Cognitive Selection Mechanism for Indoor Propagation

W. Hashim, A. F. Ismail, S. Dzulkifly, and N. A. Abd Ghafar

***Abstract*—The evolution of communication device demands for faster connection and higher data rates. This results in proliferation of new broadband technologies that are being introduced into the market for each interval of every 2 to 3 years. However, these technologies are still facing the challenge of unsatisfied users who request not only faster connection but also reliable connectivity. This paper proposes two cognitive selection mechanisms termed as successive and comparative selection which are applied in multiple broadband user terminals in order to maintain good connection rate. By employing such mechanisms, we can observe their performances in terms of optimized speed and switching delay. Cognitive radio aspects are also introduced within the selection system. These include sensing network condition capability, performing analysis and decision making for selecting the most optimum broadband network. The empirical study was conducted within the indoor environment of a residential area. The location was selected to vary the evaluation of the performance of these selection mechanisms. It was found that successive selection had shown a better optimized speed performance up to 37% improvement as compared to comparative selection. However, comparative selection shows a low switch delay performance in contrast to successive selection.**

***Index Terms*—Cognitive radio, indoor propagation, multiple broadband, intelligent system, selection mechanism.**

I. Introduction

The need for terabytes data communication in the future demands for a higher connection bandwidth [1]-[3]. Due to the scarcity of wireless spectrum resource, bandwidth aggregation or adaptive network switching are seen as one of the most potential and practical solutions to meet such demand. This is where cognitive selection mechanism (CSM) plays its role. The fundamental theory in cognitive radio (CR) comprising of three key concepts namely sensing, analyzing and decision are applied as the central frame in CSM [4]. The process of sensing and initiating changes within the radio system while providing consistent network connection are among the techniques developed in CSM. Another aspect of cognitive sciences deployed is the artificial intelligence (AI) to smartly choose and decide for best network selection. This is achievable by implementing such components in an ingenious algorithm that capable of controlling the network selection at the physical layer of a communication device.

Having described the theoretical elements of CSM, this study enhances such fundamental intelligence by incorporating several subscribed broadband services selections with new selection parameter and technique as shown by Fig. 1. These broadband services could consist of global system for mobile communications (GSM), general packet radio service (GPRS), long term evolution (LTE) and worldwide interoperability for microwave access (WiMAX).

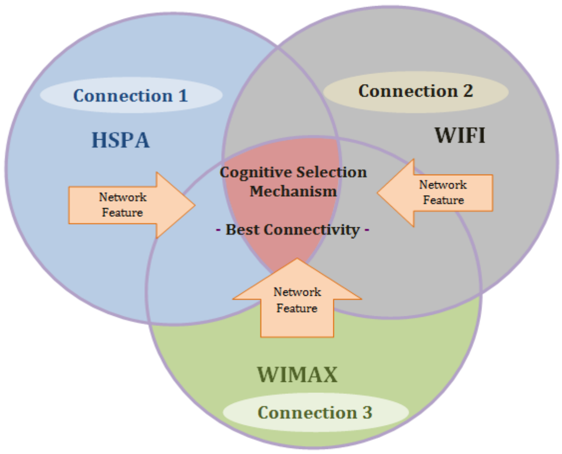

Fig. 1. Proposed cognitive selection mechanism concept.

The parameter deployed is based on the network "physical speed" in contrast to the common network selection criteria, i.e. received signal strength (RSS). This is due to the fact that high connection speed characterizes the actual network condition fast or slow as compared to RSS that solely portrays the connection strength [1] which tell more on the distance of a device to the network base station. Structured internal analysis is engaged in the selection mechanism proposed to analyze the real-time behavior of the network. This type of selection is more aggressive when implemented within busy networks.

There exist several devices that incorporate cognitive selection capabilities element such as WiFiRanger [5], MiFi2352 [6] and NCIT Mobile Wireless Router [7]. However, through the review that had been carried out, none of these products' cognitive capability able to switch network based on the network behavior let alone be network switching based on connection speed. In order to provide the communication device with a proactive decision making while maintaining minimal complexity of the system, the algorithm has to be made efficient without compromising the broadband spectrum.

