# EVALUATION OF MULTILINK COMMUNICATION METHOD COLLABORATING WITH RESOURCE MANAGEMENT FUNCTION OF 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 are being standardized. Also, wireless services, such as telephone and video streaming, have diversified as wireless systems technology has advanced. Autonomous adaptive base stations (AABSs), which switch functions depending on the availability of the wireless system and the quality of service, are advantageous in this environment. We propose a multilink (ML) communication method that collaborates with AABS's resource management function to use frequency and the hardware resources of AABSs more efficiently and more flexibly. We demonstrate the effectiveness of the proposed ML communication method using a computer simulation.

## 1. INTRODUCTION

Many wireless systems, such as IEEE 802.11 a/b/g, WCDMA, are already providing various wireless services. Software defined radio (SDR) [1], cognitive radio (CR) [2], adaptive networks [3]-[6], and multi-system multilink [7][8], among others, have been studied as technologies that can use wireless systems efficiently. Although multilink (ML) communication technology can easily speed up transmission rates and improve robustness by combining multiple communication links, no ML technology for base station and frequency use has yet been reported. We previously proposed an autonomous adaptive network system. Because the autonomous adaptive base station (AABS) changes the base station functions based on user demand, the autonomous adaptive network system can flexibly respond to fluctuations in traffic. Therefore, AABS makes it more efficient to use the hardware resources of the base station than to use those of a fixed functional base station [6].

We propose an ML communication method that collaborates with the AABS's resource management function to use wireless systems more flexibly and efficiently.

In section 2, we first explain the AABS concept and then describe in detail the proposed ML communication method that collaborates with AABS's resource management function. Section 3 discusses the performance of the proposed ML communication method as evaluated by computer simulations. Finally, section 4 briefly concludes the paper.

## 2. ML COMMUNICATION METHOD COLLABORATING WITH AABS`S RESOURCE MANAGEMENT FUNCTION

### 2.1 Autonomous adaptive base station (AABS)

The AABS 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 play the same role as the base station function of multiple wireless systems. The resource is a signal-processing device, such as a CPU, a DSP, an FPGA, a memory, or a power supply. The resource management part adds and subtracts base station functions to and from 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 using a data management table. The resource management 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. Formulas (1) and (2) are calculated, determining the change in wireless system functions AABS must carry out.

$$\sum_{j=0}^{n} T_{ij} > n * T\max_i - Ith_i \qquad (1)$$

$$\sum_{j=0}^{n} T_{ij} < (n-1) * T\max{}_i - Dth_i \qquad (2)$$

Here, T is traffic volume, Ith is increase in threshold, Dth is decrease in threshold, Tmax is maximum traffic volume, i is wireless system i, and j is number of working wireless system functions.
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. AABS can also provide band guarantee service by getting information about an application's required band with ARCCP, which is an original protocol.

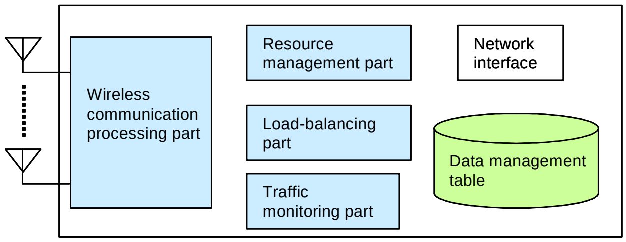


Fig. 1 Block diagram of AABS.

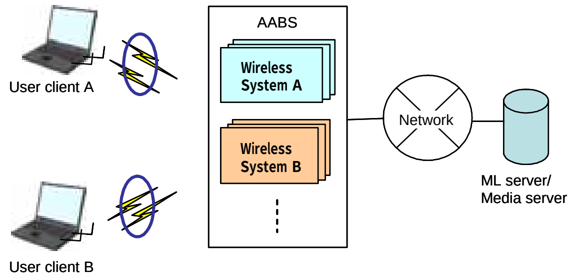


Fig. 2 Proposed ML communication system.

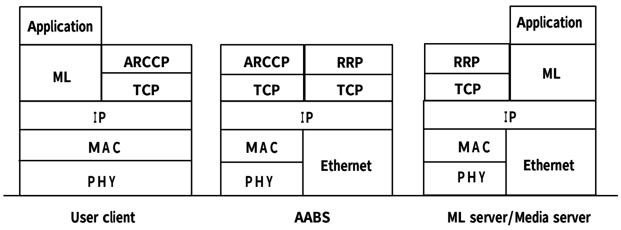


Fig. 3 Proposed ML communication protocol stacks.

