Institution: Birkbeck, University of London
Unit of Assessment: Computer Sciences and Information Systems
Title of case study: Global Standards for Smart City infrastructure: Entity Identification Systems
Period when the underpinning research was undertaken: 2007 - 2011
Period when the claimed impact occurred: March 2015 to date
Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact (indicative maximum 100 words)

Roussos's research into federated entity identification systems for the Internet of Things has led to the development of Recommendation ITU-T Y.4805, a worldwide standard for global information infrastructure set by the International Telecommunications Union. Recommendation ITU-T Y.4805 has enabled a growing number of Smart Cities to operate more efficiently, benefiting their citizens and businesses. Notably, the Recommendation provides the core ingredient in the Smart City strategy adopted by the Smart Africa Alliance, a partnership between 30 African countries. The Recommendation has also provided the basis for further work within the ITU's IoT and Smart City study group (SG20), with Recommendation ITU-T Y.4459 also building on Roussos's work, and several other Recommendations directly building on its provisions. The resulting suite of ITU-T standards provide the blueprint for Smart Sustainable City infrastructures implemented across Europe, Asia, South America and the Middle East.

2. Underpinning research

A Smart City incorporates information and communication technologies (ICTs) to support the delivery of essential services such as energy, transport and utilities. To work effectively, Smart Cities require a comprehensive and robust system of entity identification, enabling them to distinguish universally unique items such as artefacts, products, assets and buildings. Many such systems exist; however, they are typically incompatible, and some operate in direct competition. This results in expensive duplication of labour and resources due to lack of reusable solutions, slowing down innovation.

Roussos's research into the Internet of Things (IoT) and its applications for Smart Cities stems from an investigation into item-level network RFID (Radio-Frequency IDentification) systems [1, 2]. Network RFID systems are used to track objects automatically and remotely without human intervention, and work carried out by Roussos with collaborators at the Universities of Tokyo and Melbourne, UCLA and Athens University of Economics and Business [5] made seminal contributions towards: (i) the design of novel software architectures to address the unique requirements of open large-scale RFID systems, incorporating movement analytics; and (ii) the development of in-depth understanding of the multiple ways in which user control must be exercised over such systems to compensate for their unsupervised and transparent operation.

This research into Network RFID was further extended to incorporate IoT-based end-to-end low power Internet Protocol networks at full scale, which highlighted the need for an inclusive approach to entity identification [3]. Moreover, it delineated the challenge of dealing with an extensive range of existing Universally Unique Identification (UUID) schemes such as Object Identifiers (OID), Electronic Product Codes (EPC), ITU mu-codes (µ-code), JPN u-codes and numerous others, as well as the use of IPv4 and IPv6 addresses for the same purpose [5].

Roussos identified the need for a scheme that would be capable of seamlessly supporting the integration of these artefacts into Smart City systems while at the same time supporting scalable and secure operation. To address this, his 2011 paper [4] reporting on research carried out in the CASAGRAS2 project in collaboration with ISO/CEN AIDC Standards expert Paul Chartier, proposed and demonstrated a fully-functional and extensible identifier-locator resolution scheme which places no restrictions on the choice of identifier or locator specification. The paper describes the main features and elements of this scheme and identifies its main performance characteristics, demonstrating through an experimental testbed how they meet the requirements for very large-scale implementation across national borders. Further, the paper specifies a process by which legacy UUID schemes are integrated, thus making the scheme backwards-

compatible with existing technology. Finally, the paper reports on the outcomes of an investigation into the operational and maintenance issues related to the resolution and meta-data discovery of such identifiers by a globally available online service.

Overall, [4] demonstrated that the proposed federated entity identification scheme leads to a secure and scalable solution for the provision of such services, using a testbed which implemented the proposed approach and measured its effectiveness under actual traffic patterns and load encountered online. This approach is applicable to practically any standards-based or proprietary UUID specification, incorporating those established for different types of RFID and IoT verticals, and supersedes previous proposals such as the Object Naming (ONS) and the OID Resolution Service (OID RS). Legacy system support in particular is demonstrated by incorporating the long-standing artefact identification scheme specified under ISO/IEC 9834: a mapping is defined that facilitates the embedding of OID Unique Item identifiers within the address space specified by the Handle System, an Internet standard for digital entity management (RFCs 3650, 3651 and 3652); novel RFC 3652 data-types are formalised so as to address common information provision needs in this setting; and related operational and application considerations are outlined. The research showed that the approach supports object mobility; fine-grain security that is compatible with international Smart City requirements, especially with regards to governance; open, global reach; and multiple domains of control at the item level. The approach also shows superior scalability with regard to both identifier address space and traffic load compared to ONS and OID RS.

