Intelligent Caching Wireless Data Access in the Wireless Spectrum

Syazwa Mad Jais*, Sarina Sulaiman, Siti Mariyam Shamsuddin
Soft Computing Research Group
Faculty of Computer Science and Information Systems
Universiti Teknologi Malaysia, Johor, Malaysia
*Corresponding author, e-mail: syazwa_wawa@yahoo.com.my, sarina@utm.my, mariyam@utm.my

Abstract
The evolution wireless technologies are growing rapidly in upcoming years. It is expected that many users will shift to more advanced devices that will contribute to gain higher demand in wireless spectrum. However, the capacity for the allocation frequency in the wireless spectrum is typically limited in wireless data transmission. Therefore, when the loads of wireless users in the wireless communications are increasing, the need of cache mechanisms such as Web caches or Web servers are crucial. The scalability demands on internet infrastructure keep increasing as the internet continues to grow in popularity and size. Therefore, the existence and development in Web caching technologies will contribute to bandwidth savings, network latency reduction, improve content availability and subsequently server load balancing. This paper will studies and investigates the cache performance in wireless spectrum with the purpose of dealing with the data growth since the spectrum crisis becomes a serious matter lately. The performance improvement will be observed using caching scheme which allows for time shifting and load shifting in accessing the wireless data with the better cache deployment in the network system.

Keywords: caching, wireless spectrum, frequency allocation, cellular network

1. Introduction

Wireless spectrum is the public radio waves which refer to electromagnetic spectrum that have the wireless capacity which comprising of different frequency ranges for different types of application. For instances, all wireless signals such as television, Global Position System (GPS), broadband and radio that travel through the air on public over geographical distance which are the invisible signals also called spectrum. These days, wireless radio spectrum becomes a crucial issue in the upcoming year because it is a finite precious resource. Wireless network operators have their own spectrum allocation that they have bought from communication commission for every single application that being implemented.

However, most of the network operators claim that their blocks of spectrum cannot be sustained with the explosive demand that can sluggish wireless internet service such what is being faced by Smartphone and i-Phone users and also forcing dropped cellular phone calls. They cannot use more spectrum than they have bought for their users' sake. Consequently, they are fighting to get more blocks of spectrum from unused television spectrum that is also known as white space. This white space spectrum sometimes called super Wi-Fi is allocated for television network, but it is not in use by the television station. One of the mobile network providers AT&T recently, proposed spectrum combination technique with other mobile network operator which is T-Mobile for AT&T's   company to help them in mobile service for their users in America. If the deal goes through, it does not put any more spectrum into wireless broadband overall [1].

Nevertheless, the efficient use of the merger can improved its own service. One thing that needs to be sure to avoid the interference between signals is two signals that are being broadcast cannot be in the same slice of spectrum or otherwise the signals will become useless. However, the Federal Communications Commission (FCC) ensures that if any two transmitters (which are cell towers) in one area and frequency, the signals will not overlap and interferes to each other [2]. If the frequency ranges that being allocated and the implementation are not

organized in efficient way, access to the wireless spectrum will be a problem in wireless services.

The network that being built by the wireless company is based on the rank of the average expected usage. The most cases that had been faced by the network provider are the huge surge in volume that flooded the wireless spectrum, leading to many busy signals [13]. This situation happen when, there is huge number of users tries to make calls at the same time. For instance, the moment when wireless gets blacked out in New York on 2003 shows and proved to the network provider and cell phone users that the network usage that being used at that time was overload [3].

