WHITE PAPER

SMART CITIES DONE SMARTER

Updated July 2018

1. EXECUTIVE SUMMARY

The term Smart Cities has been around for many years now, with more and more of the global population converging in urban areas, and cities looking to exploit the potential for smart services and solutions to be introduced to address the demands generated by this urbanisation. Whilst many cities around the world have begun their transformation towards becoming a smart city, for many the progress has been slower than expected.

The range of potential smart services and solutions available to a smart city is vast; from services as seemingly mundane as monitoring the levels of garbage in a waste bin to ones as complex as integrated traffic management. These solutions have very different requirements and characteristics in terms of data volume, frequency and levels of latency required, which in turn leads to different connectivity options being required to optimise the cost of connectivity.

Deploying such solutions in siloed, end-to-end application stacks is often seen as the fastest route to value. In the long run, though, this leads to increased operational costs and limits the city's ability to truly be "smart" and utilise data from one use case silo to inform other applications within the city, for example, across a wider regional area or within another industry vertical.

Selecting a horizontal IoT platform which is agnostic to use case and connectivity options is a good approach for a smart city to take as it addresses these issues. However, like the number of services and solutions available, there is also an array of different IoT Platforms and approaches to consider.

City planners weighing up their IoT platform options could therefore be forgiven for feeling slightly overwhelmed. Their concern will increase further if procurement departments think they must pick technology winners from the plethora of standards and open source solutions on offer. They will also be fearful of getting locked into proprietary ecosystems.

Cities are starting to appoint people with cross-department responsibilities in order to reduce duplication of hardware and IT software. During this on-going period of austerity, with city budgets invariably cut, the need to drive greater cross-department synergies is even more important.

oneM2M is a response to the growing demand for a smarter approach to smart cities. Based on open standards developed in partnership with its some 250 members worldwide, which include eight of the world's preeminent standards development organizations (SDOs), known as Partner Type 1's, notably: ARIB (Japan), ATIS (United States), CCSA (China), ETSI (Europe), TIA (USA), TSDSI (India), TTA (Korea) and TTC (Japan), together with six industry fora, consortia or standards bodies (Broadband Forum, CEN, CENELEC, GlobalPlatform, Next Generation M2M Consortium, OMA) known as Partner Type 2's, oneM2M marks a seismic change in the IoT landscape. It combats market fragmentation by bringing the parties together whilst respective their individuality.

Instead of the vertical approach, where cities might have several dedicated IoT platforms, one for smart metering, another for waste management and so on, oneM2M enables different IoT use cases to be supported by the same platform. The horizontal approach.

Interoperability of this sort, where different apps can use the same device management and security software, or where sensor-generated data is put to multiple uses (cross-vertical data sharing is a key part of oneM2M) can reap huge cost savings for city authorities.

According to a study from Machina Research[1], now part of Gartner, an M2M and IoT research firm, cities worldwide could waste as much as $341bn by 2025 if they adopt a fragmented approach towards IoT as opposed to a standardised one. This sum, calculates Machina, comes from the extra cost of vendor lock-in, lack of interoperability and higher system-integration fees.

Machina further points out that fragmentation of different IoT platforms will dampen the rollout of connected devices and could even curtail adoption of smart city apps – hardly an appealing prospect for authorities wishing to see their cities sit higher in peer rankings and 'quality of life' indices. In an era of globalisation, businesses pay close attention to these listings before deciding where to invest.

By adopting oneM2M, however, cities have a route to much more cost-efficient IoT deployment, especially as apps and devices proliferate. There is also peace of mind. Legacy implementations, through the development of adapters, can be brought onto the oneM2M horizontal platform without disruption.

Another standout oneM2M feature is that it can encourage smart city innovation. By exposing open data subsets and IT-friendly Application Programming Interfaces (APIs) to app developers, which do not require them to know details of the underlying network, they can focus entirely on app logic. Simplicity of this sort means that oneM2M will appeal to a much wider app developer community than proprietary IoT systems. App developers will have a much larger addressable market and enjoy the benefits of being able to re-use code.

2. DIFFERENT SMART CITY APPROACHES…

Each city will have its own 'smart' priorities and vision. There is no one-size-fits-all. Deployment strategies will also differ. A report from Machina Research[2], which examined smart initiatives in 22 cities worldwide, identified three possible routes towards a mature smart city:

- **The 'anchor' route**: Cities typically aim to deploy one or more standalone applications, identified as key, and ensure they are working properly. They then think about how they might be extended and/or integrated with each other. Other applications are added as priorities evolve.
- **The 'platform' route**: The initial focus is on deploying a common platform to which a number of applications can be delivered over time.
- **The 'beta city' route**: The city continues to experiment with multiple applications without a finalised plan on how pilots might be brought to full operational deployment. Beta cities tend to view the current crop of available technologies and business models as only provisional.

2.1 …COMMON KEY REQUIREMENTS

[1] *Open standards in IoT deployments would accelerate growth by 27% and reduce deployment costs by 30%*, Machina Research (May 2016). Gartner acquired Machina Research in November 2016.

