IoT Problem Statememt

Loic Niragire

TIM-7010 Computer Networks & Mobile Computing

Dr. Phillip Davis

Applications leveraging smart cities infrastructure rely on a heterogeneous set of IoT datasets to make informed decisions. The use of IoT hubs provides a centralized and easy-to-use access point for smart city data. Moreover, large cities may support numerous sub-systems that focus on targeted domains such as power consumption, water supply or traffic. It is, therefore, crucial that applications be able to locate and retrieve relevant datasets across hubs and sub-systems. The lack of semantic of things makes cross-hub integration complicated as devices and dataset discovery follow an ad-hoc process (Lea & Blackstock, 2014). This paper explores this problem in details and examines its consequences.

This paper is structured in the following manner. I first present an overview of the problem by referencing recent studies where authors encountered the same problem. Following that, I discuss the circumstances leading to this problem and how it negatively impacts the community at large as well as produced applications. I then give two sample cases to elaborate on when this problem becomes evident. Last, I dive into why this problem exists in the first place.

Smart city infrastructure includes deployment of sensors and provisioning of open data platforms containing city related information. According to Mileo et al. (2014), smart city applications lack the ability to automatically discover and integrate heterogeneous sensor data streams. In their proposed architecture, they increased data interoperability by incorporating a dedicated semantic annotation component into their architecture. Upon receipt of IoT data stream, this component annotates syntactical information with semantic terms defined in ontologies (Gao, Ali, & Mileo, 2014). Therefore, augmenting input data with metadata that can improve cross hub integration.

Sharma et al. (2017) establishes meta-data as essential for a richer and more meaningful interpretation of IoT data in a study conducted over cross-domain city applications. In their conclusion, they restated the challenge imposed by the lack of agreed upon standards and requirements to provide meta-information. Data connectivity and interoperability is critical for smart city applications. Thus, properly cataloged IoT resources, devices, and data, should include semantic metadata for ease of discovery and usability.

Currently, there is no IoT data format standards governing the multitude datasets provided through Smart City Hubs (Sharma, et al., 2017). Additionally, available datasets lack the necessary description to enable developer's ease of use without intimate knowledge of referenced domain and dataset. Resulting in a complicated and error prone process of identifying needed resources and necessary datasets across hubs. Often this implies delayed smart city application availability as development efforts stagnate.

Mattiacci et al. (2013) reiterates the lack of a standardization for IoT systems that would facilitate integration of services and data across hubs. They argue that, despite the success of numerous existing IoT applications. Most of currently deployed IoT applications offer domain-specific or scenario-based solutions (Mattiacci, Kosta, Mei, & Stefa, 2013). The difficulty of migrating to a truly IoT environment supporting billions of devices lies at their ability to communicate to each other. Inevitably, this requires IoT devices, services, and data to be discoverable with minimum developer intervention. Without semantic of things, smart city applications can only rely on known devices and datasets because they lack the ability to discover and interact with their environment.

The lack of semantic of things in IoT is evident in the following two cases. The first case pertains to smart city applications with pre-defined dependencies on specific devices and data

sources. Whereas the second case focuses more on mature smart applications that need to discover, assess, and utilize potential resources according to their needs. Both cases illustrate the limitations imposed by this problem.

Cross-hub smart applications with pre-determined datasets need the ability to aggregate available data into a meaningful structure for usage. The lack of semantic meta-data implies that developers are often tasked with creating integration tools that provide a common API to facilitate seamless information retrieval mechanisms over datasets across hubs. Maret et al. (2014) explored the idea of combining artificial and web intelligence to further improve IoT services and data with a focus on data analysis and knowledge extraction. With the promise that semantically augmented data through ontologies and linked data can provide application developers access to self-describing datasets over the web.

One of the basic promises of IoT paradigm is the collaboration of heterogenous objects over the internet. The key to this promise is that the objects in question do not need to know of each other's existence or whereabouts. For smart city applications to exhibit this property, where new connections and exchanges are realized at runtime, IoT resources need to semantically describe themselves in a standardized format.

In this section I discuss the essence of the problem covered in this paper, i.e the lack of semantic of things in IoT. Conceptually this problem is a direct consequence of the heterogeneous nature of IoT data streams and usage of hubs as an architecture for IoT applications. Successful IoT development have addressed the heterogeneity nature of IoT environment by adopting different programming models where hardware and environmental details are abstracted away. This, however, has resulted in incompatible programming models

and ultimately an obstacle to the full interoperability required for IoT applications (Cavalcante, Alves, Batista, Delicato, & Pires, 2015).

Systems integrators and application developers for smart city applications depend on a centralized infrastructure for city data. Both static and real-time IoT streams provide the building blocks for these applications. Traditionally, onboarding a set of new devices with added functionalities to an environment requires a series of requirements gathering and integration discussions between vendors and IT teams. Successful hardware and software integration requires attention to low level details such as network interfaces, protocols and more. The challenge resulting in the need for semantic of things in IoT is that the process described above needs to automatically take place. Devices and services need to freely communicate and discover each other.

