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Optimization Of WSN Deployment Using PSO Algorithm For Forest Fire Detection

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Abstract

Forest fires are disasters that have often occurred in recent years. This has a huge impact on both the environment and society itself. Delayed handling of fires is one of the triggering factors for the large losses caused by the disaster. The use of a Wireless Sensor Network is one solution so that information related to fires is conveyed to the authorities quickly so that the handling can be done more quickly. In this study, a simulation was made to determine the optimal position of a node to detect fires optimally. This simulation is run on NS3 Software on Ubuntu 18.04 Linux Operating System. In the optimization process, the PSO algorithm is run with Google Colab. The results of each iteration on the PSO will be simulated in NS3 and the communication between nodes will be seen. There are 12 iterations of the maximum 30 iterations specified, and there are 12 simulations according to the number of iterations. From 12 simulations that have been carried out, it is known that in the last iteration of the 10 nodes installed, all nodes communicate. Communication between nodes can be seen through .pcap files and graphs on NetAnim, the communication is characterized by sending fire messages to each installed node. In the last iteration, 10 nodes received a fire message.

Keywords: *Wireless Sensor Network, Forest fires, Particle swarm optimization*

1. Introduction

Forest fires are one of the natural disasters that have recently occurred in Indonesia. According to the Ministry of Environment and Forestry, based on Landsat satellite imagery, as of September 2019, forest and land fires reached 857,755 hectares[1]. In addition to causing environmental damage, the impact of forest fires is the high cost of handling them and the relatively long post-fire recovery process. A wireless sensor network (WSN) is a distributed autonomous device that uses sensors to monitor physical or environmental conditions such as temperature, sound, vibration, pressure, and movement at different locations. Recently, WSN has been widely used to monitor a location or place that is prone to a disaster[2]. By using the WSN device to monitor forest environmental conditions, when there is a potential fire, it is hoped that the device will be able to detect it and send a message to the nearest forest supervisor. However, in the process of placing the sensor, of course, you must pay attention to the distance between the sensors so that communication between sensors can run more efficiently. To get around this, an optimization algorithm called particle swarm optimization (PSO) is used. PSO is one of the optimization algorithms that are quite popular and is inspired by the behavior of groups of fish or birds in foraging[4]. In its application, after the sensor is placed by the optimization coordinates of the PSO algorithm, it is expected that the sensor will collect data in real-time so that in the event of a potential fire the system will respond in the form of a message so that related parties can deal with fires quickly. Based on this, the system design "Optimization of Deployment WSN Using the PSO Algorithm for Detecting Forest Fires was made". The system will be made by simulation, this is done to minimize unwanted things such as errors in sensor placement or other errors.

2. Reseach Methods

In this section, the general flow of the research that will be carried out by the author will be described, namely starting with determining the problem and then collecting data and information.

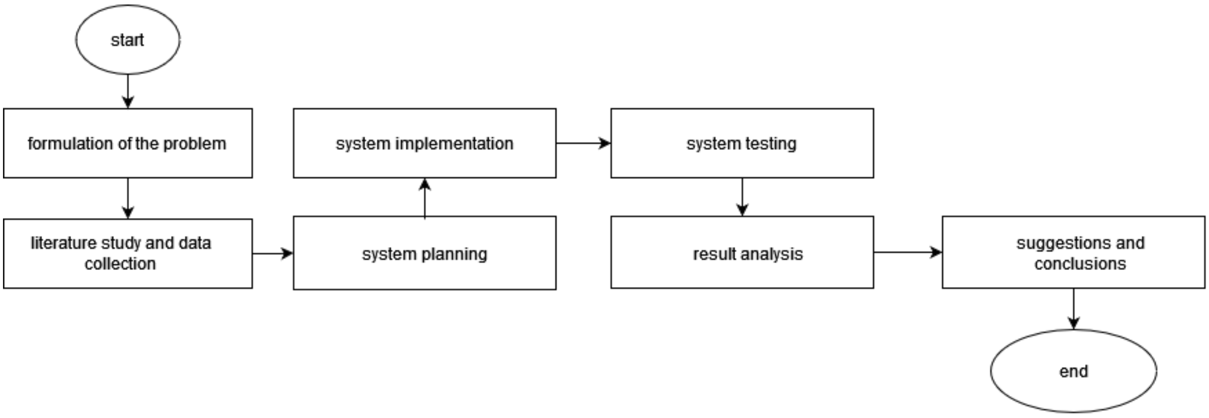
start
formulation of the problem
literature study and data collection
system planning
system implementation
system testing
result analysis
suggestions and conclusions
end

Figure 1. Research Flow

The system to be built is an implementation in a simulation. The simulation will be run with the software NS3 on Ubuntu 18.04 Linux Operating System.

