wavefront™ Smart Cities

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The Cascading Technology Trap

Implications in Smart City Deployments: Learnings from the Field

Introduction

A survey of smart city activities around the world shows that much of the focus of smart city projects remains on establishing the most basic of services such as connectivity. In fact, there is a clear lag in the deployment of technologies and services in smart city applications, versus what technologies enable. Our aim in this paper is to develop a bottom up approach in understanding the fundamental reasons for such lag. We call this the cascading technology trap.

Based on the hands-on involvement of the Xona Partners team in the design and rollout of over half a dozen smart cities, the cascading technology trap emerged as a common thread: technologies are evolving at a significantly faster pace than the ability of cities to adopt. In this paper, we illustrate how the rapid pace of technology evolution is an impediment to the adoption of smart city applications and how different cities around the world have tackled this challenge. This is not to diminish the importance of the other challenges facing smart cities, such as the financing deployments, the establishment of optimal public private partnerships, the handling of organizational structures within smart cities in a way that is consistent with governance models and a number of other challenges. However, for cities determined on implementing smart city applications, the cascading technology trap proved to be the primary and most complex challenge to overcome after having resolved other challenges.

To illustrate our thesis, we focus on one technology area – that of the city's data flow information systems, including data generation, transmission and management for simplicity, although similar challenges are present in other layers of the technology stack. We also summarize possible strategies on how to approach such challenges - some of them in early stages of implementation by select smart cities.

Anatomy of the Cascading Technology Trap

Multiple layers of challenges beset the implementation of smart city applications. Among some of the key issues are financial challenges due to tight budgets, spending subject to government procurement, and planning and implementation challenges as a result of complex organizational structures. But even cities that have allocated budgets and mitigated organizational challenges have found themselves facing a critical impediment in deploying technology on wide scale beyond pilot projects.

Xona Partners has been engaged in several smart city projects over the past decade, including Songdo (Korea), San Francisco, Barcelona, Hong Kong, Singapore, Dubai and King Abdullah Economic City (Saudi Arabia). We observed that these cities were determined at exploiting technology to improve operational efficiency and improve the life of citizens, yet technology development was at the forefront of challenges facing these cities. The crux of the challenges is based on these factors:

1. Information Technology has been mainly driven by the leading Internet and Cloud companies (e.g., Google, Amazon) over the last decade. These companies have fundamentally different models of developing and deploying technologies, which made it difficult for the rest of the industry to absorb and adopt, with smart city organizations seeing an even more exasperated challenge in doing so.
2. The rapidity of evolution of Information Technology exceeds the ability of cities to assimilate knowledge, make decisions, plan, design and deploy a particular technology at scale. This creates strong competition between multiple technologies with competing ecosystems and little stability.
3. Technological leaps are not only moving at a rapid pace, they are also increasing in complexity requiring very sophisticated skills that come at high cost. In fact, commercial entities have been battling to acquire those rare skillsets, making it harder for government organizations of smart cities to achieve the same.
4. The organizational structure of cities, the decision-making cycle, the process of evaluation and deployment is slow to assimilate complex modern technologies that cut across vertical silos around which city functions have developed.
5. Cities plan over the long term and expectation for mature technologies and validated business case. Modern technologies have a short lifespan relative to what cities seek. Often, the business case is not validated for wide scale deployment. Validating the return on investment is a time-consuming activity.

