Spectrum management issues for heterogeneous networks in commons spectrum

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Abstract

Purpose – *The purpose of this paper is to analyse some of the spectrum management policy implications of an evolving set of wireless technologies. Specially, deployment of heterogeneous networks (HetNets) as part of the rollout of long-term evolution networks and their expected use as the heart of next-generation services raises the question as to whether such networks should lead to any spectrum management policy changes.*

Design/methodology/approach – *The paper describes the use and variety of HetNets when using licensed and unlicensed or commons spectrum.*

Findings – *The paper demonstrates that there is little need to change current spectrum licensing regimes to deal with these networks in a licensed spectrum. However, it also shows that the deployment of HetNets other than WiFi in an unlicensed spectrum creates an information asymmetry, which means that spectrum regulators will find assessment of spectrum demand more difficult. The paper also highlights the problem facing spectrum regulators when there is a potential for interference to unlicensed services which are widely deployed but have no right to protection from interference.*

Practical implications – *Spectrum regulators will need to understand the extent to which an unlicensed spectrum is being used by mobile network operators to deliver wireless broadband services. This understanding is needed to be able to address potential interference with other services using an unlicensed spectrum and to be able to forecast spectrum demand.*

Originality/value – *The development of technologies that are designed to be used by existing mobile network operators for the delivery of wireless broadband services using an unlicensed spectrum creates novel regulatory challenges. This paper reviews some of these.*

Keywords *Spectrum sharing, Commons spectrum, HetNets, LTE-U, Spectrum management, Spectrum policy*

Paper type *Conceptual paper*

Introduction

A heterogeneous network or HetNet is one which uses different mechanisms to deliver information concurrently. There are a range of different forms of HetNet. A HetNet can be formed by the concurrent use of a spectrum in the same band where services are supplied using a combination of small coverage cells and macro coverage cells. Alternatively, a HetNet can be made up from services using the same technology using two separate spectrum bands or different technologies in the same or different bands.

These are set out as a four-quadrant matrix in Figure 1. The right-hand side of the matrix is where multiple bands are used, and the left-hand side is a single band. In the upper half of the matrix, there are multiple distinct technologies, and in the lower half, the technologies are homogeneous. Examples in each quadrant are based on long-term evolution (LTE) and WiFi (in accordance with one of the IEEE802.11 standards made by the Institute for Electrical and Electronics Engineers). The bottom left-hand quadrant is implemented in LTE using a pico cell overlaid with a macro cell. The top left-hand quadrant could be the aggregation of 3G high-speed packet access and LTE in a single

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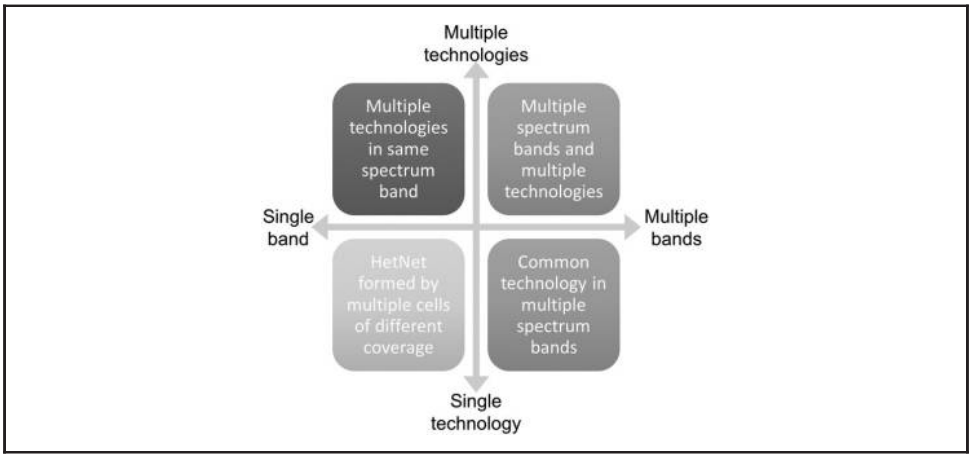
Figure 1 A matrix view of HetNet functions



band (such as 1.8 GHz). The bottom left-hand quadrant could be implemented using cross-band aggregation such as LTE-Advance (also known as LTE-A), and the top right-hand quadrant could be the aggregation of LTE and WiFi.

