

## COMPARATIVE ANALYSIS OF MANET ROUTING PROTOCOLS UNDER DYNAMIC TRAFFIC CONDITIONS

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### Abstract

Mobile Ad Hoc Networks (MANETs) are collection of nodes without static infrastructure and rely on cooperative routing among mobile nodes. It makes routing performance a critical factor in overall network efficiency. This study presents a comparison of four MANET routing protocols i.e. DSDV, OLSR, FSR and ZRP. A mobile network of 30 nodes was developed under controlled mobility and wireless communication settings in NS2. Performance analysis was conducted under two traffic scenarios. (1) Communication without background traffic and (2) communication with additional competing flows to simulate real congestion. Simulation results show that packet delivery reached approximately 94% in uncongested network, whereas, declined to around 78–90% under back-ground traffic. Throughput values varied between nearly 480 kbps in low-load conditions and about 340kbps during background traffic. Average delay increased from nearly 130ms to 250ms with rising background traffic. Routing overhead also increased notably in congested scenarios. The findings indicate that proactive routing protocols immediate route availability. On the other hand hybrid protocol demonstrates a more balanced trade-off between data delivery and delay. Such insights are very useful for applications such as disaster recovery, military communication and temporary wireless deployments where reliable and infrastructure-less network is required.

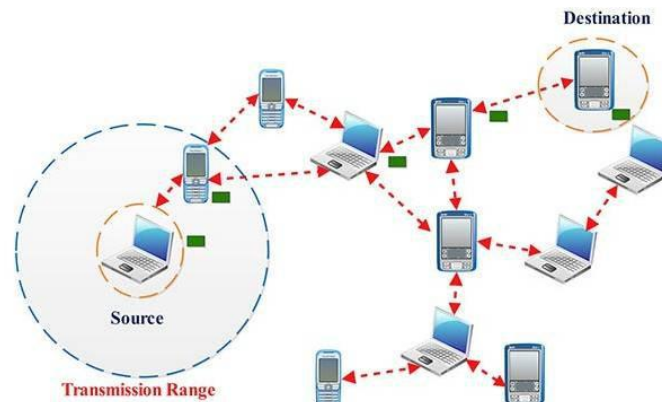
## 1 Introduction

MANETs have emerged as an advanced communication paradigm, where many devices dynamically form a network without relying on any rigid setup. Each node in such a network acts not only as an end-to-end node but also as a data forwarding router. Such a decentralized nature makes MANETs vital for scenarios such as disaster recovery, military operations and temporary communication bases where infrastructure is unavailable. However, the absence of central control and the presence of node portability introduce significant challenges. In particular, maintaining efficient routing is a challenge. The concept of MANET is shown in Figure 1, where different portable nodes are connected through wireless links. Routing in MANETs is inherently complex due to frequent topology changes, limited bandwidth and shared medium. As nodes move, links may break and re-establish rapidly. This directly impacts the performance of the routing protocol. Therefore, the effectiveness of a MANET depends on how efficient its routing protocol can discover and maintain routes while minimizing overhead (or delay). Over the years, many routing strategies have been proposed, broadly categorized into proactive, reactive and hybrid approaches, each offering different trade-offs between route availability and overhead.

Among proactive routing protocols, Destination Sequenced Distance Vector (DSDV) [1], Optimized Link State Routing (OLSR) [2], and Fisheye State Routing (FSR) [3] maintain routing information

continuously to ensure that routes are readily available when needed. While this approach reduces route discovery delay, it may increase routing overhead, especially in dynamic and congested environments. In contrast, hybrid protocols such as Zone Routing Protocol (ZRP) [4] attempt to balance these trade-offs by combining proactive and reactive mechanisms in order to improve scalability and overall network efficiency. Many studies have evaluated MANET routing protocols; the challenge remains in understanding their behavior under varying traffic conditions, particularly when background traffic introduces congestion. In the real world, networks rarely operate under ideal conditions; instead, multiple simultaneous flows compete for limited resources, affecting packet delivery, delay and throughput. Therefore, it is essential to analyze how routing protocols perform not only in isolated scenarios but also under real traffic loads.

This study presents a comparative evaluation of four MANET routing protocols, i.e. DSDV, OLSR, FSR and ZRP, using a simulation environment. A network of 30 mobile nodes is modeled under controlled mobility and wireless settings in NS2. The performance is examined under two distinct scenarios: one without background traffic and two with additional competing flows to emulate congestion. Key performance metrics including throughput, end-to-end delay, packet delivery ratio and routing overhead are used to assess the simulation behavior.



