Journal of Theoretical and Applied Information Technology
30th June 2025. Vol.103. No.12

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

SIGNAL PROCESSING IN MANET SMART ANTENNAS

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ABSTRACT

Each layer of the Mobile Adhoc Network protocol stack has subject to some kind of issues, Majorly the lower three layers are facing the major challenges in packet transmission without falls on antenna usage, Hidden and Exposed nodes issues and routing strategy. Several research works was carried out individually addressing the layers to solve the problem, but still research exists on these three layers. This article considering the three layers to give better signal processing systems in MANET antennas. The proposed work consists of combines base three layers together in to single layer named as Antenna Beams Direction Based Routing Protocol which used the smart antenna to select the beam for the transmission with the support of hidden and exposed nodes table, finally this work provides the better packet transmission and proved the best result. The proposed work was simulated with the support of NS and the result compared with the Omni directional antenna with the parameter of SNR, Radiation Intensity, Directivity, was compared and the results proved that proposed work done the best in 20 % to 30 % performance in comparing with the existing protocol stack.

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

1. INTRODUCTION

Mobile ad hoc network (MANET) antennas are essential components in wireless communication systems due to several reasons like Mobility and Dynamic Topology, Decentralized Infrastructure, Harsh and Challenging Environments, Resource Constraints and Flexibility and Adaptability [1]. The design of antennas for MANETs is crucial for achieving efficient and reliable communication. Antennas need to be compact, low-cost, and capable of handling the dynamic nature of MANETs [2]. Various types of antennas, such as Omni-directional [3], directional [4], and adaptive antennas [5], may be used depending on the exact necessities of the application Research proposes an innovative algorithm aimed at improving the efficiency of MANETs through adaptive antenna selection [5].

To provide the more antenna gain, better interference and transmission range, the Omni directional antenna was replaced by smart antenna [6], in advanced the antenna functionality were joined together with the MAC layer and Routing layer to produce more efficiency such as GPS based directional antenna [7] [8] CMD-MAC protocol [9] and IETF 6TiSCH protocol [6] with MIMO link [10]. Another set of research work was carried out in the antenna design with the support of neighboring node detection with coverage time [11], collision detection technology [12], gossip technique [13], and hardware devices [14] [15]. Latest technologies like Machine learning with

Kalman prediction [16], Q-learning model [17], and automata-based model [18].

Later the antenna design worked to address the solution to the MAC layer problem called hidden and exposed problem due to mobility among the nodes. Several MAC protocols were proposed to aid the solution to the MAC layer issues protocols like NULLMAC [19], RDBTMA [20], WiCCP [21] Wi-MARK [22], CAD-CW [23], and CFC-MAC [24] but still the MAC issues need more research. Another group of research work was carried out using the RTS/CTS signals modification signals [25] [26], Adaptive antenna array [27], recent algorithms [28] with the support of machine learning. The research is needed to incorporate the antenna work into designing the hidden and exposed nodes difficulty in the MAC layer.

In addition to the physical and MAC layer the network layer routing protocol supported the antenna functionality. RSSI based Indicator from the receiver strength, GPS and long-range technology established long-standing MANET operation [29]. EMBOA [30] combine butter fly optimization approach with a low-energy ML methodology to improve multipath routing. Some research carried out with antenna invention, few categories carried out the MAC layer and Routing. All these papers are individually concentrated on addressing the individual layers. The new dimension of the research is needed to take all the research work and implement the single vision to address the Antenna layer, Data link MAC layer and Network layer function difficulties. This article focuses on addressing all the points with the support of modern antenna design with hidden exposed nodes table routing protocol. This protocol finds the route path to overcome the hidden and exposed nodes (HEN) as well as the collision avoidance with the support of antenna beam direction focuses for transmission. The proposed protocol was name as Antenna Beams Direction Based Routing Protocol (ABDBRP).

