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Channel Optimization for Wireless Data Broadcast

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ABSTRACT

Recently data broadcast has emerged as powerful tool for information dissemination to massive number of clients equipped with portable gadgets. Wireless communication use air as medium for transferring data to exchange information between mobile client and remote server. To enhance communication capacities and avoid information clashing multichannel broadcast is preferred; which partition available air bandwidth in to small bandwidth air channels. In wireless environment plethora of data are transferred through air creating chaos on air channels. Hence broadcast channel is scared resource for wireless communication which greatly concern system performance by affecting data access time. This paper studies process of data scheduling and broadcasting for multichannel environment with optimal use of air channels. Various method of data placement over multichannel are studied and analytical model to find optimal number of air channel is developed. Simulation results of system performance in context of access time are inferred and presented.

Keywords

Broadcast scheduling, mobile client, multichannel broadcast, wireless data broadcast.

1. INTRODUCTION

The rapid development of wireless communication technology and battery-powered portable devices has led to emergence of wireless/mobile computing as a new era in data communication and processing. The advent of this technology makes it possible to access information any time, anywhere using a portable size wireless computer (e.g. laptop, PDAs, and mobile phones). These portable devices communicate with a central stationary server via a wireless channel. Wireless communication system is based on client server model (CSM) where mobile client (MC) generates a query and server has to satisfy this query. Air channel(s) acts as a mediator to process the query from client to server and response from server to client. The major shortcoming with such system is that data are accessed sequentially which cause mobile client to wait for a large time before receiving desired data item. Consequently, dependence of mobile devices on rechargeable batteries, which has limited capacities, is also another drawback of mobile data retrieval. Hence performance of wireless communication system is assessed by two parameters: *access time and tune time* where former is related to time elapse from the moment a request is initiated until all data item of interest are received while later is the amount of time spent by the client to listen for the desired broadcast data item(s). The performance of wireless communication depends largely on these two factors. These two issues are orthogonal to each other and can't be reduced in single move. Therefore performance of system depends largely on their trade off. Hence hierarchical problem of data broadcast management can be seen as problem of balancing these two parameters as shown in figure 1.

Figure 1: Hierarchical Problem of Data Broadcast Management

Since wireless environment is more error prone than traditional wired environment. It possess various challenges of resource constrain, low network band width, asymmetric communication cost, heterogeneity and overloaded network. Due to reasons of fault tolerance, application scalability, network standard and minimal communication cost multichannel environment is important than single channel [1-2]. Also due to various constraints of business, economy and technical reasons mobile service provider generally use combination of low bandwidth to obtain combine high combined band width instead of single high bandwidth channel. Therefore, the modern wireless communication is multichannel where server has a heap of data to satisfy the query of mobile client. Scheduling and clustering are two important data organisation techniques for improving data access efficiency. Scheduling decides the contents of broadcast cycle while clustering groups the data in an order based of their instinct values. A broadcast schedule is a sequence of data item broadcasted by broadcast server. The primary goal of broadcast scheduling is to minimize the mean access time while keeping tune in time considerably low. The other possible goals of broadcast scheduling are: proper ordering of data item, proper use of available channel space and optimal trade off between access time and tune in time Broadcast scheduler on server side schedule these data in order of client requirement based on some predefined formula or statistics gathered in recent past. The broadcast in which a single data item is placed once in a single broadcast channel is called flat broadcast and a broadcast in which a single data item appear more than once is called skewed broadcast. The periodic data scheduling demands skewed broadcast. To place data on multichannel we use two approaches: (i) optimal approach and (ii) heuristic approach; meaning of these approaches are elucidate properly in relevant section of this paper. Due to vital utility of wireless broadcast system the number of broadcast operator is increasing exponentially but air spectrum remains almost constant for a generation. Hence proper utilisation and relying on minimum number of channels in must. It is the main theme of this paper as well. In this context we have studied effect of channel optimization on access time.

The rest of this paper is organized as follow: section 2 formulates the problem on the basis of related work in this field. Section 3 studied data dissemination in wireless environment and explain broadcast scheduling and program generation. It theoretically develop formula for single channel and multichannel average expected delay (access time) and define various terms related to it. Section 4 gives various approaches of data placement over multichannel. Section 5 find minimum number of channels required to disseminate data with minimum delay. Finally, section 6 concludes the paper.

2. PROBLEM FORMULATION

In real time system the pure data broadcast in its generic form have low access time but to minimise energy consumption of battery we employ some techniques like indexing, partitioning, clustering of data which give rise to new version of problem of access latency. This mean dilemma of high access time itself is originated from solution of problem of minimization of tune time. Imielinski et al. have discussed this problem in one dimension, which extremely optimize one of these two performance matrices [3]. They provide two algorithms for this as shown in figure 2 below.

