Building an Integrated Service Management Platform for Ubiquitous Ecological Cities

Jungwoo Lee, *Yonsei University*
Songhoon Baik, *KT Corp.*
Choonhwa Lee, *Hanyang University*

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.

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.

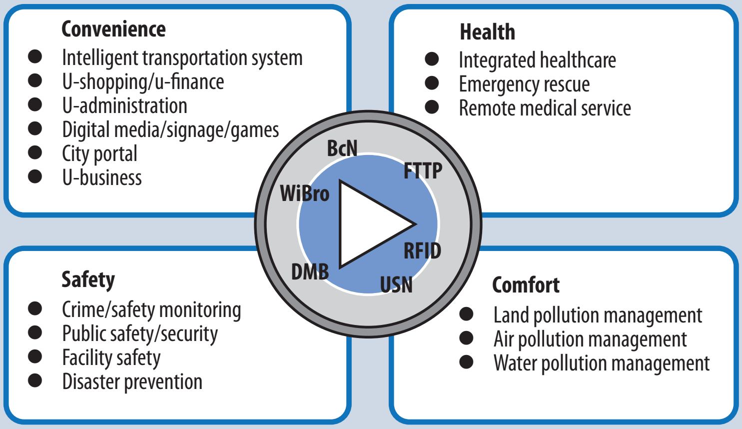


Figure 1. Technologies such as wireless broadband (WiBro), broadband convergence networks (BcNs), fiber to the premises (FTTP), radio frequency identification (RFID), ubiquitous sensor networks (USNs), and digital multimedia broadcasting (DMB) enable a wide range of ubiquitous city (u-city) services.

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.

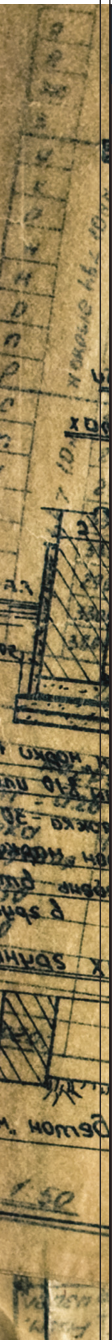
Among the 228 services identified in the survey, each IOC-UC will initially focus on 31 commonly found across u-eco cities in South Korea. Figure 3 shows these 31 services organized into five urban management domains, with supportive operational models for services, control, infrastructure, and data 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.