A study from Cisco said that bandwidth demands are expected to grow 30 times between 2010 and 2015 [4]. Having talked to a number of companies, it seems that there are four basic techniques for addressing the problem over the next few years which are additional spectrum, better use of that spectrum, offloading data onto wired networks, and increased caching [4]. One of the solutions to overcome the problem that have been stated is caching. Caching is one of the important methods that can be used to deal with the data traffic especially involving the video data [4]. It is better to predict what content users will want and then cache it to their devices, either when they are connected to a wired network, or when the wireless network is underutilized [4]. The idea is to leverage local storage to intelligently cache network content which allows for time shifting and more importantly load shifting which can be implemented by moving the bandwidth requirements from congested network at a busy time to downloading from a network in non-peak time (say overnight) or from a Wi-Fi network [4]. For example, let say a user watched the first few episodes of a drama series, it will be expected that the user will want to watch the next episodes until the end of the drama. So, this is where the caching system will take the role to cache the next episodes of the drama to the user's device within non-peak time.

1.1. Summary of Crucial Issues of Finite Wireless Spectrum and Caching Scheme

Intelligent approaches in Web caching are important to wireless network environment in order to adapt with the rapid growth of the network. There are a number of ongoing efforts in Web caching technologies that have the solutions to overcome the problems that occurs in the wireless network. Even though there are many studies in this kind of technologies, the shifting method in terms of time shifting and load shifting are still novel in Web caching. By going through the other researcher papers, journals and website, it will help the authors to have a good view on Web caching and look up for better new solution to overcome the problems that occurs in the wireless communication network.

Talley (1997) stated that the Artour Gateway and WebExpress use smart caching and solid management to gain higher speed in accessing wireless network. All IP functions, with data encryption and compression are provided by the Gateway. After the data is being received by the server, the data will be translated to the appropriate network protocol before it sends to the client through wireless network. The connection to the internet and intranet can be done by using Gateway alone and then the normal internet activities can be engaged. Nevertheless, it will be quite slow in Web browsing since the product offers only general IP transport with browsing speed at 9600bps (at best) which is very painful. There is a combination of several ways to optimize the Web browsing by the WebExpress in order to make the slow connection seem much faster. WebExpress intelligent caching technique caches different pages for different lengths of time [5]. A particular page can always be provided from cache by setting up the system and for different refreshing strategies and caching also can be done by configuring the additional pages. WebExpress also offers retrieving documents in the background automatically, so when the user needs them, the documents are already there. The documents can be downloaded immediately or leave them in the background as the system is directed by the user. However, the lack of centralized administration tools is an obstacle to the WebExpress. This is because the caching information needs to be manually add to each of the clients units by the administrator if an intranet server is added.

The survey paper that been written by Barish and Obraczka (2000) describe the trends and technique that being used in Web caching technologies. They stated that Web caching is still young industry and a number of commercial vendors pushing new solutions either with direct to research systems or architected by individuals with notable research background [6]. In the article, several caching architectures, the selection of cache deployment, and specific

design techniques are being presented. A number of ongoing issues are remaining even though better performance and scalability improvement is being offered by Web caching. One of the issues is the object integrity. Let say if an object is cached, is the user guaranteed that the cached copy is up-to-date with the version on the originating server [6]. Some technical issues are content security, the practically of handling dynamic and real time data, and dealing with complex functional objects [6]. Different scenarios may apply different architectures depending on the suitability of the system by the deployer. However, to choose which one is the best is quite difficult since there are many caching solution that exist nowadays and the caching scheme normally depends on the need and constraints of the deployer.

Tay, et al. (2000) introduce a caching scheme which is a revolutionary distributed internet caching system. In this paper, the authors proposed new structure, cache model and protocol that will be implemented in their research. The theoretical model that has been proposed has the largest combined storage space and has a guaranteed data consistency. This kind of caching system in theoretically is more reliable compare to any single or group of cache servers. However, the method to utilize the additional power of the client nodes become a key issues for the authors in order to increase the performance of the server functions so that the overall network will not affected by the inherent unreliability characteristic. A client computer will have as its first priority performs locally initiated tasks and the second priority task will be the server function and this will add to several effects such as the clients computer will become unreliable from the server functions.

