# REGULATED RR-MAC PROTOCOL FOR WIRELESS SENSOR NETWORKS

Kirubakaran M.K [#1], Dr.Sankar ram N [*2]
[#] Research Scholar, Sathyabama University
Chennai-600 119, Tamilnadu, India
[1] kiruba23@gmail.com
[*] Professor & Head Department Of Computer Science & Engineering,
R.M.K College of Engineering and Technology , Chennai-601 206, Tamilnadu, India
[2]n_sankarram@yahoo.com

***Abstract –*** This paper proposes RR-MAC, a medium-access control (MAC) protocol used for sensor networks. Wireless sensor networks uses battery power to sense the devices. It consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure and to cooperatively pass the data through the network to a main location. These characteristics of sensor networks and applications motivate a MAC that is different from traditional wireless MACs such as IEEE 802.11 in almost every way: energy conservation and self-configuration are primary goals, while per-node fairness and latency are less important. EM-MAC uses novel techniques to reduce power consummation. First pseudo number generator to reduce power consumption, Ready-to-Receive beacon and Collision avoidance. Inspired by EM-MAC, RR-MAC also subjects radios to wake up in various frequency channels at different times, in which the frequency and times are determined by pseudo number sequences. Finally, RR-MAC applies central registry to minimize power consumption in wireless sensor-network applications that require store-and-forward processing as data moves through the network.

*Keywords*: energy utilization, pseudo number sequence, registry, throughput

## 1. Introduction

In order to design a protocol for WSN we have to consider energy efficiency, fairness, latency, throughput, channel utilization etc. The energy efficiency is associated with collision, idle listening, over hearing and control packet overhead. The collision occurs whenever two nodes transmit to the same node. The overhearing is defined as the data received by the node that is not intended to the particular node. The control packet overhead is linked with sending control packet, receiving control packet and listening control packet. In over emitting the source node send data but the destination is not ready to receive. Because of this reason the energy is wasted. The hop- by-hop and end-to-end reliability [1] is defined in reliable data transfer protocols. In hop-by-hop reliability the next hop will ensure the reliability to the sink where as in end-to-end reliability the end node will ensure the reliability. The reliability redundancy is applicable for both hop-by-hop and end-to-end. The encoding/decoding is applied only in source and base station in case of end-to-end reliability where as in hop-by-hop approach the encoding/decoding is applied in intermediate nodes. The ERP [2] is used to reduce similar redundant packets which contain information about event to sink. The data aggregation is used to minimize energy spend for transmission in Wireless Sensor Networks. The metrics related with aggregation are accuracy, completeness, latency and message overhead. The accuracy is calculated as how much the consolidated value is closer to true value. The latency is nothing but the delay of data delivery. The message overhead is associated with categories of aggregation, placement of aggregation points and broad casting an aggregate value. The data receiving within the cluster and data aggregation are cleared defined in ESP [3]. In this paper we propose a regulated mechanism for the receivers that greatly enhances energy utilization of wireless sensor nodes.

## 2. Related Work

S-MAC reduces energy consumption by allowing the nodes to periodically turn off their radio receivers (and any other resources that have no work to do) and enter a low power *sleep* state. The *duty cycle* of a node is the ratio of the time it is *awake* (that is, not in the sleep state) to the total time. The lower the duty cycle, the lower is the power consumption of a sensor node. In S-MAC the channel access is contention based, using a scheme similar to the IEEE802.11 distributed coordination function[3]. However, unlike the IEEE 802.11 MAC protocol, the intervals when contention can occur are scheduled. S-MAC, therefore, combines the features of both contention based as well as time scheduled protocols. Even though the contention interval in S-MAC is scheduled, S-MAC requires much looser time synchronization than TDMA based protocols.

