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Prefer consistent connectivity to erratic high speed

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1. Why consistency is more important than speed

A consumer of fixed or wireless communications would be forgiven for imagining that speed is the only criteria of importance. Home and industrial fixed connections are sold based on data rates, with speed checkers available to test the rate received in practice. Mobile phone companies periodically advertise their record new speed while manufacturers developing advanced 4G or 5G solutions strive to deliver Gbits/s data rates. Can we ever have a fast enough connection?

Determining how much speed is "enough" is problematic. The speed that is sufficient at a given point in time for the services typically consumed can be calculated. However, new services may be devised that result in a greater demand for speed.

We can say that demand for the highest speeds and largest data volumes is almost invariably driven by video consumption. A person can only watch one video stream at a time, so understanding the number of people in a household and the data rates associated with the highest quality video feed required is a good current upper limit. This may increase in the future if higher resolution video grows (eg demand for 4k video) or if applications such as virtual reality demand more information. By way of example, 4k video requires around 20Mbits/s[2]. With three people in a home all simultaneously viewing different 4k feeds a data rate of 60Mbits/s would be needed. However, typically there are not three or more 4k-ready TVs in a house so in reality lower data rates would be sufficient.

A somewhat different question is the speed needed for instantaneous web browsing. The issue here is less one of absolute speed and more of "latency" – the time taken for a request (eg for a new page) to be sent to a server and a response received. Beyond a certain speed, other factors such as the maximum turn-around time at the server and the delays inherent in the Internet TCP/IP protocols become constraining[3]. This data rate is currently around 8Mbits/s (and hence most users will not notice an improved browsing experience once data rates rise above this point). Resolving this requires changes to Internet protocols and architectures – something that has to occur on an international basis within Internet standards bodies and key industrial players.

There is also something of a chicken-and-egg issue in that if data rates reach a point where the costs of increasing them further are very high, then developers will be aware of this and will not tend to develop applications that exceed this data rate. Hence, the point where a major technical or

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[2] For example, see Netflix recommended data rates https://help.netflix.com/en/node/306. Here they suggest 5Mbits/s for HD and 25Mbits/s for 4k UHD. Others expect coding efficiencies to improve and the UHD rate to fall, for example see https://www.videomaker.com/article/c12/17028-4k-video-streaming-issues .

[3] For a detailed discussion see https://gettys.wordpress.com/2013/07/10/low-latency-requires-smart-queuing-traditional-aqm-is-not-enough/ .

economic step change is needed to increase data rates can become self-fulfillingly "sufficient". Such a point is the speed that can be delivered without installing fibre all the way to the home, typically around 50Mbits/s although this varies hugely with factors such as distance from the cabinet and is likely to improve over time as new standards such as G.Fast[4] are deployed.

So the maximum current demand of around 60Mbits/s aligns well with maximum readily-available data rates of around 50Mbits/s. (This ignores rural areas where speeds can be much lower.) This may become a speed that is considered adequate for some time because:

- It is hard to envisage video resolution above 4k being of much benefit.
- No other applications that require data rates above 4k video are currently foreseen.
- Internet browsing will not be improved above these data rates.
- Application developers are unlikely to develop applications that require peak speeds beyond these rates, knowing that higher data rates are expensive.

In practice, demand may be very much lower. For a household with a single resident who has HD (rather than 4k) TVs, then 10Mbits/s will be perfectly adequate. This may explain why recent BT data suggests that only around 22% of those who could subscribe to BT's Infinity service have done so (Infinity takes data rates from around 10Mbits/s to around 50Mbits/s). It may also explain why, in those countries with extensive fibre-to-the-home (eg South Korea), few new applications appear to have emerged and there has been little obvious stimulation of local industry.

Broadband delivery also needs to be reliable. As we make more intensive use of connectivity the impact of connections that are unavailable, or erratic in speed, becomes greater. Fixed broadband generally builds on the copper line infrastructure which has proven highly reliable over time and so outages are rare. Because each home has a separate connection the variability in data rates is also generally small and where it does occur typically a problem at local exchange level or deeper in the network that can be resolved quickly[5]. Hence, our current fixed infrastructure appears broadly satisfactory reliable, the problems are more associated with wireless as discussed further below.

