Implementation of the Friis Free Space Propagation Model in the Dynamic Source Routing (DSR) Routing Protocol in the Vehicular Ad-hoc Network (VANET) with Variations of Road Models

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Abstract. The use of VANET technology is to create better traffic management. Different road conditions and high mobility of vehicles cause problems in VANET such as efficient search processes, network routes that need to be maintained, and data transmission problems. DSR (Dynamic Source Routing) predefines and generates routes on demand and is designed to work on multihop ad-hoc networks without centralized control. The Friis Free Space propagation model is used to model the Line of Sight (LOS) that occurs in a free space environment. The variation of road models in Indonesia is grouped into four groups, namely express roads, intercity roads, urban roads, and residential roads. In each of these road models, simulation testing is carried out based on different vehicle number scenarios. Network Simulator v3.27 (NS-3.27) and SUMO as a mobility generator were used for the simulation. The parameters of average throughput, packet delivery ratio and MAC/PHY overhead sequentially measure the DSR performance. The results on the express roads with Friis Free Space propagation produce values of 6.52 KBps, 7.71%, 39.59 KBytes. Test results on intercity roads 5.72 KBps, 11.17%, 5.48 KBytes. Test results on urban roads 16.50 KBps, 32.22%, 0.0016 KBytes. While the test results on residential roads were 12.66 KBps, 24.72%, 0.779 KBytes. The test results show that the road model in Indonesia with the performance of the DSR routing protocol with Friis Free Space propagation on the VANET network from the best to the worst, respectively, is the urban road model, residential road model, intercity road model, and express road model.

1. Introduction
The use of the Intelligent Transportation System (ITS) is a form of overcoming this problem because it can reduce the level of congestion and accidents on the road. ITS uses hardware and software from existing information and communication technology [1]. One of the technologies used is the VANET (Vehicular Ad-Hoc Network) which includes a network of nodes in the form of vehicles with mobility. VANET is a part of MANET (Mobile Ad-Hoc Network) [1].

Different road conditions and high mobility of vehicles cause problems in VANET such as efficient search processes, network routes that need to be maintained, and data transmission problems. To overcome this problem, a good routing algorithm is needed to make good use of the VANET network. DSR (Dynamic Source Routing) predefines and generates routes on demand and is designed to work on multihop ad-hoc networks without centralized control. The DSR protocol includes two main mechanisms, namely the route discovery mechanism and the mechanism for route maintenance [2].
research that for the parameters of throughput, packet delivery ratio, packet loss, delay, and collision rate in general when compared to TORA routing the performance of DSR routing is better [3].

For data transmission problems, a good propagation model is needed to support the performance of the DSR routing protocol which is good and under the VANET network, so the Friis Free Space propagation model will be implemented which is used to model the Line of Sight (LOS) that occurs in a free space environment, in the absence of an object that creates absorption, diffraction, reflection, or any other phenomenon that converts other characteristics into emitted waves. In researching the VANET network with AODV routing using the Friis Free Space and Two Ray Ground propagation models, the results show that the Friis Free Space propagation model is superior by having a smaller delay time and the number of packets received more [4].

This research uses the Friis Free Space propagation model which is applied to the DSR algorithm which will be simulated on the VANET network using Network Simulator v3.27 and SUMO with variations in road models in Indonesia. Quality of Service will be the test parameter used for the performance of the DSR routing protocol on the Friis Free Space propagation model in each road model.

The Friis Free Space propagation model will have an impact on the performance of the DSR routing protocol because DSR is a reactive routing protocol just like AODV. The denser and faster the movement of nodes will increase the influence of the Friis Free Space propagation model on the DSR routing protocol, and conversely, the denser and faster the movement of nodes will reduce the influence of the Friis Free Space propagation model on the DSR routing protocol.