This allows the S-MAC nodes to use inexpensive timing hardware and simpler synchronization algorithms. Furthermore, S-MAC does not suffer from the limited scalability generally associated with TDMA schemes. In the common control channel, using the channel selection mechanism between the sender and the receiver and using the control frames and data structures discussed earlier, the best data channel to be used for communication is selected. Firstly, the sender node gets its CIT, for an ascending ordered list of channels based on the load in the channels. This list is sent by the sender as part of the IRTS with an entry for channel list in it. Now at the receiver, the node gets its CIT for an ascending ordered list of channels based on the load in the channels and matches the first channel from the sender's list having the highest rank based on its own ranking list of channels which it has got. In a case where some of the channels are having the same information, then the highest ranked channel from the sender's list is taken. Since the channel has been selected at the end of this phase, it is important to inform the sender and the neighbors of the receiver about the selected data channel for data communication, which is done when the receiver sends the ICTS, with an entry for channel ID[4]. Once the ICTS is received by the sender, it transmits the CSM in order to inform the neighbors of the sender about the chosen data channel for communication. In addition to informing the neighbors of receiver and sender by means of ICTS and CSM respectively, they also help in maintaining an updated CIT for a node. Whenever an ICTS or CSM is transmitted the corresponding neighbors insert or update their list of CIT with the nodes and channel information part of those messages. In order to get the latest channel usage snapshot in the CIT, the nodes are timed out of the data channel once they use up the system wide time constant T, which is the maximum time nodes can spend on the selected data channel for their communication. These frames also help in solving the hidden node problem at the common control channel. IRTS and ICTS function as a way to control access of the common control channel, so neighboring nodes which receive an IRTS or ICTS sets its Network Allocation Vector (NAV) to the duration fields in the corresponding frames and delay access to the common control channel by the time required to exchange the ICTS and CSM as mentioned in the IRTS and ICTS. The duration fields part of the IRTS and ICTS do not include the time for data communication. Also, they use the binary exponential back-off times, randomly chosen from a collision window which has the minimum and maximum window limits same as in IEEE 802.11. Data frame is dropped by the sender after retransmitting IRTS seven times after failure to receive an ICTS.

### 3. Research Methodology

In RR-MAC (Receiver Reservation MAC protocol), there are multiple channels available for transmissions. As in EM-MAC, each node o f RR-MAC uses a pseudo-random sequence to determine its wake-up channel (channel in which it becomes active)[5] and another pseudo-random sequence to determine its wake-up time (time at which it has to become active in the wake-up channel). The nodes of RR-MAC can look into the pseudo-random sequences of any other node. In other words, the nodes are initially fed about the other nodes in the network and what pseudo-random sequence is pursued in each node to obtain the wake-up channel and time. Thus a sender S which has to transmit data to a receiver R will actually imitate the receiver's pseudo function to know where the receiver is active in terms of channel and time. Then the sender will also wake-up in the same channel at the same time as the receiver. When no data is there to transmit, then the node simply goes with its own pseudo-random sequence to wake-up in the channel and time obtained with its pseudo sequence, expecting data from prospective senders, if any.

