Spatial Information Research (2024) 32:119–129
https://doi.org/10.1007/s41324-023-00535-z

# Mobile wireless ad-hoc network routing protocols comparison for real-time military application

**Shams Al Ajrawi**[1] · **Bang Tran**[1]

Received: 3 March 2023 / Revised: 18 June 2023 / Accepted: 21 June 2023 / Published online: 14 September 2023


**Abstract**
Mobile wireless Ad-hoc has become more popular because it forms quickly, has an easy setup, and has easy extensibility. The mobile ad-hoc wireless networks can be further classified according to their applications as follows: Regular user ad-hoc networks are commercial communication that applies to vehicles to help avoid collisions and accidents and live connections to transfer data from car to car. Another application is disaster rescue ad-hoc networking, usually used when a normal infrastructure network is destroyed by storms, earthquakes, tsunamis, etc. Nowadays, a lot of applications, particularly those related to the military and emergency situations, rely on mobile ad hoc wireless networks, where security needs are more challenging to provide than in regular networks. We present the tactical network needs for the military. This platform attempts to assess the possible advantages of mobile ad hoc networks in tactical military applications. This work proposes route discovery using reactive (on-demand) routing protocols where nodes need to just transfer data. This eliminates the requirement for each node to store and maintain any routing tables. This study presents and contrasts the benefits and drawbacks of two fundamental mobile ad hoc routing systems (AODV and DSR). Both protocols are On-Demand routing techniques, and when data needs to be sent, the discovery phase begins. The results of the simulation, the AODV routing approach outperforms the DSV routing method under identical simulated conditions.

**Keywords** Mobile wireless ad-hoc network · Routing protocols · Military application · Real-time monitoring

## 1 Introduction

Mobile wireless ad hoc networks (MANETs) are autonomous, decentralized networks made up of mobile nodes that connect via wireless links. MANETs allow devices to interact with one another without the use of a fixed infrastructure, like a centralized router or access point. In MANETs, routing protocols oversee determining the most efficient route for data to go between devices. MANETs have gained favor as a means of providing real-time environmental monitoring systems because of their adaptability and simplicity of deployment in difficult and isolated places. Because of its adaptability to contexts that are dynamic and change quickly, MANETs have attracted a lot of attention recently. Many different applications, such as emergency response, military operations, and environmental monitoring systems, have made extensive use of MANETs. The procedure for monitoring the environment's quality is called an environmental monitoring system.

An interior weather instrument can receive data from outdoor weather sensors via a Wi-Fi weather station, which is a connection between the outdoor sensors and a home Wi-Fi internet signal. Also, a connected website or mobile app receives this information. The goal of Bluetooth wireless technology is to replace the wires that connect portable devices while maintaining high levels of security. Bluetooth is a short-range communications technology. Ad-hoc technology is a small area network with relatively little coverage. Recently, a lot of research and development efforts have been concentrated on mobile ad-hoc networks. Military applications, where the network's distributed design is an operational benefit or perhaps a need, have been the major focus of ad-hoc packet radio networks so far. Ad-hoc networks, which include networks of wireless devices carrying

✉ Shams Al Ajrawi
salajrawi2@sdsu.edu

Bang Tran
btran5774@sdsu.edu

[1] Department of Electrical Engineering, San Diego State University, San Diego, CA, USA

by individuals as well as networked wireless access points, can be employed in a variety of military applications.

One example of the use of MANETs and context-aware intelligent visual analytics for real-time environmental monitoring is in forest fire detection and monitoring. In this application, MANETs are used to collect data from various sensors deployed in the forest. The collected data is then processed and analyzed using context-aware intelligent visual analytics to detect and monitor forest fires in real-time. The collected and analyzed data is then used to identify and monitor forest fires in real time using context-aware intelligent visual analytics. Information visualization analyzes datasets using visual representations of the data utilizing cutting-edge tools and techniques. By presenting the information as infographics, tables, and mapping, users can identify trends and derive insightful conclusions. Organizations can use these insights to improve their data-driven decision-making.

Technological complementarity is defined as an overlap between patents belonging to the same class but a distinct subclass. When technology complementarity is more valuable than technological similarity, the technologies of the target and acquiring organizations are complementary, and vice versa. Technology-related items come in a variety of complimentary forms. Cell phones and phone chargers, for instance, make excellent complementary products because the phone charger is the only one that can serve both purposes. Similarly, controllers and video gaming consoles make a great pair. The results of this analysis can be used to inform firefighting efforts and prevent the spread of fires. In conclusion, context-aware intelligent visual analytics and MANETs are complementary technologies that can be utilized in conjunction to provide real-time environmental monitoring systems. When just data needs to be transferred between nodes, we shall compel the use of reactive (on-demand) routing protocols. By doing this, there is no need for each node to store and maintain any routing tables. Because nodes do not need to spend time and energy maintaining the routing table, this routing method has the benefit of reducing network traffic and allowing nodes to consume less power.

Since the knowledge regarding routes and topology is updated frequently, networks also facilitate mobility. They are thus great choices for military tactical networks, where their capacity to operate quickly and decentralized is crucial. Nothing in a wartime scenario can guarantee that every communication node is a single hop distant due to the fundamental properties of radio transmission.

Ad hoc multiloop architecture is one of the finest methods to address the connection issue in the situation. MANET is more relevant compared to the Below of Brigade because to military needs and limits.

