Chapter 3

**Bandwidth Reservation in Cellular IP Networks**

With the advancement in technology, challenges have also been introduced in wireless communication especially in cellular wireless networks. Most of these challenges are due to optimism to fetch more from the technological growth. Providing better Quality of Service (QoS) to the users in cellular system is one of the challenging tasks. As the flow of multimedia traffic, in Cellular IP network, is growing enormously the problem thereof is to be addressed well. Servicing to the traffic, especially in wireless communication, is required to meet better QoS. Non-real time traffic e.g. e-mail, text data etc., though important in Cellular IP network, is given less importance in comparison to the real-time traffic. Bandwidth reservation has often been advocated to provide better QoS in cellular systems. The work, proposed in this chapter, uses bandwidth reservation method for better QoS in Cellular IP networks. Real-time packets have been given more priority for the flow in Cellular IP network. The proposed scheme uses approach similar to the Adaptive Resource Reservation schemes studying bandwidth reservation using Support Vector Machine and Particle Swarm Optimization [12].

Evolutionary Algorithms (EAs) are often used for solving optimization problems that requires navigation from a big search space. These algorithms maintain a population of individuals (usually randomly generated initially) that evolves according to the rules of selection, crossover, mutation etc. All individuals are evaluated against a fitness function. The fittest individuals are more likely to be selected for reproduction in the next generation. An evolutionary algorithm can be summarized as follows [75].
Generate a population of individuals

Repeat {
  Test the individuals according to a fitness function
  Select individuals to reproduce
  Produce new variations of selected individuals
  Replace old individuals with new ones
}
Until satisfied

There are many Evolutionary Algorithms e.g. Particle Swarm Optimization (PSO), Genetic Algorithms (GA), Ant Colony Optimization (ACO) etc. Evolutionary Algorithms often perform well approximating solutions to all types of problems.

This chapter proposes bandwidth reservation in Cellular IP network using Particle Swarm Optimization (PSO) and Genetic Algorithms (GA). It compares the performance of the PSO based model with a related PS based model [20]. Comparative performance study between the PSO based model and GA based model has also been conducted.

Rest of this chapter is organized as follows. Section 3.1 briefs the importance of bandwidth reservation in improving QoS in Cellular IP networks. In section 3.2, the PSO based model is elaborated along with the performance evaluation and the comparison between PSO based model and PS model for bandwidth management. In section 3.3 the GA based model has been explained and evaluated. The comparative study between PSO based model and GA based model has been conducted in section 3.4. The concluding remarks, of this chapter, appear in section 3.5.

3.1 Bandwidth Reservation to Improve QoS

QoS can be affected by many factors such as the limitations in bandwidth, transmission characteristics etc. These issues impose constraints on the amount of administrative and control information to be exchanged, as a result affecting the QoS.
In order to satisfy the requirements to achieve good QoS for all the users in the network, there should be enough resources. Bandwidth is one of the prime resources. Availing bandwidth during the service time is usually done using the bandwidth reservation schemes.

Resource reservation in general and the bandwidth reservation in particular is an important task in Cellular IP network. Bandwidth reservation is an approach with which the QoS in the network can be improved. It is proved in [12] that reserving bandwidth reduces the Connection Dropping Probability (CDP) and thus leads to better QoS.

Bandwidth Reservation implies that a part of assigned bandwidth to a cell in a Cellular IP network is reserved aside and issued to high priority establishments such as real-time traffic connections. There are two types of bandwidth reservation schemes; static and adaptive (dynamic schemes) [114]. Static schemes allow a user, admitted to a cell, to reserve the required bandwidth only once and do not allow to add if the user further puts the demand for more bandwidth. It results in connection drop. Adaptive bandwidth reservation schemes are more flexible and allow the user to reserve the bandwidth as and when the need arises. Adaptive schemes perform based on the resources availability and according to the applications (user’s requirements). The aim of both the bandwidth reservation schemes, static and dynamic, is to improve the QoS in network by making the best utilization of the available bandwidth. It also results in the reduction of packet loss, delay and the jitter in the network. For the multimedia services in the wireless networks, a certain amount of bandwidth is necessary in order to meet the requirements of these services; therefore, bandwidth reservation is one of the best approaches to guarantee QoS for such services. Ad-Hoc network is one example in which bandwidth reservation is applied and the results show the improvements in QoS [116].

