Smart Cities

Technology Roadmap

Table of Contents

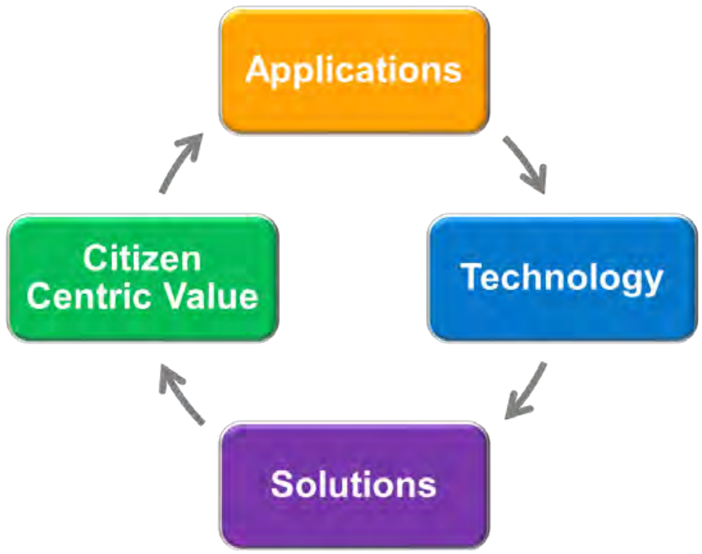
1. Introduction

Cities and communities are deeply immersed in the assessment and planning of Smart Cities projects, as transformative applications and solutions are impacting the market. The pathway from powerful Smart Cities *projects* to comprehensive Smart Cities *plans* is a significant leap, given the diverse set of needs, applications, and solutions that are shaping each city's vision. The ATIS Technology Roadmap is focused on the key technological developments that will enhance the long-term planning for Smart Cities. It is targeted to the Smart Cities' planners, technology advisors, and key decision-makers who are faced with developing comprehensive long-term visions for their municipalities and citizens.

The role of technology is best calibrated by those who ultimately deploy and operate the technological solutions. This is especially true in the case of Smart Cities, as municipal planners are faced with the challenge of smart technology alternatives that must intersect with the unique needs of cities, neighborhoods, and citizen population. In an effort to provide this valuable planning resource, ATIS has undertaken extensive discussions with city leaders, solution providers, and manufacturers who are selling to this market, all of whom are heavily invested in the evolving Smart Cities environment. This included discussions with municipal CTO and CIO resources, and other technical decision-makers, who will ultimately gain value from this Report.

One of the key learnings is the perception that technology is just one part of a much broader ecosystem connecting local government needs with citizen-centric value. This is

accomplished through ongoing citizen engagement, which ultimately leads to sustainable cities that promote livability.



Smart Cities Ecosystem

So, how does a deeper view of technology shape this ecosystem? It is understood that applications and unique city and community needs will act as the catalyst for Smart Cities growth and shape specific projects. However, a technology trajectory will provide Smart Cities planners with a guide to industry developments that will impact the creation of *integration-friendly* city-wide plans. These developments include advancements in networks, new applications that can leverage the next generation of devices, intelligent connectivity, and technology trends that will impact the public and private sectors.

Given the wide audience for the Technology Roadmap, this report has been organized to provide a layered review

structure, depending on the appropriate level of technical exploration deemed necessary by the reader. Section 2 provides an overview of Smart Cities challenges and benefits, based on outreach to city leaders and the industry. Section 3 provides a high level technology framework and summary of key technology enablers for the broader audience. For those readers interested in a more in-depth assessment of key technology developments, Section 4 includes a deeper analysis of the technology enablers that can enhance Smart Cities planning, including the current state of development and standards, a review of technology choices and an assessment of critical factors that may impact future deployment. Section 5 provides a focused assessment of each Application sector, and how it will be impacted by the various technology developments and enablers. Section 6 provides an example industry reference regarding level of uncertainty (and risk), through public and private partnerships. Finally, Section 7 delivers an overall set of conclusions, and identifies the next steps for this ATIS collaborative initiative.

2. The Road to a Sustainable Smart City

It is understood that the development of a comprehensive and long-term city-wide *plan* is a significant undertaking, both from a level of complexity as well as migration to new business models. As the Smart Cities market rapidly expands, it is the objective of the ATIS Technology Roadmap to assist local municipalities in meeting these challenges and delivering a sustainable Smart City. In this context, sustainability goes far beyond the concept of sustainable energy. The vision of a sustainable Smart City is one that optimizes its investments at every point in the build cycle and fully leverages integration across its many opportunities and solutions.

In addition to the development of a comprehensive plan, which is customized to each city's needs, the long-term sustainability of a Smart City will be shaped by the ability to implement a viable business model. While it is not the purpose of this document to articulate the details of a generic business model, it is expected that enhanced knowledge of key technology developments and enablers can be coupled with city assets to create sustainable funding and perceived citizen value across the range of applications. Topics such as next generation analytics and data stream management will be explored later in this document, and can offer opportunities for cities to leverage their data assets.

Before exploring the significant technology developments that will impact Smart Cities, it is important to assess the needs and expectations that are driving the municipal efforts thus far. ATIS has engaged its members invested in Smart Cities projects, other industry groups, and most importantly,

some key Smart City leaders, to understand the landscape and trajectory of Smart Cities strategy. Some of these key learnings include:

- **No singular definition of Smart City.**
- **Business model varies greatly from Enterprise market.**
- **First-mover application(s) generally act as a catalyst and will evolve to a more holistic approach, where a common technology infrastructure will support multiple applications and enable interoperability across organizational boundaries and applications.**
- **Grants and public-private sector partnerships will eventually progress to new financial models.**
- **Complexities of city-scale operations present challenges in building a comprehensive long-term plan because of changing administration, department budgeting processes, and other municipal realities.**
- **City needs and requirements vary across neighborhoods.**
- **Integration between government sectors and citizen-centric applications will ultimately define Smart City success.**

It is the goal of this document to apply these learnings to a deeper understanding of the technology evolution landscape and create tangible benefits to Smart City planners and key decision-makers.

These benefits include:

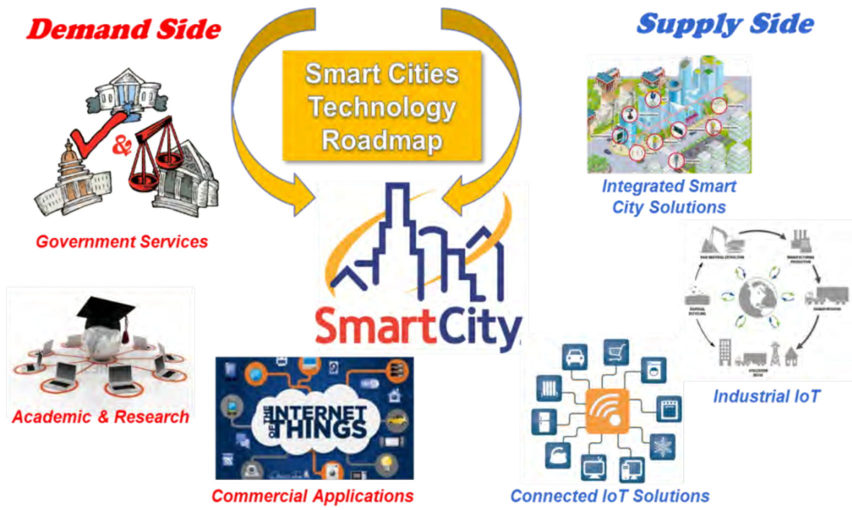
✓ **Greater confidence in sustainability of initial investments and interoperable solutions.**

✓ **Guidance on future timing and staging of technology to facilitate integrated services and opportunities.**

- ✓ **Accurate view of network-enabled developments that will promote future government and citizen applications.**
- ✓ **Baseline planning view for next-tier communities (which may not possess large city resources).**
- ✓ **Intersection with private sector developments that are key to creating Smart City ecosystems.**

Like any roadmap, the Technology Roadmap described in this document provides a view of potential pathways from a starting point (today's current state of technology in most cities) to an intended finish point, i.e., a Smart Cities vision. At the same time, it is understood that any Smart City project is continually in motion, and therefore, will continue to grow and expand as new needs and applications are defined by citizens and government. In fact, the very definition of a Smart City is that it is a dynamic and ever-changing undertaking.

The unique positioning of the Smart Cities Technology Roadmap between the Applications space and the Solutions space will serve as an enabler for this market. It is acknowledged that solutions companies are already providing forward-looking technologies and innovation to meet Smart Cities needs. The Technology Roadmap is intended to supplement these innovative solutions by providing a collaborative industry view of the developments that will impact Smart Cities over the next 1-4 years.



The scope of this report, and the elements that comprise the Technology Roadmap, go beyond a simple definition of technology developments. The objective of this work is to take a broader view of the timelines, standards, and critical developments, including dependencies and opportunities with commercial-side developments.

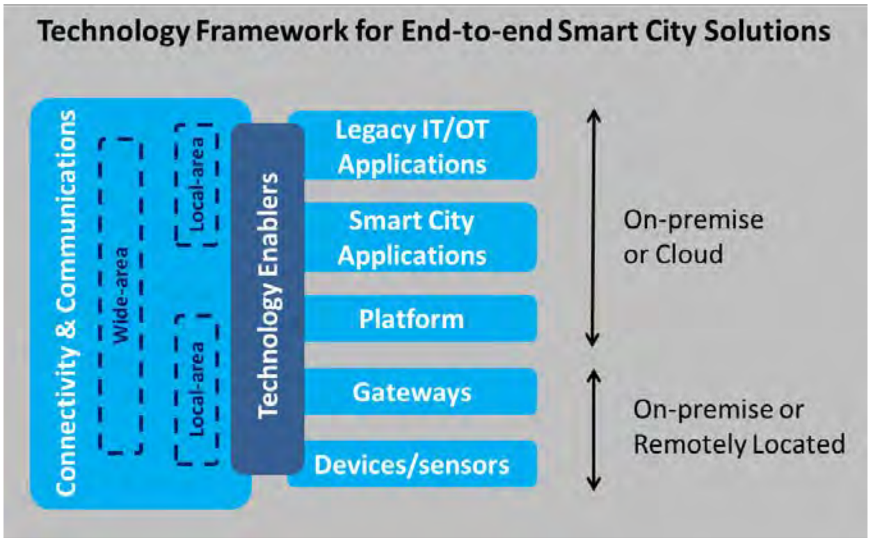
Scope of Technology Roadmap

The remainder of this document will focus on these five components and provide significant detail on technology developments and their impact on Smart City applications and opportunities.

3. Technology Framework for Smart Cities

3.1 Overview

The first step in defining the technology landscape is to adopt a technology framework that helps Smart City designers in mapping the different elements necessary to create a complete set of Smart City applications. As illustrated below, a simple smart city solution contains one or more connected devices and sensors. These provide their data, possibly via a gateway if local aggregation is necessary, to a platform. The role of the platform is twofold: one is to activate, monitor the status of devices, and remotely manage their configuration; the second role is to help developers to build, deploy, and manage individual applications, such as street lighting, smart parking, or traffic flow management. Many applications rely on data and operational policies that reside in legacy information technology (IT) or operational technology (OT) systems within a city. A patchwork of local and wide area communications technologies provides a connectivity fabric between these components, which are distributed in remote locations, within the premises of a city's technology infrastructure, or in a service provider's cloud.



Technology Enablers

The role of a *technology enabler* is to act across one or more layers of the Smart Cities technology framework and create end-to-end value for users of the Smart Cities ecosystem. Technology enablers can be further categorized into classes, depending on the primary part of the framework in which they act upon.

Access Enablers **– Create and/or manage access to sources of city or citizen data.**

- **Privacy and Security Controls**
- **Geolocation Services**
- **Context-Aware Services**
- **Internet of Things (IoT)-Enhanced Crowdsourced Data**

Platform Enablers **– Support the distribution, management, exchange, and integration of data and services.**

- **Advanced Analytics (machine learning/artificial intelligence)**

- **Data Integration Platforms**
- **Data Exchanges**
- **Augmented Reality/Virtual Reality (AR/VR) Platforms**

Application Enablers **– Apply rich content and promote the development and use of open Application Program Interfaces (APIs) for Smart City services.**

- **App Marketplaces**
- **AR/VR Content**
- **Evolution of Content Ecosystem**

Infrastructure Enablers **– Provide improved means to manage and protect city and citizen assets.**

- **Distributed Resiliency**
- **Enhanced Asset Management**
- **Disaster Preparedness**

3.2 Core Elements of Technology Framework

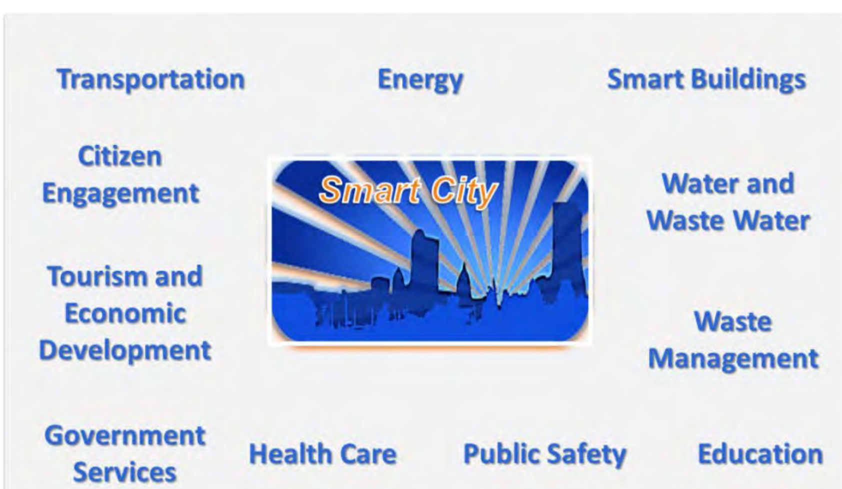
3.2.1 Applications (Future & Legacy)

It is understood that most Smart City plans will be built upon a desired set of applications, which will consist of a visionary suite of citizen-centric applications coupled with a legacy set of IT/OT applications. The current operating environments of most cities include operational technology hardware and software that has been typically deployed as part of a closed network, allowing real-time control of assets. The current infrastructure for legacy OT applications is often supported by private line circuits and municipal infrastructure, which has little interaction with commercial networks. As Smart City planning expands, there will be opportunities to migrate legacy IT/OT to new devices and platforms, and to incorporate cloud and advanced delivery

networks. The intelligent connectivity enabled by these delivery networks will offer similar benefits around performance, resiliency, and integration as they are developed to meet future Smart Cities applications.

Given the high level of activities related to Application Frameworks across the industry, it is not the intent of this document to promote a new or unique framework of Smart Cities needs and applications. In addition, it is understood that many of the existing Application Frameworks focus on first generation Smart City requirements. As new applications emerge in the future, the embedded technology platforms will need to evolve to meet new demands in terms of scale and scope. ATIS has reviewed existing and openly accessible application frameworks from international organizations such as the Smart Cities Council, IES-City Framework, ITU-T, and the GSMA, and has developed this converged view of Smart City sectors (shown below) to act as a reference for the discussion of Smart Cities applications to follow in the remainder of this document.

Application Framework



The enhancements to Smart City applications, provided by future technology enablers, will be more fully explored in Section 5 of this document.

3.2.2 Smart City Platforms

While platforms have a range of definitions in the industry, the role of platforms in a Smart Cities context includes management of connected devices plus the management and enablement of services to support applications. In this sense, platforms can be viewed as the combination of connected device platforms (CDP) and application enablement platforms (AEP), or CDP + AEP. This is a significant opportunity in terms of how municipal infrastructure has been deployed and managed in the past.

