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Throughput Maximization with Energy Harvesting in Cognitive Radio Network

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Abstract: R*ecently, the conception of Internet of Things (IoT) has been widely applied in many areas, and brings great benefits to our daily life. According to Cisco annual internet report, IoT devices will account for 60% of all global networked devices in 2024, and the ever-increasing number of IoT devices has led to a significant growth of mobile data. The huge data traffic has led to scarcities of both spectrum and energy. The cognitive radio (CR) technology is emerging as one of the solutions to address the well-known spectrum scarcity problem. CR allows unlicensed users to opportunistically access the licensed (unused or under-utilized) frequency bands, thus improving the efficiency of the current radio spectrum usage. This paper present the comparative performance analysis for the throughput and false alarm probability in cognitive radio network with energy harvesting mechanism, Simulated study show that our presents work give better results than the existing work.*

Keywords: Energy harvesting, Throughput, False alarm probability, Cognitive radio network, Software defined radio, Primary user, Secondary user.

Introduction

Cognitive radios offer the promise of being just this disruptive technology innovation that will enable the future wireless world. Cognitive radios are fully programmable wireless devices that can sense their environment and dynamically adapt their transmission waveform, channel access method, spectrum use, and networking protocols as needed for good network and application performance. We anticipate that cognitive radio technology will soon emerge from early stage laboratory trials and vertical applications to become a general-purpose programmable radio that will serve as a universal platform for wireless system development, much like microprocessors fulfill that role for computation.

There is however a big gap between having a flexible cognitive radio, effectively a building block, and the large-scale deployment of cognitive networks that dynamically optimize spectrum use. Building and deploying a network of cognitive radios is a complex task. The research community working on cognitive radio networks needs to understand a wide range of issues including smart antenna technology, spectrum sensing and measurement, radio signal processing, hardware architectures including software-defined radio (SDR), medium access control (MAC), network discovery and self-organization, routing, adaptive control of mechanisms, policy definition and monitoring, and learning mechanisms. This is a very wide range of technologies to harness and apply, and hence understanding and properly controlling the behavior of the resulting system is a challenging research task. The unused spectrum opportunities, referred to as spectrum holes are a natural consequence of the gap between the distinct scales at which regulation and use occur. This is because spectrum allocations and planning is done over a time-span of several years/decades, whereas the use of spectrum occurs at time scales of the order of seconds/minutes. This suggests that in order to solve this problem of regulatory overhead a dynamic approach to spectrum access is required. However, the exact form of these dynamic allocation strategies is debated. There have been two extreme proposals to solve the problem of regulatory overhead | spectrum privatization and spectrum commons model. Spectrum privatization advocates allocation of spectrum through real-time markets, whereas the spectrum commons proponents argued that the task of sharing spectrum must be left to the devices themselves and that advances in technology will make the devices capable of dynamically sharing spectrum efficiently. The reader is advised to refer to for a detailed survey on the history of the commons versus privatization debate, and also other regulatory issues in spectrum sharing. A hybrid model for spectrum access known as opportunistic spectrum sharing has been proposed to reduce the regulatory overhead. In this model, radios (secondary users) can opportunistically refill the spectrum holes in licensed bands (primary users) as long as they do not cause significant harmful interference to the licensed users. This model has the advantage of being implementable with very little changes to the currently existing system, and hence is a more politically feasible solution than both the privatization or commons models. The opportunistic spectrum sharing approach had gained significant traction in the last few years due to technological advances in radio technology. In particular, the advent of frequency agile and software defined radios, also known as cognitive radios has made the vision of opportunistic spectrum access technically feasible.

The term “cognitive radio" was initially coined by Mitola in the late 1990's. In a broad sense, cognitive radios are devices that can sense their environments and autonomously adapt and optimize their system parameters based on the changing operating conditions. Existing wireless systems like cellular networks and wireless local-area networks (WLANs) already have cognitive capabilities like adaptive power control, dynamic channel selection etc. However, the grand vision of the cognitive radio paradigm is for situation-awareness and system-level adaptation. There are many projects that are currently working to incorporate this vision into the next-generation wireless networks. For example, the Defense Advanced Research Projects Agency (DARPA) XG program, the IEEE 802.22 wireless regional area network (WRAN) standard (secondary use of television bands), and the European end-to-end re-configurability (E2R) research program.

