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An Enhanced multi-dimensional Adaptive Handover Algorithm for Mobile Networks

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Abstract

The next generation wireless networks will be created by putting together several heterogeneous radio access technologies, which have capabilities, abilities and limitations of their own. In these networks providing multimedia services with guaranteed quality of service is essential. The main purpose of heterogeneous wireless access networks is to realize the concept of "always best connection", in which user can connect to the most suitable and the best network based on their own service requirements at anytime, anywhere and at any conditions. For effective use of radio resources in heterogeneous networks, the joint radio resource management method has been applied. Performance and efficiency of this management method will be better than independent radio resource management in any radio access technology. The two most important challenges of network selection optimization and meeting overall goals such as load balancing are considered, and in this regard, this paper presents an architecture for managing connectivity in heterogeneous access networks. Also, the decision algorithms of user side connection and feedback production methods to meet overall goals in these networks is designed and analyzed. Generally, connection management architecture consists of three layers: the user side resource manager, the station resource manager and the network resource manager. In the proposed architecture, decisions are made locally in the user side using the received feedbacks. The decision algorithms of user side are designed to reduce overhead control, reduce decision-making time, remove the overhead of scanning the environment, reduce the handover and also to supply the requirements of users and they use many parameters to determine the optimal connection such as conditions of mobile devices, requirements of applications, velocity and mobility parameters, load and price of each of the stations and received signal intensity of them and finally the personal preferences of the end users.

Keywords: *Self-Optimization Networking, Inter RAT Handover, QoS, Multi-Dimensional Decision*

1. Introduction

Next generation wireless networks consist of multiple heterogeneous Radio Access Technologies (RATs) which of them has a different specification and special limitation [1], [2]. In these networks providing multimedia services with guarantee of their quality of services is an important issue. The overall goal of heterogeneous wireless access networks is to enable the realization of the Always Best Connected concept in which a user is seamlessly connected to the RAT best suiting its service requirements anytime, anywhere, anyhow. In the next generation heterogeneous networks all the benefits of each of these networks are usable in the best way in a mixed or integrated network and hence the concept of always best connection expressed in papers [3]. It means the users choose the best set based on their preferences and needs in various conditions among the provided services to be able to make the best use of these complementary features. In this way, the user receives the best

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possible quality of service by paying a minimum cost (because all user requirements can be mapped to a cost function). There are numerous decision-making parameters for changing conditions of every running application and network conditions and mobile terminal. If the system is supposed to not only consider physical parameters like signal quality and bit error, but also user requirements in network selection with less price and congestion, the resulted decision problem would be multidimensional and with reciprocal purposes [4], [5]. Also, choosing the best network must be based on the policy and preference and sensitivity of these measures and also its effect on more general goals like load distribution. We can take a glance to all networks have a significant role in the various heterogeneous networks through Table I.

Table I. various networks and their specifications

Network	Standard	Bandwidth	Coverage
Cellular	GSM UMTS EDGE WCDMA CDMA2000	6.9 kbps 2 Mbps	30000 m
WLAN	802.11a 802.11b 802.11g 802.11e 802.11k 802.11r	54 Mbps 11 Mbps 54 Mbps	100 m 100 m 100 m
WPAN(Bluetooth)	802.15.1	2 Mbps	30 m
Zigbee	802.15.4	250 kbps	100 m
WMAN(WiMAX)	802.16	70 Mbps	10000 m

Also, these parts of heterogeneous networks have interworking together which we can an example of this in Figure 1.

