# RC-MAC: RECEIVER CENTRIC MEDIUM ACCESS PROTOCOL FOR WIRELESS SENSOR NETWORKS

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## ABSTRACT

*Heavy traffic causes collision; there lies the challenge of providing the bias-free medium access opportunities to the sensor nodes. Hence, medium access protocol in event-driven WSN should be able to address two performance issues, energy efficiency of the system and the throughput. In this paper, we present a protocol, RC-MAC which integrates duty cycling and receiver-centric scheduling to provide high network throughput with efficient energy utilization in the system. To handle heavy traffic, nodes operate in a data gathering tree structure and supports multi-channel technique as in case of IEEE 802.15.4 RF transceivers. The receiver-centric medium access and distributed channel management technique contributes towards increasing overall throughput of the system and receiver helps in sender's coordination with respect to medium access. We carried out our extensive simulation in NS-2.35 simulation environment and analyzed the performance of RC-MAC and as well compared the performance with asynchronous X-MAC. Along with energy efficiency and throughput, receiver-centric MAC achieves improved fairness among nodes in heavy-traffic load.*

Index Terms — Wireless sensor networks, Medium access, Duty-cycling, Receiver-centric scheduling, Multi-channel

## 1. INTRODUCTION

Wireless sensor networks (WSNs), consisting of large numbers of sensor nodes, have enabled a new monitoring, and sensing paradigm for large geographical areas and different type of sensing environment. Unlike the centralized systems, the sensor networks are subjected to a couple of constraints in resources; e.g. on-board power of battery (finite), limited bandwidth for communication, energy constraints and data transmission rate etc.

In WSNs, energy efficiency is a fundamental criterion in the design of WSN protocols. The medium access control protocols for the wireless sensor network have to achieve two objectives. The first objective is the creation of the sensor network infrastructure and the second is to share the communication medium fairly and efficiently. Most designs are for the sensors to work with duty cycling mode for an efficient performance, and each node alternate between sleep and active states in periodic manner. Two nodes exchange data when both stay active, so earlier studies on MAC protocols for WSN were focused in establishing a common active period among the terminals efficiently. Resolving contention is always being taken care through CSMA/CA. While the event is detected in an area, probably many sensor nodes can report this incident. The contention scheme used by CSMA intensifies channel collision as multiple nodes contend to send data in single communication range. The nodes those sense identical event are usually sealed together, and this spatial connection between sensors motivate introduction of scheduling of channel for data delivery.

A fundamental trait of traffic in WSNs is natural formation of tree structure for information gathering in case of data delivery from sources to the receiver. So, RC-MAC defines a basic parent-children set as one parent and multiple children in which the parent located at central position acts as the ideal candidate for managing medium access of its children. By allowing only one child to transmit data at any time, it helps in reducing the contention from multiple children. Also fairness in the network is achieved by providing the required medium access opportunities to the nodes with respect to their bandwidth demand.

## 2. LITERATURE SURVEY

Due to the vital role of medium access control (MAC), it facilitates an ample amount of studies in WSN MAC protocols. The majority of these are mainly optimized for less traffic considering the energy usage. Also some of these MAC protocols are focused on incorporating duty cycling for accomplishing network operation with low power usage and improving the network performance.

A receiver-initiated MAC design [2] reduces overhearing, achieves lesser probability of collision and cost accustomed for failure recovery. The problem of idle listening leading to high energy consumption in WSN is addressed through RI-MAC which works on basis of asynchronous duty cycling. The duty cycle in RI- MAC is controlled by sleep-interval and helps in minimizing the period of keeping a wireless medium engaged by a sender and the receiver it is intended to. It improves throughput, reduces latency, reduces duty-cycling and also performance is better in terms of improved packet delivery. But this LPP-based protocol achieves higher throughput and power efficiency than X-MAC [3]. For the basic challenge of energy saving, one way is to use duty cycling. With the use of short preamble approach unlike the long preamble used in B-MAC, it retains the advantageous feature of low power listening. Asynchronous X-MAC protocol, a duty-cycle based design in that provides energy efficiency, simple and distributed structure with low overhead, low latency, high data throughput and its applications for different kinds of packetizing and bit oriented data stream. However, it suffers from delay in terms of data delivery due to preamble.

Energy efficient Predictive Wake-Up protocol [5] based on asynchronous scheduling minimizes energy utilization by making the senders to forecast receiver wake up time at each beacon interval. It is an improvement over LPP-based protocol with the prediction of the receiver’s beacon so that the sender has no need to stay awake waiting for the beacon. This prediction based retransmission mechanism takes care of collision due to multiple concurrent transceivers and retransmits the lost packets. Though PW-MAC is an energy efficient protocol even in heavy traffic WSN, it lags in terms of throughput as predictive mechanism doesn’t guarantee in 100 percent of successful data transmission.

In the protocols those employs preamble technique, sender prefixes a packet with a preamble which is long enough to be detected by any intended receiver. The use of preamble unnecessarily wakes nodes that are not intended to receive packet and causes an overhearing problem. Some protocols designed [6], [22] which divide a long preamble into series of short preambles such that the overhearing problem is avoided.

