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Joint Rate and BER Scheduling Resource Allocation for Wireless Communication Systems

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ABSTRACT Most resource allocation algorithms used in wireless communication networks arrange each user's transmission rate based on the type of user data but neglect the quality of the users' communication channels. In this paper, the relationship between rate and bit error rate (BER) was established by considering both the communication channel decay and the error control mechanism. A resource allocation based on joint rate and BER scheduling (JRBS) was proposed to satisfy the transmission power requirement generated by the quality change in communication channels. The JRBS analyzes the maximum transmission capacity requirement in each time slot, determines the variable capacity and the available channels in each time slot, and decides the transmission priority of data packets based on various quality of service (QoS). Ultimately, the JRBS algorithm improves system capacity to satisfy the BER and QoS of various services by the simulations.

INDEX TERMS Resource allocation, wireless communication, rate, BER, QoS.

I. INTRODUCTION

In wireless networks, transmission speed and transmission power are closely related to the quality of communication channels. Considering the different quality of service (QoS) requirements from various services, the design of resource allocation algorithms for wireless networks is much more complicated than those for wired networks [1]–[4]. A valid resource allocation algorithm could greatly improve the utilization of the system's bandwidth, and enable the system to serve more users with the same resources [5]–[8].

A current focus in research involving the wireless resource allocation algorithm was the resource allocation algorithm. This algorithm transmits data packets more efficiently by using the capacity fluctuation of wireless communication channels based on the bit error rate (BER) or the signal to interference plus noise ratio (SINR) requirement of the data packets. Resource allocation algorithms based on generalized processor sharing were proposed in [9] and [10]. This algorithm determines the transmission sequence of data packets based on the virtual completion time of each packet and the code restriction of mobile terminals. The calculation of virtual completion time was based on the minimum-power allocation algorithm, with consideration of multiple codes, the orthogonal variable spreading factor, and the QoS requirements of various services, in order to support mixed services. Some drawbacks of this algorithm were the complex computation of virtual completion time and the need to support incomplete connection information. Iturralde *et al.* [11] proposed using the wireless multimedia access control protocol with BER scheduling (WISPER), which first determines the priority of each packet. The priority of a batch of data packets in resource allocation was proportional to the minimum number of time slots required and inversely proportional to its lifetime. Data packets with similar or equal BERs were arranged in the same time slot in order to maximize the throughput. When data packets with different BERs were entered into the same time slot, the capacity of this time slot was decided by the lowest BER. Next, the number of transmittable packets in each batch was calculated and their positions in the frame are arranged according to their priorities. Therefore, it was possible that the maximum transmission capacity of this time slot was not fully utilized.

References [12]–[14] suggested the use of a fair packet loss sharing (FPLS) resource allocation algorithm, which would eliminate the massive data packet loss that occurs in the user data burst period by spreading data packet loss among all users based on the requirement of packet loss probability (PLP). This algorithm performed better than generalized processor sharing and WISPER. However, in order to calculate the long-term PLP, the algorithm needed each data stream's speed statistic characteristics. In addition, it didn't support data streams that have a relatively short time or unknown probability distribution of traffic.

Therefore, in this paper, we suggest a minimum-power constraint to satisfy the requirement from the quality change of communication channels based on transmission power. Meanwhile, the quality of the user's communication channel is completely neglected. The quality of the communication channel and the transmission rate, supported by the user terminal, vary based on time. In addition, BER resource allocation algorithms are based on the different BERs required by different services in different time slots. In contrast, rate allocation algorithms spare time slots with a large number of available channels for wireless terminal users transmitting a large number of data packets. Therefore, in this paper, we suggest a minimum-power constraint to satisfy the requirement from the quality change of communication channels based on transmission power. With consideration of both the error control mechanism and the communication channel decay, a relationship between the target SINR and BER requirement was established.

The following section II discusses maximum transmission capacity, section III discusses joint rate and BER scheduling allocation algorithm, performance is analyzed in section IV and some conclusions are presented in section V.

