

A Novel Approach to Multimedia Streaming over Ad Hoc Networks using MIMC Architectures

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Abstract - Real-time multimedia services such as interactive gaming, video surveillance, video-on-demand and video conferencing have gained significant popularity in recent years. These services are increasingly being integrated into diverse domains, including home automation, robotics and self-driven automobiles, forming a core component of emerging 5G technology. However, providing sufficient bandwidth to support such multimedia applications over Ad Hoc networks remains a challenging task due to shared channel transmission and limited bandwidth availability. To address these challenges and improve network performance, novel architectures—namely Multi Interface Multi Channel - Bandwidth Aggregation (MIMC-BA), Multi Interface Multi Channel - Simultaneous Receive Transmit (MIMC-SRT) and Multi Interface Multi Channel - Parallel Transmission (MIMC-PT) have been proposed and implemented using the QualNet 6.1 network simulator. Their performance is compared against conventional Single Interface Single Channel (SISC) and Multi-Interface Multi-Channel (MIMC) architectures in Ad Hoc networks.

Key Words: Ad hoc networks, MIMC architectures, Multimedia streaming, Quality of Service, Simulation

1. INTRODUCTION

In the early 1990s, the introduction of the Mosaic web browser revolutionized the internet by enabling users to access enriched multimedia content [1]. Multimedia services—comprising text, images, audio and video—rapidly attracted a large number of users, primarily through wired networks. Over time, with the emergence of wireless mobile handheld devices such as smartphones, laptops, tablets, personal digital assistants and wireless surveillance systems, access to multimedia

services over wireless Internet has grown tremendously [2]. Real-time multimedia services, including interactive gaming, video surveillance, video-on-demand and video conferencing, have gained significant popularity in recent years. These applications are expanding into domains such as home automation, enterprise systems, robotics and self-driven automobiles, demanding high data rates to support emerging 5G technologies [3].

Recent studies indicate that the future Internet will differ significantly from the current one, as it will be dominated by mobile handheld devices with diverse computational capabilities. The number of such devices is increasing rapidly and is expected to reach billions in the near future [4]. To provide seamless connectivity among these heterogeneous devices, wireless technologies such as wireless Ad Hoc networks play a crucial role by offering quick, flexible, and cost-effective solutions [5].

However, existing Ad Hoc network technologies, such as the IEEE 802.11b standard, provide a theoretical maximum throughput of 11 Mbps, while the practically achievable bandwidth is much lower due to the use of the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) mechanism [6]. Therefore, a single-channel communication approach is insufficient to meet the bandwidth demands of next-generation multimedia services. To address this limitation, multiple interfaces operating over non-overlapping channels, supported by carrier aggregation techniques, are required. By employing such techniques, the throughput at each node can be significantly enhanced at a relatively low cost [7]. Furthermore, the use of multiple interfaces and channels per node improves the overall performance of real-time multimedia services in Ad Hoc networks.

2. RELATED WORK

Several studies have explored the use of IEEE 802.11-based protocols to leverage multiple interfaces and channels in wireless networks. In [8], a protocol utilizing a dedicated control channel and multiple data channels is proposed, selecting the best channel based on SNR for efficient transmission. Similarly, [9] introduces a two-interface node design, assigning one interface for control communication and the other for dynamic data transmission across channels. A link-layer striping mechanism is proposed in [10] to enhance throughput by distributing data over multiple interfaces. In contrast, a single-interface multi-channel architecture that requires channel switching prior to communication is presented in [11]. Simulation results in [12] indicate that multi-channel configurations offer improved delay performance over single-channel systems.

In [13], the integration of multi-radio and multi-channel (MRMC) and cooperative transmission techniques is shown to effectively reduce interference and boost throughput. The parallel interaction medium access (PIMA) protocol proposed in [14] enables simultaneous transmissions through multiple radios, improving network efficiency. Additionally, [15] examines spatial reuse in dense networks, while [16] investigates channel-aware scheduling strategies to optimize CSMA performance. Lastly, [17] enhances routing efficiency in multi-channel wireless mesh networks by modifying the AODV protocol, thereby reducing overhead and improving communication quality.

3. Data Communication over Conventional Multi Interface Multi Channel (MIMC) Ad Hoc Networks

In conventional Single Interface Single Channel (SISC) Ad Hoc networks, the achievable throughput is significantly limited due to the shared medium constraint. When multiple nodes attempt to transmit data over a single channel, packet collisions occur due to interference, leading to packet loss. Moreover, a considerable portion of the channel bandwidth is consumed by channel sensing and the exponential backoff mechanism of the Carrier Sense Multiple Access - Collision Avoidance (CSMA-CA) protocol at the MAC layer. Additionally, radio switching delays at each hop further restrict packet delivery, particularly in high-speed

data networks. As a result, the overall network performance of conventional SISC systems is inadequate to meet the Quality of Service (QoS) requirements of real-time applications. To address these limitations, the use of Multi-Interface Multi-Channel (MIMC) techniques has been proposed to enhance network efficiency. In general, existing data transmission approaches in MIMC networks can be broadly classified into two schemes [8], [13], [14], [18]. In the first scheme, the number of interfaces (N) available for data transmission is less than the number of non-overlapping channels (C), i.e., ($N < C$). In such networks, each interface is assigned to a specific channel selected from the available set of non-overlapping channels. However, this approach results in underutilization of the available spectrum, as the remaining ($C - N$) channels are left unused. Furthermore, issues such as inefficient channel allocation for control messages, channel switching delays during packet forwarding and link breakages across channels adversely affect network performance.

In the second scheme, the number of interfaces is made equal to the number of non-overlapping channels ($N = C$). In this configuration, each interface is assigned to a distinct non-overlapping channel, enabling simultaneous utilization of all available channels. This approach effectively aggregates the bandwidth across channels, thereby significantly improving throughput and overall network performance. By minimizing channel switching delays and maximizing channel utilization, this scheme is better suited for supporting high data rate applications. Therefore, in this paper, the MIMC architecture is adopted by considering the number of interfaces equal to the number of non-overlapping channels. This design choice aims to enhance the Quality of Service (QoS) for real-time multimedia applications in wireless Ad Hoc networks.

4. Proposed Multi Interface Multi Channel - Bandwidth Aggregation (MIMC-BA) Architecture for Ad Hoc Networks

In general, when conventional single-interface single-channel routing protocols are employed in MIMC networks, Route Request (RREQ) messages are broadcast through multiple interfaces, leading to excessive bandwidth consumption, increased network congestion and higher packet drop rates. Furthermore, existing MAC protocols typically transmit data using a single interface over a single channel, resulting in

underutilization of the available bandwidth across other non-overlapping channels.

To overcome these limitations, a novel Multi-Interface Multi-Channel Ad Hoc Network architecture with Bandwidth Aggregation (MIMC-BA) is proposed. In the proposed MIMC-BA architecture, each node is equipped with three interfaces, with each interface assigned to a distinct non-overlapping channel, as specified in Table 1.

Table-1: Non-Overlapping Frequency Channel assigned for proposed MIMC-BA Architecture

Interface	Non-Overlapping Channel	Frequency	Order
Interface 0	Channel 1	2.412GHz	Packet 1
Interface 1	Channel 6	2.437GHz	Packet 2
Interface 2	Channel 11	2.462GHz	Packet 3

In this architecture, a low-overhead route discovery mechanism is implemented for AODV, AOMDV-SP and AOMDV-MP routing protocols at the network layer. Specifically, the highest frequency channel (2.462 GHz, Channel 11) is assigned to Interface 2 for all nodes and is exclusively used for broadcasting RREQ messages during the route discovery phase. All intermediate nodes receive and forward these RREQ messages using the same interface and channel, thereby reducing redundant broadcasts and minimizing overhead. Upon receiving the RREQ, the destination node unicasts Route Reply (RREP) messages back to the source node via Interface 2 over Channel 11, establishing the forward path for data transmission.

The use of the highest frequency channel for route discovery is motivated by its higher path loss characteristics, which help limit interference and control overhead [19]. Subsequently, data transmission is carried out over lower frequency channels, which offer better propagation characteristics and reduced packet loss probability. Moreover, the number of data forwarding paths utilized depends on the routing protocol: a single path is used in AODV and AOMDV-SP (Ad hoc On-Demand Multipath Distance Vector – Single Path), whereas multiple paths are utilized in AOMDV-MP (Ad hoc On-Demand Multipath Distance

Vector – Multipath) to improve reliability and throughput.

