Managing Multimedia Data Services with Multiple Ensemble Decoding Architecture in Digital Audio Broadcasting System

Sammo Cho, Soo In Lee, and Hyuckjae Lee, Member, IEEE

Abstract — *This paper proposes the architecture of multiple ensemble service in DAB network, in which they can transmit and receive more than one ensemble through multiple transmitters, which covers the same service area. Using this architecture, ensemble providers and transmission network providers can have more flexible management environment of DAB networks as well as they can accommodate more than 1.5 Mbps data capacity limit of one ensemble*[1].

Index Terms — Broadcasting, DAB, Ensemble

I. Introduction

Eureka-147 DAB (Digital Audio Broadcasting) system has about 2.3 Mbps of data delivery capability. The data payload is being reduced to 1.5 Mbps when we take into account the overheads such as the bits for data synchronization, error correction and multiplex configuration information. DAB broadcasters are providing CD quality audio services and multimedia data services through this 1.5 Mbps channel [1].

In the view of multimedia data service providers, DAB service can provide higher data rate per channel than existing analog broadcasting systems or cellular mobile communication systems. Still, it is not enough to provide sufficient and stable data delivery capability for the services such as video clips over DAB services and real time traffic status contents including GIS (Geographic Information Service) information [1], [2]-[3], [7].

Dual band receiver and the receiver with two tuners tried to compromise the quality or weakness of the received DAB signal through analog audio broadcasting channel or by taking advantage of the technologies such as space and frequency diversity effects [4]-[5]. They were all for the improvement of the quality of the received signal through the use of more than one RF (Radio Frequency) receiver not for the improvement of the data rate to provide multimedia service. The system structure, which is proposed in this paper, is very similar to the ideas. However, we want to explain our idea with more complex unit of Eureka-147 DAB system, named "ensemble".

An ensemble is the output frame of DAB multiplexer by multiplexing several services, which is transmitted after comprising one DAB frequency band with OFDM (Orthogonal Frequency Division Multiplex) modulation. In the multiplexing process, a service should be delivered through only one ensemble. Thus, the maximum data rate of a service cannot exceed the limit of the capacity that one ensemble can provide [1]. If there is any possibility to provide a DAB data service with more than one ensemble, there will be much more efficiencies in the management of the network as well as the increase of the data rate for the service.

Using multiple ensembles means that using multiple frequency bands. Therefore, the architecture in this paper has the similar structure as described above, but the proposed idea is mainly focused on the efficient management of the broadcasting service and data rate improvement. Therefore, the dual-mode [6] receiver can be better candidate for the receivers in the proposed idea in this paper. Still, both-band capability is more applicable to the idea in this paper.

Recently, many of the demands for the delivery of TV and video signal through DAB system are urging the target service of DAB to change their own audio service to video delivery service. DMB (Digital Multimedia Broadcasting) is one of the hottest movements of destroying the wall between radio and TV service [2]. Moreover, as more and more new digital broadcasting services are introduced, the more interactivity is needed to the future broadcasting system [7].

For the efficient management of these kinds of future interactive multimedia broadcasting service, this paper proposes a new architecture of Eureka-147 ensemble handling scheme, a multiple ensemble decoding architecture of DAB network, in which they can transmit and receive more than one ensemble through multiple transmitters, which cover all the receivers, which are receiving the service from the transmitters.

Chapter Ⅱ describes the existing and the proposed architecture of ensemble management and their implementation issue. Chapter Ⅲ describes the modeling of the service management efficiency of the proposed ensemble management architecture in the environment of interactive broadcasting service and the result of the simulation followed by the performance analysis in chapter Ⅳ.

[1] This work was supported by the Ministry of Information and Communication in Korea under the title of "The development of SmarTV technology." The authors would like to thank the referees for useful comments.

Sammo Cho is with the Electronics and Telecommunications Research Institute, Daejon, Yusong-Gu 305-350 Korea (e-mail: semo@etri.re.kr).

