SIMILAR REGULAR PLANS FOR MOBILE CLIENTS

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Abstract: The broadcast problem including the plan design is considered. The data are inserted and numbered into customized size relations at a predefined order. The server ability to create a full, regular Broadcast Plan (RBP) with single and multiple channels, after some data transformations, is examined. The Basic Regular Algorithm (BRA) prepares an RBP and enables users to catch their items avoiding wasting energy of their devices. In the case of multiple channels, a dynamic grouping solution is proposed, called Full Partition Value Algorithm (FPVA) under a multiplicity constraint. The Similar Regular Plan Algorithm (SRPA) provides faster service of the supreme sets with the use of fewer channels. The combination of FPVA and SRPA provides flexibility for finding desired solutions. This last property, can be offered by servers today providing channel availability and lower energy consumption. Simulation results are provided.

1 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 has been done for the data dissemination with flat and skewed design (Acharya et al., 1995, Yee et al., 2002, Ardizzoni et al., 2005, Bertossi et al., 2004). 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. For the skewed design ,the most frequently requested data items should be put in fast channels whereas the cold data can be pushed to slow channels. Various methods have been developed to partition the data according to their popularity using dynamic programming (Yee et al., 2002) , and the heuristic algorithm VFk (Peng et al., 2000). The minimum time broadcast problem has been addressed by computing the minimum degree spanning tree of directed acyclic graphs in (Yao et al., 2008). The Min-Power broadcast problem in wireless ad hoc networks has been answered by assigning transmission range to each node (Hashemi et al., 2007).

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 (Acharya et al., 1995) can provide broadcasting for single and multiple channels with average waiting time less than the one of the flat design. It also offers channel availability, and less energy consumption while there is no need for use of channels with different speeds.

For the regular design, the system works with a number of channels that could be of the same speed. The users of all sets, except for the last one, can get their data from the same channel. Only the users of the last set (the most unpopular set) have to switch to another channel. The data are considered homogenous or heterogeneous with multiples of a basic size. Data can be sent by a single channel or a set of channels.

In this paper, we study the problem of finding the number of channels that can send a group of data, while ensuring equal spacing of repeated instances of items. The FPVA with SRPA provides a framework for a dynamic solution under constraints, in the case of multiple channel allocations. The FPVA can be extended to the case of broadcasting updated data.

The paper is organized as follows. In Section 2, the model description is given. The BRA is developed in Section 3. In Sections 4,5 and 6 the FPVA, the SRPA and their combination are developed respectively. Finally, simulation results are provided in Section 7.

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2 MODEL DESCRIPTION

2.1 The Relations in the Broadcasting Plan

In our approach we consider three sets S_i (i=1,2,3) with their sizes S_{is} so that $S_{3s} \geq S_{2s} \geq S_{1s}$.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), we can create 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). We create a set of relations including their subrelations by considering items of different size from each set. 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 (Acharya et al., 1995).

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 7 for details.

Grouping length(g): The g is a divisor of S_{ks} (1,..,k). It is the n_rel that can provide homogenous grouping. The g_k stands for the various values of g.

Supreme sets (SS): are all the sets except the last one. (SS =S_i (i=1..n-1)\ S_n). The last set (S_n) can be named as secondary set (SS). The divisors of SS are named *last set divisors* (LD= {ld_i}, for i=1..k}). Some (or all) of the ld_i values can provide an RBP (homogenous grouping) and then $ld_i = g_k$. It is possible all ldi values to be grouping values as well ($ld_i= g_i$). *Similar Regular Plans (SRP):* are the plans that have the same subrelations for the supreme sets and different for the secondary set.

Example: Considering : (1) RBP_1 with s_sum_1= 5, s_sum_2=5, s_sum_3=8 and s_sum_4=12,(2) RBP_2 with s_sum_1= 5, s_sum_2=5, s_sum_3=8 and s_sum_4=6. The two RBPs consist an SRP.

