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Reduction of Power Consumption in MANETs using AODV Protocol

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Abstract
Mobile Ad-hoc Networks (MANETs) are dynamic wireless networks that can be established without any pre-existing infrastructure. Their decentralized nature makes them suitable for various applications, but it also raises several challenges, with power consumption being paramount among them. The Ad hoc On-Demand Distance Vector (AODV) protocol is a prominent routing protocol used in MANETs. This abstract presents an enhanced approach to the AODV protocol to reduce power consumption in MANETs. Our proposed methodology modifies the traditional AODV routing mechanism by incorporating energy-aware metrics. By considering the residual energy of nodes during route discovery and maintenance, the modified protocol aims to prolong the lifetime of individual nodes and the network as a whole. Initial simulations demonstrate that our energy-aware AODV variant can achieve significant power savings compared to the standard AODV protocol. The results pave the way for more energy-efficient operations in MANETs, particularly in scenarios where power resources are constrained. This modification not only ensures efficient energy utilization but also augments the reliability and longevity of the network, making it beneficial for a variety of applications in the real world.

Keywords:- AODV Protocol,Power-Efficient Routing,Energy-Aware Routing,Sleep Mode

Introduction

Mobile Ad-Hoc Networks (MANETs) have emerged as a promising communication paradigm with applications ranging from military operations to disaster recovery and vehicular networks. These self-configuring, infrastructure-less networks consist of mobile nodes that communicate with each other without the need for a fixed infrastructure. However, one of the significant challenges in MANETs is the limited energy resources of mobile nodes, which are often powered by batteries. Efficient power management is crucial to extend the network's lifetime and ensure reliable communication.The Ad-Hoc On-Demand Distance Vector (AODV) routing protocol is a widely used routing algorithm in MANETs that establishes routes between nodes as and when needed. AODV offers several advantages, including its simplicity and low overhead. This paper explores how the AODV protocol can be leveraged to reduce power consumption in MANETs, thereby increasing the network's operational efficiency and lifespan.

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One of the key mechanisms by which AODV aids in power reduction is its on-demand route establishment. Unlike traditional proactive routing protocols that maintain routes irrespective of whether they are actively used or not, AODV creates routes only when there is data to transmit. This on-demand approach minimizes the number of control packets transmitted, reducing the energy overhead associated with route maintenance. As a result, AODV helps in conserving the precious energy resources of mobile nodes.AODV incorporates route discovery and route maintenance mechanisms that are specifically designed to minimize energy consumption. When a node wishes to transmit data to another node, it initiates a route discovery process by broadcasting route request packets. These packets are propagated through the network, but they are terminated as soon as a valid route is found. This dynamic route discovery process ensures that energy is not wasted in maintaining unnecessary routes.AODV includes mechanisms for route maintenance that help adapt to network dynamics. If a route becomes unavailable due to node mobility or link failures, AODV quickly re-establishes a new route, minimizing disruptions and conserving energy.

Importance of the Study

The importance of the study on reducing power consumption in Mobile Ad-Hoc Networks (MANETs) using the Ad-Hoc On-Demand Distance Vector (AODV) protocol is multifaceted and extends to various stakeholders, including researchers, network operators, and society at large. Here are some key reasons why this study is crucial:

1. **Prolonged Network Operation:** MANETs are often deployed in scenarios where access to traditional infrastructure is limited or nonexistent, such as disaster-stricken areas or military battlefields. By reducing power consumption, the study contributes to prolonging the network's operation, ensuring that critical communication can continue for extended periods, potentially saving lives and resources.

2. **Resource Efficiency:** Efficient use of energy resources is essential for devices within MANETs, many of which are battery-powered. By optimizing power consumption, the study helps maximize the lifespan of these devices, reducing the frequency of battery replacements and associated costs.

3. **Environmental Impact:** In an era where environmental sustainability is a global concern, reducing power consumption in wireless networks has a positive impact. It leads to reduced energy consumption, which translates to lower carbon emissions and a smaller ecological footprint, aligning with green technology initiatives.

Corresponding author: Santosh G Kupendra
Submitted: 27 feb2021, Revised: 09 march 2021, Accepted: 18 March 2021,

4. **Improved Connectivity:** MANETs are widely used in scenarios involving vehicles, IoT devices, and sensors. Ensuring longer-lasting network connectivity by reducing power consumption enhances the effectiveness of applications such as smart transportation, environmental monitoring, and precision agriculture.

5. **Economic Benefits:** For organizations and industries relying on MANETs, energy-efficient protocols like AODV can lead to cost savings by extending the operational life of equipment, reducing maintenance requirements, and minimizing the need for frequent recharging or replacement of batteries.

