Multicast Transmission Protocol for Multimedia Services in Smart Home

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Abstract Common information can be sent to multiple users with Broadcast/Multicast services. In smart home, multimedia services can be provided to users, who want to receive multimedia data through mobile phones. Most of multimedia applications are implemented using the streaming technique from contents provider to subscribers. It is important to manage the buffering amount remained in the user side in order to support the adequate quality of video contents and minimize complaints of subscribers due to buffer starvation. In the wireless environment, it is difficult to provide several subscribers with multicast traffic stably, since the data rate which users can receive varies according to the channel state of each user. Therefore, we propose and discuss an efficient usage together with MIU (Multicast In Unicast portion) as well as MIM (Multicast In Multicast portion) in order to maximize the aggregate throughput of users and minimize the starvation duration degrading QoS supported to users. We consider the multicast partitioning problem applying list partitioning algorithm and provide the analytical foundation that the proposed scheme can be evaluated. Simulation results show that proposed model can provide enhanced performance and allowed streaming quality.

Keyword: buffer synchronization, channel situation, multicast partition

1. Introduction

Users can utilize multimedia services conveniently through their mobile phones in smart home. Broadcast/Multicast service to transmit the same information to subscribing users is being standardized in 3GPP2 [2]. In Broadcast/Multicast method, a base station periodically broadcasts information to the subscribing users in the allocated portion of resource. The profit of Broadcast/Multicast service is to save finite transmission resources because a base station concurrently transmits packets with a group rate which is minimum data rate allowed to the subscribing users. Especially in CDMA 1x EV-DO system, a base station periodically broadcasts information to the subscribing users in the allocated portion of resource.

It is essential to have a sufficient amount of buffering as to ensure streaming quality since most of multimedia applications are implemented to streaming technique. Streaming of multimedia applications over a wireless environment is a difficult problem. This is due to the stringent QoS requirements and the unreliability of wireless link [3]. In addition, such a periodic transmission with a group rate in Broadcast/Multicast can cause several user terminals to endure undesirable streaming quality owing to buffer starvation because an allowed data rate according to channel situation is changeable due to time varying wireless channel characteristics. Therefore, it is necessary that diverse requirements of user terminals are reflected in multicast transmission rate through an adequate partitioning. In this paper, we deal with the multicast partition problem for smart home applications. At that time, the hierarchical coding method will achieve the buffer synchronization due to different transmission rates [4]. In addition, we should consider the policy which a few user terminals with bad channel situation continually can be relieved from. Therefore, we propose the method which applies to an additional transmission in unicast portion together with periodic multicast delivery. Such a supplementary transmission can be accomplished by usage of spared unicast portion except the portion for multicast transmission. The part of this paper was presented in [1].

Broadcast/Multicast services are services intended to provide flexible and efficient mechanisms to send common information to multiple users. The motivation for these services lies in the need to utilize the most efficient method of delivery for the use of air interface and network resources when sending the same information to multiple users. The type of information to be sent is not limited to text messages, but could be any type of data, including multimedia (e.g voice) and streaming services that might be sent to mobile stations. The information shall originate via SMS or packet data techniques. Broadcast services shall be delivered via the most effective and efficient

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technique (SMS or packet data methods) based on the information to be sent. Multicast information shall be delivered in the most efficient and effective technique (i.e. SMS or packet data) regardless of the origination source. This means that if a multicast is originated via SMS, but the best delivery is packet data due to content then there needs to be inter-working between SMS and packet data. The services shall allow for both mobile terminated and mobile origination for multicast and mobile terminated only for broadcast. The service needs to be defined in such a way as to not limit the number of users in a user group, or the number of user groups available. Multicast user groups are generally considered to be a closed group that a member either explicitly has to subscribe to the service (public multicast group) by sending a request to the administrator, by some web interfaces, or other mechanism. A private multicast group is restricted to membership explicitly by the administrator manually adding members. Broadcast can also be divided into public and private groups. A public broadcast group is used for sending geographic specific information. All devices in the specific geographic area that have broadcast capability are in the public group and will receive this information. Examples of broadcast information for this group type are emergency weather alerts are traffic conditions. Private broadcast groups are targeted to sending specific information to a specific group of devices in a specific area. Examples of this service would be location based advertising. A user elects to receive specific advertisements when they are at the mall, but not at other times. [8]

The remaining part of this paper is composed as follows. In section 2, we describe the proposed protocol. In section 3, we show the simulation results about proposed scheme. In addition, we discuss the performance of proposed scheme and examine it from various angles. Section 4 concludes this paper.

