International Journal of Engineering Trends and Technology
ISSN: 2231–5381 / https://doi.org/10.14445/22315381/IJETT-V72I4P103

Volume 72 Issue 4, 23-31, April 2024

Original Article

Novel Beam Sector Antenna-Based Routing Protocol for MANET Hidden and Exposed Terminal Problem

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Received: 18 November 2023 Revised: 20 February 2024 Accepted: 01 April 2024 Published: 24 April 2024

Abstract *- Mobile ad hoc networks are the most widespread self-organizing and readily constructed networks for quick communication in emergency circumstances. Addressing the Hidden and Exposed node terminals in a Mobile Ad hoc Network reduces network performance. Several research projects have been proposed by incorporating the Directional antenna within the MAC layer capabilities can help with the concealed and exposed nodes problem. Initially, the Omni antenna was utilized in MANET for transmission; however, it was unable to accommodate extensive range, power optimization, or interference. This research paper explores the use of beam sector directional antennas in physical and routing protocols to address hidden and exposed node concerns in the MAC layer. This study introduced a unique routing strategy that addresses hidden and exposed nodes by creating a route table based on the beam sector antenna orientation. This proposed antenna is divided into eight sectors based on the location of the neighbor node, and the respective sector transmitter or receiver will transmit or receive the packet. This antenna also determines the receiver direction based on the location of the next hope received and focuses the packet floating. This technique supports the Hidden and Exposed node problem in MANET while also improving routing efficiency and power optimization. This study was simulated using Network simulation, and the results showed a 25% to 35% improvement in total MANET Network performance, a 30% to 40% increase in metric value, and an overall antenna gain of 18.5 dBi in the beam sector antenna.*

Keywords *- MANET, Antenna, Physical Layer, Routing protocol, MAC layer, Hidden and Exposed Terminal (HET) problem.*

1. Introduction

One of the challenging tasks of the Mobile Ad hoc Network (MANET) [1] is the packet mission. In the MANET protocol stack, packets flow into many forms to reach the destination. Right from the network layer routing process, the data link layer makes the packet of data and the physical layer involved in the transmission. Packet transmission is one of the biggest challenging tasks in MANET communication [2]. Thwart the hidden and exposed nodes [3] and collision avoidance [4] are the few. Many research works were invented for reliable packet transmission with the support of the best routing protocol [5], modifying data link layer functionality, and better usage of smart antennas. Traditional routing approaches use the routing protocol to enhance MANET battery performance and lower energy consumption [6], as packet route selection is part of power transfer with the topological ordering of MANET nodes used to select routing.

To handle battery power management, multiple MANET protocols [7] and numerous new categories of routing protocols [8] [9] are proposed. Several research articles have recently been published to improve the performance of the AODV protocol, including AOMDV [10], SQR-AODV [11], AODV-BR [12], AODV-RD [13], AODV-BR [14], ATOMDV [15], and AMORLM [16], which are supports for increasing battery life. MANET parameters, such as minimizing MANET overhead to support better power management, are also regarded as important factors in reducing battery power consumption; many optimization strategies are based on this goal. In the data link layer, several solution classes have been proposed to handle the Hidden and Exposed nodes problem in wireless networks as a result of mobility changes. The major recommended solution for solving hidden and exposed nodes is launching MAC layer protocols. A group of authors proposed protocols for the Medium Access Layer, such as NULLMAC protocol [17], RDBTMA protocol [18], WiCCP protocol [2], WiMARK protocol [19], CAD-CW protocol [20], and CFC-MAC protocol [21], in which each protocol does not achieve all performance parameters and lags on some others.

Conventionally, the antenna was used within MAC protocol through the Distribution Coordination Function in IEEE 802.11 named CSMA/CA, along handshaking technique. Recently, these antennas have been overcome by smart antennas [22] due to providing more number of nodes connectivity and gaining power; some kind of antenna support interference [9], long transmission range [24] and transmission capacity [25]. Mahmud et al. [26] proposed GPS-based MAC-designed directional antennas for defending hidden and exposed terminal problems.

Wang et al. [27] invented the CMDMAC protocol to resolve the MANET Hidden and Exposed node problem with the corporative directional antenna, and Kulcu et al. [22] proposed the smart antenna using the IETF 6TiSCH protocol for MAC layer scheduling mechanism to overcome hidden and exposed node issue. Vigneshwaran et al. [7] invented the sector-based direction antenna by dividing geographical locations into sectors and proposed the sector-based antenna. Periyakaruppan [8] uses the MIMO link to propose the COASC strategy to overcome the MAC layer problem with the support of scheduling in Physical layer network capacity.

