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COMPARISON OF TVWS STANDARDS

POREĐENJE TV STANDARDA BELOG PROSTORA

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Abstract:
There is an increased interest in deploying wireless broadband access in unlicensed spectrum. Several standardised technologies are considered as potential solutions that could be used in most attractive white space bands - VHF and UHF analogue television bands, but the two most interesting are IEEE 802.22 and 802.11af. Option to choose solution makes pressure on system designers to select most appropriate technology to the application of interest to deploy, so it is necessary to have clear understanding of possibilities of those technologies and to make a list of criteria that the technologies could be compared by. The most attractive TV white space (TVWS) technologies have been compared in this paper regarding technology complexity, throughput, propagation and potential to deploy and future development. It is concluded that multiple standards and technologies are making confusion in the market while 802.11af might have most promising future as being based on long lasting Wi-Fi technology. IEEE 802.11af will have better throughput than 802.22, while propagation effects will be the same for both technologies. Due to the higher transmission power, IEEE 802.22 will provide wider coverage areas. Because of that, IEEE 802.22 is seen as good solution for rural broadband and small office – home office (SOHO) environment in rural areas.

Key words:
TV white space, broadband access, wireless networks.

Apstrakt:
Postoji povećano interesovanje za ostvarivanjem bežičnog širokopojasnog pristupa mrežama i uslugama u nelicenciranom prostoru. Nekoliko standardizovanih tehnologija smatraju se mogućim rešenjima koja bi se koristila u najaktraktivnijim pojasevima belog prostora – visoko i ultravisoko frekventnim (VHF i UHF) analognim televizijskim pojasevima; dve tehnologije se nameću kao najzanimljivije IEEE 802.22 i 802.11af. Neophodnost da se izabere rešenje stavlja pritisak na projektante sistema da odaberu najpodobniju tehnologiju i stoga je neophodno da postoji ne samo jasno razumevanje mogućnosti postojećih tehnologija već i lista kriterijuma na osnovu kojih bi se date tehnologije upoređivale. Ovaj rad poredi najinteresantnije TVWS tehnologije u pogledu kompleksnosti, protoka, propagacije i potencijala za korišćenje i dalji razvoj. Zaključujemo da mnoštvo standarda i tehnologija pravi zabunu na tržištu; 802.11af možda ima budućnost koja najviše obećava budući da je zasnovan na Wi-Fi tehnologiji koja je već dugo u upotrebi. IEEE 802.11af će imati bolji protok od 802.22, dok će kod obe tehnologije efekti propagacije biti isti. Zbog svoje veće prenosne moći, IEEE 802.22 će obezbediti veću oblast pokrivenosti. Zbog toga se IEEE 802.22 smatra dobrim rešenjem za ruralne široke pojaseve i SOHO okruženja u ruralnim oblastima.

Ključne reči:
beli proctor, širokopojasni pristup, bežične mreže.

1. INTRODUCTION

There is an increasing interest in providing wireless broadband access in unlicensed spectrum. Recent efforts of 3GPP (Flore/3GPP, 2014) and a number of national regulators to allow LTE operation in unlicensed spectrum are only making this interest even higher. Very high and ultra high frequency bands, intended for analog TV broadcasting, are seen as most interesting candidate bands for deploying broadband access in unlicensed spectrum. There are several standards that are possible to deploy but IEEE 802.22 and IEEE 802.11af are the most promising ones. Having more than one candidate technology for a deployment requires network designers to evaluate all of them and to make objective criteria for comparing their performance.

Both IEEE 802.22 and IEEE 802.11af are intended for providing low cost broadband services to mostly underserved population. Because of that, scale of economy and price of a base station (BS) and customer premises equipment (CPE) are of great importance for successful technology deployment. Because of that, complexity of devices and overall network is one of important parameters to be analysed.

IEEE 802.22 is seen as wireless regional area network technology (WRAN) while IEEE 802.11af is treated as local wireless area network (WLAN). Because of that, their coexistence and complementary deployment should be investigated. Their radio coverage possibilities are interesting to analyse in order to estimate necessary resources and to deploy and achievable area of coverage. Together with the radio coverage, it is necessary to investigate potential throughput that could be achieved in order to determine services that could be deployed and to evaluate spectral efficiency of the selected technology.

Finally, deployed networks are intended to provide end users with services for the next decade. Because of that it is important to estimate future of each technology, their potential for further development and suitability for a number of potential future services.

The paper is organised as follows. After introduction, in Heading II description of IEEE 802.22 and IEEE 802.11af standards is given. In Heading III potential deployment scenarios are presented and are compared based on proposed criteria that are defined, especially regarding possible deployment scenarios. Heading IV gives concluding remarks.

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2. TVWS STANDARDS OVERVIEW

Two most interesting standards for technologies that could be deployed in VHF and UHF frequency bands intended for analog TV transmission are both developed by Institute of Electrical and Electronics Engineers (IEEE).

