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USER-CENTRIC BASED VERTICAL HANDOVER DECISION ALGORITHM FOR TELECARDIOLOGY APPLICATION IN HETEROGENEOUS NETWORKS

Hoe Tung Yew[a,b], Eko Supriyanto[a], M. Haikal Satria[a], Yuan Wen Hau[a*]

[a]IJN-UTM Cardiovascular Engineering Centre, Faculty of Biosciences and Medical Engineering, Universiti Teknologi Malaysia, 81300, UTM Johor Bahru, Johor, Malaysia
[b]Faculty of Engineering, Universiti Malaysia Sabah, Malaysia

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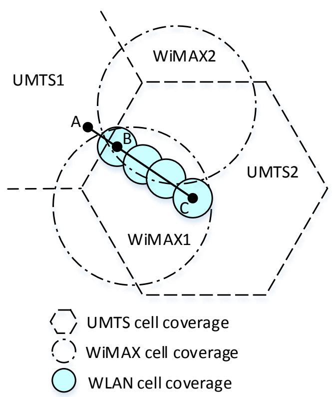
*Corresponding author
hauyuanwen@utm.my

Graphical abstract



VHO in Heterogeneous Wireless Networks

Abstract

The traditional telecardiology system which is integrated with a single wireless technology is unable to guarantee the patient always get connected to the telecardiology service provider. To overcome this problem, an adaptive user-centric based vertical handover algorithm is proposed to allow the telecardiology system operates in heterogeneous wireless technologies. The proposed algorithm guarantees the quality of service and maintains the user's satisfaction at the highest level. The algorithm was compared with traditional quality of service based and cost based vertical handover algorithms. The results show that proposed algorithm is performed better than the traditional algorithms.

Keywords: Telecardiology, vertical handover, heterogeneous wireless technologies, quality of service

Abstrak

Sistem telekardiologi tradisional yang mengintegrasikan satu wayarles teknologi tidak dapat menjamin pesakit sentiasa berhubung dengan pembekal perkhidmatan telekardiologi. Untuk mengatasi masalah ini, algoritma penyerahan menegak berdasarkan keperluan pengguna dicadangkan untuk menbenarkan sistem telekardiologi beroperasi dalam teknologi wayarles heterogen. Algoritma yang dicadangkan menjamin kualiti perkhidmatan dan mengekalkan kepuasan pengguna di peringkat yang tertinggi. Algoritma yang dicadangkan telah dibandingkan dengan algoritma tradisional berdasarkan kualiti perkhidmatan dan juga algoritma berdasarkan kos. Keputusan menunjukkan bahawa algoritma yang dicadangan mempunyai prestasi yang lebih baik daripada algoritma tradisional.

Kata kunci: Telekardiologi, penyerahan menegak, teknologi wayarles heterogen, kualiti perkhidmatan

1.0 INTRODUCTION

Telecardiology is a mechanism used to monitor cardiac patients remotely via information and communication technologies. It has been widely applied in the developed countries. However, due to the constraint of the telecommunication infrastructure, telecardiology services are only covered urban and partly suburban of the developing countries [1].

For telecardiology applications, high bandwidth wireless technologies are more desirable to guarantee the quality of service (QoS) of telecardiology services. However, high bandwidth networks coverage in developing countries are still imperfect and have coverage holes even in urban area. Thus, the traditional telecardiology system that integrates with a single wireless technology is unable to guarantee the patient always connected to the telecardiology service providers. To overcome this problem, the future telecardiology system should integrate with heterogeneous wireless technologies in order to guarantee the patients are continuously connected to the telecardiology services provider with acceptable QoS [2-5].

An architecture of telecardiology system integrates with heterogeneous transceivers is shown in Figure 1. It is assumed that each patient is equipped with a portable cardiac monitoring device. The device collects and interprets the medical data from body sensors. In normal condition, medical data is stored in the "normal" buffer queue for transmission. If critical event is detected, an emergency message that contains patient's location, time, vital signs and Electrocardiogram (ECG) signal will be generated and stored in "critical" buffer [1]. In this situation, the scheduler gives priority to "critical" buffer to transmit the data first, in order to let patient get treatment promptly. The most significant function in this system is, it able to select the most appropriate wireless network to transmit the medical data to telecardiology service provider. However, the seamless vertical handover (VHO) for telecardiology application in heterogeneous networks is still a major issue [3]. In this paper, an adaptive user-centric based VHO algorithm is proposed for telecardiology application in heterogeneous wireless network.