Several methods have been implemented to give solutions to the MANET challenges with the support of the routing protocol, MAC layer operation, Hidden and exposed terminal problems and antenna usages. However, none of the methods has proposed one technique to cover all the challenges. This article proposes a routing technique with the antenna sector direction with the support of the MANET challenges of best routing protocol can get along with MAC layer improvement, Hidden and exposed nodes solution, and better antenna usages. The antenna is divided into eight sectors; each direction is fixed to the neighbour node transmission, and the routing protocol route selection is based on the beam direction defined for each node. This kind of routing protocol could solve physical, MAC layer and Network layer challenges. The organization of this article starts with a discussion of the literature survey in Chapter 2, the proposed method of antenna mechanism, design and routing stages in Chapter 3, followed by research methods and result discussion in Chapter 4, and finally ending with conclusion and feature work in Chapter 5.

2. Literature Survey

The authors of Rao et al. [30] proposed the new energy-based route calculation protocol using an optimized genetic algorithm named GA-AOMDV, the method of choosing the optimal path from the numerous paths in accordance with shortest distance, less congestion, and minimal consumption of energy. However all the parameter estimation for finding the optimal route is cumbersome and overloaded to the source node.

Authors of Harihara Gopalan et al. [31] propose an algorithm for routing and finding the optimal path for data acceleration from the source node named Fuzzified Particle Swarm Optimization oriented Routing (FPSOR) algorithm to reduce the overhead and data loss in MANET. This algorithm uses the Fuzzified method to find out the fresh route for finding the best route but to find the fresh path, this algorithm needs to work on energy consumption, which is not perfectly predictable in all the nodes.

Ryu et al. [32] proposed the reputation-based routing protocol based on Q-Learning, which uses reinforcement learning in game theory. Finding the reputation nodes process, which excludes the attackers and intruders nodes, simulation research of the proposed routing protocol overcomes the black hole attack scenario and the gray hole attack. It produces a better packet loss ratio, end-to-end delay computation, and energy efficiency. However the adaptation of Game theory and Reinforcement learning methods into Q-Learning is needed a trained data set, and a new attacker node could not be predicted.

To address the issue of exposed nodes in MANETs, the authors of Sivaram et al. [18] suggested the RDBTMA protocol, which operates on RTS/CTS and busy tone signals. Furthermore, fast transmission is supported by NACK signals, and simulation results reveal that when compared to the present protocol, this study effort reached just the PDR (17.8%), packet delay was 38%, and throughput was 21.9%. The packet loss rate was 14.9%. The authors Liu Kai et al. [21] suggested the ETF MAC protocol with a new multichannel MAC to address the exposed terminal problem. Along with RTS/CTS discourse for channel allocation, conflict-free traffic channel work is performed; this work avoids packet collision. The simulation results are compared with the CAM-MAC protocol using only a few performance variables, such as packet drop rate, delay, and channel utilization, to determine the best. Viral et al. [2] conducted a collection of studies on hidden node issues and their solutions. This article projected the virtual Jamming issues and RTS/CTS for creating JAM in wireless networks and also addresses WiCCP protocol to resolve the hidden node issues and other techniques usages such as Omni directional antenna, increase transmission time, software enhancement is supported for improving Hidden and exposed node problem, but software updates are not precise.

Mekala et al. [33] presented the MAC protocol, which is implemented with Sensor and directional antenna support, in this research to improve the performance of wireless sensor networks. The MAC protocol, with the help of a directional antenna, helps to overcome the hidden and exposed node problem, and the research simulation results generate a multihop that is reduced across long distances and is energy optimized.

Z. Wei et al. [34] proposed gossip-based neighbor node discovery in VANET by deploying numerous sensors on the roadside and receiving information via GSIM-ND multipacket reception. Simulation results were compared to other existing CRA and SBA algorithms. The convergence time is reduced by 40 to 90% when the number of modulation modes k is set to 1. When the number of modulation modes is changed, the outcome fails to improve convergence time. This approach works well when the derivation of a neighbor node can be completed within the time constraints. Zhiqing Wei et al. [23] discovered a strategy for lowering convergence time with prior knowledge of neighbor node information for 6th generation mobile nodes. They proposed incorporating the gossip mechanism into the ISAC-enabled ND algorithm. When compared to Q-learning-based mechanisms, simulation of the proposed work lowered convergence time significantly, even when used to reinforce learning. The ND Algorithm, as well as ISAC techniques, is not required for MANET operation.