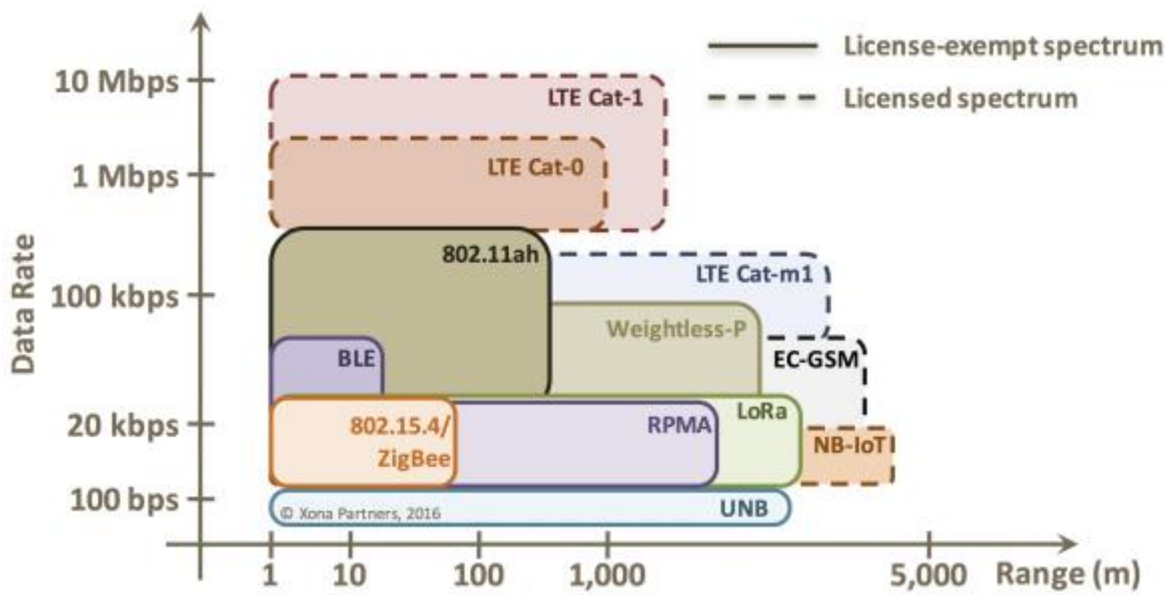
6. Modern technologies are increasingly reliant on virtualized/cloud environments, which accentuate the need for specific skillset in software and programming languages that many cities either don't possess, or find hard to attract.
7. Finally, standards have not evolved at the same pace as the technological advances, and it is difficult for risk-averse organizations to make bets on which technologies will win. This has also resulted in a large number of technologies competing in similar applications. In parallel, open source models have taken the lead in evolving technologies, making it even harder to bet on standards coming to fruition over short-term horizons.

Making the Case: A look at Connectivity & Data Systems

We illustrate the cascading technology challenge through two areas critical to the implementation of smart cities: connectivity and data system architectures, thus encompassing data generation, transmission, management and optimization mechanisms. We opted for these two as they constitute two major functions of the technology stack. Connectivity is a fundamental layer on which other layers of the technology stack are built. Data systems are at the top of the technology stack that typically garners much of the value in the chain in contrast with commodity-based connectivity solutions.

The Connectivity Layer

The connectivity layer comprises a network of one or more access technologies, which includes both wireline and wireless technologies. For the purpose of this paper, we focus on wireless technologies and particularly on wide-area access technologies. Hence, we ignore a host of short and medium range wireless technologies such as Bluetooth, ZigBee, and Wi-Fi to focus on cellular technologies that have in the past 3 years received much attention and investment capital. It is important to note that, in many applications, short-range technologies compete with wide-area networks in cost and performance, complicating the technology selection process.



The choices for wireless wide-area technologies could be categorized according to spectrum type, which governs technology, market and economic aspects:

a. Licensed-spectrum technologies: This comprises technologies traditionally used for personal communications, which in time has been adapted for machine-to-machine communications. It includes eGPRS (2G), 3G UMTS and a number of LTE-based machine-based technologies such as Cat-1, Cat-0, Cat-m1, and NB-IoT.