II. MAXIMUM TRANSMISSION CAPACITY

In literature [18], in each time slot, $W_{k,n} = \frac{m_{k,n}}{m_{k,n}+\rho_k}$ denotes the normalized capacity of a mobile terminal that used $m_{k,n}$ channels to transmit data packets of service k.

$$\sum_{k=1}^{K}\sum_{n=1}^{N_k} W_{k,n} \leq 1-\Delta \tag{1}$$

where Δ_k denotes the ratio of the transmission power used by user k to the total power, it is only meaningful when its value is within [0, 1] and satisfies $\sum_{k=1}^{n}\Delta_k \leq 1$. Reforming the above equation, and

$$\Delta_k = \frac{WN_0/P_{ps}\cdot(E_b/I_0)_k}{PG_k\cdot G_k} \tag{2}$$

$$\sum_{k=1}^{n}\frac{WN_0/P_{ps}\cdot(E_b/I_0)_k}{PG_k\cdot G_k} \leq 1 \tag{3}$$

The maximum transmission rate, or capacity, of a time slot and the optimum user arrangement, including user channels for data transmission and their transmission rates, on this time slot can be determined by establishing the optimized target.

For service k, $T_{k,l}$ is used to denote the number of mobile terminals that are assigned $l$channels in the same time slot. The normalized capacity of these mobile terminals is $T_{k,l}\frac{l}{l+\rho_k}$. For the terminal that provides service k, the number of channels assigned to it is a member of $\{1,\cdots,M_k\}$. Therefore, the normalized capacity of all terminals that provide service k is $\sum_{l=1}^{M_k} T_{k,l}\frac{l}{l+\rho_k}$, and Equation (1) can be converted into

$$\sum_{k=1}^{K}\sum_{l=1}^{M_k} T_{k,l}\frac{l}{l+\rho_k} < 1-\Delta \tag{4}$$

According to the definition of $T_{k,l}$, the terminals that provide all services in one time slot can be denoted by a vector $[T_{1,1},\cdots,T_{k,l},\cdots,T_{K,M_k}]$. C_t, used to denote the number of channels for all terminals in one time slot, can be expressed as

$$C_t = \sum_{k=1}^{K}\sum_{l=1}^{M_k} lT_{k,l} \tag{5}$$

After applying minimum-power allocation of channels, Equation (4) would be satisfied. To obtain the maximum value of C_t, an optimization must be performed, by finding the vector $[T_{1,1},\cdots,T_{k,l},\cdots,T_{K,M_k}]$ and maximization function of C_t that satisfy expression (6) below:

$$\begin{cases}\sum_{k=1}^{K}\sum_{l=1}^{M_k} T_{k,l}\frac{l}{l+\rho_k} < 1-\Delta \\ [T_{1,1},\cdots,T_{k,l},\cdots,T_{K,M_k}] \geq 0\end{cases} \tag{6}$$

According to the theory of linear planning, the maximum value of C_t occurs at the extreme points of expression (6). Those extreme points are $[(1-\Delta)(1+\rho_1),0,\cdots,0],\cdots,$ $[0,\cdots,0,(1-\Delta)(l+\rho_k)/l,0,\cdots,0],\cdots,$ and $[0,\cdots,0,$ $(1-\Delta)(M_k+\rho_k)/M_k]$. For the convenience of analysis, we used the extreme point $[0,\cdots,0,(1-\Delta)(l+\rho_k)/l,0,\cdots,0]$ in Equation (5), yielding a value of $(1-\Delta)(l+\rho_k)$ for C_t. Thus, the maximum value of C_t could be expressed as

$$C_t^* = \max\{(1-\Delta)(l+\rho_k)|l=1,\cdots,M_k,k=1,\cdots,K\} \tag{7}$$

From Equation (7), we know that when $l = M_k$, the maximum time slot capacity is

$$C_t^* = \max\{(1-\Delta)(M_k+\rho_k)|k=1,\cdots,K\} \tag{8}$$

which denotes the maximum transmission capacity for all the mobile terminals using all M_k channels in this time slot. When all channels are used, the number of mobile terminals in the time slot is the minimum. Considering the generation of orthogonal code, the inter-channel interference is also the minimum [12]. Therefore, the transmission rate of data packets by mobile terminals must follow the channel rate control mechanism so that the terminal with more packets to transmit will be allocated more available channels.

As shown in Equation (8), in order to obtain the maximum time slot capacity, C_t^*, the values of M_k^* and ρ_k^* must satisfy

$\max\{M_k + \rho_k | k = 1, \cdots, K\}$. Since the maximum capacity is obtained at extreme points, $[T_{1,1}, \cdots, T_{k,l}, \cdots, T_{K,M_k}]$ equals $[0, \cdots, 0, T_{k^*,M_k^*}, 0, \cdots, 0]$, indicating that only one type of service k^* can be handled in the same time slot; otherwise, the time slot capacity cannot be maximized. To maximize the time slot capacity, BER-based resource allocation algorithms can be adopted to assign services with different BER requirements to different time slots.