Liang et al. [28] found neighbor node detection in FANET to solve multiple channels accessing problems. They present two algorithms, BR-DA and BR-DA-FANET, as well as two protocols, ND-LP and ACI-LP, for beam tracking and channel enabling. All of this comes together to produce the FA-MMAC-DA protocol for ND discovery and interruption avoidance. When compared to the previous ND protocol, the simulation of our protocol results in less delay. However, this method fails to detect the rapid finding of ND and transmission delay. Trung Kien Vu and Sungoh Kwon [29] offer a location aware on demand routing system for mobile nodes notwithstanding the presence of node location error. They employed the Kalam filter to determine the actual node location, and the simulation results improved on prior work. However, the poor location information about the nodes, which caused incorrect routing, also reduced MANET performance.

From the literature survey, many researchers invented different solutions for the invention of routing protocol, hidden and exposed nodes challenges, and usage of antenna design. All the research work addresses the specific issues, not concentrating on all the challenges. This article proposed a new routing protocol to overcome the beam allocation in the antenna, MAC layer operations, Hidden and Exposed nodes issues and power optimization. The proposed work antenna is divided into eight sectors; each sector transmission and receiving antenna is assigned to the neighbor nodes' transmission based on the hidden and exposed nodes. The routing is determined based on the direction assigned by the antenna.

3. Antenna Array Mechanism

The objective of this article is to invent the routing protocol based on the antenna beam direction, which addresses the MAC layer issues of Hidden and Exposed nodes problem and better antenna usage, finally achieving power optimizations.

3.1. Antenna Array

The design of the antenna array is divided into eight sectors; each sector could transmit 45° in direction as given in Figure 1. Each beam sector antenna has a transmitter and receiver, as shown in Figure 2. The direction of the transmission determines the functionality of the beam sector antenna and the table was created based on the neighbor node direction.

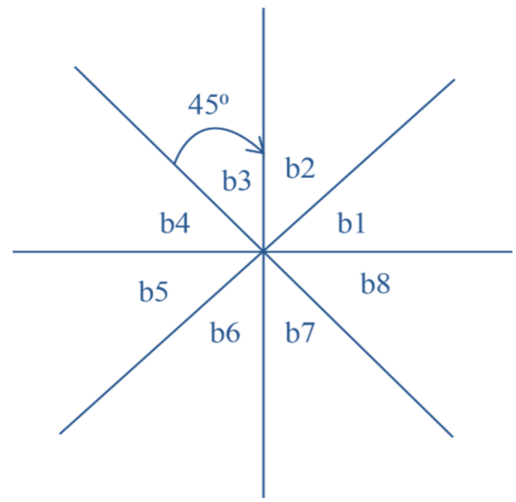

Fig. 1 Antenna model

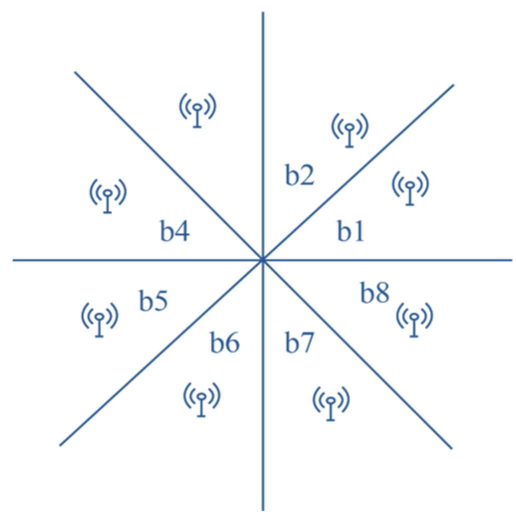

Fig. 2 Node antenna setting

3.2. Antenna Design Weight

Designing the antenna transmission and receiving signal is done with the support of the neighbor node direction. The antenna design of the receiving signal and transmission signal output is estimated by using the weight of each beam sector. Let S(t) power signal sent from an antenna transmission signal weight for each antenna sector wRi, where $1 \leq i \leq 8$. The received signal of the i^{th} antenna is estimated using Equation (1), and the received signal output is estimated using Equation (2).

$$xi(t) = s(t) \sum_{j=1}^{N} wTj\, hji \qquad (1)$$

$$Received\ signal\ output\ of\ r(t) = \sum_{i=1}^{N} WriXi(t) \qquad (2)$$

3.3. Design the Antenna Sector Beam for Neighboring Nodes

To design the beam sector transmission for the MANET nodes, Let the MANET Nodes N = {n_1, n_2, n_3...n_n}, n is the maximum number of nodes; the algorithm I for designing the MANET antenna transmission and receiving sector as follows.

