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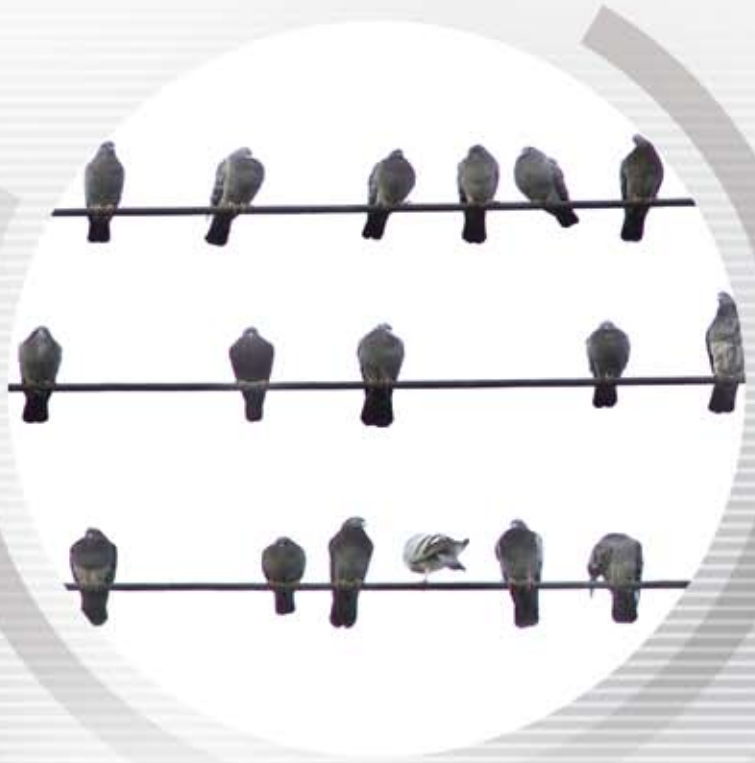
Whitespace: a revolution in wireless communications?



A workshop hosted by Cambridge Consultants

Cambridge Consultants recently hosted an event for key opinion leaders in the wireless industry. Seeding the debate with the primary focus on 'Whitespace: a revolution in wireless communications?', we asked delegates to examine what the shape of the wireless landscape might look like a decade from now, focusing on the future of whitespace.

Not only are we grateful to so many delegates for their willingness to travel considerable distances in order to attend, but also for their readiness to share their insight and experience so freely. This report attempts to accurately summarise the findings from the event, and offers a unique insight into the future of whitespace as seen through the eyes of some of the sector's key players.

We are also grateful to Kanwar Chadha, Member of the Board of Directors of CSR and Founder of SiRF Technology, for agreeing to kick-start the event with a thought provoking and stimulating presentation.

Participants

Kanwar Chadha	CSR & SiRF Technology, Inc.
Kiran Challapali	Philips
Ranveer Chandra	Microsoft Research
Joe Ciaudelli	Sennheiser
Russell Cyr	BitWave
Rolf de Vegt	Qualcomm, Inc.
VK Jones	Qualcomm, Inc.
David Konetski	Dell, Inc.
Paul Lambert	Marvell Semiconductor
Dan McCloskey	Google
James Peel	BT
Max Riegel	Nokia Siemens Networks
Soma Santhiveeran	HP
Dominik Schmidt	Intel
Avi Vaidya	Shure, Inc.
Prabodh Varshney	Nokia

Hosts

Laura Clifton

Luke D'Arcy

Tim Fowler

Patrick Pordage

Richard Traherne

Paul Williamson

Will whitespace radio revolutionise wireless?

Whitespace radio is not in itself a consumer technology - consumers don't care how their data arrives or departs, just the fact that it does. However, the unique properties of the whitespace radio frequency band lead to some important new characteristics that may solve some frustrating problems seen with existing wireless devices.

The area in question is the existing TV band, centred on 600MHz. TV broadcasters selected this band because it has excellent propagation characteristics – signals travel a long way, and pass easily through walls. This means that an access point using whitespace technology would be able to provide coverage across around ten times the area of a standard WiFi access point. This creates good coverage, but of course does limit capacity and re-use in dense traffic environments.

