Congestion Control in Wireless Sensor Networks-An overview of Current Trends

Maqbool Shah[1], Muhammad Yaseen Khan[1], Haroon khan[1], Muhammad Noman Hayat[1], Syed Roohullah Jan[1]
[1]Department of Computer Science, Abdul Wali Khan University Mardan, Pakistan

Abstract: In WSN congestion occurs when traffic load exceeds the capacity available at any point in a network. Congestion acts an important role in degrading the performance of the network or failure of the network. So it is essential to detect and control the congestion in the entire WSN. Thus one can improve the performance of the network. Different factors are involved in the congestion; the main factor is buffer over flow, packet loss, lowers network throughput and energy wastage. To address this challenge this is essential for a distributed algorithm that mitigate congestion and allocate appropriate source rate to a sink node for wireless sensor network. This paper gives some ideas how to control and manage the congestion in a wireless sensor network.

Keywords: Wireless Sensor Networks, Congestion Control, Congestion Detection and Mitigation

I. INTRODUCTION

The WSN is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical environmental conditions, such as temperature, sound, vibration, pressure motion or pollutants, at different locations [1]. WSN has significantly different communication constraints. The devices in such type of network are deployed in a huge numbers; they need the ability to assist each other to communicate data to a centralized collection point which is called a sink or a base station. The smallest devices are composed of a sensing unit, a radio, a processor integration of the sensor and having a power unit. The devices are capable of monitoring of a wide variety conditions such that temperature, humidity, soil makeup, pressure, vehicular movement, lighting conditions and noise levels, etc.

A typical example of pervasive computing applications is WSN, which has a broad range of applications such as military reconnaissance, environment monitoring, disaster relief and agriculture. The foremost aim of this type of network is to improve its life time and energy efficiency, load balancing packet transfer from sink to network as sensor of network is to conserve battery power. In WSN the powered mainly consumed for three purposes: data transmission, signal processing and hardware operation. With the rapid development and increasingly mature technology of MEMS (Micro Electro Mechanism System), wireless communications and modern networks merge into wireless sensor networks (WSN) [2]. It has created various innovative sensor network applications in near future. Today's sensor nodes are capable of sensing more than one parameter with the aid of multiple sensor boards mounted on a single radio board [3]. It is more efficient, reliable and cost effective to use multi sensing unit instead of multiple nodes with multiple functionality.

Congestion is a problem in wireless sensor networks. Some techniques are used to reduce the congestion in WSN. Fusion's Techniques mitigate congestion, queue occupancy detects congestion, hop-by-hop flow control improves the efficiency of the network and source rate limiting as will improves the fairness. Fusion improves efficiency by 3 times and eliminates starvation [4]. Different types of data generated by the sensors have various priorities. Hence it is necessary to ensure desired transmission rate for each type of data based on the given priority to meet the demands of the base stations. In such a network, the sensor nodes could in fact generate simple periodic events to unpredictable bursts of messages. Congestion occurs even more likely when concurrent data transmissions over different ratio links interact with each other or when the reporting rate to the base station increases. When the number of nodes in the entire network increases the congestion might occur frequently [5]. A typical model of Wireless sensor network is shown in Figure 1 [6].

The rest of the paper is organized as follows. In Section II, causes of congestion are discussed. In Section III, types of

Congestion are elaborated followed by congestion control mechanism in Section IV. Finally, the paper in Concluded in section V.

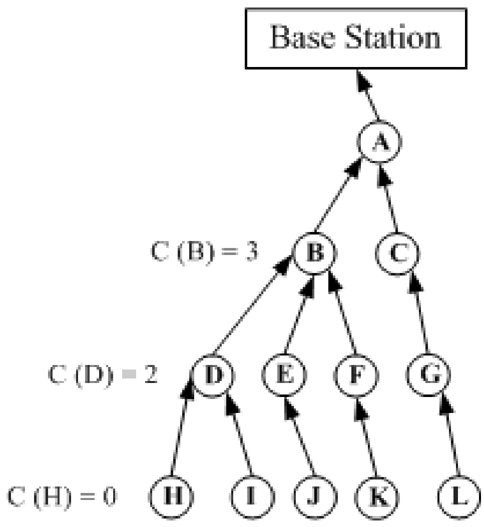

Figure 1: Wireless Sensor Network Model.

