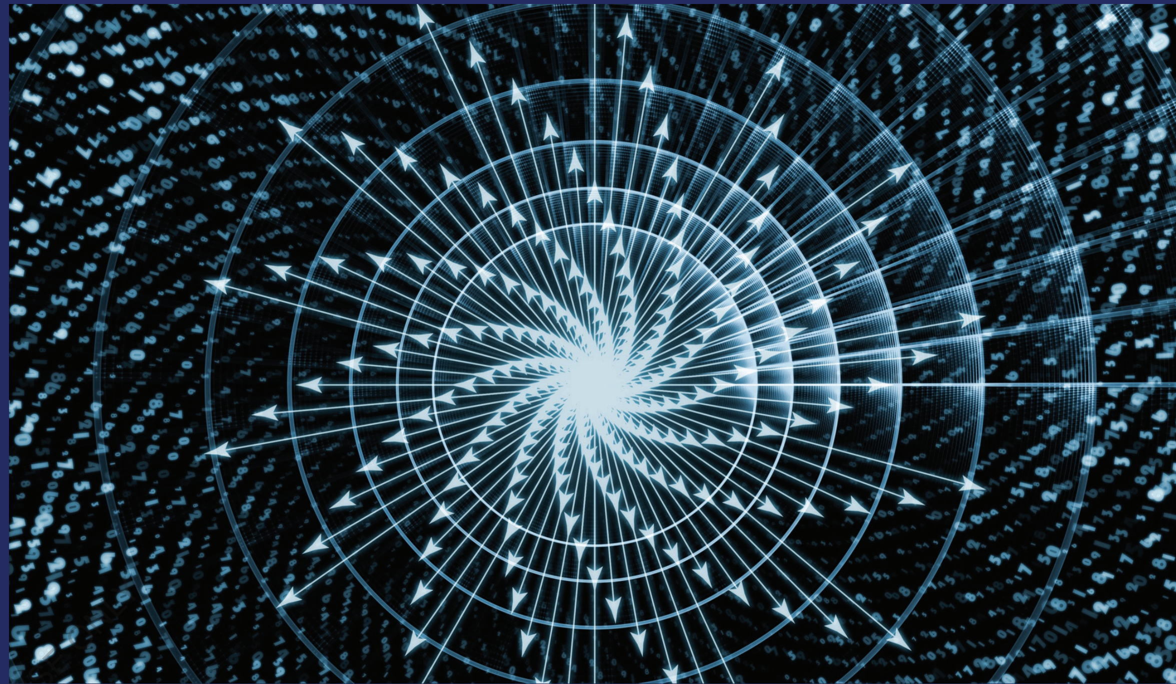
The systematic literature review has been carried out in an order to find techniques that were proposed for using swarm intelligence in MANETs. There are various techniques that exists in literature but has limitations and constraints. Therefore, Intensive research and study was done in the field to study and get in depth knowledge about the topic.
We found out that use of artificial intelligence techniques ie. Swarm intelligence techniques, are better than the traditional routing techniques used earlier. Swarm intelligence techniques such as Ant Colony Optimization, Glowworm Swarm Optimization, Artificial Bee Colony. Our work was confined to Ant Colony Optimization.



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Mehtab Alam

Applicability of Swarm Intelligence in Mobile Ad Hoc Network

Wanets, Manets and Ad-hoc

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LIST OF ABBREVIATIONS

S. No.	Abbreviation	Full Form
1	WANTEs	Wireless Ad hoc Networks
2	MANETs	Mobile Ad Hoc Networks
3	SI	Swarm Intelligence
4	AI	Artificial Intelligence
5	ACO	Ant Colony Optimization
6	PSO	Particle Swarm Optimization
7	ABC	Artificial Bee Colony
8	GSO	Glowworm Swarm Optimization
9	LAN	Local Area Network
10	OSI	
11	NIC	Network Interface Card
12	DSDV	Destination-Sequenced Distance Vector
13	OLSR	Optimized Link State Routing protocol
14	TC	Topology Control
15	MPR	Multipoint Relay
16	AODV	Ad Hoc on-demand Distance Vector
17	RREQ	Route Request
18	RREP	Route Reply
19	RERR	Route Error
20	DSR	Dynamic Source Routing Algorithm
21	LAR	Location-Aided Routing
22	GPS	Global Positioning System
23	ZRP	Zone Routing Protocol
24	ANN	Artificial Neural Network
25	F-ANT	Forward Ant
26	B-ANT	Backward Ant

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ABSTRACT

The Wireless Adhoc Networks (WANETs) are decentralized network with no infrastructure and access point to control the nodes. Since the topologies in WANETs are dynamic the routing becomes the challenging task as nodes are moving with low bandwidth and traditional routing algorithm doesn't work with WANETs. This work gives the systematic literature review of techniques and routing algorithm that exists in WANETs, also the applicability of Swarm Intelligence (SI) in MANETs. The aim of performing the survey is to gain better knowledge of Swarm Intelligence and techniques that are applied to the WANETs.

Keywords— Swarm Intelligence, MANETs, Mobile Adhoc Networks, Routing.

CHAPTER 1
INTRODUCTION

1. INTRODUCTION

A Wireless Adhoc Networks (WANETs) is a type of network that doesn’t rely on the infrastructure. It is decentralized network with no central authority to control the network. WANETs have various applications in today’s scenario. Mobile Adhoc Networks (MANETs), Smart Phone Adhoc Networks (SPANs), Internet Based MANETs (iMANETs) are some of the type of WANETs. In Adhoc Networks, there is no Access point to manage the nodes also the topology is dynamic. Therefore, traditional routing algorithm doesn’t work with WANETs. Routing in WANETs is a challenging task.

Swarm Intelligence (SI), is a branch that is inspired by the natural and artificial system. It is a study of natural phenomenon and individual’s behavior in decentralized environment. It is rapidly increasing area of Artificial Intelligence (AI). The algorithm used in SI has various applications in optimization and data analysis.

In this work, we give a systematic literature review of Swarm Intelligence techniques that are applied to the routing in WANETs. Also, the limitations that is present in traditional routing algorithms. The work justifies the applicability of SI in WANETs.

1.2 STRUCTURE OF THE THESIS

In chapter 2, a general overview about networks, fixed networks, ad hoc Network, Network topology, types of network topologies are given, with the aim of understanding the computer network system. It also includes theory about the wireless networks, wireless components used in a wireless network, types of wireless networks. The main part of the chapter describes Mobile Ad Hoc Networks and the traditional routing algorithms used in Mobile Ad Hoc Networks (MANETs). The last section on the chapter tells the drawbacks of the traditional algorithms in Mobile Ad Hoc Networks (MANETs).

Chapter 3 deals with the Study of Swarm Intelligence, swarm intelligence models. Different Models are described in brief in the section such as Ant Colony Optimization (ACO), Particle Swarm optimization (PSO), Artificial Bee Colony (ABC) and Glowworm Swarm Optimization (GSO). Ant Colony Optimization (ACO) is explained in detail. In the final part of the chapter Ant Colony Optimization implementation in MANETs is depicted.

Chapter 4 is the systematic literature review done in order to have clear cut, unbiased and complete and broader prospective about the topic. Many sources have been explored such as ACM Digital Library, IEEE Xplorer, Science Direct, Wiley Online Library and Springer.

Finally, in chapter 5, I present the main conclusions of my work, as well as possible alternatives for future research about problems that are still open.

CHAPTER 2
NETWORKS

2.1 INTRODUCTION

The great increase of the popularity of mobile wireless devices in recent years has resulted in a continuous improvement of their power, memory and communication features, nowadays common in business and personal life. Simultaneously, the possibilities of communication of these devices have grown, so that, once assumed their capability to access public or private networks such as Internet, by using wireless networks adaptors, the expected desire consists on achieving the faculty of interconnection between these mobile terminals in order to share information. The circumstances of these communications can vary tremendously depending on the context, and the traditional infrastructure networks are not functional in some occasions, for instance, when the network has to be established quickly without much infrastructure.

Therefore, the demand of easily deployable infrastructure less networks is utterly justified. Such networks are called ad hoc networks and they possess the important characteristic of having decentralized topology, so that the devices don't need the use of any kind of fixed Network element for the communication between them, but they administrate the network resources in a distributed way[1]. With this decentralized architecture, they should be able to adapt themselves to changes in the number of the nodes, their location and the traffic pattern requirements. Furthermore, the mobility of the nodes is another relevant point to allow for, and two communicating endpoints, which may be travelling too, should be unaware of any other mobility in the network.

The wireless nature of the links used in ad hoc networks and the fact that the nodes employ a part of their resources (bandwidth, power, etc.) to send other nodes' packets, limits the throughput available for each node[1]. When the number of nodes becomes high, scalability problems appear and this issue turns out to be critical. Therefore, capacity should be managed properly and the parameters affecting it should be designed carefully.

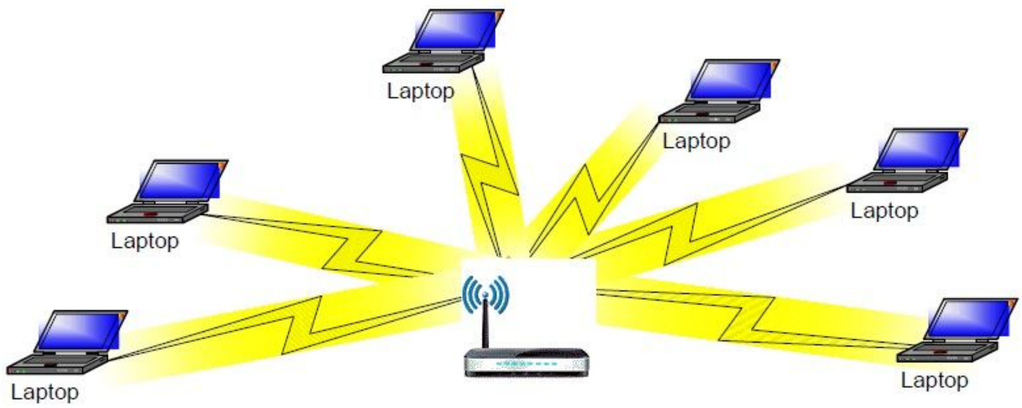

Figure 2.1: A Fixed Network

All these attributes that define the behavior of this kind of networks have important implications in their engineering, affecting to several network layers. Obviously, the form of routing, for instance, is especially specific, since two nodes that may establish an information exchange might not be able to communicate directly, so the routing scheme becomes multi hop and the cooperation between stations turns out to be fundamental in order to manage mobility and to deliver packets.

