A Novel Approach for Integrating Semantic Web Techniques into Smart Education Environment

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Abstract—**Pervasive computing and Internet of Things (IoT) have recently received considerable interest from both industry and academia to give technology, infrastructure and applications for the future internet. Availability of numerous IoT devices in smart environment shows vast diversity of heterogeneous data representation and preservation. This heterogeneity of physical devices makes interoperability a problem which needs to be solved with a persistent scalable platform. Semantic web technologies have shown promising effects for describing data objects, wrapping and aggregating shared data as information and inferring new knowledge within specified domain. This paper highlights the use of semantic web techniques for an IoT based smart environment. The paper proposes a framework that provides a way to utilize heterogeneous data captured from smart IoT devices and sensors based on their semantics. The framework supports smart environment for decision making and occurrence of rule based events using new inferred knowledge. The paper addresses the use of existing ontologies and cloud solutions for smart sensors data, adding it with ontologies for smart devices and profile of users of smart environment. A preliminary usecase scenario of smart education environment is provided for underlining the feasibility of proposed framework.**

Keywords-Smart Environment; Pervasive Computing; Semantic Web; Smart Education Environment; IoT

I. INTRODUCTION

The current direction of computing going towards the deployment of heterogeneous physical word devices into internet as Internet of Things (IoT). The emergence of wireless sensor networks and smart devices integration within smart environment known as pervasive computing, aims to provide “anytime-anywhere” computing [1]. This computing is to give support for seamless accessibility and device usage on behalf of smart environment’s user. Thus, pervasive computing inherits a specialized smart environment where smart physical devices are context-aware, personalized and adaptive as per user’s consent. Smart environment utilizes intelligence of device as ambient intelligence (AmI) which basically comes from backend network infrastructure and stat-of-art interoperable data processing techniques [2]. Therefore, within an AmI environment, the intelligence of device heavily relies on the framework by which they are deployed. Nowadays, available real-world physical devices ranges from smart phones to intelligent dishwashers. This heterogeneity among devices demands for an interoperable persistent system. Such system can model different aspects of the smart environment in a contextual manner and then intelligently process the modeled information; to achieve some environment specific and user oriented goals. The modeled environment needs to be semantically correct in order to make sound and correct intelligent actions as well on behalf of user.

Semantic web technology meant to process information which are semantically related [3]. Semantic web holds a potential to represent structured data with explicit contextual meanings along with querying, inferencing and reasoning. The role of semantic web technologies in AmI environments exhibits flexibility to utilize currently available smart IoT devices. The explicit representation of information from heterogeneous smart devices is handled by exploiting their unstructured or semi-structured outputs in structured RDF formats to go further over semantic web. The interoperability issue of smart devices is taken considered by use of REST APIs for HTTP over semantic web [4]. This structured and contextual understanding of device data is provided by ontologies which further gives supports of reason and inference for decision-making in a smart environment.

Smart environments are divided on basis of diverse usages. Some common smart environments are smart homes, smart hospitals, smart tourism, smart vehicles, smart cities, smart healthcare systems and smart classrooms. In this work we focus on smart education environment within an education institute. The need of semantic web based smart education environment subsists as it can give effective smart environment with situation awareness, which enables, smart devices, machines, application and users to better understand and interact within their surrounding environment. Semantic web based smart environment also leads toward effective time consumption during user-machine interactions and more time can go towards intellectual and research activities.

In this work we present a framework that is based on the smart education environment using semantic web technologies (RDF, OWL, and SPARQL) [5]. The proposed framework provides smart sensing and data integration from heterogeneous smart sensors and smart devices. The framework provides semantically annotated device's data using W3C's SSN ontology [6] and utilize it for event and rule based decisive tasks on behalf of users. The framework also exploits the use of semantic web's core ontologies 'foaf' [7], for the exposure of machine understandable explicit representation of user-centered data from smart device, and provide querying and reasoning based on data context and semantics. The system provides easy assistance to use smart education environment based on extracted information for user profiles from smart devices and physical status of smart sensors and learning-aid devices.