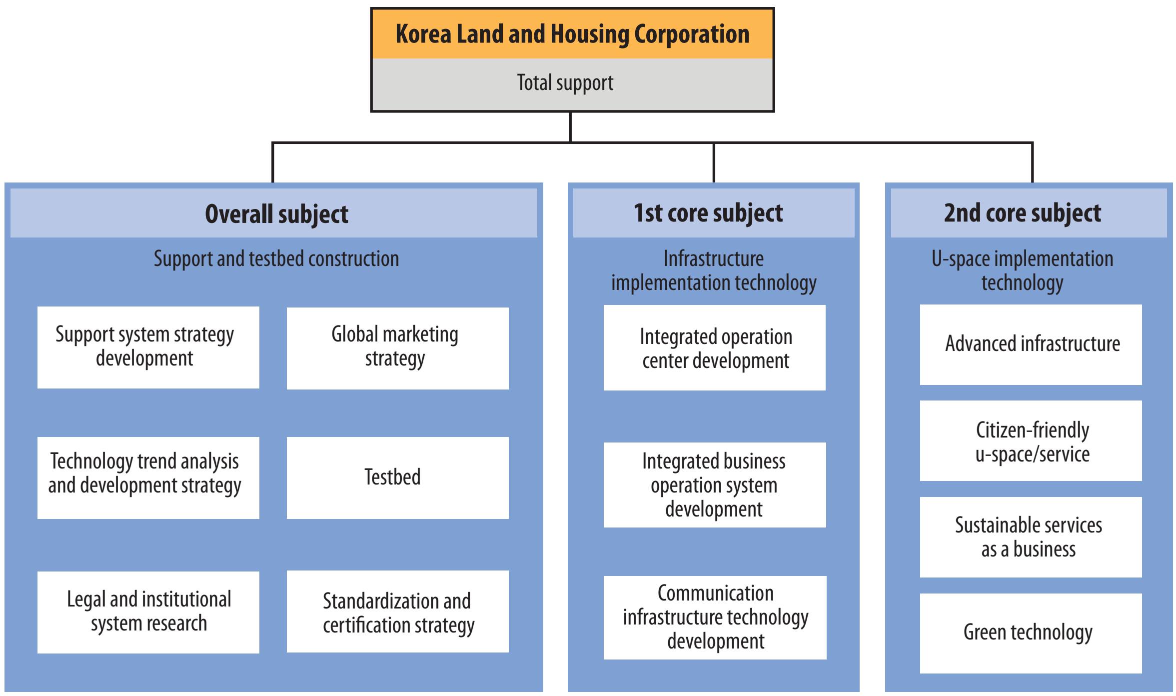


Figure A. South Korea's u-eco city development program consists of one overall group responsible for strategic planning, marketing, research, and testbed construction and two core groups charged with developing infrastructure and services.

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-

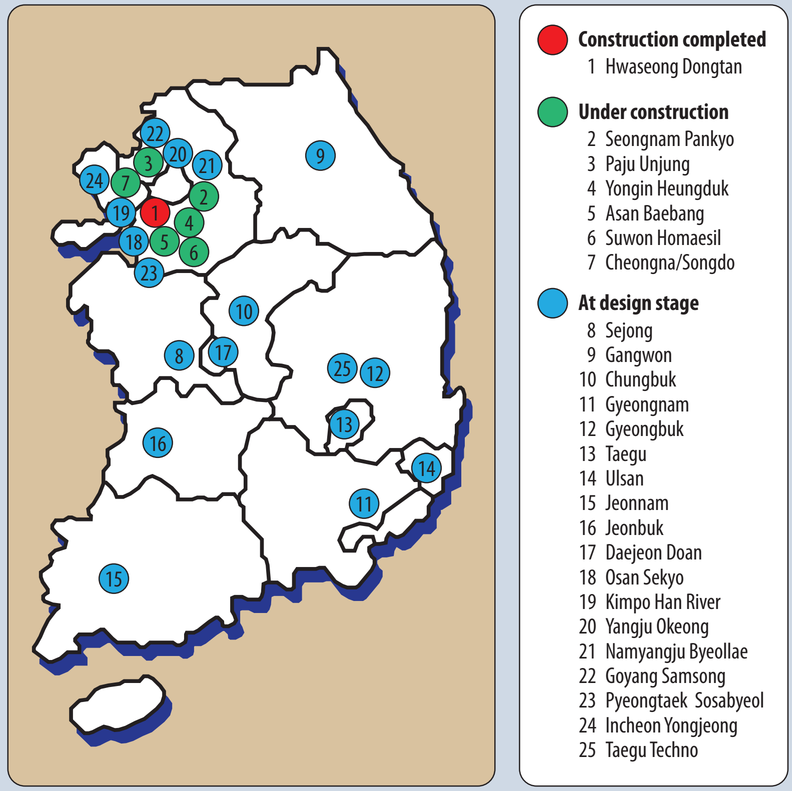


Figure 2. In South Korea, one u-eco city has been completed, six are under construction, and 18 are at the design stage.

