

## Optimizing ODP Device Placement on FTTH Network Using Genetic Algorithms

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### Abstrak

Saat ini masalah infrastruktur Optical Distribution Point (ODP) menjadi hal yang penting dalam akses jaringan fiber to the home (FTTH) karena pembangunan infrastruktur ODP bukan lagi tergantung pada permintaan, sehingga penempatan ODP secara manual tanpa sebuah metode sistematis dapat menyebabkan bertambahnya nilai redaman serat optik pada panjang kabel dan menyebabkan distribusi kabel yang menjadi tidak beraturan. Penelitian ini bertujuan untuk mengoptimalkan penempatan perangkat ODP di jaringan FTTH PT BCV dilakukan dengan menggunakan skema Travelling Salesman Problem (TSP) dengan metode pendekatan algoritma genetika (GA) dan menggunakan hybrid GA, pengujian dilakukan menggunakan software matlab. Pengujian dengan pengembangan menggunakan Hybrid GA mendapatkan jalur terbaik dengan nilai fitness 28,6457 dan waktu komputasi 89,93 detik.

**Kata kunci**—Algoritma Genetika, Pembangunan Infrastruktur, Optical Distribution Point

### Abstract

Currently, the problem of Optical Distribution Point (ODP) infrastructure is vital in fiber-to-the-home (FTTH) network access because ODP infrastructure development is no longer dependent on demand, so placing ODP manually without a systematic method can cause an increase in the value of optical fiber attenuation on the cable length and push the cable distribution to be irregular. This study aims to optimize the placement of ODP devices in PT BCV's FTTH network by using the Traveling Salesman Problem (TSP) scheme with the genetic algorithm (GA) approach and using hybrid GA; testing is carried out using Matlab software. Testing with development using Hybrid GA gets the best path with a fitness value of 28.6457 and a computation time of 89.93 seconds.

**Keywords**—Genetic Algorithm, Infrastructure Development, Optical Distribution Point

## 1. INTRODUCTION

Advances in telecommunications technology have provided many benefits to the whole community. The more people need to use the internet, the more internet service providers operate. Competition in telecommunications technology demands companies to constantly innovate by

releasing the latest services to compete and meet people's needs for internet use [1]. Process optimization is needed to maximize the resources required [2]. The community's need for communication is critical, so the demand for communication technology is increasing [3]. The demand for data, voice, and video (triple-play) services has proliferated, so stable and real-time triple-play services require wide bandwidth [4]. Fiber to the Home (FTTH) services are currently available by providing internet services simultaneously [5]. FTTH is a fiber optic cable network architecture for deploying optical fiber from the central office to the customer's house [3].

In 2018 PT BCV developed services to become Television and Internet by implementing the FTTH network. FTTH can effectively deliver various digital information up to 2.5 Gbps (gigabit per second) for longer distances [4]. FTTH has an architecture consisting of Optical Line Termination (OLT) – Fiber Termination Management (FTM) – Optical Distribution Cabinet (ODC) – Optical Distribution Point (ODP) – Rosette – Optical Network Termination (ONT) [6]. Another essential role in installing the Internet network is the ODP which functions as a place to establish single-mode fiber optic network connections, especially for connecting fiber optic cables [7]. The problem of ODP infrastructure is currently essential in FTTH network access. ODP infrastructure development no longer depends on existing customer demand, so classification based on the market over time becomes irrelevant [8]. Manual ODP placement without a systematic method can cause an increase in the optical fiber attenuation value based on the cable's length and push the cable's distribution to become irregular [9].

This research aims to overcome the optimization problem on the ODP device placement route and obtain customer data with the best response in Kampung Belian Village, Batam Kota District. The ODP placement refers to a recapitulation of using the State Electricity Company's electricity poles in Batam City, No.00115.BAP/REN.05.03/SMMULSER/2021. Optimizing the placement of ODP devices on PT BCV's FTTH network is carried out using the Traveling Salesman Problem (TSP) scheme based on the traveling salesman principle by searching for the shortest and the most optimal travel routes to be taken from the initial point of departure to the end so that a particular algorithm is needed to optimize the route [10]. Therefore research is required to find the best ODP device placement path.

