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Optimization of the 5G VANET Routing Protocol On AODV Communication with Static Intersection Node

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***Abstract* — The integration of 5G and VANET will result in an intelligent transportation system. Relay of 5G data from mobile networks to VANET which is greatly underutilized can reduce the burden on mobile networks. Wireless technology has been used in vehicles or better known as the Vehicular Ad hoc Network (VANET). One of the keys to the success of sending data on VANET is the Path Selection Algorithm which is the task of the routing protocol. The routing protocol that is widely used in research in the VANET environment is AODV (Adhoc On-Demand Distance Vector), because among other protocols, AODV is the most suitable and suitable for implementation in the VANET environment, and AODV is also one of the reactive routing protocols. This study includes an increase in the performance of a routing protocol, so in this study, the SIN (Static Intersection Node) is added to the RSU (Road-Side Unit) which is located at an intersection. Which functions as a repeater that helps send data packets to other vehicles around it so that it can increase the Packet Delivery Ratio and minimize Packet Loss and End to End Delay. The focus of this research is to determine the most ideal Static Intersection Node position as well as the most effective number of Static Intersection Nodes.**

Keywords—5G, vehicular ad hoc networks (VANETs), Adhoc On-Demand Distance Vector (AODV), static intersection node (SIN)

I. INTRODUCTION

The development of computer and cellular network technology has direct implications for the development of 5G cellular technology which aims to make cellular communication faster and more reliable as more and more devices go online. And this is stated as internet technology with speed 10 times faster than 4G [1], [2], even faster than the internet network that most people get from a cable broadband connection. It's easy to talk about how much the 5G internet will change the world, such as the more enjoyable VR and AR experiences, holographic phone calls, interconnected smart cities, etc. However, to understand how fast a 5G network [1].

The research carried out certainly gets several problems and challenges that need attention, first is the damage to the communication line due to nodes that are constantly moving in and out of the network. It is difficult to maintain a route due to changes in topology and changing vehicle density [3]. This can result in lower throughput and higher routing overhead. There is a hidden terminal problem, which is a problem that arises if there are terminals or nodes that are outside the reach of several other nodes. A hidden terminal can cause a low data packet reception centre [4]. Tall buildings in urban areas can also cause interference, such as routing loops and sending data in the wrong direction, which can increase the delay. Besides, the routing protocol must also pay attention to the type of application on the VANET. Traffic safety applications require a routing protocol capable of guaranteeing strict time delays [5].

One of the keys to the success of sending data on a VANET is the Path Selection Algorithm which is the task of the routing protocol. The routing protocol that is widely used in research in the VANET environment is AODV (Adhoc On-Demand Distance Vector), because among other protocols, AODV is the most suitable and suitable for implementation in the VANET environment, and AODV is also one of the reactive routing protocols [6]. In this protocol, to find out the path to the receiver or what is often called Path Discovery, using the Route Request and Route Reply mechanisms. The Route Request mechanism is used to find a path to the recipient, while Route Reply is used to send information on the path that Route Reply has taken to arrive at the recipient. So that the sending vehicle can find out which vehicles/paths the transmitted data passes [6]. To increase the success of sending data packets, this research uses Static Intersection Node. The Static Intersection Node is a Roadside Unit at a road junction. The purpose of the Static Intersection Node is to improve the performance of the AODV protocol in determining the data transmission path [7].

II. RELATED WORK

In this section, we classify the related work in the literature into two different classes: (i) we will cover authentication in traditional VANETs in section 1, and (ii) we will explore Algorithm Djikstra applied in 5G-enabled VANETs in section 2.

A. Authentication in VANETs

In 2019, Khan et all, in this paper, we propose a hybrid-fuzzy logic-guided genetic algorithm (H-FLGA) approach for the software-defined networking controller, to solve a multi-objective resource optimization problem for 5G driven VANETs. Realizing the service-oriented view, the proposed approach formulates five different scenarios of network resource optimization in 5G VANETs. Furthermore, the proposed fuzzy inference system is used to optimize weights of multi-objectives, depending on the type of service requirements of customers, Moreover, the proposed approach can be used to support energy-efficient optimization for service providers, as some idle BBUC's may be switched off without any adverse effect on the overall system thus, reducing the OpEx. Future directions include the possibility of implementing the proposed method in future ultra-dense networks, especially its implementation in computation offloading and resource allocation in the ultra-dense networks [8].

