An Efficient Spectrum Management Using Game Theory for CR-WSN

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ABSTRACT

In the wireless sensor networks the Multiple access methods allow the multiple nodes wherein it can segment the available sets of the channels for the data transmission. For accessing the channel(s) the nodes can co-operate or compete, so that whether a group objective or an individual can be obtained. The Game theory, is a mathematical tool developed for understanding the relation between the rational entities, it can also be applied for analyzing and modelling the group or the individual behavior of the nodes for multiple access in wireless sensor networks. We offer a comprehensive review of the game theory models within this survey (e.g., dynamic/static, co-operative/ non-co-operative and the incomplete/ complete information) which is developed for various multiple-access-schemes (i.e., contention based and contention free random-access channels) within wireless sensor networks. The important outcome through the game theory model is highlighted within the different access.

Keywords: Game theory model , Wireless sensor network MAC, Spectrum Access Game, NE(Nash Equilibria).

I. INTRODUCTION

The theory of Game is division, however mathematicsis basically used in it, where in a condition of encounter andin what wayconclusions are selected by a rational entityis highlighted.The game theory offers a high set of mathematical gears which is used for modelling and analyzing between the rational entities. The Game theory is mainly used in Economics. In Engineering, it is widely used in the data communication. Individually, in a competitive environment the game theory is used for modelling and analyzing resource and routing allocation problems. The tools of game theory are used from the layered perspective for analyzing the waveform adaptation, routing, medium access, node participation and the power control [1].Alimited radio property(e.g., the power of the transmission and channels which are wireless) isdistributedwith the help of transmission nodes,within the multi-usercommunication of wireless sensor network.Hence, to achieve the performance of the optical network the nodes share the resources so that the data can be transmitted which isone major and uncertain issue in game theory.

Multiple access techniques inwireless sensor networks can be further classified into twomajor methods called as the contention-based random access and contention-free channel access.In the technique of multiple access, to achieve the objectives i.e., QoS (Quality of Service) and the optimal throughput the nodes might cooperate orcompete. Subsequently, in wireless sensor networks, to analyze and model the multiple access technique a mathematical tool is very useful which is known as theory of game. And also, the solutions are obtained for controlling the power, allocation of resources, cooperation enforcements and assignment of the channels throughout the nodes.

To study the working of the transmitting nodes, a different model called as game model is developed such that the wireless channel(s) can be accessed and multiple access solution (or the equilibrium) can be obtained [2], [3].

The main intention of this model is to maximize performance of the network (e.g., maximization of throughput, minimizing the consumption of the resource, and to provide the Quality of Services (QoS)which is guaranteed).

In the wireless sensor networks, the inspirations of using game-theory models for optimizing, analyzing and designing of multiple accessis as follows:

- *For multiple-access methods the Theoretical foundation:*The theory of game is especially used in economics, wherein a problem of multiplayer decision is normally considered. In making the decisions of an individual for a better success or the benefits it is completely dependent on others. A theoretical basic is provided by the theory of game such that for analyzing the interactions, the systems of multiplayer includesplayers who are non-human (e.g., animals, plants and the computers) and the human as well [4]. However, to a wireless network communication it is applied in the context of sharing the resources in which the nodes (e.g., base-stations, mobile stations, and the access point) are the playersthrough the network.
- *Distributed-protocols:* In manysituations, thejudgments that arecarried out through the wireless sensor nodes are performed within a distributed (or individual) schemeinstead of the centralized scheme. Game theory is the best toolfor optimizing the wireless access network in distributive manner. In the centralized method, as the size of network increases,it becomes more expensive to resolve the problems of multiple access. And, there might be chance of prohibition of the network control overhead. Using game theory, an effective and efficient algorithm of the distributed protocol is designed which decreasesthe computation and the communication overhead.
- *The Design in Mechanism:*To design the parameters of the game, independent wireless nodes are headed in the direction of the outcome of system. However, for this type of design mechanism pricing is one of the important issue which is overcome by the usage of minimum number of radio resources and by maintaining the cost of the wireless nodes.

