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Mobile Ad-Hoc Networks: A Review on Routing Protocols.

Ratna R. Sarkar,[1*] Amitabha Chakrabarty [2] and Mohammad Zahidur Rahman[3]

[1]*Department of Computer Science and Engineering, Jahangirnagar University, Savar , Bangladesh*
ratnacse2013@gmail.com
[2]*Department of Computer Science and Engineering, BRAC University, Dhaka, Bangladesh*
amitabha@bracu.ac.bd
[3]*Department of Computer Science and Engineering, Jahangirnagar University, Savar , Bangladesh*
rmzahid@juniv.edu

Abstract

A collection of wireless nodes laid out in an arbitrary and temporary fashion formed an Ad-hoc network .This type of network is self-originated, dynamic, and does not require any specific infrastructure. Mobile phones, PDA, or other mobile devices can be a node in MANET. Mobile Ad Hoc Networks (MANETs) are established without the assistance of any additional network setup. Delay/ Disruption tolerant Networks (DTN) are a special type of MANET and are also applicable where the communicating nodes are intermittently connected or broken. People use the internet in their daily life to communicate with one another. But it requires proper infrastructure for data exchange. In some scenarios when network infrastructure is broken Pocket Switched Networks (PSN) can be an efficient alternative. In this paper, we review routing protocols in Mobile Ad-hoc paradigms, classify them into different categories, and finally, open issues for future research and possible solutions are also discussed.

Keywords: Mobile Ad-hoc Network (MANET), Delay/ Disruption tolerant Network (DTN), Pocket Switched Network (PSN), Routing.

1. Introduction

MANET comprising a distributed system with a collection of wireless mobile nodes that are autonomous in nature. These mobile nodes communicate among them without any predefined infrastructure. Because of node mobility, MANET has an unpredictable and dynamic network topology. Nodes dynamically configure this decentralized network. Ensuring security in a decentralized network

[*] e-mail : ratnacse2013@gmail.com

becomes difficult. Nodes can act both as a node and a router. MANET supports multi-hop routing as access points are not fixed here. This network works either by collaborating with other networks (i.e., internet) or in a standalone fashion. Nodes usually transmit their packets when they interact with other nodes within their radio range. A network may have selfish nodes or intermittent links which makes the network unreliable. This network can be applicable in tactical environments like military communications, commercial environments, providing emergency services, etc. [1].

Mobile wireless networks are mainly three types respectively: infrastructured networks, ad-hoc networks, and hybrid networks. In an infrastructured network, there are base stations that mainly connect the mobile nodes and the communication takes place only between them. Ad-hoc network does not require any preexisting infrastructure and base station. Ad-hoc networks are decentralized. Each node is capable of finding routes to transmit data packets to the destination. This type of network mainly takes place in some situations where no specific communication infrastructure exists i.e rural areas, an area after a natural disaster, a place for quick information sharing like conferences, meetings, etc. A hybrid network comprises by using both the concept of infrastructured network and ad-hoc network [2].

DTN is a special type of MANET which also known as Intermittently-Connected Mobile Ad-hoc Networks (ICMANET). DTN is mainly proposed for making communications among challenged environments where the communicating nodes are intermittently connected or the connection is broken [3]. Bandwidth limitation, error probability, path longevity defines some important characteristics of DTN which follows a store-carry-forward approach and does not require any end-to-end connectivity for data transmission. Unlike MANETs, DTNs mobile nodes are intermittently connected and suffer from the limited power supply. These features make data forwarding challenging [4].

PSN is a type of DTN. Typically, TCP/IP (Transmission Control Protocol/Internet Protocol) is a very effective protocol for end-to-end and reliable data transfer and also requires proper communication infrastructures. When a network suffers from a lack of proper communication infrastructure, PSN can provide an effective alternative for data transmission [5]. PSN takes the advantage of human mobility for data forwarding. Here, the forwarding paths are generated between or among the neighbor nodes and become vulnerable as the nodes are mobile. Humans carry mobile devices like mobile phones, PDAs (personal digital assistant), etc. which can transfer data by utilizing the mobility of nodes can form PSN [6]. So, for data dissemination, human mobility plays a vital role in PSN [7]. Human beings are employed as information carriers in PSN. This feature makes PSN different from DTN. PSN also differs from MANET based on the disruption duration. Both for the MANET and PSN, the end-to-end connectivity between source and destination is disrupted from time to time. In the case of PSN this disruption duration is higher than MANET [8]. PSN considers mobile devices, PDA, laptops, etc. with limited storage and power as targeted devices [9]. Some features of PSN are given below:

1.1. Mobility

PSN's mobility is one of its most important qualities.As we discussed earlier, PSN forms in such places as conferences, office spaces with high contact density along a high number of mobile nodes. In order to make forwarding decisions, PSN utilizes the advantage of human mobility and multihop data forwarding is established. PSN does not require any end-to-end connectivity for effective data forwarding. As nodes have mobility, so no communication path is specified. Sometimes mobility causes challenges in data forwarding. Various mobility models are used to define node's mobility, Random waypoint model [10] is one of them and popular also. According to this model, nodes are distributed randomly within the network and wait for a pause time. After that node moves randomly to choose the destination which is defined as a waypoint. There are also some related mobility models like random-direction model [11], random-border model [12]. The clustered-mobility model [13] mainly defines node mobility in a similar way to the Random waypoint model. Gauss-Markov Mobility Model [14] is mainly based on the Gaussian model where the value of the node's speed and direction at instance T is computed depending on the value of the instance of (T-1).