The rest of the paper is organized as follows. Section 2 presents the related works on VHO. The design of proposed algorithm is described in section 3. Section 4 is performance evaluation and conclusion in Section 5.

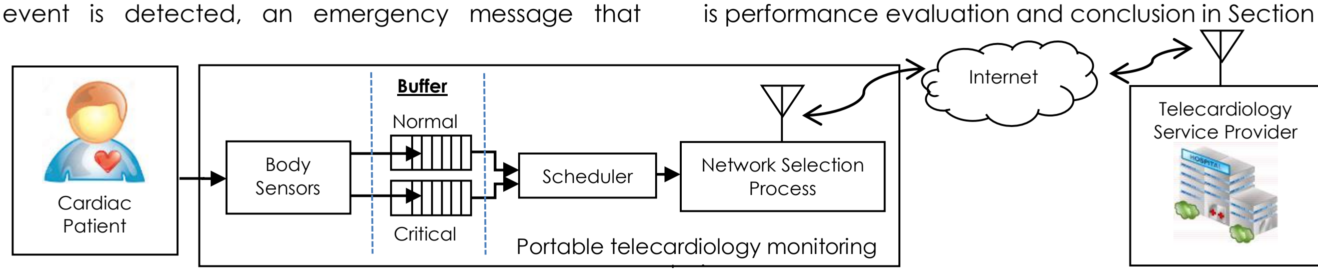


Figure 1 Architecture of proposed telecardiology system

2.0 RELATED WORKS

The VHO decision making can be done based on received signal strength (RSS), QoS, cost of service, and power consumption. RSS based scheme is not suitable for VHO decision making because RSS of different wireless technologies cannot be compared directly [6]. The QoS based method usually chooses the network with the highest bandwidth [7] and signal-to-interference and noise ratio (SINR) [8]. Cost of service and power consumption can be grouped as an user-centric based handover decision making algorithm. This algorithm selected the handover target based on the user preferences. Typically, the wireless network with lower cost and power consumption is the most preferred, but the QoS or user mobility will be sacrificed.

To balance out the QoS and user's satisfaction, multi-criteria decision making (MCDM) strategy is used in VHO process to select the most appropriate network. MCDM strategy is a weighting system which considers numerous network parameters as metrics of the network selection function. The network with the highest score will be considered as the best network. The disadvantage of this strategy is that the complexity of algorithm is increased when more criteria or parameters are taken into account. This will increase the handover delay time. Moreover, the fluctuation of networks' RSS will lead to unnecessary handover and ping-pong effect. Ping-pong effect is the scenario of repeated handover between same pair of networks in a short period of time. Ping-pong effect is undesired because it is waste of network resources and power consuming. To prevent ping-pong effect, intelligent based schemes such as Fuzzy Logic and Artificial Neural Networks (ANN) are applied in VHO process. However, these schemes have higher handover latency which may cause by ANN learning/training, and Fuzzy Logic fuzzification or defuzzification processes.

In telecardiology application, QoS based VHO decision making is preferred to ensure the selected network has sufficient bandwidth to support the telecardiology services. WiMAX has been proposed for telemedicine application due to its large bandwidth and can support high mobility [9]. However, application of the system that relies on a single wireless technology sometime is limited due to the imperfection coverage of the integrated wireless technology.

The proposed adaptive user-centric based VHO algorithm is designed in a low complexity manner to minimize the handover processing time. The main difference with the previous studies is that the proposed algorithm selects the most appropriate network based on the type of telecardiology service that had been selected by the user. Since, each service (Table 1) has different transmission data rate requirements, it is unnecessary always connect to the highest bandwidth network which require higher cost. In fact, the low cost wireless network that fulfills the service's transmission data rate requirements is more preferred.

