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A Survey of Handovers Decision Algorithms for Next Generation Wireless Networks

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Abstract: With technological advances in the telecommunications sector, everyone around the world would like to be connected seamlessly anytime anywhere through the best network. Making a transition from one network to another and moving between heterogeneous networks is not the only problem that worried specialists, scientific and mobile operators; the concern of QoS is as important as the handoff, The requirements like capability of the network, network conditions, handoff latency, power consumption, network cost, and user preferences must be taken into consideration during vertical handoff. Importance of inter working between architecture requires adaptive approaches to implement the vertical handoff mechanism in 4G wireless networks and produce an effective service for the user by considering handover parameters.

In this paper, we analyzed the main approaches for vertical handoff to offer a systematic comparison for new researchers. The survey revealed the need for new approach which satisfy the most important requirements and reduce the HO failure probability and the number of unnecessary handover.

Keywords: Wireless networks; 4G; vertical handoff, horizontal handoff, QOS (Quality of Service), Next Generation Network (NGN).

I. INTRODUCTION

Wireless telecommunication is classified into different generations of network. Each generation revolutionized the field of mobile communication. Wireless technologies were developed with different standards and these technologies offer different data rates, area of coverage and variety of services. To address this problem, the wireless telecommunication industry has been scrambling to define a new air interface for mobile communications to provide a framework for these high mobility broadband services and increase the overall system capacity, reducing latency, improving cell-edge performance and spectral efficiency.

Promising ubiquitous network access at high speed to the end users has been a topic of great interest especially for the wireless telecom industry. For the growing user requirements of wireless broadband access and the limitations of the existing wireless communication system4G seems to be the solution [1].

Fourth generation (4G) also called Next Generation Network (NGN) offers one platform for different wireless networks which are connected through one IP core 'Fig 1'. 4G integrates the existing heterogeneous wireless technologies avoiding the need of new uniform standard for different wireless systems. In 4G the integration of network and its applications is seamless therefore there is no risk of delay. While implementing 4G the cost issue needs to be taken into consideration so that users can benefit from this technological development fully.

Even though there are plenty of talks about 4G, there is not yet a universal agreed-upon definition of the 4G wireless mobile network up to now.

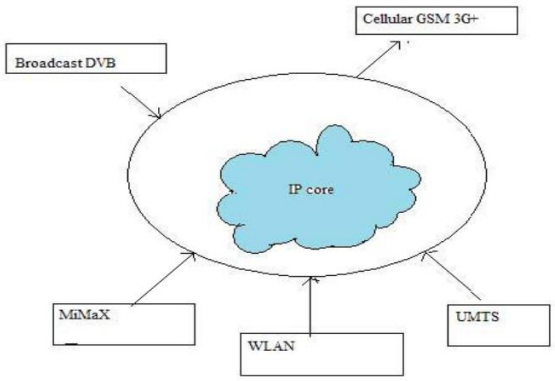

Fig. 14G networks

Mobility is the most important feature of a 4G wireless networks system. In 4G networks this mobility is represented by the mechanism of handoff (or handover) which is the process of changing the channel (time slot,frequency, spreading code, or combination of them) associated with the current connection while a call is in progress.

The traditional approach where the handover is performed on the evaluation of the signal strength is not enough anymore; it does not take into account the current context or the attachment of the user options. 4G technologies should consider adaptive and intelligent approach for vertical handover [2].

Two of the major challenges in vertical handover management are seamlessness and automation aspects in

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network switching "Always Best Connected concept" in an environment of multiple access technologies, according to policies (expressed by rules based on parameters such as network conditions or user preferences). To initiate the handover, HO management technique must choose appropriate time and the most suitable access network.
Many analyses, studies and tutorials were proposed in the literature:
RSS (Received Signal Strength) Based VHD Algorithm [3][4], Bandwidth-Based VHD Algorithms[5][6][7], Cost-Function-Based VHD Algorithms [8][9]; 'fig. 2' shows proposed classification by E.Arabmakki, S.Rashad & S.Krijestorac [10]:

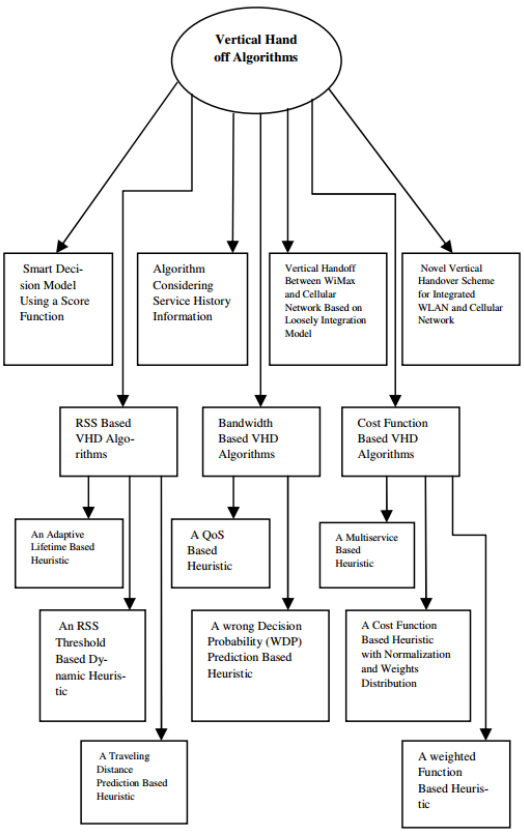

Fig. 2 Classification of Vertical Handoff Algorithms

Most of these algorithms have some advantages such as low handover blocking rates and reduced number of handover failures. However, those impose extra delay to the network.
Our paper analyses the most interesting and recent approachesfor vertical handoff in the literature and givea systematic comparison for new researchers. It will also allow us to explore an effective procedure between accuracy and cost of developing an approximate model of a complex system.

II. HANOVER MECHANISM IN 4G NETWORKS

The term 4G will refer to IMT-Advanced (International Mobile Telecommunications - Advanced) as defined by the International Telecommunications Union-Radio communication's Sector (ITU-R) and will include LTE-Advanced from 3GPP and IEEE 802.16m (Gigabit WiMAX) standard technologies, which are candidates for the IMT-Advanced or 4G certification. It is generally agreed in the mobile communications industry that 4G telecommunication systems will include an all-IP network, serving the end-users with higher data rates than are currently available on an "anytime - anywhere" bases.

In 4G networks, Handoffs are broadly classified into two main categories vertical and horizontal Handover.

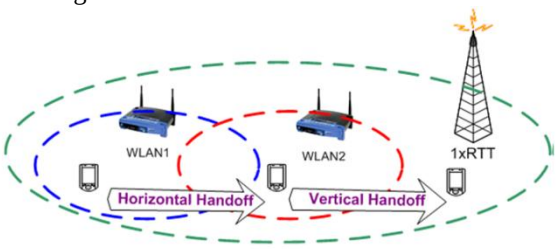

Fig. 3 Horizontal and Vertical Handover

A. Horizontal Handover

Intra-system "horizontal handoff" take place between two BSs that belong to two different FAs and both FAs belongs to the same system and hence to same gateway foreign agent (GFA)" or Link-layer handoff" Horizontal handoff between two BS, under same foreign agent (FA)"roaming when a mobile terminal departs the regulated realm of one base station and enrols into the regulated realm of another base station within the same system to maintain service continuity.

B. Vertical Handover

Vertical handoff or inter-system handoff is a handoff that occurs between the different points of attachment belonging to different network technologies. The automatic fall over from one technology to another in order to maintain communication is referring to the vertical handoff.

Vertical handoff implementation across heterogeneous cells of wireless access systems differ in several aspects such as received signal strength (RSS), data rate,frequency of operation, and the coverage area. Vertical handoffs implementation is more challenging than the horizontal handoffs implementation because of the different characteristics of the networks involved.

The network discovery, handover decision, and handover execution are the three phases of vertical handover process.
The aim of handoff initiation phase is to discern the necessity of handoff and initiating it if required during the system discovery phase, selective information of parameters such as bandwidth, RSS, network load, link speed, throughput, jitter, power consumption, cost, user preferences and network subscriptions will be accumulated. Various events triggered at various layers can be used as channels for collecting the information's. The best network for handoff (mobile terminal determines

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whether the connections should continue using the current network or be switched to another network) and the right time for handoff – these two queries primarily drive the functionality of handoff decision phase. In phase of 'handoff execution' handover process will be executed, the mobile terminal context and the profile of the user will be transferred re-routed from the existing network to the new network in a seamless manner. Security measures such as authentication and authorization will also be executed in this phase. 'Fig.4' depicts handoff management process.[12]

