Advanced Research in Electrical and Electronic Engineering
Print ISSN: 2349-5804; Online ISSN: 2349-5812 Volume 2, Number 4 January-March (2015) pp. 331-336

http://www.krishisanskriti.org/areee.html

Adaptive Spectrum Sharing in CRN

Akash[1], Prakash[2], Ramchandrappa[3] and Kailas[4]

[1,2,3]Department of Electronic & Communication Engineering Veerappa Nisty Engineering College, Shorapur-585220
[4]Department of Electronic & Communication Engineering Veerappa Nisty Engineering College, Shorapur-585220
E-mail: [1]akashshivakumar47@gmail.com, [2]kailas.uttara@gmail.com

Abstract—*Current wireless networks are characterized by a static spectrum allocation policy, where govern-mental agencies assign wireless spectrum to license holders on a long-term basis for large geographical regions. Recently, because of the increase in spectrum demand, this policy faces spectrum scarcity in particular spectrum bands. In contrast, a large portion of the assigned spectrum is used sporadically, leading to underutilization of a significant amount of spectrum. Hence, dynamic spectrum access techniques were recently proposed to solve these spectrum inefficiency problems. Spectrum measurements by FCC and other organizations (e.g., XG DARPA initiative) indicate significant temporal and geographical variations in the utilization of the licensed spectrum, ranging from 15% to 85%. These measurements motivated the need for a new technology that improves spectrum utilization without degrading the performance of licensed primary radio networks (PRNs). To cope with the rising demand in unlicensed wireless services, cognitive radio (CR) technology has been proposed. This technology allows an open access to the spectrum subject to a predetermined etiquette. In a cognitive radio network (CRN), users are aware of the radio frequencies used by existing legacy networks, and they opportunistically adapt their communication parameters to be able to communicate without affecting active PR users. Cognitive Radio refers to the intelligent radios that have spectrum scanning and parameter adjustment capability.*

1. INTRODUCTION

Current wireless networks are characterized by a static spectrum allocation policy, where govern-mental agencies assign wireless spectrum to license holders on a long-term basis for large geographical regions. Recently, because of the increase in spectrum demand, this policy faces spectrum scarcity in particular spectrum bands. In contrast, a large portion of the assigned spectrum is used sporadically, leading to underutilization of a significant amount of spectrum [1]. Hence, dynamic spectrum access techniques were recently proposed to solve these spectrum inefficiency problems.

Spectrum measurements by FCC and other organizations (e.g., XG DARPA initiative) indicate significant temporal and geographical variations in the utilization of the licensed spectrum, ranging from 15% to 85% [1]. These measurements motivated the need for a new technology that improves spectrum utilization without degrading the performance of licensed primary radio networks (PRNs). To cope with the rising demand in unlicensed wireless services, cognitive radio (CR) technology has been proposed. This technology allows an open access to the spectrum subject to a predetermined etiquette. In a cognitive radio network (CRN), users are aware of the radio frequencies used by existing legacy networks, and they opportunistically adapt their communication parameters to be able to communicate without affecting active PR users. Cognitive Radio refers to the intelligent radios that have spectrum scanning and parameter adjustment capability. In the authors measure the power spectral density (PSD) of the received 6 GHz wide signal. Indicates the underutilization of spectrum that will demand a newer technology to enhance spectrum use. The power spectral density indicates the spectrum utilization behaviour of the primary users present in the radio environment. Dynamic spectrum access schemes permit CR user to use the best existing spectrum. The working of cognitive radios is illustrated through cognitive cycle. The cognitive cycle consists of following main components: spectrum sensing (finding spectrum holes), spectrum decision (characterization of spectrum holes), spectrum sharing (allocation of sen sed spectrum) and spectrum mobility (vacate channel for primary user). The final step is necessary in order to avoid the interference with the licensed user.

The key enabling technology of dynamic spectrum access techniques is cognitive radio (CR) technology, which provides the capability to share the wireless channel with licensed users in an opportunistic manner. CR networks are envisioned to provide high bandwidth to mobile users via heterogeneous wireless architectures and dynamic spectrum access techniques. This goal can be realized only through dynamic and efficient spectrum management techniques.

