Optimal Bandwidth Allocation for Multimedia Mobile Networks Using Particle Swarm Optimization

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***Abstract* – Though significant improvement in communication infrastructure has been attained in the mobile network technology, the issues concerning the optimized bandwidth allocation to different applications in a reasonable time remain challenging and need to be solved. Also varying mobility and various service class requirements of present multimedia applications makes it more critical. It is mostly realized in the present Third Generation (3G) and Beyond 3G (B3G) mobile network system. Hence an effective and efficient bandwidth optimization schemes for a cellular mobile network system are needed. In this paper we propose an algorithm based upon the Particle Swarm Optimization (PSO) approach to solve the bandwidth allocation problem. The PSO algorithm is an adaptive algorithm based on a social-psychological metaphor; a population of individuals adapts by returning stochastically toward previously successful regions. Although PSO is a population based evolutionary technique like Genetic Algorithm it differs in that each particle or solution contains a position, velocity and acceleration. We explore and analyze the behavior of particle by examining the computational results of our PSO algorithm under different parameter settings. The performance of the PSO algorithm is compared with metaheuristic technique namely Simulated annealing (SA). Experimental results shown that the proposed PSO algorithm is an efficient and competitive approach in composing fairly good results with respect to solution quality and execution time for the bandwidth optimization problem as compared with SA.**

***Key words* – Multimedia Mobile Networks, Bandwidth, Optimization, Particle Swarm Optimization (PSO), Simulated Annealing (SA) .**

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1 INTRODUCTION

The tremendous growth of mobile network technology has increased the need for better admission control strategies and effective and efficient utilization of resources such as bandwidth, buffer etc., with better Quality of Service (QoS) guarantee. Also the mobile networks supporting non-real time and real time multimedia with different traffic requirements, providing better QoS, is a challenging task due to the scarcity of resources and different service class requirements. Of which, real time applications such as voice need stringent QoS. Apart from this, real time applications should not suffer 'call dropping' during hand off and 'call blocking' in case of new connection calls within a cell. Most of the bandwidth allocation schemes existing, deals with minimization of call blocking and call dropping probabilities. Thus probability of hand off dropping becomes an important QoS metrics in wireless networks [1].

A number of Admission control and bandwidth adaptation techniques exist in the literature. The hand-off bandwidth estimation dealt by [2] [3] mainly focus on reserved bandwidth. The shadow cluster concept proposed by Levine [4] et al deals with proposed predictive resource allocation wherein Mobile Station (MS) informs Base Station (BS) within adjacent cells about the bandwidth needed during call setup time. Through this the BS predicts its future demands. But it has the draw back of large overhead. For QoS metrics such as throughput, delay in multimedia environment, priority based admission control is proposed in [5]. The better utilization of network bandwidth using measurement based admission control is proposed in [6]. In [7], adaptive bandwidth reservation was used. By this method, if reservation fails, new hand off connections is rejected. The major drawback of this scheme is the minimization of the band width utilization, the prime need of real time multimedia applications [8] [9] [10] which possess lower bound and upper bound on network resources for any typical applications. In [11] the fair resource protocol uses both bandwidth reservation and bandwidth probabilities. It is applicable to max-min fairness protocol [12]. Also the fair resource allocation protocol compared with [13] which use a proportional fairness so as to tolerate transient fluctuations using bandwidth borrowing concept. But most of the papers [14-17] mainly deals with a much complex mathematical model with only minimum improvement in overall performance of cellular mobile and adhoc networks. The paper [18] addresses the issue of admission control in mobile cellular networks. Artificial Neural Networks (ANN) are used to solve linear programming model to obtain the lowest energy state. But it provide the solution with local optimal only. To have bandwidth optimization and to achieve global optimal value metaheuristic technique namely Simulated Annealing (SA) was proposed by the authors[19]. It leads to increasingly better solution candidates and terminates with a possibly optimal solution [19]. In this paper we solve the bandwidth allocation problem by applying PSO algorithm to explore the possibility of composing better solution.

