Research on IEEE 802.11 Wireless LANs Traffic Characteristics Analysis for Supporting Picture Archiving and Communication System (PACS)

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Summary
Nowadays, a health system uses medical imaging or Picture Archiving and Communication System (PACS) and clinical information services such as medical record system (MRS), which are becoming popular to deliver over wireless networks. There is a needed to study in PACS traffic over WLAN in order to a support QoS for network design. Recently, characteristic of HTTP, FTP, SMTP, VoIP and other Internet applications are widely studied. At this time, characteristic of PACS traffic in the IEEE 802.11 WLAN is rarely studied. Therefore, this paper presents the results of PACS traffic analysis in the WLAN. The traditional traffic analyst often represents its results in terms of bandwidth such as bandwidth utilization. In contrast, the PACS traffic analysis in this paper focuses on a term of delay since a constraint of PACS communication is based on time delay. The experimental results show relationships among the PACS's KPI, data rate (Mbps), duration time (Second) of PACS flow, packet size and the packet arrival rate (pps). Additionally, this paper presents an effect of variable PACS flows (traffic load) on duration time, packet size, and packet arriving rate (pps) based on actual measurement on the hospital network. An effect of variable bandwidth also is investigated.
Key words:
Picture Archiving and Communication System (PACS), Traffic Measurement, Traffic Characteristics, Wireless local area network (WLAN)

1. Introduction

During the last few years the Picture Archiving and Communication System (PACS) that is the most popular for health system architecture has changed from radiographic film to digital imaging called a filmless system [1]-[8]. The PACS or filmless information system is an a combination of hardware and software, which is used to capture, store, distribute and display images with the Digital Imaging and Communications in Medicine (DICOM) standard [9].

The PACS normally requires a high-speed network to transmit large picture between PACS's server and viewing workstations because a constraint of PACS communication is defined as the desirability that one-way direction of each image should be displayed on a viewing workstation screen within 5 seconds, known as Siriraj PACS's KPI.

The health system uses medical imaging or Picture Archiving and Communication System (PACS) medicine and clinical information services such as X-ray, laboratory work, and medical record system (MRS), which are popularly delivered over wireless networks. A system with wireless enables mobile carts to easily setup and be kept running at the bedside. There are many important issues that are of concern when PACS traffic is conducted over IEEE 802.11 wireless LANs in order to support QoS for network design.

Up to now, there have been many researches about traffic analysis of HTTP, Telnet, VoIP, FTP and other applications in terms of bandwidth usage, packet length (size) distribution (byte) and volume of packet arriving rate (pps) [10-15]. In [10], packet length distribution and packet interval time or packet arrival time (pps) of WAN, LAN and Intranet traffic are presented. Traffic patterns and characteristics are important for network design. Additionally, they are necessary for QoS routing which relates to a constraint of delay-sensitive applications. The constraint of VoIP is that time-delay in one-way direction of VoIP packet should be less than 150 msec [15-16]. Telnet's constraint is that teletyping in Telnet should remain below 150 msec [11], [15]. A display of each webpage on a browser (e.g. IE) should be less than 5 sec [17]. A constraint of displaying each image of PACS on viewing workstations is that it should be below 5 sec [6], [12-14]. P.Patpituck and S.Chimmanee analyses the traffic characteristic of PACS over the local area network, which focuses on relationship among the bandwidth (Mbps), the duration time (msec), and the packet arriving rate (pps)[18]. P.Patpituck and S.Chimmanee studied PACS traffic over wired-line [12]-[14].

Until recently, Traffic Analysis on PACS over wireless has been rarely studied. This paper is extended from the previous work [18], and proposes an effect of variable PACS flows (traffic load) and Wireless LANs Bandwidth connection (Data rate) on duration time, packet size, and

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packet arriving rate (pps) based on actual measurement on the Siriraj hospital wireless LANs network.

The rest of this paper is organized as follows. In section 2, background is stated. In section 3, Experiment setup is explained. Section 4 provides the experiment result. Finally, section 5 draws conclusions.

2. Background

2.1 The Picture Archiving and Communication System (PACS) History

In 1982, Picture Archiving and Communication System (PACS) was introduced, followed by development and implementation [19].

