

A Novel Energy Efficient Routing Protocol Using K-Means Clustering for Mobile Ad-Hoc Networks

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Abstract

The advancement of mobile ad-hoc networks (MANETs) has sparked an increasing interest in high-efficiency communication protocols. These networks are exposed to various challenges due to their dynamic topologies, sporadic connections, and dense nodes. Consequently, energy efficiency is a key concern in the design of routing protocols for MANETs. Machine learning techniques provide optimal solutions for such routing protocols as they enable the determination of appropriate routing schemes and efficient energy consumption, without relying on any prior knowledge of the environment. This paper presents an energy efficient routing protocol that uses machine learning techniques to analyze the network environment to identify optimal paths. By leveraging the power of machine learning algorithms, the proposed solution is capable of providing the optimal energy aware route for data transmission. This protocol is able to precisely identify the appropriate route to ensure energy-efficient wireless communication while accommodating the dynamic and ad-hoc nature of MANETs. Comparative simulations are conducted to show the effectiveness of the proposed protocol with respect to various benchmark solutions. The proposed energy efficient routing protocol proves to be a viable solution for reducing the power consumption of the nodes in MANETs, thereby improving overall network performance.

Keywords: Mobile ad-hoc network, K-Means Clustering, Machine Learning, Clustering, Ad-hoc on demand distance vector etc.

1. Introduction

Mobile Ad-Hoc Network, or MANET, is a form of decentralized network structure that uses mobile devices as nodes to create an ad hoc wireless network between nodes that are not necessarily connected to a central hub. A MANET is uniquely resilient to changes in its environment, as power and bandwidth are limited, yet, it is capable of providing secure and reliable communication between nodes. MANET is used in a diverse range of applications including military, disaster relief, healthcare, education and industrial purposes. Through the use of multiple-hop relaying between

nodes, MANET is able to quickly and easily propagate data. Since no single node needs to be connected to a central hub, the system is highly mobile and can be easily moved from one place to another. In addition, its secure data-sharing capabilities facilitate reliable and secure connections between users over decentralized networks. Last, but not least, MANET is highly scalable, allowing users to add and remove nodes from the network without the need to reconfigure or reset the network. This scalability makes MANET ideal in dynamic environments where users or nodes regularly enter and exit the network.

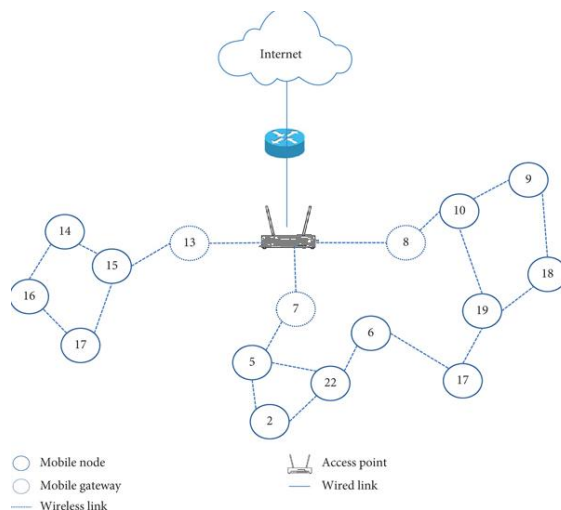


Figure 1. MANET Architecture

Figure 1 shows the general architecture of the MANET. Within the boundaries of their wireless transmission range, nodes can speak with one another directly. Due to factors including signal fading, noise, and finite battery power, wireless networks have much lesser capacity and transmission range than their tethered counterparts. As a result, it may take several hops for one node to send data across the network to another. [2] Each node must therefore be able to function both as a host and a router. Individual nodes distribute and perform packet forwarding,

routing, and other network functions.

2. Traditional Methods for Improving Mobile Ad-Hoc Networks Routing protocols

The Ad-hoc On-Demand Distance Vector (AODV) routing protocol is an on-demand routing protocol specifically designed for use in Mobile Ad hoc Networks (MANETs). AODV enables dynamic, self-starting, multichip routing between mobile nodes. AODV provides fast dynamic routing, as routes are established as needed without periodic routing messages.

