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Key Enabling Technologies of Upcoming MANET Applications

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ABSTRACT: Wireless ad hoc networks have made it possible for current 5G and future 6G standard based applications to have seamless, ubiquitous access to distributed resources and service requirements of present scenario. The main objective of ad hoc networks, in light of technological developments, is multi-objective optimization in order to address the issues that will arise in the ensuing decades due to the growing demand on the volume of traffic from mobile users. Numerous new developments in cutting edge wireless technologies allow for the simultaneous optimization of competing goals, such as reduced costs, secure information sharing, topological flexibility, and network condition based adaptive routing in ad hoc networks due to their free node movements. The capabilities of ad hoc networks applications are significantly improved by the innovations provided by key enabling techniques such as bio-inspired algorithms and their derivative technologies in a variety of fields. This paper aims to present the updated account and suggests congestion prevention routing as a way to improve the overall performance of ad hoc network applications. Ultimately, it is successfully implemented on the python platform, and the suggested method outperforms the others when compared to traditional algorithms in terms of throughput, delay and overall performance.

KEYWORDS: Ad hoc networks, Smart antenna, MAC Protocol, Cross layer Optimization, Directional hidden terminal problems, Bio-inspired algorithms.

I. INTRODUCTION

Wireless ad hoc networks are a type of network that can be set up quickly and without the need for infrastructure. Three types of wireless ad hoc networks are identified based on their intended use: WSN, VANET, and Mobile Ad hoc Network (MANET) [1]. The MANET is a network of mobile nodes that communicate via wireless links and are constantly self-organizing and infrastructure independent. Mobile devices like laptops, pocket PCs, and cell phones are examples of MANET nodes. These days, MANETs that have proven effective in military settings are taken into consideration for applications involving cooperative mobile data exchange. Wearable technology, low-cost commercial networks to expand fixed infrastructure, and networks to support IP-compliant data service requirements in disaster relief and rescue operation scenarios are a few examples of MANET applications [2]. With current technological advancements in 5G, and 6G, communication barriers like time and distance can now be overcome, giving users the ability to communicate at any time, from any location, using Key Enabling Technologies (KETs) like; Directional beam forming, MAC strategy with Smart antenna technology, Cross Layer Interaction techniques and nature inspired meta-heuristic algorithms for routing.

a. Directional Beam-forming

Due to financial limitations, MANETs up until recently either used omni-directional antennas in place of smart antennas or used smart antennas as an add-on feature. In order to meet the needs of modern users, MANETs must now make the most of the features of smart antenna technology. It is necessary to revisit MANET applications with smart antennas for higher gain, interference reduction capability, and larger traffic rate support because the limiting factors of omni-directional enabled MANETs limited transmission range, higher interference area, and restricted bandwidth usage have led to less spatial re-use.

An antenna is a device that uses radio or electromagnetic energy to create an interface between a source node and its surroundings. The quality of network service is indicated by more effective ways to radiate signal energy at the sender node and by lossless signal energy gathering at the destination node for a given set of environmental conditions. It also indicates how well the network is performing and reflects on frequency resource utilization. Digital signal processing could be used to intelligently control an antenna system to optimize its performance [3].

Now regarded as one of key technologies for beyond 3rd Generation(B3G) communication networks, smart antenna technology will become the preferred antenna technology in variety of communication systems, including Ultra Wideband (UWB), mobile satellite TV, Wireless Fidelity (Wi-Fi), Worldwide Interoperability for Microwave Access (Wi-Max), and Radio Frequency Identification (RFID), among others, because of its lower cost. However, by implementing the necessary modifications to the higher layers of the MANET and successfully resolving the new issues brought on by the beamforming nature of smart antenna technology, the benefits of this technology can be effectively investigated. The most promising advancement in MANETs is the use of smart antenna technologies, which offer a narrower focus with less interference to nearby users and a coverage range increase of 20 to 200 percent over traditional antennas. Smart antenna technologies offer a way to alleviate MANET traffic bottlenecks [4].

b. MAC Strategy with SA Technology

The most crucial component of a MANET is the Medium Access Control (MAC) layer's channel access activity, which is crucial to the successful delivery of data. Although the reduction of signal interference increases the number of simultaneous communication pairs in a given networked area of smart antenna technology enabled MANET, the unique characteristic of smart antennas, known as beamforming, result in new challenges that lower the network's throughput performance [5]. Deafness, directional hidden terminal issues, MAC layer capture, head of line blocking, and communication range underutilization are some of the difficulties. Directional hidden terminal problems and the deafness problem are the two main issues in the literature. The design of the directional MAC protocols for MANETs enabled by smart antenna technology should take into account the solutions to these new problems.

