NETWORK SELECTION IN HETEROGENEOUS NETWORK USING ANALYTIC HIERARCHY PROCESS

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ABSTRACT In future wireless network, the integration between different networks is important to offer Always Best Connectivity (ABC) to the users. The integration of various network is called a heterogeneous network. In order to answer ABC requirement, vertical handover is very important when the users move in the heterogeneous network. Recently, various study focuses on the vertical handover decision strategies. However, a few focus on using Multi-Attribute Decision Making (MADM) method as the vertical handover decision strategy. One of the MADM methods known as Analytic Hierarchy Process (AHP) will be discussed in this paper. The AHP is used to choose the preferable network using five parameters which are cell radius, data rate, applications, cost per bit and user's speed. The analytical results are presented based on user's application and user's speed. The user's application is divided into two categories which are real-time and non real-time. In addition, the user's speed is categorized into three groups which are slow speed, medium speed and fast speed. The three networks considered in this paper is 3G, WiFi and Long Term Evolution (LTE).

1. INTRODUCTION

The implementation of Long Term Evolution (LTE) is expected to complement with other technologies to empower Mobile User (MU) connectivity. The MU can be a smartphone or tablet user and it also can be a travelling user that uses laptop. Certainly, the MU is expected to have ABC regardless of time, location and application. Therefore, mobility management is important since MU will roam between the technologies.

Mobility management consists of two elements which are the location management and the handover management. The location management is a process of identifying and tracking the current position of a MU whilst the process of changing the associated network is called the handover management (Ali-Yahiya, 2011).

Handover is a process of changing the associated network to a new network while a call is in progress. The handover is categorized into two which are horizontal handover and vertical handover. The horizontal handover is a process of changing the current channel in a same network, whereas the vertical handover is a process of changing the associated channel to a new different network.

The integration amongst different technologies such as Wireless Fidelity (WiFi), Worldwide Interoperability for Microwave Access (WiMAX), Universal Mobile Telecommunication System (UMTS) and LTE require vertical handover process. However, there are several issues arising in the vertical handover process (Akyildiz, Xie, & Mohanty, 2004); access technologies, architecture and protocol between technology and service demands. Access technologies amongst the heterogeneous network use different radio technologies and different size of the coverage area. The heterogeneous networks operate on different network architectures and protocols for mobility management process. In addition, the MU demand applications that ranging from low data rate up to high speed real-time multimedia applications. Therefore, the handover decision is a challenging process in vertical handover.

AHP is a MADM developed by Dr. Thomas L. Saaty in 1971. It is a tool to solve complex decision making by reducing complex decisions to a series of pairwise comparisons and then synthesizing the results. Furthermore, AHP allows a decision maker to express personal preferences and subjective judgment about various aspects of a multi-criteria problem (David R. Anderson, Dennis J. Sweeney, Williams, & Martin, 2008). Another advantage of AHP in solving engineering problem is AHP can handle decision even though the criteria are expressed in different units or the pertinent data are difficult to be quantified (Triantaphyllou & Mann, 1995). In addition, the AHP incorporates a useful technique for checking the consistency of the decision maker's evaluations, thus reducing the bias in the decision making process (David R. Anderson et al., 2008).

The rest of this paper is organized as follows. The related works is discussed in Section II. The AHP method used for network selection is described in Section III. After that, the analytical results obtained are reported in Section IV. Finally, the conclusion conclude this paper.

2. ANALYTIC HIERARCHY PROCESS

AHP requires the decision maker to provide judgment on the criteria or alternatives in a natural way, using pairwise matrix. Then, the judgment is converted into ratio scale weight where it gives a prioritized ranking of the decision alternatives. The methodology of the AHP will be explained in the following six steps (Alessio Ishizaka, 2011; Ernest H. Forman and Saul I. Gass, 2001; Navneet Bhushan and Kanwal Rai, 2004; Triantaphyllou & Mann, 1995); Developing the hierarchy, Pairwise Comparison, Pairwise Comparison Matrix, Synthesization, Consistency and Developing Overall Priority Ranking.

2.1 Developing the Hierarchy

The first procedure is decomposing the problem into a hierarchy of the overall goal, criteria and alternatives of the decision. This is an important procedure because a different structure may lead to a different final ranking (Alessio Ishizaka, 2011). Figure 1 shows the example of the hierarchy structure.

