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The Study of Game Theory in Wireless Sensor Networks

Vinoba.V[1], Chithra.S.M[2]

1. Department of Mathematics, K.N. Government Arts college, Tamil Nadu, India.

2. Department of Mathematics, R.M.K College of Engineering and Technology, Research Scholar, Bharathidasan University, Tamil Nadu, India.

ABSTRACT

This paper presents fundamental results in game theory and their application to wireless communications and networking. It provides a foundational understanding of the current research on game theory. The application of mathematical analysis to wireless sensor networks has met with limited success, due to the complexity of mobility and traffic models, coupled with the dynamic topology and the unpredictability of link quality that characterize such networks. The ability to model individual, independent decision makers whose actions potentially affect all other decision makers . Game theory is particularly an attractive field to analyze the performance of sensor networks. Game theory is a field of applied mathematics that describes and analyzes interactive decision situations. It consists of a set of analytical tools that predict the outcome of complex interactions among rational entities, where rationality demands a strict adherence to a strategy based on perceived or measured results. There has been growing interest in adopting game-theoretic methods to model today's leading communications and networking issues, including power control and resource sharing in wireless and peer-to-peer networks. Also we discussed the challenges and limitations in the application of game theory to the analysis of wireless sensor networks and major game theoretic models.

Keywords: Game Theory, Cooperative game theory, Non-cooperative game theory, Wireless communication and Wireless Sensor Networks.

1. INTRODUCTION

Game theory's roots are extremely old. The ideas behind game theory have appeared through-out history [1], apparent in the bible, the Talmud, the works of Descartes and Sun Tzu, and the writings of Charles Darwin [2]. However, some argue that the first actual study of game theory started with the work of Daniel Bernoulli, A mathematician born in 1700. Although his work, the "Bernoulli's Principles" formed the basis of jet engine production and operations, he is credited with introducing the concepts of expected utility and diminishing returns [3]. Others argue that the first mathematical tool was presented in England in the 18th century, by Thomas Bayes, known as "Bayes 'Theorem"; his work involved using probabilities as a basis for logical conclusion [3]. Nevertheless, the basis of modern game theory can be considered as an outgrowth of a three seminal works; a "Researches into the Mathematical Principles of the Theory of Wealth" in 1838 by Augustine Carnot, gives an intuitive explanation of what would eventually be formalized as Nash equilibrium and gives a dynamic idea of players best-response to the actions of others in the game. In 1881, Francis Y. Edge worth expressed the idea of competitive equilibrium in a two-person economy. Finally, Emile Boral suggested the existence of mixed strategies, or probability distributions over one's actions that may lead to stable play. It is also widely accepted that modern analysis of game theory and its modern methodological framework began with John Von Neumann and Oskar Morgenstern book. [4]. We can say now that "Game Theory" is relatively not a new concept, having been invented by John Von Neumann and Oskar Morgenstern in 1944 [4]. At that time, the mathematical frame work behind the concept has not yet been fully established, limiting the concept's application to special circumstances only [5]. In 1950 and 1960's game theory was broadened theoretically and applied to problems of war and politic. Game theory was later explicitly applied to biology in the 1970's, although similar developments go back at least as far as the 1930's. In John Von Neumann and Oskar Morgenstern conceived a groundbreaking mathematical theory of economic and social organization, based on a theory of games of strategy [4]. Not only would this reform economics, but the entirely new field of scientific inquiry it yielded has since been widely used to analyze a host of real-world phenomena from arms races to optimal policy choices of presidential candidates, from vaccination policy to major league baseball salary negotiations [5] . In addition, it is today established throughout both the social sciences and a wide range of other sciences like Military etc.

2. GAME THEORY

Game theory, defined in the broadest sense, is a collection of mathematical models formulated to study situations of conflict and cooperation. It is concerned with finding the best actions for individual decision makers in these situations and recognizing stable outcomes. The object of study in game theory is the game, defined to be any situation in which:

- There are at least two players: A player may be an individual, a company, a nation, a wireless node, or even a biological species.
- Each player has a number of possible strategies, courses of action he or she may choose to follow.

- The strategies chosen by each player determine the outcome of the game.
- Associated with each possible outcome of the game is a collection of numerical payoffs, one to each player. These payoffs represent the value of the outcome to the different players.

