3.1 Introduction of Routing Protocols

For the very purpose of expediting communication process inside network, varied network management routing protocols are in usage for shaping finest path from the origin node to target node whereby we must keep an eye on a set of rules. Here, MANETs routing protocols are categorized, deliberated as well as equated comprehensively.

In MANETs, paths are generated through usage of multi-hop links amid the nodes where transmission of packets is carried by way of a narrow range of wireless radio propagation thereby these participating nodes are unaware about network topology, and this knowledge of topology is realized by way of routing protocols whereby broadcast messages are received from neighboring nodes belonging to the same network. Routing protocols are branded as reactive, proactive, as well as hybrid (a mix of both) based on the routing information update time. Also, on the basis of content of routing table, there exist two classes called as distance vector class as well as link state class [124, 125]. The first class maintains distance lists to target node and second one is involved in maintaining network topology which are much more stable as well as robust than their counterparts although they are more difficult for usage in MANETs which is a swiftly emergent technology which is gaining popularity primarily due to ease of positioning, infrastructure- less nature as well as their dynamic nature. MANET’s works on TCP/IP organization for providing means of communication amid mobile nodes having limited resources; therefore customary TCP/IP model needs to be refurbished for compensating mobility for providing proficient functionality [123].

Routing is process of finding feasible, shortest (i.e. minimum hop length) route to be followed by data packets from an origin node towards target node utilizing most resourceful route. Productivity of route can be gauged by evaluating a count of performance parameters such as count of hops, Mobility, etc. In MANETs, each host node performs as a specialized router [83]. Routing protocols outlines rules for administrating passage of message packets from origin towards target nodes in a network characterized by restricted power supply, restricted processing, restricted memory storage but higher degree of mobility. Here, nodes have limited transmission range, come into as well as left network dynamically thereby furnishing requirement of multiple hops for message packet to reach its target, so routing
protocols are needed for such exchanges amongst nodes in the network. Hence, routing is a decisive design subject in MANETs.

Routing basically involves two processes: First, discovering the optimal routing paths from the source towards the destination and secondly, to transport the messages or data packets from the source towards the destination. The second one is thornier as it also necessitates some control tools to guarantee the correct delivery of data packets so that the transported packets are not lost on the way towards destination. This process might involve usage of a range of protocols as well as data structures. Routes towards the destination from the source node should be announced, network capabilities be told as per the rules of the chosen routing protocol as well as they should truthfully reveal the network topology information [86].

Routing protocol is software or hardware enactment of a routing algorithm which utilizes metrics to hand-pick a route for transmitting a packet across an network that consist of following: count of network layer devices along the path (hop count), Bandwidth Delay Load, Maximum Transmission Unit (MTU) as well as Price tag (in terms of Energy Consumption and Time) etc.

3.1.1 Responsibilities of a good routing protocol
They are as follows:
- Discovering such paths which are based upon the criteria like hop length, minimal power requirement, as well as lifespan of common wireless path.
- Congregation info regarding frequent path breaks due to high mobility.
- Joining and fixing the broken paths spending minimum processing power, scarce as well as limited bandwidth.
- In-built mechanisms for allotting the network load evenly across the network for eluding establishment of regions where channel contention is very high.
- Finally, trading this newer route configuration information with all relaying nodes in topology.

3.1.2 Major challenges faced by a routing protocol
They are as follows:
- **Mobility**: This outcome in regular path breaks, collision of packets, transitory loop formation, out-of-date routing info, as well as toil in resource advance booking.
- **Bandwidth constraint**: Since, transmission common channel is heard by all participating relaying nodes, so BW availability per wireless channel hinges upon
count of nodes as well as the traffic handled by them. Consequently, only a fraction of total BW is accessible to each node.

- **Error susceptible as well as common link**: The bit error rate (BER) is very high in a wireless network as compared to wired networks. Here, the efficiency of routing protocol can be enhanced by taking into consideration factors like wireless channel state, signal-to-noise ratio (SNR) as well as path losses for routing.

- **Location-dependent conflict**: It is higher for shared channel with augmented count of nodes in a given geographical area which may result in increased collisions as well as ensuing wastage of accessible bandwidth (BW).

- **Other resource constraints**: such as computing power, battery power, and buffer storage capacity of the participating nodes

3.1.3 Main requirements of a routing protocol

They are as follows:

- **Minimal delay in path determination**: It should be minimal for a node which doesn’t have a path to a particular target, which may differ with size of network as well as load.

- **Speedy path re-configuration**: It should be performed quickly to handle quick path breaks due to dynamically changing topology and subsequent packet loses. The protocol should allow for quick establishment of routes and quick exchange of the re-route information so that they can be used before they become invalid and stale.

- **Loop-free routing**: Formation of transient loops must be avoided to avoid wastage of scarce, limited network BW available. The protocol should provide multiple loop free, feasible, minimum hop shortest paths from origin to target nodes which will help in resolving glitches of congestion. Sometimes, fewer packets start moving in network due to transitory loops which can outcome in substantial overheads such as over-consumption of scarce bandwidth as well as power. Consequently, paths derived from routing tables towards all nodes must be acyclic i.e. may not have loops.

- **Distributed routing approach**: Since MANETs are fully distributed wireless networks, so distributed routing approaches should be used to consume minimal amount of BW available.

- **Minimum control overhead**: As count of control packets exchanged gets augmented for sensing a newer path as well as for maintenance of current paths, the consumption of available scarce, limited BW increases which further result in the
collision of these control packets with data packets, thereby reducing network efficiency. When a routing protocol suffers extreme control traffic, then it leads to over consumption of available bandwidth by control traffic thereby having a detrimental impact on communication system performance. Since bandwidth of a wireless network is scarce, control overhead reduction is a vital design aspect.

- **Scalability:** As the count of nodes in a network increases, the control overhead should be minimized and routing protocols should adapt according to the network size to perform efficiently. The protocol should adapt quickly to rapidly changing topology.

- **Provision of QoS:** It should perform as per requirements of the network nodes to provide a certain level of QoS based on certain parameters like BW, delay, jitter, PDR, and throughput.

- **Supportive time sensitive traffic:** It should ably deliver backing for hard real-time as well as soft real-time traffic e.g. Tactical communication and time-sensitive applications.

- **Security and privacy:** It must be robust to intimidations as well as susceptibilities. It must have inherent capability to evade resource depletion, denial-of-service, masquerading etc. To acquire information, indispensable for efficacious malicious behaviour, nodes can draw traffic towards themselves or towards their conspiring nodes through deceitful routing announcements. A lot of statistics can be congregated this way by malicious nodes for future use to carry out more refined attacks. Denial-of-service attacks can be realized by transmitting bogus routing statistics in form of repeating old routing statistics or ‘black hole routes’ as well as by altering routing statistics either for partitioning the network or to load the network unreasonably, thus leading to re-transmissions of packets. Henceforth, nodes can resolve for advancing messages to partners in conspiracy for examination, revelation, or financial benefits; or may resolve not to advance messages at all, thus shunning communications [86].

- **Efficient utilization of battery capacity:** Here, reducing count of vigorous movable nodes diminishes expanse of signal interference as well as channel conflicts in wireline networks. Contrary to this, in MANETs, hosts needs to relay messages via intermediary nodes toward their intended target i.e. a reduction in count of mobile users can also lower performance of network. MANETs performance is severely influenced by uptime of mobile nodes. Consequently, as count of accessible nodes
declines, network may also be partitioned into minor networks. So, to elongate uptime of every node, routing protocols ought to deliberate on optimum power depletion.

- **Optimization of metrics:** Here, bandwidth, battery power, end-to-end throughput and delay are important performance metrics in MANETs. Nonetheless, the present metrics impact the design of routing protocols, following performance metrics must be taken into consideration:

  1. Maximum end-to-end throughput.
  2. Minimum end-to-end delay.
  3. Minimum total power (battery capacity).
  4. Minimum overhead (bandwidth).
  5. Load balancing (least congested path.)

### 3.2 Routing Protocols Taxonomy

Routing protocols are broadly classified on two bases:

- Based on what information is used to build routing table
- Based on when routing tables are built.

#### 3.2.1 Based on information used to build routing tables:

A. **Shortest Distance:** These Routing protocols use distance information for creating routing tables.

B. **Link State:** These Routing protocols use connectivity information for creating a topological graph used for further creating routing tables.

#### 3.2.2 Based on when routing tables are built:

A. **Proactive:** Even if not needed, routes to destinations are maintained.


B. **Reactive:** Routes to destinations are maintained only when they are needed.

  - Examples: DSR, AODV

C. **Hybrid:** For nearby nodes, routes are maintained even if they are not needed and for far away nodes routes maintained only when needed.

  - Examples: ZRP

Routing protocols have been branded in three categories: (i) Proactive (ii) Reactive (iii) Hybrid [87, 88]
3.2.3 Other Taxonomies of Routing Protocol: They set up a routing table in the routers. Researchers have proposed numerous routing protocols for wireline as well as wireless networks. These falls into four distinct categories depending on their properties:

A. Centralized Vs Distributed: In centralized one, every selected path is finished at a central node; while in a distributed one, the calculation of path is pooled amid all nodes of network.

B. Static Vs Adaptive: In a static (non-adaptive) one, path utilized by origin-target pairs is static irrespective of state of affairs of traffic and can only change in reaction to a node/ link failure. They can’t realize higher throughput in presence of a wide-ranging inputs of traffic. Maximum key packet networks utilize a type of adaptive routing protocols which on sensing congestion may alter path amid origin and intended targets.

C. Flat Vs Hierarchical: The flat one has a flat addressing system where every node contributing in routing plays same role. In comparison, hierarchical one typically allocates diverse roles to network nodes. Although numerous taxonomy of routing protocols in MANETs can be finished in numerous ways, still maximum of these are contingent on routing procedure as well as structure of the network.

