A Review on Game Theory Based Congestion Control in Wireless Sensor Networks

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Abstract – Keeping a WSN network against technical glitches, attacks and exploitation is what contributes to the research community. The growth of WSN into our lives had increasingly given access to communication and applications irrespective of time and place. Such WSN are predicted to grow in size involving large number of nodes and communications. The WSN generally suffer from congestion and as a result the network performance and quality gets affected. To overcome network congestions, several methods and techniques are proposed, and network operators constantly monitor and control traffic in different layers. One such method is game theory, which is actively used in the network and communication area for many applications. For congestion control, use of game theory is widely been accepted and still researchers actively involve with game theory to moderate congestion. This paper presents a comprehensive review of the recent studies in gamey theory and congestion control in WSN network.

Index Terms – WSN, Game Theory, Congestion Control.

1. INTRODUCTION

The WSN network connects number of devices and applications across different platforms as a result WSN has been applied to various industries and fields (Fig 1). The growth of communication and connectivity between applications and devices have witnessed congestion, as a result the network performance is affected. There are several reasons for congestion to occur, but the fundamental reasons that causes congestion is the network traffic that arrive beyond its bandwidth. It is not always possible to improve the network infrastructure to handle the congestion. Several studies came out to mitigate the congestions but still WSN suffer due to increase sudden traffic flows for many reasons. Researchers started implementing models that can detect congestion and avoid it before through number of protocols and theories.

The most widely used technique is the routing protocol to control congestion but it is not efficient in avoiding information loss. Researchers control traffic through queuing, multi-path & alternate paths, distribution, setting priority and the congestion mechanisms can be grouped into centralized and decentralized mechanisms. Also, it is more important that these mechanisms are energy efficient, high performance, and low data loss. Recently Game theory has become the most interested area to be studied in WSN especially for congestion control, as Game theory offers low-cost, high tolerance and flexibility to suit different network requirements.

Game theory is based on every player's behavior and it can be cooperative and non-cooperative types. In a cooperative game, players cooperate and form group decisions whereas in non-cooperative players act independently. Game theory can be defined as a game with set of rules and set of outcomes. It is modeling of cooperation and conflicts to make appropriate decisions and the decision taken by a player affects the other players and the other player decides according to the decision of the first players. Several algorithms are introduced for congestion control with respect to cooperative and non-cooperative games. This paper reviews different games theory model proposed for congestion control and avoidance, allocation, network performance and effective routing in WSN.

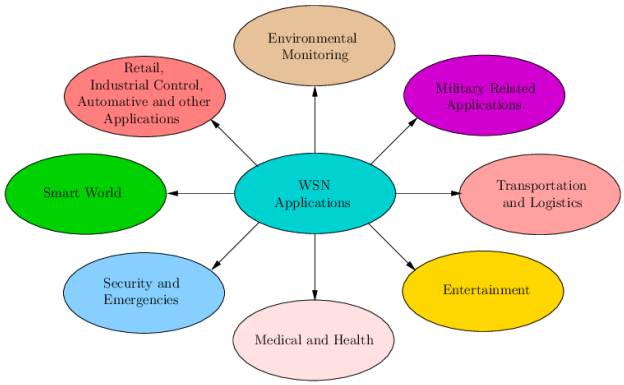

Fig 1 Application of WSN

Games & Networks	Goals & Functions
P2P networks	Avoid Free Riding
Routing Networks	Alternate path and minimizing delays
Ad hoc Networks	At what cost to forward the packets
Congestion control	Maintain inflow/outflow

Energy Control	Limits congestion based energy consumption
Transmission Networks	When to send packets

Table 1 Games & Goals

2. CONGESTION CONTROL GAME THEORY MODELS

To solve the congestion problem, it is not limited to increase new resources or extending the capabilities of the existing resources (Table 1). A large amount of theoretical and experimental work has been conducted to design stable congestion controls for high-speed heterogeneous networks through game theory. Some of the congestion control schemes for different networks are discussed below.

(Ding, Tang, L. & Ji, 2016) proposed a model to address both energy and congestion in WSN. Their method addresses the problem of congestion using flow rate and avoids congestions by finding alternate paths, the packets transfer is managed using radius of nodes this helping to find the best possible nearest nodes to forward the transmission. This method reduces energy and minimizes the packet loss.

(Sun, Huang, Liu, & Zhong, H. (2013) proposed a routing selection on the basis of energy consumption and putting the nodes in the sleeping modes. In the research they achieved network life time through sleep programming and achieved a twenty percent on energy saving. The energy consideration and path selection are fused together to achieve the network life time and energy utilization. The dynamic nature of their model to suit to different adaptation is notable.

