Journal of Information Technology Impact
Vol. 4, No. 2, pp. 121-132, 2004

Performance of Wireless Local Area Networks in Malaysian Institutions

Azrilah Abdul Aziz[1] Mohd Adam Suhaimi[2]
International Islamic University
Malaysia

Abstract

Although Wireless Local Area Networks (WLANs) are widely used in many settings little work has been done in studying their impact and benefits. This study provides empirical indicators on the performance of the WLANs implemented on Malaysian Institutions of Higher Learning

*Our research adopted Deming's P-D-C-A Model and modified it to Plan-Implement-Control-Evaluate (P-I-C-E) in establishing a performance measurement for a WLAN; hence WLAN Performance Index (WP*i*). The measurement consists of four key performance indicators (KP*i*), reflecting the performance of the four P-I-C-E dimensions. These performance indicators provide a guide for the institutions to take the necessary corrective and preventive actions in attaining an effective WLAN system.*

*Benchmarking was conducted by comparing three institutions in identifying the best WLAN system measures. The WP*i *is then applied to the three Malaysian public institutions of higher learning (MIPTA), which have implemented such WLAN system.*

*The study reveals the WP*i *of each of the MIPTA being measured, indicating the strength and weaknesses of each institutions. Also, we suggest corrective actions necessary in achieving an effective and efficient WLAN system. Gap analysis was done to the three MIPTAs findings comparative to the benchmarked WLAN system.*

Keywords: Wireless Local Area Networks, Performance Measurement, Performance Indicators, Institutions of Higher Learning

Introduction

Local area networking (LAN) enables communication between linked resources. Desktop or personal computers, mainframes, printers, servers are being connected to share and transfer information between one another (Geier, 2001). Cables like the CAT5 type or fiber optics are used to link these resources, which limits the movement of users and connectivity to the existence and length of the cables. Users were unable to get connectivity to the resources where it is impossible to laid the wired accessing point.

However, with the emergence of Wireless Local Area Networking (WLAN), users are able to get connectivity to the resources without the limitations of the cable's existence and length. In a WLAN environment, resources are shared without cables and the transmission is facilitated through air between these resources (Wheat, Hiser, Tucker, Neely, & McCullough, 2002)

With the move towards 802.11 standardization by the IEEE group (www.ieee.org) and the lowering of wireless product pricing, implementations of WLAN are more feasible. (Geier, 2001) Companies and organizations opt for a WLAN for mobility, hassle free installation-dismantling, and the cost benefit. (Andress, 2001; Charp, 2001)

Installation of a WLAN has been easy with the guidance from vendors and manufacturers, resulting tremendous implementation in organizations; public, private and learning institutions. Consultants and trainers like Intel, Lever Technology, and Gartner provide guides in achieving best WLAN implementation on an institution. (Haedtler, 2002; Lever Technology, 2003; Intel, 2003)

End-users and system integrators have limited knowledge and experience in developing and implementing the wireless network. There is also confusion over the capability and effectiveness of the 802.11 standard. (Geier, 2001; Intel, 2003; Lever Technology, 2003)

This study provides valuable empirical indicators on the performance of the WLAN system implemented on Malaysian Institutions of Higher Learning. Subsequently, the indicators shall determine the weaknesses and strength of the WLAN system enabling appropriate action to be taken in attaining an effective and efficient WLAN system.

Significance of the Study

There are many different models for system measurement developed by specialists, such as the Shewhart Cycle and the Deming P-D-C-A Model. For measuring cost we can mention the Six Sigma and the Balanced Score Card which is introduced by Harvard Business School. (Deming, 1986; Pende, 2000; Kaplan & David, 2000). The difference in the many types of models is the environment that the measurement takes place. Such environments range from manufacturing base organizations to financial base institutions.

Applications like the Team Quest Alert (www.teamquest.com), Cognos Metric Manager (www.cognos.com), and OptiView Integrated Network Analyzer (www.flukenetworks.com) are few applications that are able to do performance monitoring and highlight the status of the monitored servers. However, these applications are specific to traffic management and maintenance on the network environment.

