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# IMPROVEMENT OF SPATIAL REUSE AND THROUGHPUT USING OCSMA PROTOCOL IN WIRELESS ADHOC NETWORKS

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**ABSTRACT**

In wireless ad hoc networks (WANets), multihop routing may result in a node knowing the content of transmissions of nearby nodes. This knowledge can be used to improve spatial reuse in the network, thereby enhancing network throughput. This paper is to develop overlapped transmission techniques based on this idea and analyze several factors affecting their performance. Then develop a MAC protocol based on the IEEE 802.11 standard to support overlapped transmission in a WANet. The resulting overlapped carrier-sense multiple access (OCSMA) protocol improves spatial reuse and end-to-end throughput in a random network scenario.

**Keywords:** *Adhoc Networks, Carrier Sense, Overlapped Transmission.*

## 1. INTRODUCTION

Wireless networks present several challenging issues for the network designer that are quite different from their wired counterparts. An impairment that is due to the broadcast nature of the wireless network is interference. Since all the nodes share the same physical medium, simultaneous transmissions may result in interference at the receiving nodes. In networks that do not employ code division multiple accesses, medium-access control (MAC) protocols such as IEEE 802.11 [1] are used to allocate the channel resources to specific transmitters and receivers so as to minimize the interference in the network. Traditionally, the design of the MAC protocol is carried out independently of the physical-layer (PHY) design, assuming a simplistic collision channel model. In these models, a packet is successfully received by a node if there are no other transmissions in its interference range. These MAC protocols schedule transmissions such that the collisions in the network are minimized.

Multiuser detection (MUD) in wireless networks has been proposed as a means to increase spatial re-use by increasing the number of simultaneous transmissions in the network. MUD techniques are employed at the PHY to recover information from colliding packets at the receiver. These signal processing techniques used at the PHY enable a node to receive packets in the presence of other transmissions in its communication range.

This multi-packet reception (MPR) capability of the nodes at the PHY leads to greater spatial reuse in the network. MAC protocols were proposed in and that take advantage of the MPR capabilities of the PHY to increase the spatial reuse in networks to provide high throughput in heavy traffic and low delay in light traffic. In most cases, mobile radios do not have sufficient processing power to perform complex MUD schemes. Recent work on the transport capacity of wireless networks indicates that in the low-attenuation regime, multistage relaying using cancellation of known interference is order optimal. Here, the interference is known from the use of multi-hop routing. Using interference cancellation (IC) for only known interference may significantly improve network performance at a reasonable complexity.

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## 2. MOTIVATION

To explain how an interfering signal may be known in multi-hop routing in a wireless ad hoc networks (WANet), consider a four-node linear network consisting of nodes A, B, C, and D, in which A transmits a packet to D using multi-hop routing. In a slotted communication system employing a conventional MAC protocol, a typical sequence of transmissions for a packet would be

1: A → B; 2: B → C; 3: C →D;

Where the notation 1: A → B indicates that node A transmits a packet to node B in time slot 1, etc. Under conventional MAC protocols, in the time slot when C forwards a packet to D, A is not allowed to transmit to B since C's transmission will cause interference at B. However, when an MPR-based MAC protocol is employed, simultaneous transmissions of A to B and C to D are possible, since MUD techniques can be employed at B to recover the packet transmitted by A. Note that the packet transmitted by C to D is the same packet that B forwarded to C in an earlier time slot (ignoring the differences in the headers). If B were to retain a copy of the packet that it forwarded to C, B would have information regarding the interfering transmission. This greatly reduces the complexity of the MUD algorithms employed at the PHY to recover the packet transmitted by A.

