Energy saving in WSN using congestion controls

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***Abstract*— A Wireless Sensor Network (WSN) consists of a large number of small sensors with limited energy. In WSN, long lifetime requirement of different applications and limited energy storage capability of sensor nodes has led us to find out new horizons for reducing power consumption upon nodes. Power efficiency is a key issue in WSN due to limited power supply. Buffer management is extremely important in the scenario in WSN where the incoming traffic is higher than the output link capacity of the network since a buffer overflow causes power waste and information loss if a packet is dropped. Due to limited memory and power supply of sensor nodes, the available schemes cannot efficient to directly applied in WSN. In this work, we propose a congestion control algorithm with energy saving and buffer management which simultaneously reduces the loss of relevant packets.**

The need for synchronization is apparent. Time Synchronization also needed to determining location, or speed, it is also needed because hardware clocks are not perfect. There are variations in oscillators, due to which the clocks may drift and durations of time intervals of events will not be same between nodes. The concept of time Synchronization is needed, particularly in WSN to Synchronies the various Wireless Nodes.

We intensively studied the architecture of WSN and its requirements along with analysis of interference and power consumption in related works.

***Index Terms*— WSN, Energy efficiency, Congestion control, Time Synchronization**

I. INTRODUCTION

Due to advances in wireless communications and electronics over the couple of years, the development of networks of cheap, low-power, multifunctional sensors have received increasing attention. A WSN consists of a large number of sensor nodes which are deployed over an area to perform local computations based on information gathered from the environment. Every node within the network is provided with a battery, but it is a difficult job to change or recharge batteries [1]. These sensors are small in size and able to sense, process data and communicate with one another, usually over an RF (radio frequency) channel. A sensor network is designed to detect events or phenomena, collect and process data, and transmit A sensor network is meant to discover events or phenomena, collect and process data, and transmit perceived data to interested users.

Basic features of sensor networks are:

- •Self-organizing capabilities
- •Short-range broadcast communication
- •Compact deployment and cooperative effort of sensor nodes with multihop routing
- •Frequently ever-changing topology due to node failures
- •Limitations in energy, transmit power, memory, and computational power

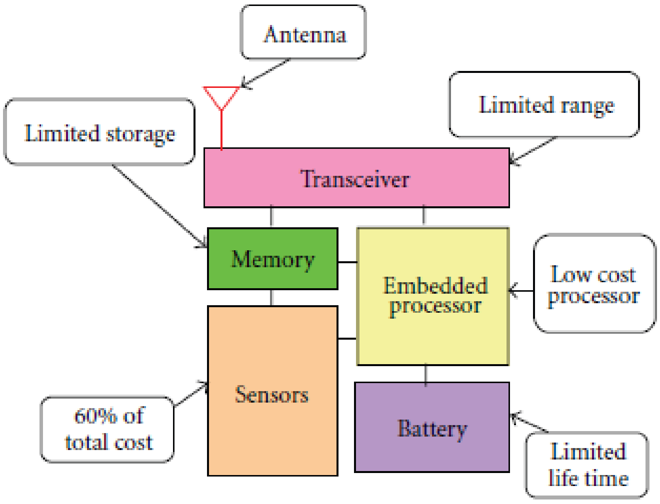

Fig 1: Block diagram of Sensor Node [2]

In WSN, the nodes mainly use a broadcast communication and the network topology can change constantly due to the fact that nodes are prone to fail. Hence, nodes should be autonomous and should be capable to operate independently. This kind of device has limited power, low computational capabilities and restricted memory. One of the main problems that should be studied in WSN is their scalability feature [2], their connection strategy for communication [3] and the limited energy to provide to the device.

The desire to advance in analyses and development of WSN was motivated by military applications such as surveillance of threats on the battlefield, mainly because WSN can replace single high-cost sensor assets with large arrays of distributed sensors. There are other interesting fields like home control, medical applications. WSN may be found in environmental monitoring applications like marine fish farms [4]. A variety of hospitals and medical centers are exploring the use of WSN technology in a wide range of applications, including pre-hospital and in-hospital patient observation and rehabilitation and disaster response [5].Also in fire detection in forest and rural areas [6].

