Home Area Network for Optimizing Telehealth Services- Empirical Simulation Analysis

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***Abstract*— Telehealth applications such as Video-over-IP and remote sensor monitoring are rapidly growing in utilisation and it has now expanded to the patient's homes. These Telehealth applications are, however highly delay sensitive and require high quality (and bandwidth priority) in order to provide satisfactory performances. However, at the patient's home area network (HAN) environment, typically there is no Internet traffic management system which highly affects the quality of these applications. As HAN expands its capacity by adding new devices in its network, the need for a network management system become urgent and necessary. In this study, we propose an infrastructure based method to improve Telehealth application quality by managing the quality and distribution of the Internet traffic among the connected devices in a HAN environment. We setup a HAN environment using existing devices readily available at home and tested the setting with typical Telehealth application needs that includes Video-over-IP, VoIP, data and other multimedia traffic. Our simulation results showed that our method is capable of providing better services. Our method indicated that it can provide ~11% lesser packet-loss under 12Mbps background traffic, while increasing 10% of the CPU load for Traffic management.**

Keywords: Home Area Network, Telehealth, Video-over-IP, VOIP & WiFi.

I. Introduction

One of the main purposes of mobile healthcare system is to reduce medical cost and provide medical services over a distance [1, 2]. Systems such as Cisco TelePresence and ViTAM are being introduced to enhance the quality of Telehealth applications by providing secure video, voice and sensor data communications [3]. However, a common problem that exists in majority of the houses is to control the Internet traffic within home area network (HAN) remains unresolved. Meanwhile some of the commercial products are available to provide such solutions; however, these are usually high in costs and require additional devices to be installed that increase cost and ease of use [1, 4]. Therefore, a solution is needed that is capable of reutilising existing infrastructure of devices and networks readily accessible at home with enhanced network management features to meet the Telehealth application requirements [5, 6].

Wireless medical devices have provided major contribution to enhance the capabilities of telemedicine. In recent years the production of wireless medical sensor devices have rapidly increased and by 2016 it is expected to reach approximately 100 million within USA [7]. However, based on our literature review it seems that there isn't much research work on how to manage/control all these wireless medical devices within HAN environment by reutilising existing devices.

Telehealth is growing base on electronic devices and latest computing services such as Internet, Cloud computing etc. These devices are getting smarter while ISPs (Internet service providers) are also providing better bandwidth facilities [1]. However, HAN is often restricted from a management issues that are caused by these devices and services. For example, Internet connection is fast enough to run Telehealth applications within acceptable quality range but when other devices at home concurrently utilise the same Internet, bandwidth can become unacceptable. Although Telehealth applications can benefit from a higher priority than other devices in a default HAN environment but all the devices usually have equal priority and are peer-to-peer based, thus giving all those devices equal priority to access the Internet. Hence, there is no particular function within HAN to manage the Internet traffic. For instance, if a single user within HAN downloads some data from the Internet, all other devices tend to be compromised with unpredictable and slower connection, as well as reduced bandwidth. Majority of the WiFi Access-Points (also known WiFi routers) being utilised at homes do not have this management capability built-in and there are some commercial devices available in the market to deliver these mechanisms but require every house holder to purchase those expensive devices in order to manage HAN [4, 5].

The motivation of this study is to provide a solution to facilitate the deployment of Telehealth application to patients at their homes. We proposed an infrastructure based solution to manage home area network (HAN) where we reutilise exiting devices to meet the Telehealth requirements by prioritising the Bandwidth priority when multiple devices are connected to the same HAN. Our method was designed for wired and wireless technologies that are utilised at home. Data, VoIP, Video-over-IP and multimedia traffic was tested on a designated network to facilitate Telehealth care scenario. Technologies included were IEEE 802.11g protocol and open source traffic shaping software.

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The organisation of this paper is as follows. The next section covers background and related work to our study. Section 3 specifies experimental test-bed while section 4 presents the results from the experiments. Section 5 outlines the discussions while section 6 includes conclusion followed by acknowledgement and references.

