

Impact of Evaporation on the Performance of Ant Colony Optimization-Based Routing Protocols on the Wireless Sensor Network

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Abstract. Wireless Sensor Network (WSN) has the characteristics limited computing, memory and energy, so a routing protocol that supports WSN network performance is needed. Routing protocols based Ant Colony Optimization (ACO) are very suitable for use in WSN for routing data packets. In this report, we will try out several kinds of parameter values that bear on the pheromone evaporation (ρ) on the ACO algorithms applied to the WSN routing protocol with grid topology on the number of nodes variables in the WSN network. Where this can increase the number of delivery packets on a busy WSN network and each node transmits a packet continuously. From the results obtained for the number of delivery packets when the value of ρ 0.75 made the WSN performance on a grid topology with 12 nodes managed to send 267 packets more than ρ 0.65 and 88 packets more than ρ 0.7. Likewise with the number of 30 nodes, the value of ρ 0.75 managed to send 4750 packets more than ρ 0.65 and 2586 packets more than ρ 0.7. But for 70 nodes with a value of ρ 0.70 managed to send 3210 packets more than ρ 0.65 and 3984 packets more than ρ 0.75.

Keyword: Wireless Sensor Network, Ant Colony Optimization, Evaporation, Routing

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1 Introduction

Wireless Sensor Network (WSN) consists of two or more sensor nodes that can be applied in various environments. The number of sensor nodes used in the sensing area may be very large. Any routing algorithm must be able to work with that many nodes.[1]

In WSN, reliability and scalability are inversely proportional [2] because the range of a sensor node is limited. The further the distance between the source node and the destination then the more nodes (routers) are required to connect as a hop. The more nodes that are scattered allow many available paths to a destination. If there are many source nodes that send data packets to a destination with great distance, a reliable routing algorithm is needed to route packets to the destination node [3].

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Ant Colony Optimization (ACO) is considered very suitable for use as a routing protocol in WSN because the ACO algorithm is decentralized just like WSN is also decentralized. WSN is more dynamic than cable networks, but nodes can run out of energy, causing path changes. The ACO algorithm has been shown to react quickly to changes in the network because it supports adaptive pathways and multipath routing. [4]

The routing protocol has the main task of ensuring the delivery of data packets (packet delivery) from source to destination. This is the responsibility of routing protocols in finding the optimal path between communicating nodes. [5]

Research [6] proves that ACO-based routing protocols are 90% better than AODV, DSDV, and DSR routing protocols from the packet delivery side of the WSN. The ACO algorithm is inspired by the behavior of ants looking for food. Ants can find the shortest path from the nest to the food source. Ants precursor will release a pheromone on the path through which it passes during the search for food sources. Other ants will follow the path of a high amount of pheromone concentration while also releasing the pheromone too. This pheromone will evaporate over time. If a path is passed a lot of ants, then the concentration of pheromones will not disappear, while the path that is increasingly rarely passed by ants, over time the pheromone concentration in the path will disappear so that no ants will pass again. In this way the shortest path is chosen. [7]

ACO has agents that act as forward ants to gather information and backward ants to update information in the node routing information table. The workings of the ACO-based routing algorithm are initiated by forming forward units to be sent during the process of finding a path to the destination. When the ant forward reaches the destination node, the backward ant will be formed. And before the forward ant is deleted, the information from the forward ant will be transferred to the backward ant first. The backward ant traces the same path as the forward ant, but in the opposite direction going back to the source node from one hop to another hop by adding the number of pheromones in each node. To avoid infinite pheromone accumulation and forget about the selection of unfavorable pathways before, pheromone evaporation [8] is used.

In this experiment, the ACO-based routing protocol used is AntHocNet which is a hybrid algorithm designed based on the ACO routing principle. This algorithm consists of reactive and proactive components. In the reactive phase, when the source node starts communication with the destination node and there is no routing information to the destination node, the source launches an ant agent called reactive forward ant by broadcast to find the path to the destination node while backward ant returns to the source to set the path.