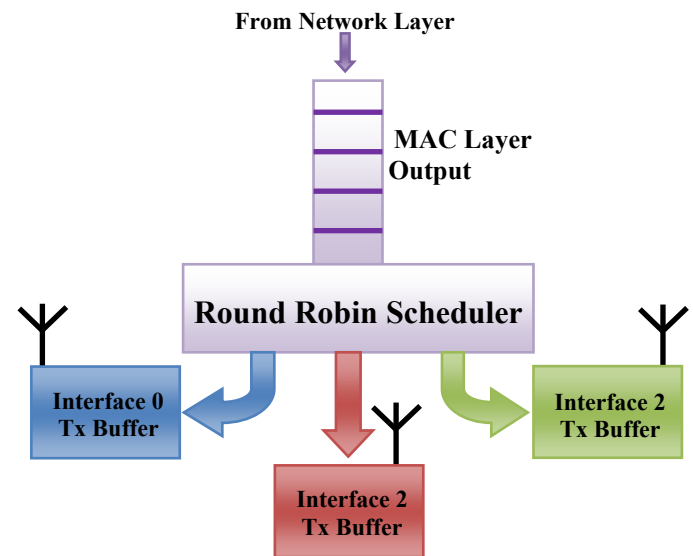


Fig-1: Source node scheduling scheme using Round Robin (RR) scheduling algorithm

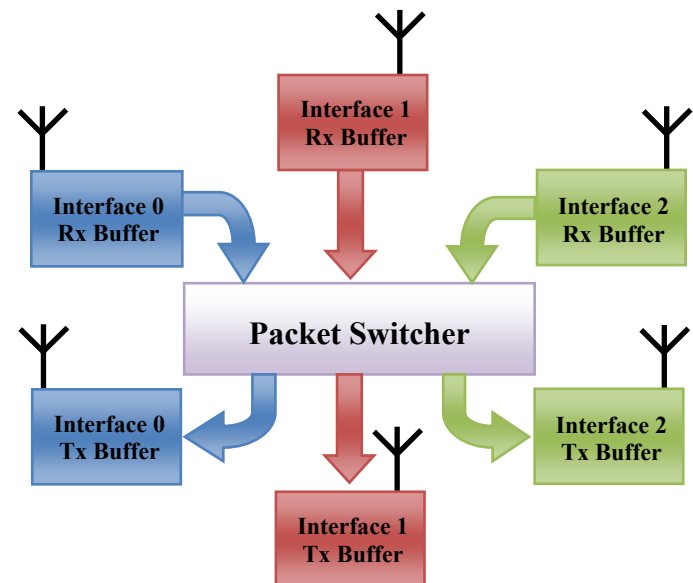


Fig-2: Packets forwarding scheduling scheme at intermediate node

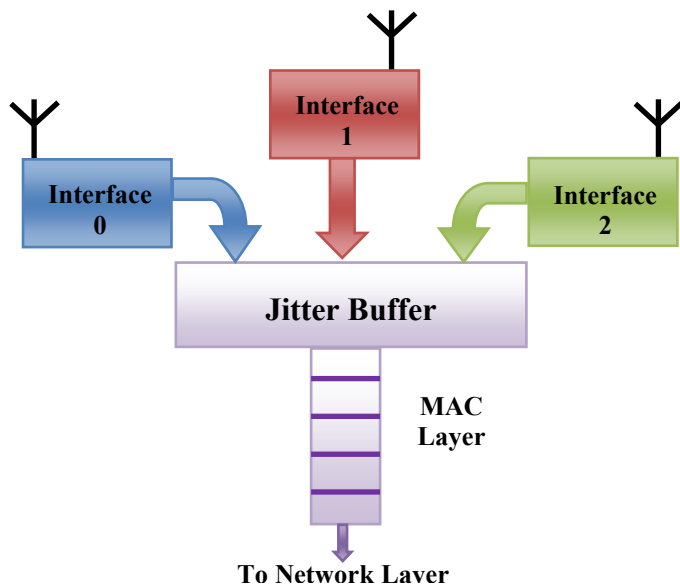


Fig-3: Packet aggregation schemes at destination node

In the proposed MIMC-BA architecture, MAC layer data scheduling schemes are implemented at both source and intermediate nodes to enhance overall network performance. At the source node, a scheduling mechanism is incorporated using a MAC buffer queue, where incoming data packets are temporarily stored before being assigned to multiple interfaces (Fig. 1). During each scheduling interval, packets from the buffer are allocated to the transmission buffer (Tx buffer) of one of the available interfaces (I_0 , I_1 , and I_2) based on a Round Robin (RR) scheduling algorithm. This ensures fair and efficient utilization of all interfaces for transmitting data to the intermediate node. At the intermediate node, the MAC layer is configured to receive and forward data packets using the same interface (I_i) and the same channel (Fig. 2). This approach minimizes channel switching delays and reduces processing overhead, thereby improving forwarding efficiency. The received packets are then passed through the network layer and delivered to the application layer at the destination node (Fig. 3).

5. Proposed Multi Interface Multi Channel - Simultaneous Receive and Transmit (MIMC-SRT) Architecture for Ad Hoc Networks

In both conventional Single Interface Single Channel (SISC) and the proposed MIMC-BA Ad Hoc networks, intermediate nodes utilize the same interface for both data reception and transmission. This approach limits throughput and introduces additional latency due to bandwidth sharing, sequential access to radio resources, and Receive-Transmit (Rx-Tx) switching delays [20].

Furthermore, using the same channel for both reception and transmission may lead to self-interference, increasing packet collisions and buffer occupancy [21].

To overcome these limitations, a novel Multi-Interface Multi-Channel Simultaneous Receive and Transmit (MIMC-SRT) architecture is proposed. In this architecture, the route discovery process and data packet scheduling at the source node are similar to those in the MIMC-BA approach. However, at the intermediate node, the interface used for data transmission (I_0) is selected relative to the receiving interface (I_i) using Equation (1), enabling simultaneous data reception and transmission without incurring Tx-Rx switching delays.

$$I_0 = I_i + DF \% N \quad (1)$$

where DF represents the Displacement Factor and N ($= 3$) denotes the number of available interfaces at each node.

In this work, DF is chosen as 2 to avoid selecting the immediately adjacent interface (i.e., $I_0 = I_i + 1$). This is because the subsequent data packet is likely to be received on the next interface, and using that same interface for transmission could increase switching delays and packet loss probability. Table 2 summarizes the operation of the proposed MIMC-SRT architecture.

Table-2: Various Interfaces are used to Receive and Transmit Data via Intermediate Node in MIMC-SRT Architecture

Current Receiving Interface (I_i)	Proposed Interface to Transmit (I_0)	Next Receiving Interface (I_{i+1})
0	2	1
1	0	2
2	1	0

To further enhance performance, a Multi Interface Multi Channel - Parallel Transmission (MIMC-PT) architecture is proposed. In this approach, the route discovery and source node scheduling mechanisms remain similar to those in the MIMC-BA architecture. At the intermediate node, the transmission interface is initially selected based on the MIMC-SRT scheme. Additionally, the status (busy or idle) of the selected interface is obtained from the physical (PHY) layer. If the interface is idle, the data packet is transmitted immediately. Otherwise, if the interface is busy, the next available interface is selected using a Round Robin

strategy after verifying its status. This process continues iteratively until an idle interface is found for transmission.

6. Proposed Multi Interface Multi Channel - Parallel Transmission (MIMC-PT) Architecture for Ad Hoc Networks

The proposed MIMC-PT architecture thus enables efficient parallel transmission by dynamically selecting available interfaces, reducing waiting time, minimizing packet loss, and improving overall network throughput.

In the proposed MIMC-BA and MIMC-SRT architectures, the interface selected for data transmission may already be engaged in transmitting or receiving data packets or control messages. In such situations, the data packet must wait until the interface becomes available, leading to increased propagation delay and a higher packet drop rate. Furthermore, as retransmissions increase due to network saturation, other available interfaces remain underutilized, as they stay idle until the ongoing transmission is completed. This results in reduced overall network utilization and efficiency.

7. SIMULATION AND RESULTS

The performance of both the proposed and conventional network architectures is evaluated under two distinct scenarios. Scenario 1 considers a single-path routing protocol (AODV), while Scenario 2 focuses on multipath routing protocols (AOMDV-SP and AOMDV-MP).

Scenario 1

The simulation scenario is designed with network sizes of 9, 25, 49, 81, and 121 nodes arranged in a grid topology, maintaining an inter-node distance of 50 meters. The Two-Ray Ground propagation model with a constant shadowing effect of mean 4 dB is employed to simulate realistic wireless channel conditions. The remaining simulation parameters used for the study are summarized in Table 3.

