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DDRC : Dynamic Data Rate for Clustered IEEE 802.15.4 Networks

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Abstract - Recently, Low Rate-Wireless Personal Area Networks are widely used in many different domains. But it faces a number of problems due to its design constraints of short range, low data rate, and power consumption. In this paper, we proposed an enhanced protocol for the congestion, and packet dropping problems. This protocol allows a network device to regulate its data rate dynamically using Congestion Notification Field (CNF) in beacon frame based on current network buffer status. For scalability and data rate control, the quantization parameter is used to maintain the target output rate. Along with this scalability is considered by modifying encoding parameters using Particle Swarm Optimization (PSO) to balance the target output rate for supporting high data rate. Thus we proposed Dynamic Data Rate for Clustered IEEE 802.15.4 Networks (DDRC). Consequently, we used NS-2 to simulate the proposed model for MAC layer protocol in wireless LANs. Finally, we test and evaluate DDRC to perform a comparative study between it and the other based adaptive data rate system. The results of the study indicate that this model enhance the Constant Bit Rate (CBR) traffic (Delay, Delivery Ratio, Packet Drop, Energy, and Throughput).

Keywords - *LR-WPAN; IEEE802.15.4 MAC; Cluster Head (CH); Practical Swarm Optimization (PSO); Congestion Notification Field (CNF)*
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1. Introduction

Rapid development of Low-Rate Wireless Personal Area Networks (LR-WPANs) technology has attracted a lot of attention due to its huge applications space. LR-WPANs adopt IEEE 802.15.4 as a communication standard. IEEE 802.15.4 based WSN standard has also gained significant attention among researchers in recent years [1].

The MAC layer of IEEE 802.15.4 standards operates in two different types of modes. They are beacon enabled and non-beacon enabled mode. Periodic transmission of beacon messages are the features of beacon enabled mode for network association and synchronization. Any transmissions of any device in the beacon-enabled LR-WPANs are controlled by the information in the Beacon frames transmitted by the central PAN coordinator [2]. Therefore, the high reliability of Beacon frame transmission is essential for beacon-enabled LR-WPANs. Furthermore, the importance of beacon-enabled LR-WPANs also increases as multimedia traffics are served over WSNs to meet QoS [3]. Beacon enabled can operate a network-wide to maintain synchronization and allows the mode to operate on slotted Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) mechanism. On the other hand, non-beacon enabled mode nodes are not synchronized, due to the absence of periodic beacon transmissions. Therefore, the decentralized communication among the nodes in this mode is facilitated by un-slotted CSMA/CA mechanism [4].

Clustering refers to the partitioning of the network into groups or clusters with a designated leader or cluster-head (CH), as shown schematically in Figure 1. Individual sensor nodes send their data to the base station (BS) in a multi-hop manner, with one or more CH nodes as intermediaries [5].

A number of clustering-based protocols have been described over the years: Time Division Multiple Access (TDMA) based Carrier Sense Multiple Access with Collision Avoidance (CSMA-CA); most of them are based on some variant of TDMA-based medium access. However, the design of an optimal TDMA schedule requires significant computational overhead [6], and efficient implementations necessitate tight synchronization of node clocks [7].

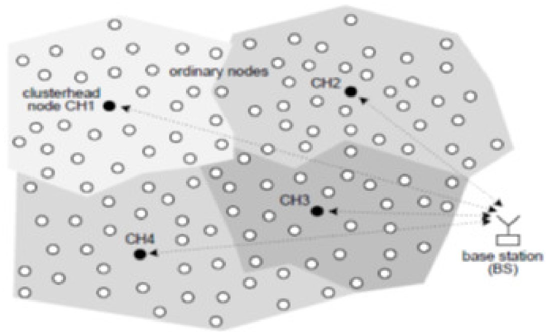

Fig. 1. Topology of a clustered WSN [5]

The default medium access protocol in IEEE 802.15.4 is CSMA-CA, but contention-free access is possible through the so-called Guaranteed Time Slots (GTSs)[8]. CSMA-CA does suffer from packet collisions and ensuing retransmissions, but it also offers much better scalability compared to the TDMA schedule-based protocols [5].

Due to small memory size at the coordinator or network interface, packet dropping may happen and congestion occurring impacts on reducing network performance, throughput and energy efficiency. To avoid the dropping of packets and enhancing the channel capacity, it is desirable to prevent overflow and underflow at the network interface buffer that is balanced by considering the congestion situation at the sensor nodes and adopting adaptive data rate control to avoid this situation [9]. When using data rate control in IEEE 802.15.4 the cost of high data rate video transmission will be lowered [10]. Rate control refers to the scalability of quality, size and frame rate, respectively in both the spatial and temporal model. Rate control involves modifying the encoding parameters in order to maintain a target output Bitrate by varying Quantized Parameter (QP) or step size to transmit a large amount of data in a very short period of time [11].

The design of a rate control system is facing a number of Challenges: -

1- When several devices want to transmit data frames from the network device to the coordinator at the same time, consequently, severe queuing delay happens and network interface buffer leads to packet dropping.
2- Allocating a large buffer size may cause an increase in the queuing delay at the network interface buffer, which could result in TCP retransmission.
3- Due to beacon enabled mode of the fixed super frame structure cannot handle the traffic optimally in varying traffic conditions, when using compression scheme for data rate control leads to delay performance, which is improper for priority of data.
4- Substantial time synchronization has been required since each GTS is assigned to a specific device.
5- When using the mechanism of an adaptive data rate in the network devices must have to take into account the delivery capability of the coordinator to the network device.
6- The main purpose of adaptive data rate control should minimize the power consumption while ensuring reliability and delay constraints in the packet transmission.
7- If active period is longer than data rate, long idle time will waste large amounts of energy. If the period is too short, many back off operations and collisions will consume large amounts of energy. 8- Abuse of dedicated bandwidth might result in the exclusion of other transmissions. 9- Control strategy should minimize the number of transmissions over the network [12][13][14].

Generally in high density wireless networks, congestion occurs at Cluster Heads (CH) and at the coordinator. As a result of this, some of the packets are dropped and the network throughput is degraded [15].

Hence we propose to develop a data rate control mechanism which mitigates the effect of congestion and admit real-time flows in IEEE 802.15.4 networks. We propose to develop a network device to regulate its data rate adaptively using the feedback message, i.e., Congestion Notification Field (CNF) in beacon frame received from the receiver side for preventing congestion and packet dropping based on current network buffer status. The network device controls or changes its data rate based on CNF value. Along with this scalability is considered by modifying encoding parameters using Particle Swarm Optimization (PSO) to balance the target output rate for supporting high data rate. For scalability and data rate control, quantizing parameter is used during encoding to maintain the target output rate.

