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An Approach to IoT Data Management for an Intelligent Monitoring System on Refrigerator

Kiran Nasim [1], Nishat I Mowla[2], Nusrat Sharmin[3], Minsoo Lee[4]
EwhaWomansUniveristy, Seoul, South Korea
[1]kiran.cse7@gmail.com
[2]nishat.i.mowla@gmail.com
[3]ns.sharmin@gmail.com
[4]mlee@ewha.ac.kr

ABSTRACT

Lately the concept of Internet of Things (IoT) is being more elaborated and devices and databases are proposed thereby to meet the need of an Internet of Things Scenario. Internet of Things is being considered to be an integral part of smart house where devices will be connected to each other and also react upon certain environmental input. This will eventually include the home refrigerator, air conditioner, lights, heater and such other home appliances. Therefore we focus our research on the database part for such an Internet of Things' fridge which we called as an Intelligent Fridge. We describe the potentials achievable through a database for an IoT refrigerator to manage the refrigerator food and also aid the creation of a monthly budget of the house for a family. The paper aims at the data management issue based on a proposed design of an intelligent monitoring system in IoT for an intelligent refrigerator leveraging the sensor technology and the wireless communication technology. The refrigeratorwhich identifies products by reading the barcodes or RFID tags is proposed to order the required products by connecting to the Internet. Thus the goal of this paper is to minimize human interaction to maintain the daily life events.

Key words: Internet of Things, Intelligent Monitoring, Machine Learning, Wireless Technology, RFID

1. INTRODUCTION

The Internet of things is a combination of the Internet and all kinds of information sensing devices such as radio frequency identification devices (RFID), infrared sensors, global positioning systems, laser scanners, etc.[1].

Internet of things semantic origin is from two words; internet and things. Where internet is the network of computers by some standard protocol TCP/IP and things here refers to two main categories of objects[2];

1. Identified objects
2. Connected devices

1.1 Identified Objects

This category can include daily life items that we usually purchase from the grocery store. Actually the word identified here acknowledges that these objects must have some unique code to identify them. We already can see most products having barcode to identify them

1.1.1 Barcode

Barcode is an optical machine readable data relating to the object it is attached to, like its manufacturing date, expiry date and price. But to be accurate these barcode are not unique, every product of the same type will have the same barcode as many products are being manufactured at the same time.

1.1.2 RFID

There is still the need to have unique codes and for it the latest technology is of Radio Frequency Identification (RFID) also known as "electronic tag".

It has the capability to track and identify the products using radio waves. RFID is actually a passive technology; i.e., itdoesn't transmit the radio waves by its own but these ID can only be read by an RFID reader. Using this technology we can have each and every object identified and we can use connecting devices to connect these objects.

1.2 Connected Devices

These devices are active devices usually requiring power source to operate and they have built-in network connectivity.

These devices have the power to take over our daily life tasks in view of Internet of Things making our life luxurious. In the near future, these connected devices will becomea part of a digital grid, monitoring the networks and making decisions by themselves.

Examples of these devices can be smart phones, sensors, laptops and our smart fridge as well and we will discuss it further in this paper. The main objective of Internet of Things is to connect everything with each other, D2D communication and also include human beings in this cycle.

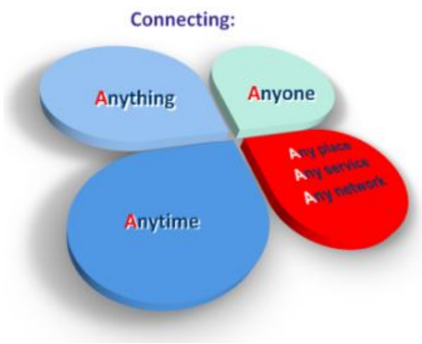

Figure 1: Internet of Things[8]

1.3 Intelligent Refrigerator

Applying the Internet of Things technology to have a refrigerator, knowing what it holds in it plus amount of everything in it, such a refrigerator can be called as "Intelligent refrigerator" or "smart fridge".

It identifies the products by barcode of RFID scanning. The expectations are that fridge can maintain our food products and keep track of all the food items by scanning the codes and it is able to order the food item whenever it is about to finish. Moreover, it can detect the product's expiry time to notify us, image an LED screen in front of our refrigerator door telling us what we have in it and how much and when will it expires. In addition, it is preventing us from the need to open the refrigerator to check the things, keeping the temperature maintained and also saving the power.

