We are IntechOpen,
the world's leading publisher of
Open Access books
Built by scientists, for scientists

5,900
Open access books available

145,000
International authors and editors

180M
Downloads

154
Countries delivered to

Our authors are among the
TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

CLARIVATE ANALYTICS
BOOK
CITATION
INDEX
INDEXED

WEB OF SCIENCE™
Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

24

Application of Game Theory to Wireless Networks

S. Mehta and K. S. Kwak
Inha University
Korea

1. Introduction

The modern information society will continue to emerge, and demand for wireless communication services will grow. Future generation wireless networks are considered necessary for the support of emerging services with their increasing requirements. Future generation wireless networks are characterized by a distributed, dynamic, self-organizing architecture (I. F. Akyildiz et al., 2006). These wireless networks are broadly categorized into different wireless networks according to their specific characteristics. Typical examples include Ad-Hoc/Mesh Networks, Sensor Networks, Cognitive Radio Networks, etc as shown in figure 1. These wireless networks could then constitute the infrastructure of numerous applications such as emergency and health-care systems, military, gaming, advertisements, customer-to-customer applications, etc. Not only their importance in military applications is growing, but also their impact on business is increasing. The emergence of these wireless networks created many open issues in network design too. More and more researchers are putting their efforts in designing the future generation wireless networks.

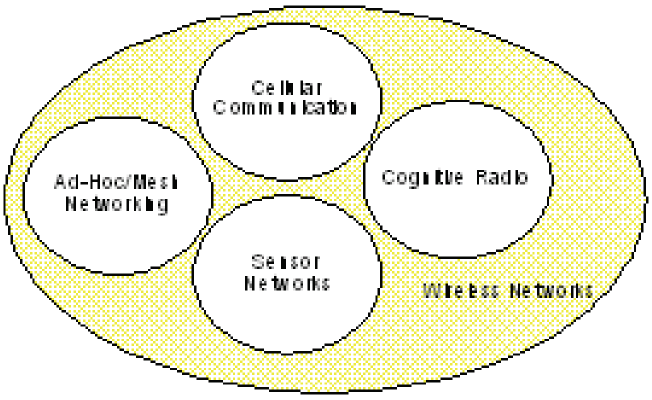


Fig. 1. Different kinds of wireless networks

Every node in the future wireless network is capable of changing its operation independently or in a small group of nodes according to the current dynamics of the network as all the nodes are distributed and self-organizing in nature. So every node in the network has conflicting situation with other nodes, and hence it is very hard to analytically model such network and to evaluate its performance.

Source: Convergence and Hybrid Information Technologies, Book edited by: Marius Crisan,
ISBN 978-953-307-068-1, pp. 426, March 2010, INTECH, Croatia, downloaded from SCIYO.COM

2. Game Theory

Game Theory is a collection of mathematical tools to study the interactive decision problems between the rational players[1] (here it is wireless nodes). Furthermore it also helps to predict the possible outcome of the interactive decision problem. The most possible outcome for any decision process is "Nash Equilibrium." A Nash equilibrium is an out come of a game where no node (player) has any extra benefit for just changing its strategy one-sidedly. From the last three decades game theory has not just applied to economics but has also found application in sociology and psychology, political science, evolution and biology. Additionally, it has drawn lots of attention from computer scientist in recent because of its use in artificial intelligence, cybernetics, and networks. Specifically, Game theory allows us to model scenarios in which there is no centralized entity with full/partial information network conditions. Because of that from last few years game theory has gained a notable amount of popularity in solving communication and networking issues. These issues include congestion control, routing, power control and other issues in wired and wireless communications systems, to name a few. Figure 2 shows the applications of game theory, especially in computer science while figure 3 shows few key research areas in wireless networking (M. Felegyhazi et al., 2006).

As we mentioned earlier game theory is a branch of applied mathematics which helps players to analyze decision making in conflict situations. Such situations arise when two or more players, who have different aims act on the system or share the same resources. A game could be two player or multi-player. In a given game, game theory provides mathematical process for selecting an optimum response to player to face his/her opponent who also has a strategy of his/her own.

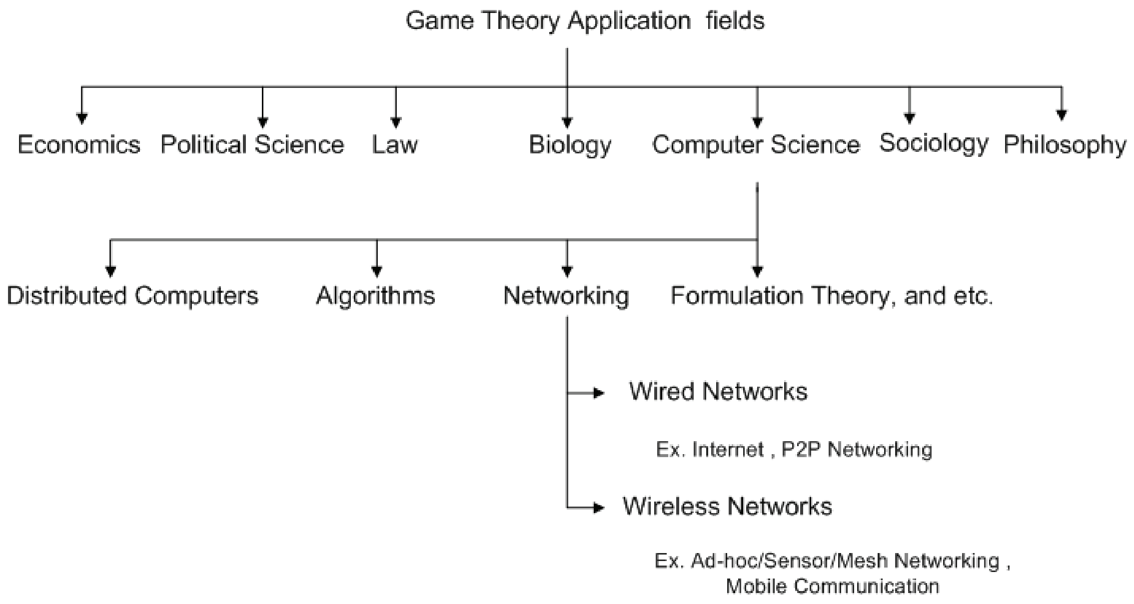


Fig. 2. Applications of game theory

---

[1] In rest of the paper we keep using terms 'node' and 'player' interchangeably.

