An Overview of Multi-Attribute Decision Making (MADM) Vertical Handover Using Systematic Mapping

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***Abstract*—The evolution of infotainment industries yet the advancement of cellular gadgets such as smartphones, tablets, and laptop had increased the request on cellular traffic demands. As a result, a Heterogeneous Wireless Network (HWN) has been introduced to fulfil users requests in having seamless mobility and better Quality of Services (QoS) for the users. A lot of research works have been done in order to provide a seamless connection to the users. Even though a lot of methods have been proposed, a Multi-Attribute Decision Making (MADM) has been seemed like a promising way due to its ability to evaluate many attributes simultaneously. Previously, many reviews based on MADM methods in a Heterogeneous Wireless Network provides a details review which required researchers time in order to determine the possible potential areas to be explored. Therefore, in this study, we present an overview of the MADM method in performing vertical handover via a systematic mapping method. This will enable future researchers to identify the trends and research opportunities within this area. This mapping study analysed 30 papers. Results from the study show eight main potential research issues can be explored by researchers, including normalisation, criteria weighting, ranking abnormality, network selection, and performance comparison between MADM algorithms, network selection for a group of calls, mobility patterns and handover triggering.**

***Index Terms*—Multi-Attribute Decision- Making (MADM); Vertical Handover; Heterogeneous Wireless Network; Systematic Mapping.**

I. INTRODUCTION

As time flies, the landscape of wireless technologies, applications, and devices had changed and increased in a very fast rate. For example, the emergence of smart devices such as smartphones and tablets with multiple networking interfaces and the availability of several wireless technologies, including the Worldwide Interoperability of Microwave Access (WiMAX) and Long Term Evolution (LTE) network had increased users' demands in having seamless connectivity. However, since user become nomadic from time to time, single wireless technology cannot cater to this requirement. Therefore, a concept of Heterogeneous Wireless Networks (HWNs) has been introduced. Heterogeneous Wireless Networks (HWNs) are formed based on different Radio Access Technologies (RATs) [1]. It is different in terms of operating parameters and characteristics. For example, bandwidth, coverage areas, and cost. Even though the Heterogeneous Wireless Networks consist of different RATs, however, it allows the Mobile Nodes (MNs) to attach with different types of the network while moving and support network services with diverse Quality of Service (QoS). Furthermore, in order to support the services, a handover is required. Handover is a process of selecting the best network with seamless services. Basically, it consists of three stages. The first stage of the handover is handover initiation. In handover initiation, the mobile nodes or Access Points (APs) in this stage will collect all of the information from the network to initiate the handover. Then, handover decision will compare the measurement result with the predefined threshold to decide either to perform handover or not and select the best network. Lastly, the handover execution phase will switch to the selected network.

Handover in HWNs is known as Vertical Handover (VHO). In order to prevent the QoS degradation, it is important to have precise timing durability [1]. As compared to homogenous network, vertical handover in HWNs need to consider many attributes as the HWNs consist of different network characteristics. Hence, a selection of the best network which meets user demands and mobile terminal capacities emerge as very challenging. As a result, Multi-Attribute Decision- Making (MADM) has been seen as a suitable approach due to its ability to evaluate many attributes simultaneously [2]. To the best of author's knowledge, there are no such methods described a Systematic Mapping (SM) studies over vertical handover in Multi-Attribute Decision-Making (MADM). Therefore, the objective of this paper is to provide researchers with the overview of potential research areas which can be explored more further in this domain.

Systematic Mapping (SM) served as a method of review, classify, and structure the papers according to a particular research field [3], [4]. It is frequently used in medically related research and started to gain more attention from Software Engineering (SE) community. In contrast with a systematic review, systematic mapping focus is to provide an overview of a wide range of papers, while systematic reviews are more focusing on the extensive analysis of works by identifying the best practices in the field [4]. Meanwhile, a systematic mapping able to present a fair evaluation of literature by identifying gaps and clusters in a set of primary studies [5]. Consequently, the rest of this paper is sorted out as beneath. Section 2 disclosed the strategy embraced to

conduct a systematic mapping. Section 3 provides the result of the investigations. Section 4 provided a discussion for the study. Finally, Section 5 presents a summary of this paper.

II. Research Method

A systematic mapping was conducted based on the process proposed by Petersen *et al.* [3]. Figure 1 illustrated the procedures performed in this study. The clarifications for each of the procedures are portrayed in the following subsections.

