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A Query Processing Method for Hybrid Wireless-Broadcast Networks

Jing CAI, Tsutomu TERADA, Takahiro HARA, and Shojiro NISHIO
Graduate School of Information Science and Technology, Osaka University
1-5 Yamadaoka, Suita, Osaka, 565-0871, Japan
{cai, tsutomu, hara, nishio}@ist.osaka-u.ac.jp

Abstract

In this paper, we propose a new effective query processing method through our Hybrid Wireless Broadcast (HWB) model, which combines push and pull based broadcast and pull-based point-to-point wireless communication. Our method provides a flexible and complementary information service in different bandwidths and service ranges. The results of simulation studies show the HWB approach shortens the average waiting time and enhances the performance of the system.

1 Introduction

With the rapid improvements of mobile computers and advances in mobile communication technology, there is an increasing requirement for high efficiency and high quality mobile information services. On the other hand, frequent disconnection, limited communication bandwidth, and limited energy, storage and computation power are still current challenges facing the mobile computing environment. In addition, the current mobile information services are mostly based on client-server or point-to-point mechanism. However, numerous mobile users concurrently demand for the services, which will give rise to the overload of server and bandwidth.

As an effective information dissemination method, data broadcast has received a lot of attention in recent years, mainly because it can scale up to an arbitrary number of mobile users, and thus facilitate efficient bandwidth usage. Accordingly, wireless data broadcast is suitable to disseminate public information, such as stock quotation, news, weather and traffic information, to massive mobile user population. Therefore, taking advantage of broadcast for mobile information services is an elegant solution to address the issues of mobile computing.

A large number of studies on data broadcast have been performed, which focus on the push-based broadcast [1], the pull based broadcast [2] or the balancing of the push and pull based broadcast [3, 4]. Some studies discuss the hybrid networking based on wireless data broadcast [5, 6]. They normally assume that the base station provides push-based broadcast and pull-based unicast channel, in which the on demand response is limited in point-to-point wireless communication; and the information service of push-based broadcast is also limited in the local scope of base station. However, there is no study considering combination of the broadcast, on-demand broadcast and on-demand wireless communication, and providing information services in different bandwidths and service ranges.

The purpose of this paper is to explore a new approach further into hybrid networking. We contribute a new effective query processing method through our Hybrid Wireless Broadcast (HWB) model, which combines push and pull based broadcast and pull-based point-to-point wireless communication. Mobile users can access the push-based broadcast; also can pull the information from the unicast wireless communication or from the pull-based broadcast. By utilizing the different advantage of the three data delivery ways, our method can provide a flexible and complementary information service.

The remainder of the paper is organized as follows. The detail of our proposed HWB approach is presented in Section 2. Simulation model is described in Section 3. Section 4 gives the primary experimental results. Finally, this paper concludes with Section 5.

2 HWB Approach

2.1 Communication Environment

As Figure 1 shows, it is assumed that our proposed HWB approach is based on a hybrid network environment, which involves a broadcast server and lots of base stations. A large number of clients holding a portable terminal such as mobile phone, PDA, and palmtop, are supposed to be able to acquire information from the base station; furthermore, can access information on air from the broadcast server.