When a source wants to connect to a destination, the On-demand Routing Protocol finds a route each time, which adds to the delay time. These technologies work well together and can help decision-makers react swiftly to shifting environmental conditions and take wise decisions. Together, technologies can support decision-makers in making quick decisions in response to changing environmental conditions. It can often be challenging to determine whether a decision has been made because the process of making decisions is so dynamic. Our perspectives on decision-making are also influenced by how directly (and in what capacity) we are involved in making decisions, as well as by how those decisions affect us. Environmental can promote or prevent human connection (and the subsequent benefits of social support). For example, a peaceful environment with comfortable chairs and seclusion can persuade a family to stay and visit with a person. People's motivations and actions are affected by their surroundings. To fully investigate this approach's potential in many applications for environmental monitoring, more research is required. Some examples of routing protocols used in MANETs include:

- AODV (Ad hoc On-demand Distance Vector): A routing protocol that establishes routes on-demand when needed and also maintains them as long as they are required.
- DSR (Dynamic Source Routing): A routing protocol in which the source device is responsible for determining the route that the data will take.
- OLSR (Optimized Link State Routing): A routing protocol that uses link state information to make routing decisions.
- TBRPF (Topology Broadcast based on Reverse-Path Forwarding): A routing protocol that uses a flooding mechanism to broadcast topology information.

Everyone is aware that security and trust are fundamental requirements for military applications. In other words, security is the most crucial concern for ad hoc networks, especially for those applications that require security. On the other side, it is asserted that the primary uses of MANET are for emergency and military purposes, all of which have security-related requirements. Because MENAT cannot meet the applications' security requirements, MANET is a faulty design.

The mobile wireless Ad-hoc network protocol includes both static and mobile devices. First, all its devices communicate through a wireless medium because it is wireless networking. Second, the letter "ad-hoc" means that this network is pre-existing infrastructure or infrastructure. The ad-hoc network does not require any center network system such as routers or switches. Instead, it constructs the connection directly from device to device (nodes to nodes).

In the interests of linking two or more mobile technologies together without utilizing typical communication network hardware, such as a wifi connection or internet connection, wireless informal networking, or WANET, is a type of local area network (LAN) that is created on the spot.

In this paper, we will force Reactive (On- Demand) Routing Protocols, and routing discovery when nodes need to transfer data only. In this way, each node does not need to store and maintain any routing tables. The transportation strategy's benefit would be that it reduces network traffic and power-saving for nodes because nodes do not need to spend time and resources to maintain the routing table. In-depth analyses of the AODV and DSR routing protocols will be performed in this research using Network Simulation 2 (NS2). Twenty nodes will be used in the simulation to demonstrate communication via UPD and TCP connections. The simulation's output will be used to compare the average throughput, immediate throughput, package delivery ratio, and transmission power of two different transportation algorithms (AODV and DSR) (Go to the destination node first) are all compared. To distinguish each RREQ packet sent to intermediate nodes during the discovery phase from others, AODV employed sequence numbers. If a node gets several RREQ packets, it will examine the sequence number and discard the longer timestamp packet. In this manner, the AODV avoids loops and quickly locates the target node.

## 2 Literature review

Tanks, ships, and unmanned aerial vehicle (UAV) communication are a few examples of military applications that use ad hoc networks. When a network center device is not there and a secure connection is necessary, this type of application is mentioned in fights. Disaster rescue ad-hoc networking is another application; it is typically employed when a standard infrastructure network is devastated by storms, earthquakes, tsunamis, etc. These programs will be an easy-to-setup network among law enforcement officers or firefighters to assist in removing hurt persons and preventing fatalities. However, the On-demand Routing Protocol causes increasing delay time due to finding a route each time a source needs to create a connection to a destination [1].

An unmanned aerial vehicle (UAV), is a military aircraft that is controlled remotely or autonomously and that contains sensors, target designators, offensive weapons, or electronic transmitters intended to disrupt or destroy enemy targets. UAVs may be astonishingly effective, giving far more range and endurance than similar human systems because of their lack of personnel, life-support systems, and design-safety constraints. A network of unmanned aerial vehicles (UAVs) that may be utilized for a variety of purposes is created by the unmanned aerial vehicle communication networks (UAVCN). To complete the task, these nodes independently fly in ad hoc mode throughout space. However, UAVs encounter some difficult problems when collaborating and communicating. Due to the fast speed of these nodes, the communication connections cannot route the traffic that interferes with the routing algorithm.

A wireless network made up of several mobile nodes connected wirelessly and devoid of any infrastructure is called a Mobile Adhoc Network (MANET). It can both configure itself and repair itself. Although MANET has many advantages, it also has several problems that must be resolved. Routing protocols in MANETs are responsible for finding the best path for data to travel from one device to another [2].

Context-aware intelligent visual analytics is one potential way to address the challenges of processing and analyzing enormous amounts of data in real-time environmental monitoring systems. A scattered group of environmental sensors monitors and save the surroundings, and they transmit real-time information to a computer through an API or bespoke connection. Once data has been transmitted to a data center, techniques are utilized to find possible false data produced by corrupted remote monitoring. Typically, a broadcast converter is used to ingest the information into a database [3]. Due to their flexibility and ease of deployment in challenging and remote areas, MANETs have grown in popularity for enabling real-time environmental monitoring systems. One sort of decentralized wireless network is a wireless ad hoc network, often known as a WANET or MANET. The network is ad hoc since it is dependent on no pre-existing infrastructure, such as wireless access points or routers. As an alternative, each node takes part in routing by sending data to other nodes. The field of analytical reasoning known as "visual analytics" is aided by interactive visual interfaces [4]. Ad hoc routing networks operate on the fundamental presumption that all nodes are "equal," allowing any node to be utilized to route packets between any sources and destinations. In military (battlefield, search, and rescue) and civilian emergency scenarios, this supposition is reasonable.

Data production has increased dramatically during the past few decades. Yet, the capacity for gathering and archiving this data is growing more quickly than that for analysis. To overcome the difficulties of huge data processing and analysis in real-time environmental monitoring systems, context-aware intelligent visual analytics is a possible solution. It is foreseen that such connections will become more prevalent in both civilian and armed services configurations in the future. As a result, several routing protocols for wireless ad hoc networks have been proposed. The interaction between MANETs and context-aware intelligent visual analytics for real-time environmental monitoring systems will be discussed in this paper [5].