A CRN has unique characteristics that distinguish it from traditional multi-channel wireless networks. Unlike traditional wireless networks, which typically occupy contiguous bands [2]–[4], a CRN is expected to operate over a set of widely-separated non-contiguous frequency bands. Communication on such bands exhibits different RF attenuation and interference behaviors. It is well known that signal attenuation increases with the distance between the two communicating users and also with the carrier frequency used for communication [5]. Therefore, when assigning transmission channels in a CRN, it is necessary to consider the signal attenuation model and the interference conditions to improve spectrum utilization. Another characteristic of a CRN is that users must operate using a relatively low transmission power (i.e., abide by a power mask) to avoid degrading the performance of the PR users [4]. These peculiar characteristics call for new MAC protocols that efficiently utilize the available spectrum while improving the overall network throughput.

The Federal Communications Commission (FCC) spectrum policy has recommended a paradigm shift in interference assessment from the largely fixed operations. This facilitates real-time interactions between a transmitter and a receiver in an adaptive manner. The recommendation is based on a new metric called the interference temperature, which is intended to quantify and manage the sources of interference in a radio environment. The interference is defined to be the radio frequency (RF) power measured at a receiving antenna per unit bandwidth. The key ideas for this new metric are as follows.

1. The interference temperature at a receiving antenna provides an accurate measure for the acceptable level of RF interference in the frequency band of interest. Any transmission in that band is considered to be “harmful”, if it increases the noise floor above the interference threshold.
2. At a given particular frequency band in which the interference temperature is not exceeded, the band could be made available to secondary users. Hence, a secondary device might attempt to coexist with the primary and the presence of secondary devices goes unnoticed. We have already proposed the spectral efficiency in our previous works[1]–[4]. Here, we mainly concentrate on minimizing the interference and improving quality of service (QoS) based on spectrum sharing using CR nodes, and the overall spectral efficiency is carried out in the present work.

2. WORK OVERVIEW

Channel assignment mechanisms in traditional multi-channel wireless networks typically select the “best” channel, or s et of channels, for a given transmission (e.g., [3], [6], [7]). In these mechanisms, the *best* channel is often defined as the one that supports the highest rate. To refer to this approach as the *best multi-channel* (BMC) approach. When the BMC approach is employed in a CRN, the blocking probability for CR transmissions, defined as the percentage of CR packet requests that are blocked due to the unavailability of a feasible channel assignment, can increase, leading to a reduction in the network throughput. To illustrate, consider an environment in which two PRNs and one CRN coexist. PRN 1 operates over a low-frequency band (CH 1), while PRN 2 operates over a high-frequency band (CH 2). Suppose that PRN 2 introduces a higher average PR-to-CR interference. Consequently, a CR receiver experiences a higher average signal-to-interference-plus-noise ratio (SINR) over CH 1 than over CH 2. Assume that two CR users A and C need to send data to CR users B and D, respectively (see Figure 1). Also assume that the distance between A and B (d_{AB}) is less than that between C and D (d_{CD}). Figure 1(a) shows that when the CR users employ the BMC approach, the transmission A → B uses CH 1, whereas the transmission C → D uses CH 2. A → B is allowed to proceed because it operates over a low carrier-frequency channel with low PR-to-CR interference for a short transmission distance. On the other hand, C → D requires relatively higher transmission power to overcome the high attenuation associated with the high-frequency/high-interference channel and the long transmission distance.

Centralized spectrum sharing: In this solution, a centralized entity controls the spectrum allocation and access procedures. Each entity in the cognitive radio network forwards the measurements of the spectrum allocation to the centralized entity. Using these measurements, the centralized entity constructs the spectrum allocation map Distributed spectrum sharing: the distributed spectrum sharing is used where the construction of an infrastructure is not necessary. In this case there is no presence of the centralized entity, each and every node is responsible for the spectrum allocation and access is based on local policies The second classification for spectrum sharing techniques in cognitive radio networks is based on the access behavior, which is of two types:

Cooperative spectrum sharing: cooperative spectrum sharing is also called as the collaborative spectrum sharing. it considers the effect of the node’s communication on other nodes, in this case the interference measurements of each and every node shared among the other nodes. All the centralized spectrum sharing solutions are considered as the cooperative spectrum sharing.

Non-cooperative spectrum sharing: this is also called as the non collaborative spectrum sharing (selfish) solution; it considers only the node at hand. The nodes will not share the measurements to the other nodes, so it is referred as the selfish

CR networks impose unique challenges due to their coexistence with primary networks as well as diverse QoS requirements. Thus, new spectrum management functions are required for CR networks with the following critical design challenges:

***Interference avoidance*:** CR networks should avoid interference with primary networks.

To decide on an appropriate spectrum band, CR networks should support QoS-aware communication, considering the dynamic and heterogeneous spectrum environment.

