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Knowledge Driven Architectural Model to Support Smart Emergency Service in Web of Objects Based Iot Environment

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Abstract

Virtualizing The Physical Devices And Resources As Well As Conceptual Entities Would Form Vos And Cvos, Which Provides Dynamicity And Intelligence Through Composition And Collaboration For Emergency Services In WoO Based Smart Shopping Mall (WSSM). Semantic Ontology In WoO Platform Supports Dynamic Composition And Collaboration Among Objects, VOs And CVOs To Provide Intelligent Services. This Paper Proposes An Architectural Model Of WoO Platform To Support The Smart Emergency Services In Shopping Mall. A Semantic Ontology Model For Wssm, And Information Reusability And Interoperability Among The Vos And Their Functional Models Have Been Presented.

Key Words : IoT, WoO, semantic ontology, smart emergency, VO, CVO

Ⅰ. Introduction

Recent advancement in the IoT[1] accompanies a smart life where real world objects including sensing devices are interconnected with each other. The Web representation of smart objects empowers innovative applications and services for various domains. To accelerate this approach, Web of Objects (WoO)[2] focuses on the implementation aspects to bring the assorted real world objects with the web applications. In this paper, we present a smart emergency service for shopping mall in the WoO based IoT infrastructure.

The general goal of the WoO is to simplify object and application deployment, maintenance and operation of IoT infrastructures. WoO also aims to provide knowledge based IoT service by enabling object virtualization, semantic ontology based service composition and collaboration. In its implementation WoO platform[2] supports semantic modeling of objects, and plays a distinguished role to achieve thinking intelligence with objects of sensors, devices, resources and information.

The heterogeneity of objects in WSSM and its application leads to adapt itself with WoO platform. WoO incorporates the application development and flexibility of access from the Web and grips the highly interconnected objects facility. [16] indicates that WoO also provides common platform for IoT applications. On the other hand WoO supports semantic modeling of objects. Vast range of web accessible information and services are exploited efficiently using semantic ontology. A semantic ontology defines common vocabulary to share information in a domain that includes machine interpretable definitions of basic concepts in the domain and relations among them. In this paper, we have developed the semantic ontology model for

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WSSM to share common understanding of the structure of information, to reuse and analyze the domain knowledge, and to separate domain knowledge from the operational knowledge.

The article presents an architectural model to provide a smart emergency service features deployed in WoO based smart shopping mall. The functional capabilities to achieve knowledge based intelligence are focused on semantic ontology model involved in collaboration of objects as well as composition of required objects dynamically.

Ⅱ. Related Work

Several attempts have been explored for incorporating the real world with the applications and services. SODA (Service Oriented Device & Delivery Architecture)[3] is an adaptation of a service-oriented architecture (SOA) for designing and building distributed software to adapt a wide range of physical devices into disseminated IT inventiveness systems. ITEA2 OSAMI common[4] project have shown the basic design of SOA (service oriented architecture) oriented platform. This knowledge can be applicable in the context of the global roadmap of the WoO.

DiYSE[5] is another approach that is easy to use for normal users but rarely suitable for professionals. And the user context identification is provided by BUTLER in the real world[6]. Enhanced model using resource and relation of entities through creation of IoT service have been addressed by IoT-A[7].

The SENSEI project[8] designed a system that provides a service of network and information management that enables reliable and efficient context information to be used in the environment with heterogeneous Wireless Sensor and Actor Networks (WSANs) into a global framework[9] proposes virtual objects of cognitive management framework and associated functionalities for IoT. SOCRADES[10] suggests new methodologies, technologies and tools for the modeling, design, implementation and operation of networked systems made up of smart embedded devices.

[11] has proposed a service architecture model to support intelligent features through objectification and virtualization of the physical things, and a semantic ontology to ensure the information reusability and extensibility among virtual objects.

Object virtualization and service composition through semantic ontology in WoO play an important role to integrate physical world and the virtual world. [12] has proposed a WoO based user centric service composition model by showing a use case in IoT environment.