II. Background and Related Works

Telehealth applications utilise various types of Internet traffic such as VoIP, Video-over-IP, data and live sensor data to provide assistance to doctors to treat or monitor patients over the Internet. The application such as VoIP and video-over-IP are highly delay sensitive compared to data traffic and requires more thorough system to manage the traffic within HAN. Within HAN there is no server oriented system that manages the Internet traffic for all users while there is an access point (AP) or also called "Internet router" that enables devices at home to be connected with Internet (wired or wirelessly). However, majority of Internet routers do not have a feature to control traffic to provide high priority to Telehealth applications that reduces the quality of service (QoS) for real-time applications (Voice & Video). QoS is a vital factor where a good quality, e.g., for VoIP can be measured if round-trip-time (RTT) delay is lesser than 150 milliseconds (ms) and packet-loss is < 3% [8, 9]. In another study [10] authors developed a new framework for wearable devices within patients home that could enhance the performance of HAN by allowing sensors to directly communicate with a local server through Ziggbe which would then communicate to other services such as Cloud e.g. However, factors such as operating range and the time stamp accuracy are still not covered.

Trend of medical services is changing from hospital-centric to home-centric with the help of powerful handheld devices that allow services like Medical Tele-consultation to be established for patients to get a treatment at their homes. The aim of this study [3] was to develop a system that consists of Android tablet application, central processing server and lightweight client software at a patient's PC while embedding client software within smart-TV. However, more user friendly devices and system are under development whereas to manage these devices within HAN is not considered.

In this paper [1] the authors designed and tested a new framework to establish Telehealth care system in rural areas. Main concept was to utilise multiple smart-phones to obtained information from patients then systematically store the collected data over cloud server. However, compatibility of different devices may cause Internet services to degrade the quality of Telehealth applications which was not considered [11].

In [2] the authors have designed a method to support Tele-medicine applications. A system was setup based on real machines which included smart-phones for nurses to operate while the performance was monitored at the hospital over the mobile Internet. The outcome pointed out that mobile Internet is still not fast enough to run multiple services concurrently whereas broadband Internet is capable of delivering it. Tests were operated on a dummy patient and were measured within a hospital.

III. Experimental Test Bed

In this experiment two types of network test-beds were established based on two different configurations. Machines included in both test-beds were two laptops, a workstation, a smart-phone and an access point. First test-bed was based on peer-to-peer (p2p) networking where Internet connection was plugged into an AP while four devices were wirelessly connected to that AP. Second test-bed was based on our proposed method where a workstation (played a server role) included two different NIC cards (LAN and WLAN) to share the Internet with AP while controlling the bandwidth and prioritising Telehealth traffic among clients using open-source tools. Traffic controlling system was manually configured with the help of open-source tools. Hence, an Internet connection was plugged into a workstation using LAN card while WLAN card was connected to an AP while other devices (2 laptops and a smart-phone) were directly connected to an AP wirelessly. Other features included IEEE 802.11g protocol and WPA 2 personal security protocol during all tests. The operating system covered were Windows 7 for a workstation and laptop-2 while laptop-1 had Windows 8 and Android OS for smart-phone.

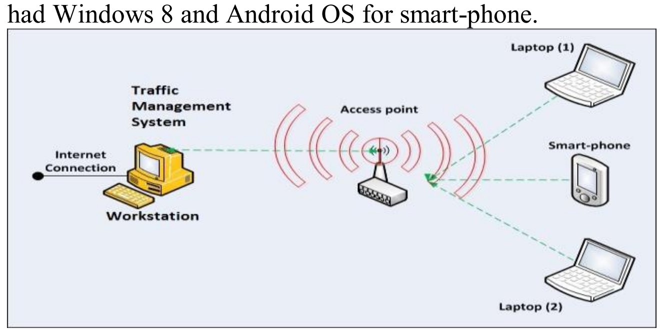

Figure 1: Proposed network infrastructure test-bed

D-ITG [12] is a tool that was utilised to generate and measure the Internet traffic. Hence, D-ITG application was run from laptop-2 to generate four types of Internet traffic which was equivalent to Telehealth application scenario. Therefore, a single connection was established from laptop-2 to send and receive VoIP, multimedia, data and video traffic concurrently in RTT (Round-Trip-Time) format. On the other hand traffic-load was increased from 0-12Mbps while testing four types of traffic from two other devices (laptop-1 and smart-phone). The parameters considered were delay, jitter, CPU utilisation and packet-loss and 10 repeated tests runs were averaged.

The hardware included for a workstation was Intel quad core with 4.00GB RAM and a portable USB NIC card (Realtek RTL8191SU) where Internet traffic was set to be controlled. On the other side laptop-2 that hosted m-health application had the following; Intel® Core™ 2 Duo CPU (3.0GHz) with 6.00 GB RAM and (Intel(R) Centrino(R) Advanced-N 6230) NIC card built-in. The laptop-1 had an Intel® Atom™ CPU N450 (1.66x2GHz) with 1.00 GB RAM. Plus a Samsung Galaxy S3 smart-phone and a D-Link access point (Wireless N750 dual band router with 3 antennas).