In 2020, Peng et all. In this article, a hybrid D2D message authentication (HDMA) scheme is proposed for 5G-enabled VANETs, in which a novel group signature-based algorithm is used for mutual authentication between vehicle to vehicle (V2V) communication. Also, a pre-computed lookup table is adopted to reduce the computation overhead of modular exponentiation operation, To speed up the computation of modular exponentiation used in the signing and verifying of messages, a pre-computed lookup table is required in the V2V authentication, which improves the efficiency greatly. Performance and security analysis show that the proposed scheme is more efficient and more practical in privacy preservation[9].

B. Adhoc On-Demand Distance Vector (AODV)

Adhoc On-Demand Distance Vector (AODV) is an on-demand routing that only performs Discovery Routing if the route is required by the source node. AODV has the main characteristic of maintaining the Timer Based State at each node according to the use of the routing table. AODV has routing discovery in the form of Routing Request (RREQ) and Routing Reply (RREP), as well as Routing Maintenance in the form of data, Routing Update, and Routing Error [6].

C. Simulation of Urban Mobility (SUMO)

Simulation of Urban Mobility (SUMO) or abbreviated as SUMO was first developed by Daniel Krajzewicz, Eric Nikolay, and Michael Behrisch in 2000 which aims to conduct accommodation studies involving the movement of vehicles on roads, especially in densely populated areas. SUMO is a simulator application software that is used to simulate vehicle-movement on a certain path and model [10].

D. Static Intersection Node (SIN)

Apart from Vehicle-to-Vehicle Communication, VANET also supports carrying out Vehicle to Infrastructure Communication (V2I). Infrastructure can be in the form of an Access Point or other network infrastructure, for example, 3G or HSDPA, which is called the RSU (Road-Side Unit). Several studies have referred to infrastructure as a Roadside Unit. One of the main problems with VANET is a dynamic topology so that the success of sending data is very dependent on the position of the node. To improve the performance of the routing protocol, one way that can be done is to add a Roadside Unit. The existence of a Roadside Unit can help nodes to send data packets to both nodes in the vicinity and other Roadside Units. Communication that occurs between nodes and nodes with the Roadside Unit is called hybrid communication. The development of the Roadside Unit is the Static Intersection Node. Static Intersection Node is a Road Side Unit located at the intersection [11], [12].

E. Algoritma DIJKSTRA

Dijkstra's algorithm was invented by Edger Wybe Dijkstra which is one type of popular algorithm in solving problems related to optimization problems and is simple. This algorithm solves the problem of finding the shortest path from vertex a to vertex z in a weighted graph, the weight is a positive number so it cannot be traversed by negative nodes, but if this happens, the solution given is infinity [7].

Dijkstra's algorithm involves labelling vertices. Let L (v) represent the label of the vertex v. On each puff, some vertices have a temporary label and others have a fixed label. Let T represent the set of vertices that have temporary labels. In describing the algorithm, a set of vertices that have a fixed label will be circled. Furthermore, if L (v) is the fixed label of the vertex v, then L (v) is the temporary label to fixed. In this section L (z) is the length, it is the shortest path from to z. The P in the Dijkstra node algorithm because the Dijkstra algorithm uses a tree diagram to determine the shortest n paths and uses a directed graph [13].

Dijkstra's Algorithm formula:

V(G) = $\{v_1, v_2, v_3, v_n\}$
L = The set of nodes V(G) which has been selected in the shortest path
D(j) = The smallest number of distance weights from v_1 to v_j
W(i,j) = Line weight of the nodes v_i to nodes v_j
W*(1, j) = The smallest number of distance weights from v_1 to v_j

Formally, Dijkstra's algorithm for finding the shortest distance is:

1. L = {}
2. V = {v2, v3, ..., vn}
3. For $I = 2, 3, ..., n$, do $D(i) = w(1, i)$
4. During $v_n \subseteq L$ do:
   a. Choose node v_k V-L with D(k) the smallest
   $L = L \cup \{v_k\}$
   b. For each vj V-L do:
   if D(j) > D(k) + w(k,j) then change D(j) with D(k) + w(k,j)
   for each $v_j \in V$, $w^*(1, j) = D(j)$.

