Service Process Modelling and Performance Analysis for Composite Context Provisioning in IoT

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Abstract: *The recent increase in the research interests towards a smart life style has introduced a huge number of devices into our life. Some devices are being used by us such as the smart phones while others are most of the time invisible to us such as proximity sensors and light sensors etc. These devices are being interconnected via Internet and are being utilized to read an environment, detect patterns and predict or forecast some events. Sharing the data and information collected by these desperate devices to clients over the Internet is called as Provision. Due to disparity in the hardware and software platforms for sensing devices, the provisioning services are also limited to providing contextual data based on single provider and there is no generic process model which can be utilized for composite context provisioning from multiple providers. This paper presents a service-oriented process model for composite context provisioning. A step by step explanation has been provided for each process involved and performance analysis has been carried out using a prototype implementation of the model.*

Keywords: *Composite context, provisioning service, sensing, data collection, service-orientation.*

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1. Introduction

The modern world of information and technology has evolved tremendously in the past decade. Smaller devices capable of extremely high computing powers and equipped with efficient communication technologies such as smartphones are being used a daily commodities. These devices are ever growing in numbers and are being reduced in size and energy requirements. The phenomenal advances in material sciences and electronics have enabled these smaller integrated devices to read physical phenomenon happening in the environment around us. These environmental phenomenon in the form of parameters such temperature, humidity etc., or human activities in the form of motion, acceleration etc. are converted into digital readings through these devices. The recent introduction of wireless sensor networks, actuator networks and Radio Frequency Identification (RFID) platforms have enabled collections of these devices to acquire the contextual data regarding any environment. On top of these networks, Provisioning services are defined in order to make this data available to the many applications used for environmental monitoring [12], industrial automation [5] and human-centric applications such as smart homes [18].

According to the study performed by Zaslavsky *et al*. [20] the deployments of sensors for various applications have increased dramatically in the last five years. According to [13], the introduction of concepts such as Internet of Things (IoT) [19] and Smart Cities (SC) [3] have attracted the attention of research both from industry and academia. This focus of attention has implicitly added to the increased production and consumption of smart devices. The population on the planet has already been outnumbered by the smart and connected devices in 2008. According to the estimation by European Commission, in 2020, the number of these devices on the planet will grow above 50 billion [13].

Context acquisition applications are used to collect the data from sensors which are deployed at locations specified by the application's data collection requirements. The acquired contextual data is then normally sent to some central point for further processing or storage and analysis. Wireless sensing has gained more attention due to the recent improvements in the short and long range wireless communication technologies along with the ability of wireless sensing networks to work in scenarios where wired networks would fail. Such scenarios include the environment around a volcano [8, 15] or wildfire [7] which may destroy the wired infrastructure. Similarly, rodents inside buildings or wild habitats have also been suggested as threat to the wired sensor networks by [4, 6, 14, 17] respectively. On the other hand, wireless sensor networks have their own delimits in the form of limited or no processing power at node level and limited power source. Once deployed, such devices can operate only for a specific duration of time because of the limitation of energy resource. Once the battery expires, the sensing node is useless and often it is not possible to change or recharge the battery. Still wireless sensor networks are more popular for data acquisition and studies have been carried out to improve their performance [2, 11, 16].

The large numbers of devices being produced presents hardware level heterogeneity. This heterogeneity in the hardware architectures and communication technologies makes the context acquisition process an active challenge for the research community. Although, there are more than enough active and operational examples of data or context acquisition via these sensing devices but most of these solutions are application and scenario specific. We still need to have a generic platform and process model which could generalize the context acquisition process.

Service oriented architecture is one of the best suited candidates for providing such a general platform. Many studies have utilized service-orientation to include the inherent flexibilities of this paradigm to their sensor and actuator networks [1, 10]. A basic study regarding our service oriented system has been presented in [9] where the context a cquisition from desperate sensing devices through a provider based model has been presented and the performance of context provisioning at service layer is performed.