II. OUTLINE OF MULTIPLE ACCESS TECHNIQUES

In this section,Basic models and the problems in performance and channel access that are completely interconnected to the design of the multiple-access in wireless sensor networks is discussed.

1. General Concepts:

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In the wireless sensor network the channel access techniques can be further classified into two important groups, called as, contention-free channel access and contention-based random channel access procedure. In the contention-free methods,the resources of the radio is assigned by multiple nodes (e.g., codes, the channels and the time slot) to the significant unit and for the diffusion of data the allocated resources are used by the nodes [5]. The contention free channel method can be used in multiple access networks of frequency division, code division and the time division.

- *TDMA (Time-division multiple access):* In time-division multiple access, the amount of time is completely classified intodifferentstructures where the length is already fixed and each of the frame is furthermore categorizedinto multiple time slot. For data transmissions,individual time slots are assigned to different nodes. In time-division multiple access, to escapeinterference, synchronization is required between the different nodes [6].
- *FDMA (Frequency-divisions multiple access):* In frequency-division multiple access, the band of radio frequency is divided intomultiple-channels. For the transmission of the data the channels are assigned to the nodes. An enhanced method of FDMA is OFDMA (Orthogonal-frequency-divisionsmultiple access) is completely based on the modulation called as Orthogonal-frequency-division multiplexing.
- *CDMA (Code-division multiple access):* In the code-divisions multiple access, the data can be transmitted consecutively on the same channel by the multiple nodes.

2. In the Multiple Access, the problems of Performance for wireless sensor networks:

The importantneeds for optimizationsand the designingof multiple-channel access methods for the sensor networks which is completely wireless [7]:

- *Increasing throughput within network:* The quantity of data that is transmitted successfully by the nodes in a given amount of time is referred as throughput. The main intention of the multiple access scheme is to maximize the overall throughput. It increases the efficiency of the spectrum in wireless sensor networks.
- *Decrease in delay:*The time taken by the packets totransmit data efficiently(however the transmission buffer is being obtained by the higher level) across the network is called as delay. As for the real-timetraffic (i.e. video and the voice) delay is one of the important implementation metric. However, for this kind of traffic the multiple channel access schememustdecrease the delay.
- *Improving the efficiency of power:* An essential performance metricfor battery powered wireless sensor nodes is efficiency of the power. Between the performance of a network and efficiency of power there is tradeoff. For minimizing the usage of power, the nodes must be kept in standby mode so thatneither the nodes will be able to transfer the packets nor receive the packets. Simultaneously, there is a reduction in throughput. In the wireless sensor network, we might see some sort of different behaviors while the nodes share the limited amount of the radio resources.

PROPOSED MODEL

The statistics of the available channels are considered and ECA for thatchannels are obtained. Let us assume that the sensors have the knowledge about how this temporal channel and the spatial distribution is used fora channel, i.e.,$G_{AB,a}$, $G_{AD,a}$,H_a ,$\mu_{bs,a}$, $\mu_{ide,a}$although the details of the primary sensor networks can be

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achievedfrom the operation of wireless sensor network. By using thisinformation, the sensor nodes can retrieve the ECA forspecific channels, i.e., $\Phi_a, a \in R,$ which is completely based on their speed. Before the transmission, the wireless sensor performs the spectrum sensing, however in this paper it is supposed to be accurate. Due to major transmissions, the ECA is equivalent tonothing i.e. (Zero) only if the channel is unavailable. We consider the bandwidth of independent channel is similar tothe identical channel, the theory of the game [8] can be used for analyzing the performance of distributed players where it is stated as the rational and selfish. For modelling the spectrum access process, a non-cooperative congestion game isused within the wireless sensor networks, where in the sensorsselects the channels through the clustersfor accessing in a circulatedmethod, trying to improve their services. By using slotted ALOHA and MAC, we identify the presence and the efficiency of the Nash equilibria (NE).