However, the new radios must incorporate advanced new technology to ensure that they do not interfere with existing TV broadcasts and wireless microphones. This will increase the cost of whitespace devices compared with existing unlicensed radios, which have already been through several cycles of Moore's law.

Will whitespace radio revolutionise the wireless industry? It was the consensus of the group that the cost, complexity and, ironically, high propagation characteristics of the technology will be a prohibitive barrier for many applications, at least in the short term, but it does offer significant potential for wireless broadband.

The longer-term view, though, is perhaps more relevant. Exponentially increasing demand for wireless products and services is making the current, static method of dividing up spectrum look inefficient and unaffordable. A new approach to spectrum usage is inevitable and spectrum sharing through cognitive radio techniques offers a way to greatly increase spectrum usage, benefiting everybody. Regardless of its immediate success, whitespace will undoubtedly be an early pioneer of the longer-term evolution of cognitive radio techniques.

Technology is no longer the main issue

TV broadcasters and wireless microphone users are understandably concerned about interference from whitespace radio devices. These concerns were not eased when several prototype whitespace radio devices failed to meet the full expectations of the FCC in initial tests. Much of the initial discussion in the group was focused on the technical feasibility of sharing the TV band without causing interference. The delegates came to an unexpected conclusion: that the technology for spectrum sharing, while no walk in the park, is no longer the main issue for whitespace.

Two methods to find free spectrum

There are two well-cited methods for finding free spectrum in the TV band:

- Spectral sensing: a traditional cognitive radio technique that uses a sensitive radio receiver to listen for transmissions on a particular channel. If the sensing algorithm finds a signal it reports that the channel is busy. It continues to monitor for other users of the channel, even while it is using the spectrum itself.

- Database look-up: the radio determines its location, for example using GPS, and then consults an online database. The database would contain dynamically updated information about free channels in all locations of the region. It tells the radio which channels it can use.

Traditional cognitive radios rely on spectral sensing to find free channels. This is attractive because it results in a self-contained device. The radio does not need to know its location, or have access to an online database, resulting in a smaller, simpler and less costly design that can be used anywhere.

However, in order to guarantee interference-free operation the sensing system must be able to detect signals hundreds of times weaker than a typical TV station. This is possible but demanding (and hence costly in the short term) in a radio device.

There was considerable disagreement amongst the delegates about whether a radio device using a sensing scheme alone could ever be made to work reliably. However, in response to this industry disagreement, the FCC has decided to select database look-up as the main method that whitespace radios will use for finding free channels.

But, while sensing promises a perfect, if so far unrealised, self-contained radio, the database does have inherent limitations that will reduce the scope of whitespace radios, at least in the short term.

Perhaps the most important of these is the need to determine, within 50 metres, the location of the radio before transmitting. GPS is the only technology that is sufficiently accurate, and whilst considered to only work well outdoors, some delegates pointed out that the latest GPS chips would offer a significant improvement in indoor performance. Still, despite these improvements, everybody agreed that there are some locations where GPS alone will not work in the foreseeable future, such as indoor shopping malls with few windows.

A second challenge is the need to react quickly. TV stations don't change frequency fast in a particular location, but wireless microphones can be turned on and off at any time and in any location. The database cannot provide protection unless the user registers the microphone before switching on.

OFCOM, the UK regulator, already runs a successful online registration program for wireless microphones (www.jfmg.co.uk). This program allows users, such as news reporters, to register the location of a microphone prior to use. They are then guaranteed clear spectrum on a particular channel for a specified period of time. This works well for professional users, and is self-funding through fees paid by the microphone users. Whether a similar scheme could be extended to cover the much larger number of semi-professional users in the US is open to debate. Whether they would be prepared to pay a fee for spectrum they are currently getting for free is even more doubtful. As one delegate stated:

> *"Illegal use would render the database useless and, unless such use can be prevented, spectral sensing is a must."*

A further challenge is the need to access the database online, before switching on the whitespace radio. To do this the radio device must have an alternative way of accessing the internet. This means that, if database look-up is mandatory, some additional means of accessing the internet will normally be required.