At each node, an ant will broadcast or unicast depending on whether the node has routing information for the destination node. The routing information for node i is represented in T_i its pheromone table. T_{nd}^i is a pheromone value that indicates the estimated goodness of the route i to d through n . If pheromone information is available, the ant will choose next hop n with the probability of P_{nd} calculated by formula 1 [adapted from [9]].

$$P_{nd} = \frac{(T_{nd}^i)^{\beta_1}}{\sum_{j \in N_d^i} (T_{jd}^i)^{\beta_1}}, \beta_1 \geq 1, \quad (1)$$

Where N_d^i is a group of neighbors of i that has a route to d , and β_1 is a parameter value that can decrease the evaporation behavior of ants.

In the proactive phase while the data session is in progress, the path is monitored, maintained, and enhanced using an ant agent called a proactive forward ant. After the proactive ant forward reaches its destination, the backward ant will return to the source to set the path just as the backward ant does in the reactive phase.

AntHocNet also uses hello message to know about its neighbors that are directly connected. And when the node does not receive hello message for a certain period of time, the node removes the neighbor from its list of neighbors and all related entries from its routing table. Then the node broadcasts a link failure notification message. If a link failure is found due to a failed packet sending data, and no other path is available for this packet, the node broadcasts the forward ant for route correction (such as a reactive forward ant) that travels to the node associated with the destination. If there is no backward ant to repair the route received, the node assumes that there is no other path to the destination and discards the data packet (drop packet) [9].

In this experiment the parameters used to optimize the performance of ACO-based routing protocol in the process of updating the pheromone is the rate of evaporation (evaporation rate). The backward ant will update the information table on the routing node. If the pheromone value has evaporated to below the minimum value, the path will be changed according to the new routing path of the new pheromone value collected by the ant. Pheromone values are stored in the node's memory to be used as information to send or forward packets to neighboring nodes. Pheromone evaporation can be calculated by formula 2 [adapted from [8]].

$$\tau_{ij} \leftarrow (1 - \rho) * \tau_{ij} \quad (2)$$

Where τ_{ij} is the pheromone value and ρ is the parameter value in the pheromone evaporation which ranges from $0 < \rho < 1$. [8]

In experiment [10], the value of ρ is 0.7 in AntHocNet compared to ANSI, AODV and OLSR, where the results AntHocNet can deliver data packets more than 70% better than the comparative routing protocol. Whereas in research [7] states the optimal value ρ of ACO is around 0.7 in the feature selection and classification problem. So in this experiment WSN performance will be tested with the AntHocNet routing protocol on several variants of ρ value with grid topology and variations in the number of nodes. Difference variation ρ values of 0.05 are expected to have a clear impact on the evaporation of pheromones which will change the WSN performance in terms of energy consumption and packet delivery.

2 Methods

The first steps taken in this experiment are the configuration stage, this is where the AntHocNet routing protocol configuration is set in the simulator, and testing is done whether it is running properly. Then at the simulation stage, the simulation will be carried out in the WSN environment with a grid topology at 12, 30, and 70 nodes. At each node, the WSN will be built using the value of the pheromone evaporation parameter ρ of 0.65, 0.70 and 0.75, respectively. It is at this stage that the calculation of pheromone evaporation occurs so that it has an impact on the amount of packet delivery and energy consumption of WSN. Then at the end of this stage, each run simulation will generate a trace file (file.tr). Then at the calculation stage of the performance value, the trace files that have been obtained will be filtered using the NS2 visual trace analyzer to get the packet delivery value and will then be filtered using the AWK script to get the energy consumption value of each number of nodes and the pheromone evaporation parameter value.

In the comparison stage of performance values, packet delivery and energy consumption values of each number of nodes and the pheromone evaporation parameter values have been obtained from the previous stage will be compared. While the final stage that will be done is to analyze the results of the comparison in terms of energy efficiency and packet delivery. The steps worked on the study are presented in figure 1.