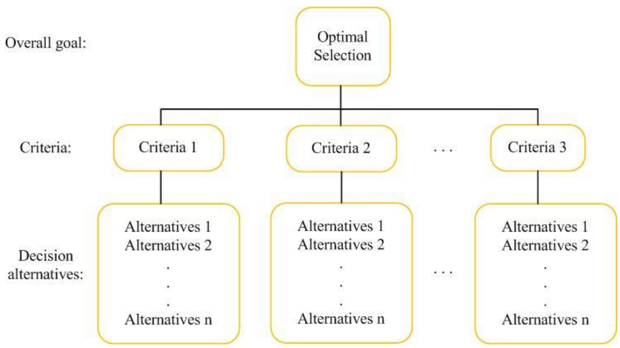

Fig. 1: The hierarchy structure

As can be seen in the Fig. 1, the hierarchy consist of three level. The first level considers the overall goal of the decision. Then, the criteria for the selection are listed at the second level. Finally, the possible decision alternatives for each criteria are listed at the third level. The hierarchy can be more than three level, depending on the decision that is going to be made.

2.2 Pairwise Comparison

In this procedure, decision maker in AHP will make comparison to the established priorities for the criteria and decision alternatives based on criteria using ratio scale. Therefore, no units are involved in making the comparison. The scale which is proposed by Dr. Saaty is listed in Table 1 (David R. Anderson et al., 2008).

Table 1 Comparison scale

Verbal Judgement	Numerical Rating
Extreme importance	9
Very, very strong	8
Very strong	7
Strong plus	6
Strong	5
Moderate plus	4
Moderate strong	3
Weak	2
Equal strong	1

2.3 Pairwise Comparison Matrix

Then, the pairwise comparison discussed before is transformed into a square matrix as in (1).

$$\begin{matrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{matrix} \quad (1)$$

a_{ij} represents the relationship between the i^{th} row and the j^{th} column. If a_{ij} is more than 1, the criteria of the i^{th} row is better than the criteria in the j^{th} column otherwise the criteria of the j^{th} column is better that the criteria in the i^{th} row.

2.4 Synthesization

Synthesization in AHP is a process to find the priority of each criteria. The priority shows the contribution to the overall goal. There are three steps involved in the synthesization procedure:

a. Sum the elements of each column *j*

$$\sum_{i=1}^{n} a_{ij} \ \forall i, j \quad (2)$$

b. Divide each element in the pairwise comparison matrix by its column total. The results are known as the normalized pairwise comparison matrix.

$$a'_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \ \forall i, j \quad (3)$$

c. Calculate the average of the elements in each row of the normalized pairwise comparison matrix. The averages show the priorities for the criteria.

$$p_{i1} = \frac{\sum_{j=1}^{n} a'_{ij}}{n} \quad (4)$$

2.5 Consistency

The priorities previously described make sense only if they are consistent. However, perfect consistency is hard to achieve in practice. Therefore, Saaty has proposed a consistency index (*CI*) which is related to the eigenvalue method. The formula of the CI is shown in 5.

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (5)$$

where n is the number of criteria. Calculation of λ_{max} is formulated in 6.

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^{n} \frac{w_{i1}}{p_{i1}} \quad (6)$$

λ_{max} also known as maximum eigenvalue. The weighted sum factor is w_{i1} and it is calculated using 7.

$$w_{i1} = p_{i1} \times A \quad (7)$$

After getting the value of *CI*, the Consistency Ratio (*CR*) can be defined using 8.

$$CR = \frac{CI}{RI} \quad (8)$$

where *RI* is the consistency index of a randomly generated pairwise comparison matrix. The value of RI depends on the number of items being compared and is given in Table 2 (David R. Anderson et al., 2008).

