Smart Cities: Engaging users and developers to foster innovation ecosystems.

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Abstract[1]

Increasingly, city planners and government officials understand that cities are engines of innovation and wealth creation. Equally, there is a growing understanding that the application of technology in support of Smart Cities helps grow the urban economy and deliver better services to citizens. However, often Smart City projects are top-down projects focused on improving city infrastructure using technology. We argue, and our experience over the last decade has shown, that often, citizen driven, or grass-roots based Smart City projects deliver better value and sustainable success. In this paper we report on our work to engage citizens and the technology community in smart city projects and highlight some lessons learnt from our experiences. We show how a modest investment in a Smart City Data Hub (using our IoT platform – WoTKit) plus development tools based on Node-RED helps bootstrap a Smart City innovation cluster.

Author Keywords
Smart Cities, Middleware, innovation, Data Hubs, Internet of Things (IoT), WoTKit, Node-RED.

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Introduction and background

Smart Cities, with their potential to drive growth of local and global economies, and to improve the lives of citizens have been a significant area of academic and commercial interest over the last decade. As part of that interest, there has been ongoing research into the technologies needed to support Smart Cities, with a focus on using information and communications technologies to manage city infrastructures like transportation, traffic control, building management, energy monitoring, and pollution monitoring. Of particular interest has been the specification and development of platforms that

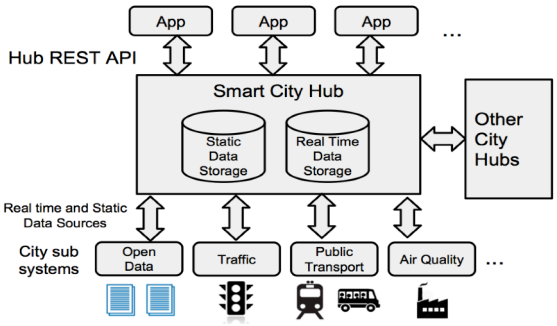

Figure 1. An IoT hub acts as a portal for Smart City Infrastructure as well as other hubs.

have sought to exploit the Internet Of Things (IoT) paradigm as the basis for Smart Cities. This has included work by partnerships between local public authorities and private companies such as IBM [13] and Cisco [18], and large-scale urban testbeds e.g. [14,15,16].

Research addressing specific city infrastructures has included, for example, the use of traffic sensing technologies such as magnetic sensors and wifi scanners to assist traffic operators [11]. Experiments with large-scale sensor networks enable real-time monitoring of critical infrastructure such as the urban water supply [6]; defining key interfaces to buildings allows smart-grid managers to interactively manage energy use for the city [12].

While initiatives that focus on infrastructure are important, researchers also recognize that citizens themselves often provide both the needed data and intelligence to make a city 'smart'. Recent efforts have begun to explore platforms to engage citizens directly or by integrating social networks into the IoT [2] and using urban crowdsourcing to augment urban data infrastructures [1,5,19].

It is expected that both the variety and quality of data streams generated by city infrastructure and citizens will continue to increase as additional solutions come online to address efficiency in urban sub-systems. Understanding that it is not enough to create different sub-systems that don't 'talk' to each other, researchers have begun to address interoperability with unified urban-scale sensor networks and large-scale architectures toward unifying Smart City systems to create open innovation platforms [17].

Smart City Hubs

As identified above, there have been a number of approaches to enabling Smart Cities and in particular, engaging a wider ecosystem in the development of the smart city. Our approach has leveraged the notion of Cloud-based data hubs that offer a promising approach to developing an IoT centric framework for smart cities and address two key issues (see Fig. 1). Firstly, they offer a consistent and easy-to-use interface for emerging IoT infrastructure within the city that systems integrators and application developers can use. Secondly, they support the system-of-systems approach to smart cities whereby a cloud-based hub can integrate a number of sub-systems that collectively make up the complete smart city software infrastructures [8].