IEEE 802.22 could be described as the successor of IEEE 82.16, known as Worldwide Interoperability for Microwave Access (WiMAX) standard. As such, IEEE 802.22 defines OFDM, TDMA based system with frame structured media access control (MAC) layer. The standard (IEEE 802.22-2011, 2011) defines several quality of service (QoS) classes that are providing parameters for defining from best effort over non-real time and real time class of services to emulated TDM services. Available service classes allow planners to combine different services and to optimize available throughput. Maximum transmission power of 4W, both for BS and CPE, is a strong advocate that could be used in a coverage limited scenario of network deployments, which is most suitable to rural broadband deployments.

Available channel bandwidths are 6, 7 and 8MHz in frequency range from 56MHz to 810MHz. Practical deployments are currently performed in UHF frequency band while VHF has not been used so far.

IEEE 802.22 selects available TV channels based on query in spectrum management database using spectrum manager function. Spectrum sensing automata and spectrum sensing function are implemented both in BS and CPE and serve for less sophisticated channel selection process (IEEE 802.22-2011, 2011; IEEE 802.22a-2014, 2014). IEEE 802.22 standard defines implementation of higher order, spectrum efficient modulations, like 64 and 256 quadrature amplitude modulation (64-QAM), thus providing practical throughputs that are on the order of a maximum of 20Mb/s on a physical layer in 8MHz wide TV channel. Also, IEEE 802.22 devices are characterized by high sensitivity that goes down to -97dBm for BPSK with ½ coding ratio (Feng *et al*., 2013). Available throughput could be divided between downlink and uplink as per needed going from almost symmetric (DL:UL=14:12) to very asymmetric throughputs. Theoretical values of 23Mb/s for 64-QAM with coding ratio of 5/6 (IEEE 802.22-2011, 2011) are at the moment more theoretical than practical value. Also, standard defines TDD duplexing mode but in practice it is possible to deploy IEEE 802.22 system in FDD or in TDD mode, thus providing additional flexibility that could be used in the process of network planning. Discontinuous channels could be bundled in order o provide higher data rates that could provide throughputs which are reaching 100Mb/s on a physical (PHY) layer. Although standard defines mash network deployment, IEEE 802.22 is not suitable for such deployment and it is intended to be used for point-to-point and point-to-multipoint deployments.

IEEE 802.11af (IEEE 802.11af-2013, 2013) is Carrier Sense Multiple Access (CSMA) based solution that has strong background in the complete 802 family of IEEE standards. The existing background allows IEEE 802.11af to base QoS features on other 802 standards like IEEE 802.11e (802.11e-2005, 2005), IEEE 802.1p (IEEE 802.1p-2005, 2005) and IEEE 802.11Q (IEEE 802.1Q-2005, 2005) which is convenient for interconnection of different systems and easier QoS classes matching. Small transmission power of 100mW is limiting the coverage range, but it also provides option for deployment in capacity limited environment. In order to support transmission with a defined transmission power, sensitivity of -64dBm is required (Feng *et al*., 2013). Available throughputs in practical systems are close to 23Mb/s on a physical layer that could be used completely by BS or CPE in an OFDM, TDD based system. Theoretical values of almost 36Mb/s for 256-QAM with 5/6 coding ratio in 8MHz wide radio channel (IEEE 802.11af-2013, 2013) is currently not available in a commercial solutions. Flexibility of IEEE 802.11af is suitable for point-to-point, point-to-multipoint and mash deployments.

IEEE 802.11af uses spectrum sensing automata and spectrum sensing function in order to estimate spectrum occupancy and TV channels availability for transmission. Unfortunately, process is not the same thus geographically collocated IEEE 802.22 and IEEE 802.11af networks will cause severe interference to each other (Feng *et al*., 2013; Kang *et al*., 2011) and their coexistence is subject of further research.

It will be necessary to perform further research in order to define mechanism for the same and different TVWS technologies coexistence in the same frequencies in the same area (Ishizu *et al*, 2014; Gardellin *et al*, 2013; IEEE 802.22.2-2012, 2012). Certain efforts have been made in IEEE 802.19 work group (IEEE 802.19.1-2014, 2014) but these recommendations still need to be improved and implemented in commercial equipment.

Also, available commercial solutions are not fully complied with IEEE 802.22 or IEEE 802.11af which makes them proprietary and mutually not compatible. This limits potential deployments at the moment and the future work of standardization body and industry associations will be to organize interoperability tests for different manufacturers' equipment in order to achieve interoperability.

