CHAPTER 2

GENERAL CONSIDERATION AND LITERATURE REVIEW

2.1 INTRODUCTION

This chapter presents background information relevant to the work presented in this thesis such as overview of wireless communication technology, and explanation of relevant characteristics of the wireless channel then a critical literature review of routing and clustering in MANET is presented.

Presently huge studies are concentrated on wireless mobile ad-hoc network [23, 24]. Developing routing protocols and clustering in infrastructure less networks has been a broad research field in present time. Several reactive, reactive and hybrid protocols have been mentioned from many perspective [24]. These protocols attempt to fulfill many parameters like effective utilization of battery and bandwidth, fast route convergence, optimization of various metrics and free from loops.

As well, mobile wireless Ad Hoc networks have two different network topologies: flat and hierarchical architecture [20]. In a flat network design, each node has essentially the same job, is adequate for very small networks, and is easy to design, implement and maintain as long as the network stays the same. But when the network grows, a flat network becomes undesirable; hierarchical network architecture becomes a better choice. In a clustered network, the nodes are distributed into small groups. Each group contains a cluster head (CH) which is mainly accountable for the route calculation and communication within that cluster. Many clustering scheme are available for dividing the large network into small network. The layout of this chapter is as follows.

Section 2.2 presents, overview of w mobile wireless ad hoc network. Section 2.3 contains protocol stacking of wireless mobile Ad-Hoc network. Section 2.4 describes the development goals for wireless mobile ad-hoc routing protocols. Section 2.5 presents clustering in MANETs. Section 2.6 investigates research review on clustering. Concluding remarks presented in section 2.7.
2.2 OVERVIEW OF INFRASTRUCTURE LESS MOBILE ADHOC NETWORK

Adhoc network has several advantages over fixed network. Sustaining a huge number of diverse individual is thus a demand for upcoming ad hoc wireless networks. Mobile wireless Ad Hoc networks are classified based on the geographic coverage in two ways.

Wireless Local Area Network (WLAN)

Wireless local area networks connects two or more nodes using some multiple access technique like spread spectrum and usually provide a association via an access point to the wider Internet. This provides freedom to roam users within coverage area (100 meter) and still be tie up with the network. Wireless Local Networks [25] are built using IEEE 802.11 standards, under the named Wi-Fi.

Wireless Personal Area Network (WPAN)

Personal Area Network consist its wearable and portable equipment. They can remain an autonomous network having coverage range of 10 meters. It describe concept of smart home and offices and fancy futuristic multimedia on the move and will offer more features when associated to a bigger network [25]

2.2.1 Applications of Ad Hoc Network

A mobile wireless ad hoc network is used in the situation where any infrastructure is not available. The classic use of MANET is in tactical networks, disaster, and extension to last mile coverage of cellular networks. As scenario changes from fixed network devices to portable devices with subsequent development in wireless communication, mobile wireless Ad Hoc networks having its demands with the widespread use of MANET applications [26,50]. Mobile wireless ad-hoc network can be setup anytime and anywhere. It permits node to enable connections in the network where nodes can join and leave the network anytime. Including old/existing uses that moved from typical wireless scenario in the infrastructure-less wireless scenario, a large range of opportunities of latest services can and will be created for the future. Some typical adhoc wireless network application are shown in the Fig.2.3.
Fig. 2.1 Wireless local area network (WLAN)

Fig. 2.2 Wireless personal area network (WPAN)
Fig. 2.3 Applications of mobile adhoc network
Table 2.1 Mobile adhoc network applications

<table>
<thead>
<tr>
<th>Name of Application</th>
<th>Possible services area/scenario</th>
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</table>
| Enterprise and House Networking              | • Home/offices wireless networking  
• Conferences hall  
• Personal Area Network (PAN)  
• In building construction sites |
| Amusement/Entertainment                       | • Musical games  
• Robotics pets  
• Theme park |
| Education                                     | • Universities, colleges  
• Virtual class rooms  
• Conferences and lecture |
| Civilian and Commercial scenario              | • Electronics payments  
• Mobile office  
• Road accidents, traffic control and weather broadcast, taxicabs  
• Sports stadium, shopping mall, airport, railway stations |
| Sensor Network                                | • Smart sensor and actuator embedded in home appliances.  
• Data tracking/recording of environmental changes, animals behaviour, biological chemical/detection  
• Body Area Network (BAN) |
| Tactical Network                              | • Automated/advance battle fields  
• Military oriented |
| Emergency Services                            | • Policing and fire fighter  
• Hospitals  
• Search and rescue operations  
• Environmental disaster |
| Extension to coverage                         | • Extending infrastructure based cellular services |
2.3 MANET PROTOCOL STACK

Wireless mobile ad-hoc network protocol stack provides a detailed picture of protocol stack, which gives better understanding about mobile wireless ad-hoc networks [27]. Fig 2.4 shows OSI model, TCP/IP model and MANET protocol stack. It consists, application layer, transport layer, data link layer physical layer. It has some resemblance to TCP/IP and OSI model. The OSI layers of application, presentation and session, layers of are combined into one layer, which is known application layer in MANET protocol stack. Mobile Adhoc network is a layered constitution model for the use of network systems.