These challenges combine to restrict the available capacity through database look-up techniques. It will be inevitable that spectrum will become 'over-booked' leading to a ceiling in the maximum efficiency of spectrum usage – the very issue driving the cognitive debate.

Despite these limitations, the group saw no fundamental technology issues in creating a database to manage spectrum usage for the whole of the US, or even the entire world. Such a system would be large and complex, but no more complex than many commercial and government systems already in use. Unlike sensing, the technology to build a database exists today.

Beachhead applications for whitespace radio

To be successful, whitespace radio needs to be more than just technically feasible; it needs to find a market that demands the unique benefits that the technology can offer. The license-exempt, long-range spectrum offered by whitespace radio is a significant advantage, but mature, low-cost unlicensed radio technologies are already available, and cellular services offer great range and coverage. As one of the delegates put it:

> *"What problem do whitespace radios solve that cannot be solved with existing technologies?"*

If whitespace radio is to revolutionise wireless there must be a truly compelling answer to this question. Delegates considered the following applications to offer the best short-term opportunities.

Wireless broadband

The long range of whitespace radio makes it a great choice for connecting devices wirelessly to the internet. Does this mean that for the first time unlicensed networks could seriously rival cellular networks for coverage in urban areas?

Advertising-supported public access WiFi networks are in operation in several cities and airports in the US. But there have been many failures, some well publicised. While the spectrum for WiFi networks is free, other costs for site rental, backhaul and base-station equipment remain.

Most, if not all, of these networks have used WiFi at 2.4GHz. The relatively poor range and wall penetration at this frequency mean that it is hard to obtain good coverage, particularly indoors. Network operators must install many access points, driving up cost.

Even then it is often necessary for users to fit an external high gain antenna to obtain an adequate signal indoors, which is a strong disadvantage for many people.

One attendee surmised that, in some areas:

> *"Advertising-supported muni WiFi is at break-even right now."*

Whitespace radio will draw considerably from the substantial legacy of WiFi technology, but its increased range and wall-penetrating abilities promise to reduce the cost of setting up an unlicensed wireless broadband network. Each whitespace access point can cover up to ten times the area of a current WiFi device. This means that for certain locations operators will be able to provide blanket coverage with far fewer access points, reducing the capital, maintenance, backhaul and site rental costs.

As a result, free-to-use or very low-cost wireless internet access may become profitable in many more neighbourhoods. Free broadband, supported by inconspicuous adverts, would be extremely attractive to many users. Whitespace radio's unique ability to make this viable is perhaps the most interesting and disruptive application for this new technology. As one delegate stated:

> *"This could let Starbucks compete with Verizon Wireless!"*

Home media distribution

Modern consumers are moving from one-size-fits-all broadcast TV to personalised streams, downloaded from sites such as Hulu or YouTube, or created with a digital video recorder. This is only possible for a TV that is physically connected to the set top box or DVR, usually the one in the living room. There is a strong demand to extend this to all the TVs in the house.

Installing new wiring to support multiple TVs is expensive and inconvenient. A wireless system would be much more convenient. Existing WiFi networks, which are already available in many homes, struggle to provide the high bandwidth and quality of service needed to support video streaming, particularly for high-definition video.

The ability of whitespace radio to penetrate walls makes it an interesting technology for video distribution around the home. However, many companies and technologies are vying to fill this niche.

One of the leading candidates is the Wireless Home Digital Interface (WHDI) standard, based on WiFi at 5GHz. The 5GHz band is relatively lightly used at present and offers a 600MHz wide swath of spectrum. This makes it suitable for carrying high-bandwidth, high-definition signals.

WiFi signals at 5GHz normally travel no more than 30 metres and are easily attenuated by walls. As a result, they are unable to stream data reliably to all rooms in a large house, even though its headline data rate is more than high enough.

