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The Game Theory: Applications in the Wireless Networks

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Abstract

Recent years have witnessed a lot of applications in the computer science, especially in the area of the wireless networks. The applications can be divided into the following two main categories: applications in the network performance and those in the energy efficiency. The game theory is widely used to regulate the behavior of the users; therefore, the cooperation among the nodes can be achieved and the network performance can be improved when the game theory is utilized. On the other hand, the game theory is also adopted to control the media access control protocol or routing protocol; therefore, the energy exhaust owing to the data collision and long route can be reduced and the energy efficiency can be improved greatly. In this chapter, the applications in the network performance and the energy efficiency are reviewed. The state of the art in the applications of the game theory in wireless networks is pointed out. Finally, the future research direction of the game theory in the energy harvesting wireless sensor network is presented.

Keywords: game theory, wireless networks, network security, network performance, energy efficiency

1. Introduction

The game theory is the subject on constructing mathematical models concerning the conflict and cooperation among the intelligent rational decision-makers [1]. Traditionally, the game theory has been applied in some economic problems owing to its utilization in the analysis of the resource management. Although the game theory is mainly used in the economics, the political science, and the psychology, it also has gained applications in the logic and the computer science recently. One of the most frequently used game models is the zero-sum game in which someone is getting the prize while results in the loss of other participants. Since the

conflict and cooperation usually coexist in the wireless networks, recent years have witnessed the applications of the game theory in the wireless networks. For instance, in the wireless communication scenario, the resources, such as the bandwidth, the media access control, the energy supply, and so on, are limited for the nodes in the same network segment. Since all the nodes in the same network segment compete for the same media resources, some regulations are required to control their behaviors. Recent years have witnessed a large number of research papers on the applications of the game theory in the wireless networks [2, 3]. In general, the game-theory-based technologies concerning the wireless networks can be divided into two main categories. One kind of the technologies adopts the game theory to improve the network performance and the other utilizes the game theory to improve the energy efficiency. In the early 1990s, the game theory was firstly used by the researchers to propose new pricing strategies for the Internet services [4]. Exactly in the same decade, the game theoretic model gained wide applications for the noneconomic problems in the wireless networks. From the late 1990s to the beginning of the 2000s, the game theory had gained applications in the wireless networks. One of the main applications of the game theory in wireless networks is to model and analyze the routing and resource allocation problems [5]. For instance, the noncooperative game theory model can be adopted to regulate the network traffic to improve the network performance.

In the wireless network scenario, there are usually many nodes existing in the same network segment, so all the nodes which intend to transmit data should share the same limited radio resources, such as the wireless channels, the transmission power, and so on. How to regulate all the nodes who share the same radio resources properly in order to achieve the optimal network performance is a critical problem. As for the multiple access wireless networks, the nodes can either cooperative or compete with each other to achieve their objectives (e.g., the optimal throughput and the quality of service). Consequently, the game theory can be a very useful mathematical tool to model and analyze the resource allocation problems in wireless networks. With the help of the game theory, the critical problems, such as the channel assignment, power control, the cooperation enforcement among the nodes, and so on, can be solved effectively.

Due to the multiple access feature existing in the wireless networks, the nodes in the same local area network (LAN) are allowed to share a set of available channels for data transmission. Therefore, the nodes can either compete or cooperate with each other to access the sharing channel for a social or an individual goal. The game theory can be applied to model and analyze the individual or the group behavior for the wireless networks owing to its ability in understanding the interactions among rational entities. Besides, the game theory can provide a distributed solution for the wireless networks owing to its solid theoretical foundations. It is the usual case that the central controlling for the wireless networks requires much information exchanges and coordination, and sometimes, it causes a huge overhead. In order to make the network more extensible, the distributed algorithm is required. However, the rational or selfish nodes tend to optimize their own payoff without considering the social performance in the absence of the central controller. Therefore, the existing centralized schemes are no longer suitable for such case, whereas the game theory has the superiority in controlling the nodes in a distributed way.

