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Simplified and improved multiple attributes alternate ranking method for vertical handover decision in heterogeneous wireless networks

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ABSTRACT

Multiple Attribute Decision Making (MADM) is one of the best candidate network selection methods used for Vertical Handover Decision (VHD) in heterogeneous wireless networks (4G). Selection of the network in MADM is predominantly decided by two steps, i.e., attribute normalization and weight calculation. This dependency in MADM results in an unreliable network selection for handover, and in a rank reversal (abnormality) problem during the removal and insertion of the network in the network selection list. Hence, this paper proposes a Simplified and Improved Multiple Attributes Alternate Ranking method referred to as SI-MAAR to eliminate the attribute normalization and weight calculation methods, thereby solving the rank reversal problem. Further, the MATLAB simulation results demonstrate that the proposed SI-MAAR method outperforms MADM methods such as TOPSIS, SAW, MEW and GRA with respect to the network selection reliability and rank reversal problems.

1. Introduction

The characteristics of heterogeneous wireless networks, Quality of Service (QoS) stipulations of applications [1,2], users' anticipation in terms of perceived QoS [3], monetary cost and battery power [4,5], and service providers' obligations introduced many challenges in 4*th* Generation (4G) heterogeneous wireless networks [6–9]. Integration of heterogeneous wireless networks like non-IEEE: GPRS, UMTS and IEEE: WiMAX, WiFi etc., is essential in 4G networks in order to provide *Always Best Connected* (ABC) anywhere at anytime [10]. Designing an optimized and efficient mobility management scheme for seamless communication [11] in heterogeneous wireless networks is a key challenge because of the diverse properties of non-IEEE and IEEE wireless access systems [9,10,12], user and application stipulations, multiple interface mobile device capabilities [13] and service providers' obligations.

Mobility management in heterogeneous wireless networks is defined as the process of Heterogeneous Information Gathering (HIG), Vertical Handover Decision (VHD) and Vertical Handover Execution (VHE) for the seamless communication of mobile devices between disparate radio access networks [14,15]. VHD is one of the prominent steps of mobility management in heterogeneous wireless networks for selecting the next suitable network for a seamless handover of mobile devices between the '*n*' available heterogeneous wireless networks [16]. Many VHD strategies [17–20] have been proposed in the literature, such as Function-based, User-Centric, Markov [21], Fuzzy Logic [22], Multiple Attribute Decision Making (MADM) [23] and Game Theory [24] with differing complexity, flexibility and reliability. In heterogeneous wireless networks, the handover may not always be due to weak received signal strength (Horizontal handover) [25], but could also be due to an improvement or degradation in the Quality of Service (QoS) attributes of the networks or variations in the expectations of the user, mobile device or applications. Multiple interface Mobile Nodes (MN) have limited resources of battery lifetime [26], computational capabilities and memory; hence it is essential to have an optimized and simple multiple attributes VHD method for seamless migration of MN in heterogeneous wireless networks. Among the existing VHD schemes, MADM is one of the strategies that considers multiple attributes with medium complexity [19,27]. On the other hand, the complexity of other VHD strategies increases with an increase in the number of attributes. Hence, in our proposed work we focus only on classical MADM methods. Table 1 shows a comparison of the salient features of different existing VHD strategies for heterogeneous wireless networks.

Many classical MADM methods [18,29] such as Simple Additive Weight (SAW), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [30,31], Multiplicative Exponent Weighting

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Table 1
Comparisons of existing VHD strategies [17,19,27,28].

VHD strategies	User consideration	Multi-attribute	Complexity	Flexibility	Reliability	Multi-service
Function-based	Medium	Yes	Low	High	Medium	No
	Merits: minimum degradation in high load and congestion situations.					
	Demerits: time consuming if services and/or available access points increase.					
User-centric	Strong	Yes	Low	High	Medium	No
	Merits: maximizes users' utility and low implementation complexity.					
	Demerits: non-real-time support, simple rate prediction method and medium precision.					
MADM	Medium	Yes	Medium	High	Medium	No
	Merits: multiple criteria consideration, easy to implement, scalable and accurate results.					
	Demerits: medium implementation complexity, selection of suitable method and normalization.					
Markov	Low	Yes	Medium	Medium	High	No
	Merits: adaptive and applicable to a wide range of conditions.					
	Demerits: implementation complexity.					
Fuzzy Logic	Medium	Yes	High	Low	High	No
	Merits: makes decisions in an autonomous way, considers multiple criteria.					
	Demerits: complexity increases if additional input parameters are considered.					
Game Theory	Strong	Yes	Medium	Medium	High	No
	Merits: efficient resource management.					
	Demerits: additional decision parameters are required in practice to ensure better quality of service.					
Reputation	Medium	Yes	Medium	Medium	Medium	No
	Merits: faster VHD decision-making.					
	Demerits: reputation sustainability needs to be addressed in greater depth.					