In the WLAN environment, Bennington & Bartell (2001) pointed out that available Simple Network Management Protocol (SNMP) is considered primitive in monitoring the network performance. Most measurement models are measuring specific and technical aspects of the system.

Measurement models like the Memory System Performance (Stricker & Cross, 1997) and the research done by the University of Washington (2004) are models specifically measuring the performance of memory usage. NetLogger (Brian et al., 1998), DART routing protocols (Eriksson et al., 2004), and Computer System Analysis (Lazowska et al., 1984) assist in diagnosing real-time problems in networks that help to eliminate bottlenecks.

Throughput performance on a WLan system is being monitored by the Access Point Manager (Eaglin & Hartman, 1999). However, the own-developed software manager allows traffic monitoring to be done specific to the monitoring needs (Bartell, 1999).

The performance measurement models available for a WLAN system are measuring and only specific sections of the entire system. The study's model of the WLAN performance measurement is a holistic model which is able to indicate the system's performance from the planning stage of the system, to the implementation stage, then the control activity and evaluation thereof.

This study provides a model to measure the performance of a WLAN System on an institution giving its Wireless Performance Index (WP*i*) and its Key Performance Indicators (KP*i*). It is an empirical performance measure that reports the WLAN's accomplishment in terms that are easily understood from a non-technical perspective. The indicators show the strength, and weaknesses of each of the dimensions within the performance measurement model, offering opportunities to improve the services of the system.

Model Development

The study adopted and modified the Plan-Do-Check-Act (P-D-C-A) Model of Deming (1986) on a quality system measurement. A model of Plan-Implement-Control-Evaluate (P-I-C-E) was developed for the WLAN Performance Measurement Model, derived from Deming's and logically modified to suit the WLAN environment.

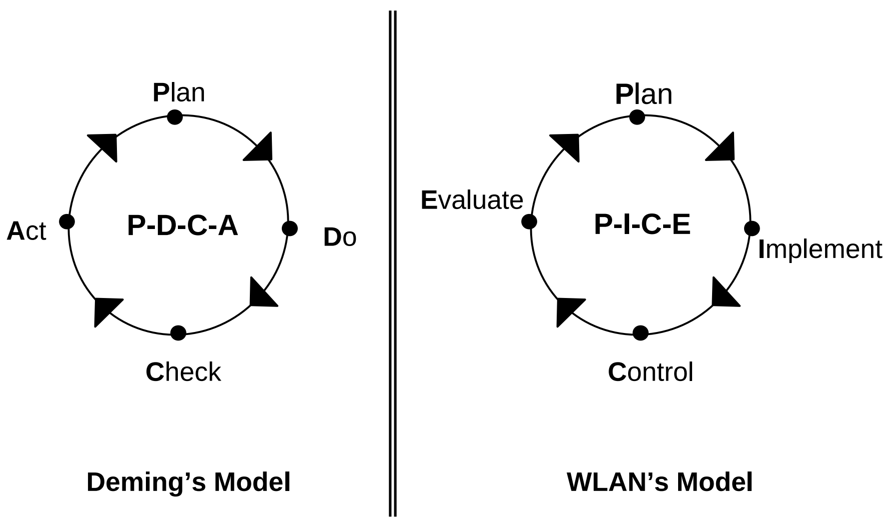

Figure 1. Modified Model Adopted from Deming

Each of the four P-I-C-E dimensions is considered a process on its own in measuring the performance of the WLAN system. Components within the dimensions were established by the Principle Component Analysis (PCA) (Anton, 1987) approach to identify the actual variables that need to be focused and measured.

Rationalization of Components

The components were derived from the guidelines provided by the trainer-consultant and users. The guidelines have been used as good design consideration in implementing a best WLAN system in an organization (Haedtler, 2002; Lever Technology, 2003; Intel, 2003). The components are the most common variables used by all three consultants.