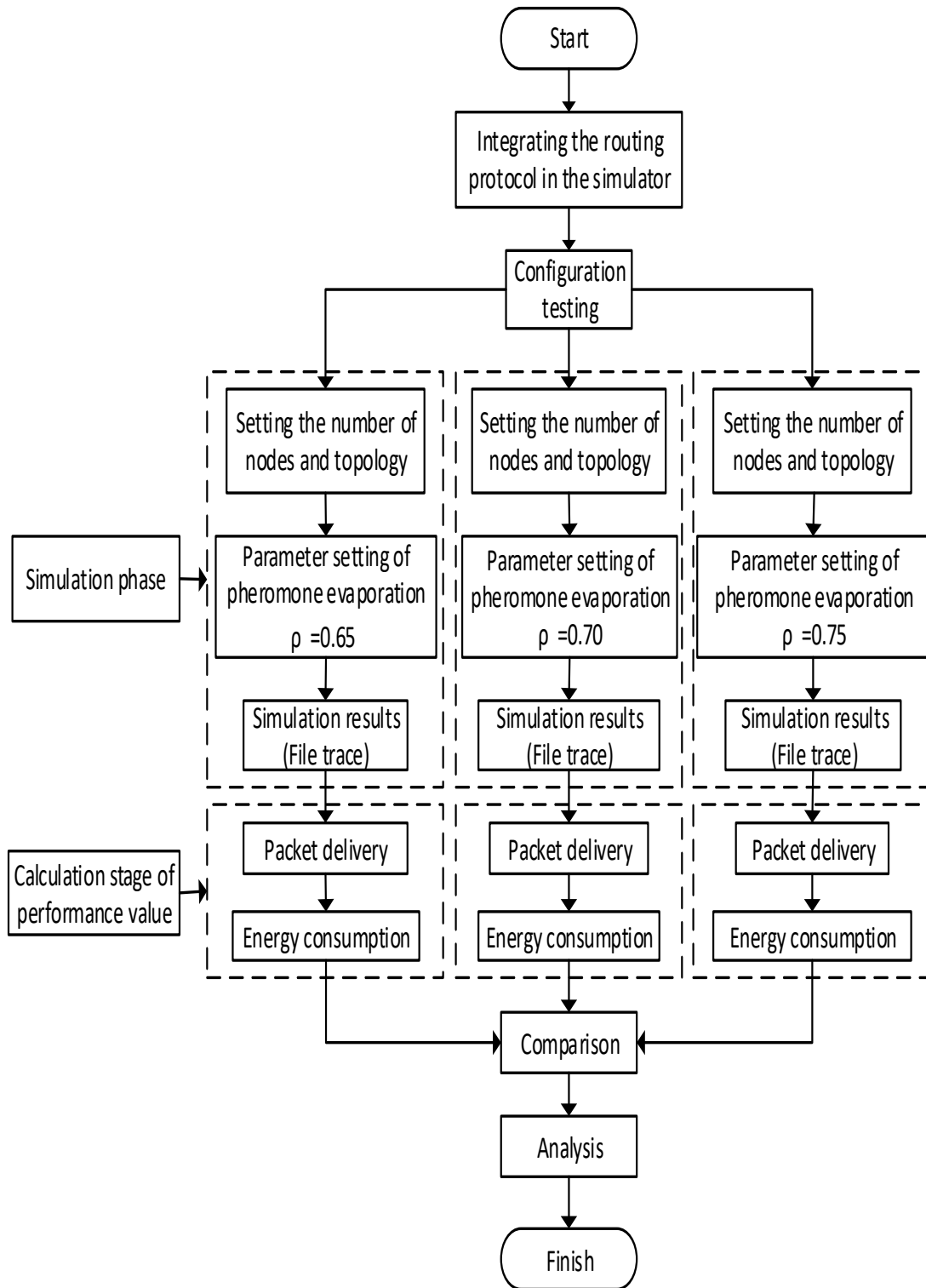


Figure 1. Research workflow

This experiment will compare several variants of the pheromone evaporation parameter values in the grid topology with varying number of nodes. The results of this comparison will be used to see the impact of evaporation in ACO-based routing protocols on WSN performance in terms of packet delivery and energy consumption.

The simulation in this experiment uses NS2 Simulator to see WSN performance with changes in ρ values ranging from 0.65, 0.7, and 0.75. WSN simulation is executed by applying the ACO-based routing protocol that is AntHocNet and 802.11 MAC protocol in WSN networks with an area of 200 x 200 m² grid topology using 12, 30, and 70 nodes. As shown in figures 2, 3 and 4.