Buffer management is also most important in the situation where the incoming traffic is higher than the output link capacity of the network since a buffer overflow causes power waste and data loss if a packet is dropped. There are convenient buffer management schemes for traditional wireless networks. However, due to restricted memory and

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power supply of sensor nodes, the existing schemes cannot be efficient to directly apply in WSN.

Congestion happens in a node when once buffer is full resulting in data loss. Congestion may be severe drawback for WSN and it causes the data to be retransmitted if the data is lost along with increased power consumption. Transceiver of a node also contributes significantly to total power consumption of a node. To avoid congestion in WSN, we have designed a congestion control algorithm which is explained in the proposed work section later in this paper.

The paper is organized as follows: Section 2: Shows some energy consumption sources. The description of the proposed heterogeneous wireless hardware network architecture that should be taken in into account for energy saving is show in section 3, also proposed Congestion Control Algorithm and time synchronization described in same Section 3. Section 4 describes the main implementation of Time synchronization. Experimental results of Congestion Control Algorithm and Time synchronization are explained in Section 5. Finally, the conclusion is drawn in Section 7.

II. Related Work

Typically, a large number of sensor nodes are randomly deployed within a geographic area to measure within or close to a certain phenomenon. The fundamental functionality of those sensor nodes is data sensing, data processing and communication with other nodes. To perform these operations the sensor nodes need to have a power supply usually a battery, which often cannot be changed and the nodes therefore serve as a one-way product. The sensor nodes collaborate to deliver data from source to sink; hence the nodes are both data originator and data router [7].

Sources of Energy Dissipation:

A. *Idle listening:* A node consumes energy during active operations like sending, receiving and waiting for transmission. It also consumes much more energy during idle and sleep mode. It is crucial to reduce this idle and sleep mode energy consumption. Usually the individual sensor node is not at any time involved in a data transmission process and thereby not every component of the node especially the transceiver does implicitly have to be in an active state. This awaiting ready to transmit data while not receiving or sending packets is called idle listening. There are different approaches to find out when the particular components are not needed or to just reduce the overall active time without further examination. The sleeping sensor nodes either switch back to active mode after a certain time span or after the processing of a wake-up signal.

B. *Collisions:* Collisions occur if nodes receive multiple data packets at the same time. These collisions lead to data corruption/loss and hence the resulting data needs to be discarded. In consequence, transmission process has to be repeated and energy is dissipated. These re-transmissions consume a lot of energy, since the energy losses are multiplied by the number of hops between source and target [8]. For reran transfers, methods like random delays can impede further collisions [9].

C. *Overhearing:* In high density sensor networks, the short distances between sensor nodes lead to interferences with non-participant neighbor nodes during data conveyance. This impact on adjacent nodes is called Overhearing. A node ideally transmits signals in a circular fashion. Several active sensor nodes within the reach of this transmission, burn up energy resource sowing to receiving and processing data that is not indented for receipt by them. This is also a major reason for higher energy consumption. Connectivity requirements have to be weighed up with the arising disadvantages regarding energy dissipation and latency caused by generously keeping nodes in active mode.

D. *Overemitting:* As Overhearing data meant for other sensor nodes causes energy dissipation, so does Overemitting, meaning information propagated during inactive phases of the data sink or as the case may be the target node, which subsequently has to be resent [10]. The repeated transmissions increase the energy expenditures of the individual nodes for sending data and the latency of the whole sensor network. No customary but thoroughly imaginable defect is the simultaneous occurrences of Overhearing and Overemitting. The ideal situation would be a previously known path through the network with timely activation of the included sensor nodes.

E. *Reduction of protocol overhead:* The transmission of protocol *header* information and control messages depletes energy resources and since this data in the end is not exploitable, it should be kept a minor share. Techniques for the reduction of the protocol overhead are for instance adaptive transmission periods, cross-layering approaches, where information from the other network layers is used for optimization, and optimized flooding. A short transmission period leads to less energy consumption and helps therefore saving resources, at the sometime latency to changes is increased [11]. In consequence a favorable value for the transmission period depends on the frequency of change.

F. *Traffic fluctuation:* Traffic peaks caused by the event-based communication in WSN can temporarily lead to congestion or high delays [12]. When the network is working on its maximum, capacity congestion rises to extremely high levels.