An architecture using learning algorithm to build user profile has been presented that extracts characteristics from user habits [13]. The architecture used wireless sensor network to monitor physical parameters and the presence of user. From the gathered sensed data, user's profile has been created such that the data can be set as system parameter automatically.

Activity and context recognition are the main challenges for implementing the smart shopping mall. Sensing based recognition has been used in the semantic ontologies. A real-time algorithm for automatic recognition of physical activities has been proposed [14]. Human activity recognition has been proposed based on the actual semantics of the human's current location by focusing on the association between things and human activities with the things[15].

A semantic ontology model for WoO based home energy management system, knowledge based system that facilitate composition and collaboration of smart distributed applications that combines information from different domains in the IoT infrastructure have been proposed[16].

Ⅲ. WoO Platform Model for Smart Emergency Services

3.1 WoO Functional Model

The WoO refers to the objects that are connected to the internet, and broadly applied through web that expose the function as a method to approach a particular object. The different kinds of objects that are provided in WoO have been designed to support dynamic composition and orchestration functions for

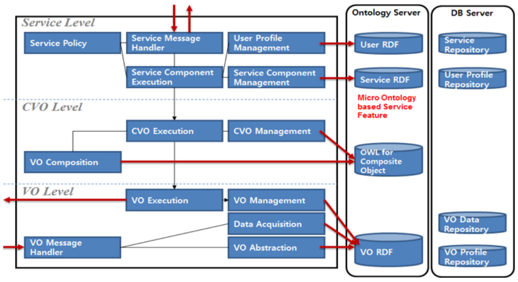

Fig. 1. Functional Architecture of WoO Platform

user-centric IoT service environment.

Fig. 1 depicts the collaborating relationship among VO, CVO on WoO platform and resource to create service function. The attribute information to characterize CVO will continuously record containing performance, time, location, profile, description, and other related data to be used in the future for information analyze purpose. The corresponding CVO entities collaborates each other in order to create a service function in response to rules (e.g., RDF and micro-ontology) defined by service designer or user. Based on this relational model to characterize service function, functional entities to express the service capability will be identified specifying one definite part of the object that obstructs serving features.

3.2 WoO Platform Architecture

The functional architecture of WoO service platform consists of three functional levels: service level, CVO level and VO level as shown in Fig. 2. The service level is assigned with executable algorithms, policy and logics that to be provided to the users. WoO service platform supports dynamic

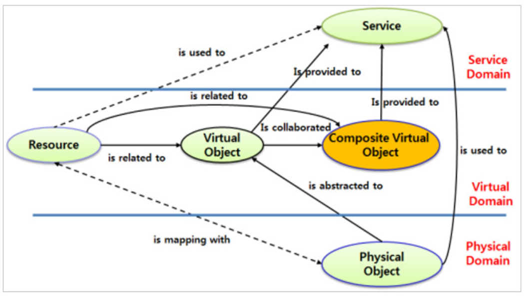

Fig. 2. Domain Relationship of WoO Ontology Model

mechanism to compose the user-centered IoT service in conjunction with semantic ontology indicating partial or full relationship among VOs. The orchestration function for smart emergency service could be designed through semantic ontology web service concept in WoO platform.

3.3 Smart Emergency Service Composition Model

Service composition system composes all the required services in the VO form according to a user's request. Fig. 3 shows semantic service composition architectural model in WoO platform. Smart shopping mall system provides a new generation smart environment for shopping mall which delivers friendly reception for customers and provides different services, such as fire alarming, digital advertising, car parking, etc. The system is facilitated to automatically compose and execute services.

