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Regulation role in Wi-Fi congestion

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Abstract

Given the ever increasing number of Wi-Fi devices in use by the public, the progressing urbanisation, and the current attempts by the industry to improve Wi-Fi system performance, we here analyse the case of apartment blocks with residents increasingly suffering from Wi-Fi over-congestion. Here, individuals use private Wi-Fi networks in an "in house" environment to achieve cordless connectivity to the Internet. We show that Wi-Fi in apartment blocks is a true commons and, therefore, over-congestion can only be avoided by having the individual access

> point (AP) operators collaborating with each other. We found that such collaboration is not inhibited by current regulation, but neither can it be enforced. However, as AP operators will most likely enter collaboration voluntarily, further regulation is not deemed necessary.

Introduction

Over the last decade, the use of portable devices has spectacularly increased. Wi-Fi connectivity has proven to be a primary asset of these devices. The Wi-Fi Alliance estimates that more than 8 billion Wi-Fi devices are currently in use around the world (Wi-Fi Alliance, 2017). Gartner expects that this number is going to increase much further, up to 21 billion devices, including not only tablets and smart phones, but ever more other types of embedded devices (called ?things?) such as smart wearables and smart meters (Plummer et al, 2016 [6]). Many of these things will have to operate within homes. By 2020, according to Gartner, 20% of homes in the US will be connected homes containing more than 25 things accessing the Internet (Plummer et al, 2016 [6]).

Also technologies other than Wi-Fi, such as Zigbee and Bluetooth, are increasingly used to connect these devices with each other and the Internet. These technologies have in common that they use so-called unlicensed or Class Licence spectrum: in most cases, individuals do not need to obtain a special licence before they can operate such wireless devices or access points (APs). The downside of this arrangement is that other operators may use these frequencies as well, also within the range of the network of the first operator, and as such introduce mutual interference, negatively influencing the performance of the networks involved.

This problem is well known to the industry, but so far it has not stopped the market surge of Wi-Fi and Bluetooth in particular. This is largely because the problem is not felt as long as the density of networks is low, i.e. as long as there are not too many networks operating concurrently within the same frequency band and within the same general location. This has certainly been the case for Wi-Fi and Bluetooth since they were invented in 1999, due to their relatively short range of about 10?20 metres indoor, which is largely determined by transmission power being capped by regulation. However, this relatively undisturbed existence is rapidly changing, not only because the number of wireless devices per household is increasing, but also because of the ever continuing urbanisation and densification of the cities.

In 2014, 54% of the world?s population was urban, a number which is expected to rise to 66% by 2050 (United Nations, 2015 [7]). In Australia, 22 million people will be living in cities by 2020, an increase of 38% since 2000. In addition, most cities are executing policies of urban consolidation. Melbourne, for instance, aims to reduce the proportion of new development occurring at low densities on Melbourne's fringe from about 60% of annual construction to 40% by redirecting new development to defined areas of established inner and middle-ring suburbs (Melbourne 2030, 2002 [8]). As a result, more and more Australian residents are living in apartment blocks. Indeed, in the first three months of 2016, 29,987 apartments commenced construction in Australia, a number that for the first time in history overshadowed the figure registered for houses (25,122) (ABS, 2016 [9]).

Although there is plenty of anecdotal evidence that many users are already experiencing Wi-Fi congestion problems in densely built-up areas, and suffer from serious performance degradation as a result (Ozyagci et al, 2013 [10]), surprisingly little research has been done so far to quantify the pervasiveness and severity of the problem (De Vries et al, 2013[11]), let alone to solve it. The European Horizon 2020 project ?Wi-5? (Wi-5, 2015 [12]) recently produced the first quantitative evidence of this issue (Den Hartog, Popescu et al, 2016[13]). It also proposes an architecture based on an integrated and coordinated set of smart solutions aimed at the efficient reduction of interference between neighbouring APs (Bouhafs, 2015 [14]). But as other authors have concluded before (De Vries et al, 2013[11]), a solution can only be successful in the market if the issue is treated as a joint engineering, regulatory, and economic problem.

