MULTI-WIRELESS STANDARDS AND WIRELESS-ORIENTED OPERATING SYSTEM FOR ANTENNA SUBSYSTEM BASED ON SPACE DOMAIN WIRELESS RESOURCE SCHEDULING

Tadahiko MAEDA, Koichi MOURI, Eiji OKUBO
Department of Computer Science
Faculty of Science and Engineering
Ritsumeikan University
1-1-1 Noji Higashi, Kusatsu, Shiga 525-8577, Japan
E-mail: tmaeda@cs.ritsumei.ac.jp, mouri@cs.ritsumei.ac.jp, okubo@cs.ritsumei.ac.jp

1. Introduction

The theme of this paper is to examine the role of multi-wireless standards and Wireless-Oriented Operating System for the efficient wireless telecommunications and assess the impact of ADSFA[1] (Adaptive and Dynamic Spatial Frequency Allocation) on restructuring the wireless communication technologies. During the progressive evolution of telecommunication, Adaptive and Dynamic Spatial Frequency Allocation can be considered as one of the landmark goals of the industry and has enormous potential in restructuring the basic framework of the industry. Although several issues [1] were pointed out in terms of lacking in any form of general support for mobile operation through the Internet, the importance of spatial management for radio resources has been receiving minor emphasis. First of all, from the purely technical point of view, conventional wireless communications are designed to use some assigned frequency bands. However, in general, fixed frequency allocations often weaken the competition and tend to drive the industry to the inefficient operation. Thus, the basic issue is how to allocate the frequency resources in the space domain based on the instantaneous demands from the application software depending upon the available technologies at the time of concern. In addition, these available technologies are becoming more interdependent and computerized. Therefore, the roles of operating system (OS) in the wireless communication and its space domain scheduling functionality for controlling the antenna subsystems, which enables the efficient use of spatial frequency spectrum, are becoming more important.

2. Frequency allocation for wireless services

The emergence of IP based telecommunications has a very strong impact on the evolution of the telecommunications market as a whole. Mobile communication technologies have not only challenged the natural monopoly, which had been dominating the telecommunication market, it has also changed the perception of the threat of the Internet, which gave the strong service differentiations in the oligopolistic market structure of wireless communications.

In evaluating the economic efficiency of wireless businesses, the frequency utilization and frequency allocation are the keys for the system and strongly affect the business model of wireless carriers because basically more than one wireless standard cannot share the same frequency band, and the separated bandwidths need to be assigned to each physical standard. During the period of ordinary mobile phone, the concept of roaming between regular telephone network and IP based network was not the major issue, however, after the advent of the IP based wireless hot spot services, roaming and inter-connectability of mobile phones became the hot issue. In order to increase the efficiency of production for wireless equipment, the allocation of frequencies and making use of a particular standard mandatory set the strong barrier to entry to the potential service providers [2]. In other words, if technology allows the dynamic assignment of frequency, this oligopolistic structure of frequency resources in the

[1] A concept to allocate frequency resources adaptively and dynamically in space domain in order to achieve the efficient use of the frequency resources between multi-wireless standards.

telecommunication industry could be solved without harmful interferences and incompatibilities between several wireless standards.

However, the situation in IP is different from that of the so-called ‘legacy’ telecommunications because of the following three factors: 1) global level competition, and 2) relatively openness of the standard, 3) competitions between multiple technical leadership of competitors. In addition, the situation of wireless IP service is complex because some part of that service is regulated and some part is not.

3. New Role of Operating Systems as a controller for antenna subsystems:

As explained before, telecommunication is not a stand-alone system. This characteristic gives a credibility of standardization and regulation to the wireless communications. Thanks to the progress of semi-conductor technologies, the gap, which is incurred by the difference of technologies at the two sides, might be removed in an efficient manner [2]. No matter what type of equipment or systems are used, they are controlled by microcomputer chips and software. All these computer chips function under the control of some OSes, and what can be done or what cannot be done always depends on the capability of the OS. Therefore, the structure of wireless technologies is strongly influenced by the nature of the OS as well as the configuration of subsystems in the OS. In addition, Internet Protocol prefers the end-to-end processing. Thus, OS is extremely important because many functions of protocol are usually realized by software. In addition, only antenna subsystem is the front-end interface to the space and can physically configure the spatial distribution of the frequency spectrum. In this sense, Wireless-Oriented Operating System enables antenna subsystems, coupled with Software Defined Radio, to achieve the total spatial wireless resource management. The key is how to establish the efficient spatial frequency allocation at the dynamic level while maintaining the coexistence between multi-wireless standards. Also, this spatial resource scheduling needs to be done autonomously and needs to drive the subsystem towards the higher frequency utilization.