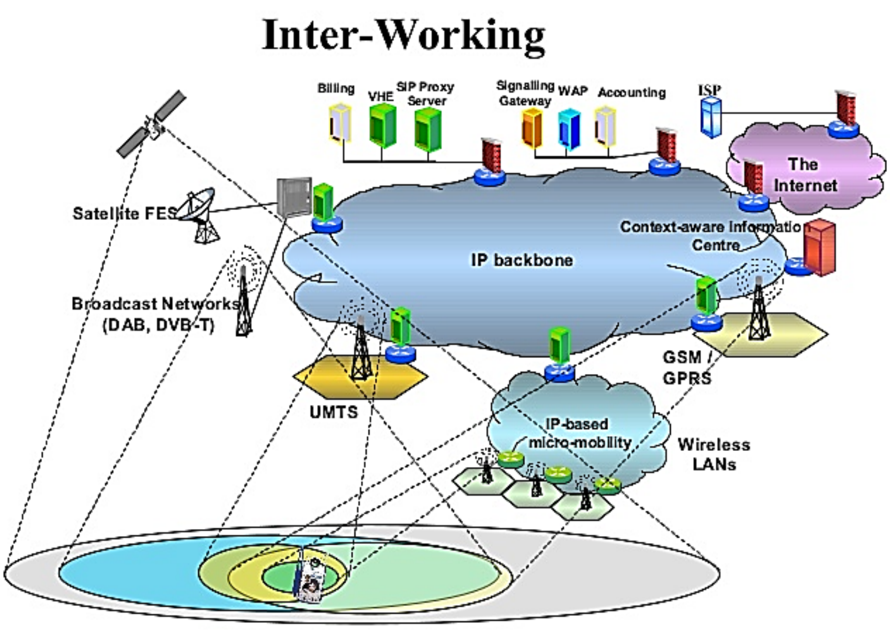

Figure 1. Methods of Network Based Communications

Another issue in the next generation heterogeneous wireless networks is its nature of distributed access. In heterogeneous networks that the selection of different access network technologies is up to users, to meet overall goals like load balancing or utilization we are faced with a distributed optimization problem [6], [7]. The steady load balancing among networks and stations not only leads to congestion, but also leads to the impartial utilization of network resources [8].

2. Distributed Resource Management

By the abundance of articles, conferences, standards that have been carried out in the field of load balancing and resource allocation in heterogeneous wireless networks in recent years, the importance of this area in the development of next generation wireless communications can be realized [9]. Most of the works have been focusing on the combined and integrated management of the two types and recently three types of wireless technologies.

2.1 The distributed architecture of wireless technologies integration:

In mobile wireless networks the objective is to provide a solution for the infrastructure that can reduce the delay due to handover among networks [10]. This type of works has proposed various handover architectures among different layers. The issue of the incompatibility of wireless standards for resolving service quality needs for users, the sudden change in the rate due to handover, the issue of the method of data collection from different standards and defining essential controls in network to facilitate and manage the network handover are among these works [11], [12]. Architectures that have applied loose integration and handover management in the top layer have been facing the challenge of network handover inefficiency and the delay due to handover, and those architectures that have used strong and integration in infrastructure and physical layer have the problem of non-compliance and non-extension.

Connection management: connection management is one of the important challenges in heterogeneous wireless networks. The decision problem of the best handover time and selecting network is one of the raised issues in such works. Keeping connection status in the optimal mode has been studied with different objectives and from many different analysis methods. The applied decision making methods, decision making metrics, decision making phases, decisions microlithic are the study topics in these works [13].

There are discussions about the most appropriate level to manage mobility. There are solutions for mobility management in different network protocol layers that relate to different types of mobility. It is possible that the real-time applications cannot tolerate delivery delay, package loss, etc. and in order to comply with the current changes they prefer to manage mobility themselves. It is possible that the non-real-time applications are not willing to manage mobility by themselves and maybe they need support from network layer. Each of these two applications must be able to work besides each other.

Mobility management includes decisions of whether, when and where the handover to another network takes place. Handover to another network is usually done because of coverage limitations of the current network, capacity demand or other application needs. Mobility management in a heterogeneous environment should interact with different application needs. Some applications require network layer to support mobility management, while others (such as context aware real-time multimedia applications) prefer to manage mobility themselves. The common issue for different types of mobility management is motion detection and choosing the appropriate action accordingly. Usually there are different types of mobility management simultaneously and one action in a system can lead to another action in another system.

Mobility management is easier in homogeneous wireless networks, as all the networks have the same standards and technologies and one method of mobility management is enough, but this management in heterogeneous wireless networks, because of different standards and technologies has its own challenges, such as coordination of different networks to move users among them, without disconnecting with the network [14].