*Figure 1. MANET example*

## 2 Related Word

The development of proactive routing in MANETs began with the introduction of the DSDV protocol by Perkins and Bhagwat [1]. Their work addressed key limitations of traditional distance-vector routing by incorporation of sequence numbers to ensure loop-free paths and avoid routing inconsistencies. According to authors although DSDV maintains updated topology information through periodic exchanges, it introduces increased control overhead particularly in highly dynamic environments. In order to build proactive routing, the OLSR [2], which introduced the multipoint relay (MPR) mechanism in order to reduce redundant message flooding. It limit retransmissions to selected nodes. OLSR improves scalability while preserves global topology awareness. However, the periodic exchange of control messages can still put large overhead under high mobility. To further enhance scalability the FSR [3] employs feature of graded up-date. In this approach nearby nodes receive frequent updates while distant nodes are updated less. It reduce routing overhead without impact of accuracy. This makes FSR suitable for large-scale networks. A broader comparison of proactive approaches in [4] highlights that such protocols offer minimum route discovery delay due to continuous route availability. Though this leads at the cost of high control traffic. A

comparative study have shown varying performance trends under different network conditions[5]. This work suggest that OLSR performs well in relatively stable environments. However, reactive and hybrid protocols adapt good under increased mobility and traffic load. Similarly, parameter sensitivity analysis in [6] emphasizes that routing performance is mainly influenced by configuration factors such timing interval (in OLSR). Investigations in [7] indicate that FSR achieves competitive throughput due to reduced flooding. DSDV struggles under high mobility even with its simple design. OLSR on the other hand demonstrates strong delay performance but suffers from overhead in dense nodes. In specialized scenarios such as Flying Ad Hoc Networks FSR maintains efficient forward and channel usage. Both DSDV and OLSR experience degradation with rapid topology changes [8].

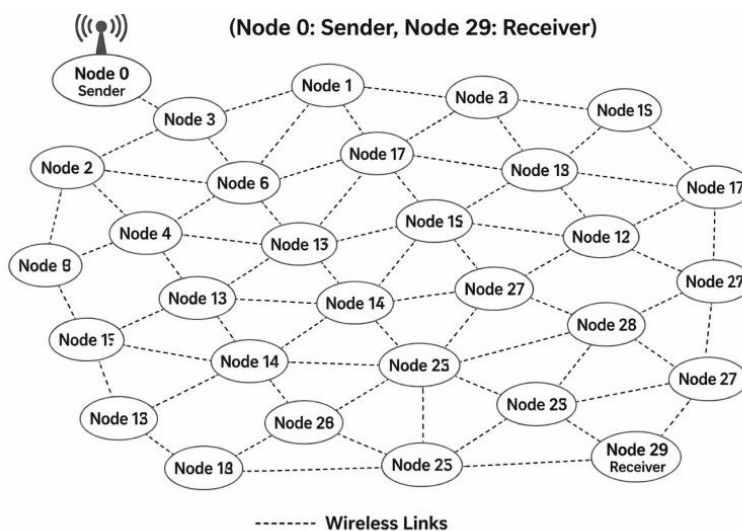
Simulations in [9] confirm that OLSR provides lower end-to-end delay due to immediate route information. DSDV performance declines with the increased mobility. Similar findings in [10] where OLSR is considered as good for delay-sensitive applications. While DSDV shows limited adaption to sudden network variations. Energy focus analysis in [11] further suggests that proactive protocols maintain stable communication under low conditions of node

speed and location, but hybrid approaches offer good efficiency under the same conditions. Other factors such as transmission power and network density also influence MANET routing. In [12], increased transmission power enhance connectivity but adds on interference where OLSR shows good adaptability. Similarly, [13] reports that DSDV maintains stable delay but incurs high overhead, while reactive protocols achieve good throughput in the most cases. QoS analysis in [14] suggest that proactive routing ensure low latency but increases signal overhead. Extension to OLSR with improved relay selection techniques have demonstrated measurable gains in throughput and delay performance [15]. However, the scalability is reported a challenge as in [16]. They also suggest proactive protocols face increased overhead with the network area. Hybrid approaches, particularly ZRP, provide a balanced trade-off between routing overhead and throughput in large scale networks [17]. In addition to this DSDV is shown to perform reliable with moderate mobile nodes but degrades with high node speed and density [18]. Experiment data in [19] indicate that proactive routing can outperform reactive approaches in certain scenarios without background traffic. While extension such as DS-OLSR improve throughput in emergency applications such as disaster [20, 21]. Recent research [22-24] also explore adaptive and intelligent routing approaches to increase performance with dynamic topology. The literature demonstrate extensive evaluation of DSDV, OLSR, FSR, and ZRP under simplified configurations [25-28]. Techniques such as scope updates and relay optimization attempt to reduce overhead but do not fully address with high data traffic performance degradation [31, 32]. The hybrid routing provide a balanced alternative. A limited work

has examined these protocols under both with and without background traffic. Background traffic all the nodes to send and receive data in addition to sender and receiver. This study addresses this gap and evaluate DSDV, OLSR, FSR and ZRP under traffic scenarios of with and without background traffic. A deep analysis on the proposed topology add the state of the art evaluation.

### 3 Simulation Framework and Data Collection

To evaluate the protocols i.e. DSDV, OLSR, FSR and ZRP a detailed simulation configuration was developed in NS-2 simulator. A separate TCL code was written for each protocol to emulate a MANET environment of 30 move-able nodes. The topology used for the simulation is shown in Figure 2 The network configuration including topology, mobility, bandwidth, propagation delay and other parameter values are shown in Table 1. Node 0 and Node 29 were configured as the sender and receiver. They both are used for the calculation of QoS parameters. The simulation for each protocol is repeated 10 times and average values are collected. For that, trace file is saved. The trace file data is too large. Later it is summarized through AWK scripting. Trace data plays an important role in validating the correctness of the simulated network. Due to the large size and complexity of trace files manual analysis is impractical. AWK scripting was employed to automate data extraction. Customized scripts were developed for each protocol to obtain key parameters such as total packets sent, received packets, packet drops, timestamps and control packet counts. These extracted values were then used to compute essential Quality of Service (QoS) metrics, packet delivery ratio, throughput, End-to-End Delay and routing overhead.