Besides, sometimes, it is expected that the future wireless networks can support a variety of services with diverse quality of service (QoS) requirements. For instance, an application mixing of delay-sensitive and delay-tolerant requirements would coexist in the same network. The scenario with mixture requirements on QoS is called the wireless media sensor networks (WMSNs) [6]. For instance, the voice applications pay more attention to the network delay, whereas the data transmission requires more bandwidth. Therefore, it is a main challenge to exploit the optimal overall performance for the network.

The main contribution of the chapter lies as follows: the basic concept of the game theory and the three main components were introduced first. Then, the concept of wireless network was presented, and the main problems existing in the media access control level or the network level were also pointed out. The superiority of the game theory in dealing with the conflict and cooperation was stated. Finally, the applications of the game theory in the wireless network were elaborated in detail.

2. The game theory

Game theory, which was presented in 1944, is a theory concerning the decision-making. It gives some guides to the participants who face a dilemma whether to cooperate or conflict so as to obtain the maximum returns. In the game theory, an important concept Nash Equilibrium was proposed in 1950 which has promoted the research of the noncooperative game. When a game model reaches the Nash Equilibrium, it means that any players can impossibly obtain more favorable utility via other actions.

The game theory is a mathematical tool for analyzing the interactions of two or more decision-makers. The game theory is capable of stimulating the players to cooperate with each other to achieve a desirable goal. Usually, a game model consists of three main components: the player set, the strategy set, and the utility function of each player. As for the wireless networks, the nodes lie in the same network segment constitute the set of the players. The strategy set consists of the choice which is made by the nodes when deciding whether to relay messages for others or not. The utility function should be designed carefully to stimulate the players to cooperate with each other to achieve a considerable overall goal. It is worth noting that in the game theory, any actions taken by the user may affect the performance of others in the same network segment.

The classical game theory bases on the assumption that all the players are perfectly rational. The prediction about the game is only agreement with the actual results when each player has perfect rationality. To be perfectly rational, it is necessary that in the model, every node should be aware of the other node's actions as well as his characteristics. Nevertheless, this demand cannot always be met owing to some practical reasons. For instance, on account of the energy constraint, not every player is acquainted with the information of others. Besides, the individual differences in intelligence and learning capacity also lead to the differences in the rational level.

The game theoretic can be also divided into two main categories: the complete information game and the incomplete information game. In the first type, all the players have complete information about all the players' strategic spaces and the corresponding objectives, whereas the players of the later type only know a little about the strategic spaces and the corresponding objectives. For example, the incomplete game model can be applied to the problem of jamming for the wireless networks. As for the resource allocation problem, the behaviors of the nodes in the wireless networks can be modeled as a series of auctions, which take place in multiple rounds until all the users' requirements are met.

There is also a kind of game model named the evolutionary game theory. The evolutionary game theory can be applied to the situation where each player is of limited rationality. It was firstly introduced by Maynard Smith in 1974 [7]. Its development dues to the efforts which aim at explaining the evolution of genetically determined social behavior in the biological science. As we all know, in the real network environment, the assumption that all the players should be rational enough to determine their decisions is obviously not always satisfied. In the wireless sensor networks, the nodes usually have limited rationality. So, the evolutionary game theory can be utilized to solve some issues in the wireless sensor networks.

3. The problems existing in the wireless networks

A wireless network is a kind of system which consists of a number of nodes communicating with each other via wireless data connection. It is usually implemented via radio communications. The communication without cable can reduce the cost of deployment and maintenance, therefore the wireless network has gained a lot of applications. Examples of the wireless networks include the wireless local area networks (WLAN), the wireless sensor networks (WSNs), the ad hoc network, and the satellite communication networks.

