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Performance Comparison of CC AODV and Optimized AODV K-Means Clustering Using NS3

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Abstract: Nowadays, many studies have been interested in Ad Hoc Wireless Networks because of their low cost, when there is a need to communicate using a network without any infrastructure. Ad Hoc On-Demand Distance Vector (AODV) is a routing protocol for mobile ad hoc networks (MANET) and other wireless ad hoc networks. AODV was co-developed in July 2003 at the NOKIA Research Center, University of California, Santa Barbara and University of Cincinnati by C. Perkins, E. Belding-Rover an S.Das. AODV is a routing protocol used by ZigBee - a low power wireless ad hoc network with low data rates. AODV is included in the proactive routing protocol. The advantage of using this routing protocol is that it has economical resources, because resources are not needed to store information about routes to other nodes. However, this AODV has a drawback, namely the packet that will be sent has a long delay in anti-node origin waiting for the protocol to find the path to be passed. There are many papers that optimize AODV, including CC AODV and K Means Clustering AODV. Based on the paper "CC-AODV: An effective multiple paths congestion control AODV", a control scheme called CC AODV has been created, namely managing routing conditions by significantly increasing packet sending rates while reducing packet drop rates, and based on the paper "An Energy Efficient Clustering Using K-Means and AODV Routing Protocol in Ad hoc Networks". Based on both paper, in this study the objectives to be achieved are: a) Analyze the performance of using CC AODV and K Means Clustering AODV based on the number of nodes. b) how much influence the number of nodes has on the performance of CC AODV and K Means clustering AODV c) Performance analysis is performed on throughput, end to end delay, packet loss, packet delivery ratio. This paper begins by looking at the literature covering MANET, AODV, CC AODV, and K-Means Clustering AODV. On the result section the test results such as end to end delay, throughput, packet delivery ratio, and packet loss ratio are documented. The conclusion summarizes key points and is followed by the references.

Keyword: *AODV, CC AODV, K-Means Clustering AODV, NS3*

INTRODUCTION

Nowadays, many studies have been interested in Ad Hoc Wireless Networks because of their low cost, when there is a need to communicate using a network without any infrastructure(Y. Mai, F. M. Rodriguez and N. Wang, 2018). Ad Hoc On-Demand Distance Vector (AODV) is a routing protocol for mobile ad hoc networks (MANET) and other wireless ad hoc networks. AODV was co-developed in July 2003 at the NOKIA Research Center, University of California, Santa Barbara and University of Cincinnati by C. Perkins, E. Belding-Rover an S.Das (Tantaoui, 2021). AODV is a routing protocol used by ZigBee - a low power wireless ad hoc network with low data rates. AODV is included in the proactive routing protocol. The advantage of using this routing protocol is that it has economical resources, because resources are not needed to store information about routes to other nodes. However, this AODV has a drawback, namely the packet that will be sent has a long delay in anti-node origin waiting for the protocol to find the path to be passed. There are many papers that optimize AODV, including CC AODV and K Means Clustering AODV. Based on the paper "CC-AODV: An effective multiple paths congestion control AODV", a control scheme called CC AODV has been created, namely managing routing conditions by significantly increasing packet sending rates while reducing packet drop rates, and based on the paper "An Energy Efficient Clustering Using K-Means and AODV Routing Protocol in Ad hoc Networks". Based on both paper, in this study the objectives to be achieved are:

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METHOD

Mobile ad hoc network (MANET) is a network consisting of mobile nodes that moves dynamically that does not need a permanent infrastructure. Those nodes in this network, responsible for finding the routes and handling every route of the nodes. In the MANET network there are several routing protocols used, one of them is AODV. This paper compares two AODV enhancements covering CC AODV and K-means Clustering AODV. The following is an explanation of the literature study in this paper:

A. MANET

Mobile ad hoc network (MANET) is a group of wireless devices called nodes, which move dynamically in and out of the network freeway, find the routes without permanent infrastructure and act as routers to forward the packets from one node to another node. Every node owns a transmitter and receiver omnidirectional (broadcast) antenna or highly directional (point-to-point) antenna that allows it to be directed, or a combination of several of these. Omnidirectional means that radio waves are emitted in all directions by a wireless transmitter device. Meanwhile, highly directional is a wave that is emitted in one particular direction.