A separate question is mobile data rates. Typically, data rate requirements on mobile devices are much lower as the screen size is too small to make high definition video attractive. Further, only one person views a mobile, so unless the mobile device is used as a Wi-Fi repeater for a household then the maximum data rates needed for video are closer to 2Mbits/s[6]. This is below the speed needed for instantaneous web browsing and hence users may see a benefit of rates up to around 8Mbits/s. Beyond this, there is rarely any real benefit. Most 4G systems can, in principle, provide data rates well above this – as long as the mobile has a good signal strength and the cell is not congested.

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[4] Theoretical performance reported here https://en.wikipedia.org/wiki/G.fast suggests data rates of 500Mbits/s or more are achievable with FTTC deployment. BT is trialling the technology (eg see http://www.ispreview.co.uk/index.php/2016/03/bt-unveil-large-ultrafast-g-fast-broadband-pilot-fttp-trials.html) and suggests 330Mbits/s initially rising to 500Mbits/s by around 2017.

[5] This is less true of those connected to cable networks where the resource is shared. However, cable operators are enhancing their network with deeper penetration of fibre, reducing the degree of sharing in the network.

[6] Discussions with UK MNOs suggest that data rates can be reduced to around 700kbits/s for video streaming to handsets before users notice any degradation in quality. Data rates for tablets need to be somewhat higher.

Therein lies the problem – those criteria of signal level and lack of congestion are rarely fulfilled and so mobile connectivity often fails to live up to its promise.

So we are at a point where, if home broadband was at "fibre to the cabinet" levels for all (delivering around 50Mbits/s), if the Internet servers were always responsive, and if mobile users always had a good signal level in uncongested cells, then speed would be more than adequate for all of the applications commonly in use today. The problem is that all of these conditions are rarely met. The situation is similar to our road networks – we would like quicker journeys but the limiting factor is not the top speed of our cars but the capacity of the roads. That is why unpublished surveys and anecdotal evidence suggests that for many speed has reached the point where further gains are of limited value and what is becoming much more important is consistency[7]. Simply, most people would rather have satisfactory data rates available everywhere than they would have blinding fast rates in some places and a lack of any connectivity in others. Likewise, for most vertical applications – for example constant connectivity even at relatively low rates would be more helpful for autonomous vehicles than erratically available high data rates.

Of course, we might expect data rate requirements to grow over time – as they have done consistently ever since the introduction of the iPlayer on fixed networks and the iPhone on mobile networks. Equally, common sense tells us that requirements cannot keep growing forever – sooner or later we will have "enough". And given that we cannot consume multiple video streams simultaneously and that there are no applications envisaged that required higher data rates than high-quality video, then there is a reasonable probability that we have indeed reached the point of "enough speed". Specifically, data rates of up to 20Mbits/s per person in a home and around 10Mbits/s per mobile phone would seem to be sufficient.

Concentrating on consistency now that we have basic sufficiency of data rates is also more likely to improve productivity and social value – certainty of having a connection would enable new methods of business, better responsiveness, etc. Conversely, speed above 10Mbits/s are currently almost entirely used for entertainment which enhances pleasure but not productivity. With Governments looking to improve productivity, global competitiveness and more, a focus on consistency rather than speed appears appropriate.

Each of us will experience different connectivity issues, but broadly the key connectivity problems include trains, rural areas, inside buildings (including homes, offices, Government and public buildings), other transport such as buses (to lesser degree), and very dense areas such as London train stations. We consider each of these in subsequent sections.

[7] This begs the question as to why some MNOs still advertise the high speeds their networks can achieve. This appears to be "bragging rights" – using an attribute few care about directly to demonstrate the strength of the network. It is akin to car makers promoting high-performance models that few will buy.