Accessing the limited unlicensed spectrum for wireless services has been increased rapidly, so the regular fixed spectrum assignment policy to the available spectrum became inconvenient. A large part of the available spectrum is allocated to licensed holders; this part is unutilized for a long time. Cognitive Radio Networks (CRNs) can be defined as a network with dynamic licensed spectrum access capabilities. It consists of wireless users and cognitive radio. Because of the spectrum scarcity problem in the unlicensed spectrum band, the underutilization of the licensed spectrum band, and the intelligence of the Cognitive Radio; a Cognitive Radio Network uses these factors in order to acquire the ability to access and share the licensed spectrum band with its legitimate users with minimum interference with them and with no degradation in their quality of service. Cognitive Radio Network can be defined as a network that consists of smart cognitive radios wireless users, and dynamic spectrum access capabilities.

II. Energy Harvest

With the extensive application of information technology in social production and life, the business volume of mobile communication network shows explosive growth. The continuous expansion of network scale, diversification of base station and other communication equipment, as well as randomization of communication equipment site selection, have brought the sharp increase of the total network energy consumption and the multiple of the difficulty of base station energy supply. The construction of a sustainable and deployable communication network has become a crucial issue. Owing to the flexible deployment and uninterrupted green pollution-free energy providing, energy harvesting (EH) technology has become a particularly potential technology to resolve the difficulty of energy depletion in the future communication structure. Researches into energy harvest technologies initially focused on solar, wind and other renewable energy-powered devices. However, this technology does not only include renewable energy. The energy obtained by communication nodes from the surrounding environment does not necessarily refer to the clean energy such as solar energy and wind energy, but may also refer to the energy sent separately by other devices, similar to wireless charging technology. Using energy access technology in the wireless communication system, attributable to the changes of energy source, the obstacles and constraint conditions of traditional stable grid energy or limited battery power supply are no more applicable, so the algorithm of wireless communication, network protocol and even the hardware of transmission node are redesigned based on the needed energy for technical characteristics?

In the wireless communication system actuated by energy harvest technology, the predicament to be dealt with firstly is the randomness of energy acquisition [19]. As a consequence of the unpredictable energy source, the energy collection technology will stack the arbitrary of accessible energy of the system in the light of the original unplanned of wireless communication channel also data arrival, thus greatly increasing the intricacy of the conundrum. The next is the causality, that is, the energy acquired can only be operated at the following time, and the energy consumed by the system cannot exceed the total energy currently acquired and stored. Finally, it is about the effectiveness of energy. Because the capacity of the energy storage device is limited, energy cannot be stored without limit, resulting in limited energy that can be used, and the part beyond the capacity can only be discarded. Meanwhile, different from the traditional power furnish network, the traditional power supply network is not constrained by energy, and its optimization goal is to ameliorate the network service performance, likely improving the throughput of the system and reducing the user's blocking rate. However, in the wireless system based on energy harvest technology, due to the limitation of this technology, the optimization of service quality in the network must be considered on the basis of the optimization of energy use. If it is only to improve the throughput of the system and lessen the blocking rate of it, once the transmission is interrupted because of energy exhaustion, the information cannot be transmitted, which will urgently affect the quality of service. Therefore, the application of energy acquisition technology in wireless communication system must be thoroughly studied.

III. Proposed Work

The need for higher data rates is increasing as a result of new wireless services and applications. However, spectrum allocation and management is still based on the old fashioned techniques from the very early days of wireless communications. Given the limitations of the natural frequency spectrum, it is obvious that the current static frequency allocation schemes cannot meet the requirements of this increasing demand. Measurement campaigns in various parts of the world have supported the finding that the static spectrum access leads to some portions of the spectrum to be overcrowded while some other to be underutilized. So called the static spectrum access falls short of effective spectrum management and results in a perception that the spectrum is scarce.

The cognitive radio networks was first introduced while trying to solve the problem of spectrum scarcity and network congestion faced when using the unlicensed spectrum band. Using the smart cognitive radio communication devices and the fact of spectrum scarcity in unlicensed spectrum band, a cognitive radio network was introduced, in order to give the cognitive radio users; named secondary users (SUs); the permission to access and share the licensed spectrum band with its original users; named primary users, but with the guarantee that the original users performance won't be affected. It is clear that a cognitive radio network doesn't have a specific spectrum band assigned to it, but it coexist with one or more primary networks in their licensed spectrum band. It can access and share the licensed frequency channels without or with minimal interference with the primary networks' users so the primary users quality of service won't be degraded. Cognitive radio networks may detect the unused portion (channels) of the licensed spectrum band by detecting the primary users' transmission, and then assign the unused channels to its users.