Conceptually, the context-related and middleware-related aspects of the middleware platform that will allow and act upon context awareness in a MANET environment may be separated. All operations involving context capturing, context processing, and knowledge extraction from various sources of contextual information are referred to as context-aspect operations. The suggested information system's middleware features include giving mobile nodes a platform for cooperation in an environment of ad hoc mobile networking. The suggested middleware should address these shortcomings. Context representation is a crucial component since a generic model needs to be modified to support information interchange on the one hand and provide a mechanism to handle different forms of context in a way that is specific to their semantics on the other. It is necessary to support interoperability among many contextual domains, with the usage of ontologies being the most obvious answer. It has been argued that mobile ad hoc networks are the perfect technology to construct in an instant communication infrastructure less for military use or a defective design. Security is the most crucial factor for the networks. Due to the military uses of Wireless Ad hoc Networks, it is much more significant. The issue of security cannot be properly resolved by the MANET.

The RMS software enables real-time monitoring of any necessary parameter. The three primary categories of environmental monitoring are water, soil, and atmospheric. The army has historically been fueled by technology. Soldiers are being aided by mobile applications in the broad examination of wartime strategy. Connecting ships, planes, tanks, drones, and soldiers to their military bases and building a network for risk assessment are other key uses of IoT in the defense sector [6]. MANETs have been extensively used in a wide range of applications. Wi-Fi, Bluetooth, or weather stations with data monitoring. Military ad hoc networks are used for communication between tanks, ships, and unmanned aerial vehicles (UAVs). A new paradigm for processing and interpreting massive amounts of data in real-time environmental monitoring systems are called context-aware intelligent visual analytics [7].

Computer vision combines computerized data analysis methods with animations making it possible to solve difficult analytical problems. This method can adapt to shifting environmental conditions because it is context-aware, and it can give decision-makers timely and pertinent information [8].

Context-aware intelligence computer vision is a paradigm shift for processing and understanding enormous volumes of data in real-time environmental monitoring systems. This approach combines machine learning, data visualization, and human-computer interface technologies to provide real-time insights into complex environmental data. Due to its context awareness and ability to provide timely and relevant information to decision-makers, this technique can adapt to changing environmental conditions. For real-time environmental monitoring systems, MANETs and context-aware intelligent visual analytics hold significant promise. MANET is free to move about and each has a limited amount of transmitting power, access to the node is only permitted within range of its neighbors, and there is no such infrastructure, the network topology may alter dynamically in an unpredictable way. MANETs are essentially peer-to-peer, data packets that carry information in a supermarket manner from a source to any destination in non-linear and non-wireless technologies. MANETs can provide a robust and reliable communication infrastructure for data collection and transmission, while context-aware intelligent visual analytics can provide real-time insights into the collected data. This combination can enable decision-makers to quickly respond to changing environmental conditions and make informed decisions [9]. There are very significant demands for multimedia services from the tactical military. For mission planning reasons, this ranges from low-latency, high-priority tactical data transmissions to digital secure voice apps coupled with applications like "white boards" and position reporting.

## 3 Methodology

### 3.1 AD-hoc on-demand vector (ADOV) routing protocol

Ad hoc devices must have a wireless network adapter or chip and be able to function as a wireless router when connected to function. Each wireless adapter needs to be set up for ad hoc mode instead of infrastructure mode when creating a wireless ad hoc network. The same service set identification (SSID) and wireless frequency channel number must be used by all wireless devices connecting to an ad hoc device. The ad-hoc wireless network can connect multiple neighborhood hops (nodes) and use these neighborhood hops as a link to communication between source and destination. This networking method's benefit is that it lessens network traffic and helps nodes conserve power. The primary units of the Integrated Rescue System aid those engaged in TA, depending on a variety of variables. This article addresses these elements. When people have been pulled from crashed cars, a traffic accident investigation is a process that involves identifying, disclosing, and documenting any civil or criminal violations of laws that may have led to the accident. Each hop can be either a source or a destination dependently [10–12]. People who believe that Mobile Ad hoc Networks are not a defective design and that we cannot utilize them in practice since most of their applications

are for military purposes are completely mistaken. It is accurate to say that mobile ad hoc networks originated with the military. However, it's possible that those people overlooked one of the most crucial factors: security. Now a day, networking engineers develop a variety of routing protocols for different applications of the mobile ad-hoc network. We can divide the wireless Ad-hoc network protocol based on routing methods, as shown in Fig. 1.

Approaches include the widely used Ad-hoc On-Demand Vector Routing (AODV) protocol for mobile communication ad-hoc. The route discovery phase has just started when the source needs to transfer data. By using AODV networking, the connection between the source and the destination is made in two phases. The On-demand Routing Protocol offers two fundamental forms of routing. These are Dynamic source routing and Ad-hoc On-Demand Distance Vector (AODV) (DSR). By using Network Simulation 2, this article will thoroughly assess both types of AODV and DSR routing protocols (NS2). Twenty nodes will communicate with each other via UPD and TCP connections in the simulation. We will evaluate the two types of routing protocols' average throughput, immediate throughput, package delivery ratio, and residual energy based on the results of the simulation (AODV and DSR). The AODV routing has two stages of setting up the connection from the source to the destination. Implementing international and commercial standards up to the network layer gives the capacity to support tactical operations using civil communications if the military communications networks sustain extremely extensive damage. Multicast is necessary for tactical military communication. A battle's outcome may depend on how well information is disseminated to the many warfighters involved.

### 3.1.1 Route discovery phase

The source uses broadcast to send Route Request (RREQ) packets to all neighborhood nodes to look for the destination node. After a certain time to live (TTL), the source will resend the broadcast RREQ if it does not receive any feedback from its neighborhood nodes [13].