D. Proactive (Table-Driven) Vs. Reactive (On-Demand-Driven) Vs. Hybrid: When routing tables are built:

- **Proactive algorithms**: maintain routes to destinations even if they are not needed.
- **Reactive algorithms**: maintain routes to destinations only when they are needed.
E. Based on transmission range: Since, these networks have limited transmission range; therefore, they need these intermediate nodes for communication to transfer data across the network. So, routing of data is possible through following methods:

- Unicasting (one to one)
- Multicasting (one to many)
- Broadcasting (many to many)

F. Unicast routing protocols: They can be categorized into following categories:

- Table Driven Routing Protocols
- Source-Initiated On Demand Routing Protocols

G. Based on the information used to build routing tables:

- Shortest Distance algorithms: algorithms that use distance information to build routing tables.

Figure 3.2: 2nd Routing Protocols Taxonomy
- **Link State algorithms**: algorithms that use connectivity information to build a topology graph that is used to build routing tables.

![](image)

**Figure 3.3: 3rd Routing Protocols Taxonomy**

### 3.3 Reactive (On-demand) Routing Protocols (RPs)

Reactive /on-demand reactive protocols do not initiate path discovery on their own till they are demanded by a source node to find a route [89, 90]. As a node wishes to converse thru other node in network, where origin node is not having a pre-existing available path towards that node, then these protocols will create a path from origin towards target node. The ‘family of classical flooding’ algorithms utilizes reactive scheme. As, these protocols inundate network to determine path, so these are not impeccable for utilization of bandwidth. Nevertheless, they scale well for frequently altering network topologies. Therefore, these are desirable in planning minimal energy RPs. Generally, a reactive protocol does the following:

1. Doesn’t discover path till claimed.
2. When attempts to discover target node “on demand”, it practices ‘flooding’ method to broadcast queue.
3. It ingests bandwidth for transporting info.
4. RPs ingests bandwidth only when node initiates transmitting the data towards target node.

Here, we have focused on two reactive protocols, namely AODV and DSR which are explained below.
3.3.1 Ad-hoc On-demand Distance Vector (AODV)
This reactive method sets up a path to Target node on request only when it senses that someone wishes to transmit data and does not care for maintaining this initiated route once the transmission is over. It initiates a ‘path discovery mechanism’ to sense the recent operational path to target node by broad-casting a route request (RREQ) as well as a route reply (RREP) queries cycle. A RREQ packet, containing origin’s Internet protocol (IP) address, target’s IP address and broadcast ID, is broadcasted by origin node to all nodes in network which is utilized by these intermediary nodes for updating their routing table information about origin node as well as they initiates a back-path to origin through the same RREQ path. Then, a RREP packet to origin node is transmitted by unicast process if the target node has an active back-path to origin; otherwise this RREQ packet is forwarded to further nodes by these intermediate nodes.

When a reply is transmitted back using RREP packet, then all the nodes on that established, active back-path can record entry for updating their routing table information about target node so as to have routing information about origin for future usage. Since, multiple paths can exist amid origin and target, thus origin can receive multiple RREQ packets. When a route failure is sensed either due to mobility or link dis-connection, a route error (RERR) packet is broadcasted towards neighboring nodes for informing about broken links as well as path discovery mechanism is invoked. A target sequence count, which is highest count for latest as well as fresh paths to origin node, is also used for avoiding routing loops thereby assuring that most recent paths are selected for further transmission. The sequence count is encompassed in RREQ as well as RRER packets. In case of RREP packets, this count must be greater or equal to count included in corresponding RREQ packets which assure that an old path is not chosen by origin node. The most efficient path must possess highest target sequence count and if several paths have similar sequence count, then path possessing lowermost hop-count to target is selected finally. This protocol is utilized in immovable networks having lower byte overheads as well as loops-free routing using target sequence counts.

3.3.2 Dynamic Source Routing (DSR)
Broch, Johnson, and Maltz [126] proposed Dynamic Source Routing protocol for routing in MANETs. DSR’s reactive / on-demand method makes use of origin-based routing mechanism for communicating data which implies that origin must possess the knowledge of the total count of hops to reach target node. It sets up a path to target on request only when it senses that someone wishes to transmit data and does not care for maintaining this initiated
route once the transmission is over. It has to perform two tasks namely: route discovery as well as route maintenance. Each network node has a route cache for storage of every known established path. When a wished-for path is not available in the cache, then a path discovery process is commenced for forwarding broadcasted RREQ packets. When every node receives the RREQ packet, then there are two possibilities arises after viewing the request identifier, same as path sequence count of AODV, from origin, either node discards it or it includes its address to request list in its cache and rebroadcasts it to its neighbors. Once, RREQ reaches to its intended target node, it transmit back a RREP packet to origin which includes accrued list address of all intermediate nodes. Finally, after receiving the RREP packet, origin node updates its route caches with the latest route information. If a link break is sensed by any of the participating node in the established path whereby a RERR (route error) packet is sent back to origin for maintaining info of route and then origin node initiates route maintenance process through initiation of a path discovery process again. This leads to deletion of the intermediate node’s route cache information about failed routes after transmitting the RERR packet to origin. Now, origin must determine the count of hops needed to transmit every packet along with sequence count of hops to be attached with packet’s header so as to educate every intermediate node about the path to target node depending upon origin routes in received packet. Due to proper usage of route cache, the real benefit of this system is the drop in the overheads of control packets associated with route discovery. Also, the disadvantage is the increased size of packet header with route length as a result of origin-based routing.

3.4 Proactive (Table-Driven) Routing Protocols
A proactive routing protocol tries to constantly appraise paths within network so that as soon as a packet needs to be advanced, then previously recognized path to target node can be promptly utilized as every node in network recognizes all nodes a priori. These protocols preserve stable of updated routing statistics for each node, store this info, reply in case of topological alteration, update these tables accordingly, and finally shares this give-and-take topological information amid participating nodes so that path info can be utilized any time when looked-for. These updates are broadcasted to entire network so as to keep a steady observation amid all nodes. The ‘family of Distance-Vector protocols’ is a kind of these scheme and enjoy an edge because as a path is requisite even before real packets can be transmitted, then delay is quite petty. However, they also take time in reaching a stable state thereby causing hitches if topological alteration happens very often. Therefore, these
strategies are well fitted in a low mobility network [91]. OLSR, DYMO are examples of PRPs explained below:

3.4.1 Optimized Link State Routing (OLSR)

Here, every network node transmit its routing tables from time to time so that all nodes have knowledge about network topology whereby updating as well as maintaining routing table at all-time so as to provide paths when required. However, a disadvantage is augmented control overhead to the network. To overcome this, multipoint relays (MPRs) are deployed which select few nodes for lessening the control packet size by reducing the count of nodes forwarding network traffic as well as transmission of routing packets. Hence, the process of ‘control flooding’ is augmented whereby a group of MRP supported nodes amid all network nodes at a distance of one-far neighbor hop are selected and every selected MPR can touch two-hop neighbor at a distance of minimum one MPR as well as broadcasts its selected MPR list from time to time instead of all neighbors list. Also, topology control packets are aired over network in case of broken links caused by mobility. All network nodes store routing table in their cache having information about paths to all accessible target network nodes. OLSR protocols do not immediately notify origin node about a route failure as well as came to know only when the next packet is broadcasted by intermediate nodes.

3.4.2 The Dynamic MANET On-demand (DYMO)

It permits responsive, multi-hop routing amongst wireless mobile nodes wishing to converse. There are two basic operations here namely route discovery as well as route management. In route discovery procedure, origin node starts broadcasting of a Route Request (RREQ) throughout network so as to locate target node whereby each intermediary node records a back path to origin node. As target node receives RREQ, then it answers back via a Route Reply (RREP) transmitted hop-by-hop toward origin node. Each node receiving RREP archives a path to target node thereby RREP is then uni-casted towards origin node. On reception of RREP by origin node, routes will be created amongst origin node as well as target node both ways. In reaction to network topological alteration, nodes preserve their paths as well as monitor links watchfully. On reception of a Data packet for forwarding in case when a path is unknown or path is broken, then origin of packet is informed. A Route Error (RERR) is transmitted towards packet origin to point out that present path is damaged. On reception of a RERR, origin node then have knowledge of initiating route discovery, when it still has packets for delivery. It also utilizes sequence counts to certify loop liberty which permits nodes to define order of path finding messages thereby avoiding usage of old routing info [1].
3.5 Hybrid protocols

Hybrid protocols make usage of strong points of reactive as well as proactive protocols, thereby combining them to have superior outcomes. Hybrid protocols split the network into areas called ‘zones’ which could be overlapping or non-overlapping contingent on the zone creation and management algorithm employed by a particular hybrid protocol. The pro-active routing protocol operates inside the zones, and is responsible for establishing and maintaining routes to the destinations located in the interior of the zones. Contrary to this, re-active protocol is accountable for establishing as well as maintaining paths towards target nodes located outside zones. Zone Routing Protocol (ZRP) is the example of Hybrid Routing Protocol [92].

3.5.1 Zone Routing Protocol (ZRP)

ZRP is locally pro-active as well as globally re-active hybrid protocol for MANETs utilized for achieving enhanced routing efficiency by generating minimal routing overhead for speedy delivery of data by choosing the most proficient protocol for usage all over the path. Also, it exhibits enhanced ability of transporting nearly every originated data packet even in continuous presence of highly movable nodes in the network. It works entirely on-demand to create a path to destination. There are two scenarios now: First, if origin-target node pair lies within the same zone, the proactive portion makes use of already cached routing table for delivering data packet instantly. In ZRP, a zone is demarcated locally around every node termed as node's “k-neighborhood”, where resides all nodes within a distance of k hops of node. Also, “Border nodes” are one having a distance of k hops exactly far from a source node. Second, if both nodes don’t reside in same local zone, then re-active protocol is initiated for sensing every consecutive zone in the path to know whether target node lies in that zone thereby avoiding routing overhead for those paths. Here, origin node communicates a ‘route request’ towards border nodes of its zone and appends its own address, target address as well as a unique sequence count. Every border node then finds its local zone for target node. If target node is not a part of this local zone, then border node appends its own address to route request packet and forwards packet to its own border nodes. If target node is a member of the local zone, it sends a route reply on reverse path back to origin. The origin node makes usage of path saved in route reply packet to transmit data packets to target node. Therefore, ZRP curbs control overhead for lengthier paths which would be compulsory if proactive routing protocols are deployed exclusively along the entire path. It also limits routing delays produced by route-discovery procedure of reactive routing protocols within a zone. Hence, Intra-zone Routing Protocol (IARP) or pro-active routing protocol, is deployed.
within same routing zone and Inter-zone Routing Protocol (IERP) or reactive routing protocol, is deployed amid inter-routing zones. Since, IARP makes use of cached routing table of origin node which is in same zone as target node whereby immediate as well as speedy delivery of packets is guaranteed, so it is deliberated as pro-active whereas IERP is deliberated as a reactive protocol. Several current proactive routing algorithms today are utilized as IARP for ZRP [127].

