GROUPING FOR THE CRITERIA BASED DATA BROADCAST IN WIRELESS MOBILE COMPUTING

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Abstract: Data broadcasting in wireless communication technology can provide mobile financial with location based services. Data can be reached in any time and place. The server fetches the requests and broadcasts the data to the air. The broadcast problem including the plan design is considered. A criteria based algorithm can discover the creation of a full or empty slot Broadcast Plan (BP) with equal spacing of repeated instances of items. This last property can guarantee the creation of a regular BP (RBP) and enable the servers use a single or a number of channels so that the users can catch their items avoiding their devices’ waste of energy. Moreover, the Grouping Dimensioning Algorithm (GDA) based on integrated relations can guarantee the discrimination of services using a minimum number of channels. The server broadcasting capability is increased for a single channel operation by the use of the HOL waiting time group (HOL-WTG) scheduler, providing service priority along with bandwidth adjustment, diminishing the waste of bandwidth, and minimizing the number of rounds. This proposed work can enrich the server infrastructure for self-monitoring, self-organizing and channel availability as well. Simulation experiments are provided.

1 INTRODUCTION

The mobile computing is based on the communication between clients and the large scale distributed database. An efficient broadcast schedule program minimizes the client expected delay, which is the average time spent by a client before receiving the requested items. The expected delay is increased by the size of the set of data to be transmitted by the server. In our approach suitable adjustment of the server’s bandwidth is made so that the data be transmitted minimizing the delay (Bertossi et al., 2004, Kenyon et al. 2000, Bar-Noy et al. 2003). The memory hierarchy can be constructed so that the highest levels contain more items broadcasting them with high frequency while the subsequent levels contain items that broadcast at lower frequency (Acharya et al., 1995). Additionally data items are assigned to different “disks “ (Bdisks) of varying sizes and speeds and are then broadcasted in the air. Items stored on faster disks are broadcasted more often than items on slower disks (Bertossi et al., 2004), (Acharya et al. 1996). There are many strategies for the broadcast delivery with two basic categories (Sumari et al., 2003). In the static broadcasting the schedule of the program is fixed (static) even though the contents of a program can change with time (Bertossi et al., 2004). In the dynamic broadcasting, both the schedule of programs and its contents can change and there exists limited support to handle user’s requests (Bertossi et al., 2004 ). In (Bowen et al., 1992) data broadcasting is developed introducing the datacycle. The server broadcasts more popular items more frequently to minimize the average access time. In (Sumari et al., 2003) a new technique for storing data on disk the “sequence” is developed and broadcasts them in accordance to their order.

Very long messages delay all the others and the service rate needs adjustment depending on the size of the message and the available amount of bandwidth that the server can provide. To this direction, the criteria broadcast plan algorithm (CBPA) is presented which examines the possibility to get a BP, by discovering the number of times that an item will be in the cycle, and the construction of the full BP (CBP). The broadcasted items can be divided into i sets depending on the items’ popularity. The CBP can be independent of the number of the serviced sets. We start with the biggest size set (S1, with the least popularity) as the basis of the button-up planning design and work...
iteratively in order to find the parameters of the optimal BP. In this work we focused on the homogenous data (items) and the heterogeneous having multiple size of the basic packet size (f.i. 512KB). Homogenous data have the same size. The terms bandwidth and weight are used interchangeably. The data can be sent by a single channel or a set of channels.

Finding the number of channels that can send a group of data providing also the equal spacing of repeated instances of items could be very interesting issue. GDA finds directly the minimum number of channels that make an RBP efficient. The surplus of the available channels from both grouping algorithms may be used for another RBP.

The rest of the paper is organized as follows. In section 2 the Model Description is described. In section 3 some analytical results with their conditions are described. In section 4 the CBPA is developed. In section 5 and 6, the GDA and the HOL-WTG are developed respectively. Simulation results are provided in section 7.

2 MODEL DESCRIPTION

2.1 General

Our work is starting from the last level of hierarchy (the less popular items) we try to find the numbers of items repetitions according to a set of proposed algorithms. The condition to have a BP for various items and numbers of times so that the most popular items be transmitted within a period is examined.