A. Research Questions

The exploration questions were built up to recognise the essential studies that investigated the MADM methods. It is defined based on the motivation of the studies. The research questions are addressed as followed:

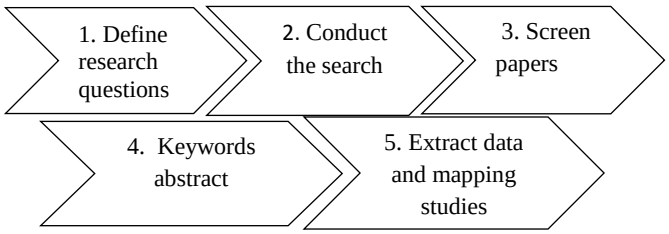

Figure 1: A systematic mapping process [3]

RQ1: What are the existing research studies of MADM methods in a vertical handover?
RQ2: What research approaches do these studies apply?
RQ3: What are the implications of these studies on MADM based vertical handover in the heterogeneous wireless network?

Consequently, the appropriate response to these inquiries will give an outline of the best state- of- the- art for the MADM based vertical handover. Furthermore, it can be used to point out the areas that need further investigation.

B. Search Strategies

A search strategy is required to find the relevant information from the databases. In this study, the electronic search was performed in IEEE Xplore, Science Direct, and Scopus databases. The following keywords are applied to the search strings:

- "Vertical handover" AND "Multi-criteria Decision-Making"
- "Heterogeneous Wireless Network" AND "TOPSIS, SAW, MEW, GRA"
- "Vertical Handover" AND "Always Best Connected"

C. Screen Papers

Inclusion and exclusion criteria were used to filter the paper from the databases. It is used to exclude studies that are not relevant to answer the research questions. The selected papers were filtered from 2012 until 2016. All of the selected papers were published in conference proceedings and journals. The inclusion (IC) and exclusion criteria (EC) are described as follows:

IC1: The studies that implemented MADM techniques in the vertical handover.
IC2: The studies that highlight the issues of MADM techniques in vertical handover

EC1: Papers published before 2012.
EC2: Papers that did not address MADM vertical handover.
EC3: Papers not related with MADM methods in the vertical handover.

D. Keywords Abstract

The study selection for the selected papers was made by using electronic search. Therefore, preselection criterion was applied to the papers, by considering the research keywords presented in the search strings strategy. About 30 papers were filtered during the screening process.

E. Data Extraction and Mapping Studies

The spreadsheet was used to extract the relevant information from the studies.

III. Results

This section discusses the result of Systematic Mapping based on the Research Questions described in Section 2.1.

RQ1: What are the existing research studies of MADM methods in a vertical handover?

There are eight categories of studies that get attention from researchers in performing the vertical handover of the heterogeneous wireless network.

The categories of the study were represented in Table 1. As this paper is just a simplified review from the systematic mapping, a brief description of each of the categories will be discussed shortly.

Table 1
Existing of Research Study of MADM Methods Based on Categories

Categories	Studies	Total No. of Study
Normalization	[2], [6]–[8]	4
Criteria Weightage	[9]–[14]	6
Ranking Abnormality	[2], [6], [9], [10], [15]–[17]	7
Network Selection	[11], [13], [18]–[26]	11
Performance Comparison of MADM algorithms	[8], [9], [12], [19], [22], [23], [27]–[29]	9
RATs selection for a group of calls	[30], [31]	2
Mobility pattern	[32], [33]	2
Handover triggering	[24], [34]	2

A. Normalization

The authors in [2], [6]–[8] had highlighted the implementation of normalisation method to eliminate the differences between dimensional unit. Among the most well-known normalisation methods used by the researchers are Euclidian normalisation, Max- min normalisation, Max normalisation, and Sum normalisation. However, applying distinctive standardisation process will make the analysed mechanism to act contrastingly. However, according to authors [7], the Euclidian normalisation able to produce a good result as compared to the others normalisation techniques.

B. Criteria Weightage

Instead of the normalisation method, the assignment of criteria weight had become as one of the focused research studies in MADM network selection strategies [9]–[14]. Therefore, the Analytical Hierarchy Process (AHP), Fuzzy Analytical Hierarchy Process (FAHP), Analytical Network Process (ANP), and Fuzzy Analytical Network Process

(FANP) and Random Weighting (RW) had become the most chosen methods in determining the importance of the criteria. However, the weightage based on the AHP or the ANP which use the scale to determine the importance of criterions led the researchers into a difficulty state especially when the number of criteria increased. As a result, it is important to find an alternative to overcome the issue, for example by using the Entropy method. Therefore, there are six studies of criteria weighting being extracted from the data extraction process.