Soo In Lee is with the Electronics and Telecommunications Research Institute, Daejon, Yusong-Gu 305-350 Korea (e-mail: silee@etri.re.kr).

Hyuckjae Lee is with the Information and Communications Engineering Department, Information and Communications University, Daejon, Yusong-Gu 305-350 Korea (e-mail: hjlee@icu.ac.kr).

Original manuscript received June 13, 2003
Revised manuscript received November 11, 2003

II. Data Service Architecture with Multiple Ensembles

Ensemble is the transmitted signal, comprising a set of regularly and closely spaced orthogonal carriers. The ensemble is the basic entity, which is received and processed in DAB transmitters and receivers.

Fig. 1 shows the simplified ensemble multiplexing block diagram in DAB transmission system. Audio and data services are being encoded with appropriate algorithm and they are multiplexed into one ensemble with their service configuration information in the FIC (Fast Information Channel). And Table I shows the basic parameters for Eureka-147 DAB system [1].

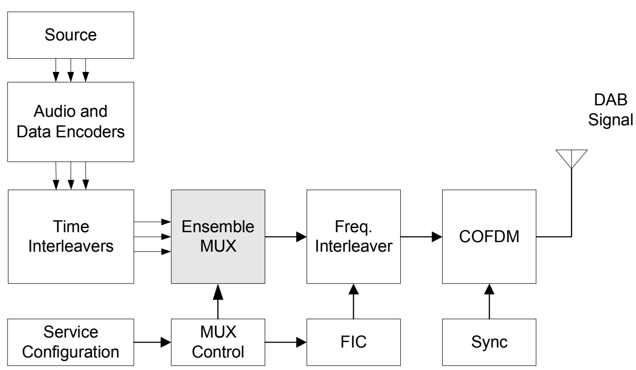


Fig.1. Ensemble multiplexing structure in DAB system

TABLE I
Eureka-147 System Parameters

Parameters	Eureka-147
Modulation	DQPSK
Channel coding	Convolutional : variable rate, constraint length=7
Time interleaving	Depth = 384 ms
Freq. interleaving	Width = 1.536 MHz
Data rate	0.8 - 1.7 Mbps
System BW	1.536 MHz

In general, an ensemble contains several program and data services. In the case of small scale broadcasting station, which covers relatively small service area, the audio and data sources of the services and ensemble multiplexer and other equipment (including transmission antenna) can be installed in one broadcasting station. However, in a relatively large scale DAB network, it is more efficient to categorize the system into several characteristic players. They are service providers, multiplex operators and transmission network providers. The service providers are taking care of the contents of the service and send their contents to multiplex operators with a specified format while gathering the signals from the receivers through backward channel. And the multiplex operators are in charge of increasing the efficiency by multiplexing the services into an ensemble. Finally, the transmission network providers have the large network of DAB radio transmitters throughout the area and provide the DAB signal to the receivers in the area after modulating the ensemble into multi-carrier OFDM signal. The example of DAB network and the players in the network are shown in the fig. 2 [1].

The following sections cover the data service architecture in existing DAB network and the proposed architecture in this paper.

A. Data Service Architecture in Existing DAB Network

Fig. 3 shows a simplified example of how DAB services are organized in one ensemble. One or several services can be incorporated in one ensemble. Likewise, several service components can be included in one service. Sub-channel (Subch) is the minimum logical unit of transferring the service components in the ensemble. In the DAB network as in the fig. 2, ensemble multiplexer gathers and organizes the available services into one ensemble with their appropriate multiplex configuration information and send it (ensemble) to the transmission network providers.