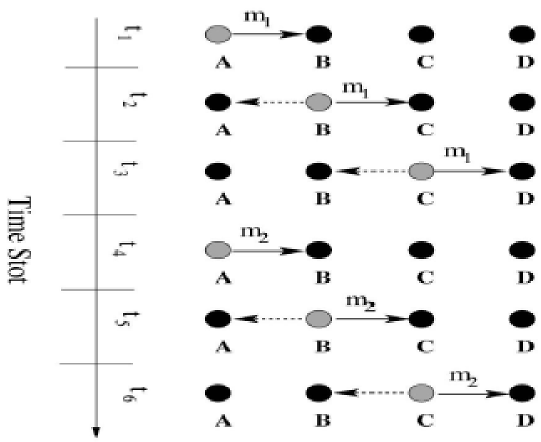


Fig.1 four-node linear network with conventional scheduling

It is assumed that the nodes can communicate only with the adjacent nodes and operate in the half-duplex mode. Node A transmits packets to node D through multihop routing. A typical transmission sequence under a conventional scheduling scheme is depicted in Fig.1, in which it takes three time slots for a packet from A to reach D. The scheduled transmissions in a given time slot are marked by solid directed arrows along with the packet identifiers, and the interference caused by these transmissions are marked by dashed arrows. Under typical carrier sense multiple access protocols with collision avoidance (CSMA/CA), when packet m1 is being forwarded by C in time slot $t_3$, A cannot transmit the message $m_2$ since C's transmission will cause interference at B.

The throughput of this network can be improved by employing simultaneous transmissions as described below. It is observed that in the time slot t3, C forwards the packet m1 that it received from B in the earlier time slot $t_2$ . If B were to retain a copy of the message m1 locally, it knows the message being transmitted by C in time slot $t_3$ (assuming that link-layer encryption is not used and any differences in the headers are ignored). If A is allowed to transmit the message m2 in the time slot $t_3$, B can use the stored information regarding m1 to mitigate the interference caused by C's transmission. It is to call this additional transmission, which results from the mitigation of known interference, an overlapped transmission. have finished, and that any node overhearing a CTS packet would defer for the length of the expected data transmission. In a hidden-terminal scenario C will not hear the RTS sent by A, but it would hear the CTS sent by B. Accordingly, C will defer its transmission during A's data transmission. Similarly, in the exposed-terminal situation, C would hear the RTS sent by B, but not the CTS sent by A. Therefore C will consider itself free to transmit during B's transmission. It is apparent that this RTS–CTS exchange enables nearby nodes to reduce the Collisions at the receiver, not the sender. Collisions can still occur between different RTS packets, though. If two RTS packets collide for any reason, each sending node waits for a randomly chosen interval before trying again. It is identified a transmission between two nodes as a primary transmission if the transmission is not predicated on the use of noncausal knowledge of the interfering signals during that transmission interval. For example, in the network in Fig.2, the transmission of message m1 from C to D in time slot t3 is the primary transmission and the nodes C and D are called the primary transmitter and the primary receiver, respectively. Similarly, a transmission between two nodes is a secondary transmission if at least one of the nodes has noncausal information about the primary transmissions in the present transmission interval and performs MUD/IC to mitigate the interference. In the network in Fig.2, the transmission of the message $m_2$ from node A to B in time slot $t_3$ for which B performs MUD/IC to

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mitigate the interference from C's transmission is the secondary transmission, and nodes A and B are called the secondary transmitter and secondary receiver, respectively.

