On The Usage of Standardised M2M Platforms for Smart Energy Management

Asma Elmangoush
Electrical Engineering and Computer Sciences Faculty
Technical University Berlin
Berlin, Germany
asma.a.elmangoush@campus.tu-berlin.de

Ronald Steinke, Adel Al-Hezmi, Thomas Magedanz
Fraunhofer FOKUS- NGNI
Berlin, Germany
{ronald.steinke, , adel.al-hezmi,
thomas.magedanz}@fokus.frunhofer.de

***Abstract*— The intention of the Machine-to-Machine (M2M) communication paradigm is to connect human and physical things related to different aspects in our daily life, in order to enable the development of Smart Cities. Recently, many initiatives emerged developing new solutions to achieve higher energy efficiency for buildings, better transportation management, and stronger Smart Grids. In this paper, we highlight our work in devolving a software reference implementation of the ETSI/oneM2M standards, which promote the research and development at academia and industry to rapidly realize proof-of-concept testbeds for Smart City, and demonstrate the interweaving with other platforms in the M2M communication and Smart Energy area.**

Keywords: Machine-2-Machine; Smart Energy; Internet of Things; Standard Platform

I. Introduction

Smart City is widely considered as a hot topic; however there is no clear definition of the Smart City concept among practitioners and academia. Authors in [1] represented the idea of a smart city as a “system of systems”, where the integrated systems forms a closed loop and are characterized by functions: sensing, information management, analytics and modelling, and influencing outcomes. Each system produces its own information and consumes others’ information in a well-defined urban planning.

The connected world is extending exponentially including physical objects besides computers and smartphones in a global Internet of Things (IoT). More than nine billion devices around the world are currently connected to the Internet, and the estimations show that by the end of 2020, there will be one trillion connected devices world-wide [2]. This will allow real and virtual objects to seamlessly integrate into a large-scale Machine-2-Machine (M2M) infrastructure. In contrast to human-to-human and human-to-machine communication, which mainly involves multimedia sessions, web browsing, and remote control, M2M provides the opportunity of deploying new services that works with limited human intervention. In M2M systems smart devices are connected through the network to novel service platforms in a self-controlled system. However, the current communication networks are designed to support human-to-human communication, concentrating on the optimization of the communication between devices that are under direct human control.

M2M communication imposes a number of challenges in the Future Internet infrastructure, such as managing devices with high level of heterogeneity, optimizing communications and energy usage, and infrastructure scalability. On the one hand, basic sensing and connecting technologies for supporting context-aware systems are available. Currently, diverse types of sensors are embedded into smart phones and tablet computers capturing location, acceleration, temperature, etc. Additionally, it is expected that billions of “things” will be connected to the Internet before the end of this decade, prompted by the decline in hardware and connectivity costs. On the other hand, the majority of available M2M solutions are incompatible and have been built in a vertical fashion, where data gathered by one platform can’t be easily reused by others. Developing a large-scale Smart environment, based on M2M communication, demands interoperability at all communication layers, between devices, gateways, and services.

In this paper, we highlight the efforts to design and develop standardized M2M platforms, and utilize it for enabling Smart City solutions. In our work, we address challenges of building Smart Environments, and investigate related research applications with emphasis on Smart Energy management.

The rest of the paper is organized as following: Section II provides an overview of related work around Smart City infrastructure and supported standard activities; Section III highlights the communication requirements to enable such solutions; Section IV presents the main features of the OpenMTC platform, highlighting the compatibility with related standards; Section V overviews main projects and joint work toward Smart Energy testbeds; Finally the paper is concluded in Section VI.

