# IEEE Control Systems Society (CSS)

## Proposal for

# Technical Committee on Smart Cities (TC-SC)

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### 1.0 Introduction

According to the Rockefeller Foundation for Resilient cities[i], 10% of global population was urban in 1910. Today it is one half, and in 2050 it will be 75%. The world's cities are its economic powerhouses and cultural centers - the flagships of nations. This is especially true in the developed world. For example, 83% of the US population is urban accounting for 90% of GDP[ii]. The developing world is less urbanized, but the McKinsey Institute estimates that in just 12 years, cities will account for over half of global population and GDP[iii].

In this 21st century, the story of humanity will be in significant measure the story of its cities. As thinkers worldwide have grasped this reality, there has been an emerging canvas of exploratory government programs, strategic products from our global corporations, and research institutes at universities. The pressures driving the canvas are overcrowding, climate change, and natural disasters. The first pressure is simply that as cities grow, they will become denser, and must therefore become more efficient in their provisioning of water, transportation, and energy. We think of this as the "Efficiency" pressure. The second pressure is the need for sustainability created by climate change, and we find programs globally on "Sustainable Cities.[iv]" The third pressure, created by natural disasters, is articulated as the need for "Resilient Cities". Cities need to become safer and better able to deal with sudden large, one-off, catastrophic events. There are multi-national Resilient City programs coordinated by the World Bank[v] and United Nations[vi].

"Smart Cities" is the promise of a solution. Solutions for Efficiency, Sustainability, and Resilience could be based on civil construction, new economic models, cultural rejuvenation, or new technology. This TC proposal is focused on ICT[1], the Smart City wielding new information, communication, and control technology to enhance efficiency, sustainability, or resilience. It is particularly relevant to note that almost no smart city reference we find mentions the last (control), though almost all assert that a smart city senses the problems of its citizens, and adapts its services in real-time. However, as yet this seems unknown as feedback control. The Brookings Institute estimates the global market for these solutions at USD 1.2 trillion. The UK Department of Business and Innovation estimates it to be USD 400 billion by 2020. In the words of Anthony Townsend in his new book[vii]:

*"A century ago, the telegraph and the mechanical tabulator were used to tame cities of millions. Today, cellular networks and cloud computing tie together the complex choreography of mega-regions of tens of millions of people."*

In Europe the European Innovation Partnership for Smart Cites and Communities started strategic pilot projects with a budget of Euro 81 million in 2011, growing to over 350 million by 2012[viii].

[1] Information and Communication Technology

There is another EU program on Sustainable Cities[ix]. On the Pacific Rim, China, Japan[x], and Singapore[xi], have established Smart City pilot and academic research activity. China is ably surveyed by Liu et.al[xii]. The network of projects spans the breadth of China and includes major metropolitan centers such as Beijing and Shanghai. According to the Smart Cities Forum of China, 6 provinces and 51 cities reported activity in their government reports as of April 2012. In the United Kingdom, strategic thinking in this area is led by the Department of Business and Innovation[xiii]. Industry associations include the Smart Cities Council[xiv].

Though many credit the American blue-chip corporation IBM as the originator of the Smart City idea xii[xv], the United States has been slower to gather steam in this area. The Obama Administration created the Sustainable Communities Initiative in 2009 to drive the inter-agency[2] goals of more sustainable transportation, affordable housing, and economic competitiveness in America's cities[xvi]. Appropriations giving teeth are just appearing. The SC2, "Strong Cities, Strong Communities" solicitation in November 2012 seems to be the first[xvii]. The Brooking Institute points out the need for strategic execution at the local and metropolitan scales engaging government and industry, as a difficulty in America's political system. However, US universities face no such agility problem, and have a healthy network of research centers on sustainable cities. See for example

- http://www.bu.edu/energy/sustainable_neighborhood/snl-projects/
- http://sci.uoregon.edu/
- http://priceschool.usc.edu/research/centers/csc/
- http://sustainablecities.asu.edu/
- http://environment.harvard.edu/related-programs/sustainable-cities
- http://sustainablecities.wustl.edu/ ,

and the academic journal http://www.journals.elsevier.com/sustainable-cities-and-society/.