[2] *The smart city playbook*, Machina Research (November 2016)

oneM2M does not recommend one route over another. Each has its own merits and city managers will have good reasons for choosing their own particular path. They will, however, share the common goal of trying to identify as many cost savings as possible on their smart city journey. Nor will they want to be locked into proprietary solutions, which increase cost and limit technology choice. Data too, must be handled securely.

After taking on board the views of city managers worldwide, oneM2M identified key requirements of a smart city IoT platform. They include:

- **Horizontal platform for new deployments**. Rather than rolling out a dedicated platform for each IoT use case, new deployments, wherever possible, should leverage an open IoT platform and existing networks. Devices with multiple uses and the sharing of software across different applications, such as device management and security, would also be enabled by a horizontal platform.
- **Open standards to avoid vendor lock-in**. City managers, by being able to mix and match vendors according to their needs, have greater control on TCO. In order to guarantee this, city solutions should be based on globally accepted standards.
- **'Vertical' deployments are not disrupted**. An 'integration path', enabling the onboarding of most legacy rollouts onto the horizontal platform, should be available through the use of adapters.
- **Data assets are fully exploited**. According to the Machina report, the "most impressive visions for smart cities include synergies and integration between applications

ONEM2M GOES GLOBAL

oneM2M is picking up momentum worldwide. In South Korea, each of the big three operators — SK Telecom, KT and LG U+ — has rolled out a oneM2M-certified IoT platform. One such example of this is the oneM2M-complaint smart cities solution used in Busan. Another example is "City Hub" (tentative name) – released by GL CNS in July 2018 – an IoT-linked platform that can manage a smart city. City Hub is designed to play the role of a brain for a smart city, a city based on wired infrastructure. It collects data from IoT sensors attached on vehicles, buildings, roads, street lights and other city infrastructure. City Hub supports not only the oneM2M standard, but also a total of 98 communication standards for industries including logistics, manufacturing and distribution. This means that City Hub has solved the problem of having only to use IoT devices operated by specific manufacturers or service providers.

In India, Tata Communications is rolling out a huge LoRa® network, supported by a oneM2M-based platform from HPE, with the aim of reaching around 400 million people in different cities. The same HPE oneM2M-compliant platform has also been selected by the Bhopal Smart City Development Corporation Ltd. (BSCDCL) to create India's first cloud-based Integrated Command and Control Center (ICCC). The centre has enabled the monitoring and administration of multiple city civic utilities and citizen services in each of these cities through a central cloud. It has also enabled state-wide monitoring of cities from a central command view. The selected cities include Bhopal, Gwalior, Jabalpur, Indore, Ujjain, Satna and Sagar.

In Europe, Deutsche Telekom has turned to oneM2M to help its Cat-NB1 push in various markets. Deutsche Telekom has also teamed up with fellow operator Orange and worked, using the open source implementation of oneM2M by Eclipse Foundation, on an interoperable cloud-based API for smart home devices. Other oneM2M city rollouts in Europe, backed by local authorities, include Bordeaux and Turin.

The Australian IoT research community and industry (IOT Alliance Australia) is also testing oneM2M compliant services in the Illawarra region, around Wollongong (80km South of Sydney).

and data sets." To help achieve such an outcome, app developers – subject to privacy legislation, citizen consent and feasibility – should have access to 'open' data in standard formats. Access to 'semantically-enriched' data, which enables multipurpose use of information in a cost-efficient way, is another key requirement.

The oneM2M value proposition for smart cities is a comprehensive response to these requirements.

3. SMARTER CITIES ARE BUILT ON HORIZONTAL FOUNDATIONS

The oneM2M framework, based on open standards and open API interfaces, enables city planners to sidestep 'vertical' rollouts that simply do not scale. Having a dedicated wireless mesh network to support a smart street lighting system, for example, can be highly inefficient.

True, there might be some time-to-market advantage by opting for a 'siloed' approach. Through painful experience, however, authorities realise that vertical deployments are not sustainable if smart cities are to include new IoT use cases and enable data re-use. It would be much more cost-efficient if a single platform could support not only street lighting, but also related services such as street parking, waste management and traffic management.

Dedicated devices, tied to a particular app and network, is another inefficiency. It would be much more cost-effective if sensors could multitask and generate data for different use cases. Much better, for example, if a temperature sensor positioned close to the street could be used not only as a tool for checking road conditions, but also a weather status/forecast tool. Single sensors reduce deployment costs and cut expenditure on communications. There is no guarantee however that just because a number of sensors can measure temperature they will provide the data in the same formats or data structure. To avoid having to perform translation of multiple temperature descriptions from multiple manufacturer's sensors, convergence in the data model is required between IoT stakeholders.

Smart city architects are already thinking along 'horizontal' lines. Cities might still see a need to deploy a number of different networks – usually with different throughput and latency characteristics to suit the specific needs of different applications – but capital outlay would clearly be reduced if the number and diversity of those networks were limited to a manageable selection.

This favourable outcome is more likely if the smaller number of networks deployed are used more efficiently. Accommodating different apps, for example, or meeting the needs of several city departments rather than just one stand-alone solution. A horizontal architecture makes all of this possible.