TCP/IP suite was designed before the OSI model. TCP/IP suite is shown in Fig. 2.4 The different layers in TCP/IP suite are not absolutely corresponding to the OSI layers. Fifth layer is similar to the merged session layer, presentation layer, and application layers of the OSI model and remaining four lower layers are the same. On the right side of Fig. 2.4 the MANET protocol stack is shown and similar to the TCP/IP suite. However, the main difference between TCP/IP and MANET protocols stack lies in the network layer. In MANET, mobile stations use routing protocol to route packets.

2.4 DEVELOPMENT GOALS FOR ROUTING PROTOCOLS

It is important to explain the development goal of mobile wireless Ad Hoc network routing protocol so that the design selections of the protocols can be better understood. As already mentioned in previous chapter, the defining traits of wireless network [27,50] include poor battery resource management policies, small available bandwidth, high data error rates, and a unstable network topology. Restricted bandwidth and poor battery power is generally the most important and limited. Some design criteria for mobile wireless Ad Hoc network routing protocols are explained as below:

**Low Control Overhead**

Control signals/packets needs bandwidth, resources for any process, and battery resources for transmitting and receiving information. Since bandwidth is scarce, so further routing protocols may not be use more bandwidth for its communication in the network, and may be designed in such a way that control information is kept comparatively small [25]. Therefore, minimizing control information packets also helps to preserve battery power.
Minimum processing overhead

Computationally composite algorithm requires important processing cycle in a node. These processing cycles further initiate the mobile node to use resources; an additional battery power is utilized. Protocols that are lightweight, require a minimum processing power from the node, maintain battery power for future use, and hence extend the overall battery lifetime[29].

Muti-Hop Routing Capability

The transmission range of a mobile node in MANET is very small. Transmitting node and destination node generally may not be within direct line of sight (LOS) of each other, therefore in MANET the communication is takes place with the help of intermediate nodes, so the routing protocol should be capable to find multi-hop routes between
sources node and destinations node, so that smooth communication between the intend nodes could be possible[29].

**Dynamics topology management**

Links breakage in wireless network may be common phenomena because of its multipath nature but it must be handled quickly with lower overheads. Due to node mobility, the links breakage may occur many times between the communicating nodes. To maintain a link between communicating nodes, a possible routing path must be maintained even while the intermediate nodes are moving including source and destination[33].

**Loop Prevention**

Loops normally formed when a station along a path include next hop to the destination via any broken /left away link of a node. When a rout exist, control and data packets may cross that route multiple times for the transmission in the network, in that case loop elimination, or the time to live of that packet reaches to zero. Since bandwidth is limited and loop formation puts extra consumption of bandwidth and is not favorable to the network. Even a momentary loop formation may be wastage of bandwidth. Thus, loop must be prevented. Considering these points, there are several types of routing have been developed for MANET[42].

**2.5 ROUTING PROTOCOLS FOR MOBILE ADHOC NETWORK**

Various interesting and important research areas are present in mobile wireless ad hoc network such as routing protocol, limited bandwidth, battery power, security, medium access control. Uncertain topology of adhoc network leads frequent change in routs between nodes. So routing protocols are very important and various such routing protocols have been developed. There are few important challenges, due to which the design of routing protocols becomes cumbersome in mobile wireless adhoc network such as Node mobility. Unpredictable and variable capacity of link and hidden and exposed node problem. Node mobility leads network partitioned and frequent change in network topology, unpredictable and variable capacity of wireless links leads frequently packet losses. Moreover, terminals have limited battery and bandwidth and need effective routing techniques.
The future application demand of stable and long life wireless network in ad hoc networks are gaining attention of researchers [28][29]. The classification of routing protocols is as follows:

2.6 CLUSTERING IN MOBILE ADHOC NETWORK

MANETs have two different network topologies: flat and hierarchical architecture [20]. In a flat network design, each node has essentially the same job. A flat network topology is adequate for very small networks and is easy to design, implement and maintain as long as the network stays the same. When the network grows, however, a flat network becomes undesirable and hierarchical network becomes a better choice. Nodes are divided into group in
a hierarchical network. Each group could have a cluster leader, which is mainly responsible for the route calculation and communication as shown in the Fig. 2.6.