In the wireless communication scenario, a large number of nodes compete with each other for the common resource, such as the wireless channel, the bandwidth, etc. When a source node need to transmit the data to the destination node, it needs the other nodes' help to relay the message. Therefore, the data transmission follows the hop-by-hop transmission pattern. However, not all the nodes are willing to relay the data for others owing to the energy or bandwidth consumption for relaying data. Sometimes, the nodes tend to struggle with each other for the limited resource; the network capacity is reduced when it happens. In the worst case, the data collision happens and it leads to the packet loss. The packet loss results in the decline of the network performance, such as the extension of the network delay. So, how to stimulate the nodes to cooperative with each other so as to improve the network performance is a problem facing the wireless network.

The wireless sensor networks (WSNs) is a kind of wireless network which consists of a huge number of tiny sensor nodes. Usually, the sensor nodes are powered by the battery and most of the WSNs are deployed in the regions out of the human's reach. Therefore, it is impossible or unpractical to recharge the sensor nodes. When the portion of the energy-exhausting nodes reaches a certain threshold, the network partition generates. For some applications,

the network partition means the termination of the network life span. In order to extend the network lifetime, the energy efficiency should be improved. In general, the energy efficiency includes twofold, namely the minimization of energy consumption and the energy consumption equilibrium. Since the "hot spot problem" exists in the wireless sensor networks, some selfish nodes tend not to relay the data for others to save their energy. The cooperation among the sensor nodes can improve the energy efficiency. Therefore, some incentive strategies should be designed to promote the cooperation among the nodes.

In conclusion, there are two main problems existing in the wireless networks, namely the network performance and the energy efficiency for the WSNs. The game theory has gained wide applications in improving the network performance and the energy efficiency. The state of the art in the applications of the game theory in the wireless networks was detailed in the chapter.

4. The applications of the game theory in the network performance

Different from the traditional local area networks (LAN), the media access control for the wireless networks is more complicated owing to the openness of the media. Any node can get access to the media as long as it lies in the transmission range of another node. If two nodes which lie in their transmission range send data at the same time, the data collision happens. The data collision has a bad influence on the network performance. Usually, the network performance is evaluated by the throughput, the packet loss ratio, the network delay, and the network delay jitters. The data collision results in the packet loss and the decline of the network capacity, sometimes even the termination of the network life span. So, it is crucial to avoid the data collision in order to improve the network performance. In a distributed wireless system, a huge number of network nodes behave cooperative toward a common goal, such as environmental monitoring, emergency rescue, enemy tracking, and so on. In such a scenario, how to attain mutual cooperation is an important scheme. Sometimes, not all of the nodes are willing to cooperate because it consumes much resource to relay messages for others. For some extreme case, the task may be hardly to be completed. Recently, a lot of works have emerged concerning the network performance and they are introduced in detail in this section.

It has been proven in the recent literature that the proper pricing techniques can be deployed among a number of users to achieve various resource allocation policies. In the wireless relay networks, the relay nodes have no incentives to relay messages for the other users without an appropriate compensation mechanism, since it leads to the energy exhaust or the decline of the network capacity. So, the pricing mechanism provides a useful scheme that reimburses the relay nodes for using their resources by making some payoff [8–10]. Thereby, the payment providing for the relay nodes makes them be willing to forward the messages for other users.

In the wireless networks, the resource allocation is usually modeled as a noncooperative game theoretic framework in order to maximize each individual's utility. However, the selfishness of autonomous users may result in the throughput unfairness which only benefits certain users. Tan et al. presented a payment-based power control scheme using game theory

in which each user announces a set of price coefficients that reflects different compensations paid by other users for the interference they produce to alleviate the throughput unfairness problem [11]. In their framework, the users who generate higher interference are required to pay more by transmitting at a lower power to give other users a fairer chance of sharing the throughput. The users could misbehave by broadcasting high price coefficients to force other users to transmit at a lower power without any incentive to play fairly. This problem was treated as a price game which resembles a prisoner's dilemma game.