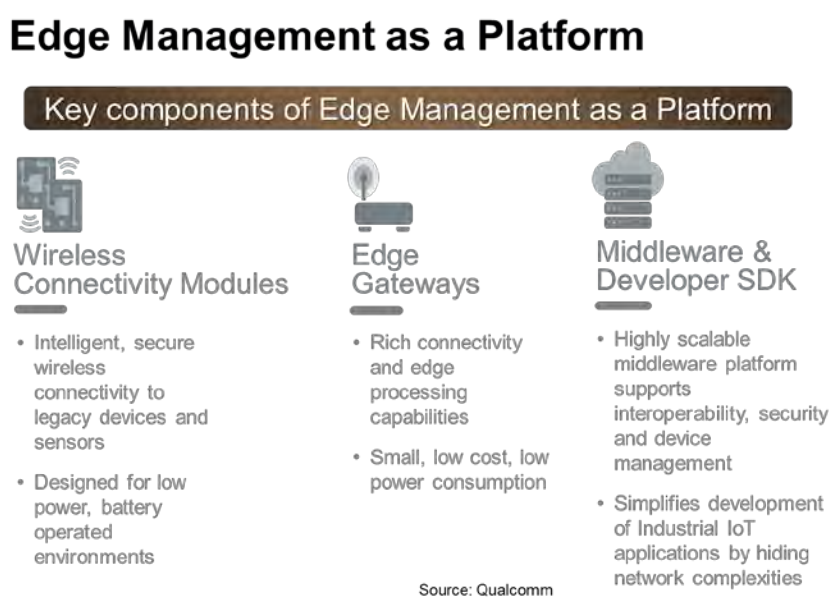
Today, many utility and municipal assets have limited connectivity. Assets that are connected frequently use conventional Supervisory Control and Data Acquisition (SCADA) systems and legacy telecommunications facilities. In addition, these assets often use disparate databases for monitoring, management, and control. Similarly, analytics are done in large proprietary and expensive back-ends.

Intelligent connectivity is a near-term opportunity for municipal planners and is defined by the following elements:

- **<u>Connectivity</u> – Localized/P2P connections (asset-to-asset, asset-to-sensor, and asset-to-human communications), including plug-and-play secure wireless connectivity.**
- **<u>Interconnect</u> – Connection between an asset and/or gateway and the cloud for processing and analysis of large amounts of information, and to facilitate operations and maintenance as well as longer-term trending.**

- **<u>Edge Processing</u> – Localized and real-time analysis of the health and state of an asset to facilitate command and control, including open and secure architecture that supports developer communities for application development.**

One of the key developments related to edge processing is the concept of edge management as a platform, which includes connectivity modules, edge gateways, and the embedded middleware and application development resources.



The introduction of edge gateways for the industrial IoT market is laying the groundwork for embedded software. These capabilities are well-suited for the Smart Cities environment, which rely upon distributed sensors and the need to manage and filter large volumes of data near the source of data collection.

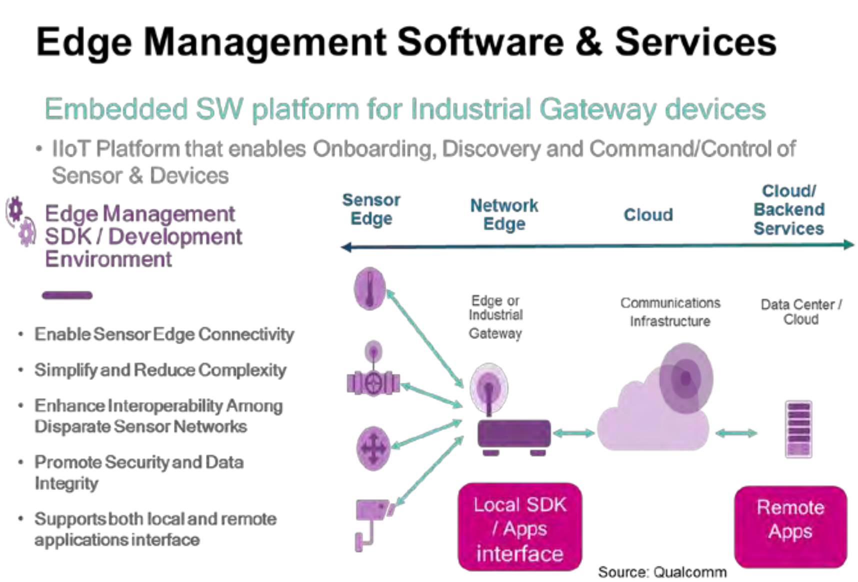
The communications infrastructure is similarly developing to support edge computing, and will play a key role in enabling intelligent connectivity and edge processing. Edge computing can essentially present an IT service environment at the Radio Access Network (RAN) edge. While network operators will see more efficient utilization of the RAN and the network resources, Smart Cities applications will realize unparalleled quality of experience, contextualized services tailored to individual needs and preferences, and innovative applications that can take advantage of optimized edge performance. This environment can enable entirely new service categories and capabilities:

- **Real-time**: Real-time delivery of live and on-demand content; robust low latency for critical communication (Examples: edge video orchestration; tactile internet; delivery of live and on-demand content; Advancements in Vehicle-to-Vehicle [V2V]).
- **Interactive**: Maximum transaction rate between device and local application for unique experience (Examples: augmented reality; indoor navigation).
- **Analytical**: Real-time analytics at the point of capture, minimum cloud ingress bandwidth (Examples: throughput guidance; IoT analytics).
- **Security and privacy**: Local communications to private networks for performance, privacy, and security (Examples: unified communications, biometric user identification).
- **Distributed**: Distributed computing for intense local tasks (Examples: unified communications, biometric user identification).

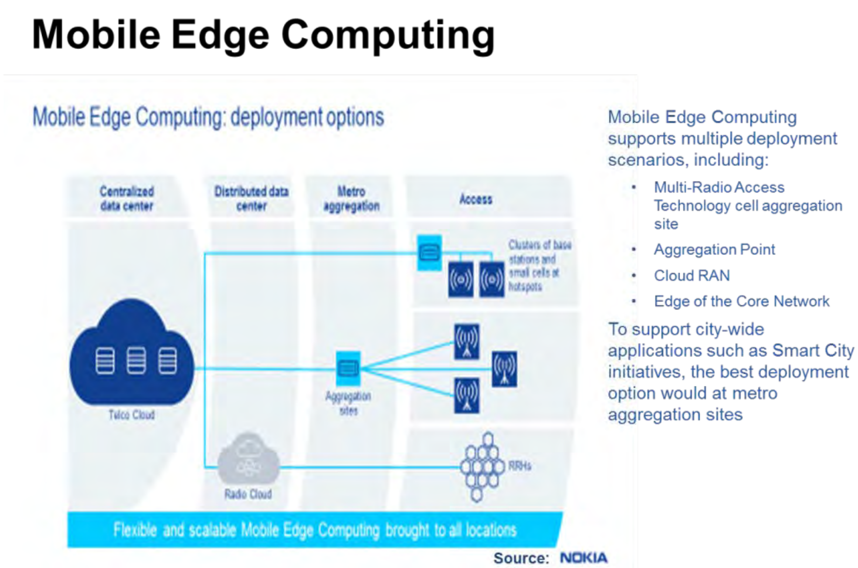
3.2.3 Smart City Gateways

Gateways may contain some platform functions, but, from a physical perspective, they can be viewed as aggregation points for local sensors and connected devices. Similar to wireless networks, where wireless access points can be the aggregator and backhaul mechanism for Wi-Fi and Bluetooth devices, Smart City gateways provide a valuable function in terms of aggregating sensor and IoT device data and providing more efficient backhaul to the city's core assets.

The introduction of edge gateways for the industrial IoT market is laying the groundwork for software platforms embedded in gateways and connected devices. These capabilities are well-suited for the Smart Cities environment, which relies upon distributed sensors and the need to manage and filter large volumes of data near the source of data collection.



Another key development that will enhance the value of edge gateways (and edge management platforms) is Multi-Access Edge Computing (MEC). MEC solutions and standards are still under development, but MEC does offer the opportunity to be extended to many points in the network and deployed in multiple scenarios.



Beyond the functional attributes of this technology, MEC does enable mobile service providers to extend cloud computing capabilities to the edge of the network, and open up application development opportunities to third parties, who can create innovative services for consumers, businesses, and Smart Cities. Targeted applications include edge analytics, processing of IoT data streams, augmented reality, and other future needs that will benefit from creating the equivalent of an IT cloud computing function at the network edge.

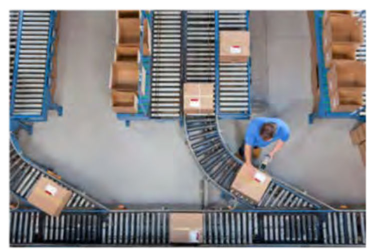
3.2.4 Smart City Sensors and Connected Devices

One of the significant advancements in the next few years will be in the development of low power WAN (LPWAN) devices and IoT-enabled sensors and devices. While 5G will open up many new use cases for the IoT market, it should not be inferred that current generation devices cannot meet the near-term needs of the marketplace.

3GPP LTE-NB technology is being introduced and supported by standards. These IoT devices are being developed to meet the need for low cost modules, low power consumption, extended battery life, and improved wireless coverage.

Enhanced IoT Solutions

- 3GPP LTE-NB IoT standards set in mid-2016
- Cat-M1 trials started end of 2016
  - ➢ Broad range of use cases
  - ➢ Expected Cat-M1 benefits:
    - ➢ Access to low-cost module technology
    - ➢ Extended battery life of 10 years or more for enabled IoT devices
    - ➢ Enhanced LTE coverage for underground and in-building areas that challenge existing coverage
- Cat-NB1 progressing
  - ➢ Lower throughput and lower power use cases
- 5G "Massive IoT"



IoT is allowing "things" that were not connected before to now work seamlessly together, making our work and our lives more efficient in ways that we never dreamed possible

Source: AT&T

The future landscape for IoT-capable devices will be heavily dependent on LPWAN technology, which is currently under a state of rapid development. A first step is to understand the basic design parameters for LPWAN, illustrated on the following page:

Low Power Wide Area Networks (LPWAN)

- The far edge of IoT access.
- Distance: kilometers.
- Data rates: 100s bytes per day.
- QoS / latency: varies.
- Cost: < $5 / module.
- Power: => 10 years on a coin cell.
- Device: constrained on all axis (CPU, RAM, FLASH, etc).

Source: Cisco

Applying LPWAN to the set of expected Smart Cities use cases yields a broad range of potential applications that will almost certainly impact this market in the next few years.

LPWAN Use Cases

Source: Cisco

3.3 Connectivity and Communications

The role of commercial and municipal-owned networks will be critical to the success of Smart City initiatives and the perception of citizens in terms of perceived value. This will include a combination of advanced wireless networks and ultra-high capacity fiber networks to deliver high bandwidth services that depend on high reliability and low latency. Perhaps the most significant development over the next few years will be the implementation of 5G networks.

The promise of high bandwidth/low latency networks are embodied in the development of 5G solutions and standards. While 5G is expected to experience widespread commercial adoption, the application to Smart Cities is impactful and extensible.

2020 and Beyond – Smart Cities (and Villages)

Characteristics of 5G technology that deliver city benefits include:

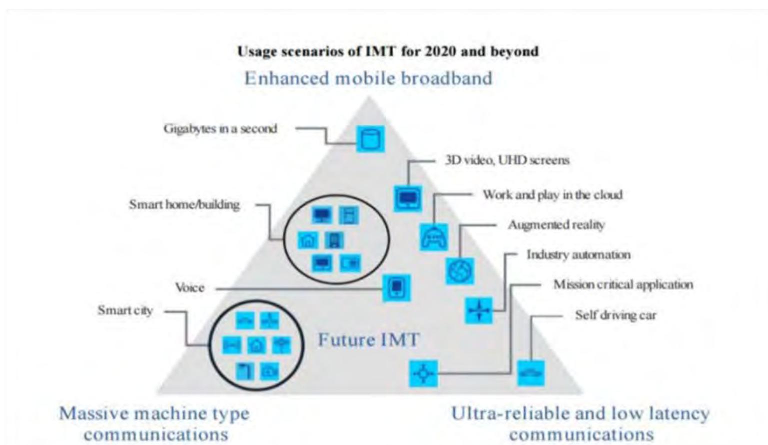
- Broadband virtually everywhere
- Reliable speed
- Adaptive
- Energy efficient
- Responsive, near real time
- Combining wireless networks
- Quality of experience

Evolution to 5G will enable rapidly growing, diverse services for both human and machine communications

Source: AT&T

The manifestation of 5G in the marketplace can be viewed as the product of three core elements: massive machine type communication, enhanced mobile broadband, and ultra-reliable low-latency communications. While IoT-enabled machine type communications is the most obvious link to Smart Cities, mobile network advancements are also key to the integration of municipal services with citizen-based commercial applications.

5G Use Cases – 2020 and Beyond



Source: Recommendation ITU-R M.2083-0

Exploring enhanced mobile broadband (eMBB) and ultra-high reliability low latency communications (UHRLLC) developments even deeper, it is apparent that Smart Cities needs and 5G-enabled use cases have a significant intersection, in both the near-term and the future.

eMBB is one of the key use cases in 5G standards development, and is a significant extension from the data rates that can be achieved today with LTE-based solutions.

Phase 1 of 5G development, targeted for commercial deployment in 2020, will include eMBB requirements, and deliver speeds that approach fiber-like solutions and operate with greater spectral efficiency.

UHRLLC use cases are targeted to future applications such as self-driving cars, eHealth, and mission-critical functions.