According to AviItzkovitch, the devices will be able to tell us in real time what we have in our fridge so we don't have to create a shopping list before heading out to the supermarket[3]. But the idea we are proposing is omitting the person entirely from the cycle. The central system is able to read the things getting low and is able to connect to person stored information, like a PayPal account, to order the things online as everything is connected by the Internet.

Our paper looks mainly into the data management and information extraction based on query processing from a database suitable for our IoT scenario and make order based on the data extracted from the database. Therefore we work on eXist DB to plan our query processing extracted from xml files where our refrigerator object information are kept.

1.3.1 Implementation Requirements

The project needed four basic requirements for real implementation, which includes,

1. IoT tools/scenario
2. Database
3. User application
4. Security

1.3.2 Objectives

We assigned ourselves three goals for the completion of this project and we accomplished all the three goals as stated below;

- *Goal 1*:Using the xml data about refrigerator milk bottle state, to query possible actions to be taken based on the current state
- *Goal 2:*Creating a user application on the intelligent refrigerator for the user to view milk bottle states
- *Goal 3*: Derive patterns from milk consumption as an aid to create a monthly budget

2. EXIST DB

EXistdb is an open source database management system. It is based on XML technology and stores XML data according to the data models. It offers index-based XQuery processing.

Its high performance engine stores textual or binary data and documents without requiring a database schema that makes eXistdbschema-less[4]. It works with Windows, Linux or Mac along with java installation, JRE/ JDK required running with administrative privileges required for full installation. It enables stand-alone java interface to make queries. The major features of eXistdb making it a suitable database for IoT are listed below:

- Schema-Less XML Data Storage
- Collections: schema-less, nested, managed in hierarchical fashion
- Index-based query processingto speed up query uses fast path join algorithms. Moreover, the database automatically applies indexing to all the nodes and then provide quick identification of possible relationships between these indices
- Extensions for Full-Text searching: it supports document centric XML very well as opposed to Xpath providing search by keyword, proximity of terms or regular expressions.

The recent versions are providing web based application development tools, based on XQuery and related standards. EXistdb is providing a user friendly environment with many examples and rich documentation. The dashboard screen capture is shown in figure 2,

Figure 2: eXistdb dashboard

3. MODULES

3.1 Load Sensor

Load cell or load sensor is a sensor to convert a load or force into an electric signal to be transmitted. The recommended load sensor in this case is Wireless *ELF*™ 2 System which is for Wireless Load and Force Measurement.[5]

Features:

- Real-time data capture
- ASCII output to data analysis software
- Adjustable sensitivity
- Includes 3 AAA batteries. Battery life up to 5 hours
- sampling rates up to 6,000 Hz
- upto 65 meters range
- small in size 3.75” X 1.83”

Performance: [5]

- **Linearity (Error):** < ±3% (Line drawn from 0 to 50% load)
- **Drift:** <5% / logarithmic time (Constant Load of 90% sensor rating)
- **Response Time:** < 5 µsec (Time required for the sensor to respond to an input force; Impact load - recorded on Oscilloscope)
- **Operating Temperature:** -40°F - 140°F (-40°C to 60°C)

Figure 3: Wireless *ELF*™ 2 System[5]

The data collected by each module is sent to the monitoring center inside refrigerator trucks by RS485 bus[1].

This sensor is provided just as an example for this scenario, we have not tested it ourselves but it is suitable for this kind of weight measurement.

3.2 Wireless Control

There is a need of wireless connection between the sensor in the refrigerator and the main control station. In the present scenario, only 1-way communication is needed as only the readability of sensor data is required. At fixed time intervals the channel will be activated by the controller, to receive data from the sensor and analyze it with the stored values and make the actions accordingly.

In the present case, Wi-Fi or even the Bluetooth connection isreasonable choice but when everything is connected to each other and the data is coming on millisecond basis then for this time-series data the connectivity needs to be highly reliable.

3.3 Remote Monitoring Center

The sensor inside the refrigerator is to be connected via a wireless channel to a central monitoring system using wireless technology and Internet. The database server, monitoring center and monitoring terminal together maintain the remote monitoring center [1]. If the central server acknowledges a certain critical condition reached, it will connect to the Internet to make an order for the product using the credit card information stored in the credit card database.