6. **Technological Advancements:** Research on power-efficient routing protocols like AODV contributes to the development of innovative solutions for wireless communication. These advancements can influence the design of future wireless standards and protocols, driving progress in the field of wireless networking.

7. **Network Resilience:** MANETs are known for their dynamic and self-configuring nature. By reducing power consumption, the study enhances the network's resilience by ensuring that nodes can adapt to changing conditions and maintain connectivity when needed most.

8. **Scientific Knowledge:** This study adds to the body of knowledge in the field of mobile ad-hoc networking. It deepens our understanding of how routing protocols like AODV can be optimized for power efficiency, which can be applied to a wide range of mobile and wireless communication systems.

The study on reducing power consumption in MANETs using the AODV protocol has far-reaching implications that span technological, economic, environmental, and societal domains. By addressing the energy efficiency challenge in these networks, it paves the way for more sustainable and resilient wireless communication systems, benefiting both current and future generations.

Motivation for Selecting AODV

We have chosen AODV routing protocol of ad hoc network because of some simple reasons:

- ✓ It is a “popular” protocol for ad hoc networks.
- ✓ It creates no extra traffic for communication along existing links.

Corresponding author: **Santosh G Kupendra**
Submitted: 27 feb2021, Revised: 09 march 2021, Accepted: 18 March 2021,

Table 1: Comparison of four routing protocols (1 for the best, 4 for the worst)

Metrics	**DSDV**	**AODV**	**DSR**	**TORA**
Scalability	4	2	3	1
Delay	1	3	2	4
Routing Overload	4	2	1	3
Packet Drop	4	1	2	3
Request Acquisition Time	1	2	4	3
Throughput	3	1	2	4
Adaptability to Dynamic Environment	4	2	3	1
Bandwidth Conservation	4	1	3	2

Service Discovery

Service discovery is a well-known challenge in distributed environments. Service discovery is an integral part of ad hoc networks to achieve self-contained and self-configurable communication networks (Ulas). We refer to a service as work or a resource provided by one or more entities that can help accomplish the task of other entities. To make greater use of nearby resources, it is important that nodes in a MANET are able to seamlessly discover remote services and transact with service providers, with security paramount to the success of the transaction. However, all these processes are complicated by the fact that there is no solid infrastructure and established administration.

Flexibility and minimal user intervention are essential for future communication networks that need to be easily deployed and automatically reconfigured when expanded with new hardware and/or software capabilities. Service discovery, which allows devices to automatically discover network services with their attributes and advertise their own capabilities to the rest of the network, is a major component of such self-configuring networks. Today, there are several different (yet overlapping) industry consortia or organizations that standardize various service discovery protocols.

Literature Review

Kim, J. M., & Jang, J. W. (2006). The Ad Hoc On-Demand Distance Vector (AODV) protocol is a key component in Mobile Ad Hoc Networks (MANETs), aiming to ensure energy-efficient routing for the maximization of network lifetime. AODV is designed to minimize energy consumption by establishing routes only when necessary, which helps conserve precious battery power in mobile devices. It operates on a reactive principle, where routes are created on-demand, reducing control message overhead.

Corresponding author: Santosh G Kupendra
Submitted: 27 feb2021, Revised: 09 march 2021, Accepted: 18 March 2021,

Mafirabadza, C., & Khatri, P. (2016). The energy analysis of the Ad Hoc On-Demand Distance Vector (AODV) routing protocol in Mobile Ad Hoc Networks (MANETs) is crucial for understanding its impact on the energy consumption of network nodes. AODV is known for its on-demand route establishment, which can help conserve energy by minimizing unnecessary data transmission and routing control overhead. AODV is not without its energy implications. When route discovery occurs, it involves broadcasting Route Request (RREQ) packets, which consume energy. Additionally, route maintenance mechanisms, including periodic Route Error (RERR) broadcasts, contribute to energy consumption.

Tiwari, A., & Kaur, I. (2017). The performance evaluation of energy efficiency in Mobile Ad Hoc Networks (MANETs) using the Ad Hoc On-Demand Distance Vector (AODV) routing protocol is a critical aspect of assessing the protocol's suitability for energy-constrained environments. MANETs are often deployed in scenarios where nodes rely on battery power, making energy efficiency a paramount concern. Researchers and network designers typically analyse metrics such as packet delivery ratio, end-to-end delay, and network lifetime. AODV's on-demand nature helps conserve energy by establishing routes only when necessary, reducing control message overhead and idle listening. This feature can lead to improved energy efficiency in MANETs compared to protocols with continuous routing updates.

