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Survey on Reactive Medium Access Control Mechanism for Peer to Peer Heterogeneous Multi Hop Networks

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Abstract

Based on the functionality, wireless multi-hop network (MANETs) can be divided as mobile ad hoc networks, wireless mesh networks (WSN). WSN is similar to MANETs with the application of monitoring, and it is an extension of infrastructure based single-hop wireless network technology. However, these multi-hop technologies have its applications and limitations depending on their implementation and operation. **Analysis:** In this work our primary focus is to review the current work on developed reactive MAC protocol for multiple -beam smart –antennas in MANETs and WMNs and secondly focus to review the current work on developed efficient and reliable MAC methods for wireless multi-hop networks. **Findings:** Based on our analysis we find the method to describe the Medium Access Control Problems for Reliable Data Communication. **Application:** This work is used to develop reactive medium access control mechanism for peer to peer heterogeneous multi hop networks.

Keywords: Antennas, MANETs, Medium Access Control, Multi Hop Network, WSNs

1. Introduction

The prime focus of Wireless multi-hop networks is to provide internet access to its users anytime & anywhere. However, capacity of network must be increased to achieve the goal and meet enlarging demand. A wireless network composed of wireless nodes constructing a wireless infrastructure network, where network can act as single-hop or multi-hop topology. In multi-hop topological network architecture an intermediary nodes work as routers to forward packets. Multi-hop wireless networks classify with respect to its functionality and infrastructure as given below.

1.1 Wireless Multi-hop Networks

A wireless network basically composed of wireless nodes communicate by the help of central coordinator access point or base station, which are connected with backbone network. This arrangement named as infrastructure based wireless network, example of such network arrangement is wireless local area network[1] (WLAN) and range of these network is limit to 100m and well suit for university campus and inside buildings. Another type of single hop network is infrastructure less single hop wireless network named as single hop MANETs[2]. This network architecture does not require the central coordinator. The nodes in a network can communicate with another node as soon as they lie within the network range of another node, example of such network arrangement is wireless personal area network and rang of network is limit to 10m and well suit for wireless keyboards and wireless mouse. Figure 1.a shows the wireless infrastructure network and wireless single-hop network.

Wireless MANETs: Wireless ad hoc network is an example of peer to peer network[3], where every node in a network act as a router as well as host, and can com

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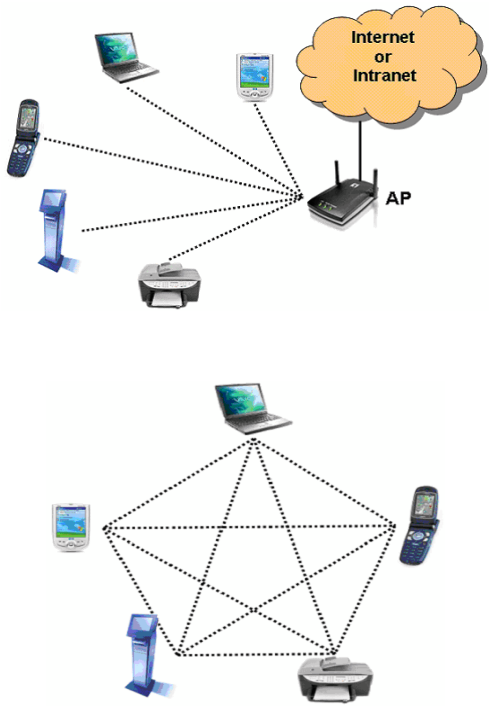

Figure 1. a wireless infrastructure-based single hop & peer-to-peer networks

municate the range of 100m without an pre defined infrastructure. The main goal of these network accesses to its nodes as similar to wired network[4]. This network is used to deploy in the place of battlefields and disaster locations. Figure 1.b shows the data transmission from source to destination mobile station through intermediary mobile station.