2. Literature review

In this research, the AODV routing protocol is based on a variety of road models and uses the parameters of average throughput, packet delivery ratio, and end-to-end delay respectively to measure AODV performance. The results show that the performance of the AODV routing protocol on the VANET network is influenced by variations in road models. The performance of AODV will be better if the vehicle speed is low and there are many roads [1]. The equation with this research is carried out on VANET, and in the research that will be carried out using the Friis Free Space propagation model in the DSR routing protocol.

In research that uses the TORA, DSR, and AODV routing protocols with changes in the number of nodes and node speed. The results show that for conditions where the packet transfer side, with a small number of nodes, the DSR protocol can produce the best performance on the network [5]. The equation with this research is carried out on VANET, and the research that will be carried out uses the Friis Free Space propagation model in the DSR routing protocol, as well as the research focus on the propagation model.

In research using the DSR and AODV routing protocols based on urban-type cars. The results of the DSR routing protocol are superior to be applied to VANETs in urban environmental scenarios using urban-type cars compared to the AODV routing protocol [6]. The equation with this research is carried out on VANET, and the research that will be carried out uses the Friis Free Space propagation model in the DSR routing protocol, focuses on the propagation model, and uses a variety of road models in Indonesia.

2.1 Vehicular ad-hoc network (VANET)

VANET is a network of autonomous vehicles and roadside infrastructure that continuously communicate with each other via Dedicated Short-Range Communication (DSRC) channels. VANET is a type of MANET with several different features. VANET’s distinctive features include. high mobility, constant change, time-critical, no power constraints, large network size, and variable network density [7]. As mentioned earlier, the VANET system consists of a vehicle and a Road Side Unit (RSU). This Fig. shows a continuous exchange of information between vehicles and towers (RSU) [8].
Routing protocols for ad-hoc networks have been studied extensively in the last few decades. Many ad-hoc routing protocols have been designed, developed, and tested with MANET for various scenarios. Since VANET is a type of MANET, the routing protocols used in MANET are also assessed and evaluated for implementation on VANETs as well. Based on this method of updating the routing protocol routes and position estimates, routing protocols have been divided into five different categories [9].

### 2.2 Dynamic source routing (DSR)

The DSR protocol has two main options in the routing process, namely, route discovery and route maintenance [10]. Route discovery occurs when the originating node sends a packet to the destination node, then the origin node first looks at its routing table. The origin node will broadcast the packet route request if the route to the destination node is not in its routing table. This packet route request consists of the destination node address, origin node address, and ID. Other nodes will see their routing table if they receive a route request packet. The node will add its address to the packet if it does not know the address of the destination node, then forwards it. When the route to the address of the destination node is known or another node knows that information in its routing table, it generates a route reply. The packet route reply will be delivered by the node to the nearest node until it reaches the origin node [11]. This process is shown in Figure 1.

![Figure 1. Route discovery process](image1)

![Figure 2. Route maintenance process](image2)

Route maintenance includes packet route errors and acknowledgments (acks) which will work when the packets sent are damaged or even lost data. At this level, the receiving node will send a packet route error to the first sending node if the MAC Layer reports a transmission failure [12]. This process is shown in Figure 2.

### 2.3 Friis free space propagation model

The Friis Free Space propagation model is used to model the Line of Sight (LOS) that occurs in a free space environment, in the absence of objects that create absorption, diffraction, reflection, or other phenomena that change other characteristics into emitted waves. This only applies in the far-field region of the transmitting antenna and is based on the inverse square law of distance which states that the power received at a certain distance from the transmitter decays by a factor of the distance squared [13].