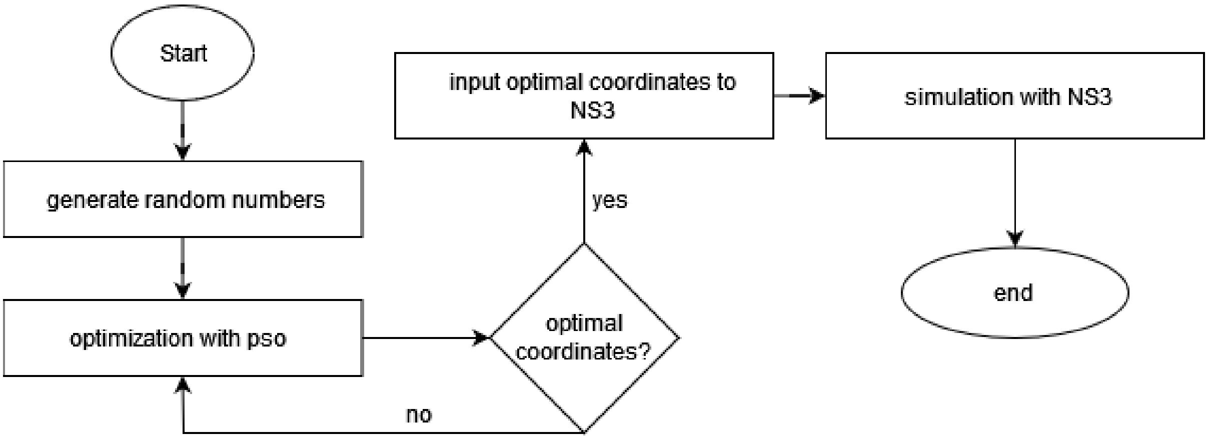

Figure 2. Simulation Flow

In this study, the simulation will be carried out using NS3 while the PSO optimization will be carried out using Google Colab.

2.1 Particle Swarm Optimization (PSO)

Particle Swarm Optimization (PSO) was first introduced in 1995. The idea of PSO stems from the natural behavior of birds foraging for food. When a group of birds forages for food together, each bird will look around the area close to itself[2]. The following is a mathematical formulation that describes the position and velocity of particles in a certain dimension of space:

$Xi\ (t) = xi1\ (t), xi2(t),\ldots,xiN(t)$ …………..(1)

$Vi\ (t) = vi1\ (t), vi2(t),\ldots,viN(t)$ …………..(2)

Where:

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X = Particle position

V = Particle velocity i = Particle index

t = Iteration to –t

N = Dimensions of space

The following is a mathematical model that describes the mechanism for updating the state of the particle Kennedy and Eberhart [1995]:

Vi(t) = vi(t – 1) + $c_1 r_1 \left(X_i^L - X_i(t-1)\right) + c_2 r_2 \left(X^G - X_i(t-1)\right)$ ………(3)

$X_i(t) = V_i(t) + X_i(t-1)$ ………………..(4)

Where $X_i^L = x_{i1}^L, x_{i2}^L, \ldots, x_{iN}^L$ represents the local best of the particle. While $X^G = x_{i1}^G, x_{i2}^G, \ldots, x_{iN}^G$ represents the global best of the entire herd. While c1 and c2 are constants that have positive values which are usually referred to as learning factors. Then r1 and r2 are random numbers with values from 0 to 1. Equation (3) is used to calculate the new particle velocity based on the previous velocity, the distance between the current position and the local best position, and the distance between the current position. with the best position of the herd (global best). Then the particle flies to a new position based on equation (4). After the PSO algorithm is run with a certain number of iterations until it reaches the termination criteria, a solution that lies in the global best will be obtained[5].

