Conceptual mobility model of vertical handover decision in heterogeneous networks

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ABSTRACT

In heterogeneous network, maintaining seamless connectivity needs excessive efforts from various aspects such as network availability and mobile node reliability. Presently, a vertical handover management is a practical approach in facilitating the service continuity for mobile users. Many researches have been conducted in this area by considering performance improvement in delay, latency, and overhead. Preserving the Quality of Services (QoS) based on user mobility and pattern movement during handover decision has become an important aspect in vertical handover management. This paper presents the conceptual mobility model of vertical handover decision in heterogeneous network. Hence, several researches in vertical handover decision management has been reviewed regarding the issues on the vertical handover decision algorithms such as RSS Based Algorithm, MADM Based Algorithm and Intelligence Based Algorithm. This paper highlights the current decision algorithms that integrate the traditional methods with intelligence algorithm for better optimization. In decision parameters, the user mobility pattern can be importance in terms of direction randomness and mobility speed. Hence, a conceptual mobility-awareness model for vertical handover are been proposed in targeting some improvement of handover performance.

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1. INTRODUCTION

Recently, mobile devices such as smartphones, laptops and tablets have been extensively used with support of advanced network technologies. An internet access and communication activity happen at anytime and anywhere. Mobility may affect the communication connectivity when the mobile node (MN) makes changes on the preferred network during the communication process. Hence, a good approach of mobility management is essential in preserving the Quality of Service (QoS) to user. Mobility management in heterogeneous wireless network has emerged and researched over the years [1]-[3]. One of the important parts in mobility management is how to manage the handover process when the mobile node changes or move away from current service network to another service network without disrupting the communication connectivity. Handover is a process when the mobile node moves from one wireless cell to another and requires the seamless connection with the next wireless cell. A seamless connectivity [2] or "Always Best Connected" is about maintaining the network connectivity of all running applications on the mobile device. This is still a challenging task to facilitate the best approach that can support the seamless connectivity while maintaining the QoS at user levels [3].

Handover management in wireless network can be carried out either horizontally or vertically. Horizontal handover happened in homogeneous environment where the network changing process occurred within the same domain of network, such as the mobile node changed the preferred network from WLAN1 to WLAN2 within the same domain. Meanwhile, in heterogeneous network, vertical handover is more challenging as the mobile node needs to change the preferred network from different network domain and technologies, such as WiMax, WiFi, UMTS/LTE and others. Moreover, the handover management procedure can be classified into three types which are hard, soft and softer handover. Hard handover is referred to breaking the connected network before make the next network connection, as the mobile node only connected to one point of attachment (POA) at a time. Meanwhile, soft handover allowed mobile node to connect to two POA for a while until the best connection obtained. However, softer handover [4] is the best approach in handover management where this fast and smooth handover can minimise the latency and packet loss during handover execution. In general, *Handover Management Architecture* consists of three parts which are *Handover Initiation, Handover Decision* and *Handover Execution.*

1.1. Handover Initiation

During system discovery, all information from mobile node and networks are collected such as battery power, network bandwidth and signal strength. QoS requirements are also taken into consideration as an input for the next handover phase.

1.2. Handover Decision

At this phase, a mobile node needs to make a new network selection because of some factors such as rapid mobile node movement and stumpy network coverage. Mainly, handover decision selects new preferred network based on the received signal strength and highest-ranking indicator collected from system discovery process. Some decision algorithms are manipulated using mathematical or computational formula for managing the handover performance like overhead and delay.

1.3. Handover Execution

When the selected network satisfies the QoS requirements of mobile node, the handover executed based on the certain handover controller. The handover management controller can be either at mobile node or network side. Hence, four types of handover process control are Network Controlled HandOver (NCHO), Mobile Controlled HandOver (MCHO), Mobile-Assisted HandOver (MAHO) and Network-Assisted HandOver (NAHO) [2].

This paper presents the conceptual mobility model of vertical handover decision in heterogeneous network and organized as follows. Section 2 discussed the current vertical handover management including the vertical handover decision algorithms analysis. Section 3 presents the proposed mobility-awareness model during network selection. Section 4 encompasses the conclusion and future recommendations on this research.

