Bandwidth Optimization using Genetic Algorithm for Video Over Wireless Network

[1]Pradeep Kumar Tiwari, [2]Sanjay Singh, [3]Satyanarayan Mishra
[1]DAMS, Kanpur, Lucknow, UP, India
[2]AMITY University Campus, Lucknow, UP, India
[3]Tata Consultancy Services (TCS), Lucknow, India

Abstract
The main objective of this paper is to design an optimization algorithm to achieve optimum bandwidth allocation in wireless networks using Genetic Algorithm (GA). It investigates the channel allocation methods for a video transmission over wireless network. Transporting MPEG-4 video over the wireless network is expected to be an important component of many emerging multimedia applications. One of the critical issues for multimedia applications is to ensure that the Quality-of-Service (QoS) requirement is maintained at an acceptable level. The Dynamic Channel Allocation (DCA) method using a Genetic Algorithm is used to monitor dynamically the traffic and adjust the bandwidth according to the QOS parameters and thus provide an optimized bandwidth allocation.

Keywords
Genetic Algorithm, Quality-of-Service, Dynamic Channel Allocation, Bandwidth

I. Introduction

Wireless communications is the fastest growing segment of the communications industry that has captured the attention of the media and the imagination of the public. Cellular systems have experienced exponential growth over the last decade and there are currently about two billion users worldwide. In addition, wireless local area networks supplement or replace wired networks in many homes, businesses, and campuses. Many new applications – including wireless sensor networks, automated highways and factories, smart homes and appliances, and remote telemedicine – are emerging from research ideas to concrete systems [1]. The explosive growth of wireless systems coupled with the proliferation of laptop and palmtop computers suggests a bright future for wireless networks, both as stand-alone systems and as part of the larger networking infrastructure. However, many technical challenges remain in designing robust wireless networks that deliver the performance necessary to support emerging applications [2]. The rapid growth in interactive multimedia applications, such as video telephones, video games and TV broadcasting has resulted in spectacular strides in the progress of wireless communication systems [3]. The current Third Generation (3G) wireless systems and the next Generation (4G) wireless systems are to support higher bit rates for multimedia data. However, the high error rates and stringent delay constraints in wireless systems are significant obstacles for multimedia applications and services. Packet losses or Dropped packets causes significant degradation in the quality of the video signal. Jitter occurring due to the different queuing times or different routes results in varying of the transmission times of the arriving packets. Video over wireless networks presents additional challenges due to the limited bandwidth available and the temporary periods of disconnectivity from the network. Retransmission is not possible due to the expensive bandwidth and the real time demands [4].

A Dynamic Channel Allocation (DCA) technique is used to allocate bandwidth for the source. It is a technique by which traffic bandwidth in a shared Client/Server medium can be allocated on demand and fairly between different users of that bandwidth. Essentially, it is bandwidth management or is also sometimes known as statistical multiplexing, where the sharing of a link adapts in some way to the instantaneous traffic demands of the nodes connected to the link [5]. The transmission of video over wireless networks using DCA is shown in fig. 1.

