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Channel adaptive diversity handover with multiple queueing models for LEO equatorial satellites

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Abstract. The development of satellite communication constellation in various countries has developed rapidly over the past decade. The satellite constellation in LEO orbit is chosen because of several advantages such as low power consumption, lower delay time, simple ground station, and high spectrum efficiency. Behind all the advantages in Low Earth Orbit, the main problem in LEO constellation is the mobility. Because of that, a handover is applied in LEO Constellation. The variation of satellite handover is Hard Handover, CASD Handover, or DDBHP handover. In this paper, the CASD model is used because it only uses one orbital plane and this model suppresses blocked and dropped calls. The modification is done by varying the queue model in this scheme, and which queueing model gives the best results. The best results of the research are in the FIFO model were carried out using the dual diversity scheme are 0.94% for blocked calls, 5.86% for dropped calls, and 93.2% for successful calls, and a total delay of 2.04 second of total simulation time for 30 seconds, caused incoming calls will be served sequentially so that no calls are served randomly and have more priority than other calls.

1. Introduction

Satellite constellation on LEO orbit become a trend in this decade, especially in the communications satellite [1]. Satellites on LEO orbit are important components for data communication networks [2]. LEO satellites have advantages such as low delay, efficient frequency spectrum utilization, and low power consumption [1,3]. A new challenge in realizing the satellite constellation in LEO orbit for communication purposes is mobility. The height of a satellite orbit is one of the factors that determine satellite speed. Based on this, an optimal handover model is needed during the design process so that it can provide good service. The satellite that will be designed has an altitude of 1200 km with a constellation of nine satellites in one orbital. Indonesia is an archipelagic country extending about 5,120 kilometers (3,181 mi) from east to west and 1,760 kilometers (1,094 mi) from north to south. So that the orbit model that is appropriate based on the location of the Indonesian territory is a satellite in equatorial orbit flies along the line of the Earth's equator and use the adaptive diversity handover channel model as shown in figure 1.

This paper modifies the adaptive diversity handover channel model by varying the type of communication queue to determine the optimal method of the resulting handover parameter values. The type of queue used is First in First Out (FIFO), Service in Random Order (SIRO), and According to Priority (PR). Using a SaVI visualization software [4] to display the constellation model as shown below.



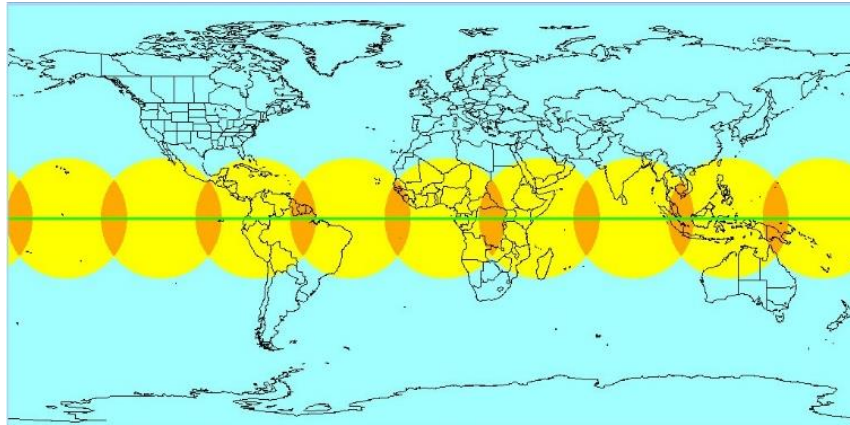


Figure 1. Constellation Model [5].