Partition value (pv): It is the common divisor of S_{is} (i=1,.., k) and gl for a given size of s_sum_i. Hence: $pv_i \mid S_{is}$ and $pv_i \mid gl$. Each set must have its own pv.

Example 4: If S_{3s} =40, g=20, considering that s_sum_3=8 then pv_3 =5 (=40/8) . Hence $pv_3 \mid S_{3s}$ and $pv_3 \mid g$

The criterion of homogenous grouping(chg): when $pv_i \mid g$.

The criterion of multiplicity constraint(cmc): This happens when: $it\_mu_{i+1} < it\_mu_i$ (i= 1,..,n-1).

The PV criterion: when $PV_i > PV_{i+1}$

The number of channels (nc): S_k / gl (where S_k is the last set)

It is considered that a|b (a divides b) only when b mod a =0 (f.e. 14 mod 2=0). The relation with the maximum value of n_rel provides the opportunity of *maximum multiplicity* for all 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. Similar description of the relations model is in (Tsiligaridis ,2009, Tsiligaridis et al., 2007).

2.2 Some Analytical Results

Two basic Lemmas provide the possibility of the FBP and RBP construction. The first deals with a particular case of the S_{2s} and S_{3s} while the second is a general case for every value of S_{2s}, S_{3s}. Proofs and details for the case of empty slots BP are not included in this work due to limited space.

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 GHA and then are broadcasting.

Example 5: 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 (particular case): 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).

Proof: For (1) if k= S_{2s} | S_{3s} then the k offered positions can be covered by items of S_{2s} and we can take a full BP. From (2) m represent the number of times (it_mu) that an item of S_2 will be in the relation. •

Example 6: (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 we have r_p =4 (2*2).

Example 7: Let's consider S_1 = {1}, S_2 ={2,3,4,5}, S_3 = {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).

Lemma 2 (general case): Given that S_{2s} and S_{3s} (and $S_{2s} \nmid S_{3s}$) with k_1 , k_2 their 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}): (a) if $k_2 < S_{2s}$ and k_2/S_{2s} (5) then there is an RBP with $it\_mu_2 = k_2/S_{2s}$ (b) if $k_2 > S_{2s}$ and S_{2s}/k_2 (6) then there is an RBP with $it\_mu_2 = S_{2s}/k_2$

The RBP will have for both cases k_2 relations.

Proof: From (3) we get that the number of S_2 items in a line $s\_sub_2 = k_1 / S_{2s}$. From (4) we have $s\_sub_3 = k_2/ S_{3s}$. 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). If (6) is valid then it means that the k_2 positions (offered by S3) can be covered by S_{2s} / k_2 •

Example 8: 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 we have 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} =we have $9 \nmid 12$.

Theorem 1: Let us consider the case of multiple channel allocation with different multiplicity of sets (such as: S1, S2, S3). Then, the validity of chg can be achieved when $pv_i = S_{is} / s\_sub_i$. If $pv_i \mid n_k$ then g = n_p and the criterion of homogenous grouping holds.

Example 9: Let's consider again the same four sets S1,S2,S3,S4 with S_{1s}=10, S_{2s}=20,S_{3s}= 40, S_{4s} =120

If gl =20 (20 is a divisor of 120) then S_{1s} / gl, S_{2s} / gl, gl / S_{3s}. The chg exists. The number of channels is: nc=120/20= 6. Considering s_sum1 = 5, s_sum_2=5,s_sum_3=8 then pv1 = 10/5=2, pv_2= 20/5=4, pv_3 =40/8=5 and since pv_1|20 ,pv_2|20,pv_3|20 then there is an homogenous grouping. With g =20

Theorem 2: For the lower values of LD that can offer an RBP, we have higher values of AWT_i for supreme set and more channels.

Proof: For lower LD values the PV_i has also lower values which means greater size of all the sub relations (s_sub_i) and finally greater values for AWTi •

2.3 The SRP

Theorem 3: For SRP increasing the LD number of groups (gi) we have lower AWTi for supreme sets and small number of channels.

