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A Comparative Review of Vertical Handover Decision-Making Mechanisms in Heterogeneous Wireless Networks

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Abstract

Background/Objectives: Heterogeneous wireless networks are converging towards an all-IP network as part of the so-called next-generation network. In this paradigm, different access technologies need to be interconnected; thus, vertical handovers or vertical handoffs are necessary for seamless mobility. In this paper, we prepare a review of existing vertical handover decision-making mechanisms that aim to provide ubiquitous connectivity to mobile users. **Methods/Statistical Analysis:** To offer a systematic comparison, we categorize these vertical handover mechanisms based on TCP/IP layers. Subsequently, we evaluate several vertical handover decision-making mechanisms in the literature and compare them according to their advantages and limitations. **Results/Findings:** The paper compares the algorithms based on the network selection methods, flexibility and complexity of the technologies used. We find that the deployment of cross-layer architecture as a handover trigger and then performs handover accordingly with multi-path transmission can reduce packet losses around the handover. **Conclusion/Application:** The cross layer design approach seems to be a best solution for attaining seamless service continuity in order to facilitate seamless connectivity.

Keywords: Cross Layer, Decision-Making Algorithm, Heterogeneous Wireless Networks, TCP/IP Layers, Vertical Handover, Vertical Handover Metric

1. Introduction

Recent decades have witnessed the astonishing development of wireless applications, devices and networks. However, the diversity of the means and purposes arising out of this revolutionary outbreak of wireless systems calls for a unique technology based on a single infrastructure, capable of serving the users with high service quality across various situations. Inevitably, the fulfillment of the vast requirements of such broad applications requires the future generation of wireless systems to communicate via technologies that are heterogeneous by nature, namely WiFi, wireless interoperability for microwave access (WiMAX) and Universal Mobile Telecommunication System (UMTS), as well as the rapidly developing Web 2.0-based mobile applications and location-based or car navigation services[1].

In the next generation of all-IP networks, all the related functions must work independently of the network technologies so that these phenomena can lead to the network, service and application convergence. This trend can be very helpful in enabling the service providers to deliver their network services in an efficient manner to

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users without worrying about the type of network or the terminal capabilities. Researchers often categorize these processes as horizontal, vertical and diagonal handovers. If a handover is accommodated within the same wireless access environment, then the process is the horizontal handover type, while the handover processes occurring in environments encompassing wireless access networks with no or minimal homogeneity are known as the vertical type. A diagonal handover is the mixture of horizontal and vertical handovers. A handover is said to be diagonal when the mobile node navigates those cells that use a common underlying technology (e.g. Ethernet)[2]. To put it another way, diverse wireless networks with different technologies must integrate and converge to achieve an interoperability that is technically seamless; this goal makes the use of techniques such as the Vertical Handover (VHO) inevitable. A vertical handover or vertical handoff entails the transfer of mobile terminals among various wireless cells/technologies.

In heterogeneous wireless networks, the VHO is an important factor in providing of seamless mobility between varied network environments. The VHO procedure contains of three key functions: System discovery, handover decision and handover execution. The VHO decision is significant for providing a low cost, highly available network environment that can achieve the greatest Quality of Service (QoS) or Quality of Experience (QoE). As summarized in Table 1, a VHO consists of three main phases, which are crucial for deciding the efficiency and applicability of the chosen handover mechanism.

Table 1. Hanover phases

Handover Phase	Description
Handover Measurement and Initiation	Mobile Node (MN) or an Access Point (AP) makes the measurements for initiating a handover towards a new network or towards a new AP in the same network.
Handover Decision	Measurement results are compared with predefined values to decide whether to perform the handover or not.
Handover Execution	New base station is added, power of each channel is adjusted and active set is updated.

Nowadays, VHO management is a vital matter as its purpose is to confirm the seamless roaming of users from one wireless access technology to another. Also, the potential of cross-layer design for improving critical performance aspects of vertical handover is widely recognized as an important property of mobile communication systems. In the perspective of future wireless networks, many studies were proposed in the literature[1–3,5] etc. No one was planned containing the different existing mechanisms in the vertical handover decision problem based on single layer and cross-layer design.

The present article surveys existing mechanisms in the vertical handover decision and summarizes their key properties in a comprehensive taxonomy. In addition, this survey can guide the interested readers familiar with vertical handover mechanism through the classification of vertical handover mechanisms based on single layer and cross layer design approaches and to help them integrate these fascinating schemes into their own studies. For this purpose, the following objectives are set:

- To identify VHO decision criteria.
- To classify the existing VHO decision-making algorithms based on single layer and cross layer design approaches.
- To compare the VHO decision-making methods based on their classification.

The remainder of this work is organized as follows. Section 2 presents an overview of VHO procedures including their main proposals for vertical mobility support. Section 3 provides a summary of the handover information-gathering phase and details the parameters collected during this phase. Section 4 classifies the diverse current strategies and offers a comparative analysis of these studies related to the decision-making phase based on different layers and employed methodology. Section 5 analyses the existing strategies and classifies the existing strategies and provides a comparison between the algorithms related to the decision- making phase. The evaluation metrics on candidate algorithms are also illustrated. Section 6 presents more details on handover execution. Section 7 describes the observed findings based on the classified algorithms. Finally, Section 8 concludes the paper.

2. Vertical Handover Overview

In heterogeneous wireless networks, a mobile user may do handovers across different network domains to keep its data connection and QoS. The process of VHO can be divided into three phases, namely; handover information gathering, handoff decision-making and handoff execution. Figure 1 shows the connections among the three needed phases to apply handovers in heterogeneous networks.

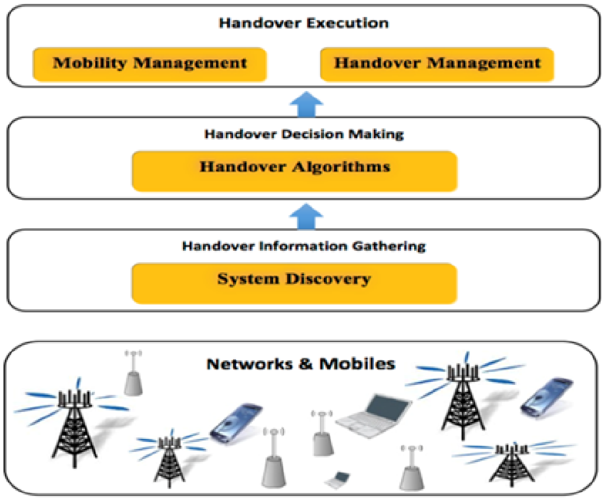

Figure 1. Three phases required implementing handover.

In the information-gathering phase, the information necessary for identifying whether or not a handover is required is accumulated. In gathering such information, both the mobile terminals and networks cooperate. More details about the information-gathering phase will explain in the next section. The acquired information is used to recognize the available and most appropriate networks for the application in question in a subsequent phase called the handover decision-making phase. When the suitable (new) access network is identified and chosen, it is necessary to transfer the communication sessions from the previous radio interface to the newly selected interface. Afterwards, a routing path is established.