Algorithm I to determine the antenna sector beam for neighbor nodes

Step 1: Generate the beacon signal and receive the location of the neighbor nodes in the region.
Step 2: For each node, find out the hidden and exposed nodes.
Step 3: Start assigning the beam sector to the neighbor node
For each node N_i, neighbor node ne_1, ne_2, ne_3...ne_n
For each beam sector, if the ne_i is not having the hidden and exposed nodes in this direction, then assign the beam sector to the ne_i.
Otherwise, check another sector.
Repeat all the nodes.

To understand the beam sector direction allocation, for all illustrations from Figure 3, and beam sector allocation as shown for node A given in TABLE I. The beam sector assigned was A1 beam for B7, A2 beam for I7, A3 beam for K7, A4 beam for K8.

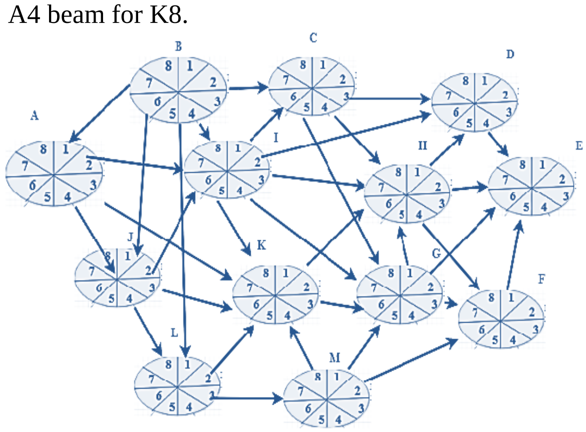

Fig. 3 Node beam antenna selections

3.4. Beam Sector Routing Protocol

This article proposed a novel routing protocol called bam sector routing protocol, which is a collaborative routing protocol based on demand. Every node has the beam sector direction of the other node's transmission, which has transmission free from the hidden and elimination direction. The beam sector routing protocol works as follows.

Step 1: Source node sends the RREQ signal to all the neighbor nodes about the route path needed for the destination.
Step 2: All the intermediate nodes flood the RREQ to the next neighbor by using the assigned path to reach the destination.
Step 3: Shortest path is determined as per the Ad hoc on-Demand Vector protocol (AODV).
Step 4: Source nodes send the packets
Step 5: Destination node sends the acknowledgement back.

4. Simulation Results and Discussion

In this section the proposed beam sector routing protocol has been implemented in AODV protocol using the Network Simulator NS2.32, where the simulation parameters are defined in the TABLE II as named as BSR-AODV protocol. Three different antennas are considered for the results to work comparison. Beam sector antenna adopted with normal AODV protocol called (N- AODV), Hidden and Exposed work in MAC layer with AODV called HE-AODV Power-related parameters like signal power and energy consumption are taken for comparison, antenna-related parameters like collision and transmission speed, efficiency are considered for the comparison and finally packet related parameters End to End delay, packet delivery ratio are considered for the comparison. Initially, 50 nodes are defined for taking the comparison, and 5 counts increase every 10 ms the node count to reach the maximum 95 nodes.

Table 1. Simulation value

S.No	Parameter	Value set
1	PHY	DSSS
2	CWmin	32 bit
3	CWmax	1024 bit
4	Channel Data Rate	11Mbps
5	Basic Data Rate	1Mbps
6	SIFS	15 µs
7	DIFS	45 µs
8	Slot time	15 µs
9	Propagation delay	1 µs
10	Packet Payload	10000bits
11	MAC Header	200 bits
12	PHY Header	150bits
13	ACK	250 bits
14	RTS	250 bits
15	CTS	250 bits
16	Hidden signal	250 bits
17	Exposed Signal	250 bits

