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LTE-Advanced in White Space—A Complementary Technology

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Overview

Long Term Evolution (LTE), the leading candidate for providing "4G" services, is the next generation mobile network of choice across the globe. Over 100 operators have stated their intention to upgrade their networks to provide LTE service in the next couple years and Infonetics Research estimates there will be 290 million LTE subscribers by 2015. LTE is driven by the ever-growing demand for a variety of data services that require higher data rates.

In an ideal LTE cell (i.e., sufficient backhaul capacity, perfect antenna configuration and radio conditions, user equipment very close to the base station, etc.) the maximum data rates defined in the standards are over 100Mbps for a maximum configurable bandwidth of 20MHz. The promise of low latency and increased data rates is very enticing as the latest and most exciting mobile data services require higher streaming rates and consistent Quality of Service (QoS).

However, higher data rates are not enough; due to the high cost of spectrum, operators tend to opt for frequency plans that operate in smaller bandwidths—thus achieving good coverage while requiring less spectrum. With the cost of spectrum being high, using "white spaces" for LTE may be a good solution. This paper focuses on the potential use of this unused spectrum for LTE, highlighting the advantages and the challenges involved in using white spaces for LTE networks.

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What is TV Band White Space?

The transition of television transmissions from analog to digital resulted in a considerable amount of unused radio spectrum. This unused TV band spectrum, originally allocated to a broadcasting service, is available for unlicensed broadband wireless devices and called "white space." As most of this spectrum is in the lower frequency bands—between 50MHz and 700MHz—this particular spectrum has excellent propagation characteristics that allow signals to reach farther and penetrate walls and other structures. Access to this spectrum could enable more powerful public Internet connections with extended range, fewer dead spots and improved individual speeds as a result of reduced congestion on existing networks.

The usage of any radio spectrum is regulated by national and international bodies and in most cases the rights to broadcast over these frequencies are licensed. In the United States, the Federal Communications Commission (FCC) has recently ruled that unlicensed devices which can guarantee that they will not interfere with assigned broadcasts can use these empty white spaces. These rules would require that white space devices consult a dynamically-updated geo-location database to avoid interference with nearby TV broadcasts or wireless microphone transmissions.

A device intended to use these available channels is known as a "white space device" (WSD). These are designed to detect the presence of existing signals, such as TV stations and other wireless users, and to then avoid the use of these channels.

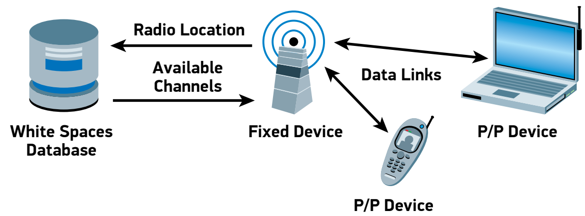

Figure 1. *White Space Network*

White Space Devices

For any device to avail white spaces, it should be capable of either sensing radio conditions or communicating with a geo-stationary database to get the available channel.

WSDs rely on the geo-location and database access mechanism to identify the available television channels consistent with the interference protection requirements. Such protection is provided for authorized and unlicensed services like digital television stations, translator receive operations, fixed broadcast auxiliary service links, unlicensed wireless microphones used by venues of large events and productions/shows, etc. The FCC has defined two types of WSDs: fixed devices and personal and/or portable devices.

The fixed devices have geo-location capability with embedded global positioning system (GPS) capability and are able to communicate with a central database to identify other transmitters in the area operating in TV White Space.

The personal/portable devices can be classified as Mode I or Mode II. Mode I devices do not have geo-location capability and depend on Mode II devices that have geo-location capability and can access the database to obtain a list of available channels.

As per FCC guidelines, fixed devices in the white space spectrum are allowed a power output of up to 4 watts EIRP. Personal/portable devices are restricted to 100 milliwatts EIRP. Because the range at which a TV band's device can cause interference increases as the height of the device's antenna increases, the fixed devices are only allowed to operate at a maximum antenna height limit of 30 meters above ground and a maximum of 76 meters above the average terrain for a tower site. This height limit was intended to balance unlicensed fixed TV band device transmission range with the distance at which those operations could impact licensed services. There are no height restrictions on personal/portable devices as it is not practical to administer an antenna height limit for those devices and the lower power and limited antenna gain of personal/portable devices would generally result in propagation over a shorter range than fixed devices.

Requirements for LTE in White Space

LTE provides a suitable technology to leverage white space and could be deployed in two configurations. The first involves active scanning of the spectrum and deciding on the available channels to use. In this approach the LTE UEs would be sensing the spectrum and sending periodic reports to the eNodeB informing it about what they sense. The eNodeB would then be capable of collating the reports and evaluate whether a change is necessary in the channel used, or if the UE ought to continue transmitting and receiving in the same channel.

The second deployment model is to have the eNodeB communicating with a geo-location database and allocating the available channels to the UEs in its cell. This is favored as there is no additional complexity added at the UE or the eNodeB for dynamic radio sensing and evaluation. Here, the LTE UE acts as a Mode I device and the eNodeB acts as a fixed device and communicates with the geo-location database once every 24 hours (as guided by the FCC).