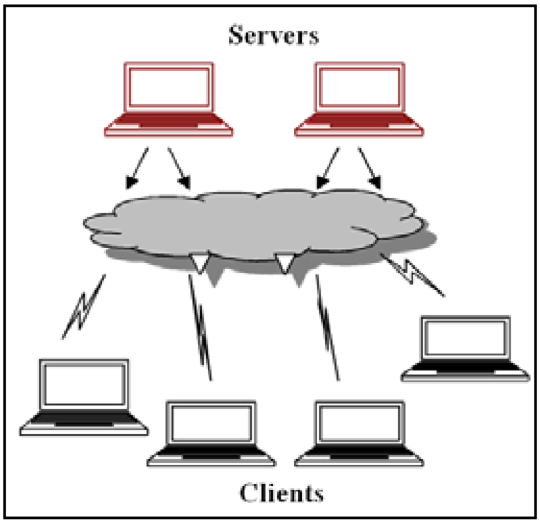

Fig. 1: Client Server Architecture

II. Literature Review of Genetic Algorithm

There exist many algorithms for allocating the bandwidth using dynamic channel allocation. Abhishek Roy and Sajal K. Das in their work have discussed a genetic algorithm for rate scaling of layered video from multiple sources in the context of a wireless video distribution system [6]. However this does not perform and optimized bandwidth allocation. Lai-Tee Cheok and Alexandros Eleftheriadis have proposed a dynamic bandwidth allocation scheme that automatically adjusts the amount of reserved resources, while guarantying the required QoS [7]. The algorithm does not consider the impact of delay and the time taken for each transmission. Genetic algorithm was first suggested by John Holland in the early seventies and has been used over the last 20 years to solve a wide range of search, optimization and machine learning problems [8]. The work proposed by T. Cooklev, School of Engineering, San Francisco State University performs dynamic bandwidth allocation and channel coding for providing QoS over local area networks [9].

A. Genetic Algorithm: An Introduction

Genetic Algorithms (GA) provide a guided random search and optimization technique, based on the basic principles of evolution: survival of the fittest. It uses probabilistic transition rules to guide the search. All generalized greedy and gradient descent search techniques suffer from getting stuck at a local optimal point. However, using the evolutionary techniques, GA has overcome

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this limitation to provide a near-optimal solution in a few iterations. The steps involved in solving an optimization problem using GA can be briefly summarized as follows:

- Random generation of a population of chromosomes
- Decoding each chromosome to evaluate its fitness
- Performing selection, cross-over and mutation operations
- Repeating steps (ii) and (iii) until a stopping criterion is satisfied

The algorithm starts by generating an initial population consisting of individuals, each encoded into a string or any other suitable forms, representing a candidate solution to a given problem. The fitness of each individual is evaluated based on an objective function for the problem. Highly fit individuals are selected as parents and portions of their genetic information are exchanged to produce an offspring in a crossover process. Mutation is then applied to slightly modify the genes so as to maintain genetic diversity and prevent the solution from being stuck in a local optimum point. The extent to which genetic information is exchanged and to which genes are modified is dependent on the crossover and mutation rates as well as their individual crossover and mutation schemes respectively. The term “chromosome” is used to refer to “binary string”.

1. Selection

The selection process copies parent strings into a tentative new population known as mating pool. Selection is usually proportional to an individual’s fitness value and thus mimics the evolutionary selection process. Roulette wheel selection, stochastic universal selection and tournament based selections are the most widely used techniques.

2. Cross-over

The key idea behind the cross-over is to exchange information between two randomly selected parent-strings to give birth to the off springs for the next generation. The selected strings from the mating pool are paired at random and a particular cross-over point is selected uniformly at random between position 1 and the string length. The off springs are generated by swapping the respective portions of the strings after the cross-over point.

3. Mutation

Mutation is the process of random alteration in the genetic structure to introduce genetic diversity. In adverse situation, when the global optimal solution resides in a particular portion of the search space not included in the population, then the mutation is the only way to direct the population to jump out from any local optimal solution by randomly altering the information in the string.

III. Dynamic Channel Allocation

Dynamic Channel Allocation (DCA) is a technique by which bandwidth in a shared telecommunications medium can be allocated on demand and fairly between the different users of the bandwidth. Essentially it is bandwidth management or a channel allocation known as statistical multiplexing where the sharing if the link adapts in some way to the instantaneous traffic demands of the nodes connected to the link. DCA takes advantage of several attributes of shared networks:

1. All users are typically not connected to the network at one time/all the time.
2. Even when connected users are not transmitting video at all times
3. Most of the data traffic is bursty – there are gaps between packets of formation that can be filled with other user traffic

