MAC PROTOCOL WITH POWER/ENERGY CONSERVATION IN MOBILE AD-HOC NETWORK

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Abstract – Mobile Ad-hoc Network (MANET) is a self configuring infrastructure-less network of mobile devices connected by wireless They have undergone rapid growth in the past several years because of their application in military and rescue service, disaster recovery operations, mobile conferencing and many other applications. The Media Access Control (MAC) data communication protocol sub-layer provides addressing and channel access control mechanisms t hat make it possible for network nodes to access common wireless channel through distributed coordination function (DCF). Wireless network adopts centralized transmission technique for transmission of power. MANETs are networks capable of communicating in a set of small, low cost, low power sensing devices. A wireless sensor networks is totally based on the limiting factor i.e. energy consumption. A wireless sensor network consists of large number of sensor nodes distributed or scattered in particular network region.

  Keywords - MANET, IEEE 802.11, Media Access Control (MAC), DCF, Carrier Sense Multiple Access (CSMA)

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I. INTRODUCTION

An ad-hoc network is formed when two or more stations come together to form an independent network. Ad-hoc networks are also termed as infrastructure-less networks since as they do not require any prior infrastructure. Two stations that are within transmission range of each other are called one hop neighbours. Multi-hop ad-hoc networks are ones in which the stations can talk to stations more than one hop away via intermediate stations.

Mobile nodes can move freely, and organize themselves randomly i.e. each host can dynamically enter and leave the network. Thus, the network topology may change frequently and rapidly. This means that the network has to adapt itself to the current topology.
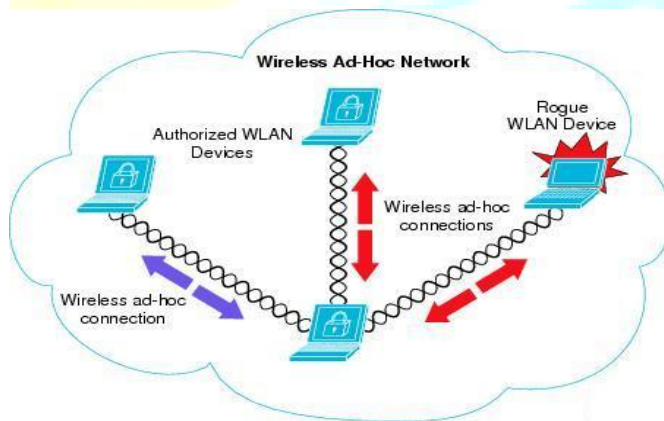
➢ **Hidden and Exposed Node Issue**

Hidden node Problem : Stations A and C become hidden to each other as station B can listen both to A and C, but stations A and C cannot listen to each other. If a packet is being transmitted from station A to station B and station C decides to start a transmission (being hidden, it does not know of A-B transmission), there will be collision at station B.

Exposed node Problem : If station B is sending data to station A, then station C becomes exposed to B and is forced to be silent even if it can send data to another station. This is because station C finds carrier busy during transmission of station B.

A simple and elegant solution to the hidden node problem is to use small packets called RTS (Request to send) and CTS (Clear to Send) for handshaking before transmission of data packet.
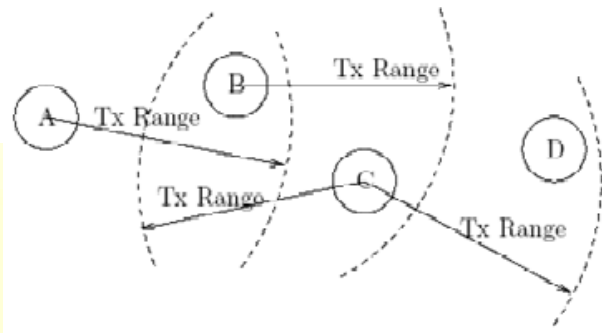

Figure .2. Hidden & Exposed nodes

II. CSMA/CA

The most important part of a MAC protocol is Channel Access Mechanism. The channel access mechanism is way of regulating the use of physical channel among the stations present in the network. It specifies when a station can send or receive data on the channel.

CSMA/CA (Carrier Sense Multiple Access) is derived from CSMA/CD (Collision Detection) which is the channel access mechanism used in wired Ethernets. Since the transmission range of wireless stations is limited, collision cannot be detected directly. This protocols tries to avoid the collision. On arrival of a data packet from LLC, a station senses the channel before transmission and if found idle, starts transmission. If another transmission is going on, the station waits for the length of current transmission, and starts contention. Since the contention is a random time, each station get statistically equal chance to win the contention.
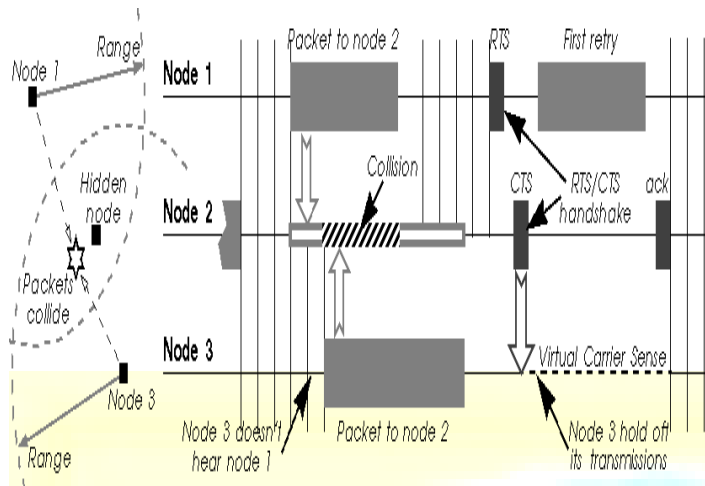
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Figure .3. CSMA Channel Access Mechanism