In a huge network, flat routing provides immoderate amount of overheads that add to wastage of bandwidth in the network. Moreover a adhoc network consists different types nodes in the network are known heterogeneous nodes which introduce some authority in their responsibilities and role within the network. Terminals having more battery power backup and with more processing capacities are important for maintaining the ad-hoc network functions. The network are called clustered network. To maintain nodes heterogeneity and excessive amount of information in large network clustered routing is good option. The basic concept behind clustering scheme is to divide the large network into small group of terminals. This lessens excessive amount of information, and makes adhoc network scalable.
Table 2.2. Flat and hierarchical network

<table>
<thead>
<tr>
<th>Flat Network Architecture</th>
<th>Hierarchical network Architecture</th>
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<tbody>
<tr>
<td>• Difficult to manage mobility</td>
<td>• Easier mobility management procedures (Just ask the cluster head)</td>
</tr>
<tr>
<td>• No backbone node</td>
<td>• Presence of backbone node</td>
</tr>
<tr>
<td>• No single point of failure</td>
<td>• Single point of failure</td>
</tr>
<tr>
<td>• Wastage of the resources</td>
<td>• Better use of the resources</td>
</tr>
<tr>
<td>• Better load balancing property</td>
<td>• No option for load balance</td>
</tr>
<tr>
<td>• Same types of nodes</td>
<td>• Different types of nodes</td>
</tr>
</tbody>
</table>

Clustering

Clustering is dividing the huge network into small networks consisting group of nodes. This virtual group of mobile nodes have bidirectional link within their transmission range. The nodes in cluster transmit with the help of single-hop and multi-hop fashion. In single-hop a node can communicate only to the immediate node or neighbor node and in multihop a node can communicate to other node with the help of neighbor nodes or backbone node which is called cluster leader. A cluster member node stays two hops away from each other [45]. A typical clustered ad hoc network is shown in Fig. 2.7.

The tiny circles in the Fig.2.7 represent the wireless mobile nodes and the lines connecting shows single hops wireless link between the nodes. Every node has an ID number and every node plays equal role and responsibility as a host and router. This type of arrangement is prone to an inundation of information known as message flooding which offers better routing efficiency but significantly diminishes the Medium Access Control (MAC) layer efficacy [100]. Clustering techniques provides network scalability, throughput energy efficiency
and frequency reuse. At the network layer, clustering helps to improve routing through reduction of the routing table size and a decrease in transmission overhead (resultant of routing table updates) following topological changes.

The condensing and the ability of each node to store only fractional amounts of data (of the total network routing information) achieved through clustering helps aggregate topology information. [28]. Clustering schemes generally utilize three types of nodes, which are chosen to assume different roles according to specific criteria briefly outlined below:

**Cluster head (CH):** In a mobile wireless adhoc network an efficient cluster have a backbone node. This node is called CH (cluster head). CH node support all necessary functions such as to calculate the route between source and destination, bandwidth allocation, power control, channel access, routing and intra cluster communication among member nodes, [52]. Cluster head is connected with gateway node for inter cluster communication. i.e if a cluster node need to send message to another cluster then on behalf of that node cluster head sent

![Fig. 2.7 clustering in mobile adhoc network](image)

that message via gateway node and vice versa. If the destination node is a different group, cluster leader sent it to that group leader via gateway node and then CH route it to the final destination [104].

Cluster Gateway Nodes: The nodes which are within the transmission range of a cluster head are known Cluster Member (CM) nodes but when a node is within the transmission range of two cluster heads then it is known gateway node. A gateway node supports communication between two clusters. A node having one CH just immediate neighbor to which it can approach second CH within two hops is known a distributed gateway which is connected to next distributed gateway node of next cluster. [93].

Cluster member (CM): The nodes within the communication range of a cluster leader are known cluster member node or ordinary node. Cluster member have least responsibility. They are responsible for communication within that cluster only to share the load of its cluster head.

2.7 CRITICAL LITERATURE REVIEW - ROUTING PROTOCOL

Routing protocol is a convention, which decides a route form source to destination node in MANET. Out of many types of routing protocols, any routing protocol can be select as per the requirement of application or scenario.

2.7.1 Proactive Routing Protocols

In table driven protocol each node manage routing table of entire network irrespective of route requirement in the network [29]. In case of any change in network topology, routing tables are periodically updated. Proactive routing is able to give instant route to the traffic but on the other side it lead to wastage of bandwidth and battery consumption [39]. Because table driven protocols manage terminal in /exit for each node in the routing table of each node, so it is not suitable for huge network [40]. There are many types of proactive routing protocols such as OLSR, DSDV, and WRP etc.

