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A Survey of Context Aware Vertical Handover Management Schemes in Heterogeneous Wireless Networks

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Abstract Modern smartphones and wireless-enabled devices are equipped with a number of interfaces to access multiple networks in heterogeneous wireless networks. Seamless mobility between these networks can be achieved by optimizing parameters related with vertical handover management. This paper presents a detailed review of the recent schemes used for context-aware vertical handover management in heterogeneous wireless networks. In particular, we reviewed user-centric, network centric, and hybrid schemes, and compare them in context of throughput, packet loss ratio, and other advantages such as handover delay, cost, energy, and bandwidth optimization.

Keywords Smartphones · Heterogeneous wireless networks · Seamless mobility · Handover management · User-centric · Network-centric

1 Introduction

Wireless networks have been undergoing a series of evolutions over the last decade. One of the most important issues related with these evolutions is the handover management across homogeneous and heterogeneous wireless networks. The handover management is classified into two categories: horizontal (between different cells of the same network) and vertical handovers (between cells of different networks). Figure 1 illustrates the difference between vertical handover (VHO) and horizontal handover. The VHO is further divided into two categories: downward VHO and upward VHO. In the first category, the mobile

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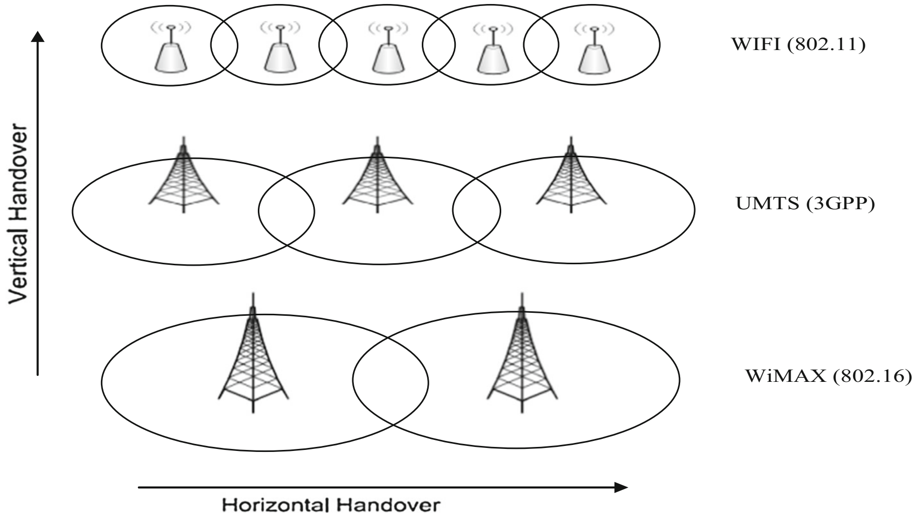

Fig. 1 Illustration of vertical and horizontal handover

node (MN) selects a larger cell with narrow bandwidth while in the second category the MN selects a smaller cell with a wider bandwidth. VHO gains more attention because an MN always demands the same quality of service (QoS) across different networks [1, 2]. A VHO is affected by various handover metrics i.e. receive signal strength (RSS), channel bandwidth, cost, user preferences, etc.

A VHO approach, which is fully controlled by an access network operator, is referred to as network-centric approach. The main advantage of network-centric approach is that an access network operator wants its full use of the access network services. The access network operator can tune operational parameters so that it provides its customers with the best connectivity to its network. These parameters include cost, data rate, bandwidth, etc. In traditional handover management schemes, the access network operator provides an MN with very little authority to perform handover decisions. Instead, handover decisions are mostly performed by the access network operator.

The MN has the only right to initiate a handover decision. The decision of selecting a network on the basis of the MN's current QoS will require high handover time; thus, an MN will experience high packet loss and handover delay. A handover scheme which efficiently optimizes both the advantages of the user and network-centric handover approaches may lead to a generic scheme for future generation of networks.

The context aware handover scheme can dynamically change its nature with the application (video streaming applications, voice etc.) running on an MN. The context can be based on either user or network centricity. In application aware handover management, a user always selects the network which fulfills the requirement of the application during the handover process. For example, if a user is running a real time application which requires high bandwidth, then the user must prefer a network which can provide high bandwidth. If the network selection phase is performed through user centric approach, it will provide every user with a control to select a network depending on their application and other factors like cost, etc. In a heterogeneous wireless network, it is not an easy task to select a network which provides optimal QoS without bandwidth fluctuations and loss of connection. In such situations, context awareness can perform better because it provides a visible structure of the service execution environment and its adaptable nature to the current system requirements. In case of user centric approach, a different context can be used to fulfill the needs of a user. Examples of these contexts include application requirements, conditions of a network, user preference, etc.

There are a number of issues related with handover management, which can degrade the performance of mobility management across different networks. It may include QoS, quality of experience (QoE), the cost of the available networks, bandwidth, etc. However, before focusing on these issues, an optimal deployment of an access point (AP) or base station (BS) is a necessary part of the network architecture. A possible solution is to deploy an AP or BS at a specific location and distance with an overlapping region for seamless handover from one network to another. The other possible way is the deployment of relay stations among different networks [3]. However, relay station deployment needs extra labor and modification in the existing architecture. Therefore, new concepts like Femtocells were introduced in the last couple of years to provide indoor connectivity to the MN without deployment of extra APs and BSs [4, 5]. Moreover, other issues include initiating a handover process on time. A threshold must be defined on the basis of various parameters like RSS, signal to interference and noise ratio (SINR), etc., which provides minimum false handover indications. A threshold criterion for handover initiation depending on RSS is very common among different access networks, but it may also lead to some serious issues while selecting a network on the basis of RSS. These issues may include selecting a network with strong RSS but less data rate, bandwidth, and high cost. As already described, network selection based on RSS is mainly provided by those access networks that follow network centric approach for handover.