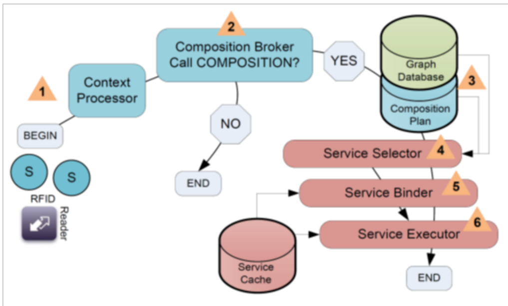

Fig. 3. A composition model in semantic service architecture

3.4 Object Virtualization

Communication among the objects in WoO requires object virtualization, thus objectification in the WoO platform is required. Physical object's resources and attributes, such as profile, resource description, sensed data, interface type, location information etc. are used for reusing, reconfiguring and recreating object with user requirements. Object virtualization enables new distinguished objects based on emergency service demand, where objects include objectified value of their attributes.

Fig. 4 shows the object virtualization process

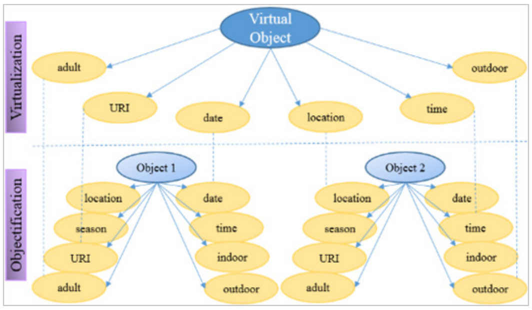

Fig. 4. Object Virtualization

from physical objects. Different attributes from different objects are combined for creating virtualized objects. For example, location of one object, date and time of other object, customer information and sensed data of sensor objects are combined to create newly specified VO as CVO that has more capability to provide services.

3.5 Service features in WSSM

Different attributes of Physical objects are used to create virtual object, packaging the virtual object with added intelligence in the virtual domain leads to knowledge base by reasoning. Monitoring and analyzing shopping mall context information, collecting environment status and the customers' location and preference as well as comparing them with the knowledge base ease the smart emergency services in shopping mall, which enables easy exchange and integration of data among interconnected smart system services. Fig. 5 shows the provided services and user notification in WSSM.

Emergency services are provided through each

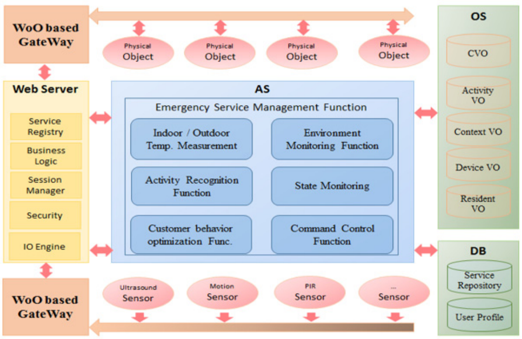

Fig. 5. Service features in SSM

specifically modified relation of monitoring, controlling, notification and automation of VO and CVO that monitor shopping mall environment, customer and guard location. The information of sensed data coming from the appliances and sensors are recorded in the history database, which would be used in case of emergency situation in order to provide better services for shopping mall. Emergency service notifies user through smart phones and digital signage as well as communicates the control service for controlling the shopping mall actuators either automatically or manually.

Ⅳ. Knowledge Driven Semantic Ontology Model

Execution of an activity in case of emergency situation in WSSM depends on its location and context. For example, safe evacuation path is provided to the user based on his/her location in the shopping mall. Ontology model for the WSSM, designed in Protégé[17] is shown in Fig. 6. Required services, context and device oriented activities recognition are the fundamental requirements for object virtualization and knowledge base in semantic ontology. Semantic ontology modeling is the basis for representing the knowledge for shopping mall in order to provide smart emergency services.

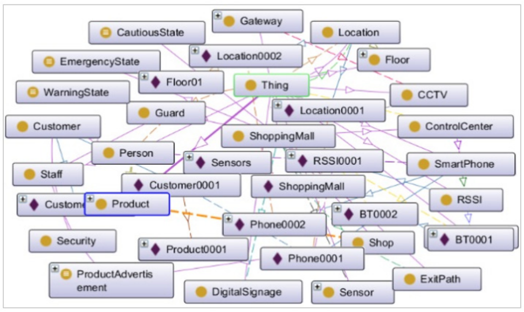

Fig. 6. Semantic Ontology Model for WSSM

4.1 Ontology Model for WSSM

Semantic ontology represents the relationship among objects containing different parts that forms composition based for reasoning. The sensors and devices located indoor or outdoor of the shopping mall gather data in a specific location. All the sensed data, status of the devices, present condition of shopping mall, customer information and location are recorded in the repository.