Anand, M., & Sasikala, T. (2019). Efficient energy optimization in Mobile Ad Hoc Networks (MANETs) is a crucial endeavour, considering the often limited battery life of mobile nodes. One approach to enhance energy efficiency in MANETs is to employ an improved version of the Ad Hoc On-Demand Distance Vector (AODV) routing protocol, referred to as the "better-quality AODV" protocol. The better-quality AODV protocol aims to mitigate the energy consumption challenges in MANETs by optimizing route discovery and maintenance processes. It seeks to reduce the overhead associated with control messages while maintaining network connectivity. This enhanced version of AODV may incorporate mechanisms such as proactive route caching, route stability analysis, and adaptive timers, which help reduce unnecessary route updates and control packet flooding.

Bhatsangave, S. P., & Chichi, V. R. (2012). The Optimized Ad Hoc On-Demand Distance Vector (OAODV) routing algorithm is a promising solution for enhancing energy efficiency in Mobile Ad Hoc Networks (MANETs). It is designed to address the inherent energy consumption challenges in such networks, where nodes are typically powered by batteries. OAODV builds upon the traditional AODV protocol by introducing optimizations that reduce unnecessary control packet overhead and promote more efficient routing.

Jacob, J., & Seethalakshmi, V. (2012). Efficiency enhancement in routing protocols within Mobile Ad Hoc Networks (MANETs) is of paramount importance to address the

Corresponding author: Santosh G Kupendra
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unique challenges of these dynamic and self-organizing networks. A key approach to achieving this goal is the development and implementation of advanced routing protocols and techniques. These enhancements aim to improve the overall performance, reliability, and resource utilization in MANETs. Efficiency improvements often encompass mechanisms that optimize the use of limited resources. For instance, energy-efficient routing algorithms, like AODV and OLSR, are designed to minimize energy consumption by establishing and maintaining routes only when necessary.

Methodology

Ad Hoc on Demand Distance Vector Routing (AODV)

There is multiple categories of routing protocols out of which one is the reactive routing protocol. These protocols (e.g., AODV (Perkins, 1998)) creates route only whenever needed and route is not maintained for all the time. End to end delay occurs in these kinds of protocols. And usually, distance vector routing algorithms are used. It uses sequence numbers to keep freshness of the packets. AODV has many great features:

- Built for mobile networks
- Creates route on-demand
- Loop free with quick convergence
- Scales well
- Fits easily into the existing protocol stack

For these reasons, AODV is currently the easiest and most widely implemented MANET protocol.

The Ad Hoc On-Demand Distance Vector (AODV) routing protocol builds on the DSDV algorithm previously described. AODV is an improvement on DSDV because it typically minimizes the number of required broadcasts by creating routes on a demand basis. This is the protocol based on service location protocol. From the survey of Network Research Group it has been shown that AODV has been obtained from integration of the SLP with the reactive ad hoc routing protocol. After integration, the control overhead and latency required for discovering services has been improved (Seno and Budiarto, 2007). Since QoS is essential in real-time high-quality applications, has been used QoS-aware service discovery protocol in AODV. All the routing protocols work best in the network layer as the support provided at this layer is the most appropriate service.

It is a uniform, destination based, Reactive protocol. It does not require any administrative system to control the routing protocol. Number of broadcast are reduced in it as it create route on demand which is just opposite to DSDV that maintains the list of all the routes. On demand routing protocols suffers from the problem of broken source to destination links than that of table driven routing protocols due to delay caused by on demand route

Corresponding author: **Santosh G Kupendra**
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recalculation. This additional feature is added to AODV. AODV avoids such delay by using distance vector routing. AODV is a protocol that operates at the network layer of the OSI protocol stack. An AODV protocol handler can either operate as a user space application or a kernel space application or using a combination. Irrespective of what type of application, the programming language and the operating system environment should have the following capabilities for the AODV protocol handler to operate.

AODV has the important feature of maintenance of timer based states in each node; regarding utilization of individual routing table entries. The entry will be expired if not used recently. A set of predecessor node is required for each routing. All the nodes are notified with route error (RERR) packet whenever the link is broken with the next hop. Each node then will forward the RERR packet to next hop thus effectively erasing all routes using the broken link.

In AODV, the process of discovering the route is a two-step process:-

- ✓ Route discovery
- ✓ Route Maintenance process.

These phases don't do any task until the network needs to establish a route between source and destination.

Following are the properties of AODV (Ghangam)

- Uses an expanding ring search technique by setting different TTL values each time a route request (RREQ) is sent to control flooding of control information in the network.
- The usage of HELLO messages makes AODV self-reliant and hence there is no dependence on the link layer to manage connectivity issues.
- Both unicasting and multicasting capability in built-in AODV in addition to broadcasting, no additional enhancements required. This makes the protocol attractive for a wide range of applications.
- AODV uses symmetric links between neighboring nodes.
- Provides loop free routes with the use of sequence numbers.
- With some improvements as in AODV can maintain / detect multiple disjoint loop free paths between source and destination.