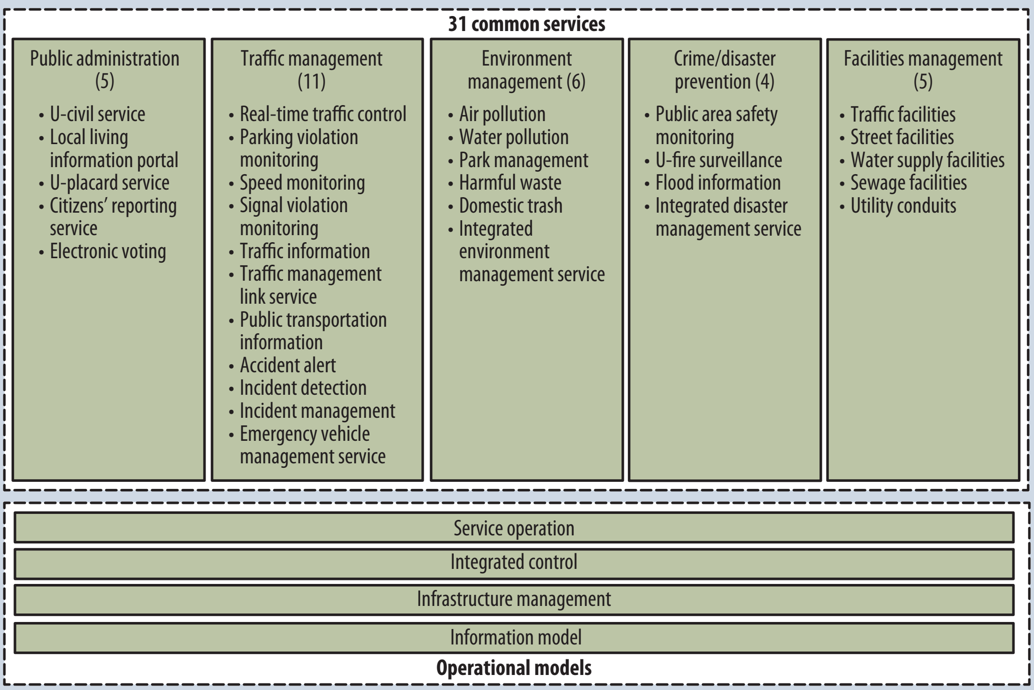


Figure 3. Each u-eco city's integrated operations center (IOC-UC) will initially focus on 31 common services organized into five urban management domains, with supportive operational models for services, control, infrastructure, and data management.

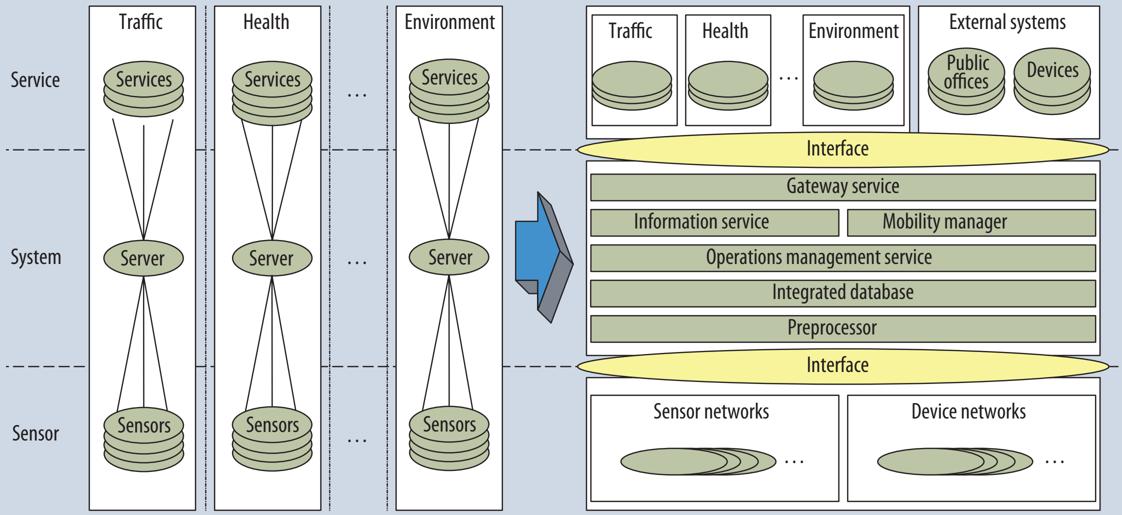


Figure 4. A u-eco city integrated service management platform (ISMP-UC) can overcome the limitations of closed stovepipe systems and enable synergistic u-eco city service collaboration.