The organization of this article as follows Summary of the related research work in the Physical layer, MAC layer and with protocol are explained in Session II, Followed by the hidden and exposed table based routing protocol proposal design in the antenna called Antenna Beams Direction Based Routing Protocol is discussed session III, Implementation of the proposed work and compared with the existing work is explained in session IV with result and discussion, session V finally ends with conclusion.

2. PHYSICAL AND MAC LAYER RELATED RESEARCH WORK

This section has concentrated the three different layers of research carried out in the MANET protocol stack of Physical layer and MAC layer and also addresses the difficulties in each layer of research.

2.1 Antenna Related Survey

The paragraph discusses various research efforts aimed at improving different aspects of wireless networks, such as neighbor node detection, antenna design, data transmission efficiency, and network management in environments like Adhoc, VANET, and IoT networks.

Neighbor Node Detection:
Researchers have proposed methods [18] like the ND method, reinforcement-based ND algorithm, radar communication technology, and gossip-based neighbor node discovery. These methods focus on improving the speed and accuracy of detecting neighboring nodes in different network scenarios. Merits include faster detection and reduced convergence time, while demerits include higher computational complexity and limitations in high-density networks.

Antenna Design:

Studies have explored steerable directional antennas, dynamic sector routing, smart antennas,[18] and hybrid designs combining Omni-directional and multi-beam directional antennas. These approaches aim to enhance signal strength, reduce interference, and improve data link strength. However, challenges include maintaining dynamic topology and slight differences in antenna gain compared to existing models.

Data Transmission Efficiency:

Various techniques have been proposed to address data transmission delay and improve throughput in wireless networks. These include cooperation-based [18] MAC protocols, techniques for minor lobe interference, and methods for fast neighbor node finding using Kalman filtering. While these approaches offer improvements in performance, there is a need for further research to overcome data transmission delay and optimize channel usage.

Network Management:

Research efforts have focused on VANET management, including packet fragmentation, disruption analysis, and fast neighbor node finding using spatial movement information. These studies aim to improve network performance and driving safety but may face challenges in the time required for neighbor node detection. Each of these research

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

areas contributes to enhancing different aspects of wireless networks, addressing challenges such as node detection speed, antenna efficiency, data transmission delay, and network management issues. However, further research is needed to overcome remaining limitations and optimize network performance effectively. Table I summarizes the antenna related research work done in MANET with merits and demerits.

Table I Survey Summary Of Antenna Research

Authors	Proposed Method	Merits	Demerits
B. El Khamlichi et al. [18]	ND method for tackling the automation discovery process model	Faster ND detection in low density networks	Slower ND detection in high density networks
Khamlichi et al [31]	Reinforcement-based ND algorithm	Overcomes latency and tail problems	Higher computational complexity
Ji et al [32]	Radar communication technology for neighbor node forecast	Utilizes radar for directional neighbor determination	Not practical for wireless nodes
Z. Wei et al. [33]	Radar and machine type communication for ND detection	Utilizes previous radar knowledge for faster ND prediction	Impractical for wireless nodes
Z. Wei et al. [13]	Gossip discovery in VANET	Reduces convergence time	Time constraints for neighbor node derivation
Zhiqing Wei et al [34]	Gossip mechanism into ISAC-enabled ND algorithm for 6th gen nodes	Lowered convergence time	Not required
Liang et al. [36]	Neighbor node detection in FANET using multiple algorithms	Less delay in comparison to previous ND protocol	Unable to detect rapid ND finding and delay
Trung Kien Vu and Sungoh Kwon [37]	Location aware	Improved node location determination	Incorrect routing due to poor node location information
Kulcu et al. [6]	Steerable directional antennas for IoT networks	Greater range transmission and lower interference	Not real-time and lacks best algorithms for performance improvement
P. Vigneshwaran and S. Suthaharan [38]	Dynamic sector routing with directional antenna	Improved signal strength and efficiency	Slight difference in antenna gain compared to present model
K. Periyakaruppan et al [10]	Advanced antenna	Optimum cost antenna with improved transmission range	Does not address mobility and energy-related issues
Mahendrakumar et al. [19]	Smart antenna in an adaptive antenna array for MANET	Increased MANET performance and problem tackling	Dynamic nature topology makes maintenance difficult
Bowen Zhen et al [39]	Digital phased antenna array for synchronization in unsynchronized nodes	Reduced synchronization time	Requires estimating geometric position, relationship, and probability distribution
Yang et al. [11]	BD-SBA technique for reception node beam receiving mode	Addresses interference problem	Unable to compare ND algorithm for performance improvement
M. T. Mahmud and	Cooperation-based	Reduced IoT data	Further focus needed on