![Routing Protocols Taxonomy](image)

Figure 3.4: 4th Routing Protocols Taxonomy

### 3.6 Bellman–Ford algorithm

It is the basic routing algorithm first offered by Alfonso Shimbel in 1955. In 1956-1958, it was suggested by Richard Bellman as well as Lester Ford, Jr., hence named after them [129]. The same algorithm in 1957 was put forward by Edward F. Moore, hence it is also called as the Bellman–Ford–Moore algorithm [128]. This algorithm computes shortest paths from a single origin node towards all of other nodes in a weighted digraph [128]. It is more flexible in handling graphs in which some of the edge weights are negative counts [130]. On the other hand, for solving similar problem, it is slower than Dijkstra's algorithm. If a graph has a "negative cycle" (i.e. a cycle whose sum of distance calculated from all nodes is a negative value) which is accessible from origin, then there is no inexpensive route; any route having a point on the negative cycle can be made inexpensive by one iteration around this negative cycle. Therefore, the Bellman–Ford algorithm can sense negative cycles as well as report their presence [128, 131]. Similar to Dijkstra's Algorithm, Bellman–Ford is founded on the norm of ‘relaxation’, where a rough calculation of the exact distance to every node is step by step substituted by more exact length of a newer established route till ultimately attaining the optimal solution. Nevertheless, Dijkstra's algorithm utilizes priority queue for greedily choosing nearest node for which distance was not calculated till now, and does this ‘relaxation’ procedure on all of its outgoing edges. In each of these repetitions, the count of vertices with correctly calculated distances raises, from which ultimately all vertices will
have their precise distances. Thus, Bellman-Ford algorithm can be used for greater variety of applications than Dijkstra. Figure 3.5 below presents exhaustive classification of routing protocols in MANETs focusing on security feature for improving performance of network. DSDV, LSP, R-DSDV, FSR, CGSR (Cluster head gateway search routing), OLSR, HSR (Hierarchical State Routing), TBRPF (Topology based reverse path forwarding), DREAM (Distance Routing effect algorithm for mobility), STAR (Source Tree adaptive routing protocol) etc. are examples of table driven routing protocols.

Figure 3.5: 5th Routing Protocols Taxonomy by B.S. Manoj et. al. [87]
3.7 Implementation Environment
Here, for carrying out simulation and analyze results obtained, Qualnet version 7.3.1 is used. The QualNet GUI can be operated on 64-bit platforms whereby distinct graphics card with at least 128 MB memory supporting hardware 3-D acceleration are used along with a 1024 x 768 resolution display. QualNet delivers a complete set of tools along with components for tailoring network modeling as well as simulation jobs. Unmatched speediness of QualNet expandability as well as reliability brands it informal for modelers to improve present networks by way of rapid model arrangement along with comprehensive analytical outfits. Models in origin practice deliver designers a concrete, broad library to construct as well as testing with newer network functions resulting in precise forecast of network performances for a varied set of usage necessities ranging from wireline networks to wire-less networks as well as MANETs. QualNet models outsized networks under dense traffic as well as mobility in rational simulation times. A passing overview of diverse modules of QualNet as well as protocol stack is introduced which founded base of QualNet architecture.

3.7.1 QualNet Simulator
It is an ultramodern simulator for big, mixed networks where dispersed applications are executed. It is an enormously expendable simulation device having high-reliability models of networks with thousands of nodes. It utilizes computational resources very well thereby modelling big-scale networks supporting dense traffic as well as mobility within realistic simulation times having multi-platform features like:
1. Quick model set-up supporting potent Graphical User Interface (GUI) for creation of custom code
2. Prompt replay of simulation outcomes to minimalize needless model implementations
3. Faster simulation outcomes for detailed examination of model parameters
4. Supports Scalability up to lakhs of nodes
5. Real-time simulation for man-in-the-loop as well as hardware-in-the-loop models
6. Multi-platform backing.
3.8. Comparative Evaluation of Various Existing Routing Protocols

Here, we have taken six protocols namely AODV, DSR, BELLMON-FORD, DYMO, OLSR, and ZRP for carrying our research. Two possibilities arise here based upon:

1. **Count (Number) of Nodes**: Here, under a constant mobility of 10m/s is considered. Count of Nodes taken here are 5, 15, 25, 35, and 45. Therefore, there are 5 scenarios here.

2. **Mobility of nodes**: Here, Count of Nodes is fixed at 25 which is a mid-sized MANET. The Mobility of nodes is changed at 10m/s, 20 m/s, 30 m/s, 40 m/s, and 50 m/s which is quite fast movement. Therefore, there are 5 scenarios here.

**In both the cases, following parameters taken are same:**

1. CBR (constant bit rate) based applications.
2. There are 15 applications each sending 200 data packets of a size of 512 bytes into the network.
3. Therefore, there are 3000 data packets injected into the network.
4. Simulation Time taken is 1000 seconds (s).
5. Qualnet version 7.3.1 is selected here as Simulator.

**Four parameters analyzed for simulated results namely:**

1. End-to-End Delay.
2. Throughput.
3. Number/Count of Packet Dropped.
4. PDR (Packet Delivery Ratio).

Six protocols selected are AODV, DSR, BELLMON-FORD, DYMO, OLSR, and ZRP.

For successful transmission of data packets from origin node towards target node, the desired parameters are as follows:

1. The End-to-End delay (second) should be as low as possible.
2. Throughput (Kilobit/second) should be as high as possible.
3. Count of Packet Dropped (number) should be as low as possible.
4. PDR (%) should be as high as possible.
### Table 3.1: Description of the Experimental Categories 1 [12]

<table>
<thead>
<tr>
<th>Simulation parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protocols</td>
<td>AODV, Bellmon-Ford, DSR, Dymo, OLSR, ZRP</td>
</tr>
<tr>
<td>Simulation time</td>
<td>1000 s</td>
</tr>
<tr>
<td>Area</td>
<td>1500 X1500 m²</td>
</tr>
<tr>
<td>Count of nodes</td>
<td>5, 15, 25, 35 and 45</td>
</tr>
<tr>
<td>MAC Protocol</td>
<td>IEEE 802.11</td>
</tr>
<tr>
<td>Mobility model</td>
<td>Random Waypoint</td>
</tr>
<tr>
<td>Node placement</td>
<td>Random</td>
</tr>
<tr>
<td>Speed</td>
<td>10 m/s</td>
</tr>
<tr>
<td>Pause time</td>
<td>10 s</td>
</tr>
<tr>
<td>Traffic type</td>
<td>CBR</td>
</tr>
<tr>
<td>Packet Size</td>
<td>512 bytes</td>
</tr>
<tr>
<td>Total count of packets sent</td>
<td>3000</td>
</tr>
<tr>
<td>Parameter Compared</td>
<td>End to End Delay, Throughput, Packet dropped, PDR</td>
</tr>
</tbody>
</table>

**Scenario 1**: It is configured to analyze various parameters namely End to End Delay, Throughput, Packet dropped, PDR of different protocols based on scalability of network. A 1,500×1,500 m² network having varied count of nodes as 5, 15, 25, 35 and 45 with a mobility of 10 m/s with CBR application running for routing protocols namely AODV, BELLMON-FORD, DSR, DYMO, OLSR as well as ZRP is created. Pause time selected here is 10 seconds. The packet size is set to 512 bytes along with 3000 packets sent. Six types of MANET routing protocols are employed in the network and their performances are evaluated for the different-sized networks based on the analysis of the performance metrics.

Now, we will analyze the two cases one by one: first is based on count of nodes and second is based on mobility of nodes.

**3.8.1 Count (Number) of Nodes**: Here, under a constant mobility of 10m/s is considered. Count of Nodes taken here are 5, 15, 25, 35, and 45. Therefore, there are 5 scenarios here.

**3.8.1.1: End-to-End Delay**: This parameter, measured in seconds, should be as low as possible for successful transmission of data packets injected by origin node towards destination node. This investigation absolutely deals with nodes in network speed as well as
effectiveness of transmission. Now, comparison of different protocols will be done for different count of nodes one by one.

**Table 3.2: End-to-End Delay (seconds) Vs Count of nodes**

<table>
<thead>
<tr>
<th>Routing Protocols</th>
<th>Count of Nodes</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>AODV</td>
<td>0.255162</td>
<td>0.185019</td>
</tr>
<tr>
<td>BELLMON FORD</td>
<td>0.192404</td>
<td>0.111932</td>
</tr>
<tr>
<td>DSR</td>
<td>3.010538</td>
<td>1.134151</td>
</tr>
<tr>
<td>DYMO</td>
<td>0.286716</td>
<td>0.934558</td>
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<tr>
<td>OLSR</td>
<td>0.090921</td>
<td>0.081426</td>
</tr>
<tr>
<td>ZRP</td>
<td>0.185159</td>
<td>0.040612</td>
</tr>
</tbody>
</table>

**Graph 3.1: End-to-End Delay Vs Count of nodes**

1. **Count of Nodes taken is 5**: For a constant mobility of 10m/s, these different protocols exhibit varied results. Here, for 5 nodes, End-to-End Delay reported for AODV is 0.255162s, for BELLMON-FORD is 0.192404s, for DSR is 3.010538s, for DYMO is 0.286716s, for OLSR is 0.090921s, and for ZRP is 0.185159s. Hence, for this scenario, End-to-End Delay for OLSR is lowest, for ZRP is 2nd lowest, for BELLMON-FORD is 3rd lowest, for AODV is 4th lowest, for DYMO is 5th lowest but DSR perform poorly with highest End-to-End Delay.
2. **Count of Nodes taken is 15:** For a constant mobility of 10m/s, these different protocols exhibit varied results. Here, for 15 nodes, End-to-End Delay reported for AODV is 0.185019s, for BELLMON-FORD is 0.111932s, for DSR is 1.134151s, for DYMO is 0.934558s, for OLSR is 0.081426s, and for ZRP is 0.040612s. Hence, for this scenario, End-to-End Delay for ZRP is lowest, for OLSR is 2\textsuperscript{nd} lowest, for BELLMON-FORD is 3\textsuperscript{rd} lowest, for AODV is 4\textsuperscript{th} lowest, for DYMO is 5\textsuperscript{th} lowest but DSR perform poorly with highest End-to-End Delay.