A method for dynamic channel allocation for multimedia streams over a mobile network is discussed. Channel also known as bandwidth, is defined as bits per second, as customary in computer communications. This approach provides the capability to provide service differentiation and allocates bandwidth based on the priority of the transmission and the type of data. Every type of multimedia data stream is further partitioned into layers of different priority. Every client has for every data type a minimum contracted QoS. If bandwidth is available a client may take more bandwidth than the minimum contracted, achieving a higher QoS. Layers of lower priority can be discarded until a minimum contracted QoS is achieved. All clients are guaranteed access at a minimum QoS by ensuring that the minimum required bandwidth by the clients does not exceed the total available bandwidth. The approach described here has the advantage that a QoS manager does not have to set aside bandwidth without knowing exactly how much is needed (a situation that almost always means some bandwidth goes unused). The QoS manager in the hub or Access Point (AP) manages the QoS for the entire network. It is called the central or AP QoS manager. Traditional QoS managers have the capability to handle packets of different priority, but they allocate bandwidth on a first-come first served basis. A client’s request for transmission can be denied if bandwidth isn’t available. Dynamic bandwidth allocation essentially minimizes the probability that a transmission request would be blocked. To achieve this bandwidth is divided in a manner shown in fig. 2.

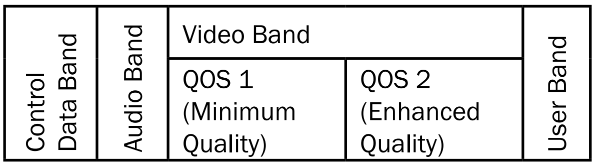

Fig. 2: Block Diagram of Bandwidth Assignment over Wireless Network

Typically there are control band, voice band, video band and user band. The voice band and the video band are further partitioned into several narrower bands of different layers of priority. The video band is partitioned into two bands, one providing minimum QoS, and one providing enhanced QoS. The signal can be partitioned into more than two bands to reflect the capabilities of a particular multimedia service provider and the service that it wants to provide. Bandwidth assignment and selection of media types are flexible and in general this is a method for differentiation of services between various service providers. Suppose that the video is subdivided into two sub bands – QOS 1 and QOS2, QOS 1 satisfies the minimum video bandwidth requirement and QOS2 enhances the quality of the media depending on the constraints and availability of resources. For example a client may elect to have all video information sent within the band QOS 1 at a minimum. A higher-paying client may elect to occupy the band QOS 2 at a minimum. A client that communicates at QOS 1 at a minimum may still be allowed to communicate QOS 2 if bandwidth is available. The functionalities of the bands are described below:

(a). Control Band: It carries the control Signal
(b). Audio Band: It carries the voice
(c). Video Band: It carries the video frames.

- QOS 1: Transmits video of minimum quality.
- QOS 2: Transmits video of enhanced quality.

(d). User Band: Transmits user data.

IV. Dynamic Channel Allocation using Genetic Algorithm

The server transmits video to the clients as per the requests from the client. Initially if the sum of the requested bandwidths does not exceed total bandwidth then the bandwidths are allocated on First Come First Served basis and fitness values for the QoS parameters are calculated. As more requests arrive the quality of the video is reduced and based on the priority re allocation is performed .Until all services meet their QOS the genetic operations such as mutation and crossover is performed on the binary encoded video strings. The process is terminated as soon as the fitness of the difference between the best chromosome and the second best chromosome is less than the precision value, which is defined by the user. The process is shown below

