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A Service-Oriented City Portal Framework and Collaborative Development Platform

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Abstract: Cities are being equipped with multiple information systems to provide public services for city officials, officers, and citizens. There are problems with efficient service implementation and provision, e.g., data islands and function overlaps between systems and applications. Service-oriented portals are efficient at facilitating information sharing and collaborative work between city systems and users. The goal is to make cities responsive, agile and to provide composite services efficiently and cost efficiently. A service-oriented framework for city portals is proposed to design, integrate and streamline city systems and applications. A model-driven collaborative development platform is developed for service-oriented digital portals of the proposed framework. The architecture and implementation issues of the platform are discussed. The service identification policies are discussed within the framework. A case study has been developed and evaluated on the platform to provide a composite service, i.e., a traffic search service on a city portal.

Keywords: Service-Oriented Architecture, Web Services, Digital City, Service-Oriented Portal, Model-Driven Architecture.

1. Introduction

Cities are being equipped with multiple information systems to provide public services for officials, officers, and citizens from public departments, businesses and communities. Some examples of these systems are: city information services, intelligent traffic systems, municipal monitoring and management systems, environmental monitoring systems, municipal planning systems, entertainment, construction, security and emergency systems. The systems involved need to work together to provide users with accurate information and efficient services. The cooperative work between these systems includes information aggregation, sharing and analyses, and application interaction and collaboration. However, there are serious data islands and function overlaps between the applications and systems because most of them are provided separately by different departments and implemented by different vendors.

To the best of our knowledge and experience, the city applications and systems are suitable to be integrated and provided as services in a city portal, to facilitate the access by residents and the world outside of the cities, to provide data for city planning and decision making, and improve the response time and processing efficiency. The portal is designed to integrate, organize and streamline the provided

information, applications, processes and services both by cities and by their businesses and public departments, e.g., shopping systems, hotel systems, hospital systems, railway/flight/bus systems, police systems, tax systems. The technical concerns with the portal involve all layers of the digital city environment, e.g., different computing infrastructures and communication protocols, different computing architectures, platforms and development tools, heterogeneous data representations, interfaces, storage security and latency, and distributed and fragmented business logics.

For the object-oriented distributed computing technologies such as CORBA, J2EE and COM/DCOM, it is a challenge to integrate the involved data, applications and processes within the digital city. These technologies are mostly for software construction, and are concerned with object-level software components and their interfaces. For the communication and integration among city applications and systems, they do not provide an open communication protocol, a unified application interface description standard, a flexible data and representation mechanism, and a function and process planning granularity. As a result, integration is expensive and time consuming when new systems are to be integrated or existing systems are extended to provide new services.

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Comparatively, Service-Oriented Architecture (SOA) has been envisioned as an appropriate computational paradigm and approach for information systems to be collaborated and integrated. The service-oriented paradigm focuses on building information systems by discovering, matching and integrating pre-developed granular services. A granular service can function independently of other components and communicate using well-defined, standardized interfaces. A service-oriented architecture can make common functionality available for all information systems and provide the flexibility to include existing legacy systems, which cannot be replaced easily and otherwise restrict further development. With open and standard application interfaces and technologies, i.e., SOAP, WSDL and UDDI, Web services implement the SOA's features to support loosely coupled applications and their integration [1]. With XML and Semantic Web technologies, they are expected to transform the Web into a distributed business computation network. With the granularity of 'service', SOA and Web services bridge the gap between business and information technologies by providing an approach for reengineering business processes with service-oriented approaches and design enterprise information systems with business-centric approaches. A number of IT companies, such as Microsoft, Sun, BEA, HP and IBM, have formed working groups to develop standards for Web services and technologies. IBM and HP have proposed "business on demand" and "adaptive enterprises" models that are based on the service-oriented paradigm, infrastructure and a number of Web services technologies.