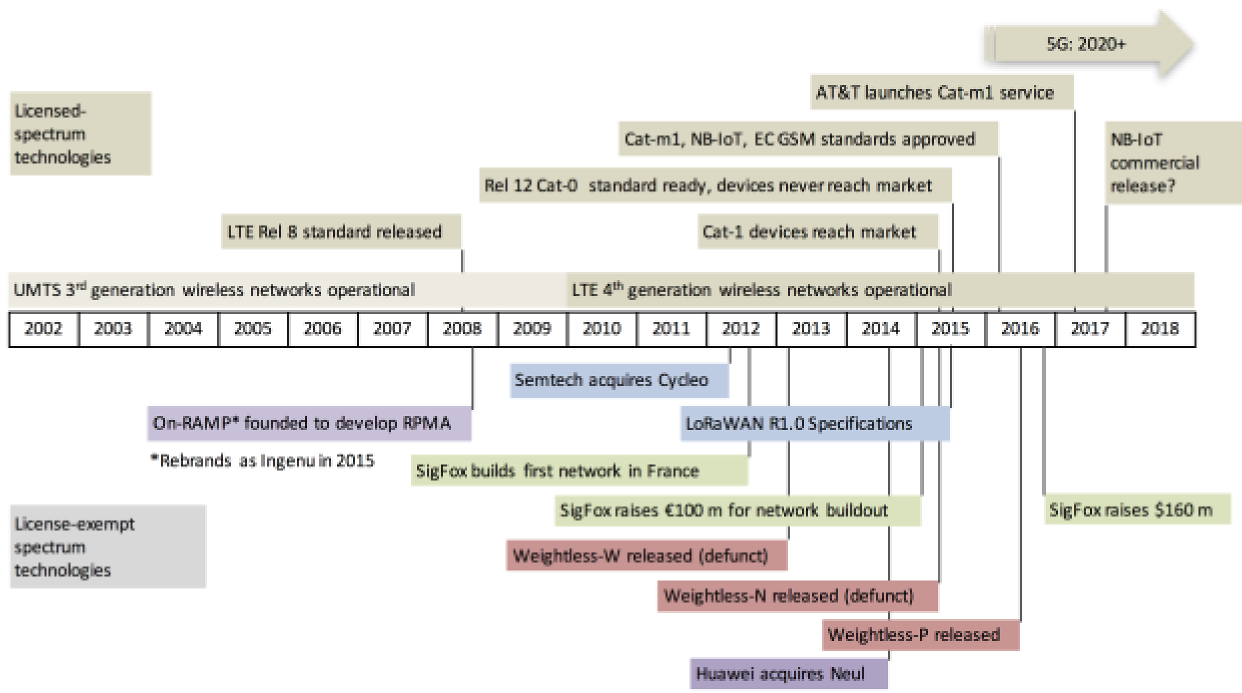
   eGPRS leads market penetration worldwide, but its market share is declining as LTE-based technologies become available commercially. Cat-1 devices are first to market among this group of technologies which began appearing on the market in 2015. Cat-m1 became commercially available this year (2017), to be followed by NB-IoT which is still in trial stage. Commercial networks based on NB-IoT are expected by the end of 2017. Additionally, the ecosystem is promising 5G technology to become commercially available by the 2020-timeframe which will introduce yet another machine-type connectivity technology.

   Successive generations of personal communication networks have an average lifecycle of 10-years from network launch to peak market penetration. On the other hand, we find that machine-type communication is being introduced at a pace of one technology every two years, corresponding to the LTE standard release cycle. Thus, the short cycle is due in part to the fact that the different technologies are derivatives off a main technology: LTE. This presents a major challenge to ecosystem players such as silicon and equipment vendors, never mind the end user. In fact, the Cat-0 technology was bypassed by the market and the few companies that invested in developing Cat-0 solutions had to write off their investments.

b. Unlicensed spectrum technologies: This comprises a host of low-power wide area (LPWA) technologies operating in different license-exempt spectrum bands. Examples include LoRa, Sigfox, RPMA, WaveIoT, Weightless, UNB, DART, NB-Fi, among many other technologies. Interest in these technologies began between 2012-2014 with a number of acquisitions and investments - for example, Semtech acquiring Cycleo, Huawei acquiring Neul, and SigFox receiving investments from a consortium of service providers. Today, LPWA technologies are at the peak of the Gartner hype cycle. In fact, perceived threat from the LPWA ecosystem forced the LTE ecosystem to scramble with a technology response exemplified in Cat-m1 and NB-IoT that are also characterized as LPWA technologies.

