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Priority-based Channel Scheduling and Route Discovery for IWSN Applications

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Accomplishing a reliable transmission of data takes a vital role in Industrial Wireless Sensor Networks (IWSN) so as to overcome the practical messes in monitoring the industrial equipment deployed in a real-time scenario. The parameters sensed from each machine get transferred over to the controlling device through a multi-hop fashion in a networking environment assisted by a ZigBee standard. Taking concern over the information transmission, the PAN coordinator deployment scores a key impact in realizing a full-fledged proficient IWSN. PAN holds the responsibility of stipulating channels for communicating sensed information from sensing devices to the controlling authority. Allocating channel with proficiency certainly, mitigates the energy exhausted for transmission. In a case of acquiring a poor channel for transmitting the sensed information, then congestion occurs that consequently leads to a congested state of a channel. The traffic accustomed out of sensing some sorts of critical criterion should get transmitted with an utmost preference amidst of regular traffic. At this juncture, the latency for transmitting other data packets significantly surges and hence, the energy disbursed with respect to waiting also increases. Many techniques prevailing at presents such as IEEE 802.15.4 and data gathering approach that involves in relying upon sensed information through a multi-fold relaying scheme does not cater a sufficient channel slot without any congestion and utilizing those freed up channels for other highly prioritized sensing devices to transmit information. In order to get rid of these issues, this paper presents an effectual Priority based Scheduling with a Slot based Route Discovery (PCS-SRD) methodology. The procedure of route discovery gets accomplished on the basis of pre-defined slots and hence, the concept of energy conservation gets fulfilled. Likewise, effectiveness in transmitting information with an extreme urgency traverses the network deprived of subjecting towards any congestion through a high prioritized channel. Hence, the proficiency of the devised mechanism gets compared with those prevailing methodologies in terms of reliability, average delay, and throughput and power consumption.

Keywords: burst request, industrial wireless sensor network (IWSN), personal area network (PAN) coordinator, priority assignment, slot scheduling

1. INTRODUCTION

Comprehensive automation in the production plant of industries guided towards the development of IWSN that is emerged as an outcome after rectifying the predicaments

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found engraved in traditional WSN. The wide-ranged coverage in spite of the energy as well as resource constraints is alleviated by means of employing a proficient IWSN. The basic claim of acquiring cost efficiency along with information reliability is accomplished in IWSN through the robustness exhibited by zig bee / IEEE 802.15.4 standard. The information sensed from the machinery are transmuted to the respective monitoring authority via implication of a cross layered mechanism. Enhancement in overall life span, as well as the mitigation of threat involved, is accomplished through the timely provision of up-to-date information regarding the machines deployed at work station. This sort of criterion is plotted as a crucial necessity for migrating towards the IWSN [1]. Even the machinery involved in a rotary motion is also monitored with an ease through utilization of IWSN in an industrial area. The ultimate motive fulfilled out of realizing IWSN within an industrial ambiance is to maintain the entire environment away from incurring any sorts of impending loss with respect to some malfunctioning nature of machinery. Manual monitoring is not all alone sufficient for the hefty sized industries and it requires an intensified monitoring methodology to cross-check the proper functionality of machinery [2]. Assimilation of well-equipped wireless sensing devices within IWSN successfully accomplishes this requisite. It can be utilized for varied activities such as pollution analysis, safety screening, production examining, leakage recognition and fault identification in order to evade and prevent those machinery from latent deterioration [3]. Owing to the necessitation of such a robust network, the inhibitions existing in it must be eradicated [4]. Any sort of mishap to be inferred is aborted in prior due to the continuous monitoring via sensor. At this juncture, the key aspect to get resolved is the intercepting nature exposed by a simple networking environment [5, 6]. Those routing procedures prevails at present usually transmits the sensed information from end devices to the controlling authority by means of deliberating a diminished number of hops as the vital criterion 7. Irrespective of the delay criterion involved, the time-oriented data acquired should not be leftover as a residue without being disseminated to the controlling authority. This action consequently leads to adverse effects in the real-time scenario of an industrial environment. Since the ZigBee serves as the proficient medium for communicating sensed information, the channel utilized for communication must get stipulated only within this restricted channel that prolongs only for a minimized bandwidth range. In order to alleviate the delay criterion involved in transmitting the information, the channel must be freed from congestions. Zigbee is capable enough to relieve all sorts of channel congestions through its inbuilt Zigbee stack layers. Owing to the incessant surging in an accomplishment of the wireless devices in accordance with the reduction of its production cost, the monitoring is eased [8] by means of deploying a large number of devices wherever necessitated. In spite of installing a vast amount of sensing devices, the sensed information must be transmuted to the monitoring controller within the stipulated time span deprived of any negotiations in QoS factors such as reliability, adaptability, affordability, and security [9]. The timely dispatch of information primarily necessitates availing a channel for communication irrespective of the pre-defined delay restrictions. In order to revoke the indulging delays owing to lack of communication channel, an effectual methodology that is capable of allocating channels on the basis of priority is devised in this paper termed as priority based scheduling with a slot based route discovery (pcs-srd) methodology. The crucial demand of transmitting that sensed information from the surrounding machinery opts for timely dispatch in order to accomplish a productive scenario is contented. Hence, the priority based channel scheduling introduced in this paper complemented with slot based route discovery for configuring the IWSN and extending its function in order to manage the machinery in a proficient manner. The development of IWSN is arranged under Zigbee standard. The IWSN used in this method to improve the efficiency of the system, and to identify the faults that is to occur in future. Also, the use of ISWN produces advantages such as cost reduction and scalability. The paper organized as follows: The detailed description of the related works on congestion-aware routing protocols deployed to accomplish a resilient IWSN is discussed in Section 2. The implementation process of Priority based Scheduling with a Slot based Route Discovery (PCS-SRD) methodology is described in Section 3. The comparative analysis of proposed approach with existing congestion-aware routing protocols provided in Section 4. Finally, the conclusions about the application of proposed work on various IWSN based communication scenarios are presented in Section 5.