Therefore, in this environment, the hosts need to behave also as routers, because they should forward the packets they receive from their neighbors by following a particular routing algorithm. Other important aspects may appear as requirements in the design, such as power constraints of the devices, security of the transmissions and quality of service in the delivery of the packets, so they have to be taken into account too.

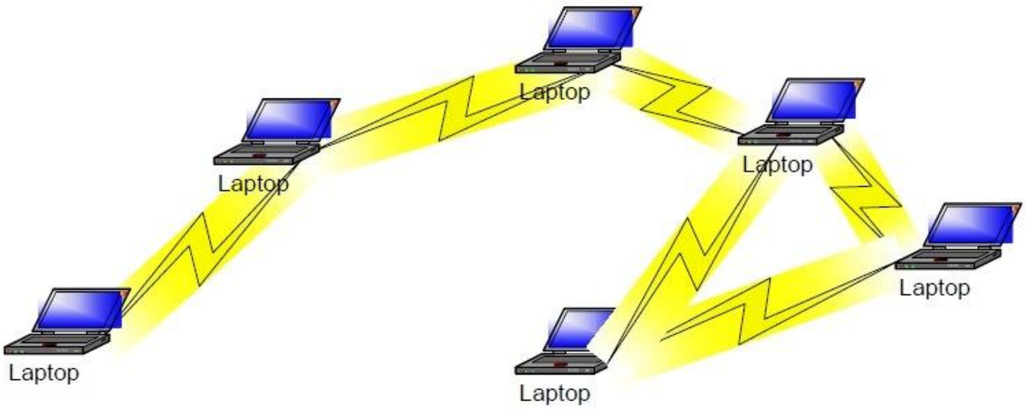

Figure 2.2: Ad Hoc Network

Consequently, they should be integrated in the architecture of the network to perform satisfactorily for the framework they were planned for, even when the size of the networks happens to be large. Managing efficiently power control in wireless ad hoc networks may carry important benefits, mainly because of its impact on battery life of the devices and on the carrying capacity of the network. Thus, energy savings and efficient use of the network resources are important reasons that make power management one of the most challenging problems is wireless communications.

Finding the shortest path between the transmitting and the receiving ends makes communication easier and quicker. The shortest path problem is solved by finding a path between two vertices in a graph in such a way that the sum of the weights of the edges is minimum.

2.2 WIRED NETWORK

A computer network or information network is an information transfer system which permits nodes to exchange information. In this, Internet enabled end user equipment's exchange information with each other utilizing a data link. The associations between nodes are built up using either cable media or wireless media. The best-known computer network is the Internet.

Internet devices that originate, route and terminate the data are called network nodes[1]. Nodes can include hosts such as personal computers, phones, servers as well as networking hardware. Two such equipment's can be said to be connected together when one und user equipment is able to exchange information with the other equipment, regardless of whether they have a direct link to each other or not.

Computer networks are different in the transmission medium which is used to carry their signals, the communications rules to maintain network traffic, the network's size, topology and hierarchical intent.

Computer networks bolster a colossal number of apps, for example, access to the World Wide Web, video, digital audio, shared use of application and storage servers, printers, and fax machines, and using of email and instant messaging applications and numerous others. Much of the times, application-specific communications protocols are layered (i.e. conveyed as payload) over other more general communications protocols.

2.2.1 NETWORK TOPOLOGY

Network topology[1] is the organization of the different components (links, nodes, etc.) of a computer network. Fundamentally, it is the topological structure of a network and may be portrayed physically or logically. Physical topology is the arrangement of the different peripheral devices of a network, including device location and link establishment. On the other hand, logical topology describes how data flows inside the network, disregarding its physical design. Separation between nodes, physical interconnections, transmission rates, or signal types may vary between two networks, yet their topologies may be indistinguishable.

The term physical topology[1] alludes to the manner in which a network is laid out physically.:

One or more equipment’s connect to a link; two or more links frame a topology.

There are two basic categories of network topologies:

i. Physical Topologies

ii. Logical Topologies.

The cable system is used to link devices is the physical topology of the network. This alludes to the system of cable, the position of nodes, and the interconnections between the nodes and the cables. The physical topology of a network is dictated by the abilities of the network access equipment’s and media, the level of control desired, and the cost related with cabling or telecommunications circuits.

The logical topology on the other hand, is the way in which the signals work on the network media, or the way that the information goes through the network from one equipment to the other without any concern to the physical interconnection of the equipment’s. A network's logical topology is not generally the same as its physical topology. For example, the twisted pair Ethernet utilizing repeater hubs was a logical bus topology with a physical star topology design. Token Ring is a logical ring topology, but is wired as a physical star from the Media Access Unit.

2.2.2 TYPES OF NETWORK TOPOLOGIES:

There are four basic topologies

i. Bus Topology
ii. Star Topology
iii. Ring topology
iv. Mesh Topology

I. BUS TOPOLOGY

A bus topology[1] is multipoint. One long cable goes as a backbone to Connect all the devices in the network. Nodes are connected to a common linear (or branched) half-duplex link called a bus. A drop line is a connection running between the equipment's and the main cable. A host on a bus network is called a Station or workstation. In a bus network, each station gets all network traffic, and the traffic produced by each station has equal transmission priority. A bus network forms a single network segment.

ADVANTAGES:

i. Easy to connect a computer system or peripheral to a linear bus
ii. Requires less cable length than in star topology bringing about lower costs
iii. It functions well for small networks.

DISADVANTAGES:

i. Entire network closes if there is a cut in the main cable or one of the T connectors break.
ii. Large amount of packet collisions on the network, which results in high amounts of packet loss.

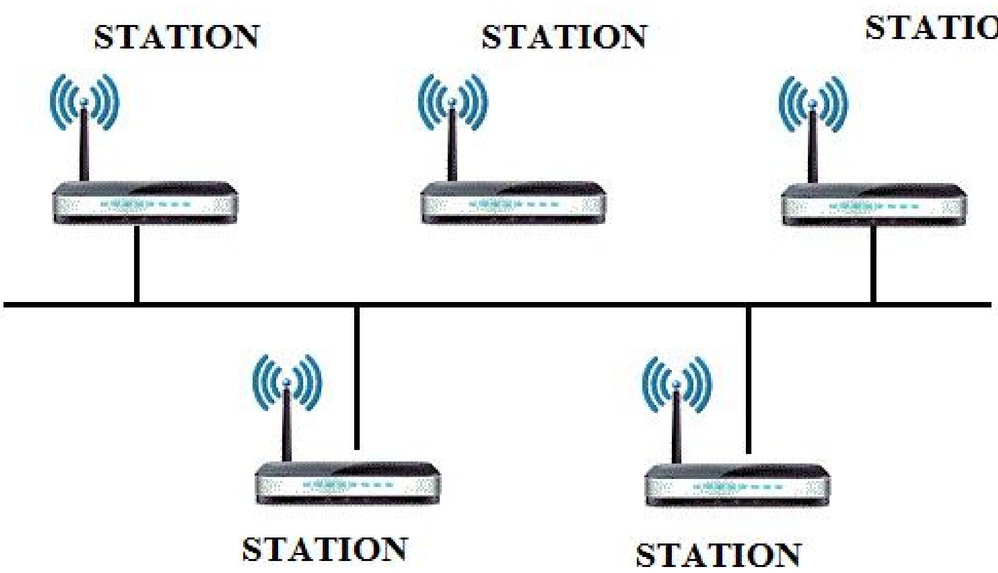

Figure 2.3: Bus Topology

II. STAR TOPOLOGY

In a star topology[1], each device has a dedicated point-to-point link only to a central controller, generally called a hub. The devices are not directly connected to each other. Not like a mesh topology, a star topology does not permit direct traffic between devices. This comprises of all nodes connected to a central node; this central node provides a common connection point for all nodes through a hub. A star topology is less expensive than a mesh topology. In a star topology, each device needs only one link and one I/O port to connect it to any number of others equipment's. This factor also makes it easy to install and reconfigure. Far less cabling needs to be housed, and additions, moves, and deletions involve only one connection: between that device and the hub. It is robust in nature. If one link fails, only that link is affected. All other links remain active. This factor also helps in easy fault identification and fault isolation. As long as the hub is working, it can be used to monitor link problems and bypass defective links. The star topology is used in local-area networks (LANs),

ADVANTAGES:

i. Star networks are extremely dependable because if one computer or its connection breaks it doesn't affect the other computers and their connections.
ii. Easy to install and reconfigure.
iii. Less expensive (As less cabling is required).

DISADVANTAGES:

i. An expensive network design to install because of the amount of cables needed.
ii. If the server crashes or stops working, then no computers will be able to access the network.
iii. If either HUB or switch fails, whole systems will crash as well.