   The LPWA ecosystem is highly fragmented with different business model for each of its constituent technology ecosystems. Deployments are the order of tens of millions, which leaves much room for future growth. Thus, not only that successive technologies are coming on market at a fast rate, but which technology will have most traction in the market is difficult to determine early in the technology lifecycle.

	Licenses-spectrum networks	License-exempt networks
Operators	Large service providers (typical) with exclusive spectrum license over wide area	Enterprises for own use, or small service providers who share the spectrum with other users
Network Type	Public network (typical)	Private or public network
Ecosystem	- Generally limited to 2-4 service providers per market - Many device vendors with modules certified to run on service provider networks	- Public networks are nascent and few and in number with limited coverage and availability today - The module ecosystem varies depending on the technology: LoRa and SigFox are among the most widely used, but numbers remain low due to early stage of market development
Cost	Typically high module cost (~$20-$40); prices are dropping as newer technologies are commercialized. Technologies such as NB-IoT promise a target of $5/unit.	Varies depending on the technology and the strength of the proponent's ecosystem. LPWA technologies promise sub $5 module price.
Intellectual Property & Standards	Equipment and devices are designed according to standards developed by international organizations (e.g. 3GPP, GSMA, ETSI). Module manufacturers pay royalties based on FRAND-basis.	Different approaches depending on the technology developer, for example: - Sigfox operates as a service provider while licensing its module technology to multiple silicon vendors. - LoRa defined a standard and certification program to promote technology proliferation. Semtech, the owner of the baseband IP, retains the right to license its IP to other silicon vendors. - Weightless developed an open standard where member companies make their IP available based on FRAND-basis



Making a decision on which wide area technology to adopt is multi-layer task that includes multiple functional areas, among which technical aspects are the perhaps the simplest. A city must decide whether it should build its own network or lease a service following proper due diligence covering financial, technical and strategic factors. For each choice, a number of technologies are available to select from, each with a set of characteristics that in most likelihood will only partially meet all of the requirements.

To summarize, based on our review of connectivity technology options, we find two critical factors that bolster our thesis:

1. Technologies are coming on market at a fast rate that is even a challenging for the ecosystem players themselves to decide on which technology to back. The challenge can only be amplified for the cities.
2. The proliferation and fragmentation of technologies each with different go-to-market strategy presents a complex mix of choices for cities to choose from.

The Data Layer

Analogous to what we have witnessed for the connectivity layer, the data layer show similar patterns and conclusions. To illustrate, we briefly revisit main components of the data layer. A smart city data architecture integrates three distinct architectural layers:

Data Source/Sink Layer

The data generation and collection layer comprises primarily of sensors, which are sources of large data sets of very different characteristics, and people, who by means of social networks can provide additional valuable information for the city management, along with all the data collection networks at the source and sink of the data being generated. Along with this, various civic bodies can act as static or real-time data repositories for data related to traffic congestion, power consumption, water consumption, environment and population. These sources can also act as sinks which can absorb information and commands and hence affect the physical or digital world.