## 2.2 Proposed ML communication method

The ML communication system and the protocol stack of the ML communication method are shown in Figs. 2 and 3, respectively. In Fig. 2, the user client has a wireless communication interface and communicates to the ML server by connecting to AABS with multi wireless links. The ML communication protocol, which executes data division, data rebuilding, data ordering control, the data retransmission control method, and so on, is executed over the IP layer. Moreover, the ML server sends messages to AABS about band reservation, wireless link change demand, etc. by using the resource reservation protocol (RRP), which is an original protocol.
The proposed ML communication method has the following two main features.
1. The ML server selects and reserves a wireless link in cooperation with AABS.
2. The base station functions of AABS are combined without interrupting user service.
The above-mentioned features are described in detail in 2.2.1 and 2.2.2. These features enable the proposed ML communication method to both increase the number of communication opportunities available to the user and to use AABS's hardware resources efficiently.

2.2.1 ML assignment
Figure 4 shows the ML communication establishment sequence. The user client informs the ML server of the required conditions of user application and all wireless interfaces for which the user client can be used. After choosing a wireless system, the number of wireless links, and the bandwidth of each wireless link to be used in the ML communication, based on information about the operating base station function of AABS, availability of hardware resources in AABS, and required conditions of the user application, the ML server reserves the channel or the band of each base station function of AABS. AABS decides to increase the number of base station functions based on the reservation from the ML server. Then, AABS increases the base station function according to the decision. The ML server notifies the user client of the channel reservations made by AABS and communicates with the user client via the ML communication method. As shown in Fig. 4, wireless systems A and B have been selected as wireless systems for ML communication.

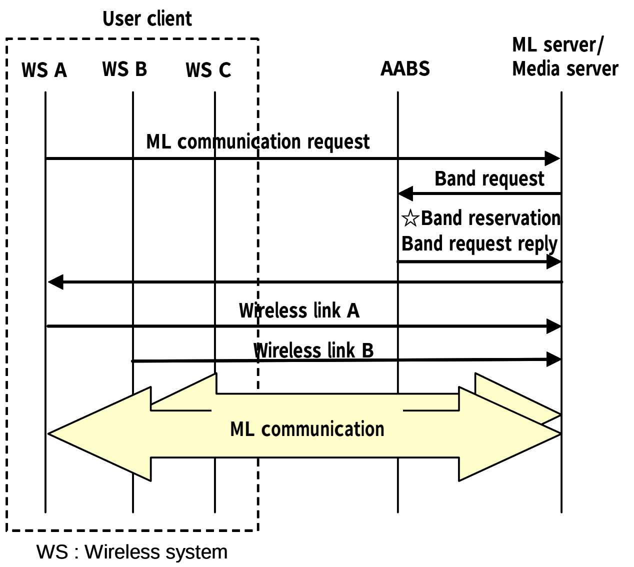


Fig. 4 ML communication establishment sequence.

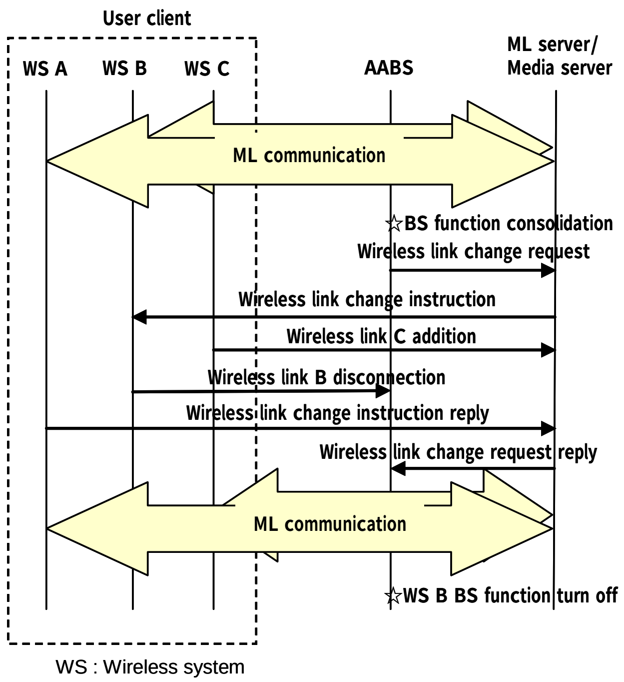


Fig. 5 Sequence of changing wireless links used in ML communication when AABS base station function is consolidated.

2.2.2 Consolidation of base station function of AABS

An example of how the wireless link used by ML communication is changed when the base station function of AABS is consolidated is shown in Fig. 5. At the end of the application shown in Fig. 5, AABS determines whether to increase or decrease the number of base station functions. Because AABS has decided to consolidate the base station function, as shown in Figure 5, it executes the consolidation processing of the base station function. At this time, if other ML users are using a base station function that will be consolidated, AABS requires that the ML server change the wireless link used by the user to a different wireless system or to another base station function in the same wireless system. The ML server notifies the user client of the change instruction of a wireless link from wireless system B to wireless system C because the base station function of wireless system B is consolidated, as shown in Figure 5. After having recently added a wireless link of wireless system C, the user client disconnects a wireless link of wireless system B based on the instruction of the ML server. After the switch of a wireless link has been executed, the user client transmits a link change indication reply to the ML server. After receiving a wireless link change indication reply, the ML server transmits a wireless link change request reply to AABS. After receiving a wireless link change request reply, AABS consolidates the base station function of wireless system B. As a result, the base station function can be consolidated without interrupting service to the user.

