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Volume. 5 Issue. 2

The Current State of Mobile Apps Development of Higher Education in Taiwan

Hsu-Chen CHENG *, Tsuei-Ping KUNG *, Chia-Ming LI *, Yu-Jou SUN *

* Wisdom Garden Research Center, Taiwan

{michael, evelyn, achilles.lee, rora}@wisdomgarden.com

***Abstract*—Mobile apps have had a large impact on many industries including higher education for many years since it emerged. The goal of this research is to deepen our understanding of the state of mobile apps development at higher education institutions in Taiwan, and it focuses on three major issues: (a) how many institutions are there in Taiwan adopting mobile apps; (b) what are the popular mobile services in higher education; (c) and whether mobile apps play a more important role than mobile webs in delivering the mobile service on campus.**

The research process was broken down into few phases. In the beginning, this research searched all the institution-related mobile apps on Apple App Store and Google Play, and determined whether it was owned by an institution based on the decision tree. Next, the classification of mobile services was proposed for analyzing the content of every official mobile app. Last, the institutions which had both mobile apps as well as mobile webs were sorted out, and the difference of mobile services between the two deliveries was compared.

The results indicates that less than half of the institutions in Taiwan have their own mobile apps, and the most popular mobile services on apps are general information as well as library services. And it also shows that the services delivered via mobile apps are more abundant than via mobile webs.

***Keyword*—Mobile App, Development, Higher Education in Taiwan, Classification of Mobile App Services, Mobile Web**

I. INTRODUCTION

IN this research, the state of mobile apps development consists of the following three issues: (a) the mobile apps usage rate; (b) the popular mobile service; and (c) the main access to mobile service. Hence, the introduction would be given by the issues above.

A. The Mobile Apps Usage Rate

In recent years, mobile apps are more and more important in higher education. The NMC Horizon Report by 2012 indicated that mobile apps were the key technology that higher education would adopt within a year [1]. Besides, the relevant surveys showed that there were upward trends of using mobile apps at higher education institutions in the United States and in Taiwan (see Fig. 1.), and the proportion got to 83% [2] and 56.7% [3] in 2014 respectively.

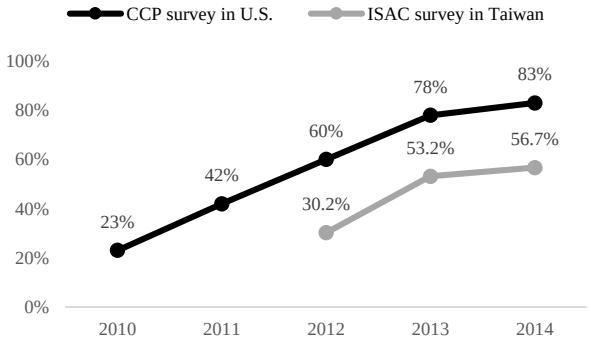

Fig. 1. The trends of adopting mobile apps at higher education institutions in U.S. and in Taiwan

Evidently, implementing mobile apps is an inevitable tendency for higher education in the future, and there would be more and more institutions starting to adopt it. In other words, the percentage of institutions adopting mobile apps in 2015 would be larger than in 2014.

As a result, it is necessary to investigate how many institutions provide its own mobile apps in 2015. The concern would be addressed specifically in Taiwan.

B. The Popular Mobile Service

The EDUCAUSE survey [4] showed that American universities and colleges tended to place high priority on student- and public-facing mobile services, and the top three of them were primary web presence, learning/course management services as well as library services.

In addition, when it came to the "killer mobile app" for higher education [4], most people regarded LMS (Learning Management System) and student services as top priority. Moreover, university libraries were moving toward the mobile web to deliver information access at the early stage of mobile enablement [5], so the library service was an important category for mobile services.

In this case, the research concerns what the most popular service is in higher education.

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Hsu-Chen Cheng is with Wisdom Garden Research Center, New Taipei City, 23444 Taiwan. (Corresponding author, phone: +886-2-7730-8100; fax: +886-2-2923-2589; e-mail: michael@wisdomgarden.com)

Tsuei-Ping Kung is with Wisdom Garden Research Center, New Taipei City, 23444 Taiwan. (phone: +886-2-7730-8100; fax: +886-2-2923-2589; e-mail: evelyn@wisdomgarden.com)

Chia-Ming Li is with Wisdom Garden Research Center, New Taipei City, 23444 Taiwan. (phone: +886-2-7730-8100; fax: +886-2-2923-2589; e-mail: achilles.lee@wisdomgarden.com)

Yu-Jou Sun is with Wisdom Garden Research Center, New Taipei City, 23444 Taiwan. (phone: +886-2-7730-8100; fax: +886-2-2923-2589; e-mail: rora @wisdomgarden.com)

C. Mobile Apps vs. Mobile Webs

A mobile app is a program which is developed for small handheld devices [6] and installed directly onto it [7]. A mobile web is a website which is also developed specifically for mobile devices [8] but accessed through the mobile browser [7].

In most cases, mobile webs are more affordable than mobile app development [9], because it can be released in any form and any time without an approval by the app store or marketplace [7]. Moreover, mobile webs could be accessed by all types of platforms [10], and it is more flexible in the light of updating and changing content [9]. From the point of view of institutions, as a result, they prefer mobile webs rather than mobile apps.

However, students prefer to use mobile apps when they have the most mobile activities in their daily affairs (e.g. weather) as well as course-related tasks (e.g. access my course schedule) [11]. In addition, they consider that mobile apps have better performance in effectiveness of speed and ease of use than mobile webs [11]. Therefore, which access to provide is a major concern for institutions.

In light of these concerns, the assumptions of the research are listed below: (a) the mobile apps usage rate would be larger than the counterpart of the ISAC survey in 2014 [3] which is the researchers' previous study; (b) LMS and library services are the most popular categories of mobile services in higher education in Taiwan; and (c) mobile apps are the main access to mobile service base on the trend of using mobile apps in higher education.

II. Research Design and Methods

The research was conducted during the period from January 25, 2015, through April 7, 2015. The content analysis was undertaken in this research and composed of five phases, which was summarized as follows:

A. Collecting Mobile Apps Related to Institutions

The related survey [3] suggested that the institutions in Taiwan preferred to publish their mobile apps for distribution via Android (100%) and iOS (70.8%). As a result, the search for mobile apps related to all the higher education institutions in Taiwan [12] would be limited to the two platforms, Google Play and Apple App Store, for this research.

Then, the researcher typed every institution's Chinese name as well as its English abbreviation sequentially in the search bar on the two platforms. Finally, around 670 apps associated with all the institutions in Taiwan were founded during the period from February 6, 2015, through February 10, 2015.

B. Determining Whether a Mobile Apps Is Official

The first issue of this paper is how many institutions are there in Taiwan adopting mobile apps. Therefore, it is necessary to justify whether an institution has its own mobile apps or not, and then the decision tree (see Fig. 2.) is developed for determining whether a mobile app is owned by an institution. The criteria was summarized as follows:

First, official mobile apps of institutions should be maintained properly, and its renewal should not be so long ago from now. As a result, if the mobile app was not updated in the past three years, it would not be regarded as an official one.

Second, the use of an institution-owned mobile app should be widespread on campus. If the installs of a mobile app did not exceed 500 times, it would be regarded as non-official.

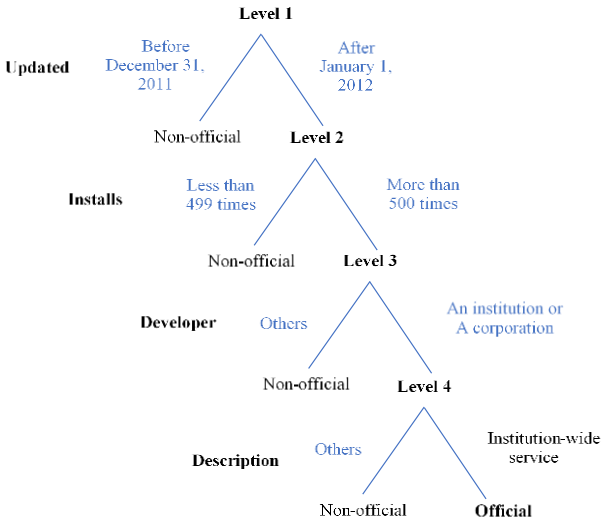

Fig. 2. The decision tree for determining whether a mobile app is official

Third, the official mobile apps should be introduced in the name of an institution or a corporation, or it would be considered as non-official. In the case of a corporation being the developer of the mobiles app, it was assumed that the institution outsourced their mobile apps to the corporation.

Forth, the services provided through an official apps should be institution-wide. If the mobile app's description did so, it would be regarded as official and would be downloaded to the researcher's mobile device.

Finally, the research got 177 official mobile apps associated with higher education institutions in Taiwan based on the decision tree.

C. Proposing the Classification of Mobile Services

In order to analyze what the content of every mobile app is, it is necessary to propose the classification of mobile services.

According to the category of the killer apps for higher education [4], the research drafted the classification of mobile services and then made use of it to examine the content of official apps in the analysis of pretest.

In the process of the pretest, the classification was adjusted and refined gradually and it became more mutually exclusive as well as collectively exhaustive. The revision of the classification of mobile services in higher education is showed on TABLE Ⅰ.

D. Analyzing the Content of Official Mobile Apps

Then, the researchers examined the content of every official mobile apps based on the classification (see TABLE Ⅰ) and recorded what services it provides. The frequency data was record by mobile apps initially, but it was converted into the statistics by institutions later.

For instance, the app 01, app 02 as well as app 03 belonged to the institution A, and the frequency of their services in sum was below: category A got three times, category B got two times, and category C got nothing. Then this research concluded that the institution A provided the service of category A and B, but not category C.

TABLE Ⅰ
THE CLASSIFICATION OF MOBILE SERVICES IN HIGHER EDUCATION

Categories	Examples
Administration	Making Complaints Punch in/out
General Information	Directory Campus Maps Events Calendar
Personal Information	Push Notification Financial Services Inquiry Social Network
LMS	Learning Management System Courses/Grades Inquiry
e-Learning	e-Books Videos/Images
Productivity	Cloud e-Mail
Student Services	Reservations Emergency Call
Library Services	Library Catalog Renew Materials
Alumni Services	Events Information

PS. Each category is including but not limited to above examples.

E. Comparing Mobile Webs to Mobile Apps

The third issue of this research is to discuss whose service is more diversified, mobile apps or mobile webs. The research design of the section is as follows:

At the beginning, the researcher visited every institution's primary websites presence via a mobile browser and determined whether it was a mobile web or not (see TABLE Ⅱ). Then it was filtered out that the institutions having both a mobile web and mobile apps, which amounted to 30 institutions.

Next, the mobile webs of these 30 institutions were categorized into two types, the general type and the special type. This research focused on the mobile webs belonging to the special type which included 16 institutions.

TABLE Ⅱ
THE CRITERIA FOR ANALYZING MOBILE WEB

Issues	Criteria
Does the institution have a mobile web?	**Yes**, if the layout of the website on the mobile browser was a responsive design. **No**, if the layout of the website was like the page of standard websites on computer.
What the type dose the mobile web belong to?	**General type**, if the layout of the page would be automatically adjusted according to a device's screen size. **Special type**, if there were additional modular icons on the page in addition to the features of the general type.
Does a mobile web provide some kind of service?	**Yes**, if the icon of a service was linked to a page with responsive design **No**, if the icon of a service was linked to a standard website.

Third, what service the mobile web provided was analyzed. If the icon of a service on the mobile web was linked to a standard website instead of a page with responsive design (RD), then it was concluded that the mobile web did not provide this kind of service.

Finally, the services between mobile webs and mobile apps of the 16 institutions were compared.

III. RESULTS

A number of interesting findings emerged from this process, but this section focused on the three issues: (a) the mobile apps usage rate; (b) the popular mobile service; and (c) the main access to mobile services.

A. The Mobile Apps Usage Rate

Around 43% of institutions, which was 68 of 159, adopted mobile apps (see TABLE Ⅲ) in Taiwan and they seemingly preferred to deploy their mobiles apps for iOS (82%) rather than Android (75%).

TABLE Ⅲ
THE MOBILE APPS USAGE RATE

	For all institutions	For institutions adopting mobile apps	
	Mobile apps	For iOS	For Android
All institutions	42.8%	82.4%	75.0%
Universities & Colleges	47.9%	85.3%	88.2%
Technical Colleges	38.6%	79.4%	61.8%
Large institutions	77.8%	92.9%	92.9%
Medium institutions	49.4%	77.5%	77.5%
Small institutions	23.3%	85.7%	50.0%
Public institutions	45.1%	91.3%	73.9%
Private institutions	41.7%	77.8%	75.6%

According to the results, institution's size did matter in reference to the mobile apps usage rate. Large institutions were more likely than medium and small institutions to adopt mobile apps with the rate at 78 percent, as opposed to 49% of medium institutions as well as 23% of small institutions.

Generally speaking, institutions in Taiwan tended to publish their mobile apps on iOS instead of Android, and small institutions was the most evident example of that viewpoint because of its greatest difference of usage rate between the two platforms among all types of institutions. However, there was a result in the opposite direction. In relation to the type of institutions by education system, universities and colleges slightly favored Android.

Interestingly, such a few types of institutions as large institutions and medium institutions had the same usage rate between iOS and Android, but it did not mean that every institution deployed their apps for the two platforms simultaneously.

Approximately two thirds of institutions (68%) owned one or two mobiles apps, leading those who had three or four (19%) as well as five and more (13%). The average for those surveyed was 2.6 units, which indicated that only a third of institutions (32%) above the average (see TABLE Ⅳ).

TABLE Ⅳ
THE DISTRIBUTION OF MOBILE APPS AN INSTITUTION OWNED

Number of official app(s)	Pct. of institutions (n=68)	Cumulated pct. of institutions (n=68)
One	33.8%	33.8%
Two	33.8%	67.6%
Three	10.3%	77.9%
Four	8.8%	86.8%
Five	4.4%	91.2%
Six	2.9%	94.1%
Seven	2.9%	97.1%
Eight and more	2.9%	100.0%

B. The Popular Mobile Service

The most popular mobile service provided by institutions through their mobile apps was general information (75%), leading library services (62%), personal information (60%), LMS (54%), e-learning (52%), student services (50%), productivity (16%), alumni services (9%), and administration (6%) (see TABLE V). The number in the parentheses referred to the percentage of institutions which offered a certain kind of mobile service and was named "the supply rate" in this research. Consequently, the result showed that six of nine mobile services were offered by more than half of institutions while the others were furnished by less than 20% of institutions. In researcher's opinion, higher education institutions in Taiwan had a strong preference in some mobile services.

TABLE V.
THE STATISTICS ABOUT MOBILE SERVICES

	Pct. of institutions (n=68)	Pct. of mobile apps (n=177)
General Information	75.0%	57.1%
Library Services	61.8%	42.4%
Personal Information	60.3%	40.1%
LMS	54.4%	37.3%
e-Learning	51.5%	36.2%
Student Services	50.0%	33.3%
Productivity	16.2%	14.7%
Alumni Services	8.8%	5.1%
Administration	5.9%	3.4%

When it came to the most prevalent mobile service in institutions' mobile apps, the ranking of mobile services was identical to the order by the supply rate. However, only one of them, general information (57%), existed in more than half of institutions' mobile apps. Less than half of mobile apps were equipped with the following mobile services, including library services (42%), personal information (40%), LMS (37%), e-learning (36%), student services (33%), productivity (15%), alumni services (5%), and administration (3%) (see TABLE V).

Besides, it was observed that institutions' preference for mobile services seemed to alter by control of school. For example, public institutions gave top priority to library services (74%) while private institutions put greater emphasis on general information (84%) (see TABLE VI). Second, e-Learning was one of the top three mobile services for private institutions but not for public institutions. Third, an ANOVA test showed that private institutions were more likely than public institutions to provide general information as well as e-Learning.

TABLE VI.
THE STATISTICS ABOUT MOBILE SERVICES BY CONTROL OF SCHOOL

	Pct. of public institutions (n=23)	Pct. of private institutions (n=45)
General Information	56.5%	84.4%
e-Learning	21.7%	66.7%
Personal Information	60.9%	60.0%
LMS	47.8%	57.8%
Library Services	73.9%	55.6%
Student Services	52.2%	48.9%
Productivity	21.7%	13.3%
Alumni Services	8.7%	8.9%
Administration	4.3%	6.7%

How many mobile services an institution offered was examined in this research. Less than half of institutions (47%) supplied three or fewer mobile services (see TABLE VII), and the average for those surveyed was 4 units. There was an obvious gap between six units (18%) and seven units (10%), which displayed that providing more than seven units of mobile services was a high threshold for higher education in Taiwan.

TABLE VII.
THE DISTRIBUTION OF MOBILE SERVICES AN INSTITUTION PROVIDED

Number of unit(s)	Pct. of institutions (n=68)	Cumulated pct. of institutions (n=68)
One	11.8%	11.8%
Two	14.7%	26.5%
Three	20.6%	47.1%
Four	13.2%	60.3%
Five	11.8%	72.1%
Six	17.6%	89.7%
Seven	5.9%	95.6%
Eight	4.4%	100.0%

Moreover, the researcher wondered how many mobile services an institution provided though a mobile app. The researcher set a value called efficiency and its formula was "the number of mobile services of the institution" divided by "the number of that institution's mobile apps. The value of efficiency presented the mean of mobile services per mobile app of an institution. The larger the value was, the more services a mobile app provided.

The institutions with value of efficiency between 1.00~1.99 accounted for 41 percent of the total, and those whose value of efficiency exceed 4.0 merely accounted 9 percent (see TABLE VIII). Interesting, there was roughly

10% of institutions with value of efficiency less than 1.00, which showed that their mobile services were overlapping largely. Briefly, the average for those surveyed was 2 units.

TABLE VIII.
THE DISTRIBUTION OF THE VALUE OF EFFICIENCY

Value of efficiency	Pct. of institutions (n=68)
5.00~5.99	2.9%
4.00~4.99	5.9%
3.00~3.99	19.1%
2.00~2.99	19.1%
1.00~1.99	41.2%
0.00~0.99	11.8%

There was a significant difference in the value of efficiency with respect to control of school: private institutions were more likely than public institutions to provide more mobile services with less mobile apps.

Next, the mobile services were focused again. In this research, two numbers, "the multi-app rate" and "the service multiple", were calculated in order to understand the degree of diversity or redundancy of a mobile service.

The multi-app rate was the proportion of institutions offering a certain kind of mobile service via two or more apps. The larger the multi-app rate was, the larger degree of diversity or redundancy a mobile service was. Among the mobile services, productivity had the highest multi-app rate (91%), leading e-Learning (69%), student services (68%) and so on (see TABLE IX).

TABLE IX.
THE DEGREE OF DIVERSITY OR REDUNDANCY OF MOBILE SERVICES

	The multi-app rate	The service multiple
Productivity	90.9%	2.36
e-Learning	68.6%	1.83
Student Services	67.6%	1.74
General Information	64.7%	1.98
Library Services	64.3%	1.79
LMS	62.2%	1.78
Personal Information	56.1%	1.73
Administration	50.0%	1.50
Alumni Services	50.0%	1.50

The service multiple was the division gained from the number of mobile apps furnishing a certain mobile service divided by the number of institutions providing the same mobile service. It displayed how many mobile apps was used to support a mobile service by an institution. The larger the service multiple was, the larger degree of diversity or redundancy a mobile service was. Among the mobile services, productivity also had the highest value (2.36), followed by general information (1.98), e-Learning (1.83), etc. (see TABLE IX).

The supply rate mentioned above stood for the degree of widespread of a mobile service because it presented "how many institutions offer the mobile service". On the other hand, the multi-app rate and the service multiple represented "the degree of diversity or redundancy of a mobile service".

From the aspect of the supply rate, personal information was one of the top three mobile services, trailing behind general information and library services, yet it came in seventh place with respect to the degree of diversity or redundancy of mobile services. It showed that personal information was offered by most intuitions via just one or two mobile apps (see TABLE X).

However, the result of productivity was in the opposite direction: productivity had a quite low ranking by the supply rate but became the top one by the degree of diversity or redundancy. That was, once productivity was offered by an institution, it would be supported by relatively more mobile apps (see TABLE X).

TABLE X.
THE RANKING OF MOBILE SERVICES BY THREE CRITERIA

	By supply rate	By multi-app rate	By service multiple
General Information	1	4	2
Library Services	2	5	4
Personal Information	3	7	7
LMS	4	6	5
e-Learning	5	2	3
Student Services	6	3	6
Productivity	7	1	1
Alumni Services	8	8	8
Administration	9	8	8

C. Mobile Apps vs. Mobile Webs

Around 33% of institutions in Taiwan adopted mobile webs (see TABLE XI). Again, the institutions' size had much things to do with the mobile webs usage rate. For example, large institutions (56%) were more likely than medium (40%) and small institutions (17%) to adopt mobile webs.

Besides, among all types of institutions, the mobile webs usage rate was always lower than the mobile apps usage rate (see TABLE XI), which indicated that the institutions in Taiwan tended to focus their mobile enablement on apps instead of webs.

TABLE XI.
THE USAGE RATE: MOBILE WEBS VS. MOBILE APPS

	Pct. of institutions adopting mobile webs (n=159)	Pct. of institutions adopting mobile apps (n=159)
All institutions	32.7%	42.8%
Universities & Colleges	32.4%	47.9%
Technical Colleges	33.0%	38.6%
Large institutions	55.6%	77.8%
Medium institutions	39.5%	49.4%
Small institutions	16.7%	23.3%
Public institutions	37.3%	45.1%
Private institutions	38.1%	41.7%

For those institutions who adopted mobile apps and mobile webs simultaneously, a certain kind of mobile service might be provided by their mobile apps but not mobile webs, and

vice versa. The four possible situations were described in Fig. 3. A mobile service was placed in the corresponding quadrant according to the situation the majority of institutions belonged to. Frist, many institutions offered general information (88%) and library services (31%) via both their apps and webs. Second, three mobile services was provided via apps but not webs, including personal information (63%), LMS (56%) and e-Learning (38%). Third, most of institutions did not provide some kinds of mobile services via neither mobile apps nor mobile webs, such as alumni services (88%), administration (81%), productivity (69%), and student services (44%). Apparently, there was no mobile service offered via mobile webs but not mobile apps.

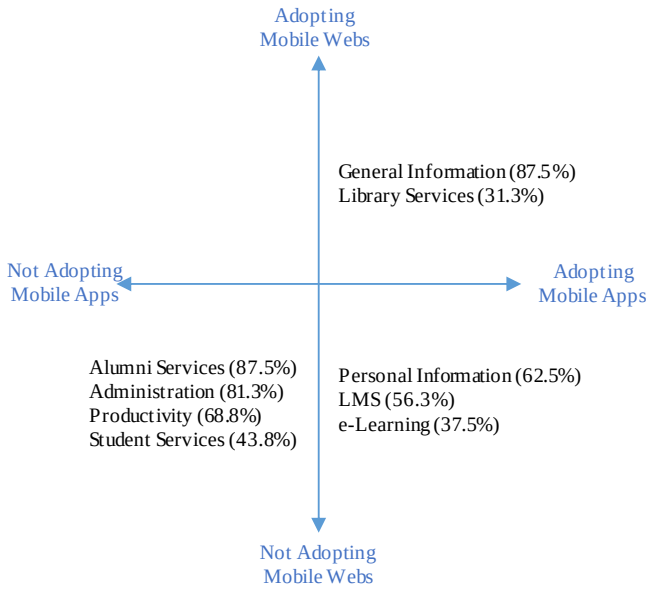

Fig. 3. The situation the majority of institutions belonged to by mobile services

Furthermore, the detail of the percentage by mobile services was viewed. Among the services provided by both mobile apps and mobile webs, only general information exceeded 80% of institutions while the other night of ten were below 35%, even four of them were zero (see TABLE XII). It showed that there was no room for mobile webs to replace mobile apps.

Besides, there were four mobile services that mobile apps provided but mobile webs did not, including personal information (62.5%), LMS (56.3%), administration (18.8%) and productivity (18.8%). It specified that the mobile services delivered via mobile apps were more abundant than via mobile webs. Hence, the conclusion of this part was that the main access to mobile service for institutions in Taiwan was mobile apps instead of mobile webs.

IV. Conclusions

The last two of the assumptions of the research are supported while the first one is not. There is an explanation for the result. Besides, four limitations of the research would be summarized.

A. Findings

The result indicates that the mobile apps usage rate of higher education institutions in Taiwan is 42.8%, as opposed to 56.7% of the ISAC 2014 survey, which rejects the first assumption. There is a way to explain such a result. The criteria of this research for determining whether a mobile app is official is strict that the percentage of adopting mobile apps declined. For example, a mobile app whose developer is a person would be regarded as non-official even though its copyright belongs to an institution or a corporation.