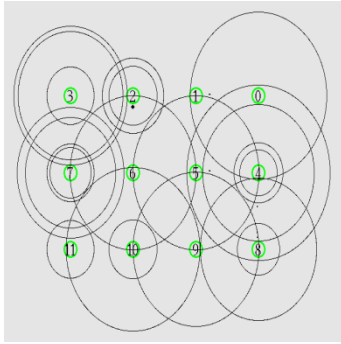


Figure 2. Display of 12 nodes

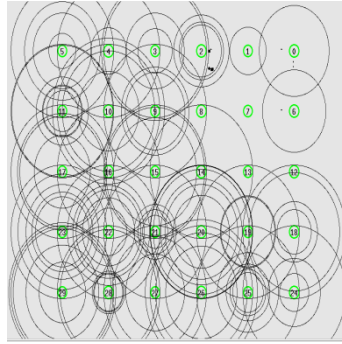


Figure 3. Display of 30 nodes

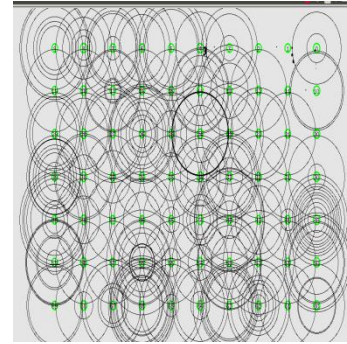


Figure 4. Display of 70 nodes

In figure 2, 3 and 4 it can be seen that the simulated grid topology has the condition of the nodes that are connected to the neighbors of at least 2 neighboring nodes and at most 4 neighboring nodes depending on where the node is located. Each simulation is run, the condition of each node sends data packets continuously using the parameters described in table 1.

Table 1. Simulation Parameters on the WSN Network

Parameter	Value
Simulator version	NS 2.35
Channel Type	Channel/Wireless Channel
Routing Protocol	Anthocnet
Propagation Model	Propagation/TwoRayGround
MAC Protocol Type	MAC 802.11
Packet Type	Udp
Traffic Type	Cbr
Area	200m x 200m
Simulation Time	40 (Seconds)
Antenna Type	Omni
Energy Model	Energy
Initial Energy	70 joules
Tx Power	1
Rx Power	1
Interface Type	Wireless
Packet Size	512 byte

3 Results

In this experiment the number of packets delivery and energy consumption in each simulation were compared to study the effect of the values of ρ 0.65, 0.70 and 0.75 on the speed of route changes in the ACO-based routing protocol on WSN with a grid topology of 12, 30 and 70 nodes.

3.1 Packet Delivery

Packet delivery is the number of data packets received by the receiving node. The higher value of the packet's delivery reflects that the network performance is getting better. All nodes in the grid topology 12, 30, and 70 nodes send packets continuously to one destination node, namely the sink node, so that in this experiment the WSN network condition will be busy and congested. In this experiment the results of the simulation are filtered in the form of a trace file using the NS2 Visual Trace Analyzer application to obtain the value of the packet's delivery.