C. Ranking Abnormality

Authors [2], [6], [9], [10], [15]–[17] highlighted the issue of ranking abnormality in their studies. Basically, the ranking abnormality is related closely with the normalisation method. This incident occurs due to the removing or adding the number of networks (alternatives) from the original decision matrix even though the original criterion value is still the same. Therefore, author [2] proposed a fresh TOPSIS-based approach for network interface selection that effectively handles the ranking abnormality problem in HWNs. The investigation demonstrated that the proposed approaches diminished or totally disposed of the rank reversal, either when networks are detached or new networks are associated. The simulation results demonstrated that the proposed method reduced the ranking abnormalities problem. The experiment result shows that different networks are selected for different traffic class (streaming, conversational and background traffic) according to user preferences.

D. Network Selection

A selection of the most appropriate network in heterogeneous wireless networks had become as one of the most critical issues, due to demands from the users to get a seamless service. Authors [11], [13], [18]–[26] proposed a variety of methods in order to select the best network score. In MADM algorithms, the Simple Additive Weighting (SAW), Multiplicative Exponential Weighting (MEW), Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS), and Analytical Hierarchical Process (AHP) had become the chosen methods. However, TOPSIS had become as the most commonly used method in selecting the best network selection [2]. Instead of the MADM algorithms, the authors in [21] had proposed a hybrid method between game theory and AHP. The experiment showed the proposed method able to give competitive results of network selection strategy.

E. Performance Comparison of MADM Algorithms

A comparison of the MADM algorithm in selecting the best network for handover is very important as it can determine the best algorithms for handover strategies. Authors [8], [9], [12], [19], [22], [23], [27]–[29] had contributed their research strategies either by comparing their proposed method with the MADM algorithms or by comparing the performance between MADM algorithms itself. Drissi et al. [27] in their research work had compared the performance of SAW, MEW and TOPSIS for best network selection strategies. The AHP was used to provide weights for the attributes. Simulation results show that the proposed parameters provide an improvement of Delay and offer allowable Packet loss in different types of applications.

F. RATs Selection for a Group of Call

Previously, there were little attempts has been made to address a problem of group calls in HWNs. Only works by authors [30] and [31] have highlighted the mentioned issue. The investigation of vertical handover in a group call is very important as current technology nowadays had enabled the user to perform multiple services simultaneously when they are moving around. For example, authors in [31] addressed the Vertical handover (VHO) decision problem for group calls in HWNs as a complex multi-criteria group decision making (MCGDM) problem. They investigated the impact of dynamic criterion and the degree of the importance of the class of call in group calls by comparing with MULTIMOORA and TOPSIS. The result showed performances of TOPSIS are seen to be unstable in the high-speed region, unlike MULTIMOORA.

G. Mobility Pattern

Authors [32], [33] highlighted that past work frequently concentrates only on the present network circumstance when making handover decisions, thus disregard future performance of the terminal. Subsequently, a handover decision which good for the present minutes may soon wind up noticeably poor when the client moves to somewhere else. Therefore, authors [32] proposed an approach for making handover decisions, by exploiting user mobility patterns. The approach guaranteed that it could deliver high-performance handover decisions over the lengthy run. By implementing the Analytic Hierarchy Process (AHP), the algorithm was compared with the random algorithm and greedy algorithm. Demonstration result shows that the proposed algorithm is superior to the conventional vertical handover algorithms.

H. Handover Triggering

Authors [24], [34] highlight the issue of traditional vertical handover method that not good enough to support seamless connectivity for the user. This is because the handover should occur at the right position and at the right time. Therefore, a handover triggering based on the data rate which required by running applications on mobile devices has been proposed by authors [34]. A lowest possible data rate threshold has been defined based on the requirements for each application. The network selection is carried out using the Grey Relational Analysis (GRA). The proposed scheme indicated superior performance, and it outperforms existing schemes used for a similar purpose.

RQ2: What are the research approaches these studies apply?

From this study, we classified the research approach into three categories.

Table 2
Research Approach Facet

Research Approaches	Studies	Description
Traditional MADM	[2], [6]–[9], [11]–[13], [15], [16], [18]–[20], [22]–[25], [27]–[29]	Used traditional MADM algorithms without any amendments
Enhanced MADM	[2], [6], [9]–[14], [17], [21], [22], [26], [28], [32]–[34]	Make an improvement on the traditional MADM algorithms
Hybrid MADM	[9], [22], [30], [31]	Implementation of MADM algorithms with various VHO decision methods or framework.