The Friis Free Space propagation equation where \( P_r \) is the received signal power in Watts which is expressed as a function of the separation distance \( d \) meters between the transmitter and receiver, \( P_t \) is the power of the transmitted signal in Watts, \( G_t \) and \( G_r \) is the advantage of the transmitting antenna and the receiver when compared to an isotropic radiator with unit gain, \( \lambda \) is the carrier wavelength in meters and \( L \) represents another loss not related to propagation loss. Parameters \( L \) can include system losses such as antenna losses, transmission line attenuation, losses in various filters, etc. The factor \( L \) is usually greater than or equal to 1 with \( L = 1 \) for the absence of a loss in the system [14]. Friis Free Space is shown in equation 1.

\[
P_r(d) = P_t \cdot \frac{G_t G_r \lambda^2}{(4\pi d)^2 L}
\]
2.4 Road model in Indonesia
In the Regulation of the Minister of Transportation of the Republic of Indonesia Number PM 111 of 2015 concerning Procedures for Determining Speed Limits, Article 3 Paragraph 2 and Article 3 Paragraph 4 explains that there are four variations of road models based on applicable vehicle speed regulations [15]. Express roads or better known as toll roads with a minimum speed rule of 60 km/hour and a maximum speed of 100 km/hour which generally have 3-4 lanes on each lane. Intercity roads are roads with a maximum speed rule of 80 km/hour that usually have 1-3 lanes in each lane. Urban roads are roads with a maximum speed rule of 50 km/hour which usually have 1-3 lanes on each lane. Residential area roads are roads with a speed rule of 30 km/hour which generally have 1-2 lanes on each lane.

3. Methodology

3.1 Requirements engineering
This research requires data in the form of a road model map in Indonesia to carry out the design by taking data from OpenStreetMap and then generating it. The following road model will be used
- Express Road
- Intercity Road
- Urban Road
- Residential Road

Data for testing in this research are also needed in addition to data for design. The required data, such as average throughput, packet delivery ratio, and MAC / PHY overhead. It will be taken from each test carried out in the form of test result data. Furthermore, the test data will be analyzed to obtain research results.

3.2 Design
The network connection used is wireless where each node can be connected using an OBU (On-Board Unit) using the Dynamic Source Routing routing protocol and the Friis Free Space propagation model as shown in Figure 3.

![Figure 3. VANET architecture](image)

The simulation design used in this research is constant or constant, where all the values and parameters used are the same for each scenario to be run. So that it is expected to get the appropriate results. The following is a simulation design shown in Table 1.
3.3 Evaluation methods
Simulation testing is done by running several program test scenarios using the DSR routing protocol on the VANET network against the Friis Free Space propagation model. The test is carried out by increasing the number of vehicle nodes in each of the variations in the road model shown in Table 2.

### Table 1. Parameter simulation

| Parameters                  | Values                                      |
|-----------------------------|---------------------------------------------|
| Network Simulator           | NS-3.27                                     |
| Routing Protocol            | DSR                                         |
| Propagation Model           | Friis Free Space and Two Ray Ground         |
| Network Interface           | Wireless                                    |
| MAC Type                    | 802.11p                                     |
| Data Type                   | UDP (CBR)                                   |
| CBR rate measure            | 256 Kb                                      |
| Vehicle Mobility            | Random Way Point                            |
| Testing Time                | 30 second                                   |
| Start Time                  | On 0,1th                                    |
| Area                        | 10000m x 10000m                             |

### Table 2. Testing scenario

| Scenario     | Number of nodes | Description                  |
|--------------|-----------------|------------------------------|
| Scenario 1   | 100 node        | Representing the quiet traffic|
| Scenario 2   | 200 node        | Represents normal traffic    |
| Scenario 3   | 300 node        | Represents heavy traffic     |

### Table 3. Testing parameters

| Parameter                  | Description                                                                 |
|----------------------------|-----------------------------------------------------------------------------|
| Average Throughput         | The average speed of successful data transmission packets sent from the origin node to the destination node in a certain time unit |
| Packet Delivery Ratio      | The ratio between the number of packets received and packets sent from the origin node to the destination node in percent |
| MAC/PHY Overhead           | Routing packets that are sent in the network                                 |
3.4 Implementation
The realization of the system design and implementation environment uses a simulation by creating a DSR algorithm script then applied to VANET using the NS3 and SUMO simulators. Furthermore, making the Friis Free Space propagation model script which is then applied to the DSR in VANET. The VANET network is created based on the conditions resulting from the resulting variation of road models in Indonesia using SUMO with different vehicle node densities.