The traditional networks are built on the assumption that all the network entities cooperate with each other to achieve the desirable network performance or scalability. However, the assumption may not always found owing to the emergence of some users who change the network behavior in a way in order to benefit themselves at the cost of others. Sometimes, the node with more ration would only act to achieve an outcome that he gets most. That case is more common in the multihop wireless networks like ad hoc network or sensor network which often consists of wireless battery-powered devices and the networks that need cooperation with each other to complete a task. However, the cooperation may be hard to achieve because of the limited resource, such as the bandwidth, the computational power, and the energy supply. Ng et al. presented a game-theoretic approach to strengthen the cooperation for the wireless multihop networks [12]. Tan et al. [11] applied the game theory to achieve collusive networking behavior in the multihop networks. Pricing, promiscuous listening, and mass punishments were avoided together via the game theory. Besides, the authors also provided a proof of the viability of the model under a theoretical wireless environment and showed the model can be applied to design a generic protocol which was called the Selfishness Resilient Resource Reservation protocol.

A cloud-assisted model for the malware detection and a dynamic differential game against malware propagation were presented by Zhou et al. [13]. An SVM-based malware detection model was constructed with data sharing at the security platform in the cloud. Besides, the number of malware-infected nodes was calculated precisely basing on the attributes of WMS transmission. A dynamic differential game and target cost function were successively derived for the Nash Equilibrium between the malware and WMS system. Finally, a saddle-point malware detection and suppression algorithm was proposed basing on the modified epidemic model and the computation of optimal strategies. Brown and Fazel proposed a game theoretic scheme to improve the energy efficiency for the cooperative wireless networks [14]. The tools from both cooperative and noncooperative game theory were utilized and the pareto-efficient cooperative energy allocation strategy was achieved to resist the selfish nodes, basing on the axiomatic bargaining technique. Besides, they developed the necessary and sufficient conditions under the nonfading channel without extrinsic incentive mechanism or altruistic node. Finally, they developed the technique to endogenously form the cooperative partnership without any central control. Sergi et al. exploited the game theory to model the problem via setting up a cluster of cooperative nodes in a wireless network as a multiplayer noncooperative game [15]. In their game model, all the nodes belonging to a potential relay cluster constitute the set of players and the set of actions for each player consists of only two options. Finally, a novel strategy for the management of node participation to a distributed cooperative link was derived. Seigi et al. adopted the game theory to derive a novel solution to

manage the virtual antenna array basing on the transmissions in the ad hoc wireless network which consists of selfish nodes [16]. In their strategy, each node decides whether and when to transmit data packets over a shared wireless channel in an autonomous fashion. Simulation shows it offers a higher throughput level and a higher efficiency than other communication protocols which implement selection diversity in the distributed multiantenna system.

As a promising approach for the system-level analysis for the power control (PC) in wireless networks, Ginde et al. extended the game theory to the study of link adaptation, which involved the variation of modulation parameters, in addition to PC [17]. The game model in Ref. [6] was called the Link Adaptation Game (LAG) and a Nash Equilibrium (NE) was proven to be existing. Finally, a distributed algorithm was proposed to discover the NE, and it was analytically shown to converge to an NE via treating it as a point-to-set map.

Banchs et al. addressed the problem of selfishness in the Distributed Opportunistic Scheduling (DOS) from the game-theoretic's standpoint firstly [18]. The key idea of the algorithm is to react to a selfish station by using a more aggressive configuration that punishes the station. They designed a mechanism for the punishment that was sufficiently severe to prevent the selfish behavior and was not so severe to render the system unstable building on multivariable control theory. Finally, the algorithm was proven to be effective against selfish stations through conducting a game-theoretic analysis-based repeated games.

Ren et al. proposed a game theoretic model of the topology control to analyze the decentralized interactions among heterogeneous sensors [19]. They studied the function for the node to achieve the desirable frame success rate and the node degree, while minimizing the power consumption. Besides, they proposed a static compete-information game formulation for power scheduling and then proved the existence of the Nash Equilibrium with simultaneous move. They applied the game theory to analyze the distributed decision-making process of the individual sensor node and to analyze the desirable utilities of the heterogeneous sensor node. A new game theoretic model yields decentralized optimization for joint topology control and power management in their paper, and the global game equilibrium was iteratively reached by considering the individual node degree, the message delivery ratio, and the cost of increasing power.