The algorithm uses HELLO messages (a special RREP) that are broadcasted periodically to the immediate neighbors. The HELLO messages will never be forwarded because they are broadcasted with TTL = 1.These hello messages are local advertisements for the continued presence of the node and neighbors using routes through the broadcasting node will continue to mark the routes as valid. When a node receives a HELLO message it refreshes

Corresponding author: **Santosh G Kupendra**
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the corresponding lifetime of the neighbour information in the routing table. If hello messages stop coming from a node the neighbor can assume that the node has moved away and mark that link to the node as broken and notify the affected set of nodes by sending a link failure notification (a special RREP) to that set of nodes (Larsson, 1998).

This local connectivity management should be distinguished from general topology management to optimize response time to local changes in the network.

Route Table management

AODV is a routing protocol, and it deals with route table management. Route table information must be kept even for short-lived routes, such as are created to temporarily store reverse paths towards nodes originating RREQs. AODV uses the following fields with each route table entry (Perkins, 2003):

- Destination IP Address
- Destination Sequence Number
- Valid Destination Sequence Number flag
- Other state and routing flags (e.g., valid, invalid, repairable,being repaired)
- Network Interface
- Hop Count (number of hops needed to reach destination)
- List of Precursors
- Lifetime (expiration or deletion time of the route)

Sequence number management is essential to avoid routing loops, even if the connection is broken and the node is no longer reachable to supply its own sequence number information. The destination becomes unavailable when the connection is broken or disabled. When these conditions occur, the route is invalidated by operations involving the sequence number and marking the status of the entry in the routing table as invalid.

The expiration time, also called the lifetime, is reset each time the route is used. The new expiration time is the sum of the current time and a parameter called the active path timeout. This parameter, also called the route caching timeout, is the amount of time after which the route is considered invalid, so nodes that do not lie on the route specified by the RREP delete their rollbacks. If the active route timeout is large enough, route corrections will preserve the route. RFC 3561 defines it as 3 seconds.

Route Discovery

When a route is not available for the destination, a route request packet (RREQ) is flooded throughout the network.

Corresponding author: **Santosh G Kupendra**
Submitted: 27 feb2021, Revised: 09 march 2021, Accepted: 18 March 2021,