2. How to deliver consistency

2.1. Introduction

True consistency is hard to deliver and hard to measure – there will always be a basement or remote area that does not have coverage. Better than a generic focus on consistency is to look at those areas where coverage or capacity is most obviously problematic. These include:

- Transport, specifically trains and to a lesser extent buses.
- Rural areas.
- Buildings including homes, offices and public buildings.
- Very dense areas such as major train stations.

We consider each of these below.

2.2. Trains

MNOs have been trying to provide good coverage within trains for many years, with variable success. Coverage problems tend to occur when any of the following happen:

- Cuttings or tunnels that block the radio signals from getting to the outside of the train.
- Metallised windows on carriages which create a block between the outside and the inside.
- High speed trains where handovers can occur so frequently that handover traffic dominates.
- Trains operating in dense urban areas where the demand for capacity is very high.

The best solution to most of these is a Wi-Fi repeater within the train – and indeed this is becoming increasingly widely deployed. A repeater overcomes the isolation problem caused by metallised windows – indeed it benefits from this isolation as it reduces any external interference which helps in areas with high demand. It also solves the handover problem as far as the devices inside the carriage are concerned as they stay registered onto the one internal Wi-Fi access point. It can also help somewhat with the problem of cuttings and tunnels by using an external antenna mounted on the roof of the train with much better performance than handsets within the train.

The repeater could also transmit cellular signals alongside Wi-Fi signals. However, this tends to be problematic because cellular transmissions have to be on licensed frequencies owned by the MNOs. Gaining their approval and then selecting frequencies that do not cause interference to their external network is difficult. The repeater becomes much more complex, having to cover multiple bands. Finally, for most users, data connectivity is more important than voice because they can then browse, receive emails and can make calls using voice-over-Wi-Fi solutions such as Skype and WhatsApp. The only problem is not being able to receiving incoming calls via the cellular network.

However, the repeater transfers the coverage problem to the backhaul connection between the carriage and the network. With many tens of users in a carriage, all able to use laptops or tablets, data rate requirements could readily exceed 500Mbits/s. That is beyond the capacity of most Wi-Fi routers and of most backhaul solutions. Backhaul to a carriage could make use of both cellular connectivity and satellite connectivity. The best solutions use both, relying on satellite when outside of cellular coverage. But neither satellite nor cellular can provide anything like 500Mbits/s. Instead around 10Mbits/s is more likely. And both fail in tunnels.

So to properly resolve coverage on trains a two-fold approach is needed:

- Wi-Fi repeaters installed in all carriages.
- Better backhaul coverage to carriages.

The first is an economic and logistical problem. There is a cost involved with the installation and it can only be performed when a carriage can be routed to a depot. This can only be solved by appropriate economic incentives (such as a requirement on franchise owners to provide repeaters) and by allowing sufficient time for carriages to rotate through depots or be replaced with newer rolling stock.

The second problem requires cellular base stations mounted alongside the track where they can provide good coverage along a length of line, especially into cuttings. It may require specialised solutions such as leaky-feeder cable installation, in tunnels. This has previously been problematic because each MNO needs such access and because restrictions on track-side working and deployment of equipment have made such base stations expensive and in some case intractably difficult to deploy. However, railway network operators generally manage to deploy their own base stations to provide cab communications. A requirement to share the infrastructure that they use to do this with a commercial entity that then deployed cellular equipment that all MNOs could utilise would be a potential solution. This equipment could be configured to provide optimal backhaul connectivity (rather than direct to the phone connectivity) with broad 20MHz channels and carrier aggregation.

These are predominantly logistical problems, requiring legislation and incentives on various players in the railway industry to resolve. They could materially improve train communications although even with these enhancements data rates beyond perhaps 100Mbits/s to the carriage are unlikely meaning that users on trains will have to accept low quality video streaming. That would still be a big improvement on the situation today.