Both the receiver-initiated MAC [2] and X-MAC [3] leaves contention handling to CSMA/CA. In earlier studies of MAC designs like in Z-MAC [20] demonstrates that use of TDMA provides higher throughput than CSMA/CA when multiple nodes start contending at the same time. But the drawback of using TDMA is channel utilization is low in case there are few nodes intended to send. High overhead caused due to time slot assignment doesn’t allow the scheme to be adaptive towards assigning slots to the currently active nodes of the network. So some MAC protocols [4], [20], [21] integrates both CSMA/CA and TDMA to increase channel utilization. Funneling MAC addresses the issue of amplifying traffic intensity due to funneling, by incorporating a hybrid channel access method which takes TDMA for scheduling and CSMA/CA for handling conflict and operate in region with high intensity of funnel. It improves throughput and loss incurred in sensor networks whereas lags in terms of fairness and efficient energy usage.

Another MAC protocol, TRAMA [7] is a design adaptive to traffic. It selects the receivers based on the schedules broadcasted through the transmitters as a part of distributed election scheme. TRAMA performs better than contention based protocols like S-MAC, CSMA in terms of energy saving and throughput.

Efficient Multichannel MAC [6] outperforms other network MAC protocols in case of interference exhibited in wireless transmission or jamming. EM-MAC avoids using heavily loaded channels or the channels those are undesirable due to interference or jamming. Senders accurately forecast wake-up channel and timeslot of receivers and hence contributing towards energy-efficiency. Although the multichannel MAC scheme performs better for achieving energy competency and packet delivery latency but does not guarantee high throughput in a contention-based scheme.

In FMAC, [9] fairness problem is being addressed mainly seen in multi-rate WSNs. In multi-rate wireless environments, the channels are occupied by slow nodes for a long time than fast nodes, hence overall network throughput reduces. FMAC protocol makes use of medium delay periods and utilizes the unused time slots, reduces amount of collision and also quantity of retransmissions and hence reduces energy consumed. So, with the use of FMAC, transmission becomes faster with less power consumption but however throughput is affected.

S-MAC [8] challenged the task of reduction of energy wastage for WSN. The new means for proactive system to exchange the status among sensor nodes is used for avoiding unnecessary idle listening entertained through cross-layer approach which fully makes use of information from the physical layer. The problem of ideal listening has been avoided using this approach.

There is an analysis [10] on IEEE 802.15.4, a flexible MAC practice which provides efficiency over transmission of data by being adaptive to its parameters according to distinctiveness of diverse applications. Basically, there raised two proposals and also being tested for improving effectiveness of CSMA/CA mechanism used by IEEE 802.15.4 MAC Layer. First and foremost, the backoff exponent is adjusted dynamically based upon the queue level for each terminal point, following that, the next step is variation of the number of successive clear channel assessments (CCA) for packet transmission which helps in the significant improvements in IEEE 802.15.4 MAC standards.

On some basic analysis of media access control [12] its being demonstrated that the wireless medium is a shared resource, hence the main theme is controlling the channel access. The channel access is the measure to determine the capability of the wireless network and also has an impact on the system complication and the cost. According to analysis in [11], IEEE 802.15.4 was designed to achieve mostly the requirements for simple, low-power and low-cost wireless communication. Standard, IEEE 802.15.4 suffers from the interference by some other wireless technologies that work in the ISM band; for example IEEE 802.11 and Bluetooth standards. The medium access control (MAC) helps enabling the MAC frame transmission with the use of physical channel. Besides the data service, it helps constructing a network management interface and also manages access to the physical channel and beaconing of the setup which greatly impacts packet transmission. The proposed RC-MAC embodies the advantage of using multi-channel technique as in IEEE 802.15.4.

Improved IH-MAC [13] considers a decentralized approach, that guarantees in attaining maximum effectiveness in terms of security, energy consumed, control over jamming and time management. IH-MAC utilizes CSMA and TDMA approach along with broadcast, link scheduling as well. It uses the strengths of Q-MAC and Z-MAC [6]. This helps in reducing energy consumption having a control over transmission power used by various nodes in wireless sensor networks. But still the design lags in terms of network delay

All these proposed designs lag in terms of throughput, reliability or fairness of the network in different conditions, so here we look for a novel design that contributes towards better throughput while providing each sensor node a fair chance to participate in network operation. It also takes care of energy efficiency of the network through the use of duty-cycling of parent-children set. RC-MAC boosts the data throughput by trying to assign different channels to different parent-children sets rather than using different links. It makes use of few orthogonal channels for non-overlapping channel assignment. Dynamic assignment is adaptable to traffic in multi-channel scenarios. In the proposed design, a parent children set will stay in a channel for receiver-centric scheduling. For reduction of interference, each parent children set in this MAC design gets unique channel.

The dynamic channel hopping scheme like in EM-MAC [6], face the challenge of neighbor nodes interfering in the same channel.