2. RELATED WORK

A unified management of wireless sensor devices requires the industrial authorities with the capabilities of provisioning the network infrastructure support to IWSN applications. N. Yang, *et al.* [10] endorsed an inventive segmented slot assignment methodology for enhancing the proficiency of retransmission and reliability of the information being passed within the multi-hop IWSN being deployed through three varied approaches such as Fast Slot Competition (FSC), free node Scheduling and Segmented Slot Assignment (SSA). The information transmission was unquestionably boosted with a restricted range of resources being slotted within a network constructed on the basis of a Time Division Multiple Access. Accomplished a diminished rescheduling cost while lagging with node failure estimation and discovery of an alternative way with an increased computational complexity. Vitturi, *et al.* [11] concentrated on improving the reliability of timely communications involved within the industrial environment by means of exploiting Rate Adaptation (RA) methodology. The transmission rate involved transferring packet was gradually diminished with respect to confinement of SNR value to a fixed level in a predefined manner still it invulnerability towards managing the noisy inputs was uncertain. Hassan, *et al.* [12] suggested an effectual methodology through assimilating dynamic priorities acquired in Guaranteed Time Slot (GTS) with respect to variation in traffic and revising the duty cycle in a dynamic manner in order to enhance the proficiency of IEEE 802.15.4 standard protocol.

An accurate balance between end-to-end delay as well as the power consumption was accomplished through a regulated allocation methodology. Beyond all of these gainful outcomes, the data transmission along with optimization in facilitating a storing mechanism with respect to its escalating size was complicated in duty cycle revisions.

Ouanteur, *et al.* [11, 13] established a Low Latency Deterministic Network (LLDN) methodology for IEEE 802.15.4e by means of incorporating a three-dimensional Markov chain model through the appropriating stationary probability distribution. The devised LLDN approach realized an enhanced reliability in transmitting the information accompanied with the mitigated consumption of energy that consequently leads to an improvement in terms of throughput owing to the alleviation of collision probability. However, the restriction observed with LLDN was its inability for reconfiguring itself in a dynamic manner in accordance with the wavering traffic that differed from time-to-time. Sheng, *et al.* [14] deliberated the industrial ecosystem on the basis of sensor management in a real-world scenario for monitoring the equipment that was deployed in the industrial arena through an incorporation of cloud based RESTful web service as well as lightweight cross-layer design. The devised industrialized ecosystem was accounted for its diminished complexity and proficiency towards managing the devices subjugated within an IoT environment. The restriction in rendering a service with an effectual QoS was restrained towards limitation of resources.

Marchenko, *et al.* [15] performed an experimental analysis in accordance with the three-fold relaying scheme defined on the basis of periodic, reactive and adaptive manner. Although the devised approach incurred a better delivery ratio, it was incapable of coping up with the data transmission without any delay amidst of interferences arising in the sensing field. Another restriction found was a lack of adaptive scheduling with respect to the transmission slot allocated that affected the lifetime of the entire resources. Ding, *et al.* [16] developed a risk analyzing approach meant for examining the industrial operations relying upon indoor WSN termed as Real-time Big Data Gathering (RTBDG) algorithm. Though, many sorts of complications arose with the lifetime of resources that were provided with the limited energy constraints.

De Guglielmo, *et al.* [17] discussed about IEEE802.154e for the enhancement and additional functions for IEEE802.15.4 standard to identify the emerging needs of embedded industrial applications. The limitations of IEEE802.15.4 was overcome by the 802.15.4e standard. Also 802.15.4e of standard IEEE helps to provide better performance of the system. Hodge, *et al.* [18] surveyed on varied configuration utilized for sensor deployment in order to resolve the practical complications involved in sustaining the robustness of the railway industry under the control of an IEEE 802.15.4 standard though, it was not subjected to the boundaries confined for the diversified ambience that contained fluctuating communication channels without a stipulated constraint.

Du, *et al.* [19] dealt with widespread analysis that encompassed both beacon enabled as well as non-bacon enabled mode that were deployed in accordance to the synchronizing methodologies of beacon tracking. Moreover, the devised methodology was unfair to resolve the crisis in disastrous circumstances. Suto, *et al.* [20] recommended a Wireless Computing System (WCS) that was capable managing the entire industrial environment both in terms of energy as well as delay criterions by means of utilizing a sleep scheduling methodology. Though the issue of power consumption was resolved, the unpredictable and emergency traffic, the excessive delay and the instability in operation occurred.

