CHALLENGES TO THE DEVELOPMENT OF SMART CITY SYSTEMS

This briefing elicits some challenges to the development of smart city systems under a system-of-systems (SoS) perspective.

FINDINGS

As an active domain of research in recent years, *systems-of-systems* (SoS) arise from interactions among widespread independent, heterogeneous complex systems with their own purposes and that collaborate with each other to fulfill common global missions. Inherent characteristics of SoS are the operational and managerial independences of constituent systems, geographical distribution, evolutionary development, emergent behaviors, and dynamicity.

Smart cities typically encompass several systems engaged in complex relationships, including the integration and interaction with other systems towards providing new functionalities. This makes a smart city to be holistically viewed as an ultimate SoS.

Although an SoS perspective seems to be a natural (even obvious) choice to develop smart city systems, many existing approaches are indeed fragmented, non-integrated (or integrated in a limited way), thus creating unmanageable and unsustainable island solutions.

Developing smart city systems under an SoS perspective can be helpful to provide a city with higher capabilities, performances, new services to citizens, and other important concerns than would be possible with a traditional system view. Many city processes can hence benefit from the integration of different systems forming an SoS, e.g.:

- means of exploiting several information sources about human behavior and environmental variables to better allocate resources as the city evolves
- coordination of infrastructure management activities
- cross-agency visibility of planned interventions
- integration of multiple data sources to represent the interdependency of urban domains at real-time

Shedding light on an SoS perspective for urban systems is important to look forward to the provision of efficient, scalable, and suitable services and applications to citizens, thereby contributing to fully realize the smart city concept.

While viewing smart cities as SoS is interesting to better understand the relationships among these constituent systems, important challenges arise in terms of their design, engineering, and operation:

- **Scale and inherent complexity.** Besides integrating different smart city systems to achieve a larger, more complex system (an SoS), each of these constituents might be SoS themselves. This hence increases matters of scale and complexity in the design, engineering, and operation of these systems.

- **Multitude of stakeholders.** SoS environments embrace a broader range of stakeholders, including the ones of the individual constituent systems and the ones of the overall SoS. Smart city SoS must hence deal with such a variety of stakeholders with conflicting interests, requirements, and priorities.

- **Multiple disciplines and domains.** A smart city SoS embracing the different sectors of the city must inherently involve constituent systems from different domains. Different types of information, models, notations, etc. from different disciplines and with different purposes need to be considered at the same time.

- **Heterogeneity and interoperability.** A challenge to the engineering a city-wide SoS is the high heterogeneity of its constituent systems. Therefore, a successful smart city SoS must imperatively have effective means of promoting interoperability among the existing constituent systems while preserving their operational and managerial independences.

- **Effect of emergent behaviors.** Emergent behaviors associated to the interactions among constituent systems may be desirable (to be maximized) or even undesirable (to be minimized). Addressing these concerns is quite important in smart city SoS since this may not have the desired effect or even imply in damages to life and safety of citizens.

- **Unification on information.** The main challenges in managing smart city data are the need for common information models and the ability to safely share information across multiple agencies within a city and among multiple cities in a metropolitan region, thus making it possible to obtain a more complete picture of urban activity.

- **Data granularity.** Beyond sharing, proceeding and transforming produced into value-added information for a variety of stakeholders and systems in a smart city, another challenge is related to the granularity level of information.

- **Data analytics.** There is a need of analyzing large volumes of data created by a myriad of information sources in near real-time to generate actionable insights to streamline operational workflows to make better operational decisions.

Who is this briefing for?

Software engineering researchers and practitioners who want to reflect on the challenges and opportunities on the development of smart city systems.

Where the findings come from?

All findings of this briefing result from (i) an ad-hoc literature search on the development of SoS targeting smart cities and (ii) experiences in integrating different systems in the smart city initiative of Natal, Brazil.

What is included in this briefing?

A holistic view of smart city systems as a complex SoS.

A discussion about challenges to the development of smart city systems (-of-systems).

What is not included in this briefing?

Description of other studies and initiatives having the same perspective of viewing smart cities as SoS and how they address challenges to software development.

For additional information about the Smart Metropolis Project at UFRN (Natal, Brazil):

http://smartmetropolis.imd.ufrn.br/?lang=en