Table 1. Tabulation of Dimensions and respective entities

Dimension		Common entities
Plan	**P**	• Cost • Technical specification • Coverage capability
Implement	**I**	• Adaptability • Dependability • Scalability
Control	**C**	• Network monitoring • Maintenance
Evaluate	**E**	• Acceptability • Technology enhancement

Plan dimension

In the Planning stage, it is obvious that knowing the expected number of users and the technical specification of the WLAN are critical before realistic cost projections and cost comparisons can be completed (Kime, 2004; ICMA, 1997). There is a triangular correlation between the technical specification, coverage size, and the cost. A high cost enables better choice of technical specification and thus gains a better coverage area; on the contrary, a low budget restrains the choices of product reliability and transmission coverage.

The study considers the annual product cost spent which consists of the number of wireless cards and the number of access points converted to monetary value. Through the findings from the benchmarking process from three different institutions, Cisco Aironet 1200 series's cost is used as base line (www.cisco.com), converted into Malaysian ringgit; at RM485.00 per piece for a wireless card and RM2,576.00 per piece for an access point (www.getronics.com). A standard price is needed to establish a consistent monetary value irrespective of the product used by the institutions.

The second component in the Plan dimension is Technical Specification. It measures the WLAN technology chosen by considering the bandwidth capability. The bandwidth capability is the most obvious factor in choosing the many different wireless products available, due to the standardization acknowledgement from the group IEEE. (Riezenman, 2002)

The third component within the Plan dimension is measuring the average wireless users growth that is indicated by the Coverage Capability indicator. The three components within Plan dimension are variables, which focus on decision-making management level on a global perspective.

Implement dimension

The Implement dimension indicates the performance of the system on the operational level or on the infrastructure perspective. Investigations need to be carried out in the areas which is specific and sensitive to the system in order to determine the problematic issues. (Baker, 2004) There are three components in Implement dimension; Adaptability, Dependability, Scalability. These three components are the sensitive and specific areas within the WLAN system.

The Adaptability component measures the familiarization aspect of the system indicated by the ratio of wireless cards sought by users. Dependability component, measures the reliability and confident level of the system reflected on the users, by comparing the differences of access nodes on the wired network and the wireless network. The Scalability component, measures the size of the WLAN system by quantifying the average access points throughout the system.

Control dimension

This dimension measures the checking and controlling activity of the WLAN in ensuring that the community of the institution benefited from the wireless facility provided (Headtler, 2002; Lever Technology, 2003; Intel, 2003). The two components explored in the Control dimension are Network Monitoring and Maintenance.

The Network Monitoring component worked as the indicator in balancing out the growth between the wireless users and the areas covering the service; departments applying wireless connectivity. It is as an assurance not to have a congested area at one location but a balanced number of users with enough access point for seamless connectivity to the network. Additionally, the Maintenance component measures the number of wireless access nodes available to the wireless users, in providing convenient and ample choice for connectivity to the network.

Evaluate dimension

A good performance measurement allows performance measures that can be used to support additional resource requests (Leithe, 1998). Therefore, the study has included the Evaluate dimension to permit an evaluation be done on the WLAN system to support future action or progress. The Evaluate dimension consists the Acceptability and the Technology Enhancement components.

The Acceptability component reveals the acceptable level of the WLAN system on the institution's community. It measures the ratio of wireless users compared to the entire community in the institution. The Technology Enhancement, measures the frequent upgrading of WLAN technology applied in the institution, as it emerges for use.

Model Development

Prior to formulating the Index and the Indicator performance, we performed a benchmarking process in determining the best WLAN system in an institution. Three institutions were chosen, according to the study's requirements. The three institutions, Institution A, Institution B, and Institution C, were investigated according to their dimensions and components, and a comparative analysis was summarized.

Institution C was unable to satisfy all the four P-I-C-E dimensions in the WLAN Performance Model. Institution B, however, managed to satisfy only the Evaluate dimension out of the four dimensions. On the other hand, Institution A satisfied all the dimensions and components prescribed and it is chosen as the benchmark WLAN System for this study. Each dimension provides an indicator on the performance of the respective dimension, for example the Key Performance Indicator (Plan). The KP*i* is derived by giving each component in the dimension, a score based on the Score Rating Criterion and multiplied by the weightage of each component.

