendation Y.1541, which defines the upper bounds of QoS parameters for specific applications or classes of services. By declaring the QoS level in this way, we will avoid a complex examination of QoS parameters by users as well as the additional load of user's terminals and other network elements.

Security level, as well as the previous criteria, may be declared by the service provider, and it represents the security measure for the information transfer in the network. For most users, depending on the application, security plays a great part in making a decision on the adequacy of a network for transferring the desired content. When the information exchanged is confidential, a network with high encryption is preferred. The security level concept, sometimes called Level of Security (LoS), is similar to level of service in QoS management. LoS is a key piece of information within a security profile and is used to determine whether data are allowed to be transferred by a particular network or not.

Cost of service can significantly vary from provider to provider, but in different network environments. In some cases cost can be the deciding factor for optimal network selection, and it includes the traffic costs and the costs of roaming between heterogeneous networks. In some context cost of service is in tight relation with available bandwidth, QoS level, security level, but in next generation wireless environment, cost of service is fast time differentiable function dependable of many others parameters [6].

Mentioned metrics are affecting the moment of the handover initiation and optimal access network selection. The number of criteria, and dynamic variability of some parameters significantly increases the complexity of the handover heuristic, and because of that, the choosing of adequate criteria is of great importance. After the definition of the convenient parameters, the question often arises is how to transfer the metrics information from the network entities to the user's multimode terminals. Through the End to End Reconfigurability (E^2R) project, concepts and solutions for a Cognitive Pilot Channel (CPC) were developed [7]. It was concluded that CPC will be able to provide enough information for network selection, when users are preceding either initial connection or handover.

Performance analysis of the network selection heuristic can be performed through the determination of mean and maximum handover delays, number of handovers, number of handovers failed due to the incorrect decisions, handover failure probability, resource utilization, etc [8].

Handover delay refers to the duration between the initiation and completion of the handover process. It is related to the complexity of the applied heuristic. Reduction of the handover delay is especially important for delay-sensitive voice and multimedia sessions.

Reducing the number of handovers is usually preferred, as frequent handovers would cause wastage of network resources. A handover is considered as superfluous when a mobile terminal is coming back to the previous PoA is needed within certain time duration ("ping-pong" effect), and such handovers should be minimized.

A handover failure occurs when the handover is initiated, but the target network does not have sufficient resources to complete it, or when the mobile terminal moves out of the coverage area before the process is finalized. In the first case, the handover failure probability is related to the resource availability (e.g. channel availability) of the target network, while in the second case, it is related to the terminal mobility.

Resource utilization is defined as the ratio between the mean amount of utilized resources and the total amount of resources in a system. In the case of efficient channel utilization, the ratio between the mean number of channels that are being served and total number of channels in a system is taken into account.

For efficient network selection strategy the following important issues have to be fulfilled:

- Only considerable parameters must be analyzed,
- Equilibrium among user's preferences, service's requirements and network's performance must be achieved,
- Technique has to be reliable and transparent to the user,
- Heuristic has to minimize handover latency, blocking probability and number of superfluous handovers,
- Flexible and suitable implementation in real environment is necessary.

III. Cost Function based Heuristics

Perspective network selection heuristic for the each active session that relies on a cost function is proposed in [9]. In this scenario, the mobile terminal maintains a list of current active sessions, arranged in priority order. Than, the cost function is evaluated for the highest priority service. The optimal target network is chosen by minimizing the per-session cost

$$\min C_s^n = \sum_s W_{s,j}^n Q_{s,j}^n \,, \quad E_{s,j}^n \neq 0 \,, \qquad (1)$$

where $Q_{s,j}^{n}$ is the normalized QoS provided by network *n* for parameter *j* (e.g. bandwidth, delay) and service session *s* (video, voice). $W_{s,j}^{n}$ is corresponding weight coefficient which indicates the impact of the QoS parameter on the user or the network, and $E_{s,j}^{n}$ is the network elimination factor, indicating whether the minimum requirement of parameter *j* for service *s* can be met by network *n*. The algorithm of the proposed heuristic is shown in Fig. 1.

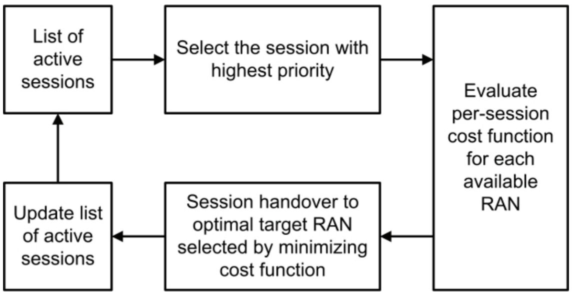

Fig. 1. Example of cost function based heuristic

Similar to the previous technique, the article [10] analyzes the application of cost function in the process of evaluating the qualitative performance of potential target networks. By using the normalization and weights distribution methods, cost function determines a network quality factor

$$Q_i = f(w_c \frac{1}{C_i}, w_s S_i, w_p \frac{1}{P_i}, w_d D_i, w_f F_i)\,, \qquad (2)$$

where C_i is the cost of service, S_i security, P_i power consumption, D_i network condition and F_i network performance, while the w_c, w_s, w_p, w_d and w_f are weights for each of the network parameters which are proportional to the significance of a parameter to the vertical handover decision. Due to the heterogeneous parameters, it is necessary to make a normalization of the function. High overall throughput and user's satisfaction can be regarded as major advantages of this heuristics.