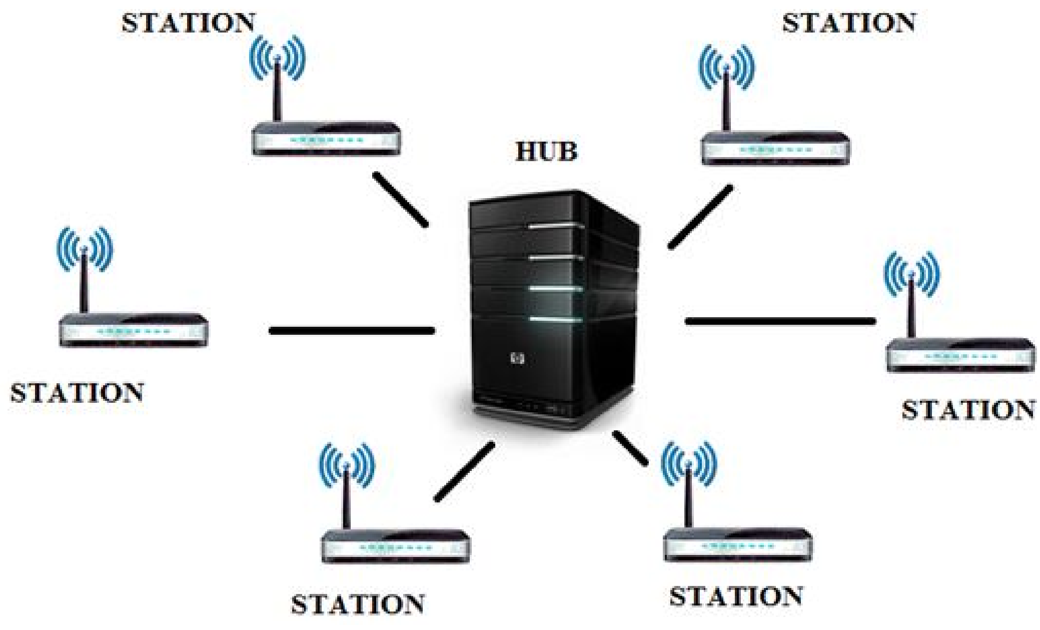

Figure 2.4: Star Topology

III. RING TOPOLOGY

In a ring topology[1], each node associates with precisely two different nodes, forming a solitary persistent pathway for signals through each node - a ring. A signal is transmitted along the ring in one direction, from device to device, until it reaches its destination. Each device in the ring works as a repeater. When a device receives a signal intended for another device, its repeater regenerates the bits and passes them ahead. A ring is comparatively easy to install and reconfigure. To add or delete a device requires changing only two connections. Generally, in a ring, a signal is circulating at all times. If one device does not receive a signal within a predefined period, it can issue an alarm. The alarm alerts the network operator to the problem and its location. Notwithstanding, unidirectional traffic can be a disadvantage. In a simple ring, a break in the ring (such as an incapacitated station) can disable the whole network. This weakness can be solved by using a dual ring or a switch capable of eliminating the break.

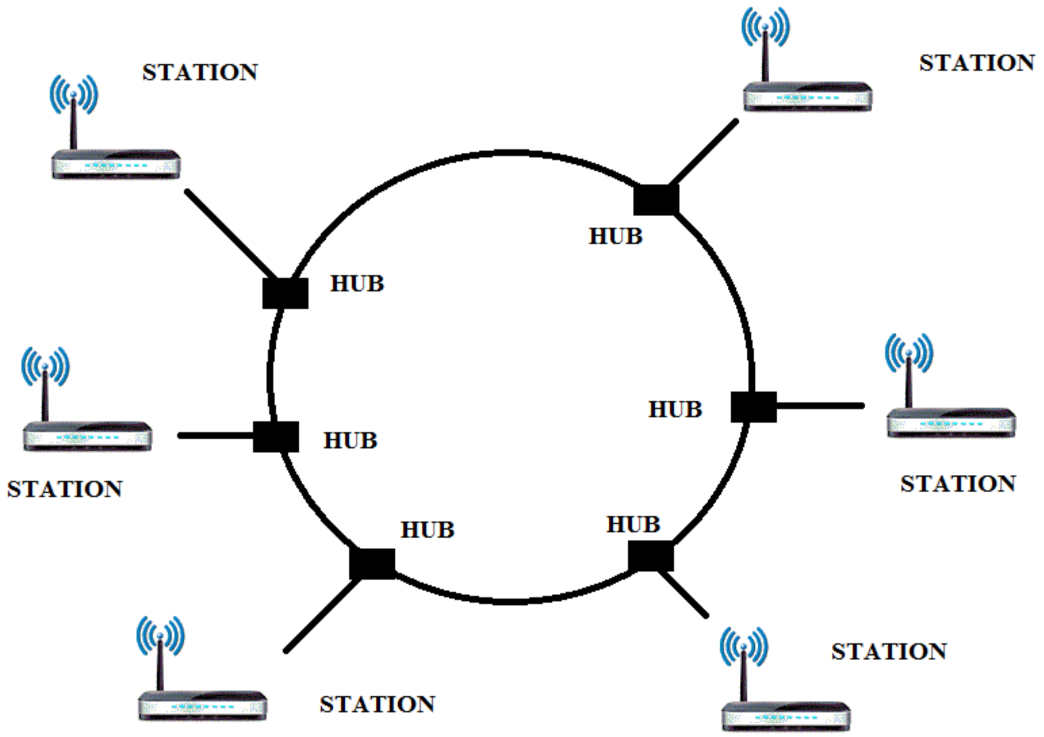

Figure 2.5: Ring Topology

ADVANTAGES:

i. Very organized network where every device has access to the token and the opportunity to transmit
ii. Performs better than a bus topology under heavy network load
iii. Does not require a central node to manage the connectivity between the computers
iv. Due to the point to point line configuration of devices with a device on either side (each device is connected to its immediate neighbor), it is quite easy to install and reconfigure since adding or removing a device requires moving just two connections.
v. Point to point line configuration makes it easy to identify and isolate faults.
vi. Reconfiguration for line faults of bidirectional rings can be very fast, as switching happens at a high level, and thus the traffic does not require individual rerouting.

DISADVANTAGES:

i. One malfunctioning workstation can create problems for the entire network. This can be solved by using a dual ring or a switch that closes off the break.
ii. Moving, adding and changing the devices can affect the network.
iii. Communication delay is directly proportional to number of nodes in the network.
iv. Bandwidth is shared on all links between devices

IV. MESH TOPOLOGY

In a mesh topology[1], every device has a dedicated point-to-point link to every other device. The term *dedicated* means that the link carries traffic only between the two devices it connects.

The use of dedicated links, in mesh topology, guarantees that each connection can carry its own data load, thus eliminating the traffic problems that can occur when links must be shared by multiple devices. A mesh network whose nodes are all connected to each other is a fully connected network. Fully connected wired networks have the advantages of security and reliability: problems in a cable affect only the two nodes attached to it. However, in such networks, the number of cables, and therefore the cost, goes up rapidly as the number of nodes increases. Point-to-point links make fault identification and fault isolation easy in mesh topology.

ADVANTAGES:

i. Eliminates traffic problem
ii. It is robust
iii. Advantage of privacy and security
iv. Fault identification and fault isolation is easy

DISADVANTAGES:

i. It is expensive
ii. Installation and reconnection is difficult
iii. The hardware required to connect each link (I/O ports and cable) can be prohibitively expensive.

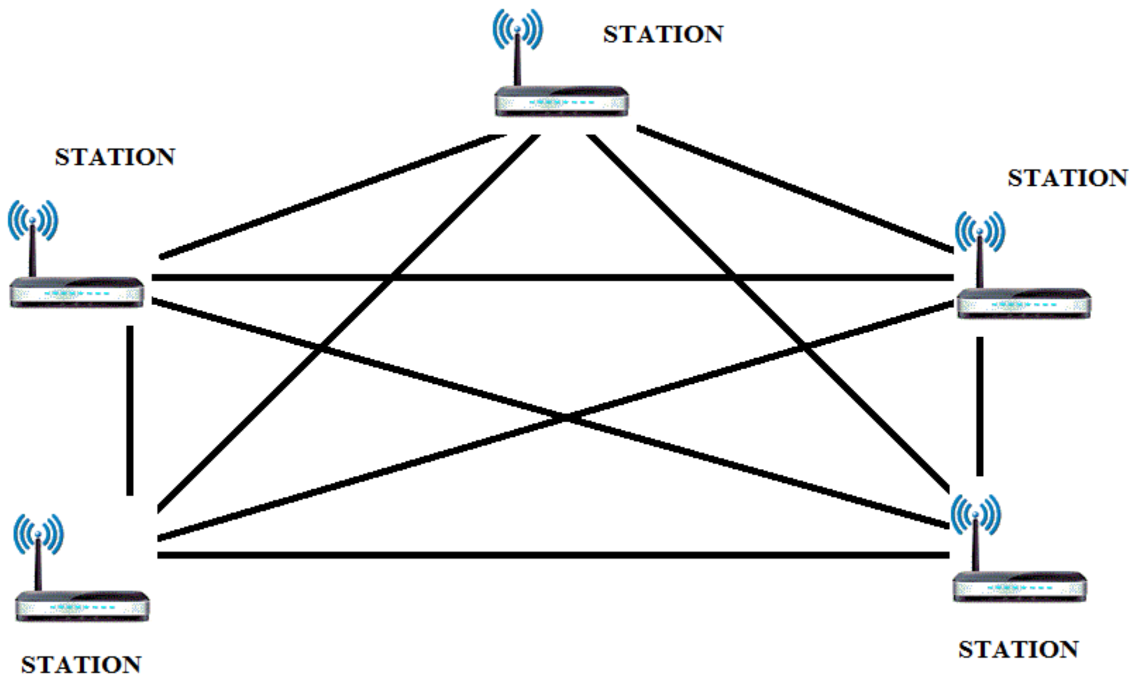

Figure 2.6: Mesh Topology

2.3 WIRELESS NETWORKS

A wireless network is any type of computer network that uses wireless data connections for connecting network nodes.[2]