The usual spectrum management policy approach to HetNets is a deconstructive one. That is, the spectrum regulatory agency licenses the use of each spectrum band and, if technological determinism is used, each form of technology. The effect is that the regulatory approach does not address the use of HetNets. The absence of regulatory intervention does not affect the ability of licensees to offer telecommunications services which use spectrum aggregation.

However, one of the approaches taken to the delivery of a HetNet is to use a spectrum which is commonly used for WiFi services. In general, this spectrum is internationally harmonised for "industrial, scientific and medical" (ISM) services. The consequence of the ISM harmonisation is that there is usually very light-touch spectrum regulation of these bands. In addition to ISM, some spectrum at around 5 GHz is treated in similar fashion. The US designator for this spectrum is "Unlicensed National Information Infrastructure" (U-NII). They are referred to as: "unlicensed" in some jurisdictions such as the USA; "licence exempt" in the UK; or "class licensed" in Australia. In each case, the characteristics of the devices which do not require an individual licence are specified by the spectrum regulator. There is no protection from interference granted to the users of the ISM spectrum and, as a consequence, interference from microwave ovens, industrial heating and other services is to be expected. Bluetooth, WiFi and a range of other communications services operate concurrently with such interference in the 2.45-GHz band.

One implementation of a form of LTE is designed to use U-NII and ISM bands and is known as LTE-U, where the "U" refers to unlicensed. There are two sets of issues associated with the use of ISM and U-NII spectrums to provide wireless broadband services. The first is that the regulator loses an understanding of the nature of the networks that have been deployed and specifically loses an understanding of the level of spectrum demand for wireless broadband services. The second issue flows from the "commons" nature of ISM and U-NII spectrums. Will the deployment of LTE-U adversely affect the existing WiFi services?

This article aims to address the policy implications that flow from the increased use of HetNets in licensed and unlicensed spectrums. The article shows that this is an important area of work as the information asymmetry between spectrum regulators, and spectrum users can lead to regulatory policy decisions that have unintended consequences. These consequences include the risk of over-supply or under-supply of spectrum and the invalidation of assumptions as to substitution. This opacity is driven by the absence of tools, both data-based and physical, to monitor the utilisation of an unlicensed spectrum.

This article begins by locating the work in the context of the technological literature on HetNets. It also touches on some of the fundamental thinking that has driven spectrum policy and the regulation of spectrums in the era before HetNets began to be widely deployed. There is a description of the arguments about spectrum commons in an environment where sharing was expected to be the usual outcome. The article then moves on to describe the types of HetNets that are deployed or planned for wireless broadband services. It reviews HetNet applications in fourth-generation (4G) and next-generation (5G) environment and describes why mobile network operators deploy such networks in terms of lowering production costs. It also reviews some of the limitations of HetNets.

The article then has two sections dealing with policy matters associated with HetNets. The first, which deals with a licensed spectrum, highlights the small extent to which the existing spectrum management policy might need a change to facilitate the efficiency gains that HetNets offer in a 4G world. The second deals with the specific issues associated with the deployment of LTE-U, including proposed variants of that technology. There is a short analytical section which summarizes the need for policy and regulatory change before conclusions are drawn and recommendations for further work are presented.

Positioning the work

In the context of existing 4G networks, the primary rationale for the use of HetNets is to improve spectral efficiency, that is, the objective is to increase the bit/s per hertz per unit of area as this is a good proxy for increasing the bit/s per hertz per network user (Andrews, 2013; Bhat *et al.*, 2012; Bjerke, 2011; Insoo *et al.*, 2013). However, a review of the literature suggests that there has been less work published on the policy implications that flow from the deployment of HetNets. To some degree, this is unsurprising, as spectrum management is primarily concerned with an efficient use of a spectrum.

