Riot: tracking disruptive technology and its impact in industry

Anatomy of a 5G Smart City

What makes a smart city once 5G arrives?

Riot: tracking disruptive technology and its impact in industry

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1). Introduction

Ever-increasing urban migration and populations are going to put serious strains on cities that do not adopt technologies to accommodate the influx of people to their streets. New technologies like Software Defined Networking (SDN) will be key to supporting the massive scales required to manage growing populations—which threaten to overwhelm existing services. This month Riot talked to the City of Bristol, to try to work out what are the right ingredients to make your City truly smart. Bristol in the UK is hoping to find a formula that can power its next-gen citizen services, and eventually monetize those findings through licensing the technologies.

Each week, around a million people migrate to cities, in a trend that will continue for the next thirty years – meaning that by 2050, two-thirds of the expected global population of 9bn will live in cities. Many cities are already embracing smart city tech, with the likes of Singapore, London, Barcelona, San Francisco, and Tokyo usually populating the 'top smart cities' polls. Bristol's fiber network, which enables its SDN deployment, has allowed it to become a leading smart city in the UK—overtaking London by many measures.

Bristol is the largest urban area in South West England, and is situated about two hours' drive West of London. With a population of 454,000, the port city has a strong industrial heritage – both in transatlantic trade, and engineering works (many of which powered the UK's Industrial Revolution), and is also the home of Rethink Technology Research.

It is pursuing a smart city strategy via Bristol Is Open (BIO) - a project involving local and national governments, media companies, universities, and technology providers. Governed as a joint venture between the University of Bristol and Bristol City Council, long-term members can join the advisory panel that guides the project, and together they decide on the experiments carried out in the city.

The goal is to create an open and programmable city, which can give its citizens more ways to participate in the running of Bristol – via the data generated by the system. Termed 'City Experimentation as a Service,' Bristol Is Open is not so much a smart city, as a testbed to find the best ingredients for a smart city, not just for Bristol, but for its technology partners. This will allow it to manage its data and services, use an open and technology agnostic approach for its procurement, and share its findings with the wider smart city community via its adherence to OpenDaylight standards – a Linux Foundation project for software-defined networks (SDN).

Bristol's smart city project has its origins in ducting installed by cable TV company Rediffusion, originally used for putting TV into all the houses in Bristol around ten years ago. The ducts now house the fiber optic cabling that powers the Bristol is Open network – after Rediffusion went bust and the council bought up the underground assets—before smart cities were really a 'thing'.

The city began using the fiber for connecting council offices and depots, but in 2012, the national government's Department for Media, Culture, & Sports (DMCS) launched its Connected Cities funding initiative—and Bristol has used the cash to explore some bleeding-edge smart city approaches, which are explored here.

Participants:

BIO is led by the City Council and the University of Bristol. The Industry Partners are the next tier down, and consist of InterDigital (wireless and mobile developer), NEC (ICT product and service provider), and Nokia (networking specialist).

Joining as local host and ecosystem partners (LHEP) are fellow academic institutions; University of Bath, University of the West of England (UWE), and Bath Spa University. Other local councils that have joined at this tier include Bath and North East Somerset, and South Gloucestershire, and the West of England Local Enterprise Partnership (WELP – a regional business development organization).

The other LHEP partners are mostly local Bristol businesses, ranging from legal advisors to charities. The Supporters tier, the UK Department for Culture Media & Sports, Department for Business Innovation & Skills, the techUK development group, the government backed Digital Catapult and Future Cities Catapult projects, and the Open Data Institute.

Recent Projects—a quick recap:

The list of Supplier members will likely prove more familiar to non-Bristolian readers: Blu Wireless (wireless chips, specialist in 60GHz), Brocade (storage and networking equipment, now owned by Broadcom), Dell (IT services and products), Evans & Sutherland (digital planetariums), Hangzhou Huatai Optic (HFC broadband optical transmission equipment), Hitech Global (FPGA board provider), Infivision (video gateways), Laser 2000 (photonics provider), Mellanox (InfiniBand and Ethernet networking), National Instruments (testing equipment), and PLDA (PCI networking and FPGA developer boards). As you can see, having a strong fixed line underpinning is just one step, you still need a list of partners as long as your arm.

In November 2015, the Open Networking Foundation announced its support for BIO's Software-Defined Networking projects, which brought with it the support of the ONF members – which include Deutsche Telekom, Facebook, Google, Microsoft, and Verizon, and their enthusiasm for promoting open SDN technologies, like OpenFlow.

InterDigital joined the BIO project in December 2015, and a couple of months later, in February 2016, NEC Corporation signed up as a long-term partner, expanding on a previous Memorandum-of-Understanding that saw NEC supply BIO with IT and communications tech that included SDN-compatible network switches, LTE small cells, and iPASOLINK microwave systems.

In March 2016, Lund University researchers and National Instruments set a new world record for 5G wireless spectrum efficiency, using multiple antenna (MIMO) tech to create a base station with 128 antennae to achieve a 79.4 bits/Hz throughput that is akin to 1.59Gbps in a 20MHz channel in the 3.5GHz range. The MIMO demo was carried out at a Bristol University building, as part of BIO, and can be seen here.

Nokia joined the BIO project in October 2016, as did Zeetta Networks – both of which are covered later in this report. The next month saw BIO win the World Communications Award's smart cities contest, and then in February 2017, BT and BIO announced additional MIMO trials for 5G – which saw BT, National Instruments, and Lund University expand that spectral efficiency record to over 100 bits/Hz and exceed 2Gbps in a 20MHz channel.

The 5G testing is going to continue in the coming months – with a prominent test due to begin, although it should be noted that it is not a BIO project. Nokia, BT, and the University of Bristol will be firing up a 5G-based proof of concept test in March 2018, built in the city-center.

Using Nokia radio access points, BT spectrum (in 32GHz and 33GHz), and backhauled via the BIO fiber core, with plans to eventually expand the project into nearby Bath. Bristol is a somewhat unique testing ground because of that fiber core, which should be capable of supporting the huge potential bandwidths of 5G networks. Every other smart City out there has to contend with the issue of how can the City itself backhaul its own 5GG.