SOA and Web services have attracted considerable attention from politicians and public servants in digital cities as a solution for expanding their information systems and leverage investments in legacy systems running the critical city applications. This work will investigate Web services' feasibility, implementation methods and performance for sophisticated dynamic and automatic services collaboration and composition in the cases of digital cities. The objective is to apply service-oriented architecture and Web services into the planning, design, implementation and integration of digital city, and to make the digital city flexible and responsive to meet dynamic requirements and evolvments. SOA aims to increase the city portal's manageability through the design of large granular services to be constructed from smaller ones, to split up a complex problem into smaller problems to be solved independently, and to improve openness and flexibility. With SOA paradigm, new services can be added and removed from the architecture and each single service can be replaced by another component without affecting the others.

A service-oriented portal framework will be proposed and a case study will be developed to illustrate how to plan and integrate a digital city and make it an

on-demand city. The portals of this framework will be developed in a service-oriented collaborative development environment, which has been developed by authors in a previous project [8]. This work is conducted with a key venture program of Shanghai municipal government. The proposed portal framework and development platform has been evaluated and referenced by the Science and Technology Commission of Shanghai Municipality in building IT infrastructure for a brand-new satellite city, i.e., Shanghai Yangshan Digital Port City.

The rest of the paper is organized as follows. Section 2 presents the challenges and related work with service-oriented portal, framework and implementation techniques. Section 3 discusses the objective, involved services, processes, and functional requirements of a city portal. Section 4 proposes a service-oriented city portal framework to meet the identified requirements. Service identification policy and implementation issues are discussed. Section 5 describes a collaborative development environment for service-oriented city portals of the proposed framework. Section 6 describes a case study involving the development of an intelligent traffic service on the collaborative platform, to demonstrate the concepts of city portals and evaluate the platform. Section 6 concludes the work.

2. Challenges and Related Work

Numerous websites are using the city metaphor to provide public information and services around the world. Based on their themes, content layout and information infrastructure, we are calling them the "city guide" [2], "3-D virtual city [3]", "social digital city [4]", "city market [5]", and "demographic and social digital city [6]". The mentioned digital cities are mostly digital platforms for community networks and information spaces. Their missions are to provide a social information infrastructure for urban life including shopping, business, transportation, education, welfare etc.

One of the challenges for the city platforms is that most of them provide both profit and non-profit services and therefore face a dilemma in trying to balance the two different types of services [7]. Service-oriented architecture provides a suitable paradigm to categorize the services provided and design their cooperation.

Another challenge with the city platforms is the integration of data and applications between the heterogeneous systems involved. From a technical viewpoint, a city portal is similar to many enterprise portals. The main difference is that a city portal is more distributed and heterogeneous with versatile applications and participants. Like the idea of e-Business on-demand, a digital city should be responsive in real time, flexible in cost structure, and secure among the service providers and requestors in order to meet the needs of the residents and the changes in the technology

landscape. The business integration solutions are the key enablers to make on demand business a reality and deliver business values to the customers.

City portals are not expected to be integrated in as sophisticated and thorough a manner as the applications within an enterprise. The data and applications are more data-level interlinked and service-level collaborated than completely integrated. Therefore, it is important to have a set of appropriate integration technologies, e.g., SOA/Web services, to support the on demand cities. This work will explore, from an implementation point of view, how the on demand cities can be implemented efficiently and effectively using service-oriented paradigm and Web services technologies in order to meet the needs of the residents.

To evaluate the feasibility and performance of the complicated city portals, this article will propose a service-oriented digital city portal framework and a devoted development platform. Among the related technical works are the literatures on service-oriented architecture, city portal frameworks and implementation environments.