Energy harvesting is one of the major common features of the system models included in recently. It is the process by which energy is derived from external sources and stored in the battery of the communication device. It has gained significant research interest recently. This is motivated by multiple different reasons. One of the major reasons is the increase of energy consumption in newer generation wireless communication devices. A typical non-replenish able finite sized battery is not adequate in tackling this ever-growing energy requirement due to its limited energy and lifespan. Thus, renewable energy sources have garnered attention from the research community and utilization of such sources has brought a paradigm shift in energy consumption and replenishment processes in industrial settings. One of the other significant benefits of using such systems is the decreasing usage of fossil fuels as the source of energy, thus indirectly helping in mitigating the effects of climate change by minimizing carbon footprints. Additionally, for wireless devices deployed in remote and potentially hazardous locations, replenishing batteries might be really tricky. Thus, running networks consisting of such devices in remote locations through power grid connections might not be a practical option. Energy harvesting from the surroundings in such a scenario provides a viable solution to the energy management problem. It is also beneficial for smaller devices with low battery capacity like wireless sensors. This is due to the fact that, without energy harvesting, these devices will not be able to continue its operation for the required life time. However, some devices might not be able to harvest significant amount of energy from their surroundings, due to practical limitations of the physical process by which the energy is harvested. In such cases, sharing energy from one device to another might be a good alternative. In general, energy can be harvested from four different types of sources, namely, solar, thermoelectric power, mechanical motion and electromagnetic radiations.

Energy harvesting wireless devices typically harvest energy from ambient sources like solar, wind, motion and vibration signals. The main drawback of using ambient sources for energy harvesting is that they may not guarantee Quality of Service (QoS) of different applications due to the uncertainty in time, location and weather conditions. To ensure QOS, one might also envision a hybrid scenario, where the wireless device has access to traditional dedicated energy sources in addition to the energy harvested by ambient sources. However, the deployment of such dedicated power sources incurs additional cost which in turn increase the performance requirements. Recently, there has been much work on using opportunistic RF energy harvesting which is specific to the CR system. The SUs not only utilize the PU spectrum holes for transmission but also exploit the PU busy periods to harvest RF energy from PU transmission. Some authors used the stochastic geometry paradigm to analyze the SU transmission probability in an opportunistic RF energy-harvesting CR system. Optimal SU density and transmission power level were obtained to maximize the throughput of the CR network while satisfying the outage probability constraints at the PUs and SUs. In a multichannel system with RF energy-harvesting SU, an optimal channel-access policy was derived to maximize the SU throughput by using an MDP framework for the case when model parameters for the SU transmission and harvesting, and PU channel state occupancy were available. An online learning algorithm was proposed for the case when no information was available. In a similar multichannel system with multiple SUs, optimal channel-access policies were obtained for the SUs cooperating in a round-robin and a decentralized manner. It shown that a greater SU throughput can be achieved by considering the hybrid energy-harvesting and transmission modes as compared to that obtained by only operating in overlay mode using ambient energy sources.

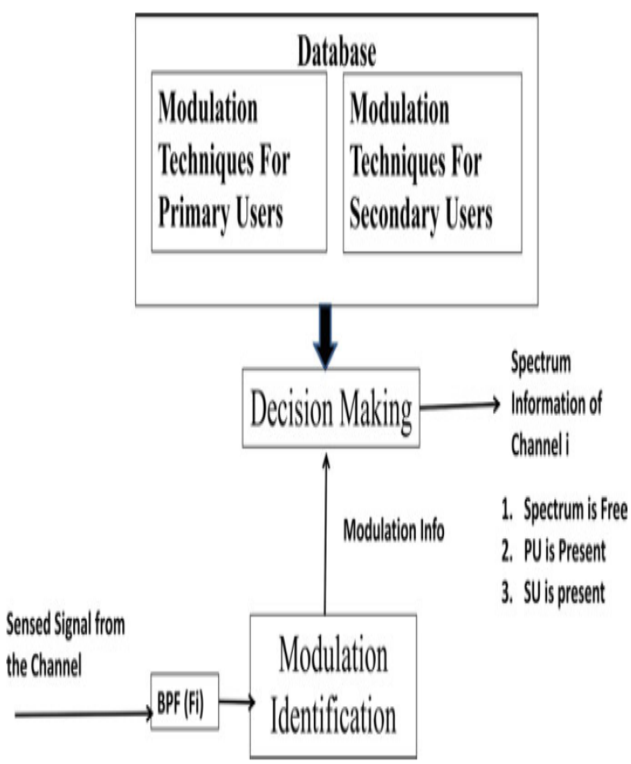

Fig. 1: Proposed block diagram for the cognitive radio network sensing.

