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Ad Hoc Mobile Wireless Networks Routing Protocols – A Review

Geetha Jayakumar, and G. Gopinath
Department of Computer Science, Bharathidasan University,
Tiruchirapalli-620 023, India

Abstract: Mobile ad hoc networks(MANET) represent complex distributed systems that comprise wireless mobile nodes that can freely and dynamically self organize into arbitrary and temporary ad-hoc network topologies, allowing people and devices to seamlessly internet work in areas with no preexisting communication infrastructure e.g., disaster recovery environments. An ad-hoc network is not a new one, having been around in various forms for over 20 years. Traditionally, tactical networks have been the only communication networking application that followed the ad-hoc paradigm. Recently the introduction of new technologies such as Bluetooth, IEEE 802.11 and hyperlan are helping enable eventual commercial MANET deployments outside the military domain. These recent revolutions have been generating a renewed and growing interest in the research and development of MANET. To facilitate communication within the network a routing protocol is used to discover routes between nodes. The goal of the routing protocol is to have an efficient route establishment between a pair of nodes, so that messages can be delivered in a timely manner. Bandwidth and power constraints are the important factors to be considered in current wireless network because multi-hop ad-hoc wireless relies on each node in the network to act as a router and packet forwarder. This dependency places bandwidth, power computation demands on mobile host to be taken into account while choosing the protocol. Routing protocols used in wired network cannot be used for mobile ad-hoc networks because of node mobility. The ad-hoc routing protocols are divided into two classes: table driven and demand based. This paper reviews and discusses routing protocol belonging to each category.

Keywords: MANET, Routing Protocol, On-demand, active and reactive protocols

INTRODUCTION

Wireless network has become very popular in the computing industry. Wireless network are adapted to enable mobility. There are two variations of mobile network. The first is infra-structured network (i.e. a network with fixed and wired gateways). The bridges of the network are known as base stations. A mobile unit within the network connects to and communicates with the nearest base station (i.e. within the communication radius). Application of this network includes office WLAN. The second type of network is infrastructure less mobile network commonly known as AD-HOC network. They have no fixed routers. All nodes are capable of moving and be connected in an arbitrary manner. These nodes function as routers, which discover and maintain routes to other nodes in the network. Non infrastructure based MANET are expected to become an important part of the 4G architecture. Ad-hoc networks can be used in areas where there is little or no communication infrastructure or the existing infrastructure is expensive or inconvenient to use. Some applications of ad-hoc network are students using laptop to participate in an interactive lecture, business associates sharing information during a meeting, soldiers relaying information about situation awareness in a battlefield, and emerging disaster relief after an earthquake or hurricane. Ad hock networks are created, for example, when a group of people come together and use wireless communication for some computer based collaborative activities; this is also referred to as spontaneous networking [1].

An ad-hoc network is a collection of mobile nodes, which forms a temporary network without the aid of centralized administration or standard support services regularly available on conventional networks. The nodes are free to move randomly and organize themselves arbitrarily; thus the network's wireless topology may change rapidly and unpredictably. Such a network may operate in standalone fashion, or may be connected to the larger internet. Mobile ad-hoc

Corresponding Author: Mrs. Geetha Jayakumar, Department of Computer Sciences, Bharathidasan University, Tiruchirapalli-620023, India, Phone: +91-431-2331663; Fax: +91-431-2331662

networks are infrastructure less networks since they do not require any fixed infrastructure such as a base station for their operation. In general routes between nodes in an ad-hoc network may include multiple hops and hence it is appropriate to call such networks as “multi-hop wireless ad-hoc networks”. Each node will be able to communicate directly with any other node that resides within the transmission range. For communication with nodes that reside beyond this range the node needs to use intermediate nodes to relay the messages hop by hop.

TAXONOMY OF AD-HOC NETWORK

Mobile ad hoc network protocol (MANET) routing protocols are classified according to several criteria, reflecting fundamental design and implementation choices. Simple MANET architecture is shown in figure 1.