The Score Rating Criterion has been specified in the study for consistent, convenient, and usable score grading in measuring WLAN performance on the other institutions. The criterion was derived by analyzing the average mean, the average growth, and the even ratios of the data provided by the MIPTAs. Whereas, the component's weightage was prearranged by the study's benchmarked institution, Institution A. The weightage was based on the priority or the strength of the components in one particular dimension.

$$\textit{Key Performance Indicator} = \frac{\text{Total of all component points in that dimension}}{\text{Maximum points of each dimension} = 50} \times 7 \text{ (on Likert scale)}$$

The study consists of four KP*i* , each KP*i* represents each dimension and x, y, z are the components score

1.	KP*i* (Plan)	= Σ (Plan)	= Plan (x + y + z)
2.	KP*i* (Implement)	= Σ (Implement)	= Implement (x + y + z)
3.	KP*i* (Control)	= Σ(Control)	= Control (x + y)
4.	KP*i* (Evaluate)	= Σ (Evaluate)	= Evaluate (x + y)

The sum of all the indicator points yields the WLAN Performance Index for the institution.

$$WPi = \frac{\Sigma(\text{Plan}) + \Sigma(\text{Implement}) + \Sigma(\text{Control}) + \Sigma(\text{Evaluate})}{4}$$

Validating the measurement

The WP*i* and the KP*i* were validated on the study's subsets population that is all the seventeen Malaysian public higher learning institutions (MIPTA).

The MIPTAs were informed about the study and data was collected accordingly through e-mail. The respective authorized personnel were searched through browsing each of the website available on the Internet. More than one individual was identified and contacted, in making certain that the e-mail is being responded to.

The study managed to obtain three complete sets of data in order to perform the WLAN performance measurement. Most of the MIPTA did not reply to the study's e-mail and few replied but with no data provided. Therefore, we decided to continue and measure the performance of the WLAN system on the three MIPTA that forwarded the completed set of data according to the study's data collection inquiry.

Results and Discussion

The performance measures revealed that the WLAN system in the three MIPTA is on or below average performance compared to the benchmarked WLAN system from Institution A.

A scale from 1 to 7 was chosen in reflecting the performance level of the WLAN system. Scale of 7 indicates an excellent performance while a 1 reflects the poorest performance of the WLAN system.

Case 1

MIPTA1 demonstrated an average WLAN system's performance with WP*i* (MIPTA1) of 4, and it attained a 4 for all the KP*i* in the four P-I-C-E dimensions.

MIPTA1 made available sufficient number of wireless cards for its wireless users, and planned to implement the highest bandwidth wireless technology as soon as the technology was released. It is seen also that MIPTA1, maintained a good ratio of wireless users and wireless nodes access.

However, MIPTA1 was seen spending less on its high growth of wireless users. The low spending resulted the low wireless access point's growth, which further implied low wireless access nodes connectivity, compared to wired. Therefore, the provision of wireless access nodes to wireless users was low with 4 wireless users sharing 1 wireless node. Even though MIPTA1 has a high wireless users growth but it was a low number of users compared to the overall institution population.

MIPTA1 needs to improve on its wireless nodes availability in order to gain much reliability, recover its scalability, and to have proper growth of its wireless users and the departments employing WLANs.