The conceptual framing and practical implementation of spectrum management processes have been well recognised, and there are a number of sources in this area (Cave and Webb, 2015; Salant, 2014; Kwerel *et al.*, 2002). Minervini reviewed some of the issues in spectrum management (Minervini, 2014) and cited an earlier version of the Cave and Webb text on supply and demand matching and highlighted work by Bohlin *et al.* (2007) on European approaches. Cave and Webb also demonstrated the approaches to spectrum management that are required to implement spectrum-sharing arrangements (Cave and Webb, 2012).

Managing an unlicensed spectrum is a core role for spectrum management agencies (Cave and Webb, 2015). Some of this work is in specifying the parameters of use of a spectrum on an unlicensed basis. For example, the requirements of the equipment might be specified in broad terms, and interference between unlicensed users is minimised by setting limits on the effective radiated power of devices. This is the approach taken for both WiFi and Bluetooth, both of which use the 2.45-GHz ISM band. Much of the work on spectrum sharing through cognitive radio and the use of white spaces is based on devices being able to geolocate themselves (Webb, 2012). In an environment where there are competing technological uses for an unlicensed spectrum, some types of devices (e.g. wireless microphones) have been actively managed to use different spectrums (Freyens and Loney, 2013). There are also challenges that spectrum regulators must meet in allowing unlicensed devices to use a spectrum which is already licensed to others in either narrowband "holes" or on a wideband basis (Freyens *et al.*, 2014).

In the middle of the first decade of the twenty-first century, there was a debate as to which are the most efficient mechanisms for spectrum allocation. The extremes of the debate were "everything should be licensed" and "everything in a commons". An extensive literature emerged which looked at appropriate solutions to the spectrum management policy options flowing from the debate (Cave and Webb, 2004, 2015; Hatfield and Weiser, 2005b, 2005a; Lehr and Crowcroft, 2005; Peha, 2005, 2009). Although the discussions remain relevant, the major use of bands in which unlicensed devices are permitted follow recognised standards. As a consequence there is both experience and understanding of the nature and limitation of sharing. This has not always been the case as was shown publicly when Steve Jobs was demonstrating the iPhone 4 for the first time and could not get WiFi access because of the number of simultaneous connections (Liu, 2011).

As this article shows, there are some aspects of HetNets that require little or no policy intervention. Their deployment may change the spectrum demand slightly but not to a great extent. However, where HetNets are deployed using a spectrum which is utilised by unlicensed devices, the spectrum policy issues become more complicated. To show where these issues arise, the next section reviews the current and anticipated applications of HetNets in the delivery of mobile broadband services.

Application and use of HetNets

As set out in Figure 1 above, the basic concept of a HetNet is merely that there are multiple networks with some degree of heterogeneity creating a single solution for at least one device. From a network operator perspective, one of the advantages that the use of HetNets provides is the ability to off-load demand for wireless broadband access onto WiFi. In this case, the traffic that is off-loaded is unmanaged. An alternative implementation is to off-load from a macro cell to a managed small cell in an area covered by the macro cell. It is the ability to coordinate the management of the potential interference between a small cell and the macro cell that leads to an increase in the efficiency of throughput. In practice, there is also a second efficiency in that coverage at the edge of the macro cell can be maintained by small cell deployment to increase the cell-edge throughput.

In a 4G world, there are three potential forms of HetNets and these sit in the right-hand pair of quadrants of Figure 1.

In the first form of HetNet, there is a macro cell and a small cell within the coverage area of the macro cell. When a user equipment is in macro-cell coverage, it may use carrier aggregation (as part of LTE-A) across two licensed LTE bands with one radio for each band. For the purpose of this example, we choose these to be 850 MHz and 1.8 GHz. The macro cell is the primary cell, and the small cell is the secondary cell. To improve efficiency, the user equipment could be handed from the macro cell to a small cell in respect of one of the bands (say 850 MHz). There is still carrier aggregation of the two licensed bands and a single radio access technology (LTE). The carrier aggregation is managed at the link level using the media access control (MAC) layer.