CSMA/CA is asynchronous mechanism for medium access and does not provide any bandwidth guarantee. It's a best effort service and is suited for packetized applications like TCP/IP. It adapts quite well to the variable traffic conditions and is quite robust against interference.
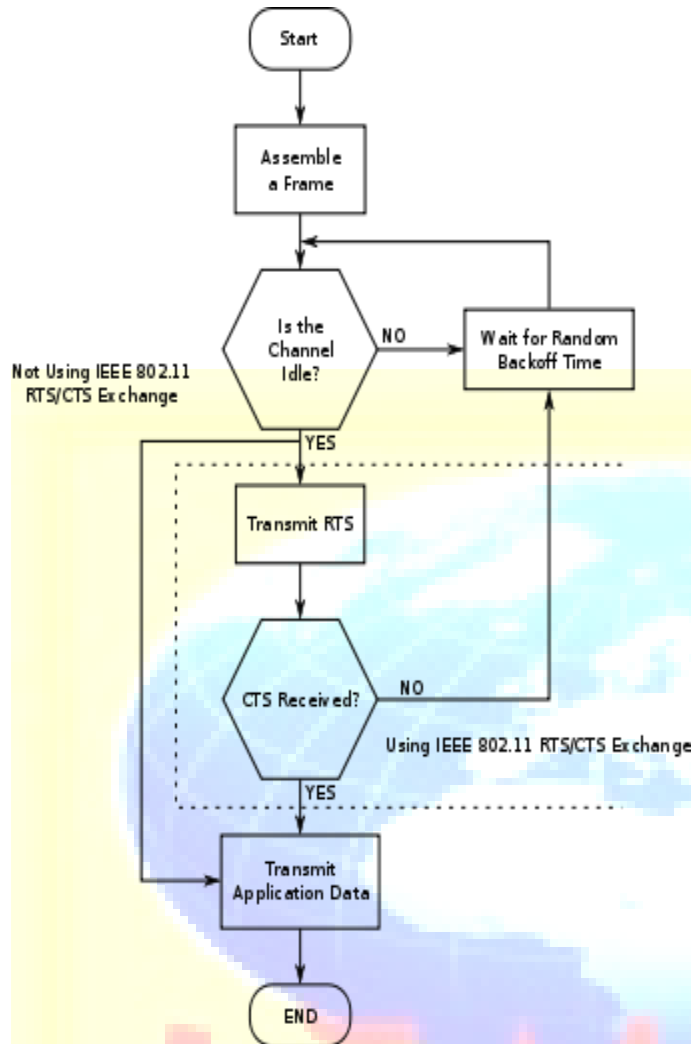
Figure .4. Flow chart of CSMA/CA

III. CLASSIFICATION OF MAC PROTOCOL

MAC protocols for ad-hoc wireless networks can be classified into several categories based on various criteria such as initiation approach, time synchronization, and reservation approach. Ad-hoc Network MAC protocols are classified in three types;

☐ Contention based protocols.

☐ Contention based protocols with reservation mechanism.

_____

◻ Contention based protocols with scheduling mechanism.

A. Contention Based Protocols

These protocols follow a contention based channel access policy. A node doesn't make any resource reservation in priori. Whenever it receives a packet to be transmitted, it contends with other nodes for access to the shared channel. These are further divided into two types;

• Sender initiated protocols

• Receiver initiated protocols

B. Contention Based Protocol with Reservation Mechanisms

Ad-hoc wireless networks sometimes may need to support real time traffic, which requires QoS guarantees to be provided. In order to support such traffic, certain protocols have mechanism for reserving bandwidth in priori. These protocols are classified into two types;

• Synchronous protocols

• Asynchronous protocols

C. Contention Based Protocol with Scheduling Mechanisms

These protocols focus on packet scheduling at nodes, and also scheduling nodes for access to the channel. Node scheduling is done in a manner so that all nodes are treated fairly. Scheduling based scheme are also used for enforcing priorities among flows whose packets are queued at nodes.
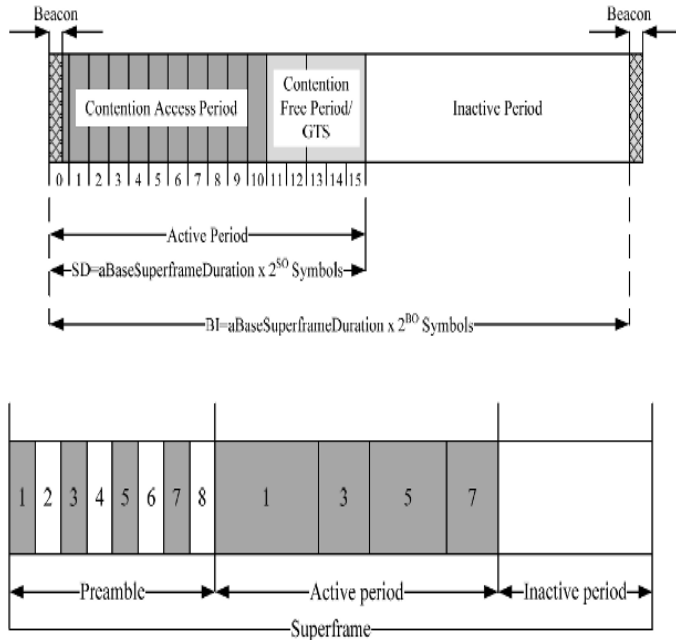
Figure .5. MAC Architecture

IV.   IEEE 802.11 OPERATION

The IEEE 802.11 MAC offers two kinds of medium access methods, namely Distributed Coordination Function (DCF), and Point Coordination Function (PCF). DCF is the basic access method in 802.11 and requires no infrastructure.

Figure .6. Data link layer (LLC+MAC)

The IEEE 802.11 MAC offers two kinds of medium access methods, namely Distributed Coordination Function (DCF), and Point Coordination Function (PCF). DCF is the basic access method in 802.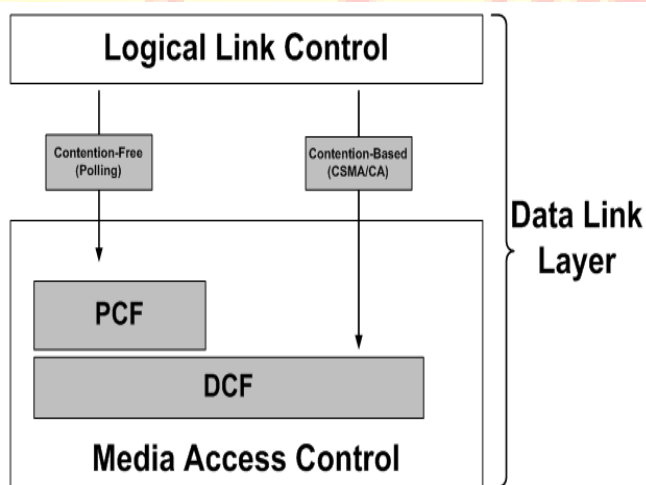11 and requires no infrastructure. When wireless stations are within transmit range of each other, they form a Basic Service Set (BSS), and can communicate to each other using DCF. If the BSS contains only two stations, it is called Independent Basic Service Set (IBSS). Many BSSs may be connected by a Distribution System (DS) to form an Extended Service Set (ESS). An access point (AP) is the station that provides access to DS services.
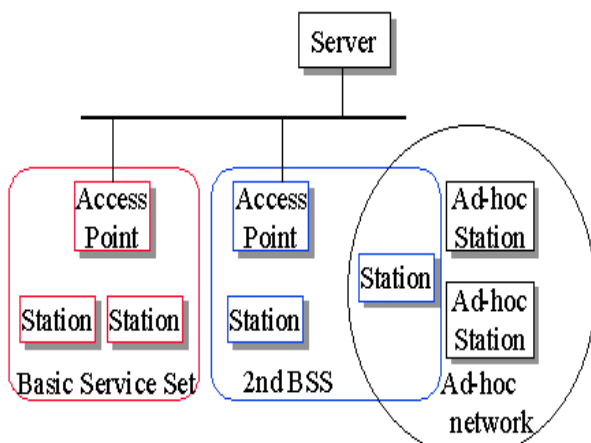