		Benchmark		MIPTA1		MIPTA2		MIPTA3	
No.	**Component**	**Score**	**KP*i***	**Score**	**KP*i***	**Score**	**KP*i***	**Score**	**KP*i***
Dimension 1: Plan									
1	Cost	5		1		1		1	
2	Technical Specification	5		4		1		4	
3	Coverage Capability	5	7	4	4	2	2	1	3
Dimension 2: Implement									
4	Adaptability	4		5		1		5	
5	Dependability	5		1		2		3	
6	Scalability	5	6	1	4	1	2	1	5
Dimension 3: Control									
7	Network Monitoring	5		1		1		1	
8	Maintenance	5	7	4	4	1	1	1	1
Dimension 4: Evaluate									
9	Acceptability	3		2		1		1	
10	Technology Enhancement	5	5	5	4	4	3	3	3
	WP*i*		**6**		**4**		**2**		**3**

Figure 2. Summarized WLAN System's Performance

Case 2

MIPTA2 managed a WLAN system's performance of WP*i* (MIPTA2) = 2. It's performance fall below the average performance of 4, with all of its KP*i*'s fall below the average score.

MIPTA2 spent below the minimum average spending of the benchmarked system, and has a low wireless users growth. It has chosen a low bandwidth WLAN technology, and planned to implement highest of only 4Mbps technology. MIPTA2 even has a high number of wireless cards which had not been used by wireless users, indicating low adaptability performance of WLAN system.

The low average product spending reflected in the low number of APs. This consequently caused the low provision of wireless access nodes compared to the wired access nodes, indicating a low dependability towards the WLAN system.

Even though the WLAN technology progression was seen in MIPTA2, the ratio of wireless users was still very low compared to whole population of the institution.

MIPTA2 should enhance its WLAN system to have a higher bandwidth wireless technology in attracting more wireless users. Expanding of the WLAN system should be observed carefully on providing enough wireless access nodes to wireless users. This will further promote the community to use wireless connectivity, by means of convenient access.

Case 3

MIPTA3 reached a WP*i* (MIPTA3) = 3 but still fell below the average performance. It however, managed one KP*i* (Implement) = 5 and the rest of the KP*i*'s fell below level 4.

MIPTA3 had a high average product spending over five (5) years compared to its low wireless users growth. The high spending reflected on the high number of APs on the institutions. This further resulted wastage of three (3) wireless nodes provision to every wireless user. Consequently, MIPTA3 has low AP growth and a low implementation level by the departments in the institution.

However, credit has to be given to MIPTA3 for its 11Mbps wireless technology chosen, its careful provision of each wireless card to every wireless user, and ample option of wireless nodes in every three (3) wired connectivity. MIPTA3 should increase the number of wireless users in reaching a higher ratio of users compared to the whole campus population, making use of the excessive access points and wireless nodes available.

Summary

Through gap analysis and Data Envelopment Analysis (DEA), (Charnes, Cooper & Rhodes, 1978) it is discovered that MIPTA's WLAN performance is by average seven (7) years gap from the benchmarked WLAN system. MIPTA1 is expected to reach optimum performance of 6 by year 2007, MIPTA2 needs another 6 years that will be in year 2010. MIPTA3 has to go a long way up to 12 years i.e. in year 2016.

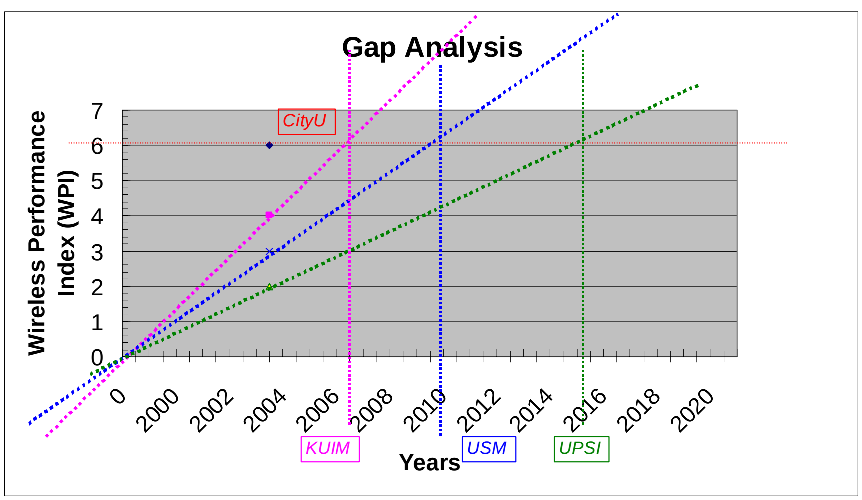

Figure 3. Gap Analysis

Conclusion

The seven (7) years of gap is regarded as being not practical due to:

a. Technology is very versatile and emerges frequently, and it is not prudent to have a 7 years outdated technology. By the time the expected implementation is achieved new technology is out replacing the obsolete one.
b. Demand in teaching methodology changes, from teaching with conventional transparencies to multimedia on a networking environment. Therefore requires enhanced technology that is able to deal with complex applications and users demand.
c. Nowadays, learning is shifting towards problem-based learning. The current technology facilitates the learning by applying the problem solving experience to a similar environment.

The study suggests that proper measures need to be implemented in order to intercept the lagging trend and accomplish effective and efficient WLAN system through

a. Implementation policy should be focused towards pro-active decisions, to install and explore rather than wait and see.
b. Technology consideration should be as current as the released technology.
c. Network monitoring and system maintenance should be of preventive nature, not as and when it receives complaints from users.
d. System scalability and flexibility should be a prime consideration in order to allow possible use and migration of the best available technology.

References

Allen, J. R. (1996). *The uses of performance measurement in government*. Government Finance Review 12(4), 11-15

Andress, M. (2001). *Wireless LAN Security*. Indiana, USA. Sams Publishing

Anton, H. (1987). *Elementary Linear Algebra 5e*. John Wiley & Son Inc

Baker, D. (2004). *Performance Improvement*. Retrieved September 25, 2004, from www.ishinc.com/white_papers/performance.htm

Bartell, C. R. (1999). *Wireless Networking Directions*. TechTalks. Retrieved October 24, 2002, from at www.cren.net

Bennington, B.J., & Bartell C. (2001). *Wireless Andrew: Building a High Speed, Campus-Wide Wireless Data Network*. Mobile Networks and Applications 6, 9-22.

Charnes, A., Cooper, W.W. & Rhodes, E. (1978). *Measuring the efficiency of decision-making units*. European Journal of Operations Research, 429-44.

Charp, S. (2001). *Wireless Networks*. T.H.E Journal. Retrieved June 24, 2003, from www.thejournal.com.

Cuinas, I., Sanchez, M.G. (2001). *Measuring, Modelling and Characterizing of Indoor Radio Channel at 5.8GHz*. IEEE Transactions on Vehicular Technology, 50(2).

Deming, W. E. 1986. *Out of the crisis*. Cambridge, MA: MIT Press.

Eaglin, R. and Hartmen, J. (1999). *Wiring For A Wireless Campus*. TechTalks. Retieved October 34, 2002, from www.cren.net

Eriksson, J., Faloutsos, M. & Krishnamurthy, S.V. (2004). *Scalable ad hoc routing: The case for dynamic addressing*. In IEEE INFOCOM, Hong Kong.

Geier, J. (2001). *Wireless LANs: Implementing High Performance IEEE 802.11 Networks*. Indiana, USA. Sams Publishing.

Gore, A. (1997). *Serving the American public: best practices in performance measurement*. Washington D. C.: National Performance Review

Hacker, T.J., Noble, B.D., & Athey B.D. (2004). *Improving Throughput and Maintaining Fairness using Parallel TCP*. Retrieved 8 October, 2004, from http://www.personal.engin.umich.edu/~hacker/papers/infocom04.pdf

Haedtler, D. (2002). *Wireless Access, Mobile Business Workshop Notes*. Retrieved April 26, 2004, from www.gartner.com/2_events/best_practices/020413_wireless.pdf

Intel. (2003). *Deploying Wireless LANs*. Retrieved April 26, 2004, from www.intel.com/business/bss/infrastructure/wireless/deployment/deploy_wlan.pdf

Intermec. (2004). *Defining A Successful Wireless Solution*. Retrieved April 26, 2004, from epsfiles.intermec.com.eps_files/eps_wp/SuccessfulWirelessSolution_wp_web.pdf. Intermec.