3. Handover Information Gathering Phase

The information-gathering phase is referred to by a number of different terms in the literature including system discovery, handover initiation or network discovery[3]. This phase is carried out to detect and discover available access networks. An available network is a reachable and authorized network considered for an eventual handover. During the information-gathering phase, mobile terminals equipped with multiple interfaces must determine which networks can be used and what services are available in each network. The handover information-gathering phase is not only effective for collecting network info, but also efficient for gathering information about access points, user preferences, mobile devices and network properties. The information must then be used in the handover decision-making phase.

Ultimately, the available networks links are announced using the accrued information on factors including the throughput, handover rate, cost, location, packet loss ratio, Received Signal Strength (RSS), carrier interference ratio, Signal-to- Interference and Noise Ratio (SINR), bit error rate and QoS parameters. The gathered data can provide the mobile device status, indicating the service class, resources, speed and even the battery charge status. Other attributes and user preferences such as the required services and the user's budget can be derived from the information gathered.

Generally, the information-gathering phase is critical in the handover process. To reach the "Always Best Connected" (ABC) and "Always Best Satisfying" (ABS) paradigm[4], the collected information must be sufficiently comprehensive to enable the decision-making phase to be performed. This phase involves finding out all of the neighbor networks, which are willing to support its ongoing services. In other words, this phase is done periodically in order to gather information about the interface statistics, current radio environment information, application priority scores and user preferences. The collected data are used to decide whether or not handover is needed. These inputs are fed into the decision engine for making decisions about the handover.

At times, the present network is unable to process the ongoing connectivity; for example, the radio prerequisite conditions or the QoS may fall below the predefined thresholds[5]. Hence, performing the discovery process would be necessary in such cases. Otherwise, the discovery process collects the required information concerning the QoS and the available and appropriate networks to prepare the required data for the VHO algorithm so that it can make decisions throughout the handover selection stage. Table 2 presents the descriptions of some specific criteria in dealing with the handover process.

4. Handover Decision Phase

In this section our proposed classification of the VHO decision-making approaches is described. The proposed

Table 2. Vertical Handover Decision Criteria.

Source	Metric	Description
Network	Latency E2E	Total time from when a request initiates to send to a destination's network.
	Band width available	Important parameters that directly affect the QoS are the offered and available bandwidths.
	Load	It shows higher performance in case the network is capable of providing higher bandwidth.
	Security	Handover process requires improved security and privacy from eavesdropping, registration hijacking, session teardown and Denial of Service (QoS) attacks.
	Network Delay	Time acquired to send a packet. Delay is the total time to send a message from source to destination.
	Coverage	Network coverage is strongly associated to the signal strength received by a Mobile terminal.
	RSS	It decreases when a user travels away from the currently accessed networks' access point.
	CIR	Carrier Interference Ratio is ratio of the signal power to the power in the interference components.
	RTT	It is essential to monitor the current QoS status and to detect changes in QoS to promptly identify the cause of QoS degradation.
	Retransmission	It ensures reliable data transfer between two end nodes.
	BER	Bit Error Rate is the number of received bits that have been altered due to noise and interference, divided by the total number of transferred bits during a time interval.
	SINR	Signal to Interference and Noise Ratio is crucial parameter greatly affecting and reflecting the QoS of a network.
	Packet Loss	Handover entails link switching, which at times may fail in operating in exact coordination with rapid handover signaling.
	Throughput	Throughput denotes the data rate supplied for the MNs in any given network.
	Link Capacity	Bandwidth offered by a candidate Network.
	Network Jitter	Jitter can be defined as the maximum packet delay minus the minimum packet delay over a short time period.
	Overhead	Extra management packets in the network
	Cost	Every network provides certain services to its users, which are usually charged against a cost.
Available RATs	User preference	This is related with the trade-off between price and QoS offered by a certain technology,
	Distance	It is the distance between the current position of the mobile terminal and the coverage area of a given target RAT.
	Coverage	It is the expected distance in which the terminal will have coverage of RAT.
	Bit rate in RAT	It is an estimation of the bit rate that the mobile terminal can obtain when transmitting in RAT.
	CPICH Ec/No	It can be define by the received energy per chip divided by the power density in the band.
Operator	Revenue	Revenue maximization must consider for network providers.
	Resource	Since resource is limited, resource management, especially in multimedia application, has been a critical problem in wireless networks.
User	Budget/Cost	User Budget to spent in Using Networks
	Preferred Network	User choice
	Security	The level of security adapted for user
	QoE	Quality of Experience
Terminal	Velocity/Speed	Fast successive handovers can result in high overheads of signaling and delay of response.
	Interference	The technologies accessible by the device.
	Battery Consumption	Network with lower energy consumption can assign the handover.
	Location	It is criterion in choosing between two coexisting technologies with acceptable signal levels.
	Movement	Denotes the movement direction changes.
VHO	Number of VHO	A handover is considered as surplus when a handover back towards the actual access point and number of this kind of handovers must be reduced (Ping-Pong Effect).
	VHO Success Rate	The ratio of VHO events successfully performed
	VHO Latency	Latency VHO = Latency Gathering + Latency Decision + Latency Execution.
	QoS	Includes type of service and its capabilities and Quality of Service.

Table 3. Vertical Handover Decision Methods based on single layer design

Method	Advantages	Weaknesses	Study
Single Layer-based	SCTP can quickly determine the loss of a packet; Congestion Control; Transport-Layer Fragmentation.	SCTP uses a comprehensive 32 bit CRC32c check sum which is expensive in terms of CPU time.	[13]
	Provide the necessary handoff support.	Requires upgrading both transport layer and applications on both mobile hosts and Internet servers. So, the deployment cost is still too high to become feasible.	[14]
	Performance improvement	Lack of consideration on setting up the information server; Non management on the MIIS	[18]
	Successful Handovers; Intelligent network selection	High Resource consuming by receiving current network condition information Wasteful in the variable wireless environment	[8]
	Focused on network and terminals	Complexity of computing	[19]
	Improved the energy efficiency at the end-user mobile device, while maintaining good user perceived quality levels	No generate the weight of the effective NS parameters	[9]
	D-PMIPv6 can improve the performance in terms of the packet delivery cost	Does not fit for flat architectures	[15]
	The solution is realistic and not very complex to implement in current mobile devices and networks	No consideration on user location	[10]
	Maintain connections; Maximize user throughput.	No consideration on details of the network integration as well as the handoff management.	[20]
	Optimal network selection	Non-support on same level of quality to the packet flow during and after the handoff.	[17]
	Can be easily implemented; proposed scheme works better for the downward vertical handoff; Avoids packet loss.	No consideration on reputation information exchange.	[16]
	Prevent some packet-flooding attacks		[15]

classification is presented in Figure 2. Every VHO method should go through a decision-making process to assess the available wireless access networks. The result of the procedure is the identification of the network that is most appropriate for the handing over of a mobile terminal based on the criteria collected and assessed in the information-gathering stage. Although the standards do not give the decision-making algorithms in detail, numerous suggestions can be found in the literature[6].