Figure .7. 802.11 Architecture

The IEEE 802.11 MAC is designed for wireless LANs. The requirements of multi-hop ad-hoc networks are more challenging than those of wireless LANs. In this research, we investigate the operation of IEEE 802.11 MAC in centralized multi-hop ad-hoc networks. The terms station and node are used interchangeably throughout the thesis. Multi-hop cooperative wireless ad-hoc networks will be simply referred to as multi-hop networks.
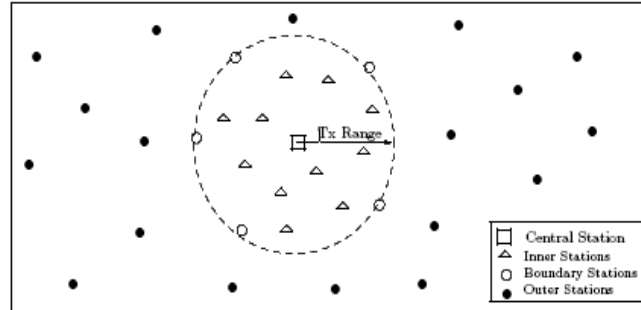
Figure .8. Multi-hop Scenario

Consider a multi-hop centralized scenario, as shown in the figure. For convenience, the stations inside the network are classified into following categories:

Central station : is the central controlling station. Most of the traffic in the network is directed towards it.

Inner stations : are within one hop boundary of the central station.

Boundary stations : are at one hop boundary of the central station. These stations act as relaying stations for the stations outside the reach of central node. Outer stations are outside the communication range of central node.
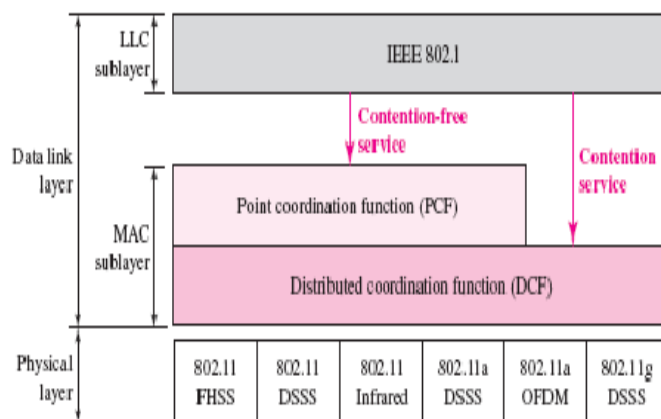

Figure .9. IEEE 802.11 Detailed Protocol Architecture

V. IEEE 802.11 SCHEME SPECIFICATION

IEEE 802.11 specifies two medium access control protocols, PCF (Point Coordination Function) and DCF (Distributed Coordination Function). PCF is a centralized scheme, whereas DCF is a fully distributed scheme. We consider DCF in this paper.
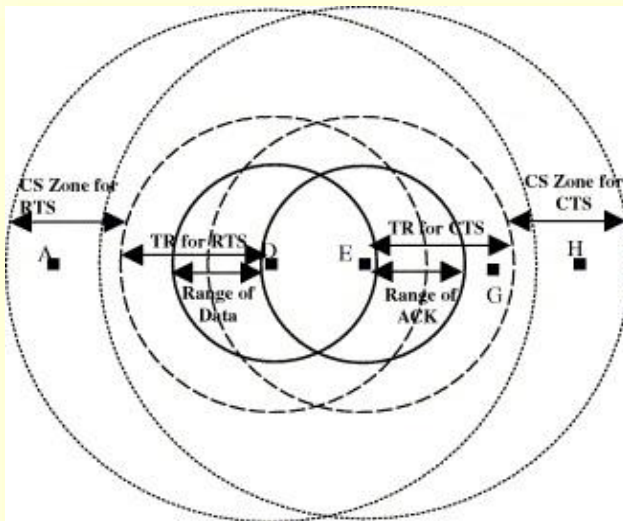

Figure .10. Transmission & Carrier Sensing Ranges

- **Transmission range :** When a node is within transmission range of a sender node, it can receive and correctly decode packets from the sender node. In our simulations, the transmission range is 250 m when using the highest transmit power level.

- **Carrier sensing range :** Nodes in the carrier sensing range can sense the sender's transmission. Carrier sensing range is typically larger than the transmission range, for instance, two times larger than the transmission range. In our simulations, the carrier sensing range is 550 m when using the highest power level. Note that the carrier sensing range and transmission range depend on the transmit power level.

- **Carrier sensing zone** : When a node is within the carrier sensing zone, it can sense the signal but cannot decode it correctly. Note that, as per our definition here, the carrier sensing zone does not include transmission range. Nodes in the transmission range can indeed sense the transmission, but they can also decode it correctly. Therefore, these nodes will not be in the carrier sensing zone as per our definition. The carrier sensing zone is between 250 m and 550 m with the highest power level in our simulation.
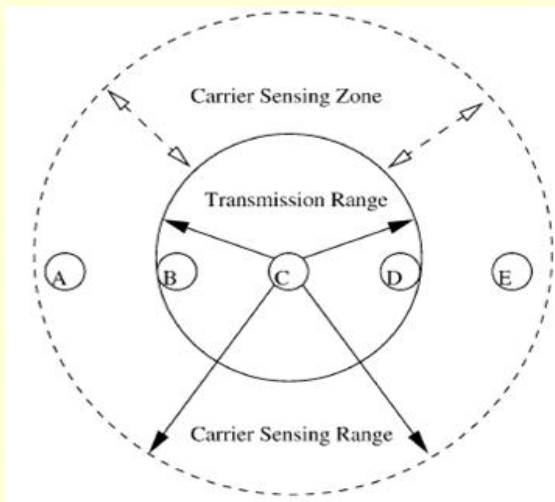

Figure .11. Carrier Sensing

VI. MAC Sub layer in IEEE 802.11

The IEEE standard 802.11 specifies the most famous family of WLANs in which many products are already available. This means that the standard specifies the physical and medium access layer adapted to the special requirements of wireless LANs, but offers the same interface as the others to higher layers to maintain interoperability.

