# Quality of Service Enhancement in Wireless LAN and MANET

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## Abstract

In this dissertation, the author introduces a novel MAC technique that uses directional antennas to reduce interference, allowing the channel effectively reuse in various places. A node will wait for the Additional Control Gap (ACG) period after exchanging the RTS/CTS packet using the suggested protocol before starting the transmission of data packets. Other nodes in the area may plan simultaneous transmission at this ACG time by exchanging RTS/CTS packets with one another. This technique of installing directional antennas to avoid interference while simultaneously ensuring simultaneous transmissions among nodes in the vicinity may enhance the overall throughput and latency of wireless ad hoc networks. The suggested MAC protocol, in combination with TCP, serves to lessen the possibility of medium congestion and collisions in multi-hop situations by scheduling simultaneous transmissions. After identifying the bottleneck node on the high-traffic route, the heavy-traffic route moved to a different dedicated path to facilitate longhop flow. This makes it feasible for longhop flow to use the completely available bandwidth of the recently allotted dedicated lane and ensures that traffic on the congested route will reduce. Additionally, the dissertation offers a simple but efficient hybrid model as a solution to the issues that could come up when carrying out disaster relief activities. According to the suggested concept, stationary SANET grid nodes that is installed will allow mobile MANET nodes that are more than 13 kilometres outside of the transmission range of the infrastructure network to connect to the internet and the central command. In the case of a disaster, this method increases the coverage area of MANET nodes, enabling those nodes to connect with and exchange data with the rescue and relief operations centre

**Keywords:** MANET; Traffic; Additional Control Gap; Sanet; Throughput and Latency

## 1. Introduction

An ad-hoc network formed by potentially mobile hosts without using any fixed infrastructure and can be set up when installing a standard network would be difficult or unfeasible financially. Complex distributed systems without a defined topology referred to as ad-hoc networks. When the receiver is inside the sender's broadcast coverage region, a wireless node may immediately connect with another node. The packets instead sent to an intermediary node within the transmission range of the transmitting node, which then relays them to the destination node if the intended destination node is beyond the coverage region. Ad-hoc networks provide a number of significant benefits, including self-configuration, scalability, and simple and rapid implementation. Ad-hoc networks have disadvantages like tough and complicated routing processes and a lack of complete knowledge about neighboring nodes since they are created on extremely dynamic network topologies, as is obvious. These

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restrictions make it difficult for nodes to coordinate tasks like time management, power management, and packet scheduling. Every ad-hoc network is made up of wireless mobile or stationary nodes that have the ability to dynamically self-organize, creating 'ad-hoc' network topologies. Mobile Ad-hoc Network (MANET) refers to an ad-hoc network produced using mobile wireless nodes, while Static Ad-hoc Networks refers to an ad-hoc network formed with stationary wireless nodes (SANET). Thus, MANET and SANET are both referred to as ad-hoc networks. Each node in an ad-hoc network has access to a transceiver, an antenna, and a battery.

The nodes may be utilized in a variety of ways, such as clients, servers, or both. Depending on the circumstances, some of the nodes could serve as routers, passing packets from one node to the next [1], [2]. Recent years have seen a focus on research and development efforts on the need for seamless connection inside the multi-hop situation of a MANET. Applications for wireless LANs, particularly MANETs, include monitoring harsh environments, mobile computing environments, search and rescue during disaster relief efforts, and combat communications. In a multi-hop situation, MANETs differ from wired and infrastructure wireless networks in a number of distinctive ways [3], [4]. These characteristics include unpredictably changing channel characteristics over time, mobility causing frequent route failures and network fragmentation, a lack of power for complicated calculations, security concerns, concealed terminals, exposed terminals, and capture effects. Therefore, MANETs in a multi-hop situation provide a number of difficult challenges for research teams.

## 2. Proposed Architecture

In recent years, a number of other MAC protocols based on multiple beam antennas have been proposed for usage in multi-hop MANETs [6]. We propose the Stack Beam Smart Antenna Array MAC (SBSAA-MAC) protocol as a novel media access control (MAC) mechanism for wireless networks. Though it draws inspiration from the IEEE 802.11 [7] DCF system, the new MAC protocol also works well in multi-hop deployments. The SBSAA-MAC protocol is able to enhance the network's throughput performance via the simultaneous scheduling of many broadcasts and the usage of directional antennas [8].