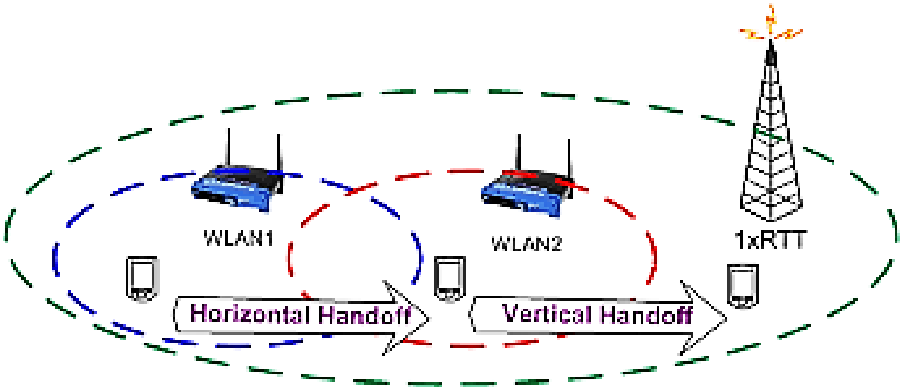

Figure 2. Handover scenario in HetNet environment

2.2 Shared resource management in wireless technologies:

Due to the nature of distributed networks optimization the goal is to manage shared resources of access networks. If radio resources can work together in an architecture of wireless technologies integration and connection management issues resolve, radio resources unit management may have a significant improvement in resource utilization. Many of these designs are in network side and using a shared link of shared resources. Shared management in some of the works have been inspired by the IEEE 1900.4 standard. Another important issue categorized in these articles is load balance issue.

In this study, the goal is to provide an architecture for connection management in heterogeneous access networks and designing and implementing algorithms related to architecture components performance. Generally, the architecture of connection management includes three layers: the user side resource manager, the station resource manager and the network resource manager. The decision algorithms of user side are designed to reduce overhead control, reduce decision-making time, remove the overhead of scanning the environment, and reduce the handover and also to supply the requirements of users. The station resource manager and the network resource manager must cooperate with users to optimize the overall goals notwithstanding the local goals.

Another goal is to meet user needs and satisfaction. In order to maximize the user satisfaction, it is essential to model and explain user needs. A user in the network not only has a profile and interests and preferences of his own, but also the device that connects him has its specific limitations and conditions. In addition to the applications that have their specific connection requirements, they should be modeled and be anticipated in the connection management system.

The implementation of connection management algorithms should be done according to the nature of decision making parameters. Decision making parameters of connection management in heterogeneous wireless access networks are divided into two categories of static and dynamic based on their nature. Static parameters refer to the nominal characteristics of each of the different types of implemented technologies in heterogeneous wireless environments and dynamic parameters refer to the changing conditions and status of stations and users. For this reason, decision making algorithms of connection management must be able to intervene these two groups of parameters in decision making. Also, the number of calling and activation of these algorithms are different based on the variability of parameters that should be designed in an appropriate way.

3. Proposing an architecture of connection management

The architectures of connection management in past mostly performed decision making on network side. But, the trends of new generation networks are going towards the simplification of networks and assignment of tasks in a distributed manner to users themselves. As there are numerous essential parameters in connection management, some constraints checking can be done jointly with the station and network management and the final decision and list of authorized options can be sent to each user. In this way, the created model is the simultaneous management of multiple heterogeneous networks with the participation of users and network.

3.1 Network selection algorithm

In this section, an algorithm of network selection is proposed which gives a ranking to each of the radio access technologies. This ranking will be integrated later in radio station selection algorithm. This means that it assesses type of station technology as a parameter with an algorithm presented in this section.

Basically, the characteristics and features of a radio access technology can be categorized in three types. In other words, apart from the dynamic characteristics, user has service expectation from network services in three layers. First, meeting the preferences and selections of the user himself in the form of profile can be saved for different occasions. Secondly, special conditions of communication device of the user and third, the applications that need a special network service. Thus, each of the network service providers can be ranked based on their performance in meeting these three needs. Here, AHP method seems appropriate which is used to assess and compare measures and breaks measures into sub measures. In addition, this method can provide the same results as in ranking the needs. Also, because of the limitations of the whole scenario and the quantity of radio access technologies, once ranking and saving and then reusing these ranks makes AHP the best candidate in design.

