From Space to Stage: How Interactive Screens Will Change Urban Life

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Framed digital displays will soon give way to walls and facades that creatively motivate individual and group interaction. A stage serves as an apt metaphor to explore the ways in which these ubiquitous screens can transform passive viewing into an involved performance.

In many ways, cities have become utilitarian networks that people traverse on their way to somewhere more interesting. Individuals pass one another with rarely a second look, and billboards or other public displays are usually predictable, rectangular frames that garner only cursory attention.

City venues were not always so uninteresting. Before the digital age, the city was a highly interactive stage on which society played out a variety of creative experiences. European traders invested in elaborate facades to ensure that their houses stood out in an already impressive town square. Great town halls created displays of public life. Each person had a social role, and public venues were the place for all to act their parts, typically by being seen in clothing and accessories that reflected how they wanted others to view them.

With the digital age, much of this stage has become virtual, with the Internet serving as a powerful platform for creative and interactive play. Facebook, YouTube, Twitter, and Flickr have replaced the bustle of a city square. Like their ancestors, modern actors and actresses invest huge amounts of time to enhance their images and foster their community roles. The stage has moved from the town square to the living room and office, and public places have become shadows of their former color—spaces with very little opportunity for self-expression.

Screen technology is promising to return the interactive experience to urban spaces. Economies of scale are enabling any surface to become a display, offering a window to the Internet. No longer are displays limited to the conventional frame shape but can accommodate arbitrary shapes and sizes, walls, and even entire squares and streets.

As a result, surfaces and environments need no longer be passive. With the aid of large-scale automation and ubiquity, pervasive computing can transform urban areas into the most impressive stages the world has yet seen. Through this metamorphosis, city spaces become more lively, and inhabitants become more aware of their community.

THE STAGE IN EVERYDAY LIFE

Creating and shaping these impressive arenas requires first understanding what constitutes a stage. A play usu-

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ally takes place inside some kind of magic circle, where performers enact roles using props and interactions to elicit a fictional space. The performance relies on a socially interpretative act, "translating real bodies, words, and movements into the objects of another, hypothetical world."[1]

In a sense, everyday social life is also a play in which people can take one of many roles.[2] In this interpretation, social space can be front stage (what the audience sees) and backstage (what the actors see), and an individual can be both audience and actor. For a salesperson, for example, the salesroom is the front stage, where he performs the specific role of showing customers the products. However, when he enters the storage room—the backstage—he plays a different role. In this play, the salesperson can switch roles and change behavior instantly, and even take on new roles, becoming a husband, father, or another persona once he leaves the job.

This role changing implies that the main power of stages and props stems from their ability to frame situations. If the salesperson changes into shorts, grabs a racket, and moves to a tennis court, his role changes from salesperson to tennis player. Similarly, if a man wearing a police uniform is shouting at another man in rags, the impression is that the other man might have committed some crime. If both men are wearing business attire, the impression might be quite different. Location can also influence impressions, as can spotlight and shadow. Thus, control over the stage implies the ability to control a situation's framing.

Framing is equally important in imaginative play. People readily use local props and media to experience fictional situations, such as those in pervasive games.[3] Performance behavior and playfulness are emerging in various strands of everyday life such as entertainment, advertising, and general social interaction. All these efforts aim to tell a story, evoke emotions, and sometimes even move the audience to some action.

TOWARD UBIQUITOUS SCREENS

Digital signage—the use of digital displays to replace analog signs—is a promising way to augment the everyday stage and make it more flexible and engaging. According to several industry reports, digital signage is already a billion-dollar business, and the markets are expected to grow more than 20 percent annually through 2013. Most of this growth is for signage in public or semipublic spaces.[4]

At present, most digital screens show videos or graphics according to some predetermined schedule, and users cannot manipulate them. However, such passive screens will soon give way to interactive displays such as touch screens, fueling the growth of the interactive public display market at a pace that is expected to exceed that of the market for public noninteractive screens.[4]

Most digital signage installations operate remotely: the screens connect through the Internet to a digital content management system, which operates scheduling and updates videos and graphics. Theoretically, the same system could deliver updates in real time, allowing installations to adapt to their environments.

Currently, LCD and LED technology drive the digital screen market. Alternative technologies, such as electronic ink, are on the horizon. Such novel technologies are expected to provide new design economies as displays become paper-thin, transparent, and flexible. In a decade or so, some researchers expect more advanced technologies such as displays based on carbon nanotubes to replace conventional technologies, pushing the market even more aggressively toward increasingly less expensive and larger installations.

If these projections and expectations even approach reality, a significant part of the wall space in popular public and semipublic spaces will be covered with digital screens. This proliferation will undoubtedly redefine how the space will look as well as how people will use it.

Digital signage—the use of digital displays to replace analog signs—is a promising way to augment the everyday stage and make it more flexible and engaging.

INTERACTING WITH DISPLAYS

So far, human-computer interaction research has involved primarily scenarios in which a single user interacts with the system through a personal display. Design paradigms and usability factors differ considerably when multiple users access the display simultaneously[5,6] or when people interact with a screen only in passing.[7] Relative to the single-user scenario, these design and usability shifts require the study of many more design aspects and considerations, such as those in Table 1.

Basically, public display interaction paradigms require either *touch interaction*, which can also be a tangible interface, or *distance interaction*, through, for example, a mobile device or camera installed with the display. Public displays most commonly provide information or advertising, but other use cases are certainly possible. For example, people can use the display interface to post photos or just as a way to have fun. Euclide's virtual puppets[8] and Magical Mirrors are evidence of how a display can offer entertainment value.

Table 1. Current and future design challenges for interactive public displays.

Design issue	Considerations
Multiple users	Can social interaction occur through the display or around the display? Does the interaction design and visualization allow simultaneous use?
Implicit interaction	Does the display support implicit interaction based on behavioral cues from video and acoustic features? These are generally difficult because of noise and lighting conditions.
Adaptive screen	Does the display adapt to general conditions (such as weather, time, and events), social dynamics around the display, and person or role identification?
Interaction sessions and life cycle	Does the display support different interaction phases: passing by, viewing and reacting, subtle interaction, direct interaction, repeat interaction, follow-up, and memorabilia?
Screen form and shape	Does the screen's form suit its purpose? Many shapes and form factors are possible, from cylindrical to wall and facade displays, including multiple display orchestration.
Environmental factors	Have developers taken architecture and urban design, lighting, sound, safety, and connectivity into account?
Privacy	Does the system protect the data created in interaction, to avoid exposing identity by managing private and public interfaces?

Interaction perspectives

Researchers view human-display interaction from both the user and system perspectives. From the user perspective, interaction occurs in phases: passing by, viewing and reacting, subtle interaction, direct interaction, multiple interactions, and follow-up actions.[9] From the system perspective, the display has different behavior and thus requires varied interaction techniques, depending on the user-interaction phase.

In the first three phases—passing by, viewing and reacting, and subtle interaction—camera-based techniques can facilitate interaction. With camera-based detection, designers can exploit many natural interfacing techniques, such as pointing, gazing, facial expression, and posture. Most important, such detection enables the screen to recognize that a person is in front of it. Speech and sound recognition can also provide presence information, although the interfacing techniques are more limited.

Camera-based detection might include identification techniques such as face recognition. Mobile phone mechanisms, such as Bluetooth identification, radio frequency identification, and optical markers can also identify

EUCLIDE'S VIRTUAL PUPPETS

Visitors to the Cittá della Scienza science museum in Naples can interact with virtual puppets that entertain while explaining various exhibits, adapting dialog to a particular visitor, such as a child. The Euclide system uses a data glove, standard and MIDI keyboards, and a mouse to operate puppets at five museum stations. The puppeteer at a control system sees what the puppet sees through a camera and microphone at each station and can rapidly switch between stations and choose to interact with passersby.

Pupils interact with the virtual puppet display while a puppeteer controls the puppet using multimodal interfaces at the hidden station.

MAGICAL MIRRORS

In 2006, SAP and the Berlin University of Arts installed Magical Mirrors as a temporary art project in the street-level windows of a Berlin office building. The mirrors were four large public displays that showed a mirror image of the environment in front of them and used optical effects, such as aura, flexibility, and luminescence, to react to audience movement. Users could observe the gesture-based interaction of others or be an audience to their own gesturing image. The degree of interaction depended on age and role. For example, children were highly interactive, playing freely, while policemen tended to avoid interaction.

From left to right: hand motion creates an aura; a flexible band (next two photos); and luminescent numbers (last two photos).

an individual. Identification personalizes the interface, making it a powerful medium for optimizing usability, tailoring a marketing message, and enabling more complex social interaction and communication through a display. For example, a screen might recognize a first-time user and provide feedback that a frequent user wouldn't need. This usability optimization ensures that the screen adapts to each user's background. The first-timer isn't lost and frustrated, and the experienced user doesn't have to wade through unnecessary components and endure redundancy.