As shown in Table 2, we classified the research approaches into three categories, which are traditional MADM, enhanced MADM, and hybrid MADM approaches.

1) Traditional MADM Approach

In this context, the traditional research approach used traditional MADM algorithms either in weighting or ranking stages. For example, authors [18] used the Analytic Network Process (ANP) the to determine the weights attributes the Grey Relational Analysis (GRA) method to rank the alternatives. Yadollahi et al. [16]; used SAW and TOPSIS for attribute weighting and ranking to reduce the processing delay and the number of extra vertical handovers.

2) Enhanced MADM Approach

We classified the enhanced MADM approaches as an improve methods on the traditional MADM algorithms either in weighting or ranking stages. Authors [9], [11], [13] had enhanced the weighting algorithm by using the fuzzy logic on the AHP and ANP which later on called as FAHP and FANP. Therefore, [10] had proposed the Enhanced- TOPSIS (E-TOPSIS) as a network ranking method in order to reduce the ranking abnormality and number of handover.

3) Hybrid MADM Approach

The classification of hybrid MADM approaches implemented the MADM algorithms with various vertical handover (VHO) decision methods or framework. For example,[21] modelled the network selection problem as the evolutionary and bankruptcy game in heterogeneous wireless networks. The Analytical Hierarchy Process (AHP) was utilised to calculate the weights of different attributes according to service requirement and evolutionary, and bankruptcy game theory was used as a ranking method to select the best network.

RQ3: What are the implications of these studies on MADM based vertical handover in the heterogeneous wireless network?

The implications of this mapping study on MADM based vertical handover were represented in Figure 2. The bubbles in Figure 2 shows the distribution of research papers according to the categories facet and research approach facet. Therefore, it is important to note that the total number of papers in the graph does not equal to the number of the papers analysed in the existing of a research study of the MADM methods as described in RQ1 and RQ2 due to the frequent map of papers in multiple categories.

In Figure 2, the bubble plots indicate that Performance Comparison between MADM algorithms and Network Selection had gained more attention from the researchers as compared to the other research studies. However, the algorithms used for performance comparison and network selections are more focusing on traditional algorithms of research approach in order to give the best result or the best network selection.

As a result, this study able to guide the researchers to focus on the other side of potential research areas, such as group call, mobility pattern and handover triggering. Besides, the researchers have some option, either to use the traditional, enhanced or hybrid methods as their research approach.

IV. Discussion

Instead of a common issue in MADM methods such as normalisation, weighting criteria, and ranking abnormality, the evidence from mapping study show that there is another potential research area can be explored more by researchers. These research areas include the RAT selection for a group of calls, mobility patterns, and the handover triggering.

As known, a heterogeneous wireless network able to support multiple services or calls such as email, file downloading and voice call at the same time. Hence, it requires the introduction of group decision- making and the assignment of priority weights to the multiple applications in the MADM algorithms [31]. In past research, there is a lack of evidence shows that the researchers considered this QoS environment. Therefore, the handover decision based on the MADM algorithms can be explored more by considering the group calls.

Beside of the group call category, the past research based on MADM approach also did not take into account regarding the handover triggering. Most of the research is focusing on the way to select the best network but did not consider the right time the handover can be performed. For example, a research done by [34] had opened new potentials of research gap as researchers have the option to manipulate MADM algorithms with different types of techniques.

Furthermore, there is also another potential of research areas can be explored by researchers. The existing work often focuses only on the current network condition when making handover decisions, ignoring the future performance of the terminal. As the user moves around, the handover decision good for the current moment may soon become poor when the user moves to another place. Hence researchers can explore the future performance of the terminal as one of the criteria to perform the handover.

Moreover, based on the result from Table 1 and Table 2, we had identified that the Euclidian method, max-min method, max method and sum method had become as the most common normalisation techniques used in MADM based vertical handover the in the heterogeneous wireless network. Besides, the AHP, ANP, FAHP, and FANP are among the most selected of MADM algorithms used to assign weight criteria.

