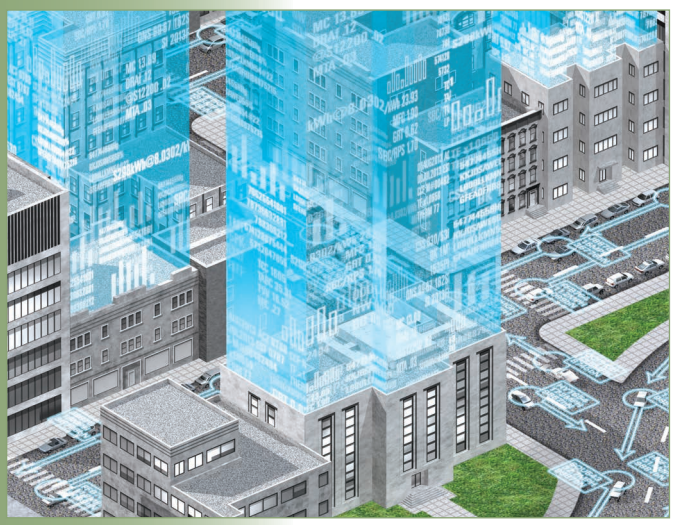

# Smart Cities

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Urbanization has dramatically increased over the past few years, and forecasts show that people's migration to urban areas isn't going to decrease.[1] Mega-cities with tens of millions of inhabitants are no longer exceptional. This concentration of population within cities poses numerous challenges in terms of both city governance and peoples' lives. As a consequence, "smarter" solutions are necessary to better address emerging requirements in urban environments.

Smart cities have claimed a central position in the innovation agendas of governments, research organizations, and technology vendors, posing unique and difficult challenges in terms of problem domain, scope, and significance. From a research perspective, smart cities are inherently interdisciplinary: they require investigation and cooperation across several disciplines, spanning from economics to social sciences, from politics to infrastructure management. Specifically, researchers are actively pursuing advances in information and communication technologies (ICT). This interest has a natural focus around Internet technologies. This special issue illustrates a set of research efforts representing the state of the art in the field, including managing and interpreting information from social media, energy infrastructures, buildings, and other sensor systems.

## The Importance of Smart Cities

Cities have dominated economy, culture, and government since ancient times. In addition, they have always tried to be "smart," be it through education centers, centralizing commerce, optimizing trade routes, or serving as governmental nerve centers. Modern ICT technologies are letting cities go even further, integrating operations and information much more effectively.

So, what is a smart city? In the context of Internet computing, we believe that the simplest definition is that a smart city can effectively process networked information to improve outcomes on any aspect of city operations. Such operations cover a very broad domain: surfacing information to authorities, businesses, and citizens, optimizing energy and water production or consumption, traffic management, public safety, and emergency response.

To address smart cities' multifaceted and cross-domain challenges, the Internet plays a fundamental role in communication, information sharing and


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processing, data transfer and analysis, and distributed computing. The rise of the Internet of Things and the large-scale adoption of Web technologies in urban environments have proven that Internet-based solutions can successfully address societal challenges. Still, holistic answers to open issues must face urban environments' intrinsic complexity.

## Smart City Challenges and Directions

Research on smart cities has also been pushed forward by the ever-increasing availability of data related to the urban environment. Open challenges include how to represent and reason on the spatial, temporal, and contextual aspects of this data, as well as the increasing demand for search and exploration capability.[2,3]

Managing the life cycle of city data requires de-noising, cleaning, anonymization, and privacy protection. Integrating heterogeneous sources of urban data — including sensors and social media — calls for further exploration of fusion, interpretation, lifting, aggregation, analysis, and correlation techniques.[4]

City systems are increasingly ubiquitous and pervasive[5]: this implies a need for advances and optimizations in software engineering and service-oriented architectures, together with scalable processing of distributed, networked, dynamic, or heterogeneous city data.

Given that cities are shaped by their inhabitants, it's essential that we investigate social aspects of information systems, such as citizens as sensors, urban dynamics, and citizen participation in public life and decision-making.[6]

Successful outcomes and achievements in the aforementioned fields are needed to bring tangible services and solutions to citizens: smart city research is more and more directed toward creating innovative applications in several relevant sectors, such as public safety, commerce, transportation, resource management, and government.

Taking a pragmatic approach, we can look at who is actually developing and deploying smart city technologies. As part of the larger Smarter Planet initiative, IBM has deployed technologies in Rio de Janeiro, Zhenjiang, Dubuque, New York, Dublin, and Nairobi, among many others (www.ibm.com/smartercities). Siemens has deployed its Sustainable Cities technologies on infrastructure projects across the board (www.siemens.com/sustainable-cities). Oracle is focused on an IT platform to consolidate city services (www.oracle.com/us/industries/public-sector/smart-cities.htm). Atos has introduced technologies to improve communication among citizens and the city (http://atos.net/en-us/home/your-business/government/mycity.html). Microsoft has recently entered the smart city arena with its CityNext platform (www.microsoft.com/citynext). Technology vendors across the board aren't just investigating smart cities, they're building them!