II. CAUSES OF CONGESTION

When the data traffic of source nodes nearby sink grows, the offered lead exceeds capacity available and the network becomes congested. The congestion has buffer overflow, channel contention, interference, packet collisions and many to one flow nature. When the number of packets is more than the available space of buffer the buffer over flow occurs. Contention occurs between the different flow and different packets of a flow. Interference occurs along multiple path of a network among the nodes nearby due to simultaneous transmission [7]. Packet collisions lead to packet drops. Many to one nature of data communication between many sources and sinks result in bottleneck around sink [15-33]. Congestion results to degrade the channel quality, packets loss per unit time.

III. TYPES OF CONGESTION IN WSNs.

Congestion can be classified into two major categories.

1. Location based.
   a. **Location based congestion** includes, Source congestion and sink congestion.
   b. **Source congestion:** The event occurred is detected by all the sensor nodes in the special, these nodes are source nodes for next transmission. If the node's radi ranges is greater the sensing range will also be greater. If the sources fall in each other's radio range, the can communicate with each other. If all the source nodes, start sending packets to the same time to the sink at high rates, then a hot spot zone will be formed around the sources ant within this hot sport a large number of packet will be dropped.

2. **Sink congestion:** When the sensors observe an event at a high date rete, sink nodes and the nodes around them will sense a high traffic volume. If a hot spot occurs around the sink, the packet will be lost inside the congested area near the sink, and dropping of a packet around the sink needs recovery of packets by some means.

3. **Forwarder Congestion:** The date sensed must be reached to the destination by source and sink nodes. Data in a sensor network has multiple paths and these paths are interconnected with each other. The area surrounded the intersection will possible become a hot spot for congestion.

a. Causes of Packet loss:

It has mainly two types (Buffer over flow and link collision)

1. **Buffer over flow** (Node level congestion). When the packet arrival rate exceeds the packet service rate this type of congestion occurs. In most cases this is occur in sensor nodes near to sink node.

2. **Link collision** (Channel congestion/ Link level congestion): For WSNs where wireless channels are shared by several nodes using CSMA like Protocols [34-42], collision could occur when multiple active sensor nodes try to seize the channel at the same time. Link level congestion increases packet service time, and decreases both link utilization and overall throughput and wastes energy at the sensor nodes [8].

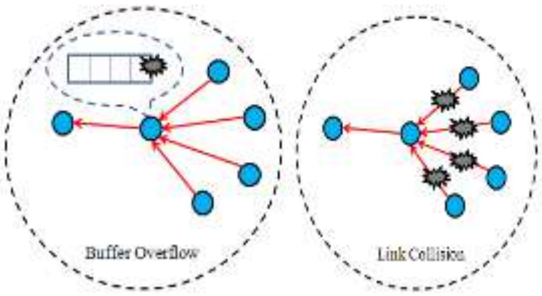

Figure 2: Congestion in WSNs [9]

IV. CONGESTION CONTROL MECHANISM

Two main types of congestion in a WSN are buffer congestions and channel collision. Channel Collision can be overcome using Data Link Layers' mechanisms: CSMA (Carrier Sense Multiple Access), FDMS (Frequent Division Multiple Access). Through these mechanisms the medium can be shared with frequent division FDMA, time division TDNA and sampling medium on the existence of the transmission of some other node CSMA.[10]

V. SCHEMES OF CONGESTION CONTROL

Congestion control can be divided into two main categories: (1) Centralized Congestion Control Schemes, (2). Distributed Congestion Control Schemes.

a. Centralized Congestion Schemes:

This scheme is consist of routing protocols with congestion control. In this scheme a centralized approach is used as all the actions for controlling the congestion is undertaken by base station / sink node. All the activities such as congestion detection and avoidance are taken by the sink. Decision is always taken by the centralized node, the sink node applies the command and the decision is taken according to the centralized scheme. The sink/ base station periodically collects data from the sensor nodes, detects the possibility of congestion, and accordingly sends messages to the involved sensor to mitigate the congestion. **Table 1** has a summarized detailed discussion on some centralized congestion control schemes [11].