In this article, we focus on the regulatory aspects of Wi-Fi congestion in apartment blocks. Here, individuals use private Wi-Fi networks to achieve cordless connectivity to the Internet in an "in house" environment, instead of receiving a public Wi-Fi service from a commercial Service Provider. In the following section we describe the problem at hand in economic as well as technical terms. We then show that, from an economic perspective, we are dealing with a typical example of the Tragedy of the Commons. As a consequence, a solution can only be formulated in terms of some form of coordination among the APs' operators. We first give a simple example of how this could work in practice, and then postulate a generic business model for the more complex cases. We then treat the regulatory aspects of this business model in more depth, especially from the perspective of European and Australian spectrum access and antitrust laws.

Congestion of Class Licence spectrum

Spectrum commons

Much literature has been written on the question if spectrum for wireless communication is a common or a public good, or even a private good or a club good. Currently, most of the radio spectrum is managed and regulated by governments in a command-and-control fashion, i.e. spectrum is treated as a public good. A brief history on how this has evolved over the decades is provided by Peter Anker (Anker, 2017 [15]). In practice this means that national regulators are the centralised authorities for spectrum allocation and usage decisions. The usage is often set to be exclusive: each band is licensed to a single provider, thus maintaining interference-free communication. To enable international business and operation, national governments try, not always successfully, to standardise their policies in the ITU-R (International Telecommunication Union ? Radiocommunications sector). In Australia, spectrum is regulated by the Australian Communications and Media Authority (ACMA). The Australian Government and ACMA follow the recommendations of the ITU as far as practical but not necessarily exclusively.

For the first time in 1947, the ITU-R set aside a number of frequency bands for the use of industrial, scientific and medical (ISM) purposes other than telecommunications. This allows devices that use RF for the purpose of heating (e.g. microwave ovens), medical diagnostics, etc. to ?leak? radio waves as long as specified limits on transmit power are not exceeded. Operators of such devices do not need to acquire a licence. Well-known worldwide ISM bands include the frequency ranges of 2.4-2.5 GHz and 5.725 GHz - 5.875 GHz. As these ISM devices typically only emit and do not (intend to) receive signals, the ISM spectrum is rather a dump than a commons.

This changed in the 1980?s, when communication systems were also allowed to use these ISM bands, under strict limitations such as the use of spread spectrum and listen-before-talk technology. In the US, this type of use is regulated by the Federal Communications Commission (FCC) in the Code of Federal Regulations, Title 47, Part 15 (GPO, 2016 [16]), and is called ?unlicensed?. As a consequence, the frequency bands used by these devices became popularly known as ?unlicensed spectrum?. In contrast to the original use of the ISM band, the unlicensed spectrum is a commons which every communication device operator can use at its own discretion, whilst having to accept the interference caused by other devices. The regulatory and economic aspects of these commons have been discussed and analysed by many authors already, also in this journal, especially in the context of public Wi-Fi deployment (De Vries et al, 2013 [11]; Weiser & Hatfield, 2005 [17]; Speta, 2008 [18]; Reed & Lansford, 2013 [19]; Potts, 2014 [20]; Goggin, 2014 [21]; Lambert et al, 2014 [22]).

Interestingly though, when discussing public Wi-Fi, Jason Potts (Potts, 2014 [20]) concludes that Wi-Fi is not a commons but a club good (Buchanan, 1965 [23]), as it is excludable (access can be denied) and non-rivalrous (access by one does not exclude access by others). The latter, though, is a consequence of the fact that the roll-out of public Wi-Fi by competing instances is regulated by governments by means of issuing Carrier Licences. In Australia, as in other countries, under the Telecommunications Act 1997 (Telecommunications Act, 2016 [24]), every owner of a Wireless Local Area Network (WLAN) network unit must have a Carrier Licence if the network unit is used to supply a carriage service to the public, i.e. to people outside the immediate circle of the network unit owner. This is not how Wi-Fi-enabled home gateways and other customer premises equipment (CPE) are typically used, and thus this rule does not apply.

Nevertheless, Australian law requires that all radio communications transmitters must be operated under the authority and in accordance with the requirements of a radio communications licence. This includes Wi-Fi devices and other devices operating in the ISM bands. So, technically speaking, unlicensed bands do not exist in Australia. For the majority of low-powered transmitters, the relevant licence is a so-called Class Licence, in this case the Radiocommunications (Low Interference Potential Devices) Class Licence 2015 (ACMA, 2016 [25]). This is a licence for which an operator does not need to apply and for which no licence fees are payable. Under a Class Licence, all users share the same spectrum segment and are subject to the same conditions. And as Wi-Fi-enabled CPE operation is Carrier Licence exempt, the Class Licence spectrum in densely populated residential areas such as modern apartment blocks, can be treated as a spectrum commons: it is non-excludable (resident A cannot forbid resident B to have a Wi-Fi home network), and it is rivalrous (if resident A uses his Wi-Fi, it will have a negative effect on the performance of the network of resident B due to interference and congestion).