Our approach can (1) create an innovative broadcast program design (2) with the RBP it also provides energy efficient access to items by minimizing the user average waiting time (AWT).

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2.2 The Design of the Relation

The possibility of providing BP (full or not) is examined iteratively starting from the last level of hierarchy $S_3$. The size of a set stands for $S_i$ (where $i=1,2,3$). It is considered that $S_{3s} \geq S_{2s} \geq S_{1s}$, and the number of $S_3$ items will be sent only once while for the other sets at least twice. We create a set of relations including their subrelations by considering items of different size from each set. This is achieved by finding the integer divisors of $S_{3s}$ ($k_1, k_2, k_3,...,k_n$) and put them at a decreasing order in an array (ar). Each relation has three subrelations. It is also assumed that $S_{2s}$, $S_{1s}$ are not prime numbers. For the BP design in case that $S_{2s}$ is a prime number, it is possible to add only one empty slot at the end of the last major cycle. The next integer number of a prime is a composite number. This idea helps to create the BP. The following definitions are essential:

Definition 1: The size (or horizontal dimension) of a relation ($s_{rel}$) is the number of items that belong to the relation and it is equal to the sum of the size of the three subrelations ($s_{rel} = \sum s_{sub}$). The number (or vertical dimension) of relations ($n_{rel}$) with $s_{rel}$ define the area of the relations ($area_{rel}$).

Example 1: The relation $A=(a, b, c, d, f)$ has the following three subrelations starting from the end one; the 3-subrelation (f) with $s_{sub3}=1$, the 2-subrelation (b,c,d) with $s_{sub2}=3$, and the 1-subrelation (a) with $s_{sub1}=1$. The $s_{rel}=5$
Definition 2: The area of the i-subrelation (area_i_sub) is defined from its size (s_sub) and the number of the relations (n_rel) that are selected. It is given by (s_sub) x (n_rel).

Example 2: From a relation with s_rel=5 and if n_rel=5 then the area of this relation is 5x5. Hence there are 25 locations that have to be completed.

Example 3: If two relations are: (1,2,3,5,6,7), (1,3,4,8,9,10) with s_sub=3, s_sub=2, then : 2-subrelation_(2,3) and 2-subrelation_(3,4). The last two subrelations ((2,3),(3,4)) comes from S_2 = {2,3,4} having 3 as repeated item.

Definition 3: An BP is full if it provides at least 2 repetitions of items and it does not include empty slots in the area_rel

Definition 4: The number of items that can be repeated in a subrelation is called item multiplicity (it_mu) or number of repetitions (n-rep).

Definition 5: The optimal BP for S_1s < S_2s < S_3s, is the full BP taken with the maximum effective n_rel (providing also the maximum items multiplicity for the subrelations). For optimal BP the most popular items are transmitted more often. Our full BP is also optimal BP since the items of S_2 and S_1 are repeated more than one times.

Definition 6: Integrated relations (or integrated grouping) are when after the grouping, each group contains relations with all the data of S_2 and S_1. This happens when: (∪ (2-subrelation) = S_2 ) ∩ ( (1-subrelation) = S_1). See example 7 for details.

Definition 7: An FBP is direct when k ≤ S_div and S_2s | k (S_div < k). It is indirect when k > S_div and k | S_2s (k>S_div).

It is considered that a|b (a divides b) only when b mod a =0 (i.e. 14 mod 2=0). The relation with the maximum value of n_rel provides the opportunity of maximum multiplicity for all the items of S_2 and S_1 and finally creates the minor cycle of a full BP. The major cycle is obtained by placing the minor cycles on line. The S_div contain all the divisors of S_2. Hence S_div={d1,d2,...,d_n}.

3 SOME ANALYTICAL RESULTS FOR BP AND RBP CREATION

A set of Lemmas can discover the possibility of having a full equal spacing BP. from the sets (S_is / i=1,2,3).