### *2.1 Antenna Model*

It is presumable that each node has a radio trans-receiver as well as a Stack Beam Smart Antenna (SBSAA) [9]. The Switched Beam Array of Smart Antennas Array (SBSAA) [10] is capable of identifying the precise Angle of Arrival (AoA) of an incoming packet since it is made up of smart antennas. Each SBSAA composed of Y components is capable of forming Y distinct zones that do not overlap, each of which extends across an angle of 360/Y degrees [11].

The transmitted signal will be completely attenuated when it is outside the beam pattern, the beam shape will be conical, and there won't be any side lobe interference [12]. For the purposes of performance analysis, gains from spatial reuse are taken into account, but the directional range is assumed to be constant and equal to the omnidirectional range. The formula PTOTAL/Y is used to evenly distribute the total antenna power, denoted by PTOTAL, overall Y beams. A directional beam can be created by applying a complex weight vector to a received vector, also referred to as a collection of multiple signals received at various antenna array elements [13]. This is used to find the particular AoA. The aforementioned procedure is carried out backward in order to create a beam that faces the receiver.

### *2.1 The Proposed SBSAA-MAC Protocol*

The proposed Stack Beam Smart Antenna Array Media Access Control (SBSAA-MAC) protocol is an adaptive and asynchronous media access control system that utilizes a single channel and an architecture made up of a single electrical transmission. This protocol's contention-based CSMA/CA underpinnings were taken directly from the IEEE 802.11 [14] specifications. The most crucial elements of the protocol that support concurrent transmission are listed below:

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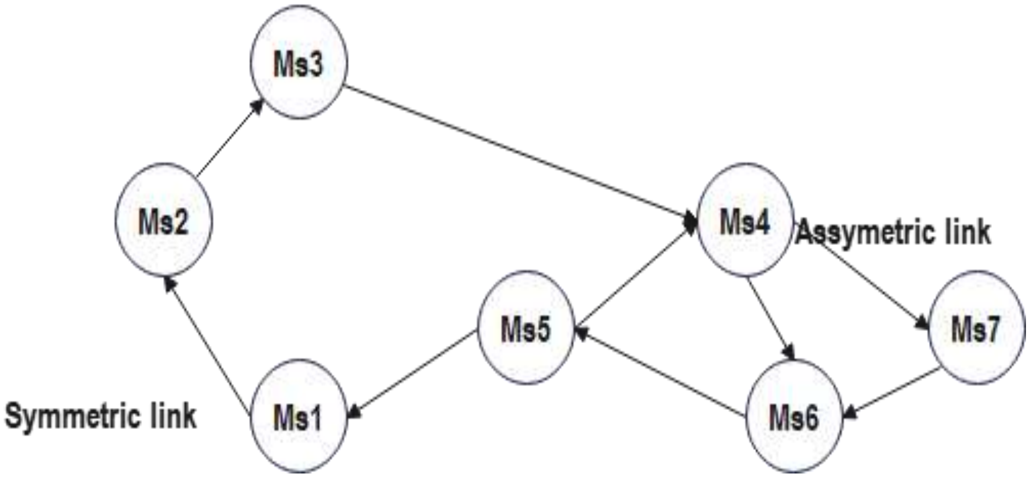

Figure 1: Wireless Network in MANET

### Additional Control Gap (ACG)

In contrast to IEEE 802.11, an additional Control Gap (ACG) inserted between the successful exchange of RTS/CTS and DATA packet transmission. This carried out to give neighbouring nodes a chance to exchange their own RTS/CTS and to plan concurrent data transmission. Information on Preventing Collisions discovered in the Control Frame the control frames (RTS/CTS) contain information on how to avoid collisions, and the nearby nodes can use this information to decide whether it is feasible for them to schedule their transmissions.

That is not synchronized because of a process that is controlled locally; neighbouring nodes' concurrent transmissions take place at various times. The concurrent transmissions made by nearby nodes that are close to nodes that are sending or receiving data are what cause the information overhead of SBSAA-MAC [16]. This method may be used when centralized control is not required, such as in large-scale wireless ad-hoc networks. Executing concurrent transmissions requires awareness of the transmissions that are already active in the vicinity of a node. The Active Neighbour List (ANL) data structure, which is present in each node of the SBSAA-MAC network, serves as a repository for this data. Consider three nearby nodes with the labels a, b, and c.