3.4 Internet Connection

According to Steve Leibson, who identifies himself as “occasional docent at the Computer History Museum,” the address space expansion means that we could “assign an IPV6 address to every atom on the surface of the earth, and still have enough addresses left to do another 100+ earths.”[8]

Whenever the controller decides to connect to the internet to order the product, it will use existing database of person’s credit card and stored URL to goonlinetothe grocery shop and will make the order.

4. ALGORITHM STAGES

The paper explains an Internet of Things scenario for a smart fridge and how it can have conditions on the data to maintain the food in the fridge. By maintain thr food, the food amount and its expiry date is meant here. The same idea can be extended to any other product to monitor in the fridge or to another device to connect to the internet. The scenario is presented in the figure 4 shown below,

Figure 4: Milk maintain scenario in a smart fridge

We implement our idea by following the below mentioned steps:

1. First we take the measurement of milk bottle & store into the xml file the measurement of milk bottle on specified time of a day.

2. Create an XQuery on the xml file which will show the measurement of milk bottle on specified time.

3. We assume that from above mentioned steps we can get the weekly measurement of our milk bottle which will be able to show us the weeklyconsumption of milk in a month. To accomplish that we made another XML file. Base on the XML file we present graph representation of the milk consumption in a month.

4. We made a web application for the user based on our query by using eXistdb which will help user to know about the measurement of milk bottle and also show whether it need to order for milk from the shop or not.

4.1 First Stage: Data Generating

4.1.1 XML:

XML is the core of data exchange these days between different organizations so it is expecting that Internet of Things basis can rely on XML database system. The main benefit of XML is that it is self-describing and supports user defined tags so handling XML is quite easy. Moreover, it can automatically built applications and can change behavior of applications or optimize the performance by simply changing the way information is expressed without changing the code.

In this case we generated a simple XML file without any schema definition to define our data. As the internet of things environment is not available at present so it should be noticed that the data is imaginary only.

So for preparing data the very first step for implementing our idea is to make a XML file which will contain the measurement of milk bottle on specified timeevery day in a week. Based on the xml we will do XQuery for getting the output. The main xml syntax behind our xml file is as follows:

```
<fridge>
        <MilkBottle>
                <amount></amount>
        </MilkBottle>
</fridge>
```

We implement another xml file that will contain the measurement of milk bottle for everyday in a week which will further help us to know the monthly consumption of milk. The main syntax used is as follows:

```
<period>
        <day></day>
</period>
```

The figure 5 is showing as an example that our XML file that is use for XQuery.

4.2 Second Stage: Data Storage

Next, we have to manage our XML data in eXistdb and for that we used eXistdb collection feature. The process we adopted is to create a new collection in eXistdb and put the XML file in that collection.

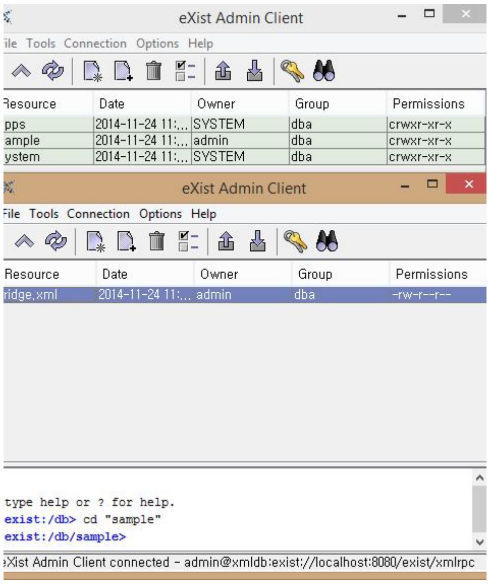

Figure 5: XML file for query

Figure 6 is showing as an example that our XML file is stored in the sample collection of eXistdb.

Figure 6: Storing data in eXistdb

eXistdb offers to create new collections to handle different types of data efficiently. We stored our data files in eXistdb "sample" collection. Collection feature provides efficiency in terms of storing large documents, which can be divided into small chunks and stored in a single collection to make access easily possible. Xmldb:x collection() function can be used in the query to specify a certain collection and it will make all files in it accessible.