Lemma 1: Let us be k any integer divisor of S_2. If k≥S_2s (i=2,3) and S_is | k then we can take a full direct BP.

Proof: If k≥S_2s and S_is | k => k = S_is * m (m ∈ I) and any item of S_is can be repeated for m times. Hence it_mu_i = k / S_is. Since this happens for all the sets, a full BP can be produced using just the items of the S_is.

Example 4: (full BP) Consider the case of: S_1 = {1}, S_2 = {2,3}, S_3 = {4,5,6,7,8,9,10,11}. Finding the integer divisions of S_3s (=8) which are 4(8/2) and 2(8/4). The n_rel could be 4(8/2) or 2(8/4). Hence S_div = {d1,d2} = {4,2}. If n_rel=4 the format of the four relations with S_1 could be: ( * * * * 4,5), ( * * * * 6,7), ( * * * * 8,9), ( * * * * 10,11). For n_rel= k =4 then 4=2 and it_mu_i = 2=4/2 it means that there is a full BP for S_1. Using again the same for the S_2, we take 4=1 and it_i_mu = 2=4/1 it means that there is a full BP for S_2. One relation of the full, direct could be: (1,2,4,5).

Lemma 2: If k≤S_is (i=2,3) and k | S_is then we can take a full indirect BP. In this case the total number of items (t_n_i) that transferred and the S_is, can be easily computed.

Proof: If k≤S_is (i=2,3) and k | S_is then S_is = k*m (m ∈ I) and this gives again it_i_mu=S_is/k. Additionally, a predefined it_i_mu for S_is can be defined so that t_n_i = S_is * it_i_mu and S_sub = t_n_i / n_rel.

Example 5: Let's consider S_1 = 1, S_2 = {2,...,13}, S_3 = {15,...,32} with: S_is = 1, S_2 = 12, S_3 = 18. Finding the integer divisors of S_2s (=18) which are 9(18/2), 6(18/3), 3(18/6). The decreasing order is: 9,6,3. (a) For n_rel=k=9, since 9<12 and 9|12 only empty slot BP possibility. (b) Taking the next k value (k=6), since 6<12 and 6|12 there is a FBP with it_i_mu=2, t_n_i=12*2=24, s_sub=t_n_i / k = 24/6=4. Hence the 2-subrelation for the 6 relations can be: (...2,3,4,5,...), (...6,7,8,9...), (...10,11,12,13,...), (...2,3,4,5,...), (...6,7,8,9...), (...10,11,12,13...) having two repetitions for each item. Hence 1-subrelation = 6, 2-subrelation=4.

Lemma 3: If k≤S_is (i=2,3) and k | S_is then it is not possible to take a full BP.

Proof: Because it_i_mu=k/S_is ∉ I.

Example 6: Let us consider S_1 = 1, S_2 = {2,3,4}, S_3 = {5,...,22} with: S_is = 1, S_2 = 3, S_3 = 18. Finding the integer divisors of S_2s (=18) which are 9(18/2), 6(18/3), 3(18/6). Decreasing order 9,6,3. For n_rel=k=9, since 9>3, (from (1,2)) with it_i_mu=3/9 there is a strong 3-subrelation: (1,2,5,6), (1,3,7,8), (1,4,9,10), (1,2,11,12), (1,3,13,14), (1,4,15,16), (1,2,17,18), (1,3,19,20), (1,4,21,22). The BP is an RBP (equal spacing for all the sets), for
data of $S_2$ (period$_2$=11) and $S_1$ (period$_1$=3). Using a single channel for all the data (the relations) you can take the same average waiting time AWT for the users interested in data of $S_1$ and $S_2$. For “2” the AWT$_2$=11/2=5.5. Making groups of three relations and using three channels we get again the same AWT for the users interested in data of $S_1$ and $S_2$. On the contrary, for users interested in data of $S_3$ the AWT is much longer when a single channel is used instead of multiple ones.