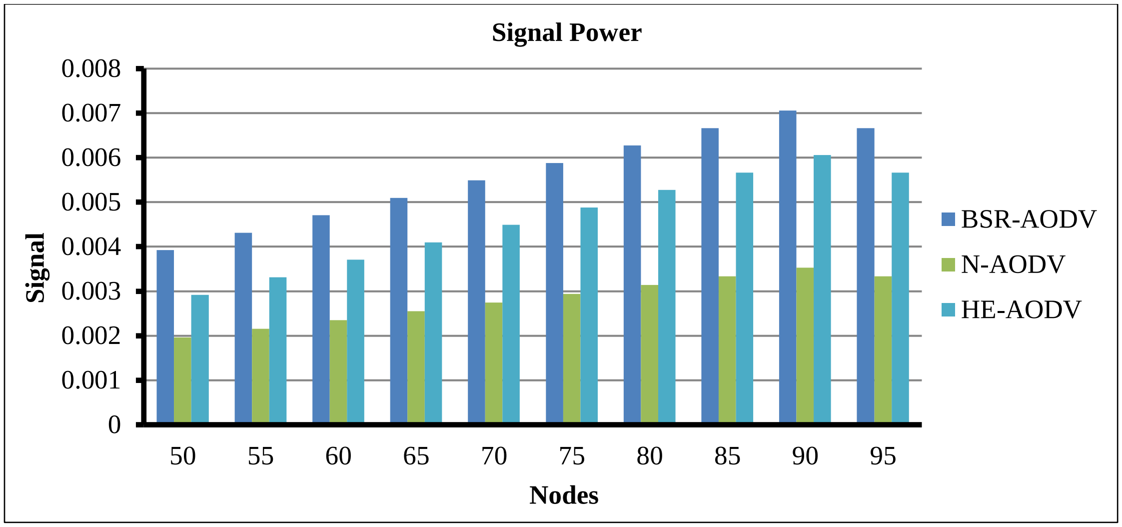

Fig. 4 Signal power

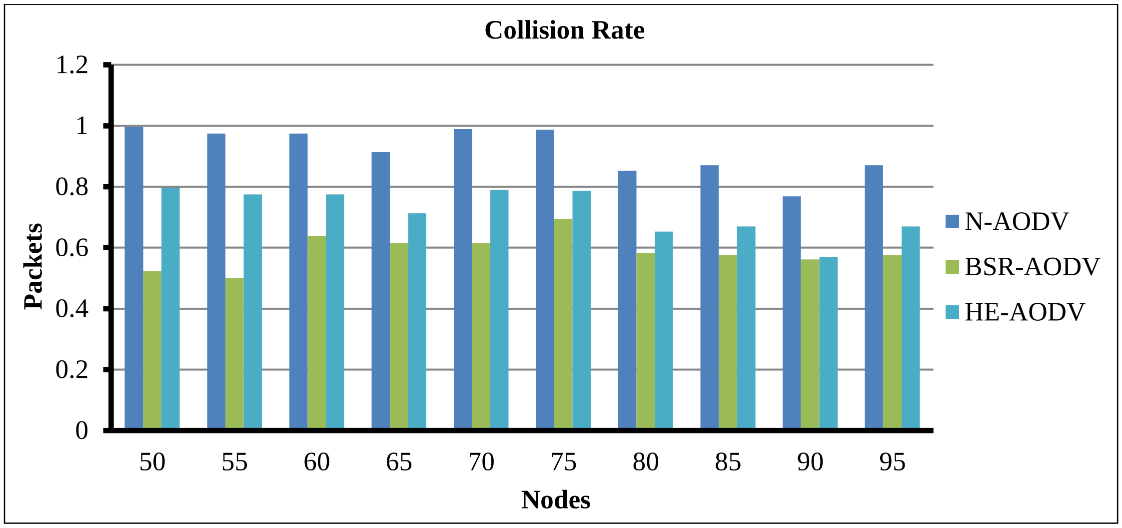

Fig. 5 Collision rate

4.1. Signal Power

The beam sector routing protocol signal power values are compared with the other methods of normal AODV and Hidden and Exposed AODV antenna design.

The nature of the BSR routing is that the power transmission is done only in the assigned sector of 45 degrees rather than 360 degrees of other antennas. So the signal power is double the transmission range is 10 % more than the other work. The comparisons among the BSR-AODV, N-AODV and HE-AODV are shown in Figure 4.

4.2. Collision Rate

The beam sector routing protocol collision rate is compared with the other methods of normal AODV and Hidden and Exposed AODV antenna design. The nature of the BSR routing is about the power transmission only in the assigned sector of 45 degrees rather than 360 degrees of other antennas. So the collision is less than 40 % more than the other work. The comparisons among the BSR-AODV, N-AODV and HE-AODV are shown in Figure 5.

4.3. Transmission Speed

Since the use of the Beam sector antenna, any one of the beams from the eight sectors is selected for the transmission and receiving of the packets. So the speed for the packet transmission from the antenna transmitter is compared with the proposed antenna speed.

The antenna speed is compared with the proposed PMBS-Antenna, which is depicted in Figure 6. The beam sector antenna produced more transmission of packets compared with the N-AODV and HE-AODV since all the beams are transmitting the packets, even the nodes get increased in the simulation, The beam sector AODV antenna transmission speed is 65%.