Table-3: Simulation Parameters

Property		Value
Simulation-Time		30 seconds
Simulation-Area		1000m ²
Radio Type		IEEE802.11b
Channel Frequenc	SIMC	2.462 GHz
	MIMC	2.412 GHz, 2.437 GHz, 2.462

y		GHz
Number of Interfaces		1 and 3
Node placement type		GRID
Inter node distance		50m
Network layer Protocols		AODV, AOMDV-SP and AOMDV-MP
MAC layer Protocol		IEEE 802.11
Traffic type		CBR
Shadowing		Constant shadowing with mean 4dB
Path Loss		Two ray
Energy		Generic
Battery type		Linear

Initially, simulation studies are conducted for the conventional Single Interface Single Channel (SISC) network architecture by considering a network of 9 nodes, with a Constant Bit Rate (CBR) traffic connection of 1 Mbps established between the source and destination. Each node is equipped with a single interface operating on a single channel. A snapshot of the simulation scenario is presented in Figure 4. The performance metrics evaluated include throughput, average end-to-end delay and average jitter.

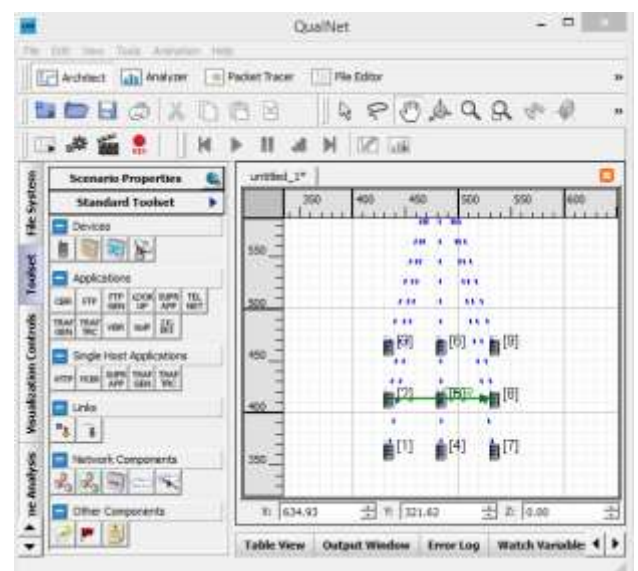


Fig-4: Snap shot of 9 nodes scenario designed to evaluate the performance of SISC Ad Hoc network architecture

The simulations are then extended by increasing the data rate from 2 Mbps to 10 Mbps in increments of 2 Mbps, and from 10 Mbps to 30 Mbps in increments of 5

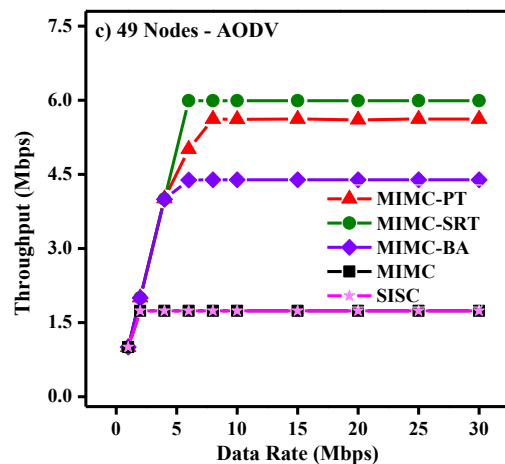
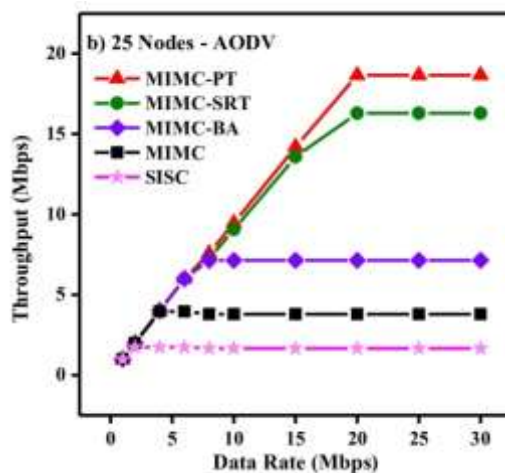
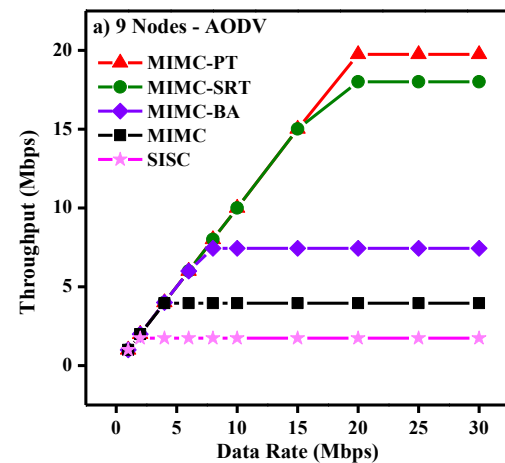
Mbps. This process is repeated for Scenario 1 with network sizes of 25, 49, 81, and 121 nodes to analyze scalability and performance under varying network densities.

A similar set of simulation experiments is carried out for the conventional Multi-Interface Multi-Channel (MIMC) network architecture, where each node is equipped with three interfaces, each assigned to a distinct non-overlapping frequency channel as specified in Table 1. Furthermore, the same simulation methodology is applied to evaluate the proposed MIMC-BA, MIMC-SRT, and MIMC-PT architectures, with each node configured with three interfaces operating over non-overlapping channels as defined in Table 1.

Figure 5 (a-e) illustrates the throughput performance of SISC, MIMC, MIMC-BA, MIMC-SRT, and MIMC-PT architectures for node densities of 9, 25, 49, 81, and 121 under varying data rates using the AODV routing protocol. In the SISC architecture, a single interface is used for data transmission. In contrast, the MIMC architecture employs multiple interfaces (three interfaces in the present study), each assigned to a distinct non-overlapping channel. This enables different nodes to utilize different interfaces for communication, thereby reducing self-interference and resulting in a marginal improvement in throughput compared to the SISC architecture.

Furthermore, Figure 5 (a-e) clearly indicates that the proposed MIMC-BA, MIMC-SRT, and MIMC-PT architectures outperform both conventional MIMC and SISC architectures in terms of throughput. This improvement is attributed to the effective utilization of aggregated bandwidth across multiple non-overlapping channels associated with multiple interfaces [22][23].

In addition, the proposed architectures employ a dedicated high-frequency channel (e.g., Interface 2) for route discovery, which reduces control overhead compared to conventional MIMC approaches. The higher frequency channel exhibits greater path loss, which limits excessive propagation of control packets and thereby reduces unnecessary overhead. Subsequently, data transmission is carried out using lower frequency channels, which offer reduced path loss and improved signal propagation, enabling more reliable packet delivery to the destination node [24]. This combination of efficient route discovery and optimized data transmission contributes to the enhanced throughput performance observed in the proposed architectures.



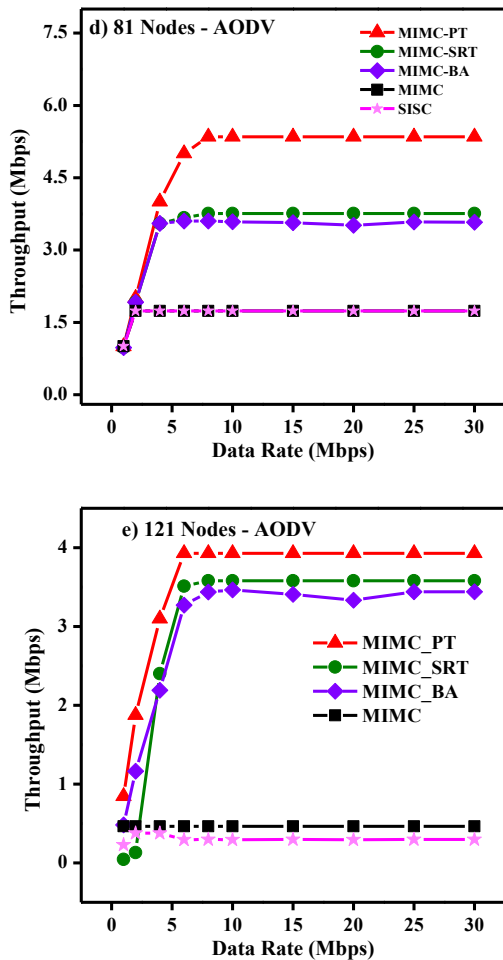
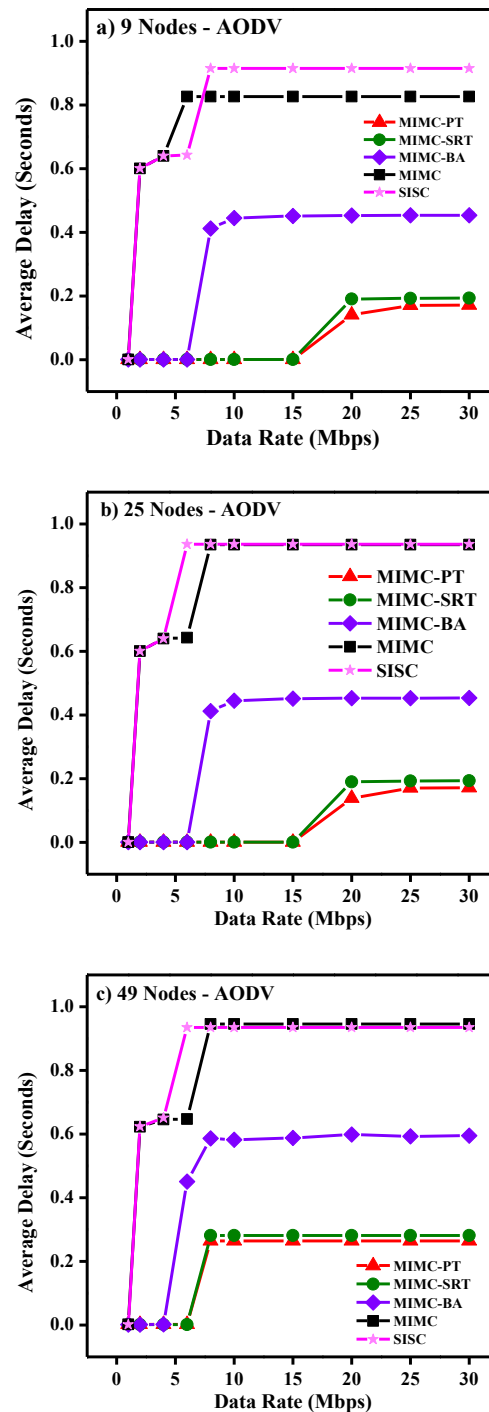