II. Related Work

A. *Smart City Infrastructure*

More and more devices are being connected to the Internet every day. In the past 5 years, numbers of connected M2M devices increased by 300% [2]. In the near future, almost any kind of object will be allowed to seamlessly integrate into a large-scale M2M environment, where Smart devices are connected through networks to novel service platforms in a self-controlled system; nevertheless, the current communication networks are designed to support human-centric communication, optimized for devices, which are under direct human control. Many initiatives have been started to address the creation of Smart Cities worldwide. Some examples are presented in [3] [4] [5]. The common research challenges faced by all these initiatives towards a Smart City infrastructure could be summarized as follows:

1) Scalability:

Considering the rapid increase in number of smart devices coupled with heterogeneity in sensor networks, scalability is a main technical challenge for enabling ubiquitous access including mobility and service continuity in large-scale deployment of smart environments. Existing technologies make the IoT concept feasible but do not fit well with the scalability and efficiency requirements at different levels, including: naming and addressing, communication and networking, data management, and service provisioning.

2) Governance:

Smart City services involve many different stakeholders, such as distinct application providers, devices vendors, and radio and core network providers. In order to be able to manage the overall system consistently, flexible horizontal solutions are needed for sharing skills, network infrastructures, and devices between stakeholders.

3) Reliable Testbeds:

To perform reliable large scale experimentation for the validation of research results, the need of a city scale testbed emerges. Many existing testbeds [6] [7] provide a good proof-of-concept, however they just offer experimentation and testing limited to specific environments or application specific deployments and do not allow conclusive experimentation. Additionaly, a Smart City deployment involves different non-technical stakeholders. Hence, many non-technical constraints must be considered such as users, public administrations, vendors, government, etc. Large-scale testbeds are required to provide the necessary critical mass of experimental businesses and end-users required for testing of IoT as well as other Future Internet technologies for market adoption.

B. M2M Communication Standard activates

Recognizing the need for reliable network infrastructures, various standards developing organizations (SDO) have recently promoted standardization activities in the M2M domain.

The 3rd Generation Partnership Project (3GPP) started standardization activities on M2M in September 2008 under the title “Machine Type Communications” (MTC). 3GPP Rel 10 specifications cover use cases, service requirements, and a functional architecture for MTC intended for application to mobile networks. In 3GPP Rel 11, the LTE-advanced (LTE-A) standard defined a set mechanisms to allow devices to turn off their radio interfaces when no data needs to be received or transmitted from/to the base station, and thus optimize enrage consumption [8].

In 2009, the European Telecommunications Standards Institute (ETSI) created a Technical Committee (TC) whose standardization work is mainly focusing on the service middleware layer. The ETSI M2M Release 1 standards are finalized in 2012, enabling integration of different M2M technology choices into one managed platform. Release 1 has been published in three parts: requirement [9], architecture [10], and protocol [11]. The Open Mobile Alliance (OMA) develops mobile Service Enabler specifications, and has several standards that can be mapped into the ETSI M2M framework. A link has been established between both standardisation bodies in order to map OMA Enablers into ETSI M2M Service Capabilities. The OMA Device Management (DM) protocol is considered as a stable starting point to provide the desired associations between ETSI M2M standards and OMA supporting Enablers. OMA DM has been designed to provide remote device configuration-related functions such as: configuration management, performance management, and fault management. OMA is currently working on extending lightweight DM protocols for M2M gateways and devices [12].

To avoid the competition between M2M standards a consortium of seven standards development bodies, including ARIB, ATIS, CCSA, ETSI, TIA, TTA, and TTC has set up a new global organisation (oneM2M) in mid-2012. oneM2M specified common M2M Service Layer Functions (CSF) that could become a vehicle to transport Smart services in various domains (e.g., metering, grid, and health) and relied upon to connect the myriad of devices in the field of M2M applications [13]. More than 260 participating partners and members has joint oneM2M to participate in the standardization of M2M communication system, including ETSI and OMA. The participating organizations intend to transfer all standardization activities in the scope of M2M service layer to the oneM2M. First oneM2M release is expected to be finalized end of 2013.