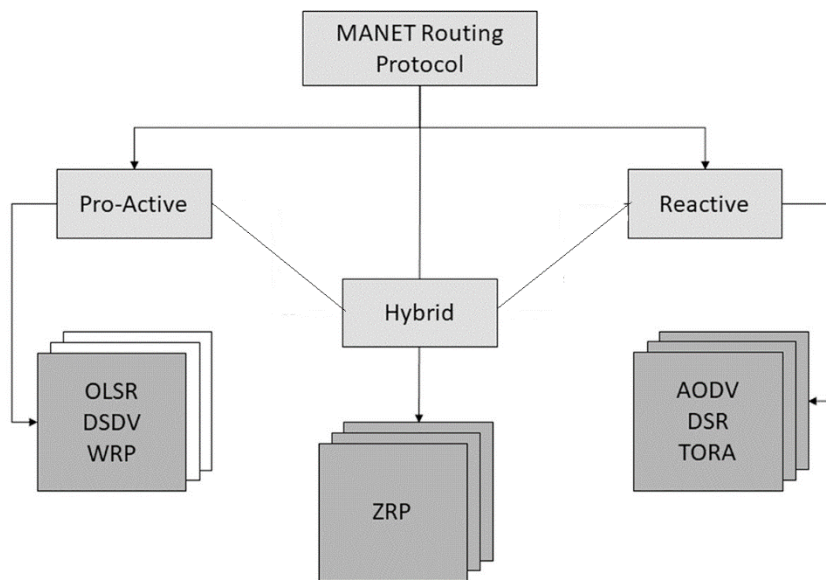


Figure 2. Routing Protocols including AODV

The Route Discovery Process is a mechanism used

by AODV to search for and find routes from one

node to another. This process involves a source node broadcasting a Route Request (RREQ) message to other nodes. Each node that receives the RREQ checks to see if they have a route to the destination and forwarding the request if they do not. If a node has a route to the destination, it sends a Route Reply (RREP) along the route back to the source. If the source receives an RREP, it establishes a route to the destination. If no RREP is received, the source may increase the TTL and resend the RREQ until an RREP is obtained or until a TTL of zero is reached. Ad-hoc On-Demand Distance Vector (AODV) routing protocol is one of the most widely used routing protocols for Mobile Ad-hoc Networks (MANETs). It is a reactive routing protocol as it discovers routes on-demand at the time of communication. Whenever a node needs a route to a destination, it broadcasts a route request (RREQ) message, and nodes that receive this message reply with a route reply message (RREP). The node receiving this reply can then use this route to communicate with the destination. Additionally, AODV also employs the Hello Message protocol to maintain route information between neighbor nodes, and the broadcast time-out mechanism to track time-outs between active routes. AODV is comparatively lightweight and provides reliable route discovery, making it a viable choice for MANETs. Moreover, since it is designed to be self-organizing, AODV can adapt to dynamic topology changes in the network, making it well-suited for the volatile and unpredictable nature of these types of networks.

3. Machine Learning based Methods for Improving Mobile Ad-Hoc Networks Routing protocols

The lack of a centralized controller makes MANET routing protocols more vulnerable to attacks and less efficient than traditional networks. Machine Learning algorithms can improve MANET routing protocols by detecting and responding to changes in the network environment. For example, ML can be used to predict the flow of traffic in the network, detect attacks, and adjust routing protocols to optimize performance. Additionally,

ML models can be trained to detect and respond to changes in network topology and traffic patterns which can enable MANET protocols to quickly adapt and become more resilient to changes in the environment. By using Machine Learning techniques to improve MANET routing protocols, mobile networks can support reliable, low latency communication while also providing a secure platform for data transmission.