3.2 PSO based Model for Bandwidth Management

The proposed model uses dynamic bandwidth reservation that allows the user to reserve the available bandwidth from the neighboring cells belonging to the same
group of cells (swarm) based on some statistics, parameters, and the user's requirements. It is an on-demand scheme as it caters to immediate requirement.

3.2.1 Model Description

Particle Swarm Optimization (PSO) algorithm is employed to reserve the bandwidth for the real-time users that exist in a cell within a swarm. The swarm, in this model, consists of seven cells; one central cell surrounded by six neighbor cells. The cell announces that there are some real-time users and their connections may be dropped in case there is not enough bandwidth. Reservation scheme is employed with the swarm shown in Figure 3.1. The central cell of the swarm in the figure is cell A.

![The Swarm of Seven Cells](image)

Fig. 3.1 The Swarm of Seven Cells

Bandwidth reservation in the swarm for the cell asking for bandwidth is done in central cell A, to which the bandwidth available in any of the cells of the swarm will be transferred. Eventually, the bandwidth may be given to the cell asking for it. This is because cells are away from each other but are close to the central cell to which the bandwidth is transferred.
Bandwidth reservation is done through two-step reservation procedure. In the first step the swarm will search, executing PSO algorithm, for any free bandwidth available in all cells of the current swarm. If there is some available bandwidth, it is designated as free bandwidth and will be reserved in the cell A. The swarm will adjust accordingly. It will then calculate the fitness value (CDP) of the cell asking for the bandwidth. If the swarm could satisfy the requirement of the seeking cell, it is served. Otherwise, the swarm will search for another solution by reserving the bandwidth in each cell assigned to the on going non real-time traffic in the swarm. It is done keeping in mind that the real-time traffic has higher priority than the non real-time traffic. Though it is to be handled carefully and should not affect the ongoing non real-time sessions in any of the cells of the swarm. After that the swarm will execute PSO algorithm and adjust it according to the new reserved bandwidth.

In the presented model, the study over the CDP is performed. CDP can be derived as follows. Available bandwidth for real-time users in the cell is \( AB_r \) (Mb/sec) and required bandwidth to complete a real-time session is \( R_b \). The probability of completion of this real-time session is \( \frac{AB_r}{R_b} \). The probability of dropping the session is

\[
\text{Connection Dropping Probability. CDP} = 1 - \frac{AB_r}{R_b}
\]

In any PSO based model there are two parameters to be updated, one is the velocity of each individual and the other is the position of each individual. In the present work, PSO is applied for bandwidth management to reduce the CDP. In this work, each individual is represented by the two parameters; available bandwidth for real-time users represents the position of the individual and the borrowed bandwidth represents the velocity of the individual.

3.2.2 The Algorithm

PSO based algorithm, used in this work, has been applied in two-steps. In each step, the same PSO algorithm is applied with some modifications in bandwidth reservation. Algorithm is described as follows.
Initialization

1. Distribute the available amount of bandwidth randomly among the cells in the swarm, where each cell will have a part of this distributed bandwidth assigned to real-time traffic in the cell. The other part of this bandwidth is assigned to the non real-time traffic in the same cell. Also some part of this bandwidth is designated as free bandwidth. Each type of the distributed bandwidth (real-time, non-real-time, and free) has been generated (for experimental purposes) and distributed randomly among the cells.

2. Users start arriving to any cell of the swarm. They start their real-time or non real-time sessions and therefore start generating random of packets. Depict 1 for real-time packets and 0 for non real-time packets. Also for each live session, which is going on, assign the session number.

3. Calculate the number of users and the required amount of bandwidth (to continue the connection) in each cell for each user. Take the decision according to these statistics.

PSO1

4. Initialize the best available bandwidth $AB_{best}$ for every individual as the initial value.

5. Initialize the global best value of available bandwidth $G_{best}$ in the swarm as the best initial value of available bandwidth among all the individuals.

6. Compute the fitness function for each individual as: $CDP = 1 - \frac{AB_r}{R_b}$

7. For the given number of iterations repeat steps 8 to 13.

8. Update the velocity of each individual (borrowed bandwidth), taking into account that borrowed bandwidth is from bandwidth assigned as free bandwidth in the other cells, as in the following equation.

$$B_j^{k+1} = wB_j^k + c_1r_1(AB_{best_{r,j}} - AB_{r,j}^k) + c_2r_2(G_{best} - AB_{r,j}^k)$$
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Where $B_j$ is the borrowed bandwidth from the other cells.

