Relaying Node Selection Technique For IEEE 802.15.6

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ABSTRACT: *IEEE 802.15.6 supports two hops extended star topology. The multi-hop (two hop) topology is especially useful for extremely low power in-body and around-body implanted devices that can decrease energy consumption by transmitting to hub through near-by relayed node(s). IEEE 802.15.6 defines the message exchange necessary for the announcement and selection of relaying node. However, the standard does not define the metrics based on which the relayed node should select the relaying nodes. In this paper we propose a relaying node selection mechanism that uses packet drop, packet service time and packet retries as the basic metrics. Also, another novelty of this work is that the decision of node selection is made by the relayed node based on the feedback provided by relaying node. On the other hand, IEEE 802.15.6 suggests that the decision should be made by relayed node without the involvement of relaying nodes. The experimental analysis reveals that the relaying node selection based on the feedback of different metrics results in better throughput and low latency of communication.*

Key words: WBAN, Relaying node, relaying node, two-hops extended topology.

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1. Introduction

A wireless body area network (WBAN) is specifically design to operate independently to connect sensor inside or outside the human body [4] for variety of real-time health monitoring and entertainment applications. To support short range wireless communication in the vicinity of human body IEEE society released a separate standard referred as IEEE 802.15.6 [2,3]. WBAN operates in star topology fashion. However, IEEE 802.15.6 also supports both star and extended star topologies. In the extended star topology the node requesting for the relay facility is referred as relayed node, whereas the node providing this facility is relaying node. The node can request for a relaying node because either it is unconnected or cannot directly reach hub or it wants to ensure its energy by transmitting through relaying node. In the later, the distance between relayed node and relaying node is less than the distance between relayed node and hub. Here, the relay node discovery procedure both for connected and unconnected cases is briefly discussed.

1.1 Relay discovery procedure for connected node

A sensor node discovers a relaying node as follows: when the sensor node overhears an Acknowledgement frame (ACK) for data or management frames originated from relaying node and destined to the hub within the same BAN. This implies two things:

1) Relaying node: provide relaying facility and present in between hub and the relayed node.

2) The link between the relaying node and the hub is a fairly reliable link.

A new link is established with the discovered relaying node by sending a connection request to the relaying node. Then, if relaying node accepts the connection request from the node, it relays the connection request to the hub.

1.2 Relay discovery procedure for unconnected node

In case of an unconnected relaying node acts as a micro-hub and can provide synchronization to the relayed node. This is achieved when relaying node sends a Broadcast Message (BM) which contains a time stamp and resource allocation specification in which sensor node can communicate with the relaying node. The purpose of this broadcast message is two-fold:

1) To provide synchronization to new node, or a sensor node having a bad connection.

2) To provide an opportunity for establishing a connection to relayed node in order to relay their transmission to hub.

How often the relaying node will send the broadcast message is a policy issue and should not violate the power consumption constraint of the relaying node and the availability of resource allocation in the network. The broadcast message will assist the sensor node to discover a relaying node and to wake up at the resource allocation advertised by the relaying node BM, to establish connection with the relaying node. A relaying node has option to exercise admission control over connection requests from nodes to restrict the number of nodes that can support relaying taking into account its power consumption, link quality and other policies such as security policy to prevent third party attack etc.

The IEEE 802.15.6 provides mechanism for announcement and association of relaying and relayed node. But do not specify the metrics to be used for relaying node selection by the relayed node. A few research efforts in [6-14] have been made but these are upper layer solutions. In this paper, we present a novel MAC layer solution for relaying node selection.

This paper is organized into four sections. Section 1 presents the introduction of WBAN and its standard IEEE 802.15.6. Section 2 provides overview of two hop extension mechanism of 802.15.6. In section 3, the proposed novel scheme is presented whereas the experimental analysis is given in section 4.

2. Overview of Two Hop Extension Mechanism of 802.15.6

IEEE 802.15.6 supports a two-hop star topology extension as shown in Fig 1. It has a relayed node, relaying node and a hub. The relayed node transmits data to the hub through relaying node. The relaying node is selected by pre-arrangement or overhearing / receiving ACK/T-Poll frames sent/broadcast.