Wi-Fi

Today, IEEE 802.11-2016 (IEEE 802.11, 2016 [26]) is the main standard for WLANs, and the main implementations of IEEE 802.11 currently on the market are known as Wi-Fi. It includes all amendments to the original IEEE 802.11 standard from 1997, including IEEE 802.11b (?.11b?), IEEE 802.11g (?.11g?), IEEE 802.11n (?.11n?), and IEEE 802.11ac (?.11ac?), which are now commonly found in many households. Versions .11b and .11g operate in the 2.4 GHz ISM band only. Depending on the nationally specified width of the ISM band, these standards divide the band into 11-14 heavily overlapping channels. Every .11b or .11g WLAN is working on one of these channels, which is manually configured or auto-configured by a frequency selection algorithm in the AP. Only 3 channels can be chosen such that they do not overlap, e.g. channel 1, 6, and 11, or 1, 7, and 14.

The newer extensions of the standard, .11n and .11ac, also specify operation in the so-called 5 GHz band. This band stretches from 5.150-5.875 GHz. Technically speaking, it is not a single band though. The upper part of the band (5.725-5.875 GHz) is an ISM band, whereas the lower part is divided up into a multitude of sub-bands for which different rules apply regarding the maximum transmit power, indoor or outdoor use, how to implement channel bonding, and the obligation of implementing radar signal avoidance mechanisms such as Dynamic Frequency Selection (DFS) and Transmit Power Control (TPC). These regulations also differ slightly from country to country. As a result, most vendors have implemented only the lower four channels, i.e. a single band for which the requirements are everywhere the same.

Wi-Fi congestion and over-congestion

In 2013, Jean Pierre de Vries and co-authors published a comprehensive overview of the literature on Wi-Fi congestion, and concluded that excessive load is quite rarely observed, and very seldom well documented (De Vries et al, 2013[11]). Often, when authors want to indicate the existence of congestion, figures similar to Figure 1 are shown. Figure 1 shows how many different APs, operating at different channels, are concurrently using the 2.4 GHz band, as observed in January 2017 with the tool inSSIDer (Home Version, version 3.0.7.48, MetaGeek), in a large apartment block in Belconnen (Canberra), Australia. In this case, 69 APs were found to be using overlapping channels. The measuring laptop was attached to the NetComm Wireless Service Set Identifier (SSID).

[27]

Figure 1. A typical example of, per AP, the signal strength (dBm) vs. Wi-Fi channel number in the 2.4 GHz band, as observed in a densely populated apartment block.

But figures such as Figure 1 do not evidence actual congestion. Wi-Fi systems apply a Media Access Control (MAC) communication protocol with which they ?listen-before-talk?, i.e. they try to send traffic only when they perceive the media as being ?free?. Congestion happens when an AP perceives all channels as being occupied with traffic virtually all the time. Wi-Fi?s MAC protocol then still allows that AP to transmit, due to its random-back-off mechanism, but ultimately the total capacity will be shared with the other APs, and the performance (achievable throughput) of every individual AP will go down.

Congestion is not the same thing as interference. In the case of congestion, the AP recognises the received signal as Wi-Fi traffic emitted by other APs (or by devices communicating with those other APs). The MAC layer protocol then steps in and controls when APs and devices that can sense each other may have access to the media. When the AP does not recognise the received signal as Wi-Fi traffic, it registers it as interference or noise. Interference is typically caused by ISM devices in the neighbourhood, or devices using a different communication protocol such as Bluetooth or Zigbee (Zhang & Shin, 2011 [28]), or Wi-Fi devices emitting on different but overlapping channels.