Fig-5 (a-e): Throughput performance of SISC, MIMC, MIMC-BA, MIMC-SRT and MIMC-PT network architectures with (a) 9, (b) 25, (c) 49, (d) 81 and (e) 121 node density for different Data Rates for AODV routing protocol

It is also evident from Figure 5 (a–e) that the throughput performance of the proposed MIMC-SRT architecture is superior to that of the MIMC-BA architecture. This improvement is achieved because, in the MIMC-SRT architecture, simultaneous reception and transmission of data packets is enabled by selecting the transmission interface using a Round Robin scheme among the available three interfaces, ensuring that it is different from the receiving interface. This mechanism significantly reduces self-interference and packet collisions at intermediate nodes. In contrast, the MIMC-BA architecture utilizes the same interface for both data reception and transmission, which may lead to dropping of subsequent packets due to interface contention and switching delays.

Figure 5 (a–e) further shows that the proposed MIMC-PT architecture achieves better throughput performance compared to the MIMC-SRT architecture. This is because MIMC-PT selects a passive (idle)

interface for data transmission after verifying the status of the selected interface at the PHY layer. In contrast, both MIMC-BA and MIMC-SRT architectures may select interfaces that are currently busy in transmitting or receiving data packets. In such cases, packets must wait until the interface becomes free, resulting in increased end-to-end delay and higher packet discard probability.



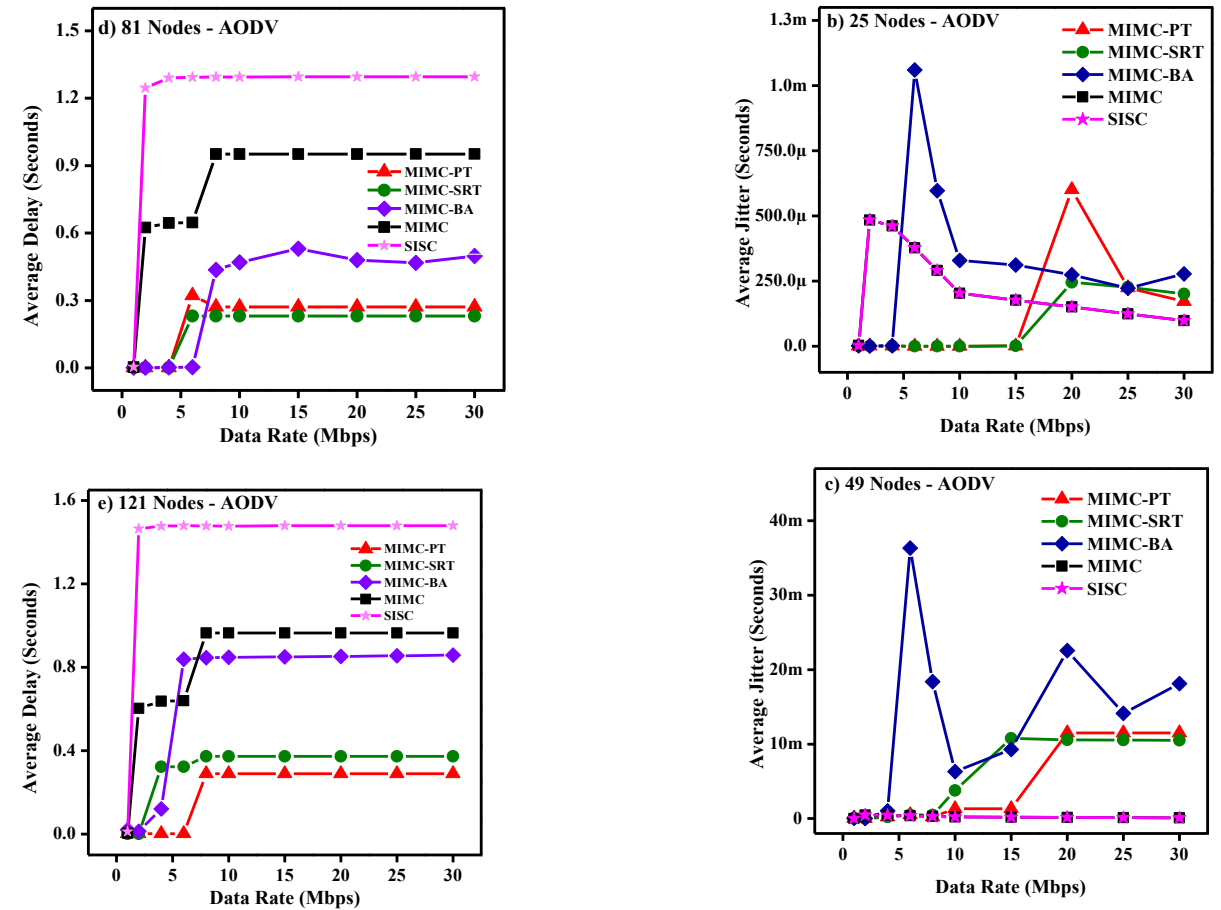


Fig-6 (a-e): Average delay performance of SISC, MIMC, MIMC-BA, MIMC-SRT and MIMC-PT network architectures with (a) 9, (b) 25, (c) 49, (d) 81 and (e) 121 node density for AODV routing protocol

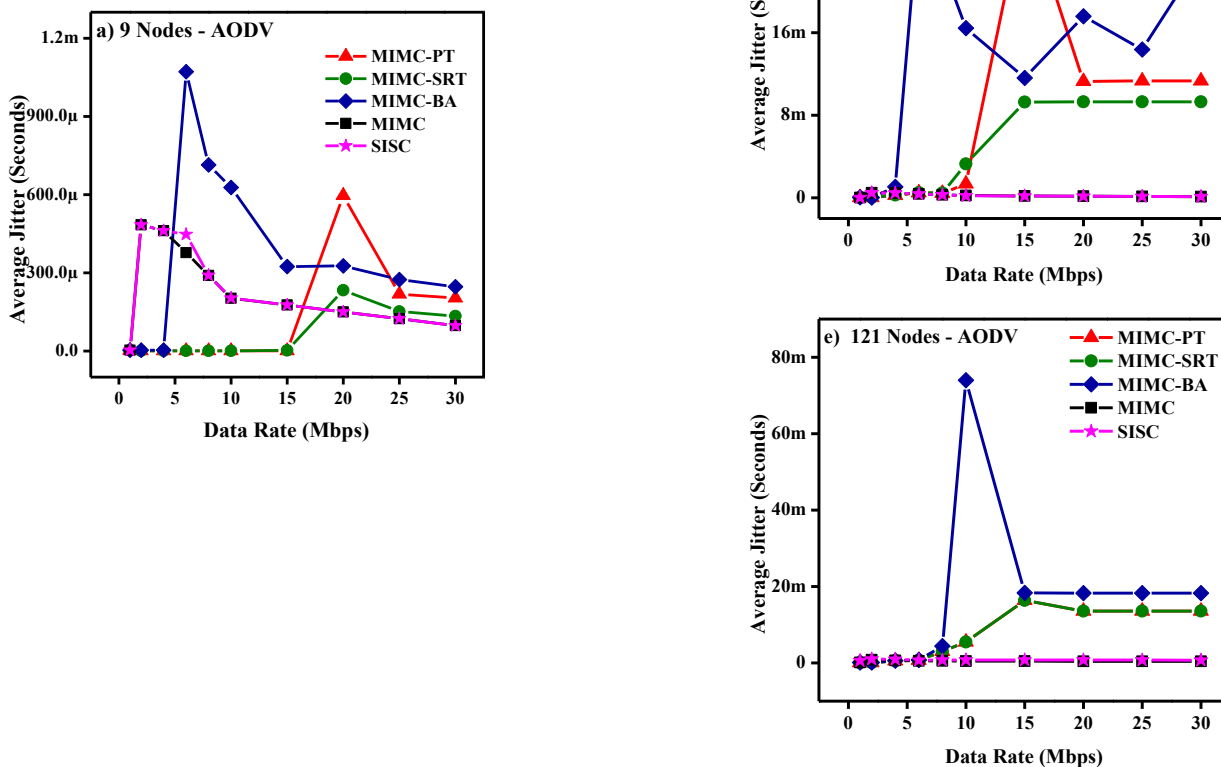


Fig-7 (a-e): Average jitter performance of SISC, MIMC, MIMC-BA, MIMC-SRT and MIMC-PT network architectures with (a) 9, (b) 25, (c) 49, (d) 81 and (e) 121 node density for AODV routing protocol

architectures with (a) 9, (b) 25, (c) 49, (d) 81 and (e) 121 node density for AODV routing protocol

