# (5) Wireless QoS Control Technology

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*In the Fourth-Generation (4G) mobile communication system, it is assumed that all communication, including real-time communication such as voice, video and streaming, will be packet multiplexed for wireless transmission to increase transmission path efficiency. Because the delay characteristics of wireless packets vary greatly with changes in both traffic and wireless quality, new wireless QoS control technology is proposed to compensate for that variation and realize highly efficient real-time communication at a variety of rates.*

## 1. Introduction

The Fourth-Generation (4G) mobile communication system will make it possible to support various application services by means of high-speed transmission. Those applications will have individual requirements for bandwidth and permissible transmission delay, which is to say Quality of Service (QoS). On the other hand, a packet scheme in which all signals are packet multiplexed for transmission is suitable from the viewpoint of transmission efficiency in this kind of system. Therefore, wireless QoS control for efficient wireless packet multiplexing that takes changes in radio propagation and interference into account while satisfying the QoS request of each application is a key technology for implementing the system [1],[2].

In this article, we present the wireless QoS provision functions that are currently being investigated, as well as the architecture and the new wireless QoS control technologies that are proposed. Those technologies include "hybrid scheduling", "admission control considering adaptive modulation", "reverse link packet reservation access technology" and "adaptive battery conservation management".

## 2. Wireless QoS Provision Functions

The QoS control functions provided in the proposed system include those described below.

(1) Guarantee Class and Best-effort Class

Guarantee class services for implementing voice, video, streaming and other such real-time communication at various rates and best-effort class services will be offered.

(2) Linking with IP-QoS

By assigning guarantee class packets to the Diffserv Expedited Forwarding (EF) class and assigning best-effort class packets to the Best Effort (BE) class, a link can be established between IP-QoS within the network and the wireless QoS of the wireless section on a packet-by-packet basis.

(3) Area-free Guarantee Services

A constant user transmission speed that does not depend on the location of the terminal within the cell will be provided for the guarantee class services in spite of adaptive modulation which changes transmission speed respond to radio environment.

The provision of services according to the wireless QoS described above is summarized in **Table 1**.

## 3. Wireless QoS Architecture [3]

For implementation of the functions described above and provision of a high level of QoS, a total control that spans the Radio Resource Control (RRC) layer, Medium Access Control

**Table 1 Examples of service provision according to wireless QoS and control**

| Service/Applied technology | | | Guarantee class | Best-effort class |
|---|---|---|---|---|
| Provided Service contents | | | •Constant rate service is provided regardless of changes in interference or location<br>•Guaranteed rate (reception rate) is set in the range between user requests for maximum and minimum rates according to traffic. | Best Effort service provision |
| QoS guarantee | | | Transmission rate or delay time | |
| Application type | | | Real-time | Non real-time |
| Control element | Admission control | | Applied (QoS request and changes in wireless conditions are considered) | Not applied |
| | Multistage hybrid scheduling | Scheduling between guarantee and best-effort classes | Priority control is applied in the order of Packets within the guaranteed rate → Best-effort packets → Packets outside the guaranteed rate. | |
| | | Scheduling among users of the same class | Guaranteed rate, fairness, etc. are considered. | Fairness and wireless conditions are considered |

(MAC) layer and wireless resource control is essential. This control mechanism is called the QoS architecture. The proposed wireless QoS architecture is shown in **Figure 1**. Internet Protocol (IP) packets are first mapped to the guarantee and best-effort classes according to their DSCP (DiffServ Code Point) class (EF, BE, etc.) in the RRC layer. For guarantee class packets, the amount of traffic is restricted by admission control to prevent overloading the channel. For best-effort class packets, on the other hand, further classification by relative priority may be possible. (The Assured Fowarding (AF) class is used for this). Next, in the MAC layer, a different scheduling algorithm that takes into account the respective requirements of the guarantee and best-effort classes is used. In addition, guarantee class priority scheduling is applied to both classes in the multi-stage scheduling (Fig. 1 ③). In this way, the two classes completely share the resources, yet the rate for the guarantee class can be guaranteed regardless of the best-effort class traffic. This hierarchical scheduling scheme is defined as hybrid scheduling. After that, the appropriate transmission parameters are selected, wireless resources are allocated and the packets are transmitted.

