Architecting a Low Cost Television White Space Network For Developing Regions

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ABSTRACT

There has been a number of Television White Space (TVWS) deployments in developing regions, using equipment designed for the western market. In this paper we assess a solution that addresses three of the limiting factors of existing solutions: high cost, database dependence and high power consumption. We argue that as there is enough TVWS spectrum availability especially in rural areas in developing regions, we do not need to use any geolocation databases nor do we need a tight transmit spectrum mask. We propose a low cost and an energy efficient TVWS network device that uses an embedded linux board equipped with a miniPCI card operating in the TVWS frequencies, for which we test the RF performance and power consumption for comparison to those of a commercial TVWS equipment.

1. INTRODUCTION

Television White Spaces (TVWS) is currently seen as a promising wireless technology to provide efficient and affordable communications using dynamic spectrum sharing. TVWS are vacant channels (or guard bands) between used radio bands that were allocated to avoid interference between adjacent used channels. Several measurement studies carried out on spectrum occupancy have reported that most of the allocated spectrum is currently heavily underutilized [1], [2,[3],[4]. Furthermore, analyzing the recent deployments of TVWS networks in developing countries, we can draw the following conclusions:

1. They are all database driven. While a requirement for cities and densely populated areas, it is not necessary for rural areas where most of the spectrum is available.

2. They all use expensive equipment, making it difficult for the deployments to scale-up.

3. Low power consumption is not considered as a priority.

4. A good spectrum mask is considered very important for deployments in cities in order to prevent interference to incumbent users.

If a TVWS network is to be used for large scale deployments in developing regions, those constraints must be addressed. We propose a low cost and an energy efficient TVWS device that uses an embedded linux board equipped with a miniPCI card operating in the TVWS frequencies, for which we test the RF performance, spectrum mask and power consumption. We then compare these features with those of a commercially available TVWS equipment.

2. PROPOSED TVWS DEVICE

From our previous experiments with the Alix box, a single board computer running Linux, it is clear that it is flexible and powerful enough to fulfill our needs. For the radio card, we selected the TVWS-80 miniPCI from Doodle-Labs. This card works on TVWS frequencies and is compatible with the Open Source ath5k Linux Kernel driver. The TVWS transceiver can span 80 MHz in steps of 5 MHz. The band center frequency is hardware configured at factory. Although TV channels are from 6 to 8 MHz wide, higher throughput can be achieved by using 20 MHz wide channels when there is enough spectrum available, as is often the case in rural areas. The RF output power is software configurable up to 30 dBm, and the receiver sensitivity goes from -96 to -72 dBm, depending on the modulation scheme and the channel bandwidth.

3. EVALUATION

We evaluated RF behavior, power consumption and cost. Notice that the power consumption issue is relevant to both CAPEX and OPEX since a major recurring cost of rural telecom deployments is energy provision of remote base stations. A typical installation of a base station with five clients costs about USD 6000 for the Carlson Wireless solution, whereas the same configuration with Alix boards and Doodle Labs would be 250 X 6 = 1500 USD (Board, Card, pigtail and weatherproof box). Antennas can be supplied locally at low cost in many countries.

3.1 RF evaluation

We connected an Agilent 9344C spectrum analyzer to the output of the Doodle Labs card through a 50 dB attenuator and the result is shown in Figure 1. It is apparent that the spectrum is much wider than a single TV channel. This would prevent using this solution in areas in which there is

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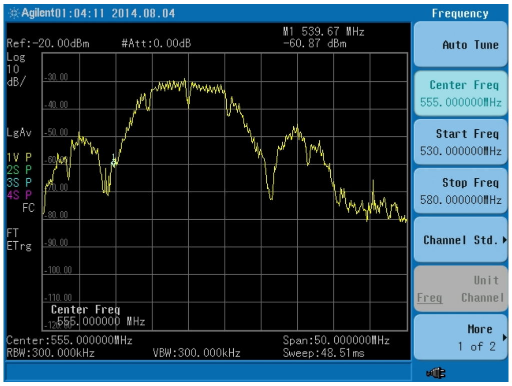