(MEW) [29], ELimination Et Choice Translating REality (ELECTRE) [29], Grey Relational Analysis (GRA) [29,32] and Preference Ranking Organization METHods for Enrichment Evaluations (PROMETHEE) are extensively discussed in the literature [20]. These classical MADM methods are not only limited to the field of networking, but are also popularly used in areas like Logistics and Supply Chain Management, Design, Engineering and Manufacturing Systems, Business and Marketing Management, Health, Safety and Environmental Management, Human Resources Management, Energy Management, Chemical Engineering, and Water Resources Management [29,30].

Table 2 shows a comparison between the different classical MADM methods with respect to procedure- and application- based merits and demerits.

The major problem with classical MADM methods is their dependency on the attribute normalization and weight calculation methods. Hence, these dependencies not only provoke unreliable selection of the network for handover [27], but also give rise to a rank reversal (abnormality) problem in the case of the removal and insertion of the network in the network selection list during network ranking [34]. The rank reversal problem with classical MADM methods leads to the reversal of the relative ranking of the networks if an alternative network is removed from or inserted into the candidate network selection list. For example, consider the ranks of three different networks N1, N2 and N3 as $Rank_{N1} > Rank_{N2} > Rank_{N3}$. The removal of network N1 should result in the rank of the other two networks becoming $Rank_{N2} > Rank_{N3}$. However, as in classical MADM methods, computation of network rank and score depends on the remaining other networks' attribute values, the removal of network N1 may result in the rank of the other two networks becoming $Rank_{N3} > Rank_{N2}$, resulting in a rank reversal problem. The same may be observed when a new network is inserted into the network selection list. Moreover, the presence of a rank reversal problem with classical MADM methods raises a reliability issue with respect to the selected network for handover.

The unreliability in network ranking and the rank reversal problem of classical MADM methods are the key challenges for the seamless handover of MNs in heterogeneous wireless networks. This is as wrong selection of a network during the VHD in heterogeneous wireless networks results in poor Quality of Service (QoS) of the applications in terms of high packet delay, packet loss, unnecessary handover (ping-pong effect) and handover failure (rejecting the MN handover request by the selected network due to insufficient resources). Further, this may lead to user dissatisfaction and high consumption of mobile device resources such as memory and battery life. Hence, there is a need for improving the reliability of the network selection of classical MADM methods, thereby eliminating dependence on the attribute normalization and weight calculation methods.

The main challenge in improving the reliability of network selection and eliminating the rank reversal problem is replacing the existing VHD's heterogeneous attribute normalization by its equivalent, as well as removing the VHD's heterogeneous attribute weight (which signifies its importance) during the computation of the network rank. In classical MADM methods, executing attribute normalization and weight computation are the two specific steps to proceed with the ranking of the networks: this motivated us to design a novel and simplified MADM method to overcome the unreliable network selection and the rank reversal problem of classical MADM methods. The main idea of our proposed simplified and improved MADM method is to overcome the key limitations of existing classical MADM methods used for VHD in heterogeneous wireless networks. To overcome unreliable network selection and the rank reversal problem of classical MADM methods, we propose a mobile device controlled Simplified and Improved Multiple Attributes Alternate Ranking method referred to as SI-MAAR. This can be achieved by replacing attribute normalization and weight calculation methods by a simple closeness index (utility) matrix which is computed by the networks' attributes and the expectations of the same. Further, to overcome the rank reversal problem, we propose new positive and negative ideal solutions based on the benefit and cost attributes.

Our key research contributions in this paper are, to the best of our knowledge:

- The first paper on mobile device controlled Simplified and Improved Multiple Attributes Alternate Ranking method referred to as SI-MAAR which is independent of the attribute normalization and weight calculation methods for achieving 100% network selection reliability.
- The first approach for completely avoiding the rank reversal problem of classical MADM methods.

The rest of the paper is organized as follows: Section 2 addresses the background and related work in the area of VHD; Section 3 presents a performance analysis of the classical MADM methods: TOPSIS, SAW, MEW and GRA; Section 4 presents the proposed method for solving the network selection unreliability and rank reversal problems; finally, the conclusion and future work are given in Section 5.