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Regular Data Broadcasting Plan with Grouping in Wireless Mobile Environment

John T. Tsiligaridis

***Abstract*—**The broadcast problem including the plan design is considered. The data are inserted and numbered at predefined order into customized size relations. The server ability to create a full, regular Broadcast Plan (RBP) with single and multiple channels after some data transformations is examined. The Regular Geometric Algorithm (RGA) prepares a RBP and enables the users to catch their items avoiding energy waste of their devices. Moreover, the Grouping Dimensioning Algorithm (GDA) based on integrated relations can guarantee the discrimination of services with a minimum number of channels. This last property among the self-monitoring, self-organizing, can be offered by servers today providing also channel availability and less energy consumption by using smaller number of channels. Simulation results are provided.

***Keywords*—**Broadcast, broadcast plan, mobile computing, wireless networks, scheduling.

I. Introduction

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. A lot of work have been done for the data dissemination with flat and skewed design [1],[2],[3],[4]. For the flat design when the cycle becomes large the users have to wait for long until they catch the data in case they had lost them previously. When the broadcast cycle has long size, the flat scheduling needs many channels to avoid the user delay. The regular design with the equal spacing property [1] can provide broadcasting for single and multiple channels with average waiting time less than the one of the flat design. It also provides channels availability and less energy consumption. The data are considered homogenous or heterogeneous with multiple of a basic size. 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 a very interesting issue. GDA finds directly the minimum number of channels that produce an efficient RBP. The surplus of the available channels from both grouping algorithms may be used for other RBP. The rest of the paper is organized as follows. In section II the Model Description is described. In section III and IV the RGA and GDA are developed respectively. Simulation results are provided in section V.

J. T. Tsiligaridis is with the Heritage University, Toppenish, WA 98908, USA (phone: 509-865-8551; fax: 509-865-8679; e-mail: tsiligaridis_j@heritage.edu).

II. Model Description

A. The Relations in the Broadcasting Plan

In our approach three sets S_i (i=1,2,3) with their sizes S_{is} so that $S_{3s} \geq S_{2s} \geq S_{1s}$ are considered. The possibility of providing full BP (it does not include any empty slot) is examined iteratively using relations starting from the last level of hierarchy S_3. The number of S_i items (or items of multiplicity (it_mu $_i$)) will be sent at least one from S_3 ,while for the other two sets at least two. Given the size S_{3s} , S_{2s} , S_{1s} from the integer divisions of S_{3s} , using array (arr), a set of relations S_{div} (j< S_{3s}), with different number of relations (n_rel) and subrelations in each set (i-subrelation, i=1,2,3) can be created. A set of relations including their subrelations by considering items of different size from each set is created. Each relation has three *subrelations*.

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= $\sum_{i=1}^{3} s\_sub_i$). 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 $s\_sub_3 = 1$, the 2-subrelation (b,c,d) with $s\_sub_2 = 3$, and the 1-subrelation (a) with $s\_sub_1 = 1$. The s_rel=5

Definition 2: The *area of the i-subrelation (area_i_sub)* is defined from its size (s_sub_i) and the number of the relations (n_rel) that are selected. It is given by (s_sub_i) x (n_rel).

Example 2: From a relation with s_rel=5 and if n_rel=5 then the area of this relation is 5x 5 . 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 $s\_sub_3=3$, $s\_sub_2=2$, then : 2-subrelation_1 =(2,3) and 2-subrelation_2=(3,4). The last two subrelations ((2,3),(3,4)) comes from S_2 ={2,3,4} having 3 as repeated item.

Definition 3: A BP is *full* if it provides at least 2 repetitions of items and it does not include empty slots in the area_rel. A BP is regular if it is full and provides equal spacing property [1].