### *1.1 Optical Fiber Technology*

Optical fiber is a long, thin pure glass with a small diameter. The principle optical fiber uses is a perfect reflection by making the two refractive indices of the core and different cladding so that light can reflect and propagate in it [11].

In the absorption process, due to light loss caused by impurities in the optical fiber, the scattering process during the radiation loss causes the optical fiber to attenuate less than 20 decibels (dB)/km [12]. Optical fiber uses light as its transmission to send data, and it is famous for its speed in transmitting data. The structure generally consists of the outermost part, the coating, cladding, or tube, and the core is on the inside [13]. Optical fiber typically has 12 cable tubes in one large cable; in 1 cable tube, there are 12 cable cores of 12 different colors.

Optical fiber has a diameter of approximately 120  $\mu\text{m}$  and consists of 2 models: single and multimode. The single model has a tiny diameter between 8.3 - 10  $\mu\text{m}$ . Whereas for multimode, the core diameter is 50-100  $\mu\text{m}$ . The wavelength for single model cable is 1310-1550nm, while for multimode, it is 850-1300nm [14]. One example of the application of fiber optic technology at this time is FTTH.

### *1.2 Fiber to the Home*

Fiber to the Home (FTTH) is one of the most essential architectures in pulling fiber optic cables. With the development of technology, people's desire for quality internet services is increasing [15].

FTTH is a series of fiber optic networks from the provider's center to the customer's home as a transmission medium, and there are three services in one infrastructure: internet access,

telephone network, and video. FTTH has the advantage that it can reduce operating costs and can provide better services to customers [16]. In a general architecture of an FTTH network. The distance between the service center, namely the head office and the customer, can be a maximum of 20 km. The head office has devices inside, namely OLT (Optical Line Terminal) and FTM (Fiber Termination Management). FTM is a device that functions as a cable termination from OLT. In addition, several essential devices operate to distribute signals via optical fiber to subscribers [14].

### 1.3 FTTH Attenuation

The FTTH network needs attenuation calculations to avoid interference from the transmission media so that there is a minimum and maximum attenuation so that the FTTH network is not disturbed in its transmission. The minimum attenuation is 13 dB, and the maximum attenuation is 25 dB. If the attenuation is more than 25 dB and less than 13 dB, there will be interference on the transmission line [16].

### 1.4 Gigabit Capable Passive Optical Network

Gigabit Capable Passive Optical Network (GPON) is a technology based on optical fiber as a transport medium for subscribers. GPON is a technology that uses the G.984 or Ftx standard. Downstream security uses 128-bit encryption in sending upstream and downstream data using Wavelength Division Multiplexing (WDM) technology over optical fiber [15].

The advantage of GPON is that it can offer bandwidth up to 2.488 Gbps to subscribers without losing bandwidth. The benefits of GPON are as follows [15]:

1. Data transmission is more efficient.
2. It can transmit data, voice, and video.
3. It can share up to 32 ONU bandwidth, and the bandwidth sharing can be managed from the server.
  - a) Downstream is the speed in retrieving data from the server to the computer.
  - b) Upstream is the speed of sending data from the user to the server.
  - c) Network feasibility standard according to ITU-T G.984 GPON technology standard from BPON evolution. It has a bandwidth of 2.5 Gbps with 93% efficiency using a larger QoS (Quality of Service) frame. The network eligibility standard is -28dB, 10 Gbps downstream, and 2.5 Gbps upstream

### 1.5 Optimization

Optimization is a form of activity or business to get the best results with the conditions or rules given [17]. Optimization algorithms are generally used to solve engineering problems [18]. An algorithm is a sequence of logical stages of problem-solving that are systematically and logically arranged. The word "logical" is a keyword in the algorithm. The steps in the algorithm must be logical and must be determined to be true or false [19]. Algorithms have several characteristics, namely [20] [21] [22]:

1. Algorithms have limited steps, which means an algorithm must stop after doing a series of tasks
2. Each step does not have a double meaning or cannot be corrected; in other words, each step must be precisely defined
3. Has an initial condition or input (input)
4. Has a final condition or output (output)
5. Correctly followed algorithm will solve the problem

In general, there are two algorithm methods for solving optimization problems, namely as follows [23] [24] [25] [26]:

1. Conventional (Deterministic) method using pure mathematical calculations. Several methods are often used to solve optimization problems, namely the Dijkstra Algorithm, the Floyd-Warshall Algorithm, and the Bellmanford Algorithm.
2. Heuristic/meta-heuristic methods. Several algorithms from the heuristic/meta-heuristic way are often used in optimization problems, including the Taboo Search Algorithm, Artificial Neural Networks, Ant Algorithms, Genetic Algorithms, and others.

### *1.6 Traveling Salesman Problem*

Traveling Salesman Problem (TSP) generally uses a heuristic approach in finding a solution because TSP is known as a problem that is Nondeterministic Polynomial-Hard (NP-Hard) [27]. The main problem of TSP is how a peddler can arrange his travel route to visit several cities with a known distance from one town to another so that the distance traveled is the minimum distance where peddlers can only see the city exactly once [28]. TSP is shown in Figure 2.

TSP has rules that must visit each city exactly once, not more or less, then all cities must be called in one trip, then start and end at the same city [29]. In general, the purpose of TSP method is used to obtain the shortest or closest travel distance so that it can have an impact on the distribution costs incurred by the company. The TSP method can solve distribution problems by finding savings in length, travel time, and total travel time [30].

### *1.7 Genetic Algorithm*

Genetic algorithms (GA) are designed to solve complex industrial problems in the process of solving problems with conventional methods [26]. GA was developed by Goldberg, who stated that the concept of GA is a computational science that solves a problem by finding a solution naturally. GA is a type of evolutionary algorithm that is widely implemented in complex issues, such as optimization problems with complicated mathematical models with the required computational time, which also tends to be stable. The most miniature arrangement of GA is the character, symbol, or number of a problem [31] [32] [33] [34] [35].

The evolutionary process in GA begins by selecting a set of solutions at random, described by chromosomes, which is called the population. When the initial population does not reach a good solution, the process of crossing over and mutation is carried out [36] [37]. Crossbreeding is needed to get the best answer and combination from the current population into the new population, where the selection depends on the best value. Mutations are random features that change individual chromosomes [38] [39] [40]. The effect of mutation usually affects only a few genes [41] [42] [43] [44].

GA is a solution to optimization problems. GA has advantages over other algorithms, namely [45] [46] [47] [48]:

1. GA does not use many mathematical requirements in completing the optimization process. GA can be applied to several types of objective functions with several limiting functions, both linear and non-linear, to speed up the calculation process.
2. The evolution operation of GA is very effective for observing random global positions.
3. GA has the feasibility to be implemented efficiently on specific problems.

GA has differences in four respects, namely:

1. Genetic algorithms work with variable code structures [49] [50].
2. Using multiple search points [51] [51] [52].
3. The information needed is only the objective function, thus making the implementation more straightforward [53] [54].
4. Using stochastic operators with guided search [55] [56].

## 2. METHODS

The design was carried out in Kampung Tua Belian, which is in the Batam Center City area, where at that location, there are still locations where fiber optic lines still need to be built. The route was chosen because it has a good level of marketing within a year. The construction of this fiber optic line is expected so that all points in the location to be designed can experience fast data communication services. The design in this study will start from January 2022 to April 2022. Figure 3 shows the location of Kampung Tua Belian.