This paper proposes a service-oriented process model for composite context provisioning via the application layer. The main features of the proposed model includes the composite context from multiple providers based on service mashup, abstraction of the underlying heterogeneity due to the different hardware technologies of the sensing nodes, Centralized processing of the acquired context, In-network virtual representation of the devices and data and provision of acquired context to users at multiple levels in the system hierarchy. This paper presents performance analysis of the proposed model in terms of a composite contextual data provisioning service and its comparison to the simple context provisioning service of the previous implementation [9].

The rest of the paper is organized as follows. Section 2 presents a brief overview of the context acquisition platform in terms of the layers and major functionalities performed at these layers. Section 3 presents the service-oriented process model for composite contextual data generation and provision with explanation of all the processes involved. Section 4 provides a brief description of the development technologies used to implement the model. Section 5 describes detailed illustration of the experimental setup for the performance analysis of the proposed model along with the description of the results. The performance of composite context provisioning service is also compared with the simple context provisioning service results. Finally, section 6 concludes the paper.

2. Composite Context Provisioning Architecture

Figure 1 describes the underlying architecture for the provisioning of the composite context. The architecture has been presented from the perspective of general service-oriented context acquisition in [9] and is described in detail. In order to illustrate the operation of the presented provisioning service, the architecture will be described briefly as follows.

Physical layer is where all the hardware for the collection of information related to any context resides. The nature of this hardware may be highly heterogeneous due to the underlying communication and operational platforms of different devices.

The middleware layer consists of gateways to provide connection points for the hardware devices. The gateways implement interfaces for communication and interaction with the hardware devices. The middleware provides an abstraction layer from the heterogeneous collection of sensing hardware and provides a uniform interface to connect and acquire data produced by the sensing devices.

Middleware utilizes the services exposed by respective providers at the service layer to forward the collected contextual data. Using the service interfaces, the middleware gets the information regarding the registered devices from the service providers and configures itself. The collected contextual data is forwarded to the corresponding service provider where the data is stored at a repository with a predefined schema. The repository also holds the information regarding the type, model etc. of the registered sensing hardware.

The information and sensing, state data at the service layer creates a virtual representation of the hardware devices in the system which reduces the actual communication overhead with the physical layer. As shown in the figure, it is not important for a service provider to have an associated middleware. The service provider can be an individual entity in the system which generates information in the form of a service and based on the users' needs. An example of such an entity would be map service provider, which has its own graphical data divided into buildings, floors, spaces etc.

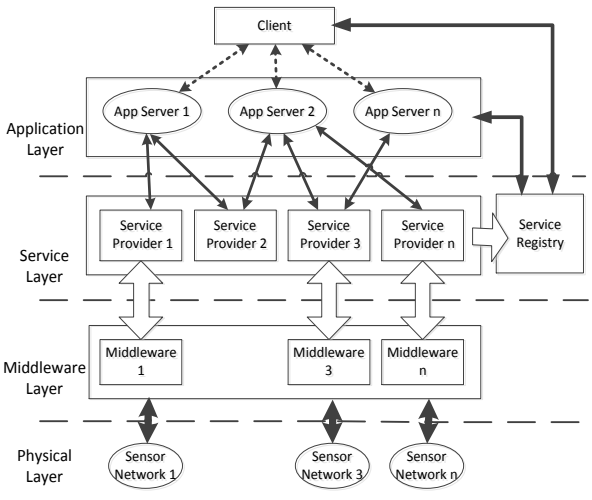

Figure 1. IoT architecture for context acquisition.

Interfaces termed as provider services are exposed at the service layer in order to enable clients to connect with the providers and be provided with the data stored in repositories. In order for clients to choose the required provider services, a service registry module provides interfaces for publishing and searching services. The service providers utilize the publish interface to register their service information while the clients use the search interface to find and utilize their required services. The addition to the previously presented architecture and the idea in this article is the provisioning of composite context in terms of multiple bound services at the application layer.

The binding of services means that a composite schema is defined at the application layer to store the data from user selected services as composite contextual data records. These bound services are exposed as a single service interface at the application layer and published for utilization by the users through the service registry. Now the clients of the system will be able to select individual services exposed by a specific provider or the composite services exposed at the application layer.

