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Design and Implementation of a Simulation Framework for Wireless Data Broadcasting based on Data ID Space Partition

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Abstract

For the information services supporting requests of data items from a great number of mobile clients, wireless data broadcasting is an effective way because it can accommodate any number of clients. In the wireless data broadcasting, various air indexing schemes and data scheduling schemes have been developed in order to enable the clients to access their desired data items efficiently. The broadcasting system needs a method to simulate newly designed air indexing and scheduling schemes of the system, and to evaluate the performance parameters of the schemes. In this paper, we design an expandable and efficient simulation framework for the wireless data broadcasting based on the partition of data ID space. The framework can adopt regular and irregular space partition and evaluate various performance parameters of the broadcasting system. We implement a testbed of the broadcasting system using the framework, that adopts IIP, GDI and EXP as its air indexing schemes. We simulate the system using the testbed and evaluate the performance parameters of the system. Thus, we show the efficiency and expandability of the designed and implemented framework.

Key words: *Wireless data broadcast system, simulation framework, air index, data ID space partition, multiple data access.*

1. Introduction

High-performance mobile clients like smartphones and an ultra-speed communication network like 5G enable us to access various information services anyplace and anytime. In the environments, it is very important for the information server of the services to support a great number of mobile clients that try to access their desired data items.

Wireless data broadcasting is the effective way to deliver data items to a great number of mobile clients, regardless of the number of the clients. In the broadcasting, the server disseminates data items to a wireless broadcast channel, then the clients access the channel and download their desired data items [1-3]. For example, Figure 1 shows a wireless data broadcasting system that disseminates stock prices of companies. The server broadcasts stock prices of the companies like Microsoft, Google, and Apple. The mobile clients tune into the

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channel, listen to it, and download the data items they desire for. Thus, the server does not need to expand the

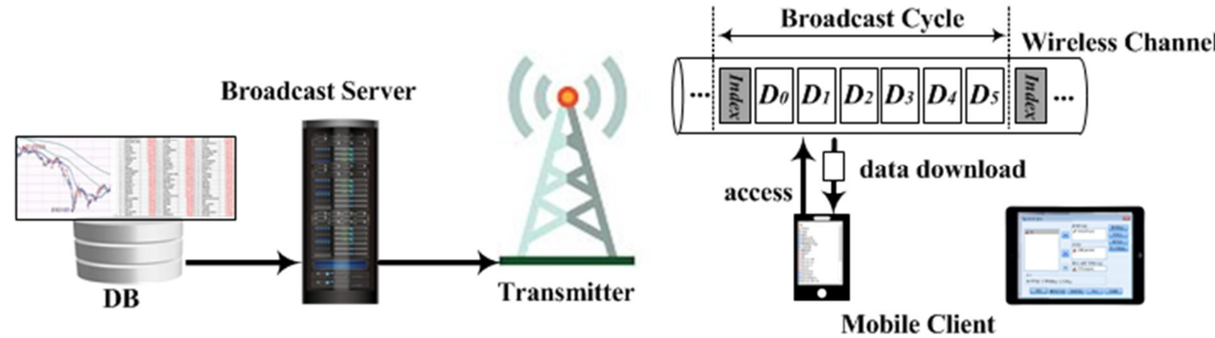

Figure 1. A Wireless Data Broadcasting System

capability although the number of the clients increases abruptly [4].

In the wireless data broadcasting system, the access time and tuning time are the performance parameters to evaluate. The access time is from the beginning a client tunes into the channel to the end of downloading all the desired data items. The tuning time is the sum of times for the client to listen to the channel for downloading them.

The naïve data broadcasting scheme that disseminates only data items to the wireless channel, makes the mobile clients spend lots of energy in downloading the queried data items, because the clients have to listen to the channel continuously until the desired data items appear to the channel after tuning into the channel. That means the clients have to spend lots of energy because they consume more energy in listening to the channel, than in staying in the doze mode, not listening to it. Air indexing scheme is introduced to reduce the energy consumption of the clients for their processing queries. The air index carries the information on the broadcasting time of each data item. The mobile clients can predict the broadcasting times of their desired data items using the air index. For the air indexing scheme, the server disseminates data and index information together in the manner of interleaving data and the index. Using the index information on the channel, the clients listen to the queried data items selectively. Thus, the air indexing scheme can lessen the amount of energy consumption of the clients at a cost of increasing the access time [5-7].

Data scheduling scheme can also affect the performance of the broadcasting system. The server can select the way of arranging data items on the wireless channel. The server can arrange each data item only once on the channel, or repeat some data items several times on the channel, that the clients prefer to access.