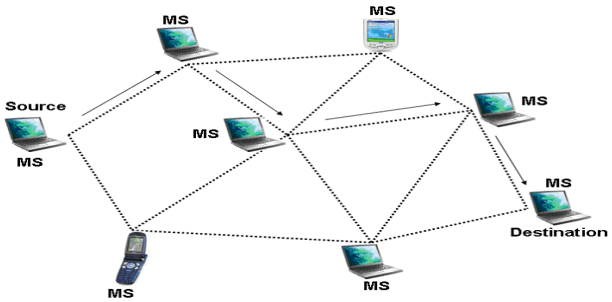

Figure 1. b Mobile Ad Hoc Networks.

Wireless Mesh Networks: -It is infrastructure based single-hop wireless network, where communication between nodes is relayed on wired gateway and intermediary mesh routers. Mesh routers are basically static & wireless nodes are mobile/ immobile. The aim of wireless mesh network is to provide network access to its mobile nodes. Figure 1.c shows an example of wireless mesh network.

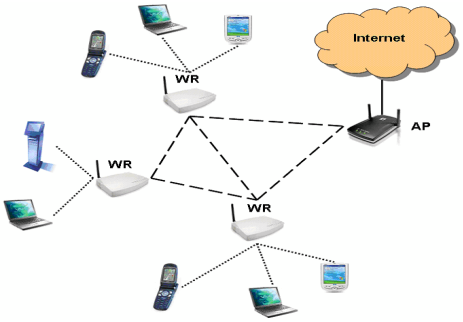

Figure 1. c Architecture of WMNs.

Applications of these networks include public safety, intelligent transport system and public internet access[5]. Wireless mesh networks are attracting the researchers towards the last mile broadband access.

Wireless Sensor Networks: The architecture of WSNs[6] is similar to the wireless ad hoc networks. However, the main goal of this network is to provide monitoring to the inaccessible terrains. Nodes in a network are immobile with short communication range of few meters. Network contains tiny/small battery equipped nodes called motes. And also network contain greater battery and processing capacity node called as super node. Communication in network takes place through intermediary nodes towards the super node. The applications of WSNs are monitoring in ocean, battlefields & plants

1.2 Smart Antenna Technology

Currently Omni directional antenna technology is used for multi-hop wireless networks. Omni antenna sends the signal in all direction with equal power; this limits the system capability due to spatial reuse[7]. Work[8] discussed that the optimal throughput for wireless mesh network is calculated by

$$\text{MWN is } \Theta = \left(W / \sqrt{n} \right),$$

Where n is number of nodes and W is the transmitting rate. Throughput can be enhanced by using smart antenna or beam-forming antenna technology. Smart antennas can be divided into two types i.e., Single-Beam Smart Antennas (SBSAs) & Multiple-Beam Smart Antennas (MBSAs). Single beam directional antennas

send/receive the signal power in only one particular direction, thus divide the omni-directional space as separate angular sectors known as beams. Beam shape is depends on directivity of antenna. Figure 2.a shows the different concurrent communication among wireless nodes with beam-forming antennas in compare with omni-directional antenna.

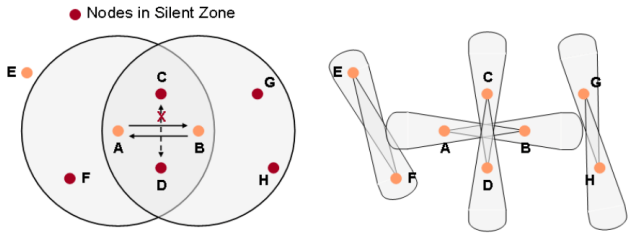

Figure 2. a OMNIDIRECTIONAL&BEAMFORMINGANTENNAS: - DATACOMMUNICATION.

Work[9] discussed that the through put is increased when node employed with single beam directional antenna.

Co-channel interference is decreased by single beam directional antenna technology, in turns it will reduce the noise level & collision probability. Thus it will enhance the transmission capacity of the sender node in comparison with omni directional antennas. Link stability is increased by increase in transmission range and signal strength which directly enhance the capacity of network. Concurrent transmission and reception of multiple packets in different beams are possible by the MBSAs. The aim of MBSAs is effective utilization of available spatial bandwidth and simultaneous packet transmission and reception. It should be noted that antenna can only either support reception or transmission but not support both at a time.

