© 2005 – ongoing JATIT & LLS

ISSN: 1992-8645

www.jatit.org



# CLUSTERED HEED SCHEME FOR CONGESTION AVOIDANCE IN COGNITIVE RADIO SENSOR NETWORKS

# <sup>1</sup>JANANI .S, <sup>2</sup>RAMASWAMY .M<sup>2</sup>, SAMUEL MANOHARAN .J<sup>3</sup>

<sup>1</sup>Assistant Professor, Department of ECE, A.V.C College of Engineering, Mannampandal, India-609305. <sup>2</sup>Professor, Department of Electrical Engineering, Annamalai University, Annamalai Nagar, India-608002. <sup>3</sup>Professor& Head, Department of ECE, Bharathiyar College of Engineering and technology, Karaikal, India-609609.

E-mail: 1 jananiphd15@gmail.com, 2 aupowerstaff@gmail.com, 3 samuel1530@gmail.com

# ABSTRACT

Reliable and high throughput data delivery in cognitive radio sensor networks (CRSN) remain an open challenge owing to the inability of the source to quickly identify and react to challenges in spectrum availability. The paper proposes a novel congestion control scheme called Enhanced congestion detection and avoidance (ECODA) for CRSN to operate in a mobile framework. It articulates a clustered HEED based mechanism in an effort to exploit the available spectrum on the principles of the cognitive radio technology. The ECODA involves a threefold methodology in order that it uses a dual buffer threshold and weighted buffer difference for congestion detection and a bottleneck-node-based source sending rate control and multi-path loading balancing. The attempt owes to evaluate its performance on a NS2 platform and bring out the improvement in indices through the use of the congestion avoidance mechanism. The results project far reaching impacts in the sense it portrays the viability of the procedure and allows it for exploring fresh applications in this domain.

Keywords: Cognitive radio sensor networks, ECODA, Clustered HEED, Throughput

# 1. INTRODUCTION

The demand for radio spectrum continues to increase due to the emergence of wireless applications in different perspectives and as a consequence augurs the growth of communication infrastructure in a variety of fields. The existing wireless networks characterized by static spectrum channel allocation belong to a licensed user, known as primary user (PU) on a long-term basis. However the existence of licensed spatially- time idle relates to inefficient utilization of large portion of the wireless spectrum.

A cognitive radio based wireless sensor network (CRWSN) or cognitive radio-based sensor network (CRSN)falls in the category of a multichannel wireless network in which the sensor nodes dynamically adapt themselves to the available communication channel[3].The CRWSN accrues a host of advantages that include communication reliability and multi-path environment[4].Leveraging on the benefits of the opportunistic spectrum access provided by cognitive radio technology, the wireless sensor

networks (WSNs)acquire the potential of operating at lower licensed spectrumband[2].

The cognitiveradio (CR) forges to be a promising paradigm forspectrum utilization within decreased quality of service (QoS) in wireless sensor networks. It urges to be the key technology for dynamic spectrum access (DSA) and enjoys the capability to share the wireless spectrum with licensed users. It results to improve spectrum efficiency and network performance by adaptively organizing the channel access to different users according to the radio environment characteristics.

The interference avoidance to the PU signal by the other user trying to access the channel opportunistic allows to be of paramount importance in CR. It becomes imperative for the other user known as the secondary user (SU) to detect the presence or absence of the PU signal through channel sensing. The right of the PU to the channel requires to be protected by the SU while it maintains its own quality of service requirements [1].

ISSN: 1992-8645

control. The

www.jatit.org

of

number

5675

plan the distribution of the slots and channel offsets across the entire network topology graph [11].

A traffic aware scheduling algorithm that builds a centralized schedule based on the network topology has been articulated. The traffic scheduling algorithm has been ordained to manage queue eliminating traffic congestion and thus avoid packet drops due to overflow of memory buffer [12]. It has been framed to allocate timeslots and channel offsets based not only on network topology but also on traffic conditions.

The traffic load generated by each node has been formulated together with a distributed version of the scheduling algorithm [13]. Within the 6TiSCH architecture, the 6top sub-layer has been entrusted to schedule the communication resources in time and frequency. The on-the-fly (OTF) bandwidth reservation module has been evolved as a distributed approach for adapting the scheduled bandwidth to network requirements.