IV. Experimental Results

Experiment 1: Delay (RTT)

For all the tests, we have considered four types of Internet traffic that was typical of Telehealth application needs comprising of VoIP, Video-over-IP, data and multimedia. We designed and implemented three different scenarios such as WAT, WOCT and WCT.

WAT: stands for without-any-traffic which means that in this setup no additional background traffic was used by other devices.

WOCT: stands for without-controlled-traffic which means that in this setup no traffic management system was implemented and Internet traffic was utilised by all the devices connected to an AP.

WCT: stands for with-controlled-traffic which means that in this setup a traffic management system was implemented and Internet traffic was controlled by a main PC before sharing through an AP to other devices. This graph presents results for delay RTT (round-trip-time) that were obtained from our three scenarios

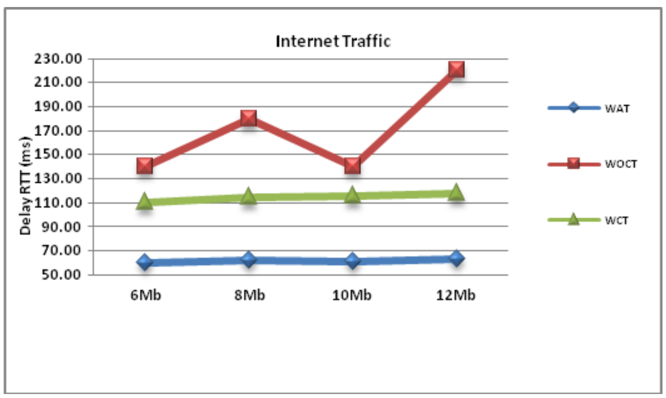

Figure 2: RTT comparison for three scenarios

Fig.2 presents the RTT results for Telehealth application that shows if no additional devices are utilising the bandwidth from an AP and only one PC has all the available bandwidth, then Telehealth application would have a delay average similar to WAT. WAT produced ~60-65 milliseconds of delay while WOCT had impacted that traffic and increased delay under different traffic-load.

The background bandwidth limits were set (6, 8, 10 & 12Mbps) during tests. WOCT scenario covers utilisation of bandwidth required by other devices while Telehealth application is running. Therefore, Telehealth application gets impacted when other devices utilise bandwidth (that should have been reserved for Telehealth application) and cause higher delay. As it can be seen in WOCT that delay is unpredictable as there is no traffic management tool or traffic shaping mechanism available in HAN.

WOCT caused ~80ms delay over WAT when other devices required 6Mb bandwidth while ~120ms when 8Mb bandwidth was required. It also impacted ~80ms delay when 10Mb bandwidth was required while caused ~180ms delay when 12Mb bandwidth was required.

WCT is a designed system established to control and limit bandwidth by first PC in the network. Hence, it can be seen that by limiting the bandwidth we were able to maintain the average delay between ~110-120ms for Telehealth application while other devices were lower prioritized than Telehealth application. Overall it can be drawn that utilising our method (WCT) can manage bandwidth at home area network without any additional cost and equipments.

Experiment 2: Jitter

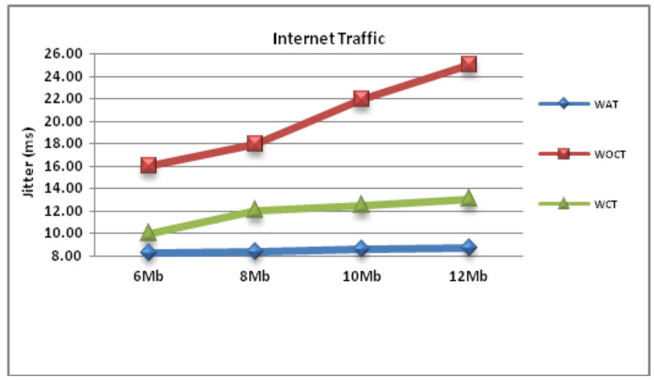

Figure 3: Jitter comparison for three scenarios

The results of jitter are shown in Fig. 3 above. As we can see that WAT had produced ~8-9ms jitter. However, other devices can make it higher unpredictably as shown in WOCT that WOCT caused ~8ms jitter over WAT when other devices required 6Mb bandwidth while ~10ms when 8Mb bandwidth was required. It also impacted the additional ~14ms jitter when 10Mb bandwidth was required while caused ~16ms additional jitter when 12Mb bandwidth was required.