colleagues [7]	Adaptive and Reliable MAC for IoT networks	transmission delay	overcoming data transmission delay
Y. Wang [40]	CMDMAC technique for minor lobe interference in directional Adhoc networks	Improved throughput in multiple data channel MAC protocol	Designed assuming a single data channel
Joao et al [41]	Study on VANET management for packet fragmentation and disruption	Identifies issues for future VANET improvement	And finding may take time
C. Liu et al. [16]	Fast neighbor node finding in VANET using Kalman filtering	Higher performance improvement compared to other algorithms	And finding may take time
Jose Vicente et al. [12]	Research on predicting neighbor nodes in wireless Adhoc networks	Better PDR, less overhead, and less energy consumed	Inability to solve CDH protocol
B. Zeng et al. [42]	Hybrid design of Omni Directional Antenna and Multi Beam Directional Antenna	Improved data link strength	-
Palanisamy et al. [43]	Adhoc and infrastructures network architecture-based communication	Ideal collision rate and improved efficiency	-

From the above survey related to the physical and MAC layer the research work summarizes that to improve the physical layer the special work was carried out in neighbour detection, antenna design, network management as well to improve the MAC layer protocol invention, resource allocation, sensors designed for the HEN problem. Some work of the physical layer supports the MAC layer by combining [7] [40] likewise some work of MAC layer combines the Physical layer [45]. The survey reveals that the cross-layer functionality could achieve better results. This article proposed the new technique design of the physical layer with the support of antenna design which avoids the hidden and exposed nodes as well as the new routing strategy named as Antenna Beams Direction Based Routing Protocol. This result could minimize the overload of the MAC layer and Network Layers functionality with the support of smart beam sector antenna design.

3. PROBLEM IDENTIFICATION

From the Literature survey, the research work reveals that the MANET has vast innovation is still needed to overcome the Physical and MAC layer issues while transmitting the Packets. This article finds the problem identification of reducing the Lower three layers in the MANET protocol stack, altogether the activities is done by the single layer as shown in the Figure 1 which is named as Physical MAC and Network Layer in short called as PMN layer and designed protocol named as Antenna Beams Direction Based Routing Protocol.

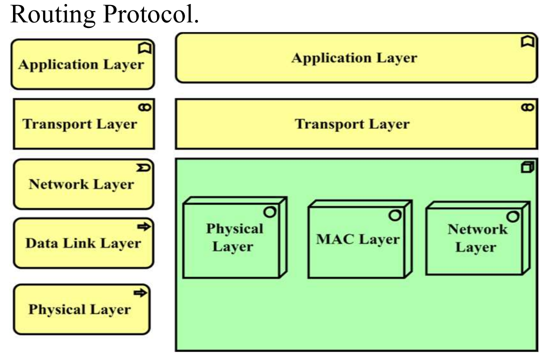

Figure 1 Proposed MANET protocol Layer

3.1 Modification done on Physical Layer

3.1.1Smart antenna Base station with digital signal processor

The research work finds the small modification which is done in Physical layer

Journal of Theoretical and Applied Information Technology
30th June 2025. Vol.103. No.12
© Little Lion Scientific
ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

with the support of smart antenna since the smart antenna has the capability of pattern adaptive capabilities, reasonable antenna gains and less expensive. In the smart antenna the knowledge is applied in to antenna algorithms using the digital signal processor, the main role of Digital Signal processor comprises of direction of arrival in all impinging signal and design of antenna pattern. the work of smart antenna promotes research on DOA and adaptive beam forming. DOA does the corrective analysis, array signal eigen analysis and signal to noise where the adaptive beam forming adjust the magnitude of the antenna.