Wang et al. provided a noncooperative game theoretic solution to enforce the cooperation in the wireless networks in the presence of channel noise [20]. They focused on the one-hop information exchange and modeled the packet forwarding process as a hidden action game with imperfect private monitoring. Besides, a state machine-based strategy was proposed to reach the Nash Equilibrium, and the equilibrium was proved to be a sequential one with the carefully designed system parameters. Furthermore, their discussion was extended to a general wireless network scenario by considering how cooperation can prevail over collusion via using the evolutionary game theory.

5. The applications of the wireless networks in the energy efficiency

In wireless networks, the intermediate nodes are chosen as cooperative nodes to relay packets for the source-destination pairs. However, not all the nodes are willing to relay data for others

in the networks with inherent selfish nodes. Especially for the wireless sensor networks (WSNs), which consist of a large number of tiny sensor nodes, which are usually energy-limited. So, most of the nodes tend to reserve their energy to achieve the longer lifetime. As a result, the energy exhausts quickly if each source node sends data directly to the sink. The nodes far from the sink tend to use up their energy before those close to the sink. Therefore, how to stimulate the selfish nodes to relay messages is of great importance for the WSNs. The development of extrinsic incentive mechanisms is adopted to solve the problem, e.g., virtual currency, or the insertion of altruistic nodes in the networks to enforce cooperative behavior.

As a kind of autonomous system, the WSNs are becoming increasingly integrated into the daily life owing to their cheap deployment expense. However, the sensor nodes are powered by the battery usually, so the energy for them is limited. How to improve the energy efficiency and extend the network lifetime attracts many researchers' attention. The game theory was widely applied in the energy-efficient algorithm for the WSNs because of its superiority in regulating the behaviors of many players. Li et al. proposed an energy-efficient algorithm which combined the game theory and the software-defined network theory [21]. They integrated an SDN into the WSNs and presented an improved software-defined WSNs (SD-WSNs) architecture. Basing on the improved SD-WSNs architecture, they proposed an energy-efficient algorithm which introduced the game theory to extend the network lifetime. Like any other energy-efficient schemes, the residual energy and the transmission power were taken into consideration to prolong the life span as long as possible.

In addition to the energy-efficient routing protocols, the topology control was also adopted to improve the energy efficiency. According to the first-order radio model, the energy for transmitting a certain amount of data is in proportion to the square of the transmission distance, sometimes even the fourth power of the transmission distance. Therefore, the data transmission usually follows the hop-by-hop pattern to reduce the energy consumption. When the message is transmitted via the hop-by-hop pattern, the nodes near the sink exhaust the energy early this phenomenon is called the "hot spot problem". The "hot spot problem" leads to the network partition and the termination of the network lifetime. The main cause of it lies in the unequal energy exhausting. So, how to make the energy dissipation more evenly is also a factor to improve the energy efficiency. Topology control was adopted to evenly distribute the energy dissipation. Namely, deploying more nodes in the area which is close to the sink is an effective scheme to improve the energy efficiency.

D'Oro et al. proposed a computationally efficient algorithm to maximize the energy efficiency in the multicarrier wireless interference network [22]. Via suitably allocating the system radio resources, such as the transmit power and subcarrier assignment, the problem can be formulated into the maximization of the global energy efficiency with subject to both maximum power and minimum transmission rate constraints. Finally, it was converted into a challenging nonconvex fractional problem and was tackled through an interplay of fractional programming, learning, and game theory.

