Catalyzing the Internet of Things and Smart Cities: Global City Teams Challenge

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***Abstract*— Many smart city and Internet of Things (IoT) solutions are suffering from fragmentation and lack of economies of scale. To address this issue, the National Institute of Standards and Technology (NIST) initiated the Global City Teams Challenge (GCTC) to catalyze collaboration among different stakeholders. The goal is to design and deploy IoT and smart city solutions that are replicable, scalable, and sustainable, thereby leading to the identification and adoption of a consensus framework for smart city technologies. The second round of GCTC is currently in its first phase. Future smart city projects would benefit from a widely distributed IoT communications fabric that can serve as an infrastructure for the deployment of truly sharable and replicable smart city solutions.**

***Index Terms*—Internet of Things, Smart City, Global City Teams Challenge, GCTC, Replicability, IoT Fabric**

I. Introduction

The concept of Cyber-Physical Systems (CPS) or Internet of Things (IoT), which has been around for more than a decade [1], is currently creating a great deal of buzz in the marketplace and media, with a promise to enhance the way we live our lives. There are three major arenas for IoT applications—in the consumer, industrial, and public sectors. Recent interest has mainly focused on the consumer side, including consumer appliances, home area networks and other applications Industrial applications are promising to improve business outcomes for many sectors, including manufacturing, asset management and healthcare.

In the case of public sector applications, the Internet of Things is a major enabling concept to accelerate the development and deployment of smart city solutions. This article discusses the overall architecture of IoT and the issues of current practice of smart city deployments. The article then presents a new collaborative approach that uses the concept of a "challenge" for the acceleration of broader and faster adoption.

II. IoT and Smart Cities Architectures

To understand the basic characteristics of IoT and smart cities, it is useful to analyze the composition of a typical IoT solution and show how the architecture can be mapped to that of smart cities. Figure 1 illustrates a simplified layered architecture of IoT.

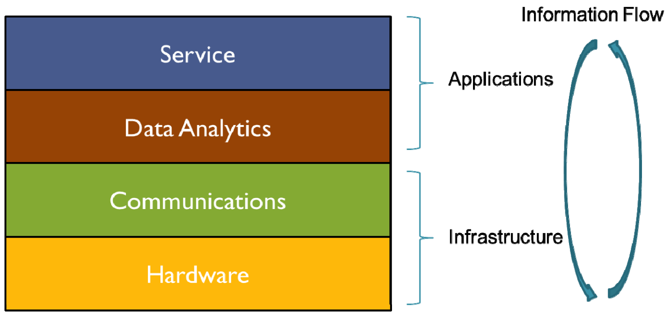

Figure 1: Simplified IoT and Smart Cities Architecture

At the bottom of the structure is the **Hardware layer**, where tangible hardware elements such as sensors, actuators, chips, and radios are found. The elements in this layer typically interact directly with the environment, with other hardware elements, or sometimes with the users/consumers.

The next layer is the **Communications layer**, which is sometimes called "connectivity." This layer connects and binds different components in the Hardware layer so that information can flow between layers or between hardware components. This is where well-known technologies such as Ethernet, Wi-Fi, cellular, and short-range wireless are found. For some applications, the Communications layer is minimal (e.g., scaled down to an internal bus or to simplified connectivity among different hardware components).

The next layer is the **Data Analytics layer**. This layer receives data from the Communications layer, and then stores, analyzes, and processes them. This is where "big data" applications could reside, for example, in the case of applications that require collection and analysis of data from a large number of sources. However, it should also be noted that this layer could be relatively thin and simple, especially in the case of embedded applications. In other words, the Data Analytics layer does not necessarily imply the need for a huge database and an extremely fast processor.

Many distributed IoT-based control systems employ a relatively small-scale Data Analytics layer. An example of a small-scale layer can be found in a smart thermostat that could also function as a local decision maker within the home network.

On the other hand, many IoT solutions deployed at a city-wide scale may require a big centralized data repository and more powerful processors to handle a larger amount of data from multiple sectors and applications. An example of such a system could be a city's disaster command center that is designed to provide simultaneous visibility into different departments (e.g., water, energy, transportation, healthcare, etc.).

The main function of the Data Analytics layer is to collect data from the lower layers and extract useful information from the set of data. Note that the set of data itself may not have significant value and may not be very useful to the user. The information extracted from the data, however, could be valuable in taking actions and achieving a desired end result.

The top layer is the **Service layer**. This layer is where intelligence resides and decisions are made. This layer receives information from the Data Analytics layer, and then makes decisions on next steps. The next steps could include displaying the information on a monitor screen or operating and controlling actuators. The Service layer is important because it is in the position in the architecture to create the highest value for the users of the system. Many business decisions are made in this layer, including human-in-the-loop actions. The human-machine interface can be an important factor in this layer.

Once the decision of the next step is made at the Service layer, sometimes (but not always) information starts flowing in the reverse manner (i.e., from Service layer down to the Hardware layer). This is especially true for systems based on some type of autonomous control. On the other hand, it is sometimes a human being who makes the decision and executes it. In either case, the end result is some type of action that closes the loop of the information flow. A similar representation of IoT data flow was proposed in another article [2].

