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Smart City as a Service (SCaaS) -

A Future Roadmap for E-Government Smart City Cloud Computing Initiatives

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Abstract **- The concept of a smart city has been identified as not only representing a crucible for technological innovation, a medium for realizing global integration but also as an exemplar response for addressing current and impending global issues (societal, environmental economic and governance). There is now general consensus that emerging information communication technologies (ICT) such as cloud computing can be deployed as a vehicle for catalyzing smart city innovation. There is also evidence to suggest that cloud computing has become a strategic direction for many e-government initiatives as evidenced by the emergence of global government clouds (G-Cloud). In this paper, we delineate the concept of a smart city and explore the propitious potential of cloud computing to enable the development of smart cities. We review the current state of the art pertaining to a selection of cloud schemes currently being operationalized by international governments aimed at capitalizing on the nascent innovation capabilities of the technological paradigm, and present a future research roadmap for cloud facilitated smart city development.**

Keywords - cloud computing; smart city; innovation; government; g-cloud

I. INTRODUCTION

"There is a pervasive feeling that the future has already arrived...the pace of the future is dramatically faster than the speed of the past. Should the future carve a roadmap for us to tread or should we become competent enough to construct a roadmap for our future? This needs a concerted decision. Let's make it now". [28]

In 1964, American author and Professor Issac Asimov, following a visit to the world fair technological conference, penned his imagining, in an article for the New York Times, of what technological advances would come to be in the world of 2014 [1]. Remarkably, he was quite accurate in his extrapolating of not only future global population growth and corresponding technology chasms but also with regard to future technological advances based on the exhibits displayed at the fair. Examples of Asimov's envisioning included:

"Communications will become sight-sound and you will see as well as hear the person you telephone. The screen can be used not only to see the people you call but also for studying documents and photographs and reading passages from books."

"In 2014, there is every likelihood that the world population will be 6,500,000,000.... Although technology will still keep up with population through 2014, it will be only through a supreme effort and with but partial success. Not all the world's population will enjoy the gadgetry world of the future to the full.... Nor can technology continue to match population growth if that remains unchecked."

"the I.B.M exhibit at the present fair has no robots, but is dedicated to computers which are shown in all their complexity.... if machines are smart today, what may not be in the works 50 years hence? It will be such computers, much miniaturized..."

It is now 2014, and despite Asimov's unrealized predictions for "underwater luxury hotels" "moon colonies" and "robot maids", we live in a world, which has been largely moulded by rapid accelerated advances in technology over the past 50 years, where information, communication and technology (ICT) pervades all facets of modern society, industry and government. Concurrent to advancements in ICT, "the acute crisis of economic recession exacerbates the problems plaguing all cities, including the quality of public education, gaps in health care, crime rates, transportation, and preparation for a globally competitive digital future" [2]. In addition, rapidly increasing urban sprawl and population growth have only served to compound these issues. The word urban population is expected to increase by 72 percent by 2050, from 3.6 billion in 2011 to 6.3 billion in 2050 [3]. City services and infrastructure, which are already experiencing excessive strain, will experience great difficulties when attempting to provision the most rudimentary of services [4]. However, [2] profess their vision for future smart cities in

which world leaders combine technological capabilities and social innovation to enable the development of a smarter, sentient even, world comprising smarter communities that sustain the eudemonia of all citizens. Cities however "can only be smart if there are intelligence functions that are able to integrate and synthesize data to some purpose, ways of improving the efficiency, equity, sustainability and quality of life in cities" [5]. This paper contributes to the e-government literature because currently, to the best of our knowledge, no research has specifically explored the role of cloud computing in the development of smart cities. This research represents an initial step in a series of planned future research aimed at investigating how the nascent capabilities of the cloud computing paradigm can be harnessed by governing authorities. To this end, we first discuss the concept of a smart city and explore the role ICT has played in the evolution of smart cities. In Section III, we delineate cloud computing and review the current state of art pertaining to a selection of global e- government cloud initiatives currently being operationalized. Section IV outlines a future roadmap for smart city research and we also formulate a proposal detailing how cloud technology initiatives can be mobilized by governing authorities in order catalyze smart city development. Finally, we conclude the paper in section V.