In addition to infrastructure management, cloud based hubs also offer a framework to integrate both static and real time urban data sets from government, community groups and participatory sensing systems. To manage and deliver these diverse data sets, hubs can act as a curated portal for end users and an easy-to-use service access point for developers. Applications accessing these hubs can use this data to adapt themselves to current or expected conditions, addressing needs in areas such as multi-modal transportation, environment waste management, and load management, driven by the needs of urban authorities, or by local entrepreneurs and citizen groups.

By aggregating many systems under a hub, efforts toward interoperability or federation of Smart City functionality can focus on hub integration, rather than the integration of individual city sub-systems. Through the use of interoperable data hubs, application developers can more easily create reusable applications that work in multiple cities.

Deployments

We have been building smart city applications for a number of years. Our early work focused on projects that engaged community groups around the city in deploying new technologies to solve their issues. More recently we have developed and deployed the Smart City Hub (described above) in two main deployments, one in the UK and the second in Canada [8].

Smart Streets: The Smart Streets hub was developed as part of the UK's strategic research into IoT hubs and funded by the Technology Strategy Board (TSB). Overall, eight industry-led projects were funded to deliver IoT clusters in the spring of 2014. These projects all explored the use of an IoT hub to represent clusters of things from different aspects of smart cities and smart infrastructure. These clusters covered a range of areas including smart schools, urban transportation, airports, smart homes and critical infrastructure such as roads and highways.

As developers of the Smart Streets IoT Hub, our focus was the Highways maintenance sector which gathered data from a variety of sources related to the UK's national and regional road network. Data included real-time traffic flows, incidents that affected traffic flows, road works, flood and rain data, all of which were made available via the Smart Streets Hub.

Urban Opus Urban Opus is a Smart City innovation cluster based in the Metro Vancouver area in Canada, which is a small urban region comprising 23 local authorities and approx 2.4m inhabitants. A particular focus of UO has been engaging local community groups and using them as the prime driver of projects and activities. Typically a UO project goes through a number of phases. Initial needs/requirements are identified by a community group or organization and presented to UO. UO then attempts to identify technical, design and program management needs and broker introductions to other city stakeholders who may be able to help the community group. As a project evolves, UO aims to help the project team develop a sustainability strategy so that the project can exit UO and become self sustaining, in some cases this is via ongoing community support, in others, UO helps the project to transition to a commercial (perhaps non-profit) enterprise using the accelerators and incubation facilities around the Metro Vancouver region.

To support this effort, the Urban Opus Hub provides data storage and federates existing data sources to provide a single on-line presence and point of access to these data sets. The system shares the same basic architecture as Smart Streets with support for both real time and static data, and an easy to use API for developers.

Experiences working with user and developer communities

Building a user ecosystem

Our own experiences, and that of [7, 15,16] have clearly identified the need for user engagement when developing smart city services. Users in these situations range from stakeholders such as community groups, non-profits to private citizens. In all cases, critical to success is a clear need for a service - too many times, smart city projects are not led by end users or stakeholders who have clearly identified a need, but by entities promoting a technological or infrastructure.

EARLY WORK WITH CITIZEN ENGAGEMENT

Two early experiments we made into smart city services focused on user engagement and the issues of developing and maintaining a user community that was involved in the evolution of the service. These two services, Park Quest, focused on the city's parks and My Everyday Earth, focused on home energy consumption. In both cases we explored the use of gamification as a way to engage users, and on user participation in goal setting to foster a community.

Park Quest: PQ was developed in conjunction with the city parks and a non-profit group that worked to engage citizens in the use and maintenance of the parks. PQ was designed with educational and entertainment goals and was targeted at the young adult demographic. PQ consisted of a set of quests or challenges, that user undertook. The quests were designed to educate the users about the park system, the facilities and aspects of the flora and fauna in the parks.

A variety of techniques were used to foster engagement, these included classic gamification techniques such as points, badges and leaderboards, all aimed to foster a sense of community and engagement.