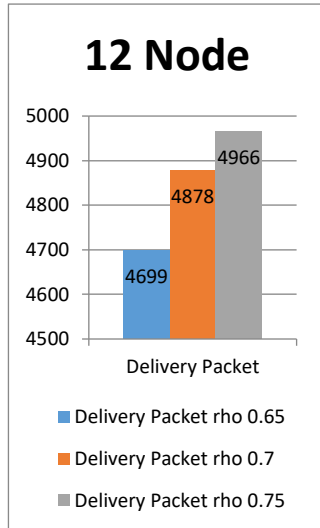


Figure 5. Chart of packet delivery for 12 nodes

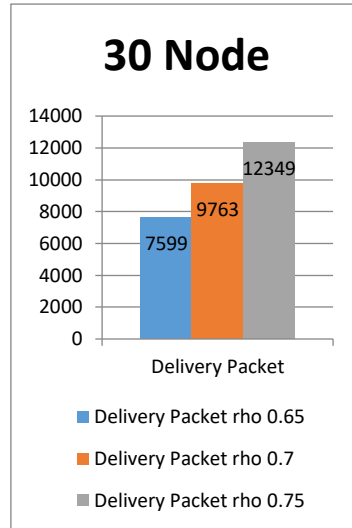


Figure 6. Chart of packet delivery for 30 nodes

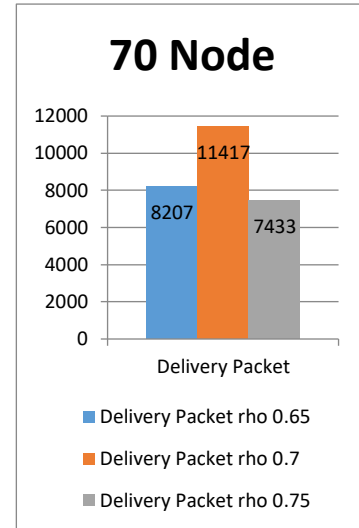


Figure 7. Chart of packet delivery for 70 nodes

In figure 5, WSN performance in 12 node grid topology has a higher number of packet delivery when the value is ρ 0.75. Then in figure 6 it can be seen that WSN performance in the 30 node grid topology has a higher number of packet delivery when the value of ρ is 0.75. Whereas in figure 7, the WSN performance in the 70 node grid topology has a higher number of delivery packs when the ρ value is 0.7.

3.2 Energy Consumption

Energy consumption is the amount of energy used by nodes to operate according to their duties in the WSN network. In this experiment, the initial energy at each node is 70 joules. The simulation results are in the form of a filtered file using the AWK script to get the energy consumption results for each node and the total energy consumption in the simulation.

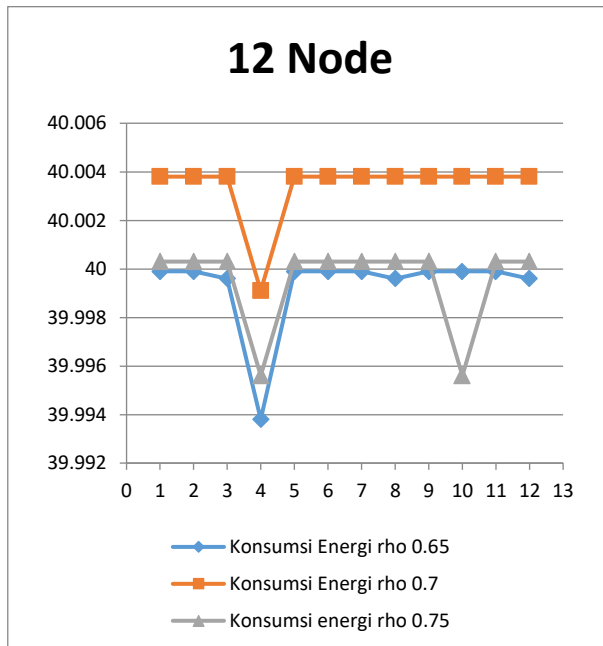


Figure 8. Graph of energy consumption for each node in WSN with 12 nodes

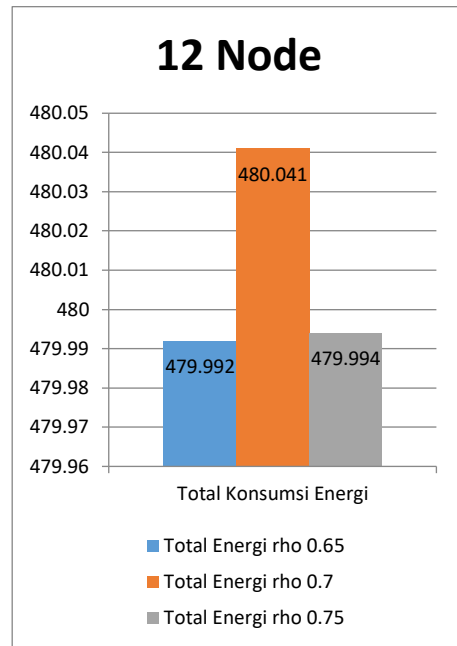


Figure 9. Chart of total energy consumption in WSN with 12 nodes

From figure 8 and 9, it can be seen that when the value of ρ 0.65, WSN work in a 12 node grid topology can consume less energy so that it has higher energy efficiency.