III. JOINT RATE AND BER SCHEDULING (JRBS) ALLOCATION ALGORITHM

As the discussion in Section 2 demonstrates, in a wireless environment, the transmission rate supported by the system is closely influenced by the quality of the communication channels between the base station and users. Therefore, a good resource allocation algorithm should reasonably arrange each user's transmission rate based on the quality of the communication channel in order to maximize the system's overall transmission rate. The data types of various user services should be considered as well. Different services often have different QoS requirements on the packet delay, packet loss rate, and throughput. Packet delay primarily consists of queuing delay and transmission delay. A service sensitive to time delay often requires the transmission system to support bounded delay. Generally, the main causes of data packet loss are transmission error, overtime, and full queue. There is a certain coupling relationship among the throughput, packet loss, and packet delay. In this study, we assumed that all data packets that can be received as target SINR can be received correctly, and the packet loss caused by transmission error can be ignored. We also assumed that the pool between the base station and user terminals was large enough to avoid loss caused by a full queue when data packets arrive. User data packets usually occur suddenly, and different services have different degrees of tolerance to delays; thus, resource allocation algorithms have a certain degree of freedom. By coordinating the transmissions, interference among users in the same cell can be reduced, thereby utilizing the transmission power more efficiently [19], [20]. Another problem awaiting a solution is the equal treatment of users. Equity can be evaluated in terms of three aspects: the user data throughput, the user occupancy of communication, and the packet loss rate. The equity in arranging data throughput is directly associated with the user's experience of service quality. Consistently assigning resources to the users with the best communication channel quality would maximize the system's transmission capacity, whereas consistently assigning resources to the users that have been in the queue for the longest time or to the users' data with the shortest lives would reduce packet loss rate and average delay. However, these two approaches both cause inequity among users. The indicators conflict with each other, necessitating a compromise.

In a frame period, a mobile base station receives transmission requests from mobile terminals, and its control center calls the resource allocation algorithm. Prioritized grouping determines that services with higher QoS requirements are handled first. The JRBS algorithm assigns appropriate time slots and channels to the data packets. The resource controller regulates the maximum transmission capacity of each time slot and calculates the receiving power of each channel. Since the JRBS algorithm requires the maximum capacity of each time slot to be known in advance, this algorithm cooperates with the resource controller.

To reduce the transmission delay and packet loss, a prioritized grouping policy is adopted in the proposed algorithm to ensure that services with higher QoS requirements are handled first. A group's priority is proportional to the number of packets remaining in the group and is reversely proportional to the group's remaining transmission time. In addition, the transmission rate requested by access control must be satisfied. This mechanism works through the following steps.

First, each group's priority is decided based on its remaining transmission time. For the i-th group, the priority can simply be calculated with the following equation

$$\phi_b^{(i)} = \frac{N_b}{T_d^{(i)} - T_c + T_{fr}} \tag{9}$$

where $T_d^{(i)}$ and T_c are the current group i's transmission time and used transmission time, respectively, N_b is the number of remaining packets in the group, and T_{fr} is the length of a frame. The difference between $T_d^{(i)}$ and T_c decides the remaining transmission time of the group. If the packets cannot be transmitted in the assigned time, they will be discarded; the transmission time cannot exceed T_{fr}. Therefore, in Equation (9), $\phi_b^{(i)}$ is positive, and groups will be arranged by descending order of their priorities.

Then, data packets in the group with the highest priority are transmitted.

- If group i adopts a constant bit rate (CBR) connection, its data packets will be transmitted once its required transmission rate is satisfied. Similarly, data packets of other groups that adopt this connection will be transmitted. After this step is completed, group i will not repeatedly occur in this connection.
- If group i adopts a variable bit rate (VBR) connection, its data packets will be transmitted once the minimum transmission rate of this connection is satisfied by the group; otherwise, its packets will not be transmitted. However, in the latter condition, the data packets of other groups that adopt this connection will be handled. After the completion of this step, group i will repeatedly occur in this connection.
- If group i does not adopt real-time service connections, only the packets in this group will be transmitted.

The two steps, deciding priority and transmitting data packets with the highest priority, are repeated until the data packets in all groups are transmitted.

