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# Efficient Mechanism for Data Gathering and Transmission in Multihop Wireless Sensor Networks

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***Abstract*— In this paper, we propose an efficient mechanism for data gathering and transmission in multi-hop wireless sensor networks. In wireless sensor networks, data packets are transferred to the sink node. So many packets are gathered around the sink, resulting in significant delay and collision. To solve this problem, the proposed mechanism used a two-way method; one method works between 1-hop nodes from the sink node and the sink node. In this method, the data packet is transmitted in predefined time to reduce collision and delay. The other method works between nodes except the sink node. In this method, receiver nodes use BRN (backup receiver node) mechanism to reduce energy consumption, thereby increasing the lifetime of the entire networks. In the BRN mechanism, a receiver node that has received a data packet once does not participate in receiving data packets twice in succession by changing its status value. The reason that the receiver node participating in the data packet transmission once does not participate in receiving the second consecutive data packet is to solve the hot spot problem in which two receiver nodes alternately receive the data packet. Also, we propose an enhanced method for data gathering. The proposed method is used for the intensity and direction of the signal in order to increase the reliability of the duplicate data packet. Our simulation and numerical analysis results show that our mechanism outperforms X-MAC in terms of transmission delay and energy consumption.**

***Keywords*— packet transmission; lifetime; data gathering; MAC protocol; WSNs.**

## I. INTRODUCTION

In a Wireless Sensor Networks (WSNs), sensor nodes are randomly distributed in the area [1]-[4] Sensor nodes are collected for purposes such as environmental monitoring and object detection. And, the data packet is transmitted in an ad-hoc method toward the sink node. Since sensor nodes forward data packets to the sink node, nodes located near the sink node must send a lot of data [5]-[7]. This is called the funneling effect. Increasing transmission traffic may cause severe data packet collision, congestion, and loss between sink nodes and adjacent sensor nodes due to funneling effects [7]-[9].

In this paper, to solve this problem, sink nodes and sensor nodes of more than two-hops are transmitted in a contention-based method. And, a node of 1 hop distance proposes a transmission method like a non-contention-based method. In addition, we propose a transmission method for data collision prevention and data gathering.

## II. MATERIAL AND METHOD

### A. Overview

The efficient packet transmission mechanism proposed in this paper uses the modified beacon frame of the QAEE MAC protocol [11].

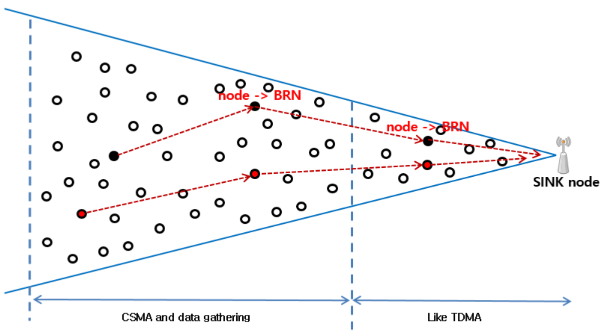



Fig. 1 The environment proposed in this paper

The receiver node broadcasts Rx-beacon frame in order for the sender nodes and the sink node receives Tx-beacon frame from its sender node for a fixed time [11]. In this paper, using Rx-beacon and Tx-beacon frame, data packets can be transmitted between the sink node and one hop away nodes in a predefined time slot like TDMA reducing packet losses and collisions. And duplicated packet from one hop away nodes will be discarded to reduce packet energy consumption and transfer delay. The operating environment of the proposed data packet transmission mechanism is shown in Fig. 1.

### B. *The Frame Format of the Proposed Mechanism*

Fig. 2 shows the beacon frame format used in this paper. The frame format is a modified one of the IEEE 802.15.4 [12] frame adding 1-bit field. As shown in Fig. 2, 1 bit of relay and detect was added. If the bit is 1, it says that the data packet is relayed data packet from its neighbor node. And if this bit is 0, it means that the packet is measured data by the node itself. Using this bit, the receiver nodes can Fig. 2 out whether the received data packets are measured packets or relayed packets.