There is a delicate balance between personalization and privacy threats, however. Adaptive and sentient displays that can constantly store interaction data pose privacy issues. Anonymizing methods attempt to address these issues. Another approach is to use interaction data only locally and then delete it. Regardless of the method, the displays must put people in control of their screen interaction and any revelation of personal data and provide a way to transparently convey this control.

Environmental variables

An alternative to user identification is to base adaptivity on environmental variables, such as weather, time, traffic, people flow, news, or Web activity. This begs an interesting research question: How do you know when a flow of people is an environmental variable versus a crowd of interacting individuals? Similar to implicit interaction and adaptivity, cameras, sounds, or mobile devices can aid in implementing crowd or large-group interaction. For example, during breaks in Finnish hockey games, simple audio- or camera-based crowd interaction games on large stadium displays engage the spectators and enhance their shared experience (www.uplause.com/what_is_it). In crowd interaction, the public screen cannot provide individual feedback for single users, which significantly limits the possible screen designs. On the other hand, multiple users create a significant amount of social content, so even a simple design can quickly become lively and complex when many people are interacting.[10]

Shape and size

Many people assume that public displays must be framed, which is not surprising since current manufacturing technology limits production to flat, rectangular displays with a physical frame. Like a painting, these displays hang on the wall, except that the viewer has a window to the virtual world. And, similar to a painting, a framed display clearly differentiates the virtual world inside the frame from the real world outside and defines an optimal viewing position some distance from the frame's center.

New display technologies will change all this. Any surface, regardless of its shape, will be a candidate for serving as a frameless display. Freed from its restrictions, screen content will become part of the real world instead of being always virtual.

Between these two extremes are semiframed displays of various shapes. Cylindrical displays, for example, have a frame at the top and bottom, but not at the left and right, which gives them extreme flexibility in the horizontal view and removes the need for a single dominant viewing po-

DIGITAL ADVERTISING COLUMN

The digital advertising column is a cylindrical display that can detect user movements and react accordingly: for example, by drawing flowers in relation to the user's movements. The round shape invites users to stay in motion more than a flat screen. Furthermore, a flat screen has a single preferred standing position in the center front. Possession of this position identifies a single main user or performer. In contrast, all the positions around a cylindrical display are equal, making it easier for others to join the performance.

A passerby discovers the column and explores it from several positions. Unlike a flat display, all vantage points are equally important. Because it isn't necessary to occupy the center-front position to get the display's full value, more people can join in the viewing.

sition. The digital advertising column is an example of a semiframed display.

WHAT DOES A MEDIA STAGE OFFER?

Clearly, public-display interaction has multiple design dimensions. Interaction modalities and social dynamics, adaptation and personalization, screen layout, and multiple-screen orchestration all influence design. General space variables, such as lighting and sound, safety, and indoor-outdoor considerations are also critical design factors. In a sense, the design of a public digital display is akin to staging a theater play or an art installation, requiring careful attention to visual details. Also, gaining the community's trust and engagement is a delicate matter that often involves public relations work. And deploying a physical public-display installation requires special attention to practicalities from avoiding vandalism to moderating user creativity.

The tradeoff for all this extra work is the amazing potential of a media stage: it can create a social place, increase an event's visibility, foster a collective awareness that can change behavior, and even serve as an outlet for spontaneous creative performances.

Social place

Ubiquitous displays offer a way to transform an urban space into a sociable place. A place is a space with meaning: spaces are merely constructed areas, while places include the practices and cultural understanding of the people in the space.[11] Positioning interactive screens that encourage participation in an urban landscape can make places into spaces that serve as a stage for social interaction.

Configurability is an environment's capacity to become adaptable to different uses and provide varied experiences.[12] Developers can use ubiquitous media technologies to facilitate configurability, creating places that open people's eyes to the unique features of their living space.

Event visibility

Cities are filled with special events, but many go unnoticed. In addition to promoting transformative events such as the Olympic Games, public displays can make even small events more visible, giving the impression of a more lively and social urban life. As people discover that old familiar places have something new to offer and explore, the city can regain its capacity to surprise.

Public displays offer an alternative to receiving event news through a broadcast e-mail or webpage. Instead, users learn about the event through a location familiar to them. Traditional posters serve a similar purpose, but with an interactive digital screen, advertisers can change the message more rapidly and target it more accurately to the intended audience. Ultimately, a digital screen can extend the actual event—for example, with live streaming—or event organizers can design specific remote interfaces for those outside the event to participate in the event and interact as a spectator crowd. An event might even be distributed, using public displays to connect remote locations.

Indeed, the extended event stage is already in practice. All large concerts feature a screen that increases the artist's visibility, and some of the larger events stream a live broad-

CITYWALL, A MEDIA EXPLORATION

CityWall, an experiment we conducted in one of Helsinki's central pedestrian areas, turns a store window into an interactive display. The area is between bus and railway stations and major shopping centers, thus connecting two key locations. It consists of several small shops and cafes and often hosts temporary attractions that attract random groups.

Repurposing an existing architectural element—the store window to an interactive display—is very different from introducing an architectural element into the space as a new construct. CityWall effectively transforms an architectural object into an interaction of space and events. In the window, it is, of course, highly visible, yet it also changes how people use that space. For example, passersby initially grouped around CityWall's shop window to seek shelter from the rain, but then started using the space in front of the display to engage in playful and social media explorations.

Clockwise from left: passersby play with images on the CityWall timeline; the display from a street view; and two users share comments on pictures of Helsinki.

cast to another location. During the 2010 World Cup finals in Netherlands and Spain, massive crowds gathered to participate in an event that took place on the other side of the world. They could have watched the same stream in their homes, but chose instead to join the crowd experience.

At present, such event visibility enhancements involve only massive events and temporary infrastructures, but as permanent public-display infrastructure proliferates, similar arrangements will become feasible for lesser events. The technical setup is not complicated, making it suitable for short events as well. Connecting remote locations to a place of central importance is one basic use case: the action hotspot is the main stage, but public displays can partially reproduce that stage's physical and social presence for people at another location.

Collective awareness and group behavior

People constantly adapt their behavior according to what they see others do and what feedback they receive for their actions. A major goal in this social process is to maintain role consistency—to ensure that actions don't contradict the desired roles, but strengthen them. In the context of this goal, a media stage can support behavioral change in three significant ways. The first is by letting users be the audience, observing how others (their role models) behave so they can change their behavior accordingly.

A media stage can also support behavioral change by providing immediate and continuous feedback about the users' actions. Nuage Vert, or Green Cloud (http://hehe.org2.free.fr/?language=en), is a city-scale display that illuminates the vapor emissions of Helsinki's Salmisaari power plant to show local residents their current electricity consumption level. A laser ray traces the cloud during the night, turning it into a citywide neon sign.

Such persistent feedback on collective behavior can be an efficient way to help communities achieve some common goals, such as cutting energy consumption or riding bicycles instead of driving cars. Feedback is essential to learning how to change behavior, and it is relevant to a range of applications, from safety and security to antisocial behavior prevention. Using public displays as a feedback channel in a city space can transform the way its inhabitants approach responsible living and use the city's resources.

Finally, the media stage can encourage participatory civic discourse and critique,[13] particularly in light of the increasing reliance on social media platforms to express opinions. For example, by providing a forum for posting pictures about Helsinki, our CityWall experiment effectively uses a media stage as content for public debate. The stage can also serve its conventional purpose, which is to allow creative expression. Spontaneous playful interaction can nurture self-esteem and embolden individuals to be more proactive in other walks of life.

Almost any surface might soon become a digital display, which will transform the appearance of cities, bring the Internet out of homes and offices, and return the center of social life to the public places where it originated. Turning billboards into media stages can benefit both organizations, which have a new influence channel, and individuals, who can present themselves in desired roles.

A challenging open issue is how cities, individuals, and organizations will share influence on the media stage. Many cities have forced organizations to adopt a shared brand appearance, where the organization must adapt its logo to the city's style. It is likely that cities will grant the right to deploy display technology only if they can influence how deployment affects public appearance. Traditionally, cities prescribe only the number of billboards and their location. Digital displays allow much more fine-grained negotiation on what appears on the screen, when, and how. Public and private organizations are likely to negotiate influence, such as screen time and mixed content, but individuals must also have a say.

Regardless of the perplexities surrounding any sharing arrangement, public-display installations will fuel the next wave of social change. Broadcasting media made people more globally aware. Social media has made them more socially aware. Public display-based ubiquitous media will make them more community aware. C

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COVER FEATURE

Experiences inside the Ubiquitous Oulu Smart City

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The UrBan Interactions (UBI) research program, coordinated by the University of Oulu, has created a middleware layer on top of the panOULU wireless network and opened it up to ubiquitous-computing researchers, offering opportunities to enhance and facilitate communication between citizens and the government.