Proof: Increasing ld_i results to having less data for the Sk (secondary set) in the relations which minimize the AWT_i (i=1..k-1). This theorem can be applied to FPVA. •

The number of channels is determined by the S_{ks} and the g_k (#channels= S_{ks} / g_k).

Example 10: Lets consider S_{1s}=10, S_{2s}=20,S_{3s}= 40, S_{4s} =120 and PVA_1 = 2, PVA_2=4, PVA_3=5, PVA_4 =5. For g_k = 10 we have: s_sub_1=5, s_sub_2=5, s_sub_3=8, s_sub_4=12 and AWT_1=15 (30/2), n_ch = 12(120/10). For g_k =20, s_sub_1=5, s_sub_2=5, s_sub_3=8, s_sub_4=6 and AWT_1=14 (24/2). , n_ch = 6(120/20).

From Theorem 3 it is obvious the SRP's ability to provide lower values of AWT for the SRP with fewer channels (12 to 6). This is the advantage the SRP offers for the RBP design.

For any BP the upper and lower bound of AWT (UA, LA) is depending on the size of s_sub_i (i=1..n). For a SRP, the UA and LA depend on the value of s_sub_4. They can be defined considering the possible upper and lower values of s_sub_4.

Theorem 4: For any RBP there is always a LA with the unit correspondence.
Unit correspondence is the case when in each relation only one item of S4 is considered. In that case we can have the same LA for different g values but with different n_ch.
Example 11: Let's consider LA and for: $s\_sum_1=5$, $s\_sum_2=5$, $s\_sum_3=8$ and $s\_sum_4=1$ with broadcast cycle = 19 (5+5+8+1). The AWT_3 = 52.5 ((5*19 +10)/2).

The AWT_3 remains the same independently of the value g. So if g=60 , AWT_3=52.5 while n_ch = 2 (120/60). On the other hand if g=20 , AWT_3=52.5 ,and n_ch = 120/20 =6. The UA for the SRP can be found for the non unit correspondence. The max(s_sum_4) can provide an UA when the conditions to create an RBP are valid.
The conditions are: $pv_i \mid g$

3 THE BASIC REGULAR ALGORITHM (BRA)

The BRA is based on the conditions to find a RBP and provide opportunities for multiplicity on the items of Si (i<n) and it is for a single channel allocation.

```
BRA: //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
km ∈ I and km > 1
//particular case
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,
//general case
If k1 = n/S2s and k2 = n/S3s (for given: S2s, S3s, n)
      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 (Yee et al., 2002), (not shown in this work), (b) construction of FBP and RBP, (c) grouping of data lines and (d) sending them to a minimum number of channels.

4 THE FULL PARTITION VALUE ALGORITHM (FPVA)

The FPVA focuses on solving a problem using as many available channels as possible and minimizing the AWT of the supreme set (S_1,S_2,S_3,S_4) as in Theorem 2.For all the predefined number of integrated relations (g) we try to discover the values of pv_i ($i \le n$) so that the criterion of homogenous grouping is valid and the multiplicity constraint is satisfied.
It works with no grouping or BRA. When no available channels exist (or when the system prefers not to use all the available channels) we move to the next satisfactory solution. The LD has set the ld_i at an increasing order according to Theorem 2. It starts from a maximum number of available channels solution, tests for chg and cmc and continues until it finds the solution with the most appropriate number of channels. The AWT_i is examined so that when it goes above a threshold an LD increase is made (new pace).