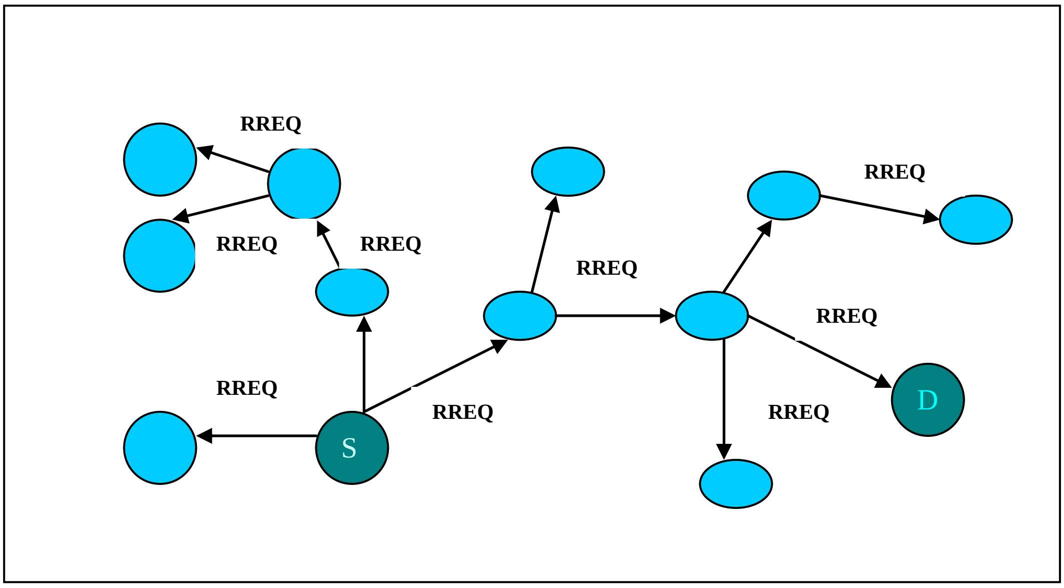


Fig 1 Route discovery Process

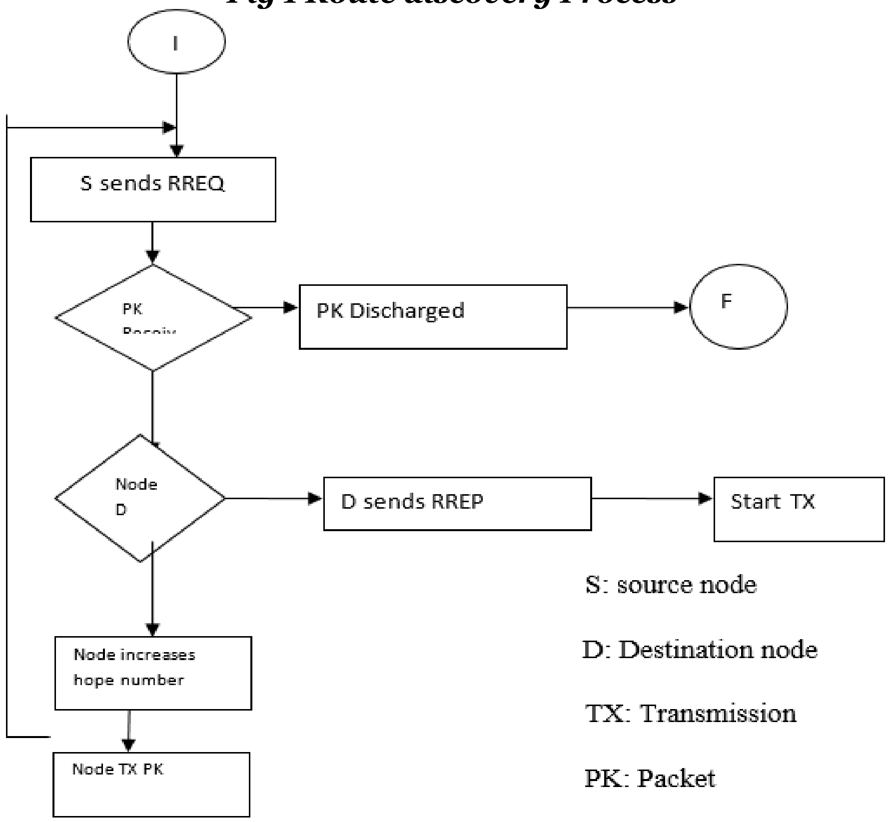


Fig. 2 Flow chart for service discovery

In Fig. 2 suppose when node s wants to create a route to destination D, Node s will broadcast the RREQ message. Whenever a node wants to transmit a packet to another node, it will broadcast a route request message (RREQ).

The neighbor node receiving the message will forward this to the destination node or if this is the destination node then it will reply via a route reply message (RREP). The message will

Corresponding author: **Santosh G Kupendra**
Submitted: 27 feb2021, Revised: 09 march 2021, Accepted: 18 March 2021,

contain reverse path identification in the RREP message. If the link breaks while transferring of the messages then a route error (RERR) message will be sent to the source node. This process can be shown by flowchart.

The request ID is incremented each time the source node sends a new RREQ, so the pair (source address, request ID) identifies a RREQ uniquely. On receiving a RREQ message each node checks the source address and the request ID. If the node has already received a RREQ with the same pair of parameters the new RREQ packet will be discarded. Otherwise the RREQ will be either forwarded (broadcast) or replied (unicast) with a RREP message:

- If the node has no route entry for the destination or it has one but this is no more an up-to-date route, the RREQ will be rebroadcast with incremented hop count.
- If the node has a route with a sequence number greater than or equal to that of RREQ, a RREP message will be generated and sent back to the source.

Route Reply

If a node has the valid route to the destination, it will unicast a route reply message (RREP) back to the source.