2. Description of Protocol

2.1 The Role of Multicast Partition and Hierarchical Coding

We assume that the number of optimal partition is two and these two partitions have time slot of same portion (left and right). At that time, the decision of a partition point applied to proposed scheme complies with the list partition algorithm [5]. This algorithm offers the optimal partition method to maximize the aggregate throughput of group users. In the wireless environment, if the users which belong to the left partition move to the right partition or vice versa, there will happen the synchronization problem due to the different amount of buffering. Multicast transmission by different data rate can not avoid resulting in the synchronization problem. Therefore, we apply the hierarchical coding method [4] in order to solve this problem. Hierarchical coding has been ideal to multicast transmission over links with different bandwidths and channel environment.

2.2 Description of MIM and MIU Protocol

A base station transmits packets to subscribing users periodically during the multicast part (T_M) as shown in Fig. 1. We assume that a broadcast duration consists of one hundred slots and this duration is called a frame. All of user terminals can receive packets for T_M in a frame (T_S). Especially we call the transmission in the T_M interval MIM (Multicast In Multicast portion) and the transmission in the T_U interval MIU (Multicast In Unicast portion). The data rate which the base station can transmit in every frame is called a group rate. The group rate means the minimum rate which the subscribing users can receive.

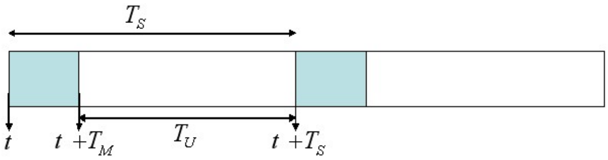

Fig. 1. Frame structure of Broadcast/Multicast system

The available rate of each user terminal changes according to channel environment continuously. Although there is only one user terminal which has a bad channel situation in a group, the terminals which have good channel situation relatively can not help receiving packets to the low data rate. In case of live streaming contents, constant streaming rate at user side should be sustained and a sufficient amount of buffering should be ensured in order to achieve guaranteed service quality. However, subsequent buffering degradation of group users due to a user terminal which has a bad channel situation will make the service quality of multimedia application fall off and frequent buffer starvation will cause the user terminals to irritate. Therefore, we intend to apply multicast partition method so as to prevent some user terminals from receiving packets to undesirable data rate.

First of all, a base station can find the user terminal that will go through a buffer starvation in a current frame before transmitting packets. The base station preferentially determines the user terminal with MIU service as mentioned above since the base station knows information about the data rate that each user can receive and streaming rate at the user side. Once, the base station determines several user terminals which will receive MIU service in the current frame only. However, the goal of our scheme previously prevents some receivers from going through buffer starvation in a current frame as well as in a next frame. If the buffer starvation is held in the next frame as well as in the current frame, streaming quality at the user's display will be largely damaged continuously. Our scheme takes into account this case and then includes the channel situation in the next frame.

The decision of MIU service applied to our proposal gets achieved by the foundation shown as following Table 1.

The MIU decision of each user terminal is performed in case there exists the possibility that buffer starvation will be occurred in a current frame and in the multicast portion of a next frame. Therefore, the decision point is shown as follows.

$$B_i(t+T_M) = [B_i(t) + R_{current} T_M \alpha_L - R_s T_M]^+ \quad (1)$$

$$U_i = B_i(t+T_M) - T_U R_s + E(R_{next}) \cdot T_M \alpha_L - T_M R_s < 0 \quad (2)$$

Table 1. Description of Parameters for MIU Decision

$B_i(t)$	buffer occupancy of user i in a current time t
R_s	streaming rate at the user side
$R_{current}$	group rate which can receive in a current frame
α_L	the left portion of multicast transmission
α_R	the right portion of multicast transmission
$E(R_{next})$	expectation value of group rate which can receive in a next frame
U_i	the amount for the decision of MIU service (i th user)

In the next section, we will deal with the model for obtaining $E(R_{next})$.

