EVALUATION OF A RESOURCE MANAGEMENT METHOD FOR AN AUTONOMOUS ADAPTIVE BASE STATION

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ABSTRACT

Many wireless systems, such as cellular and wireless LAN systems are now in use, and standardization of many of these wireless systems, is advancing. Also, wireless services, such as telephone and video streaming, have diversified as wireless systems technology has advanced. However, the sudden proliferation of wireless systems and diversification of wireless service causes problems such as unexpected traffic variations, unexpected interference, and lack of space for base stations. To solve these problems, we propose the autonomous adaptive base station (AABS), which changes the function of the base station depending on the availability of the wireless system and the quality of service. To test the efficiency of the proposed method, we evaluated its performance with computer simulations. We also developed the AABS prototype and evaluated its performance. As a result, we were able to demonstrate the effectiveness of the proposed method.

1. INTRODUCTION

Many wireless systems, such as cellular and wireless LAN systems are being used, and standardization of many of these wireless systems, such as IEEE 802.16 and IEEE 802.22, is advancing. Software defined radio (SDR) and adaptive network technologies make effective composite wireless systems possible. A lot of wide-ranging research on SDR technologies and concepts such as element technology, test beds, regulation, business models, and so on, has been reported [1]-[2]. Adaptive network technology has also made it possible to respond to various user requests by combining multiple wireless systems in heterogeneous wireless system environments [3]-[8]. Wireless services, such as telephone and video streaming, have also diversified as wireless systems have developed. However, the sudden proliferation of wireless systems and diversification of wireless services causes problems such as unexpected traffic variations, unexpected interference, and lack of space for base stations. To solve these problems, we propose the autonomous adaptive base station (AABS), a facility that changes functions depending on the availability of the wireless system and the quality of service.

Section 2 of this paper describes the proposed AABS concept and the AABS's resource management method in detail. In section 3 we discuss the performance of the proposed resource management method as evaluated by computer simulations. Section 4 provides an overview and describes the performance of the AABS prototype. Finally, section 5 briefly concludes the paper.

2. AUTONOMOUS ADAPTIVE BASE STATION

We propose the AABS, which makes autonomous decisions about which wireless system should be used and changes functions to the appropriate one. Figure 1 is a block diagram of the AABS. The AABS is composed of a wireless communication processing part, a resource management part, a load-balancing part, a traffic monitoring part, a data management table, a network interface, and so on. The wireless communication processing part has resources that equal the base station function of multiple wireless systems. The resource is a signal-processing device, such as a CPU, a DSP, a FPGA, a memory, or a power supply. The resource management part adds and subtracts the base station functions to the wireless communication system by managing resources in the wireless communication processing part based on the traffic load observed in the traffic monitoring part. It also manages base station information with the data management table.

This adaptability makes it possible to increase the number of channels in the wireless system in which the access is concentrated and discontinue the wireless system functions not being used in order to save power.

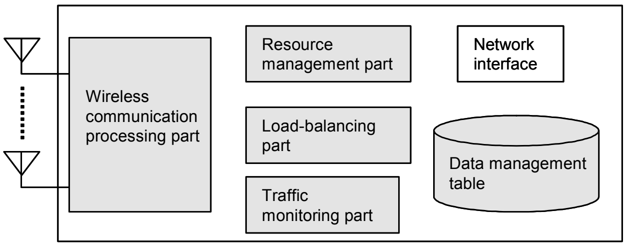

Fig. 1 Block diagram of AABS.

2.1. Resource Management Method

Our proposed resource management method controls the resources of the AABS based on traffic volume and required QoS of each wireless system. The procedure is executed as follows for each wireless system operated by AABS.