Simulation results with a time of 30 seconds using the DSR protocol without the Friis Free Space propagation model. Data packets will be sent from one node to another with each node moving at a speed under applicable road rules. The results can be seen in the form of cmd and netanim in Figure 4 and Figure 5.

![Figure 4. DSR with Friis Free Space Propagation in cmd](image1)

![Figure 5. DSR with Friis Free Space Propagation in netanim](image2)

4. Result and discussion

4.1 Average throughput

| Table 4. Average Throughput with Friis free space propagation |
| Node | ER | IR | UR | RR |
|------|----|----|----|----|
| 100  | 3.7491 | 2.5269 | 15.624 | 7.5478 |
| 200  | 7.9354 | 7.3001 | 16.284 | 12.403 |
| 300  | 7.8709 | 7.3331 | 17.589 | 18.019 |
| Avg  | 6.5185 | 5.7200 | 16.499 | 12.656 |

In Table 4 the high to low Throughput values are the urban road model (UR) 16.50 KBps, the residential road model (RR) 12.66 KBps, the express road model (ER) 6.52 KBps, and finally the intercity road model (IR) 5.72 KBps.
Average Throughput without Friis Free Space propagation for node changes in Figure 6 shows that as the number of nodes increases, the average throughput value also increases. This shows that increasing the number of nodes improves network performance. This can happen because the addition of nodes on the same road conditions will improve communication so that data transmission can be faster and does not burden network bandwidth and overall vehicle mobility is good. In the urban road (UR) model, it can be seen that the resulting average throughput value is random. In the simulation with the number of 200 nodes is higher (better) than the simulation of 100 nodes and 300 nodes. This can happen because there is a simulation with bad results which affects the average value, and the distance between the sending node and the receiving node is quite far, while between the two nodes there are almost no other vehicles as hop nodes that can be reached.

Average Throughput with Friis Free Space propagation for node changes in Figure 7 shows that the model of express roads (ER), intercity roads (IR), urban roads (UR), and residential roads (RR), it can be seen that as the number of nodes increases, the average throughput value also increases. This shows that increasing the number of nodes improves network performance. This can happen because the addition of nodes on the same road conditions will improve communication so that data transmission can be faster and does not burden network bandwidth and overall vehicle mobility is good.

Overall, in each road model, the throughput value has increased because it uses the Friis Free Space propagation model which optimizes data transmission so that data is faster from the origin node to the destination node.
4.2 Packet delivery ratio

| Node | ER  | IR  | UR  | RR  |
|------|-----|-----|-----|-----|
| 100  | 7.1935 | 4.9354 | 30.516 | 14.741 |
| 200  | 7.9032 | 14.258 | 31.806 | 24.225 |
| 300  | 7.9032 | 14.322 | 34.354 | 35.193 |
| Avg  | 7.7096 | 11.172 | 32.220 | 24.720 |

It can be seen from Table 5 that the high to low PDR values are the urban road model (UR) 32.22%, the residential road model (RR) 24.72%, the intercity road model (IR) 11.17%, and finally the express road model (ER) 7.71%.

PDR without Friis Free Space propagation for node changes in Figure 9 shows that the model of express roads (ER), intercity roads (IR), and residential roads (RR) can be seen that as the number of nodes increases, the PDR value also increases. This shows that increasing the number of nodes improves network performance. This can happen because the addition of nodes on the same road conditions will improve communication so that the ratio of successful data transmission is high and does not burden network bandwidth and overall vehicle mobility is good. In the urban road model (UR), it can be seen that the resulting PDR value is random. In the simulation with the number of 200 nodes is higher (better) than the simulation of 100 nodes and 300 nodes. This can happen because...
there is a simulation with bad results which affects the average value, and the distance between the sending node and the receiving node is quite far, while between the two nodes there are almost no other vehicles as hop nodes that can be reached.