In order to evaluate efficiently the performances of the broadcasting system adopting various air indexing schemes and data scheduling schemes, we need a simulation framework to support to implement a simulation testbed. In this paper, we design and implement a simulation framework based on data ID space partition, that has expandability adopting various air indexing schemes and scheduling schemes and time-efficiency supporting quick implementation of the simulation testbed.

The rest of the paper is organized as follows. Section 2 reviews the scheme to partition data ID space. In Section 3, we design the simulation framework that consists of broadcast server, mobile client, and wireless broadcasting channel. Section 4 presents the implementation of the designed framework and experiments using the framework that evaluate the performance parameter of the system. In Section 5, we conclude the paper.

2. Related Works

In the broadcasting system adopting air indexing scheme, the way to arrange the air index on the channel can affect the performance of the systems. We can consider two ways: the first is to partition the data ID space regularly, the second is to partition the space irregularly. In the first way, the air index is allocated to every same interval of space that is partitioned regularly. On the other hand, the second way arranges the air index every same number of data items that is determined by irregular space partition [7].

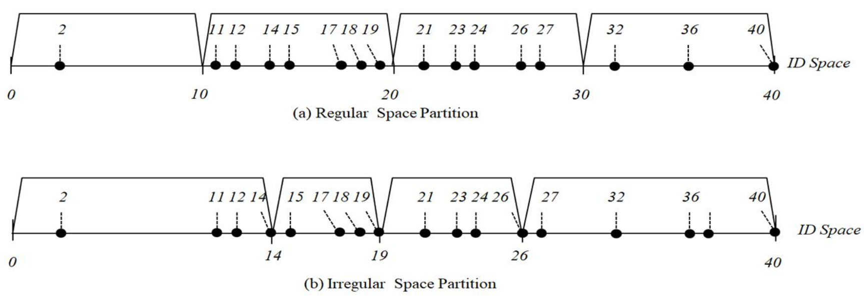

Figure 2. Data ID Space Partition Scheme

For example, Figure 2 shows the two ways, regular and irregular ID space partition. In the figure, 16 data items, *d2*, *d11*, *d12*, *d14*, *d15*, *d17*, *d18*, *d19*, *d21*, *d23*, *d24*, *d26*, *d27*, *d32*, *d36*, and *d40*, are items to be broadcast. The items distribute over *IS*, data ID space, $0 \le IS \le 40$. Figure 2(a) depicts the regular partition of IS. In the way, air index is allocated to every 10 ID, then, the distances between two neighboring air indexes on the wireless channel are different. However, Figure 2(b) shows the irregular space partition. In the way, air index is repeated every four items by irregular space partition on the wireless channel. Thus, the distances between two neighboring air indexes on the channel are same. The way to partition data ID space can affect the performance of broadcasting system because of the distances between two neighboring indexes.

To evaluate the performance of a broadcasting system, we need an expandable and efficient simulation framework to handle various space partition way and to adopt various air indexing schemes, and data scheduling schemes.

3. Design of a simulation framework based on data in space partition

We design a simulation framework that enables to implement a testbed for the wireless data broadcasting system and to adopt various air indexing schemes based on data ID space partition and data scheduling. For the framework, we design a broadcast server consisting of several modules for data broadcasting, and a mobile client with several modules for accessing data items from a wireless data broadcasting channel.

3.1 Broadcast server

We design the broadcast server in the framework as shown in Figure 3, which is structured with modules, broadcast manager, ID space partitioner, data scheduler, index generator, and channel organizer.

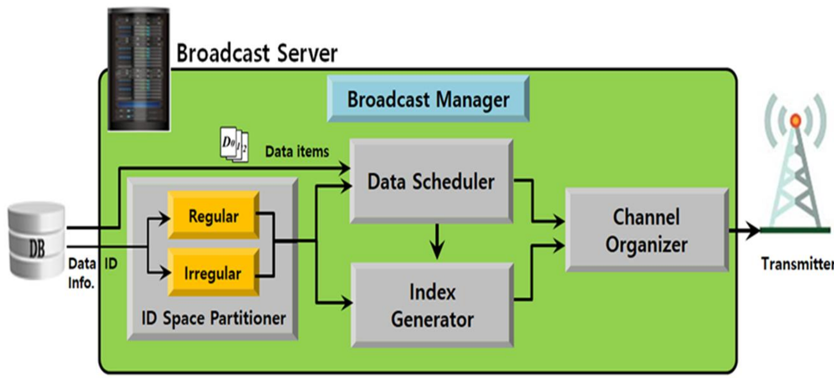

Figure 3. The Structure of the Designed Broadcasting Server

Each module in the broadcast server has its role as follows:

- Broadcast manager initiates the entire broadcasting process and manages the modules in the server.
- ID space partitioner receives the information on data ID to be broadcast from DB and partitions ID by groups accordint to the specified way from the broadcast manager.
- Data scheduler receives the information on ID groups from the ID space partitioner and data items to be broadcast from DB. The scheduler arranges the ID groups in a list, and then places data items into the groups containing them.
- Index generator receives the information on ID groups from the ID space partitioner and also obtains the information on the data broadcast scheduling from the data scheduler. The generator organizes the index for the broadcast, which keep the information about a data item and the time when it to be broadcast.
- Channel organizer interleaves the index and data items following the scheduled order by the data scheduler. The organizer sends the organization of the index and data items to the transmitter to broadcast over a wireless channel.

3.2 Procedure of data broadcasting

The broadcast server disseminates data items and the index after organizing the wireless channel. The entire broadcasting process is shown in Figure 4.

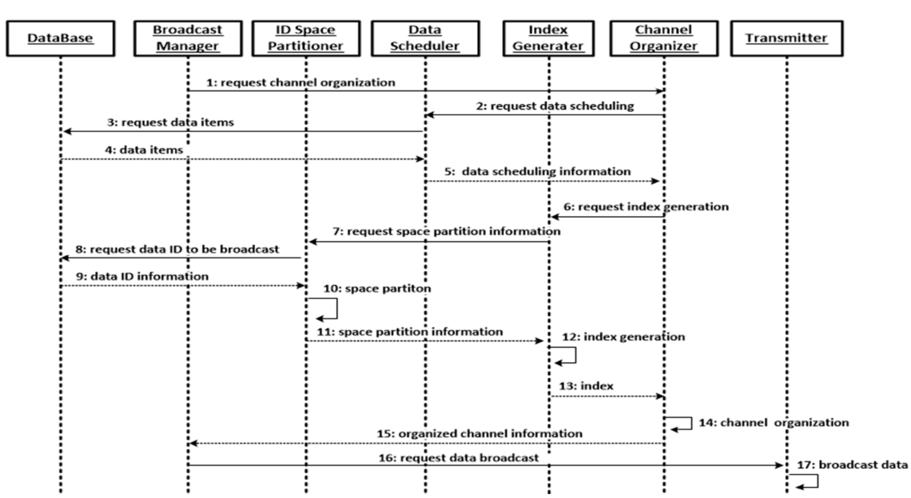

Figure 4. The Sequence Diagram for the Broadcasting Process

1: The broadcast manager requests the organization of the channel, which is the list of data items and index, for broadcasting to the channel organizer.
2: The channel organizer requests scheduling data items to be broadcast to the data scheduler.
3, 4, 5: The data scheduler searches data items to broadcast from the database and the database returns the requested data items to the scheduler. Using the data items, the scheduler arranges them and makes a list of them and returns the list to the channel organizer.
6, 7: The channel organizer requests the index information to the index generator. In order to generate the index, the generator requests the information on the ID space partition, specifying the way to partition the ID space, i.e., regular or irregular manner.
8, 9, 10, 11: The ID space partitioner request IDs of the data items to be broadcast to the database. With the information, ID space partitioner makes ID groups of data items, partitioning the space using the specified partitioning way, Then, the partitioner returns the information on ID groups to the index generator.
12, 13: The index generator organizes the index which holds the time information when each data item is broadcast, and returns the organized index to the channel organizer.
14, 15: The channel organizer arranges data items and the index information in a list by interleaving items and the index. Then, the channel organizer returns the organized channel to the broadcast manager.
16, 17: The broadcast manager requests the organized list of data items and the index to the transmitter. Then, the transmitter broadcasts the list of data items and index to the wireless channel.

3.3 Mobile clients

We design the mobile client with the structure shown in Figure 5 for the wireless broadcasting framework. The client consists of the channel access module, the query processor with the index analyzer and the query analyzer, and the data downloader.