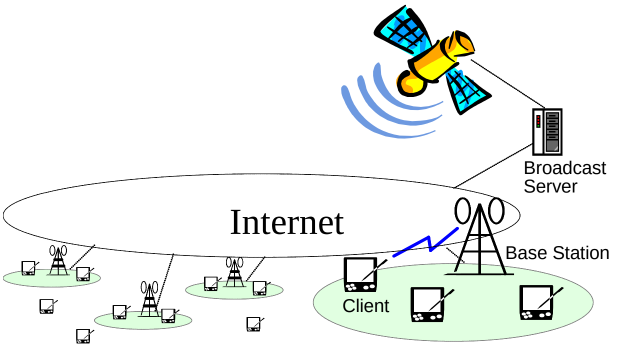

Figure 1. HWB Environment

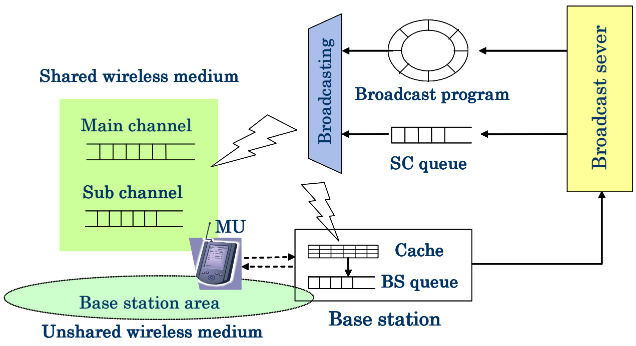

Figure 2. Communication Model

2.2 Communication Model

Figure 2 indicates the communication model of the HWB approach. Broadly speaking, it is divided into two main kinds of information dissemination: the broadcasting information from the broadcast server in a large scope, and the wireless information from the base station (BS) in a limited area. Furthermore, the bandwidth for broadcast is classified as the main channel and the on-demand sub channel (SC). Consequently, mobile users (MU) can receive the response from one of the above data delivery ways: the main channel, the on-demand sub channel, and the on-demand wireless channel. Their different features are illustrated in the following.

The main channel, which provides the push-based broadcast, sequentially and periodically broadcasts the whole data of the broadcast server. Bandwidth does not need to be scaled as the increasing number of mobile users accessing the channel. On the other hand, any access request would not get responded to until the required data arrives. It may not be able to acquire the reply quickly, even though the quantity of the issued queries is small.

The sub channel is used for the pull-based broadcast, which sequentially but not periodically broadcasts on-demand data. Any on-demand data broadcast in the sub channel can also be accessed by a large number of mobile users. Therefore, it is efficient for the responding of queries, while many clients request the same data.

The wireless channel of the base station offers pull-based point-to-point wireless communication. Both the sub channel and wireless channel are used to respond on-demand data. However, unlike the pull-based broadcast, the wireless channel is unshared due to the point-to-point communication. On the other hand, each base station has a cache and provides services only for the mobile clients in its responsible area, who normally have some common interest in the local data. As a result, it is good at increasing the cache hits, when caching a lot of local data.

Additionally, the bandwidths are also different. The main channel has a high-bandwidth; the wireless channel has a low-bandwidth; whereas the sub channel has a middle-bandwidth. Taking advantage of these different features, our proposed HWB approach can provide a complementary information service.

2.3 Query Processing

We consider the broadcast server containing N data items of equal size D, and assume that the bandwidths for the main channel, the sub channel and the wireless channel are B_m, B_s and B_w, and the waiting times are T_m, T_s and T_w, respectively. The query processing is performed as the following procedure:

Step 1: Calculate the three waiting times with the suitable formula, in terms of different status.

Assume that N_t is the position of the data item in the broadcast program, which is currently broadcasting through the main channel; N_i is that of the requested data item. According to the relative location of the requested data item and the current broadcasting data item, T_m is calculated as follows:

$$T_m = (N_i - N_t) \times D \,/\, B_m; \qquad (N_i \geq N_t)$$
$$T_m = (N - N_t + N_i) \times D \,/\, B_m. \qquad (N_i < N_t)$$

As to the sub channel, if the requested data item has been placed into the queue, where N_s is the location of the requested data item in the sub channel queue,

$$T_s = N_s \times D \,/\, B_s;$$

or if it has not been existed in the queue, where L_s is the length of the sub channel queue,

$$T_s = L_s \times D \,/\, B_s.$$

For the wireless channel, the base station needs to check its cache. If there is the requested data in the cache, where L_w is the length of the base station queue,

$$T_w = L_w \times D \,/\, B_w;$$

otherwise, the wireless channel cannot be used for the query, because the waiting time is infinite, i.e., $T_w \rightarrow \infty$.

Step 2: Compare the three waiting times and select the shortest one to reply to the query.