In the research of SOA/Web services, academic groups and industries emphasize different aspects of Web service according to their different views on the value chain of Web services. Gartner focused on standard interfaces and loose-coupling of Web services. Microsoft is interested in the integration of Web services, XML, Web and component-oriented technologies. IBM emphasizes service-oriented architecture and composition and Web services' integration capabilities. SUN promotes the employment of Web services' intelligence in order to support customized service, business intelligence, and custom relationship management. In its latest version of SOA specification, W3C enforces Web services' open standards and highlights Web services' capabilities of cross-platform, machine recognizable, and semantic processing. In the previous works [8], we have proposed a semantic service meta-model to promote service-oriented software engineering.

Among the related efforts on city portals are several e-Government programs by municipal governments. Some of them have applied and addressed the concerns with service-oriented architecture. For example, UK Government initiated the GovTalk / e-GIF [9]. The e-GIF specification covers the areas of interconnectivity, data integration, and content management metadata and e-services access. The policy for Web services and their repositories are specified. The information infrastructure and standards of the office of the Hong Kong Government Chief Information Officer specifies the common applications and services provided to bureaus and departments to facilitate the efficient delivery of services to the public [10]. The elaborated measures have been released for Government Directory Service, Electronic Service Delivery Scheme, and Interoperability Framework for E-Government, IT

Security Infrastructure in Government, and e-Government Infrastructure Service. The Interoperability Framework of the standards is based on XML and specifies the data-centered registry and interoperability.

There is much literature about service-oriented e-Governments; however, they have not touched upon the frameworks and common implementation platforms. Medjahed et al. [11][12] designed an infrastructure for e-government Web services to improve government-citizen interactions through an infrastructure built around the "life experience" of citizens. They adopted Web services in e-government systems to enable government agencies to provide value-added services by defining new services that outsource from other e-government services; to uniformly handle privacy issues; and to standardize the description, discovery, and invocation of social programs. Another case study to demonstrate the effectiveness of the use of Web services in e-Government information and process integration is by Cherrie et al. [13] They formulated a conceptual model for the transport network and Emergency Route Advisory System (ERAS) implementation architecture to handle the emergency response. They used Web services to implement information integration from various governmental departments and public services. ERAS interacts with the call centers of emergency service departments (such as the police, fire services, and ambulances) through alert mechanisms to integrate emergency processes.

To implement a large-scale service-oriented digital city portal rapidly, it needs a secure, reliable, and efficient framework for service-oriented application and software engineering. The framework should provide a generic software model and common infrastructure for development and runtime environments. Currently, the popular frameworks supporting Web services are J2EE and .NET. Based on these two frameworks, the major application vendors, such as SAP, Oracle, Microsoft and IBM, have provided SOA business platforms [14-17]. Many businesses have published Web services and have decided to develop their information systems using SOA. Web services have seen several successes in commercial applications, e.g. Amazon and Google, which provide the developers with Web services to customize their own online book stores and search tools.

A unified framework is critical and efficient for system design and development [18]. For service-oriented system implementation, authors proposed and implemented a multi-model driven collaborative development platform for service-oriented e-Business systems [8]. The platform has three basic modeling views, i.e., business view, process view, and service view, to model an e-Business system. The three views provide basic modeling tools to support service-oriented software engineering and application developments. The proposed views are driven by three models respectively, i.e., service meta-model, process model

and business model. Out of the three models, service model is to support semantic service description and operations, process model is consistent with that of Business Process Execution Language for Web services (BPEL4WS), and business model considers services, providers, adapters and their relationships for specified businesses. The city portals of the framework in this paper will be implemented on the collaborative development platform. The platform will be customized for city portals with the three views, i.e., business view, process view, and service view to support service-oriented software engineering, top-down city portal design and bottom-up service-oriented portal development. On the platform, business and technical consultants/engineers can use the designated views for their roles to collaborate for a service-oriented digital city portal based at the distributed sites.

3. Requirements for a City Portal

The proposed service-oriented city framework is based on the comprehensive requirements for a city portal. To design the framework, the functional, design and user requirements of a portal need to be discussed.