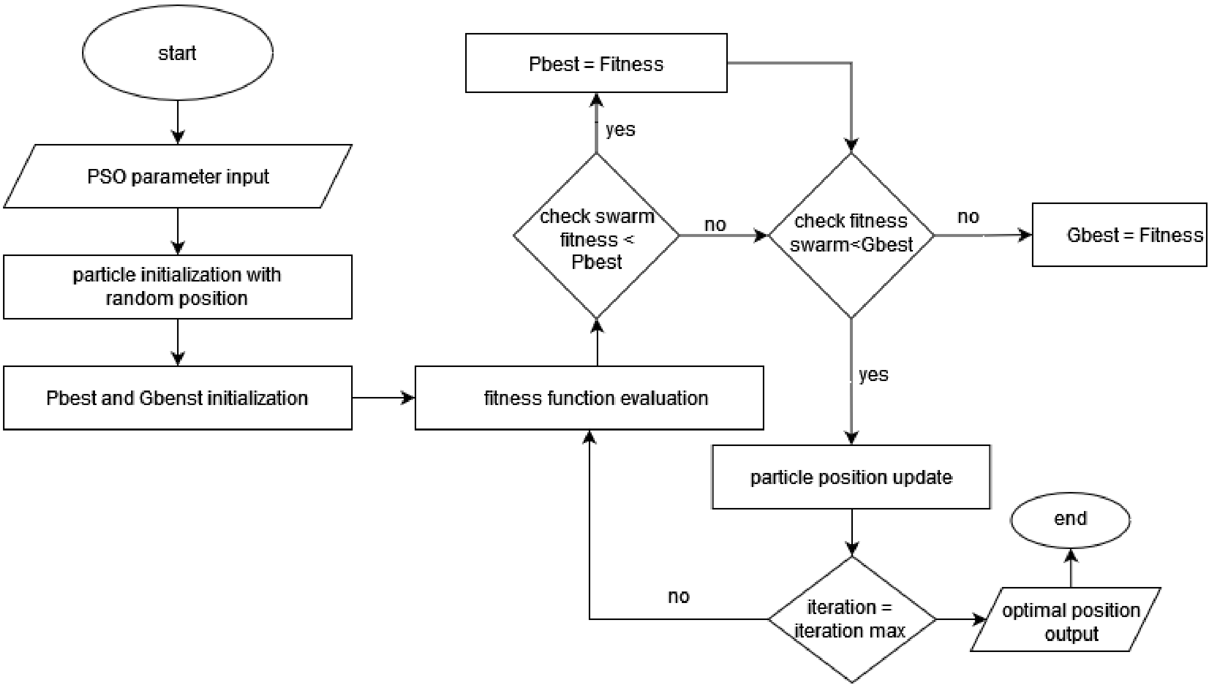

start
PSO parameter input
particle initialization with random position
Pbest and Gbenst initialization
fitness function evaluation
check swarm fitness < Pbest
yes
no
Pbest = Fitness
check fitness swarm<Gbest
no
Gbest = Fitness
yes
particle position update
iteration = iteration max
no
optimal position output
end

Figure 3. PSO Algorithm

In the figure, it can be seen that the optimization process begins by inputting several parameters such as the number of particles, the maximum number of iterations, and several other parameters. After determining the number of particles, the initialization of the position (X, Y) of each particle with random numbers is carried out using a linear congruential generator (LCG). From the position of each particle that has been determined, then initialized the Pbest and Gbest values. After all the values are obtained, the fitness value of each particle will be evaluated, and then the results are used to determine the Pbest and Gbest values in the next iteration. After that, the next process is to update the latest position of each particle based on the latest Pbest and Gbest values. At the final stage, it will be checked whether the iteration has reached the maximum iteration, if it has not eaten, an evaluation of the particle fitness function will be carried out and the process will be carried out as before. If the iteration reaches the maximum then the results of each iteration will be printed and the optimization process is declared complete. The results of the optimization process for each iteration will then be tested in a simulation with NS3.

2.2 Simulation

The simulation stage is carried out to test the connection between sensor nodes, testing is done by creating a hotspot node that sends fire messages to the nearest node. The fire message will then be sent to each sensor node and it will be seen which nodes are connected and which are not[3]. The simulation was carried out for 1500 seconds with the sensor coverage radius set at 100 meters. The number of nodes used in this simulation is 10 sensor nodes and 1 fire node. The simulation will be run per iteration until it reaches the maximum iteration, so there will be several simulations until it reaches the maximum iteration.