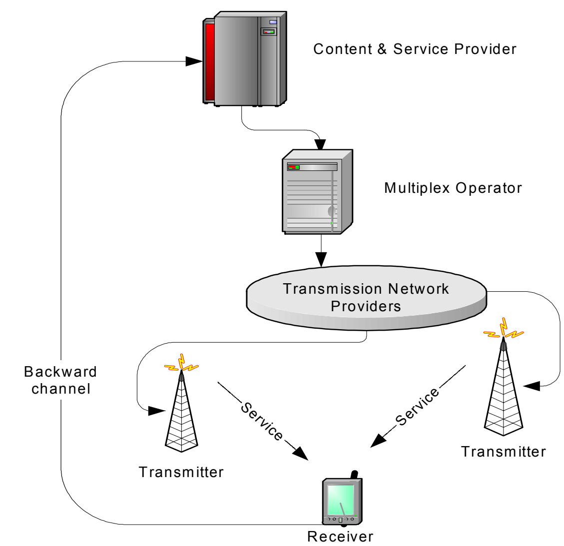


Fig. 2. An example of DAB service network

In existing DAB network, a service must be provided and received with only one ensemble. That is, a service is being provided through one or several sub-channels of one DAB transmission ensemble. Thus, the maximum data rate of the service cannot exceed the limit of the capacity that one ensemble can provide. If there is any method to provide a DAB data service with more than one ensemble, there will be much more efficiencies in the management of the network as well as the increase of the data rate for the service. The following section describes the main architecture of multiple ensembles handling architecture in this paper.

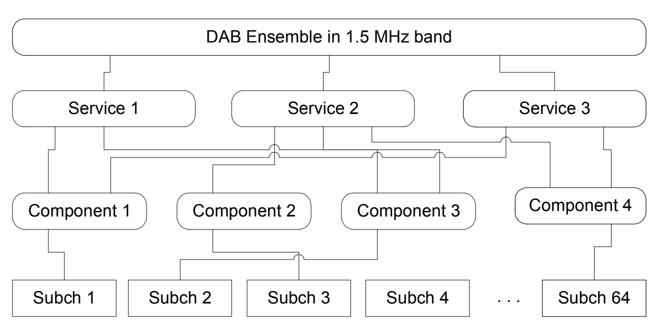


Fig. 3. Services and their service component structure in one ensemble

B. Data Service Architecture with Multiple Ensembles

The existing DAB service architecture can provide only one ensemble to the receivers (no ensemble management). This is because the receiver is tuned to only one frequency at a time and decodes the ensemble that is associated only to that frequency. For multiple ensembles decoding, the receiver should be tuned to more than one frequency at the same time in order to receive the necessary number of ensembles at the receiver. This kind of multi-frequency processing capability can be implemented by using multiple RF parts or by using SDR (Software Defined Radio) technology. Direct conversion technologies of multiple frequency bands and other similar technologies will be improved more and more in the future [6].

Fig. 4 shows an example of providing a service with multiple ensembles in DAB network. In the figure, the multiplexer generates two ensembles for transmission site 1 and transmission site 2. And the receiver can receive the DAB ensembles both from the site 1 and the site 2. In this case, the program 1 comes from both of the transmission sites after being divided into two parts at the ensemble multiplexer in each of the ensembles.

To divide a service and transmit them through separate transmitters, the ensemble multiplexer should have a kind of functionality that decides whether to divide the program to use multiple ensembles or not. And also at the receiver side, there should be the similar functionalities for reassembling the separate frames into one data frame for one service.

