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AUTONOMOUS NETWORK SELECTION STRATEGY FOR TELECARDIOLOGY APPLICATION IN HETEROGENEOUS WIRELESS 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, Malaysia
[b]Faculty of Engineering, Universiti Malaysia Sabah, Malaysia

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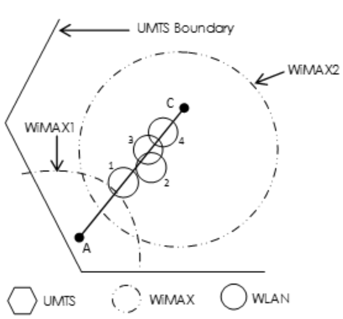
*Corresponding author
hauyuanwen@utm.my

Graphical abstract



Abstract

Existing telecardiology systems are mostly relying on a high bandwidth wireless technology. However, in developing countries, the coverage of high bandwidth wireless network is still imperfect. Thus, the existing telecardiology systems are unable to guarantee users are always connected to the healthcare service provider at anywhere. To overcome this issue, an autonomous network selection strategy for telecardiology application in heterogeneous wireless networks is proposed. This strategy is aware of user velocity, network quality, and telecardiology service setting (e.g. image, vital signs, ECG, etc.). It performs handover from one network to another without disruption to the link. The simulation results show that the proposed strategy outperforms conventional bandwidth-based strategy in term of handover rate, ping-pong effect and handover failure. It has successfully reduced the handover rate up to 97%, eliminated the ping-pong effect and handover failure in both high and low speed scenarios.

Keywords: Network selection, Telecardiology, Handover failure, Handover rate, Ping-pong effect

1.0 INTRODUCTION

Telecardiology is a tool used by healthcare professionals to monitor cardiac patient's health condition distantly via information and communication technologies (ICT). It can be operated in either stored-and-forward or real-time modes. Stored-and-forward mode is patient stores the medical data (e.g. vital sign, electrocardiogram (ECG) etc.) and transmits to healthcare service provider at a later time. In contrast, real-time mode allows instantaneous interaction between healthcare professional and patient, for example, live video-conferencing. The advantages of using telecardiology include better management of hospital resources such as beds in tertiary hospital and ambulances, reduce the morbidity and mortality, and bridging the gap between healthcare professional and patient [1-6]. Therefore, it has been used to solve the problem of healthcare professional shortage in sub-urban and rural areas of developing countries [7].

The quality of telecardiology service is highly dependent on telecommunication technologies. The main factor that may affect the performance of telecardiology service is insufficient network bandwidth. It may cause high latency and packet loss in transmission. A disruption of medical data in transmission may lead to misdiagnosis. Thus, in telecardiology application, high bandwidth networks such as Wireless Local Area Network (WLAN), Worldwide Interoperability for Microwave Access (WiMAX) and 4G-LTE (Fourth Generation-Long Term Evolution) are highly desirable to guarantee the quality of telecardiology service.

However, these high bandwidth networks are still under deployment and their coverage are imperfect even in urban of developing countries. Users (ambulances or patients) may experience connection breakdown whilst passing through the coverage holes or travels out of the network coverage. Thus, telecardiology system that relies on a high bandwidth network could not guarantee the users are always connected to the healthcare professional.

In this paper, an autonomous network selection strategy for telecardiology application in heterogeneous wireless networks is proposed to ensure users are able to connect to their healthcare professional at anywhere and maintain the quality of telecardiology service at the highest level.

The rest of the paper is organized as follows. Section 2 presents the related works on wireless telecardiology system and network selection strategies. The design of proposed algorithm and experiment design are discussed in Section 3 and 4, respectively. The result and discussion are presented in Section 5 and conclusion in the last section.

2.0 RELATED WORKS

This section discusses the related works on existing wireless telecardiology system and also the network selection strategies in heterogeneous wireless networks.

2.1 Existing Wireless Telecardiology System

Previous studies have proposed telecardiology systems with different type of wireless technologies, such as WLAN, WiMAX, satellite, and cellular network. A WLAN-based monitoring system that monitors the inpatients ECG signal within the hospital has been presented in [8]. The limitation of this system is the patient's monitoring area is restricted due to the small WLAN cell coverage. To overcome the coverage problem, research works in mobile health [9-13] has been rapidly raised in recent years with the help of evolution in mobile phone technologies and cellular network, as shown in Table 1.