3. **Count of Nodes taken is 25:** For a constant mobility of 10m/s, these different protocols exhibit varied results. Here, for 25 nodes, End-to-End Delay reported for AODV is 0.181094s, for BELLMON-FORD is 0.10657s, for DSR is 0.332335s, for DYMO is 0.32894s, for OLSR is 0.127285s, and for ZRP is 5.409557s. Hence, for this scenario, End-to-End Delay for BELLMON-FORD is lowest, for OLSR is 2\textsuperscript{nd} lowest, for AODV is 3\textsuperscript{rd} lowest, for DYMO is 4\textsuperscript{th} lowest, for DSR is 5\textsuperscript{th} lowest and for ZRP is highest. Hence, ZRP performs poorly with highest End-to-End Delay.

4. **Count of Nodes taken is 35:** For a constant mobility of 10m/s, these different protocols exhibit varied results. Here, for 35 nodes, End-to-End Delay reported for AODV is 0.186149s, for BELLMON-FORD is 0.142480s, for DSR is 0.667434s, for DYMO is 0.299387s, for OLSR is 0.147135s, and for ZRP is 4.055927s. Hence, for this scenario, End-to-End Delay for BELLMON-FORD is lowest, for OLSR is 2\textsuperscript{nd} lowest, for AODV is 3\textsuperscript{rd} lowest, for DYMO is 4\textsuperscript{th} lowest, for DSR is 5\textsuperscript{th} lowest and for ZRP is highest. Hence, ZRP performs poorly with highest End-to-End Delay.

5. **Count of Nodes taken is 45:** For a constant mobility of 10m/s, these different protocols exhibit varied results. Here, for 45 nodes, End-to-End Delay reported for AODV is 0.191451, for BELLMON-FORD is 0.150657s, for DSR is 0.562434s, for DYMO is 0.258501s, for OLSR is 0.160808s, and for ZRP is 4.156563s. Hence, for this scenario, End-to-End Delay for BELLMON-FORD is lowest, for OLSR is 2\textsuperscript{nd} lowest, for AODV is 3\textsuperscript{rd} lowest, for DYMO is 4\textsuperscript{th} lowest, for ZRP is 5\textsuperscript{th} lowest and for DSR is highest. Hence, both DSR as well as ZRP performs poorly with highest End-to-End Delay.

Hence, it is finally concluded that as the count of nodes increases from 5 to 15 to 25 to 35 to 45, then different protocols performs like this as described below:

a) **AODV:** End-to-End Delay first decreases and then remains the same as count of nodes increases from 5 to 45.
b) BELLMON-FORD: End-to-End Delay first decreases as count of nodes increases from 5 to 25 and then increases as count of nodes increases from 25 to 45.

c) DSR: End-to-End Delay first decreases as count of nodes increases from 5 to 25 and then increases as count of nodes increases from 25 to 45.

d) DYMO: End-to-End Delay first increases as count of nodes increases from 5 to 15 and then decreases as count of nodes increases from 15 to 45.

e) OLSR: End-to-End Delay first decreases as count of nodes increases from 5 to 15 and then increases as count of nodes increases from 15 to 45.

f) ZRP: End-to-End Delay first decreases as count of nodes increases from 5 to 15 and then increases from 15 to 25, then decrease from 25 to 35 and finally remains constant from 35 to 45 as count of nodes increases from 15 to 45.

Hence, for Average End-to-End Delay, as count of nodes increases at a constant mobility of 10m/s, different protocols performs in this order:

1. OLSR performs best (0.121515s)
2. BELLMON-FORD (0.140809s)
3. AODV (0.199775s)
4. DYMO (0.42162s)
5. DSR performs poorly (1.141378s)
6. ZRP performs very poorly (2.769564s)
3.8.1.2 Throughput: This parameter, measured in kilobit/second, should be as high as possible for successful transmission of data packets injected by origin node towards destination node. Now, comparison of different protocols will be done for different count of nodes one by one.

Table 3.3: Throughput (Kb/s) Vs Count of nodes

<table>
<thead>
<tr>
<th>Routing Protocols</th>
<th>Count of Nodes</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>AODV</td>
<td>880.5407</td>
<td>3742.799</td>
</tr>
<tr>
<td>BELLMON FORD</td>
<td>885.964</td>
<td>3642.856</td>
</tr>
<tr>
<td>DSR</td>
<td>1044.576</td>
<td>4105.89</td>
</tr>
<tr>
<td>DYMO</td>
<td>918.7232</td>
<td>5152.51</td>
</tr>
<tr>
<td>OLSR</td>
<td>913.3165</td>
<td>3418.608</td>
</tr>
<tr>
<td>ZRP</td>
<td>827.3212</td>
<td>3592.468</td>
</tr>
</tbody>
</table>

Graph 3.3: Throughput (Kb/sec) Vs Count of nodes

1. Count of Nodes taken is 5: For a constant mobility of 10m/s, these different protocols exhibits varied results. Here, for 5 nodes, Throughput (Kb/sec) reported for AODV is 880.5407, for BELLMON-FORD is 885.964, for DSR is 1044.576, for DYMO is 918.7232, for OLSR is 913.3165, and for ZRP is 827.3212. Hence, for this scenario, Throughput for
DSR is highest, for DYMO is 2\textsuperscript{nd} highest, for OLSR is 3\textsuperscript{rd} highest, for BELLMON-FORD is 4\textsuperscript{th} highest, for AODV is 5\textsuperscript{th} highest but ZRP perform poorly with lowest Throughput.

\textbf{2. Count of Nodes taken is 15:} For a constant mobility of 10m/s, these different protocols exhibits varied results. Here, for 15 nodes, Throughput (Kb/sec) reported for AODV is 3742.799, for BELLMON-FORD is 3642.856, for DSR is 4105.89, for DYMO is 5152.51, for OLSR is 3418.608, and for ZRP is 3592.468. Hence, for this scenario, Throughput for DYMO is highest, for DSR is 2\textsuperscript{nd} highest, for AODV is 3\textsuperscript{rd} highest, for BELLMON-FORD is 4\textsuperscript{th} highest, for ZRP is 5\textsuperscript{th} highest but OLSR perform poorly with lowest Throughput.

\textbf{3. Count of Nodes taken is 25:} For a constant mobility of 10m/s, these different protocols exhibits varied results. Here, for 25 nodes, Throughput (Kb/sec) reported for AODV is 2811.486, for BELLMON-FORD is 988.458, for DSR is 1370.46, for DYMO is 2491.086, for OLSR is 1858.329, and for ZRP is 1968.461. Hence, for this scenario, Throughput for AODV is highest, for DYMO is 2\textsuperscript{nd} highest, for ZRP is 3\textsuperscript{rd} highest, for OLSR is 4\textsuperscript{th} highest, for DSR is 5\textsuperscript{th} highest but BELLMON-FORD perform poorly with lowest Throughput.

\textbf{4. Count of Nodes taken is 35:} For a constant mobility of 10m/s, these different protocols exhibits varied results. Here, for 35 nodes, Throughput (Kb/sec) reported for AODV is 4258.148, for BELLMON-FORD is 995.1283, for DSR is 766.7434, for DYMO is 2704.113, for OLSR is 1832.383, and for ZRP is 983.1481. Hence, for this scenario, Throughput for AODV is highest, for DYMO is 2\textsuperscript{nd} highest, for OLSR is 3\textsuperscript{rd} highest, for BELLMON-FORD is 4\textsuperscript{th} highest, for ZRP is 5\textsuperscript{th} highest but DSR performs poorly with lowest Throughput.

\textbf{5. Count of Nodes taken is 45:} For a constant mobility of 10m/s, these different protocols exhibits varied results. Here, for 45 nodes, Throughput (Kb/sec) reported for AODV is 2527.621, for BELLMON-FORD is 684.3316, for DSR is 1667.704, for DYMO is 2728.091, for OLSR is 1652.64, and for ZRP is 710.2692. Hence, for this scenario, Throughput for DYMO is highest, for AODV is 2\textsuperscript{nd} highest, for DSR is 3\textsuperscript{rd} highest, for OLSR is 4\textsuperscript{th} highest, for ZRP is 5\textsuperscript{th} highest but BELLMON-FORD performs poorly with lowest Throughput.

Hence, it is finally concluded that as the count of nodes increases from 5 to 15 to 25 to 35 to 45, then different protocols performs like this as described below:

a) AODV: Throughput first increases from 5 to 15 nodes, then decreases from 15 to 25 nodes, then increases from 25 to 35 nodes and finally decreases as count of nodes increases from 35 to 45.
b) BELLMON-FORD: Throughput first increases from 5 to 15 nodes, then decreases from 15 to 25 nodes, then increases from 25 to 35 nodes and finally decreases as count of nodes increases from 35 to 45.

c) DSR: Throughput first increases from 5 to 15 nodes, then decreases from 15 to 25 nodes, again increases from 25 to 35 nodes and finally decreases as count of nodes increases from 35 to 45.

d) DYMO: Throughput first increases from 5 to 15 nodes, then decreases from 15 to 25 nodes, again increases from 25 to 35 nodes and finally remains almost the same as count of nodes increases from 35 to 45.

e) OLSR: Throughput first increases from 5 to 15 nodes, then decreases from 15 to 25 nodes, remains almost the same from 25 to 35 and finally decreases as count of nodes increases from 35 to 45.

f) ZRP: Throughput first increases from 5 to 15 nodes, then decreases from 15 to 25 nodes, again decreases from 25 to 35 and finally decreases as count of nodes increases from 35 to 45.