\( w, c_1, c_2, r_1, r_2 \) are as explained in chapter two.

9. Update the position (available bandwidth) of each individual as in the following equation.

\[
AB_{i,j}^{k+1} = AB_{i,j}^k + B^k
\]

10. Update $AB_{\text{best},i}$ as follows.

If \( (CDP(AB_{i}) < CDP(AB_{\text{best},i})) \)

\[
AB_{\text{best},i} = AB_{i}
\]

11. Update the $G_{\text{best}}$ as follows.

If \( (CDP(AB_{\text{best},i}) < CDP(G_{\text{best}})) \)

\[
G_{\text{best}} = AB_{\text{best},i}
\]

12. Compute the new value of fitness function (CDP) as

\[
CDP = 1 - \frac{AB_i}{R_b}
\]

13. Display the value of CDP.

**PSO2**

14. If $CDP < 0.5$ terminate; else go to step 15.

15. Reserve the available bandwidth for non real-time traffic in each cell by transferring it to the cell $A$ (central cell) and eventually to the cell asking for it. Take into account that none of the ongoing non real-time sessions are dropped.

16. Repeat steps 8 to 13.

3.2.3 Simulation Experiments

For the performance evaluation of the model, simulation has been carried out.
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Experiment 1: Effect of available bandwidth on CDP

This experiment considers that the cell asking for bandwidth contains four real-time users and four non real-time users. Size of every packet is 10 Kbytes. The CDP obtained are shown by graph in Figure 3.2.

![CDP for real time traffic with different amounts of Bandwidth](image)

Fig. 3.2 Effect of Available Bandwidth on CDP

Experiment 2: Effect of number of users asking for bandwidth (real-time) on CDP

Experiment considers size of every packet as 10 Kbytes, available amount of bandwidth as 40 (Mb/sec) and the number of packets in each session as 10. The CDP obtained are shown by graph in Figure 3.3.
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Fig 3.3  Effect of Number of Users on CDP

Experiment 3: Effect of real-time packets in the real-time sessions on CDP

It is when the number of packets in the on-going session changes due to the data exchanged between the users. This experiment is carried out for 4 real-time users and 4 non real-time users in the cell asking for bandwidth. Size of each packet is 10 Kbytes and the available amount of bandwidth is 40 (Mb/sec). Figure 3.4 shows the effect of number of packets on the CDP for real time traffic.

Fig 3.4  Effect of Number of Packets on CDP
Experiment 4: To study CDP with PSO1 over the iterations

This experiment is carried out with the following input data: available bandwidth is 40(Mb/sec), number of real-time users in the cell asking for bandwidth is 4, the number of non real-time users is 4, number of packets in each session is 10, size of each packet is 10 Kbytes. The CDP over the iterations is shown in Figure 3.5.

![CDP for real-time traffic after executing the first step of the model over the iterations](image)

**Fig. 3.5** CDP in Step 1 over Iterations

Experiment 5: To study CDP with PSO2 over the iterations

Again an experiment is carried out for this purpose with the following input data: available bandwidth is 40 (Mb/sec), number of real-time as well as non real-time users in the cell asking for bandwidth is 4, number of packets per session is 10, size of each packet is 10 Kbytes. After PSO1, if CDP is still greater than 0.5 then the swarm searches for another solution over the iterations. Figure 3.6 exhibits the result.
Experiment 6: To Compare the Proposed Model with the Probabilistic Resource Estimation Semi-reservation (PS) model

The comparison between PSO based model and PS model [20] is done with the following input data; number of real-time users in the cell asking for bandwidth is 4, number of non real-time users is 4, number of packets per session is 10, size of each packet is 10 Kbytes. The comparison between the two models is shown in Figure 3.7.
Experiment 7: To study the change in CDP on real-time and non real-time traffic

This experiment is conducted with the following input; the available amount of bandwidth is 40 (Mb/sec), number of real-time users and non real-time users each in the cell asking for the bandwidth is 4, number of packets per session is 10, size of each packet is 10 Kbytes. The observation in the CDP is done for real-time and non real time traffic. Figure 3.8 shows CDP for both real-time and non real-time traffic with specified number of users with non real-time packets. It is conspicuous that CDP for real-time traffic in the cell demanding the bandwidth decreases when the swarm reserves the bandwidth assigned to the non real-time users. Also, the Connection Dropping Probability increases for these non real-time users, but without reaching to the value that drops this connection.