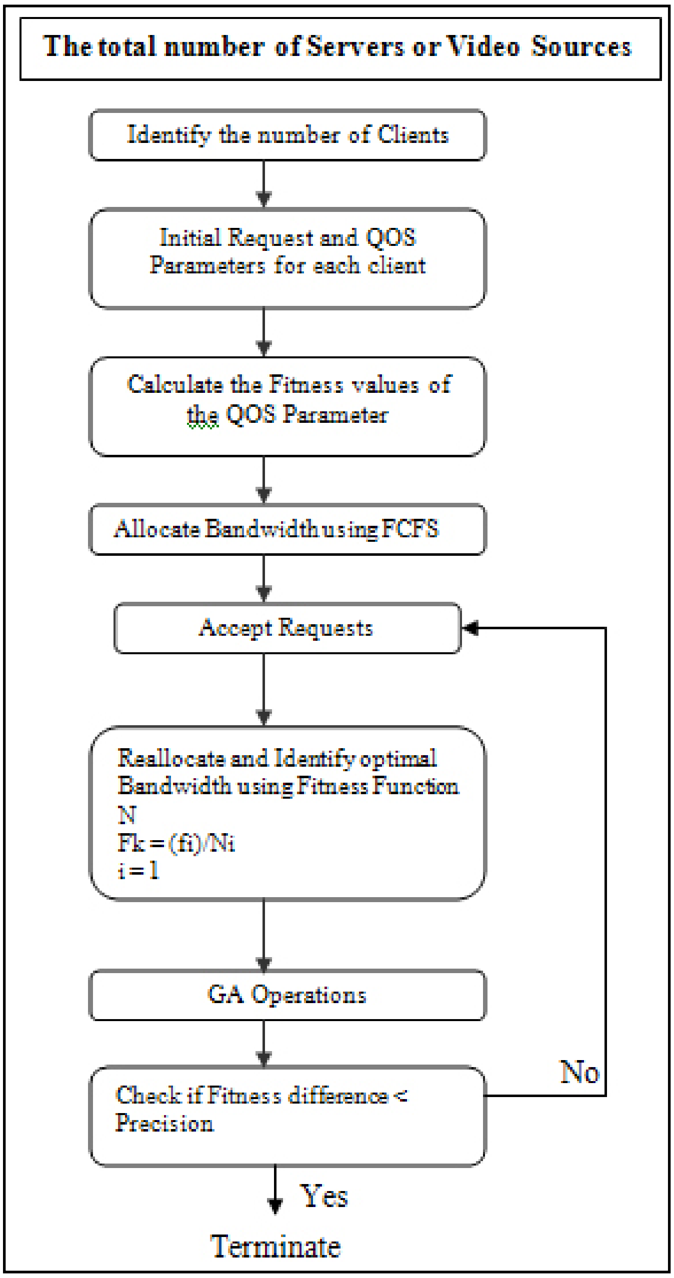

Fig. 3:

V. Proposed Algorithm Outline of the Algorithm

The proposed algorithm uses the genetic process of obtaining an optimum bandwidth. Hence Population, P and a comparison set C are created. The comparison set is created to ensure that the individual reproduced via crossover and mutation give feasible solutions.

A. The Proposed Algorithm

- Identify the video servers or sources
- Obtain details about all the clients.
- Obtain the QOS parameters of initial Request
- Create initial population with the initial set of requests.
- Calculate the fitness values for the QoS parameters.
- Allocate the bandwidth based upon FCFS.
- Generate a comparison set C from the population.
- While (new fitness value – old fitness value)>precision repeat steps 9, …, 13 Else goto step 14.
- Accept more requests.
- Compare new requests Fitness value with those of C.
- Check if bandwidth can be reallocated such that all requests are served. If yes GOTO Step 9.
- Select two strings in a random manner from the population.
- Perform Crossover and Mutation operations, Goto Step 11.
- Terminate.

Let there be N video sources, each jth source is encoded into Li layers of video streams. The first layer is the base layer, layers 2,…,Li are the enhancement layers. Let pik and bik, be the quality and bit rate of the kth layer of the jth source where, where k is (1…....Li). Cumulative quality, qij, and bit rate, sij , are given by the equation:

$$qij = \sum_{k=1}^{k=i} p\,ik \quad , j = 1,\ldots..,Li \qquad (1)$$

$$Sij = \sum_{k=1}^{k=i} p\,ik \quad , j = 1,\ldots.., Li \qquad (2)$$

The quality of the jth source with L layers is given by- vj = {(qj1,sj1) (qi2,si2) ….. (qjisji)} where i = 1 …. L.

VI. Genetic Representation

An encoding scheme is designed utilizing a binary chromosome representation where each chromosome contains sub-strings of bits. Although these sub-strings are independent of one another, the bits in each sub-string are tightly bound by the constraint given in fig. 4.