2. RESEARCH METHOD

2.1. Vertical Handover Decision (VHD) Algorithm

Several literatures have presented an overview of vertical handover decision strategies in different categories. In research [5], the authors make the comparison between vertical handover decision strategies in five categories such as Decision Function (DF), User Centric (UC), Multiple Attribute Decision (MAD), Fuzzy Logic/Neural Network (FL/NN) and Context-Aware (CA). They proposed a new handover decision scheme contains two components which are Fuzzy Logic System (FLS) and Network Selection (using AHP method). Authors in [6], propose a vertical mobility management architecture named as Context-Aware Mobility Management System (CAMMS) which support the cross-layer, context-aware and seamless handover for user and services. They design four main components of functional entities that responsible for context gathering, intelligent handover decision-making, accurate handover triggering and post-handoff management.

J. Márquez-Barja et al. [7], review on algorithms, protocols and tools in vertical handover management. The paper focus on vehicular network, where vehicle as a node that have several constrained such as topology restrictions, mobility patterns, power consumption, scalability, reliability and speed. Research in [8] categorized the VHO Algorithm into four types which are Location Based Handover, Mobility Based Handover, Policy Based Handover and Learning Based Handover. Meanwhile, authors in [9] conducted a survey of handover decision algorithms for LTE-A femtocells. They classified the HO Algorithm into five aspect which are RSS, Speed, Interference-aware, Cost-function and Energy-efficient. They also highlighted on the need of future research on multiple-macrocell multiple-femtocell scenario where RSS and

RSQ as main parameters. Yan et al. in [10], summarize the vertical handover decision algorithm into four categories which are RSS Based VHD Algorithms, Bandwidth Based VHD Algorithms, Cost Function Based VHD Algorithms and Combination Based VHD Algorithms. Twelve VHD algorithms have been analyzed and they presented the advantages and disadvantages of each algorithm. The current vertical handover decision can be categories into RSS based Algorithm, MADM based Algorithm and Intelligence based Algorithm as shown in Figure 1.

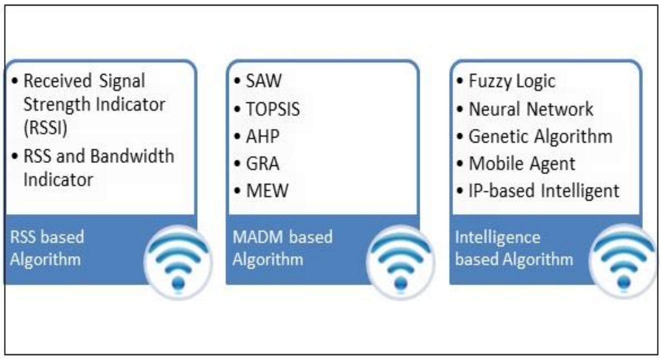

Figure 1. Vertical handover decision schemes

2.1.1. RSS based Algorithm

Received Signal Strength (RSS) is a common handover decision. In [11], a mathematical model based on VHO prediction approach has been review by considering some parameters such as RSS, UE velocity, load and cost per user bandwidth. The proposed algorithm has been simulated in Matlab and follows the Jake's model. Evaluation of the network performance is based on user velocity and handover numbers. Handover process evaluated in WiFi and WiMax access networks. Authors in [12]-[13], evaluate the handover performance based on Received Signal Strength Indicator (RSSI) algorithm for WLAN/Cellular network for Mobile Voice users. Ning et al. in [12], proposed handover algorithm based on RSS and Markov mobility model for minimizing the number of handovers.

2.1.2. MADM based Algorithm

Multiple Attribute Decision Making (MADM) based algorithm is a popular decision method. MADM methods can facilitate the need of multi-criteria solution for avoiding inappropriate handover decision as highlights in [5]. In research [13], Maaloul et al. proposed an efficient handover decision algorithm based on MADM method. The paper highlights some MADM methods such as Simple Additive Weighting (SAW), Weight Product Method (WPM), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Grey Relational Analysis (GRA), Distance to Ideal Alternative (DIA), VIKOR and ELECTRE. They proposed a Ranking Scheme based on provided QoS algorithm where considering context-awareness in the evaluation parameters like coverage area, RSSI, available bandwidth, delay, response time, jitter, security, user preference and cost. This research compared the proposed algorithm with some MADM methods mention earlier. Result shows some improvement in handover performance; however, the algorithm complexity may increase the handover delay and overhead.