This paper highlights two proposed concept of real-time network behavior based cognitive selection mechanism for multiple broadband devices i.e. 1) successive selection and 2) comparative selection. For our empirical study, we have incorporated these two concepts into our multiple broadband radio system and evaluate each selection mechanism performance within the indoor propagation environment. The

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evaluations include the performance improvement with and without the proposed concepts in terms of the reliable connection speed as well as delay of the decision making process when switching from one network to another.

The rest of this paper is organized as follows. Section II describes the selection mechanism, system model and the experimental setup. Section III covers brief explanation on the system parameters. Experimental results and discussion are elaborated in Section IV. Finally, Section V presents the concluding remarks.

II. Selection Mechanisms

This section describes on our proposed selection mechanism i. e. successive selection and comparative selection concepts as well as the experimental set up.

A. Successive Selection

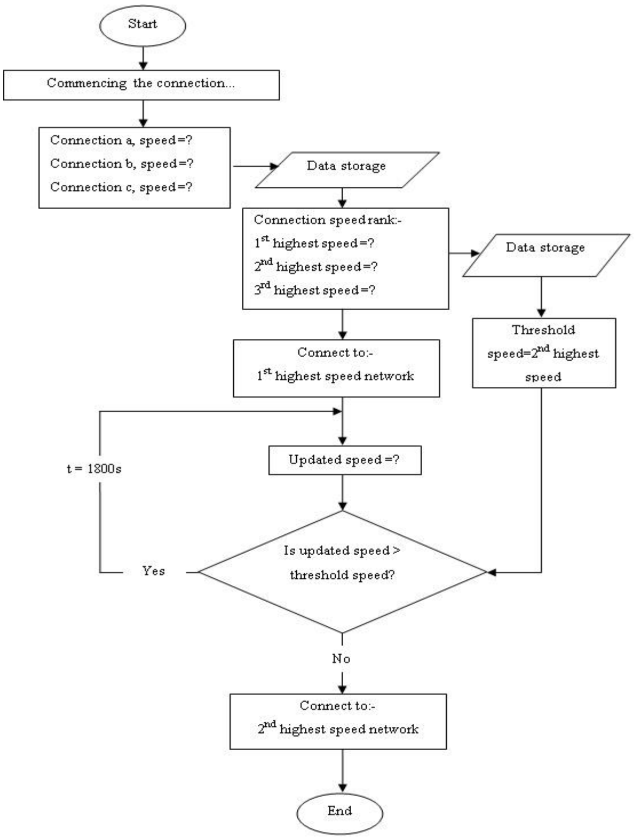

Fig. 2. Successive selection mechanism.

Our proposed successive selection able to perform the scanning, evaluating and sorting process for finding the best available subscribed wireless broadband connections within specified interval period of time. It is through scanning and evaluating process that this concept manipulates the behavior of the network in its decision making. Fig. 2 highlights the flow diagram of successive selection. It begins with randomly connect to any subscribed network. Once connected, the selection mechanism will start by downloading a specified file size that would indicate the connection speed. This is then captured and stored within a temporary database. It is then disconnects with the first network and repeats the same process with the rest of the networks. The connection speeds that had been captured in the database are then ranked in the descending order. The selection mechanism will select and connect to the network with the highest connection speed.

This process will be repeated for an interval period of time. The time interval is established depending on the rate of connection speed fluctuation. The fluctuation could vary based on several factors such as the state of the terminal whether mobile or stationary, wireless interference e.g. broadband signal interfered with another signal of similar frequency, network traffic congestion etc. In this study 1800s was specified as the interval of time for the program to repeats its evaluation and selection of the best connectivity process. Due to this repeated scanning process within the specified time interval, this selection mechanism suffers moderate network switching delay. The approximate delay will be discussed in Section IV of this paper. Such switching delay may cause inconvenient network interruption to the users.

B. Comparative Selection

Comparative selection is developed to overcome the limitation endured by the successive selection. In this selection mechanism concept, a specified threshold value is introduced. The model switches the connectivity only when the "in progress" connection speed is identified as lower than the threshold value. This is the divergence between successive and comparative selection model. Fig. 3 illustrates the simplified version of comparative selection concept.