## 3. BACKGROUND

Most of the MAC designs in WSN use duty-cycling technique in the process of achieving better energy efficiency. Duty-cycle technique is the process of interleaving between very short active and long sleeping periods by the sensor nodes based on the system transmission paradigm. Still there is a challenge of adapting to low duty cycling without affecting the power consumption and system data transmission rate as well. The proposed receiver-centric design addresses this issue with an effective way of beacon construction and transmission mechanism, powered with an offset calculation strategy for toggling among active and sleep periods. The activist parents in parent-children sets of a data gathering tree synchronize with children node and populate the bandwidth demand in packet to the receiver and receiver-oriented channel assignment helps in achieving an effective medium access scheduling in RC-MAC. Receiver-centric MAC uses multi-channel technique and also makes use of channel switching and sharing among sets based on the traffic condition on event-detection.

## 4. PROBLEM STATEMENT

The requirements of Medium access control (MAC) layer vary in Wireless sensor network environment for communication perspective based on the specific application it is optimized for. On event detection in a sensor network there is a constraint that whether all the nodes get equal opportunity to participate in data transmission. And also the other challenge is meeting bandwidth constraint of all the nodes.

Once the network is loaded with heavy traffic, is it prone to data or packet loss due to collision. There is also the question whether the medium access method manages channel for a reliable transmission. Although there are various MAC protocols are designed to boost the sensing for WSN, however, these MAC protocols are not efficient whenever data generation by sensor nodes is much higher. Therefore, it is essential to design MAC protocol that can cope with huge traffic and perform better in terms of end-to-end delay and data delivery rate.

So, the MAC protocol is designed in a way as follows:

RC-MAC (S1, S2………Sn)

where, Si (i=1 to n) is a sensor node in WSN,

Subject to

$$\sum_{i=0}^{n}(Throughput)_{RC-MAC} \geq (Throughput)_{th}$$

$$\sum_{i=0}^{n}(Avg\_Energy)_{RC-MAC} \leq (Avg\_Energy)_{th}$$

$$(Medium\ Access)_{Si} = (Medium\ Access)_{Sj}$$

## 5. PROPOSED RC-MAC

The receiver centric MAC protocol otherwise known as RC-MAC is a novel design for medium access for wireless sensor networks which integrates both duty cycling and receiver centric scheduling. The objective of the proposal is as mentioned in following section.

RC-MAC functions based upon the unique tree structure, created through data gathering in the network, and a receiver-centric scheduling method used that address the problem of collision in basic parent-

children set. During data gathering phase, it uses the neighbor information to construct parent-children set and nodes in each set acknowledge each other's activity by exchanging the ACK packets.
A scheduling pattern used to ensure fairness between source nodes. Throughput is not sacrificed as demand for diverse bandwidth of various terminals and packet processing time is taken into consideration.
The multichannel scheme helps in achieving parallel data gathering.
When more than one parent-children sets has to share a channel, a dynamic scheduling adjustment mechanism contributes and hence fairness is achieved among sets of nodes.

**5.1Architecture of RC-MAC**

In architecture of RC-MAC, starting with adapting to duty cycle mode of operation to contention between parent-children set is shown in fig 1. RC-MAC consists of four components:
Duty cycling mode of operation
Formation of Data gathering tree
Medium access scheduling
Contention between parent-children sets

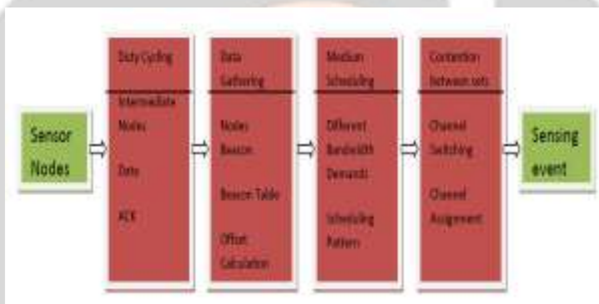


Fig. 1. System Architecture of RC-MAC

Duty Cycling Mode of Operation
When the event of concern is sensed in a sensor network, heavy traffic is generated if more number of sensors detect the event, With the aim of improving the energy efficiency, RC-MAC adapts to low duty cycle.
In case of RI-MAC [2], low power probing initiated by receiver helps in improving communication as it avoids medium absorption in favor of preamble transmission. The senders stay awake while waiting for beacon from receiver hence resulting in energy reduction. To keep track of neighbor's beacons PW-MAC [5] makes use of pseudo random wake up schedules.
Formation of Data Gathering Tree
The nodes are part of the parent-children set based on the Euclidian distance between the sensor nodes. A node acts as a child and parent for both the sets. RC-MAC takes care of nodes scheduling in the set through duty cycling. Nodes use beacon table to schedule its transmission as parent or stay as child for some other parent node and uses the channel accordingly.
Depending on the clock drift time, nodes in the network update the beacon offsets periodically. Since, a node keeps information of its one-hop neighbor's beacon offsets, it has to wake up before the neighbors. As a node updates the beacon offsets of all the neighbors in a periodic fashion, it tries to obtain link information and estimates the quality of link. The link quality is updated once event is detected and actual data transmission takes place. The child sends notification to its parent about bandwidth demand on detection of event and the same is transmitted to receiver.
Medium Access Scheduling

RC-MAC helps in achieving fairness in the network by providing each node a uniform medium access on event detection and then the process of channel distribution starts at the receiver. After receiving beacon from parent each node compete in the network with its siblings for sending. In case of a packet received with bandwidth demand embodied in it, duty cycling is disabled by the node and it responds through an ACK packet to next intended receiver through its ID. If the channel is idle, after receiving the ACK, the scheduled child transmits packet. The protocol takes care of the bandwidth requirement of the nodes instead of scheduling it in a round robin manner as shown in fig. 2.