In [14], a network selection based on context awareness services has been proposed by the authors. This context-awareness algorithm combines the fuzzy mathematics evaluation and TOPSIS-MADM approach. From their simulation results, fuzzy mathematics evaluation has performed better regards to network selection speed. The TOPSIS-MADM approach supports well in utility performance measurement. Authors in [15] compared handover performance for four MADM based vertical handover algorithm namely MEW (Multiplicative Exponent Weighting), SAW, TOPSIS and GRA. Based on their simulation result, GRA has slightly higher bandwidth and lower delay value when concerning the weight of attributes such as bandwidth, delay, jitter and bit error rate (BER). In [16], the research presented the handover performance evaluation on seven MADM methods which are SAW, MEW, TOPSIS, GRA, ELECTRE, VIKOR and WMC. The numerical simulation is designed in MATLAB software under means of different application scenarios such as voice, data and cost-constrained connection. The outcome shows that SAW and GRA has low computational complexity and a possible solution for seamless vertical handover. Meanwhile, when considering the types of applications like voice and data, VIKOR and MEW are the best MADM decision methods.

2.1.3. Intelligence based Algorithm

Traditional RSS and MADM based algorithm still have some limitations when applied in heterogeneous networks. These methods create only small difference values in ranking accuracy [17] and fixed network discovery method [18]. Hence, combining the traditional methods with intelligence-based algorithm may leads to better handover performance. Authors in [18] works on an type-2 fuzzy logic algorithm that specifically focused on vehicular heterogeneous networks. Pink et al. in [19] presented a fuzzy-based vertical handover decision algorithm which can adapts with device and network capabilities. The research has been experimented in real environment with controlled device which considering the UMTS/WLAN networks. The evaluation focused on QoS and resource consumption. Result show that mobility affects the QoS as the mobile node changes the path, the signal strength may changes accordingly. In minimising the resource consumption, the algorithm slightly decrease the maximum device runtime up.

Research in [20] proposed a new hybrid algorithm technique using combination of ABC (Ant Bee Colony) and PSO (Particle Swarm Optimization in the process of selecting the best wireless network. Meanwhile, authors in [21] develops a model for handover decision algorithm by applying hybrid Artificial Neural Network (ANN). Both approaches able to reduce the cost and ping-pong effects in handover. Luo et al. [22], proposed a new handover prediction algorithm based on Hidden Markov Model. The experiment conducted for wireless network in office environment by considering the controlled situation. Hence, the user's mobility in predictable and RSS value is accurately measured. Still, the research has limitation on the mobility model and emission probability need to know and learns on each other better. Table 1 show the summary of current vertical handovers decision algorithms.

Table 1. Summary of Vertical Handovers Decision Algorithms

	RSS	MADM	Intelligence Algorithms
Review papers	Survey and review papers on mobility management [5]-[10],[23]		
Basic - RSS	Received Signal Strength [11]-[12],[24]-[25]	Ranking Scheme [13] MEW, SAW, TOPSIS, GRA [15] SAW, MEW, TOPSIS, GRA, ELECTRE, VIKOR, WMC [16]	NA
Fuzzy Logic (FL)	RSS, Fuzzy [26] Fuzzy[27]	MCDM Fuzzy-AHP [3] Fuzzy-TOPSIS [14] Fuzzy-AHP [28] MCDMFuzzy-TOPSIS [29] Fuzzy MADM [30] MADM – GRA [31]	Fuzzy-MADM [17] Type-2 Fuzzy [18] Fuzzy [19]
Artificial Neural Network (ANN)	NA	NA	ANN [21]
Ant Bee Colony (ABC)	NA	NA	Cloud Assisted Handover (IoT) – ABC [32]
Particle Swam Optimization (PSO)	NA	NA	PSO-ABC [20] PSO [33]
Markov Chain	MDP [34]	NA	Hidden Markov [22]
MIH & SDN	MIH [35]	VIKOR [36]	NA

Note: NA – Not Applicable

Research in [37] focus on distributed handover and mobility pattern prediction by using Markov theory and statistical theory. They proposed an algorithm named Pattern Prediction and Passive Bandwidth Management Algorithm (3P-BMA) which apply Markovian Prediction scheme. Yet, this research only focused on guarantees the service continuity in wireless cellular networks. Authors in [38] also focused on mobility prediction for wireless cellular network, in optimizing the Call Admission Control (CAC) by proposed the In-advance Multiplexing Call Admission Control (IAM-CAC) scheme. This new CAC scheme based on threshold approach has been perform wells in terms of Call Blocking Probabilities/Call Dropping Probabilities.