Cellular wireless network such as 1G, 2G and 3G offer large coverage, hence could extend the telecardiology services to the population in sub-urban and rural areas. However, its bandwidth is still insufficient to support the services that require high bandwidth such as transmission of high quality medical images or conducting real-time consultation through video-conference.

Table 1 Evolution of Cellular Network [7]

Cellular network generation	**Service type**
1G	Analogue voice.
2G & 2.5G (GSM, GPRS)	Digital voice, higher capacity, packetized data.
3G (UMTS)	Higher capacity, broadband data up to 384kbps.
4G (LTE)	Complete IP based with speed > 100 Mbps (still under deployment).

bps: bit per second
GSM: Global System for Mobile
GPRS: General Packet Radio Service
IP: Internet Protocol
LTE: Long-term Evolution
UMTS: Universal Mobile Telecommunication System
#G: # Generation

In order to guarantee the quality of telecardiology services, WiMAX based telecardiology systems are proposed in [14, 15]. The advantages of WiMAX technology are large coverage and high throughput. It could compensate the limitation of WLAN (small cell coverage) and cellular networks (low bandwidth). However, in developing countries, WiMAX coverage is still imperfect and has coverage hole even in urban. To solve this issue, authors in [14] extended their work by integrates WLAN and WiMAX networks in their proposed telecardiology system [16], where WLAN is mainly for indoor application and WiMAX is for outdoor environment.

For the areas that out of the all ground networks' coverage, satellite communication becomes an only solution. Satellite communication based telecardiology system is suitable for offshore oil platform and military application [17, 18]. However, it is not widely used due to the high delay, poor quality during poor weather and extremely cost expensive in terms of satellite installation, maintenance and management.

Based on the discussed telecardiology systems, the existing systems are mostly relying on a single wireless technology. Two main problems facing by these systems are limitation of network coverage and bandwidth. To overcome these problems, existing telecardiology systems require a network selection strategy to assist them to select the most appropriate wireless network based on the user requirements and perform seamless handover in heterogeneous wireless networks to ensure the users are always connected to the healthcare professional with guarantee of services quality.

2.2 Network Selection Strategies

Network selection strategy is a scheme of keeping user connection remains active when the mobile device migrates from one network access point to another. The network selection strategies can be categorized into RSS-based, cost-based, bandwidth-based and multi attribute based strategies. RSS-based strategy is the traditional method which usually applies in intra-network. For inter-networks handover, RSS-based strategy is inappropriate due to RSS of different wireless technologies cannot be compared directly [19]. The cost-based strategy chooses the handover target based on the cost of the available networks. Typically, the wireless network with lower cost is the most preferable. On the other hand, bandwidth-based strategy usually selects the network with the highest bandwidth or throughput to maintain the quality of service at the highest level.

In order to find a balancing point between the bandwidth and cost, multiple attributes decision making (MADM) strategy has been proposed by many researchers in network selection process. MADM strategy is a weighting system that considers various network parameters (e.g. RSS, cost, velocity, bandwidth, etc.) as metrics of the network selection function. The network with the highest weight sum will be considered as a targeted network to handover. The main disadvantage of this strategy is that the algorithm complexity will be increased when more parameters are taking into account, hence increasing the handover latency.

To improve the handover performance, fuzzy logic and Artificial Neural Networks (ANN) are applied in network selection process. These intelligent based strategies are more reliable and has high successful rate in connecting to the best network. However, they suffer from high handover latency which caused by ANN learning or training process, and fuzzy logic fuzzification or defuzzification processes.

In our proposed strategy, MADM method is used to select the best network based on the user requirement and contextual information (velocity). However, weighting system is not used in our proposed strategy because the weight assignment on input parameters of the existing MADM schemes is mostly done manually and fixed based on certain scenarios. This could lead to a degradation of service quality when different services are applied by user or unlike scenarios are happened.