The decision-making phase is the vital core stage of the VHO process because it selects the most suitable network for fulfilling both the user and system demands. Many proposed VHO algorithms can be found in the interoperability literature. In basic terms, three steps constitute the decision-making phase: 1. Selecting the parameters. 2. Managing the parameters and 3. Collecting the parameters. In the first step, only those parameters that are used by the algorithm for evaluating and weighting a candidate connection are considered for selection. In the second step, all the parameters are normalized; merging of the value parameters containing diffuse information is performed using a number of techniques such as fuzzy logic, neural networks and certain functions for extracting the relevant data. In the last step, an algorithm aggregates and evaluates each parameters weight on the basis of the decision criteria and chooses the most appropriate candidate. This three-step process applies to the majority of proposed approaches but authors typically alter this process to make it better fit their needs[7].

Several protocols are proposed for NG all-IP-based wireless systems. These methods try to support vertical handover process from different layers of the TCP / IP protocol stack reference model. We classify these vertical handover decision methods into the following categories:

Single layer-based decision-making methods

- Application layer-based decision-making methods.
- Transport layer-based decision-making methods.
- Network layer-based decision-making methods (layer 3 methods).
- Link layer-based decision-making methods (layer 2 methods).

Cross layer-based decision-making methods

Application layer methods provide handover-related features at the application layer. By moving the mobility handling to the application layer, the need for tunneling of the data stream can be eliminated. Also, handover management at the application layer means that it can be installed easily, which allows the most common mobile application, voice, to enjoy mobility before mobile IP is widely implemented. Network layer methods provide mobility related features at the IP layer. The handover trigger is generated by the link layer in the mobile node and received by the mobile node's network layer (vertical triggering). Link layer methods provide mobility-related features in the underlying radio systems. They ensure uninterrupted communications when Mobile Terminals (MTs) change positions within the scope of an access router. Cross-layer methods are mainly proposed for handoff management. In this review, we mostly focus on cross layer (layer 2+3). They aim to achieve layer 3 handoff with help from layer 2. By achieving signal strength reports and movement discovery information from the link layer in advance, the system can make well arrangement for the network layer handoff so that the packet loss is eliminated and the handoff latency is reduced.

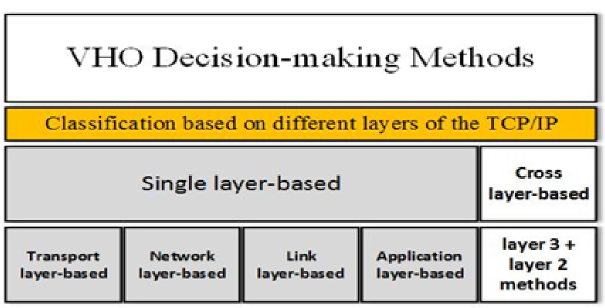

Figure 2. The Proposed Classification of Vertical Handover Decision Methods.

In the proposed classification, the classes are categorized based on the different layers that are responsible for triggering the handover decision. Based on the layer employed to process the vertical handover, the VHO decision-making methods can be classified as follows: Single layer and Cross layer decision-making methods. Each of the handover decision-making classes for assisting vertical mobility in wireless networks is discussed separately. In continue, summarizes each VHO decision-making methods, then each of the sub-classes are described.

4.1 Single Layer-based Decision-Making Methods

4.1.1 Application Layer-based Decision-Making Methods

Based on[8], an IP tunnel is maintained between every MH and the HS such that all application layer communications are bound to the tunnel interface instead of any actual physical interfaces. This provides handoff transparency to upper layer applications.

Trestian et al.[47] proposed an NS method that employs multiplicative exponent weighting as a scoring method in the repeated cooperative game model. Among various criteria considered in a user-centric strategy regarding VHO decision-making, the user preferences in terms of the price and QoS are the most noticeable policy parameter. The model proposed in[10] is based on the handover decision, evaluated from the user perspective in terms of the most convenient handover appropriate to the user particular needs. The authors introduced two handover policies that could fix a threshold value between GPRS and WiFi networks: 1. The mobile terminal will never leave the GPRS connection with no connection blackouts and 2. The algorithm will search just for the WiFi access points upon each one of the connection blackouts.

4.1.2 Transport Layer-based Decision-Making Methods

Zekri et al in[11] propose a VHO management solution combining the use of reputation as a Quality of Experience (QoE) indicator for fast decision-making. By users expressing their experiences, the system aggregated those individual score to give a reputation value for WiFi, WiMAX and UMTS networks.

SIGMA[12] is a transport layer mobility mechanism based on SCTP, similar to MSCTP. It was designed to be an end-to-end handover solution, which does not require any infrastructure support. A key problem with SIGMA is that it does not consider any QoS parameters when making a handover decision.

Some approaches suggest new transport layer protocols such as SCTP[13] and TCP-MH[14] to provide the necessary handoff support. The Stream Control Transmission Protocol (SCTP) is a standard transport-layer protocol for the IPv4 and IPv6 Internet. The security mechanisms commonly used in transport protocols are relatively weak, similar to the random initial sequence numbers in TCP.

4.1.3 Network Layer-based Decision-Making Methods (Layer 3 Methods)

The author in[15] suggests splitting the functionality of the Localized Mobility Anchor (LMA) of PMIPv6 into two distinct nodes: A control plane LMA (CLMA) and a data plane LMA (DLMA). The former maintains the mobility sessions for the MNs, whereas the second is the anchor for the MNs' traffic. The CLMA also assigns the most suitable DLMA to the MNs. This study showed the LMA's burden, but, in general, does not fit for flat architectures, as the DLMA/MAG hierarchy is protected, along with the tunnels, which are established for the whole duration of a data session. The research, however, imagines an operating mode by which, if the MN and CN are under the same CLMA's administration, route optimization can be set up between the corresponding MAGs.

Taking note of the complexity of almost all of the strategies, the recently introduced proposals include experience-sharing approaches with the purpose of reducing the delays and costs of VHO procedures. Another approach, useful in cooperation scenarios and decision-making problems, is the reputation systems method having recently been studied and applied in the wireless environment, specifically in mobile ad hoc networks, wireless mesh networks and internet- based peer-to- peer networks.

Nguyen et al.[17] presented a heterogeneous handover process that is fully controlled by the terminal, and where the network selection is user-centric, power saving, cost-aware and performance-aware. Total mobility management, including interface management, handover decision and execution, is also detailed. Generally, a mobility management system includes two essential elements: A handover decision management phase and a handover execution phase. These two phases are supposed to be executed in a short time to allow the mobile node to be reached on any access point to which it wants to move.