TABLE XII.
Content Analysis Across Mobile App And Mobile Web

Does It Provide?	App does Web does (n=16)	App doesn't Web does (n=16)	App does Web doesn't (n=16)
Administration	0.0%	0.0%	18.8%
General Information	87.5%	12.5%	0.0%
Personal Information	0.0%	0.0%	62.5%
LMS	0.0%	0.0%	56.3%
e-Learning	25.0%	12.5%	37.5%
Productivity	12.5%	0.0%	18.8%
Student Services	12.5%	6.3%	37.5%
Library Services	31.3%	18.8%	25.0%
Alumni Services	0.0%	37.5%	0.0%
Others	12.5%	12.5%	12.5%

PS. The number is the percentage of institutions.

The most popular mobile services provided by institution in Taiwan via official apps are as follows: general information, library services, personal information and LMS. In addition, more than half of the institutions offer these services. Hence, the second assumption is supported.

The services delivered via mobile apps are more abundant than via mobile webs, which indicates that mobile app is the main tool for delivering mobile services for higher education in Taiwan. As results, it is concluded that the third assumption is supported and serving users takes priority over cutting cost in the consideration of the institutions in Taiwan.

TABLE XIII.
The Outcomes Of The Research

Assumptions	Results
The usage rate of the institutions of this research is larger than the counterpart of the ISAC survey in 2014.	The percentage of this paper is 42.8% as opposed to 56.7% of the ISAC 2014 survey.
LMS and library services are the most popular categories of mobile services in higher education in Taiwan.	In terms of frequency, library services and LMS are at top 2 and top 4 respectively, and both of them are provided by more than half of institutions in Taiwan.
The main access to mobile services for institution in Taiwan is mobile app instead of mobile web.	The services delivered via mobile apps are more abundant than via mobile webs

B. Limitations

First, if the name or the developer of an official app was irrelevant to the institution's name then researchers could not find it out, which may affected the usage rate.

Second, there was no information about the installs of an app on Apple App Store. If the installs of an app were less than 500 times then the researcher could not cross it out.

Third, it was impossible to analyze the content of some mobile services on the mobile app or the mobile web due to no user accounts to log in. If the researcher could not ensure that the institution did provide the service, then it didn't.

Finally, a concise method of analysis was taken because of the restriction of time. For mobile apps, the researcher regarded the app on iOS and Android as the same in case that its name, developer and user interface are the same. The analysis result of one of them would be applied to the other. For mobile webs, analyzing the institutions belonging to the special type of 16 were focused on instead of the general type of 30.

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Hsu-Chen CHENG became a Member (M) of IEEE in 2000. He earned his Ph.D. in information management in National Taiwan University, Taipei, Taiwan, in 2005. He is the PRESIDENT of WisdomGarden in Taipei and has been working in the field of educational technology in higher education for more than 20 years with a focus on campus IT research, implementation of credit systems, teachers' IT literary, and ICT integration in teaching and learning. Prior to his current role, he served as a campus CIO and an associate professor, accumulating rich knowledge and experiences in campus IT operation, IT management, and student teaching.

He is also a regular speaker at many important educational technology conferences and a project initiator for developing innovative educational products. So far his products have been used by over 30 universities and enterprises in Greater China, and are awarded several patents in USA, mainland China, and Taiwan.

Tsuei-Ping Kung earned her MA degree in learning, design and technology in Stanford University, CA, USA, in 2008. She is the MANAGING CONSULTANT of WisdomGarden in Taipei and has been working in the field of educational technology for nearly 10 years. At her current role, she is responsible for formulating institutional strategies, reengineering business processes, implementing academic ERP, and conducting campus IT research of higher education. Prior to that, she served as a consultant in IBM, aiming to apply multiple technologies and blended learning methods to enterprise learning. With her professionalism, many of the top 100 enterprises had been successfully transformed to vigorous learning enterprises.

Chia-Ming Li graduated with a degree in history in 2009 and earned his MBA in 2013 both from National Chengchi University (NCCU), Taipei, Taiwan. Now he is the RESEARCHER of WisdomGarden in Taipei, and takes responsibility for industry study of educational technology in higher education. Furthermore, he is in charge of collecting, organizing and carrying out complex data analysis in support of management as well as customer requests, and also involved in reporting statistical findings to developing data-driven strategies with senior managers.

Prior to the current position, Mr. Li served as a second lieutenant while fulfilling his compulsory military service in 2010. Besides, Mr. Li had an overseas internship for two months at Sinyi Realty in Shanghai, China, when he was an MBA student in 2012.

Yu-Jou Sun earned her MBA in 2014 from Feng Chia University, Taichung City, Taiwan, and Double Bachelor Commerce Degrees in 2012 in financial and economic law as well as finance from Chihlee Institute of Technology, New Taipei City, Taiwan. Now she is the ASSISTANT RESEARCHER of WisdomGarden in Taipei, and responsible for industry study of educational technology in higher education. Prior to the current position, she had an overseas internship for two months at ACE group International Management Consulting Co. in Dongguan, China, when she was an undergraduate in 2011.

Investigation of Different Ethernet Wiring and Different Frame Size to Enhance the Performance of LAN

Ashraf M. Khalaf*, Mostafa S. Abd El Salam**, Khalil A. Ahmed*

*Faculty of Engineering, Department of Electricity, Minia University, Minia, Egypt

**Egyptian Electricity Holding Company, Cairo, Egypt

ashkhalaf@yahoo.com,mostafashokry0@gmail.com, khalilaa47@gmail.com

***Abstract*—A computer network that covers only a small area networks abbreviated Local Area Network LAN, is used in campus computer networks, buildings, offices, in homes, schools or smaller.Currently, most LANs based on the IEEE 802.3 Ethernet technology using devices such as hubs and switches, which have a data transfer speed of 10, 100, or 1000 Mega bit /s (Mbps). In this paper, we are investigating the different Ethernet wiring standard and different frame size.**

***Keyword*—frame size,10BaseT,100BaseT,LAN performance,Switch, Hub.**

I. INTRODUCTION

A LAN is a computer network limited to a small area such as an office building, university, or even a residential home. Most mid to large-sized businesses today use LANs, which makes it easy for employees to share information. Currently, the most common type of LANs are Ethernet-based.

The Ethernet standard comprise several wiring and signaling variants of the OSI physical layer in use with Ethernet. The original 10BASE5 Ethernet used coaxial cable as a shared medium. Later the coaxial cables were replaced with twisted pair and fiber optics links in conjunction with hubs or switches.

System communicating over Ethernet divide a stream of data into shorter piece called frames. Each frame contains source and destination addresses and error-checking data so that damaged data can be detected and re-transmitted. As per the OSI model. Ethernet provides services up to and including the data link layer.

Collisions happen when two stations attempt to transmit at the same time. They corrupt transmitted fata and require stations to transmit. The lost data and retransmissions reduce throughput. In the worst case where multiple active hosts connected with maximum allowed cable length attempt to transmit many short frames, excessive collisions can reduce throughput dramatically.

LAN is found in many business environments thatlinks a workgroup of task-related personal computers (PCs), for example, engineering workstations or accounting PCs. One of the computers is given a large capacity disk drive and become a server toall other PCs. Software can be stored on this server and used by the wholeclients of the group.

In the implementation of LAN, we use different types of devices such as repeater, switches, hubs, connectors and different cables. Currently, most LANs based on the IEEE 802.3 Ethernet technology using devices such as hubs and switches, which have a data transfer speed of 10, 100, or 1000 Mega bit/s (Mbps).

In the work done in [1], they are measuring the LAN performance. Their work depends on variation of the time of simulation and the number of hubs and making the frame size fixed value of (46, 2000 bytes)with segmentation (1500 bytes).

In the work done in [2], they are evaluating the performance of the LAN by varying the frame size between (1500, 1024 and 512) only and the variation of the Ethernet wiring standard.

In this paper, we evaluate and test the performance of LANs under different conditions of Ethernet wiring (10BaseT and 100BaseT) and different frame size (1500, 1024, 512, 128 and 64 bytes). The collision count, utilization, data traffic received and data traffic sent is calculated in each case of conditions for hub. For switch the parameters that will be measured is data traffic sent, data traffic received and filtered traffic. Simulations are performed by using Riverbed Modeler Academic edition. In our work we are seeking to simulate 1000BaseT as another type of Ethernet cables with data transmission speed 1000Mbps but the problem that the simulation tool that we used contains 10BaseT, 100BaseT and 10Gig but not contains 1000BaseT as an Ethernet cable.

A network station wishing to transmit will first check the cable plant to ensure that no other station is currently transmitting (CARRIER SENSE) since the communications medium us one cable, therefore, it does allow multiple stations access to it with all being able to transmit and receive on the same cable (MULTIPLE ACCESS). Error detection is implemented throughout the use of station “listening” while it is transmitting its data. Two or more stations transmitting cause a collision (COLLISION DETECTION), jam signal is transmitted to network by a jam signal is transmitted to

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Ashraf M. Khalaf is with the Faculty of Engineering, Department of Electrical Engineering. (Ashraf M. Khalaf, Phone: +20 86 2355261; fax: +20 86 2346674; e-mail: ashkhalaf@yahoo.com).

Mostafa S. Abd El Salam, was with Egyptian Electricity Holding Company, Houston, Ministry of Electricity and Renewable Energy (Phone: +20227271045; e-mail: mostafashokry0@gmail.com).

Khalil A. Ahmed is with the Faculty of Engineering, Department of Electrical Engineering. (E-mail: khalilaa47@gmail.com).

network by the transmitting stations that detected the collision, to ensure that all stations know of the collision. All stations will "back off" for a random time. Detection and retransmission is accomplished in microseconds.

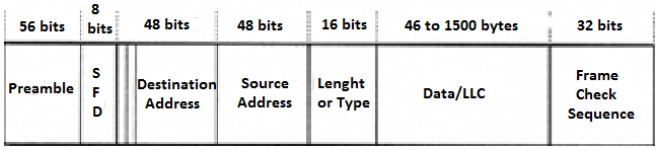

Fig. 1. The Ethernet frame format

Figure 1 demonstrate the minimum and maximum value of Ethernet frame size in bytes. We can see that the maximum value of the frame size at the case of Ethernet is 15018 bytes while the minimum value of the frame size is 64 bytes.

If the data packet size is larger than the maximum size so we will use the segmentation where one of them will be the maximum size and the other segment will be the remaining bits.

If the data packet size is smaller than the minimum value of the frame size, there are padding bits will be added to the frame size to make its value reach to the minimum value of frame size. [3]

II. LAN Components

A. Network media

Network media, sometimes called Network medium, is the physical channel that used for transmission in network. There are two types of mediums used in the implementation of computer networks. One is guided medium and another is unguided medium.

Guided Media (wired)

In guided medium electrical/optical signals are passed through a solid medium such as Copper UnshieldedTwisted Pair (UTP), Copper shielded Twisted Pair (STP), Copper co-axial cables and fiber optics cables.in guided mediums, the signals are confined within the wire and do not propagate outside of the cables.

Unguided Media (wireless)

In unguided medium the data is transmitted by sending electromagnetic signals through free space and hence the signals are not guided in any specific direction. All unguided transmission mediums are classified as wireless transmission.

10BaseT cables

It is a twisted pair Ethernet wiring standard for LAN implementation that support 10Mbps data rate. The maximum transmission length is 100 meters.

100BaseT cables

It is another twisted pair Ethernet wiring standard for LAN implementation that supports 100Mbps data rate. The 100BaseT Ethernet wiring standard is the most commonly used in LAN creation due to its highspeed, robustness and low cost. It is alsocalled fastEthernet because it is ten times faster than 10BaseT [4]- [5].

TABLE I
COMPARISON BETWEEN GUIDED CABLES

Media	Frequency range	Typical attenuation	Repeaters
Twisted pair	0 - 3.5 kHz	0.2 dB/Km At 1KHz	2 km
Coaxial cable	0 -500MHz	7 dB/km At 10MHz	1 - 9 km
Optical fiber	186 -370THz	0.2 to 0.5 dB/km	40km

Table I shows the comparison between the guided cables (Twisted pair, Co-axial cables and optical fiber).

B. Hub

Hub is the simplest component in any local area network (LAN). Any data packet coming from one port is sent to all other ports it is then up to the receiving computer to decide if the packet is for it or not.Since every packet is sent out to every computer on the network there is a lot of wasted transmission, so the network can be easily become bogged down.Hubs are typically used on small networks where the amount of data going across the network is not very high.

C. Switch

Switch has multiple ports. When the packet comes through a switch it is read to determine which computer to send the data to. This leads to increase the efficiency and the performance of the device because the packets are not going to computers that do not require them [6].

The switch can determine the address of the sender and the receiver according to its MAC address table, where it's a table in each switch which store the MAC address transmission easy when any device need to send data several times.

III. Simulation Software and Parameters

The simulation will be done by using Riverbed Modeler Academic Edition 17.5 [7].Riverbed Modeler Academic edition is a high-level event based network level simulation tool, it contains a huge library of accurate models of commercial available fixed network hardware and protocols. Riverbed Modeler Academic Edition can be used as a research tool or as a network design/analysis tool. It consists of high level user interface, which is constructed from C and C++ source code with a huge library of Riverbed Modeler specific functions. Modelling in Riverbed is divided into three main domains. The first one is Network domain that is responsible for networks, sub networks, network topologies, geographical coordinates and mobility. The second one is Node domain that includes single networknodes such as routers, workstations, mobile devices. The last model called Process domain that represent single module and source code inside network nodes such as data traffic source model and IP protocol. For this work we will create an office LAN which consists of hubs, switch, twenty Ethernet stations,10 devices per each hub, under 10baseT (for scenario 1) and 100baseT (for scenario 2) Ethernet wiring standard.

A. Riverbed Modeler Academic Edition 17.5

Riverbed Modeler is software that is specialized for network research and development.This release replaced

OPNET IT guru academic edition "Optimized Network Engineering Tool". I used that software to implement the office LAN because it offers relatively much powerful visual or graphical support for the users.

B. *Parameters of nodes*

Traffic Generation Parameters

Start time in seconds will be constant (5.0), ON State Time in second is constant (1000), OFF state Time is (0).

Packet Generation Arguments

Packet size in bytes will be varied according to the frame size in each case which will be (1500,1024,512,128,64), segmentation size in bytes will be No segmentation.

C. *Performance parameters*

For Hub

Utilization, Collision count, Traffic forwarded (bits/sec) and Traffic received (bits/sec).

For Switch

Traffic forwarded (bits/sec), Traffic received (bits/sec), Traffic filtered (bits/sec).

D. *Running time parameters*

The simulation are performed for 4 min and we make the time of simulation is constant for all the scenarios that we made.

IV. SIMULATION SCENARIOS

In our simulation we used two different scenarios for implementation of LANs with two different wiring Ethernet standard. At each scenario we changed the frame size to calculate some parameters of the network, then we evaluate the performance of the network.

A. *Scenario 1*

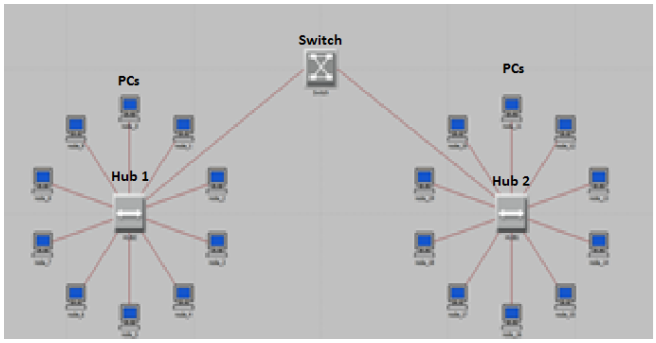

Fig. 2. Office LAN under 10BaseT wiring standard

Figure 2 illustrates scenario 1 which contains connection of 20 Ethernet stations to hubs, each hub connected to 10 Ethernet stations, and the hubs connected to Ethernet switch. 10BaseT Ethernet wiring standard will be used in that scenario.

B. *Scenario 2*

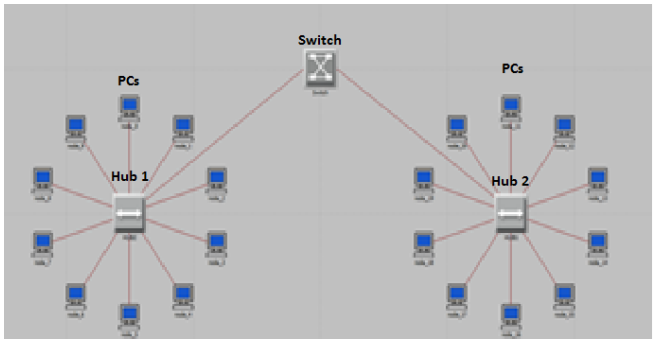

Fig. 3. Office LAN under 100BaseT wiring standard

Figure 3 illustrates scenario 2 which contains connection of 20 Ethernet stations to hubs, each hub connected to 10 Ethernet stations, and the hubs connected to Ethernet switch. 100BaseT Ethernet wiring standard will be used in that scenario.

V. SIMULATION RESULTS

After we made the simulation we took the results that measure and evaluate the performance of LAN under different Ethernet wiring standard with different frame size as following:

A. *Number of collision counts at Hub 1*

TABLE II
NUMBER OF COLLISION COUNTS AT HUB1 (AVG.)

Time duration	4 minutes	
Devices	Collision count Hub 1	
standards	10BaseT (scenario1)	100BaseT (scenario2)
1500 bytes	3,456.19	24.24
1024 bytes	1,558.101	14.051
512 bytes	333.03	7.753
128 bytes	26.292	5.589
64 bytes	13.54	4.7

Table II shows the comparison between the collision count number at hub 1 under 10BaseT (scenario 1) and 100BaseT (scenario 2) for 1500, 1024, 512, 128 and 64 bytes of frame size.This table shows that the value of the collision count at the case of using 10BaseT Ethernet cables is larger than value of the collision count at the case of using 100BaseT regardless the value of frame size is.

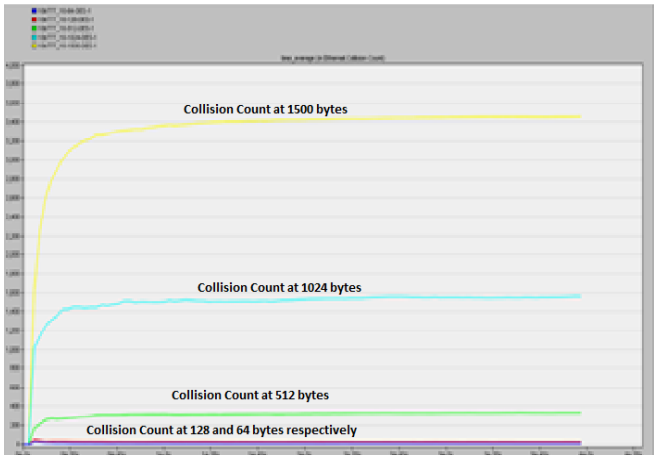

Fig. 4. Comparison between numbers of collision count at Hub1 under different frame size at 10BaseT Ethernet wiring standard.

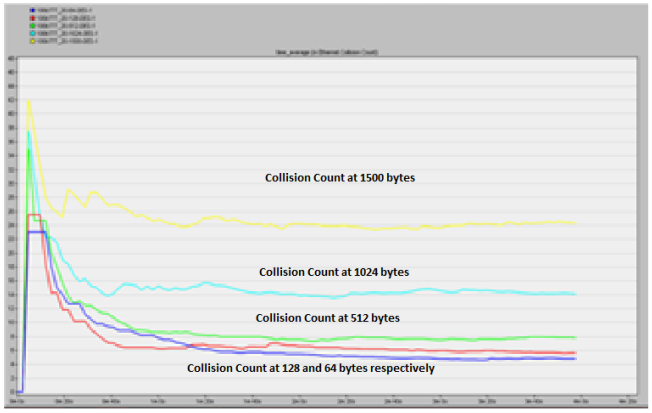

Fig. 5. Comparison between numbers of collision count at Hub1 under different frame size at 100BaseT Ethernet wiring standard

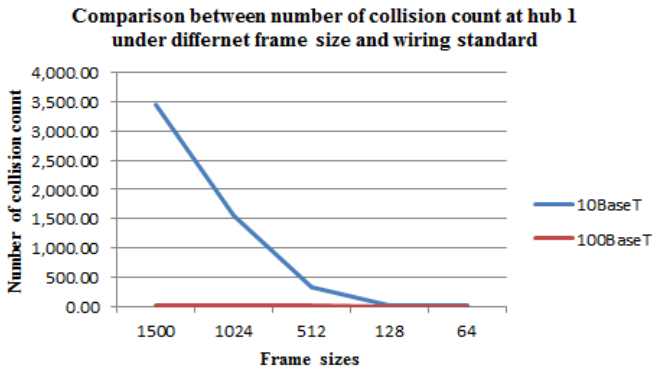

Fig. 6. Graphs for number of collision count at Hub1

Figures 4, 5 and 6 show that the number of collision counts in 10BaseT is more than 100BaseT for all frame sizesregardless the value of the frame size which is used.

B. Utilization of Hub

TABLE III
UTILIZATION OF HUB1 (AVG.)

Time duration	4 minutes	
	Utilization	
Devices	Hub 1	
standards	10BaseT (scenario1)	100BaseT (scenario2)
1500 bytes	0.883	0.091
1024 bytes	0.627	0.062
512 bytes	0.321	0.032
128 bytes	0.092	0.009
64 bytes	0.053	0.005

Table III shows the comparison between the utilization of hub 1 under 10BaseT (scenario1) and 100BaseT (scenario2) for 1500, 1024, 512, 128 and 64 bytes of frame size.This table shows that the value of the utilization at the case of using 10BaseT cables is larger than the value of the utilization when using 100BaseT cables regardless the value of the frame size that is used because the value of utilization proportional directly with the value of the collision count.

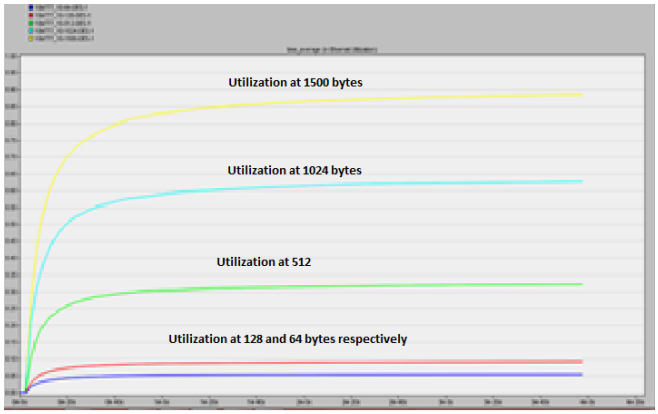

Fig. 7. Comparison between utilization at Hub1 under different frame size at 10BaseT Ethernet wiring standard.

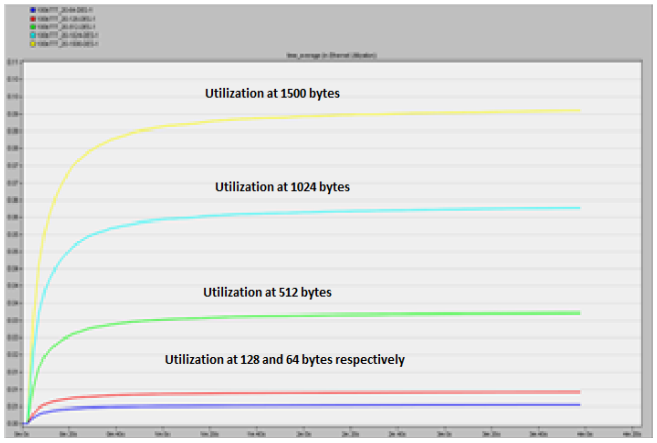

Fig. 8. Comparison between utilization at Hub1 under different frame size at 100BaseT Ethernet wiring standard

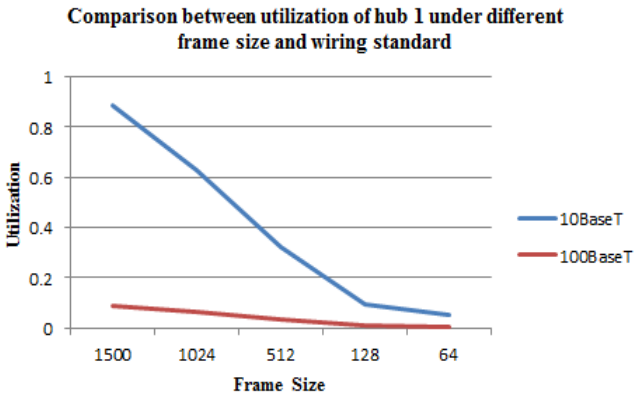

Fig. 9. Graphs for Utilization of Hub1

Figures 7, 8 and 9 demonstrate that the utilization in 10BaseT is more than 100BaseT for all frame sizesregardless the value of the frame size that is used.

