# A Survey on Recent Congestion Control Schemes in Wireless Sensor Network

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***Abstract*—Wireless sensor network (WSN) is the vast area of research in the field of networking. A number of challenges are faced by such type of battery operated networks. In WSN, the sensors are attached to the hardware motes devices. These sensors are responsible to sense the certain events happening in the near surrounding. This sensed data is communicated with the radio/antenna attached to the sensor nodes via wireless medium. There are basically four layers discussed in WSN, namely, physical layer, MAC layer, network layer and application layer. In our paper, we discussed some recent congestion control techniques of 2013, 2014 and 2015 also.**

***Key Words*- Congestion mitigation, wireless sensor networks, packet loss and traffic control.**

## I. Introduction

Wireless sensor networks (WSNs) is a wireless network in which number of sensor nodes, commonly called as motes, are deployed randomly or in deterministic manner in order to sense the physical surroundings and process the gathered data and then send it to the base station via Internet. Wireless sensor networks has number of applications like enemy tracking in army, weather forecast, checking the quality of plants and vegetables, monitor patients health remotely when doctor cannot be there with patient every time, detect and control city traffic congestion and can also be used to avoid road accidents and forest fires. Another last and most important application of WSN which has never been discussed in any other paper is that it can also be used to allow the communication for deaf, dumb and blind people using the bend sensors and accelerometer tilt sensors. Thus WSNs hold vast number of applications where human approach is difficult. If used in every field, they would prove to be really beneficial for the country and help in successful development of underdeveloped countries like India. Since there are wide uses of WSNs, there are also some issues and challenges faced in such type of networks. Mostly discussed issue is the energy consumption and battery problem issue which has been the most important part of discussion in this field. The next most important issue is the security issue as the sensor nodes cannot know that whether the node to which they are communicating is normal node or malicious node. So it is also the major area of concern. We have focused on another major area of concern in health care applications of WSN which is congestion problem faced by the wireless sensor network. This paper discusses the most recent techniques to control congestion in WSNs. Congestion, which means jamming, in a network whether it is wired or wireless occurs whenever the incoming traffic on the network is more than it can handle. It can also be due to the slower processing speed of device. Network can be warned about the congestion problem using either explicit congestion notification or implicit congestion notification. Mostly, implicit congestion notification is used as the former has the overhead of sending the extra control packet.In health care applications, it becomes more necessary to handle such problem [11] as this can lead to the death of the patient who is being monitored with sensor nodes.

The following figure 1 shows the simple scenario of a personal wireless sensor network. A gateway node is attached to a laptop with wire and sensor nodes are placed near to the gateway node. When any event will occur close to one of these sensor nodes, they will sense the event and send the report to the gateway node. This report about the event can be viewed on the laptop using any software which can read the readings generated by sensor nodes.

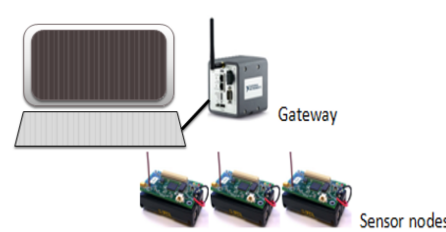


Figure 1. Representation of WSN

The paper is organized as follows. Section II describes the previous related work. Section III discusses some of the recent congestion control protocols. Finally, section IV lists out the conclusion.

