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Study and Analysis of Reliable MAC Protocols for Wireless Sensor Networks

Umesh Kumar Singh[*1], Kailash Chandra Phuleriya[*2],LokeshLaddhani[*3]
Institute of Computer Science, Vikram University Ujjain (M. P.)INDIA

***Abstract*-- Wireless Sensor Networks (WSNs) become more and more important in emerging new applications as message delivery timeliness is highly concerned. However, supporting reliability, real-time and Quality of Service in sensor networks have faced many challenges due to their wireless nature, limited resource, dynamic network topology, and the demand of distributed architecture.Reliable data delivery in real time (latency aware) and Energy efficiency are the two most important parameters for designing protocol. Hence, reliable data delivery in real time is required to ensure that a packet reaches its desired destination in actual time and energy-saving mechanisms are required for battery constrained sensor networks.The aim of the paper is to study the latency aware and energy efficient Medium Access Control (MAC) protocolsfor wireless sensor network andto motivate the researcher, while showing the future aspects in the area of Wireless Sensor Networks.**

***Keywords*--** Real-time, Wireless Sensor Networks, Medium Access Control and Energy Efficiency.

1. INTRODUCTION

Wireless Sensor Networks [1, 2], are an emerging technology that has become one of the fastest growing areas in the communication industry. Its consist of sensor nodes that use low power consumption which are powered by small replaceable batteries that collect real-world data, process it, and transmit the data by radio frequencies to their destination. The IEEE 802.15.4 [3] standard has received considerable attention as a low data rate and low power protocol for wireless sensor network applications in industry, control, home automation, health care, and smart grids [3, 4, 5]. Many of these applications require that packetsare received with a given probability of success. In addition to such a reliability constraint, other applications ask for timely packet delivery. It is known that IEEE 802.15.4 may have poor performance in terms of power consumption, reliability and delay [6], unless the MAC parameters are properly selected.In these applications, timely and reliable delivery of the data is very important for positive results as out-of-date data will lead to failure effects. Without loss of generality, real time systems are categorized as hard real time and soft real time systems. In hard real time systems, deterministic end to end delay bound is required otherwise disastrous results will occur while on the other hand in case of soft real time system some delay is tolerable i.e. probabilistic results are accepted.In supporting delay constrained applications, a WSN can be modeled as a distributed real time system. But, it differs dramatically from the traditional real time systems due to its wireless nature, limited resources, low node reliability and dynamic network topology [7]. In fact the transmission delay is often random due to the automatic retransmission mechanisms of the physical layer protocol.However, in the rest of this paper we still use the term HRT whenever the MAC protocols provide deterministic behavior from real time support on the resulting end-to-end delay can only be probabilistically bounded. It should be noted that while considering real time support in WSNs, energy efficiency should never be ignored. There is often a tradeoff between these two considerations.

2. RELATED WORK

The basic requirement of a sensor network is reliable delivery of data with minimum latency and energy consumption. There are two basic methods for achieving reliable data communication viz. forward error correction (FEC) and retransmissions. Since a sensor node typically has low processing power and a small memory, only FEC schemes having relatively low complexity may be used. Consequently, most of the existing schemes use retransmissions or transmission of multiple copies packets to achieve reliable transmission of information between remote nodes over multiple hops despite channel errors, collisions and congestion. The HHR (Hop-by-Hop Reliability) and HHRA (Hop-by-Hop Reliability with Acknowledgements) schemes [8], rely on sending multiple copies of the same packet.In this context, MAC protocol plays a very important role in determining the channel access delay, utilization and energy consumption.

Wei et al [9], presented sensor-MAC (S-MAC), Sensor MAC (S-MAC) is a contention based protocol proposed for energy-constrained devices. Based on CSMA mechanism, it essentially trades energy for throughput and latency by utilizing the sleep mode of the radio. Each node then switches to sleep mode for scheduled periods of time in a TDMA fashion. The protocol, however, fails to deliver reasonable throughput at higher loads. Tijs van