Zappone et al. proposed an energy-efficient power control and a receiver design in the relay-assisted DS/CDMA wireless networks via the game theory [23]. The noncooperative power strategies for the uplink of relay-assisted DS/CDMA wireless networks were considered through the game-theoretic tools. It was assumed that each user was interested in maximizing

his own energy efficiency which is measured in bit/Joule and denoting the number of error-free delivered bits for each energy-unit used for transmission. Several noncooperative games were presented and analyzed, and extensive simulation was conducted to confirm the theoretical findings.

In addition to the traditional wireless sensor networks which are powered only by the battery, a kind of energy harvesting wireless sensor network (EHWSN) emerges recently. For the EHWSN, the energy harvesting technology is utilized to prolong the life span of the network. The EHWSN can recharge the nodes or the network by harvesting the renewable energy from the environmental sources, such as the sun, the wind, the vibrations, and so on [24–26]. Although the energy harvesting technology provides a feasible scheme to extend the lifetime of the sensor nodes to some extent, the intermittent as well as the random EH process and the complexity in achieving global network information need to manage the energy efficiency and optimize the resource in a distributed way. Namely, the process of energy harvesting is intermittent and random in nature owing to the uncertain and dynamically changing environmental conditions. In most existing works, it is assumed that either the transmitter possesses noncausal information on the exact data arrival or the transmitter knows the statistics of EH and the data arrival processes. However, the characteristics of energy harvesting process and the data arrival process change with time in most of the practical scenarios.

Besides, the emerging of the EH nodes makes the centralized energy management more challenging because the complexity in achieving optimal energy utilization policies increases significantly with the amount of the nodes in the network [27]. Furthermore, the global knowledge of the sensor nodes sometimes is hard to obtain or even unattainable. Thereby some distributed optimization schemes which only base on the local information are required. The game theory is a kind of promising mathematical tools which model interactive decision-making processes and can be widely utilized in a distributed way in the wireless sensor networks.

Meshkati et al. provided an overview of the game theoretic schemes for the energy-efficient resource allocation in the wireless networks [28]. A direct-sequence CDMA (DS-CDMA) network where each user tends to locally and selfishly choose its action so as to maximize its own utility and satisfy the QoS requirements was considered by the authors. The multiple access feature of the wireless channel makes it possible that any user's strategy choice will affect others' performance. For instance, the choice of the transmit power, the transmission rate, the packet rate, the modulation, the multiuser receiver, the multiantenna processing algorithm, or the allocation strategy will have a great influence on the others' energy efficiency.

Liu et al. presented a game-based coordination for the wireless sensor and actor networks basing on the assumption that the better cooperation among actors can bring a better balance between the energy consumption and the energy efficiency improvement [29]. The authors introduced a game theoretic approach called coalition game into their model which was named cooperative-game-based actor-to-actor coordination algorithm. It was a multiplayer strategy which consisted of many actors. The game performs at each time when an action needs to be executed in an event area. Finally, the task allocation problem in WSANs was converted into a utility assignment in the actor-alliance. Besides, the game theory strategy was evaluated through the network simulator NS2, and the results show a better energy efficiency.

In the wireless networks scenario, there is a lack of any central controllers. Thus, usually, the node makes its own decision independently. Therefore, the fully cooperative behaviors are encouraged to increase the system capacity at the given energy budget. It has been proven that power control is an efficient scheme to meet the quality of service request. On the other hand, in some wireless networks scenario, several service providers coexist to offer multiple access for the customer. Multihop routes exist in that case. If the providers cooperate with each other via jointly deploying and pooling their resources, such as the spectrum and infrastructure, and agree to serve each other's customers, their aggregate payoffs, and individual shares, may substantially increase through opportunistic utilization of resources.