The incident that happens in New York on 2003 is shocking every resident since the blackout also give an impact to wireless network as stated by La Monica (2003). The situation become frustrating and turns out to be more annoying when many wireless customers were unable to use their mobile phone during that time. This circumstance happen because of huge number of callers tries to make a call at the same time. This will contribute to huge surge in volume and lead to many busy signals and drop calls. Spectrum is a finite resources and the network provider build up their network within the frequency allocation that have been gain from the associated government commissioner based on average expected usage levels. Since the wireless is too dependent on the external power supply, the blackout should put pressure on the major wireless carriers to bulk up coverage in already high-traffic network and takes more steps to ensure that wireless antennas can keep running even in the event of a power outage [6].

The deal of spectrum merger by the AT&T and T-Mobile give an issue to the Ovide (2011) regarding on the limited resource which is spectrum. The definition of spectrum and the importance for users of mobile devices also have been provided through this paper. AT&T proposed $39 billion to T-Mobile for the merger to help the company to meet the demand of the network. If the merger goes through, the deal does not put any more spectrum into wireless network overall, but the combination can improve its own service. Nevertheless, the insufficient spectrum limits a carrier's coverage, service quality and data connection speeds [1]. Since the spectrum available for the network provider is already fixed for them, they need to organize their network in efficient way to give better service to their users.

Table 1. Summary of crucial issues of finite Wireless Spectrum and Caching Scheme

Author	Brief Description	Limitations
Talley (1997) [5]	• Gateway client component provides IP connectivity over non-IP networks and provides all IP functions as well as data encryption and compression. • WebExpress adds complementary client and server pieces. It caches different pages for different lengths of time.	• Web browsing would be slow because the product offers only: 1. General IP transport 2. Web Browsing at 9600bps (at best) • WebExpress lack of centralized administration tools.
Barish and Obraczka (2000) [6]	• Survey the state of the art in caching designs, presenting taxonomy of architectures and describing a variety of specific trends and techniques.	• To decide which one is the best since the effectiveness of a Web Caching largely depend on the need and constraints of the deployer.

	• The appeal of Web Caching because of the unparralled growth of the Internet.	• There remain a number of open issues: 1. Content security 2. The practically of handling dynamic and real time data. 3. Dealing with complex functional object (for example Java programs)
Tay, et al. (2000) [7]	• In the proposed structure, every client computer in the network takes on the additional role of a cache server, serving the objects it had previously requested and received to other client computers that also request the object. • A comprehensive set of protocol for the access, storage and serving function is developed.	• When putting the server functions as second priority tasks: 1. A definite quality of service with respect to the server functions cannot be guaranteed. 2. Makes the client computer unreliable from the server function perspective. • Key issues: 1. The method to utilize the additional power of the client nodes to increase the performance of the server functions. 2. A direct implication of the proposed OS initiated server functions in the client node is system security.
La Monica (2003) [3]	• Explain the incident that happen in the New York metropolitan area, where many wireless customers, parts of the Midwest and Canada were unable to use their cell phones during the blackout, which made a frustrating situation even more annoying.	• In most cases, the biggest problem was a huge surge in volume (everybody all trying to make calls at the same time) that flooded the wireless spectrum, leading to many busy signals. • Wireless is too dependent on the external power supply and since wireless phones are becoming the main phone line for many people, the industry has to make sure that customers have the same kind of reliability as with landlines.
Ovide (2011) [1]	• Explain the definition of spectrum and the importance for users of mobile devices. • Discussion on the spectrum merger of two network provider namely AT&T and T-Mobiles's in order to look on the improvement of the country's wireless network situation overall.	• Because there are only so many usable frequencies, and things are not organized in the most efficient way, access to spectrum is a limiting factor for wireless services. • Insufficient spectrum limits a carrier's coverage, service quality, and data connection speeds.