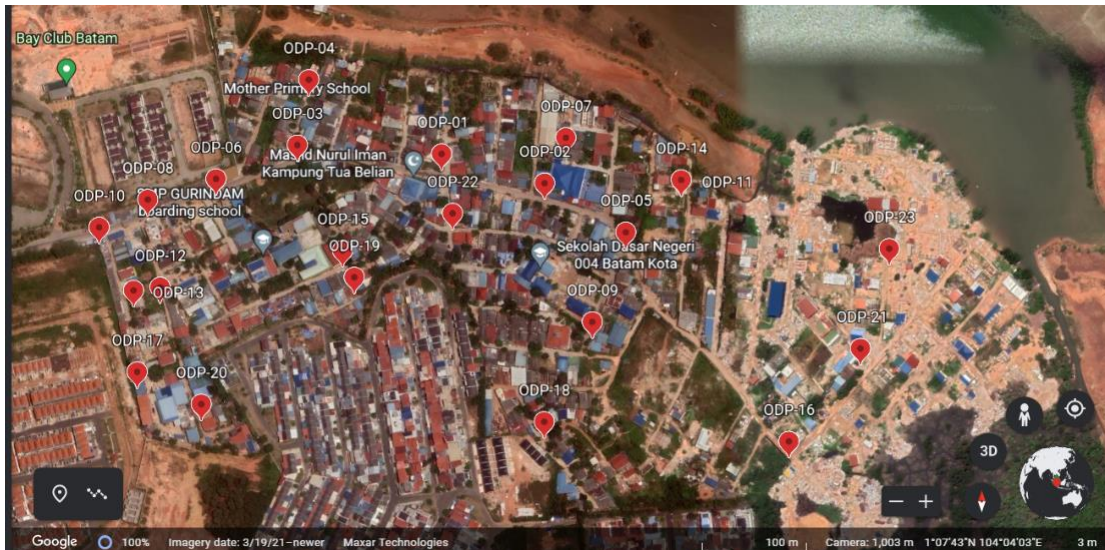


Figure 1. Location map designed by the FTTH Network in Kampung Tua Belian

There are two main supporting tools in this research, namely:

1. MATLAB R2016a software is software used to design FTTH access networks at every point using TSP problems.
2. Google Earth, used to make device placement points to be used in the design and to obtain data in the form of coordinates (latitude and longitude).

The steps used in solving the problem are:

1. Initialization
 

Population Each chromosome contains genes that represent the ODP point sequence number. The number of genes in each chromosome is equal to the number of ODP points. The inputs for this function are UkPop (population size or the number of chromosomes in the population) and JumGen (the number of genes in the chromosomes, which also represents the number of ODP points; 0,1).
2. Individual Evaluation
 

The calculation of the fitness value implemented in this function is three variables, namely Chromosome, GenGen, and XYlocation. The XY location variable contains the coordinates of all ODP points. The variable total cost (TB) and the fitness value of a chromosome are expressed by  $\text{fitness} = 1/\text{TB}$ .
3. Linear Fitness Ranking
 

To avoid the tendency to converge at the local optimum, a fitness value scaling process is carried out so that fitness values are obtained that are in the interval  $[\text{MaxF}, \text{MinF}]$  so that a new fitness value is obtained, which is better and has a high variance.

