Performance Evaluation of Web Portals

Article *in* International Journal of Modeling and Optimization · January 2011

DOI: 10.7763/IJMO.2011.V1.67

4 authors, including:

Ruzairi Abdul Rahim
Universiti Teknologi Malaysia

Haslinda Ibrahim
University of Bahrain/Universiti Utara Malaysia

Sharipah-Soaad Syed-Yahaya
Universiti Utara Malaysia

Performance Evaluation of Web Portals

R. Abdul Rahim, H. Ibrahim, S. S. Syed Yahaya, and K. Khalid, *Member, IACSIT*

***Abstract*—Performance of Web portals at the system level has not been given much attention. The evaluation at the system level is importance for systems maintenance or further improvement. This study develops an evaluation model based on queuing theory at a system level of web portals performance for a university. A system level performance model views the system being modeled as a 'black box' which considers the arrival rate of packets to the portals server and service rate of the portals server. These two parameters are important elements to measure web portals performance metrics such as server utilization, average server throughput, average number of packet in the server and mean response time. This study refers to infinite population and finite queue. The proposed analytical model is simple in such a way that it is easy to define and fast to interpret the results but still represents the real situation. The results present the performance of six parallel web portals.**

***Index Terms*—Web portals performance, queuing system, queuing model.**

I. Introduction

Many research have been done to analyse the web server system, however not all of them analyse the performance system since most of the research focus on the durability or characteristics of file saving. The evaluation model is important due to the structure of the web system especially the traffic environment and the different capabilities of the server from one web to another.

Size effects of the web server does not elucidate on how to overcome the problem of measuring the performance of the web server. The structure of the program of a website may be applicable in structuring the website on a web server, but it is not relevant to modeling the web server [1].

The performance of three different servers running on the Windows NT platform using a performance device from NT OS and Web stone benchmark. Web stone, however, was found not to be suitable to model the real behavior of users of www. It simply could not explain all the results of the experiment [2]. Therefore, they planned to develop an analysis model which could present and predict the web server.

Today, there are literally millions of users surfing the websites each day. This in turn would cause an overload when the arrival rate reaches the maximum capability of the server. To manage this, an overload control can be used where some requests may be allowed and others may be denied by the web server [3]. Overload controller is a study dependent on precise performance model. Thus, the web server may be able to reach a suitable serving time in compliant with the requests.

In the university environment, it is frequently stressed that the Internet, Intranet and the web source need to be optimised through the intra campus communication, added educational technology dissemination, campus marketing with business functions and services. Server hardware, web server software and internet connectivity are known to be costly elements of the web site. An understanding of the effects of the three elements is required towards the performance of the web server [4]. Unsatisfying system performance will eventually lead to users' dissatisfaction when surfing the web. University Utara Malaysia (UUM) is one of the local universities situated in Sintok, Kedah in the northern region of Malaysia. Although it is located some distance away from the city, the internet is extensively used by the staff and students of UUM. A variety of computer systems have been developed to accommodate easy access to the systems online. The UUM Computer Centre was set up on 1 March 1998 to mark a concerted effort by UUM to computerize various activities on campus. The centre provides a comprehensive computerized system and network infrastructure to support the learning and research activities of UUM students and staff. The Computer Centre also assists university administration in implementing and maintaining its own computer system. One of the vital systems developed by the Computer Centre is the UUM web portal. The web portal is a web based systems application which allows information and services at UUM be accessed and used through the internet. Among the many services and information that can be accessed through the web portal is the students' personal information, account statement, computer loan statement, examination grades submission by lecturers and others. The structure of the university web portal is as shown in Figure 1 below:

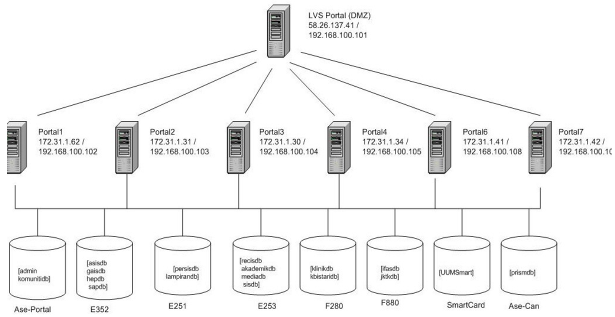

Fig. 1. The university web portal design.