Table II. Different Layer's Network Selection Parameters

Network Selection Parameters					
User Level		Terminal Layer	Application Layer		
Security	Cost	Energy Consumption	Delay	Jitter Level	BER

Various telecom effective indicators can impact in the decision making process which perform decision making process of many designs based on one parameter, but in this research we intend to introduce a multidimensional decision making model has an acceptable accuracy level.

Two very important parameters, which involve in the determination of intra system handover condition also known as roaming, are the level of received signal strength from user and the level of received signal quality in dedicated functional mode. These two indicators are specified as follows:

- RSCP
- EC/N0

As it can be seen form the figure below, roaming action occurs in a condition that one of the two parameters in the receptor is less than a threshold, depending on that another cell or service provider can provide service with stronger signal or higher quality. Figure 3 has indicated a decision making in intra frequency handover scenario.

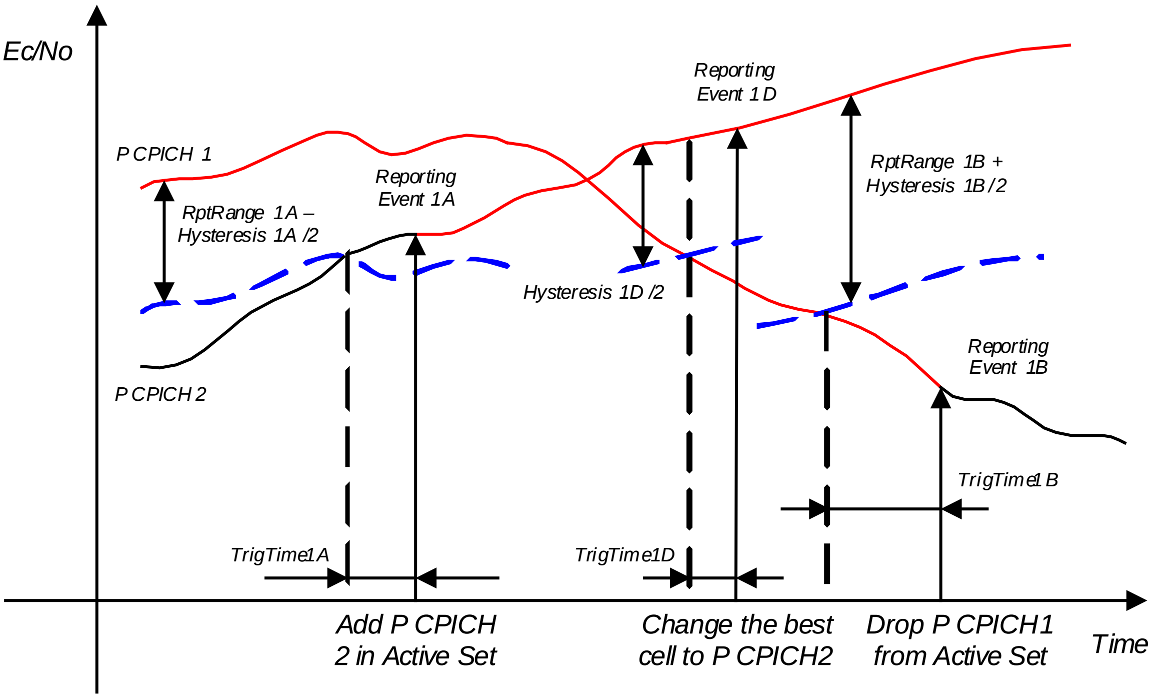

Figure 3. Decision making in intra frequency handover scenario

Meanwhile, in heterogeneous networks in order to prevent the occurrence of Ping-Pong, a specified amount offset as hysteresis is used. As it can be seen in Equation (1).