A schedule based on the fly has been constructed according to the change in nodes demand and obtain a slot-based "step-by-step" energy consumption model of the TSCH schedule mechanism [14]. It has been applied to different scenarios for bringing out the potential effects of network congestion. The reliable, efficient, fair and interference aware congestion control (REFIACC) has been sought to prevent the interferences and ensure a high fairness of bandwidth utilization nodes by scheduling among sensor the communications [15]. The congestion and interference in inter and intra hot spots have been mitigated taking into account the dissimilarity between the links capacities in the scheduling process.

The congestion d etection and avoidance (CODA) has been extracted by jointly sampling the channel loading during every epoch and monitoring the buffer length for being filled to predict the occurrence of congestion [16]. It has been noticed that the backpressure message intensifies congestion due to high channel loading and needs explicit ACK from the sink to enable the lowering of the sending rate.

The cluster head (CH) has been seen to govern the energy associated with each node and the lifetime of each node judged by its energy level [17,18]. The periodic sensing of the channels has been drawn from two levels that include the duration of sensing and transmission to identify the

# Each node uses the packet transmission duration to estimate the channel capacity in congestion control and fairness (CCF) [6]. The congestion control becomes necessary in diverse range of applications and consists of the congestion and interference detection and a rate control mechanism establishment to adjust the reporting rate. The mechanism based on rate regulation between nodes use additive increase multiplicative decrease (AIMD) methods to balance the offered capacity, but does not support the nodes interference which turns out to be the main cause for the loss of packets [8]. The slew of metrics used for detecting congestion include the buffer length, packet inter arrival time, packet service time and channel load among others [7].

The occurrence of congestion reduces the

retransmissions which indirectly reduces the lifetime of the network [5]. It emanates either from a

transient nature caused by link variations or due to

persistent state because of source data sending rate.

The congestion control mechanism can be

classified into two categories in the form of end-to-

end congestion control and hop- by-hop congestion

performs exact rate adjustment at source and

intermediate nodes according to current QoS level

at sink node. The end-to-end orients to heavily

rely on round-trip time (RTT), which results in

slow response and low convergence [5].

End-to-end congestion control

throughput and increases the

A TDMA schedule has been laid to ensure maximum throughput and fair rate allocation by taking into account the requirement imposed on the network lifetime [8]. The lexicographic Max-Min algorithm has been used to formulate the rate allocation along with fairness, maximum throughput and slots reuse in the purpose to reach a minimum frame length [9].The initiative nodes have been forced to follow a schedule in order to transmit, receive or sleep in a slotted manner in accordance with the time synchronized channel hopping (TSCH) [10].

The TSCH schedule has been developed to indicate which channel to use as IEEE 802.15.4e and which neighbour to communicate within the concerned active slot for allowing many couples of nodes to communicate at the same slot using different channel offsets [5]. It has been proposed for optimizing the performance of low-power multi-hop networks along with an innovative approach for matching and coloring procedures to



ISSN: 1992-8645

<u>www.jatit.org</u>



E-ISSN: 1817-3195

vacant channels and enable the reduction in congestion.

The congestion has been avoided by means of setting thresholds and fixing priority [19], hop by hop congestion control scheme and persistent congestion bottle-neck based rate control attempted to increase the throughput of the network. The sending rate of collecting cognitive radio sensor in rate based generic additive-increase multiplicative decrease (AIMD) and additive increase and additive decrease(AIAD)congestion control schemes has been showcased to reduce congestion in sensor network [20].

Despite the developments in either identifying or preventing the occurrence of congestion, still the procedure requires enhancements in the process of routing to ensure the safe delivery of the packets to the destination.

# 2. PROBLEM DESCRIPTION

The main emphasis entices to formulate a multipronged strategy to avoid the occurrence of congestion in a CRSN and assuage an increase in the throughput of the network. It orients to trace the path of ECODA that serves to detect the congestion, bring in a control of the sending rate and be-hive a multi-path loading balancing facility. The procedure revolves around the use of a cluster based philosophy and examines the performance using NS-2 based simulation for HEED routing method. It bestows to establish the merits of the HEED scheme through the metrics obtained and enumerate its suitability for use in practical networks.