Many developers consider IoT to be the combination of just the two bottom layers (Hardware and Communications). It is important to note, however, that these two layers are merely a part of the whole IoT architecture. In many cases, the top two layers (Data Analytics and Service) play more important roles in defining and producing the real value from the system. Also in many cases, the design and implementation of the top two layers may be more complex and unclear than the bottom two layers. In many cases, the top two layers are heavily coupled with business cases that are important factors in determining sustainability and replicability of the solutions.

In the case of smart city applications, it is often easier to conceptualize the architecture as two groups of layers—Infrastructure and Applications. "Infrastructure" typically refers to the bottom two layers of the IoT architecture, and "Applications" refers to the top two layers. In some cases, however, the Data Analytics layer could belong to the infrastructure group, depending on the nature of its functionality. Many solutions/products that belong to the application group have more flexibility in deployments than the ones belonging to the infrastructure group. This simple IoT architecture can serve as an initial template to map different smart city solutions to build consensus on their technical interoperability, which is essential in addressing the challenges in accelerating the market momentum for IoT and smart cities..

III. Challenges for Advancing IoT in Cities

Smart cities use smart technologies such as IoT and CPS to improve the quality of life of the residents and citizens. Although progress in deploying IoT solutions has been quite impressive, the IoT market still suffers from the issue of "fragmentation, [3]" and the smart city market shares similar concerns. Many smart city solution projects are isolated and heavily rely on custom-solution developments. Naturally, many of them are "one-off" projects with heavy emphasis on customization and inadequate consideration for future upgradability and extensibility. As a result, these deployments are isolated and do not enjoy economies of scale. Although many cities share the same issues (i.e., parking problems, traffic jams, air pollution, etc.), they often do not share best practices and end up reinventing the wheel. In this landscape, it is very difficult to create common standards for development and deployment of interoperable solutions.

IV. Global City Teams Challenge

To address this issue, the National Institute of Standards and Technology (NIST) has teamed up with US-Ignite and private sector partners to create the Global City Teams Challenge (GCTC) program [4][5]. The goal of GCTC is to establish and demonstrate replicable, scalable, and sustainable models for incubation and deployment of interoperable, standards-based IoT solutions and to demonstrate measurable benefits in smart communities/cities. "Replicability" means that the solutions should be designed to operate in more than one city or community with minimal customization. "Scalability" means that the solution should be functional regardless of the size and volume of the deployment. "Sustainability" means that the project should be designed to last beyond its initial funding stage. In other words, the deployed solution must either (1) create its own revenue to support the operational cost or (2) provide enough tangible benefits that the municipal governments are willing to cover the operation cost using their budgets. Many of today's smart city deployments lack one or more of these characteristics. GCTC places significant emphasis on the ability to measure tangible benefits for residents and citizens, thus empowering leaders within communities to demonstrate the benefits of adoption.

A. Approach

To achieve the goal of GCTC, the program was designed to create a voluntary environment for multi-stakeholder collaboration. As can be seen in Figure 2, multiple cities and technology innovators are brought into the program and asked to coalesce around shared challenges (e.g., air pollution, traffic management, emergency response) to create teams called "Action Clusters." Each Action Cluster creates a project plan with a timeline to demonstrate their accomplishments in a tangible manner. Because each action cluster includes multiple members, it is likely that the outcome of the solution will be replicable to other cities. In the case that a team has only one municipal partner, the team is encouraged to establish additional partnerships with other cities by demonstrating measurable and quantifiable benefits of the solution. It is also important to note that replicability and interoperability should be based on collaboration that is global rather than just regional.

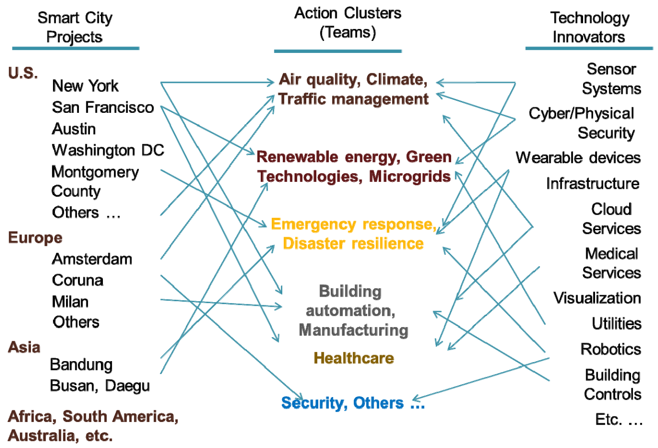

Figure 2: GCTC Approach

Cities have two strong reasons for participating in GCTC. For the cities that have already gone through successful deployments, it is an opportunity to promote their solutions and be the origin of replication for other cities that are facing similar challenges. For the cities that are just starting to consider the deployment of smart city solutions, it is an opportunity to learn from other cities' projects and to showcase their own city as a ready partner to organizations with replicable smart city technologies.

For corporations, GCTC is an opportunity to identify new business partners, demonstrate their proven solutions, and enlarge their market.