Based on the user and network-centric approaches, the IEEE published a generic handover management standard called IEEE 802.21 media independent handover (MIH) standard in November 2008 [6]. MIH standard provides a solution to combine all of the IEEE family and 3GPP networks on one platform in the context of handover. The MIH standard suggests that an MN must be equipped with multiple interfaces to access more than one access technology. The MN will search the point of attachment (PoA) of different access technologies before handover initiation.

Many of the mobile phone, laptop, and PDA companies initiate a step in making such devices which can support more than one interface for accessing multiple networks [7–11]. For example, Intel Corporation is working on the development of chips and network adapters for next generation of mobile phones, PDAs and laptops [12–14]. They test different chips and adapters on test beds in an environment of 2.5/5 GHz, and its results are remarkable [15, 16]. The advances in such devices have rapidly grown toward the mobile market, and such devices will become very small and portable. Therefore, in the last couple of years, researchers diverted their focus toward smart handover management schemes. The future handover management scheme should be made compatible with the next generation technology requirements. Thus, moving parallel with such advancement can only be possible if we focus on the context-aware handover management. The terminal based management schemes are not sufficient and are even diminished with the passage of time.

This survey provides an in-depth analysis of the context-aware handover management schemes. The rest of the paper is structured as follows. Section 2 provides a basic idea of the VHO management process. Section 3 provides an analysis of the context-aware handover management with the user, network, and hybrid (user and network) centric approaches. Section 4 provides a comparative summary of the schemes reviewed in the paper. Finally, Sect. 5 presents the conclusion and future directions.

2 VHO Management Process

A VHO management process consists of three phases: handover initiation, network selection, and handover execution phases [17, 18]. In handover initiation phase, an MN checks its connectivity with the current network. If the signal strength from the current network is not enough to hold a connection, then the MN initiates the handover process. This connectivity can be checked by different ways, which are listed in Sect. 4. Network selection phase is sometimes called handover decision phase. In this phase, an MN collects the information required for handover and then selects a network with the best QoS on the basis of collected information. After the selection of appropriate network for handover, the MN executes handover to that network. The resources that are reserved for the MN in a new network are assigned to it and the resources of an old network are released by the MN. A more detailed structure of the VHO process is illustrated in the following sections.

2.1 VHO Decision

There are two methods for triggering a handover process: imperative and alternative mechanisms. In the imperative mechanism, handover is triggered using physical events. In the MIH standard, the link layer information is sent to the upper layers using the MIH function. If the information of the link quality is not enough to hold a connection, then a handover is triggered by the attached MN using LINK_GOING_DOWN event. Similarly, MIH function has different events used to control the communication of an MN and an AP or BS.

The alternative handover is sometimes called user handover. The handover is triggered by user policies or preferences. If a user does not get the required information, then the user initiates the handover process. For example, if a user experiences a lack of bandwidth from the current AP or BS, then the user performs handover to the AP or BS with sufficient

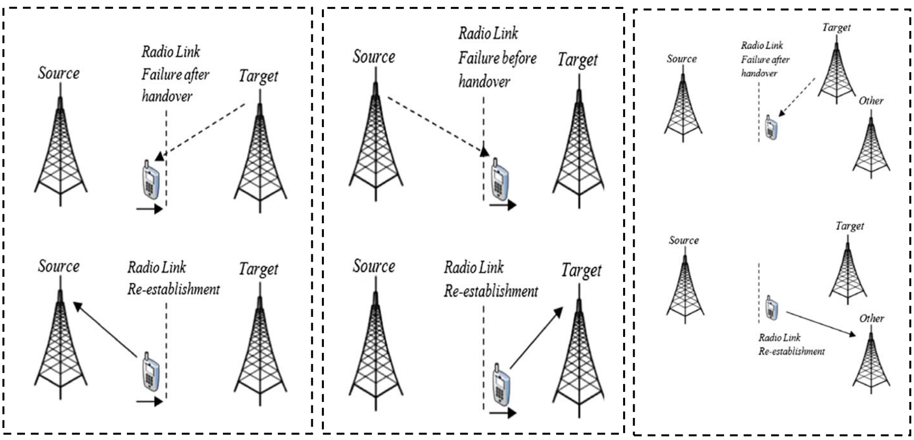

Fig. 2 Too early, too late, and wrong cell handover

bandwidth. Similarly, triggering a handover in a fast moving vehicle is also a challenging task. When an MN is moving rapidly in a heterogeneous wireless networks, its mobility pattern changes very quickly. Thus, computing the exact position for handover triggering is a difficult task to accomplish. There are a number of schemes present in the literature for handover triggering. These schemes efficiently trigger a handover; thus, saving extra packet loss and handover delay. Mobility robustness optimization provides an MN with the support to detect and correct three types of triggering issues i.e. too early, too late, and to a wrong cell. Researchers proposed various techniques to enhance the process of handover triggering, avoid these three types of issues, and reduce false handover indications. If a handover is triggered too early, it uses the network resources in an inefficient way, and an MN does not successfully connect to the target network. Similarly, in case of too late handover, the MN moves far away from the current network; hence, it disconnects from the current network during handover. These three types of issues are explained in Fig. 2. Various handover triggering schemes are based on the location services such as GPS and location service server (LSS) [19, 20]. The MN first checks the RSS level if it drops below than a predefined threshold then the MN checks a decision function to determine whether a handover trigger is needed or not. The decision function collects different handover information from LSS. However, these types of handover triggering mechanisms do not evaluate the handover dropping rate.