➢ **System Architecture**

The basic service set (BSS) is the fundamental building block of the IEEE 802.11 architecture. A BSS is defined as a group of stations that are under the direct control of a single coordination

function (i.e., a DCF or PCF) which is defined below. The geographical area covered by the BSS is known as the basic service area (BSA), which is analogous to a cell in a cellular communications network.
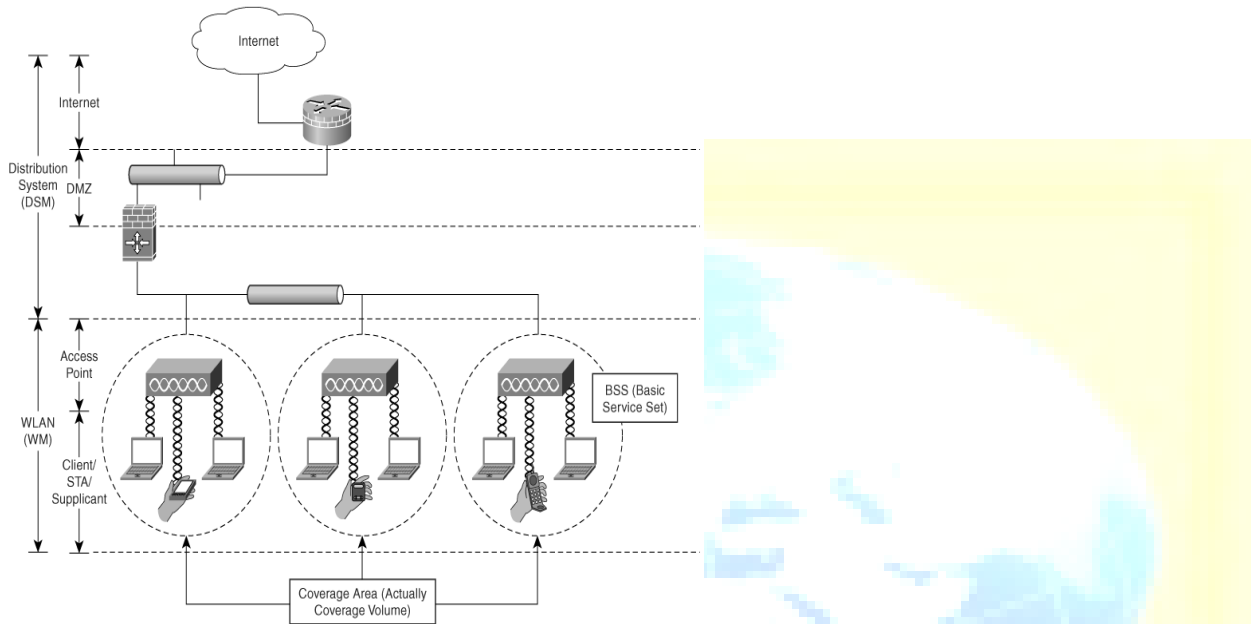
Figure .12. System Architecture of Ad-hoc network

In contrast to the ad hoc network, infrastructure networks are established to provide wireless users with specific services and range extension. Infrastructure networks in the context of IEEE 802.11 are established using APs. The AP supports range extension by providing the integration points necessary for network connectivity between multiple BSSs, thus forming an extended service set (ESS).
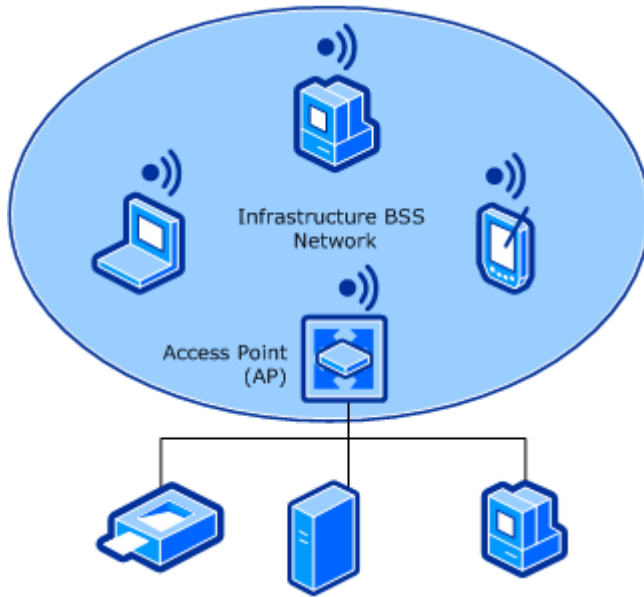
Figure .13. Example of infrastructure network

VII. DCF OPERATION

The DCF is the fundamental access method used to support asynchronous data transfer on a best effort basis. The DCF is based on CSMA/CA. The carrier sense is performed at both the air interface, referred to as physical carrier sensing, and at the MAC sub layer, referred to as virtual carrier sensing. Physical carrier sensing detects presence of other users by analyzing the activity in the channel through the received signal strength.

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 back-off time following a busy medium condition. The DCF shall be implemented in all stations, for use within both IBSS and infrastructure network configuration.

The DCF in IEEE 802.11 is based on CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance). Carrier sensing is performed using physical carrier sensing (by air interface) as well as

virtual carrier sensing. Virtual carrier sensing uses the duration of the packet transmission, which is included in the header of RTS, CTS, and DATA frames. The duration included in each of these frames can be used to infer the time when the source node would receive an ACK frame from the destination node. For example, the duration field in RTS includes time for CTS, DATA, and ACK transmissions. Similarly, the duration field for CTS includes time for DATA and ACK transmissions, and the duration field for DATA only includes time for the ACK transmission.
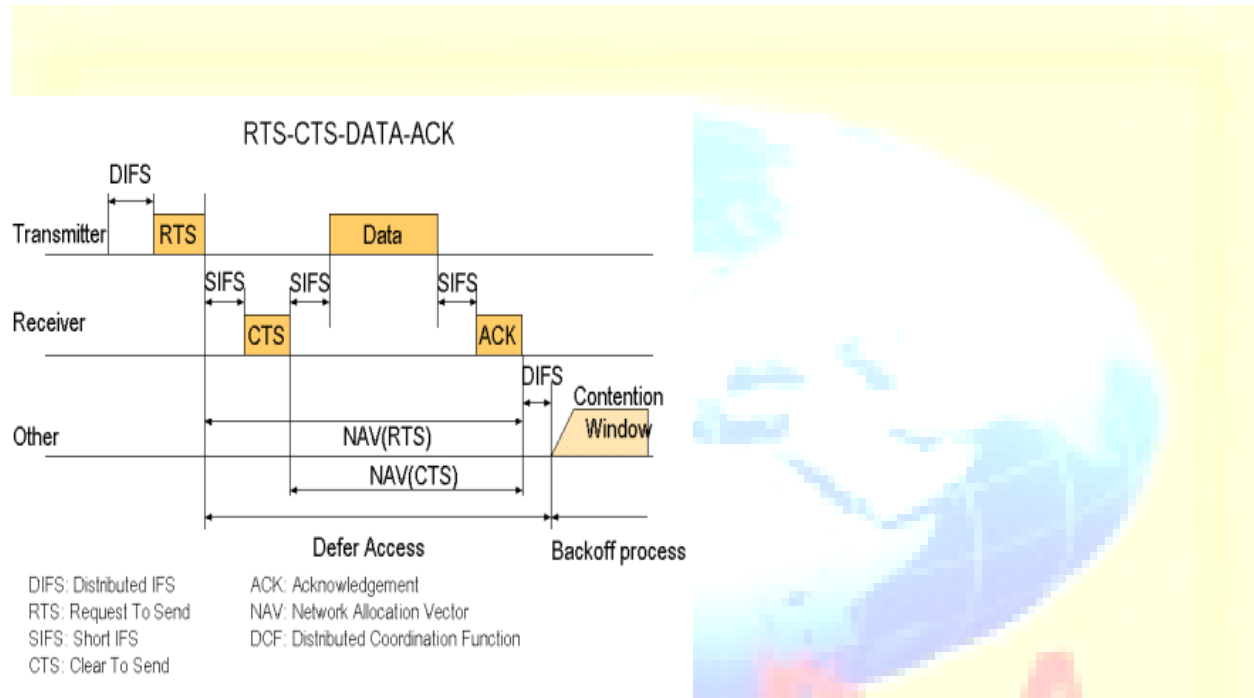