3. TVWS SYSTEMS DEPLOYMENT POSSIBILITIES

There are several deployment scenarios for TVWS systems that are seen as most favorable (Vujic *et al*., 2014; Sum *et al*., 2011, IEEE 802.22.2-2012, 2012):

- Systems providing broadband services to rural areas;
- Backhauling systems in remote areas;
- Deployments in critical situations, *e.g.* after natural disasters;
- Geolocation services and distribution of local information;
- Specific deployments like SCADA, industrial networking (machine-to-machine), smart grid networks *etc.*

TVWS systems are mostly seen as systems capable of providing rural broadband services to underserved population. This is the most common TVWS deployment scenario. In the case of such deployment, it is necessary to determine users' density and expected services. Obviously, in areas with low user density and lower data rates, higher transmission powers are needed. On the other side, in capacity limited environment, lower transmission power, lower antenna heights and directional antennae are required to better utilize existing spectrum.

IEEE 802.22 with 4W of maximum transmission power is better solution for coverage limited networks. Also this is a solution that could provide quality of service (QoS) to end users and it can cope with additional rise in number of users by adding additional channels without having problems associated with CSMA. On the other hand, lower transmitted power and native support for Ethernet make IEEE 802.11af a good candidate for capacity limited environment, such as wireless local area networks (WLAN). Although CSMA is not flexible enough to support large number of concurrent users, combination with IEEE 802.11g/n/ac in 2.4GHz and 5GHz frequency bands could be a solution. A combination of IEEE802.22 and IEEE 802.11af is also possible solution. Such solution would assume IEEE 802.22 to be used for regional coverage, while IEEE 802.11af would serve for local (hot spot) coverage.

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Both standards are intended to be deployed in the same frequency band or at least in UHF frequency band that is seen as most attractive. Because of that, it could be said that both technologies would provide same coverage areas for the same transmitted power. IEEE 802.11af, as technology with shorter guard interval (2.25μs or 4.5μs) (802.11af-2013, 2013) is more seen to provide coverage to shorter distances comparing to IEEE 802.22 (with guard interval equal to at least 7μs) (IEEE 802.22-2011, 2011) in real life environment. Also, IEEE 802.22 is characterized by longer transmit-to receive turnaround gap of 210μs (IEEE 802.22a-2014, 2014) and receive-to transmit turnaround gap time with minimum value of 81.8μs (IEEE 802.22a-2014) allowing much longer communication links comparing to IEEE 802.11af.

Although theoretical throughputs with channel bundling are very high (*e.g.* over 300Mb/s in the case of IEEE 802.11af), it will be hard in real life deployments to see such data rates as they require a number of radio channels, so technologies should be compared on a single channel throughput or at most 2 bundled channels. Practical deployments show that IEEE 802.11af is with smaller overhead and with higher data rate comparing to IEEE 802.22.

Throughput parameter is of great importance in situations where backhauling service in needed. TVWS network could be used as backhauling solution for security cameras or isolated areas and venues monitoring. Since such service requires transmission of video signal, throughput and latency are very important. IEEE 802.11af with smaller latency and higher throughput at physical and Internet protocol (IP) sublayer declares itself as a better candidate for such deployments.

Economy of scale is most important non-technical parameter and a key for successful commercial deployment. IEEE 802.22 is seen as WiMAX successor. Number of deployed units based on WiMAX is relatively small comparing to mobile phones and Wi-Fi enabled devices, thus making equipment (especially CPEs) expensive. Also, most interesting deployment scenario for IEEE 802.22 is rural broadband in regional networks which are, by default, characterized by the small number of users. Because of that, IEEE 802.22 might have similar market presence as it was with WiMAX networks in the previous years. On the other side, IEEE 802.11af devices could be incorporated in a number of Wi-Fi enabled devices by implementing multiband chipsets (*e.g.* TVWS, 2.4GHz and 5GHz) which would boost number of produced units and lower the price of it.

Technical complexity of the equipment could be estimated as similar. Most challenging requirements at the moment are effective design of tight spectrum masks for TVWS devices and flexible change to the radio channel selected for the transmission.

4. CONCLUSION

New telecommunication services require higher data rates. Also, there are still regions worldwide that could be described as underserved regarding available telecommunication services. In order to achieve economically viable solution that could provide broadband services with low capital and operational expenditure, it is necessary to deploy a new technology that will compile those two opposite requests. IEEE 802.22 and IEEE 802.11af are standards that are most promising for new networks deployed at TVWS. Nevertheless, IEEE 802.11af seems to be in advances as technology that could provide larger throughputs with better scale of economy, while achieving same level of technical complexity as IEEE 802.22. IEEE 802.22 will have lower market share and we expect it to be deployed in specific situations like in natural disasters situation, some machine-to-machine communication and regional networks with large coverage and relatively low data rates densities required per area.

Nevertheless, future of TVWS is not fully confirmed and it is necessary to continue research work in order to provide mechanism for coexistence of heterogeneous networks in TVWS (*e.g.* coexistence of 802.22 and IEEE 802.11af networks). In addition it is necessary to assure national regulators worldwide that deployment of such networks would bring more benefits to society than just selling the spectrum to mobile operators or any other interested party.

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