*Figure 2. Network topology*

#### 4 Performance Metrics and Simulation Scenarios

The performance of the network was evaluated using four QoS metrics: Packet Delivery Ratio (PDR), throughput, End-to-End delay and routing overhead. PDR measures the reliability of packet transmission, while throughput reflects the successful data delivery rate. End-to-End delay represents the time taken by packets to travel from source to destination which indicate network responsiveness. Routing overhead accounts for the control traffic generated to maintain routing information. Together, these metric provide a comprehensive assessment of network performance in terms of reliability, efficiency, latency and control cost. To analyze protocol behavior under different conditions three scenarios were considered.

##### 4.1 Scenario 1: Communication Without Background Traffic

In this scenario a network of 30 nodes was deployed in a 1000m by 1000m area using the Random Waypoint mobility model. Nodes were allowed to move dynamically forming multi-hop communication paths. Node 0 acted as the sender while Node 29 served as the receiver. The bandwidth was set between 1-5 Mbps, with a simulation time of 300 seconds and

propagation delay of 50 ms. Traffic was generated using Constant Bit Rate (CBR) over UDP. The nodes in the middle act as router and not generate any data.

##### 4.2 Scenario 2: Communication With Background traffic

This scenario introduced additional traffic flows to simulate network congestion. Along with the primary communication between Node 0 and Node 29, other nodes also generated traffic it create competing transmissions. All other parameters remained the same as Scenario 1. This configuration reflects more realistic MANET conditions where multiple nodes communicate simultaneously.

##### 4.3 Scenario 3: Combined Average Performance

This scenario represents an analytical combination of results obtained from the previous two scenarios. Instead of running a separate simulation the average values of QoS metrics were computed to provide an over-all comparison of protocol performance. The results were illustrated using graphical representations such as pie chart, highlighting the contribution of each protocol in terms of throughput, delay, packet delivery ratio and routing overhead.

**Table 1:** *Configuration*

Parameter	Configuration
Bandwidth	1-4 Mbps
Background Traffic	1. Disable, 2.Enabled
Propagation Delay	50 ms
Transport Protocol	TCP
Routing Protocol	DSDV,OLSR,FSR,ZRP
Sending Node	Node 0
Receiving Node	Node 29
Traffic Type	FTP
Area	1000 × 1000 m <sup>2</sup>
Packet Size	512 Bytes
Propagation Model	Two Ray Ground
Speed	1-20 m/s
MAC Protocol	IEEE 802.11a
Number of Nodes	30
Simulation Time	300 s
Interface Queue Type	DropTail
Queue Length	50
CBR Start Time	1 s
Node Configuration	Ad hoc Routing
Mobility Model	Random Waypoint



## 5 Throughput Analysis

In this study, throughput is measured based on the data packets transmitted by Node 0 and successfully received by Node 29. It indicates the ability of the network to sustain continuous communication under vary traffic condition. The evaluation is carried out under two scenarios. Communication without background traffic and communication with additional background traffic.

### 5.1 Throughput Without Background Traffic

Under normal network conditions, where no competing traffic is present, the network remains

**Table 2:** *Throughput without Background traffic*

Protocol	Throughput (kbps)
DSDV	410
OLSR	455
FSR	390

largely un-congested. This allows packets to traverse the network with minimal contention and reduced collision probability, resulting in stable throughput values across all routing protocols. The throughput average results are shown in Figure3(a). The results indicate that throughput is highest when the network operates without congestion. In such conditions, packet retransmissions remain minimal and interface queues are stable and channel access delays are reduced. Consequently, most trans-mitted packets successfully reach the destination.

ZRP

480

As shown in Table 2 the ZRP achieves the highest throughput of 480 kbps, indicates efficient channel utilization and stable packet forwarding. In contrast, FSR records the lowest throughput of 390 kbps reflecting comparative low bandwidth utilization. OLSR also demonstrates strong performance with a throughput of 455 kbps due to its efficient route availability in a contention-free environment. This scenario confirms that the network can maintain high

throughput when operating under low load conditions.

**5.2 Throughput With Background traffic**

In the presence of background traffic multiple nodes generate simultaneous transmissions, leading to increased contention over the shared wireless medium. This introduces congestion and affects overall network performance. It can be seen in Figure 4(a).