Lin, *et al.* [21] examined the ways for accomplishing spectrum evenness through exploiting a predefined set of procedures termed as Local Equilibrium-guided autonomous Channel switching (LEQ-AutoCS). The channel occupancy was segregated and uniformed in an autonomous manner through a fair means of spectrum utilization. The restriction was observed with periodically surging count of wireless devices that made the LEQ-AutoCS incapable of sharing the spectrum with respect to restrictions in resources.

Zou and Wang [22] deliberated the seizing tendency of the Industrial Wireless Sensor Network (IWSN) in transferring the sensed information from a particular sensor node to the sink node by means of manipulating an optimal sensor scheduling methodology. In order to assess the proficiency of the entire IWSN, an eavesdropping attacker node was deployed within the network of wireless transmitting lines through which the radio waves were usually propagated. Though the intercept probability was significantly mitigated through the physical layer, the QoS constraint was not efficient to meet the transmission of sensed information within a stipulated time. In case of sensing some information in a temporal basis, then it can be discarded completely.

Zhang, *et al.* [23] recommended an inventive integrated channel-timeslot allocation algorithm formulated on the basis of routing-tree coloring mechanism, which was specifically designed for an IWSN that certainly necessitated a proficient timeslot as well as channel assignment strategies. It was accomplished in a two-fold manner and hence, achieved a proficient utilization of resources existing within an operating channel. Though, the devised algorithm was not adaptive with the channel allocation that would alter in a dynamic manner with respect to the interference range.

Hwang, *et al.* [24] endorsed a time-slot scheduling algorithm for both distributed time as well as constant time in order to get rid of the issue arising due to the Time-slotted Channel Hopping (TSCH) policy deliberated in the MAC layer. Although the devised methodology accomplished a diminished delay in transmitting packets within a minimized duty cycle, the appropriate balance in allocating channels was not adaptive with respect to the alterations happening within the network.

The problem being revealed out of surveying those prevailing methodologies accounted for the following issues,

- Unconfined duty cycles for transmitting data with respect to intensifying information size
- Maladaptive channel scheduling mechanism for wavering network traffic
- Huge consumption of power irrespective of a power-constrained scenario
- Not resilient towards attack interfering into the network at the time of transmitting data
- Leaving out the information being sensed on the timely basis without being transmitted

The detailed literature review presented in this section conveyed that the trade-off between the high throughput and low energy are the major issues in the IWSN-based industrial monitoring. This paper overcomes the issues in traditional protocols with the combination of fusion techniques with the priority assignment through the recursive process.

3. PRIORITY-BASED CHANNEL SCHEDULING WITH SLOT-BASED ROUTE DISCOVERY

This section converses the implementing strategy of the suggested Priority based Channel Scheduling accompanied with Slot based Route Discovery (PCS-SRD). The PCS-SRD is proposed to provide superior performance over reliable communication. Whereas, IEEE802.15.4e used in the existing system gives only support to the industrial applications. However, the existing system provides high reliability, low energy consumption, high throughput, and reduced delay the performance is not superior. Hence, the novelty of this approach overcomes the issues in existing system and provides better performance in the industrial wireless communications. PCS-SRD is meant for configuring the IWSN and prolonging its functionality for managing the machinery in a proficient manner. IWSN devised in this paper is deployed under a Zigbee standard that factually initiates the Personal Area Network (PAN) coordinator along with its sensor nodes in a star topology. The PAN node simply serves as a data collector and also it is accountable for managing the sensor nodes deployed in the sensing field. Whole responsibility of managing deployed network lies on the PAN coordinator in terms of receiving the sensed information from the Reduced Utility Network (RUN) nodes through the Full Utility Network (FUN) nodes. The PAN finds the initial set of a node that exists in a single hop of its vicinity is termed as FUN nodes and the other sensor nodes employed to sense the machinery is termed as RUN nodes. After deployment of the entire network, the RUN node searches for a route to reach the PAN through FUN nodes. On receiving the initial slot from the controlling PAN coordinator, every single RUN commences their operation of sensing and probably transfers the information being sensed, to the FUN in a single slot initiated. If the FUN nodes are free enough to accommodate the information being sent by the slotted RUN node, then the data transmission is initiated abruptly without any sorts of delay factors. If the controlling FUN node is busy in transmitting information sensed by some other RUN node, then the search is prolonged until another FUN node found at a feasible transmission range. The provision of guaranteed channel access in real-time IWSN applications is done by Time Division Multiple Access (TDMA) slots. The unit in TDMA that allows the transaction once refers time slots. The scheduling algorithm implemented here utilizes a priority based time slot schedule. The channel being stipulated for each RUN node for transferring the information sensed completely depends upon the monotonicity of information perceived from the particular sensor for certain instance of time. On realizing such an occurrence the priority of channel stipulated for that particular sensor is re-slotted into non-prioritized sensor. Owing to this criterion, the information being sensed is not transmitted to the immediate FUN node. These slots incurred in surplus are allocated to other RUN nodes that are prioritized with an utmost preference. The nodes that are re-slotted to the longest time span were shifted to sleep mode. Fig. 1 illustrates the overall flow of the proposed PCS-SRD methodology.