2. Research method

2.1 Channel adaptive diversity Handover

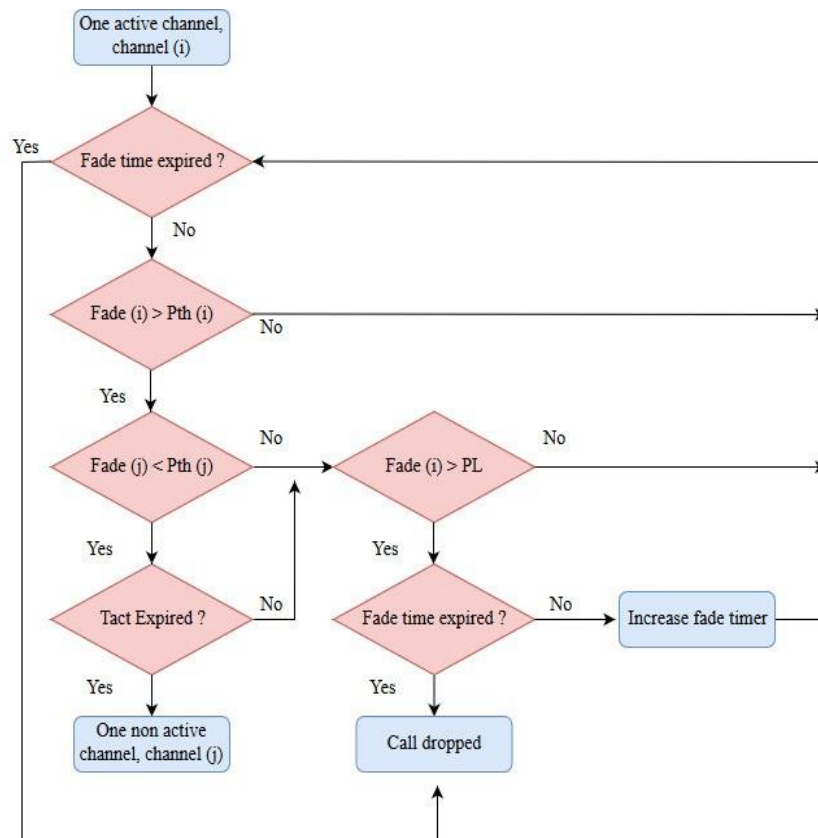


Figure 2. CASD Flowchart [6].

Based on [6,7] channel adaptive diversity (CASD) handover is one type of spotbeam handover. CASD is the development of hybrid diversity handover. CASD uses two threshold values to see the value of critical conditions in each channel. This model aims to know whether the power threshold on the first satellite can serve users. When the power threshold does not meet the requirements, another channel on the adjacent satellite will be prepared considering the drop time and channel activation time on the satellite [7].

From the flowchart in Figure 2, it can be seen the algorithm of the CASD using two different thresholds P_{th1} and P_{th2} . The threshold value determines acceptance and drops on communication requests in two available channels. The value from P_{th1} is bigger than the value of P_{th2} . The value of $PL = -|fade\ margin|$ used as the lowest value so that the user be able to communicate, then the relationship between the two threshold values can be seen in equation (1).

$$P_{thi} = PL + |H_i|, i = 1, 2 \quad |P_{th1}| > |P_{th2}| \quad (1)$$

Where H_i is the value of hysteresis power. Hysteresis time or set up time here introduced a value from one obstacle. Here, the estimated value for the fade duration to do cellular transmission is 75 km/hour or 0.3 seconds. In addition, 0.3 seconds is enough to build a repeat communication or known as Time activation (T_{act}) [7]. This value is used to prepare the adjacent satellite before falling under the fade margin. If the signal level active when the satellite is below the acceptable threshold value to communicate before the adjacent satellite is ready, then it is called hard handover. Dropping time (T_{drop}) is used to initiate both processes when both channels are used [8].

Table 1. Handover Criteria [1]

Criteria	Hard	CASD	DDBHP-Based
Handover strategy	Hard	Soft	Guaranteed
P_b (Blocking Probability)	Depends on available channels	Depends on available channels	Depends on the degree of guarantee
P_f (Dropping Probability)	High	Low	Zero
Traffic Condition	Performance degrades in critical channel condition	Can work on critical channel condition	Does not matter

2.2 Queueing models

Here is some queueing model that used in this research:

- FIFO (First in First out)
- SIRO (Service in random order)
- PR (According to priority)

2.2.1 FIFO (First In First Out)

This queue model can be interpreted as a normal queue model because the first incoming connection will be served by the first server as well and will be sequential until the last connection, here is an overview of the FIFO queue model [9,10].

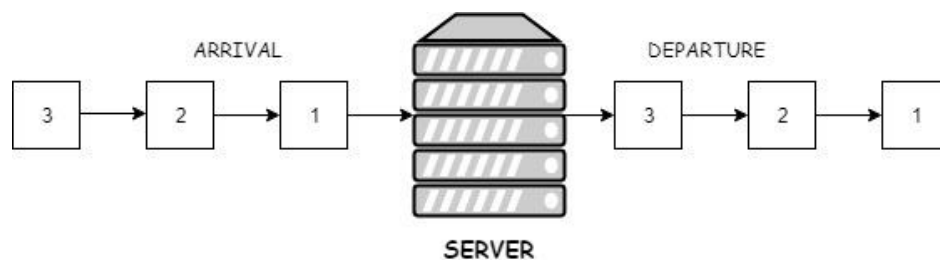


Figure 3. FIFO Model.