## II. RELATED WORK

Mohamed Amine Kafi, et al. [2] wrote a survey on congestion control protocols in which transport protocols are analyzed in terms of their suitability to detect the congestion and warn the concerned nodes to take appropriate action. Eight different congestion detection strategies are discussed i.e. packet loss, buffer length, channel load, channel busyness ratio and throughput measurement, packet service time, packet service time and queue length, ratio of packet service time and packet inter-arrival time, and delay. They have concluded that applying the upper bound fidelity is of high importance like ESRT and PORT protocols. For some applications, applying same type of congestion control at all nodes would not ameliorate the throughput so different congestion control schemes can be applied to different nodes like source nodes, sink nodes, relay nodes and intermediate nodes. Upon congestion detection, either traffic control is applied or resource control is applied. Traffic control can be performed in avoiding or reacting manner. Avoiding manner is based on the concept of either scheduling the transmission to avoid collision or to limit the sending rate. With reacting- based traffic control, both interference and buffer overflow are mitigated. Some protocols neither apply traffic control nor resource control but rather they apply aggregation strategies. The authors of this paper has also discussed the various evaluation metrics like network efficiency, energy efficiency, energy tax, packet loss ratio, fairness, packet latency, control packet overhead, total throughput at sink, instantaneous queue size, memory requirements, fidelity index, and generated rate to evaluate the sensor network performance under congestion scenario using simulations. Traffic control protocols are divided into six categories i.e. equal or weighted rate partitioning (ARC, ESRT, EECC, FUSION, CCF, PCCP, MCCH, APRC, NCC, HCCP, DST, CCF2, FACC, WRCP), rate control based Scheduling (TDMA like, MCCP), exact rate control protocols(ATP, PORT, RCRT, LATP, ECODA, CONSISE), interference-based rate partitioning protocols(IFRC, FLUSH, CADT), interference aware scheduling, and buffer overflow avoiding protocols. Resource control protocols are divided into five categories i.e. alternative path use, congestion reacting multipath, interference avoiding scheduling, dual emission-based protocols, and duty cycling-based protocols. Hence, a deep comprehension of the mechanism above and their efficiency permit the design of comprehensive transport protocol that deals with reliability.

In [3], an overview of congestion control techniques for constrained environment is made and an idea of improving the mechanism of CoAP is proposed to address the need of resource constrained nodes (e.g., 8-bit microcontrollers with only a small RAM and ROM) with weak network connection (e.g., 6LoWPAN with speed of 250 kbps). CoAP protocol is the implementation of REST architecture which is delivered by compressing HTTP. CoAP protocol is based on unreliable UDP transport layer which does not provide internal congestion control mechanism so it has to be provided by upper layers. Authors of this paper believe that combination of Active Queue Management mechanism (AQM)- BOB-RED and explicit congestion notification bits can be very effective combination for congestion control mechanism. They did a background study of stack protocols of wireless sensor networks (WSNs). They discussed the different techniques deployed by different layers of OSI stack. They have used their idea based on BOB-RED technique which divides the traffic on real time and non-real time. The technique uses marking packets in IPv6 header together with CoAP acknowledgment because with this it becomes easier to inform the nodes about the congestion. When the end device receives the packet, it replies with CoAP acknowledgement. If the end point receives the marked packet, it sends an acknowledgement with marked field. This mark tells the sender to reduce the transmission by 1 and increase the retransmission timeout value from the interval (1,5* recent value;1, 9*recent value). Whereas, the end device doesn't receive anything if the queue length exceeds the threshold value defined in device as the upcoming packet is dropped by the device. Network security was also considered in CoAP to handle the flood attack by the attacker.

In [5], the authors demonstrated the fact that Radio Duty Cycling (RDC) technique is an inevitable technique that should be used while designing congestion control algorithms. The authors have argued that many congestion control algorithms ignore RDC mechanism which results in lower throughput than it could be using RDC. According to RDC, the sensor node switches off its radio for some time period. This reduces the idle listening of sensor nodes which consumes extra energy. When this idle listening period is over, all sensor nodes turn on their radios simultaneously. The sensor nodes will then exchange the information with each other and go to sleep.Authors also demonstrated that how RDC could affect the congestion detection in IPv6 WSNs.