Figure 1: Spectrum of Doodle Labs as shown by an Agilent 9344C Spectrum Analyzer

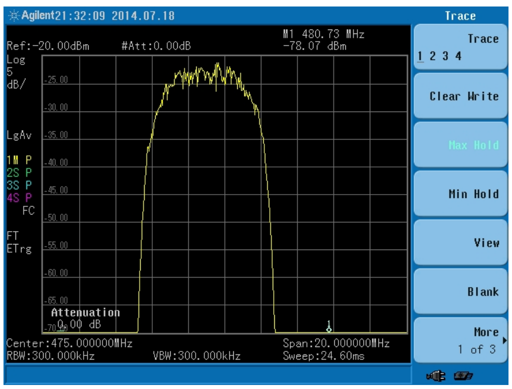

Figure 2: Spectrum of Carlson Wireless TVWS radio as shown by an Agilent 9344C Spectrum Analyzer

a single TVWS channel available. The signal is centered at 550 MHz, with a peak power of -30 dBm. Although most of the signal is concentrated in the 20 MHz nominal bandwidth, which corresponds roughly with the first spectrum nulls, there are side lobes which peak at - 37 dBm at 570 MHz which would violate the -20 dB Mask. The signal power drops 20 dB at the frequencies of 568 MHz and 537 MHz, spanning 31 MHz. If we look at a more stringent -30 dB drop, we find that the occupied spectrum is 37 MHz. The total power output is 33 dBm, as measured with the power channel feature of the spectrum analyzer over a nominal 20 MHz channel bandwidth. It is possible to configure the radio to a nominal bandwidth of 10 or 5 MHz, to reduce the spectrum occupancy accordingly.

It is worth noting the difference with the Carlson Wireless radio spectrum, as shown in Figure 2, which has a very steep skirt and no spectrum regrowth. This will comply with most regulator's spectrum mask requirements The channel power for the Carlson is 30 dBm. Notice the difference in the horizontal scale, the span is now 20 MHz whereas in the previous case was 50 MHz.

3.2 Power consumption evaluation

Average power use for the Geode LX processor is just over 1.8 W under load while running at 500 MHz, and 0.9 W while idle. In operation the CPU produces so little heat that it does not require a fan or even a heat sink. The companion chipset on the board, the AMD CS5536, uses just 2.4 W. This brings the total power requirements for the board up to 4.2 W. After inserting the radio card, we performed measurements over 24 hours that show an average of 5 W in total. The power consumption measurement was done while transmitting at the full 1 W power output, so this would be the total wattage if using an omnidirectional antenna. In contrast, we measured the Carlson Base Station consumption at about 28 W, while the clients drew an average of 10 W. The fact that the Doodle Labs client uses half of the power with respect to the Carlson's solution is particularly relevant in rural areas of developing countries, because in many cases they use photovoltaic systems, and halving the power requirements means halving the size of the solar panel and the capacity of the battery, drastically reducing the cost.

4. CONCLUSIONS

White Space technology is poised to have a significant impact in providing Internet access in rural areas. We have performed measurements on two different solutions. The first one is provided by Carlson Wireless, an off-the-shelf commercially available system that shows a very tight spectrum that complies with FCC strict requirements, but draws considerable power, has significant latency, and is more expensive. The second solution is based on a radio card developed by Doodle Labs, that can be housed in any board with a miniPCI slot. We chose the Alix board, which is energy efficient and has the versatility to also accommodate a second radio card that can be used to provide local WiFi access. Furthermore, since it is based on open software, it lends itself to full customization to fulfill the local needs of different communities. The power consumption is half of that of the commercial CPE, a very relevant factor in rural areas in which power provisioning is particularly costly. The spectrum occupancy is much greater, so this would prevent its use in highly populated areas at maximum RF power, but this aspect may lack relevance in places in which few TV broadcasting stations are deployed, as is the case in most rural areas of developing countries. The proposed device can also be used as local content server, even in the absence of Internet connectivity, and lends itself to peer-to-peer applications.

5. REFERENCES

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