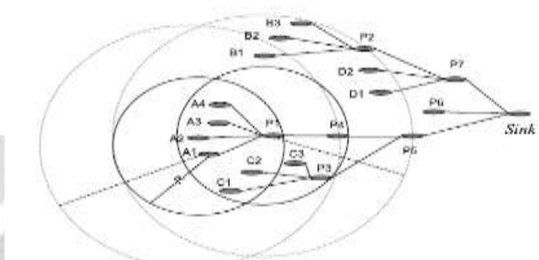


Fig. 2. Nodes in a Data gathering tree

Fairness of the network improves as each node in the set gets medium access opportunities as close they desire.

Contention between parent children Set

The basic problem of collision in parent children set is solved in RC-MAC by using many-to-one relationship of data gathering tree. Then it takes up the next challenge of address contention between parent-children sets. In the data gathering tree, the nodes keep track of three channels, default common channel, data gathering channel and the data forwarding channel. When nodes stay in duty cycling mode at the initial setup phase all the nodes use the common channel. On event detection, the nodes become full active and start utilizing multiple channels. Nodes keep the note of all three channels, but it has the need of the data gathering channel only when data is to be received.

**5.2 Issues addressed through RC-MAC**

The design of RC-MAC addresses several issues in an event-driven WSN environment which are defined as follows.

Adapt to Low Duty Cycle

RC-MAC is designed to be effective under heavy traffic load when events of interest are detected. In order to improve the energy efficiency, RCMAC should be able to adapt to the widely adopted duty cycling technique. The method requires a node to keep calculating the next beacon of all one-hop neighbors so that it does not lose track of the pseudo-random sequences. The periodic beacons allow a node to perform the calculation only when it has data to the receiver.

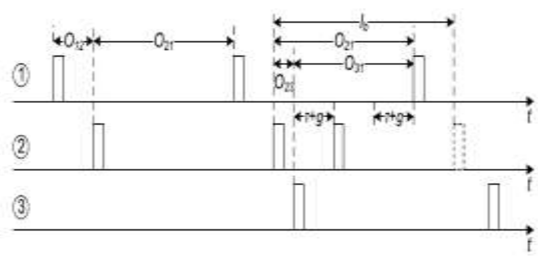

Fig. 3. Probing Schedule Adjustment

When nodes are deployed, they first enter in the setup phase and stay awake during the phase. Each node selects a random time to broadcast a beacon and periodically broadcasts the beacon every beacon interval Ib. When a node i receives a beacon from node j, it calculates the offset between the neighbor's beacon time Bj and its own beacon time Bi (i.e., Oij ¼ Bj - Bi) as shown in fig. 3.. Each node constructs a beacon table that records its one-hop neighbors' IDs and their corresponding beacon offsets. When a node has data to a neighbor, it estimates the receiver's beacon time by inverting the offset calculation (i.e., Bj ¼ Bi + Oij). If two nodes' beacon schedules are similar, they may interfere with each other when receiving data. Therefore, we define a minimum offset requirement t that is long enough for transmitting a few packets. If a node detects an offset that is smaller than ζ, the node adjusts its beacon schedule

Medium Access Scheduling

Nodes initially operate in the duty cycling mode, and when a node wakes up slightly earlier than its parent when it has data to send. Once it receives a beacon from its parent, it starts to contend for sending. When a node receives a data packet with bandwidth demand, it disables the duty cycling and responds an ACK that contains the ID of the next sender. If a child does not respond for several polls, it will be removed from the active list. The parent will reinitialize the active list to include all children in the next cycle. Therefore, in each cycle, the active list starts with a complete children list and gradually converges to a list of active children. Upon receiving an ACK that contains the next-sender ID, the scheduled child transmits immediately if the channel is detected to be idle. On the contrary, neighboring nodes will refrain from sending for a random period of time and then start to contend if the specified child does not respond. We keep the contention mechanism because there is a gap between an ACK reception and a data transmission. Designing different contention window sizes for the random backoff can distinguish unscheduled children of parent from nodes that are not the children of the parent. Upon receiving an ACK, scheduled child must respond within T1 and unscheduled siblings perform in group contention with contention window (CW) (T1, T2], nonchildren nodes perform ongoing-transmission contention with CW (T2, T3], and nodes within the interference range use network allocation vector (NAV) as virtual carrier to address the hidden terminal problem when they sense the transmission.