3. References to the research (indicative maximum of six references)

1. Shin'ichi Konomi and George Roussos (2007), 'Ubiquitous computing in the real world: lessons learnt from large scale RFID deployments', *Personal and Ubiquitous Computing* 11: 507. https://doi.org/10.1007/s00779-006-0116-1
2. George Roussos and Vassilis Kostakos (2009), 'RFID in pervasive computing: State-of-the-art and outlook', *Pervasive and Mobile Computing*, 5(1): 110-131. https://doi.org/10.1016/j.pmcj.2008.11.004
3. Katina Michael, George Roussos, George Q Huang, Arunabh Chattopadhyay, Rajit Gadh, BS Prabhu, Peter Chu (2010), 'Planetary-Scale RFID Services in an Age of Uberveillance,' in *Proceedings of the IEEE* 98(9): 1663-1671. https://doi.org/10.1109/JPROC.2010.2050850
4. George Roussos and Paul Chartier (2011), 'Scalable ID/Locator Resolution for the IoT,' *Proceedings of the 2011 International Conference on Internet of Things and 4th International Conference on Cyber, Physical and Social Computing*, Dalian, 2011: 58-66. https://doi.org/10.1109/iThings/CPSCom.2011.66
5. George Roussos (2008), *Networked RFID: Systems, Software and Services*, Springer SMB, London. https://doi.org/10.1007/978-1-84800-153-4

Details of External Research Grant:
CASAGRAS 2, funded by the European Commission from June 2010 – May 2012,
https://cordis.europa.eu/project/rcn/95714_en.html
Birkbeck was the project coordinator for this grant, which included partners from Brazil, mainland China, Hong Kong, India, Japan, Korea, Russia, Malaysia and the USA. Its goal was to facilitate international cooperation supporting the European agenda for realising the concept of the Internet of Things, recognising the need to do this in a way that was compatible with the global context.

4. Details of the impact

Roussos's research on large-scale interoperable entity identification systems [3, 4] fostered collaborations with researchers worldwide through the CASAGRAS2 project, notably at the Corporation for National Research Initiatives (CNRI) in the USA, under the leadership of Robert E. Kahn (one of the "Fathers of the Internet"). In 2010, Roussos presented to CNRI his research on augmenting the Handle System to incorporate IoT-enabled physical entities. Invented by Kahn, Handle is best known as the technology that underpins the Digital Object Identifiers (DOI) assigned to scholarly publications. Moreover, the extensions to Handle proposed by Roussos involved the federation of proprietary and open universally unique IoT identification schemes [4]. These discussions informed work undertaken by CNRI in cooperation with ETIRI, the research institute of the Chinese Ministry of Industry and Information Technology, in response to the

widely publicised incident in 2008 where a number of infants were poisoned by milk formula adulterated with melamine. Their solution involved a nationwide tracing platform based on federated integration, which permits purchasers to track the formula they are purchasing from production plant to shelf. The system was introduced in Guangdong Province (China's largest province, with a population of 113 million) in June 2014. 'By the end of that year, the number of registered handles for this application had exceeded 92 million' [C]. The use of this system become mandatory nationwide in 2015 as a requirement of Chinese food safety law, and has influenced practice globally. In February 2020, French brand Danone announced plans to expand its use of this system from China to its French, German, Australian and New Zealand markets.

Impact on global standards for Smart City infrastructures

Roussos's publication on federated entity identification systems [4] brought his research to the attention of the International Telecommunications Union (ITU), the United Nations' specialist agency for information and communication technologies. The ITU sets global standards for such technologies through the issue of Recommendations, which 'act as defining elements in the global infrastructure of information and communication technologies' (itu.int/about). With IoT technologies becoming increasingly widespread, the ITU deemed it necessary to provide regulation and guidance in this field. Interoperability was a key concern: the 'divergence [of IoT platforms] has led to an urgent need for stakeholders to come together to mitigate the risk of data "silos" emerging' [A, *Unleashing Potential*].