3.0 PROPOSED NETWORK SELECTION STRATEGY FOR TELECARDIOLOGY APPLICATION

The proposed network selection strategy as shown in Figure 1 is a low-complexity algorithm to minimize the handover latency. It consists of two major phases: self-inspection and quick evaluation. The input parameters for the proposed strategy are received signal strength (RSS), user's velocity (V_{user}), signal-to-noise ratio (SNR), network channel bandwidth (B) and minimum data transmission rate required by user (DR_{req}).

The first parameter, RSS, is used to discover the present of neighboring networks. Second parameter, V_{user}, is required to avoid handover failure by comparing the user traveling time in specific network cell coverage with handover execute time (HET). Handover failure occurs when the travelling time in network cell is less than HET. Hence, the small coverage network such as WLAN should be avoided in high speed scenario as user may move out from cell coverage before the completion of handover process.

Parameter SNR represents network quality or capability of data transmission rate. The higher SNR value means the better network quality and provide higher data transmission rate. Thus, SNR is needed to guarantee that the selected network has capability of supporting the telecardiology services. In this strategy, the SNR of a network candidate is required to determine capability of data transmission rate (DR_k). On the other hand, the total data transmission rate required by user (DR_{req}) is according to the telecardiology services that have been preset by user. DR_{req} for each type of telecardiology service is shown in Table 2. The relationship between SNR_k, B_k and DR_k is given by:

$$DR_k = B_k \log_2(1 + SNR_k) \qquad (1)$$

Where, B_k is channel bandwidth of network *k* in Hertz (Hz). The network k can be any wireless network (e.g. WLAN, WiMAX or cellular network).

Table 2 Telecardiology service requirement [22]

Telecardiology service	Data rate (DR_{req})
Voice	4 kbps
Diagnostic sound	32 kbps
High quality diagnostic video	640 kbps
ECG (12 channels)	24 kbps
Vital sign	5 kbps

Proposed Network Selection Strategy

	Input parameters: RSS_k, SNR_k, V_{user}, DR_{req} , B_k
	Predefined threshold: RSS_{kT}, V_{kT}
1	**DO**
2	$DR_{req} \leftarrow$ User telecardiology service setting
3	$F(V)=F(V_{CCNT} - V_{user})$
4	$F(RSS)=F(RSS_{CCN} – RSS_{CCNT})$
5	$DR_{CCN} = B_{CCN} \log_2 (1 + SNR_{CCN})$
6	$Q_{CCN} = F(V)*F(RSS)* (DR_{CCN} - DR_{req})$
7	**WHILE** ($Q_{CCN} > 0$)
8	k = 0
9	N = 0
10	Scan for neighboring networks based on RSS
11	Count = Total number of detected network candidates
12	**IF** (Count == 0)
13	Maintain at CCN
14	Back to step 1
15	**ELSE**
16	**WHILE** (k < Count)
17	Obtain network parameters RSS_k, V_{user}, SNR_k, B_k
18	$DR_{req} \leftarrow$ User telecardiology service setting
19	$F(V)=F(V_{kT} - V_{user})$
20	$F(RSS)=F(RSS_k – RSS_{kT})$
21	$DR_k = B_k \log_2 (1+SNR_k)$
22	$Q_k = F(V)*F(RSS)*(DR_K - DR_{req})$
23	**IF** ($Q_k > 0$)
24	Network k is a qualified network
25	N = N + 1
26	**ELSE**