Ubiquitous-computing research traditionally has concentrated on smart homes and smart offices, where the physical dimensions of the smart space are constrained within a building or a small geographical area. However, with the deployment of urban wireless infrastructures in cities all over the world, the vision for developing smart cities is finally taking shape.

Moreover, unlike other ubiquitous-computing research topics that are primarily motivated and driven by academic or industrial groups, the research on smart cities has brought together a diverse group of participants, including governments, urban planners, sociologists, and traditional ubiquitous-computing researchers. Several governments have already undertaken ambitious programs to build smart cities by augmenting existing city infrastructure with embedded sensing as well as communication and interaction technologies.

One such endeavor, the First International Open Ubiquitous City Challenge, offered international ubiquitous-computing researchers the opportunity to implement and evaluate innovative applications and services for the Open Ubiquitous Oulu testbed, a real smart-city environment located in Oulu, Finland.

SMART CITIES AROUND THE WORLD

The vision for smart cities originated as a natural evolution of research in smart homes and other smaller-scale smart spaces. The Universal City project[1] envisioned smart cities as a means of extending ubiquitous-computing services beyond the traditional smart home environment, forming the basis of interaction within an entire community on a much larger geographical scale. In that environment, smaller smart spaces such as smart homes interoperate with each other and interact with other external infrastructure components such as embedded outdoor sensors and mobile terminals while providing a unified and personalized interface for their residents.

Unlike other projects in which smart cities are being built from the ground up, the Amsterdam Smart City project's goal (www.amsterdamsmartcity.com) has been to integrate smart technologies into an existing historical city to make it more eco-friendly and energy-efficient. A key achievement of this project has been the installation of green energy infrastructure such as solar panels, household wind turbines, and electric-car charging stations in an attempt to reduce the city's carbon footprint. These in turn become a part of a smart grid system that includes the virtual power plant concept, in which households can sell excess energy generated from domestic solar panels, wind turbines, and biomass plants to the city to generate income.

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Figure 1. A UBI hotspot in the Ubiquitous Oulu Smart City.

This not only provides a medium for citizens to have a say in citywide initiatives to encourage environmentally friendly behavior but also gives them an incentive to actively participate in such efforts.

The SmartCity initiative (www.smartcity.ae) is attempting to create a global network in which each smart city is a self-sustained business township with advanced ICT infrastructure. Currently, the SmartCity network consists of three smart cities, one each in Dubai, Malta, and India. The goal is to build each smart city as a cluster of knowledge and talent pools while sharing intelligence, talent, and opportunities with other smart cities in the network.

South Korea has been at the forefront of the development of the *ubiquitous city* concept. A u-city is a smart city in which knowledge and services are available to residents through the use of ubiquitous computing, with sensing and communication resources embedded in urban elements such as residences, building infrastructure, and open spaces.[2] These cities use the information and communications technology infrastructure to provide interlinked services organized within specific domain areas. For example, u-life services provide related functionalities for residents such as home automation and monitoring. U-business provides work-related services such as videoconferencing, information management, and document sharing. U-government provides services that empower citizens by making them aware of traffic and health hazards and enables them to participate in the governance process anytime, anywhere.

A u-city is designed from the ground up to be completely user-centric, providing more personalized yet nonintrusive services for its residents. The first Korean u-city, Hwaseong Dongtan, has been partially completed and is currently operational. Another u-city, New Songdo City, is being constructed on a 1,500-acre man-made island off the coast of Incheon, South Korea. This city is centered on u-life, a proposed lifestyle that utilizes smart cards with RFID technology to provide personalized services and user interfaces for residents anywhere within the city.

OPEN UBIQUITOUS OULU

Open Ubiquitous Oulu enables ubiquitous-computing research in authentic urban settings with real users on a broad scale and in a sufficient time span. Such studies are important because real-world ubiquitous-computing systems are culturally situated and can't be reliably assessed with lab studies detached from the real-world context. By deploying a system for a sufficiently long time, researchers can establish technical and cultural readiness and identify the critical mass of users needed to determine whether the system can be deemed either successful or unsuccessful.[3]

The UrBan Interactions (UBI) program is developing UBI-hotspots, interactive public displays embedded with computing resources such as two cameras, an NFC/RFID reader, panOULU wireless access points, and high-speed Internet access to provide rich interaction between physical, virtual, and social spaces.[4,5] In addition to the UBI-hotspots, the testbed comprises a wide variety of pervasive computing resources deployed across the city, including a panOULU LAN/Bluetooth/wireless sensor network and middleware resources.

The UBI-hotspots alternate between two states. In the passive broadcast state, the entire screen is allocated for the UBI-channel, a digital signage service. In the interactive state, the screen is split between the UBI-channel and the UBI-portal, which can embed any Web service found on the Internet. As Figure 1 shows, the UBI-portal provides access to a wide range of interactive services such as directories, games, a street gallery of new media art exhibitions, sending of UBI-postcards, or uploading of personal photos and videos. Currently, all interactive events such as face detection and launching of specific services by users are logged for reporting and research purposes.

The panOULU wireless LAN is a citywide Wi-Fi network comprising approximately 1,270 IEEE 802.11 access points.[6] The access points provide open and free wireless Internet access to all public users without any limitations. However, comprehensive real-time network traces currently are archived for reporting and research purposes. For example, in February 2011, 26,013 devices used the

Figure 2. A panOULU wireless LAN access point (WLAN AP), wireless sensor network edge router (WSN ER), and Bluetooth access point (BT AP).

network, for a total of 658,742 sessions, culminating in usage of 19.3 million online minutes.

The panOULU Bluetooth network includes 30 access points scattered across the city center. Eighteen of these access points are installed on traffic lights, and they use the panOULU wireless LAN for Internet access. Twelve additional access points are placed inside UBI-hotspots. All access points sniff nearby Bluetooth radios, and the real-time traces are suitably anonymized and used for modeling pedestrian and vehicular flows and networks. The 12 access points inside the UBI-hotspots are also used for pushing multimedia content to mobile devices via Bluetooth.[7]

The panOULU WSN is an IP-based wireless sensor network comprising 13 edge routers (ERs) located across the city. The ERs are equipped with an IEEE 802.15.4 radio on the 2.4-GHz and 868-MHz bands, and the 6LoWPAN protocol stack, which offers low-power wireless connectivity. Twelve ERs are installed inside the WLAN mesh access points, as shown in Figure 2, and one ER is also placed inside a UBI-hotspot. An ER has a line-of-sight in the 500-m range with 1 mW transmission power. The MediaTeam Oulu research group is currently developing the panOULU WSN infrastructure to automatically meter energy consumption in homes[8] and for environmental monitoring using low-power sensors.

These heterogeneous computing resources constitute a large distributed system that's organized with a middleware layer. It provides various resources for supporting technology experiments, developing ubiquitous-computing applications, and managing and monitoring the applications and the testbed.

This kind of a large-scale testbed deployment presents many challenges, including establishing financial and technological viability and sustainability. After the initial capital investment, mostly from public sources, sufficient funding must be obtained to cover operational expenses and renewal. For example, a portion of the capacity of the UBI-hotspots is sold commercially to generate revenue, which in turn conflicts with research use. A practical challenge is the operational execution of maintenance, which is expensive and time-consuming and is an area in which research organizations typically aren't efficient.

Another important challenge is the measurement of success, whether it's assessing the socioeconomic impact of the testbed or the merit of any application or service deployed within it. These assessments are difficult due to the shortage of comprehensive data over a sufficiently long period and the lack of a universally accepted methodology for evaluating real-world deployments. Finally, any deployment in a city center is subject to daily scrutiny by the general public and media, which can become ill-tempered and impatient at times.

To strengthen the testbed's long-term prospects, the UBI program is integrating it into OULLabs (Oulu Urban Living Labs; www.oullabs.fi), a regional living lab initiative. This project brings together a range of testbed and human resources to facilitate various activities such as user-driven open innovation in developing and testing new technologies and applications in authentic urban settings with real users.

THE UBI CHALLENGE

Because they realized that few researchers have access to such a versatile u-city testbed for development, deployment, testing, and learning purposes, the MediaTeam Oulu research group wanted to make this testbed openly available to as many researchers as possible. The First International Open Ubiquitous City Challenge (www.ubioulu.fi/en/UBI-challenge), or UBI Challenge, is being organized for this purpose in collaboration with several leading international ubiquitous-computing experts. This competition challenges the global R&D community to design, implement, deploy, and evaluate novel applications and services in real-world settings in the city of Oulu.

The motivation for the challenge is to stimulate global research collaboration on urban informatics in a concrete manner and provide the international research community with an opportunity to transfer ideas from labs into real-world urban environments where they can make an impact. The goal is also to support the development of metrics for evaluating urban computing infrastructure and applications in real-world settings.