1.2 Opportunistic Network

Whenever devices interact with one another, they connect and exchange data by forming a class of networks known as opportunistic Networks (OppNets). That means, whenever the opportunities come the network is formed. When devices are connected through Bluetooth and exchange data, then the OppNets is formed. OppNets mainly fall in the category of MANET [15]. OppNets follows social concepts where heterogeneous nodes are always looking for an opportunity to participates in making communication [16]. When a node interacts with an intermediate node(a node closer to the source node), it exchanges data. Information sprinkler is a dedicated node that does not have mobility, mainly used to distribute data to all the network nodes. Data sharing protocol is used for data distribution[17].

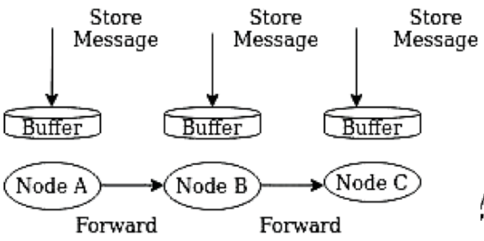


Figure 1. Store-carry and forward approach.

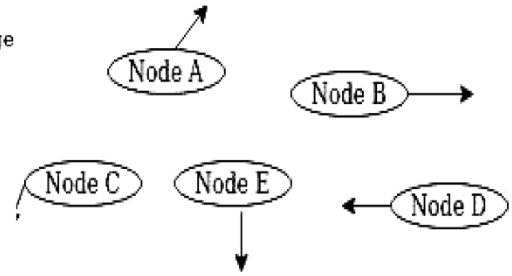


Figure 2. Nodes's mobility.

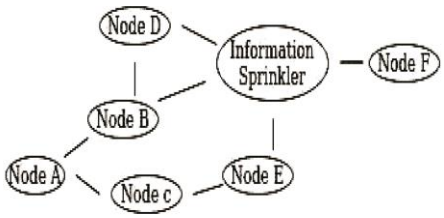


Figure 3. Opportunistic Network.

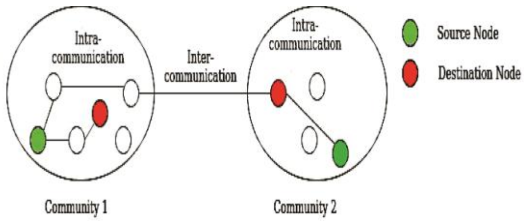


Figure 4. Community based communication.

1.3 Social Concept

PSN utilizes the social features and considers humans as an information carrier [18]. In order to form a social graph, a person with a communicating mobile device can be considered as a vertex. Community indicates a group of nodes sharing information within a specific range. Centrality can be measured by a node with strong interaction with other nodes. Friendship invokes the relationship among different nodes. Modularity measures the stability of a community [19]. Figure 4 represents the concepts of community-based communication.

2. ROUTING PROTOCOLS OF AD-HOC NETWORKS.

A set of rules that are responsible for data dissemination is known as routing protocol. Considering the applicability of Ad-hoc networks, researchers have proposed various routing protocols to enhance the network performance based on different parameters like PDR, Energy consumption, Latency, etc. According to Djenouri et al. [20] routing protocols for Ad-hoc networks can be classified based on the activities of the mobile nodes during the process of routing determination. Figure 5 represents the taxonomy of different routing protocols of Ad-hoc Network.

2.1. MANET: A Quick Overview

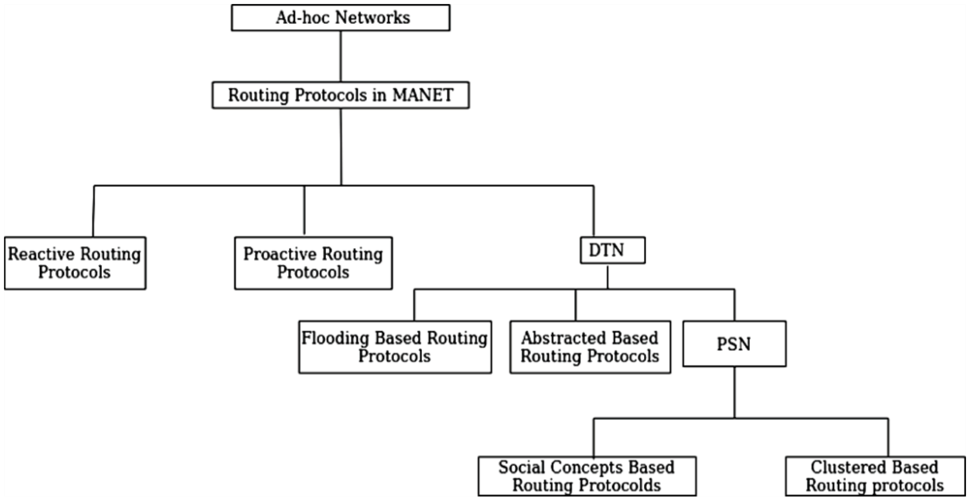
Dynamic topology, mobile nodes, Infrastructure less networking approach, etc are the main features of MANET. Routing protocols for MANETs have been classified as follows.