## III. CONGESTION CONTROL PROTOCOLS

1. AODV-CSNM [1]: In WSNs, energy management and packet loss have been the focus of discussion. Many routing protocols have been designed for these problems. These routing protocols can be used to reduce energy consumption and distribute traffic. However, with increasing number of nodes, packets processed by each node significantly increase. There is no guarantee that nodes with large flow do not exhaust all energy or have traffic congestion due to overloading, leading to packet loss or node failure. Therefore the existing routing protocol solution is to change the transmission path when packet traffic over the loading limit. Although it works in some cases, but when the traffic of all other paths exceeds loading limits in the same time, the WSNs will collapse. At this point, new nodes are needed to be added in the network to quickly work together with the original nodes. AODV-CSNM was compared with AODV, AFA and BB schemes. The results shown that AODV-CSNM has better packet receiving rate than the other three schemes and hence can avoid the congestion in a better manner. In terms of residual energy, it is only better

than AODV whereas AFA and BB schemes are better than AODV and AODV-CSNM.

2. SUIT [6]: It is a first and innovative image transport protocol for controlling congestion in wireless multimedia sensor networks (WMSNs). The probability of congestion to occur is more in WMSNs than the simple WSN because the multimedia involves images, video as well as audio content too which produces high load traffic over the network. SUIT uses multiple congestion indicators i.e., buffer occupancy, ratio of number of incoming packets to the number of outgoing packets, because it can provide more good congestion detection performance. Most WMSN applications use JPEG images due to their low complexity. SUIT can discover any target in its field of view (FoV). There is no backpressure mechanism used in SUIT which is commonly used in other congestion control algorithms in order to improve the frame delivery performance. It uses the error resilience advantage of PJPEG (progressive JPEG) format. The principle of PJPEG is that the image is transmitted in several layers. When the user receives the first layer of image, user can see the blurred image which is recognizable. When the rest of the layers start arriving, the image quality increases. Error resilience means that when there is error or data loss in any one of seven layers, the whole frame is not considered to be corrupted and JPEG frame can still be recreated using previous layers. SUIT adapts the frame rate on the sending nodes and quality of image frame is reduced only at forwarding nodes. This is done by the transport layer. It does not use any type of ACKs to apprise the sender regarding transmission result. Another advantage of SUIT is that it reorders the packets and this is done by the SUIT application layer. Every SUIT packet contains ID of source, sequence number and frame number which is incremented by one for each new packet. SUIT does not differentiate packets because it has only single packet which is video fragment packet. Hence, there is only one queue for single packet type at the transport layer. It assigns a score or a value for each packet to prioritize them for QoS improvement. It gives number one priority to the packets which have minimum average delay and which is a fragment of the first frame of detected target. SUIT was compared with FCE and QCC. It proved to be better from FCE and QCC in terms of average received frame rate at sink, average frame rate at source nodes, average frame loss, average frame latency and average energy expenditure per sensor node. For example, the average frame loss for the number of intruders taken as 3 was 4 for SUIT, 10 for FCE and 18 for QCC. Hence SUIT performed better than QCC and FCE.

3. CADA [11]: It give the different solutions for handling three different types of congestion scenarios that may occur in wireless sensor network i.e. congestion near all source nodes sensing the same event, congestion near the sink, and traffic intersection due to multiple sinks in network. For avoiding the congestion, authors conclude that the nodes which are farther away from the event must not report the data to the sink as those nodes tend to provide inaccurate information. So, it's better for these farther nodes to be suppressed. The authors also present a representative node selection algorithm. If a node can not become representative node and its timer expires, then it calculates the correlation degree between the received data and its own data. Two timers are used. One for backoff timer and second for updating the representative nodes set. The proposed technique uses buffer occupancy and channel utilization to detect the congestion. Resource control in CADA is done by selecting alternative path called detour path. Detour path is created by the merger node by flooding the merger-to-distributor message to the distributor node. Special care is taken to avoid the interference between the detour path and original path. Low priority packets are sent through detour path. Traffic control in CADA is done by using source reporting rate regulation policy which is similar to adaptive increase multiplicative decrease approach. CADA was compared with TARA and NOCC (NO congestion control). Results has shown that CADA's packet delivery ratio is more than NOCC and TARA.