Intermediate nodes continue forwarding the RREQ packet by adding their IP address to the packet. A route reply (RREP) packet is sent to the source whenever the Sequence number reaches the intended node through the active path

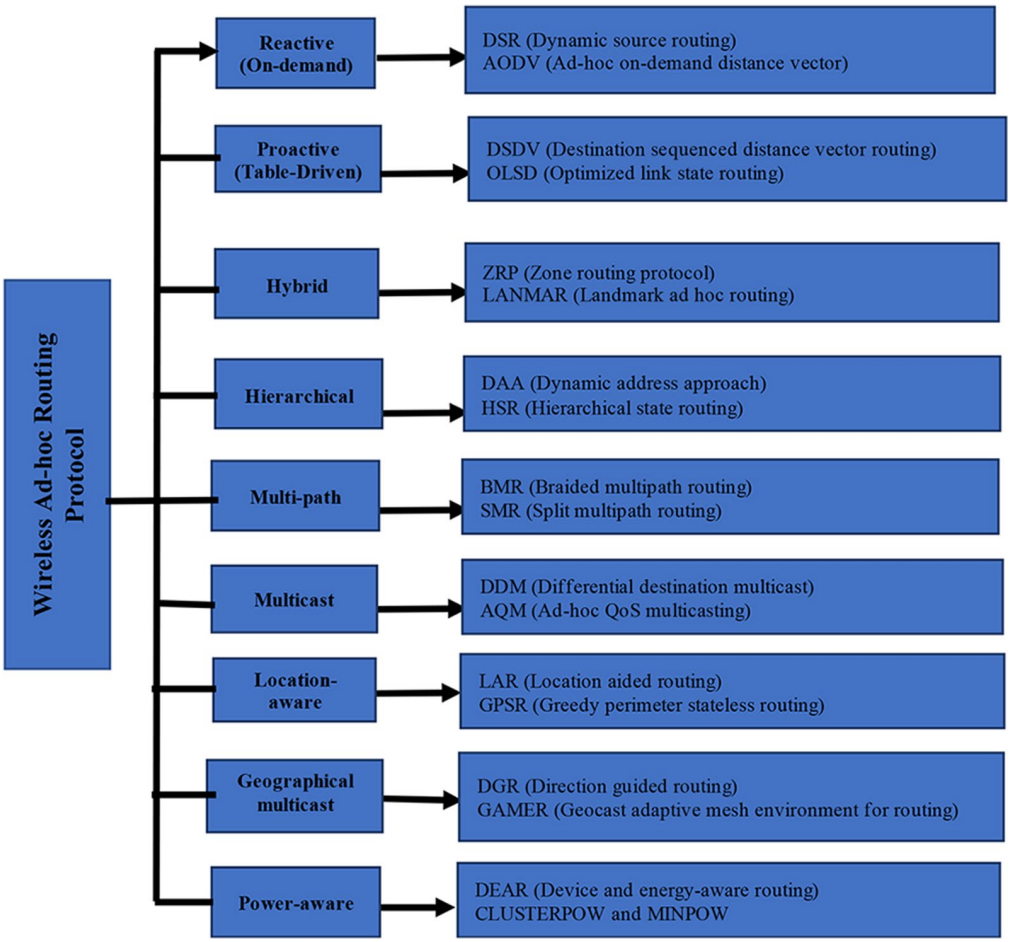


**Fig. 1** Types of wireless ad-hoc routing

by the unicast method [14]. Making critical decisions requires the rescue team to exchange information. In this case, the active path was determined on the path that has less the number of hops or less time travel [15].

This paper will deeply evaluate both types of AODV and DSR routing protocols by Network Simulation 2 (NS2). The simulation will demo communication between twenty nodes with UPD and TCP connections. Based on the simulation result, we will compare the comparison of two types of transportation algorithms' average throughput, instant throughput, package delivery ratio, and transmission power (AODV and DSR) (Come to the destination node first). During the discovery phase, intermediate nodes may be received more than one RREQ packet from other nodes, so AODV used sequence numbers to mark each RREQ packet. If a node receives more than one RREQ packet, it will check the sequence number and drop the longer timestamp packet. In this way, the AODV is loop-free and easily finds out where is the destination node. Military applications and associated research projects both heavily rely on ad hoc networks. People think that MANET will serve as the primary network architecture in situations where conventional wireless networks cannot be built, such as during emergencies or military applications. They believe that the fact that Wireless Ad-hoc networks are independent of a fixed infrastructure is what most distinguishes them from cellular networks. Mobile Ad-hoc networks, in their opinion, are also highly appealing for tactical communication in the military and in law enforcement. Once more, they are of the opinion that Wireless Ad hoc Networks will be crucial not only for military and emergency applications, but also for use in public forums like convention centers, conferences, and virtual classrooms.

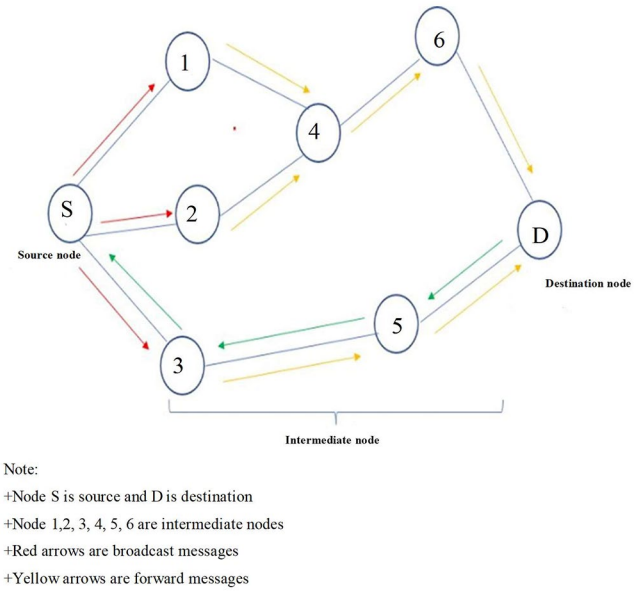


**Fig. 2** Discovery phase of AODV routing protocol

#### 3.1.2 Route maintenance phase

After the source receives the RREP packet, the connection is set up. The data was transferred through the active path from source to destination. When the source moves, the discovery phase will restart again. While the intermediate node moves, its neighborhood nodes realize that the link failure happened. These neighborhood nodes will send a notification (route reply error_ RRER) upstream and then to the source. In this way, the source can maintain the connection and reinitiate the discovery if needed.