3.1 MIDDLEWARE MUSCLE

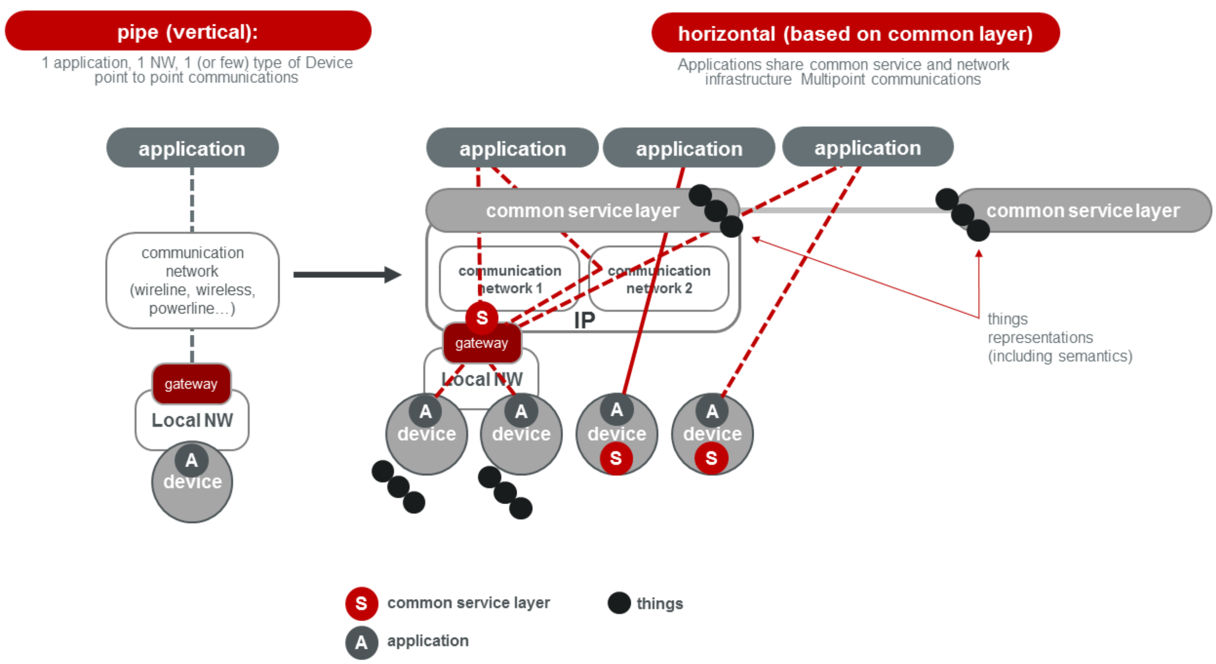
To meet these numerous requirements, oneM2M has developed a horizontal platform architecture (*see Figure 1*). oneM2M software is found in the M2M Common Services Layer (CSL), which sits below the M2M application layer and above the transport layer. The CSL middleware breaks down silos by enabling apps to share a common services platform.

The middleware also automatically allocates apps to the underlying network elements that are best suited to supporting specific performance criteria, whether it is best served by fibre, satellite, cellular or other types of data transport. In this way, cities can better manage device and app proliferation, as well as make more efficient use of existing networks.

Furthermore, because oneM2M is based on open standards, cities can avoid vendor lock-in and reap the benefits of a much larger and more price-competitive ecosystem, comprising commercial off-the-shelf (COTs) hardware with readily available oneM2M functions. Equipment can be mixed and matched to a city's own requirements. Several multi-vendor oneM2M rollouts have already been achieved in various cities, including Busan (South Korea) (*see sidebar: Busan takes open source route to oneM2M*), Bordeaux (France) and Turin (Italy).

If cities turned to system integrators to manage their multi-vendor environments, they would no doubt find themselves trapped in another form of supplier lock-in. OpEx, too, is likely to be much higher by going down the system integrator route.

Figure 1: The oneM2M architecture



3.2 A REUSE CULTURE

When oneM2M published its Release 1 set of specifications in February 2015, it paved the way for devices to connect securely to apps residing in either the cloud or the gateway across a horizontal architecture.

Connectivity is enabled by a library of Common Service Functions (CSF), which forms part of the CSL. Functions include discovery and registration, as well as location and communication management. These functions can all be shared by multiple IoT applications, which is another cost-saving efficiency of the oneM2M horizontal architecture. There is no need for app-specific software, other than the application logic itself.

The device management (DM) function is provided by the well-established DM standard from the Open Mobile Alliance (OMA), which serves as an important reminder that oneM2M is not built from scratch. As our smart city blueprint illustrates, oneM2M can leverage both the standards work and open source initiatives from other industry groups (*see Figure 2*). In this way, city planners can exploit the best solutions available for their particular requirements.

In the case of network-independent protocols such as OMA DM and OMA LwM2M (highly suitable for IoT devices), it has the necessary commands, messages and mechanisms to download firmware updates, over-the-air, to devices already deployed in the field. It is an important feature if smart meter devices and other low-power smart city sensors are to realise their lengthy (and budget-friendly) lifespans which, in some cases, reach up to 20 or 30 years.