In addition, authors in [39], focused on link-layer inter-technology handovers, in supporting the limitations of user mobility randomness, high handover overhead, optimality requirement. The paper proposed a new handover decision making that exploits the data traces of user mobility in real mobile environments. They are mining the data from Dartmouth College, a campus environment for assuming the strong regularity with user mobility. The decision process was formulates using Markov decision process (MDP) and employs using MADM-AHP approach. The algorithm has been compared with random and greedy algorithm, with the results that shown the new algorithm performs better. However, this method requires extensive data traces and simulation scenarios.

2.2 Proposed Methods

The proposed scenarios for vertical handover are shown in Figure 2. A few scenarios will be setup for collecting the human mobility pattern. The sample data will be collected from several mobile nodes in campus network environment. The data will be identified using Livelab network measuring source code. The chosen access technologies will be a WLAN (WiFi:IEEE 802.11) and a LTE network. The designed mobility pattern model will be included in vertical handover framework.

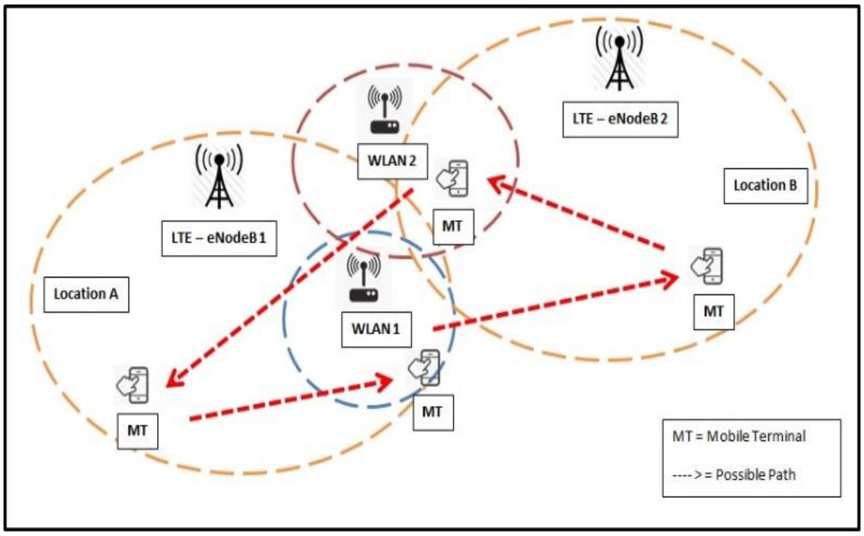

Figure 2. Proposed scenarios for vertical handover

The proposed scenarios will refer to research in [40] as shown in Table 2. The collected data will be measured and analyzed for respected parameters such as user's movement pattern, speed and location. From this real data traces, a pattern model will be construct and used in latter proposed algorithm. A sample data from online database named CRAWDAD also will be used as benchmark value in comparison with the real data traces collected in Livelab Networks. In addition, a crowdsourcing application named as OpenSignal will be used for collecting and retrieving network performance statistics, at target location respectively. This application can records the performance statistics of connections between mobile nodes with the eNodeB (LTE) and WLAN (WiFi). It also provides an aggregated statistics of network coverage that presented in the form of coverage maps.

Table 2. Scenarios for Collecting Online Mobility Pattern

Scenarios	Network Selection	Data Technologies	Applications
Case 1	LTE to WiFi	General/Conventional	Web Browser, Voice, SNS
Case 2	WiFi to LTE	General/Conventional	
Case 3	LTE to WiFi	Streaming	Video, Live TV
Case 4	WiFi to LTE	Streaming	

3. RESULTS AND ANALYSIS

3.1. Random Mobility Model and Algorithm

In recent years, several researches began focusing on the mobility issue as mobile node may have different mobility speed and movement direction. Hence, considering the randomness of mobile node's movements and variety of mobility speed is still a challenging task in vertical handover management. Commonly, main parameters in vertical handover decision are based on network conditions such as received signal strength and available bandwidth. Besides, at the user side (mobile node), several conditions also being considered like mobile energy, connection cost and user preferences. Table 3 show the parameter metrics for Random Mobility Parameters in Mobility-awareness of Vertical Handover Management for LTE-WLAN networks. Meanwhile, a block diagram in Figure 3 show the Fuzzy-Topsis with Mobility-awareness model.