In 1950 John Nash demonstrated that finite games always have a Nash equilibrium (also called a strategic equilibrium). Nash equilibrium is a list of strategies, one for each player, which has the property that no player can unilaterally change his/her strategy and get a better payoff. This is the central concept of non-cooperative game theory and has been a focal point of analysis since then. Game theory received special attention in 1994 with the awarding of the Nobel Prize in economics to John Nash, John Harsanyi and Reinhardt selton.

3. TERMINOLOGIES OF GAME THEORY

The different terminologies that are associated with the game theory are now defined.

1. Players: A player is an agent who makes decisions in a game. That is there are two players in a game. The players maybe any two companies (for e.g. Company A and company B) competing for tenders, two countries were planning for trade gains in a third country, two persons bidding in a game, etc.

2. Strategy: It is a course of action taken by a player, for e.g., giving computer furniture's free of cost, giving 30% additional hardware, gibing special prize, etc., while selling computer hard ware. In a game in strategic form, a strategy is one of the given possible actions of a player. In an extensive game, a strategy is a complete plan of choices, one for each decision point of the player. The strategy can be further classified into pure strategy and mixed strategy. Let m be the number of strategies of player A and n be the number of strategies of player B, p_i be the probability of selection of the alternative i of player A, i = 1,2,3,….m. Let q_j be the probability of selection of the alternative j of player B, for j = 1,2,3…..n. The sum of the probabilities of selection of various alternatives of each of the players is equal to 1 as shown below. $\sum_{i=1}^{m} p_i = 1$ & $\sum_{j=1}^{n} q_j = 1$.

(i)**Pure strategy**: If a player selects a particular strategy with a probability of 1, then that strategy is known as a pure strategy. This means that the player is selecting that particular strategy alone ignoring his remaining strategies. If player A follows a pure strategy, then only one of the p_i values will be equal to 1 and the remaining p_i values will be equal to 0. A sample set of probabilities of selection of the alternatives for player A is shown below: $p_1 = 0$, $p_2 = 1$, $p_3 = 0$. The sum of these probabilities is equal to 1.That is $p_1 + p_2 + p_3$ =0+1+0=1.

(ii)**Mixed strategy**: If a player follows more than one strategy then the player is said to follow a mixed strategy. But the probability of selection of the individual strategies will be less than one and their sum will be equal to one. $q_1 = 0.65$, $q_2 = 0$ $q_3 = 0.35$. It is clear that the sum of the probabilities is equal to 1. That is $q_1 + q_2 + q_3 = 0.65 + 0 + 0.35 = 1$

3. **Payoff matrix**: A payoff is a number, also called utility that reflects the desirability of an outcome to a player, for whatever reason. When the outcome is random, payoffs are usually weighted with their probabilities. The expected payoff incorporates the player's attitude towards risk.

4. **Nash equilibrium**: A Nash equilibrium also called strategies equilibrium, is a list of strategies, one for each player, which has the property that no player can unilaterally change his strategy and get a better payoff.

5. **Perfect information**: A game has perfect information when at any point in time only one player makes a move, and knows all the actions that have been made until then.

6. **Dominating strategy**: A strategy dominates another strategy of a player if it always gives a better payoff to that player, regardless of what the other players are doing. It weakly dominates the other strategy if it is always at least as good.

7. **Rationality**: A player is said to be rational if he seeks to play in a manner which maximizes his own payoff. It is often assumed that the rationality of all players is common knowledge.

8. **Strategic form**: A game in strategic form, also called normal form, is a compact representation of a game in which players simultaneously choose their strategies. The resulting payoffs are presented in a table with a cell for each strategy combination.

9. **Zero-sum game**: A game is said to be zero-sum if for any outcome, the sum of the payoffs to all players is zero. In a two-player zero-sum game, one player's gain is the other player's loss, so their interests are diametrically opposed.

10. **Two-person zero-sum game** : In a game with two players, if the gain of one player is equal to the loss of another player, then that game is called two-person zero-sum game.

11. **Maximum Principle**: This principle maximizes the minimum guaranteed gains of player A. The minimum gains with respect to different alternatives of A, irrespective of B's alternatives are obtained first. The maximum of these minimum gains is known as the maximin value and the corresponding alternatives are called as maximin strategy.