# 2.1 HEED Protocol

The Hybrid Energy Efficient Distributed Clustering (HEED) uses a distributed clustering architecture where it creates the cluster through a specific number of iterations. The clustered HEED owes to identify a set of CHs which can cover the entire field and deployed with n sensor nodes. Each node belongs to exactly one and only one cluster and engages to communicate with the CH in a single hop. While the clustering occurs in iterations of fixed numbers, the nodes perform the role of either CH (considering nodes with high residual energy and high proximity to the BS) or a regular node. The main feature of HEED relates to the convenience of multiple transmission power levels at the sensor nodes and since the cluster formation revolves around the theory of maximum load balance and increased life time, it allows HEED to

be applicable for those which require scalability, fault tolerance and extended life time.

The HEED works on first in the initialization phase, where the sensor nodes prompt probabilities to become CHs, and in the main processing phase the various procedures elect the CHs. The sensor nodes join the least communication-cost CH or announce itself as a CH in the finalization phase. It follows it up with a dynamic re-clustering at the beginning of each round in a predefined period of time.

The main advantage of HEED augurs the fact that it does not allow any node to be in more than one cluster. It enables a uniform CH distribution; but terminates after a fixed number of iterations and requires re-clustering to be initiated again. The HEED clustering improves network lifetime as it considers the nodes energy level for CH selection. The nodes only require local (neighbourhood) information to form the clusters. The energy distribution leads to enhancement in the lifetime of the nodes and stability within the network.

The Fig.1 explains the steps involved in the process of HEED based data transfer.



www.jatit.org

<u>15<sup>th</sup> September 2018. Vol.96. No 17</u> © 2005 – ongoing JATIT & LLS

### ISSN: 1992-8645

### 3. SYSTEM MODEL

The CRSN comprises of a large number of sensor nodes deployed either inside or very close to it and each node consists of sensing and data communication components to process the information before being sent to the base station. The sensor nodes characterized by a small memory power operating with little battery power selforganize themselves with each other in a wireless manner.  $T_C = \frac{R}{\sqrt{2C}}I\tag{7}$ 

Where I is the number of users.

The energy detection is given by Eqn.8

$$E = \sum_{n=1}^{N} y(n)^2 \tag{8}$$

When the primary user is inactive, the secondary user received signal as seen from Eqn. 1 is

$$y(n) = u(n) \tag{1}$$

When the primary user is active, the secondary user received signal turns out to be as in Eqn.2

$$y(n) = s(n) + u(n) \tag{2}$$

The normalized throughput is given by Eqn.3

$$T_h = \frac{T_F - T}{T_F} \left( 1 - P_f \right) P_C \tag{3}$$

Where  $T_F$  is the frame duration

 $P_C$  is the probability that primary user does not start transmission

 $P_f$  is the false alarm probability

When the primary user follows an exponential onoff traffic model with mean durations of on periods denoted by  $\beta$ , $P_C$  is given by Eqn.4 and T<sub>h</sub> by Eqn.5

$$P_{\mathcal{C}} = \exp(\frac{-T_{PF+}T_F}{\beta}) \tag{4}$$

Then

$$T_h = \frac{T_F - T}{T_F} (1 - P_f) \exp(\frac{-T_{PF+} T_F}{\beta})$$
(5)

The average overhead per user is given by Eqn.6

$$T_C = \frac{R}{\sqrt{2C}} \tag{6}$$

Where C is the speed of light

When the number of user's increases,  $T_C$  increases and the overhead is given by Eqn.7

The Total delay, T<sub>d</sub> denoted by Eqn.9

$$T_{d} = Propagation \ delay + \frac{Total \ data}{Data \ capacity \ of \ path}$$
(9)

### 3.1 Proposed Methodology

The cluster-based topology in Fig.2 includes a cluster head (CH) for communicating with several other surrounding non-mobile members in the cluster. The Fig..3 depicts the philosophy of the scheme under study where the CH forms a full function device with cognitive radio capabilities and operates as the central controller within a cluster. It coordinates the communication activities within a particular cluster and aggregates data transmitted from the members to the sink.