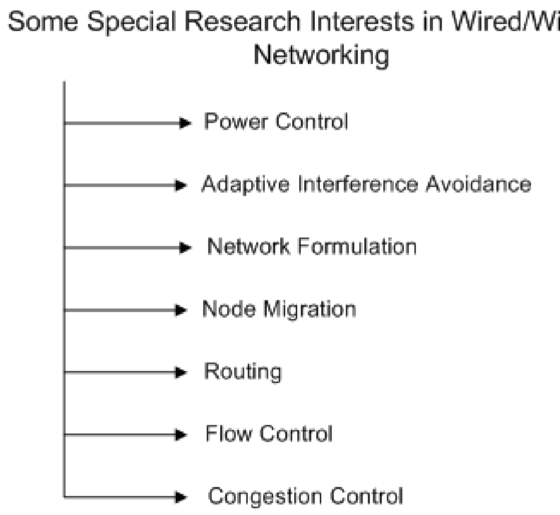


Fig. 3. Few key research areas in networking

2.1 Game theory: assumptions, challenges, advantages, and classification

In game theory (generally non-cooperative game theory) players usually make the following assumptions

- Each player has two or more well-specified moves/strategies.
- Every player has possible combinations of moves/strategy that leads to an optimum response (End-state like win, loss or draw) in a given game.
- Each player has a specified payoff for each optimum response.
- All players are rational; that is, each player, given the two moves/strategies, will choose that one that gives him/her the better payoff.

The use of game theory to analyze the performance of wireless networks is not without its challenges. We point out few challenges as follows:

- Assumption of rationality
- Realistic scenarios require complex model
- Choice of utility functions
- Mechanism design
- Mapping variables in the game

We will learn more about these challenges in subsequent sections of this chapter. Even with these challenges we have certain advantages in using game theory for analyzing wireless networks

- **Analysis tool for distributed systems:** As we mentioned earlier game theory is a natural choice to study the distributed systems as both deal with independent decision makers. With game theory we can investigate the steady state of such systems and also make the out come of an individual node both in the interest of the system and its own.
- **Cross layer designing and optimization:** In wireless networking, a node often needs to take its action based on some other layers to optimize its own performance but this could hurt the performances of that particular layers. In this situation game theoretic approach can provide a proper insight as well as mathematical back ground to optimize the overall protocol stack's performance.
- **Incentive Scheme:** As we mentioned above the selfishness of nodes is the biggest threat to the performance of the network and it's necessary to remove or discourage the selfish

behavior of nodes. Game theory tools such as mechanism design can assists the network designer to develop some networks rules that can discourage the nodes form selfish behavior and in some case provide some incentives for actively participation in network. Hence, we can get the desired outcome of the nodes from a network point of view.

Games can be classified formally at many level of detail, here; we in-general tried to classify the games for better understanding. As shown in the figure 4 games are broadly classified as co-operative and non-cooperative games. In non-cooperative games the player can not make commitments to coordinate their strategies. A non-cooperative game investigates answer for selecting an optimum strategy to player to face his/her opponent who also has a strategy of his/her own. Co-operative game can, and often does, arise in non-cooperative games, when players find it in their own best interests.

Conversely, a co-operative game is a game where groups of player may enforce to work together to maximize their returns (payoffs).Hence, a co-operative game is a competition between coalitions of players, rather than between individual players. There are lots of fundamental things need to be discussed about co-operative games which are simply out of the scope of this chapter. Furthermore, according to the players' moves, simultaneously or one by one, games can be further divided into two categories: static and dynamic games. In static game, players move their strategy simultaneously without any knowledge of what other players are going to play. In the dynamic game, players move their strategy in predetermined order and they also know what other players have played before them. So according to the knowledge of players on all aspects of game, the non-cooperative/co-operative game further classified into two categories: complete and incomplete information games. In the complete information game, each player has all the knowledge about others' characteristics, strategy spaces, payoff functions, etc., but all these information are not necessarily available in incomplete information game (M. Felegyhazi et al., 2006, M.J. Osborne & A Rubinstein , 1994, V. Srivastava et. al , 2005).

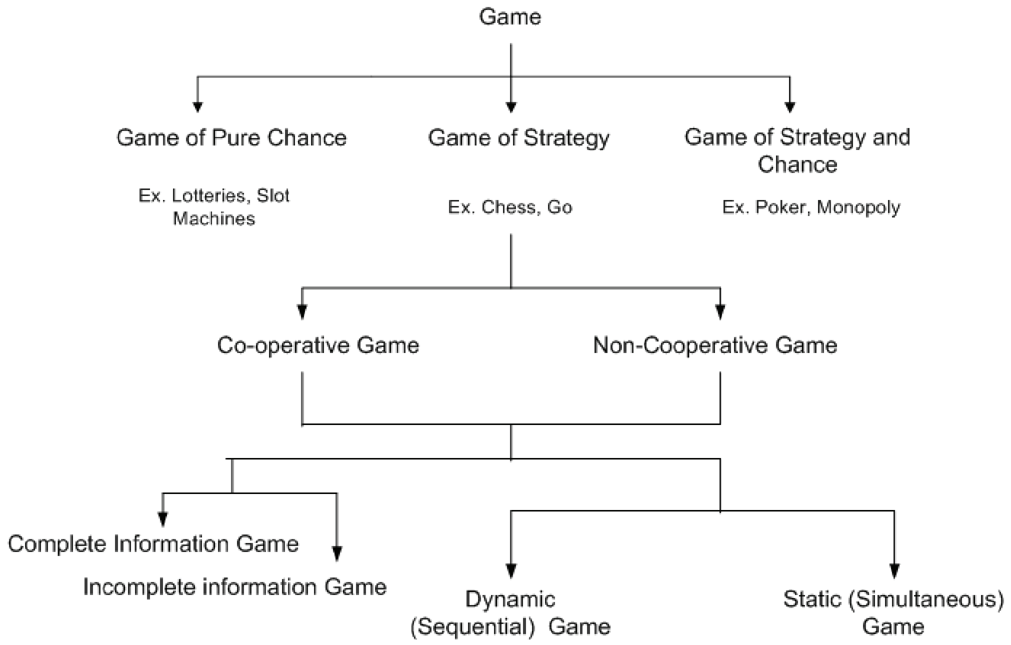


Fig. 4. Classification of games

A game is set of there fundamental components: A set of players, a set of actions, and a set of preferences. Players or nodes are the decision takers in the game. The actions (strategies) are the different choices available to nodes. In a wireless system, action may include the available options like coding scheme, power control, transmitting, listening, etc., factors that are under the control of the node. When each player selects its own strategy, the resulting strategy profile decides the outcome of the game. Finally, a utility function (preferences) decides the all possible outcomes for each player. Table 1 shows typical componets of a wireless networking game.