1.2. Spectrum Allocations in Malaysia

The allocations of frequency spectrum in Malaysia are allocated by the Malaysian Communications and Multimedia Commission (MCMC) in assigning the different frequency allocations for different applications. Basically, the normal frequency ranges in allocations of spectrum that provided by government commissioner are between 3 kHz to 300GHz. For microwave communication and Wireless LAN (Local Area Network), the frequency ranges are between 300MHz to 30GHz whereby the designation bands are UHF (Ultra High Frequency) and SHF (Super High Frequency) as shown in the Figure 2.
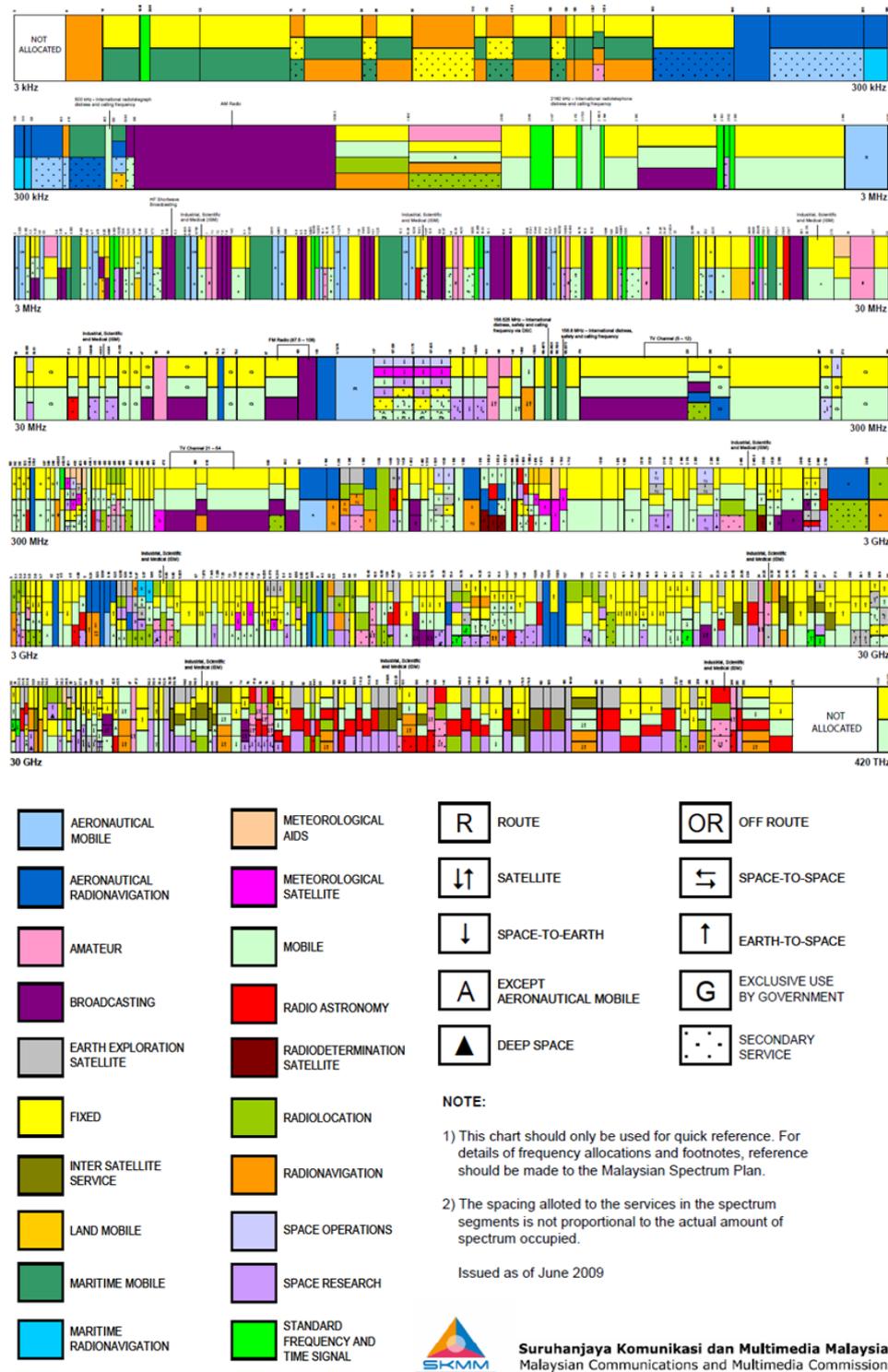
Figure 2. Spectrum Allocations in Malaysia [2]