dam [10] et al, introduced T-MAC, a contention based Medium Access Control protocol for wireless sensor networks. Timeout-MAC enhances the performance of S-MAC for higher loads, while Dynamic Sensor-MAC [11] reduces its overall latency.Tao Zheng [12] et al, proposes a new MAC protocol, called PMAC, where the sleep-wake up times of the sensor nodes are adaptively determined. The schedules are decided based on a node's own traffic and that of its neighbors. Sung-Chan Choi [13] et al, proposed PS-MAC (Probability Sensor-MAC), a time slotted MAC protocol like S-MAC but unlike S-MAC in which all nodes have the same synchronized and periodic listen and sleep cycle, in this protocol, different transmitter and receiver node pairs have asynchronous and non-periodic listen and sleep schedules. Biswas [14] et al, proposed an on-demand reliable MAC protocol (R-MAC) that enables timely delivery of data. In order to design a good reliable MAC protocol: - Collision, Congestion, Channel error, Control overhead, Idle listening, Overhearing, Hidden node, Transmission rate control, Latency. Consider this issues author present a novel medium access control protocol named RMAC. RMAC is a CSMA/CA-based MAC protocol. In [15], Jain et al present a novel medium access protocol, Energy-Efficient Reliable Medium Access Control (E2RMAC) protocol, which tries to achieve both reliable data delivery and energy conservation with minimal latency. The E2RMAC protocol is a CSMA-based MAC protocol that aims to achieve energy-efficiency, while maintaining reliability and latency bounds.

In [16], Campelli et al proposed SPARE MAC Protocol. A SPARE MAC Protocol is a TDMA based medium access control (MAC) scheme for data transmission in Wireless Sensor Networks (WSNs). SPARE MAC implements a dynamic Time Division Multiple Access (TDMA) scheme, where all the nodes are time-synchronized. Time synchronization can be achieved via low-power synchronization receivers or through other proposed methods. RajgopalKannan et al [17], introduced ER-MAC (Energy and Rate), the distributed energy aware MAC protocol is based on TDMA and hence possesses the natural ability of avoiding extra energy wastage. AnirudhaSahoo et al [18], produced RT-MAC, a TDMA based MAC protocol that can provide delay guarantee. In [19], Shanti &Sahoo propose a Time Division Multiple Access (TDMA) based energy efficient integrated MAC and routing protocol, called Delay Guaranteed Routing and MAC (DGRAM) protocol, which provides deterministic delay guarantee. The design is based on slot reuse to reduce the latency of a node in accessing the medium, while ensuring contention free medium access.In [20], Lee et al designed a Flexi-MAC protocol. It is a self-healing protocol for periodic data gathering applications. It is a TDMA-based MAC protocol, in which nodes only transmit and receive packets at their own time slot(s) and sleep until their slots turn up again. Flexi-MAC is fault tolerant and energy efficient, and guarantees end-to-end data delivery, while achieving energy and memory efficiency, for different network configurations. A key feature of our study is a routing metric that balances timing constraints against reliability requirements, that is, reliability constraints are relaxed in order to find a sufficiently fast route while increasing reliability by using parallel multi-path transmissions.

3. CHARACTERISTICS OF RELIABLE MAC PROTOCOLS

The following attributes are to be considered, while designing a good MAC protocol for the wireless sensor networks:-

- Latency: Latency requirement basically depends on the application. In the sensor network applications, the detected events must be reported to the sink node in real time so that the appropriate action could be taken immediately.
- Reliability: Reliability in wireless sensor networks can be examined from both the packet level and the event level. Packet level reliability refers to how many packets are successfully received at the final destination. Event level reliability refers to the delivery of certain data objects or events to the receiver.
- Energy Efficiency: The sensor nodes are battery powered and it is often very difficult to change or recharge batteries for these sensor nodes.
- Fairness: In many sensor network applications when bandwidth is limited, it is necessary to ensure that the sink node receives information from all sensor nodes fairly. However among all of the above aspects the energy efficiency and throughput are the major aspects. Energy efficiency can be increased by minimizing the energy wastage.

4. RELIABLE PROTOCOL DESIGN CONSIDERATIONS

In general, reliable data delivery MAC protocol for wireless sensor networks should consider a number of factors which are:

- The reliable data transport protocol should be able to provide robustness to the network and be able to adapt to different scenarios, such asnode failure and route changes. The initiation process of the MAC protocol should be as simple and as quick as possible. For example, consider a remote monitoring wireless sensor network application, in which sensor nodes spend most of their lifetime in idle or sleep mode, but should be able to switch to transmitting mode and start the reliable data transport in a very short period of time when an event occurs in the network.