The paper is divided into six sections. Section II identifies a motivating smart education environment with supportive scenarios on which our proposed framework can be employed. Section III explains the proposed framework architecture and outlines the structural components of the framework. Section IV gives the implementation and prototyping details of our proposed framework. Section V highlights some existing related works. Finally, section VI concludes the paper and provides future directions.

II. Motivating Usecase Scenario: SWSEE

In order to better understand the feasibility of our proposed framework, we present transition of smart education environment to Semantic Web based Smart Education Environment (SWSEE) as our motivating example. The principal working domains of SWSEE are illustrated in Fig.1. The SWSEE inhibits features of smart environment with usage of multiple interconnected smart devices and smart sensors. Traditionally smart education environment enables data sharing among different connected devices through conventional web services through internet and mobile communication. However, our proposed SWSEE not only aims to provide semantics to the shared data but also to enable AmI with this shared data using semantic web REST-ful services. The explicit representation of data using RDF in semantic web enables its interoperable utilization with inherent reasoning and inferencing capabilities. The inferred knowledge can be used in isolation by desired audience or as event-based decision rules to exhibit controlled device output. The proposed framework when applied as SWSEE would be practiced by a semantic web application whose targeted role audience can broadly include: teacher, student and administrative staff. An exemplary scenario with each role is discussed as below:

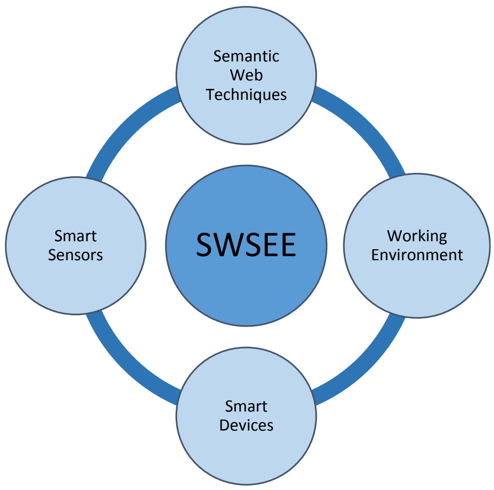

Figure 1. SWSEE Scope

1) Teacher:

A teacher *T* wants to conduct a seminar for a group of students. To start with, *T* firstly checks for availability of seminar room (smart education environment) and schedule to use it at desired date and time using SWSEE framework. T generates time-based events for smart device controller to issue queries to check status of audio and visual devices and put them on standby mode before 10 minutes of seminar. *T* further generates another event for activation of heating and cooling controller to get activated at desired time prior of seminar. *T* activates an event for smart device controller to extract seminar slides or notes a minute before start of seminar and give as input to smart projectors for display on smart screen. *T* further activates an event to broadcast education material to smart devices of seminar attendees. Before start of seminar, by using semantic web application, *T* inquires about number of seminar attendants and their level of knowledge on topic.

At the end of the seminar, the level of understanding of attendants is calculated by using their smart devices with smart device controller and semantic web application inquires the results for *T.*

2) Student:

A student *S* inquires about events to be happened in desired duration of time using semantic web application tool. *S* wishes to attend a seminar to be conducted by teacher *T*. *S* registers in that seminar and send status via smart device controller to personal smart phone for reminder. At time of seminar, *S* receives add-on education material on his personal smart devices connected within environment.

At time of seminar, smart device controller inquires about presence of registered student *S* and *T*. As *T* is indicated to be connected within environment and education slides are as input on display device, lights are lowered down and noise sensors data is fetched with predefined time intervals for identification of breaks, questions & answers session and end of seminar.

3) Administrative Staff

An administrative staff *A*, can use semantic web application to inquire about status and schedule for smart education environment. Moreover, *A* can use smart device controller to schedule use of smart environment with predefined states of IoT devices and smart sensors (e.g. status of temperature level and lighting level at particular times, etc.).