The quests covered a number of areas including task based puzzles physically set in the parks and requiring players to gather information and solve clues through the parks through to photo competitions that asked users to find and photograph (using mobile phones) specific items in the parks. Users were active participants in the evolution of these quests, for example suggesting photo topics,

or creating virtual geocaches and challenging other participants to find them using cryptic clues.

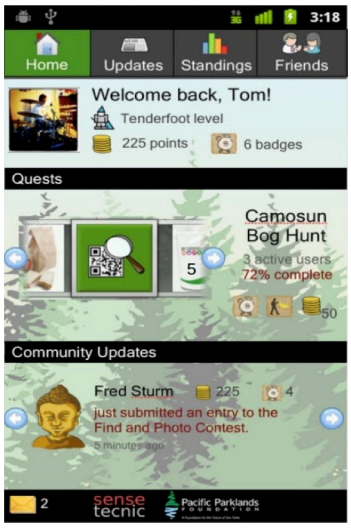

Figure 2. Park quest: Using gamification to engage youth in park based activities.

My Everyday Earth: MEE followed a similar design to PQ and was designed to engage young adults in a series of quests and challenges around sustainability and energy use. It used the notion of challenges to encourage participants to reflect on their consumption of resources ranging from food and transport through to heating and light. Again a gamification model was used that relied on points, rewards and leaderboards.

As in Park Quest, a variety of challenges were developed. A daily-action challenge asked participants to register their intent to use less water (shorter showers), take public transit or walk/bike, discard less food - and then awarded them points based on their actual actions. This challenges used a pledge model that reinforced actions by asking for a pledge at the start of the day and reviewing success at the end of the day. Another challenge took the form of a treasure hunt through the city that explored how the city was reducing waste and encouraging sustainability.

After our initial deployment, the MEE application was retargeted as part of a nationwide student competition - "Do it In the Dark" (DIITD) that aimed to reduce energy in student accommodation. Again we used a variety of quests to influence, or nudge behaviour.

The DIITD competition ran for 1 month (November) and defined 4 challenges for the which covered a variety of activities related to sustainability and energy reduction. They included:

- Do It Daily: a set of 11 actions that students were asked to perform each day and report on. Actions ranged from turning off lights, putting on a sweater through to showering for shorter periods in colder water and even sharing fridges,
- Do it together: a set of events organised by individual residences that encouraged students to come together and participate in awareness events, e.g. Dine in the Dark where students shared cooking/eating facilities and reduced energy by turning off lights.
- Do It with your politician: a civic engagement challenges that informed