Wireless networking is a method by which homes, telecommunications networks and enterprise (business) installations avoid the costly process of introducing cables into a building, or as a connection between various equipment locations.[3] Wireless telecommunications networks are generally implemented and administered using radio communication. This implementation takes place at the physical level (layer) of the OSI model network structure.[1]

Wireless components:

i. Wired Based Connections
ii. Wireless Router (Access Points)
iii. Wireless NIC (Wireless Clients)

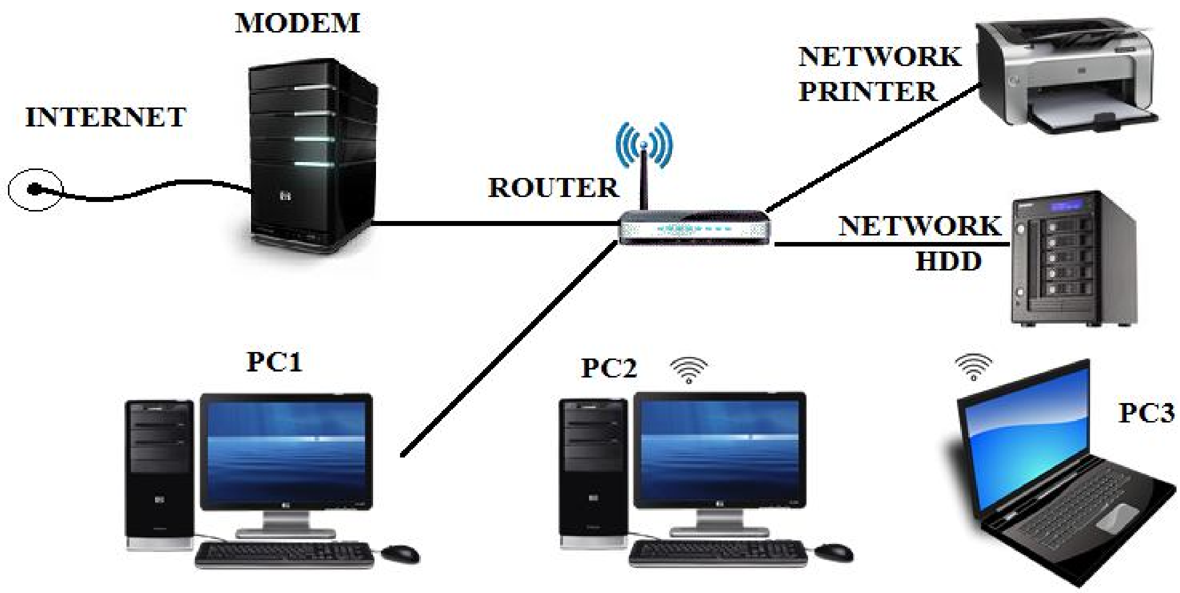

Fig 2.7: Wireless Components

TYPES OF WIRELESS NETWORKS

i. INFRESTRUCTURE
ii. ADHOC

INFRASTRUCTURE BASED

Infrastructure based wireless[4] network have base stations, also called access points deployed throughout a given area. These base stations provide access for wireless clients to a backbone wired network. Base station coordination in infrastructure based wireless networks provides a centralized control mechanism for tramission scheduling, dynamic resource allocation, power control, and handoff.

Most networks with infrastructure are designed so that mobile terminals transmit directly to a base station, with no multi hop routing through intermediate wireless nodes. Single hop routes have lower delay and loss, higher data rates and more flexibility than multi hop.

The performance of infrastructure based wireless networks tends to be much better than in networks without infrastructure.

2.3.1 MOBILE AD HOC NETWORK

A Mobile Adhoc Network (MANETs)[5] is a collection of two or more wireless devices having the capacity to communicate with each other without the aid of any centralized administrator. Each node in wireless Adhoc network functions as both a host and a router. The network topology is in general dynamic because the connectivity among nodes may vary with time due to node mobility, node departures, and new node arrivals. Hence, there is a need for efficient routing protocols to allow the nodes to communicate. Ad hoc nodes or devices should be able to detect the presence of other such devices so as to allow communication and information sharing. Besides that, it should also be able to identify types of services and corresponding attributes. Since the number of wireless nodes changes quickly, the routing information also changes to reflect changes in the link connectivity. Therefore, the topology of the network is very dynamic and the changes are often unpredictable as compared to the fixed nature of existing wired networks.

The dynamic nature of the wireless medium, fast and unpredictable topological changes, limited battery power, and mobility raise many challenges for the designing a routing protocol. Due to immense challenge in designing a routing protocol for MANETs, a number of recent developments focus on providing an optimum solution for routing. But a majority of these solutions attain a specific goal (eg. Minimizing delay and overhead) while compromising other factors (eg. Scalability and route reliability). Thus, an optimum routing protocol that can v=cover most of the applications or user requirements as well as cope up with the stringent behavior of the wireless medium is always desirable.

Each of the nodes has a wireless interface and communicates with each other over the radio. Laptop computers and other devices communicate directly with each other are some examples of nodes in the ad hoc network. Nodes in ad hoc network are often mobile, but can also consist of stationary nodes, such as access points.

An ad hoc network uses no centralized administrator[6]. This ensures that the network would not collapse just because one of the mobile nodes moves out of the transmitter range of the other nodes. Nodes should be able to enter or leave the network as they wish. Because of the limited transmitter range of the nodes, multihops may be needed to reach other nodes. Thus every node acts both as a host and a router. A node can be viewed as an abstract entity consisting of a router and a set of affiliated mobile hosts. A router is an entity that, among other things, runs a routing protocol. A mobile host is simply an IP-Addressable host or entity in the traditional sense.

Figure 1.1 shows a simple ad hoc network with three nodes. The outermost nodes are not within the transmitter range of each other. However, the middle node can be used to forward packets between the outermost nodes. Node B is acting as a router and nodes A, B and C have formed an Adhoc network.

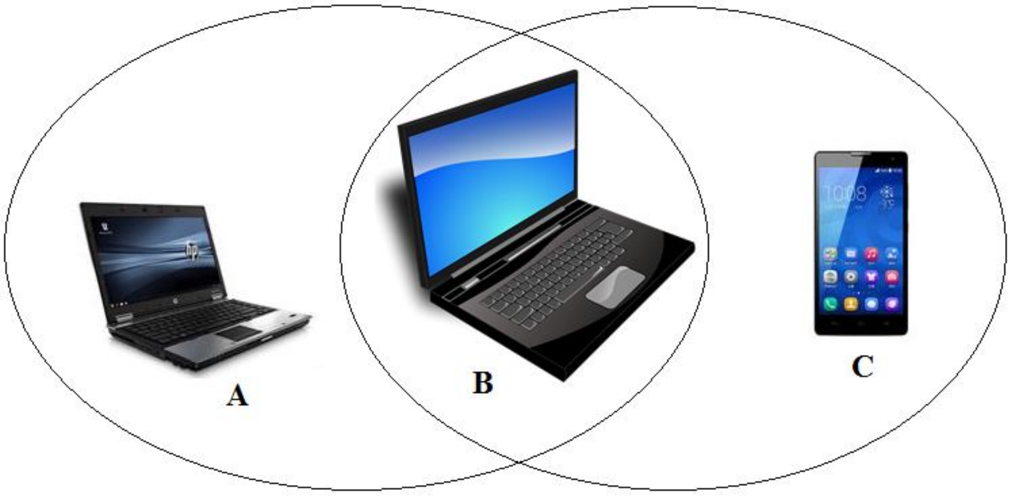

Figure 2.8: Mobile Ad Hoc Network

Ad hoc networks are also capable of handling topology changes and malfunctions in nodes[5]. They are fixed through network reconfigurations. For example, if a node leaves the network and causes link breakages, affected nodes can easily request new routes and the problem will be solved. This will slightly increase the delay, but the network will still be operational.

2.3.2 TRADITIONAL ROUTING ALGORITHMS IN MANETS

The term routing is very important for a network. Routing is a process of finding an efficient, reliable and secure path from a source node to a destination node via intermediate nodes in a network. Routing in MANET is a challenge due to dynamic topology in network as mobile nodes can move in any direction in the MANET [7]. Mobile ad-hoc networks are easy to deploy and configure which causes its popularity in comparison to wired networks. Instant network setup is the main feature of MANET. MANET is useful in places that have no communications infrastructure or when that infrastructure is severely damaged. A small network for sharing resources can be setup by mobile nodes (laptop, personal digital assistant, smart phones [5]. Routing algorithms in MANET should provide following primary expectations:

- Stable loop free connectivity
- Secure routing
- Reduced control overhead
- Have scalability and distributed routing
- Support QoS traffic prioritization
- Respond to changes in node mobility.

Routing algorithms in MANET are categorized in three heads: Proactive routing algorithms, reactive routing algorithms and hybrid routing algorithms [8].

I. PROACTIVE ROUTING ALGORITHMS FOR MANET

Proactive routing algorithm maintains routes to destination even if they are not required. Proactive routing algorithms maintain up-to-date routing information on every node in the network periodically. Advantage of proactive routing algorithm is that connection time is fast as path is already available on each node in the network. A disadvantage of proactive algorithm is that they continuously use resources to communicate routing information, even when there is no traffic which causes the overhead of control information [9]

i. **Destination-Sequenced Distance Vector (DSDV)** [10]

- Each node maintains a table with an entry for every possible destination.
- Nodes exchange their routing tables with their neighbors periodically.
- Based on the received tables, nodes update their routing tables.
- Each entry in table specifies
  - Destination identifier.
  - Next hop on the route to the destination.
  - Distance (in terms of hops) to the destination.
  - A sequence number that specifies how fresh the route is.

