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Abstract. The usage of Information Communication Technology (ICT) has become more prevalent in modern society, resulting in the development of intelligent. In particular, the use of unlicensed low-power wireless devices has been rapidly increasing which requires strategic management. The discourse regarding the environment for the usage of radio waves has primarily been focused on improving the economic feasibility and utilization of radio frequency from an administrative standpoint; however, the increase in the usage of low-power unlicensed bandwidth has led to an increase in radio frequency interference, resulting in a need to manage and monitor relevant bandwidths. These advancements have been hindered by glaring limitations in the efficiency of existing management systems of radio waves in addition to restrictions on current technological development processes. This paper will investigate the limitations on existing applications of radio wave technologies and propose efficient countermeasures for radio frequency interference and suggests smart grid systems as the alternative.

Introduction

The central keypoint of the fourth industrial revolution is the convergence of core technologies in the fields of physics, digital technology, and medicine. In particular, technologies such as smart city, autonomous vehicles, cloud computing and IoT are derived from applications of radio spectrum technology in addition to applied sciences in AI and sensor-based data collection [1]. Statistics show that the number of Internet-connected devices will increase from 18.2 billion in 2015, to 18.2 billion by 2020, and as a result, the M2M market will become a $16.5 billion-dollar industry by 2020. This statistic demonstrates that “hyper-connectivity” will become a core foundation for the future data-driven society [2]. Due to the development of short range telecommunication technologies, such as RFID and Bluetooth, excessive usage of short range devices (SRDs) may result radio frequency interference (RFI) and the gradual depletion of radio spectrum resources [3].

The lower-end of the spectrum in frequency allocation is primarily used for everyday wireless devices such as the keyboard, mouse and headsets; however, because only 0.023% of the allocated frequency was used with authentication, this particular section was not actually monitored via spectrum management. However, due to the rapid increase in the demand for wireless devices, examining crucial issues such as the gradual depletion of limited spectrum resources and RFI are becoming more important [4]. While various strategies and programs have been proposed to counteract some of these dilemmas, a majority of these countermeasures have inherent limitations. For instance, a stationary system for spectrum monitoring is restricted by the fact that it cannot observe its blind spots during its monitoring processes [5]. This stationary system is cost-inefficient due to its high expenses in the installation of large stationary equipment. Therefore, as the widespread use of new spectrum services increases, resulting in a subsequent increase in the socio-economic value of spectrum resources as well as frequent occurrences of RFI, it will become necessary to systematically manage the limited resources in the radio spectrum.
Spectrum Management System for Short Range Devices

Definition and Utilization of SRDs

Generally, SRDs refer to short-range unlicensed wireless devices that are used in daily life, such as Wi-Fi routers and RFID devices [6]. SRDs feature an output of less than 1W and are exempt from typical RFI guidelines for operational purposes. According to a ITU (2014) research report, the guidelines for SRD frequency and technology standards for international spectrum management recommending not to excessively regulate SRDs were proposed [7]. In the United States, operations in the ISM band are unlicensed in order to systematically manage the usage of SRDs, via designating spectrum allocated to safety services such as wireless positioning and remote medical services, while taking their functionality characteristics into account [8]. ISM (Industrial, Scientific and Medical) devices refer to equipment designed to utilize radio wave energy for industrial, scientific, medical and household uses with the exception of applications in the telecommunication sector.

According to a UK Ofcom research report (2011), the UK is currently expanding the spectrum range of SRDs through the research of spectrum sharing such as studies on power levels to expand existing 10GHz to 100GHz for underlay sharing and inspections of SRDs using Cognitive Radio functionalities in the DTV band [9]. Underlay, in addition to UWB, has a low power output and does not interfere with shared services, while overlay, similar to CR, increases the output of radio waves when nearby spectrum is not being used by other users.

In Korea, as mobile communication services are expanded, radio spectrum is allocated to support various SRD services [10]. Short range spectrum is utilized in the field of wireless LAN and PLC (Programmable Logic Controller) by digital code responder and RFID tag manufacturers. Domestic SRD spectrum is continuously distributed for sensing, radar and medical. To cope with new technologies and services, the guidelines for unlicensed wireless devices was changed in 2005.