2. Research Method

This section will present a methodology that will be implemented in completion of this research and to enhance the performance of the data access in the wireless spectrum. A flowchart of the research methodology is very important for the project to ensure that the implementation of the project can be done smoothly with specific tasks.

The research is started with the study and investigation of the relationship between Web caching and wireless spectrum. This first stage is essential in order to develop an understanding in both areas, namely Web caching and wireless spectrum so that the knowledge that have been gained can be applied through this research. The cache position will be the next step to be done for the system since there are three main cache deployment choices in network which are near the content consumer (consumer-oriented), near the content provider (provider-oriented) and at strategic points in the network based on user access patterns and network topology [6, 8]. Each of the deployment features has their own benefits but, to apply the deployment, it will depend on the requirement of the network system and the compatibility with the system.

Input data or input messages are needed to have the simulation result, so that the result can be analyzed at the end execution of the project. When a request is made for an object currently in the cache, it is returned to the client but, when a request is made for an object not currently in the cache, the cache retrieves the object and simultaneously feeds bytes to the client and stores the object into memory. If the network at that time is busy, it will allows for time shifting and load shifting where it will move the bandwidth requirements from congested network at a busy time to downloading from a network in non-peak time (say overnight) or from a Wi-Fi network. Lastly, after the data required have been cache, the data will be sending to the client or user. The research methodology should be completed as shown in flow chart in Figure 1.
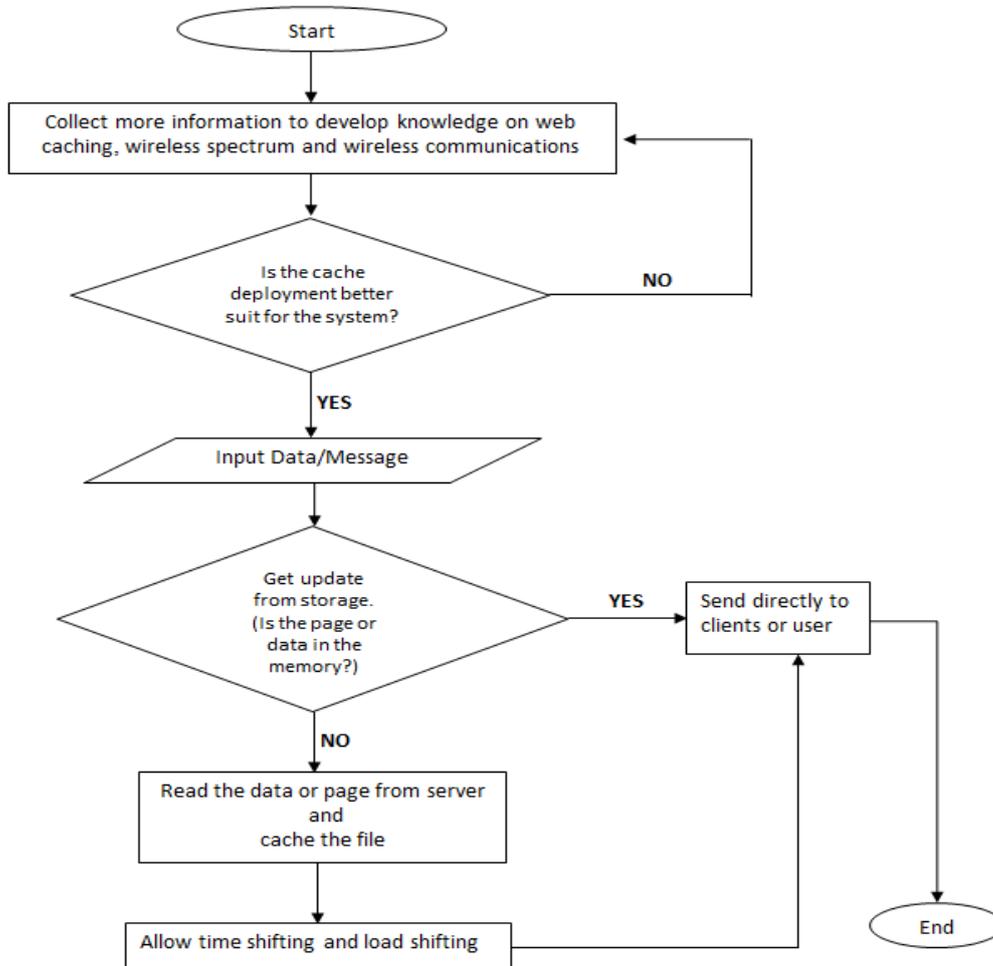