III. PROPOSED FRAMEWORK ARCHITECTURE

The proposed software architecture framework is based on semantic web techniques for pervasive computing over heterogeneous semi-structured data of IoT devices. The framework aims to incorporate AmI in smart environment and provide a meaningful explicit data representation environment for smart sensors and devices. Interconnected physical sensors and devices together as IoT are coined up with cloud storage solutions such as Xively [8].

Semantic web techniques promisingly describe data in a machine interpretable format. These techniques provide better solution for describing data objects, aggregating information and inferring knowledge. Hence, utilization of semantic web techniques provides widely acceptable data representation, abstraction, accessibility, operability, searching and discovery, with reasoning and inferencing for heterogeneous data from 'things' of IoT.

Fig.2 represents data acquisition from heterogeneous smart devices (e.g. smart phones, tablets, iPad, gadgets, boards etc.) and smart sensors (e.g. temperature sensors, humidity sensors, motion sensors, voice sensors etc.). This acquired data is used in semantic web space for further processing.

Fig.3 depicts the general architecture of our proposed software framework. It consists of Semantics Wrapper, Semantics Aggregator, Triple Database (TDB), a Query Engine and a Smart device Controller. The framework accepts data from smart environment which is used within a semantic web application.

A. *Semantics Wrapper*

Semantics wrapper is software component for mapping raw data from different smart devices and formatting it into meaningful RDF for semantic computing. The wrapper obtains data from different applications of smart devices such as notification status of device (ringing, vibrating, mute), location information and current environment temperature measurements using GPS and Google Maps etc. The wrapper gathers data from sensor devices using Xively which is a cloud solution provider for physically connected IoT devices. The sensory data for temperature, light, noise, humidity obtained from ARDUINO (Wi-Fi and Ethernet) devices which send their readings to Xively cloud. Currently Xively supports JSON, XML and CSV formats which needs to be mapped into RDF triple format. Semantics Wrapper after mapping these data into useful RDFs forwards to Semantic aggregator.

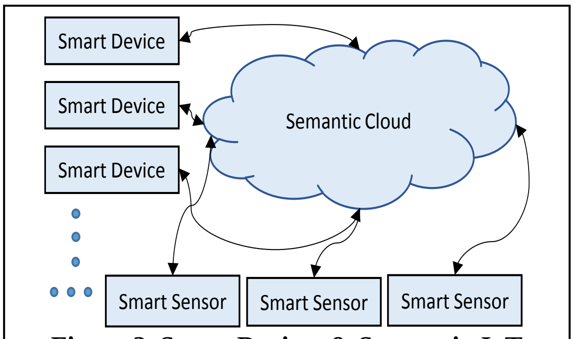

Figure 2. Smart Devices & Sensors in IoT

B. *Semantics Aggregator*

This component gathers RDF generated by the *semantics wrapper*. It has the capability to aggregate different RDF triples from wrapper and store them into unique RDFs in the triple database. Different inference rules can be specified as input into this component. The aggregator is responsible to generate rule based RDF triples with re-gathering and merging values from existing RDF triples. The pre-fetched and newly generated RDF triples are stored in TDB for later utilization by query engines.

C. *Query Engine & Triple Database(TDB)*

The RDF triples are stored in a *TDB* and queried using SPARQL launched from a *Query Engine*. The query engine acts as a local host server for providing query end points over HTTP to access RDF triples from TDB.

D. *Smart Device Controller Application*

In the smart environment with IoT, there is a need of centralized commanding controller for devices to set up their status and accept meaningful data and information and generate decisive commands accordingly. The controller puts event or time-based queries using query engine and based on the obtained RDF results, applies rule-based decisions commands to smart devices. Smart Device controller is also responsible to inquire about environment attributes and manage behavior of connected smart sensors and devices. (E.g. temperature controlling, display power standby with respect to motion, noise and audio sensor outputs, etc.)