2.3. Rural areas

Covering rural areas is predominantly a matter of economics. It could be achieved with widespread deployment of cellular masts but these masts would generate less revenue than they would cost to deploy and maintain. Hence, few if any mobile operators would voluntarily deploy. Getting better coverage could be achieved by:

- Appropriate financial incentives such as payment from the Government in return for achieving certain coverage objectives.
- Technology that enables a greater range from a base station thus requiring fewer base stations and so making the coverage more economic.

The first tends to happen indirectly using coverage obligations in spectrum licenses. However, a better approach might be to encourage MNOs and others to bid to achieve the required coverage. The Government would then select the best bid and pay the winner to deploy their solution. That could then be shared among all MNOs such that all subscribers gain coverage at the lowest cost to the Government.

Standards bodies have not tended to focus on technology that extends range as this is generally at the expense of higher data rates. The classic solution, used extensively in many IoT systems, is to use data spreading (known as “direct sequence spread spectrum - DSSS”) to increase the range at the expense of the data rate. This is precisely the solution used by GPS satellites to enable a low-power transmission from orbit to be received by small devices. Adding a DSSS mode into the standards would give operators flexibility to trade off data rate against range when it was appropriate to do so, facilitating rural coverage. Unfortunately, such a mode does not currently appear to be on the agenda of the key standards bodies.

2.4. In the home

For most, data coverage in the home is provided via self-deployed Wi-Fi, generally giving excellent data rates as long as the home broadband connection is acceptable, there is not significant Wi-Fi interference, and the signal level throughout the home is strong. Interference can often be addressed by changing channel and poor signal levels by using repeaters or better siting of the access point.

The issues are then cellular coverage and possibly coverage for visitors.

Cellular coverage can be important, particularly in receiving incoming calls. Outgoing calls can be made from the home cordless phone or using Wi-Fi calling apps. Various attempts have been made by MNOs in the past to get in-home coverage using femtocells but mostly these have failed because:

- Home owners do not want an extra box in the home.
- The solution is tied to one MNO (unless multiple boxes are installed) which makes switching harder and may not suit all members of the family.
- Integrating the home femtocell into the MNO’s network can be complex and expensive.

As Wi-Fi continues to gain traction it seems unlikely that femtocells will see a resurgence, instead ways around poor cellular coverage using Wi-Fi will be developed for the home.

Wi-Fi coverage for visitors can be achieved just by telling the visitor the password. This is workable but somewhat clunky and a more-automated process could be envisaged. This might be part of a broader solution to automate the process of signing into Wi-Fi access points and is discussed in more detail in the next section.

2.5. In the office

To a fair degree this is the same set of issues as in the home. Wi-Fi provides a good solution but cellular coverage can be poor. Femtocells and small cells have not proven widely popular and that seems unlikely to change. Using the same set of solutions as the home to provide Wi-Fi calling and a simplified way to gain passwords would resolve most issues.

2.6. In public buildings

Technically, public buildings are not materially different from office buildings (other than some, such as museums, can be larger and so more challenging to cover). Hence, as with the home and the office, the same solutions apply of relying on Wi-Fi. Administratively, this requires the deployment of

Wi-Fi[8] and a mechanism to enable easy access. If Government did deploy a universal password solution for public buildings, this might be of value in delivering universal password solutions more widely – for example the same solution could be adopted for homes and offices. Alternatively, Government could make use of developing solutions in the private sector.

2.7. Dense areas

Areas of very high user density such as major train stations and stadium present particular problems. Cellular solutions struggle to cope with the need for extremely small cells in often a very open environment where there is little to prevent interference from one cell to another.

In stadium there are specific Wi-Fi solutions where access points are deployed across the inside of the roof, providing targeted downward pointing beams that might illuminate only ten or twenty seats. Similar solutions could be deployed for cellular, but again it is difficult to deploy one solution per operator and the building owner may prefer to deploy a self-owned and operated solution rather than negotiate with the mobile network operators.