Participation was encouraged by advertising that up to five proposals would be selected as finalists for deployment in Oulu, with each group receiving grants of up to 10,000 euros and having the opportunity to present their research at the International Conference on Mobile and Ubiquitous Multimedia (MUM 2011). Out of the numerous proposals received, the international jury invited four to compete in the finals. All four finalist teams will arrive in Oulu in mid-2011 to finalize the implementation and deployment of their services. Thereafter, the jury's Oulu-based members will meet and assess each of the services in situ according to various performance and usability metrics.

MOTIVATING CITY RESIDENTS TO EXERCISE

A sedentary lifestyle increases the likelihood of developing obesity, diabetes, and cardiovascular disease. Estimates indicate that the healthcare cost of these chronic diseases is rapidly approaching US$1 trillion and that a strong association exists between increased physical inactivity and the emergence of chronic diseases in 21st-century industrialized societies.[9] Private companies have found that they can reduce healthcare costs by offering employees cash to quit smoking or by serving healthy food in the cafeteria.

Some governments are also following a similar model. For example, the government of Nova Scotia, Canada, offers economic incentives to parents who register children in sports or recreation activities that offer health benefits. Recently, the US Department of Health and Human Services announced that it's devoting economic resources to encourage citizens to participate in health improvement programs (www.letsmove.gov).

Smart cities can become the cornerstone for promoting healthier lifestyles by using their urban wireless infrastructures to implement mechanisms that directly encourage residents to play sports and exercise or serve as tools to measure actual involvement in exercise programs.

During recent years, several tools have been developed for tracking performance while exercising, especially while running, walking, hiking, or biking. Tools like Nike+, RunKeeper, Endomondo, Strands, and Nokia Sports Tracker help users keep records of information pertaining to their sports activities, such as duration, distance, pace, speed, elevation, calories burned, and the course traveled on a map. This information is uploaded to a Web-based cloud service where participants can share statistics and make detailed comparisons. Most of these applications seek to keep different kinds of users motivated by offering personal or collective challenges—for example, men versus women, aiming to complete 10 miles a week or run a total of 500 miles, or competing against the user's own previous workouts or against other people's workouts along a route. However, these applications usually require carrying a GPS-enabled smartphone, which discourages many potential users due to the cost of the device. Moreover, a user who wants to update his or her position and statistics on the Web-based service in real time must maintain a persistent data connection to the cloud.

One way to keep participants motivated to exercise is to create social networks in which they can share their performance with their friends and also compete against them. Developers can enhance existing tools with related features supported by smart city infrastructures. For example, instead of using a GPS device, it's possible to use the urban wireless infrastructure to keep track of a user's performance. Moreover, smart cities are designed to be adapted to their specific environment and the target user base. Exploiting this characteristic can stimulate people to engage in sports activities because their friends and acquaintances who use the system are located in the same area. Participants also can be encouraged to compete against others in a similar physical condition or to follow a regimen that's suitable for their level of fitness.

> **The goal is also to support the development of metrics for evaluating urban computing infrastructure and applications in real-world settings.**

RunWithUs

We're designing RunWithUs, a service that will be deployed in the Ubiquitous Oulu Smart City, with the goal of motivating citizens to practice jogging, letting them

- select a route according to length, difficulty, groups or friends currently following it, number of runners in a similar physical condition who usually follow this route, number of runners in the area, and weather conditions or pollen levels;
- compare differences in performance between runners following the same route, competing with other users' performances, or competing against one's own previous workouts (phantom runner); and
- promote sports practice and social life by establishing rankings: for example, biggest group of the month, most regular group of the month, and so on.

Figure 3 shows the RunWithUs system architecture, which includes Wi-Fi-enabled phones or tags that are connected to the wireless infrastructure and tracked by the UBI middleware, weather or other environmental sensors, and user interfaces such as a UBI-display or a Web browser on a PC or a smartphone.

Because RunWithUs was selected as one of the four finalists in this year's UBI Challenge, we'll have the opportunity to implement the system in a real-world smart city, thereby identifying difficulties and user concerns related to the location methodology's precision as well as issues related to privacy.

Location methodology

Implementing these features requires estimating each user's location. For this purpose, we're using the panOulu wireless infrastructure to locate personal Wi-Fi devices such as mobile phones and MP3 players. We're also taking advantage of existing Ubiquitous Oulu and social networking APIs to offer several user interfaces (top layer in Figure 4) to configure the system, including

- city displays that show a map with information about groups of runners, statistics, or promotional videos and animations, and users can join a group at any moment, even when they're already running;
- a website providing the same information as in the urban displays, including a special version for mobile devices; and
- a Facebook interface to share results, comments, and so forth with friends or other runners.

In a typical use case, a new user who wants to access RunWithUs must register using a UBI-hotspot. The user provides a login, a password, and a MAC address, usually from the mobile phone's Wi-Fi, an MP3 player, or a Wi-Fi badge. This MAC address tracks the user throughout the city. Once registered, the user can log into the system through any of the available interfaces.

Privacy

Naturally, users might be concerned that such a system could track them while they aren't running or when they don't desire to. Initially, we implemented a procedure to activate and deactivate the tracking service, for example, pressing a "Start Running" button in the RunWithUs user portal. This action allows the infrastructure to check the MAC address location and start tracking until the user presses "Stop Running." These actions are needed to differentiate when users are running versus when they're engaged in other nonexercise-related activities. When users are engaged in other activities, although the infrastructure could still detect their MAC address, the system won't update their location information. But since it's highly likely that users will forget to stop the tracking service, we implemented a timer to stop it by requiring users to select the amount of time they're going to run when they start the service.

Currently, the system uses panOULU Wi-Fi access points to track runners. Following an increasing trend, a recent report indicates that approximately 15 percent of the total number of mobile phones in Finland has Wi-Fi support.[10] A user who doesn't own a Wi-Fi-enabled phone or doesn't want to carry it while running could use a smaller Wi-Fi tag such as AeroScout, Ekahau, or RedPine. By using Wi-Fi access points for tracking, a runner's location can only be roughly estimated based on an access point's coverage area, but the hypothesis is that this will be adequate for this use case. Nevertheless, the deployment in Oulu will reveal whether or not this supposition is correct. For example, because we expect poor Wi-Fi coverage in parks, we'll need to adapt RunWithUs to overcome this limitation. Bluetooth access points could provide a finer-grained location, but the low number of currently installed units will likely reduce their effectiveness.

Figure 5 depicts the various elements that comprise the RunWithUs service. The different user interfaces provide unregistered users information

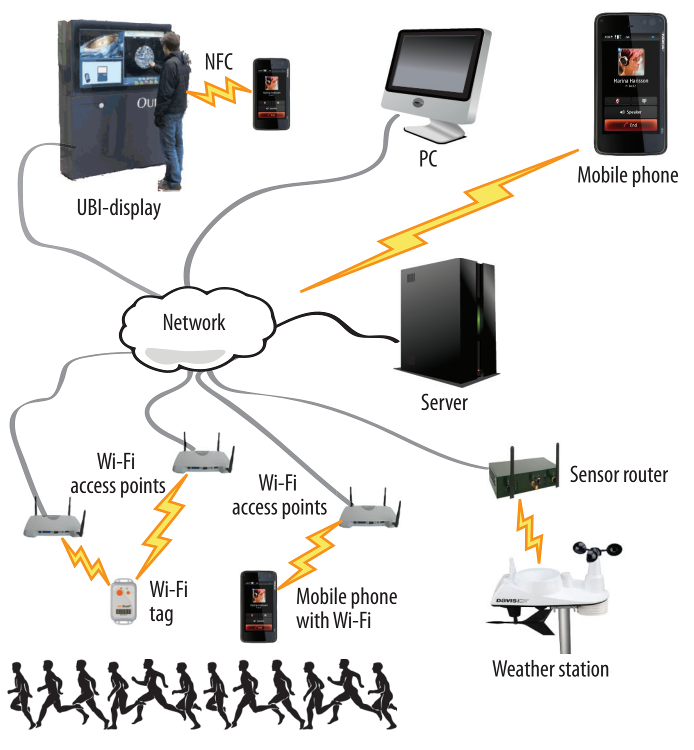

Figure 3. RunWithUs system architecture.

about the system such as routes, statistics, or public events. Unregistered users can also get some minimal and anonymous information about who's running right now or what the most popular routes are at a given time. There are two main reasons for making this information available. The first is to make the service attractive to potential future registered users; the second is to help tourists find a place to exercise comfortably and safely by finding appropriate routes suitable for their physical condition in safe areas.