3.1 Objectives of a city portal

With functional features of data integration, information sharing and system collaboration, a city portal is more than a lightweight information space and social community. It should enable and facilitate the collaborative work and information sharing between professional applications, systems and residents. The portal users include public departments and their officers, businesses and their employees, and civilian residents. The information includes space data, geographic data and circumstance data. The provided services include city planning, management and decision making such as transportation planning, residential planning, industry planning, and education planning. From the viewpoint of system infrastructure, the portal will provide a framework to integrate the heterogeneous applications and information of city planning, e-government, e-commerce, and public services, and to streamline their processes, integrate distributed applications, keep processes sufficiently flexible and coordinated, and reach their residents quickly.

3.2 Services provided by a city portal

Generally, these are the services provided by a city portal, based on their providers, user groups and business properties;

- 1) Public services for residents, for example, tax services, healthcare services, police services, law services, fire-fighting services, which are provided by public departments.

- 2) Public services for businesses, for example, tax services, healthcare services, police services, law services, which are provided by public departments.

- 3) Information services, for example, phone, weather, geographic information, facility information, traffic, and hotel information services, which are provided by non-profit or for-profit businesses and are valuable for residents and travelers.

- 4) Entertainment services, for example, game services, tourist services, resort services, which are provided by non-profit or for-profit businesses and valuable for residents and travelers.

- 5) Community services for open communication and blog, for example, community for human resources, community for tourists, community for students, community for drivers, community for houses, community for religions, and so on.

These 5 categories of services are user-oriented and named for portal users. From the portal viewpoint, these services are Web services requestors and provide user interfaces for city residents usually through Internet browsers such as IE or Firefox. The requestors invoke Web services from the related applications and systems within or beyond the city scope. However, some of the portal services are not suitable or ready to be implemented by Web services invocation or composition. For example, the community services are usually local portal applications, and do not need to be developed completely through Web services. The games of the entertainment services need to be real-time and not suitable for Web services. Therefore, the mentioned portal services should be designed in service-oriented paradigm, and implemented in an evolving plan to adopt Web services.

3.3 Scheme of a city portal

As illustrated in Figure 1, a city portal can be designed into six layers, i.e.,

- 1) user-oriented service layer to provide functional services, some of which are composite services;

- 2) application-oriented interface layer to provide application integration infrastructure. It is necessary to provide a customization environment to package involved systems and applications into Web services;

- 3) data-oriented layer to organize the city and system data with unified data IDs and associations into knowledge base;

- 4) city resident-oriented infrastructure layer to provide information and city systems;

- 5) operation-oriented policy layer to set up government rules like government policies, online laws within a digital city;

- 6) IT Specifications to support communication and interaction security incurred by different layers' collaboration: Information, Security, and Data Specifications

The categorized services in Figure 1, i.e., infrastructure services, government services, public

services, and community services, will be identified in the next section.

Figure 1. Scheme of a city portal

3.4 Functional Requirements

From the viewpoint of city information, a city portal is an entryway to an information discovery and retrieval service. The information infrastructure from all city-involved systems such as space systems, traffic systems, city monitoring systems, and public systems are combined and organized at this point to form a knowledge base, including professional databases, city databases and geographic databases. The city knowledge base is managed by a single city data center. The center is equipped with intelligent information processing and mining services, network services, data security services, information storage and sharing services. The above information and management services enable the operation and cooperation of professional systems and applications on the portal.

From the viewpoint of city application, a city portal should be a service platform with integrated resources, management and composing capabilities. The portal is a unified user interface independent of businesses and

applications. It is required to be streamlined, open, and responsive, to support secure access, collaborative work, single-point entry, and integrated services. The portal will integrate the heterogeneous applications and information of city planning, e-government, e-commerce, and public services. It will provide an integrated platform and environment to facilitate the collaborative work and information sharing between professional applications, systems and residents, to provide complex services by multiple applications or systems.