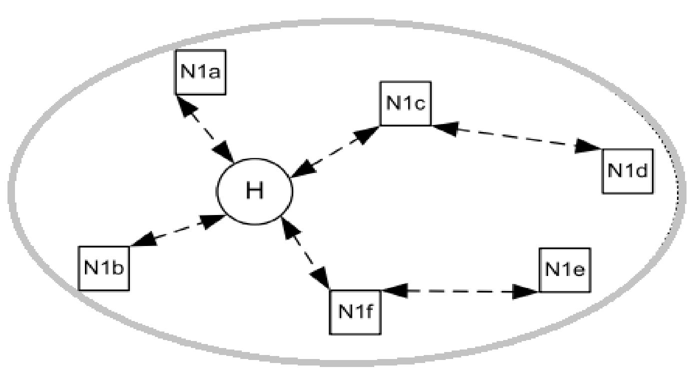

Figure 1. IEEE 802.15.6 two-hop extended star topology

Upon connection request and its connection assignment frame in return, the path relayed node-relaying node-hub is established [13-14]. The connection assignment frame contains data from relayed node to hub via relaying node. The connection is also established in the RAP in case of overhearing the ACK frame, or in MAP when it receives T-Poll frame. Once the connection is established, the relayed node cannot transmit the frame to hub directly in MAP [6]. In short, the relay mechanism has three processes:

1) Channel assessment: by overhearing/receiving, ACK/T-Poll frames from others.

2) Relaying node election: by connection request/assignment frames exchange.

3) The data relaying in the scheduled allocation in MAP.

IEEE 802.15.6 standard suggests transmission of data of relayed node in MAP only. This allows normal EAP and RAP traffic to proceed without any contention from relay nodes. But, the relayed node traffic suffers a lot of delay as it can only be transmitted by relayed node during MAP. In [22], a modified superframe structure of IEEE 802.15.6 is presented in which relayed node traffic can be transmitted in all superframe modes EAP, RAP and MAP. However [22] does not suggest strategy for relaying node selection.

3. Related work

In [8] wake-up schedule control procedure is used to re-select its relaying node by a node even though there are different wake-up schedules for nodes in the network. In [9] the human body is divided into several parts with different weight assignments to know the impact of Speciûc Absorption Rate (SAR) on human body. Optimal place for the relaying nodes is calculated using Particle Swarm Optimization (PSO) algorithm. It also provides lowest SAR and higher packet delivery rate. In [10] relay mechanism the data relaying failure rate is decreased using dynamic scheduling of slot allocation in the superframe for all nodes. In [7] the position of optimal relay nodes is studied using real testbed. Sleeping positions of patients in hospital were studied to observe the link loss and disconnection between body sensors. Later, based on observed positions the optimal positions of relay nodes are suggested in [7]. In [11] correlation characteristics of on-body channels is used to know “when to relay” and “who to relay” on the last known channel states. It outperforms in terms of energy efficiency and provides transmission reliability. In [12], a BANMAC protocol, channel fluctuations and schedules transmissions are monitored. The author also differentiated service and handled interference between multiple co-located BANs in same vicinity.

4. Proposed Scheme

The proposed scheme is designed on two hops extended star topology based IEEE 802.15.6 in beacon enabled mode with the aim of optimum relaying node selection mechanism. We consider only EAP1, RAP1 and MAP1 period in superframe and EAP2, RAP2, MAP2 and CAP is not used. According to standard IEEE 802.15.6 it is not necessary to use all modes of communication. In the proposed scheme, a node decides to use relay facility if its connection with hub is weak or it needs to conserve its energy. It discovers the relaying node using standard procedures available in the standard. Furthermore, we have used explicit notification in the MAP for this purpose. The relaying capable nodes send broadcast message for potential relayed nodes. Also, the relaying nodes communicate their network status to the potential relayed nodes in the broadcast message. The status of node defines the basic metric based in which the relayed node can be selected by relaying node. We have used three different metrics such as number of packets drops, number of retries made for successful transmission of data packet and packet service time of relaying node.

In this work, we have used the aforementioned metrics and each relaying node calculates the moving average of these metrics in each beacon interval. All the metrics are node based and are independently calculated by each relaying node without the assistance or feedback of either neighboring nodes or hub. The moving average is calculated using eq 1.

$$status = \alpha * status + \beta * current\_status \quad (1)$$

Where, current_status the value of any metric observe in the last beacon interval, whereas status represents the predicted value for the next beacon interval. α and β are weights which are assigned to previous status values and currently observed value respectively.