Experiment 3: Packet loss

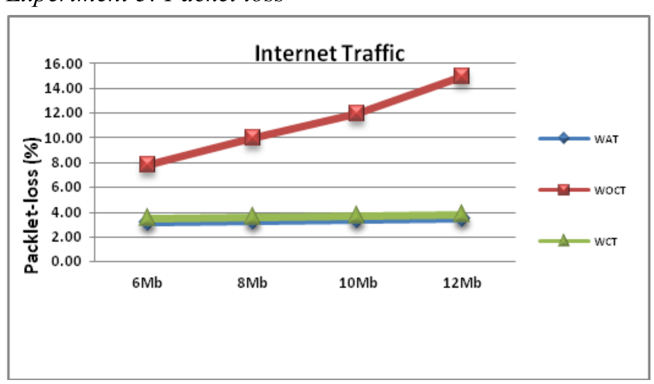

Figure 4: Packet-loss comparison for three scenarios

The results for packet-loss indicated that using WOCT can unpredictability cause higher packet-loss, especially when more traffic-load is put by other devices. As it can be seen in Fig. 4, WAT can provide approximately 3.5-4% of packet-loss while having no background traffic. However WOCT had ~8% packet-loss under 6Mb background traffic while ~10% under 8Mb. It continued to rise as background traffic-load was set to 10Mb and it showed ~12% while ~15%

under 12Mb. WCT showed that it is capable of controlling the traffic as it kept packet-loss within a consistent range of ~3-4 under 6, 8, 10 and 12Mb background traffic-load. Comparison between WCT and WOCT showed that WOCT produced ~12% more packet-loss than WCT under 12Mb background traffic load.

Experiment 4: CPU

TABLE 1: ADDITIONAL HARDWARE RESOURCE UTILISATION

Bandwidth management (Mbps)	Percentage of CPU (%)
6Mb	4
8Mb	6
10Mb	8
12Mb	10

Table 1 shows that additional resource utilised by our bandwidth quality management system. We noticed that 6Mbps bandwidth management put ~4% extra load while ~6% when 8Mb was processed. The observation also showed that 8% was noticed when 10Mb was processed whereas 10% was measured when 12Mb was processed. Overall, it can be said that 10% of additional hardware resources could provide better bandwidth management system because normally computers at homes do not require maximum CPU resources.

V. DISCUSSION

In this study we quantified the performance of Telehealth application over a home area network (HAN) environment. We proposed a method to manage HAN to enhance the quality of Telehealth applications. Our three scenarios were tested and the outcomes were as follows:

Telehealth application including four types of Internet traffic (VoIP, Video-over-IP, data and multimedia) was measured over HAN; meanwhile background traffic-load was increased from 6-12Mb. First scenario WAT indicated that without any additional traffic-load Telehealth application had good level of communication as delay, jitter and packet-loss was at its minimal level in our best cases. However, with the second scenario, WOCT showed that bandwidth required by other devices in HAN dramatically impacted the Telehealth communication and lead to loses in the communication that resulted in poorer quality in all our measures.

Our proposed WCT indicated that it is capable of controlling traffic as it ensured that Telehealth application remains within acceptable quality range while managing other devices in the network. However, WCT requires additional CPU utilisation when managing other devices as it used ~1% extra CPU resource while managing 2Mbps bandwidth addition to Telehealth application.

VI. CONCLUSION

In this paper we have investigated the quality of HAN to support Telehealth applications. We identified the problem and proposed a method that enables Telehealth application to get a higher priority by managing other devices' bandwidth without any additional cost and equipments. Our proposed method was tested and the results showed that it is capable of enhancing the performance of Telehealth applications in a HAN environment. Our WCT scenario performed much better as it kept delay, jitter and packet-loss within acceptable range. The only resource drawback was that a computer which is enabled to manage bandwidth for whole HAN requires additional 10% of CPU resources utilisation.

Our future research studies will cover new methods and techniques to enhance home area network to support Telehealth applications. The quality of more recent operating systems e.g., Windows 8, Android, iPhone etc., and newer voice, video and multimedia protocols would also be quantified.

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