3.5 Service-oriented system features

To be intelligent and on demand, a digital city should be able to accommodate, organize, coordinate, and manage all available resources, including city information, systems, services and users based on an integrated platform. Generally, a service-oriented city portal should apply a service-oriented paradigm and implement the following system features by service-oriented architecture:

1. Loosely coupled between different city applications and systems. There are not predefined contracts between city services or service providers. Services can be replaced to upgrade, change providers or reengineer processes.

2. Service discovery and matchmaking. A city portal can use service registry to find new provided services.

3. Service composition based on process modeling and optimization. A city portal may construct new applications or services by dynamically recomposing the available services.

4. Process management and monitoring. A city portal should be equipped with a process management and execution engine to monitor service performance and quality.

5. Rapid integration between distributed and heterogeneous applications. A service-oriented city portal can use open Web services protocols to interlink and integrate city applications by setting up interaction policies between the services by their providers.

6. Business information transfer, aggregation and sharing with sophisticated secure considerations. Data-level integration is one of the important performances for a city portal. The distributed data can be packaged into data services and composed to attain a unified and integrated data or knowledge resource for residents.

7. User management. User authorization and management mechanism is a prerequisite for information sharing and access control in a city portal. A unified user register and a global user database should be designed to manage service and information access.

8. Security infrastructure. A city portal needs a set of security policies and supporting tools to secure the provided services and their data intercommunication. Service-level security and privacy techniques should be implemented as well as communication and application levels of security infrastructure.

9. Quality and performance. A city portal should be open and interoperable to integrate systems and applications from different vendors. This work assumes that SOA and Web services are efficient in ensuring that the portal performs with flexibility, interoperability, scalability, robustness, etc.

4. A Service-Oriented City Portal Framework

A service-oriented framework for city portals has been proposed to meet the presented system and functional requirements. The framework is designed to identify the basic architecture, service categorization, and implementation considerations.

4.1 Service-oriented architecture of the portal

Service-oriented architecture is applied to implement the presented functional and system requirements of a city portal. As shown in Figure 2, data is collected from city systems and applications and formed into an information and knowledge base. The information is organized, stored and provided as data services for city systems and applications or for portal users oriented services directly. The system and applications are packaged into Web services to be invoked by user-oriented portal services (Web services requestors). The portal services are implemented through composing the Web services. With the UDDI registration service, the user-oriented portal services are able to discover service candidates and choose according to the pre-defined criteria. Based on this policy, Web services are kept emerging with new systems and applications are developed and published as Web services, or packaged into Web services by city portal engineers.

Figure 2. Architecture of a digital city portal

4.2 Collaboration-oriented service identification

It is a challenge to identify the services involved within a digital city. City is a wide concept and a digital city could consider, integrate or provide as many services as the users require. The system users within a city include communities, businesses, public departments, residents, travelers, public officials, and professionals. The services provided could be data, information, and services. The providers could be for-profit or non-profit. In this work, we set up a basic policy for service identification considering the services should be open for partner/client invocation, suitable for being composing with partner services and dynamic process reengineering, secure for exchange data between Web service providers and portal service requestors. There are four types of services identified and categorized based on this rule, as follows,

1) Infrastructure services: Certificate Authorization Services, Electronic Data Exchange Center, UDDI services, ...

2) Government Services: Taxation services, Welfare Services, Firefighting Service, Business Registration Services, Environmental Services, Police Services ...

3) Public Services for residents and businesses: News Services, Traffic Services, City Monitoring Services, Vehicle Services, House Services, Power Services, Map Services, Yellow Page Services...

4) Community Services: Security Services, Electronic Services, House Services, ...

4.3 User interaction model of a portal

A city portal is used by both regular users with no programming background and technical users developing all kinds of applications. In the proposed framework, the user interface of a city portal is composed of portlets that are managed by a portlet container. User-oriented services are invoked by the portlet. Portlets can be composed to form portlet services. Some services are composed of other services. A concept model for the city portal is illustrated as Figure 3.