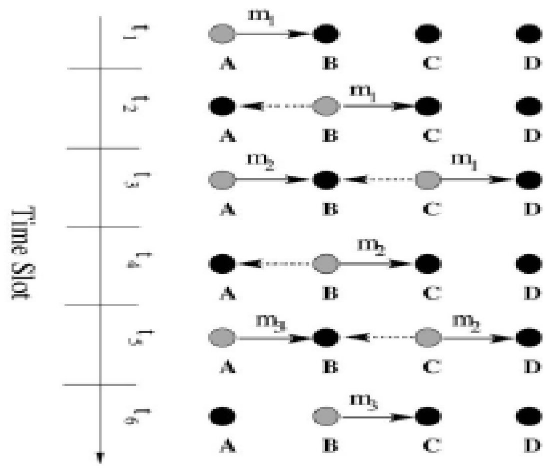


Fig.2 Four node linear network with overlapped transmissions

## 3. SYSTEM MODEL

Consider first a WANet with nodes distributed according to a two-dimensional homogeneous Poisson point process with density _ nodes per unit area. Each node is equipped with a transceiver and communicates with other nodes in half-duplex mode. We assume that each node has an infinite packet buffer, and each radio retains copies of the packets it forwards unless that packet is transmitted to its final destination or until that packet has been forwarded one by one of its neighbours. To investigate some of the issues that will limit the performance of overlapped transmission, we analyze the use of overlapped transmission in a system using slotted communications. In this model, each node transmits in a given time slot with probability 'p'. We also assume that the secondary transmitter is informed of the corresponding primary transmission and performs overlapped transmission at the same time as the primary transmission. The received power $P_r$ (in the far field) can be expressed as

$$P_r = K_p d_r^{-\alpha} P_t$$

where $P_t$ is the transmitted power, $d_r$ is the distance between the transmitter and the receiver, $K_p$ is a constant, and  is the path-loss exponent. In the absence of interference, we assume that a transmission at the maximum power level will be received correctly if and only if the intended receiver is within a distance of one unit from the transmitter. We also assume that there is some interference range, which is typically larger than the transmission range. Nodes within the interference range but outside the transmission range of a transmitter can detect the presence of a transmission but will not be able to correctly decode the packet being transmitted. In this section, we consider some limitations on the ability to utilize overlapped transmissions to improve the throughput in a WANet. These limitations come from the following two sources:

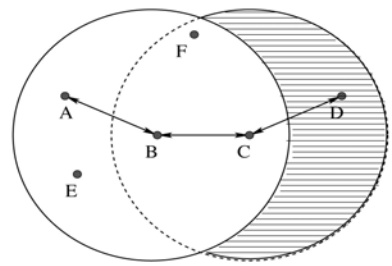


Fig. 3 Ad hoc network

### 3.1 Interference Due To Secondary Transmission

Since the secondary receiver has noncausal knowledge of the primary transmission, it can mitigate the interference due to the primary transmitter and recover the intended message. However, the secondary transmission causes interference, possibly to several primary transmissions. we evaluate the amount of interference that a secondary transmission may cause at the primary receiver and suggest how this interference can be controlled by adapting the power level of the secondary transmission to meet the specified signal-to-interference ratio (SIR) and outage requirements or by careful selection of the secondary transmitter.

### 3.2 Probability Of Secondary Transmission

Overlapped transmissions depend on the availability of suitable secondary transmitters and the successful reception of the messages at the secondary receiver. The analytical results are based on the network shown in Fig.3, which can be considered to be a part of a larger network. Nodes A and C are in the transmission range of B, and B transmits packets to D through C by employing multihop routing. Hence, D is in the transmission range of C but not in the transmission range of B. This particular region is shown in Fig.3 with dashed lines. We also assume that A has packets for B. The network in Fig. 3 is used to simplify the analysis

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yet illustrate the important aspects of overlapped transmission.

## 4. OVERLAPPED CARRIER SENSE MULTIPLE ACCESS (OCSMA) PROTOCOL

The OCSMA protocol is based on the distributed coordinated function (DCF) mode of the IEEE 802.11 MAC protocol [1, Section 9.2]. Unless stated explicitly, the terminology used in the following sections corresponds with that in the IEEE 802.11 standard. The timeline of the protocol for the example network is shown in Fig. 4, and the frame formats are shown in Fig. 5. The operation of the protocol can be divided into five phases as follows.