Table 1 Minimum data rate required by different type of telecardiology services [10]

Telecardiology Services	Minimum Data Rate
Video (High Quality)	640 kbps
Audio (Diagnostic Sound)	32 kbps
ECG	24 kbps / 12 leads
Vital Signs	5 kbps

3.0 ADAPTIVE USER-CENTRIC BASED VHO ALGORITHM

The aims of the proposed algorithm are to guarantee the QoS and maintain the user's satisfaction at the highest level. The user satisfaction can be optimized by reducing the number of handover failure and select the low cost network whilst maintaining the QoS. This algorithm is able to handle different scenarios by aware of the type of telecardiology services applied by patients, contextual information (MT velocity), and patient condition (whether patient is in normal or critical condition).

The handover parameters used in this approach are RSS, SINR, velocity and cost. RSS is used to discover the present of wireless networks. The SINR parameter is used to measure the transmission data rate of the network candidates to ensure that the network transmission data rate meets the requirement. The velocity is an important parameter used to reduce the number of handover failure. If patient is in high mobility, the handover priority is given to the wireless network with large coverage because in small coverage cell, MT may move out of the coverage cell before handover completion, known as handover failure. Cost is a common parameter used to improve the user satisfaction.

This algorithm consists of three steps. First step is monitoring current connected network's quality and user requirements. Second step is a pre-handover filtering process. Third step is network transmission data rate and operation cost evaluation. The detail of network selection process is shown in Figure 2.

In this algorithm, the system is first monitors the biosignal status, current connected network quality, MT velocity and telecardiology service requirements, repeatedly. The biosignal status is in digital form, 'High' represents patient is in normal condition and 'Low' is in critical. The handover process initiates only when the current connected network is unable to fulfill the telecardiology service requirements. This is to reduce the number of unnecessary handover and minimize the power consumption.

The second step, pre-handover filtering process, is to filter out the available network candidates that are not fulfilling the user requirements in terms of RSS and velocity. At this step, only two parameters are applied, they are RSS and velocity.

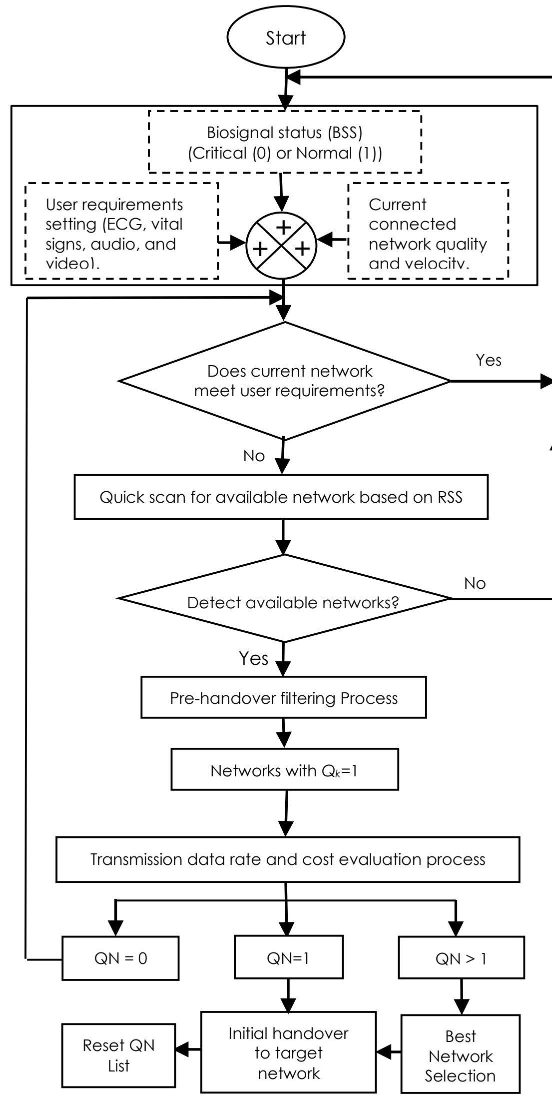


Figure 2 Proposed adaptive user-centric based VHO algorithm

$$Q_k = F(RSS_k - RSS_{Tk}) \times F(V_k - V_{MT}) \quad (1)$$

Where RSS_k denotes the RSS of network k, RSS_{Tk} is predefined RSS threshold of network k, V_k represents the maximum capable velocity of network k and V_{MT} is the velocity of MT/patient. Network k can be Wireless Local Area Network (WLAN), WiMAX or UMTS. The functions, $F(x)$, in equation (1) are unit step functions.