CVOs are created by inference engine to provide services. It depends on the recorded history, such as season, date, indoor and outdoor condition and the customer location.

Table 1 represents the objects condition where objects are identified by their identifier.

Physical objects are represented by VOs along with their properties and type. CVOs are created combining the different properties of VOs in order to determine emergency situation type and status in shopping mall to represent the knowledge and provide smart emergency services in shopping mall. CVOs are created by applying rules on VOs. Rules are created by protégé and applied on VOs by inference engines to infer new status of the shopping mall.

Table 1. Relational object's value

ObjectID	Property	Value
tempSens001	Value	25°C
customer432	Location	3,2,4
humSens001	Value	30°C
guard234	Location	3,2,1
cctv423	Location	3,5,8
coSens021	Model	Xv3fd
Co2Sens293	hasDeviceType	WoO:dt_Sensor

4.2 Defining VO and CVO

WSSM collects and measures indoor and outdoor data through sensors in order to control and maintain physical objects including actuators, digital signage, sprinkler, etc. Fig. 7 shows VO ontology model for customer designed in protégé. VOs are defined using their properties and relation with other VOs in the shopping mall.

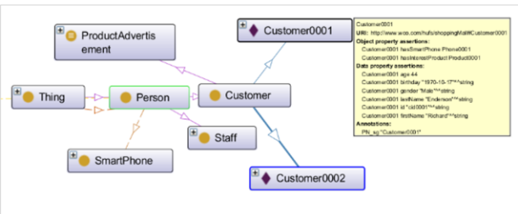

Fig. 7. Virtual Objects for Customer in WSSM

```
ShoppingMall
 and (hasSensors some
  (Sensor
   and ((hasCO2Sensors some
    (CO2Sensor
     and (sensorValue some (float[>= 1000.0f] and float[<= 2000.0f]))))
   and (hasCOSensors some
    (COSensor
     and (sensorValue some (float[>= 3.0f] and float[<= 4.0f]))))
   and (hasHumiditySensors some
    (HumSensor
     and (sensorValue some (float[>= 20.0f] and float[<= 30.0f]))))
   and (hasTemperatureSensors some
    (TempSensor
     and (sensorValue some (float[>= 40.0f] and float[<= 55.0f])))))))
```

Fig. 8. Class Expression for Emergency State

VOs collaborate to create CVOs which are used to represent shopping mall status. CVOs are created by applying rules and inference on different VOs of WSSM ontology model. Fig. 8 shows class expression [18] to create Emergency State CVO in WSSM which is self-explanatory. Sensors value and predefined threshold rules are used to define different states CVO, which is used to analyze shopping mall status.

V. Knowledge Based System for WSSM

Knowledge acquisition, representation and application are the key factors in a knowledge based system that lies in the virtual domain. Knowledge base is update from the gathered experiences and supports semantic ontology by reasoning[19]. A knowledge based system includes two subsystems which are knowledge base and inference engine as shown in Fig. 9. Knowledge base represents VO and inference engine represents logical condition regarding VO.

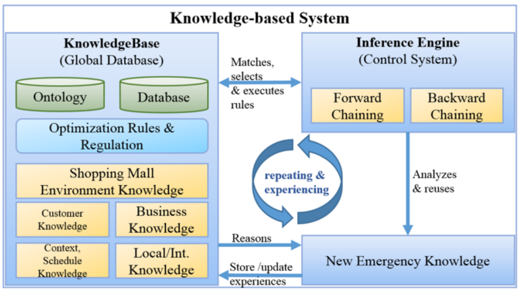

Fig. 9. Knowledge based System

5.1 Knowledge base

Knowledge base represents information in a structured way such as hierarchies of classes and subclasses, relations among classes[20]. Knowledge base learns and experiences from the individual, social environment, indoor and outdoor activities based on schedule.