2.2 Handover Decision Metrics

Handover decision metrics is categorized into three types: network based, terminal based, and user preference based. The network based metrics include RSS, SINR, bandwidth, data rate, security level, cost, and bit error rate (BER). The terminal based metrics consist of velocity, the location of MN, and battery power of MN. User preference based metrics includes user policies, profile, and preference. There are a number of handover decision schemes present in recent literature based on one or more metrics from the categories above. These schemes perform handover decision based on either user or network preferences. However, the availability of several networks in a heterogeneous environment makes a network more attractive than another; thus, deciding a handover to a network on the basis of a single metric is not a good criterion. Therefore, most of the schemes in the recent literature are based on multiple metrics. Most of the handover decision metrics are not fully context-aware and they are not always taking the information of handover decision from multiple sources. These schemes are always biased toward the requirement of a network operator rather than deciding handover on the basis of user preferences.

2.3 Handover Decision Time

A handover decision time must be carefully selected for an optimal handover process. Otherwise, there is a possibility of false handover indication which degrades the functionality of a handover process. In traditional approaches, the decision of handover is based on RSS from a current AP or BS [21–23]. If the RSS from the current network is getting weaker and it drops below a predefined threshold, the MN initiates a handover process. In recent literature, various parameters have been identified which directly affects a handover process. This includes cost, network conditions, terminal conditions, functionality, services offered by a network, and user demand.

3 Context Aware Handover Management

We divide the context-aware handover management into three approaches: user-centric, network centric, and hybrid schemes based on both user and network-centric approaches.

3.1 User Centric Approaches: State of the Art

In a user-centric approach, the decision of handover and selection of network is controlled by the user. Some of the well-known approaches in this regard are presented below.

A VHO for context-aware streaming video is presented in [24]. The proposed scheme consists of VHO based TCP-friendly rate control (TFRC) server and TFRC client. The TFRC client has the VHO decision function. The proposed scheme uses various context parameters such as current QoS, target network, data rate, and RSS. The server is monitoring the transmission rate and then decides a particular sending rate during VHO. A LINK_UP event message is sent to the upper layers upon the transition of MN from one network to another. The upper layers notify the server of switching of MN to the new network. The server redirects the streaming to the new network that contacts the MN. The scheme uses the MIH standard for VHO. The proposed scheme uses a decision function in the MN to select the best network for handover. This function selects the network based on two contexts: RSS and video feature. The MN sets a particular threshold for each context. When the MN experiences that threshold, it starts the VHO using MIH standard. The proposed scheme is using MIH standard which has several limitations. For example, if the streaming server is a number of hops away, then the proposed scheme will have long handover delay; thus, it experiences packet loss and connection termination. Furthermore, the proposed scheme only targets those handovers which involve only multimedia communication. The proposed scheme is implemented and tested on a number of MNs. The results show a significant decrease in packet loss and increase in throughput even if the numbers of MNs are increased to more than 100 nodes.

A similar scheme has been presented in [25]. The proposed scheme is based on context-aware VHO for multimedia applications. It works on four different types of context data i.e. sensed context, the static context, profiled context and derived context. It efficiently utilizes these four types of data for fast VHO in wireless networks. There are two types of components used by the proposed scheme for handover i.e. context manager and adaptability manager. The context manager collects, manages and evaluates context information while the adaptability manager consults the context manager about a particular change in context data. When the context manager notifies the adaptability manager, it makes a decision of handover. The proposed scheme efficiently utilizes the user information for handover initiation. The scheme is performed better in some specific scenarios. The scheme does not provide any sophisticated threshold mechanism of the context data.

A user-centric based VHO has been proposed in [26]. The user selects an optimal AP based on two contexts. One is cost, and other is user preferred services. The user first makes a profile of frequent applications and services. Then, the MN requests for the required resources from different APs. The APs send the required information to MN, and the MN selects the target network based on information received from different APs. The scheme performs better in selecting an optimal network, but it lacks different implementation criteria. The scheme does not check the SINR from different APs because SINR gives a more accurate decision in scenarios where MN moves with high velocity. Similarly, the coverage area of a WLAN AP is smaller as compared to the coverage area of a

GSM's BS. An MN can experience frequent handovers during its movement in an environment where more APs are present than BSs. Thus, in a smaller coverage area of an AP, selecting an optimal network and then handover to it requires more handover time which can cause extra handover delay. The proposed scheme does not provide any mechanisms to deal with frequent handovers. Thus, the proposed scheme cannot be used as a generic scheme for VHO management in heterogeneous wireless networks.

A user-centric handover based on optimal network selection is presented in [27]. The authors explore the problem of accessing the same network by multiple users during handover. The proposed scheme provides a solution to balance the number of users of different networks using a novel scheme called quantified adaptive delay selection (QADS). It computes a weighted score for each access network based on two different context information, cost, and bandwidth. If the information of a network is enough to accept new connections, then the MN performs handover to that particular network. Otherwise, the MN selects another network.

A context computing support for network-assisted seamless VHO has been presented in [28]. The proposed scheme optimizes the network selection objectives using the analytic hierarchy process (AHP) [29]. The AHP works in three steps. In the first step, it identifies the relative importance of the optimization objectives. In the second step, it compares the weight of each objective for each network. In the third step, it computes the score of each network. The unnecessary handover is avoided using dwell timer concept presented in [30]. dwell timer helps in maintaining a call session during a specific cell. The concept of the dwell timer is modified using user speed and handover latency for various amounts of time rather than a fixed value. The procedure of the handover process is shown in Fig. 3.