$$F(x) = \begin{cases} 1, & x > 0 \\ 0, & x \leq 0 \end{cases} \quad (2)$$

If $Q_k = 0$, it means network k does not meet the user requirements and will be rejected. Only the network candidates with $Q_k = 1$ will be proceeded to third step for evaluation process.

In third step, network candidate's transmission data rate can be obtained based on the *SINR* value that has been collected. By using a Shannon capacity theorem, the achievable transmission data rate, *DR*, of each network candidate is calculated as

$$DR_k = W_k \, log_2(1 + SINR_k) \quad (3)$$

$$(DR_k - DR_{req}) > 0 \quad (4)$$

Where W_k is channel bandwidth of network *k* and DR_{req} is a minimum data rate required by selected telecardiology service (Table 1). The network candidates' data rate must be higher than the minimum requirement (as expressed in equation (4)) in order to maintain the QoS of the telecardiology service.

After completion of third step evaluation process, the algorithm usually falls into three possible conditions. First condition is does not has any qualify network (QN=0), the system maintains in current network connection. Second condition is only one qualify network detected (QN=1). The system is handover to the sole network directly. Third condition is more than one qualify networks are detected (QN > 1). In this condition, the best network is determined by

$$Max\left(\frac{DR_k - DR_{req}}{C_k^{BSS}}\right) \quad (5)$$

Where C_k is predefined cost of network *k* and *BSS* denotes biosignal status. The network with the highest score is selected as a best network to handover. If user is in critical condition (BSS = 0), the cost parameter is ignored because the quality of patient treatment is depending on the highest guarantee of data integrity, transfer delay and prompt diagnosis [1].

4.0 PERFORMANCE EVALUATION

In this section, two scenarios are generated to evaluate the performance of the proposed algorithm. The first scenario is MT moving in high velocity (70km/h) from point A to point C (Figure 3). In second scenario, the MT is moving from point A to point C at the walking speed (3km/h). The simulation parameters are shown in Table 2. The MT was first connected to UMTS base station 1 (UMTS1). When it reached point B, the RSS of UMTS1 was dropped below the predefined threshold value (Q_{UMTS1} = 0). The system starts to scan for available networks. Assumed four networks (WLAN, WiMAX1, WiMAX2, and UMTS2) are available at point B with RSS above the threshold.

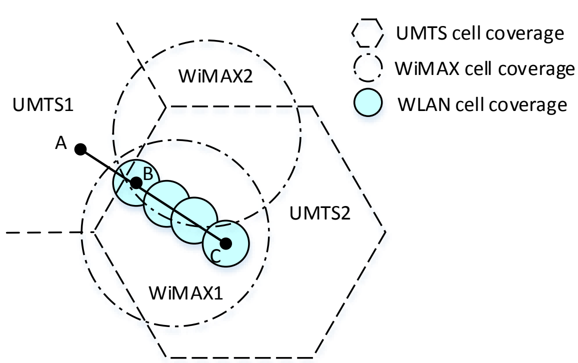


Figure 3 Simulation scenario

Table 2 Simulation parameters

Network	WLAN	WiMAX1	WiMAX2	UMTS2
Channel bandwidth	20MHz	10MHz	10MHz	5MHZ
RSS Threshold (dBm)	-115	-110	-110	-95
Supported Velocity	5km/h	80km/h	80km/h	120km/h
Cost (cent)	1	5	5	10
Radius (km)	0.1	10	10	30
SINR (dB)	10	10	5	10
Telecardiology services	Real-time (ECG signal + Vital signs + Audio)			
Scenario 1	Velocity = 70km/h			
Scenario 2	Velocity = 3km/h			

In the first scenario, the results obtained from the pre-handover filtering process were Q_{WLAN} = 0, Q_{WiMAX1} = 1, Q_{WiMAX2} = 1, *and* Q_{UMTS2} = 1. The qualified wireless network candidates were WiMAX1, WiMAX2, and UMTS2. WLAN was not qualified due to the MT velocity was beyond the maximum velocity that able supported by WLAN. Among the qualified networks (WiMAX1, WiMAX2, and UMTS), the best network to handover was determined by using equation (5). In this case, WiMAX1 has higher score compared to WiMAX2 and UMTS2 (Figure 4). The MT was then triggered the handover to WiMAX1.