1. Each wireless system's amount of traffic, amount of requested service bands, and AABS's resource use are determined.
2. Formula (1) and formula (2) are calculated, determining the change in wireless system functions AABS must carry out.

$$\sum_{j=0}^{n} T_{ij} > Ithi * n * T\max i \qquad (1)$$

$$\sum_{j=0}^{n} Tij < (n-1) * T\max i * Dthi \qquad (2)$$

Here, T is traffic volume, Ith is increase threshold, Dth is decrease threshold, Tmax is maximum traffic volume, i is wireless system i, and j is number of working wireless system functions.

3. PERFORMANCE EVALUATION

3.1. Simulation Model

The proposed method was evaluated by computer simulation before the prototype was evaluated. AABS operates as a cell station (CS) of PHS and an access point (AP) of a wireless LAN. The simulation model is shown in Figure 2 and the simulation conditions are shown in Table 1. At this point, we assumed that AABS had resources equal to the capacity of four CSs and APs. We also assumed that CSs and APs consume the same amount of resources. To respond to a PHS and a wireless LAN at any time, the AABS is assumed to be operating one CS function and one AP function. The PHS client and wireless LAN client use the streaming service that guarantees band service. In this model, the wireless line is error-free, and the PHS client and wireless LAN client remain fixed.

To evaluate the proposed method, the service failure ratio and the AABS operating ratio, which are defined respectively as follows, were evaluated.

$$Service\ failure\ ratio = \frac{(N_{c\_loss} + N_{s\_fail})}{(N_{c\_req} + N_{s\_req})} \qquad (3)$$

Here, N*c_loss* is the number of PHS call losses, N*s_fail* is the number of Wireless LAN service failures, N*c_req* is the number of PHS call requests, and N*s_req* is the number of Wireless LAN band guarantee service requests

$$AABS\ operating\ ratio = \frac{T_{ope}}{N_{\max\_func} + T_{eva}} \qquad (4)$$

Here, T*ope* is AABS operating time, N*max_func* is maximum number of base station functions, and T*eva* is evaluation time.

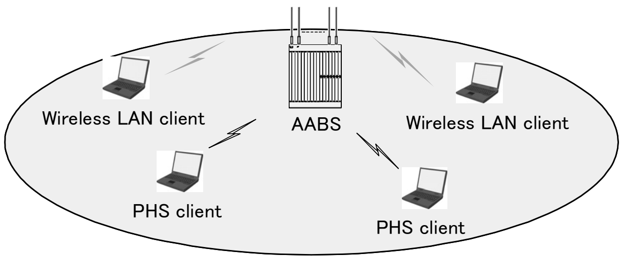

Fig. 2 Simulation model.

Table 1 Simulation conditions

Wireless system	PHS, IEEE 802.11a
Birth rate	Poisson distribution
Service time	Exponential distribution Mean service time = 300 [s]
Service type	Streaming service PHS:1ch/service IEEE 802.11a:5[Mbit/s]/service
The maximum resource of AABS	4
Resource consumption	1/CS 1/IEEE 802.11a AP

3.2. Evaluation Results

Figures 3 and 4 show the relationship between the mean λ of service birth rate and the service failure ratio and the relationship between the mean λ of service birth rate and the AABS operating ratio, respectively. The ratio of PHS clients and wireless LAN clients changes periodically at equal intervals of 1:4, 1:1, and 4:1. The conventional method fixes the function and the number of CSs and APs and always operates all CSs and APs, as shown in Figs. 2 and 3. The proposed method achieved a lower service failure ratio than the conventional method, as shown in Figure 3. This is because the proposed method flexibly responds to traffic change by adding and subtracting base station functions. In a word, using the proposed method, where traffic periodically changes and where it's difficult to predict traffic, is effective.

As shown in Fig. 4, the AABS operating ratio of the conventional method is one because the conventional method always operates all CSs and APs. However, because the proposed method adaptively operates the base station functions based on observed traffic amount, the AABS utilization rates of the proposed method are lower than those of the conventional method when mean λ of service birth rate is low. Though this effect is most distinct at a low traffic ratio, this is because the proposed method shuts down superfluous base station functions depending on traffic amount. These results show that the AABS uses base station functions effectively based on amount of traffic. Therefore, we can prevent interference with other systems by stopping transmission of unnecessary electric waves and reduce power consumption using the AABS.