For group i with the highest priority, appropriate time slots and channels must be assigned. In order to transmit as many data packets in one time slot as possible, the JRBS algorithm assigns channels for group i in different time slots.

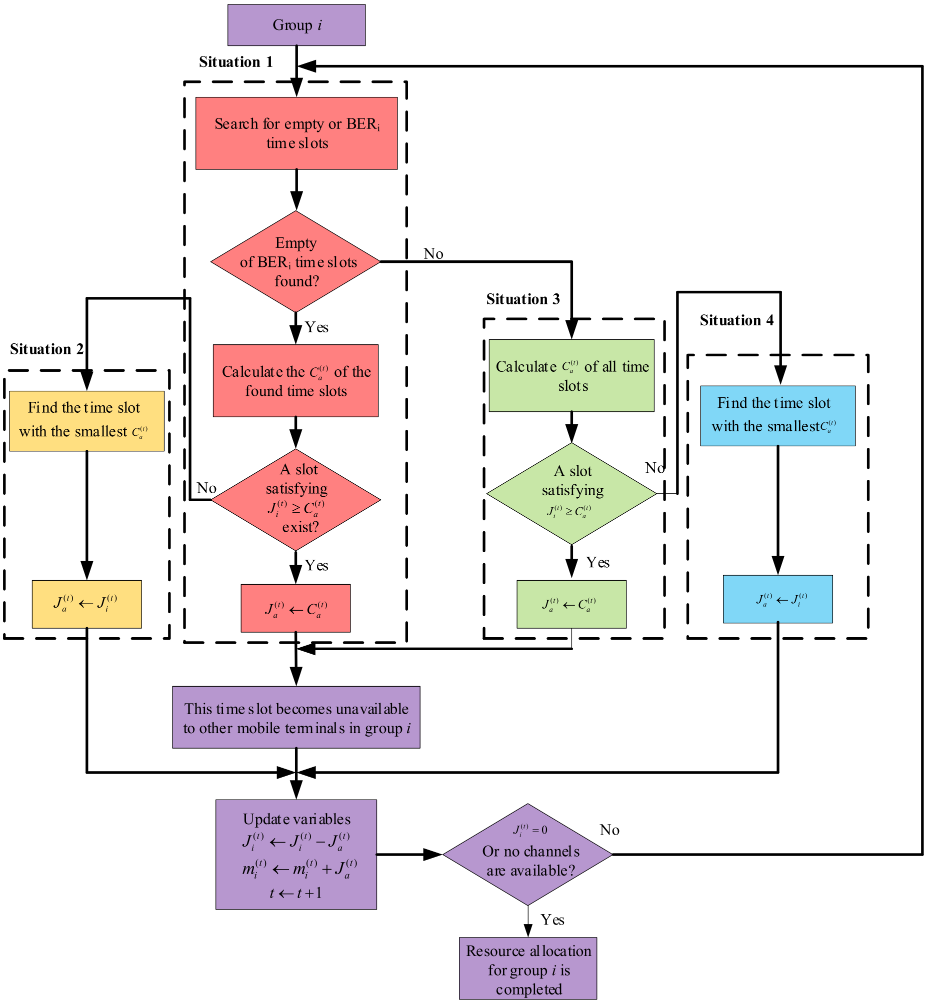

FIGURE 1. Flow of the JRBS algorithm.

The available channels in each time slot are identified by the minimum-power allocation algorithm. After assigning the time slots and channels, the receiving power of each channel is calculated.

As shown in Figure 1, the JRBS algorithm executes itself repeatedly until all the packets in group i are transmitted, or until no channels are available in the current frame. If the channels are all used, and there are packets remaining in group i, these packets will be transmitted in the next frame. If the transmission of group i is overtime in the next frame, the remaining packets would be discarded. The repetition of the JRBS algorithm is divided into two steps in Figure 1.

The following four situations are possible when assigning channels for packets in different time slots.