4.1.4 Link Layer-based Decision-Making Methods (Layer 2 Methods)

Emmelmann et al.[18] proposed the design and prototype of a seamless handover mechanism for high-speed vehicles using a dynamic dwell timer. This scheme is designed for IEEE 802.11 networks and aims at reducing the handover delay for the provision of telemetry services. The proposed prototype consists of micro-cellular and macro- cellular coverage areas that operate on the same frequencies. The proposed handover phases can reduce overall handover latency. The researcher's in[18] also introduced the fast L2 scheme for horizontal handovers. Using this method, the scanning time is reduced through employing information about the candidate point of attachment. The performance improvement of this scheme was verified through simulation results.

Analytic Hierarchy Process (AHP) method is based on the provision of adequate services (any time and anywhere) to the users, network applications and services must be aware of their contexts and should automatically adapt to their changing contexts.

Authors of the paper[19] have employed an Analytic Hierarchy Process (AHP) to initialize the implementation gain function. The AHP prepares a logical and comprehensive framework for decision-making when multiple criteria are involved. AHP generally includes four steps. In the first step, modeling of the decision process requires that the AHP to construct a hierarchy for it. The key factors lie on the second level and the available base stations constitute the bottom nodes. In the second step, all available nodes existing on the third level are related in pairs in relation to each factor lying on the second level. The result of each comparison determines the numerical measure ratio of each factor. The third step has been assigned to computing of the normalized Eigen vector of the output matrix that shows the weights of the elements. And finally in the fourth step, the weights of various elements on all of the levels are aggregated and ultimately the performance is calculated. This study has been undertaken focused on the link-layer inter-technology vertical handovers. Several major challenges affect the vertical handovers like randomness of the user mobility, high overhead of the handover and the requirement for optimality. This study exploits user mobility patterns that can lead to high-performance handover decisions in the long run.

The author's in[20] propose a new user centric algorithm for vertical handover, which combines a trigger to continuously maintain the connection and another one to maximize the user throughput (taking into account the link quality and the current cell load). They showed that the layer 2 throughput achieved by the MS, as a function of the load ratio between WiFi and WiMAX, for different values of the SINR of the WiFi connection.

4.2 Cross Layer-based Decision-Making Methods (Layer 3 + Layer 2 Methods)

Mohanty et al.[21] proposed a handover decision-making algorithm from a Wireless Local Area Network (WLAN) to 3G networks on the basis of the comparison of the current RSS level and a dynamic RSS threshold value in a scenario where a mobile network is connected to a WLAN access point. Using a dynamic RSS threshold assists in decreasing the number of unnecessary handovers and it also keeps the number of handover failures under a predefined limit. Mohanty et al. showed that the probability of handover failure increases in cases where a fixed value of RSS threshold is used and there is an upsurge in either the velocity or handover signaling delay.

Packet flow delays increase due to the utilization of increased lifetime metrics because of bad channel conditions. This is critical for real-time applications and it ultimately degrades their overall performance. In order to tackle these issues, Park et al.[22] proposed an application-aware scheme to lift the QoS of multimedia streaming services. They did so by reducing the channel scanning time and the number of channels involved in each scanning. To obtain an adaptive solution, they modified the scanning method according to the application type. For packet loss and delay-sensitive applications such as voice over IP, they augmented the channel frequency and rescanning duration but this also increased the consumption of battery power. The author's in[22] presented an architecture that suggests using location and cross-layer information to trigger vertical handovers. They compared two handover algorithms from the perspective of how differences in the effective data rates, the terminal velocity and the amount of handover delay affect the mean throughput in a region, both in moving in and moving-out scenarios.

The author's in[23] proposed a handover scheme based on an enhanced mobile IP that employs L2 information for handover decisions (such as the RSS, bandwidth and link indicator) because the L2 information is continually accessible and can provide the data on the neighboring access networks. In their proposed algorithm, the conventional mobile IP message constituents are modified to reduce the latency and packet loss ratio.

In[24] Ben-Jye Chang and Jun-Fu Chen propose a cross-layer-based polynomial regression predictive RSS approach with the Markov Decision Process (MDP) based optimal network selection for handoff in heterogeneous wireless networks was proposed. However, there is no dwell time to check the condition of the RSS comparison in order to avoid the ping-pong effect and the computation of Markov process depends on the number of WLAN networks.

Moreover, the MIH standard[25] defined in the IEEE 802.21 specification supports vertical handovers across heterogeneous networks. Service disruption time can be reduced significantly using the fast L2 HO. The commands carry the upper layer decisions to the lower layers on local device entity or at remote entity. MIH functions are implemented between Data Link and Network layer, in both mobile device and core network.

The author's in[26] proposed a link quality-based handover mechanism by exploiting the benefits of the ANN. They employed the packet success rate parameter as a link estimator instead of the RSS for making the handover decision. This is because the packet success rate helps in reducing handover delay. ANNs assist in learning the network behavior and the correlation function among network entities for their respective contexts such as packet length, SINR, RSS and the number of connected mobile users to a specific access point. During this learning phase, some measurement samples are collected and are later generalized for making the handover decision in any scenario. This helps in reducing the handover decision processing delay and overall handover latency. Packet loss is also kept limited to a certain level by employing different ANN functions.

Kang et al.[27] presented a fuzzy logic-based scheme for handover decision-making. They used a large number of parameters as context information to design their autonomic-oriented approach, such as QoS, cost, user preferences, and service type and battery level. They defined two metrics for assessing the capabilities of the future point of attachment: 1. The access point acceptance value (APAV), and 2. The access point satisfaction value (APSV). These metrics help a mobile node to better select a future point of attachment.

Adiline and Anandhain[28] proposed a user centric approach for controlling the handover between heterogeneous networks. This method includes a mobility management which is fully controlled by the terminal, and network selection is user-centric, power-saving, cost aware, and performance-aware. However, they did not mentioned how the proposed handover metrics is achieved; moreover, they based the handover execution phase only on the Mobile IPv6. As well as, they protocol is not possible for any wireless network.

In another technique of this kind, a simulation setup using the NS2 network simulator was designed by the author's in[29] to assess the performance of their method. A WiMAX and a WiFi point of attachment of 1000 m and 50 m coverage, respectively, constituted their simulation environment. A multi- interface with two video and audio applications was also integrated into the system that can travel through the above range at a random velocity of between 5 and 25 m/s on average. The results of the simulation showed that the proposed method reduced almost half of the handoff latency with the FMIPv6 for video and audio applications. The extensions proposed in this paper to an IMS enabled MN to support transparent handover for the end-user applications. In this new architecture, any calls to the lower layers to retrieve the MNs IP address receives back a private/loop back IP address. In addition, TRIM introduces two new functional entities into an IMS terminal: a handover manager and an address translator.