III. REQUIREMENTS OF SMART CITY APPLICATIONS

As we move from the static web to social networking (Web 2.0) to ubiquitous computing web (Web 3.0), the Internet is stepping toward a fully integrated Future Internet, and the need for sophisticated Smart applications increases significantly. The M2M communication promises to enable connecting everyday existing objects, and allow more non-human content providers to feed the Internet with data in various formats. Smart City services should have substance to use these data in effective and intelligent way. There are many domains and environments in which smart services would likely improve the quality of our lives, just to mention a few:

- Transportation and logistics domain.
- Healthcare domain.

- Smart environment (home, office, plant) domain.
- Personal and social domain.

Smart services gained strong momentum through the advances of technology in distributed computing, networking and sensor networks. Smart Communication middleware aims to enable seamless combination of services through providing a single point of access that support various application layer technologies for communication services and networks. The main requirements of deploying M2M applications in large-scale systems can be summarized as following:

- Supporting services deployed and hosted by 3rd party developer.
- Delivering services rapidly to the market.
- Co-existing and collaborating with current core networks and new deployment.
- Delivering and handling different kind of content and supporting variant bit rates.
- Being compliant with standards based services.

The process of designing Service Enablers and Application Programming Interfaces (APIs) is critical because it is intended to be written once and used many times and for various use cases which can influences the design. Later changes or update may impact users due to compatibility issues. We present here a taxonomy for centric enablers that will aid in defining requirements of Smart Communication and Future Internet. Table I shows an analysis of required service enablers from each category in building Smart applications for various domains.

A. Human-to-Human (H2H) communication:

In H2H both participants of the session are humankind using a Smart devices (e.g. mobile, PC), and want to exchange voice, video or data during the time of the session. Applications targeting H2H communications require service enablers that could value-add the communication session between participations, such as: Address book, presence and file transfer enables.

B. Machine-to-Machine (M2M) communication:

M2M refers to the paradigm of communication that enables machines to communicate autonomously with each other with little or no human interaction. It leverage the independent communication between large number of objects, devices and service platforms, which in turn presumes the transmission of large amount of data of heterogeneous types and sizes over the network. Service enablers for M2M should be designed with keeping in mind the fact that devices are not under direct human control.

C. Overarching Services:

This category includes all types of management and control services that are required in association with H2H and M2M communications, such as security and Quality of Service

Table I. Service enablers required for some application domains in Smart City

Enabling Services		Business / Collaboration	Utility Metering	E-Health	Utilities	Facility Management	E-Energy	Logistics
Machine-2-Machine	Push/Pull content		x	x	x	x	x	x
	Control devices			x	x	x	x	x
	Subscription/notification			x		x		x
	Discovery	x				x		x
	Location			x				x
Human-2-Human	A/V Call	x		x	x	x		
	A/V conference	x		x	x	x		
	Messaging / File transfer	x	x	x	x	x		
	Presence	x				x		x
	Location	x	x	x	x	x	x	x
	Address Book	x				x		
Overarching enablers	QoS	x		x	x	x		
	Device/entity mgmt	x	x	x	x	x	x	x
	Security	x	x	x	x	x	x	x

(QoS) controlling.

IV. OpenMTC Platform

The OpenMTC platform [14] implemented features are aligned with ETSI M2M Rel.1 specifications [9] [10] [11]. The aim of the OpenMTC platform is to provide a standard compliant middleware platform for M2M oriented applications and services enabling Smart City implementation, through supporting application domain driven scenarios such as eHealth [15], mobile tracking [16], and Smart metering services. As illustrated in Fig. 1 the second release of the OpenMTC platform covers all ETSI M2M architecture interfaces, and Gateway and Network Service Capabilities Layers (GSCL and NSCL). Although the oneM2M specifications are not finalized yet, however the first drafts describing the oneM2M architecture are corresponded to ETSI. In the following, we discuss how the OpenMTC platform can address the requirements identified in the previous sections for M2M Communication and enable Smart City solutions deployment:

1) *Applying ETSI M2M interfaces*

ETSI specifications define three interfaces: mIa, dIa, and mId, as depicted in Fig. 1, which offer generic and extendable mechanism for interactions with the xSCL. The mIa interface mediates the interactions between applications in the application domain (NA) and the Network SCL (NSCL), the dIa interface mediates the interactions between applications in the M2M network area - being Gateway applications (GA) or Device Applications (DA) – and the gateway SCL, and the mId interface mediates interactions between xSCL. OpenMTC supports a client/server based RESTful architecture, and communication over all interfaces is independent of the transport protocol. HTTP is commonly used as transport protocol with RESTful-based services, CRUD operations (i.e. Create, Retrieve, Update and Delete) are mapped to HTTP methods POST, GET, PUT, and DELETE. Currently, only HTTP is supported as a transport protocol in OpenMTC platform. However, M2M devices are generally resource-constrained devices, i.e. they are limited in memory, energy, and computation power. Therefore, HTTP is most likely difficult to implement in them, and many protocols have been standardized to incorporate such devices into the Internet. The Constrained Application Protocol (CoAP) is emerging to support essential features required for constrained M2M devices, such as low header overhead. Future work in OpenMTC will consider supporting CoAP.

2) *Event-Based Architecture*

OpenMTC supports a client/server based RESTful architecture with a hierarchical resource tree defined by ETSI. This style governs how M2M Applications (xA) and gateway and network capability layers (xSCL) are exchanging data with each other. Each entity in the M2M system (being an application, gateway, or device) is represented by a uniquely addressable resource in the hierarchical tree, which can be accessed and manipulated by CRUD verbs over different stateless transport protocols (e.g. HTTP). The OpenMTC Reachability, Addressing and Repository (RAR) capability manages a subscription and notification mechanism. Through this mechanism, applications, gateways and the OpenMTC platform are able to receive notifications from each other, enabling management and control of devices which belong to the same service provider or using the same technology family. The MongoDB NoSQL database was used in the RAR implementation, due to its performance and scalability.

3) *Security and privacy*

From a security perspective, ETSI M2M builds on top of existing proven technologies and protocols standardized by other organizations. The types of security considerations addressed by ETSI M2M include key management, authentication, and cryptography. OpenMTC renders privacy by allowing each entity in the system to assign different access policies (READ, WRITE, DELETE, UPDATE, DISCOVER) of its own resources to others. In future work secure bootstrapping and mutual authentications procedures of M2M devices and gateways will be implemented in OpenMTC.

4) *Associated Software Development Kit (SDK)*

The OpenMTC platform is associated with a Software Development Kit (SDK) to support the development of M2M applications and make the core assets and service capabilities available to 3rd party developers. The OpenMTC SDK consist of a set of high-level abstraction Application Programming Interfaces (APIs) which hide internal system complexity, and allow the developer to focus on the implementation of the application logic. In [17] we present and describe our work in designing a set of APIs for the OpenMTC platform. Adopting the RESTful style facilitates the development of M2M applications, due to its simplicity in comparison with most SOA technologies.

5) *OpenEPC Integration*

ETSI M2M defines handling between the M2M service provider and the access network provider for QoS enforcements, communication channel management and bootstrapping. Therefore, OpenMTC is integrated with the OpenEPC freamwork, which provide enhanced communication management capacities. Communication between xSCL and Store and Forward (SAF) for applications is handled using the EPC capabilities. This feature enable the handling of different traffic streams based on their priority In addition, mobility management for gateways and devices is supported. Policies for handling communication channels have to be distributed from the OpenEPC towards the NSCL and from there via device management to the devices or gateways. For bootstrapping Generic Bootstrapping Architecture (GBA) and Extensible Authentication Protocol (EAP) with Methods EAP-SIM and EAP-AKA will be implemented as access network provider based authentication and will be tested against OpenEPC. GBA is used for authentication in mobile networks like 2G or 3G and EAP will be used in networks like Wi-Fi and WiMAX. So a flexible deployment with only using the SIM card for authenticating could be achieved.