# Journal of Theoretical and Applied Information Technology

<u>15<sup>th</sup> September 2018. Vol.96. No 17</u> © 2005 – ongoing JATIT & LLS



<u>www.jatit.org</u>

E-ISSN: 1817-3195



*Figure-2. Clustered network topology* 



Fig.3 Flowchart for Proposed Approach

**Congestion Detection** The philosophy assuages to precisely measure local congestion level at each node through the use of dual buffer thresholds and the difference between the weighted

buffers. The buffer defined using accept, filter and reject states as Fig.4.1 1 indicates long with the two thresholds Qmin and Qmax serve to border the different buffer states, which reflect different channel loading, The reject state echoes that a good number of packets may be rejected because of a higher buffer utilization. In the event of a node's buffer occupancy exceeding a defined threshold and its data enjoying a higher priority in the neighborhood, it sets the corresponding congestion level bit in the outgoing packet header.

Accept State		Filter State	Reject State
0	$Q_{min}$	Q <sub>max</sub>	Queue

# Figure-4.1.Buffer States

On the occurrence of congestion, it envisages dropping packets from the tail rather than any position in the queue. However if the queue in a sensor node becomes nearly full because of low priority packets, then it necessitates to ensure that the arrival of a high priority packet drops the low priority packet.

The presence of two sub-queues for local generated traffic and route-through traffic as seen in Fig. 4.2 allows the packets to be grouped by sources in the route-through traffic queue. It sorts the packets using their dynamic priority and follows a round robin algorithm for transferring the data, in the sense when a packet travels from one source to route-through traffic queue, immediately thereafter it allows a local generated packet.



Fig.4.2 Queue Model

With the total buffer size of a node being Q, the dynamic priorities of packets denoted respectively denoted as  $DP_1$ ,  $DP_2$ ...  $DP_n$ , where n represents the total number of priorities, then the total number of packets  $N=NDP_1+NDP_2+NDP_3....+NDP_n$ .

If  $0 \le N \le Q_{min}$ , it buffers all the incoming packets on account of the queue utilization being low.



If  $Q_{min} \leq N \leq Q_{max}$ , then it drops some packets with low dynamic priority or engages to be overwritten by subsequent packets with high dynamic priority as a result of which the expected average buffer length increases at a rate of  $R \leq \delta 1$ .

If  $Q_{max} \le N \le Q$  it drops some packets with high dynamic priority or overwrites to enable the expected average buffer length increase at a rate of  $R \le \delta_2$ .  $\delta_1$  and  $\delta_2$  constitute the two variables that can be tuned to achieve an optimal system performance.

When the transfer reaches  $Q_{min}$  the traffic around the node becomes slightly congested and drops some packets with low dynamic priority to limit R $\leq \delta_1$ .

On the other hand when it reaches Qmax, it drops some packets with higher dynamic priority to limit  $R \leq \delta_2$ 

The procedure allows each source node Si ( i=1, 2, 3....) to maintain its data sending rate Gi and periodically update it according to its neighbor's congestion level. Owing to the many to one characteristic, even if the source nearby nodes send data smoothly, there exists a possibility for the occurrence of congestion in the downstream (sink side).

The process involves the use of the bottleneck node based source data sending rate control for regulating the traffic. It includes determining the routing path status from a certain node to sink, detecting bottleneck node and sending the source data increase its data sending rate additively. In ECODA, the source data sending rate can be exactly set as  $1/D_{max}$  upon receiving a message from downstream.

Though the current approaches usually adopt single buffer threshold to measure congestion, multiple and different buffer thresholds appear to maintain the identical data sending rate of the neighbourhood nodes to ensure fairness. The two thresholds  $Q_{min}$ and $Q_{max}$ seen in Fig. 4.1 serve to differentiate between the different buffer states of either accept or filter or reject, which reflects the different channel loading. If a node's buffer occupancy exceeds a certain threshold and its data accrues a higher priority among its neighbourhood, then the corresponding congestion level bit goes to be set in its outgoing packet header.

The tree structure in a conventional sensor network owes to be unfair in bandwidth allocation for nodes at different depths of the network. While the nodes near a sink enjoy a greater priority to send their own generated packets to the sink, those far from the sink require sending their packets through many hops and experience a long delay. The Flexible Queue Scheduler distinguishes between locally generated and route-through traffic be-hives every packet with static and dynamic priority.

The packet static priority represented as an integer carries the lowest static priority *SP* (packet) = 0.The dynamic priority DP expressed using Eqn.10 changes with the number of hops and delay and involves two parameters ( $\delta_1$ ,  $\delta_2$ ) to limit buffer increasing rate and filter packets with the delay measuring the time from the time of packet generation time to the current time.