A network selection and decision method is proposed by Ioannis et al.[30] using fuzzy TOPSIS in order to find the best balance between the network resources and to eliminate the conflictions in network selection process in heterogeneous wireless networks. Authors use various parameters in a utility function like network conditions, QoS, energy and user preferences for selecting an optimal network in terms of energy efficiency for real-time and non-real-time applications. This function also helps in normalizing the handover decision process by removing the existing inconsistency problem of ranking the networks, where multiple networks are present.

Cheng et al.[31] suggested a QoS-based VHO decision scheme by considering the available bandwidth and user preferences for deciding the handover direction from a WLAN to WAAN and the reverse. They have discussed the architecture of integrated WLAN and WAAN networks based on Mobile IPv6. When a mobile node is connected to a WLAN, the proposed scheme is initiated by checking the state of the terminal and by comparing the RSS level with a predefined threshold. If the mobile node is found in the idle state, then a handover is performed towards the preferred access network; otherwise, the application type is considered for making the handover decision. This study proposes a vertical integration of layers 2 and 3 mobility management scheme HiMIPv6+. The network interface selector, positioned between the application layer and the MAC layer, cooperates with the routing agent (RT agent) to make decision about switching network interface and triggers vertical handoff through the vertical handoff algorithm.

According to another study[32], seamless mobility and roaming are of great importance in heterogeneous wireless networks. In particular, the horizontal and vertical handovers must support both ABC and ABS features in order to provide optimum personalized mobile services. The authors proposed an innovative handover decision-making method to support ABS on the basis of the preferences of the end-user and the context information. This method introduces a personalized handover decision-making technique to find an access point that is able to best fulfill the end-users requirements for a certain context. This paper proposes cross-layer based predictive event handover architecture and a QoS classification mechanism after investigating late or early link trigger costs for investigating handovers.

The proposed mechanism reduces packet loss and handover latency. Joe and Shin[33] proposed a novel prediction algorithm based on mobility that used dynamic LGD information to trigger the vertical handover through employing the information server of IEEE 802.21 MIH. This algorithm can predict a mobile terminals possible moving area on the basis of the mobility information (speed of movement, coordinates, location, detection of movement etc.) in the information server. Since the possible movement algorithm specifies the next target cell to which to assign the handover, it can move forward the LGD trigger point dynamically to make preparations for the handover in advance. The results of the analysis showed that this algorithm decreased the latency of handover for MIPv6 and fast handover for FMIPv6 through moving the LGD trigger point forward. In this study, when applied proposed algorithm, handover latency decreased more. Because channel scanning, authentication procedure of L2 handover and DAD procedure of L3 handover was performed beforehand.

In[34], the MIH is a middleware for heterogeneous networks, which has a set of protocols and mechanisms that allows IEEE or non-IEEE technologies to be integrated, while ensuring both vertical and horizontal handovers. However, MIH alone is unable to provide either an ABC approach or QoE assurance for videos over wireless clients. Roy et al.[34] proposed an integrated protocol stack whereby a blend of two modules, namely, the Generic Virtual Link Layer (GVLL) and the MIH, is placed above the media access control layer, which includes both the WLAN and WiMAX media access control. The impact of the generic virtual link layer in guaranteeing the QoS on QoS deterioration and the impact of MIH in attaining a seamless handover were analyzed.

Zhu and McNair[35] proposed several VHO decision-making algorithms that rely on a cost function that is used to calculate the cost of possible target networks compared to the available ones. The proposed cost function lines up all the running applications and a cost for each candidate network is calculated using the relevant application preferences. The total cost of a candidate network is calculated using the sum of the cost of available QoS parameters such as the bandwidth, battery consumption and network delay. The mobile user is handed over to the network that offers the lowest cost for maximum services.

Table 4. Vertical Handover Decision Methods based on cross layer design

	Advantages	Weaknesses	Study
Cross Layer-based	Use of link layer information gives better performance in term of handoff latency and packet loss.	No consideration on switching cost	[23]
	Reduced handover failure; Reduced Ping-Pong effect; Reduced handover delay.	Increased Packet loss; Increased signaling; Unsuitable for real time applications	[22]
	High adaptation; Throughput Improvements	Higher Handover delays	[21]
	Provide no dropping probability; Avoid unnecessary handoff.	No dwell time to check the condition of the RSS comparison	[24]
	Increased QoS	Higher packet loss	[25]
	Successful Handovers; Better Network Selection; Lower handover processing delay.	High Latency; Slow training and learning;	[26]
	Reduced handover delay; Reduced packet loss; Intelligent network selection; User satisfaction for QoS.	Increased Complexity; Higher decision processing delays	[29]
	Removing access router discovery; Reduce information access time.	Lack of target selection method	[27]
	Much lower computational cost; Optimization functions for Applications (voice, video and web).	Not examine handover triggering; High ping-pong effect; Lack of efficient network scanning mechanism.	[30]
	Supports better (ABS); Provides context-aware handover.	Need more tolerant when Experiencing.	[32]
	Successful Handovers; Reduces the signaling overhead; Minimizes packet loss.	Handover execution phase only on the Mobile IPv6; Protocol is not open for any wireless network	[28]
	Low Signaling Cost; Guaranteed QoS	Lack of ubiquitous access of data; Lack of QoS mapping procedure	[31]
	Reduce handover latency; Reduce Ping-Pong effect.	Computational problems	[33]

Cross Layer-based	Low handover blocking rate; High throughput; Optimized handover decision delay	Excessive load; High handover latency; Difficult to estimate cost	[35]
	Low handover blocking rate; Reduced Ping-Pong effect; Ranked network selection; Reduced processing delay.	High Latency; Degraded QoS; Minimum number of parameters is considered.	[36]
	Satisfied load balancing criteria without overloading.	No consideration on other parameters in utility functions.	[37]
	Adaptive to a wide range of conditions	Complexity	[38]
	SWGoS has competitive utilization; Adaptive approach.	Complexities of the algorithms; None dropping probability.	[39]
	Improvement over SAW and GRA.	Implementation complexity	[40]
	Avoid unnecessary handoffs.	No consideration on switching cost from the aspect of users.	[41]
	Improved performance of the FMT in a real environment; Reduced packet losses; Limited the redundant traffic.	Implementation complexity.	[43]
	Efficient resource management; Improved efficiency.	Additional decision parameters are required to ensure better QOS.	[32]
	Reduced latency; Decreased number of signaling	Increased tunneling overhead.	[44]
	Have low signaling cost.	Handover latency and failure.	[45]
	Low complexity.	No consideration on the user location	[46]
	Sustained cooperation between users and networks.	No consideration on network reputation building.	[47]
	MN can better informed decision; Reduced the amount of handovers.	Additional decision parameters are required	[48]

A Multiple Attribute Decision-Making (MADM)-based score function ranks the networks according to user needs for appropriate network selection. Tawil et al.[36] that combine the MADM and simple additive weighting methods proposed a distributed VHO decision-making algorithm. They treated the decision-making process as an MADM problem using a score function. The score function consolidates a set of performance parameters such as the network conditions, network bandwidth, monetary cost, power consumption, handover latency and network security.