![CDP for real time and non real time traffic while reserving the Bandwidth assigned to non real time traffic for real time users](image)

Fig. 3.8 Bandwidth assigned to non Real-time Users is Reserved without Connection Drop

Experiment 8: Effect of packet generation rate on CDP

Packet Generation Rate is an important factor and plays an important role in CDP. Study of the effect of packet generation rate is done in this experiment by choosing 5 real-time users, 2 minutes as a session time and the available bandwidth as 40 (Mb/sec). Results obtained from this experiment are shown in Figure 3.9.
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Fig. 3.9 Effect of Packet Generation Rate on CDP

Experiment 9: Effect of Time on CDP

The time of session has been changed every time with 5 real-time users and 40(Mb/sec) as available bandwidth and 30 packet/sec as packet generation rate. Effect of change in time is shown in Figure 3.10.

Fig. 3.10 Effect of Session Time on CDP
3.2.4 Observations

In all the experiments, the availability of bandwidth has been taken care of as the bandwidth is a limited resource.

Each cell in the swarm gets different amount of bandwidth. Sometimes free bandwidth in some cells is zero or very small due to random distribution; therefore CDP by reserving the free bandwidth did not improve i.e. it is almost similar to the CDP before using the PSO algorithm. After using PSO the improvement is observed in terms of decreased CDP. It is obvious that the CDP will be less when the available free bandwidth is higher. These observations are clear from figures 3.2, 3.3 and 3.4.

When real-time traffic increases, the demand for the bandwidth will also increase and consequently the consumed bandwidth. By applying PSO, CDP reduces when the traffic increases. By using PSO for bandwidth reservation, the swarm can accept more users (real-time users) without dropping their connections and even the available amount of bandwidth for the swarm remains the same. This is an important achievement of the model. This is clear from figure 3.3.

The ability of the swarm to accept more real-time users is applicable for non real-time users as well because as mentioned before, the model takes into account that even the connection for non real-time users is not dropped.

It is obvious that CDP increases when the number of packets per session increases. But using PSO we can increase the number of exchanged packets per session without fast reaching to the dropping probability value (in the model value greater than 0.5) at which the connection will be dropped. This issue is important in saving the time of the users (by sending more packets per session) where a user can send all the packets in one or two sessions instead of four or five sessions for instance and this eventually will save the time of the network. This is shown in figure 3.4.

In all the experiments it is found that the cell demanding bandwidth from the swarm to save its real-time users from being dropped is never satisfied by the free available
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bandwidth. It doesn’t mean that it is impossible to satisfy it by the free bandwidth. There is a possibility for this case to occur but it is not shown in the experiments due to the following reasons. One, it is rare to happen in these experiments and two when this happens the swarm will not be loaded in a high load traffic. Therefore, it is a minor case to be shown.

By increasing the number of iterations it is observed that the CDP is decreasing. Thus after certain number of iterations the swarm searches for a good solution and the CDP is decreased to a small value. Though there is a tradeoff in terms of time as the decision is to be taken as quickly as possible.

The experiment of iterations (experiment 4 and 5) is conducted exclusively for different numbers of iterations for PSO1 and PSO2. It is because in PSO1 the amount of bandwidth is less and therefore tolerance to reserve more bandwidth is less. The tolerance in case of PSO2 is more due to more availability of bandwidth reserved from non real-time traffic. Increasing number of iterations is important in PSO2 because it leads to good results. This is obvious from figures 3.5 and 3.6.

In comparison with Probabilistic Resource Estimation semi-Reservation scheme [20], it is observed that the Probabilistic Resource Estimation model doesn’t take care of non real-time traffic while the proposed model takes care of real-time traffic along with any ongoing non real-time session. Apart from this, CDP for real-time users for the same number of cells and the same amount of bandwidth is also less with the proposed model. The comparison is shown in figure 3.7.

Overhead, in this model is in terms of number of dropping of non real-time users if there is no available bandwidth for real-time users. The connection will be dropped in order to avail the bandwidth to the real-time users whose connection mustn’t be dropped. Figure 3.8 shows this.
3.3 GA based Model for Bandwidth Management

Another model for bandwidth management has been proposed in this chapter that uses GA for the optimization of the Connection Completion Probability (CCP).