2.2.2 SIRO (Service In Random Order)

Another model is service in random order (SIRO). The difference with the FIFO model is that the connection that is served is done randomly by the server. So, the first incoming connection is not necessarily going to come out first. This model has a smaller potential for success because each connection will be chosen randomly [10].

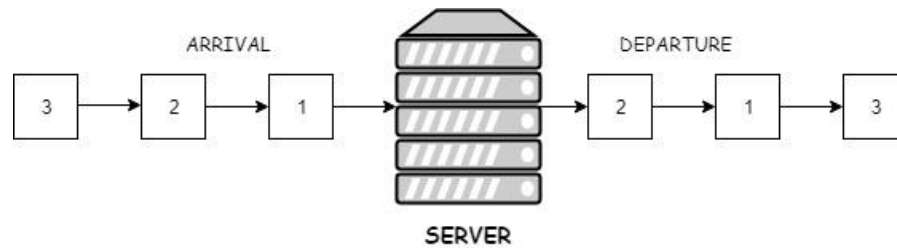


Figure 4. SIRO Model

2.2.3 PR (According to Priority)

In the priority queue, high priority elements are served before low priority elements. In some implementations, if two elements have the same priority, they are served according to the order in which they are anticipated, while in other implementations, ordering elements with the same priority are undefined [9,10].

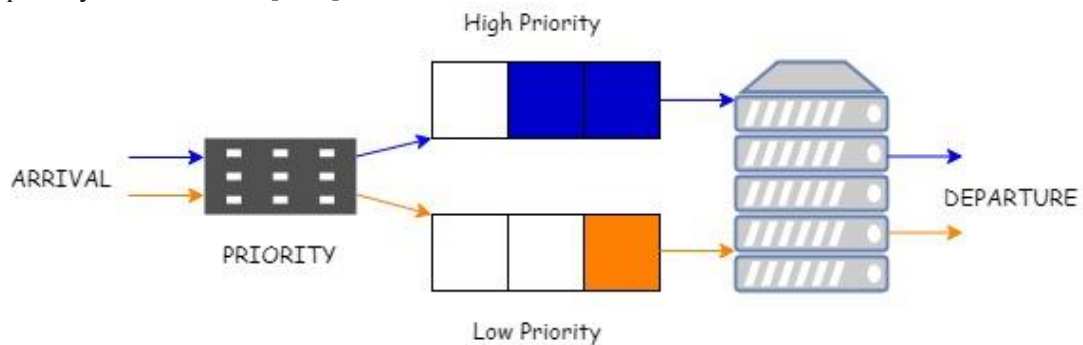


Figure 5.PR Model.

3.Result & Analysis

3.1 Link simulation result

Table 2. Parameters Simulation

Parameter	Nilai
Power threshold satellite 1 (Pth-1)	2dB
Power threshold satellite 2 (Pth-2)	4dB
Power Minimum (PL)	1dB
Dropping Time (Dt)	30s
Activated Time (Tact)	0.3s

Indonesia is an archipelago that extends from 90° East to 142° East [11], from the constellation model in Figure 1, the revolution time of the satellite is 01 hours 57 minutes 50 seconds and the satellite provide service time as long as 41 minutes 30 seconds.

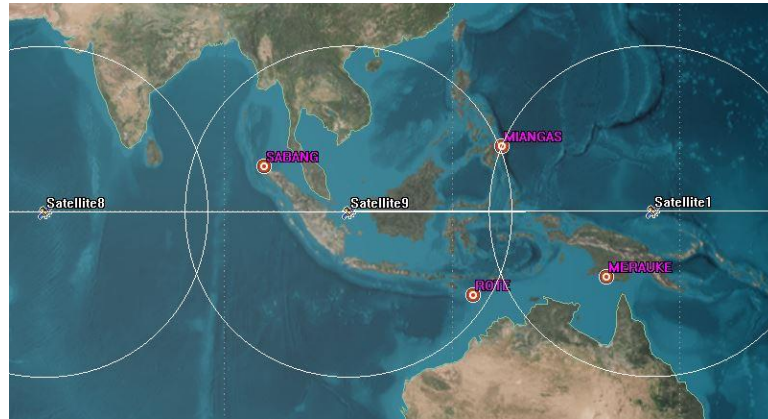


Figure 6. Area of Simulation Model.