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: A subrelation i (i-subrelation) that belongs to set S_i is *strong* if, in its area, it can provide the same number of repetitions of all the items of a set (without empty slots) for all the relations. *The strong i-subrelations create strong relations.*
Definition 6: Integrated relations (or integrated grouping) is when after the grouping, each group contains relations with all the data of S_2 and S_1. This happens when: ($\cup$ (2_subrelation) = S_2) $\wedge$ ($\cup$ (1_subrelation) = S_1). See example 8 for details.

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.

B. Some Analytical Results

Two basic Lemmas provide the possibility of the FBP and RBP construction. Proofs and details for the case of empty slots BP are not included in this work due to limited space.

RGA provides a geometric approach to the construction of a RBP. After making sure that there is a RBP the data from the array (the minor cycles for each array line) are transferred to queues for broadcasting. For multiple channels, the data from integrated relations are grouping with GDA and then are broadcasting.
Example 4: The relation A= (a, b, c, d, f) has the following three subrelations (s_sub_i) starting from the end one; the 3-subrelation (f) with s_sub_3 = 1, the 2-subrelation (b,c,d) with s_sub_2 = 3, and the 1-subrelation (a) with s_sub_1 =1. The size of relation (s_rel) =5.
Lemma 1: The basic conditions in order from a set of data to have a regular broadcast plan are: k= S_{2s} | S_{3s} (1) and m= it_mu_2= S_{2s} | k (2) (item multiplicity). If (s_sub_3 / s_sub_2) >1 *repeated points* are produced (r_p = S_{2s} * it_mu_2) from S_2. If (s_sub_3/s_sub_2) =1 *repeated parallel lines* are provided (r_p_l = it_mu_2).
Proof: For (1) if k= S_{2s} | S_{3s} then the k offered positions can be covered by items of S_{2s} and a full BP is formed. From (2) m represent the number of times (it_mu) that an item of S_2 will be in the relation. •
Example 5: (full BP) Consider the case of: S_1 = {1}, S_2 ={2,3}, S_3 = { 4,5,6,7,8,9, 10, 11}. Moreover k= S_{2s} | S_{3s} = 4(8/2) , and m=2(4/2) the it_mu_2 =2=4/2 . The relations for the full BP are: (1,2,4,5), (1,3,6,7), (1,2,8,9)(1,3,8,9). Since (s_sub_3 / s_sub_2) >1 the r_p =4 (2*2).
From the geometric representation of data (Fig. 1) with s_sub_1 =1, the continuous bold line with r_p = 4 (=2*2), (such as: (2,5), (3,7), (2,9), (3,11)), show the possibility of the RBP solution.

If it is not possible to create the piecewise continuous bold line, the RBP is not possible to be created.

Analogous example with Empty Slots is not provided due to limited space.
Example 6: Let's consider S1 = {1}, S2 ={2,3,4,5}, S3 = {6,7,8,9, 10, 11,12,13}. Again, k=2(8/4), m= it_mu_2=2(4/2). Hence the FBP is (1,2,3,6,7), (1,4,5,8,9),(1,2,3,10,11) ,(1,4,5,12,13). The subrelations (2,3) ≠(4,5). Since s_sub_3 / s_sub_2 =1 the r_p_l=2 *repeated parallel lines.*

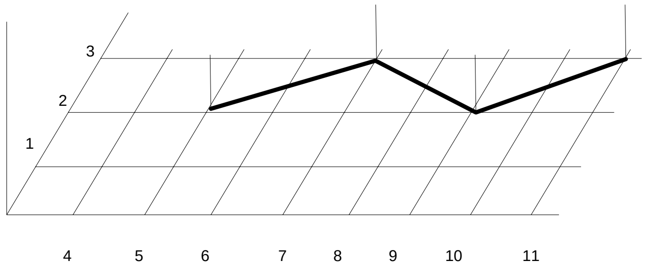

Fig. 1 Repeated points piecewise continuous line

From the geometric representation of data (Fig. 2) there are 2 parallel bold lines that are connected with dashed ones. If it is not possible to create the parallel lines it is not possible to create an RBP with subset multiplicity. Details for subset multiplicity are not provided here, due to limited space.