Communication model: Protocols can be designed based on multi-channel and single channel communication. Multi-channel protocols are low-level routing protocol, which combines channel assignment and routing functionality. Such protocols are used in TDMA or CDMA based networks. Examples include CGSR. Larger classes of protocols assume that nodes communicate over a single logical wireless channel. These protocols are CSMA/CA oriented, where they relay on specific link layer behaviors. Some MANET routing protocols are based on specific link layer properties, such as RTS/CTS control sequence used by popular IEEE 802.11, MAC layers to avoid collisions due to hidden and exposed terminals. Specifically, before transmitting a data frame the source station sends a short control frame, named RTS, to the receiving station announcing the upcoming frame transmission. Upon receiving the RTS frame the destination station replies by a CTS frame to indicate that it is ready to receive the data frame. Both the RTS and CTS frames contain the total duration of the transmission that is the overall time needed to transmit the data frame and the related ACK. This information can be read by any station within the transmission range of either the source or the destination station. Hence station become aware of transmission from hidden station and the length of time the channel will be used for transmission. The exposed terminal problem results from situations where a permissible transmission from a mobile station to another station has to be delayed due to the irrelevant transmission activity between two other mobile stations within the senders transmission range. It is worth pointing that the hidden-station and the exposed station problems are correlated within the transmission range. The transmission range is determined by the transmission power and the radio propagation properties. By increasing the transmission range, hidden station problem occurs less frequently but the exposed station problem becomes more important as the TX range identifies the area affected by the single transmission. In addition to the transmission range, also the Physical carrier sensing range and the interference range must be considered to correctly understand the behavior of wireless networks.

There are few protocols that are based on physical layer information such as signal strength, or geographic position into the routing algorithm.

Structure: Routing protocols are categorized as uniform or non-uniform protocols

- **Uniform protocols:** In a uniform protocol, none of the nodes take a distinguished role in routing scheme; each node sends and responds to routing control messages in same way. No Hierarchical structure is imposed in the network.
- **Non-uniform protocols:** In this type of protocol routing complexity can be limited by reducing the number of nodes participating in routing computation.

State information: Protocols described in state information as

- **Topology based protocol:** These protocols are based on link state protocols. Nodes participating in topology-based protocol maintain large-scale topology information. Each node makes decisions based on complete topology information.
- **Destination based protocols:** These protocols are Distance vector protocols, where each node maintain a distance, and vector (next hop) to a destination. Each node exchanges its distance estimates for all other network nodes with each of its immediate neighbors. Such algorithms behave poorly leading to routing loops and slow convergence- in a dynamic environment. Other destination-based protocol maintains distance vector routing information for active destination to which they are sending and forwarding traffic.

A preliminary classification of the routing protocols can be done via the type of cast property, i.e., whether they use a [2].

- Unicast,
- Geocast,
- Multicast, or
- Broadcast forwarding

Broadcast is the basic mode of operation over a wireless channel; each message transmitted on a wireless channel is generally received by all neighbors located within one-hop from the sender. The simplest implementation of the broadcast operation to all network nodes is by naive flooding, but this may cause the broadcast storm problem due to redundant re-broadcast. Schemes have been proposed to alleviate this problem by reducing redundant broadcasting. Surveys [3] existing methods for flooding a wireless network intelligently. Unicast forwarding means a one-to-one communication, i.e., one source transmits data packets to a single destination. This is the largest class of routing protocols found in ad hoc networks. Multicast routing protocols come into play when a node needs to send the same message, or stream of data, to multiple destinations.

Geocast forwarding is a special case of multicast that is used to deliver data packets to a group of nodes situated inside a specified geographical area. Nodes may join or leave a multicast group as desired; on the other hand, nodes can join or leave a geocast group only by entering or leaving the corresponding geographical region. From an implementation standpoint, geocasting is a form of ‘‘restricted’’ broadcasting: messages are delivered to all the nodes that are inside a given region. This can be achieved by routing the packets from the source to a node inside the geocasting region, and then applying a broadcast transmission inside the region. Position-based (or location-aware) routing algorithms, by providing an efficient solution for forwarding packets towards a geographical position, constitute the basis for constructing geocasting delivery services.

Scheduling: MANET routing protocols are typically subdivided into two main categories [4]:

- proactive routing protocols and
- reactive on-demand routing protocols

Proactive routing protocols are derived from legacy Internet distance-vector and link-state protocols. They attempt to maintain consistent and updated routing information for every pair of network nodes by propagating, proactively, route updates at fixed time intervals. As the routing information is usually maintained in tables, these protocols are sometimes referred to as Table-Driven protocols. Reactive on demand routing protocols, on the other hand, establish the route to a destination only when there is a demand for it. The source node through the route discovery process usually initiates the route requested. Once a route has been established, it is maintained until either the destination becomes inaccessible (along every path from the source), or until the route is no longer used, or expired [5].