Step 3: According to the compared result, take a corresponding action.

If the wireless channel is the shortest, the base station will put the request into its waiting queue, and respond to the query by itself; if the sub channel is the shortest and the data item has not been placed into the sub channel queue, the base station will transfer the query to the broadcast server through the Internet. In other cases the base station will not respond or transfer the query, that is to say, the requested data will soon be broadcasted through the main channel or the sub channel.

3 Simulation Model

The HWB environment is modeled in our simulation model, which specifically consists of the client model, the base station model, and the server model.

3.1 Client Model

The exact number of clients is not specified, instead all the client population is modeled as a single module that generates the independent query interval. The generation of query interval follows the Poisson distribution.

To model in what access pattern clients issue each query, all the data items of the database are divided into several data groups. It is assumed that the clients in the same base station area have a higher tendency to issue a query from its own data group and a lower tendency to request from other data groups. Moreover, the skewed query is provided for the queries inside the data group, which employs the Gaussian distribution.

3.2 Base Station Model

The base station takes responsibility for the cache management and query processing. Each base station has a LRU cache, which stores local data requested by clients in its area. Moreover, the base station processes the queries. As depicted in subsection 2.3, it needs to calculate and compare the three waiting times for the main channel, the sub channel, and the wireless channel; and then according to the compared results, it takes a corresponding action: respond by itself, transfer the query to the broadcast server, or do nothing.

3.3 Server Model

The broadcast server manages the broadcast of the main channel and the sub channel. The broadcast program of the main channel is fixed in random sequence; whereas the on demand data of the sub channel is dynamically changed as the client's request. When the server receives the request for some data item from the base station, it will insert that data item into its sub channel queue, if the requested data item has not been placed into the sub channel queue.

Table 1. Parameter Settings

Parameters	Values
Database Size [Data Items]	5,000
Data Item Size [KB]	100
Number of Base Station	10
Cache Size of BS [Data Items]	100
Main Channel Bandwidth [Mbps]	100
Sub Channel Bandwidth [Mbps]	10
Wireless Bandwidth [Mbps]	1
Time Slot [D/Bm]	20,000
Query Interval [ms]	200 $\sim$ 2,000
Data Group Size [Data Items]	500
access tendency [%]	80
Deviation for Gaussain	10
Time Out [s]	10

4 Experiments and Results

Our experiments examine some important factors of the simulation model in two main performances: the average waiting time and the success rate of the query. To evaluate our proposed HWB approach more precisely and objectively, some other approaches are introduced into our experiments: random WB approach, push/pull approach, push/w approach, pure pull approach, and pure push approach.

The communication mode of the random WB approach is the same as the proposed HWB approach: both of them hold the base station cache and offer the three data delivery ways, which are the main channel, on-demand sub channel and on-demand point-to-point wireless channel, as a response to every request issued from the mobile clients. The only difference is the selection method of query processing. Random WB approach randomly adopts one way from the above three data delivery ways.

Push/pull approach provides push and pull based broadcast, respectively using main channel or on-demand sub channel; while push/w approach uses push-based broadcast with main channel, and point-to-point on-demand wireless channel. Both of them adopt the better way, with much shorter waiting time, from those two possible data delivery ways to respond to each query.

The parameters and their main values used in our experiments are presented in Table 1. The number of data items in the database is 5,000; while the base stations is 10. To provide the different bandwidths, the main channel is 100Mbps, the sub channel is 10Mbps, and the wireless channel is 1Mbps. Each experiment runs 20,000 time slots with the average query interval varying from 200ms