ADVANTAGES:

- Route from source node to destination node is always available as each node has path from other nodes from itself.

DISADVANTAGE:

- Large routing overhead, Uses only bidirectional links. Suffers from count to infinity problem.

ii. **Optimized Link State Routing protocol (OLSR)** [11] [12]

- The Optimized Link State Routing Protocol (OLSR) is an IP routing protocol optimized for mobile ad hoc networks, which can also be used on other wireless ad hoc networks.
- OLSR is a proactive link-state routing protocol, which uses *hello* and *topology control* (TC) messages to discover and then disseminate link state information throughout the mobile ad hoc network.
- Individual nodes use this topology information to compute next hop destinations for all nodes in the network using shortest hop forwarding paths.
- In figure 2.9, node C and E are multipoint relay (MPR) of node A
    - Multipoint relays of A are its neighbors such that each two-hop neighbor of A is a one-hop neighbor of one multipoint relay of A
    - Nodes exchange neighbor lists to know their 2-hop neighbors and choose the multipoint relays

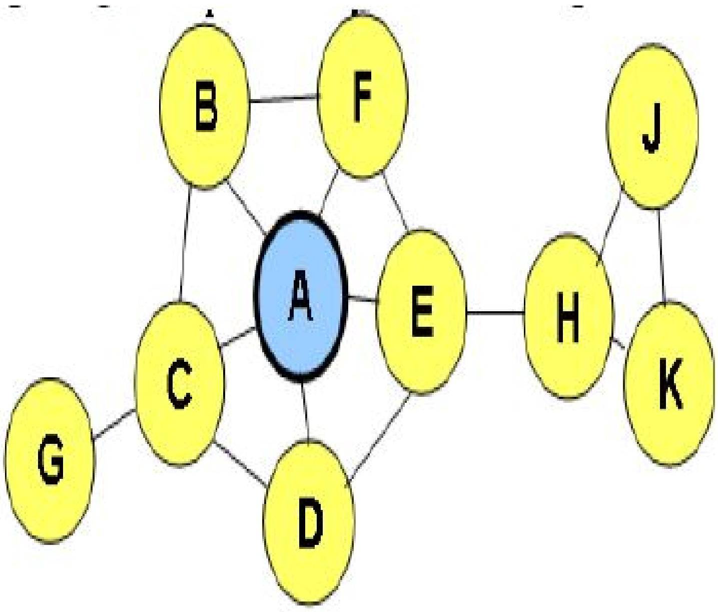

Figure 2.9

- In Figure 2.10
  - Nodes C and E forward information received from A
  - Nodes E and K are multipoint relays for node H
  - Node K forwards information received from H

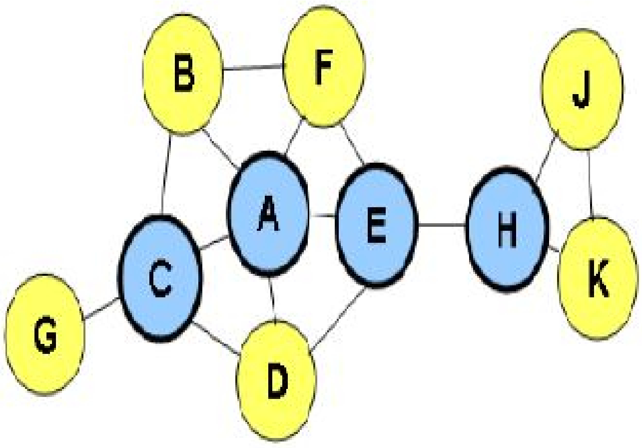

Fig 2.10

ADVANTAGES:

- Reduces control information
- Efficiently minimizes broadcast traffic bandwidth usage.

DISADVANTAGES

- Although OLSR provides a path from source to Destination, it is not necessarily the shortest path, because every route involves forwarding through a MPR node
- OLSR also has routing delays and bandwidth overhead at the MPR nodes as they act as localized forwarding routers.

II. REACTIVE ROUTING ALGORITHMS

In Reactive routing algorithm routing tables are not always up-to-date. Instead, a node tries to find a route only when it wants to send a packet. The advantage of reactive routing algorithms is that it reduces the traffic needed for routing. A disadvantage of reactive routing algorithm is that it introduces a delay when the first packet is sent to a host as path is not readily available.

i. **Ad Hoc on-demand Distance Vector** [13] [14]

Three message types are used in the AODV which are route request (RREQ), route reply (RREP), and route error (RERR).

- In figure 2.11, node 1 desires to communicate to node 8.
- Node 1 flood the network with route request (RREQ) messages.
- Each node receiving a RREQ message stores the previous hop and distance to source for the originating RREQ and forwards the RREQ to its neighbors.
- When the RREQ message reaches the designation node 8, the destination sends a unicast route reply (RREP) message back to the source using the previous hop on which it received the RREQ.
- Each node receiving the RREP message in turn forwards it to the next hop with the smallest distance to the source as shown in Figure 4.
- This process effectively builds the routing table at each node, and when any source destination pair establishes a route, the intermediate nodes learn the route as well.

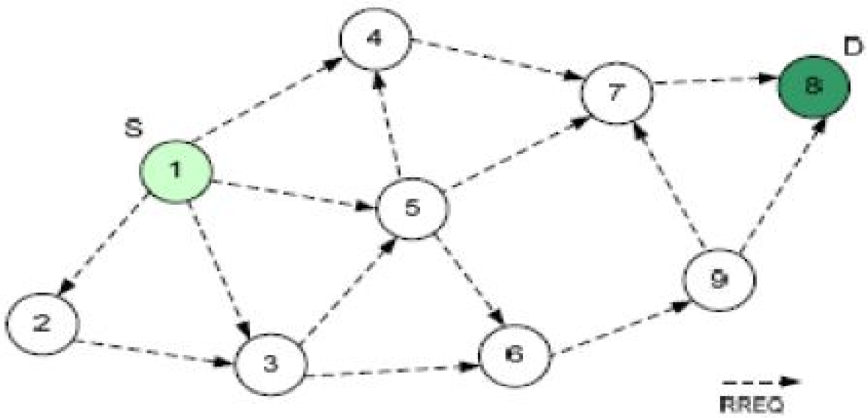

Figure: 2.11

ADVANTAGES

- AODV creates routes only on demand, which greatly reduces the periodic control message overhead associated with proactive routing protocols.

DISADVANTAGES

- Route setup latency exist when a new route is needed. ADOV queues data packets while discovering new routes and the queued packets are sent out only when new routes are found. It causes throughput loss in high mobility scenarios, because the packets get dropped quickly due to unstable route selection.

ii. **Dynamic Source Routing Algorithm (DSR)** [8]

A complete ordered route is maintained in the packet in dynamic source routing (DSR). This makes it easy to control the route from the source node and guarantees loop-free paths.

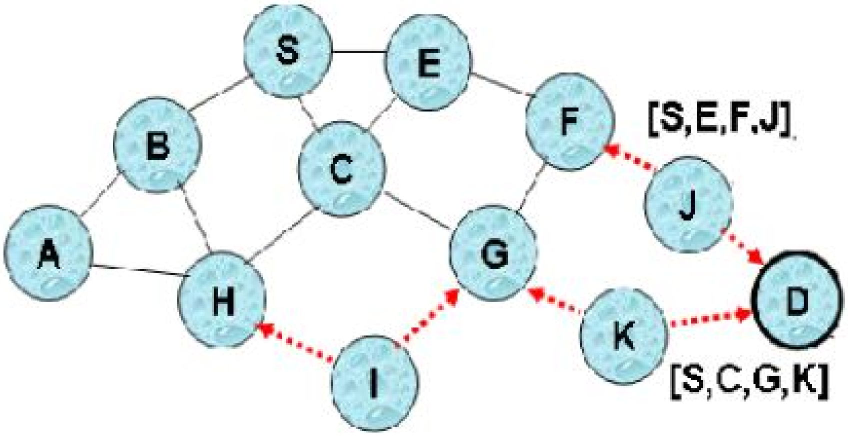

Fig 2.12

- In figure 2.12, node S wants to send a packet to node D, but does not know a route to D, node S initiates a route discovery
- Source node S floods Route Request (RREQ) Each node *appends own identifier* when forwarding RREQ

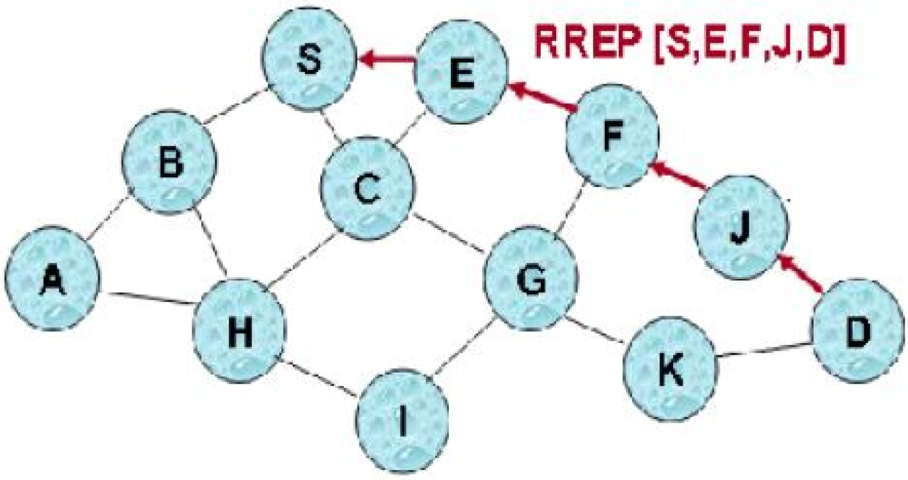

Fig 2.13

- In figure 2.13,
    - Destination D on receiving the first RREQ, sends a Route Reply (RREP)
    - RREP is sent on a route obtained by reversing the route appended to received RREQ