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27                  Reject network k
28              ENDIF
29              k = k + 1
30          ENDWHILE
31      ENDIF
32      N = Total number of qualified network
33          IF     (N == 0)
34                  Maintain at CCN
35          ELSE
36                  Targeted network = Max (Qk)
37                  Trigger handover to targeted network
38                  CCN = New targeted network
39          ENDIF
40      Back to Step 1
```

CCN: Current connected network
DR_k: Capability of network k transmission data rate
DR_{req}: Transmission data rate required by user
F(V): Velocity function (as equation 3)
F(RSS): RSS function (as equation 4)
Q_k: Quality of network k
Q_{CCN}: Quality of CCN
RSS_k: RSS of network *k*
RSS_{kT} : Predefined threshold value for RSS network k
RSS_{CCN}: RSS of current connected network
RSS_{CCNT}: Predefined threshold for RSS of current connected network
SNR_{CCN}: SNR of current connected network
SNR_k: SNR value of network k
V_{CCNT}: Maximum velocity support by current connect network
V_{kT}: Predefined maximum velocity supported by network *k*
V_{user}: User velocity

Figure 1 Proposed Network Selection Strategy

The parameters B_k, RSS_k and SNR_k values can be obtained via Media-Independent Handover standard (MIH). MIH is IEEE802.21 standard which enable seamless handover and interoperability between two different wireless technologies. It also provides information such as neighboring network, network configuration, and network quality [20, 21]. In this proposed algorithm, the authors assume each portable telecardiology monitoring device is integrated with an accelerometer to measure the user velocity.

In self-inspection process (step 1 to 7 in Figure 1), it monitors the RSS_{CCN}, SNR_{CCN}, V_{user} and existing user's telecardiology service setting (e.g. ECG, image, video, etc.) in every 0.5 second to ensure that the current connected network (CCN) is achieving the user's requirements. The objective of this self-inspection process is to avoid ping-pong effect and reduce the number of unnecessary handover. Ping-pong effect is a scenario that user performs handover forth and back repeatedly between two different wireless network in a short period of time. It is waste of energy and network resources. The proposed strategy only scans for other networks whilst the CCN failed to fulfill the user requirements ($Q_{CCN} \leq 0$).

In quick evaluation process (step 8 to 40 in Figure 1), the quality of each detected network candidates (Q_k) will be evaluated based on the input parameters. Q_k can be determined by:

$$Q_k = F(V) * F(RSS) * (DR_K - DR_{req}) \quad (2)$$

Where,

$$F(V) = F(V_{kT} - V_{user}) = \begin{cases} 0, & V_{kT} \leq V_{user} \\ 1, & V_{kT} > V_{user} \end{cases} \quad (3)$$

$$F(RSS) = F(RSS_k - RSS_{kT}) = \begin{cases} 0, & RSS_k \leq RSS_{kT} \\ 1, & RSS_k > RSS_{kT} \end{cases} \quad (4)$$

The network candidate with $Q_K > 0$ is the qualified network and will be added to the qualified network list, N, otherwise reject. The best network among the qualified network candidates can be determined by:

$$Max\ (Q_k) \quad (5)$$

4.0 EXPERIMENT DESIGN