The relationship between mean λ of service birth rate and service failure ratio and between mean λ of service birth rate and AABS operating ratio, when the threshold for judging the increase and decrease in the CS function changes, are shown in Figs. 5 and 6, respectively. The ratio of PHS clients to wireless LAN clients changes periodically at equal intervals of 1:4, 1:1, and 4:1. The service failure ratio is reduced by setting the reduction threshold in the state with an empty channel, as shown in Fig. 5. However, the AABS operating ratio increases so that a surplus base station function may operate by securing an empty channel, as shown in Fig. 6. Though the service failure ratio decreases by 96%, the AABS operating ratio increases by 4.3% when $\lambda = 0.005$ as shown by the results in Figs. 5 and 6. Therefore, we must set a threshold based on the operating policy because the relationship between the service failure ratio and the AABS operating ratio is a trade-off.

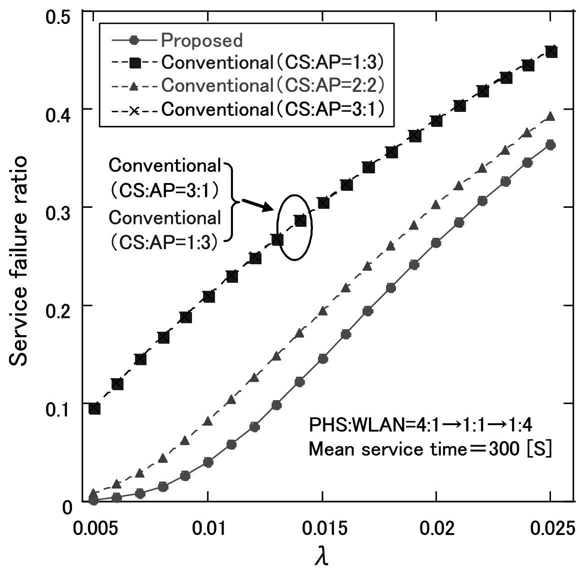

Fig. 3 Service failure ratio dependence on mean λ of service birth rate.

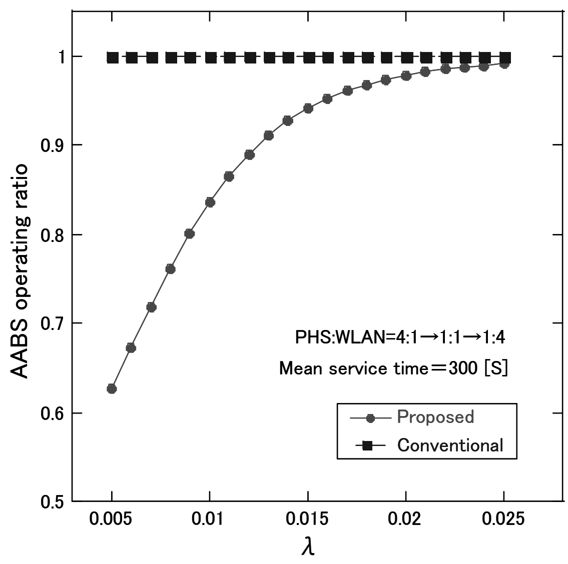

Fig. 4 AABS operating ratio dependence on mean λ of the service birth rate.