The AODV handshake and transfer data showed in Fig. 2. Where:

Red arrows are broadcast messages RREQ from the source.

Yellow and purple arrows forward RREQ to neighborhood nodes.

Green arrows indicate the active path the RREP was sent back to the source.

## 4 Results and discussion

### 4.1 Dynamic source routing (DSR) protocol

Another on-demand networking technology is Optimized Link state Forwarding (DSR). It employs a shortest path method in which all nodes must have a cache to store route records.

#### 4.1.1 Route discovery phase

In the DSR protocol, a source node also starts discovering the destination by broadcasting a route request (RREQ) packet to its neighbors, such as in the AODV protocol. The (RREQ) packet is forwarded from node to node in a network. An intermediate node that received the RREQ packet will forward the RREQ packet by adding its address if it could not find any current paths to the destination in its cache [16–21]. Otherwise, an intermediate node will send a route reply (RREP) packet back to the source node to inform the route to the destination. The RREP packet also is sent by destination to source when intermediate nodes do not have any information about a destination. By this method, the source routing technique can develop multiple paths. The source nodes will find the most efficient routing to become an active path. The discovery process of the DSR protocol shows in Fig. 3.

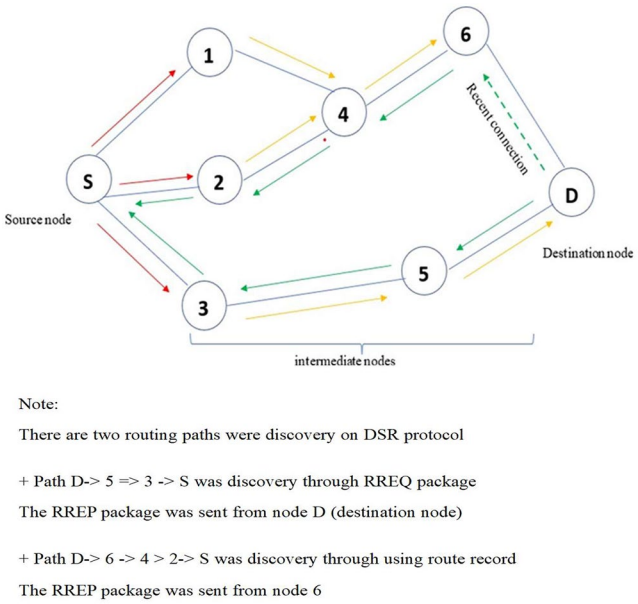


**Fig. 3** Route Discovery phase of DSR routing Protocol

### 4.1.2 Route maintenance phase

The DSR protocol maintains source routing by monitoring sending packages. If a node could not send a package to a neighbor, it declares routing related to that neighbor node was broken. Then it also sends a route relay error (RRER) packet to the sources to update the route record in the source's caches of the associated route.

## 4.2 Comparison ADOV & DSR routing

A key characteristic of mobile ad-hoc networks is their lack of physical infrastructure. They are very dynamic networks. These networks' nodes perform the role of routers, finding and maintaining the routes to other nodes in the network. Nodes in these networks may move and coordinate with other nodes. Mobility allows for dynamic changes to connections in the network and the addition and removal of nodes at any moment. A source-initiated routing protocol is AODV. It is a reactive protocol since nodes are not required to maintain routes to destinations that are not actively utilized in communication and only requests a route when necessary. The main distinction between AODV and DSR is that while DSR maintains the entire route from source to location, covering all nodes in between, AODV just keeps an address of the next hop to the target. The packet's sender determines the whole path through which to forward the packets. To compare the performance of two routing protocols (AODV and DSR). We set up a basic network of mobile ad-hoc network with 20 nodes in the Network Simulation Program (NS2). Such big bad events have the potential to