Taking the next k value (k=6), since 6>3 and it$_{mu2}$=6/3 again we get a strong 2-subrelation. The subrelations are: (1,2,3,5,6,7), (1,3,4,8,9,10), (1,2,3,11,12,13), (1,3,4,14,15,16), (1,2,3,17,18,19), (1,3,4,20,21,22). This BP is not equal spacing because the 2-subrelation$_1$=(2,3), and 2-subrelation$_2$=(3,4) have a common item (3). Obviously for k=3 we take it$_{mu1}$=1 and it is also a strong 1-subrelation. The best BP is taken with k=9, the maximum multiplicity value for $S_2$ providing also equal spacing possibility.

4 THE CRITERIA BROADCAST PLAN ALGORITHM (CBPA)

Our CBPA approach is very different than the previous ones (Acharya et al.,1995), (Acharya et al., 1996) and it is based on the creation of the optimum size of relations of i sets of items, that can cover the desired number of repetitions (copies) of items. The broadcasted items can be separated into i sets depending on their items popularity. The CBPA is independent of the number of the serviced sets. We start with the largest set size ($S_i$, with the least popularity) as the basis of the bottom-up planning design and we basically find a number of relations (n_rel) that may provide a full BP. Starting with the maximum value of n_rel, the CBPA provides plans of the items distribution from the other two sets (level by level) for the remainder empty positions of the relation, in order to complete the kth size subrelations. The optimum planning is achieved using a set of two allocation criteria so that to maximize the number of sending items of the upper sets ($S_2$, $S_3$). Additionally the items of the sets are inserted direct into the queues,without the use of an intermediate list, and the scheduler start the servicing. There are three criteria that must be completed for the selection of the optimum plan:

Criterion 1: It shows the possibility of having a direct full BP according to Lemma 1. The number of $S_i$ data must be allocated into integer number of relations. The divisors are sorted in decreasing order ($S_{div}$={$d_1,d_2,...,d_n$}, $d_{i-1} > d_i$) and for each one, a number of items $n_{it}$ ($n_{it}$=$S_i/d_i$) defines the number of $S_i$ items in the more right position of the relation. The rest positions of the relations are covered with items of $S_2$ and $S_3$ using the next criterion. Details are in examples 5,6.

Criterion 2: It examines the case for indirect full BP according to Lemma 2. Details are in example 6. This criterion will be used iteratively in order to find the numbers of items for each next upper set (level) in the relations. In case that the size of any set is less than the n_rel (as it happens for $S_1$) the item is simply repeated m$_{n_{rel}}$ times in the relations. For our example, the broadcast plan (BP) is: (1, 2, 4,5), (1, 3, 6,7), (1, 2, 8,9), (1,3, 10,11).

Criterion 3: It provides the condition of not having a full BP according to Lemma 3.

The basic condition in order to achieve the optimum BP is that: the size of $S_i <$ the size of $S_{i+1}$. The optimum BP can be achieved when the basic condition is valid and the criterion 3 can not be applied at any level.

From all the above the pseudo code for the CBPA is the following:

```
CBPA
// $S_{1i}$, $S_{2i}$, $S_{3i}$ are the sizes of the three sets ($S_i$ is the most popular set of items)
if the basic condition is valid
{/ criterion 1, find the set of divisors of $S_{div}$={$d_1,d_2,...,d_n$}
for each $d_i \in S_{div}$
$n_{it}=d_i$;
(1)if $n_{rel}$ $\geq S_2$ and $n_{rel}$ $i=1,2$
{/ start, get a direct BP
// fill up the right most items of the
// relations with $S_2$ items }
// criterion 2
(2)if $n_{rel}$ $< S_2$ and $n_{rel}$ $| S_3$ $i=1,2$
{/ get an indirect BP
// criterion 3
if $n_{rel}$ $< S_1$ and $n_{rel}$ $| S_3$ $i=1,2$
{ no possibility to get a full BP}
// end
```

From all the above, criterion 1 examines the case of a full direct BP, criterion 2 deals with a full indirect BP and criterion 3 finds the case of no possible full BP. Criterion 4 complements the criteria 1 and 2 for finding equal spacing BP. In case that CBPA discovers that a full (or optimal) BP can be achieved the construction of this full BP (CBP) follows. The parameters for the construction of a BP such as $n_{rel}$, it$_{mu}$, for each i set are used for the
CBP. With the CBP, data are transferred one by one from the lines of the area_rel into queues and then the scheduler starts the service directly.