Direction of Arrival

When the antenna array receives all the incoming signal from all the direction but the DOA determines the direction of incoming signal based on the computing time delay. Let's estimate the time delay, Assuming the planner array which has the M*N and x axis inter element spacing d_x and the y axis inter element spacing d_y. Let S(t) is a carrying baseband signal at the angle (ϴ, φ), then the computation of time delay based on the geometry value of antenna, elements value and spacing. The time delay signal s(T) at the planar array at the signal s(t) is estimated using Eq (1)

$$\Gamma_{mn} = \frac{\Delta_r}{v_o} ----(1)$$

Where Δ_r is a differential distance and v_o is speed of the light and the differential distance Δ_r is estimated using Eq (2)

$$\Delta_r = d_{mn}\cos(\psi) \quad ----- (2)$$

$$d_{mn} = \sqrt{m^2 d_x^2 + n^2 d_y^2} ----(3)$$

$$\cos(\psi) = \frac{a_r . a_p}{|a_r||a_p|} -------(4)$$

Where a_r and a_p are the unit vector direction of incoming signal.

The signal-to-noise ratio (SNR) represents the ratio between the average signal power and the interference from noise sources, expressed in decibels (dB). Implementing beam-based antennas in transmission reduces the likelihood of collisions and interference, thereby enhancing signal power and minimizing interferences. Consequently, the SNR improves by 50% compared to Omni directional antennas, as depicted in Figure 2 and TABLE IV, which lists the simulation values of SNR determined using Equation (12).

Where d_{mn} is the distance from the planar array M*N to then origin and ψ is the angle between the vector at the direction of the signal s (t). d_{mn} and cos(ψ) are computed using the Eq (3) and (4)

4. RESULTS AND DISCUSSION

The proposed Antenna Beams Direction Based Routing Protocol is implemented using the network simulator with the simulator parameter shown in the TABLE III, Performance factors are taken for comparisons are physical layer antenna parameters like Signal to Noise Ratio. Radiant Intensity, Directivity and Antenna Efficiency, MAC layer parameter are Bit Error Rate, Delay, routing layer parameters are Energy Consumption, Throughput, yield result value is compared with the Omni directional antenna. The following table presents a set of parameters and their corresponding values for a wireless network system:

TABLE III Simulation Value

PHY layer: DSSS
Contention Window min: 32 bits
Contention Window max: 1024 bits
Data Rate: 11 Mbps
Short Interframe Space: 15 µs
DIFS (Distributed Interframe Space): 45 µs
Time: 15 µs
Delay: 1 µs
Payload: 10000 bits
MAC layer Header: 200 bits
PHY layer Header: 150 bits
Acknowledgment: 250 bits
Request to Send: 250 bits
Clear to Send: 250 bits
Hidden: 250 bits

$$SNR = \frac{Transmission\ Power}{Link\ Distance} ----(12)$$

TABLE IV. SIMULATION VALUE OF SNR

Nodes	Signal to noise ratio of Beam Sector Antenna	Signal to noise ratio of Omni Directional Antenna
50	22.3	23
100	22.4	24

150	23	25
200	24	26
250	25	27
300	30.2	32
350	30.5	31.6
400	33	35
450	35	38
500	40	47
550	42	49
600	48	52
650	53	55
700	58	59
750	65	62
800	70	75
850	75	80
900	80	81
950	81	84
1000	84	86