4. HRTC [12]: It is the hybrid scheme merging resource control and traffic control schemes to control and avoid congestion in wireless sensor network. A decision is made among all nodes that whether to apply resource control or traffic control at any point. Traffic control is applied on source node and resource control is applied on the intermediate nodes if backpressure message did not reach the source node. If the intermediate node can create the secondary path it stops the backpressure message otherwise this back pressure message is forwarded till it reaches the source node. HRTC scheme takes assumption that there is always at-least one path available from source to sink. Nodes which cannot communicate with the sink directly or indirectly, their flag field is set to zero. Thus, HRTC helps to improve the throughput and the lifetime of the network. Prowler simulator was used to simulate this protocol. It was compared with traffic control and resource control algorithms. Hence, it proved to be better than these in terms of sink throughput and average throughput.

5. Optimized Congestion Management Protocol for Healthcare WSNs [8]: This protocol was proposed specially for the health care applications of WSNs like in hospitals. There can be the situation where the priority of the multi-sensors may vary. For example, a heart patient has more priority than a diabetic patient. The proposed congestion management protocol is divided into four stages i.e. Active Queue Management, Automata Based Congestion Detection, Optimized Rate Adjustment and Implicit Congestion Notification. They have used two mechanisms: Congestion Avoidance and Congestion control mechanisms. Congestion control is done in case if congestion occurs after applying the congestion avoidance mechanism. Congestion avoidance mechanism uses the concept of virtual queue to store the incoming packets from child node. Virtual queue means that the physical queue is shared virtually between the child node's traffic and source node's traffic. In order to decide that whether there is a need to control the congestion or not, the packet drop probability is calculated.

Based on calculated probability, packet is either dropped or queued. If the packet is queued then the proposed mechanism calculates the status of congestion using three state automata. Congestion level is calculated using two parameters, namely, current virtual queue and automaton status. New sending rate for child nodes is calculated using Optimized Rate Adjustment formula. Proposed protocol also guarantees fairness between source and child node traffic using weighted fair queuing (WFQ) algorithm. It performs better than PCCP and CCF protocols in terms of evaluation parameters, namely, delay, jitter, throughput, energy performance, fairness and packet loss.

6. GH-MAC [13]: It is the combination of G-ETDMA protocol for intra-cluster communication and Game theory-based nanoMAC (G-nanoMAC) for inter-cluster communication. In ETDMA MAC protocol, clusters are built based on the energy level. Clustering and communication process is divided into three phases, namely, first one is contention period, the second is a data transmission period and the third is idle period. In the first period, the radio of cluster head (CH) will remain OFF and that of non-CH nodes remain ON. Firstly, a slot is assigned by CH to non-CH nodes to transmit a control message. Then again, a time schedule is assigned to non-CH nodes for data transmission. If a sensor node has no data to transmit, it enters the idle period. Energy consumed by cluster head, child nodes, and total system energy is calculated. Similarly, different stages of a receiver/sender CH sensor node, for inter-cluster communication, is defined based on whether the packet is sent /received or not. Repeated Game theory is applied to H-MAC in which the game is repeated for number of times and the player observes the previous outcomes before attending the next repetition. Here, sleeping strategy is defined as the action which is played by the sensor nodes (players) in a cooperative manner. Proposed protocol was analyzed in MATLAB simulator. GH-MAC proved to be efficient in terms of energy and delay as compared to hybrid MAC. The drawback of this protocol is that one needs to experiment with hardware in order to make game theory based decisions.