In the second form of HetNet, the user equipment uses two radios. The first radio and modem connects to a macro cell using LTE in a licensed band. The second radio and modem connects to a WiFi access point, which is not controlled by the mobile network operator. The macro cell is the primary cell, and the WiFi access point is the secondary cell. In this case, there is carrier aggregation of the licensed band and the unlicensed WiFi band and two radio access technologies (LTE and WiFi). The carrier aggregation is managed at the link level using the packet data convergence protocol layer.

In the third form of HetNet, the same macro cell is the primary cell, and an LTE-U cell is the secondary cell. Although LTE-U uses an unlicensed spectrum, the cell is controlled by the mobile network operator. In this case, there is carrier aggregation of the licensed band and the unlicensed LTE-U band and a single radio access technology (LTE). Similar to the first form of HetNet, carrier aggregation is managed using the MAC layer.

The concept behind 5G is that it is based on dense HetNet architectures (Bangerter *et al.*, 2014). As these authors point out:

> HetNets are among the most promising low-cost approaches to meet the industry's capacity growth needs and deliver a uniform connectivity experience.

These HetNets are implemented as small cells (Jungnickel *et al.*, 2014). Part of the application of HetNets to 5G revolves around the broad requirements expected of the services. To some extent, 5G can be considered as being both an overlay of 4G and a HetNet and/or underlay of 4G. The overlay is to address the demands of the Internet of Things (IoT). The "things" are devices, some of which will be mediated via a gateway. The requirements of IoT are likely to be very low data rates where latency may be very unimportant, but availability will need to be very high over the anticipated 10-year battery life of the device. The IoT overlay is expected to consist of a massive number of devices. The extent to which an additional spectrum is required for the devices will be determined by the extent to which there will be mediation or aggregation of internet access. For example, on rural property, a pump might need to talk to a rain gauge and a dam level measure, but none of them requires internet access. This application also indicates the availability requirement. A failure to manage water could lead to a disaster.

The underlay or HetNet part of 5G will use a spectrum above 5 GHz, and this is sometimes called a millimetrewave spectrum. These cells will have very bursty or opportunistic communications characteristics, where the data rate is measured in gigabit per second and the latency will need to be of the order of 2 ms. However, for most applications, the availability will be expected to be consumer-grade.

HetNets provide the increased efficiencies over single or aggregated radio networks that were described above in terms of data throughput, particularly at cell edges. This might potentially mean that the demand for a new spectrum would be tempered by the efficiency gains arising from HetNet deployment. However, and as a practical matter, the gains have been offset by an increased demand from consumers for broadband access, taking advantage of the improved customer experience delivered by HetNet deployment. There is a very low likelihood that the setoff will mean that the deployment of HetNets is spectrum demand-neutral.

Policy and regulatory issues with licensed-spectrum HetNets

There are arguably no significant spectrum management issues that arise from the use of HetNets in a licensed spectrum. The licensing regime is likely to ignore the effects of cross-band aggregation and, as a consequence, the licensing analysis is of separate radios in the user equipment and the radio access network communicating with each other. That cross-band aggregation occurs does not affect compliance with the licence for each of the bands used. Even if some of the demand is off-loaded to WiFi, as described above, this has no impact on the licensing arrangements.

There is an issue that relates to spectrum demand. If WiFi off-loading is reducing the demand for a spectrum or slowing the increase in the demand for a spectrum, then the regulator can see this through both the registers of telecommunications infrastructure (whether held by the regulator or urban planning authorities) and by monitoring the use of individual bands. That is, although off-loading onto WiFi using an unlicensed spectrum means that the spectrum regulator does not see the demand which is met by WiFi, it still has visibility of the use of a licensed spectrum and the extent to which mobile network operators are deploying larger cells. The level to which this is cell splitting is an indicator of spectrum demand. The spectrum management regulator will usually have other indicators of the level of spectrum use. In jurisdictions outside of the USA, these include regulatory and statistical reporting. Information as to the data usage of a licensed spectrum and the amounts paid provide an indication of spectrum use. This information may be supplied as part of regulatory compliance (especially coverage) reporting and often forms part of the statutory reporting of the owner of the mobile network operator. To some extent, the spectrum use can be confirmed by the use of a spectrum monitoring system. However, spectrum monitoring generally provides a measure of spectrum occupancy rather than throughput.