A. The Spectrum-Access Game Formulation

The problem of spectrum-access is designed as the game of congestion,n number of resources and players are consideredin it and for particular player by choosing a particular resource which is connected to different multiple-players picking up the same resources [9].

Within this work, the spectrum-access congestion game design is cleared as$\prod = \{S, K, \{T_b\}_{b \in S}, \{Z_b\}_{b \in S}\},$ where $S = \{1, \dots, S\}$ is the players which are in finite set, i.e., sensors in the cluster. The density of the sensor is associated as S, it is represented asβ_i ; $X = \{1, \dots, K\}$ is a regular channel which are accessible, where accessiblerepresents thatit is recognizedas inactive and $X \subseteq R;$ $T_b$is represented as strategies which is completely pure which is related with sensor b,$Z_b$is the service functions of $b$sensor.

B. Channel Access Game within the Nash Equilibria

Nash equilibria (NE) is the recognizedtheorywhere the outcome of the game can be analyzed, wherein it indicates that in equilibrium, a strategy of utility maximizing can be selected by everyuser, it provides theschemesfor different operators.

Definition-1: A summary of the scheme for different player$T^* = (t_1^*, t_2^*, \dots, t_S^*,)$is a Nash Equilibria if and only if

$$Z_b(t_b^*, t_{-b}^*,) \geq Z_b(t_b', t_{-b}^*,) \ \forall \, b \in S, t_b' \in \ T_b \qquad (1)$$

Which states that, its utility cannot be increased by anyone except by doing any changes in its own scheme, providing scheme for different operators.Therefore, if the summary of scheme$T$in (1) is acceptance, only then it is known as Nash Equilibria (NE).

In this work, the pure Nash Equilibria (NE) is mainly considered; hence the expressionsi.e., Nash Equilibria and pure Nash Equilibria is interchangeably used.

InGame of spectrum access$\prod$, provided a summary of scheme, if none of the sensors can develop its service by transferring to the different channels, then a summary of scheme is mentioned to the pure Nash Equilibria. Denoted by $T = (t_1, t_2, \dots, T_S)$a summary of the scheme of all sensors, where in$t_a$is a particular channel. Denoted by $z(T) = (h_1, h_2, \dots, h_K)$ as the congestion vector, which displays that the n number of sensor has selected each of the channels, which is corresponded to the summary of scheme T.

As per the Definition 1, the pure Nash Equilibria(s) is available in the game of spectrum access Πif and only if, for each player$b \in S$.

$\Phi_{t_b} m(h_{t_b}) \geq \Phi_q m(z_q + 1), \quad \forall q \in X \quad q \neq t_b.$ (2)

C. Uniform MAC

The easiest method of distributing the channels throughout the multiple users is to provide access to the channel uniformly for selected operators, wherein it is denotedas the uniform MAC [10]. By each sensor a backoff process takes place, although some time is casually chosenalong with the window which is fixed. Suppose one of the sensorsrecognizes that its own backoff is beingterminated, then the channels arepreservedas idle, then for that whole-time slot the channel will be able to access it, however the other sensor nodesshould be quiet. In the Uniform-MAC, the distribution of the resource task$m(h) = \frac{1}{h}$; accordingly, the utility function.

$$Z^{a}_{b[ufm]} = \frac{\Phi_a}{h_a} \quad (3)$$

Note that$d_{ufm}(h) = 1$. The game which uses the uniform MAC will be having a pure NE (Nash Equilibria) which is clearly discussed in [10]. In the proposition-1, the situation of pure Nash Equilibria is obtained when the Uniform-MAC is engaged,it might express that the multiple Nash Equilibria groups exists.