Users of the university web portal are categorized as

Manuscript received November 20, 2011; revised December 19, 2011. This work was supported in part by the Ministry of Science, Technology and Innovation of Malaysia and University Utara Malaysia under Grant BS123456.

A. R. Rahim, H. Ibrahim and S. S. Syed Yahaya are with the School of Quantitative Sciences, University Utara Malaysia, 06010, Sintok, Kedah, Malaysia.(e-mail:rahela@uum.edu.my;linda@uum.edu.my;sharipah@uum.

K. Khalid is with Management science University, Kuala Lumpur, Malaysia.(e-mail: khairini@yahoo.com).

registered students, staff and the general public. In general, all information and services that can be accessed through this portal are characteristically static and dynamic in nature. The computer centre may be satisfied with the performance of the web portals used for the university community portal. This may be due to the assumption that problems rarely occur when users access the web portal. But would the assumption be true even during busy or peak activity hours? A number of risks have been identified should a web portal performance analysis be ignored. Chiefly among the complaints are seen in the reduction of users or customers and decreased productivity among workers through the lack of participation due to dissatisfaction [5]. With no correct model of the web portal, it would be virtually impossible to forecast a performance metrics. A performance model would not only be determined if the system reaches its objectives, it would also assist in understanding how the performance can be elevated. In answer to that predicament, a performance model has been developed to assess and evaluate the performance of the university web portal.

II. Related Works

Many attempts have been made to invent a performance model for the web server. [6] Focused on the analysis and evaluation of the performance of the Internet web server and intranet using the multi-layer queuing model. A performance evaluation model using queuing model in the environment distribution is presented in [7], however, the researchers were more focused to low level details related to protocol and computer software

[8] Proposes a shared performance process model for the internet including the web server. The model explains the basic characteristics of traffic flow. They put forward a simple relationship of capacity and its use to access and ascertain download time of objects from the internet. [9] Elleithy et al (2002) presented a performance analysis model for the web server using an open queuing network. The main objective was to present a model to illustrate hardware and software in details; however it was not enough to produce performance results based on the relationship between the server and network speed.

Web server can be modeled as a tandem queuing network [10]. The model was used to predict the metrics performance of the web server and verified through measurement and simulation. The analytical model such as a queuing model has been popularly used to model the flow arrival process and behavior of internet application [11]. Most of the models previously presented were complicated and more focused on performance at component level. It lacks simple models that measure the performance at the systems level. Therefore, this study uses generalized system-level model that is one of the queuing analysis models to examine web server performance for UUM web portal. The study will include observation on model performance from the system level aspect which is contrary to looking from the component level aspect. It is the most suitable model owing to its speed and ease in interpreting result. Therefore in this study the queuing model is developed to study the performance of the six web servers used to access the university web portals. Observation is limited only to the web server level where the rate of clients and service are taken into account. The study on the component level, however will not be in detail.

III. Objectives of The Study

The performance model can be built on by looking from two different perspectives; one, is to look from the systems point of view or; two, from the components point of view. The main objective of the study is to develop a queuing model to evaluate the performance of the web server when accessing the university web portal. The main objective of this study is to develop a queuing model to evaluate the performance of the web portal when accessing the university community portal. A number of specific objectives have to be established in order to succeed:

1) Designing a queuing model for the systems stage of the web portal used for accessing the university community portal.
2) Determining the metrics performance scale in the queuing system for the web portals.
3) Identifying initial problem which causes 'bottleneck' capacity in the system.