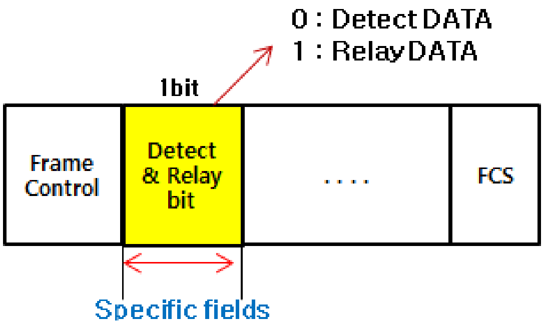



Fig. 2 Tx-beacon frame format

### C. *Receiver-Node Transmission Method*

In this paper, we use the QAEE MAC protocol, which was a variation of the RI-MAC protocol [13]. The QAEE MAC protocol was asynchronous, and the sender and receiver nodes asynchronously periodic sleep and wakeup. The sender node with the data to send waits for the Rx-beacon signal from the receiver node. The receiver node periodically wakes up and broadcasts an Rx-beacon signal to indicate that its node is ready to receive. When a sender node receives an Rx-beacon signal from a receiver node, it sends a Tx-beacon signal to indicate that it has data to send. Furthermore, it sends the data packet. However, this method may cause a problem that the same node becomes a receiver node, and the energy was quickly depleted as time passes. In the WSNs, the energy consumption of sensor nodes also affects the lifetime of the entire network. In this paper, we use the backup receiver node (BRN) method to solve this problem. This approach is similar to the various methods of selecting cluster headers (CHs) in LEACH [14],[15], but is different [16]. The start proceeds in the same way as the QAEE MAC protocol. However, a node once used as a receiver node is selected as a backup receiver node (BRN) and does not participate in the next data transmission. This way, we can solve the problem of one node being used as a receiver node continuously.

Fig. 3 shows the efficient data packet transmission method of the proposed receiver node. In Fig. 3, the sender node looks like one node but refers to all nodes that need to send data. When a sender node that needs to send data occurs, if receiver 1 node receives the first data among the receiver nodes that can receive data, the status table value of receiver 1 is changed to 2.

Secondly, when a sender node that needs data transmission occurs, receiver 1 does not participate in data reception because it does not send an Rx-beacon signal even if it receives the Tx-beacon signal of the sender node.

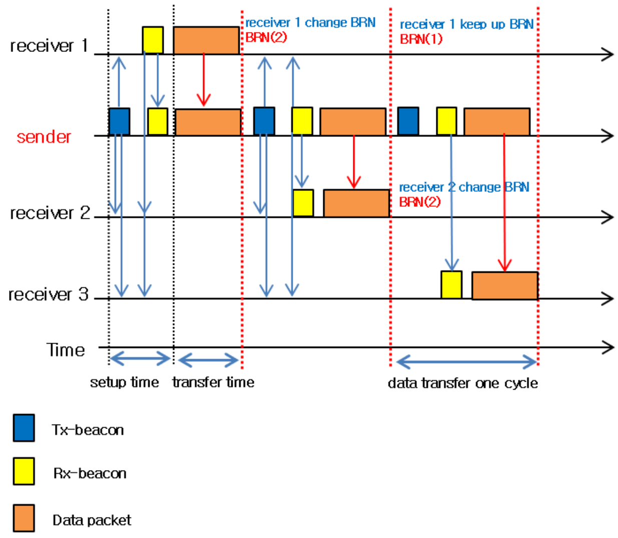



Fig. 3 receiver node efficient data packet transmission mechanism

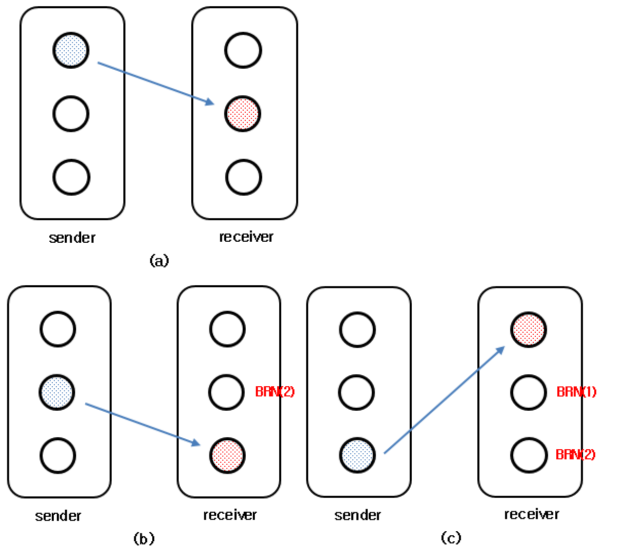



Fig. 4 sender node and receiver node in 1-hop, and the change in the status of the BRN