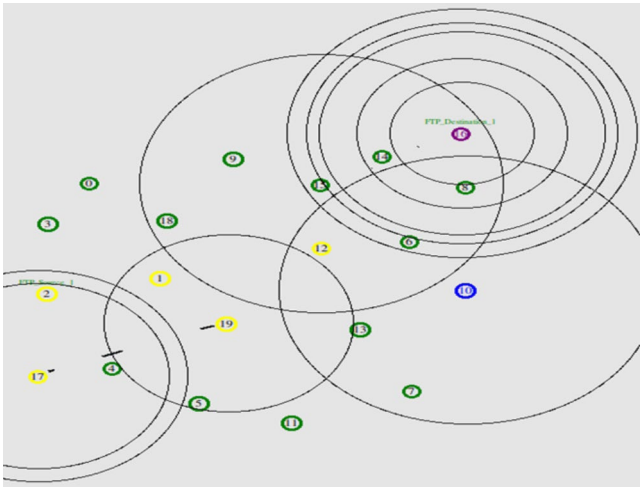

**Fig. 4** Simulation of 20 nodes of Mobile Wireless Ad-hoc

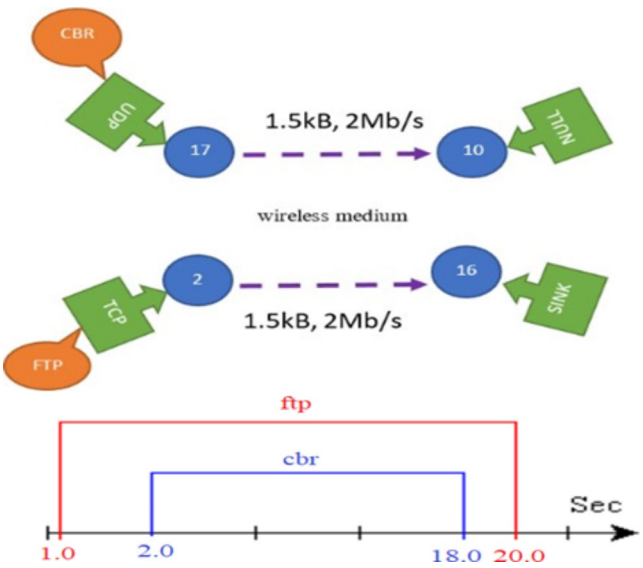


**Fig. 5** Schematic diagram of simulation setup for UDP and TCP modes

cause physical destruction and a devastating loss of life. They can stun entire villages and sometimes arrive as a surprise. Those who suffer a catastrophe could feel emotionally upset. It is usual to have anxiety before, during, and after catastrophes, as well as ongoing worry, trouble sleeping, and another negative affect. Many people can "bounce back" after disasters with help from friends, families, and the neighborhood, but some individuals might need adequate help to manage and remain on the road to recovery. These nodes move randomly in an area of $1000 \times 1000$ m and transfer data through the wireless medium with a simulation time of 20ms (Fig. 4).

This model simulates both UDP and TCP connections simultaneously, as shown in Fig. 5. Node 2 connects to node 16 through TCP, and node 17 connects to node 10 through UDP. In this simulation, we also include an energy model to

**Table 1** Comparison of different ad-hoc network routing protocol [15]

| Parameters | AODV | DSDV | DSR | TORA | WRP |
|---|---|---|---|---|---|
| Routing approaches | Demand-Based Routing | Table-based Routing | Demand-Based Routing | Demand-Based Routing | Table-based Routing |
| Procedure types | Ad-hoc on-demand Distance Vector | Distance Vector with Destination Sequencing | Routing Sources Dynamically | Routing Algorithm with Temporary Order | Protocol for Wireless Routing |
| Routing Structure | Flat Structure | Flat Structure | Flat Structure | Flat Structure | Plane Structure |
| Routing Maintenance | Map-reading Table | Map-reading Table | Map-reading Table | Map-reading Table | ------ |
| Routing Transparency | High | High | High | High | High |

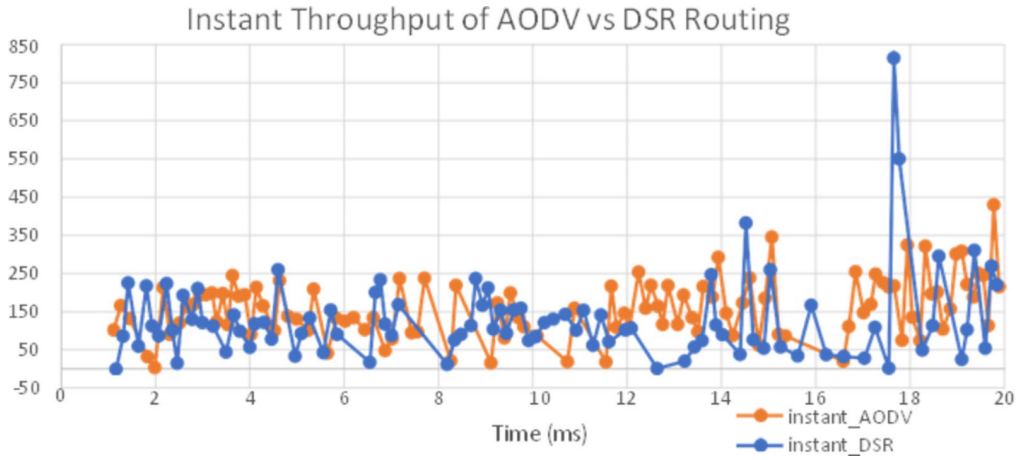


**Fig. 6** Instant Throughput of both AODV & DSR Routing vs. time

**Table 2** Average throughput of both AODV and DSR routing

```
jimmy@jimmy:~/Downloads/ns-allinone-2.35/Project Code_Bang
Tran$ awk -f average_throu.awk AODV.tr
Start Time 1
Stop Time 19
Received Packets 262
The throughput in Kbps is ©0.116677
jimmy@jimmy:~/Downloads/ns-allinone-2.35/Project Code_Bang
Tran$ awk -f average_throu.awk DSR.tr
Start Time 1
Stop Tine 19
pecetved Packets 198
The throughput in kbps is 0.083653
[mmya3temy: /Downloads /ns-allinone-2.35/Project Code_Bang
Trans$
```

check the node's residual energy [14]. The routing procedure is the subject of the most active and creative research in the MANET sector due to its difficulties and complexity as well as the significance of routing protocols. The two protocols are On-Demand routing techniques, and when data must be sent, the discovery phase begins. Ad hoc networks for mobile devices offer mobility, independence, and self-adaptation. For military purposes, they are essential due of these traits. MANETs in the military have extra issues with multicast traffic and security. AODV uses less electricity and performs better while transporting data. On the contrary, when the connecting link is down, DSR has quicker routing and fewer traffic.

We analyze and compare the AODV and DSR routing performance by four measured parameters: instant throughput, average throughput, residual energy, and package delivery ratio. Based on the simulation, the AODV routing gives more advantageous results than the DSV routing method in the same simulation conditions. Comparison of different Ad-Hoc Network Routing Protocol is illustrated in Table 1.

First, the instant throughput (Fig. 6) shows that the transferred data of AODV is more stable. Second, the AODV routing gives us a higher average throughput (110 bit/s compare to 83 bit/s – Table 2).