Table 1. Comparison of the existing centralized routing protocols with the congestion control.

S.No	Protocol	Operational Strategy	Congestion Detection Criteria	Priority Criteria	Packet Drop Priority	MAC
1	Directed diffusion	Routing with aggregation, distributed in nature	Buffer Overflow	No	No	CSMA
2	ESRT	Routing with congestion support, centralized in nature	Buffer Overflow	No	No	CSMA
3.	PSFQ	Routing with congestion support, centralized in nature	Buffer Overflow	No	No	CSMA
4	RCRT	Centralized congestion detection, rate adaptation, and rate allocation	Buffer Overflow	No	No	CSMA
5	I2MR	Routing aided by congestion control	Buffer Occupancy, and exponential weighted	NO	No	No

			moving averages for long term congestion detection			
6	TADR	Routing with congestion control	Buffer and Rate, hybrid scalar potential field	No	No	NA

b. Distributed Congestion Control Schemes.

The congestion in this case is distributed in nature. The congestion control is dispersed over the entire sensor field. The scattered deployment nature of sensor nodes results in the distribution of congestion control algorithm into various routines and sub routines across the wireless sensor network. These routines are executed by certain events in the sensor fields called stimulus and accordingly produce response. The result of one routine/subroutine may act as a stimulus to another subroutine. Table 2 summarizes the congestion detection criterion in Distributed congestion Control Scheme. [12]

Table 2: Mutual Comparison of existing distributed congestion control protocols.

S.No	Protocols	Operational strategy	Congestion detection criteria	Priority Criteria	Packet Drop Priority	MAC
1	CODA	Congestion Control	Single Buffer Occupancy congestion detection criteria	No	No	CSMA(VC)
2	ECODA	Congestion Control	Dual Buffer Occupancy	Yes	Yes	CSMA with AIMD
3	ECODA	Congestion Control	Buffer Occupancy, Incoming Flows	Probabilistic Algorithm		
4	DAIPaS	Congestion Control	Buffer Occupancy Channel Interference	NO	NO	NA
5	ADCC	Congestion Control	Transient Buffer Monitoring Using EWMA	NO	NO	NA
6	LPCC	Congestion Control	Transient Buffer Monitoring using EWMA	NO	NO	NA
7	PCCP	Congestion Control	Buffer monitoring, Packet inter arrival time and service reflecting congestion	NO	No	NA
8	DPCC	Congestion control	Buffer occupancy and traffic flow	NO	NO	CSMA, Back off interval
9	LACAS	Congestion control	Learning automata	Pre defined rules	Pre defined rules	NA
10	Fusion	Flow control, rate limiting,	Buffer and rate	NA	NA	CSMA with RTS/CTS

		and prioritized MAC				
11	Buffer based congestion avoidance	Congestion control	Buffer occupancy	NA	NA	CSMA with implicit ACKs and TDMA with fix scheduling

VI. CONGESTION CONTROL MECHANISMS IN WSNS.

It has mainly three phases (Detection, Notification & Rate adjustment)

a) Congestion Detection:

In WSN congestion can be detected by several ways like, buffer occupancy, channel sampling and packet service rate and scheduling rate.

b) Congestion Notification:

When the congestion is detected the entire network is informed about it in one of the ways below:

a. Explicit congestion notification
b. Implicit congestion notification

c) Congestion control approaches:

(Resource management and Traffic control)

Resource Management: To mitigate the congestion the network resource management tries to extend network resources. In wireless networks, power control and multiple radio interfaces can be used to increase bandwidth and weaken congestion.