One of the major issues in MIH standard is that it cannot select the best network for handover. It only selects the network whose RSS is strong enough. However, RSS does not work well as a handover criterion in many situations. A scheme has been proposed to improve the resource management decision using prediction algorithms in [31]. Achieving reconfigurable interoperability between hybrid communication infrastructures is a challenging task. A project was introduced with the support of NATO called reconfigurable interoperability of wireless communications systems (RIWCoS). The project was later on briefly described in different research works [32–35]. RIWCoS modified the existing MIH standard for integrating new services to support user centricity and making handover decisions on the basis of different contexts like MN's position extrapolation, maximum data flow rate, and signal power of a PoA. The RIWCoS offers user based reconfigurability. The user profile, rules, and policies must be taken into consideration, and the network preferences should not be applied. The development made in the [26–29] is combined in a software prototype shown in Fig. 4.

The interoperability manager (IM) handles monitoring network devices. The MN performs handover based on either link layer information or user policies defined after consulting MIIS server. The rest of the operation is similar to the MIH standard. The connection is switched from the current network to the new network, and the data buffered during handover is redirected to the PoA of the new network.

The amount of energy consumed during a handover process is a key context, and it should be carefully considered during a handover process. The QoS of a network is also dependent on the energy consumption. Nowadays, smartphones are equipped with more than one interface for accessing multiple networks i.e. GSM, WiFi. Thus, a smartphone requires more energy as compared to a cell phone with a single interface. A number of schemes have been presented in the current literature, which uses energy consumption as one of the parameters for VHO in heterogeneous wireless networks [36–43]. Unfortunately,

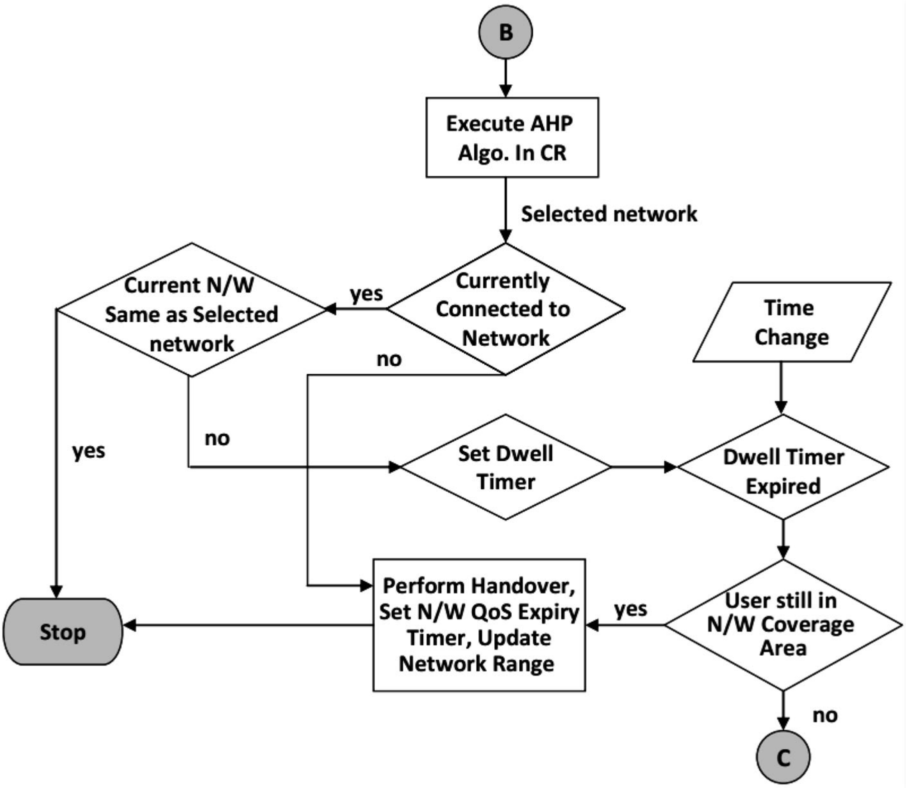

Fig. 3 Flowchart showing handover decision and execution phases [29]

all of these schemes do not focus on a generic scenario. Rather, they mainly focus on specific scenarios. Therefore, these schemes cannot be considered as energy efficient handover schemes for the next generation networks. A handover scheme based on energy efficiency has been presented in [44]. The proposed scheme computes the context information for energy-centric VHO decision. The scheme is divided into three auxiliary and one primary module. The first auxiliary module monitors and gathers real-time raw-data for different energy parameters. The second auxiliary module defines different energy contexts from this raw-data. The third auxiliary module discovers new networks, and it lists down the available PoAs. Finally, the primary module makes a decision of handover based on the available energy context information. The process of energy efficient handover is illustrated in Fig. 5.