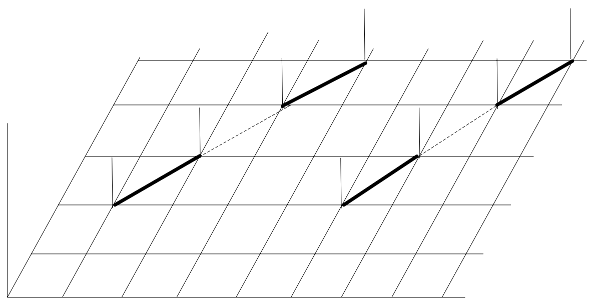

Fig. 2 Two parallel lines representation

Lemma 2.: If k = S_{2s} | S_{3s} (k∉I) and k_1 , k_2 the common divisors as: k_1 = n/S_{2s} (3) and k_2 = n/S_{3s} (4) (where n= common divisors of S_{2s} and S_{3s}) and if k_2/S_{2s} (5) then there is an RBP with it_mu_2 = k_2/S_{2s}
Proof: From (3) the number of S_2 items in a line s_sub_2 = k_1 / S_{2s}. From (4) s_sub_3 = k_2/ S_{3s}.
If (5) is valid then it means that the k_2 positions (offered by S_3) can be covered by k_2/S_{2s} items (it_mu_2). •
Example 7: S_1 = {1}, S_2 ={2,..,13}, S_3 = { 15,..,32} , S_{2s} = 12, S_{3s} = 18. If n =3, k_1 = 3/12 =4, k_2 = 3/18=6, and k_2/S_{2s} = 6/12 = 2. Hence the 6 relations and the 2-subrelations are: (….,2,3,4,5,…),(…,6,7,8,9…),(…,10,11,12,13,…), (….,2,3,4,5,…),(…,6,7,8,9…),(…,10,11,12,13,…). If n=2, k_1 = 2/12 =6, k_2 = 2/18=9, and from k_2/S_{2s} (9 □ 12) .
For the geometrical representation a set of three parallel lines is used. More details on the geometric attributes are not included here due to the limited space.
The RBP relations can be grouped in a number of compound relations and be sent to a single or various numbers of channels providing the same average waiting time for the users interested in data of S_1 and S_2. Hence, RBP can provide availability for the used channels.

Example 8: Let us consider $S_1 = 1$, $S_2 = \{2,3,4\}$, $S_3 = \{5,\ldots,22\}$ with: $S_{1s} = 1$, $S_{2s} = 3$, $S_{3s} = 18$. Applying RGA: k= S_{2s} | S_{3s} =3 (18/3), it_mu_2= S_{2s} | k = 2 (3/3). The FBP is: (1,2,5,6,7), (1,3,8,9,10), (1,4,11,12,13), (1,2,14,15,16), (1,3,17,18,19), (1,4,20,21,22). The FBP is an RBP (equal spacing for all the sets), for data of S_2 ($period_2$=14) and S_1 ($period_1$=5). 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 item "2" the AWT_2=14/2=7. Making groups of three relations *(in order to create integrated relations)* and using two channels the same AWT is taken again 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.

III. The Regular Geometric Algorithm (RGA)

The pseudocode of RGA is as follows:

```
RGA: input //input: the S1, S2, S3 , num_set (=2)
//output: define k the max. # of relations (n_rel)
          that can support a full BP
//variables: k,m,n ∈ I, n=common divisors of S2s and
S3s
if (k= S2s | S3s ) and m= it_mu2= S2s | k
    {there is a full BP for S2s, with k lines
     each item of Sis (i=1,2) will be repeated for m
times,
     if (s_sub3 / s_sub2) >1
          {r_p = S2s * it_mu2 } //repeated points
     if (s_sub 3/s_sub 2) =1
          {r_p_l = it_mu2 }  //repeated paral.lines
if k = S2s | S3s (k∉I) and k1 = n/S2s and k2 = n/S3s
   and k2/S2s
   { there is an RBP with it_mu2 = k2/S2s  }
```

From all the above the model steps are: (a) partition of data according to their popularity using probably dynamic programming[2], (not shown in this work), (b) construction of FBP and RBP, (c) grouping of data lines and (d) sending them to the minimum number of channels.