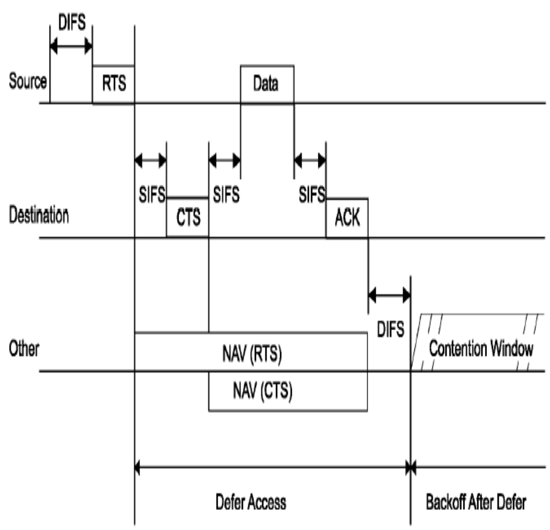


Fig 4 RTS/CTS/data/ACK and NAV setting

### 4.1 Distributed Coordination Function (Dcf)

The basic medium access protocol is a DCF that allows for automatic medium sharing between compatible PHYs through the use of CSMA/CA and a random backoff time following a busy medium condition. In addition, all individually addressed traffic uses immediate positive acknowledgment (ACK frame) where retransmission is scheduled by the sender if no ACK is received. The CSMA/CA protocol is designed to reduce the collision probability between multiple STAs accessing a medium, at the point where collisions would most likely occur. Just after the medium becomes idle following a busy medium (as indicated by the CS function) is when the highest probability of a collision exists. This is because multiple STAs could have been waiting for the medium to become available again. This is the situation that necessitates a random backoff procedure to resolve medium contention conflicts. CS shall be performed both through physical and virtual mechanisms. The virtual CS mechanism is achieved by distributing reservation information announcing the impending use of the medium. The exchange of RTS and CTS frames prior to the actual data frame is one means of distribution of this medium reservation information. The RTS and CTS frames contain a Duration field that defines the period of time that the medium is to be reserved to transmit the actual data frame and the returning ACK frame. All STAs within the reception range of either the originating STA (which transmits the RTS) or the destination STA (which transmits the CTS) shall learn of the medium reservation. Thus, a STA can be unable to a data frame. Another means of distributing the medium reservation information is the Duration/ID field in individually addressed frames. This field gives the time that the medium is reserved, either to the end of the immediately following ACK, or in the case of a fragment sequence, to the end of the ACK following the next fragment. The RTS/CTS exchange also performs both a type of fast collision inference and a transmission path check. If the return CTS is not detected by the STA originating the RTS, the originating STA may repeat the process (after observing the other medium-use rules) more quickly than if the long data frame had been transmitted and a return ACK frame had not been detected. Another advantage of the RTS/CTS mechanism occurs where multiple BSSs utilizing the same channel overlap. The medium reservation mechanism works across the BSA boundaries. The RTS/CTS mechanism may also improve operation in a typical situation where all STAs can receive from the AP, but may not be able to receive from all other STAs in the BSA. The RTS/CTS mechanism cannot be used for MPDUs with broadcast and multicast immediate destination because there are multiple recipients for the RTS, and thus potentially multiple concurrent senders of the CTS in response.

### 4.2 Primary Handshaking

This phase of the OCSMA protocol is similar to the Request- To-Send (RTS)/ Clear-To-Send (CTS) exchange of the IEEE 802.11 protocol. When a node has data to transmit to another node in its transmission range, it initiates the handshake by sending an RTS frame. The node that receives the RTS sends a CTS frame if it senses the medium to be free. The node initiating the handshake is the primary transmitter, and the node that responds to