The fundamental benefit of cost function usage and handover independent initiation for different services is reduced failure (blocking) probability. However, parameter normalization and weights coefficients determination techniques are not discussed.

IV. Neural Networks based Heuristics

Network selection heuristic based on the artificial neural network is proposed in [11]. Applied feedforward neural network topology, which consists of input, hidden and output layer, is shown in Fig. 2. The input layer is made of the *h* nodes representing different criteria for optimal network selection, while the hidden layer consists of the *n* nodes that represent the available access networks. Logistic sigmoid activation function $f(x) = 1/(1+e^{-x})$ is applied to determine the cost function. For the training process error backpropagation algorithm is used. Output layer is formed by a node that generates the identification of the optimal access network.

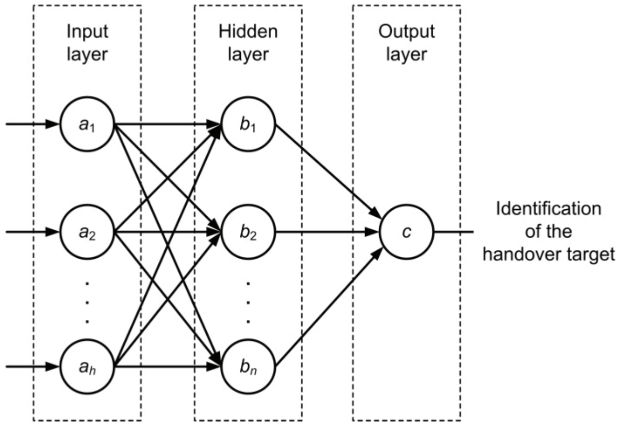

Fig. 2. Topology of the neural network as network selection heuristic

During the simulation, the authors in [11] adopted the same cost function as in [10]. The performed simulations have shown high accuracy and reliability of the model while selecting the optimal network. The lacks of the algorithm are reflected to the complexity of the system and to increased handover delays due to the training process.

V. Multi-Criteria Decision Making based Heuristics

With tight association to the nature of problem, a great number of the network selection heuristics available in the open literature are based on Multi-Criteria Decision Making (MCDM). MCDM tools relay on certain indices to estimate the performance of alternatives and finally rank them.

In [12] the authors develop a network selection mechanism for an integrated WLAN/cellular system. The design goal is to provide the user the best available QoS at any time. The suggested network selection mechanism relies on the combination of Analytic Hierarchy Process (AHP) and Grey Relational Analysis (GRA) of the multiple criteria analysis method. This method mathematically presents a complex solution and unnecessarily takes into account a large number of QoS parameters (delay, jitter, response time, bit error rate, etc.) only for 3G and WLAN networks. Processing a large number of parameters leads to the computational time increasing, while the terminal and infrastructure network elements are additionally loaded. Thus, this model is interesting from theoretical point of view, but not adequate for a direct implementation. These lacks are recognized in [13], but in general forms.

Network selection solution proposed in [14] represents interesting and promising solution while combining the heuristics of the fuzzy logic systems and MCDM (Fig. 3). In the process of handover initiation, proposed technique uses fuzzy logic analyzing the criteria such as: *RSS,* bandwidth (*B*), network coverage (*NC*) and terminal velocity (*V*). Based on 4 related functions and 81 predefined rules, a system determines whether handover is necessary or not. By application of AHP method and Saaty's scale on criteria such as cost of service, preferred interface, battery status and QoS level, the optimal access network is determined.