In wireless networks, packet drops are mainly caused by buffer overflow and congestion. Avoiding buffer overflow is the responsibility of both sender and receiver Wireless Node. Balancing speed of packetization among available sender and receiver Wireless Node would reduce the potential for reaching the maximum capacity of the in-bound traffic buffer in relay nodes. In our congestion control algorithm, the buffer management strategy has to ensure out-bound flow is high enough to stop the number of backlogged packets from exceeding the maximum buffer size.

III. Proposed Work

In our network we did heterogeneous network by including different Wireless Nodes like PIC Wireless Node, ARM Wireless Node and PC Wireless Node as shown in Fig 2.

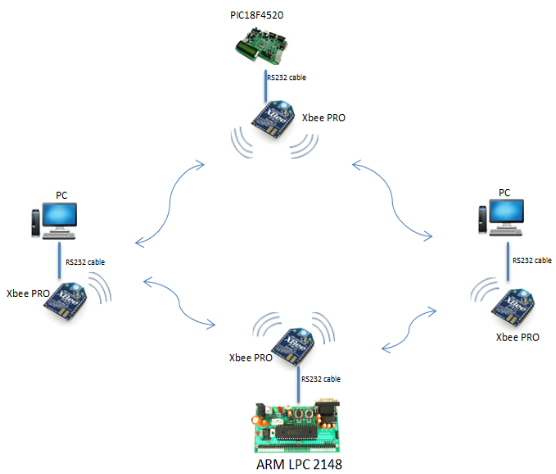

Fig 2: Heterogeneous network

In heterogeneous network, PIC Wireless Node contain PIC microcontroller with Wireless Device. The PIC microcontroller architecture is based on a modified Harvard RISC (Reduced Instruction Set Computer) instruction set with dual-bus architecture, providing fast and flexible design.PIC and Wireless Device are connected by using RS – 232 cables. In case of ARM Wireless Node, ARM processors require significantly fewer transistors than typical CISC x86 processors in most personal computers. This approach reduces heat and power use. These are desirable traits for light, portable, battery-powered devices. In PC Wireless Node, Wireless Device is connected to personal computer by using RS 232 NULL modem.

Time synchronization in sensor networks has attracted attention in last few years. While preparing this heterogeneous network, time synchronization is challenging because the network contains heterogeneous nodes like PIC Wireless Node, ARM Wireless Node and PC Wireless Node. These are physically isolated systems and time synchronization between all these nodes needs to be achieved.

Ganeriwalet.al. Proposed a network-wide time synchronization protocol for sensor networks, which they call Time Synchronization Protocol for Sensor Networks (TPSN) [13]. Their protocol works in two phases: “level discovery phase" and “synchronization phase". The aim of the first phase is to create a hierarchical topology in the network, where each node is assigned a level. Only one node is assigned level 0, called the root node. In the second phase, a node of level i synchronize to a node of level i-1. At the end of the synchronization phase, all nodes are synchronized to the root node and the network-wide synchronization is achieved [14].

Time Synchronization Algorithm:
Level Discovery Phase: This phase is run once at the network deployment. First a node should be determined as the root node. This could be a sink node in the sensor network, and the sink may have a GPS receiver. In this case, the algorithm will synchronize all nodes to an external time .If such a sink is not available, sensor nodes can periodically take over the functionality of the root node. An existing leader election algorithm might be used for this periodic root node election step.

The root node is assigned level 0, and initiates the level discovery phase by broadcasting a level discovery packet. This packet contains the identity and level of the sender node. Upon receiving this packet, the neighbors of the root node assign themselves level 1. Then each level 1 node broadcasts a level discovery packet with its level and identity in the packet. Once a node is assigned level, it discards further incoming level discovery packets. This broadcast chain goes on through the network, and the phase is completed when all nodes are assigned a level.

Synchronization Phase: The basic building block of the synchronization phase is the two-way message exchange between a pair of nodes. Consider the clock drift between a pair of nodes is constant in the small time period during a single message exchange. The propagation delay is also supposed to be constant in both directions.

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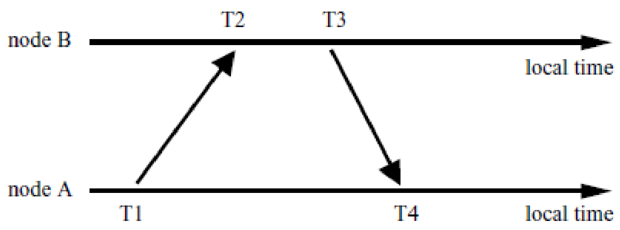

Fig 3: Message exchange between nodes [14].