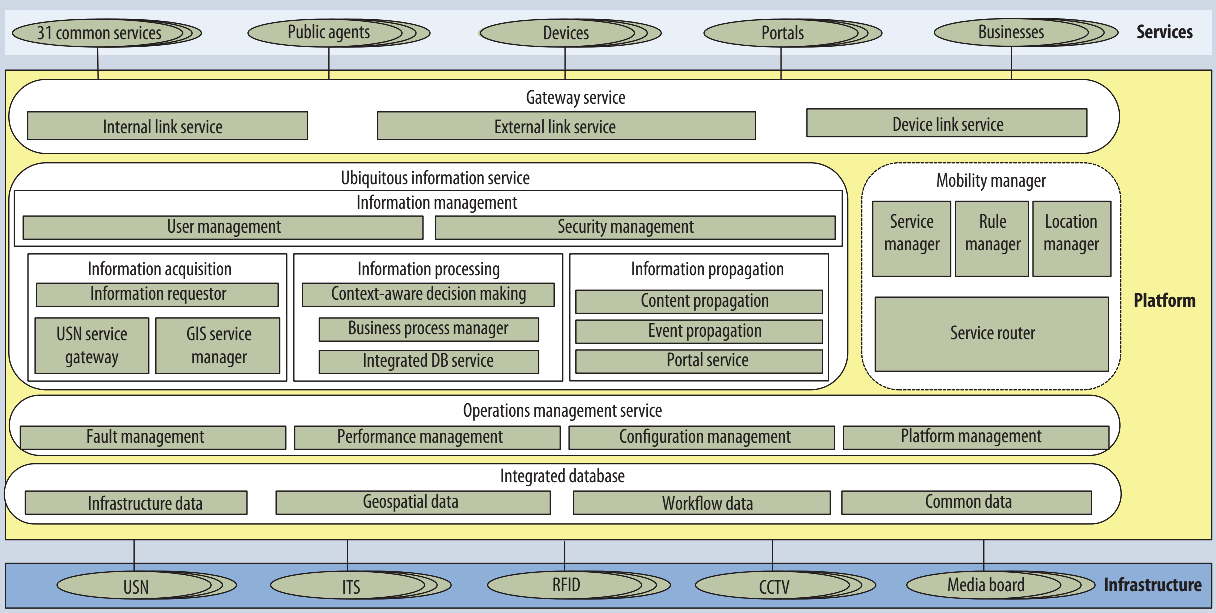


Figure 5. The ISMP-UC middleware includes a gateway service, a ubiquitous information service, a mobility manager, an operations management service, and an integrated database.

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.

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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 front-runners 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.

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***Jungwoo Lee**, a professor in the Graduate School of Information and director of the Information Technology Strategy and Policy Research Institute (ITSPRI), Yonsei University, Seoul, South Korea, currently leads the U-Eco City R&D Center's ISMP-UC development project. Lee received a PhD in computer information systems from Georgia State University. He is a member of the IEEE Computer Society and the ACM. Contact him at jlee@yonsei.ac.kr.*

***Songhoon Baik** is a research engineer with KT Corp., South Korea. He led a project team that designed and developed KT's u-eco city service platform, Ubi-Cahn, and is currently participating in the U-Eco City R&D Center's ISMP-UC development project. Baik's research interests include geospatial information systems and construction-ICT convergence technologies. He received a PhD in civil engineering from Chungnam National University, South Korea. Contact him at baiksh01@paran.com.*

***Choonhwa Lee** is an assistant professor in the Division of Computer Science and Engineering at Hanyang University, Seoul, South Korea. His research interests include mobile networking and computing, peer-to-peer protocols, and middleware and services computing technology. He received a PhD in computer science from the University of Florida. Contact him at lee@hanyang.ac.kr.*