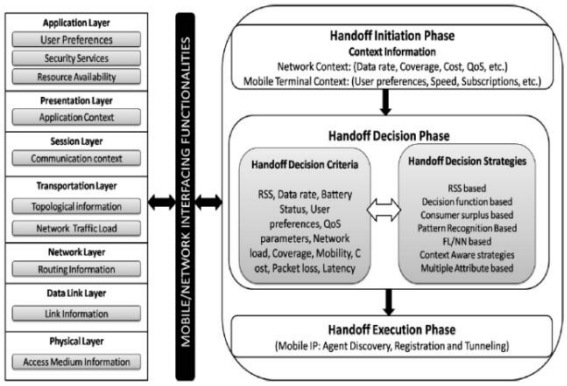

Fig. 4 Handoff management Process in collaboration with network layers

In order to maintain the connection with the moving device during the active data transmission, handoff management aims at controlling the change of an AP.

Handoff procedures between APs of heterogeneous technology have to be taken into account, because of the presence of AP adopting different technologies hence vertical handoffs. [13]

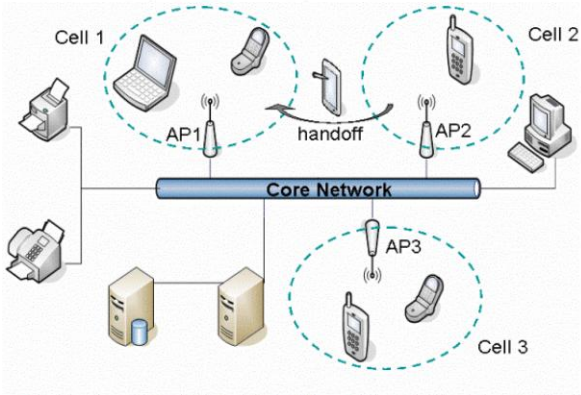

Fig. 5 Vertical Handoff in heterogeneous networks

The rest of the paper is organized as follows. In section 3 we discuss the existing mechanism for vertical handover and on the basis of previous works discussed in this section we describe the requirements for vertical handoff decision model for heterogeneous 4G networks in the section 4 and evaluate the existing work listed on the basis of those parameters.

In last section we conclude the paper.

III. VERTICAL HANDOFF ALGORITHMS

In order to identify the requirements for vertical handover mechanism for 4G wireless networks, it is essential to study existing vertical handover mechanisms.

As per the present knowledge few approaches for vertical handover have been found, in the literature three main approaches for vertical handover algorithms are recorded. A class of approach is based on "Received Signal Strength (RSS)" this method selects the strongest received BS at all times, that may be combined with other parameters such as network load and network cost. The second approach uses artificial intelligence techniques (complex and may be difficult to implement in practical systems) combining several parameters such as network conditions and Mobile Terminal's (MT) mobility in the handoff decision. The third approach combines several metrics such as access cost, velocity of a host, power consumption, and bandwidth, quality of service in a cost function estimated for the available access networks. [14]

The policy enabled handoffs was introduced by Wang et al. [8] in which they describe a policy-enabled handoff system that allows users to express policies and to find out the best network on the basis of dynamic parameters such as Network conditions (load, traffic….), user conditions (mobility…) and static parameters such as bandwidth, latency, power consumption, charge model. However, the cost function presented in that paper is very preliminary and cannot handle sophisticated configurations.

This paper was followed by several papers on similar approaches such as [9], where the Automatic Handover Manager (AHM) provides a solution for determining the best network interfaces for the services based on the autonomic computing concept.

In Automatic Handover Manager the decision is made by using the context information from the mobile node, networks and the user as well as the received signal strength. Thus, according to their preferences in 4G networks, the end-users can enjoy efficient services. It provides a good policy for the vertical handover using the context information without user's interventions.

AHM has four major functions such as monitoring, analysing, planning and executing. More concrete context information and improvements can be made in AHM by optimizing the context evaluation function in future work.

The objective of research work presented in [5] is to determine the conditions under which vertical handoff should be performed for heterogeneous wireless networks.

In this paper, they propose a vertical handoff decision algorithm for heterogeneous wireless networks. There work incorporated the connection duration and the signalling load incurred on the network for vertical handoff decision. The algorithm is based on the Markov decision process (MDP) formulation with the objective of maximizing the expected total reward of a connection. Numerical results show that their proposed MDP algorithm "An MDP model consists of five elements: decision time, states, actions, transition probabilities, and recompense." gives a higher expected total reward and lower expected number of vertical handoffs than SAW (Simple Additive Weighting) and GRA (Grey Relational Analysis), and two heuristic policies under a wide range of conditions.