Consider a two-way message exchange between nodes A and B as shown in Fig 3. Node A initiates the synchronization by sending a synchronization pulse packet at time T1 (according to its local clock). This packet includes A's level number, and the value T1. Node B receives this packet (according to its local clock) at time T2 = T1+¢+ d, where ¢ is the relative clock drift between the nodes, and d is the propagation delay of the pulse. Node B responds at time T3 with an acknowledgement packet, which includes the level number of B and the values T1, T2, and T3. Then, Node A can calculate the clock drift and propagation delay as in formula, and synchronize itself to Node B [14].

$$\Delta = \frac{(T2 - T1) + (T4 - T3)}{2}$$

$$d = \frac{(T2 - T1) + (T4 - T3)}{2}$$

Where Δ is clock drift and d is propagation delay.

As our Wireless Node accepts serial data, it waits before packetizing and transmitting the data. The packetization timeout sets how long it will wait before transmitting the incoming serial data. If packetization value is too short, it may cause problems in that data we transmit becomes fragmented. In Testing and Configuration we wanted the data to be sent as one transmission, but during doing a calculation, the first bunch of data is transmitted. By increasing the value of packetization delay we can help ensure our data stays together and is sent in one transmission.

Congestion control algorithm:
Setting parameter of node (Baud rate, delay, buffer size, pin selection, I/O directions, register selection, port initialization)

Initialize variables

Start to send data from Wireless Node 1 to Wireless Node 2

Initially Packetization delay value is set to be 0.i.e. speed of data sending is high

STEP 1: ***If*** (numbers of packet N>= Threshold th1)
{
Increase Packetization delay by 3
Send packets by same speed of data
}

If (numbers of packet N>= Threshold th2)
{
Go to step 1
}

The value of packetization delay is the number of character times the node should wait before sending the collected data. At 9600 bps, each character requires approximately 1 ms (0.1 ms per bit) With a default packetization value, the node will wait approximately that much time before packetizing and sending data in the buffer. This value can be increased to FF (255 decimal) for a timeout value of over 255 ms at 9600 baud.

Any increase in the value of packetization delay also leads to an increase in the energy consumption. However, a decrease in the value of this parameter leads to more packet loss.

Here in congestion control algorithm the value of threshold is decided after doing practical experiments on Wireless Network. In practical experiment we are sending 50 numbers of packets at a time in network. While sending that packet from Wireless Node 1 to Wireless Node 2 we received only 13 packets and then congestion is occur in network so we are set threshold th1 as 10 packets.

After 10 packets are received at Wireless Node 2 the value of packetization delay is increased by 3ms and continue to send next packets but as we need to save energy so that after sending next 15 packets decrease packetization delay value again to initial value 0, so the value of threshold th2 is 15.

IV. Implementation

In this section the result of experiment after design the network as shown in Fig 2. These results show the Time Synchronization readings and effect of Congestion Control Algorithm on network and how avoid congestion during communication.

We were implemented Time Synchronization algorithm on ARM Wireless Node, PIC Wireless Node and PC Wireless Node to synchronize time between all of them. Results are as follow,

Table 1: Wireless Node 1 to Wireless Node 2

No. of character	Wireless Node 1		Wireless Node 2		Relative Drift	Propagation delay
	Initial (TX) T1	Final (Rx) T4	Initial (Rx) T2	Final (TX) T3	((T2-T1)-(T4-T3))/2	((T2-T1) + (T4-T3)) /2
1	43590	44140	10230	10230	26224	275
10	2900	3500	29590	29590	26390	300
50	48540	49260	15240	15290	33635	335
100	28470	28860	55000	55110	26390	140
200	27740	28670	54270	54600	26230	300
300	11020	12120	37550	38040	26225	305
400	9540	10800	36010	36730	26200	270
500	51790	53210	18260	19190	33775	245
1000	53960	56870	20440	22360	34015	495

In the Table 1 we calculate relative drift and propagation delay where PC to PC communication.