MANETs are used in many areas like disaster or war areas. Where it's impossible to build a permanent network to communicate between posts or on transportation sites that are always moving. Frequently, in a place that does not fix the infrastructure while the communications happen. Cars, soldiers, airplanes, buses, vessels and wireless devices that can represent MANETs like Fig 1. Sometimes the nodes run out of the range so that the networks need to be reconfigured. There are several MANET types, including VANETs (Vehicular Ad Hoc Networks), SPANs (Smart Phone Ad Hoc Networks), iMANETs (Internet Based Mobile Ad Hoc Networks), and military or tactical MANETs.

As we know, MANETs consist of mobile platforms (such as routers and wireless devices) in this case called “nodes” which are free to move anywhere

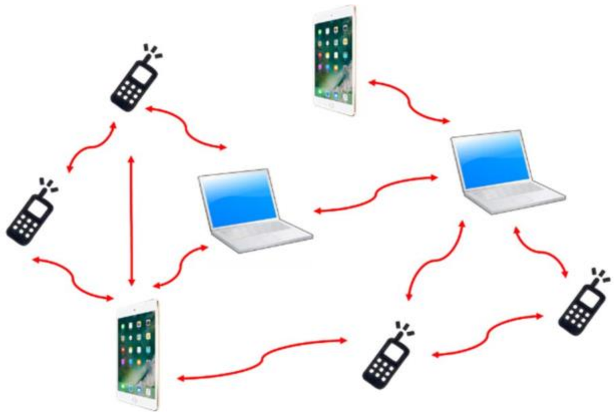

Fig. 1. Example of MANET

These nodes can be on planes, ships, cars, and anywhere else. The rationale is that new incoming nodes will listen for broadcast messages from their neighbors. A node will learn new nodes nearby and how to reach these new nodes. Routing protocol is like a router that communicates with other devices to spread information and allows route selection between two nodes in the network, each node will have capabilities like a router that forwards messages between surrounding nodes. The MANETs routing protocol can be distinguished into three characteristics : proactive, reactive and hybrid.

a. Proactive

This proactive protocol works by distributing the routing table throughout the network, so each node has a complete routing table, meaning that a node will know all routes to other nodes in the network. When carrying out maintenance, there is routing information through the routing table and it is updated periodically according to topology changes, but if this proactive method is implemented it will cause large bandwidth consumption because all nodes broadcast the routing table to all nodes. some example of proactive protocols are B.A.T.M.A.N (Better Approach to Mobile Ad Hoc Network), OLSR (Optimized Link State Routing Protocol), DSDV (Destination Sequenced Distance Vector), HSR (Hierarchical State Routing Protocol), and WAR (Witness Aided Routing).

b. Reactive

Reactive routing protocols carry out the process of searching for destination nodes in an on demand manner, which means that the route search process is only carried out when the source node requires communication with the destination node. So the routing table owned by a node contains route information for the destination node only. However, this protocol will establish a connection if the node requires a route in transmitting and receiving data packets but it takes more time than proactive routing protocols, so this method does not require too much bandwidth consumption and minimizes battery resources. some example of reactive protocols are AODV (Ad Hoc On demand Distance Protocol), DYMO (Dynamic MANET on Demand), DSR (Dynamic Source Routing), FSDSR (Flow State in the Dynamic Source Routing), ARAMA (Ant Routing Algorithm for MANET), and BSR (Backup Source Routing).

c. Hybrid

Hybrid routing protocol is a method of combining both protocols between proactive and reactive routing. Some examples of hybrid protocols are HWMP (Hybrid Wireless Mesh Protocol), ZRP (Zone Routing Protocol) and HRPLS (Hybrid Routing Protocol for Large Scale MANET). Ad Hoc On-Demand Distance Vector (AODV) is one of MANET's reactive routing protocols.

B. AODV

AODV (Ad Hoc On-Demand Distance Vector) routing designed to use mobile devices as nodes in ad hoc networks. Which can adapt with dynamic conditions quickly, has a low processing so that it can process almost in every mobile device and a low network utilization, also can decide the unicast route to destinations node in the ad hoc network. AODV uses destination node sequence number to confirm the path is free all the time even when facing an anomaly routing control messages, and evade such a counting to infinity issue that is associated with distance vector protocol. Also known as a hop-by-hop protocol which every node uses their routing table to find the next hop in the way to find the destination node.