The goal of the physical layer in such a network is to provide excellent, yet simple, performance. Specifically for LTE to be deployed in white spaces, the PHY layer must be flexible enough to adapt to different conditions and to shift from channel to channel without errors in transmission or losing clients (UEs). This flexibility is also required to dynamically adjust the bandwidth, modulation and coding schemes based on the changing white space conditions. Since the LTE radio is OFDMA-based it is possible to achieve this fast adaptation needed for the eNodeBs and UEs. To be able to access the opportunistic channels, the PHY layer must be capable of considering the dynamic nature of spectrum in case of a white space network.

For this solution, the Medium Access Control (MAC) layer at the eNodeB is required to support scheduling of UEs in dynamic spectrum. The MAC layer at the UE also needs to support reception of grants that are allocated in dynamic spectrum. Additionally, the MAC layer is required to have the knowledge of availability of white spaces for efficient spectrum usage.

Finally, the Radio Resource Control (RRC) and Radio Resource Management (RRM) layers need to be able to support the dynamic configuration of bandwidth based on the availability of white space—as well as include the appropriate algorithms for choosing among various white space spectrum that may be available in its specific location.

LTE Networks in White Space

Due to the dynamic nature of white space, the devices in a white space-based network must be aware of its availability. In order to deploy an LTE network in white space, the LTE UEs and the eNodeB need to act as WSDs and need to be able to schedule and transfer the data in the white space whenever it is available.

To meet the dynamic spectrum/channel allocation nature of a white space network, a method is available in the LTE-Advanced standards known as "Carrier Aggregation." Carrier aggregation allows expansion of effective bandwidth delivered to a user terminal through concurrent utilization of radio resources across multiple carriers. According to the Layer 1 (L1)/PHY specification of LTE-A, carrier aggregation can be for both contiguous and non-contiguous component carriers with each component carrier (CC) limited to a maximum of 110 Resource Blocks. As each TV channel is a minimum of 6MHz and LTE networks can be accommodated within 5MHz, it is possible to configure a UE to aggregate a different number of component carriers of possibly different bandwidths in the uplink (UL) and the downlink (DL). Hence a network can be deployed with Secondary Cells (SCells)—a cell, operating on a secondary frequency, which may be configured once an RRC connection is established and which may be used to provide additional radio resources, *in available white space spectrum* as depicted in Figure 2.

According to the LTE-A MAC Specification, if the UE is configured with one or more SCells (the ones in the white space), the eNodeB may activate and deactivate the configured SCells. This can be done based on the availability of the white space. The Primary Cell (PCell) is always activated. The UE does not monitor the PDCCH of a deactivated SCell and does not receive any downlink assignments or uplink grants associated to a deactivated SCell. The UE does not transmit on UL-SCH on a deactivated SCell. The eNodeB activates and deactivates the SCell(s) by sending the Activation/Deactivation MAC control element. To send this control element, it needs to act as a fixed device and talk to an "on-the-fly updated geo-location database" that provides the availability of the spectrum.

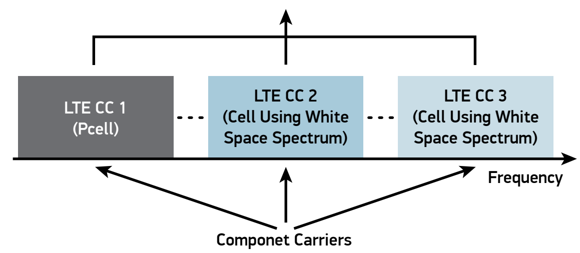

Figure 2. *Cell to Carrier Mapping*

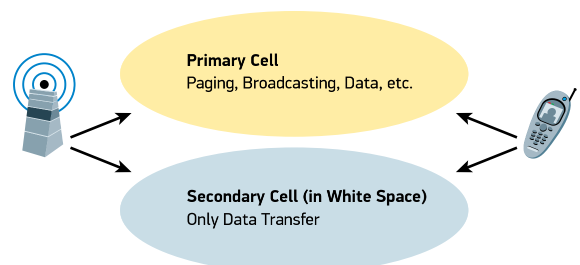

Figure 3. *Secondary Cell (SCell) in White Space*

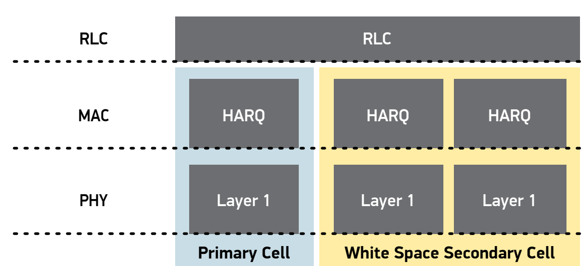

Figure 4. *Additional Entities in Carrier Aggregation*

The transmission blocks (TBs) from different component carries can be aggregated at the MAC for LTE-Advanced systems. In a MAC layer data aggregation scheme, each component carrier (e.g., transmitting power, modulation and coding schemes, and multiple antenna configurations) has its own transmission configuration parameters in the physical layer, as well as an independent hybrid automatic repeat request (HARQ) entity in the MAC layer. Figure 4 is a pictorial representation of this. Hence considering the physical properties of the white space, they can be configured independent of the PCell thereby giving more flexibility to the system.