II. SMART CITY

City and urban environments represent abstruse social ecosystems which comprise of local government, citizens and organisation entities. Currently these entities are experiencing specific requirements relating to salient themes such as business and employment creation, sustainable development, energy and water, public safety, environment, healthcare, education and public services, all of which are, in some form or another, are being increasingly facilitated and enabled by ICT. Concurrently to these requirements, the latest turbulent global economic downturn is increasingly placing pressure on cities to cut budgets resulting in deleterious effects not only on the maintenance and upgrade of current ICT infrastructure and facilities but also on future innovation polices. However, the concept of a "smart city", also known in the guises of intelligent city, information city, digital city, e-city and virtual city, has been identified as being an exemplary example of a response to address the current and future complex challenges of increasing resource efficiency, reducing emissions, sustainable health care services for ageing populations, empowering youth and integrating minorities [6, 7].

Smart cities have been characterized as "places generating a particular form of spatial intelligence and innovation, based on sensors, embedded devices, large data sets, and real time information and response" [8]. [9] propose a holistic definition for a smart city which embodies a city where "investments in human and social capital, transport and modern ICT infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources through participatory government". Two salient issues identified in the aforementioned definition include the requirement for investments in modern ICT and also the requirement for participatory government, a concept which refers to the empowerment of cities citizens, a form of "democratic innovation", first popularised by [10], which

denotes the increasing ability of enterprises and consumers, utilising software products and services, to innovate for themselves. [5] propose a typology which delineates the typical functions inherent in a smart city comprising smart economy (competitiveness), smart people (social and human capital), smart governance (participation), smart mobility (transport and ICT), smart environment (natural resources) and smart living (quality of life). Innovative ICT can be used by "visionary, innovative leadership to create sustainable solutions that reduce costs, focus resources on issues high on the public agenda and forge connections amongst organisations and agencies with similar goals" [2]. Cities worldwide are increasingly undertaking the role of facilitators of innovation in critical areas such as business, health, environment and inclusive ICT [7]. City authorities are striving to deploy intelligent cost effective ICT solutions in their management of everyday public services. The emergence of innovative low cost technological platforms such as cloud computing can equip city and urban policy makers with the technological arsenal not only to analyse data and business metrics for cogent decision making but also enable them to anticipate issues to resolve them proactively and coordinate city resources to operate more efficiently.

A. Smart City Evolution

From antiquity to modern times, ICT has been utilised by ruling authorities to augment their ability to govern and support cities. [11] provides examples of four case studies to illustrate the cogent role which information systems played in the development of the lost city civilisations of Shurrupak (Sumerian city), Sumer (Mesopotamia Empire), Cuzco (capital city of Inca Empire) and Hattusa (capital city of Hittie Empire). For example, the city of Shurrupak, active between 3000BCE and 2000BCE, operationalized an administrative system which enabled the structure and life of the city to be sustained via flows of information which drove economic activity. These flows of information were documented in tablet form, which resembled 'dynamic computers', and stored in tablet houses. While the purpose of these aforementioned information systems served the best interests of the ruling elite, there is no reason to deduct that the purpose of present day information systems is any different, driving the political agendas of powerful stakeholders in government and in the private sector [11].

In the 1960s, the concept of "model cities" was contrived in the U.S as means of creating an effective city and social net, however due to political discord and the inherent failure to address the interconnected nature of government, enterprises and citizens, the initiative never came to fruition [2]. The arrival of the "New Economy" during the 1990's, encompassing the commercialization of the internet and corresponding advancements in innovative ICT, provided governments, existing enterprises, de novo entrants and customers with opportunities to exploit new virtual market places and rejuvenate economic prosperity [12]. By 1996, public organizations were coming under increasing pressure to capitalise on the commercial success of the web, thus resulting in the initiation of the first digital city initiatives [13].

Following the collapse of the dot.com bubble in the early 2000s, it became apparent that there had been a widespread misconception amongst these entities on how to best leverage ICT advancements. However, driving factors such as the emerging knowledge economy, the restructuring of global financial services, increasing demand for efficient and effective public services and increasing environmental awareness, have catapulted the propitious capabilities of emerging ICT back into the policy arena. In the next section, we define the cloud computing paradigm and we also discuss how the nascent capabilities of the cloud are being leveraged by city authorities as a vehicle for catalysing their smart city agenda.