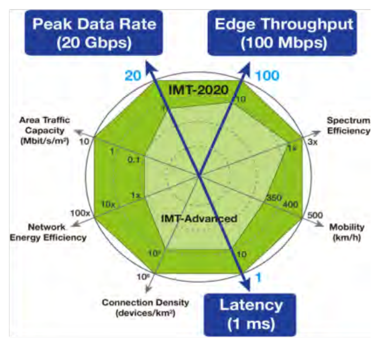
Enhanced Mobile Broadband & UHRLLC Use Cases

Enhanced Mobile Broadband (eMBB)

- Expected throughput of 5 Gbps +
- Example Use Cases:
    - UHD video (4k, 8k), 3D video (including broadcast services)
    - Virtual Reality
    - Augmented Reality
    - Tactile Internet
    - Cloud gaming
    - Broadband kiosks
    - Vehicular (cars, buses, trains, aerial stations, etc.)
- High spectral efficiency (3.5x of LTE)
- Ultra dense network

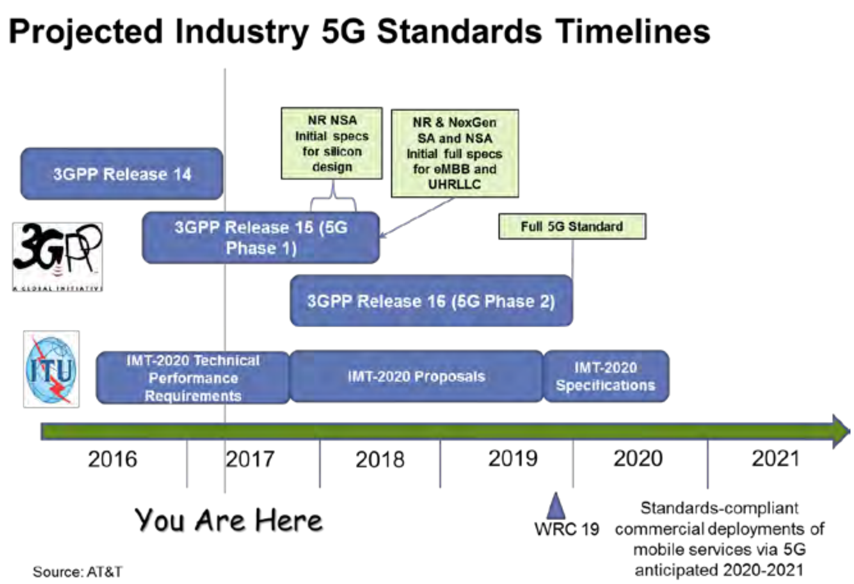
Ultra High Reliability and Low Latency Communications

- Ultra low latency (~ 1msec)
- High reliability > 99.999%
- Example Use Cases:
    - Industrial control
    - Remote manipulation
    - Mission-critical applications e.g. ehealth, hazardous environments, rescue missions, etc.
    - Self-driving vehicles

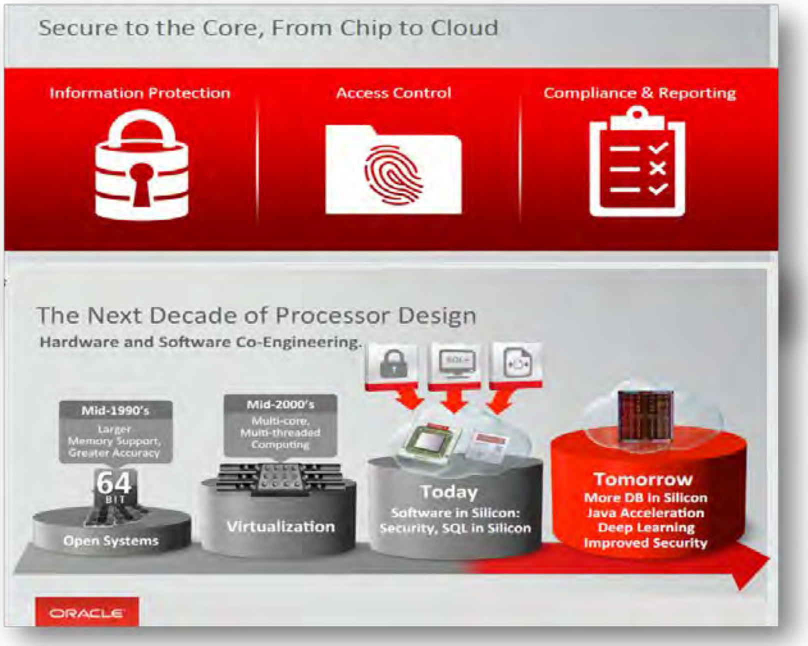


Source: ITU-R

The following diagram provides projected timelines for 5G standards development and associated outcomes over the next four years.



Cloud networks will act as an important component of the communications infrastructure surrounding Smart Cities. One of the key advancements in cloud design will be the co-engineering of hardware and software, defining the next generation of processor design. This approach will provide a number of benefits, including better integration efficiency, platforms that are capable of supporting deep learning, and improved security. Improvements to data protection and access control will be made possible by incorporating designed-in security.



Smart Cities will need to evaluate a number of different cloud approaches, based on their specific needs. One of the cloud alternatives that will offer new opportunities to Smart Cities planners is hybrid cloud. This technology will utilize a combination of private cloud and public cloud resources to create an orchestrated computing platform that can adapt to changing workloads and offer higher efficiency and resiliency.

By deploying hybrid cloud solutions, Smart Cities can defer some infrastructure investments by leveraging public cloud solutions. Hybrid clouds can then be coupled with edge processing and data analytics to provide end-to-end solutions that can benefit many Smart City sectors. One of the key challenges to be met is the orchestration and manageability between clouds – which will ultimately require APIs (most likely from open source development) and networking between on-premises and public cloud solutions.

4. Technology Enablers

4.1 Access Enablers

The role of *access enablers* is to create and/or manage access to sources of city or citizen data. In the future, this will not only include an exponentially increasing number of data sources, but also the availability of location, movement, and contextual information that will add significant value to Smart City applications.

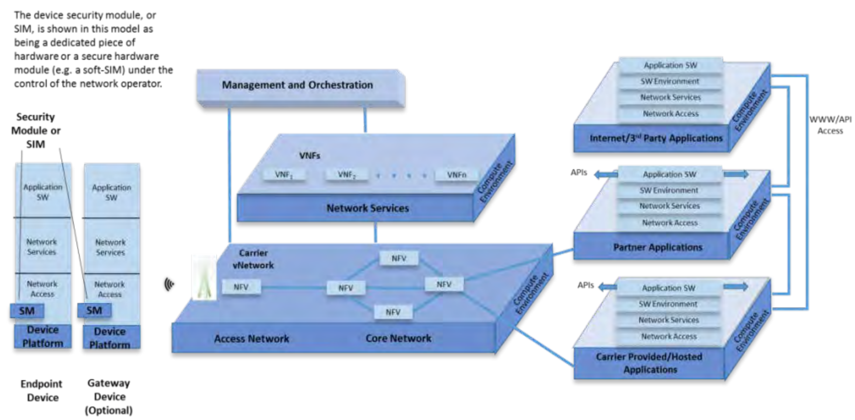
4.1.1 Privacy and Security Controls

One of the obvious outcomes from greater citizen engagement is more data from a growing number of citizen-oriented data sources. Therefore, one of the key challenges to Smart Cities implementations will be security, privacy, and confidentiality of government and citizen data, and the protection of municipal resources against intrusion and unauthorized access. In the context of Smart Cities, security and privacy policies will need to be assessed with respect to three classes:

(1) City infrastructure (hardware and software) typically deployed as sensors or control networks, cameras, surveillance devices, edge management platforms.
(2) Data and information sourced from city assets or citizen devices.
(3) Mission-critical IT management systems.
In response to the growing number of IoT devices being deployed by consumers, enterprises, and government institutions, ATIS has undertaken the development of standards for securing IoT services[1]. In addition to surveying existing industry work on IoT/Machine-to-

[1] ATIS-0100056 "ATIS Standard on Securing Internet of Things (IoT) Services Involving Network Operators" to be published May 2017

Machine (M2M) security, ATIS has developed an assessment of Trust Boundaries and Trust Domains under various IoT deployment models.



As part of this effort, ATIS has identified a list of security features that should be included in any IoT platform:

- Data encryption to prevent eavesdropping.
- Data integrity protection to prevent data tampering.
- Access control covering access to software facilities and data.
- Authentication and authorization control to prevent identity spoofing.
- Credential management to allow security credentials to be managed and securely stored.

The issue of data privacy and layered privacy controls is being broadly explored and discussed from many different angles, including technical, operational, business, and legal implications. Cities have already undertaken analyses with respect to open data platforms and securing data, all the way from the source to the systems that manage, analyze, and present data. In the future, city landscapes will be dominated by an exponentially growing number of new data sources (characterized by IoT devices) and the ability to appropriately treat "personally identifiable information" from citizens and government resources. In this environment, privacy cannot be de-coupled from security.

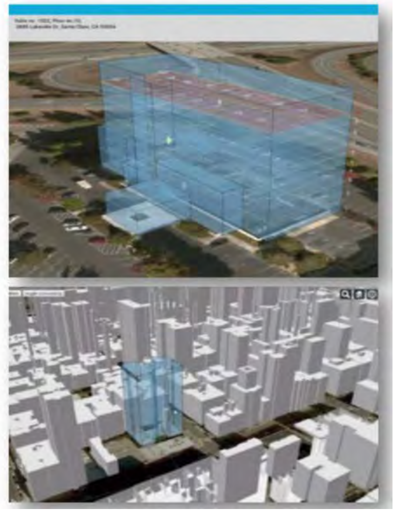
The concept of data exchanges, discussed later in this document, provides a mechanism for cities to define a set of privacy and accessibility rules around how data can be published and shared, and the security controls that help to ensure that privacy needs are maintained across the Smart City ecosystem.

4.1.2 Next Gen Geolocation Services

In the public safety context, one of the areas most essential to emergency response personnel is improvements to indoor geolocation, especially in dense parts of cities and high-rise structured buildings. GPS is the foundation for public services based on accurate position or timing, but has limitations indoors and in urban areas. Smart Cities will have the opportunity to leverage pervasive and reliable 3D geolocation to support public safety response and first responder safety, asset tracking, city worker productivity, geofencing, and other mission-critical needs. The following use cases represent an early view of opportunities for cities to leverage next generation geolocation services.

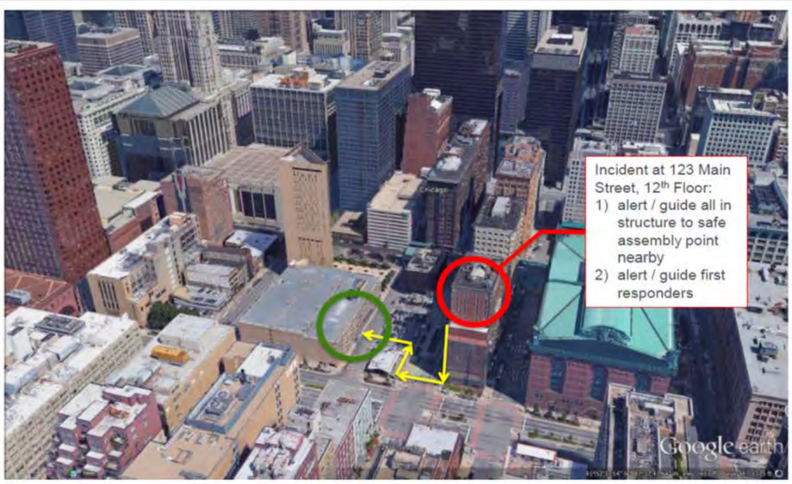
Use case: Public Safety “Blue Force” Tracking

- Public safety personnel are “at-risk” as soon as they exit their vehicle – location is unknown
- Managing dismounted assets at specific events and especially indoors also presents a challenge
- In a vertical urban environment, altitude is almost as important as horizontal coordinates
- Rather than a 2D street-map, 3D visualization becomes highly relevant for incident management, responder safety and many other applications
- Instant and dynamic visibility for assets and opted-in individuals



Source: NextNav

Use Case: Geo-Targeted Incident Management



Source: NextNav

Use Case: Indoor E911

- In 2015, the FCC adopted "all call" location accuracy standards, with a focus on indoor wireless E911 caller geolocation; requirements progress to 50m (or dispatchable location), 80% of the time for all wireless E911 calls, with a vertical standard to be introduced in 2018
- Driving testing / adoption of new technologies to supplement "outdoor-only" GPS:

	Description	Considerations
OTDOA	• Timing technology using cellular RAN • Part of LTE Spec	• Expect lower accuracy • Spectrum (up to 1-4% of LTE capacity) / network config. and maintenance
WiFi / BLE	• Crowd-sourced WiFi finger-printing to position • Can be stake-holder created or OS-based	• Fails in power outages • OS-based solutions cede substantial control • May be challenged in low-broadband areas • 1st-floor vs. upper floors
NEAD Database	• National Database to relate WiFi MAC-Device-Geo Address	• Penetration • Privacy, cyber, power
Metropolitan Beacon System ("MBS")	• Terrestrial Constellation of GPS-like beacons • GPS-like Call-Flows • Urban Focus	• Stand-alone network on separate spectrum (cellular RAN independent) • Deployment timing • Handset penetration timing

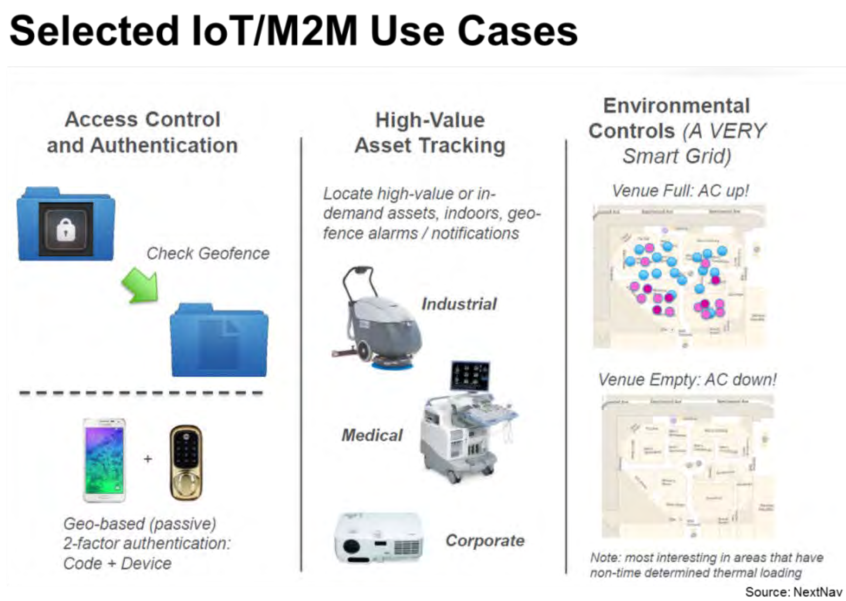
Source: NextNav

Use Case: Autonomous Vehicles

- Autonomous and driverless systems, including cars and "beyond line of site" drones, rely on reliable and pervasive communication and location
- Typically GPS provides approximate location and imaging, RTK and sensors provide fine navigation and collision avoidance
  - NASA UTM requires X-Y accuracy of sub 10m (95%) outdoors
  - NASA UTM requires Z accuracy of sub 15m (95%) outdoors
- In Urban areas, GPS is challenged and there is a need for reliable, pervasive high precision X/Y/Z across a metro area
- Key issues for autonomous industry:
  - Navigation in Urban environments
  - Geofencing / access control and spacing across a metropolitan area
  - Route planning, tracking
  - Backup to GPS

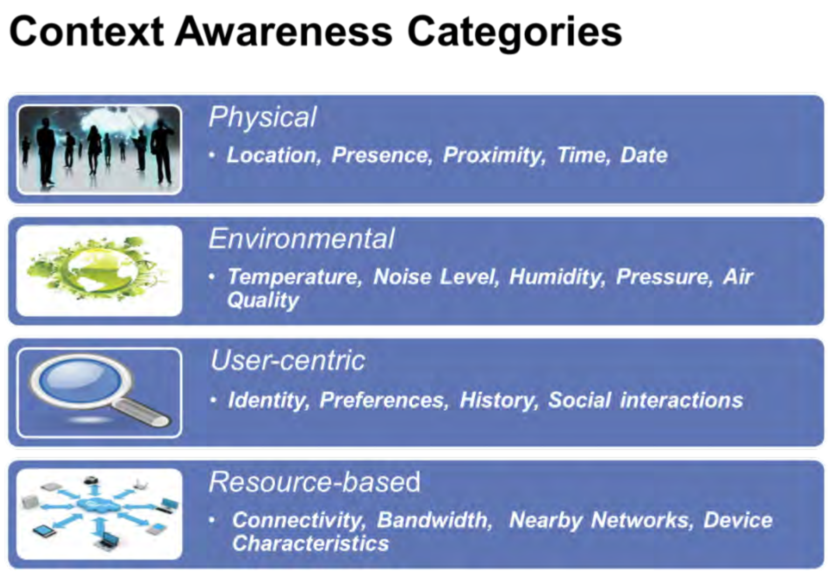
Source: NextNav

Reliable Wide-Area location is a key enabler for pervasive Autonomous, Driverless and Beyond-Line-of-Site Operations



4.1.3 Context-Aware Services

Context-aware technology embeds contextual information into data or semantics to provide a richer user experience, and execute applications based on greater intelligence and pervasive analytics. There are several categories of Smart Cities applications that could be enhanced through contextual awareness:



As context-aware solutions begin to emerge and be deployed in city environments, there are key developments that will impact Smart Cities planning decisions and shape the landscape of context-aware applications:

- **Elimination of dependency on centralized processing of context-based services.**
- **Contextual processing logic will be increasingly applied at the edge of the network or at device level.**
- **Data analytics will continue to evolve to allow simpler presentation of *anonymized* contextual information.**
- **Enhanced security by leveraging context-aware data from multiple sources (beyond access control).**
- **Context-based information will enable better dynamic allocation of resources in high-speed communications networks.**

4.1.4 IoT Enhanced Crowdsourced Data

Crowdsourcing is a broad area of development that has been applied for over a decade. In a general sense, crowdsourcing has many recognizable components:

Traditional Crowdsourcing Applications

Promote innovation

Partition microtasks

Solving complex problems

User engagement

Crowdfunding

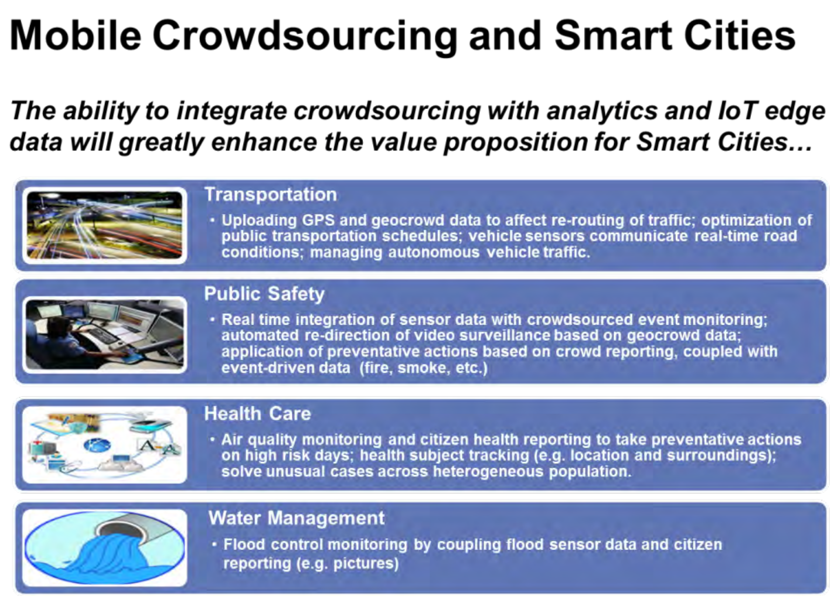
S/W development (e.g. open source)

Identify labor resources

Lower development costs

The concepts that appear most relevant to Smart Cities are user engagement, promoting innovation, and solving complex problems. Considering crowdsourcing in the context of full mobility of devices and applications, there are increasing levels of value that could be achieved as crowdsourcing moves from passive to participatory, and then to IoT-enhanced crowdsourcing. The ability to combine device-generated data (e.g., sensors) with crowdsourced information from machines and human interactions provides the best future opportunity to apply contextual information to decision-making. At this level of development, the benefits include:

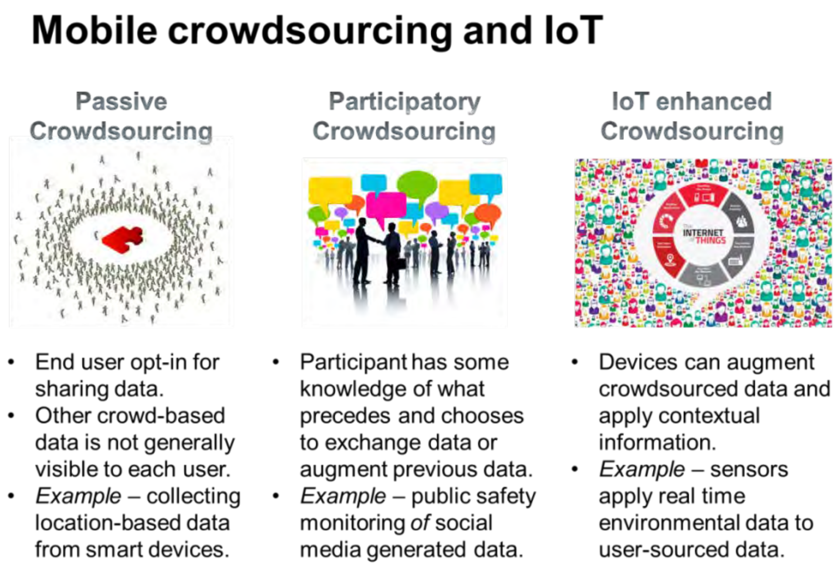
- **Crowdsourcing can help to protect the anonymity of data (once processed) and address privacy concerns.**
- **Integration of crowdsourcing with IoT-collected data can promote reliability and validate the authenticity and interpretation of crowdsourced data in *real-time*.**
- **Crowdsourcing applications can help to complement new infrastructure investments by cities, as value is created by crowdsourced population and citizen engagement.**



One of the greatest opportunities for Smart Cities, related to public safety needs, is the ability to supplement traditional sources of information with new data sources, predictive analytics, and context-aware applications to perform real-time assessment of public-impacting events. With the evolution of crowdsourcing, there are increasing benefits to public safety as new capabilities evolve in the marketplace.

Today's passive crowdsourcing capabilities are primarily based on passive techniques, where location-based services associated with smart devices provide valuable information. In the case of an unplanned event, public safety could be assisted by knowing that a large body of citizens is collecting at or dispersing from a specific location based on location data only. To extend this example to participatory crowdsourcing, public safety could monitor social media applications to collect additional useful information from citizens, as each social media posting will provide incremental data based on observed, perceived, or forwarded data from other users.

Finally, with the future evolution of crowdsourcing, where crowdsourced data is integrated with IoT-sourced data, there are significant improvements in the ability to validate crowdsourced information with IoT-generated data, that could include contextual information, such as temperature, noise level, fire detection, and air quality. In this manner, crowdsourced data from citizens and businesses is combined with actual data from sensors to provide a more complete view to public safety entities. If this capability were further enhanced by applying some level of predictive analytics in real-time, public safety could take immediate actions based on more verifiable information and an analysis of most likely outcomes.



4.2 Platform Enablers

The central role of *platform enablers* is to support the distribution, management, exchange, and integration of data and services. This is one of the most significant areas of development, in terms of the capability to apply add-on analytics, utilize the fast-developing capabilities around machine learning and artificial intelligence, and to apply these capabilities to business models that incorporate data integration and data exchanges. Extending into the future, augmented reality is expected to offer tremendous market potential, and many of the applications fit squarely in the Smart Cities ecosystem.

4.2.1 Advanced Analytics

It is generally agreed that data and analytics provide the greatest potential for monetizing an asset and creating direct citizen value. It is also agreed that this area of technology presents some of the greatest challenges in terms of the multitude of new data sources, the filtering and storing of data, and managing the complexities of data

privacy, confidentiality, and security. But, it is important to think about data analytics as a dynamically developing component of technology that will extend into promising new fields of machine learning, crowdsourcing, and contextual data applications.

From a municipal needs perspective, cities are already facing complex application demands with respect to data:

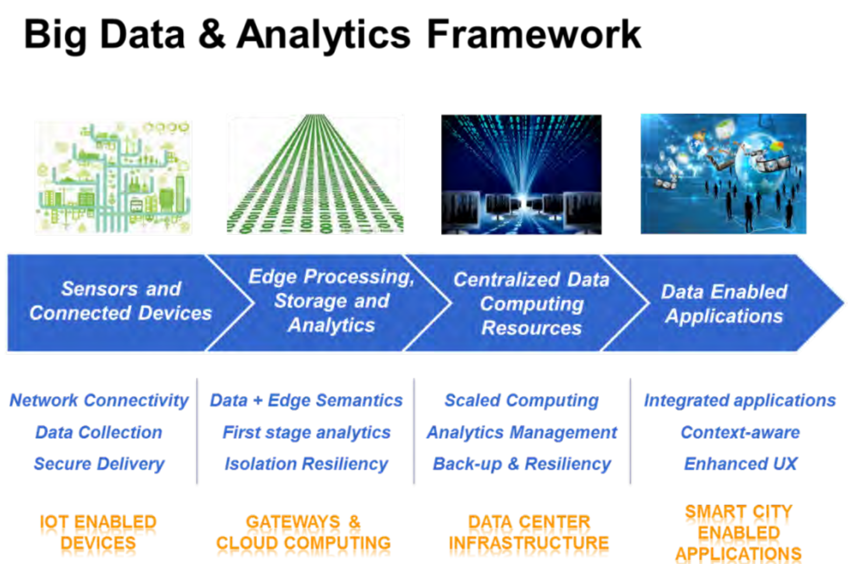
- Increasing number of applications, sensor populations, and data volumes, and the technical skills to manage these assets.
- Need for more sophisticated analytical techniques (evolution from simple rules to machine-learning and adaptive techniques).
- Cross-silo interoperability (data sharing across cooperative applications as well as public/private environments).

Data collection, management, and usability will be areas that can be leveraged in the near term and provide measurable benefits. At the same time, the concept of data as a city asset does introduce challenges:

- Potential for loss of connectivity to core assets demands greater resiliency and operation continuity at the edge of the network.
- Management of data streams (e.g., permissions-based ownership and routing) must be effectively integrated.
- Acceptable privacy and confidentiality framework for data.

A useful first step is to look at Data and Analytics as four components of a framework: (1) Sensors and Connected Devices; (2) Edge Processing, Storage, and Analytics; (3)

Centralized Data Computing Resources; and (4) Data Enabled Applications. In the future, it is possible that different entities may manage and administer the data assets at each of these component levels, or a single entity may own and control the data from an end-to-end perspective.



While the field of Big Data and Analytics has been developing and is being applied to networks, enterprises, and IT environments, there are a significant number of developments underway in the academic and private sector that will impact Smart Cities opportunities. The following is a future trajectory of Data and Analytics developments expected over the next few years:

Advanced Analytics – New analytical techniques based on machine learning and artificial intelligence (AI) decision-making.

Data Stream Management **– New frameworks to publish, subscribe, process, and apply data ownership/access controls.**

Gateway and Edge Device Integration **– For local responsiveness and continuity during loss of full network connectivity.**

Technology Packaging **– To increase usability and enable high-level programming and abstraction.**

Data Exchanges **– To act as trusted data brokerages, providing clean/value-added data, and supporting new business models.**

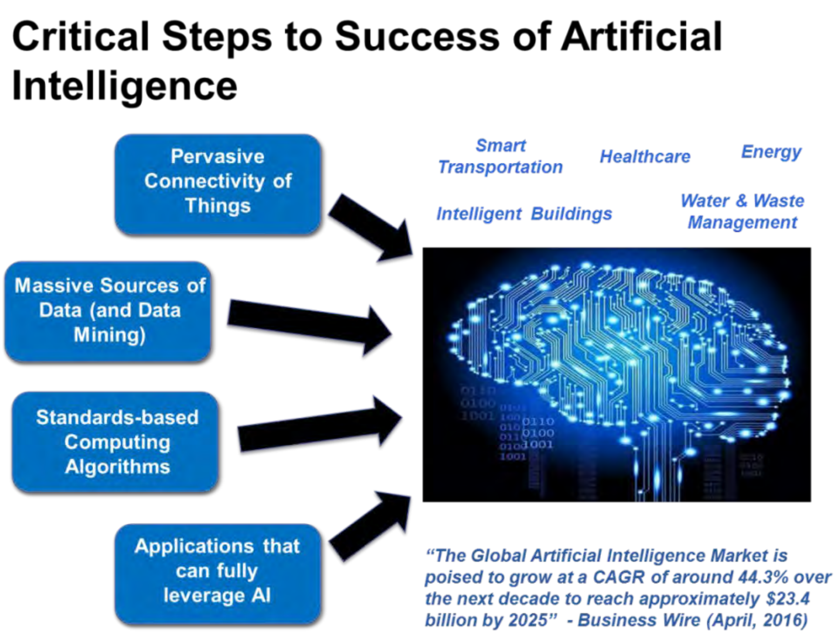
Whereas these advancements will offer benefits to many industries, there are specific value propositions for Smart Cities that will be possible by integrating these new analytical techniques:

- **Evolve from the collection of data to the rich applications that rely on *information* and *context-aware content*.**
- **Apply new analytical techniques that couple information, machine learning, and artificial intelligence to enable predictive action and real-time processing.**
- **Distribute analytics between edge gateways, cloud solutions, and core infrastructure assets in an application-oriented manner.**
- **Rapidly analyze and act upon vast amount of data from sensors, next gen networks, and new sources (e.g., Unmanned Aerial Vehicles).**
- **Provide new monetization opportunities for cities to expand Smart City assets and builds.**

To fully understand the potential for data utilization in the future, it is important to look at a key area of development: machine learning, which is a type of artificial intelligence.

Machine learning is the ability for computing devices to learn from data analysis and predictive processes, without being directly programmed, thus gaining artificial intelligence and exhibiting cognitive functions.

The challenges to machine learning and artificial intelligence will ultimately be addressed at many levels: academic advancements in the algorithms, next generation networks that enable the wealth of data that will be required, and finally, rich applications that leverage machine-based learning.



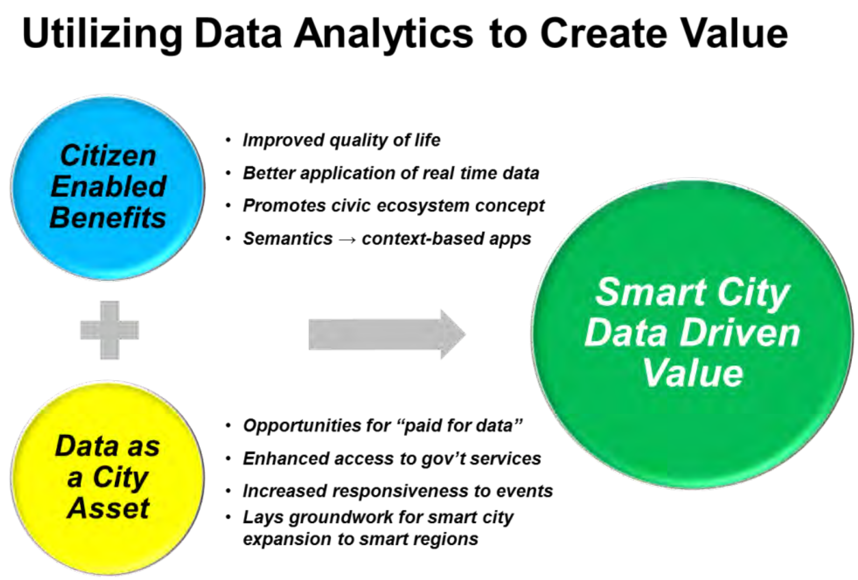
4.2.2 Data Integration Platforms

This section focuses on the integration of data analytics and edge management functions across Smart Cities sectors and between Smart City municipal applications and private sector applications (e.g., transportation and autonomous vehicle applications). The integration opportunities will be increasingly supported as new capabilities are advanced, including more peer-to-peer connectivity, advanced analytics, machine learning, and shared cloud infrastructure.

Smart Cities Smart Integration

Source: TELUS

From an opportunity perspective, data and analytics, if designed and integrated properly, offer value derived from two key dimensions: "Citizen Enabled Benefits" and "City as a Data Asset". The intersection of these two benefits can be defined as Smart City Data Driven Value.



