Selection of Multimedia Code Set using GA in Optical CDMA Network

Meng-Hong Chen and Yang-Han Lee

Abstract — **In this paper we design a central controller in the optical CDMA network which assigns multimedia code set to users. Because different kinds of services can tolerate different degree of reliability, we can assign codes to users according to its request service type. For example, users who transmit data service must guarantee the transmission efficient, thus we assign high reliable codes to users. On the contrary, voice and video services can tolerate some errors in its transmission process, thus we assign a low reliable codes to these kinds of services. In this paper, we use genetic algorithm (GA) to select the code set which contains different degree of reliable codes. By this solution, we can easily select the code set and assign to users according to the user's request.**

Index Terms — **Optical CDMA, Genetic Algorithm, Multimedia CDMA, Code Set Selection.**

I. INTRODUCTION

With the growth of WWW applications, multimedia services have been provided extensively in the internet. Therefore, the demand for the fast data rate and more tremendous bandwidth requirement push the application of optical processing forward to the network design. Due to the simple implementation, techniques of fiber-optic code division multiple access (FO-CDMA) has been proposed recently [1][2]. Many classes of binary signature sequence have been studied and the prime code was identified as a suitable candidate for FO-CDMA. Moreover, synchronous code division multiple access (S/CDMA) and the modified prime code have been investigated in [3] to improve the capacity. Because CDMA technology has the benefit in processing multimedia services, we design a central controller in the optical CDMA network to provide multimedia code set selection.

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The central controller assigns each user's transmission code according to the user's request service type. Since each service has different degree of reliability, we use this rule to design different services codes. For example, data service tolerates low BER (bit error rate) but voice and video services can tolerate high BER. Therefore, the transmission of data service must use high reliable code however voice and video services use low reliable codes. Because the code set selection is very complicated, we use genetic algorithm (GA) to select it. Genetic algorithm has recently been used as robust stochastic searching algorithms for various optimization problems, such as multiprocessor scheduling [6], topology design and bandwidth allocation [7], channel allocation [8], code design [9] and maximal simultaneous users code set selection [10]. Therefore, we use GA to select the multimedia code set according to the user's request. From the simulation result, the code set can be selected easily and guarantee conforming the users' requests.

The rest of the paper is organized into six sections. The description of network architecture and multimedia code set will be in Section II. In Section III, we introduce the fundamental of Genetic Algorithm and the multimedia code set selection of prime code in section IV. Finally, some results will be in Section V and the conclusion is given in Section VI.

II. NETWORK ARCHITECTURE AND MULTIMEDIA CODE SET

The network architecture is designed as *Fig.1*. Stations (STAs) and the central controller (CC) are connected to an optical coupler. When station has data to transmit, he first transmits a request to the CC. The request contains the service type that he wants to transmit. The CC assigns a modified prime code [3] according to the request and other codes still used in the network. The multimedia codes is defined as follows:

$$m = \min Ni, \quad \{i = 0,1 \ldots P-1\} \tag{1}$$

In (1), Ni is the number of interference made by other users at the ist '1' (chip) location. P is the prime number defined in the modified prime code. [3] Finally, m is the minimal interference among all locations '1' of the code. Thus, m denotes the reliability of this code and the degree is increase with the decrease of m. For example, we can define the number m of data, voice and video service are 0, 1 and 2, respectively. Then we can gather the user number of each service and use genetic algorithm to find the exact code set. Thus, the data service code will not be interfered by other codes because the code has one location that no other user used. *Table I* is an example which shows the relationship between m, Ni and the code set.

III. FUNDAMENTALS OF GENETIC ALGORITHM

Genetic algorithm, first specified by John Holland[11] in the early seventies, is becoming an important tool in machine learning and function optimization. Unlike other optimal methods that follows only one search path at one time, the GA searches through several paths simultaneously and the convergence rate is faster. This algorithm initially generates a set of random solutions knows as *population.* Each individual solution in the population is called a *chromosome.* Each chromosome represents a feasible solution by a sequence of binary or real numbers know as *genes.* Through an evolution process, a new *generation* of chromosomes replaces the current population. The new population consists of the new generated chromosomes known as *offspring* which are generated by three genetic operators *reproduction, crossover* and *mutation.* Reproduction operation forms a new population by selecting chromosomes from the old population according to its *fitness value.* The fitness value indicates the quality of the chromosome which is evaluated by the *fitness function.* Chromosomes with higher fitness value would have a higher chance of surviving to the new generation. The crossover operation merges two parent chromosomes and forms two new chromosomes. Mutation modified one or more genes of the selected chromosomes. After the three genetic operations, a new population will be generated to the next generation. This evolutionary process continues until either a limited number of generations reaches or no more better chromosomes will be generated.