There is a limit to this visibility and it is associated with indoor coverage. In this case, there may be no infrastructure that needs to be registered. For example, all mobile network operators could provide coverage in a shopping centre using separate or common infrastructure, and there is no visibility of demand to the spectrum regulator. However, the level of demand can still be assessed as the devices used in the shopping centre are used elsewhere.

As HetNets improve spectral efficiency, there is a benefit for the spectrum regulator in promoting this efficient use, as it means that other bands do not need to be cleared for release to mobile broadband services at the rate that they otherwise would. HetNets offer a lower production cost measured in dollars per megabyte served. LTE has a lower production cost for data than 3G expressed in cost per megabyte served (Kumar *et al.*, 2010). Voice over LTE is more efficient than running a parallel circuit-switched network. In each case, the mobile operator has all of the costs on an end-to-end basis with the consequent incentive to improve efficiencies in a manner that also improves each retail customer's experience or perceived value for money.

There may be an issue for spectrum regulators in allocating spectrum for HetNet services as these are being standardised. There are broadly three approaches that could be taken, and these options are particularly important to consider as 5G trials are deployed.

The first is to ask the mobile network operators to take the technology risk. That is, the spectrum regulator offers a spectrum for an (reasonable period) assignment using a price-based allocation such as an auction. In this case, there is a risk that mobile network operators will bid at a level that reflects this technology risk, and the price paid at the auction will reflect this. The design of the auction may mean that the winning mobile operator does not have to declare the technology that it proposes to deploy.

The second is to set aside a spectrum for a specific and technologically determined trial. This option has the risk that the trial will delay the deployment of a practical solution. This is the approach that was taken by the Infocomm Development Agency (IDA) in Singapore in respect of its 2015 HetNet trial in the Jurong Lake District. In this trial, four mobile network operators (Singtel, M1, StarHub and MyRepublic) were granted a temporary use of spectrum in the 2.3 to 2.335-GHz and 2.6 to 2.615-GHz bands. The IDA called for participants for the trial. The bands that were made available on a temporary basis are those scheduled for the round of spectrum auctions in Singapore that followed the trial. In this case, the regulator was proactive.

The third is to have a process where access to an unused or a clear spectrum is made available for trials when requested by a mobile network operator. The approach could be by a temporary assignment by the licensee if the spectrum is licensed but unused or by the granting of a short-term trial license. As an example, these trial licenses are referred to as scientific licenses when they are issued by the Australian Communications and Media Authority in Australia. In this case, the regulator is reactive.

Policy and regulatory issues with unlicensed-spectrum HetNets

In principle, LTE-U can be implemented as an LTE radio access network using a spectrum assigned for unlicensed use in the 5-GHz band. The earliest forms of standardisation by the standardisation body known as the 3GPP mapped this to occur in Release 13 of the 3GPP standard that covers LTE. However, there are two alternative variants to LTE-U that have an impact on the spectrum management policy.

The first is LTE-license assisted access or LTE-LAA. This differs from the original specification of LTE-U in two ways. The primary difference is that the radio network operates in accordance with spectrum sharing rules for a secondary service. This includes the potential for a form of clear channel assessment (e.g. "listen before talk"), where the radio system does not use the spectrum that is currently being used. The secondary difference is that LTE-LAA is designed for lower-power indoor use. In LTE-LAA, in common with LTE-U, the backhaul for the radio access network is provided by the mobile network operator. LTE-LAA always uses a licensed spectrum band as the primary cell. In the original LTE-U, the cell in an unlicensed spectrum could be the primary or secondary cell.