The application of the Dijkstra algorithm is carried out by first determining which point will be the starting node, then weighting the distance from the first node to the closest node one by one, Dijkstra will develop a search from one point to another and the next point step by step. This is the logical sequence of Dijkstra's algorithm [7]:

- Give a weight (distance) value for each point to another point, then set a value of 0 on the initial node and an infinite value for the other (not filled) nodes.
- Set all nodes "Not yet passed" and set the initial node as "Initial Node".
- From the starting node, consider the neighbouring untreated node and calculate the distance from the starting point. For example, if the starting point 1 to 2 has a distance weight of 7 and from 2 to 3 is 10, then the distance to 3 passing through 2 becomes 7 + 10 = 17. If this distance is smaller than the previous distance (which has been previously recorded) delete old data, restore the distance data with a new distance.
- When we have finished considering each distance to neighbouring nodes, mark the past nodes as "Passed nodes". Nodes passed will never be checked again, the stored distance is the last distance and the least weighted one.
- Set the "Unpassed node" with the smallest distance (from the initial node) as the next "starting node" and continue to return to step 3.)

Dijkstra's algorithm can also use arrays S=[s_i] with pseudocode, as follows [13].

S_i = 1, if vertex i belongs to the shortest path
S_i = 0, if vertex i is not included in the Shortest path and array / table D=[d_i] which in this case,
d_i = length of path from initial vertex to vertex i

Dijkstra's shortest path algorithm (search for trajectory shortest from vertex a to another vertex).
Step 0 (initialization):
Initialize si=0 and di=mij for i = 1,2, ..., n
Step 1:
Fill in sa with 1 (because vertex a is the vertex from which the shortest path originated, so it is selected)
Fill in da with ∞ (there is no shortest path from vertex a to a)
Steps 2,3, ..., n-1:
Find j such that sj=0 and dj=min {d1, d2, dn}
Fill sj = with 1
Update di, where i = 1,2,3, ..., n
where: di (new) = min {di (old), dj+mij}

To obtain valid data, in each of the scenarios above, an experiment will be carried out with 4 different vehicle mobility that has been prepared in advance. Some of the parameters presented in Table I. In Table I, the standard parameters used are the Network Simulator using NS-4.2 which functions to map the map into vector form, for Routing using AODV it functions to maintain the Timer Based State at each node, the simulation time is 100 seconds, with a test area of around 1200 m / 1200 m with 4 different vehicle mobility (Many Vehicle) (25, 50, 75 and 100 vehicles). with a transmission radius of 100 meters, for maximum speed in each vehicle 8 m / s (30 km / h), the data sent is in the form of UDP (User Datagram Protocol) via CBR (Constant Bit Rate) packets that are sent 1 packet per second using MAC protocol IEEE 802.11 is in a real map, and this study also uses Wireless Channel as a signal amplifier, so that it can be measured how many data packets reach the destination and how many data packets have failed to be received by the destination node and the average time it takes data to reach the destination node.

Based on the coverage of each density level is measured by the number of vehicle units divided by the length of the road using the following formula [7]. The things that are the main things in the analysis of the results are the following points:

$$Density = \frac{Number\ of\ Vehicle}{Length\ of\ Road} \qquad (1)$$

TABLE I. SIMULATION PARAMETERS

No	Parameters	Specification
1	Network Simulator	NS-4.2
2	Routing Protocol	AODV
3	Simulation Time	100 Second
4	Simulation Area	1200 m / 1200 m
5	Many Vehicles	25, 50. 75, 100
6	Transmission Radius	100 m
7	Maximum Speed	8m/s (30 km/h)
8	Data Type	UDP (CBR)
9	Protocol MAC	IEEE 802. 11
10	Map	Real Map
11	Channel Type	Wireless Channel

- Packet Delivery Ratio, namely the ratio of data packets that are successfully received by the destination node which can be obtained through the following formula:

$$PDR = \frac{Packet\ Received}{Packet\ Sent}\ x\ 100\% \qquad (2)$$

- Average End to End Delay is the average time it takes for data to arrive at its destination which can be obtained through the following formula:

$$Delay = \frac{\sum_{i\leq sent}^{i=0} t_{received[i]} - t_{sent[i]}}{Packet\ sent} \qquad (3)$$

- Packet Loss, namely the number of packages that did not arrive at their destination which can be obtained through the following formula.

$$PL = \frac{Packet\ Sent - Packet\ Received}{Packet\ Sent}\ x\ 100\% \qquad (4)$$

III. PROBLEM ANALYSIS AND PROGRAM DESIGN

This study sends data from a node on one side of the map to another node on the other side of the map without a direct relationship between the two nodes. The data sent is CBR (*Constant Bit Rate*) data using the UDP (*User Datagram Protocol*) protocol.