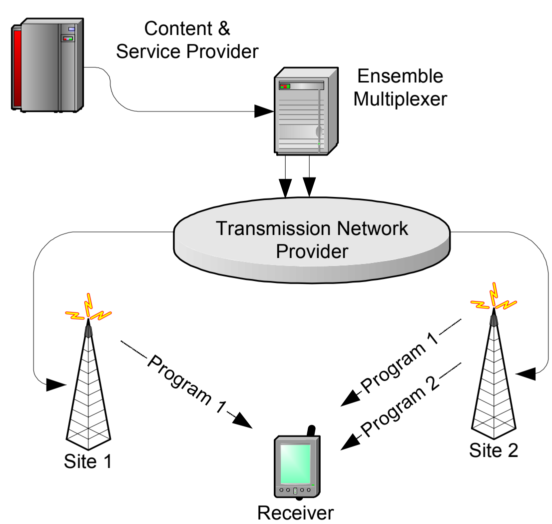


Fig. 4. Multiple ensemble transmission structure in DAB network

The reasons of the program division come from a few facts. The data rate needed by the program 1 may exceed the capacity remained for that service in the ensemble 1 from the transmitter site 1. And enough data capacity can be obtained by additively using the remnant capacity from ensemble 2. Or the program 1 itself needs the data rate of more than one ensemble. For the efficient management of regional ensemble resources multiple ensembles handling architecture also gives some profitable outcomes.

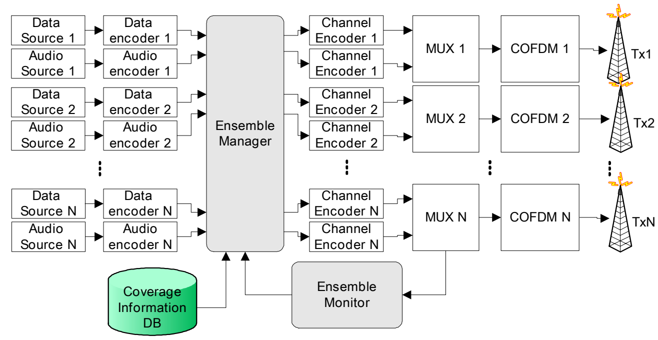


Fig. 5. Efficient ensemble multiplexing

Fig. 5 shows an example of monitoring and controlling current ensemble capacity just before the DAB ensemble multiplexer. The ensemble monitor in the figure checks remaining CU (capacity unit)s in the current output ensembles and gives the information back to the ensemble manager. The ensemble manager uses this information when deciding which service should be divided and multiplexed into which output ensembles. Although the ensemble monitor and ensemble manager seem to work rather centralized control and management, with the help of control line (Ethernet, for example) between ensemble multiplexers and other devices including ensemble managers, the information between the devices can be shared in the distance in the DAB network.

Once an ensemble is received at the receiver, other ensemble information can be obtained by decoding FIC (Fast Information Channel). Other ensemble information in the FIG (Fast Information Group)s in FIC already has the information such as the frequencies, service information of other ensembles that are available at the receiver. This can be very useful for receiving and decoding multiple ensemble services.

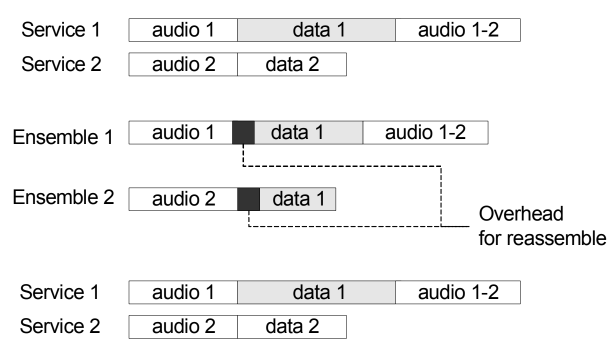


Fig. 6. Frame handling of two ensembles

Fig. 6 shows the example of ensemble structure for one data service using two DAB ensembles. The service 1 in DAB ensemble 1 has two audio services and one data service. The data service channel of the service 1 is divided into two and each of them is transmitted through ensemble 1 and ensemble 2 from each of the transmitters respectively after being added by special header information for the re-unification at the receiver. Finally, they are merged into one data service at the receiver for their application.

In the aspects of ensemble and transmission network providers, this architecture will provide highly efficient ensemble management environment, because they can utilize remaining pieces of sub channels for another data services by merging them into one available service channel. For multimedia data service providers, another high capacity data service such as SD (Standard Definition) type video may be possible, because the whole three ensembles can be merged into one 4.5 Mbps data channel. The division and reassemble process of SD type video will be more difficult issue than just sending file type video clips because of the real time streaming requirement [2].