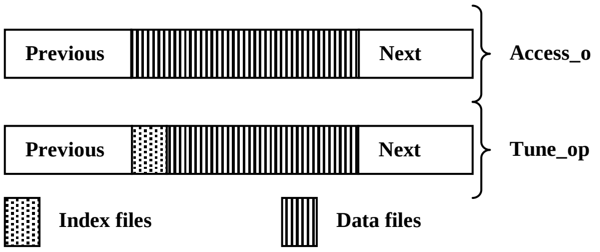


Figure 2: One Dimensional Data

The *Access* opt algorithm provides the best access time with a very large tuning time. The best access time is obtained when no index is broadcasted along with the file. The size of the entire broadcast is minimal in this way. Clients simply tune into the broadcast channel and filter all the data till the required records are downloaded.

The *Tune opt* algorithm provides the best tuning time with a large access time. This algorithm suggests the process of indexing the data item to save active time of MC. The MC once get the information about exact time of arrival of requisite data item and goes to doze mode and till the data item is available to him for download. In this way it can save considerable amount of battery power. The tuning time is equal to the number of levels in the multi-leveled index tree plus one level for the final probe to download the record. This method has got the worst access time because; clients have to wait till the beginning of the next broadcast cycle.

The performance of these two algorithms is reciprocal to each other and can not be improved without having adverse effect on other. We need to create a balance between these two by extending the problem in two dimensions so that one parameter can be optimised at the cost of tolerable limit of other. In this scenario role of proper data organisation play an important role.

3. DATA DISSEMINATION IN BROADCAST ENVIRONMENT

From above discussion it is clear that multichannel broadcast is integral part of modern communication system. To overcome the complexities involved data organisation for such system various terms need to be explained properly. This section formulates useful terms used in this paper.

3.1 Broadcast Scheduling

This section discusses the basics of broadcast schedule design. The problem of finding access latency-minimal broadcast schedules has been extensively discussed by both the networking and the database communities, but from slightly different perspectives.

The network community focuses on finding infinite broadcast schedules for single and multiple broadcast channels while the database community seeks for perfectly periodic broadcast schedules for single and multiple broadcast channels which can be efficiently indexed and additionally allow clients to know a priori when exactly the data of interest is scheduled. Nearly all proposals from the network community follow the argument of Square Root Rule (SRR), first introduced in teletext systems by Ammar and Wang (1985) and verified by Vaidya and Hameed (1995, 1999) having definition 1 below [4, 5, 6, 7]. The multichannel schedule is obtained by distributing in a round robin fashion the schedule for a single channel. For uniform length and constant number of channels the best algorithm proposed so far is the Polynomial Time Approximation Scheme (PTAS) while for non uniform length item the problem is strong NP – hard even for single channel and can be solved by heuristic method in stead of obtaining exact solution [8]. Various possible exact and heuristic solutions of broadcast problem are discussed in section 4.

On the other hand, researches in the database community on broadcast tend to focus on data integrity, client-side cache management and indexing rather than average expected delay performance per se. For instance, version information can be periodically transmitted to guarantee mutual consistency among items. Such works rely on predictable cyclic data transmission with a Periodic Broadcast Schedule (PBS) which can easily be indexed and defined by definition 2 below. For the single channel, the obvious schedule that admits index is the flat one but for this index is trivial because each item will appear once with exactly at the same relative time, within each period. Hence a multiple channel environment best satisfy the periodicity property properly.

Definition 1: (SRR) - For a fixed length item broadcast with equally spaced instances of each item with minimum overall mean access time the is frequency of broadcast of i^{th} item (f_i) is proportional to square root of its demand probability p_i and inversely proportional to its item length z_i i.e. $f_i \ \alpha \ \sqrt{\frac{p_i}{z_i}}$.

Definition.2: (PBS) - Broadcast schedules with minimum overall mean access time having equal intervals between successive instances of the same item.

The real time environment does not support all the conditions imposed by the SRR at the same time. Hence, much of the work done by networking community precludes that done by database community and vice versa. For example, the dynamic broadcast scheduling makes impossible to the pre-broadcast of indexing information. On the other hand, periodic data scheduling typically uses bandwidth inefficiently. To overcome this difficulty, the researchers from the network community follow the approach of relaxing on the periodicity property (definition 2) of the schedule while maintaining the frequency property (definition 1). In this work we will consider a blend of both arguments (definition 1 and 2) to model the system.