Table 3. Random Mobility Parameters in Mobility-awareness of Vertical Handover Management

Parameter	Indication Value	Parameter	Indication Value
Received Signal Strength	Rss	MT Move Out	MTmo
Available Bandwidth	bd	Speed	s(n)
MT Move In	MTmi	Directions	d(n)

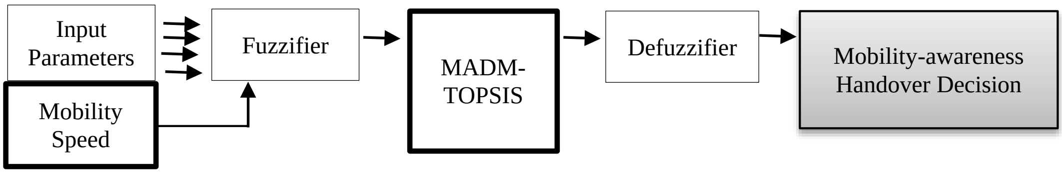

Figure 3. Fuzzy-TOPSIS block diagram with random mobility-awareness

3.2. Network Performance and Availability

Figure 4 show the network performance statistics, at targeted location respectively based on a crowdsourcing application named as OpenSignal. This application can record the performance statistics of connections between mobile nodes with the eNodeB (LTE) and WLAN (WiFi). It also provides an aggregated statistics of network coverage that presented in the form of coverage maps.

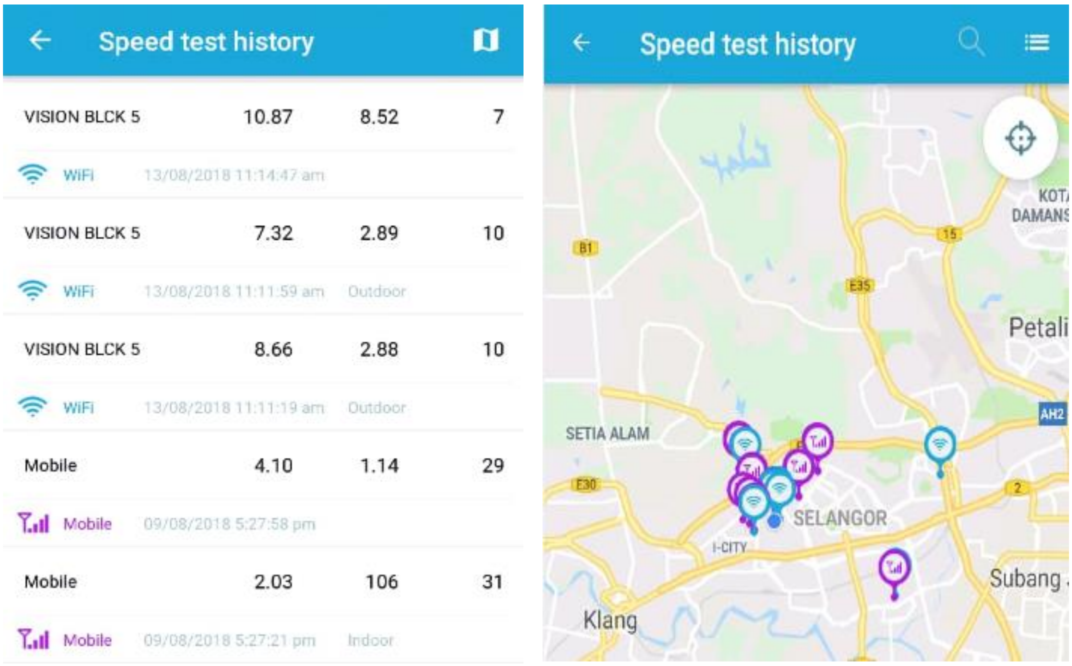

Figure 4. Network performance speed test history and coverage maps from OpenSignal Apps

3.3. Conceptual Model of Mobility-awareness Vertical Handover Management

Relatively, a proposed new vertical handover decision that exploits mobility-awareness model should consider the mobile node's speed and pattern randomness as shown in Figure 5.