The rest of the paper is organized as follows: Section 2presented the background. Related work presented in Section 3. Section 4 described DDRC architecture. Section 5 is the design and implementation of DDRC.

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The simulation parameters and Results are presented in 6. Finally, the paper concludes in Section 7, with opening the scope for further research.

2. Background

2.1 IEEE 802.15.4

IEEE 802.15.4 is a standard for Wireless Personal Area Networks known as ZigBee that specifies the physical layer and the MAC sublayer that aimed for designing low data rate, low power consumption and low cost in short-range wireless communications by supporting two topologies such as star and peer-to-peer [16].

The physical layer allows for the use of three frequency bands and 27 channels with different varying data rates. The bit rates are 20 Kb/s in the European 868 MHz band with a single channel (868-868.6 MHz), 40 Kb/s in the North American 915 MHz band with 10 channels (902-928 MHz), and 250 Kb/s in the worldwide 2.45 GHz band with 16 channels (2.4-2.4835 GHz). MAC sublayer operates based on CSMA/CA with two modes of operation: the un-slotted-CSMA with non-beacons and the slotted-CSMA with beacon enabled mode and maintains guaranteed time slot (GTS) allocation [10][17].

The network device in beacon-enabled LR-WPAN waits for a beacon message from the PAN coordinator. If the Guaranteed Time Slots (GTS) is not allocated to the network device, it has to transmit its data frames during the contention period based on the CSMA/CA procedure as in Figure2 (a, b).

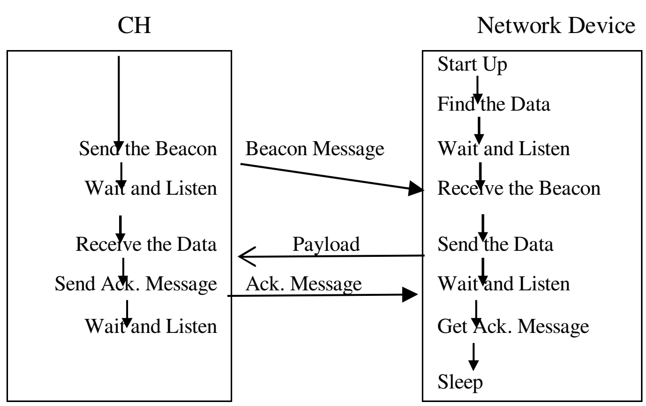

Fig. 2.a CSMA-CA Access Protocol

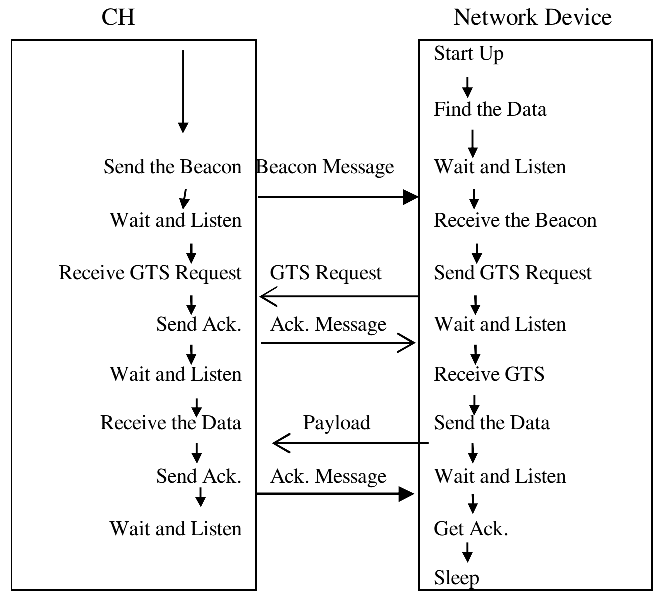

Fig. 2.b TDMA access with an explicit GTS request
Fig. 2. Access modes for intra-cluster communication

Advantages:-

- Ease of installation
- Reliable data transfer
- Short range operation
- Extremely low cost and a reasonable battery [18]

Factors affecting performance of IEEE802.15.4 networks:-

- When the data is transmitted using CSMA-CA mechanism sometimes possible for data get lost or corrupted.
- If the channel is busy due to heavy traffic, the data may not get delivered.
- The data rate is significantly reduced in indirect data transmission due to sending the data periodically [16].
- If two devices most likely choose the same back-off time due to the small CW collision may occur.
- Using broad CW for decreasing collision leads to reduction of network utilization if the network load is light [19].
- Unless the MAC parameters are properly selected may have poor performance in terms of power consumption, reliability and delay [20].
- If the node has reserved a GTS, it can contend for channel access in the CAP period, which will clearly decrease the usable bandwidth for other devices.
- Scheduling the CFP at the end of the active portion of the super-frame gives the normal data a faster channel access than the real-time data, since the real-

time data may wait until the end of the CAP to get deterministic channel access [21].

Major headings are to be column centered in a bold font without underline. They need be numbered. "2. Headings and Footnotes" at the top of this paragraph is a major heading.

2.2 Super-frame

The IEEE 802.15.4) standard allows the optional use of a super-frame structure. The format of the super-frame is defined by the coordinator [22]. Super-frame is bounded by network beacons sent by the coordinator and is divided into 16 equally sized slots. Optionally, the super-frame can have an active and an inactive portion. During the inactive portion, the coordinator may enter a low-power mode. The beacon frame is transmitted in the first slot of each super-frame. If a coordinator does not wish to use a super-frame structure, it will turn off the beacon transmissions. The beacons are used to synchronize the attached devices. Figure 3 shows that the super-frame structure [23]. Super-frame can have an active and an inactive portion. The duration of the active portion of the super-frame, SD, is determined through the so-called super-frame order SO as SD = 48 *2SO, expressed in unit back-off periods [15]. The active portion consists of CAP (Contention Access Period) and CFP (Contention Free Period). Any device wishing to communicate during the CAP shall compete with other devices using a slotted CSMA/CA mechanism. On the other hand, the CFP contains GTS (guaranteed time slots) [23]. The part of CFP granted to a single node for exclusive access is referred to as a guaranteed time slot (GTS); there can be at most seven such slots in a super-frame. GTSs are deallocated on explicit request from a node, automatically upon expiry of exclusive access, or by the coordinator if some time needs to be freed in order to maintain the duration of the CAP above the minimum prescribed by the standard [8]. More details on the various aspects of IEEE 802.15.4 operation can be found in the standard [5].