2.1.1. Reactive Routing Protocols

In the reactive routing approach, the route for data forwarding is not always available and is mainly formed on an on-demand basis (when data dissemination becomes necessary). Perkins et.al [21] proposed AODV (Ad hoc on-demand distance vector routing) which forms a loop-free route for data transmission and a reactive routing approach [22]. In order to discover a routing path (forward and reverse), it uses the broadcast route discovery mechanism [23]. For establishing forwarding and reverse routing paths it uses respectively a route request packet (RREQ) and a route replay (RREP). AODV controls data traffic throughout the network so that the load can be minimized by dropping the redundant RREQ.Assumes some notifications, Source node (*S*), neighbor node (*N*) ,Intermediate node (N en) ,source address s addr, destination address (d - addr) , sequence number of source node (s seq), sequence number for destination node (d seq), sequence number for intermediate node (en seq) ,number of travelled node (h c) and a broadcast id (*broadcastId*) ,Exhalation time for reverse path (*Et*).Then RREQ and RREP can be represented as given in Algorithm 1. An efficient power-aware AODV (EPAAODV) Routing Protocol for MANET is proposed by c. Mafirabadza et.al [24]. Nodes in MANET suffer from energy limitations which may cause the death of nodes. EPAAODV enhanced transmission range along with lower hop count. This algorithm considers an additional field of RREQ named residual energy and sets a threshold for it . According to this algorithm when an intermediate node receives an RREQ it checks residual energy and calculates the cost metric of the node from which the RREQ has emerged. Algorithm 2 shows the working procedure of EPAAODV. Another improved routing algorithm based on AODV named (IAODV) is proposed by Shrivastava et.al [25]. This algorithm mainly focuses on enhancing the packet delivery ratio (PDR) and reduction on end-to-end delay. *PDR* is measured (Equation 1) by the ratio of total number of received packets(R_{pkt}) to total number of sent packets(S_{pkt}). End-to-end delay (E_{delay}) can be calculated (Equation 2) by the ratio of the difference between packet arrival (P_{at}) and sending time (P_{st}) to the summation of the number of connections (N_c).

$$PDR = \sum R_{pkt} \; / \; \sum S_{pkt} \tag{1}$$

$$E_{delay} = \sum (P_{at} - P_{st}) \; / \sum N_c \tag{2}$$



Algorithm 1 AODV.

Step 1: Path discovery for each source node *S*
if *N* satisfy *RREQ* **then**
$S \leftarrow RREP$
OR
N of neighbors ← *RREQ*
$h\_c \leftarrow h\_c + 1$
else
Store ← $s_{addr}, d_{addr}, s_{seq}, broadcastId, Et$
Setup ← Reverse path
end if
Step 2 : Forward path setup from *S* to destination
While N_en receives *RREQ*
if en_seq≥d_seq of *RREQ* **then**
N_en← Reply to *RREP*
else
propagate no reply

end if
Step 2.1: While a node receives the first *RREP*
$S \leftarrow$ propagate *RREP*
Step 2.2: While a node receives the further *RREP* compare en_seq and h_c of present and previous *RREQ*
if (*present* en_seq > *previous* en - seq) ∧ (*present* h - c < *previous* h - c) **then**
$S \leftarrow$ propagate *RREP*
end if
Step 3: Reverse path setup from Destination to *S*
Setup reverse path ← *RREQ* travels all the N_en back to *S*

Algorithm 2 EPAAODV.

Notification: residual energy of a node R_e,Threshold T_h,time t, cost metrics C_m ,hop count h_c When an intermediate node receives *RREQ*

if $R_e \geq T_h$ **then**
calculate $C_m = R_e / h_c$
Store R_e, C_m and wait for another *EERQ* for time t.
After receiving another *RREQ*
Again, calculate $C_m = R_e / h_c$
Compare R_e and C_m of present and previously stored *RREQ*
if present $R_e \geq$ previous R_e ∧ present $C_m \leq$ previous C_m **then**
Forward present *RREQ*
else
Forward previously stored *RREQ*
end if
else
Drop *EERQ*
end if

Algorithm 3 Steps to Improve PDR.