Figure 2 shows the experiment design to evaluate the performance of proposed strategy. It is assumed that the user travels from point A to point C with a constant velocity. The performance of the proposed network selection strategy is compared with the conventional bandwidth-based network selection strategy under two different scenarios. The first scenario is user travels at high speed (30m/s) and second scenario is at low speed (2m/s). The traveling path is covered by three different wireless networks, WLAN, WiMAX and UMTS. The RSS of all these networks from point A to point C are shown in Figure 3, whereas, the experiment parameter settings are as shown in Table 3. The experiment is aim to transmit high quality diagnostic video which requires minimum 640kbps data transmission rate, according to Table 2.

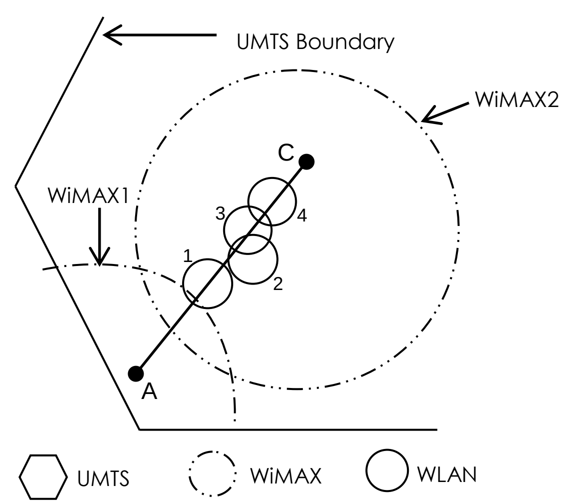

Figure 2 Scenario in heterogeneous wireless network

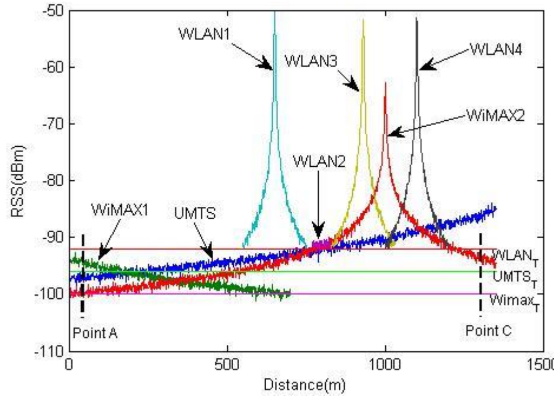

Figure 3 RSS of various wireless networks coverage along the travelling path from point A to point C

Table 3 Parameters' Setting

Parameter		WLAN	WiMAX	UMTS
RSS_{kT} (dBm)		-92	-100	-96
V_{kT} (m/s)		5	40	95
Cell Radius (m)		100	1000	3000
B (MHz)		20	10	5
User setting (DR_{req})		High quality diagnostic video (640kbps)		
User velocity (V_{user})		Scenario 1: 30m/s or 108km/h Scenario 2: 2m/s or 7.2km/h		
Time Interval (Monitoring)		0.5 second		
HET	Intra-network	1 second		
	Inter-network	2 seconds		

5.0 RESULTS AND DISCUSSION

The performance of the proposed strategy is evaluated based on number of handover failures, unnecessary handover and ping-pong effect according to two aforementioned scenarios. The handover failure occurs when the traveling time (TT) in specific network is less than HET. The HET for intra-network and inter-network handovers are set to 1 second and 2 seconds, respectively, according to the value recommended by [23, 24]. The TT in specific network is equal to time interval between two handovers, as shown in equation (6).

$$TT = Handover\ Time_{i+1} - Handover\ Time_i \qquad (6)$$

In term of percentage of unnecessary handover (%UH), it is computed as,

$$\%UH = \frac{HR_{BW\_based} - HR_{proposed}}{HR_{BW\_based}} X\ 100 \qquad (7)$$

Where, HR_{BW_based} and $HR_{proposed}$ denote the handover rate of conventional bandwidth-based and proposed network selection strategies, respectively. Ping-pong effect is also considered as a part of unnecessary handover. It happens when numerous unnecessary handover between two networks occur in a short period of time.

5.1 Scenario 1: High Speed (30m/s)

In high speed scenario, WLAN is rejected by proposed strategy because user velocity is above the predefined maximum velocity supported by WLAN ($V_{user} > V_{kT}$). Note, this predefined velocity threshold is not applicable to conventional bandwidth-based strategy. Typically, conventional bandwidth-based strategy selected the highest bandwidth network based on the RSS and bandwidth of network candidates without restriction of user velocity.