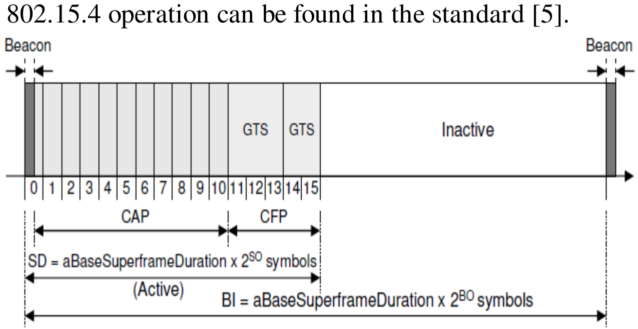

Fig. 3. An Example of the Super-frame Structure [23]

2.3 Adaptive Data Rate Systems

There are many researches working in the data rate control. The most two points are: 1- Eliminate the dropping message 2- control in the data rate. In this section, we will discuss the adaptive data rate systems from the previous points [9, 15].

2.3.1 Eliminate the drop of packets

The CH capacity is controlled based on current network interface buffer status, thereby deploying an adaptive data rate control mechanism. Then CH is prevented from dropping of packets from the network devices as shown in Figure 4.

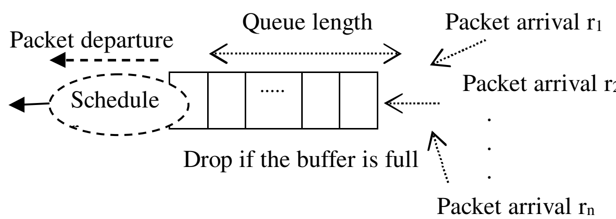

Fig 4: Network Interface buffer structure [15]

Now, we describe the three premises required for the mechanism.

- The network interface buffer of the CH has a maximum storage capacity of L packets.
- The packet generation and arrival process from each network device to the CH follows a Poisson distribution.
- The service time for packets to be transmitted from the network interface buffer of the CH follows a general distribution. Consequently, the arrival rate per unit time at the CH can be described by the following equation.

$$r = \sum_{i=1}^{n} r_i \quad (1)$$

Where $i = i_{th}$ node, n=# of nodes

The performance can be optimized by preventing overflow and underflow at the network interface buffer. If there is any overflow at the network interface buffer, unnecessary transmissions occur which reduce energy efficiency, and this results in a lower throughput.

Large buffer size allocation increases the queuing delay at the network interface buffer, which leads to TCP Retransmission. The retransmissions can be avoided by the requirement of low cost for LR-WPANHW, preferred to make the buffer size small.

Therefore, packet dropping should be denied in spite of the small size network interface buffer by appropriately changing the value of ri.

For supporting an adaptive data rate, the network devices should consider the delivery capability of the CH to the network devices.

As in figure 5, the CH always consistently or periodically monitors the amount of packets in its network interface buffer based on the threshold value. If the number of packets to be serviced is over a certain threshold which is configurable by the operator, the LR-WPAN deduces the current state as congestion. Simultaneously, the CH has to broadcast a beacon message to all network devices to inform them of this state of congestion.

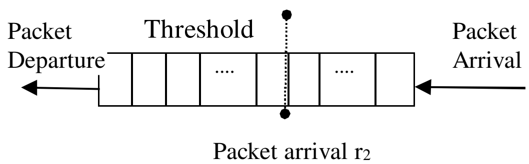

Fig 5: Network Interface buffer monitoring [9]

2.3.2 Adaptive Data Rate

The beacon message objective is network searching, delivering broadcast information, network coordination and synchronization, such as for the allocation of Guaranteed Time Slots (GTSs). The schematic beacon message fields are shown in Table 1.

The LR-WPAN defines 4 types of MAC frame, namely Data, ACK, and Command and beacon message to support the various messages including the beacon message.

- Super-frame Specification Field: It includes the parameter to depict the super-frame structure.
- Pending Address Specification Field: includes all the numbers and types in the Address List Field.
- Addressing Field: includes the list of devices to transmit packets to the PAN coordinator
- Beacon Payload Field: It uses when the PAN coordinator has a packet to broadcast over its coverage area.
- Congestion Notification Field (CNF): occupies one octet in the payload field. CNF field is set to 1 when congestion occurs at the network interface buffer. Or else it is set to 0. This field may also include the identity of the CH as shown in figure 6.

Table 2 Schematic view of beacon frame [9]

fields	***Size***
Frame Control	2
Sequence number	1
Addressing Fields	4 or 10
Auxiliary Security Header	0,5,6,10 or 14
Super-frame Specification	2
GTS Fields	k
Pending Address Fields	M
CNF	1
Beacon Payload	n-1
FCS	2

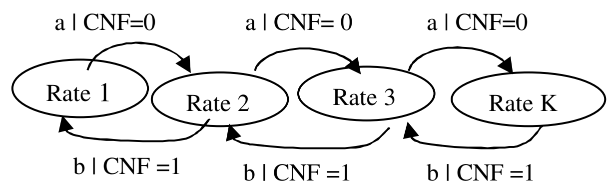

Fig 6: adaptive data rate control scheme [9]

Based on this CNF value, all of the network devices perform the data rate control scheme which is depicted in the following equation:

$$P\{D_{j+1} \mid D_j\} = a \; , \; P\{D_{j-1} \mid D_j\} = b \quad ..... \; (2)$$

Here, Dj is the current data rate of a certain network device and a and b are random probability parameters
If this device receives a beacon message with CNF value= 0, it has to change its data rate to D_{j+1}.
Otherwise, if the device receives a beacon message with CNF value= 1, it has to change its data to D_{j-1}.
This control scheme is very simple to implement. The network device or flow could not guarantee the congestion.

$$D_i = \lim_{t \to \infty} r_i \;\; \forall i$$

The transmission data rate of the network device is trying to be nearly equal to the arrival rate at the CH. Di is the transmission data rate of the i'th network device. This equation will be almost satisfied when there is little congestion at the CH. Therefore, the value of ri will converge to Di.

3. Related Work

The event driven nature of Wireless Networks leads to unpredictable network load and causes the congestion [25]. The congestion control is a complex task and needs cross layer approach. However, many researchers used different techniques to control the congestion [15]. We found out that these researches fall into two directions :- 1) eliminate the dropped packet: - monitoring the network interface buffer and reducing the congestion. 2) Control the data rate: adapting the data rate and improving the throughput.

3.1 Eliminate the dropped packet:-

Dhongo Lee and Kwangsue Chug, [26], presented adaptive duty cycle based congestion control mechanism in which required service time is calculated based on the incoming packet information.

Kai Shi et al., presented receiver assisted congestion control by adjusting the congestion window [27].

Sudip Mishra et al., developed Learning Automata-based congestion avoidance scheme for healthcare wireless sensor networks, in which they detected the congestion by Learning from the past packet drop probability and used data rate control to reduce the congestion [28].

C.Wang et al., used Packet inter arrival and service times for congestion detection and priority based rate control to reduce the congestion [29].

T. Zhong et al., proposed an idea of extending existing active period of work, by using an additional communication period (ACP), in the inactive period of the standard IEEE802.15.4 MAC super-frame [30].