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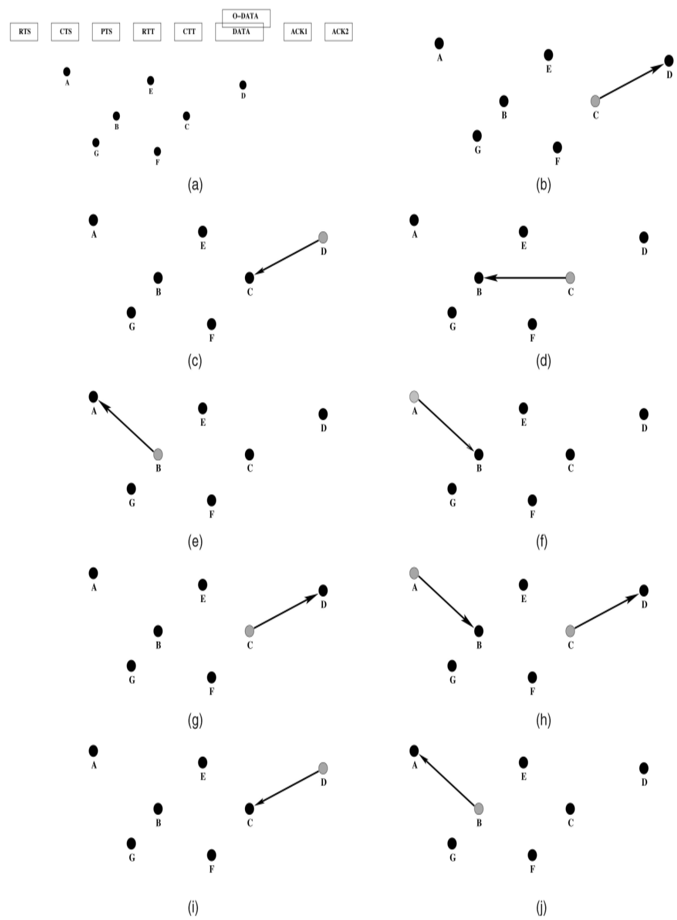
the RTS is the primary receiver. All the other nodes that receive the handshake set their transmit allocation vectors (TAVs) for the duration of the transmission.

### 4.3 Secondary Handshaking

The secondary handshaking can be thought of as a secondary RTS/CTS exchange to determine the possibility of performing overlapped transmission with the primary transmission. Upon receipt of the CTS, the primary transmitter sends a Prepare-To-Send (PTS) frame to the node from which it received the present data frame in an earlier transmission. If the data is locally generated, no PTS is sent, and transmission of the data frame starts after an SIFS [1, Section 9.2.5]. If the PTS is sent, the primary transmitter defers the transmission of the data frame until the completion of the secondary handshaking.The format is similar to the format of an RTS frame except for the additional fields Destination Address (DA) and Packet ID (PID). The DA field contains the address of the primary receiver, and the PID field contains the unique ID of the data frame that is being transmitted to the primary receiver. The node receiving the PTS frame is called the secondary receiver. Being a secondary receiver implies that the present node has information regarding the primary transmission and is capable of receiving an overlapped transmission. Upon receipt of the PTS, the secondary receiver ensures that its TAV is set only by the primary transmitter. Note that the TAVs store information regarding the transmitter and receiver of any valid frame it receives that is not addressed to the receiving node. This is to ensure that there are no other transmissions occurring in the range of the secondary transmitter except for the primary transmission. If this is true, it identifies a suitable partner for secondary transmission as described below. Once the secondary receiver identifies the medium to be free except for the primary transmission, it generates a list of potential partners. The nodes are identified based on the following criteria:

1. The node should not cause excessive interference to the primary transmission. In this paper, we consider only one of the two approaches described, in which the secondary receiver knows the locations of the neighbouring nodes and uses this information to identify potential candidates for the secondary transmitter.
2. The node should have transmitted a frame to the secondary receiver in an earlier time slot. The information regarding the receipt of frames from all the other nodes is maintained in a cache at the MAC layer. The second condition is based on the heuristic that if a node has transmitted a frame to the secondary receiver in an earlier time slot, it is very likely that there might be more frames destined for the secondary receiver. This ensures that there is a greater probability of secondary transmission for any particular partner. A node is chosen randomly3 from the potential candidates to be the secondary transmitter. The secondary receiver sends a Request-to-Transmit (RTT) frame to the selected secondary transmitter. The format of RTT is similar to the format of RTS except that it also contains an additional field, Primary Address (PA), which contains the address of the primary