An important property of commons is that if access to it is unlimited, it may lead to the so-called Tragedy of the Commons (Lloyd, 1833 [29]; Hardin, 1968 [30]). This is a situation within a shared-resource system where individual users acting independently according to their own self-interest behave contrary to the common good of all users by depleting or spoiling that resource through their collective action. As an apartment block is typically inhabited by a limited number of users, this situation does not seem to apply. However, the amount of devices that each user is operating at any given time is virtually unlimited, and if these devices interfere with each other, the Tragedy will take effect: all devices will operate at their maximum transmit power level in order to achieve an acceptable performance, and as such, ruin the media for each other.

Contrary to popular believe and what many authors have assumed so far (De Vries et al, 2013 [11]; Reed & Lansford, 2013 [19]; Nguyen et al, 2016 [31]), the effect called ?Wi-Fi congestion? is *not* an example of the Tragedy. Adding APs to an apartment block does not *per se* reduce the overall Wi-Fi system capacity. As explained before, it rather just redistributes the available capacity over the operating APs and devices. In many cases it even enlarges the total available capacity slightly, as not every AP will be interfering equally as much everywhere in the apartment block. Certainly, if resident A has two APs, and resident B has only one, resident A may enjoy twice the capacity of resident B, causing resident B to buy his own additional AP. But that in itself does not deplete the commonly available resource.

But then, in 2013, Ozyagci, Sung and Zander (Ozyagci et al, 2013 [10]) showed that a system consisting of a continuously increasing number of Wi-Fi APs in an indoor environment will ultimately end up in an *over*-congested state. The difference between mere congestion and over-congestion is schematically depicted in Figure 2, which we copied from Ozyagci et al?s article. A Wi-Fi system in an over-congested state uses an increasingly larger portion of the total available capacity for control traffic generated by the MAC protocol trying to mitigate the traffic congestion and packet collisions. The end result is actual depletion of the common resource. We therefore conclude that the Tragedy of the Commons does not apply to Wi-Fi congestion, but it does to Wi-Fi over-congestion.

Although Wi-Fi over-congestion is less common than Wi-Fi congestion, we recently showed that even if residents have only one AP and a few devices in operation per apartment, the system can be in a state of over-congestion at peak times, if the frequency planning is done badly (Den Hartog, Popescu et al, 2016 [13]). The conclusion for the short term is evident: operators and users should immediately stop trying to solve their Wi-Fi performance problems in densely populated areas by just adding APs and repeaters.

[32]

Figure 2. Wi-Fi over-congestion: decline of the area throughput (total available bits/s/m^2) of an indoor Wi-Fi system consisting of a number of APs (WLANs) with increasing number of APs beyond the point of congestion (Ozyagci et al, 2013 [10]).

It is also a popular belief that migrating Wi-Fi systems to the 5 GHz frequency band and adding MIMO (Multiple-Input Multiple-Output) technology will alleviate the situation (Reed & Lansford, 2013 [19]). However, as long as vendors are not inclined to enable operation over the full frequency range available in the 5 GHz band, that alleviation will be short lived. In Figure 3 we show the observed signal strength vs. Wi-Fi channel number in the 5 GHz band, as observed in a high-rise building in The Hague, The Netherlands. Apparently, many channels are already occupied by multiple APs. Besides, as long as the demand in Wi-Fi connectivity seems to be growing faster than governments are adding capacity in the form of Class Licence spectrum, over-congestion will be a reality. Interestingly, the current approach of the industry to mitigate this issue is to improve frequency agility techniques (Sarijari et al, 2014 [33]), i.e. have a system automatically avoid frequencies which are already in use. This is not going to solve anything. It just surrenders the commons to the first and strongest players.

[34]

Figure 3. Relative signal strength vs. Wi-Fi channel number in the 5 GHz band, as observed in the head office of TNO in The Hague, The Netherlands.

Collaboration

A simple example: frequency selection

Most scholars studying commons economics agree that the first step towards a solution should be to stimulate players to design a form of self-regulation, i.e. come to a consensus about how the resource can be distributed as fairly as possible. How this could work in practice is illustrated by the following example. Imagine two close neighbours, residents A and B, both operating a Wi-Fi WLAN. Assume that the only parameter they have under their control is the selection of the frequency channel. Residents A and B observe that they both operate their WLAN at overlapping frequency channels. They decide to come to a consensus on who is going to reconfigure their AP to another, non-overlapping channel.

From a regulatory point of view, a number of questions then arise, including:

1. What is the legal status of such a deal; can it be enforced?
2. Imagine that residents A and B run competing businesses from home; is such a deal then legally allowed from an anti-trust perspective?
3. Imagine that resident A runs a business from home, and resident B does not; is resident A allowed to pay resident B to obtain an exclusive right to use a particular frequency, and how can the right price for such a deal be determined?