Academic institutions participate in order to find opportunities for joint R&D with cities/communities and partners that will enable the joint development and deployment of new technologies. The process also allows researchers to identify key common characteristics and components among different applications and implementations, which will help the market to find convergence on best practices and eventually lead to broadly adopted standards.

B. GCTC 2015

The first round of GCTC culminated on June 1, 2015, after a nine-month-long process of team building, incubation, solution development, and deployment. More than 60 teams, composed of over 200 organizations and three dozen cities/communities around the world, gathered at the National Building Museum in Washington, D.C., to present and demonstrate the impact of their smart city solutions. Many high-profile visitors and speakers, including King Willem-Alexander and Queen Maxima of the Netherlands and U.S. Secretary of Transportation Anthony Foxx, came to celebrate and encourage the teams' accomplishments. The event was attended by over 1300 people and was covered by many media outlets.

C. GCTC 2016-2017

Based on the success of GCTC 2015, the next round was launched in November 2015. This new GCTC round is composed of two phases. The first phase will continue until June 2016, with the focus on building the teams and defining the project goals, timelines, and Key Performance Indicators (KPI) of the quantifiable impacts to residents and citizens. Participants will demonstrate and pilot the solutions and will build partnerships with as many cities as possible. The second phase will focus on deploying the solutions, achieving the goals (based on the KPIs devised during Phase 1), and measuring the impacts. Phase 2 will culminate in June 2017.

GCTC 2016-2017 carries over the key elements of GCTC 2015, and adds two more ambitious goals, encouraging the teams to:

- deploy the shared and replicable solutions in multiple cities, potentially on multiple continents and
- provide tangible measurements of the improvements made by the solutions, such as reduction of average commute time, reduction of air pollution, reduction of water loss.

V. Further Discussions: IoT Smart City Fabric

One of the missing links in accelerating the deployment of IoT/CPS and smart city solutions is the lack of a "connectivity fabric"--a commonly shared IoT/CPS network infrastructure among cities and communities [6]. As of today, there is no easy mechanism for an IoT solution to be deployed and become operational in a plug-and-play manner. For example, a simple flood-level sensor deployed in one city may not share the same backbone infrastructure required to exchange data with sensors in other cities. The current landscape of IoT and smart city is similar to that of the communications infrastructure of pre-Internet days.

It is essential that a communications fabric infrastructure be developed that can enable IoT devices and smart city solutions to identify and communicate in a plug-and-play manner, to create synergy between sectors, to reduce overhead, and to catalyze the mass adoption of affordable solutions by the residents in cities and communities. The IoT/Smart City fabric would enable sharing and replication of the solutions beyond the city limit, just as the Internet broke the physical-distance barrier for communications and commerce. Combined with multi-stakeholder collaboration programs such as GCTC, the IoT/Smart City fabric—built to be open and neutral--could allow many cities and communities, large and small, to enjoy the benefits of advanced technologies to improve the quality of life.

Starting with its Challenge programs [7][8], NIST has already taken steps in the direction of promoting consensus around reference architectures for interoperability. Informed by GCTC, NIST has taken the first step to establish an international technical public working group to help develop an "IoT-Enabled Smart City Framework." [9]

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REFERENCES

[1] Industry Advisory Board, RWTH Aachen University, "Cyber-Physical Systems - History, Presence and Future," February 2013.
http://www.ima-zlw-ifu.rwth-aachen.de/fileadmin/user_upload/INSTITUTSCLUSTER/Publikation_Medien/Vortraege/download//CPS_27Feb2013.pdf

[2] E. P. Goodman, Rapporteur, "The Atomic Age of Data: Policies for the Internet of Things," Communications and Society Program, The Aspen Institute, 2015, p. 5.
http://csreports.aspeninstitute.org/documents/Atomic_Age_of_Data.pdf

[3] M. Smolaks, "Internet Of Things In Danger Of Fragmentation" TechWeek Europe, July 2013
http://www.techweekeurope.co.uk/workspace/internet-of-things-in-danger-of-fragmentation-120566

[4] Global City Teams Challenge
http://www.nist.gov/cps/sagc.cfm

[5] Global City Teams Challenge
https://www.us-ignite.org/globalcityteams/

[6] S. Rhee, G. Mulligan, "SmartAmerica Challenge," 2013-2014, p. 6.
http://www.nist.gov/el/upload/Smart-America-Challenge-r1-25p.pdf

[7] E. P. Goodman, Rapporteur, "The Atomic Age of Data: Policies for the Internet of Things," Communications and Society Program, The Aspen Institute, 2015, p. 48.
http://csreports.aspeninstitute.org/documents/Atomic_Age_of_Data.pdf

[8] S. Rhee, "Internet of Things and Global City Teams Challenge," January 2015, p. 33.
http://www.nema.org/Policy/Documents/IoT%20Global%20City%20Summary_NEMA_Sokwoo%20Rhee_01.08.2015.pdf

[9] International Technical Working Group on IoT-Enabled Smart City Framework
https://pages.nist.gov/smartcitiesarchitecture/