

A Dynamic Channel Allocating Method Adapted to Users' Preferences in Circuit Switching of W-CDMA

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Abstract

Recently a number of browser phones which can transmit data by using cellular phones has been increasing rapidly. At present, a number of subscribers to IMT-2000 (International Mobile Telecommunication 2000) such as W-CDMA and CDMA2000 of the third generation service is increasing gradually in Japan, and multimedia transmission become very familiar to us. Additionally, broadband data communications using browser phones such as HSDPA (High Speed Downlink Packet Access) and the fourth generation mobile communications are being developed. However, as radio resource is limited, it is difficult for the current circuit switching systems to provide the satisfactory streaming service from the viewpoint of high quality image and bandwidth satisfying users' requests because the circuit switching allocates fixed 64kbps channels to all users.

This paper focuses on the streaming service for the circuit switching systems, and considers how to provide a satisfactory communication service. In addition, it proposes a channel allocation method in consideration of users' importance preferences regarding bandwidth, calling loss and cost. The proposed system provides a management server at the base station where user preference is analyzed by using AHP (Analytical Hierarchy Process). Additionally, it uses the QDM method based on value engineering for the channel allocation algorithm to allocate the most appropriate channels ranging from 32kbps to 128kbps. Moreover, this paper evaluates the validity of the proposed system by simulations from the viewpoint of the SLA (Service Level Agreement).

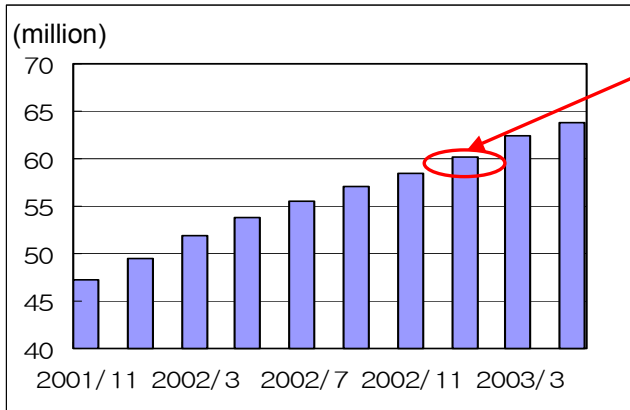
From the results obtained by simulation, we found that the proposed system can provide users with the good service of high satisfaction to guarantee connectivity even if traffic is heavy.

Keywords: IMT-2000, SLA, User Satisfaction, Dynamic Channel Allocation, AHP, QDM

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Introduction

- Recently a number of browser phones which can transmit data by using cellular phone has been increasing rapidly.



Over the 60 millions
December in 2002

MCPC*prediction

In 2004, over 84
million people
will subscribe to
cellular phone

IP cellular phone subscriber
(Telecommunications Carriers Association
)

*Mobile Computing Promotion Consortium

1. Introduction

Recently a number of browser phones which can transmit data by using cellular phones has been increasing rapidly. According to a report published by Telecommunication Carrier Association (TCA), the number of subscribers to IP cellular phone has exceeded sixty millions in December 2002 [2]. Additionally, the third generation mobile systems called IMT-2000 such as CDMA2000-1x of "au" using CDMA2000, FOMA of "NTT DoCoMo" and Vodafone Global Standard of "J-Phone" using W-CDMA started in operation in 2002 and a number of third generation subscribers are increasing. "NTT DoCoMo" also announced that HSDPA (High Speed Downlink Protocol Access) defined in 3GPP Release 5 which realize up to 14.4Mbps communication service will start in 2004 and is performing an experiment of the fourth generation mobile system which will be targeted in service in 2010. Mobile communications using cellular phones will be able to provide high-speed communications as wired dedicated line communications, and data communications by using cellular phones will be increasing more and more in the future.

As stated above, when many users switch over to the third generation mobile systems, it will become more difficult for the current circuit switching service to provide the satisfactory communication service corresponding to multimedia traffic from the viewpoint of "picture quality" and "broadband" on users' requests, because it allocates fixed channels to all users.