Design constraints that are specific to ad-hoc networking [6] are :

Autonomous and infrastuctureless: MANET does not depend on any established infrastructure or centralized administration. Each node operates in distributed peer-to-peer mode, acts as an independent router and generates independent data. Network management has to be distributed across different nodes, which brings added difficulty in fault detection and management.

Multi-hop routing: No default router available, every node acts as a router and forwards each other’s packets to enable information sharing between mobile hosts.

Dynamically changing network topologies: In mobile ad-hoc networks, because nodes can move arbitrarily, the network topology which is multi hop can change frequently and unpredictably resulting in route changes, frequent network partitions and possibly packet losses.

Variation in link and node capabilities: Each node is equipped with one or more radio interfaces that has varying transmission/receiving capabilities and operate across different frequency bands [7,8]. This heterogeneity in node radio capabilities can result in possibly asymmetric links. Each node has a different software/hardware configuration resulting in variability in processing capabilities. Designing network protocols and algorithms for this heterogeneous network can be complex which requires dynamic adaptation to the changing condition.

Energy constrained operation: Because batteries carried by each mobile node have limited power supply so the processing power is limited, which in turn limits the services and application that can be supported by each node. This becomes a bigger issue in MANET because each node acts as both an end system and a router at the same time; additional energy is required to forward packets from other nodes.

Network scalability: Many MANET applications involve large networks with tens of thousands of mobile nodes as found for example in sensor and tactical networks [9]. Scalability is critical to the successful deployment of these networks. The steps toward a large network consisting of nodes with limited resources are not straightforward and present many challenges that are not solved in areas such as addressing, routing, location management, configuration management, interoperability, security, high capacity wireless technologies etc.

ROUTING PROTOCOLS

As shown in Figure 2 routing protocols may be generally categorized as

1. Table driven
2. Source initiated (demand driven)

Table Driven Protocols: Table driven protocols maintain consistent and up to date routing information about each node in the network. These protocols require each node to store their routing information and when there is a change in network topology updation has to be made throughout the network. Some of the existing table driven protocols are

The different types of Table driven protocols are:

Destination sequenced Distance vector routing (DSDV)
Wireless routing protocol (WRP)
Fish eye State Routing protocol (FSR)
Optimised Link State Routing protocol (OLSR)
Cluster Gateway switch routing protocol (CGSR)
Topology Dissemination Based on Reverse path forwarding (TBRPF)

The Destination-Sequenced Distance-Vector (DSDV) protocol [9] is a distance-vector protocol with extensions to make it suitable to MANET. Every node maintains a routing table with one route entry for each destination in which the shortest path route (based on number of hops) is recorded. To avoid routing loops, a destination sequence number is used. A node increments its sequence number whenever a change occurs in its neighborhood. This number is used to select among alternative routes for the same destination. Nodes always select the route with the greatest number, thus selecting the most recent information. CGSR extends DSDV with clustering to increase the protocol scalability [10]. In addition, heuristic methods like priority token scheduling, gateway code scheduling, and path reservation are used to improve the protocols performance. Unfortunately, setting up the structure in a highly dynamic environment can adversely affect protocol performance since the structure might not persist for a very long time. WRP is another loop-free proactive protocol where four tables are used to maintain distance, link cost, routes and message retransmission information [11]. Loop avoidance is based on providing for the shortest path to each destination both the distance and the second-to-last hop (predecessor) information. Despite the variance in the number of routing tables used, and the difference in routing information maintained in these tables, proactive routing protocols like DSDV, CGSR and WRP are all distance vector shortest-path based, and have the same degree of complexity during link failures and additions.