6) *M2M Area Network Integration*

For adding sensors and actuators, which use existing protocols and are not ETSI aware, specific inter-working proxies are integrated. Each proxy is responsible for a technology and is acting as a controller for the external devices and map these devices for monitoring and controlling into the M2M resource tree. FS20 and ZigBee are example implementations. More inter-working proxies can be added with the help of the associated SDK.

7) Hardware Platforms

The NSCL in the network and the D/GSCL at the gateways and devices have different requirements. The NSCL needs more performance and resources so that it is usually deployed at a server with x86 platform running Linux. Devices have lesser requirements in computing performance but requirements like energy consumption are more important, so they run on specific hardware. Like smartphones which can act as gateway for other devices in the Personal Area Network (PAN), e.g. eHealth sensors. To meet these demands OpenMTC supports the Android platform for mobile devices and the Arduino platform for developing with constrained devices.

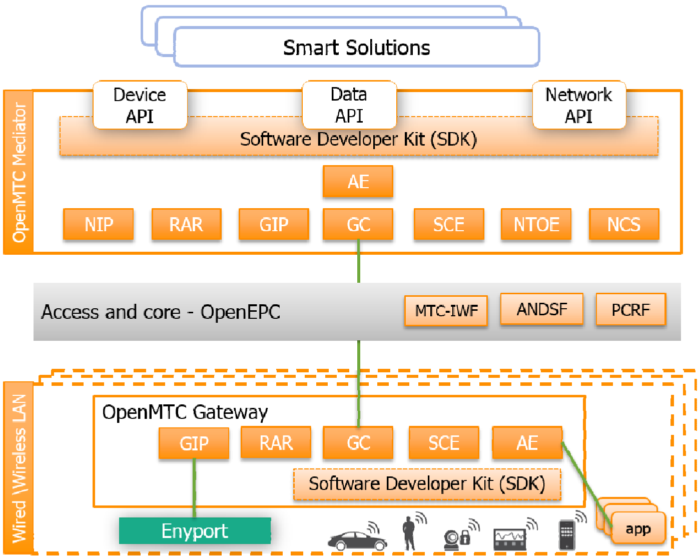

Fig. 1. OpenMTC Architecture

V. Testbeds for Smart Energy Lab

Energy efficiency and reduction of carbon emissions is one of the promising fields in developing Smart environment solutions. Many initiatives address the challenges of energy management as a key infrastructure in developing new urban, applying Internet and communication technologies [18] [19] [20]. In this section, we highlight the effort of using standard based M2M platforms in R&D for Smart Energy activity.

The Unifi Project, started in 2012, is an initiative of the Chair of Next Generation Networks (AV) at the Technical University of Berlin [21]. The objective of the UniFI project is to build sustainable teaching and research infrastructures in the areas of Future Internet and Smart Cities through global collaboration among academic institutions. This project also includes the creation of Competence Centers for a sustainable development and bundling of local expertise in Chile, Vietnam, South Africa and Thailand with a strong collaboration and technology transfer between collaborated academic partners at TUB in Germany, University of Chile, Hanoi University of Science, University of Cape Town, and Chulalongkorn University. The federation of seamless Labs that support Smart City prototyping is another important goal of UniFI [21]. OpenMTC platform provides a state-of-the-art standard prototype for ETSI M2M communication. Its capabilities, as described in previous section, enable the development of Smart City testbeds for various domains and use cases. Fig 2 depicts the main partners of the UniFI testbeds.

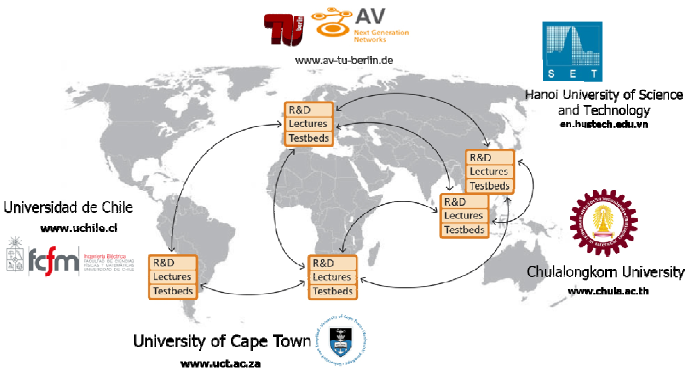

Fig. 2. UnifI Project testbed.