$$10 \cdot \mathrm{LogM}_{\mathrm{New}} + \mathrm{CIO}_{\mathrm{New}} \geq W \cdot 10 \cdot \mathrm{Log}\left(\sum_{i=1}^{N_A} M_i\right) + (1-W) \cdot 10 \cdot \mathrm{LogM}_{\mathrm{Best}} - (R_{1a} - H_{1a}/2) \tag{1}$$

In this condition, a roaming strategy can be modeled in the mode of no change in frequency through the below equation. Equation (1) determines that intra system roaming action only occurs in a condition that received signal strength level mean in the receptor plus a fixed amount of hysteresis, should be less than the total amounts of received signal strength from any other technologies and amount of CIO offset considered to control the number of intra system roaming in a time period.

$$10 \cdot \mathrm{LogM}_{\mathrm{New}} + \mathrm{CIO}_{\mathrm{New}} \geq 10 \cdot \mathrm{LogM}_{\mathrm{InAS}} + \mathrm{CIO}_{\mathrm{InAS}} + H_{1c}/2 \tag{2}$$

Also, the Equation (2) can be used as a principle in decision-making process. The difference is that in the new equation, the computing complexity of network is reduced and thus the total amount of computed load is reduced.

$$10 \cdot \mathrm{LogM}_{\mathrm{NotBest}} + \mathrm{CIO}_{\mathrm{NotBest}} \geq 10 \cdot \mathrm{LogM}_{\mathrm{Best}} + \mathrm{CIO}_{\mathrm{Best}} + H_{1d}/2 \tag{3}$$

Applying the Equation (3) can also be used in the determination of thresholds in a network consisting of several radio technologies. In such a model the decision making is performed based on the comparison of signal strength level and the best available signal in the list of out of the active nodes set. That is the received signal strength or quality of service of a technology that was not a good candidate for the camp, is desirable enough that in this mode the component of the network with current condition is the best option of intra system roaming. It is also important to note that as mentioned, the priority of camping a service receptor on another technology is signal strength or received service quality and in wireless networks mostly signal strength level has a negative relationship with distance. Thus, it can be mentioned that one of the main conditions for roaming from a receptor on another communication technology is the coverage level of secondary network in that region, in a way that all mentioned relations are discussable in a condition that in all of the areas under investigation, the coverage of all the networks forming heterogeneous networks be available. Figure 4 represents seeking target cell among all the neighbors based on their priority which has determined based on the distance between each cell and UE.

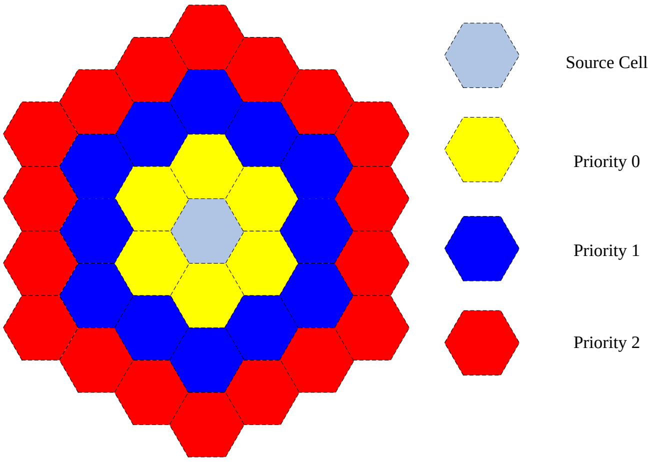

Figure 4. Different layer of neighbors based on distance measurement

The above mentioned equations for roaming with changing frequency is as below:

$$Q_{frequencyj} = 10 \cdot LogM_{frequency\ j} = W_j \cdot 10 \cdot Log\left(\sum_{i=1}^{N_{A\ j}} M_{i\ j}\right) + (1 - W_j) \cdot 10 \cdot LogM_{Best\ j} \quad (4)$$

In Equation (4) we try to study the decision making based on the received signal quality in different signals based on the technologies of different air connectors. As it is clear from the above equation, the amount of received service in the condition of connection with source technology, and the level of received service quality in the case of receptor's connection with other technologies is assessed. In such a condition, decision making is performed based on the effects of all the network service providers with different frequencies.

$$Q_{NotBest} \geq Q_{Best} + H_{2a}/2 \quad (5)$$

In addition, in order to control active sets of secondary roaming network selection, we use the Equation (5) and based on the level of received signal quality in dedicated functional mode.