Similar solutions could be envisaged in train stations. At present, most Wi-Fi in these venue is provided by shop owners or similar in an ad-hoc manner and so tends to have poor coverage in some areas and to interfere in others. Centralising the planning and deployment of Wi-Fi would dramatically improve the situation. This would require agreement from shop owners, some of who might deploy specific solutions as part of their franchise (eg Starbucks access). As with railway coverage, it might take direct Government intervention to bring about an improvement in major train stations. In areas such as malls, there may be sufficient commercial self-interest from the mall owner to make centralised deployment occur.

2.8. Summary

Across the various solutions there have been a number of common threads, namely:

- Intervention from Government in aspects such a train franchises, Wi-Fi in major stations and trackside coverage to force through change and in awarding contracts for rural coverage.
- Sharing of infrastructure among all MNOs alongside train tracks and in rural areas.
- The addition of a DSSS mode in cellular to enable greater range for rural coverage.
- The ability for incoming cell-phone calls to be re-routed across Wi-Fi such that if there is no cellular connectivity people are still in contact.
- The ability for devices to be sent information on SSID and passwords rather than users having to ask for it and manually enter it. This could be generic (along the lines of OpenZone where any OpenZone customer can use the Wi-Fi router of any other customer) or it could be based on various criteria (eg allowing friends on Facebook access to the password, linking hotel booking made using a browser with a download of the Wi-Fi details, etc).

We consider these further in subsequent sections.

[8] The EC has recently proposed to make funding available to assist in such deployments, see COM(2016) 589 - 2016/0287 (COD), amending Regulations (EU) No 1316/2013 and (EU) No 283/2014 as regards the promotion of Internet connectivity in local communities.

3. A "Wi-Fi first" world

3.1. Introduction

Previous calls for enhanced coverage have mostly focussed on cellular, and previous efforts to provide widespread Wi-Fi "municipal" coverage have generally been seen as a failure. The steps set out in the previous section would move Wi-Fi back centre-stage in the world of communications. Is this plausible, and have lessons been learnt from previous attempts to deploy widespread Wi-Fi?

It is worth recalling that we already live in a Wi-Fi-first world. Over 85% of the traffic from our mobile phones flows over Wi-Fi and typically 100% of the data from tablets and laptops. Wi-Fi carries at least an order of magnitude more data than cellular, perhaps even two orders of magnitude. We typically own only one cellular-connected device but often five or more Wi-Fi connected devices. There are probably around 20 million Wi-Fi access points in the UK, only around 60,000 cellular base stations. A hotel or office without Wi-Fi would be seen as unacceptable, one without cellular coverage merely irritating. This is not to underplay cellular which has a critical role in providing coverage while on the move and will remain an essential part of our communications infrastructure for the foreseeable future.

There are good reasons why Wi-Fi is preferred in most cases. Cellular is expensive to provide and has inherently limited capacity. Wi-Fi is almost free to provide and we are still a long way from reaching the capacity of current systems. This is not because of technology or spectrum – both use near-identical technologies (OFDM) and have near-identical amounts of spectrum available to then (around 500MHz in total). The difference comes from the deployment model. Deploying coverage "inside – out" is much more efficient than "outside -in". With most data usage taking place inside buildings and with the outer walls of the buildings forming a partial barrier to radio waves, then delivering the radio signal from inside the building ensures users have a strong signal and takes advantage of the isolation provided by the walls to reduce interference to other users. Conversely, cellular systems have to aim to blast through the outside walls, delivering poor signals inside which reduce overall cell capacity, and result in interference between outdoor cells. In principle, cellular could deploy indoors too – and many attempts to do so using "femtocells" and similar have been tried. But the scale of the deployment challenge is beyond a single company and only achieved with Wi-Fi through the actions of millions of users deploying their own access points. Now that we have Wi-Fi widely deployed the rationale for also deploying cellular indoors is reduced and a self-fulfilling movement towards Wi-Fi only-devices has happened knowing that Wi-Fi connectivity is likely.

This is not to attempt to replace cellular. Wi-Fi can never provide connectivity in rural areas, along most roads and for most people when moving. Cellular is an essential component of our complete communications infrastructure, just not the best way to deliver the final elements needed for ubiquity in most cases.