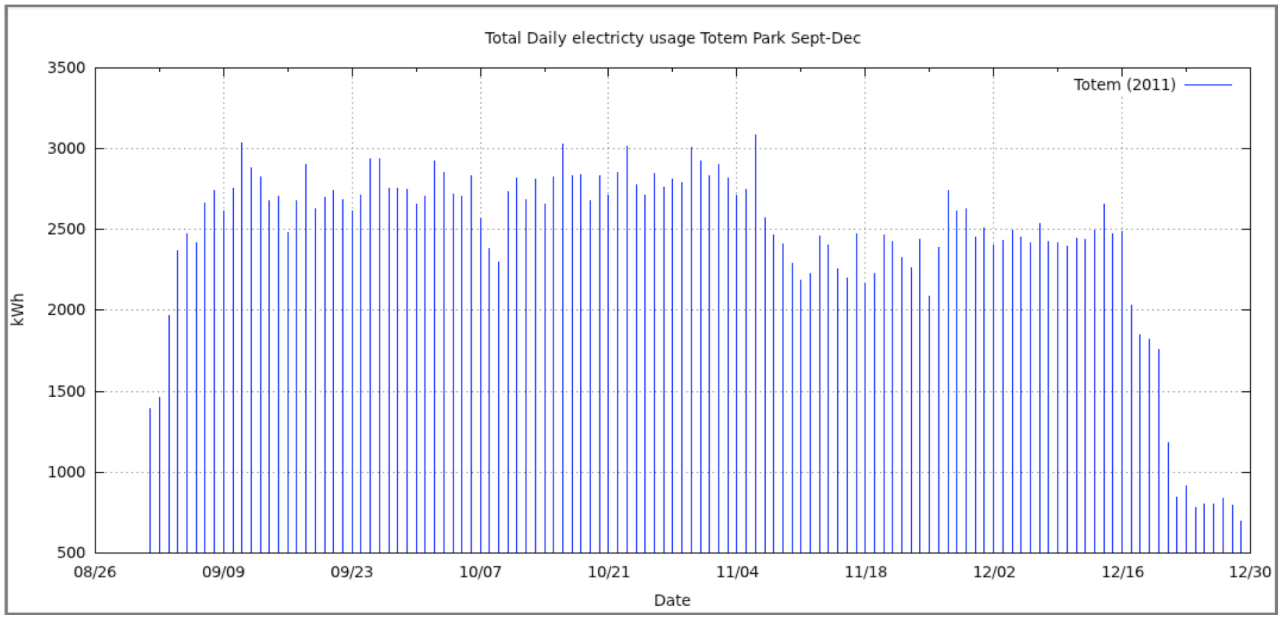

Figure 3: Electricity usage before (Sept-Oct), during (Nov) and after (Dec) the Do it in the dark competition

students about a local issue relating to sustainability and encouraged them to voice their opinion by contacting a local politician.
- Do it on Camera: students were encouraged to create Video Blogs (vlogs) discussing their activities and sharing tips for reducing energy.

A total of 646 students across the 6 universities actively signed up for the MEE application and recorded results.

At the University of British Columbia (UBC), a total of 360 students signed up for MEE with 201 of those students residing in Totem Park and the rest (159) residing in Place Vanier. UBC students collectively carried out over six thousand (6510) daily actions which were designed to reduce their energy consumption, with UBC activities mirroring the overall trends seen above. A detailed analysis is available in [21].

As part of the competition, electricity usage was recorded in student accommodation and during the course of the competition, we observed a 15% drop in electricity use on one of the campuses. See figure 3 below. Of note is that after the competition, electricity usage rose, but did not return immediately to pre-competition levels.

Recent Work: Urban Opus

As indicated in the introduction, our more recent work has been carried out within the Urban Opus (UO) project. One key resource that UO maintains as a community service is the Smart City Data Hub. This hub acts a data repository for a variety of city data and consists of real-time data captured from sensors around the city, plus a variety of open data assets. The role of the hub is to facilitate data driven applications acting as a trusted data broker that citizens will be comfortable entrusting data to. We encourage UO projects to use both the data hub, via a set of well-defined APIs, and to contribute new data.

Returning to the theme of user engagement, UO has experimented with a number of projects and services that place user engagement at their core. Some examples include:

Tribes: The Tribes project has a primary focus on understanding citizen issues and concerns as they relate to daily life in the city. It takes a simple approach to engaging citizens, based around a 'question of the day' which solicits feedback on a range of issues. These questions may be based on city wide issues, on local community issues or individual issues. Tribes is delivered as a mobile app, featuring a number of gamification techniques to promote engagement. One of the key research questions is to extent to which micro-demographics affects opinions and actions. As such tribes has a self-identified nature, asking users to identify which demographic group they feel they belong to, and allowing them to create new groups if nothing fits.

Tribes is designed to generate two key sets of data that are then stored in the hub and made available to other users and developers. Firstly, user provided demographic information and secondly, aggregate information on a set of issues that affect the city ranging from transportation through to day-care facilities.

Community Locus: A second project that also focuses on community feedback is Community Locus. In this case, citizens are encouraged to rate aspects of their local neighbourhood with a particular focus on aspects they feel are important or 'special'. This project was a response to a popular real estate service 'WalkScore' that attempts to provide a score of the walkability of a neighbourhood. However, WalkScore is a static map based services and doesn't take into account actual usage patterns. Data from Community Locus is obviously of use to other members of a community, but also to city planners in understanding 'hidden' aspects of a neighbourhood, or features that citizens value highly.