2 SYSTEM MODEL

Figure 1 shows a typical multimedia wireless cellular network system with hexagonal shaped cells. Each cell is having a Base Station (BS) which allocates and reserve bandwidth for Mobile Stations (MS). The MS communicate with their home BS's via the air interface . Number of BS's are connected to a Mobile Switching Center (MSC) which in turn connected to the backbone wired networks. The bandwidth can be shared for 03 types of applications namely *Running, Hand off and New applications*. Let us assume that already scheduled applications are called as running applications. The calls from MS moving from adjacent cell to the target cell are termed as hand off applications. New calls coming from the same target cell are called as new applications. The network service provider has to provide a sufficient bandwidth for handoff calls and new calls. For this the bandwidth from running applications has to be utilized optimally without degradation in QoS.

The handoff connection or Call Dropping Probability (CDP) is the dropping of the hand off call when there is insufficient bandwidth. A new call with denied access into the network is called as Call Blocking Probability (CBP). These are the major QoS parameters in a multimedia wireless networks. From end user perspective the call blocking is more acceptable than call dropping. So the optimum design in dynamic bandwidth adjustment is such that CDP of handoff calls can be minimized and CBP of new calls should be maintained at an acceptable level.

The multimedia applications can be classified into real time and non-real applications. The real time applications are time sensitive applications with tight constraint on delay and delay variation. Also real – time applications have strict QoS requirements and negotiates its QoS such as minimum delay, delay variation etc during call set up with the network. Examples for real time applications are compressed voice and video, compressed voice with silence suppressions and standard digitized voice at 64 Kbps.

The non-real time applications are time insensitive applications but with tight constraint on information loss. These data applications require reliable transport. So these data applications are more tolerant to delay as compared to real-time applications . The noval Dynamic Call Admission Control (DCAC) scheme maximizes wireless channel utilization with respect to bound on call dropping and packet loss probability for VBR. The paper [21] aims at studying how the accuracy of prediction method can influence network QoS in specific context of CAC. Due to diverse QoS requirements and various traffic descriptors, it is mandatory to design a suitable network system accorded with different priorities and optimized resource requirements, without much degradation in QoS.

3 OPTIMIZATION TECHNIQUES

Optimization techniques are becoming increasingly popular in engineering due to the availability of high speed computers. These are used in engineering optimization problem which contain multiple optimum solutions with one or more absolute minimum or maximum solutions. These absolute optimum solutions are called global optimum solution and other optimum solutions are known as local optimum solution. [22] Ideally we are interested in global optimum solution when compared with absolute optimum objective function value.

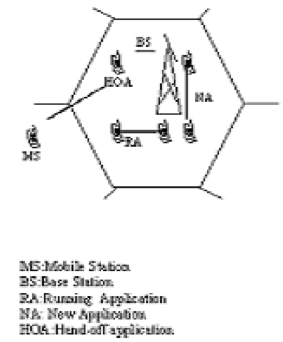

Figure 1 : Cell Network Model

The objective of resource allocation in our case is the maximization of bandwidth allocation without violating the QoS requirements of each application in a cellular mobile networks. The principle used in [18] is mainly devoted to admission control by maintaining QoS guarantee to existing applications and to increase the percentage of admission to real time and non-real time application. The optimization technique minimizes the already scheduled applications bandwidth without degradation in QoS. It is helpful in obtaining a large quantity of available resources for scheduling the remaining hand-off and new applications. The problem is formulated as below.

Maximize $$\sum_{i=1}^{r} C_i R_i \qquad (1)$$

Subject to $$\sum_{i=1}^{r} R_i \le (1-\Omega)(P-\Theta) \qquad (2)$$

$$R_i^{\min} \le R_i \le R_i^{alloc} \qquad (3)$$

$$R_i \ge 0, \forall_i \in [1, r] \qquad (4)$$

Where R_i is the decision variable to be solved to provide new bandwidth for running applications on solving above problem. C_i is the weight chosen for minimum and maximum requirement. Ω is the reduction parameter and P is the maximum bandwidth and Θ is the remaining bandwidth. Note that each application has its own rate and thereby for different running application (r) optimum bandwidth requirement is changed accordingly.

