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White Space

Apart from choosing a new president on November 4th, the US or rather the FCC voted to allow White Space devices to be deployed into the US UHF TV band.

This simple decision has potentially profound consequences for the broadcasting industry, the cellular industry and other communities with an interest in how regulated and unregulated and licensed and unlicensed spectrum is used in the future, both in the US, the UK, Europe and Asia.

The White Space ruling is the direct result of robust petitioning from the **Wireless Innovation Alliance**
supported by eight technology companies, Microsoft, Google, Dell, HP, Intel, Philips, Earth link and Samsung Electro Mechanics.

White space devices based on spectrum sensing principles already applied in the 5 GHz U-Niii band have been heralded as the birth of a new age in fixed, portable and mobile broadband access. In addition to the core companies in the WIA, other companies such as **Motorola** are actively promoting White Space for municipal wide area WiFi.

Alternative suggestions include the use of the spectrum for low cost cellular wireless backhaul.

The deployment of these devices is however controversial. Existing users in the band including TV and wireless microphones contend that interference issues remain unresolved.

Cellular operators who have either already invested in the band (AT and Verizon in the US) or are preparing to bid in future 700 MHz auctions question the impact that White Space Devices will have on present and future mobile broadband business plans.

Additionally White Space Devices could be deployed in other bands in other countries. This could be perceived either as a threat or an opportunity for cellular operators and the service provider community.

The assumption is that as this is unlicensed spectrum, wireless access can be provided on a more cost economic basis, for example for free. In comparison broadcasters using this spectrum have to cover their costs through licence fee or advertising income. Cellular operators using this spectrum have to recover their costs by charging an access fee.

The assumption that unlicensed spectrum is inherently more cost economic than licensed spectrum is only partly true and dependent on certain preconditions. The 2.4 GHZ and 5 GHz ISM spectrum is 'free' in as far as there are no license fees that need to be paid but there are still access costs that need to be recovered.

In domestic and SME applications, costs are limited to buying a wireless router and paying for an ADSL connection. Hardware costs are low because the ISM band is, more or less, a global allocation and this has allowed vendors to realise substantial economies of scale.

However in other applications, for example public WiFi in hotels, airports, trains and hospitals, significant hardware installation and real estate costs can be incurred which can in turn prompt aggressive access pricing. Similar constraints would apply to White Space devices.

For White Space devices to be successful they must have similar scale economies to existing WiFi and Wi Max and cellular handsets.

The devices must support equivalent or faster data rates than existing cellular products and or cellular handsets and when used as portable devices should use similar amounts of DC power.

However the receive and transmit functions have to work across operational bandwidths that are far wider (when expressed as a percentage of the centre frequency of the band) than all other existing mainstream radio systems. Additionally the receiver dynamic range needed from these devices is substantially more than cellular or WiFi handsets.

This introduces a number of practical performance and cost issues.

Spectrum sensing

White Space Devices need to be able to detect when signals are present and not present. The signals to be detected are either high power TV or low power wireless microphones

One of the discussion points when discussing the detection of TV signals is how reliably the pilot tone in an ATSC signal can be detected at a range of flux densities.

Companies such as **Adaptrum** , founded by Robert Broderson the co founder of Atheros, claim that time domain matched filter techniques working across the whole of the 6 MHz ATSC channel provide robust signal sensing techniques. Motorola have added in geo location to provide additional protection.

The broadcasters however remain sceptical. Even if sensing an ATSC signal can be achieved consistently down to low flux densities it is still feasible for devices to be in areas shadowed by buildings or hills - the hidden node effect. If the devices need to work in countries with DVB TV (with 7 or 8 MHz channel spacing) they would need to detect a signal with a much more complex (and by implication hard to detect) pilot symbol structure.

Wireless microphones are different - these devices use FM modulation and are inherently low power.

The requirement to detect two different types of signals has to be realised in the presence of relatively high incident received energy from other adjacent channels. These signals potentially desensitise the receiver front end thus potentially compromising the sensing function of the device.

Transmission efficiency

To date most technical work has focussed on receiver performance parameters but white space devices are suppose to deliver two way wireless connectivity.

The difficulty here is the bandwidth over which the devices will need to operate.

In the US this would be somewhere or anywhere between channels 21 and 51 (512 to 698 MHz) or potentially from channel 2 upwards (54 MHz).

The maximum power of these devices is relatively modest, of the order of 100 milliwatts, but difficult to deliver efficiently across these operational bandwidths.

Producing a device that would work in other markets, for example Europe, would mean devices would need to work somewhere or anywhere in UHF band 4 extending up to 790 MHz.

Designers of cellular phones know how hard it is to deliver efficient RF power amplifiers at lower frequencies over extended operational bandwidths. Getting an RF power amplifier to work efficiently across 40 MHz at 800 MHz is challenging let alone 100 MHz or more at 600 MHz.

As a comparison the widest cellular bandwidth as a percentage of centre frequency is presently GSM 1800. 75 MHz at a centre frequency of 1747 MHz is equivalent to 4.3%. The 80 MHz ISM band at 2.4 GHz is 3.3 %. White Space Devices could be in the order of thirty to forty percent - an order of magnitude greater.

Scale economy efficiency

One solution would be for White Space devices to be market specific which would mean White Space devices for the US market (Region 2), and re banded devices for Region 1 (Europe) and Region 3 (Asia).

However this would make it impossible to achieve sufficient scale economy. This would be particularly true if only deployed in the US. By 2014 the US will constitute less than 10 % of the global market for cellular devices. RF development today is typically amortised over hundreds of millions of devices. Such volumes would be inconceivable from the US White Space Market alone.