Contention between Sets

After solving the collision problem in a many to one relationship scenario of basic parent children set on a data gathering tree, the next challenge is address contention between sets. RC-MAC uses the multichannel technique supported as in case of IEEE 802.15.4 RF transceivers.

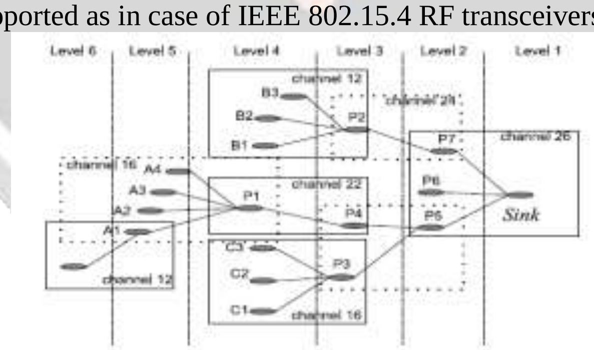


Fig.4. Receiver-centric Channel Assignment

As seen in fig. 4. when sink gathers data and at the same time P2,P4,P3 (its grandchildren) also gathers data. If charge incurred in deployment is taken into account, usually sensors are deployed with half-duplex transceivers. So, in this case it is reasonable that nodes at odd levels gather data simultaneously and same time even level nodes should forward data, also vice versa. To identify the extinction of the scheduling cycle, an ACK is sent by the sink in order to promote initialization of scheduling by the next intended sender. While the child of a node receives ACK from the parent it starts a timer to keep track of channel switching. Based on the prediction of timer the nodes toggle back to parent's data gathering channel to be a part of data forwarding activity. Each level in the tree performs this action and finally sink finishes one level of scheduling.

The sensors obtain the interference list and keep track of the channels interfering with each other to assign individual channel to each of the parent-children sets. Nodes has most probable data assembling conflict with nodes deployed at the same level, and also with upper two levels, and lower two levels as they data is collected at the same point of time. A node hence forms an interference list that stores the IDs of the interfering nodes and helps to pass up the channels those are used by the possible interference source nodes.

In fig. 4., node P4 should not use the channels used by Sink, P3, and A1 to A4 as they lie in the two-hop communication range of P4 and have conflicts on data assembling with P4. If P1 and B1 lay one hop away from each other, P4 and P2 are close with each other. Hence for removing this interference, RC-MAC assigns distinct channels to P4 and P2 even though both stay three hops away. To check whether neighbors have possible data gathering conflict with the terminal, it should be aware of the level of its neighbors in the tree. A node determines its level on joining the gathering tree and then it broadcasts the level it is in along with its ID in the beacons. This helps a node to recognize the nodes that have probable conflict over collecting data with the neighbor nodes in the three-hop communication range.

In case the node wins several channels to start its data forwarding, it mostly uses the first one. If a node is refrained from getting ownership over anyone channel, the channel is used gets the secondary priority to be used by the node. But also one channel can be used by multiple nodes based on the priority of data transmission. If the data gathering tree undergoes harsh interference, node instructs its children for switching over next channel on which it had least priority.

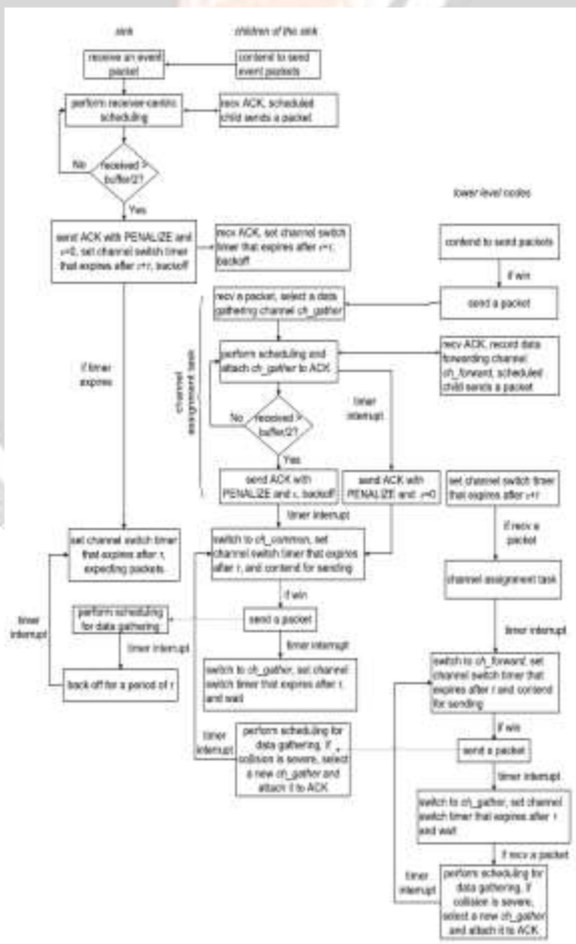


Fig. 5. Channel Management in RC-MAC

Suppose n number of channels are deficient for ensuring that every parent-children set can obtain a non-overlapping channel. In this situation, few sets have to use a channel by sharing, but the sensor sets in a particular channel should be less in number. The next sender RC-MAC selects through its scheduling pattern is stays ready for sending and hence responds instantly. If one set easily wins medium access than others, the parent's buffer fills rapidly. As a result, the set is improbable to keep on scheduling, and in such case dynamic adjustment is the scheme for preventing any other set from absorbing the channel solely. On reception of an ACK with PENALIZE, neighbor nodes compete for sending without delay since no other data follow such kind of ACK. All the children of the set, will abstain from contention for some rounds of transmission of packets over network. This is the procedure followed by RC-MAC to reduce the overall contention and also it helps in balancing the traffic as the same set will not get the access of medium repeatedly.