Asking these questions seems to be rather exaggerated in the context of this simple example, especially from an anti-trust perspective as regulators routinely target only large companies, but the reality of an apartment block is far more complicated.

Introducing the Spectrum Usage Broker and the Wi-5 System Operator

In the case of an apartment block, there may be more than a hundred residents, who do not necessarily know each other or have good relationships with each other. They may not be technically knowledgeable enough to be able to configure their AP. And apart from frequency channel, there are various other parameters that could be tuned in order to optimise the use of the spectrum, including transmit power and the ability to hand over devices to other, more suitable APs (horizontal handover) or even to a mobile network (vertical handover, reverse off-loading). Including these parameters as variables makes the process of consensus formation and the actual execution of the policy a task too complex to achieve without professional and automated assistance.

In the Wi-5 project we therefore introduced a generic business model with two new actors or business roles (Den Hartog, Kempker et al, 2016 [35]). They are the Spectrum Usage Broker and the Wi-5 System Operator. The Spectrum Usage Broker devises and maintains sensible spectrum sharing strategies between AP operators in a cooperative context. This may include a pricing agreement. The Wi-5 System Operator is in charge of operating a technology platform needed to automate the execution of the spectrum sharing strategies as devised by the Spectrum Usage Broker. An architecture of such platform is provided in the Wi-5 project deliverable D2.4 (Bouhafs, 2015 [14]).

In the use case of the dense apartment block, the new business roles could be implemented as follows. An apartment block has many other commons available to the tenants: hallway, joint garden, parking lot, etc. (depending on the details of the arrangement they may be club goods, but this does not alter our line of reasoning). Spectrum can be dealt with just as the other commons: tenants make mutual agreements about its use, and a caretaker has to execute the agreements. The making of the mutual agreements can be facilitated by the Owners? Corporations or the building?s Body Corporate, which is often an official entity, and tenants already pay a mandatory yearly subscription fee to their Corporation. The Corporation thus fulfils the role of Spectrum Usage Broker, and tries, within the bounds of regulation, to broker fair shares of the spectrum for every Local AP Manager. It may be aided in this task by a Code of Practice to be developed by, for instance, the Australian telecommunications self-regulatory body Communications Alliance.

After the Spectrum Usage Broker successfully matches the offer and demand of spectrum / capacity in the apartment block, the resulting policy is then handed to the Wi-5 System Operator, i.e. an entity that can control the individual APs. This could be an independent subcontractor, e.g. an IT company specialised in running a Wi-5-type platform, possibly ?as a service? from the cloud. It could also be one of the broadband access providers servicing the apartments. Many access providers already have the knowledge and technology in place to take up such an additional role.

Regulation

Spectrum access

As said before, the use of, or access to, Class Licence spectrum for communication services is regulated in the national laws for telecommunications. In Australia, this is the Radiocommunications (Low Interference Potential Devices) Class Licence 2015 (ACMA, 2016 [25]). In the European Union, Commission Decision 2006/771/EC (EC, 2006 [36]) and Commission Recommendation 2003/203/EC (EC, 2003 [37]) apply. Two important aspects of the access rights are:

1. Usage on a non-protected basis: operators should accept the risk of interference between different users;
2. The use of the spectrum is not subject to individual rights; the spectrum is made available on a

non-exclusive basis.

Stated differently, everybody has the fundamental right to access the spectrum anytime and anywhere, but has to accept possible interference from other users. This means that, in our use case of the apartment block, entrants such as new residents cannot be forced to participate in the collaboration, as this would equate to making the spectrum excludable, i.e. turning it into a club good where the Owners? Corporation is the club. This means that entrants should be enticed rather than forced to participate in the collaboration scheme. While assuming that all players act rationally, this will be achieved if joining the collaboration leads to lower operational costs and/or better network performance for all players involved. Said otherwise, their business case should be attractive. The Wi-5 project is currently carrying out simulations applying a combination of cooperative and non-cooperative game theory to establish the benefits of defecting the collaboration, and to find out how many defectors our collaboration scheme can handle before it falls apart completely. Preliminary results indicate that collaborating is always beneficial in terms of obtained network performance (Van Heesch, 2016 [38]).