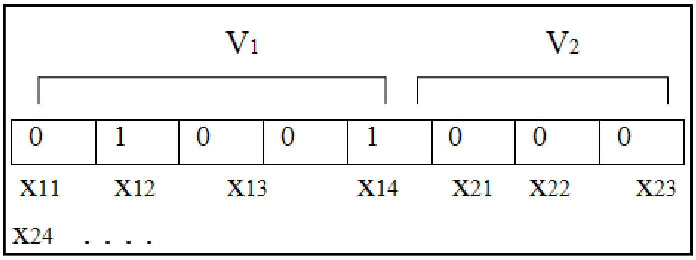

Fig. 4: A Binary Representation of Chromosome

Fig. 4, illustrates an example scheme for V1, V2,…..., VN, where V1 refers to the first video source and N the total number of sources. We encode the video stream from each source into layers. Each jth source is encoded into Li layers. The first layer is the base layer that provides basic quality; layers 2,…..,Lj are the enhancement layers that refine the base layer quality. Each source offers a set of Lj quality/bit rate choices. As in the example, Li = 3 so there are 4 bits for each Vi. x11 = 1 indicates the selection of first layer (i.e., the entire video layers are not selected), x12 = 1 indicates the selection of the second layer and so on . In the given example, first layer of V1 is selected and base layer of V2 is selected. The binary encoding scheme shown above is subjected to the following conditions:

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$$\sum_{j=1}^{N} Xij \qquad i = 1,\ldots L \tag{3}$$

$$\sum_{i=1}^{N} \sum_{j=1}^{L} CijXij < C \tag{4}$$

where, cij is the bit-rate of the jth item of the ith video source and C the bandwidth constraint. Eq(3) implies the sum of the quality of each video source. Eq(4) checks if solution is feasible, i.e., whether bandwidth constraint is satisfied. Each selected choice is indicated by setting xij = 1. Hence Vi = xij, = {1,…,.Li+1). Denoting pij as the PSNR value of the ith layer of jth video source, the fitness of each V and the fitness of chromosome are computed as follows:

$$fj = \sum_{j=1}^{L} PijXij \tag{5}$$

$$fk = \left(\sum_{i=1}^{N} fj \right) / Ni \tag{6}$$

VII. Generating Initial Population

The first step is to generate an initial population of feasible solutions of size P. For each chromosome k, which is a video source, the procedure randomly sets one bit of each sub string analogous to selecting one layer of each source V. The result of the random selection of bits/layers may yield an infeasible solution. The Fitness values are calculated. Each chromosome is also checked to see if it is identical to any existing chromosomes in the population. Any identical string is discarded to ensure that the initial population contains only unique solutions.

VIII. Binary Tournament Selection

Once an initial set of feasible unique candidate solutions are generated, we applied the classic binary tournament operator to select two parents for producing an offspring, which represents a video source, is applied. A binary random generator is used for partitioning the initial population S into two sub-populations T1 and T2. An individual with the highest fitness is selected from each sub-population as parent. Random partitioning of the population into two sub-populations gives better results than always picking the best two parents from the entire population.

IX. Crossover

Instead of randomly exchanging genetic information between two parents, a crossover operator based on the simple concept of interleaving by using even and odd segment masks is implemented as shown in fig. 5. Every segment is representations of a video source .There are two basic modes of operation: odd and even. When operating in the "odd" mode, the offspring inherits odd segments (sub strings) from one parent P1 and even segments from the other parent P2. Likewise, when in "even" mode, the offspring inherits even segments from P1 and odd segments from P2. As an example, above figure illustrates the crossover operator running in the "odd" mode for N=3 (i.e., 3 video sources). m1 is applied to P1 by performing a simple bitwise AND operation to extract the odd segments whereas m2 is applied to P2 to derive even segments. The offspring is produced by recombining the resultant chromosomes via an OR operation. The two modes are alternated during every other, crossover operation. Alternating these modes ensures better diversity so that the algorithm will not get stuck producing the same solution.