12. **Minimax Principle**: This principal minimizes the maximum losses. The maximum losses with respect to different alternatives of player B, irrespective of player A's alternatives, are obtained first. The minimum of these maximum losses is known as the minimax value and the corresponding alternatives are called as minimax strategy.

13. **Saddle Point**: In a game, if the maximum value is equal to the minimax value, then the game is said to have a saddle point. The interesting cell corresponding to these

values is known as the saddle point. If the game has a saddle point, then each player has a pure strategy.

14. **Value of the game**: If the game has a saddle point, then the value of the cell at the saddle point is called the value of the game

4. WIRELESS SENSOR NETWORK

The wireless sensor network (WSN) is an emerging technology which facilitates human life in great ways. WSN may have many inexpensive wireless sensor nodes, each capable of collecting, storing, processing environmental information, and communicating with neighboring nodes for communication. WSN used in broad range of applications related to military and civil applications such as target field imaging, intrusion detection, weather monitoring, security and tactical surveillance, distributed computing, detecting ambient conditions like temperature, movement, sound, light, or the presence of certain objects, inventory control, and disaster management (Akyildiz Su *et al.* 2002). Wireless Sensor Networks (WSN) typically consists of a large number of sensor nodes distributed over a certain region and the position of sensor nodes need not be engineered or pre-determined. They usually transform data into electric signals, which are then processed to reveal some of the characteristics about the phenomena where it is located. The unique nature of the sensor networks is the cooperative effort of sensor nodes. Wireless sensor network can assist rescue operations by locating survivors, identifying risky areas, and making the rescue team more aware of the overall situation in a disaster area. The sensor nodes have the ability to communicate either among each other or directly to an external base station (BS). A larger number of sensors were used for sensing over large geographical regions with greater accuracy. The wireless sensor nodes are the central element in a wireless sensor network. Figure 3.1 shows the architecture of a sensor node. The node consists of sensing, processing, communication, and power subsystems. They may also have additional application dependent components such as a location finding system, power generator and mobilize. Sensing units are usually composed of two sub units: sensors and Analog-to-Digital Converters (ADCs).

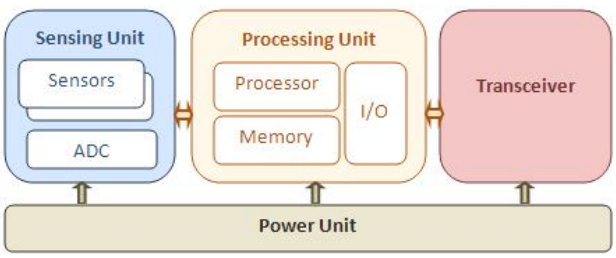

Figure 3.1 Architecture of a Sensor Node

The analog signals produced by the sensors based on the observed phenomenon are converted to digital signals by ADC, and then fed in to processing unit (Akyildiz Su *et al.* 2002). The processing unit plays the vital role in a sensor node and the choice of a processor unit determines the tradeoff between flexibility and efficiency in terms of both energy and performance. There are several processors such as microcontrollers, digital signal processors, application-specific integrated circuits, and Field Programmable Gate Arrays. A transceiver unit contains both transmitter and receiver which transmit/receive to and from the network. One of the most important components of a sensor node is the power unit and this unit may also be supported by a power scavenging unit such as solar cells. Most of the sensor network, routing techniques and sensing tasks require the knowledge of location with high accuracy. Thus, it is common that a sensor node has a location finding system. A mobilize may sometimes be needed to move sensor nodes when it is required to carry out the assigned tasks. All of these subunits may need to fit into a matchbox-sized module (Intanagonwiwat *et al.* 2000) and the required size may be smaller than even a cubic centimeter (Potties and Kaiser 2000) which is light enough to remain suspended in air. The sensor nodes are usually scattered in a sensor field, each of these scattered sensor nodes has the capabilities to collect and route data to the sink (Base Station) by a multihop infrastructure less architecture as shown in Figure 3.2.

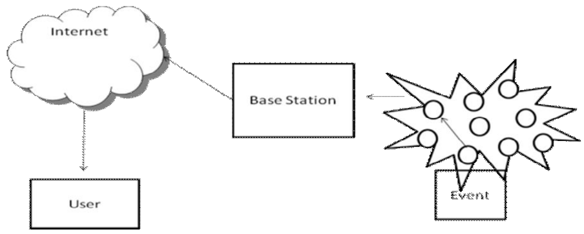

Figure 3.2 The Communication Architecture of Sensor Network

The sink may communicate with the user (task manager) node through the Internet or Satellite. The protocol stack used by the sink and all sensor nodes is given in Figure 3.3. This protocol stack combines power efficiency, routing awareness, data integration and network participation. The protocol stack consists of the application layer, transport layer, network layer, data link layer, physical layer, power management plane, mobility management plane and task management plane.