Proposed System

◆ Dynamic channel allocating method in consideration of users requests

- ✦ Extract user preference parameters such as bandwidth, cost, connectivity and sent them to the base station.
- ✦ Allocating channels according to users' requests (satisfactory parameters) by using AHP



Enable to provide data communications that satisfies users' preference requests

2. Proposed system

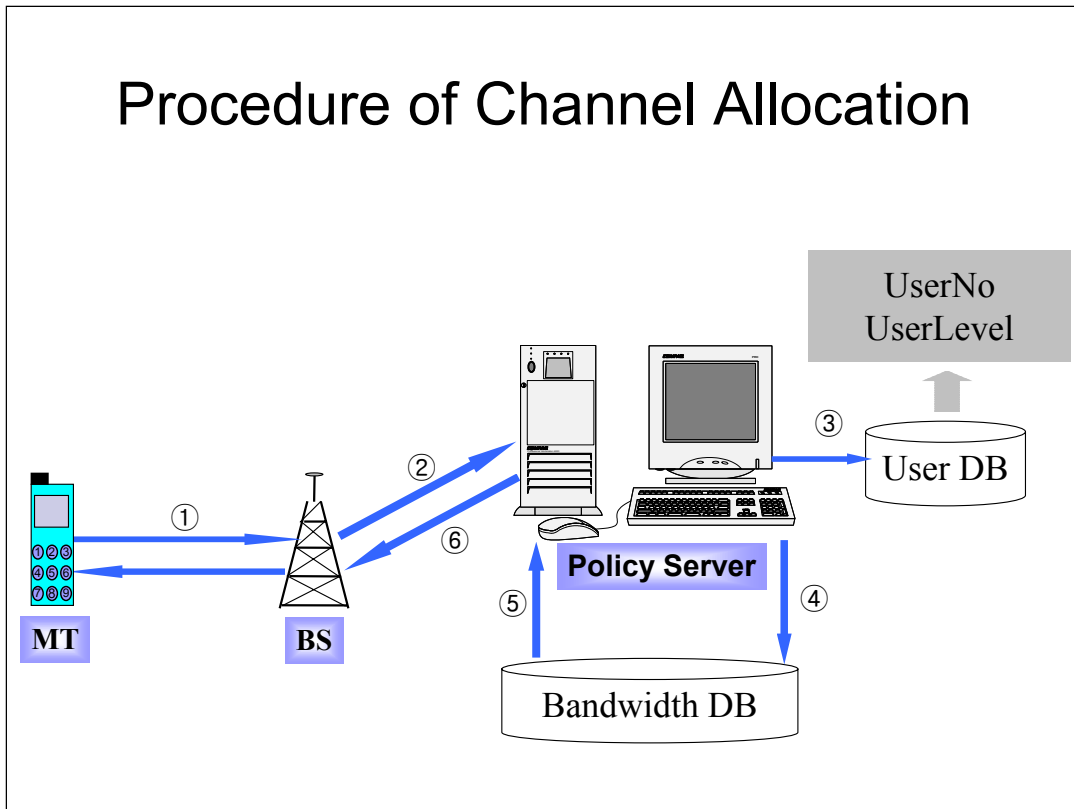
We consider that it is important for future wireless communications to provide more elaborate services for individual users in consideration of users' important parameters based on users' preferences. Additionally, future wireless communication services can be expressed from the viewpoint of 4W1H as indicated in [3].

- Who users' variety, freedom and selectivity of communication partners
- What richness, variety and selectivity of information contents
- When personal diversification in the aspect of time transcendence
- Where enable to communicate corresponding to the location wherever user and his/her partners are
- How how to provide the personally customized service

In this research, we focus on the "How" aspect and consider how to provide streaming delivery service that can best reflect users' preferences. Conventional circuit switching streaming system using 3GPP's 3G-324M can not provide streaming services with a variety of image quality because it can not appropriately allocates channels according to traffic. It may cause many calling loss when traffic is congested, and can not utilize channels efficiently. Therefore, users tend to be unsatisfied with their communications.

In this study, we propose a channel allocation system based on users' preferences which can be specified by using a java application running on cellular phones. The proposed system analyzes what are significant for users by using AHP and obtain significant levels with numerical values.

Procedure of Channel Allocation



3. Traffic Management System

3.1 System Architecture

The traffic management system in the proposed system consists of a Base Station (BS), a Radio Network Controller (RNC), Mobile Terminals (MT) and a Policy server, a Bandwidth DB and a User DB which is placed at the BS .