- RREP includes the route from S to D on which RREQ was received by node D
- Node S on receiving RREP, caches the route included in the RREP
- In figure 2.14, when node S sends a data packet to D, the entire route is included in the packet header hence the name source routing
- Intermediate nodes use the source route included in a packet to determine to whom a packet should be forwarded

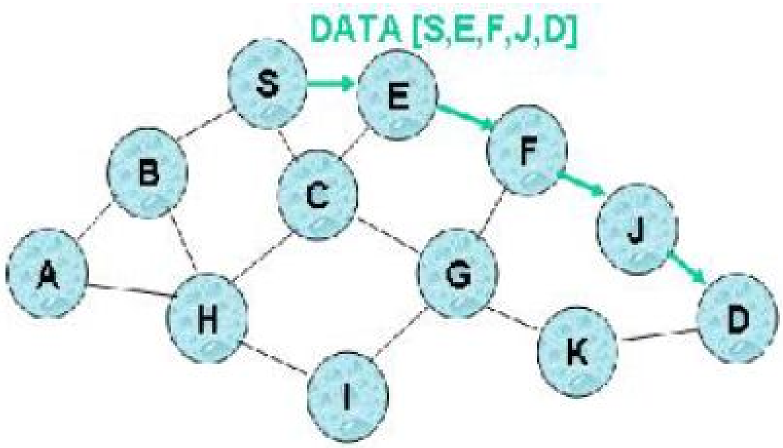

Figure 2.14

ADVANTAGES

- Does not flood the network with table update messages periodically.
- Intermediate nodes also utilize the route cache information efficiently to reduce the control overhead.

DISADVANTAGES

- Route maintenance mechanism does not locally repair a broken link.
- Connection setup delay is higher than in table-driven protocols.
- Performance degrades rapidly with increasing mobility.
- Routing overhead is involved due to the source-routing mechanism employed in DSR. This routing overhead is directly proportional to the path length.

III. HYBRID ROUTING ALGORITHMS [15]

Hybrid routing algorithm combines the advantages of both reactive and proactive routing algorithms. Initially proactive approach is used to have route information then reactively demand of the route is served to the needy node.

i. Location-Aided Routing (LAR) [16]

Location-aided route discovery based on limited flooding. LAR [16] Use location information to reduce the number of nodes to whom route request is propagated. Location information may be obtained using Global Positioning System (GPS)

- LAR Exploits location information to limit scope of route request flood using GPS
- Expected Zone is determined as a region that is expected to hold the current location of the destination. Expected region determined based on potentially old location information, and knowledge of the destination's speed
- Route requests limited to a *Request Zone* that contains the Expected Zone and location of the sender node

ADVANTAGES

- Reduces the scope of route request flood
- Reduces overhead of route discovery

DISADVANTAGES

- Nodes need to know their physical locations
- Does not take into account possible existence of obstructions for radio transmissions

ii. **Zone Routing Protocol (ZRP)** [17]

Zone routing protocol is hybrid routing algorithm which use the advantages of both proactive and reactive routing algorithms. ZRP was proposed to reduce the control overhead of proactive routing protocols and decrease the latency caused by route discovery in reactive routing protocols.

- All nodes within hop distance at most d from a node X are said to be in the routing zone of node X.
- All nodes at hop distance exactly d are said to be peripheral nodes of node X's routing zone
- Intra-zone routing: Proactively maintain routes to all nodes within the source node's own zone.
- Inter-zone routing: Use an on-demand protocol (similar to DSR or AODV) to determine routes to outside zone.

ADVANTAGES

- Less control overhead as in a proactive protocol or an on demand protocol. **1.2)**

DISADVANTAGES

- Short latency for finding new routes.

2.3.3 DRAWBACKS OF TRADITIONAL ALGORITHMS

i. Large routing overhead, Uses only bidirectional links. Suffers from count to infinity problem.
ii. Although OLSR provides a path from source to Destination, it is not necessarily the shortest path, because every route involves forwarding through a MPR node
iii. OLSR also has routing delays and bandwidth overhead at the MPR nodes as they act as localized forwarding routers.
iv. Route setup latency is exist when a new route is needed. ADOV queues data packets while discovering new routes and the queued packets are sent out only when new routes are found. It causes throughput loss in high mobility scenarios, because the packets get dropped quickly due to unstable route selection.
v. Route maintenance mechanism does not locally repair a broken link.
vi. Connection setup delay is higher than in table-driven protocols.
vii. Performance degrades rapidly with increasing mobility.
viii. Routing overhead is involved due to the source-routing mechanism employed in DSR. This routing overhead is directly proportional to the path length.
ix. Nodes need to know their physical locations
x. Does not take into account possible existence of obstructions for radio transmissions
xi. Short latency for finding new routes

CHAPTER 3
SWARM INTELLIGENCE

3.1 SWARM INTELLIGENCE

A swarm is a large number of homogenous, simple agents interacting locally among themselves, and their environment, with no central control to allow a global interesting behavior to emerge. Swarm-based algorithms have recently emerged as a family of nature-inspired, population-based algorithms that are capable of producing low cost, fast, and robust solutions to several complex problems [18] [19].

Swarm Intelligence (SI) is a branch of Artificial Intelligence that is used to model the collective behavior of social swarms in nature, such as ant colonies, honey bees, and bird flocks. Although these agents (insects or swarm individuals) are relatively unsophisticated with limited capabilities on their own, they are interacting together with certain behavioral patterns to cooperatively achieve tasks necessary for their survival.

The social interactions among swarm individuals can be either direct or indirect [20]. Examples of direct interaction are through visual or audio contact, such as the waggle dance of honey bees. Indirect interaction occurs when one individual changes the environment and the other individuals respond to the new environment, such as the pheromone trails of ants that they deposit on their way to search for food sources. This indirect type of interaction is referred to as stigmergy, which essentially means communication through the environment [21].

In the past decades, biologists and natural scientists have been studying the behaviors of social insects because of the amazing efficiency of these natural swarm systems. In the late-80s, computer scientists proposed the scientific insights of these natural swarm systems to the field of Artificial Intelligence. In 1989, the expression "Swarm Intelligence" was first introduced by G. Beni and J. Wang in the global optimization framework as a set of algorithms for controlling robotic swarm [22]. In 1991, Ant Colony Optimization (ACO) [23] [24] [25] was introduced by M. Dorigo and colleagues as a novel nature-inspired metaheuristic for the solution of hard combinatorial optimization (CO) problems. In 1995, particle swarm optimization was introduced by J. Kennedy et al. [26] [27], and was first intended for simulating the bird flocking social behavior. By the late-90s, these two most popular swarm intelligence algorithms started to go beyond a pure scientific interest and to enter the realm of real-world applications. It is perhaps worth mentioning here that a number of years later, exactly in 2005, Artificial Bee Colony Algorithm was proposed by D. Karabago as a new member of the family of swarm intelligence algorithms [28] [29].

3.2 SWARM INTELLIGENCE MODELS

Swarm intelligence models are referred to as computational models inspired by natural swarm systems. To date, several swarm intelligence models based on different natural swarm systems have been proposed in the literature, and successfully applied in many real-life applications.

Examples of swarm intelligence models are:

i. Ant Colony Optimization [30]

ii. Particle Swarm Optimization [26]

iii. Glowworm Swarm Optimization [31]

iv. Artificial Bee Colony [28]

v. Bacterial Foraging [32]

vi. Cat Swarm Optimization [33]

vii. Artificial Immune System [34]

In this paper, we will primarily focus on Ant Colony Optimization. Brief about all the above models is presented in the next section.

3.2.1 ANT COLONY OPTIMIZATION (ACO)

In the natural world [30], ants (initially) wander randomly, and upon finding food return to their colony while laying down pheromone trails. If other ants find such a path, they are likely not to keep travelling at random, but instead to follow the trail, returning and reinforcing it if they eventually find food.

Over time, the pheromone trail starts to evaporate, thus reducing its attractive strength. The more time it takes for an ant to travel down the path and back again, the more time the pheromones have to evaporate. A short path, by comparison, gets marched over more frequently, and thus the pheromone density becomes higher on shorter paths than longer ones.

3.2.2 PARTICLE SWARM OPTIMIZATION

Particle swarm optimization (PSO) [26] is a population based stochastic optimization technique developed by Dr. Eberhart and Dr. Kennedy in 1995, inspired by social behavior of bird flocking or fish schooling.

PSO shares many similarities with evolutionary computation techniques such as Genetic Algorithms (GA). The system is initialized with a population of random solutions and searches for optima by updating generations. However, unlike GA, PSO has no evolution operators such as crossover and mutation. In PSO, the potential solutions, called particles, fly through the problem space by following the current optimum particles.

Each particle keeps track of its coordinates in the problem space which are associated with the best solution (fitness) it has achieved so far. (The fitness value is also stored.) This value is called *pbest*. Another "best" value that is tracked by the particle swarm optimizer is the best value, obtained so far by any particle in the neighbors of the particle. This location is called *lbest*. when a particle takes all the population as its topological neighbors, the best value is a global best and is called *gbest*.

The particle swarm optimization concept consists of, at each time step, changing the velocity of (accelerating) each particle toward its p*best* and *lbest* locations (local version of PSO). Acceleration is weighted by a random term, with separate random numbers being generated for acceleration toward *pbest* and *lbest* locations.