3.3.1 Model Description

GA is employed to reserve the bandwidth for the real-time users that exist in a cell of the Cellular IP network. As described in section 3.2.1, the cell announces that there are some real-time users and their connections may be dropped in case there is no sufficient bandwidth. When a cell has a low Connection Completion Probability (CCP) for real-time users then the model will search for reserving the free bandwidth in the same cell. If there is no free bandwidth in the same cell then it will search in the neighboring cells. When the search is over and the model is not able to avail any bandwidth from available free bandwidth in all neighboring cells, it will reserve the bandwidth assigned to the non real-time users. The model has been described as follows.

3.3.1.1 Assumptions

- In this model a Cellular IP network consisting of 50 cells is considered.
- The cells are of hexagonal shape as shown in Figure 3.11.
- Bandwidth is distributed among the cells in the network randomly and is divided into three parts: part one reserved for users having real-time traffic, part two reserved for users having non real-time traffic and part three as free bandwidth in the cell.
- Users, distributed randomly among the cells, are of two types: real-time users and non real-time users.

3.3.1.2 Encoding Used

- Each cell is represented by a chromosome.
- The chromosome in the problem is an array of length 9, as shown in Figure 3.12. Data representation in the chromosome is real and each gene is signified as given below.
Gene (0) is Number of real-time users.
Gene (1) is Number of non real-time users
Gene (2) is Number of real-time packets.
Gene (3) is Number of non real-time packets.
Gene (4) is Size of real-time session.
Gene (5) is Size of non real-time session.
Gene (6) is Bandwidth assigned for real-time users.
Gene (7) is Bandwidth assigned for non real-time users.
Gene (8) is free bandwidth in the cell.

Fig. 3.11 Simulated Cellular Model
3.3.1.3 Modules Used

The modules used in the algorithm for the proposed model are as follows.

1) Bandwidth distribution: this module distributes the bandwidth randomly among all the cells in the Cellular IP network and divides the bandwidth into three parts: real-time bandwidth (for real-time users), non real-time bandwidth (for non real-time users) and free bandwidth.

2) User distribution module: for random users’ distribution among the cells in the network and classifying them into two types: real-time users and non real-time users.

3) Borrow: this module performs borrowing bandwidth in the same cell (borrowing the free bandwidth) or borrowing bandwidth from another cell (borrowing free bandwidth or bandwidth assigned to the non real-time users from another cell)

4) Crossover: the crossover operation occurs between two chromosomes (two arrays) and generates two offspring from them. Crossover used in this model is a single site crossover with probability one.

5) Mutation: this operation is used to generate new offspring that may have better fitness values by mutating one site of the parents’ chromosomes.

6) Fitness function: this function is used to measure the fitness values of the population. The chromosome with the good fitness value is selected for further crossover and mutation. The fitness function in this model is Connection Completion Probability.

The following symbols are used for calculating the fitness function

- $AB_r$: Available bandwidth for real-time users.
- $S_r$: Size of real-time session.
- $P_r$: Packet size.
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\(N_p:\) Number of packets.

\(N_r:\) Number of real-time users.

\(T_s:\) Time of a session.

\(P_r:\) Packet generation rate.

CCP: Connection Completion Probability.

The model tries to maximize \(CCP\) calculated as below.

\[
CCP = \frac{AB_r}{S_r}
\]  (3.1)

Available bandwidth for real-time users in the cell \((AB_r)\) is the amount of bandwidth given to the cell when performing bandwidth distribution module.

Size of real-time session is calculated as:

\[
S_r = P_s \times N_p \times N_r
\]  (3.2)

Number of packets generated in a session is:

\[
N_p = P_r \times T_s
\]  (3.3)

From (3.1), (3.2) and (3.3) the fitness function is obtained as

\[
CCP = \frac{AB_r}{P_s \times P_r \times T_s \times N_r}
\]  (3.4)

3.3.2 Simulation Experiments

In this section, the performance of the proposed GA based model is evaluated. The experiment has been performed up to 50 generations with different number of users and different amounts of bandwidth measured in (Mega bit per second). The initial size of the population is 50. The crossover and mutation probability is 1 and 0.4 respectively.