Underlying Technologies and Architectural Choices Challenges

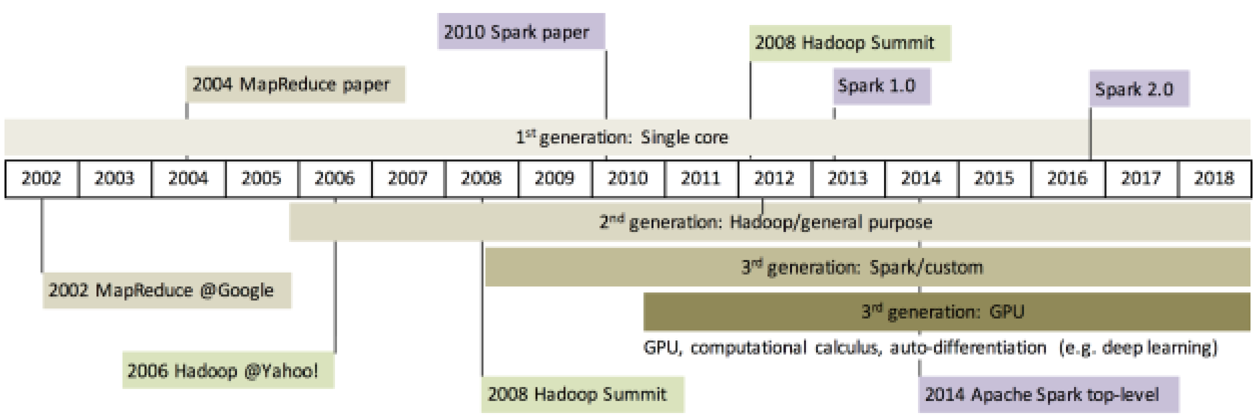
Sensor technologies are central to the data generation and collection processes. Choosing such technologies has its own challenges, not only because of the relation to connectivity decisions, but also due to different aspects that relate to data resiliency, scalability, privacy and security. Addressing reliability has mainly been approached via various data filtering, prediction and anomaly detection techniques, and more broadly under the umbrella of artificial intelligence (AI). Scalability has been addressed via backend platforms, with a mix of local, edge and cloud aggregation models. Ensuring data privacy has relied on a set of fast evolving authentication, cryptographic and anonymization techniques. Finally, data security has been one of the most challenging angles to master; work is in progress to find the proper balance between the sophistication of security techniques such as encryption, tokenization, and isolation against the cost of such deployments. Over the last decade, iterations of these diverse technologies were developed and deployed, forcing any organization aiming at addressing these challenges to have the proper expertise, which is hard to find, costly and with continuously increased sophistication. This has particularly been the case for smart city design teams.

Analytics Layer

The data analysis layer is the interface between the data source layer and application management layer. The analytics layer deals with data storage and transformation to usable form, and with data processing through analysis models to churn out important insights, which are used by the application layer. The analytics layer includes a knowledge base, which has a-priori domain knowledge rules, user profiles, and pattern information to help in data analysis. After data is transformed and aggregated, several rules from the knowledge base are applied to generate alerts in real time and outputs in forms that are easy to ingest by the application layer. Said in another way, the analytics layer is where the intelligence of the city lies and where complex decisions are processed and taken. This is the layer where the big data techniques and data sciences techniques come into play.

Underlying Technologies and Architectural Choices Challenges

Data management techniques have been rapidly evolving making design goals a moving target for most organizations. Adding to the complexity of making the appropriate data management decisions at scale is the selection of the appropriate deployment model. Three such models have been popular over the last decade. First, the open source models where the leading cloud/internet companies open-sourced their big data followed by their artificial intelligence code. Some fast followers built open source experienced teams and led their own deployments. Second, a consolidation happened around the leading open source models, which forced a concentration of options for the end users. This has been the case for the big data solutions demonstrated by the offering of MapReduce, Cloudera, HortonWorks, Pivotal and a few others centred on Hadoop Big Data frameworks. A similar consolidation occurred for AI and Machine Learning around frameworks such as TensorFlow, Mahout, Torch, MLlib among a few others. Third, a parallel track emerged of commercial vendors with proprietary Big Data and AI implementation and niche market specialization. The variety of choices and constant shift in optimal cost vs. functionality outcome has made it challenging for many organizations, including smart city design teams, to make timely decisions.



Application Management Layer

The application management layer includes several applications, which can be particular to smart city in addition to management applications. Decision makers use the applications to take preventive measures, make policy changes or issue orders in case of adversities. The applications maintain the health report of end devices and can point out the areas, which have been overlooked. The application management layer eases the decision-making process with access to results and analysis carried by the analytics layer.