C. *Traffic forwarded (bits/sec) at Hub 1*

TABLE IV
TRAFFIC FORWARDED (BITS/SEC) TO HUB 1 (AVG.)

Time duration	4 minutes	
	Traffic Forwarded (bps)	
Devices	Hub 1	
Standards	10BaseT (scenario1)	100BaseT (scenario2)
1500 bytes	8,815,602	9,100,506
1024 bytes	6,259,192	6,263,042
512 bytes	3,209,531	3,214,534
128 bytes	919,988	918,550
64 bytes	538,601	538,967

Table IV shows the comparison between the traffic forwarded to Hub 1 under 10BaseT (scenario1) and 100BaseT (scenario2) for 1500, 1024, 512, 128 and 64 bytes of frame size.

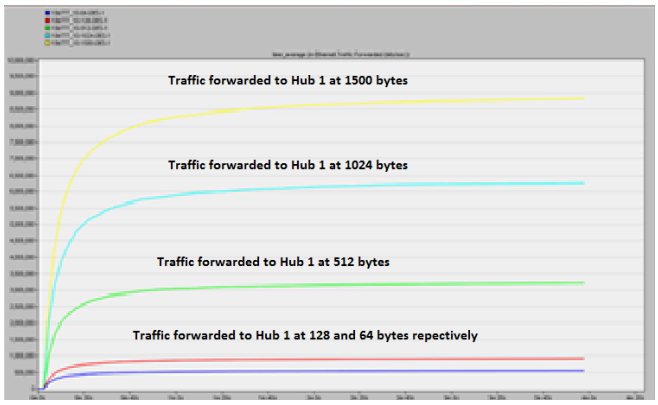

Fig. 10. Comparison between traffic forwarded (bps) at Hub1 under different frame size at 10BaseT Ethernet wiring standard

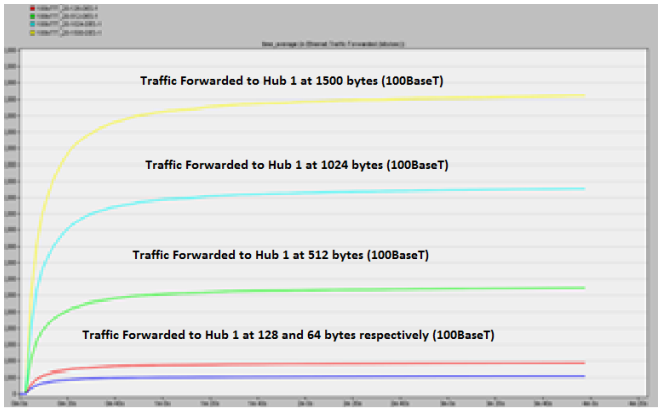

Fig. 11. Comparison between traffic forwarded (bps) at Hub1 under different frame size at 100BaseT Ethernet wiring standard

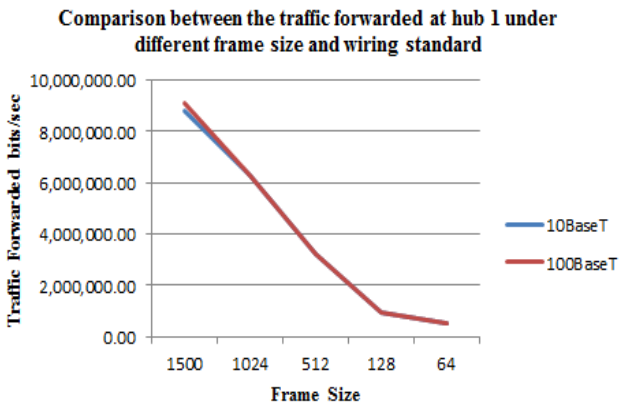

Fig. 12. Graphs of traffic forwarded at Hub1 (bit/sec)

Figures 10, 11 and 12 show that at some points both curves overlap to each other; it means that traffic forwarded to hub1 is approximately same at these points.

D. *Traffic received (bits/sec) at Hub 1*

TABLE V
TRAFFIC RECEIVED (BITS/SEC) TO HUB 1 (AVG.)

Time duration	4 minutes	
	Traffic Received (bps)	
Devices	Hub 1	
Standards	10BaseT (scenario1)	100BaseT (scenario2)
1500 bytes	8,815,602	9,100,506
1024 bytes	6,259,192	6,263,042
512 bytes	3,209,531	3,214,534
128 bytes	919,988	918,550
64 bytes	538,601	538,967

Table V shows the comparison between the traffic received to Hub 1 under 10BaseT (scenario1) and 100BaseT (scenario2) for 1500, 1024, 512, 128 and 64 bytes of frame size.

Tables V and IV shows that the value of the traffic sent in bits per second and the value of the traffic received in bits per second at the case of hub is equivalent because hub doesn't understand addressing the data which the hub receive is broadcasted to all device in the network so the amount of received data is the same as the amount of sent data.

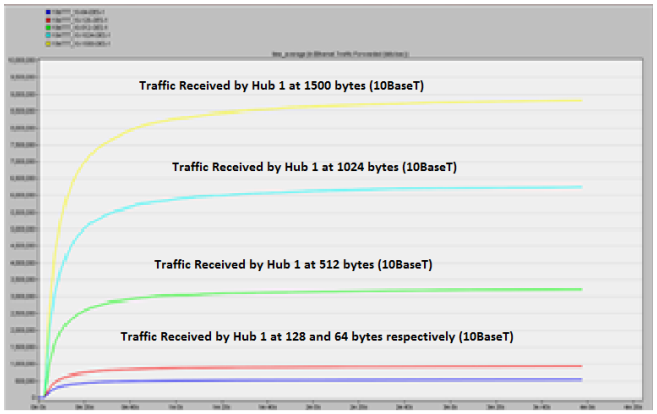

Fig. 13. Comparison between traffic received (bps) at Hub1 under different frame size at 10BaseT Ethernet wiring standard

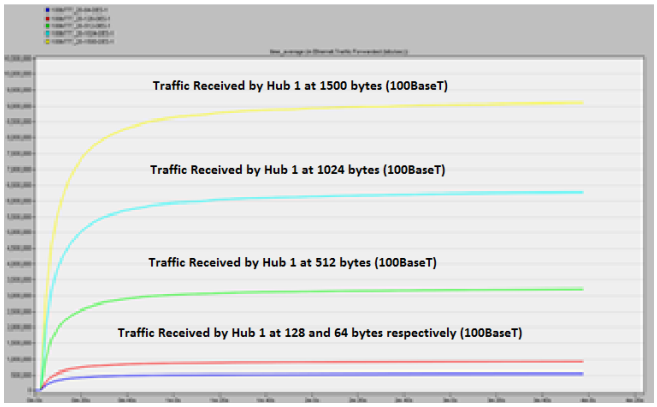

Fig. 14. Comparison between traffic received (bps) at Hub1 under different frame size at 100BaseT Ethernet wiring standard.

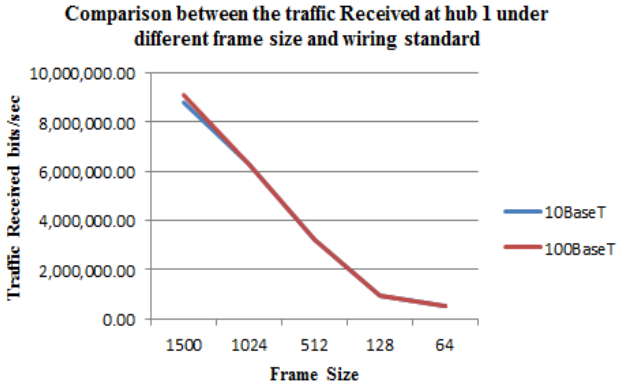

Fig. 15. Graphs of traffic received at hub1 (bit/sec)

Figures 13, 14 and 15 demonstrate that at some points both curves overlap to each other; it means that traffic received to hub1 is approximately same at these points.

E. Number of collision counts at Hub 2

TABLE VI
NUMBER OF COLLISION COUNTS AT HUB 2 (AVG.)

Time duration	4 minutes	
	Collision count	
Devices	Hub 2	
Standards	10BaseT (scenario1)	100BaseT (scenario2)
1500 bytes	3,435.919	27.70
1024 bytes	1,572.666	14.877
512 bytes	340.3	7.626
128 bytes	29.4	5.29
64 bytes	12.4	5.13

Table VI illustrates the comparison between the collision count number at hub 2 under 10BaseT (scenario 1) and 100BaseT (scenario 2) for 1500, 1024, 512, 128 and 64 bytes of frame size.The table VI illustrates that the value of the collision count at the case of using 10BaseT Ethernet cable is larger than the amount of collision count when using 100BaseT cables regardless the value of the frame size that is used.

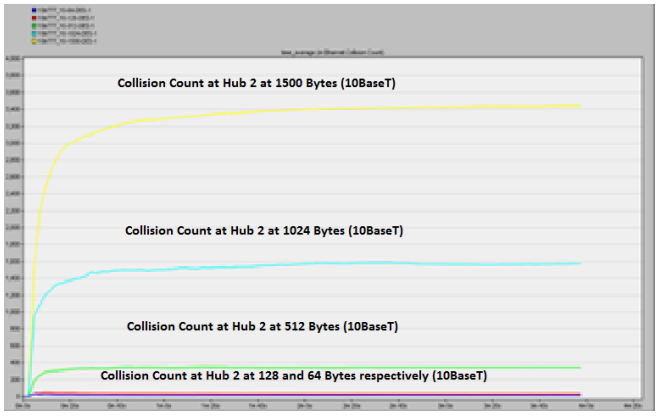

Fig. 16. Comparison between numbers of collision count at Hub2 under different frame size at 10BaseT Ethernet wiring standard

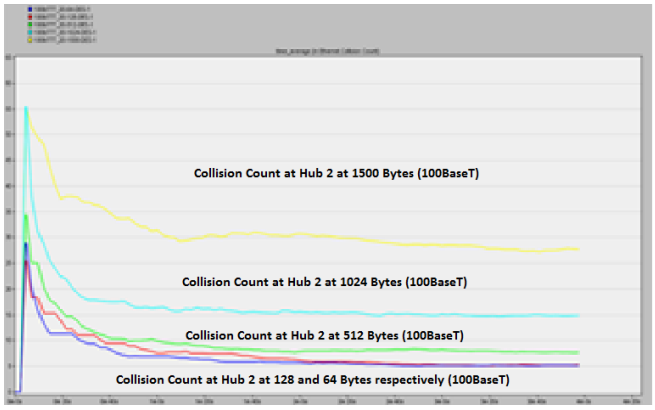

Fig. 17. Comparison between numbers of collision count at Hub2 under different frame size at 100BaseT Ethernet wiring standard

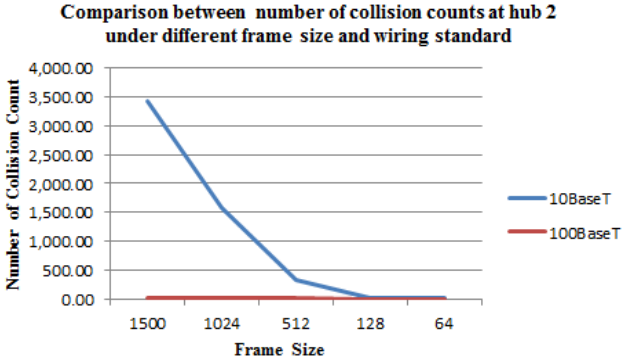

Fig. 18. Graphs for number of collision count at Hub2

Figures 16, 17 and 18show that the number of collision count in 10BaseT is more than 100BaseT for all frame sizesregardless the value of the frame size that is used.

F. Utilization of Hub 2

TABLE VII
UTILIZATION OF HUB 2 (AVG.)

Time duration	4 minutes	
	Utilization	
Devices	Hub 2	
Standards	10BaseT (scenario1)	100BaseT (scenario2)
1500 bytes	0.8836	0.0910
1024 bytes	0.6288	0.0626
512 bytes	0.3217	0.0321

128 bytes	0.092	0.009
64 bytes	0.053	0.005

Table 7 shows the comparison between the utilization at hub 2 under 10BaseT (scenario 1) and 100BaseT (scenario 2) for 1500, 1024, 512, 128 and 64 bytes of frame size. The table demonstrates that the value of collision count at the case of using 10BaseT Ethernet cable is larger than its value when using 100BaseT cables regardless the frame size which used because the value of collision count proportional directly with the value of collision count.

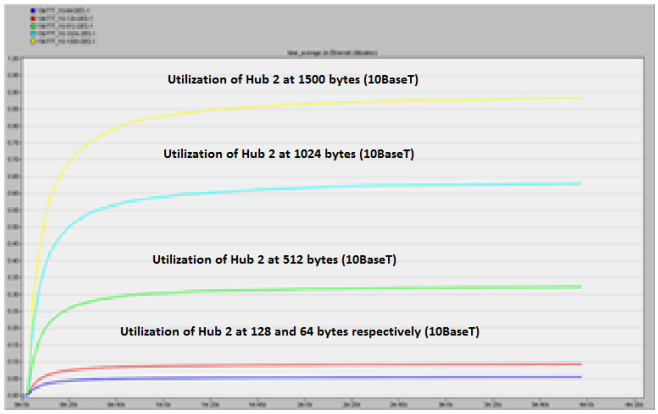

Fig. 19. Comparison between utilization at Hub2 under different frame size at 10BaseT Ethernet wiring standard

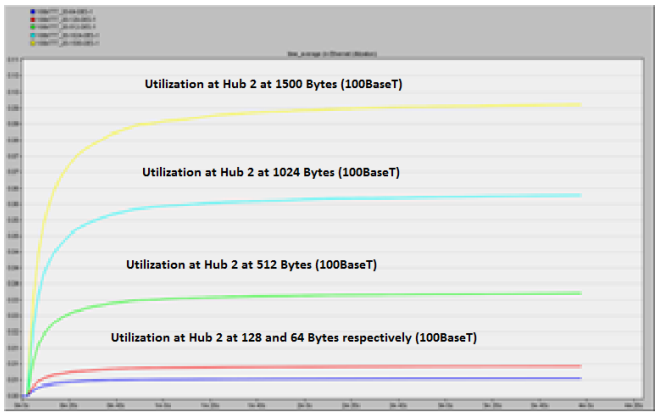

Fig. 20. Comparison between utilization at Hub2 under different frame size at 100BaseT Ethernet wiring standard

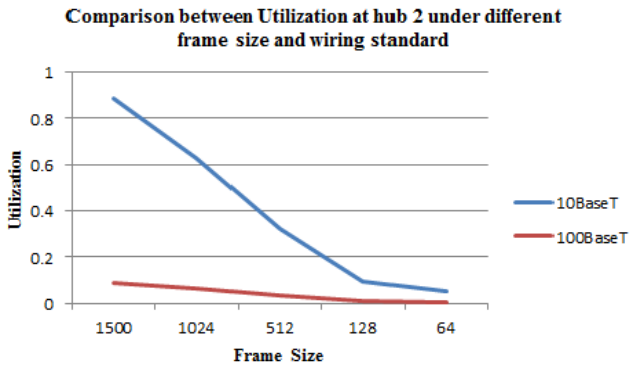

Fig. 21. Graphs for Utilization of Hub2

Figures 19, 20 and 21 illustrate that the utilization in 10BaseT is more than 100BaseT for all frame sizesregardless the value of the frame size which is used.

G. *Traffic forwarded (bits/sec) at Hub2*

TABLE VIII
TRAFFIC FORWARDED (BITS/SEC) TO HUB 2 (AVG.)

Time duration	4 minutes	
	Traffic Forwarded (bps)	
Devices	Hub 2	
Standards	10BaseT (scenario1)	100BaseT (scenario2)
1500 bytes	8,813,873	9,105,746.133
1024 bytes	6,276,727	6,266,542.4
512 bytes	3,214,211	3,212,418.33
128 bytes	920,963.466	918,889.6
64 bytes	538,082.4	539,042.4

Table VIII shows the comparison between the traffic forwarded to Hub 2 under 10BaseT (scenario1) and 100BaseT (scenario2) for 1500, 1024, 512, 128 and 64 bytes of frame size.

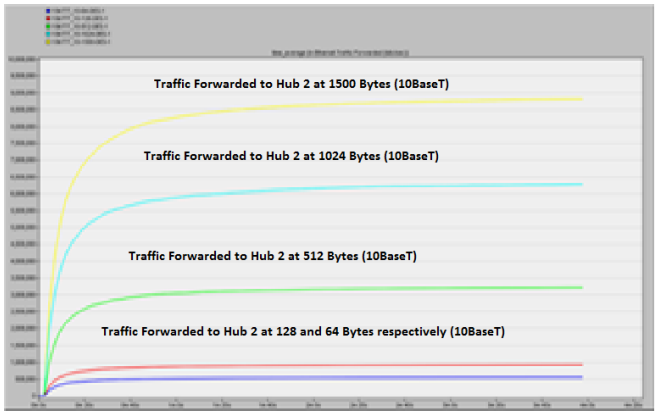

Fig. 22. Comparison between traffic forwarded (bps) at Hub2 under different frame size at 10BaseT Ethernet wiring standard.

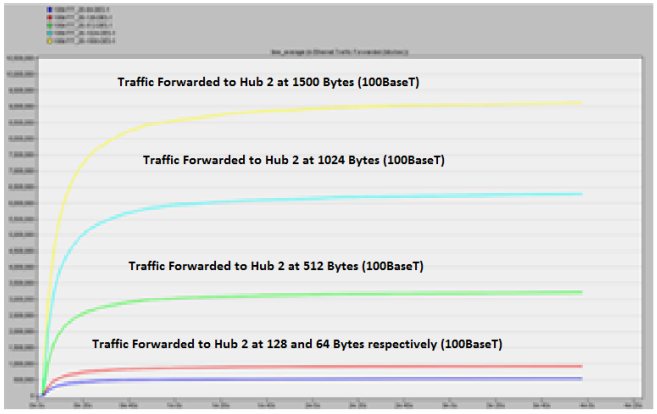

Fig. 23. Comparison between traffic forwarded (bps) at Hub2 under different frame size at 100BaseT Ethernet wiring standard.

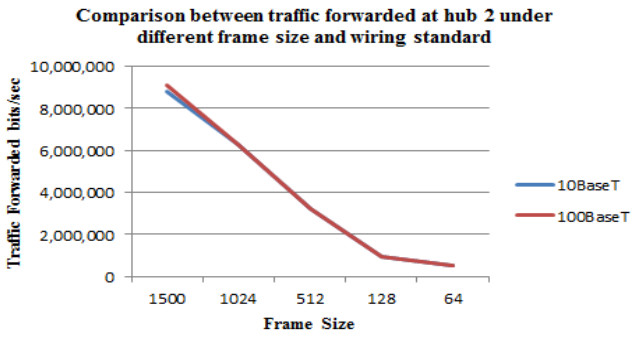

Fig. 24. Graphs of traffic forwarded to hub2 (bit/sec)

Figures 22, 23 and 24 demonstrate that at some points both curves overlap to each other, it means that traffic forwarded to hub2 is approximately same at these points.

H. Traffic received (bits/sec) at hub 2

TABLE IX
TRAFFIC RECEIVED (BITS/SEC) TO HUB 2 (AVG.)

Time duration	4 minutes	
	Traffic Received (bps)	
Devices	Hub 2	
Standards	10BaseT (scenario1)	100BaseT (scenario2)
1500 bytes	8,813,873	9,105,746.133
1024 bytes	6,276,727	6,266,542.4
512 bytes	3,214,211	3,212,418.33
128 bytes	920,963.466	918,889.6
64 bytes	538,082.4	539,042.4

Table IX shows the comparison between the traffic received to Hub 2 under 10BaseT (scenario1) and 100BaseT (scenario2) for 1500, 1024, 512, 128 and 64 bytes of frame size.

Tables VIII and IX shows that the value of the data traffic sent in bits per second and the data traffic received in bits per second for hub are the same because hub is broadcasting all the incoming data to all the devices in the same network without filtering the traffic.

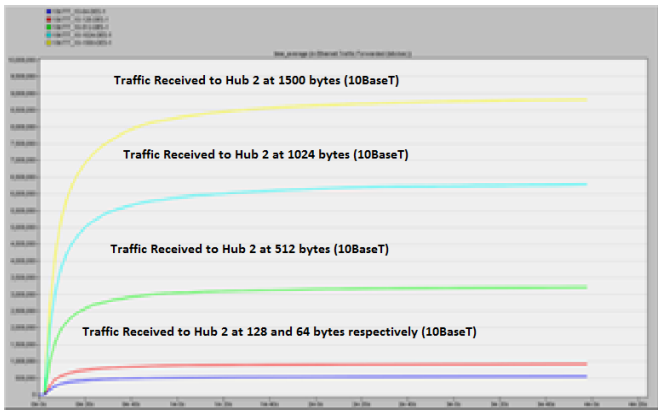

Fig. 25. Comparison between traffic received (bps) at Hub2 under different frame size at 10BaseT Ethernet wiring standard

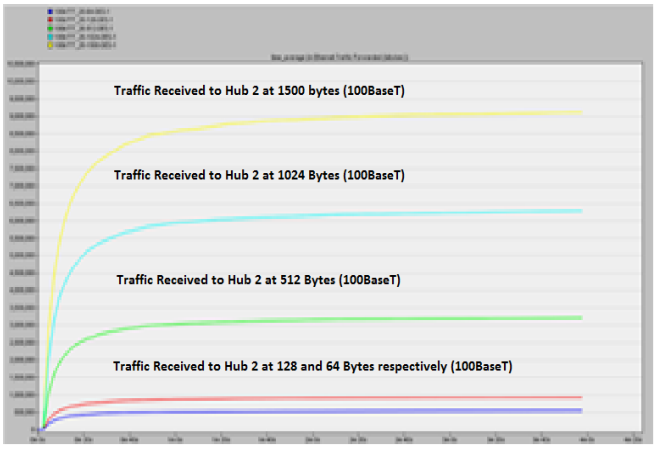

Fig. 26. Comparison between traffic received (bps) at Hub2 under different frame size at 100BaseT Ethernet wiring standard.

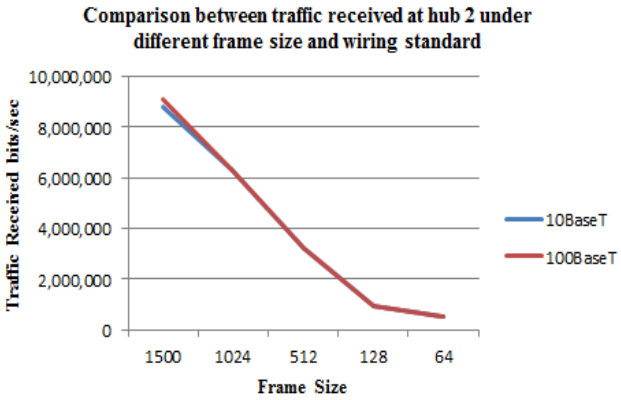

Fig. 27. Graphs of traffic received to hub2 (bit/sec)

Figures 25, 26 and 27 show that at some points both curves overlap to each other; it means that traffic received at hub2 is approximately same at these points.

I. Traffic forwarded (bits/sec) at switch

TABLE X
TRAFFIC FORWARDED (BITS/SEC) TO SWITCH (AVG.)

Time duration	4 minutes	
	Traffic Forwarded (bps)	
Devices	Switch	
Standards	10BaseT (scenario1)	100BaseT (scenario2)
1500 bytes	6,091,588.533	6,281,372.066
1024 bytes	4,312,105	4,327,995
512 bytes	2,212,381.533	2,220,971.6
128 bytes	634,480	633,561.133
64 bytes	370,812	372,297

Table X shows the comparison between the traffic forwarded to switch under 10BaseT (scenario1) and 100BaseT (scenario2) for 1500, 1024, 512, 128 and 64 bytes of frame size.