III. CLOUD COMPUTING

In its entirety, cloud computing represents the evolution and convergence of several independent computing trends such as Internet delivery, 'pay-as-you-go' utility computing, elasticity, virtualisation, grid computing, distributed computing, storage, and more [14]. These components are typified and converged in the description presented by [15] as that proposed by the American National Institute of Standards and Technology (NIST), describing cloud computing as "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (for example, networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction." Further, this description is specific in detailing cloud computing as comprising five essential characteristics, four deployment models, and three service models. The cloud infrastructure consists of a physical layer (hardware resources) and an abstraction layer (software deployed across physical layer) which resides on top of the physical layer. This definition for the continually evolving cloud computing paradigm is "intended to serve as a means for broad comparisons of cloud services and deployment strategies, and to provide a baseline for discussion from what is cloud computing to how to best use cloud computing" [15].

A. Catylyisng Smart City Development with Cloud Computing

In an effort to improve efficiencies, reduce expenditures and deliver a high standard of living expected by citizens while balancing budgets, city authorities are increasingly looking to innovative ICT [4]. The technical architecture of a smart city is comprised of a hardware layer (transducers, signal conditioning, communication links, energy harvesting and so on) and an application layer (data presentation, big data analysis, geolocation, web integration and so on) which is enabled by smart technologies such as cloud computing [16]. Cloud computing can enable "economies of scale, standardisation of applications and turnkey solutions for software as a service (SaaS), which dramatically decrease the development costs associated while accelerating the learning curve for operating smart cities" [6]. [17] argue that smart government, which "interconnects dynamically with citizens, communities and enterprises in real time to spark growth, innovation and progress", represents a fundamental

component for the development of a smart city where operations and services are truly citizen-centric.

Government G-clouds have been identified as "promising models for smart cities, creating urban clouds that reduce IT costs, and providing platforms for small business applications and e-services" [13]. [18] opine that government cloud initiatives represent promising models for larger cities which not only enable a reduction in IT costs, but also create effective innovative platforms for applications and e-services which may be leveraged by enterprises and citizens. According to [19] cloud computing represents "a fundamentally different way for government to architect computing resources, allowing governments to leverage powerful IT infrastructures in a fraction of time." Use of emerging technologies such as cloud computing can enable the "development of smart governance infrastructures which provide transparency of public efforts, promotes cultural flourishing and can increase accountability [20]. A ubiquitous/pervasive computing infrastructure has been identified as constituting a key technological component in the development of a smart city enabling the provision of "interoperable, Internet-based government services that allow ubiquitous connectivity to transform key government processes, both internally across departments and employees and externally to citizens and businesses"[17]. [21] explored the enterprise resource planning (ERP) potential of cloud computing for e-Government as a viable mechanism for replacing the traditional cumbersome implementation process of ERP. The authors identified particular aspects of the cloud computing model of direct relevance to public sector cloud-based ERP such as low implementation, continuing, licencing and support costs; faster implementation of IT projects, increased agility and the enhanced ability to demolish public sector silos in order to align public service legacy systems and processes. On a global level, a number of government agencies, having witnessed the capabilities of the cloud in the private sector arena, rather than paddling are diving in to the cloud computing waters.

In South Korea, the government are currently in the process of migrating to the cloud with the intention of becoming the "strongest cloud computing country in the world by 2014" [22]. Their comprehensive strategy to promote pan-governmental cloud computing will initially commence with migrating public sector service agency services, involving the integration of 40 government departments, to the cloud with the intention of laying a foundation for rejuvenating the private sector market in South Korea. The government have adopted a private cloud for their migration process, in contrast to other international governments who have adopted public clouds, due to security concerns. The South Korean government recognise that in order to have a consistent cloud implementation across all public sector agencies, there needs to be cohesive implementation of laws, policies, project promotion, technology development, personal nurturing, and public relations (PR) at pan-governmental level thus necessitating the requirement for a robust governance system [22]. Furthermore, the South Korean government in conjunction with the private sector have collaborated on a cloud computing project entitled "Next-Generation Digital

Service in a Cloud Computing Environment" which has developed such projects as the *N-Screen Service*, which "enables data sharing on multiple platforms for mobile phones, tablet computers, televisions, and personal computers" [19].