A. *Significance of the Study*

The queuing analysis model developed will improve understanding and comprehension of the importance of the system level model of the web server. It will furnish an effective solution in identifying the problematic component which causes the system's performance degradation based on the result of the performance metrics by presenting the percentage of web server usage and the average receiving time. Furthermore, it will provide basic result in evaluating web server uptime in detail in order to ensure that the performance needs of the web server are achieved. Also, the model will allow systems designer to suggest the best configuration for the web server. In addition, the study of the application of queuing model may be extended to other systems with similar setting but different parameters used at the university. Finally, this study will inevitably facilitate the management's decision in relation to the enhancement of the system's performance in increasing web server access of the university Computer Centre.

IV. The Methodology

As stated, this study uses the generalized system model which is one of the queuing system models to analyze the performance of the web portal when accessing the university community portal. It is furthermore an observation of the performance model from the aspect of the system and contrary to an observation from the aspect of the component. The generalized system model represents the "black box" of the system where in this study, the internal part of the box such as the processor, disk and network are not modeled in detail. The model will only assess the arrival rate of the client and the rate of service. This is the key in determining the performance metrics of the web portal. The generalized system model is represented by the flow diagram of the system's arrival and service rate. Client arrives at the web portal at a rate of λ packet/second, waits in queue for service, receives service at a rate of μ packet/second and exits queue. The number of clients in the system is bounded by W number of packets.

A. The Queuing Model

Agner Krarup Erlang, Danish engineers working for the Copenhagen Telephone Exchange, published the first study on the Queuing theory in 1909. Later, it was corroborated with the same concept in an operating research in the context of the web server. In the 60's the queuing theory which is related to mathematical technique began to gain attention. At the same time, the mathematical theory is revealed gradually, simplified and combined with other theories related to the stochastic process. Thus, the queuing theory became an important area and its application is widely used in modelling and analysing real-world situations such as in the production, communication, transportation and computer systems.

The performance model had been studied using the queuing theory. In essence, the queuing theory was the first application in the communication system applicable even until today [12]. The queuing system is applied in the capacity planning including forecasting whether the metrics performance system such as service time and computing capability achieve the service acceptance level [13].

The performance model is an abstraction of a real system and developed to identify the main factor in determining the performance system. It completes the quantitative forecast and the understanding of the structure and behaviour of the real model. It is absolutely useful in the design area. After the model has been identified it can be used in various studies which in turn will allow for the evaluation of the performance system. Early detection of problems in the beginning stages is pertinent in saving cost.

In the area of design, the performance model is simple and abstract and when more information is gathered, the better the model can be studied. At the same time, the model can be adapted accordingly to the particular study.

The performance metrics being considered use the following notation:

U = web portal usage, X = average packet produced by each web server, N = average number of packet in each web portal, R = average response time.

The performance metrics value can be measured by referring to mathematical equation constructed below.

$$U = \frac{\lambda}{\mu}\left(1 - \frac{\lambda}{\mu}\right)^{W} \quad (1)$$

$$X = U \times \mu \quad (2)$$

$$N = \left(\frac{\lambda}{\mu}\right)\left[W\left(\frac{\lambda}{\mu}\right)^{W+1} - (W+1)\left(\frac{\lambda}{\mu}\right)^{W+1}\right] \quad (3)$$

$$R = \frac{N}{X} \quad \text{for } \lambda \neq \mu \quad (4)$$

B. Data Collection

Six functioning web portals located at the computer centre had been identified. The web portals were known as Portal 1, Portal 2, Portal 3, Portal 4, Portal 5 and Portal 6. Performance metrics of each working portal will be measured. Collection of data had been done in the period of approximately one month. The time taken was during working hours from 8.00 a.m. until 5.00 p.m. from Sunday to Thursday. The time period was utilized due to the availability of staff and students on campus. The parameters obtained from data collection are arrival rate, λ packet/second, and service rate, μ packet/second in every working period. The queuing theory will consider each single queue from one or more servers. If the arrival rate, λ is less than the service rate value, μ queuing system is stable where all requests are served and the average queuing size will be limited. The condition will also be true vice versa. If λ value is more than μ value, the queuing system is unstable and the average queuing size will increase without limits.