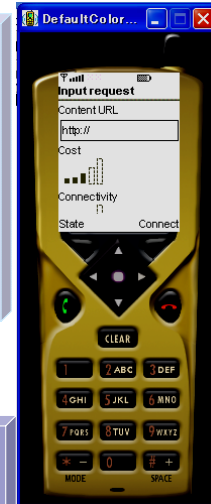
Users input importance levels of each parameter regarding bandwidth, connectivity, and cost from the MT when starting data communications, and they send over to the BS. It is assumed that users can obtain some channels which correspond to users' requests.

The proposed traffic management system allocates channels according to the following procedure.

- 1) The user inputs satisfactory parameters which the user consider significant and send its result with data size and an application name.
- 2) The BS requests the Policy Server to provide service which conforms to SLA level
- 3) The Policy Server registers users' SLA level to the User DB.
- 4) The Policy Server inquires to the Bandwidth DB whether it is possible to provide the service which conforms to SLA level.
- 5) The Policy Server answers the user whether it is possible to provide the service which conforms to SLA level based on the answers from the Bandwidth DB .
- 6) The user makes a decision whether to start data communication or not based on the answers from the BS.
- 7) If communication quality falls below the predetermined threshold, the BS reconfigures user channels.

Specifying User Preferences

- Specifying operation
 - Use Java application implemented in cellular phone
- Input of importance levels on users' preferences
 - Select a level from "most important", "more important", "important", "less important", "least important" (Importance levels are easily understood)



Input image

Input data will be sent to the management server at the BS and be evaluated as significant values by using AHP.

3.2 Informing Users' Preferences

Here, we propose the method of inputting users' preferences by using a java application running on mobile systems, where input data is converted to numerical value by AHP. AHP is a decision making method proposed by T. L. Saaty[4]. It evaluates importance levels of users' satisfactory parameters by expressing user's decision with numeric value.

By selecting importance levels of each parameter based on the paired comparison table, users' importance levels of each parameter can be evaluated. Incidentally, importance levels of parameter should be easy to imagine for the users, so users select their preferences from "most important (9point)", "more important (7point)", "important (5point)", "less important (3point)" and "least important (1point)".

Input data will be sent to the BS with an application name after required items are received and "Enter button" is pushed. After that, the weights of parameters are determined by using AHP based on the importance levels which users inputted by using AHP.

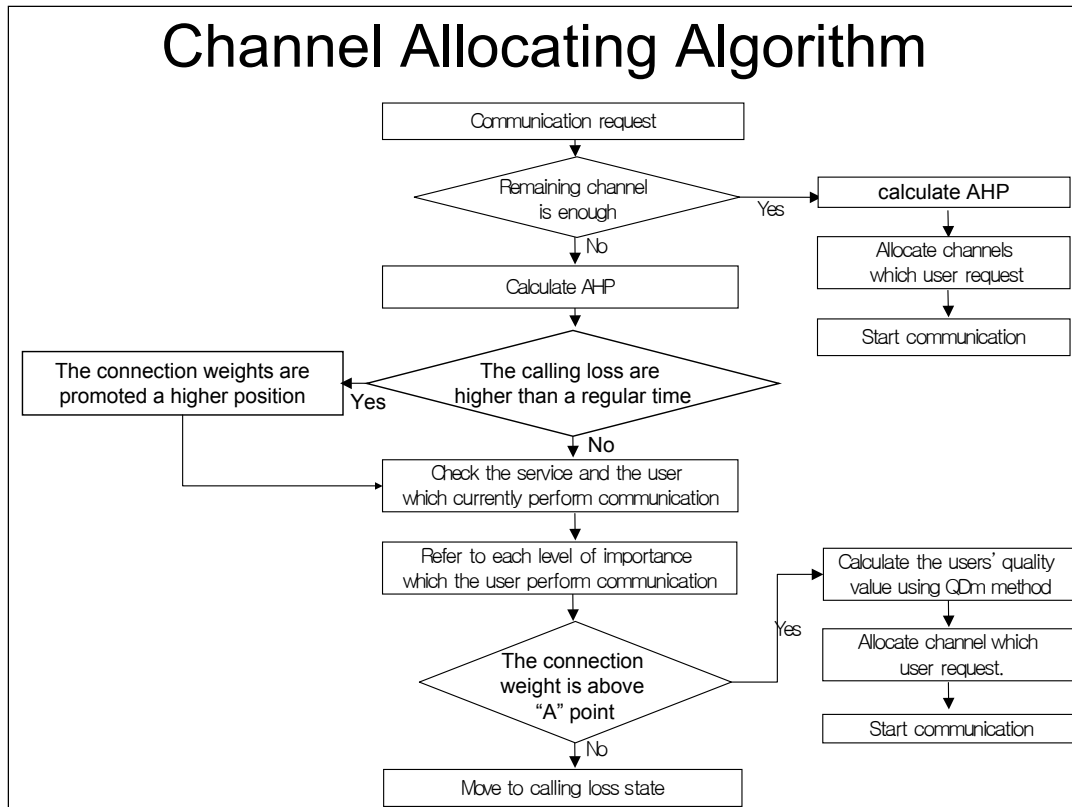
An example of formulating the AHP is shown as Table 1. For instance, when the user inputs importance levels of each parameters such as "Connectivity (most important)," bandwidth (important)" and "Cost (least important)", users' evaluation weights is calculated by making a paired comparison table based on input data.