Three different schemes proposed to get *current_status* is:

1**) Packet drop:** is the total number of packet drops at beacon interval at the relaying node. it is the standard metric numerous protocol for measuring congestion over a node. The basic idea of using this metric is to avoid relaying packet through a congested node.

2) Packet service time: It is the time a packet is received or generated by the application and placed in the buffer for future transmission. As soon as the medium is available, a packet from the queue is schedule for transmission by the medium access layer. Therefore, it represents the waiting time of the packet at any node. Hence, service time is another metric reflecting the load over a node and the level of contention around any node.

3) Retries: represent the number of unsuccessful attempt a node has made to transmit a packet. It is a good measure of contention faced by a node in a busy medium.

4.1. Operation of proposed algorithm

In proposed algorithm the relayed node is responsible for the checking of link quality between hub and relayed node, between relaying node and relayed node and between relaying node and hub. In every beacon interval or superframe the relaying node observe the metric i.e. drop packets, service time and retries. The currently observe value of metric, a value obtain is the current status of relaying node. The nodes that are currently using relaying nodes or want to use them receive this packet, others just dropped the packet including hub.

```
RN : RelayedNode
R_yNode RelayingNode
LS: Link Status
if (SNR_node < threshold)
{
 LS – weaker
 SET: RN = TRUE;
 SET: RN = LISTENING;
 if (Pkt_rcv = ACK)
 SET R_yNode
Repeat: After each beacon interval in (MAP)
 Status of R_yNode ;
 if(BS > 0);
 { Broadcast BM; }
 if (RN == TRUE)
 SET: BUCKET [NID] [BS] = BufferStatus
if (Beacon_Count == beacon interval)
{     for(i = 1; i ≤ No.R_yNode; i + +)
 { Select Min_status Value from BUCKET ;}
 }
 if (Min_status == CurrentR_yNode)
{
 SET Beacon_count = 0;
 FOUT;
}
else
 {
SET Beacon_count = 0;
 Send Connection Request
}
```

Figure 3. Proposed algorithm

The next step is to select the proper relaying node by checking the *minimum value* of each possible relaying node. Information is updated after each beacon interval or superframe. Relayed node check minimum value and made decision after energy or appropriate beacon intervals. The selection criteria is to find the minimum (min) value of all possible relaying nodes in relayed node which is being updated in every map (schedule slot allocated to every nodes). If the min status value found is that of the relaying node that is currently used by the relayed node then it continuous with old relaying node. Otherwise, the new relaying node with min value is selected and encapsulated connection request frame is send to hub, according to frame reception and sending rule of 802.15.6 standard [4].

The proposed algorithm is given in Fig 3. The relaying node algorithm is triggered in MAP after each beacon interval at all possible relaying nodes. Whereas, relayed node algorithm is triggered after every beacon or after specific number of intervals according to settings provided by superframe.

5. Simulation

This section presents results simulated in Opnet in terms of throughput, PDR and latency.

The simulation parameters used for simulation analysis are shown in Table 2. Two different UP (UP6 and UP7) are used for data reporting. Data reported in both periodic (without contention) and continuous (with contention) manner. In case of periodic reporting the relaying node periodically after certain intervals generates data to the hub. At one time only one relaying node is transmitting data to the hub. Therefore, it is not facing any contention from neighboring relaying node. In case of continuous reporting more than one relaying nodes are transmitting data to the hub and they content for medium using CSMA/CA technique as specify by IEEE 802.15.6.

Parameter	Value
Simulation time	500 s
Frequency band	2.4 GHz
Traffic Type	UP6 and UP7
Packet Size	100 B
Number of nodes	10
Number of hubs	1
Data Rata (kbps)	971.41
Initial energy	34560 Joules
Transmit mode	17.4 mA
Receive mode	24.8 mA
Sleep mode	6.1 μA
Idle mode	26.1 μA
Data reporting	With and without contention
IEEE 802.15.6 slot length	0.128s
EAP1 duration	14 slots
RAP1 duration	17 slots
MAP1 duration	08 slots
EAP2,RAP2,MAP2	Not used
Buffer Size	25

Table 2. Simulation parameters

In the remaining of the section the performance analysis of the relaying node selection scheme is carried out against throughput, PDR and latency.