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

Table 1. Components of a wireless networking game

It is important to note that game theory models are only appropriate for the scenarios where decision of a node could impact the outcome of other nodes. Hence, a clear distinction should be drawn between a multiple decision making problem and an optimization problem where a single decision making entity is involved. Furthermore, appropriate modelling of preferences is one of the most challenging aspects of the application of game theory, so optimizing network's performance with game theory needs careful considerations (V. Srivastava et. al, 2005).

2.2 Game theory: networks games

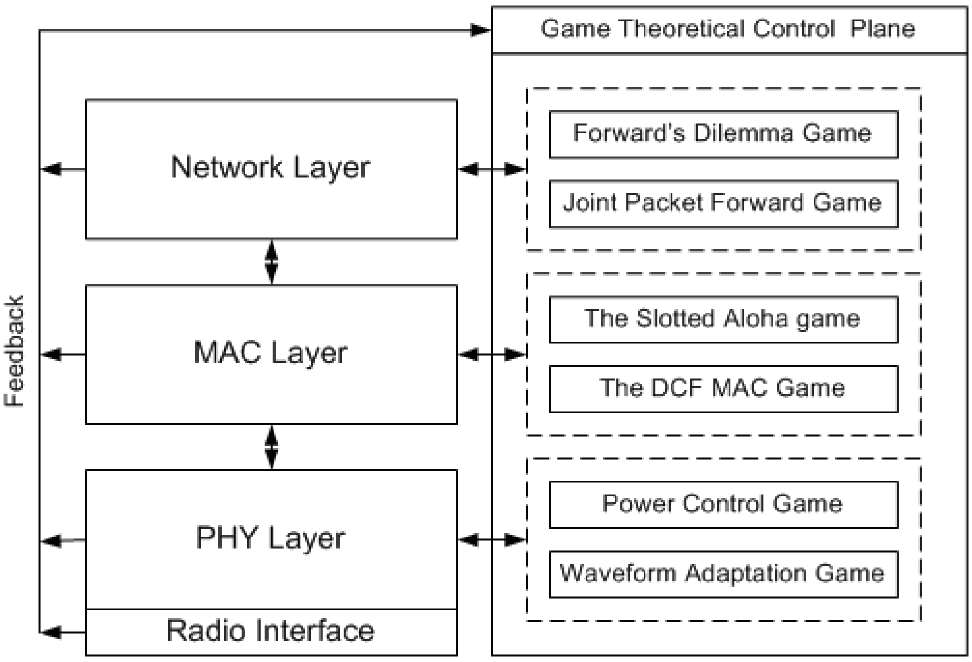


Fig. 5. Networks games at different levels of protocol stack

As shown in the figure 5 game theory can be applied to the modeling of a wireless network at the physical layer, link layer, and network layer. Applications at the transport layer and above exist also, but we restrict our discussion up to network layer. At all the mentioned levels we can formulate a game to optimize the performance of a network. The main objective of these games is to remove the selfish behavior of the nodes. Generally, selfish behavior is very serious problem for overall network performance. For example a node always refuse to forward data packets from other node can create unnecessary partition in the network, and hence limit the connectivity of the network.Here, we briefly describe a few games at different levels of protocol stack (M. Felegyhazi et al., 2006).

Physical Layer Games:

- **Power Control and waveform Adaptation games:** These games are representing very basic problems of improving performance at physical layer. At physical layer performance is generally measure in terms of signal to interference plus noise ratio at the nodes. When the nodes in a network respond to changes in perceived SINR by adapting their signal, a physical layer interactive decision making process occurs. This signal adaptation can occur in the transmit power level and the signaling waveform In power control game signals of other terminals can be modeled as interfering noise signals, the major goal of this game is to achieve a certain signal to interference (SIR) ratio regardless of the channel conditions while minimizing the interference due to terminal transmit power level. Waveform adaptation in wireless networks involves the selection of a waveform by a node such that the interference at its receiver is reduced. The interference at the receiver is a function of the correlation of a user's waveform with the waveforms of the other users in the network. Also, in general, the individual nodes involved in transmission have no or very little information about the receiver's interference environment. Hence to minimize the adaptation overhead, distributed waveform adaptation algorithms that require a minimal amount of feedback between receivers and transmitters need to be developed for these networks.

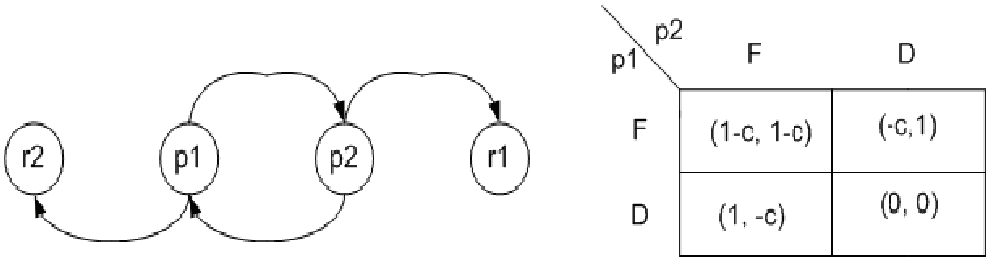
MAC Layer games:

- **Medium Access Games-The slotted aloha and DCF Games:** In these medium access control games, selfish users seek to maximize their utility by obtaining an unfair share of access to the channel. This action, though, decreases the ability of other users to access the channel. In slotted Aloha game, in a given slot, each user has two possible actions: the user can transmit or wait. If exactly one user chooses to transmit in a given slot, then that user's transmission is successful. If multiple users transmit in a slot, then all of their transmissions are unsuccessful. We assume that the payoff associated with a successful transmission is 1, while the cost of transmission (whether successful or unsuccessful) is c, where $0 < c < 1$. A user who waits will receive a payoff of 0; a user who transmits will receive a payoff of either $1 - c$ (if the transmission is successful) or $-c$ (if the transmission is unsuccessful).In this game main aim is to maximize the payoff (in terms of less cost) with fair access to the Medium. Similar to slotted aloha game, when a node has data to transmit, it autonomously decides when to transmit in IEEE 802.11 DCF based networks. Because the wireless channel is a shared channel, the transmission of a node often interferes with those of other nodes. For example, if there are two neighboring nodes transmitting their data frames simultaneously, both transmissions will fail. Therefore, one node must compete with its neighboring nodes so that it can transmit as many packets as possible. Authors in (M. Felegyhazi et al., 2006) model the IEEE 802.11 DCF with game theory and name the model the DCF game. In the DCF game, each player (node) has two strategies: Transmit or Not transmit (i.e., wait) and here again aim is the same as slotted aloha game.