Fig.5 Typical frame exchanges in the OCSMA




protocol. (a) Ad hoc network. (b) RTS. (c) CTS. (d) PTS. (e) RTT. (f) CTT. (g) DATA. (h) O-DATA.(i) ACK1. (j) ACK2

transmitter. The secondary transmitter compares the address of the primary transmitter against the transmitter info of the TAVs (if it is available), and

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all the TAVs that are set by the primary transmitter are reset. This ensures that the TAV of the secondary transmitter is not set by either the RTS or the PTS sent by the primary transmitter. If it finds the medium to be free and has a suitable packet to be transmitted, it responds with a Clear-to-Transmit (CTT) frame whose format is the same as that of CTS Transmission of the CTT implies that the secondary transmitter is capable of transmitting overlapped data without causing interference to any of the transmissions (including the primary transmission) in its communication range.

### 4.4 Primary Transmission

A timer at the primary transmitter is set to expire upon completion of the secondary handshaking. Note that its TAV timer will not be set during the transmission of the secondary handshaking We note that this differs from the typical NAV implementation of the IEEE 802.11 protocol. When the timer expires, it transmits its data frame to the primary receiver.

### 4.5 Secondary Transmission

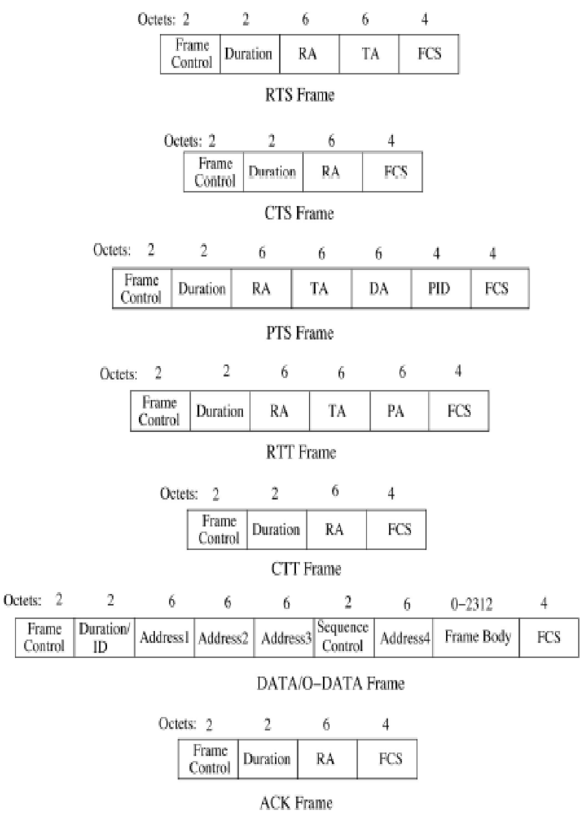


Fig .6 Frame formats of the OCSMA protocol

The secondary transmitter starts its overlapped transmission after the commencement of the primary transmission This overlapped delay zero is designed to allow the secondary receiver to acquire the timing and phase of the primary transmission, which greatly simplifies the IC mechanism at the PHY. It does not ensure perfect symbol or phase synchronization of the primary and secondary transmissions at the secondary receiver. The format of the overlapped data (O-DATA) frame is the same as the data frame. The secondary receiver cancels the interference and recovers the overlapped data. This phase is illustrated in Fig. 8h, which depicts node B receiving an O-DATA frame while cancelling out the interference caused by C's transmission (primary transmission). Note that the secondary transmission is allowed to terminate _1 seconds after the end of the primary transmission.