1: Graphical design represents the connectivity among the nodes.
2: The distance between nodes is calculated using the Euclidean distance method.
3: The Dijkstra algorithm is used to find the shortest transmission path.
4: Starts transmission.

IAODV uses the steps of algorithm 3 to improves PDR. The distance between nodes is measured using the Euclidean distance method..Assume that two nodes $I(a_i, b_i), J(a_j, b_j)$. According to the Euclidean distance method the distance between these nodes can be measured. The Dijkstra algorithm is primarily used to discover the shortest path from a source node to a destination node in a network.. Assume that, a weighted graph, $G = (E, V)$. Here source vertex *Src* along with the all other vertex $v \in V$. According to this algorithm , initially the distance *D* of source and other vertex is set as respectively $D(Src) \leftarrow 0$ and $D(v) \leftarrow \infty$. For all the visited vertices initially a set $S \leftarrow \emptyset$ and a queue $Q \leftarrow V$ are defined. After that it selects an element with minimum distance from *Q* and add it to *S*. For all *v* the minimum distance is checked, so that the desire shortest path is found. IAODV uses the CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance), FCFS (First Come First Serve), SJF (Shortest Job First) and Priority scheduling algorithms to reduce end-to-end delay. Algorithm 4 depicts the methods for reducing end-to-end delays.CSMA/CA is used to sense the status of the channel (busy or free) .when the channel is free , FCFS is used for scheduling the processes based on the first come first serve . SJF schedules the processes based on the shortest burst time. Priority scheduling algorithm firstly gets the arrival and burst time. After that, a priority is set for all the available processes. It schedules the processes based on the highest priority.

DSR (Dynamic Source Routing) [26] provides a negligible loop-free routing and also resolves the requirement of getting up-to-date routing information for intermediate nodes. This algorithm is mainly applicable for Adhoc networks consisting of mobile nodes.it allows a node to discover a route dynamically for data forwarding. Each data packet header contains the discovered route for data forwarding that provides an easy way to get the routing information by other nodes.

2.1.2. Proactive routing protocols

A proactive routing approach is a table-driven approach where the routing information is updated periodically and the route for data dissemination is always defined. DSDV [27]is a hop-to-hop distance vector routing protocol. Bellman-Ford routing algorithm [53] is mainly considered for a periodical broadcast of routing updates for each node. The routing table contains information about the nexthop and the number of hops for each reachable destination [56][57] and a sequence number[54][55] that removes loop formation. This routing table is maintained by each node and simultaneously sends it to neighbors [51][52] Both time-driven and event-driven concepts are considered for updating the routing table. If significant updates are available, the routing table is transmitted to a reachable neighbor node either by using a “full dump” or an “incremental” concept[58] [59]. OLSR (Optimized Link State Routing) falls in the category of Proactive based routing algorithm that requires the information of nodes that are two hops away [28]. This algorithm exchanges data (hello message and topology control message) periodically through multipoint relay nodes [60][62][63]. OLSR employs IP4 addressing and allows for multiple interfaces on a single node[61].

2.1.3. Delay/ Disruption tolerant Networks (DTN): A Quick Overview

Basically in DTN the routing protocols can be classified based on single copy and multiple copies.

- Single-copy-based Routing approach: First Contact routing protocol falls in the category of single-copybased routing protocol which mainly forward messages whenever it encounters a node [29].
- Multiple copies based Routing approach : An example of multiple copies based routing protocol is prophet [30] which mainly calculate the probability of message delivery and based on that find the shortest path for successful message delivery.

The Performance of different single copy and multiple copies based routing protocols is analyzed by Talukdar et al [31]. This analysis considers First Contact routing algorithm from the category of single copy and Epidemic[32], Spray and Wait[33], prophet[30] from the category of multiple copies based routing approach in ICMN scenario. Overhead on message copies and time to live, message delivery, average buffer time and latency, and rate of message generation are considered as performance measurement metrics. As a result of this analysis, the performance of Spray and Wait[33] is found better than others. DTN nodes are mobile and suffer from limited energy. Routing protocols along with limited energy consumption and higher delivery probability is needed. The performance of different routing protocols is analyzed based on energy consumption [34]. Epidemic [32] Spray and Wait [33], First Contact routing [29], prophet [30] and

Maxprop routing protocol [35] are considered for this analysis and mainly sets priority both for scheduling packet transmission and packet drop. For all message $\forall_M$,hop count H_c ,higher rank H_r,lower rank L_r , delivery probability D_p and a threshold T_h is considered. When $H_p \geq T_h$, then M is deleted from L_r and D_p is increased. Otherwise, M is transmitted from H_r which also increases D_p . Maxprop[35] outperforms alternative protocols in terms of delivery probability, average delay, and buffer time, according to this investigation. Spray and wait[33] protocol performs better in terms of average remaining energy, average hop count,number of dead nodes and overhead ratio. In terms of average buffer time first contact protocol performs better than others. Another analysis is done on different DTN Routing algorithm based on the impact of TTL.