Figure 6 (a–e) presents the average end-to-end delay performance of SISC, MIMC, MIMC-BA, MIMC-SRT, and MIMC-PT architectures under AODV routing for varying data rates and node densities of 9, 25, 49, 81, and 121 nodes. It is observed that the proposed architectures (MIMC-BA, MIMC-SRT, and MIMC-PT) outperform conventional MIMC and SISC architectures in terms of delay performance. This improvement is attributed to the use of multiple interfaces operating on non-overlapping channels, which reduces network congestion, minimizes buffering delay and decreases packet retransmissions. Additionally, the use of separate interfaces for transmission and reception in MIMC-SRT further reduces delay. Among all, MIMC-PT exhibits the best delay performance due to its ability to utilize only passive interfaces for transmission.

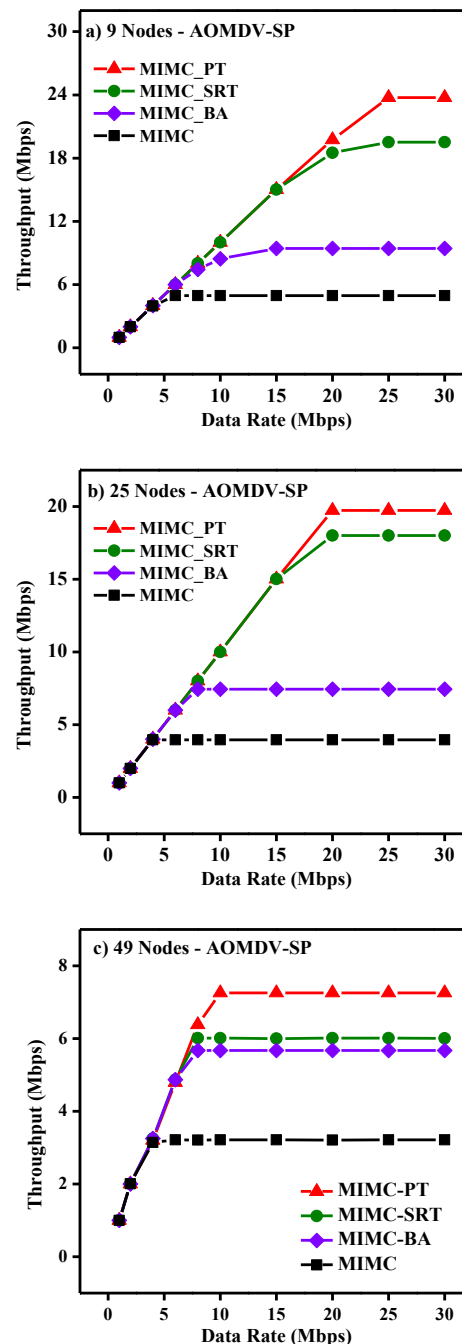
Figure 7 (a–e) illustrates the average jitter performance of SISC, MIMC, MIMC-BA, MIMC-SRT, and MIMC-PT architectures under AODV routing for increasing data rates and varying node densities. It is observed that conventional MIMC and SISC architectures exhibit lower jitter compared to the proposed architectures. This is because packets in these conventional systems are transmitted over relatively static channels, resulting in more uniform congestion levels and reduced variation in delay.

In contrast, the proposed MIMC-BA, MIMC-SRT, and MIMC-PT architectures experience higher jitter due to packet transmission over multiple channels with varying congestion levels. Among the proposed schemes, MIMC-SRT shows better jitter performance compared to others, as it uses dedicated interfaces for reception and transmission, ensuring more stable packet handling. MIMC-PT exhibits lower jitter than MIMC-BA since it transmits packets only through passive interfaces, reducing waiting time variability. In MIMC-BA, however, packets may be scheduled over busy interfaces and are transmitted only after ongoing transmissions complete, leading to increased variability in delay and consequently higher jitter.

Scenario 2

Simulation parameters of Scenario 1 are retained for Scenario 2. The same set of simulation studies is repeated for node densities of 9, 25, 49, 81 and 121 nodes to evaluate the performance of the proposed

MIMC-BA, MIMC-SRT, and MIMC-PT architectures, along with the existing MIMC architecture, under AOMDV-SP and AOMDV-MP routing protocols using the QualNet 6.1 network simulator.



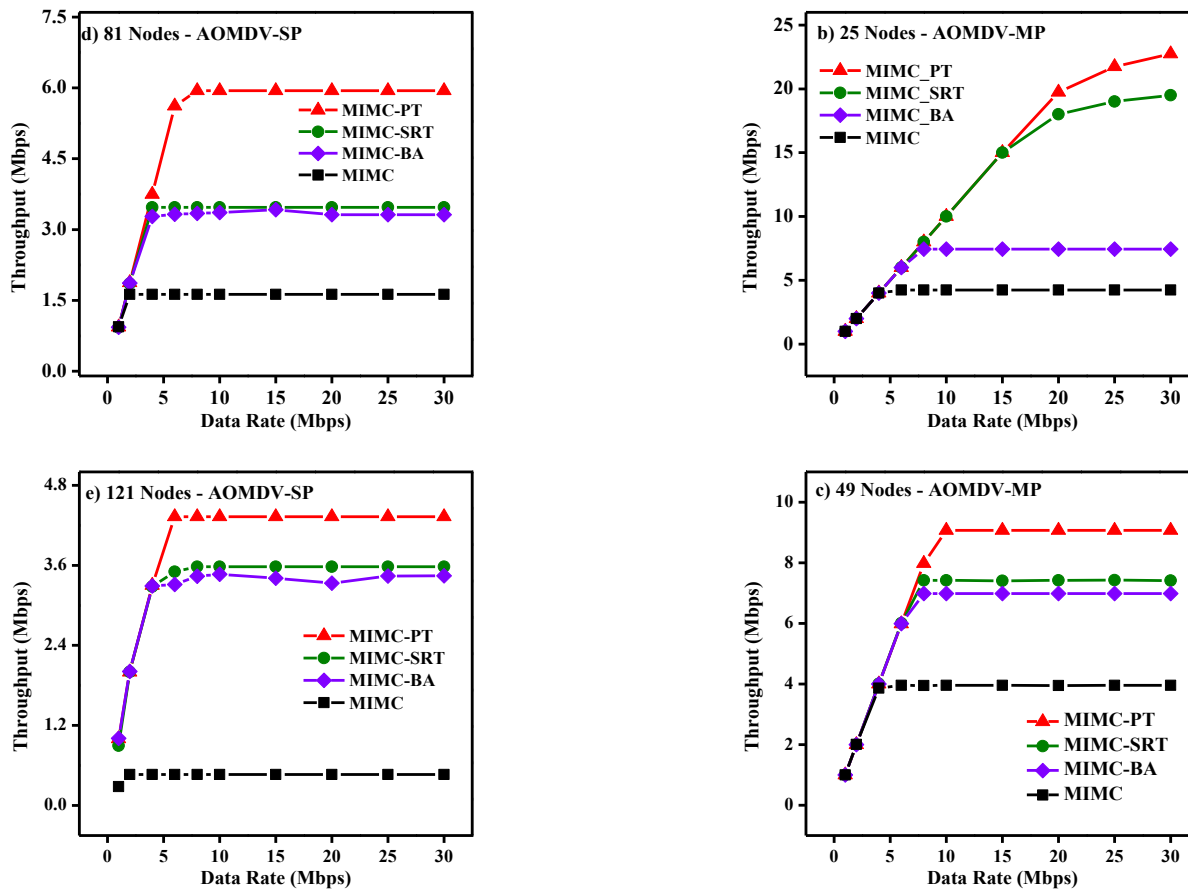


Fig-8 (a-e): Throughput performance of MIMC, MIMC-BA, MIMC-SRT and MIMC-PT network architectures with (a) 9, (b) 25, (c) 49, (d) 81 and (e) 121 for AOMDV-SP routing protocol