Above discussion on broadcast scheduling wrap up it as an important part of data broadcast management. Though indexing allows the client to sleep and save battery energy but the client expected delay is half of the schedule period hence can become infeasible for a large period. Also the index is trivial in the uniform length items on single channel. To overcome this drawback, skewed allocations with multiple channels have been proposed where items are partitioned according to their popularities so that the most requested items appear in a channel with shorter period and vice versa. The resulting problem is slightly different from the broadcast problem because it presents a more comprehensive approach of data management by pertaining two level solutions as: (i) allocating flat or skewed data to multiple channels and (ii) scheduling flat or skewed data with in each channel. The combination of these two possibilities sketches a 2×2 matrix. The assumptions of skewed allocation to channels and flat scheduling per channel in order to minimize the client expected delay are examined by Pinotti et al. (2003) in [8]. This variant of the problem is easier than the Broadcast Problem. Indeed, the problem has been shown to be polynomial time solvable for uniform length data items and it has been proved to be computationally intractable (NP-hard) for non-uniform length data items. This problem is having high run time complexity. The assumptions of skewed allocation to channels and skewed scheduling per channel in order to minimize the client expected delay are examined by Seifert et al. (2006) in [9]. Such system is found flexible in the sense that it reduces cost of generating broadcast program simultaneous to access latency and has low run time complexity than other state of art scheduling techniques.

3.2Broadcast Program Generation

Consider a set $C = \left\{ C1, C2, ... C_K \right\}$ of 'K' identical channels and a set $D = \left\{ d1, d2, ... d_N \right\}$ of 'N' data items. Each item d_i is characterized by a popularity p_i and length z_i, with $1 \le i \le N$. The popularity p_i represents how frequently item di is requested by the clients, and it may vary along the time. Popularities can be either arbitrary positive integers, or real numbers normalized in the range (0, 1] such that $\sum_{i=1}^{i=N} p_i = 1$. The length z_i of data item denotes how much time units are required to transmit data item di and for uniform size data item $z_i = z$. Note that the demand probability is obtained as an average over all clients served by the server and there are several feedback-based methods to estimate it. The probability estimation is discussed in succeeding section. Let physical channel C_j has a bandwidth capacity bc_j and the total bandwidth of all channels is given by $BC = \sum_{j=1}^{j=K} bc_j$.

Basically the problem of data broadcast generation requires mapping of data vector set (D) to channel vector set (C), i.e.

$$< \vec{D} > \to < \vec{C} > \text{..}(1)$$

Obviously this can be achieved by exploiting the available bandwidth capacity of each physical channel by partitioning set D in to a set $G = \left\{ G_1, G_2, ... G_K \right\}$ of K data group such that $G_j \in C_j$. The cardinality of G_j is denoted by N_j and channel length is denoted by $Z_j \in \sum_{d_i \in G_i} z_i$. The sum of popularities of all data items on a channel is denoted by $P_j \in \sum_{d_i \in G_i} p_i$. And for uniform data access is $Z_j = N_j$.

Single Channel Average Expected Delay (SCAED)

Let s_i denotes the interval between two successive broadcast of same item and the average access time for data item d_i is denoted by a_i, then average expected delay for all data item aoverall can be represented by formula

$$a_{overall} = \sum_{i=1}^{i=N} p_i \times a_i \text{ .... ….}(2)$$

The average expected time (a_i) for i^th item is the average wait by a client needing item i until it starts receiving it from server. We assume that client is equally likely to need an item at all instances of time. Hence it is the average time until the first instances of item i is transmitted, from the time when a client starts waiting for this item. Therefore, $a_i = \frac{s_i}{2}$.

The Single Channel Average Expected Delay (SCAED) is given by formula

$$SCAED = \frac{1}{2} \sum_{i=1}^{i=n} p_i s_i \text{ .... }(3)$$

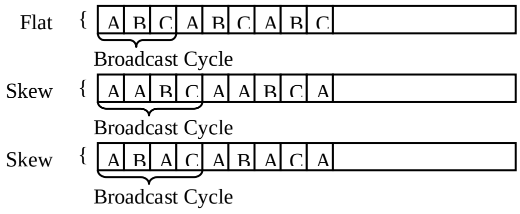


Figure 3: Different type of Broadcast

The single channel for two data items d_i and d_j having s_i and s_j as interval between two successive instances of same item respectively from definition 1 following relation holds

$$\frac{\sqrt{p_i \cdot z_j}}{\sqrt{p_j \cdot z_i}} = \frac{s_j}{s_i} \text{ …………………. }(4)$$

Hence, for a fixed length broadcast cycle

$$\frac{s_i^2 \, p_i}{z_i} = const. \text{ ……………………..…...……….}(5)$$

The final SCAED is given by formula

$$SCAED = \frac{1}{2} \sum_{i=1}^{i=n} \frac{\sqrt{z_i}}{\sqrt{p_j}} \text{ ……………………}(6)$$

For instance, consider a database of three equal-length data items, A, B, and C, and a single client. The client accesses items A, B, and C with probabilities p_A, p_B, and p_C

respectively. The broadcast server is able to broadcast different items with different frequencies, so provide more bandwidth to the popular pages than to the unpopular ones. Furthermore, we consider three schedules given below which are presented in figure 3.