Traffic Management: Have two methods for traffic control in WSN.

A. The hop-by-hop congestion control: It has faster response, it is usually difficult to adjust the packet forwarding rate at intermediate nodes mainly because packet forwarding rate is dependent of MAC protocol and could be variable.
B. The end-to-end congestion control: It imposes exactly the rate of adjustment at each source node and simplify the design at intermediate nodes, it results in slow response and relies highly on the round trip time (RTT) [14].

VII. CONCLUSION

WSNs experiences congestion, so it is required solution to control congestion. A lot of research and solutions are published to overcome the congestion problem. We made a survey on congestion control mechanisms for WSNs and underlined some suitable techniques and assumption to mitigate the congestion problem in the wireless sensor networks.

REFERENCES

[1] Luha, A. K., Vengattraman, T., & Sathya, M. (2014). RAHTAP Algorithm for Congestion Control in Wireless Sensor Network. *International Journal of Advanced Research in Computer and Communication Engineering*, *3*(4), 6250-6255..

[2] Luha, A. K., Vengattraman, T., & Sathya, M. (2014). RAHTAP Algorithm for Congestion Control in Wireless Sensor Network. *International Journal of Advanced Research in Computer and Communication Engineering*, *3*(4), 6250-6255.Monowar, M. M., Rahman, M. O., Pathan, A. S. K., & Hong, C. S. (2008, July). Congestion control protocol for wireless sensor networks handling prioritized heterogeneous traffic. In *Proceedings of the 5th Annual International Conference on Mobile and Ubiquitous Systems: Computing, Networking, and Services* (p. 17). ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering).

[3] Durand, C. P., Andalib, M., Dunton, G. F., Wolch, J., & Pentz, M. A. (2011). A systematic review of built environment factors related to physical activity and obesity risk: implications for smart growth urban planning. *Obesity Reviews*, *12*(5), e173-e182..

[4] N. Tdhrimoorthy and Dr. T. Anuradha, "A review on congestion control mechanisms in Wireless Sensor Networks"

[5] Dashkova, E., & Gurtov, A. (2012). Survey on congestion control mechanisms for wireless sensor networks. In *Internet of Things, Smart Spaces, and Next Generation Networking* (pp. 75-85). Springer Berlin Heidelberg.

[6] Thrimoorthy, N., & Anuradha, T. (2014). A review on congestion control

mechanisms in wireless sensor networks. *Int Journal of Engineering Research and Applications*, *4*(11), 54-9.

[7] Thiagarajan, L. N., & Rani, R. U. (2015). Congestion in Wireless Sensor Networks and Mechanisms for Controlling Congestion. *IJRIT*, *1*(5), 79-81.

[8] Monowar, M. M., Rahman, M. O., Pathan, A. S. K., & Hong, C. S. (2008, July). Congestion control protocol for wireless sensor networks handling prioritized heterogeneous traffic. In *Proceedings of the 5th Annual International Conference on Mobile and Ubiquitous Systems: Computing, Networking, and Services* (p. 17). ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering).

[9] Thrimoorthy, N., & Anuradha, T. (2014). A review on congestion control mechanisms in wireless sensor networks. *Int Journal of Engineering Research and Applications*, *4*(11), 54-9.

[10] Thrimoorthy, N., & Anuradha, T. (2014). A review on congestion control mechanisms in wireless sensor networks. *Int Journal of Engineering Research and Applications*, *4*(11), 54-9.

[11] Shah, S. A., Nazir, B., & Khan, I. A. (2016). Congestion control algorithms in wireless sensor networks: Trends and opportunities. *Journal of King Saud University-Computer and Information Sciences*.

[12] Thrimoorthy, N., & Anuradha, T. (2014). A review on congestion control mechanisms in wireless sensor networks. *Int Journal of Engineering Research and Applications*, *4*(11), 54-9.