In March 2015, Roussos was invited to chair a plenary event on emerging trends in the IoT and Smart Cities at the ITU headquarters in Geneva. The event was attended by key IoT stakeholders including senior executives of device manufacturers and the telecommunications industry and led to the formal decision to establish a new ITU study group, Study Group 20 (SG20), focusing on the Internet of Things and its applications including Smart Cities and Smart Communities. SG20 formally convened in October 2016 to address this challenge and to 'support the creation of an inclusive, interoperable IoT ecosystem capable of making full use of the data generated by IoT-enabled systems' [A, *Unleashing Potential*]. SG20 continues to operate today, with Roussos in the role of Associate Rapporteur on one of this group's 'key areas of activity' [E], namely a work package on end-to-end connectivity, networks, interoperability, infrastructures and Big Data related to the Internet of Things and Smart Cities and Communities. This represents 'a central part' of the work of the study group as a whole [A, *Unleashing Potential*].

Roussos's research [4] was accepted during the inaugural meeting of SG20 in 2016 as the basis for a new work item with the code ITU-T Y.SC-Interop ('Identifier service requirements for the interoperability of Smart City applications'). This work item was developed by SG20 over the following year before being accepted by the ITU in August 2017 as Recommendation ITU-T Y.4805 [D], enabling a growing number of Smart Cities to streamline their delivery of essential services as part of ITU's global suite of Internet of Things standards.

Recommendation ITU-T Y.4805 specifies the functionality for federated entity identification services in Smart City applications, ensuring that such systems are interoperable and secure. Federation is achieved through the specification of Service, Data, and Operation Models. The Service Model specifies the structure of the identifier resolution infrastructure, including detailing its components and the relationships between them. The Data Model defines the data structures necessary to represent identifier attributes in the Smart City context, as well as security and operations. The Operation Model describes the essential operations that should be provided by the identifier service, as well as features crucial to facilitating cohesive, transparent and trustworthy operations that integrate different identifier service components as required.

Roussos's research [4] continues to contribute to the ongoing work of SG20. In January 2020, a further Recommendation was accepted: Y.4459, which details the concrete implementation of Recommendation Y.4805.

Impact on Smart Cities in China and the Smart Africa Alliance

As attested by DONA, an independent international foundation whose mission is to foster interoperability across global information systems, Roussos's work and the associated

development of ITU-T standards has helped tremendously in the adoption of DOA [digital object architecture] technology in many application fields. The Operations and Planning Department (OPD) of the ITU Telecommunication Standardization Bureau (TSB) confirms that Recommendation ITU-T Y.4805 addresses a key challenge in emerging Smart City systems by establishing the foundation for seamless interoperability across already deployed legacy devices and new and emerging naming and identification schemes. For this reason, there is strong interest in this Recommendation, with exploratory implementations initiated in China and by the Smart Africa Alliance.

The Smart Africa Alliance unites 30 African countries (with a total population of approximately 750 million people) and is concerned with implementing, monitoring and evaluating the SMART Africa Manifesto. This is a formal commitment to facilitate socioeconomic development on the continent through access to broadband and the use of ICTs, which was approved by the African Union (comprising 53 states) in 2014 and which has overseen the introduction of numerous Smart City initiatives across the continent. In 2016, the Rwandan government formally linked the country into a system based on Recommendation ITU-T Y.4805 and operated by DONA. Jean Philbert Nsengimana, Minister for Youth and ICT, identified the importance of the system for the secure management of information in the government's programme of digital transformation: 'There is loss of information or it ends up in the wrong hands. [This] system addresses such issues. It is about interoperability, flexibility, scalability and simplicity for information handling for the future. It will help us to better manage information in a way that is resourceful to our citizens' [F]. In 2017, the Rwandan government launched a year-long pilot project in collaboration with Inmarsat, Ericsson and Intel, aimed at transforming the country's capital Kigali. A total of 67 innovation projects included applications in farming, transit, security, and water distribution, the latter aiming to prevent sanitation-related disease causing the death of 2,000 children annually. The project has progressed to full operational implementation providing the focus for foreign collaborations and investment including $50 million from the UAE-based Cheikh Rakadh Group for the implementation of the Masterplan.

Also in 2017, the Rwandan government unveiled the Smart Cities Blueprint, intended to accelerate Smart City creation across Africa. The Blueprint offers guidance on planning Smart Cities and refers explicitly to the standardisation work of SG20, as well as examples already implemented in Rwanda and elsewhere [G]. One such example, presented at ITU SG11 in 2017, saw the introduction of an anti-counterfeiting system to electronic device supply chains. The system integrates UUIDs from distinct legacy identification systems such as GSM and IEEE 802.3 to provide a unified application infrastructure and prevent reuse of unlawfully obtained devices [K].