2.3 Channel Estimation Method

In the previous section, we estimated the channel situation of each user terminal in a next frame in order to obtain $E(R_{next})$ of (2). We estimate the channel situation of a next frame using Markov model with eleven states. Related model is shown as Fig. 2 [6] and parameters are shown in Table 2, 3, and 4 [6].

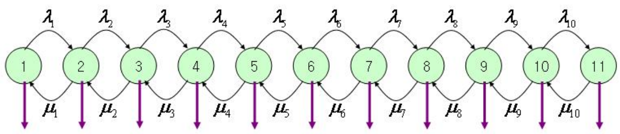

Fig. 2. State transition diagram of HDR system

Table 2. Transmission Rate Supported in HDR System

	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}	R_{11}
Rate (Kbps)	38.4	76.8	102.6	153.6	204.8	307.2	614.4	921.6	1228.8	1843.2	2457.6

Table 3. State Transition Rate

	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6	λ_7	λ_8	λ_9	λ_{10}
Rate	0.995	0.99	0.02	0.99	0.40	0.75	0.005	0.99	0.08	0.10
	μ_1	μ_2	μ_3	μ_4	μ_5	μ_6	μ_7	μ_8	μ_9	μ_{10}
Rate	0.01	0.25	0.01	0.53	0.25	0.995	0.01	0.74	0.20	1.0

Table 4. Probability which a Process Remains in Each State

	π_1	π_2	π_3	π_4	π_5	π_6	π_7	π_8	π_9	π_{10}	π_{11}
Rate	0.001	0.01	0.04	0.08	0.15	0.25	0.18	0.094	0.13	0.06	0.005

We assume that the state distribution of each user terminal in a current frame is

$$\{R_k,\ R_{k+1},\ R_{k+2},\ \cdots\cdots R_{th}\}\{R_{th+1},\ R_{th+2},\ \cdots\cdots\}.$$

The following notations can be defined in Table 5.

Table 5. Description of Parameters for an Analytical Model

$NL_{\min}$	the number of users with minimum rate in the left portion
$NL_{\min+1}$	the number of users with (minimum rate + one state) in the left portion
$NL_{\max}$	the number of users with maximum rate in the left portion
$NR_{\min}$	the number of users with minimum rate in the right portion
$NR_{\min+1}$	the number of users with (minimum rate + one state) in the right portion
λ_k , μ_k	state transition rate for upward and downward respectively
R_k	transmission rate which can receive in a state k
π_k	probability that the users remain in a state k
α_i	portion of a specific slot duration

In these state distributions, the left portion of multicast transmission is partitioned in user terminals up to R_{th} rate and the right portion is partitioned in user terminals after R_{th+1} rate. If there is i th user in the left portion or the right portion of current frame, the group rate in a next frame can be summarized as follows.

- $i \in$ **Left Portion of current frame**

(a) The probability that a group rate is R_k in a next frame.

$$P_k = \{1-\binom{NL_{\min}}{NL_{\min}}(1-\pi_k)^{NL_{\min}}\} + \binom{NL_{\min}}{NL_{\min}} p_k^{NL_{\min}} \times \{1-\binom{NL_{\min+1}}{NL_{\min+1}}\cdot(1-q_k)^{NL_{\min+1}}\} \quad (3)$$

(b) The probability that a group rate is R_{k+1} in a next frame.

$$P_{k+1} = \binom{NL_{\min}}{NL_{\min}} p_k^{NL_{\min}} \times \binom{NL_{\min}}{NL_{\min}} (1-q_{k-1})^{NL_{\min+1}} \quad (4)$$

(c) The probability that a group rate is R_{k-1} in a next frame.

$$P_{k-1} = 1-\binom{NL_{\min}}{NL_{\min}}\cdot(1-q_{k-1})^{NL_{\min}} \quad (5)$$

(d) The probability that a group rate is R_{th+1} in a next frame.