```
FPVA input: S1,S2,S3,S4, Sis (i ≤4), n_ch: the
# of channels, exist_v: the variable for chg,
pred_v: predefined value
output: the homogenous grouping for multiple
channels
//find the divisors set D4 of  S4 (d4∈D4 )
increasing order
//find pvi that divide di and Si (i≤3) and s_sumi
//D3 for S3, D2 for S2, D1 for S1
//d3 ∈ D3, d2∈ D2, d1∈ D1
//find the n_ch =  D4/ d4
for each divisor (d4) of set  S4                    (a)
    for all Si (i≤4)
     {  if  (pvi|di && pvi|Si (i=1..3) )
             it_mui = di /pvi , exist_v ='y'
             if (d4 = min(D4)) {//max avail. chan.
                    sol}
             else {a sufficient sol.}
        while (it_mui ∉ I)  // (i <4)
           { j=i;  exist_v ="n";
             //find new s_sumi ,
              go to (b) }
        if exist_v="y"
        //examine the multiplicity constraint
        it_mu_all="y"
       if (it_mui+1 < it_mui)
          { the  PVA provides solution for Si,Si+1
            homogenous grouping and for n_ch }
       else {//find another d4
                it_mu_all="n";
```

Example 12: Consider the sets: S_{1s}=10,S_{2s}=20, S_{3s}=40, S_{4s} =120. The divisor of S_{4s} are: LD={20,30,40}. For ld_i =20 the number of channels (if an RBP can be created) , n_ch =120/20 =6.
The divisors of S_i($i \le n$), D_3= {8,5}, D_2=(5,4),D_1={5,2}. Taking : d_3= 8,d_2=5,d_1=5 . Considering as ld_i =20 , s_sub_3=8(=d3), s_sub_2=5 (=d2), s_sub_1=5(=d1) then we have:

pv_3=40/8=5, and it_mu_3= 20/5=4
pv_2=20/5=4, and it_mu_2= 20/4=5
pv1=10/5=2, and it_mu1= 20/2=10

So the chg and the cmc are valid (it_mu_3<it_mu_2<it_mu_1) and an RBP can be created with $g_4 = ld_i$
If the divisors of S4 are at a decreasing order (e.i.,60,40,20) the n_ch will take the lower value. This is used when the design of RBP is only for a minimum number of channels.
The RBP for all the available channels can be achieved when the divisor of S4 are at an increasing order. This comes from the n_cl formula (D_4/ d_4). In addition a new parameter (AWT) has be considered and if it is above a threshold then two choices come up: (a) apply FPVA-SRPA or (b) only increase d_4.

5 THE SIMILAR REGULAR PLAN ALGORITHM (SRPA)

The SRPA focuses on providing a solution using the available number of channels minimizing the AWT of the supreme set (S1,S2,S3) as Theorem 3. The new RBP can provide better AWT with less number of channels. This is an economical solution because with fewer channels we have faster server service. SRPA can include all the AWT i (i≤k-1, k=4) and not just the AWT_1 . A number of saving channels (s_ch) is produced from the SRPA.

```
SRPA input: s_sum_i , n_ch (from FPVA),d4
output : new s_sum_4 , new RBP, new s_ch
while (AWT1 > pred_v)
   for each next divisor  d_4 (of set D4)
        find new s_sum4  < old c_sum4
find new n_ch (n_n_ch)
     prepare the new RBP with new s_ch
```

Example 13: Let us consider that: d_4 = 10, s_sub1=5, s_sub2=5, s_sub3=8, s_sub4=12 and AWT_1=15 (30/2), n_ch = 12(120/10). D_4 = {6,2} . For d_4=20, s_sub_1=5, s_sub_2=5, s_sub_3=8, s_sub_4=6 and AWT_1=14 (24/2). , n_ch = 6(120/20). We have savings of 6 channels (12-6).

6 THE FULL PARTITION VALUE ALGORITHM (FPVA-SRPA)

The combination of FPVA and SRPA provides the opportunity to find a new RBP with possibilities to change the parameters in order. First, the FPVA finds an RBP and then the SRPA finds the most desirable solution (lower number of channels) by saving more available channels that could be used for another broadcasting. It works as FPVA but it uses an additional step, the SRPA.