These routing algorithms are respectively Epidemic [32], Spray and Wait[33] , Prophet [30]. For this analysis delivery probability, average latency, and the overhead ratio is considered. In the case of Spray and Wait,the delivery probability is increased and the overhead ratio is decreased along with the increment of TTL than other protocols. overall latency increases along with the increment of TTL for all the routing protocol [36]. Routing protocols in DTN are classified in the following categories based on the routing strategies in different tactical scenarios where connectivity among nodes is almost broken.

Flooding based routing Protocols. Epidemic [32] routing protocol considers flooding strategy for routing.Messages are transmitted to every encountered node which ensures successful message delivery along with low latency. Spray and wait protocol [33] mainly works in two different phases respectively spray and wait phase. In the spray phase it floods the message to all the encountered nodes and in the wait phase direct transmission strategy is considered. Algorithm 5 represents an efficient method for ensuring security of routing in DTN proposed by C C Sobin et al [38]. For ensuring security, public key cryptographic algorithm RSA [37] is considered which utilize the concept of public and private key (Secret key) pairs.

Algorithm 5 In DTN, an Efficient Method for Secure Routing.

1: Notification: Message M, private key K_{pri}, public key $k_{pub,\,source}$ node S_N, destination node D_N, Relay node $Relay_N$, Encrypted message $E(M)$, Receiver public key R_{pub}, Receiver private key R_{pri}

2: **while** Transmitting M **do**

3: key generation and distribution ← execute $\forall(N)$

$\forall(N) \leftarrow \{k_{pri}, k_{pub}\}$
end while
while S_N transmits M **do**
$E(M) \leftarrow$ Encrypt M_{Rpub}
$Relay_N \leftarrow$ transmits M
end while
while D_N Receives M **do**
$M \leftarrow$ Decrypt $E(M)_{Rpri}$
end while

- **Abstracted based routing approach.** DTN nodes suffer from limited energy and buffer space. So, proper buffer management can enhance the performance of routing algorithms. Adaptive Spray and Wait Protocol for VDTN [39] is a modification of the existing Spray and wait protocol [33] based on the number of stored messages which provides an improvement on the probability of message delivery. According to this adaptive spray and wait (70-80) % copy of messages is transmitted to the encountered node which enhances the probability of successful message delivery. Algorithm 6 presents an efficient method for buffer management [40], which enhances the message delivery and reduces overhead ratio. This methods considers replica count (R_c) and hop count (H_c) for efficient buffer management.R_c is incremented when a message M transmits to a relay node.H_c is incremented along with the transmitting of M from one node to another. MaxHopCount [41] (Algorithm 8) focuses on message dropping policy to ensure proper buffer management and also provides better performances on message delivery, network overhead, and latency.

Algorithm 6 An Efficient Method for Buffer Management in DTN.

Notification: Encountered node EN_{node}.
if EN_{node} buffer $\leftarrow$ Available space **then**
$EN_{node} \leftarrow$ transmits M.
else
Sort the Buffer of EN_{node}
if $\sum R_c, H_c$ is low **then**
High priority to transmit M.
else
High priority to drop M.

10: **end if**
11: **end if**

- **Pocket Switched Networks (PSN): A Quick Overview**

  The routing approach in PSN can be classified respectively on social concepts based routing approach and clustered based routing approach.

- **Social concepts based routing approach**: ChitChat [42](Algorithm 9) which works based on social interests, is proposed for efficient data dissemination in a scattered environment and is applicable both for unicast and multicast environments. Whenever a node encounters another node it creates a copy of a message and forwards the replicated copy.

  Source nodes keep the message in the buffer until the desired destination is encountered or TTL (Time to Live) has expired. When a node encounters others, they compute and exchange their TSR (Transient Social Relationship) which is computed using the decay model, and the growth model is used to compute the growth of their TSR. According to this algorithm 9, social interest is represented by a unique id *Sid*, and social profile (Equation 4) S_p is defined by set of S_{id}.

$$S_p = Sid_1, Sid_2, \ldots, Sid_m \quad (4)$$

  Suppose at time T_s a user u encounter another and $T_s - T_0 \geq 1$. Then the the current weight of each social interest in TSR is calculated using decay function γ. when $Sid_i \notin S_p$ then the current weight is computed by using equation 5.

$$W_u(Sid_i, T_s) = \frac{W_u(Sid_i, T_{di})}{\gamma(T_s - T_{di})} \quad (5)$$

  when $Sid_i \epsilon S_p$ then the current weight is computed by using equation 6.

$$W_u(Sid_i, T_s) = \frac{W_u(Sid_i, T_{di}) - 0.5}{\gamma(T_s - T_{di})} + 0.5 \quad (6)$$

  Another social interest-based routing algorithm Gossip [43] is proposed based on ChitChat [42]. For effective data forwarding, a social profile that is formed with the social interest of individual nodes is considered and applicable for the sparse environments. PNGP (Popular Node Gateway Protocol)[44] is a social relationship based routing algorithm in PSN that considers the popularity of nodes within a community for making efficient forwarding decisions.