Figure 4 and Table 4 show the handover performance of the conventional bandwidth-based network selection strategy, whereas, Figure 5 shows the handover performance of the proposed strategy. It can be observed that total of 9 handovers occurred while user travels from point A to C, whereas, only one handover is performed by the proposed network selection strategy. Referring to Figure 4 in more detail, ping-pong effect is occurred at overlap region of WiMAX1 and WiMAX2 where there is total of 3 handovers occur consecutively within 1.5 seconds (H_1 to H_3 in Table 4). Furthermore, two handover failures occurred at H_1 to H_2 and H_5 to H_6 (Table 4). Conversely, the proposed network selection strategy has no ping-pong effect and handover failure along the journey from A to C.

Table 5 summarizes the performance comparison between bandwidth-based strategy and proposed strategy at high speed scenario which the user traveling speed is 30m/s. It can be observed that the proposed strategy has successfully reduced the unnecessary handover up to 89% (equation 7). The proposed strategy connects to WiMAX2 instead of UMTS networks because WiMAX2 has higher data transmission rate.

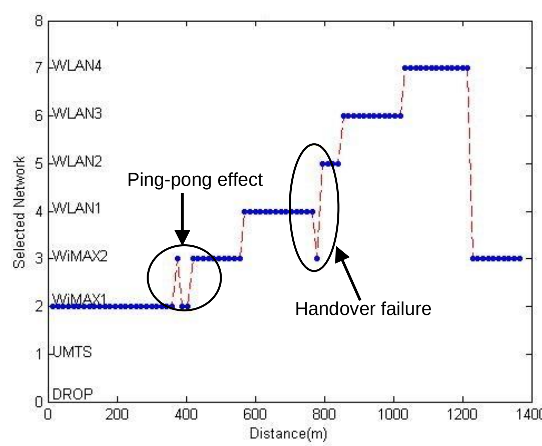

Figure 4 Handovers performed by conventional bandwidth-based network selection strategy from point A to point C at speed of 30m/s

Table 4 Detail of handovers performed by conventional bandwidth-based network selection strategy at high speed

Handover (H_i)	At time (Sec)	Distance from point A (m)	Handover to	Remark
1	12.5	375	WiMAX2	Ping-pong effect
2	13.0	390	WiMAX1	
3	14.0	420	WiMAX2	
4	19.0	570	WLAN1	
5	26.0	780	WiMAX2	Handover failure
6	26.5	795	WLAN2	
7	28.5	855	WLAN3	
8	34.5	1035	WLAN4	
9	41.0	1230	WiMAX2	

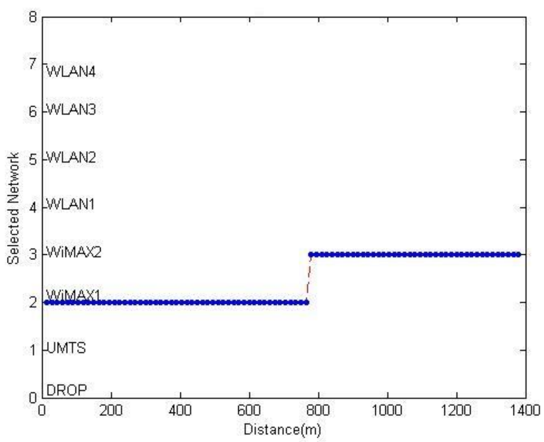

Figure 5 Handover performed by proposed network strategy at speed of 30m/s

Table 5 Performance comparison between conventional bandwidth-based and proposed strategy at speed of 30m/s

Network Selection Strategy	Number of Handovers (HR)	Number of Handover Failures	Ping-pong Effect	Number of unnecessary handover
Proposed	1	0	No	0
Bandwidth - based	9	2	Yes	8

5.2 Scenario 2: Low Speed (2m/s)

Figure 6 shows the handover performance of the conventional bandwidth-based network selection strategy, whereas, Figure 7 shows the handover performance of the proposed strategy, with both of them apply to low speed scenario at pedestrian speed of 2m/s. It can be observed that bandwidth-based strategy suffers from 32 handover failures out of 67 total handovers. On the other hand, the proposed strategy only requires 2 handovers with no handover failure or ping-pong effect.

Table 6 shows the summary of performance comparison between two strategies. It is proven that the proposed strategy can reduce unnecessary handover percentage up to 97% at low speed scenario.

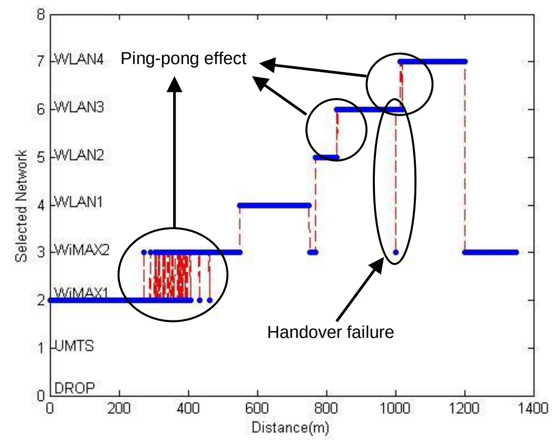

Figure 6 Handovers performed by conventional bandwidth-based strategy at low speed scenario (2m/s)

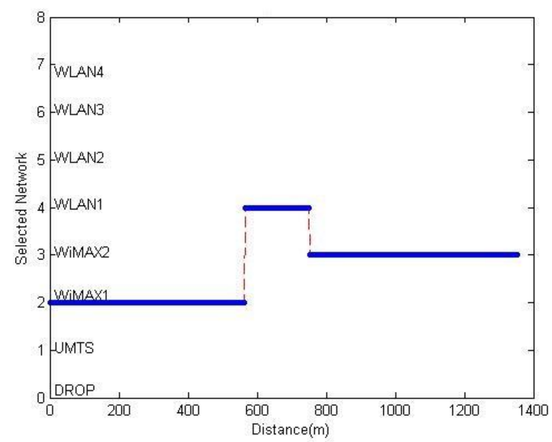

Figure 7 Handovers performed by proposed strategy at low speed scenario(2m/s)

Table 6 Performance comparison between conventional bandwidth-based and proposed strategy at speed of 2m/s

Network Selection Strategy	Number of Handovers (HR)	Number of Handover Failure	Ping-pong Effect	Number of unnecessary handover
Proposed	2	0	No	0
Bandwidth-based	67	32	Yes	65

6.0 CONCLUSION