Network Layers Games:

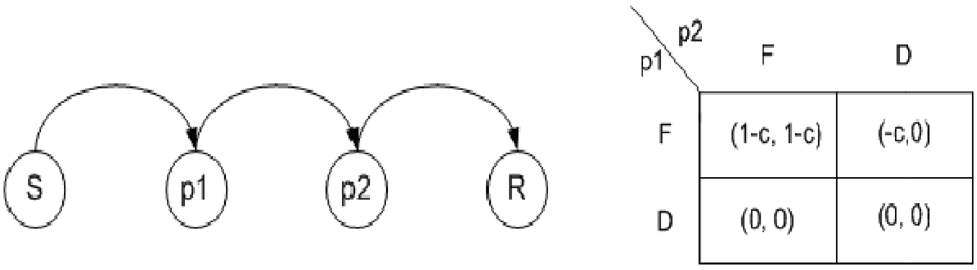
The main functionalities of network layer are establishing and updating routes and forwarding the packets along those routes. The presence of selfish nodes in those routes can degrade the overall network performance as well as the life time.

- **Forward's dilemma and Joint packet forward games:** In forwards dilemma game, as shown in figure 6 (a) the p1 intends to send a packet to node r1 through p2, while player p2 intends to send a packet to r2 through p1. The cost of transmitting a packet equals c, where c << 1 and reflects the energy spent by a node in forwarding a packet. If a packet is successfully received by the receiver then the sender gets a reward of 1. Each player has two possible actions: forward the packet (F) or drop the packet (D) of the other player. Similar to this game , in the joint packet forwarding game as shown in figure 6 (b) nodes intend to send a packet to node r through two intermediate nodes p1 and p2. If the packet successfully reaches r then each of the forwarding nodes gets a reward of one, otherwise none of the intermediate nodes gets any reward. The cost of forwarding a packet is c and has the same meaning as that in the forward's dilemma game. The players may take two actions: forward the packet (F) or drop the packet (D). The aim of both these game is to maintain the routing path as long as possible and hence a network connectivity (M. Felegyhazi et al., 20062).



p2 p1	F	D
F	(1-c, 1-c)	(-c,1)
D	(1, -c)	(0, 0)

Fig. 6. (a) Forward's Dilemma problem and its game form presentation



p2 p1	F	D
F	(1-c, 1-c)	(-c,0)
D	(0, 0)	(0, 0)

Fig. 6. (b) Joint Packet Forward problem and its game form presentation

3. Case study: IB based MAC protocol for wireless sensor networks

Communication in wireless sensor networks is divided into several layers. One of those is the Medium Access Control (MAC) layer. MAC is an important technique that enables the successful operation of the network. MAC protocol tries to avoid collisions so that two interfering nodes do not transmit at the same time. The main design goal of a typical MAC protocols is to provide high throughput and QoS. However, a good amount of energy gets wasted in traditional MAC layer protocols due to idle listening, collision, protocol overhead, and over-hearing (W. Ye et al , 2002).

There are some MAC protocols that have been especially developed for wireless sensor networks. Typical examples include S-MAC, T-MAC, and H-MAC (W. Ye et al , 2002, T.V. Dam et. al , 2003, S.Mehta et al, 2007). To maximize the battery lifetime, sensor networks MAC protocols implement the variation of active/sleep mechanism. S-MAC and T-MAC protocols trades networks QoS for energy savings, while H-MAC protocol reduces the comparable amount of energy consumption along with maintaining good network QoS. However, their backoff algorithm is similar to that of the IEEE 802.11 Distributed Coordinated Function (DCF), which is based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) Mechanism. The energy consumption using CSMA/CA is high when nodes are in backoff procedure and in idle mode. Moreover, a node that successfully transmits resets it Contention Window (CW) to a small, fixed minimum value of CW. Therefore, the node has to rediscover the correct CW, wasting channel capacity and increase the access delay as well. It is necessary to estimate the number of nodes in network to optimize the CSMA/CA operation.

In nutshell, during the CSMA/CA mechanism, backoff window size and the number of active nodes are the major factors to have impact on the energy-efficiency as well as the QoS performance of WSNs. As presented in (L. Zhao et. al, 2008) the concept of incomplete cooperative game theory that can improve energy efficiency as well as the QoS performance of MAC protocol in WSNs. Based on game theoretic model presented in (L. Zhao et. al, 2008) we use a fixed-size contention window, but a non-uniform, geometrically-increasing probability distribution for picking a transmission slot in the contention window interval to improve the energy efficiency of MAC protocol.

3.1 Incomplete cooperative game

As we mentioned earlier energy efficiency of MAC protocol in WSN is very sensitive to number of nodes competing for the access channel. It will be very difficult for a MAC protocol to accurately estimate the different parameters like collision probability, transmission probability, etc., by detecting channel. Because dynamics of WSN keep on changing due to various reasons like mobility of nodes, joining of some new nodes, and dying out of some exhausted nodes. Also, estimating about the other neighboring nodes information is too complex, as every node takes a distributed approach to estimate the current state of networks. For all these reasons an incomplete cooperative game could be a perfect candidate to optimize the performance of MAC protocol in sensor networks.

In this case study, we considered a MAC protocol with active/sleep duty cycle[2] to minimize the energy consumption of a node. In this MAC protocol time is divided into super-frames, and every super frame into two basic parts: active part and sleep part. During the active part a node tries to contend the channel if there is any data in buffer and turn down its radio during the sleeping part to save energy.