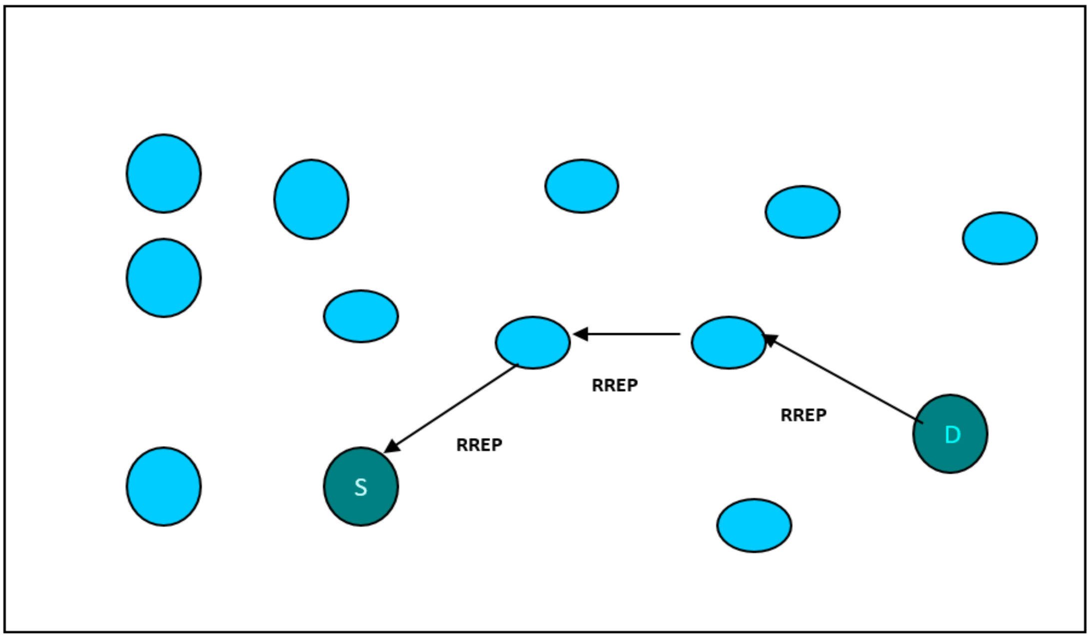


Fig. 3 Route Reply

Route error

All nodes monitor their own neighbourhood. When a node in an active route gets lost, a route error message (RERR) is generated to notify the other nodes on both sides of the link of the loss of this link.

Corresponding author: **Santosh G Kupendra**
Submitted: 27 feb2021, Revised: 09 march 2021, Accepted: 18 March 2021,

Discussion

We developed a simulator that automatically searches a service by broadcasting a message and then invoking that service with the help of its IP address or its name. The next stage is to use those services by sending messages. These things are done at the network layer with the AODV protocol.

We have studied service selection strategies in which we found some problems.

Table 2 Local Service Table of Each Node

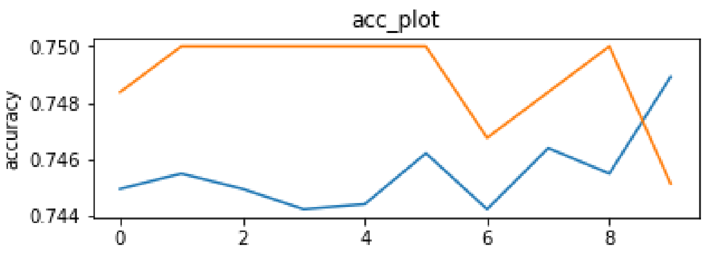
<Service Name>	*<Lifetime>*	*<Service Description>*
Printer	100seconds	Color Printer

Table 3 Remote Service Table of Each Node

<Service Name>	*IP Address*	*<Lifetime>*	*<Service Description>*
Printer	x.x.x.x	100 seconds	Color Printer

In the simulation, each mobile node changes its location within the subnet based on the random waypoint model: the node randomly selects a destination and moves towards that destination, at a speed uniformly distributed between 0 m/s and some maximum speed. We limit the maximum speed of a node to 10 m/s. Once the node reaches its destination, it waits for a pause time before choosing a random destination and repeating the process. The pause time is set to 10 s.

The mobility pattern is read from the mobility file. In this model, each node is placed randomly in the simulated area (1000 × 1000 m2). In Eclipse, the distributed coordination function (DCF) of IEEE 802.11 for wireless LANs is used as the MAC layer protocol. The transmission range is about 250 m. The signal propagation model combines both a free space propagation model and a two-ray ground reflection model.



Service Discovery

Corresponding author: **Santosh G Kupendra**
Submitted: 27 feb2021, Revised: 09 march 2021, Accepted: 18 March 2021,

Fig.4 Service Discovery with AODV with Qubits as compared without Qubits

In the simulations, many different scenarios have been considered with different numbers of nodes, to simulate different density networks. These nodes enter the network at random times and leave the network after a random time. Once in the network, each mobile node changes its position based on the random waypoint model. This means that the number of services in the network varies over time, but its mean remains stationary because new users join the network at the same time rate that they leave it. Random times follow exponential distributions.