In this paper, a low complexity autonomous network selection strategy is proposed for telecardiology application in heterogeneous wireless networks. It has successfully eliminated the ping-pong effect and handover failure. It also reduced up to 97% and 89% of unnecessary handover at low speed and high speed scenarios, respectively, as compared to conventional bandwidth-based network selection strategy whilst satisfying the user requirement.

In future, the parameters such as cost and power consumption can be added to the proposed strategy to improve the user's satisfaction. Typically, user prefers the high bandwidth with low cost network such as WLAN. WLAN also has less power consuming compared to the other networks (e.g. WiMAX, UMTS) due to its short transmission distance. However, the small WLAN cell coverage has put some limitation on user mobility. Thus, utilization of WLAN at outdoor environment and high velocity scenario is still an open issue and future direction of research.

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References

[1] Maarop, N., and Win, K. T. 2012. The Interplay of Environmental Factors in the Acceptance of Teleconsultation Technology: A Mixed Methods Study. *Open International Journal of Informatics*. 1: 46-48.

[2] Brunetti, N. D., De Gennaro, L., Dellegrottaglie, G., Procacci, V. and Di Biase M. 2013. Fast and Furious: Telecardiology in Acute Myocardial Infarction Triage in the Emergency Room Setting. *European Research in Telemedicine*. 2: 75-78.

[3] Sorensen, J. T., Clemmensen, P. and Sejersten, M. 2013. Telecardiology: Past, Present and Future. *Rev Esp Cardiol.* 66(3): 212-218.

[4] Chaudhry, S. I., Barton, B., Mattera, J., Spertus, J. and Krumholz, H. M. 2007. Clinical Trials: Methods and Design, Randomized Trial of Telemonitoring to Improve Heart Failure Outcomes (Tele-HF): Study Design. *J Cardiac Fail.* 13(9): 709-714.

[5] Brown, J. P., James, E., Dunford, V., and Yehuda, O.B. 2008. Effect of Prehospital 12-Lead Electrocardiogram on Activation of the Cardiac Catheterization Laboratory and Door-to-Balloon Time in ST-Segment Elevation Acute Myocardial Infarction**.** *American Journal of Cardiology.* 101(2): 158-161.

[6] Brunetti, N. D., De Gennaro, L., Amodio, G., Dellegrottaglie, G., Pellegrino, P. L., Di Biase, M. and Antonelli, G. 2010. Telecardiology Improves Quality Of Diagnosis and Reduces Delay to Treatment in Elderly Patients with Acute Myocardial Infarction and Atypical Presentation. *European Journal of Cardiovascular Prevention & Rehabilitation*. 17(6): 615-620.

[7] Yew, H. T., Aditya, Y., Satria, H., Supriyanto, E. and Hau, Y.W. 2015. Telecardiology System for Fourth Generation Heterogeneous Wireless Networks. *ARPN Journal of Engineering and Applied Sciences*. 10(2): 600-607.

[8] Ken, C. and Liang, X. 2010. Development of WI-FI based Telecardiology Monitoring System. *Intelligent Systems and Applications (ISA), 2010 2nd International Workshop.*

[9] Mitra, S., Mitra, M. and Chaudhuri, B.B. 2008. Rural Cardiac Healthcare System–A Scheme for Developing Countries. *TENCON 2008 IEEE Conference*.1-5.

[10] Elena, M., Quero, J. M., Tarrida, C. L. and Franquelo, L. G. 2002. Design of a Mobile Telecardiology System Using GPRS/GSM Technology. *IEEE Proceeding of the Second Joint EMBS/BMES Conference, (Houston USA)*.