In this study, two satellites that were adjacent and had a handover were simulated. The parameters used in this simulation are assumption parameters based on [3]. The value in table 2 are the parameters used in the simulation. Based on Figure 6, it can be seen in the simulation, there are four areas observed, namely Sabang, Rote, Miangas and Merauke these four cities were chosen because they were at the Indonesian border. These four cities were also chosen to find out the satellite coverage limitations that were designed and to determine the value of the power threshold in the outermost region. Handover occurs in all four regions during the service time. Service time lasts for as long as 2,490 seconds. In Sabang, the handover occurs at the 810th second, Rote at 1,350th second, Miangas at 1,430th second, and in Merauke handover occurs at 1,700th second. Handover occurs when the satellite power is at the minimum point when receiving the data communication. The minimum power is 1 dB.

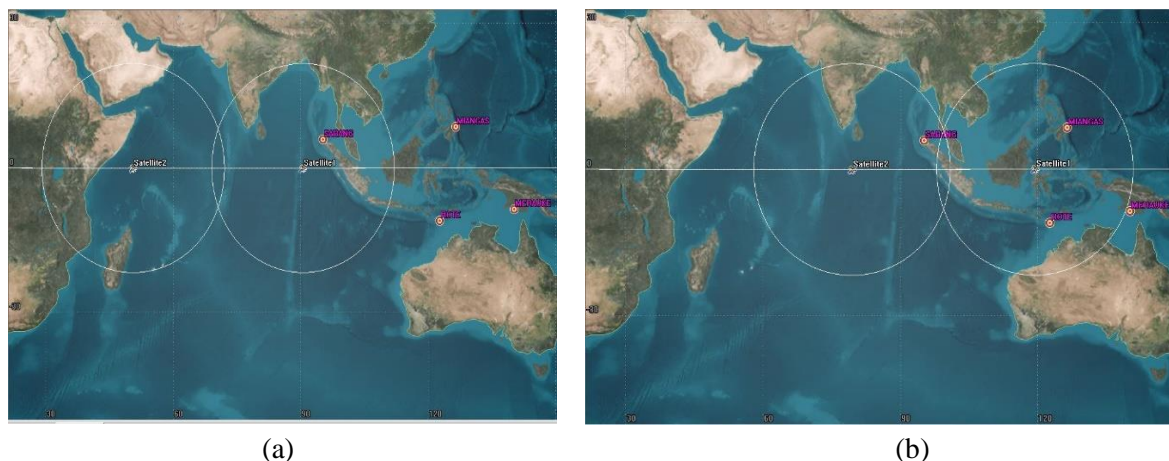


Figure 7. Handover Coordinate, (a) 90° , 48° , (b) 120° , 78° .

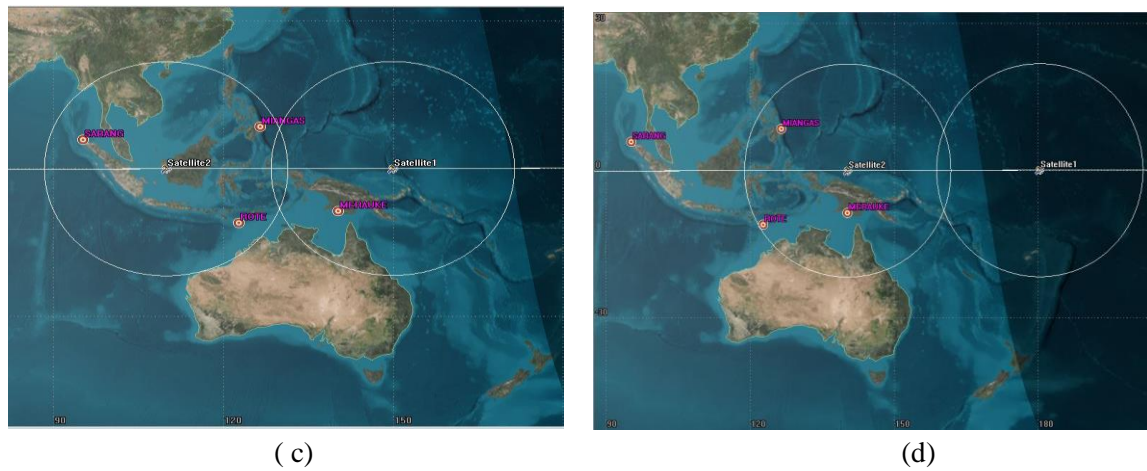


Figure 8. Handover Coordinate (c) 150°,108°, (d) 180°,138°.