Table 1 lists some of the Directional MAC (DMAC) protocols that have been proposed for resolving directional hidden terminal issues in wireless ad hoc networks, along with their uniqueness and methods of use.

Table 1: Summary of the DMAC protocols addressing directional hidden terminal problems

PROTOCOL and YEAR	ANTENNA TYPE	NULLING	CARRIER SENSING IDLE LISTENING	RTS/CTS Transmission	UNIQUE FEATURES	MECHANISM FOR ALLEVIATING HIDDEN TERMINAL PROBLEM	CHANNEL DIVISION as CC and DC
CWDMAC [6] 2010	Adaptive Antenna	No	Omni-directional	Omni-Omni	Supplement the RTS/CTS by the index of the beam	Once RTS received, restrict beamed signal when beam index is same as of sender. Neighbours also set DNAV's.	No
CDMAMAC [7] 2011	Switched Beam	No	Omni-directional	Omni-Omni	CDMA with directional antennas	Segregate channels as DC and CC to avoid collision	Yes
Dholey [8] 2012	3-Sector Switched Beam	No	Omni-directional	Omni-Omni	Enhancement of CSMA/CA	Unblock the nodes, sets up NAV with RTS/CTS control messages. Alters the CSMA/CA timing schedule	No
DAMAC [9] 2015	Switched Beam	No	Omni-directional	Dir/Dir	Deafness effect analysis using	Node deafness and packet collisions conditions	Yes

					Discrete time Markov chain model	separated with logical data plus CC helps reduce wastage of network resources. Retransmission efforts are less	
FDDMAC [10] 2015	Switched Beam	No	Omni-directional	Dir / Dir	A scanning scheme over the antenna sectors is designed	Random periods are marked in scanning for listening and sending alternative ly	No
NNBMAC [11] 2018	Adaptive Antenna	Yes	Omni-directional	Dir / Dir	Neural network based approach	Each sector uses separate link establishment. Neural network approach points null precisely	No

c. Cross Layer Design Approach

The layered architecture design assumed by the majority of protocols proposed for MANETs is extremely strict or rigid with each layer specific protocol architecture focusing solely on the interface to neighbouring layers. In order to improve network performance, MANET protocols have placed a greater emphasis on creating meaningful interactions between the different network stack layers in recent years as a result of KETs [12]. In dynamic MANET environments, the cross-layer design (CLD) approach, which introduces stack wide layer interdependencies, is advantageous. The CLD technique creates adaptive protocols by utilizing the state information that is currently available across the network stack. The physical layer estimates the channel based on the link's SINR, which results in the transmission delay at each link. The routing protocol will use this delay and the network load distribution to determine the best course of action. Conceptually, the CLD approach to network architecture sits where the three bases converge.

The goal of CLD is to link the resources of all communities to create a network that can share information amongst the system's various modules and is very adaptable to changing environmental conditions. Numerous functional requirements, such as node mobility management, Quality of Service (QoS) awareness, node cooperation, energy conservation, and security aspects, can be successfully implemented by leveraging and combining the mechanisms of all MANET layers. The rigorous layering that creates the protocols for every layer independently needs to be eliminated in order to implement this. The strategy must now use an integrated, intra-dependent, and hierarchical framework setup in order to benefit from the interdependencies between layers. Information flow between various layer determines the kind of interactions between the network stack's layers.

d. Nature Inspired Meta heuristic Algorithms for Routing

The social insects of nature, such as termites, ants, wasps, and bees, provide inspiration for solving MANET problems. The meta heuristic approach is an effective way to solve the peculiar behavioural characteristics of MANETs, such as: i) Locality of interactions, ii) Existence of multiple paths, iii) Self-organization nature, iv) Backup strategy for failure and v) Quick and robust adaptation measures in changing topological and traffic conditions. Swarm intelligence (SI), a branch of computational intelligence, is an effective way to handle a lot of complicated optimization problems. The global behaviour of MANETs, which results from the repetitive local interaction of individual agents with their surroundings and each other, has been thoroughly studied using a number of population-based metaheuristic algorithms, such as Ant Colony Optimization (ACO), Particle Swarm Optimization, and Bee Colony Optimization [13]. Social insect colonies exhibit collective behaviour in which each individual, despite acting independently of the others, produces the necessary and planned output. The ACO approach, a well-known and distinct flavour of the SI paradigm, places an emphasis on the bottom-up design method to improve MANET protocol performance.