All experiments have been conducted in Cellular IP network on many parameters affecting QoS e.g.: number of users, available bandwidth, packet size, packet generation rate, time of the session in each cell of the network. In this model the
observation is done on the effect of varying number of users and the available bandwidth. In all the experiments the input parameters are as follows. Packet generation rate = 20 packet/sec, maximum packet size = 100 bytes. Time of the session is randomly generated in each cell. Bandwidth is measured in Mega bit per second (Mbps). The model is trying to optimize the CCP for real-time users.

A. 500 Users, 100 (Megabit per second) Bandwidth

![Graph showing connection completion probability over generation number for 500 users and 100 Mbps bandwidth.](image.png)

**Fig. 3.13 500 Users, 100 (Mbps)**
B. 500 users, 200 (Mega bit per second) Bandwidth

![Graph showing connection completion probability for 500 users, 200 Mbps.](image)

Fig. 3.14 500 Users, 200 (Mbps)

C. 500 users, 300 (Mega bit per second) Bandwidth

![Graph showing connection completion probability for 500 users, 300 Mbps.](image)

Fig. 3.15 500 Users, 300 (Mbps)
D. 500 users, 400 (Mega bit per second) Bandwidth

![Graph](image1.png)

Fig. 3.16 500 Users, 400 (Mbps)

E. 500 users, 500 (Mega bit per second) Bandwidth

![Graph](image2.png)

Fig. 3.17 500 Users, 500 (Mbps)
F. 500 users, 600 (Mega bit per second) Bandwidth

![Graph 3.18: 500 Users, 600 (Mbps)](image)

*Fig. 3.18 500 Users, 600 (Mbps)*

G. 500 users, 700 (Mega bit per second) Bandwidth

![Graph 3.19: 500 Users, 700 (Mbps)](image)

*Fig. 3.19 500 Users, 700 (Mbps)*
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H. 500 users, 800 (Mega bit per second) Bandwidth

![Graph for 500 users, 800 Mbps](image)

Fig. 3.20  500 Users, 800 (Mbps)

I. 1000 user, 500 (Mega bit per second) Bandwidth

![Graph for 1000 users, 500 Mbps](image)

Fig. 3.21  1000 Users, 500 (Mbps)
J. 1000 users, 600 (Mega bit per second) Bandwidth

![Connection Completion Probability Graph for 1000 users, 600 Mbps]

Fig. 3.22 1000 Users, 600 (Mbps)

K. 1000 users, 700 (Mega bit per second) Bandwidth

![Connection Completion Probability Graph for 1000 users, 700 Mbps]

Fig. 3.23 1000 Users, 700 (Mbps)
1. 1000 users, 800(Mega bit per second) Bandwidth

![Graph showing connection completion probability for 1000 users, 800 Mbps]

3.3.3 Observations

The observations derived from the experiment have been listed as follows.

- One of the input in each experiment, bandwidth is varied from low value (100 Mbps) to high value (800 Mbps). Observable fact is that when bandwidth is large, we are getting good CCP from 1st generation itself. Whereas it takes time to get good CCP when the bandwidth is small (figure 3.13 to figure 3.20).

- When the available amount of bandwidth is increased the Connection Completion Probability (CCP) is getting better. Even when the amount of bandwidth is small in comparison with the number of users, the model converges toward an optimal solution.

- Due to the nature of GA, not each and every time the solution (offspring) coming out from the old parents is optimal solution; therefore it's been observed in the experiment that the solutions sometimes are not good solutions as in figure 3.18 (500 users, 600 Mbps) where the best solution in generation number 42 is going away from the optimal solution.
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- It is observed that when small amount of bandwidth is allocated, some of the cells are allocated zero bandwidth due to the random distribution. Chromosomes representing these cells are being discarded as they are not passing through the fitness function. It is to be observed that GA is giving, most of the time, good solutions and good convergence to the optimal solutions.

- It has been observed that using this model, a Cellular IP network can host good number of users with good Connection Completion Probability (CCP) even if the available amount of bandwidth is less as is figure 3.21 (1000 users, 500 Mbps).

3.4 Comparison between PSO based Model and GA based Model

Both the proposed models for bandwidth management have been compared for Connection Dropping Probability (CDP) on the following parameters.

3.4.1 Comparison for Available Bandwidth

Available bandwidth: 10, 20, 30, 40, 50 Mbps. Number of users in the cell: 4 real time, 4 non real-time.

Packet generation rate: 30 packet/sec.

Time of each session has been randomly generated.