The Table IV presents data regarding the signal-to-noise ratio (SNR) of both Beam Sector Antennas and Omni Directional Antennas across different distances (in meters). At a distance of 50 meters, the SNR for the Beam Sector Antenna is 22.3, while for the Omni Directional Antenna, it's slightly higher at 23. As the distance increases, the SNR values for both antennas generally rise. For instance, at 100 meters, the SNR for the Beam Sector Antenna is 22.4, and for the Omni Directional Antenna, it's 24. This trend continues with increasing distance, indicating improved signal quality over longer distances. However, it's noteworthy that at certain distances, such as 300 meters and beyond, the SNR values for the Beam Sector Antenna experience significant jumps, reaching 30.2 at 300 meters, and progressively increasing to 84 at 1000 meters. On the other hand, the SNR values for the Omni Directional Antenna exhibit a steadier increase, reaching 32 at 300 meters and 86 at 1000 meters. These findings suggest that, while both antennas generally offer improved SNR with greater distance, the Beam Sector Antenna demonstrates more pronounced enhancements over longer ranges compared to the Omni Directional Antenna.

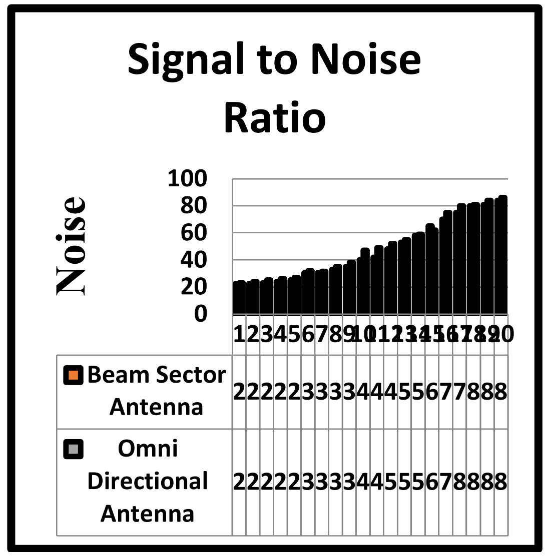

Figure.2. Signal to Noise Ratio

B. Radiation Intensity

Antenna radiation intensity for the direction is defined as the power radiation from the antenna per unit solid angle. It is a far filed parameter which is obtained from simply multiplying the radiant density by the square of the distance. The mathematical expression

$$U = r^2 W_{rad} \; ----(13)$$

Where U is a radiation intensity, r is a distance and W_{rad} is a radiation density unit is (W/m2).

TABLE V Radiation

Time (Ms)	Beam Sector Antenna	Omni Directional Antenna
1	0.1	0.3
2	0.675	1.125
3	2.8	3.6
4	5	6.25
5	8.1	9.9
6	12.25	14.7
7	19.2	22.4
8	26.325	30.375
9	35	40
10	48.4	54.45
11	64.8	72

12	80.275	88.725
13	98	107.8
14	118.125	129.375
15	147.2	160
16	173.4	187.85
17	210.6	226.8
18	243.675	261.725
19	280	300
20	319.725	341.775

The table V presents data comparing the performance of Beam Sector Antennas and Omni Directional Antennas across different sectors. Each row corresponds to a specific sector number, with corresponding values indicating the radiant intensity in watts per steradian (W/sr) for both types of antennas. For Beam Sector Antennas, the radiant intensity values range from 0.1 W/sr in Sector 1 to 319.725 W/sr in Sector 20. Conversely, Omni Directional Antennas exhibit lower radiant intensity values across all sectors, ranging from 0.3 W/sr in Sector 1 to 341.775 W/sr in Sector 20. The data illustrates the varying performance of Beam Sector Antennas and Omni Directional Antennas across different sectors, with Beam Sector Antennas generally demonstrating higher radiant intensity values compared to Omni Directional Antennas. This difference highlights the directional nature of Beam Sector Antennas, which focus their radiation in specific sectors, while Omni Directional Antennas radiate uniformly in all directions. Graphical comparison representation is shown in the Figure 3.