Another way of making the collaboration attractive is by monetising the right to access, i.e. resident A paying resident B to obtain an exclusive right to use a particular frequency. Although this may effectively lubricate the collaboration, resident A cannot force resident B to abstain from using resident A?s frequency. This is because resident A cannot claim any individual rights, even though they paid for it. Said otherwise, it is not possible to turn the common good into a private good. In 2014, this has been confirmed by the FCC in the US, which did not allow Marriot International Incorporated to interfere with and disable Wi-Fi networks established by consumers in one of Marriot?s conference centres, as Marriot claimed that within their premises consumers should only be allowed to connect to Marriot?s Wi-Fi networks (FCC, 2014 [39]).

Anti-trust

Finally, we need to consider whether a collaboration as described is legally allowed, even though it cannot be enforced. From the point of view of antitrust regulation, this only concerns the cases where the roles of Spectrum Usage Broker or Wi-5 System Operator are taken up by large market players such as nationally operating service providers. In the use case of large apartment blocks, this can be realistically expected for the role of Wi-5 System Operator.

In the European Union, antitrust is defined in the Treaty of Lisbon, Article 101,(EC, 2008 [40]) which prohibits ?agreements or concerted practices that limit or control production, or share sources of supply among undertakings?. The role of the Spectrum Usage Broker is to assign a source of supply (spectrum) to the different Local AP Managers in an area, which suggests law infringement. However, clause 3 of article 101 makes an exception for such ?agreements or concerted practices which contribute to improving the production or distribution of goods, while allowing consumers a fair share of the resulting benefit, albeit that such agreements or concerted practices do not limit or even eliminate competition in respect of the product.?

This exception seems to be applicable to the case at hand: collaboration enlarges the size of the available Wi-Fi resources, allowing wireless users a fair share of the resulting benefit, and as such contributing to the improvement of the production of goods for which Internet access is needed, without limiting competition in respect of the product. Nobody is suffering from this collaboration. In Australia, anti-trust legislation is provided by the Competition and Consumer Act 2010 (Cth) (CCA, 2010 [41]), and the cartel provisions in Part IV of the CCA amount to the same effect.

A final consideration is the risk of monopoly formation, as there is only one Spectrum Usage Broker and one Wi-5 System Operator in any given system. This risk can be mitigated by requiring these roles to be oversighted and/or executed by a not-for-profit organisation with transparent governance. In the case of the Owners? Corporation taking up the role of Spectrum Usage Broker, these requirements seem to come naturally. However, broadband access providers acting as Wi-5 System Operators may require such additional measures to be taken.

Conclusions

In this article we investigated the role of regulation in preventing Wi-Fi over-congestion in densely populated areas such as apartment blocks. From an analysis of the current trends in urbanisation, the number of Wi-Fi devices in use, the introduction of other technologies using the Class Licence bands, and the current approach that the industry takes to improve Wi-Fi system performance, we conclude that Wi-Fi over-congestion is unavoidable. Worse still, the currently popular strategy to solve performance problems by just adding APs and repeaters is only aggravating the problem in densely populated areas. Telecommunication service providers should immediately stop offering these ?solutions? to their city-dwelling customers.

Over-congestion can only be avoided by having the relevant AP operators collaborating with each other. This follows directly from our conclusion that, in contrast to public Wi-Fi, Wi-Fi in apartment blocks is a true commons to which the Tragedy of the Commons applies. Here, we also make a clear distinction between congestion, over-congestion, and interference. Contrary to what is suggested in the literature, congestion is not depleting the resource. It just redistributes it.

The current regulations regarding spectrum access and anti-trust do not inhibit such collaboration, but they make it impossible to enforce it. Participation should be voluntarily, and AP operators should be enticed to collaborate by means of a positive business case. Preliminary results from the Wi-5 project indicate that this is feasible. We therefore conclude that, in contrast to earlier papers discussing Wi-Fi regulation (De Vries et al, 2013 [11]; Weiser & Hatfield, 2005 [17]), that further regulation is most likely not needed. However, the actors devising, maintaining, and executing sensible spectrum sharing strategies between AP operators have a monopoly position and should be oversighted or regulated in the cases where these roles are taken up by large market players. We propose that Codes of Practices are to be developed for these roles by, for instance, the Communications Alliance.

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