Figure 1. Flowchart of the methodology

3. Expected Result

As demand for wireless network communications continuous to explode, leveraging the intelligent caching wireless data access is vital to the network provider in order to give a high-quality consumer experience. In this research, the caching scheme that will be used is the cache will learn and predict the data especially data that involved with video content where the user likes to surf and when and where the user wants to access it.

This caching scheme will also predict network availability and then the better opportunity to download the data will be chosen. The expected outcome from this research is to give a new high quality experience for subscribers whenever and wherever they want to access the data with no buffering since it will predict the good wireless network that available such as Wi-Fi. This is because packets are lost and delayed when network congestion occurs that will result in a poor user experience. Additionally, studies have shown users have low tolerance for a poor video experience and are quick to surf away [9]. When everyone is simultaneously tried to access the same content that will lead to buffer, or delays, most of the users will click away. Refer to Figure 3 that have been shown below, within ten seconds, more than 10 percent of audiences have surf away when the content that being surfed by them need buffering and delays.
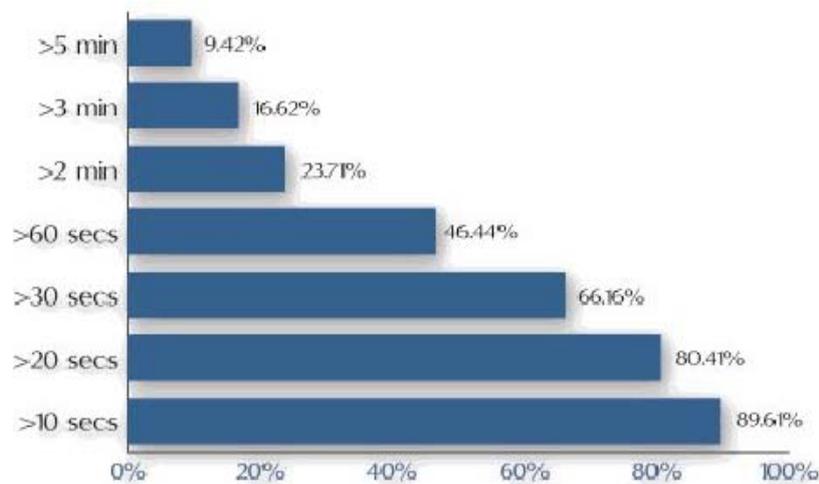

Figure 3. Audience Attention span [4]

The idea of this research is to enable caching data content for users in an intelligent and predictive way to deliver the requested content by downloading it during non-peak time and subsequently maximize the user's experience.

4. Conclusion

The increasing traffic demand in wireless spectrum every year gives impact to most of the network providers which are struggling to have enough spectrums to meet the growing demand. The network itself is a hybrid of landline connections that form the backbone network or packet core and wireless portion for the last mile [8]. Therefore, the proposed intelligent caching is very useful to allow on demand delivery to support the huge growth of network traffic.

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