- In situation 1, where a time slot, empty or non-empty, exists and satisfies $J_i^{(t)} \geq C_a^{(t)}$, $C_a^{(t)}$ packets of group i would be assigned to this time slot. In this situation, the mobile terminals of group $i$would use as many channels in this time slot as possible. The calculation of $C_a^{(t)}$ is presented in the next section. Upon the completion of $J_a^{(t)} \leftarrow C_a^{(t)}$ allocation, all time slots and channels in group $i$would be used, and, correspondingly, the time slots would become unavailable. Then, the JRBS algorithm is executed.
- In situation 2, where a time slot, empty or non-empty, exists but does not satisfy $J_i^{(t)} \geq C_a^{(t)}$, $J_i^{(t)}$ would be assigned to the empty time slot with the smallest $C_a^{(t)}$ or the non-empty BER_i time slot. Therefore, time slots with greater values for$C_a^{(t)}$ could be spared for groups with more data packets. This is also a goal for transmission rate-based allocation algorithms. Upon the completion of $J_a^{(t)} \leftarrow C_a^{(t)}$ allocation, no packets would be remaining in group i.
- In situation 3, where no empty or non-empty time slots exist, but $J_i^{(t)} \geq C_a^{(t)}$ is satisfied in other types of time slots, $C_a^{(t)}$ packets in group I would be assigned to the time slot with the smallest $C_a^{(t)}$, i.e., $J_a^{(t)} \leftarrow C_a^{(t)}$. Therefore, this time slot would be unavailable to the mobile terminals in group i.
- In situation 4, where no time slot satisfies $J_i^{(t)} \geq C_a^{(t)}$, $J_i^{(t)}$ packets would be assigned to the time slot with the smallest $C_a^{(t)}$, i.e. $J_a^{(t)} \leftarrow J_i^{(t)}$.

TABLE 1. Simulation parameters.

Service	BER	SINR(dB)	t_{out} (frame)	M	r_b (kbps)	p_c (%)	N_s
Speech	10^{-3}	5.31	2	1	12.2	65	8
CBR Video	10^{-5}	9.32	5	6	12.2	8	4
VBR Video	10^{-6}	11.34	4	5	12.2	12	3
Email	0	2.94	∞	1	12.2	5	13

First, $J_a^{(t)}$ data packets will be removed from group i, i.e., $J_i^{(t)} \leftarrow J_i^{(t)} - J_a^{(t)}$. In the current time slot, $J_a^{(t)}$ packets of group i will be transmitted, i.e. $m_i^{(t)} \leftarrow m_i^{(t)} + J_a^{(t)}$; similarly, $t \leftarrow t+1$.

Upon execution of the JRBS algorithm, the receiving power of each channel in each time slot is calculated based on the minimum-power allocation algorithm. Since the number of channels is determined with the constraint of Equation (27), the minimum power allocated to each channel should satisfy the BER requirement of mobile terminals. The received power of each channel can be determined based on Equation (4) and interference measurements, while the transmit power can be calculated from transmission loss and received power.

The value of $C_a^{(t)}$, mentioned in the previous section, is determined by the resource controller and is calculated through the following steps.

First, the maximum value of $C_a^{(t)}$ is calculated and denoted by $C_i^{(t)}$. According to the minimum-power allocation algorithm, code set $\{m_{k,n}|n = 1, \cdots, N_k^{(t)}, k = 1, \cdots, K\}$ and $C_a^{(t)}$ meet the constraint of Equation (1), i.e.,

$$\sum_{k=1}^{K}\sum_{n=1}^{N_k^{(t)}} W_{k,n} - \frac{m_i^{(t)}}{m_i^{(t)}+\rho_i} + \frac{C_a^{(t)}+m_i^{(t)}}{C_a^{(t)}+m_i^{(t)}+\rho_i} \leq 1-\Delta \tag{10}$$

Therefore, the maximum value of $C_a^{(t)}$ is

$$C_i^{(t)} = \frac{\rho_i}{\sum_{k=1}^{K}\sum_{n=1}^{N_k^{(t)}} W_{k,n} - \frac{m_i^{(t)}}{m_i^{(t)}+\rho_i} + \Gamma} - \rho_i - m_i^{(t)} \tag{11}$$

Then, the value of $C_a^{(t)}$ is obtained.

A mobile terminal in group i has channels in M_i; thus, the channels available to this group must satisfy $m_i^{(t)}+C_a^{(t)} \leq M_i$, the value of $C_a^{(t)}$ is

$$C_a^{(t)} = \min\{C_i^{(t)}, M_i - m_i^{(t)}\} \tag{12}$$

IV. PERFORMANCE ANALYSES

A. SIMULATION MODEL

Table 1 presents the typical services provided by wireless communication networks. Three typical services were chosen in this study to simulate the proposed JRBS algorithm.