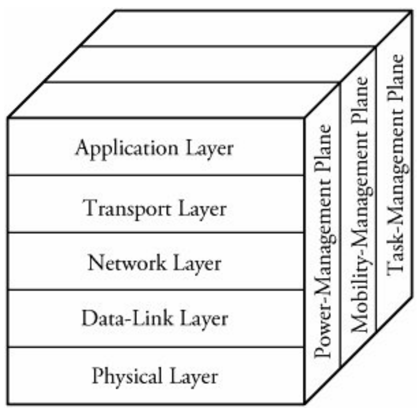

Figure 3.3 The Sensor Networks Protocol Stack

The physical layer addresses the needs of simple and efficient modulation, transmission/receiving techniques and also it is responsible for frequency selection, carrier frequency generation, signal detection and data encryption. The choice of a good modulation scheme is critical for reliable communication in a sensor network. The data link layer is responsible for the multiplexing of data streams, data frame detection, medium access and error control. The Medium Access Control (MAC) protocol must be power-aware and able to minimize collision with neighbor's broadcasts. The network layer takes care of power efficiency of the node and route data supplied by the transport layer. The transport layer helps to maintain the flow of data if the sensor networks application requires it. This layer is especially needed when access to the system is planned through Internet or other external networks. Depending on the sensing tasks, different types of application software can be built and used on the application layer. In addition, the power, mobility, and task management planes monitor the power, movement, and task distribution among the sensor nodes. These planes help the sensor nodes to coordinate the sensing task and reduce the overall power consumption.

5. MOTIVATIONS

In recent years, WSN has mainly used in applications such as health, military and environmental monitoring. This growth has been fueled by the widespread popularity in wireless communication. However, there are limits due to energy constraint. Owing to the energy level variation, the network lifetime gets reduced; therefore considerable effort has been invested in making more efficient use of it. To maximize the network lifetime, the energy consumption of node should be reduced. Recently a major research focus in this area and many authors are currently focusing on the design of power aware protocols and algorithms for sensor networks, apart from these protocols the researchers has been focused on coverage area of sensor nodes through the use of centralized and localized k-coverage algorithms. These proposed algorithms states that, depending on the network size, the network is reconfigured to any one of the algorithm to minimize the wastage of energy. Among many alternative approaches, game theory has been increasing applied in the design of wireless sensor networks, thus the scope of this paper is restricted to the use of game theory for wireless sensor networks. From 2003 to 2013, about 390 research papers with topics on or closely related to game theory for WSN were published. Among the variety of developed methods using GT, the main differences and remarkable features can be briefly summarized below. Cooperative game theory provides analytical tools to study the behavior of rational player when they cooperate and consider the utility of all the players. [6, 7]. Non cooperative game theory also covers a broad range of applications in WSN [8, 9]. In non cooperative game theory, the nodes buy, sell, and consumer goods in response to the prices that are exhibited in a virtual market. A node attempts to maximize its profit for taking a series of actions. Whether or not a node receives a profit is decided by the success of the action. Note that non cooperative game theory is mainly focused on each user's individually utility rather than the utility of the whole network. On the contrary, cooperative game theory can achieve general pareto-optimal performance and maximize the entire network's payoff while maintaining fairness. In addition to cooperative and non cooperative game theories, repeated game theory is concerned with a class of dynamic games, in which a game is played for numerous times and the players can observe the outcome of the previous game before attending the next repetition.

6. GAME THEORY IN WIRELESS SENSOR NETWORKS

5.1 COMPONENTS OF A GAME

A game is a set of three fundamental components: a set of players, a set of strategies, and a set of payoffs. Players or nodes are the decision takers in the game. The strategies are the different choices available to nodes. Finally, a utility function (payoffs) decides the all possible outcomes for each player. Table 1. Shows typical components of a wireless sensor networking game.