A Smart City, where the integration of multiple parties, devices and applications is a key requirement, presents its own security challenges. Security has always played an important part in oneM2M. Through the Release 1 specifications, security keys and algorithms can be upgraded to protect critical smart city infrastructure. Subsequent releases have improved security and increased the functional capabilities in line with the increased focused on this key set of requirements. For example, the Access Control Policy (ACP) capabilities on oneM2M ensures that only the appropriate applications etc. have access to resources and is often highlighted as an important benefit of oneM2M to Smart Cities in particular

BUSAN TAKES OPEN SOURCE ROUTE TO ONEM2M

Busan, the second-largest city in South Korea with a population of 3.6 million, delivers more than 25 smart city services across a oneM2M platform. The IoT use cases are diverse, spanning community safety, traffic improvement, urban living and energy conservation. From school-zone smart traffic to location-based marketing services (using proximity beacons), Busan is a hot bed of IoT innovation.

The South Korean government selected oneM2M after rejecting proprietary IoT platform solutions and other standards-based approaches that did not enjoy the same level of international backing. Previously, the government had relied on several IoT platforms, in each of the country's main cities, to support different IoT use cases. This approach was eventually discarded as being too inefficient.

Another oneM2M advantage is that all data, generated from sensors installed in the city, can be collected and shared. Citizens, service providers and innovative local start-ups can all exchange ideas and help develop a 'smart' Busan.

Commercial implementation of oneM2M was swift, helped by an 'open source' approach called OCEAN. The South Korean government and the Korea Electronics Technology Institute (KETI) established OCEAN (open alliance for IoT standards). The aim of OCEAN is to share open source code based on IoT standards, and to encourage co-working between its members. - OCEAN has more than 750 members worldwide.

There is, however, no universal approach when it comes to security. In some cases, manual configuration of security credentials on devices can be overly burdensome and costly, particularly in consumer-oriented IoT scenarios. This can prevent timely and cost-effective deployment.

In order to address the complexity of security frameworks, amongst the additional specifications in oneM2M's Release 2, published in September 2016, included the introduced 'dynamic access control'. This function allows devices to be given temporary authorisation, which provides cities greater flexibility on how they allocate security policies.

The latest version of the specifications, Release 3, published in September 2018, continues this enhancement of security capabilities and includes distributed authorization and decentralised authentications together with oneM2M secure environment abstraction and public key framework. Release 3 also provides for automated certification enrolment, therefore reducing the time spent and costs incurred with on-boarding huge volumes of devices in a secure manner.

Moving forward, oneM2M will continue to work with the IoT industry and customers such as smart cities to ensure that new security challenges are addressed in Release 4 and beyond.

4. SQUEEZE THE MOST OUT OF DATA

Current successful implementations of smart cities are often focused on areas of education and scientific development with high volumes of data relating to the operational processes of the city, the environment and its citizens. In such cases, innovation is being positioned in line with business models to encourage enterprises to exploit the data collected or the improved mobility capabilities of the city.

Most cities are at an embryonic stage of development, experimenting and investing in narrow areas. The recent smart cities study by ATIS a oneM2M level 1 Partner (http://www.atis.org/smart-cities-data-sharing/) lays out a road map of how cities are likely to evolve by a) making better use of joined-up-data and b) adapting their approaches to work over greater geographic domains. Large cities will increase innovation, backed by investment, and this will pave the way for smaller and medium sized cities to follow suit.

The efficient collection and exchange of data is central to any successful smart city. Ideally, data should be provided either via open data portals or through paid-for data marketplaces. In both cases the expectation is that third parties may further exploit the data beyond what is useful for the city itself.

Transport-sector data (city-controlled diversions/planned road works, traffic patterns, parking/public transport capacity utilisation etc.) is highly valuable on a regional basis because it helps citizens within a city's boundaries, as well as (business and individual) commuters from outside the region. The ways that cities export locally-developed applications is also valuable as it helps other, resource-constrained cities to learn, re-use and adopt deployment best-practices.

Access to and control over data has become a strategic asset for cities. City administrations are aware of that, and cities are conscious of tensions around platform models (of the likes of Uber, Airbnb) and sharing economy models. Most importantly, they conceive their own city administration role as that of a body that can act and regulate in order to come up with "more equitable access to resources and services".[3]

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[3] Smart Cities at the Crossroads: New Tensions in City Transformation, in special issue City Innovation Berkeley California management review 2016, authors Esteve Almirall, Jonathan Wareham, Carlo Ratti, Pilar Conesa, Francesca Bria, Anibal Gaviria, and Amy Edmondson

The work done by the oneTRANSPORT™ initiative in the UK, using the oneM2M standard, demonstrates the value city data and a horizontal approach to the city, its citizens and the wider community, including central governments. Another such example is in France, where the Parisian City administration collects royalties on profits realised by companies using the data published by the city of Paris. From 2018, all French cities have had an obligation to publish open data in their possession.

THE oneTRANSPORT™ DATA MARKETPLACE

Built to manage a wide variety of data associated with smart city, smart region and intelligent transport solutions, the oneTRANSPORT™ Data Marketplace is a cloud-based system for real-time and non-real time data.