A joined effort between Fraunhofer FOKUS in Germany, Fraunhofer Chile Research FOKUS InnoCity and the University of Chile, is building the Reference Architecture for Smart City Communicational Platforms developed by FOKUS [22]. So far, the partnership has implemented this platform in Chile as a combination of technology between vendor Labs and platforms from FOKUS. Smart Energy is one of the main research area in this joint work.

Fraunhofer FOKUS Berlin is currently developing a prototype for Smart Energy Management based on OpenMTC platform as M2M middleware that can be used to integrate sensors and actuators operate over existing protocols. As depicted in Fig 3, OpenMTC gains the ability to control a wide variety of devices through integration with the "Enyport Energy Management and Control Gateway", which is an ARM micro controller platform. The implantation enables the user to monitor and control home devices remotely.

The TRESCIMO project (Testbeds for Reliable Smart City Machine-to-Machine Communication), aims to address challenges of efficiency power supply of cities within underdeveloped countries such as South Africa. The main approach is to interweave an ETSI/oneM2M compliant Machine-to-Machine (M2M) communication framework (i.e. OpenMTC) and another sophisticated Smart City platform form The South African Council for Scientific and Industrial Research (CSIR), which provides an integration of Internet connected devices via chat protocols such as XMPP [23]. Concretely, this pilot exploits various features of the platform, such as: Using of wake-up systems to communicate to sensors with power constraints (energy-efficient solution), and classifying and prioritizing collected data from sensors in a cost effective manner without the need for an existing infrastructure based on Delay Tolerant Networks. The outcomes of this project advance the state-of- the-art in the corresponding areas, including context awareness, Multi-hazard disaster terminals, and enhanced system for environments with energy restrictions.

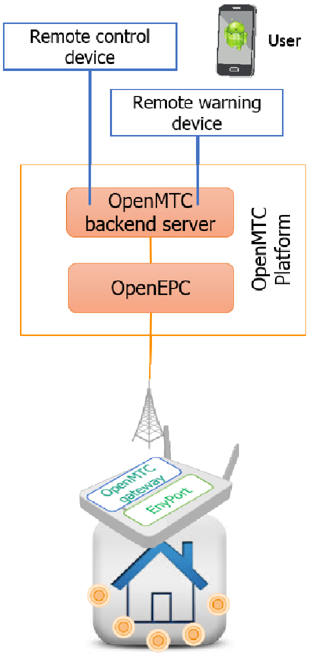

Fig. 3. OpenMTC - Enyport Smart Energy

VI. CONCLUSION

Building Smart Cities requires cooperation of innovative firms, governments, infrastructure providers, and users. All these different actors need a communication platform to support their cooperation through a set of capabilities, which overcome different technical barriers in the road of Smart City deployments. This paper highlights the efforts to develop standard prototype Machine-to-Machine platform, and investigate related research applications with emphasis on Smart energy management. This is being achieved by the joint collaboration and interconnection of a Smart City testbed platform that allows for these applications being designed, tested and evaluated in collaborated Universities.

REFERENCES

[1] M. Naphade, G. Banavar, C. Harrison, J. Paraszczak, and R. Morris, "Smarter Cities and Their Innovation Challenges," *IEEE Computer*, vol. 44, no. 6, pp. 32–39, 2011.

[2] J. Manyika, M. Chui, J. Bughin, R. Dobbs, P. Bisson, and A. Marrs, "Disruptive technologies: Advances that will transform life , business , and the global economy," no. May. McKinsey Global Institute, 2013.

[3] T. Bakıcı, E. Almirall, and J. Wareham, "A Smart City Initiative: the Case of Barcelona," *Journal of the Knowledge Economy*, no. January, Jan. 2012.