Proposition-1: For spectrum-access gameΠ by using uniform-MAC, if the congested vectors$z = (h_1, h_2, \dots, h_K)$produces NE-*set*$(K)$, the subsequentsituationmust be satisfied:

$$\begin{cases} h_a = \left\lfloor \dfrac{\Phi_a S - \sum_{q \neq a,\ q \in X} \Phi_q}{\sum_{q \in X} \Phi_q} \right\rfloor + M_0 \quad a = 1,2,\dots,K \\ \sum_{a=1}^{K} h_a = S \end{cases} \quad (4)$$

Where,

$$M_0 \in \left\{0,1,2,\dots,\left\lceil \Phi_a|S| + \frac{\Phi_a(|X|-1)}{\sum_{q \in X} \Phi_q} \right\rceil - \left\lfloor \Phi_a|S| - \sum_{q \neq a,\ q \in X} \Phi_q \right\rfloor - 1 \right\}$$

D. Slotted-ALOHA

To the Uniform-MAC comparison, the slotted-ALOHA is additional to the typical-MAC which is mainly used within the sensor network, which also includes the Wireless sensor networks. In the slotted ALOHA, each sensor accesses the channelswith the probability $k$and for each sensor the throughput is$pl(k) = k(1-k)^{h-1}$.For maximizing the throughput, let$pl'(k) = 0$. Then, we get$k = \frac{1}{h}$, and by using the slotted-ALOHA the resource allocation function is

$$m_{TQ}(h) = \frac{1}{h}\left(1 - \frac{1}{h}\right)^{h-1} \quad (5)$$

It is presented, for the slotted ALOHA,$d_{TQ}(h) = (1 - 1/h)^{h-1}$,with $d'_{TQ}(h) < 0$ and $d''_{TQ}(h) > 0$ (as proved in [10]).

Furthermore, if h goes to limitless, thenoverall output of the throughput of slotted ALOHA is

$$\lim_{h \to \infty} d_{TQ}(h) = \frac{1}{r} \quad (6)$$

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The utility of sensor b that selects the channel a using slotted ALOHA is given by

$$Z_{b[TQ]}^{a} = \Phi_a \frac{1}{h_a}\left(1 - \frac{1}{h_a}\right)^{h_a - 1} \quad (7)$$

Unlike from the uniform MAC, by using the slotted-ALOHA it is much more challenging toobtain the clearsituation of pure Nash Equilibria.

E. Efficiency Analysis

In the Earlier sections, the presence of pureNash Equilibria(s) in game of spectrum access Π is verified. In common, sincethe players perform in egotistic manner the Nash Equilibria does not obtain the global optimality. For evaluating the utilization of the resources the effectiveness of a Nash Equilibria (NE) is evaluated, wherein it is cleared as the number of total services of all the different players in Nash Equilibria.In spectrum-access gameΠ, effectiveness of a pure Nash Equilibria is explained:

$$\Omega_T = \sum_{b=1}^{S} Z_b^a = \sum_{b=1}^{S} \Phi_{t_b} m(h_{t_b}) = \sum_{a=1}^{K} \Phi_a h_a m(h_a) \quad (8)$$

Where$T$is summary of the schemewhich is a pure Nash Equilibria.

The social-optimality Spt_Π is elaborated as the number of services of all the different players amongst entirelypotential summary of the scheme. The social-optimality Spt_Π is permanent for that particular game. This is verified in [10] that the social-optimality Spt_Π inΠ:

$$Spt_\Pi = \begin{cases} \sum_{a=1}^{S} \Phi_a, & ,S \le K \\ \sum_{a=1}^{K-1} \Phi_a + \sum_{a=K}^{S} \Phi_{K^m}(S - K + 1) & ,S > K \end{cases} \quad (9)$$