Figure 6 is showing two windows, one having a collection named "sample" and the other window is showing inside sample which in this case has our data file "fridge.xml".

4.3 Third Stage: Data Query

As we have generated the data, now the next part is to write XQuery for our scenario. We used eXistdb platform to write the query. We defined our critical level with a simple algorithm as follows:

```
Let min_weight=1litre
If
        weight<min_weight
                connect_to_pc
                order_milk
                milk_is_weight_litre
Else if
        weight=min_weight
                critical_level
                milk_is_weight_litre
Else if
        weight>min_weight
                sufficient_milk
                milk_is_weight_litre
Else
        record_milk
```

We made the query using FLWR syntax of XQuery, to put the conditions on our data.Figure 7 is an example of the query processing which describe how we implement our logic in XQuery.

Figure 7: XQuery on fridge.xml

First, access the xml document then search for a specific where condition, this field can be modified by the user to set specific times at which user wants to check the status of milk bottle. After that, if and else statement is used to print out specific message related to amount, this data is provided through wireless connection between the controller and the weight sensor. Based on this message the next decision will be made that either it is required to proceed further to order more milk or the amount is enough and the next process is not required.

For the next process, it is assumed that the person's credit card information has been stored in the system and the system is capable of connecting to the internet to go to some specific online grocery store and identifying the barcode or RFID tag to make milk ordered successfully.

4.4 Fourth Stage: Web Application

In the present world, everything is connected to Internet somehow or is expected to be connected in near future, so as an additional part of the project, we included a web application for our scenario by using eXistdb based on our query.

HTML is used to implement the query, as HTML is the basic of information exchange applications and the web applications.

The application will enable the user to know about the measurement of milk bottle on a particular time so that user can check the measurement through the application from anywhere and anytime without opening the door of the fridgeandthus saving the power. Figure 8, is showing the web application that is implemented for this project.

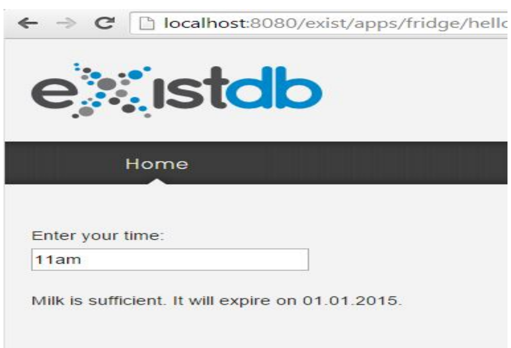

Figure 8: Application demo for user information display

This part is additional to the planned goal, as we wanted to bring this aspect in notice that on average a person open fridge door at least 10 times a day and imagine if there are more than five person in a home then this application can save a good amount of power as no one needs to open the fridge door just to check what is in it and how much, one can easily access the things inside just for inspection. This application can benefit also when you are at a grocery store and by chance you forget the grocery list you made at home, thus making your smart refrigerator accessible at anytime and anywhere.

5. ANALYSIS OF DATA

The analysis of data is divided into three parts:

a. Firstly, we show a demo of what sort of query is required on our saved xml files for the refrigerator objects, here we do our experiment with a milk bottle.
b. Secondly, we analyze with a demo of what sort of application user interface can be used to show the condition of the refrigerator object for the family members to check.
c. Thirdly, we analyze how the data can aid in finding patterns of usage, here again with the example of a milk bottle, to help in the creation of a monthly budget based on whole month's usage patterns.

5.1 Application for Intelligent Refrigerator Milk Bottle

Our application is mainly for the user to get a display of the refrigerator object updates to check and see the expiry dates and such others. We created a demo application which will show information for the user based on information saved about the milk bottle of our example. Figure 8 shows a screen shot of our demo application.

5.2 Finding Patterns

We created an xml file where the total amount usage on a per day basis will be incrementally saved with the information taken by the sensor connected to the milk bottle. In this we have taken example data assuming the data here will be dynamically saved from the sensor devices.

Figure 9 shows our results for a sample pattern analysis, having four pie charts for each week of a month. We choose January as an example month; the next step can be to extend it to 12 months a year for trends and predictive purposes.