VI. MULTIMEDIA CODE SET SELECTION USING GENETIC ALGORITHM

In this paper, a genetic algorithm is proposed for selecting the multimedia code set in FO-CDMA network. The genetic algorithm concepts and operations can be referred to [11]. Although there are some variants in GA according to the different problems, the fundamental is similar. Our algorithm is shown in *Fig.2* and the definition and each function description show in following.

A. DEFINITION

In this paper, we use the binary string as a chromosome to represent the code selection. Each string is consisted of P^2 bits. '1' and '0' represents the corresponding modified prime code to be selected or not, respectively. Taking $P=3$ as example, a solution may be as 010001010 to represent the used codes as $\{C_{01}, C_{12}, C_{21}\}$[3].

B. INITIALIZATION

Initialization of the genetic algorithm, we need to randomly generate an initial population and the number of chromosomes in the population is population size. In each chromosome, we randomly select N codes from the P^2 codes. N is the number of users which requesting in the network and P is the prime number of prime code. Therefore, every chromosome uses the number of N codes in the initial state.

C. EVALUATE THE FITNESS VALUE

First, we define the difference value as follows:

$$Diff_i = \sum_j \left| RN_j - CN_{ij} \right| \qquad (2)$$

RN_j is the request user numbers in the network which m value of service type is j. CN_{ij} is the number of users in chromosome i which m is j. Thus, $Diff_i$ is the differential value compare to that we purpose to obtain. In our algorithm, the large fitness value indicates the chromosome is better, thus we inverse the difference value as the fitness value as follows:

$$Fitness_i = Max_{Diff} - Diff_i + 1 \qquad (3)$$

Max_{Diff} is the largest difference value among chromosomes in the population. We avoid the fitness value equal to 0, thus the minimal fitness value is 1 in our algorithm. Finally, $Fitness_i$ is the fitness value of chromosome i.

D. Reproduction

We use the roulette wheel parent selection to implement the reproduction where each chromosome in the population occupies a slot size proportional to its fitness value. And then we generate a random number to determine which chromosome will be selected to the new population. Because chromosomes with higher fitness value will have large slots, they have larger opportunity to be selected. To improve the performance, we make a slight modification by always passing the best chromosome from current population to the new population.

E. Crossover

In our algorithm, the number of '1' in each chromosome must always equal to *N*. Thus we randomly select two chromosomes from the new population after reproduction and cross with the *crossover probability.* If the crossover is performed, we randomly select two points C_1, C_2 (where $C_1 < C_2$) from the chromosome and create a FILO (First In Last Out) stack to store the bit position k corresponding to the opposite bit pair (A_k,B_k). A_k and B_k are said to be opposite if $A_k \oplus B_k = 1$, where $\oplus$ denotes the exclusive or operator. We start from C_1 and moving right until an *i* is found such that $A_i \oplus B_i = 1$. We push *i* into the FILO stack and continue the process until we find a *j* such that $A_j \oplus B_j = 1$. Then we compare A_i with A_{s1}, where s1 is the top element in the stack. If they are the same, we push *j* into the stack, otherwise, we swap the pair indexed by *j* with the index by s1 and pop s1 from the stack. The process continues until C_2 is reached. *Fig.3* is an example of crossover function.

F. Mutation

Each chromosome in the new population mutates with the *mutation probability.* If the mutation is performed, we randomly select one '1' and one '0' in the chromosome and inverse the two values such as shown in *Fig 4.*

V. Result

In this paper, we use the following parameters in the algorithm:

- population size = 20
- crossover probability = 0.8
- mutation probability = 0.15
- maximum number of iteration = 1000

In the *Fig.5,* we show an example for selecting the multimedia code set by genetic algorithm as the number of users in each service type is 7, 7 and 9, respectively. The value *m* of each service type is 0, 1 and 2. The algorithm converges as generation is 70 and we obtain the code set in *Table II.* By this example, we can easily select the code set by genetic algorithm and the convergence rate is very fast.