Huawei UK Smart Cities Index:

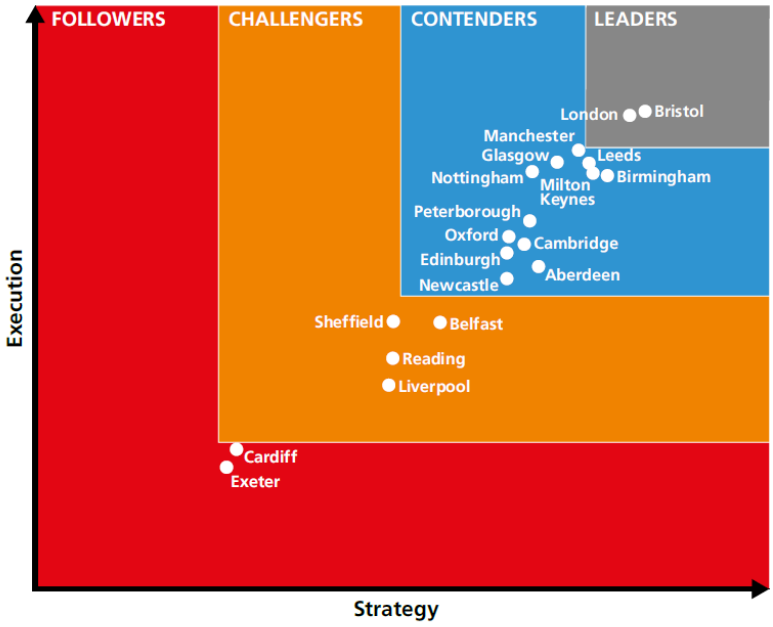
BT's Chief Architect, Neil McRae, said "we're gaining a real-world understanding of how 5G can be used within dense urban environments. This is crucial to building meaningful use-cases for future macro-scale 5G networks. 5G is teaching us that collaboration is essential." Work on developing the best methods for installing the high-frequency RAN equipment will be a priority, as the frequencies being targeted for 5G networks will support huge bandwidths, with the trade-off of very poor signal penetration.

Huawei named Bristol as top city in its UK Smart Cities Index, in a study carried out by Navigant Research. Published in October 2017, it aimed to compare the leading twenty smart cities in the UK – which were evaluated according to readiness, digital innovation, social care, urban mobility, energy, education, and sustainability.

To cut a long story short, Bristol edged ahead of London in the 2017 index, largely because of its strong momentum in the period – establishing its City Operations Center and improving its program integrations with the city operations. Bristol received the Star Award from Huawei for its IoT innovations, with the index noting "a unique environment for IoT testing, an extensive partnership ecosystem, and established pathways for scaling successful projects."

Bristol's notorious traffic problems mean it probably isn't going to appear in the Transport shortlist on the Huawei index for a while, but it did pick up a commendation in the Energy list. "Bristol has been another leader in the establishment of a city energy company, and is also examining the intersection of energy with other areas such as transport and housing." The upgraded open data platform in the city also drew the praises of the index, in the Data and Analytics shortlist.

Chart 3.1 - UK Smart Cities Index 2017



Source: Navigant Research

Huawei's index says the Bristol area has one of the largest concentrations of microprocessor and network architects, and strong creative and digital media sectors. Going against it are the city's social inequality, congestion problems, housing issues, and the need to improve skills and employability in its young people.

As for the state of smart cities in the UK, Huawei notes that one of the most fundamental reasons for investing in smart city tech is to deliver more efficient services. City transport is an area of focus here, both in terms of infrastructure improvements and in changing user patterns. Carbon emission reductions are another target, with most UK cities aiming for the planned 80% reduction by 2050 – but Huawei notes there are considerable variations in the short and medium-term targets for the national goal. Huawei says that Bristol's time as EU Green Capital in 2015 helped establish international credentials.

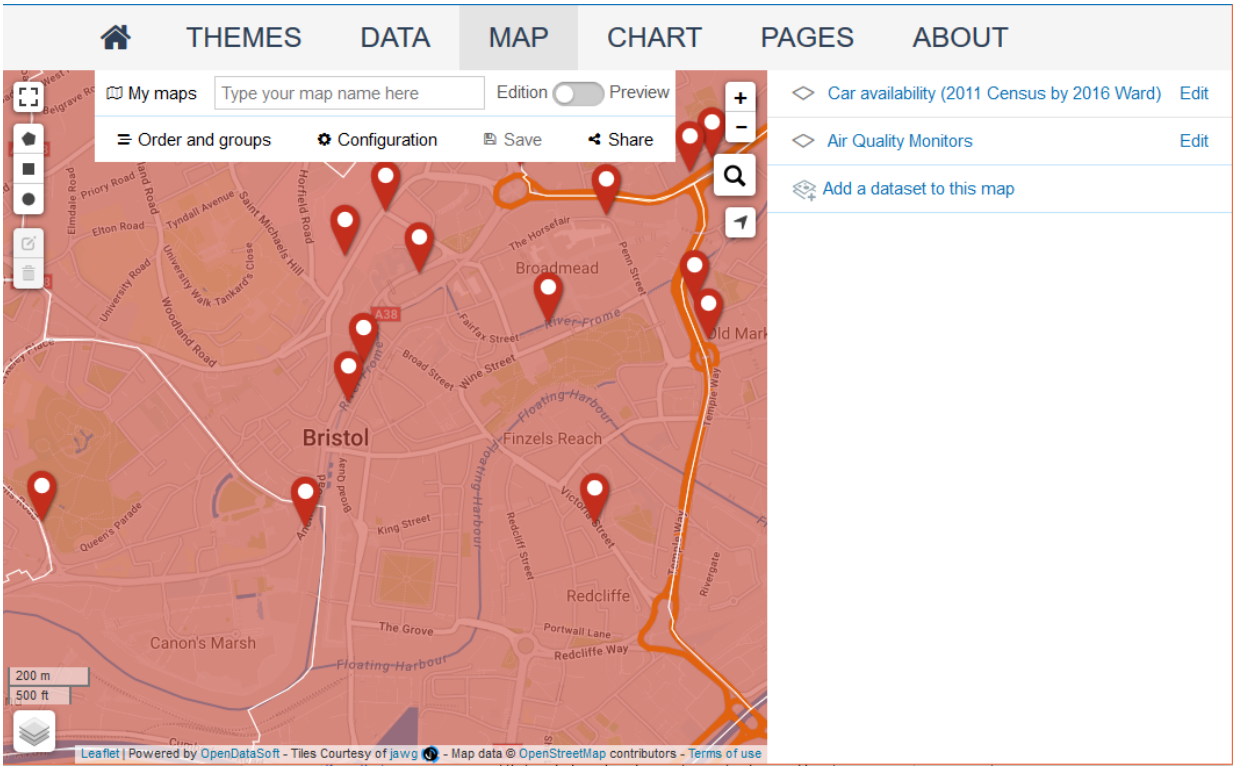
As for key initiatives, the Brunel Mile WiFi and LTE project, which will also play host to 5G trials, is cited, as well as the Silver Spring Networks' Wi-SUN RF mesh network deployed on 1,500 lamp posts. This combined network has plans for expansion over the wider region, eventually covering around a million people, reaching over Bath, South Gloucestershire, and North Somerset.