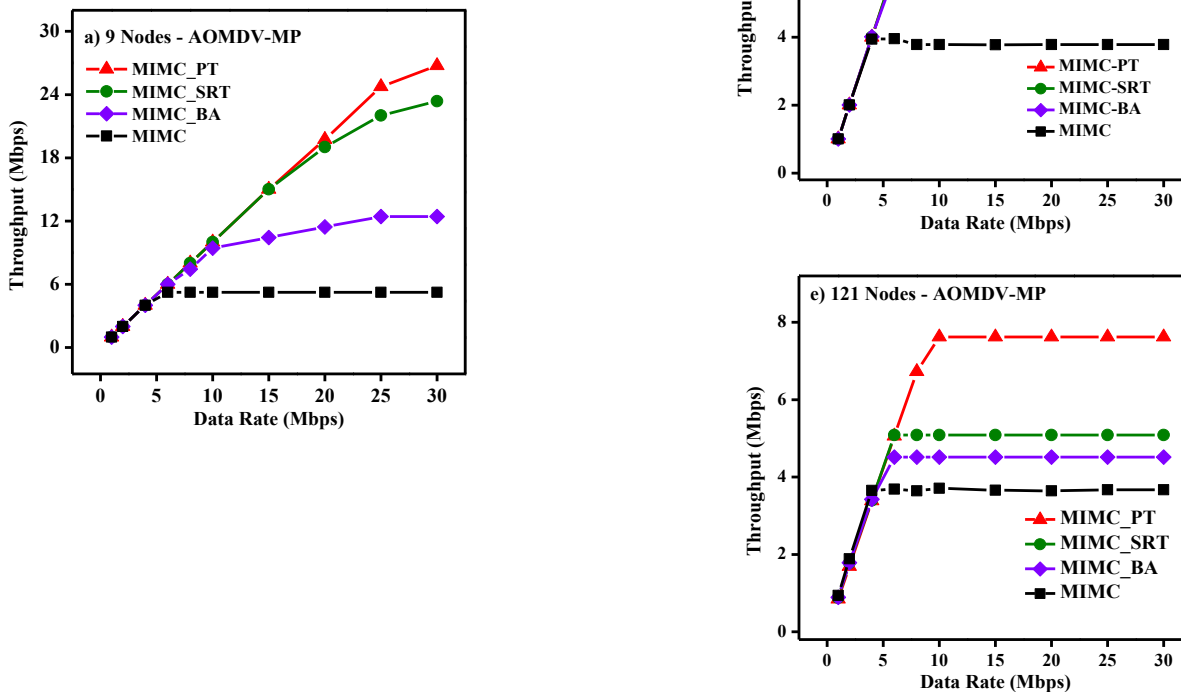


Fig-9 (a-e): Throughput performance of MIMC, MIMC-BA, MIMC-SRT and MIMC-PT network architectures with (a) 9, (b) 25, (c) 49, (d) 81 and (e) 121 for AOMDV-MP routing protocol

with (a) 9, (b) 25, (c) 49, (d) 81 and (e) 121 node density for AOMDV-MP routing protocol

Figure 8 (a–e) illustrates the throughput performance of MIMC, MIMC-BA, MIMC-SRT, and MIMC-PT architectures under the AOMDV-SP routing protocol for increasing data rates across different node densities. Similarly, Figure 9 (a–e) presents the throughput performance of the same architectures under the AOMDV-MP routing protocol for the same set of network conditions.

The observed results indicate that the throughput performance trends of the proposed MIMC-BA, MIMC-SRT, and MIMC-PT architectures, as well as the conventional MIMC architecture under AOMDV-SP and AOMDV-MP routing protocols, are consistent with the results obtained using the AODV routing protocol in Scenario 1. Furthermore, the throughput performance under the AOMDV-MP routing protocol is superior to that of AOMDV-SP for both conventional and proposed architectures. This improvement is due to the ability of AOMDV-MP to utilize multiple disjoint forward paths for data transmission between source and destination nodes, thereby distributing network traffic, reducing congestion, and minimizing packet drop probability caused by self-interference [25].

In contrast, AOMDV-SP employs a single-path routing strategy, where data transmission continues over one primary path and switches to an alternate path only upon link failure. As a result, data transmission remains restricted to a single path, similar to AODV, leading to higher congestion and lower throughput when compared to AOMDV-MP.

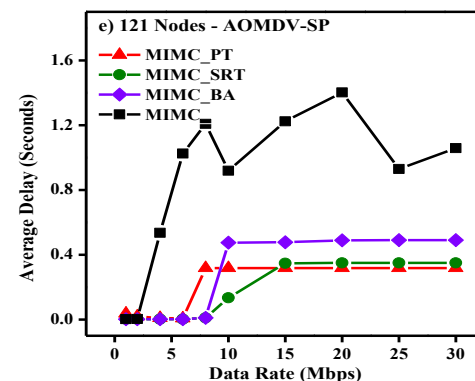
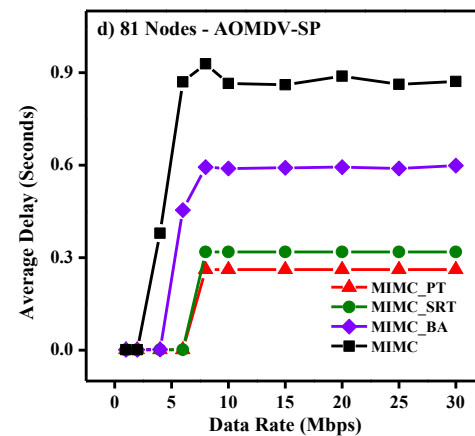
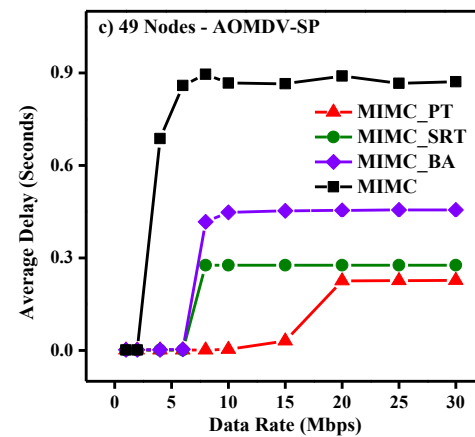
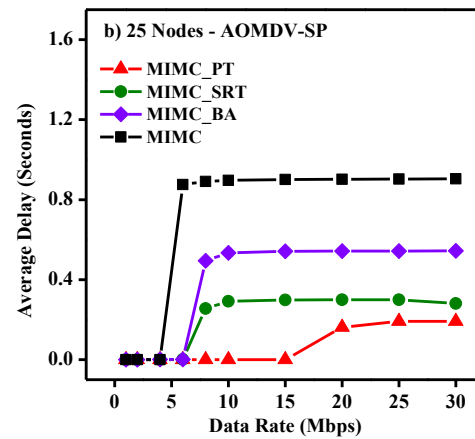
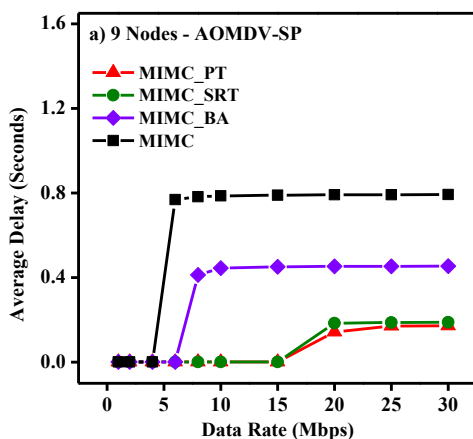


Fig-10 (a-e): Average delay performance of MIMC, MIMC-BA, MIMC-SRT and MIMC-PT network

architectures with (a) 9, (b) 25, (c) 49, (d) 81 and (e) 121, node density for AOMDV-SP routing protocol