Also, in a condition that our purpose is only going from one service provider technology to another radio access technology, the Equation (6) is presented as a decision making criteria.

$$Q_{UTRAN} = 10 \cdot LogM_{UTRAN} = W \cdot 10 \cdot Log\left(\sum_{i=1}^{N_A} M_i\right) + (1 - W) \cdot 10 \cdot LogM_{Best} \quad (6)$$

3.2 Radio station selection algorithm

In this section, the algorithm of selecting the best radio station for handover is discussed. As mentioned above, the information related to user, terminal and application is sent through MT-Proposal message to the network and in response, after implementing CAC access acceptance algorithms, a list of radio stations near user is sent to the user so that user is responsible for the final decision making of radio station selection. In the chapter part connection management design in heterogeneous wireless networks the benefits of this method have been discussed. In this part, designing an algorithm for selecting the best radio station is discussed.

To select radio station, unlike ranking the access technologies which were static, radio stations' status is dynamically changing. Their calling trigger also occurs frequently. Thus a method of decision making design should be selected that not only have an appropriate speed, but also it should be a method independent of user's actions and interactions. Because user should not be involved with radio station changing selection frequently and it should be clear from his perspective. These decision making methods that investigate conditions and parameters of the options without applying decision maker's preferences is known as the objective method of decision making. DEA method is one of the best objective methods in decision making that as it is transformed into a linear problem, it is solved as polynomial and very fast. Below parameters represented in Equation (7) are in NET-Proposal message in target model.

$$\begin{aligned} &N = \{BS_1, BS_2, \ldots, BS_n\} \\ &\text{where } BS_i = (D_i, L_i, F_i, R_i, Q_i, S_i),\ i = 1,2,\ldots,n. \end{aligned} \tag{7}$$

In which, each of the parameters has a weight factor specified in the effective decision making process.

Based on a multi-dimensional decision making algorithm, achieving to a efficient comprehensive model for managing the resource distributions based on network factors will be possible. In these networks user has an important role and does the network selection and handover based on his quality parameters. First, these parameters are divided into two categories of static, which is related to the heterogeneous networks, and dynamic which is related to the stations in these networks. As the decision making scenarios of static network parameters are limited, AHP algorithm has been used. This pairwise algorithm compares networks based on each criteria and ranks them. Then, according to the comparison in a higher level among the measures, considering all the measures, performs the final ranking. For dynamic parameters, because of scenario limitations and numerous modes of decision making and frequent activation, DEA algorithm is used to model the decision making. We used efficiency cross matrix to rank and using the efficiency cross matrix we reached to a final decision. These two algorithms, DEA and AHP, are combined to achieve a comprehensive algorithm of selecting station in heterogeneous wireless networks.

4. Conclusion and Future Works:

This paper presents an architecture for managing connectivity in heterogeneous access networks. Also, the decision algorithms of user side connection and feedback production methods to meet overall goals in these networks is designed and analyzed. Generally, connection management architecture consists of three layers: the user side resource manager, the station resource manager and the network resource manager. In the proposed architecture, decisions are made locally in the user side using the received feedbacks. The decision algorithms of user side are designed to reduce overhead

control, reduce decision-making time, remove the overhead of scanning the environment, reduce the handover and also to supply the requirements of users and they use many parameters to determine the optimal connection such as conditions of mobile devices, requirements of applications, velocity and mobility parameters, load and price of each of the stations and received signal intensity of them and finally the personal preferences of the end users.
Also, the following suggestions are proposed for future work towards the completion of this thesis:

- Decision making based on additional measures, such as user terminal battery, the power consumption, etc.
- Considering the different classes of services with different quality of service requirements in terms of delay, vibration, etc.
- Considering the priority for channel access in different service classes and giving priority to higher level classes of channel access.
- Reducing the possibility of blocking requests with regard to the system queue for new requests and handover to the system in Petri net model, and obtaining the average delay imposed to the user.

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