Now in Congestion Control Algorithm, there are three Wireless Nodes on which we are sending data, before and after apply Congestion Control Algorithm on network at Wireless Node 1 we receive 100% data. In case of Wireless Node 2 before apply algorithm 49% packets are received and after apply algorithm 98% packet received as shown in Fig 4.

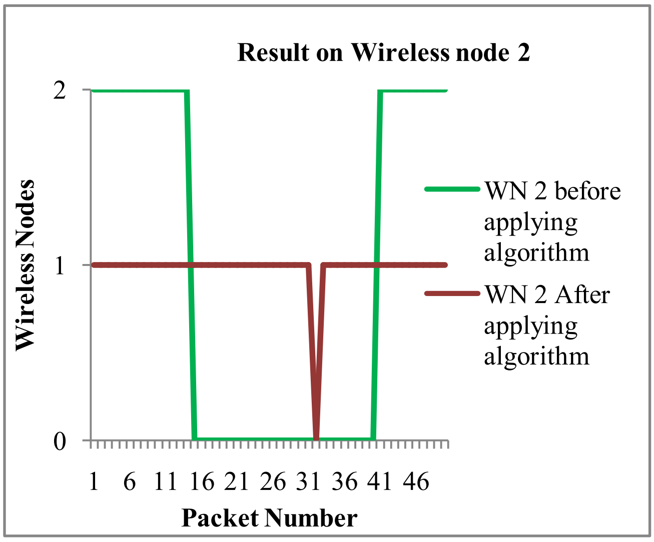

Fig 4: Result on Wireless Node 2

In case of Wireless Node 3 before apply algorithm 25% packets are received and after apply algorithm 96% packet received as shown in Fig 5.

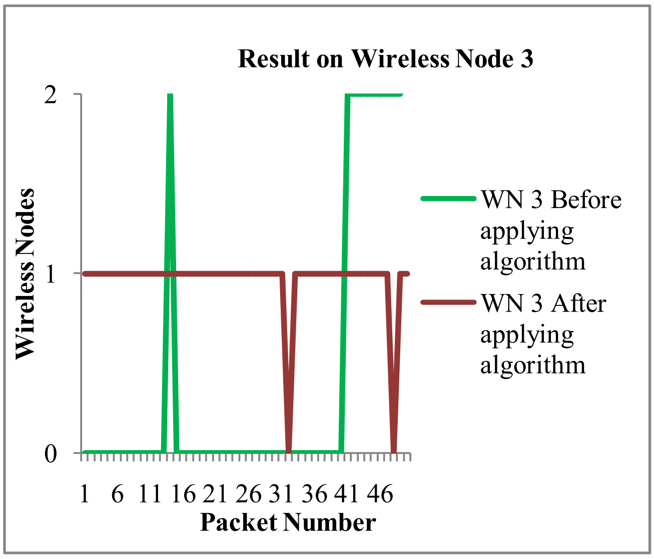

Fig 5: Result on Wireless Node 3

In Fig 6 here the graph plotted as number of packets verses our Wireless Node. We are sending 50 packets. Out of total 50 packets we got all packets at Wireless Node 1 but at Wireless Node 2 we loss 51% and at Wireless Node 3 we loss 75% because of congestion.

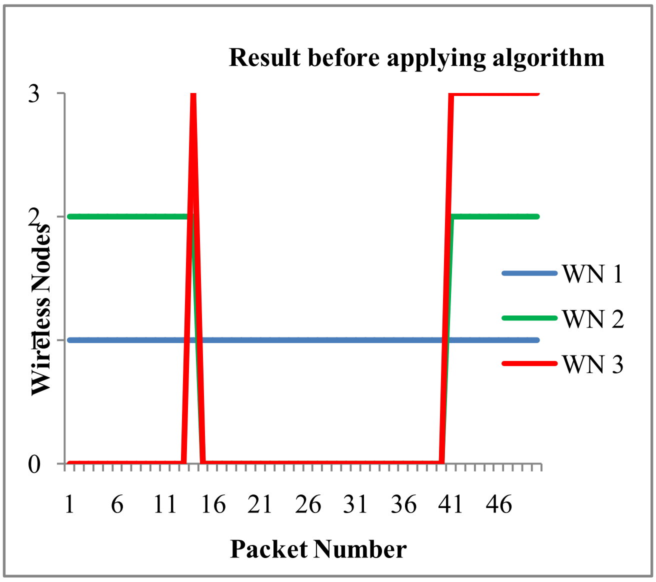

Fig 6: Result before applying algorithm

So we were created an algorithm in which we set the optimum value of packetization delay to save energy and avoid congestion.