2.2 IEEE 802.11 Wireless Standards

The first wireless local area network (WLAN) standard was created in 1997 by the Institute of Electrical and Electronics Engineers (IEEE), and it was called as IEEE 802.11. There are many versions of the initial standard which have been launched such as the following: IEEE 802.11a, IEEE 802.11b, IEEE 802.11g, and IEEE 802.11n.

2.3 Traffic Characteristics Analysis

In [20], [10], traffic analysis was represented in terms of packet arrival time and packet length (bytes). Henry J. Fowler et al, studies traffic characteristics of congestion on local area networks with connectionless service. This analysis is presented in terms of packet arrival time by time of day in order to understand congestion management [10]. In [20], there are three traffic models measured as follows: LAN, WAN and Intranet. This focuses on the relationship of IP packets length in bytes and frequency as percentage. Up to now, research of PACS traffic analysis in term of traffic volume and packet delay over wireless LANs has not yet been properly analyzed. P.Patpituck and S.Chimmanee [18] conducted research on the Wireless LANs Traffic Characteristics and relationships among the PACS's KPI, data rate, duration time of PACS flow and the packet arrival rate.

3. Experimental Setup

This section consists of two subsections. One is network configurations and the other is experimental configurations.

3.1 Hospital Network Configuration (Siriraj Intranet)

Siriraj Hospital Management Information System, called as SiHMIS Network is a network for the main part of Faculty of Medicine Siriraj Hospital, Mahidol University, Thailand as shown in Figure 1. A network diagram in the figure 1 can be divided into three zones: PACS server zone, medical equipment zone, and workstation zone that contains both wire and wireless workstations

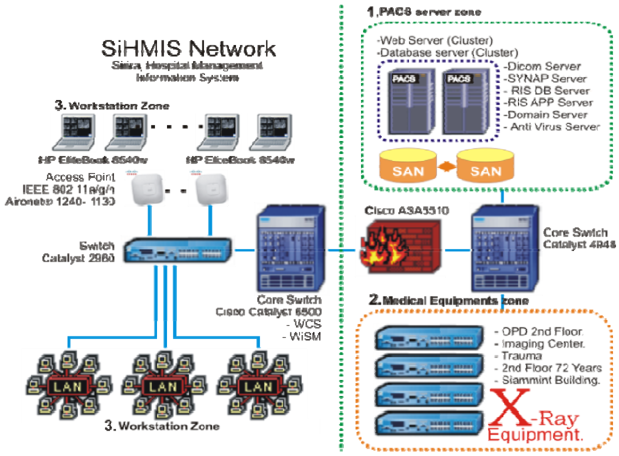

Fig. 1 shows a major part of Siriraj Hospital Network divided into three zones. Note that Siriraj hospital is the biggest hospital in Thailand in which there are 2,368 beds for serving patients.

(i) In the first zone, the main servers are Web, Database, Synapse, and Radiology Information System (RIS), including Storage Area Network (SAN). All interfaces of PACS servers connected via a core switch, i.e., are Gigabit Ethernet links.

(ii) The second zone (called as Medical equipment zone) is connected to access switches e.g. Cisco Catalyst 4948. The access switches are connected to a distributed switch e.g. Cisco Catalyst 2960. All interfaces of the distributed switches connected to the core switch are Gigabits.

(iii) In the third zone, there are 2 types of viewing workstations, which can access the PACS server via the access switch and accesspoint, distributed switch, firewall, and core switch. The Siriraj PACS (SiPACS) contains PACS server and medical equipment zone as shown in the figure 1. SiPACS is separated from SiHMIS network by firewall for security. All access switches in SiHMIS zone are connected to all workstations with speed 10/100/1000 Mbps and also connected to wireless access point with IEEE 802.11a/g/n. A firewall shown in the figure1 is Cisco ASA 5510.

3.2 Experiment Configuration

The viewing workstations for testing on all experiments are using HP Elitebook 8540W Mobile Workstation with CPU Intel Core i7-720QM Processor speed 1.60 GHz, Display 15.6-inch diagonal 16:9 LED-backlit HD

1920x1080 resolution, DDR3 4,096 MB, Wireless Intel Centrino Advanced-N6200AGN, Hard drive SATA II 500GB. Their operating system is Windows XP Professional with service pack 3 and web browser is internet explorer (IE) version 8.