7. HTAP [14]: This algorithm select the secondary path to the destination sink node to mitigate the congestion occurring at the nodes. The authors assume a grid based densely deployed network in a random manner. Nodes know their location and sink location is also known. HTAP uses Local Minimum Spanning Tree (LMST) algorithm to construct and maintain network topology. In LMST, initially all sensor nodes exchange their ID and location information using 'HELLO' messages. Nodes then calculate the Euclidean distance and construct minimum spanning tree which is local in the network. Using this, node finds out its six neighbors which are one hop away from them. After setting minimum spanning tree, nodes set their transmitting power in order to reach their farthest neighbors. Instead of keeping the track of all neighbors, it keeps track of only those nodes which are nearest to the sink because nodes near to sink could be helpful in building the alternative paths. In order to find out near sink nodes, each node collates its position with its neighbor's position and sink position. Source node self-assigns itself at level 0. When the source broadcasts the discovery message to its neighbors, the nodes which receive this message become its child nodes and are assigned at level 1. This activity is continued until the discovery message reaches the destined sink node. In case if a node does not have any upstream node or is unable to forward the level discovery message, then that node is ejected out from the network. Congestion is detected when buffer of node starts becoming full and node triggers an alternative path selection mechanism to its upstream nodes. Here, the upstream nodes are those from which it is receiving packets. The upstream node then stops transmitting data packets to downstream node and checks its neighbor table to find another downstream node on that level to which it was sending data earlier.

HTAP protocol also handles the state when the nodes get exhausted due to limited power by ejecting the powerless node from the network. It was compared with SenTCP, TARA, no Congestion control on the basis of following parameters, i.e., throughput, total energy consumption, percentage of successfully received packets and network's remaining energy.

8. RAHTAP [15]: It is the extension of the existing protocol HTAP (Hierarchical Tree Alternative Protocol). It reduces the physical redundancy in the network, which is defined as receiving the same data from multiple sensors. In redundancy check algorithm, every node runs redundancy detection whenever a packet is received. When the receiver node receives a packet, it checks its queue that whether it already has received the packet of same id earlier or not. If yes, then it discards the redundant packet. The experiment was performed in Qualnet simulator. Experiments showed that RAHTAP gives more received packets ratio as compared to HTAP because the additional overhead due to duplicate packets is removed. Also, the energy consumption is less in RAHTAP in contrast to HTAP.

9. Light weight buffer management in sensor networks [16]: This approach used a small buffer using scheme in which (1/k)th buffer solution has been used in order to avoid the congestion as well as collision. The value of k was set to be equal to 6 to efficiently balance the load on the receiver. One can use value of k as 3,4 or 5 but this will be large value for buffer to hold and 6,7 or 8 will be too small. Nodes will transmit their buffer space in addition to data packets. Other nodes in neighborhood overhear the buffer space and restrain themselves from sending the packet. Those neighborhood nodes will send a reserved message to reserve their next transmission. The proposed scheme also avoids congestion in case of hidden terminal problem. In short, the sensor node will only transmit if the receiver sensor node has queue space to carry that packet. This avoids the packet drops and wastage of energy. This 1/6th advertisement of buffer space helps in avoiding packet drops when the two neighbor nodes are not in each other's range and hence cannot overhears other message transmission. The value of k increases by 1

Table I
ANALYSIS OF CONGESTION CONTROL PROTOCOLS

| Experimental Analysis | | | |
|---|---|---|---|
| Protocol Name | Congestion Detection | Number of sensors | Performance metrics |
| AODV-CSNM | Buffer loading | 150 | Packet received rate, average residual energy, network lifetime |
| SUIT | Buffer Occupancy, Traffic Load, Number of Contenders | 256 | Average received frame rate at sink, average frame loss, average frame latency, average energy expenditure, average frame rate at source node |
| CADA | Buffer Occupancy, Channel loading | 2000 | Delivery ratio, bit energy consumption, throughput at sources, average per-hop delay |
| HRTC | Buffer Occupancy, Remaining Power of node | 30 | Sink throughput, residual energy, average throughput varying source data rate |
| Optimized Congestion Management | Virtual Queue status, Three state machine | 15 | Packet loss, energy efficiency, end-to-end delay, fairness |
| GH-MAC | Collisions at MAC layer | 100 | Average energy consumption, average delay |
| HTAP | Buffer Level | 100 | Total energy consumption, average hop-by-hop delay, network throughput, received packets ratio |
| RAHTAP | Buffer Level | 12 | same as HTAP |
| Light weight buffer management | Buffer Size | 500 | Ratio of lost packets, source rate, routing distance per packet, routing delay per packet, energy expenditure |
| DRR | Buffer Occupancy | 6 for chain topology, 26 for random topology | Fairness index, average energy consumed for chain topology and average packet delivery ratio per hop, average packet loss ratio per hop for random topology |