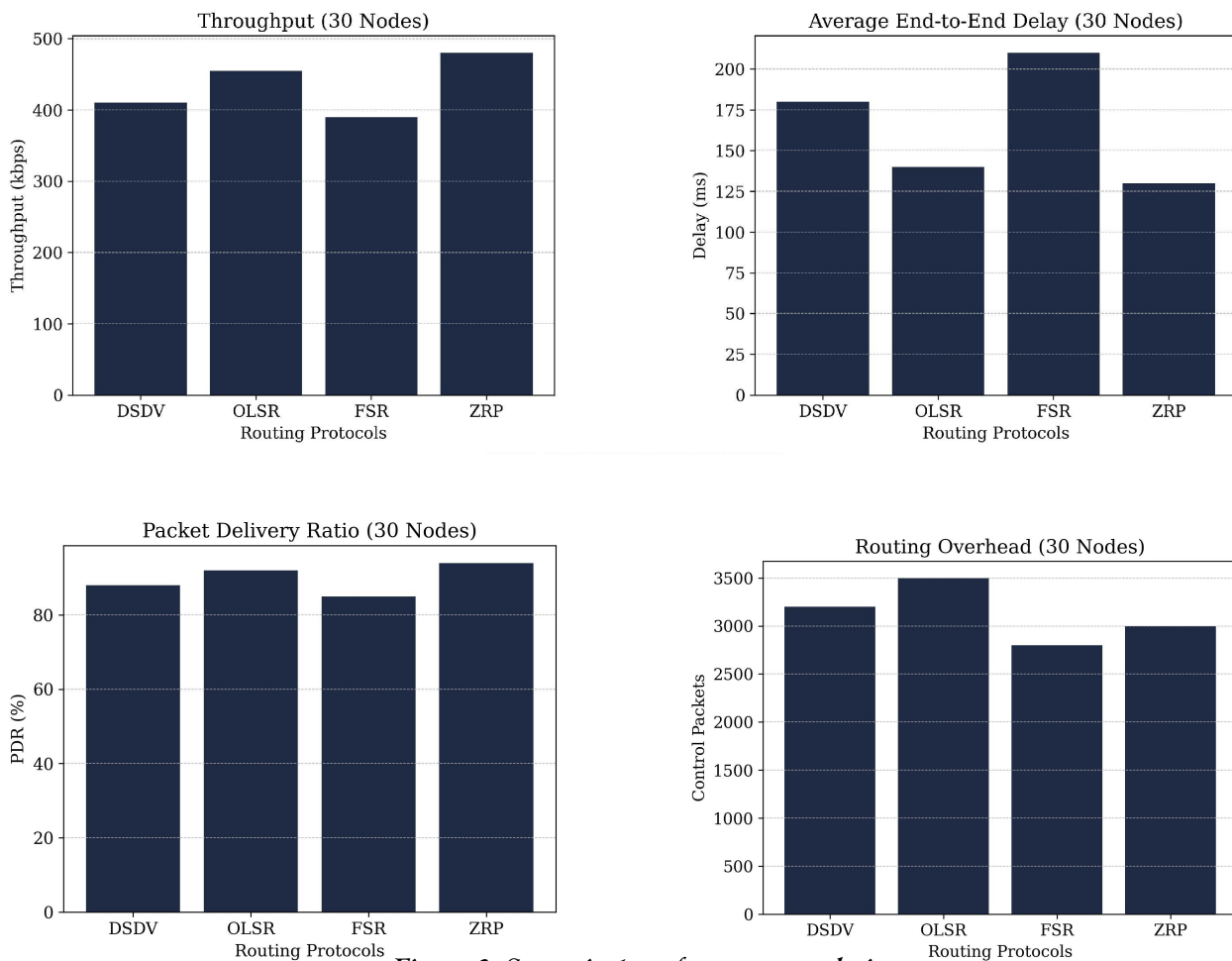


Figure 3. Scenario 1 performance analysis

**Table 3:** *Throughput with Background traffic*

Protocol	Throughput (kbps)
DSDV	360
OLSR	395
FSR	340
ZRP	420

A noticeable reduction in throughput is observed across all protocols due to increased background traffic. The presence of competing flows leads to higher packet collisions, increased queuing delays and additional retransmissions at the MAC layer. Furthermore, contention for channel access among multiple nodes reduces the efficiency of data transmission, while buffer overflow at intermediate nodes may result in packet loss. Despite these challenges the network is still able to sustain moderate throughput levels. ZRP again achieves the highest throughput of 420 kbps, demonstrates better adaptability under congested conditions. OLSR and DSDV achieve throughput values of 395 kbps and

360 kbps. While FSR shows the lowest performance at 340 kbps. Such results are presented in Table 3.

A comparison of both scenarios clearly shows that throughput performance is strongly influenced by network load conditions. The introduction of background traffic increases medium access contention and reduces the availability of transmission opportunities, resulting in throughput degradation. While uncongested networks allow efficient bandwidth utilization, congested environments create transmission bottlenecks that reduce effective data rates. Among all protocols ZRP consistently outperforms others due to its hybrid nature, which balances routing overhead and adaptability. The average throughput summary is shown in Table 4.

**Table 4:** *Comparative Throughput Analysis*

Scenario	Average Throughput
Without Background traffic	High
With Background traffic	Reduced

## 6 End-to-End Delay Analysis

End-to-End Delay represents the total time required for a data packet to travel from the source node (Node 0) to the destination node (Node 29). It includes all possible delays of transmission from Node 0 to Node 29. Delays are processing delay, queuing delay, propagation delay and transmission delay. It also include re-transmission delay caused by packet

collisions. In ad hoc networks delay is a critical QoS metric for emergency applications.