Figure .14. DCF access using RTS/CTS

➤ **Inter frame Spacing**

IFS is the time interval between frames. IEEE 802.11 defines four IFSs – SIFS (short inter frame space), PIFS (PCF inter frame space), DIFS (DCF inter frame space), and EIFS (extended inter frame space). The IFSs provide priority levels for accessing the channel. The SIFS is the shortest of the inter frame spaces and is used after RTS, CTS, and DATA frames to give the highest priority to CTS, DATA and ACK, respectively. In DCF, when the channel is idle, a node waits for the DIFS duration before transmitting any packet.

In figure, nodes in transmission range correctly set their NAVs when receiving RTS or CTS. However, since nodes in the carrier sensing zone cannot decode the packet, they do not know the duration of the packet transmission. To prevent a collision with the ACK reception at the source node, when nodes detect a transmission and cannot decode it, they set their NAVs for the EIFS duration. The main purpose of the EIFS is to provide enough time for a source node to receive the ACK frame, so the duration of EIFS is longer than that of an ACK transmission. As per IEEE 802.11, the EIFS is obtained using the SIFS, the DIFS, and the length of time to transmit an ACK frame at the physical layer's lowest mandatory rate, as the following equation :

EIFS = SIFS + DIFS + [(8·ACKsize) + Preamble   Length + PLCP Header Length] / Bit Rate

where ACK size is the length (in bytes) of an ACK frame, and Bit Rate is the physical layer's lowest mandatory rate. Preamble Length is 144 bits and PLCP Header Length is 48 bits . Using a 1 Mbps channel bit rate, EIFS is equal to 364 μs.
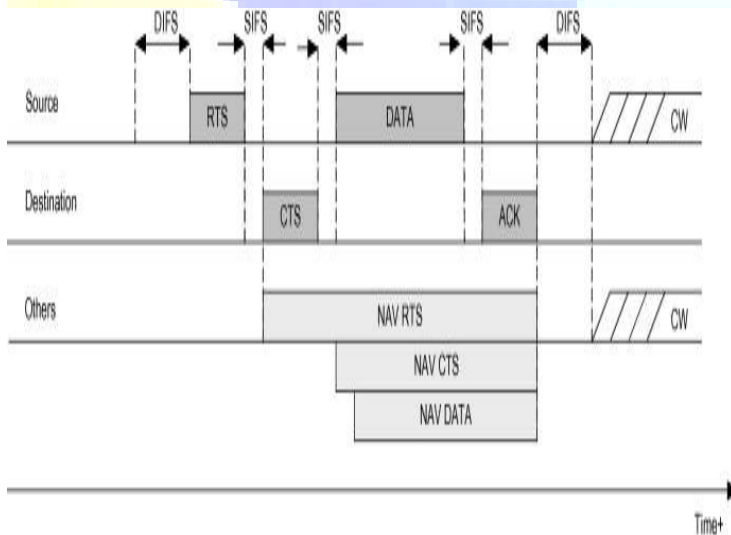

Figure .15. NAV duration in transmission range and carrier sensing zone

➢ **PCF Mechanism**

A PCF offers a guarantee of access to the medium for stations in a BS. This is beneficial for time-bound application such as voice or video. A PCF consists of a point coordinator (PC) and stations that can respond to the contention free (CF) polling frame. The PC controls the access of the medium during the contention free period. Once polled, a station may transmit only one frame to any station. All station, including the PC may "piggyback" the acknowledgement using data frame subtypes to increase the efficiency of the CFP.
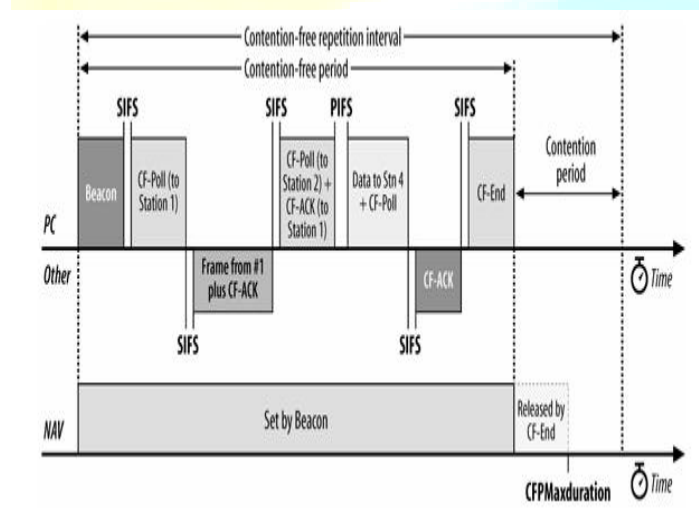

Figure .16. PCF Scheme

VIII.   BASIC POWER CONTROL PROTOCOL

Power control can reduce energy consumption. However, power control may introduce different transmit power levels at different hosts, creating an asymmetric situation where a node A can reach node B, but B cannot reach A.
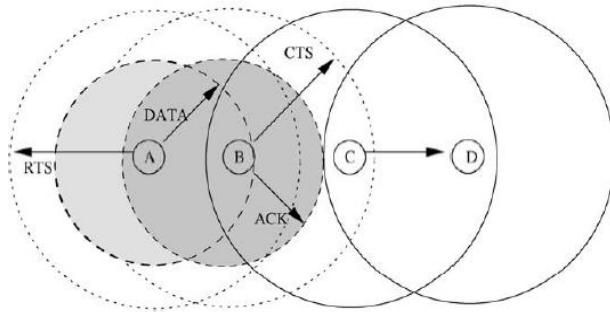
Figure .17. Basic Scheme

In the Basic scheme, the RTS–CTS handshake is used to decide the transmission power for subsequent DATA and ACK packets. This can be done in two different ways as described below. Let pmax denote the maximum possible transmit power level.