The paired comparison table base on users' input data.

The evaluation weights of each parameter calculated from paired comparison

Table 1 . An example of formulating the AHP

			C	
Connectivity				WT=0.07
			1	



3.3 Channel Allocating Algorithm

As for the determination method of the channel allocation, we propose an algorithm which make s use of QDm applying value engineering. Channel allocating procedure is shown as follows. Here, the average value of an AHP parameter is set to “A” for this occasion.

The QDm method will be described later.

- 1) The user sends a communication request.
- 2) The BS refers to an application name and evaluation parameters which the user prioritizes.
- 3) (a) If there exit open channels, it allocates necessary channels which user requests for streaming service. Then it goes to (9)
(b) If there exist no open channels, it goes to (4).
- 4) (a) If a number of users’ calling loss are higher than a fixed value, users’ connectivity priority is promoted a higher position.
(b) If a number of users’ calling loss is less than a fixed value, it goes to (5).
- 5) The user currently under communications, and the service level are referred to the BS database.
- 6) The evaluation weight of each parameter of the user currently under communications is referred, and compares with the evaluation weight of the other user who is requesting to start to communicate.
- 7) The evaluation weight about connectivity is compared,
(a) if the weight of the user who requests communications is heavier than the value “A”, it goes to (7) .
(b) Otherwise, the user is placed in the waiting state.
- 8) The users’ quality value is calculated using the QDm method.
- 9) Allocate the channel in the highest point using QDm method.
- 10) The user starts communication.

Method to Determine User Quality

- Use QDm (Quality Deployment for Market pricing) method which applies “AHP” and “value engineering”

Valuation of satisfactory level regarding bandwidth and cost, connectivity

Evaluated by AHP

	Present Quality	Ideal Quality	Evaluation Weight
Bandwidth	5	5	42
Connectivity	5	5	32
Cost	4	5	23
Image Quality	3	5	3
Evaluation Value	4.71	5	100
Quality	0.942	1	

