Data Dimensioning for Delay Differentiation Services in 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 while avoiding wasting energy by their devices. In the case of multiple channels a dynamic grouping solution is proposed, called the Partition Value Algorithm with Less Dimension (PVALD), under a multiplicity constraint. In order to provide an RBP under relative delays a Dimensioning Algorithm (DA) is developed. The DA, with the criterion of ratio, offers the differentiation of service. This last property, in addition to the self-monitoring, and self-organizing, can be offered by servers today providing also channel availability and lower energy consumption by using a smaller, number of channels, of equal bandwidth. 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 have 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 work the dynamic grouping solution is developed by examining the possibility of filling up an area starting from less values especially from the cold set (the less dimension principle, LDP).

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 PVALD algorithm provides a dynamic solution using the less dimension principle with constraints. The constraints can be applied with the use of certain criteria. The DA can

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discriminate the services according to relative delays and provide the appropriate RBP. Both PVAMD and DA provide servers with new approaches for service discrimination. The paper is organized as follows. In Section 2, the model description is given. In Sections 3, 4, and 5 the BRA, the PVALD, and DA are developed, respectively. Finally, simulation results are provided in Section 6.

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. In this work it is considered that each relation has three or four *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. The *integrated relation dimension (id)* can be described as id [1,2] or simply [1,2].

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 7 for details.

Grouping length(gl): The gl is a divisor of S_{ks} (1,..,k). It is the n_rel that can provide homogenous grouping.

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

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

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

The criterion of PV (cpv): when: $pv_i < pv_j$ (for i<j).

The chg along with cpv can guarantee the cmc for different multiplicity (Theorem 1) and because of that the cmc is not necessary to be examined.

The pv criterion can guarantee differential multiplicity service. For having an RBP the criterion of chg along with pv have to be held.

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.

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 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 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).

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 $9 \nmid 12$.

The less dimension principle, LDP, coming from the diminishing of the size of cold set s_sum_{k-1} (for k sets), the provides an opportunity to minimize the delay (especially for the hot data) by using smaller number of data in s_sum. If an RBP is feasible for the low dimension of values this area can be copied many times and provide an RBP for all the available channels.

Example 9: Let us consider S_{1s}=10, S_{2s}=20,S_{3s}=40,S_{5s}=120. Taking: d_1= 5,d_2=5,d_3=5,d_4=1 with s_sum = 16 the AWT_1 = 32(=4+5+5+1 + 4+5+5+1 + 1). For d_1= 5,d_2=5,d_3=8,d_4=1 with s_sum = 19 the AWT_1 = 38.

Considering smaller size of s_sum for an RBP the size of PV_i is increasing. Finally : from LDP the AWT (LDP) is less that any other size of s_sum

Theorem 1 : Let us consider the case of multiple channel allocation with different multiplicity of sets (such as: S_1, S_2, S_3). Then, if pvi|d4, the validity of multiplicity constraint (it_mu_{i+1} <it_mu_i (i=1,..,k-1) can be achieved from the pv criterion (pv_i <pv_{i+1} , i<k, k=#sets). Similarly the pv criterion can guarantee the multiplicity constraint criterion.

Proof: Lets prove that if pv_i< pv_{i+1} (1) then it_mu_i > it_mu_{i+1}. (2). From (1) =>1/ pv_i > 1/ pv_{i+1} => d_4/ pv_i > d_4/ pv_{i+1}. If (d_4/ pv_i) ∈ I, => it_mu_i > it_mu_{i+1}. Following the reverse order we can go from (2) to (1). Therefore, it is not necessary to examine the multiplicity criterion and the pv criterion can provide the multiplicity. •

Example 10: Let's consider again the same four sets S_1,S_2,S_3,S_4 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_sum2=5,s_sum3=8 then pv_1 = 10/5=2, pv_2= 20/5=4, pv_3 =40/8=5. We have pv_1<pv_2<pv_3 (pv criterion) and since pv_1|20 ,pv_2|20,pv_3|20 (or d_4 | pv_i) ∈ I) then the chg is valid and and an RBP can be constructed. From all this process it is evident that there is no need to test the cmc .

Theorem 2: If pv_i (i<k, k =#sets) are analogous to a_i the AWT_i are also analogous to the a_i and pv1 / AWT1 = pv_2/AWT_2 =…= pv_k / AWT_{k-1}.

Proof: Let us consider k=4. and (pv_1/a_1) = (pv_2/a_2) = (pv_3/a_3) (1)

Finding AWT1: AWT1= s_sum*pv1 (= s_sum1-1+s_sum2 + s_sum3 + s_sum1 -1= s_sum*a1 = s_sum * pv1). In analogous way : AWT2 = s_sum*a2 = s_sum*pv2, AWT3= s_sum*a3 = s_sum* pv3,.., AWTk-1 =s_sum*a_{k-1} =s_sum*pvk-1. Taking the ratio: For $AWT_1 / a_1 = AWT2/ a_2 = AWT_3/ a_3 = \ldots = AWT_{k-1} / a_{k-1}$ (2)
Dividing the ratios (1),(2) : $pv_1 / AWT_1 = pv_2/AWT_2 = \ldots = pv_k / AWT_{k-1}$. •

Lemma: The LDP can provide an RBP with more # of channels.