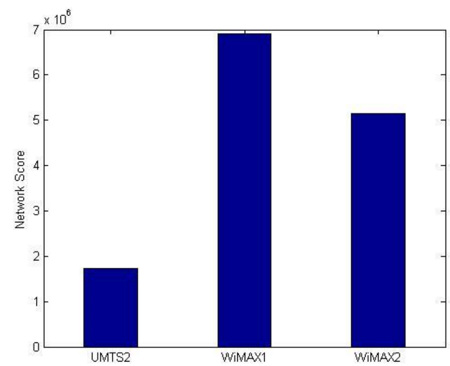


Figure 4 Scenario 1 (70km/h): networks' scoring result

At low speed (second scenario), all available networks (WLAN, WiMAX1, WiMAX2 and UMTS2) were qualified. All these network candidates were added into the qualify network (QN) list. According to the simulation result (Figure 5), WLAN was selected as a targeted network to handover because it has the highest data rate per unit cost.

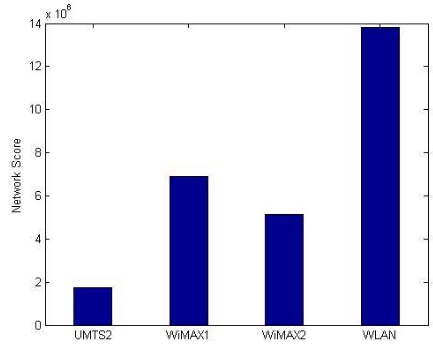


Figure 5 Scenario 2 (3km/h): networks' scoring result

The comparison of proposed handover scheme and the traditional QoS and cost based handover schemes was shown in Table 3. In the traditional handover schemes, WLAN was selected as the best network to handover because it has the highest transmission data rate and the lowest cost. However, at high velocity (scenario 1), the connection time in WLAN cell is limited. The short connection time in WLAN does not benefit to MT. In addition, WLAN has higher probability of handover failure compared to WiMAX (Figure 6). Thus, handover to WLAN at high velocity is wasted of power and network resource. This type of unbeneficial handover may degrade the user satisfaction.

Table 3 Comparison between the proposed and the traditional schemes

Handover scheme	Best Network to Handover		Handover rate from point A to point C (scenario 1)
	Scenario 1	Scenario 2	
QoS based	WLAN	WLAN	4
Cost based	WLAN	WLAN	4
Proposed	WiMAX1	WLAN	1

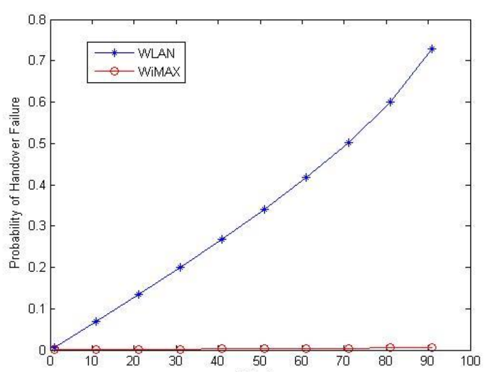


Figure 6 Relationship of probability of handover failure and velocity

5.0 CONCLUSION

In this paper, we proposed a new VHO algorithm for future telecardiology system that integrated with different types of wireless technologies for developing countries. An adaptive user-centric based vertical handover decision making algorithm in heterogeneous wireless networks for telecardiology application has been proposed and discussed. This algorithm considers the patient's velocity, biosignal status, QoS and network cost. We compared the proposed algorithm with the traditional QoS and cost based schemes. The results shown that the proposed algorithm has better performance than the traditional handover schemes in term of network selection and user satisfaction.

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