User quality is determined

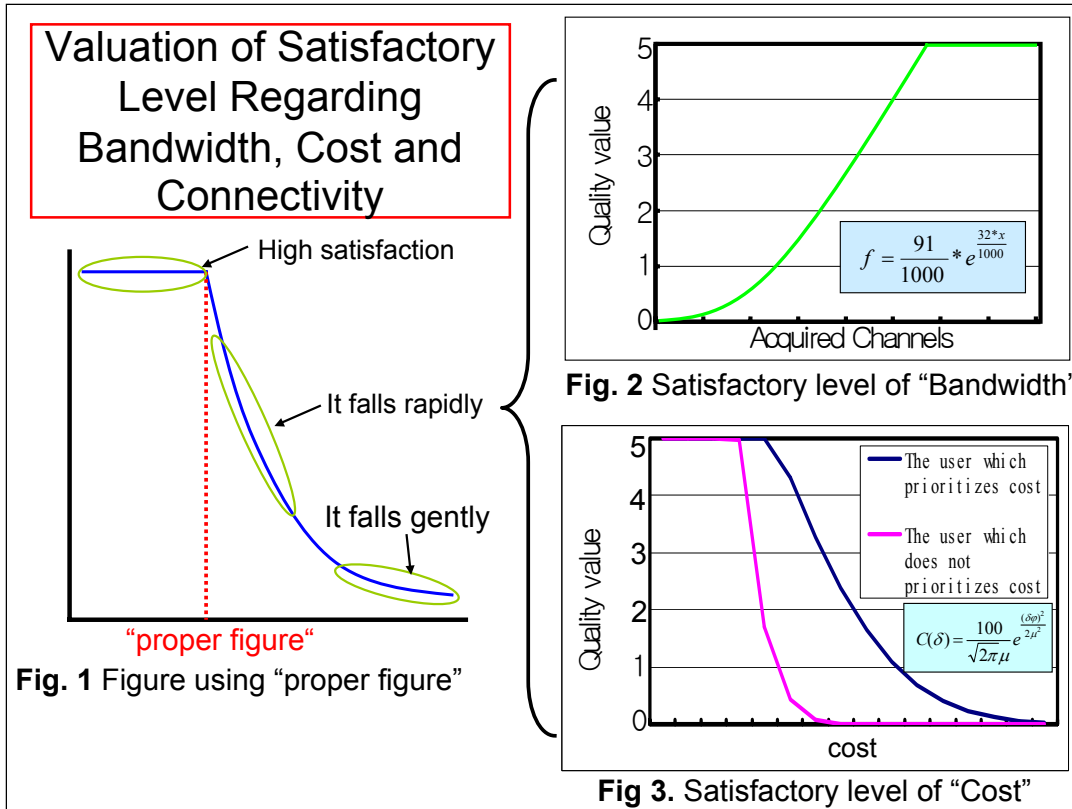
4. Evaluation of User Quality and Valuation of Satisfactory Level

4.1 Determination of User Quality

In order to calculate total value of user quality, we use the QDm method which applies AHP and “Value Engineering” [5]. The QDm is an evaluation method to determine planned pricing for new products based on the concept of quality and standard price. Quality elements are listed and those elements are weighted, for instance, by using AHP. Then, the weighted quality is calculated and the quality coefficient is defined by comparing the weighted quality with best practice. The price ratio is also calculated by comparing the planned price and the best practice. Therefore, it can get relative cost-performance is derived from those quality coefficient and price ratio. This relative cost-performance can be considered as user satisfaction. By using this method, we can calculate user satisfaction practically, because it can evaluate not only objective quality (quality target which a designer defines), but also subjective quality which differs from one person to another by using weights calculated by AHP and can compare the service which can practically provide with the service which users request.

The user quality calculation takes the following procedure.

- 1) Calculate “Evaluation weights” of each parameter by using AHP mentioned before.
- 2) Calculate present satisfactory level w_j and ideal satisfactory level of each item which are rated from one to five, by using the valuation of satisfactory level decision method which will be described in the next section.
- 3) Calculate presence evaluation value “ ” and ideal evaluation value “ ”, using
- 4) Calculate users’ quality by
$$Q = F \square E f = \sum \left\{ (F_j \times f_j) \times w_j \right\} \frac{Q_r}{Q_j}$$



4.2 Satisfactory Level Regarding Bandwidth, Cost and Connectivity

In order to decide user satisfactory level of each item, we apply the idea based on “proper figure” of the QoS concept in [6]. The “Proper figure” means the ideal quality which users’ requests. The figure using “proper figure” is shown in Figure 1.

When “proper figure” and the service quality which can be provided are consistent, in other words it can provide the service quality which users request, the user satisfactory level is high. However when it becomes impossible to provide the service quality which users request, the user satisfactory level falls rapidly. We formulate these satisfactory levels on cost, bandwidth and connectivity by using this idea.

4.2.1 Bandwidth

In order to determine the satisfactory level of bandwidth, we formulated it based on the “proper figure”. The satisfactory level is shown in Figure 2.

For instance, if a channel bandwidth require for streaming contents was 96kbps, the satisfactory level would be 5 when the channel, which can be allocated to user, is 96kbps and more. However, the satisfactory level falls rapidly when the requested channel can not be allocated.

4.2.3 Cost

User satisfaction regarding cost is high when costs are low. However, when costs reach at certain point, cost satisfaction drops rapidly. As the definition of this cost satisfaction level, cost is defined by the amount of the fundamental usage of the channel as well as priority levels of bandwidth and connectivity. Additionally, the cost satisfactory level is defined by using the cost which users use the channel, guarantee level regarding bandwidth and connectivity, and sharing channel bandwidth. Quality valuation of cost satisfaction is shown in Figure 3.