In [15], the objective of research work is to define a system-wise entity that is activated when a user is in an

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area with over-lapping access technologies and needs to decide what is the best technology to be used and in order to optimize the overall system performance metric in terms of throughput and capacity limitation where the entity performs technology selection. The simulation results validate the efficiency of this method and show that it is also applicable to other combinations of access technologies. It shows improvement in the following network components: battery usage, load balancing, and performance while the network is a combination of Wi-Fi APs with same coverage of WiMAX BSs.

An interesting issue to investigate in future work is either fixed or mobile APs (wireless AP) that retrieve their bandwidths (hosts connecting to the AP) from the BS. Another way to think of those APs is as of super hosts. Also investigate the differences between the case of a wireless AP servicing several hosts and several hosts connecting directly to the BS.

Similar work was done by Chen et al.[6] in their study they proposed a Smart Decision Model to decide the "best" network interface and "best" time moment to initiate the HO. A score function is utilized in the model to make the smart decision based on the properties of available network interfaces, the system information, user preferences, and various factors.

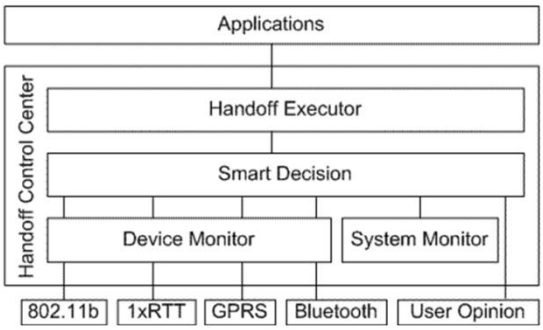

Fig. 8 Smart Decision Model

By using Universal Seamless Handoff Architecture (USHA) and by their testing experiments, they presented a detailed example to show how their model works with given a set of coefficient functions. The Smart Decision Model is simple and applicable not only for USHA, but also for other vertical handoff approaches.

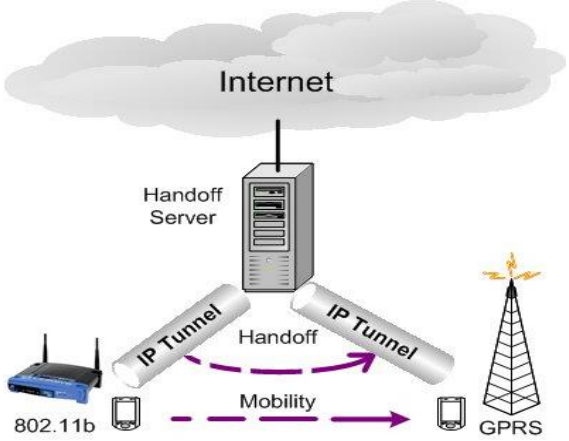

Fig. 9 Universal Seamless Handoff Architecture

Hasswa et al. [16] discussed the different factors and metric qualities that give an indication of whether or not a handoff is needed. They describe a vertical handoff decision function (VHDF), which enables assignment of weights by the devices to different network factors such as personal preference, monetary cost, quality of service, power requirements, requirements, and mobility (velocity and current position); but they considered the factors without proper simulation of analytical results.

Goyal et al. [17] proposed dynamic decision model that make the right vertical handoff decisions by determining the "best" network at "best" time among available networks based on, dynamic factors such as "Received Signal Strength(RSS)" of network and "velocity" of mobile station with static factors like Link capacity(offered bandwidth) and power consumption.
Fig. 10 depicts the proposed dynamic decision model.

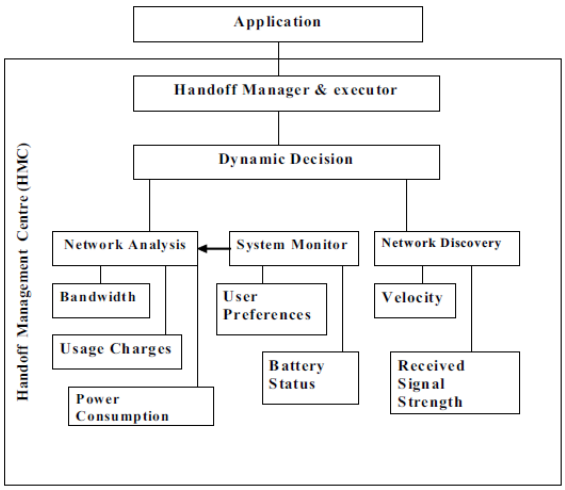

Fig. 10 Dynamic Decision Model

A Handoff Management Center (HMC) monitors the various inputs collected from the network interfaces and their base stations (BS)analyse this information, took handoff decisions and provides the connection between the network interface and the upper layer applications.