TABLE I: AVERAGE PARAMETER ACQUIRED FROM EACH PORTAL

Web Server	Portal 1	Portal 2	Portal 3	Portal 4	Portal 5	Portal 6
λ (packet/second)	25.13	27.03	24.87	4.94	27.75	52.11
μ (packet/second)	29.47	31.07	29.25	10.24	31.38	56.89
W (packet)	18	20	18	6	21	26

Based on Table I, it was found that λ is less than μ value for each web portal. Therefore, the performance metrics can be estimated.

V. RESULTS AND ANALYSIS

All values of λ, μ and W obtained from data collection are used in the relative equation and the performance metrics result for each web portal is calculated. The results show that, the usage percentage of the web portal, U for each web portal is similar except for Portal 4 which has the lowest percentage. Portal 6 has the highest percentage which is 90.73% compared to other web portals. This shows that Portal 6 was the busiest and Portal 4 was the least busy. The average packet, X produced by Portal 6 at each hour is 51.62 packets which is the highest among the other web portals. Meanwhile, the average packet produced by Portal 4 is the lowest which is 4.91packets/second. The average number of packets, N of Portal 6 is the highest which is 8.12 packets and the average number of packets of Portal 4 is still the lowest which is 0.89 packets.

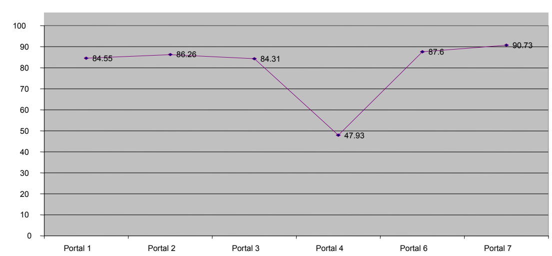

Fig. 2. Percentage of web portals usage u.

the average packet value produced, X by Portal 7 at each hour is 51.62 packets which is the highest among the other Web servers. Meanwhile, the average packet value produced by Portal 4 is the lowest at only 4.91 packets/second. Figure 4 shows the average number of packets, N of Portal 7 that is the highest at 8.12 packets and the average number of packets of Portal 4 is still the lowest at 0.89 packets.

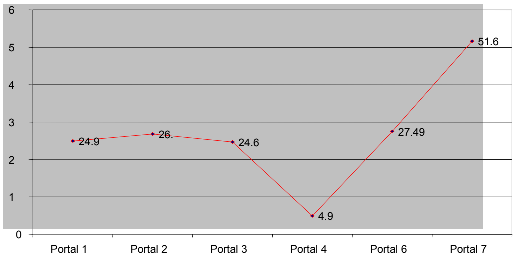

Fig. 3. Average packet produced, x for each web portal

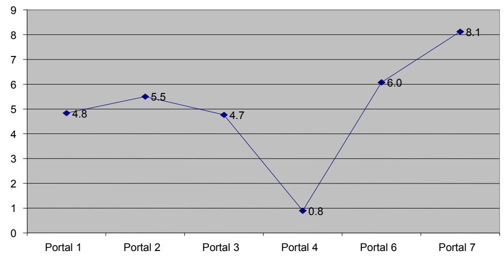

Fig. 4. Average number of packet, n for each web portal.

The model also measure the average receiving time, R for each web portal. Although the average receiving time, R of Portal 4 is less than other web portals, the average receiving time of Portal 6 is the lowest which is 0.157. This indicates that Portal 6 has the fastest receiving time among all the web portals. Based on the results obtained, it is found that Portal 6 is the most active web portals. This is in accordance to a real system as Portal 6 is the main web portal used to access the university community portal and Portal 4, on the other hand, is the last option to receive the number of packets entering the system.

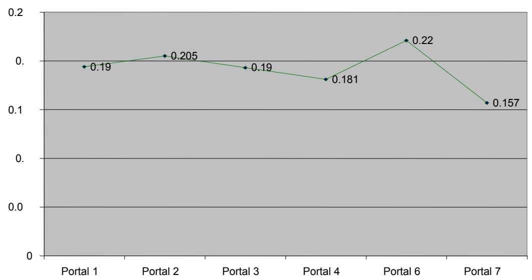

Fig. 5. Average receiving time, r for each web portal.