A. Design Sistem

The system to be designed goes through several stages. In Fig. 1, it can be explained that at the beginning of this research, by building a road map that is traversed by vehicles, in this case, the City of Makassar, as the object of research, then to make the mobility of our vehicles using the *Simulation of Urban Mobility* (SUMO) application in For operation, the researcher designed data transmission using the Djikstra algorithm to read every moving node, when the interconnection network lost, there needs to be reinforcement by installing Static Intersection Nodes at every intersection, so that the AODV protocol works optimally and the results of data transmission can be analysed immediately.

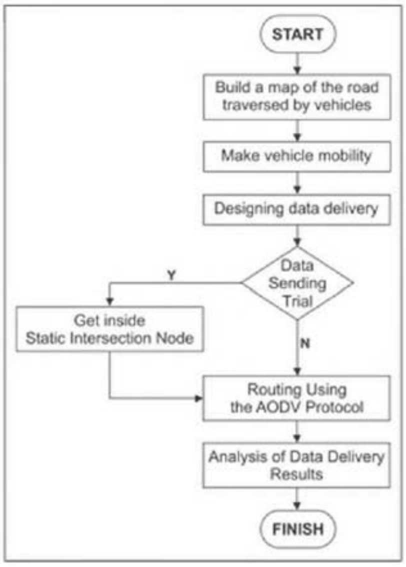

Fig. 1. Flowchart System

Fig. 2. Distribution of Nodes on the map of Makassar City

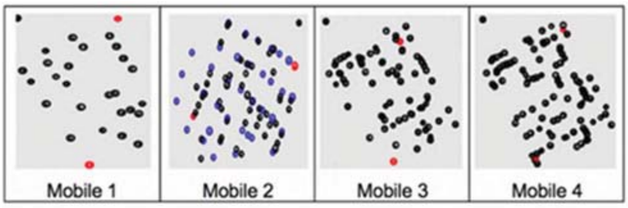

Fig. 3. Testing without Static Intersection Node

B. Spread of Nodes

The user will select the nodes to be visited or passed in the meter reading route, then the system will perform calculations and determine the shortest path that must be traversed with the Dijkstra algorithm starting from Fly Over Pettarani as the starting node to the last node to be determined, the picture below shows the distribution of nodes on the map of the Makassar city area that will be used in the JOSM application (Fig. 2).

Nodes are locations where Static Intersection Nodes (SIN) are installed such as forks, intersections, or public facilities such as shopping centre's (malls). The entered nodes are then numbered to make it easier to identify the location on the graph. The graphical form of the nodes on the map can be explained in this scenario, data is sent from node A to node B (red circle) via a vehicle between node A and node B. Visual display of the position of the vehicle on the map at 10 seconds in each mobility can be seen in Fig. 3.

From Fig. 3, it can be seen the position of node A & node B (coloured red) and the vehicles passing between them (black). The image is taken from the Network Animator's display at the 15th second. Data transmission experiments are carried out by sending 1 packet/second for 100 seconds (100 packets are sent). In the process of sending data using the shortest path, the researcher uses the Djikstra algorithm as an application in the process of sending data. Due to Dijkstra's nature, namely greedy (greedy) where the calculation process is imposed on all existing nodes, for ease of calculation of this meter reading route a Bounding Box is used, namely by selecting only certain nodes in the direction where the node is most likely to be traversed or missed in one reading route. This makes Dijkstra's calculations faster and more efficient.