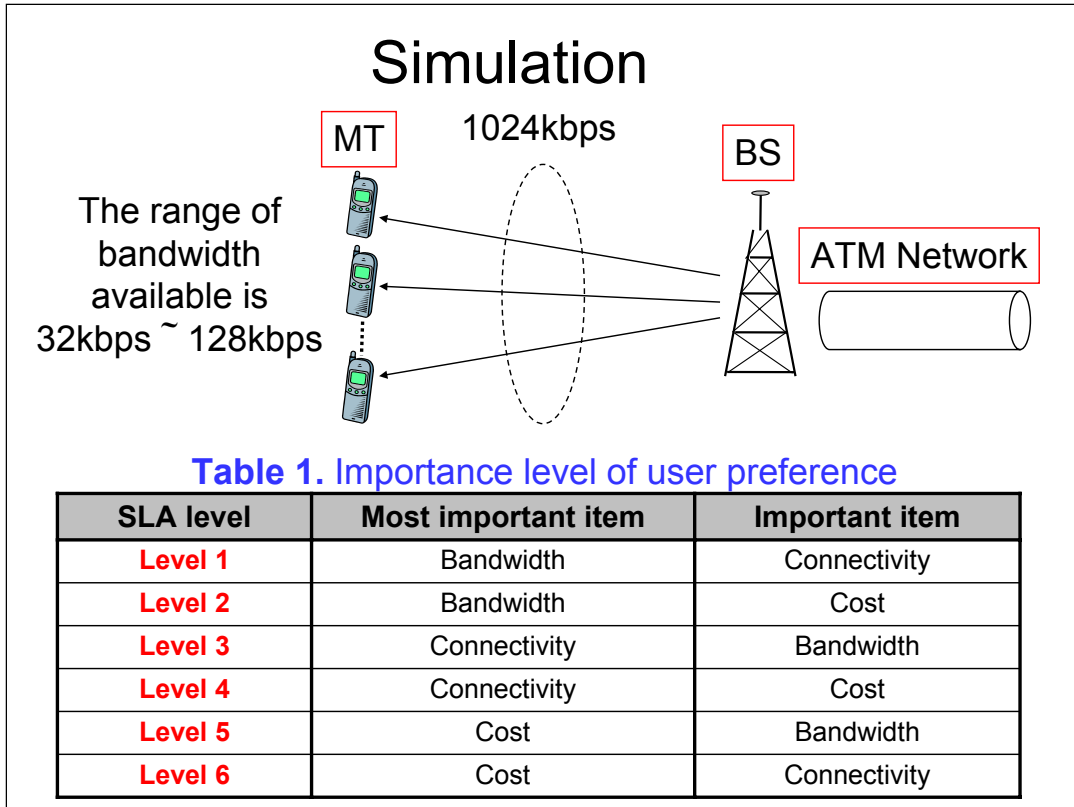
4.2.2 Connectivity

The satisfactory level of connectivity is formulated by a pessimistic view. For example, the satisfactory level of the user who emphasize the importance of connectivity falls rapidly when the user connectivity request is refused even once. On the other hand, the satisfactory level of the user whose minimum requirement is to connect falls gently even if user connection requests are refused once or twice. The satisfactory level of connection is as follows.

$$G(n)$$

$$G(n) = \frac{100}{a} \sqrt{a^2 - n^2}$$

(a : guarantee level n : number of calling loss)



5. Simulation

5.1 Simulation Environment

Because we consider that the wireless transmission part will be the bottleneck in future data communications, in this simulation, we focus communications solely between the BS and the MT, without considering the wire part.

Simulation environment is as follows.

- Transmission method : W-CDMA
- User number : 100
- Call generating probability : Poisson distribution
- Data size : rectangular distribution
- Available bandwidth : 32, 64, 96, 128kbps
- Application : streaming

Although in the current world of communications Mail is dominating, the generating frequency is set to Mail(60%) and WWW(40%). Because we consider WWW will be dominating data communications in the future, data size, generating ratio of WWW (text) and Streaming based on [7] and [8] are as follows.