In summary, we propose Smart Cities as a field defined by a geography, a type of tools, and at least three targets. The geographical scale is urban or greater urban, such as the San Francisco Bay Area, Greater London, or Shanghai. Our tools will be from Information, Communication, and Control (ICC), in contrast to today's Smart City papers, which write only of ICT – Information and Communication Technology. Our targets will include Efficiency, Sustainability, and Resilience. Within this framework, we propose this TC should follow its members into every kind of urban system, be it in energy, water, transportation, or other city infrastructure not yet conceived. Thus the TC should be multi-disciplinary and composed to engage with a variety of other TC's within the control systems society, as well as researchers outside our professional society.

## 2.0 Why does CSS need this TC?

The historical circumstances of cities are evolving to enable closing the loop, around citizen, home, apartment block, or city block, or city. The past two decades have made clear that computing, sensing, and actuation are coming to be embedded in these environments. In some infrastructure, such as the highway network, the trend is obvious and CSS already includes members controlling urban highway networks. A more futuristic loop might be the one around the citizen. The smartphone revolution is with us, and people can permit their smartphones to sense, and create time series data on personal behavior, while new sciences like Behavioral Economics suggests theories of actuation by Recommendation Engines, Apps, or Social Networks. The controllable home appears to be at an intermediate stage with learning thermostats, motion detectors, or smart plugs being installed to sense or actuate heat and light, but in an early days, haphazard style without standards providing the uniform communication interfaces required to apply feedback control at scale. Researchers estimate fully 40% of household water consumption to be waste and hence reducible. However, the actual deployment

[2] HUD, DOT, and EPA

of water sensing and control infrastructure may be at an even more primitive stage than the energy one, meaning this type control researchers has to build her own field laboratory to get the data for system identification and formulation of control problems, much as Varaiya did in the early days of highway control.

Thus the Smart Cities TC can provide technical resources and collaboration opportunities spearheading the growth of CSS in this dynamic new area. The TC can create a new larger-scale, cross-cutting enterprise for CSS members already working on transportation networks, water systems, and energy grids. It can complement the Smart Grids TC, by effort on energy control at the scales of the single family home, multi-family apartment buildings, city blocks, or cities, phasing out as at larger scales it becomes more of a grid control problem. Citizens make many choices controlling these systems. These are influenced by market norms (price signals), or social norms (information signals). Control by price signals is an engagement with microeconomics, which is established within CSS. Control by information signals may be an engagement with behavioral economics, breaking new theoretical ground for the Society. Finally, there are interactions between water, transportation, and energy at city scales. As the road network moves people from home to work, energy and water demand lags but follows. We hope a multi-disciplinary energy, water, and transportation TC such as this one, will seed the formulation of multi-infrastructure control problems, thereby endowing the field of Smart Cities with distinct mathematically articulated intellectual foundations.

## 3.0 Structure of the TC

We propose a matrix structure illustrated in Table 1 to promote multi-disciplinary work. We propose TC members able to work both horizontally and vertically, i.e., people invested in one or more amongst transportation, energy, and water, and one or more amongst the rows of the table. We anticipate some intersections of the rows and columns having more members and achieving higher levels of activity, some less, and some perhaps none at all. If at least 3 or 4 of the horizontal-vertical intersections solve problems, create workshops, or conference tracks, the Smart Cities TC would be successful.

The labels in the cells describe related fields wholly or partly outside CSS. For example Ramp Metering in the Transportation and Measures section is a field shared by control and transportation engineers. Some labels, such as Green Buildings, cut across Transportation, Energy, and Water. By including a field in the table, we suggest that it is desirable for the Smart City TC to interact with it. For example, participatory sensing based on mobile phones has been shown by Bayen etal., to be useful for feedback control of arterial roads. We do not mention control in the table because it is omnipresent. Some fields, such as Persuasive Technology, are newer and speculative. The ACM Persuasive Conference shows papers on systems persuading people to save water, travel greener, or reduce energy use.