DP (Packet) = $\alpha$ \* hop +SP (Packet)/1+ $\beta$ \*delay(10)

If buffer incoming rate is BI and buffer outgoing rate BO, then the buffer changing rate and the weighted buffer changing rate respectively written as in Eqns.11 and 12

$$WR=DP(BO)-DP(BI)$$
(12)

The weighted queue length is defined as in Eqn. 13

$$WQ=\Sigma DP (Packet_i)$$
(13)

Rule 1: Suppose a series of packets  $\{p_1, p_2, p_3, ...\}$ , their SP and DP are respectively denoted as SP(p\_1), SP(p\_2), SP(p\_3), ... DP(p\_1), DP(p\_2), DP(p\_3), ... If SP(p\_1) < SP(p\_2) < SP(p\_3)..., then the following relationship is determined : DP(p\_1) < DP(p\_2) < DP(p\_3)...

Combining Def.1 and Rule 1, it follows that packets with same SP may inherit a different DP and packets with higher SP to carry a higher DP.

The algorithm for rate control algorithm follows the steps explained as

# Event {

a0: receive back pressure message;

- a1: receive downstream maximum one hop delay Action Set {
- b0: additively increase data forwarding rate;
- b1: multiplicativelydecreasedata forwarding rate;
- b2: multiplicativelydecreasedata sending rate;
- b3: set data sending rate tobe  $1/D_{max}$
- b4: adjust data sending rate for different paths

#### <u>www.jatit.org</u>

### Node type {

c0: anode which forward data generated by other nodes

c1: anode which generates data, but does not forward data c2: anode has c0 and

c1simultaneously

}

### **3.3Operations in forwarder node:**

Step 1: If node is of c0 type and not of c1 type, perform b0 action.

Step 2: Else if perform b1 action.

Step 3: If event is not equal to a0, perform b0 action or else perform b1 action.

Step 4: If multiple path exist perform b4 action.

# **3.4Operations in source node:**

Step1: If node is of c1 type and not of c0 type, perform b3 action.

Step2: If event is of a0 or a1 type, perform b3 action.

Step 3: If event is of a0 type, perform b2 action. Step 4: If multiple path exist perform b4 action.

The CHs may be assigned to handle additional tasks such as the collection and dissemination of spectrum availability information and the local bargaining of the spectrum. It assuages the inherent resource constraints and the requirements of the opportunistic access in CRSN.

# **4. SIMULATION RESULTS:**

The NS2 network model in Fig.5shows the two hundred and fifty nodes distributed in a space of 1000 m x1000 m and remain free from energy dissipation in the idle or carrier sensing mode. The nodes form the clusters and elect the CH based on the energy level of the nodes. It urges to carry the data between the chosen three source and destination nodes in the network.

The Heed based clustering algorithm follows a distributive methodology in the sense it considers energy by utilizing the residual energy of nodes and communication cost to choose the best set as cluster head (CH) nodes. At the beginning of the grouping phase, a node with higher energy level is more probable to be selected as a CH. When several nodes are candidates for being a CH, the node with the lowest inter-cluster cost emerges to be the CH.

The probability of a node to be a CH is given by the formula in Eqn. 14.

$$C_{HProb} = C_{Prob} \times \frac{E_{Residual}}{E_{Max}}$$
(14)

Where

### $C_{Prob}$ is the probability of being cluster head $E_{Residual}$ is the energy remained in the node $E_{Max}$ is the maximum energy of node



Figure.5 Network Model

The methodology formulated on the principles of the EHeed (ECODA based Heed) operates in the clustered environment to move the sensed data and ensures the minimum average expenditure of energy in each round. The exercise evaluates the performance of the transfer of data across a range two hundred seconds from the source to the preferred destination.

The Table.1 includes the parameters used insimulation.

Table.1 Simulation Parameters

Simulation parameters	Value
Number of sensor nodes	250
Communication range	250m
Buffer size	50 Packets
Packet size	1000 to 5000
Transmission power	0.8w
Reception power	0.6w

E-ISSN: 1817-3195

# Journal of Theoretical and Applied Information Technology

<u>15<sup>th</sup> September 2018. Vol.96. No 17</u> © 2005 – ongoing JATIT & LLS JATIT

ISSN: 1992-8645

<u>www.jatit.org</u>

E-ISSN: 1817-3195

 Table 2: Performance of PDR For HEED Routing
 Protocol

Protocol	Packet Size	PDR % (Normal Routing)	
	1000	92.47	
	2000	92.94	
HEED	3000	91.26	
	4000	87.2	
	5000	87.28	

The Table.2 shows the values of PDR with normal routing of data over range of 1000 to 5000 packets without congestion avoidance technique.

