Hunger 마케팅과 블록체인을 이용한 무선 스펙트럼 관리 기술

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Hunger marketing and Blockchain Technology: Applications in Wireless Spectrum Management

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Abstract

Due to the ever-increasing demand by bandwidth-hungry mobile applications and the prevalent growth in wireless communication, effective spectrum management continues to constitute an important issue. So many spectrum management techniques have been employed in different areas including broadband satellite systems, cognitive acoustic networks, railway cognitive radio networks, and smart grid network environments. Spectrum management mechanisms have evolved to meet the different requirements of increasing spectrum use efficiency. In this paper, we discuss two state of the art approaches for spectrum management: Hunger marketing and Blockchain technology. We summarize the pros and cons of these technologies and their application in spectrum management.

Ⅰ. Introduction

A "spectrum"can be defined as a conceptual tool that is used to organize and map a set of physical phenomena. It can also be defined as a form of electric and magnetic fields that produce electromagnetic waves that move through space at different frequencies [1],[2]. As stated by *D. N. Hatfield*, spectrum management can be construed as all activities essential to regulating the use of the radio spectrum; this includes the structure and processes for allocating, allotting, assigning, and licensing the scarce resource, and also enforcing the associated rules and regulations. Owing to this definition, spectrum management can be seen as a broad and complex topic [3],[4]. With the continuous development of modern communication, the ever-increasing demand for bandwidth by mobile application users and the ever-growing new applications in wireless communication, spectrum management has come to be a major cause for concern. It is no doubt that the radio spectrum is a key resource for all wireless communication technologies that need to be effectively managed to bolster the wireless communication industry and provide many services and applications with good Quality of Service (QoS). We currently live in an era of emerging wireless technologies, where everything is connected wirelessly with heavy data traffic. As a result of this rapid growth in the wireless sector, the demand for extra spectrum is snowballing rapidly [5].

In 1990 there were about 12 million mobile subscriptions worldwide with no data services. By 2015, the total number of mobile subscriptions exceeded 7.6 billion (GSMA Mobile Economy 2016) with the amount of data on networks reaching 1,577 exabytes per month by the end of 2015 [6]. Wireless technology continues to transform the society, with over six billion persons communicating over cellular networks and over a billion using WiFi. Sadly, it is just a limited section of the total electromagnetic spectrum that supports radio communication, thereby making it necessary to use this treasured resource in a very productive way. Greater capacity can be delivered by the same amount of spectrum, once a more efficient technology is applied. This could be achieved by either delivering more bits per second of capacity to every user or by extending the services to more users. Furthermore, armed with the knowledge of how efficiently different applications use spectrum, policy makers are better equipped to wisely allocate spectrum and make better decisions pertaining to the effectiveness of spectrum for mobile broadband or television broadcast in the society [7].

Radio spectrum is not only a key enabler of technology, it is also an economic growth engine, as stated in the 2012 U.S. President's Council of Advisors on Science and Technology (PCAST) report, "*Realizing the full potential of government-held spectrum to spur economic growth*" [8].

A large number of spectrum management techniques have been employed in different areas including broadband satellite systems [9], cognitive acoustic network [10], railway cognitive radio network [11], and smart grid network environments [12]. Some authors have even discussed artificial intelligence techniques applied in spectrum management [13], such as reinforcement learning [14] and unsupervised machine learning [15]. These various techniques applied increased by leaps and bounds as research progresses.

In this paper, we review two novel approaches that have been implemented in tackling the spectrum management problem: Hunger marketing and Blockchain technology. We discuss their application in spectrum management, and the benefits and limitations of these technologies.

Ⅱ. Spectrum Management Techniques

1. Hunger Marketing

Hunger marketing may simply be termed a marketing technique in which the service provider actively limits consumer supply in order to achieve the trend of excess demand [16]. This psychological marketing strategy relies on human emotions, making them hunger for things that other people also want. Researchers advocate the use of hunger marketing strategy in satellite spectrum management in order to address unpredictable user demands [9]. As illustrated in Figure 1, the system maintains a certain spectrum supply shortage when implementing hunger marketing, thus stimulating users' ability to schedule and commit their bandwidth requirements in advance, making their actions more consistent and benefiting satellite systems [9].