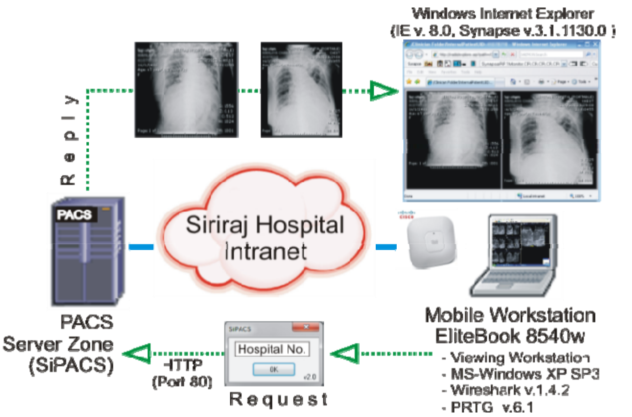

Fig. 2 displays the network connection between PACS servers and a sniffer computer that is a viewing workstation for experiment 1 to 5.

There are five experiments as follows:

(i) Experiment 1: Investigating the nature of PACS traffic in term of delay over wire (LAN 100Mbps) and wireless (WLAN 54Mbps) during October17 to 6 November, 2010 using PRTG (Paessler Router Traffic Grapher) Traffic Grapher.

(ii) Experiment 2: to studying an effect of variable bandwidth on Siriraj PACS's KPI or constraint of PACS over Wireless LANs with 4 data rates as 54Mbps, 48Mbps, 36Mbps, and 24 Mbps, respectively.

(iii) Experiment 3: packet length distribution and packet interval time was investigated in terms of probability density function (PDF).

(iv) Experiment 4: The relationship among bandwidth connection, duration time and packet arriving rate were observed. 15 PACS flows were sent from PACS server to the sniffer computer on July 27, 2010 during 11:30 to 11:56. In addition, there were varying data rate connections as follows: 54Mbps, 48Mbps, 36Mbps, and 24Mbps

(v) Experiment 5: to studying an effect of variable on PACS flow with constraint of displaying the image (duration time) on viewing workstation should be below 5 sec.

(vi) Experiment 6: to analyze the effect when variable bandwidth from 54 Mbps to 1 Mbps.

(vii) Experiment 7: to investigate relationships among number of PACS flows, Duration time (sec), Ping Delay time (msec), Data rate, and PPS.

4. Experimental Result

4.1. Result of experiment 1: a nature of PACS Traffic in term of delay over wire (LAN 100Mbps) and wireless (Wireless LAN 54Mbps)

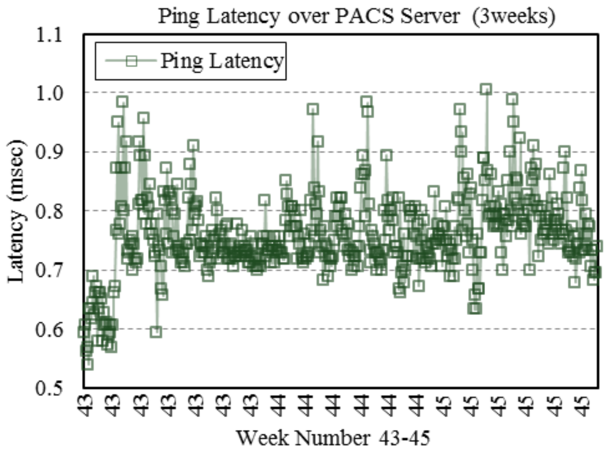

Fig.3 displays the measurement result of PACS Traffic in term of delay during three weeks.

In a figure 3, the PACS's traffic delay (Server site) during three weeks (on week number 43 to 45, 2010) is presented in a graph of delay time using the PRTG network monitor tool. Note that the packet size equal to 1,024 bytes was implemented. Comparisons of PACS delay time between Wireless LAN 54 Mbps and Local Area Network 100 Mbps at the client site in the same time are shown in figures 4 and 5. It's was done on December 27, 2010 during 9.20 AM to 10.30 AM. As for the results, it is interesting to note that the nature of PACS traffic over wireless 802.11g in terms of delay is different from such LAN traffic.