Out of these, a and b are actively transmitting, and c is listening in on their exchange of control packets. For each of the active nodes a and b that are close to node c, the following information is kept in the ANLc:

$$\{Baddress, Gab, T\,data^{(ab)}, Tack^{(ab)}, X\} \qquad (1)$$

Where:

The address of the running node b is known as B-address.

Gab is calculated as the anticipated channel gain between nodes a and b.

Prx(b) is the signal power of node b's received control packet, and Ptx is the single transmission power. Gab = Prx(b)/Ptx (common to all nodes).

The notations T data (ab) and Tack (ab), respectively, indicate the commencement time of the DATA and ACK packets of the transmission between nodes a and b. Examples of relative timings found in control packets are T data (ab) and Tack (ab). In relation to the present time, they provide an estimate of the remaining amount of time [17]. To differentiate the transmitter from the receiver, a single-bit tag called X is used. If the control packet came from a transmitter, it will be given the value 1, but if it came from a receiver, it will be assigned the value 0.

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$$\begin{aligned} x1 &= s1a1 + s2a2 \\ x2 &= s1a3 + s2a4 \end{aligned} \tag{2}$$

During the process of scheduling a transmission, if both the sender and the corresponding receiver do not have any active nodes in their immediate area (that is, their ANLs are empty), then this transmission is considered a primary transmission, and the sender and the receiver are referred to as the primary transmitter and primary receiver, respectively. The ANL of a primary node will be populated when it's time for the first ACG time interval. Other scheduled transmissions will adjust their transmission times of DATA/ACK [18] packets according to the information that is overheard by the primary transmission that is adjacent to them. Because of this, the other transmissions are referred to as secondary transmissions and the nodes that participate in them are referred to, respectively, as secondary transmitters and secondary receivers.

### *2.2 SBSAA-MAC Protocol: Basic Functionality*

The transmitter and receiver must first establish their relative motion to one another before starting any data transmission or receiving. Any successful data transfer must have this. During the operation of the SBSAA-MAC [19] protocol, an idle node would utilize its antenna to listen to ongoing communications over all of its beams. When a node wants to transfer data, it first sends RTS to the target node, which is then packed into all of its antenna components.

$$NCC = \frac{\sum_{m=1}\sum_{n=1} OW_{m,n} RW_{m,n}}{\sqrt{\sum_{m=1}\sum_{n=1} OW_{m,n}^2 \cdot \sum_{m=1}\sum_{n=1} RW_{m,n}^2}} \tag{3}$$

Let's assume that node A wants to send a data packet to node B but is unsure of B's exact location in order to gain an understanding of the basic operations. As a consequence, each and every one of the antenna components on node A transmits an RTS control message [20]. If node B is not otherwise occupied, it will watch for the RTS signal and note the transmitter's position. The answer is then sent back to Node A using the CTS control packets on all of Node B's antenna components.

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Algorithm 1: Proposed Filtering with routing

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Raw signal input; filtered signal output;
First, get the signal as an input;
Step 2: Calculate the Signal's row and column sizes;
I = 2 to r in step 3
Fourth step: for j=2 to c H
Where r denotes the signal's row size and c its column size;
Project a 3x3 window on the Signal for the variable P w as the fifth step;
Apply mean value to temp in step 6 and save the outcome in M "temp";
Step 7: M "temp"; 40 F; P d= temp-
* Where, P d denotes the variance between individual window pixels and their average value. It is shown as a 33 matrix;
Step 8: M Pw=median(P w) j if N Pa>2
Step 9: Substitute M Pw pixel values for the original Signal pixel values; where N (P d) denotes the total number of pixels in P d that are greater than two;
10th step: End if;
Step 11: Cut off the loop
Step 12: Collect the results
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The direction of node B is noted by node A at the moment of reception. Nodes A and B must then transmit and receive directional DATA and ACK packets on the antenna elements that are facing one another and were previously used in the RTS/CTS exchange after successfully exchanging RTS and CTS control packets. This information is used by all neighbors of nodes A and B that receive RTS/CTS packets to decide whether or not to interfere with the present transmission.

By planning two or more concurrent transmissions, the SBSAA-MAC protocol improves spatial reuse as shown in Figure 2.