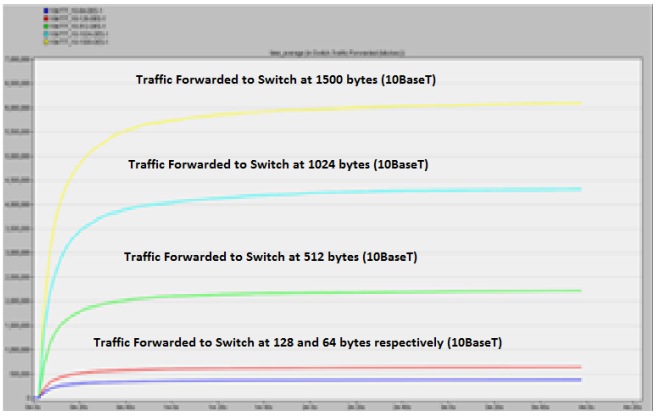

Fig. 28. Comparison between traffic forwarded (bps) at Switch under different frame size at 10BaseT Ethernet wiring standard

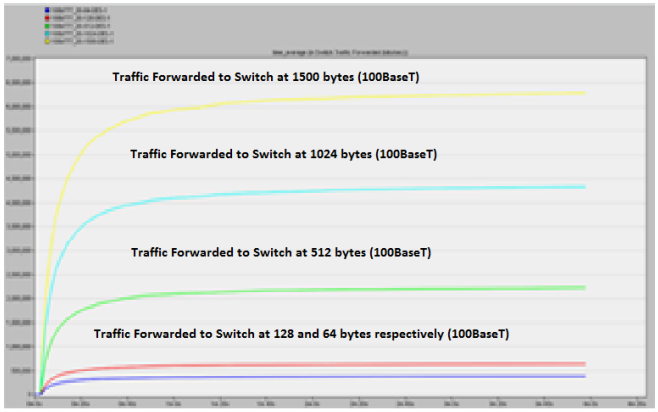

Fig. 29. Comparison between traffic forwarded (bps) at Switch under different frame size at 100BaseT Ethernet wiring standard

Fig. 30. Graphs of traffic forwarded to switch (bit/sec)

J. *Traffic received (bits/sec) at switch*

TABLE XI
TRAFFIC RECEIVED (BITS/SEC) TO SWITCH (AVG.)

Time duration	4 minutes	
	Traffic Received (bps)	
Devices	Switch	
Standards	10BaseT (scenario1)	100BaseT (scenario2)
1500 bytes	11,559,450	11,924,876.13
1024 bytes	8,223,810	8,201,585
512 bytes	4,211,356	4,205,994.33
128 bytes	1,206,466.8	1,203,874.466
64 bytes	705,867	705,708

Table XI shows the comparison between the traffic received by switch under 10BaseT (scenario1) and 100BaseT (scenario2) for 1500, 1024, 512, 128 and 64 bytes of frame size.

Tables X and XI shows that the amount of the data traffic sent in bits per second and the amount of data traffic received in bits per second at the case of switch is not the same as the case of hub. The amount of data traffic received is larger than the amount of data traffic sent because there are some filtered data. At the case of switch not all the incoming data is broadcasted because it knows the address of the sender and receiver by using the MAC address table.

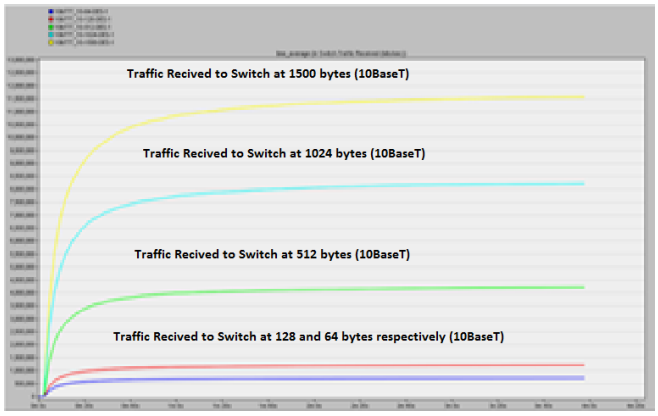

Fig. 31. Comparison between traffic received (bps) at switch under different frame size at 10BaseT Ethernet wiring standard

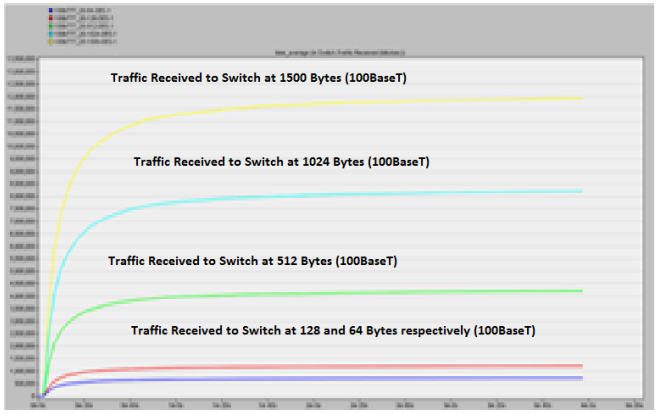

Fig. 32. Comparison between traffic received (bps) at switch under different frame size at 100BaseT Ethernet wiring standard

Fig. 33. Graphs of traffic received at switch (bit/sec)

K. *Traffic filtered (bits/sec) by switch*

TABLE XII
Traffic received (bits/sec) to switch (Avg.)

Time duration	4 minutes

	Traffic Filtered (bps)	
Devices	Switch	
Standards	10BaseT (scenario1)	100BaseT (scenario2)
1500 bytes	5,467,861.67	5,643,504.04
1024 bytes	3,911,705	3,873,590
512 bytes	1,998,974.8	1,985,022.7
128 bytes	571,986.8	570,313.33
64 bytes	335,055	333,411

Table XII shows the comparison between the traffic received by switch under 10BaseT (scenario1) and 100BaseT (scenario2) for 1500, 1024, 512, 128 and 64 bytes of frame size.From the table we can see that the amount of filtered traffic at the case of using frame size 1500 bytes is larger when using 100BaseT than 10BaseT which indicates better performance, but when we decrease the frame size to 512, 128 and 64 the amount of filtered traffic at the case of using 10BaseT is larger than the amount of filtered traffic when using 100BaseT which indicated better performance for switch.

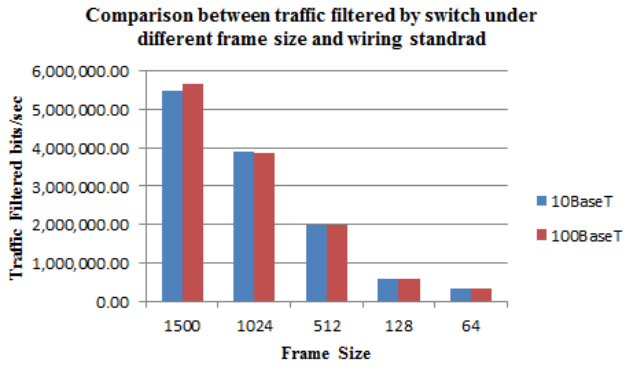

Fig. 34. Comparison between the traffic filtered by switch under different frame size and wiring standard

Figure 34 shows that the initially filtered traffic is better in case of 100BaseT for 1500 bytes frame size than 10BaseT. For 1024, 512, 128 and 64 bytes frame size the switch under 10BaseT filtered more traffic than 100BaseT, it means that the performance of 10BaseT Ethernet wiring standard is become better at the case of low traffic data.

VI. Conclusion

Computer Simulation are outperformed by using Riverbed Modeler Academic edition tool. The performance of LANs is tested and investigated under different conditions of Ethernet wiring and different frame size. The result remarks and observations from our simulations outcomes are:

- The number of collision counts in 10BaseT is always more than 100BaseT for all the frame sizes because of the nature of 10BaseT [8], [9].
- Hubs are more utilized in case of 10BaseT because of the large value of collision count so the more retransmission attempts will be required.
- The performance of a switch is better for 100BaseT wiring standard at the case of 1500 bytes frame size than that the case of 10BaseT because it filters more traffic.When the frame size is 1024 bytes, filtered traffic will be approximately the same for both 10BaseT and 100BaseT.When frame size is further reduced to 512, 128 and 64 the results show that the performance of 10BaseT becomes better than 100BaseT because the switch filtered more traffic than 100BaseT.
- If we have LAN in which high traffic is not required and the frame size will be fixed to 512, 128 or 64 bytes,10BaseT will give us good result and performs better as compared to 100BaseT Ethernet wiring standard.
- At the case of small frame size we will not able to transfer more traffic per seconds (traffic receiving and forwarding is less) so we cannot use them in heavy traffic (refer tables X and XI).

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Ashraf A.M. Khalaf (M'98) received his B.Sc. and M.Sc. degrees in electrical engineering from Minia University, Egypt, in 1989 and 1994 respectively. He received his Ph.D in electrical engineering from Graduate School of Natural Science and Technology, Kanazawa University, Japan, in March 2000. He is currently works as an associate professor at electronics and communications engineering Department, Minia University, Egypt.

Mostafa S.A. Mokademwas born in Aswan at 1989. He got his B.Sc. degree from faculty of engineering, department of communication and electronics at 2011. He works as an engineer in the Egyptian Electricity Holding company, Ministry of Electricity and renewable Energy.
He is currently a master course student for M.Sc. degree in Electrical Engineering (Communication and Electronics)-Faculty of Engineering, Minia University, El-Minia, Egypt.

Khalil A. Ahmadis a professor in the department of electrical engineering, faculty of engineering, Minia University, Minia, Egypt.

Internet of Things:
Security and Privacy Issues and Possible Solution

Davar PISHVA

Ritsumeikan Asia Pacific University, 1-1 Jumonjibaru, Beppu, Oita 874-8577 Japan

dpishva@apu.ac.jp

***Abstract*—In this paper, the author demonstrates how commonly used communication scheme and information retrieval which are carried out via Internet using numerous types of smart devices, can turn the Internet into a very dangerous platform because of its built-in nature of making its users' identity easily traceable and discusses some countermeasures that can be used to prevent existing and projected security breaches. It initially provides some introductory information on technology advancement, penetration of the Internet to all aspects of our life and its associated conveniences. It then discusses vulnerability of internet services, presents some typical attack cases that are carried out via smart home appliances, and explains security implementation challenges on such devices from technical, social, and practical aspects. Finally, it proposes an appropriate security model, demonstrates relevant counter measures for numerous attack scenarios, and explains why and how numerous stake holders are needed to get together for its commercial implementation.**

***Keyword*—Internet of Things, IoT, Smart, Social Cybernetics, Social Networking, Facebook, Online Advertising, Security, Privacy, Network Tracing Tools.**

I. Introduction

The 21st century has been regarded by many as the information era and penetration of Internet into all aspects of our life is a new dimension along which technologies continue to grow. The advancement in technology has been changing the way of our life and digital information has now become a social infrastructure. We are surrounded by technologies and there are computer technologies in our cars, phones, watches, entertainment systems, and home appliances. The idea is to make use of existing electronics in the devices and, in conjunction with some specialized software, create an intelligent network with access to the Internet.

Since the expansion of the Internet in 1990s, network infrastructure has become an indispensable part of social life and industrial activity for mankind. The idea of using existing electronics in smart home appliances and connecting them to the Internet is a new dimension along which technologies continue to grow, and in recent years mankind has witnessed an upsurge of usage of devices such as smart phone, smart television, home health-care device, etc. Their build-in internet-controlled function has made them quite attractive to many segments of consumers and smart phone has become a common gadget for social networking. Commercial advertising has also greatly benefitted from Internet services and social networking is also being used for online advertising and business transaction.

With adoptions of cloud computing, mobile applications and virtualized enterprise architectures have led to a tremendous expansion of applications that are connected to Internet resources [1]. Just to mention a few examples, we use Internet for various sorts of communication like VoIP and email, multimedia services like Online Music and Online Movie, business transaction like e-Banking and e-Business, administrative work like e-Governance and e-Administration, networking activities such as Online Advertising and Social Networking. Furthermore, along with the development of Internet, e-Commerce has become an efficient marketing tool for many companies and Social Networking with Facebook is an emerging market which has recently become the most visited website in the world [2][3].

Traditionally social networking was done in person and in places like schools, communities, neighborhoods, workplaces etc. and hence limited in size. Although the use of social networking for business and advertisement is not something new, its traditional approach had limited size as it required face-to-face or mouth-to-mouth interactions. Since the expansion of the Internet, however, social networking has grown exponentially and according to Statista [4], Facebook's registered accounts have surpassed one billion users as of March 2015. According to the same source, approximately 347 million people are active on LinkedIn, 300 million uses Google+ and another 288 million use twitter. There are of course many other social networking sites, but none of them even existed at the beginning of the 21st century. In fact, when Facebook was launched in 2004, many people considered it as a place for kids to share their pictures and emotions. Today, however, businesses and marketers love social media and indeed, 90 percent of marketers are using social media for business [5]. Seventy percent have used Facebook to successfully gain new customers and 34 percent have used Twitter to successfully generate leads [6].

In Japan, many audio visual equipment can already be connected to the Internet, enabling people to enjoy network based services, such as Video on Demand (VOD), Music on

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Davar Pishva is a professor in ICT at Ritsumeikan Asia Pacific University (APU) Japan (+81-977-78-1261, fax: +81-977-78-1261, e-mail: dpishva@ apu.ac.jp).

Demand (MOD), remote update, e-Commerce, remote control, and other similar services. Network connectivity is likely to be equipped in all AV equipment in the near future. Such developments have been leading mankind to a new era of technology, the era of the "Internet of Things" (hereafter: IoT), where all the appliances are getting tiny and controllable via the Internet, thus enabling people to enjoy network based services like Video on Demand (VOD), Music on Demand (MOD), remote update, e-Commerce, remote control, and other similar services.

Furthermore, researchers around the world have come up with an abundance of resourceful ideas on how to effectively use microprocessors and Internet in other everyday household appliances. 'Smart' is the new buzzword that we can hear these days; for example, in 'smart' homes, 'smart' kitchens, 'smart' ovens, 'smart' refrigerators, etc. [7]. Table 1 indicates functional classification of smart home appliances [8][9]. There is also a tremendous business potential for them because of foreseen future demand by elderly people, where the number of people over the age of 65 is expected to double to 70 million by 2030 [10]. According to a study conducted by International Data Corporation, 212 billion "things" will be installed based on IoT with an estimated market value of $8.9 trillion in 2020 [11]. Those "things" will be nothing special but daily used appliances ranging from watch, light bulb to smart television, refrigerator and so on.

TABLE I
FUNCTIONAL CLASSIFICATION OF SMART HOME APPLIANCES

No	Function	Example of Product or Usage
1	Content Retrieval	Broadband TV, Microwave Oven, HDD Recorder (for TV program, etc.)
2	Content Storage/Usage	HDD Recorder (for TV program, etc.), MP3 Player
3	Communication/Messaging	VoIP , IP-TV Phone, All kinds of Emails System, Healthcare System
4	Remote Surveillance	Security Camera, Gas/Fire Sensors, Refrigerator, Lighting Fixture, Door Lock
5	Remote Control	Air Conditioner, Lighting Fixture, TV, TV Program Recording
6	Remote Maintenance	Firmware Update, Trouble Report
7	Instrument Linkage	Networked AV Equipment
8	Networked Game	Family Type Game Machine

Commercial advertising has also greatly benefitted from Internet services and online advertising can even be considered as the foundation of web economy. However, the system of online advertising is quite unique. Unlike conventional forms of advertising, the system of online advertising allows its target to receive something in return in exchange for viewing the advertisement. Besides getting information from the advertisement itself, the target of online advertising is usually allowed to use the advertisement host website's service. For example, as shown in Figure 1, video2mp3.net, a website that offers free file conversion from YouTube video to mp3 format, has numerous advertisements displayed on its page [12]. It even goes as far as setting a hidden advertisement that will only appear when the user clicks the "High quality" option. Nevertheless, the users are not required to pay for the service. They are instead offered a premium service where they can get exclusive access to the website without advertisements popping up along the way. In this way, online advertising has defined a new term of "free service", where four parties – the advertisers, the ad network, the ad hosts, and the users - are involved within it [13].

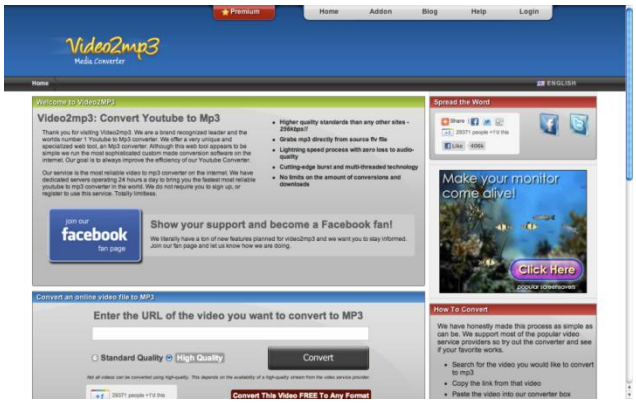

Fig. 1. A view of Video2mp3.net. On the right side is one of its many advertisements.

In other words, today's business activities depend highly on information systems and every enterprise has its own information for its business. In an industrialized country like Japan, most enterprises use information technology to establish their management governance. This helps them improve their efficiency and cost performance. As it is called 'IT governance', information systems have significant impact on the operations. Information assets have thus become valuable commodities for business and information systems are the key factors to ensure the growths of enterprises. Hence, it is essential to control the design process, development cycle and effective utilization of information systems. Nonetheless, as information and its value continue to increase, so does the management complexity, vulnerability and attractiveness to malicious attacks. Security threats can come in the form of unauthorized accesses, computer viruses, or cyber-attacks.

II. VULNERABILITY OF INTERNET SERVICES

For various reasons, however, today's networks are vulnerable to numerous risks, such as information leakage, privacy infringement and data corruption. One of the main underlying factors is operating nature of the communication protocol used in the Internet domain and availability of many free software that can carry out most of these attacks. The Internet protocol suite which is commonly known as TCP/IP (Transmission Control Protocol and Internet Protocol), is used for most Internet applications. IP serving as its primary component carries out the task of delivering packets from source host to destination host solely based on the IP addresses contained in the packet headers. In order to achieve proper operation of such transaction worldwide, this requires source and destination to have unique IP address and included

it in the packet headers of their information packets. Since every IP address is associated with a unique entity, identity of IP address holders can be traced using their IP addresses contained in the packet headers. This section briefly discusses vulnerabilities of some Internet services.

A. Vulnerabilities of e-Commerce

It is a known fact that privacy is implicated in e-Commerce because of the risk involved in disclosing personal information such as email addresses or credit card information, which is required for most electronic transactions. Specific privacy concerns in this realm include use of customers' information by companies for electronic surveillance (e.g., 'cookies'), email solicitation (e.g., 'spam'), or data transfer (e.g., when customer database information is sold to third parties or stolen) resulting in identity or credit card theft [12][13]. Online advertisement which is a major component of e-Commerce uses cookies as a mean to identify users and deliver targeted advertising by tracking their movements in the website. Such cookies are called tracking cookies and an ad network company like Google uses this type of cookies for delivering ads that are relevant to the user's interests, controlling the number of times the user sees a given ad, and "measure the effectiveness of ad campaigns" (Google Policies & Principles, 2012).

The problem with tracking cookies is that when the user visits multiple websites with the same ad provider, the same cookies from the ad provider will be used. This means that the ad provider will be able to track the user's activity in numerous sites just by compiling the information via tracking the cookies without the user's knowledge. The result of this action means the loss of anonymity to the users, which is a blatant breach of information security as well as privacy. Although the ad network are obliged to comply with privacy act and use the information only for marketing strategy, users cannot be sure if it is not used for other purposes. In fact, personal information is being freely traded without the consent of their owners for money making purposes. Personal information related to interest and habit of prospect customers are an essential component for delivering online advertising and can be considered as the lifeline of many websites.

It is only recently that people and governments started to pay attention to this previously un-scrutinized golden goose. The Wall Street Journal's investigation in 2010 revealed an array of cookies and surveillance technologies, with real time function and deactivation resistance, are being used to monitor the users' personal information. The investigation also found out that online tracking is not a small business. The top 50 websites kept close tabs on their users by installing, on the average, 64 different pieces of surveillance technology [14]. As such approaches could unconsciously victimize both technical and non-technical users, anonymous communication is becoming more and more important on Internet environment since it can protect people's right to online privacy and reduce the possibility of getting recognized and thus victimized.

B. Vulnerabilities of Social Networking

In recent years, because of dramatic increase in the use of social networking platforms by many non-technical people, social-engineering technique is also being widely exploited to victimize users. Phishing is a good example of social engineering intrusion technique in which a hacker just needs to tempt the innocent users to fill in only their Facebook ID and password. The aftermaths of releasing such information are detrimental since huge amount of private information such as user's address, birthday, job, education history, hobbies, friends, relationship and a bunch of other sensitive information could be accessed from the Facebook account.

Although Facebook filters all URLs which link its users to an external website and warns them of fraudulent websites, the approach does not always work. For example, after clicking to the link: http://anhhot-duthi.ucoz.net/, which is a fraudulent website created by a Vietnamese hacker [2][3], Facebook will warn the user about the vulnerability of the site through a dialog box shown in Figure 2. This, however, does not always happen since hackers keep on creating new fraudulent web pages in order to penetrate through loopholes of Facebook's security. Furthermore, oftentimes, non-technical people may unconsciously press the "Continue" button instead of the "Cancel" button.

Now let us see what happens when either Facebook's

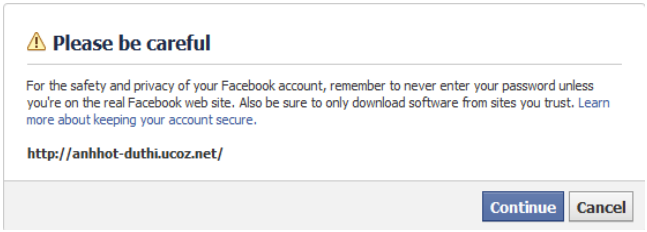

Fig. 2. Vulnerability warning of Facebook.

security does not detect the above mentioned fraudulent website or a user clicks the "Continue" button. As shown in Figure 3, the control would transfer to a phishing site that has the appearance of Yahoo Vietnam website, containing Facebook Logo and a login form which resembles that of the official website. Although a technical user could easily display HyperText Markup Language (HTML) view of the page to determine where the information would be sent, some innocents users may just fill up the form and press the submit button. As indicated in the highlighted section of Figure 3, information content of the form would simply be sent to http://allforms. mailjol.net/, a site which provides free Form-to-Mail service. In other words, filling out the form and pressing "submit" button, will transfer ID and password of Facebook user directly to the email address of the attacker [2][3].

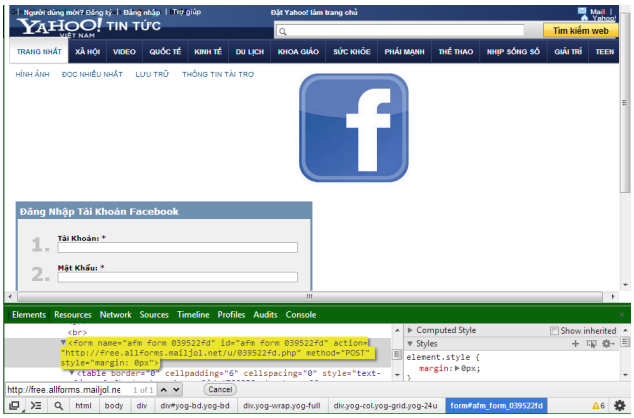

Fig. 3. An example of a phishing website http://anhhot-duthi.ucoz.net/.

After obtaining the first victim's Facebook account, the attacker can easily exploit more users in a targeted manner by taking advantage of the victim's personal information and Facebook's internal working mechanism. Facebook has a built-in feature called "important friends" the function of which is to internally keep track of people with whom a Facebook user communicates frequently and shares some commonality (e.g., same high school, hometown, fan page, etc.). In a targeted phishing Facebook, since the phishing link is being sent from Facebook account of an important friend, i.e., trustable and authentic source, attacker may easily persuade the recipient friend to click the link and supply the requested information. The chain reaction of such approach will enable the attacker to easily victimize many Facebook users in a short period of time.

According to the 2013 Data Breach Investigations Report [15], cyber threat derived from social-engineering technique is increasing dramatically as shown in Figure 4. Although its percentage is still low compared to "Malware" and "Hacking", threat caused by social-engineering intrusion has increased by more than 4 times within one year. Considering the rapid development of social networks, it can be foreseen that social engineering intrusion will continue to increase in the coming years, thus necessitating appropriate countermeasures.

C. Vulnerabilities of Smart Home Appliances

Connecting smart home appliances to the Internet can also makes us vulnerable to malicious attacks. An intruder can steal private information such as contact info, shopping or eating preferences, lifestyle and relaxation habits, or credit card information used to pay for such services. With the rapid growth of online content in the last decade, advertisers became more aware that demographic information would allow more targeted approach in the advertisement. As database-mining techniques become more and more sophisticated, advertisers find more effective strategies, e.g. contextual targeting, in order to attract the attention of more targeted audiences as opposed to the basic targeting techniques such as time, frequency, demography, etc. [14]. They can also use smart appliances as launching pads to carry out malicious attacks into other systems. Table 2 shows a list of common attacks that can be carried out through smart home appliance and the next section discusses some specific attack cases[8][9].