**6.1 End-to-End Delay Without Background traffic**  
Figure 3(b) illustrates the delay performance under Scenario-1 network conditions where no background traffic. In Scenario-1 the wireless medium remains relatively ideal for transmission. It allows packets to traverse multi-hop routes with minimal interference and also saves buffer space.

**Table 5:** *End-to-End Delay without Background traffic*

Protocol	Delay (ms)
DSDV	180
OLSR	140
DSR	210

The obtained results show that delay remain low across all protocols under Scenario-1 conditions. Due to minimal channel contention the packets experience short waiting time and few retransmissions, while, routing paths remains stable. As shown in Table 5, ZRP reach the lowest delay of 130ms, reflecting efficient packet forwards and minimum buffering. In contrary, FSRs data show the highest delay of 210ms, which means high latency. DSDV and OLSR reach moderate delay values (i.e. 180ms and 140ms), which are acceptable for MANET. The Scenario-1 demonstrates that average delay remains stable when Nodes 1 to 28 are configured as forwarding.

### 6.2 End-to-End Delay With Background traffic

Figure 4(b) presents the delay performance when background traffic is introduced for the Nodes 1 to 28. In Scenario-2 all nodes transmit data simultaneously result in increased competition for channel access and high network congestion. But our focus is to monitor only Node 0 and Node 29. In Scenario-2 a noticeable increase in delay is observed across all protocols due traffic generators (Node 1 to 28). Packets waits long

times in queues. For that, increased retransmission attempts and additional latency caused by background traffic. Buffer overflow at intermediate Nodes 1 to 28 also contribute to delays and packet loss for Node 0 and 29. Despite these challenges, ZRP continues to maintain the lower propagation delay of 175ms indicate better adaptability under background traffic (Table 6). FSR shows the high delay of 260ms, while DSDV and OLSR achieve delay values of 230ms and 190ms. The Scenario-2 highlight the impact of background traffic on network responsiveness and delay performance.

A analysis of Scenario-1 and Scenario-2 highlights the direct influence of background traffic on end-to-end delay (see Table 7). The presence of additional traffic flows increases channel occupancy causes packets to wait long before transmission. This results in higher queuing delays and increased contention, ultimately leads to greater end-to-end latency. The comparison confirms that delay performance is not only dependent on routing efficiency but is also significantly affected by network traffic conditions.