Jobin, J., Faloutsos, M. & Tripathi S. K. (2001). *Performance Evaluation of Mobile Wireless Networks: A New Perspective*. The fourth ACM International Workshop on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWiM). Rome. Retrieved October 20, 2004, from http://www.cs.ucr.edu/~michalis/papers.html

Kalim Susanto. (2001). *Wireless Local Area Network. Michigan*. UMI Dissertation Services.

Kaplan R. S., and David P. N. (2000). *The Strategy – Focused Organization: Balanced Scorecard. Boston*. Harvard Business School.

Kime, C. H. (2004). *Performance Measurement Systems*. Retrieved January 27, 2004, from www.public.asu.edu/~ckime/writeguides.html

Lazowska E.D., Zahorjan J., Graham G.S., & Sevcik K.C. (1984). *Quantitative System Performance: Computer System Analysis Using Queuing Network Models*. Prentice-Hall. Retrieved October 8, 2004, from http://www.cs.washington.edu/homes/lazowska/qsp/

Lee, D. J. Y., & Lee, W. C. Y. (2000). *Propagation Prediction in and through buildings*. IEEE Transactions on Vehicular Technology, 49(5).

Leithe, J. (1998). *Guidelines for budget making*. American City & County 113(9), 8.

Lever Technology. (2003). *802.11 Wireless Networks A White Paper Outlining Planning, Survey and Implementation*. Retrieved April 26, 2004, from bluemedianet.co.uk/_blueclient/documents/Planning-and-Development.pdf

Lewis, T. (2003). Computer Network Definition. Retrieved June 27, 2002, from http://auth.grolier.com/cgi-bin/authV2?bffs=N

Mitchell, B. (2003). *Networking Basics*. Retrieved April 24, 2003, from www.compnetworking.about.com

Pende, P. S., Neuman, R. P., & Cavanagh, R. R. (2000). *The Six Sigma: How GE, Motorola, and Other Top Companies Are Honing Their Performance*. USA. McGraw-Hill.

Riezenman, M. J. (2002). *Wireless 802.11 Trends*. Retrieved May 15, 2004, from www.spectrum.ieee.org/webonly/resource/sep02/802abcs.html.

Stricker, T., Cross, T. (1997). *Global Address Space, Non-Uniform Bandwidth: A Memory System Performance Characterization of Parallel Systems*. 3rd IEEE Symposium on High-Performance Computer Architecture (HPCA '97): p.168.

The Wireless LAN Alliances. (1999). *Introduction to Wireless LAN*. Retrieved June 24, 2003, from www.wlana.com

Tierney, B., & Gunter D. (1998, July). *The NetLogger Methodology for High Performance Distributed Systems Performance Analysis*. The Seventh IEEE International Symposium on High Performance Distributed Computing (HPDC-7), p.260.

University of Washinton, (2004). *Internet Systems Measurement and Analysis Projects at University of Washington*. Retrieved October 8, 2004, from http://www.cs.washington.edu/research/networking/websys/

Wheat, J., Hiser, R., Tucker, J., Neely, A. & McCullough, A. (2001). *Designing a Wireless Network. Massachusetts*. Syngress Publishing , Inc.

---

[1] Ms. Azrilah Abdul Aziz is a graduate student of Management Information Systems at the International Islamic University Malaysia. She can be reached at Kulliyyah of Information and Communication Technology, International Islamic University Malaysia, Jalan Gombak, 53100, Kuala Lumpur, Malaysia. E-mail: azrilah@pd.jaring.my

[2] Dr. Mohd Adam Suhaimi is an Associate Professor and Dean of the School of Information and Communication Technology at the International Islamic University Malaysia. He can be reached at the Kulliyyah of Information and Communication Technology, International Islamic University Malaysia, Jalan Gombak, 53100, Kuala Lumpur, Malaysia. E-mail: adam@iiu.edu.my; Phone: +(603) 2056 5152