$$P_{th+1} = 1 - \binom{NL_{\max}}{NL_{\max}} (1 - p_{th})^{NL_{\max}} \tag{6}$$

- $i \in$ **Right Portion of current frame**

(a) The probability that a group rate is R_{th+2} in a next frame.

$$P_{th+2} = \binom{NR_{\min}}{NR_{\min}} (p_{th})^{NR_{\min}} \times \binom{NL_{\max}}{NL_{\max}} (1 - p_{th})^{NL_{\max}} \times \binom{NR_{\min+1}}{NR_{\min+1}} (1 - q_{th+1})^{NR_{\min+1}} \tag{7}$$

(b) The probability that a group rate is R_{th+1} in a next frame.

$$\begin{aligned} P_{th+1} = & \{1 - \binom{NR_{\min}}{NR_{\min}} (1 - \pi_{th+1})^{NR_{\min}}\} \\ & + \binom{NR_{\min}}{NR_{\min}} (p_{th+1})^{NR_{\min}} [\{1 - \binom{NR_{\min+1}}{NR_{\min+1}} (1 - q_{th+1})^{NR_{\min+1}}\} \\ & + \{1 - \binom{NL_{\max}}{NL_{\max}} (1 - p_{th})^{NL_{\max}}\}] \\ & + \binom{NR_{\min}}{NR_{\min}} (q_{th})^{NR_{\min}} \\ & \times [\{1 - \binom{NR_{\min+1}}{NR_{\min+1}} (1 - q_{th+1})^{NR_{\min+1}}\} + \{1 - \binom{NL_{\max}}{NL_{\max}} (1 - p_{th})^{NL_{\max}}\}] \end{aligned} \tag{8}$$

(c) The probability that a group rate is R_{th} in a next frame.

$$P_{th} = 1 - \binom{NR_{\min}}{NR_{\min}} (1 - q_{th})^{NR_{\min}} \tag{9}$$

Therefore, the expectation value about a group rate in a next frame can be represented as follows.

When i th user exists in the left portion of current frame,

$$E(R_{next}) = P_k \cdot R_k + P_{k+1} \cdot R_{k+1} + P_{k-1} \cdot R_{k-1} + P_{th+1} \cdot R_{th+1} . \tag{10}$$

When i th user exists in the right portion of current frame,

$$E(R_{next}) = P_{th+2} \cdot R_{th+2} + P_{th+1} \cdot R_{th+1} + P_{th} \cdot R_{th} . \tag{11}$$

We can obtain $E(R_{next})$ value of equation (2). If we assume that N user terminals are provided with MIU service in a current frame and lined up orderly, the i th user terminal can receive the amount of data expressed in equation (12).

$$\sum_{i=1}^{N} \sum_{j=1}^{j=i} r_j \alpha_j T_U \quad where \ \sum_{j=1}^{N} \alpha_j \leq 1 \tag{12}$$

As above (12), although MIU service is provided with the specific user terminal, the user terminals which data rate is higher than that of the target user also can receive same data. This result is due to the broadcasting characteristic of wireless transmission. While, α_j value means the ratio which would assign time slots to i th user. In order to minimize the average starvation duration of all active user terminals, the following condition (13) should be needed.

$$Maximize \ \sum_{i=1}^{N} U_i + \sum_{i=1}^{N} \sum_{j=1}^{j=i} r_j \alpha_j T_U \quad where \ \sum_{j=1}^{N} \alpha_j \leq 1 \tag{13}$$

With this observation, we may improve the streaming quality for all active users if we design α_j value carefully. We will show some examples with different α_j value and discuss each example via simulation.

2.4 Synchronous Mode

In this section, we deal with the buffer synchronization problem. The modified protocol is proposed assuming not to apply the hierarchical coding method.

Fig. 3 shows that MIU service slots are divided into priority MIU slots (T_{PU}) and shared MIU slots (T_{SU}) and it also represents a modified frame structure which priority MIU portion (T_{PU}) is added to. The role of T_{PU} is to resolve the problem about buffer synchronization according to the movement between the left partition and the right partition. The priority MIU portion is preferentially served if there is the user which needs the buffer synchronization. Otherwise, the priority MIU portion is converted into the shared MIU portion. In detail, the description of modified protocol is as follows.