CR networks should provide seamless communication

SINR over the selected channel is greater than the SINR threshold. For both channels, to set the SINR threshold and the interference mask to 5 dB and 60 mW, respectively. Assume that CR receivers B and D experience the same level of total interference over both channels (0.05 μW). Given the above parameters and using the propagation model in [8] with path loss exponent of 2, the required transmit powers over CH 1 and CH 2 for A → B are 2.2 mW and 16 mW, respectively. For C → D, these powers are 56.18 mW and 399.5 mW. According to the BMC scheme (Figure 1(a)), A → B can proceed over CH 1 (the power mask is not violated), whereas C → D cannot proceed over CH 2 (the required transmit power exceeds the power mask)

It is worth mentioning that in a given (one-hop) neighborhood, the *optimal* channel assignment that maximizes the number of simultaneous CR transmissions can be formulated as an integer linear programming (ILP) problem [9], [10]. Since computing the optimal solution for the ILP problem grows exponentially with the size of the network [9], heuristic algorithms with suboptimal performance are needed. Such algorithms should attempt to compute channel assignment with reasonable computational/communication overhead.

In this work, to develop a novel CSMA-based MAC protocol that aims at enhancing the throughput of the CRN subject to a power mask constraint. The proposed protocol (DDMAC) employs an intelligent stochastic channel assignment scheme that exploits the dependence between the RF signal attenuation model and the transmission distance while taking into consideration the local traffic conditions.

As per the spectrum measurements performed by the FCC and other organizations it revealed that significant temporal and geographical variations were observed in the utilization of licensed spectrum, ranging from 15% to 85%. Hence there was a need for new technology that improves spectrum utilization without degrading the performance of licensed primary radio networks (PRNs).

To overcome the rising demand in unlicensed wireless services, cognitive radio (CR) technology has been proposed.

The other drawback of traditional multichannel wireless networks is that they typically occupy contiguous bands.

Through this paper an opportunistic distance-dependent MAC protocol for CRNs (DDMAC) is been proposed. DDMAC improves the CRN throughput through cooperative channel assignment, taking into consideration the non-adjacency of frequency channels and the imposed power masks.

A heuristic stochastic channel assignment scheme is also being proposed that dynamically exploits the dependence between the signal attenuation model and the transmission distance.

This scheme also accounts for traffic dynamics wherein it assigns channels with lower average SINR to shorter transmission distances to increase the number of simultaneous transmissions.

It has been proved that, under moderate and high traffic loads, DDMAC achieve about 30% increase in throughput over the BMC scheme, with manageable processing overhead.

Taking account of all these drawbacks and solutions it can be concluded that DDMAC provides better spectrum utilization by reducing the connection blocking probability and increasing the system throughput and it emerges to be the first CRN MAC protocol that utilizes the radio propagation characteristics to improve the overall network throughput. The swift expansion in the wireless technology has shaped the spectrum bandwidth scarce. This lack of spectra has pushed the spectrum management authorities to devise new ways for the efficient utilization of the existing spectrum. According to Federal Communication Commission (FCC) more than 70% of the available spectrum is not utilized optimally. Due to the shortage of available frequencies the bandwidth becomes a precious resource. For optimal and efficient usage of spectrum one possibility is to scan the whole spectrum to determine the opportunity for transmission (Dynamic Spectrum Access). The term Cognitive Radio refers to the intelligent radios that have spectrum scanning and parameter adjustment capability. This paper presents schemes for intra-network spectrum sharing in centralized cognitive radio networks. In such schemes a central entity called spectrum server is responsible to share the spectrum among the cognitive radio users. We assumed that all transmitters have fixed power and signal-to-interference determines the quality of a link. Dynamic Spectrum Sharing Scheme (DSSS) fulfills user’s data requirement by utilizing the existing scheduling based spectrum sharing schemes. All of the techniques try to maximize different parameters with the sole objective of maximizing the utility of spectra.