The UE applies the system information acquisition and change monitoring procedures for the PCell only. For SCells, E-UTRAN provides, to a UE supporting carrier aggregation, all system information relevant for operation in the concerned cell in RRC_CONNECTED via dedicated signaling when adding an SCell. For SCells, change of system information is handled by release and addition of the concerned SCell, which may be done with a single *RRC Connection Reconfiguration* message.

Why is LTE in White Space Attractive?

Operators are increasingly offering unlimited data services to stay competitive and therefore there is growing demand and subsequent strain on cellular networks. The FCC ruling to make TV white space bands available for unlicensed use has opened a new and very promising market to meet this demand for broadband wireless services and products. It is attractive as it is both non-disruptive to existing services and it creates an opportunity for small or regional operators who generally would have a difficult time acquiring adequate licensed spectrum.

Adding to that, white space frequencies include attractive properties such as good non-line-of-sight propagation characteristics as well as low industrial noise and reasonable antenna sizes for fixed and nomadic broadband applications. With regard to good propagation characteristics, the coverage range for white space frequencies is large due to the lower propagation loss as compared to those in the 2.4GHz and 5.8GHz bands. This is particularly attractive in rural areas where subscriber density is low and availability of white space is large due to fewer TV stations. Deploying an LTE-A network in these regions using TV white space may be an option as the low cost of entry is necessary to create the business case to deliver services in a less populated area.

Additionally, white space has a number of very attractive RF propagation characteristics that hold out promise for wide-area wireless broadband applications. In particular, the much lower frequencies occupied by TV spectrum (e.g., under 700MHz, compared to Wi-Fi operating at 2.4GHz or above 5GHz) imply that signals can carry over much longer distances and propagate much better through obstructions such as foliage and building walls. This is expected to translate to a significantly lowered cost-of-coverage, as fewer base stations will be required to establish a wide-area coverage footprint. Since propagation in urban canyons and indoor penetration have been historical challenges to wireless broadband, the opening up of lower frequency spectrum has been greeted with considerable excitement. Thus, LTE deployment in white space promises innovation and growth.

Challenges for LTE in White Space

However, despite the promise of LTE in white space spectrum, there do remain multiple challenges. First off the devices themselves must be more complex. For example, the fixed and Mode II devices must access the geo-location database at least once a day to verify continuing availability of channels. The WSDs must also be equipped with automatic power control to limit operating power to the minimum necessary for successful communication without interference and must incorporate security measures to prevent devices from accessing unapproved databases. They must also ensure that unauthorized users cannot modify the device or control features and that they are capable of obtaining lists of available channels only with authorized database administrators to prevent corruption or unauthorized interception of data.

Also, implications of this spectrum for system capacity need to be explored in depth. As the radius covered by a base station is expanded, the capacity available over the airwaves at that base station is effectively spread out over a larger area, resulting in a lower system capacity per square mile. This trade-off between larger cell sizes and lower cell capacities is illustrated by the industry’s move over time to smaller cells to increase the carrying capacity of cellular networks.

From the viewpoint of wireless system design, the most valuable use of the white space spectrum will be in expanding coverage, rather than expanding network capacity. It offers the possibility of cost-effectively creating a broad-area coverage underlay using TV spectrum, employed in conjunction with higher-frequency shorter-range/higher-capacity unlicensed wireless spectrum. The use of white spaces to expand coverage is thus complementary to the use of higher-frequency unlicensed spectrum to create the higher-capacity dense cells needed by mobile broadband applications and is not a stand-alone solution.

Summary

This paper provided an overview of white space and summarized the rules stated by the FCC for any device to operate in white space spectrum. It talked about making use of the already defined “Carrier Aggregation” feature to deploy an LTE-A network in white space. Undoubtedly, utilizing white space for an LTE-A network will facilitate the provision of high rate streaming services resulting in greater customer satisfaction. This, in turn, will result in more traction for LTE which is already gaining importance as a promising technology for the future.

About Radisys

Radisys (NASDAQ: RSYS) is a leading provider of embedded wireless infrastructure solutions for telecom, aerospace, defense and public safety applications. Radisys’ market-leading ATCA, IP Media Server and COM Express platforms coupled with world-renowned Trillium software, services and market expertise enable customers to bring high-value products and services to market faster with lower investment and risk. Radisys solutions are used in a wide variety of 3G & 4G/LTE mobile network applications including: Radio Access Networks (RAN) solutions from femtocells to picocells and macrocells, wireless core network applications, Deep Packet Inspection (DPI) and policy management; conferencing and media services including voice, video and data, as well as customized mobile network applications that support the aerospace, defense and public safety markets.

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