C. The closest node search pseudocode

It is carried out through several processes, namely the process of calculating the entire distance of the node from the destination in kilometres (km) followed by finding the smallest distance. The pseudocode for calculating distance is as follows:

Procedure for distance of all nodes (INPUT lat1: destination latitude, lng1: destination longitude, lat2: node latitude, lng2: node longitude) {
Radians = 0.0174532925199433
a = 6378.137
f = 0.0033528107
lat1 = (latitude1 x radians)
long1 = (longitude1 x radians)
lat2 = (latitude2 x radians)
long2 = (longitude2 x radians)
U = (lat1 + lat2)/2.
G = (lat1 – lat2)/2.
J = (long1 – long2)/2.
M = (sin(G) x sin(G) x cos(J) x cos(J)) + (cos(U) x cos(U) x sin(J) x sin(J)).
N = (cos(G) x cos(G) x cos(J) x cos(J)) + (sin(U) x sin(U) x sin(J) x sin(J)); w = sqrt(M/N).
P = sqrt (M x N)/w.
D = 2 x w x a.
E1 = (3 x P-1)/ (2 x N).
E2 = (3 x P+1)/ (2 x M).
s = D x (1 + f x E1 x sin(U) x sin(U) x cos(G) x cos(G)-f x E2 x cos(U) x cos(U) x sin(G) x sin(G)); distance (km) = s;}

Furthermore, the pseudocode to find the smallest distance is: Nearest node distance procedure (result INPUT km [n]: matrix) {Order = Number of while matrices Order is not 0if the result of km [n] is smaller than the previous value set this as the smallest value endif end while return the smallest number}Implementation and Analysis of Trial Program Results. Testing of calculations in the application can be tested or compared with manual calculations based on the Dijkstra algorithm, the results obtained can be seen in Table II.

In Table II, with the test without Static Intersection Node, the average PDR of data transmission is still small at 38%, while PL is too large to lose data transmission with a rate of 70% and EED is still too large with an average of 2 08%. Furthermore, in this scenario, the researcher also adds a Static Intersection Node at each intersection on the map. This is done to prove that the use of Static Intersection Node contributes to the optimization of the AODV protocol in sending data packets. The results of data delivery experiments in this scenario can be seen in Table II.

TABLE II. TEST RESULTS WITHOUT STATIC INTERSECTION NODE (SIN)

No	Trial Package	Testing without Static Intersection Node (SIN)				
		Mobile 1	*Mobile 2*	*Mobile 3*	*Mobile 4*	*Averege*
1	Packet Delivery Radio (%)	14	21	77	40	38
2	Packet Loss (%)	85	77	46	70	70
3	End to Delay (%)	2,32	1,97	0,52	3,51	2,08

TABLE III. RESULTS OF EXPERIMENTS WITH SIN

No	Trial Package	Testing without Static Intersection Node (SIN)				
		Mobile 1	*Mobile 2*	*Mobile 3*	*Mobile 4*	*Averege*
1	Packet Delivery Radio (%)	79	84	70	72	76
2	Packet Loss (%)	45	27	40	49	40
3	End to Delay (%)	0,82	2,23	1,86	0,28	1,30

In Table III , with the test without Static Intersection Node, the average PDR of data transmission is 76% fast, while PL has decreased so that the loss of data transmission is 40% and EED is by following by under an average ratio of 1.30 %. Then put the Static Intersection Node on each intersection above. So that the data transmission experiment was carried out with 4 different vehicle mobility scenarios, then to see the average experimental results with SIN at the optimal intersection can be seen in the Table IV. In Table IV, the Average Experiment Results with SIN at the optimal intersection, the average PDR of data transmission is 78% fast, while PL has decreased so that the loss of data transmission is 38% and EED is by following per under the average ratio. 1.56% average. The results of the data transmission experiment carried out on the map using Static Intersection Nodes at each intersection are compared to Static Intersection Nodes at certain intersections and without Static Intersection Nodes on the map can be seen in Fig. 4.