In[37], authors identified a number of optimization problems in the area of access selection and resource allocation in NGWNs. Utility functions are suitable tool to depict user satisfaction from the QoS offered, with respect to some predefined QoS requirements. In this work, utility functions are based on the Rate allocated. They analyzed the parts constituting such optimization problems, along with the possible variations in the kind of parameters involved, and they combined these variations in some interesting cases. All these problems are quite similar to well-known NP-hard problems such as the Knapsack and the Generalized Assignment Problem.

The author's in[38] proposed a VHO decision-making algorithm for heterogeneous wireless networks. The proposed decision-making process follows these steps: Normalization of the weights of the decision factor, building of a Weighted Markov Chains transition matrix, computing the stationary distribution vector and selecting the available network. The higher performance of these approaches was shown in terms of the delay compared with the TOPSIS.

The research reported in[39] executed the predicted L2 trigger utilizing the advantages of several methods based on the auto regressive integrated moving average and a polynomial regression using a hysteresis algorithm. This approach comprises a procedure made of two phases. The first phase consists of a predictive RSS that relies on the polynomial regression in the form of a hysteresis algorithm, which predicts whether a mobile node gets closer to or retreats from the wireless network under monitoring. The second phase is devoted to determining the optimal target network in which to hand off. The time complication of the suggested approach can be analyzed as O (N) or O (M), where N and M are the number of WLANs and WMANs, respectively. The numerical findings showed that the proposed scheme performed by far better than other approaches in respect of the number of vertical handovers and the sum of the weighted grade of service, while indicating competitive usage.

The author's in[40] proposed a VHO decision-making algorithm for heterogeneous wireless access networks. The problem was expressed as an MDP in which a function of the link reward is considered based on the applications QoS needs.

The author's in[41] suggested a solution of totally terminal-controlled mobility across the heterogeneous networks. They also proposed a reward function, which constructed to assess the QoS during each connection, and the G1 and entropy methods applied in an iterative way, by which they could work out a stationary deterministic handoff decision policy.

Haddad et al.[42] proposed a framework for decision making of vertical handover in cognitive networks of heterogeneous characteristics. The authors have modeled the problem as a Nash-Stackelberg fuzzy Q-learning. In this model the network plays the role of a leader that tries to maximize his income and the mobile nodes are the leaders groups that seek to heighten their QoS.

In[43] the main goals are implementing of two parts: How to use the cross-layer architecture that carries the frame-retry information without degradation of system performance and how to switch the transmission mode for VoIP communication.

According to[44], in the reactive fast handover process, a mobile node is able to send the fast binding updates only after attaching to the new access router. They have developed a comprehensive cross-layer solution.

A predictive handover method was introduced in[45] with channel borrowing to reduce the connection blocking probability and handover dropping probability. The authors introduced a new handover approach called the "predictive group handover" with channel borrowing for user groups with the aid of a mobile relay station mounted on large vehicles such as a light rail or bus. The introduced scheme utilizes the location and direction data for predicting the target base station and pre-notifying the base station on the connection information of the user in order to effectively reduce the probability chance of connection blocking and handover dropping. The results of the simulation matched the system analysis results closely.

The cross-layer approach for performing vertical handovers based on MIH triggers[46] is also new in the domain of user-centric handover approaches. The information is taken from the media access control layer, transport layer and application layer for handover triggering.

In[47], the authors proposed a theoretical framework for combining reputation-based systems, game theory and network selection mechanism. They defined a network reputation factor, which reflects the networks previous behavior in assuring service guarantees to the user. Using the so-called prisoners dilemma game, they modeled the user network interaction as a cooperative game and they showed that by defining incentives for cooperation and disincentives against defecting on service guarantees, repeated interaction can sustain cooperation. The network reputation is computed based on the user's payoff.

In[48], the authors presented a reputation-based VHO decision rating system by proposing the use of the grey model first order one variable (GM (1, 1)). Their proposed solution provides a quick and efficient prediction of the reputation score for a target network in the handover decision-making progress.

5. Comparative Analysis of the Proposed Classification

In the previous section, our classification of handover decision-making schemes was presented and discussed. The schemes were divided into two groups and the candidate algorithms for the handover decision-making process were described. In Table 7, an overall comparison of the discussed groups is described based on their features in relation to the following aspects: The networking technologies on which they can be applied, user consideration, multi-criteria, layer supported, flexibility, and complexity. Because layer supported, technique employed and domain applicability play critical roles on handover process, these critical aspects, are discussed in more detail.

5.1 Layer Supported

Collecting reliable information for the decision-making procedure is significant for the VHO process. Generally, the required information should be gathered at all layers of the protocol stack so that all the possible information sources could be covered. Various proposals dealing with this phase have been based on the monitoring of the layers. In this study, we mostly considered on cross layer (layer 2+3). However, we reviewed other approaches for cross layer design such as[43] which used cross-layer architecture. Also, in[34] the cross layer architecture designed on transport, MAC layer and application layers.

The authors made the classification of the mobility management solutions in[49] as follows:

- Solutions pertaining to network layer (L3 solutions)
- Solutions for Link layer (L2 solutions)
- Solutions relevant to Cross-layer (L3 + L2 solutions)

In[49], the authors provided network layer solutions with features related to the mobility at the IP layer. They also proposed the cross-layer solutions principally for the handover management. These solutions follow the aim of achieving L3 handover with the aid of L2. Primarily through gaining signal strength reports as well as movement detection data from the link layer, the system will be better prepared for the network layer handover. Consequently, the packet loss will be eliminated and the latency in handover will be decreased. The work in[50] proposed link layer modules that implement the monitoring function. Seigneur et al.[51] used the application-programming interface under a different operating system for monitoring devices and networks to investigate the effect of exposure on triggering the VHO. At the same time, efficient location management[52] techniques are required to identify the mobility profile of the user for assisting the prediction process of network layer.

The MIH Function middleware protocol offered by the IEEE 802.21 is capable of encapsulating different networks underlying technologies (e.g. 802.3, 802.11, 802.16, 3GPP and 3GPP2) to the above layers, enabling the process of handover management to act without dependency on the other layers such as the physical and link layers.

In the literature, we can find several VHO proposals. Some of them take into account, in a direct manner, the handover decision-making task by considering only the lower layer information given by the media independent information service; most of the proposals combine the metrics and parameters of the diverse components to build an accurate cross-layer handover algorithm. In this review, we detailed the candidate algorithms for the handover decision-making process based on the activity of every layer of the protocol stack.

Comparisons of network layer solutions are conducted in[16,17] based on different criteria. All the solutions try to localize most of the signaling traffic into one domain to reduce global signaling. Intelligence-based methods take advantage of robust IP forwarding. Indeed[53], clearly describes that the transport layer control is the strongest approach for handover management in such an environment.