5 THE GDA

The GDA works with creation of the groups using less number of channels. Economy of channels is very important factor for large size broadcast cycle. The grouping is formed so that the AWT_3 is less than a predefined aver. waiting time for S_3 data. Our goal is to share the integrated relations to the channels without changing the RBP. Additionally, with GDA, the unused channels can be used for another broadcast data circle dissemination in case the server works with more than one BP. The pseudocode of GDA is as follows:

Example 7: Let us consider S_1 = 1, S_2 = {2,3,4}, S_3 = {5,...,76} with: S_1s = 1, S_2s = 3, S_3s = 72, pre av wt_3 = 40. Here S_3s >> S_2s >> S_1s . Using CBPA (Lemma 1) the int. divisor of 72 are: 36, 9,8,6,3. The n_rel=36 , it m_wt_3 = 36/3 =12. Hence any item of S_2 will be 12 times in BMP.

We have n_int_rel = 12 (36/3). Because there are 36 relations and the data of S_2 are spread along each of three of them. Analytically the 36 relations are: (1,2,5,6), (1,3,7,8), (1,4,9,10), (1,2,11,12), (1,3,13,14), (1,4,15,16), ...(1,2,71,72), (1,3,73,74), (1,4,75,76). The 12 integrated relations are: (1,2,5,6,1,3,7,8,1,4,9,10), (1,2,11,12,1,3,13,14,1,4,15,16), ...(1,2,71,72,1,3,73,74,1,4,75,76).

The int. divisors of 12: 6,4,3. For k=6, m =2 (12/6) we have the integr. relations: (1,2,5,6), (1,3,9,40) and (1,4,14,42),...(1,4,75,76). The AWT_3 is: 72. Since 72 > 40 a new loop for k=4 is needed. For k=4, m=3 (12/4) we have the integr. relations: rel.1: (1,2,5,6),...(1,4,21,22), rel.2: (1,2,23,24), (1,3,39,40), rel.3: (1,3,41,42),...(1,4,57,58), rel.4: (1,3,59,60), (1,4,75,76).

The AWT_3 = 36< 40. Hence, the minimum number of channels is: 4 and this can guarantee the service discrimination.

6 THE HOL-WTG SCHEDULER

We use a Group Round Robin (GRR) scheduler that provides the service queue order of all the minor cycles of the sets in a round. The waiting time for an item i (WT_i) starts when it becomes HOL until the beginning of service. When WT_i becomes greater than a predefined threshold GRR starts the service of queue i data. The HOL-WTG (Tsiligaridis et al., 2007) works like GRR (serves a group of items at a predefined order) after the weight adjustment (by an integer multiple of the packet size) and sends the data to a single or multiple channels.

Lemma 4: The service condition without any waste of bandwidth must be an integer multiple of the packet size (ps).

Proof: Let us consider as gi the size of a minor circle (i=1,2,3) which is gi = ps * n_pac,(1) (where n_pac is the number of packets, ps is the number of packets) and bw = kc * ps (k\in I) (2). Dividing (1) by (2) we take gi/bw = ps * n_pac / kc. If kc=1, then gi = bw + n_pac and the bw is used exactly n_pac times in order to service gi . If kc \neq 1, then gi = bw + n_pac / kc . If (n_pac /kc) = m (m \in N) then there is a surplus of weight (waste) that services the remainder of data (gi mod bw). Obviously there is a waste of bandwidth.
Example 8: For \( g_1 \) (items) = 270b (=30*9), \( bdw = 60b = 2*30b \) and \( (n_{pac}) / kc = 9/2 = 4.5 \). The remainder is 30b \((270 \ mod \ 60)\) is serviced by 60b \((bdw)\). The waste of bandwidth is 30b \(=60b-30b\) and loss percentage is: 0.5 (30/60).