But Bristol's biggest achievement, in Huawei's eyes, is the creation of the City Operations Center (COC), which combines traffic management and control, CCTV, telecare services, alarm monitoring, and out of hours calls. Collectively, the COC currently handles 60,000 calls per month. With plans to add more operations to the COC, Huawei praises the plan to create a single place from which to control the city – with COC data being pushed to Bristol's Open Data platform.

Damp Busters, a sensing project that used a frog-shaped sensor to monitor damp and humidity problems inside rental accommodation, was also singled out for praise – part of the larger Citizen Sensing project. Real-time data to influence driver habits was also noted, with the city apparently having one of the highest levels of car use in the UK, and Autonomous Vehicle trials and EV charging stations are also part of this mobility focus.

The Open Data Platform:

Presented as a web portal, Bristol City Council's Open Data website is well worth some exploration. With 125 current data sets, the data can be exported or accessed via an API, allowing businesses and developers to use the data in their applications or research.
The data sets range from demographic information (ethnicity, religion, population), to social (deprivation, quality of life, child obesity), and information about the city (street light locations, road maintenance reports, trees, and public transport). There are other specialist APIs, such as a transport one, which require payment to access.



An example of the portal, mapping Air Quality over Car Availability, on a map

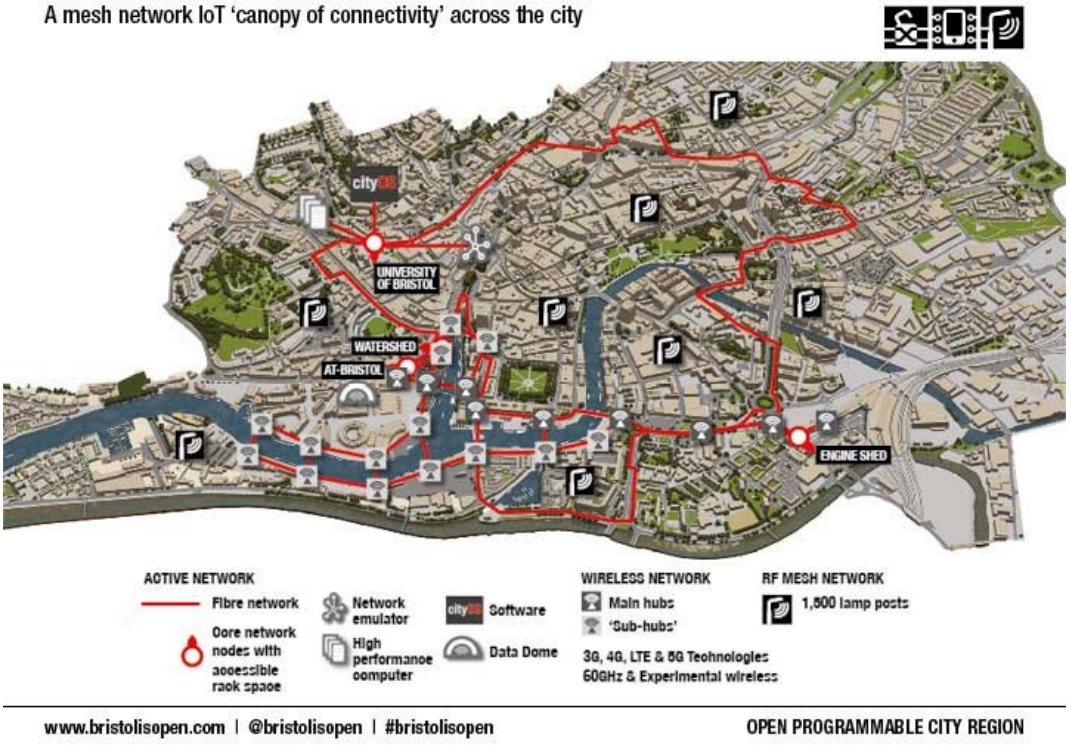
The council allows other stakeholders to publish data through the platform, but there is a process to go through and complete. The council's data is published under an Open Government License or Creative Commons, and does not contain personal, confidential, or commercial data – information which would prevent it being published in such a way. For the city, anything that isn't covered under the UK's Data Protection Act should be open.

2). Bristol is Open's Next Step

Bristol is Open has recently appointed Julie Snell as its new Managing Director. Seven weeks into the new post, and in the process of moving to the city properly, Snell is responsible for evolving BIO's bleeding-edge startup approach into one that creates a sustainable business model that can do more than experiment – using her experience in Vodafone and BT, and involvement in the early days of the Global Wireless Broadband Alliance. An end-goal is to create a model that is replicable in other cities.

When walking through Bristol, it is not easy to spot any clues that obviously give away the presence of the smart city technologies. Snell said that she would love to have thought it was a conscious choice in the early stages of BIO to make the installations invisible, but that it was more likely a pragmatic concession to the city's character – which wouldn't have liked lampposts becoming festooned with antenna and additional struts, like Christmas trees as Snell quipped.