[11] Lin, C. T, Chang, K. C., Lin, C. L., Chiang, C. C., Lu, S. W., Chang, S. S., Lin, B. S., Liang, H. Y., Chen, R. J., Lee, Y. T. and Ko. L. W. 2010. An Intelligent Telecardiology System Using a Wearable and Wireless ECG to Detect Atrial Fibrillation. *IEEE Transactions on Information Technology in Biomedicine*. 14(3): 726-733.

[12] Abo-Zahhad, M., Ahmed, S.M. and Elnahas, O. 2014. A Wireless Emergency Telemedicine System for Patients Monitoring and Diagnosis. Hindawi Publishing Corporation, International Journal of Telemedicine and Applications, Article ID 380787. 11.

[13] Huang, A., Chen, C., Bian, K., Duan, X., Chen, M., Gao, H., Meng, C., Zheng, Q., Zhang, Y., Jiao, B. and Xie, L. 2014. WE-CARE: An Intelligent Mobile Telecardiology System to Enable mHealth Applications. *IEEE Journal of Biomedical And Health Informatics*. 18(2): 693-702.

[14] Niyato, D., Hossain, E. and Diamond. J. 2007. IEEE802.16/WiMAX-Based Broadband Wireless Access and Its Application For Telemedicine/E-Health Services. *IEEE Wireless Communication*. 14 (1): 72-83.

[15] Chorbev I., Madzarov, G. and Mihajlov, D. 2008. Wireless Telemedicine as Part of an Integrated System for E-Medicine. *The 14th IEEE Mediterranean Electrotechnical Conference, Ajaccio (France)*. 264-269.

[16] Niyato, D., Hossain, E. and Camorlinga, S. 2009. Remote Patient Monitoring Service using Heterogeneous Wireless Access Networks: Architecture and Optimization. *IEEE Journal on Selected Areas in Communications*. 27(4): 412-423.

[17] Mair, F., Fraser, S., Ferguson, J. and Webster, K. 2008. Telemedicine Via Satellite to Support Offshore Oil Platforms. *J Telemed Telecare*. 14(3): 129-131.

[18] Alberto H. A. B. 2011. *The Spanish Ministry of Defence (MOD) Telemedicine System.* InTech, Advance in Telemedicine: Technologies, Enabling Factors and Scenarios. ISBN 978-953-307-159-6l.

[19] Yan, X., Sekercioglu, Y. A. and Narayanan, S. 2010. A Survey of Vertical Handover Decision Algorithms in Fourth Generation Heterogeneous Wireless Networks. *Computer Networks.* 54(11): 1848-1863.

[20] Oliva, A. de la, Soto, I., Banchs, A., Lessmann, J., Niephaus, C., Melia, T. 2011. IEEE802.21: Media Independence Beyond Handover. *Computer Standards & Interface.* 33: 556-564.

[21] Ghahfarokhi, B. S. and Movahhedinia, N. 2013. A Survey on Applications of IEEE802.21 Media Independent Handover framework in nest generation wireless network. *Computer Communications.* 36(10-11): 1101-1119.

[22] Gállego, J. R., Hernández-Solana, A., Canales, M., Lafuente, J., Valdovinos, A., and Fernández-Navajas, J. 2005. Performance Analysis of Multiplexed Medical Data Transmission for Mobile Emergency Care over the UMTS Channel. *IEEE Transactions on Informations Technology in Biomedicine*. 9(1): 13-22.

[23] Hussain, R., Malik, M.A., Abrar, S., Riaz, R.A., and Khan, S.A. 2013. Vertical Handover Necessity Estimation Based on a New Dwell Time Prediction Model for Minimizing Unnecessary Handovers to a WLAN Cell. *Wireless Pers. Commun.* 71(2): 1217-1230.

[24] Yan, X., Mani, N., and Sekercioglu, Y.A. 2008. A Traveling Distance Prediction Based Method to Minimize Unnecessary Handovers from Cellular Networks to WLANs. *IEEE Communications Letters*. 12(1): 14-16.