At the receiver, which has the multiple ensembles handling capability, it is the key to receive as many ensembles as possible. For this to be done, another type of ensemble planning is needed to give sufficient number of ensembles for the receivers. Ensemble planning issue for the multiple ensemble service architecture is described in the following section.

C. Ensemble Planning for Multiple Ensemble Service

The digital audio broadcasting system not only provides superior audio quality and various data rates of multimedia applications, but also gives the efficiency in the use of scarce frequency resource. Moreover, multiple ensemble management architecture gives much more efficiency in the management of ensembles, which mean the frequency bands.

In general, ensemble planning is similar to the problem of assigning the frequency for the service area. This is because one ensemble is transmitted with one OFDM frequency block (one block occupies the bandwidth of 1.5 MHz in the case of Eureka-147 DAB system). Most of the frequency assignment problems are for the solution of assigning frequencies to cover as much area as possible with one available service without interfering each other. However, for the multiple ensemble service is to be realized, more than one ensemble (frequency) should be assigned to the service area for the target program. On the other hand, the multiple ensemble services are confined to the areas where the receiver can receive more than one ensemble from the different transmitters with different frequency blocks (overlapped service area). Fortunately, in most cases of analog radio service, a receiver can receive several frequency bands at one position. But the case of DAB system will not be the same.

In the case of receiving more than two frequency bands for a service, the DAB receiver should decide and display the availability of the service when both of the divided data frames from both of the ensembles are available as well as all the single ensemble services.

Specific ensemble planning algorithm is beyond the scope of this paper and it is more necessary to integrate the planning of the ensembles with the frequency assignment step in the planning of ensembles especially for the implementation of multiple ensemble services [8]. The following section describes our trial to prove the improvement of the proposed idea over no management scheme.

III. MODELING AND SIMULATION

There are three kinds of data scheduling method in data broadcasting system – push-based broadcast, on-demand (or pull-based) broadcast and hybrid broadcast. Push-based broadcasting is for simplex broadcasting, where the service provider just pushes the available data to the receivers through broadcasting channel. On-demand broadcasting is the broadcasting that has some kinds of return channel from receivers back to service providers. Broadcasters push the data to the receivers by gathering and analyzing the requirements from the receivers. Hybrid broadcasting uses the characteristics from both types of scheduling methods [7].

In general, some portions of ensemble broadcasting needs long-term based data scheduling, for example, MOT (Multimedia Object Transfer) data carousel for somewhat long retransmission period [9]. However, even that case can be modeled as dynamic when we regard relatively long average service time. Therefore, in the simulation in this paper, we regarded that all the data services are fully dynamic and they are all on-demand broadcasting. That is, the broadcasting service has the return channel through which the requirement from the receiver can always be given back to their service providers.

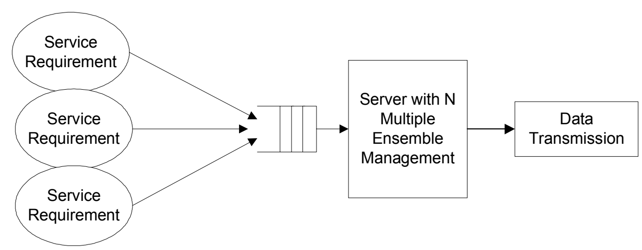


Fig. 7. Data scheduling model

Fig. 7 shows the simple model of data scheduling in this paper. In the multiplexer, which has multiple ensemble management capability, the service requirements generated by the broadcasting schedule or user demand goes into the queue before the data transmission server, which has the right to handle N ensembles. The service requirements are processed following FCFS (first come first served) strategy. The basic inputs to the system are random service start time, service time and also, the random data rate requirement for each of the service.

When we assume that the receiver exists in the service area of the transmitters, and the requests of the broadcasting of the data packets by the data providers (or by on-demand data scheduling) follow Poisson distribution, and the service duration follows the exponential distribution, this situation becomes the case which is similar to the combinations of M/M/1 queue, where the number of server is the number of ensembles and the available service data rate for each of the services is defined between the data rate requirement and the remnant capacity in all the ensembles.