➢ Suppose that node A wants to send a packet to node B. Node A transmits the RTS at power level pmax. When B receives the RTS from A with signal level pr, B can calculate the minimum necessary transmission power level, pdesired, for the DATA packet based on received power level pr, the transmitted power level, pmax, and noise level at the receiver B.

We can borrow the procedure for estimating pdesired from. This procedure determines pdesired taking into account the current noise level at node B. Node B then specifies pdesired in its CTS to node A. After receiving CTS, node A sends DATA using power level pdesired. Since the signal-to-noise ratio at the receiver B is taken into

consideration, this method can be accurate in estimating the appropriate transmit power level for DATA.

➢ In the second alternative, when a destination node receives an RTS, it responds by sending a CTS as usual (at power level p max). When the source node receives the CTS, it calculates p desired based on received power level, pr, and transmitted power level (p max), as

$$P \text{ desired } = p \text{ max/pr} \cdot Rxthresh \cdot c,$$

where Rxthresh is the minimum necessary received signal strength and c is a constant. We set c equal to 1 in our simulations. Then, the source transmits DATA using a power level equal to p desired. Similarly, the transmit power for the ACK transmission is determined when the destination receives the RTS.
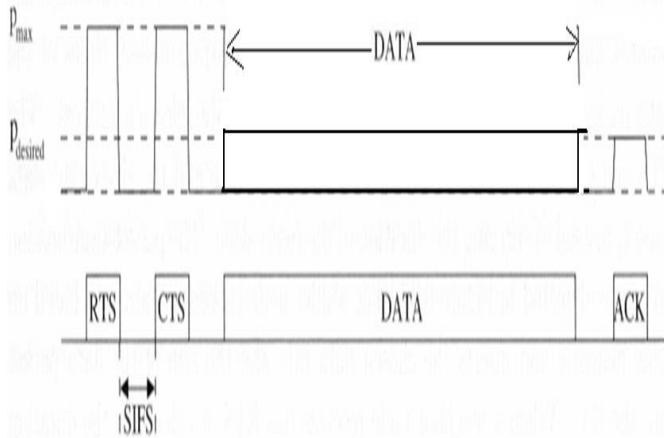

Figure .18. Basic Power Control Protocol.

IX.   DRAWBACK OF THE BASIC PROTOCOL

In the Basic scheme, RTS and CTS are sent using pmax, and DATA and ACK packets are sent using the minimum necessary power to reach the destination.
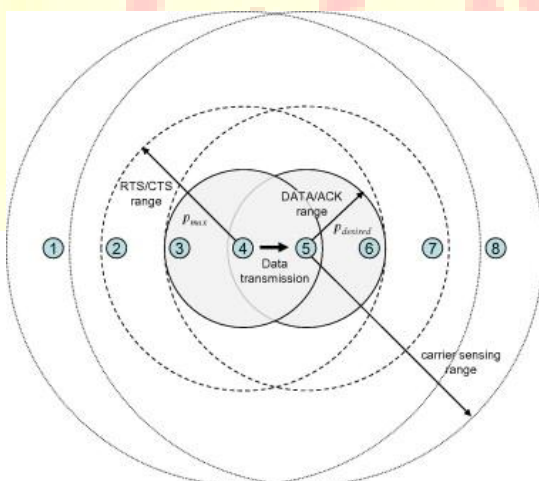

Figure .19. Scheme showing sensing ranges during data transmission

When the neighbour nodes receive an RTS or CTS, they set their NAVs for the duration of the DATA–ACK transmission. When D and E transmit the RTS and CTS, respectively, B and C receive the RTS, and F and G receive the CTS, so these nodes will defer their transmissions for the duration of the D–E transmission. Node A is in the carrier sensing zone of D (when D transmits at pmax) so it will only sense the signals and cannot decode the packets correctly. Node A will set its NAV for EIFS duration when it senses the RTS transmission from D. Similarly, node H will set its NAV for EIFS duration following CTS transmission from E.

When transmit power control is not used, the carrier sensing zone is the same for RTS–CTS and DATA–ACK since all packets are sent using the same power level. However, in Basic, when a source and destination pair decides to reduce the transmit power for DATA–ACK, the transmission range for DATA–ACK is smaller than that of RTS–CTS; similarly, the carrier sensing zone for DATA–ACK is also smaller than that of RTS–CTS.
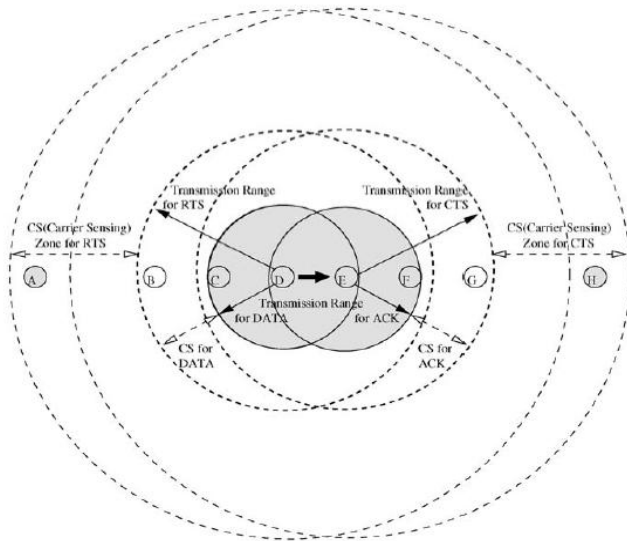

Figure .20. Basic Scheme

X.   PROPOSED POWER CONTROL MAC PROTOCOL

Proposed power control MAC (PCM) is similar to the Basic scheme in that it uses power level pmax for RTS–CTS and the minimum necessary transmit power for DATA–ACK transmissions. We now describe the procedure used in PCM.

1. Source and destination nodes transmit the RTS and CTS using pmax. Nodes in the carrier sensing zone set their NAVs for EIFS duration when they sense the signal and cannot decode it correctly.

2. The source node may transmit DATA using a lower power level, similar to the BASIC scheme.

3. To avoid a potential collision with the ACK (as discussed earlier), the source node transmits DATA at the power level pmax, periodically, for just enough time so that nodes in the carrier sensing zone can sense it.

4. The destination node transmits an ACK using the minimum required power to reach the source node, similar to the BASIC scheme.