Destination-Sequenced Distance-Vector Routing Protocol (DSDV)

DSDV is originated from Bellman–Ford routing protocol [41]. In DSDV, all nodes are required to keep routing table of entire network, which include all available routes and number of hops between nodes. Each list entry has sequence number, allotted by source node. Any change in topology is informed periodically to updates the routing tables immediately. The update in routing table may be event driven or periodic. Every terminal instructed to transmit
its routing table to its immediate neighbor’s node. As per the update routing table of that node, the neighboring nodes update its routing table and came to know about any change that has happened in the network due to the topology change [33].

**Wireless Routing Protocol (WRP)**

Wireless Routing Protocol [42] is the set of distributed algorithms that calculate the shortest path taking shortest length and less number of hops from source to destination [41-43]. It lessens the occurrence of temporary routing loop. In wireless routing protocol, every node maintains following points.

1. A routing table
2. A distance table
3. A link-cost table
4. MRL (Message Retransmission List)

WRP send updates periodically to their neighbors’ node. The neighbor’s nodes acknowledge the received update message using MRL. If there is no change from the update, the terminals transmit simply Hello message in response just to confirm connectivity. A node from the last update information can look and decides for a better path. After getting a appropriate route, this message is send to the originating terminal to list that upgrade route in its routing tables. The original node updates its Message Retransmission List after receiving the acknowledgment. This constant process of update check in the routing information by every node, avoid routing loops and always attempt search the best routes.

**Cluster Gateway Switch Routing Protocol (CGSR)**

CGSR is suitable for clustered or small network. The large network is first divide into small chunk of nodes, with the help of cluster head algorithm. Cluster leaders are nominated based on different criteria such as based on lowest id, highest connectivity, max-min d-hop clustering or by k-connectivity schem. One cluster head (CH) is accountable for one particular cluster and their cluster member (CM) nodes. The frequent change in topology, which is a big issue of adhoc network, leads to change in cluster heads, which is a drawback in
terms of loss of information, bandwidth, performance of routing protocols and end to end delay.

Cluster gateway switch routing protocol is derived from Distance sequence distance vector routing protocol and hence provide same overhead as distance sequence distance vector. The only difference, cluster gateway switch routing incorporates distance sequence destination vector enabling a hierarchical cluster-head-to-gateway scheme to destined a packet from origination to destination. A node that falls between the transmission zones of two Cluster leaders is known as cluster gateway node. A datagram from an ordinary terminal is first destined to cluster leader, and cluster leader route it to a gateway node and thus gateway node route to another cluster head.

2.7.2 Reactive (on demand) Routing Protocols

In reactive routing protocol, nodes discover route whenever it is required in the network instantaneously. Source terminal check routing table list for the required path if there is no path exist then source node take the authority for path search process. The Reactive routing protocols have two phases [34]:

**Route discovery:** In this process, origin terminal takes the opportunity to discover route as per requirement. Source terminal checks its routing table for required route if the path does not exist in the list, then source terminal takes the initiative for path search. The source terminal adds the destination address and the intermediate terminals address to the destination in the packet.

**Route maintenance:** The nature of adhoc network is uncertain, due to which routes change frequently and hence frequent link breakage between the nodes which must be maintain for proper communication in the network, so route are repaired by the protocol itself with the help some acknowledgement mechanism. In reactive protocols routes are selected by route, discover mechanism on demand basis, so it provides some latency to the network. Every intermediate terminal participate in the path search process contribute latency. So reactive routing schemes reduce the routing overheads so reactive protocols are suitable in the scenario where low routing overhead is required. Example of reactive routing protocols such as AODV, DSR, AODV, LMR, and TORA [28]
Dynamic Source Routing (DSR)

DSR relies on link state routing schemes [36]. Source node starts path search based on requirements. The source terminal decides path between two communicating node and at the same time it records intermediate terminals address in the packet. This protocol is suitable in small multi hop networks. In DSR, no Hello message or beacons are interchanged between the terminals to find out of neighbors terminals [29].

Ad Hoc On-Demand Distance Vector Routing (AODV)

AODV Routing [37] is a reactive protocol and is derived from DSDV proactive routing protocol. It reduces overheads by finding the path on demand, basis, which does not possible in DSDV protocol. Before transmitting any packet, a terminal broadcast a route request (RREQ) packet. The nearby node forwards that RREQ packet further to its neighbors on the way to destination terminal. At the time of RREQ, all intermediate terminals record he id of the terminals from which the packet is originated, this helps for maintaining a reverse path. The duplicate RREQ packets are omitted. The reply is broadcast via same route. Any change in topology, leads route breakage then route is repaired then source node can perform a path search operation again. If an intermediate node moves out, the nearby node of that terminal find the path breakage and inform this path failure news it is immediate nearby terminal. This procedure keeps on until the path breakage news arrives at source terminal. After getting path breakage information, source terminal take the opportunity to s search path.