Technically, AODV used two kinds of operation that are Route Discovery and Route Maintenance, with Route Discovery as the first common operation used to find the destination node. In the route discovery journey, there are three messages defined by AODV : Route Requests (RREQs), Route Replies (RREPs), and Route Errors (RERRs). Start with the source node broadcast Route request (RREQ) messages that contain the destination node address and wait for Routes Reply (RREP). When a node receives that RREQ so it will make a reverse path to the source node by the previous hop if it's a valid destination node to send a RREP or if it's not the destination node the current node will broadcast RREQ again by the next hop while the throwing the RREQ duplication away. Those messages are usually received via UDP, and will process an IP header, which expects the IP address as the originator. While broadcasting, 255.255.255.255 is used as a limit of broadcast address, which means the messages are not blindly forwarded. However, AODV operations need a certain message to be disseminated widely that might affect the throughput of the ad hoc network. This means route maintenance needed to send RRER by predecessor maintained link to all detected links own the link failure when there is a failure link detection. The disseminating range can be indicated by the TTL of the IP header.

C. CC AODV

CC-AODV (Congestion Control-Ad Hoc On Demand Vector) is a development of AODV to lower the performance degradation caused by the packet congestion while the data is delivered. Furthermore, CC-AODV defines which path can be passed by the data using the congestion counter label that is archived. The archived label will be observed by stress at the nodes that pass every time the RREQ are formed and sent through the node, the congestion counter will add on the counter as shown in Fig 2.

The source node will send a flooding broadcast of the RREQ package in the network. It is sent to every node on the network that is limited by the broadcast address. So that when the RREQ arrives at the middle node, the router checks the congestion counter, it contains a certain predetermined value or less. If it contains less than the counter, routing tables will not update and forward it to the next router, or it will drop the RREQ packages. If it drops the packages, it will contain the failure link that can trigger RERR when the failure broadcast is detected. Once the RREQ arrives at the destination, it will trigger the router to generate RREP.

In CC-AODV, there is an additional congestion control flag in the RREP header. Commonly, there are two cases when the RREP is generated and built upon the RREQ. First, is from the neighbor nodes to maintain the route.

When the destination node receives the RREQ, it will generate RREQ with a true congestion flag. While the RREP unicast back to the source node, pass the middle nodes, the router will check the value of the congestion flag. The true value will increase the counter; otherwise it will keep the same value at the counter. Then the router will update the routing information.