Multiple beam smart antennas are obtained from the omni-directional antenna's array elements. Directional beam is obtained by Applying complex weight vector to set of different omni-directional antennas array elements known as received signal vectors[10]. The reverse procedure is used for transmission. Thus SDMA technique is facilitated by multiple beam smart antennas and it will support multiple spatially different users in the identical frequency[11]. But in the process of constructing beam all the antenna array elements are involved, so that it can support simultaneously either transmission or reception but both the beam cannot work independently.

Two beam forming techniques commonly involved in the formation of smart antennas I,e. Adaptive beam technique & switched beam technique. These techniques differ in formation of beam patterns, adaptive beam technique form the beam-patterns dynamically but in case of switched beam technique form the beam-patterns proactively at desired locations & it is quite simple in comparison with adaptivebeam technique but it contains interfering devises in beams. Figure 2.b shows the different beam pattern techniques for MBSN

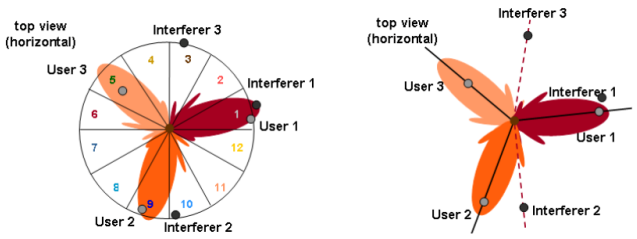

Figure2. b AntennapatternsforMBSA (adaptive&switched beam)

2. An Overview of MAC Protocols

Medium Access Control mechanisms are needed to access the channel in contending wireless nodes. They make use the effective antenna technologies at physical layer in order to access the channel. In this section we discuss the medium access control protocols and also discuss about two reactive Medium Access Control protocols for omni-directional antennas. We also describe the current MAC schemes for WSNs and MANETs with beam forming antennas.

2.1 Scheduling Vs Reactive Protocols

MAC schemes for wireless networks are divided into *reactive or contention-dependent MAC schemes* and *scheduling or contention-independent MAC schemes*. Reactive MAC protocols are also known as On-demand or distributed MAC schemes, well suited for a synchronous communication. Here, devises in network simultaneously try to communicate for accessing channel and hence chance of collision and no guaranty of successful communication as multiple devises try to access the channel simultaneously. *Contention-free MAC protocols*, on the other hand, time is divided into distinct time slots and each device in a network provided with slot by the centralized scheme or by using two-hop information, this mechanism ensure the successful communication. Each type of mechanism has its own disadvantages & advantages as given below:

- *Contention-based* Mechanisms dynamically distributes channel resources to nodes in a network, SO as to making network more scalable.
- Contention-based protocols are immune to changes in network topology. Contention-free protocols, however, needs new schedules to changes in network topology.
- Contention-free protocols require strict time synchronization, where as Contention based protocols do not require.
- Contention-based MAC schemes are not efficient with respect energy as sensor nodes in a network always act in a sensing mode irrespective of communication. Hence there is a requirement of energy efficiency in Wireless sensor network[12].
- Contention-free protocols can effectively use the simultaneous transmission/ reception capacity of smart antennas as compared with Contention-based protocols. Unfortunately they are not well suited for wireless mobile network environment.

2.2 Architecture of Slotted Aloha

It is a synchronous reactive scheme[13] & It divides the time into fixed size time slots, each one is for packet transmission time. Anode wish to send the packets starts its transmission at the start of next fixed size time slot. Node need to wait for a random number fixed size time slots during collision & transmit the data again. Figure 3 shows the neighbour nodes C & B begins their communication simultaneously to identical destination causes to collision at fixed size second slot.