Table 1: Components of a wireless sensor networking game

Components of a game	Elements of a wireless sensor networks
Players	Nodes in the wireless sensor network
A set of strategies	A modulation scheme, Coding rate, transmit power level, etc.
A set of payoffs	Performance metrics (e.g. Throughput, Delay, SNR, etc.)

Game theory has emerged in divers recent works related to communication networks, cognitive radio networks, wireless sensor networks, resource allocation and power control.

5.2 GAME CHARACTERISTICS

There are several game theory models which can be categorized or the basis of factors like the number of players involved in the game, the sum of gains or losses, the number of strategies employed in the game and it can be designed as a one-player game, two-player game or n-players game. The terminology used in game theory is inconsistent, thus different terms can be used for the same concept in different sources. The commonly used Game theory methods for solving WSN problems and several main terminologies are listed in Table 2.

Game Theory Methods	Common Terminologies in Game Theory
(i) Cooperative game theory (ii) Non cooperative game theory (iii) Repeated game theory (iv)Coalitional game theory (v)Evolutionary game theory (vi)Guar game theory (vii)Bargaining game theory (viii)Dynamic game theory (ix)TU game theory (transferable-utility game) (x)NTU game theory(non-transferable-utility game) (xi)Ping-pong game (xii)Zero-Sum game and Non-Zero-Sum game (xiii)Jamming game	(i) Nash Equilibrium (ii) Pareto Optimal (iii) Nash Bargaining Solution (iv) Shapley Value (v) Core (vi) Mechanism Design (Computational) (vii)Incentive compatible (viii)Strategy proof Mechanism (vii) Auction (viii) Viceroy-Clarke-Groves(VCG) Mechanism (ix) Utility Function (x) Bayesian Nash Equilibrium(BNE)

Table 2. Typical Game Theory methods and common terminologies of Game Theory used in Wireless Sensor Network.

7. NON-COOPERATIVE GAME THEORY

Non-cooperative game theory is concerned with the analysis of strategic choice and explicitly models the process of player's making choices out of their own interests. Non-cooperative games can be classified into a few categories according to several criteria. According to whether the players' moves are simultaneous or not, non-cooperative games can be divided into two categories: static and dynamic games. In static game, players make their choices of strategies simultaneously, without knowledge of what the other players are choosing. i.e., a game is also simultaneous when players choose their actions in isolation, with no information about what other players have done or will do, even if the choices are made at different points in time. Static games are most often represented diagrammatically using a game table that is called the normal form or strategic form of the game. In the dynamic game players involve strategic situations in which there is a strict order of play. Players take turns to make their moves, and they know what players who have gone before them have done. Dynamic games are most easily illustrated using game trees, which are generally referred to as the extensive form of a game. The trees illustrate all of the possible actions that can be taken by all of the players and also indicate all of the possible outcomes from the game. According to whether the players have full information of all payoff relevant characteristics about the opponents or not, the non-cooperative game can be classified into two types: Complete information and incomplete information games. In the former each player has all the knowledge about others' characteristics, strategy spaces, payoff functions, and so on, but this is not so for the latter. The following Table 1.Shows four kinds of non cooperative games, corresponding equilibrium concepts, and main research areas of the three Nobel Prize winners.

	Static Game	Dynamic Game
Complete information game	Complete information static game. Nash Equilibrium. John Nash (1950, 1951).	Complete information dynamic game. Reinhardt Shelton (1965).
In complete information game	In complete information static game. Bayesian Nash equilibrium. John Harsanyi (1967-68).	In complete information dynamic game. Perfect Bayesian Nash equilibrium. Reinhardt Shelton (1975).

Table 1: Categories of non-cooperative games, corresponding equilibrium, and the main research areas of the three winners of the 1995 Nobel Prize in economics.