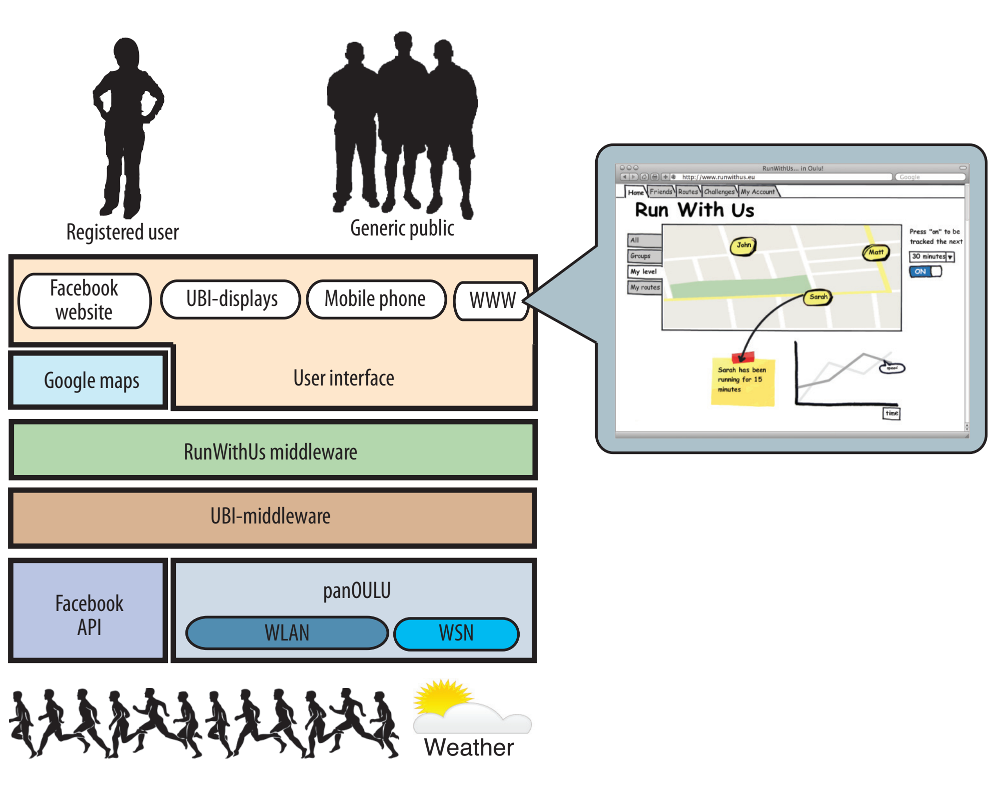

Figure 4. RunWithUs software stack.

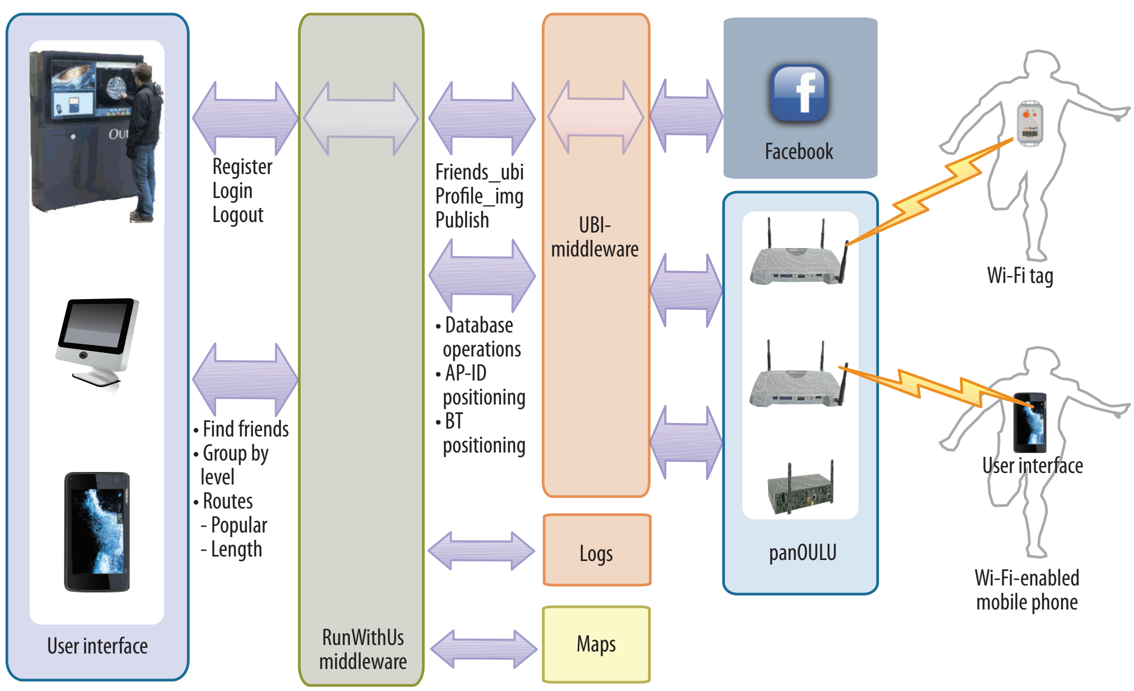

Figure 5. RunWithUs in operation.

In addition to the information provided to unregistered users, registered users can get information their friends want to share, such as their favorite routes or their performance. Registered users can also view who among their friends is running now, including their names, physical condition level, and corresponding location. Users also can determine who intends to go jogging at a particular time in case they want to join their friends.

The RunWithUs service's middleware layer tracks runners and uses that information to create routes and recommendations. This layer is also responsible for creating dynamic webpages for the different user interfaces. Routes and runner positions are overlaid on maps using the Google Maps API. For registered users, the system can filter results from their Facebook friends or publish statistics as text or images. Personal statistics such as total distance traveled, fastest kilometer, and so on can also be published according to user preferences using the Facebook API.

RunWithUs is still in its early stages, but we've already confronted several challenges. Implementing a multiscreen application designed to operate in devices with different sizes, resolution, and input interfaces isn't a trivial endeavor. Furthermore, applications developed for smart cities should be adapted to the environment in which they're going to be installed, making it necessary to perform onsite tests, especially when using APIs and interfaces interacting with citizens or mobile devices. But for RunWithUs, the main challenges are related to using Wi-Fi to track users. This technology can only offer precision at several hundred meters, and the fastest person in the world needs only roughly 10 seconds to cover 100 meters, making it necessary to find the optimal periodicity of location requests to offer maximum precision without overloading the servers. The low precision also makes it necessary to use postprocessing and additional information to determine whether users are following a predefined route, running together, or creating teams, or to store precise information about the track.

As the number of smart cities continues to increase, the number of related research initiatives is also increasing rapidly. However, it's still difficult for researchers to get access to a full-featured real-world testbed. Thanks to initiatives such as the UrBan Interactions research program, it's now possible to create and test smart-city applications and services designed to provide benefits to the community at large, discovering limitations that were not foreseen during the design phase and iteratively refining them until they become a ubiquitous and helpful part of people's daily lives.

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Building an Integrated Service Management Platform for Ubiquitous Ecological Cities

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As one of the frontrunners in the race to build smarter cities, South Korea is pushing the envelope by promoting the development of a standard architecture for a service management platform that integrates ubiquitous computing and green technologies.

Dramatic technological progress in recent years has brought unprecedented changes to every corner of our society and transformed daily life. In particular, wireless and mobile communications, radio frequency identification (RFID), and wireless sensor networks have paved the way for ubiquitous networking, and Internet-enabled devices are increasingly being used for accessing and processing information as well as communications.

Smart mobile devices along with high-speed, far-reaching access networks and sensors embedded in the environment provide the technical foundation for a ubiquitous city—or *u-city*—where objects and people are intimately connected. As advances in information and communications technology (ICT) open up opportunities for more effective and efficient urban management, innovations will be needed to provide new infrastructure services to cope with the changes.

FROM U-CITIES TO U-ECO CITIES

Current urban development trends emphasize the use of ICT to build smarter cities and, ultimately, a smarter planet.[1] Ubiquitous computing technology plays an increasingly important role in these efforts, enabling intelligent transportation systems (ITSs), geographic information systems (GISs), smart homes and workplaces, and environmental monitoring.[2-6]

A u-city is a smart city in which physical infrastructure instrumented with various sensors, such as power grids and oil pipelines, and mobile objects, such as humans and vehicles, are connected through ICT. In this dynamic and evolving ecosystem, everyone—from citizens to facilities managers to emergency responders to traffic control operators—can access a wide variety of advanced technologies and services, like those shown in Figure 1, using any device anywhere, anytime.

Countries around the globe have launched u-city projects, with South Korea at the forefront. In fact, the South

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Korean government is pushing the envelope by advocating ubiquitous ecological cities. A *u-eco city* combines core u-city technologies such as integrated city management/operations and citizen services with green technologies to increase convenience, safety, and quality of life while reducing carbon emissions—in short, a place where people, technology, and the environment coexist in harmony. The "South Korea's U-Eco City Initiative" sidebar describes the evolution of this national urban development effort.

The nation's first u-eco city, Hwaseong Dongtan (www.udongtan.or.kr/english/cyber/cyb_01_1.aspx), was completed in 2008. As Figure 2 shows, six additional u-eco cities are under construction, and 18 are at the design stage.