OLSR protocol [12] is an optimization for MANET of legacy link-state protocols. The key point of the optimization is the multipoint relay (MPR). Each node identifies (among its neighbors) its MPRs. By flooding a message to its MPRs, a node is guaranteed that the message, when retransmitted by the MPRs, will be received by all its two-hop neighbors. Furthermore, when exchanging link-state routing information, a node lists only the connections to those neighbors that have selected it as MPR, i.e., its Multipoint Relay Selector set. The protocol selects bi-directional links for routing, hence avoiding packet transfer over unidirectional links. Like OLSR, TBRPF [13] is a link-state routing protocol that employs a different overhead reduction technique. Each node computes a shortest path tree to all other nodes, but to optimize bandwidth only part of the tree is propagated to the neighbors. The FSR protocol [14] is also an optimization over link-state algorithms using fisheye technique. In essence, FSR propagates link state information to other nodes in the network based on how far away (defined by scopes which are determined by number of hops) the nodes are. The protocol will propagate link state information more frequently to nodes that are in a closer scope, as opposed to ones that are further away. This means that a route will be less accurate the further away the node is, but once the message gets closer to the destination, the accuracy increases. LANMAR [15] builds on top of FSR and achieves hierarchical routing by partitioning the network nodes into different mobility groups; a landmark node is elected within each group to keep track of which logical subnet a node belongs to, and facilitate inter-group routing; FSR is used for intra-group routing.

<table>
<tr><td rowspan="2">Applications
&
Middleware</td><td>application 1</td><td>application 2</td><td>application k</td><td rowspan="6">Security and Cooperation
Energy Conservation
Simulation
Quality of Service

Cross Layer issues</td></tr>
<tr><td colspan="3">middleware
Service Location, Group Communication shared memory</td></tr>
<tr><td>Networking</td><td colspan="3">Transport and network layer protocols

TCP, IP routing, Addressing, Location, Multicasting, Interconnection</td></tr>
<tr><td rowspan="2">Enabling Technologies</td><td>802.11</td><td>Bluetooth</td><td>HiperLAN</td></tr>
<tr><td colspan="3">Medium Access Control, Antennas, Power Control</td></tr>
</table>