If the receiver 2 node receives the second data, receiver 1's state table value changes from 2 to 1, and receiver 2's state table value changes to 2. Thirdly, when a sender node that needs data transmission occurs, receiver 1 and receiver 2 do not participate in data reception because they do not send an Rx-beacon signal even if they receive the Tx-beacon signal of the sender node. If the third data is received by the receiver 3 node, the state table value of receiver 1 is changed from 1 to 0, and it participates in the next data reception competition. And, the state table value of receiver 2 is changed from 2 to 1, and the state table value of receiver 3 is 2. The reason for having a table with three status values is to avoid problems such as the hot spot problem [17]-[19] where two receiver nodes rotate each other. Fig. 4 shows the sender node and receiver node in 1-hop, showing the data transfer and the change in the status of the BRN.

### D. *Sink-Node Transmission Method*

The proposed data packet transmission method is consisting of two operation modes. One mode works between a sink node and one hop away nodes. In this mode, node send their data packets in a predefined time slot like in TDMA. So data packets collision can be avoided. In the other mode, the duplicated data packets cannot be transmitted. The operation of the proposed data packet method is described in the following part [20].

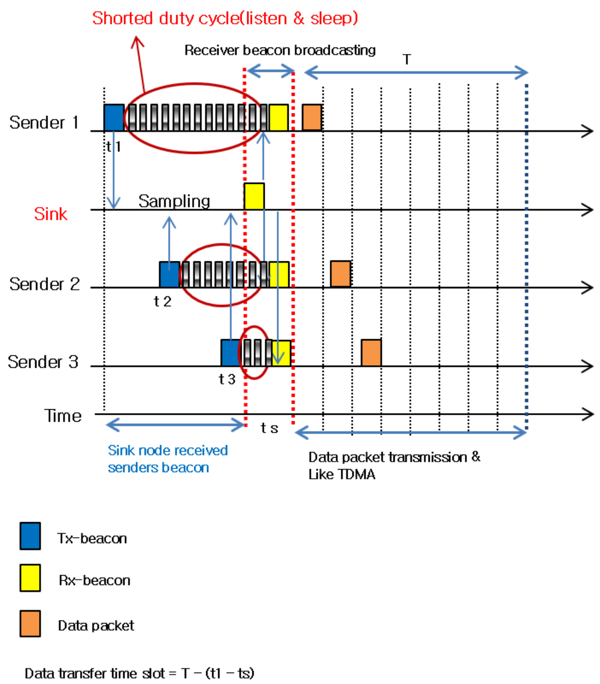



Fig. 5 Data transmission between a sink node and nodes.

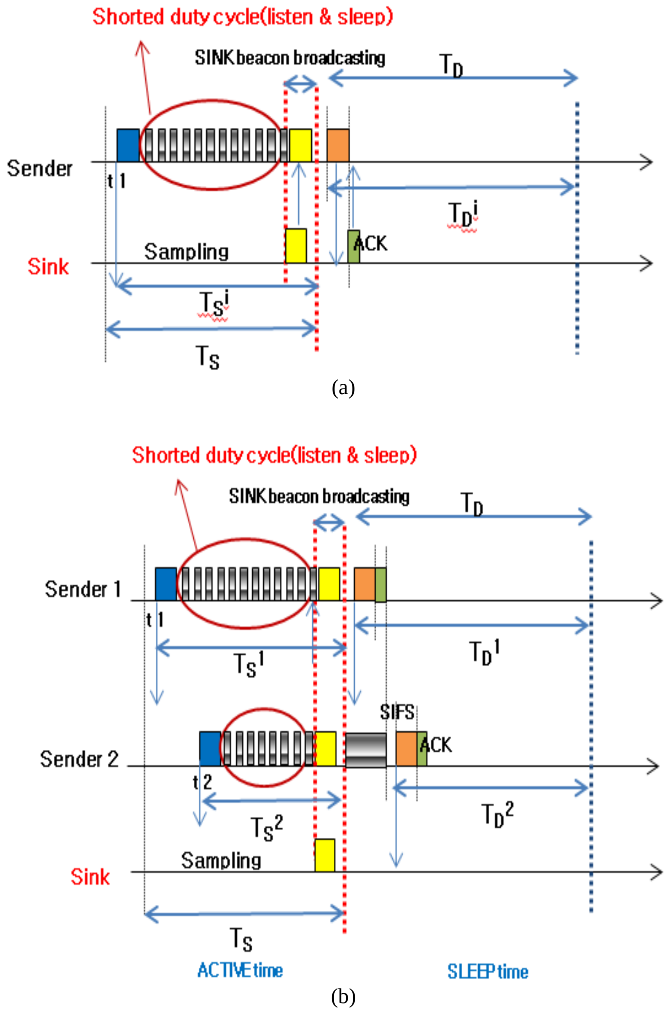
Fig. 5 shows the case where many sender nodes send data packet to a single sink node. As shown in Fig. 5 sender node first sends Tx-beacon frame before sending a data packets. After receiving Tx-frames from its neighbor nodes for some time being, the sink node broadcasts Rx-beacon frame and notifies them whether it ready to receive the data packet. The transfer node may transmit a data packets at a different time obtained via the mapping function using the Rx-beacon frame reception time of the sink node and their Tx-beacon frame transmission time. We used here a mapping function to determine the slot times.