Associativity-Based Routing (ABR)

ABR considers a different routing parameter named degree of association stability [38]. In ABR, a path is elected based on degree of association stability. All nodes individually originates hello message periodically to show their presence. All nodes receive the hello message, an updates their tables. A high degree of associatively tick message shows that the station is relatively static.

Temporarily Ordered Routing Algorithm (TORA)

TORA[47,75] is an on demand routing protocol with some proactive advancement in which a link between node is maintained creating a Directed Acyclic Graph (DAG) of the route from the source to the destination. This protocol considers a link reversal model in route discovery. A route discovery query is broadcasted and forwarded in the entire network until it
TORA considers a metric parameter named “height”. It is a measure of the distance between responding node and destination node. In the route discovery process, this parameter is returned to the querying node.

As the query response informed back, each intermediate node updates its routing table with height and path to the destination node. The source node then uses the height to select the best path to destination node. In place of shortest route, TORA has an important characteristic that it always selects the most convenient route. TORA tries to minimize the routing management traffic overhead.

### 2.7.3 Hybrid Routing Protocol

Hybrid routing protocol is eliminating the drawbacks of proactive and reactive routing protocols. Hybrid routing protocol is an optimization of proactive and reactive protocols. Proactive protocols provide more overhead and less latency and reactive protocols gives less overhead and more latency. Hybrid routing protocol is the combination of reactive and proactive routing protocol. It has route discovery procedure of on demand protocol and the table maintenance procedure of table driven protocol to eliminate control overheads and latency issues. It is suitable for huge networks. Huge network is divided into set of zones where routing within the zone is performed by using table driven basis approach and outside the zone on demand routing approach can be used. There are several hybrid routing protocols for adhoc wireless adhoc network for example SHARP, ZRP [49].

#### Zone Routing Protocol (ZRP)

ZRP is appropriate for large mobile wireless adhoc network [48,77]. In ZRP, every node retains station within a confined area, named as routing zone. Path discovery process use RREQ and RREP mechanism. For making zones, a station required to familiar about its nearby stations to form a zone. For the communication in two zones, neighbor discovery information is used [49]. In place of blind broadcasting, Zone Routing Protocol uses a route query process to minimize overheads governing query messages on the side from the query source and inside within covered zones. When any station receive the query packet then that station try to find out whether it is forwarded by nearby station or not. If yes, then it records all these neighboring nodes in its area as covered one [29]. The search remain continue till the
destination. The destination receiving search packet sends a reply packet following the same reverse path.

**Sharp Hybrid Adaptive Routing Protocol (SHARP)**

SHARP [50] lies between table drive and on demand routing by promptly broadening the size of routing messages shared proactively. SHARP create the proactive zones around some nodes. That zone has a specific radius. All nodes within the zone radius known member of proactive zone for that node. In case if a destination station does not belong to that proactive zone then reactive routing scheme is used to search the path to that destination station. In SHARP, proactive zones are maintained automatically if some destinations station is sought in the network. The proactive zones performs as a collectors of packets, which forward the packets effectively to the destination, once the packets reach any node at the zone vicinity [29]. Table 2.3 shows critical literature of AODV and DSR routing protocols simulation comparison.