PDR with Friis Free Space propagation for node changes in Figure 10. In the model of express roads (ER), intercity roads (IR), urban roads (UR), and residential roads (RR) it can be seen that as the number of nodes increases, the PDR value also increases. This shows that increasing the number of nodes improves network performance. This can happen because the addition of nodes on the same road conditions will improve communication so that the ratio of successful data transmission is high and does not burden network bandwidth and overall vehicle mobility is good.

Overall, in each road model, the PDR value has increased because it uses the Friis Free Space propagation model which optimizes data transmission so that the successful data transmission ratio is high from the origin to the destination node.

4.3 MAC/PHY Overhead

Table 6. Mac/phy overhead with friis free space propagation

| Node | BH   | AK     | PK    | PM    |
|------|------|--------|-------|-------|
| 100  | 67.674 | 12.317 | 0.20750 | 2.6613 |
| 200  | 31.633 | 2.8715 | 0.0005493 | 0.0005202 |
| 300  | 19.467 | 1.2572 | 0.0006516 | 0.0006793 |
| Avg  | 39.591 | 5.4822 | 0.0015979 | 0.77855 |

It can be seen from Table 6 that the low to high overhead values are the urban road model (UR) 0.0016 KBytes, the residential road model (RR) 0.779 KBytes, intercity road model (IR) 5.48 KBytes, and finally the express road model (ER) 39.59 KBytes.
MAC/PHY without Friis Free Space propagation for node changes in Figure 12 shows that the model of express roads (ER), intercity roads (IR), urban roads (UR), and residential roads (RR), it can be seen that as the number of nodes increases, the overhead value also decreases. This shows that increasing the number of nodes improves network performance. This can happen because the addition of nodes on the same road conditions will improve communication so that it does not burden network bandwidth and overall vehicle mobility is good.

MAC/PHY with Friis Free Space propagation for node changes in Figure 13 shows that the model of express roads (ER), intercity roads (IR), urban roads (UR), and residential roads (RR), it can be seen that as the number of nodes increases, the overhead value also decreases. This shows that increasing the number of nodes improves network performance. This can happen because the addition of nodes on the same road conditions will improve communication so that it does not burden network bandwidth and overall vehicle mobility is good.

Overall, in each road model, the overhead value has decreased because it uses the Friis Free Space propagation model which optimizes data transmission thereby reducing network load when the originating node is routing to the destination node.

5. Conclusion

5.1 Conclusion
Based on the analysis that has been done, according to the formulation of the problem, several conclusions are obtained.

- Implementation of the DSR routing protocol on VANET networks on express roads, intercity roads, urban roads, and residential roads is affected by changes in the number of nodes. The more the number of nodes, the better the performance of the DSR protocol, and conversely the fewer the number of nodes, the lower the DSR performance.

- The implementation of the Friis Free Space propagation model affects the DSR routing protocol on the VANET network with a variety of road models in Indonesia, including residential road models, urban road models, intercity road models, and express road models. Friis Free Space can improve DSR performance on the network on VANET.

- The results on the express roads with Friis Free Space propagation produce values of 6.52 KBps, 7.71%, 39.59 KBytes. Test results on intercity roads 5.72 KBps, 11.17%, 5.48 KBytes. Test results on urban roads 16.50 KBps, 32.22%, 0.0016 KBytes. While the test results on residential roads were 12.66 KBps, 24.72%, 0.779 KBytes. The DSR performance with Friis Free Space will get better when the vehicle speed is low or more roads are formed.
5.2 Future research
Suggestions for further research include:
- Implement the DSR routing protocol and the Friis Free Space propagation model in real-time.
- Make tests with a longer simulation time so that they get more accurate results.
- Discusses the security problems that occur in the DSR protocol and the Friis Free Space propagation model.

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