In the U.S, the costs savings experienced by the private sector companies has also manifested in public sector organizations that have transitioned to cloud based technology solutions [29][30]. Under the umbrella of the governments *First Cloud* initiative, which mandates that governmental agencies harness the full capabilities of cloud computing technology, the city of Washington D.C. experienced cost savings of 48% following their transition to cloud computing. In May 2013, the United Kingdom (UK) government adopted a 'cloud first' strategy as an extension to their established G-Cloud initiative, which mandates that purchases through the cloud should be the primary option considered by public sector information technology departments when procuring information technology (IT) products and services. The main aims of the *G-Cloud* and corresponding *First Cloud* strategies are to: increase the adoption of cloud technologies across the public service; create more agile structures which facilitate enhanced IT delivery which supports government technological policies and strategies; meet sustainability and environmental targets and create a dynamic procurement which supports emerging suppliers.

In Ireland, November 2011 marked the launch of the Irish Government's Public Service Reform Plans, which contained commitments to cloud computing and shared services. Specifically, the reform plans outlined a commitment to maximize new and innovative service delivery channels through piloting the use of cloud computing and evaluating a roll-out across the public service. There is also a commitment to the establishment of consistent baseline performance information across a number of functional areas e.g. Finance, HR, ICT. In February 2012, the Irish government unveiled its first cloud computing initiative *Cloud4Gov*. The *Cloud4Gov* programme, a synergetic partnership between IDA Ireland and the EMC Corporation, involves the construction of a cloud center with hubs in government networks. The Cloud4Gov programme has been lionized not only as a vehicle for driving the smart economy but also as a means of putting Irish e-government on the map as a "first mover" in its attempts to leverage the innovation capabilities afforded by cloud computing.

Despite the Hong Kong government's optimistic view of cloud computing that "collaboration and communication – internally, between departments, and with citizens – hold maximum potential with a shift to cloud technologies" they are maintaining a cautious and parsimonious approach to migrating specific public sector services to the cloud which is mainly rooted in security and privacy concerns [19]. In an attempt to improve operational efficiency and reduce costs, the Japanese government, with their Kasumigaseki strategy, hope to unify all government ICT systems into a single cloud [23]. However, following an in-depth analysis of cloud service implementation strategies in the US (First Cloud), UK (G-Cloud) and Japanese (Kasumigaseki), Song et al. [22] concluded that comprehensive government guidelines are required not only to overcome problematic issues but also to assist with the organizational and cultural changes associated with migrating to the cloud.

[19] acknowledges that due to the lack of technology acceptance research a public sector arena there is a need to "develop and gain empirical support for models of technology acceptance within the public sector, and to examine technology acceptance and utilization issues among public employees to improve the success of implementation in this arena". In order to assist governments in promoting cloud services as a medium of improving public sector services the authors propose a framework to "identify the antecedents of users' intentions to adopt cloud computing in the public sector". They outline a number of recommendations, based on factors drawn from their framework model, for governments which include; cloud service providers in conjunction with governments should actively engage in the promotion of increased transparency with regards cloud security issues, policies must clarify the application of trade disciplines to the delivery of cloud services, regulators and policymakers must collaborate to ensure robust privacy regulations, governments must ensure open access across public clouds and guidelines must be designed concerning scalability tolerance and risks.

The use of emerging technologies such as cloud computing can enable governing authorities to design systems that engage societal challenges proactively and develop "smart governance infrastructures which provide transparency of public efforts, promotes cultural flourishing and can increase accountability"[20]. However, current smart city technological solutions "are more vendor push than that city government pull based" [6]. Therefore, further research is warranted into exemplar examples of smart city initiatives which investigate the dynamics of various stakeholders and the mechanics of policy innovation in city governments [17]. Further research is also warranted into the development of effective smart city strategies which incorporate urban development objectives and strengths, weaknesses, opportunities and threats (SWOT) analysis [8].

In the next section, we outline a future roadmap for smart city research also explicate our proposal for city authorities contemplating utilizing cloud computing to mobilize their future smart city agenda.