Table 2.3 Literature review AODV and DSR routing protocol

<table>
<thead>
<tr>
<th>Author/Year</th>
<th>Approach</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samir R. Das et al., 2000,[109]</td>
<td>Performance of AODV and DSR using random way point mobility model with variable pause time using ns-2 simulator</td>
<td>They investigated that DSR performs better than AODV in delay and throughput for small number of nodes and lower load and mobility while AODV performs better than DSR in more load, high mobility. They also found that DSR low throughput and delay was due to aggressive use of caching and stale routes.</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Title</td>
<td>Experiment Details</td>
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<td>--------------------</td>
</tr>
<tr>
<td>Bijan Paul et al., 2011,[110]</td>
<td>Behavior of AODV and DSR over TCP and CBR connection with varying speed and node density using random waypoint mobility model and ns-2 simulator.</td>
<td>They investigated that in low density with low speed the packet delivery ratio of TCP and CBR connection for both protocols is high while end-to-end delay is high for TCP connection but low for CBR. With high speed PDR for AODV using TCP is average but high for DSR. In high density with low speed, PDR of TCP and CBR connection for AODV was average but high for DSR. If the speed was high the PDR for AODV and DSR using CBR was low, but using TCP AODV performed average and DSR performs high. Performance of both AODV and DSR outperformed each other based on the different traffic pattern.</td>
</tr>
<tr>
<td>Muazzam Ali Khan Khattak et al., 2008,[111]</td>
<td>Performance of AODV, DSR and DSDV protocol in ns-2 simulator by varying the node density and mobility using UDP and TCP traffic</td>
<td>They investigated that all protocols performed well under TCP packet while packet delivery ratio is low in case of UDP due to no retransmission. In addition, they found that DSDV is poor protocol in mobility environment due to low coverage time</td>
</tr>
<tr>
<td>Sapna S. Kaushik et al., 2009,[112]</td>
<td>Performance of AODV and DSR protocol in ns-2 simulator using various performance metrics</td>
<td>They investigated that DSR performs well when the number of nodes are less and performance declines with increase in number of nodes due to more traffic. AODV performance decreases and remains constant as the number of node increases. DSR performs well when number of nodes is less but slightly</td>
</tr>
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</table>
underperforms with increase in the number of nodes. The packet dropped is much less compared to the performance of AODV.

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Study Details</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Josip Lorincz et al. 2007,[113]</td>
<td>Performance of AODV and DSR based on the FTP throughput comparison in multi-hop static environment</td>
<td>They found that DSR-UU throughput was higher and had less relative deviation than AODV-UU. Variation was possibly due to shorter route timeout settings in AODV-UU and due to DSR source based routing, also DSR route caching has advantage in case of link breakage but DSR-UU takes more time to reroute because of source routing</td>
</tr>
<tr>
<td>Rajiv Misra et al.2005,[114]</td>
<td>Performance of AODV and DSR based on constrained situation (Congestion) using Glomosim simulator</td>
<td>They concluded that DSR outperformed AODV in constrained situation. There was 30% reduction in performance for AODV and 10% reduction in DSR as compared to the normal situation. DSR ability to store more than one route per destination and route caching provided better result than AODV during congestion. They also proposed a local route repair algorithm for AODV that takes the route through the destination using lightly load neighbor thereby reducing local congestion and thus reducing the packet drop during congestion. The same was simulated and found to be better</td>
</tr>
<tr>
<td>Mehdi Barati</td>
<td>Performance of AODV and DSR routing protocols using</td>
<td>The studied that increases in energy consumption for AODV was more than</td>
</tr>
<tr>
<td>Reference</td>
<td>Methodology</td>
<td>Findings</td>
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<tr>
<td>et al., 2012, [115]</td>
<td>ns-2 simulator based on energy consumption</td>
<td>DSR in low traffic while DSR energy consumption was high in high traffic. Less energy was required for DSR in terms of varying mobility pattern compared to AODV due to its route caching behavior thus requiring less route discovery. DSR performed better in low and high load, AODV consumed more energy than the DSR with reference to area.</td>
</tr>
<tr>
<td>Richa Agarwal et al., 2011, [116]</td>
<td>Effect of wormhole attack on AODV and DSR routing protocols using Qualnet simulator using various node density, random way point mobility model</td>
<td>They analyzed that for a steady wormhole link there is no effect on the functioning of these protocols because the link behaves as a high speed directional link for routing messages. With the increase in length of obstructive links the performance of DSR degrades more compared to AODV.</td>
</tr>
<tr>
<td>Asma Tuteja et al., 2010, [117]</td>
<td>The performance of AODV and DSR routing protocols using ns-2 simulator.</td>
<td>Overall performance of AODV decreased with the increase in packet size, in DSR overhead increased with increasing packet size subsequently throughput decreased with increasing packet size, DSR was the best performer compared to AODV protocol.</td>
</tr>
<tr>
<td>Koushik Majumder et.al., 2009,[118]</td>
<td>The performance of AODV and DSR in hybrid network that is a combination of wired and wireless ad-hoc network. The simulation was carried out using ns-2 simulator and varying pause time with different number of sources.</td>
<td>They found that PDR (Packet Delivery Ratio) was almost same for AODV and DSR. With decrease in mobility and increase in pause time PDR also increased for both the protocols. AODV had less end-to-end delay compared to that of DSR; which was mainly due to source routing nature of DSR and stale route. With increasing mobility and decrease in pause time delay also increased. DSR was found to be better in case of normalized routing load mainly due to route discovery process for AODV as it maintains only one route to the destination and in case of link breakage, it needs to initiate route discovery process thereby increasing the number of control packets</td>
</tr>
<tr>
<td>Shaily Mittal et. al. 2009,[119]</td>
<td>Compared the performance of AODV and DSR routing protocols using Qualnet simulator and varying pause time in random way point mobility model.</td>
<td>They found that AODV and DSR performed better in terms of Packet Delivery Ratio. Average hop count remained constant for DSR while for AODV the hop count increased continuously. AODV has low end-to-end delay compared to DSR.</td>
</tr>
<tr>
<td>Mohammed Bouhorma et. al., 2009[120]</td>
<td>Studied and compared the performance of AODV and DSR routing protocols using ns-2 simulator and random waypoint mobility model and varying number of nodes.</td>
<td>Found that AODV Packet delivery Ratio was higher compared to DSR and end-to-end delay for DSR with varied pause time was less compared to that of AODV. As mobility increased, AODV performed better.</td>
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</tbody>
</table>
2.8 CRITICAL LITERATURE - CLUSTERING IN MANET