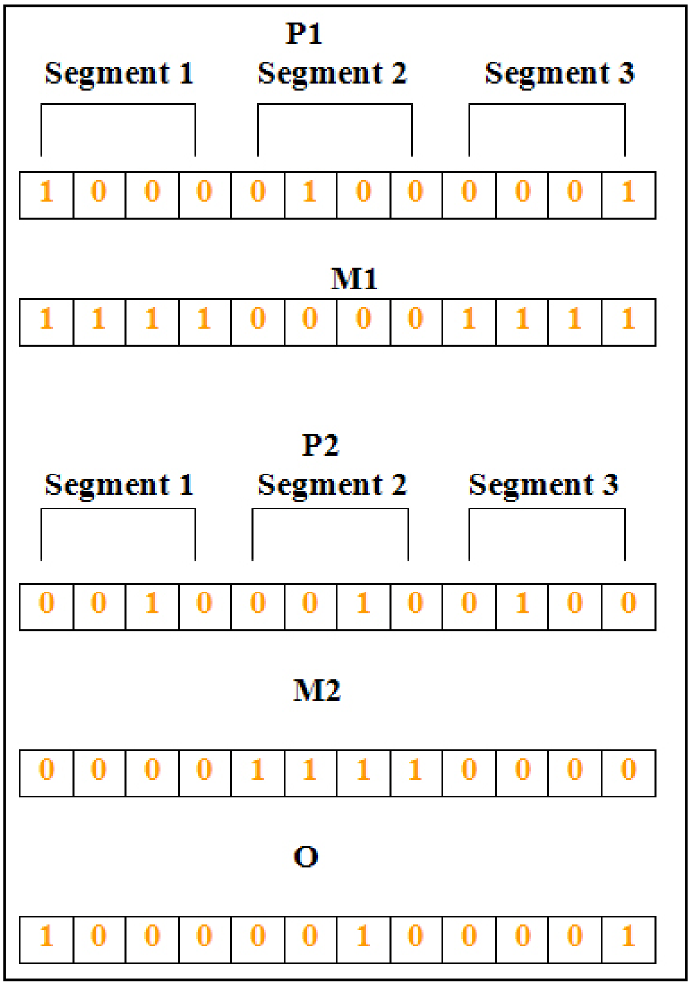

Fig. 5: Crossover Operation

X. Mutation

Mutation is applied to a number of bits in the binary string of the video source. The probability of inverting each bit is dependent on the mutation rate. A high mutation rate decreases the "selective pressure" leading to slower convergence whereas a low rate reduces the diversity of the population. The mutation scheme has two levels of mutation; one at the sub-string level, the other at the bit level. The procedure first randomly picks one or more sub-strings to mutate given the mutation rate. The rate is applied only at the sub-string level. For each sub-string chosen to undergo mutation, the procedure then randomly sets one of the bits (which has not already been set) to '1', independent of any mutation rate, and clears the rest to '0's.

XI. Conclusion

In this paper a dynamic channel allocation scheme is proposed that can significantly improve bandwidth utilization in wireless networks for video applications. It adjusts the amount of reserved resources using genetic algorithm, while guarantying the required QoS. This algorithm is implemented in C++ and results show that average fitness of the entire population converges to best fitness and the convergence rate is faster using this method. The proposed algorithm provides better solution compared to the other dynamic channel allocation techniques. For future work the use of video sequencing for achieving a higher degree of optimization, will be investigated.

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Pradeep Kumar Tiwari working as a Lecturer in Dayanand Academy of Management Studies Kanpur. his research area is parametric programming and networking.

Prof. Sanjay Singh working as a professor in Amity Institute of Information Technology, Amity University, Lucknow Campus, Lucknow, he has author of many books related to computer science and published many International and national papers in various reputed journals.

Satyanarayan Mishra working as a system Engineer in TCS, Lucknow, his research area is networking and testing of software.