3.2 Network Centric Approaches: State of the Art

Most traditional handover management techniques are based on network-centric approaches. The network is solely responsible for making handover decision on the basis of user location, speed, and intensity of the receiving signals. These schemes have many benefits and limitations. The limitations may include the selection of expensive and overloaded network. Its benefits may include the full usage of the network resources, QoS, high

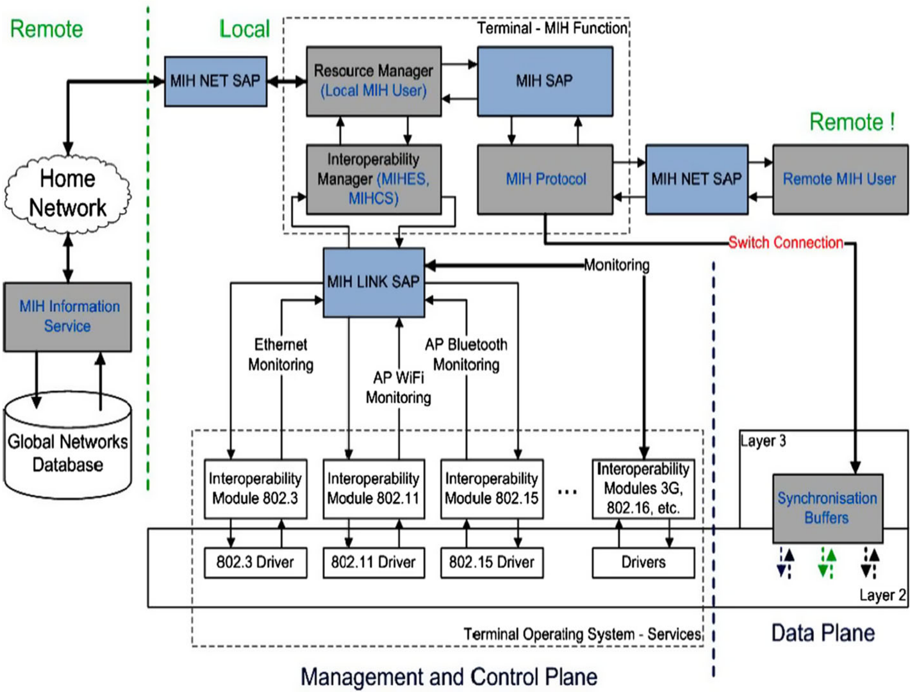

Fig. 4 RIWCoS software prototype's architecture [32]

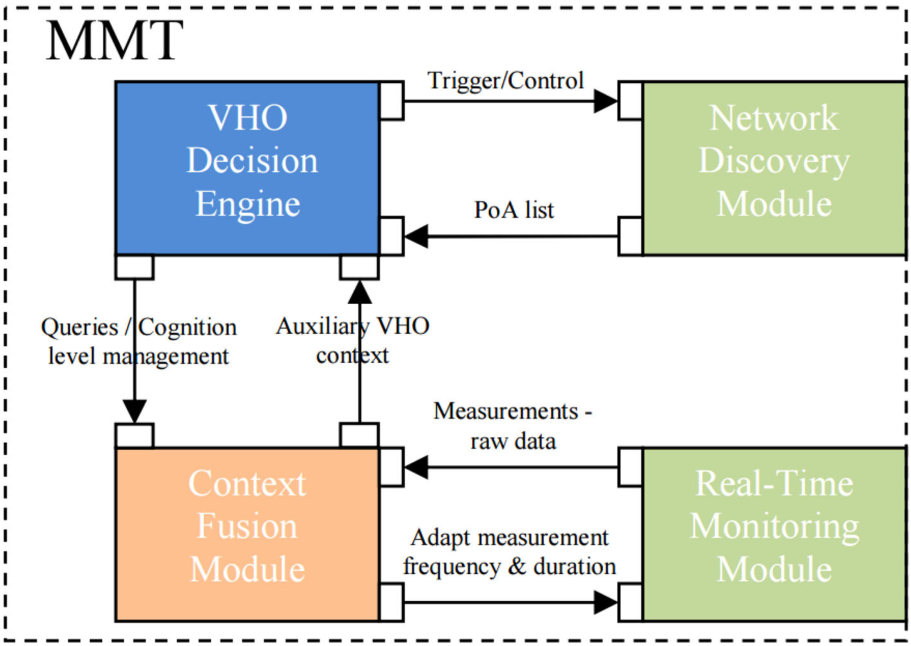

Fig. 5 Proposed VHO framework [44]

bandwidth, etc. In this section, we briefly overview the handover schemes based on network-centric approach.

A ubiquitous server based cross-network mobility scheme has been presented in [45]. The proposed scheme uses the location information of the user as a context to perform cross-layer handover. The location information includes user's presence, the position of neighboring devices and PoA, available bandwidth, priority parameters, and applications used by the MN. Different technologies are integrated to achieve cross-layer mobility. The cross-network handover functionality is enabled through MIRAI [46]. The advantage of using MIRAI is that it provides separate data and signaling path. The signaling method provides a user with location update, paging and handover functionalities. The proposed scheme is designed by combining the advantages of MIRAI agent and service mobility proxy for cross-device handover [47]. The ubiquitous networking server (UNS) is placed on the entrance of a home or a network. The MN is always connected with the UNS, which forwards the incoming packet to the MN upon checking its location. The MN does not need to perform handover because it is always connected to the UNS. The proposed scheme allows a user to watch efficiently videos while an MN is switching from one network to another. The throughput is increased by performing handover on time and minimizing false handover indications. This system is good for small offices and living apartments. However, it must be installed with new architecture and technologies for a large network.