3. Result and Discussion

3.1 PSO Calculation Results

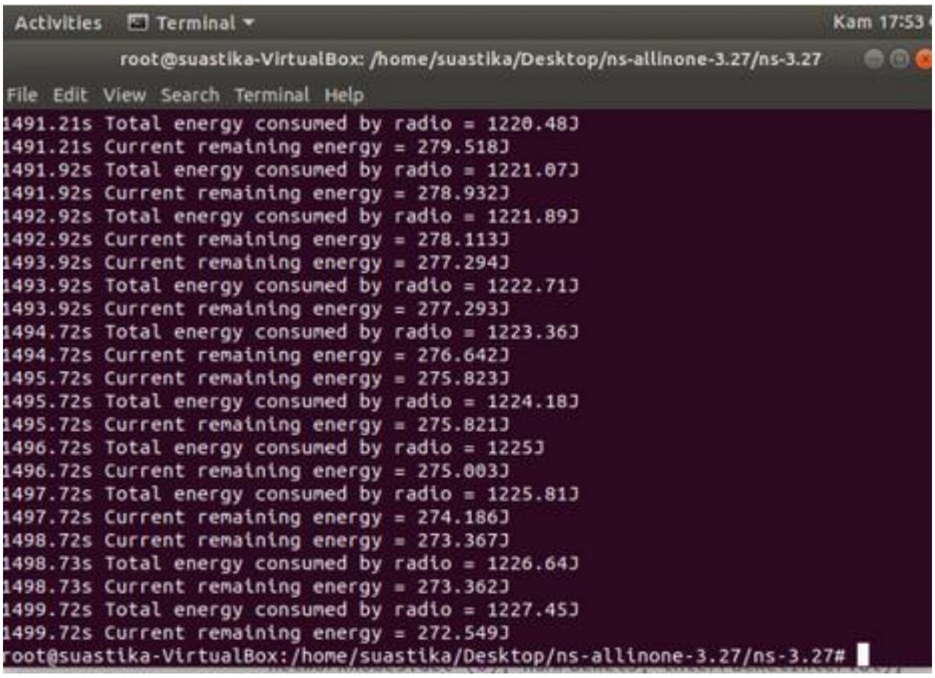
The results of the PSO calculation reach the maximum results in the 12th iteration of 30 iterations. The following is the result of the 12th iteration.

Table 1. The most optimal PSO results in iteration 12

Iteration	Node Sensor	X	Y
12	**Sensor 1**	22.590523	34.094393
	Sensor 2	40.471378	29.488389
	Sensor 3	20.5098	34.668839
	Sensor 4	28.421732	30.019085
	Sensor 5	17.184822	22.69669
	Sensor 6	25.440409	38.304829
	Sensor 7	24.444198	44.115399
	Sensor 8	43.317781	7.871107
	Sensor 9	16.623386	39.321243
	Sensor 10	31.836154	0

3.2 Simulation with NS3

After the implementation of making the program is complete, then the program will be run with certain commands that have been previously configured. These commands will adapt to the simulation scenario being run. Before running the simulation, the program must be built and compiled first.


Activities
Terminal
Kam 17:53
root@suastika-VirtualBox: /home/suastika/Desktop/ns-allinone-3.27/ns-3.27
File Edit View Search Terminal Help

```
1491.21s Total energy consumed by radio = 1220.48J
1491.21s Current remaining energy = 279.518J
1491.92s Total energy consumed by radio = 1221.07J
1491.92s Current remaining energy = 278.932J
1492.92s Total energy consumed by radio = 1221.89J
1492.92s Current remaining energy = 278.113J
1493.92s Current remaining energy = 277.294J
1493.92s Total energy consumed by radio = 1222.71J
1493.92s Current remaining energy = 277.293J
1494.72s Total energy consumed by radio = 1223.36J
1494.72s Current remaining energy = 276.642J
1495.72s Current remaining energy = 275.823J
1495.72s Total energy consumed by radio = 1224.18J
1495.72s Current remaining energy = 275.821J
1496.72s Total energy consumed by radio = 1225J
1496.72s Current remaining energy = 275.003J
1497.72s Total energy consumed by radio = 1225.81J
1497.72s Current remaining energy = 274.186J
1498.72s Current remaining energy = 273.367J
1498.73s Total energy consumed by radio = 1226.64J
1498.73s Current remaining energy = 273.362J
1499.72s Total energy consumed by radio = 1227.45J
1499.72s Current remaining energy = 272.549J
root@suastika-VirtualBox:/home/suastika/Desktop/ns-allinone-3.27/ns-3.27#
```

Figure 4. NS3 Run Results

After compiling, simulate NetAnim, by going to the NetAnim folder and running the command. (`./NetAnim`).