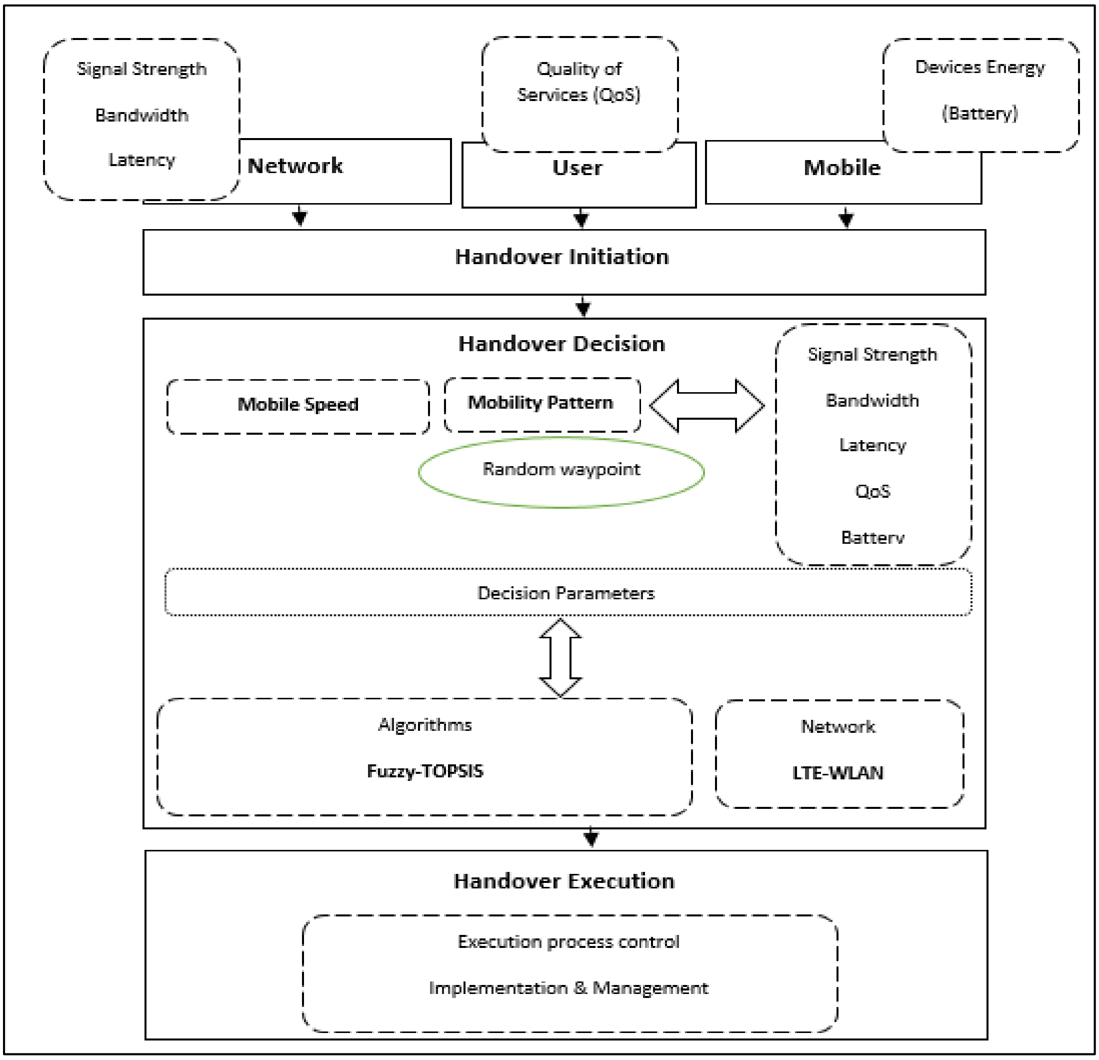

Figure 5. Mobility-awareness vertical handover management

4. CONCLUSION

This paper presents the conceptual mobility model of vertical handover decision in heterogeneous network. Hence, maintaining network connectivity in heterogeneous network requires astounding effort in academia and industries. Rapid mobility has become a bigger challenge in facilitating the service continuity to mobile users. Furthermore, variety of network access such as WiFi, WiMAX, 3GPP and LTE also creates chaotic mobile environments when the handover process not being conducted precisely. Hence, this paper reviews several current researches on vertical handover management architecture. In addition, the literatures on vertical handover decision algorithm also being analyse and categorised into three sections which are RSS Based Algorithm, MADM Based Algorithm and Intelligence Based Algorithm. Most current researches focused on combining the RSS and MADM approaches with intelligence algorithm like Fuzzy logic, to enhance the handover performance such as overhead and delay. From the related reviews, this paper proposed a mobility-awareness vertical handover management that encompasses mobility speed and pattern as an important attribute during the handover decision process. Hence, we hope the future vertical handover management can provide more seamless network connectivity.

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