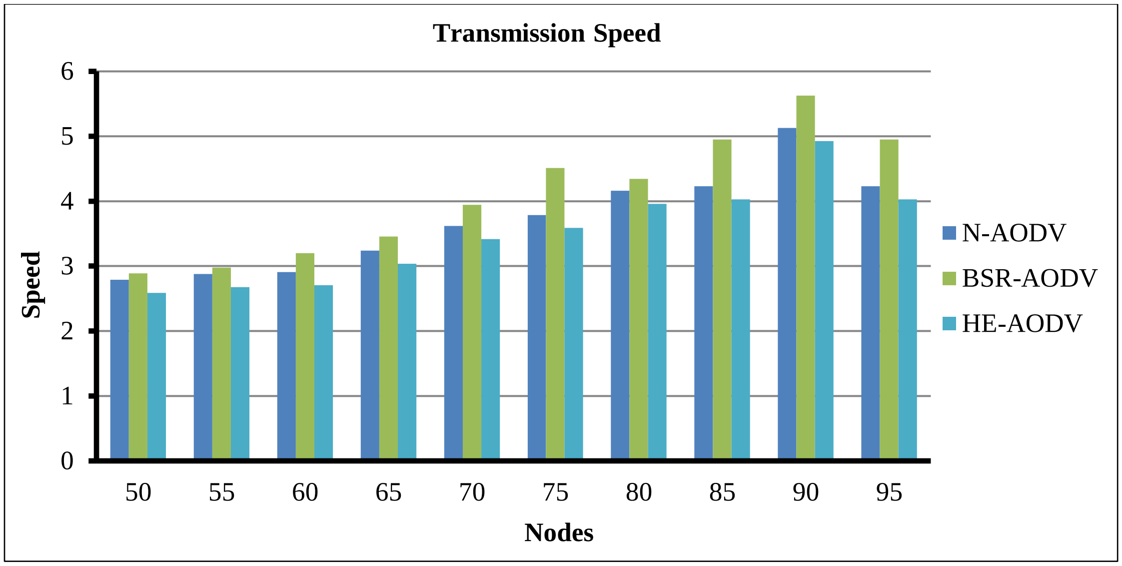

Fig. 6 Transmission speed

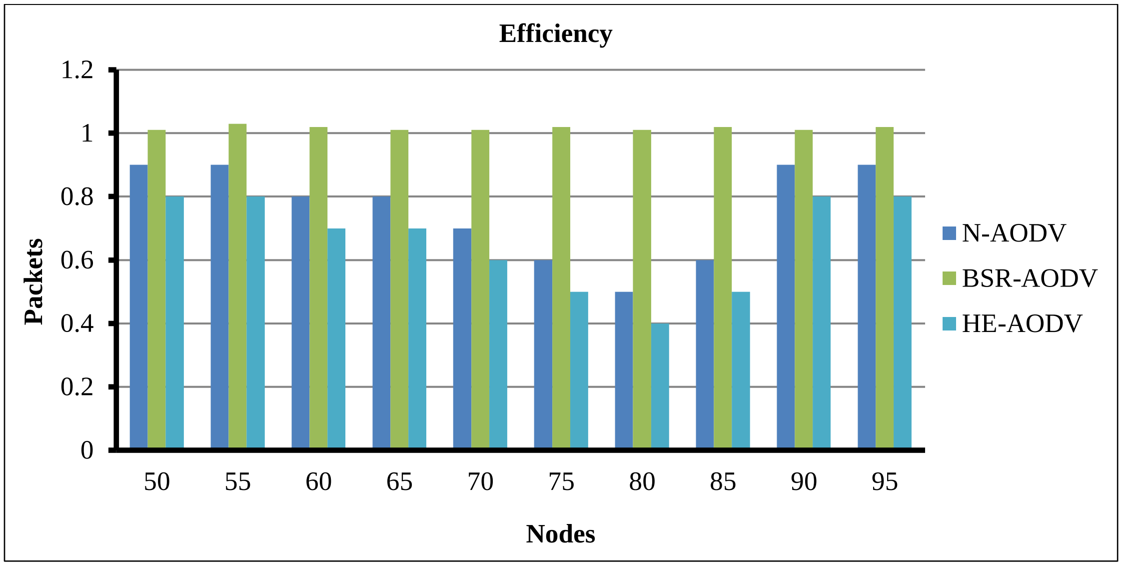

Fig. 7 Efficiency

4.4. Efficiency

The Beam Sector antenna Efficiency is compared with the N-AODV and HE-AODV antenna, which is depicted in Figure 7. The Beam sector Antenna shows more efficiency compared with the N-AODV and HE-AODV; even though the nodes get increased in the simulation, the other antenna could not produce better efficiency, where the proposed BSR-AODV Antenna efficiency is 25 % more than with other.