3.2 Control the data rate:-

Hsueh-Wen et al., have proposed adaptive contention control strategy (ACCS) based on a two-stage approach for increasing the transmission-efficiency of IEEE 802.15.4 networks. In the first stage of ACCS, memorized back off scheme (MBS) is used to detect the traffic load of IEEE 802.15.4 networks and to dynamically adjust the size of the back-off window based on the network load. If the network load is considered as a heavy state by MBS, the second stage of ACCS is a load-aware packet scheduling scheme (LAPS) to distribute the tremendous amount of downlink packet transmission to the inactive period [19].

Wook Kim and Sun-Shin, have proposed Differential Dynamic Traffic Control (DDTC) scheme for dynamic traffic conditions by measuring recent traffic status to determine the appropriate super-frame duration and used two-level queue scheduling for differential service. Coordinator obtained the delivery ratio through the data frame during the active period by measuring period traffic when accessing the channel. After classification of data type as priority type and non-priority type, priority means the device forwards the data to the transmission queue otherwise transferred to the compression queue for compression and waits until waiting time expires. After the expiration, data is compressed as a single packet then this process is repeated for non-priority data in the compression queue and forwards it to the transmission queue [12].

Pangun Park et al., have developed Markov model of the of the slotted CSMA/CA mechanism of beacon-enabled IEEE 802.15.4 by considering retry limits, ACKs, and unsaturated traffic regime. Based on developed Markov model then proposed adaptive tuning of MAC parameters such as macMinBE, macMaxCSMABackoffs, macMaxFrameRetries using the physical layer measurement of channel sensing for constraints of reliability and timely communication of the packet delivery while minimizing the total energy consumption [20].

Indong Yeo et al., have proposed an adaptive data rate mechanism to avoid the dropping of packets and develop the channel capacity in the LR-WPAN. That approach focused on the network interface buffer capacity of the receiver (CH or coordinator) by monitoring the network interface buffer state to determine whether it exceeds the threshold or not. The threshold parameter is used as a linear measure of the congestion at the network interface buffer. If the number of packets in the network interface buffer exceeds the threshold, the coordinator broadcasts a new beacon message with a modified payload field to inform the network devices to control their data rate [9].

Bih-Yaw Shih et al., have proposed hybrid hashing channel selection mechanism to improve the performance of IEEE 802.15.4 in MAC layer by focusing on reducing collisions. When collision occurred, hybrid channel selection mechanism has used which consisting of random method and enhanced linear probing. Random method which assigned the random channel using random prime generator before sending the packets and Enhanced linear probing used alternative slots until an empty cell is found. If the end of the table was reached, had no empty slot the search continued from the beginning of the table [24].

Tiberi U et al., have proposed Adaptive Self-triggered Control over IEEE 802.15.4 Networks by focusing the problem of system-level design of Networked Control Systems to reduce the number of transmissions and saving energy. For ensuring the stability, self-triggered sampling strategy have been used by IEEE 802.15.4 Networked Control Systems where the feedback channel is closed that taken protocol parameters into account and then decentralized algorithm have used for energy consumption of the IEEE 802.15.4 network while guaranteeing the stability of the closed loop system [13].

Iman Samizadeh et al., have proposed adaptive scalable rate control using Particle Swarm Optimization (PSO) technique based on CBR by modification of Quantized Parameter value set during the encoding process in order to maintain the bitrate at the target output bitrate for streaming MPEG-4 video-codec over ZigBee. The target bit rate calculated using the number of frames in the GOP and the minimum and maximum level of bits that are available by calculating the prediction P-frame rate. During the encoding process, the output rate of the encoder carried out closely with PSO by determining the optimum Q-scale size in an ad-hoc way [11].

Rambabu A. Vatti et al., propose Rate Adjustment Algorithm (RAA) to avoid the congestion at the coordinator. The RAA monitors the buffer occupancy level at the coordinator and informs the current status of the buffer occupancy level to the transmitting nodes and cluster heads using a modified beacon frame. Based on the current buffer occupancy level, the transmitting nodes will either decrease their data transmission rate to reduce the congestion at the coordinator, or increase the data transmission rate to avoid the underutilization of the network. In both the cases, the throughput will be improved [15].

Our contribution in this work is a complete solution of the network capacity. It consists of two stages: Eliminate the dropped packet by dividing the network interface buffer into a number of regions depending on the occupancy rate and then Control the data rate by using a dynamic data rate.

4. DDRC Architecture

In this section, we will present the general architecture of our system Dynamic Data Rate for Clustered IEEE 802.15.4 Networks (DDRC).
DDRC issues:

- It is difficult to transmit the data to the coordinator at a static data rate.
- If the LR-WPAN allocates slots to the network device using only the RTS/CTS procedure, it results in congestion in the coordinator, as it ignores the latter’s capacity and capability.
- In case of a cluster-tree network, several CHs may want to transmit data frames from the network device to the coordinator at the same time and, as a result severe queuing delays may occur in the CH’s network interface buffer. This may results in packet dropping.
- This phenomenon may even worsen if a lot of data frames converge into a small number of CHs and coordinators based on a static data rate.
- An increase in the number of dropped packets is not desirable from the viewpoint of the network throughput. Also, dropped packets lead to unnecessary retransmission and inefficient energy consumption.

DDRC Assumption:
- The max number of packets in network interface buffer = N
- The max data rate = RM = 256 Kbps
- The calculated rate = The required rate

Our work aims to eliminate the dropping of packet and choose a suitable data rate (dynamic data rate) as a result of the occupancy rate of the network interface buffer (NIB). We modified the adaptive data rate in section (2.3) to DDRC. It will used to work with video signal. The design of DDRC passed through five operations as shown in figure 7:-
1. Calculate a required data rate.
2. Check the number of serviced packets in the network interface buffer (NIB) (the occupancy rate).
3. Choose a suitable data rate as a result of the occupancy rate of NIB.
4. Announce the appropriate data rate.
5. Wait and listen to GTS request.

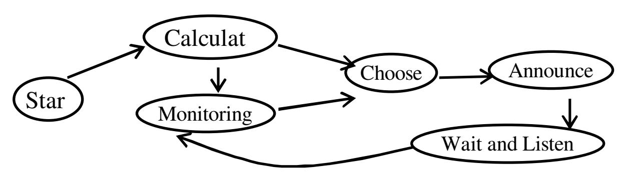

Fig (7) DDRC Operation Steps

Calculate the required data rate

The encoding parameters are modified to maintain a target output bitrate thus providing rate control. The Quantized Parameter (QP) or step size is the most obvious parameter as increasing QP reduces coded bitrate, with lower decoded quality. Quantization has a significant impact on rate control which is set during encoding to maintain the bitrate at the target bitrate.