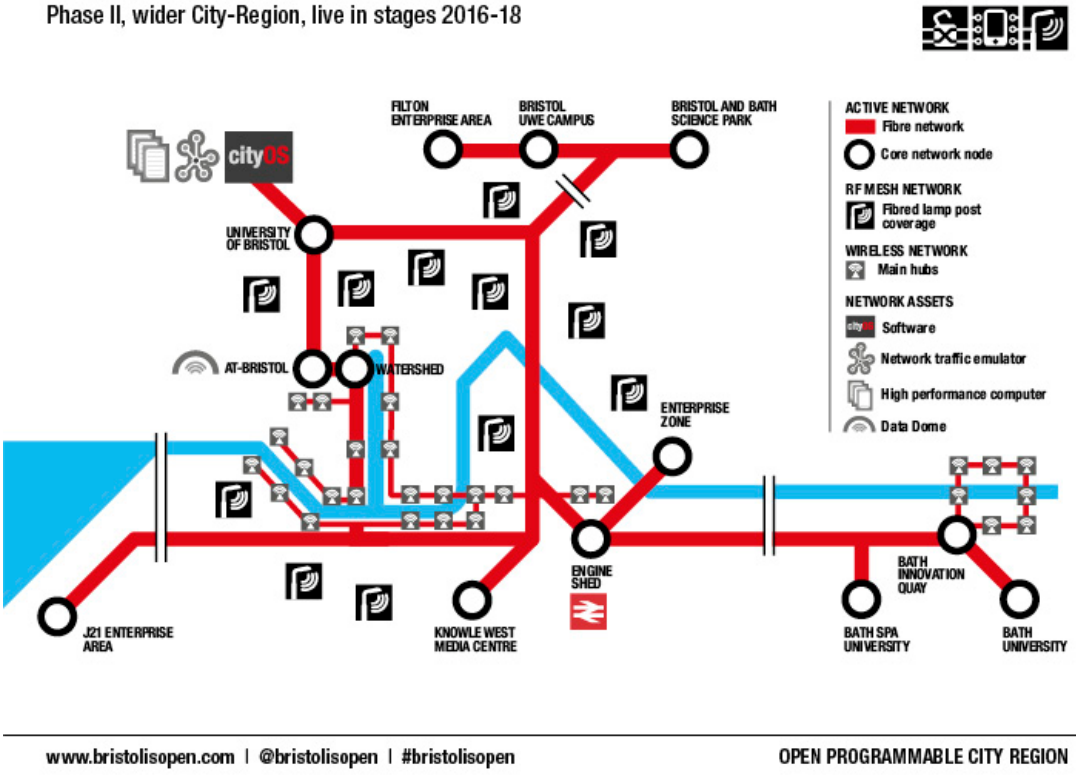
Moving forward, Snell said that BIO will have to start thinking carefully about the street furniture it uses, so that the technologies don't disrupt the city and its looks. On this topic, Snell said that retrofitting technology is very hard, especially in Bristol – constrained by its valley position, its abundance of water in the city center, and the complexity of old architecture. It makes citing RF equipment problematic, but there is a balance to strike between aesthetic concessions for citizens and the optimum positioning of wireless infrastructure.



The BIO network architecture, overlaid on a map of Bristol.

BIO will continue as an R&D business, rolling out the network to other areas of the city. For commercial opportunities, Snell said that exporting an API model would make sense as a licensing opportunity – as BIO is looking to find new ways to fund its ongoing research, and its business model is not concrete yet. The funding that BIO has received from both the UK and EU governments can't continue indefinitely, so repeatable revenue needs to be secured – and the BIO research partnerships, where companies like Nokia contribute funding in exchange for using the BIO network resources for its own testing, might not provide enough funds to cover the desired network expansion.

As for future plans, when asked about adding something affordable like LoRa, Snell said doing so would be a good plan – as LoRa has a distinct role and different technologies would be required for particular applications. BIO also has access to several tall buildings that could house antennas, allowing BIO to very quickly canvas the city from just a handful of locations – and might also be able to partner with The Things Network's existing LoRa network in the city.



The BIO network and its interconnects, in more detail

Snell also pointed to New York's citizen WiFi network, entered around old pay phone booths that have been converted into kiosks that provide WiFi, digital signage opportunities, and internet access via a computer terminal – by a company called Intersection for the LinkNYC project, which has rivals including LQD WiFi (now Verizon), and Civiq (part of the Intersection consortium). Adding such equipment in Bristol would be a good ap-

proach in her view, an opinion that we would agree with, given the advertising opportunity that can be used to justify the business model pretty easily.

However, Snell noted that there are still questions to solve there, such as whether Bristol would want to become a service provider with all its associated responsibilities. While the benefits of providing a municipal city-wide WiFi network are pretty clear, there is a pretty strong chance of upsetting the MNOs and ISPs in that market, as their mobile customers will simply jump to the WiFi network when it is available, opting not to use up 5G data allowances.

Snell said that until you trial such a deployment and find out, using a live lab, you aren't going to know the outcome. Following on from the topic of MNO disruption, we asked if there was scope for cities to buy spectrum licenses to operate their own LTE networks.

A view of Clifton Suspension Bridge—an illustration of the challenging RF landscape that the city has to accommodate

The new MD said there would be room for municipal WiFi services in some cities, with the city being able to charge businesses for access to that spectrum in order to recoup their costs, but Snell noted that there have been enough examples of large projects going wrong to make BIO nervous of such an undertaking.

An alternative might be having a city network run by a service provider, and Snell said that this wouldn't be ideal for a city like Bristol – where the city would want to roll out a network to the currently uncovered areas, a profit-seeking service provider might choose to prioritize covering the higher-margin areas. Similarly, it might be hard for the provider to monetize the network in poorer areas.

BIO aims to act as an incubator testbed, allowing the city to work out what projects are viable before they can be spun out as standalone council services or businesses.

Snell notes that many BIO partners are a lot more receptive to the project because other smart city trials never lead to a graduation – where they would become a live commercial project that a vendor or provider can sell into. As these graduations are a core focus for BIO, not simply its research, the initiative should continue to attract the likes of Nokia and InterDigital to the city.

One potential application for the multi-protocol network is tracking patients with dementia, using WiFi or Bluetooth when in the home before moving to something like LoRa and cellular when away from the home. With BIO building its network to support all these protocols, its APIs should enable developers to use the framework for applications like the tracking system, without BIO having to touch anything in that developer's codebase – greatly simplifying a deployment.

As for the citizens themselves, Snell said that in her personal view, BIO has a responsibility to test the ethical impact of its technologies before rolling anything out. Snell thinks the current privacy laws are outdated and are not catching up with the market reality quickly enough.

Riot has written around the subject previously, and Snell agrees that upcoming generations of citizens are not as privacy-focused as current generations – and are able to see the value in sharing their personal data with a city, in exchange for a personal benefit. Snell said an academic paper on moral obligations here would be valuable, and that it was imperative that an opt-out mechanism was in place for those citizens that were not on board.

But a project like BIO could generate a huge pool of city and citizen data that could be used to generate internal savings for the city council. While marketers would like access to this information, a council could use it for congestion prevention, local business partnerships, or resource deployment decisions – all while hopefully assuring the citizens that their data is in safe hands.