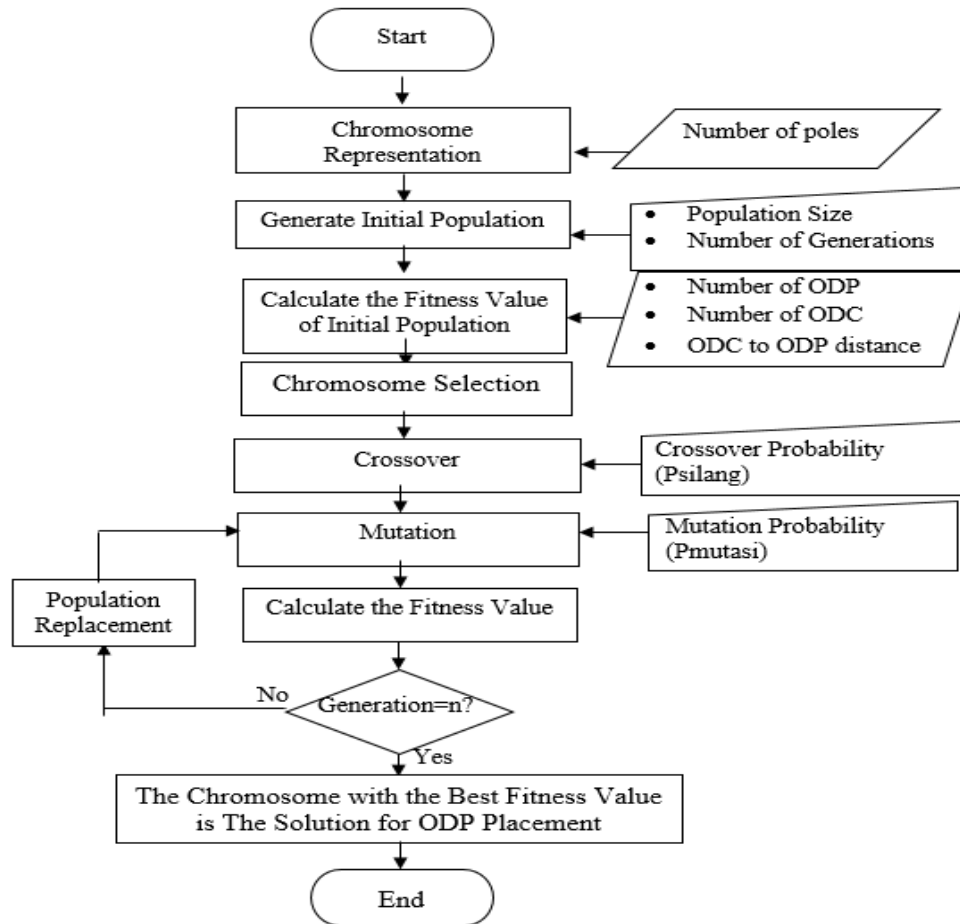


Figure 2. Research Flow Diagram

#### 4. Roulette-wheel

Then proceed with the roulette-wheel function to get the output in the form of Pindex, which is the index of the individual selected as the parent.

#### 5. Crossover

Then with an order crossover scheme, one part of the chromosome is exchanged while maintaining the ODP point sequence that is not part of the chromosome.

#### 6. Mutation

In the mutation scheme, swapping mutation is used. Functions consist of Chromosomes, Number of Genes, and Mutations. For all genes in the chromosomes, if the generated random number  $[0,1)$  is less than the  $P_{\text{mutation}}$ , then the gene value will be exchanged with the value of another gene that is randomly selected.

### 3. RESULTS AND DISCUSSION

Parameter scenario analysis can be determined by conducting several experiments by changing the parameters that we have previously selected to be tested. The parameters that produce the best fitness value will be used next in the created program.

The parameters to be tested consist of population size, maximum iteration, crossover probability, and mutation probability. Scenario analysis parameters determined by UkPop of 10, Psilang of 0.25, and  $P_{\text{mutation}}$  of 0.025 with maximum generations of 1000; 2000; 5000; 10000, and 15000 iterations are shown in Table 1 and Figure 3.