As described in the above part, the mapping function is used to determine slot time, in which data packets from sender nodes can be transmitted without collision. As shown in Fig. 6 (a), the sender sends its Tx-beacon frame to the sink node when the channel is idle. Then the sender node enters into short sleep and listen modes repeatedly until it receives Rx-beacon frame from the sink node. The length of the sleep and listen period is short enough to receive the Rx-beacon frame.

Then the sender node calculates its transmission time slot. The mapping function is as follows;

- $T_S$: time active
- $T_D$: time sleep
- $T_S^i$: time difference between Tx-beacon frame the transmission start time of i node and end of active time
- $T_D^i$: time difference between data packet the transmission start time of i node and end of sleep time

$$\frac{(T_D - T_D^{\,i})}{(T_S - T_S^{\,i})} = \frac{T_D}{T_S} \qquad (1)$$




(a)

(b)

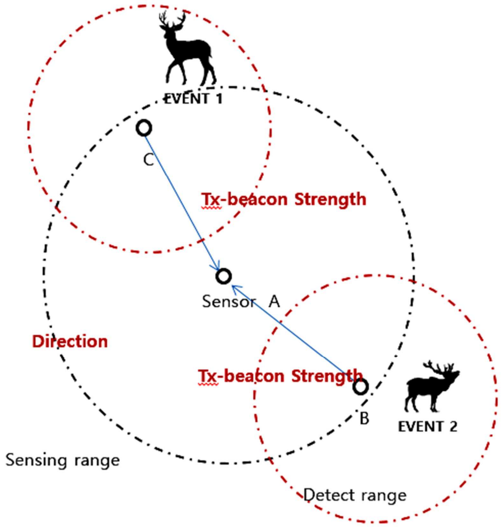
Fig. 6 Mapping function. (a) single mapping function, (b) multi-mapping function

Since Rx-beacon frame includes the information of the sink node's active time period, the above parameters in the Eq. (1) can be obtained. As shown in the formula, the transmitting node can calculate its data transmission time using the ratio of the time difference between sleep time and active time. The operation of data transmission using a mapping function is shown in Fig. 6 (b). In this case, we assume that there are more than one sender nodes. Each node calculates its data transmission time using the equation (1). Furthermore, the sender node's wake up time can be obtained using the equation (2). Each sender node stays in sleep mode until the wake-up time. Using the formulas above, each transmitting node may reduce the loss of data packets due to the energy consumption and collision.

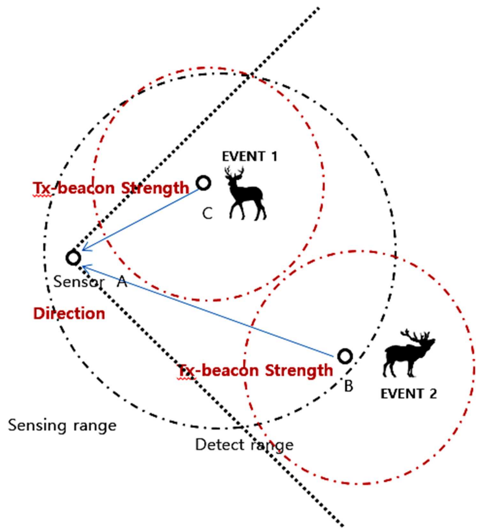
- $T_{ACK}$: Acknowledgment frame transmission time

$$T_{wakeup} = (T_S - T_S^{\,i})\frac{T_D}{T_S} + T_{ACK} \quad (2)$$

### *E. Duplication Data Transmission Method*




(a)