[13] Khan, F., Bashir, F., & Nakagawa, K. (2012). Dual Head Clustering Scheme in Wireless Sensor Networks. in the IEEE International Conference on Emerging Technologies (pp. 1-8). Islamabad: IEEE Islamabad.

[14] Khan, F., & Nakagawa, K. (2012). Performance Improvement in Cognitive Radio Sensor Networks. in the Institute of Electronics, Information and Communication Engineers (IEICE) , 8.

[15] Khan, F., Kamal, S. A., & Arif, F. (2013). Fairness Improvement in long-chain Multi-hop Wireless Adhoc Networks. International Conference on Connected Vehicles & Expo (pp. 1-8). Las Vegas: IEEE Las Vegas, USA.

[16] Q. Jabeen, F. Khan, S. Khan and M.A Jan. (2016). Performance Improvement in Multihop Wireless Mobile Adhoc Networks. *in the Journal Applied, Environmental, and Biological Sciences (JAEBS*), vol. 6(4S), pp. 82-92. Print ISSN: 2090-4274 Online ISSN: 2090-4215, TextRoad.

[17] Khan, F., & Nakagawa, K. (2013). Comparative Study of Spectrum Sensing Techniques in Cognitive Radio Networks. in IEEE World Congress on Communication and Information Technologies (p. 8). Tunisia: IEEE Tunisia.

[18] Khan, F. (2014). Secure Communication and Routing Architecture in Wireless Sensor Networks. the 3rd Global Conference on Consumer Electronics (GCCE) (p. 4). Tokyo, Japan: IEEE Tokyo.

[19] M. A. Jan, P. Nanda, X. He and R. P. Liu, “PASCCC: Priority-based application-specific congestion control clustering protocol” Computer Networks, Vol. 74, PP-92-102, 2014.

[20] Khan, F. (2014, May). Fairness and throughput improvement in multihop wireless ad hoc networks. In *Electrical and Computer Engineering (CCECE), 2014 IEEE 27th Canadian Conference on* (pp. 1-6). IEEE.

[21] Khan, S., Khan, F., & Khan, S.A.(2015). Delay and Throughput Improvement in Wireless Sensor and Actor Networks. 5th National Symposium on Information Technology: Towards New Smart World (NSITNSW) (pp. 1-8). Riyadh: IEEE Riyad Chapter.

[22] Khan, F., Khan, S., & Khan, S. A. (2015, October). Performance improvement in wireless sensor and actor networks based on actor repositioning. In *2015 International Conference on Connected Vehicles and Expo (ICCVE)* (pp. 134-139). IEEE.

[23] Khan, S., Khan, F., Jabeen. Q., Arif. F., & Jan. M. A. (2016). Performance Improvement in Wireless Sensor and Actor Networks. in the Journal Applied, Environmental, and Biological Sciences Print ISSN: 2090-4274 Online ISSN: 2090-4215

[24] M. A. Jan, P. Nanda, X. He and R. P. Liu, “A Sybil Attack Detection Scheme for a Centralized Clustering-based Hierarchical Network” in Trustcom/BigDataSE/ISPA, Vol.1, PP-318-325, 2015, IEEE.

[25] Jabeen, Q., Khan, F., Hayat, M.N., Khan, H., Jan., S.R., Ullah, F., (2016) A Survey : Embedded Systems Supporting By Different Operating Systems in the International Journal of Scientific Research in Science, Engineering and Technology(IJSRSET), Print ISSN : 2395-1990, Online ISSN : 2394-4099, Volume 2 Issue 2, pp.664-673.

[26] Syed Roohullah Jan, Syed Tauhid Ullah Shah, Zia Ullah Johar, Yasin Shah, Khan, F., " An Innovative Approach to Investigate Various Software Testing Techniques and Strategies", International Journal of Scientific Research in Science, Engineering and Technology(IJSRSET), Print ISSN : 2395-1990, Online ISSN : 2394-4099, Volume 2 Issue 2, pp.682-689, March-April 2016. URL : http://ijsrset.com/IJSRSET1622210.php

[27] Khan, F., Jan, SR, Tahir, M., & Khan,

S., (2015) Applications, Limitations, and Improvements in Visible Light Communication Systems" In *2015 International Conference on Connected Vehicles and Expo (ICCVE)* (pp. 259-262). IEEE.