The Priority Phase of The algorithm for dynamic decision is used to remove all the unwanted and ineligible networks from the prospective candidate networks. Normal Phase is used to furnish user-specific preferences regarding the usage of network interfaces. User preferences are expressed in terms of weight factors.

The Decision Phase is finally used to select the "Best" network and executing the handoff to the selected network.The algorithm for dynamic decision is described in 'Fig. 11'.

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Dynamic Decision Process

Priority Phase: (Network Discovery)

1. Add all the available network into candidate list
2. Scan all the networks and record their Received Signal Strength(RSS)
3. Record the velocity of the mobile station(MS)
4. Remove the networks which do not satisfy the required RSS and velocity criteria.
5. Calculate and assign the priorities to all the candidate networks based on the difference between RSS and its threshold value RSST.
6. Continue with Normal Phase

Normal Phase: (Network Analysis)

7. Collect current system status from SM component and determined the weight factors.
8. Collect information on every wireless interface in the candidate list.
9. Calculate static score "*S*" using a *Cost function* for every network.
10. Continue with Decision Phase

Decision Phase: (Network Selection and Execution)

11. Calculate a dynamic *score "DScore"* by multiplying the *priority* of each candidate network with it's static score "*S*"
12. Select the network with the highest value of "*DScore*"
13. Handoff all current information to the "Selected network" if different from current network.

Fig. 11 Algorithm for Dynamic Decision Process

Mrs. Chandralekha et al. [18] proposed a theory for selection of the best available wireless network during handoffs based on a set of predefined user preferences on a mobile device. Neural network model has been presented to process multi-criteria vertical handoff decision metrics.
The features used from generated data has been carefully selected and used as inputs for the neural network in order to have high performance rate. Adaptive resonance theory (ART)' has been designed as a modified type of competitive learning to overcome the problem of learning stability.
The proposed method is capable of selecting the best available wireless network with a reasonable performance rate. However, there is still room for improvement.
In [19] they develop a VHO decision algorithm that enables a wireless access network to not only balance the overall load among all attachment points (e.g., base stations and access points) but also maximize the collective battery lifetime of mobile nodes (MNs).

IV. HANDOFF METRICS REQUIREMENT IN HETEROGENEOUS NETWORKS

Handoff metrics are used to indicate whether or not a handoff is needed. In this section the requirements for vertical handoff decision model for heterogeneous 4G networks are listed on the basis of previous works discussed in section 3.

A good handoff mechanism decision model has to consider both dynamic and non-dynamic metrics.

A. BANDWIDTH

Higher offered bandwidth ensures lower call dropping and call blocking probabilities, hence higher throughput [14]. Bandwidth is the difference between the upper and lower frequencies in a continuous set of frequencies. It's a measure of the width of a range of frequencies in hertz.
During movement bandwidth requirement of mobile node should be managed to provide seamless handover with good Quality of service (QoS) in wireless environment.

All discussed techniques satisfy this requirement.

B. RECEIVED SIGNAL STRENGTH (RSS)

Traditional handover algorithms depend on comparing the differential signal power level between the serving BS and target BSs to a fixed handoff hysteresis value which is designed to reduce the Ping-Pongeffect in the handoff procedure.
Therefore, selection of this hysteresis value becomes important for optimizing handover performance. Several unnecessary handoffs may be processed increasing the network load if h is too small. However, the long handoff delay may result in a dropped-call or low QoS [20] if h is too large. As discussed earlier in this paper, VHO includes three sequential steps handover initiation, handover decision and handover execution. Handoff initiation is concerned with measurement of RSS.
Handoff decision model for all the presented techniques include the RSS except [18] (Use of Adaptive Resonance Theory for Vertical Handoff Decision in heterogeneous Wireless Environment), [8] (Policy-Enabled Handoffs across Heterogeneous Wireless Networks) and [19] (Vertical Handoff Decision Algorithms for Providing Optimized Performance in Heterogeneous Wireless Networks)

C. VELOCITY

In vertical handoff, the velocity factor has a larger weight and imperative effect in handoff decision than in traditional horizontal handoffs.
Because of the overlaid architecture of heterogeneous networks, when traveling at high speeds processing handover to an embedded network with small cell area is discouraged since a handoff back to the original network would occur very shortly after that [14] when the mobile terminal leaves the smaller embedded network. Mobile users are connected to the upper layers and benefit from a greater coverage area [21].
This requirement is satisfied by [9] (Towards Autonomic Handover Decision Management in 4G Networks), [15] (Efficient decision handoff mechanism for heterogeneous network) and [17] (A Dynamic Decision Model for Vertical Handoffs across Heterogeneous Wireless Networks).