According to Bauer et al. (2019), the fragmentation of the IoT ecosystem has resulted in silos systems without the ability to share information. In their white paper discussing advances in semantic technologies and its application to the interoperability problem in IoT, the following levels of interoperability as described; technical, syntactic, semantic, and organizational interoperability. Whereby communication across IoT systems require the semantic level.

References

Baccelli, E., Mehlis, C., Hahm, O., Schmidt, T. C., & Wählisch, M. (2014). Information centric networking in the IoT: experiments with NDN in the wild. *Proceedings of the 1st ACM Conference on Information-Centric Networking* (pp. 77-86). ACM.

Bauer, M., Bilbao, S., Baqa, H., & Corchero, A. (2019, October 22). Semantic IoT Solutions - A Developer Perspective. *ResearchGate*, p. 52.

Cavalcante, E., Alves, M. P., Batista, T., Delicato, F. C., & Pires, P. F. (2015). An Analyis of Reference Architectures for the Internet of Things. *Proceedings of the 1st international Workshop on Exploring Component-based Techniques for Constructing Reference Architectures* (pp. 13-16). ACM.

Gao, F., Ali, M. I., & Mileo, A. (2014, October). Semantic Discovery and Integration of Urban Data Streams. *CEUR Workshop Proceedings* (p. 1280). Riva del Garda, Italy: ResearchGate.

Kanuparthi, A., Karri, R., & Addepalli, S. (2013). Hardware and embedded security in the context of internet of things. *Proceedings of the 2013 ACM workshop on Security, privacy & dependability for cyber vehicles* (pp. 61-64). ACM.

Kim, J. Y. (2015). Secure and Efficient Management Architecture for the Internet of Things. *Proceedings of the 13th ACM Conference on Embedded Networked Sensor Systems* (pp. 499-500). ACM.

Lea, R., & Blackstock, M. (2014). Smart Cities: an IoT-centric Approach. *Proceedings of the 2014 International Workshop on Web Intelligence and Smart Sensing* (pp. 1-2). ACM.

Li, X., Wang, M., Shi, S., & Qian, C. (2019). VERID: towards verifiable IoT data management . *Proceedings of the International Conference on Internet of Things Design and Implementation* (pp. 118-129). ACM.

Maret, P., Ishikawa, F., Honda, S., Yonezawa, T., Akerkar, R., & Riedel, T. (2014). International Workshop on Web Intelligence and Smart Sensing IWWISS'2014. *Proceedings of the 2014 International Workshop on the Web Intelligence and Smart Sensing* (pp. 1-6). ACM.

Mattiacci, D., Kosta, S., Mei, A., & Stefa, J. (2013). Supporting interoperability of things in IoT systems. *Proceedings of the 11th ACM Conference on Embedded Networked Sensor Systems* (pp. 1-1). ACM.

Muniz, M. H., David, J. M., Braga, R., Campos, F., & Stroele, V. (2019). Pragmatic interoperability in IoT: a systematic mapping study . *Proceedings of the 25th Brazillian Symposium on Multimedia and the Web* (pp. 73-80). ACM.

Sharma, A., Acharya, S., Rajaraman, V., Ramesh, R., Babu, A., & Bharadwaj, A. (2017). Poster Abstract: Schemas for IoT interoperability for Smart Cities . *Proceedings of the 4th ACM international Conference on Systems for Energy-Efficient Built Environments* (pp. 1-2). ACM.

Speed, C., & Shingleton, D. (2012). An internet of cars: connecting the flow of things to people, artefacts, environments and businesses. *Proceedings of the 6th ACM workshop on Next generation mobile computing for dynamic personalised travel planning* (pp. 11-12). ACM.

Semantic of Things in Smart Cities Hubs

This week's reading material

1. Information centric networking in the IoT: experiments with NDN in the wild (Baccelli, Mehlis, Hahm, Schmidt, & Wählisch, 2014)
2. An Analyis of Reference Architectures for the Internet of Things (Cavalcante, Alves, Batista, Delicato, & Pires, 2015)
3. Hardware and embedded security in the context of internet of things (Kanuparthi, Karri, & Addepalli, 2013)
4. Secure and Efficient Management Architecture for the Internet of Things (Kim, 2015)
5. International Workshop on Web Intelligence and Smart Sensing IWWISS'2014 (Maret, et al., 2014)
6. An internet of cars: connecting the flow of things to people, artefacts, environments and businesses (Speed & Shingleton, 2012)
7. Smart cities: an IoT-centric approach (Lea & Blackstock, 2014)
8. Semantic Discovery and Integration of Urban Data Streams (Gao, Ali, & Mileo, 2014)
9. Poster Abstract: Schemas for IoT interoperability for Smart Cities (Sharma, et al., 2017)
10. Pragmatic interoperability in IoT: a systematic mapping study (Muniz, David, Braga, Campos, & Stroele, 2019)

11. Supporting interoperability of things in IoT systems (Mattiacci, Kosta, Mei, & Stefa, 2013)
12. VERID: towards verifiable IoT data management (Li, Wang, Shi, & Qian, 2019) (Bauer, Bilbao, Baqa, & Corchero, 2019)
13. Semantic IoT Solutions – A Developer Perspective