---

[2] We can easily relate the “Considered MAC Protocol” with available MAC protocols and standards for wireless sensor networks, as most of the popular MAC protocols are based on the active/sleep cycle mechanism.

In incomplete cooperative game, the considered MAC protocol can be modeled as stochastic game, which starts when there is a data packet in the node's transmission buffer and ends when the data packet is transmitted successfully or discarded. This game consists of many time slots and each time slot represents a game slot. As every node can try to transmit an unsuccessful data packet for some predetermined limit (Maximum retry limit), the game is finitely repeated rather than an infinitely repeated one. In each time slot, when the node is in active part, the node just not only tries to contend for the medium but also estimates the current game state based on history. After estimating the game state, the node adjusts its own equilibrium condition by adjusting its available parameters under the given strategies (here it is contention parameters like transmitting probability, collision probability, etc.). Then all the nodes act simultaneously with their best evaluated strategies. In this game we considered mainly three strategies available to nodes: Transmitting, Listening, and Sleeping. And contention window size as the parameter to adjust its equilibrium strategy.

In this stochastic game our main goal is to find an optimal equilibrium to maximize the network performance with minimum energy consumption. In general, with control theory we could achieve the best performance for an individual node rather than a whole network, and for this reason our game theoretic approach to the problem is justified.

Based on the game model presented in (L. Zhao et. al, 2008), the utility function of the node (node *i*) is represented by $\mu_i = \mu_i(s_i, \overline{s}_i)$ and the utility function of its opponents as $\overline{\mu}_i = \overline{\mu}_i(\overline{s}_i, s_i)$. Here, $s_i = (s_1, s_2, \ldots, s_{i-1}, \ldots, s_n)$ represents the strategy profile of a node and $\overline{s}_i$ of its opponent nodes, respectively. From the aforementioned discussion we can represent the above game as in table 2.

		Player 2 (all other *n* nodes)		
Player 1 (Node *i*)		Transmitting	Listening	Sleeping
	Transmitting	$(P_f, \overline{P}_f)$	$(P_s, \overline{P}_i)$	$(P_f, \overline{P}_w)$
	Listening	$(P_i, \overline{P}_s)$	$(P_i, \overline{P}_i)$	$(P_i, \overline{P}_w)$
	Sleeping	$(P_w, \overline{P}_f)$	$(P_w, \overline{P}_i)$	$(P_w, \overline{P}_w)$

Table 2. Strategy table

As presented in (L. Zhao et. al, 2008), we define P_i and $\overline{P}_i$ as the payoff for player 1 and 2 when they are listening, P_s and $\overline{P}_s$ when they are transmitting a data packet successfully, P_f and $\overline{P}_f$ when they are failed to transmit successfully, and P_w and $\overline{P}_w$ when they are in sleep mode, respectively. Whatever will be the payoff values, their self evident relationship is given by

$$P_f < P_i < P_w < P_S \tag{1}$$

and similar relationship goes for player 2. As per our goal we are looking for the strategy that can lead us to an optimum equilibrium of the network. As in (L. Zhao et. al, 2008) we can define it formally as

$$\begin{cases} s_i^* = \arg\max\limits_{s_i} \overline{\mu}_i(\overline{s}_i, s_i) \mid (e_i < e_i^*) \\ \overline{s}_i^* = \arg\max\limits_{\overline{s}_i} \mu_i(s_i, \overline{s}_i) \mid (\overline{e}_i < \overline{e}_i^*) \end{cases} \tag{2}$$

where $e_i, e_i^*, \overline{e}_i$ and $\overline{e}_i^*$ are the real energy consumption and energy limit of the player 1 and 2, respectively. Now to realize these conditions in practical approach we redefine them as follows

$$\begin{cases} s_i^* = \underset{(w_i,\tau_i)}{\arg\max} \begin{array}{l} [(1-\overline{\tau}_i)(1-\overline{p}_i)(1-\overline{w}_i)(1-w_i)\tau_i\overline{P}_s + (1-\overline{\tau}_i)(1-\overline{w}_i)(1-w_i)\tau_i\overline{P}_i \\ +(1-\overline{p}_i)(1-\overline{w}_i)(1-w_i)\tau_i\overline{\tau}_i\overline{P}_f + \overline{\tau}_i\overline{p}_i(1-w_i)\overline{P}_f + w_i(1-\overline{w}_i)\overline{P}_w] \mid (e_i < e_i^*) \end{array} \\ \overline{s}_i^* = \underset{(w_i,\tau_i)}{\arg\max} \begin{array}{l} [(1-\overline{\tau}_i)(1-\overline{w}_i)(1-w_i)\tau_i P_s + (1-\tau_i)(1-\overline{w}_i)(1-w_i)P_i \\ +\tau_i\overline{\tau}_i P_f + \overline{w}_i(1-w_i)P_w] \mid (\overline{e}_i < \overline{e}_i^*) \end{array} \end{cases} \tag{3}$$

Here, we define τ_i and $\overline{\tau}_i$ as the transmission probability of the player 1 and player 2, respectively. Similarly, w_i and $\overline{w}_i$ represents the sleeping probability of player 1 and player 2 while $\overline{p}_i$ is the conditional collision probability of player 2. Here we could not go into many details about these equations due to space limitation, so readers are referred to (S.Mehta et al., 2009) for more details on the same.

From the strategy table and equation (3) we can see that every node has to play its strategies with some probabilities as here the optimum equilibrium is in mixed strategy form. In addition, we can observe from the above equations that players can achieve their optimal response by helping each other to achieve their optimal utility. So the nodes have to play a cooperative game under the given constrained of energy.

As we mentioned earlier every node change its strategies by adjusting contention window size (i.e. properly estimating the number of competing nodes). There are some methods, especially (G. Bianchi et al., 2003, T. Vercauteren et al, 2007), to name a few, to accurately predict the number of competing nodes in the networks , however they are too complex and heavy to implement in wireless sensor networks. Also, we cannot expect to find an algorithm that can give the theoretical optimum solution, as the above mentioned problem has been proven to be NP-hard (M. S. Garey et al., 1979). So in this case study we present a sub optimal and a simple solution to achieve the optimum performance of a network.

3.2 Improved backoff

In this section we briefly introduce the improved backoff (IB), for more details on the same readers are refereed to (S.Mehta et al., 2009). This is very simple scheme to integrate with any energy efficient MAC protocols for WSNs. This method doesn't require any complex or hard method to estimate the number of nodes. Furthermore, IB can easily accommodate the changing dynamics of WSNs.