Table 1. Parameter Combination Results of 10 Populations

UkPop	Psilang	Pmutasi	Number of Iterations	Fitness Value	Computing Time (second)
10	0.25	0.05	1000	38.509	22.30
			2000	37.672	45.78
			5000	46.029	114.01
			10000	47.841	226.28
			15000	49.546	392.61
		0.025	1000	39.675	20.64
			2000	37.775	40.96
			5000	47.032	107.41
			10000	47.054	215.40
			15000	45.551	338.94
		0.005	1000	31.444	20.03
			2000	35.997	40.54
			5000	39.670	103.92
			10000	47.322	212.60
			15000	42.883	330.64

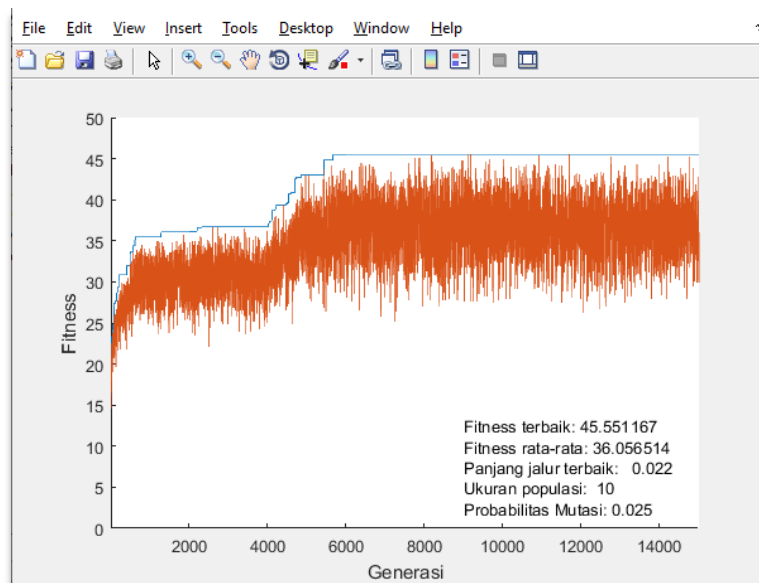


Figure 5. Graph of Program Testing After 15,000 Iterations

Based on the results obtained in Table 1 and Figure 3; the larger the number of iterations tends to give better results. This can be seen from the greater fitness value obtained from each combination after several iterations. Although better fitness results cannot be obtained by increasing the number of iterations, some fitness values decrease after a higher number of iterations. This can be seen at UkPop = 10, Psilang = 0.25, and  $P_{\text{mutation}} = 0.025$ , and at UkPop = 10, Psilang = 0.25 and  $P_{\text{mutation}} = 0.005$ .

Based on Table 2. it can be seen that the best combination to get the highest fitness value is:

- UkPop = 10, Psilang = 0.25 and  $P_{\text{mutation}} = 0.05$  at 15,000 iterations.
- UkPop = 10, Psilang = 0.25 and  $P_{\text{mutation}} = 0.025$  at 10,000 iterations.

- UkPop = 10, Psilang = 0.25 and  $P_{\text{mutation}} = 0.005$  at 10,000 iterations. However, the higher number of iterations will consume the longer the computation time.

In addition. The greater the mutation probability and crossover probability tend to give better results. This can be seen from the more excellent fitness value obtained from each combination after several iterations. However, a greater likelihood of mutation and crossover probability does not necessarily guarantee better results.

#### 4. CONCLUSIONS

Based on the parameter scenario analysis we carried out. Several conclusions were obtained. Including:

- In the parameter scenario analysis using a UkPop of 10. Psilang of 0.25 and Permutation of 0.025 with a maximum generation of 1000; 2000; 5000; 10000, and 15000 iterations. It is found that the best combination to get the highest fitness value (49.546) is UkPop = 10. Psilang = 0.25 and  $P_{\text{mutation}} = 0.05$  at 15,000 iterations. However. The computation time for this parameter combination is high. Which is 392.61 seconds.
- The combination to get the 2nd best fitness value (47.322) is at UkPop = 10. Psilang = 0.25 and  $P_{\text{mutation}} = 0.005$  at 10,000 iterations. Which is the lower computation time for this parameter combination of about 212.60 seconds.
- Taking into account the fitness value and computation time, then we recommended using the parameters UkPop = 10. Psilang = 0.25. Pmutation = 0.005, and the number of iterations is 10,000 for the best solution.

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