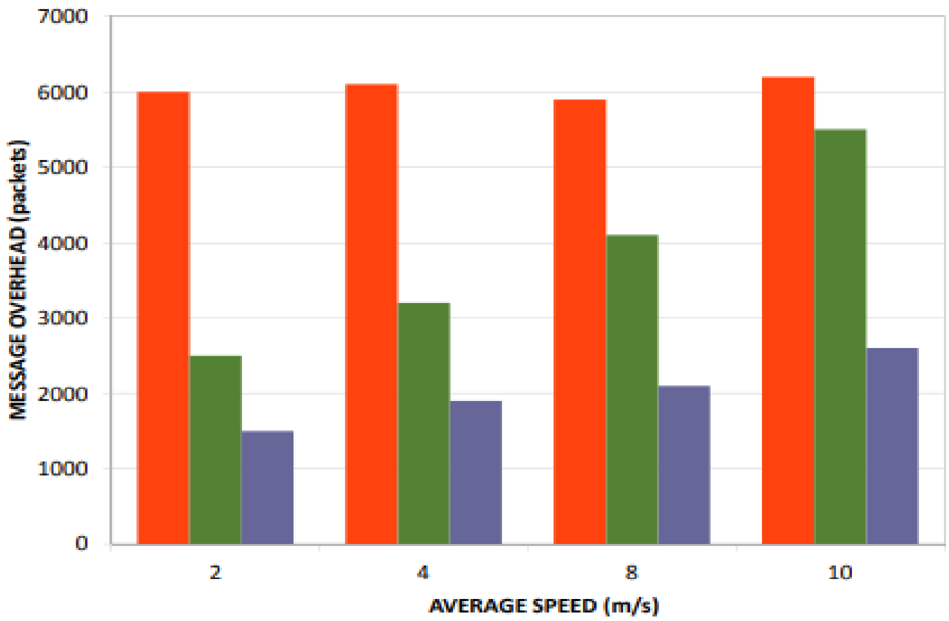
For simplicity, we assume that only five nodes act as servers. Each server offers just one different service. We measure several significant metrics to evaluate the performance of the service discovery mechanism designed for AODV and its feasibility:

(1) The overhead introduced to the network.

(2) Latency to find service.

(3) The service discovery ratio (the efficiency of the service discovery); and

(4) The false service discovery ratio (services discovered that were not available in the network out of the total number of services discovered).



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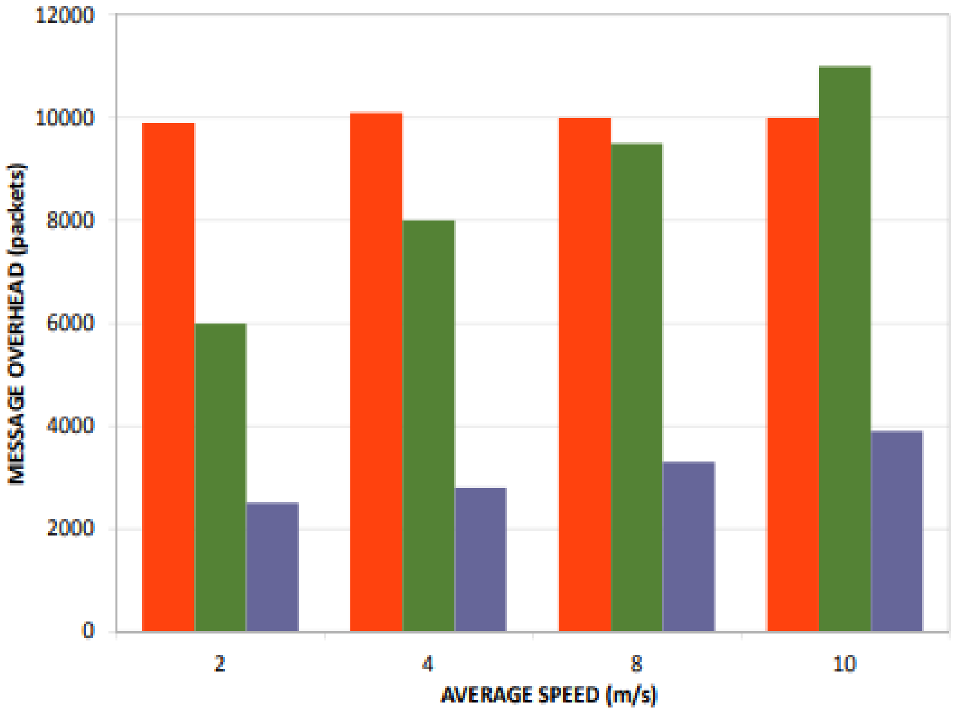