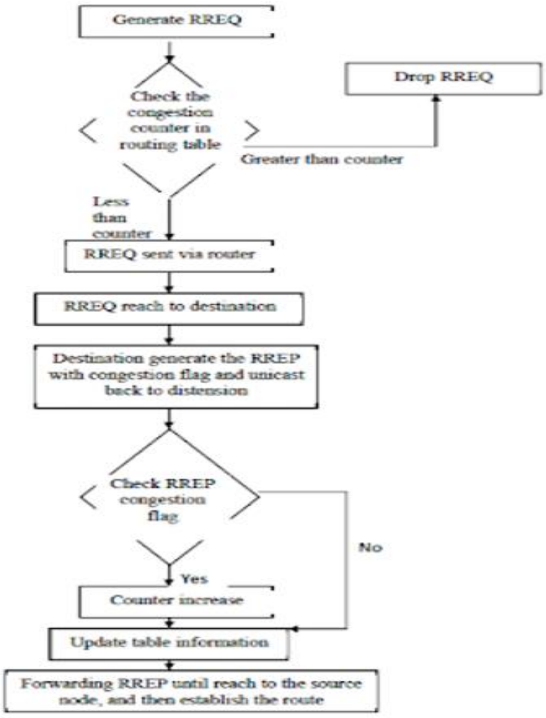

Fig.2. Process of CC-AODV flow chart

While it is implemented using NS3, it is required to follow the rules. That is a 32 bit congestion flag has to be added to the RREP header as shown in Fig 3. Moreover, we need to add the routing table to congestion control entries, there are initial congestion counters, increment the congestion counter, decrement of the congestion counter, and reset the congestion counter.

```
New-RREP:
Route Reply (RREP) Message Format
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |     Type      |R|A|    Reserved     |Prefix Sz|   Hop Count   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                     Destination IP address                    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                  Destination Sequence Number                  |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                    Originator IP address                      |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                           Lifetime                            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                       Congestion Flag                         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Fig. 3. New-RREP Packets

D. K-Means Clustering in AODV

K-Means is an unsupervised learning algorithm that aims to group data into a cluster. This algorithm is designed to group a bulk of data into different categories easily without a training process. K-Means has two primary task, ther are :

a) Determine best value for K node or centroid with iterative process
b) Define every node to the closest K center node, that can be clustered

In AODV routing, often route discovery that is done by flooding broadcast of RREQ to all the nodes in the network causes re-transmission of RREQ packages and the RREP generated resulting collision and congestion packet in the network. The K-Means role to solve this issue is to select which is the best cluster of RREQ packages before sending broadcast, that can reduce unnecessary control packet transmission in the network thus reducing the congestion and end-to-end delay of the network. K-Means clustering algorithm using distance of the destination, transmission error number and the free buffer space from the neighbor nodes to optimize the cluster.

E. NS-3

Simulation is a technique that is used to execute the developed theory of the network or anything in the computer without building a real permanent infrastructure, to calculate the behavior of the network with mathematical calculation used by the network organization [12]. There are several kind of simulation tools, some of them are stochastic simulator, determined simulator, terminating simulator, non-terminating simulator, steady state simulator, dynamic simulator, discrete event simulator, continuous event simulator, hybrid simulator and local simulator.

NS-3 is one of a discrete-event network Internet systems simulator, usually used for research and education. NS-3 is a free, open-source software, licensed under the GNU GPLv2, that is maintained by a worldwide community. Steps usually applied in NS-3 to build a simulation are defining topology, model building, link and configuration of the node, execution, analysis performance and graphic visualization.

The advantages compared with the previous version is that NS-3 is more documented and continuously developed regarding new technology. NS-3 is a modular simulator tool with real condition and supports virtual integration, also equipped with input and output validation.

RESULT AND DISCUSSION

To verify that the AODV, CC AODV, and K-Means Clustering AODV performs better when compared, simulations have been carried out using the Network Simulator 3 (NS3). The values of the parameters are described in the following table.

Table 1. Parameter For Simulation

Parameter	Value