[28] Syed Roohullah Jan, Khan, F., Muhammad Tahir, Shahzad Khan,, (2016) "Survey: Dealing Non-Functional Requirements At Architecture Level", VFAST Transactions on Software Engineering, (Accepted 2016)

[29] M. A. Jan, P. Nanda, X. He, and R. P. Liu, "A Sybil Attack Detection Scheme for a Forest Wildfire Monitoring Application," *Elsevier Future Generation Computer Systems (FGCS)*, "Accepted", 2016.

[30] Puthal, D., Nepal, S., Ranjan, R., & Chen, J. (2015, August). DPBSV--An Efficient and Secure Scheme for Big Sensing Data Stream. InTrustcom/BigDataSE/ISPA, 2015 IEEE (Vol. 1, pp. 246-253). IEEE.

[31] Puthal, D., Nepal, S., Ranjan, R., & Chen, J. (2015). A Dynamic Key Length Based Approach for Real-Time Security Verification of Big Sensing Data Stream. In Web Information Systems Engineering–WISE 2015 (pp. 93-108). Springer International Publishing.

[32] Puthal, D., Nepal, S., Ranjan, R., & Chen, J. (2016). A dynamic prime number based efficient security mechanism for big sensing data streams.Journal of Computer and System Sciences.

[33] Puthal, D., & Sahoo, B. (2012). Secure Data Collection & Critical Data Transmission in Mobile Sink WSN: Secure and Energy efficient data collection technique.

[34] Puthal, D., Sahoo, B., & Sahoo, B. P. S. (2012). Effective Machine to Machine Communications in Smart Grid Networks. ARPN J. Syst. Softw.© 2009-2011 AJSS Journal, 2(1), 18-22.

[35] M. A. Jan, P. Nanda, M. Usman, and X. He, "PAWN: A Payload-based mutual Authentication scheme for Wireless Sensor Networks," *Concurrency and Computation: Practice and Experience*, "accepted", 2016.

[36] M. Usman, M. A. Jan, and X. He, "Cryptography-based Secure Data Storage and Sharing Using HEVC and Public Clouds," *Elsevier Information sciences*, "accepted", 2016.

[37] Jan, S. R., Khan, F., & Zaman, A. THE PERCEPTION OF STUDENTS ABOUT MOBILE LEARNING AT UNIVERSITY LEVEL. *NO. CONTENTS PAGE NO.*, 97.

[38] Khan, F., & Nakagawa, K. (2012). B-8-10 Cooperative Spectrum Sensing Techniques in Cognitive Radio Networks. *電子情報通信学会ソサイエティ大会講演論文集, 2012*(2), 152.

[39] Safdar, M., Khan, I. A., Ullah, F., Khan, F., & Jan, S. R. Comparative Study of Routing Protocols in Mobile Adhoc Networks.

[40] Shahzad Khan, Fazlullah Khan, Fahim Arif, Qamar Jabeen, M.A Jan and S. A Khan (2016). "Performance Improvement in Wireless Sensor and Actor Networks", Journal of Applied Environmental and Biological Sciences, Vol. 6(4S), pp. 191-200, Print ISSN: 2090-4274 Online ISSN: 2090-4215, TextRoad.

[41] M. Usman, M. A. Jan, X. He and P. Nanda, "Data Sharing in Secure Multimedia Wireless Sensor Networks," *in 15th IEEE International Conference on Trust, Security and Privacy in Computing and Communications (IEEE TrustCom-16)*, "accepted", 2016.

[42] Shah, S. A., Nazir, B., & Khan, I. A. (2016). Congestion control algorithms in wireless sensor networks: Trends and opportunities. *Journal of King Saud University-Computer and Information Sciences.*