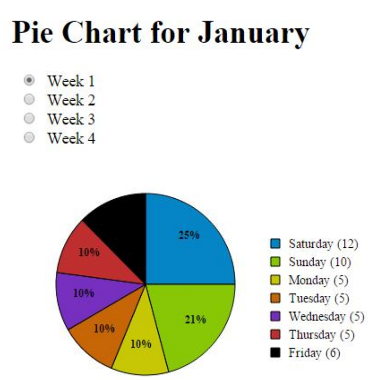

Figure 9a: Pie chart showing usage pattern for week 1

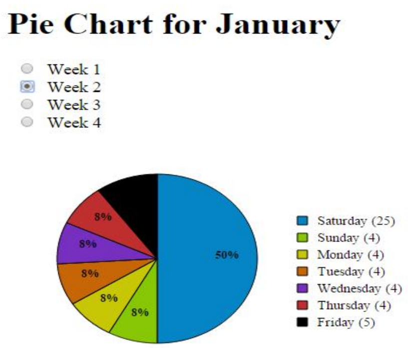

Figure 9b: Pie chart showing usage pattern for week 2

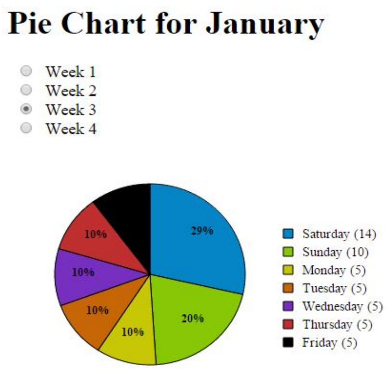

Figure 9c: Pie chart showing usage pattern for week 3

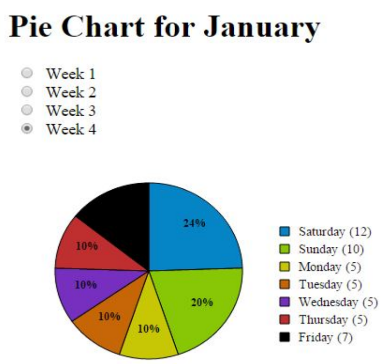

Figure 9d: Pie chart showing usage pattern for week 4

We used the xml file to extract some demo results to visualize the usage patterns and also the total amounts of per day milk usage for budget calculation services. The demo results tried to depict how the milk usage may vary over different days with different amounts consumed over weekdays and weekends. Here the data is shown as weekends have more milk consumption than weekdays. Also in the second week of January on Saturday the milk consumption was almost half the total amount consumed over the week. This was used to depict a special day of the year like the user's birthday or a yearly celebration day. All these days measured over a long period of time can help the application to make predictions on milk consumption and create a monthly budget for the user. Thus the patterns generated from these can be utilized.

The example can be extended to other objects in the fridge as well and also to other appliances.

5.3 Pattern Recognition and Artificial Intelligence

Pattern recognition is a branch of machine learning that focuses on the recognition of patterns and regularities in data. The terms pattern recognition, machine learning, data mining and knowledge discovery in databases (KDD) are hard to separate, as they largely overlap in their scope[10].

It can be said that artificial intelligence has been provided to the smart fridge by using the previous data from database as training data and thus predicting the future trends from history.

In best case, with time the intelligent refrigerator can gain enough intelligence to recognize the patterns from the previous data and use these trends to be prepare in the future and it can monitor and maintain the products more efficiently.

6. E-SHOPPING

e-shopping or online shopping or e-store are all virtual types of stores which allow customers to directly buy products or services over the internet using a web browser. [11]

The best and the most popular online retailing stores are;

- Amazon.com
- eBay
- Gmarket
- Alibaba

With the growth of online shopping, comes a wealth of new market footprint coverage opportunities for stores that can appropriately cater to offshore market demands and service requirements. [11]

6.1 Payment

The most common methods of online payments these days are

1. Credit card
2. PayPal account

However, as this online shopping trend in increasing day by day, so to facilitate and to attract more customers many systems are offering alternative means of payment such as

- Cash on Delivery (C.O.D)
- Cheque
- Debit Card
- Wire transfer
- Invoice

and some more.

In this project, it is assumed that central controller has all the related information of payment method already stored.