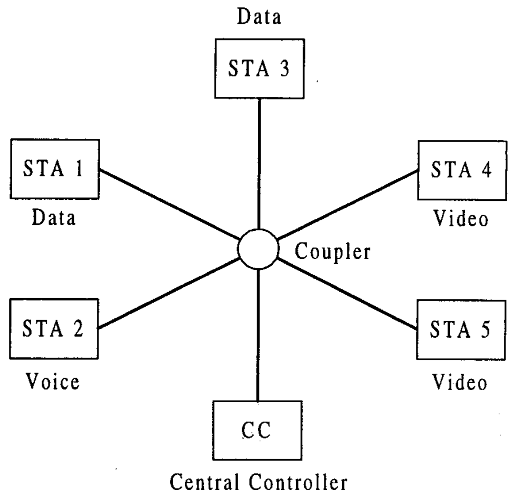

Figure 1. The network architecture in FO-CDMA

		N1	N2	N3	m
$C_{0,1}$	001 001 001	1	1	0	1
$C_{0,2}$	010 010 010	1	1	0	1
$C_{1,1}$	010 001 100	1	1	1	2
$C_{2,1}$	001 010 100	1	1	1	2

Table I. An example of multimedia code set

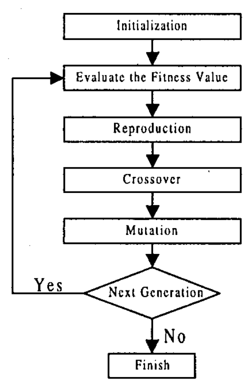

Figure 2. Genetic Algorithm

Before Cross over   After Cross over

String1: 1 1 0 1 0 0 1 0 0 ⟹ 1 1 0 0 0 1 1 0 0

String2: 0 1 0 0 0 1 1 1 0   0 1 0 1 0 0 1 1 0

Figure 3. Crossover

Before Mutation   After Mutation

String1: 1 1 0 0 0 0 1 0 0 ⟹ 1 0 0 0 0 1 1 0 0

Figure 4. Mutation

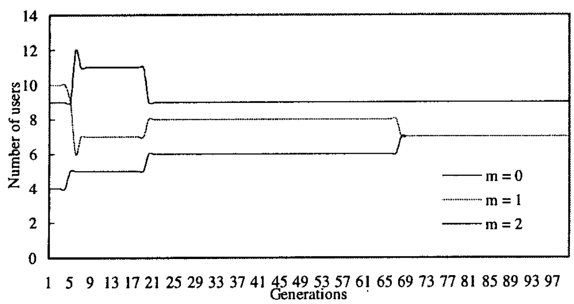

Figure 5.The number of each service type code set obtained by GA at different generations

Generation	m	CN	Code set
6	0	5	$C_{11}, C_{31}, C_{34}, C_{36}, C_{54}$
	1	7	$C_{10}, C_{12}, C_{14}, C_{41}, C_{42}, C_{44}, C_{55}$
	2	11	$C_{00}, C_{06}, C_{16}, C_{23}, C_{30}, C_{32}, C_{43}, C_{51}, C_{56}, C_{63}, C_{65}$
19	0	6	$C_{11}, C_{31}, C_{34}, C_{36}, C_{41}, C_{54}$
	1	8	$C_{10}, C_{30}, C_{32}, C_{42}, C_{44}, C_{55}, C_{65}, C_{66}$
	2	9	$C_{02}, C_{06}, C_{14}, C_{16}, C_{23}, C_{43}, C_{51}, C_{56}, C_{63}$
67	0	7	$C_{10}, C_{31}, C_{34}, C_{41}, C_{42}, C_{54}, C_{65}$
	1	7	$C_{05}, C_{06}, C_{11}, C_{14}, C_{36}, C_{60}, C_{63}$
	2	9	$C_{02}, C_{16}, C_{23}, C_{30}, C_{43}, C_{44}, C_{51}, C_{56}, C_{66}$

Table II. The exact code set obtained by GA at different generations

VI. Conclusion

In this paper, we propose a multimedia code set selection solution using genetic algorithm. From the simulation result we can obtain the exact code set and the convergence rate is very fast. Thus, we can use this methodology in the central controller of the FO-CDMA network. In the future, we will design the dynamic central controller and analyze the performance.

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