## 3. PERFORMANCE EVALUATION

The simulation model is shown in Fig. 6, and the simulation conditions are listed in Table 1. AABS operates as an access point (AP) of IEEE 802.11a. At the time of the simulation, we assumed that AABS had resources equal to the capacity of four APs. The user client has four IEEE 802.11a station interfaces and uses a streaming service that guarantees band service. There are three kinds of streaming services (about 2 Mbps, 6 Mbps, and 10 Mbps), and the probability of any of these services being generated is about equal. The birth rate and service time of a streaming service follow the Poisson distribution and the exponential distribution, respectively. In this model, the wireless line is error free, and the user client remains fixed. Also, the user client communicates with AP at the speed of 54 Mbps, and the AP function guarantees band service of 12 Mbps.

To evaluate the proposed method, the service failure ratio and the AABS operating ratio, which are defined in Eqs. (3) and (4), respectively, were evaluated.

$$\text{Service failure ratio} = 1 - \frac{\sum w^* N_{s\_succ}}{\sum N_{s\_req}} \qquad (3)$$

Here, $w$ is weight proportional to the use band of service, N*s_succ* is the number of Wireless LAN band guarantee service successes, and N*s_req* is the number of Wireless LAN band guarantee service requests

$$AABS\ operating\ ratio = \frac{\int N_{ope} dt}{\int N_{max\_func} dt} \qquad (4)$$

Here, N*ope* is the number of an operating base station's function resources, N*max_func* is the maximum number of base station function resources.

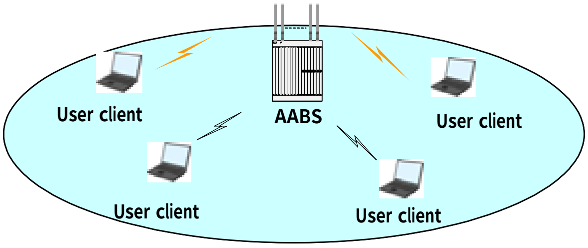


Fig. 6 Simulation model.

Table 1 Simulation conditions

| | |
|---|---|
| Wireless system | PHS, IEEE 802.11a |
| Birth rate | Poisson distribution |
| Service time | Exponential distribution<br>Mean service time = 900 [s] |
| Service type | Streaming service<br>2, 6, 10 [Mbit/s]/service |
| The maximum resource of AABS | 4 |
| Resource consumption | 1/IEEE 802.11a AP |

Figures 7 and 8 show the relationship between the traffic load and the service failure ratio and the relationship between the traffic load and the AABS operating ratio, respectively. As the figures show, the proposed ML communication method can reduce the service failure ratio without increasing the AABS operating ratio. The AABS operating ratios with and without ML are almost the same because of the efficiency of the AP consolidation processing. In other words, because the ML communication enables flexible response to user requirements, the hardware resources of AABS and the frequency can be used efficiently.

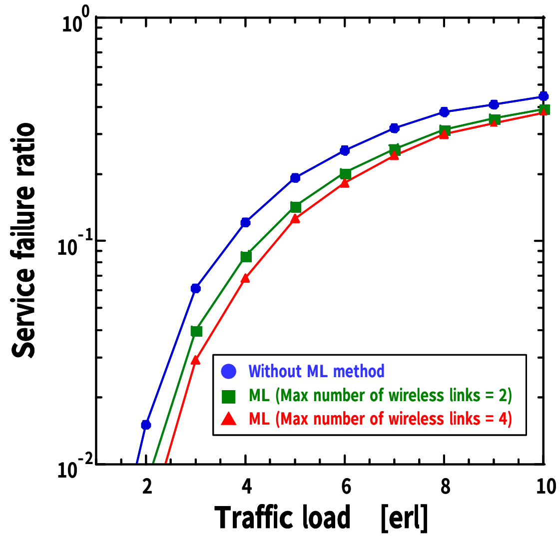


Fig. 7 Service failure ratio vs. traffic load.
(Maximum AP number = 4))