Using the oneM2M standard, the solution combines private partners' expertise in city planning and transportation economics, IoT technology, sensor network management and advanced analytics. It underwent a two-year field trial, during which it was tested in three use cases of varying size and scope. These were defined by four UK county councils – Buckinghamshire, Hertfordshire, Northamptonshire and Oxfordshire.

The smallest use-case served a Park and Ride in Oxford, while the mid-scale one targeted ring-road congestion and parking management in the town of Watford on match days hosted by its Premier League football team.

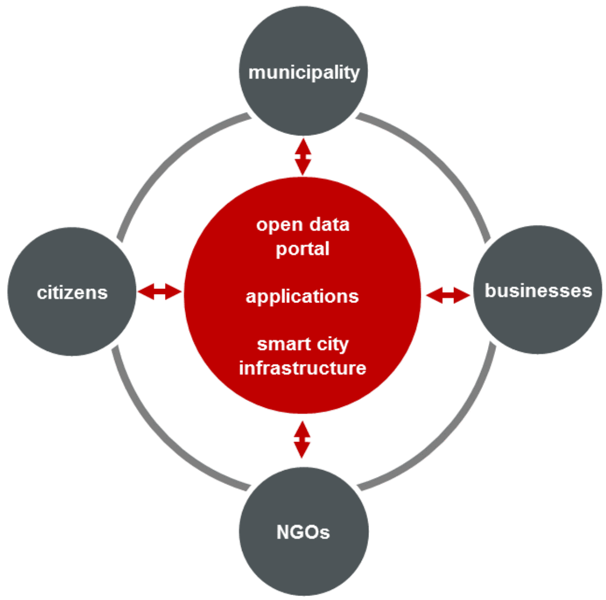
Finally, the large-scale use-case helped Silverstone racetrack cater for more than 250,000 trips, involving spectators and race personnel, over the Formula 1 race weekend. Silverstone resides at the intersection of three counties and effective event planning depends on adapting to traffic diversion decisions taken in each county.

Over the course of the trial the implementation partners fed data from more than 300 asset types through the marketplace. This included local live traffic information such as average speed, congestion, diversion and incidents, local parking status, air quality measurements and geospatial data.

The ability of oneTRANSPORT Data Marketplace to manage a wide scope of data sources and protocols was clearly demonstrated throughout the project. Significant improvements in areas such as traffic flow, congestion and the overall citizen experience were evident. Following the successful trials, it is now available as a commercial, cloud-based service, where a mix of public and private sector organisations are already using it across the UK.

A mature smart city would enable individual citizens, businesses, NGOs and the municipality itself to both contribute and extract data, and to create and make use of applications based on that data (*see Figure 2*). It is especially important to integrate data contributed from inhabitants living and working in the city. This increases citizen engagement and makes it more likely that city services are adopted. oneM2M provides such a platform.

Figure 2: A conceptual model of a mature smart city



Source: Machina Research, 2016

The oneM2M standard is agonistic to use case or industry vertical. As such developments designed to increased market adoption and reduce complexity from one vertical such can be easily adapted for use in another. For example, the Smart Device Template (SDT) schema, originally developed to establish a common syntax for Smart Home device models and spur innovation and integration in Smart Home applications, is also applicable for use in Smart Cities.

The SDT is the cornerstone of an abstraction layer approach for various IoT domains, comprising both schema and a set of modules. An abstraction layer isolates applications, both in the cloud and in the field, from the multiplicity of local network protocols and device drivers, enabling applications to communicate easily and with a common information model with smart devices, regardless of technology type or the communication protocol used by the device.

Primarily used currently for Smart Homes, the SDT schema comprises a common syntax to describe IoT devices and functionalities. These open sets of functionalities are building blocks which can be used to easily create a description of any type of Smart City device.

The SDT schema provides a framework to create a consistent representation of, for example, Smart Home devices. For telecom service providers, this is a great step to ease the deployment of innovative applications on the Home Gateway or in the cloud. It also assists manufacturers, as their products can communicate with a wide variety of applications. This approach could equally be adopted in the Smart Cities markets and deliver similar benefits to the cities, device and application providers as well as the telecom service providers in order to provide an open and domain-independent IoT abstraction layer.

4.1 LIFE MADE EASIER FOR APP DEVELOPERS

Increasing citizen engagement as part of a Smart Cities deployment is often a secondary consideration rather than a core requirement, meaning that many cities fail to maximise the opportunity presented to them. One way to address this is through the use of common applications that drive citizen inclusion which mean that citizens are able to have the same experience across multiple cities. This is very important in instances where the citizen lives in one jurisdiction but works in another – without a common user experience it is less likely that they will use the apps and maximise the value of the smart city services. Cities can still differentiate themselves even with common standards and apps to maintain their own identity, whilst still delivering benefits to their citizens and enterprise customers.

This is made much more achievable by providing app developers with a so-called '*abstract layer*', which masks the underlying complexity of the network, so developers can focus on application logic rather than on communication and device management. They do not need to be communications experts.