The knowledge base is created in terms of individual and group knowledge; social knowledge; location and schedule knowledge; local and international knowledge[21]. Knowledge regarding individual or group is modeled by individual or group as a team experience, which is created by the relation with other individual or group that is related to the context and condition by means of socialization. The shopping mall as a whole actually composed of different elements, individual, group, devices. The rules and procedures applied on these data are compared in terms of VO and CVO for reasoning new new knowledge, which are analyzed and used by inference engine. The new deduced knowledge is updated and stored in the database, thus enhancing experiences.

5.2 Inference Engine

Inference engine applies logical rules based on condition to the knowledge base. Inference engine matches, selects and executes rules in an iteration manner to the knowledge base as each new VO could trigger additional rules. Inference engine includes forward and backward chaining. Forward chaining states new facts from the known facts where backward chaining achieves goal by backward. The forward and backward chaining iterates matching, selecting and executing rules to deduce new knowledge. The new deduced knowledge is updated in the knowledge base to enhance experience to avoid repetition of what action should be taken for a specific case happened at home to save energy.

Ⅵ. Prototype Implementation

In order to implement the prototype ontology are designed using protrde and represented in OWL[22] in the ontology database. VOs and CVOs are represented in RDF/XML[23] format in the database which are accessed by ontology server using SPARQL [24]. For test purpose Hermit 1.3.7 is used for reasoning in protsed. In the deployment environment Apache Jena[25] default inference engine is used to infer new knowledge.

6.1 WSSM Implementation Architecture

The WSSM Implementation architecture has been shown in Fig. 10. The architecture consists of WoO Gateway, Ontology Server, history database, VO and CVO databases, ontology database, and Application Server. The WoO Gateway connects the sensors and actuators with application server. Application Server has several functions including monitor and context analyzer, emergency services, knowledge analyzer and control services.

Ontology Server maintains the VO and CVO databases in order to keep synchronization with physical objects. The history database is maintained by Application Server to keep track of history time to time which might incorporate in decision making or providing services in future.

Ontology Server also has the inference engine to apply the rules on the VO and CVO. The ontology and the rules have been made using Protégé. The communications between application server and WoO Gateway is based on HTTP connections. Application server also communicates via HTTP with ontology server using SPARQL.

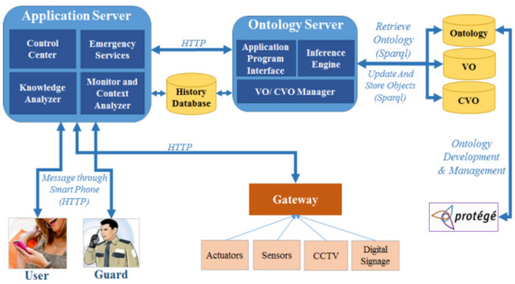

Fig. 10. WSSM Implementation Architecture

6.2 Creation and Management of VOs and CVOs

Ontology for WSSM is designed using Protégé and deployed into the ontology storage. The designed ontology shown in Fig. 6 includes the description of VOs and their relation with other VOs as well as CVOs. Creation of VOs is possible using SPARQL at run time as well as predefined using protégé. In our implementation we have defined the VO using protégé according to the shopping mall scenario.

The VOs are managed by VO/CVO manager function of Ontology Server. The VO/CVO manager provide interface to the Application Server to create, read, update and delete operations on VO/CVO databases. Fig. 11 shows example of customer VO definition which is described as owl individual. It includes the properties of a specific customer and the relation with other VOs i.e. smart phone, product. The relation among the VOs might help Application Server to extract useful information through SPARQL query.