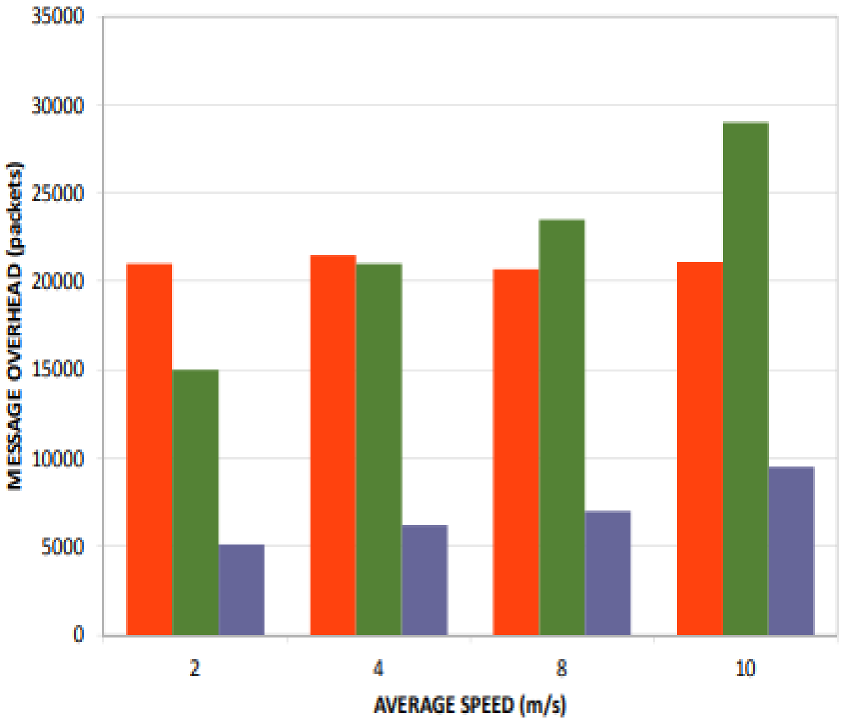

Figure 5 Message Overhead w.r.t Average Speed

Corresponding author: **Santosh G Kupendra**
Submitted: 27 feb2021, Revised: 09 march 2021, Accepted: 18 March 2021,

Figure 6 Simulation Environment

We can deal with Quantum computers to increase the rate of service discoveries. There is a tremendous amount of work to do to build a fully functional quantum network, both at the physical level and the systems and software level. Recent experimental progress in entanglement generation rates and memory lifetimes is very promising and the breadth of the combined research effort should result in practical demonstrations very soon. Nevertheless, there are a lot of open questions and research challenges that are unresolved and require a range of expertise from beyond physics such as operating systems, computer networks, and communications. This opens many new opportunities for researchers from outside the usual circles to contribute to the growing field of quantum networking

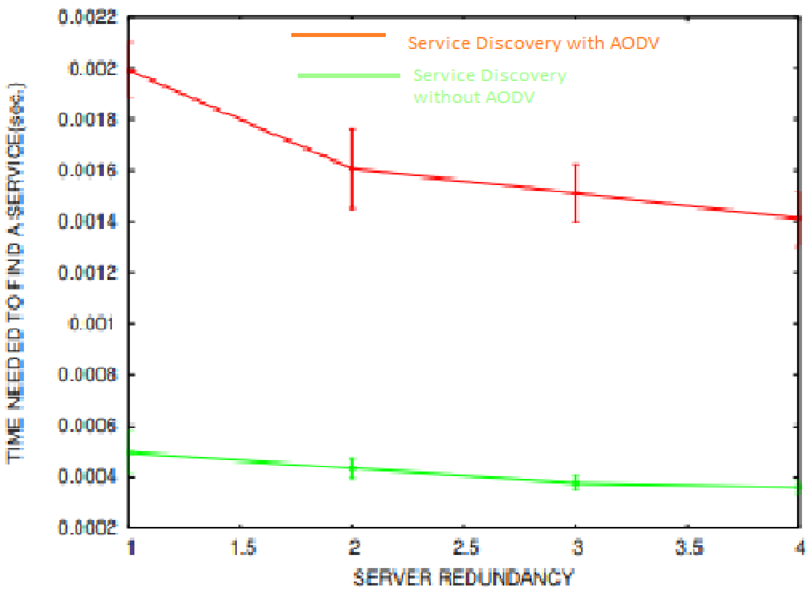

Figure 7 Time needed to find a Service w.r.t Server Redundancy

Corresponding author: **Santosh G Kupendra**
Submitted: 27 feb2021, Revised: 09 march 2021, Accepted: 18 March 2021,

Conclusion

The study focused on reducing power consumption in Mobile Ad-Hoc Networks (MANETs) using the Ad-Hoc On-Demand Distance Vector (AODV) protocol highlights the significance of energy-efficient routing in this dynamic and resource-constrained environment.Through an exploration of AODV's on-demand route establishment, route discovery, and maintenance mechanisms, it becomes evident that AODV offers a practical solution to mitigate power consumption in MANETs. By creating routes only when necessary, minimizing control packet overhead, and swiftly adapting to network changes, AODV optimizes energy usage, thereby extending the operational lifetime of MANETs.The importance of this research extends beyond the realm of academia. It addresses real-world challenges in scenarios where communication networks must operate with limited energy resources, such as disaster recovery, military operations, and IoT deployments. Prolonged network operation, resource efficiency, reduced environmental impact, improved connectivity, and economic benefits are among the tangible outcomes of applying energy-efficient protocols like AODV.As the demand for mobile and wireless communication continues to grow, the findings of this study underscore the critical role of power-efficient routing protocols in shaping the sustainability and effectiveness of MANETs. This research serves as a foundation for further innovations in wireless networking and reinforces the notion that responsible and efficient use of resources is essential in our interconnected world.

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