4.5. Energy Consumption

The Beam Sector antenna energy consumed is compared with the N-AODV and HE-AODV antenna, which is depicted in Figure 8. The Beam sector Antenna BSR-AODV shows less energy consumed because of routing selection, collision-free, hidden and exposed terminal avoidance, but the other methods show consumed more energy, even though the nodes get increased in the simulation, the other antenna could not produce better usage, where the proposed BSR-AODV Antenna energy consumption is 35 % more than with other.

4.6. Packet Delivery Ratio

The packet delivery ratio of the Beam Sector antenna BSR-AODV is compared with the N-AODV and HE-AODV antenna, which is depicted in Figure 9.

The Beam sector Antenna BSR-AODV delivered more packets because of better routing selection collision-free, hidden and exposed terminal avoidance, but the other methods showed less packet delivery; even though the nodes increased in the simulation, the other antenna could not produce a better packet delivery ratio, where the proposed BSR-AODV PDR is 45 % more than with other.

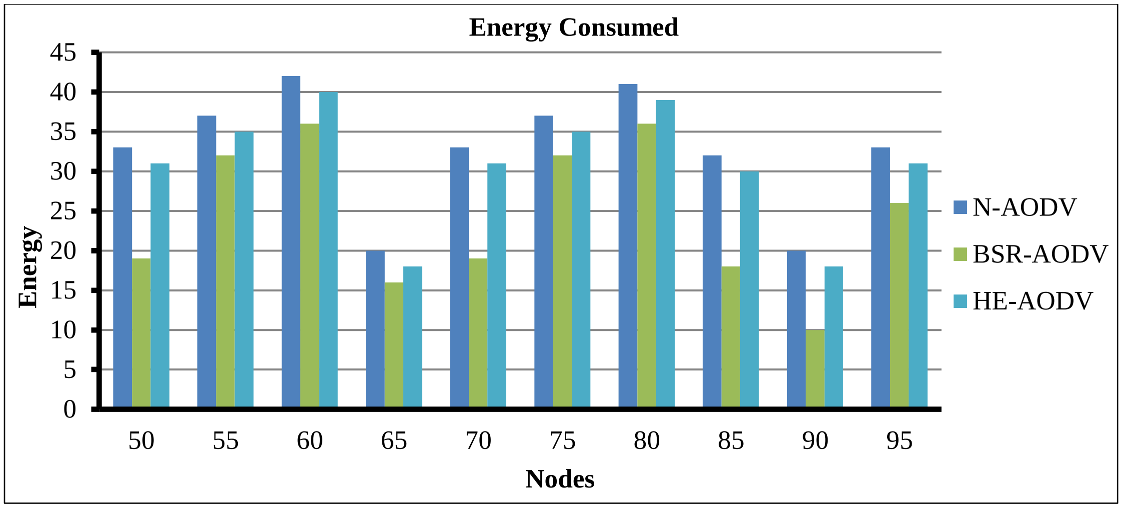

Fig. 8 Energy consumed

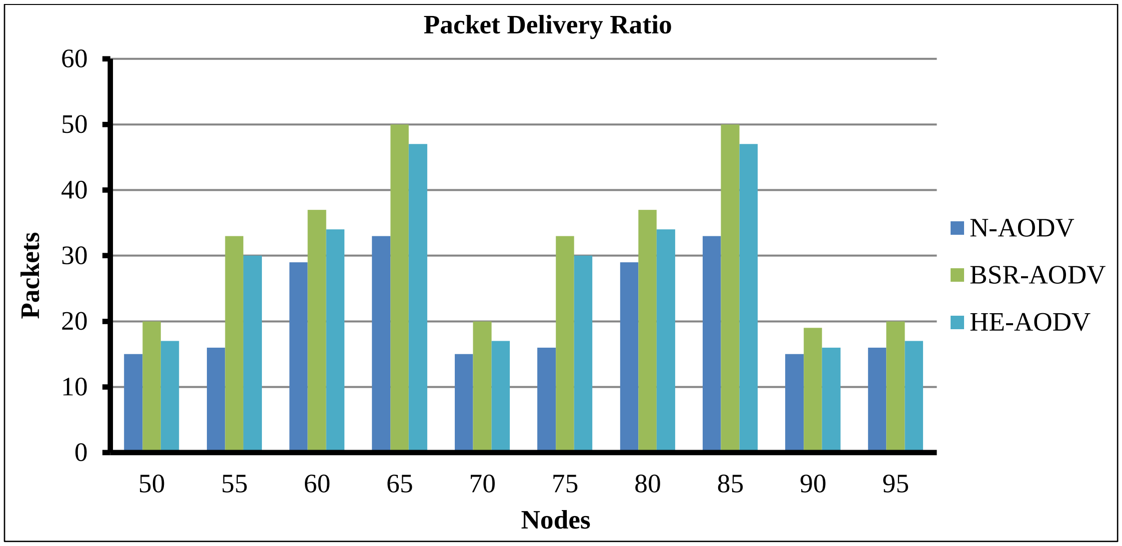

Fig. 9 Packet delivery ratio

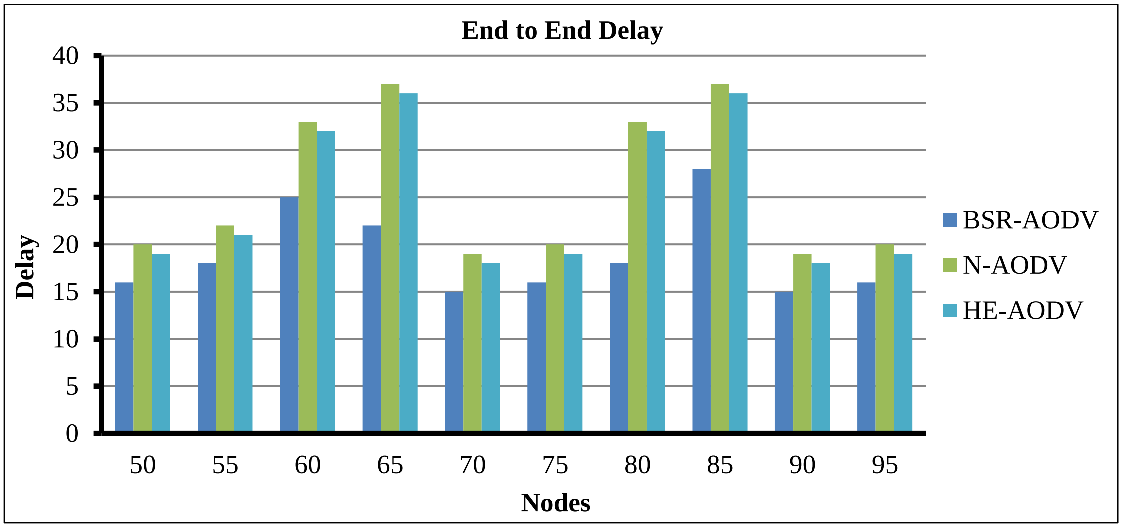

Fig. 10 End to End delay

4.7. End to End Delay

End to End Delay occurs when more time is taken to transmit of packet from the sender to the receiver. Beam sector-based antenna, the transmission beam and receiving beam are determined and hidden and exposed nodes collision avoided which aids in improvement of reducing the delay.