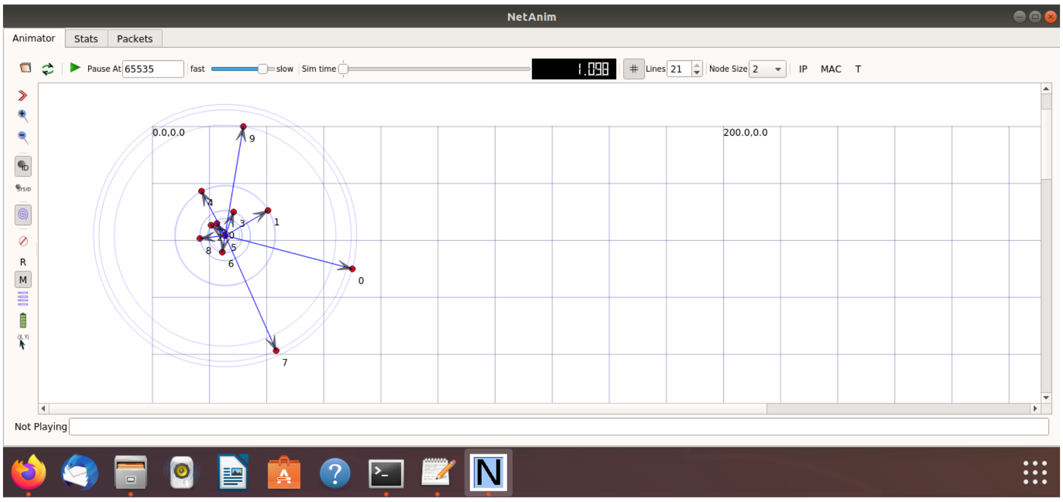
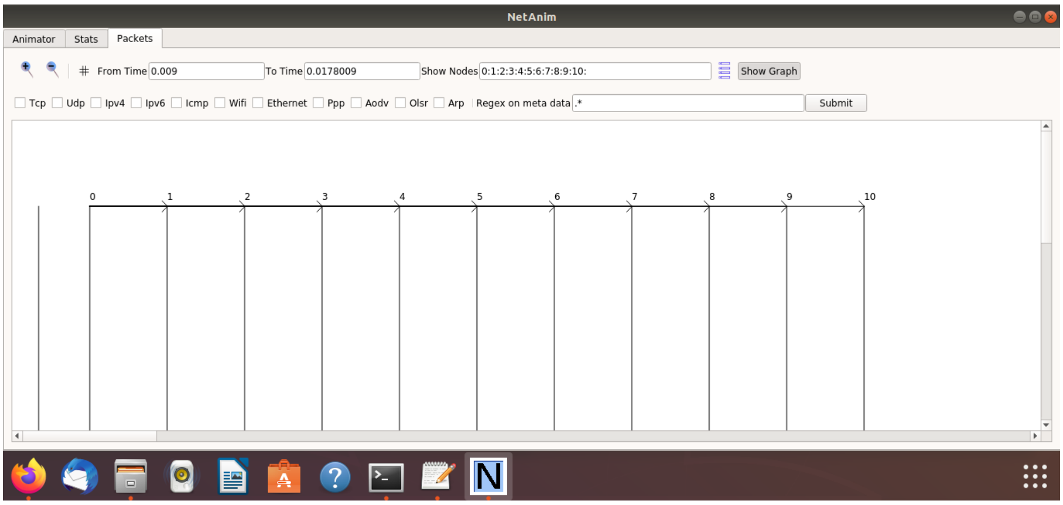


Figure 5. 12th Iteration Node Position


NetAnim
Animator
Stats
Packets
Show Graph
□ Tcp □ Udp □ Ipv4 □ Ipv6 □ Icmp □ Wifi □ Ethernet □ Ppp □ Aodv □ Olsr □ Arp
Submit
0
1
2
3
4
5
6
7
8
9
10

From Time 0.009 To Time 0.0178009 Show Nodes 0:1:2:3:4:5:6:7:8:9:10:

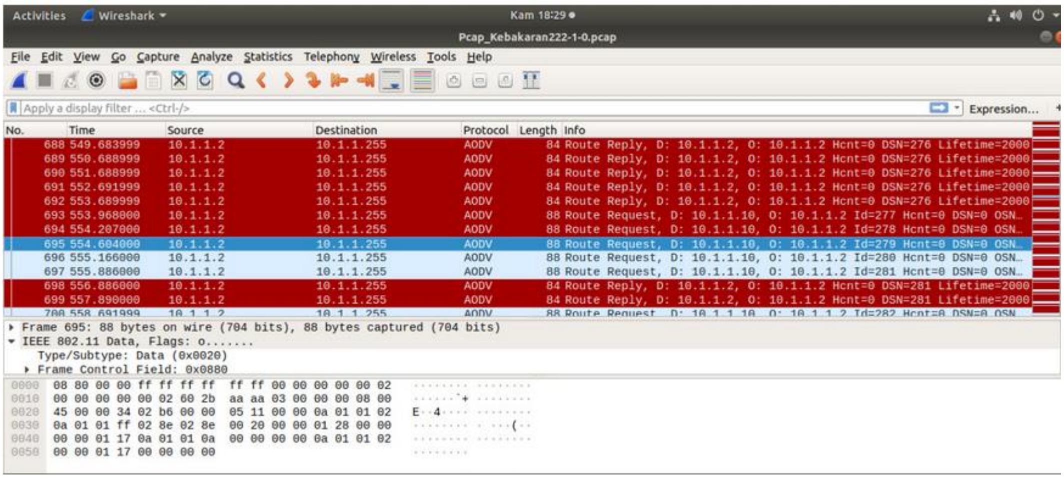
Regex on meta data .*

Figure 6. Iteration node communication

From the figure, it can be seen that all of the 10 nodes set up received the message. Based on this, of the 12 iterations carried out the 12th iteration is the most there are communicating nodes, namely 10 sensor nodes, it can be concluded that the results in this iteration can be considered the most optimal.

3.3 Pcap Results

After the program is finished executing, it will produce output in the form of a .pcap file, the file is a file created for network analysis with Wireshark. Here is what the .pcap file looks like when run with Wireshark.


Activities
Wireshark
Kam 18:29
Pcap_Kebakaran222-1-0.pcap
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>
Expression...