Long et al. designed a noncooperative power control algorithm without pricing mechanism [30]. The interaction among the users' decision on power control was viewed as a repeated game. A reinforcement learning algorithm to properly schedule the user's power level was proposed by the authors. The potential of the cooperation can be achieved when each service provider intelligently decides with whom it would cooperate, when to cooperate, and how to deploy as well as share the resources during the cooperation. Singh et al. modeled the cooperation via the theory of transferable payoff coalitional games [31]. The cooperation strategy involved the acquisition, deployment, and allocation of the channels and the base stations. The optimum strategy can be computed as the solution of a concave or an integer optimization. It was also shown that the optimal cooperation strategy and the stabilizing payoff shares can be obtained in polynomial time via respectively solving the primals and the duals of the above optimization.

Ren et al. proposed a pricing and distributed power control in the wireless relay networks to stimulate the nodes to cooperate with each other [32]. A wireless network with amplify-and-forward relay was taken into consideration and a pricing framework that enables the relay to set the proper price to maximize either its revenue or any desirable system performance was also presented. Specifically, the relay nodes set price and correspondingly charge the users basing on the quality of the received signals. Provided the specified price, the users compete with each other to employ the relay nodes to forward their messages. Each user was modeled as a rational player and he can maximize his own net utility through the proper power allocation. The competition among all the nodes was analyzed within the framework of a noncooperative game theory, and there always exists a unique pure Nash Equilibrium point that can be achieved via distributed iterations. Finally, a low-complexity uniform pricing algorithm and an optimal differentiated pricing algorithm were proposed. It has been shown that any system utility can be maximized via applying the differentiated pricing algorithm which enforces the users to transmit at a certain power level.

In most of the existing literature, the works were related to the distributed game theory-based strategies which were usually deployed for the battery-powered WSNs. Only a few game theory-based works focused on the energy harvesting wireless sensor networks. The game theory-based energy-efficient strategies for the EHWSN were introduced in detail.

The complex interactions among the individual sensor nodes were taken into consideration, and the game theory was utilized to optimize the general multichannel multiaccess problem in an EHWSN in a distributed way [33]. In their work, the strict delay constraints were

imposed for the process of data transmission. The struggle for the common channel access among the sensor nodes were formulated into a noncooperative game, and it was proved to be an ordinal potential game which has at least one Nash Equilibrium (NE).

6. The future research direction

For many wireless networks, such as the wireless sensor networks, the ad hoc networks, the transmission between two different nodes has to be accomplished with the help of an intermediate node due to the transmit power or other constraints [34]. The traditional network resource allocation problem mainly depends on the centralized control scheme, which requires all the users to cooperate with each other, whereas in many scenario, the nodes are not willing to work together owing to the consideration of reserving their own resource. In the wireless networks, the resource is limited for the nodes lying in the same network segment; therefore, the nodes will not relay messages for others for the sake of saving the channel or the energy resource. With the development of the energy harvesting technology for the wireless sensor networks, the new challenge emerges for the wireless sensor networks to keep it cooperating. So, the new strategy should be proposed to improve the network performance and the energy efficiency. Besides, the development of the wireless energy transfer has induced a new kind of wireless transmission technology, namely the Simultaneous Wireless Information and Power Transfer (SWIPT) technology [35], the new features need novel strategy to be designed to promote the cooperation among the nodes. It gives new challenge for the game theory application in the wireless networks.

7. Conclusion

In this chapter, the game theory was introduced first. The components of the game theoretic model were discussed in detail. As a mathematical tool, the game theory model has gained a lot of applications in the economic, the biology, and the telecommunication, and so on. Recent years have witnessed a lot of applications of the game theory in the wireless networks owing to its superiority in stimulating cooperation of the individual. The applications of the game theoretic can be divided into two main categories: the applications in network performance and that in the energy efficiency improving. Therefore, in this chapter, the state of the art of the game theoretic applications in the wireless networks was discussed in detail. Finally, the future research direction of the game theoretic applications in wireless networks was also provided.

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Conflict of interest

We declare that we have no financial and personal relationships with other people or organizations that can inappropriately influence our work; there is no professional or other personal interest of any nature or kind in any product, service and/or company that could be construed as influencing the position presented in, or the review of, the manuscript entitled "The game theory: applications in computer science".

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