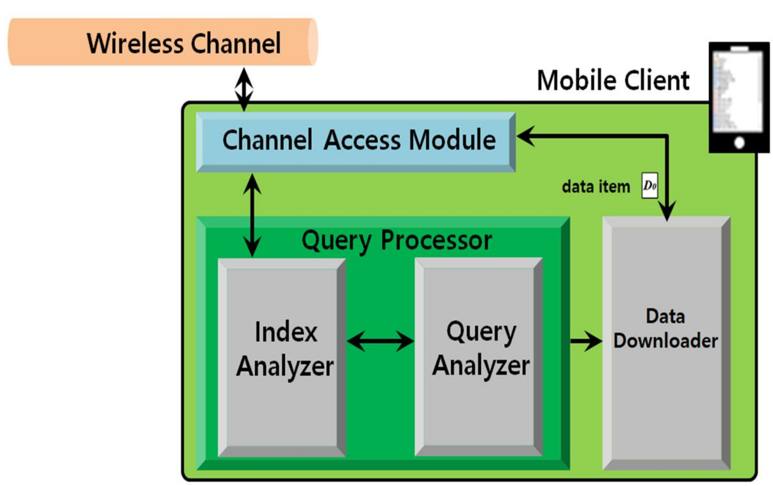

Figure 5. The Structure of a Designed Mobile Client

The role of each module in the mobile client is as follows:

- Channel access module accesses the wireless channel in order to obtain the data items and index information. The module downloads data items and index information when requests occur.
- Data downloader requests data items to the channel access module and returns them to the system.
- Query analyzer determines the data items to download from the wireless channel for a given query and the broadcasting times for them. For this process, the query analyzer requests index analysis to the

index analyzer.

- Index analyzer requests the index information to the channel access module and determines the broadcasting times to be downloaded for the given query.

3.4 Processing Queries and downloading the data items

The entire process that the mobile client searches and downloads the queried data items from the wireless channel is as shown in Figure 6.

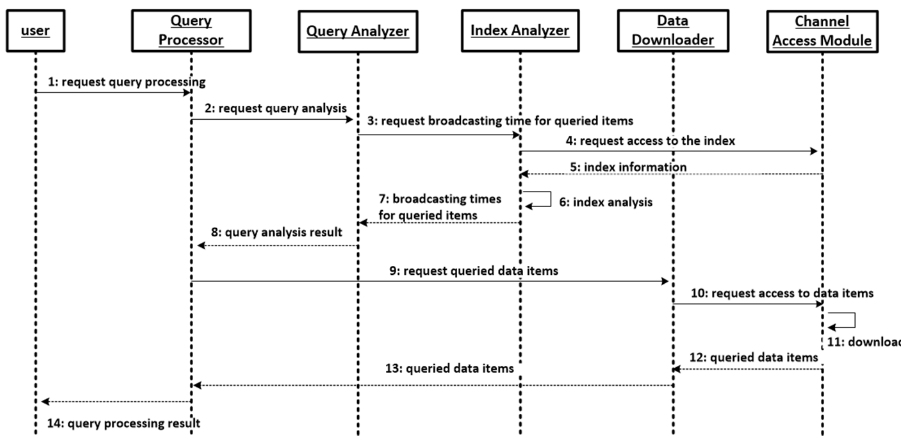

Figure 6. The Sequence Diagram for Processing a Query

1: The user requests processing a given query to the query processor that consists of the index analyzer and the query analyzer.
2: The query processor sends the query to the query analyzer for downloading the queried data items.
3: The query processor determines which data items have to be downloaded for the given query, and requests the broadcasting time of the queried data items to the index analyzer.
4, 5: The index analyzer requests the index information to the channel access module to determine the broadcasting time. Then, the channel access module downloads the index information from the wireless channel and returns it to the index analyzer.
6, 7: The index analyzer determines the broadcasting times of the queried data items using the index from the channel access module, and returns the times to the query analyzer.
8, 9: The query analyzer returns the broadcasting times for the queried data items to the query processor. Then, the query processor sends the time information for the queried items to the data downloader.
10: The data downloader requests downloading the queried data items to the channel access module by sending the time information.
11, 12: The channel access module downloads the queried data items at the times received from the downloader, and returns the data items to the data downloader.
13, 14: The data downloader returns the data items from the channel access module to the query processor. Then, the query processor returns the queried data items to the user.

4. Implementation and experiments

With the designed simulation framework, we implemented a testbed for the wireless data broadcasting system, that consists of the broadcast server, the wireless channel, and the mobile client. Using the testbed, we simulated the wireless data broadcasting system based on the regular data ID partition and irregular partition, and evaluated the performance parameters.

4.1 Implementation of the proposed framework

Figure 7 shows the stack of softwares for the implementation, based on JAVA. We use SimJava, the discrete time scheduler, for managing time in the implementation. We implement the wireless data broadcasting system using the proposed framework, that consists of the broadcast server, the wireless channel, and the mobile client. Figure 8 shows the console window of the wireless data broadcasting simulation. Through the simulation, we can monitor various performance parameters of the data broadcasting. Figure 8 shows two performance parameters, the access time and the tuning time, of the broadcasting.