(1) Throughput

Fig 5 shows the throughput observed at hub using proposed schemes and IEEE 802.15.6. Performance of IEEE 802.15.6 is severely degraded, as there is no dynamic selection of relaying node and the transfer of data in MAP period only for relayed node, hence packets are dropped due to no dynamism and small transmission portion. Proposed algorithm uses dynamic selection of relaying node by relayed node after checking the status of every possible relaying node. Therefore, its performance is better than IEEE 802.15.6 and Patent [22].The proposed algorithm's relayed node outperforms 802.15.6 even in the presence of high contention.

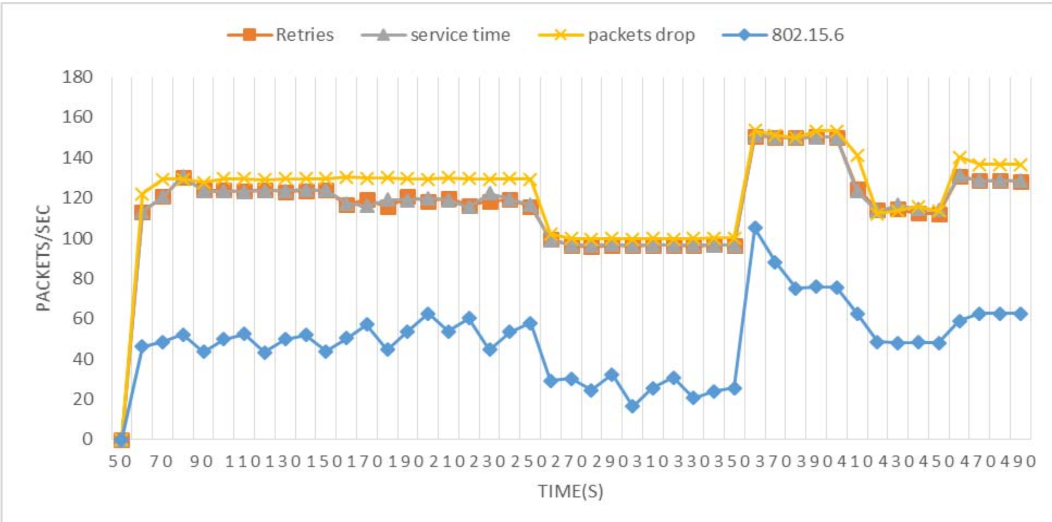

Figure 5. Throughput of relayed node of proposed schemes and IEEE 802.15.6

Average throughput of our algorithm, IEEE 802.15.6 and patent at different data rates and source nodes is shown in Fig 6. The overall data rate is used in these simulations are 50, 100 and 150kbps. Contention is directly and throughput is inversely proportional to source nodes traffic speed. Since IEEE 802.15.6 uses MAP period in two hop topology of relayed node and no