Energize: The energize project leverages our earlier work on sustainability and energy usage and uses a similar set of gamification techniques to encourage teenagers to consider sustainability and energy use in the home. Targeted specifically at the 8-15 age group, it aims to educate users on energy use and cost and encourage behaviour changes that reduce energy consumption in households.

Raise Pad: as a final example of a community driven application, Raise Pad has been designed to foster the 'sharing economy' with a particular focus on charitable giving. Raise Pad provides a service brokerage whereby local community groups and charities can advertise 'needs' that their members have. Rather than focusing on cash donations, these needs target services such as household work, gardening equipment/services, help with shopping etc. Members of the local community can offer to provide these services, or can pledge time and equipment to the charity to meet its needs.

In all of the above cases, we have focused on Smart City services that are community driven. They are ideas that have been suggested by community members and they are developed into projects that maintain the end user involvement as the project evolves. Like [7,15,16] our experience has been that top-down Smart City projects often fail when there is no grassroots engagement or 'pull' for the service. Additionally, all our projects have a goal of either consuming or creating citizen generated data that is made available through the Urban Opus data Hub.

Building a developer ecosystem

A second significant part of our activities has been around fostering a developer community that uses the Urban Opus Hub to develop new and innovative Smart City applications. We have experimented with a number of approaches to this that can be broadly

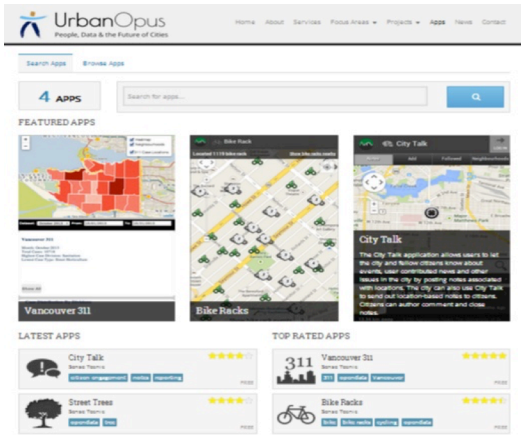

Figure 5. The Smart City Hub supports an 'app store' allowing developers to upload and promote their apps.

categorized into technical infrastructure and tech community engagement.

INFRASTRUCTURE

We provide 3 key components that we use to accelerate Smart City application development. The core Smart City Hub API, a mobile application

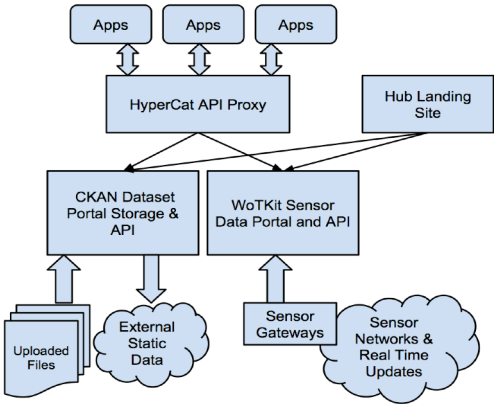

Figure 4. The core IoT infrastructure supports access to real-time and non-real time urban data streams.

framework and a visual programming tool for rapid application of smart city applications.

Smart City Hub API

The Urban Opus data hub has been built from two core components. Firstly, our own IoT platform called the Web of Things Tool Kit (WoTKit) [3] and secondly, an open source system called CKAN [10] designed to support static data management. We integrated the CKAN open-data portal as well as the WoTKit platform, allowing users to retrieve information about both static and real-time data sources using the same interface. Obviously these two functional components support sophisticated APIs appropriate to their functionality – WoTKit is designed around real-time device (or Thing) management and focuses on two way control of things as they are used in Smart City apps. CKAN is a federated data/document management tool targeted at Open Data resources.

As shown in Fig. 4, in addition to the two system-specific APIs, we also developed and deployed the HyperCat [20] IoT Catalogue API to provide a common abstraction across both underlying systems, allowing developers to quickly determine what resources are available on the Smart City Hub before using the appropriate API to access a particular resource (i.e. real-time sensor data or static open data set).