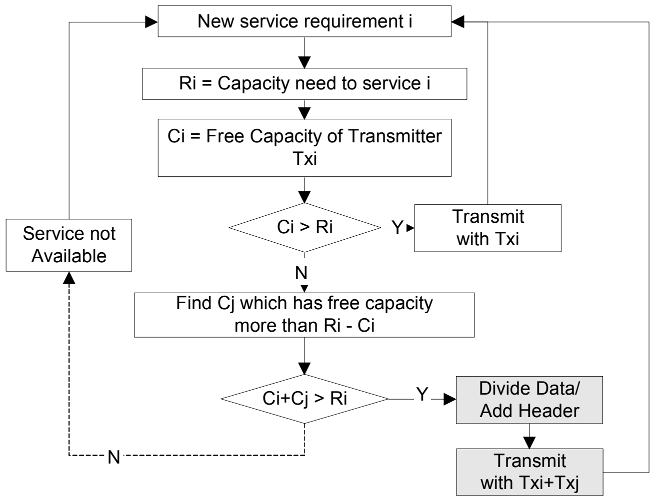


Fig. 8. Ensemble management procedure example

Fig. 8 shows a simple example of ensemble capacity management when the receiver can receive up to two ensembles. Firstly, the ensemble manager checks the data rate requirement for new incoming requirement *i*. And the ensemble manager decides whether the service can be served to the available service area or not. When all the combinations of remaining CUs (sum of C*i*s) of all the ensembles under control of the ensemble manager are not large enough for the new services (R*i*), the ensemble manager blocks the requirement of the service. The performance may vary with the types of blocking strategies, LCC (Lost Call Clear), LCH (Lost Call Hold) [10].

In the simulation, we assumed that the DAB system is the terrestrial broadcasting system which is using mode I. The parameters for mode I is summarized in the Table II.

TABLE II
PARAMETERS FOR MODE I

Parameters	Value
Application	Terrestrial Radio
Frequency Bands	< 375 MHz
Normal Maximum Transmitter Separation (km)	96
Number of Sub carriers	1,536
Sub carrier Spacing (kHz)	1
Guard Interval (μ s)	246
Symbol duration (μ s)	1,000
Total Symbol Duration (μ s)	1,246
Null Symbol Duration (μ s)	1,297
Frame Duration (ms)	96
Fast Information Blocks per Frame	12
CIF(Common Interleaved Frame)s per Frame	4
Available Symbols per Frame	76
Timing Frequency Phase Reference Symbol	1
OFDM symbols for FIC/frame	3
OFDM symbols for Main Service Channel/frame	72
Total bits per FIC/frame	9,216
FIC bits/sec	96
Total bits per Main Service Channel/frame	221,184
Data bit/sec in Source Level	2,304,000
Capacity Units per 24ms CIF	864

As the data services are provided with the units of 8 kbps, we let the random input service requirement data rates vary with the units of 8 kbps. We estimated the blocking probability of the proposed ensemble management strategy comparing with that of the existing method. The comparison result and performance discussions are as the followings.

IV. DISCUSSIONS OF THE PERFORMANCE

The estimation and comparison of the efficiencies of the ensemble management schemes in DAB networks will not be an easy work. The data rates required by scheduled program and backward channel will vary from 0 kbps to 1.5 Mbps or more. Short data services will cause the multiplexers to switch their configuration more often than relatively large size of file transmission. In order to prevent the frequent change of schedule in the DAB transmitter, he service providers and ensemble managers may let the short and low data rate services be provided with dedicated and fixed channel. Simply, we assumed that the mean rescheduling time is one hour for the simulation in this paper. The rescheduling time can be changed to any values following the system status.