- Second, since a WSN is an energy-constrained multi-hop network, a reliable data delivery MAC protocol should try to avoid any packet drop unless absolutely necessary. This is because data packets normally have to travel many hops before they reach their destinations. If a packet is dropped during the transmission, all the energy and bandwidth that have already been spent on the packet in the previous hops are completely wasted.
  However, there are cases where packet dropping is inevitable. Since sensor nodes have limited storage space, when the buffer is full of data packets and a new packet arrives, a data packet must be discarded.
- Finally, fairness may be another consideration in the reliable data delivery MAC protocol design. As a data collecting network, most of the data flows are transmitted from sensor nodes to the sink. Such a multi-hop many-to-one routing structure can often result in unfairness in the network, in that the packets from nodes far away from the sink have a higher possibility to get lost during transmission than packets from closer nodes.

5. COMPARISON OF MAC PROTOCOLS

Classification of MAC protocols:-

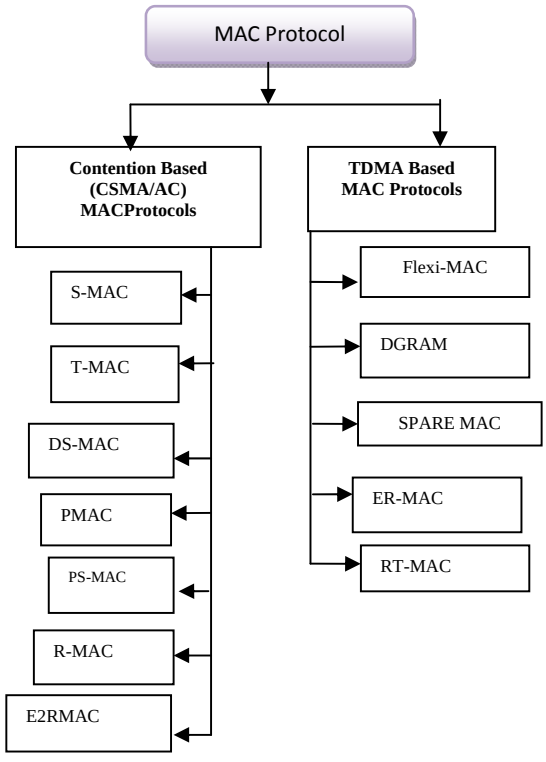

Fig:1 Classification of MAC protocol.

A comparison of the aforementioned MAC protocols is given in following Table to identify their real time support and major differences.

Table 1. Comparison of MAC protocols

Protocol	MAC type	Real Time type	Energy efficiency	Scalability
S-MAC	CSMA/CA	Moderate	Moderate	Good
T-MAC	CSMA/CA	Moderate	high	Good
PMAC	CSMA/CA	Moderate	high	Good
DS-MAC	CSMA/CA	Moderate	high	Good
PS-MAC	CSMA/CA	HRT	Moderate	N/A
R-MAC	CSMA/CA	HRT	high	moderate
E2RMAC	CSMA-based	Good effort	high	Good
Flexi-MAC	TDMA based	Good effort(but used two radio)	Moderate	100%
DGRAM	contention-free TDMA-based	Good effort	moderate	Low
SPARE MAC	TDMA based	Good effort	Moderate	Moderate
ER-MAC	TDMA based	Good effort	low	Good
RT-MAC	TDMA based	Good effort	moderate	Good

6. FUTURE DIRECTION

In the recent years a large number of medium access control (MAC) protocols for the wireless sensor network have been published by the researchers. The detailed study reveals that up to now we have no such protocol that honestly supports both the reliability and energy efficiency in real time communication. This shows that it will be more fruitful to develop such a protocol that will provide simultaneously both reliability and energy efficiency in real time communication.

7. CONCLUSIONS

Recently several medium access control protocols for the wireless sensor network have been proposed by the researchers. We have studied the basic two categories of MAC protocol; CSMA/CA based and TDMA based in terms of reliability, latency, QoS and energy efficiency. Although several designs may have good energy efficiency and delay performance, for clear real time service support, there are still many challenges.

Most of the MAC protocols show better and efficient features for real time applications but there are still many more challenges that need to be solved in the sensor networks there is still need to find out the suitable solution for real time support and energy efficiency because CSMA/CA based MAC protocols are energy efficient but they don't guarantee the real time support while TDMA based protocols give real time support but lack in energy efficiency.The Supporting real time communication and energy efficient protocols in WSNs

will be a challenging and interesting area in the coming years for researchers.

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