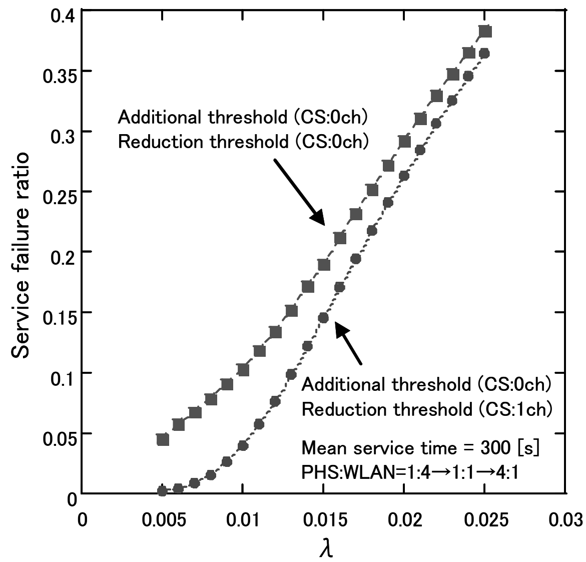

Fig. 5 Relationship of mean λ of the service birth rate to service failure ratio.

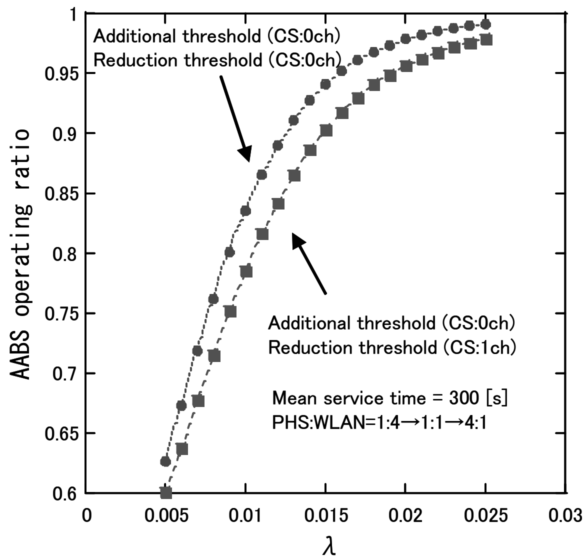

Fig. 6 Relationship of mean λ of the service birth rate to AABS operating ratio.

4. AUTONOMOUS ADAPTIVE BASE STATION PROTOTYPE

4.1. AABS Prototype Overview

Figure 7 is a picture of our developed prototype, which supports PHS and IEEE 802.11a. Table 2 summarizes the specifications of the AABS prototype, which operates as a CS of PHS and an AP of a wireless LAN. AABS can operate up to four CSs and APs at the same time. AABS operates the traffic monitoring, load balancing, QoS control, and interference avoidance functions, as the major functions. AABS operates an original resource control protocol to provide a band guarantee service in the wireless LAN system.

Fig. 7 AABS prototype.

Table 2 AABS prototype specifications

Wireless system	PHS, IEEE 802.11 a/b/g
Maximum number of resources	4
Network interface	ISDN, Ethernet
Major functions	Traffic monitoring, Load-balancing, Resource control, QoS control, Interference avoidance

4.2. Performance Evaluation

4.2.1. Evaluation model

Figure 8 shows the experimental configuration. Experimental conditions are summarized in Table 3. Each client is connected with the traffic generator by cable and initiates and ends the streaming service based on instructions from the traffic generator. All clients are using indoor stationery communications.

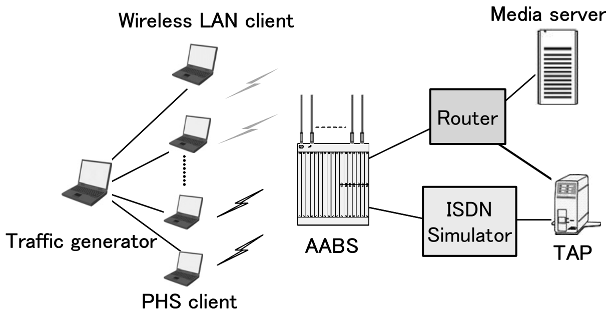

Fig. 8 Evaluation model.