Fig.1: Simple MANET architecture

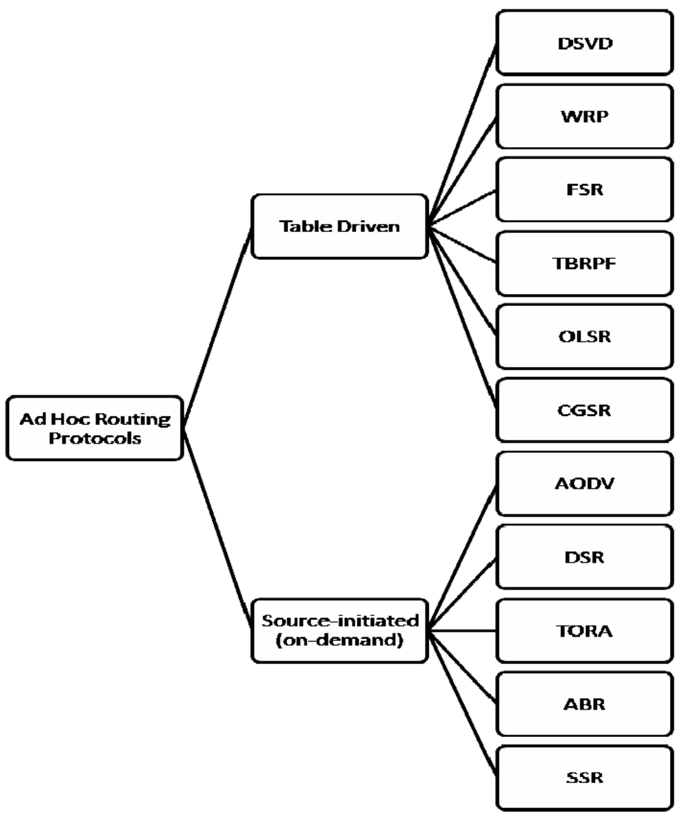

Fig. 2: Categorization of ad hoc routing protocols

Table 1: Applications of MANET

Applications	Descriptions/services
Tactical Networks	• Military communication, operations • Automated battlefields
Sensor Networks	• Home applications: smart sensor nodes and actuators can be buried in Appliances to allow end users to manage home devices locally and remotely • Environmental Application include tracking the movements of animals (e.g., birds and insects), chemical/biological detection, precision agriculture, etc, • Tracking date highly correlated in time and space, e.g., remote sensors for weather, earth activities
Emergency Services	• Search and rescue operations, as well as disaster recovery; e.g., early retrieval and transmission of patient data (record, status, diagnosis) from/to the hospital • Replacement of a fixed infrastructure in case of earthquake, hurricanes fire etc.,
Commercial Environments	• E-Commerce: e.g., Electronic payments from anywhere 9i.e., taxi) • Business ° Dynamic access to customer files stored in a central location on the fly ° Provide consistent databases for all agents ° Mobile office • Vehicular Services ° Transmission of news, road condition, weather, music ° Local ad hoc network with nearby vehicles for road/accident guidance
Home and Enterprise Networking	• Home/Office Wireless Networking (WLAN) e.g., shared whiteboard application; use PDA to print anywhere; trade shows • Personal Area Networks (PAN)
Educational applications	• Setup virtual classrooms or conference rooms • Setup ad hoc communication during conferences, meetings, or lectures
Entertainment	• Multi-user games • Robotic pets • Outdoor Internet access
Location aware services	• Follow-on services, e.g., automatic call-forwarding, transmission of the actual workspace to the current location • Information services ° Push, eg., advertise location specific service, like gas stations ° Pull e.g., location dependent travel guide; services (printer, fax, phone, server, gas stations) availability information

Source Initiated Demand driven: In on-demand routing protocols routes are created as and when required. When a source wants to send to a destination, it invokes the route discovery mechanisms to find the path to the destinations. The route remains valid till the destination is reachable or until the route is no longer needed

The different types of On Demand driven protocols are:

Ad hoc On Demand Distance Vector (AODV)
Dynamic Source routing protocol (DSR)
Temporally ordered routing algorithm (TORA)
Associativity Based routing (ABR)

These protocols depart from the legacy Internet approach. To reduce the overhead, the route between two nodes is discovered only when it is needed. Representative reactive routing protocols include: Dynamic Source Routing (DSR), Ad hoc On Demand Distance Vector (AODV), Temporally Ordered Routing Algorithm (TORA), Associativity Based Routing (ABR), and Signal Stability Routing (SSR).

DSR is a loop-free, source based, on demand routing protocol [16], where each node maintains a route cache that contains the source routes learned by the node. The route discovery process is only initiated when a source node do not already have a valid route to the destination in its route cache; entries in the route cache are continually updated as new routes are learned. Source routing is used for packets forwarding. AODV is a reactive improvement of the DSDV protocol. AODV minimizes the number of route broadcasts by creating routes on-demand [17], as opposed to maintaining a complete list of routes as in the DSDV algorithm. Similar to DSR, route discovery is initiated on-demand, the route request is then forward by the source to the neighbors, and so on, until either the destination or an intermediate node with a fresh route to the destination, are located. DSR has a potentially larger control overhead and memory requirements than AODV since each DSR packet must carry full routing path information, whereas in AODV packets only contain the destination address. On the other hand, DSR can utilize both asymmetric and symmetric links during routing, while AODV only works with symmetric links (this is a constraint that may be difficult to satisfy in mobile wireless environments). In addition, nodes in DSR maintain in their cache multiple routes to a destination, a feature helpful during link failure. In general, both AODV and DSR work well in small to medium size networks with moderate mobility.

TORA is another source-initiated on-demand routing protocol built on the concept of link reversal of the Directed Acyclic Graph (ACG) [18]. In addition to being loop-free and bandwidth efficient, TORA has the property of being highly adaptive and quick in route repair during link failure, while providing multiple routes for any desired source/destination pair. These properties make it especially suitable for large, highly dynamic, mobile ad hoc environments with dense nodes populations. The limitation in TORA applicability comes from its reliance on synchronized clocks. If a node does not have a GPS positioning system, or some other external time source, or if the time source fails, the algorithm fails. ABR protocol is also a loop free protocol, but it uses a new routing metric termed degree of association stability in selecting routes, so that route discovered can be longer-lived route, thus more stable and requiring less updates subsequently. The limitation of ABR comes mainly from a periodic beaconing used to establish the association stability metrics, which may result in additional energy consumption. Signal Stability Algorithm (SSA) [19] is basically an ABR protocol with the additional property of routes selection using the signal strength of the link.

RESULTS: COMPARISON OF ON-DEMAND REACTIVE PROTOCOLS AND PROACTIVE ROUTING PROTOCOLS

In general, on-demand reactive protocols are more efficient than proactive ones. On-demand protocols minimize control overhead and power consumption since routes are only established when required. By contrast, proactive protocols require periodic route updates to keep information current and consistent; in addition, maintain multiple routes that might never be needed, adding unnecessary routing overheads. Proactive routing protocols provide better quality of service than on-demand protocols. As routing information is constantly updated in the proactive protocols, routes to every destination are always available and up-to-date, and hence end- to- end delay can be minimized. For on-demand protocols, the source node has to wait for the route to be discovered before communication can happen. This latency in route discovery might be intolerable for real-time communications.