IV. FUTURE ROADMAP

Enterprises such as Ericsson, IBM, Cisco and Microsoft are also largely involved in the moulding of the smart city research agenda. These companies are conducting innovative research into how next generation ICT, such as wireless network sensors, the internet of things (IoT), open data, semantic web and cloud computing can be applied to address the challenges and issues facing future cities. Ericsson labs research is focused on technology enablers which facilitate the development of 'future-connected megacities' that embody the tagline: *the Safe City, the Creative City and the Greener City*. In 2008, IBM launched their smarter planet vision which envisaged that future smart cities would benefit from instrumented (embedding of sensors across entire ecosystems), interconnected and intelligent systems.

IBM have also developed several tools, including the Smarter City Assessment Tool, the Actionable Business Architecture, and the Municipal Reference Model, which enable governing authorities to evaluate their smart city needs and identify opportunities for innovation. However, there is an urgent need for governments to "coordinate and integrate technologies that have hitherto been developed separately from one another but have clear synergies in their operation and need to be coupled so that many new opportunities which will improve the quality of life can be realized" [5]. European commission pilot smart city schemes such as FP7-ICT and CIP ICT-PSP are currently experimenting with user-driven innovation environments. The main aim of these initiatives are to demonstrate that smart cities possess the potential to assume the role of innovation ecosystems that can "empower the collective intelligence and the co-creation capabilities of user/citizen communities for designing innovative living and working scenarios" [6].

[6] have identified a number of actors that will have pertinent roles to play in the development of user driven open innovation smart city ecosystems which include: citizens, governments, enterprises and researchers. The authors argue that the synergistic partnering and linkages, incorporating clear cooperation strategies and frameworks amongst these aforementioned stakeholders, will enable them to effectively share technical, research and innovation resources such as user communities, experimental ICT platforms and tools, methodologies and know-how.

[18] present a technological innovation roadmap comprising of a two dimensional mapping of layers and several time periods, specifically 2014, 2017 and 2022. The vertical dimension addresses factors such as technological change, business change, policy change and social change. The time dimension incorporates short term, medium term and long term targets. The proposed innovation roadmap identifies a number of salient themes at the interchange of future internet technologies and smart cities. Recurring themes of the innovation roadmap, which are identified as being of important significance for city policy makers worldwide, include smart city pilot cloud schemes, city-wide open platforms for embedded systems and migration to cloud computing. Cloud computing is identified as being a significant enabler, over the forthcoming 8 years, for governing authorities intending to deploy strategies for smart cities, e-infrastructure and e-services that will address the challenges of sustainable development. The authors argue that that innovation roadmap can provide guidance for city authorities in their endeavours to formulate robust policies which can address the challenges of planning for future smart cities and the interlinked layers of technology, people driven innovation ecosystems, infrastructure and urban activities.

We propose that one possible avenue for governing authorities to leverage the capabilities afforded by cloud computing would be to transition and consolidate a number of core city services, on a pilot project basis, into a single G-Cloud project (fig.1). This G-Cloud pilot, comprising a collaborative effort between government, citizens, businesses and researchers, could perhaps trial and implement a

number of cloud technologies on a hosted platform to support and assist with the standardisation of core city services. As smart city research is currently being steered by salient priorities concerning contemporary urban development and city governance [6], we suggest that this G-Cloud pilot project could harness the propitious capabilities of two emerging open innovation platforms in the form of living laboratories and crowdsourcing for enabling the participation and intelligence of citizens and enterprises.

The living laboratory concept, which embodies open business models of collaboration, represents a fundamental methodology for the manner in which user-driven ecosystems should be organised. Cities such as Amsterdam (Visible City), Copenhagen (Realtime City) and Rome (Wiki City) have established pilot networked *Living Lab* initiatives, for investigating how ICT interacts with citizens and how those citizens are moulding these ICT solutions to incorporate them into their everyday lives [13]. The 'European Platform for Intelligent Cities' (EPIC) living laboratory project combines cloud computing platforms with emerging internet technologies to provide advanced e-Government service applications which support city administrations, citizens and enterprises via the creation and distribution of effective, sustainable user driven smarter city services.