Scalar quantization handle with both the forward and inverse transform by dividing or multiplying the constant parameters. Different scalar quantization (Q-scale) values influence the amount of compression. Q-scale value can be set for Prediction (P), Bidirectional (B) and Intra (I) frames separately on a scale of 1 to 31.With the larger number, more the video will be compressed and hence video can be easily transmitted but greatly affecting video quality.

Hence we use particle swarm optimization so that we can balance the bitrate and maintain good video quality. With PSO, the output rate of the encoder can be closely controlled during the encoding process as it determines the optimum Q-scale size in an ad-hoc way. This approach should eliminate any data loss and packet drops. The proposed intelligent system, based on CBR and PSO, should minimize data loss and distortion whilst ensuring that the decoder does not suffer from underflow or overflow.

The target bit rate is calculated based on the number of frames in the Group of Picture (GOP) n and the minimum and maximum level of bits available by calculating the prediction P-frame rate. If the previous frame is an I-frame, it is used as a reference to predict the next frame's complexity and is allocated a suitable number of bits and subsequently the quantization step size Q(quantization interval)for the following P and B frames is calculated. The desired bit rate or target rate is expressed as

$$TR = \left[\frac{N}{FR\ (24)} \right]$$

Where TR is Target rate, N = Number of frames, FR= frame rate
The bitrate of an uncompressed video is determined using resolution and frame rate, and lossless video using approximations of quality.

$$Bitrate = (a * y) * \frac{MF}{B} * rate$$

Where a, is the frame width, with 176 pixels, and y is the height with 144 pixels. MF is the Motion Factor and B is the no. of bits which is 8 bits, and 1000 is the rate value.

The value of frame bit rate is passed to the PSO for optimization.

Modified Network Interface Buffer Monitoring

As shown in figure 7, the CH always consistently monitors the amount of packets in its network interface buffer according to occupancy value. We divide the network interface buffer (NIB) into 4 regions as a result of the occupancy rate as shown in figure 8:

1. Green Region : the occupancy rate is less or equal 40%
2. Yellow Region : the occupancy rate is more than 40% and less than or equal 70%
3. Brown Region: the occupancy rate is more than 70% and less than or equal 80%
4. Red Region: the occupancy rate is more than80%.

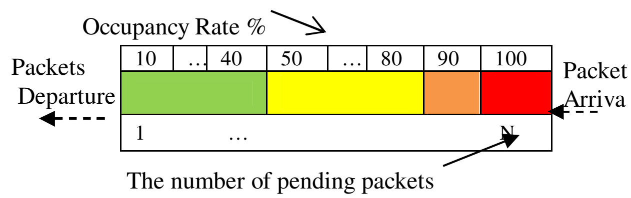

Fig 8: Modified Network Interface Buffer Monitoring

Dynamic Data Rate

We also modify the data rate by replacing the static data rate with a dynamic data rate by using a programmable beacon message. Figure (9) shows the relationship between the occupancy rate and data rate. When the occupancy rate is high (NIB is red), CH broadcast a beacon message to network driver to stop the transition of the message to CH. The red region helps us to eliminate the dropping packets. The green region asks the network device to transmit by the maximum data rate. But when the occupancy rate exceeded than 40% the network device will decrees the data rate until reaching to the brown region. In the brown region the data rate will be fixed. It equals the calculated data rate to transition the video message.

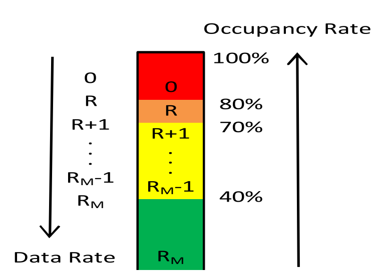

Fig. 9. The relation between the data rate and occupancy rate of NIB

There are a relationship among Occupancy rate, NIB regions, values of CNF, and the data rete as in . Table (2).

TABLE 2 THE RELATIONSHIP AMONG OCCUPANCY RATE, NIB REGIONS, VALUES OF CNF, AND DATA RETE

Occupancy Rate	*NIB Region*	*CNF*	*Data Rate*
<= 40%	Green	(00)2	RM
>40%&&<= 70%	Yellow	(01)2	RM : R
> 70%&&<= 80%	Brown	(10)2	R
>80%	Red	(11)2	0 (Suspend)

Fig (10) shows the state diagram between CNF and the data rate. The data rate changed dynamically related to the change of the CNF (actually related to the occupancy rate).

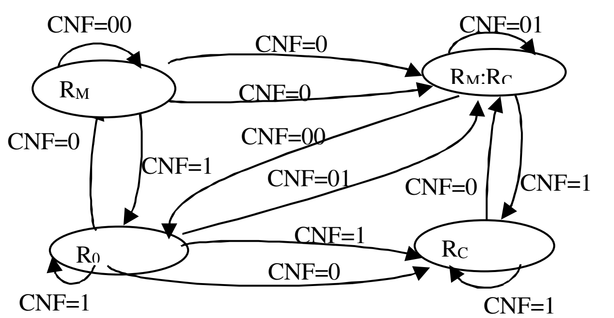

Fig (10) Stat Diagram of CNF and the data rate

5. DDRC Design

In this section we will descript the sequence of operations and the algorithms of DDRC as the architecture in 4. Figure (11) describe the sequence of operations of DDRC.

a. Algorithms

In the following, we will present the algorithm of the CH and network device that perform the architecture of section (4).

Algorithm 1: CH Algorithm

Send Beacon message
Wait and listen
If (Receive a new GTS Request)
Checking the occupancy rate
{
Monitor the network interface buffer
If Occupancy Rate <= 40
Set CNF = $(00)_2$
Else if Occupancy Rate >40 and <=70
Set CNF= $(01)_2$
Else if Occupancy Rate >70 and <=80
Set CNF = $(10)_2$
Else
Set CNF = $(11)_2$
}
Send ACK message (announce the GTS message)
Wait and listen ---- 1
If (Receive the data)
Send ACK
Else
Go to step ------1
Else
Wait and listen

Algorithm 2: Network Device Algorithm

Wait and listen
If (Find out the data)
Wait and listen
If (Receive Beacon message)
Send GTS request message
Wait and listen
If (Receive GTS announce message)
Check CNF value
{
Monitor the congestion network field (CNF) --- adjustment the data rate
If CNF= $(00)_2$
set the data rate $R=R_M$
Else if CNF= $(01)_2$
if $R=R_M$
Decrease R
Else if R=Rc
Increase R
Else if R=0
R=Rc+1
Else
Increase R
Else if CNF= $(10)_2$
set the data rate $R=R_c$
Else if CNF= $(11)_2$
set the data rate R=0 (Suspend)
}
Send the data
Wait and listen
Receive ACK
Go to sleep
Else
Wait and listen