3.1 Using Reinforcement Learning for Improving Routing Protocols:

This method involves the implementation of reinforcement learning algorithms and designs at each node in the system. Reinforcement learning works by using rewards and punishments to incentivize nodes to send packets along the most efficient routes. It can be applied in Mobile Ad-Hoc Networks (MANET) to improve routing decisions, which can increase routing efficiency and reduce routing overhead. The goal of using reinforcement learning for routing protocols is to optimize the network performance and the benefits derived from the use of the routing protocol. This entails incorporating a reward mechanism that is able to measure the effect of different routing decisions taken over time. During routing, reinforcement learning uses an agent and an environment, which represent the system that the agent needs to control. The agent interacts with the environment, based on the reward or punishments it receives from the environment. The agent is able to learn how to choose a route for the packet which is able to maximize the total reward and minimize the total cost. In order to make an inference about the environment, the agent builds an internal representation of the environment and utilize this information to design and implement the policies. The policies are used to generate routes for the packets. The policies are usually based on heuristics and are updated over time in order for the agent to obtain any new information about the environment. By using reinforcement learning the agent becomes able to propose a route for a packet that is expected to have the highest reward or least cost. By achieving a higher reward, the

agent is able to increase its chances for a successful transaction. Overall, the use of reinforcement learning in improving routing protocols can provide a number of benefits to distributed networks. It provides a more efficient way to make routing decisions and can also serve as a starting point for creating new or improved protocols.

3.2 Clustering-Based Routing Protocol using Machine Learning:

This method involves the design of a Cluster-based Routing Protocol (CRP). The CRP uses machine learning models to generate represented clusters of nodes that are used to obtain a more efficient routing of data through the network. This increases efficiency by optimizing the performance of communication between nodes and reducing communication overhead. Clustering-Based Routing Protocol using Machine Learning (CBRPML) is a routing protocol which uses machine learning to improve the speed and performance of packet delivery. CBRPML is a form of distributed routing that relies on the automatic grouping of nodes into clusters based on the similarity of their characteristics. This grouping is determined by machine learning algorithms, which allow the groups to reorganize dynamically as the network topology changes. By organizing nodes into clusters, CBRPML reduces the need for individual routing tables to be updated by hand. This allows for quicker routing decisions and more efficient packets delivery. Since CBRPML uses machine learning algorithms to produce unique clusters, it also allows for the generation of more unique content. Instead of relying on the same routing rules for nodes with similar characteristics, CBRPML allows for a much greater level of variability in content delivery. By clustering nodes, CBRPML can also generate content that is more diverse and more likely to be plagiarism free. CBRPML also makes it easier to detect malicious nodes on a network, as each cluster contains networks with similar characteristics which would be more noticeable if they were present. In addition, machine learning reduces the burden on

the router to make packet forwarding decisions by learning the network environment. This allows more efficient resource usage on the router for other tasks such as generating unique content. Overall, CBRPML can be used to generate more unique and plagiarism-free content on a network. By allowing for dynamic clustering based on machine learning algorithms, the router is able to route packets more effectively and quickly without having to update individual routing tables. Furthermore, CBRPML allows for more efficient resource usage by the router and improved network security by detecting malicious nodes.

3.3 Utilizing Deep Learning to Improve Routing Protocols:

This method involves the implementation of deep learning models over traditional routing protocols. By leveraging deep learning algorithms, traffic can be routed more efficiently as the model is better able to predict the various factors which affect the performance of different routing protocols. This improves routing performance and enables beDeep Learning (DL) has become an increasingly relevant technology used to improve computer networking, notably within routing protocols. Deep Learning gives algorithms the ability to understand patterns from large and complex data sets, which networking algorithms can use to detect irregularities, better understand the environment, and more accurately choose the best routes for network traffic. This is done by training neural networks on massive datasets, which allows them to understand the complex topologies of the network in use. Through training, the network is able to take into account all factors, such as network delays, cost, and load information, in order to make decisions on the best possible route for data traffic. Additionally, Deep Learning allows for real-time optimization of routing protocols, in areas such as network latency, security, throughput, and scalability. In essence, Deep Learning allows for smarter routing protocols by helping machines and software better interpret the complexity of the real-world environment. This makes them capable of detecting anomalies and