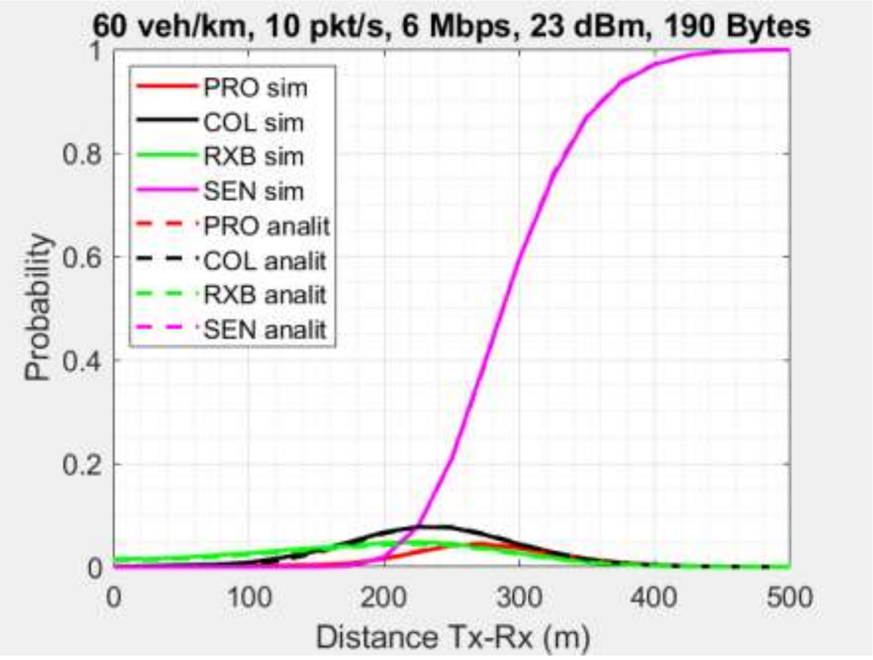

Figure 2: Illustration of Concurrent transmissions X→Y and P→Q

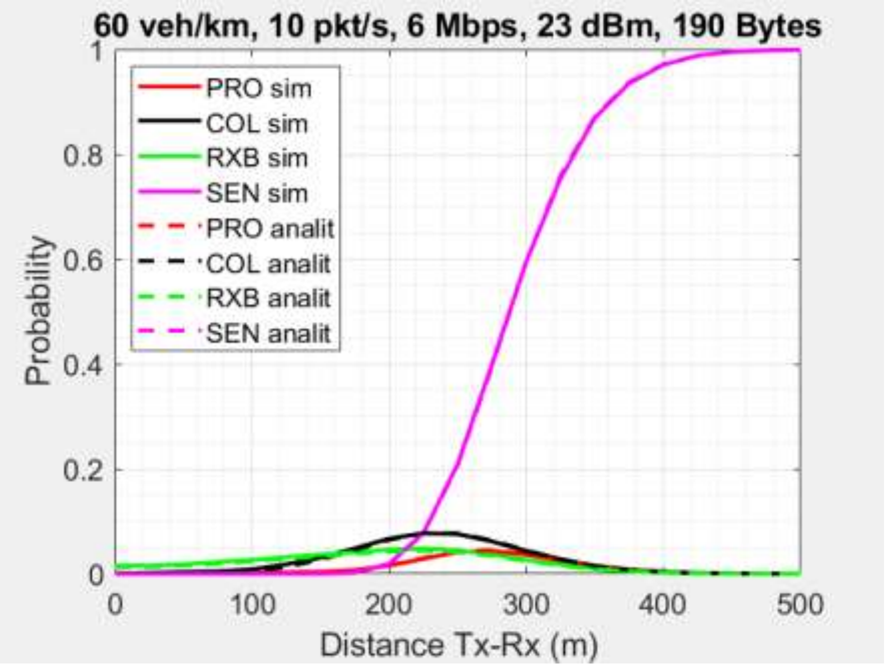

Figure 3: Timing Considerations for concurrent transmissions X→Y and P→Q

To better comprehend the concurrent transmission strategy used by the SBSAA-MAC protocol; let's take a closer look at the transmissions X-Y and P-Q that are seen in Figure 3. The anticipated start time of DATA/ACK denoted, as T data XY / Tack YX is included in an RTS packet that Node X initially sends out. Node X uses every component of its antenna to transmit the RTS packet. There is no need for a synchronized clock to be present since T data and Tack are provided in reference to the time at which the associated control packet was received. Every time node Y gets an RTS packet, it records the antenna element that is receiving the strongest RTS signal in order to pinpoint the location of node X. Now, node Y will respond with a CTS packet that contains timing details similar to those of node X for each of its antenna components.