IB Mechanism:

In contrast to traditional backoff scheme, IB scheme uses a small and fixed CW. In IB scheme, nodes choose non-uniform geometrically increasing probability distribution (P) for picking a transmission slot in the contention window. Nodes which are executing IB scheme pick a slot in the range of (1, CW) with the probability distribution P. Here, CW is contention window and its value is fixed. More information on CW we will be presented in the later sections of this paper. Figure 8 shows the probability distribution P. The higher slot numbers have higher probability to get selected by nodes compared to lower slot numbers. In physical meaning we can explain this as: at the start node select a higher slot number for its CW by estimating large population of active nodes (n) and keep sensing the channel status. If no nodes transmits in the first or starting slots then each node adjust its estimation of competing nodes by multiplicatively increasing its transmission probability for the next slot selection cycle. Every node keeps repeating the process of estimation of active nodes in every slot selection cycle and allows the competition to happen at geometrically–decreasing values of n all within the fixed contention window (CW). In contrast to the probability distribution P, in uniform distribution, as shown in fig. 8 , all the contending nodes have the same probability of transmitting in a randomly chosen time slot. Here, it is worth to note that IB scheme doesn't use timer suspension like in IEEE 802.11 to save energy and reduce latency in case of a collision. The only problem with the IB is fairness, however, for WSNs, fairness is not a problem due to two main reasons. First, overall network performance is more important rather than an individual node. Second, all nodes don't have data to send all the time (i.e. unsaturated traffic condition). Using IB may give us the optimum network performance as it reduces the collision to minimum.

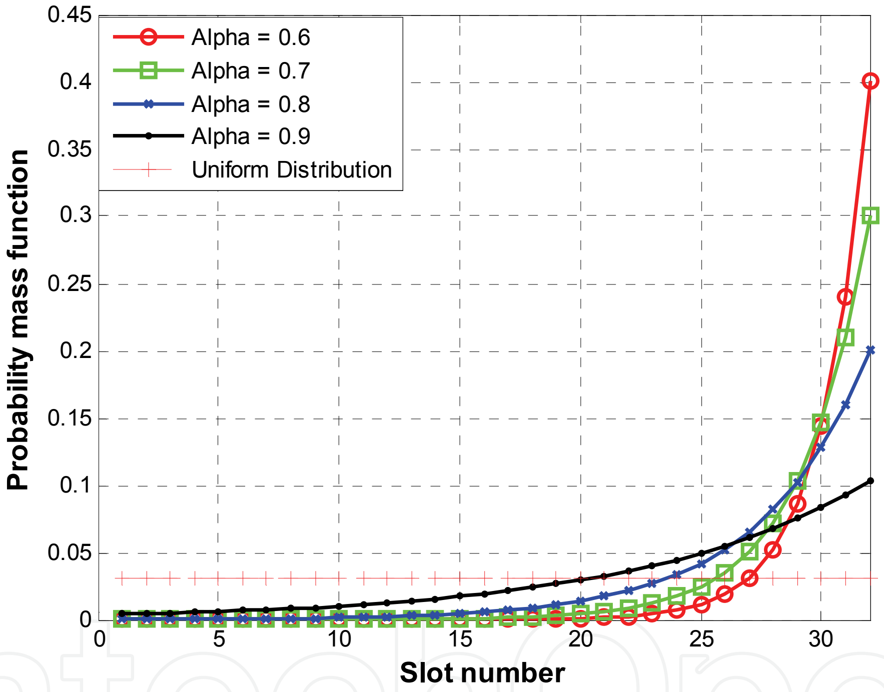


Fig. 8. Difference between uniform and truncated geometric distributions

3.3 Performance evaluation

In this subsection we present the performance comparison of incomplete cooperative game, ie. Incomplete Game, our "considered" or "normal" MAC protocol, and IB based MAC protocol in terms of channel efficiency, medium access delay and energy-efficiency . Latter two protocols are same in nature except for their backoff procedure. For the performance analysis we carried out simulation in Matlab. The main parameters for our simulation are listed in table 3. For calculating the energy consumption in nodes we choose ratio of idle: listen: transmit as 1:1:1.5, as measured in (M. Stemm et al., 1997). For the "normal" MAC protocol maximum retry limit is set to 3 (m=3), minimum contention window is set to 16 (also for the IB Based MAC), and traffic model is set to non-saturation.

As we have described in previous section channel efficiency is mostly depends on number of active nodes and contention window size. As shown in figure 9, at first "Normal MAC" (NM) gives high channel throughput at lower number of nodes. The reason is very obvious, less collision and low waiting time in backoff procedure, and as number of contenders increases channel throughput start decreasing. In contrast to NM, "IB based MAC" (IBM) maintains high channel efficiency due to its unique quality of collision avoidance among the competing nodes. In IBM most of the nodes choose higher contention slots while very few nodes selects lower contention slots, hence less or no collision and low waiting time in backoff procedure. For "Incomplete Game" channel efficiency almost keep constant after 30 nodes, as each node can adapt to the variable game state and choose corresponding equilibrium strategy. At start it shows lower channel efficiency because contention window is still too big for given number of nodes.

Parameters	**Values**
$CW_{\min}$	16
Packet size	1024 Bytes
Nodes	5~100
Data Rate	1 Mbps
Transmitting Energy	50x10-6 J/Bit
Idle/listening Energy	75x10-6 J/Bit