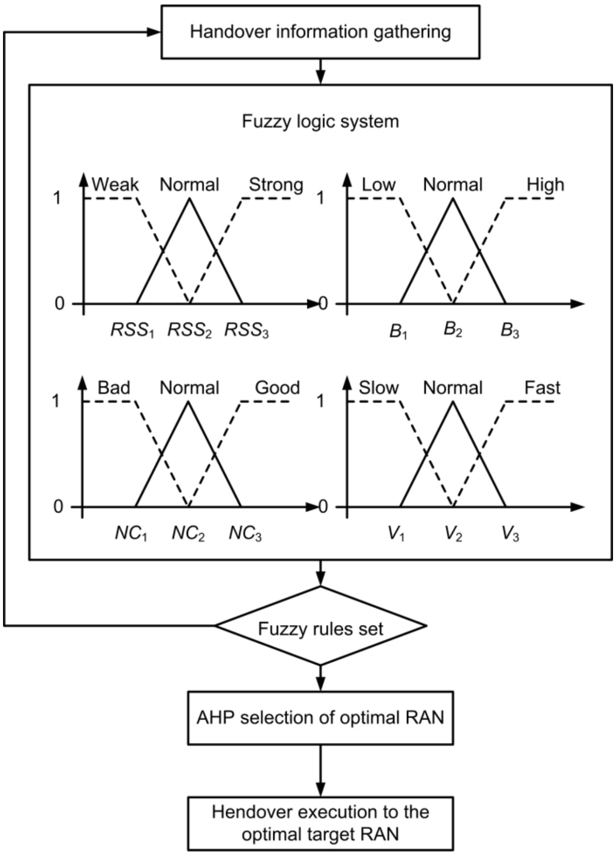

Fig. 3. Example of network selection heuristic based on fuzzy logic system and MCDM

On the other hand, by applying fuzzy logic in decision making process the number of unnecessary handover are reduced, as well as signaling traffic and handover delays. Inflexibility of the impact of user's preferences on the system is basic lack of applied AHP method, which could possibly be exceeded by using some other MCDM techniques, e.g. TOPSIS [15].

VI. Conclusion and Future Work

The scope of this research is to address the issue of network selection in vertical handover procedure. The main challenges involved in the network selection are pointed out and synopsis of approaches encountered in the open literature is presented. Currently proposed network selection heuristics for vertical handover require more significant challenges to overcome, before being successfully deployed in real environment. Selection of the most suitable heuristic is the crucial research direction in the field of heterogeneous wireless networks.

Concerning further research, all activities will be dedicated to possible quantitative evaluation of perspective network selection heuristics taking in to account various mobility models and traffic characteristics (e.g. traffic load, blocking probability, etc.).

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References

[1] J. Akhtman, L. Hanzo, "Heterogeneous Networking: An Enabling Paradigm for Ubiquitous Wireless Communications", Proceedings of the IEEE, vol. 98, no. 2, pp.135-138, 2010.

[2] X. Gao, G. Wu, T. Miki, "End-to-End QoS Provisioning in Mobile Heterogeneous Networks", IEEE Wireless Communications, vol. 11, no. 3, pp. 24 – 34, 2004.

[3] ITU-R Rec. M.1645, "Framework and Overall Objectives of the Future Development of IMT-2000 and System beyond IMT-2000", 2003.

[4] 3GPP TS 24.312, "Access Network Discovery and Selection Function (ANDSF) Management Object (MO)", 2009.

[5] IEEE 802.21**,** "Media Independent Handover Services", www.ieee802.org/21.

[6] D. Niyato, E. Hossain, "Competitive Pricing in Heterogeneous Wireless Access Networks: Issues and Approaches", IEEE Network, vol. 22, no. 6, pp. 4 – 11, 2008.

[7] Y. Ji, et. al., "CPC-assisted Network Selection Strategy", 16th IST Mobile and Wireless Communications Summit, Budapest, Hungary, 2007.

[8] X. Yan, Y. A. Şekercioĝlu, S. Narayanan, "A Survey of Vertical Handover Decision Algorithms in Fourth Generation Heterogeneous Wireless Networks", Computer Networks, vol. 54, no. 11, pp. 1848-1863, 2010.

[9] F. Zhu, J. McNair, "Multiservice Vertical Handoff Decision Algorithms", EURASIP Journal on Wireless Communications and Networking, vol. 2006, no. 2, pp. 1-13, 2006.

[10] N. Nasser, A. Hasswa, H. Hassanein, "Handoffs in Fourth Generation Heterogeneous Networks", IEEE Communications Magazine, vol. 44, no. 10, pp. 96-103, 2006.

[11] N. Nasser, S. Guizani, E. Al-Masri, "Middleware Vertical Handoff Manager: A Neural Network-based Solution", Proc. IEEE ICC´07, pp. 5671-5676, Glasgow, Scotland, 2007.

[12] Q. Song, A. Jamalipour, "Network Selection in an Integrated Wireless LAN and UMTS Environment Using Mathematical Modeling and Computing Techniques", IEEE Wireless Communications, vol. 12, no. 3, pp. 42-48, 2005.

[13] Q. Song, A. Jamalipour, "A Quality of Service Negotiation-Based Vertical Handoff Decision Scheme in Heterogeneous Wireless Systems", European Journal of Operational Research, vol. 191, no. 3, pp. 1059-1074, 2008.

[14] M. Kassar, B. Kervella, G. Pujolle, "An Intelligent Handover Management System for Future Generation Wireless Networks", EURASIP Journal on Wireless Communications and Networking, Article ID 791691, 12 pages, 2008.

[15] B. Bakmaz, Z. Bojkovic, M. Bakmaz, "Network Selection Algorithm for Heterogeneous Wireless Environment", Proc. IEEE PIMRC 2007, pp. 347-350, Athens, Greece, 2007.