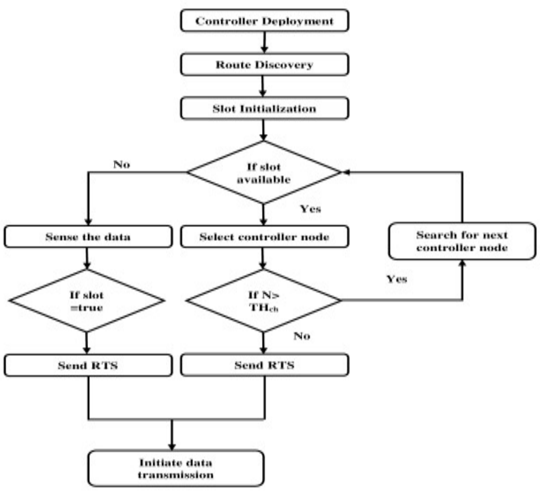

Fig. 1. Work flow of proposed PCS-SRD approach.

The controller is being deployed for each and every node. The route discovery decides through which slot the data to be transmitted. Then the slot initialization is done. Then, check whether there is an availability of slot. If yes, then select the controller node. In case, the node error is minimum then RTS is transmitted and hence the transmission of data will be initiated successfully. Rather, the node error is greater than TH_{ch}, then again the slot search for the next controller node and check the slot availability. The process of searching the next controller node and the availability of node is continued till N becomes lesser than TH_{ch}. Similarly, while focusing on slot availability process, and if there is no slot then the data will be sensed until the slot becomes true condition. Once the slot achieves true condition then the RTS will be sent and data transmission will be initiated. Thus, based on these processes the energy utilized for transmitting the information sensed is preserved in an efficient manner. While comparing PCS-SRD with the IEEE802.15.4e LLDN, the proposed methodology provides significant distance performance over reliable communication based on the support of adaptive slot for communication.

3.1 ISWN Formulation

A proficient IWSN is formulated through manifold stages by means of positioning varied nodes getting readily operated within the industrial arena.

(i) PAN Deployment

The devised IWSN scenario is formulated by means of exploiting a zig bee standard that comprised of a Personal Area Network (PAN) coordinator, which holds the responsibility of controlling the entire network communication [25]. The entire architecture is positioned upon the IEEE 802.15.4/Zigbee stack. Both physical layers, as well as MAC layer, is managed under IEEE 802.15.4 standard in order to enhance the overall reliability of links between nodes and hence makes the system robust to withstand against interferences and noises realized at the time of transmitting data. Other two trailing layers stated as network layer and application layer is managed under the reign of Zigbee standard that incorporates a multi-hop traversal for spreading out the network framed to a wider arena. Thus, the link between connected nodes lying within the network is prolonged in a smooth manner even if there exist any sorts of link breakage in intermediate stages. This tendency certainly enriches the capability of self-restorative and auto-configuring nature for the deployed IWSN. Network communication utilized here accounts for a cross-layered approach that is simply concerned about both sensing and monitoring of the deployed industrial equipment within a confined area. The devised approach gets into an operation through utilization of the MAC layer of the WSN that completely depends upon the IEEE 802.15.4 standard.

A cluster-tree formulation is trailed to articulate the entire IWSN within a star topology by means of incorporating IEEE 802.15.4 standard as plotted in Fig. 2. Here in this network formed, the PAN coordinator serves as the root of tree from where all the controlling signals are passed on to all other nodes being connected. The network topology is initiated by opting for a PAN coordinator that subsequently mitigates the total amount of energy being consumed for accomplishing the network operation along with diminished routing delay. The PAN coordinating node is employed in such a way that the traversing complexity incurred by other nodes within the network experiences a minimized number of hops to reach it. Hence, the energy utilized in transferring information through multiple hops is significantly mitigated.

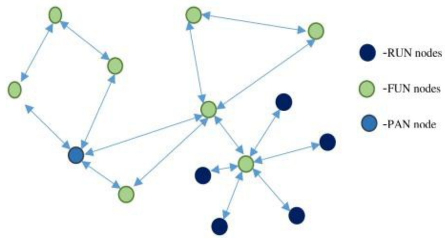

Fig. 2. Deployed IWSN scenario.

(ii) Positioning Secondary Nodes

After deploying the PAN coordinator, the secondary nodes involved for fulfilling the sensing strategy is organized around the deployed PAN coordinator node. A peculiar strategy of deploying nodes in a two-fold way trailed at this stage. Nodes at the vicinity, probably a node positioned in a single hop with a maximum amount of energy forms the set of FUN nodes. The nodes that are lying within its reach are assigned as RUN nodes for every single FUN node. Other nodes employed within the network are not supposed to communicate with those Run nodes employed in the sensing field. All sorts of FUN nodes as well the PAN coordinator is responsible for accomplishing an efficacious information transmission right from the sensing field to the centralized authority (PAN). Parameters involved in stating the functionality of particular machinery, where it is implanted for monitoring are relayed by the RUN nodes. The parametric information dispatched from those end nodes usually holds the position of a leaf node in cluster-tree architecture, traverses all through the network by following a multi-hop strategy.