II. PROBLEM STATEMENT AND MOTIVATION

Finding the best path that is, the path that is free of congestion from the source to the destination is a difficult task in the current research on routing in MANETs. Additionally, there is still unmet demand for reducing average delays and minimizing traffic congestion [14]. The prior routing algorithm selected the path based on the QoS requirements of the data flow. How the system modifies the route to guarantee timely QoS when the link becomes congested is another problem that needs to be resolved in the context of the current research project [15]. We are motivated to suggest a congestion prevention-based routing technique by the aforementioned issue.

III. LITERATURE

In the literature/related work section, several research papers based on congestion prevention based routing were proposed. These are described as follows.

In 2021, Guo and Yuan et al. [16] had put forth a plan for traffic optimization and network intelligent control. To achieve intelligent network control and traffic optimization, the methods used for routing calculation are examined. The sole disadvantage, however, was that it was hard to tell if the suggested approach would be effective in a real-time scenario.

In 2021, Biswas and Wu [17] had put data centers in place to lessen the number of rules when rerouting some traffic from the congested link. To cut down on the number of rule modifications needed to reroute traffic, two problems have been developed. The first problem takes into account a flow to direct and a congestion link. Schemes based on Dijkstra and rule merging are suggested as solutions to this issue. The cost and complexity of storage are the main disadvantages.

In 2022, Su et al. [15] had suggested a congestion-controlled, QoS-guaranteed open flow routing scheme for effective routing. In order to identify the state of impending congestion, it first divides the link into different congestion levels from the transmission links. Based on the results of the simulation, it is evident that the suggested system sought to reduce latency and ensure network dependability. Nonetheless, maintaining packet security and controlling network congestion continue to be difficult tasks.

IV. METHODOLOGY

The ability of the conventional path finding method in routing protocols to conserve network resources makes it a popular choice. The shortest path scheme is one of the most widely used algorithms among these techniques because it is simple to implement. Based on a wealth of historical, the network's detailed information is gathered, and the appropriate technique can dynamically modify particle size in response to the link's condition and forecast link traffic with high accuracy [18]. By eliminating local congestion, network traffic management improves network quality and overall network utilization. This work introduces routing based on congestion prevention. First, to address the traffic problems and identify the congestion that occurred, a meta-heuristic hybrid optimization algorithm is suggested.

4.1 Congestion Control

When sending packets, source and destination endpoints must assess bandwidth and delay parameters. To ensure that the data is sent on time, an interactive user uses delay information to request the packet. In order to choose how many packets should be delivered, the user also needs to know the band width. Presumably, requesting a large amount of data maximizes the delay if the client requests a minimum number of packets, which does not utilize enough of the available bandwidth. Additionally, not many packets in the network need to be buffered. The algorithm used in this study produces precise and timely estimates of the delay and available bandwidth.

4.2 Fitness Parameters

The following fitness parameters are optimized to create a network or channel for packet forwarding that is free of congestion or traffic control.

Path Cost: The path cost as a whole is regarded as one of the fitness parameters. For many QoS requirements, the minimum path cost is guaranteed [19].

Bandwidth: Bandwidth is the maximum rate at which packets can be sent from one end to the other over the specified optimal path [19].

4.3 Gannet Optimization Algorithm (GOA)

Inspired by the predation behaviour of gannets, GOA is a novel meta heuristic optimization technique [20–22]. In order to mimic the predatory behaviour of pond geese, it is divided into two phases, such as exploration and exploitation. Additionally, it consists of four different predation behaviours: sudden rotation, random wandering, U-shaped dive mode, and V-shaped dive mode [23]. This swimming behaviour helps to achieve effective congestion prevention by improving bandwidth and overall efficiency.

4.4 POA Algorithm

The POA algorithm draws inspiration from the behaviour of pelicans, which attack and hunt prey in order to update the candidate solution. The exploration stage and the exploitation stage, for example, served as the models for this hunting technique. Moving to prey is done during the exploration stage, and winging on the water's surface is done during exploitation stage. POA reduces the cost, delay, and smoothness of the path.