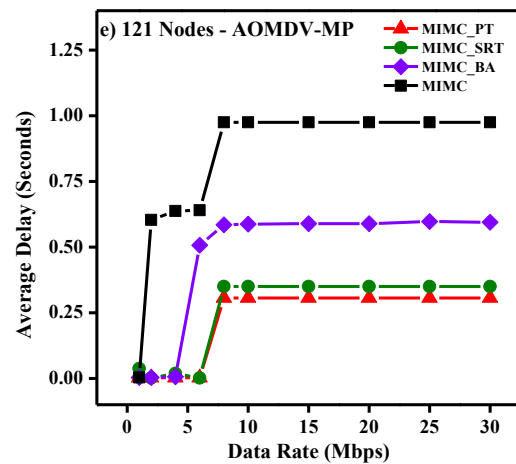
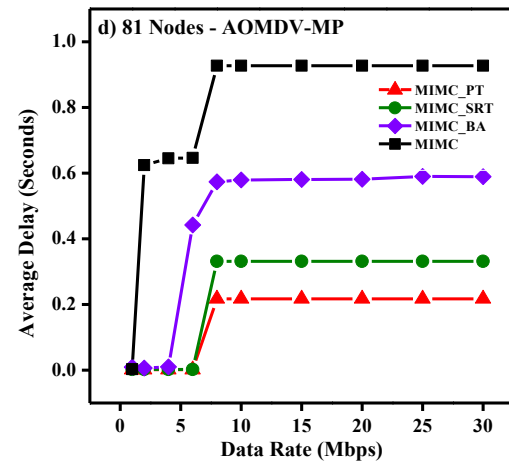
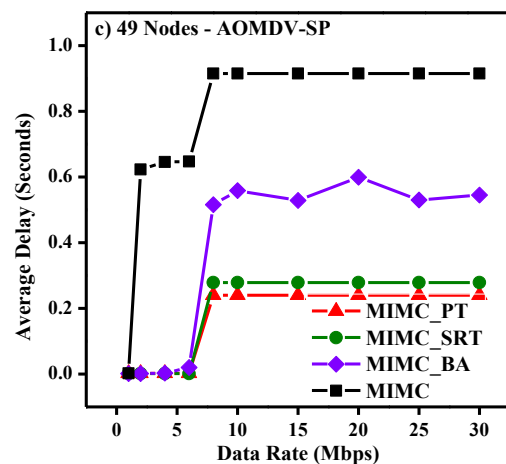
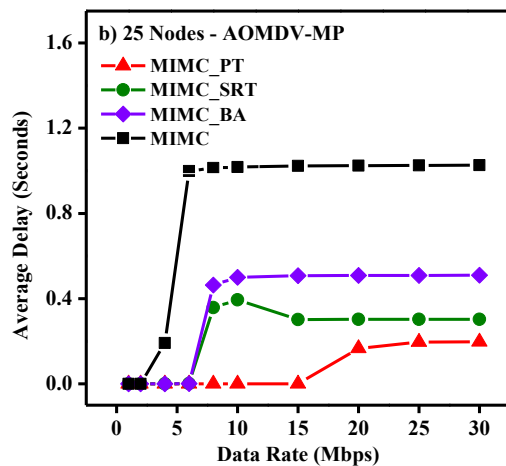
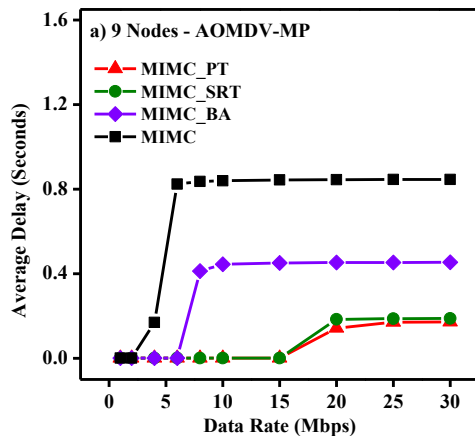


Fig-11 (a-e): Average delay performance of MIMC, MIMC-BA, MIMC-SRT and MIMC-PT network architectures with (a) 9, (b) 25, (c) 49, (d) 81 and (e) 121 node density for AOMDV-MP routing protocol

Figure 10 (a-e) presents the average end-to-end delay performance of MIMC, MIMC-BA, MIMC-SRT, and MIMC-PT architectures under the AOMDV-SP routing protocol for varying data rates and node densities (9 to 121 nodes). Similarly, Figure 11 (a-e) depicts the average delay performance of SISC, MIMC, MIMC-BA, MIMC-SRT, and MIMC-PT architectures under the AOMDV-MP routing protocol for the same network configurations.

It is observed from Figures 10 (a-e) and 11 (a-e) that the average delay performance of the proposed MIMC-BA, MIMC-SRT, and MIMC-PT architectures, as well as the conventional MIMC architecture under both AOMDV-SP and AOMDV-MP routing protocols, is consistent with the results obtained using the AODV routing protocol in Scenario 1.

In the AOMDV-MP routing protocol, data packets are transmitted over multiple disjoint paths, enabling

effective bandwidth aggregation and reduced network congestion. Furthermore, distributing traffic across multiple forward paths reduces packet buffering overhead at intermediate nodes, thereby improving (reducing) the average end-to-end delay compared to AOMDV-SP.

In contrast, the AOMDV-SP routing protocol exhibits comparatively higher delay performance since data transmission is restricted to a single path with limited bandwidth resources. This leads to increased congestion at intermediate nodes, resulting in higher buffering time and overall increased average delay when compared to AOMDV-MP.

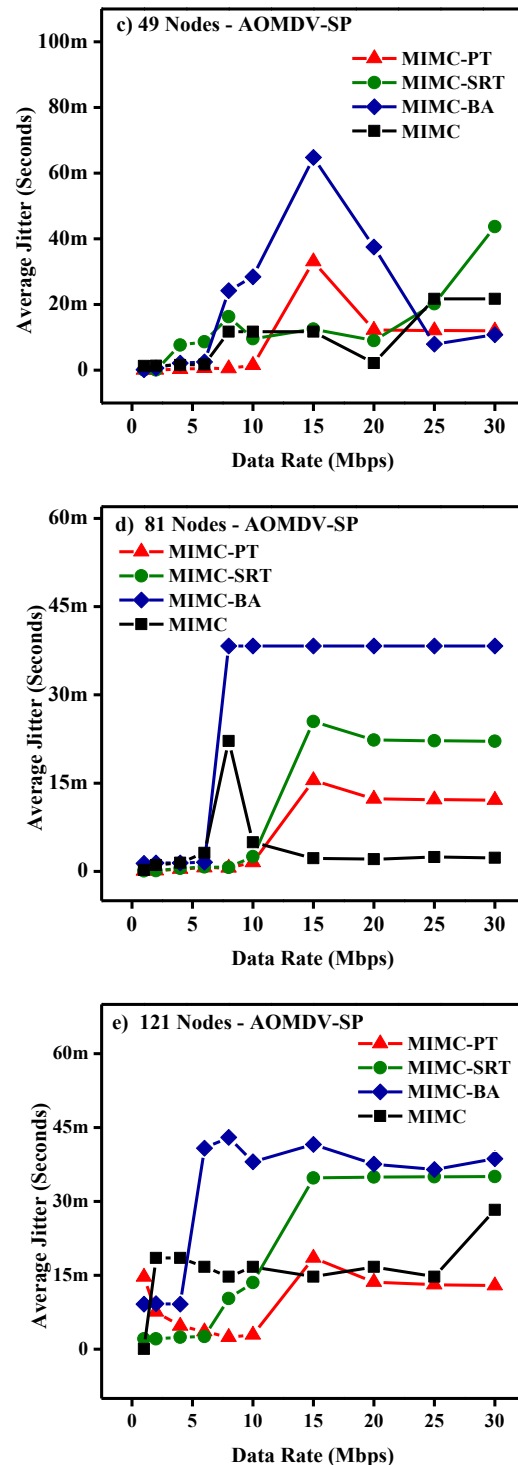
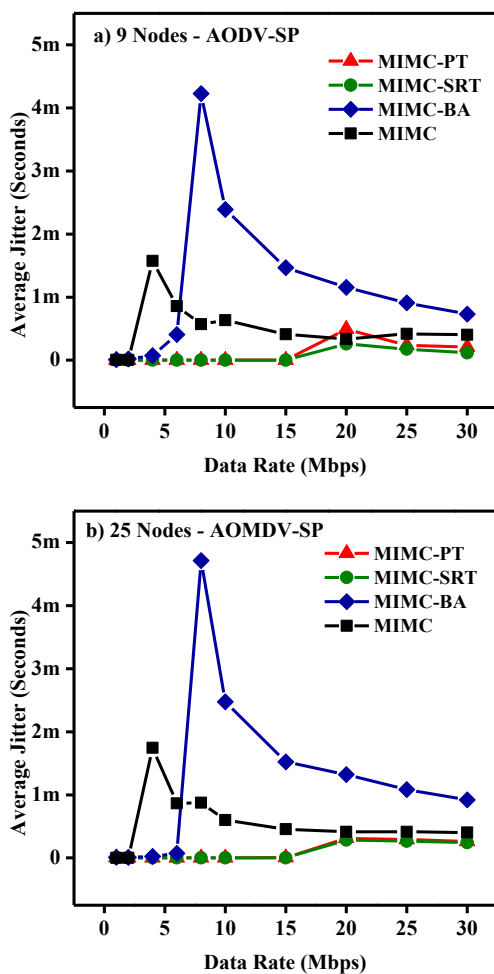