(iii) PAN Coordinator Impact on Energy Consumption

The position of PAN node also creates an impact with energy consumed for undertaking a complete transmission of information incurred from the sensing device. Total amount of energy expended out of managing the real-time traffic being generated from the sensing field is segregated into a dual-fold manner given as,

- Carrying out information transmission along the route path found in prior probably denoted as $E_{routing}$.
- On realizing a corruption in transmitted information or some inaccessibility of a MAC layer, an information re-transmission is accomplished E_{mac}.

In order to explore a routing path from the source node *i.e.*, from RUN node to a PAN through FUN, with a mitigated computational complexity, a hierarchical approach is employed in the formulated cluster-tree networking structure. A parent-child association is found out from the RUN nodes all through FUN nodes. Unlike the conventional approach that does perform data gathering the data packets are sent and received through the nodes that are positioned in a 1-hop distance. In a similar way, the information being sensed from the end device probably a RUN node deployed in the sensing field transmits the information being sensed to its immediate neighbor that may be another RUN or even a FUN node. Thus, the information reaches the PAN coordinator in a 1-hop reach itself. Through this approach, the overall energy spent for aggregating information is eradicated and the parent node simply receives the information from its child node and promotes to its parent node concerned and the similar procedure reiterates in a reverse order.

$$E_{routing} = (E_{tx} + E_{rx}) \times \tilde{L} \times N \tag{1}$$

The energy being toiled out of receiving and sending data packets is computed as Eq. (1). Where, E_{tx} and E_{rx} account for the energy utilized out of transmitting and receiving the packets among those nodes, $\tilde{L}$ indicates the mean level of nodes acquired and N specifies the total number of nodes clustered within the tree. In such a network deployment no two RUN nodes are permitted to converse with each other unless there exists a FUN node in between them.

3.2 Slot Based Route Discovery

The routes are revealed by every single node as per their own slot being stipulated. Since the industrial environment holds the only the pre-defined number of sensing devices that is the RUN nodes employed in a fixed manner. These set of nodes are organized in such a way that all sorts of nodes are capable of reaching its mastering parent FUN node in a single-hop distance. In general, the initial slots are allocated for each and every RUN nodes as a single slot. Hence, all sorts RUN nodes initiate its sensing and start transmitting its information regarding the physical as well as surrounding conditions of particular machinery on which it is being fixed. In order to transfer the sensed information, from the sensed RUN node to the respective FUN node the route to reach the obvious destination must be excavated initially. Hence, route exploration from RUN node stated as sensor node i to the FUN node j is carried out first by means of sending route request (RREQ) packet from the source RUN to the target FUN node. On receiving the route reply packet (RREP) the route is successfully established. The priority on which the channels for discovering route is allotted by the PAN coordinator by means of assessing its role_label () being defined in the request sent by the sensor.

Time (*t*)	**Priority (*p*)**	**Status (*s*)**	**Role_label (*r*)**

Fig. 3. Fields contained in sensor information.

Fig. 3 illustrates the overall structure of sensor information traversed from a sensor. The parameter t represents the time at which the information is sensed from that particular machine. s resembles the status defined by the user that is utilized to stipulate the priority for that particular information. On prolonging the sensing procedure, the priority gets altered on the basis of the urgency of information concerned for every sensed data and the status of each and every node is postulated as the Sleep () or in Active () position. The priority assessment for every information is done by means of employing a specific Channel Information based Priority Assignment (CIPA) approach.

3.3 Priority Based Channel Scheduling

Priority based channel scheduling is accomplished by means of applying the CIPA approach in which the channels being allocated for every sensing node assessed on the basis of channel availability. After initiating the communication slot the data being sensed by each and every sensor gets traversed to reach the PAN through FUN on themselves stipulated slots. At certain specified instance if the PAN notifies the monotonicity in the information being perceived from that particular sensor then sensor concerned is meant to get scheduled in a delayed manner. The channel slot allocated for that particular sensor is certainly freed to stay back with its process of transmission and hence, it is made available for the other devices. In case, a sensor node tends to experience a dreadful condition in the functionality of a machine, then it tends to reach the PAN node with an utmost urgency. At this juncture, the RUN node simply checks for the availability of controller node *i.e.*, the FUN node. On realizing its accessibility, it readily accomplishes that particular node to transmute the information possessed by it. If not the search for next controller begins by means of initiating a new route discovery procedure.

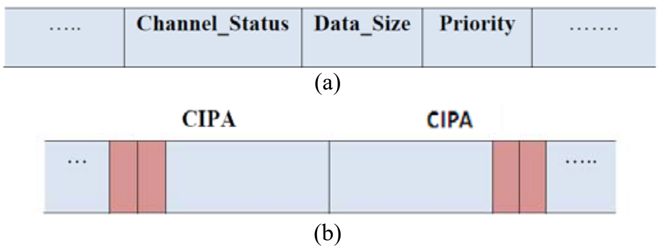

Fig. 4. (a) General time slots and (b) CIPA based time slots.