Collision detected by sender by not receiving the Ack packets from destination in specified time interval

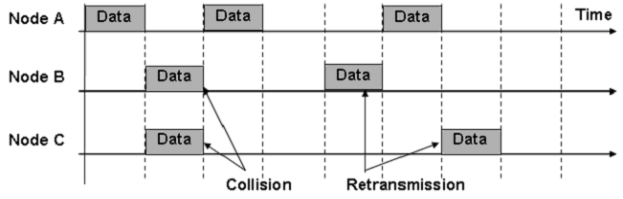

Figure 3. Collision at Slotted Aloha scenario.

2.3 CSMA/CA

Carrier Sense Multiple Access with Collision Avoidance is a reactive asynchronous method based on CSMA with collision avoidance[14]. Basic mechanism for channel access WLAN & MANETs is IEEE 802.11 DCF and is mainly designed for omni-directional antennas. In CSMA/CA, in an idle conditions node want to participate in communication needs to wait for small duration of time known as DIFS (*distributed interframe space*). If node detect that channel is idle then it waits for extra random interval duration time prior communication. This mechanism reduces the simultaneous communication of two devises. If at all device found the channel is busy it waits till channel become idle, for this device freeze its backoff timer. This technique reduces the probability of two nodes to communicate simultaneously. A random deferral by every device also assure fair channel award in the long term & is determined below:

$$randombackoff = aSlotTime \times Random() \quad (1)$$

where, return value of Random() is integer pseudo-random value from an interval [0,CW] in an uniform distribution and a Slot Time is the characteristic physical layer . Contention Window is an integer value in the range of physical layer characteristics, viz. a CW min and a Cmax, hence aCWmin ≤ CW ≤ aCWmax. Three ways of communication flow control mechanisms based on IEEE 802.11 MAC.

3. MAC for Beam-forming Antennas

Beam-forming antenna has a feature to direct the transmission & reception in desired direction, in order to increase the effective range and decrease the interference with neighbors. But deafness problem occur due to ability of listening in intended directions while being deaf to the other may impair the VMAC. Deafness occurs whenever a source device is unaware the busy state of the destination. Due to deafness a major MAC problem occur due to beam-forming antenna's directional communication. As shown in Figure 4, let consider that nodes A & B are engage in communication and consider directional control packet transmission.

Hence nodes X, Y are oblivious to the present communication session between A & B. Thus, they continue transmits the RTS control messages to node A. As node A is deaf to these control packets, nodes X & Y undergoes into backoff state by not receiving the CTS control packet from node A. Deafness problem increases the retransmission & leads to increases in contention window size. This also leads to increase in delay of entire network. If the maximum limit of retransmission is crossed then packet will get loss. Then network layer consider this situation as broken route, and initiate the new route from source to destination, and may cause the wastage of network

resources. More than that control packets can disturb the current communication and may cause the collision at destination nodes

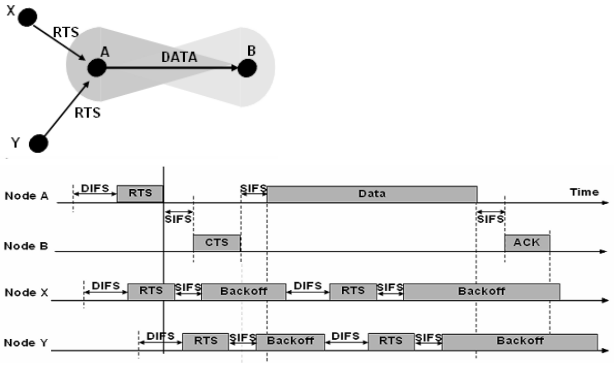

Figure 4. Effect of deafness Scenario.

In order to mitigate deafness Research work discussed various MAC protocols for beam-forming antennas. Work[15], presented two MAC protocols one is for omni-directional transmission of CTS control messages and second is for omni-directional transmission of RTS control messages. A directional virtual carrier sensing protocol is presented[16] in similar to IEEE 802.11 DCF & this method is used to maximize the spatial reuse. Evaluation of various mechanisms control packet controlling don by Elbatt etal.[17], and shows the piggybacking beam indices in control messages to indicate the neighbor nodes about beam pattern.