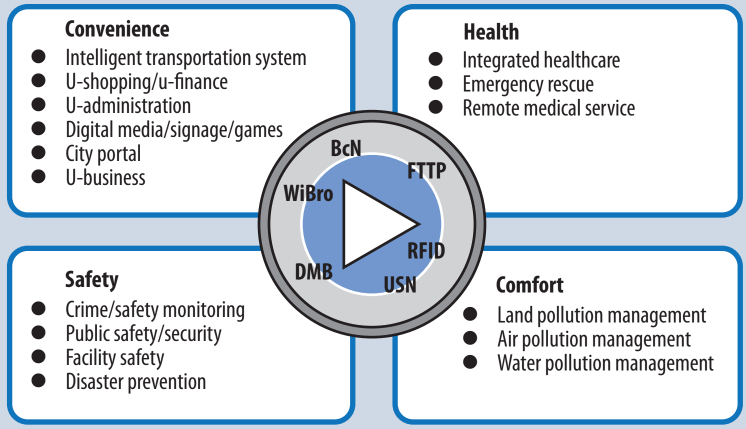

Figure 1. Technologies such as wireless broadband (WiBro), broadband convergence networks (BcNs), fiber to the premises (FTTP), radio frequency identification (RFID), ubiquitous sensor networks (USNs), and digital multimedia broadcasting (DMB) enable a wide range of ubiquitous city (u-city) services.

As u-eco cities began to emerge around the country, policymakers expressed concern about incompatibility among various operation and management platforms developed by South Korean ICT companies, which could lead to duplicated investments at the national level. Consequently, U-Eco City R&D Center researchers are developing a standard architecture for an integrated service management platform designed to enhance the efficiency of u-eco city management and communications.

INTEGRATED OPERATIONS CENTER

A comprehensive survey of South Korean u-eco cities under development[7] reveals a total of 228 potential services, which can be grouped into 11 categories:

- administration,
- transportation,
- welfare (health and medical services),
- environmental management,
- crime and disaster prevention and response,
- facility management,
- education,
- culture and tourism,
- logistics,
- labor and employment, and
- other services.

These services vary widely in scope and functionality, and the lack of coordination among u-eco city development efforts has hindered progress.[8] No reference model is available, let alone a national standard.

The first step in addressing this problem will be the creation of a u-eco city integrated operations center (IOC-UC) that will gather, process, and store information on all services and make appropriate recommendations to service operators.

Among the 228 services identified in the survey, each IOC-UC will initially focus on 31 commonly found across u-eco cities in South Korea. Figure 3 shows these 31 services organized into five urban management domains, with supportive operational models for services, control, infrastructure, and data management. By developing individual services within this framework, a u-eco city can provide a coherent view of its services and administrative organization to residents.

The IOC-UC also provides support for day-to-day monitoring, managing, and provisioning of a u-eco city's infrastructure as well as its services.

INTEGRATED SERVICE MANAGEMENT PLATFORM

The various u-eco city service platforms developed in South Korea have been designed and implemented as isolated stovepipe systems in which sensors and devices are connected to servers dedicated to a particular application domain, and networks are separated from one another. There are no defined application programming interfaces—adding a new service requires ad hoc, hardwired customization by a specific vendor. In addition, it is not possible to synergistically use data collected from different services, and there is no support for system integration of neighboring cities or communications and control handovers. All of these characteristics significantly limit the benefits of u-eco city services.

As Figure 4 shows, a u-eco city integrated service management platform (ISMP-UC) can overcome the limitations of closed stovepipe systems and enable

SOUTH KOREA'S U-ECO CITY INITIATIVE

Policymakers and technological leaders in South Korea conceived the vision of a u-eco city around 2003, when the deployment of ICT infrastructure such as code division multiple access (CDMA) and fiber to the premises (FTTP) was sufficient to accommodate every individual and business in the country.

In 2004, after soliciting public input, the Ministry of Information and Communication and the Ministry of Land, Transportation, and Maritime Affairs began coordinating efforts on a national-scale u-eco city development program. Two years later, the U-Eco City R&D Center (www.ueco.or.kr) was established under the auspices of the Korea Land Corporation (later merged with the Korea Housing Corporation) to fund and oversee the program, which was formally launched in August 2007.

As Figure A shows, South Korea's u-eco city development program consists of one overall group responsible for strategic planning, marketing, research, and testbed construction and two core groups charged with developing infrastructure and services. The projected total budget for all u-eco city projects from 2007 through 2013 is US$130 million.

South Korea's private sector has also recognized the potential opportunities of u-eco cities and has created a forum to promote and discuss the initiative (www.ucta.or.kr/en/ucity/background.php). Participating members include major ICT players such as KT, Samsung SDS, and LG CNS.

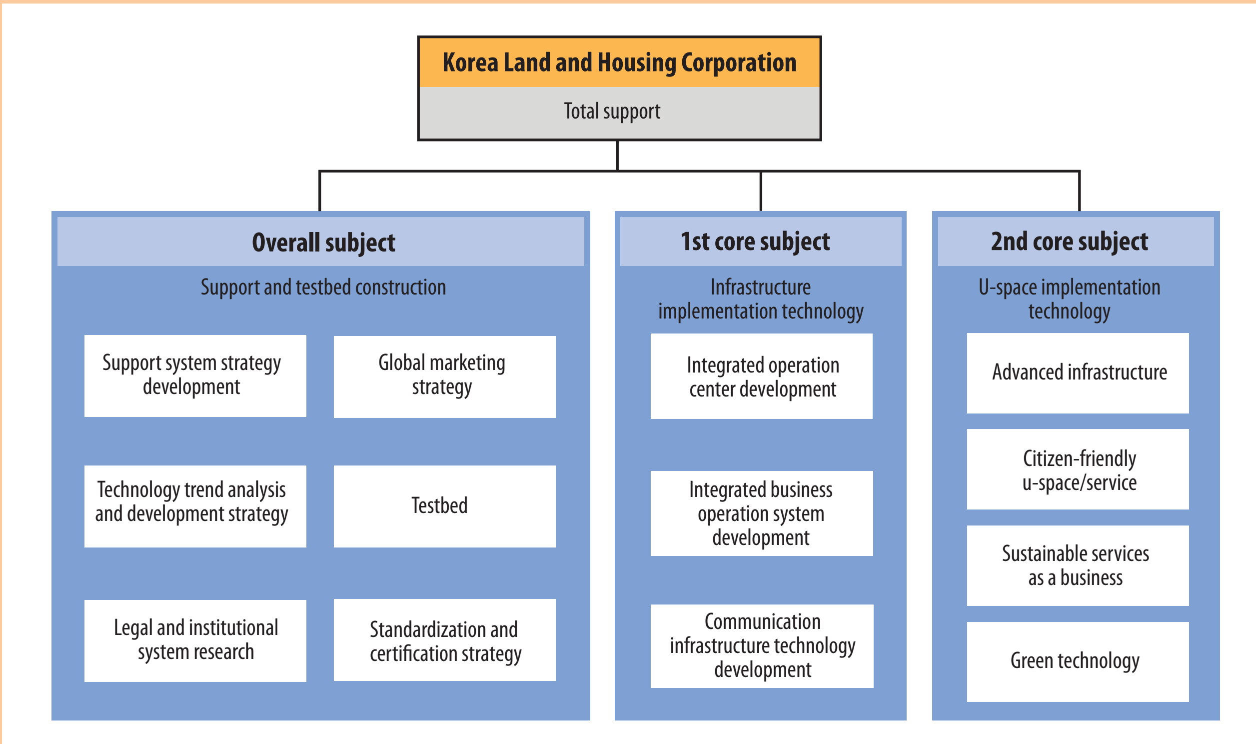

Figure A. South Korea's u-eco city development program consists of one overall group responsible for strategic planning, marketing, research, and testbed construction and two core groups charged with developing infrastructure and services.

synergistic service collaboration. The ISMP-UC makes operational decisions based on input from sensors and other networks and sends control commands to system components or external entities. For example, if sensors on the road detect an automobile accident, the system can notify a nearby police station and hospital. The system could also automatically identify involved vehicles and drivers from data collected by streetlight-mounted cameras. The ISMP-UC can also create new services by combining information from different sources.

To handle the diversity and dynamism inherent in a u-eco city, the service architecture should be as flexible and extensible as possible.[9] The ISMP-UC has three basic layers. The bottom layer consists of various types of sensors, actuators, and other devices distributed about the city. On the top layer is a range of u-eco city services. Between these layers lies the middleware that collects and processes data and contextual information. The middleware's service-oriented architecture enables services to be developed independently and invoked through standardized Web services interfaces.

As Figure 5 shows, the ISMP-UC middleware includes a gateway service, a ubiquitous information service, a mobility manager, an operations management service, and an integrated database.

Gateway service

The gateway service is a collection of interface adapters for connecting middleware components and entities that are either internal or external to the system. By keeping open its interface to information systems and various user devices and sensors, the GS can cope with the ever-changing needs of an evolving urban space and its residents by accommodating new devices and services without the need for any change to existing services or other parts of the architecture.