IV. The GDA

The GDA works with creation of the groups using fewer channels. Economy of channels is very important factor for large size of broadcast cycle. The grouping is made so that the AWT3 must be less than a predefined average waiting time for S_3 data. 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. Our goal is to share the integrated relations to the channels without changing the RBP. The pseudocode of GDA is as follows:

```
GDA input: n_rel: # of relations from RGA,
n_rel_per_s: is the integrated # relations for S2
n_ch: #of channels that provide RBP,
pre_av_wt3: is the predefined aver. waiting time for the S3
n_int_rel: is # of integrated relations from a RBP
variables: AWT3: the aver. waiting time for the
concatenated relations for data of S3
output: min_n_used_ch : the min # of channels that will be
used with predefined AWT3
for (i= 2: n_ch; i++)
{
n_int_rel = n_rel / n_rel_per_s
if  (n_int_rel = 2p, p∈I )                          (A)
   { find ki the integer divisors of n_int_rel
    // k1>k2>k3>..>kn , K={k1,k2,k3,..,kn }
    for each k ∈ K   // # of channels
      { ma = n_int_rel / k
         grouping by m integrated relations and create the
                    k concatenated relations
        if  (AWT3 ≤ pre_av_wt3)
          { min_n_used_ch = k ;
           send k concatenated relations to k  channels}
       } } }
if  (n_int_rel = 2p+1, p∈I )
   { we work with 2p integrated relations as in (A)
     and the last one (the 2p+1) is added to the last
      channel }
 } // end for
```

Example 9: Let us consider $S_1 = 1$, $S_2 = \{2,3,4\}$, $S_3 = \{5,\ldots,76\}$with: $S_{1s} = 1$, $S_{2s} = 3$, $S_{3s} = 72$, $pre\_av\_wt_3 = 40$. Here $S_{3s} >> S_{2s} >> S_{1s}$. Using RGA, k= 24 (72/3), it_mu_2= 8(24/3), a RBP with 24 lines is created. The 24 relations (n_rel) are (1,2,5,6,7),(1,3,8,9,10), (1,4,11,12,13), (1,2,14,15, 16),…,(1,4,74,75,76). The 8 integrated relations (with n_rel_per_s =3) can be created from the 24 relations are: ((1,2,5,6,7),(1,3,8,9,10), (1,4,11,12,13)), ..,((1,2,68,69,70), (1,3,71,72,73),(1,4,74,75,76)). If a single channel is used, AWT_3= 72 (72>25), grouping is needed with multiple channels in order to have less AWT_3. The n_int_rel = 8 (24/3), and the int. divisors of 8 are: 4,2. For k=4, ma =2 (8/4) the grouping integrated relations for 2 channels are as follows: *channel 1:* ((1,2,5,6,7), (1,3,8,9,10),(1,4,11,12,13), (1,2,14, 15,16), (1,3,17,18,19), (1,4,20,21,22), (1,2,23,24,25), (1,3,26, 27,28), (1,4,21,30,31), (1,2,32,33,34), (1,3,35,36,37), (1,4,38, 39,40)).
channel 2: ((1,2,41,42,43), (1,3,44,45,46), (1,4,47,48,49), (1,2,50,51,52),(1,3,53,54,55),(1,4,56,57,58), (1,2,59,60,61), (1,3,62,63,64), (1,4,65,66,67), (1,2,68,69,70), (1,3,71,72,73), (1,4,74,75,76)).
The AWT_3 is: 58. Since 58>40 a new loop for k=4 is needed.
For k=4, m=4 (8/2) the four integr. relations for the four channels are: *channel 1* : ((1,2,5,6,7),.., (1,4,20,21,22)),
channel 2: ((1,2,23,24,25),.., ,(1,4,38,39,40)),
channel 3: ((1,2,41,42,43),.., (1,4,56,57,58),
channel 4: ((1,2,59,60,61),.., (1,4,74,75,76)).