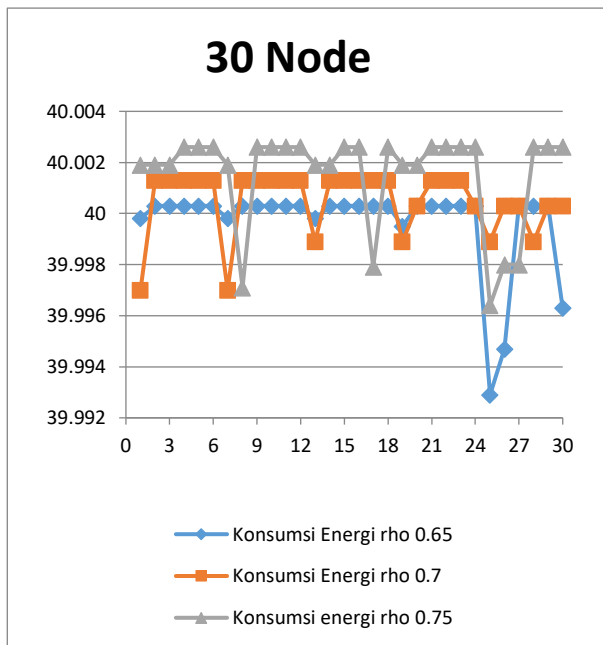


Figure 10. Graph of energy consumption for each node in WSN with 30 nodes

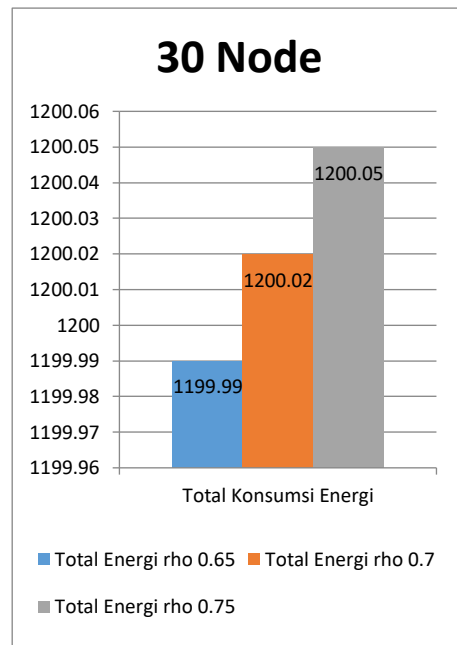


Figure 11. Chart of total energy consumption in WSN with 30 nodes

Then from figure 10 and 11 can be seen when the value of ρ 0.65, WSN work in a 30 node grid topology can also consume less energy so that it has a higher energy efficiency.