Hence, for Average Throughput, as count of nodes increases at a constant mobility of 10m/s, different protocols perform in this order:

1. AODV performs best (2844.119 kb/s)
2. DYMO (2798.905 kb/s)
3. OLSR (1935.055 kb/s)
4. DSR (1791.075 kb/s)
5. ZRP performs poorly (1616.334 kb/s)
6. BELLMON-FORD performs very poorly (1429.348 kb/s)

Graph 3.4: Bar Graph Throughput (Kb/sec) Vs Count of nodes
3.8.1.3 Packet Dropped: This parameter, measured in count of packets dropped, should be as low as possible for successful transmission of data packets injected by origin node towards destination node. Now, comparison of different protocols will be done for different count of nodes one by one.

Table 3.4: Packet Dropped Vs Count of nodes

<table>
<thead>
<tr>
<th>Routing Protocols</th>
<th>Count of Nodes</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>AODV</td>
<td>2067</td>
<td>68</td>
</tr>
<tr>
<td>BELLMON FORD</td>
<td>1257</td>
<td>90</td>
</tr>
<tr>
<td>DSR</td>
<td>658</td>
<td>0</td>
</tr>
<tr>
<td>DYMO</td>
<td>2121</td>
<td>112</td>
</tr>
<tr>
<td>OLSR</td>
<td>2217</td>
<td>179</td>
</tr>
<tr>
<td>ZRP</td>
<td>214</td>
<td>0</td>
</tr>
</tbody>
</table>

Graph 3.5: Packet Dropped Vs Count of nodes

1. Count of Nodes taken is 5: For a constant mobility of 10m/s, these different protocols exhibits varied results. Here, for 5 nodes, Count of Packets Dropped reported for AODV are 2067, for BELLMON-FORD are 1257, for DSR are 658, for DYMO are 2121, for OLSR are 2217, and for ZRP are 214. Hence, for this scenario, Count of Packets Dropped for ZRP is...
lowest, for DSR is 2nd lowest, for BELLMON-FORD is 3rd lowest, for AODV is 4th lowest, for DYMO is 5th lowest but OLSR perform poorly with highest Count of Packets Dropped. There are two reasons for this high Count of Packets Dropped. First, these five nodes might have travelled so far that they have gone out of transmission range of each other in selected large area size leading to high Count of Packets Dropped. Second, even when selected area size is decreased, large amount of applications, 15 here, running simultaneously have choked the transmission bandwidth of the transmission link leading to high Count of Packets Dropped.

2. Count of Nodes taken is 15: For a constant mobility of 10m/s, these different protocols exhibits varied results. Here, for 15 nodes, Count of Packets Dropped reported for AODV is 68, for BELLMON-FORD is 90, for DSR is 0, for DYMO is 112, for OLSR is 179, and for ZRP is 0. Hence, for this scenario, Count of Packets Dropped for ZRP as well as DSR is lowest, for AODV is 2nd lowest, for BELLMON-FORD is 3rd lowest, for AODV is 4th lowest, for DYMO is 5th lowest but OLSR perform poorly with highest Count of Packets Dropped.

3. Count of Nodes taken is 25: For a constant mobility of 10m/s, these different protocols exhibits varied results. Here, for 25 nodes, Count of Packets Dropped reported for AODV is 163, for BELLMON-FORD is 3, for DSR is 66, for DYMO is 535, for OLSR is 436, and for ZRP is 117. Hence, for this scenario, Count of Packets Dropped for BELLMON-FORD is lowest, for DSR is 2nd lowest, for ZRP is 3rd lowest, for AODV is 4th lowest, for OLSR is 5th lowest, and for DYMO is highest. Hence, both OLSR as well as ZRP performs poorly with highest Count of Packets Dropped.

4. Count of Nodes taken is 35: For a constant mobility of 10m/s, these different protocols exhibits varied results. Here, for 35 nodes, Count of Packets Dropped reported for AODV is 157, for BELLMON-FORD is 84, for DSR is 9, for DYMO is 343, for OLSR is 354, and for ZRP is 97. Hence, for this scenario, Count of Packets Dropped for DSR is lowest, for BELLMON-FORD is 2nd lowest, for ZRP is 3rd lowest, for AODV is 4th lowest, for DYMO is 5th lowest and for OLSR is highest. Hence, both DYMO as well as OLSR performs poorly with highest Count of Packets Dropped.

5. Count of Nodes taken is 45: For a constant mobility of 10m/s, these different protocols exhibits varied results. Here, for 45 nodes, Count of Packets Dropped reported for AODV is 132, for BELLMON-FORD is 46, for DSR is 343, for DYMO is 313, for OLSR is 272, and for ZRP is 136. Hence, for this scenario, Count of Packets Dropped for BELLMON-FORD is lowest, for AODV is 2nd lowest, for ZRP is 3rd lowest, for OLSR is 4th lowest, for DYMO is
5th lowest and for DSR is highest. Hence, DSR, DYMO as well as OLSR perform poorly with highest Count of Packets Dropped. Hence, it is finally concluded that as the count of nodes increases from 5 to 15 to 25 to 35 to 45, then different protocols performs like this as described below:

a) AODV: Count of Packets Dropped first decreases from 5 to 15 nodes, then increases from 15 to 25, remains the same from 25 to 35 nodes and finally decreases as count of nodes increases from 35 to 45.

b) BELLMON-FORD: Count of Packets Dropped first decreases from 5 to 15 nodes, then decreases further from 15 to 25, then increases from 25 to 35 nodes and finally decreases as count of nodes increases from 35 to 45.

c) DSR: Count of Packets Dropped first decreases to zero from 5 to 15 nodes, then increases from 15 to 25, then decreases from 25 to 35 nodes and finally increases as count of nodes increases from 35 to 45.

d) DYMO: Count of Packets Dropped first decreases from 5 to 15 nodes, then increases further from 15 to 25, then decreases from 25 to 35 nodes and finally decreases again as count of nodes increases from 35 to 45.

e) OLSR: Count of Packets Dropped first decreases from 5 to 15 nodes, then increases further from 15 to 25, then decreases from 25 to 35 nodes and finally decreases further as count of nodes increases from 35 to 45.

f) ZRP: Count of Packets Dropped first decreases to zero from 5 to 15 nodes, then increases further from 15 to 25, then decreases from 25 to 35 nodes and finally increases as count of nodes increases from 35 to 45.

Hence, for Average Count of Packets Dropped, as count of nodes increases at a constant mobility of 10m/s, different protocols performs in this order:

1. ZRP performs best (112.8)
2. BELLMON-FORD (296)
3. DSR (215.2)
4. AODV performs poorly (517.4)
5. DYMO performs poorly (684.8)
6. OLSR performs very poorly (691.6)
3.8.1.4 PDR (Packet Delivery Ratio): This parameter, measured in percentage, should be as high as possible for successful transmission of data packets injected by origin node towards destination node. Now, comparison of different protocols will be done for different count of nodes one by one.

**Table 3.5: PDR Vs Count of nodes**

<table>
<thead>
<tr>
<th>Routing Protocols</th>
<th>Count. of Nodes</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>AODV</td>
<td>31.1</td>
<td>97.73333</td>
</tr>
<tr>
<td>BELLMON FORD</td>
<td>58.1</td>
<td>97</td>
</tr>
<tr>
<td>DSR</td>
<td>78.06667</td>
<td>100</td>
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<tr>
<td>DYMO</td>
<td>29.3</td>
<td>96.26667</td>
</tr>
<tr>
<td>OLSR</td>
<td>26.1</td>
<td>94.03333</td>
</tr>
<tr>
<td>ZRP</td>
<td>92.86667</td>
<td>100</td>
</tr>
</tbody>
</table>

**Graph 3.6: Bar Graph Packet Dropped Vs Count of nodes**
1. **Count of Nodes taken is 5**: For a constant mobility of 10m/s, these different protocols exhibit varied results. Here, for 5 nodes, PDR reported for AODV is 31.1%, for BELLMON-FORD is 58.1%, for DSR is 78.066%, for DYMO is 29.3%, for OLSR is 26.1%, and for ZRP is 92.8665%. Hence, for this scenario, PDR for ZRP is highest, for DSR is 2nd highest, for BELLMON-FORD is 3rd highest, for AODV is 4th highest, for DYMO is 5th highest but OLSR perform poorly with lowest PDR.

2. **Count of Nodes taken is 15**: For a constant mobility of 10m/s, these different protocols exhibit varied results. Here, for 15 nodes, PDR reported for AODV is 97.73333%, for BELLMON-FORD is 97%, for DSR is 100%, for DYMO is 96.2667%, for OLSR is 94.03333%, and for ZRP is 100%. Hence, for this scenario, PDR for DSR as well as ZRP is highest, for AODV is 2nd highest, for BELLMON-FORD is 3rd highest, for DYMO is 4th highest but OLSR perform poorly with lowest PDR.

3. **Count of Nodes taken is 25**: For a constant mobility of 10m/s, these different protocols exhibit varied results. Here, for 25 nodes, PDR reported for AODV is 94.56667%, for BELLMON-FORD is 99.9%, for DSR is 97.8%, for DYMO is 82.16667%, for OLSR is 85.46667%, and for ZRP is 96.1%. Hence, for this scenario, PDR for BELLMON-FORD is highest, for DSR is 2nd highest, for ZRP is 3rd highest, for AODV is 4th highest, for OLSR is 5th highest but DYMO performs poorly with lowest PDR.

4. **Count of Nodes taken is 35**: For a constant mobility of 10m/s, these different protocols exhibit varied results. Here, for 35 nodes, PDR reported for AODV is 94.76667%, for BELLMON-FORD is 97.2%, for DSR is 99.7%, for DYMO is 88.56667%, for OLSR is
88.2%, and for ZRP is 96.76667%. Hence, for this scenario, PDR for DSR is highest, for BELLMON-FORD is 2nd highest, for ZRP is 3rd highest, for AODV is 4th highest, but DYMO as well as OLSR performs poorly with lowest PDR.