Smart city experiments are no longer limited to research labs. The state of the art has moved beyond defining roadmaps and now focuses on getting tangible results. In this light, this special issue includes articles covering a broad spectrum of smart city projects and gives particular attention to deployment and evaluation.

## In This Issue

This special issue on smart cities attracted considerable interest in the Internet computing community. We received a high number of submissions, covering a broad range of challenges and technologies, and after generous support from the reviewers, we still had a hard time selecting which articles to include. Those ultimately chosen cover different topics and highlight research results addressing heterogeneous yet complementary aspects of smart city governance.

What does the data in a smart city look like? "Urban Sensor Data Streams — London 2013," by David E. Boyle, David C. Yates, and Eric M. Yeatman, inventories the sensor data available in London, an example of a technologically advanced capital. According to the authors, sensor data is not only available, but can be accessed using standard protocols such as HTTP. This work represents a "reality check," providing readers with better tools for understanding and facing the practical aspects and actual constraints of urban environments.

Traffic management systems are one of the first fields in which complex sensing and control has been applied to an urban environment. Thus, they could be considered the precursor to smart cities; still, they are a hot topic in research and development, as demonstrated by two articles in this special issue.

Some approaches capture and summarize information coming from various sources. "Traffic in the Smart City: Exploring City-Wide Sensing for Traffic Control Center Augmentation,"

by Vassilis Kostakos, Timo Ojala, and Tomi Juntunen, describes harnessing technologies typically found in advanced traffic systems, such as induction coil-based traffic measurement, and Internet technologies such as Wi-Fi to assist traffic operators. The authors discuss a deployment in Oulu, Finland, highlighting the challenges of introducing new technology solutions and modifying preexisting processes and procedures within traffic control centers.

At the opposite end of the spectrum, in "Tokyo Virtual Living Lab: Designing Smart Cities Based on the 3D Internet," Helmut Prendinger and his colleagues introduce a novel approach to modeling and studying driver behavior. They tackle the traffic problem from the drivers' viewpoint, and the aim is to better understand the conduct of citizens under different traffic conditions. Instead of instrumenting real-world devices, the authors propose a virtual-reality-based approach. They construct a 3D model for a part of Tokyo based on information coming from the Internet and study automobile driver behavior as part of an immersive user experience. This article is an excellent example of how we can capture individuals' behavior in a virtually reconstructed smart city.

A smart city infrastructure is one that scales with the increase in information that infrastructure provides. "Scalable Anomaly Detection for Smart City Infrastructure Networks," by Djellel Eddine Difallah, Philippe Cudré-Mauroux, and Sean A. McKenna, proposes a multiple-level approach for real-time anomaly detection, applied to water management. A stream processing and an overlay network layer aggregate and pre-process information, so as to reduce network traffic and improve performance. An array data management system processes information globally. This work is a good demonstration of how Internet technologies can be layered for ease of deployment, robustness, and low latency.

How much "intelligence" should be put in smart city buildings to monitor the provision of fundamental services such as energy or water? In "Fine-Grained Access to Smart Building Energy Resources," Eun-Kyu Lee, Peter Chu, and Rajit Gahd present the characteristics and design principles of the energy service interface (ESI) system and illustrate their experience with a prototype testbed to access energy resources in a building. Such interfaces are a critical part of the smart grid, where energy management occurs more efficiently by making available finer-grained information and remote building control mechanisms.

Finally, smart cities need to tap not only on the information from various sensors, but on citizens themselves. Indeed, citizens are not only passive actors and final users of smart city services, but can play an active and fundamental role in improving the urban ecosystem and addressing its challenges. In addition, where the state of the art in ICT doesn't allow for automated processing, citizens can collect, filter, and assess information with a crowdsourcing approach. "CrowdSC: Building Smart Cities with Large-Scale Citizen Participation," by Karim Benouaret, Raman Valliyur-Ramalingam, and François Charoy, proposes a platform for large-scale citizen participation for providing decision-makers with citizens' knowledge and collaboration to address and solve smart city issues. The authors investigate various execution strategies for their crowdsourcing process.

The results in these articles address different topics of smart city research. All the reported experiences illustrate actual evaluations of Internet computing technologies and, in most cases, testbed deployments sponsored or supported by governments and city decision makers throughout the world. Smart city projects have long left the lab: open the door and see them in action.

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