IV. Experimental Result Analysis

With unprecedented growth in wireless data services, the demands for power are constantly increasing, leading to a battery depletion problem for wireless nodes/devices. Energy harvesting provides us with many promising advantages and unique features for future wireless communications that cannot be offered by conventional battery or grid power operated communications, including self-sustainable capability, reduction of carbon footprint, truly wireless nodes without requiring battery replacement and tethering to electricity grids, easy and fast deployment in any toxic, hostile or inaccessible environments, etc.

Fig. 2: This figure shows that our code experimental environment window.

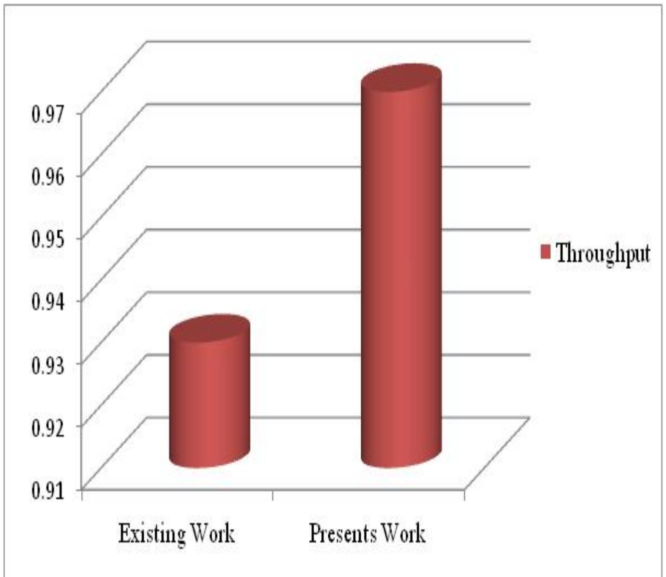

Fig. 3: This figure shows that experimental window of parameters i.e. throughput using existing and present work, and our present work gives better results than the existing work.

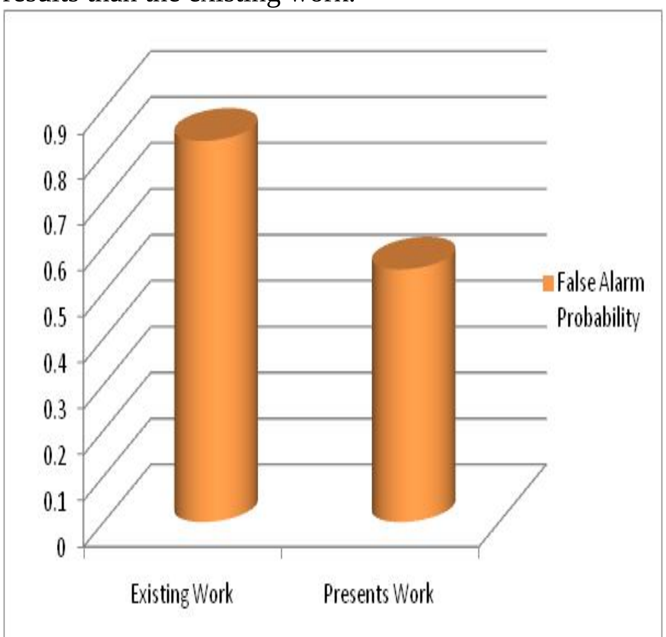

Fig. 4: This figure shows that experimental window of parameters i.e. false alarm probability using existing and present work, and our present work gives better results than the existing work.

V. Conclusion

To fulfill ever-increasing demands for wireless services and applications, cognitive radio (CR) technology has been emerged to lighten severe shortage of spectrum resources. CR technology allows the secondary users (SUs) to access the spectrum licensed to the primary users (PUs), based on the premise that the quality of service (QoS) requirement of the PUs must be guaranteed. Radio-frequency (RF) energy-harvesting technology is a good candidate solution for charging the low-power wireless devices, which can conquer the uncontrollability and intermittency of wireless devices powered by the renewable energy sources, such as wind, solar and vibrational energy. In this paper we present the energy harvesting mechanism with cognitive radio network experimental result analysis on the basis of performance parameters, and our present work gives better results than the existing work. We find that the present work scheme could improve the performance parameters value effectively.

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