Table 2. Data size and generating ratio of application

Application	Maximum traffic	Minimum traffic	Generating frequency
Mail	30 Kbyte	3 Kbyte	60%
WWW	48 Kbyte	16 Kbyte	22%
Streaming	200 Kbyte	50 Kbyte	18%

Simulation Results(1)

* λ = calling rate (per sec)

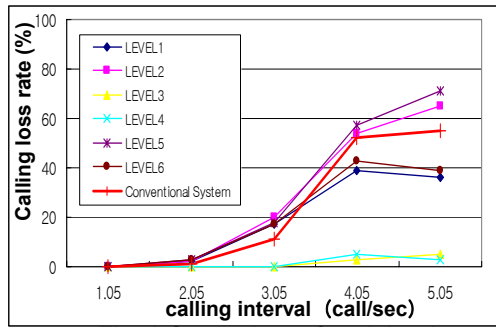


Fig. 1 Comparison of each level with calling loss rate

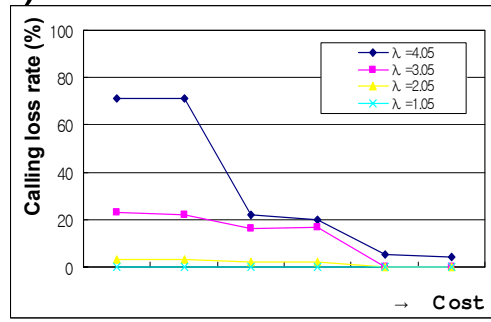


Fig. 3 Relationship between cost and average calling loss rate

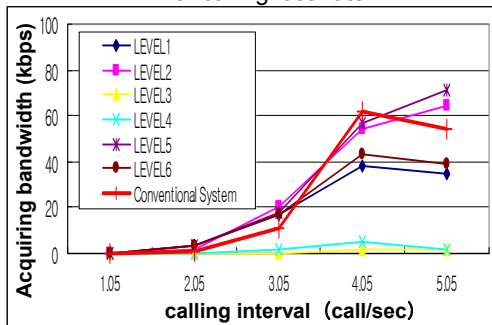


Fig. 2 Comparison of each level with average acquired bandwidth

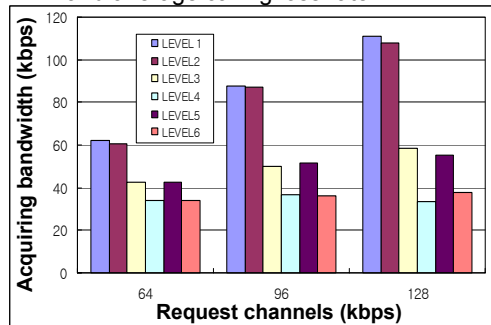


Fig. 4 Average acquired bandwidth of each level ($\lambda=4.05$)

5.2 Simulation Results

The comparison of average calling loss in each level is shown in Figure 1. Channels are allocated by taking into consideration of SLA levels. As opposed to about 54% of calling loss in the conventional system, since channels are allocated for the user users whose SLA levels of connectivity are high the proposed system is able to hold down about 3% of calling loss even in the high calling rate. On the other hand, level 2 and level 5 users whose SLA levels of connectivity are low have high calling loss rate. Therefore, based on this result the proposed system can guarantee the connectivity for only users who prioritize connectivity as shown in Figure 1.

The comparison of average acquired bandwidth in each level is shown in Figure 2. Since the users who prioritize to acquire enough bandwidth have high priority such as level 1 and level 2 differently from the conventional system, the proposal system can allocate the channels for the users of these levels corresponding to the users' requested quality.

Next, we simulate how much proposed system has a difference among SLA levels and how much proposed system can guarantee the user whose SLA levels are high from the viewpoint of "bandwidth" and "cost". Simulation results are as follows.

Relation between cost and average calling loss rate is shown in Figure 3. From Figure 3, it turns out that, although data communication cost become high, the user which give high priority to "connectivity" can connect even in the case of heavy traffic.

The average acquired bandwidth regarding to each SLA level in the case of high calling rate are shown in Figure 4. From Figure 4, it turns out that the user such as level 1 and level 2 which give high priority to "bandwidth" can be allocated channels which suitable for the user requests even in the case of high connectivity request.

From the simulation results, it turned out that the proposed system can provide the service which is suited to individual needs compared with the conventional system.