In general, a context-aware based handover approach requires more time as compared to the traditional handover approaches, but it can select an optimal network for handover. In high mobility scenarios, computing network information is a challenging task. To deal with such scenarios, a scheme based on learning the context information in vehicular networks has been addressed in [48]. The proposed scheme uses the relay vehicle concept to obtain information of a high QoS network for handover. The author uses the model presented in [49] for computing SINR. The context information of the path loss and fading prediction is computed using the information of speed, location, and trajectory information while employing the GPS functionality in the proposed scheme. The handover margin (M) and trigger time are optimized for each vehicle. The optimization of both these parameters minimizes the number of false handover indication. The handover process starts with Event A3 presented in [50]. Assuming that the received signal from the current BS and the new BS are denoted by m and n, respectively, then event A3 checks the condition of $\frac{R_m}{R_n} \geq \mathrm{M}$ for handover initiation. If this condition is satisfied, then the proposed scheme checks too-early and to-late handover. If all of these three conditions are satisfied, then the handover process is executed. Otherwise, the MN waits for a time (T). Obtaining context information in the high mobile environment is a challenging task, but the proposed scheme efficiently computes these contexts. Similarly, the RSS is optimized for minimizing false handover indications and throughput is increased by improving channel quality. The system is not yet tested in the real world in a vehicular environment. The system should be tested on test beds to avail its performance in vehicular handover management.

One of the major issues in WCMA networks is the choice of a cost function while an MN wants to perform handover from one cell to another. The performance of the WCDMA networks can be optimized by many parameters. One way to optimize these parameters is to select a cost function with minimum weight. A scheme based on the derivation of second order gradient method for minimizing cost function is addressed in [51]. The author proposed a combination of the key performance indicator (KPI) as a choice for the cost function. In real-time networks, there are many problems which affect the optimization of the cost function i.e. variation in traffic types, the number of users, and load on a network.

Real time networks are normally dynamic and mostly dependent on the variation of the time factor. The author proposed an algorithm which shows how to evaluate these values at any given time. This algorithm starts by finding a cost function on a time t_1. Then, it finds the increase and decrease in the weight of parameters which affects a cost function. In the last step, the MN selects an appropriate WCDMA network for handover on the basis of cost value which is obtained from the cost function. The advantage of the proposed scheme is that it selects a new cell on the basis of weighted cost function. The proposed scheme provides a cell with minimum cost and low blocking. The system still has a few issues. It is not a generic scheme for all types of WCDMA networks. Therefore, the system cannot be considered as a generic scheme for handover in the next generation networks.

The weighted product method (WPM) and technique for order preference by similarity to ideal solution (TOPSIS) have been designed to assign a weight to a particular parameter like cost and speed of an MN [52, 53]. A scheme based on decision making has been proposed in [54]. The proposed scheme modified WPM on the basis of a weighted distribution method using the state of a user at a given time. The author used service oriented architecture (SOA) platform to achieve context-aware services in the proposed scheme [55]. The platform is divided into three parts (1) Service registry and management (2) Service provider and (3) Service consumer. There are different contexts that can be considered in each of those three parts of SOA [56–58]. The availability and reliability of a context are very important. A better contextual decision is always dependent on the quality of context (QoC) [59–61]. Once the context aggregation part is carried out, the next step is to build a user profile on the basis of available context. Further, each attribute of a context is assigned a weight. The modified WPM is used to rank the attributes of a particular access network in the context of bandwidth, delay, cost, and packet loss ratio. The context with the greatest preference is chosen for handover. The optimization of weight assignment greatly maximized the throughput of the system. Similarly, other contexts used in the system are also optimized for maximum performance.

In the last decade, several schemes were presented to focus on setting signal strength threshold for handover [62–65]. Some of the schemes were presented to enhance the process of link going down (LGD) event and improve the performance of a network [66–70]. The MIH standard initiates handover and selects the new network on the basis of RSS strength. A scheme based on the integration of context awareness functionality in the MIH standard has been proposed in [71]. The context aware functionality enhances the process of LGD event. The handover triggering mechanism is based on LGD time and handover preparation time required by a user [72]. The handover preparation time is computed on the basis of historical data and current packet loss ratio. Thus, it provides the user with sufficient time to make handover decisions. The context aware module is divided into four different parts i.e. context data, estimator, adaptor, and result. The context data consists of the history handover preparation time and current packet loss ratio. The estimator performs estimation on user history preparation time and current packet loss ratio context. The adaptor compares the estimated information with the history information of context data, and finally the results from the adaptor are saved in the result part. The proposed scheme efficiently optimizes the handover preparation time for a user and significantly reduces the time required for handover. The proposed scheme also minimizes the number of false handover up to a great extent, and this helps in increasing application throughput. One of the limitations in this scheme is that it uses RSS for handover indication which sometime leads to inappropriate selection of the network during handover.

3.3 Hybrid (Network and User Centric) Approaches: State of the Art

The hybrid scheme has many advantages. It can select an optimal network on the basis of user preferences and can perform handover on the basis of network centricity. The detailed survey of such schemes is presented here.

A context-aware VHO based on maximizing the computational capabilities of various needs in a pervasive computing environment has been presented in [73]. The architecture of the home and the foreign agent has been used in a variety of traditional Mobile IP (MIP) handover management schemes [21, 74–77]. The protocol requirements in MIPv4 in the pervasive systems are different in many contexts like routing, security, etc. The MN in pervasive systems uses triangular routing while moving from the home agent to the foreign agent. The triangular routing produces longer end-to-end (E2E) delay; hence, it is not a good choice for multimedia applications. The authors proposed a new architecture for the handover management in pervasive systems. They provide a scalable mechanism to obtain context information and perform handover on the basis of the information. The architecture of the proposed scheme was tested on different heterogeneous networks. The system is illustrated in Fig. 6.

As depicted in Fig. 6, each of the active nodes performs context management, evaluation and decision during each personal computing environment (PCE). The network dispatches a node to the most appropriate node on the basis of its location. The active node can perform handover to different types of networks such as GPRS/UMTS, WiFi, and Bluetooth networks. The central context repository (CCR) uses three type of context information i.e. static, dynamic, and infrastructure for handover. The CCR transfers these three types of context information to the active nodes to perform handover to the appropriate network. Filter repository is used to filter the information that is duplicated during a handover process. Table 1 shows the context information available in static, dynamic and infrastructure context.