RC-MAC takes care of scheduling between parent children set in a distributed manner as well handles contention in an efficient manner. It increases the throughput of the network without constraining the energy consumption as in case of other MAC that uses probing technique for transmission of data. The whole sequence of RC-MAC operation is shown in fig. 5.

**5.3 Design Steps**

Considering the design of RC-MAC it is carried through the steps as mentioned below.

SetUp Phase

Determination of Neighbor nodes and formation of clusters

Discovery of nodes in the clusters

Formation of parent-children set

Receiver initiated channel allocation

Contention between sets of channels

SetUp Phase

In a wireless environment, first the nodes are deployed and it stays awake at this phase. After the network being set, the sensor nodes go through the process of determining its neighbors leading towards the formation of sets of sensor nodes. Each node calculates the distance between all other nodes in network and itself. If the calculated distance'd' is less than the minimal threshold distance 'dth', then the node is recognized as the neighbor of the corresponding node. The neighbor cluster is created on the base of node recognized based on the threshold distance. The nodes in the sets sends 'hello' packet to all other nodes in the set to being acknowledged in the network.

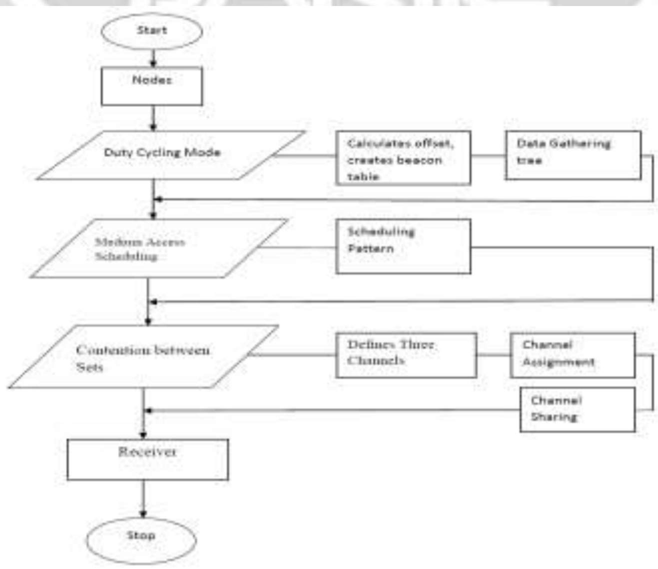

Fig. 6. Control Flow Diagram of RC-MAC

Formation of Parent-children Set

The parent children set in the set of sensors is determined on account of energy content of node. After the nodes being discovered in the neighbor set, undergoes through the phase of energy calculation. At a particular time, the sensor node having maximum energy in the set of neighbor nodes, is considered as the parent node in the set. The parent in each set notifies the receiver by sending acknowledgement. The energy remaining for each node is determined periodically that helps in formation of the parent-children set hence provides a uniform medium access opportunity.

Algorithm 1: Neighbor node calculation

```
 Compute the distance among the nodes:
 n = number of nodes in the network
 For (i = 0 to n){
     For (j = 1 to n){
        Calculate distance between the nodes:
           D = ((xj - xi)2 + (yj - yi)2 )1/2
     }
}
Determine the neighbor node:
Dth = threshold value for forming neighbor node set
If (D < Dth)
      Put node xj into neighbor set of xi
Explore the neighbors in the neighbor set:
N = Set of neighbor nodes
   If (i Є N)
       Send Hello packet to all the nodes in set
```

Receiver-initiated Channel Allocation

After receiving the notification from the parents in the network, the receiver provides medium access to the parents. Once the channel is allocated to the parent in a parent-children set, it sends the beacon to its children to notify about the medium access.

The parent nodes in the sets stay awake during the channel allocation and then go to sleep state, after receiving ACK from the children set the parent becomes active. It assigns the channels to its children set once after event being detected.

Algorithm 2: Formation of Parent Children Set

```
Compute the energy of node for a particular time ‘t’ and store in energy[]
Calculate cost value for each node and store in cost-value set cost[]
Define high-energy = energy[0]
Cost = cost[0]
For (i = 0 to m) // for all the clusters{
    For (i = 0 to p) // for all the cluster members{
     If (a[i] != a[i+1]  AND energy[i] == energy[i+1])
        If (cost < energy[i]){
           Cost = energy[i]
        }else{
```

```
              If (high-energy < energy[i]){
                  High-energy = energy[i]
              }
        }
}
}
```

Set the node ‘a[i]’ as parent node with high-energy for the cluster ‘a’

Clusterhead or parent sends ACK messages to all other nodes in parent-children set formed.