(Hao, Gong, Hou, Liu, 2014) introduced a power control game model which governs channel allocation and power control. The model identifies the energy remainders and promotes allocation using non cooperative games. Their model achieved a stable energy relay and improved network performances.

(Kemal,Ibrahim, Bulent, Pala, 2012) studied using neighboring sensor nodes as the empowered to administer other header nodes. Using different administrators the nodes cooperate for transmitting data packets and avoid disconnection on the path of the transmission relay. As a result they achieved a longer network lifetime and reduced packet drops or transmission disconnections.

(Abd, Singh, Rubeaai, 2014) studied game theory based routing protocol for WSN. Using geographic routing, a transmission range is defined for every forwarding nodes and their energy levels are tracked. The network nodes and its density are rearranged into the transmission range so that the exact nature of traffic data is gathered. Using the traffic data and game theory the data transmission is governed through selecting the nodes in the transmission range. And simulation results proved that their model is efficient in improving network life time and better energy utilization.

(Miao, XN. & Xu, 2013) studied cooperative game theory to address energy efficiency and transmission delays. Their study proved that game theory is potential enough to control energy consumption and finding alternate paths to avoid transmission delays. They also studied the fairness of the each node that participate and the total cost of the cooperation consumes.

(Sun, Ding, Jiang, Geng, Chen, 2014) investigated the fairness of the network through routing coalition. They found that there is an impact on fairness and network efficiency. Using shapely value they achieved a fairness and quality of the network using CRG. Their results finally improve the network performances compared to other methods.

(Dasgupta, Dutta, 2013) studied selecting cluster heads where other nodes that are not participating in the cluster head formation, selective voting based scheme and scheduling of nodes to take roles of cluster heads are mainly discussed. They extensively studied the decision making process using game theory. Their results proved that the proposed method is better than leach and heeds while selecting the cluster heads.

Abidi W., Ezzedine T. (2018) proposed a new energy conserving technique by choosing cluster heads. They proposed a new approach of selecting the cluster heads using fuzzy logic methods. During their study they also adopted the parameters of finding distance between the cluster heads, their energy levels and number of nodes. Finally the proposed algorithm achieved better performance and improved network life time by reducing the energy.

(Ma, Sheu, & Hsu, 2016) introduced a novel congestion model for RPL. The model significantly improved the network throughput through altering a parent selection scheme. The study compared the same protocol in two simulators and found that the proposed protocol has improved the throughput double times against contikiRPL.

(Yao, Yin, Tan, and Bao, 2017) proposed a game theory framework for NDN networks, using game theory, the network flow rate in NDN is controlled through a cooperative game. Using Nash bargaining, the framework controls the hop count by flow aware, where each player is aware of the possible hop count needed and the congestion is controlled by minimum allocation and through which the congestion is avoided. The framework shows improvement in resource allocation, and throughput.

(Ghavami, et al., 2016) studied that in cloud, tenants that share networks often gets congested and leads to additional cost to the service provider. To maximize the bandwidth among the tenants and minimize the cost to the service provider, proposed a game model using response strategy to balance the usefulness

of sharing a balanced bandwidth and resources. The allocation of bandwidth to tenants using game theory improved performance and reduce the cost invoke due to congestion.

(Menache, & Ozdaglar, 2011) address the selfish agent participation in the network and studied resources allocation and delay & packet loss in the network using game theory. The model improved the overall performance of the network and proved that the degree of freedom of each player play an important role in congestion reduction and better allocation through maintain the network equilibrium. The model also improved the network energy of the network enabling to energy efficient.

(Gai et al, 2016) proposed a linear packet dropping function similar to RED in the internet protocol. The dropping function helps the server to drop packets using game based model to add incentives to queuing games. As the server operates in a first come first serve basis, the liner mechanism affects the network delay time and increases packets to drop. The game model helps the server to act dynamically to balance the queues and packet dropping.

(Kwon, & Rhee, 2016) proposed a game theoretic approach to handle congestion in vehicular network. The beacon broadcasting system gets congested when there is a high density of transmission and influx, to avoid congestion; an algorithm using game theory model is suggested to improve the network efficiency. The game model offers each transmitter to make decisions independently with reference to energy level and transmission state.

The BNE is kept at single point in the network game and to avoid the independent decision makings, the protocol finally showed an improved equilibrium point and improved the network performance and delay time in transmission.

(Hu, & Guo, 2016) proposed an additive-increase multiplicative-decrease adjustment strategy for improving the network performance through reducing the congestion. The game theory strategy follows a neighboring feedback scheme to achieve proper scheduling in a clustered WSN. The proposed system is capable of addressing the congestion and improved the network scheduling and the system is more effective through forming linear matrix inequalities.