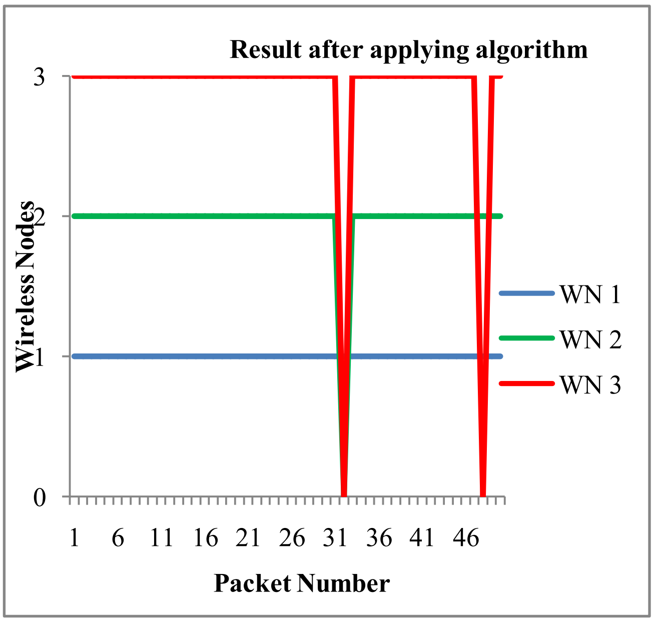

Fig 7: Result after applying algorithm

In Fig 7 result after we applied congestion control algorithm we are loss minimum numbers of packets. At Wireless Node 1 we got all50 packets while at Wireless Node 2 we got 98% and Wireless Node 3 we got 96%.

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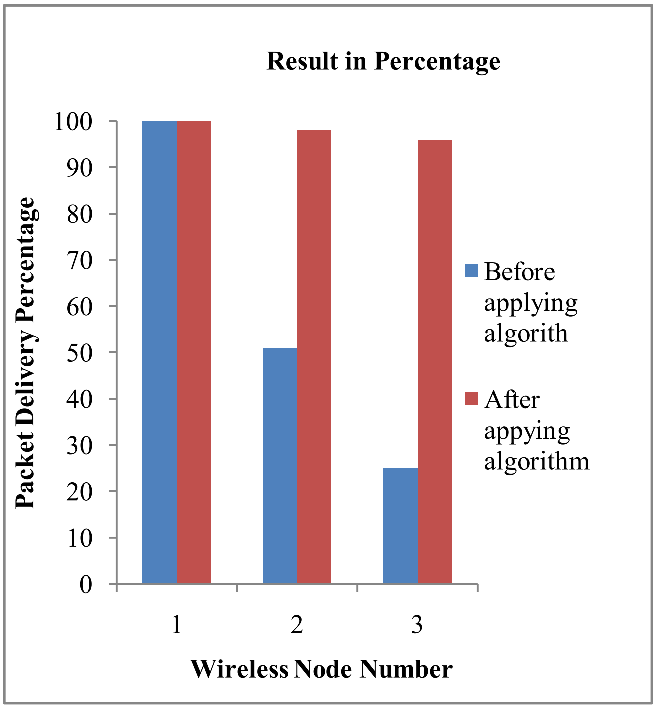

Fig 8: Result in percentage

Here in Fig 8 the result of both before applying algorithm and result after applying algorithm in percentage. At Wireless Node 1 the 100% packets are received in both case before and after applying algorithm but at Wireless Node 2 only 51% packets received before applying algorithm while after applying algorithm we get 98% of packets at Wireless Node 2.same at Wireless Node 3 before applying algorithm 25% of packets received before applying algorithm but after applying our congestion control algorithm we got 96% of packets at Wireless Node 3.

V. Conclusion

In this work, we are saving energy by sending our data as fast as possible with avoiding congestion. The proposed scheme well as it shows a high success rate of packet delivery and avoids congestion. As we are working so we got interference problem and solution for the same. There is no simulation so we did time synchronization between heterogeneous devices.

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