if there is buffer overflow and decreases by 1 if no buffer overflow is encountered. The disadvantage of this scheme is that a small amount of buffer overflow may happen as the value of k is increased and decreased dynamically. The proposed schemes provide fairness in buffer space by allowing the nodes to transmit one packet at one time. The scheme also utilizes Congestion Free Multipath Routing Scheme (CFMF) to avoid congestion in the network. Hence, the proposed scheme is very well efficient in improving the network lifetime and reducing the congestion even in hidden terminal problem. Authors have discussed the implementation of the scheme with other MAC based schemes like CSMA/CA, CSMA with ACK and CSMA with implicit ACK. For evaluation purpose, authors have compared their technique with three kind of techniques which are global rate control, backpressure technique which was used in CODA and the last when no congestion control technique is employed. The results concluded that this scheme proved to be better than others in terms of lost packets, average energy consumption, routing distance, routing delay and achievable source rate.

10. Differed Reporting Rate [17]: This protocol improves the throughput, packet delivery ratio and packet loss in a network. DRR uses buffer occupancy to notice any congestion in network. If the buffer of a sensor node exceeds the threshold limit then the congestion notification bit is set in header of the outgoing packet so that sending rates of nodes could be decreased. Queuing theory is used to see the effect of different reporting rates and to find the relation between buffer occupancy and reporting rates. Buffer occupancy is calculated using queuing theory. To estimate the reporting rate of each sensor node, Adaptive Flow Rate Control (AFRC) is used. Nodes near to sink are assigned minimum reporting rates and it goes on increasing as we move away from sink. Using DRR, Packet delivery ratio, fairness index and network throughput has increased and energy consumed by the network is less. Buffer occupancy is controlled at every node and it goes on decreasing from sink node to sensor nodes after applying DRR algorithm. Hence, buffer overflow is avoided and packet drop ratio is reduced. Hence, congestion is mitigated in the network. DRR is evaluated using parameters: packet delivery ratio, packet loss ratio and energy consumption. It is not compared with any other protocols but the results are compared with the situation when DRR is not applied.

## IV. CONCLUSION

In this survey paper, we discussed some of the recent protocols which can be used to mitigate the loss of information due to congestion occurring in the network. The problem can be resolved by either changing the route or by decreasing the data transmission rate of the sending nodes. Most of the protocols use rate control approach. Congestion warning can be sent by a congested node in two ways, namely, either using ECN (explicit) or ICN (implicit). Congestion control protocols are divided into two categories, namely, sink based feedback and intermediate node feedback. Brief overview of each protocol is explained in table 1. It is very necessary to avoid the occurrence of congestion in the network in order to get the accurate data without any packet loss and wastage of time in running congestion control algorithms. Protocols must be designed for congestion avoidance rather than controlling congestion after it happens. Its better to avoid it and you are sure about it.

## REFERENCES


[1] Joy Iong-Zong Chen, Chu-Hsing Lin, "Wireless Sensor networks: Throughput Evaluation of a Novel Scheme to Mitigate the Congestion over Wireless sensor networks", in Wireless Personal Communications, Vol.75, Issue 4, pp.1863-1877, April 2014.

[2] Mohamed Amine Kafi, et al., "Congestion Control Protocols in Wireless Sensor Networks: A Survey", in IEEE Communications surveys and tutorials, Vol.16, Issue 3, pp.1369-1390, March 2014.