- The flat one, which schedules pages cyclically. Thus, all pages are broadcast with the same frequency. The schedule will be A, B, C, A, B, C…………
- The skewed 1, in which item A is broadcast twice as often as items B and C. Furthermore, subsequent broadcasts of page A are clustered together. Thus, the schedule will be A, A, B, C, A, A, B, C………
- The skewed 2 one, differing from the above in such a way that instances of the same item are separated by equal gaps. Thus, the schedule will be A, B, A, C, A, B, A, C………

The average waiting time for a schedule can be calculated by multiplying the probability of access for each item with the associated waiting time and summing up the results. The calculated average waiting time for above schedules with different assumed probabilities is shown in table 1.

Table 1: Average waiting time for different access probabilities

Data Access Probabilities			**Single Channel Average Expected Delay (SCAED)**		
p_A	p_B	p_C	**Flat schedule**	**Skew Schedule1**	**Skew Schedule2**
0.33	0.33	0.33	1.50	1.75	1.65
0.60	0.30	0.10	1.50	1.55	1.40
0.80	0.10	0.10	1.50	1.40	1.20

Above calculations show that for flat schedule SCAED is same for all schedules but it decreases for skew broadcast. Further, SCAED is least for periodic schedule as suggested by definition 2.

Multichannel Average Expected Delay (MCAED)

The discussion so far assumed that the server is broadcasting items over a single channel and all the clients are tuned to this channel. Due to various reasons of business and fault tolerant capacity it is prudent to use a combination of low bandwidth channels instead of single high bandwidth channel. In such environment different clients listen to different number of channels depending on the desired quality of service. The data broadcast management for multiple channels is similar to that of single channel upto large extent because multiple channels can be obtained by bandwidth division on single channel. This division of bandwidth cause mobile client to hopping among channels. Generally client is able to have instantaneous hopping among multichannel; hence it is neglected for calculation purpose.

As per the above system design assumption when $d_j \in C_j$ and cardinality of channel is N_i. Then average expected delay for single item on jth channel, $a_j = N_i / 2$ and probability of access of item d_i from channel C_i, $P_i = \sum_{d_j \in C_i} p_i$

The total expected delay for jth channel,

$$a_{j\_total} = \frac{N_i}{2} \times P_i \quad \text{…………………………..} \quad (7)$$

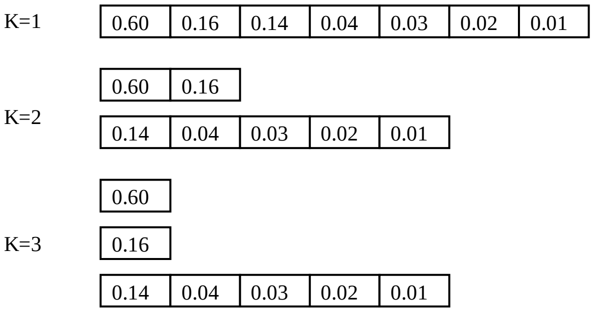
In worse situation Multi Channel Average Expected Delay (MCAED) is half of the sum of average expected delay for all channels. Therefore

$$MCAED = \frac{1}{2}\sum_{i=1}^{i=K}\left(N_i \sum_{d_j \in C_i} p_i \right) \text{………} (8)$$

This equation can be used to measure the performance of multichannel broadcast scheme. For instance, consider a system with K=3 and N=7 having popularities respectively:

$$p_1 = 0.6, p_2 = 0.16, p_3 = 0.14, p_4 = 0.04, p_5 = 0.03, p_6 = 0.02, p_7 = 0.01$$

Then data can be placed on three channels starting from the single channel and subsequently scheduling data on second and third channel as shown in figure 4.



K=1
0.60 | 0.16 | 0.14 | 0.04 | 0.03 | 0.02 | 0.01

K=2
0.60 | 0.16
0.14 | 0.04 | 0.03 | 0.02 | 0.01

K=3
0.60
0.16
0.14 | 0.04 | 0.03 | 0.02 | 0.01

Figure 4: Broadcast Schedule for Single and Multiple Channels

The average expected delay for these schedules can be calculated from SCAED (equation 6) and MCAED (equation 8). The MCAED calculated for this data distribution is shown in table 2.

The average expected delay is found to decrease with increase in number of broadcast channels that is

$$AED_{K=3} < AED_{K=2} < AED_{K=1} \text{……………...} \quad (9)$$

Table 2: Average Expected Delay for Schedule with Single and Multiple Channels

Data Access Probabilities							**Average Expected Delay**		
p_1	p_2	p_3	p_4	p_5	p_6	p_6	K=1	K=2	K=3
0.60	0.16	0.14	0.04	0.03	0.02	0.01	3.5	1.36	0.98

From above example *broadcast program generation* may be defined as follow:

Definition 3: (Broadcast Program Generation) – Let we have ‘N’ data items and ‘K’ broadcast channels and we are aware of access frequency of each channel then the problem of broadcast program generation is to split ‘N’ data items in to ‘K’ groups with minimum value cost function SCAED or MCAED in such a way that for every set G_h and G_j having $d_i \in G_h$ and $d_j \in G_j$ (i) if $N_h < N_j$ holds then

$p_i \geq p_k$ is always true and (ii) if $p_i > p_k$ holds than $N_h \leq N_j$ is always true.