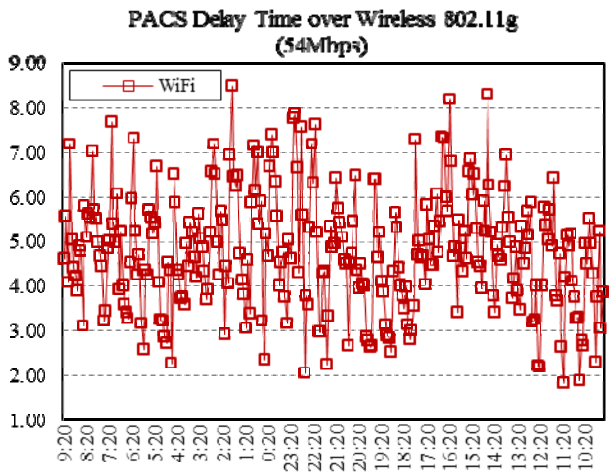

Fig.4 displays the PACS delay effect over Wireless 802.11g.

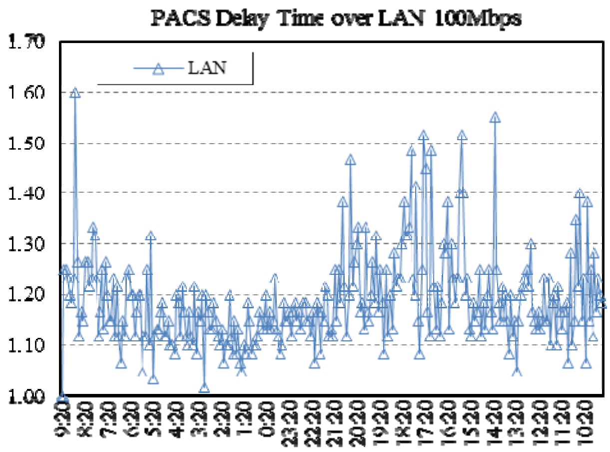

Fig.5 displays the PACS delay effect over LAN 100 Mbps

Table 1. Experiment results of PACS delay time between WLAN 54 Mbps and LAN 100 Mbps.

Type	Min. (msec)	Max. (msec)	Avg. (msec)	STDev. (msec)
WirelessLAN 54Mbps	1.8333	8.5000	4.7795	1.3272
LAN 100 Mbps	1.0000	5.9667	1.2046	0.2969

Table 1 shows the minimum, maximum, average, and standard deviation of PACS delay time between Wireless LAN 54 Mbps and LAN 100 Mbps. The result in column 4, finds that the LAN 100 Mbps introduces a better performance than the WLAN. In standard deviation at column 5, it the contrast of value between data rate (Mbps) and delay time (msec) is shown.

4.2. Result of experiment 2: the constraint of displaying the image on viewing workstation should be less than 5 sec

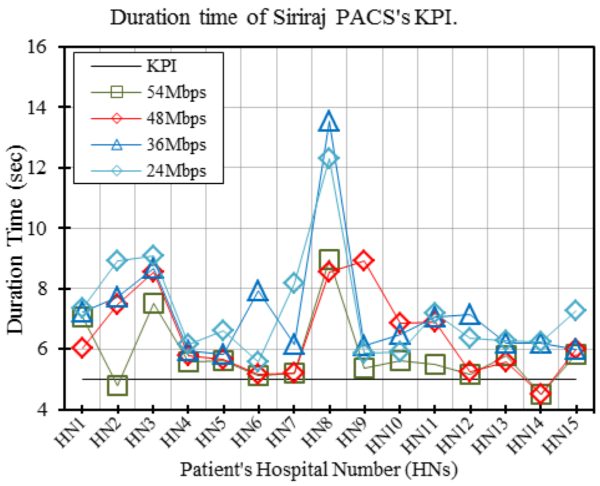

Fig.6 displays the duration time of HN.1 to HN.15. There are four data rats as follows: 54 Mbps, 48Mbps, 36Mbps and 24 Mbps, in order. this was done on August 19, 2010 from 09:00-09:30 AM.