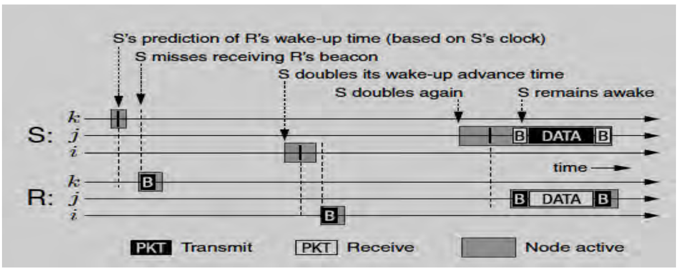


Fig.1. sender S sends data packets to receiver R using EM_MAC

Only three of the channels are shown here, labeled *i*, *j*, and *k*. At the time of *R*'s second beacon, no node has a packet waiting to send to *R*. When there are two senders S1 and S2 to transmit data to receiving node R, then both senders imitate the pseudo sequence at the receiver node to obtain the receiver's next wake-up channel and next wake-up time. Since, there is no control channel here, both senders are unaware of each other They may both imitate the receiver and wake up simultaneously at the receiver's channel time (little earlier than actual wake-up time so as not to miss the receiver's–Ready beacon). When the receiver wakes up in the channel, there are also two senders waiting out there to reach the receiver. The receiver follows the standards of transmission, wherein, it sends a –Ready beacon first to indicate it's availability to any prospective senders. The two senders upon getting this –Ready beacon from the receiver come to know the active existence of receiver and begin their transmission. This leads to collision of packets from the two senders. In EM-MAC the collision is attempted to be resolved by exponential back-off algorithm[6]. Upon a collision, the senders will back-off and retransmit the packets after their respective back-off time. The back-off time is calculated individually at each sender. Thus the two senders are likely to retransmit after different back-off time intervals and collision is avoided. This technique serves well under low traffic conditions. Under high traffic there can be large number of senders to one receiver. Upon collision, all o f them back-off and reattempt transmission. There is a high probability that after first back- off, still some nodes undergo collision or sense the channel busy and again back-off second time. Gradually, as the back- off continues each sender will be able to access channel without collision and close the transmission one by one. As it can be seen, the senders undergoing collision have to attempt back-off and retransmit. Under high traffic, a sender may have to back-off several times,before succeeding in its transmission. This also adds time delay along with energy drain for iterative retransmissions.

Energy waste and time delay due to back-offs are major drawbacks of EM-MAC. RR-MAC aims at minimizing these 2 source of energy waste. Every node in RR-MAC also uses the pseudo-random sequence as in EM-MAC to decide its frequency and wake-up time. In addition it can also imitate the pseudo-random sequence of other nodes to identify the frequency channel and wake up time of other nodes. Based on this imitation, a sender will identify the frequency and wake up time of the receiver node. When the receiver wakes up, the sender also wakes up to transmit the data. However, unlike EM-MAC[10] where back offs normally occur if many senders wake up to transmit data to same receiver, RR-MAC incorporates an orderly approach for the senders. RR-MAC maintains a central registry wherein each sender upon imitating the receiver's wake up channel and wake up time, will register its Reserve for transmission (RFT) for that receiver. Each sender before registering it's RFT will verify there is reservation from any other sender. If so, it will reserve the time after the last sender. In short the receiver's wake up time is shared by the senders with each sender completing its transmission and succeeded by the next sender. The succession proceeds according to the RFT[9] registered in the central registry. In this way, the wake up time of the receiver is shared among the senders. In other perspective, it enables time division of the receiver's wake up time based on RFT's registered on the central registry.

1. Sender S1 intends to transmit to Receiver R.
2. S1 imitates the pseudo sequence of R to wake up at R's wake up time tr in wake up channel fr.
3. S1 registers a RFT (Reserve For Transmission) for R in Central registry from time tr till (tr+ts1), where ts1 depends on the size of data at S1.
4. Another Sender S2 intends to transmit to R.
5. S2 registers a RFT in central registry from time (tr+ts1) till (tr+ts1+ts2), where ts2 depends on the size of data at S2
6. The next sender, if any, makes reservation into the registry for its transmission respectively.
7. R follows Regulated wake up - it wakes in its wake up channel fr at time tr, if and only if there is RFT registered by atleast one Sender - else it skips this wake up.
8. Senders S1, S2,… complete their transmission one after another in the order of the RFT's registered.

## 4. Experimental Results

RR-MAC is implemented initially with a typical network comprising of two sources transmitting to a receiver. Matlab simulator is used.

Table.1. RR-MAC neteork Parameters

| Attribute | Value |
|---|---|
| No. of Nodes | 3 |
| Transmission Speed | 100 kbps |
| Sleep Interval | 1000 ms to 3000 ms |

The proposed protocol and existing protocol are applied onto the network with above parameters(Table I) to obtain the number of packets transmitted in course of time. The below plot is made for RR-MAC vs. EM-MAC for the packets transmitted.