Simulation Results(2)

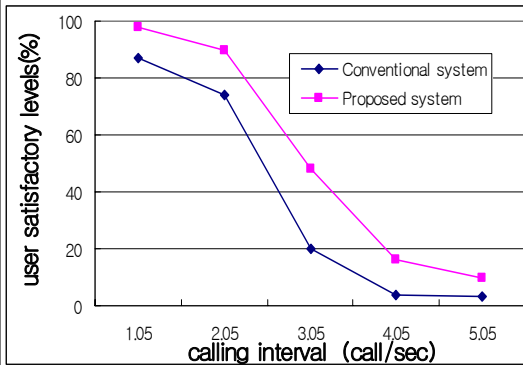


Fig. 5 Relationship between user satisfaction levels and calling interval

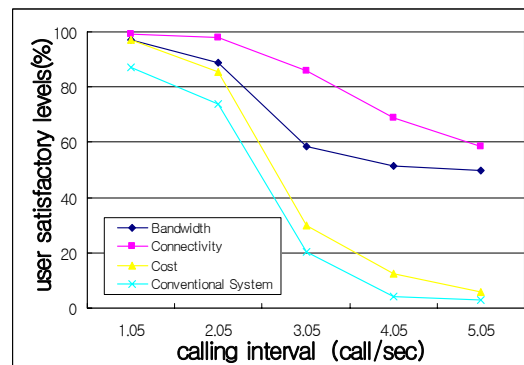


Fig. 6 Comparison of each importance parameter with user satisfaction level

※ λ = calling rate

5.3 Simulation Results on User Satisfaction Level

Next, we simulate how much the proposed system has differences among SLA level and how much the proposed system using QDM can guarantee the user satisfaction whose SLA levels are high from the viewpoint of “bandwidth” and “cost”. This time user satisfaction level is formulated based on AHP as follows. Additionally, f_{λ} , f_{λ} , f_{λ} are importance levels of each parameter.

User Satisfaction

$$= f_{\lambda} \times \text{BandwidthSatisfaction} + f_{\lambda} \times \text{ConnectivitySatisfaction} + f_{\lambda} \times \text{CostSatisfaction}$$

Simulation results based on user satisfaction level are as follows. Comparisons of user satisfactory levels between the proposed system using QDM and conventional system are shown in Figure 5. From Figure 5, it is found that when calling rate is low user satisfaction level exceeds 80%. However, since the conventional system allocates fixed channel, when calling rate is above 3.05 the user satisfaction level fall down from 74% to 20%. On the other hand, since the proposed system using QDM makes consideration of user requests, user satisfaction level is improved above 10% in the case of traffic rate 1.05 and 2.05. Moreover, even if traffic is heavy, since the proposed system makes consideration of the parameter which users emphasize and allocates channel dynamically, user satisfaction is improved more than two times.

Next we compare each importance parameter with the user satisfactory level. As shown in Figure 6, since the proposed system allocates channel in consideration of user SLA levels, when calling rate is heavy the user satisfaction level is high. Especially, since the user who emphasizes connectivity can be allocated the channel preferentially and the user who emphasize bandwidth can acquire high rate channel, the user satisfaction level exceeds 50% in the case of traffic rate 5.05.

Conclusion

We realize that the proposed system is effective for users who want to acquire enough “bandwidth”, to establish “connection” even under heavy traffic, and to make reasonable communications to guarantee items which users request preferentially .

Future works

1. Guarantee of End-to-End QoS
2. Comparison in the case of packet switching method applying proposed system

6. Conclusion and future works

We realize that the proposed system is effective for users who want to execute high quality communications, to establish “connection” even if traffic is heavy, and to make reasonable communications to guarantee items which user request preferentially. Our future works are listed as follows.

(1) End-to-End QoS

In this research, since we consider that future network’s bottleneck will be in wireless parts, we focus on only wireless parts. However we will study End-to-End QoS systems including ATM network for W-CDMA core network and ISP which supply the streaming contents by using RTSP.

(2) Packet switching

In this research, we focus on circuit switching streaming distribution. However it is important for future wireless systems such as EW-CDMA, the fourth generation mobile communications, to provide streaming services in packet switching. Therefore, we will apply the proposal system to the packet switching system, and evaluate its effectiveness.

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