The second is a Qualcomm proprietary system known as "MuLTEfire". Here, the LTE service is not linked to a specific mobile network operator, and backhaul is provided by the radio access network provider in a way similar to that in which WiFi is provided. The rationale behind this product offering is that the spectral efficiency of LTE is greater than that of WiFi. However, it is less clear that this technology would be attractive to mobile network operators.

There are two critical significant spectrum management policy issues that flow from the deployment of any of the LTE-U family of technologies by mobile network operators and from the deployment of MuLTEfire by WiFi access providers. The first is that there is a loss of visibility of the demand for a spectrum. The second is that interference to services that use unlicensed or class-licensed spectrums will lead to political demands for the spectrum management of commons spectrum. One of the drivers of conventional spectrum management is the principle that a spectrum is a scarce resource and should be dealt with as such. The encouragement of spectrum trading, the use of spectrum auctions and an increasing requirement for managed spectrum-sharing services by spectrum regulators reflect the scarce resource analysis. In the case of LTE-U, spectrum regulators no longer have an indicator of the demand for a spectrum. One of the characteristics of the unlicensed spectrum environment is that there are no individual licenses. If the LTE-U infrastructure is primarily used for indoor applications, there is unlikely to be a need for the infrastructure to be registered. This means that LTE-U has the potential to create an information asymmetry between the regulator and mobile network operators.

Unlike a licensed spectrum, where reporting as described above will assist the regulator, there will be no transparency as to the level of unlicensed spectrum use. The volume of data and the amount paid will not indicate whether the spectrum being used is licensed or unlicensed. Spectrum monitoring systems are less useful in a spectrum where there are a large number of concurrent users with heterogeneous technologies. The risk that flows from this asymmetry, which is discussed in more detail below, is that only mobile operators will have a real understanding of their demand for the spectrum, and the consequence is that allocation processes, including auctions, will become less efficient.

The second issue relates to the existing deployed WiFi services. WiFi is widely deployed in homes, businesses, educational establishments and public places. These services were deployed on the basis that the spectrum used is unlicensed and the major sources of on-channel interference would come from neighbouring WiFi services. In practice, many households simply deployed WiFi for convenience, without considering that there might be regulatory or interference issues. If LTE-U and its variants are to be widely deployed, they will share a 5-GHz spectrum with the existing WiFi access points. Although there is no expectation of protection from interference in an unlicensed spectrum, this does not mean that the effect of interference to WiFi services can be ignored by the spectrum regulator. As a practical matter, an indication of the issues that are likely to arise can be gauged from the responses to the Federal Communications Commission public inquiry into LTE-U and LTE-LAA (ET Docket No. 15-195). This inquiry, launched by the Office of Engineering Technology, has generated heated discussion as to the adverse effect of LTE-U on existing WiFi deployment. The proponents of LTE-U point to the clear channel assessment and the lower level of use of the 5-GHz spectrum by WiFi than a 2.45-GHz spectrum. Those opposed suggest that potential interference is being understated.

Analysis

It is usual for policy to be driven by evidence. It is also usual that spectrum management policy does not respond to technology changes until the change becomes well established. There are good reasons for this as the alternative would be for regulators to try and respond to every technological change, regardless of uptake. The problem for spectrum management is that there is very rapid, standards-based development in the area of mobile broadband and a significantly slower rate of development in areas such as the fixed satellite service. This means that the risk of a too slow response of spectrum regulators may be higher than the risk of over-responding. A critical issue with evidence-based policy is that “Policy decisions emerge from politics, judgement and debate, rather than being deduced from empirical analysis” (Head, 2008).

HetNets provide a good example of the reason for measured and delayed response. In the case of a licensed spectrum, the use of HetNets has very little effect on spectrum licensing policy. No adverse effect flows from the fact that the licensing regime does not comprehend that a spectrum may be being aggregated or that large cells and small cells are providing concurrent coverage in a single geographic area. There are benefits to both the mobile network operator and the consumer of broadband services that flow from HetNet deployment in a licensed spectrum. The article has demonstrated that there are at least three alternative ways in which new HetNet deployment can be licensed. There is no policy change required to implement any of these.