Moreover, we also observed that the package delivery rate of AODV is higher than DSR, which means the AODV has more success transferred data than DSR (Table 3).

The last performance parameter that we make a comparison with is residual energy which is the energy left after nodes transfer data. The chart shows that the AODV routing method consumes less power than DSR, so its residual energy on each node is higher than DSR's nodes (Fig. 7).

The less consumed power reflects the way that AODV makes routing between nodes. It is hop-by-hop routing and does not need a cache to store routing recodes for future connections. The pros of AODV also its cons because cache less makes the routing process -finding the active path- take more time than DSR. Table 4 shows some advantages and disadvantages of both AODV and DSR routing protocols. It

**Table 3** Packet delivery ratio of AODV and DSR routing

```
jimmy@jimmy:~/Downloads/ns-allinone-2.35/Project Code Bang
Tran$ awk -f pdr.awk AODV.tr
The sent packets are 2859
The received packets are 262
The forwarded packets are 1277
The Packet Delivery Ratio are 0.091640
jimmy@jimmy:~/Downloads/ns-allinone-2.35/Project Code_Bang
Tran$ awk -f pdr.awk DSR.tr
The sent packets are 2777
The received packets are 198
The forwarded packets are 1995
The Packet Delivery Ratio are 0.071300
jimmy@jimmy:~/Downloads/ns-allinone-2.35/Project Code_Bang
Trans$
```

concludes that a TCP connection takes less time to establish using an Adaptive distance vector (ADV) protocol. Additionally, it offers more TCP connections over CBR traffic than DSR and AODV protocols, which results in better throughput. Compared to AODV and DSR, the DSDV has a low capacity but a significant routing load. The performance of AODV and DSR protocols is excellent. Although AODV occasionally beats DSR, DSR consistently performs the best, particularly when measured using the average end-to-end latency. Additionally, altering the packet size has an impact on AODV and DSR efficiency but not DSDV efficiency. When protocols are compared based on node mobility, they all perform well. Similar, to the AODV protocol, DSR is a source initiated/reactive protocol. After analysis, we can conclude that the DSR protocol performs marginally better than the AODV protocol, which performs much better than the DSDV protocol. The DSR protocol's throughput declines as packet size rises. With an increase in packet size, routing overhead also increases. As packet size increases, the average end-to-end latency gets less. This indicates that the DSR protocol performs well even with smaller packet sizes, except for routing burden.

## 5 Conclusion

MANET are dynamic, dispersed, complicated, multi-hop, and lack infrastructure. Without a permanent and dedicated infrastructure, a node can communicate directly or via intermediary nodes. Therefore, creating a routing protocol for ad-hoc networks that can effectively handle MANET's problems is essential. Routing between mobile nodes is a difficult and complex operation because mobile ad hoc networks are so dynamic and the architecture of the network is continually changing in unanticipated ways. Due to its challenges and complexity as well as the importance of routing protocols, the routing process is the focus of the MANET industry's most active and innovative research. This paper quickly reviews and compares the advantages and disadvantages of two basic mobile ad-hoc routing protocols (AODV and DSR). Both protocols are On-Demand routing methods in which the discovery phase happens when data need to be transferred. Mobile ad hoc networks provide mobility and are independent and self-adaptive. They are necessary for military applications because of these characteristics. These networks must function well if they are to succeed. Overall, it is possible to draw the conclusion from the tests done on this platform that OLSR routing appears to be well suited to military mobile ad hoc networks. To introduce quality of service and enable service differentiation in such networks, more effort is required. Multicast traffic and security

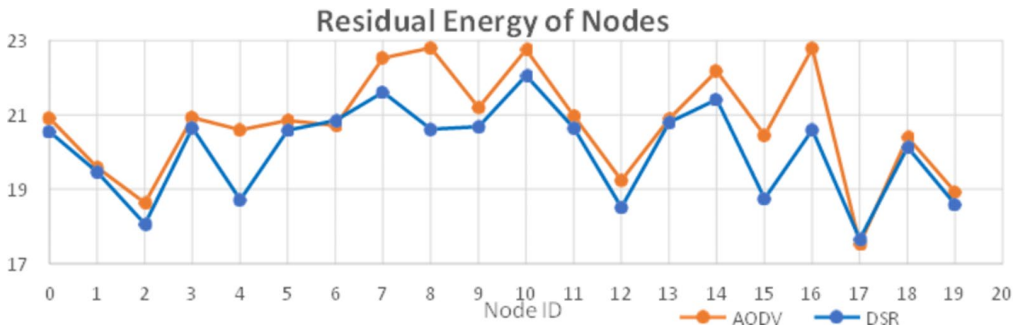


**Fig. 7** Residual Energy of 20 nodes

**Table 4** Pros vs. Cons of AODV and DSR routing protocols

| AODV Routing | DSR Routing | Pros vs. Cons |
|---|---|---|
| Hop-by-hop routing (single active path) | Source routing (multiple active paths) | Hop to hop routing is simple, so AODV performs better in higher-mobility scenarios. However, AODV easily loses route when connecting link breaks. |
| Cache-less | Cache | Cache help DSR less overhead finding route. Cache also causes more consumption of power. |
| Hop count for the active path | Efficient route for the active path | AODV got an active path by hop count. It is not the shortest and most efficient route. |

are additional problems for MANETs in a military setting. AODV has better performance in transmitting data and less consumption power. In contrast, DSR has faster routing and less traffic when the connection link is broken. Therefore, we will choose a suitable protocol depending on the application, situation, and network properties. It is essential to create effective routing protocols considering the types of applications and services needed for the deployment of UAVs. Numerous routing protocols have been developed, but each has its setbacks. In the future, the objective is to analyze various routing protocols, including AODV, DSDV, DSR, OLSR, AOMDV, and HWMP, to assess FANETs' real-time performance. In our upcoming work, we can also take other performance metrics—like the number of nodes and pause time—into account in various network scenarios. The PDR for AODV and DSDV decreases while the PDR for DSR increases when node mobility is assumed to be very low. At a higher range of simulation times, AODV and DSDV throughput is superior to DSR or not.