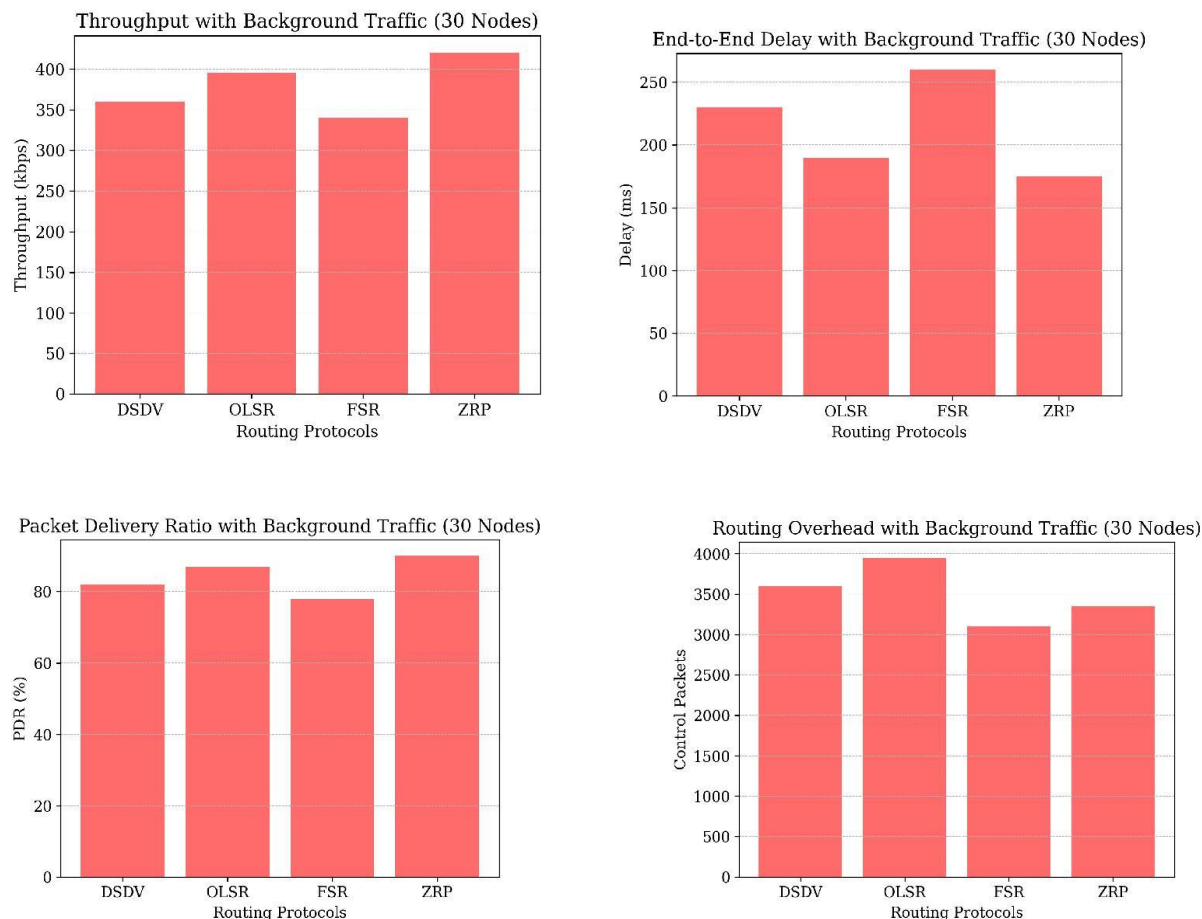


Figure 4. Performance comparison based on Scenario 2

Table 6: End-to-End Delay with Background Traffic

Protocol	Delay (ms)
DSDV	230
OLSR	190
FSR	260
ZRP	175

Table 7: Comparative Delay Analysis

Scenario	Average Delay Trend
Without Background Traffic	Lower delay
With Background Traffic	Higher delay

### 7 PDR Analysis

PDR is a key performance metric used to evaluate the reliability of data transmission in a network. It represents the percentage of data packets successfully received at the destination node (Node 29) compared

to the total number of packets transmitted by the source node (Node 0). This metric reflects how effectively the network maintains communication in the presence of mobility, interference and varying traffic conditions. The PDR performance of DSDV,

OLSR, FSR and ZRP is analyzed under two scenarios: communication without background traffic and communication with additional background traffic.

### 7.1 PDR Without Background Traffic

Figure 3(c) illustrates the packet delivery performance under normal network conditions where no additional traffic flows are present. In this scenario, the wireless medium remains largely uncongested, allowing packets to travel across multi-hop paths with minimal interference and reduced collision probability. The results indicate that packet delivery remains consistently high across all protocols in the absence of congestion. Since only primary traffic flows

**Table 8:** *PDR without Background Traffic*

Protocol	PDR (%)
DSDV	88
OLSR	92
FSR	85
ZRP	94

### 7.2 PDR With Background Traffic

Figure 4(c) presents the packet delivery performance when additional background traffic is introduced. In this scenario multiple nodes transmit data simultaneously that lead to congestion and increased competition for channel access. A reduction in PDR is observed across all protocols due to increased network load (see Table 9). The presence of background traffic raises the probability of packet collisions and leads to higher queuing delays. As interface buffers become saturated, packets arrive at full queues are dropped and retransmission attempts increase. In addition the mobility combined with congestion may delay route updates. Further it affects packet forwarding efficiency. Despite these challenges, the

**Table 9:** *PDR with Background Traffic*

Protocol	PDR (%)
DSDV	82
OLSR	87
FSR	78

are active, the probability of packet collision at the MAC layer is reduced, and retransmission attempts are minimal. As a result, packets experience limited buffering delay and are delivered successfully. Among the evaluated protocols as presented in Table 8 ZRP achieves the highest PDR of 94% demonstrate efficient routing and stable communication. OLSR follows with a PDR of 92%, while DSDV records 88%. FSR shows comparatively lower performance with a PDR of 85%, which may be attributed to its update mechanism under mobility conditions. This scenario confirms that packet delivery performance remains strong in uncongested network environments.

protocols maintain acceptable delivery performance. As of Table 9 ZRP again achieves the highest PDR of 90%, followed by OLSR with 87% and DSDV with 82%. FSR records the lowest PDR of 78% indicates high sensitivity to congestion. In uncongested environment packets experience fewer transmission conflicts, results in higher delivery ratios. However, when background traffic is introduced the channel contention increases, leading to packet loss and retransmissions. This comparison confirms that PDR is highly dependent on network load conditions rather than only routing path availability. A comparison of both scenarios (Table 10) highlights the strong influence of traffic conditions on packet delivery performance.

ZRP 90

**Table 7: Comparative PDR Analysis**

Scenario	Average PDR Trend
Without Background Traffic	Higher PDR
With Background Traffic	Reduced PDR

### 8 Routing Overhead Analysis

Routing overhead represents the amount of control traffic generated by routing protocols such as DSDV, OLSR, FSR and ZRP to establish, maintain, and repair communication paths within the network. Unlike data packets, routing packets do not carry application-level information. Instead, they support network function through route discovery, topology updates, neighbor detection and error handling. Routing overhead is a critical factor affects overall efficiency as excessive control traffic consumes bandwidth, increases channel utilization and reduce the capacity available for actual data transmission. Therefore, analysis of routing overhead provide insight into how efficiently network resources are utilized under different traffic conditions.