E. *Semantic Web Application*

The semantic web application acts as an end-user application for obtaining desired information and

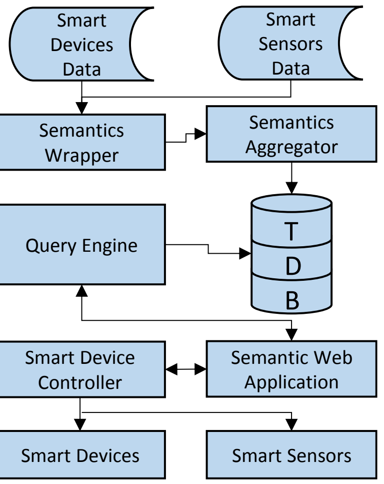

Figure 3. Semantic Web based Smart Environment

querying RDF from TDB. The semantic web application accepts SPARQL queries from users and access query engine to extract desired RDF triples. The query result provides desired information about devices and sensors connected within smart environment. The exclusive set of users for this application ranges among groups or roles, to provide fine-grained data accessibility.

IV. IMPLEMENTATION OVERVIEW

Based on the semantic web based smart environment architecture mentioned in section III, we are currently prototyping a complete system that aims to realize the scenario we have described in section II. Smart sensors are connected to Xively REST-ful APIs that stores the devices data to a cloud data storage. Currently, Xively supports JSON, XML and CSV data formats which are converted into RDF N3/Turtle formats within *semantic* wrapper component. The *semantics wrapper* and *semantics aggregator* are prototyped using Java based semantic web toolkit - Apache Jena [9], which provides core RDF APIs and general inference APIs for RDFS and OWL reasoners. *Query engine* prototype is deployed using ARQ which is a query processor for Jena applications. For storage of RDF triples collected and inferred by *semantics aggregator*, a Jena based *TDB* store has been deployed. It supports full range of Jena APIs and can provide high performance RDF storage. To use *TDB* dataset a server application that is *semantic web application* has been prototyped based on Fuseki, which provides SPARQL server to access to RDF triples from TDB and supports REST-style SPARQL Query and Update using SPARQL protocol over HTTP.

V. RELATED WORK

There are a number of researches made on improving the experience of traditional learning environments using semantic web technologies. Smart classroom in Tsinghua University [10], enables support for remote student-teacher interactions and communication. The infrastructure is based on the multi-agent system architecture using conventional Web Service technology through internet in Smart Space. S-CRETA [11], provides use of a real-time AmI system for a smart classroom. The assistance system exploits the use of ontologies to model the context and extract information to use it for machine learning, further targets for high-level activity recognition. Another work that explores the use of semantic web for IoT presented by [12]. This work offers a general object identification system to extend the functionality of the control application. The approach is based on use of M3-based interoperability framework [13] to provide base functionality for a sensor–actuator network and secondly extent functionality by using an object identification system for reference data access. Many previous works [14] [15] [16] [17] [18] also provides solutions for smart classroom environment using mobile communications.

The current research is mainly towards context extraction from physical smart sensors and context utilization for high-level activity recognition within smart classroom environment. This bottleneck leads for innovative research to exploit the semantic information from physical IoT devices, sensors and education learning material. Semantic information further provides assistance to connected devices to perform decisive tasks on behalf of users. The physical activities are extracted from smart sensors and considered in parallel for high-level activity recognition and managerial control of smart education environment. Our proposed framework not only focusing on the physical activities recognition and device management but also on the learning material and intended level of usage of education materials. The proposed system aims to provide a novel solution with user's learning intention and provides an easy accessibility to the education material.

VI. CONCLUSION AND FUTURE WORKS

This paper proposes a framework for exploiting IoT using semantic web techniques within smart education environment. The framework follows a general structure as discussed in section III. The paper highlights the benefits and feasibility of the framework by providing motivating usecase scenarios within smart education environment. Overall, the system aims to provide a semantics based information accessing, rule based decision making and reasoning capabilities to manage physical smart sensors and devices on behalf of users. The system provides a querying platform as a semantic web application for easy accessibility of desired information e.g. get access to related education material, inquire status of environment user, physical state of any smart sensor or state of smart environment itself, etc. The paper also describes the prototype implementation details of the proposed framework. In future, we plan to fully implement and evaluate the proposed framework on a real-time education environment with multiple physical smart sensors and devices for IoT, processing of extracted data semantics and its utilization over semantic web application.

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