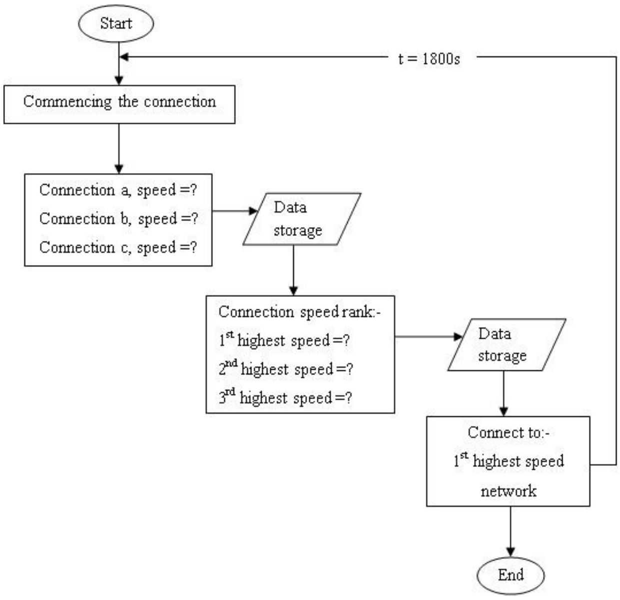

Fig. 3. Comparative selection mechanism.

At the initialization stage, this comparative mechanism automatically scans the speed of each individual connection. Connection speed data are then stored and ranked in a temporary database. The second highest connection speed rate is established as the threshold and become primary trigger in changing the connection. The model then selects and connects to the network with highest speed value. The network is then being monitored within the time elapse of 30 minutes or 1800s to check its updated speed connectivity. The current connection speed value retrieved is compared with the threshold value. If the new connection speed value is higher than the threshold speed value, it remains with the same connection. However, if the new connection speed rate is lower than the threshold speed rate, it will switch the connectivity to the threshold network. The applicability of this concept is subject to the frequent of threshold value updates in the system.

If the threshold value is only one off at the beginning, whenever the current connection speed is starting to go down, the comparison with the threshold is not the most recent one of the day. However this concept certainly reduces the delay since it does not require any network scanning everytime switching is required. The performances of these two concepts are compared in real environment.

C. System Architecture

The system architecture is best illustrated in Fig. 4 whereby the selection algorithms are incorporated in the communication device with subscribed broadband networks.

Fig. 4. Multiple broadband communication device with network selection algorithms.

D. Experimental Set Up

Fig. 5. Residential experimental set up

A computer was emulated as an access point with two subscribed broadband networks namely HSPA and WiMAX (Fig. 5). Wi-Fi was added as the third network. Selection algorithms are preprogrammed in the access point. The instruments were assembled and positioned at specified fixed spot within the residential area.

The first stage of the investigation was gathering the individual connection speed data. The data were averaged within a period of time to observe the connection speed pattern. The second stage involved supervising the two selection mechanisms. These two selection mechanisms were then compared to the individual connection speed data as presented in the experimental results section of this paper.

E. System Parameters

Our system parameters for laboratory experiment are listed in Table I.

TABLE I: SYSTEM PARAMETERS

Parameter	**Description**
Spectrum band	HSPA – 2.1 GHz, WiMAX – 2.3 GHz, WiFi – 2.4 GHz
Operating system	Ubuntu 12.04 LTS
Location	Residential indoor environment
GPS location	3 °2' 59.4996", 101 °45' 49.6944"
Data monitoring time	8am – 5pm
Subscribed network	HSPA, WiMAX
Free network	WiFi
No of days monitoring	1 month
Download file size	2 Mbit

F. Connection Speed and Delay Quotient

The selections capability to provide optimized connection speed and switching delay are the key criteria in evaluating their performance. Is it carried out by enumerating the average overall connection speeds, *n* and delays, *d*. Equation (1) denotes the connection speed performance calculation while equation (2) denotes the network switching delay performance.

$$P_s = \sum_{i=1,\, j=1}^{n} \frac{n_{i,i+1,i+2...k}}{n_{j,j+1}} \tag{1}$$

In (1), P_s is the connection speed performance; n_i is the connection speed; and n_j is the number of connection speed data.

$$P_d = \sum_{i=1,\, j=1}^{d} \frac{d_{i,i+1,i+2....k}}{d_{j,j+1}} \tag{2}$$

In (2), P_d is the network switching delay performance, d_i is the network switching delay and d_j denotes the number of switching delay data.