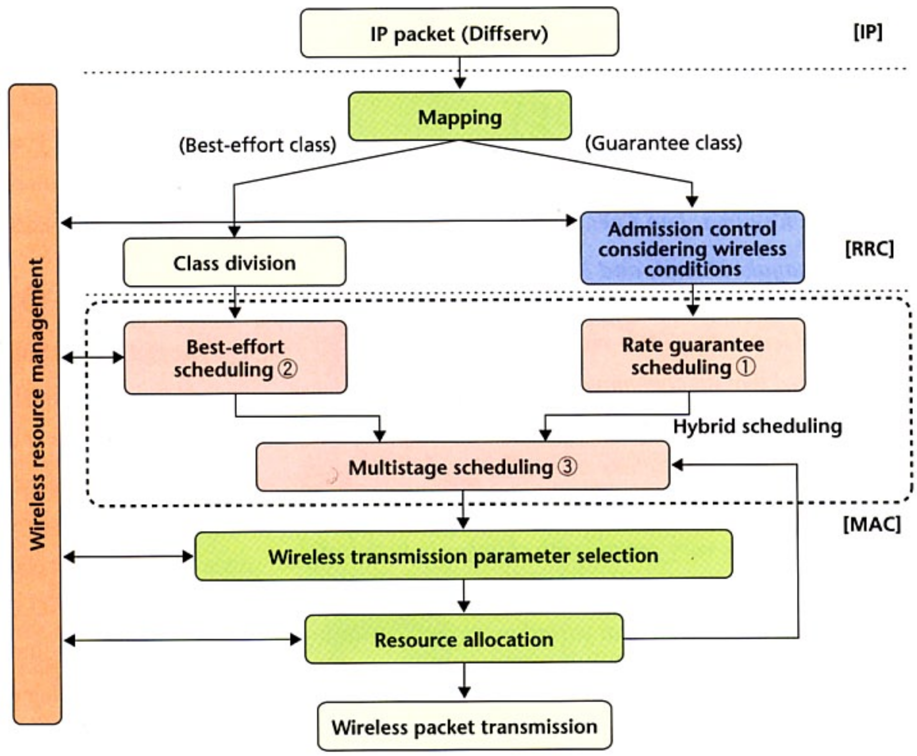


**Figure 1 Wireless QoS architecture**

Admission control and hybrid scheduling are explained in detail below.

### 3.1 Admission Control Considering Radio Conditions [4]

Recently many communication applications have functions to respond flexibly with changes in transfer rate by variable rate coding. Therefore, the guaranteed rate can be set flexibly within the range of permitted variation in the user rate. The number of users accommodated can be increased by using this flexible admission control.

Also, although the transfer rate varies with changes in the propagation and interference conditions for a user in a wireless environment where adaptive modulation is used, the proposed system has the feature of providing a fixed guaranteed rate under the area free conditions. That is accomplished by using the lowest transfer rate with the modulation parameter set that is used for packets when the Signal to Interference and Noise power Ratio (SINR) is low, such as at the cell edge, etc., as the criterion value of the link capacity. (See **Figure 2** (a).) Furthermore, to give consideration to the efficiency of resources, the receivable rate is calculated on the basis of actual traffic measurements rather than the already received guaranteed rate, as shown in Fig. 2 (b). The guarantee class satisfaction rate obtained by simulation-based evaluation and the best-effort class transfer rate are presented in Fig. 2 (c) and (d). The RR in the figure indicates the characteristic for round robin without admission control and the Priority Scheduling (PS) indicates the characteristic for unconditional priority placed on the guarantee class. From these characteristics, we can see that the proposed system (wireless QoS) is enable to increase the satisfaction rate for the guarantee class users without greatly degrading the transfer rate for the best-effort class users by setting the guaranteed rate dynamically set within the range between the maximum and minimum rates requested by the users and performing scheduling that takes the guaranteed rates into consideration.