Fig-12 (a-e): Average jitter of MIMC, MIMC-BA, MIMC-SRT and MIMC-PT network architectures with (a) 9, (b) 25, (c) 49, (d) 81 and (e) 121 node density for AOMDV-SP routing protocol

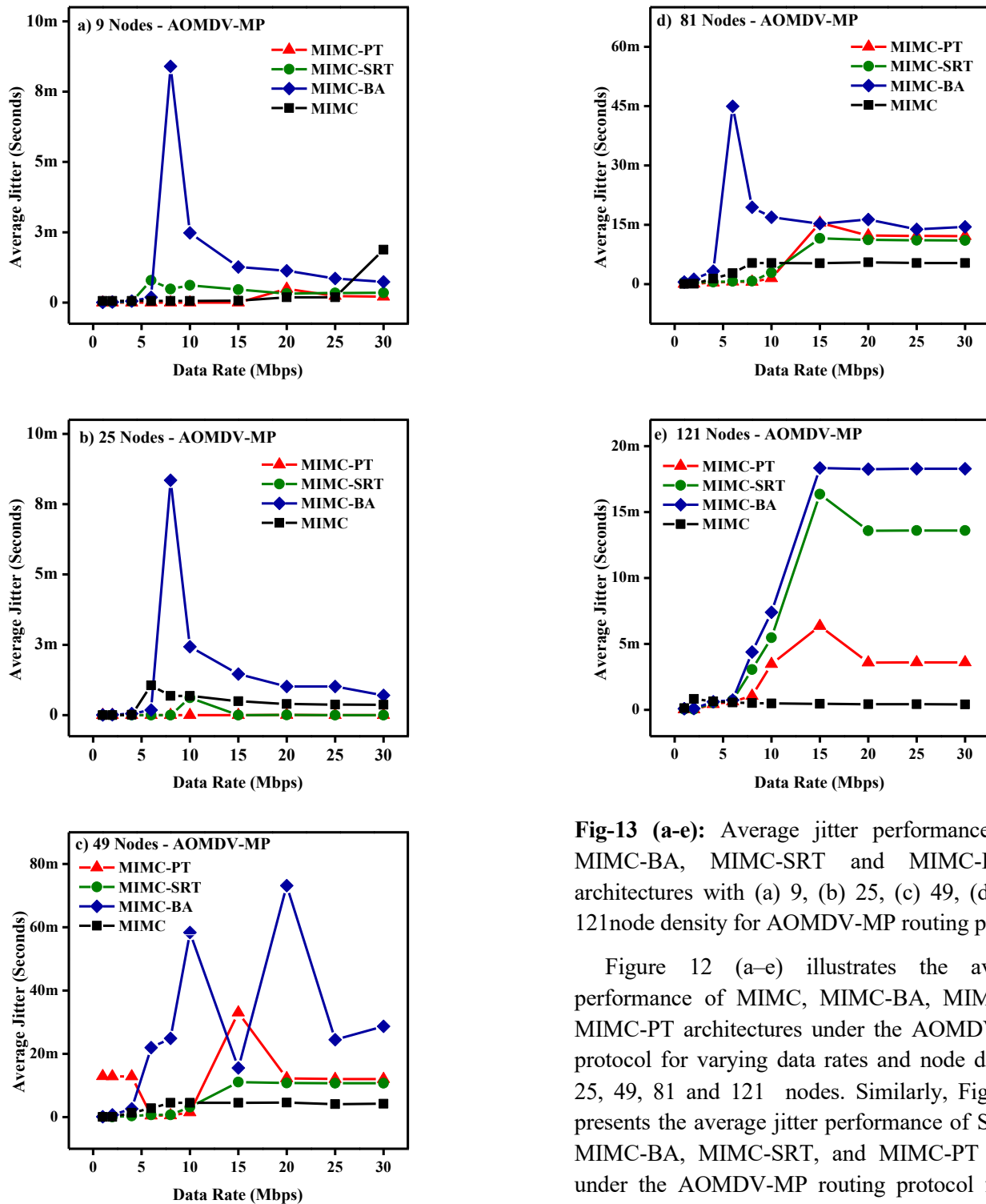


Fig-13 (a-e): Average jitter performance of MIMC, MIMC-BA, MIMC-SRT and MIMC-PT network architectures with (a) 9, (b) 25, (c) 49, (d) 81 and (e) 121 node density for AOMDV-MP routing protocol

Figure 12 (a-e) illustrates the average jitter performance of MIMC, MIMC-BA, MIMC-SRT, and MIMC-PT architectures under the AOMDV-SP routing protocol for varying data rates and node densities of 9, 25, 49, 81 and 121 nodes. Similarly, Figure 13 (a-e) presents the average jitter performance of SISC, MIMC, MIMC-BA, MIMC-SRT, and MIMC-PT architectures under the AOMDV-MP routing protocol for the same simulation conditions.

It is observed from Figure 13 (a-e) that the average jitter performance of both the conventional MIMC architecture and the proposed MIMC-BA, MIMC-SRT, and MIMC-PT architectures under the AOMDV-MP routing protocol is higher than that of AOMDV-SP. This is because AOMDV-MP distributes data packets across multiple paths with different hop counts, resulting in variations in end-to-end delay and consequently higher jitter. In contrast, AOMDV-SP forwards packets through a single path with relatively uniform hop counts, leading

to more stable delay characteristics and lower jitter values.

Table-4: Standard Video Qualities with Resolution and Required Bit Rate

Quality	Resolution	Video Bit Rate (Kbps)
Low	480 x 270	400
Medium	640 x 360	800 -1200
High	960x 540	1200 - 1500
HD 720	1280x 720	1500 - 4000
HD 1080	1920x 1080	4000 - 8000
4K	3840x 2160	8000 - 14000

Table 4 presents the recommended bit rate requirements for various video resolutions. Table 5

Table-5: Maximum throughput achieved and the best video streaming services sufficed by proposed MIMC-BA, MIMC-SRT, MIMC-PT architectures by considering AODV, AOMDV-SP and AOMDV-MP routing protocols for the density of 9 nodes

Network Architecture	AODV		AOMDV-SP		AOMDV-MP	
	Maximum Throughput	Best Video Quality Supported	Maximum Throughput	Best Video Quality supported	Maximum Throughput	Best Video Quality supported
MIMC-BA	7.44 Mbps	HD 720	9.44 Mbps	HD1080	12.43 Mbps	HD 1080
MIMC-SRT	18 Mbps	4K	19.50Mbps	4K	23.3 Mbps	4K
MIMC-PT	19.7 Mbps	4K	25.0 Mbps	4K	26.7 Mbps	4K

8. CONCLUSIONS

This paper proposes three novel Multi-Interface Multi-Channel (MIMC) architectures, namely Multi-Interface Multi-Channel Bandwidth Aggregation (MIMC-BA), Multi-Interface Multi-Channel Simultaneous Receive Transmit (MIMC-SRT), and Multi-Interface Multi-Channel Parallel Transmission (MIMC-PT), to enhance multimedia communication over wireless Ad Hoc networks. The performance of the proposed architectures is evaluated and compared with conventional Single Interface Single Channel (SISC) and Multi-Interface Multi-Channel (MIMC) architectures using AODV, AOMDV-SP, and AOMDV-MP routing protocols in the QualNet 6.1 simulation environment.

Simulation results demonstrate that the proposed architectures significantly improve network performance by effectively utilizing and aggregating the bandwidth available across multiple non-overlapping channels. Among the proposed schemes, MIMC-PT achieves the highest throughput and lowest end-to-end delay by dynamically selecting idle interfaces for data

summarizes the maximum throughput achieved and the best video streaming quality supported by the proposed MIMC-BA, MIMC-SRT, and MIMC-PT architectures under AODV, AOMDV-SP, and AOMDV-MP routing protocols for a 9-node scenario. From Table 5, it is evident that the proposed multi-interface multi-channel architectures support a maximum data rate of 26.7 Mbps in Ad Hoc networks under the AOMDV-MP routing protocol, enabling 4K video streaming applications. In contrast, the conventional MIMC and SISC architectures support only HD 1080p and high-quality video streaming applications, respectively.

transmission, while MIMC-SRT minimizes self-interference through simultaneous reception and transmission on different interfaces. The proposed architectures consistently outperform conventional SISC and MIMC networks in terms of throughput and delay performance.

The enhanced bandwidth utilization, reduced network congestion, and improved Quality of Service (QoS) make the proposed architectures well suited for bandwidth-intensive real-time multimedia applications, including interactive gaming, video surveillance, video-on-demand, and video conferencing. The results indicate that the proposed MIMC architectures provide an effective and scalable solution for supporting next-generation high-data-rate wireless communications and emerging 5G-enabled multimedia services over Ad Hoc networks.

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