### 4.6 Data Acknowledgments

The format of the ACK frames is the same as in the IEEE 802.11 protocol [1, Section 7.2.1.3]. How the nodes then contend for channel access is an important design consideration that significantly affects the performance of OCSMA. Consider first the primary and secondary receivers. If the DATA and O-DATA packets were successful, both of these nodes have packets to transmit and will contend for channel access. If the primary receiver sends an RTS before the secondary receiver, then it will become the primary transmitter for that packet, and the secondary receiver from the previous overlapped transmission will have the appropriate packet to act as a secondary transmitter for an overlapped transmission. However, if the secondary receiver gains access to the channel before the primary receiver, then an overlapped transmission will depend on the availability of appropriate packets further back in the network. To increase the chance of the primary receiver contending for the channel first, the primary receiver acts as a successful receiver in the IEEE 802.11 protocol [1, Section 9.2.5.1]. To give the secondary receiver a high probability of choosing to defer longer than the primary receiver, it will choose a random backoff value in a window that is twice the size of its current contention window (CW) value, once it senses the channel to be idle. Next, consider the reception of acknowledgments at the primary and secondary transmitters. Upon reception of ACK, the primary transmitter resets its CW parameter as in the IEEE 802.11 [1, Section 9.2.5.5] protocol. If it has a packet to transmit, the channel access mechanism is the same as the mechanism in the IEEE 802.11 protocol. However, the secondary transmitter does not reset its CW.

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This ensures that with high probability, the secondary transmitter does not contend with the primary transmitter for channel access. The CW parameter of the secondary transmitter is reset when it receives an ACK for any DATA frame (and not an O-DATA frame) that it transmits later. We observed that in networks with linear flows, this design leads to a greater probability of overlapped transmission.

## 5. DESIGN CONSIDERATIONS

In this section, we discuss various design issues concerning the OCSMA protocol. In particular, we compare and contrast the OCSMA protocol with the IEEE 802.11 MAC protocol, on which it is based.

SIMULATION SETUP

Table 1

| Parameter | Default value |
|---|---|
| Data rate | 1 Mbps |
| Simulation duration | 4000 s |
| Warmup time | 400 s |
| Routing protocol | AODV |
| Channel model | Two ray propagation |
| RTS Threshold | 150 Bytes |
| Transmission radius | 250 m |
| Carrier-sensing radius (Interference range) | 550 m |
| IFQ length | 100 |
| Overlapped Delay $\Delta_0$ | 240 $\mu s$ |
| $\Delta_1$ | 240 $\mu s$ |
| STA Retry Limits (Short, Long) | (7,4) |

## CROSS-LAYER INTERACTION

The design of the OCSMA protocol involves a greater level of cross-layer interaction compared to the IEEE 802.11 protocol. For instance, when a node receives an RTT, the MAC needs to interact with the higher layers to determine if a packet of suitable length can be sent to the secondary receiver. It is also possible that a packet might need fragmentation such that the transmission of overlapped data is terminated within 1 seconds of the termination of the primary transmission Similarly, when the secondary receiver receives a CTT, the MAC needs to indicate to the PHY that interference mitigation will be needed to recover the overlapped transmission. Cross-layer interaction is also needed at the secondary transmitter when identifying potential partners for overlapped transmission.

## 6. SIMULATION RESULTS

In order to route packets from one node to another AODV routing protocol is been used. Evaluated the performance of the OCSMA protocol under different network topologies and traffic conditions using Network Simulator (ns2) [3]. Since it is evaluated only the performance of the MAC protocol, it is assumed perfect IC at the PHY and that the O-DATA packet can be recovered whenever there is an overlapped transmission with the corresponding primary transmission being the only source of interference. First evaluated the OCSMA protocol in a fixed 20-node random network, with a source and destination located at either end of the network. The nodes are placed at regular intervals, with adjacent nodes being in the communication range of each other and nodes two hops apart being in the interference range of each other. The transmission power of the secondary transmission is the same as that of the primary transmission. It is observed that the throughput of the IEEE 802.11 MAC protocol increases until too few bytes, and then as packet size increases the throughput starts decreasing. However the throughput of the OCSMA increases more than the IEEE 802.11.Due to overlapped transmission and collision packet drop is been occurred.