Figure shows how the transmit power level changes during the sequence of an RTS–CTS–DATA–ACK transmission. After the RTS–CTS handshake using pmax, suppose the source and destination nodes decide to use power level p1 for DATA and ACK. Then, the source will transmit DATA using p1 and periodically use pmax. The destination uses p1 for ACK transmission.
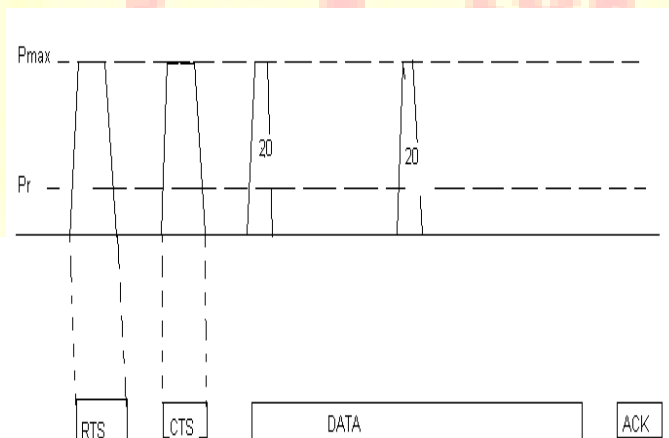

Figure .21. Proposed Model

(PCM increases periodically)

The main difference between PCM and the Basic scheme is that PCM periodically increases the transmit power to pmax during the DATA packet transmission. With this change, nodes that can potentially interfere with the reception of ACK at the sender will periodically sense the channel as busy, and defer their own transmission.

Accordingly, 15 μs should be adequate for carrier sensing, and time required to increase output power (power on) from 10% to 90% of maximum power (or power-down from 90% to 10% of maximum power) should be less than 2 μs. Thus, we believe 20 μs should be enough to power up (2 μs), sense the signal (15 μs), and power down (2 μs). In our simulation, EIFS duration is set to 212 μs using a 2 Mbps bit rate.

In PCM, a node transmits DATA at pmax every 190 μs for a 20μs duration. Thus, the interval between the transmissions at pmax is 210 μs, which is shorter than EIFS duration. A source node starts transmitting DATA at pmax for 20 μs and reduces the transmit power to a power level adequate for the given transmission for 190 μs. Then, it repeats this process during DATA transmission. The node also transmits DATA at pmax for the last 20 μs of the transmission.

With the above simple modification, PCM overcomes the problem of the BASIC scheme and can achieve efficiency comparable to 802.11, but uses less energy.

The proposed power control protocol is modified such that in this the Data and ACK is transmitted at lower power level but after a certain duration it is transmitted at higher power level for a very fraction of time, in order to make the neighboring nodes understand that transmission is going on and they should restrict their transmission during that period so that collision does not take place hence saving power consumption.

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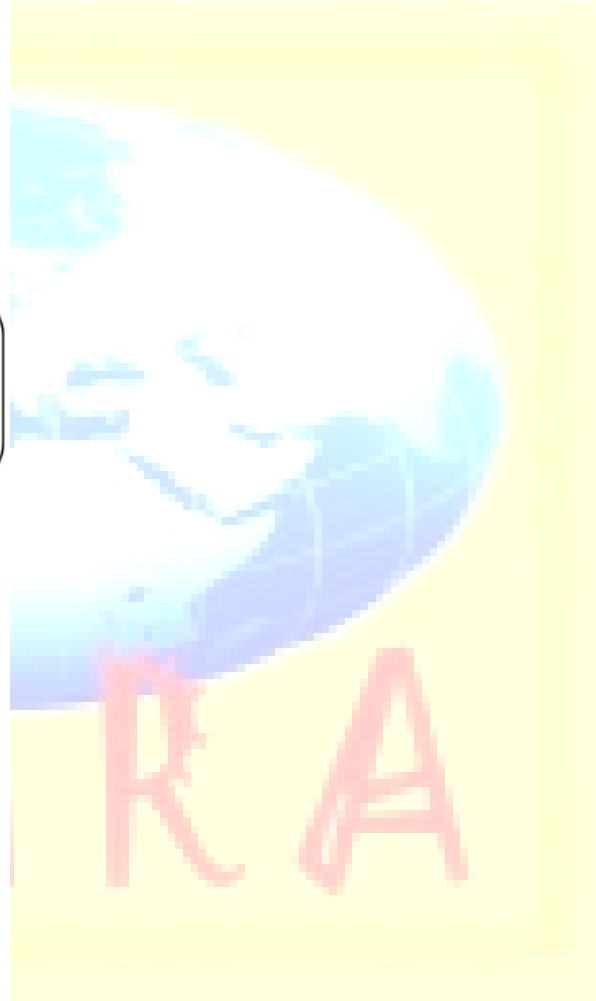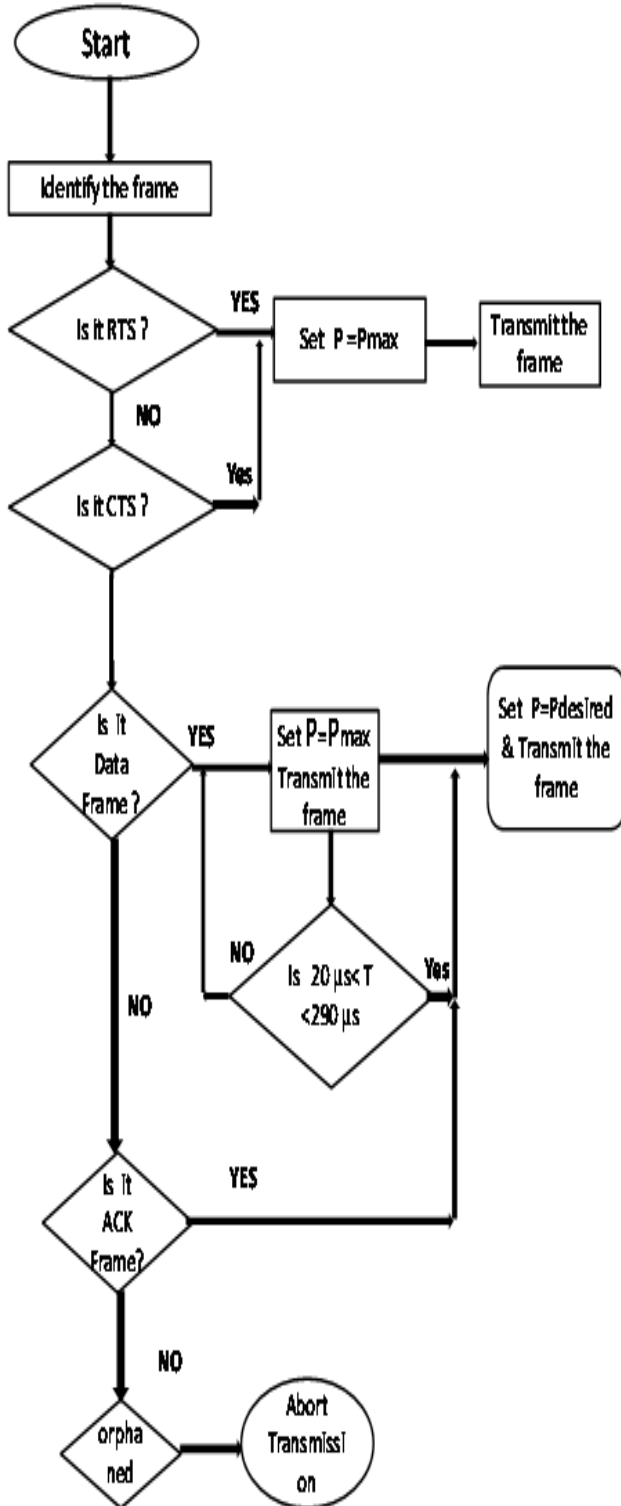**http://www.ijmra.us**