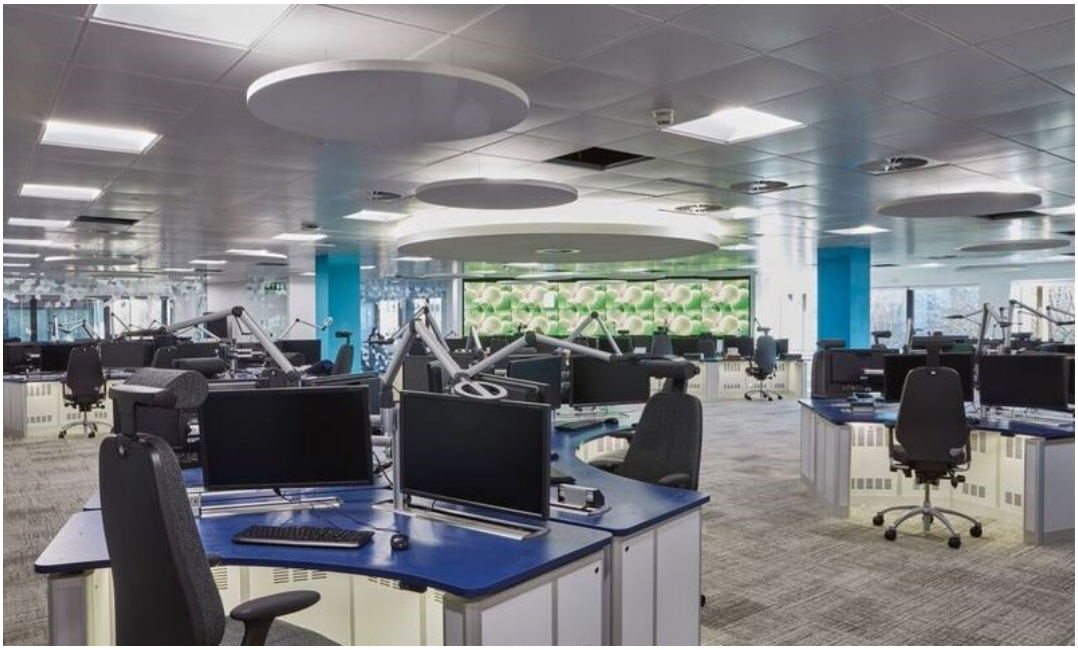
Snell discussed an example application that would leverage a citizen WiFi network, which could provide navigation services for tourists and residents – helping to push coupons or promotions to the app users that could benefit the local economy. Similarly, the city can use the data to help guide both foot and road traffic, to accommodate potential congestion via traffic shaping – sending people down quieter routes if it looks like the main thoroughfare is about to get too busy.

However, while there are obvious public safety benefits to having this kind of system, Snell noted that you can't sell the app on this basis as citizens will infer that they are currently unsafe – which isn't a good idea. The app could form the basis for citizen messaging and interaction services too, which would allow them to report things like damaged city property, water leaks, or anti-social behavior. However, Snell says that you need an incentive to get citizens using the application in the first place, and that free WiFi, via the app as a portal, is an excellent choice.

That portal could prompt citizens to report issues to the council, or act as a survey system to gather feedback or sentiment. The council could also provide updates to the citizens that have reported a problem, showing the action that has been taken as a way to foster more interactions with the service. Snell said BIO would love to secure a testing partner for this kind of application.

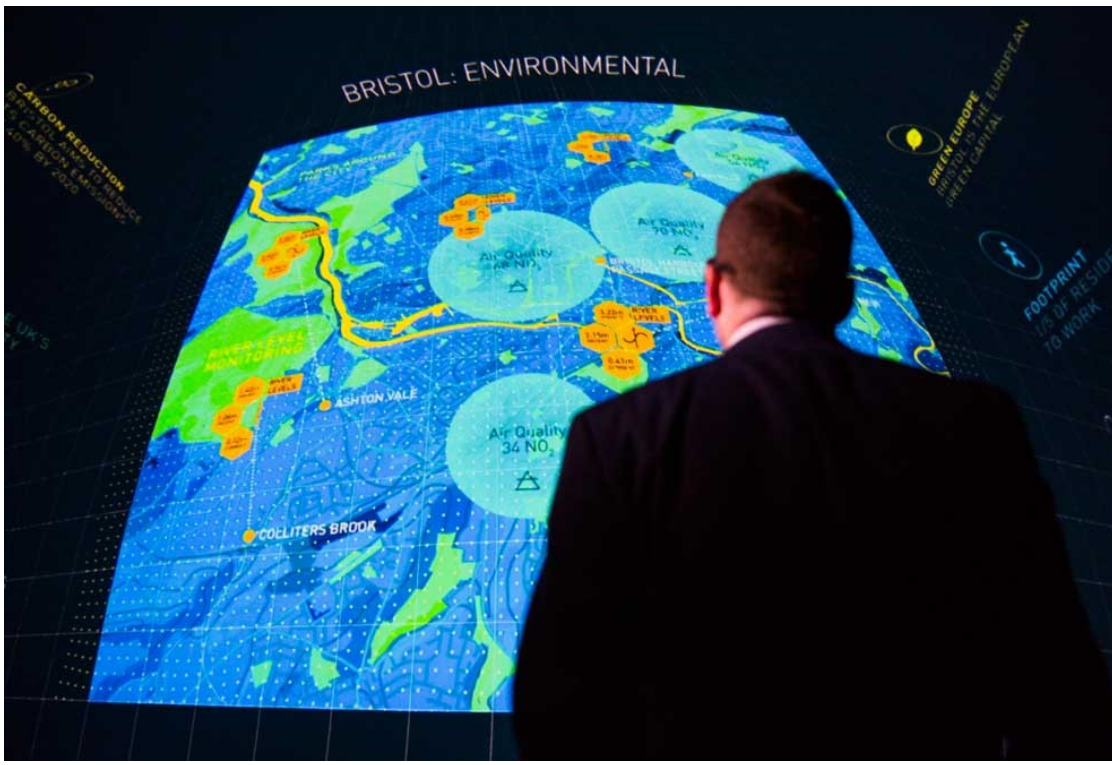
As for Bristol's position, Snell said that its fiber ring and Operations Center are huge advantages, calling the center the start of real intelligence in the city services, thanks to linking traffic, buses, first responders, and telecare systems. Snell said that you can do great things when moving things in coordination, and that breaking down silos between operations is key. She added that you can initially start these kinds of projects as cost-saving measures, but at the correct stages, bringing them together achieves better results.