Developments in Spectrum Monitoring Systems

Definition

Spectrum monitoring is the monitoring of radio waves by surveillance agencies for the purposes of efficient management of limited spectrum resources and the establishment and administration of spectrum usage [11]. There are four major classifications of spectrum monitoring: illegal spectrum monitoring, radio quality monitoring, radio station operations inspection and mobile radio wave surveillance. Illegal spectrum monitoring involves an automated searching of the 20MHz-2GHz spectrum bandwidth within the frequency surveillance network to track illegal radio waves and illegal radio stations. Radio quality monitoring is the measurement of spectrum tolerance, occupied bandwidth and spurious emission intensity of radio waves emitted from a radio station. Radio station operations inspection is an investigation confirming whether a radio station is operating in compliance with relevant spectrum regulations and with required authorizations. Mobile spectrum surveillance is an inspection process conducted in areas of disorganized radio wave usage requiring stationary monitoring, generally involving the administration of operation surveillance, quality surveillance, illegal radio wave inspection in the 10KHz-40GHz frequency band.

Spectrum Monitoring Systems in Leading Countries

Japan’s spectrum monitoring is currently operating across 11 regional telecommunication supervisory stations focusing on radio operations surveillance and illegal radio station monitoring rather than radio quality surveillance (10%) [12]. Throughout the duration of 1993-2002, the DEURAS-D, M, R, and H facilities, the latest technology in spectrum monitoring systems, were constructed and operated funded by spectrum usage fees. The primary purpose of these systems was to efficiently search for noncompliant and illegal radio stations. The DEURAS-D sensor station developed in 1995 was built using state-of-the-art technology; additionally, the collected spectrum usage fees were invested into the maintenance of spectrum monitoring systems, the construction of
an integrated radio station control system, and the research on the utilization of unused spectrum bandwidth.

In the United States, the NTIA and the Federal Communications Commission (FCC) of the US Congress are currently cooperating towards the planning and implementation of spectrum control plans [13]. Spectrum monitoring and survey work are being conducted in order to resolve complaints from the public sector in cases of spectrum interference. Currently there are 25 field offices throughout the United States that consist of 6 stationary monitoring systems and 76 mobile monitoring systems for the inspection and measurement of mobile radio stations and unauthorized operations detection. For the purposes of spectrum management, spectrum allocation, and permitting bandwidth usage, automated systems such as RSMS, MSAM, and Spectrum21 are currently being utilized.

Changes in South Korea’s Spectrum Monitoring

South Korea’s spectrum monitoring system is currently in the process of introducing a network system that adapts to the modern environment where usage of spectrum in everyday life is continuously increasing [13]. In the first generation of spectrum monitoring systems, the monitoring process was traditionally carried out primarily with regards to spectrum quality, illegal radio wave inspection, high speed spectrum measurement, radio reception environment research, and radio wave coverage measurements. However, because illegal radio stations and spectrum interferences are continuously generated within the area of spectrum monitoring where stationary radio wave measurements systems are not installed, it is crucial to formulate countermeasures such as the operation of a semi-stationary spectrum measurement system. A semi-stationary type of spectrum measurement system performs radio wave monitoring work such as illegal radio wave inspection, spurious measurements, and radio noise measurement; however, in order to develop a measurement standard for spectrum sharing, radio wave quality measurement, and illegal wave inspection, an advanced surveillance system is currently being operated.

The third-generation spectrum management system utilizes a stationary-type form factor that combines spectrum measurement and direction detection functionalities being developed with the goal of providing a solution to the problems of spectrum interference in the license exempted bandwidth and large-scale data management. In the case of existing stationary spectrum monitoring systems, there is a limited number of visible areas in stationary direction detection facilities in the Seoul metropolitan area, resulting in difficulties in securing radio station related buildings [5]. Additionally, since there is a limited number of stationary direction detection facilities in urban areas except the metropolitan areas, it is difficulty to accurately locating sources of radio signals. Therefore, advanced spectrum monitoring technology has become necessary in densely populated cities.