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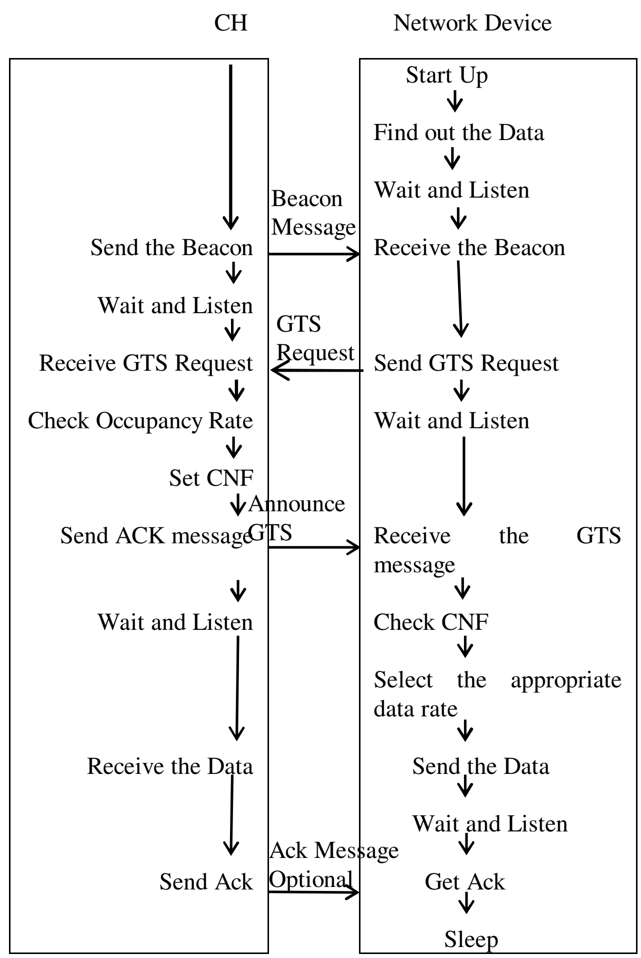

Fig. 11. DDRC Sequence of operation

6. Evaluation and Performance

6.1 Simulation

In this section, we evaluate the performance of GAS in terms of its ability to satisfy the time constraints and its ability to achieve high GTS utilization using the NS-2simulator [29].

Simulation Parameters

We use NS-2 to simulate our proposed Dynamic Data Rate Control for Clustered Architecture (DDRC) protocol. We use the IEEE 802.15.4 for wireless LANs as the MAC layer protocol. It has the functionality to notify the network layer about link breakage. In our simulation, the packet sending rate is varied as 10, 30, 50, 70 and 90Kb. The area size is 50 meter x 50 meter square region for 50 seconds simulation time. The simulated traffic is CBR and Exponential (Exp.). Our simulation settings and parameters are summarized in table 3.

TABLE 3. Simulation parameters

Item	***Identification***
No. of Nodes	100
Area	50 X 50
MAC	802.15.4
Simulation Time	50 sec
Traffic Source	CBR and Exp
Rate	10, 30, 50, 70 and 90Kb
Propagation	TwoRayGround
Antenna	OmniAntenna

Performance Metrics

We evaluate performance of the new protocol mainly according to the following parameters. We compare the Adaptive Data Rate Control (ADRC) [9]protocol with our proposed DDRC protocol.

Average Packet Delivery Ratio: It is the ratio of the number of packets received successfully and the total number of packets transmitted.

Average end-to-end delay: The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations.

Throughput: The throughput is the amount of data that can be sent from the sources to the destination.

Packet Drop: It is the number of packets dropped during the data transmission

6.2 Results

The simulation results are presented in the next sections.

Based on Rate (CBR)

In the first experiment we are varying the rate as 10, 30, 50.70 and 90 Kb for CBR traffic.

Figures 12 to 16 show the results of delay, delivery ratio, packet drop, and throughput and energy consumption by varying the rate from10Kb to 90Kb for the CBR traffic in DDRC and ADRC protocols. When comparing the performance of the two protocols, we infer that DDRC outperforms ADRC by 30% in terms of delay, 25% in terms of delivery ratio, 21% in terms of packet drop, 9% in terms of energy consumption and 34% in terms of throughput.