4. Current Operating System and the extension for higher frequency utilization

It is very clear that the next-generation wireless Internet cannot exist without high-speed and high-capacity transmission technologies in telecommunications. On the contrary, there is a strict restriction for the high-speed and high-capacity transmission in wireless transmission because of the shortage of the frequency spectrum. This is the most critical problem for future wireless Internet communications, and new advanced technologies have been developed since the middle of the 80s. However, all these approaches have usually been taken independently from OS; thus, OS cannot directly contribute to the most important issue for wireless communications: spatial frequency utilization. Current OSes manage basic resources such as CPU and memory, and peripherals such as hard disk drive and network interface.

There are several physical standards like Ethernet, ATM (Asynchronous Transfer Mode) and wireless LANs as a network media, which can be used by network interfaces. In all cases, OS manages bandwidth of any network media. Therefore, the role of the current OSes is managing the bandwidth, which is given by some specific hardware interface, in terms of the ‘time-axis’. This means that the managing method is based on time, but is not based on spatial utilization of wireless resources. History tells us that new systems having higher frequency utilization give more competitiveness to the new systems and drives the price equilibrium downward. However, this price adjustment mechanism is done with the strict restrictions because the frequency resources for both old and new systems cannot be optimized by the current functions of independent OSes (each OS controls independent wireless system).

Also, the current hardware configuration of the wireless system is not appropriate to accelerate the competition between multi-wireless standards. In order to achieve a fair and appropriate level of competition towards the higher efficiency of production in the wireless communications, there are two important technologies: 1) multi-wireless standards support technology (reciprocal operation technology) and 2) Wireless-Oriented Operating Systems which enables mobile equipment the efficient use of frequency spectrums

5. Wireless-Oriented Operating Systems and space domain wireless resource scheduling with antenna subsystem

In addition to the bandwidth as a parameter for measuring the wireless resources, the managing method proposed in this paper has a feature that the Wireless-Oriented Operating System controls the spatial radio wave resources dynamically as a network media used by hardware. In other words, Wireless-Oriented Operating System manages 1) Time, 2) Frequency[2] and 3) Space used by radio communications through Software Defined Radio followed by antenna subsystem. Wireless resources can be used efficiently in the space domain by optimizing these three parameters adaptively and dynamically based on the demands and nature[3] of the required services of the application software.

The key idea is as follows: Wireless-Oriented Operating System is given the authority to control the physical layer parameters of radio and antenna subsystems since the Wireless-Oriented Operating System is the only supervisor that can control the total system resources. Hardware for SDR (Software Defined Radio) can handle how much computation power can be used for error correction to compete with the poor transmission characteristics of wireless communications. For example, the current OS cannot choose the optimum physical channel, nor to pick out or modify the physical layers on an instantaneous basis. It is true that the physical layer is preferred to be transparent from OS in the OSI mode, but it is not appropriate to apply this philosophy rigidly to the wireless communications from the space domain frequency utilization point of view. In addition to the virtual [3] soft hand off [4], the followings are several candidates for the expected functionality of Wireless-Oriented Operating System and Software Defined Radio:

1) Support for dynamic route diversity data transfer from multiple base stations: With fast closed loop feed back to monitor the channel quality between base stations and the target mobile terminal, this function enables OS to choose the optimum base station to communicate on an instantaneous basis. Fast closed loop feed back is introduced to select the best base station in order to avoid transmitting the same data from more than one base station. This can improve the frequency utilization without sacrificing the quality of received data.

2) Support for dynamic adaptive error control: Regarding the wireless applications, the basic problem for the current OS is that OS has not been given the privilege or the authority for error control at the physical level. There are three major methods to control the robustness against the error: coding, error correction, and re-transmission. Which method to be used or how to combine these methods depends on the instantaneous channel conditions and requirements that are determined by the contribution of OS based on the nature of application. In theory, OS is the best candidate to do that because OS knows how much quality or latency is acceptable for the current services.