### 3.2 Hybrid Scheduling

Scheduling in which the transmission order is set when

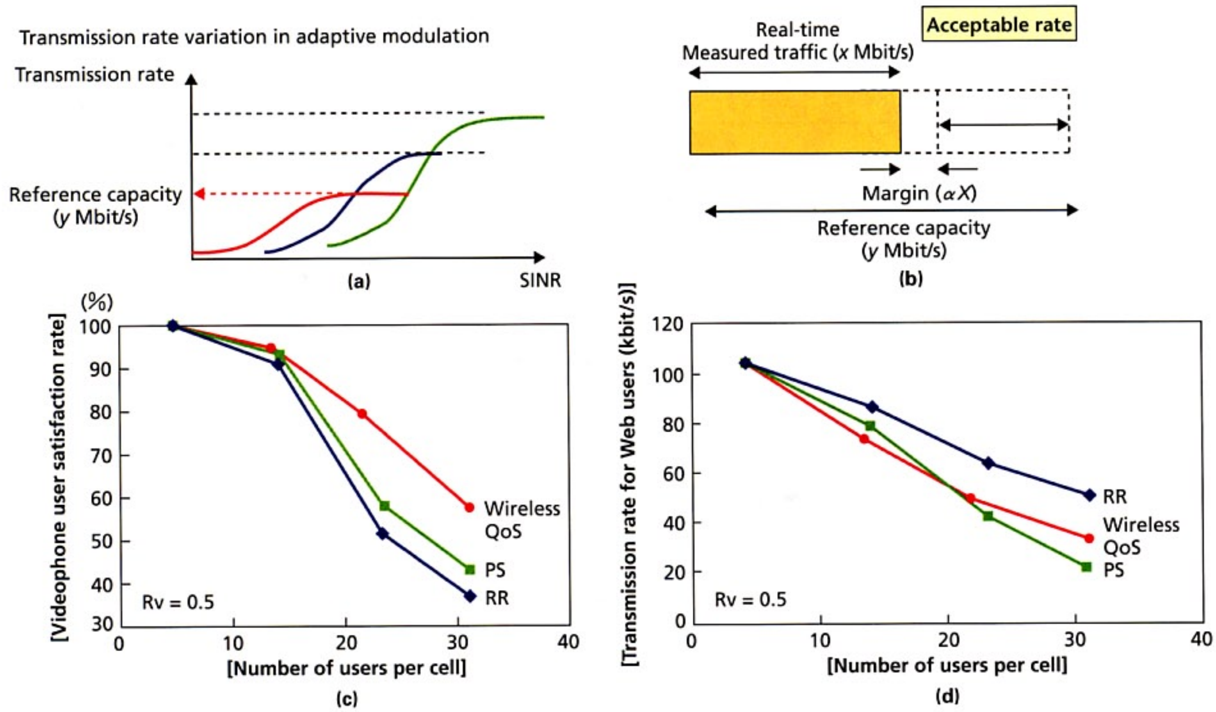


**Figure 2 Principle of admission control taking wireless conditions into account**

packets addressed to multiple users are transmitted over a shared channel is an important technology for achieving QoS. The efficient use of frequency bands, transmission power and other such wireless resources is also needed in a mobile communication environment, and increasing the efficiency of those wireless resources is also an objective of scheduling. There have been many proposals for scheduling that takes QoS requests into account [3] or scheduling whose purpose is to increase wireless resource efficiency [4]. However, the 4G system, for which implementation of QoS is one of the requirement, aims both for implementation of QoS by the coexistence of scheduling for different user QoS and for increased efficiency of wireless resources. Hybrid scheduling [5],[6] has been proposed as a means of achieving that objective.

The configuration of hybrid scheduling is shown in **Figure 3**. Here, we explain the downward transmission. As described in section 3, each packet is first classified as either a guarantee class packet or a best-effort class packet. The classified packets are placed in transmission buffers. Those addressed to a guarantee class user go to a buffer prepared for that user; those addressed to a best-effort class user go to a buffer prepared for each user or QoS class. This buffer configuration is used because, from the viewpoint of QoS guarantee, control based on individual user guarantee rate and permitted delay is necessary for guarantee class users, while control based on QoS class is sufficient for best-effort class users. However, when scheduling that takes wireless channel efficiency into account is performed, as described below, it is necessary to consider the propagation situation of each user, and a configuration in which there is a buffer for each user becomes necessary.

Next, flow control that takes into account the guaranteed rate set by the admission control described in section 3.1 is performed for the guarantee class user; for the best-effort class user, scheduling that emphasizes wireless channel efficiency and fairness between users or between classes is performed. Specific scheduling examples for guarantee class and best-effort class users are described below.

(1) Guarantee Class

- Weighted Round Robin (WRR): Each user sends the weighted amount of packets in turn.
- Header Early First (HEF) [7]: A time stamp (TS) is attached to each packet, and the time stamps of the packet at the top of the buffers are compared. Then the packet having the lowest time stamp is taken first.

  In either method, the number of packets taken from the buffer depends on the guaranteed rate set by the admission control.

(2) Best-effort Class

- Proportional Fairness (PF) method [8]: Packets are transmitted in order of largest (instantaneous SINR)/(mean SINR)

