Smart City Hubs: Opportunities for Integrating and Studying Human CPS at Scale

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I. Introduction

The allure of smart city technologies lies in its promise to enrich the lives of residents by empowering the stakeholders to make efficient and informed decisions. At its core, a smart city is a large-scale, multi-domain CPS, built over a number of foundational technologies such as Internet of Things (IoT), resilient control and cloud computing. While challenges in CPS that integrate the physical environment, the network and the cyber elements are well understood and extensively researched, integration of human elements in CPS feedback loops has much open issues where even the precise problem formulation is an open challenge. This is because (a) analyzing human behavior is difficult due to complex physiological and psychological aspects and (b) human CPS (H-CPS) has additional design concerns of human computer interfaces, decision support systems and incentives engineering to keep humans engaged with the system.

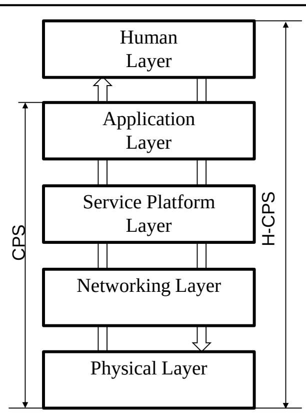

Figure 1 From CPS to H-CPS (Human-CPS systems)

With the advent of newer technologies such as smart phones, tablets, and wearable computing, the way humans interact with each other has changed dramatically over the last decade. While on one hand, the design and usage of H-CPS has to be adapted to the new behavioral needs, on the other hand it is important to develop an understanding of how human behavior influence physical processes.

Consider the public transportation system of the city of Nashville, which is significantly underutilized – Nashville ranks as 74 out of 100 in the number of passengers per capita [1]. Improving the transit services and increasing its efficiency and usage are strategic priorities of the Nashville Metropolitan Transport Authority (MTA). Key to attracting new users, in addition to providing services that are competitive with personal automobiles and that can meet basic service needs, is to make public transit easier to use and to improve the image of the services. For those who seldom use public transportation, it can be difficult to figure out how to interpret schedules and how to pay the fare, for example. Potential new customers have to be convinced that riding transit will be a pleasant experience, and people like themselves use transit. However, without the ability to model, it is almost impossible to efficiently design, configure and deploy such a system. This lack of understanding is an impediment to improvement and deployment of smart city technologies at large scale [6].

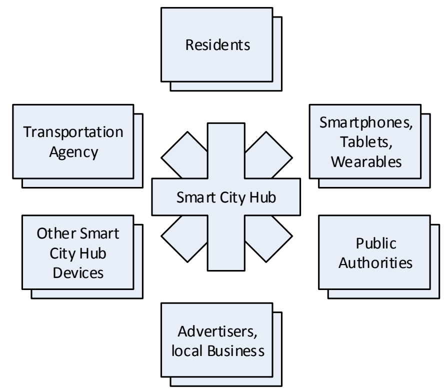

Figure 2 Smart city hub Framework provides a platform for information integration and providing an interactive experience to city residents with the purpose of enhancing their quality of life.

Our team is utilizing the smart city hub framework that is being developed by the Siemens Corporation, Corporate Research (see Figure 2). A city hub works in the context of a system of interconnected systems. The smart city hub relies on information transmitted and processed between cars, trucks, car sharing and public transportation. In order to add value for individuals, the city hub must also incorporate traffic and parking management systems as well as other traffic or commuting-related systems. To influence individuals, and to help them in decision making, the devices as wearables, smartphones or traditional computers must be integrated as well. Information that effects commuting and travelling in an urban environment as sport events, concerts or weather events can be used to help citizens to make smarter decisions about their commute or business.

We are building a solution approach with smart city hub that will enable us to rapidly configure, test and evaluate integration between humans and CPS at large scales. Our current work is related to integrating and deploying these hubs for a smart transportation scenario within the city of Nashville.

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Key contributions of this approach is gaining experiences with a large scale human CPS system and allowing development, integration and testing of (1) algorithms for predictive real-time data analytics using embedded traffic simulator, (2) decision support systems that guide citizens to optimize their response to a traffic situation, and (3) experimenting with incentive mechanisms for improving the effectiveness of the created H-CPS control loops, and (4) provide a platform for rapidly prototyping and evaluating design alternatives.

II. Challenges and Solution Approach

One of the key challenges in enabling a city-hub framework is the ability to collect and disseminate sensor data from the selected element of the city infrastructure and then analyzing the data in almost real-time. However, this is difficult because of scale and network heterogeneity. While mostly we can depend on the availability of cellular (e.g., 3G/4G and LTE) networks, we also have to contend with WiFi LAN (e.g., DSRC/802.11p), WirelessHART and Bluetooth technologies. Furthermore, all actionable information delivered to a nearby hub has a useful lifetime and must be disseminated prior to its temporal bound.

Our approach for solving the data dissemination problem will be based on our prior work - Android Mobile Middleware Objects (AMMO) [7], a novel middleware developed for tactical applications on mobile devices by Vanderbilt University for the DARPA Transformative Apps program. The goals of AMMO were to support multiple communication/data distribution paradigms over a diverse suite of networking technologies – from low bandwidth tactical radios to cellular technology and WiFi. Communications paradigms such as broadcast, publish-subscribe with content filtering, client-server are supported. While developed primarily for tactical applications, the capabilities of AMMO are an excellent match for resource constrained dynamic networks typical of a city wide deployment. For example, smart phones with AMMO middleware were used for situational awareness during the presidential inauguration in January 2013 by first responders with the National Guard, Washington DC Metro Police, National Park Service, and local Fire Department.

An effective decision support system is critical to an H-CPS like city hub [2]. A practical solution for building a decision support system is a multi-model simulation approach that facilitates the precise integration of heterogeneous, multi-model simulations. Simulation integration frameworks, such as High-Level Architecture (HLA) [4], address the composition of simulators using discrete event semantics. In this regard, we will build upon our prior work on Command and Control Wind Tunnel (C2WT) [3], a simulation integration framework that facilitates assessment of C2 systems performance in presence of network disruptions.

Conducting experiments to understand how humans interact with the decision support system combined with incentive mechanisms is necessary to understand how these technologies can improve the utilization of the transportation infrastructure and how these technologies can support the optimization of the delivered user experience. Good *Human Computer interface* is essential for engaging residents. At the core of the city hub are city hub devices, which provide a modular service platform with customizable compute, communication and sensor capabilities and can be used to create a city wide information network. The City hub device also provides a smart multi-modal user interface framework, which can adapt to the environmental and user context. For example, it can sense its surrounding and adapt to the different user - hub relation contexts attract, reveal, and interact by detecting the distance to the current user and potential users. The hub also enables to create a seamless user experience between participants using its mobile devices and the hub. The user can interact directly with a smartphone using e.g. Bluetooth or near-field communication technology, extending the hub's user interface to a mobile participant.

III. Summary

In the full paper, we will describe the architecture of the smart city hub frameworks and how it integrates several technologies. We will also describe a public transportation use case and a smart parking use case. Once operational, these developments will give H-CPS loops the ability to inter-operate and adapt to open dynamic environments, and to achieve: (1) faster operation, (2) richer spatial interconnectedness, (3) better incident management capability, and (4) improved resilience. The Smart City Hub provides a generic platform for a number of other services beyond traffic and public transportation, including maps and way finding, municipal communication, emergency management and others.

IV. References

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