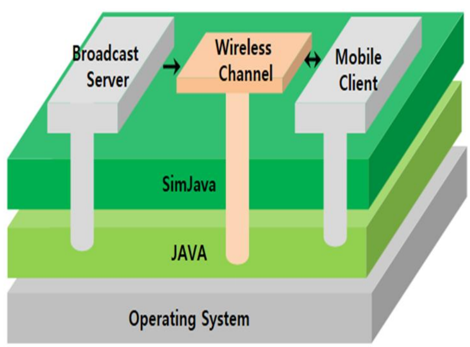

Figure 7. The Stack of Softwares for the Framework

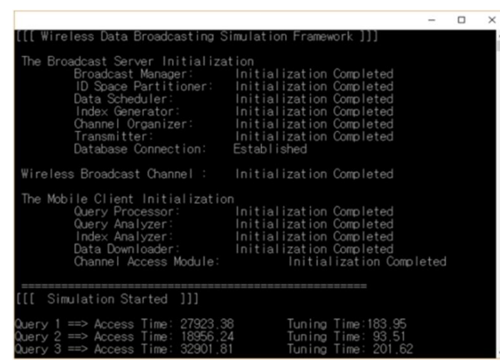

Figure 8. Wireless Data Broadcast Simulation

4.2 Experiment

Using the implementation, we simulate the wireless data broadcasting. We use 10,000 data items of which ID spreads in irregular distribution. For the simulation, we adopt three indexing schemes, IIP(Index based on Irregular Partition) [7], GDI(Grid partition Distributed Index) [6], and EXP(Exponential Index) [5] for indexing the data items. The mobile client processes multipoint queries that access k data items from the wireless broadcast channel. For IIP indexing scheme, the broadcast server adopts irregular space partition. Also, the server adopts a regular space partition and an exponential table for GDI and EXP, respectively.

Figure 9 shows the access time of the three indexing schemes, varying k from 5 to 50. The figure shows that IIP by irregular space partition outperforms GDI in regular space partition and EXP with exponential table. The figure reveals that the irregular space partition lessens the access time than regular space partition and exponential table.

Figure 10 shows the tuning time of the three indexing schemes for $k = 15$. The figure demonstrates IIP and GDI based on space partition are advantageous for reducing the tuning time.

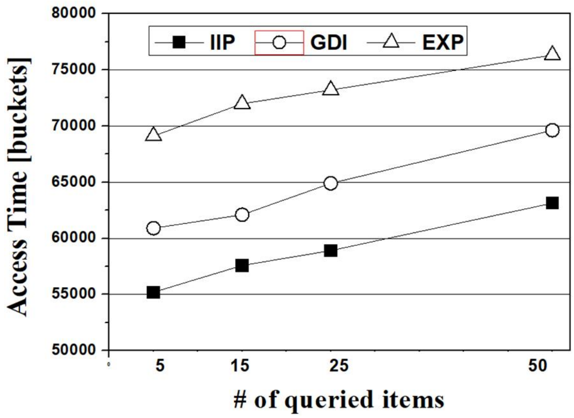

Figure 9. Comparison of the Access Time

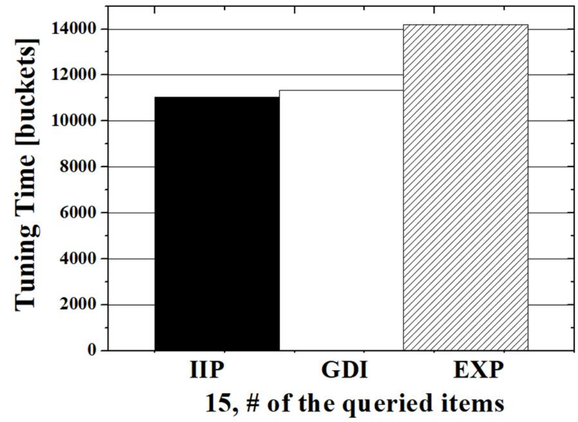

Figure 10. Comparison of the Tuning Time

The proposed framework for wireless data broadcasting can evaluate the performance of indexing scheme and data scheduling based on regular/irregular space partition.

5. Conclusion

We design a framework for the wireless data broadcasting, and implement a simulation testbed using the framework. The framework based on data ID space partition can adopt regular or irregular partition and various data scheduling schemes. Also, the framework enables to evaluate the various performance parameters of the wireless data broadcasting system. In order to show the expandability and efficiency of the framework, we simulate wireless data broadcasting adopting various indexing schemes, IIP, GDI, and EXP using 10,000 data items in irregular ID distribution. The designed framework can be adopted efficiently for evaluating the performance evaluation of the wireless broadcast system based on ID space partition and various data scheduling schemes.

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