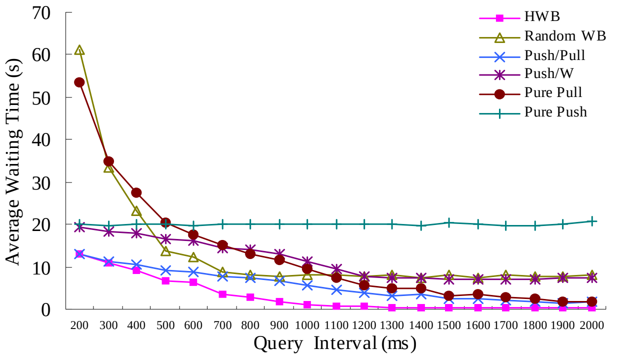

Figure 3. Waiting Time vs. Query Interval

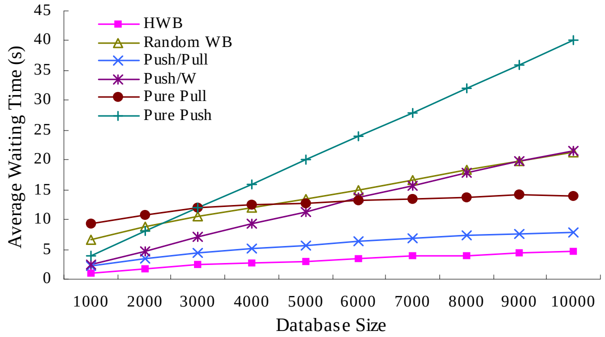

Figure 5. Waiting Time vs. Database Size

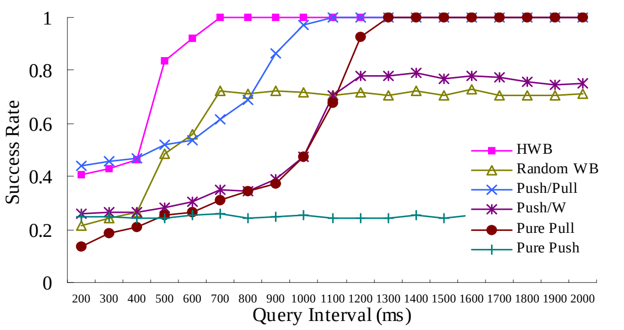

Figure 4. Success Rate vs. Query Interval

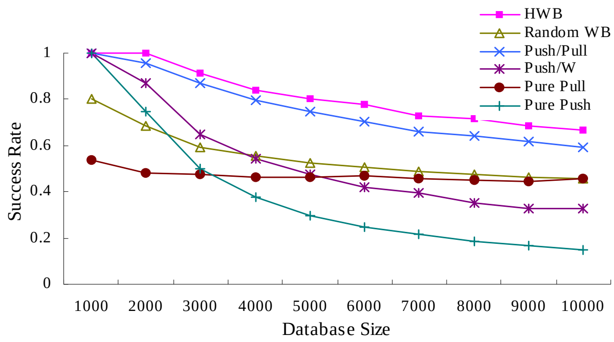

Figure 6. Success Rate vs. Database Size

to 2,000ms; while a time slot is the time that a data item is broadcast through the main channel.

4.1 Impact of Query Frequency

First, we evaluate the performance of the average waiting time and the success rate under different workloads. Observing the whole process of the Figures 3 and 4, as the query interval decreases the workload increases, and the performance declines for almost all the approaches. However, the degrading degree for the HWB approach usually is the smallest, that is to say, the proposed HWB approach normally outperforms the other approaches, of which the average waiting time is the shortest and the success rate is the highest.

It is clear that the performance between the HWB approach and the random WB approach is quite different, even though they have the same communication mode. As Figure 4 shows, the highest success rate for the random WB approach is only around 0.7, which is lower than 1 of the HWB approach. Because the methods of query processing are rather different; for the HWB approach, all the time it only selects the one with the shortest waiting time from the three data delivery ways; on the other hand, for the random WB approach, it not only may select the shortest one, but also maybe the longest one.

4.2 Impact of Database Size

Secondly, we examine the influence of the number of data items in the database. Figure 5 shows that the average waiting time of almost every approach, except for the pure pull approach, is proportional to the number of data items, but at different slopes. The gradient of curve clearly reveals the performance, the smaller the gradient the shorter the average waiting time. Pure push approach sequentially broadcasts the every data item of the database by using the main channel. Based on the broadcast of the main channel, the other approaches add one or two other data delivery ways. The push/w approach and the push/pull approach respectively add the on demand wireless channel of the base station, or the pull-based broadcast of the sub channel. Moreover, the HWB approach adds both the on demand wireless channel and the on demand sub channel; therefore it outperforms the others with the smallest slope.