The GS has three components. The *internal link service* relays information and control signals between the ubiquitous information service/mobility manager modules and the IOC-UC and its 31 common services. The *external link service* transfers information and control commands between these mod-

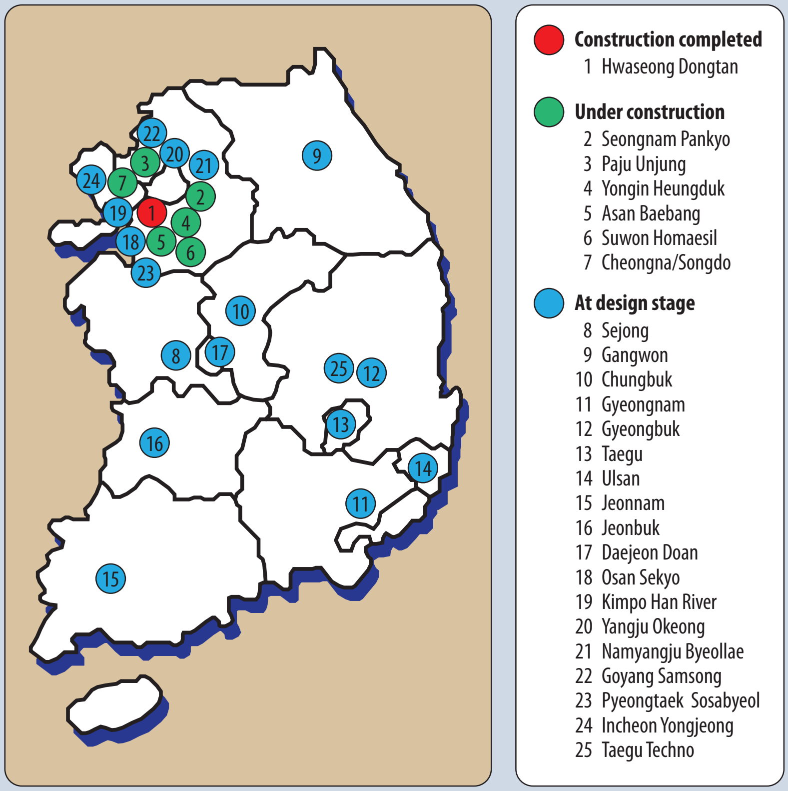

Figure 2. In South Korea, one u-eco city has been completed, six are under construction, and 18 are at the design stage.

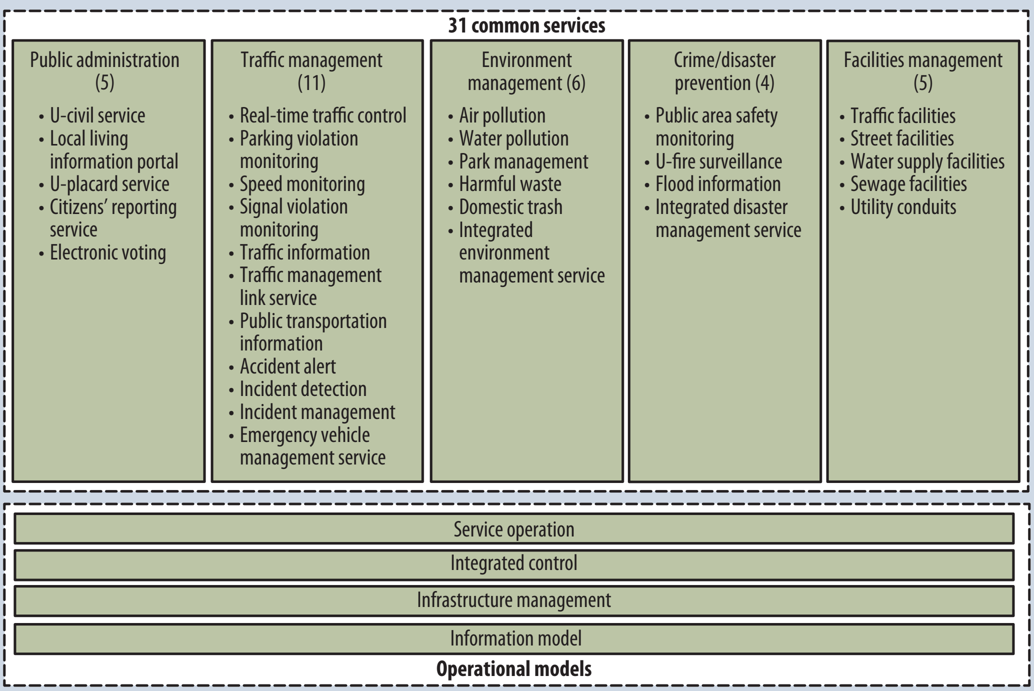

Figure 3. Each u-eco city's integrated operations center (IOC-UC) will initially focus on 31 common services organized into five urban management domains, with supportive operational models for services, control, infrastructure, and data management.

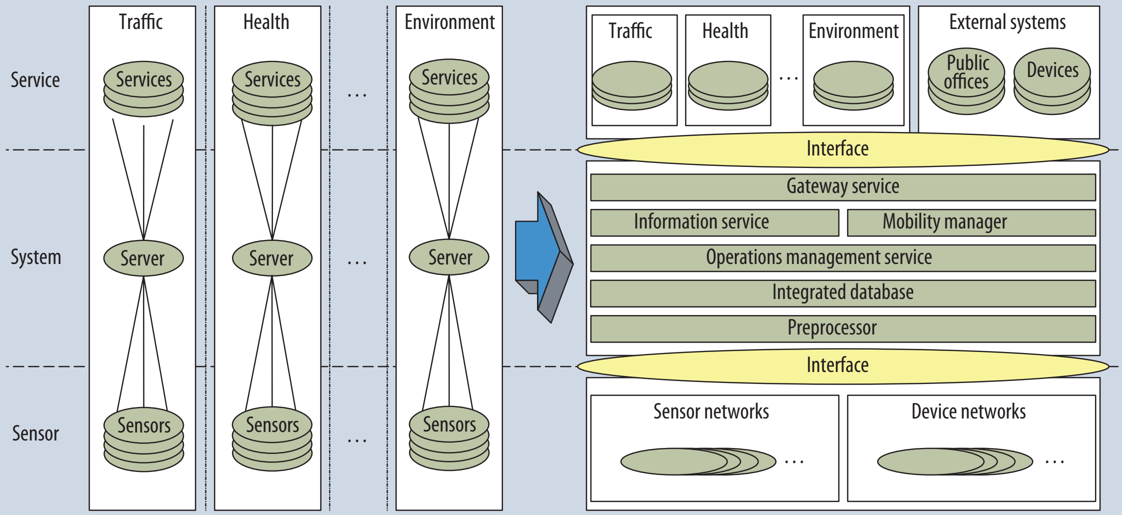

Figure 4. A u-eco city integrated service management platform (ISMP-UC) can overcome the limitations of closed stovepipe systems and enable synergistic u-eco city service collaboration.

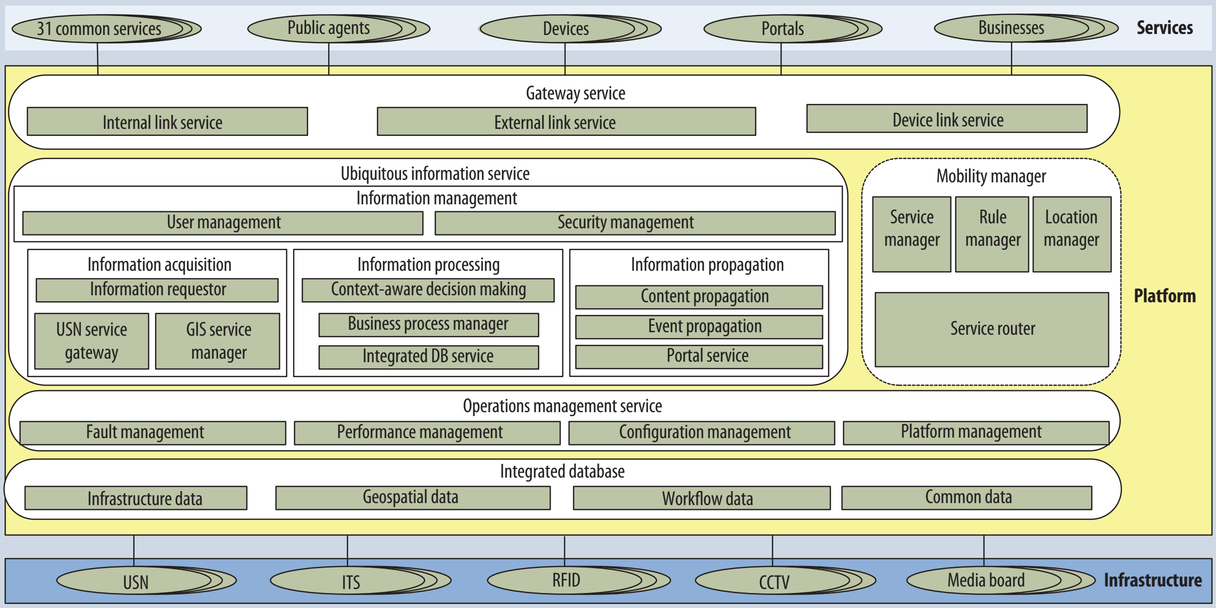

Figure 5. The ISMP-UC middleware includes a gateway service, a ubiquitous information service, a mobility manager, an operations management service, and an integrated database.

ules and systems run by outside agencies, institutions, and companies. The *device link service* interacts with mobile devices, service networks, and sensor nodes with computation capability, providing communication paths to the information service and mobility manager at a lower level.