The sensor periodically validates the communicating slot to check whether the monotonous information exists or not. Here, the Channel Information based Priority Assignment (CIPA) table is maintained to improve the flow entry in the burst flow in priority based scheduling based on the assigned wavelength as depicted in Fig. 4 (a). The frame consists of a channel_status in which the availability of channel whether it is active or idle is indicated. Next component indicates the size of the data being sent and the final signifies the priority prescribed for that message concerned. Fig. 4 (b) illustrates the CIPA time slots allocated for checking channel availability and for assigning priority for the messages as per the situation prevailing in the sensing field. The components in the CIB (Channel Information Base) are match fields, counters, instructions and the flow information. The flow information field in the CIB contains the following parameters:

- Number of total bursts
- Number of bursts with successful reserving capability
- Packet identities

If the status of a slot is switched over for an Active () state then it enters into the sensing mode and starts transmitting the sensed information. If the slot is not still allocated in the callback () timer and also elongates for more than a specific amount time period, that particular sensor is meant for getting subjected to a sleep () mode and is inhibited from transmitting the sensed information by means of altering its priority. Subsequently, if a sensor is waiting for a slot with a critical information to be transferred, it is stipulated with the highest priority through the inducement of a burst_request () and is sent to the PAN coordinator. The PAN coordinator holds the responsibility of formulating remedial measure by incorporating the necessitated information from other sensors.

Algorithm for scheduling communication channels based on priority

Residual energy ← E_{res}, Required energy ← E_{req}, Threshold energy ← E_t, Congested path ← $path_c$, No. of devices ← N, Contention Window ← W, Back_off period ← T_{back}, Free channel evaluation ← ch_{free} Slot → s, No. of connections ← N_c, threshold value of channel ← TH_{ch}
For ($s = 1: N$)
    If ($N_c < TH_{ch}$ && $E_{res} > E_{req}$)
    Select T_{back};
    Path ≤ no congestion;
        Else if ($N_c > 1$ && $E_{res} > E_t$)
        Select next route;
        Else if ($path_c == 1$)
        If (Data.critical == true)
        Set RREQ for parallel transmission;
        Route path = true
        Break;
        else
            wait for callback;
        else
            select next route;
        end if
    end if
end for
If (Route_path == true)
//*Set congestion control*
Compute queue size with (2), (3) and (4)
End if

As a means of resolving the burst_request () the congestion available in every feasible path found is assessed. Next, the PAN coordinator reset the priority of communication to the maximum value and proceeds with other functionalities. Initially, the threshold involved in a channel is computed by means of assessing the optimal number of RUN nodes capable of getting connected with a single FUN node as well as the residual energy present in a particular node. A next route opts if the threshold of node concerned exceeds or if the residual energy remaining in it accounts for a highly minimized value. In case if the sensed information is labeled as critical, then the parallel transmission is initiated by means of splitting the sensed information into different routes. At this juncture, congestion control is employed for making the queue available. Before opting for a device its queue size is assessed, if there is a queue space available in spite of waiting packets this critically labelled packet is also sent through it.

$$Qmint = 25\% QueueSize \tag{2}$$
$$Qmaxt = 3 * Qmint \tag{3}$$
$$Qavg = (1 - Wtq)\ Qavg + Occupied\ Q * Wtg \tag{4}$$

Where, *Wtq* represents the overall time for the packets waiting in the queue to get executed. *Qmint*, *Qmaxt* and *Qavg* indicates the minimum, maximum and average queue size respectively.

Before allocating, the callback () time is checked it the time is so long then the search of next route is enabled. The slots freed from those non-prioritized sensors are re-allocated for the highly prioritized sensors. Thus the critically labeled packets reach the PAN coordinator. Consequently, the actual nature of the ambience from where the burst_request () being generated is crosschecked by the PAN coordinator. It simply enables all slots necessitated for checking the criticality of the particular machine. At this time the RUN subjected to a Sleep () mode also is activated and the real condition is analyzed. Hence, the non-prioritized slots are completely utilized to resolve such a hectic issue.

4. PERFORMANCE ANALYSIS

This section elucidates the proficiency of the devised PCS-SRD algorithm in terms of transferring the sensed information to the PAN coordinator for accomplishing some sort of remedial deeds at needful times in contradiction to other prevailing approaches such as Slotted Carrier Sense Multiple

Access with Collision Avoidance (CSMA/CA), IEEE 802.15.4, Dynamic Properties (DP) & Dynamic Duty Cycle (DDC) with respect to consideration of parameters such as power consumption, average delay incurred for both slot allocation as well as packet transformation, success probability, reliability and throughput. The simulation parameters to validate the proposed MAC algorithms in NS 2 simulator are listed in Table 1.

Table 1. Simulation parameters.

Parameters	Values
Physical layer	IEEE 802.15.4
Network Size	50 × 50 m
CN location	25 m
Number of nodes	100
Data packet size	4800 bits
Simulation Period	150 secs
Listen Interval	10 ms
Buffer size	32
Initial Energy	1 J
Sample rate	10 samples / secs
Bandwidth	20 MHz
Data rate	250 ps

4.1 Throughput

The number of data packets sent over the total simulation period refers throughput. The mathematical formulation for throughput is expressed as

$$Throughput = \frac{Number\ of\ data\ packets\ received\ (bits)}{Simulation\ time\ period\ (secs)}. \tag{5}$$

The variation in simulation period and the corresponding throughput values are plotted in Fig. 5.