Table 2. Lists duration time of PACS over wireless LAN in four data rate

No. / Data rate	HN. 1	HN. 2	HN. 3	HN. 4	HN. 5
54 Mbps	7.043	4.800	7.492	5.563	5.619
48 Mbps	6.042	7.484	8.527	5.769	5.638
36 Mbps	7.242	7.718	8.672	5.924	5.805
24 Mbps	7.328	8.919	9.078	6.141	6.616
	HN. 6	HN. 7	HN. 8	HN. 9	HN. 10
54 Mbps	5.117	5.216	8.970	5.349	5.616
48 Mbps	5.139	5.181	8.527	8.936	6.841
36 Mbps	7.912	6.139	13.527	6.121	6.460
24 Mbps	5.572	8.183	12.299	5.875	5.890
	HN. 11	HN. 12	HN. 13	HN. 14	HN. 15
54 Mbps	5.483	5.173	5.795	4.499	5.820
48 Mbps	6.893	5.250	5.557	4.499	5.998
36 Mbps	7.051	7.160	6.177	6.177	6.001
24 Mbps	7.163	6.345	6.292	6.250	7.283

Siriraj PACS's Key Performance Indicators (KPI) indicates that the constraint of displaying the image on viewing workstation should be below 5 sec [6]. From results of Figure 6 and Table 2, there are only 2 flows (13.33%) from 15 flows of HN that meet the Siriraj PACS's KPI at data rate 54Mbps. In data rate 48Mbps, there is only 1 flow (6.66%) from 15 flows of HN that meet the Siriraj PACS's KPI. In data rate 36Mbps and 24Mbps, there are no any flow which meets the Siriraj PACS's KPI.

4.3. Result of experiment 3: packet length distribution and packet interval time was investigated in terms of PDF.

The goal of this experiment is to study the distribution of packet size (byte) and packet interval (msec). This experiment was divided into two sub-experiments: PACS with actual 120 flows measurement in packet interval time and packet size distribution over wireless LANs traffic. There are about 740,000 packets. This was done on December 12, 2010.

Figures 7 and 8 display the packet interval times of PACS between 0 to 1 msec and above 1 msec are orderly in the form of PDF. At the highest probabilities are those between 0.025 to 0.10 msec, as shown in figure 7. The figure 9 represents the same result as figure 7-8 in the order of high probability to low probability.

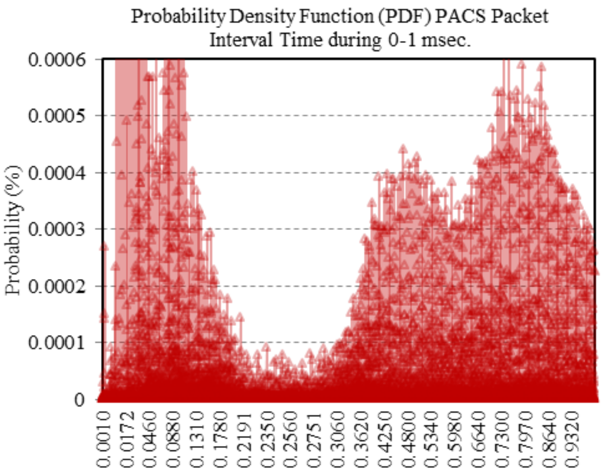

Fig.7 displays the 120 PACS flows of packet interval time in form of PDF

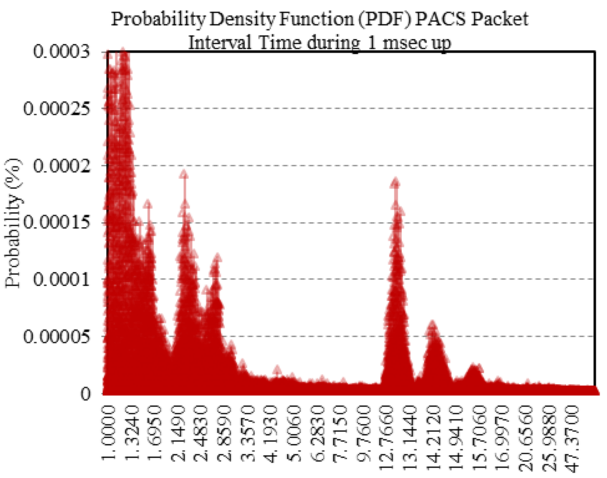

Fig.8 shows PACS packet interval time more than one milliseconds.