Example 11: For S1s=10,S2s=20,S3s=40, S4s=120, and $d_1=5,d_2=5,d_3=5$ the $pv_1=2,pv_2=4,pv_3=8$ and n_ch= 120/8=5. For $d_1=2,d_2=2,d_3=2$ $pv_1=5,pv_2=10,pv_3=20$ and n_ch=120/6=20.

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 S_1, S_2, S_3 , 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 S_{2s} and S_{3s}
km ∈ I and km > 1
//particular case
if (k= $S_{2s} \mid S_{3s}$) and m= $it\_mu_2 = S_{2s} \mid k$
 {there is a full BP for S_{2s}, with k lines
 each item of S_{is} (i=1,2) will be repeated for m times,
//general case
if $k_1 = n/S_{2s}$ and $k_2 = n/S_{3s}$ (for given: S_{2s}, S_{3s}, n) and k_2/S_{2s}
 { there is an RBP with $it\_mu_2 = k_2/S_{2s}$ }

4 THE PARTITION VALUE ALGORITHM WITH LESS DIMENSION (PVALD)

The PVAMD addresses the cases of minimum size of integrated relations of all sets. It works with neither grouping nor BRA. For k sets, PVALD starts with the lower value of d_4 and s_sum_i (i < k) and d_k =1.As soon as a BRP is feasible, so that the criterion of homogenous grouping , pv and multiple constraint are valid, the maximum number of desired channels can be computed. The grouping is used in order to adapt the RBP to the available number of channels.

PVALD input: S1,S2,S3,S4, Sis (i ≤4), n_ch: the # of channels, m_n_ch: the max # channels,a_ch:#avail.chan.
thr_ch: # of desired channels for an RBP
output: the homogenous grouping for multiple channels
find the divisors set D_4 of S_4 ($d_4 \in D_4$, increasing order)
find the divisors of the S_1,S_2,S_3 (in increasing order)
//D_3 for S_3, D_2 for S_2, D_1 for S_1
//$d_3 \in D_3$, $d_2 \in D_2$, $d_1 \in D_1$
for each s_sum (s_sum_i , $s\_sum_i = d_i$ (i<4)) (a)
 for each divisor (d_4) of set S_4 (b)
 for all S_i (i≤4)
 { //define the $s\_sum_i = d_i$ (i<4)
 $s\_sum_i = d_i$ (i<4)
 $pv_i = S_{is} / s\_sum_i$
 if $pv_i \mid d_4$ (c)
 {the chg criterion is valid, "there is multiplicity"}
 else {go to (b) }
 if ($pv_i < pv_{i+1}$)
 {"the pv criterion is valid "
 the m_n_ch = D_4/ d_4;
 if (a_ch ≥ m_n_ch)
 { creation of an RBP for m_n_ch channels}
 else { grouping for an RBP with a_ch}
 else { go to (b)}
 if (n_ch <thr_ch)
 {$d_4 = 2 * d_4$, go to (c) }
 if (there is not an RBP for all d_4 –b-)
 {go to (a) , new s_sum}

Example 12: Let us consider: S_{1s}=10, S_{2s}=20,S_{3s}= 40, S_{4s} =120 ,thr_ch=4. Considering : (a) for s_sum_1 =2, s_sum_2=2,s_sum_3=2 , (or [2,2,2]), d_4=20, the pv_1 = 5(10/2), pv_2= 10 (20/2), pv_3= 20 (40/2). Also $pv_1 \mid d_4$ (=8=20/5), $pv_2|d_4$ (=2=20/10), $pv_3|d_4$ (=1=20/20) and $pv_1 \le pv_2 \le pv_3$. The pv and multiplicity criterion is valid. n_ch= 120/20=4> thr_ch. So [2,2,2] with d_4=20 can not provide the desired RBP. (b) for s_sum1 =2, s_sum2=2,s_sum3=2 , (or [2,2,2]), d4=40(=2*20), the pv1 = 5(10/2), pv2= 10 (20/2), pv3= 20 (40/2). Also $pv_1 \mid d_4$ (=8=40/5), $pv_2|d_4$ (=4=40/10), $pv_3|d_4$ (=2=40/20) and $pv_1 \le pv_2 \le pv_3$. The pv and multiplicity criterion is valid. n_ch= 120/40=3< thr_ch. So [2,2,2] with d_4=40 can provide the desired RBP.

5 THE DIMENSIONING ALGORITHM (DA)

The DA is very useful for finding the AWTi by applying the Theorem 2. In addition any change to the integrated relation (s_sum) or any subrelation (s_subi) can easily be translated into delay. This is very important for the server making decision process and for having successful differentiation of services.