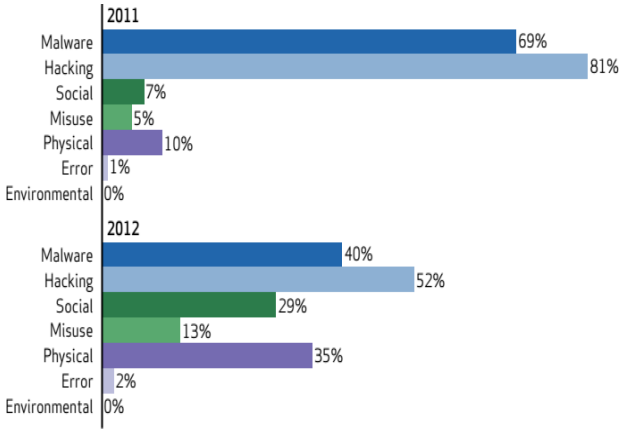

Fig. 4 Threat action categories in 2011 and 2012 (Verizon Enterprise, 2013).

TABLE II
A LIST OF COMMON ATTACKS

No	Common Threat	Example of an Attack
1	User Impersonation	Impersonation using password
2	Device Impersonation	Impersonation of a device using its faulty certificate
3	Service Interruption	Distributed Denial of Service (DDOS)
4	Data Alteration	Data alteration of transmitted or stored data
5	Worm/Virus Infection	Infiltration and/or damaging of a computer system
6	Phishing/Pharming	Impersonation of users' destination
7	Data Wiretapping	Information leakage through wiretapping
8	Firmware Alteration	Replacing of firmware at will
9	OS/Software Vulnerability	Launching of worms and attacks using such vulnerabilities

III. TYPICAL ATTACK CASES

The author has previously shown how the nature of Internet Protocol could accidentally put its user's identity into high risk of being revealed due to the existence of private information behind the IP address in the packet header, which can be easily extracted and observed by various IP tracer and deep packet inspection tools [2][3]. In addition, the use of sniffing tools such as Wireshark or other network monitoring applications, though not new, turn out to be very efficient for attacking IoT networks too. Table 3 shows threat likelihood level of a given smart home appliance type for a particular attack based on past and present security-related incidents, where H, M and L indicate high, medium, and low level threat likelihood, respectively and '-' entries implies no supporting data available. The rest of the section briefly discusses certain classical techniques that have recently been employed to carry some of these attacks on the smart home appliance system not only to steal personal information but also abuse the devices and make them serve cyber criminals' numerous illegal purposes.

TABLE III
THREAT LIKELIHOOD LEVEL OF A GIVEN SMART HOME APPLIANCE

No	Common Threat → / Function ↓	1 User Impersonatio	2 Device Impersonatio	3 Service Interruptio	4 Data Alteration	5 Worm/Virus Infection	6 Phishing Pharming	7 Data Wiretapping	8 Firmware Alteration	9 OS/Software Vulnerabilit
1	Content Retrieval	H	H	M	L	M	L	L	-	L
2	Content Storage/Usage	-	-	L	L	M	-	L	-	L
3	Communication /Messaging	H	H	M	L	M	M	L	-	L
4	Remote Surveillance	H	H	L	L	L	L	L	-	L
5	Remote Control	H	H	H	H	L	L	L	-	L
6	Remote Maintenance	H	H	H	M	L	L	L	L	L
7	Instrument Linkage	M	M	M	L	L	L	L	-	L
8	Networked Game	H	H	H	M	M	L	L	-	L

A. Man-In-The-Middle Attack

In March 2014, a Vulnerability Research Firm named ReVuln, published a video which describes how to employ man-in-the-middle attack to penetrate into the Philips Smart Television through the wireless network that the device connects to. Consequently, the cybercriminal could steal the cookies from the built-in web browser of the television and generate a session hijacking attack to gain access to victim's personal pages [16].

After observing the attack video, one can easily say that TV's configuration for connecting to wireless network through a default hard-coded password is not appropriate. Though it may be convenient for the users, it is quite dangerous if the cybercriminal is also within the range of wireless router. It could even cause more serious aftermath since remote control TV application can easily be downloaded from the Internet. Through such application the hacker could obtain the TV's configuration files and control the TV if he knew the IP address of the television.

B. Denial-of-Service (DOS) Attack

DOS attack is not a new technique and the main attacking mechanism is that a huge amount of packets are generated and sent simultaneously to a targeted appliance. As a consequence, the appliance is either brought down causing permanent crash, or reset to factory setting automatically and making it lose its configuration, stored data and applications.

This kind of attack has recently been reported [17]. A hacker named, Hemanth Joseph, shared on his blog a very simple way to carry a DOS attack on a Pebble Smart Watch. The attacker just needs to know the victim's phone number, Facebook ID, or any other way to interact with the Watch's IP address. Considering that the watch has a function of showing messages received from Facebook, tablet or phone on its screen without character limitation, the attacker can keep on sending many lengthy messages so as to cause a DOS attack on the watch. As a consequence, the Smart Watch could be brought down, reset to factory setting, and lose all of its data as shown in Figure 5

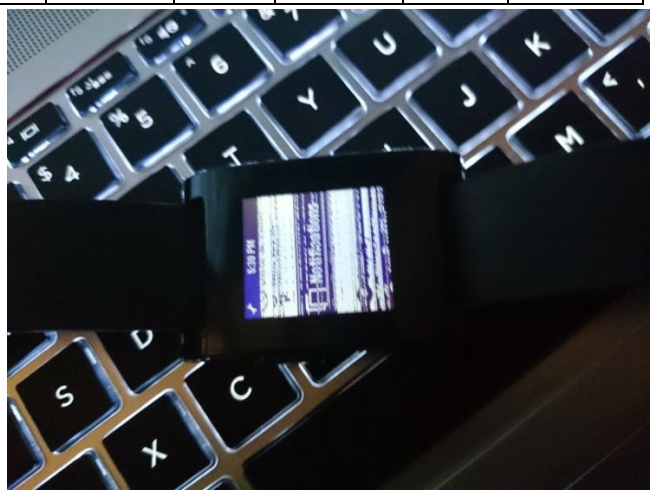

Fig. 5 After DOS attack, the Watch's screen is full of white straight lines, all data and applications are erased because of reset to factory setting (Hemanth Joseph, August 2014)

In addition to the IoT network of home appliances, cyber criminals can also easily penetrate into internet-based-control public appliances. A study published in August 2014 by security researchers from the University of Michigan demonstrates how a series of vital security vulnerabilities in traffic light systems in the US could allow adversaries to quite easily take control of the whole network of at least 100 traffic signals from a single point of access [18].

By carefully examining the above cases, one can easily trace the main reason behind such vulnerability to the fact that those appliances make use of unencrypted wireless radio signals thus can be monitored and compromised by cybercriminals.

C. Thingbot

Thingbot is an abbreviation similar to the word botnet, which itself is a combination of the words "robot" and "network". In a similar manner, thingbot is comprised of the words "thing" and "robot".

In order to create a huge botnet network, many computers are compromised and abused by malware to launch cyber-attacks without awareness of internet users. In a very similar manner, thingbot composed of smart home appliances and other devices in IoT network, can be infected and easily turned into slaves by the attackers because of lack of proper security. After knowing the real IP addresses of such compromised devices, it becomes easy for the hacker to generate cyber-attacks such as spamming, or executing Distributed Denial of Service (DDOS) by manipulating them via standards-based network protocols such as Internet Relay Chat (IRC) and Hypertext Transfer Protocol (HTTP), [19].

Although no serious DDOS attack originating from IoT network has yet been reported, it is predictable that DDOS attack scheme from IoT will be on its upward trend in a near future as mentioned in a warning press from Kaspersky blog [20]. Just to do a small calculation as a reference, let us assume that only 0.01% of the IoT network is compromised by 2020. This will make around 20 million appliances vulnerable to cyber-attacks. Even granting that most of the IoT will only transmit relatively small amounts of data, considering their enormous size, the DDOS attack will be severe enough and should have no difficulty in bringing down a server, or any single host. Moreover, unlike DOS attack which is generated in a pinpointed manner from a single computer or server to flood a target, DDOS attack has an integrated effect of a huge number of compromised devices. Once it occurs, blocking becomes extremely difficult since each compromised element has its own unique IP address.

D.Some Specific Attack Cases in Japan

A DVD/HDD video recorder in Japan, which implemented a proxy server and was acessible without authentication under its default configuration, was used as an open proxy server base for spamming [21], as shown in Figure 6.

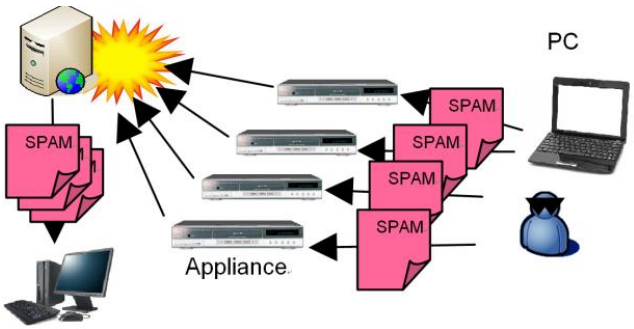

Fig. 6 A spamming incident

In another incident, a music player, which was infected with a virus in the factory, corrupted its user's computer upon connection [22], as depicted in Figure 7.

In an example of privacy violation, a poorly implemented 'referrer' feature in a cellular phone constantly transmitted previously accessed page information even when the page was reached via direct addressing (i.e., non-hyperlink access). The browser flaw caused private information, which may had been required to access a previous page (e.g., user name, password), to be revealed to the next link. It also revealed the user's favorite sites by transmitting information on a previously accessed page [23]. A Japanese researcher has also successfully exploited buffer overflow vulnerabilities in embedded home routers and managed to remotely gain complete access to peripheral devices [24].

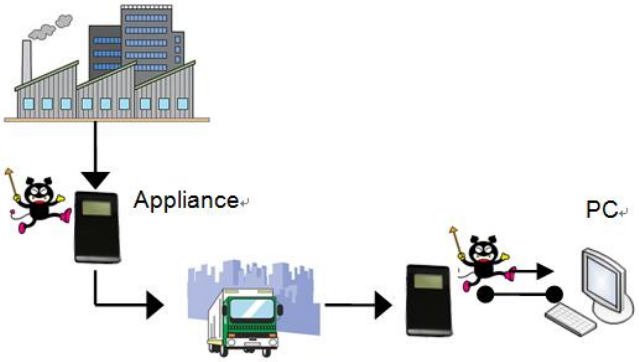

Fig. 7 A PC Infection Incident

IV. SECURITY IMPLEMENTATION CHALLENGES

Considering the above mentioned attacks aimed at smart appliances, it is apparent that the attack techniques are not new. However, what have been changed are the attack targets, which are the smart home appliances and devices in IoT network. In most cases, the attackers make complete use of the nature of Internet Protocol to have the access to those appliances; and oftentimes, the devices do not have full-functional display or screen so it is really hard for the victims to even detect that they are being attacked and abused internally. Furthermore, different from human-controlled computers, most of smart appliances (such as LED light bulbs smart system, smart refrigerators and smart meters) can easily be accessed due to their 24 hours around-the-clock availability on the Internet. Last but not least, because each appliance is designed to serve only a specific purpose, marketability factors such as low cost, portability, tinier size, etc. make built-in full cryptography capability infeasible in most of such appliances.

Therefore, implementing security on these devices presents more challenges than traditional computer security due to the limited resources (e.g., toy CPUs that cannot handle computationally expensive cryptographic computations and battery power that prohibits long-lasting or high-peak computations). Moreover, because security of a network depends on its weakest link, security of networked smart home appliances would rely on the security of its most primitive home appliance e.g., a coffee maker or a toaster. The problem is further aggravated by the fact that home appliance users cannot be considered as "skilled" administrators, but are instead technology-unaware people in many cases.

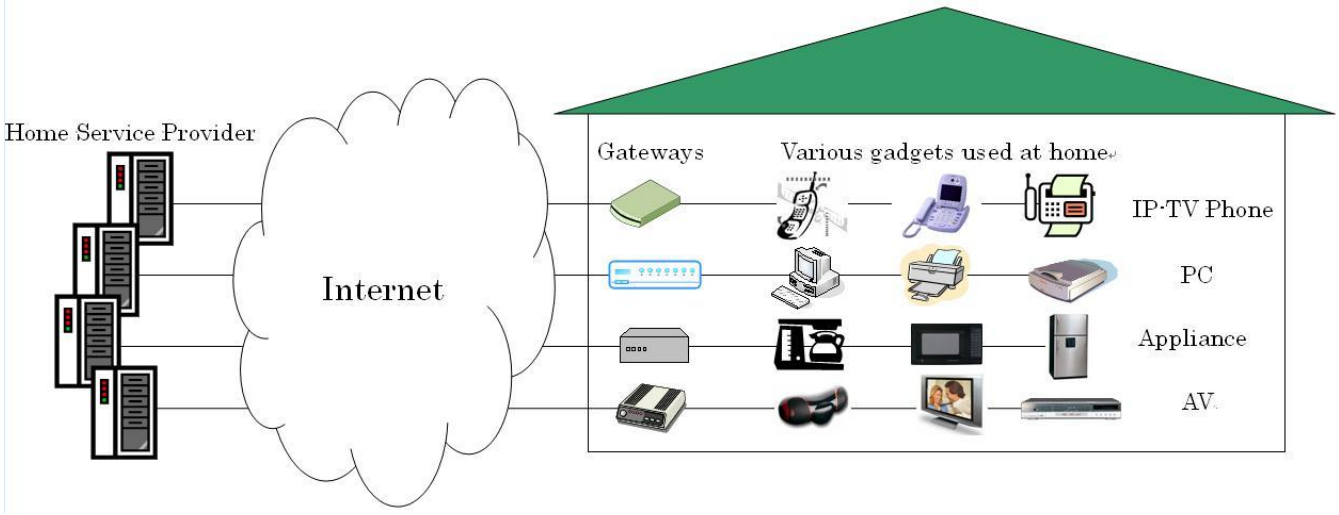

Fig. 8. A heterogeneous home network and its service Providers

As such, continuous growth of diverse smart home appliances and development of numerous networking technologies make management of home network security and their associated services complex to both users and service providers, as can be seen from Figure 8.

V. APPROPRIATE SECURITY MODEL

Though it is essential to make the smart home appliance system more secure from aforementioned cyber-attacks, it is obvious that equipping each of them with its own built-in security function against cyber-attacks in the same manner that has been done on personal computers and web servers is not the right approach. In a previous work, the author together with Mr. Hoang proposed implementation of TOR-based anonymous communication into the IoT network as an effective alternative way to help smart home appliance users protect their privacy and make the smart home appliance system more secure from aforementioned cyber-attacks [2][3]. Although such approach can be effective, particularly for technology-aware and expert users, in this paper the author would like to emphasize the concept of universal home gateways and involvement of network operators in their security challenges [8][9] so as to effectively protect technology-unaware people who are the main users of such devices.

In order to come up with a model that can deal with the security requirements of smart appliances, a functionally categorized list of which shown in Table 1 along with a list of common attacks in Table 2 and likelihood of the attacks in Table 3, this section examines a proposed countermeasures shown in Table 4 in a conventional manner for each of the common attack and demonstrates how to tailor them for smart appliances via universal home gateways.

TABLE IV
SUMMARY OF PROPOSED COUNTERMEASURES

No	Common Threat	Proposed Countermeasure
1	User Impersonation	Introduce a certificate mechanism through memory card like devices.
2	Device Impersonation	
3	Service Interruption	Control through network and access mechanism to outside world.
4	Data Alteration	Introduce access control and certificate mechanism.
5	Worm/Virus Infection	Use virus protection software and prepare to handle new vulnerabilities.
6	Phishing/Pharming	Consider using SSL to assure genuineness of displayed sites.
7	Data Wiretapping	Protect communication via IPSEC, SSL/TLS.
8	Firmware Alteration	Use physical access control for update procedure.
9	OS/Software Vulnerability	Educate R&D people on security and conduct product test.

A. *Counter Measures*

This subsection examines in some details the countermeasures for common attacks listed in Table 4 and recommends how to tailor them for smart appliances.

1) User/Device Impersonation: In this scenario, a malicious attacker tries to make an unauthorized access to the appliance and possibly perform some configuration changes on the system. Since the risk level of such an attack is high for smart appliances, a certification mechanism based on standard and public-key infrastructures (PKI) must be used among the entities involved as shown in Figure 9.

Following is a list of required certification mechanisms:

- A standard certification mechanism between user and server.
- An easy-to-use certification mechanism (e.g., through a memory card like device, a built-in speech recognizer, or biometrics recognition method) between the following entities:
  - Appliance ⇔ User
  - Appliance ⇔ PC
  - Appliance ⇔ Server
  - Appliance ⇔ Appliance
- An SSL server certificate between the appliance and server.

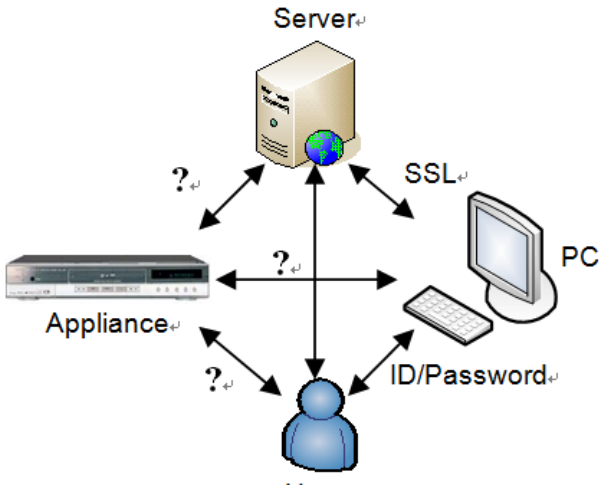

Fig. 9. Use of Certification Mechanism

2) Service Interruption: Smart home appliance can also be used as a launching pad for a distributed denial of service (DDOS) attack. The risk posed by this threat is medium to high across the various types of appliances and the following methods are recommended as countermeasures:

- Provide a suitable access control for external accesses based on an authentication mechanism.
- The appliance should neither implement redirection nor allow internet access via user input. It should also thoroughly examine the input.
- To prevent attack against a currently accessed site, the appliance should not hard code access address and should make it easily changeable.
- Redundancy and other usual prevention methods against service interruption should be implemented.

3) Data Alteration: This threat involves misuse of the link between the appliance and PC to alter data or system configuration in an unauthorized manner. The risk posed by this threat is high for remote controlled appliances, medium for networked games and remotely maintained appliances, and low for the remaining items. We can cope with these threats by:

- Implementing certification mechanisms for all appliances.
- Implementing access control based on the authentication method.

Presently most of the network media players that are available in the market do not have an authentication and access control system.

4) Infection by Worm or Virus: Worm/virus infected appliances can become a secondary source of damage for external access and poses a low to medium risk. We can employ the following methods to safeguard against these infections:

- Virus protection software, which is practical even from resource and operational points of view.
- Use of firewall or intrusion detections system (IDS) to deter infection.

Use of distributed patch programs for established vulnerability information.

5) Phishing/Pharming: In this scenario, a malicious entity tries to guide the appliance user into a different server for either marketing purposes or try to deceive the user to steal his/her personal information. Except for the Communication/Messaging appliance, the risk of such an attack is relatively low. Nonetheless an SSL certificate mechanism can be used to prevent its occurrence. For server certificate verification, however, a mechanism wherein the user could clearly verify would be necessary. Furthermore, a design which prevents user information from being sent to the server is required.

6) Data Wiretapping: Wiretapping is a covert means of monitoring communication, the risk of which is quite low for smart appliances. The following methods can be considered as countermeasures:

- Use IPSEC, TLS or SSL for the communication.
- Use server certification mechanism from access points to the appliance. Or, facilitate the router's VPN or NAPT settings.

7) Overwriting Firmware: This involves unauthorized external access to the appliance and overwriting of its firmware. Appliances which are remotely maintained are susceptible to this attack. In order to prevent the risk of such attack, the appliance should require some form of direct user operation for its firmware update.

8) OS/Software Vulnerabilities; In this attack, a malicious user takes advantage of OS/software vulnerabilities and freely executes any code externally. The attacker can also misuse back doors that are left open for R&D and maintenance purposes for their malicious purpose. Although the risk of such an attack is relatively low for the smart appliances, the following methods can be employed to counteract the threat:

- Educate system designers and R&D people on secure development system.
- Familiarize R&D people on the vulnerabilities of back doors that are left open.
- Conduct an exhaustive test on projected vulnerable components during test phase of the product.

B. Discussion

As can be observed from the above, security requirements of smart appliances depend on their functions. To address such functionally dependent security requirements, one has to consider whether a given smart appliance is to be utilized on a stand-alone basis, or several of them are to be used in an interconnected manner in a family area network (FAN) environment. Although it is simpler to meet the security requirements of a single appliance, in reality however, several appliances will be used in an interconnected manner. Therefore, security of the FAN and its underlying technologies, e.g., dedicated wiring, existing power or phone wiring, or wireless, must also be considered. Similarly, while it is ideal to address security requirements of smart appliances by local means and without any need for a background online system, it is not clear what such a security infrastructure will look like at present. Hence, it becomes essential to also employ PKI in this field. Furthermore, because appliance users are technology-unaware people, network operators appear to be in an excellent position to offer the required security services. They handle various network technologies, have experience with PKI and direct access to the users, and are capable of managing large-scale infrastructures.

C. Implementation Guidelines

It seems that no single vendor/manufacturer may be able to solve the problems faced. Nevertheless, the best way to proceed is to develop the security model around smart home appliances and network components that conform to certain standards. There are standards bodies which specify how to build these devices and meet their various requirements. It is essential to conform to these standards when building, managing and providing services for smart home appliances in the future. Such an approach will encourage more vendors/manufacturers to conform to these standards, and the standards themselves will evolve as needs arise.

The following subsections briefly explain some of the existing standards that define how to build and manage universally deployable smart home appliances. It also specifies implementation guidelines to set up a prototype system using an open architecture and a modular development scheme.

1) Association of Home Appliance Manufacturers: The Association of Home Appliance Manufacturers (AHAM) has completed an ANSI standard for generic object models for all of the major white goods in the home, including refrigerators, washing machines, dryers, dishwashers, microwave ovens, room air conditioners and ranges [25]. The AHAM Standard for Connected Home Appliances-Object Modeling (CHA-1) was also created to provide interoperability with higher-level protocols such as Universal Plug and Play (UPnP), Versatile Home Network (VHN) and others. It enables both appliance manufacturers and third-party developers to create new value-added services and features that will allow remote operation and monitoring of appliances from anywhere in the home or even when you are away from home.

2) ECHONET Consortium: ECHONET develops specifications of home network for networked household appliances, facilities and sensors. ECHONET Consortium has formulated the ECHONET Specification, which can be used to centrally monitor and control smart home appliances that are connected through an ECHONET compatible network interface and a controller [26]. The ECHONET specifications can ensure interoperability between devices of different vendors and realize easy home network at low cost. Also, ECHONET promotes the development of attractive service and application systems using the ECHONET ™ specifications.

ECHONET routers have conversion functions to accommodate home appliances that use different transmission media. The ECHONET, which had previously only supported transmission media such as power lines, low-power radio frequency, and infrared radiation, has come to support other transmission media such as Bluetooth and Ethernet since the release of its version 3.00. Therefore, when there are multiple transmission media in the same domain, the installation of an ECHONET router specified by the ECHONET Specification will allow seamless connection between different types of transmission media.

The ECHONET consortium has over 100 members and its major sponsors are "Hitachi, Ltd.," "Matsushita Electric Industrial Co., Ltd.," "Mitsubishi Electric Corporation," "Sharp Corporation," "Tokyo Electric Power Company, Inc.," and "Toshiba Corporation." Smart home appliances built by major Japanese companies are ECHONET compliant.

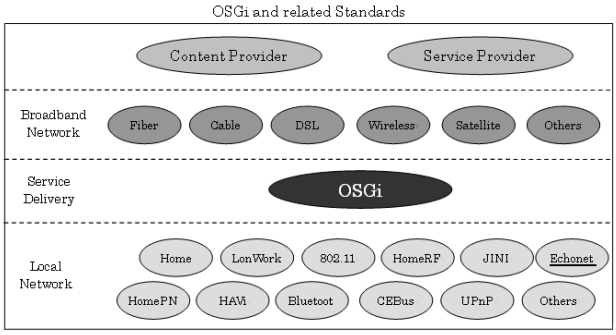

Fig. 10. *OSGi and other Standardized Technologies*

3) Open Services Gateway Initiative Alliance: The OSGi Alliance is an open forum. Their mission is to specify, create, advance, and promote an open service platform for the delivery and management of multiple applications and services to many types of networked devices. Their specifications were initially targeted at residential gateways for the connection of home devices to an external network or for interconnections between the different protocols that are used in devices at homes but have recently been extended to accommodate vehicle, mobile and other environments [28].