Case 1

The users which belong to left partition move to the right partition in a current frame.

Fig. 4 shows the buffering amount of the users which exist each partition and the following procedure describes the protocol behavior of case 1.

(1) The buffering amount of user which moves from the left partition to the right partition.

(2) The buffering amount of user which exists in the right portion originally.

(3) The buffering amounts of (1) and (2) are synchronized by the additional MIU service on the T_{PU} portion.

(4) If the buffering amount of (1) can not reach that of (2) due to the limited resource, the users of (1) will go

through starvation duration for the unsolved buffering portion.

Case 2

The users which belong to right partition move to the left partition in a current frame.

Fig. 5 shows the buffering amount of the users which exist each partition and the following procedure describes the protocol behavior of case 2.

(1) The buffering amount of user which exists in the left portion originally.

(2) The buffering amount of user which moves from the right partition to the left partition.

(3) The user of (2) can not be served until the buffering amounts of each user are synchronized.

(4) If the users of both (1) and (2) are not synchronized at the end of frame, the remained buffering amount of (2) should be dropped.

As above the description, the addition of priority MIU portion presents the possibility which can solve the buffer synchronization problem. However, it is inevitable that the resource efficiency is degraded due to the additional resource consumption.

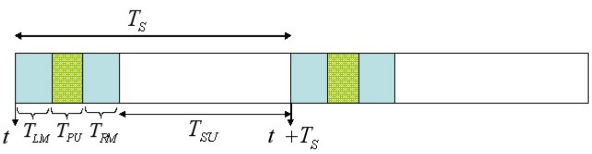

Fig. 3. Frame structure of synchronized broadcast/multicast system

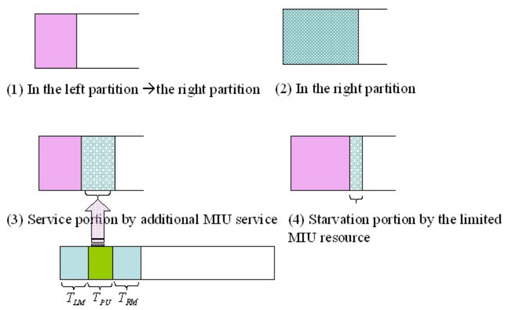

Fig. 4. Usage of priority MIU portion (L → R)

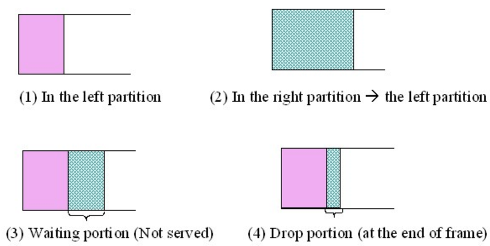

Fig. 5. Behavior for the buffer synchronization (R → L)

3. Simulation Results

We carry out simulation to evaluate the performance of HDR system applying to the proposed algorithm. We make use of NS-2 (Network Simulator version 2) [7] that is popular for network performance evaluation as simulation tool. Simulation scenario is shown as Fig. 6.

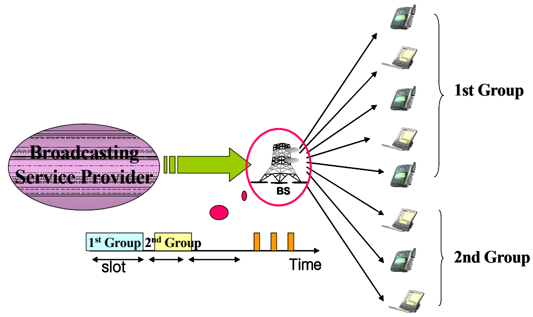

Fig. 6. Simulation scenario of proposed scheme

A base station provides total M mobile users with live broadcasting contents. Contents information from service provider is transmitted to a base station with a Constant Bit Rate (CBR). A base station transmits information to subscribing users with multicast group rate partitioned to two in the allocated portion of a frame. We apply to the proposed algorithm related to keep pace with MIU method. The assumptions of our simulation are as follows. The default value of multicast portion is 30%. Packet size is fixed to 1024 bit and transmission rates supported to user terminals are fully 11 rates. We assume that RF environment is Rayleigh fading channel and packet loss is ignored owing to using the perfect error correction. Traffic type of contents provider is CBR source supported in NS-2, since live broadcasting contents are transmitted by usage of streaming technique. Streaming rate at the user side is 100 Kbps. Start up delay is set to average 600 ms.