The main objective is to focus on proposing a novel *distance-dependent* MAC protocol for CRNs. The protocol, called DDMAC, attempts to maximize the CRN throughput. It uses a novel probabilistic channel assignment mechanism that exploits the dependence between the signal’s attenuation model and the transmission distance while considering the traffic profile. DDMAC allows a pair of CR users to communicate on a channel that may not be optimal from one user’s perspective, but that allows more concurrent transmissions to take place, especially under moderate and high traffic loads. Later simulation is been done to reduce blocking rate of CR requests consequently improving the network throughput

3. METHODOLOGY

In this work, to develop a novel CSMA-based MAC protocol that aims at enhancing the throughput of the CRN subject to a power mask constraint. The proposed protocol (DDMAC) employs an intelligent stochastic channel assignment scheme that exploits the dependence between the RF signal attenuation model and the transmission distance while taking into consideration the local traffic conditions. The channel assignment scheme accounts for the interference conditions and the power constraints at different bands. In particular, the scheme assigns channels with lower average SINR to shorter transmission distances, and vice versa. In addition, our scheme associates more preferable channels to the most frequent transmission distances and less preferable channels to the less frequent distances. In other words, the assignment process identifies a “preferable” channel list for each CR user. Such a list indicates which channels are preferable to use depending on the estimated distance between the transmitter and the receiver. To propose two variants for the channel assignment scheme. The first variant is suit-able for offline planning of spectrum sharing in networks with known deployment and traffic patterns. In this case, there is no need for distance-traffic pattern prediction. The second variant is suitable for online dynamic network operation with unknown traffic patterns. To estimate the distance-traffic pattern in a given neighbourhood, the second variant employs a stochastic learning technique that adapts to network dynamics (i.e., mobility, interference conditions, and traffic conditions).

To evaluate the performance of DDMAC, simulations over a dynamic CRN with mobile users is done. Simulation results show that by being distance- and traffic-aware, DDMAC significantly improves network throughput while preserving fairness. The results also indicate that compared with typical multi-channel CSMA-based protocols, DDMAC decreases the connection blocking rate in a CRN by up to 30%. By injecting artificial errors into the estimated distances, evaluation reveals that DDMAC is robust against estimation errors. In DMAC, the preferable channel list per node is constructed by accounting for the challenges associated with CRs (i.e., low transmit power, presence of PR users, widely separated non-contiguous available bands).

Unlike DDMAC, the objective in MMAC was not to address spectrum sharing while improving the overall throughput, but rather to handle multi-channel hidden terminals using a single transceiver and to balance the channel usage over all available channels.

Centralized spectrum sharing: In this solution, a centralized entity controls the spectrum allocation and access procedures. Each entity in the cognitive radio network forwards the measurements of the spectrum allocation to the centralized entity. Using these measurements, the centralized entity constructs the spectrum allocation map

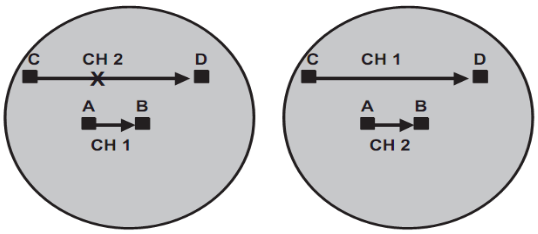
Distributed spectrum sharing: The distributed spectrum sharing is used where the construction of an infrastructure is not necessary. In this case their is no presence of the centralized entity, each and every node is responsible for the spectrum allocation and access is based on local policies fairness, spectrum utilization and throughput, both the approaches are considered such the cooperative approaches also consider the effect of the channel allocation on the potential side. The results show that cooperative spectrum sharing outperforms the non cooperative spectrum sharing. Coming to the comparison of the centralized and distributed spectrum sharing, the distributed spectrum sharing closely follows the centralized spectrum sharing. But, this is not always valid in the cognitive radio networks. To exploit the performance of the cognitive radio spectrum access solutions game theory was proposed, game theory is exploited to analyze the behavior of the cognitive radio for distributed adaptive channel allocation. The comparision between the cooperative and non cooperative spectrum sharing techniques has been presented using the game theory The evaluations reveal that Nash equilibrium point for cooperative users is reached quickly and results in a certain degree of fairness as well as improved throughput, more over fairness and spectrum utilization are degraded by using the non cooperative spectrum sharing. The communication and information exchange required by selfish users is very low.