III. EXPERIMENTAL RESULTS

This section provides itemized analyses on the cognitive selection algorithm that had been developed. It is also presents detailed analyses on each particularized connectivity speed that had been accumulated for specific measurement period. Illustrated in Fig. 6 is the average individual connection speed, namely HSPA mobile broadband, WiFi and WiMAX. The data was gathered to justify the assumption that the networks connection speeds display fluctuations while the user terminal is static, i.e. not in motion for 24 hours. From Fig.6, the connection speeds of the three network broadbands vary with HSPA mobile broadband showing an average speed of 4.16 Mbps, WiFi 0.92 Mbps, and WiMAX 2.52 Mbps. Despite high average speed shown by HSPA, its connection had suffered connection speed degradation at a certain point of time (i.e. at 1.30 pm, 10.30 pm and 7.50 am the next day). Similar occurrence can be noted for the other connection; WiMAX and WiFi. From the individual analyses that had been carried out, the appropriate loop time frame for the selection mechanisms was specified to 30 minute or 1800 seconds.

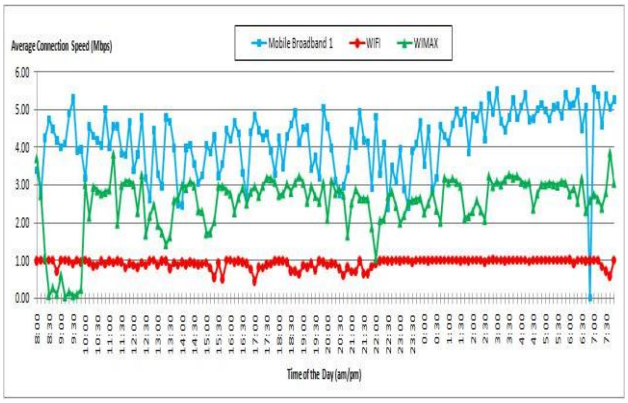

Fig. 6. Connection speed behavior of subscribed networks without any selection algorithm.

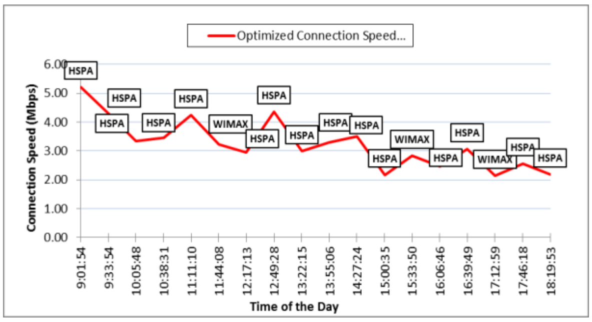

Fig. 7. Connection speed behavior with successive algorithm.

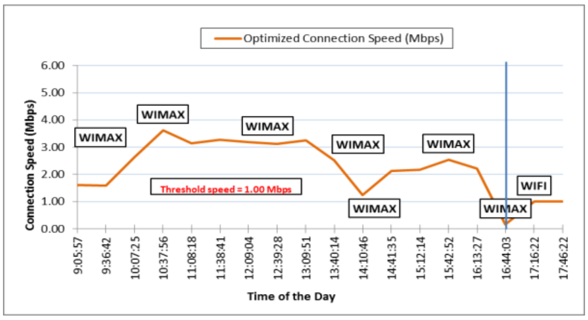

Fig. 8. Connection speed behavior with comparative algorithm.