Specifications for Monitoring and Strategy for Smart Grid System Use

System Operations

Due to the low power, broadband and spatial characteristics of the spectrum utilization environment, it is important to establish a miniaturized and decentralized system for spectrum monitoring [14]. Regarding Korea’s cases of the spatially dispersed network utilized by current Base Transceiver Stations (BTS), it is important to consider the advantages of mobile communication BTS when formulating spectrum monitoring based on spatially dispersed networks and a software solution for spectrum and network monitoring. In the case of Decodio, it has the capacity to handle the collection and analysis of distributed signals and the subsequent analysis of data content. However, there are limitations to standardized monitoring technologies based on spatially based services that arise from the increase in usage of SRDs. Therefore, cooperative monitoring based on sensing technology, which uses group control of sensors distributed within an area, is a sufficient countermeasure. Various heterogeneous data integration technologies and multidimensional analysis technology based on GIS networks need to be developed in addition to
data processing and information analysis of regional and spatial cluster units in response to network-based spectrum monitoring technology.

**Smart Grid System**

Smart Grid (SG) is a term used for advanced delivery systems utility services (electricity, gas and water) from sources of generation and production to consumption points, and includes all the related management and back office systems, together with integrated modern digital information technologies. Ultimately, the improved reliability, security, and efficiency of the SG distribution infrastructure is expected to result in lower costs for providing utility services to the user. SG will provide the information overlay and control infrastructure, creating an integrated communication and sensing network [15]. The spectrum management functionalities, such as spectrum sensing, spectrum decision, spectrum sharing, and spectrum mobility, are vital for the cognitive cycle, which is the required task to determine the accurate communication parameters of SG [16]. Spectrum sensing is the process of becoming aware of the available spectrum bands and the presence of the PUs and detection of the spectrum holes [17]. Spectrum sensing operation is an extensive power-consuming approach and poses great challenges to provide cost-effective communications in large-scale SG deployments [18]. Spectrum sharing process focuses on the selection of the best channel and power allocation and some of the functionalities resemble the core functionalities of medium access control (MAC) protocols, which add redundant challenges, e.g., time synchronization [17]. Furthermore, accurate time measurements and time synchronization may be required for some SG applications, e.g., phasor measurement monitoring applications and equipment fault diagnostics [18].

The environment of the SG requires infrastructure of the network which incurs a significant cost. Since Korea has an environment that satisfies these requirements, Korea has a significant advantage in the introduction of SG. Statistics show that Korea has a significantly high quality of LTE mobile network infrastructure [19]. Wireless Internet broadband LTE recorded download speeds of 120.09Mbps and upload speeds of 41.93Mbps in downtown Seoul. This result is twice the speed of those measured in Toronto (69.56Mbps, 26.85Mbps). Other countries’ usage environments of mobile communication services have improved compared to the past in terms of coverage and speed. However, subway tunnels in major cities such as New York, London and Paris are unable to gain access to wireless services and suffer from poor quality. Also, there are some instances where it is difficult to carry out quality inspections. In Korea, by utilizing the advanced infrastructure of high speed Internet and telecommunications, the nation can expect to minimize the construction and maintenance costs by utilizing the existing infrastructure [20].

**Conclusion**

As the usage of LPWA increases, the consequent usage environment of radio spectrum becomes more complex. The economic limitations in spectrum management and blind zones inherent in existing stationary systems and eventually demands for active radio wave management and
measurement systems utilizing new technologies. Because mobile communication networks and Base Transceiver Stations are distributed evenly in the domestic environment, this paper examined the current domestic state of radio wave technology and management in addition to the prospect of introducing SG systems in radio wave surveillance operations. It was confirmed that the download speed of domestic carriers were three to four times faster than their counterparts in Tokyo, Japan and in New York, USA.

The application of the SG system has the potential to collect and utilize data with regards to radio wave management; therefore, it is necessary to develop applications of new radio wave technology [7]. Real-time analysis of radio environment information measured from heterogeneous systems utilizing Big Data is expected to result in active radio wave surveillance that can predict and adapt to malicious radio interference. However, it is necessary to further develop this study through empirical analysis and review through these aspects.

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Reference