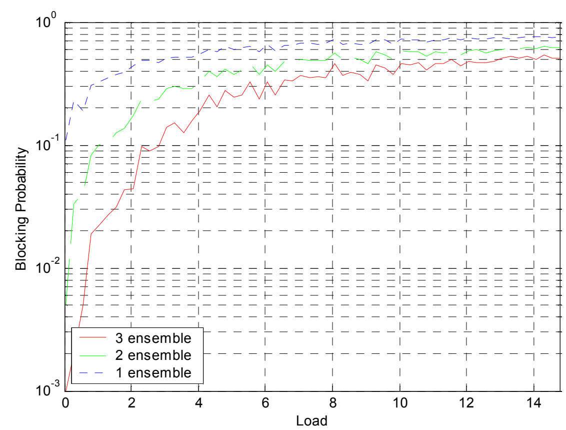


Fig. 9. Blocking probabilities (mean arrival and interval are 1 hour)

Fig. 9 shows the comparison result of the blocking probabilities at the ensemble manager according to the numbers of ensembles (1-3), when we assumed that both the average service time and the interval between the starts of the services as one hour. Fig. 10 shows the comparison result between existing method and the proposed architecture. In order to measure the performance of the proposed architecture, we estimated the service blocking probability with the LCC scheme. When there is not enough remnant space in the ensembles, the incoming service requirements will be discarded by the ensemble manager to accommodate the service requirement and never check that again later.

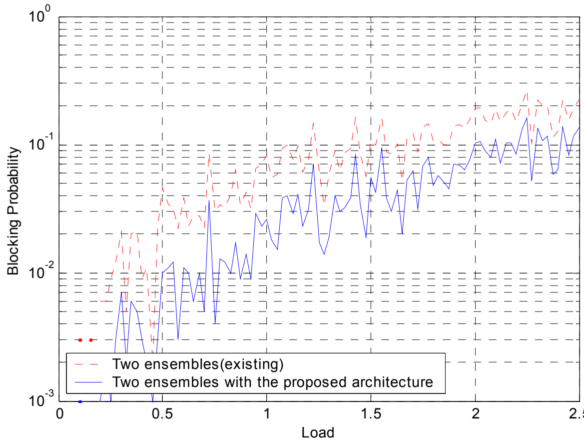


Fig. 10. Blocking probabilities (mean arrival and interval are 1 hour)

Performance of the proposed algorithm mainly depends on the size of the data rates needed to serve the requirements of the service providers. When the data rate requirements are very small, hardly any improvement can occur but causing the increase of the processing time and lack of the capacity in the ensemble due to the overhead for dividing and re-assembling the data frames. But when the required data rates of services are rather large, the probability of decision to divide data frames increases and shows the better performance than the existing no management schemes. Therefore, for the high load data service which need large file transfer to the receivers such as geographic information and long time movie clips, the proposed architecture shows the better results.

However, as we mentioned earlier in this paper, implementation of the proposed architecture needs some of the prerequisites to be satisfied. Firstly, coverage maching should be considered when using the proposed architecture, because the proposed architecture can be used only when the receivers are in the service area of several transmitters. This can be done with the study of precise coverage analysis and the problem can be handled with ensemble planning techniques [8]. Secondly, for the real-time service like SD television, another type of schemes should be studied to make it easy to separate and reassemble the video streams. Third, the receiver with multi-band capability and multiple ensemble processing function should be available to receive the services of these kinds.

V. Conclusion

This paper proposes a new architecture of multiple ensemble service schemes in DAB network, in which we can transmit and receive more than one ensemble through multiple transmitters and receivers. Using this architecture, ensemble providers and transmission network providers can have more flexible environment in the management of DAB networks as well as they can overcome the limit of one ensemble capacity. This is done by inserting an ensemble manager and an ensemble monitor in the transmitter system and let them manage all the ensembles to be multiplexed in the most efficient way. And in the receiver side, multiple frequencies handling capability is necessary of each of the receiver.

The simulation result shows that when the required data rates are rather large, the proposed architecture shows better performance than the existing architecture.