From Fig. 4, adding Static Intersection Nodes to the map can increase the Packet Delivery Ratio by 77.50 by using the Djikstra algorithm. In this graph, it can also be seen that the placement of the Static Intersection Node at the intersection which has a low vehicle density also has a significant contribution in increasing the Packet Delivery Ratio by 80% on mobile 3 (node75) when compared to the scenario without using Static Intersection Node with numbers 38%. As for Packet Loss, which is the number of data packets sent from node A but failed to be received by node B, it can be seen in Fig. 5. From Fig. 5, placing the Static Intersection Node on the map can reduce Packet Loss by 37%, namely the number of data packets that node B fails to receive. The causes of packet loss are quite diverse apart from changes in network topology due to vehicle mobility, it can also be caused by memory in the vehicle through which the data packet is full so that the data packet must be dropped. it can also be affected by limited bandwidth so that not all packets can be sent to the next vehicle. For End-to-End Delay, which is the average time it takes for a data packet since it is sent to its destination, it can be seen in Fig. 6. from Fig. 6 it can be explained that Static Intersection Node has a significant contribution in suppressing End to End Delay with a figure of 1.56%, which means that the smaller the End-to-End Delay value, the faster the data reaches the destination.

TABLE IV. AVERAGE EXPERIMENT RESULTS WITH SIN IN OPTIMAL INTERSECTION

No	Trial Package	Testing without Static Intersection Node (SIN)				
		Mobile 1	*Mobile 2*	*Mobile 3*	*Mobile 4*	*Averege*
1	Packet Delivery Radio (%)	76	72	80	82	78
2	Packet Loss (%)	35	43	35	37	38
3	End to Delay (%)	0,88	2,64	0,24	2,46	1,56

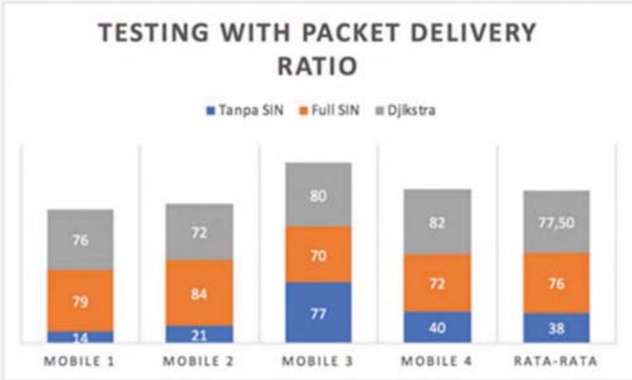

Fig. 4. Average Packet Delivery Ratio

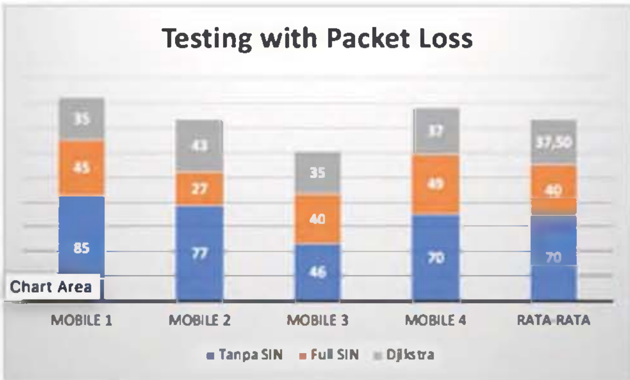

Fig. 5. Average Packet Loss On The Map

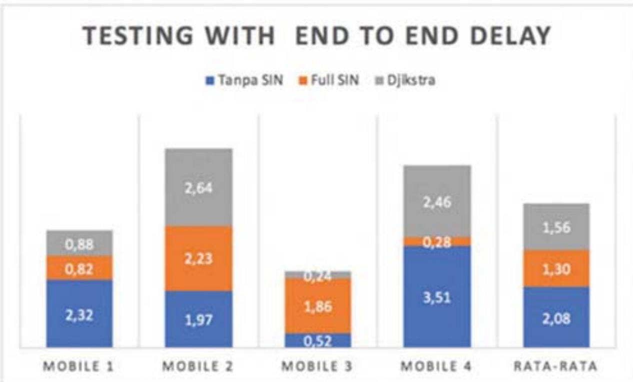

Fig. 6. Average End to End Delay On Map

CONCLUSION

In this study, it can be concluded that the presence of Static Intersection Nodes on the map is proven to improve the performance of the AODV protocol in sending data. This is evidenced by the results of research which show an increase in Packet Delivery Ratio by an average of 77.5% after placing Static Intersection Nodes at several optimal points on the map. Likewise, the Packet Loss Ratio decreased by an average of 37.5% and the End-to-End Delay also decreased by an average of 1.56 seconds which indicates that data packets are received more quickly by the receiver nodes.

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