Table 3: Performance of Overhead For HEED Routing Protocol

Protocol	Packet Size	Overhead (Normal Routing)
	1000	5
	2000	7
HEED	3000	9
	4000	11
	5000	15

Table 4: Performance of Delay For HEED Routing Protocol

Protocol	Packet Size	Delay in Seconds (Normal Routing)
	1000	7.3
	2000	7.94
HEED	3000	8.5
	4000	11.27
	5000	13.2

Table 5: Performance of Throughput For HEED RoutingProtocol

Protocol	Packet Size	Throughputin Kbps (Normal Routing)	
	1000	8.97	
	2000	20.72	
HEED	3000	32.21	
	4000	41.71	
	5000	52.11	

Table 6:	Performance	of Energy	For	HEED	Routing
	i	Protocol			

Protocol	Packet Size	Energyin Joules(Normal Routing)	
	1000	8.28	
	2000	13.91	
HEED	3000	19.98	
	4000	24.04	
	5000	30.95	

Similarly the Tables.3,4,5,6 display the values of overhead,delay,throughput and energy respectively and show that it increases as packet size inceases without congestion avoidance technique

The emphasis owes to avoid traffic congestion through a process of re-routing the data in alternate paths to ensure the timely delivery to the destination. It avails the theory of ECODA which involves the use of the next available route and orassigning a priority status to the current data using a buffer state threshold. The mechanism compares the five indices namely throughput, energy consumed, delay, packet delivery ratio (PDR) and overhead before and after the occurrence of congestion to bring out the benefits of EHEED.

The Figs. 6-8 relate to a higher overhead, smaller delay and lower losses for EHEED for contributing to the increase in the network efficiency. It extracts the highest throughput in the

# Journal of Theoretical and Applied Information Technology

<u>15<sup>th</sup> September 2018. Vol.96. No 17</u> © 2005 – ongoing JATIT & LLS

ISSN: 1992-8645

<u>www.jatit.org</u>



E-ISSN: 1817-3195

sense it allows the maximum number of transfer number of packets between the source and destination with normal routing and with the inclusion of congestion avoidance in the process of data transfer as observed from Fig. 9.





Packet Loss vs Number of Packets

Figure.8 Packet Loss Vs Packet Size



Figure.9 Throughput Vs Packet Size

The Figs.10 and 11 explain that the nodes consume the least energy when the data transmission relays and correspondingly a better PDR for EHeed thereby increasing the lifetime of network.

ISSN: 1992-8645

www.jatit.org

E-ISSN: 1817-3195



Figure. 10 Energy Vs Packet Size



Figure.11 PDR Vs Packet Size

# 5. CONCLUSION:

A congestion avoidance strategy has been developed using ECODA to comply the transfer of data in the CRSN. The theory of cluster has been incorporated to enhance the performance and bring about resurgence in the ability of the network to address issues relating to congestion. The benefits have been realized in terms of fostering the network to balance the load in the traffic congested scenario and extract the best metrics The ECODA based HEED protocol has been found to enjoy resource usage efficiency across the network, exhibiting its suitability for use in practical networks.

# ACKNOWLEDGEMENT:

The authors acknowledge with thanks the authorities of Annamalai University for providing the facilities to carry out this work.