**Table 1: Possible Activities and Related Fields**

<table>
<tr><th></th><th>Transportation</th><th>Energy</th><th>Water</th></tr>
<tr><td rowspan="2">Measures: Resilience, Sustainability, Efficiency</td><td>Ramp Metering, Smart Parking, CBD Congestion, Cordon Pricing</td><td>Zero-Energy Buildings, Campuses, Blocks</td><td></td></tr>
<tr><td colspan="3">Multi-Infrastructure Control Problems, Green Buildings</td></tr>
<tr><td>Computing Substrates</td><td colspan="3">Cyber-Physical Systems, Embedded Computing, Building Operating Systems, City Operating Systems, Urban Robots</td></tr>
<tr><td>Urban Infrastructure</td><td>Parking sensor networks</td><td>City EV Charging Infrastructure</td><td>Precision Watering, Sensor</td></tr>
</table>

| | | | |
|---|---|---|---|
| **Design** | | | *Networks* |
| | *Participatory Sensing, City Cloud Computing, Logistics* | | |
| **Building City Laboratories** | *Instrumenting vehicles, homes, apartments, campuses* | | |
| **Big Data** | *Data handling tools, Analytics, Machine Learning GIS* | | |
| **Economics** | *Pricing signals, Incentives, Information Signals, Behavior Change Technology, Persuasive Technology.* | | |

We envisage the Measures and Economics rows as the ones primarily concerned with the formulation of control problems, algorithm development, and advancement of control theory. The Economics sub-group would have a particular focus on problems including human choice. The other four groups are more supporting tool oriented. Their activities might be to only educate control people on tools, for example big data handling platforms, or perhaps to develop them. Some might argue that the proper development of a Building Operating System requires collaboration between a computer scientist who understands operating systems, and a control engineer who understands what the OS is to be used for. The Smart Cities TC should be prepared to evolve with CSS and its members.

## 4.0 Collaboration with other TC's

We see possible collaborations with several TC's including

- Discrete Event Systems
- Hybrid Systems
- Intelligent Control
- Medical and health care Systems
- Networks and Communication
- Smart Grids
- Systems with Uncertainty

Collaboration should include special issues of CSS journals/magazine, *IEEE Transactions,* and *Proceedings of the IEEE*. We also propose collaborations on symposia, conferences, and the organization of special topic workshops at ACC, MSC, and CDC.

## 5.0 About the proposed TC chair

Raja Sengupta received his doctoral degree from the EE:Systems Division at the University of Michigan. His doctoral work was on optimal supervisory control and failure diagnosis using discrete event models. Applications of the latter were to building HVAC systems. His prior degrees are in Power Systems from Jadavpur University, India, and he worked as a Shift Charge Engineer operating a coal fired power plant owned by the Calcutta Electric Supply Company, prior to graduate school. He was one of the first control researchers to work in Intelligent Transportation Systems, publishing first on traveler routing as an optimal control problem, and later on the optimal control for urban traffic signal networks. One can find his citation profile at http://scholar.google.com/citations?user=hSUP-4cAAAAJ&hl=en, with an h-index of 35.

After his doctoral work, he came to the University of California Berkeley as a staff scientist with the Path Program and subsequently joined the faculty at its Department of Civil and Environmental Engineering. As a faculty member he co-founded the CEE:Systems Program where he serves today as Professor and Program Leader.

His first research contributions at Berkeley were to Automated Highway Systems. He led the Safety Evaluation team for USDOT's National Automated Highway Consortium. Subsequent to this large-scale systems engineering work, he became interested in the advancement of wireless local-area networks for the coordinated control of cars. He published on the design of a wireless token bus protocol, and an H-infinity approach for the analysis of feedback control over these networks. He was one of the early people to publish on Dedicated Short Range Communications (DSRC), a spectrum block allocated by FCC for cars. USDOT recognized his contributions to this field with its Technology Challenge award for the Connected Vehicle program in 2012. His design is one of two being evaluated in 2013 for national standardization by NHTSA's Vehicle Safety Communications Consortium.