3.2.3 ARTIFICIAL BEE COLONY

Artificial Bee Colony (ABC) [28] is one of the most recently defined algorithms by Dervis Karaboga in 2005, motivated by the intelligent behavior of honey bees. It is as simple as Particle Swarm Optimization (PSO) and Differential Evolution (DE) algorithms, and uses only common control parameters such as colony size and maximum cycle number. ABC as an optimization tool, provides a population-based search procedure in which individuals called foods positions are modified by the artificial bees with time and the bee's aim is to discover the places of food sources with high nectar amount and finally the one with the highest nectar. In ABC system, artificial bees fly around in a multidimensional search space and some (employed and onlooker bees) choose food sources depending on the experience of themselves and their nest mates, and adjust their positions. Some (scouts) fly and choose the food sources randomly without using experience. If the nectar amount of a new source is higher than that of the previous one in their memory, they memorize the new position and forget the previous one. Thus, ABC system combines local search methods, carried out by employed and onlooker bees, with global search methods, managed by onlookers and scouts, attempting to balance exploration and exploitation process.

In ABC, the colony of artificial bees contains three groups of bees: employed bees associated with specific food sources, onlooker bees watching the dance of employed bees within the hive to choose a food source, and scout bees searching for food sources randomly. Both onlookers and scouts are also called unemployed bees. Initially, all food source positions are discovered by scout bees. Thereafter, the nectar of food sources is exploited by employed bees and onlooker bees, and this continual exploitation will ultimately cause them to become exhausted. Then, the employed bee which was exploiting the exhausted food source becomes a scout bee in search of further food sources once again. In other words, the employed bee whose food source has been exhausted becomes a scout bee. In ABC, the position of a food source represents a possible solution to the problem and the nectar amount of a food source corresponds to the quality (fitness) of the associated solution. The number of employed bees is equal to the number of food sources (solutions) since each employed bee is associated with one and only one food source.

3.2.4 GLOWWORM SWARM OPTIMIZATION

Glowworm swarm optimization (GSO) [31], introduced by Krishnanand and Ghose in 2005 for simultaneous computation of multiple optima of multimodal functions. The algorithm shares a few features with some better known algorithms, such as ant colony optimization and particle swarm optimization, but with several significant differences. The agents in GSO are thought of as glowworms that carry a luminescence quantity called luciferin along with them. The glowworms encode the fitness of their current locations, evaluated using the objective function, into a luciferin value that they broadcast to their neighbors. The glowworm identifies its neighbors and computes its movements by exploiting an adaptive neighborhood, which is bounded above by its sensor range. Each glowworm selects, using a probabilistic mechanism, a neighbor that has a luciferin value higher than its own and moves toward it. These movements—based only on local information and selective neighbor interactions—enable the swarm of glowworms to partition into disjoint subgroups that converge on multiple optima of a given multimodal function.

3.3 ANT COLONY OPTIMIZATION (ACO) MODEL

The first example of a successful swarm intelligence model is Ant Colony Optimization (ACO), which was introduced by M. Dorigo et al. [23] [24] [25], and has been originally used to solve discrete optimization problems in the late 1980s. ACO draws inspiration from the social behaviour of ant colonies. It is a natural observation that a group of *'almost blind'* ants can jointly figure out the shortest route between their food and their nest without any visual information. The following section presents some details about ants in nature, and shows how these relatively unsophisticated insects can cooperatively interact together to perform complex tasks necessary for their survival.

3.3.1 ANTS IN NATURE

Since tens of millions of years ago, ants have survived different environments, climates and ages that dinosaurs, for example, did not. The secret of the remarkable ecological success of ants can be explained by a single word: sociality [35]. Ants have demonstrated exceptional social organization in several ways: They are inclined to live in organized societies made up of individuals that cooperate, communicate, and divide daily tasks. Ants have impressive abilities in finding their way, building their nests, and locating food supplies. They are not only efficient, but hard-working and thrifty creatures that can adapt to different ecosystems and survive harsh weather conditions.

3.3.2 ANTS STIGMERGIC BEHAVIOUR

Ants, like many other social insects, communicate with each other using volatile chemical substances known as pheromones, whose direction and intensity can be perceived with their long, mobile antennae [36].

The term "pheromone" was first introduced by P. Karlson and M. Lüscher in 1959, based on the Greek word pherein (means to transport) and hormone (means to stimulate) [37]. There are different types of pheromones used by social insects.

One example of pheromone types is alarm pheromone that crushed ants produce as an alert to nearby ants to fight or escape dangerous predators and to protect their colony [38].

Another important type of pheromone is food trail pheromone. Unlike flies, most ants live on the ground and make use of the soil surface to leave pheromone trails, which can be followed by other ants on their way to search for food sources.

Ants that happened to pick the shortest route to food will be the fastest to return to the nest, and will reinforce this shortest route by depositing food trail pheromone on their way back to the nest. This route will gradually attract other ants to follow, and as more ants follow the route, it becomes more attractive to other ants as shown in Figure 3.1.

This autocatalytic or positive feedback process is an example of a self-organizing behavior of ants in which the probability of an ant‘s choosing a route increases as the count of ants that already passed by that route increases.

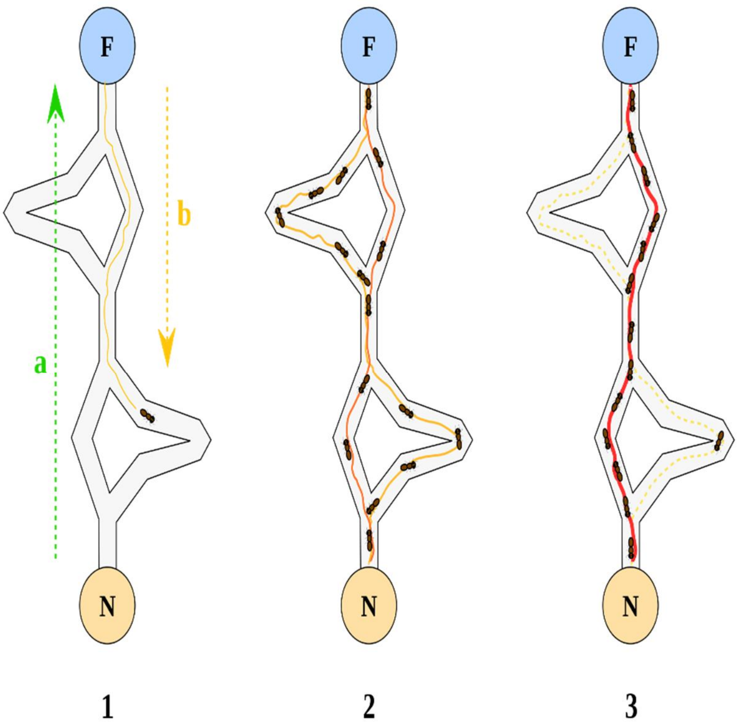

Figure 3.1

When the food source is exhausted, no new food pheromone trails are marked by returning ants and the volatile pheromone scent slowly evaporates.

This negative feedback behavior helps ants deal with changes in their environment. For instance, when an already established path to a food source is blocked by an obstacle, the ants leave the path to explore new routes. Such trail-laying, trail-following behavior is called stigmergy (interaction through the environment), and can be considered as an indirect type of communication in which ants change the environment (soil surface) and the other ants detect and respond to the new environment. Stigmergy provides a general mechanism that relates individual (local) and colony-level (global) behaviours: individual behaviour modifies the environment (trail-laying), which in turn modifies the behaviour of other individuals (trail-following) [39].

A relatively close paradigm to ACO metaheuristic would be the artificial neural network (ANN), since both can be considered as a type of a *connectionist* system in which individual units (artificial ants of ACO or artificial neurons of ANN) are connected to each other according to a certain pattern [40].

Both ACO and ANN are quite similar in some aspects, for example:

i. The knowledge resulted from the learning process is numerically embedded in both of them (either in the weights of the network connections in case of ANN, or in the pheromone concentrations on the construction graph in case of the ACO metaheuristic).
ii. Both ACO and ANN are based on the same principle: reinforcement of portions of solutions that belong to good solutions either by adding more pheromone amounts in case of ACO or increasing network weights in case of ANN.
iii. In ACO the pathways to solutions are usually not predefined but emergent, and likewise the pathways to solutions in most ANNs are hidden in its black-box nature.

ACO differs from ANN in the following ways:

i. the individual units of ACO have a mobility feature, unlike ANN‘s individual units (neurons) do not have a mobility feature, but they should be preconfigured with a structure that does not change in run time.
ii. The dynamic nature of ACO‘s connectivity helps to continuously adapt to changes in real time, making ACO more applicable to dynamic problems such as urban transportation systems [41] and adaptive routing in telecommunication networks [42].
iii. (iii) The two main learning approaches of ANN training (supervised and unsupervised learning1) do not get feedback from the environment, whereas ACO primarily depends on the feedback from the environment, which is used as a medium of coordination and indirect communication among ants (stigmergy).

Despite the advantages of ACO, it does have some limitations (as many other optimization algorithms) that do not let it to always work well [39].
For example, ACO does not work well when a large number of edges on the construction graph are equally likely to be part of good paths. This happens when many edges have similar cost and therefore similar probability of being selected as portions of good paths (e.g., a TSP problem whose cities are *uniformly* randomly distributed with a relatively equal distance from one another). Since ACO‘s objective is to reinforce all edges on the problem‘s construction graph that belong to good solutions/paths, a large number of edges will receive a relatively equal high amount of pheromone and will be equally likely selected. In this case, the original ACO would not perform well as it would take longer time to differentiate between such many good paths in an effort to eventually converge/select one of them [40].