6.2 Advantages and disadvantages

Online shopping facilitates customers by providing at home services most of the times cheaper and also providing a lot of options to choose from. Thus, it is convenient for most of the people to shop online without wasting their time in markets.

But, there is risk in ordering things online as you cannot guarantee the material, but most of the systems have good return policies also. But the greatest concern here is of privacy and security which is discussed in section 8.

7. BUSINESS SCENARIO

It is obvious that like any new technology, the InternetofThings has the potential to drastically improve our personal lives, work place and industrial capabilities as it is affecting our life directly. But end user acceptance is necessary for any new technology.

By the trends and the history of user acceptance, the expectation is that it may take time for users to adapt to new technologies andopportunities of the internet of things, just as mobiles and e-commerce have taken years to be successful[9].

Once IoT establishes its ground, we can imagine a totally new environment in our future; it will be user friendly and more users independently. One can imagine what ads companies will do with IoT, how everything will be flourished.

8. SECURITY ISSUES

Data exchange is critical in today's networked world. We already are facing the cybercrime challenges and now if we are expecting to have a huge interconnected world of devices and humans we have to look at our security systems requirement.

Today, our emails can be hacked so now our intelligent refrigerator can also become a victim of this hacking. So being connected to the internet always would mean the possibility of more surveillance, both good and bad. It also means the possibility for more fraud, scams and cyber-attacks.[6]

In order to ensure that the personal data collected is used only be the authorized service, solutions have already been proposed that is usually based on 'privacy broker'.[7]

One of the most important requirements in IoTis that of security. Here, the person's card information or account information are potential and attractive targets of hacking. Therefore it needs to be specially considered while designing IoT scenarios. In our case, the information can be saved with a secured encryption method with a key k which will be changed periodically to avoid hacking of information.

Another security issue is to have control over the intelligent refrigerator so that it can be deactivated and also activated again because there can be times when the user doesn't want to order a certain object any more or when the user is going to some place for a long time. In that case if the refrigerator keeps ordering refrigerator food on its own then it's going to be a catastrophe.

9. CONCLUSION

The intelligent refrigerator in the paper is explained by a simple example of a daily product, milk bottle. We described an IoT refrigerator scenario and analyzed the data management for such a device with queries, user application and pattern analysis which can aid in budget creation. The same idea can be expanded to have each and every item of the fridge stored in the database to maintain the fridge without getting person to worry aboutmaintaining a healthier lifestyle.

Howeverthe idea may or may not be applicable to all the objects with the same sensors and therefore the application of different kinds of sensors can be expected in this IoT scenario.

Ultimately the scenario can be devised for each and every device of home to have an 'intelligent home' system. And the results can be that each device in the world is connected together without the need for human intervention to have a global impact. In future we hope to extend our work by connecting our database system to a real IoTtestbed.

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REFERENCES

1. **Yonghui Zhang. Intelligent Monitoring System on Refrigerator Trucks Based on the Internet of Things**, Institute for Computer Sciences, Social Informatics and Telecommunications Engineering 2012, pp. 201–206

2. **The Internet of Things (and the myth of the "Smart" Fridge)** http://www.xgmedia.com/2013/06/the-internet-of-things-to-come-demystifying-the-myth-of-the-smart-fridge/#.VHLvlYuUeCk

3. AviItzkovitch, **The Internet of Things and the Mythical Smart Fridge**. ARTICLE NO. 1089 SEPTEMBER 18, 2013

4. **eXistdb**, http://exist-db.org/

5. **Wireless *ELF*™ 2 System** http://www.tekscan.com/

6. **9 Real-Life Scenarios That Show How The Internet Of Things Could Transform Our Lives**, Dave Bonouvrie

   http://www.businessinsider.com.au/

7. **A proxy for privacy: the discreet box**, G.V. Lioudakis, in: EUROCON 2007, Warsaw, Poland, September 2007

8. **Internet of Things** http://whatis.techtarget.com/definition/Internet-of-Things

9. Dieter Uckelmann, Mark Harrison,Architecting**the Internet of Things. 1st ed. Springer Science & Business Media** 2011, pg 276

10. **Pattern recognition** http://en.wikipedia.org/wiki/Pattern_recognition

11. **Electronic Commerce** http://en.wikipedia.org/wiki/Online_shopping