The management of an unlicensed spectrum is more problematic. The premise on which a spectrum is made available on an unlicensed basis is that there should be no expectation of protection. The spectrum is made available on a “commons” basis, with users sharing without spectrum management. The issue that flows from the use of LTE-U and its variants to implement HetNets is that the commons concept is disturbed if a substantial portion of the unlicensed spectrum in a given band is now managed by the few mobile network operators that exist in any jurisdictions. Commons spectrum management makes the implicit assumption that there are many users rather than a few. It does not matter whether the many users are offering services for a fee, but if a few large operators control a significant proportion of the devices using a commons band, then assumptions upon which the band is managed are invalidated. The problem is compounded in the 5-GHz band by the existing deployment of WiFi services. It raises the problem as to whether the regulatory or policy response is to provide protection for services that do not currently have protection from interference or to let the commons decide, with the associated risk of “tragedy”.

If the problem was merely that of managing a commons, this would be a low-order issue. However, the effect of large-scale managed networks in an unlicensed spectrum is to adversely impact the spectrum regulator in its other roles. The creation of an information asymmetry changes the understanding of the spectrum regulator in relation to spectrum demand. The impact of this adverse effect is that spectrum assignment will become less efficient. The spectrum regulator may assign too early and inefficiently or too late and inefficiently. If the assigned spectrum is tradable, the consequences of these errors may be mitigated to some extent.

It would be feasible for mobile network operators to be required to share information regarding their spectrum needs. However, the incentives to do this are limited. Instead, a more practical approach would be for a relevant body, such as the body which represents the interests of mobile operators worldwide, the GSM Association, to develop a reporting framework for use of LTE-U that removes the asymmetry created by the use of an unlicensed spectrum. Spectrum regulators would then use this standard report in determining the spectrum demand. However, this would be a new obligation for the GSM Association, and there are no clear precedents for this type of framework. Another alternative would be the standardisation of the reporting framework by 3GPP. Regardless of the standardisation body, spectrum regulators would still need local mobile network operators to appropriately deliver the reports.

Of course, removing the asymmetry only resolves part of the problem. If there is to be wide-scale use of an unlicensed spectrum to deliver services, there will need to be technological controls to ensure that WiFi services are no more adversely affected than would be expected from the next release of IEEE802.11. The pressure on the spectrum regulator here is more likely to be a political one. The risk that arises from such political pressure is that the regulatory intervention will impose some form of licensing regime on a spectrum which is currently lightly regulated.

Conclusions and recommendations for further work

This article has provided an introduction to some of the spectrum policy issues that flow from the deployment of HetNets. In broad terms, the deployment of HetNets using a licensed spectrum can be regarded as "business as usual" from a spectrum policy perspective. HetNets are deployed to increase the productive efficiency of a mobile network operator's 4G network. The effect from a user perspective is that data throughput is improved, even at the cell edge. Although spectrum licensing regimes are not likely to recognize the cross-band aggregation that is occurring in the network, no adverse effects flow from this. The benefits to both operator and consumer are likely to drive demand, so the deployment of HetNets in a licensed spectrum is unlikely to alter demand levels significantly.

On the other hand, the deployment of HetNets which use an unlicensed spectrum for part of their delivery can raise issues for spectrum regulators. In particular, the introduction of LTE-U and its variants can adversely affect the spectrum regulator's visibility of demand. The spectrum regulator will also need to be able to deal with potential interference to WiFi networks, despite the fact that they use a spectrum where there is no assumption of protection from interference.

A problematic issue that arises in the examination of potential policy issues for HetNets is their novelty. As Adams *et al.* (2015) point out, the formation of policy is triggered by "people trying to work out what they should do about a problem". The issue here is that the standardisation of 5G will be based on the deployed LTE solutions. As LTE-U is already part of 3GPP Release 13, it may already be deployed by those mobile network operators that would find it beneficial. It seems reasonable to suggest that future work will need to focus on reversing the information asymmetry that flows from such deployments. The regulatory challenge will be to address the issues before interference with WiFi services becomes a political issue.

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