3. Service-Oriented Context Provisioning

This section describes the processes involved in the generation of composite context but in order to understand the operation of the overall system, a brief description of all the processes involved at the different layers of the system will be provided. A detailed illustration of the composite context generation and provisioning service follows the brief descriptions of the basic processes.

3.1. Configuration Process

The service setup or the configuration process performs the initial setup of the system modules. The configuration/setup process involves the Sensor management module, sensor service provider, service registry module and application server management module. The process takes place in the following sequence.

Sensor management module at the service data and management layer is responsible for the creation of sensor information (ID, Type etc.). This information is stored in the sensor service provider's data repository at the service layer. The sensor management module creates the sensor provider's service information registers the sensor provider's service to the service registry module at the service layer. The published service is now available to be searched and utilized by the clients as well as other components of the system. Every service provider at the service layer follows the same procedure to make their provider services available to the clients through the service registry at the configuration step of the system.

3.2. Service Publish Process

Publish service is the interface provided by service registry module for providers and application servers to make their service exposed to the clients. Using the publish service interface, the provider's service information xml is stored at the service repository at the service registry from where the clients can select and utilize it using the search service. The management modules for providers and application servers create the information regarding their respective services in the form of an xml file. This information is then sent to the service registry module using the publish service. The service has the necessary implementation to send and store the provider service information at the information repository at the service registry module. The clients may then search and utilize the registered servicesusing the search service interface.

3.3. Search Process

The search service is exposed by the service registry module and it must be implemented by every client in order to search services based on the keywords they provide. The search service process involves the interaction between application layer and the service layer. The provider services are registered with the service registry module in the form of xml service information. Using the search service, the clients can get access to provider services and utilize these services. The provider services deliver sensor or related data in the raw form while the application server provider services, which are composed of the individual provider services and can provide composite data from multiple service providers, may also be accessed and utilized using the same search service.

3.4. Composite Service Creation Process

The search and publish services exposed by the service registry module are used by the providers at the service layer, the management modules and the clients at the application layer. The application layer searches the available services exposed by the providers and these services are used to create composite services which in turn are used by the clients to acquire composite contextual data for their use. The process of creation of a composite service is illustrated in Figure 2.

The application server management module searches the provider service information in the service registry module and sends it to application server provider to enable the administrator to create composite services. For example, context acquisition in an indoor environment, the integration of sensor service provider and space information provider is performed in order to enable the clients to acquire sensor data combined with the space visualization where the sensor are collecting data from.

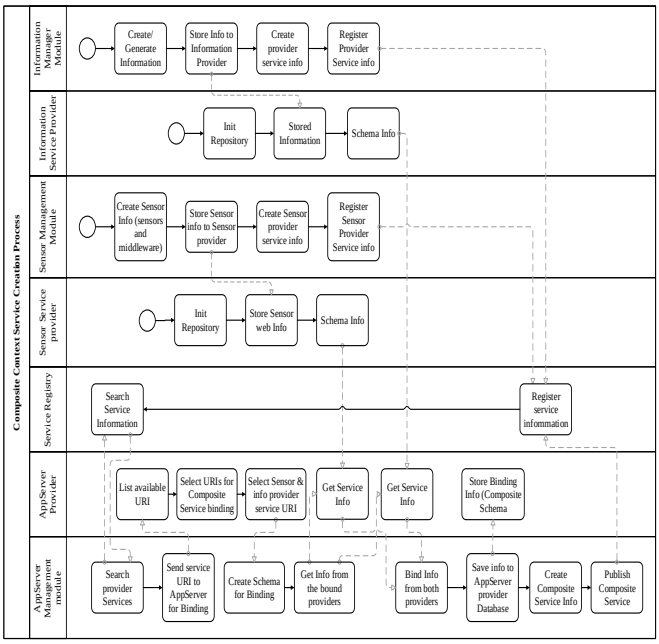

Figure 2. Composite service creation process.

In order to enable an application server to host composite data from multiple providers, a composite schema must exist. The management module provides the functionality to create the composite schema. As shown in the figure, the application server provider contacts the respective service providers for which the services have been selected to create a composite service. The information schema is provided by the corresponding providers and this information is used to create a composite schema. The composite schema acts as an integrated reference to all the information from multiple providers that would combine to create a record of the composite contextual data.