A. Model Validation

The performance model is considered valid if the performance metrics measured by a comparative model with the measurement of a real system follows the allowable margin of error that is a difference percentage of up to 30% . For the reason that the performance metrics was not obtained through a real system, a simulation model is developed to validate the results obtained by the queuing system model.

A simulation model was developed using Arena 7.0 software as in Fig. 6:

Web traffic data is distributed through exponent [14]. Thus, the type of rate between packet arrival, 1 λ used is the random exponent variable type. Service time also uses the random exponent variable type. The model was running for 9 hours to represent data collection period starting from 8.00 a.m. until 9.00 p.m. It was put through the cycle three times to get an average value for each performance metrics

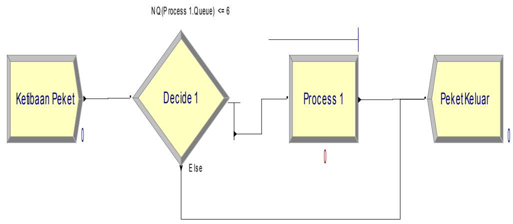

Fig. 6. Simulation model of a web portal.

From the results, performance metrics comparable to the generalised system model are:

1) Portal Scheduled Utilisation = Web server usage (U)
2) Process 1 Number Out / 32400 seconds = average packets produced by each Web server (X)
3) (Process 1 Accum Wait Time + Process 1 Accum VA Time) / 32400 seconds = average number of packets in the Web server (N)
4) (Process 1 Accum Wait Time + Process 1 Accum VA Time) / Process 1 Number Out = average receiving time (R)

The results obtained from simulation model were compared with the results obtained using queueing model and are shown in the following tables. Table II to VII show percentage differences between the queuing model and simulation model of Portals 1 to 7:

TABLE II: PERFORMANCE RESULTS OF PORTAL 1

Performance metrics	Queuing model	Simulation model	Difference (%)
U	84.55	84.54	0.01
X	24.92	24.96	0.16
N	4.83	4.98	3.01
R	0.194	0.199	2.51

TABLE III: PERFORMANCE RESULTS OF PORTAL 2

Performance metrics	Queuing model	Simulation model	Difference (%)
U	86.26	86.44	0.21
X	26.8	26.86	0.22
N	5.5	5.68	3.17
R	0.205	0.212	3.30

TABLE IV: PERFORMANCE RESULTS OF PORTAL 3

Performance metrics	Queuing model	Simulation model	Difference (%)
U	84.31	84.56	0.30
X	24.66	24.73	0.28
N	4.76	4.99	4.61
R	0.193	0.202	4.46

TABLE V: PERFORMANCE RESULTS OF PORTAL 4

Performance metrics	Queuing model	Simulation model	Difference (%)
U	47.93	48.18	0.52
X	4.91	4.93	0.41
N	0.89	0.92	3.26
R	0.181	0.186	2.69

TABLE VI: PERFORMANCE RESULTS OF PORTAL 5

Performance metrics	Queuing model	Simulation model	Difference (%)
U	87.60	87.92	0.36
X	27.49	27.58	0.33
N	6.07	6.39	5.01
R	0.221	0.232	4.74

TABLE VII: PERFORMANCE RESULTS OF PORTAL 6

Performance metrics	Queuing model	Simulation model	Difference (%)
U	90.73	90.79	0.07
X	51.62	51.65	0.06
N	8.12	8.39	3.22
R	0.157	0.162	3.09

Based on the values acquired, it was found that the difference between the proposed queuing model and simulation model is less than 30%. Therefore, the proposed queuing model for evaluating the performance of the university portals is validated.

VI. CONCLUSION

The main objective of the study is to evaluate the performance of six web servers used to access the UUM web portal by designing a generalised system model at system level has been achieved. The model presents the system as a black box where only the packet arrival rate into the system and service rate of each packet are evaluated in measuring the performance metrics value of the web server. Assumption made to the model development was time between arrivals is the random variable exponent known as memoryless or Markovian assumption. Each web server was assigned to a fixed capacity. Thus, the number of packets waiting in queue has been limited to ensure the web server was performing well. The study referred to unlimited population, unlimited queue and queuing discipline known as FIFO queuing.