Corollary 1: The most popular items are allocated to less loaded channels so that they appear more frequently. As a consequence, if the items are sorted by non-increasing popularities, then the group sizes are non-decreasing.

This definition is applicable for both single channel and multiple channel environments. If there were only one channel in broadcast system than all items will comprise single group and assigned to single channel in increasing or decreasing popularities. To achieve optimal access latencies in multiple broadcast channel environment following conditions needs to be satisfied:
The partitioning of data must satisfy definition 3.

The partitioning of 'N' data items into a set $G = \{G_1, G_2, ...G_K\}$ leads to segmentation with following generic layout :

$$\underbrace{d_1,..........d_{b_1}}_{G_1},\ \underbrace{d_{b_i+1},..........d_{b_2}}_{G_2},............\ \underbrace{d_{b_{m-2}+1},..........d_n}_{G_K}$$

Where b_m is index for last item. Seifert et al. (2006) following SRR envisaged that partitioning of 'N' data item into 'K' group will be optimum if following inequality holds for all $G_j \in G$ [10]:

$$\frac{bc_j \cdot \Sigma_{i=1}^{i=N} \sqrt{p_i}}{BC} \leq \Sigma_{i=d_{b_{j-i}}+1}^{i=d_{b_j}} \sqrt{p_i} \ .... \quad (10)$$

For optimal scheduling each data item di on channel C_j must be allocated a part of bandwidth directly proportional to square root of its popularity according to definition 1. The fraction f_i of total bandwidth of bc_j is given by:

$$f_i = \frac{\sqrt{p_i}}{\Sigma_{K=d_{b_{j-1}}}^{K=b_j} \sqrt{p_K}} \ .... \quad (11)$$

- For obtaining optimal scheduling consecutive instances of same data item di on channel C_j should be equally spaced apart with spacing $s_i = 1/f_i$.

While first two conditions can be easily fulfilled by broadcast scheduler but the last two cause collision of schedule of distinct data item in real time hence may not be full filled simultaneously. Hence a relaxation from either cyclic or square root property is required in practice, which leads design of near optimal multiple channel broadcast instead of perfect optimal broadcast schedule. There above four conditions presents theoretical design guidelines for evolving close to optimal broadcast schedule.

4. DATA PLACEMENT OVER MULTICHANNEL

When client have complete knowledge of broadcast schedule, the placement of data over broadcast channel two major concerns related to the exploitation of a multichannel broadcast system. The first consideration is related to the capability of the server to concurrently transmit in all channels; the second is related to the capability of the client to tune only one channel at a time and also perform instantaneous hopping among channels. In such scenario we make following two assumptions which guarantee a predictable schedule:

- The broadcast is cyclic, that is, it has a beginning and an end.
- The interval between successive transmissions of an item is constant for all broadcast cycles.

This section surveys various methods to find solution of the problem of optimal data placement over multichannel. Many researches have tried to find solution to this question but it is always not possible to find optimal solution to this problem as data placement problem may be knapsack in some cases. In such cases heuristic solutions for data placement over multiple wireless channels are developed. The succeeding literature discusses it in details.

4.1 Optimal Approaches for Data Placement

There exists an optimal solution to the problem described by Definition 3. This solution has been formulated into two different natural algorithms. The first was presented in Peng and Chen (2003) and is based on the A* optimization method, whereas the second was presented in Yee, Omiecinski, and Navathe (2001) and is based on a dynamic programming approach [10, 11]. The optimal solution for average access delay denoted by optimal_minimal, for allocating items from '1' to 'N' on 'K' channels, can be obtained under following two prepositions [11]:

Proposition 1: The time complexity of the dynamic programming algorithm is $O(K \times N^2)$.

Proposition 2: The space complexity of the dynamic programming algorithm is $O(K \times N)$.

The time complexity of the optimal dynamic programming solution is too high. In applications where the access frequencies change quite frequently or new items are to be broadcast, this approach turns out to be inapplicable. Therefore, various heuristics have been proposed in order to generate the partitioning very fast, producing average access time very close to the optimum. In the next section, we survey heuristic approaches.