1) SPEECH SERVICE

Statistically, depending on the speech coding technique used, a single speech source can be divided into two phases: active phase and silent phase. When a speech signal is coded with a variable bit rate, the active phase corresponds to the speech, while the silent phase corresponds to the pauses during speech. Generally, the silent phase accounts for 60 to 65% of the signal length. More specifically, the average active phase and silent phase are 352 ms and 650 ms, respectively. In a normal speech, the active phase fits an exponential distribution very well and the silent phase less well. In most literature, an assumption that both phases fit exponential distribution is made.

2) AUDIO SERVICE

Audio service uses a constant bit rate of 32 kbps, and the lengths of audio streams, with an average length of 180s, follow nominal distribution.

3) CBR (CONSTANT BIT RATE) VIDEO SERVICE

CBR video service adopts a constant bit rate of 64 kbps. For different users, the transmission time follows an exponential distribution, with an average value of 360 s.

4) VBR (VARIABLE BIT RATE) VIDEO SERVICE

This service consists of multiple states, with each state's duration following an exponential distribution. The data rate varies in a dynamic range of 16 to 64 kbps. The average transmission time of this service is 180 s.

The input parameters for the simulation include the BER values and the target SINR required by each service; the basic transmission rate, r_b, of one channel; the available number of channels, M, for each mobile terminal in one time slot; the maximum number of channels, N_s, that can be provided by each service in one time slot; the overtime, t_{out},configuration in the unit of frame; and the probability, p_c, of each service being requested. These simulation parameters are also presented in Table 1.

Target SINR is decided by the communication channel decay, error control, modulation mode and target BER. The basic transmission rate, r_b, is decided by both the packet length and error control code rate. In this study, the basic spreading code rate of 3.84 Mchips/s was assumed, with each data domain consisting of 1952 chips. Since QPSK modulation mode was adopted, and the value of SF was 16, the length of each packet was $1952 \times 2/16 = 244$ bits. For remote login service, the error control redundancy is large, and the basic transmission rate is relatively low. For Email service,

TABLE 2. Parameters of wireless communication system.

Parameter	N_{fr}	U_{du}	W	t_{fr}	R_c	G_P
Value	15	1.5	5.0MHz	10ms	3.84Mchip/s	16

although the target SINR is low, a zero-BER is necessary; thus, the ARQ error control mechanism was adopted.

The wireless system involves multiple parameters, including processing gain, G_P; frame length, t_{fr}; the number of time plots in each frame, N_{fr}; the uplink-downlink asymmetry ratio, U_{du}; communication channel bandwidth, W; and spreading code rate, R_c; as presented in Table 2.

Among the parameters presented in Tables 1 and 2, the target BER and M should be specified by the mobile terminal and notified to the base station, while G_P, r_b, N_{fr}, t_{fr}, W, and W_c are known to the base station. The value of U_{du} is generally constant in the system, but the locations of switching points in a frame are random. The value of p_c controls the proportions of various services.

The output parameters include the average packet loss ratio, l_p; the average packet delay, d_p; throughput, t_r; and probability of congestion, b_p. For a given service, l_p can be determined by

$$l_p = \frac{N_t}{N_t + N_l} \tag{13}$$

where N_l is the number of lost packets when the time delay is greater than the set time, and N_t is the number of successfully transmitted packets. The average packet delay consists of two components:

$$d_p = d_r + d_t \tag{14}$$

where d_r is the waiting time for a code to be assigned to a packet, and d_t is the packet's transmission time. Since the uplink-downlink switching points are randomly distributed in a frame, d_t accounts for approximately half the length of a frame. The throughput t_r denotes the number of successfully received packets in a frame. When the CAC algorithm is applied, some real-time services may be blocked. Assuming that C_b and C_a represent the numbers of blocked connections and successful connections, respectively, the blocking probability b_p can be expressed as

$$b_p = \frac{C_b}{C_b + C_a} \tag{15}$$

B. NUMERICAL ANALYSIS

This section describes the simulation and numerical analysis of the proposed resource allocation algorithm. Based on the system's input parameters and service models, the simulation performed in this study returned results consisting of parameters that reflect the system's performance, such as average packet delay, average packet loss ratio, and call blocking probability. To avoid unnecessary, repeated simulation of various services, VBR video service and time delayed Email service were chosen for simulation.

The proposed JRBS resource simulation algorithm was compared to the wireless multimedia access control protocol with the BER scheduling (WISPER) [12] algorithm and the fair packet loss sharing (FPLS) [14] algorithm.