The next objective is to determine the performance metrics measurement in the queuing system. The performance metrics values of the web server measured are web server usage, U, average packets produced by each server, X, average number of packets in the web server, N, and the average receiving time, R. Based on the results obtained, it was discovered that U for each web server is almost similar with the exception of Portal 4 which has the lowest percentage and Portal 7 having the highest value. This illustrates that Portal 7 has the highest web server usage and Portal 4 is the least busy web server.

In terms of X and N, Portal 7 produced the highest value among the other web servers. In contrast, the average packet value produced by Portal 4 is the lowest.

Subsequently, the study looks at the R value. Although the receiving time, R of Portal 4 is more or less the same as the other web servers, the receiving time of Portal 7 has the lowest figure. This shows that Portal 7 has the fastest receiving time average among the other web servers. Based on the results Portal 7 seems to be the most active web server. It corresponds to the real system as Portal 7 is the main web server used to access UUM web portal and Portal 4 is the last web server to receive the number of packets into the system.

The third objective is to prepare early information in identifying bottleneck capability in the system depending on the above analysis. It could occur during the receiving period or service period of the web server itself.

Even though the queuing model had been developed successfully, it still had limitations in this study. The first limitation is the data collection. Owing to the limited time frame, the results were based on data acquired from study reports completed previously. Data collection was limited only to a period of approximately one month. The second limitation is the validity of the queuing model could not be verified through a comparison with a real system. It is verified only through a comparison with a simulation model.

Therefore, it is recommended that data collection is done thoroughly at the UUM Computer Centre for a longer time period and the queuing model can be verified through a real system in the future. These measures need to be taken to ensure that results will be more detailed in subsequent studies.

In conclusion, observation at system level will be studied in the following research where the content of the box such as the processor, disk and network can be modeled in detail in order to examine the relationship between one component and the other. Hence, bottleneck capability can be further identified through this analysis.

ACKNOWLEDGMENT

First and foremost, we would like to extend our sincere thanks to Ministry of Science, Technology and Innovation, and UUM for providing this research grant, thus making this research possible. The Department of Quantitative Sciences has provided the support and equipment we have needed to produce and complete our research.

We attribute our appreciation also to our colleagues and friends who had provided guidance and ideas as well as encouragement that has definitely encourage us to complete this research, without their encouragement and effort this report, would not have been completed or written.

We also wish to express our gratitude to the officials and other staff members of Research and Innovation Management Center of UUM who rendered their help during the period of our research work. Last but not least we wish to avail ourselves of this opportunity, express a sense of gratitude and love to our beloved family for their manual support, strength, help and for everything.

REFERENCES

[1] M. Brij and S. Myra, "Web Usage Analysis and User Profiling." *WEBKDD'99*, vol. 1, no. 2, pp 108-110, 1999.

[2] V. A. F. Almeida, J. M. D, Almeida, and C. S. Murta. Performance analysis of a WWW server, Performance Analysis of a WWW Server, *CMG'96 - 22nd International Conference on Technology Management and Performance Evaluation of Enterprise-Wide Information Systems*, San Diego. USA, December 1996.

[3] J. Cao et al, "Web server performance modeling using an M/G/1/K*PS queue," *in Proc. of 10th International Conference on Telecommunication,* pp. 452-457, 2003.

[4] K. M. Elleithy and A. Komaralingam "Using a Queuing Model to Analyze the Performance of Web servers" *In Proc. International Conference in Infrastructure for Electronic Business, Education, Science and Medicine on the Internet*. Available : http://www.ssgrr.it/en/ssgrr2002w/papers/74.pdf

[5] M. R. Stadelmann and Agrawal S. C "UNIX Web server Performance Analysis" *in Proc. of International CMG conference*, 1996, pp. 1026-1033.

[6] J. Dilley et al. "Web server performance measurement and modeling techniques," *Performance Evaluation an International Journal,* vol. 33: pp. 5-26, 1998.