```
FPVA-SRPA: input: RBP
output: new RBP with
while (n_ch > pred_n_ch)
   { FPVA
    if AWTi> pred_v
        { apply SRPA }
   }
```

7 SIMULATION

For our simulation, Poisson arrivals are considered for the mobile users' requests. The items are separated into three categories according to their popularity using Zipf distribution. Three scenarios have been developed:

Scenario 1: In Fig. 1, data in various sizes with equal spacing (RBP) from S_1 and S_2 sets, and flat (for all the sets) (Acharya et al., 1995) 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.

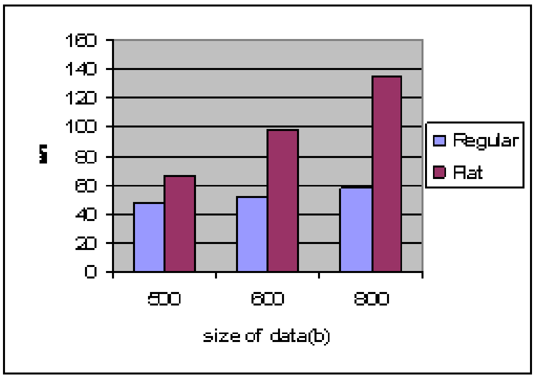

Figure 1: The AWT for regular and flat data.

Scenario 2: Considering S_{4s} = 120, S_{3s}=60,S_{2s}=40,S_{1s}= 20. The AWT for S_1,S_2,S_3 remain the same (Fig. 2) because PAV could find the same values of pv_i for all the number of channels(6,3,2).The AWT_4 has increasing trend, and it depends on the # of channels the PAV discovers. The lower the # of channels is the greater the AWT_4. For S_4 it is considered that for each relation there is one element (no repetitions). In other words the s_sub$_i$ (i=1,..,4) remains the same for all the cases of the number of channels.

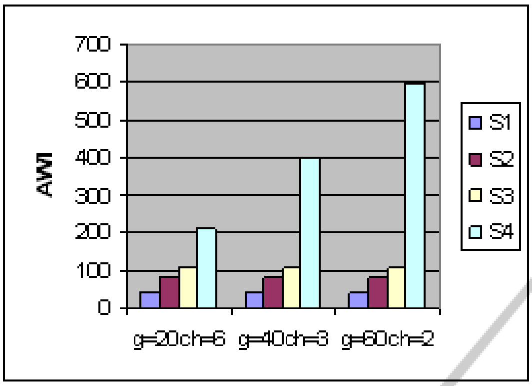

Figure 2: The AWT for the same s_sub$_4$.

Scenario 3. This is the SPRA approach. Let us consider: S_{4s} = 120, S_{3s}=60,S_{2s}=40,S_{1s}= 10 and same values of s_sub$_i$ from all the sets except the s_sub$_4$. In that case s_sub$_4$ diminished from 4 to 2 with increasing g (from 30 to 60). The n_ch is reduced by a factor of two (from 4 to 2). As shown in Fig.3 there is almost a double increase of AWT_4 (from 339tu to 609tu). The AWT for the other sets (S_1,S_2,S_3) has only a small difference. This is due to the combination of increasing g and diminishing s_sub$_4$.

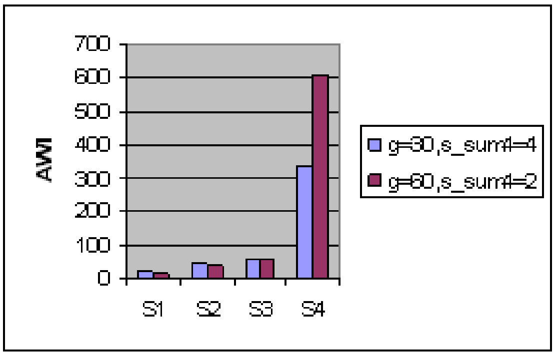

Figure 3: New AWT for SPRA.

8 CONCLUSIONS

A new framework for a broadcast data model plan with a set of algorithms is presented. Our proposed model with parametric changes can guarantee faster service with fewer channels for the supreme set. Applying these algorithms the next generation servers and their components with the scale up possibilities, tools etc can enhance their self-sufficiency, self-monitoring so that they may also address quality of service, and other issues with minimal human intervention.

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