4. MAC for WSNs

The main requirement for WSNs is reliable communication with efficient energy utilization & minimum delay. Wireless sensor network characterized by distributed environment with unpredictable changing in network, in such environment TDMA scheme is not well suitable as it is suffer from synchronization problem. Thus, reactive MAC protocols are well suited choice as these protocols follows the CSMA scheme and may reduce the collision. Moreover, At lower traffic loads CSMA scheme offers less delay and maximum throughput.

4.1 Reliable Medium Access Control Schemes

To achieve reliable communication in wireless networks following mechanisms are generally used

4.1.1 Multiple Transmissions

In order to increase the probability of receiver's packets receiving capacity, these methods allow more than one transmissions of the same data packets. An example of these schemes is Hop-by-Hop Reliability & Hop-by-HopReliability with Acknowledgement. Reduce the retransmitted packets by utilizing broadcast characteristic of wireless medium. Above Work concluded that this scheme performed better in wireless sensor networks environment. ReInForM et al.[18] is proposed similar method of more than one copies of the same data packets are sent over the route. Unfortunately all these methods assume that environment is collision free but it is not true in wireless sensor network.

4.1.2 Retransmissions and Power Control

In order to achieve reliable communication, some Medium Access Control mechanisms use the Link Quality Indicator (LQI) for controlling the power and retransmission mechanism. For example MAC scheme with LQI is low at destination, indicates the transmitting node to send the next packet with higher power level, in order to enhance the signal strength at destination. MAC protocol[19], uses the E T X (Expected Transmissions) to removing the bad links and selection of optimum route between source to destination with respect to power.

4.1.3 Error Detection and Control

Error control/detection scheme provide the better reliability but increases the delay & computationally difficult. These schemes facilitate the literature about era sure coding (Reed-Solomon coding) & Slepian-Wolfbasedsourcecoding[20]. However as already noted, sensor mote typically has constrained processing capacity with respect to power & memory. So low complexity error correction scheme is used, due to multiple packets transmitted immediately needs an encoding mechanism to handle these packets

4.1.4 Energy-efficient Medium Access Control Mechanisms

Energy efficiency methods basically consider the nodes sleep and wakeup movement. Based on these sleep wakeup cycles, the existing energy-efficient Medium Access Control mechanisms can be broadly differentiated as given below:

4.1.5 Adaptive Duty-Cycling

In these schemes a time interval is defined for sleep wakeup time duration, but this cycle introduce the overhead in terms of delay as sleep delay. Example of cited MAC protocols is cited MAC protocols

4.1.6 Wakeup Reactive

These schemes consider that the wireless sensor nodes in a network are two types of radios high power radio & low power radio, one for communication and another for wake up for another respectively. These schemes generally contain lower delay. STEM is the scheme based on two radio communication architecture, namely STEM-B is high power radio for transmitting the data and STEM-T is low power radio used to wake up the other radio. The schemes based on STEM-T utilize the filter messages sent by source to destination, to remove the overhearing by transmitting neighboring devises back to sleep.

5. Reactive MAC for MBSA in MANETs and WMNs

Lot of work carried out by researcher for designing Medium Access Control protocols for omni and SBSAs. However, little research work has been done for designing MAC for MBSAs. Multiple beam smart antennas are capable of supporting multiple receptions/ transmissions simultaneously in order to increase the system capability. To achieve optimal throughput of system below things should be satisfied

- Synchronization of sending devises to initiate their simultaneous transmission for the identical receiver
- Synchronization of receiving devises to start their simultaneous transmission for the

For (SPR) simultaneous packet reception First condition is must, and for enabling (SPT) Simultaneous packet transmission where second condition is must. Present medium access protocols do not support simultaneous communication by node. Thus a novel mechanism is needed for medium access control for MBSAs.

5.1 Synchronous and Asynchronous Protocols: Challenges

Reactive MAC protocols classified as Asynchronous and synchronous medium access protocols. Node at beginning of transmission and reception synchronized to a slot in synchronous protocols, and this condition more applicable for multiple beam smart antennas. But the performance of asynchronous protocols for higher loads is much better than synchronous protocols. Thus a systematic work needed to decide which protocol is best suited for MBSAs.