However, a number of companies have developed Multiple In Multiple Out (MIMO) antenna arrangements to improve the wireless performance.

The standardisation process for 5GHz video distribution is well underway, and is well supported by consumer goods manufacturers. Delegates pointed out that low-cost silicon from multiple manufacturers will soon reach the market, and that we are unlikely to see similar low-cost chips for whitespace radio for several years. As a result, they found it hard to see whitespace radio making a wholly disruptive impact in home media streaming, whatever advantages it may have.

Always-on wireless, for every gadget

It's easy to forget how uncommon cell phones were only 15 years ago. In those days, handheld wireless devices were the preserve of high-flying businessmen and the super-rich, who were prepared to pay premium prices for the service, or status offered by what were then novel devices.

Wireless services and products have now become truly pervasive and form a central part of modern life in all developed (and many developing) regions. Even the least technology literate individuals use cell phones regularly, and expect them to work wherever they happen to be. Sales people anchor their travel plans to coffee shops where they can get online. Young people instantly upload events in their lives, however tiny, to Facebook via smartphones. All of this demands wireless broadband as ubiquitous and easy to use as the air we breathe.

Smartphones such as the iPhone and Blackberry have turned handsets into small computers, hugely increasing the demand for data. But this may turn out to be the thin end of the wedge. The delegates agreed that data-hungry mobile devices are set for explosive growth over the next few years. It should come as no surprise then that current wireless networks are creaking. Existing cellular networks based on 2.5G and 3G technology will certainly not be able to meet this new demand. Even with today's relatively low volume of data they are groaning under the strain. It's common to hear complaints from users about poor 3G data rates and coverage. Many people who have purchased 3G data dongles thinking that they would receive multi-megabit network connections have been similarly disappointed. And yet, we're approaching the limit of how many bits we can transmit in a given bandwidth. Now, more bits increasingly means more bandwidth.

Next generation networks may help a little. Long Term Evolution technology (LTE), promises up to 100Mb/s data rate: faster than wired broadband. However, just as with current 3G systems, the real data rate will be much lower.

So, will LTE improve network speeds sufficiently to support all of the new devices? Overall the delegates thought not. The consensus was that it will offer a very welcome improvement, but that it will come nowhere near to solving the impending data crush caused by the huge increase in connected devices. As a result, they felt that traditional network operators will have much to gain by using whitespace to offload data traffic.

Most advanced wireless devices contain unlicensed radios such as WiFi and Bluetooth. WiFi is designed for data transfer and can be used to take some data traffic off the mobile network. Could this help enough to solve the impending data crush?

Many smartphones already switch to WiFi whenever an access point is in range, such as when the user is having coffee at Starbucks. Whitespace radio has the potential for much greater coverage than a WiFi access point, so it will be possible to offload data to an unlicensed wireless network far more often, making the broadband connection faster on average, and more reliable.

This technique, assuming it is implemented in a way that is transparent to the user, certainly has the potential to greatly reduce the load, improving performance for everybody. Encouragingly there is plenty of room for expansion. Only one of the three main unlicensed bands is heavily used today.

How much can unlicensed spectrum really help?

The 60GHz and 5GHz unlicensed bands offer plenty of free spectrum. Making full use of this is undeniably attractive. It will certainly help to ensure speedy internet access for some users, but will these bands accommodate the huge growth in connected devices that we can expect over the next few years?

The delegate consensus view was that they will be insufficient. Certain cellular operators enforce a policy that makes iPhones switch to WiFi for data connections whenever an access point is in range. Despite this, many obtain reports of slow connections and poor 3G coverage. And this is with today's relatively low usage.

Current hotspots mainly use the 2.4GHz unlicensed band. Switching to 5GHz will increase the bandwidth available to users who are in range of a WiFi access point. Instead of a 50Mb/s 802.11b/g connection, they will be able to use 802.11n at 5GHz with a data rate of 100s of Mb/s. At 60GHz the data rate could potentially be even higher.

However, users rarely complain about slow data rates when they are connected via WiFi. Instead, the issue is poor bandwidth when they are not in range of an access point. Even for the operators with the largest hotspot networks, it's still hard for users to find an access point without making a special trip to a coffee shop.