[7] P. Reeser and R. Hariharan, *An Analytic Model of Web Servers in Distributed Computing Environments*. Telecommunication System, vol. 21, no. 2-4, pp. 283-299, 2002.

[8] J.V.L. Beckers et al. "Generalized Processor Sharing Performance Models for Internet Access Lines" *in Procs. of 9th IFIP Conference on performance modeling and evaluation of ATM & IP networks, Budapest*, pp. 45-52, 2001.

[9] M., Anderson, et al. " Performance Modeling of An Apache Web Server With Bursty Arrival Traffic" in *Proc. of the International conference on Internet computing*, 2003, pp. 23-29.

[10] R. D. Van Der Mei, R. Hariharan, and P. K. Reeser, "Web Server Performance Modeling," *Telecommunication System*, vol. 16, no. 3-4, 2001, pp. 361-378.

[11] B. Urgaonkarl, "An Analytical Model for Multi-tier Internet Services and Its Applications," *in Proc. of SIGMETRICS'05*, 2005, pp 291-302.

[12] S. Ozekici, *Queueing theory and application*. Hemisphere Publishing Corporation, Bristol, 1990, ch. 4.

[13] D. A. Menasce and V. A. F. Almeida. *Capacity planning for Web performance: metrics, model, and methods*. Prentice Hall, New Jersey, 2002, ch. 2.

[14] M. F. Arlitt and C. L. Williamson, "Internet web servers: Workload characterization and performance implication," *IEEE/ACM Transactions on Networking*, vol. 5, pp. 631-645, 1997.

R. Abdul Rahim , was born in Penang in 22 April 1969. Received her Bachelor of Mathematics degree from University of Malaya, Malaysia in 1993, Masters in Information Management from University of Sheffield, United Kingdom in 1995 and Doctor of Philosophy from University Utara Malaysia, Sintok, Kedah in 2004.

She has been with University Utara Malaysia for sixteen years. Her primary research areas of interest include mathematical modeling, queueing model and decision science. She has published numerous articles in research publications including *The Journal of Information and Communication Tecnology, Journal of Quality Measurement and Analysis and Journal of Modern Science* . Before joining School of Quantitative Sciences, she was a lecturer at School of IT. Her current research interest is in mathematical modeling.

Dr Rahim is a member of Lab Publication Committee at University Utara Malaysia. The task includes promote the publication activities among scholars in her departments.

H. Ibrahim obtained her bachelor degree in Mathematics in 1992(Michigan State University, USA), Master in Mathematics in 1996(Indiana State University) and PhD in Mathematics in 2003 (Southern Illinois University, USA). She is well known for her profound contributions in combinatorics domain especially in Combinatorial Design Theory. Her current research interests include graph theory, combinatorial design theory, enumerative theory and optimization theory. Her work experiences include deputy dean of postgraduate, head of Mathematics Department, and Coordinator for Postgraduate program. She has been awarded several awards such as University Best Research Award (Universiti Utara Malaysia), Dissertation Research Award (Southern Illinois University, USA), Outstanding PhD Teaching Assistant (Southern Illinois University, USA) and Bronze Medal Award, 9th Malaysia Technology Expo: Invention and Innovation Award (Malaysia). She is also a member for American Mathematical Society (AMS) and Malaysia Mathematical Science Society (PERSAMA). She is also an editorial board for Journal of Mathematics Research. She has published over 50 articles in journals and conference proceedings.

S.S. Syed Yahaya was born in Kedah, Malaysia in 1962. She received her Ph.D (Statistics) from Universiti Sains Malaysia in 2005, M. Sc (Mathematics) and B. Sc (Mathematics) from Indiana State University, USA in 1985 and 1983 respectively. She has been with this institution since 1986. She specializes in Robust Statistical Methods and Statistical Quality Control. Currently she is teaching Statistical Quality Improvement, supervising Ph.Ds and Masters students in the specialized areas, and conducting research related to the two areas.

Dr. Syed Yahaya is a Member of Malaysia Institute of Statistics (ISM), and Malaysian Mathematical Science Society (PERSAMA).