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Node X starts keeping track of node Y's direction as soon as it gets a CTS message. Node X waits for the amount of time specified by ACG after finishing the transmission of ACK packets and before starting the transmission of DATA packets after the successful conclusion of the RTS/CTS exchange. Neighbouring nodes P and Q will have the chance to plan their broadcasts and exchange control packets during this ACG period. The simultaneous X-Y and P-Q transmissions start once the ACG time has passed if the transmission between nodes P and Q is accurately timed. In the event that more than one neighbouring node attempts to access the channel while the ACG period is in place, the IEEE 802.11 contention-based CSMA/CA mechanism is implemented. In order to achieve better spatial reuse without sacrificing performance, a longer ACG length is necessary.

The nodes nearby may not have enough time to exchange their control packets if the ACG is too short. On the other hand, if the ACG is too large, scheduling the concurrent transmissions may be delayed, which will have a detrimental effect on performance. Any desired number of Access Slots may be specified to make up the ACG (AS). An AS period is the total time required to transmit RTS, CTS, and the maximum back-off period when the contention window (CW) is equal to 31. This time has been set in stone and cannot be altered. The exchange of the control packets and the planning of one potential secondary transmission can both take place during the ACG period, which is just long enough.

The number of Access Slots used by the primary transmission is dynamically modified after the initialization process is finished to reflect the most recent data stored in the ANL. The crucial element for concurrent transmission is the Active Neighbour List or ANL. A node will update its ANL if it receives control packets intended for other nodes. As soon as a node receives a control packet, it immediately extracts the information inside of it, and an entry is then made in the node's ANL. The entries in ANL indicating the end of the current transmission will then be deleted by the transmitter and receiver nodes once they have received the ACK packet indicating that the transmission was successfully completed. The ANL entries for nearby nodes that aren't taking part in the transmission will be removed if they receive a DATA/ACK packet from a different transmission in the vicinity.

## 3. SBSAA-MAC Protocol: Performance Evaluation

Using simulation-based methods, the performance of the proposed SBSAA-MAC protocol was assessed, and the results were contrasted with those of the standard IEEE 802.11 DCF protocol. The simulation's settings were set to the following values.

SIFS: 10 s, DIFS: 50 s, Data Rate: 6 Mbps, SINR: 6 dB, Data Packet Size: 2 KB (Fixed),

One hop separates the Rx Node from the source Node, and 15 dBm of transmit power is sent in an omnidirectional manner. Free Space Path Loss Model, Propagation Model, and Transmission Model 400 meters separate the transmitter and receiver.

Rx Threshold is -82 dBm, while Rx Sensitivity is -94 dBm. 800 meters is the carrier sense range.

The RTS packet is implemented with an extra 2-byte field for Tack, while the CTS packet is built with an additional 8-byte field for Tack and the sender's address, according to the results of the cost analysis done on the recommended SBSAA-MAC protocol. According to IEEE 802.11, the ACK packet's size is supposed to be 36 bytes. The size of RTS/CTS packets has risen by around 13% compared to their original size since the RTS and CTS packets used by IEEE 802.11 are, respectively, 40 and 36 bytes long and the physical header is 24 bytes long (40 bytes plus 36 bytes equals 76 bytes). The overall cost of control packets is around 4.8% ((98/2048)x100) of the size of a data packet, which is generally 2K Bytes, but the throughput will increase by about 81% if two concurrent transmissions are successfully scheduled. Data packets typically have a size of 2K Bytes, while control packets generally cost 40 (RTS) + 36 (CTS) + 10 (Tack) + 36 (ACK) - 24 (Header) = 98. Additional increases in the number of broadcasts running simultaneously will lead to further improvements in the amount of work completed. A free space route loss model has been presumptively employed to calculate the upper limit for both the MAC protocol performance. The sender node's creation of packets is modeled as a Poisson process with a constant mean arrival time.

### 3.1 Performance Results: Random Grid Topology

For the purposes of simulation, a random grid topology with an 800 by 800 square meter area is taken into account. One node is then randomly given to one of the smaller squares after this square area is partitioned into n by n smaller squares. It is assumed that there are m sender nodes, or m transmission pairs, in this scenario, and that each sender always has a packet to transmit. The related sender nodes in the nearby grids are utilized in each transmission to choose at random the receiver nodes that will receive the data. Due to the fact that all nodes in the IEEE 802.11 system are situated inside one another's carrier sensing range, only a single transmission is possible at any one time.