Algorithm 7 Adaptive Spray and Wait.

1: Notification: Message M, source node S_n, relay node R_n, Encountered node E_n, destination node D_n
2: **if** E_n is encountered **then**
3: $E_n \leftarrow$ propagate 70%or80% of M
4: $S_n v R_n \leftarrow$ set remaining M
5: **else**
6: Go to step 7
7: **end if**
8: **if** Number of M of $S_n v R_n > 1$ **then**
9: Repeat from step 2 to 6
10: **else**
11: $D_n \leftarrow$ Transmit M
12: **end if**

Algorithm 8 MaxHopCount.

1: Notification: Message M, *Message* size M_s, Buffer size B_s,hop cont H_c.
2: **if** $M_s > B_s$ **then**
3: M is not stored.
4: **end if**
5: **while** Available $B_s < M_s$ **do** 6: Initialize M with max H_c.
7: **if** $M = \emptyset$ **then**
8: Buffer is empty and no M is removed
9: **else**
10: M is removed.
11: **end if**
12: **end while**
13: M is inserted in Buffer.

Algorithm 9 ChitChat Routing Algorithm.

1: Notification: Message M, Source node N, Set of users $u = u_1, u_2, ..., u_n$, Encounter node E_n, social interest of source node and encountered node are respectively S_N and S_{En}.
2: **while** $E_n \epsilon u$ **do**
3: **if** $M.destination = E_n$ **then**

$E_n \leftarrow M$ is forwarded.
Delete M from the buffer of N.
end if
if $M \notin M.E_n$ **then**
compute S_N and S_{En}
if $S_{En} > S_N$ **then**
$E_n \leftarrow$ Forward M
end if
end if
end while

Algorithm 10 PNGP Routing Algorithm.

Notification: Message M , Source node S_n , Encounter node E_n.
while $S_n.Community = E_n.Community$ **do**
Check whether E_n is the most popular node within the community.
if $E_n = M.destination$ **then**
$E_n \leftarrow$ Transmit M .
else
Floods M within the community.
end if
end while

- **Clustered based routing protocols:** Cluster (a group of nodes together)[45] is consist of cluster head, gateway, and cluster members where only gateway and cluster members are able to transmit data. An Effective Infrastructure for PSN named ZoneCluster [46] is proposed based on the clustering approach. When a node *m* encounters another node *n*, then the connection is defined by the following equation 7.

$$m_{nodeCount} = \sum(m,n). \quad (7)$$

lowest-ID approach [47] is used by ZoneCluster to break the tie , if the hop count of nodes *m* and *n* is the same. The gateway node is elected by using algorithm 11.

Algorithm 11 The process of the Gateway Election.

Notification: Ordinary node O_n , Encounter node E_n, clusterheads C_H, Gateway node G_n
For each O_n
if count of encountered $C_H > 1$ **then**

4: $G_n \leftarrow$ becomes O_n .
5: **else**
6: O_n remains same.
7: **end if**

ZoneCluster [46] also follows the re-election process when no clusterhead is encountered neither by ordinary node O_n nor Gateway node G_n. For the message forwarding process, the cluster approach is generated by using a probabilistic based approach.

3. DISCUSSION

Taxonomy of Ad-hoc Network and different routing approaches of these paradigms presented above.The Ad-doc network has mainly endured the mobility of nodes and that's why the topology is not fixed. Overall routing in these decentralized networks becomes challenging. This paper mainly focused on the routing approaches of three individual Ad-hoc paradigms proposed by different researchers which can be applicable in tactical situations. All the routing approaches mainly focus to enhance the overall performance of the network based on different criteria like PDR, latency, overhead ratio, buffer management, security, etc. Table 1 and Table 2 show respectively the categories and applications of different routing protocols. This review opens some issues for further research in these paradigms.

Table 1. Categories of Routing Protocols in Ad-hoc paradigms.

Routing protocol	**Ad-hoc paradigm**	**Category , Mobility**
AODV [21]	MANET	Reactive and Unicast , Yes.
EPAAODV[24]	MANET	Reactive and Unicast, Yes
IAODV[25]	MANET	Reactive and Unicast Yes.
DSDV [27]	MANET	Proactive and Unicast, Yes.
OLSR [28]	MANET	Proactive and Unicast, Yes.
DSR [26]	MANET	Reactive and Unicast, Yes.
Spray and wait[33]	DTN	Flooding Based, Yes.
Adaptive Spray and Wait [39]	VDTNs	Abstracted,yes
Epidemic[32]	DTN	Flooding Based, Yes.
An efficient method for	DTN	Flooding Based,Yes.
secure routing[38] An efficient method for	DTN	Abstracted, Yes.

buffer management[40] MaxHopCount [41]	DTN	Abstracted, Yes.
ChitChat [42]	PSN	Social concepts based , Yes.
Gossip[43]	PSN	Social concepts based , Yes.
PNGP [44]	PSN	Social concepts based , Yes.
ZoneCluster[46]	PSN	clustered based , Yes.