(b)

Fig. 7 Examples of duplicated packet decision error cases (a) by only strength (b) by the only direction

Many sensor nodes may detect the same event and try to transmit the same information to the same sink node. Duplicated data packets may waste bandwidth and cause a transmission delay. So, it is important to eliminate these duplicated data packets. To solve this problem, one special bit is included in a Tx-beacon frame [21]. Using this bit, a node can identify whether the received packet is the sender's measured one or not. If the received data packets are relayed one by the previous sender, then the receiver node should transfer the received packet to its neighbor node or sink node since the packet is not a duplicated one. But if the received data packets are a previous node's measured one, then the packets may be duplicated one. To ensure the reliability of the duplicated data packets, the direction of the packet was used [20]. Two or more sender nodes are detected events. The sender node has a different signal strength. In the OBMAC protocol, the sender node transmits a duplicate data packet. The sender node does not transfer a duplicate data packets, using a directional antenna.

Fig. 7 (a) shows an example of a wrong packet's deletion case. The deleted packets are not duplicated one. But the packets were deleted because only the strength of a signal was used to determine the duplicated packets. OBMAC [22] follows this procedure. The packets from node B and C are generated from different events. So, these packets should be transmitted to the sink node. Another method to distinguish the duplicated packets is suggested [20]. A directional antenna was used to distinguish the duplicated packets. But in this case, wrong packet deletion may also happen. Fig. 7 (b) shows the case. As shown in Fig. 7 a node B and a node C detected different events each other and sent data packet to node A. Since two packets from node B and node C came from the same direction. The node A deleted one of these two packets.

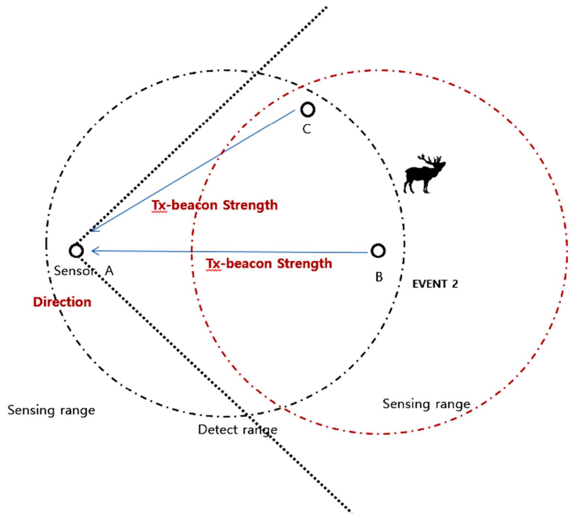



Fig. 8 Duplicated packet decision method

In the paper, we propose a method to enhance [20]. Proposed method is used the intensity and direction of the signal in order to increase the reliability of the duplicate data. The receiving node is determined the intensity and direction of the Tx-beacon frame. If the duplicate data, the received node notifies the sender node. Through Rx-beacon frame sender node determines whether or not the transmission. If the duplicate data, the sender node is deleted the data packet in the buffer. The proposed mechanism is shown in Fig. 8.

### *F. Algorism*

The following shows the transmission algorism of the sender node.

*1: Data Generation & relay*
*2: Channel sensing*
*3: if channel == busy*
*{waiting}*
*4: else if channel == idle*
*{ TxBeacon frame transmission*
*TimeSenderNo = TxBeacon time}*
*{ waiting Rx-beacon frame }*

*5: if ReceivedNode == Sink*
*6: if ReceiveBeacon == TxBeacon*
*{ waiting RxBeacon frame }*
*7: else if ReceiveBeacon == RxBecon*
*{ TimeSink = RxBeacon time*
*TimeTransferSlottime = TimeData - (TimeSenderNo - TimeSink) }*
*8: if Time != TimeTransferSlottime*
*{ sleeping }*
*9: else { data packet transmission }*
*10: else if ReceivedNode == Receiver*
*11: if SendeControl == RxbBeaconDelete*
*{ Deleted SenderBuffer = null }*
*12: else { data packet transmission }*

The following show the algorism of the receive node and sink node.