[4] H. Hielkema and P. Hongisto, "Developing the Helsinki Smart City: The Role of Competitions for Open Data Applications," *Journal of the Knowledge Economy*, pp. 1–15, 2012.

[5] L. Hao, X. Lei, Z. Yan, and Y. ChunLi, "The application and Implementation research of Smart City in China," in *International Conference on System Science and Engineering*, 2012, pp. 288–292.

[6] M. Smolnikar, "LOG-a-TEC: An experimental sensor network testbed for spectrum sensing and cognitive radio," in *8th Technical Meeting of WUN Cognitive Communications Consortium*, 2012.

[7] J. Wan, D. Li, C. Zou, and K. Zhou, "M2M Communications for Smart City: An Event-Based Architecture," in *IEEE 12th International Conference on Computer and Information Technology*, 2012, pp. 895–900.

[8] S. Ye, S. H. Wong, and C. Worrall, "Enhanced Physical Downlink Control Channel in LTE Advanced Release 11," *Communications Magazine, IEEE*, vol. 51, no. February, pp. 82–89, 2013.

[9] ETSI TS 102 689 V1.1.2, "Machine-to-Machine communications (M2M); M2M service requirements," 2011.

[10] ETSI TS 102 690 v1.1.1, "Machine-to-Machine communications (M2M); Functional architecture," 2011.

[11] ETSI TS 102 921 v1.1.1, "Machine-to-Machine communications (M2M); mIa, dIa and mId interfaces," 2012.

[12] Alliance Open Mobile, "Lightweight Machine to Machine Architecture V1.0." 2012.

[13] "OneM2M." [Online]. Available: http://onem2m.org/.

[14] "OpenMTC platform." [Online]. Available: http://www.open-mtc.org/index.html.

[15] V. Suryani, A. Rizal, A. Herutomo, M. Abdurohman, A. Elmangoush, and T. Magedanz, "Electrocardiagram Monitoring On OpenMTC Platform," in *1st IEEE International Workshop on Machine to Machine Communications Interfaces and Platforms 2013 Mobile*, 2013, no. 2, pp. 1–5.

[16] M. Abdurohman, A. Herutomo, V. Suryani, A. Elmangoush, and T. Magedanz, "Mobile Tracking System Using OpenMTC Platform Based on Event Driven Method," in *1st IEEE International Workshop on Machine Communications Interfaces and Platforms 2013 Mobile*, 2013, pp. 914–918.

[17] A. Elmangoush, T. Magedanz, A. Blotny, and N. Blum, "Design of RESTful APIs for M2M Services," in *16th International Conference on Intelligence in Next Generation Networks*, 2012, pp. 50–56.

[18] L. Lugaric and G. S. Member, "Smart City - Platform for Emergent Phenomena Power System Testbed Simulator," in *Innovative Smart Grid Technologies Conference Europe (ISGT Europe), 2010 IEEE PES*, 2010, pp. 1–7.

[19] P. Bellavista, G. Cardone, A. Corradi, and L. Foschini, "The Future Internet convergence of IMS and ubiquitous smart environments: An IMS-based solution for energy efficiency," *Journal of Network and Computer Applications*, May 2011.

[20] S. Karnouskos, D. Ilic, and P. G. Da Silva, "Using flexible energy infrastructures for demand response in a Smart Grid city," in *2012 3rd IEEE PES Innovative Smart Grid Technologies Europe (ISGT Europe)*, 2012.

[21] "Unifi Project." [Online]. Available: http://daad-unifi.org/unifi-project/.

[22] "FOKUS InnoCity." [Online]. Available: http://www.fokus.fraunhofer.de/en/fokus/angebot/fokus_innoCity/index.html.

[23] J. Mwangama, A. Willner, N. Ventura, A. Elmangoush, T. Pfeifer, and T. Magedanz, "Testbeds for Reliable Smart City Machine-to-Machine Communication," in *Southern African Telecommunication Networks and Applications Conference (SATNAC)*, 2013.