For both the minimized as well as the maximum amount of simulation time offered the throughput acquired by the devised PCS-SRD methodology gets linearly increased in a constant manner amidst of the surging load. The overall throughput criterion escalates on applying the suggested PCS-SRD approach is certainly better than other prevailing methodologies by 22%. Similarly, throughput obtained by IEEE802.15.4e LLDN mechanism is higher. Also, it is seen that throughput affected by collisions are minimized in IEEE802.4e LLDN respectively. When retransmission occurs in a dedicated timeslot, then there will be reduction in overhead. Thus, when comparing with the existing method, the proposed result shows that throughput is higher in LLDN IEEE 802.15.4e.

4.2 Average Delay

The lag in time horizon realized until a bit of information reaches the determined sink node right from the initialization of the sensing process is referred as the average the average delay. Here, in this paper the average delay parameter is computed in a dual-fold manner given as the average delay inferred with respect to allocation of a guaranteed slot as well as the restriction recognized in transferring the packets accumulated with respect to the surging number of devices deployed within the entire IWSN.

The disparities recognized in allocating slots for the particular device is illustrated in Fig 6. Among those prevailing methodologies analyzed the DP & DDC approach resulted in the minimized amount of average delay with respect to increasing number of slots being awaited by many devices employed in the sensing field. The GTS time slot in DP&DDC developed among total GTS length limit for more transmission of packets per GTS reduces the queuing delay. Average delay experienced by the sensing devices for

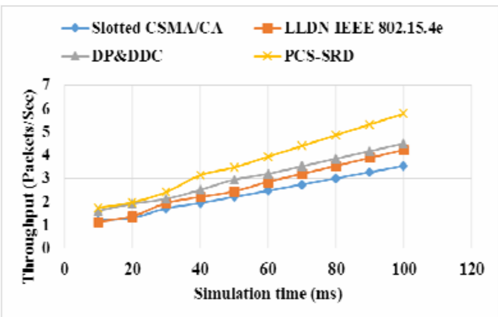

Fig. 5. Throughput analysis.

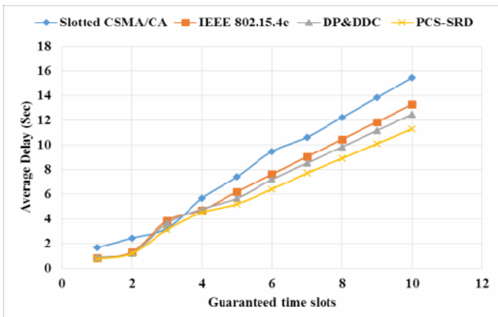

Fig. 6. Average delay analyzed for slot allocation.

getting into the slot on exploiting the DP & DDC methodology incurs a value of 12.475 sec while the formulated PCS-SRD approach experiences the mitigation in average delay by scoring a guaranteed slot in 11.286 sec itself and thereby subjected to the mitigation in average delay by 9%. Therefore, it can be stated that DP&DDC algorithm provides better performance due to its dynamic nature of the proposed methodology.

The enhancement realized with the proposed approach is due to the priority based channel scheduling applied in it. Fig. 7 evidently depicts the mitigation in average delay of the proposed PCS-SRD approach against those prevailing methodologies for sending the accomplished packets in a successful manner. From the figure it has been analyzed that when delay increases automatically number of device also increases dynamically. Among those existing methodologies analyzed the DP & DDC approach realized minimum average delay of 0.0594 sec that is certainly defeated by the proposed PCS-SRD methodology by exposing an average delay of 0.0486 and hence, measures a moderate contraction in average delay by 18%. Though the delay being realized is linearly increaseed, the proposed methodology highly suffices the requirement by mitigating the delay.

4.3 Success Probability

The measure of success probability P_s accomplished typically replicates the total number of successful transmissions realized within the network with respect to the load offered from the MAC layer of the network. The mathematical formulation is derived as,

$$P_s = T/L_{mac}. \tag{6}$$

The success probability rate gets linearly decreased as the load increases in a corresponding manner within the network. Though, the exposed success probability is higher than other prevailing methodologies by 8%. The success probability is calculated as function of offer load from the MAC layer of the network. Also, it is used to define the load balancing success over distributed system and helps to determine the probability during work load and measure of effectiveness of the system. Hence, based on aforementioned definition success probability proves to be greater than the other prevailing methodologies respectively. Fig. 8 illustrates the success probability inferred with respect to the load offered in comparison with other prevailing methodologies.

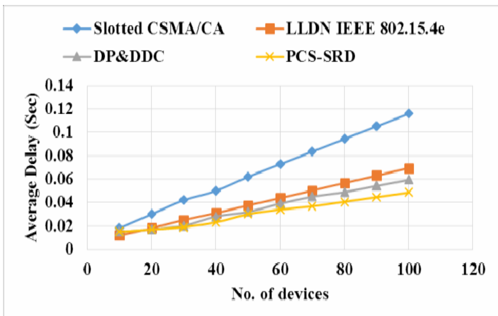

Fig. 7. Average delay analysis.