Table 2. Applications of Routing Protocols of Ad-hoc paradigms.

Routing protocols	Working Principle	Applications
AODV[21]	Forwarding routes are formed on an on-demand basis.	Emergency services,community based networking,Conferencing.
EPAAODV[24]	Enhance transmission range along with lower hop count.	Enhance network lifetime, avoid network reconstruction.
IAODV[25]	Enhance packet delivery ratio and reduce latency.	Overcome the data transmission problem that MANET faces.
DSDV [27]	Routing information is maintained by nodes using a table-driven approach.	Archaeological sites, visitor Tracking System (VTS).
OLSR [28]	Utilizes multipoint relay-based concepts for data transmission periodically .	Different traffic scenario of VANET.
DSR [26]	Provides a negligible loop-free routing algorithm along with up-to-date routing information.	Multi-Hop Wireless Ad-Hoc Networks.
Spray and wait[33]	Apply flooding-based and data-transmission based strategies respectively in the spray and wait, phase for data transmission.	Enhance the performance of flooding-based routing strategy.
Adaptive Spray and Wait[39]	Enhance the probability of successful message	Enhance the performance of VDTN along with spray

	delivery.	and wait routing protocol.
Epidemic[32]	Flooding message to each encountered node to enhance message delivery.	Data forwarding, either with, no or partial communication path.
An efficient method for Secure routing[38]	Ensure secure message transmission using RSA[37].	Sparse environment.
An efficient method for Buffer management [40]	Enhances the message delivery and reduces the overhead ratio.	Challenging and harsh networking.
MaxHop Count [41]	Focused on message dropping policy to enhance network performance.	Implement drop policy for optimal buffer management.
ChitChat [42]	Focused on the social profile of nodes for enhancing message delivery.	Sparsely-connected PSNs
Gossip [43]	Focused on the social profile of nodes to enhance PDR.	Sparsely-connected PSNs.
PNGP [44]	Focused on social relationship and popularity of nodes to enhance PDR.	Community-based routing.
Zone Cluster[46]	Clustered based infrastructure for efficient routing.	Lager networks.

4. Open Issues

Several routing algorithms of the Ad-hoc paradigm along with their classification are discussed in this paper. The main focus of these routing algorithms is to enhance the overall performance of the network by considering different parameters like PDR, the overhead of nodes, latency, etc. The above reviews also identify some new open issues that are seldom addressed.

4.1Buffer Management

Nodes in these types of networks suffer from limited memory size, that deteriorates the overall performance. In these paradigms, the store-carry-forward approach is applied for data transmission. As a result, nodes need to store a large number of messages until a suitable transmission opportunity is found. As messages are stored into the node buffer, so congestion of buffer and proper buffer management is a vital concern. On the other hand, sometimes messages are stored for a longer time,and message replication also becomes the cause of storage overhead and usage of higher bandwidth [49]. As discussed earlier methods for buffer management are proposed respectively an efficient buffer management [40] and MaxHopCount [41]. This above-discussed issue can draw the attention of the researcher for future research so that the real-life application for these different Ad-hoc paradigms can be enhanced. Applying message dropping policies from the buffer whenever buffer overflow can be an effective solution for this issue. TTL expired messages can be dropped after a certain period of time, which may be effective both for the overhead reduction and efficient utilization of buffer space.Message forwarding scheduling policies determine which message should be forwarded and also assists with well-ordered buffer management. Selecting and utilizing the relay node for the message distribution may also reduce overhead and ensure adequate buffer management.

4.2 Clustering based routing approach

According to this review, in table 4.1 almost all the algorithms are applied on the flat approach except ZoneCluster[46]. Flat approaches are potent for the smaller network but in the case of larger networks, the overall performance degrades. This approach comprises simple architecture and each node acts a similar role in the case of data forwarding. Consequently a network along with the flat approach suffers from scalability issue. Node’s mobility mainly causes unpredictable topology which creates challenges for data forwarding. Consequently, the above-discussed algorithms may suffer from scalability. A clustering-based routing approach can be an effective alternative for reducing this suffering. Partitioning a network into smaller sub-units with a set of concentratedly connected nodes refers to as clustering. The clustering approach assists to unfold a larger network into different smaller parts which may enhance the scalability of the network. Besides that, nodes in the clustering approach acts different significant roles in the case of data forwarding which also reduces the complexity of routing. Vincent D Blondel. etal [50] proposed a method that works in two different phases to unfold a large network and plays a significant role in clustering.Basically, the procedure enhances the overall scalability of the network. As discussed above ZoneCluster[46] follows the clusteringbased approach to provide effective infrastructure for data forwarding which also fruitful to enhance the scalability of the network. As nodes in these types of networks are sparsely connected and heterogeneous in nature, that cause challenges in detecting clusters (Figure 6). This issue may add a new dimension for further research to increase the scalability of the network.