5. Count of Nodes taken is 45: For a constant mobility of 10m/s, these different protocols exhibits varied results. Here, for 45 nodes, PDR reported for AODV is 95.6%, for BELLMON-FORD is 98.46667%, for DSR is 88.56667%, for DYMO is 89.56667%, for OLSR is 90.933335%, and for ZRP is 95.46667%. Hence, for this scenario, PDR for BELLMON-FORD is highest, for AODV is 2nd highest, for ZRP is 3rd highest, for OLSR is 4th highest, for DYMO is 5th highest but DSR performs poorly with lowest PDR.

Hence, it is finally concluded that as the count of nodes increases from 5 to 15 to 25 to 35 to 45, then different protocols performs like this as described below:

a) AODV: PDR first increases from 5 to 15 nodes, then decreases from 15 to 25 nodes, then increases from 25 to 35 nodes and finally decreases as count of nodes increases from 35 to 45.

b) BELLMON-FORD: PDR first increases from 5 to 15 nodes, then decreases from 15 to 25 nodes, then increases from 25 to 35 nodes and finally decreases as count of nodes increases from 35 to 45.

c) DSR: PDR first increases from 5 to 15 nodes, then decreases from 15 to 25 nodes, again increases from 25 to 35 nodes and finally decreases as count of nodes increases from 35 to 45.

d) DYMO: PDR first increases from 5 to 15 nodes, then decreases from 15 to 25 nodes, again increases from 25 to 35 nodes and finally remains almost the same as count of nodes increases from 35 to 45.

e) OLSR: PDR first increases from 5 to 15 nodes, then decreases from 15 to 25 nodes, remains almost the same from 25 to 35 and finally decreases as count of nodes increases from 35 to 45.

f) ZRP: PDR first increases from 5 to 15 nodes, then decreases from 15 to 25 nodes, again decreases from 25 to 35 and finally decreases as count of nodes increases from 35 to 45.

Hence, for Average PDR, as count of nodes increases at a constant mobility of 10m/s, different protocols perform in this order:

1. ZRP (96.24%) performs best
2. DSR (92.82667%)
3. BELLMON-FORD (90.13333%)
4. AODV (82.75333%)
5. DYMO (77.17333) performs poorly
6. OLSR (76.94667) performs very poorly

**Scenario 2:** It is configured to analyze various parameters i.e. End to End Delay, Throughput, Packet dropped, PDR of different protocols based on scalability of network. A 1,500×1,500 m² network having varied Mobility of nodes as 10, 20, 30, 40 and 50 m/s with a Constant Count of nodes at 25 with CBR application running for routing protocols namely AODV, Bellmon-Ford, DSR, Dymo, OLSR as well as ZRP. Pause time selected here is 10 seconds. The packet size is set to 512 bytes along with 3000 packets sent. Six types of MANET routing protocols are employed in the network and their performances are evaluated for the different-sized networks based on the analysis of the performance metrics.

Now, we will analyze the two cases one by one: first is based on count of nodes and second is based on mobility of nodes.

**3.8.2 Mobility of Nodes:** Here, under a fixed Count of Node (Number) i.e. 25 are considered. Mobility of Nodes taken here is 10m/s, 20m/s, 30m/s, 40m/s, and 50m/s. Therefore, there are 5 scenarios here which are discussed below one by one.
Table 3.6: Description of the Experimental Categories 2 [12] (Mobility)

<table>
<thead>
<tr>
<th>Simulation parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protocols</td>
<td>AODV, Bellmon-Ford, DSR, Dymo, OLSR, ZRP</td>
</tr>
<tr>
<td>Simulation time</td>
<td>1000 s</td>
</tr>
<tr>
<td>Area</td>
<td>1500 X1500 m²</td>
</tr>
<tr>
<td>Count of nodes</td>
<td>25</td>
</tr>
<tr>
<td>MAC Protocol</td>
<td>802.11</td>
</tr>
<tr>
<td>Mobility model</td>
<td>Random Waypoint</td>
</tr>
<tr>
<td>Node placement</td>
<td>Random</td>
</tr>
<tr>
<td>Speed</td>
<td>10 m/s, 20 m/s, 30 m/s, 40 m/s, 50 m/s,</td>
</tr>
<tr>
<td>Pause time</td>
<td>30 s</td>
</tr>
<tr>
<td>Traffic type</td>
<td>CBR</td>
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<tr>
<td>Packet Size</td>
<td>512 bytes</td>
</tr>
<tr>
<td>Total count of packets sent</td>
<td>3000</td>
</tr>
<tr>
<td>Parameter Compared</td>
<td>End to End Delay, Throughput, Packet dropped, PDR</td>
</tr>
</tbody>
</table>

3.8.2.1 End-to-End Delay: This parameter, measured in seconds, should be as low as possible for successful transmission of data packets injected by origin node towards destination node. Now, comparison of different protocols will be done for different Mobility of nodes one by one.

Table 3.7: End-to-End Delay (seconds) Vs Mobility of nodes

<table>
<thead>
<tr>
<th>Routing Protocols</th>
<th>Mobility of Nodes (m/s)</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
<td>20</td>
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<tr>
<td>AODV</td>
<td>0.174745</td>
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<tr>
<td>BELLMON FORD</td>
<td>0.092853</td>
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</tr>
<tr>
<td>DYMO</td>
<td>0.197388</td>
<td>0.223468</td>
</tr>
<tr>
<td>OLSR</td>
<td>0.109061</td>
<td>0.087211</td>
</tr>
<tr>
<td>ZRP</td>
<td>3.927347</td>
<td>0.729417</td>
</tr>
<tr>
<td>DSR</td>
<td>2.287029</td>
<td>0.572978</td>
</tr>
</tbody>
</table>
1. **Mobility of nodes taken is 10m/s**: For constant count of nodes i.e.25, these different protocols exhibits varied results. Here, for Mobility of nodes at 10m/s, End-to-End Delay reported for AODV is 0.174745s, for BELLMON-FORD is 0.092853s, for DYMO is 0.197388s, for OLSR is 0.109061s, for ZRP is 3.927347s, and for DSR is 2.287029s. Hence, for this scenario, End-to-End Delay for BELLMON-FORD is lowest, for OLSR is 2nd lowest, for AODV is 3rd lowest, for DYMO is 4th lowest, for DSR is 5th lowest but ZRP perform poorly with highest End-to-End Delay.

2. **Mobility of nodes taken is 20m/s**: For constant count of nodes i.e.25, these different protocols exhibits varied results. Here, for Mobility of nodes at 20m/s, End-to-End Delay reported for AODV is 0.170539s, for BELLMON-FORD is 0.054391s, for DYMO is 0.223468s, for OLSR is 0.087211s, for ZRP is 0.729417s, and for DSR is 0.572978s. Hence, for this scenario, End-to-End Delay for BELLMON-FORD is lowest, for OLSR is 2nd lowest, for AODV is 3rd lowest, for DYMO is 4th lowest, for DSR is 5th lowest but ZRP perform poorly with highest End-to-End Delay.

3. **Mobility of nodes taken is 30m/s**: For constant count of nodes i.e.25, these different protocols exhibits varied results. Here, for Mobility of nodes at 30m/s, End-to-End Delay reported for AODV is 0.222161s, for BELLMON-FORD is 0.05859s, for DYMO is 0.33504s, for OLSR is 0.084184s, for ZRP is 0.058088s, and for DSR is 0.44787s. Hence, for this scenario, End-to-End Delay for BELLMON-FORD as well as ZRP is lowest, for OLSR is 2nd lowest, for AODV is 3rd lowest, for DYMO is 4th lowest, for DSR perform poorly with highest End-to-End Delay.
4. **Mobility of nodes taken is 40m/s**: For constant count of nodes i.e.25, these different protocols exhibits varied results. Here, for Mobility of nodes at 40m/s, End-to-End Delay reported for AODV is 0.161635s, for BELLMON-FORD is 0.053407s, for DYMO is 0.296365s, for OLSR is 0.071042s, for ZRP is 0.050652s, and for DSR is 0.59514s. Hence, for this scenario, End-to-End Delay for BELLMON-FORD as well as ZRP is lowest, for OLSR is 2nd lowest, for AODV is 3rd lowest, for DYMO is 4th lowest, for DSR is poorly with highest End-to-End Delay.

5. **Mobility of nodes taken is 50m/s**: For constant count of nodes i.e.25, these different protocols exhibits varied results. Here, for Mobility of nodes at 50m/s, End-to-End Delay reported for AODV is 0.227042s, for BELLMON-FORD is 0.04864s, for DYMO is 0.309126s, for OLSR is 0.070824s, for ZRP is 0.050652s, and for DSR is 0.3994s. Hence, for this scenario, End-to-End Delay for BELLMON-FORD is lowest, for ZRP is 2nd lowest, for OLSR is 3rd lowest, for AODV is 4th lowest, for DYMO is 5th lowest but DSR perform poorly with highest End-to-End Delay.

Hence, it is finally concluded that as the Mobility of nodes increases from 10m/s to 20m/s to 30m/s to 40m/s to 50m/s, then different protocols performs like this as described below:

- **a) AODV**: End-to-End Delay first decreases from 10 to 20m/s, then increases from 20 to 30 m/s, again decreases from 30 to 40 m/s, and then finally increases as Mobility of nodes increases from 40 to 50 m/s.

- **b) BELLMON-FORD**: End-to-End Delay first decreases from 10 to 20m/s, then remains constant from 20 to 30 m/s as well as from 30 to 40 m/s, and then finally decreases as Mobility of nodes increases from 40 to 50 m/s.

- **c) DSR**: End-to-End Delay first increases from 10 to 20m/s, then decreases from 20 to 30 m/s, again increases from 30 to 40 m/s, and then finally decreases as Mobility of nodes increases from 40 to 50 m/s.

- **d) DYMO**: End-to-End Delay first increases from 10 to 20m/s, then again increases from 20 to 30 m/s, then decreases from 30 to 40 m/s, and then finally increases as Mobility of nodes increases from 40 to 50 m/s.