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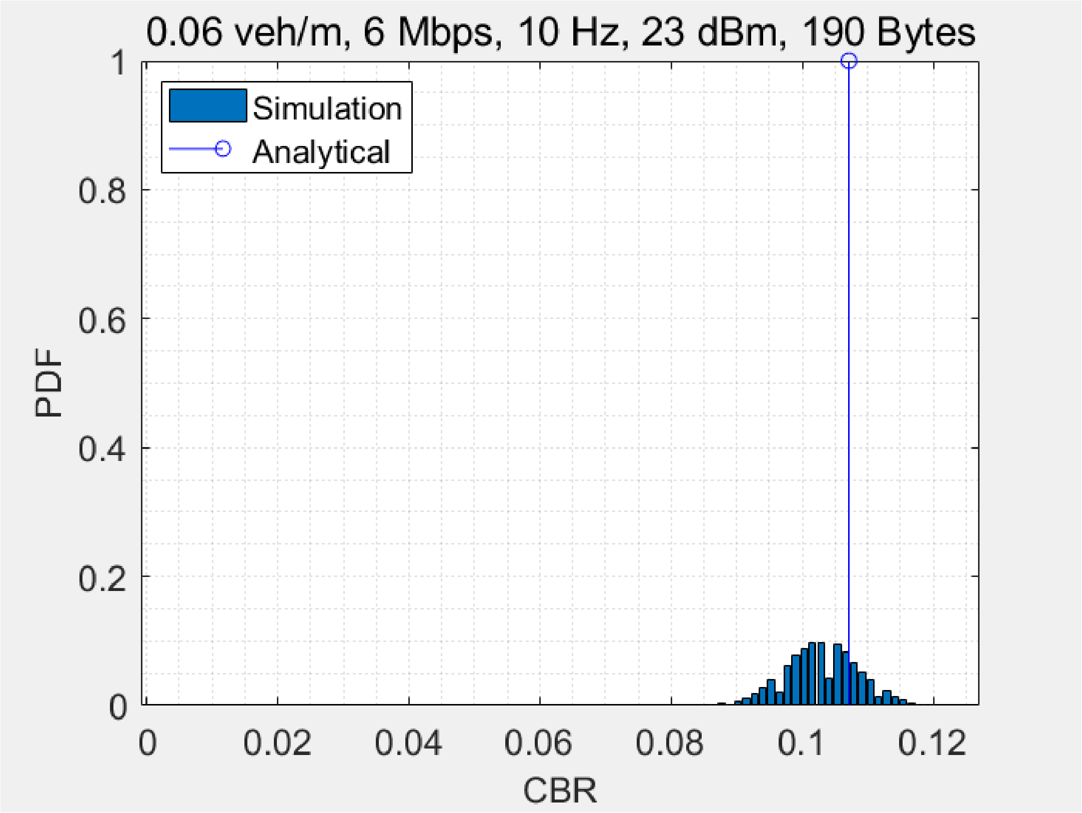

Figure 4: Comparative Performance of SBSAA-MAC & IEEE 802.11

Figure 4 illustrates how, in the case of the proposed SBSAA-MAC protocol, the node density significantly affects the network performance. The average distance between a transmitter and a receiver reduces when there are more nodes in a given region. Because a receiver is more likely to be found in grids close to the sender, this is the case. At the same time, the normal separation between the nodes that make up the different transmissions widens. As a consequence, it is possible to prepare for more simultaneous transmissions, which significantly boosts the network's total throughput. The number of transmissions vying for network space at any one moment also has an impact on throughput. This is because the throughput will decrease as the number of transmissions increases; nevertheless, if transmissions are in competition with one another, the number of concurrent transmissions will grow. According to Figure 4, the suggested SBSAA-MAC system performs better in terms of throughput when there are more competing transmissions. Regardless of the node density, this is accurate.