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Figure .22. Flow Chart of Proposed Protocol

XI. SIMULATION RESULTS

The given table shows all the different parameters taken into account for conducting the simulation in NS-2 atmosphere. In this table the values of all the different parameters are shown, using which the simulation for aggregate throughput and total data delivered per joule in accordance with Data rate per flow and Packet size is calculated for all three schemes namely, BASIC, 802.11 and Proposed protocol's.

Parameters	Values
Number of nodes	50
Simulation Area(m)	800x800
Topology	Random
Transmission range	50,100,150,200,250
Radio Propagation model	Shadowing
Traffic model	CBR, TCP
Packet Size	256,512,1024 bytes
Simulation times	150 seconds,300 seconds
Bandwidth	2 Mbps
Routing	DSR

A. Simulation Result for Aggregate Throughput vs Data Rate Per Flow
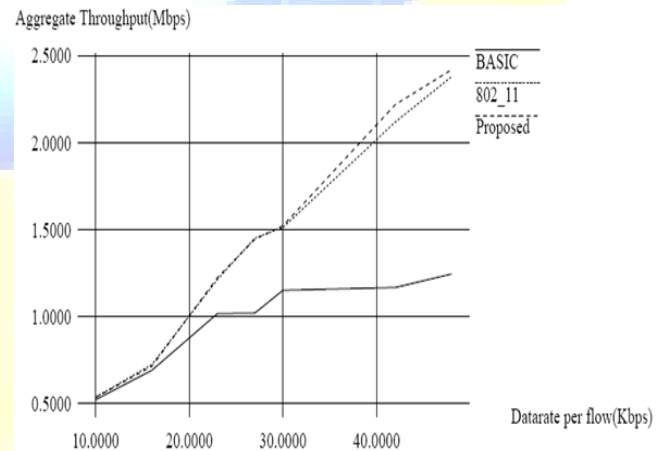
B. Simulation Result for Aggregate Throughput vs Packet Size

Aggregate Throughput(Mbps)
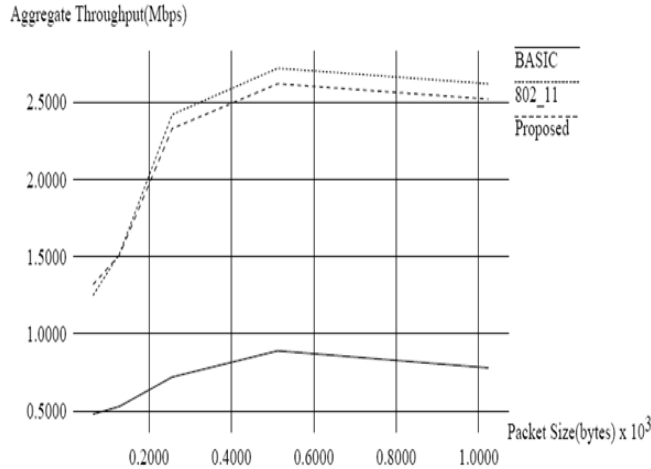
C. Simulation Result for Data Delivered per Joule vs Data rate per flow

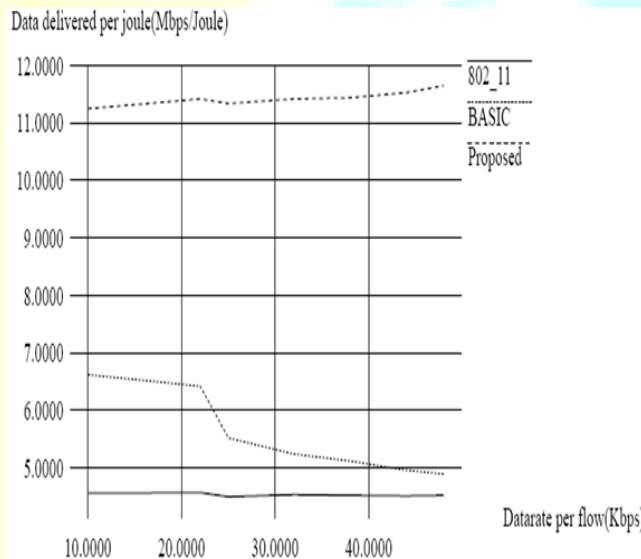Data delivered per joule(Mbps/Joule)

D. Simulation Result for Data Delivered per joule vs Packet Size

Data delivered per Joule(Mbps/Joule)
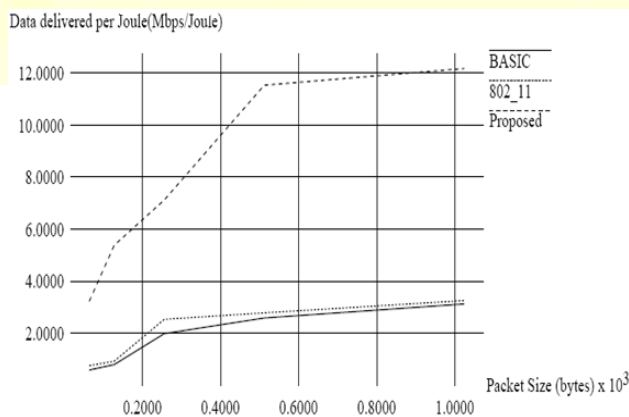
XII. CONCLUSION

It is shown that the Basic scheme increases collisions and retransmissions, which can result in more energy consumption and throughput degradation. Hence, the proposed protocol is more efficient than Basic scheme and 802.11 yielding better throughput and saves considerable amount of power as well. Hence the proposed protocol is optimized and conserves power, finally resulting in energy consumption.

XIII. SUGGESTION FOR FUTURE WORK

➢ We have shown the throughput of proposed protocol comparable to 802.11 with less power consumption, we can also try to increase the number of nodes in dynamic applications.

➢ In future the same power consumption scheme will also be conducted for grid topology.

One possible approach to the mobile ad hoc network power control scheme is that, it is only applied to the Random topology ad hoc scenario but it can also be made applicable for Grid Topology power control scheme without degrading the throughput. Where the nodes will be placed sequentially in a proper arranged manner.

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