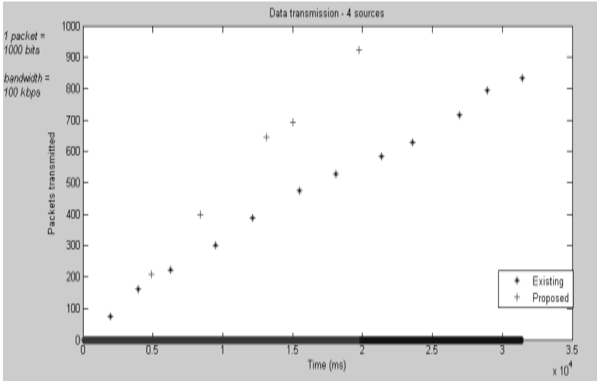


Fig.2. Two sources transmitting packets to receiver

As can be seen in fig 2, more packets are transmitted in RR-MAC for the same time as compared to EM-MAC protocol.(Kirubakaran *et al.*, 2012)

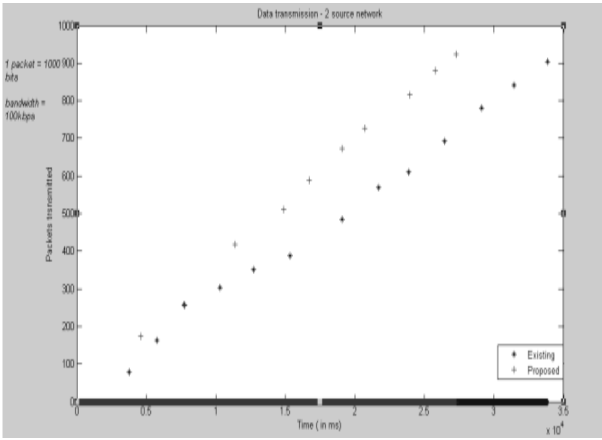


Fig.3. Four sources transmitting packets to a receiver

As the number of nodes increased to four, the performance of RR-MAC against EM-MAC was studied. When more senders transmit data to a receiver, the RR-MAC gives still better results. This can be accounted by the fact that, when collision occurs all four sources back–off and reattempt to transmit independently. It takes course of time for all four nodes to pick up the channel when it is free and complete transmission to the receiver. In RR-MAC, the four nodes complete their transmission without any back-off, each completing the transmission as per the reservation made on the receiver. The packets transmitted in the four source network are shown in fig 3[9]

In EM-MAC, back off makes a significant source of energy drain. This becomes a further problem when there are more senders giving remarkable time delay before all the collided senders complete their transmission in subsequent reattempts and backing off. If the sleep interval is small the nodes wake up frequently, allowing the senders to reattempt quickly as they wake up more number of times than it was with long sleep intervals. Also receiver will be available frequently due to shorter sleep intervals, benefiting the reattempting senders.

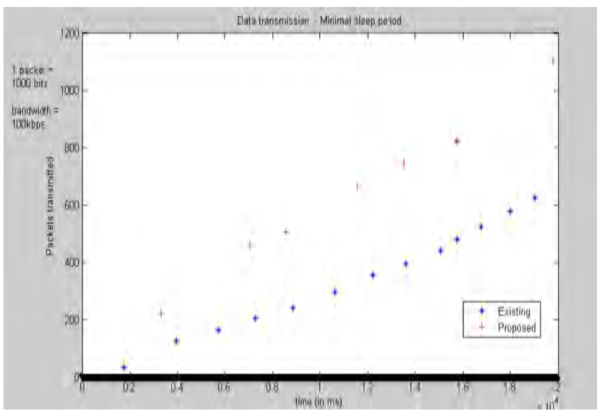


Fig.4.Four sources transmitting packets with short sleep interval

All senders can complete the transmissions earlier when compared to long sleep interval. In order to study the behavior of EM-MAC and RR-MAC with frequent wake ups, the sleep interval was shortened to 1000ms-1500ms. The results are plotted in fig 4.