Link layer mobility support for intersystem roaming requires additional inter working entities to help information exchange between different systems. Under all the proposed methods in[18–20], new methods are designed for intersystem location management. All the proposed methods are connected to the mobility management entities in individual systems, provide format transformation and address translation.

Mobility solutions exist for all major protocol layers. Link-layer mobility protocols avoid IP address changes. Network-layer protocols (e.g., Mobile IP) hide them from the layers above. Transport-layer mobility protocols maintain a continuous connection between two endpoints over address changes. Higher, session and application layer mobility support protocol (e.g., SIP) which does not support handover management. Also, these protocols re-establish transport-layer connections after an address change. All these solutions have their advantages and disadvantages.

As described previously, cross-layer solutions are mainly proposed for handoff management techniques. The proposed cross layer solutions show that cooperation between the network and link layers is able to improve the performance of mobility management in IP-based heterogeneous communication environment. Information from the link layer, such as signal strength and velocity of mobile terminals, may help the decision making of mobility management techniques at the network layer. Therefore, cross-layer optimization for mobility management is worthy of further investigation.

5.2 Technique Employed

In this section, we have compared these vertical handover measurement and decision mechanisms based on their employed techniques and parameters. In Table 5, we present the given strategies based on their employed techniques.

5.2.1 RSS-based Decision-making Methods

In RSS-based decision-making methods, the criterion for making the handover decision is typically based on the RSS value. Other criteria might also be used but, generally, they are for assisting the handover procedure and not directly involved in the handover decision-making process. In RSS-based decision-making algorithms, the RSS of the current attachment point is compared with the RSS of the other available networks for making a handover decision. At first initial network the mobile node to check the availability of candidate wireless networks in the neighborhood performs scanning. Then, their RSS levels are measured and compared either with the RSS of the current network or a predefined RSS threshold. If these measurements give a satisfactory result for the RSS, then a handover is performed; otherwise, the process switches back to the network discovery phase.

5.2.2 Network Intelligence-based Decision-making Methods

In order to improve the performance of handover (in terms of throughput, unnecessary handovers and handover latency etc.), it is very important to make the handover decision intelligently and in a timely manner. The concept of network intelligence arises when we want to tackle the issue of information visibility and consider the real-time network traffic.

5.2.3 QoS-based Decision-making Methods

In such converged systems, the synchronicity of heterogeneous access technologies with different features such as cost, bandwidth and coverage area falls out with the handover asymmetry that varies from the traditional horizontal handover. Thus, vertical handovers must be QoS-aware.

Table 5. Technique employed

Technique / Study	RSS Based	Network intelligence Based	QoS Based	Context Based	Decision function Based	Usercentric Based
[18]	■					
[21]	■					
[22]	■					
[25]	■					
[8]		■				
[26]		■				
[27]		■				
[28]		■				
[29]		■				
[30]			■			
[31]			■			
[32]			■			
[19]				■		
[33]				■		
[34]				■		
[35]					■	
[36]					■	
[37]					■	
[17]						■
[20]						■
[46]						■

5.2.4 Context based Decision-making Methods

Context is formally defined as any information that is pertinent to the situation of an entity (person, place or object.)[7]. However, keeping in mind computer networks in our view point, it is the delivery of correct and accurate information to the end users for making a decision and it allows the characterization of networks that need same content i.e., mobile users in similar circumstances must obtain the same information.

5.2.5 Decision Function-based Decision-making Methods

In heterogeneous networks with ubiquitous access facilities, the decision-making and selection processes become more complex because different access technologies usually provide different characteristics (QoS support, billing schemes, reliability etc). Handover decision-making and proper network selection becomes a multi-criteria decision-making problem that involves a number of parameters and complex trade-offs between conflicting criteria. A VHO decision-making function is a measurement of the advantages acquired by switching over to a specific wireless network.

5.2.6 User-centric-based Decision-making Methods

User-centric strategies are primarily concerned about user satisfaction rather than the network. Overall, we treat the users as the first party to be concerned about in terms of their satisfaction and they should decide by themselves the QoS-cost trade-off. As the literature shows, the user-centric functions suggest handover decision criteria and policies that are principally focused on the user satisfaction and non-real- time applications. In deciding the most appropriate network to assign the handover so that it can fulfill the user satisfaction and the network efficiency, some more criteria extracted from various available networks as well as more advanced techniques need to be considered. Some of these techniques are related to the user preferences in terms of the QoS and cost, and the terminal capability.

5.3 Domain Applicability

Table 6 shows the technologies used by the different mechanisms. This table provides a comparison of the candidate algorithms, which use the UMTS, WiMAX, WiFi and Bluetooth as their technologies.

Table 6. Domain Applicability

Class	Applicable Area					Study
	GPRS	WLANs	WiMAX	Wifi	UMTS	
Single Layer-based	■	■				[22]
			■	■		[19]
Cross Layer-based		■				[33]
		■				[29]
		■				[25]
		■				[26]
		■				[32]
		■	■		■	[30]
		■	■		■	[48]
		■				[39]
		■				[38]
		■				[45]
			■	■		[46]
		■				[43]
		■				[46]
		■				[47]

Due to the limitations of 3G[47] such as bandwidth, multimedia service requirements, spectrum allocation and end-to-end seamless mobility, it is not sufficient to support future mobile communication strategies; therefore, research on 4G technologies has gained momentum[48].

The existence of heterogeneous wireless networks to provide services anywhere at any time are an inevitable trend in the development of the 4G networks. Therefore, there is a significant need for a single unified approach that integrates and enables mobile terminals to seamlessly roam between access networks[50].

Hence, most of the proposed schemes focus primarily on evaluating the VHO existence on WLAN. Moreover, few studies have concentrated on evaluating the VHO on Bluetooth. The serious drawback of such a vast variety of solutions lies in that none of them is proposing a single homogeneous approach that can be adapted to all of the currently available wireless technologies. The research community in line with the convergence of various wireless networking technologies has made significant attempts. For example, a recent discussion has been widely followed by researchers in the literature on the integration of the WLAN and cellular 3G systems. The IEEE 802.11 WLAN coverage extends to hotspot areas (e.g. in offices, hotels and campuses), capable of providing wider bandwidth but cheaper low mobility; on the other hand, we have the 3G cellular network that can overlay the WLAN, introducing more expensive low bandwidth with higher mobility and wider coverage. Hence, an overly network constituted by two dissimilar interfaces, that is WLAN and the 3G cellular network, can provide optimum unification of higher mobility and wider bandwidth.

6. Handover Execution

The third phase of the VHO process focuses on execution. Execution of the handover is principally based on a preplanned routine, is bound to take into account the implementation procedures, and issues so that it could incur the least interruptions possible to the relevant infrastructure. Once the information is collected in phase one and processed in phase two by selecting the network candidate, the execution phase will trigger a network binding update. With this purpose, this phase is concerned with control, security, session and mobility, among other issues in order to perform a seamless handover.