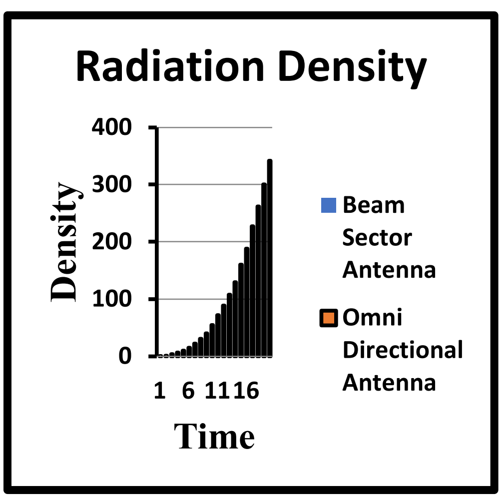

Figure 3 Radiation Density

C. Directivity

Directivity is defined as the ratio of radiant intensity from the given direction from the antenna in the average of all direction.

$$D = \frac{U}{U_0} = \frac{4\pi U}{P_{rad}} - - - - - - -(12)$$

Where U is the radiation intensity, U_o maximum directivity, 4π is the antenna division. p_{rad} is the total radiant power.

Table VI Directivity

S.NO	Directivity of Beam Sector Antenna	Directivity of Omni Directional Antenna
1	0.01	0.03
2	0.0675	0.1125
3	0.28	0.36
4	0.5	0.625
5	0.81	0.99
6	1.225	1.47
7	1.92	2.24
8	2.6325	3.0375
9	3.5	4
10	4.84	5.445
11	6.48	7.2
12	8.0275	8.8725
13	9.8	10.78
14	11.8125	12.9375
15	14.72	16
16	17.34	18.785
17	21.06	22.68
18	24.3675	26.1725
19	28	30
20	31.9725	34.1775

The Table VI compares the directivity values of Beam Sector Antennas and Omni Directional Antennas across different sectors and the figure 4 shown the pictorial representation. Each row corresponds to a specific sector number, with corresponding values indicating the directivity of the antennas. For Beam Sector

Antennas, the directivity values range from 0.01 in Sector 1 to 31.9725 in Sector 20. Conversely, Omni Directional Antennas exhibit lower directivity values across all sectors, ranging from 0.03 in Sector 1 to 34.1775 in Sector 20. The data highlights the varying directivity of Beam Sector Antennas and Omni Directional Antennas across different sectors, with Beam Sector Antennas generally demonstrating higher directivity compared to Omni Directional Antennas. This difference underscores the directional nature of Beam Sector Antennas, which focus their radiation in specific sectors, while Omni Directional Antennas radiate uniformly in all directions.

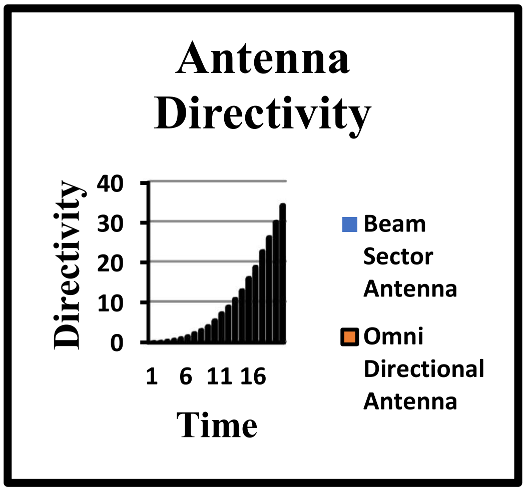

Figure 4 Antenna Directivity

5. CONCLUSION

This Research article find the challenges in the bottom three layers of Mobile Adhoc network and address the solution with the support of the Smart beam antenna, HEN table , And routing strategy , Finally proposed the Physical MAC and Routing models to address the all the issues , the results was simulated in Network simulator and the performance comparison was done with the Omni antenna with the parameter of Signal to Noise Ratio, Radiation Intensity, ,Directivity , Antenna Efficiency , Delay, Bit Error Rate, Throughput, Energy consumption Comparison and results proved that proposed work was better in 20 to 30 % . in feature this proposed work could be compared with the other antennas to get the better antenna for the communication use.

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