The performance for all the approaches declines as the database size increases. However, the HWB approach still outperforms the other approaches all the time, with the shortest average waiting time and the highest success rate (cf. Figure 5, 6).

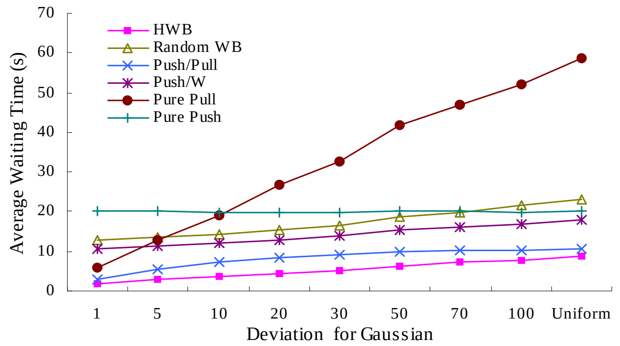

Figure 7. Waiting Time vs. Query Deviation

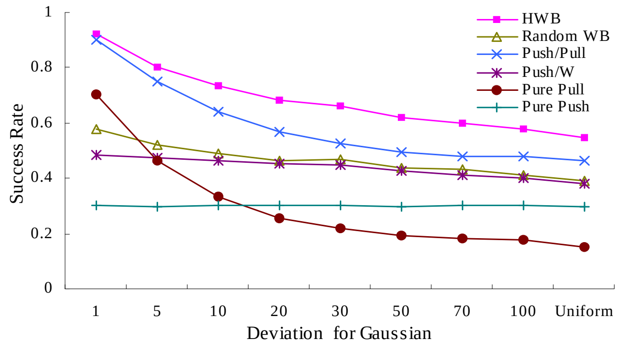

Figure 8. Success Rate vs. Query Deviation

4.3 Impact of Access Pattern

The evaluation about the access pattern is illustrated in Figures 7 and 8, by varying the deviation of the Gaussian distribution for the skewed query and comparing with the uniform query. As the deviation is smaller, namely, the queries become increasingly skewed, the performances of almost all upgrade, and the skewed queries still perform much better than the uniform query; especially there is a large improvement for the pure pull approach; only the pure push approach has no change. Across the entire region of the evaluation, the HWB approach has the best performance among all the approaches.

4.4 Summary of Experiments

We conclude from all of the above evaluation results that our proposed HWB approach shortens the average waiting time and enhances the performance of the system; at the same time, even when the system workload increases, the degrading degree of the HWB approach usually is the smallest. In other words, the HWB approach works effectively and outperforms the other approaches all the time, by taking advantage of both on demand sub channel and on demand wireless channel. Furthermore, in comparison with the Random WB approach, it is clarified that two core parts of the HWB approach, namely HWB communication model and HWB query processing stated in Section 2, cannot be divided.

5 Conclusion

In this paper, we have put forward a novel information delivery mechanism to contribute hybrid networking through our Hybrid Wireless Broadcast (HWB) model, which combines push and pull based broadcast and pull-based point-to-point wireless communication. Moreover, based on the HWB model we have proposed an effective query processing method, which can provide a flexible and complementary information service in different bandwidths and different service ranges. Furthermore, a simulation model has been developed to evaluate the performance of the data delivery system. The experimental results showed that our proposed HWB approach shortens the average waiting time and enhances the performance of the system; and the degrading degree usually is the smallest, even when the system workload increases.

As future work, the benchmark of the optimal selection from the proposed three data delivery ways, not only simply considering the waiting time of query, we will take the response cost into account to investigate more effective query processing algorithms.

6 Acknowledgments

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