About half of its members are based in North America, a third are based in Europe, and the rest are based in the Asia/Pacific region. A number of products developed by member companies are based on the OSGi Service Platform specification [29].

The OSGi specification is not a new protocol technology that replaces existing ones; but rather assumes that multiple protocols could be used within the target device. Its relationship to other standards is schematically shown in Figure 10, where OSGi maps existing local network standards to broadband networks and provides portal services.

Figure 11 shows OSGi architecture which consists of OSGi Framework and a set of bundles [28].

The OSGi Framework provides the basic functionality for executing OSGi bundles which are software components that contain algorithms and protocols for controlling a device. When a bundle is required, it can be downloaded from a server on the network and then executed. This feature makes it possible to download and use the latest and most optimal bundles and allows customization of gateway functions for each user. Since only the bundles that are needed are downloaded and stored, little memory space is required.

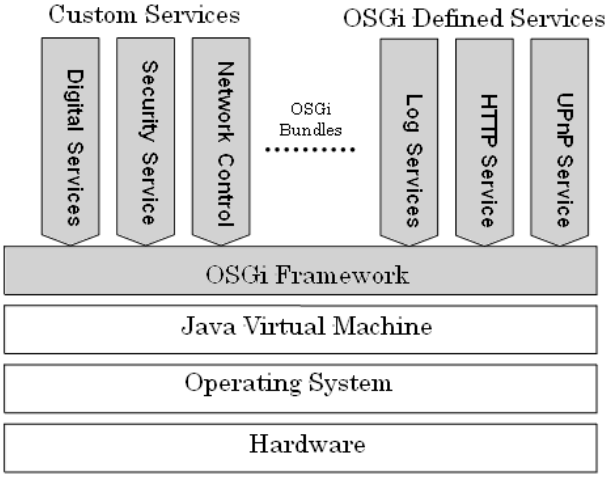

Fig. 11. *Structure of OSGi Gateway*

4) Next Generation Gateways: Even with the existence of standardized smart home appliances and standard specifications on how to network them together, a major challenge still falls on capabilities of gateways that connect all of these devices to the network, control the devices, and provide portal capability for using services offered by the external networks, including the Internet. The OSGi specification can be used to implement such gateway capabilities through software component technologies that use the Java language.

There are vendors like ProSyst [30] Bosch Group that use OSGi specification in their modular and open service platform. Companies like Motorola integrate ProSyst's Service Gateway software in their advanced residential products and there are forums like Home Gateway Initiative [31] which define the next generation of residential gateway. There are also forums like UPnP [32] which provides architectural framework for self-configuring, self-describing devices.

The next logical step is to develop an experimental, secured service application for a home network consisting of open standard compliant home appliances and network components that are manufactured by different vendors. Although when using off-the-shelf products, one may need to employ several gateways and a computer as a service gateway, the above described OSGi specification maybe used to answer such problems. The next generation gateway should enable adoption of a uniform approach regardless of underlying technology and manufacturer.

D. A New Security Architecture

Considering the abovementioned security requirements and the various associated challenges, the most effective way to address security issues of the smart appliances are to:

- Engage a network operator to build dedicated but nonproprietary home gateways and become the preferred trusted third party.
- Motivate internet-enabled smart appliance manufacturers to develop device drivers and application software that can run on such universal home gateways to control and operate the appliances.

This idea is schematically shown in Figure 12, where a universal home gateway, managed by a network operator, functions as an entry point to the networked appliances. In this architecture, all transactions with the smart appliances, whether local or remote, are done via universal home gateways.

1) Basic Usage Scenarios: There are three basic usage scenarios here; one is access of local services by a user from within a FAN (e.g., watch a movie using a video recorder located in another room), the other is downloading remote services, and the third one is control of smart appliances interconnected in a FAN environment, by a remote user (e.g., turn on air conditioner from the office).

From within the FAN, users can be authenticated through a common-password-based, log-on approach. Each user's access control information (e.g., no adult movies for kids below 17, or no movies for school-going children after 11 p.m. etc.), which is stored in the universal home gateway, can be used for access granting. To access a remote service site from within the FAN, the universal home gateway authenticates the user through an authentication server, establishes the user's access control privilege, and initiates a secure communication between the remote service provider and the user for the transfer of the requested service. Remotely accessing home appliances is the counterpart of remote service access where the universal home gateway checks and validates a remote user's access control privileges and allows secure communication for legitimate data transfer.

2) Desired Features of the Universal Home Gateway: In general, universal home gateways, in addition to having the general functions of supporting the underlying FAN technology, and acting as a gateway between a telecom operator's network and the FAN and as an access point to the smart appliances for digital service providers and remote users, are envisioned to have the following security functions:

- Authenticate a user from within FAN through either a common-password-based log-on approach or by the plugging of a memory card like device, containing user's access control information, into the system. A more user-friendly approach would require a built-in speech recognizer or biometrics recognition method.
- Act as a security server and maintain each user's access control information (security attributes and the basic key for communication with remote services).
- Provide secure communication and deal with security issues on behalf of the appliance users. Enable remote management services through providers, intermediaries, and network operators. Allow network operators to use universal home gateways to authenticate their users, or bill them on behalf of a third party e.g., service providers.
- Detect connection of a new appliance to the FAN and prompt users to insert its manufacturer supplied driver/application software. Such a plug and play type auto configuration mode, however, should be manually selectable (i.e., be enabled when needed) in order to

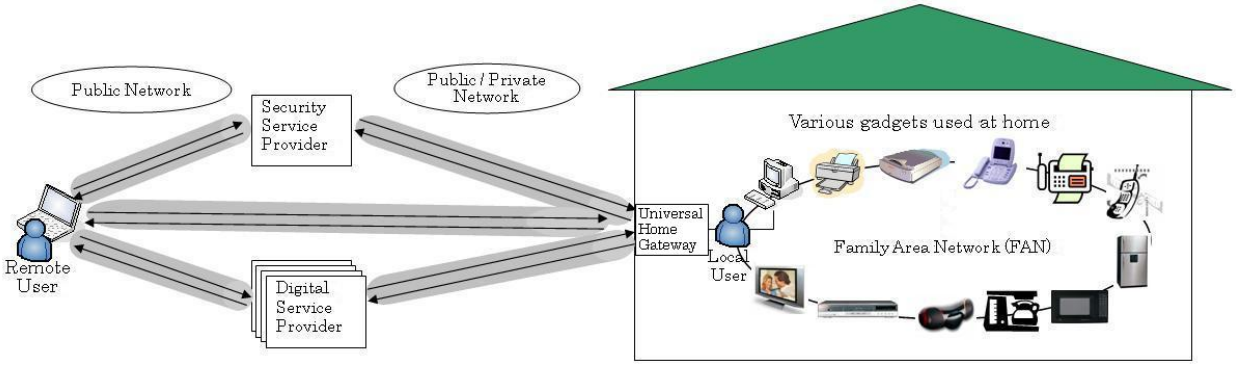

Fig. 12. Smart Appliance Security via Network Operator

provide an added security for wireless FAN and prevent arbitrary connection from the neighborhood.

- Automatically disable, via software selectable functions, an appliance when it is detached from the FAN and auto configure when a previously detached appliance is re-connected.
- Be equipped with firewall and virus protection software

Such functionalities could meet security measures which were discussed earlier. Moreover, because security requirements are handled via central universal home gateways, it could offset resource limitations of individual smart appliances.

3) Existing and Envisioned Technologies: Although at present there are some vendors who market their own brand of smart appliances, which are equipped with a central controller that links the appliances together in a FAN environment and offer limited security and exclusive digital services [33][34], history shows that such propriety approaches are prone to fail. Similarly, while some researchers, e.g., those at the University of Illinois [35], have done ingenious work in coming up with protocols and schemes that could provide security for smart home appliances, a universally deployable, user-friendly system, which is acceptable to a wide range of users, is the key issue.

VI. CONCLUSION

This paper demonstrated how commonly used communication scheme and information retrieval which are carried out via Internet using numerous types of smart devices, can turn the Internet into a very dangerous platform. After providing some introductory information and necessary background knowledge, it examined a number of security incidents that are carried out via smart devices, identified existing challenges and showed that the security requirements of smart appliances depend on their functions. The security requirements of the appliances, categorized based on their functions, were then identified and appropriate solution for each category was proposed. PKI was identified as an essential security component and easy-to-use authentication mechanisms were recommended. It considered compliance with existing standards and liaise with appropriate fora to downstream new requirements important when trying to address security requirements of smart home appliances. It argued that successive security implementation involves cooperation of manufacturers, network operators and service providers. An architecture wherein security issues are managed through universal home gateways by network operators in a product based fashion is proposed and manufacturers and service providers are recommended to adapt the technology, in order to offset resource limitations of individual smart appliances and make their security issues straightforward to ordinary users.

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Davar Pishva is a professor in ICT at the College of Asia Pacific Studies, Ritsumeikan Asia Pacific University (APU) Japan. In teaching, he has been focusing on information security, technology management, VBA for modelers, structured decision making and carries out his lectures in an applied manner. In research, his current interests include biometrics; e-learning, environmentally sound and ICT enhanced technologies. Dr. Pishva received his PhD degree in System Engineering from Mie University, Japan. He is a Senior Member of IEEE, a member of IEICE (Institute of Electronics Information & Communication Engineers), and University & College Management Association.

CampusSense - A Smart Vehicle Parking Monitoring and Management System using ANPR Cameras and Android Phones

Mohammed Y Aalsalem, Wazir Zada Khan
Farasan Networking Res. Lab, Faculty of Computer Science & Information System, Jazan University, Kingdom of Saudi Arabia
{aalsalem.m, wazirzadakhan}@jazanu.edu.sa

Abstract-- **Vehicle parking monitoring and management has become a big challenge for educational institutions with increasing enrollments, high percentage of vehicle ownership and decreasing parking supply which in result triggering blockage of vehicle, congestion, wastage of time and money. In university campuses particularly in Kingdom of Saudi Arabia, vehicle parking monitoring and management problem is getting worse and more frustrating due to the fact that majority of students, faculty and staff members own cars and drive through them to the university campuses. These common problems include finding out people (evidence) who are responsible for the damages (hitting, scraping, scratching and dents) to other cars and the blockage of car due to wrong car parking which takes much time to locate the owner of the car. Moreover, locating or forgetting their car park location another difficulty that is often faced by the students, faculty and staff members. The existing cameras located at the parking lots are only for video surveillance and cannot help in such situations as there is a lack of proper vehicle parking monitoring and management system. To cope with above mentioned problems and to ensure a better parking experience by accommodating increasing number of vehicles in a proper convenient manner, we propose a smart vehicle parking monitoring and management system called CampusSense. In CampusSense, Automatic Number Plate Recognition (ANPR) cameras and android based mobile application is developed to efficiently monitor, manage and protect the parking facilities at university campuses. Parking problems around the university campus faced by the students, faculty and staff members are analyzed by conducting a survey.**

Keywords—**Smart Vehicle Parking Monitoring and Management, Android based Mobile Phones, License Plat Recognition, Locating Vehicle, Mobile Sensing.**

I. INTRODUCTION

Vehicle parking monitoring and management is challenging problem due to the growing number of vehicles at university campuses and also for catching the responsible persons for damaging the vehicles (like scratches, dents, scraps etc.) of other people's inside a campus who remain anonymous and also result in confusion, annoyance and wastage of time.

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Mohammed Y Aalsalem is currently Dean Faculty of Computer Science and Information System, Jazan University, KSA and Founder & Director of Farasan Networking Res. Lab. (Corresponding author, Phone: +966173230004; fax: +966173210850; e-mail: aalsalem.m @ jazanu.edu.sa).

Wazir Zada Khan is currently with Faculty of Computer Science and Information System, Jazan University, KSA and Member & Co-Founder of Farasan Networking Res. Lab. (e-mail: wazirzadakhan@jazanu.edu.sa).

The problem is getting more severe day by day due to the fact that a the number of student enrolments is increasing year by year and a huge percentage of students and faculty own cars with the limited number parking lots. Blocking the other parked vehicles in the parking lots by people while parking their cars improperly is an important issue in vehicle parking. Due to this, finding the responsible persons and remain stuck and frustrated for the blocked vehicle owners until they get the vehicle out of the parking lot. The security guards at the parking lots are unable to help in this regard because of the lack of any monitoring and management enforcement systems and policies. Due to this, it takes much time in pursuing the responsible person which consequently results in the wastage of precious time of students as well as faculty and staff members. Another critical problem (that arises due to the reserved and limited number of vehicle parking lots) is that students (for whom no reserved parking is available) may damage other parked vehicles while improper and wrong vehicle parking. The damaged vehicle owners remain unsuccessful in finding out the responsible persons for damaging their vehicles and no one can help out in this concern because there is no proper monitoring system that can keep record of the in and out information (i.e. entrance and exit) of the vehicles and parking information (like parking location, parking duration) of vehicles. Moreover, in case of suspected vehicles (involved in any criminal activity) are unable to trace out by current system as there is no record or way to identify them. Another most common problem faced by students, faculty and staff members is they often forget where they have parked their vehicles in the parking lots. So, finding out a vehicle in such a scenario without any automated management system is results in anger, exasperation and wastage of time and it is also difficult and time consuming task.

Smart phones are now days the key computing and communication device and these mobile phones are equipped with a rich set of embedded sensors. These specialized sensors including ambient light sensor, accelerometer, digital compass, gyroscope, GPS, proximity sensor and general purpose sensors like microphone and camera. These sensors collectively enable new applications across a wide variety of domains like homecare, healthcare, social networks, safety, environmental monitoring, ecommerce and transportation [1-2]. Mobile sensing provides the opportunity to track dynamic information about environmental impacts and develop maps and understand patterns of human movement, traffic, and air pollution [3]. Using these extraordinary monitoring capabilities of smart phone sensors a wide range of mobile application are developed for traffic monitoring for example monitoring

road and traffic conditions, detecting road bumps, honks, potholes etc. Such traffic monitoring systems include [4-9].

The current vehicle parking monitoring and management system at the Jazan University is fully manual which only allows the authorized vehicles that are registered by having the entrance sticker. The whole university area including entrance and exit gates, academic area, administrative and parking zones are all under video surveillance. But this can only serve for video capturing and storing and are not connected to any proper monitoring and management system.

In this paper we have proposed a smart vehicle parking monitoring and Management system called *CampusSense* to overcome the above mentioned problems which encountered while vehicle parking in the parking area of the University campus. We have also review the contribution in [10] and after further investigation the CampusSense system by discussing the design and the system features in more details. CampusSense consist of hardware (ANPR Cameras) and software components (Mobile Application and Management System) and can assist the security department to handle the parking problems more effectively such as locating the car if a person forgets its exact parking location or to locate and pursue the liable person for damaging or blocking some ones car while wrong car parking in the parking lot.

A quantitative questionnaire based survey is also conducted to investigate the problems encountered by the students, faculty and staff members. The results of the survey provide a confirmation of the above mentioned problems that the students, faculty and staff members are facing and thus our proposed system fulfills all the requirements that need to be addressed by providing appropriate solutions of these problems.

The proposed CampusSense system aims to provide an appropriate solution for all the problems which have been identified by analyzing the conducted survey. The aims and objectives of the proposed systems are as follows:

- To implement a vehicle parking monitoring and management system that will automate the existing parking management system by keeping all the in/out information and parking information of vehicles at university campus.
- To facilitate the security department in assuring the safety and satisfaction of the students, faculty and staff members while parking at the university campus.
- To develop a mobile application which will facilitate in reducing the frustration and annoyance of those who often forget the exact parking location of their cars.
- To assist the security department in finding out the car owners who have blocked other cars by parking cars improperly.
- To help the security department for tracing out the suspected or abundant (long term parked) vehicles at university campus.

The rest of the paper is organized as follows: Section II describes the existing parking management systems. Section III presents the design & working of the proposed system. In Section IV the survey statistics are discussed. Finally Section V concludes the paper.

II. RELATED WORK

In this section, first we have covered the Sensor and RFID based vehicle parking monitoring and management systems and secondly the mobile sensing applications related to traffic monitoring.

In the literature the available vehicle parking monitoring and management systems are either sensor based [11-13] or RFID [14-16] based and they mostly address the issue of finding a vacant parking location in the parking lot. These systems are only helpful in determining the occupancy status of parking space but are unable to figure out the solutions for the above mentioned problems like the information about responsible persons who either block or damage other cars while parking their own. So of the parking problem encountered at universities campuses are studied in [17].

The parking management systems based on sensors have a problem as mostly sensors are unable to detect obstacles that are not visible because of their flatness to the ground level and thus they cannot distinguish pedestrians or objects from the vehicles of interest, in result have more false positives. Another challenge in Sensor and RFID based systems is that they are prone to many attacks [18] like denial of service attacks (DoS)[19], selective forwarding attack[20-21], node replication attack[22-24], Sybil attack[25-26], wormhole attack[27], black hole attack[27] and Signal or Radio Jamming attack [29-30] etc. RFID based systems are also suspect to many attacks like [31-32]. Many mobile sensing based systems are proposed for traffic monitoring for example monitoring road and traffic conditions, detecting road bumps, honks, potholes etc, these systems include Nericell [4], VTrack [5], TrafficSense [6], Mobile Millennium [7], TARIFA [8] and Road Bump Monitor [9]. TABLE I shows the comparison of CampusSense with other mobile sensing system.

Prashanth Mohan et al. have proposed two systems Nericell [4] and TrafficSense [6] to detect potholes, bumps, braking, and honking using phones sensors like accelerometer, microphone, GSM radio, and/or GPS. The authors have used the idea of triggered sensing, where dissimilar sensors are used in tandem to conserve energy. The data is gathered through GPS-tagged cellular tower measurements during several drives over the course of 4 weeks. GPS-tagged accelerometer data measurements are also separately gathered on drives on some of the same routes over the course of 6 days. Cellular tower measurements are also gathered over the course of a few days in the Seattle area. The system could be used to annotate traditional traffic maps with information such as the bumpiness of roads, and the noisiness and level of chaos in traffic, for the benefit of the traffic police, the road works

TABLE I
COMPARISON OF CAMPUSSENSE WITH OTHER MOBILE SENSING BASED APPLICATION

Systems	Smart Mobile Phone Used	Software Used	Mode of Communication	Phones Sensor Used	Applications
NeriCell [11]	Nokia N95, HTC Typhoon	Perl, windows mobile 5.0,Windows mobile 2003, Python, C#	GSM, GPRS, UNTS, EDGE, Wifi, Bluetooth	Microphone, GSM Radio, GPS, Accelerometer, Camera	Bump, Breaking and Honking Detection
V-Track [12]	iPhone, Nokia N95	Not Mentioned	Wifi, Bluetooth	GPS	Detecting and Visualizing hotspots, Real time Route planning
TrafficSense [13]	HPiPAQ nw6965, HTC Typhoon	Windows mobile 5.0, Windows Mobile 2003	Bluetooth, Wifi, GSM	Microphone, Camera, GPS Sensor, Accelerometer, GSM Radio	Monitoring of Roads and Traffic Conditions
Road Bump Monitor [45]	HPiPAQ nw6965, Samsung SGHi780, HTC Adrantoge 7510,7501	MS Windows Mobile 5.0, 6.1, Windows 7, C#, C/C++	Bluetooth, GPRS, EDGE, 3G Radio	Microphone, Camera, GPS Sensor, Accelerometer	Road Bumps Detection
CampusSense	Any Android based smart mobile phone	Android Studio, C#, SQL Server	3G/4G, Wifi	GPS, Camera	Locate the vehicle using map, retrieve vehicle owner information form management system

department, and ordinary users. Nericell uses honk detection to identify noisy and chaotic traffic conditions like that at an unregulated intersection. TrafficSense monitor road and traffic conditions in complex varied road conditions (e.g., potholed roads), chaotic traffic (e.g., a lot of braking and honking), and a heterogeneous mix of vehicles (2-wheelers, 3-wheelers, cars, buses, etc.) called TrafficSense. The effectiveness of the sensing functions in Nericell and TrafficSense are evaluated based on experiments conducted on the roads of Bangalore, with promising results.

Arvind Thiagarajan et al [5] have proposed a system called VTrack. VTrack performs map matching, which associates each position sample with the most likely point on the road map, and produces travel time estimates for each traversed road segment. VTrack provides real-time estimates recent to within several seconds to users. It also compiles a database of historic travel delays on road segments. In VTrack data was gathered using iPhone 3G application, and from GPS and WiFi radios embedded in-car. It is shown that VTrack can tolerate significant noise and outages in these location estimates, and still successfully identify delay-prone segments, and provide accurate enough delays for delay-aware routing algorithms.

R. Herring et al. [7] have proposed a system called Mobile Millennium to estimate traffic on all major highways in and around the target area, as well as on major arterial roads. The Mobile Millennium architecture consists of a physical component: GPS-enabled smart phones onboard vehicles (driving public), and three cyber components: a cellular network operator (network provider), cellular phone data aggregation, traffic service provision and estimation. A back end server aggregates data from a large number of mobile devices and pushes the data to UC Berkeley estimation engine for data assimilation, which combines the cell phone data with other information such as loop detectors to produce the best estimate of the current state of traffic.

Georgios Adam et al [8] have proposed a system called TARIFA (Traffic and Abnormalities Road Instructor For Anyone) that estimates road traffic as well as road abnormalities, and makes the collected information available to anyone that has Internet access. This system is capable of spotting potholes and can also provide information for the traffic using the GPS receiver. The architecture of the system consists of two independent parts. A smart phone that is equipped with an accelerometer and a GPS receiver is placed inside a car. There is also a local database for the temporary storage of data. A heuristic algorithm is used to detect potholes and other surface abnormalities.

T. Das et al. have propose a system called Road Bump Monitor [9] which is an application of PRISM platform to detect and locate road bumps automatically without any user involvement. The sensed (accelerometer) data is processed locally on the phones to extract the desired information (the location of road bumps), before it is shipped back to the server. Then the road bump monitoring application was opportunistically deployed on the phones and the bumps detected by the application were compared with the manual recording of road bumps.

The existing car parking management system at the university is fully manual which only allows the authorized vehicles that are registered by having the entrance sticker. Security department provides three types of stickers for entering into the University, which are for students, faculty and staff members. The whole university area including Entrance and exit gates, academic zone, administrative and parking zones are all under video surveillance. But this can only serve for video capturing and storing and are not connected to any proper management and monitoring systems. In case of any acute incident, a sequential video search is required which is time consuming and unfruitful process. There are reserved (by name) parking lots for most of the staff members and dedicated areas (on first come first serve basis) are available for students and the faculty members.

III. CAMPUSSENSE

This section presents a smart vehicle parking monitoring and management system called CampusSense. The CampusSense is consist of both hardware and software components.

- The hardware component will consist of Automatic Number Plate Recognition (ANPR) cameras which are mounted on the entrance and exit gates and parking lots of the campus.
- The software components will include a parking management system and a mobile application.

CampusSense leverage ANPR cameras for capturing the license number plates of the vehicles instead of Sensor or RFID based existing vehicle parking management systems. These ANPR cameras are more advantageous than other technologies. ANPR cameras are known with different names like ALPR (Automatic License Plate Recognition), LPR (License Plate Recognition), CPR (Car Plate Recognition) and AVI (Automatic Vehicle Identification). It provides faster traffic management at parking areas, ability to automate access control systems with a setup of ticket free systems providing new and more effective law enforcement. ANPR cameras are suitable in all weather conditions and can be mounted at higher mounting locations to assure a wider field view of the whole parking lot.

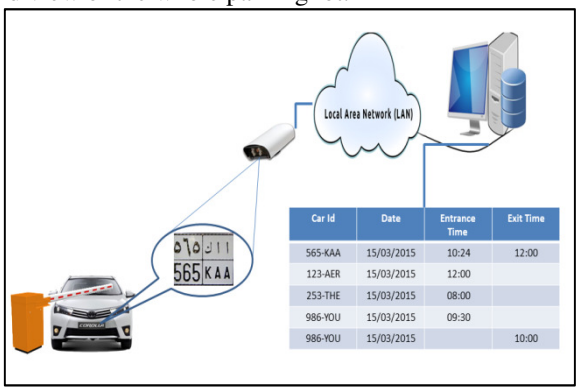

Fig. 1. Capture the vehicle license plate using camera at entrance and store it in the database.