This schema is associated with a new service reference created by the application server management module and is exposed for utilization by the clients through the publish service interface. This composite service is now available for the clients to be searched and used for composite context acquisition without the need to maintain multiple services references in the client application as well as the need to process data for integration purposes.

3.5. Composite Context Provision Process

Once the composite service is published to the service registry, clients can search and utilize the service. The application server exposing the composite service is now able to provide composite contextual data to the clients using this service.

Figure 3 provides a step by step illustration of the provision service utilization by the client.

Client searches the composite service reference from the Service Registry and establishes a connection with the associated application server. The server in turn gets the service providers' service references from the composite schema and acquires data from each of those providers. The acquired data from multiple providers is then integrated according to the composite schema and integrated data object is forwarded to the client of the composite service.

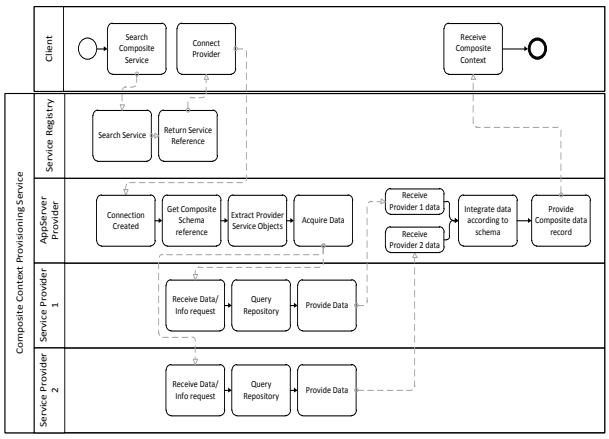

Figure 3. Composite context provision service.

4. Implementation

The service interfaces in this model are implemented using Windows Communication Foundation (WCF) technology in the .Net framework. The data and service repositories are implemented using SQL server 2010. The data requester for the utilization of the services and data is implemented using Microsoft Silverlight.

5. Performance Analysis

5.1. Experimental Setup

Table 1 summarizes the hardware specifications and software platforms used to carry out the performance analysis of the composite context provision service. Figure 4 presents the experimental setup. This setup is focused towards the performance analysis of the new service and ultimately to compare the results with the previous analysis hence, the setup is kept similar to the previous experiment.

Table 1. Hardware and Software specifications.

	Middle ware	Service Provider 1 & 2	App Server	Data Requester
Operating System	Windows 07	Windows 07	Windows 07	Windows 10
Development Environment	.Net Frame work 3.5, 4.0	.Net Frame work 3.5, 4.0	.Net Frame work 3.5, 4.0	.Net Frame work 4.5
Development Tool	Visual Studio 2010	Visual Studio 2010	Visual Studio 2010	Visual Studio Community
Programming Language	C#, XML	C#, XML	C#, XML	C#, XML
DBMS		SQL Server 2010	SQL Server 2010	
Hardware	CPU: Intel® core 2 Duo 2.9 GHz RAM: 4 GB Graphic: 8400 GS	CPU: Intel® Xeon ® 2.4 GHz RAM: 4 GB Graphic: 9600 GT	CPU: Intel i5-4570 3.2 GHz RAM: 8 GB Graphics: GT 440	CPU: AMD A08 2.4 GHz RAM: 4GB

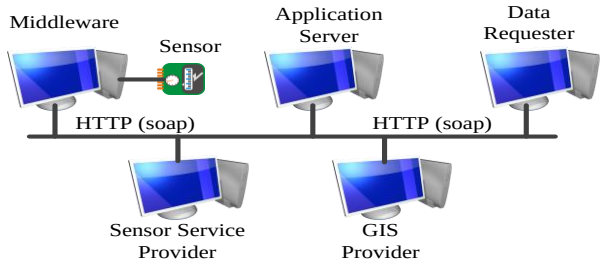

Figure 4. Experimental setup.