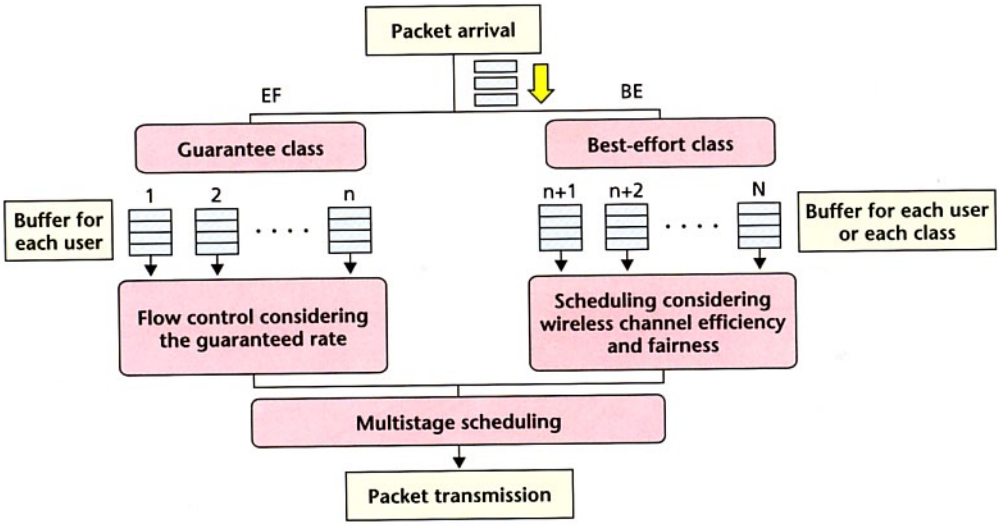


**Figure 3 Hybrid scheduling**

measured in a certain area. The efficiency of wireless resources and fairness of transmission opportunity among users are taken into account.

- Class-Based Queuing (CBQ): When class-based QoS control with transmission buffers configured for each class is used, a weight is assigned to each class according to its priority and packets are taken from the buffers according to their weights.

In the multistage scheduling, the guarantee and best-effort classes undergo further scheduling in the priority order of (1) guarantee class packets that are within the guaranteed rate, (2) all best-effort class packets, and (3) guarantee class packets that are not within the guaranteed rate. The packets are then sent to the lower layer.

The hybrid scheduling described here makes it possible to aim for efficient use of wireless resources while guaranteeing the delay and transmission rate for guarantee class users and maintaining some degree of fairness among users by taking wireless channel efficiency and fairness into account for best-effort class users.

## 4. Reservation Type Reverse Link Packet Transmission Protocol

For downward transmission, resource allocation on a packet by packet basis is relatively easy because the base station can manage the all transmission on forward packet channel. For reverse link packet transmission, on the other hand, the random access scheme is used basically, and signal error due to Multiple Access Interference (MAI) may occur if multiple packets are sent at the same time, thus causing a transmission delay. Under such conditions, achieving guarantee class packet transmission requires a means of allocating resources to guarantee class packets with priority while restricting the amount and rate of guarantee class traffic with the admission control and scheduling techniques described above and adjusting the transmission timing to prevent excessive overlapping of packets. We therefore propose to introduce the following techniques to MAC protocol, based on reservation access for uplink access protocol and aim for coexistence of both high efficiency and guaranteed QoS.

(1) Prioritized Resource Allocation (PRA) [9]

When resources are allocated on a reservation basis, prioritized allocation of resources is implemented by allowing a larger precedence temporal area for guarantee class packets than for best-effort class packets. PRA operation is shown in **Figure 4**.

(2) Individual Control Channel Allocation in Units of Bursts

The allocation of an individual low rate control channel in units of packet bursts (sending and receiving a series of packets on the level of, for example, the downloading of one Web page), and then using that channel to send reservation signals to the base station from terminals requesting the allocation of resources, together with executing closed loop high-speed

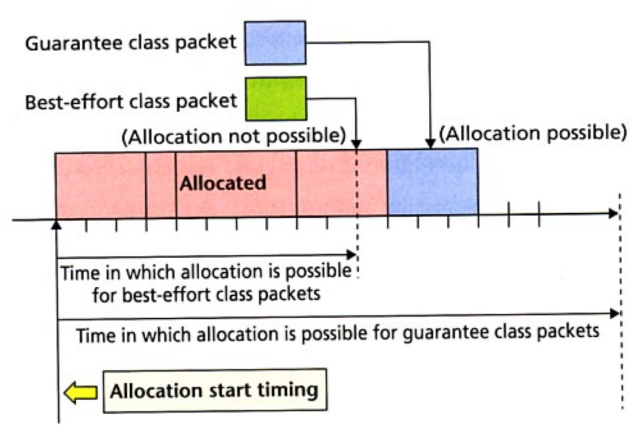


**Figure 4 Outline of PRA operation**

Transmission Power Control (TPC). This procedure makes packet by packet power ramping unnecessary and makes it possible to increase channel capacity [10],[11]. This channel can also be used to carry acknowledge signals for Hybrid ARQ (H-ARQ), Channel Quality Indicator (CQI) notifications for Adaptive Modulation and Coding (AMC), and training signals for adaptive array control.