From the plot, the EM-MAC transmits more packets with short sleep intervals than it did previously with longer sleep interval, as the nodes wake up more number of times and sender nodes can back-off more number of attempts in a given time in order to reach the receiver. However, shortening the sleep intervals also favors the RR-MAC. The efficiency of RR-MAC has only improved nevertheless on shortening the sleep intervals [9].

The RR-MAC methodology needs the Receiver to wake up to send a Ready beacon signal so that the RFT to receiver R can be fulfilled. The senders S1, S2,… complete their intended transmissions to the Receiver one after another in the order of the RFT's (Request For Transmission) registered in Central registry. However, when there is no RFT registered, the Receiver wakes up to send a Ready beacon signal and waits for a time Twait expecting RTS (Ready To Send) beacon signal from prospective senders. Upon receiving no RTS from any sender, the Receiver then goes back to sleep. This waiting period Twait has a negligible significance towards energy efficiency in a high traffic network, as there will be RFT always from senders to transmit to R. However, under low traffic condition, this Twait can cause significant energy waste to the network. Under low traffic, most of the time, there could be no RFT from any sender to transmit data to receiver R.

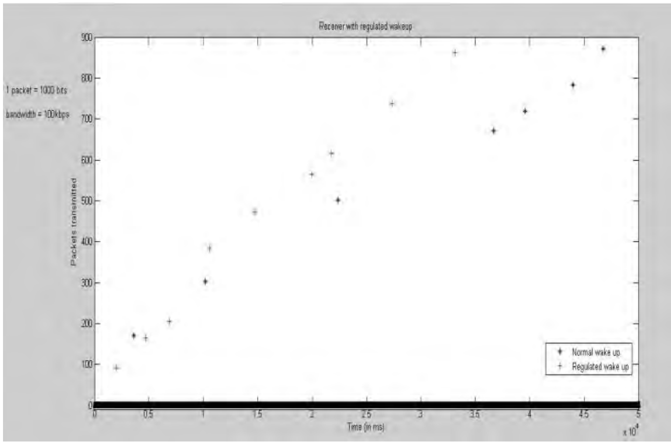


Fig.5. Regulated RR MAC in low traffic conditions

The receiver is subjected to regulated wake ups with Twait of 10ms. Regulation mechanism make use of the central registry where all senders register their RFTs. Regulated wake up methodology allows the receiver to wake up only when there is RFT from any sender for that wake up time tr. When the Central registry has no RFT registered for a wake up time, the receiver simply skips that wake up thus preventing unnecessary energy exhaustion. RR-MAC with Regulated wake up mechanism and RR MAC without regulation mechanism are compared in a four source network and the results are shown in fig 5. The Regulation mechanism gives better result under low traffic conditions. As the receiver skips unwanted wake up, the energy waste of the nodes is considerably minimized.

## 5. Conclusion

The regulated wake up mechanism increases energy efficiency of RR MAC protocol, especially for low traffic networks. In future work, a bursting algorithm is to be devised which can improve energy efficiency for high traffic networks. With this bursting algorithm implemented, a sender can transmit data partially to the receiver and transmit the remaining packets to the receiver in the next wakeup. This algorithm will be proactively adopted especially when there is high data traffic and the data sent by sender is relatively huge. In such cases, a sender having a huge data to transmit may reserve the receiver for a very long time to complete its huge data transmission. This will cause the receiver potentially unavailable to other senders for a long duration, adding time delay to transmissions which otherwise could have completed sooner. The bursting algorithm will enable to handle such data transmissions efficiently by allowing partial data transmission and complete remaining data transmission later.

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