Above this core Hub technology, we have developed an App Store (see Fig. 5) as a place for developers to make their apps available and to act as a storefront for the Urban Opus smart city apps.

City Impact

From our experiences with mobile MUSE and early projects like Park Quest, we realized that not all developers have the resources or technical ability to develop mobile apps for a variety of platforms. To ease this burden, we have developed a mobile application framework designed to allow developers to quickly develop and deploy mobile apps that use our Smart City API. The framework consists of a native 'container' app for the main platforms, iOS, Android and Windows Mobile which supports an extensible set of 'mini-apps' that are launched from the container (Fig. 6).

These mini-apps are HTML5 based and so relatively simple to develop. We deploy instances of the City Impact for a number of local cities, each one seeded with a set of generic apps including City News, events, tweets, photos. Projects are then free to 'add' new mini-apps to the system, which are then dynamically loaded when users refresh their main container.

Visual programming tool - FRED

A final tool we have developed to help the technical community engage with Urban Opus is a rapid application development tool, FRED. In contrast to the mobile app framework, this tool is focused on making it easy for developers to access and manipulate smart city data and uses a visual programming metaphor for rapid development.

FRED has been developed using the Node-RED [9] system developed by IBM for IoT application development. We have extended Node-RED so that it can be used as a cloud based (SaaS) tool supporting multiple users (and instances) within the cloud.

FRED uses a data-flow programming model, with messages flowing from source to sink nodes across directed graphs of processing nodes. This programming paradigm has been shown to make it easy to make use of loosely coupled asynchronous data sources, such as those found at the heart of Smart Cities.

In addition to a standard set of programming *nodes* that users wire together to form processing *flows*, we have developed a number of specific processing nodes suitable for our Smart City Hub which provide direct access to city data feeds.

Technical community engagement

The final piece of our engagement strategy with the technical community is designed to complement the tools based approach described above. We have found that it is not enough to simply provide tools and the data hub. The developer community needs active engagement. Our preferred approach to this has been a combination of technical Hackathons and a set of targeted meet-ups. In both cases the user community suggests specific themes or problems and then events are organized around those themes. In the case of hackathons, we have run a number of weekend length hackathons, starting Friday night and running until Sunday evening. At the hackathons, individual problems are presented by users along with short presentations on the Hub,

Figure 6. City Impact is a 'container' for a variety of Smart City services, written as HTML5 apps, which can be dynamically added and removed.

some of the data resources, the tools. During the course of the event, experienced developers are on hand to help newer participants. Meet-ups are used as lightweight workshop sessions, usually run as an evening event and consisting of short technical presentations followed by a social/networking session.

Lessons and conclusions

Our experiences building smart city applications over the last decade has taught us a number of key lessons ranging from the absolute need for community engagement through to the provision of sufficient technical tools such as a Smart City Data Hub.

- Top-down, technology driven projects often don't deliver significant value. Cities are not machines and a focus on improving infrastructure efficiency, while laudable, is not always the best use of city resources.
- Community engagement is critical. It needs to drive projects ideas, be engaged during development and is required for uptake and service sustainability.
- To bootstrap projects, and help develop a thriving ecosystem, technical resources are needed to support community needs. Our experiences have shown that a modest investment in a city wide data hub and simple development tools is sufficient.
- Trust is essential. By actively engaging citizens, it is possible to build trust such that citizens will engage and will provide useful data that can be used to develop new services.

Building an innovation ecosystem that brings together the various stakeholders in any urban setting is a complex task. Our experiences have shown that focusing on community engagement and using them to drive projects and tools brings significant rewards. A particular need is to bridge between non-technical community and user groups and the technical developer community.

It is clear that Innovation ecosystems are fragile and need nurturing. Our experiences this far suggest that community driven ecosystems are more robust and self sustaining and are able to energize participants, tap into community needs and self sustain. We plan to continue building the Urban Opus ecosystem and look forward to working with similar international efforts to improve the lives of urban citizens.

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