This type of model as shown in above figure 2.8 is designed to divide network into sub network. These sub networks are often known as groups or clusters [51,102]. Clustering has been a very popular area of research in recent years. Communication in a network can be established through a central authority known as Cluster Head (CH) and gateway node. This section briefs about few method used for clustering in mobile ad-hoc network.

Work in [52] propose a clustering algorithm called Cluster Technique in mobile Ad-hoc network composed of proactive source routing protocol. CTMAN uses Dijkstra’s algorithm to find the shortest path among the nodes in cluster reducing the overhead in the network.

An efficient overhead aware leader election algorithm has been proposed in [54]. This algorithm maintains a list of all the nodes in the network in descending order with respect to their ID (Identity) in the network. A node with the highest ID becomes the CH (Cluster Head). When a CH fails instead of sending a CH election procedure to every node it is send to a node with a ID next to crashed node. This reduced the network overhead by reducing the number election message passed.

Cooperative clustering based secure leader election model for intrusion detection in mobile adhoc network [66] uses partner clustering Algorithm (PCA), which calculates the suitability score of a node to become a CH. Suitability score of a node is calculated based on distance it covers, its transmission power and speed of a node. The suitability score once evaluated is broadcasted through beacon. A node with the highest suitability score becomes the CH. Disadvantage with this approach is that if a beacon is lost a node with lower suitability score may declare itself a CH.

Author in [55] proposed an approach where a CH is elected based on mobility pattern of a node. A node, which is comparatively stable in the network, is chosen as a CH.

In [58] a work concentrating on security aspect of hierarchical network is proposed. This algorithm chooses a CH based on its reputation, its degree and its stability. These factors together give the weight of a node and a node with highest weight becomes a CH.
Work in [59] proposed on demand Weight clustering algorithm (WCA) that detects a cluster head supported the weight of a node.

Leader Election algorithm [60] does not have any mechanism to discover the malicious nature of a node within the network.

Scheme in [62] puts forth a Vice Cluster head in cluster based Routing Protocol (VCH-CBRP) that is an extended version of CBRP. In this approach once a CH becomes idle, a vice node within the network declares itself as a CH provides it has a bidirectional link to at least one or more neighbors. This approach could fail once a node declared as vice moves out of the range of CH.

Highest degree algorithm proposed in [90,92] is based on the number of its neighboring nodes that is defined as the degree of node. A node having highest degree becomes a cluster head.

Another ID based algorithm rule [90,93] assign a unique ID to every node and a node with lowest ID is chosen as a cluster head.

In [65] authors propose a clustering scheme based on the real distance between the nodes. This distance is measured based on received signal strength of a message. This approach selects the foremost stable node however might not work efficiently because there is hardly any node in Ad Hoc network that is stable.

Work in [101] project a cluster based trust aware routing protocol that protects the transmitted packets from the malicious node and if one is detected it is isolated from the network. Lowest–ID algorithm are simpler where a node with the lowest assigned ID is elected cluster head.

More recently, methods have been proposed using criteria ranging from the distance between nodes [96] and weight-based distributed clustering algorithms [98] to geographical positioning [99].

Work in [74] further extended in clustering by proposing a cluster based trust model against attacks in the Ad Hoc network. The method involves designating the node with the highest trust value as head.
Roberto Carlos Hincapi et. Al. in his survey found that Clustering methods improve network scalability, routing and topology management of MANET.