The sensor VOs are updated using SPARQL query from Application Server to Ontology Server over HTTP. An example SPARQL update query is shown in Fig. 12. In the history database values of sensors are also saved. In order to reduce history

```
<owl:NamedIndividual rdf:about="&shoppingMall4;Customer0002">
    <rdf:type rdf:resource="&shoppingMall4;Customer"/>
    <shoppingMall4:birthday rdf:datatype="&xsd;string">
        1990-08-26
    </shoppingMall4:birthday>
    <shoppingMall4:age rdf:datatype="&xsd;integer">
        24
    </shoppingMall4:age>
    <shoppingMall4:lastName rdf:datatype="&xsd;string">
        Farnandes
    </shoppingMall4:lastName>
    <shoppingMall4:gender rdf:datatype="&xsd;string">
        Female
    </shoppingMall4:gender>
    <shoppingMall4:firstName rdf:datatype="&xsd;string">
        Rebeca
    </shoppingMall4:firstName>
    <shoppingMall4:id rdf:datatype="&xsd;string">
        cid0002
    </shoppingMall4:id>
    <ace_lexicon:PN_sg>
        Customer0002
    </ace_lexicon:PN_sg>
    <shoppingMall4:hasSmartPhone
        rdf:resource="&shoppingMall4;Phone0002"/>
    <shoppingMall4:hasInterestProduct
        rdf:resource="&shoppingMall4;Product0002"/>
</owl:NamedIndividual>
```

Fig. 11. VO description in OWL

```
prefix+"delete {"
    + '?x woo:sensorValue "'+value[index]+'"^^XSD:float} '
    + 'insert {?x woo:sensorValue "'+value[(index+1)%value.length]+'"^^XSD:float} '
    + 'where {?x woo:sensorID "sid0005"^^XSD:string}'
```

Fig. 12. SPARQL update query of a sensor VO

database size only few information are saved. However, using some properties more information about a VO can be retrieved from the Ontology Server.

Initially the rules to create CVOs are defined using class expression in Protégé. However, in the deployment phase class expressions are converted into SPARQL query which is shown in Fig. 13.

There are some tools for converting class expression in SPARQL. In our implementation we manually converted the rules as there only few rules to determine emergency symptoms.

```
prefix+"SELECT * FROM <http://www.woo.com/hufs/shoppingMall>  WHERE{"
    + "?shoppingMall a woo:ShoppingMall."
    + "?shoppingMall woo:hasSensors ?sensor."

    + "?sensor a woo:Sensor."
    + "?sensor woo:hasTemperatureSensors ?x."
    +"?x a woo:TempSensor."
    +'?x woo:sensorValue ?vx . FILTER(?vx>=46 && ?vx<=80).'
    +'?x woo:connectedTo ?tempLoc.'

    +"?sensor woo:hasHumiditySensors ?y."
    +"?y a woo:HumSensor."
    +'?y woo:sensorValue ?vy . FILTER(?vy>=10 && ?vy<=19)'
    +'?y woo:connectedTo ?humLoc.'

    +"?sensor woo:hasCO2Sensors ?z."
    +"?z a woo:CO2Sensor."
    +'?z woo:sensorValue ?vz . FILTER(?vz>=5000 && ?vz<=10000)'
    +'?z woo:connectedTo ?CO2Loc.'

    +"?sensor woo:hasCOSensors ?p."
    +"?p a woo:COSensor."
    +'?p woo:sensorValue ?vp . FILTER(?vp>=7 && ?vp<=8)'
    +'?p woo:connectedTo ?COLoc.'

    +"?sensor woo:hasWindSensors ?w."
    +"?w a woo:WindSensor."
    + '?w woo:windspeed ?windspeed.'
    + '?w woo:windDirection ?windDirection.'
    +'?w woo:connectedTo ?windLoc.'

    + "}"
```

Fig. 13. Rules converted from Class Expression

6.3 Scenario and Work flow in WSSM

Application Server continuously monitors the sensed data received from the sensors. Ontology Server updates the VOs in the VO instance database and apply inference rule on them. Customers and guards are registered using android application. A customer can register himself/herself as a handicap person to get special services in emergency situation i.e. Application Server sends notification to guard's smart phone to rescue him/her. Application Server also track location of customers in the shopping mall to provide normal services like location based information based on history of a customer preference. Digital signage displays and provide product promotion in normal condition in shopping mall, which is used to display emergency alert in emergency situation. Ontology Server updates VOs and apply inference rules on them. In case of abnormal situation like cautious state, warning state or emergency state corresponding CVO is created that indicates responsible sensors for that situation. Application Server searches history to provide better decision, such as pre-calculated safe evacuation path might be decided if the current emergency situation matches with history data.