Contention between sets of channels

Receiver traverses through all the parents in the network and allocates non interfering channels. Before assigning distinct channels for parent-children set the receiver obtains the interference list. On event detection, the nearby nodes sense the event and pass the packets to its neighboring nodes. Sequentially, all the nodes become active in the network. In each parent-children set, each children notifies that it is in active state to its parent by sending ACK. Then considering all the network constraints, path is set from the event to the receiver.

Algorithm 3: Receiver-centric Channel Allocation and Contention between sets

```
Form the parent node set and store it in leader[]
For (i = 1 to m) where, m Є leader[] {
   Receiver allocates channel ‘c’ to all the parent-children set:
      Checks for the interference list.
      Calculates the winner node ‘N’ of channel.
         If (c > 1){
          Allocates first channel
         }
}
On event detection:
Each children in parent-children set notifies the parent by sending ACK
Based on energy content of node at time ‘te’, where te is event detection time, path is set upto the receiver.
For (i = 1 to c) where, c Є C[] {
   For (j = 2 to c) {
     if(ci > cj)
        ci  is selected as the channel for communication
     if(ci = cj) {
         Check for the packet reception ratio p
             if(pi > pj) {
             Select ci as the winning channel
             }
         }
   }
}
```

## 6. SIMULATION SET UP

| Parameters | Values |
|---|---|
| Routing Protocol | DSR |
| Simulation Area | 1300*1000 sq. m |
| Simulation Time | 40 seconds |
| Mobility Model for initial set up | Random Generation |
| Deployment Scheme | Deterministic |
| Radio Propagation Model | Two Ray Ground |
| Antenna Type | Omni-directional |
| Channel Type | Wireless |
| Maximum packet Length | 500 |
| MAC Type | IEEE 802.11 |
| Initial Energy) | 100 J |
| Transmission Power | 0.14 W |
| Reception Power | 0.36 W |
| Antenna Height | 1.5 |

Simulation parameters are listed in simulation table and Dynamic Source Routing protocol as the transmission protocol for packet or data transfer in the wireless network. Two Ray Ground radio propagation model is used. Each node in the network has the initial energy of 100 Joule.

## 7. PERFORMANCE ANALYSIS

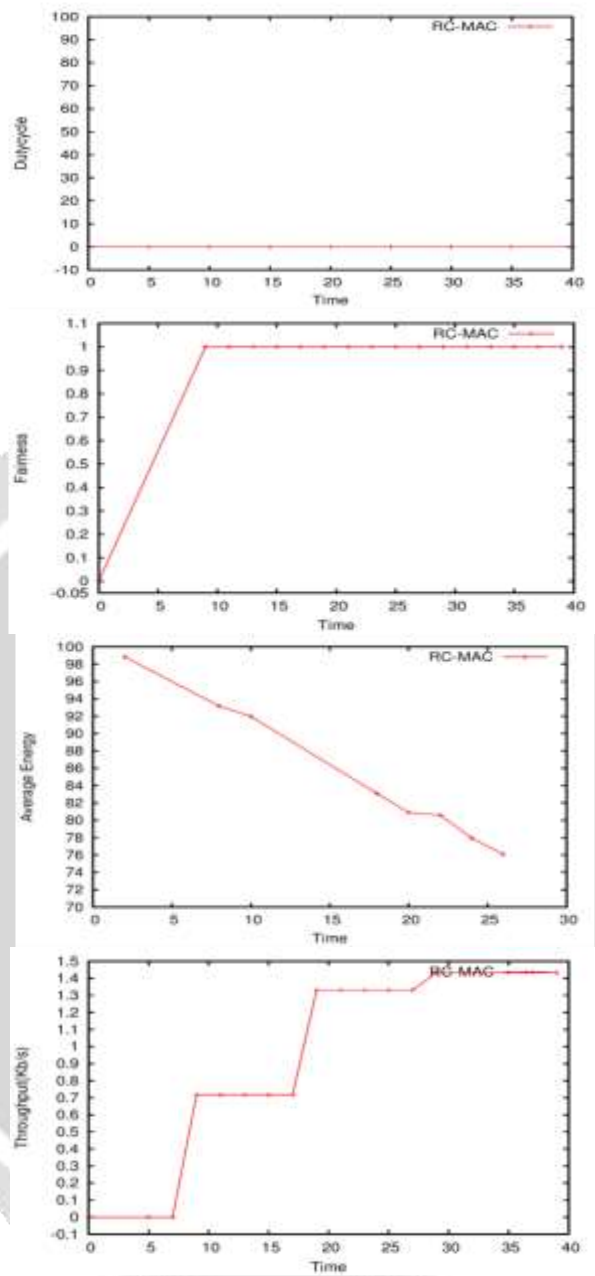


Fig. 7. Performance Analysis of RC-MAC [(a) DutyCycle, (b) Fairness, (c) Average Energy Consumption and (d) Throughput]