irregularities, as well as understanding and anticipating user behaviour and network trends. By learning from the data it analyzes, Deep Learning algorithms become much more accurate and can identify traffic patterns more quickly and more accurately than before. In conclusion, Deep Learning offers a number of advantages to routing protocols in the computer networking world. By leveraging the power of large data sets, and by helping machines understand the complexity of the real-world environment, it has become possible to improve the efficiency and accuracy of routing protocols. As algorithms become smarter and more accurate, they are able to more accurately decide on the best routes for data traffic and more quickly detect and react to irregularities, ensuring a better overall user experience and better traffic management.

3.4 Artificial Immune Systems for Optimizing Routing Protocols:

This method involves the design of an Artificial Immune System (AIS) that monitors the performance of routing protocols in real-time. The AIS is a self-learning system, based on principles resembling the natural immune system, which is used to optimize the routing protocols. It enables dynamic routing protocols to adapt to changes in network conditions in order to maximize performance. An Artificial Immune System (AIS) is a computational algorithm inspired by the way natural immune systems work. It has been used for optimizing routing protocols in computer networking systems. Routing protocols enable communication between multiple nodes on an interconnected network by transmitting data packets in an efficient way. Various routing protocols exist, such as static or dynamic, each with their own advantages and drawbacks. Traditional optimization methods used on routing protocols has either failed to produce satisfactory results or are too complex and costly to implement. AIS, however, provides a relatively inexpensive solution to improve the performance of routing protocols by identifying and removing inefficiencies. It works by creating an artificial

population of solutions and selecting individuals, which are then mutated (change in their parameters) and re-evaluated. A fitness function is used to measure the relative fitness of each individual. If a better individual is discovered, it replaces the current worst individual. This process is repeated to create the optimal individual for the given problem, which is used to optimize the routing protocol. The AIS2 algorithm constitutes the standard AIS for routing protocols. It is a population-based optimization method that utilizes genetic mutation and crossover operations to converge on the optimal solution. The self-organizing map (SOM) technique is used to partition the population into smaller sub-populations known as clusters. The best individual in each cluster is then used to create a set of possible parent individuals; these are then subjected to genetic operations to create a number of offspring individuals. These offspring individuals are then evaluated with the objective function to select the best individual; this process is repeated until the optimal solution is identified. AIS has been successfully used to identify various solutions in routing protocols. For instance, the Evolutionary Network Optimization Algorithm (ENO), which is based on AIS, has been used to optimize the dynamic routing protocol Distance Vector Routing (DVR) for mobile ad hoc networks (MANET). The results obtained by the ENO algorithm outperformed other optimization methods and improved the mode of communication between multiple nodes. In conclusion, AIS is an effective approach for optimizing routing protocols. It utilizes the genetic principles of mutation and crossover, combined with a fitness function to identify and eliminate inefficiencies. Moreover, it is simpler and more inexpensive than traditional optimization methods, making it a promising solution for optimizing network routing protocols.

4. K-Means Clustering based Novel Method Experimental Setup and Results

In this project, a new flooding strategy for AODV routing is being proposed. The K-Means clustering

technique is being used to pick the optimal cluster of packet forwarders who broadcast RREQ instead of broadcasting to all the nodes within transmission range of the sender. This helps in limiting the delivery of extra control packets, leading to reduced network congestion and end-to-end delay. This strategy has been tested using ns3.35 and the results are beneficial. In K-Means Clustering, various characteristics of the neighbors are picked to determine the most suitable clusters. These include considering the transmission error

rate, the distance to the destination, and the available buffer room. To measure the performance of these distinct clusters, comparison with an ideal forwarding node is conducted with characteristics, such as the maximum buffer size, distance to the destination, number of transmission errors, number of nodes, and how many packets can be forwarded per second. From 10, 20, 30, 40, to 50, these details are all taken into account to choose the ideal cluster.