This representation of *value* is not meant to minimize the challenge to cities, in terms of how to collect and leverage this data, especially when many of the sources of this data fall outside of city-owned sensors and devices. In the future, there will be boundless new sources of data from citizen devices, crowdsourced data, and machine-generated data that reside outside of the control of government. The answer may be that business models will have to evolve from the concept of tightly controlled "data as an asset" to be more consistent with the concepts of a "shared economy". While cities could certainly establish individual business relationships with commercial entities that collect and manage data, it is also possible that data exchanges may play a critical role in sharing data between cities and commercial entities. These exchanges can also fill a need to maintain the confidentiality, privacy, and anonymization of data from many sources.

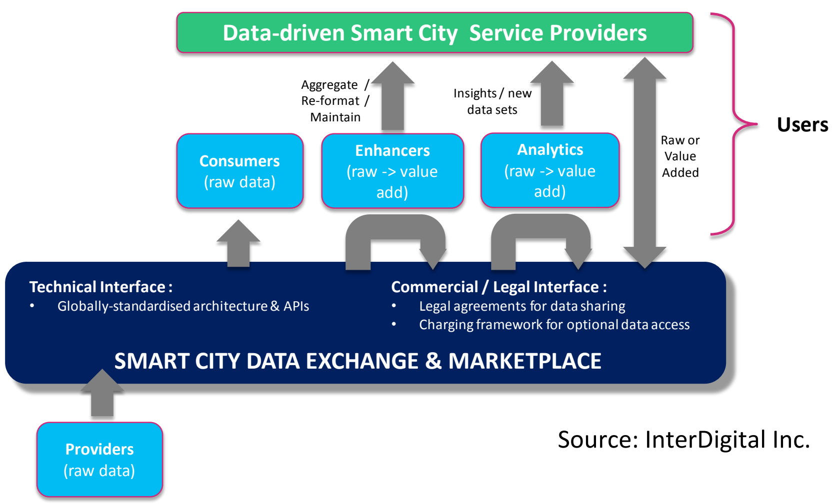
4.2.3 Data Exchanges

A data exchange is a software-based environment that enables the exchange of data between multiple suppliers and consumers. Suppliers include data sources such as sensors (e.g., environmental sensing, car-park occupancy sensors, traffic-flow monitors), connected devices (e.g., street furniture, waste collection trucks), organizational IT systems (e.g., resource planning systems, maintenance schedule manifests), and crowd-sourced data from Apps operated by city residents. Data consumers include IT systems and Apps that use ingested city data to deliver an application or service. Examples include journey planning, arrival-time reporting applications that offer convenience and time savings to citizens and local businesses.

Data exchanges should form a part of the basic infrastructure of all Smart Cities. The value creation opportunity for cities, however, comes from applying such a capability to foster a data marketplace. The difference between a data exchange and a data marketplace involves the application of a set of rules that govern the publication and consumption of data. Publication rules could, for example, specify the terms under which data is published in the data exchange; data may be offered for free or for a fee, with restricted or unrestricted terms of usage. Similarly, data consumers may be permitted to consume data anonymously or to have their usage patterns disclosed to data providers and the marketplace manager.

As the data marketplace matures, it creates opportunities for new business formation in the shape of data management and analytics firms. Data management firms can operate within the data marketplace to catalog, clean, and promote raw data sets. Analytics firms can create value-added data sets from raw data and enable fresh and combinatorial insights into published data to optimize existing city operations and to enable new services.

The following high-level illustration of a Smart City data exchange and marketplace illustrates the principles of data providers (raw data streams) and several data consumer categories. Some users may subscribe to raw data and handle their own post-processing. Other users may specialize in adding value to raw data by supplying clean or meta data streams. And, another category might specialize in analytics to extract features or insights that enable Smart City services.



Source: InterDigital Inc.

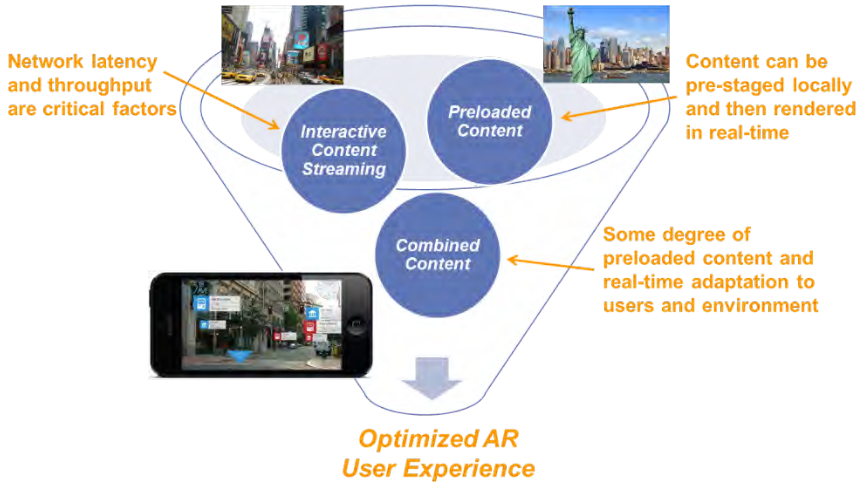
Initially, the value of a data marketplace to Smart Cities is to create a low-cost IT infrastructure to publish and share city data. Secondly, the marketplace promotes innovation and economic development by encouraging App developers to deliver App-based services to city authorities, residents, and the business community. And, thirdly, the marketplace becomes a new commercial opportunity for Smart Cities to generate a financial contribution to its operating budget.

Technologically, a data marketplace depends on a horizontal software capability that is designed to ingest data from a mixed population of multiple sensor types and data-delivery formats. This software capability must allow different Smart City applications to subscribe to relevant data streams via simple controls that mask the complexity of underlying sensor and communications technologies for Smart City service providers. The use of open standards is important in accommodating multiple hardware (sensor, device, gateway) suppliers and their preferred communications protocols.

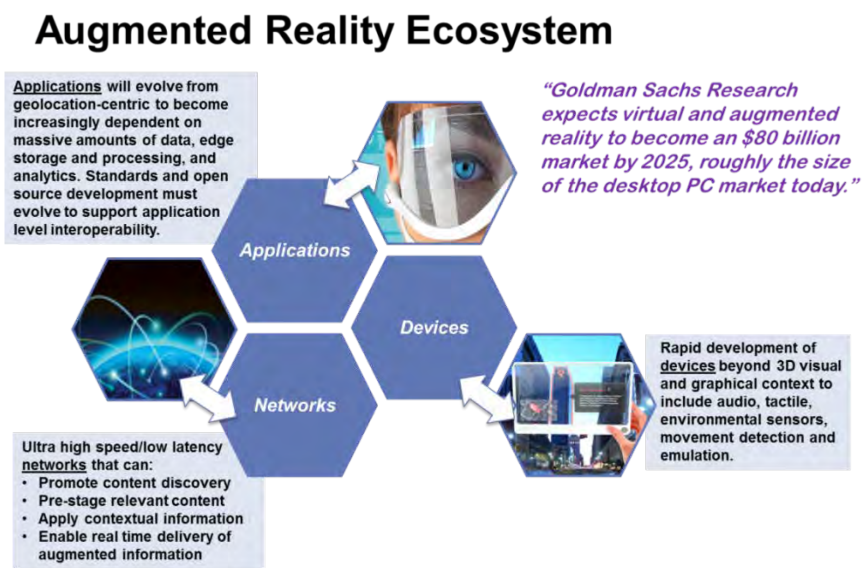
Standardization is also important to enable integration between neighboring data exchanges. This arises in situations where several cities share common applications. It also occurs where the concept of a Smart City extends to a smart region. This leads to the need to support integrated citizen and transit services across metropolitan and suburban zones or neighboring counties, for example.

4.2.4 AR/VR Platforms

In the context of Smart Cities, augmented reality is a real-time translation of the physical real world by augmenting information and content with sensory data to create a richer user experience. While many applications are still under development, augmented reality will likely leverage some mixture of pre-staged content with real-time adaption in order to create an optimized end user experience. Networks will play an important role, as these applications will depend on low-latency and high-throughput network performance.



The realization of widespread augmented reality will depend on three components: Applications, Networks, and Devices. Today's applications rely heavily on location-based services that are applied to pre-loaded and real-time content. Over time, applications will logically evolve to leverage many types of data sources, sensors, and contextual information. Networks are already developing to support the high-bandwidth and low-latency needs of augmented reality applications. Devices that build upon recent breakthroughs with virtual reality technology and incorporate smartphone devices, wearables, and 3D visual and tactile capabilities will continue to be introduced to the market over the next few years.



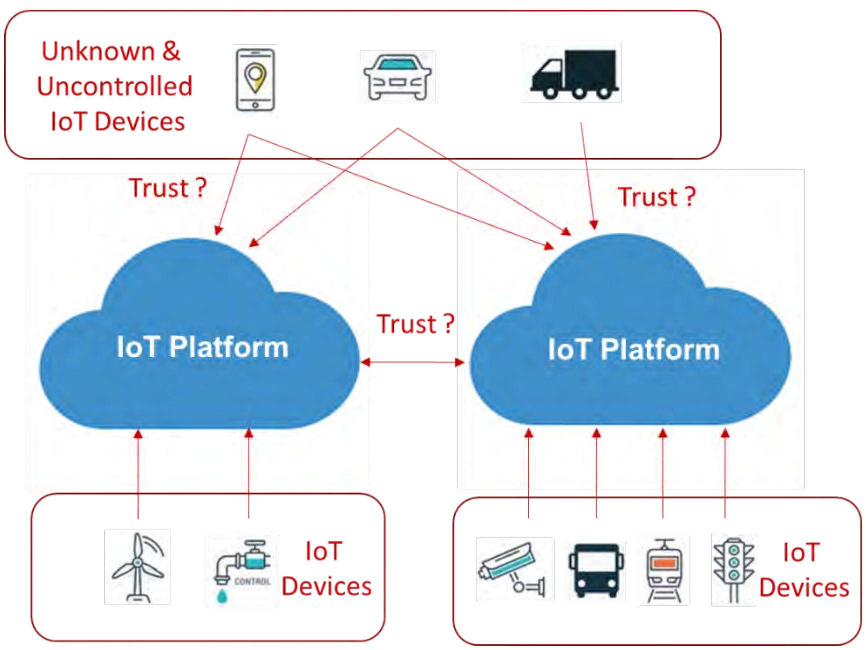
4.3 Application Enablers

Applications will ultimately define the value of Smart City projects, and the ability to apply rich content and promote the development and use of open APIs for Smart City services will be critical to the success. While there will be unique applications that service each city, it is also recognized that the ability to replicate and utilize application development will hasten the adoption of citizen applications and allow cities to leverage standardized application approaches. Beyond open API frameworks, there are also evolutionary approaches to content discovery, distribution, and consumption that are the subject of recent research and development activities across the industry.

4.3.1 Application Marketplaces

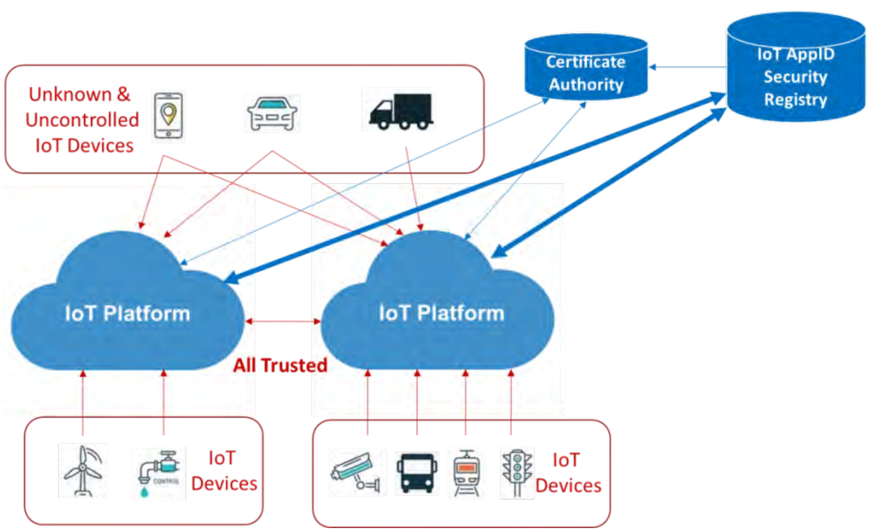
An IoT AppID Security Registry

The IoT ecosystem of today is a fragmented environment of proprietary technical implementations, often with weak security, which results in vulnerabilities that restrict interoperability. This fragmentation inhibits the value potential of IoT application data in a Smart City marketplace, as security, trust, and privacy issues abound. Enabling secure trusted interoperability of IoT application data will allow Smart City planners to unleash unparalleled economic growth.



Source: iconectiv

An IoT AppID Security Registry can provide a central trusted repository of IoT application identities and profiles to enable IoT platforms to identify and authenticate IoT device application data from known trusted sources, through an automated process. The IoT AppID Security Registry provides virtual trust between IoT platforms. Such a registry provides the foundation for IoT security across the ecosystem for all stakeholders, and ensures that IoT applications and the data they produce can be trusted. This will facilitate the sharing and commercialization of IoT data while protecting consumer privacy. Importantly for the Smart City marketplace, delivery of innovative services can flourish knowing that the underlying framework is secure and trusted.



Source: iconectiv

One of the key global organizations focused on M2M interoperability is oneM2M. ATIS is a founding partner of oneM2M – a global organization to facilitate the efficient deployment of M2M communications systems. oneM2M develops specifications that address the Common Service Layer that can be readily embedded in hardware and software to afford verticals interoperability to connect devices with application servers in an access-independent manner. ATIS is currently acting as a Management Authority (MA) for the oneM2M App-ID Registry.

4.3.2 AR/VR Content

As networks explore new architectures to optimize content discovery, delivery, and consumption, applications are rapidly evolving that can leverage content created, stored and processed, and acted upon at the edge of the network, including augmented reality.

According to International Data Corporation (IDC), worldwide revenues for the augmented reality and virtual reality (AR/VR) market will grow from $5.2 billion in 2016 to more than $162 billion in 2020[2]. This rapid growth of the AR/VR market will need to be supported by new devices, enhanced networks, and the creation of AR/VR content.

The development of content is heavily related to the desired device or display type. Hardware devices could range anywhere from current smartphone, tablet, and eyeglasses to a set of AR contact lenses or spatial displays. The rapid evolution of devices and displays will also shape the type of content and the ability to create content that is associated with specific applications. Today's AR content is generally classified as geospatial (typically associated with

[2] IDC's *Worldwide Semiannual Augmented and Virtual Reality Spending Guide*

smartphones and location/motion detection), flat (consistent with reading pane applications), and 3D (the basis for the content rich applications of the future).

For the applications of augmented reality that are dependent on pre-loaded content and the intermingling of real-time content, networks will have a major impact on the performance characteristics of the AR applications, due to bandwidth and latency parameters. ATIS has recently published a Report that includes an assessment of AR/VR network performance as part of *5G Reimagined: A North American Perspective* (Issue 2)[3].