Where$\Phi_a$is ordered such that$\Phi_1 \ge \Phi_2 \ge \cdots \ge \Phi_K$. Therefore, to evaluate the effectiveness of a Nash Equilibria, we describe a ratio such that the ER of Nash Equilibriaamong the social-optimality Spt_Π and the efficiency given by

$$NH_T = \frac{\Omega_T}{Spt_\Pi} \quad (10)$$

F. Achieving a Nash Equilibriawith High ER

Subsequently, for spectrum sensing, individual sensor has the information of available channel, $a \in X$, and ECA of that channel, i.e.Φ_a.The list of the channelwithin X isconserved by the sensor nodein the decreasing direction ofΦ.Lastly in the distributed game spectrum accessΠ they are mainly contributed. However, in distributed way the sensor is performedwithin networks of wireless sensor, for the game the better solution is a pure Nash Equilibria. As per the proposition 2, the each of the sensor nodes can obtain the pure NE which sequentially chooses the ER.

III.SIMULATION RESULT AND ANNALYSIS

The environment of the system uses the operating system with 64-bit Quad core, windows 7 with 8GB of RAM and 4GB dedicated CUDA graphic card. For the proposed work we have used programming languages such as C# 6.0 and .NETframework 4.0. On several following parameters, an experimental study is performed that is the transmission of packet done successfully, the collisions of packets per unit channels and as per channels the throughput is achieved. The network area is allocated as 50*50 meters, for the sensor nodes it is allocated as 10 and 40, 7 is for the frequency slots and for time slots it is allocated as 8 which is overall incorporated within the spectrum. 27mbps is considered as the maximum amount of bandwidth. As the existing model, the slotted-ALOHA Mac is considered and as the proposed model we have considered PS-MAC .

In Fig.1, the simulation result of the throughput obtained as per the channel is presented. From 10 and 40 sensor devices the sensor nodes is varied and over the existing model the throughput improved is shown in the proposed model. When the sensor node is equal to 10 an average throughput improvement of 10.06% is obtained. And when the sensor node is equal to 40 the throughput improvement of 13.72% is obtained.

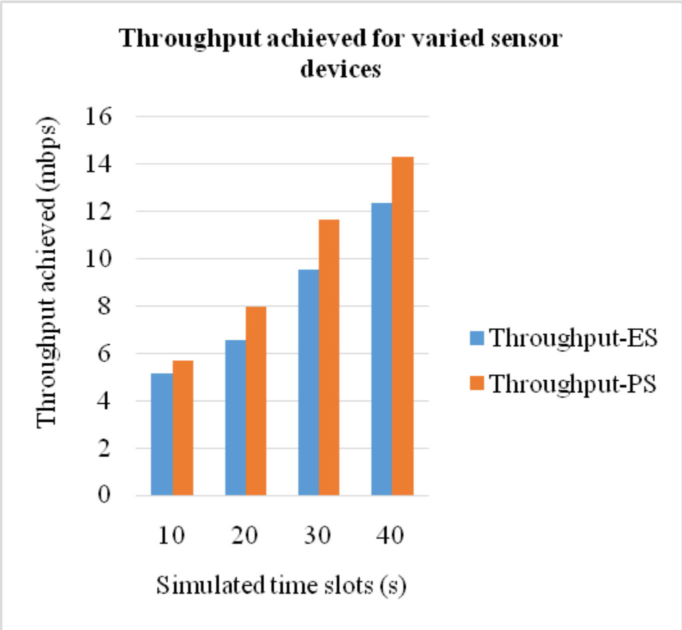

Fig 1:Throughput achieved per slot for varied sensor devices.

In Fig. 2, for the collision of packets the simulation outcome is shown. From 10 and 40 sensor devices, the sensor nodes are different and therefore result shows that the collision of the packet is minimized in the proposed model over the existing model. When the sensor nodes are equal to 10 the collision reduction is obtained as 82.35% and when the sensor nodes are equal to 40 then the collision reduction is obtained as 83.71%. In the graph represented we see that as the number of sensor devicesrises then there is an increase in the collision for both approaches i.e., the proposed and existing approach.