- **e) OLSR**: End-to-End Delay first decreases from 10 to 20m/s, then remains constant from 20 to 30 m/s, from 30 to 40 m/s, and then finally from 40 to 50 m/s.

- **f) ZRP**: End-to-End Delay first decreases from 10 to 20m/s, then decreases from 20 to 30 m/s, remains constant from 30 to 40 m/s, and then finally decreases as Mobility of nodes increases from 40 to 50 m/s.
Hence, for Average End-to-End Delay, as Mobility of nodes increases at a constant Count of Nodes i.e.25, different protocols performs in this order:

1. BELLMON-FORD performs best (0.061596s)
2. OLSR (0.084464s)
3. AODV (0.191224s)
4. DYMO (0.272277s)
5. DSR performs poorly (0.860483s)
6. ZRP performs very poorly (0.964594s)

Graph 3.10: Bar Graph End-to-End Delay Vs Mobility of nodes

3.8.2.2 Throughput: This parameter, measured in kilobit/second, should be as high as possible for successful transmission of data packets injected by origin node towards destination node. Now, comparison of different protocols will be done for different Mobility of nodes one by one.

Table 3.8: Throughput (Kb/s) Vs Mobility of nodes

<table>
<thead>
<tr>
<th>Routing Protocols</th>
<th>Mobility of Nodes (m/s)</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>AODV</td>
<td>2290.035</td>
<td>2145.321</td>
</tr>
<tr>
<td>BELLMON FORD</td>
<td>789.216</td>
<td>1043</td>
</tr>
<tr>
<td>DYMO</td>
<td>2780.879</td>
<td>2456.743</td>
</tr>
<tr>
<td>OLSR</td>
<td>1105.131</td>
<td>1459.44</td>
</tr>
<tr>
<td>ZRP</td>
<td>1039.344</td>
<td>801.3454</td>
</tr>
<tr>
<td>DSR</td>
<td>1601.215</td>
<td>1111.539</td>
</tr>
</tbody>
</table>
1. Mobility of nodes taken is 10m/s: For constant count of nodes i.e.25, these different protocols exhibit varied results. Here, for Mobility of nodes at 10m/s, Throughput (Kb/sec) reported for AODV is 2290.035, for BELLMON-FORD is 789.216, for DSR is 1601.215, for DYMO is 2780.879, for OLSR is 1105.131, and for ZRP is 1039.344. Hence, for this scenario, Throughput for DYMO is highest, for AODV is 2nd highest, for DSR is 3rd highest, for OLSR is 4th highest, for ZRP is 5th highest but BELLMON-FORD performs poorly with lowest Throughput.

2. Mobility of nodes taken is 20m/s: For constant count of nodes i.e.25, these different protocols exhibit varied results. Here, for Mobility of nodes at 20m/s, Throughput (Kb/sec) reported for AODV is 2145.321, for BELLMON-FORD is 1043, for DSR is 1111.539, for DYMO is 2456.743, for OLSR is 1459.44, and for ZRP is 801.3454. Hence, for this scenario, Throughput for DYMO is highest, for AODV is 2nd highest, for OLSR is 3rd highest, for DSR is 4th highest, for BELLMON-FORD is 5th highest but ZRP perform poorly with lowest Throughput.

3. Mobility of nodes taken is 30m/s: For constant count of nodes i.e.25, these different protocols exhibit varied results. Here, for Mobility of nodes at 30m/s, Throughput (Kb/sec) reported for AODV is 1710.425, for BELLMON-FORD is 1043, for DSR is 1111.539, for DYMO is 2456.743, for OLSR is 1459.44, and for ZRP is 801.3454. Hence, for this scenario, Throughput for AODV is highest, for DYMO is 2nd highest, for DSR is 3rd highest, for OLSR is 4th highest, for ZRP is 5th highest but BELLMON-FORD performs poorly with lowest Throughput.
4. Mobility of nodes taken is 40m/s: For constant count of nodes i.e.25, these different protocols exhibits varied results. Here, for Mobility of nodes at 40m/s, Throughput (Kb/sec) reported for AODV is 2578.502, for BELLMON-FORD is 773.20118, for DSR is 838.8265, for DYMO is 3419.19, for OLSR is 1043.677, and for ZRP is 756.5475. Hence, for this scenario, Throughput for AODV is highest, for DYMO is 2nd highest, for OLSR is 3rd highest, for DSR is 4th highest, for BELLMON-FORD is 5th highest but ZRP perform poorly with lowest Throughput.

5. Mobility of nodes taken is 50m/s: For constant count of nodes i.e.25, these different protocols exhibits varied results. Here, for Mobility of nodes at 50m/s, Throughput (Kb/sec) reported for AODV is 1902.487, for BELLMON-FORD is 502.6809, for DSR is 581.8530, for DYMO is 2219.722, for OLSR is 625.6242, and for ZRP is 398.3752. Hence, for this scenario, Throughput for DYMO is highest, for AODV is 2nd highest, for OLSR is 3rd highest, for DSR is 4th highest, for BELLMON-FORD is 5th highest but ZRP perform poorly with lowest Throughput. Hence, it is finally concluded that as the Mobility of nodes increases from 10m/s to 20m/s to 30m/s to 40m/s to 50m/s, then different protocols performs like this as described below:

a) AODV: Throughput first decreases from 10 to 20m/s, again decreases from 20 to 30 m/s, then increases from 30 to 40 m/s, and then finally decreases as Mobility of nodes increases from 40 to 50 m/s.

b) BELLMON-FORD: Throughput first increases from 10 to 20m/s, then decreases from 20 to 30 m/s, increases from 30 to 40 m/s, and then finally decreases as Mobility of nodes increases from 40 to 50 m/s.

c) DSR: Throughput first decreases from 10 to 20m/s, then decreases from 20 to 30 m/s, again decreases from 30 to 40 m/s, and then finally decreases as Mobility of nodes increases from 40 to 50 m/s.

d) DYMO: Throughput first decreases from 10 to 20m/s, then decreases from 20 to 30 m/s, again decreases from 30 to 40 m/s, and then finally decreases as Mobility of nodes increases from 40 to 50 m/s.

e) OLSR: Throughput first increases from 10 to 20m/s, then decreases from 20 to 30 m/s, increases from 30 to 40 m/s, and then finally decreases as Mobility of nodes increases from 40 to 50 m/s.

f) ZRP: Throughput first decreases from 10 to 20m/s, then decreases from 20 to 30 m/s, increases from 30 to 40 m/s, and then finally decreases as Mobility of nodes increases from 40 to 50 m/s.
Hence, for Average Throughput, as Mobility of nodes increases at a constant Count of Nodes i.e.25, different protocols perform in this order:

1. DYMO performs best (2308.597 kb/s)
2. AODV (2125.354kb/s)
3. DSR (1037.258 kb/s)
4. OLSR (1016.566 kb/s)
5. BELLMON-FORD performs poorly (725.9359 kb/s)
6. ZRP performs very poorly (716.3294 kb/s)

Graph 3.12: Bar Graph of Throughput (Kb/sec) Vs Mobility of nodes

3.8.2.3 Packet Dropped: This parameter, measured in number of packets dropped, should be as low as possible for successful transmission of data packets injected by origin node towards destination node. Now, comparison of different protocols will be done for different count of nodes one by one.

Table 3.9: Packet Dropped Vs Count of nodes

<table>
<thead>
<tr>
<th>Routing Protocols</th>
<th>Mobility of Nodes (m/s)</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>AODV</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>136</td>
<td>409</td>
</tr>
<tr>
<td>BELLMON-FORD</td>
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<tr>
<td></td>
<td>31</td>
<td>7</td>
</tr>
<tr>
<td>DYMO</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>415</td>
<td>544</td>
</tr>
<tr>
<td>OLSR</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>436</td>
<td>632</td>
</tr>
<tr>
<td>ZRP</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>125</td>
</tr>
<tr>
<td>DSR</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>245</td>
</tr>
</tbody>
</table>
1. **Mobility of nodes taken is 10m/s**: For constant count of nodes i.e.25, these different protocols exhibits varied results. Here, for Mobility of nodes at 10m/s, Packet Dropped reported for AODV is 136, for BELLMON-FORD is 31, for DYMO is 415, for OLSR is 436, for ZRP is 8, and for DSR is 3. Hence, for this scenario, Packet Dropped for DSR is lowest, for ZRP is 2nd lowest, for BELLMON-FORD is 3rd lowest, for AODV is 4th lowest, for DYMO is 5th lowest but OLSR has highest Packet Dropped. Hence, both DYMO as well OLSR performs poorly.

2. **Mobility of nodes taken is 20m/s**: For constant count of nodes i.e.25, these different protocols exhibits varied results. Here, for Mobility of nodes at 20m/s, Packet Dropped reported for AODV is 409, for BELLMON-FORD is 7, for DYMO is 544, for OLSR is 632, for ZRP is 125, and for DSR is 245. Hence, for this scenario, Packet Dropped for BELLMON-FORD is lowest, for ZRP is 2nd lowest, for DSR is 3rd lowest, for AODV is 4th lowest, for DYMO is 5th lowest but OLSR perform poorly with highest Packet Dropped.

3. **Mobility of nodes taken is 30m/s**: For constant count of nodes i.e.25, these different protocols exhibits varied results. Here, for Mobility of nodes at 30m/s, Packet Dropped reported for AODV is 391, for BELLMON-FORD is 29, for DYMO is 540, for OLSR is 541, for ZRP is 128, and for DSR is 314. Hence, for this scenario, Packet Dropped for BELLMON-FORD is lowest, for ZRP is 2nd lowest, for DSR is 3rd lowest, for AODV is 4th lowest, for DSR AS well as DYMO performs poorly with highest Packet Dropped.

4. **Mobility of nodes taken is 40m/s**: For constant count of nodes i.e.25, these different protocols exhibits varied results. Here, for Mobility of nodes at 40m/s, Packet Dropped reported for AODV is 454, for BELLMON-FORD is 20, for DYMO is 646, for OLSR is 728,
for ZRP is 74, and for DSR is 204. Hence, for this scenario, Packet Dropped for BELLMON-FORD is lowest, for ZRP is 2nd lowest, for DSR is 3rd lowest, for AODV is 4th lowest, for DYMO is 5th lowest and OLSR performs poorly with highest Packet Dropped.