This means two things. First, IoT apps are 'thinner' and can be developed quicker. Second, by 'hiding' the underlying network technical specifications, the oneM2M platform is accessible to a wider pool of app developer talent. This may well encourage local app developers, who better understand the needs of their fellow citizens, to participate. Additionally, an abstraction layer that hides the complexity of large-scale wide area communication network from the developer community also helps to addresses a key requirement from network operators; that the developer / application can cause no harm to network". This requirement is driven out of the issues created 10 years ago when some Smartphones application without such an abstraction layer approach caused degradation of service across the network.

Freely exposing subsets of city data to app developers, such as weather, maps and transport information, is another important platform feature. In the hands of innovative app developers, combining different datasets of this sort, or data mashups, can lead to new apps and create extra value.

For example, static historical data about car accident history (where and when incidents occurred) may not be all that interesting in itself. Meld that information with weather and traffic management data, however, and it is possible to create another app, one that reroutes car journeys if traffic and weather conditions suggest a likelihood of delays on the original route.

City authorities also have the option of securely controlling access to certain types of data, perhaps restricted to approved organisations. They must of course ensure that any data exposure has citizen consent and does not violate personal data legislation rules.

4.2 SEMANTIC INTEROPERABILITY

Another cornerstone of oneM2M innovation is semantic interoperability. Unveiled as part of Releases 2 and 3 and in combination with the Smart Device Template, semantic interoperability uses meta data and ontologies to allow different apps to share 'meaningful' data with one another.

Thinking back to our roadside sensor, it generates various numbers. Unless we know that these numbers represent temperature values in Celsius, the information has little meaning (except if known beforehand by a consuming app). Meta-tagged data, however, which shows what the information is about and what it can be used for, can be shared with other apps. The roadside sensor can not only feed information into an app measuring road conditions, but, through semantic interoperability, be exploited by other apps, such as ones monitoring and forecasting weather.

Another example, on a bigger scale, is the sharing of traffic information across different city departments. Police and other emergency services will obviously find traffic conditions relevant, particularly in the case of a disaster (an earthquake, perhaps) when it becomes vital to know which roads are open or blocked. Taxi and other drivers would also find this sort of information useful. Collating traffic patterns over days, weeks and months may also be relevant for city planners. Traffic information could come from multiple sources, including video cameras, or sensors installed on buses and taxis driving around the city.

In the oneM2M context, this would mean posting the meta-tagged data to a oneM2M resource on a gateway, which either notifies interested entities or can be found by 'semantic discovery'.

In a small IoT setting, attaching 'meaning' to what the data represents might not be necessary. The meaning is often implicit for apps developed for a particular purpose. City planners seeking to fully exploit data assets, however, will be greatly restricted without semantic interoperability. As the number of apps producing and consuming information increases, so too will data integration costs if information repeatedly needs to be configured in a particular way. Information available for multiple uses is also likely to be limited in such a scenario, which is sub-optimal. The true value of an IoT system is often only realised by having access to all information.

There will be some initial costs in bringing apps up to speed with semantic interoperability but, as apps and devices proliferate, the alternative method of achieving similar levels of interaction – traditional data integration processes – will see costs shoot up exponentially.

It should also be noted that oneM2M not only supports semantic annotations but also provides with, for example, TS-0023 already a set of well-defined information models, which implicitly already have semantic meaning.

5. ONEM2M INTERWORKING

Most city planners contemplating a move from a 'stove pipe' to horizontal architecture will not want to disrupt legacy IoT implementations. Instead, they will want an integration path to bring existing rollouts on to the new platform. Reassuring for city planners, then, that oneM2M, through the use of adaptors, can potentially interwork with any IoT wireless protocol in the field area network. These include LoRa®, SIGFOX™, Ingenu, ZigBee® and Z-Wave®, as well as cellular-based LPWA systems such as Cat-NB1 Cat-M1 and EC-GSM-IoT.

They can also be secure in the knowledge that oneM2M's network-agnostic platform can work with a wide range of IoT industry initiatives. oneM2M's generic interworking specification, for example, published in Release 3 considerably expands device and 3GPP interoperability.

The generic interworking specification also makes interworking with OMA's Lightweight M2M (LwM2M) system possible. The drivers for LwM2M devices are ones that smart city designers will no doubt be familiar with, particularly when it comes to smart metering over a mobile or wireless network.

For sensors that need to conserve battery power, LwM2M conveniently caters for long-running and 'sleeping devices.' The LwM2M system can also onboard devices onto a communications network, as

well as manage and troubleshoot the communication layer for characteristics and problems which are unique to mobile networks. Furthermore, all this can be done even in 'constrained environments' such as limited CPU resources or harsh operating conditions.
By being able to leverage the useful work of other industry groups with minimal effort, city authorities can avoid onerous system integration costs and ramp up oneM2M's economy-of-scale benefits even further.

One of the reasons that the oneM2M platform is so flexible is because it can accommodate a wide range of IoT communication protocols. Rather than attempt to pick technology winners, oneM2M supports a wide range of established IP-based protocols for use on its reference points (interfaces between the CSL, network and application layers). These include CoAP, MQTT, Websockets and HTTP.

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Flexibility of this sort should give peace of mind to city planners. Not only on ease of interworking with today's wide array of third-party initiatives (should they wish to), but also reassurance they will not be prevented from interworking with other popular IP-based IoT systems that might emerge in the future. oneM2M offers a future-proof solution.