V. Conclusion

As a conclusion, this study focused on the MADM based vertical handover in the heterogeneous wireless network. Three electronic databases have been used to investigate the studies by selecting 30 papers. From the systematic mapping study, we had identified another potential research direction that can be considered by researchers, including group call, mobility pattern and handover triggering. Furthermore, researchers can also focus on the several types of research approach methods, whereby they can integrate the traditional MADM based algorithm with the other vertical handover techniques, such as game theory. Therefore, this study mapping can serve as research gap and directions for researchers as previous review papers only focused methods and algorithms used to handover decision but do not redirect the researchers to find another potential of research directions in MADM based vertical handover of the heterogeneous wireless network.

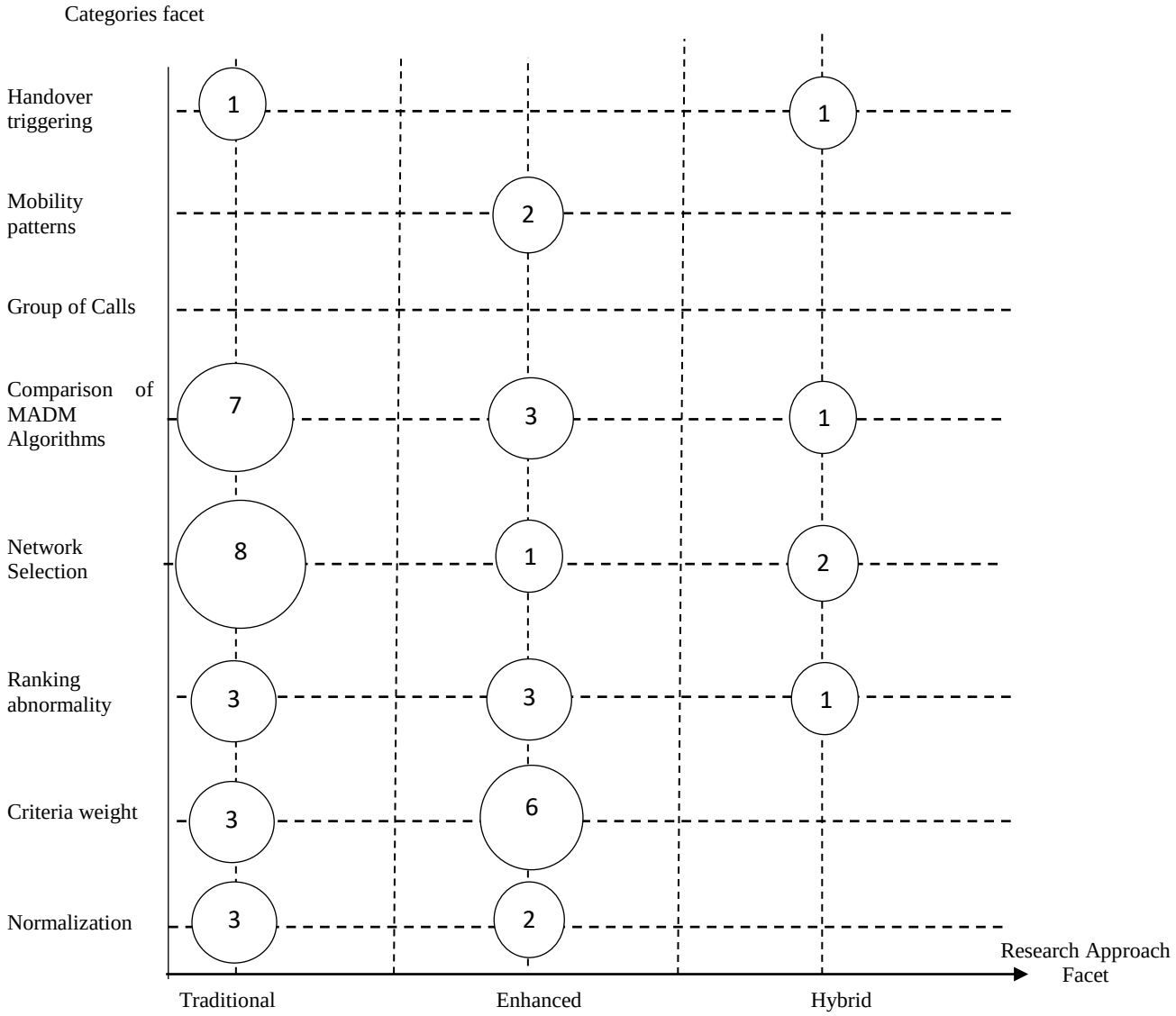

Figure 2: Bubble plot for the main categories against research approach facet.

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