The AWT_3 = 28< 40. Hence, the minimum number of channels is: 4 and this can guarantee the existence of RBP (keep the service discrimination for all the sets).

V. 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 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. Two scenaria have been developed:

Scenario 1: 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. The same results of the RBP are provided for the users interested in data of S_1, S_2 if more channels were used.

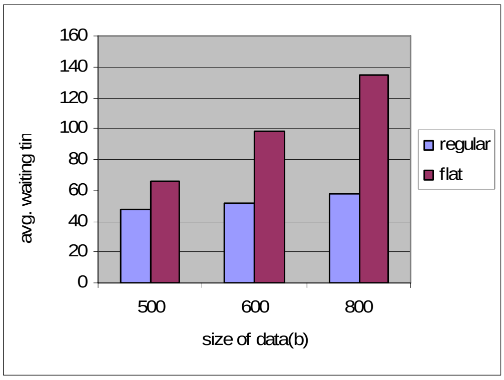

Fig. 3 The AWT for regular and flat data

Scenario 2: 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, in the second case four channels are used instead of three in order to provide the same AWT_3. The number of channels are selected according to GDA considering $pre\_av\_wt_3$ = 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 AWT3 (18 sec comparing with 16sec) and a decrease of AWT2 (from 8sec to 6sec).

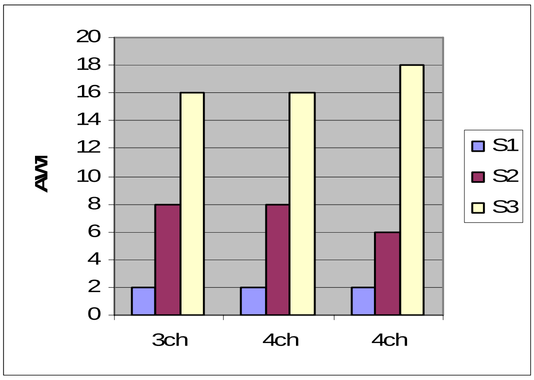

Fig. 4 AWT with GDA grouping

VI. Conclusion

A new broadcast data model plan has been presented. A relation developed method provides the design of regular broadcast plan. The GDA with RGA can guarantee the creation of an RBP and the grouping with the minimum available channels. The next generation servers and their components with the scale up possibilities, tools etc applying these kind of algorithms can enhance their self-sufficiency, self-monitoring and they may address quality of service, and other issues with minimal human intervention.

References

[1] S. Acharya, M.Franklin, S. Zdonik, R.Alonso, "Broadcast disks: Data management for asymmetric communications environments", Proc. of the ACM SIGMOD Int. Conf. on Management of Data, San Jose, May 1995, 199-210.

[2] W.Yee, S. Navathe, E. Omiecinski, C.Jermaine," Efficient Data Allocation over Multiple Channels of Broadcast Servers", IEEE Trans. on Computers, vol. 51, No.10,Oct 2002.

[3] E. Ardizzoni, A. Bertossi, M. Pinotti, S. Ramaprasad, R. Rizzi, M.Shashanka," Optimal Skewed Data Allocation on Multiple Channels with Flat per Channel", IEEE Trans. on Computers , Vol. 54,No. 5, May 2005.

[4] A. Bertossi, M.Pinotti, S. Ramaprasad, R. Rizzi, M. Shashanka, "Optimal multi-channel data allocation with flat broadcast per channel", Proceedings of IPDS'04, 2004, 18-27.