As the proposed architecture requires several condition to be effective in the DAB network such as ensemble planning problems and multi-band capability of the receivers, there needs to be many areas of further studies, an optimal ensemble planning for multiple ensemble services, as well as SDR technologies for multiple frequencies capability for each of the receivers.

References

[1] *ETSI EN 300 401* v1.3.3, "Radio Broadcasting Systems; Digital Audio Broadcasting (DAB) to mobile, portable and fixed receivers," Sep. 2001.

[2] Marko Grube, Peter Siepen and Christian Mittendorf, "Applications of MPEG-4 : Digital Multimedia Broadcasting," *IEEE Transactions on Consumer Electronics*, vol. 47, no. 3, pp. 474-484. Apr. 2001.

[3] M Tsavachidis, R Biehn and H keller, " DAB for a New Quality of Dynamic Traffic Information," *Proceedings of Road Transport Information and Control*, pp. 37-40. 2000

[4] "Dual band Digital Audio Broadcast (DAB) Receiver," *EP 1 139 589 A2*

[5] "Receiver for receiving broadcasting signals comprising two tuners, at least one of which is a receiver for receiving a Digital Audio Broadcast signal, comprising a means for comparing the output signals of the two receivers as well as a means for selecting either of those signals," *EP 1 041 757 A2*

[6] Jussi Ryynänen, Kalle Kivekäs, Jarkko Jussila, Aarno Pärssinen and Kari A. I. Halonen, "A Dual-Band RF Front-End for WCDMA and GSM Applications," *IEEE Journal of Solid-State Circuits*, vol. 36, no. 8, pp. 1198-2001, Aug. 2001.

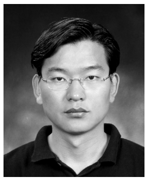
[7] Jianliang Xu, Dik-Lin Lee, Qinglong Hu and Wang-Chien Lee, "Data Broadcast," *Handbook of Wireless Networks and Mobile Computing,* pp.243-265, John Wiley & Sons, 2002.

[8] Albert Gräf and Thomas McKenney, "Ensemble Planning for Digital Audio Broadcasting," *Handbook of Wireless Networks and Mobile Computing,* pp.267-288, John Wiley & Sons, 2002.

[9] *ETSI EN 301 234 v1.1.1* "Digital Audio Broadcasting (DAB); Multimedia Object Transfer (MOT) protocol," Jan. 1998.

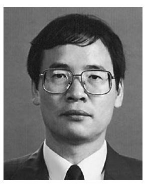
[10] Alberto Leon-Garcia, *Probability and Random Processes for Electrical Engineering*, Addison-Wesley, 1994.

BIOGRAPHIES



Sammo Cho received the M.S. degree in electronics engineering from the Kyungpook National University, Korea, in 1994. In 1993, he joined radio resource management research team in ETRI (Electronics and Telecommunications Research Institute) in Korea. He is currently a senior research member of mobile multimedia broadcasting research team in ETRI. His current interest includes software radio, digital communications and digital multimedia broadcasting system.

Soo In Lee received the B.S., M.S. and Ph.D. degrees in electronics engineering from the Kyungpook National University, Korea, in 1985, 1989 and 1996, respectively. Since 1990, he has been with Broadcasting System Division in ETRI (Electronics and Telecommunications Research Institute) in Daejon, Korea.. He is currently a director of his division and his current interest includes channel coding, digital modulation and digital multimedia broadcasting system.



Hyuckjae Lee was born in Inchon, Korea. He received B.S. degree in electronic engineering from Seoul National University, Korea, in 1970, and the Ph.D. degree in electrical engineering from Oregon State University, Corvallis, in 1982, where he specialized in electromagnetic fields and microwave engineering. Since 1983, he has been with the Radio Technology Department, Electronics and Telecommunications Research Institute (ETRI), and has been working in the fields of radio technology, IMT2000, broadcasting technology, and satellite communications system. He is currently a professor of Information and Communications University, Daejon, Korea.