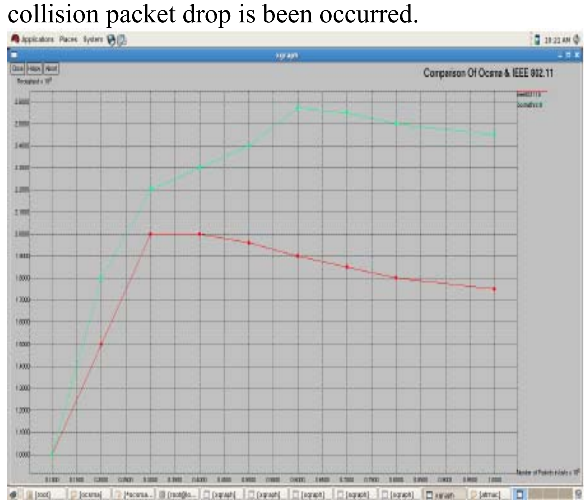


Fig 7 Throughput comparison in TCP traffic

In the above fig 7 it is to compare two protocols IEEE 802.11 and OCSMA , where red colour is IEEE 802.11 and green colour for OCSMA protocol. It is clear that the throughput is been improved in the above graph. Traffic is shown in an NAM (network animator) file below; in this it is shown that packet transfer is going to take place in an animation model. Here two of nodes are moving throughout the network to collect information of

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every node, i.e. observing the scenario by the node. If energy is considered as an parameter to analyse, then in OCSMA protocol energy consumption is more because as it involves in more control signals in the network. So energy utilized is increased when compared with IEEE 802.11 MAC protocol.

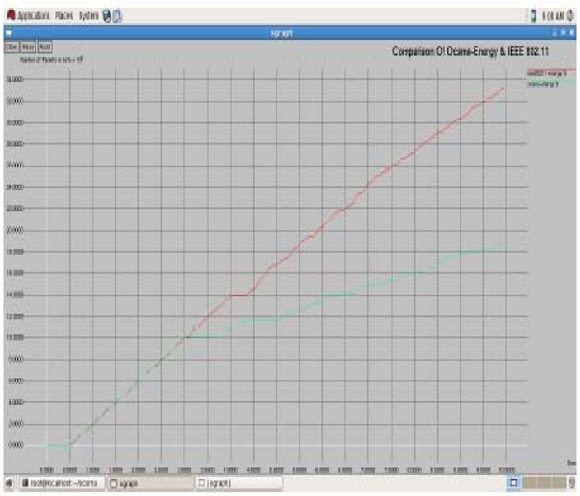


Fig. 8 Comparison of OCSMA and IEEE802.11 in terms of energy

The maximum throughput under OCSMA is achieved for a packet length of 1,400 bytes, at which point it provides 21 percent throughput gain over IEEE 802.11. Since the collision rate for OCSMA protocols is higher than that of IEEE 802.11, next analyze the impact of the STA Short Retry Count (SSRC) and STA Long Retry Count (SLRC) limits [1, Section 9.2.5.3] on the throughput of OCSMA. The design of the protocol and the frame formats are to a large extent compatible with the existing IEEE 802.11 frame formats. Hence, they can be integrated with existing IEEE 802.11-based wireless networks with minimal changes.

## 7. CONCLUSION

This paper developed overlapped transmission schemes to enhance the spatial reuse and throughput of wireless networks. By taking advantage of a priori knowledge of the interfering packet, the receiver can employ a simplified IC scheme to receive a packet in the presence of interference. It is analyzed some of the factors that limit the use of overlapped transmissions in an ad hoc network. Therefore developed the OCSMA protocol based on the IEEE 802.11 MAC protocol to support overlapped transmissions in a wireless network .

## 8. FUTURE WORK

This can be extended as by reducing the overhead. The overhead of the OCSMA protocol can be reduced considerably if no such conformity is required. For instance, the CTT packet can be eliminated without a significant penalty on the throughput. The elimination of the CTT packet results in reduced protocol overhead but increases the power consumption at the PHY of the secondary receiver since IC has to be turned on more often.

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