Deploying both successive and comparative selection mechanism into the system had shown to improve the average connection speed by switching among those three networks as illustrated in Fig.7 and Fig. 8 respectively.

Further analysis was carried out to compare how much improvement these two selection mechanisms could provide. With reference to Fig. 9, indicated by the green bar in the graph is the average of the three individual connection speeds that had been gathered i.e. 2.37 Mbps. Successive selection, the purple colored bar has shown a significant increase in average connection speed from 2.37 Mbps to 3.24 Mbps due to optimized selection. Meanwhile, the blue colored bar that indicate the comparative selection has shown a very small decrement of connection speed with average value at 2.28 Mbps.

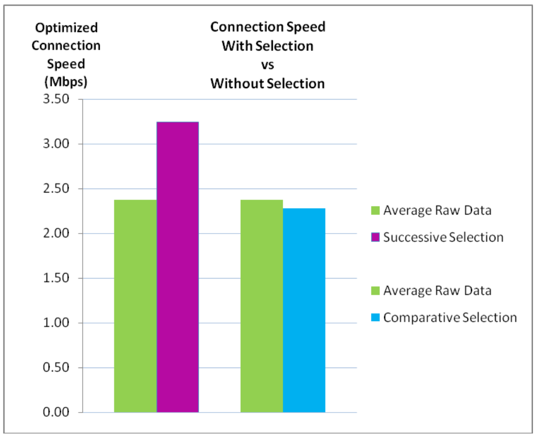

Fig. 9. Connection Speed with the selection vs. without selection.

The slightly low optimized connection performance shown by comparative selection is compensated by low network switching delay when compared with successive selection. This is illustrated in Fig. 10. Comparative selection suffered the delay with the factor of 0.16 whilst successive selection experienced 0.54 delay factor. Such high delay factor makes successive selection not suitable for real-time data communication such as video call but more suitable for non-real time application.

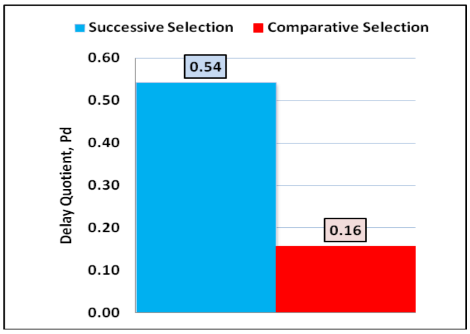

Fig. 10. Delay quotient of successive selection vs. comparative selection

TABLE II: SELECTION ALGORITHMS DEGREE OF IMPROVEMENT

Improvement Criteria	Successive Selection	Comparative Selection
Connection speed improvement (%)	0.37	- 0.04
Switching delay quotient	0.54	0.16

Summarized in Table II is the degree of improvement posed by successive and comparative selection in terms of connection speed and switching delay. Successive selection depicts an optimized connection speed improvement of 37% as compared to average individual connection speed. Comparative had shown slightly low performance which is – 0.04. This might occur due to non-reactive characteristic that exists within the selection. However, comparative had shown low switching delay, P_d=0.16 as compared to successive selection P_d=0.54. This means comparative able to provide connectivity without high interruption to user.

IV. Conclusion

The speed of service in wireless broadband packages are all founded on the best efforts basis. This is the kind of broadband service that has no service level assurance. It has been observed that the actual speeds experienced may be slower than the package subscribed and can vary significantly throughout the day and over time. Among factors affecting delivered speeds include: time of the day where the amount of internet traffic varies throughout the day and at bust times where speeds may be reduced, another involves contention as uptake of broadband i.e. number of user, increases in a given base station where speeds may as well reduce over time

Cognitive selection mechanisms have been researched in the pursuit of securing the best internet connectivity at all time. The selection algorithms have shown promising results where performance improvement in terms of optimized speed and switching delay respectively had been achieved. Such successive selection can be employed by the system or user that requires continuous optimized connection speed but less critical on the delay. Whereby for user or system that requires constant and stable network connection regardless of the connection speed could utilize comparative selection. These selection mechanisms are best suited to be applied within the user's broadband device to cater the demand of getting good connectivity.

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