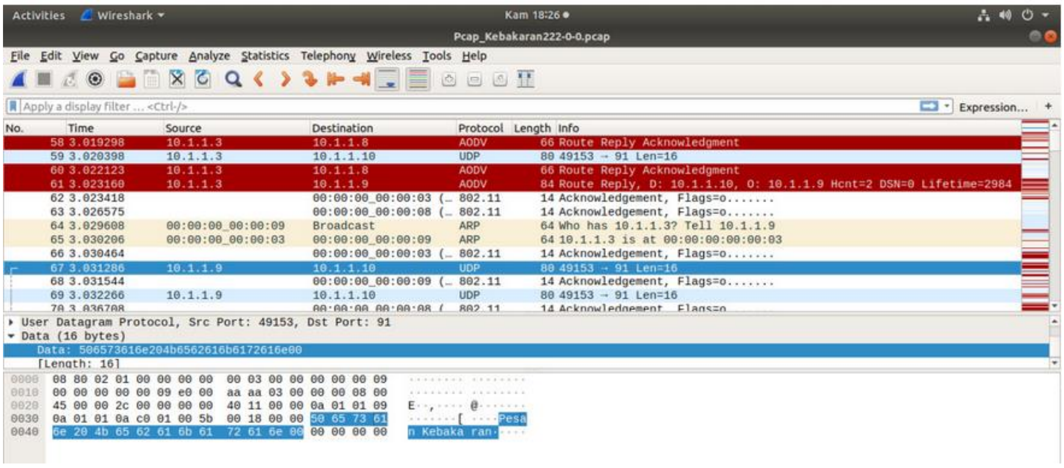
```
No.    Time         Source      Destination   Protocol  Length  Info
   688 549.683999   10.1.1.2    10.1.1.255    AODV      84 Route Reply, D: 10.1.1.2, O: 10.1.1.2 Hcnt=0 DSN=276 Lifetime=2000
   689 550.688999   10.1.1.2    10.1.1.255    AODV      84 Route Reply, D: 10.1.1.2, O: 10.1.1.2 Hcnt=0 DSN=276 Lifetime=2000
   690 551.688999   10.1.1.2    10.1.1.255    AODV      84 Route Reply, D: 10.1.1.2, O: 10.1.1.2 Hcnt=0 DSN=276 Lifetime=2000
   691 552.691999   10.1.1.2    10.1.1.255    AODV      84 Route Reply, D: 10.1.1.2, O: 10.1.1.2 Hcnt=0 DSN=276 Lifetime=2000
   692 553.689999   10.1.1.2    10.1.1.255    AODV      84 Route Reply, D: 10.1.1.2, O: 10.1.1.2 Hcnt=0 DSN=276 Lifetime=2000
   693 553.968000   10.1.1.2    10.1.1.255    AODV      88 Route Request, D: 10.1.1.10, O: 10.1.1.2 Id=277 Hcnt=0 DSN=0 OSN…
   694 554.207000   10.1.1.2    10.1.1.255    AODV      88 Route Request, D: 10.1.1.10, O: 10.1.1.2 Id=278 Hcnt=0 DSN=0 OSN…
   695 554.604000   10.1.1.2    10.1.1.255    AODV      88 Route Request, D: 10.1.1.10, O: 10.1.1.2 Id=279 Hcnt=0 DSN=0 OSN…
   696 555.166000   10.1.1.2    10.1.1.255    AODV      88 Route Request, D: 10.1.1.10, O: 10.1.1.2 Id=280 Hcnt=0 DSN=0 OSN…
   697 555.886000   10.1.1.2    10.1.1.255    AODV      88 Route Request, D: 10.1.1.10, O: 10.1.1.2 Id=281 Hcnt=0 DSN=0 OSN…
   698 556.886000   10.1.1.2    10.1.1.255    AODV      84 Route Reply, D: 10.1.1.2, O: 10.1.1.2 Hcnt=0 DSN=281 Lifetime=2000
   699 557.890000   10.1.1.2    10.1.1.255    AODV      84 Route Reply, D: 10.1.1.2, O: 10.1.1.2 Hcnt=0 DSN=281 Lifetime=2000
   700 558.691999   10.1.1.2    10.1.1.255    AODV      88 Route Request, D: 10.1.1.10, O: 10.1.1.2 Id=282 Hcnt=0 DSN=0 OSN…

▸ Frame 695: 88 bytes on wire (704 bits), 88 bytes captured (704 bits)
▾ IEEE 802.11 Data, Flags: o.......
    Type/Subtype: Data (0x0020)
  ▸ Frame Control Field: 0x0880

0000  08 80 00 00 ff ff ff ff  ff ff 00 00 00 00 00 02   ........ ........
0010  00 00 00 00 00 02 60 2b  aa aa 03 00 00 00 08 00   ......`+ ........
0020  45 00 00 34 02 b6 00 00  05 11 00 00 0a 01 01 02   E··4···· ········
0030  0a 01 01 ff 02 8e 02 8e  00 20 00 00 01 28 00 00   ········ · ···(··
0040  00 00 01 17 0a 01 01 0a  00 00 00 00 0a 01 01 02   ········ ········
0050  00 00 01 17 00 00 00 00                            ········
```

Figure 7. Pcap file node not receiving fire message

The image is a pcap file for the sensor node which is out of reach of other nodes so that the node does not receive any messages.


Activities
Wireshark
Kam 18:26
Pcap_Kebakaran222-0-0.pcap
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>
Expression...

```
No.   Time        Source              Destination             Protocol Length Info
   58 3.019298    10.1.1.3            10.1.1.8                AODV     66 Route Reply Acknowledgment
   59 3.020398    10.1.1.3            10.1.1.10               UDP      80 49153 → 91 Len=16
   60 3.022123    10.1.1.3            10.1.1.8                AODV     66 Route Reply Acknowledgment
   61 3.023160    10.1.1.3            10.1.1.9                AODV     84 Route Reply, D: 10.1.1.10, O: 10.1.1.9 Hcnt=2 DSN=0 Lifetime=2984
   62 3.023418                        00:00:00_00:00:03 (… 802.11   14 Acknowledgement, Flags=o.......
   63 3.026575                        00:00:00_00:00:08 (… 802.11   14 Acknowledgement, Flags=o.......
   64 3.029608    00:00:00_00:00:09   Broadcast               ARP      64 Who has 10.1.1.3? Tell 10.1.1.9
   65 3.030206    00:00:00_00:00:03   00:00:00_00:00:09       ARP      64 10.1.1.3 is at 00:00:00:00:00:03
   66 3.030464                        00:00:00_00:00:03 (… 802.11   14 Acknowledgement, Flags=o.......
   67 3.031286    10.1.1.9            10.1.1.10               UDP      80 49153 → 91 Len=16
   68 3.031544                        00:00:00_00:00:09 (… 802.11   14 Acknowledgement, Flags=o.......
   69 3.032266    10.1.1.9            10.1.1.10               UDP      80 49153 → 91 Len=16
   70 3.036708                        00:00:00_00:00:08 (… 802.11   14 Acknowledgement, Flags=o
▸ User Datagram Protocol, Src Port: 49153, Dst Port: 91
▾ Data (16 bytes)
    Data: 506573616e204b6562616b6172616e00
    [Length: 16]
0000  08 80 02 01 00 00 00 00  00 03 00 00 00 00 00 09   ········ ········
0010  00 00 00 00 00 09 e0 00  aa aa 03 00 00 00 08 00   ········ ········
0020  45 00 00 2c 00 00 00 00  40 11 00 00 0a 01 01 09   E··,···· @·······
0030  0a 01 01 0a c0 01 00 5b  00 18 00 00 50 65 73 61   ·······[ ····Pesa
0040  6e 20 4b 65 62 61 6b 61  72 61 6e 00 00 00 00 00   n Kebaka ran·····
```