A good solution, then, would be to increase the range of each access point. This would allow users in a wider area to connect, benefiting from fast connection rates for themselves, and freeing up the cellular network for other remote users. Unfortunately, neither the 5GHz nor the 60GHz band can help with this. They both offer considerably shorter range than current 2.4GHz access points.

There is absolutely no shortage of bandwidth available for short-range wireless connections. Users who are prepared to go to a specific location, for example a coffee shop, home or office, are already well served by existing 2.4GHz wireless technology, and will be exceptionally well served as 5GHz and 60GHz services become more widely available.

However, customers are demanding always-on services that are not tied to a particular location. To make these work effectively more spectrum is urgently required. To provide the required range the spectrum must be at a relatively low frequency; below 2GHz.

Why not just create a new, sub-2GHz unlicensed band?

Unfortunately the spectrum below 2GHz is already allocated. This leads to the depressing conclusion that it will be impossible to accommodate the forecast growth of wirelessly connected products.

However, in reality there is a glimmer of hope. Whilst the spectrum allocation chart suggests that all of the frequencies below 2GHz are constantly in use, field measurements consistently show very low utilisation.

For example, a well-known study conducted by the University of Chicago showed that 80% of all spectrum capacity below 3GHz was unused, when measured in real urban situations. In less dense suburban and rural areas there is even less real use of spectrum.

There was a consensus among the delegates that cognitive radio, pioneered by whitespace, offers a way to exploit this valuable, underused asset. They felt that if we are to avoid a wireless spectrum crunch in the future, it must surely play a significant role in spectrum planning.

So, will whitespace radio revolutionise wireless?

It was clear from the workshop that whitespace radio does offer some extremely interesting new possibilities for wireless devices, but will it really revolutionise the industry?

The delegates felt that the wireless microphone industry will certainly be revolutionised. Makers of wireless microphones were the first to raise legitimate concerns about possible interference from whitespace devices. Ironically, many delegates felt that this group now stands to be among the first companies to gain financially from the FCC's decision, as more efficient methods of spectrum usage are inevitable and therefore users will have no option but to upgrade to more sophisticated interference-resistant devices.

Other wireless devices will benefit directly from the additional spectrum offered by whitespace radio. Many delegates made the point that there is no technological silver bullet that will solve the problem of connecting millions of data-hungry devices to the internet simultaneously and at high speed. Put simply, this task requires more spectrum. There are only two ways to get this: more spectral reuse, for example by a massive and complex roll-out of femtocells, or more efficient use of the existing spectrum.

Femtocells will undoubtedly play some part in solving this problem, but they are only effective in specific locations, just like WiFi access points. By offering a way for mobile devices to access more sub-2GHz spectrum, cognitive radio will revolutionise in many instances the delivery of fast, always-on wireless connections that users crave.

About Cambridge Consultants

For 50 years we have helped clients turn business opportunities into commercial successes. We do this in a whole range of ways, but some of the most common include:

- turning their ideas into 'first-to-market' products
- radically reducing the cost of existing products
- keeping a client's competitive advantage through the introduction of new technologies

In short, we develop breakthrough products. Because our engineers rarely 'switch off', we also have a knack of creating valuable intellectual property that is available to license. And with all their technology and development expertise, we also provide business consultancy on technology-critical issues.

With a team of 350 engineers, scientists and consultants, in offices in Cambridge (UK) and Boston (USA), we are able to offer solutions across a diverse range of industries including medical technology, industrial and consumer products, transport, energy, and wireless communications.

With one of the largest independent radio design teams in the world, our wireless communications division has created a number of world firsts. We're experts in a bewildering array of wireless technologies but agnostic to all of them. What we care about most is creating the right solutions for a client's problem in order to give them a truly world-class product. Further information about our work can be found on our website.

As part of our ongoing commitment to the wireless industry, we would be pleased to hear your feedback on the content of this report and to discuss your views on the future direction of the industry.

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