### 3.2 Performance Results: Random Topology

The efficacy of the proposed SBSAA-MAC protocol was then evaluated after being subjected to a random topology. For the sake of the simulation, it is assumed that 100 randomly placed nodes may be accommodated in an area that is 1000 meters on each side. Assume that there are m end-to-end flows between a set of sender and receiver nodes that were chosen at random. The consequences of conducting the experiment are shown in Figure 5. The proposed SBSAA-throughput MACs are about equal to that of the IEEE 802.11 system when m is set to low values. However, when m grows, more simultaneous transmissions are made, which improves the performance of the recommended SBSAA-MAC over the IEEE 802.11 system. As end-to-end flows (m) grow, the suggested SBSAA-performance MACs significantly improve.

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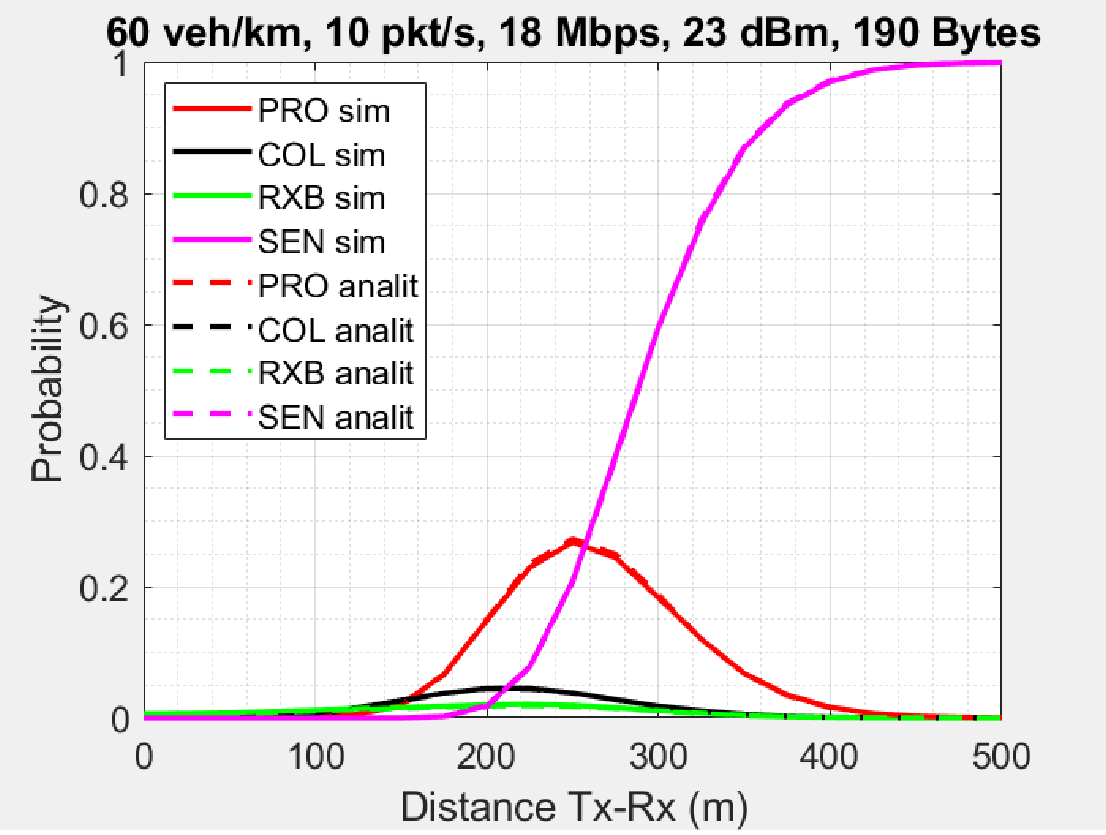

Figure 5: Comparative Performance of SBSAA-MAC & IEEE 802.11 (Random Topology)

## 4. Performance Results: Cluster Topology

The best approach to explain real-world instances of wireless ad hoc communication is via cluster topology. The sender (a node) will almost always communicate with receivers (also nodes) that are a part of the same cluster when using a topology based on clusters, and will only rarely communicate with nodes that are a part of other clusters. For the purposes of the simulation, a cluster topology with 16 nodes divided into four groups and dispersed over an area of 400 by 400 meters has been used. Each group is given a space of 100 meters by 100 meters at one of the area's four corners. Let's use p as the probability of communication across clusters and p minus 1 as the probability of communication inside a cluster. Four transmitters are used in the simulation to mimic the circumstance. It is assumed that each transmitter has a packet production rate of n packets per second. Every node in this scenario is within the transmission range of every other node, so if IEEE 802.11 MAC is used, it should work protocol is used, and only one transmission should be possible at any given time. Figure 6 displays the simulation findings.