(Akella, et al., 2002) studied the stability of the network with respect to selfish player. The study concluded that the selfish behavior of users in the TCP network can be a threat to the network stability and concluded that use of RED routing and dropping methods like CHOKE+ using game theory can help maintain the network stability. The user's greedy behavior cannot be predicted in advance and recovery of data loss is impossible but using game theory model, the user behavior and losses can be maintained in the NE and the network can be maintained stable with higher performance.

(Garg, et al., 2002) address the problem of congestion due to unresponsive flows rates, multiple parallel connections and TCP fairness using game theory. Using Diminishing weights Scheduler and Rate inverse Scheduling services, the behaviors that causes congestions is discouraged and the fair users are rewarded in NE.

(Wang et al 2012) proposed a game theory based model routing algorithm to counter attacks. The study proposed a congestion control algorithm NESD for DTN. The congestion at the node memory is reduced largely and the messages are transferred is guaranteed using NESD algorithm. The overall result on avoiding flooding attacks through routing algorithm improved the network performance and message delivery time.

(Farzaneh & Yaghmaee, 2015) proposed a resource control mechanism using game theory for WSN. They introduced EGRC control protocol for effective resource allocation. The proposed protocol controls the transmission power and resources using non cooperative game where the protocol adjusts the transmission rate with respect to congestion level and node energy. The study finds that EGRC improves throughput and conserves energy and packets.

(Yukun et al., 2017) proposed a centralized congestion control protocol using multi metrics (CCRPM) for lossy networks. By combining the energy left over's, buffer rate, link quality, and number of players, the protocol assigns players to new parents to reduce the network congestion taking place. Whenever the congestion takes place, the players are shifted to the new parents. The protocol was efficient in reducing the network congestion and increasing the network life time and decrease delay time.

(Oikonomou et al., 2013) introduced stateless multicast RPL forwarding algorithm using tickle multicast (TM). The experimental study shows that SMRF is effective in improving delay time and suitable for low energy devices. However there is a small loss is noted in the packets and the protocol improves the throughput of the RPL network.

(Kandris et al., 2017) proposed a protocol for WSN to control and minimize congestion. The proposed COALA protocol controls congestion through altering the paths. The altering path module is based on cost function, where nodes use the cost functions that are accumulated during congestion. The proposed COALA showed an improved reduction in losses, transmission delays, and energy depletion. The accumulated cost function enables the network throughput to be higher by reducing the congestion by alternating the paths.

3. CONCLUSION

Game theory continues to offer benefits to networking with respect each layer. In the physical layer it offers power control, spectrum allocation, and cooperative communications. In the data link layer it offers medium access control. In the network

layer it offers solutions to routing and forwarding of packets. In the transport layer it offers congestion control and load balancing. Though game theory offers more promising approaches towards networking still it can be explored further to attain a maximum benefits in conditions that are specific to applications.

Due to growing networking capability and application scalability, congestion takes places due to unavoidable reasons. To ensure network with high performance and functioning, congestion avoidance and mitigation plays a crucial role in network performance. Though new models and schemes are being introduced to solve networking problems, Game theory is found to be promising as game theory from the past literatures states that it is a powerful tool and most valuable in addressing networking problems. This paper discussed some of the game theory based approaches on networking problems such as energy control, routing and packet forwarding, packet loss, throughput increase and time delay. Especially game theory is well suited for low power and lossy networks where the network has low energy levels and high chance of instability.

REFERENCES

[1] Ma, C., Sheu, J. P., & Hsu, C. X. (2016). A game theory based congestion control protocol for wireless personal area networks. Journal of Sensors, 2016.

[2] Yao, J., Yin, B., Tan, X., & Bao, Y. (2017). A Game Theoretic Framework for Congestion Control in Named Data Networking. Information Technology And Control, 46(4), 605-618.

[3] Ghavami, A., Li, Z., & Shen, H. (2016, December). Game Theory-Based Nonlinear Bandwidth Pricing for Congestion Control in Cloud Networks. In Cloud Computing Technology and Science (CloudCom), 2016 IEEE International Conference on (pp. 214-221). IEEE.

[4] Menache, I., & Ozdaglar, A. (2011). Network games: Theory, models, and dynamics. Synthesis Lectures on Communication Networks, 4(1), 1-159.

[5] Gai, Y., Liu, H., & Krishnamachari, B. (2016). A packet dropping mechanism for efficient operation of M/M/1 queues with selfish users. Computer Networks, 98, 1-13.