4.2 Heuristic Approaches for Data Placement

There is various procedure of determining a partition of data to place on channel "top down," "bottom up," or "one scan." In the top-down approach, we start from a large partition, possibly including all the items, and gradually split it into smaller pieces [12, 13, 14]. In the bottom-up we start with many small partitions which gradually grow [15], whereas the one-scan approach makes a single scan over the access probabilities vector assigning items to channels based on some attribute value [16]. The top-down and bottom-up make multiple passes over probability vector and make splitting or concatenating decisions based the computations of equation 6 and 8. Various heuristic methods are:

- *The Growing Segments Scheme*

The growing segments scheme starts with an initial "minimal" allocation assigning one item to each channel, which acts as the initial "seed" partition [17]. Then, it enlarges each segment by including a number of items equal to the user-defined parameter increment and computes which of these enlargements gives the greatest reduction in average delay. Next, it selects the corresponding partition as the new seed partition and continues until the partition covers the whole P. The parameter increment is very important and has a trade-off associated with it, that is, the greater the value of increment, the lower complexity the algorithm it has and vice versa. The complexity of the growing segments method is $O\left(N^2 \times \frac{K}{incriment}\right)$.

- *The Variant-Fan-Out Tree Scheme*

The variant fan-out (VFK) scheme adopts a top-down approach. It starts with an initial allocation where all the items have been assigned to the first channel [13]. Then repetitively, it determines which channel incurs the largest cost so far and partitions its contents into two groups. The partitioning is done by the routine partition, which tries all possible partitions that respect the property that no channel can have more items than its next channel. The first group remains in the current channel and the newly created group is allocated to the next channel, shifting all the other channels downwards. This procedure repeats until all available channels are allocated. The cost of this algorithm is O (k) times the cost of the Partition procedure. The cost of this procedure depends on the number of items of the channel that is to be partitioned, which in turn depends on the distribution of the access probabilities. The complexity of the VFK method is $K \times \left(O\left(K \times \log\left(K\right)\right) + O\left(N\right)\right)$.

- *The Greedy Scheme*

The greedy scheme adopts the top-down approach and it is very similar to the VFK scheme [14]. It performs several iterations. In every iteration, it chooses to partition the contents of the channel whose split will bring the largest reduction in access time. The partitioning point is determined by calling the routine partition. Thus, in the every iteration, the greedy scheme computes (if not already computed) and stores the optimal split points for all channels that have not been split so far. Hence, it differs from VFK in two aspects. First, it differs in the partitioning criterion (recall that VFK splits the channel which incurs the largest access time). Second, after each split it will compute and store the optimal split points of every channel. The complexity of the greedy method is $O\left(\left(N + K\right) \times \log\left(K\right)\right)$.

- *The Data-Based Scheme*

The data-based scheme is similar to VFK, but avoids taking the local optimal decision of the Partition routine of VFK, which splits a channel into two. DB has several phases [12]. At each phase, it decides the contents of a particular channel starting from the smallest channel, which will accommodate the more frequently accessed data. First, it determines which one is the maximum allowable number of items that can be accommodated into the considered channel. The complexity of the data-based method is $\sum_{i=1}^{i=K} y_i \times \left(N - z_i\right)$ where z_i is the number of items allocated to channels C_1 to C_{i-1} and y_i is equal to the range of items.

- ***The Cascaded Webcasting Scheme***

The Cascaded Webcasting scheme starts from a very basic intuition of partitioning and claiming that there are three classes of items [15]:

- a practically constant number of items with high probability
- items belonging to a few large groups
- leftover items, which contribute negligibly to the total delay.

Using this intuition about the partitioning, Cascaded Webcasting is a bottom-up scheme that uses "predetermined" initial seed partitions, which subsequently are greedily concatenated until the number of partitions becomes equal to the number of available broadcast channels. Initially, the seed partitions $\overset{0}{P1}, \overset{0}{P2}, \overset{0}{P3}, \ldots\ldots, \overset{0}{P_\nu}$ are generated, with sizes equal to $2^0, 2^1, 2^2, \ldots\ldots$ then, $\nu - K$ merging steps are $\left(\lceil \nu = \log_2\left(N+1\right) \rceil\right)$ performed.

Due to the way the partitions are concatenated and the size of partitions is the initial seed, it is obvious that at each step of the algorithm, the size of a partition is always smaller than the size of its successive partition. The complexity of Cascaded Webcasting is dominated by $O\left(N\right)$.

A comprehensive performance evaluation of the aforementioned algorithms has been conducted in Katsaros and Manolopoulos (2004) [15]. Therefore the greedy scheme, VFK, and DB perform very close to optimum with respect to the reduction of the average access delay, but they incur significant execution cost. The fastest running algorithms are bucketing and Cascaded Webcasting, with the latter producing partitions not far from the optimum with respect to the average access delay.

5. CHANNEL OPTIMISATION FOR MULTICHANNEL ENVIRONMENT

In general, the data items are broadcast over a single channel with the underlying reason that it provides the same capacity as multichannel and abbreviate the data broadcast organization and allocation scheme [18]. The use of a single channel shows its limitation when there is a very large number of a data item to be broadcast. In fact, a cell can support upto 200 channels [19]. Hence for a broadcast program with large number of data items, it is beneficial to distribute the data over multichannel. The allocations of a broadcast cycle to an optimal number of broadcast channels will reduce access latency by eliminate the possibility of long delay before obtaining the desired data items. The process of splitting data to multichannel continues until the access time reaches the optimal value. Figure 5 illustrates the advantage of splitting of a broadcast channel into two channels. In the following example 12 data items each costing 100 bytes on channel are broadcasted on single and multichannel. Case 1 and case 2 unearth the access time gap between single and multichannel.