3.2 Handover & QoS Parameters

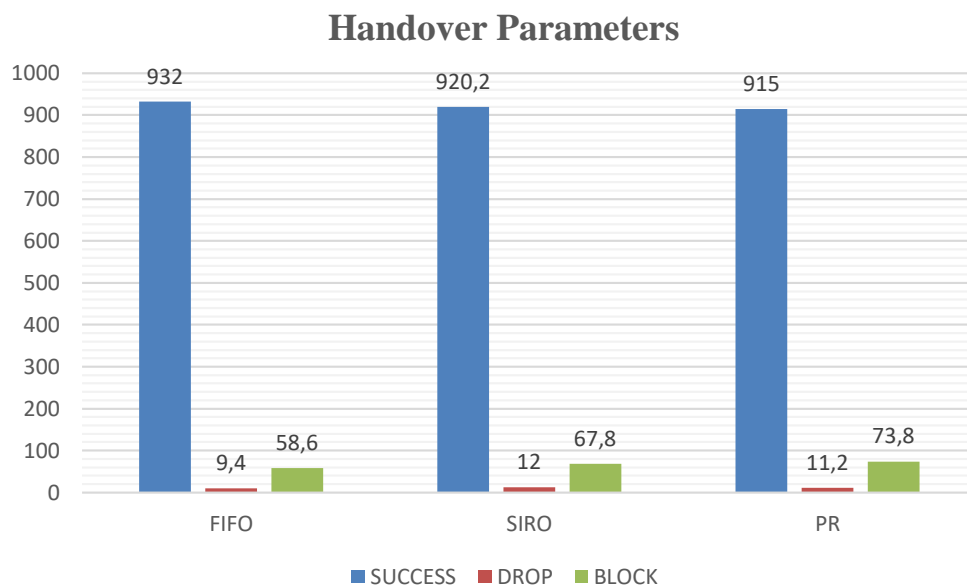


Figure 9. Handover Parameters Simulation Results.

Table 3. QoS Parameter			
	Delay (s)	Jitter (s)	Packet loss (Ncall)
FIFO	2.04	2.085	68
SIRO	2.394	2.37	79.8
PR	2.55	2.58	85

Simulations were carried out for three queuing models namely FIFO, SIRO, and PR using the handover parameter in Table 2, the simulation results can be seen in Figure 8. In the graph, it can be seen for each queue model, the number of Successful, Drop and Block calls is different. The highest successful call value is when using the FIFO queue, while the lowest successful call value is obtained when using the PR queue model. The highest number of calls dropped when using the SIRO queue model while the lowest number of drop calls when using the FIFO queue. For calls that are blocked, the highest number is when using the PR queue and the lowest when using the FIFO queue. Based on the simulation results, the type of queue used for the initial design is to use the FIFO queue model because it provides optimal results. They are 0.94% for blocked calls, 5.86% for dropped calls, and 93.2% for successful calls.

Based on QoS Parameters by looking at the values of Delay, Jitter, and Packet loss from the three queuing models, the results are obtained as shown in Table 3. It can be seen, the lowest delay value when using the FIFO queue model is 2.04s and the highest delay value when using the PR queue 2.55s. The lowest jitter value when using the FIFO queue 2.085s, while the highest jitter value when using the PR queue 2.58s, the lowest value of packet loss when using FIFO is 68 calls, while 85 calls are the highest packet loss value when using PR model. FIFO queue model can produce a parameter handover better than others because this model does not have a priority as in the PR queue, all incoming connections are served if a power threshold greater than or equal to the fading margin. The process of entering the queue is also regular, unlike the SIRO model which in one time can have more than one incoming connection.

4. Conclusion

Simulation of CASD handover is done by modifying the queue model on the incoming call. This study simulates 1000 calls for the 30seconds. Based on the simulation result, the FIFO gives the best results because based on this queueing model, incoming calls will be served sequentially so that no calls are served randomly and have more priority than other calls.

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