Underlying Technologies and Architectural Choices Challenges

Building applications has evolved into two major directions. The first one has focused on leveraging commercial or open source backend platforms, which are mainly positioned as Internet of Things (IoT) platforms. The second has focused on building native applications that would leverage IoT data at scale. In both cases, challenges have been significant: IoT platforms are highly fragmented and limited on interoperability and backward compatibility. On the other hand, building web-scale applications over cloud platforms meant mastering web scale software design, and most importantly, aspects related to continuous integration, continuous delivery (CICD) and microservice-based design over evolving cloud, virtualization and containerization models. Here again, very specific expertise is required in order to make the right design decisions and long-term architectural choices. This has been a major challenge for smart city design teams.

In summary, a review of the data layer indicates the following critical factors:

1. Technologies are being introduced at a fast rate and are especially bolstered by the open source approach.
2. New technologies rely on and modern software development processes such as CICD. This stresses smart cities teams who need to possess rare skills to take advantage of these new technologies.

Avoiding the Trap

Cities around the world are cognizant of the cascading technology challenge. In response, cities have adopted different approaches, which are still evolving. We can discern four fundamental strategies, aside from ones that combine elements of the four:

1- Involve startups and early stage ventures: Several cities have taken this path, but perhaps Singapore exemplifies this approach as illustrated in the May 24th, 2017 direct budgeting of smart city contracts to startups. The strategy is simply: much fast-moving innovation comes from startups that are probably the best at integrating rapidly evolving technologies and deploying them economically. The cities that have taken this path did so primarily via a model where governments award contracts to startups, among others parties, for solving specific smart city problems. How addressable problems and corresponding startups are selected and how viable the approach is, are still work in progress. This approach has the beneficial side effect of fast tracking the development of the local startup ecosystem. Dubai is among the cities embarking down this path, as seen from the Dubai Future Accelerator, and the newly launched Smart Cities accelerator on May 31st 2017. The downside is the inherent risk of working with startups, which has to be mitigated through a well-balanced model of ensuring that the selected ventures have a good likelihood of survival.

2- Involve Internet and cloud players in the smart city design: this is the case in Kansas City among other cities. The premise is straightforward: Cloud players are leaders in data and information technologies who aim at disrupting the status quo in adjacent markets. Thus, players, such as Google, are welcomed to deploy their solutions with the goal of heightening the competitive landscape and leading the remaining players to adapt. The city is advantaged by ensuring that the right technology decisions are made. Seoul, South Korea, followed this path with SK Telecom acting as the lead player. The advantage of this model is that it ensures that the latest technologies are deployed. On the other hand, the high rivalry between the cloud players and other players in the ecosystem shifts the challenges to regulatory and politically sensitive ones, especially when the cloud players operate in foreign countries.

3- Slow down and make progressive smart city decisions: This is the case for cities where decisions are linked to a relatively progressive roadmap according to a fast-follow model. Hong Kong exemplifies this category with an approach that relies on building progressive smart city blueprint, the latest of which targets the end of 2017, and a deployment based on proven business case led primarily and independently by distinct government groups within the city. European cities, such as Paris and London, have also been followed this model. This model has the advantage of optimizing the deployment cost structure at the expense of deployment timeline. On the other hand, it has been hard to overcome the challenge of making technology decisions prior to such technologies moving into their next development iteration.

4- Consortium based smart cities decisions: Barcelona is an example in this model. The strategy relies on building an ecosystem that includes city government, technology players, R&D labs, telecom operators, startups and universities. Solutions are chosen based on a cooperative model among all parties in order to share experiences and minimize risks. Other cities in Europe, such as Stockholm, have to some extent been following this model. This model has the advantage of creating additional synergies between the various players in the smart city value chain. On the other hand, decision-making tends to be complex and proper governance has to be in place.

Strategy	Pros	Cons	Example
Startup catalysts	Fastracks development of local startup ecosystem	Risk associated with startups	Singapore, Dubai
Majors lead	Ensures latest technologies are implemented	Requires proper regulatory and governance to mitigate downside on intense rivalries	Kansas City, Seoul
Progressive implementation	Optimizes cost structure	Slow technology decisions	Hong Kong, Paris, London
Consortium approach	Creates synergy across value chain	Complex decision making; requires proper governance	Barcelona, Stockholm

Various other models have emerged to address the cascading technology challenge. Some cities, such as Tallinn, Estonia, have leveraged their small size and agile nature to attempt to overcome this challenge. Others focused primarily on greenfield cities to perform initial validations such as different smart cities in Saudi Arabia. Yet others focused on vertically organized governance, in divergence with most smart city frameworks that tend to be horizontally organized and optimized.