7. Findings

As can be seen, based on the proposed classification, all of the studies usually serve in heterogeneous wireless environments where the mobile users experience different network conditions. Essentially, multi-homing is a critical issue in the heterogeneous wireless environments and this issue is very well adapted by cross layer schemes where the main purpose is to facilitate a mobile user in the best possible way in terms of QoS and QoE by choosing a network that best suits his/her preferences. In Table 7, we summarized the given strategies compared based on different characteristics such as flexibility, user consideration, multi-criteria choice and complexity. In terms of complexity, single layer decision-making mechanisms are somewhat complex, as they need to gather and normalize different network parameters. Cross layer decision-making mechanisms are much simpler than single layer methods.

The studied VHO decision-making mechanisms are also compared in regard to their flexibility. It must mention that the implementation of cross layer methods seems to have a high level of flexibility for the use of VHO policies due to this class showing wider adoption with additional functionalities. In addition, this class attempts to guarantee the high flexibility that is required in the heterogeneous environment[50].

Moreover, user consideration plays a vital role in VHO decision-making. User preferences and user satisfaction can be a segment of user consideration, and this aspect is clearly closely related to the cross layer class.

In Table 5, we summarized the given strategies based on their employed techniques. In continue, we compare the given mechanisms based on different characteristics such as flexibility, user consideration, multi-criteria choice, and complexity. In terms of complexity, network intelligence and context-based classes are complex, due to the fact that in network intelligence and context-based classes various network parameters are used, On the contrary, decision function-based classes are somewhat complex, as they need to gather and normalize different network parameters. QoS-based decision-making mechanisms is much more simple than intelligence-based methods and may also deal with imprecision as they have a global vision of the QoS already experienced by previous users in different networks and may predict the future behavior according to some contextual information such as mobile location and running applications.

Since cost or utility functions (decision function) class is fitting with more parameters or functionalities, this class can offer a high level of flexibility. In addition, the context-based class attempt to offer the high flexibility that is required in the heterogeneous environment. The intelligence-based algorithms seem to be the least flexible. However, when it comes to real-time applications, user-centric and some function-based strategies are less reliable compared to other mechanisms like intelligence-based algorithms.

In terms of user consideration, most of the studied algorithms consider user preference but this aspect is associated to the context-based class. In addition, user preferences and user satisfaction can be a section of user consideration.

Essentially, the multi-criteria characteristic plays an essential role of feature during VHO decision-making. In some cases, strategies are only based on one measure (i.e. RSS measurements)[54]; in other cases, such as decision function-based or network intelligence-based or context-based classes the strategies can be designed on multi-criteria choice.

For a better understanding of the performance of diverse VHO algorithms, a quantitative comparison of the algorithms is provided based on the performance metrics discussed in the next section. However, different performance parameters are considered in the proposed algorithms, direct comparisons are impossible. In Table

8, the information provided in the studies is illustrated to provide a quantitative comparison based on the following nine performance parameters: VHO delay, bandwidth, throughput, VHO packet loss and battery consumption, number of handovers, cost, jitter and velocity.

According to the parametric evaluations presented in Table 7, we have observed that the VHO decision algorithms on different single layers have the same level of delay among all the categories but complexity can affect delay in the network intelligence-based classes. In the cross layer-based, a majority of the approaches obtains fewer handover delays due to the pre-selection of the handover target networks and usually anticipated handovers. In the case of packet loss, the cross layer-based algorithms tend to receive comparatively less packet loss as the decision is based on multiple criteria and the aim remains not only to provide connectivity but also to satisfy users in terms of QoS.

For throughput, cross layer-based classes are capable of attaining higher throughput levels than the single-layer groups. In terms of cost, in our view, the successful handover rate of the decision cross layer-based schemes will be higher than in other solutions because a handover decision is based on the user satisfaction. For the number of handovers, the cross layer-based is able of keeping the unnecessary handovers at a low level by reducing the

Table 7. Comparison on Proposed VHD Approaches

Class	Flexibility	User consideration	Multi-criteria	Complexity
Single layer-based	Medium	Medium	Yes	Complex
Cross layer-based	High	High	Yes	Usually Complex

Table 8. Comparison of the Proposed Methods based on Evaluation Metrics

Class	Study	Evaluation Metrics								
		VHO Delay	Bandwidth	Throughput	VHO Packet Loss	Battery Consumption	Number of VHO	Cost	Jitter	Velocity
Single layer based	[17]	Low				Low		Low		
	[15]	High						Low		
	[16]		High		Low					
	[18]	Low			High			Low		
	[20]					Low				
Cross layer based	[47]	Low				Low				
	[23]	Low			Low		Low			
	[25]	Low	High							
	[26]	Low			Low		Low	Low		
	[27]	Low		High	Low		Low			High
	[28]			Low			Low			
	[30]	Low				High	High			
	[32]	Low				Low		Low		
	[48]	Low	High					Low	Low	
	[35]	Low				Low				
	[33]	Low					Low			
	[34]	Low						Low		
	[48]	Low	High						Low	
	[45]				Low		Low			
	[40]	Low	High		Low					
	[39]	Low					Low			
	[36]	Low	High			Low	Low	Low		
	[46]	Low	High		Low			Low		High

so-called ping-pong effect. Today, using the best VHO decision-making algorithm is an important issue in wireless networks that aim to meet the needs of both the users and the network providers. Several methods have been proposed in the literature, but we found that there is no standard and efficient method to satisfy both user and network requirements with QoS. Moreover, we realized that VHO in heterogeneous wireless networks still faces difficulties at different levels including architectural, decision- making and protocol sides. For decision-making, the main difficulties are the result of a lack of up-to-date information at the decision points. Considering cooperative decisions (game-like approaches) can be helpful for making better decisions.

Cross-layer optimization is needed for improving mobility management in further investigation. The provision of QoS information between non-adjacent protocol layers requires a cross-layer design. Hence, the QoS coordination plane must facilitate the communication of QoS information and coordinate the provision of QoS across multiple layers.

8. Conclusion

In the revolution to next-generation networks, the integration of IP-based core networks with heterogeneous wireless networks is expected. In this work, an overview of the handover schemes and algorithms proposed for wireless communication systems in mobile environments were presented. Following a layered perspective, the proposed schemes in this area were categorized into two groups and compared in terms of parameters, network selection methods and their features. Based on our analysis, the existing decision-making schemes either lacked an adequate reflection of various network parameters or the studies reporting these classes fell short of sufficient detail for implementations in the real world. With the rapid development of the mobile internet, handover management solutions in next-generation mobility architectures and protocols are definitely based on the mobile IP, which provides a flat network platform. For this purpose, novel handover mechanisms and new systems should be designed in order to make handovers more efficient and reliable. In this study, we find that cross layer optimization for mobility management is valuable of future investigation in heterogeneous environment.

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