Operating System	Ubuntu 22.04
Simulator	NS3 (NS3-3.35 and NS3-3.36)
Channel Type	Wireless Channel
Number of Nodes	10,15,20,25,30,35,40,45,50,55,60,65,70,75, 80,85,90,95, 100
MAC protocol	WLAN 802.11
Simulation Tool	NS-3
Speed Minimum	20 s
Routing Protocols	CC AODV and K-Means Clustering AODV
Data Type	UDP

Simulations have been carried out using a different number of nodes in a network to symbolize different practical applications of wireless networks.

This measurement is carried out in a simulation timespan to get throughput, end to end delay, packet loss ratio, packet delivery ratio and total packet loss. The definitions of the five targets achieved are as follows:

a. Throughput is the speed of data transmission in a period of time

b. End-to-End Delay is the difference between delivery time and package arrival
c. Packet Loss Ratio is the ratio of the number of packets lost to the corresponding destination.
d. Packet Delivery Ratio is the ratio of the number of packets successfully delivered to the corresponding destination.
e. Packet loss is total loss packets during the delivering

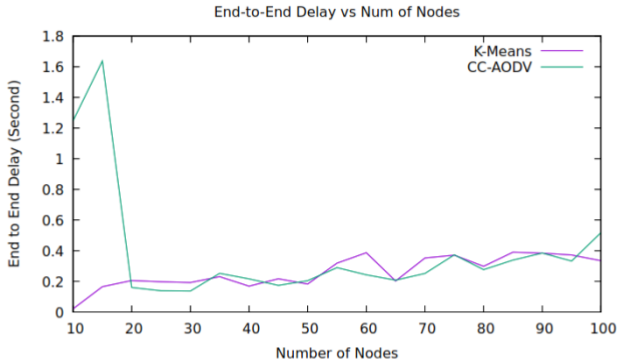

Fig. 4. End to end delay

In this simulation, experiment of end to end delay, it is shown that CC-AODV has higher end to end delay in early nodes than K-Means, but after that, CC AODV and K-means have almost the same results. This indicates that for end to end delay between CC AODV and K-Means there is not too much difference.

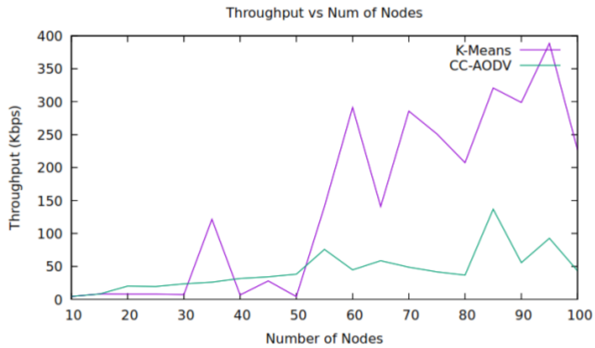

Fig. 5. Throughput

In this simulation, the Throughput experiment shows that the K-Means experiment is better than CC-AODV. In the initial simulation until the middle simulation, CC-AODV can still keep up with K-Means. but when there are more nodes, K-Means has a higher Throughput compared to CC-AODV.

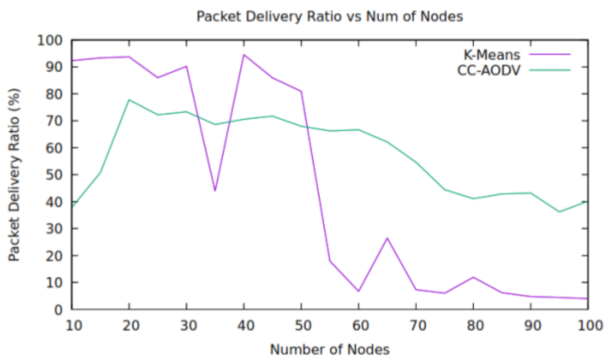

Fig. 6. Packet delivery ratio

In this simulation shown in the Packet Delivery ratio experiment, the experiment with the K-Means algorithm did not show good results. From this experiment it can be seen that CC-AODV produces a much better packet delivery ratio.

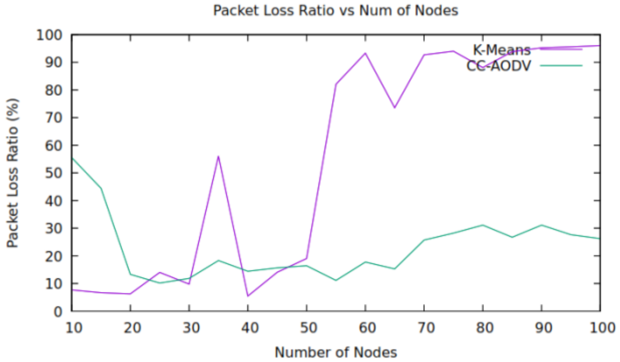

Fig. 7. Packet Loss Ratio

In this simulation, the results of the Packets Lost Ratio experiment, the performance of CC-AODV is much better than the experiment using the K-Means algorithm.

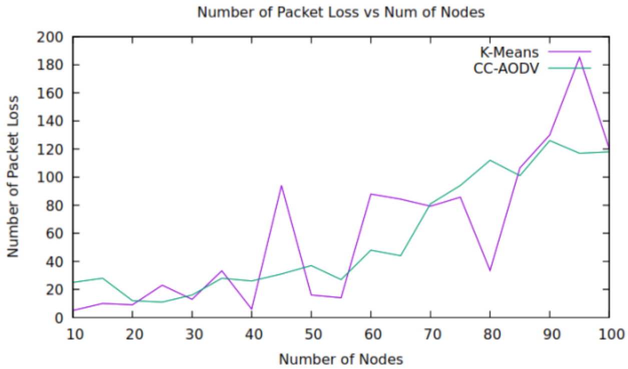

Fig. 8. Total Packet Loss

In this simulation, the results of the Packets Lost. The performance of K-Means if averaged in this simulation, K-Means has a slightly better value than CC-AODV. Pada bagian ini haruslah menjawab masalah atau hipotesis penelitian yang telah dirumuskan sebelumnya.

CONCLUSION

Performance Comparison of CC AODV and Optimized AODV K-Means Clustering Using NS3 is proposed in this paper. Simulations have been carried out and results are compared between the CC-AODV and the proposed K-Means clustering based on five different parameters. The performance of CC-AODV when compared to the K-Means algorithm shows better numbers in the Packet Delivery Ratio, Packet Loss Ratio and Throughput experiments.

However, the performance of the K-Means algorithm produces smaller delays and total packet loss as well, because before sending RREQ the sending cluster is first selected so that it will reduce transmission of packets that are not needed in the network, therefore the value of Packet Loss is much more and the Packet Delivery Ratio is much less when compared to CC-AODV. The performance of CC-AODV is much better than K-Means Clustering, even K-Means can minimize delay. But CC-AODV shows that the congestion counter can help reduce the network “busy” nodes by enhancing the network throughput. Hopefully, in the future work the K-Means clustering algorithm and CC-AODV can be combined to optimize the performance of CC-AODV.

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