6. SMART CITY BLUEPRINT

Each city has its own priorities in terms of IoT requirements, so oneM2M does not prescribe a particular interpretation of the horizontal architecture. However, the blueprint of a smart city data centre in *Figure 3* – which can be hosted in a public or private cloud – provides a framework that city planners might find helpful.

What may be apparent from the outset is the numerous open source and standards initiatives that complement oneM2M. As can be seen from the blueprint, oneM2M CSL sits in the front-end of the data centre facing devices, gateways and the underlying network. It is designed to handle a massive number of connections to devices and apps, and handle device management and enrolment, data collection, interworking and protocol adaption.

Devices and the gateways deployed in the field domain generally use protocols developed by the ICT industry, e.g. LwM2M, or by the vertical industries. There are a large number of those protocols such as TALQ for streetlight management, WITS for water management or DLMS/COSEM for smart metering. The front-end role is to separate the actual protocol being used for data exchange (which is irrelevant for the back-end functions) from the actual processing of the data.

The back-end of the data centre, however, will not scale the same way. It focuses on various data functions, including replication, anonymization, VM management and availability. Open source initiatives and projects, such as FIWARE™, Eclipse Mosquitto™ and RabbitMQ®, can play an important broker role, integrating different software building blocks within the smart city data centre. Similarly, the ATIS-initiated open source OS-IoT (http://os-iot.org) is an open source software library that provides device-side support for fundamental oneM2M defined functions and therefore simplifies the development of IoT devices that connect to an open, interoperable ecosystem.

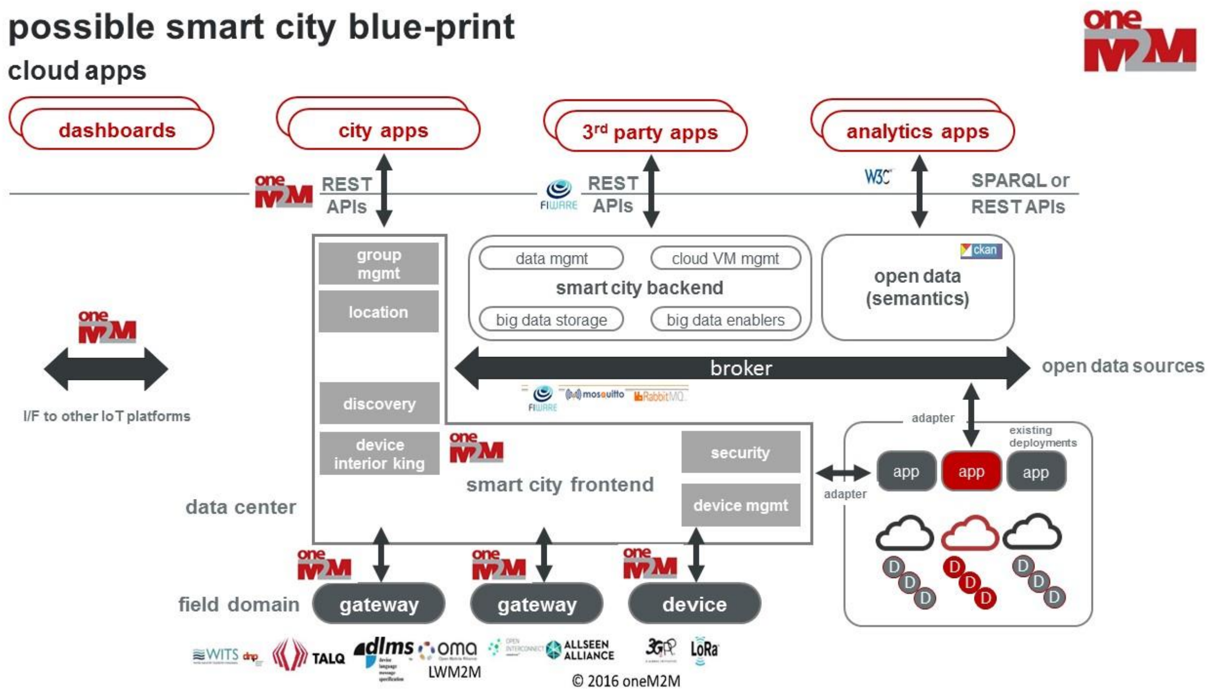
In the case of FIWARE™, it is building up something of a reputation as a provider of 'smart city middleware,' not least because it received significant funding from the European Commission. oneM2M, however, is not in competition with FIWARE™, both are complementary, residing as they do in different parts of the data ecosystem. Indeed, FIWARE™ implementation could use a oneM2M platform to connect the different components and collect the data in an harmonised format.

An additional requirement of the broker is to integrate with other data sources from non-IoT entities. Maps, for example, or banking. If smart parking or other smart city apps require payment, relevant bank details will be needed to make secure transactions.

The exposure of open city data, an important requirement for city app developers, can be performed using an open source implementation, such as CKAN (ckan.org) targeted at data publishers (typically the cities) wanting to make their data open and available. Typically, the data stored under the open data repository is about long term historical data, often anonymised, in order to enforce privacy. On the other hand, a latest value of say a temperature sensor would be consumed by applications using the API offered by the front-end (left hand side of the blue print).