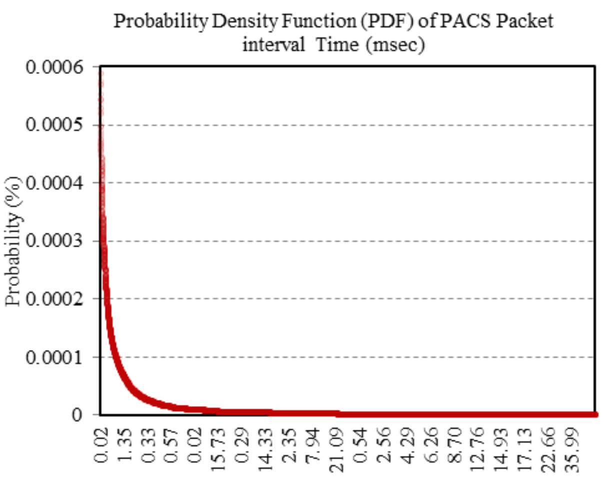

Fig.9 displays the packet interval time of 120 HNs (about 740,000 packets). These were done on December 12, 2010 during 01:00-04:00 PM.

The second sub-experiment includes about 740,000 of PACS packets with the packet size from 54 bytes to 1514 bytes based on actual PACS traffics at Siriraj hospital network during 09.00-10.30 AM on January 1st, 2011. Figure 10 shows a PACS PDF packet size in order of small to large size. Figure 11, represents an order of high probability to low probability.

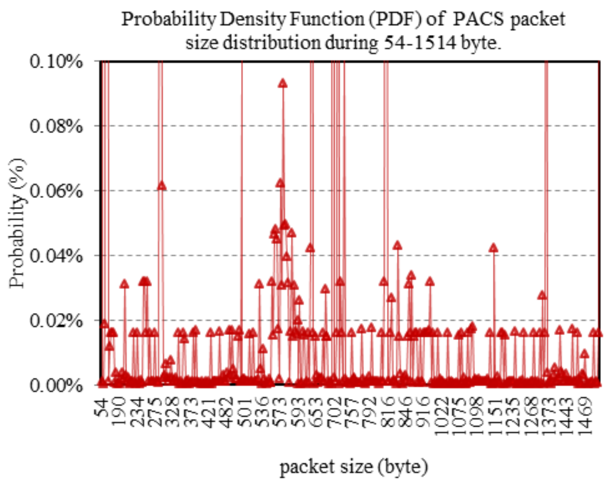

Fig.10 displays the PACS PDF packet size (small to large size)

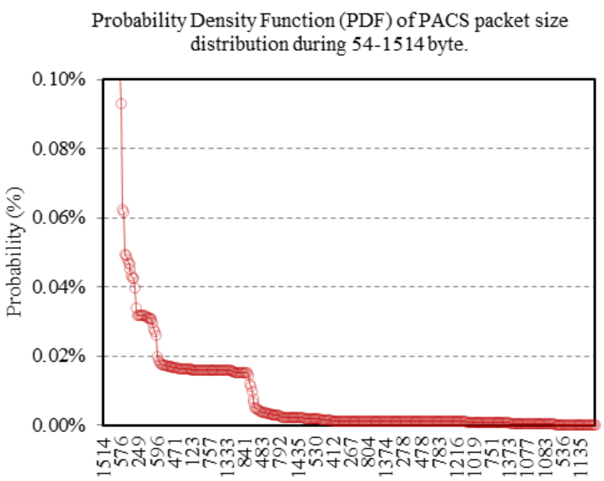

Fig.11 displays the PACS PDF packet size from high to low.

4.4. Result of experiment 4: The relationship among bandwidth connection, duration time and packet arriving rate.

There are three factors of concern for PACS traffic in this experiment as follows: data rate (Mbps), duration time (sec), and packet arriving rate (pps). Figure 12 shows the relationship by comparing to four graphs where each graph displays the relationships between duration time and packet arriving rate.