Snell explained that you have to bring the data together to do more with it, while working collaboratively. Being 'smart' in this case isn't simply about the technology, but is about enabling people to do things on top of the platforms that are built by the likes of BIO. In addition, Snell sang the praises of current city mayor Marvin Rees, and added that the cities that are making the most progress nearly always have a very involved mayor. Snell said he has made some incredible progress in solving some of the city problems, and has brought in business expertise to the council – something that Snell had not seen anywhere else. Bucking the trend of an enthusiastic internal project leader who eventually runs out of money and has to shutter the project, Snell believes that Bristol will excel.



The City Operations Center, where Bristol is integrating multiple city services, to improve their operational efficiency—using shared resources and centralization, combining emergency services, traffic, and social care. It was launched in October 2017.

The Bristol Planetarium, a 3D-capable hemispherical display, designed to provide immersive cinematic experience (also known as the Data Dome), situated at the heart of the city in the At-Bristol Science Center.



Rolls Royce's early experiments with the Data Dome, in which the company visualized data from its Trent XWB aeroplane engine. It has also explored how to display data from city sources onto 3D maps, for better visualization opportunities.

3). Nokia—test bed now, future showcase opportunity

Nokia joined BIO in October 2016, and was the first major telecoms vendor to sign up. With ties to the University of Bristol through its Nokia Bell Labs division, particularly in the area of photonics, Nokia plans on providing both consulting and IP networking infrastructure and support, as well as funding. On top of this, Nokia pledged to provide its ngConnect application ecosystem. Nokia's first BIO project was a video analytics system for the city's 1,700 CCTV cameras.

Nokia CMO Barry French said, at the time, "there is a great deal of talk around smart cities, but there are not many places where talk has led to action. This innovation program will show what can be achieved by bringing together experts from various technology areas to deliver integrated solutions that actually improve people's lives, a fundamental principle driving our everyday work."

Nokia is also part of the Smart Tampere project in Finland, its home country, and has also published its *Smart City Playbook* report that conveyed three different approaches to smart city best practice.

The first, the 'anchor' route, involves deploying a smart city application to tackle a single problem, and then expanding on the deployment over time, adding new applications to the 'anchor.' The second approach, the 'platform,' would build the underlying infrastructure to support a variety of smart city functions, and the third approach was 'Beta Cities,' - where multiple application pilots are carried out, before being used to justify a long-term deployment decision. Bristol sits somewhere between the second and third, as its fiber infrastructure is more of a happy accident than a deliberate smart city decision.

The current Nokia smart city stack spans from edge-network infrastructure up to the cloud applications – housed inside Nokia's IMPACT PaaS. Using its core portfolio of networking products, Nokia is hoping to sell into cities that are looking to add the communication networks needed to build the foundation for a smart city – as well as the application management platform that will make use of those data connections.

Currently, Nokia is pushing LTE (regular, and unlicensed MulteFire), WiFi, and also LoRa, for connectivity – but also has its fixed network offerings. Above that access layer, its IP/MPLS and Microwave products will herald that data up to the IMPACT cloud, which Riot has covered previously.

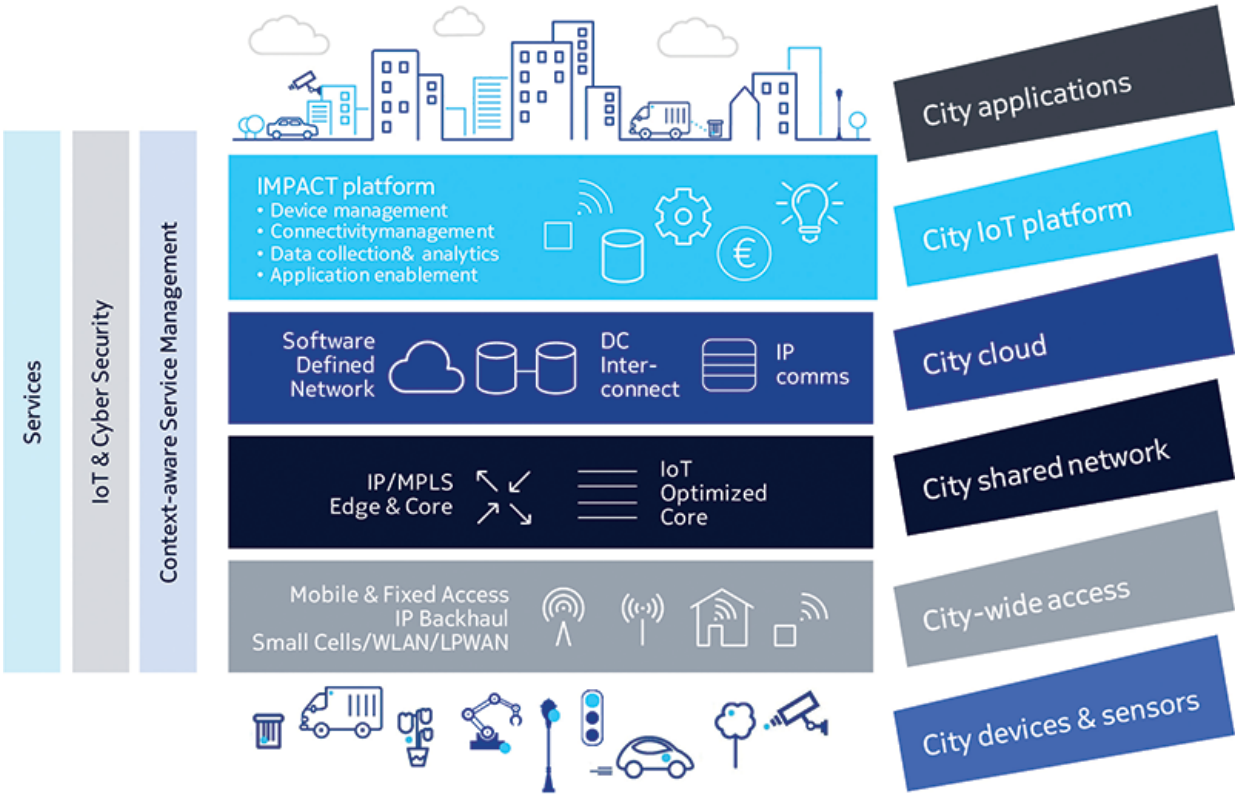
Competing with Ericsson and Huawei to install telco infrastructure, Nokia's position in smart cities would be as the main provider of the wireless networking equipment and associated services in the back-end of those networks. In addition, Nokia would be hoping to sell its IMPACT Platform-as-a-Service (PaaS) offering, to act as the basis for smart city applications. There is a lot more competition at the PaaS layer for Nokia, but its selling point will be close integrations between the PaaS systems and deployed network equipment.