4. METAHEURISTIC SCHEMES

The critical factor with the optimization problem enforces the need for effective tools. But the traditional technique such as Linear Programming (LP) was not fruitful due to its solution of local minima only. This motivated us to develop a heuristic approach in Evolutionary computing [23] which introduced two robust metaheuristic techniques namely Simulated Annealing (SA) [24] and Particle Swarm Optimization [25]. We expect that the already mentioned two methods will provide better global optimal solutions than using complex mathematical model for a mobile wireless networks in a real time environment. But the quality of solution in comparison to classical optimization technique is often traded off against computation time and it is possible to reach a near optimal solution within bounded computation time. Hence we propose an algorithm based on SA. The algorithm takes the available constraints, resources etc and finds an optimal or near optimal solution for bandwidth allocation in mobile multimedia networks.

The SA is an alternative stochastic optimisation technique that mimics the physical process by which a crystal is grown from a melt. Physical systems may be coaxed into a minimum energy conformation (e.g., crystal) by a slow annealing process. If the reduction of the temperature is slow enough, the system is able to pass out of local energy minima, and arrives at the global minimum configuration. This principle may be applied to solve optimisation problems. [19]

The design aspects of SA has 05 important steps The design aspects of SA fundamental has the following elements namely,

a. Set of allowed configuration.
b. Cost function.
c. Feasibility (Perturbation mechanism)
d. Cooling schedule.
e. Acceptance criterion

In our optimization problem, the feasible solution is a resource allocation – bandwidth within bounded values.

5 PROPOSED SA SCHEME

The proposed SA based solution algorithm for our problem is described as below.

Step 01:

Choose an initial point $x^{(0)}$. (initial values are calculated as the average of $\left(R_{\min} + R_{alloc}\right)$ } Set T a sufficiently high value (same for all the applications), number of iterations to be performed at a particular T as n, and set $t = 0$. $\{t$ varies from 0 to $n\}$

Step 02: Calculate a neighboring point

$$x^{(t+1)} = \left(x^{(t)}\right) + \varepsilon$$

where ε is a random value generated and is proportional to the temperature, As temperature goes down the range of random values is reduced.

Step 03:

If $\Delta E = E(X^{(t+1)}) - E(X^{(t)}) < 0$

Set $t = t + 1$; (accept the values)

Else create a random number (r) in range $(0,1)$

If $r \le \exp(-\Delta E / T)$ set $t = t + 1$;

(accept the values)

Else go to step 2.

Step 04:

If T is very small terminate

Else if $(t == n)$ then lower T by a factor of 2

Then go to step 2

Else go to step 2

6 PARTICLE SWARM OPTIMIZATION (PSO)

The PSO is one of the most powerful algorithms in solving global optimization problem. Kennedy et al. proposed it as an optimization method in 1995. PSO algorithm aim to obtain approximate solutions within a practical calculation time. Generally metaheuristic technique like PSO contain parameters. If appropriate parameters are chosen for search then good results can be obtained.

PSO optimizes an objective function by undertaking a population based search and is initialized with a population of random solutions called particles [26]. Each particle swarm in PSO has two primary operators called velocity update and position update. During each generation each particle is accelerated toward the particles previous best position and the global best position. At each iteration a new velocity value for each particle is calculated based on the current velocity, the distance from its previous best position and the distance from the global best position. The new velocity value is then used to calculate the next position of the particle in search space. This process is then iterated a set number of times or until a minimum /maximum objective function is satisfied. [27-28]

The PSO algorithmic steps are as below.

Step 1 : Set the velocity and position of all particles randomly but within predefined ranges.

Step 2: For each iteration update the velocity as below:

$v_i=v_i+c_1R_1(p_{i,best} - p_i)+c_2R_2(g_{i,best} - p_i)$ (5)

Where p_i and v_i are the position and velocity of particle i. $p_{i,best}$ and $g_{i,best}$ is the position with the 'best' objective value found so far by particle i and the entire population respectively; R_1 and R_2 are random variables in the range [0,1]. c_1 and c_2 are the factors controlling the related weighting of corresponding terms. The random variables used in PSO with the ability of stochastic searching.

Step 3: Update Position : The positions of all particles are updated as below:

$P_i=P_i+ v_i$ (6)

After updating, p_i should be checked and limited to the allowed range.