The remainder of this section considers the changes and additions that might be needed to Wi-Fi in order for it to properly fulfil its central role.

3.2. Re-routing incoming cellular calls

For a device only connected to Wi-Fi (and not via cellular), while making a call is simple, the routing of an incoming call made to the cellular number can be problematic. It generally requires the MNO to receive signalling from the phone with details of the current connection and then to take appropriate action. Other options are possible. A simple one is to use a numbering scheme not tied directly to cellular which aims to contact the handset via Wi-Fi - effectively a Skype or WhatsApp "handle" acts in this manner. However, this may not be convenient for the user. Alternatively, the automatic divert on not-reachable for an incoming cellular call could be to a Wi-Fi access enabler to assess whether a voice-over-Wi-Fi call is possible.

Some regulatory intervention might be needed if MNOs refused to allow any access to their numbering systems or call routing functionality.

3.3. Automated passwords

It is normal for travellers to ask "what's the Wi-Fi password?" at check-in, even before they enquire about breakfast and other arrangements. Manually selecting networks and entering passwords is a workable solution but far from ideal. There are a number of reasons why password protection is used:

- To prevent those nearby freely using the resource and hence not having to pay for their own broadband connection. (Or similarly, to ensure only particular customers gain the benefit of Wi-Fi access.)
- As part of legal restrictions that may require password protection along with provision of identification in order to enable tracking of illegal activities (eg downloading copyright material).
- To make it harder for hackers to gain entry into the network.

There are also a number of approaches to facilitating entry:

- Common passwords across multiple access points such as all the stores in a chain of coffee shops or more broadly across all access points provided by a particular operator (BT's OpenZone is a good example of this).
- Devices that remember passwords and automatically sign into networks on a repeat visit.
- Use of other authentication mechanisms such as that within a cell phone to authenticate users.
- Use of techniques such as Hot Spot 2.0.

Partitioning of the access point can overcome many of the issues above. Having a separate part that others can access which has no direct connection to the owner's network and over which the owner's traffic has priority prevents concerns over hackers and makes free-riders less of an issue.

Modes of operation could be envisaged where an unknown device was allowed onto a network purely for the purposes of sending an automated registration request along with suitable credentials. A valid request would receive the password in response which would then allow full access to the network. Such modes, and other approaches are likely to steadily evolve over time and can be facilitated by Governments removing regulations that require identification of users for legal purposes. In the interim, we will need to continue to manually enter the password.

3.4. Security

Wi-Fi can provide excellent security as long as appropriate modes of encryption are used. The biggest threat is "rogue" access points which seem to provide connectivity but filter traffic, looking for passwords and similar. Many ways to resolve this could be envisaged such as:

- User applications encrypting data end-to-end to prevent a "man-in-the-middle" being able to extract important information. This is already done routinely.
- Use of a central validation server. For example, a Wi-Fi device could send the SSID and password used to this server along with other contextual information such as the SSIDs of other visible Wi-Fi nodes. This would allow the validation server to verify that the node was known and had been appropriately certified.
- Use of a system managed by a single company – again the BT OpenReach system is a solution to this.

There does not appear any significant security-related reason for Wi-Fi to adopt a more significant role.

3.5. Reliance on unlicensed spectrum.

Wi-Fi uses unlicensed spectrum that could, in principal, become congested or suffer interference. In practice, we have seen firstly that congestion builds slowly over years, allowing time for it to be addressed, and secondly that regulators have provided additional frequency bands, such as at 5GHz, when needed. In the future, any emerging problems will likely happen slowly and be addressed through regulation or similar.

This does imply that regulators should pay close attention to unlicensed spectrum. With a "Wi-Fi first" policy, spectrum for Wi-Fi becomes more important than that for cellular, and commensurate resources should be devoted to it. This might involve more monitoring to understand congestion and a preference to provide unlicensed spectrum over licensed spectrum. Statements suggesting that the regulator would address issues that reduced the efficiency of Wi-Fi as a matter of great importance would also help reassure users and investors.