Figure 3. A concept model for the city portal

4.4 Services and processes implementation

The services can be separate and provided by a single provider or composites of a number of services from different providers, public or proprietary, information or processes, business to business, business to residents, government to business, or government to residents. To implement such a diverse and complex portal, we use SOA to design the portal architecture, use Web services to provide user services, and use Web services oriented technologies to integrate the applications, coordinate the systems and aggregate information.

It is a prerequisite to identify the services, applications that provide services, service collaboration mechanisms, and information policies. With the identified services and service processes, a streamlined portal layout and user interface are another concern to make the portal a success. Besides the collaboration and integration between services, there are also concerns with data-level aggregation. One of the reasons for data integration is that there are many information services, which are functional based on an aggregated database. The involved data are more suited to being aggregated rather than integrated by service composition. Therefore, there will be several large-scale city databases or knowledge bases, for example, public security knowledge base, public city knowledge base, and city geographic knowledge base, as shown by Figure 2.

There are a number of key techniques and tools that need to be developed in order to implement the city portal. The collaboration models among popular city-related applications and systems are valuable for making the portal a reality. The adapters to connect city applications are a prerequisite for Web service based integration and collaboration. Process modeling techniques and tools are another key for service composition to provide the most powerful services. To this end, it is necessary to investigate the possible city services, processes and the involved systems and applications, and find their collaboration mechanisms, information flow logics and rules, and security issues.

To support the portal development, we have developed a service-oriented city development platform based on our previous work [9]. The platform is equipped with the described tools and services, and can be used by the portal designers and developers to facilitate the portal development and maintenance, as will be introduced briefly in the following section.

5. Collaborative Development Platform for City Portals

5.1 The Collaborative SOA Development Platform

To implement a city portal as proposed, developers need to capture business requirements and incorporate them into IT systems. Two roles are usually involved in digital city planning, design and implementation, i.e., business engineers and technical engineers. Business engineers communicate with city managers and residents to identify business requirements. Technical engineers have the knowledge of information technologies and approaches to support the portal. The problems with the communication and understanding among the business and technical engineers exist because they express their points in different languages. SOA aims to bridge the gap between business and IT. A unified and collaborative platform is therefore valuable, especially in implementing service-oriented city portal.

Based on the above observations, we have proposed and implemented a multi-model driven collaborative development platform for service-oriented e-Business systems. It supports top-down business planning and bottom-up service-oriented development. The platform supports service-oriented software engineering and application development. The proposed platform is, in itself, driven by three models, i.e., service meta-model, process model and business model. In addition to these three models, a service model is designed to support semantic service description and operations, a process model supports the consistency between business process and Business Process Execution Language for Web services (BPEL4WS), and a business model considers services, providers, adapters and their relationships for specified businesses. Please reference the literature [18] for details of the platform.

5.2 The Customization for Development of City Portal Framework

In this work, we have customized the platform to fit the development of city portals. As stated in 4.2, we identified five kinds of user-oriented services for the city portal framework. When city portal users log on the portal, they should be provided with different user interfaces according to their rights. When users operate on the portal, user-oriented services are invoked to fulfill the users' requests.

SOA development platform should be customized to assist in the development of user-oriented services of city portal. The development of user-oriented services involves business modeling to capture user's needs and business processes, process modeling for service orchestration and service development. The following will customize the SOA development platform from those aspects.

The SOA development platform provides a business view for business engineers. The functional requirements of city portal users are identified and

modeled by business engineers with concepts of services which can be easily understood by portal users. To assist this modeling, commonly used services concepts in the city environment should be identified and stored in the SOA development platform. The users' requirements are often embedded in business processes accomplished by different entities and their interactions. Typical city processes are stored in the SOA platform for use by portal developers. Through city portal entities and typical city processes, the business view of the SOA development platform is customized as a business view of a collaborative development environment for the city portal. A business engineer can use the development environment for the city portal to quickly capture the needs of the portal users..