4. WORKING

In this project, to develop a novel CSMA-based MAC protocol that aims at enhancing the throughput of the CRN subject to a power mask constraint. The proposed protocol (DDMAC) employs an intelligent stochastic channel assignment scheme that exploits the dependence between the RF signal attenuation model and the transmission distance while taking into consideration the local traffic conditions. The channel assignment scheme accounts for the interference conditions and the power constraints at different bands. In particular, the scheme assigns channels with lower average SINR to shorter transmission distances, and vice versa. In addition, our scheme associates more preferable channels to the most frequent transmission distances and less preferable channels to the less frequent distances. In other words, the assignment process identifies a “preferable” channel list for each CR user. Such a list indicates which channels are preferable to use depending on the estimated distance between the transmitter and the receiver. To propose two variants for the channel assignment scheme. The first variant is suitable for offline planning of spectrum sharing in networks with known deployment and traffic patterns. In this case, there is no need for distance-traffic pattern prediction. The second variant is suitable for online dynamic network operation with unknown traffic patterns. To estimate the distance-traffic pattern in a given neighbourhood, the second variant employs a stochastic learning technique that adapts to network dynamics (i.e., mobility, interference conditions, and traffic conditions). The primary advantage of our assignment scheme is that it is based on passive learning. This is because in DDMAC, CR users always listen to the control channel in order to overhear control-packet exchanges, including those not destined to them. CR users use the control information to identify the preferable channels.

DDMAC has the following attractive features:

- It does not make any assumptions about the activity patterns of the underlying networks or about user distribution.
- It is easy to implement in practical settings, and its processing overhead is small.
- It is transparent to PR users, i.e., does not require coordination with them.
- It inherently improves the fairness among CR users compared to typical multichannel CSMA-based protocols.
- Under low load and several available channels, DDMAC gracefully degrades to the BMC approach.



(a) BMC channel assignment (b) Distance-dependent channel assignment

Fig. 1: Scenarios in which two CR transmissions can/cannot proceed simultaneously.

MMAC does not support multiple-channel assignment (it is limited to one channel per user). Specifically, the channel selection criterion in MMAC is to use a channel with the lowest count of source destination pairs that have selected the channel. In DDMAC, the preferable channel list per node is constructed by accounting for the challenges associated with CRs (i.e., low transmit power, presence of PR users, widely separated non-contiguous available bands). Unlike DDMAC, the objective in MMAC was not to address spectrum sharing while improving the overall throughput, but rather to handle multichannel hidden terminals using a single transceiver and to balance the channel usage over all available channels. In addition, MMAC requires global network synchronization, which is not a requirement in DDMAC.

DDMAC is the first CRN MAC protocol that aims at improving the CRN throughput by exploiting the dependence on the RF signal's attenuation model and the transmission distance while considering the prevailing traffic and interference conditions.

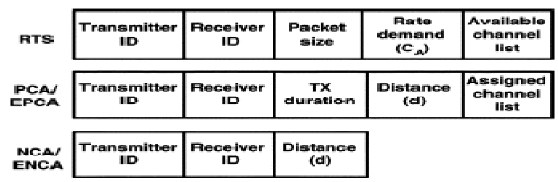
DISTANCE-DEPENDENT CHANNEL ASSIGNMENT ALGORITHM

The assignment process identifies a "preferable" channel list for each CR user. Such a list indicates which channels are preferable to use depending on the estimated distance between the transmitter and the receiver. To use any scheme such as Received Signal Strength Indicator (RSSI), the Time of Arrival (ToA), and the Time Difference of Arrival (TDoA) for estimating the transmitter-receiver distance in wireless networks. Two variants of the channel assignment mechanism are proposed. The first variant is suitable for offline planning of spectrum sharing in networks with known traffic patterns, whereas the second variant is for online spectrum allocation in dynamic (mobile) networks with unknown traffic patterns.

DDMAC PROTOCOL

The proposed DDMAC is a CSMA/CA-based scheme that uses contention-based handshaking for exchanging control information. In designing the channel access in DDMAC, to focus on extending the CSMA/CA scheme due to its maturity and wide deployment in many wireless packet networks. Besides mitigating the hidden-terminal problems, there are two other main objectives for the use of RTS/CTS:

1. Conducting and announcing the channel assignment; and
2. Prompting both the transmitter and the receiver to tune to the agreed on channels before transmission commences.

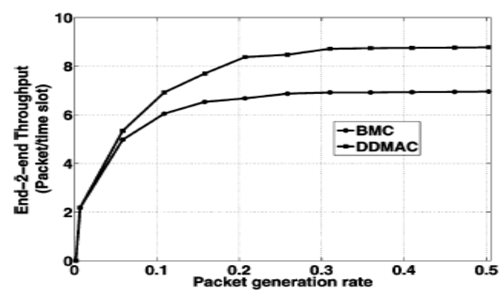


Formats of DDMAC control packets.