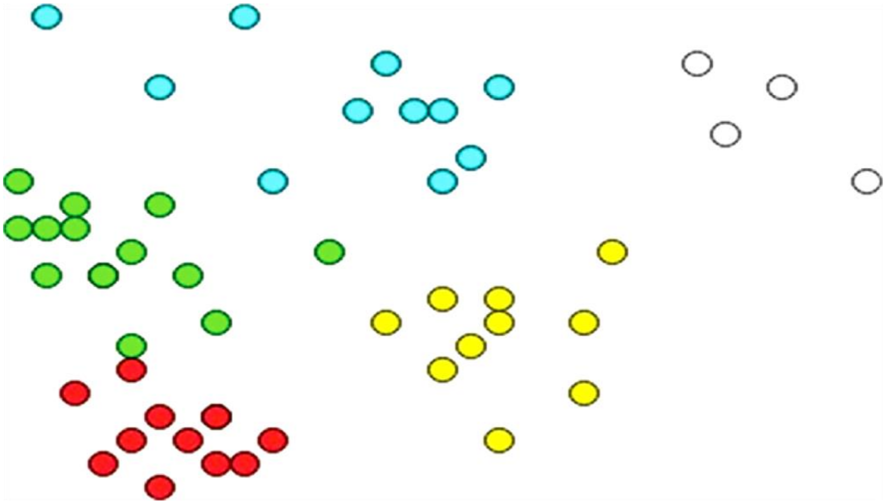


Figure 6. Clustering Approach

4.3 Security

Ad-hoc networks suffer from security issues because of intermittent connectivity among nodes or for the presence of selfish nodes. Nodes that are not willing to forward data without the associates can be denoted as a selfish node.In some states, nodes need to share personal information with the encountered node or relay nodes, it may break privacy. When a node suffers from limited power supply may act as selfish node. Sometimes these types of networks may suffer from internal attacks. Like, a node may unable to forward data and becomes a failed node. Additionally, a node may interrupt the data forwarding process deliberately. On the other hand, the network may suffer from different security attacks like denial of services, eavesdropping, spoofing, etc. Network authenticity is also required for ensuring the security and integrity of data. Unauthorized access may cause insecurity and mislead in case of data transmission. Applying effective encryption or any other security methods may ensure reliable and effective data transmission.

According to this review, some researchers have proposed efficient methods for secure routing[38]. Apart from this, there is scope to do further research to ensure secure and reliable transmission.

In this review, different routing approaches in Ad-hoc paradigms are discussed comprehensively. The above discussion unfastens some challenging issues regarding the routing in the Ad-hoc paradigm. This review resultant some proposed solutions to overcome these challenges. Overall, this review opens a new era for the research in these Ad-hoc paradigms as well as can perceive proper direction to do further research. In different tactical settings when nodes are sporadically linked or the entire connection is interrupted, new techniques and routing protocols for effective data forwarding might be provided to improve the overall performance of the network.

5. Conclusion

People use the internet in their daily life for making communication which requires prefix infrastructure. In the case of extreme scenarios when connectivity among nodes is intermittent or broken, TCP/IP is not suitable for establishing communications. Ad-hoc networks can be applicable in such extreme scenarios, as it does not require any preexists infrastructure. In this article routing algorithms of different Mobile Ad-hoc networks (MANET,DTN and PSN) are reviewed. As in these types of networks, nodes have mobility and no specific infrastructure is present, so routing becomes challenging. In MANET a node can act both as a router or node for effective data forwarding. Both DTN and PSN utilizes the node's mobility for making forwarding decisions. This review assists researchers to enhance their understanding of these networking paradigms. In the discussion part, some open issues are discussed that enhance the scope of research in the future.

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Authors

Ratna R. Sarkar received M.Sc in Computer Science and Engineering from BRAC University, Bangladesh and she did B.Sc in computer science and Engineering from Hajee Mohammad Danesh Science and Technology University, Bangladesh. Currently, she is pursuing her PhD in Computer Science and Engineering at Jahangirnagar University, Bangladesh. Her research interests include Pocket Switched Networks, Ad-hoc Networks, internet of things (IOT), Telemedicine.

Amitabha Chakrabarty, received PhD from Dublin City University (DCU), Ireland. He did M.Sc in Computer Science and Engineering from University of Rajshahi, Bangladesh. Currently, he is working as an Associate Professor of Computer Science and Engineering at Brac University. His research interests include Switching theory/High performance switching, Network Security, Handover management in cellular networks, Sensor Network routing and applications, and Location based services.

Mohammad Zahidur Rahman received PhD from University Malaya, Malaysia. He did M.Sc in Computer Science and Engineering and B.Sc in Electrical and Electronics from Bangladesh University of Engineering and Technology (BUET), Bangladesh. Currently, he is working as a professor of Computer Science and Engineering at Jahangirnagar University, Bangladesh. His research interest includes E-Commerce, Computer Security, E-Governance, Communication, and Telemedicine.