Table 2. Reference table for RI value

n	3	4	5	6	7	8
RI	0.58	0.90	1.12	1.24	1.32	1.41

The pairwise comparison matrix is only acceptable if the value of *CR* meets the requirement as below.

$$CR = \begin{cases} = 0 & \text{Complete consistency} \\ \leq 0.10 & \text{Allowable} \\ > 0.10 & \text{Unallowable} \end{cases}$$

2.6 Develop Overall Priority Ranking

Pairwise comparison matrix discussed before is stated for criteria only. To calculate the overall ranking, after checking the consistency of the criteria, procedure in Section 2.2-2.4 are repeated for the alternatives. Therefore, the overall ranking can be calculated using formula in 9.

$$O\_Ranking = \sum_{i=1}^{n} w_{i1} x t_{i1} \quad (9)$$

where t_{i1} is the weighted sum factor for the alternative whilst w_{i1} is the weighted sum factor for the criteria.

3. RESULT AND DISCUSSION

The main consideration for the overall priority is the application used. The application considers are real-time and non-real time whilst the speed are slow speed, medium speed and fast speed. The range of the slow speed is 0-10 m/s, considering walking speed, cycling speed and very low car speed. The range for the medium speed is 11-25 m/s, considering the normal car speed in urban and suburban area. The range of the fast speed is 26-35 m/s, considering car speed in Malaysia's highway. The preferable network selection for real-time application is shown in Fig. 2.

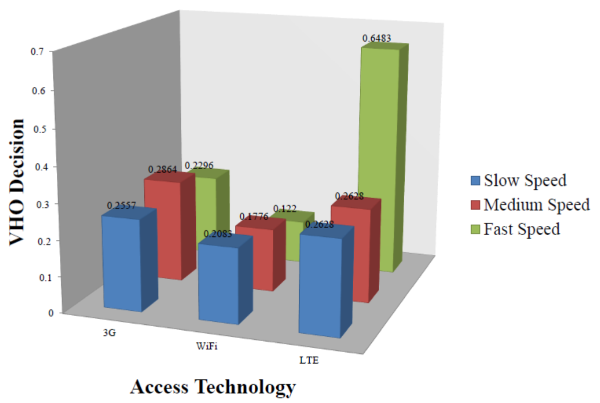

Fig. 2: Real-time application

As can be seen in Fig. 2, LTE network is the most preferable network for fast speed user followed by 3G network and WiFi network. This scenario happens due to the high data rate offered by the LTE network and it supports high speed users. 3G network becomes the second candidate because it offers less data rate than 4G and also support mobility user. WiFi network is not suitable for the moving users because it has smallest area coverage and IP handover suffers high handover latency and not suitable for real-time application.

The next analysis is on non-real time application and the result is shown in Fig. 3.

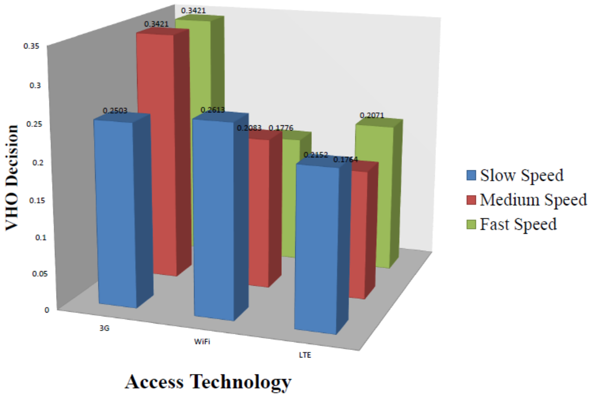

Fig. 3: Non-real time application

In this scenario, WiFi network is the best candidate for slow speed user due to the probability that the user will not handover to another network. Besides the application is tolerated with time, user pays less using WiFi network and does not need high data rate. Conversely, when the user is moving at medium or fast speed, 3G network becomes the best network candidate. For medium speed users, WiFi network has higher priority compared to LTE. This is because data rate and cost per bit offered by WiFi is acceptable for the application. Though, for the fast speed user, LTE network has higher priority compared to WiFi network because WiFi network does not support fast speed user.

CONCLUSION

In this paper, AHP is used in the vertical handover decision strategy. The goal of the handover decision is to select the best network amongst WiFi, 3G and LTE. There are five criteria considered in making the decision which is cell radius, data rate, application, cost per bit and user's speed. The results obtained is based on user's application and three categories of user's speed; slow, medium and fast. The obtained results are in priority form, where the highest priority is the most preferable network to choose. This proposed method and solution shows the best answer for ABC and vertical handover strategy as it gives high flexibility, high efficiency and low in complexity.

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