In [5,78] proposed cluster TDMA for supporting real-time traffic in MANETs. In bandwidth-constrained MANETs, the limited resources available need to be managed efficiently. To achieve this goal, a dynamic clustering scheme is used in cluster TDMA. In this clustering approach, nodes are split into different groups. Each group has a cluster-head (elected by members of that group), which acts as a regional broadcast node and as a local coordinator to enhance the channel throughput. Every node within a cluster is one hop away from the cluster-head.
Fig. 2.8 Ad-hoc network divided in-group or cluster

Table 2.3 various clustering schemes in mobile Ad-hoc network

<table>
<thead>
<tr>
<th>Clustering Scheme</th>
<th>Characteristics</th>
<th>Clusterhead selection criteria</th>
</tr>
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<tbody>
<tr>
<td>Lowest-ID [97]</td>
<td>Based on node ID</td>
<td>Lowest node ID among one-hop neighbors</td>
</tr>
<tr>
<td>Highest degree [98]</td>
<td>Based on highest degree (connectivity value)</td>
<td>Highest connectivity value among its direct neighbors</td>
</tr>
<tr>
<td>k-CONID [87]</td>
<td>Combines Highest-degree and Lowest ID Forms k-hop clusters</td>
<td>Highest degree as a first criterion and node ID as a second criterion</td>
</tr>
<tr>
<td>(α, t) cluster framework [91]</td>
<td>Clusters are formed based on path availability</td>
<td>No clusterheads are selected</td>
</tr>
<tr>
<td>Max-min d-cluster [90]</td>
<td>d-hop clusters are formed Uses node id Cluster formation is based on 2d rounds of flooding Three rules based on the registered entries of each node after 2d rounds of flooding are followed</td>
<td></td>
</tr>
<tr>
<td>Mob Dhop [93]</td>
<td>d-hop clusters are formed Based on the received signal strength by each node Lowest value of local stability among neighbors</td>
<td></td>
</tr>
<tr>
<td>DMAC [962]</td>
<td>Cluster formation is mostly message-driven Each node is assigned a weight value and an ID Highest weight value among one-hop neighbors</td>
<td></td>
</tr>
<tr>
<td>WCA [98]</td>
<td>A combined weight metric based on the number of nodes handle, mobility, transmission power and battery power Minimum weight value among neighbors</td>
<td></td>
</tr>
</tbody>
</table>
Formation of clusters and selection of cluster-heads is done in a distributed manner. Clustering algorithms split the nodes into clusters such that they are interconnected and cover all the nodes. Three such algorithms used are, lowest-ID algorithm, highest-degree (degree refers to number of neighbors which are within transmission range of a node) algorithm, and least cluster change (LCC) algorithm listed in Table 2.3. Various clustering schemes are proposed in the literature for MANETs [89]. Formation of clusters and selection of cluster-heads is done in a distributed manner. Clustering algorithms divided the nodes into clusters such that they are interconnected. The features and functions that should be implemented in the cluster head (CH) approach to support performance have been extensively discussed.

2.9 RESEARCH GAPS

Several methods have been proposed in the literature for performance analysis of suitable routing protocols and clustering scheme in infrastructure less Mobile Ad-Hoc networks. While various studies and approaches have demonstrated good agreement for improving both but because of various issues and challenges of infrastructure less mobile wireless networks, providing suitable routing protocol and clustering scheme is more challenging task than the one in the fixed networks and always an open issue in infrastructure less Mobile Ad hoc wireless network. After a critical literature review, finally the research gaps are identified.

- A key challenge in infrastructure-less mobile network is that communication has to be carried out with the changing (dynamic) network topology due to node mobility. Each node in wireless infrastructure less network communicate directly to the neighbor nodes within its transmission range, for communicating with nodes that reside beyond this range, the node needs to use intermediate nodes to pass its messages hop by hop with the help of routing protocol. So it is necessary to study and identifying suitable and efficient routing protocols for different applications in Mobile Ad-Hoc Network

- Currently popular network management algorithms were mostly designed to work on fixed or relatively small wireless networks. Many mobile ad hoc network applications involve large networks with tens of thousands of nodes, such as in sensor networks and tactical networks, which are difficult to manage. Clustering is an important research
area for mobile ad hoc networks (MANETs) as it increases the capacity of network, reduces the overheads and makes the network more manageable in the presence of both high mobility and a large number of mobile nodes. So there is a need of identifying and developing a new clustering algorithm for dividing the large network into small manageable networks.

- In clustering the cluster head (CH) manages and store recent routing information and gateway node provide the inter cluster communication. The frequent change of cluster head (CH) and gateway node leads to loss of routing information stored and battery efficiency of nodes, changes the route between two nodes, affects the performance of the routing protocol and makes the cluster structure unstable. Communication overhead in terms of exchanging messages is needed to elect a new cluster head. It is important to prevent loss of routing information to keep the cluster head (CH) and gateway node change as least as possible and to make cluster structure more stable. Most of the literature review available on clustering is based on electing Cluster Head (CH) and Gateway node separately. Therefore, there is great need to identify new technique for clustering in infrastructure less mobile wireless networks.