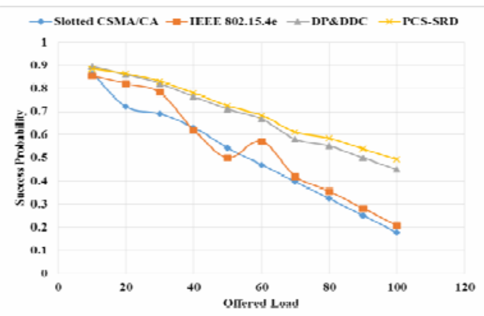

Fig. 8. Success probability analysis.

4.4 Reliability

The reliability metric is assessed with respect to the packet length realized for being transmitted from the RUN node to FUN node. Since reliability is one of the important aspect to design a network, the proposed methodology is almost sustained in a constant manner for the increasing number of devices persistently added into the network. When there is a decrease in congestion between the nodes then there will be a gradual increase in reliability. However, prevailing methodologies like LLDN IEEE 802.15.4 and DP & DDC methodologies serves almost in par with the proposed methodology. Hence the PCS-SRD typically performs better results when compared to the other techniques. The proposed reliability gets increased to about 5% than the other. Fig. 9 illustrates the reliability analysis done between various prevailing methods against proposed PCS-SRD methodology. As a result, the reliability of PCS-SRD proves to be greater than the slotted CSMA/CA for number of devices respectively.

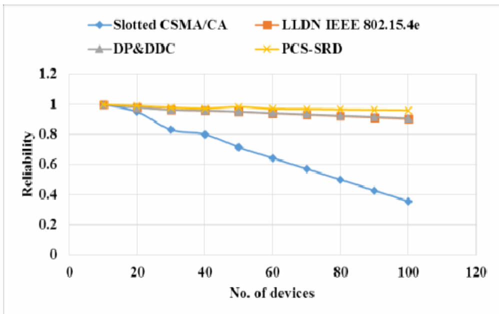

Fig. 9. Reliability analysis.

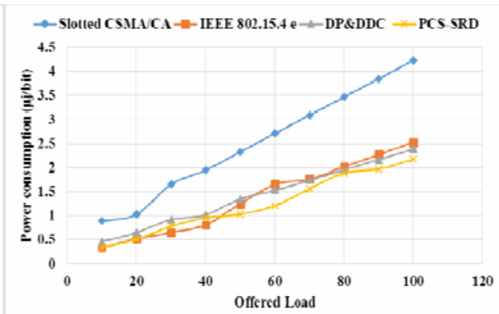

Fig. 10. Power consumption analysis.

4.5 Power Consumption

The power consumed by each and every node for transferring for transferring the exactly perceived number of bits with respect to varying load offered within the entire network is assessed through this analysis. The load contributed within the network is typically the average load implicitly added in the MAC layer among the information acquired form each and every node. This section investigates the effect of proposed PCS-SRD methodology on all nodes with respect to maximum load offered.

$$Power\ Consumption = \frac{E_{avg}}{P_s C} \tag{7}$$

The variations of Power consumed on nodes for varied load offered for unlike methods are shown in Fig. 10. In existing methods, the DP & DDC provides minimum amount of power consumption of 2.385 $\mu j/bit$ even at the maximum load of 100 due to the lack of slot based route discovery to forward the sensed information. But, the enhancement accomplished in scheduling scenario of the proposed work diminishes the power consumption to 2.1782 $\mu j/bit$ for an utmost level of load. Similarly, the slotted CSMA/CA requires high bits than the other transmissions due to its collision which is in the need of retransmission and high power usage. It is known that increase in high load may also increase the power consumption for all transmission nodes that are spontaneous due to its high transmission and power consumption. Thus, the comparison between the proposed PCS-SRD approaches with the prevailing methodologies clearly exposes the effectiveness of the devised approach indicating a lessening of 8% with the overall power consumed.

5. CONCLUSION

In this paper, we proposed a consistent and reliable provision of a transmission channel for communicating the information sensed from machinery to accomplish a full-fledged monitoring of the industrial area. On the basis of criticality of the information being sensed, the priority is assigned to every single sensor in order to adopt a communication channel with an utmost preference. The slots are re-scheduled by means of exploiting an effectual CIPA approach. Hence, the delay incurred in communication is highly mitigated and the devised PCS-SRD methodology exposed a significantly outpacing performance in accomplishing a reliable communication by means of providing an adaptive slot for communication. The overall delay experienced in waiting for accomplishing a communication channel slot is modestly mitigated and hence, the energy disbursed in waiting is clogged. Since the congestion in channel is avoided on the basis of priority assigned for the information being sensed, the overall power consumed for accomplishing a successful communication is highly mitigated 8% when compared with other prevailing methodologies that usually assist in performing a perfect industrial monitoring.

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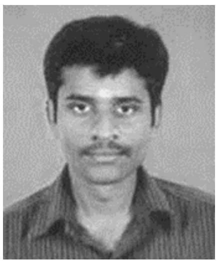

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