**Funding** Open access funding provided by SCELC, Statewide California Electronic Library Consortium

## Declarations

**Ethical approval** This research does not involve Human Participants and/or Animals.

**Consent for publication** All the authors have given their consent for this publication.

**Conflict of interest** The authors disclose no potential conflicts of interest.



## References

1. Da Silva, M. M. (2020). *Cable and wireless networks: Theory and practice*. CRC Press.
2. Akyildiz, I. F., Su, W., Sankarasubramaniam, Y., & Cayirci, E. (2002). A survey on sensor networks. *IEEE Communications Magazine*, *40*(8), 102–114.
3. Choo, K. K. R., Liu, C. C., & Wang, Y. (2014). A survey of context-aware mobile computing research. *Journal of Ambient Intelligence and Humanized Computing*, *5*(2), 159–180.
4. Wang, Z., Jiao, L., Chen, W., & Zhang, Y. (2019). A survey on visual analytics of big data in environmental monitoring. *Journal of Cleaner Production*, *238*, 117869.
5. Zeiler, M. D., & Fergus, R. (2014). Visualizing and understanding convolutional networks. In D. Fleet, T. Pajdla, B. Schiele, & T. Tuytelaars (Eds.), *Computer Vision–ECCV 2014. Lecture notes in Computer Science* (vol. 8689, pp. 818–833). Cham: Springer.
6. Selvaraju, R. R., Cogswell, M., Das, A., Vedantam, R., Parikh, D., & Batra, D. (2020). Grad-CAM: Visual explanations from deep networks via gradient-based localization. *International Journal of Computer Vision*, *128*, 336–359.
7. Kahng, M., Andrews, P. Y., Kalro, A., Chau, D. H., & ActiVis (2018). Visual exploration of industry-scale deep neural network models. *IEEE Transactions on Visualization and Computer Graphics*, *24*(1), 88–97.
8. Liu, M. C., Shi, J. X., Li, Z., Li, C. X., Zhu, J., & Liu, S. X. (2017). Towards a better analysis of deep convolutional neural networks. *IEEE Transactions on Visualization and Computer Graphics*, *23*(1), 91–100.
9. Ming, Y., Cao, S., Zhang, R., Li, Z., Chen, Y., Song, Y., & Qu, H. (2017). Understanding hidden memories of recurrent neural networks. In *Proceedings of the IEEE conference on visual analytics science and technology* (pp. 13–24).
10. Mojamed, M. A. (2020). Integrating mobile ad hoc networks with the internet-based on OLSR. *Wireless Communications and Mobile Computing*, 8810761, 16 pp. https://doi.org/10.1155/2020/8810761
11. Raza, N., Umar Aftab, M., Qasim Akbar, M., Ashraf, O., & Irfan, M. (2016). Mobile ad-hoc networks applications and its challenges. *Communications and Network*, *8*, 131–136. https://doi.org/10.4236/cn.2016.83013
12. Deepika, S., Nishanth, N., & Mujeeb, A. (2021). An assessment of recent advances in AODV routing protocol path optimization algorithms for mobile ad hoc networks. In *Fourth international conference on microelectronics, signals & systems (ICMSS)* (pp. 1–6). https://doi.org/10.1109/ICMSS53060.2021.9673632
13. Cai, B., Lu, H., Xiang, Y., Wang, W., Wu, J., & Gao, R. (2016). Implementation and optimization of AODV for Internet connectivity. In *18th international conference on advanced communication technology (ICACT)* (pp. 503–509).
14. Beard, C., Stallings, W., Zhu, L., & Xu, K. (2017). Wu Xian Tong Xin Wang Luo Yu Xi Tong. *Wireless Communication Networks and Systems*.
15. Amiri, E., & Hooshmand, R. (2019). Improving AODV with TOPSIS algorithm and fuzzy logic in VANETs. In *27th Iranian conference on electrical engineering (ICEE)* (pp. 1367–1372).
16. Alaparthi, S., Parvataneni, S. R., Vaishnavi, C. S., Sathvika, P., Chandrika, M., & Sharanya, P. (2019). Dynamic source routing protocol—A comparative analysis with AODV and DYMO in ZigBee-based wireless personal area network. In *2019 6th international conference on signal processing and integrated networks (SPIN)* (pp. 1042–1046). https://doi.org/10.1109/SPIN.2019.8711689
17. Jabbar, W. A., Ismail, M., & Nordin, R. (2017). Energy and mobility conscious multipath routing scheme for route stability and load balancing in MANETs. *Simulation Modelling Practice and Theory*, *77*, 245–271.
18. Singh, A., Dhaka, V. S., & Singh, G. (2016). Comparative analysis of dynamic path maintenance routing protocols for mobile ad-hoc networks. *Indian Journal of Science and Technology*, *9*(28), 1–6.

19. Bamhdi, A. M. (2020). Efficient dynamic-power AODV routing protocol based on node density. *Computer Standards & Interfaces*, *70*, 103406.
20. El-Semary, A. M., & Diab, H. (2019). BP-AODV: Blackhole protected AODV routing protocol for MANETs. *Based on Chaotic*, *95211*. https://doi.org/10.1109/ACCESS.2019.2928804
21. Goyal, M., Goyal, D., & Kumar, S. (2020). Dragon-AODV: Efficient ad hoc on-demand distance vector routing protocol using dragon fly algorithm. In *Soft computing: Theories and applications. Advances in Intelligent Systems and Computing* (vol. 1053). Singapore: Springer.