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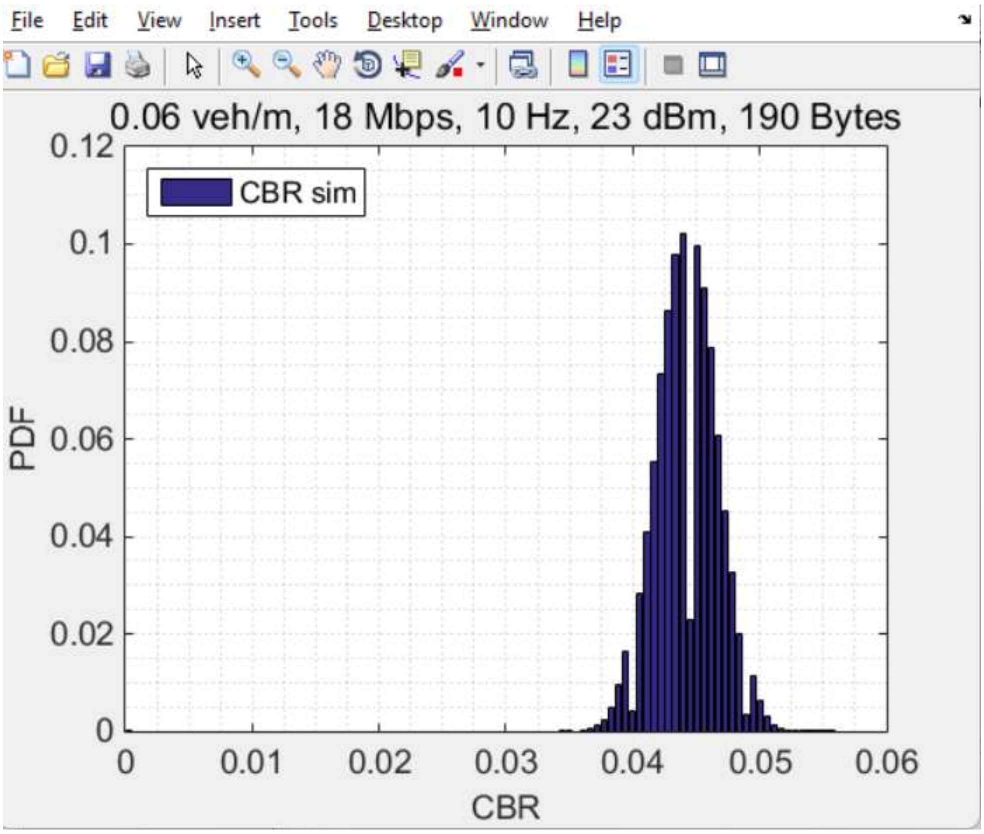

Figure 6: Comparative Performance of SBSAA-MAC & IEEE 802.11 (Cluster Topology)

The performance findings show that when p=0.25, SBSAA-throughput MAC's performance achieves an increase in throughput of around 81% over the conventional IEEE 802.11 protocol as network traffic increases. The throughput performance will improve considerably more if communication is limited to cluster members (the chance of communication across clusters will be equal to zero). In this case, when network traffic volume increases, SBSAA-throughput MAC's performance reaches its maximum, representing an improvement of around 169% above the IEEE 802.11 standard protocol.

## 5. Conclusion

This proposed work proposes a novel medium access control (MAC) protocol called SBSAA-MAC. The suggested protocol's effectiveness was then evaluated for MANETs using simulation and compared to the earlier IEEE 802.11 MAC standard. Three different network topologies were used in the simulation: the random grid topology, the random topology, and the cluster topology. The results of the performance testing show that MANETs operating under the proposed SBSAA- MAC protocol perform considerably better in terms of throughput than MANETs running under the established IEEE 802.11 MAC standard. As with the IEEE 802.11 standard, the proposed SBSAA-MAC protocol operates with a single transceiver on a single transmission power across a single channel for both data and control packets. As a consequence, it works with the vast majority of presently available hardware devices. It has been shown that the proposed SBSAA-MAC protocol's throughput performance is superior to that of the previous IEEE 802.11 standard. Comprehensive simulations in various topologies were used to achieve this. The results show that the throughput that SBSAA-MAC can accomplish on a network is about 169% greater than the throughput that can be attained using the conventional IEEE 802.11 protocol.

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