*1: Periodic sampling*
*{ received TxBeacon frames }*
*2: if SamplingTime == null*
*{ broadcast RxBeacon frame }*
*3: Data periodic*
*{ received Data packets }*

*1: Periodic Wakeup*
*2: { waiting TxBeacon frame }*
*3: if BeaconFrame == TxBeaconDetect*
*4: if BeaconTime <= BeforeTxBeaconTime + (OneTransmissionTime+$\alpha$)*
*5: if BeaconStrength <= BeforTxBeaconStrength + $\alpha$*
*6: if BeaconRange <= BeforTxBeaconRange + $\alpha$*
*7: RxBeaconDelete = 1*
*8: { transfer RxBeacon frame }*
*9: { sleeping }*
*10: else {RxBeaconDelete = 0, transfer RxBeacon frame}*
*11: else {RxBeaconDelete = 0, transfer RxBeacon frame}*
*12: else {RxBeaconDelete = 0, transfer RxBeacon frame}*
*13: else {RxBeaconDelete = 0, transfer RxBeacon frame}*

## III. RESULTS AND DISCUSSION

In this paper, the new mechanism proposed in this paper is compared to other similar mechanisms. The simulation finite state machine is shown in Fig. 9. For performance comparison, we divided the packet transmission range into two-part. One region is between the sender node and the sink node, and the other region is between the receiver node and the sender node. The parameters used in the networks are shown in Table 1.

We assumed here that there are ten sensor nodes and one sink node. Moreover, we simulate ten times and take average values. Fig. 10 shows the results of energy consumption and transmission delay.

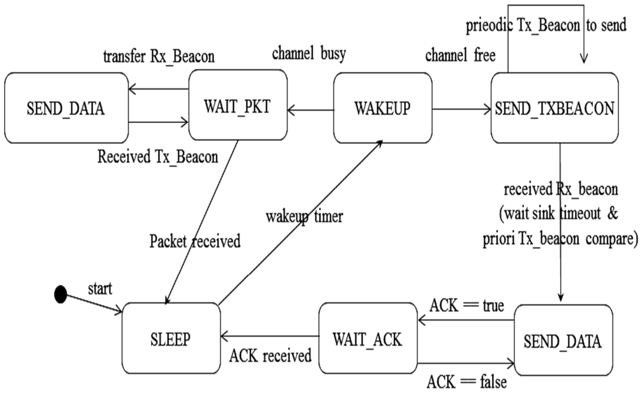


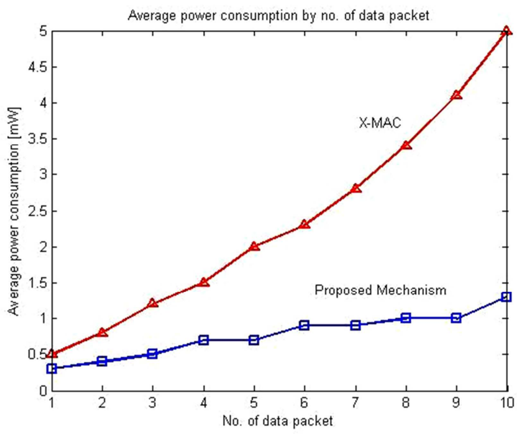

Fig. 9 Proposed mechanism MAC layer-finite state machine

TABLE I
NETWORKS PARAMETERS [13][23][24]

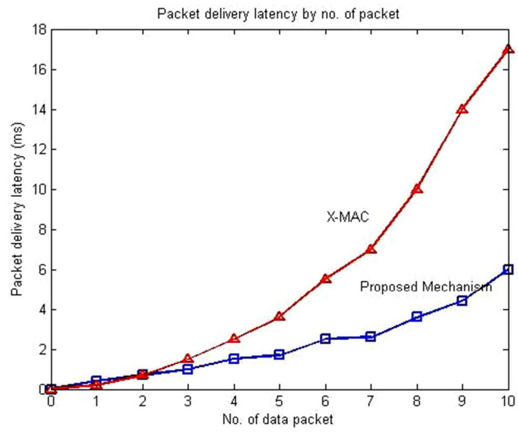
| Parameter | Explanation | Value |
|---|---|---|
| $P_{TX}$ | Power consumption in TX mode | 57.6 mA |
| $P_{idle}$ | Power consumption in idle mode | 10 mA |
| $P_{sleep}$ | Power consumption in sleep mode | 10 μA |
| $P_{RX}$ | Power consumption in RX mode | 10 mA |
| $T_{data}$ | Data packet transfer time | 7.744 ms |
| Data_Rate | Data rate | 250kbps |
| $B_{capacity}$ | Battery capacity | 100 mA h |
| BEACON | Beacon size | 44byte |
| DATA | Data packet size | 220byte |
| SIFS | Short Interframe Space | 192 μs |
| ACK | Acknowledgement size | 5B |
| preamble | Short preamble size | 6B |