D. USER PREFERENCES

User preferences (such as preferred network operator, preferred technology type, user application requirements 'real time, non-real time', service types 'Voice, data, video', Quality of service, preferred maximum cost)

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should be used to cater special requests for one type of network over another[22].
Handoff decision model for all the presented techniques include this metric except [8] (Policy-Enabled Handoffs across Heterogeneous Wireless Networks) and [17] (A Dynamic Decision Model for Vertical Handoffs across Heterogeneous Wireless Networks).

E. COST OF SERVICE

The cost is to be minimized during VHO in wireless networks. The cost of services offered is a major consideration to users since different network operators and service providers may employ different billing plans and strategies that may affect the user's choice of access network and consequently handoff decision [22].

For this requirement all discussed mechanisms are using cost functions to analyse the network cost during switching of networks by a mobile node except [15] (Efficient decision handoff mechanism for heterogeneous network).

F. SECURITY

Secure and seamless handoff has become an important factor in wireless networks with the increasing demand of wireless networks.
The ability of a network to stand against attack from software virus, intruders and hackers, and to protect network infrastructure, services, prevent and monitor unauthorized access, modification, misuse, and network-accessible resources, confidentiality and integrity of customers data is a major issue and could sometimes be a decisive factor in the choice of a network. Only [18] (Efficient decision handoff mechanism for heterogeneous network) considers this parameter.

G. POWER CONSUMPTION

In 4G networks, handover technique should consider power Consumption. Power is consumed by user terminal, attributed to base station equipment and also consumed during mobile switching or handoffs.

All Handoff mechanisms consider this metric except [5] (A Vertical Handoff Decision Algorithm for Heterogeneous Wireless Networks) and [18] (Use of Adaptive Resonance Theory for Vertical Handoff Decision in Heterogeneous Wireless Environment).

H. NETWORK THROUGHPUT

Network Throughput refers to the volume of data that can flow through a network and it's is measured in bits per second (bps). Network Throughput is constrained by factors such as the network protocols used, the type of cabling, and the capabilities of routers and switches. Network Throughput in wireless networks is constrained further by the capabilities of network adapters on client systems.
Handoff mechanisms such as [9] (Towards Autonomic Handover Decision Management in 4G Networks), [5] (A Vertical Handoff Decision Algorithm for Heterogeneous Wireless Networks), [15] (Efficient decision handoff mechanism for heterogeneous network) and [18] (Use of Adaptive Resonance Theory for Vertical Handoff Decision in Heterogeneous Wireless Environment) are able to satisfy this requirement.

I. HANDOFF LATENCY

Handover latency which can cause numerous packets to be dropped while a mobile user is migrating from one access network to another.
Good handoff decision model should conceder Handoff latency and minimize it to improve user experience.
To minimize the handoff latency (Policy-Enabled Handoffs across Heterogeneous Wireless Networks) [8] and (Use of Adaptive Resonance Theory for Vertical Handoff Decision in Heterogeneous Wireless Environment) [18] incorporate this factor in their handoff decision models.

J. TRAFFIC BALANCING

To avoid deterioration in quality of services the handoff procedure should balance traffic in adjacent cells, thus eliminating the need for channel borrowing, simplifying cell planning and operation, and reducing the probability of new call blocking.
Almost all of the proposed handoff mechanisms consider this parameter except [9] (Towards Autonomic Handover Decision Management in 4G Networks) and [17] (A Dynamic Decision Model for Vertical Handoffs across Heterogeneous Wireless Networks).

K. NETWORK CONDITIONS

Network-related parameters such as available bandwidth, traffic, congestion (packet loss), and network latency may need to be considered for effective network usage [22].

V. CONCLUSION

The fourth generation wireless networks are expected to include heterogeneous wireless networks that will coexist and use a common IP core to offer a diverse range of high data rate multimedia services to end users since the networks have characteristics that complement each other.
In this paper, we studied the basic concepts of different handovers approaches in heterogeneous wireless networks and provide a literature survey to news researchers regarding handoff management in 4G networks.

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