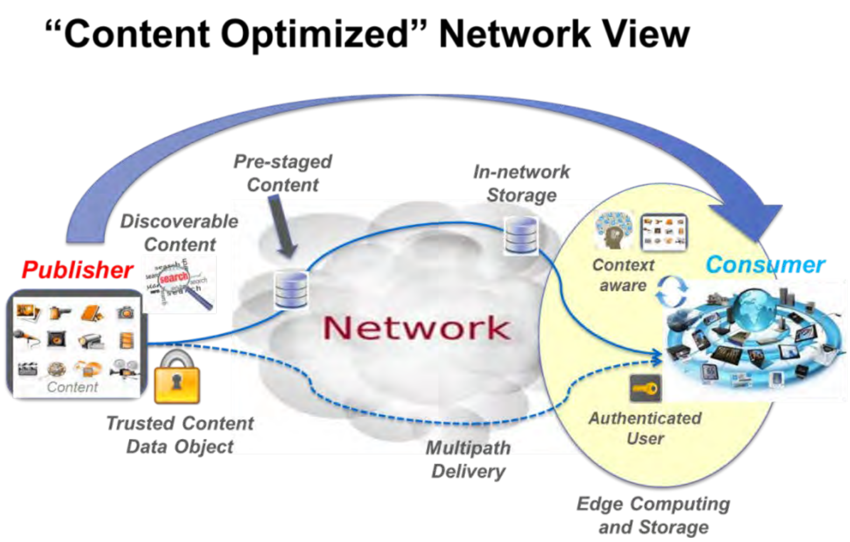
4.3.3 Evolution of Content Ecosystem

The content market is continuing to rapidly evolve, as users' expectations for content continue to increase and all segments of the content ecosystem look for new ways to create, distribute, market, and deliver content to consumers and businesses. This evolution will be especially relevant to Smart Cities, as citizens will look to content-rich applications to define their perception of a Smart City.

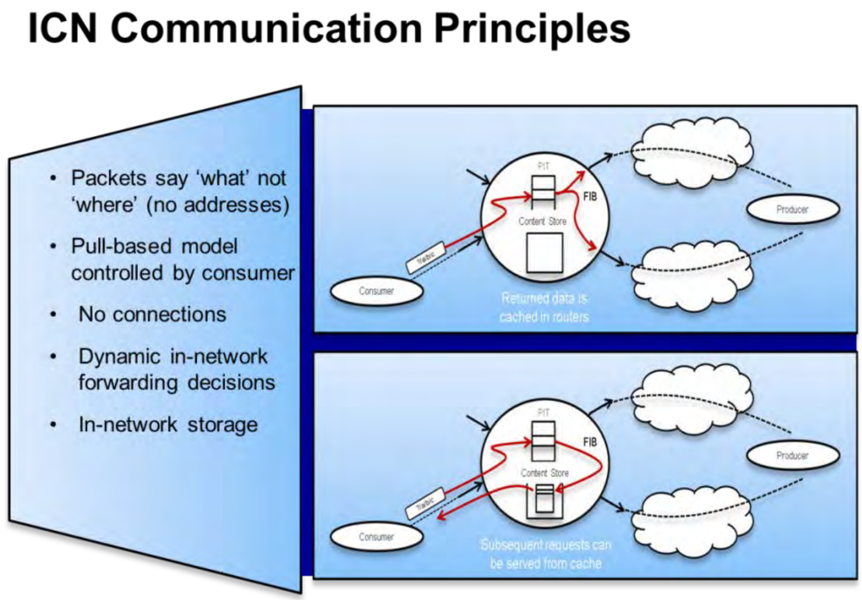
At a fundamental level, the content ecosystem can be viewed as a relationship between a content producer and a content consumer.

[3] ATIS-I-0000050-v002, *5G Reimagined: A North American Perspective (Issue 2)*, February 2017.

In order to translate this publisher-consumer view of the future content market to a network view, there are a number of aspirational improvements that could become the basis for an evolution from today's Internet Protocol (IP)-based network to a future architecture based on named objects. The ability to perform in-network storage of content and deliver content utilizing multipath delivery are key functions that could enhance content delivery and consumption, especially given the increasing amount of edge-managed content. This includes a more efficient means to discover dynamic content and position pre-staged content for applications such as augmented reality.

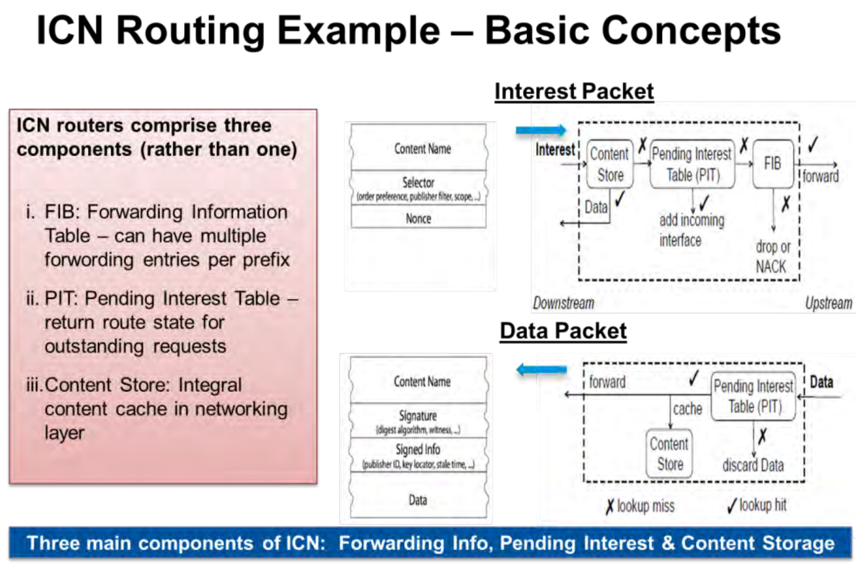


Over the last decade, there has been significant research and development related to *information centric networking* (ICN) architectures. Academic research activities and pre-standards development of protocols and architectures have been focused on solutions that rely upon naming of data objects as the basis for next generation networks. This differs from today's connection-oriented IP-based networks, where there is inherent dependency on establishing sessions between an information source and destination.



Developments are underway through various academic partnerships with industry, and protocol work is beginning at Internet-related standards organizations, like IETF. There are a number of key challenges that will need to be solved to bring ICN-based solutions to a state of network readiness, including alignment on protocol standards, naming and caching parameters, security and trust model, and recognition by the full content ecosystem. However, it should also be noted that ICN-based solutions will likely be introduced in a manner that co-exists with IP-based architectures (like ICN over IP).

Following is a simple representation of ICN-based routing principles and packet types:



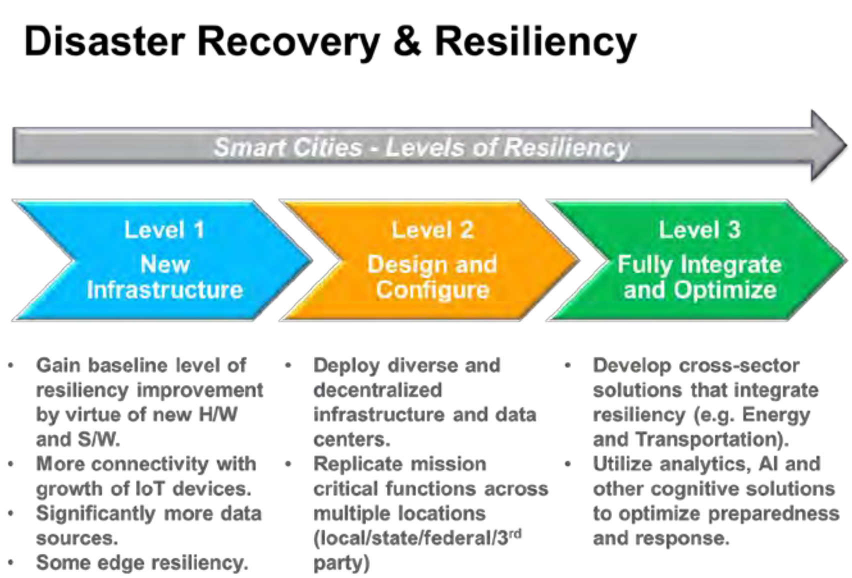
4.4 Infrastructure Enablers

Beyond the universe of future Smart Cities applications and services, it is important to highlight the benefits of a wide range of infrastructure enablers that provide improved means to manage and protect city and citizen assets. The intersection of technology developments with new infrastructure presents a unique opportunity to take advantage of new capabilities such as distributed resiliency, diversity, asset management, and emergency preparedness.

4.4.1 Distributed Resiliency

One of the key enhancements to government services will be the opportunity for new disaster recovery and infrastructure resiliency that can leverage the technology developments highlighted in this document. For example, the emergence of edge management capabilities in platforms, gateways, and devices will offer distributed resiliency opportunities to allow retention of some key government services in the event of a loss of full core operations.

However, the roadmap to improved resiliency will likely occur through a series of steps, starting with the benefits of new infrastructure. As essential services become more decentralized, cities can leverage a combination of distributed resiliency and replication of critical infrastructure resources with other cities or levels of government. Ultimately, cities will want to integrate residency across all municipal sectors and utilize the expected advancements in predictive analytics and machine learning to maximize preparedness and rapidly recover from unplanned events.



4.4.2 Enhanced Asset Management

Asset management is generally applied to the tracking and overall management of fixed assets and mobile assets. Extending this definition to Smart Cities, assets may consist of fleet vehicles, distributed infrastructure (e.g., monitoring devices, sensors, and cameras), human assets, and city-owned or managed facilities. Over time, technology enablers can greatly enhance the overall management of these assets

and create better usability of these assets for citizen-centric applications.

At a foundational level, intelligent connected devices can serve as the first step in enhanced asset management, as devices can be deployed and tracked, utilizing edge management capabilities to integrate and analyze data for appropriate handoff to asset management and dashboard systems. 5G, IoT, and cloud-based platforms will enable more efficient management and tracking, through wide-scale connectivity and new capabilities for mobile assets to move between public and private networks. Overall improvements to asset management for IoT devices in the commercial enterprise sector can be effectively leveraged by cities in the near-term, as part of a suite of Smart City asset management applications.

One of the differentiators with Smart Cities is the opportunity to integrate citizen assets with city-owned assets. While citizen assets should be viewed in the context of valuable data sources (e.g., crowdsourcing scenario), they do represent a resource that adds significant value to the overall Smart City ecosystem, and therefore must be part of the evolution to enhanced asset management. In addition, cities will have access to a broader range of virtual assets (e.g., commercial sensors) that can provide valuable data, but reduce the need for cities to invest valuable infrastructure dollars, and reduce the need to create sensor networks where they may already exist. As highlighted throughout this report, data exchanges can act as a conduit, with appropriate security and privacy controls, to commercial and citizen-generated data.

4.4.3 Emergency Preparedness

At the core of any city's resiliency and sustainability vision is an effective and implementable emergency preparedness program. While the same basic requirements will still exist into the future, such as situational awareness, rapid deployment of resources, and coordination across assets, developments regarding real-time data integration, predictive analytics, and new solutions for emergency management operations will greatly enhance emergency preparedness.

In the future, contextual data, crowdsourced information and next generation geolocation capabilities can greatly enhance knowledge of real-time situational awareness and actions based on predictive analysis. The key to Smart City emergency preparedness will be developing non-compartmentalized data-sharing solutions that eliminate silo-level reporting and access. It is understood that every aspect of Smart City planning has a contribution to emergency preparedness, such as smart lighting, smart transportation, smart energy, and of course, public safety. Traditional citizen reporting can be supplemented by access to real-time data at an event or emergency occurrence. Resiliency can be duplicated between edge and core computing assets, and between city and diversified operations with neighboring local, state, or federal resources. In the future, it is likely that the first indication of a government or citizen-impacting event will actually be realized through automated reporting of data via edge sensors and citizen-owned devices. In this situation, surveillance and cameras can be automated to react to verifiable event-driven data in real-time.

At a more strategic level, cities can make use of new capabilities around machine learning and augmented reality to be better prepared to deal with emergencies, even at the predictive stage. In the future, machine learning can be

integrated into infrastructure to rapidly process vast amounts of data related to impending or actual emergencies, and produce a set of actionable steps. Augmented reality can be used to greatly assist emergency response personnel and centers. In some cases, augmented reality can rapidly identify a change in environment across a wide view of a city, and thus act as an immediate alert to city personnel and public safety entities.

5. Technology Enabled Smart City Applications

This section provides an assessment of opportunities for technology to enhance specific Smart Cities application sectors and drive future investments.

Transportation

Technology Enablers
5G, Edge Computing Gateways, Geo-location Services, Context Aware Services, Advanced Analytics, AR Platforms

Overview

Transportation acts as a catalyst for initial investments by many Smart Cities. Some of the primary factors that impact citizen livability perceptions are traffic congestion during peak commuter travel hours (including first and last mile challenges) and better utilization of public transportation resources. Traffic congestion is largely shaped by the existing patterns of commuter vehicle routes and the geography of roads, bridges, tunnels, etc., that exist within a metropolitan area. Public transportation presents a complex set of challenges based on the interworking of various public transport options that exist within a city's transportation system. These challenges are further related to areas such as pedestrian and bike safety and economic and business development across the neighborhoods that comprise a city or community.

Key Technology Developments

- **Advancements in data collection (via sensors and user-enabled device applications) and predictive analytics will be key to solving transportation challenges. Knowledge of commuter start and destination points, routes, timing, and other location-based information (collected as anonymized data) can be overlaid with city**

transportation grids to improve transportation flow and improve first mile/last mile efficiency.

- **In the longer term, machine learning will offer significant opportunity for improvement, as it will offer real-time predictive and actionable data to better utilize transportation infrastructure and react to event-driven challenges.**
- **Transportation hubs are a prime opportunity for the use of augmented reality applications in the future. Opt-in knowledge of a citizen's or tourist's destination can be integrated with local content and then interact with location and movement detection capabilities within a device to guide the user through the transportation center and on/off the best optimized transportation options, based on real-time routing.**
- **Proximity of public transportation staging locations with other city assists like smart lighting, video surveillance, public safety alerting stations, etc., will offer significant opportunities for integration and better efficiency and utilization of Smart City infrastructure.**
- **Edge management platforms deployed near public transportation locations can enable real-time applications by processing and analyzing information near the data source and taking appropriate action to optimize traffic flow.**
- **Advancements in Vehicle-to-Vehicle (V2V) communications will directly benefit cities in terms of city-owned fleets and transportation assets. Integration of V2V applications in the commercial sector will provide additional troves of transportation data that can interwork with Smart City applications to react to normal transportation flows as well as event-driven needs.**

- **5G commercial networks will be introduced over the next few years that should greatly increase the bandwidth and reliability of network-based applications and provide low latency platforms that will benefit many transportation needs. This will include the capability to move more efficiently between networks, including commercial, municipal, and private networks.**

Planning Considerations

Transportation improvements can be achieved in an incremental fashion, starting with investments in edge devices, embedded analytics, and edge management platforms. Over time, the ability to integrate new sources of user-embedded data sources (like smartphone location-based information) can be achieved and effectively combined with city-owned assets.

Given the need to filter the vast amount of raw data that originates at endpoints and devices, next gen (predictive) analytics and machine learning – implemented within edge platforms and core infrastructure – will offer a future evolutionary path that can leverage the early investment in sensors, IoT-connected devices, and edge management solutions.

Energy

Technology Enablers
Edge Computing Gateways, Data Exchanges, Data Integration Platform, Advanced Analytics

Overview

Energy represents an intersection of industrial IoT developments and Smart City applications and needs. There exists a broad set of energy applications that include smart energy grids, oil and gas infrastructure, and utility-related areas. Today, many of these applications are still dominated by SCADA systems, which include sensors and controls connected by dedicated infrastructure and circuits. These applications are prime candidates for modernization, as smart devices, intelligent connectivity and networking, and analytics pave a course to sustainable cities. In fact, according to the United Nations, 75% of global energy consumption occurs in cities, and 80% of Greenhouse gas emissions come from these urban centers[4]. Energy represents an area where direct operational efficiencies and CAPEX savings can be archived by investing in Smart City solutions.