3.1 Simulation of Proposed Protocol

(1) The Variation of Starvation Duration according to Multicast Portion

The first simulation is the case that 40 users receive the only MIM service. Fig. 7 shows that starvation duration is decreased according to an increase of multicast portion. Fig. 7 also shows that the multicast service of 45% portion barely can accomplish the starvation duration less than 6%. These results show that the only MIM service can not support good streaming quality.

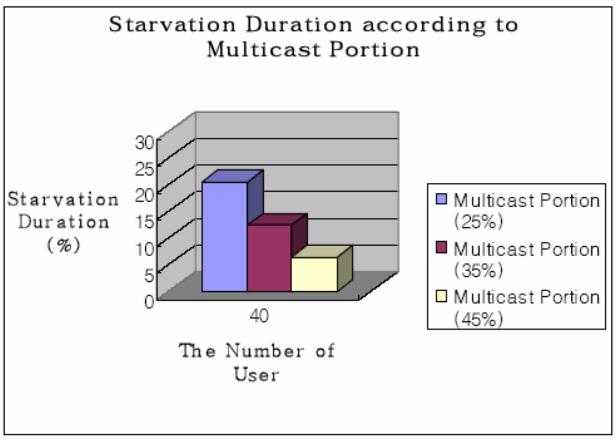

Fig. 7. Starvation duration according to the variation of multicast portion

(2) Performance comparison according to partition types

We carry out simulation to compare a fixed partition mode with a movable partition mode. (See Fig. 8) In the fixed partition mode, the right group rate is fixed to 614.4 Kbps and in the movable partition mode, it is determined from the list partition algorithm as above mentioned in section 2. Simulation results show that there is no difference between two partition methods according to the increase of the number of user terminal.

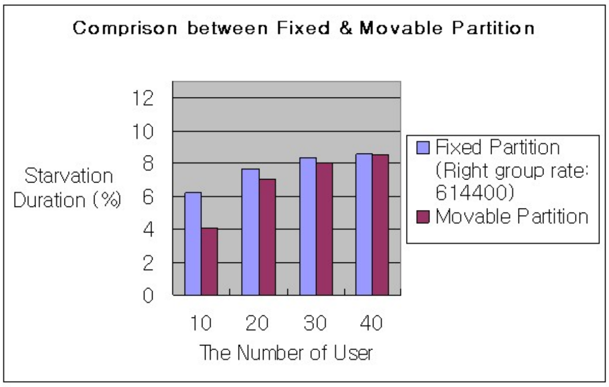

Fig. 8. Starvation duration according to two partition methods

(3) The effect of MIM service together with MIU service

In this section, we discuss a result when MIU service is used together with MIM service. In order to compare MIM service only with MIM together with MIU service fairly, we applied to the equal amount of transmission slots (45%). In MIU service, the channel prediction method mentioned in the section 2 has not used. Fig. 9 shows that MIM service together with MIU service has better performance than MIM service only about 3-4%.

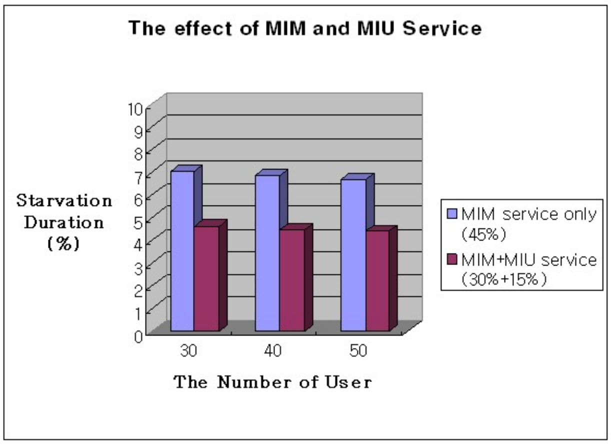

Fig. 9. Effect of MIM and MIU service

(4) Performance comparison according to the different α_j value in the MIU service

In this section, we discuss the performance variation according to allocation policies in the MIU service. Fig. 10 shows the performance comparison about three policies.