In addition to proactive and reactive protocols, another class of unicast routing protocols that can be identified is that of hybrid protocols. The Zone- Based Hierarchical Link State Routing Protocol (ZRP) is an example of hybrid protocol that combines both proactive and reactive approaches thus trying to bring together the advantages of the two approaches. ZRP defines around each node a zone that contains the neighbors within a given number of hops from the node. Proactive and reactive algorithms are used by the node to route packets within and outside the zone, respectively.

In terms of metrics comparisons between the two routing protocols are: *Throughput:* proactive protocols perform well then reactive protocol; *End to end delay:* proactive protocols perform well than reactive protocols; *Routing load:* reactive protocols perform well than proactive protocols. The MANET applications are given in details in Table-1.

DISCUSSION AND CONCLUSION

In coming years, mobile computing will keep flourishing, and an eventual seamless integration of MANET with other wireless networks, and the fixed Internet infrastructure, appears inevitable. Ad hoc networking is at the center of the evolution towards the

4th generation wireless technology. Its intrinsic flexibility, ease of maintenance, lack of required infrastructure, auto-configuration, self administration capabilities, and significant costs advantages make it a prime candidate for becoming the stalwart technology for personal pervasive communication. The opportunity and importance of ad hoc networks is being increasingly recognized by both the research and industry community, as evidenced by the flood of research activities, as well as the almost exponential growth in the Wireless LANs and Bluetooth sectors.

In moving forward towards fulfilling the opportunity, the successful addressing of open technical and economical issues will play a critical role in achieving the eventual success and potential of MANET technology. Despite the large volume of research activities and rapid progress made in the MANET technologies in the past few years, almost all research areas (from enabling technologies to applications) still harbor many open issues. This is characteristically exemplified by research activities performed on routing protocols. Most work on routing protocols is being performed in the framework of the IETF MANET working group, where four routing protocols are currently under active development. These include two reactive routing protocols, AODV and DSR, and two proactive routing protocols, OLSR and TBRPF. There has been good progress in studying the protocols behavior. The perception is that large number of competing routing protocols lack of WG-wide consensus and few signs of convergence. To overcome this situation, a discussion is currently ongoing to focalize the activities of the MANET Working Group (WG) towards the design of IETF MANET standard protocols and to split off related long term research work from IETF. MANET WG proposes a view of mobile ad hoc networks as an evolution of the Internet. This mainly implies an IP-centric view of the network, and the use of a layered architecture. Current research points out though that this choice may limit developing efficient solutions for MANET. Other promising directions have been identified [20]. The use of the IP protocol has two main advantages: it simplifies MANET interconnection to the Internet, and guarantees the independence from wireless technologies. On the other hand, more efficient and lightweight solutions can be obtained, for example, by implementing routing solutions at lower layers [21]. Furthermore, masking lower layers_ characteristics may not to be useful in MANET. The layered paradigm has highly simplified Internet design, however when applied to ad hoc networks, it may result in poor performance as it prevents exploiting important interlayer dependencies in designing efficient ad hoc network functions. For example, from the energy management standpoint, power control and multiple antennas at the link layer are coupled with power control and scheduling at MAC layer, and with energy-constrained and delay-constrained routing at network layer. Relaxing the Internet layered architecture, by removing the strict layer boundaries, is an open issue in the MANET evolution. Cross-layer design of MANET architecture and protocols is a promising direction for meeting the emerging application requirements, particularly when energy is a limited resource.

In this paper we have provided descriptions of several routing schemes proposed for ad-hoc mobile networks. We have also provided a classification of these schemes according the routing strategy .i.e., table driven and on demand. We have presented a comparison of these two categories of routing protocols, highlighting their features, differences and characteristics. Finally we have identified possible applications and challenges facing ad-hoc wireless networks.

While it is not clear that any particular algorithm or class of algorithm is the best for all scenarios, each protocol has definite advantages and disadvantages and has certain situations for which it is well suited. The field of ad-hoc mobile networks is rapidly growing and challenging, and while there are still many challenges that need to be met, it is likely that such networks will see wide-spread use within the next few years.

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