Fig. 10 (a) shows the energy consumption according to the increasing number of data packets from sender nodes. As shown in Fig. 10, the proposed mechanism is decreased energy consumption than X-MAC protocol. Fig. 10 (b) shows the transmission delay increases according to the data packet. As shown in Fig. 10, the proposed mechanism is decreased transmission delay than X-MAC protocol. The proposed mechanism is reduced to delay and conflict by sending a data packet at a given time.

The parameters used in this simulation are shown in Table 2. We assumed here that one cluster is generated 1 or 2 events. The events are generated randomly. Furthermore, we simulate seven times and take average values. Fig. 11 shows the energy consumption and the delay between the sender and the receiving node. Fig. 11 (a) shows a transmission delay of the data packet. As shown in Fig. 11, the proposed mechanism is decreased transmission delay and energy consumption than X-MAC protocol. The proposed mechanism is to reduce energy consumption since it does not transmit the duplicate data packets. And it is to reduce the transmission delay.




(a)

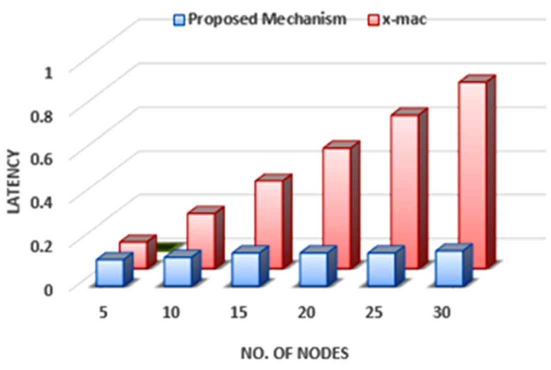



(b)

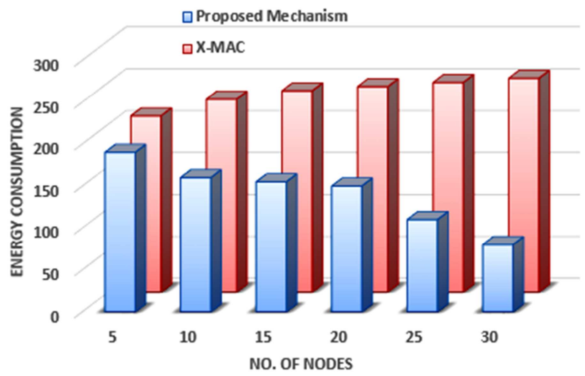
Fig. 10 Energy consumption & delay of 1-hop node from the sink.
(a) average power consumption vs. no. of the packet (b) packet delivery latency vs. no. of the packet.

TABLE II
SIMULATION PARAMETERS [22]

| **Parameter** | **Value** |
|---|---|
| Number of nodes | 5 ~ 20 |
| Receive sensitivity | -98 dBm |
| Battery energizer lithium AA | 2900 mAh |
| Processor (active/sleep | 8 mA / 15 ㎂ |
| RF power | 3 mW |
| Acive/Sleep period | 0.1 / 9.9 s |
| Simulation time | 500 s |




(a)




(b)

Fig. 11 Energy consumption & delay of over 2-hops node from the sink.
(a) latency vs the number of nodes (b) energy consumption vs the number of nodes.

## IV. CONCLUSION

In the paper, we propose an efficient for data gathering and transmission in multi-hop wireless sensor networks. The sensor nodes in the sink node one hop are transmitted to the data packets through a mapping function. It is like a scheduling scheme. Another method is to use BRN. Through this, the sensor node is reduced data packets collision, and retransmission due to collision is also reduced. In the one more hop sensor node, we proposed a method for determining whether or not duplicated data according to the same event, for efficient packets transmission. We were found useful in a delay and energy consumption in comparison to X-MAC protocol by the performance analysis. Later we will proceed with the study of the reliability and efficiency in a variety of network environments. And we will take place in the study of the parameter and the threshold value.

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