Key Technology Developments

- **Much of the early development of IoT devices and sensors has been focused on the industrial IoT sector. These sensors and actuators can be connected and networked as part of modernization programs across**

[4] United Nations Habitat Settlement Programme, UN Commission on Sustainable Development, 15th Session, New York, 30th May – 11 May 2007

local government operating environments. Industrial IoT and M2M communications are areas of intense standardization.

- Although collection devices generate a significant amount of data today, it is generally agreed that a very small percentage of this data is actually utilized and acted upon by public entities and government agencies. Edge management and analytics represent an early opportunity to collect, prioritize, and present this data in a way that promotes energy-saving and sustainable solutions across city ecosystems.
- Smart energy does create a myriad of opportunities for Smart City applications to interwork with transportation solutions and with private sector energy needs. Intelligent transportation solutions would clearly reduce overall fuel usage within a municipal footprint and interoperability with V2V data, as well as availability of vehicle charging stations for electric vehicles would represent citizen-centric solutions that intersect with the private sector.
- One of the most significant improvements enabled by Smart City investments will be the availability and usability of near real-time data (as opposed to historical data). These capabilities will be enabled through networked collection devices (and in some cases, gateways). At the same time, this does require designed-in security and permissive access to data sources.

Planning Considerations

Energy usage and metrics are perhaps the most quantifiable component of Smart City ecosystems. Smart grid distribution and delivery – coupled with applications like Smart Buildings and Lighting – and Fleet and Asset

Management represents a highly visible value proposition in terms of sustainability and livability.

Availability of energy-related data to other agencies is important to fully leverage this opportunity. Energy is critical to almost every sector, including Transportation, Smart Infrastructure, Public Safety, Healthcare, Water, and Waste Management. One of the most important developments related to the creation of value around data is the emergence of data exchanges, which can be a viable solution for sharing data between agencies and commercial applications across the city. Data exchanges and data marketplaces can work jointly to catalog and publish data for appropriate dissemination to the Smart City ecosystem. In the case of data exchanges, there will be numerous opportunities to add value to the data, as it is shared and integrated across sector needs. Ultimately, standardization, in terms of how data is exchanged between these entities, will be key to realizing the full value of the data and creating robust applications.

Smart Lighting and Smart Buildings

Technology Enablers
Platform, Data Integration, Data Exchange

Overview

Smart lighting and smart buildings represent an initial area of business focus for many of the Smart City solution providers. The benefit to the city ecosystem and to citizens is apparent and highly visible. In most cases, cities who have pursued smart lighting solutions have taken a more holistic approach, beyond improved lighting capabilities, to also include integration with transportation, public safety, monitoring, and other related sectors.

Smart buildings are typically viewed as a means to reduce energy usage and pollution, but they are also designed to create secure and productive work and living environments. The US Department of Energy reports that the country wastes about 30 percent of its overall energy, so smart buildings represent a significant improvement opportunity. Building performance can be achieved through much greater automation and control of energy use, space utilization, smart lighting, and movement of personnel and product through the structure.

Key Technology Developments

- **Intelligent LED lighting solutions are typically deployed to reduce energy usage, decrease maintenance costs, and support lower operating costs. These lighting devices are often coupled with smart sensors that can control and activate lights on/off, dim lighting as needed, and react to pedestrian activity and transportation flow.**
- **The value of smart lighting can be amplified by integrating lighting applications with other sector applications that can leverage the investment in this infrastructure. This includes triggering surveillance cameras as a result of event-driven or citizen requests for assistance, platform for temperature sensors and air quality, communication hotspots, linking lighting effects to transportation arrival/departures, and promoting local tourism through digital signage (in some cases reacting to contextual data).**
- **Smart lighting coupled with smart buildings provides a powerful combination that can leverage street level data to interwork with conditions within structured buildings. In some cases, smart lighting could assist emergency and law enforcement personnel in directing these resources to a specific building or part of a building.**
- **Smart buildings can further assist public safety agencies in the future by providing emergency response personnel with a real-time view of the building structure and layout, and even using augmented reality applications in the future to allow first responders to move throughout building structures that may be obstructed by smoke, fire, or darkness.**

Planning Considerations

Smart lighting and buildings offer a near-term opportunity for Smart City needs that can be incremented and integrated with additional capabilities in the future. Certainly, a longer-term knowledge of applications that could be enabled or built on-top of smart lighting would guide the tactical planning for optimized deployment of smart lighting infrastructure.

As smart buildings become more pervasive in Smart City projects, including government and commercial buildings, a more cohesive planning strategy will likely be needed to coordinate requirements across energy, public safety assistance, tourism, water and waste management, etc. In addition, the data collected within a smart building structure will become increasingly valuable, as it becomes shared across the broader ecosystem of the Smart City.

Healthcare

Technology Enablers
5G, Geo-location Services, Platform

Overview

There are significant changes in the healthcare industry and related services provided by local and federal government that are being enabled through emerging technology developments. The exponential growth in healthcare costs is driving government and private sectors to look at alternative healthcare approaches. First, there is a trend toward value-based home health care that relies on dramatic improvements to patient monitoring and remote medical care. When appropriate, patients can receive care outside of physical hospital or medical treatment centers and take advantage of remote monitoring, patient surveillance, and other capabilities.

Additional developments around patient health data collection and analysis and predictive analytics are laying the groundwork for new approaches to healthcare. Of course, the reliability and security of this data are absolute requirements, but the potential exists to improve medical care through leveraging health data as a strong asset in the future. At a more macro level, monitoring health data across a broad population that resides in or visits a city could offer significant advantages in terms of disease control and pandemic threats.

Key Technology Developments

- **IoT sensors, wearables, and medical measurement devices will be the basis for collection of health data. Today, collected data is often captured by a centralized device in the home, but with varying level of success in terms of integration. IoT interoperability standards, including M2M communications, are being undertaken today and should provide a more uniform framework.**
- **Predictive analytics, cognitive-based applications, and machine learning will be key contributors to the healthcare market. Today's healthcare decision-making by medical experts is heavily driven by historical clinical data as well as patient and patient family health history. This information, coupled with a greater amount of patient data collected inside and outside of medical treatment facilities, will lead to more informed outcomes as predictive analytics algorithms, machine learning capabilities, and cognitive data become available.**
- **Smart City sensors will offer greater real-time information to citizens on health-related factors such as air quality, pollen level, temperature warnings, and weather-related events. This is especially important in urban centers where the effects of health-related issues like air quality can be quickly amplified by factors such as traffic.**
- **Geolocation devices will help to locate patients who may be suffering from chronic medical issues or may be experiencing cognitive disorders. The ability to transmit this information to healthcare or public safety professionals in real-time will be critical in locating a patient in a life-saving timeframe.**
- **Remote patient care will become increasingly dependent on data and video surveillance information transmitted to**

healthcare professionals. This highlights the need for reliable high-bandwidth networks, as enabled by 5G networks, and networks optimized for content delivery.

- Augmented reality technology will provide significant long-term benefits across the healthcare landscape, ranging from assisting surgeons in the operating room to providing instructional information to remote patients.

Planning Considerations

Access to quality healthcare remains a centerpiece of a citizen's view of a city's livability, but the definition of access will evolve as the healthcare industry transforms patient care. While much of this landscape is speculative, it is apparent that value-based healthcare in the future will be impacted by the emergence of interoperable IoT devices, high bandwidth networks to connect patients to healthcare professionals, and new applications that leverage big data, predictive analytics, machine learning, and augmented reality.

The broader issues such as pandemic planning and reliable exchange of healthcare records will be enabled through greater availability of real-time data, secure exchange of this data, and analytics platforms that can allow city officials to take appropriate actions.

Citizen Engagement, Tourism and Economic Development

Technology Enablers
5G, Platform, Gateway, Data Exchanges, Geo-Location, AR Platform

Overview

In a holistic sense, citizen engagement encompasses the entire suite of applications across the Smart City fabric. At the same time, it is understood that a citizen's perspective of value will vary, based on factors such as neighborhoods or essential services that are accessed by an individual. Today, many cities are using tools such as customized Smart City applications to create a greater partnership and awareness between local governments, citizens, and business.

While a city's ability to influence outcomes around areas such as transportation, energy, healthcare, etc., may vary, it is clear that local government maintains a great degree of control in segments such as tourism and economic development. While some innovative approaches to promoting cities' business development and tourist industry are already being deployed, there exists great potential to use technology in the future to expand these efforts.

Key Technology Developments

- **Augmented reality applications, in the context of smart cities, will find early opportunities in the tourism and city promotional areas. Tourists can be guided by overlaying targeted information and user preferences onto real time view of a user's environment. This data may be related to restaurants, attractions, sports venues, and other user customized needs. In a museum setting, tourists can immerse themselves into a specific exhibit or point of interest, or gain additional insight.**
- **Similarly, user experience surrounding economic development activities in a city could be greatly improved through the use of augmented reality. Citizens could point a device to a neighborhood development initiative, such as a park or new sports arena, and be immersed in a transformation of a real-time view to a future view of a completed project. Potential developers could envision a new building or renovation project and create a future view on top of their real-time experience.**
- **As context-aware and crowdsourcing applications become more pervasive, citizens could derive value by virtue of cities taking proactive actions, based on environmental conditions, noise, crowd flow, air quality, and other metrics.**
- **In the longer term, predictive analytics and machine learning could be embedded into areas such as tourism and economic development to predict outcomes, which could enhance civic planning activities that have been traditionally based on historical data.**

Planning Considerations

Tourism, economic development and citizen engagement consistently rank at the top of local government priorities and objectives. These areas represent some early opportunities to partner with commercial entities and experiment with new technology developments, such as augmented reality, to improve user experience and promote citizen involvement activities. In the future, a citizen's perspective of value will become increasingly dependent on whether a Smart City is able to address their unique needs. Applications that apply customized information on top of real-time experiences will shape the view of a Smart City. Similarly, cities can take advantage of crowd data and patterns to deal with needs at a more macro level, and user-sourced data can act as a major contributor.

One of the key factors driving Smart City success will be the ability to integrate large amounts of user-sourced data with city wide information. Solutions such as data exchanges and app marketplaces will offer a means to leverage this data, regardless if it is collected through city-owned assets or the private sector. The ability to share this data in a standardized way will create new opportunities to increase the value of citizen and government data and drive civic needs, such as tourism and economic development.

Public Safety

Technology Enablers
Geo-location Services, Data Integration platform, Crowd Sourcing, Context Aware Services, Advanced Analytics, AR Platforms

Overview

Public safety represents a significant opportunity for improvement as Smart Cities begin to deploy new applications and infrastructure. Applications such as improvements to indoor geolocation capabilities will enhance responsiveness in urban areas and structured buildings. Additionally, the integration of new capabilities such as crowdsourcing and cognitive analytics will provide valuable tools to city operations and the first responder community.

Several recurring themes related to this sector will reverberate as cities begin to apply direct solutions to this area and integrate public safety with other Smart City sectors to leverage investments. The themes include situational awareness, interoperability of systems and devices, and rapid sharing of information across agencies.

Key Technology Developments

- **While advances in location accuracy continue in support of public safety dense urban environments and structured buildings continue to present challenges to emergency dispatchers and responders. 3D geolocation capabilities will offer significantly improved accuracy information and virtualization for emergency response and incident management.**
- **Public safety data will come from several sources, including citizen calls to emergency response locations, monitoring of social media, and sensors and connected devices. In the future, overlaying contextual information (e.g., video, audio, air quality, environmental metrics) from sensors, as well as crowdsourced data, will greatly increase the amount of useful information and act as a means of validating or interpreting data that is presented by citizen calls and social media outlets.**
- **One of the key attributes of public safety is situational awareness. A challenge for both emergency dispatch and dismounted assets is real-time visualization of the building structure or venue. From this perspective, augmented reality could offer significant long-term solutions, especially when it is coupled with geolocation capabilities. A first responder could see the actual building structure (hallways, rooms, etc.) even when obscured with smoke or fire. First responders could use mediated reality to subtract content from their view and focus on key elements that will enable their mission-critical needs.**
- **In the longer term, machine learning solutions and article intelligence applications could greatly benefit the public safety sector by rapidly analyzing a situation, providing**

predictive outcomes, and alerting emergency management operations to potential events.

Planning Considerations

From a data perspective, public safety can be enhanced as increasing amounts of sensor data become available, and public safety entities are able to leverage crowdsourced and contextual based information. In many cases, public safety may be able to utilize data from other city assets and applications. However, it will be important to provide emergency response and first responders with data that is near real-time, has been filtered and prioritized through edge analytics, and is rapidly shared across agencies.

Since public safety entities must always assess the validity of data that they receive directly or indirectly, it will be important to apply contextual information to raw data related to an emergency situation. This will provide greater trust in the data and allow emergency response agencies to rapidly deploy assets and control devices like video cameras.

Although the IoT device area will be rapidly developing, it will be important to promote interoperable frameworks for devices that are deployed as city assets. It would also be desirable that law enforcement and first responder agencies have interoperability, to the extent possible, with commercial security and monitoring devices like video surveillance. While this may be challenging for existing infrastructure, it would be beneficial for the industry to work with Smart Cities to pursue device interworking and standardized APIs for public safety applications.

Education

Technology Enablers
Geo-location Services, Data Integration platform, Crowd Sourcing, Context Aware Services, Advanced Analytics, AR Platforms

Overview

Education capabilities can clearly be enhanced through Smart Cities projects. One of the most fundamental aspects of improving education is connecting students with the information and resources that can advance their learning experience. These resources may exist within their local educational institution and teaching experience, or, in many cases, may exist at higher level institutions or commercial entities. The ability to connect students, educators, and resources will be a key component of any Smart City.

Key Technology Developments

- While the education process can be enhanced through greater broadband infrastructure and Internet access for all students, there are additional developments that will shape the experience and encourage the student to seek greater insight and knowledge. The emergence of 5G networks and ultra-high speed optics will afford new opportunities for schools to tap into research and experiments that may exist across the country or around the world. While there have been a number of dedicated (proof of concept) networks built to connect institutions, commercial availability of new high speed/low latency networks will promote a more pervasive means for

schools and classrooms to share information and research.

- **Virtual classrooms will supplement traditional on-campus alternatives to provide a broader set of opportunities tailored to student needs. Virtual reality/augmented reality platforms will provide new immersive opportunities for education that would not be possible in today's environment.**
- **As new education opportunities are enabled by global Smart City projects, it will become increasingly important to provide widespread access to this information, and break down barriers that might limit these opportunities (like language or geography). Proliferation of cloud networks, for example, will provide greater access to educational resources and allow institutions to share infrastructure costs.**
- **From the aspect of educators, machine learning and advanced analytics capabilities (that can be shared across academic institutions) could assist teachers in detecting patterns of student learning and taking appropriate actions on a proactive basis, to shape and customize the learning experience of students.**

Planning Considerations

In the larger view of a Smart City, education cannot be viewed in isolation from other citizen-centric aspects of livability. Smart transportation, safety, lighting, buildings, energy, healthcare and many other factors will contribute to the overall success of education. However, education will be a lynchpin in helping to promote the future expansion of Smart Cities, as students are able to gain a broader knowledge base and apply this expertise to solving sustainable city challenges in the future.

It is unlikely that schools will be able to leverage dedicated infrastructure in the future, as the goal is to maximize connectivity to wherever educational resources may exist, which may be local or global in nature. This will require a partnership among educational institutions, government resources, and the commercial sector to provide collaborative learning experiences. High speed networks and cloud-based solutions will serve as the foundation for many of the rich educational applications that will be developed in the near future. Data exchanges and data marketplaces can also promote the sharing of information and resources on a more universal basis.