5.2 Analytical Models

In order to get complete understanding of asynchronous & synchronous protocol performance with multiple beam smart antennas we evaluate and develop a frame work to analyze the throughput of two reactive protocols i.e., CSMA & slotted Aloha. At higher loads the performance of CSMA (asynchronous protocol) is better compare with slotted Aloha (synchronous protocol), but at medium loads the performance of slotted Aloha is better. CSMA performance is better at higher loads but not stable due to poor simultaneous packet reception capacity. Thus we conclude from this analytical study that a hybrid protocol desired for MBSAs.

5.3 Reactive MAC with MBSAs

Presently, IEEE 802.11 DCF is most popular de fault MAC protocol for wireless networks & is developed for omni directional antennas. In order to analyze the performance over MBSAs, we develop four different protocols and we concluded that simultaneous packet transmission is achievable and simultaneous packet reception is import from IEEE802.11DCF method

5.4 Explicit Synchronization through Implicit Feedback

Simulation study about IEEE 802.11 DCF shows that the purpose of achieving Simultaneous packet reception any protocol design for MBSAs should be locally synchronized and to achieve stability at greater loads protocols should be globally asynchronous. In order to achieve dual behavior we developed an Explicit Synchronization through Implicit Feedback (ESIF) aim is firstly get SPR with MBSAs in MANETs.

5.5 Co-existence of Omni-directional Antenna and MBSAs

Omni directional antenna is more preferable compare to multiple beam smart antennas due to its efficient cost and complexity. Subscriber have the own choice to use any

antenna for commercial use of MWN applications. Thus, protocol for MBSAs should be compatible with present existing standard protocol of omni antennas & single beam antennas.

5.6 Hybrid Medium Access Control Mechanism

Hybrid Medium Access Control (*HMAC*) mechanism provides the SPR by using ESIF protocol by using its channel access method and it is assure the backward compatibility. HMAC uses novel channel access mechanism instead of feedback control messages. HMAC packet format is identical to 802.11 in order to provide compatibility between two protocols so that node can maintain two antennas technology in same network environment. Compare to ESIF, design of HMAC is very simple and provide optimization techniques

6. MAC for Wireless Mesh Networks

WMNs, is one of the new paradigms for last mile broadband access. In contrast to MANETs, WMNs is a hybrid adhoc & wireless infrastructure based networks. Diffrent Vendors have developed their own propriety wireless devices and protocols for WMNs. Recent research shows considerable interest in exploiting beam-forming antennas for WMNs. Work[21], discussed directional antennas (parabolic grid antennas) for rural networks. Work explained in efficiency of IEEE 802. 11 in such networks & developed a synchronous Time Divisions Multiple Access based mechanisms, in every node interchanges between reception & transmission modes. However, the mechanism considers multiple radios at anode, one for each link. This consideration puts an extra constraint on scalability & topology management of the system. Another method to extend the capacity of WMNs is by utilizing multiple channels in omni-directional communication. Work[22] explains multiple channels using a single radio. Each beacon interval communicating nodes choose a channel for communication such that several concurrent omni-directional communications can proceed in the neighborhood. Work[23], multiple channel communication is supported by using multiple radios at each node. Multiple radios provide a node to carry out simultaneous receptions & transmission on different radios. Work[24] enhanced the method by using multi-radio and multi-channel in Wireless Mesh Networks by utilizing directional antennas. This allows spatial differentiation and more than one orthogonal channel for frequency differentiation as compared to omni-directional antennas and thus resulting of better throughput. However, multi-channel mechanism can facilitate good better performance when MBSAs are used instead of using single-beam antennas. Thus, it becomes imperative to explore and adapt the use of MBSAs in WMNs.

In principle, Hybrid MAC also provides the same MAC method but a different channel contention resolution algorithm, in order to reduce feedback dependency from neighbour nodes. Hence, Hybrid MAC uses identical packet format of IEEE802. 11 DCF and to make both the protocols compatible. Now we summarize different problems involved in developing a Medium Access Control protocol for wireless multi-hop networks with nodes containing Multiple Beam Smart Antennas.