Fair Allocation

Fair allocation policy equally provides the MIU service users determined by a base station with MIU time slots. Such a fair allocation does not take into account each user's buffer amount or channel environments. With the characteristic of a wireless transmission, the data packets transmitted by time slot allocated to each MIU service user will be also served to user terminals that have better channel situation than selected user.

$$\alpha_j = \frac{1}{The\ Number\ of\ MIU\ Service}$$

Weight Allocation

The slot distribution by this policy is determined from U_j value for MIU service decision. The larger U_j value of each user has, the more time slots allocated to each user are. Therefore, if amount of buffer is relatively scarce, more MIU service will be provided. Fig. 10 shows that weight allocation policy has the best performance of three policies. However, the limited transmission resources do not affect the performance of three policies (less than 1%).

$$\alpha_j = \frac{U_j}{\sum_{j=1}^{N} U_j}$$

Specific Allocation

With this allocation policy, a base station selects only one user terminal which has the smallest U_j value of all active users and performs MIU service to the selected user.

$$\alpha_j = \arg\ Min\{U_1, U_2, U_3, ..., U_N\}$$

Fig. 10 shows that specific allocation policy has not worse performance than other policies.

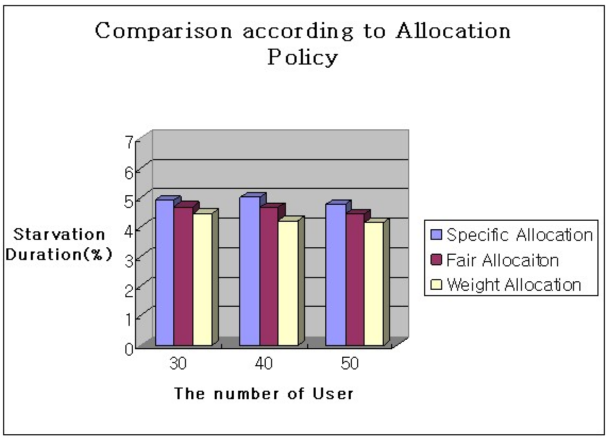

Fig. 10. Starvation duration according to allocation policies

(5) Effect of channel prediction method

In this section, we discuss the effect of the channel prediction method mentioned in the previous section. The channel environment of a next frame is predicted by Markov modeling and the estimated channel information provides the foundation that a base station determines MIU service users in a current frame. Intuitively, such as the protocol can prevent user terminals with a bad channel from going through continual buffer starvation. Fig. 11 shows the effect of channel estimation. In Fig. 11, MIU service decision by the channel estimation of a next frame results in the enhanced performance about 1.5%. The combination of MIU service with channel estimation method makes the average starvation duration dropped down as half than that of only MIM service.

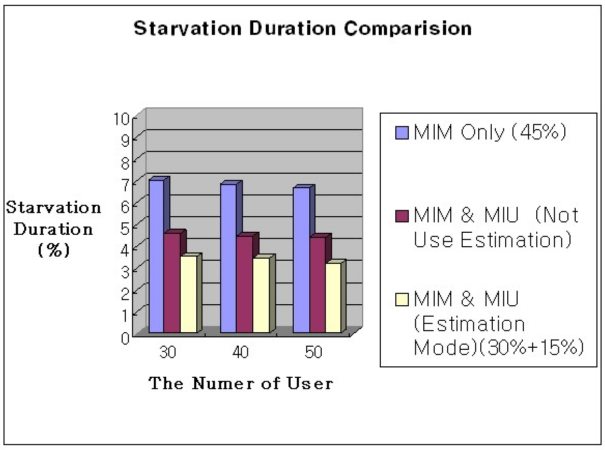

Fig. 11. Effect of channel estimation

3.2 Simulation of Synchronous Mode

In this section, we carry out the simulation in order to examine the performance variation according to the additional MIU slots in case the hierarchical coding is not used. Simulation parameters are same as those of setting up in the previous section.