Table 3. Simulation Parameters

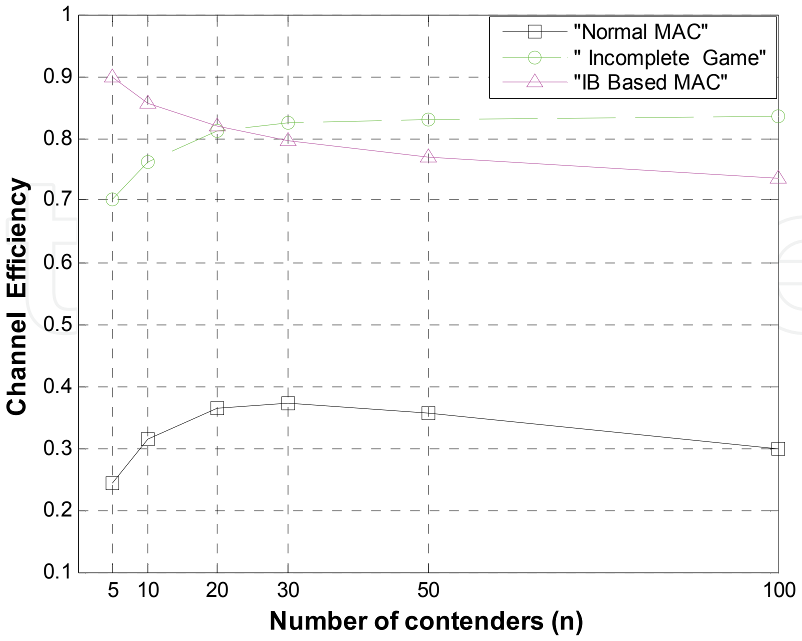


Fig. 9. shows the channel efficiency of "Normal MAC", "Incomplete Game" and "IB Based MAC".

Figure 10 shows the average medium access delay performances of NM, Incomplete Game and IBM. Here, medium access delay is defined as the time elapsed between the generation of a request packet and its successful reception. In NM scheme, as a large number of stations attempt to access the medium, more collision occurs, the number of retransmissions increases and nodes suffer longer delays. In IBM, as we expected access delay is very low compared to NM. This is because of low or no collision and less idle waiting time in backoff procedure. In "Incomplete Game", access delay performance is far more better than "NM",

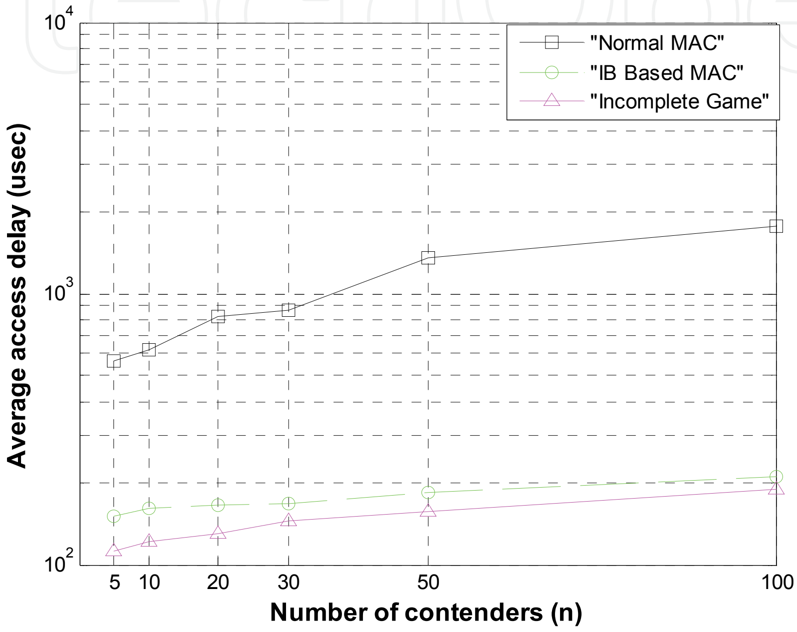


Fig. 10. Average access delay vs. number of nodes

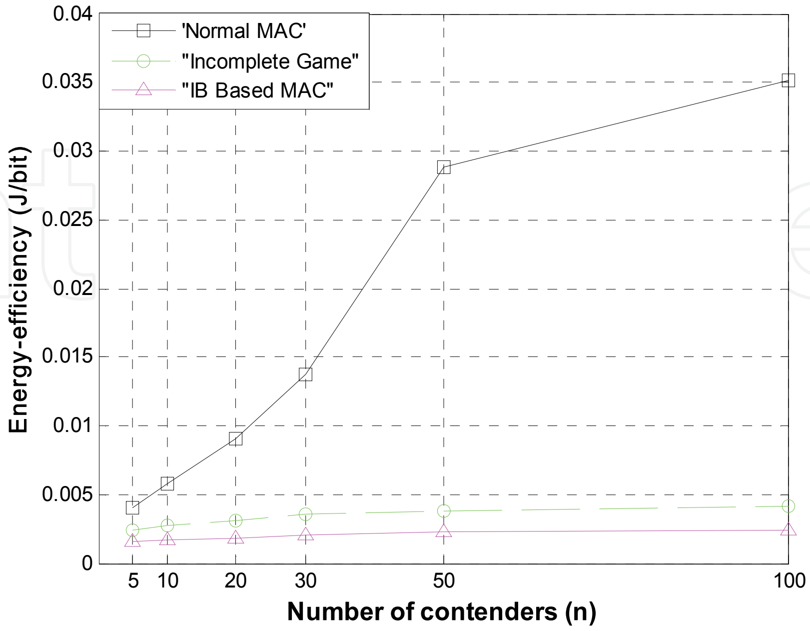


Fig. 11. Energy-efficiency vs. number of nodes

and comparable with "IBM", as it take some time to adjust its contention window according to number of nodes. Figure 11 illustrates the impact of CW on energy efficiency of NM, incomplete game, and IBM schemes.
From figure 11 we can see that as number of nodes increases NM scheme waste more energy due to increase in collision and retransmission attempts. In contrast IBM wastes very less energy due to its unique characteristics of collision avoidance. Similarly, "Incomplete Game" can also give the comparative performance to IBM, as it also reduces collision by adjusting its equilibrium strategy. From all aforementioned results we can see the superiority of IBM over NM. Accepting IBM as backoff scheme can increase the overall performance of an energy efficient MAC protocol to a large extends and we can also get the sub optimal solution for an incomplete cooperative game.

4. Related works

Along with the aforementioned examples and a case study there are notable amount of work presented in the area of game theory and wireless networks. We summarize some of the important current related works/trends as shown in the table 4. As describe in the above mentioned games selfish behavior by nodes in a wireless network may lead to a suboptimal equilibrium where nodes, through their actions, reach an undesirable steady state from a network point of view. Hence, incentive mechanisms are needed to steer nodes towards constructive behavior (i.e., towards a desirable equilibrium). Even though the bulk of work done in the past few years to answer above mentioned games still they are at a nascent stage.