In this blueprint, protocol adapters can be built (towards the frontend or toward the broker) to collect relevant data on the northbound of legacy vertical deployments. As such it becomes possible to preserve existing deployments while allowing an efficient use of IoT data sets for smart city based data economy.

Fig 3: A possible smart city blueprint



7. CASE STUDY: THE CITY OF BORDEAUX, HOW TO BRIDGE THE GAP BETWEEN IT AND OT[4]

In early 2017, the public lighting services of "Bordeaux Métropole" (Greater Bordeaux) and the City of Bordeaux, in southwestern of France, with a population of close to 750k, had the opportunity to benefit from public funding to deploy an IoT experiment using a city reference district.

The experiment consisted of deploying a street light service consisting of 220 lampposts in a district located at the north of Bordeaux district. The district hosts public facilities that are used only occasionally during events. Those facilities include mainly the exhibition centre, the convention centre, the MATMUT Atlantique stadium used for football games and concerts, and the velodrome.

Very quickly, significant energy and financial savings were identified as the district no longer needed to be illuminated on a permanent basis. Street lights are only switched-on when there is an event or when street sensors detect vehicles or pedestrians.

The experiment was perceived to be a success. "The appetite comes with eating" – and other city departments also expressed interest to connect several OTs according to the IoT model. The identified use cases include:

- The supervision of boilers for a group of schools and sports facilities
- Electric vehicle charging stations
- Access control gates
- Water, electricity and gas meters

[4] Operational Technologies

- Points for collection of voluntary contributions of goods
- Garbage collection bins

To pilot all these sensors / actuators, the Digital Department did a study of the network to be deployed and the use that could be made of it given the volume and diversity of the OTs to be connected. Very quickly, it became clear that the OTs used different connectivity and data model technologies such as KNX, DLMS/COSEM, Dali, BACnet, or Modbus.

The digital department reached a key conclusion: Building IoT in silos will not scale. An abstraction model to bridge the gap between diverse OTs and the digital world was needed, otherwise it would be difficult to master the total cost of ownership. The city concluded that a standard such as oneM2M provides the unique value proposition of connecting diverse OTs in an open manner, therefore avoiding lock-in to a specific provider.

It was therefore natural that a special technical clause was included in the call for tenders stating:

"The holder shall propose a connection method based on the oneM2M Release 2 standard published in September 2016 and available under www.oneM2M.org." This statement was updated when Release 3 is published later in 2018.

"It is very encouraging to see that interoperability standards such as oneM2M allow communities to invest, on a large scale, with confidence in the sustainability and extension of services offered to users, at the pace allowed by the financial capacities and the political priorities of the moment," declared Christophe Colinet, Smart City Project Manager of Bordeaux Métropole. "oneM2M provides a standards-based glue between diverse Operational Technologies."

8. CONCLUSION

Cities that are serious about getting smart know that they cannot rely on traditional ways of doing things. Vertical rollouts, where each IoT use case is propped up by a dedicated network, use case-specific data exchange mechanisms, and single-use devices, do not scale.

As city planners strive for greater cross-departmental synergies, it is essential that both networks and devices, as well as data, can be used for more than one purpose. Even better if various functions, such as device management, security and communication management, can be shared by multiple IoT applications. oneM2M, through development of open standards and open APIs, makes this much more cost-efficient horizontal approach possible.

There is also peace of mind. By using oneM2M, cities will not be locked into proprietary ecosystems that limit technology choice and increase costs over time. They will be able to mix and match solutions from multiple vendors according to their specific needs as they arise.
oneM2M. Smart cities done smarter.

GLOSSARY OF TERMS

API	Application Programming Interface
CoAP	Constrained Application Protocol
CPU	Central Processing Unit
HTTP	Hypertext Transfer Protocol
IoT	Internet of Things
LPWA	Low Power Wide Area
LTE-M	LTE-Machine
M2M	Machine-to-machine
MQTT	MQ Telemetry Transport
NB-IoT	Narrowband Internet of Things
NGO	Non-Governmental Organization
OCF	Open Connectivity Foundation
RFP	Request for Proposal
TCO	Total Cost of Ownership
WAN	Wide Area Network

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ABOUT ONEM2M

oneM2M is the global standards initiative that covers requirements, architecture, API specifications, security solutions and interoperability for Machine-to-Machine and IoT technologies. oneM2M was formed in 2012 and consists of eight of the world's preeminent ICT standards development organizations: ARIB (Japan), ATIS (North America), CCSA (China), ETSI (Europe), TIA (North America), TSDSI (India), TTA (Korea), and TTC (Japan), together with seven industry fora, consortia or standards bodies (Broadband Forum, CEN, CENELEC, GlobalPlatform, HGI, Next Generation M2M Consortium, OMA) and over 200 member organizations. oneM2M specifications provide a framework to support applications and services such as the smart grid, connected car, home automation, public safety, and health. oneM2M actively encourages industry associations and forums with specific application requirements to participate in oneM2M, to ensure that the solutions developed support their specific needs. For more information, including how to join and participate in oneM2M, see: www.onem2m.org.