The authorized vehicles will be registered in the parking management system along with their owner information. The information about the parking zones and parking lots will already be stored in the system with the other related information (e.g. which camera is monitoring the parking lot with their physical locations (x & y coordinates).

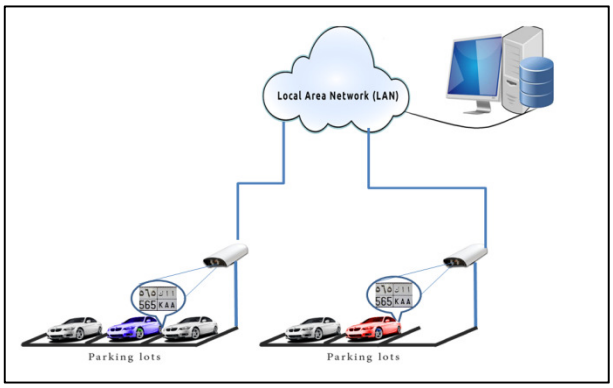

Fig. 2. Capture the vehicle license plate using camera at parking lots or when change the place then store it in the database.

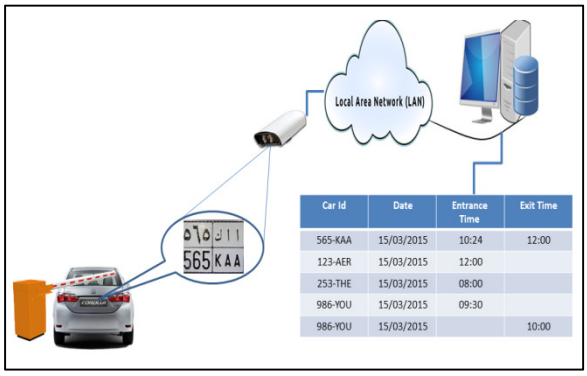

Fig. 3. Capture the vehicle license plate using camera at exit and store it in the database.

The vehicle license plate number will be capture using ANPR cameras on entering/exiting the gates and at the parking lots and will be store to vehicle management system. Fig. 1 and Fig. 3 show the capturing of vehicle license plate using camera at entrance/exit and store it in the database. Fig. 2. Shows the capturing of vehicle license plate using camera at parking lots or when change the place then store it in the database. A mobile application has two features. First, it is responsible for locating the car if a person forgets its exact parking location. This feature is for general purpose and can guide all the persons who are parking in the parking zones of the University. Second, it can assist the mobile security units to locate and pursue the liable person for damaging or blocking some ones car while wrong car parking in the parking lot. This feature is specifically built for security purposes that can aid the security department to ensure the safety of the students, faculty and staff members while car parking. Fig. 5 shows the working of the mobile application to retrieve the required information.

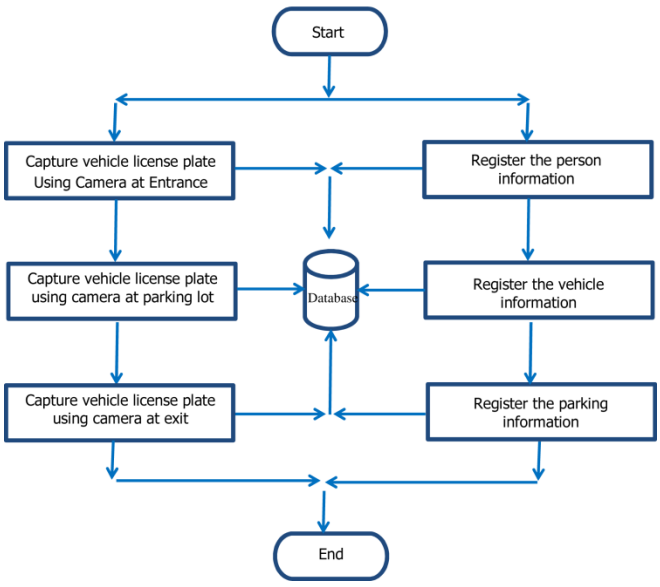

Fig. 4. Flow Chart for the working of ANPR Cameras integrated with vehicle management system.

The working of the ANPR cameras can be easily comprehended by the flow chart in Fig. 4. It shows that the ANPR cameras that are mounted on the entrance and exit gates of university and placed as well in all the parking lots will first capture the License plate number while entering/exiting/parking of the vehicles and then store it in the database. The ANPR cameras are integrated with the Vehicle Parking Management System which contains the

records of entrance and exit timing information of the authorized vehicles along with the parking location and their owner's information. In case when any parked car is damaged by the some other car, the information about the vehicle and liable person for damaging the parked car in the parking lot can be found by the system records. This can be done by searching out the information about the timing and parking location of the cars nearby the damaged car/vehicle.

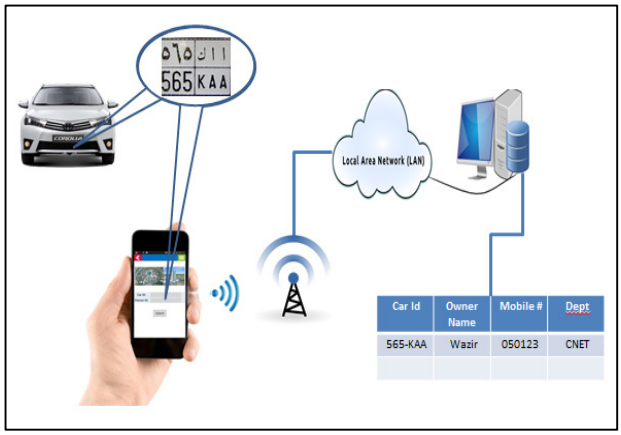

Fig. 5. Working of the mobile application to retrieve the required information.

The working of a mobile application can be shown in the form of a flow chart as in Fig. 6. This mobile application can assist the security manger to handle two problematic situations during car parking in the university campus. In case if any car is blocked by wrong car parking then this application can locate the owner of the car who has blocked the other parked car. This application can also help the persons who often forget the exact location of their parked cars. This mobile application keeps the personal information about the vehicle owners as a secret and only the security department personnel are able to see that information. For developing the prototype mobile application Android Studio is used and for parking management system the database is developed in SQL Server and the user interface is design & developed in C#.

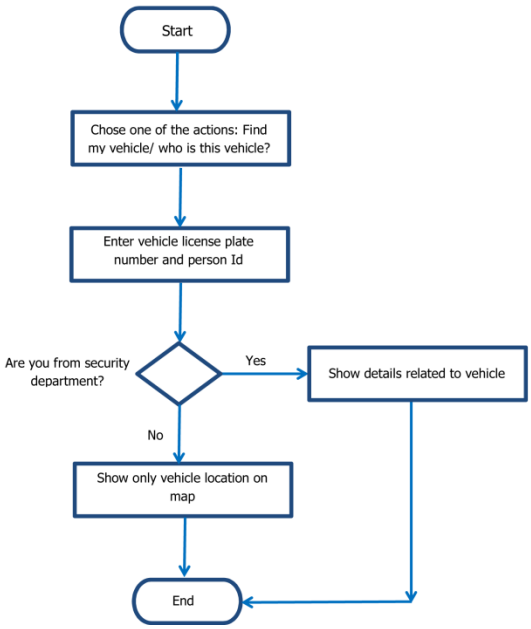

Fig. 6. Flow Chart for the working of the mobile application.

The screen shots of the proposed prototype mobile application are shown below in Fig. 7. These screen shots show the two main features of the prototype application i.e. locating the exact parking location of the car (*Find my Car*) and finding out the owner of the vehicle who has blocked another car (*Who is this Car*).

Fig. 7. Screen shots of the prototype mobile application.

The Proposed CampusSense has following benefits:

- Helps the security department to find out the responsible for the damages (hitting, scraping, scratching and dents) to other cars.
- Helps the security department to locate the owner of the car which cause blockage.
- Helps the students, faculty and staff to locate their cars on forgetting their car park location.
- Helps in finding out the owner of those cars that are parked from many days.
- The security department can retrieve all the history of any particular car.

IV. SURVEY STATISTICS

A survey from 26th to 30th of October 2014 was conducted by filling out a quantitative questionnaire. A total of 88 persons participated in the survey out of which 53 were students and 35 were faculty and staff members. A number of questions were asked from the participants. Fig. 8 (a) shows the percentages of the different age groups of the staff/ faculty members and Fig. 8 (b) shows the percentages of the different age groups of students the. The survey results show that majority of the participants from staff and faculty were above 26 years old (91%) and on other side majority of students were between 22 to 25 years old (66%).

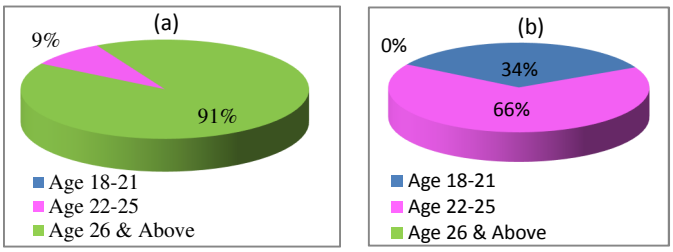

Fig. 8. Percentages of different age groups of the participants.

Fig. 9 (a) shows the percentages of different modes of transportation for reaching the university campus used by the staff/ faculty members and Fig. 9 (b) shows the

percentages of different modes of transportation for reaching the university campus used by the students. The survey results show that majority of the participants from staff and faculty come to campus by their own vehicles (88%) and on other side majority of students who own cars were (81%).

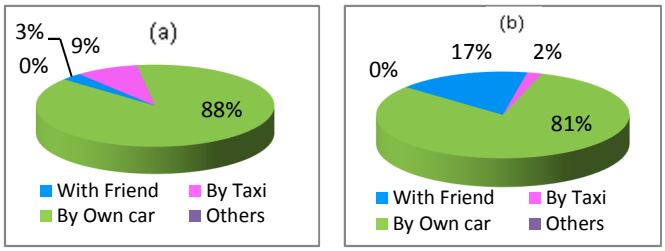

Fig. 9. Percentages of modes of different transportation.

Fig. 10 (a) shows the percentages of the staff/ faculty members whose vehicles were damaged by other vehicles while wrong parking at university campus and Fig. 10 (b) shows the percentages of student whose vehicles were damaged during parking. The survey results show that majority of the student vehicles were damaged during parking (65%) as camper to faculty/ staff (29%). The reason was no reserve parking for students at university campus.

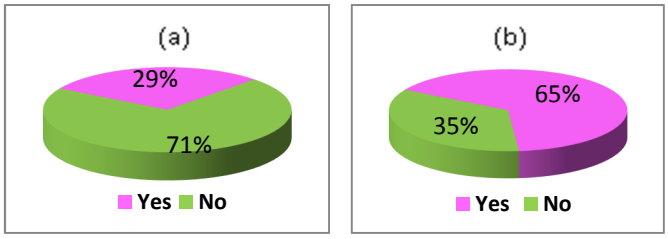

Fig. 10. Percentages of vehicle dames during parking.

Fig. 11 (a) shows the percentages of staff/ faculty members whom are able to find the responsible persons for damaging their vehicles in the parking lot and Fig. 11 (b) shows the percentages of the students whom are able to find the responsible persons for damaging their vehicles in the parking lot. The survey results show that majority of the participants were unable to find the responsible persons who damaged their vehicles (i.e. 71% faculty/ staff and 65% students).

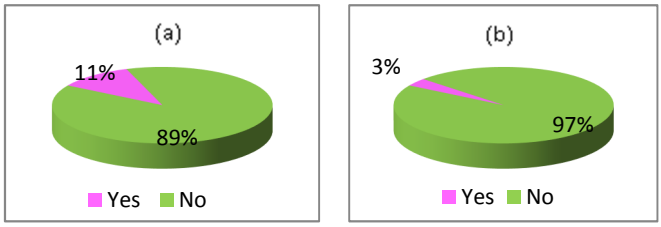

Fig. 11. Percentages of persons who have found responsible persons for damaging other cars.

Fig. 12 (a) shows the percentages of those staff/ faculty members those whom cars are blocked by others cars that are parked wrong and Fig. 12 (b) shows the percentages of those student whom vehicles are blocked by others vehicles that were parked wrong. The survey results show that majority of the students vehicles were the blockage (85%) as compared to faculty/ staff member (58%). The reason is the reserve parking for staff/ faculty members at university campus.

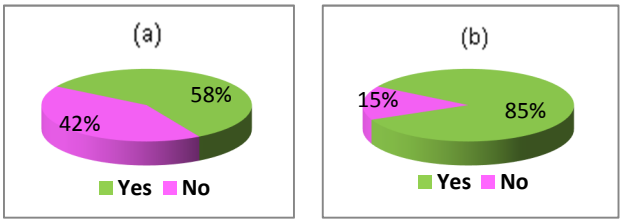

Fig. 12. Percentages of car blockage.

Fig. 13 (a) shows the percentages of staff/ faculty members whose vehicles were blocked and they have waited until clearance of blockage and Fig. 13 (b) shows the percentages of time taken to clear the blockage vehicles by the students. The survey results show that majority of the students waited more than 30 min to clear the blockage (67%) as compared to faculty/ staff member (50%).

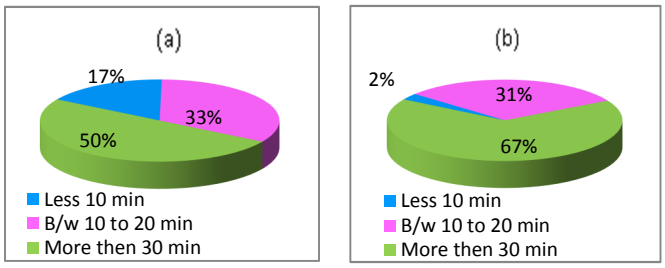

Fig. 13. Percentages of time consumed due to car blockages.

Fig. 14 (a) shows the percentages of staff/ faculty members those who have found difficulties in finding their vehicles in the matter of forgetting the location where they parked their vehicles and Fig. 14 (b) shows the percentages of those students who forget their vehicles in the parking lot. The survey results show that majority of the students forget their vehicles most of the time (65%) as compared to faculty/ staff member (35%). The reason is the reserve parking for staff/ faculty members at university campus.

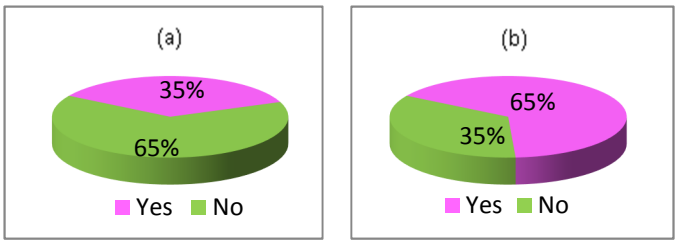

Fig. 14. Percentages of participants forgetting the location of their parked cars.

V. Conclusion and Future Work

Parking problems at university campuses continue to prevail and have become a major concerning issue. In this paper we have proposed a smart Vehicle Parking Monitoring and Management System called CampusSense for Jazan University whose students, faculty and staff members are facing parking problems while parking their cars in parking lots of the University. The key concern of our proposed system is to automate the existing manual parking management system with efficient and effective use of the parking lots. This system contributes to reduce the frustration and annoyance of the students, faculty and staff members while car parking in the University parking zones. We have also conducted a survey by distributing the questionnaire to the students, faculty and staff members. The results of the survey confirm the car parking problems faced by the participants. Our future research includes the real-

time implementation of our proposed system with additional features like searching for vacant parking spaces in an effective manner and also automating the mobile application by adding some OCR techniques to take vehicle number plates form camera images instead of entering it manually.

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Dr. Mohammed Y Aalsalem is currently Dean Faculty of Computer Science and Information System, Jazan University, Kingdom of Saudi Arabia. He received his PhD in Computer Science from Sydney University. His research interests include real time communication, network security, distributed systems, and wireless systems. In particular, he is currently leading in a research group developing flood warning system using real time sensors. He is Program Committee of the International Conference on Computer Applications in Industry and Engineering, CAINE2011. He is regular reviewer for many international journals such as King Saud University Journal (CCIS-KSU Journal).

Dr. Wazir Zada Khan is currently with Faculty of Computer Science and Information System, Jazan University, Kingdom of Saudi Arabia. He received his PhD from Electrical and Electronic Engineering Department, Universiti Teknologi Petronas (UTP), Malaysia and his MS in Computer Science from Comsats Institute of Information Technology, Pakistan. His research interests include network and system security, sensor networks, wireless and ad hoc networks. His subjects of interest include Sensor Networks, Wireless Networks, Network Security and Digital Image Processing, Computer Vision.

An Effective Speedup Metric Considering I/O Constraint in Large-scale Parallel Computer Systems

Guilin Cai*, Wei Hu*, Guangming Liu*,**, Qiong Li*, Xiaofeng Wang*, Wenrui Dong*

*College of Computer, National University of Defense Technology, Changsha, China

**National Supercomputer Center in Tianjin, Tianjin, China

cc_cai@163.com, { huwei, liugm}@nscc-tj.gov.cn, qiong_joan_li@yahoo.com.cn, xf_wang@nudt.edu.cn, dongwr@nscc-tj.gov.cn

***Abstract*—With supercomputer system scaling up, the performance gap between compute and storage system increases dramatically. The traditional speedup only measures the performance of compute system. In this paper, we firstly propose the speedup metric taking into account the I/O constraint. The new metric unifies the computing and I/O performance, and evaluates practical speedup of parallel application under the limitation of I/O system. Furthermore, this paper classifies and analyzes existing parallel systems according to the proposed speedup metric, and makes suggestions on system design and application optimization. Based on the storage speedup, we also generalize these results into a general storage speedup by considering not only speedup but also costup. Finally, we provide the analysis of these new speedup metrics by case studies. The storage speedup reflects the degree of parallel application scalability affected by performance of storage system. The results indicate that the proposed speedups for parallel applications are effective metrics.**

***Keyword*—storage speedup, general storage speedup, scalability, system classification**

I. INTRODUCTION

With the scaling up of supercomputers, the system performance advances considerably. In the latest TOP500 supercomputing list in 2015, Tianhe-2 consisting of 3,120,000 cores reaches the performance of 33.86 petaflop/s [1]. Planed exascale supercomputers (10^{18} floating point operations per second or 10^3 petaflop/s) are promising to come in this decade [2].

Since the 1980s, the average growth of processor performance could reach 60%, while the read and write bandwidth of disk which is the main storage device only increased by 10% to 20% per year. In addition, the computing system scales much faster than I/O system. Both of above reasons exacerbated the mismatch between application requirements and I/O performance. For I/O-intensive applications, the performance is not only determined by compute system, but also greatly affected by I/O system.

Due to the increasing scale of the supercomputer system and parallel application, the I/O performance and storage capacity requirements of the supercomputer increase rapidly. The concerns about the storage scalability are not only the performance can be obtained but also the cost-effectiveness related to investment. The larger the system is, the more investments improving system performance needs. How to evaluate and promote the effectiveness of the investments of the storage system is another important problem need to be addressed.

In this research, we analyze and quantify the effects of storage bottleneck of supercomputers. Our theory provides the new metric on how to quantify the impact of I/O system on application performance, and we also present the new method to evaluate the cost-effectiveness of the storage system of supercomputer. The main contributions of our work lie in the following aspects.

- This paper introduces a new speedup metric called storage speedup taking into account the I/O performance constraint. The new metric unifies the computing and I/O performance, and evaluates practical speedup of parallel application under the limitation of I/O system.
- The existing parallel systems are classified and analyzed according to the storage speedup, and the suggestions are acquired on system design and application optimization.
- Based on the storage speedup, a general storage speedup is generalized to evaluate the cost-effectiveness of the storage system by considering not only speedup but also costup.
- Through the case studies, the effectiveness of these new

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G. Cai is with the College of Computer, National University of Defense Technology, Changsha, 410073, China (e-mail: cc_cai@163.com).

W. Hu is with the College of Computer, National University of Defense Technology, Changsha, 410073, China (corresponding author, phone: +86-22-65375500; fax: +86-22-65375501; e-mail: huwei@nscc-tj.gov.cn).

G. Liu is with the College of Computer, National University of Defense Technology, Changsha, 410073, China (e-mail: liugm@nscc-tj.gov.cn).

Q. Li is with the College of Computer, National University of Defense Technology, Changsha, 410073, China (e-mail: qiong_joan_li@yahoo.com.cn).

X. Wang is with the College of Computer, National University of Defense Technology, Changsha, 410073, China (e-mail: xf_wang@nudt. edu.cn).

W. Dong is with the College of Computer, National University of Defense Technology, Changsha, 410073, China (e-mail: dongwr@nscc-tj.gov.cn).

speedup metrics is validated.

The rest of paper is organized as follows. Section 2 reviews the related work. Section 3 defines the storage speedup, classifies the existing systems according to it and presents the general storage speedup. Section 4 uses some case studies to analyze the I/O architecture in supercomputing system to validate the effectiveness of the new metrics. Finally, in section 5 we conclude this paper and discuss some future works.

II. Related Work

The essentiality of supercomputer is to reduce the execution time of applications by parallel computing, while speedup has been almost exclusively used for measuring scalability in parallel computing [3].

In 1967, Amdahl advocated a speedup model for a fixed-size problem [4]:

$$S_{Amdahl} = \frac{1}{f + (1-f)/P}$$

where P is the number of processors and f represents the serial ratio of the program. Obviously, the equation reveals a pessimistic view on the usefulness of large scale parallel computers since the maximum speedup cannot exceed $1/f$.

In 1988, Gustafson introduced a scaled speedup for a fix-time problem [5], which scales up the workload with the increasing number of processors to preserve the execution time:

$$S_{Gustafson} = f + (1-f)P$$

This speedup proves the scalability of the parallel computers and overcomes the shortcomings of Amdahl's speedup model.

Sun and Ni [6] presented a memory-bounded speedup model which scales up the workload according to the memory capacity of the system, demonstrates the relationship among memory capacity, parallel workload and speedup.

Culler [3] proposed a speedup model taking the communication and synchronization overhead into account. Researchers can improve the system performance depending on this model by reducing the overhead of communication and synchronization such as overlapping communication and computing, load balancing and so on.

Yang [7], [8] studied the reliability and power issues of supercomputers, introduced the reliability and power related speedup. They provided a new perspective to solve reliability and power related issues.

In this work, we develop our storage speedup metric to analyze and quantify the effects of I/O performance for parallel applications in supercomputing.

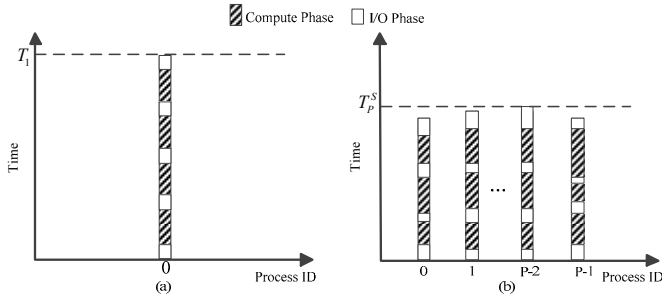

Fig. 1. Execution state of a program on a P node system. (a)Single process. (b)P processes in parallel.

III. Storage Speedup

Suppose a parallel system consisting of P nodes of single core processor, denoted by $N_1 ... N_P$. Let a parallel program Q be executed on the system with one process per node, resulting in a total of P processes. If a processor has more than one core or one node has more than one processor, P denotes the number of cores in the system with cores being treated as nodes. Hereby, there will be one process running on each core. In the following paper, it is assumed that there will be one process running on one node to simply the model.

A. Definition for Storage Speedup

As shown in Figure 1, for a given program Q which has I/O workloads can be divided into two kinds of phases: I/O phases and compute phases. The compute phases are denoted as shaded parts compared with the I/O phases denoted as the white parts. The single process execution case is shown in Figure 1(a), where 0 represents the process and T_1 denotes the execution time. The execution case of parallel system is shown in Figure 1(b), where P represents the number of processes and T_P^S denotes the practical execution time of parallel program. The I/O workloads mainly consist of reading the raw data, storing intermediate data, writing the final results and so on. Every I/O phases we denoted as an I/O operation point.

For the serial program Q running on one compute node in Figure 1(a), let N^S be the amount of I/O operation points. I^{sint} is the average time interval among I/O operation points, and on each I/O operation point the average I/O service time is I^{sser}, then all the execution time of I/O-free phases is T^{snon}, so the time of the program Q runs on a node serially is:

$$T_{Sto}^S = T^{snon} + N^s \bullet I^{sser} = T^{snon} + \left(T^{snon} / I^{sint}\right) \bullet I^{sser} \quad (1)$$

For the parallel program Q running on P compute nodes in Figure 1(b), in regard to the *i-th* ($0 \le i < P$) process in the P processes, we denote that N_i^P is the amount of I/O operation points, I_i^{pint} is the average time interval among I/O operation points, I_i^{pser} is the average I/O service time on each I/O operation point, and T_i^{pnon} is the execution time of I/O-free phases, so the average values of the parameters related to all processes can be given as follows.