The first simulation result is about the relation MIM portion and priority MIU portion. In Fig. 12, each percentage of MIM portion and priority MIU portion means the upper bound which can be served by the base station. In other words, each user may not consume the allocated slots if they are not needed in the current frame. Simulation results show that the MIM portion of 30% and the priority MIU portion of 20% have the best performance.

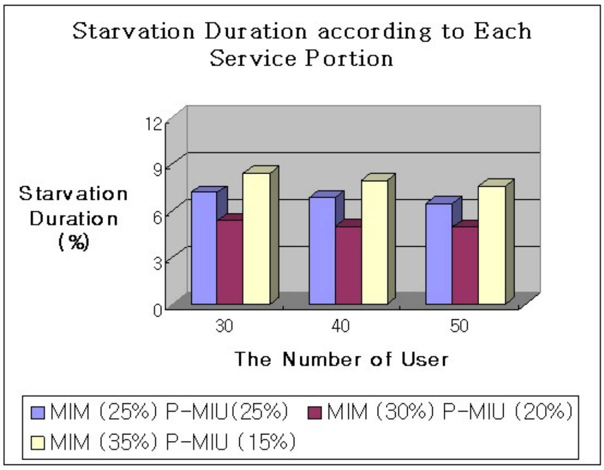

Fig. 12. Starvation duration according to each service portion

In the next simulation, we deal with the streaming performance according to the variation of priority MIU portion. In this simulation, the portion of MIM service is fixed to 30%. The rise of priority MIU service portion can prevent some users from going through starvation duration caused by the imperfect buffer synchronization. However, Fig. 13 shows that the enhanced performance can not be obtained largely in case of the priority MIU portion allocated over 20%.

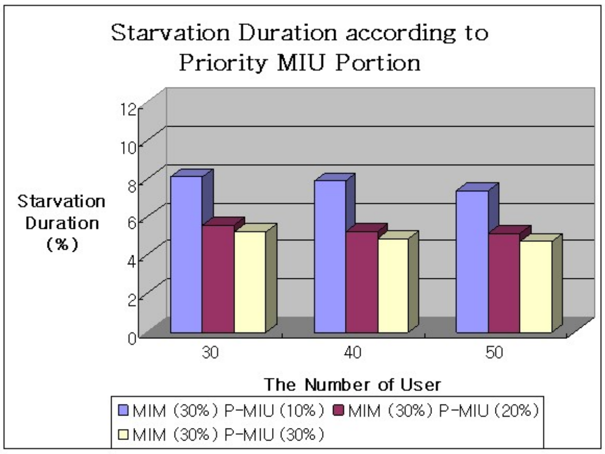

Fig. 13. Starvation duration according to priority MIU service portion

4. Conclusion

In this paper, we suggest the new multicast transmission protocol for smart home applications. Multimedia services can be provided to users through mobile phones in smart home. The exchange of multimedia services in smart home has been increased, and the useful multicast transmission protocol is needed. Especially, we show that the proposed protocol is suitable for live broadcasting applications to use streaming technique and to require multicast transmission. In the proposed protocol, we apply to list partition algorithm to frame based multicast partition and enhance the streaming quality in case of a few subscribers. In addition, MIM & MIU service is supplementary method for simple periodic transmission via multicast partition. We also show that MIM & MIU service has the enhanced performance in comparison with only MIM service. While, we prove that the methods for slot allocation in MIU service do not affect the streaming QoS in terms of buffer starvation. In addition, we also execute the channel modeling of the next frame using Markov model and analyze the expectation probability via binomial concepts. The application of channel prediction via Markov model leads to the reduced buffer starvation about 2% and indicates the possibility to be able to estimate the channel situation in the future. Finally, we introduce the modified protocol that takes into account buffer synchronization problem. In the modified protocol, we can obtain the trade-off relation between MIM service portion and priority MIU portion. Also we can find the adequate allocation of priority MIU portion.

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