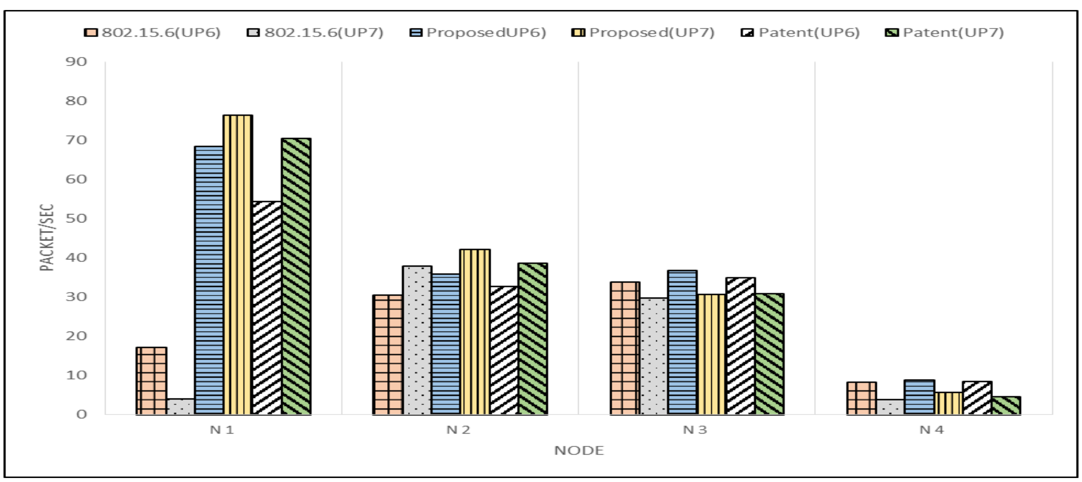

Figure 6. Average throughput (UP6 &UP7) of Proposed scheme, 802.15.6 and Patent

dynamism in selection of relayed node, its performance is severely affected. Patent and proposed algorithm schemes uses EAP and RAP but in proposed solution dynamic Selection of relaying node is implemented. Therefore, our schemes out performs IEEE 802.15.6 and Patent in all cases.

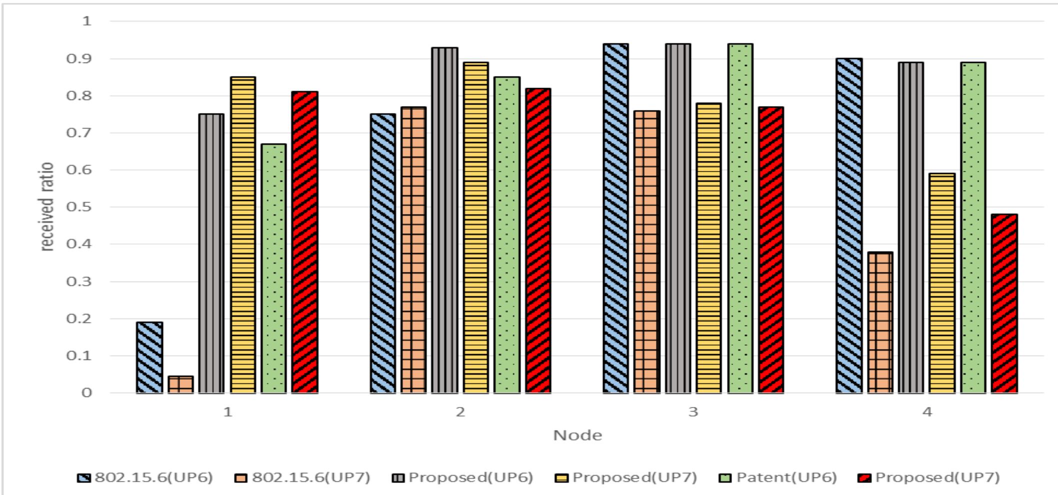

Figure 7. Packet delivery ratio (UP6 &UP7) of Proposed algorithm, IEEE 802.15.6 and Patent [22]

In Fig 7 it is observed that using proposed schemes packet delivery ratio is higher than IEEE 802.15.6 and Patent [22] of each node. The delivery ratio is directly related to the packet drop status. While, in IEEE 802.15.6, and Patent [22] no proper relaying node is selected so performance is decreased.

Fig 8 shows the selection of relaying node during simulation time from 0 to 250 sec, using the proposed scheme. In this scenario, only packet drop metric is used as other metrics have similar behavior. Our proposed relaying node selection mechanism result in switching of relaying nodes based on best possible relaying node according to used metric.

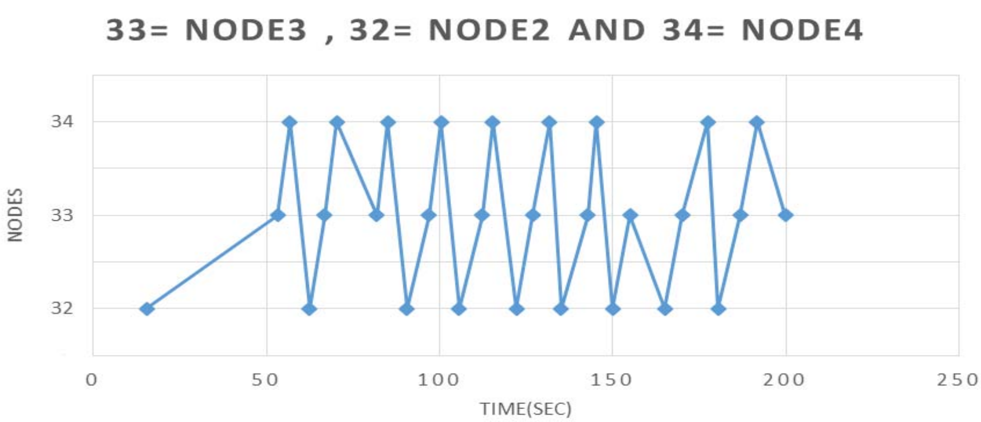

Figure 8. Selection of relaying node during simulation

An important optimization problem for the proposed relaying node selection mechanism is the duration of decision interval that is the interval after which a relayed node decides to switch or not to switch the current selected relaying node. Fig 9 shows the impact of using different decision interval using packet drop as relay node selection metric. The best results are obtained for the decision interval 3 with superframe duration approximately 5 seconds.