5. Mobility of nodes taken is 50m/s: For constant count of nodes i.e.25, these different protocols exhibits varied results. Here, for Mobility of nodes at 50m/s, Packet Dropped reported for AODV is 407, for BELLMON-FORD is 18, for DYMO is 36, for OLSR is 793, for ZRP is 145, and for DSR is 280. Hence, for this scenario, Packet Dropped for BELLMON-FORD is lowest, for DYMO is 2nd lowest, for ZRP is 3rd lowest, for DSR is 4th lowest, for AODV is 5th lowest but OLSR perform poorly with highest Packet Dropped.

Hence, it is finally concluded that as the Mobility of nodes increases from 10m/s to 20m/s to 30m/s to 40m/s to 50m/s, then different protocols performs like this as described below:

a) AODV: Packet Dropped first increases from 10 to 20m/s, then decreases slightly from 20 to 30 m/s, increases from 30 to 40 m/s, and then finally decreases as Mobility of nodes increases from 40 to 50 m/s.

b) BELLMON-FORD: Packet Dropped first decreases from 10 to 20m/s, then increases from 20 to 30 m/s, then decreases from 30 to 40 m/s, and then finally decreases slightly as Mobility of nodes increases from 40 to 50 m/s.

c) DSR: Packet Dropped first increases from 10 to 20m/s, then again increases from 20 to 30 m/s, then decreases from 30 to 40 m/s, and then finally increases as Mobility of nodes increases from 40 to 50 m/s.

d) DYMO: Packet Dropped first increases from 10 to 20m/s, then remains constant from 20 to 30 m/s, then decreases from 30 to 40 m/s, and then finally increases as Mobility of nodes increases from 40 to 50 m/s.

e) OLSR: Packet Dropped first increases from 10 to 20m/s, then decreases from 20 to 30 m/s, then increases from 30 to 40 m/s, and then finally increases again from 40 to 50 m/s.

f) ZRP: Packet Dropped first increases from 10 to 20m/s, then remains constant from 20 to 30 m/s, then decreases from 30 to 40 m/s, and then finally increases as Mobility of nodes increases from 40 to 50 m/s.

Hence, for Packet Dropped, as Mobility of nodes increases at a constant Count of Nodes i.e.25, different protocols perform in this order:

1. BELLMON-FORD performs best (21)
2. ZRP performs poorly (96)
3. DSR performs very poorly (209.2)
4. AODV (359.4)
5. DYMO (436.2)
6. OLSR (626)

Graph 3.14: Bar Graph of Packet Dropped Vs Count of nodes

3.8.2.4 PDR (Packet Delivery Ratio): This parameter, measured in percentage, should be as high as possible for successful transmission of data packets injected by origin node towards destination node. Now, comparison of different protocols will be done for different count of nodes one by one.

Table 3.10: PDR Vs Mobility of nodes

<table>
<thead>
<tr>
<th>Routing Protocols</th>
<th>Mobility of Nodes (m/s)</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>AODV</td>
<td>95.46667</td>
<td>86.36667</td>
</tr>
<tr>
<td>BELLMON FORD</td>
<td>98.96667</td>
<td>99.76667</td>
</tr>
<tr>
<td>DYMO</td>
<td>86.16667</td>
<td>81.86667</td>
</tr>
<tr>
<td>OLSR</td>
<td>85.46667</td>
<td>78.93333</td>
</tr>
<tr>
<td>ZRP</td>
<td>99.73333</td>
<td>95.83333</td>
</tr>
<tr>
<td>DSR</td>
<td>99.9</td>
<td>91.83333</td>
</tr>
</tbody>
</table>
1. **Mobility of nodes taken is 10m/s**: For constant count of nodes i.e.25, these different protocols exhibits varied results. Here, for Mobility of nodes at 10m/s, PDR reported for AODV is 95.466675%, for BELLMON-FORD is 98.96667%, for DSR is 99.9999%, for DYMO is 86.16667, for OLSR is 85.46667, and for ZRP is 99.73333. Hence, for this scenario, PDR for DSR is highest, for ZRP is 2nd highest, for BELLMON-FORD is 3rd highest, for AODV is 4th highest, for DYMO is 5th highest but OLSR performs poorly with lowest PDR.

2. **Mobility of nodes taken is 20m/s**: For constant count of nodes i.e.25, these different protocols exhibits varied results. Here, for Mobility of nodes at 20m/s, PDR reported for AODV is 86.36667, for BELLMON-FORD is 99.76667, for DSR is 91.83333, for DYMO is 81.86667, for OLSR is 78.93333, and for ZRP is 95.83333. Hence, for this scenario, PDR for BELLMON-FORD is highest, for ZRP is 2nd highest, for DSR is 3rd highest, for AODV is 4th highest, for DYMO is 5th highest but OLSR performs poorly with lowest PDR.

3. **Mobility of nodes taken is 30m/s**: For constant count of nodes i.e.25, these different protocols exhibits varied results. Here, for Mobility of nodes at 30m/s, PDR reported for AODV is 86.96667, for BELLMON-FORD is 99.03333, for DSR is 89.53333, for DYMO is 82.00000, for OLSR is 81.96667, and for ZRP is 95.73333. Hence, for this scenario, PDR for BELLMON-FORD is highest, for ZRP is 2nd highest, for DSR is 3rd highest, for AODV is 4th highest, for DYMO is 5th highest but OLSR performs poorly with lowest PDR.

4. **Mobility of nodes taken is 40m/s**: For constant count of nodes i.e.25, these different protocols exhibits varied results. Here, for Mobility of nodes at 40m/s, PDR reported for
AODV is 84.86667, for BELLMON-FORD is 99.33333, for DSR is 93.2, for DYMO is 78.46667, for OLSR is 75.73333, and for ZRP is 97.53333. Hence, for this scenario, PDR for BELLMON-FORD is highest, for ZRP is 2nd highest, for DSR is 3rd highest, for AODV is 4th highest, for DYMO is 5th highest but OLSR performs poorly with lowest PDR.

5. Mobility of nodes taken is 50m/s: For constant count of nodes i.e.25, these different protocols exhibits varied results. Here, for Mobility of nodes at 50m/s, PDR reported for AODV is 86.43333, for BELLMON-FORD is 99.4, for DSR is 90.66667, for DYMO is 98.8, for OLSR is 73.56667, and for ZRP is 95.16667. Hence, for this scenario, PDR for BELLMON-FORD is highest, for DYMO is 2nd highest, for ZRP is 3rd highest, for DSR is 4th highest, for AODV is 5th highest but OLSR performs poorly with lowest PDR.

Hence, it is finally concluded that as the Mobility of nodes increases from 10m/s to 20m/s to 30m/s to 40m/s to 50m/s, then different protocols performs like this as described below:

a) AODV: Throughput first decreases from 10 to 20m/s, remains constant from 20 to 30 m/s, again decreases from 30 to 40 m/s, and then finally increases as Mobility of nodes increases from 40 to 50 m/s.

b) BELLMON-FORD: Throughput first increases from 10 to 20m/s, then decreases slightly from 20 to 30 m/s, increases slightly from 30 to 40 m/s, and then finally increases slightly as Mobility of nodes increases from 40 to 50 m/s.

c) DSR: Throughput first decreases from 10 to 20m/s, then further decreases from 20 to 30 m/s, then increases from 30 to 40 m/s, and then finally decreases as Mobility of nodes increases from 40 to 50 m/s.

d) DYMO: Throughput first decreases from 10 to 20m/s, then increases slightly from 20 to 30 m/s, again decreases from 30 to 40 m/s, and then finally decreases as Mobility of nodes increases from 40 to 50 m/s.

e) OLSR: Throughput first decreases from 10 to 20m/s, then increases from 20 to 30 m/s, decreases from 30 to 40 m/s, and then finally decreases further as Mobility of nodes increases from 40 to 50 m/s.

f) ZRP: Throughput first decreases from 10 to 20m/s, then remains constant from 20 to 30 m/s, then increases from 30 to 40 m/s, and then finally decreases as Mobility of nodes increases from 40 to 50 m/s.

Hence, for Average PDR, as Mobility of nodes increases at a constant Count of Nodes i.e.25, different protocols perform in this order:
1. BELLMON-FORD performs best (99.3%)
2. ZRP (96.8%)
3. DSR (93.02667%)
4. AODV (88.02%)
5. DYMO performs poorly (85.46%)
6. OLSR performs very poorly (79.13333%)

Graph 3.16: Bar Graph of PDR Vs Mobility of nodes

3.9 Summary: Here, varied Routing Protocol of MANETs have been discussed extensively along with their responsibilities, major challenges faced by them, main requirements of a routing protocol, their varied Taxonomies. Also, Comparative Analysis along with Evaluation of Various Existing Routing Protocols for two parameters namely Count of Nodes (Number of Nodes) as well as of Mobility of Nodes on four Simulation Metrics namely End-to-End Delay (seconds), Throughput (Kb/second), Packet Dropped (Number), and PDR (%) using Qualnet as Simulator is carried out. Here, we have taken six protocols namely AODV, DSR, BELLMON-FORD, DYMO, OLSR, and ZRP for carrying our research. Two possibilities arise here based upon: First is based on Count (Number) of Nodes (5, 15, 25, 35, and 45) where, under a constant mobility of 10m/s is considered For these five scenarios, varied protocols performance, after simulation on Qualnet and exhaustive analysis, is found in this order: ZRP performs best, AODV, BELLMON-FORD, DSR, OLSR and DYMO. Second is based on Mobility of nodes where Count of Nodes is fixed at 25 which is a mid-
sized MANET. The Mobility of nodes is changed at 10 m/s, 20 m/s, 30 m/s, 40 m/s, and 50 m/s which is quite fast movement. For these five scenarios, varied protocols performance, after simulation on Qualnet and exhaustive analysis, is found in this order: BELLMON-FORD performs best, AODV, DYMO, ZRP, DSR, and OLSR. However, it is also established from simulation results of varied routing protocols that all of them exhibit different results under uniform MANET’s traffic environment, scenario and application environment.