More generally, a review of policy towards unlicensed spectrum and its role and value in the modern environment at both a national and international level would be appropriate.

3.6. Failure of municipal Wi-Fi

There have been various attempts to cover entire cities with Wi-Fi which have all failed, mostly because the scale of the challenge is large and the revenues small. The suggestion here is different – not to expand Wi-Fi coverage into areas where there already is cellular coverage, but to selectively deploy Wi-Fi, predominantly indoors, to provide consistency, funded mostly by Government in various ways[9].

[9] These might include direct funding, self-provision on Government buildings at Government's own cost and indirect funding via licence obligations on franchises and similar.

3.7. 5G

Much of 5G is focussed on higher data rates and much-increased capacity in dense areas. We have suggested here that the delivery of ever-higher speeds, above the 100Mbits/s already theoretically possible with 4G, is unnecessary. Delivering increased capacity in dense urban areas would be of value, but the key solution proposed of using small cells and microwave frequencies appears uneconomic and unlikely to address the majority of data users who are indoors.

Some elements of 5G are useful. The separation of control and data planes and the possibility of better linkage to Wi-Fi could help form a more seamless use of cellular and Wi-Fi networks. Similarly, the use of software defined networks (SDN) or virtual networks (VFN) could make integration with third-party systems simpler and faster.

3.8. Summary

In summary, cellular is already what we use when Wi-Fi is not available – it is our fall-back (and hence the reason we are not inclined to pay higher monthly fees for cellular connectivity). This approach to enabling consistency recognises and builds on this in a pragmatic manner.

4. Regulatory and Governmental action

4.1. Introduction

For such a world of consistent communications to happen requires Government action of various sorts, as listed earlier. Governments and regulators need to change policies away from those focussed on speed and towards those aimed at connectivity. This section considers those policies that are no longer needed and the new ones that should be started.

In considering policy and regulatory stance, some thought is needed as to potential industry structure under such a vision. At present consumers typically have a contract for their home line with a company like BT, and a contract for their mobile with a company like Vodafone. Wi-Fi is self-provided or they use multiple different hot spots run by various companies like Starbucks. Regulation is typically focussed on engineering as much competitions as possible. In mobile this is through maintaining three or four MNOs. In fixed it can be through unbundled access or other forms of competition above the physical access layer. Success of regulation is measured through access speed and consumer cost with some interest also in universal service provision on fixed lines.

In future, consumers might also add some form of Wi-Fi access enabler to their list of contracts. This could be a company like BT OpenZone actually providing hot spots in some cases, or like Google, providing passwords and certification of access points deployed by others. They may also have accounts with the Government for access in Government buildings. The majority of their data traffic might flow across this Wi-Fi network. Their phone may be provided by their Wi-Fi access enabler rather than their MNOs, pre-programmed to work effectively using voice over Wi-Fi solutions. Incoming calls might be routed first to the Wi-Fi access enabler and only onto the MNOs if access over Wi-Fi is not available. The contract with the MNO might even be handled by the Wi-Fi access enabler.

Shared network access is likely to grow. MNOs will deliver some of their services across Wi-Fi. Backhaul to Wi-Fi on trains might be delivered through a shared network owned by a third party but using spectrum from the MNOs. Similarly, a single rural network might be constructed that all MNOs use.

This is not a radically changed world, but it does have significant changes. Policies need to allow for the innovation and investment needed.

4.2. Policies no longer needed

Such a policy would render some regulatory and Governmental approaches unnecessary including:

- Fibre to the home initiatives and more generally a desire to be high in global speed league-tables. A universal service obligation set at around 10Mbits/s to the home is appropriate but broadly most home broadband needs can be met via solutions such as FTTC and then VDSL or G.Fast over the last drop. Requiring more in this area takes investment time and money away from areas such as universal Wi-Fi networks that incumbents are typically well placed to deliver.