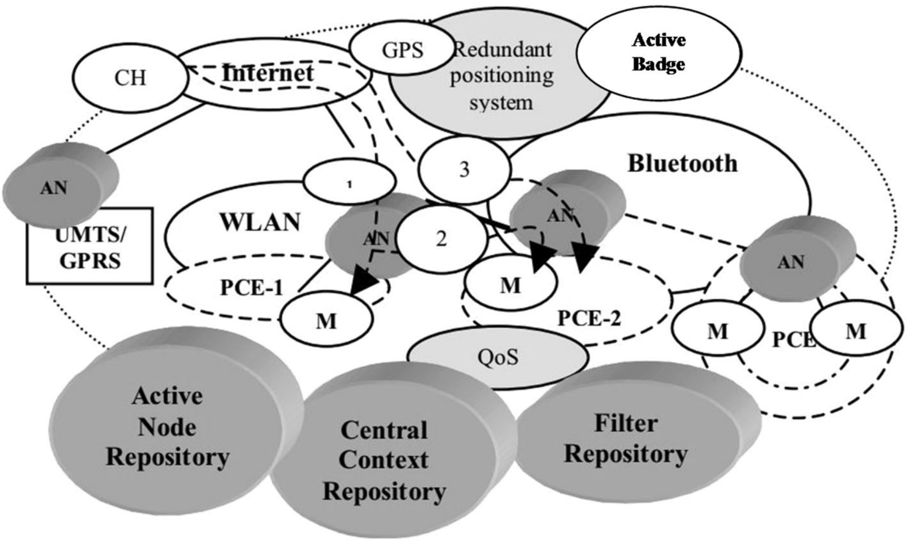

Fig. 6 Architecture of the proposed scheme in [73]

Table 1 Context information used in [74]

Context	Information
Static	User QoS perceptibility requirements User mobility history Location positioning system
Dynamic	User and device location Network QoS i.e. delay, loss rate, bandwidth, and jitter
Infrastructure	Network coverage Type of nodes in the network i.e. routers, base station, etc. Capacity of each node

The system uses the new infrastructure in the existing system, which leads to high cost and technology. The redundant positioning system (RPS) has been presented in [78]. The RPS provides the accurate location of the user across multiple administrative domains. The MN performs handover on the basis of a decision process. This process checks user mobility, performance and device change or degradation of QoS in a network [79]. A similar scheme for context-aware VHO based on multimode mobile devices in heterogeneous networks has been presented in [80]. The handover decision in 3GPP networks is solely based on the network operator. The proposed scheme provides an additional mobility support function (MSF) to support handover decision on the basis of user preferences. It also integrates the network policies and user preference for handover decision. The user defines a list of the applications and services frequently used during handover, and the required bandwidth is computed and assigned to each application and service. The MSF provides a common interface between an MN and access network for handover. The proposed system uses an intelligent context model. This model is designed on the basis of static and dynamic information available in Table 1. The information for terminal side consists of display size, resolution, battery life, memory, processor speed, and available interface. On the network side, the information consists of the service provider profile (provider identity, charging model) and current QoS parameters of APs. The handover decision model is based on six primary objectives: interface priority, minimum cost, maximum throughput, minimum delay, minimum jitter, and minimum BER. On the basis of these objectives, an MN defines three priorities, (1) primary objective priority (2) available networks priority and (3) application priority. Once the context of each network is computed by the multimode MN, it makes a table and assigns context capability to the access network. The multimode node is moving inside a heterogeneous network, before performing handover, compares the context of capabilities of different networks. After comparing the context, the multimode node performs handover to the network with the largest context. The author did not provide quantitative analysis of the cost and other contexts used in the system. The system should be tested in real time networking to checking its performance against the existing infrastructure used for similar purpose.

Another scheme (similar to [73, 80]) for mobility management between 3GPP and other technologies has been presented in [81]. This scheme also uses MSF for handover management. The MN sends some information to the MSF: (1) capabilities of the UE, (2) scanned access networks, and (3) request for acceptance of a network among many available networks. The MSF replies to MN with three types of information: (1) one of the acceptable network from the list generated by MN, (2) handover procedure i.e. authentication, and (3) request to execute handover.

Table 2 Comparative summary of user-centric, network centric, and hybrid schemes

Proposed scheme (Literature Survey)	Used parameters	Throughput	Packet loss ratio	Advantages
User-centric				
Pyun [24]	Throughput	12 % Increased	47 % Reduced	Enhanced QoS streaming Communication cost increased
Indulska et al. [25]	Distance	Not provided	Avg. 1.35 %	Avg. 1979 ms handover time plus notification delay Communication cost decreases
Fiterau et al. [27]	A set of bandwidth, throughput and cost	20 % Increased	Substantial decrease	Handover delay 60 % decreased Monetary cost is reduced due to group network selection
Pawar et al. [28]	Location information	12 % Increased	20 % Reduced	Handover delay decreases by 10–15 % Cost values are not provided
Gavrilescu et al. [31]	Predication of PoA using pattern matching of previous handovers	Not provided	Not provided	Handover predication rate is 27–53 % Cost values are not provided
Network centric				
Inoue et al. [45]	GPS system	Throughput application increases for watching video applications	Not provided	Energy per application is highly reduced
Liao et al. [48]	Optimized RSS	Channel quality is increases	Significantly decreases	False handover rate is greatly minimized Energy consumption analysis is not provided
Flanagan and Novosad [51]	Weighted cost function	Not provided	Not provided	Cost function and blocking decreased by 40 and 1 %, respectively. Energy consumption by mobile terminal is significantly reduced
TalebiFard and Leung [54]	Weighted criteria based on bandwidth, delay, cost, jitter, security, packet loss ratio	Increased in case of weight assignment	30 % Decreased	Handover Delay, jitter, power, bandwidth, and cost is optimized by 25, 50, 60, 30 and 20 %, respectively. Identifying low power network for handover
Xiong et al. [71]	Signal strength prediction	Not provided	Not provided	Handover Preparation time is efficiently addressed Low power LGD events generations
Hybrid centric				