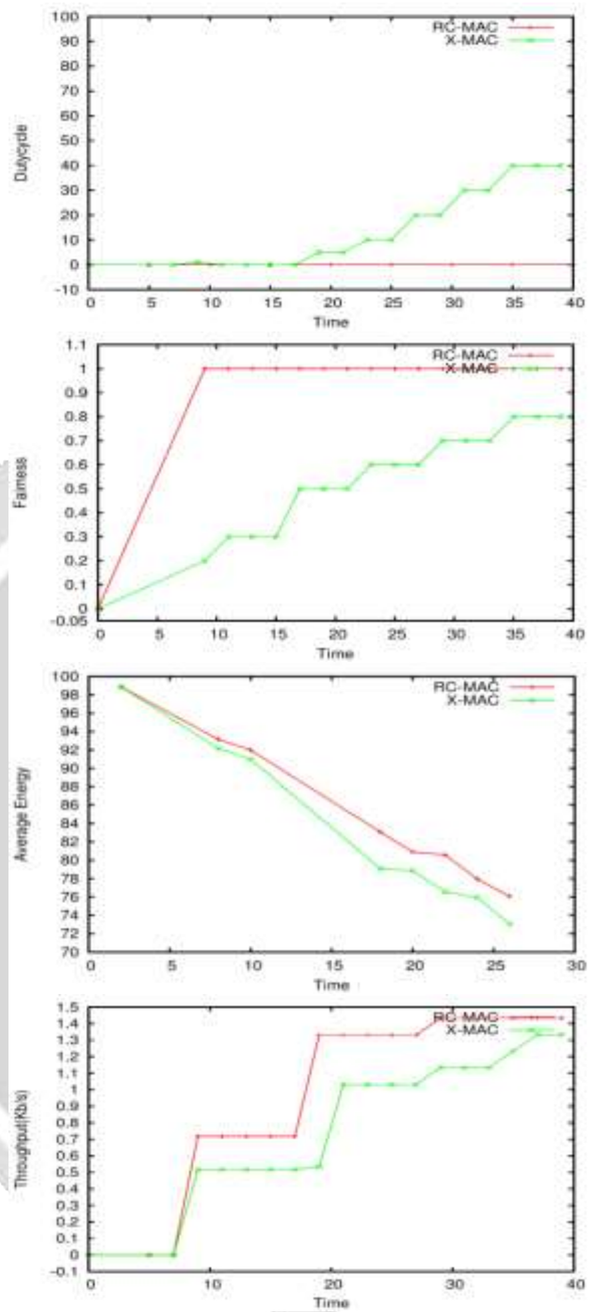


Fig. 8. Performance Comparison of RC-MAC with X-MAC [(a) DutyCycle, (b) Fairness, (c) Average Energy Consumption and (d) Throughput]

Fig. 7 and 8 shows the simulation results of the proposed receiver centric MAC and its comparison with X-MAC. When the duty-cycle of RC-MAC is compared with that of X-MAC, it shows a lower rate compared to the preamble approach oriented MAC. X-MAC takes longer time to deliver data due to preamble transmission, whereas average duty cycle of RC-MAC is lower than former as it does not follow any preambling approach for data delivery and this emphasizes a lower and consistent duty cycle over time. The scheduling pattern in RC-MAC, which takes care of bandwidth demand of nodes and dynamic adjustment in case of too many packets queued, leads to achieving a the fairness among nodes. Although the fairness in X-MAC increased over protocol performance over time, it shows a lower rate than the receiver centric approach due to its preamble technique to choose node for data delivery, each node in the network does not get an equal chance to participate in sensing. The average energy consumption over time in RC-MAC decreases over time, but at much lower rate than other MAC protocols, because the tree approach takes care of channel allocation and the receiver centric method of scheduling and dynamic adjustment of channels discards the requirement of advertising or broadcast of packets each time a node in network needs to transmit data which in terms saves energy. The throughput of RC-MAC is increased due to the coordination among nodes; the next sender in this MAC design is always ready to send after another finishes its part over the channel in the sensing path. But throughput of X-MAC is affected due to the contention due to heavy-traffic which is well managed by receiver-centric channel allocation and scheduling in RC-MAC.

## 8. CONCLUSIONS

The RC-MAC's effectiveness when compared with X-MAC in terms of average energy consumption, with the increase of load, it shows a better performance and also the data throughput is achieved better for the proposed mechanism due to its receiver centric scheduling. In case of fairness, the receiver centric access leads in terms of fulfilling bandwidth demand and medium access as well. In case of X-MAC the preamble transmission leads to high duty cycle with the increase of load. As RC-MAC supports parallel data gathering and bandwidth demand is managed beforehand and hence duty cycle rate is less and the growth rate is minimal. But still the performance of medium access may be affected in terms of delay that might be introduced due to dynamic channel management scheme on event detection. So along with receiver centric channel management the design can be improved resulting in a delay free sensing environment.

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