The shopping mall area is divided based on the location and the zone of the floor to create map and calculate safe evacuation path. In case of cautious state, Application server sends notification to the nearest guard regarding cautious or warning zone to confirm emergency. Emergency State Service Flow has been described in Fig. 14. Based on guard's confirmation, Application Server Sends Emergency Alert to the control center and searches locate the fire using CCTV. After that Application Server calculates the safe evacuation path considering the direction in which fire might progress, outside wind, humidity, etc. Application Server also search previous history to find similar situation in same place. In that circumstance existing calculated safe evacuation path might be useful sometimes. Safe evacuation path is sent to the customers based on their location.

If Application Server finds any registered handicap person in the shopping mall, it sends notification to the nearest guard to rescue. In Fig. 15 an example of evacuation scenario in WSSM has

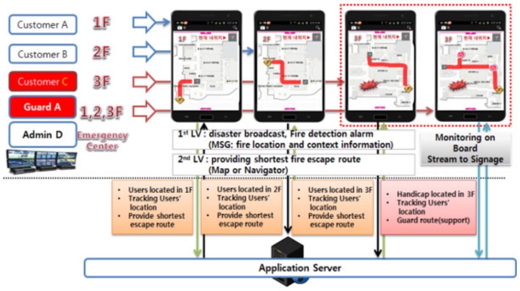

Fig. 15. Emergency State Scenario

been shown using android application of customers and Application Server communication.

6.4 Implementation Specification

In order to monitor the shopping mall, four types of sensors are deployed such as temperature sensor, humidity sensor, CO2 sensor, and CO sensor. Sensors are connected to the WoO Gateway using Zigbee[26]. CCTV is also connected to the WoO gateway which can act as actuator in shopping mall such as showing the location of fire. Fig. 16 show a subset of prototype implementation environment.

To locate the user Bluetooth is deployed in the shopping mall prototype environment. The android application in the users' smart phone detects RSSI[27] and send it to the Application server which helps to locate customer's and guard's positions. Application Server is developed using Node.js[28] and the Ontology Server is running on Java. It provides API to the Application Server using Java servlet[29]. To store history MongoDB[30] is used for less complexity and Ontology, VOs and CVOs are stored in TDB[31].

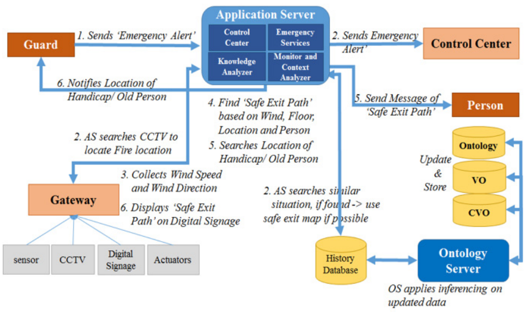

Fig. 14. Emergency State Service Flow

Fig. 16. Implementation Environment

Ⅶ. Conclusion

A comprehensive semantic ontology model leads WoO based knowledge driven approach for emergency services in smart shopping mall at application level. Semantic ontology model for knowledge based service creation and the implementation architecture of WSSM have been discussed. In this context, a prototype on knowledge based smart shopping mall has been implemented and thus the implementation process for creation of ontology using OWL, storing history in MongoDB, storing VO and CVO in TDB and updating VO using SPARQL have been presented. Creation of CVOs from multiple VOs have been deduced using inference engine that provides emergency services. WoO platform provides features for monitoring real time data, comparing and analyzing the context based on previous history data and thus decides the emergency services in smart shopping mall.

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