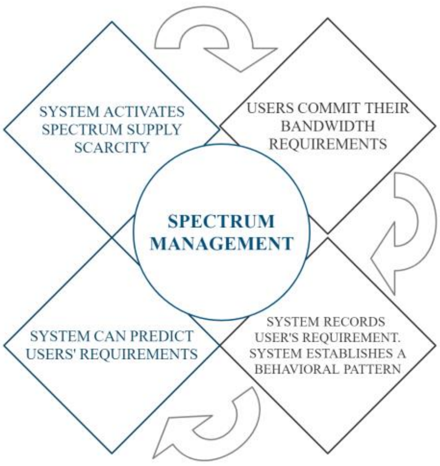

Figure 1: Illustration of Hunger marketing in spectrum management.

A two-stage dynamic game model is used in their proposal to represent the response between the interference pricing of the satellite system and satellite user's power control. They consider a multibeam satellite system which stays in geostationary tracks and adopts spectrum reuse techniques to enhance spectrum efficiency. The proposed satellite spectrum scheme is expected to be implemented in a scenario where satellite users need to purchase bands from satellite systems, and the satellite band resource is expected to be fairly adequate [9].

The proposed scheme, however, makes the following assumptions:

i) Satellite user' spectrum demand is continuous and stochastic,
ii) The number of satellite bands available is relatively adequate,
iii) Spectrum shortage is allowed until the settled maximal threshold is met,
iv) Periodic checking on spectrum dealing will be carried out by satellite systems.

The aim while formulating the spectrum management of the satellite is to analyze every cost of satellite systems and achieve an optimal spectral level in spectrum pool on the basis of the satellite user's stochastic demand.

The major benefit of hunger marketing in spectrum management is the increased predictability of users' behavior and eventually improved spectrum management.

2. Blockchains

Blockchains can be described as distributed databases that can be securely and iteratively updated [17]. Even though the concept has been in use since the early 1990s [18], it is only recently that applications employing blockchains been developed, to enable secure, private financial transactions and, as a particular application, as Bitcoin, making it a well-known technology. This technology is gradually being investigated for application in various aspects of wireless communication including efficient spectrum management. To better illustrate how blockchains work, let us assume that *Alice* wants a service from *Bob* in exchange for virtual currency. After they have agreed on the specifics of the transaction, the virtual wallet of *Alice* will initiate the change in the blockchain. This will result in a decrease in the virtual currency in *Alice*'s virtual wallet and an increase in *Bob*'s virtual wallet. To verify this, the other users will check if *Alice*'s virtual wallet has enough funds. Then after verification, miners will start to create a new block to be added to the chain. This leads to an updated chain [19]. The hash value of each transaction that occurred during a specific interval must be added to a Merkle tree to update the blockchain. This combined hash value, with the hash value of the header of the previous block and a timestamp, make up the header of the new block. The header then becomes part of a puzzle that can only be solved by trial-and-error. A miner who finds the answer earlier is awarded virtual currency and the new blockchain is formed [20].

In their paper, *Khashayar,* et. al. propose the use of blockchain technology to improve the medium access protocol and security of cognitive radios (CRs) desiring access to unused licensed spectrum [19]. They take advantage of the open-source nature of blockchain to propose a secure distributed medium access protocol for CRs to lease and access available wireless channels. In their scheme, every spectrum lease transaction is verified and cleared, then stored within a block. The new block then gets linked to the previous block, thereby forming a chain. Each block records the transactions of thousands of users in a way that records cannot be altered by a malicious user or users. The authors employ four main features of blockchains:

i. Distributed: Blockchains have a distributed database which makes the system robust against hacks. They propose a distributed medium access protocol that is open to any secondary user.
ii. Secure: The distributed database is encrypted via a two-key system.
iii. Public: This implies that there is no central authority that validates or records the data which yields a very transparent system with no loss of security hence the protocol has no central authority.
iv. Permissionless: There is no central authority, hence applications can be added to the entire system without seeking the approval of other users.