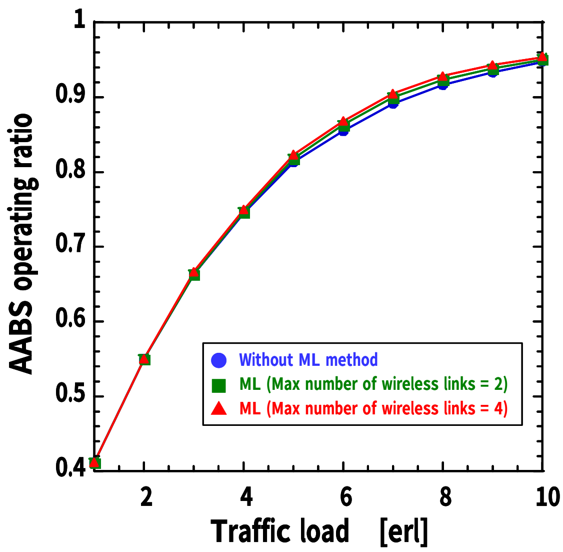


Fig. 8 AABS operating ratio vs. traffic load.
(Maximum AP number = 4)

We evaluated the effect of the proposed ML communication method when the amount of AABS hardware resources is increased. In this evaluation, we assumed that AABS operates as an IEEE 802.11a/g access point (AP). Also, AABS had resources equal to the capacity of four IEEE 802.11a APs and three IEEE 802.11g APs. The user client had four IEEE 802.11a station interfaces and three IEEE 802.11g station interfaces. Other conditions are the same as in Table 1. Figures 9 and 10 show the relationship between the traffic load and the service failure ratio and the relationship between the traffic load and the AABS operating ratio, respectively. As the figures show, the proposed ML communication method can reduce the service failure ratio without increasing the AABS operating ratio. Moreover, the amount of AABS hardware resources increases, and AABS gains the ability to more flexibly select a wireless link of ML communication. Therefore, the method is effective in decreasing the service failure ratio to enlarge the maximum number of wireless ML communication links. However, the service failure ratio is almost the same in Figure 9 when the maximum numbers of ML links are 4 and 7. This is because an AP that can be used in ML communication does not increase, so AABS can consolidate AP functions.

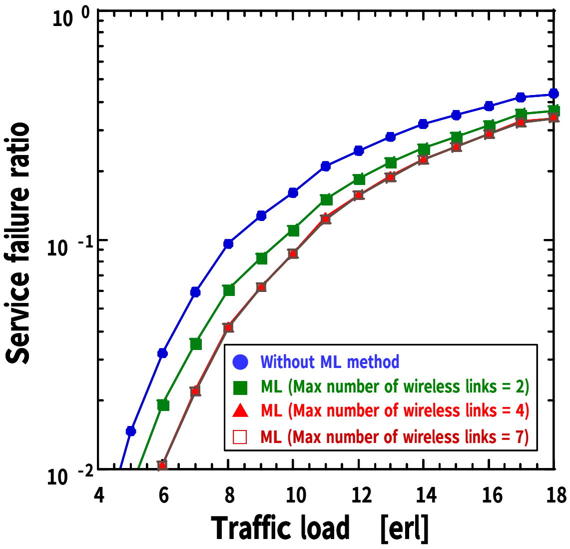


Fig. 9 Service failure ratio vs. offered load.
(Maximum AP number = 7)

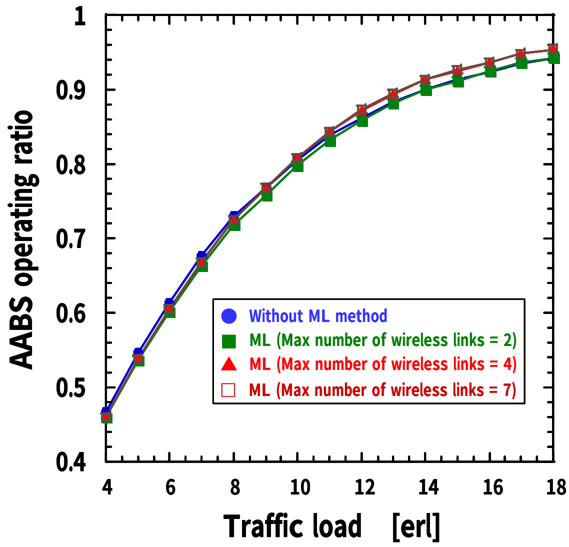


Fig.10 AABS operating ratio vs. offered load.
(Maximum AP number = 7)

## 5. CONCLUSION

We proposed an ML communication method that operates in cooperation with the resource management function of AABS. The proposed method works by selecting a wireless link and reserving it in collaboration with the ML server and AABS. In addition, the proposed ML communication method enables consolidation of the base station function of AABS without interrupting service to the user. To test the efficiency of the proposed method, we evaluated the service failure ratio and the AABS operating ratio by computer simulation. The results showed that application of the proposed ML communication method can reduce the service failure ratio without increasing the AABS operating ratio. In other words, the proposed ML communication method can increase the traffic load in AABS because it uses AABS's hardware resources more effectively.

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