Subject	The Proposed work/solution	References
Ad-hoc Networks	Cooperation with and without incentives -Currency & reputation -Virtual money and Cost -Reducing Selfish behaviour	(S.Mehta and K.S Kwak, 2007/8, and references in there.)
Sensor Networks	Cooperative Packet forwarding, Mac Protocol, non-cooperative Solutions, etc.	
Cognitive radio	Major works in resource allocation and IEEE 802.22 Working Group	
Cellular and Wi-Fi Networks (WWANs and WLANs)	Resource Allocation, Selfish behaviour, and reputation based networks	

Table 4. Summery of related works

5. Conclusions

In this chapter, we present the introduction of Game theory and show its application to wireless networks. Game theory can model the various interactions in wireless networks as games at different levels of protocol stack. With these games we can analysis the existing Routing/MAC protocols and resource management schemes, as well as the design of equilibrium-inducing mechanisms that provide incentives for individual nodes to behave inline with the network goals. We also present a case study on IB based MAC protocol as a concrete example of applicability of game theory to wireless networks. In short, this chapter paper serves three main objectives; first, to model some of the fundamental questions on wireless networks as interactive games between the nodes. Second object is to gain our understanding on inter-discipline research issues and third to motivate students and researchers to peep at this fascinating analytical tool, and encourage them in modeling problems of wireless networks.

6. References

Garey, S.M., & Johnson, D. S. (1979). Computers and Intractability: Guide to the Theory of NP-Completeness. W. H. Freeman, New York.

Osborne, M.J. & A Rubinstein.(1994).A course in game Theory. Cambridge, MA : The MIT Press.

Stemm, M., & Katz, R.H. (1997). Measuring and reducing energy consumption of network interfaces in hand-held devices. *IEICE Transactions on Communications E80-B (8)*, pp.1125–1131.

Bianchi, G. (2000) Performance Analysis of the IEEE 802.11 Distributed Coordination Function. *IEEE Jour. SAC, 18 (3)*, pp. 535-547.

Ye, W. & Heidemann, J. & Estrin D. (2002) . An Energy- Efficient MAC Protocol for wireless Sensor Networks. *In proceeding of IEEE INFOCOM 2002*, New York,pp.1567-1576.

Dam, T. V. & Langendone, K. (2003). An Adaptive Energy-Efficient MAC Protocol for Wireless Sensor Networks. *In proceeding of SenSys'03*, Los Angeles, pp.171-180.

Bianchi, G. & Tinnirello I. (2003). Kalman Filter Estimation of the Number of Competing Terminals in an IEEE 802.11 Network. *In proceeding of INFOCOM'03*.

Tay, Y. C., Jamieson, K. & Balakrishnan, H. (2004). Collision-Minimizing CSMA and Its Applications to Wireless Sensor Networks. *IEEE JSAC, Vol.22, No.6*, pp.1048-1057.

Srivastava, V. ; Neel, J. ; Mackenzie, A. B. ; Menon, R.; Dasilva, L. A. ; Hicks, J. E.; Reed, J. H., & Gilles, R. P. (2005). Using Game Theory to Analyze Wireless Ad-hoc Networks. *IEEE communications and survey, Fourth Quarter*, 2005.

Felegyhazi, M. & Hubaux, J.-P. (2006). Game Theory in Wireless Networks: A Tutorial. *In EPFL technical report*, LCA-REPORT-2006-002.

Akyildiz, I. F.; Lee, W. Y.; Vuran, M.C.; & Mohanty, S. (2006) NeXt generation/dynamic spectrum access/cognitive radio wireless networks: A survey. *Computer Networks 50 (2006)*, pp.2127–2159.

Vercauteren, T., Toledo, A.L., & Wang, X. (2007). Batch and Sequential Bayesian Estimators of the Number of Active Terminals in an IEEE 802.11 Network. *In IEEE Trans. on Signal Processing,* vol. 55, no. 2, pp. 437-450.

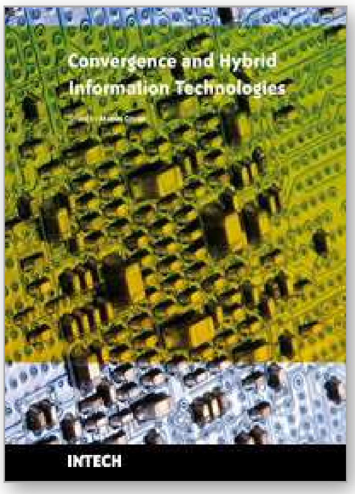
Zaho, L., Zhang, H. & Zhang, J. (2008).Using In complete Cooperative Game Thory in wirless Sensor networks. *In proceeding of IEEE WCNC 2008*.pp . 1483-1488.

Mehta, S. & Kwak, K.S. (2007/8). Game Theoretic approach to Cognitive Radio based Tactical Maneuvering Networks. *Project Proposal*, UWB Research Center, Inha University.

Mehta, S. & Kwak, K.S. (2009). A GCSMA Based Contention Scheme for Wireless Sensor Networks. *Technical Report-6*, UWB Research Center, Inha University.

IntechOpen

IntechOpen



Convergence and Hybrid Information Technologies
Edited by Marius Crisan

ISBN 978-953-307-068-1
Hard cover, 426 pages
Publisher InTech
Published online 01, March, 2010
Published in print edition March, 2010

Starting a journey on the new path of converging information technologies is the aim of the present book. Extended on 27 chapters, the book provides the reader with some leading-edge research results regarding algorithms and information models, software frameworks, multimedia, information security, communication networks, and applications. Information technologies are only at the dawn of a massive transformation and adaptation to the complex demands of the new upcoming information society. It is not possible to achieve a thorough view of the field in one book. Nonetheless, the editor hopes that the book can at least offer the first step into the convergence domain of information technologies, and the reader will find it instructive and stimulating.

How to reference
In order to correctly reference this scholarly work, feel free to copy and paste the following:

S. Mehta and K. S. Kwak (2010). Application of Game Theory to Wireless Networks, Convergence and Hybrid Information Technologies, Marius Crisan (Ed.), ISBN: 978-953-307-068-1, InTech, Available from: http://www.intechopen.com/books/convergence-and-hybrid-information-technologies/application-of-game-theory-to-wireless-networks

INTECH
open science | open minds

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

© 2010 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike-3.0 License, which permits use, distribution and reproduction for non-commercial purposes, provided the original is properly cited and derivative works building on this content are distributed under the same license.

IntechOpen

IntechOpen