8. APPLICATIONS OF NON-COOPERATIVE GAME THEORY IN WIRELESS SENSOR NETWORK

Non-cooperative game theory studies strategies between interactions among competing players. In the game, a player is called an agent and his goal is to maximize its utility by choosing its strategy individually, in other words, each player is selfish but rational in a non-cooperative game. Non-cooperative game theory uses a utility function to find the Nash Equilibrium. Non-cooperative game theory is mainly applied in distributed resource allocation, congestion control, power control, spectrum sharing in cognitive radio and many others. Haksub et al. proposed a non-cooperative game based energy efficient MAC algorithm which makes the sensor nodes consume their energy efficiently. Stankovicacute et al. considered the problem of distributed convergence to a Nash Equilibrium based on minimal information about the underlying non-cooperative game. Interference problems for spectrumagile networks were addressed by allowing the networks to dynamically change channel in literature [9]. For insight into dynamic channel-change strategies, authors modeled the networks as autonomous players in a multistage non-cooperative game- theoretic model. Here the networks are assumed to be highly interfering, i.e., when two or more networks exist on a single channel they cannot successfully carry traffic. Each network seeks to minimize its time to find a clear channel. The game-theoretic analysis reflects the motivations and choices of independent, rational, selfish decision makers that do not trust one another. They analyzed appropriate game-theoretic solutions in an un-trusted environment, and compare results with socially optimal decisions that would maximize the expected benefit of all coexisting networks in a trusted environment. Sensor energy is limited, and the sensor is selfish but rational in WSN. If a node cannot get some profits, it will not perform the task. Of course, there will be some nodes that may exaggerate their real capacities to get some more tasks for profits. These dishonest or selfish behaviors will seriously affect the efficiency of WSN. Therefore, incentives should be provided to force nodes to obey the prescribed algorithms and report truthfully their capacity. Mechanism design in game theory can resolve this problem. Mechanism design not only provides the right incentives, but also to ensure the participants tell the truth. It can balance individual interests and common interests. In a mechanism design, strategy proof condition will make all participants report their true value, and voluntary participation condition can ensure that all participants are willing to participate.

9. COOPERATIVE GAME THEORY

A cooperative game also called coalitional is a game in which the players can make binding commitments, as is not the case in the non-cooperative game. Analysis in cooperative game theory is centered on coalition formation and distribution of wealth gained through cooperation within these two areas, finding procedures leading to outcomes that are most likely to occur under reasonable rationality assumptions in various game situations, and devising solution concepts showing attractive stability features are primary concerns in most research endeavors. Cooperative game theory is most naturally applied to situations arising in political science or international relations, where concepts like power are most important.

The definition draws the usual distinction between the two theories of games, but the real differences lies in the modeling approach. While in non-cooperative game theory the notion of the Nash equilibrium is pervasive in capturing most aspects of stability, in cooperative game theory there is no solution concept dominating the field in such a way? Instead, there is a multiplicity of solutions, which is not due to the weakness of the theory, but rather to the inherent diversity of conflict situations into which it attempts to provide insight. Moreover, the main focus of the non-cooperative game is individual rationality and individual optimal strategy, but the cooperative game emphasizes collective rationality, fairness, effectiveness, etc., which mean different things to different people.

10. APPLICATIONS OF COOPERATIVE GAME THEORY IN WIRELESS SENSOR NETWORK

To reduce the whole WSN's energy consumption and prolong its lifetime, some nodes will cooperate and form a coalition. Coalitional game theory is one of the most important cooperative game theory, thus, cooperative game theory is sometimes denoted as coalitional game theory [7]. For a WSN obeying the cooperative game theory, cooperative groups are formed and players choose strategies to maximize their own group's utility, coalitional game theory allows a reduction of power consumption in WSN by forming coalitions. **Saad et al.** proposed a merger and split approach for coalition formation, which calculates the value of the utility function for every possible permutation of nodes and finds groups with the best utility value. Here, grouping is treated as basic method to organize sensor nodes for cooperation between nodes. In this formation, the nodes know nothing about the grouping. On the other hand, a group leader is assigned as a special node which processed the information of the newly entered sensor nodes and decides who will be their possible group member in a group. We can group the nodes in two ways for different applications

- All the sensor nodes have similar sensed data could be placed in the same group, for example, sensing application.
- The sensor nodes with shorter distances between them are allocated in the same group, for example, sending data from a source node to the sink.

Apt and Wetzel proposed a generic approach for coalition formation through simple merge and split operations. Cooperative game theory can be further categorized into two branches:

- Transferable-utility game (TU game) **-** In TU game the payoff of the measurement allocation game is transferable.
- Non-transferable-utility game (NTU game) – In NTU game the payoff for each agent in a coalitional depends only on the actions selected by the agents in the coalition.