The average value of I/O operation points:

$$N^p = \frac{1}{P}\sum_{i=0}^{P-1} N_i^p$$

The average value of average time intervals among I/O operation points:

$$I^{pint} = \frac{1}{P}\sum_{i=0}^{P-1} I_i^{pint}$$

The average value of average I/O service time on every I/O operation point:

$$I^{pser} = \frac{1}{P}\sum_{i=0}^{P-1} I_i^{pser}$$

The average value of average I/O-free execution time:

$$T^{pnon} = \frac{1}{P}\sum_{i=0}^{P-1} T_i^{pnon}$$

Then the real execution time of program Q on P processors is approximated as follows:

$$T_{Sto}^P \approx T^{pnon} + N^p \bullet I^{pser} = T^{pnon} + \left(T^{pnon} / I^{pint}\right) \bullet I^{pser} \quad (2)$$

So we give the definition of storage speedup model.

Definition 1 (Storage Speedup). When program Q runs on a parallel system, the storage speedup achieved is defined

as follows:

$$S_{Sto}^{P}=\frac{T_{Sto}^{S}}{T_{Sto}^{P}} \tag{3}$$

According to (1) & (2), suppose that S_P is the speedup of the I/O-free part in the program Q, while $N=I^{pser}/I^{pint}$ and $M=I^{sser}/I^{sint}$, the storage speedup can be converted below:

$$\begin{aligned} S_{Sto}^{P}&=\frac{T_{Sto}^{S}}{T_{Sto}^{P}}\approx\frac{T^{snon}+\left(T^{snon}/I^{sint}\right)\bullet I^{sser}}{T^{pnon}+\left(T^{pnon}/I^{pint}\right)\bullet I^{pser}}\\ &=\frac{T^{snon}\left(1+I^{sser}/I^{sint}\right)}{T^{pnon}\left(1+I^{pser}/I^{pint}\right)}=S_P\bullet\frac{1+M}{1+N}=S_P\bullet\frac{1}{1+\frac{N-M}{1+M}} \end{aligned} \tag{4}$$

Let us define

$$O(P)=\frac{N-M}{1+M} \tag{5}$$

which reflects the variation of I/O execution with the parallel application scaling and is called the storage workload factor.

As a result, our storage speedup formula is refined to

$$S_{Sto}^{P}=S_P\bullet\frac{1}{1+O(P)} \tag{6}$$

which indicates the speedup affected by I/O performance variation with the processors scales.

In formula (6), if S_P is instantiated by Amdahl's speedup and Gustafson's speedup, we obtain different storage speedup formula as follows.

Amdahl Storage Speedup

$$S_{Amdahl-Sto}^{P}=S_{Amdahl}\bullet\frac{1}{1+O(P)}=\frac{P}{1+f(P-1)}\bullet\frac{1}{1+O(P)} \tag{7}$$

Gustafson Storage Speedup

$$S_{Gustafson-Sto}^{P}=S_{Gustafson}\bullet\frac{1}{1+O(P)}=\left(f+P(1-f)\right)\bullet\frac{1}{1+O(P)} \tag{8}$$

Due to the competition of I/O resources, I/O service time is prolonged in parallel computing, resulting in $O(P)\neq 0$. Ideally, if $O(P)=0$, our two storage speedup models are simplified into the traditional Amdahl's and Gustafson's speedup formulas.

$$S_{Sto}^{P}=S_P \tag{9}$$

B. System Classification

First we make some symbols conventions. We denote $f(x)\succ g(x)$ if $\lim_{x\to\infty}f(x)/g(x)$ is ∞ and $f(x)\succeq g(x)$ if $\lim_{x\to\infty}f(x)/g(x)$ is a positive constant or ∞. Adversely, $f(x)\prec g(x)$ indicates $\lim_{x\to\infty}f(x)/g(x)$ is 0 and $f(x)\preceq g(x)$ indicates $\lim_{x\to\infty}f(x)/g(x)$ is a non-negative constant. Suppose $\Theta(x)$ is a set consisting of all functions of x, $f(x)\in\Theta(x)$ and $g(x)\in\Theta(x)$. If $\lim_{x\to\infty}f(x)/g(x)$ is a positive constant, it denotes $f(x)=\Theta(g(x))$ or $g(x)=\Theta(f(x))$.

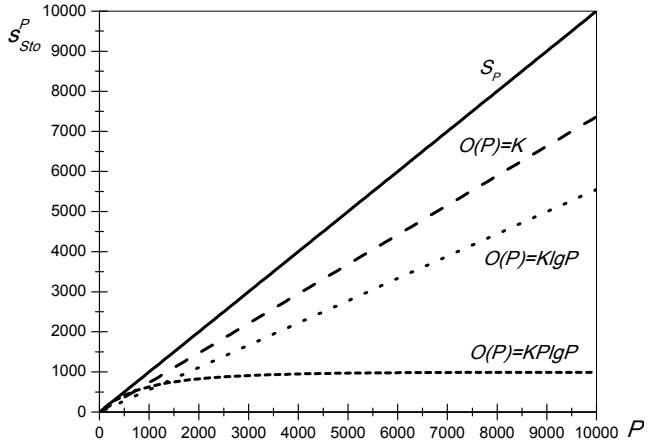

Fig. 2. Three examples about storage speedup of different kinds of systems based on $O(P)$.

From the definition of storage speedup formula (6), it is easy to observe that $O(P)$ is the key factor in storage speedup variations. According to the characteristic of $O(P)$ related to different parallel systems, considering these systems to be classified as follows.

Definition 2 (Constant and Incremental Systems). Suppose that a program Q satisfying $\lim_{P\to\infty}S_P=\infty$ runs on a W system. If $O(P)\preceq\Theta(1)$, the W system is considered to be a constant system. And if $O(P)\succ\Theta(1)$, the W system is considered to be an incremental system.

As shown in Figure 2, there are three examples about the classification based on $O(P)$. If $O(P)=K\preceq\Theta(1)$, where K is a positive constant, the W system is a constant system. We find the storage speedup increases linearly with the number of nodes which indicates that the scalability of the application is not bound by the I/O performance obviously.

If $O(P)=KP\lg P\succ\Theta(1)$, the W system is an incremental system. This is different from above; the scalability of the application is bound by the I/O performance.

C. General Storage Speedup

In this subsection we generalize the storage speedup by considering not only the time cost introduced in the last subsection but also costup related to investment. Due to a powerful support provided by supercomputer, scientific exploration develops rapidly. Since more and more data need to be analyzed or calculated, I/O-intensive applications are becoming an important part of the scientific applications on the supercomputer. In order to meet the requirements of I/O-intensive applications, storage system of supercomputer need more large capacity and high performance equipment, and also more flexible and efficient software stack. All of these lead to more cost. The expansion of supercomputer system not only meets the requirements of applications, but also considers the cost-effectiveness of all the investment of manpower and money. So we want to find a metric to measure the cost-effectiveness of investment for supercomputer under the storage constraint.

We generalize a new speedup called general storage speedup to try to solve the problem. This generalization is increasingly important for modern petascale especially future exascale supercomputing systems as the storage systems employed can be more costly.

Based on the costup presented by D. A. Wood and Mark Hill [9], we introduced costup$_S$ to analyze the storage scalability which is more cost-effective related to various I/O architecture.

Definition 3 (Storage Costup). When program Q runs on a parallel system from one processor to P processors, the storage costup is defined as follows:

$$\cos tup_S=\frac{cost_P^S}{cost_1^S} \tag{10}$$

The cost could include not only the compute system cost but also the storage system cost. And the cost also include the

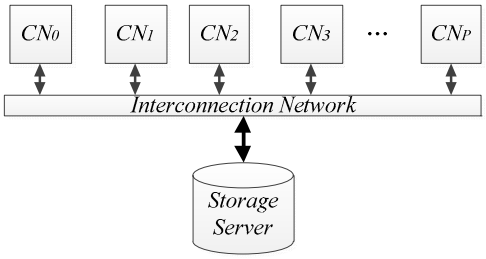

Fig. 3. Centralized I/O Architecture.

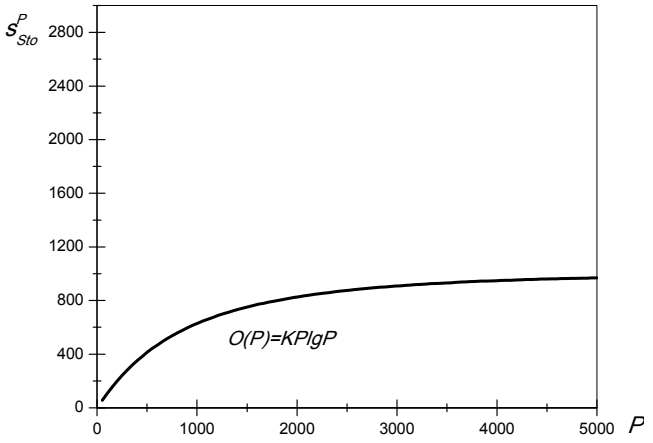

Fig. 4. Centralized I/O Architecture.

hardware and software cost. We assume that the compute system cost grows proportionally with the application scale P.

$$\cos tup_S = \frac{cost_P^{comp} + cost_P^{sto}}{cost_1^{comp} + cost_1^{sto}} = \frac{cost_1^{comp} \bullet P + cost_P^{sto}}{cost_1^{comp} + cost_1^{sto}} \tag{11}$$

Let us write C as $cost_1^{sto} / cost_1^{comp}$, M as $cost_P^{sto} / cost_1^{sto}$. So we have

$$\cos tup_S = \frac{P + MC}{1 + C} = P\frac{1 + (M/P)C}{1 + C} \tag{12}$$

Obviously, M represents storage investment trends which are closely related to system architecture, market variation, application requirements and so on.

Definition 4 (General Storage Speedup). When program Q runs on a parallel system, the general storage speedup achieved is defined as follows:

$$S_{Sto}^{GP} = \frac{S_{Sto}^{P}}{\cos tup_S} \tag{13}$$

According to (12), we have

$$S_{Sto}^{GP} = \frac{1 + C}{P(1 + (M/P)C)} S_{Sto}^{P} \tag{14}$$

Since C is a constant, the general storage speedup is determined by P, M and storage speedup.

M denotes the growth rate of the storage system cost with the compute system scaling. The general storage speedup allows us to study both the performance effect and cost effect of storage system to the whole parallel system.

IV. I/O Architecture Analysis

According to the interconnection relationship between compute and storage in supercomputing systems, the architecture of supercomputing storage systems can be divided into three categories: centralized architecture, distributed and parallel architecture, centralized, distributed and parallel architecture (The following in the paper is abbreviated as CDP I/O architecture). The analyses for each I/O architecture related to storage speedup and general storage speedup are as follows.

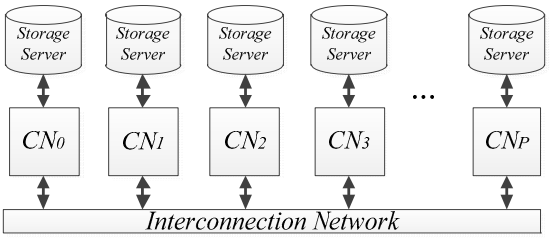

Fig. 5. Distributed and Parallel I/O Architecture.

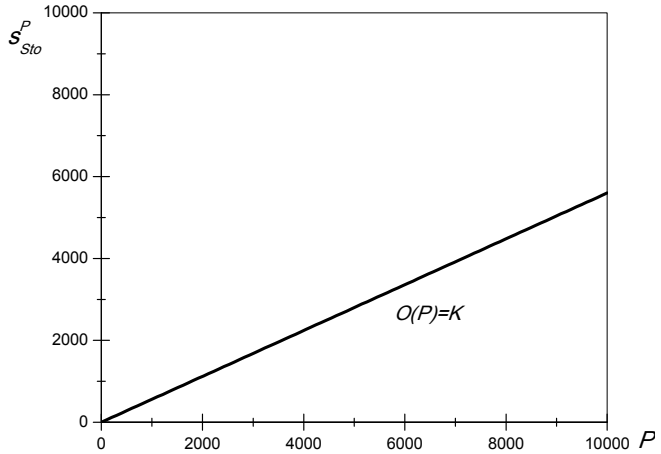

Fig. 6. A case about storage speedup which is not affected by the I/O performance related to distributed and parallel I/O architecture.

A. The Analysis of Storage Speedup

Centralized I/O Architecture

Figure 3 shows a centralized I/O architecture which is often used in small-scale supercomputers, such as NAS. The supercomputer storage system with centralized I/O architecture is easy to be configured and managed, but has a poor scalability. It can only scale up instead of scaling out, since the storage system cannot scale horizontally to multiple servers but only to enhance the performance of a single server vertically. Therefore the performance of storage system is severely limited by the I/O architecture. As the

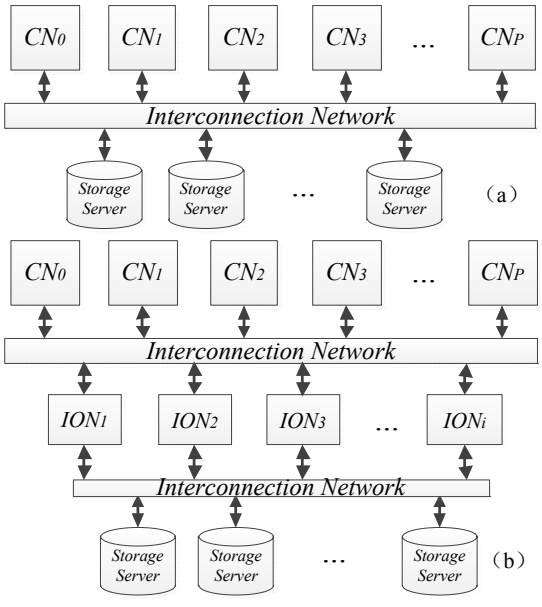

Fig. 7. Centralized, Distributed and Parallel Architecture.

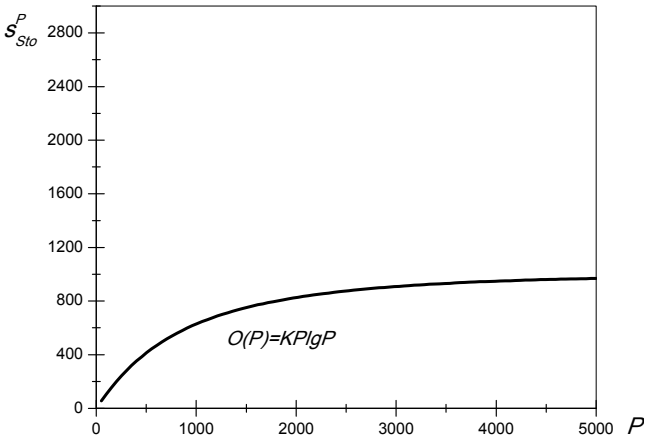

Fig. 8. A case about storage speedup which is constrained by the I/O perfermance related to centralized, distributed and parallel architecture.

storage system with centralized I/O architecture cannot scale out to more storage nodes, we obtain $O(P) \succeq \Theta(P)$. According to definition 2, the supercomputer with centralized I/O architecture is an incremental system whose parallel computing scalability is constrained by the performance of I/O system. Figure 4 shows us a case about supercomputer with centralized I/O architecture whose storage speedup is bounded by the I/O performance.

Distributed and Parallel I/O Architecture

Figure 5 shows a distributed and parallel I/O architecture. A supercomputer storage system with distributed and parallel I/O architecture usually refers to the architecture in which each compute node with built-in storage or directed attached storage server. Each compute node has file system which can provide I/O service to itself and other compute nodes. Due to this special nature, the implementations of the parallel file system are complicated due to I/O scheduling and data global consistency. And the storage servers have different positions to the compute nodes themselves and other compute nodes; therefore the system load balance also becomes a problem. So, distributed and parallel I/O architecture is usually adopted by supercomputers with small or medium scale.

For distributed and parallel I/O architecture, the storage nodes and compute nodes scaling equally. So we obtain $O(P) = \Theta(1)$. The supercomputer with distributed and parallel I/O architecture is a constant system and the parallel computing scalability is not constrained by the performance of I/O system, as the Figure 6 shows. With the node number increasing, the performance of storage system expands proportionally.

Centralized, Distributed and Parallel Architecture

Figure 7 shows a CDP I/O architecture which is dominant in the supercomputers of TOP500 [1]. For the Medium-sized supercomputers (the amount of compute nodes reaches 10^3), compute nodes and storage servers are connected directly through interconnection network as shown in the Figure 7(a). Parallel storage system consists of storage servers which are usually installed with parallel file system, such as Lustre, PVFS and so on, while compute nodes access the storage system by the client of parallel file system. Typical systems are Titan, Tianhe-1A and so on. With the supercomputer's development, I/O nodes (ION) are inserted between compute nodes and parallel storage systems to provide the function of I/O forwarding and management, as the Figure 7(b) shows. On the one hand, the amount of compute nodes can increase continually without the limitation of the client amount of parallel file systems. On the other hand, I/O performance can be improved by I/O scheduling and caching. All of these are attributed to the introduction of I/O nodes in the systems. The typical systems are IBM Bluegene series and Tianhe-2. Although the system has been improved by the I/O nodes, the essence of I/O architecture doesn't change. Thus, to simplify the model, I/O node layer is omitted in the subsequent analysis.

In the CDP I/O architecture, the storage system can not only scale up, but also scale out. But they still have limitations, first, for a specific supercomputer the scale of storage system is fixed within a certain time period; second, parallel file system usually has up limits on the number of storage nodes, the aggregate performance and the storage capacity. So we can also obtain $O(P) \succeq \Theta(P)$. According to definition 2, the supercomputer with CDP I/O architecture is an incremental system whose parallel computing scalability is constrained by the performance of I/O system as shown by Figure 8.

The performance of storage system with CDP I/O architecture is much higher than the system with centralized I/O architecture, so the speedup affected by the I/O

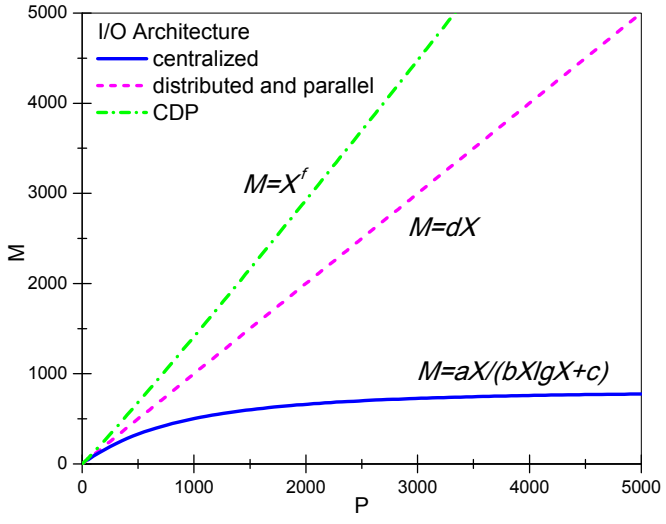

Fig. 9. Examples of changing law of parameter M under different I/O architectures when the storage system scaling with compute system. a, b, c, d and f are different constants.

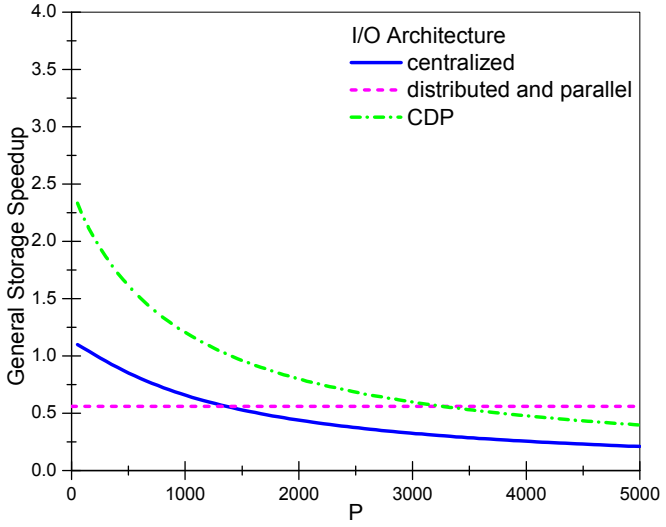

Fig. 10. Examples of changing law of general storage speedup under different I/O architectures when the storage system scaling with compute system.

performance is not obvious until the parallel application increases to a huge scale.

B. The Analysis of General Storage Speedup

Storage speedup is used to evaluate practical speedup of parallel application under the constraint of I/O system, while general storage speedup can be used to show how cost-effective when the storage system of supercomputer scaling. Since the market variation and the private cost details of system construction, there is no specific system to be described. Instead in this subsection we illustrate some examples of general storage speedup related to typical I/O architectures.

Figure 9 shows the examples of M function which is a key factor to reveal the variation ratio of storage cost with the scale of parallel application increasing. Due to a wide range of storage devices and complex price variability, these cases are only used to reveal the possible laws of M function under different I/O architectures. Different scaling methods need distinct types and quantities of hardware and software equipment, and this lead to different variation trends of M. M can be measured according to specific system at a specific time.

Figure 10 shows the examples of general storage speedup of different I/O architectures with the scale of parallel application increasing. Since the different extension methods of supercomputer storage system under different I/O architecture, general storage speedup reflects all kinds of cost-effective characteristics of storage systems. According to the definition, the larger value of general storage speedup represents a higher cost-effectiveness.

The examples in the figure 10 shows that the general storage speedup decreases slowly with the compute system and storage system scaling for the centralized I/O architecture and CDP I/O architecture, and the storage system with CDP architecture is more cost-effective than centralized I/O architecture. Since storage system scales with compute system proportionally under distributed and parallel I/O architecture, the general storage speedup is approximately to be a stable value. So, when the storage system expands to a larger scale, the system with distributed and parallel I/O architecture has better and more stable cost-effectiveness.

V. Conclusions

This paper introduces a new speedup metric called storage speedup taking into account the I/O performance constraint. The new metric unifies the compute and I/O performance, and evaluates practical speedup of parallel application under the limitation of I/O system. The existing parallel systems are classified and analyzed according to the storage speedup, and the suggestions are acquired on system design and application optimization. Based on the storage speedup, a general storage speedup is generalized to evaluate the cost-effectiveness of the storage system by considering not only speedup but also costup. Through the case studies, the effectiveness of the two new speedup metrics is validated.

In the future, our efforts will mainly focus on the following aspects. For the storage speedup, we will refine the theory and explore more factors. At the same time, we will make further research on characteristics of massively parallel applications and supercomputer storage systems to improve the scalability of system.

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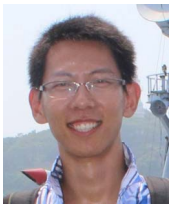
Guilin Cai is a doctor student in the College of Computer at National University of Defense Technology in China. She received the B.S. and M.S. degrees in computer science from National University of Defense Technology in 2005 and 2010, respectively. Her main research interests include high performance computing, cyber security and proactive defense.

Wei Hu received the B.S. degree from PLA University of Science and Technology, China, in 2004, and the M.S. degree from National University of Defense Technology, China, in 2010. He currently pursues the Ph.D. degree in the College of Computer, National University of Defense Technology, Changsha, China. His research interests include high performance computing and machine learning.

Guangming Liu received the B.S. and M.S. degrees from National University of Defense Technology, China, in 1980 and 1986 respectively. He is now a professor in the College of Computer, National University of Defense Technology. His research interests include high performance computing, massive storage and cloud computing.

Qiong Li received the B.S., M.S. and Ph.D. degrees from National University of Defense Technology, China, in 1993, 1996 and 2010, respectively. She is now a professor in the College of Computer, National University of Defense Technology. Her research interests include high performance computing and massive storage.

Xiaofeng Wang has been working as an assistant professor in the College of Computer at National University of Defense Technology in China. He received the B.S., M.S. and Ph.D. degrees in computer science from National University of Defense Technology in 2004, 2006 and 2009 respectively. His research interests include trustworthy networks and systems, applied cryptography, network security.



Wenrui Dong received the B.S. and M.S. degrees from National University of Defense Technology, China, in 2009 and 2011, respectively. He currently pursues the Ph.D. degree in the College of Computer, National University of Defense Technology. His research interests include high performance computing and massive storage.

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ICACT-TACT JOURNAL

Global IT Research Institute

1713 Obelisk, 216 Seohyunno, Bundang-gu, Sungnam Kyunggi-do, Republic of Korea 13591

Business Licence Number : 220-82-07506, Contact: secretariat@icact.org Tel: +82-70-4146-4991