The authors propose a virtual currency they term 'Specoins', which is used both in transactions and as a reward for mining to update the blockchain. These Specoins can equally be used by secondary users to lease available spectrum owned by a primary user. The primary user signals the beginning of the auction to the other parties. The winning bidders use Specoins to buy that spectrum. Secondary users can earn Specoins by making the blockchain or through direct exchange. All transactions are recorded in the blockchain and updated by miners. This blockchain is then used to validate any transactions.

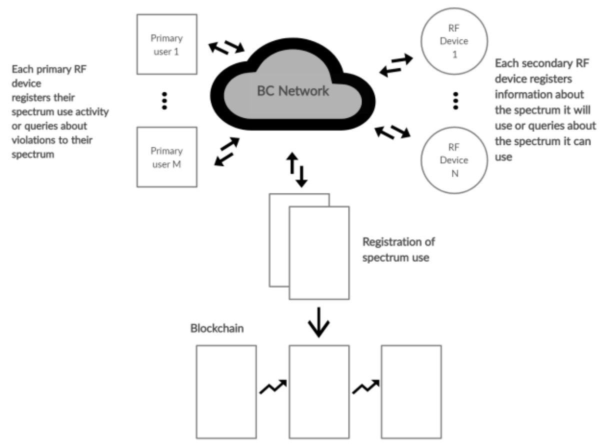

Figure 2: Registration of spectrum use in a secondary non-cooperative environment using Blockchain [21].

Martin et al also explore the potential application of blockchain technology to four major categories of spectrum sharing; primary cooperative sharing, secondary cooperative sharing, secondary non-cooperative sharing, primary non-cooperative sharing [21], and like Khashayar et al, they leverage the features of blockchain. Technically, a distributed ledger is implemented through blockchain technology [22]. Blockchain ledgers are replicated among many nodes, making them extremely valuable even if certain nodes are inaccessible. The first step to take in accessing the usefulness of blockchain is to ask whether the characteristics are relevant for the application at hand. Spectrum sharing systems such as TV White spaces (TVWS) and the Citizens Band Radio Service (CBRS) use management mechanisms using databases. Since blockchains are a form of database, it is worth exploring whether they could be used to improve the efficiency of the different forms of spectrum sharing. Access rights and usage information can be stored on a distributed ledger and managed using smart contracts. In contrast to centralized databases, distributed ledgers offer advantages for tracking property rights and assets which could make them effective tools for spectrum management [21]. Other foreseen benefits of applying blockchains in spectrum management include:

i. An increased speed in the assessment of the usable spectrum resources within a given area and registering spectrum use without the processing delay of a regulator's authorization [21]
ii. The information in the distributed ledger can be used by regulators to evaluate spectrum access performance, measure spectrum usage fees and implement spectrum access regimes [21].

Every technological revolution suffers from treacherous passes. The same goes for the blockchain technology. In reality, there are two major limitations that could make it inappropriate for application in spectrum management.

i. Tendency of errors: since a blockchain is used as a database, it is important that the information it receives is of impeccable quality as like all centralized databases, a blockchain system of records operates in a 'garbage in', 'garbage out' fashion.
ii. The 51 percent attack: This may well be the most serious of all the blockchain limitations as it is an unavoidable security flaw in blockchain and its applications. Suppose more than half of the computers working as nodes in a blockchain network validate something, it is considered to be true. In the same vein, if half of the nodes tell a lie, then the lie will be considered as the truth by the entire blockchain [23].

Ⅲ. Conclusions

Spectrum management is a compelling research area and it is already very essential today. In this paper, we investigated two novel techniques for spectrum management: Hunger management and Blockchain technology. These techniques have been applied in the marketing and financial industries and as we have seen, these are unique unusual techniques that have not been fully explored. Inasmuch as there are obvious benefits in the application of hunger marketing and blockchain-based approaches to spectrum management, it is also fraught with its limitations. However, once these issues and complexities are solved, there will be an unprecedented change in spectrum management. It is therefore important for future researchers to consider exploring ways to tackle the limitations posed by the application of these technologies.

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