The city business processes are further transformed to an IT process by the SOA development platform. The portal developer could adjust the IT processes and add more information to invoke corresponding services. To assist this adjusting, commonly used city services should be stored in the SOA development platform. The service view of the SOA development platform provides service-modeling tools, which should be customized to assist different levels of city services development, such as data accessing and legacy system packaging.

The lowest level of services is related to aggregation of city data. During the development of a city portal, city data needs to be analyzed and aggregated in the city knowledge base. A large-scale city database should be aggregated with unified data IDs. Data services should be developed to assist in the information layer development of the city portal framework. These services can be modeled and developed in the services view of SOA development platform. However, there are common services in all kinds of city knowledge base, such as unification of data ID, information storage and retrieval. These services should be identified and stored in the SOA development platform to assist in the development of the information layer of the city portal framework.

The second level of services relates to existing systems and applications. In the application interface layer of a city portal framework, involved systems and applications, such as space systems, traffic systems, city monitoring systems, and public systems, are packaged into web services. Although existing systems vary greatly in different city portals, or we can develop adapters from scratch in the SOA development platform, there are many foundational services that are common to all. For example, no matter which GIS system is used in a city, the adapter for the GIS systems returns the location of target. These common services should be identified through investigating the systems that are valuable for a city portal. The rules are to facilitate Web service based service integration and collaboration. The customized SOA development

platform with these adapters will be more suitable for the development of a city portal framework. The variation of different vendors of common system is shielded, and the portal development would be more consistent.

With these services, new services could be developed to meet the needs of the city portal. The portal developer could adjust IT processes to invoke these web services. The corresponding BPEL process would invoke these services to fulfill the business goals. The BPEL process itself is packaged into user-oriented services to be called upon by city portal developers.

These services are stored in a service repository of collaborative development environment for the city portal and registered using the registration service of the SOA development platform. When developing a city portal using the customized platform, developers can use the registration service to discover these services that form service layer of the portal.

All these services should be managed. As shown in Figure 2, security services are provided in the data, network, application and service levels, which provide the foundation for the security layers of a city portal development.

5.3 Benefit of the Collaborative Development Platform for the City Portal

Based on the proposed architecture and design policies, the collaborative development platform for the city portal has been implemented by customizing the SOA development platform with city portal entities, typical city processes, common knowledge base services, common adapter services and security services. The development of the information layer, application interface layer, service layer and security layer of the city portal framework is supported by the common knowledge base services, common adapter services, and model transformation of the collaborative development environment for the city portal.

The platform provides views and modeling tools for city portal business design, service-oriented process design, service design, service packaging, service adapter. Further, templates and common services are developed for city portal development and improvement. The efficiency and time-to-market could be greatly improved when city portal engineers integrating emerging city applications and data to provide new services with the tools and facilities.

With the customized development platform, different background of city portal engineers can work efficiently. The business engineers of the city portal framework can capture the users' needs rapidly and portal rollout is easy to conduct. The portal developer can communicate more easily with the business engineers so that the developed city portals could be user-friendly and well meet the business requirements.

6. Case Study and Evaluation

This work is supported by the Shanghai municipal government to provide a technical reference in designing an integrated portal for a brand-new city, i.e., Yangshan Digital Port City. The new city is developed based on China's economy strategy and Shanghai's city plan. It will become a satellite city with modern equipment manufacturing as the major industry, high-profit advanced manufacturing and high technology businesses as intended industries, such as modern logistics, research and development, export-oriented production, and education and training.