Table 3 Evaluation conditions

Wireless system	PHS : 3ch/cs WLAN:IEEE 802.11a
resource	4
Birth rate	Poisson distribution, λ=0.013
Service time	Exponential distribution Mean service time = 900 [s]
Service type	Streaming Service PHS:1ch/service IEEE 802.11a:5[Mbit/s]/service
Total clients	16
Propagation environment	Indoor

4.2.2. Evaluation results

To evaluate the effectiveness of the proposed method to respond to traffic bias in detail we evaluated the service failure and AABS operating ratios with a fixed mean λ of service birth rate was fixed and a changing ratio of PHS and wireless LAN clients. Figure 9 shows the relationship between the PHS client and service failure ratios. Figure 10 shows the relationship between the PHS client and AABS operating ratios. The number of PHS clients increases as the value of the PHS client ratio increases. The conventional method fixes the function and number of CSs and APs and always operates them all, as shown in Figs. 9 and 10. The measured results of the prototype agree well with the simulated results of the proposed method. From these results, we confirmed that the prototype operated as designed and that the proposed method makes it possible for the prototype to respond flexibly to variation in traffic and to use AABS's resources efficiently.

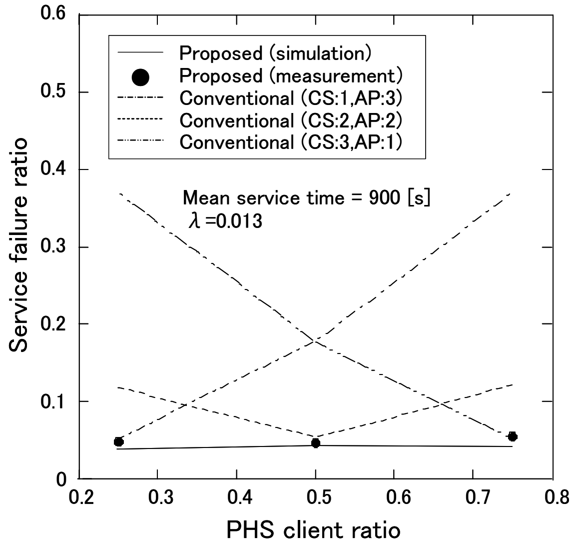

Fig. 9 Relationship of PHS client and Service failure ratios.

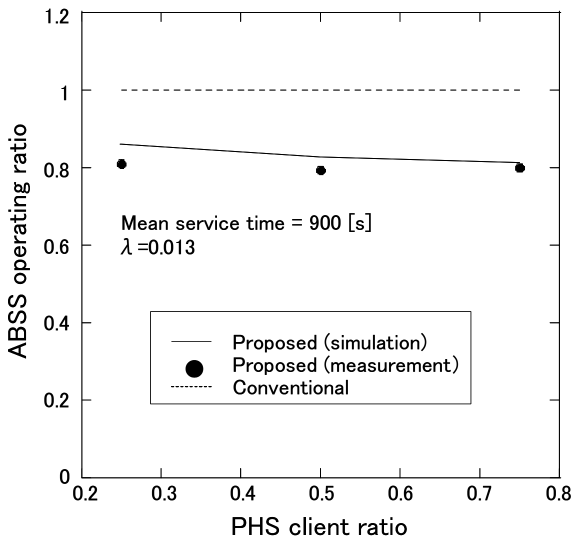

Fig. 10 Relationship of PHS client and Service failure ratios.

5. CONCLUSION

We proposed the autonomous adaptive base station (AABS), which makes autonomous decisions about which wireless system should be used and changes the function to the appropriate wireless system. We also evaluated the efficiency of the proposed method by computer simulation and by testing a prototype. From the results, we demonstrated that the proposed method makes it possible to respond flexibly to variations in traffic and to use AABS's resources efficiently.

Moreover, since AABS can shut down an unnecessary base station function when traffic is light, we can prevent interference with other systems and reduce power consumption. We confirmed that the prototype operated as it was designed and demonstrated that the proposed method operates effectively by testing the prototype.

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