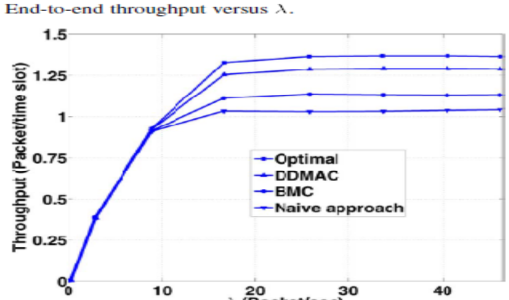
Formats of DDMAC Control Packets

The performance of DDMAC is then simulated and compared with CSMA/CA variants.

5. SIMULATION RESULTS



. End-to-end throughput versus λ.



6. CONCLUSION

In this paper, we proposed an opportunistic distance-dependent 0MAC protocol for CRNs (DDMAC). DDMAC improves the CRN throughput through cooperative channel assignment, taking into consideration the non adjacency of frequency channels and the imposed power masks. We presented a heuristic stochastic channel assignment scheme that dynamically exploits the dependence between the signal attenuation model and the transmission distance. Our scheme accounts for traffic dynamics.

It assigns channels with lower average SINR to shorter transmission distances to increase the number of simultaneous transmissions. We integrated the channel assignment process in the design of DDMAC. We compared the performance of DDMAC with that of a reference multichannel MAC protocol that is designed for typical multichannel systems (BMC). We showed that, under moderate and high traffic loads, DDMAC achieves about 30% increase in throughput over the BMC scheme, with manageable processing overhead. Although DDMAC requires a pair of CR users to communicate on a channel that may not be optimal from a user's perspective, we showed that the average per-user throughput of DDMAC under moderate and high traffic loads is greater than that of the BMC scheme. Furthermore, DDMAC preserves (even slightly improves) throughput fairness relative to BMC. In summary, DDMAC provides better spectrum utilization by reducing the connection blocking probability and increasing the system throughput. To the best of our knowledge, DDMAC is the first CRN MAC protocol that utilizes the radio propagation characteristics to improve the overall network throughput.

REFERENCES

[1] FCC, "Spectrum policy task force report," ET Docket No. 02-155, 2002.

[2] H. B. Salameh, T. Shu, and M. Krunz, "Adaptive cross-layer MAC design for improved energy efficiency in multi-channel wireless sensor networks," *Ad Hoc Netw.*, vol. 5, no. 6, pp. 844–854, 2007.

[3] N. Jain, S. Das, and A. Nasipuri, "A multichannel CSMA MAC protocol with receiver-based channel selection for multihop wireless networks," in *Proc. 9th IC3N*, Oct. 2001, pp. 432–439.

[4] H. B. Salameh and M. Krunz, "Channel access protocols for multihop opportunistic networks: Challenges and recent developments," *IEEE Network*, vol. 23, no. 4, pp. 14–19, Jul.–Aug. 2009, Special Issue on Networking over Multi-Hop Cognitive Networks.

[5] M. Riback, J. Medbo, J. Berg, F. Harrysson, and H. Asplund, "Carrier frequency effects on path loss," in *Proc. VTC*, May 2006, pp. 2717–2721.

[6] T. Shu, S. Cui, and M. Krunz, "Medium access control for multi-channel parallel transmission in cognitive radio networks," in *Proc. IEEE GLOBECOM*, Nov. 2006, pp. 1–5, WLC05-3.

[7] A. Nasipuri and S. Das, "Performance of multi-channel ad hoc networks," *Int. J. Wireless Mobile Comput.*, vol. 1, no. 3/4, pp. 191–203, 2006.

[8] T. S. Rappaport, *Wireless Communications-Principles and Practice*, 2nd ed. Upper Saddle River, NJ: Prentice-Hall, 2001.

[9] E. Arikan, "Some complexity results about packet radio networks," *IEEE Trans. Inf. Theory*, vol. IT-30, no. 4, pp. 681–685, Jul. 1984.

[10] A. Behzad and I. Rubin, "Multiple access protocol for power-controlled wireless access nets," *IEEE Trans. Mobile Comput.*, vol. 3, no. 4, pp. 307–316, Oct.–Dec. 2004.