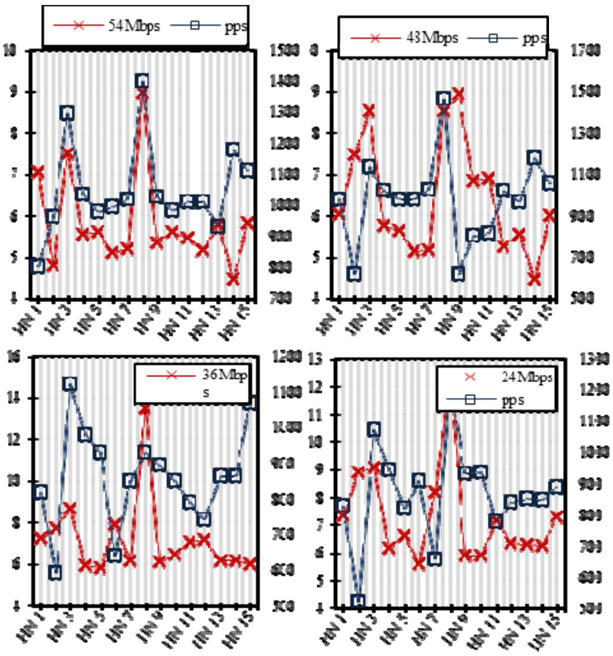

Fig.12 Displays the Relationships between Duration Time and PPS

4.5. Result of experiment 5: to test variable PACS flow with constraint of displaying the image (duration time) on viewing workstation for less than 5 sec.

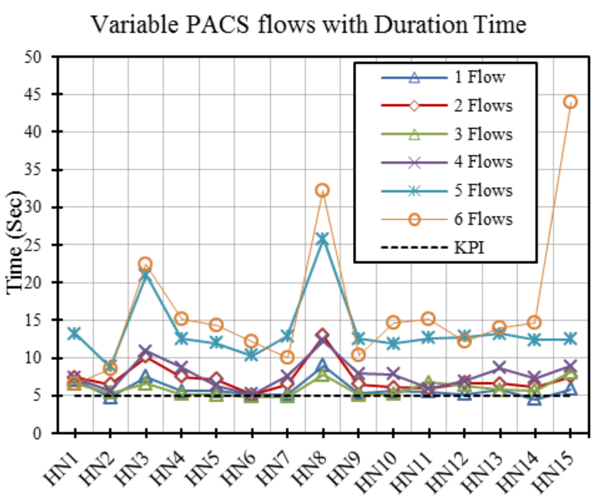

Fig.13 displays the effect of duration time when variable PACS flow from 1 to 6 Flows at the same time.

This experiment investigates the effect of PACS delay time on variable number of PACS flow from 1 to 6. From figure 13, when the PACS flows increases, the Duration time also increases in the same direction. It is interesting to note that the effect of increasing PACS flow from 5 to 6 becomes more apparent. Some variables from 1 to 3 flows can only meet the PACS's KPI.

4.6. Result of experiment 6: to analyze the effect when variable bandwidth moves from 54 Mbps to 1 Mbps.

In this experiment investigates the effect of bandwidth connection on PACS duration time. Figure 14 shows that when the bandwidth connection is increasing linearly, the capture duration time is slightly growing, except for the bandwidth at 1 Mbps.

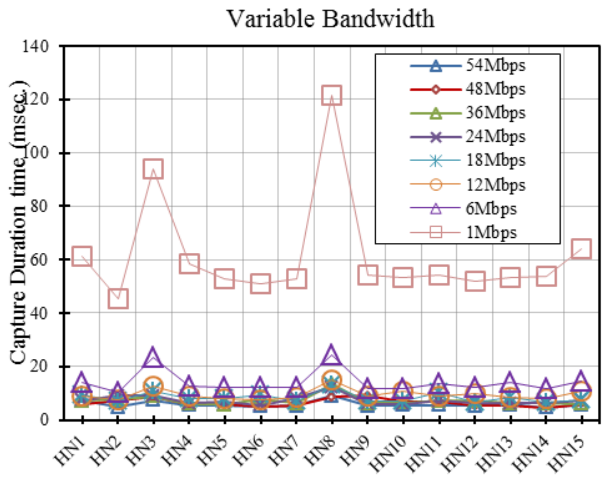

Fig.14 displays the effect of bandwidth when variable data rate from 1Mbps to 54Mbps.