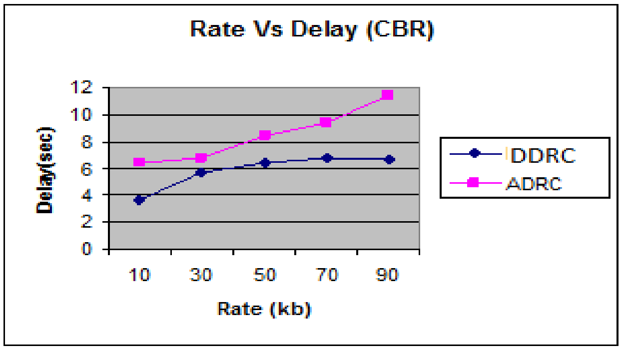

Fig 12: Rate Vs Delay

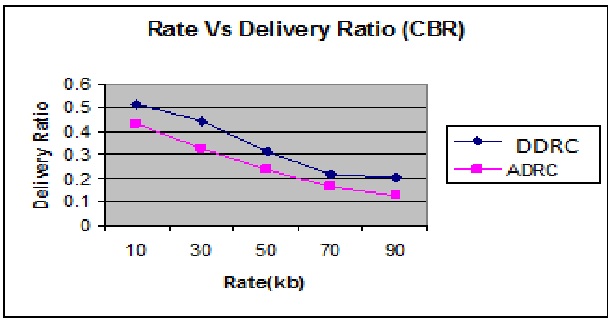

Fig 13: Rate Vs Delivery Ratio

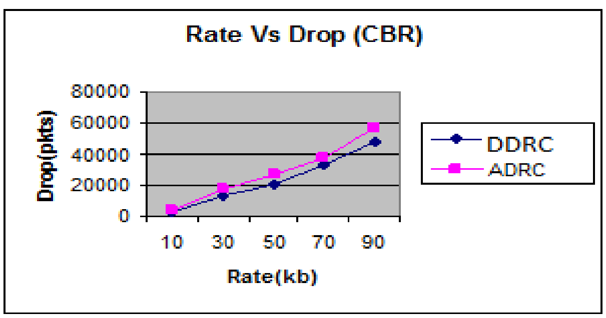

Fig 14: Rate Vs Drop

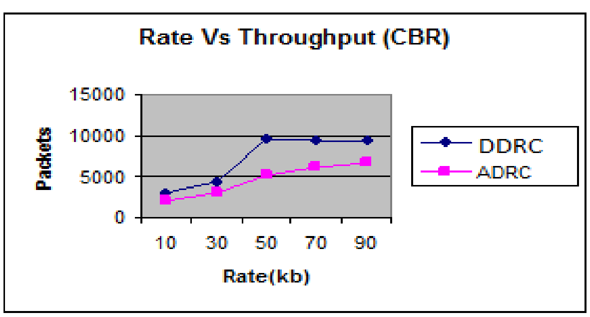

Fig 15: Rate Vs Throughput

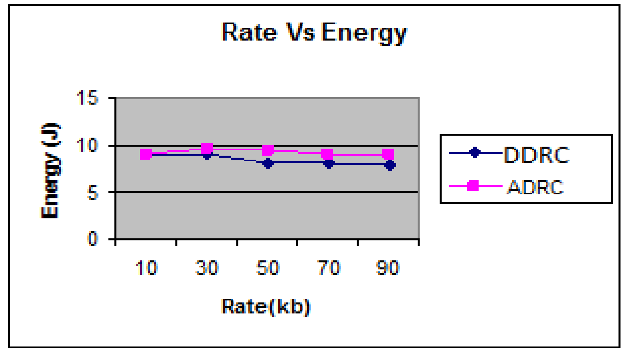

Fig.16. Rate Vs Energy

Based on Rate (Exp.)

In the second experiment we are varying the rate as 10, 30, 50, 70and 90kb for Exponential traffic.

Figures 17 to 21 show the results of delay, delivery ratio, packet drop, throughput and energy consumption by varying the rate from10Kb to 90Kb for the Exponential traffic in DDRC and ADRC protocols. When comparing the performance of the two protocols, we infer that DDRC outperforms ADRC by 54% in terms of delay, 34% in terms of delivery ratio, 47% in terms of packet drop, 24% in terms of energy consumption and 60% in terms of throughput.

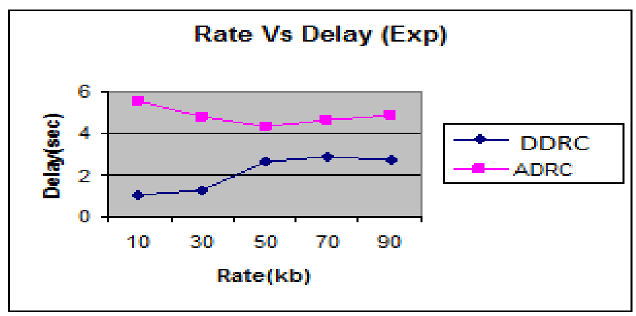

Fig 17: Rate Vs Delay

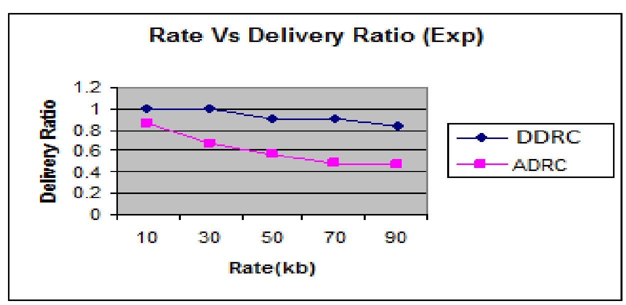

Fig 18: Rate Vs Delivery Ratio

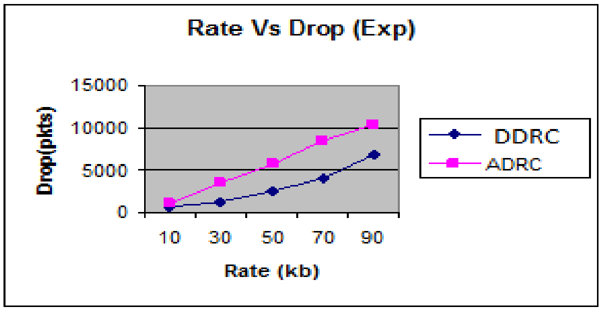

Fig 19: Rate Vs Drop

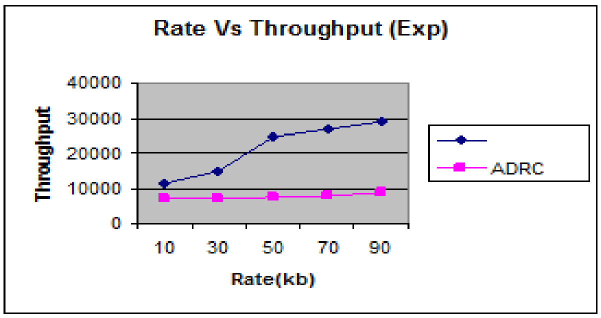

Fig 20: Rate Vs Throughput

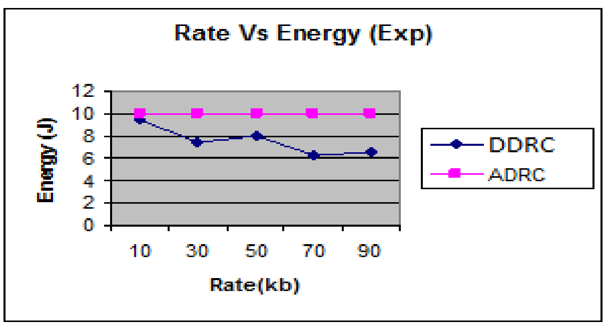

Fig 21: Rate Vs Energy

7. Conclusion

We discussed dynamic data rate control for clustered architecture in IEEE 802.15.4 Networks to mitigate the effect of congestion and admit real-time flows. A network device is designed to regulate its data rate dynamically using the feedback message, i.e., Congestion Notification Field in beacon frame received from the receiver side for preventing congestion and packet dropping based on current network buffer status. The network device controls or changes its data rate based on CNF value. The scalability is considered by modifying encoding parameters using PSO to balance the target output rate for supporting high data rate. For the scalability of data rate control, quantized parameter is used during encoding to maintain the target output rate. Also, when the occupancy rate is high (red region), CH broadcasts a message to the network devices to stop the transmission to eliminate the dropping message before fulfilling the network interface buffer. But when the occupancy rate is low (green region), CH asks the network device to transmit by maximum data rate to improve the throughput.

Simulation results showed that the proposed Dynamic Data Rate for Clustered IEEE 802.15.4 Networks (DDRC) technique reduced the packet drop and energy consumption. Moreover, it improves the throughput and packet delivery ratio when compared to the existing techniques.

Our future works will further investigate solutions to improve the elimination of the packet dropping increase the throughput, and enhance the performance by allowing the beacon frame to be transmitted in an interference-free channel, or adaptive interference-aware multi-channel clustering algorithm and storing packets in the network interface buffer. The linked or hierarchy storing method will eliminate the congestion.