Government Services

Technology Enablers
Data Exchange, Data Integration platform, Advanced Analytics, Cloud platform

Overview

Access to citizen-centric government services is one of the key opportunities for Smart Cities and has a direct relationship to a citizen's perception of livability. It is understood that the transformation of government services will most likely be achieved through an incremental progression of improvements and greater electronic access to eGovernment services. While most cities have pointed to interoperability of systems as being one of the major challenges, it is understood that migration to a higher level of compatible systems and processes will be dictated by local needs and investments. However, there are significant opportunities for cities to achieve greater sustainability, reliability, resilience, and accessibility through investments in new technologies.

Key Technology Developments

- Cloud-based solutions coupled with Big Data analytics represent one of the best opportunities for improving Smart City government services. A wide range of cloud architectures exist today, which can be leveraged through on-premises cloud solutions or hybrid cloud solutions. Hybrid clouds and cloud-bursting services will offer cities the ability to utilize a desired level of shared infrastructure and defer some investments.

- **A hybrid cloud approach typically involves on-premises cloud infrastructure to support mission-critical functions, and some level of shared public cloud capability to support supplemental workload needs and functions outside of the core IT operation. In this way, IT operators are able to balance investments in dedicated cloud computing resources and achieve some additional built-in resiliency, as well as handle spikes in cloud computing requirements.**
- **Big data analytics will be important to cities as populations continue to grow and data sources rapidly expand. While big data has traditionally been applied at the core of the network, cities can take advantage of edge processing and storage to partition computing needs appropriately across the core and edge of their municipal infrastructure.**
- **Looking into the future, government services can also be advantaged through a greater amount of crowdsourced data, context-aware data, and predictive analytics, as governments can apply this information to real-time dashboards and be in a position to take proactive actions.**

Planning Considerations

While expansion and greater accessibility of government services to Smart City citizens is heavily dependent on local infrastructure investments, there also exists opportunities for government services to leverage data and infrastructure that is outside of local government assets. This is especially true in the case of data that could be derived from commercial sensors or devices in the public domain. This opportunity highlights the need for data exchanges and data/application marketplaces that can create value through

cataloging, analyzing, and publishing data, thus integrating with the needs of citizen-centric services. Standardization will be an important element to creating widespread utilization of data exchanges and marketplaces and allow an evolution to smart regions.

Water Management

Technology Enablers
LPWAN, Data Integration Platform, Edge Platforms

Overview

Water and wastewater management is emerging as an important area of Smart City development from multiple standpoints: operational efficiency, conservation of water resources, citizen quality-of-life, and improvement to collection, distribution, and consumption of valuable water resources. It is understood that water management improvements involve a long-term investment strategy and must be sustainable for many decades. Water and wastewater management is particularly important as cities grow and populations expand. Strategically, areas such as water management and flood control will often impact a large geographic area and have major implications as Smart Cities expand to smart regions.

Key Technology Developments

- **Fundamental to the development of smart water solutions are intelligent sensors that can measure and report water flow, pressure, and delivery. Similarly, stormwater and flood monitoring are essential elements of a city's day-to-day operations and emergency preparedness. IoT sensors can be intelligently networked and provide additional benefits over many currently deployed sensing systems, including individually addressable and controllable sensors.**

- The addition of edge management solutions to IoT-based sensors can provide incremental benefits by providing edge analytics and data correlation across a sub-system or specific region of a city.
- Given the current limitations of systems to interact across a city IT landscape, intelligent IoT reporting devices will offer the ability to transmit specific profiles of data to other city agencies on a near real-time basis. For example, water management indicators could be predictors of ensuing transportation, energy, or public safety events. Wastewater events can quickly lead to transportation flow interruptions or public safety alerts.
- On a more regional basis, flood control can be greatly enhanced by collection of data from flood sensors and the application of predictive analytics to provide public alerts and have city officials take appropriate actions. In the future, context-aware data and machine learning capabilities will provide even greater proactive analysis for cities to dispatch resources and deliver alerts to the public.

Planning Considerations

Improvements to water and wastewater management have broad impacts beyond the conservation of water resources and proper distribution of wastewater. Most cities' energy consumption is highly impacted by the energy costs of water treatment and disposal infrastructure. Cities who have undertaken smart water initiatives have therefore realized significant economic benefits in energy cost reductions, and realized related benefits in terms of impacts to transportation, economic development and other areas. However, it is important that smart water investments be designed with a broader strategy of delivering data across

city agencies, in order to take full advantage of the benefits of intelligent connectivity and data integration.

Typical estimates of water loss across U.S. cities are in the range of 30% of total water flow not reaching its intended destination. The future demands of urbanization will place significant demands on cities to take steps in water conservation. Partnerships among cities, utilities, residents, and businesses that can measure the flow and consumption of water from water sources to delivery points will require intelligent monitoring and control access the entire smart water ecosystem.

Waste Management

Technology Enablers
LPWAN, Data Integration Platform, Edge Platforms

Overview

As municipal populations grow, the challenge of smart waste management is continuing to impact cities even with significant advancements in recycling and improved handling of hazardous waste materials. Many cities have already undertaken new smart waste management projects to reduce operating costs, create improved livability, and optimize proper collection and disposal of waste. But the benefits go far beyond expense reductions, as waste management has a direct correlation to issues of public health and healthcare.

The cost of waste management varies dramatically across cities in North America and the globe, but removal of solid waste has a significant impact on the ongoing city operating budget. Therefore, many cities have already begun to optimize the collection of waste and recyclables by using intelligent sensors to monitor and report waste accumulation levels. This enables much more efficient collection, transport, and disposal of waste materials in urban environments.

Key Technology Developments

- **Smart Waste sensors represent the most immediate application of technology to waste management. These devices are already being deployed by cities to optimize collection schedules and decrease costs related to removal. The waste management data can be further optimized by analytics to predict deviations to collections based on time of year, special events and other factors.**
- **Generally, there is uneven use and disposal of various recyclables materials, e.g., glass, plastics, paper, metal, etc. In some municipalities, this forces non-optimized collection of materials based on the most commonly used recyclable. However, the type of material varies by business, residence, city sector, etc. In the future, IoT low-cost sensors could optimize this collection and even assist in providing recyclable disposal containers that are sized to the disposal rate.**
- **As water management sensors and applications continue to improve, it will become increasingly beneficial to coordinate waste management sensing with applications that may be utilized by businesses and residents. For example, notice of pick-up schedule adjustments can be communicated to the public. Likewise, residents and businesses could realize savings based on maximizing collection and avoiding the empty trash bin scenario. This points to continued developments of data sharing and marketplaces that are focused on citizen-centric needs.**

Planning Considerations

The perspective of waste management as a silo is rapidly changing across city operations, as the financial and operational impacts are fully realized in terms of traffic congestion, public health, energy consumption, and other factors. Even beyond improved waste and recyclables management within a municipality, some cities are already implementing solutions that treat waste as an asset. Globally, cities are already demonstrating how waste-to-energy has become a viable business model. All of this suggests that a holistic waste management strategy is needed that incorporates technology, people, and processes as a key component of a city's long term sustainability plan.

6. Strategic Framework for Managing Uncertainty – For City Planners

In setting up smart cities, city leaders may find themselves dealing with strategic technology uncertainty. The purpose of this section is to provide an example overview of a strategic framework for managing strategic uncertainty used by some players in the private sector. Managing strategic uncertainty is not new to the private sector and partnering with the private sector could provide benefits as cities address new territory in uncertainty management. This framework is included to help city planners in setting up their own methods for strategic uncertainty management. The framework is based on the following Harvard Business Review article:

***Strategy under Uncertainty*, by Hugh Courtney, Jane Kirkland, and Patrick Viguerie**
https://hbr.org/1997/11/strategy-under-uncertainty

Once a city or governmental entity decides to explore or move down the Smart City path, they will be entering a space that is driven by technology and application choices where technologies and applications are at different places in life-cycle and provide different potential value plays – all in an evolving environment that is inherently dynamic. This calls for a strategic framework to understand and manage uncertainty.

The following are key aspects of the framework based on the reference above:

- **Level of Uncertainty: This ranges from Clear Enough Future to True Ambiguity.**
- **Strategic Posture:**
  - **Shaper (a city leading the way that reduces uncertainty for itself and others by its choices and actions).**
  - **Rapid Adopter (a city that acts as quickly as possible once uncertainty is reduced to an acceptable level; its choices and actions help to reduce uncertainty further for itself and others).**
  - **Reserve Adopter (a city that reserves the right to play and is waiting for a significant reduction of uncertainty to avoid premature commitment).**
- **Strategic Moves:**
  - **Big Bet (a move that yields high value or success in one future scenario but does not yield value in other future scenarios).**
  - **Option (a move that yields appropriate value in some future scenarios but does not yield value in some other future scenarios).**
  - **No Regrets Move (a move that yields appropriate value in all future scenarios).**

The cities and other governmental entities are already engaging such a strategic framework (implicitly) regarding Next Generation 911 where there are 6000+ Public Safety Answering Points (PSAPs) at various stages of development. PSAPs could be characterized by Strategic Posture (Shaper, Rapid Adopter, or Reserve Adopter). Typically the Shapers make multiple Strategic Moves (Big Bets, Options, No

Regrets Moves); whereas Reserve Adopters (in a time of uncertainty) may make no moves or make low cost Option Moves or No Regrets Moves.

This strategic framework for managing uncertainty is intended for a single city or governmental entity to develop a strategy for its use. It is not the purpose of this roadmap document to develop a generic strategy for all. In addition, there is the implicit meshing of strategies by all players in the supply/service chain. For example, in an atypical case, a city deciding to make a Big Bet move to deploy and operate a high speed broadband network on its own (i.e., no public/private partnership) implicitly causes Service Providers to rethink broadband deployment strategy in such an area.

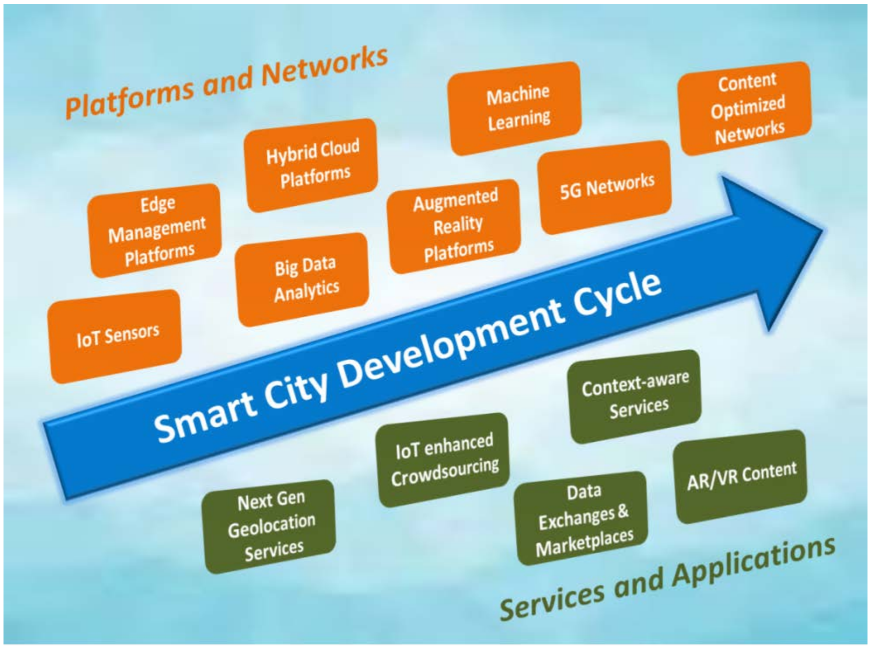
7. Conclusions – ATIS' Role in Promoting Future Investments in Smart Cities

The ATIS Technology Roadmap described in this document provides a strategic trajectory of key technology developments to Smart City planners. These developments are presented as part of an overall technology framework and a collection of technology enablers that will almost certainly impact every Smart City landscape. The objective of this document is to articulate a generic 1-4 year view of network and application level advancements, which can fuel Smart City investments and support the development of a comprehensive vision for each city or community.

It is understood that Smart City initiatives may range from incremental to disruptive. Deployments will be shaped by many factors, including funding and financing, local government and citizen needs, application developments, and technology choices. As Smart Cities projects become more pervasive across each region and geography, technology and applications will need to be a contributor to a viable business model that works for a city and its population. Customized requirements will need to be balanced with replicable solutions. The goal of the ATIS Roadmap is to identify key developments that can help provide an intersection between technology solutions and cities' vision of a sustainable Smart City ecosystem that promotes citizen-centric value.

The industry-level guidance contained in this document covers a wide-range of topics, spanning networks to devices. Understanding that cities will have a diverse set of requirements, priorities and approaches, the following diagram is intended to summarize some of the key

developments over the next 4 years that will impact a Smart City plan:



From a platform and network perspective, it is clear that IoT devices and edge management platforms will play a key near-term role in providing cities with new sources of data that can be intelligently integrated across a wide set of government services and citizen needs. This vast wealth of data will drive new opportunities for using big data analytics and new forms of predictive analytics to create value and promote real-time actions by city governments. To this end, data exchanges and new application marketplaces will emerge and can become valuable assets in terms of integrating city data and leveraging data from citizens and third parties. New cloud-based solutions, like hybrid cloud platforms, will allow cities to invest in intelligent solutions that can optimize city-owned infrastructure and shared resources.

Networks will be going through a cycle of rapid transition in the next few years, as 5G solutions are introduced. The evolution to 5G will deliver the promise of high bandwidth, low latency, and pervasive connectivity, offering Smart City ecosystems a new generation of applications that can leverage these network improvements. Machine learning and augmented reality will continue to evolve and enable an even greater level of real-time applications that will meet the long-term vision of a Smart City.

As these platforms and networks become more embedded in city landscapes, new content-rich services will be the link to citizen applications. Citizen-government ecosystems will continue to evolve as new services and applications are built on top of capabilities like crowdsourcing, context-aware services, 3D geolocation, AR/VR content, and the information exchanges that can create value and accessibility across citizen and government needs.

As a significant next series of steps, ATIS plans to continue its outreach to city and community CTO and CIO organizations, including mayors' offices, to promote the use of this report, and more importantly, to gather feedback from Smart City thought leaders on collaborative activities that can advance North American city commitments and investments. Some early insight, gained through discussions with city leaders, has identified two key areas that can promote innovation through collaboration:

1. Development of requirements for Smart City data exchanges, application marketplaces, and registries. The requirements should lead to a standardized means of creating value from the collection and sharing of data within a Smart City ecosystem, including

greenfield/brownfield sensor networks and data from public and private sources.

2. **Explore opportunities to standardize foundation-level aspects of Smart City infrastructure in order to promote solutions that can be replicated, but allowing for customization and innovation to meet Smart City visions. Standardization of foundational requirements for Smart City infrastructure would promote consistent hardware platform approaches that can then be tailored to meet unique city needs and support innovative product solutions.**

ATIS appreciates the contributions of its industry members and the guidance of city leaders in developing the Smart Cities Technology Roadmap.

For additional information, please contact:

http://www.atis.org/01_strat_init/SmartCities/contact.asp

8. Acknowledgements

AT&T

Bell Canada

C-Spire

CenturyLink

Cisco

Cox Communications

Ericsson

Fujitsu

HPE

iconectiv

InterDigital

JMA Wireless

Motorola

NextNav

Nokia

Oracle

Qualcomm

Sprint

TELUS

Verizon

Viavi

West Safety Services

Published by

Alliance for Telecommunications Industry Solutions
1200 G Street, NW, Suite 500
Washington, DC 20005

Printed in the United States of America.