Signalling efficiency

White Space devices will have to measure and continuously re measure bandwidth occupancy and share these measurements with other devices or access points in the network. The IEEE presently has a working group specifying these protocols but essentially this is a complex measurement process.

This means that the devices will not be spectrally efficient and more important from a users perspective will not be power efficient irrespective of the network topology adopted. The use of mesh network topologies for example would result in particularly poor spectral and power efficiency.

White Space devices would therefore be likely to have much poorer duty cycles than equivalent cellular devices.

Power efficiency loss as a result of a need for wide dynamic range
The need for a wide dynamic range in the receiver front end would further reduce session duty cycles by increasing DC power drain. This would effectively invalidate any business plans predicated on the use of mobile or portable equipment.

Uneconomic network density as a function of transceiver TX and RX inefficiency
Unless White Space devices somehow escape the fundamental laws of physics, it will be hard to realise transmission or receive efficiency across the required operational bandwidth.

The lack of consistent channel pairing would make an FDD band plan problematic so the assumption has to be that this would be a TDD interface. This will result in additional loss of receive sensitivity particularly when devices need to transmit and receive at the same time.

This will compromise the measurement capabilities of the devices (see spectrum sensing above) but additionally implies a network density that would be unlikely to be cost economic. Mesh networks are not a solution. (See signalling efficiency above).

TDD also implies a loss of capacity over extended distances, a function of the time domain guard band overhead needed to accommodate round trip delay. This implies a relatively dense network topology.

Note that TV receivers are inherently insensitive due to their need to tune over an extended frequency range. This does not matter if signals are being received through a high gain roof mounted antenna but it does matter for devices with internal antennas and or for devices used at ground level. White Space Devices will be used typically at ground level and may or may not have internal antennas. They will need to tune across similar bandwidths but additionally have to generate transmit power for the uplink, not something a television has to do. This will result in further receive desensitisation which will translate into lower downlink data rates and or denser more costly networks.

Cognitive radios already exist - why not extend them into White Space spectrum?
Cognitive radios already exist in mass market applications. DECT cordless phones are one example and it could be argued that cellular handsets are cognitive in that they measure channel quality. The admission control algorithms in LTE networks for example are based on the channel quality indicator measurements received from LTE handsets.

The difference here is that the search and measurement parameters are relatively modest. DECT handsets work over just ten channels within a 20 MHz channel allocation. WiFi measurement and access algorithms at 2.4 and 5 GHz are similarly comparatively straight forward. Most 2.4 GHZ systems only use three 22 MHz channels across the 80 MHz bandwidth allocation.

In cellular networks, the measurement options are theoretically broad but practically narrow. Channel access will usually be in the same band and often on the same channel (a simple shift to another time slot).

In DECT and WiFi and cellular networks, the devices are measuring identical signal waveforms to the waveforms they need to demodulate.

White Space Devices have to detect different wave forms that may be similar or different to the waveforms they need to demodulate. This is a significantly more complex task.

An implied need to rethink the White Space Space

This suggests that White Space devices as presently conceived will have poor transmission efficiency which will translate into low uplink data rates and or limited uplink range and a limited RF uplink power budget.

The limited power budget will be compounded by a relatively high measurement and signalling overhead that will reduce session duty cycles. The devices will not work as well as cellular devices and or W iFI and Wi Max devices and will cost more due to smaller market volumes.

This would tend to suggest that present White Space business models are fragile at best.

However as White Space proponents point out, hundreds of MHz of spectrum are unused or under used at certain times at certain places.

This White Space spectrum has a social and economic value.

The problem is that White Space Devices as presently conceived are not an efficient mechanism for realising that value.

The answer may be to encourage the broadcasters (the NAB in the US the EBU in Europe) to develop a White Space Device specification which could be integrated with existing (DVB) and planned (ATSC) portable TV specifications.

This would have several benefits.

The present dispute over potential interference problems would be resolved.

A new business model could be developed based on a closer coupling between terrestrial TV and two way wireless internet access.

It would provide a broader industrial base over which RF development costs could be more efficiently amortised.

It would be even better if the cellular community could be encouraged to work with the broadcast community on a common White Space standard to provide compatibility with ATSC and DVB and LTE 700 and 800 MHz devices.

The imminent commercial failure of mobile TV makes this apparently unlikely scenario rather more plausible.

Similarly the future of terrestrial TV will be dependent on building closer relationships with cellular service providers. TV transmissions from cellular infill sites are for example the only credible way forward if ATSC based portable TV is ever going to work.

White Space White House
So in theory White Space Devices are a great idea - an opportunity to realise value from presently unused or under used spectrum.

As such the 4th November decision to make a swathe of new unlicensed spectrum available for innovative services must still look superficially attractive to the new US administration - a populist policy with tangible social political and economic benefits.

In practice these practical benefits can only be realised if devices can be developed to work in most if not all global markets.

This is politically, commercially and technically challenging and implies a need to work with rather than against the broadcast and cellular community and to work across national and international boundaries.

In common with licensed spectrum, unlicensed spectrum incurs access costs that have to be recovered from access charges or from other sources such as tax revenue or market subsidy.

To quote President Roosevelt 'We have never realised before our interdependence on each other'

Seventy five years on and faced with similar recessionary pressures we should recognise that inter dependency implies a need for to explore and exploit collaborative rather than competitive market opportunities and avoid the unnecessary and presently unsustainable costs introduced by conflicting market interests.

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RTT, the Shosteck Group and The Mobile World are presently working on a number of research and forecasting projects in the cellular, two way radio, satellite and broadcasting industry.

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