DA: input: s_sumi (i<k, k:#sets), PAi/ai : the desired ratio
output: RBP with desired AWTi ratio
for each s_sum (s_sum$_i$, s_sum$_i$ = d_i (i<4)) (a)
  for each divisor (d_4) of set S_4 (b)
  //find PVi
  PAi = Sis / s_sumi
  if $pv_i \mid d_4$
    {chg criterion is valid}
  else {go to (b) }
  if ($pv_1 < pv_2 < \ldots < pv_{k-1}$)
   {the pv criterion is valid}
  else {go to (b) }
  if ($pv_1/a_1 = pv_2/a_2 = \ldots = pv_{k-1}/a_{k-1}$)
   {$AWT_1/a_1 = AWT_2/a_2 = . . = AWT_{k-1}/a_{k-1}$
    there is a RBP with the predefined ratio}
  else {go to (b) }
  if (there is not an RBP for all d_4 –b-)
    {go to (a) , new s_sum}

Example13: Let's consider: S1s=10,S2s=20, S3s=40, S4s =120. The divisor of S4s are: d4={10,20,30,40}. The purpose is to see for: AWT1/2 = AWT2/4 = AWT3/8. For d_4 =10 and s_sum$_1$=5, s_sum$_2$=5,s_sum$_3$=5, the pv1 = 10/5 = 2, it_mu1=10/2=5, pv2= 20/5 = 4, it_mu2= 10/4 $\not\in$ I, pv3=40/5=8 , and it_mu3= 10/8 $\not\in$ I (pv criterion no t valid). For d_4 =20 and s_sum$_1$=5, s_sum$_2$=5,s_sum$_3$=5, the pv1 = 10/5 = 2 , it_mu$_1$=20/2=5, pv2= 20/5 = 4, it_mu$_2$= 20/4 =5, pv3=40/5=8 , and it_mu$_3$= 40/8=5 (pv criterion is valid). Also $pv_1 < pv_2 < pv_3$ (2<4<8) so the pv criterion is valid.
The pv ratio is: $pv_1/2 = pv_2/4 = pv_3/8$ give the $AWT_1/2 = AWT_2/4 = AWT_3/8$.

6 SIMULATION

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

Scenario 1: Considering S_{4s} = 120, S_{3s}=60,S_{2s}=40,S_{1s}= 20. For the lower values of s_sum (s_sum1=2, s_sum2=2,s_sum3=2 or [2,2,2] (from integrated relation dimension –id-, using PVAMD, we have the lower number of available channels. For the other for two cases like: [5,5,5] and [10,5,5] it is needed the same # of channels since they have the same d_4=8. It is considered that s_sum$_4$=1 for both cases.

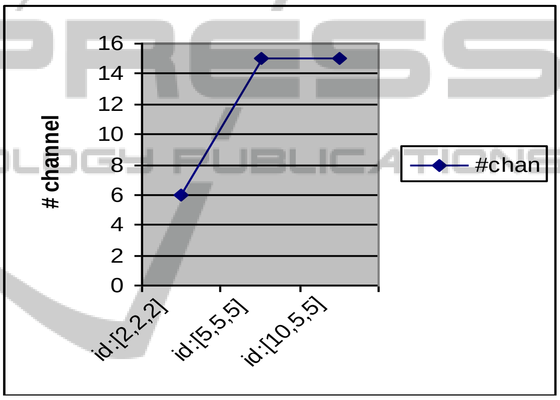

Figure 1: The AWT for the PVAMD.

Scenario 2: Let us consider the same size of sets as Scenario 1. The AWTi (i≤4) for [2,2,2] and [5,5,5] have greater values for [2,2,2] since the lower size of s_sumi can define greater values of pvi and more times of repeated s-sum (including also the s_sum$_k$ =1).

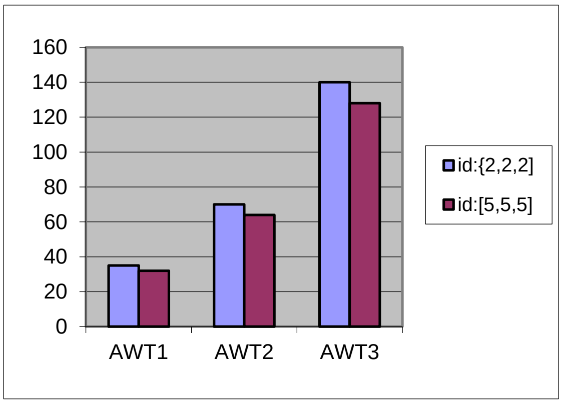

Figure 2: The AWT for the different size of s_sum.

7 CONCLUSIONS

A new broadcast data model plan with a set of algorithms has been presented. The PVAMD start finding RBP by using the less dimension principle with constraints. The DA provides opportunities for finding the desired delays of a set of services. By applying these algorithms the next generation servers and their components with the scale up possibilities, tools etc can enhance their self-sufficiency, self-monitoring and they may address quality of service, and other issues with minimal human intervention.

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