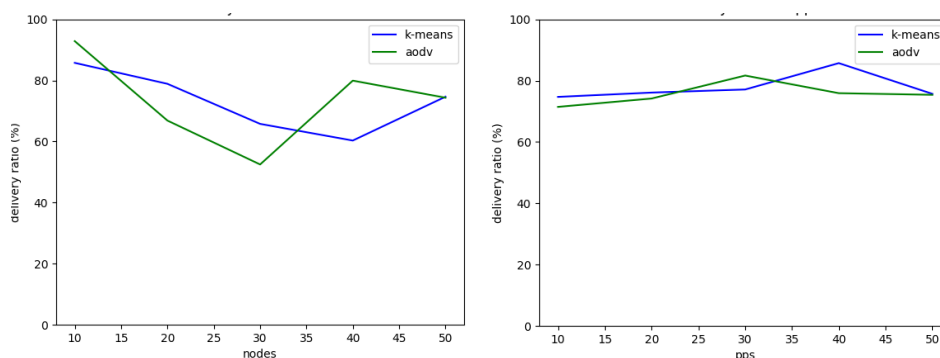


Figure 3. K-Means and AODV a) Delivery Ratio Vs Node b) Delivery Ratio Vs pps

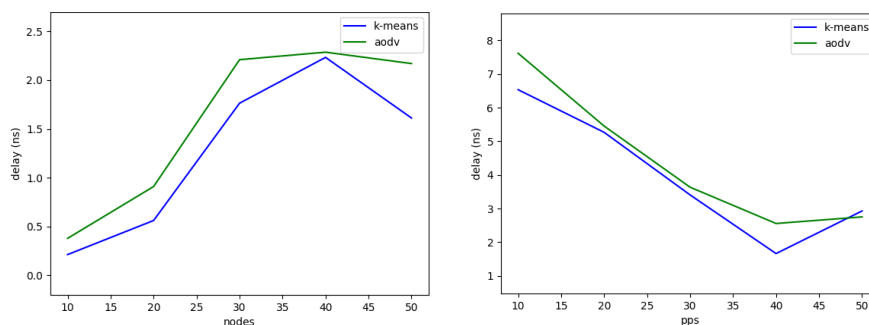


Figure 4. K-Means and AODV a) Delay Vs Node b) Delay Vs pps

The data suggests that the modern algorithm has a slightly lower delivery ratio compared to AODV. Despite the lower number of forwarders set up by this technique, the variation of delivery ratio is negligible. On the other hand, the contemporary approach hold an exquisite advantage over the solely AODV approach in terms of the end-to-end delay. This is attributed to the fewer RREQ and RREP packets used by the improved algorithm, which expedites the route identification process. Therefore, even though the deployment of K-Means clustering for selective forwarding may

result in a minor adjustment in the delivery rate, the up-to-date strategy abolishes end-to-end delay substantially.

5. Conclusion and Summary

This proposed work introduces the use of k-Means machine learning method, a clustering technique, to implement an energy conservation mechanism. The energy consumption level of the node is estimated based on the prediction of the system and the K Means clustering algorithms are utilized

alongside AODV routing to select the route with the least possible energy expenditure. The control packets in the network are managed, by limiting their unnecessary delivery, thus avoiding network congestion and delay of the end-to-end routing. The delivery of the request message packet (RREQ) is further improved by choosing the best cluster of forwarders through the K-Means clustering technique. This proposed work introduces the use of a K-Means clustering machine learning method to help conserve energy in a network while improving routing, message delivery, and reducing congestion. The energy consumption of a node is predicted based on the system, and the K-Means technique is used with an AODV routing algorithm to select the route with the lowest possible energy expenditure. The control packets in the network are managed to reduce unnecessary delivery, and the K-Means clustering technique is used to select the best cluster of forwarders for improved delivery of request message packets (RREQ).

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