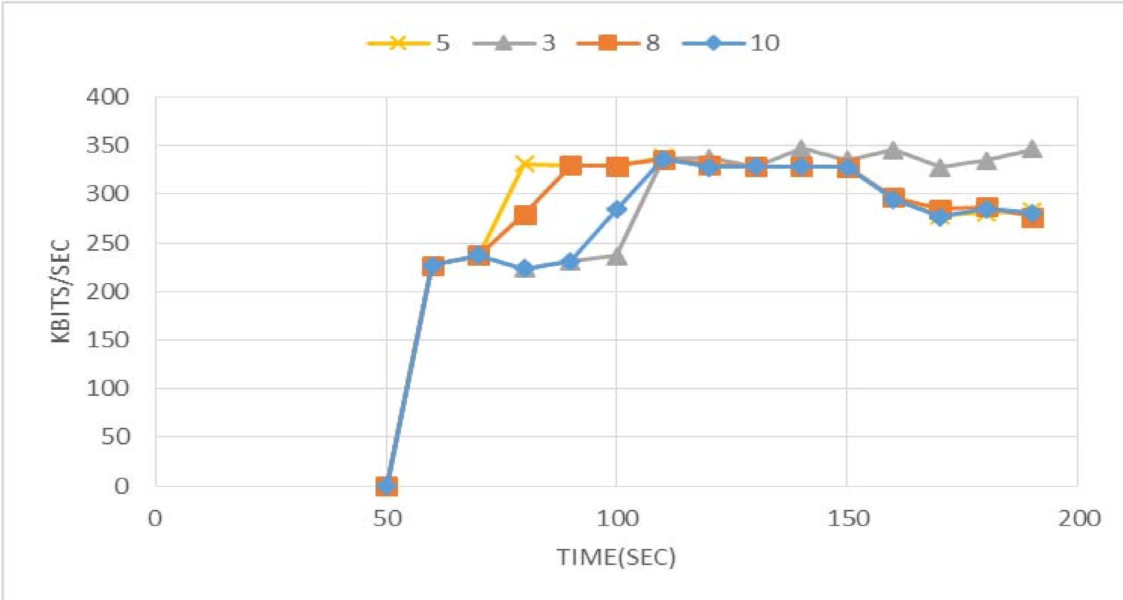

Figure 9. Average Throughput (UP6 & UP7) of proposed algorithm with different decision interval

(2) Latency

The average end-to-end delay of proposed algorithm and 802.15.6 standard is shown in Fig 10. It is evident from the figure that results in lower latency, as it efficiently select relaying node and the impact of EAP and RAP of proposed algorithm.