#### 8.1 Routing Overhead Without Background Traffic

Figure 3(d) presents the routing overhead observed when the network operates without additional traffic load. In this scenario, only primary communication

**Table 11: Routing Overhead without Background Traffic**

Protocol	Routing Overhead (Packets)
DSDV	3200
OLSR	3500
FSR	2800
ZRP	3000

#### 8.2 Routing Overhead With Background Traffic

Figure 4(d) illustrates the routing overhead when background traffic is introduced into the network. In this scenario, multiple nodes generate additional traffic flows to increase channel utilization and congestion level. An increase in routing overhead is observed across all protocols under congested conditions. The

flows are active that is Node 0 (send) and Node 20 (receive) and the wireless channel remains relatively uncongested. The results indicate that routing overhead remains moderate in the absence of background traffic. Since the network experience minimal contention the routing packets are transmitted with few collisions and reduced retransmissions. In addition, low mobility-induced disruptions contribute to stable routing behavior, requiring fewer route maintenance and repair messages. As the network stabilizes after initial route establishment the amount of control signaling becomes consistent. In this scenario FSR records the low routing overhead of 2800 packets, reflecting efficient control message management (Table 11). In contrast, OLSR shows the high overhead of 3500 packets due to its frequent topology updates. DSDV and ZRP demonstrate intermediate overhead values of 3200 and 3000 packets. The scenario con-firms that routing overhead remains controlled under light traffic conditions and does not impact available bandwidth.

presence of background traffic introduces additional challenges, including higher packet collision rates and increased retransmissions of lost routing messages. As traffic load increases, interface queues become saturated, leading to packet drops and the need for control packet regeneration. Furthermore congestion may delay topology updates trigger additional signal

exchanges to maintain accurate routing information. OLSR exhibits the high routing overhead at 3950 packets indicate major control message exchange under congestion. FSR maintains the low overhead at 3100 packets, although, this value still reflects an

**Table 12:** *Routing Overhead with Background Traffic*

Protocol	Routing Overhead (Packets)
DSDV	3600
OLSR	3950
FSR	3100
ZRP	3350

Compared to no background traffic conditions where routing packets propagate efficiently with minimal retransmissions. However, when background traffic is introduced the routing packets must compete with data packets for channel access. This competition increases transmission delays and packet loss which leads to repeated control message generation. As a

**Table 13:** *Comparative Routing Overhead Analysis*

Scenario	Overhead Trend
Without Background Traffic	Lower overhead
With Background Traffic	Increased overhead

### 9 Average Throughput Share

Figure 5(a) presents the throughput share. It reflect the proportional efficiency of bandwidth utilization. ZRP again achieves the highest share at 27.7%, demonstrate its ability to maintain stable data transmission with reduced route discovery delay and limited control overhead (Figure 5(a)). OLSR follows with a throughput share of 26.2%, benefits from optimized MPR forwarding, which reduces retransmissions and improves channel utilization. However, periodic control signaling slightly limits available bandwidth for data transmission. DSDV records a moderate share of 23.7%, where stable routing tables support communication but convergence delays can interrupt data flow during topology changes. FSR exhibits the low throughput share of 22.5%, as reduced update frequency for

increase compared to the uncongested scenario. DSDV and ZRP show moderate increase reach to 3600 and 3350 packets. The summarized data is shown in Table 12.

result, overall routing overhead increases. The comparison demonstrates that traffic congestion amplifies signal requirements even when the underlying network topology remains unchanged. A comparison of routing overhead across both scenarios highlights the impact of traffic load on control signaling behavior (Table 13).

distant nodes may lead to route inaccuracies and retransmissions. The results indicate that a balanced trade-off between routing overhead and route freshness plays a crucial role in order to achieve high throughput.

### 10. Average End-to-End Delay Share

Figure 5(b) illustrates the delay share, where higher values indicate poorer latency performance. FSR occupies the largest delay share at 31.0% primarily due to its fisheye routing mechanism. In this approach, packets travel toward distant nodes may rely on outdated routing information, increasing delay. DSDV records the second-largest share at 27.1%, as periodic updates introduce waiting time before fresh routes are established. OLSR achieves a lower delay share of 20.8%, supported by its link-state routing and MPR optimization, which ensure faster route

availability. ZRP shows the small delay share of 20.1% which mean superior latency for both Scenario-1 and Scenario-2. Its hybrid design allows the most communication to occur in proactive style. It also reduces the need for route discovery. Combined analysis of Scenario-1 and Scenario-2 shows the importance of routing responsiveness for delay calculation.

### 11 Average PDR Share

Figure 5(c) illustrates the combined contribution of Scenario-1 and Scenario-2 of each protocol for PDR value. ZRP occupies the largest share of 46.4% which mean superior and reliable when compared to DSDV, OLSR and FSR. This dominance is because of the hybrid nature of ZRP with the advantage of proactive action within the local system. ZRP also reacts reactive nature for distant nodes in order to avoid unnecessary data flooding. The switching of ZRP minimizes packet loss caused by stale routes and the background traffic (or congestion). OLSR reach the second good share of 25.7%. It is due to its MPR mechanism, which optimizes flooding and maintains accurate topology update. However, the frequent control message exchange in OLSR consumes bandwidth that could otherwise be used for data transmission. DSDV contributes a moderate share of 24.4% due to its periodic routing table updates. Although sequence (in DSDV) numbers prevent routing loops the slow adaptation to mobility reduces delivery. FSR records the lowest share of 23.4% as its scoped update mechanism may lead to outdated routing information for distant nodes which lead to packet loss. The distribution indicate that hybrid routing provides more reliable communication across varying network conditions.