Reference

[1] Surender, R., and P. Samundiswary. "Performance Analysis of Node Mobility in Beacon and Non-Beacon enabled IEEE 802. 15. 4 based Wireless Sensor Network." International Journal of Computer Applications 76.12 (2013).

[2] Zhang, Yanjun, et al. "Performance analysis of wireless sensor network based on NS-2." Systems and Informatics (ICSAI), 2012 International Conference on. IEEE, 2012.

[3] Bae, Hong Min, et al. "Performance Improvement in Beacon-enabled LR-WPAN-based Wireless Sensor Networks." Proceedings of the 5th International Confererence on Sensor Networks (2016): 89-94.

[4] Gribaudo, Marco, et al. "Transient analysis of IEEE 802.15. 4 sensor networks." IEEE Transactions on wireless communications 10.4 (2011): 1165-1175.

[5] Tavakoli, Hamidreza, et al. "Energy-efficient cluster-head rotation in beacon-enabled IEEE 802.15. 4 Networks." IEEE Transactions on Parallel and Distributed Systems 26.12 (2015): 3371-3380.

[6] Srivathsan, R., et al. "Enhanced Genetic algorithm for solving broadcast scheduling problem in TDMA based wireless networks." Communication Systems and Networks (COMSNETS), 2010 Second International Conference on. IEEE, 2010.

[7] Boyinbode, Olutayo, Hanh Le, and Makoto Takizawa. "A survey on clustering algorithms for wireless sensor networks." International Journal of Space-Based and Situated Computing 1.2-3 (2011): 130-136.

[8] "IEEE Standard 802.15.4-2011", *IEEE Standard for Local and Metropolitan Area Networks—Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs).*

[9] Yeo, Indong, Jonghyune Kim, and Sunshin An. "Adaptive data rate control for throughput improvement and energy efficiency in low rate WPAN." Proceedings of the 1st international conference on Ambient media and systems. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 2008.

[10] Zainaldin, Ahmed, Ioannis Lambadaris, and Biswajit Nandy. "Adaptive rate control low bit-rate video transmission over wireless zigbee networks." Communications, 2008. ICC'08. IEEE International Conference on. IEEE, 2008.

[11] Samizadeh, Iman, et al. "Adaptive scalable rate control over IEEE 802.15. 4 using particle swarm optimization." Information, Communication and Automation Technologies (ICAT), 2013 XXIV International Symposium on. IEEE, 2013.

[12] Kim, Wook, and Sunshin An. "Differential Dynamic Traffic Control for IEEE 802.15. 4 Networks." J. Inf. Sci. Eng. 26.1 (2010): 255-266.

[13] Tiberi, Ubaldo, et al. "Adaptive self-triggered control over IEEE 802.15. 4 networks." Decision and Control (CDC), 2010 49th IEEE Conference on. IEEE, 2010.

[14] El Gholami, Khalid, Kun-mean Hou, and Najib Elkamoun. "Enhanced superframe structure of the ieee802. 15. 4 standard for real-time data transmission in star network." International Journal of Computer Applications51.15 (2012).

[15] Vatti, Rambabu A., and Arun N. Gaikwad. "Throughput Improvement of High Density Wireless Personal Area Networks." Computational Intelligence and Communication Networks (CICN), 2014 International Conference on. IEEE, 2014.

[16]]Babita and SanjeevIndora, “Survey on Performance of IEEE 802.15.4 Low Rate - Wireless Personal Area Networks (LR-WPAN)”, International Journal of Advanced Research in Computer Engineering & Technology (IJARCET), vol. 3, Issue 4, April 2014.

[17] Wavage, Rajashri, and Aman Kaushik. "Performance Analysis of Beacon Enabled IEEE 802.15. 4 Using GTS in Zigbee." International Journal of Computer Science & Applications (TIJCSA) 2 (2014): 12.

[18] Jing, Hui, and Hitoshi Aida. "An analytical approach to optimization of throughput for IEEE 802.15. 4 slotted CSMA/CA networks." Consumer Communications and Networking Conference (CCNC), 2011 IEEE. IEEE, 2011.

[19] Tseng, Hsueh-Wen, et al. "An adaptive contention control strategy for IEEE 802.15. 4-based wireless sensor networks." IEEE Transactions on Vehicular Technology 58.9 (2009): 5164-5173.

[20] Park, Pangun, Carlo Fischione, and Karl Henrik Johansson. "Adaptive IEEE 802.15. 4 medium access control protocol for control and monitoring applications." Wireless Networking Based Control. Springer New York, 2011. 271-300.

[21] Huang, Yu-Kai, Ai-Chun Pang, and Hui-Nien Hung. "An adaptive GTS allocation scheme for IEEE 802.15. 4." IEEE transactions on parallel and distributed systems 19.5 (2008): 641-651.

[22] Cho, Hyung Wook, Sueng Jae Bae, and Min Young Chung. "Utilization-aware dynamic GTS allocation scheme in IEEE 802.15. 4." Communications (APCC), 2010 16th Asia-Pacific Conference on. IEEE, 2010.

[23] Lee, Hyeopgeon, Kyounghwa Lee, and Yongtae Shin. "A GTS allocation scheme for emergency data transmission in cluster-tree WSNs." Advanced Communication Technology (ICACT), 2012 14th International Conference on. IEEE, 2012.

[24] Shih, Bih-Yaw, et al. "The development of enhancing mechanisms for improving the performance of IEEE 802.15. 4." International Journal of Physical Sciences5.6 (2010): 884-897.

[25] Tao, Liqiang, and Fengqi Yu. "A novel congestion detection and avoidance algorithm for multiple class of traffic in sensor network." Cyber Technology in Automation, Control, and Intelligent Systems (CYBER), 2011 IEEE International Conference on. IEEE, 2011.

[26] Lee, Dongho, and Kwangsue Chung. "Adaptive duty-cycle based congestion control for home automation networks." IEEE Transactions on Consumer Electronics 56.1 (2010).

[27] Sharma, Tripti, Brijesh Kumar, and G. S. Tomar. "An efficient condensed cluster stable election protocol in wireless sensor networks." International Journal of Smart Device and Appliance 1.1 (2013): 17-28.

[28] Shi, Kai, et al. "Receiver-assisted congestion control to achieve high throughput in lossy wireless networks." IEEE Transactions on nuclear science 57.2 (2010): 491-496.

[29] Misra, Sudip, Vivek Tiwari, and Mohammad S. Obaidat. "LACAS: learning automata-based congestion avoidance scheme for healthcare wireless sensor networks." IEEE Journal on Selected Areas in Communications 27.4 (2009).

[30] Zhong, Tang, Mei Zhan, and Wang Hong. "Congestion control for industrial wireless communication gateway." Intelligent Computation Technology and Automation (ICICTA), 2010 International Conference on. Vol. 1. IEEE, 2010.