Smart Cities Ecosystem: Recommendations

How can cities address the cascading technology trap? The experiences of some of the highlighted cities provide indications on possible approaches. However, our conviction is that solutions have to be tailored to the specific ecosystem. Hence, solutions would differ depending on a number of factors such as size, location, governance structure, economic conditions and other factors. Given the diversity of cities, we can only offer high-level recommendations that apply broadly:

1- Startups involvement: progressively develop models that allow startups and innovative companies to engage in smart city solutions. This includes defining a startup-friendly deal-flow and procurement process and encouraging compatibility of startup solutions with those from larger solution providers. The scope varies and includes, for example, co-creation studios and hackathons among many other approaches.

2- Global view: Bridge from a local perspective into a global perspective by optimizing the learnings from other cities, primarily those related to technical solutions. There are multiple approaches to achieve this objective, with one of the most relevant being establishing a task force to review and analyze results of select technology deployments in global cities.

3- Link to leading technology players: Bridge into globally leading technology players that have a fair control over technologies central to smart cities. Primary approaches include providing incentives to global players to dedicate resources to smart cities experimentation models and enacting favorable regulations for such players, for example, related to wireless frequencies, data privacy, drones, etc.

4- High-end talent: to bridge the divide between new technologies and their implementation timelines is key ultimately requires building capable technology teams. This could be achieved as a federated exercise across cities where the pool of resources is shared along with returns.

No one strategy to avoid the cascading technology trap is perfect; hybrid models will develop. Cities have much in common but also differ in important aspects that necessitate tailored models. But if there’s one fundamental common thread in all models is that the integration of specialized technology experts within smart city organizations is critical.

Conclusion

The evolution towards smart cities has primarily been synonymous with leveraging new information and data management solutions to optimize operations and offer important services to citizens. Such solutions are evolving rapidly with successive technologies coming onto market faster than cities, and even technology companies, can absorb and leverage. This cascading technology challenge is at the forefront of challenges for cities determined to implement their progressive vision of smart city solutions. In response, leading cities developed different models to address this challenge. These models remain evolving. While no single model is best, successful cities integrate highly specialized technology personnel within the smart city framework.

Acronyms

3GPP	Third Generation Partnership Project
AI	Artificial Intelligence
Cat-x	Category x
CICD	Continuous Integration, Continuous Delivery
eGPRS	Enhanced General Packet Radio Service
ETSI	European Telecommunications Standards Institute
FRAND	Fair Reasonable and Non Discriminatory
GSMA	Groupe Spéciale Mobile Association
IoT	Internet of Things
LoRa	Long Range
LPWA	Low Power Wide Area
LTE	Long Term Evolution
NB-FI	Narrowband Fidelity
NB-IoT	Narrowband IoT
RPMA	Random Phase Multiple Access
UMTS	Universal Mobile Telecommunications System
UNB	Ultra-Narrow Band

About the Contributors

About Xona

Xona Partners (Xona) is a boutique advisory services firm specialized in technology, media and telecommunications. Founded in 2012 by a team of seasoned startup technologists, managing directors in global ventures, and investment advisors, Xona draws on its founders' cross-functional expertise to offer multidisciplinary technology and investment advisory services. Xona works with private equity investors and technology corporations in pre-investment due diligence, post investment lifecycle management, and strategic technology management to develop new sources of revenue. For additional information, visit http://xonapartners.com.

About Wavefront

Wavefront is Canada's leader in transforming business through mobile and IoT innovation. We are a centre for commercialization for companies in the wireless and IoT technologies space and our vision is to build a globally relevant, nationally connected ecosystem that delivers digital capacity, competitiveness and prosperity for Canadians. Please visit www.wavefront.ca to learn more.

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