Step 4: Update Memory – Update $p_{i,best}$ and $g_{i,best}$ when condition is met,

$P_{i,best} = p_i$ if $f(p_i) < f(p_{i,best})$

$g_{,best} = g_i$ if $f(g_i) < f(g_{i,best})$ (7)

Wheref(x) is the objective function to be optimized.

Step 5: Stopping Condition – The algorithm repeats Step 2 to 4 until certain stopping conditions as defined by number of iterations or until minimization/maximization function is satisfied. After then the algorithm reports the values of g_{best} and

$f(g_{best})$ as its solution. The pbest and gbest are useful in getting closer to the global optimal point, with different direction all agents gradually get closer to global optimum.

7 EXPERIMENTAL RESULTS

Platform used for experiments are Linux and Windows system with P IV processor. SA algorithm is used to find out the optimized solution for first group of experiments, namely the objective function and constraints for different applications. For the second group of experiments PSO algorithm is used. The execution time varies with the size of the problem and SA parameters.

In order to find out SA parameter values that give the best result, experiments are performed using different parameter values on different data sets. Experiments are repeated for PSO and the optimized bandwidth values are studied and tabulated. Then the the performance of SA is compared with PSO technique.

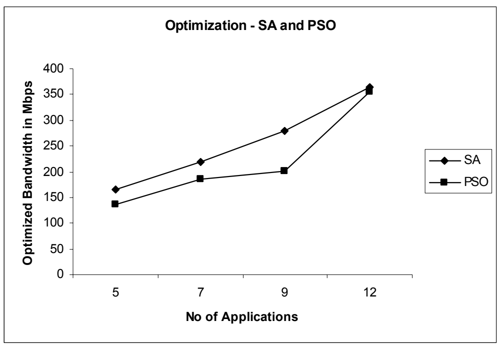

Figure 2. Optimization of SA and PSO

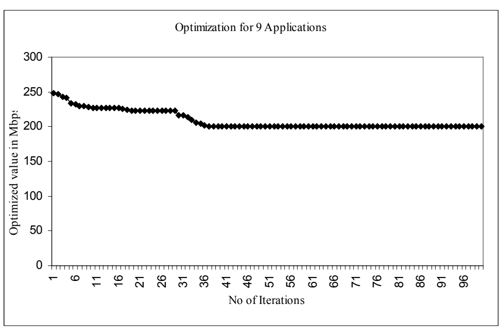

Figure 3. Optimization in PSO for 9 applications

248.200653	246.412292	243.561005	241.290466	233.701233
231.746841	229.112823	229.112823	228.041931	226.857300
226.857300	226.857300	226.583069	226.583069	226.583069
226.583069	225.875977	224.319061	223.255264	223.255264
223.255264	223.255264	223.255264	223.255264	223.255264
223.255264	223.255264	223.255264	223.199692	216.875824
216.875824	213.828110	209.764343	206.154083	204.473068
202.117615	200.152237	200.152237	200.152237	200.152237
200.152237	200.152237	200.152237	200.152237	200.152237
200.152237	200.152237	200.152237	200.152237	200.152237

Figure 4. Optimization convergence in PSO for 9 applications

8 CONCLUSION

In this work a comparative study has been made using SA and PSO meta heuristic technique. we have addressed the problem of ever increasing concern for optimal bandwidth allocation in a multimedia mobile network. In this context the significance of proper planning for resource allocation to hand off calls and new calls towards optimality is explained. Next the optimal bandwidth allocation problem is formally stated and mathematically formulated describing the relevant constraints. The non-differentiable nature of the formulated problem has called for a meta heuristic based non-traditional optimization technique. Better results are obtained and some of which are presented. It appears that PSO is a strong candidate solution provider for optimal Bandwidth allocation problem in mobile multimedia networks in comparison to SA. Also the time taken for optimization process is comparatively higher for SA (2-4 secs) than PSO algorithm (<2 secs) for above typical applications.

As far as the future work is concerned the focus will be on the development of Hybrid based optimization scheme for resource allocation in multimedia mobile cellular networks. In addition, further study will be done to evaluate the buffer allocation and scheduling policies with more number of applications.

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