# **REFERENCES:**

- [1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam and E. Cayirci, "Wireless Sensor Networks: A Survey", Elsevier Computer Networks, vol. 38, no. 4, (2002).
- [2] I. F. Akyildiz, W. Y. Lee, M. C. Vuran and S. Mohanty, "Next Generation/Dynamic Spectrum Access/Cognitive Radio Wireless Networks: A Survey", Elsevier Computer Networks, vol. 50, no. 13, (2006).
- [3] O. Akan, O. Karli and O. Ergul, "Cognitive Radio Sensor Networks", IEEE Network, vol. 23, no. 4, (2009).
- [4] MatteoCesana, Francesca Cuomo, EylemEkici,"Routing in Cognitive Radio Networks: challenges and solutions", Elseveir, Adhoc Networks, pp.1-21, 2010.
- [5] C.T.Ee.R.Bajcsy, "Congestion control and fairness for many to one routing in sensor networks", ACM.Sensys, 2004, pp.148-161
- [6] Ekaterina Dashkova and Andrei Gurtov,"Survey on Congestion Control Mechanisms for Wireless Sensor Networks", Springer, pp .75-85, 2012.
- [7] M.Kafi, D.Djenouri, J.Ben-Othman, N.Badache, "Congestion control protocols in wireless sensor networks: a survey", communication survey tutorial, IEEE 16(3) (2014)1369-1390.
- [8] M.Yao, C.Lin,P.Zhang, Y.Tian,S.Xu," TDMA Scheduling with maximum throughput and fair rate allocation in wireless sensor networks", IEEE ICC2013-Adhoc and Sensor Networking Symposium,2013.
- [9] Klein R.S., Luss H., Smith D.R. (1992) A lexicographic minimax algorithm for multiperiodResource allocation. Mathematical Programming, 55, 213–234.
- [10] P.Thubert,"An Architecture for IPV6 over the TSCH mode of IEEE 802.15.4", Technical Report, 2015.
- [11] M.Palattella, N.Accettura, M.Dohler, L.Grieco,G.Boggia, "Traffic aware scheduling algorithm for reliable low-power multihop IEEE 802.15.4e networks in

	©	2005 – ongoing JA	ATIT & LLS	JATIT
ISSN:	1992-8645	www.jatit.org	L.	E-ISSN: 1817-3195
[10]	personal Indoor and Mobile Communications(PIMRC)",2012 23 <sup>rd</sup> InternationalSymposium 2012,pp.327-332.	e Radio IEEE on	"Modelling of Ra in Cognitive R Adhoc Networks,	ate- based control schemes adio Sensor Networks", July 2015.
[12]	Palattella,N.Accettura,M.Dohler, G.Boggia, "Decentralized Traff scheduling for multi hop low po networks in the internet of things 14 <sup>th</sup> International symposium workshops on a world of wireles and Multimedia Netwo MoM),2013,pp.1-6.	L.Grieco, ic aware wer lossy " in IEEE and s ,Mobile rks(WoW		
[13]	M.Palattella,N.Accettura,Q.Wang oka,D.Dujovne,L.Grieco,T.Engel, Fly bandwidth reservation for	g,K.Mura "Onthe 6TiSCH		
[14]	wireless industrial sens.J.IEEE16(2)(2016) 550-560. X.Vilajosana, Q.Wang,	networks, F.Chraim,		
	T.Watteyne, T.Chang, K.Pister,"A energy consumption model for Networks, sens. J.IEEE 14(2) (20 489.	Realistic or TSCH 014) 482-		
[15]	Mohamed Amine Kafi,Jale Othman,AbdelraoufOuadjaout,Mil a,NadjibBadache, "REFIACC: ,efficient, fair and interference congestion control protocol for sensor networks", Communications(2016)1-11	l Ben- oudBaga Reliable ee aware wireless Computer		
[16]	C-Y Wan,S.BEisenman,A.T ( "CODA: Congestion detecti avoidance in sensor netwo Proc.ACM SenSys,Nov.2003.	Campbell, on and orks" in		
[17]	A blalfazl A fabarzadah Kazaraani	Uamadial		
	odar,JavadAramideh, "Leach a clustering in wireless sensor Net Qualitative Study", Advances ir and Technology,Vol.9,No. 2015,Pages 7-11.	nd Heed works: A Science 25,March		
[18]	Ahmed S.Kadhim and Ha Alsabbagh,"Throughput Analy Cognitive Systems"International Journal of Networks and Communications No.4, July 2012.	ider M. sis for Radio Computer s, Vol.4,		
[19]	L.Q.Tao and F.Q.Yu," Congestion Detection and Avoid multiple class of traffic in networks", IEEE Transactions on Electronice Vol 56 No.3 August	Enhanced dance for sensor consumer 2010		
[20]	Vahid Esmaeelza .S.Hosseini,RezaBerangi,OzgurB.	deh,Elahe Akan,		