Table 2 continued

Proposed scheme (Literature Survey)	Used parameters	Throughput	Packet loss ratio	Advantages
Balasubramaniam et al. [73]	Positioning system	Not provided	Not provided	Average handover time with double cast is 37 ms Power consumption is unaffected Cost values are not provided
Ahmed et al. [80]	Application profile in term of cost, interface priority, and maximize quality	Not provided	Reduced due to minimizing of delay	Interface detection and decision-making time is average 20 and 5 ms, respectively Selection of cheapest network Power-aware interface selection
Kuhn et al. [81]	Mobile IP based handover	Increases throughput by reducing scanning time	Reduced by properly selecting a QoS aware AP or BS	Scanning time is highly reduced, MSF is used for supporting mobility Communication cost is reduced power-aware region based scanning
Zekri et al. [82]	optimized RSS	Increases by lowest cost	Not provided	Efficiently select the best network on the basis of user preference and perform handover on the basis of network centricity Best network selection on the basis of cost Energy consumption of the proposed system is not provided

An intelligent context-aware solution based on user and service requirements has been presented in [82]. The proposed scheme is composed of three phases. In the first phase, the MN collects context information necessary for selecting an appropriate network for handover. On the network side, these context information are network coverage, RSS, the speed of an MN, load, bandwidth, BER, delay, and jitter. On the user side, the context information is cost and QoS. In the second phase, the MN makes a decision on the basis of information gathered in the first phase. The MN initiates handover when its RSS drops below a predefined threshold used in [83]. A fuzzy logic scheme is used to check the QoS of the current network [84, 85]. The fuzzy logic scheme uses previous handover data for computing QoS of a network. If the QoS of the current network is not good enough to provide better service, then the MN initiates the handover process. After initiating a handover process, the MN selects an appropriate network based on a priority matrix called analytic hierarchal process (AHP). The MN selects the network with the highest QoS and initiates handover to that particular network. In the last phase, the MN executes handover. The new network provides MN with the association, resource allocation, and routing services. The scheme employs fuzzy logic for computing the network quality, and it sometimes leads to the selection of inappropriate quality. The previous handover data should always be updated in case of system failure. The system is good where the network is less congested.

4 Comparison of the User, Network and Hybrid Centric Approaches

In this research, we studied mainly those context-aware VHO schemes which provide enhanced throughput and minimum packet loss. Research in context-aware VHO management is still a challenging area. The main difficulty is devising a generic context-aware VHO management scheme based on achieving high throughput and minimum packet loss. All of the schemes discussed in this survey are combined, and their achievements in the context of throughput and packet loss ratio and other advantages such as handover delay, cost, and bandwidth optimization are combined in Table 2.

5 Conclusion

In this paper, we investigated the well-known schemes used for context-aware VHO management in heterogeneous wireless networks. An efficient handover management scheme can be designed by keeping a balanced relation among different handover parameters. These parameters can be tuned either by a user or a network, but the best possible approach is to design a scheme that takes care of both user satisfaction and full use of network resources.

An optimized handover triggering mechanism can initiate a handover decision on a perfect time. Most schemes presented in the current literature lack the quality of handover triggering mechanism, and they are mainly based on RSS from current AP or BS. Similarly, various other issues to be addressed are presented in the current literature. These issues include high handover delay from WLAN to cellular networks, redirection of high bandwidth data from one AP or BS to another, and selection of inappropriate network for handover. Network selection algorithms can be based on different parameters like bandwidth, data rate, cost, user preference, etc. Unfortunately, most of these schemes lack the resourceful criteria for the selection of the best network for handover. We identified different issues in the existing schemes in Sect. 3. The key purpose of this survey is to provide a generic platform for the design of context-aware VHO management for the next generation of networks.

After carefully examining the schemes used for context-aware VHO management in this survey, we suggest the following points for designing a context-aware VHO management scheme for the next generation of networks. A generic context-aware VHO management scheme can be designed if the network selection is performed by the user while the handover initiation and execution is carried out by the access network operator. In the future, a user will have multiple options to build its personal profile for different networks. Nowadays, the modern smart phone provides a user with different options to build a profile for energy consumption (power saving mode), connection time to a particular network and connecting to a low-cost network. A generic system needs to be designed on the basis of different contexts like bandwidth, cost, signal strength, availability, handover delay, jitter, packet loss, and performance. In the next generation of networks, a user will use a particular access network operator for all of these contexts and then decide the network with the highest context. This process can be made more efficient if every access network operator provides the information of the above contexts to a central server. When a user wants to perform a handover, it will contact the server and obtains the relevant information of contexts. Thus, a user can easily choose one of the appropriate networks for handover in heterogeneous wireless networks using the context information of the available networks.

We provided an extensive summary of the VHO schemes in the context of best network selection algorithm, decision making, and handover time optimization. The technicality of the schemes presented in the literature was summarized in user, network, and hybrid centric approaches.

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