![Comparison between PSO and GA for available bandwidth](image)

Fig. 3.25 CDP against the Bandwidth
3.4.2 Comparison for Number of Real-time Users

Number of real-time users in the cell: 5, 6, 7, 8, 9. Packet generation rate: 30 packet/sec.
Available bandwidth: 40 Mbps.
Time of the session has been generated randomly.

![Comparison between PSO and GA for number of real-time users](image)

Fig. 3.26 CDP against the Number of Real-time Users

3.4.3 Comparison for Number of Real-time Packets

Number of real-time packets: 5, 10, 15, 20, 25 packets.
Available bandwidth: 40 Mbps.
Number of users in the cell: 4 real-time, 4 non real-time.
Packet generation rate: 30 packets/sec.
Time of the session has been generated randomly.
3.4.4 Comparison for Packet Generation Rate

Packet generation rates: 10, 20, 30, 40, 50.
Available bandwidth: 40 Mbps.
Number of real-time users: 5 (same as in PSO based model).
Time of the session has been generated randomly.
3.4.5 Comparison for Session Timing

Session times: 2, 4, 6, 8, 10 minutes.
Available bandwidth: 40 Mbps.
Packet generation rate: 30 packet/sec.
Number of real-time users: 5 (same as in PSO based model).

![Comparison between PSO and GA for session timing](image)

Fig. 3.29  CDP against the Time of the Session

3.4.6 Observations

Comparing GA based model with PSO based model, in terms of available bandwidth, shows that both of them reduces the CDP when the available bandwidth is more but GA based model is performing better in reducing CDP.

When number of real-time users increases, the demand on bandwidth increases; therefore, CDP is bigger every time there are more real-time users in a cell. From the graph in figure 3.26, it is clear that CDP is going up when real-time users are increasing in number; though both GA and PSO are controlling CDP below 0.5 with GA based model giving better values for CDP.

When real-time users generate bigger number of packets, the consumed bandwidth is more resulting in bigger CDP with fixed amount of bandwidth. Both the models
(PSO-based and GA-based) are able to handle this problem easily but again the GA based model is performing better.

It is observed that when the rate of packet generation is bigger, the required amount of bandwidth to complete a call is also bigger. Also when real-time users generate more packets, PSO and GA both tolerate the increment in packet generation rate. Though CDP increases in both the models, but it is still less than the value that drops a connection. CDP values obtained from GA model are less than those which have been obtained from PSO model.

The effect of session’s time is not less important than the effect of the other factors on CDP according to equation 3.4. When the time of a real-time session increases there is a possibility of more packet generation thus consuming more bandwidth. GA model is performing better than PSO model in controlling CDP with the increment in session’s time as obvious from figure 3.29.

The discussion is concluded stating the reason behind the better performance of GA based model. PSO is not using crossover operation (i.e. there is no material exchange between particles) that makes the particles same without change but they are influenced by their own previous best positions and best positions in the neighborhood in the global population. In GA there is a crossover operation (i.e. there is exchange in the material between the individuals in the population) that means there is a chance to generate new offspring with better specifications than the parents. GA is better in sense of values obtained every generation but PSO is better in sense of time taken for convergence.

3.5 Concluding Remarks

The chapter proposes two models for on demand bandwidth management on the principle of resource reservation. The model improves the QoS in Cellular IP networks by serving the real-time users and giving them the bandwidth on-demand.

The chapter aims at applying Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) to find the best solutions for serving real-time users in a cell
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Bandwidth Reservation in Cellular IP Networks

demanding the bandwidth and reduces the Connection Dropping Probability (CDP) which is the main challenge for QoS in Cellular IP networks. The effect of many parameters on CDP has been studied while applying PSO in two phases.

GA is also applied for the given number of users. The effect of available bandwidth on Connection Dropping Probability has been studied. Crossover and Mutation are applied in the GA based model.

Even the model reserves the bandwidth in the cell assigned to the non real-time users for real-time users; the connection for non-real time users is not dropped. Optimizing CCP for non real-time users may be an extension to this work.

Comparison between bandwidth management using PSO and bandwidth management using Probabilistic Resource Estimation Semi-Reservation model (PS) reveals that the performance of PSO based model is better than the performance of the PS based model. Further, comparison between PSO based model and GA based model for bandwidth management shows that the performance of GA based model is better than the performance of PSO based model.