3) Support for dynamic optimum physical channel selector or combiner: This is the key because OS can choose the optimum physical channels based on the current characteristics of the transmission channel and the requirements. For example, suppose one user is inside an office building and able to use the wireless LAN service there; it is better to use it instead of the cellular system not only from the frequency resource point of view but also from the communication cost point of view. While he is moving from the office building to go outside, OS will automatically change or combine its physical channel to enable the end-to-end transparent mobility of the terminal.

6. Scheduling of time, frequency and space domain wireless resources

Resource management and reservation seem to be prudent when resources are scarce, like wireless communication [5]. In order to optimize utilization of wireless resources in the space domain, behavior and nature of the demands of the application, which creates traffic dynamically, must be grasped by OS in advance. In case of executing real-time applications such as VoIP (Voice over Internet Protocol) and movie streaming application, OS can estimate when and how much the application transfers data.

---

[2] Code is also a possible parameter.

[3] Acceptable delay, total amount of data, and duration of data, etc.

Operating System can also estimate to whom the application communicates. For real-time application, QoS (Quality of Service) required by the specific application must be guaranteed. As network QoS, there are three major parameters for end-to-end communication: 1) Bandwidth, 2) Delay, and 3) Jitter [6]. These parameters can be converted to the resource requests for time, frequency and space domain in order to allocate those wireless resources to SDR and the antenna subsystem. Therefore, required QoS can be guaranteed at the level of physical resources. On the other hand, in case of executing non-real-time applications, OS handles non-real-time traffic as quasi real-time periodical traffic by using the following procedures: 1) Reserves time, frequency and space domain periodically to transfer inestimable traffic, 2) Accumulates data of the traffic in the buffer temporarily until next period, and 3) Makes period shorter, or increases data size for a period when traffic grows. This method is an application of sporadic server [7], which is one of real-time CPU scheduling method, for network scheduling.

Time, frequency and space domain wireless resources can be scheduled efficiently because Wireless-Oriented Operating System can estimate the expected traffic with above procedure. Therefore, OS determines which radio base station to communicate with, which channel and radiation pattern to be used, and how much data is needed to transfer. These functionalities can be achieved only when all wireless interfaces and device fully collaborate with OS, the center of software.

7. Conclusions

The role of multi-wireless standards and Wireless-Oriented Operating System for the efficient wireless telecommunication and the impact of Adaptive and Dynamic Spatial Frequency Allocation on restructuring the wireless communication technologies have been described. The key idea of Wireless-Oriented Operating System presented in this paper is that the Wireless-oriented Operating System controls spatial radio resources dynamically as a network media used by Software Defined Radio and antenna subsystems. The operating systems are given the authority to manage the wireless resources, which can be measured in 1) Frequency, 2) Time, 3) Code, and 4) Space domain environments for wireless communications in order to achieve the efficient use of the frequency spectrum. Those wireless resources needed to be allocated in terms of the higher level QoS based on the demands and requirements of each application.

The new feature of Wireless-Oriented Operating System coupled with Adaptive and Dynamic Spatial Frequency Allocation can be seen as one of the key technologies to open the door to the efficient spatial resource management for the future IP based wireless communications.

References

[1] Alex C. Snoeren, Hari Balakrishnan, and M. Frans Kaashoek, " Reconsidering Internet Mobility", IEEE Proc. Eighth Workshop on Hot Topics in Operating Systems, pp. 41-46, 2001.

[2] Kano, S, "Technical innovations, standardization and regional comparison – a case study in mobile communications", Telecommunications Policy, 24, 305-321.

[3] Faramak Vakil, David Famolari, Shinichi Baba, Tadahiko Maeda, "Virtual Soft Hand-off in IP-Centric Wireless CDMA Networks", 2001 International Conference on Third Generation Wireless and Beyond, Proc. Of 3G wireless 01, pp. 704-709, 2001.

[4] Liberti, J. C., and Rappaport, T, "Smart Antennas for Wireless Communications", pp. 45 and 47, Prentice Hall PTR , 1999.

[5] Dan Chalmers and Morris Sloman, "A Survey of Quality of Service in Mobile Computing Environments", IEEE Communications Surveys, http://www.comsoc.org/pubs/surveys, Second Quarter 1999.

[6] Ashishi Mehra, Atri Indiresan, Kang G. Shin, "Structuring Communication Software for Quality-of-Service Guarantees", IEEE Transactions on Software Engineering, pp. 616-634, 1997.

[7] Andre van Tilborg, Gray Knoob, "Foundation of Real-Time Computing", Kluwer Academic Publishers, 1991.