Crowdsourcing may be also leveraged by city policy makers, for catalysing user driven smart city open innovation [24-26]. According to La Vecchia and Cisternino "a natural convergence of crowdsourcing techniques is toward cloud computing". One example is the Amsterdam smart city living lab that currently operationalises crowdsourcing experiments as a means of extracting wisdom from the collective intelligence of citizens "smart crowd" to find solutions to policy and technological problems. The overall aim of this G-Cloud pilot project would be to deliver prerequisite minimum capability and depending on the results of the G-Cloud pilot project could provide the foundation for the aligning and standardising of mission critical city services on a mass scale (fig. 2).
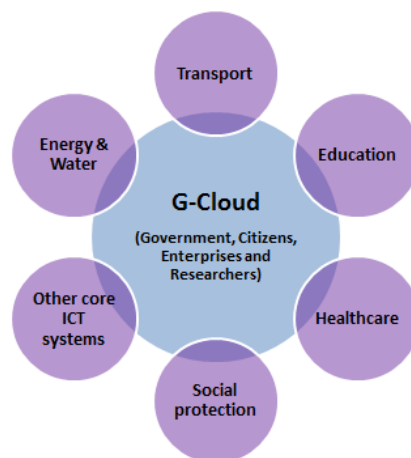
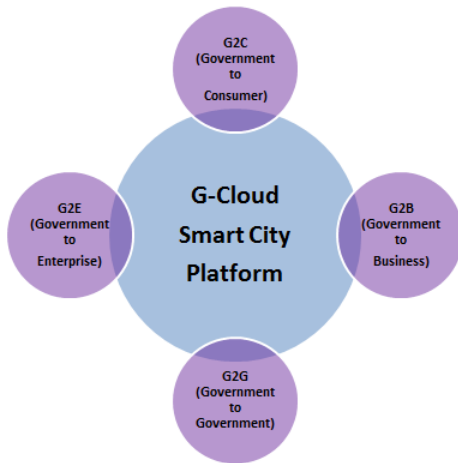

Fig.1. Pilot smart city G-Cloud project

Fig.2. Smart city G-Cloud platform

V. CONCLUSION AND FUTURE WORK

The research is in its early stages and to date has focused on theory building. However, we are in the process of conducting a single, exploratory pilot case study. The pilot study has been designed to explore how e-government can establish strong smart city cloud initiatives. The primary data collections sources will entail the use of face-to-face semi-structured interviews, questionnaire, and documentary evidence. The theme of the semi-structured interviews will concentrate on the interviewee's (government policy makers) attitude and experience pertaining to the use of using cloud computing in current and future smart city e-government policies. Topics will also encompass obstacles and challenges policy makers are currently experiencing in their efforts to operationalize G Cloud computing solutions. Interviews will be recorded and transcribed with the consent of each interviewee. The interview transcripts will be proofread and annotated by the researcher and the coded using nVivo. The coding approach will use techniques as proposed by [31].

In 1945, Vaanevar Bush declared, in his *Endless Frontier* report issued to the president, that research was the "pacemaker of technological progress" and "a nation which depends upon others for its new basic scientific knowledge will be slow in its industrial progress and weak in its competitive position in world trade, regardless of its mechanical skill" [27]. Thus, as cloud computing is currently in a state of flux, due to rapidly changing technological and legal landscapes, further research is warranted by academics and industry in order to formulate recommendations and guidelines to assist governing bodies transition to the cloud and utilize the propitious technology platform not only as an instrument for public value creation and innovation but also for creating a sustainable pathway

for the development of smart cities. We have contributed to this research priority by proposing a cloud computing smart city strategy which would enable governing authorities to cultivate their e-government and smart city agendas prior to deployment on a mass scale.

This research represents an initial step in a series of planned research activities aimed at identifying how cloud computing can catalyze the smart city research agenda. However, It can take upwards of a decade for a city to become smart with the impetus emanating from a prodigious government investment or from "visionary leaders who galvanize the citizenry and business community to channel their energy and resources into such a project" [4]. It is envisioned that governing authorities who readily embrace cloud computing on their e-government and smart city agendas as a vehicle for changing the status quo and who are adept at fostering a culture of collaboration and innovation with their citizens and enterprises will reap the rewards in their endeavors to build a sustainable future.

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