[6] Kwon, Y. H., & Rhee, B. H. (2016). Bayesian game-theoretic approach based on 802.11 p MAC protocol to alleviate beacon collision under urban VANETs. International Journal of Automotive Technology, 17(1), 183-191.

[7] Hu, X., & Guo, W. (2016). A robust congestion control scheme for cluster wireless multimedia sensor networks with propagation delay and external interference. International Journal of Distributed Sensor Networks, 12(12)

[8] Akella, A., Seshan, S., Karp, R., Shenker, S., & Papadimitriou, C. (2002). Selfish behavior and stability of the internet:: a game-theoretic analysis of TCP. In ACM SIGCOMM Computer Communication Review (Vol. 32, No. 4, pp. 117-130). ACM.

[9] Garg, R., Kamra, A., & Khurana, V. (2002). A game-theoretic approach towards congestion control in communication networks. ACM SIGCOMM Computer Communication Review, 32(3), 47-61.

[10] Wang, C., Zhao, B., Yu, W., Wu, C., & Gong, Z. (2012). Routing Algorithm Based on Nash Equilibrium against Malicious Attacks for DTN Congestion Control. In International Conference on Availability, Reliability, and Security (pp. 488-500). Springer, Berlin, Heidelberg.

[11] Farzaneh, N., & Yaghmaee, M. H. (2015). An adaptive competitive resource control protocol for alleviating congestion in wireless sensor networks: an evolutionary game theory approach. Wireless Personal Communications, 82(1), 123-142.

[12] Yukun, Y., Jiangbing, L., Dongliang, X., Zhi, R., & Qing, H. (2017). Centralized congestion control routing protocol based on multi-metrics for low power and lossy networks. The Journal of China Universities of Posts and Telecommunications, 24(5), 35-43.

[13] Oikonomou, G., Phillips, I., & Tryfonas, T. (2013). IPv6 multicast forwarding in RPL-based wireless sensor networks. Wireless personal communications, 73(3), 1089-1116.

[14] Kandris, D., Tselikis, G., Anastasiadis, E., Panaousis, E., & Dagiuklas, T. (2017). COALA: A Protocol for the Avoidance and Alleviation of Congestion in Wireless Sensor Networks. Sensors, 17(11), 2502.

[15] Ding, W., Tang, L., & Ji, S. (2016). Optimizing routing based on congestion control for wireless sensor networks. Wireless Networks, 22(3), 915-925.

[16] Sun, D., Huang, X., Liu, Y., & Zhong, H. (2013). Predictable energy aware outing based on dynamic game theory in wireless sensor networks. Computers & Electrical Engineering, 39(6), 1601-1608.

[17] Liu Q., Xian X., Guo S., Wu T. Repeated-game theory of cooperative model in wireless sensor network routing. Chin. J. Sens. Actuat. 2010;23:1322–1327.

[18] Xiao-Chen Hao , Qian-Qian Gong , Shuang Hou , Bin Liu, Joint Channel Allocation and Power Control Optimal Algorithm Based on Non-cooperative Game in Wireless
Sensor Networks, Wireless Personal Communications: An International Journal, v.78 n.2, p.1047-1061, September 2014

[19] Bicakci, K., Bagci, I. E., Tavli, B., & Pala, Z. (2013). Neighbor sensor networks: Increasing lifetime and eliminating partitioning through cooperation. Computer Standards & Interfaces, 35(4), 396-402.

[20] Abd, M. A., Singh, B. K., Al Rubeaai, S. F., Tepe, K. E., & Benlamri, R. (2014, April). Game theoretic energy balanced (GTEB) routing protocol for wireless sensor networks. In Wireless Communications and Networking Conference (WCNC), 2014 IEEE (pp. 2564-2569). IEEE.

[21] Miao, X. N., & Xu, G. (2013). Cooperative differential game model based on trade-off between energy and delay for wireless sensor networks. Annals of Operations Research, 206(1), 297-310.

[22] Sun, R., Ding, E., Jiang, H., Geng, R., & Chen, W. (2014). Game theoretic approach in adapting QoS routing protocol for wireless multimedia sensor networks. International Journal of Distributed Sensor Networks, 10(3), 745252.

[23] Dasgupta, S., & Dutta, P. (2013). A novel game theoretic approach for cluster head selection in WSN. International journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN, 2(3), 2278-3075.

[24] Abidi, W., & Ezzedine, T. (2017, June). Energy Efficiency Cluster Head Election using Fuzzy Logic Method for Wireless Sensor Networks. In International Conference on Software Engineering Research, Management and Applications (pp. 167-177).