Ubiquitous information service

At the heart of the ISMP-UC architecture is the ubiquitous information service, which includes four basic building blocks for u-eco city services.

Information acquisition. Upon receiving a request for sensor or geographical data from external entities or internal components, the information acquisition service passes it through the link services to either the *USN gateway* or the *GIS service manager*. The integrated database temporarily saves the responses from these networks for further processing.

Information processing. This service is responsible for processing all data in the system. With the help of the *context-aware decision-making service*, a business process manager orchestrates the interactions of component services and procedural logic within and across services. In addition, an *integrated database service* manages various data, whether inside or outside the platform, collected from different sources and created by context-aware analyses and other business processes.

Information propagation. This service has three components: the *content propagation* and *event propagation* modules deliver processed data and event data, respectively, to higher-level objects, while the *portal service* is responsible for the operator-friendly display of processed results.

Information management. This service contains two modules. The *user management service* provides information about users and groups requested by other components and services, and controls access privileges to middleware components and application services. The *security management service* prevents data from being transferred to unauthorized entities and supports encryption functions.

Mobility manager

The proliferation of smartphones and other Internet-enabled devices as well as digital signage makes it possible to deliver rich content to users anytime, anywhere. The mobility manager (MM) provides for the delivery of information such as traffic, weather, and news to mobile devices. The MM can also convey data via digital billboards, kiosks, and variable message signs.

The MM effectively separates the service and device layers so that u-eco city applications can be developed independently of particular hardware devices and platforms. Applications in the service layer can use Web APIs to display information on a target device. The MM can identify a group of devices in a particular geographical area and broadcast data only to that group. This allows for efficient information dissemination to, for example, an accident site or disaster area.

The MM combines user profiles, device capabilities, and adaptation processes such as transcoding and resizing to deliver context-aware information. It supports both always-connected devices and intermittently connected devices or mobile terminals for emergency situations.

Operations management service

The operation management service (OMS) monitors faults in system components and devices, performance of system components, service composition and device networking, and proper functioning of the platform itself. The OMS has four primary modules. The *fault management* module analyzes failures or errors in services and sensors connected to the system and recommends solutions when available. The *performance management* module tracks system performance and, in real time, periodically analyzes and manages various system capabilities. The *configuration management* module configures system components and application services and manages network resources. The *platform management* module provides administrative support for the IOC-UC including faults, performance, backups, and security.

Integrated database

The integrated database serves as the repository for data from all system component modules and application services. It contains infrastructure and workflow data in addition to common business data about users and organizations. The database also stores geographic and spatial information about roads and urban facilities such as sewage treatment plants.

IMPLEMENTATION AND ROLLOUT

A prototype implementation of the ISMP architecture is expected to be completed by the first half of 2011. Performance fine-tuning and further customization will begin soon after that. In addition, the U-Eco City R&D Center is developing and testing sample u-eco city services.

A prototype implementation of the ISMP architecture is expected to be completed by the first half of 2011.

Researchers are creating a full-scale, realistic testbed in the new Cheongna u-eco city in the Incheon Free Economic Zone (IFEZ) on the west coast of South Korea. Established in 2004, the IFEZ is an eco-friendly, mixed-use environment situated midway between major East Asian cities like Beijing, Shanghai, Tokyo, and Hong Kong. Aside from its locational advantages for business, the IFEZ will incorporate ubiquitous computing technologies for all aspects of urban life.

Figure 6 shows an artist's rendering of Cheongna, where the 77-story World Trade Center with neighboring business and commercial facilities, along with a high-tech industrial park, are already under construction. The master plan for Cheongna includes an IOC-UC based on the ISMP-UC architecture. Thirteen u-eco city services are being considered for first-phase deployment.

Sejong, a u-eco city that will be built south of Seoul beginning in 2013, will serve as another testbed for the ISMP-UC as well as interoperability with Cheongna's IOC-UC. Other candidate cities for ISMP-UC deployment include Busan, the second largest city on the southern coast. Unlike Cheongna and Sejong, u-eco city services in Busan will be part of a downtown rejuvenation project.

Figure 6. Artist's rendering of Cheongna, Incheon Free Economic Zone, which will contain a full-scale, realistic testbed for u-eco city services.

CHALLENGES

The U-Eco City R&D Center must address several key challenges to fulfill the vision of South Korea's ambitious u-eco city initiative.

Service interoperability

Interoperability is a major concern when developing ubiquitous services that evolve independently yet rely on one another to accomplish a larger purpose. For example, two closed-circuit TV (CCTV) broadcasting system manufacturers might use different time stamps. Service developers and device manufacturers must agree on message-passing protocols, naming conventions, service invocation requests, and results. There must also be agreement on higher-level service representations such as tickets for traffic violations, as local authorities could have various management formats and structures.

Beyond syntactic data interoperability is the more challenging issue of service-level interoperability. As semantic interactions among different government agencies and manufacturers are not yet standardized, adapting u-eco city service modules will require significant effort. The solution calls not only for technical expertise but also for social and institutional consensus building.

Service developer concerns

Before the ISMP-UC, which makes service interfaces public, third-party city service developers had developed their own proprietary solutions for sewage management, water supply monitoring, and so on in isolation. For example, a CCTV network monitoring traffic in a business district was separate from a CCTV network monitoring crime in a residential district. Services on the two networks could not communicate with each other.

These legacy systems must be modified and incorporated into the ISMP-UC platform. The ISMP-UC provides common functions and a Web services API that third-party developers can use to compose their application services. These Web services will be able to communicate with each other so that, for example, a crime-prevention CCTV network can interact with a traffic-monitoring CCTV network, providing appropriate authorities with better information to track criminals across the city.

However, third-party service developers have raised concerns that these changes would reduce their role and thus impact their profits. They have also resisted providing technical details about their proprietary systems that are essential for ISMP-UC implementation. The U-Eco City R&D Center has spent considerable time persuading developers that the ISMP-UC will benefit their business in the long run by making it easier to develop new services using existing service modules. The proliferation of new services would in turn increase economies of scale for third-party developers.

Institutional resistance

Conceived as a central monitoring and control point, the ISMP-UC must interact with other systems already in place. For example, an automobile accident monitoring and report service would need to access a vehicle registration database, resident registration information, insurance company databases, and possibly hospital patient management systems. However, sharing databases across different government agencies and companies requires complex approval processes. As u-eco city services spread over various domains, involved institutions must reach agreement on information sharing.

The U-Eco City R&D Center is developing a secure brokering system for stakeholders, but this is taking much longer than initially expected. Different institutions have their own requirements established in accordance with government regulations and business logic. Because resolution of the institutional boundary problem could take a long time, the Cheongna testbed will use interface emulators rather than actual databases and information collected from real devices.

Supply-push versus demand-pull

U-eco city development efforts in South Korea have largely been driven from the top down rather than by consumer needs. As ISMP-UC development progressed, however, U-Eco City R&D Center researchers began to realize that user acceptance and other socioeconomic issues are a bigger hurdle to the rollout of u-eco city services than technological obstacles.

It is not yet clear who will be responsible for the cost of u-eco city service deployment and maintenance. Residents will be reluctant to foot the bill. Several studies are exploring the business opportunities of ubiquitous services, but the market is not yet mature enough to attract numerous entrepreneurs. A new business model and new incentives are needed to sustain the initiative.

U-eco city efforts have been conceived primarily by technology experts who foresee the needs of future ICT-based city management. During this period of interpretive flexibility, however, residents and other social groups must be involved in exploring alternative designs.[10] Efforts are needed to build public awareness and understanding of the benefits of u-eco city services, nurture a market for the services, and eventually establish them as essential components of urban social infrastructure.

Over the past several years, u-cities have begun to emerge around the globe. As one of the frontrunners in the race to build smarter cities, South Korea is taking the extra step of integrating cutting-edge ubiquitous computing and green technologies into the development of new cities. The ISMP-UC middleware architecture for u-eco city operation centers is the first step toward realizing this vision. Once successfully completed and tested for performance and interoperability, it will be a solid reference model for u-eco city services and could serve as a standard reference model for worldwide u-city developments. C

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