In 1998, Raja Sengupta leveraged Berkeley's work on automated cars to start its first Unmanned Air Vehicle (UAV) research program in collaboration with Shankar Sastry and Karl Hedrick. He served as PI and Co-PI to several ONR research projects over a decade, and continues research on drones today as PI of an NSF project on Cyber-Physical Cloud Computing. He has published on vision-based control and navigation of drones, collaborative control of multiple drone networks, and most recently on mixed drone, autonomous drifter and submarine systems for the management of oil spills. His theoretical contributions to the area include approximation results for the multi-vehicle traveling salesman problem, the dynamic traveling repairman problem, and the BigActor model of computation for cyber-physical systems (see http://cpcc.berkeley.edu/ ).

His most recent research interests are in Behavior Change Technology. He has published on a system called Quantified Traveler designed to influence people to drive less using information signals. He is engaged in still unpublished research using ubiquitous computing to measure people's preferences over risk and reward when making financial decisions, and the temporal evolution of emotional state and memory in bus commuters. These are collaborations with behavioral economics and psychology, with some information at http://xmobile.berkeley.edu/.

He served as Program Chair of the IEEE Conference on Autonomous Intelligent Networked Systems 2003 and Co-General Chair of the first ACM MOBICOM Workshop on Vehicular Ad-hoc Networks held in 2004, Co-Chair of the Program Committee for the second ACM MOBICOM Workshop on Vehicular Ad-hoc Networks held in 2005, Theme Chair for Control of Transportation Systems at the ACC 2007, Program Chair for the First International Symposium on Vehicular Computing Systems 2008, and Co-General Chair of IEEE WIVEC 2011. He has served as Associate Editor for the IEEE Control Systems Magazine and the Journal of Intelligent Transportation Systems.

## 6.0 Potential members of the TC

Proposed member include

- Karl Henrik Johannson, KTH, Sweden, Co-Chair
- Tariq Samad, Honeywell, Minneapolis, USA
- Christos Cassandras, Boston University, Boston, USA
- Carlos Canudas-de-Witt, CNRS, France
- Shinji Hara, Univ of Tokyo
- Venkat Venkatasubramanian, Columbia
- Ge Ming, Hangzhou Dianzi University, China
- Roberto Tempo, Politecnico di Torino, Italy
- Fei-Yue Wang, Chinese Acad of Sci
- Vladimir Havlena, Honeywell, Czech Republic
- Hock-Beng Lim, Nanyang Tech Univ, Singapore
- Anuradha Annaswamy, MIT

With the exception of Karl Johannson, who has agreed to serve as the TC co-chair, the above individuals have not been approached as yet for their interest in participating in the TC.

However, they are all active in related research activities and we are optimistic that the majority will enthusiastically agree to participate.

**Contact information for the proposed TC chair:**

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[i] http://100resilientcities.rockefellerfoundation.org/resilience
[ii] http://www.brookings.edu/research/opinions/2011/07/26-cities-katz
[iii] http://www.mckinsey.com/client_service/sustainability/expertise/sustainable_cities
[iv] http://hbr.org/2013/07/building-sustainable-cities/
[v] http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/EASTASIAPACIFICEXT/0,,contentMDK:21845641~pagePK:146736~piPK:226340~theSitePK:226301,00.html
[vi] http://www.unisdr.org/we/campaign/cities
[vii] http://www.amazon.com/Smart-Cities-Civic-Hackers-Utopia/dp/0393082873
[viii] http://ec.europa.eu/eip/smartcities/
[ix] http://www.sustainablecities.eu/
[x] http://jscp.nepc.or.jp/en/
[xi] http://www.ida.gov.sg/Infocomm-Landscape/Infrastructure/Smart-City-Programme-Office
[xii] u Liu, Zhenghong Peng, "Smart Cities in China," *Computer*, 16 April 2013. IEEE computer Society Digital Library. IEEE Computer Society,
[xiii] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/246019/bis-13-1209-smart-cities-background-paper-digital.pdf
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