At the Beijing Development Forum in 2017 [L], the Chinese City of Chengdu presented their implementation of Recommendation ITU-T Y.4805 as the foundation for their deployed Smart City infrastructure. In their deployment, entity identification services are used to unify access to all city assets including transportation and communication networks, public spaces and government buildings. It integrates diverse identification schemes relevant to verticals using Recommendation ITU-T Y.4805, which is viewed as offering a considerable advantage over alternatives.

Impact on Smart Sustainable Cities

Recommendation ITU-T Y.4805 is one of a number of ITU standards deriving from the research in [4] and the work of SG20, which together set out specifications for the design and maintenance of sustainable Smart Cities worldwide. A Project Officer at the ITU Standardization Bureau, identifies Y.4805 as an exemplar of ITU standards on Smart Sustainable Cities [H] where interoperability needs to be ensured among heterogeneous and distributed systems in SSC. According to the same presentation [I], cities designed in accordance with or currently working towards the blueprint established by ITU standards including Recommendation ITU-T Y.4805 are: Dubai (UAE), Singapore, Valencia (Spain), Wuxi (China), Foshan (China), Kairouan (Tunisia), Montevideo (Uruguay), Maldonado (Uruguay), Manizales (Colombia), Pully (Switzerland), Guangshan (China), Bizerte (Tunisia) and Moscow (Russia).

The changes made as these cities work towards the Sustainable Smart City standards have benefited their citizens in diverse ways. Singapore's Outpatient Pharmacy Automation System used robotics and RFID technology to automate the delivery of patient prescriptions in the

pharmacy setting, eliminating the possibility of human error in prescription delivery and thereby improving patient safety. The city of Pully introduced ICT to its water network and was able to conserve water by detecting leaks more swiftly. Moscow's Project Magistral tracked commuter patterns and used the information to redesign its suburban public transport network, resulting in a 50% increase in passenger numbers and helping the city to move from being the second most congested in Russia to a position outside the top 20 [M].

The Director of ITU-T identifies the growth of Smart Sustainable Cities as a core ingredient in achieving the United Nations Sustainable Development Goals: 'Smart Sustainable Cities will contribute to the achievement of the Sustainable Development Goals by leveraging information and communication technologies (ICTs) to set cities on a development course characterised by environmental sustainability, resilience, and equitable social and economic growth.' [A, *Shaping Smarter*] The McKinsey Global Institute further quantifies the impact of this work: 'Cities that use smart technologies effectively can make significant progress in quality-of-life dimensions such as time saved, health and safety outcomes, environmental impact, and social connectedness and civic participation, improving some key metrics by 10-30 percent. These issues directly touch tens of millions of lives... we found that smart technologies can reduce fatalities by 8-10 percent, accelerate emergency response times by 20-35 percent, shave the average commute time by 15-20 percent, reduce the disease burden by 8-15 percent, lower greenhouse gas (GHG) emissions by 10-15 percent, and reduce water consumption by 20-30 percent.' [J, p.35]

5. Sources to corroborate the impact (indicative maximum of 10 references)

A. Chaesub Lee (Director of the ITU Telecommunication Standardization Bureau), introductions to ITU publications: *Unleashing the Potential of the Internet of Things; Shaping Smarter and More Sustainable Cities.* Both ITU: Geneva, 2016.
B. [redacted]
C. Dr Jian Zhou, 'Tracing Dairy Products with the Internet of Things', ITU news article, December 2014
D. ITU Recommendation ITU-T Y.4805
E. Testimonial from [redacted], Operations and Planning Department at the International Telecommunications Union
F. Steven Muvyuni, 'New system to enhance digital management', *The New Times (Rwanda)*, 21 October 2016.
G. Smart Africa (2017), *Smart Sustainable Cities: A Blueprint for Africa*.
H. ITU-T Focus Group on Smart Sustainable Cities, 'Setting the framework for an ICT architecture of a smart sustainable city', May 2015.
I. Reyna Ubeda, 'ITU transforming cities to make them smarter and more sustainable', *Third Meeting of the United for Smart Sustainable Cities Initiative*, April 2018. https://www.unece.org/fileadmin/DAM/hlm/Meetings/2018/04_26/Documentation/4_02_Reyna_Ubeda.pdf
J. McKinsey Global Institute, *Smart Cities: Digital Solutions for a More Livable Future,* June 2018
K. Alex Ntoko, "Combating counterfeit ICT devices: a demo using Digital Object Architecture", 2018.
L. Lin Zhang, "Internet+E-government: A Practical Model From City of ChengDu", Deputy Director, E-government and Big Data Office, Chengdu Government in 2017 Beijing DOA Development Forum booklet.
M. ITU case studies on Smart Sustainable Cities for Moscow, Pully, Singapore