A variety of information systems will be developed for the construction and management of the city. The new city needs a long-term plan and portal program for its information infrastructure and city-related businesses such as e-Commerce, e-Government, and public services. The systems and applications involved may have heterogeneous data, structure, and technologies. Service-oriented architecture and Web services are well-recognized technologies to make the systems to be integrated into the city portal for city services, and enable loosely coupled application integration and collaboration among different city service providers and requestors.. Comparing the complicated information and application integration issues in the cases of existing cities, it is a feasible case and an opportunity for applying and evaluating the proposed service-oriented city framework.

The city portal is required to design and meet the city architect, municipal and functional plan, and service-oriented provisions by public departments. It should be an integrated and personalized platform, which is

independent of all of the city systems and applications. The platform will be developed with a UDDI service to support service-oriented operation and with a user registry service and database to provide personalized service and data access. The service-oriented portal is designed to be able to interlink newly provided services. However, the city is under construction and there are no existing information systems to be integrated. Basically, the case study in this work is a start-up concept design and a solution to be referenced by municipal information officers. The architecture and city services are those presented in the above sections. The security and privacy specifications have been assigned to another parallel project.

The design will be discussed on a common application, i.e., intelligent traffic service, which has been specified by the city officers in the supporting project. The service will be developed on the customized collaborative development platform for city portal. It is a route search service as a public service for residents on the portal. The architecture for the case is shown in Figure 4. The search service is a Web client of an intelligent traffic system, and the traffic system invokes GIS services to get traffic locations. A UDDI service is used to support GIS services discovery and update. The traffic system has been packaged into a Web service and the browser is a user-oriented client to provide search service. In the scenario of this case, there are 10 interactions for a resident to visit the portal and look up the location of "The Bund", as shown in the left dialog of Figure 6. Figure 5 is an interaction diagram of the case.

Figure 4. A case study of traffic service for a digital city

Figure 5. An interaction diagram of the case

1. The resident submits a search request to the intelligent traffic system through its browser client,
2. The traffic system service looks up the UDDI service,
3. The UDDI service responses with available GIS services,
4. The traffic system service chooses and invokes a GIS system service,
5. The GIS service responds with the location of “the Bund”,
6. The traffic system service provides the location to the resident,
7. The resident resubmits the location to search for the route to “the Bund”,
8. The traffic system invokes the GIS service with the location,

9. The GIS service responds to the traffic system service with the route,

10. The traffic system service responds to the resident with the route.

The resident can repeat the above search to get more results. Figure 6 and Figure 7 illustrate the case development on the service-oriented collaborative platform. Figure 6 is a snapshot of the modeling of the service-oriented business scenario of the search service. The left of Figure 6 is BPEL4WS-based process modeling of the search service, in which the intelligent traffic service is modeled as a process service. To the right of Figure 6 are actions during the search process. The platform has been evaluated and certified with the above case by an authority located in Shanghai.

Figure 6. A multi-model driven collaborative development platform for service-oriented e-Business systems

Figure 7. BPEL4WS-based process modeling of the search service and actions during the search process

7. Conclusions

A digital city should be responsive in real time, flexible in cost structure, and secure among the service providers and requestors in order to meet the residents' needs and the changes in the technology landscape. The business integration solutions are the key enablers to make on demand business a reality and deliver business values to the customers. Therefore, it is important to have a set of appropriate integration technologies, e.g., SOA/Web services to support the on demand cities. In this work, we consider, from an implementation point of view, how the on demand cities can be implemented efficiently and effectively using the service-oriented paradigm and Web services technologies in order to meet the needs of the residents.

A service-oriented city portal is an efficient infrastructure to facilitate the collaborative work and information sharing between professional applications, systems and residents. A service-oriented portal framework for digital cities is proposed to apply service-oriented architecture and Web services into the planning, design, implementation and integration of digital cities. The goal is to make cities responsive and provide powerful services to their residents. A model-driven collaborative development platform has been developed to facilitate the development of the portal development of the city framework. A special service for a digital city, i.e., traffic search, has been developed and evaluated on the platform to integrate intelligent transportation systems and GIS systems.

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