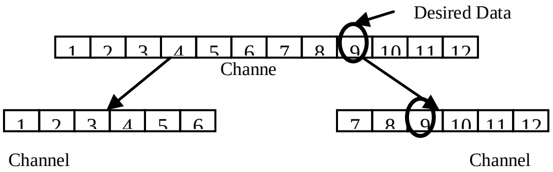


Figure 5: Multi Channels Architecture

Case 1: Data items 1 to 12 are broadcast over a single channel. In this case, all data items are available on a single channel. The client who wants to retrieve data item #9, has to wait until the desired item arrives on channel. The total access time required to retrieve data item #9 will be (100 x 9) = 900 bytes.

Case 2: Data item 1 to 12 are distributed over two broadcast channels each having 6 data items as shown in Figure 5. In this case, the client can switch in between the channels and search for the data item. Thus, the total access time for client to retrieve data item #9 would be (100x3) = 300 bytes.

This typical example shows that in comparison to data broadcast over single channel the access time is much reduced on multichannel. Now the question arises, what should be the optimal number of broadcast channel in a broadcast schema? To determine the optimum number of broadcast items theoretical description is provided in section 5.1 and analytical models are presented in section 5.2.

5.1 Optimal Number of Broadcast Channels

The optimum number indicates the minimum number of broadcast channels required to transmit data with minimum energy consumption and optimal access time. Optimal point is a point to split the broadcast cycle and allocate the data items to the new channel. Once the optimum number is located, the length of broadcast program is cut in fractions and every time a portion of total bandwidth is allocated to fraction. Hence the numbers of broadcast channels is increased every time optimal number is reached. The other factors which affect optimality are: request arrival rate, service rate, number of request, size of data item, size of request, number of data item to retrieve and bandwidth. This optimal point is determined by knowing initial search point, from where client start first probe to channel and defining a cut off load which channel can support. Figure 6 shows splitting of a single broadcast cycle into three minor broadcast cycles. For this purpose a data broadcast scheduling scheme presented in section 3 for a multi-broadcast channel environment can be applied.

In the light of above issues the data access frequency play a crucial role. On the basis of access frequency broadcast scheme can further classified into two categories, namely a broadcast program with replication and without replication. A broadcast program with replication corresponds to the case where the data items appear with different frequencies. The basic idea of a broadcast program with replication is that the most popular data items will be broadcast more often than others. Consequently, the majority of mobile clients will have a considerably shorter access time as their data of interest arrives more frequently in the channel. On the other hand, a broadcast program without replication applies when all data items are broadcast with equal frequencies or uniform frequencies.

5.2 Analytical Model of Broadcast Channels

In figure 6, the broadcast cycle is partitioned into three areas: area A contains data segments preceding data segments in area B; area B contains the number of desired data segments, and area C includes the rest of data segments. 'x_t' is the total number of ticks required in complete broadcast cycle. There are three different scenarios where a mobile client probes into one of these areas corresponds to the size of the data item. The broadcast cycle here is considered to be uniform. The downlink bandwidth is denoted by 'b_s'. The following scenario is used to calculate the average access time ($T_{average.access}$) for retrieving data from channel.

Here $X_t = A + B + C$. The mobile client can initially probe the data item from any of the region A, B or C.
Probe A: When mobile client probes into area A, the average access time is given by:

$$T_I = \frac{\sum_{A=0}^{A-1} (A-i+B).s}{b_S} = \frac{\left[A(A+2B+1)\right]s}{2b_S} \;\ldots\ldots\ldots \quad (13)$$

Probe B: When mobile client probes into area B, then the average time is equal to the total length of broadcast cycle (A+B+C)

$$T_{II} = \frac{(A+B+C).B.s}{b_S} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

Probe C: When mobile client probes into area C, the average access time can be calculated from:

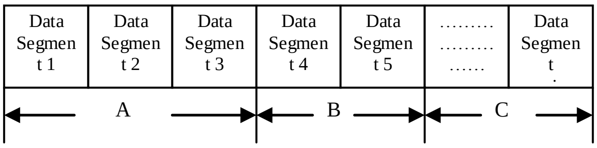


Figure 6: Broadcast Cycle Partition Area

$$T_{III} = \frac{\sum_{i=0}^{C-1} (A+B+C-i).s}{b_S} = \frac{C(2A+2B+C+1).s}{2b_S} \;.. \quad (15)$$

Based on the three scenarios, the average access time from equation (13), (14), and (15) can be calculated as follows:

$$T_{average.access} = \frac{[A.\,(A+2B+1)+2B.\,(A+B+C)+C.\,(2A+2B+C+1)].\,s}{2\;\;(A+B+C)\;\;b_S} \quad (16)$$

Above equation can be rewritten as

$$T_{average.access} = \frac{\left[\left(x_t-B\right)^2 + \;(2B\;\;x_t)\; + \left(2B\;\left(x_t-B\right)\right) + \left(x_t-B\right)\right]}{2x_t\;b_S}. \quad (17)$$

Equation (16) and (17) are generic and can be used in single channel and multichannel environment.