Lemma 5: (Bandwidth Adjustment) We consider \( g_i (=ps*n_{pac}) \) and bandwidth \( bdw (=kc*ps) \) having the packet size \( (ps) \) as common factor. In order to increase the service rate we simply increase \( kc \) to \( m \) so that \( m/n_{pac} \). The variable \( kc \) is called increasing coefficient.

Proof: From \( g_i = ps * n_{pac} \), and \( bdw = kc*ps \) we take the ratio: \( g_i / bdw = n_{pac} / kc = n_1 \) and \( n_1 \leq 1 \). To increase the service ratio we simply find a value \( q \) so that \( n_{pac} / (kc + q) = n_2 \) and \( n_2 < n_1 \).

Example 9: For \( g_i \) (items) = 300b (=30*10), \( bdw = 60b = 2*30b \) and \( (n_{pac}) / kc = 10/2 = 5 \). In order to reduce the 5 rounds and complete the service to 2, we increase \( kc \) from 2 to 5 (by adding 3). Finally 10/5 = 2.

7 SIMULATION

For our simulation, a system with three cooperative levels is developed: The Application, the Queue and the List level. In the Application level the items from the arrays are inserted into the queues. Poisson arrivals are considered for the mobile users' requests. The items are separated into three categories according to their popularity using Zipf distribution. The Zipf distribution is typically used to model non uniform access patterns. Three sets are created; \( S_1 \) has the fewest items (most popular), \( S_2 \) has the next fewest items (less popular) and \( S_3 \) has the largest number of items (the least popular).

Using the CBPA and then the process of CBP, the items as encapsulated packets (with ID, queue number, arrival time, user number) are finally inserted from the arrays into the correspondent queues and the HOL-WTG scheduler start their service. The space of queues is considered as non-restricted. For our experiments it is considered that the server has additional bandwidth \( (weight) \) available in order to be able to adjust the weights. Four scenaria have been developed:

Scenario 1: The service time of a RR scheduler and HOL-AW scheduler are compared in a broadcast program with the three categories of sets. The HOL-AW scheduler (Fig. 1) reduces the service time by adjusting \( (increasing) \) the weight provided better results \( (450 \ tu \ instead \ of \ 630 \ tu)\).

Scenario 2: In Fig. 2 there is an increasing waste of weight before the use of the HOL-WTG scheduler.

Scenario 3: In Fig. 3, data in various sizes with equal spacing \( (RBP) \) from \( S_1 \) and \( S_2 \) sets, and flat \( (for \ all \ the \ sets) \) with long broadcast cycle size are depicted. For the data with equal spacing the AWT is less than the one of the flat data. It is considered a single channel service. We will also take the same results of the RBP for the users interested in data of \( S_1, S_2 \) if more channels were used (as in example 6).

Scenario 4: Three set of data are used and three cases (each one for each set) are developed starting from left to right in Fig. 4. All of them have the same \( S_1 \) data. The second set has more data \( (relations) \) of \( S_3 \) and the same size of \( S_2 \) data \( (relations) \). Because of this, the second case four channels are used instead of three in order to provide the same AWT. The number of channels are selected according to GDA considering \( pre\ ave\ wt_3 \) = 40sec. The third set has more data on S3 and less data on S2 comparing with the data of the second set. Because of this there is an increase of AWT \( (18 \ sec \ comparing \ with \ 16sec) \) and a decrease of AWT \( (from \ 8sec \ to \ 6sec)\).
8 CONCLUSIONS

A new method for regular data broadcasting, based on criteria, has been developed. The proposed method of designing broadcast plans with the ability of HOL-WTG scheduler to reduce the service time of users’ data, according to the desired waiting time, can provide new opportunities for the scale-up servers. It can enhance their self-sufficiency, self-monitoring. Such servers may address quality of service, and other issues with minimal human intervention.

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