### 12 Average Routing Overhead Share

Figure 5(d) presents the distribution of routing overhead among the protocols. OLSR contributes the highest overhead share at 28.1% mainly due to continuous HELLO and topology control message

exchanges required for maintaining global network awareness. DSDV follows with 25.7%, as periodic routing table updates generate consistent control traffic. ZRP maintains a moderate overhead share of 24.0% where proactive updates are limited to local zones and reactive discovery is used only when necessary. FSR achieves the lowest overhead share at 22.3%, as its graded update mechanism reduces the frequency of control messages. This distribution reflects the tradeoff between routing accuracy and transmission cost where protocols with higher accuracy tend to generate more overhead.

### 13 Conclusion

MANETs are very useful for applications such as disaster recovery, military communication, online healthcare and temporary wireless deployments where reliable and infrastructure less network is required. For that, a comparative performance evaluation of emerging routing approaches is carried out under varying simulated traffic. The simulations show that MANET performance is strongly depends on background load and traffic. In Scenario-1 with no background traffic all protocols demonstrate stable behavior. However, in Scenario-2 with background traffic the performance degradation is evident. ZRP is consistent and demonstrates good balanced performance across QoS metrics due to efficient route availability. ZRP limits unnecessary control data which improved reliability, throughput, delay under Scenario-1 and 2. OLSR performs well in terms of delay and delivery (PDR and throughput) but leads to high overhead due to continuous topology updates. DSDV was moderate but is less responsive to dynamic changes (overhead). FSR offers low overhead but causes route inaccuracy in Scenario-2. It is suggested that no single protocol is optimal for all conditions. However, hybrid strategies provide a more effective balance in MANET environments. Future research

can extend this work to heterogeneous network environments.

The inclusion of video streaming can provide deeper insights into QoS performance

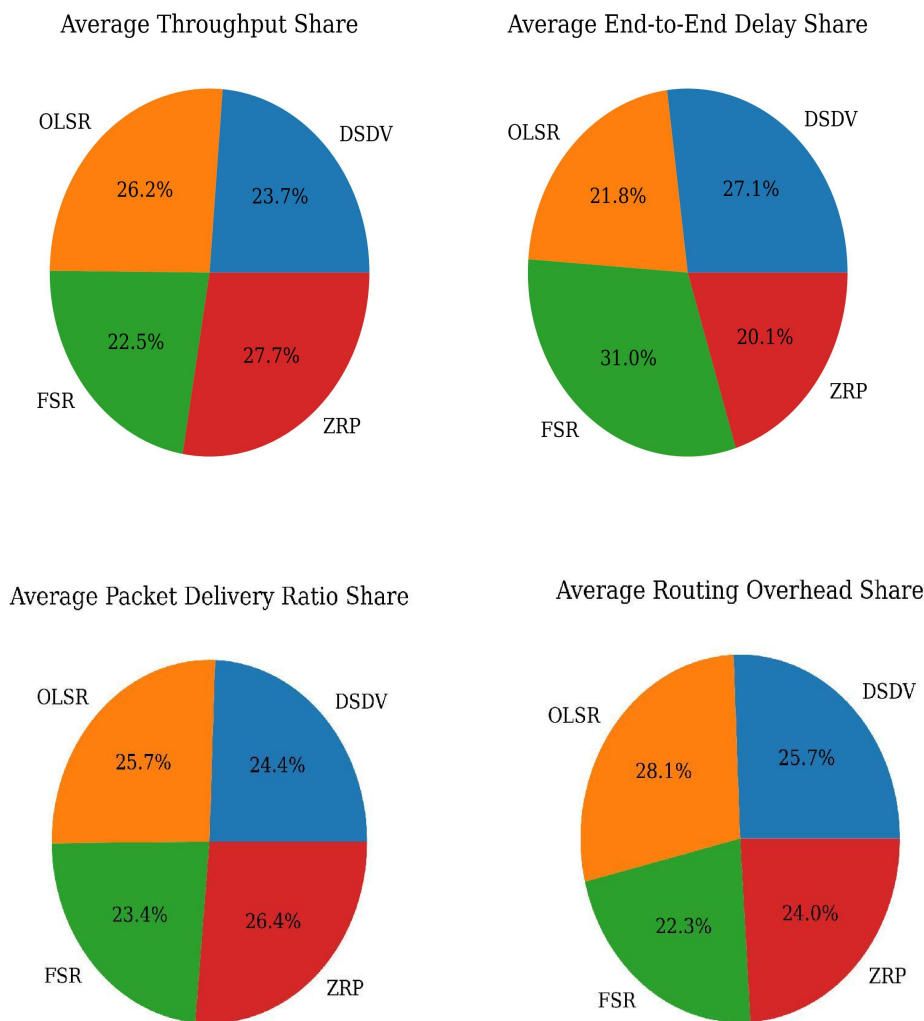


Figure 5. Performance comparison based on Scenario 3

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