Shapley value is derived from the solution concept in cooperative game theory which was defined by Shapley[15]. It is one of the most important solution concepts in cooperative game theory and a representative single-valued solution concept in the theory of cooperative games. An agents Shapley value gives an indication of its prospects of playing the game in cooperative game theory. It is useful when there is a need to allocate the worth that a set of players can achieve if they agree to cooperate. The Shapley value was defined for TU games and NTU games in regard to conflicts among players. Gharehshiran and Krishnamurthy used cooperative game theory as a tool to devise a distributed dynamic coalition formation algorithm in which nodes autonomously decide which coalition to join while maximizing their feasible sleep times. The sleep time allocation problem is formulated as a non-convex cooperative game and the concept of the core is exploited to solve this problem.

11. THE CAUSE FOR THE RELEVANCE OF THE GAME THEORY TO WIRELESS COMMUNICATION AND NETWORKING

Ad hoc networks have occupied a preeminent place in the wireless communications and networking literature for the last several years. An ad hoc network is a self-configuring, multihop network in which there is no central authority. Thus, every aspect of the configuration and operation of an ad hoc network must be completely distributed. Furthermore, nodes in an ad hoc network are often severely energy and power constrained. In emerging wireless networks, such as sensor networks, mesh networks, and pervasive computing systems, many of these same features –decentralized operation, self configuration, and power energy awareness are often desirable. Game theory, as we have seen, is the study of the interaction of autonomous agents. At this point, it should be clear how game theory may be of help when analyzing modern wire networks. In a modern wireless sensor networks each node running a distributed protocol must make its own decisions. These decisions may be constrained by the rules of algorithms of a protocol, but ultimately each node will have some lee way in setting parameters or changing the mode of operation. These nodes, then, are autonomous agents, making decisions about transmit power, packet forwarding, back off time, and so on. In some cases, nodes may seek the "greater good" of the network as a whole. In other cases, nodes may behave selfishly, looking out for only their own user's interests. In a final case, nodes may behave maliciously, seeking to ruin networks performance for other users.' In the second and third cases, the application of game theory may be straight forward, as game theory traditionally analyzes situations in which player objectives are in conflict. In the first case, node objectives may be aligned (as all players seek the "greater good" of the network), but game theory may still offer useful insights. Even when nodes have shared objectives, they will each have a unique perspective on the current network state, leading to possible conflicts regarding the best course of action.

12. HOW ONE CAN USE GAME THEORY PROPERLY

There are many potential pitfalls on the road to the application of game theory to wireless communications and networking. One of these pitfalls has already been mentioned-mistaking a simple optimization problem for a game. As we have already discussed, a problem is only a game if there are multiple agents involved in making decisions. In some cases, it may be that artificially creating multiple agents to play a game is worthwhile; in many cases, though, one would be better served by using an optimization algorithm or technique. So, if it is not clear who the agents are, one should carefully consider whether or not the use of game theory is warranted. A second common mistake in applications of game theory is confusion between the theories of cooperative and non-cooperative games. In this article, we focus on non-cooperative games, which have been primary in the study of game theory for the last 25 years or so. Perhaps, the most common mistake among legitimate applications of game theory, though, is a failure to clearly define the game and the setting in which it is played. Who are the players of the game? What actions are available to the players? What are the player's objectives? Does equilibrium exist for the game? Is it unique? Is there a dynamic process by which players update their strategies? If so, what is it and is it guaranteed to converge? Finally, there are two general "philosophies" on applying game theory, and it is extremely important to consider which philosophy you are using. The first philosophy might be called a direct application of game theory. In this philosophy, the user's actual preferences are said to be modeled by the player's utility functions. The second philosophy might be called an "engineering" application of game theory. This philosophy assumes that the engineer is capable of programming the devices in the system to behave as if they are maximizing a chosen utility function. Since the engineer chooses the utility function, it can be whatever the engineer desire.

13. CONCLUSION

Game theory is the study of how players should rationally play games, and it is a powerful tool in many areas, such as war, politics, economics, sociology, psychology, biology, and communications, networking and so on where the conflict and cooperation exist. In this article we propose a game model to interpret the working mechanism and also point out the some directions that deserve study. Our results show that game theory is an appropriate tool to research and analyze the performance of wireless sensor networks. Of course, most networks are enormously complex, it is usually impossible to delineate all conceivable strategies and to say what outcomes they lead to, and it is not easy to assign payoffs to any given outcome. However, by building and analyzing a simple game that models some important features of the complex network, we can gain insight into the original situation, which is just what we expect in many cases.

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