- *Performance Analysis*

The performance of above analytical model is analysed using MATLAB 7.4. Performance analysis plot between number of data item and average access time for different values of required data items (B = 200,300 and 350) is shown in figure 7 and calculated analytical average expected delay is tabulated in table 3.

Table 3: Average Access Time with Number of Data Items on Broadcast Cycle

Number of Data Items	Average Access Time		
	B = 200	***B = 300***	***B = 350***
150	0.007370	0.003880	0.000833
170	0.008712	0.006245	0.003863
190	0.009881	0.008222	0.006365
210	0.010926	0.009922	0.00849
230	0.011881	0.011416	0.010335
250	0.012766	0.012755	0.011969
270	0.013597	0.013973	0.013438
290	0.014385	0.015094	0.014776
310	0.015139	0.016138	0.016008
330	0.015864	0.017119	0.017154
350	0.016566	0.018047	0.018229
370	0.017249	0.018931	0.019244
390	0.017915	0.019778	0.020208
410	0.018566	0.020593	0.021129
430	0.019206	0.02138	0.022013
450	0.019835	0.022144	0.022865

6. CONCLUSION

This paper presented data broadcast management schemes to optimize number of broadcast air channel in wireless communication. The problem of data scheduling, placement broadcast program generation has been presented in section 3. It appears just a problem of partitioning 'N' data items in to 'K' groups and scheduling each group in flat or skewed outline on each channel. This rises to a version of problem of balancing access time and tune time, one at the cost of other, as shown in figure 1. The assumptions of skewed allocation to channels and flat scheduling per channel in order to minimize the client expected delay is found to be computationally intractable (NP-hard) for non-uniform length data items. Also it has high rum time complexity and can only be solved heuristically. The assumptions of skewed allocation to channels and skewed scheduling per channel in order to minimize the client expected delay is found flexible in the sense that it reduces both cost of generating broadcast program and access latency and has low run time complexity than other state of art scheduling techniques but its capacity to reduce access latency is lower bounded. Therefore, it is prudent to use skewed allocation to channels and flat scheduling per channel in a scenario where non uniform data access pattern is followed and skewed allocation to channels and skewed scheduling per channel in a scenario where flexibility and adaptability is required.

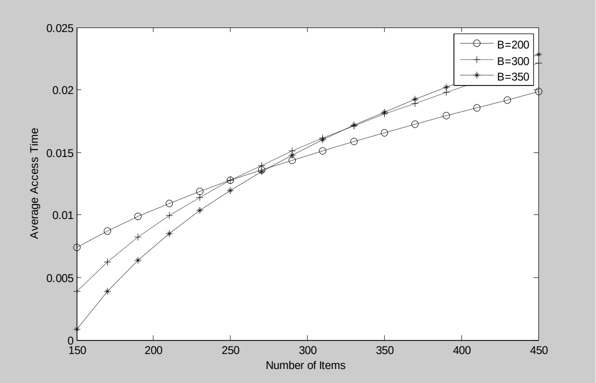


Figure 7: Plot of Variation of Average Access Time with Number of Data Items on Broadcast Cycle

To study broadcast system under different situations simulating the broadcast environment and evaluate its performance on suitable test bed is a well known technique. Here in this thesis we will use zipf distribution to synthesize the broadcast data set and MATLAB 7.4 to simulate and testify the broadcast system. In section 4 optimal and heuristic solutions for data placement problem are presented. The heuristic solutions are more adaptive to broadcast environment because they are useful to skew and non uniform access pattern. The Greedy scheme developed by Yee et al. (2002) do best iterative solution but has high time complexity and the Webcasting Scheme developed by Katsaros et al. (2004) is profound in term of space and time complexity. A theoretical and analytical scheme to find optimal number of broadcast channels in a broadcast is presented in section 5. Determination of optimal number of broadcast channel is important as it help in determining proper schedule and efficient program generation. The results of analytical model are tabulated in table 3 and plotted figure 7. These results clearly indicates that number of data items on a broadcast program and required data items both have adverse effects on average access time.

In net shell, contributions of this chapter involve how queries are generated, transmitted and retrieved in wireless environment. Here we have considered the strategies to optimize access time and have not considered indexing of data items which care for tune time. In our further work we introduces the broadcast indexing scheme which will enable clients to efficiently and effectively obtain data items of interest over the broadcast channel.

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