The Omni directional antenna End to End Delay is compared with the proposed PMBS-Antenna, which is depicted in Figure 10. The Omni directional antenna delay is more due to the collision among the nodes, and compared with the proposed PMBS-Antenna, even if the nodes get increased in the simulation, the proposed antenna delivers less delay with more number of packets because of collision-free transmission. The proposed PMBS-Antenna End to End Delay is 45 to 50 % less than the Omni directional antenna.

5. Conclusion and Future Work

This research article proposed the better use of beam sector directional antennas in physical and routing protocols to address hidden and exposed node concerns in the MAC layer with a unique routing strategy that addresses hidden and exposed nodes by creating a route table based on the beam sector antenna orientation. The antenna is divided into eight sectors based on the location of the neighbor node, and the respective sector transmitter or receiver will transmit or receive the packet. This antenna also determines the receiver direction based on the location of the next hope received and focuses the packet floating. This technique supports the Hidden and Exposed node problem in MANET while also improving routing efficiency and power optimization. This study was simulated using Network simulation, and the results showed double in the transmission range is 10 % more than the other work, collision is less than 40 % more than the other work, antenna transmission speed is 65%, efficiency is 25 %, energy consumption is 35 % BSR-AODV PDR is 45 % End to End Delay is 45 to 50 % lesser than the Omni directional antenna. In feature, this work can be enhanced into other antennas to support the Hidden and Exposed nodes problem and improve the MANET performance.

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