V. EXPERIMENTAL SETUP

The system used to run the simulation has a CPU running at 3 to 60 GHz and 16 GB of RAM. Version 2.3 of Mininet is used by the system. X. Mininet emulator is used in the simulation. A software switch running on virtual machines is used to instantiate each switch in Mininet. Within the Mininet, random traffic flows are created that correspond to source and destination pairs in the network. UDP traffic is used in the simulation at data rates ranging from 80 MBPS to 200 MBPS. There are 100 nodes in use, the buffer size is 200 packets, and the link band width is 300 MBPS.

VI. RESULTS AND DISCUSSION

Performance metrics like throughput and end-to-end delay are used in the simulation performance of the suggested congestion prevention and optimal route with congestion prevention. These metrics are compared with those of earlier mechanisms to show how effective the proposed system is in comparison to a number of existing systems, including the Dueling DQN deep reinforcement algorithm (DRL-TP) [24], Dijkstra [25], and Open Shortest Path First (OSPF) [26].

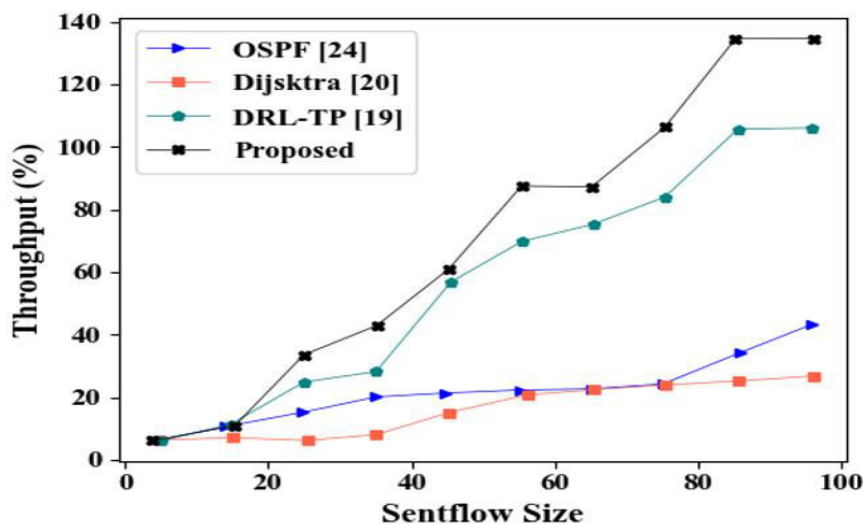


Figure 1. Comparison of network throughput.

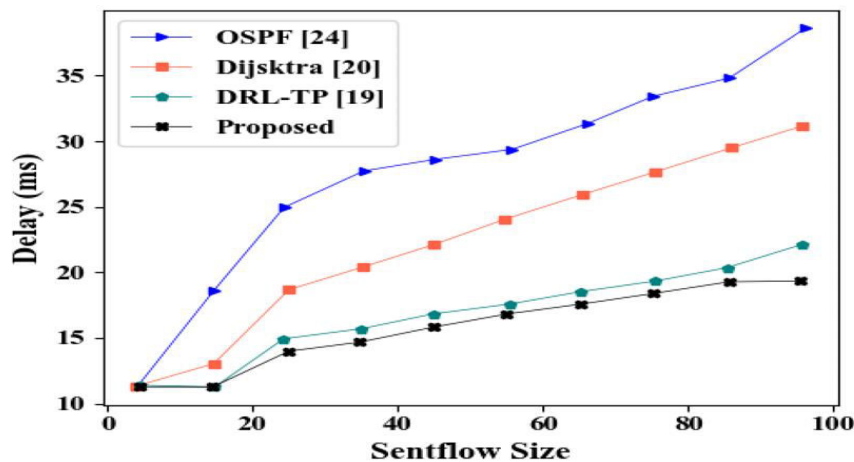


Figure 2. Comparison of network Delay

VII. CONCLUSION

In order to identify network congestion, congestion prevention is successfully applied in this work. A route-finding algorithm that is optimal is then run. Examined are the objection functions, such as end-to-end delay, in order to determine the shortest path among all n-paths. According to the experimental results, a throughput of 140 percent was attained because of a 17 ms. decrease in delay. The introduced model is more successful in preventing network congestion. Furthermore, the effective routing algorithm helps it reach a higher rate of convergence.

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