(3) Interleave Reservation

Reservation control generally involves a rate drop associated with the Round Trip Time (RTT) for reservation and grant control. The rate drop can be prevented by executing multiple reservation control process on one terminal in parallel.

## 5. Adaptive Battery Conservation Management

The generally used method of conserving the terminal batteries is to receive the paging signal transmitted from the base station intermittently while in stand-by mode. In existing connection oriented mobile communication systems, in which communication starts after a connection between the mobile terminal and the base station has been established at the beginning of a call, each call has a clear beginning and end. When the call ends, the terminal immediately changes to the stand-by state. Also, the period for intermittent reception is usually set to only one period.

In connectionless packet communication systems such as a wireless LAN, in which communication is accomplished on a packet by packet basis without establishing a connection, the link layer is not explicitly notified of the beginning or end of a call, so a timer is used to trigger the transition to the stand-by state. It is assumed that all communication in the 4G system will be transmitted by means of wireless packet multiplexing. Therefore, if the conventional battery conservation method is used, the paging delay associated with intermittent reception, etc. may result in, for example, loss of the initial packets in a real-time communication. To overcome that problem, Adaptive Battery Conservation Management (ABCM) has been proposed as a method that can be used for connectionless communication and also takes QoS into consideration [12].

Packet communication mostly involves two states, one in which packet bursts are received in succession and one in which nothing happens at all. Focusing on this characteristic, ABCM defines a new Battery Saving Mode (BSM) to improve battery conservation.

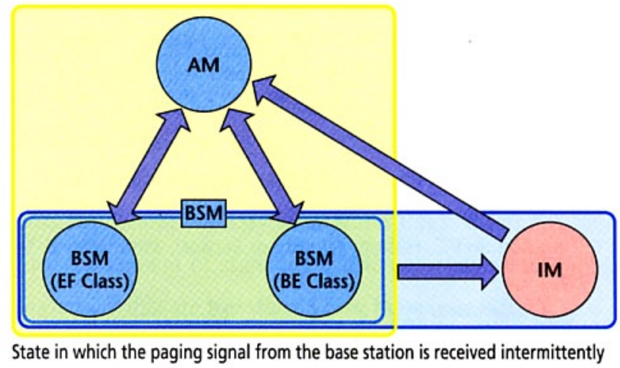


**Figure 5 ABCM state transitions**

The state transition diagram of the terminal for ABCM is shown in **Figure 5**. Three terminal states are defined: Active Mode (AM), Idle Mode (IM) and BSM. For BSM, multiple save modes (BSM-EF and BSM-BE) are defined in correspondence with the QoS classes specified by DSCP. State transitions are controlled by a timer.

BSM is an intermediate state between AM and IM, and the control signal from the base station is received intermittently, as in IM. The difference between BSM and IM is that the intermittent receive period is set according to the DSCP in BSM, and a shorter period is set for the EF class, which has strict delay requirements, than for the BE class. Furthermore, the timer for transition to the BSM state is also set according to the DSCP, so the timer used for the EF class is longer than the one used for the BE class.

This method makes it possible to guarantee the packet delay time for the EF class, although the battery conservation is less effective than that obtained with the conventional method. For the BE class, on the other hand, effective battery conservation is possible (although a maximum increase in delay equivalent to the intermittent receive period can be expected), and the results of simulation evaluation show that an estimated improvement of about 30% relative to the convention method in which BSM is not used can be obtained.

## 6. Conclusion

We described wireless QoS technology that has been proposed for the 4G system and is under evaluation. In the future, we plan to evaluate the technology in more detail by means of simulation and to test compatibility and effectiveness in various actual applications using a prototype system.

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## Abbreviations

ABCM: Adaptive Battery Conservation Management
AM: Active Mode
AMC: Adaptive Modulation and Coding
BE: Best Effort
BSM: Battery Saving Mode
CBQ: Class-Base Queuing
CQI: Channel Quality Indicator
Diffserv: Differentiated Services
DSCP: DiffServ Code Point
EF: Expedited Forwarding
H-ARQ: Hybrid ARQ (Automatic Repeat reQuest)
HEF: Header Early First
IM : Idle Mode
IP: Internet Protocol
MAC: Medium Access Control
MAI: Multiple Access Interference
PF: Proportional Fairness
PRA: Prioritized Resource Allocation
PS: Priority Scheduling
QoS: Quality of Service
RR: Round Robin
RRC: Radio Resource Control
RTT: Round Trip Time
SINR: Signal to Interference and Noise power Ratio
TPC: Transmit Power Control
WRR: Weighted Round Robin