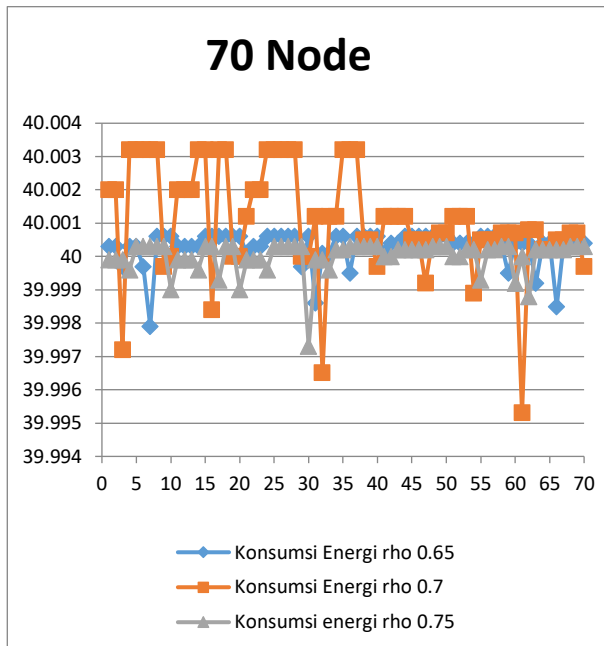


Figure 12. Graph of energy consumption for each node in WSN with 70 nodes

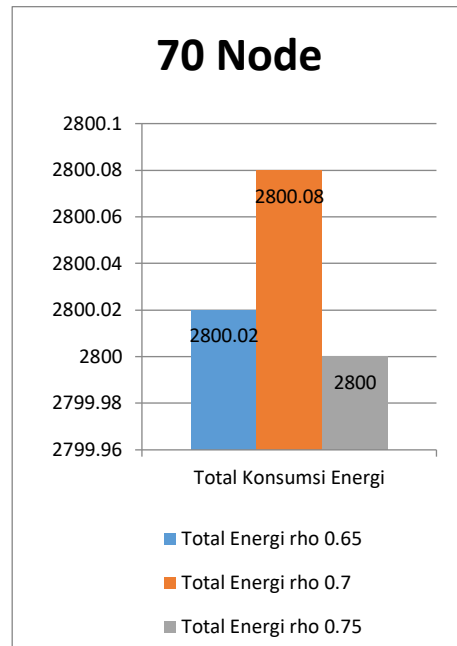


Figure 13. Chart of total energy consumption in WSN with 70 nodes

Whereas the figure 12 and 13 are seen when the value of ρ 0.75, WSN work in a 70 node grid topology can consume less energy so that it has higher energy efficiency.

4 Discussion on Simulation

In this experiment the WSN network uses ACO-based routing protocols on the grid topology with the number of nodes 12, 30, and 70 which are tested with ρ values varying from 0.65, 0.70 to 0.75. The results of each simulation will be compared based on the value of the parameter ρ which influences the performance of the pheromone evaporation to see the WSN performance in each simulation in terms of the packet's delivery and the energy efficiency whether it is better (B), good (G) or not good (N). In terms of packet delivery, B means the most number of packets sent, N means the least number of packets sent, while G means the number of packets sent is more than N but less than B. Whereas in terms of energy efficiency, B means the least amount of energy consumption, N means the most amount of energy consumption, while G means the amount of energy consumption is less than N but more than B. This comparison of WSN performance is presented in table 2.

Table 2. Comparison of WSN Performance Based on Pheromone Evaporation Parameter Values

Performance measure	Values								
	12 Nodes			30 nodes			70 nodes		
	Value ρ			Value ρ			Value ρ		
	0.65	0.70	0.75	0.65	0.70	0.75	0.65	0.70	0.75
Packet delivery	N	G	B	N	G	B	G	B	N
Energy Efficiency	B	N	G	B	G	N	G	N	B

With a small value of ρ will make pheromone evaporation (evaporation) become faster and the change of path will also occur faster. But because the path changes that are too fast to make the routing information collected by the ants is not too optimal to get the optimal path.

While with the slow evaporation, the routing information collected by ants is more optimal. This will make a path is considered optimal based on sufficient routing information. Therefore the path chosen with the small number of nodes (12 nodes) and the medium (30 nodes) with a value of ρ 0.75 can produce a better number of packets delivery.

Meanwhile, on the large number of nodes (70 nodes) with grid topology, making the number of hops and the choice of paths to get to the destination node, thus making the WSN network time-consuming in determining the optimal path. Because there will often be path changes to get the optimal path. In this condition, the correct evaporation value is needed so that the moment of path change is appropriate to support the condition of the WSN network in terms of packet delivery.

And then for energy efficiency in grid topology network conditions with a small number of nodes (12 nodes) and moderate (30 nodes) it is better to use a small value on ρ , whereas a large number of nodes (70 nodes) is better if using a large ρ .

5 Conclusion

Based on the results of experiments conducted, it can be concluded that the pheromone evaporation parameter ρ influences WSN performance in terms of the number of packet delivery. The greater value of ρ , the more number of packet delivery for WSN networks with grid topology with a small to medium number of nodes. But for many nodes, the greater ρ does not always affect the number of packet delivery because here has a large number of hops too. And from the simulation results on WSN with a 12 node grid topology, it can be seen that with the right value of ρ (0.75) can improve WSN performance from the packet delivery side with good energy efficiency. So that it can be said with path changes that are too fast to make the collection of routing information is not optimal. So it can be said that the performance of WSN with ACO-based routing protocols can be affected by the events of route changes at the right time (the correct ρ value) and of course also considering the type of topology as well as the number of nodes used.

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