- 5G testbeds and similar that focussed on high data rates. Instead, testbeds that improve integration between cellular and Wi-Fi, that demonstrate improved rural connectivity or better backhaul to trains would be valuable.
- Seeking competition among the mobile players – other providers may be more important and MNOs may be encouraged into network sharing in some cases.

Of these, broadband to the home (and office) is the most significant, with major national and international focus including at the EC in moving to a fibre-to-the-home world. A change in stance away from this will require huge effort, both in changing regulatory policy and in culture and communications.

4.3. Policies to be started

We have introduced the various policies that Government needs to embark upon in previous sections. These include the following areas:

- Investment in Wi-Fi networks in public buildings including museums, schools, hospitals, universities and offices in city centres. This includes not only the deployment of the access points but also the introduction or adoption of a universal sign-in system. This should be a relatively inexpensive investment, with access points purchased in bulk and installed by the buildings team.
- Investment in rural cellular coverage through awards of funds against specific coverage objectives.
- Obligations on railway franchise holders and possible also bus franchise holders to deploy Wi-Fi with accompanying obligations on track owners to work to enable effective backhaul provision.
- Potentially greater regulation for Wi-Fi in areas such as spectrum, security and with competition regulation for any Wi-Fi providers that might have significant market power.
- Potentially regulation to assist in routing incoming calls to Wi-Fi connected phones. This could be a modified form of number portability or similar.

Each of these are clear and can be embarked upon immediately. They typically do not require new legislation and the funding requirements are relatively modest.

5. Conclusions

This paper has set out how speed of data connection is now becoming less important than consistency – the ability to be connected at a reasonable speed everywhere. Rather than aiming for ever-faster connections it suggests that delivering enhanced coverage in a number of known problematic locations such as trains and rural areas would generate greater value for the economy and be preferred by most consumers.

In most of these locations Wi-Fi is a better solution than cellular, with the exception of coverage in rural areas. This reflects a trend that has been underway for years towards increasing use and reliance on Wi-Fi to the extent that it is now the preferred method of communication for most. Developing policies for a "Wi-Fi first" world is becoming increasingly important for Governments and regulators.

The end result – connectivity everywhere – would be one well worth striving for. A great road system is no longer one with unlimited maximum speed, but one with minimal congestion and excellent safety. A great communications system is one available everywhere, all the time with minimal congestion and at low cost. Time to re-focus.

Biography

William is a Director at Webb Search Consulting, a company specialising in providing the highest level of advice in matters associated with wireless technology, strategy and regulatory issues. He is CEO of the Weightless SIG, the standards body developing a new global M2M technology. He was President of the IET – Europe's largest Professional Engineering body during 14/15.

He was one of the founding directors of Neul, a company developing machine-to-machine technologies and networks, which was formed at the start of 2011 and subsequently sold to Huawei in 2014 for $25m. Prior to this William was a Director at Ofcom where he managed a team providing technical advice and performing research across all areas of Ofcom's regulatory remit. He also led some of the major reviews conducted by Ofcom including the Spectrum Framework Review, the development of Spectrum Usage Rights and most recently cognitive or white space policy. Previously, William worked for a range of communications consultancies in the UK in the fields of hardware design, computer simulation, propagation modelling, spectrum management and strategy development. William also spent three years providing strategic management across Motorola's entire communications portfolio, based in Chicago.

William has published 14 books, over 100 papers, and 18 patents. He is a Visiting Professor at Surrey and Southampton Universities, an Adjunct Professor at Trinity College Dublin, a Board member of Cambridge Wireless, a member of the Science Advisory Council at DCMS, other oversight Boards and a Fellow of the Royal Academy of Engineering, the IEEE and the IET. In 2015 he was awarded the Honorary Degree of Doctor of Science by Southampton University in recognition of his work on wireless technologies and Honorary Doctor of Technology by Anglia Ruskin University in honour of his contribution to the engineering profession. His biography is included in multiple "Who's Who" publications around the world. William has a first class honours degree in electronics, a PhD and an MBA. He can be contacted at wwebb@theiet.org.