Nokia's involvement in Bristol's smart city project predates Bristol is Open, and stems from its acquisition of Alcatel-Lucent, which was exploring R&D opportunities in the city in 2014. Paul Adams, Nokia's Customer Marketing Director for the UK and Ireland, explained that Nokia's interest in the project is its live testing environment – which is a powerful sales tool.

Adams says that Nokia was drawn to Bristol as there was something tangible there – in contrast to many IoT stories that deal in the theoretical. Adams explained that Nokia views BIO as a testbed, not a sales opportunity, but admits that the access could prove useful when it comes to commercial relationships with other BIO partners. In addition, he noted that it would be useful to be able to bring potential customers to see the Bristol tests – as a way of presenting a tangible example or story.

To date, Nokia's two main use case platforms in BIO have been environmental sensors mounted to bus stops in the city, to provide a live map of current air pollution, and video analytics for mapping ,pavement around the city, with a focus on improving public safety.

Nokia's Impact PaaS serves as the basis for the two projects, which allows Nokia to collect and analyze the data from the city. The bus stop tests used a similar device as used in a test with Chorus in New Zealand, while the CCTV cameras are a mix of city-owned devices and cameras that Nokia installed itself, and backhauled using BIO street infrastructure.



Nokia's Smart City stack—some of which Bio already has on tap

Adams gave the example of asthma sufferers, who would be able to use the map to better manage their condition – avoiding areas with high air pollution, ensuring they carry the right medication with them, or perhaps even changing the route of a trip. The video analytics use case has not yet been completed, but its benefits are pretty clear – although as with most public safety applications, it should be noted that defining a clear return on such an investment can be a little tricky.

When asked about what was next for Nokia, Adams noted that the company would wait to work through any challenges that arise from the video analytics test before deciding. He also added that it was challenging to find the sensor units needed for the air quality testing, and Nokia ended up building its own – requiring partnerships with sensor makers.

But the next phase will probably focus on smart parking and lighting applications, with Adams saying that it was likely that the lighting projects could integrate CCTV cameras as well as security alarm systems – and eventually integrate things like Automatic Number Plate Recognition (ANPR) for fleet management, which might also find a use among police and traffic management applications.

A more achievable immediate result could be Adam's suggestion of spotting fly-tipping (illegal dumping of waste) in the city, which could help catch offenders and coordinate a cleanup. The street lighting could be used as an active deterrent, illuminating an area if a vision-based system detects something suspicious – with the cameras ready to record someone in the act, if needed. Adding an intercom system might make the situation a bit too 1984 for some, but it could act as a very effective deterrent.

In that sort of a situation, many citizens would gladly accept the use of an intercom, as long as it is providing a concrete benefit – in this case, keeping their neighborhoods clean. If used sparingly, many citizens would not know it existed, as they would not encounter the intercom in use – making an active system appear passive, for the majority of the time.

In the Nokia projects, you can see the potential scope of the smart city opportunity, which is built on top of the strong networking core that Bristol enjoys. For other cities, installing a comparable backhaul network to support their smart city plans is imperative, but as BIO will tell you, there's an awful lot of complexity built on top of the fiber to manage too.

When pushed on the sales and marketing strategy, Adams said that while Nokia can always fly potential customers to its laboratories in Espoo, the environment is just not the same as a living city. Customers are able to look at a live deployment in a very different light, and Adams added that it was very helpful that BIO is a multi-vendor environment.

This is because it helps dispel the fear of vendor lock-in that a customer might have, showing the opportunity available in a more open ecosystem – despite what a systems integrator might promise, with their managed installations and services. Of course, Nokia would love to sell a smart city customer as much equipment and software as possible (and Ad-

ams quipped that Nokia wishes BIO had picked its SDN services), but smart cities are perhaps the best example of a customer that should rightly be afraid of vendor lock-in.

Adams said that Bristol is a powerful demonstrator for Nokia's portfolio, and that the company is fielding inquiries from all over the globe – lucrative opportunities for both BIO (down the line, once it begins monetizing its findings and methods), and for Nokia. He added that this interest also helps the UK, as a means of attracting foreign investment.

4). Zeetta Networks—the Uni spin-out at heart of BIO

Zeetta Networks is a spin-out from the University of Bristol, which has grown to some 25 staff – and had to expand from its Engine Shed offices to make room. Selling its software in a subscription model, with some levels of customization available. CEO Vassilis Seferidis explained that Zeetta is installing, maintaining, and supporting BIO's 'Experimentation-aaS' deployment, chiefly through its NetOS system – the middleware between the BIO network and the businesses. Seferidis likened it to the Android operating on a smartphone that acts as a bridge between the handset's Bluetooth, WiFi, and LTE radios that enables the third-party applications to use those data links.

NetOS powers the Software Defined Network (SDN), and is based on open networking standards and technologies – meaning BIO isn't subject to the risk of vendor lock-in that many IoT projects are wary of, with some overlap with the Telecom Infrastructure Project (TIP).

The SDN supports Network Slicing, which is the practice of defining subnetworks (slices) that then grant access to the application's traffic – isolating this application from the rest of the network through software isolation. It is comparable to virtualization in computation, with each app confined to a specific Virtual Machine (VM). This is expected to happen increasingly in 5G networks.

Seferidis said that thanks to the slicing, a developer can take a particular part of the BIO infrastructure and develop applications for it, while NetOS manages the connected assets, their network identities and the flow of data between them. Seferidis said that the SDN system allows a device to send its first packet into the system before NetOS takes over and routes its data over the best current connection medium. Accordingly, this allows NetOS to set Quality-of-Service (QoS) policies, which will help ensure things that are mission-critical are prioritized ahead of other messages that have some time tolerances.

A good example of this ability is in the separate Ashton Gate football stadium deployment, in which Seferidis says Zeetta can provide internet access to thousands of fans that can be dynamically halted to ensure that emergency services or security personnel will always have the network capacity to do their job. The recent quarter-final game between UK giant Manchester United and Bristol City, in which the hosts won 2-1, was a good test for the system.