3.4 ACO IN MANETS

The characteristics of ants are similar to the characteristics of MANETs. This helps us to apply the food searching characteristics of ants for routing packets in MANETs.

i. Each network node sends a number of discovery packets that is, called forward ants (F-ANT) are sent towards the selected destination nodes of the network
ii. The routing tables maintained at each node are replaced with stochastic tables, which select next hops according to weighted probabilities available.
iii. Accordingly, the ants deposit pheromone on the crossed links, that is, in the nodes routing tables are changed for selection of the next node in the network.
iv. When forward ant (F-ANT) reaches the destination node, it generates a backward ant (B-ANT) and then dies. Similarly in MANETs routing, the new packet created and sent back to the source will propagate through the same path selected by the forward ant (F-ANT).
v. Now backward ant (B-ANT) deposits pheromone on the crossed links. It means that it updates the routing table of the nodes along the path followed by forward ant (F-ANT).
vi. After arrival to the source node, the backward ant (B-ANT) dies.

CHAPTER 4
LITERATURE REVIEW

4.1 LITERATURE REVIEW

In order to have clear cut, unbiased, complete and broader prospective many sources have been explored. The literature review has been carried out according to the guidelines proposed by Kitchenham []. The objective of carrying literature review was to gain deeper understanding of mitigation techniques that exists in literature and to find gap in the study. The extensive literature reviews has been carried out in the following journals:

1. ACM Digital Library
2. IEEE Explorer
3. Science Direct
4. Wiley Online Library
5. Springer

The reason behind exploring these databases is their library of journals with high impact factors. The review also takes into account conference proceedings.

The Search term was "**Swarm Intelligence and ad hoc networks**". The search was filtered to include the papers and conferences of previous 10 years. This was done to limit the scope of research to the present trends instead of exploring unverified and undeveloped techniques.

The results are summarized as follows in the table:

S. No.	JOURNAL NAME	SEARCH RESULT	RELEVANT PAPERS
1.	ACM	35	7
2.	IEEE	16	7
3.	Science Direct	22	4
4.	Wiley	271	5
5.	Springer	5	1

Table 4.1: Search Result and relevant papers

Total 25 relevant papers were selected for review. The papers in journals and conferences are taken into consideration.

One of the earliest paper was published in 2005 by Diego Pinto and Benjamin Baran [43]. Their work multiobjective algorithms for Multicast Traffic Engineering using Ant Colony Optimization. The other paper of 2005 was published by Gianni, Frederick and Luca Maria. They used ACO to describe AntHocNet, an algorithm for routing in mobile ad hoc network.

In 2006 Masoud, Ali, Ashkan, Zainanabedin, Mottaghi and Fatemi [44] presented a routing model for minimizing hot spots in the network on chip using ACO. They also compared the model with the XY, Odd Even, and DvAD routing models

In 2008 Sabari and Duraiswamy [45] proposed that tree based and mesh based on demand protocols are not necessarily the best choice, since associated overhead will be more. ACO minimizes the cost of the tree under multiple constraints. It also presented a design on ant colony based multicast routing algorithm for MANET's.

In 2009, 4 different papers were published, first was published by Floriano and Mauro [46]. They proposed a novel routing algorithm over MANETs called LBE-ARAMA. This algorithm is based on ACO. Second paper was published by Wang, Osagie, Thulasiraman and Thulasiram [47]. They proposed a hybrid routing algorithm for MANETs based on ACO and zone routing framework of border casting. The algorithm, HOPNET, based on ants hopping from one zone to the next, consists of the local proactive route discovery within a node's neighborhood and reactive communication between the neighborhoods. Next paper was given by Sinha and Chaki [48], they described a new routing algorithm for MANETs using Ant Colony Optimization technique. Special attention was given to the load balancing and congestion control in network. Last paper was given by Shokrani and Jabbehdari [49]. They proposed a novel QoS routing algorithm based on ACO. Algorithm used ant like agents to discover and maintain paths, that satisfy more requirements of the incoming traffic and at the same time by control energy level of nodes, increase lifetime of network as much as possible.

In 2010, first paper was published by Daisuke, Tomoko, Fukuhito, Hirotsugu Toshimitsu [50]. They used ACO to bring robustness to construct paths that are not likely to be disconnected during a long period. They proposed a new ACO routing algorithm based on robustness of paths for MANETs with global positioning system(GPS). Next paper Fernando and Teresa [51], they used Simple Ant Routing Algorithm (SARA) which offers a low overhead solution, by optimizing the routing process. They used three complementary strategies: during the route discovery they used a new broadcast mechanism, called the Controlled Neighbor Broadcast (CNB). During the route maintenance phase, they further reduced the overhead, by only using data packets to refresh the paths of active sessions. Finally, in the route repair phase was also enhanced, by using a deep search procedure as a way of restricting the number of nodes used to recover a route. Thus, instead of discovering a new path from the source to the destination, they started by trying the discovery of a new path between the two end-nodes of the broken link. A broadest search is only executed when the deeper one fails to succeed.

In 2011 first paper was given by Ashima, Srinivas, Debajyoti [52]. They introduced a new ant based routing protocol to optimize the route discovery and maximize the efficiency of routing in terms of packet delivery ratio (PDR) using the blocking expanding ring search (Blocking-ERS), third party route reply, local route repair and n-hop local ring techniques. Next paper was given by Sathish, Thangavel and Vaidehi [53]. The use ACO to propose a cache based ant colony routing for mobile ad hoc networks for building highly adaptive and on-demand source initiated routing algorithm. Next paper was given by Orhan, Abdullah and Alice [54]. They proposed a dynamic mobile ad hoc network (MANET) management system to improve network connectivity by using controlled network nodes, called agents. A new approach to measuring connectivity using a maximum flow formulation was proposed-this was both responsive and tractable. Next paper was published by Dorigo, Oca, Oliveira and Stutzle [55]. They researched on ACOand proposed that A key aspect of ACO algorithms is the use of a positive feedback loop implemented by iterative modifications of the artificial pheromone trails that are a function of the ants' search experience; the goal of this feedback loop is to bias the colony toward the most promising solutions.

In 2012 first paper was given by Barreiras, Munaretto, Delgado, Viana [56]. They presented a new routing protocol for Delay Tolerant Networks (DTNs), based on a distributed swarm intelligence approach. The protocol was called Cultural Greedy Ant (CGrAnt), as it uses a Cultural Algorithm (CA) and a greedy version of the Ant Colony Optimization (ACO) metaheuristic. The second paper was given by Deepalakshmi and Radhakrishnan [57]. They worked on Mobile ad hoc, another mesh-based multicast approach for mobile ad hoc networks in two scenarios, namely typical scenario and collaborative scenario. The simulation was carried out in NS-2 and comparison was conducted for the metrics packet delivery ratio, group reliability ratio, and end-to-end average delay by varying node mobility and by increasing number of senders in each group.

In 2013, 5 papers were published. First was published by Nancharajah and Mohan [58]. They used ACO and PSO to find the best solution over the particles position and velocity with the objective of cost and minimum end to end delay. The hybrid algorithm exhibited better performance when compared to ACO approach. Next paper was given by Guangyu and Boukhatem, they proposed VACO (Vehicular routing protocol based on Ant Colony Optimization), a new adaptive multi-criteria VANET routing protocol. VACO combined both reactive and proactive components to respectively establish and maintain best routing paths. Reactive forward and backward ants were sent between source and target intersection (closest intersection to the destination vehicle) to explore and set up best routes consisting of a list of intersections. Next paper was given by Istikmal, Leanna and Rahmat [59], they investigated result of AODV, DSR and DSDV that applied an Ant-algorithm which are AODV-Ant, DSR-Ant, and DSDV-Ant. DSDV represents of proactive routing type protocol based on table driven, while AODV and DSR represents of reactive routing protocol type based on demand. Performance analysis includes end to end delay, throughput, routing overhead and hop count for various scenario of node velocity, pause time and network traffic. Next paper was given by Istikmal [60]. he used optimized routing protocols in mobile ad hoc network (MANET), the optimization was done on the routing protocol DSR (Dynamic Source Routing) which was reactive routing protocol using ACO algorithm. Then the analysis and evaluation of the performance of this routing protocol in various scenario and comparsion of the result with standard DSR routing protocol was done. Final paper was published by Salim, Melloukand and Fowler [61]. They proposed a new quality of service multicast and multipath routing protocol for VANETs, based on the paradigm of bee's communication, called multicast quality of service swarm bee routing for VANETs (MQBV). The MQBV finds and maintains robust routes between the source node and all multicast group members.

In 2014 the first paper was given by Rajinder, Parvinder and Manoj [62]. They proposed and implemented the security based algorithmic approach in the mobile adhoc networks. Next paper was given by Nancharajah and Mohan [63] they proposed that a modified Ant Colony Optimization algorithm performs better compared to existing algorithms (AODV and Cooperative Opportunistic Routing in Mobile Adhoc Networks i.e. CORMAN) in terms of end- to-end delay, route acquisition time, throughput, total cache replies and packet delivery ratio. Final paper was given by Saeed, Abdolhossein and Mehrdad [64]. They proposed a novel algorithm to improve the lifetime of a wireless sensor network. The algorithm employed swarm intelligence algorithms in conjunction with compressive sensing theory to build up the routing trees and to decrease the communication rate.

CHAPTER 5
CONCLUSION
&
FUTURE SCOPE

5.1 CONCLUSION

The systematic literature review has been carried out in an order to find techniques that were proposed for using swarm intelligence in MANETs. There are various techniques that exists in literature but has limitations and constraints. Therefore, Intensive research and study was done in the field to study and get in depth knowledge about the topic.

We found out that use of artificial intelligence techniques ie. Swarm intelligence techniques, are better than the traditional routing techniques used earlier.

Swarm intelligence techniques such as Ant Colony Optimization, Glowworm Swarm Optimization, Artificial Bee Colony.

Our work was confined to Ant Colony Optimization.

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