A special data requester module is designed for the sake of the experiment to simulate the behaviour of single and multiple clients requesting composite context data. The composite context provision service is utilized by the data requester to acquire data from multiple service providers via a single service channel through the application service provider. As the main focus of this study is to analyse the performance of the composite context provisioning service, the results from the previous study must be included to compare the performance results. The performance evaluation results for context provisioning from the service layer (individual Provider) [9] are shown in Figure 5 while the results for the composite context provision service have been described in the next subsection along with a comparison between the previous and the new results.

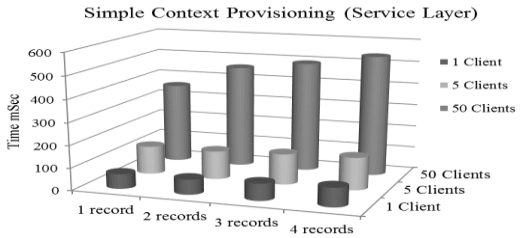

Figure 5. Performance evaluation for simple context provisioning at service layer.

5.2. Results

The graph in Figure 6 shows the performance evaluation for the composite context provision service, through which the clients can access integrated context composite data from multiple service providers by consuming a single composite service reference from an application server. Graph in Figure 6 shows the delay in milliseconds for 1, 5 , and 50 clients to simultaneously request 1 to 4 records of composite contextual data records and get the requested data. All the results are average times delay for 20 executions of the experiment. The average time taken by 1 client to request and receive 1, 2, 3, and 4 records of sensing data through the provider service is 78.2 ms, 79.3 ms, 83.9 ms and 96.2 ms respectively. For 5 clients requesting simultaneously, the average time of request and receiving back 1, 2, 3, and 4 records of the composite context data via the application Server is 133.8 ms, 130.5 ms, 152.5 ms and 190.6 ms respectively. Similarly, for 50 clients requesting simultaneously, the average time to request and receiving back 1, 2, 3, and 4 records of composite context data is 397.8 ms, 419.2 ms, 502.3 ms and 590.2 ms respectively.

For comparison purpose, the average delay for an individual record of contextual data provided from the individual service provider has been plotted against the individual record of composite contextual data provided from the application server.

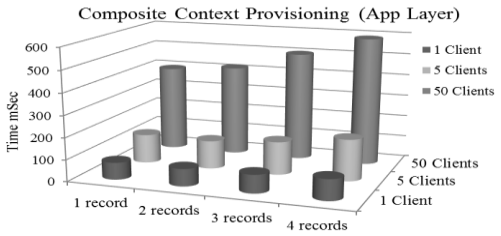

Figure 6. Performance evaluation for composite context provision at Application layer.

The average time for the provision of a single record of data was calculated separately for cases when provisioning was made to 1 client, 5 clients and 50 clients simultaneously. The plotted data is shown in Figure 7, which clearly indicates the performance for normal context provisioning service and the composite context provisioning service is almost similar. Although the graph in Figure 7 does not show it but the useable data received by the client in the form of composite contextual data record is double as compared the data received from an individual provider. This indicates that the performance of the composite context provisioning service is twice as better as that of the normal context provisioning service.

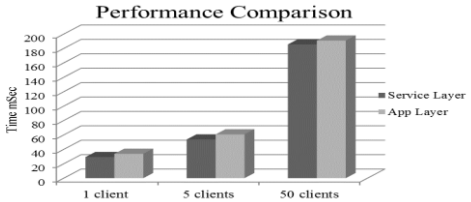

Figure 7. Context provisioning service performance comparison.

6. Conclusions

This paper presented a service-oriented model for composite context provisioning in scenarios related to IoT. The model has been divided into separate services an-d each one is explained as a separate process in the form of process model diagram. The proposed model supports utilizes the service-orientation to generate composite context provisioning service model. Apart from providing an in-network virtual representation information & data of the hardware devices producing contextual data, the composite context provisioning service relieves the clients of maintaining multiple

services references and additional processing power for the integration of contextual data from desperate providers. The presented model was implemented using WCF in. Net environment, tested for performance and the performance of the composite context provisioning service was compared to the previous implementation of context provisioning service based on single provider service.

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