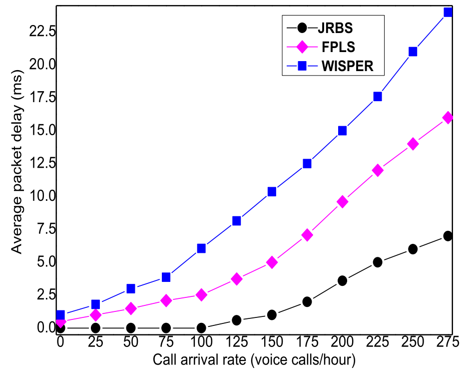

FIGURE 2. Average packet delay for VBR video service.

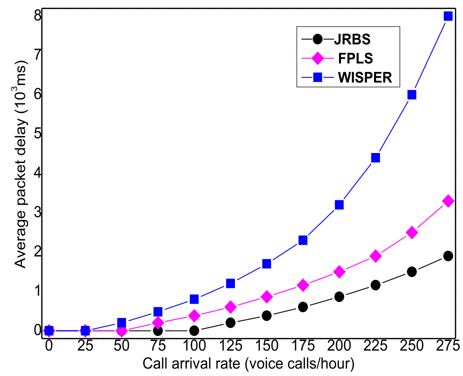

FIGURE 3. Average packet delay for Email service.

Figures 2 and 3 show the average packet delays for VBR video service and Email service, respectively. As seen in the simulation result, speech, audio, CBR and VBR video services all have similar trends of time delay, except for their maximum average time delays. The latter three have maximum average time delays of 2.3, 12.3 and 11 ms, respectively. Remote login service and Email service have similar trends of time delay, while the time delay of remote login service is shorter than that of Email service by approximately two magnitudes.

The average packet loss ratio for VBR service is shown in Figure 4. The average packet loss ratios for speech, audio and CBR services show similar trends as well. With the proposed resource allocation algorithm, these three services have maximum average packet loss ratios of 0.33, 0.25 and 0.05, respectively. Since Email service and remote login service have little requirement on time delay, the packet loss for these

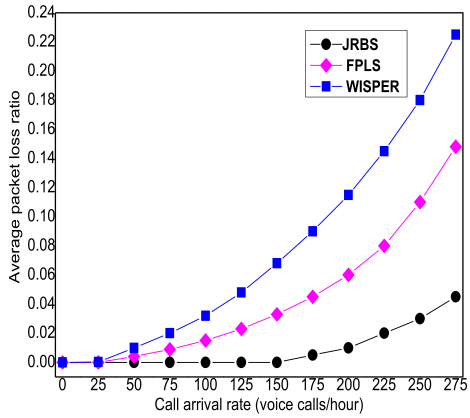

FIGURE 4. **Average packet loss ratio for VBR video service.**

two services can be estimated as 0. Figure 5 presents the characteristics of the system's throughput.

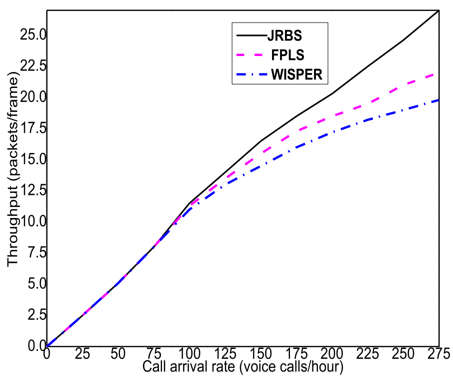

FIGURE 5. **The system's throughput.**

As the comparison demonstrates, the proposed resource allocation algorithm performed better compared to WISPER and FPLS. This improvement in performance can mainly be attributed to the adoption of the JRBS algorithm, which integrates the minimum-power allocation in order to improve the capacity of each time slot. Improving each time slot's capacity allows for the transmission of more data packets in each frame. Therefore, although under the same load, the time spent on assigning channels to data packets is reduced.

In our experiment, the influence of inter-cell interference on the scheduling algorithm's performance was considered. Inter-cell interference derives from two sources. One source is the operational loads of neighboring cells; as these neighboring cells increase, the inter-cell interference increases as well. The other source is the path loss of base station and neighboring cells. Figures 2 to 5 illustrate the influences of inter-cell interference, Δ, on average packet delay, packet loss ratio, and system throughput.