In order to Design Protocols of Wireless Sensor Networks (WSNs) most considerable parameters are energy and reliability. WSNs consist of dense sensor nodes with high resolution and best network coverage. Dense network nodes increase the fault-tolerance & robustness of the network. If Network not handled properly may cause concession in system, and may lead to data collision. But wireless network is unpredictably changed and error-prone. Thus a reliable communication required to successful transmission packets to desire destination, else energy utilized for packet communication is get wasted. So energy efficient methods are fundamental prerequisites of energy constrained wireless sensor networks. We have proposed a reactive energy efficient reliable MAC (E2RMAC) mechanism to achieve energy efficiency along with data reliability .We compare our method to existing energy efficient reliable protocols with respect to latency, scalability and reliability

7. MAC for Wireless Sensor Networks

Wireless Sensor networks provide a new paradigm for monitoring environment and collection of information, and consist of tiny wireless sensor nodes capable of monitoring environment and deliver the monitored information to its users. But constrained battery capacity of nodes limits the overall operation of nodes. But wireless network is unpredictably changed and error-prone. Thus a reliable communication required to successful

transmission packets to desire destination, else energy utilized for packet communication is get wasted. So energy efficient methods are fundamental prerequisites of energy constrained wireless sensor networks. Most of the existing works either concentrate on reliability[25]orenergy-efficiency[26]. Reliable communication is an important issue for real-time deployment of sensor networks.

Throughput degrade can occur due to hidden node problem and channel feeding in real time applications. If application is critical event monitoring, energy efficiency is most considerable factor. Furthermore, methods providing data aggregation at intermediate nodes, reeds a reliability in link layer, else all the resources are used for communication is get wasted if data packets does not reach the destination.

Thus, it becomes imperative to require a Medium Access Control protocol that efficiently distributes the wireless channel and assures reliable data delivery.

Efficient energy utilization important design parameters to consider a design issue of wireless sensor networks. Constrained energy of sensor nodes needs energy conservation methods to assure the lifetime of network. This chapter deals with the dual objective of providing are liable and energy-efficient Medium Access Control scheme for WSNs.

8. Medium Access Control Problems for Reliable Data Communication

To develop a good reliable Medium Access Control protocol, the following MAC issues need to be solved:

- Collision: When a receiver simultaneously receives multiple packets, packets get collide even if they coincide partially. Collide packets removed from system and need to be retransmitted, which increases energy consumption and delay.
- Congestion: Every node has a buffer to store the packets; congestion is a concept of packet loss due to buffer overflow. Losing the packets at intermediate node cause the wasting of energy of packet forwarded node.
- Control overhead: Control messages consume some part of energy for its transmission and reception ,So need to minimize the number of control packets…Idle listening: Idle state of network listening by node should avoid .
- Overhearing: This issue also cause the wastage of energy by node receives those packets which destined for author node.
- *Channel error*: The packets received at the physical layer get corrupted due to high channel error, which require retransmission of the packet. This can be done by using positive\negative Acks for each successful\unsuccessful reception or sending multiple copies of the same packet on the same or multiple routes.
- *Hidden terminal*: The hidden terminal problem is mitigated with the help of RTS and CTS control messages. But it may cause the overhead in wireless sensor networks scenarios.
- *Transmission rate control*: In multi-hop routing environment, sending nodes to throttle its sending rate so as to allow the multi hop node to forward the packet. if not, second hop node can lead to collision at the first hop node due to hidden terminal problem.

9. Conclusion

MAC schemes are divided into two parts i.e, contention based & contention free schemes. For dynamic network topology like MANETs, contention based schemes are suitable and for static network topology like sensor networks, contention-free protocols are suitable. However, contention-free schemes need considerable overhead to decide on common schedules for neighbouring nodes. Based on our analysis we find the method to describe the Medium Access Control Problems for Reliable Data Communication. This work is used to develop contention-based reactive mechanism for multi-hop wireless networks and to develop reactive medium access control mechanism for peer to peer heterogeneous multi hop networks.

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