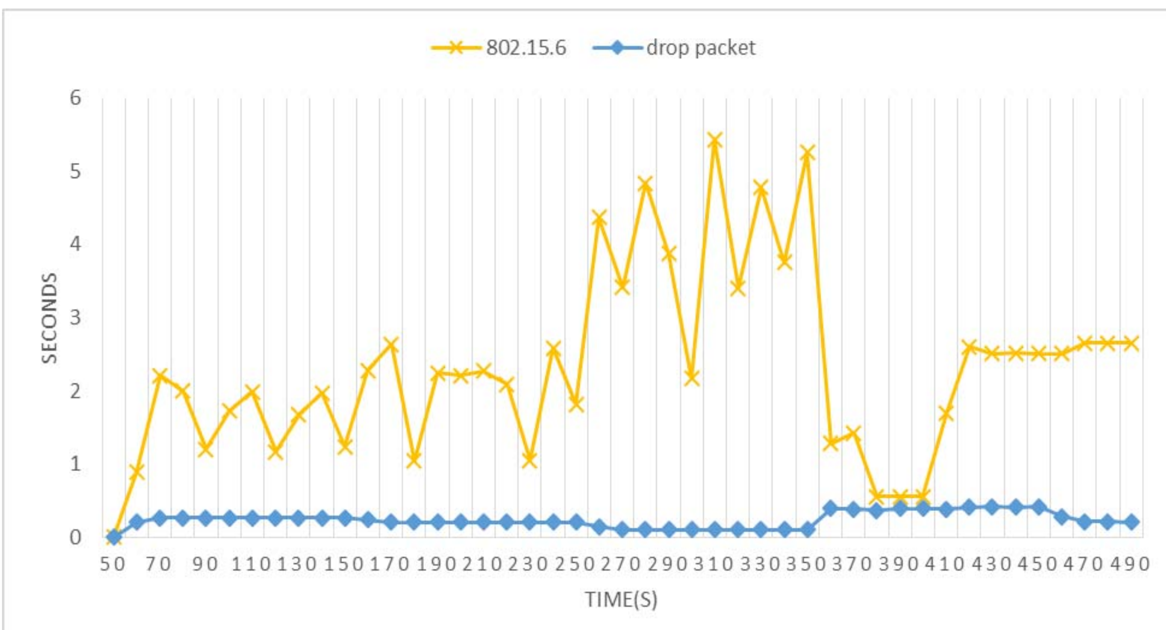

Figure 10. Data latency of proposed algorithm and 802.15.6

Fig 11 shows the simulation result between the proposed schemes and according to simulation result and in the given scenario, drop packet scheme outperforms the packet retries and service time scheme.

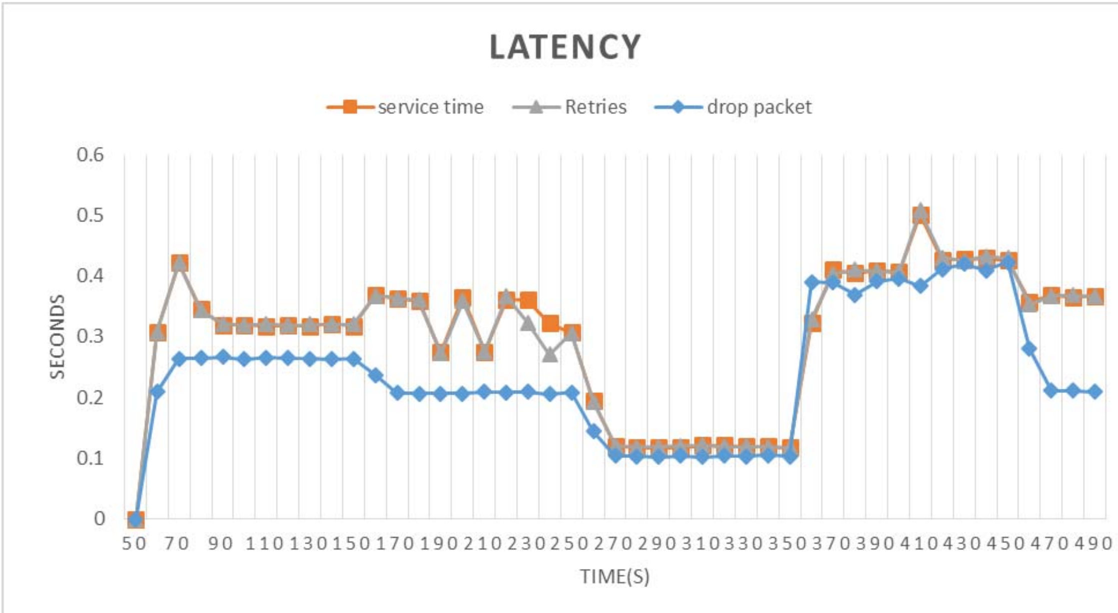

Figure 11. Data latency of service time, retries and drop packet

Conclusion

IEEE 802.15.6 supports extended two hop star topology with the help of relaying node. The standard specify message exchange necessary for the announcement and selection of relaying nodes by the relayed node. In this paper, we have proposed different metrics (packet drops, retries and service time) for the selection of relaying node. The aforementioned metrics are calculated by the relaying node during a beacon interval and communicated to the relayed node after every beacon interval. As a result, propose relaying node selection schemes are able to dynamically select appropriate relay node depending upon network condition.

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