When $\Delta = 0.2$, the maximum average time delays for speech, audio, and CBR services are 6.9, 21 and 17.6 ms, respectively, and their maximum average packet loss ratios are 0.35, 0.44 and 0.25, respectively. The non-real time service, including Email and remote login, have similar maximum average time delays when $\Delta = 0.2$. However, the time

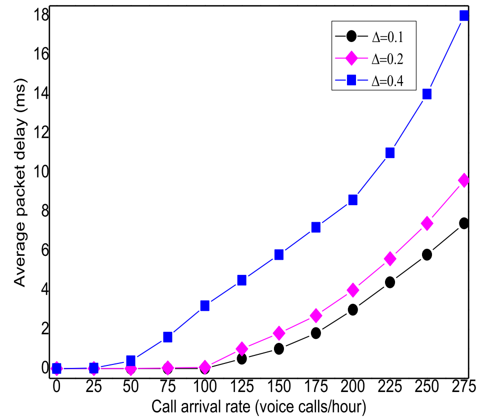

FIGURE 6. **Average packet delayfor VBR video services at different levels of interference.**

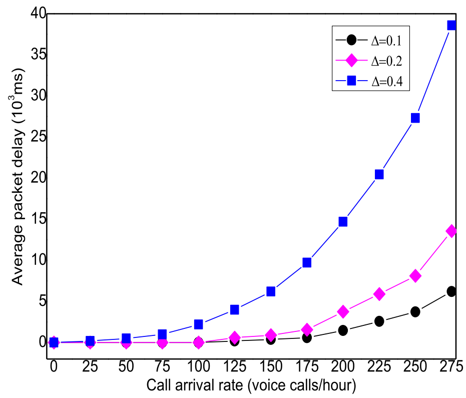

FIGURE 7. **Average packet delayfor Email service at different levels of interference.**

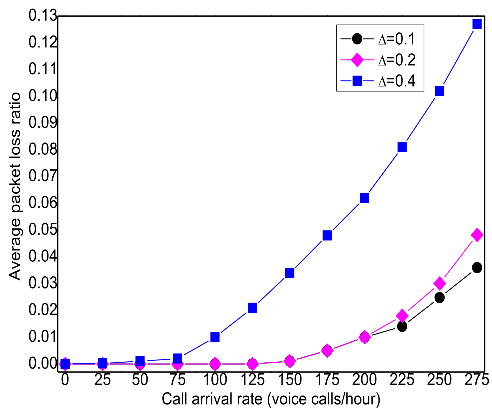

FIGURE 8. **Average packet loss ratios for VBR video service at different levels of interference.**

delay for remote login service is shorter than that of Email service by approximately two magnitudes. The maximum average time delay for Email service could reach 3.9×10^4ms.

As shown by Figures 6 through 9, the influence of inter-cell interference on the scheduling algorithm's performance is negligible when $\Delta < 0.1$. In such a condition, no inter-cell interference elimination device is needed. However, when $\Delta = 0.4$, the inter-cell interference greatly impacts the performance of the proposed algorithm; thus, a high-quality

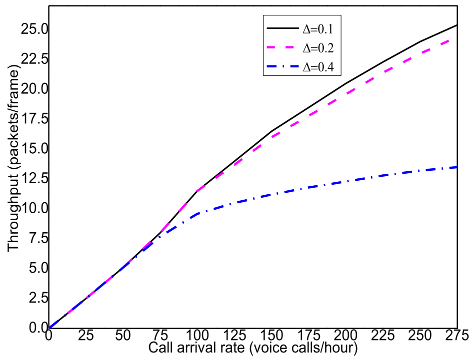

FIGURE 9. System throughput at different levels of interference.

inter-cell interference elimination device is needed to reduce or eliminate the impact.

V. CONCLUSIONS

Existing wireless resource allocation algorithms primarily arrange the transmission of data packets based on delay and signal to noise ratio (or BER) and omit the quality of users' communication channels. The implementation of a minimum-power constraint was proposed to satisfy the requirement generated by the quality change in communication channels resulted from transmission power change. In addition, a JRBS algorithm was proposed. This algorithm analyzes each time slot's requirement on maximum transmission capacity, identifies each time slot's variable system capacity and available channels, and determines the transmission priority of data packets based on QoS requirements of various services. Ultimately, this algorithm increases system capacity to satisfy the BER requirements and QoS requirements of different services.

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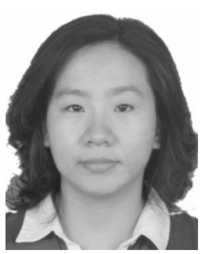

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