Figure 8. Pcap file node receiving fire message

From the two images, it can be seen that nodes connected to other nodes will communicate by sending text messages in the form of "Fire Messages".

3.4 Effect of Number of Iterations on Nodes receiving Fire messages

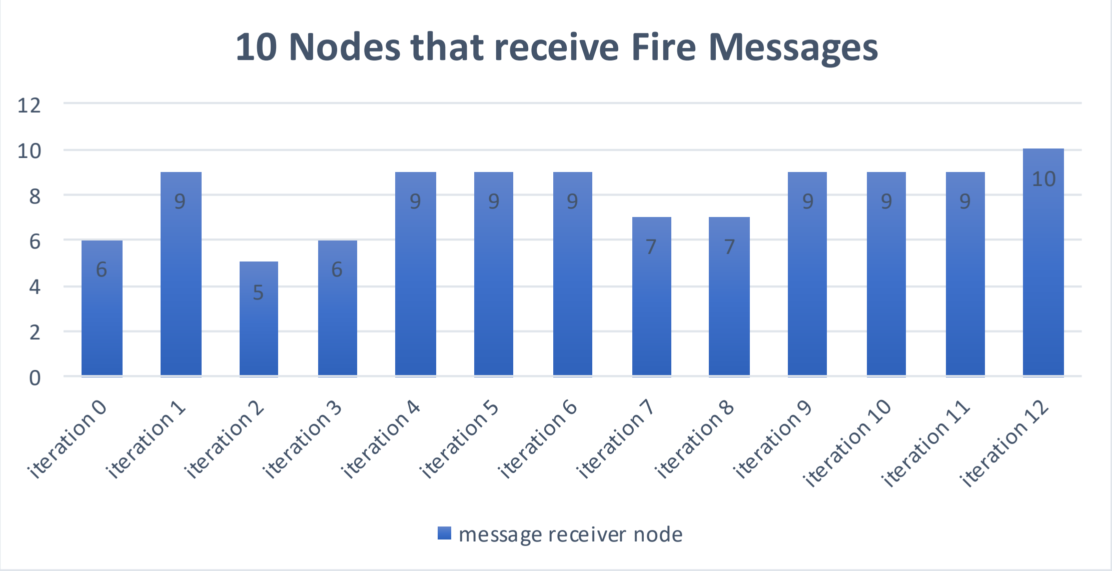


Figure 9 Graph of fire message receiving nodes

From the graph, it can be seen that the number of iterations affects the node that receives the fire message. In the implementation of the simulation in NS3, the distance of nodes that are too far is the main factor that affects node communication, the farther the distance between nodes, the more difficult or even impossible it is to communicate with other nodes. From the diagram, it can be seen that the last iteration, namely the 12th iteration, is the maximum iteration, this is evidenced by the number of nodes that can communicate, all of which are sensor nodes.

4. Conclusion

Based on the research and simulations that have been carried out, the following conclusions can be drawn:

- he sensor node Deployment Simulation process can run well on NS3 on Ubuntu 18.04 Linux Operating System. Simulations are carried out to determine the number of connected sensor nodes so that fire messages can be sent properly. The simulation visualization is shown using the NetAnim application, while the fire message delivery details are shown via a .pcap file.

- In the testing phase, each iteration of data on the PSO will be simulated so that it can be seen the number of nodes that are connected and which are not. The optimal level will be seen from how many nodes are connected in the iteration, the more nodes connected, the more optimal the results in that iteration.

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