Running on a Linux server, typically installed on-premises, the NetOS system is currently being examined to see how best to integrate it into BIO's Operations Center, in order to enable third-party applications and platform interfaces. Serefidis wanted to emphasize the importance of NetOS' network slicing capabilities here, as it enables smaller companies to develop much more flexibly. In the past, according to Seferidis, such development would have been a large IT infrastructure project, which would mostly have been hoping for the best, but with slicing, you don't have to hand over the whole physical network to the developer – allowing you to keep control, and letting the developer prove the business/use case first.

Broadly, Software-Defined Networking is designed to counter the static and decentralized networking architectures of old, and take advantage of advances in cloud computing. There's overlap with Network Function Virtualization (NFV) here, as bespoke hardware gets converted to software, but SDN involves moving the dispersed network routing decision making to a centralized controller.

This allows more tasks to be performed in software running on commodity cloud computing hardware, which can be scaled up and down as the demand for resources changes – saving an adopter money, by avoiding the sort of situation where a large and expensive network switch idles and wastes its potential for 94% of its life (the same argument in favor of ride-sharing cars).

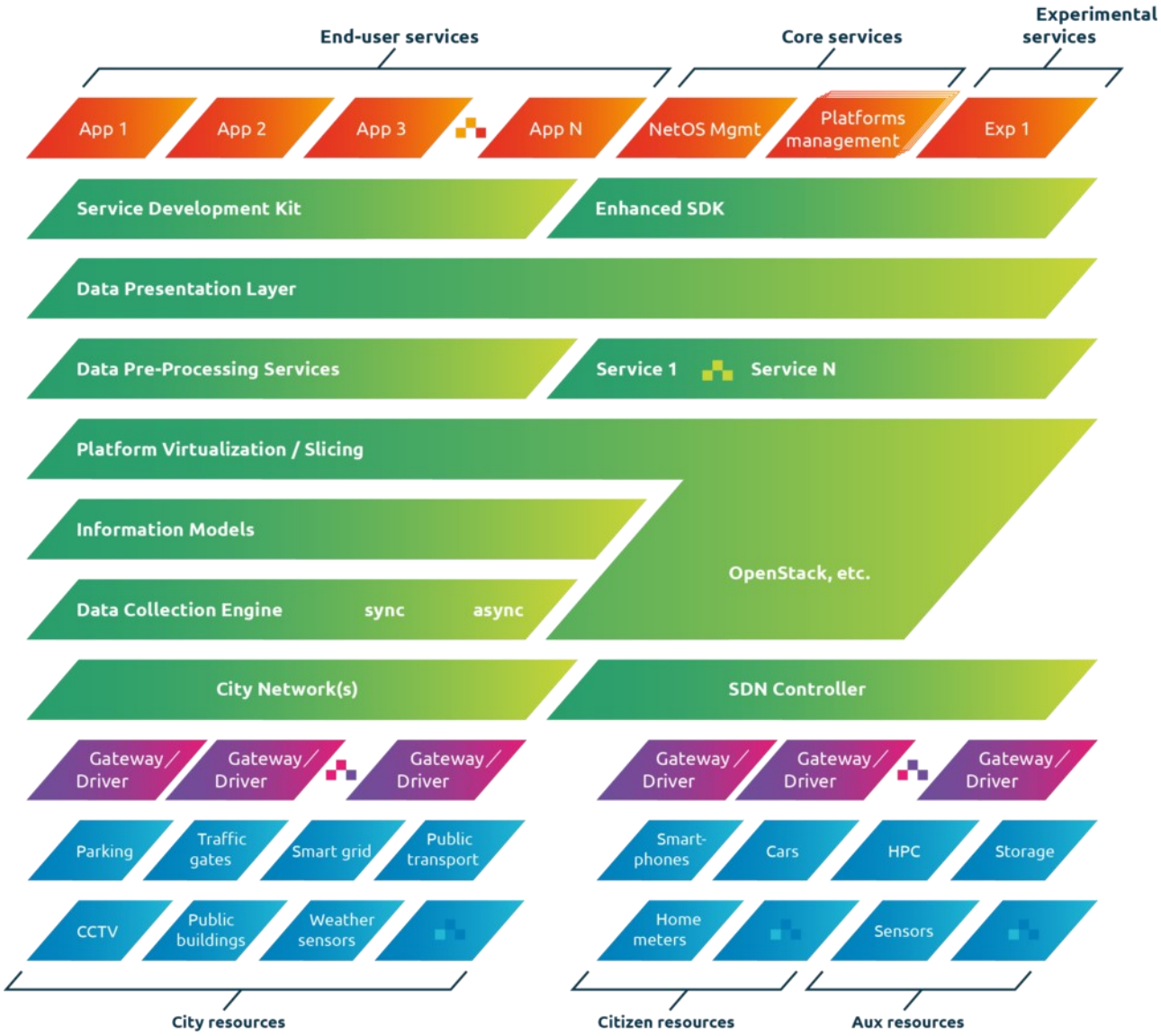
The intricacies of the networking architecture itself are a little beyond the scope of this report, but SDN is gaining traction. It is not an easy fix, and requires a great deal of work to deploy in the first place, but it does have huge potential for installations like smart cities – where multiple tenants and millions of users bring in an awful lot more sensitive data traffic.

In addition, because SDN is something of a response to the increased burden of mobile devices on traditional networking architectures, it seems that it will be essential for dealing with the complexity of the IoT – which will involve much more of the complex east-west network traffic than the north-south client-server traffic that was the norm.

For Wide Area Networks (WANs), an SD-WAN may be a preferable architecture, as it can help negate some of the traditional expenses of installing dedicated lines for the networks – the Multiprotocol Label Switching (MPLS) lines that telcos rely on to quickly route packets of data without having to read their entire network addresses and packet contents, which 'tunnel' traffic between specific points, rather than have them travel across the larger and slower public networks.

With SD-WAN, a network operator could use pre-existing commercial networking lines, leased from their owners, rather than having to commission MPLS installations. In theory, an SD-WAN could be installed without have to perform any physical visits (zero-touch), but that might be more of an absolute best-case scenario than a common outcome.

Zeetta's SDN stack—both incredibly powerful and complex



Riot: tracking disruptive technology and its impact in industry

Riot is published by:

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