4.7. Result of experiment 7: to investigate relationships among the number of PACS flows, Duration time (sec), Ping Delay times (msec), Data rate, and PPS.

In this experiment result, ping protocol is used for investigating the network congestion as shown in figure 15. When the ping delay time increases, the duration time also increases in the same direction. However, at 2nd and 5th flows, the ping delay time is much higher because the background traffic of the intranet rather than the increasing of PACS traffic flow. In the other word, the background traffic is more significant than the increase PACS traffic flow in this case.

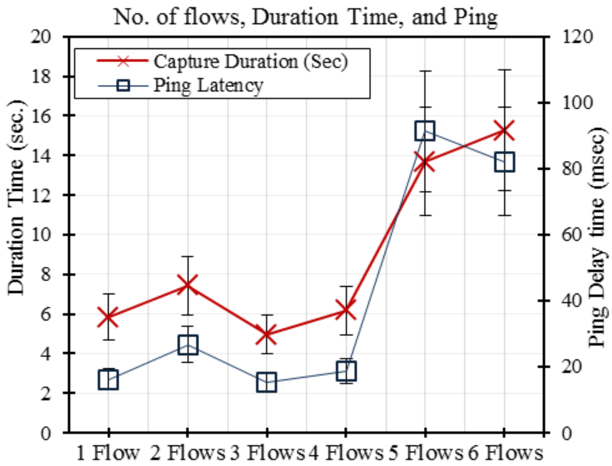

Fig.15 displays the No. of flows, Duration Time, and Ping

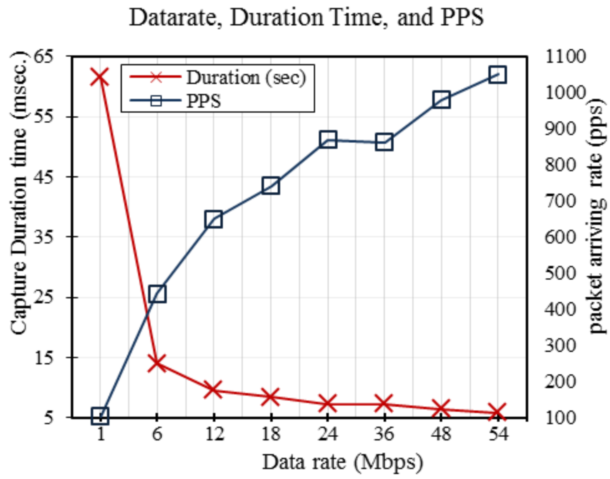

Fig.16 displays the Data rate, Duration Time, and PPS

This experiment represents the relationship of three factors as following: Data rate (Mbps), Packet arriving rate (pps), and Capture Duration time (msec). It is found that when the bandwidth is on increasing from 12 to 54 Mbps, duration time is slightly decreasing. On the other hand, the pps increases nearly parabolic.

The most significant point is that when the bandwidth is large, the duration time will be short but the packet arriving rate (pps) is also high.

5. Conclusion

In this paper, the traffic characteristic of PACS application over IEEE 802.11g in the hospital network is investigated from our experiments, it is found that a relationship exists among the bandwidth (Mbps), the duration time (msec), and the packet arriving rate (pps).The bandwidth and the packet arriving rate increase or decrease in the same direction, but the duration time moves in the opposite direction. Overall, when the bandwidth connection is increasing linearly, the capture duration time is slightly growing. Totally, at flow 5th and 6th, the delay time is increased sharply. Additionally, there is only 13.64% of HN that passes the criterion of Siriraj's KPI. Therefore, there is a need to design a network for PACS with respect to PACS traffic pattern, its relationship of several parameters, and its constraints in order to enable PACS services quality to be above the KPI. Additionally, information of PACS analysis in this paper is much more for PACS traffic simulation benefit.

In future work, PACS network design and simulation by using the proposed PACS analysis and graph relationships presented in this paper will be studied.

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