[3] Ekaterina Dashkova and Andrei Gurtov , "Survey on Congestion control mechanisms for wireless sensor networks",in Internet of Things, Smart Spaces, and Next Generation Networking, Vol.7469, pp.75-85 ,2012.

[4] Saima Zafar, "A survey of transport layer protocols for wireless sensor networks", in International journal of Computer applications(0975-8887) Vol.33, No.1, pp.44-50, November2011.

[5] Vasilis Michopoulos et al, "A Comparative study of congestion control algorithms in IPv6 Wireless Sensor Networks", in Distributed Computing in Sensor Systems and Workshops, pp.1-6, June 2011.

[6] Cagatay Sonmez et al., "Fuzzy-based congestion control for wireless sensor networks", in EURASIP Journal on Wireless Communication and Networking, Vol.63, pp.2-17, April 2014.

[7] Patil, D., Dhage, S.N., "Priority-based Congestion Control Protocol for controlling upstream congestion in Wireless Sensor Network", in Communication, Information and Computing Technology (ICCICT), 2012 International Conference, pp.1-6, Oct 2012.

[8] Abbas Ali Rezaee, Mohammad Hossein Yaghmaee, Amir Masoud Rahman, "Optimized Congestion Management Protocol for healthcare Wireless Sensor Networks", in Wireless Personal Communications journal, Vol. 75, Issue 1, pp 11-34, March 2014.

[9] J. Y. Teo, Y. J. Ha and C. K. Tham, "Interference-Minimized Multipath Routing with Congestion Control in Wireless Sensor Network for High-Rate Streaming", in IEEE Transactions on Mobile Computing ,Vol.7, no.9, pp.1124-1138, 2008.

[10] J. Paek and R. Govindan, "RCRT: Rate-controlled reliable transport for wireless sensor networks", in Proc.5th ACM Conf. Embedded Netw. Sensys, Sydney, Australia, pp.305-319, Nov 2007.

[11] Wei-Wei FANG, Ji-ming CHEN, Lei SHU, Tian-shu CHU, De-pei QIAN, "Congestion avoidance, detection and alleviation in wireless sensor networks", in Journal of Zhejiang University-SCIENCE C (Computers and Electronics), Vol.11, Issue 1, pp 63-73, Dec 2009.

[12] Charalambos Sergiou and Vasos Vassiliou, "HRTC: A Hybrid Algorithm for Efficient Congestion Control in Wireless Sensor Networks", in New Technologies, Mobility and Security (NTMS), 2014 6th International Conference, pp.1-5, March 30- April 2, 2014.

[13] Raja Periyasamy and Dananjayan Perumal, "A Game Theory-Based Hybrid Medium Access Control Protocol for Congestion Control in Wireless Sensor Networks", in Game Theoretic Analysis of Congestion, Safety and Security, Springer Series in Reliability Engineering 2015, pp 1-25, January 2015.

[14] Charalambos Sergiou, Vasos Vassiliou, Aristodemos Paphitis, "Hierarchical Tree Alternative Path (HTAP) algorithm for congestion control in wireless sensor networks" in journal of ad-hoc networks, Vol.11, Issue 1, pp.257-272, Jan 2013.

[15] Ashish Kumar Luha, Vengattraman T., Sathya M, "RAHTAP Algorithm for Congestion Control in Wireless Sensor Network", in International Journal of Advanced Research in Computer and Communication Engineering, Vol. 3, Issue 4, pp.6250-6255, April 2014.

[16] Shigang Chen, Member, IEEE, and Na Yang, "Congestion Avoidance based on Light weight Buffer Management in Sensor Networks", in IEEE Transactions on Parallel and Distributed systems, Vol. 17, NO. 9, September 2006.

[17] Vivek S. Deshpande, Pratibha P.Chavan, Vijay M.Wadhai, Jagdish B.Helonde, "Congestion control in Wireless Sensor Networks by using Differed Reporting Rate", in 2012 IEEE in 2012 World Conference on Information and technologies, pp.209-213, Oct 2012.