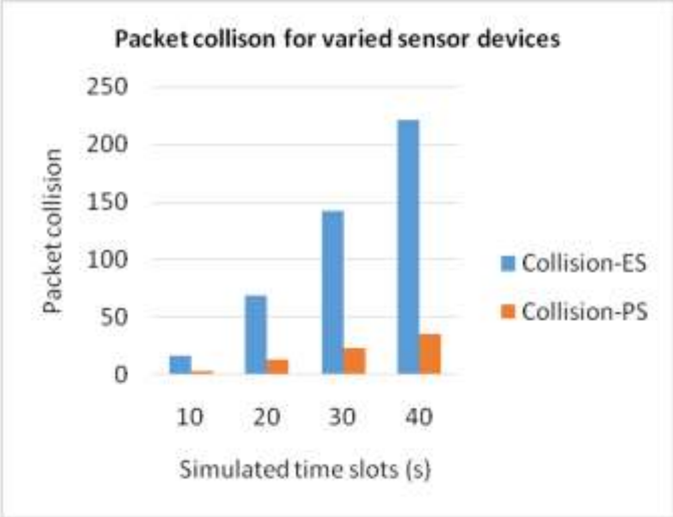

Fig 2: Packet collision for varied sensor devices.

In Fig. 3, the simulation outcome of packet transmission is shown. The sensor nodes are varied from 10 and 40 sensor devices and outcome shows the proposed model improves the packet transmission over existing model. An improvement of the transmission of 18.42% is obtained when the sensor node is equal to 10 and improvement in transmission of 22.42% is obtained when sensor node is equal to 40. It is seen from graph as we increase the number of sensor devices the transmission also increases for both proposed and existing approach.

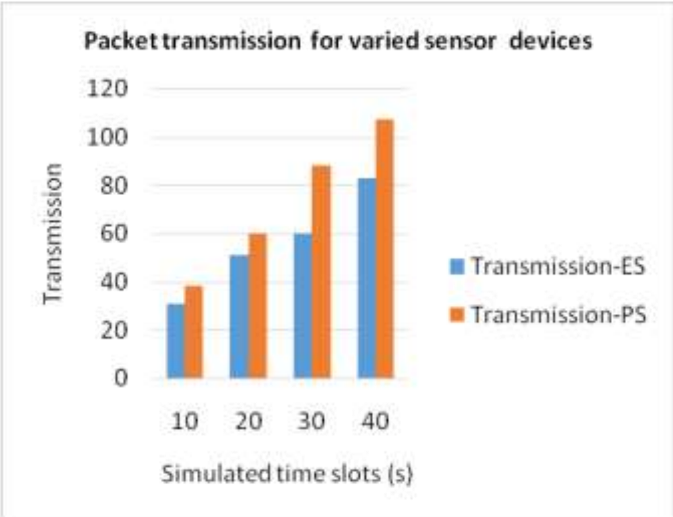

Fig 3: Packet transmission for varied sensor devices.

IV.CONCLUSION

The theory of Game is generally used for analyzing and modelling the cooperative and the non-co-operative behaviors of the sensor node in the framework with the multiple-access. In wireless sensor network, the mechanismsof distributed-channel access is designed by the game theory model,Such that an effective and stable solutions can be obtained. In this work, we have represented a comprehensive game-theory models survey which is developed for the multiple-access in networks of wireless sensors. Based-on different forms of

proceduresthat is contention-based and contention-free and different kinds of games (e.g., the information which can be incomplete and complete, and static and dynamic games) the game theory model is categorized.
Therefore, important areas from the game theory model isdiscussed in this paper. The behavior of nodes, Unavailabilityfor the complete information, the system consideration (i.e., implementation) are the important aspects which provides a growth to the main challenges for designing the game theoretic model scheme of the multiple-access in the networks of wireless sensors.End of this, in most of the ways, there is path which is opened for the research.

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