Agent based Semantic Internet of Things (IoT) in Smart Health care

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ABSTRACT

Internet of Things (IoT) is to connect objects of different application fields, functionality and technology. These objects are entirely addressable and use standard communication protocol. Intelligent agents are used to integrate Internet of Things with heterogeneous low-power embedded resource-constrained networked devices. This paper discusses with the implemented real world scenario of smart autonomous patient management with the assistance of semantic technology in IoT. It uses the Smart Semantic framework using domain ontologies to encapsulate the processed information from sensor networks. This embedded Agent based Semantic Internet of Things in healthcare (ASIOTH) system is having semantic logic and semantic value based Information to make the system as smart and intelligent.

This paper aims at explaining in detail the technology drivers behind the IoT and health care with the information on data modeling, data mapping of existing IoT data into different other associated system data, workflow or the process flow behind the technical operations of the remote device coordination, the architecture of network, middleware, databases, application services. The challenges and the associated solution in this field are discussed with the use case.

Keywords

IoT; Swarm Intelligence; Agent; Data Model; Hospital Management; Healthcare, Semantic, Ontology

CCS Concepts

• Applied computing~Health care information systems

1. INTRODUCTION

The Internet of Health care devices makes the medical research and hospital management as smart and autonomous. The IoT allows people and things to be connected Anytime, Anyplace ,with Anything and Anyone. IoT [5,14] has the potential to change the way healthcare is delivered. It refers to physical devices, such as a weight scale, thermometer and patients' vital monitoring devices (glucose, blood pressure, heart beat rate & activity monitoring, etc.) connect to the internet and transforms information[13] from the physical world into the digital world which enables the "Digital Hospital".

IoT has challenges[16,17] in many directions including 1. Scalability – As the billions of IoT devices gets connected to the network, large volume of data needs to be processed. The system which stores, analyses this information from the IoT devices needs to be scalable.

2. Interoperability – Technological standards in most areas are still fragmented. These technologies need to be converged. This will help to establish the common framework and the standard for the IoT devices.

3. Safety of patients – Most of the times IoT devices are left un-attended, since they are attached to the real world objects. If used on patients as implantable or wearable, due to the purpose and nature of IoT devices, any breaches in security are life threatening and considered very critical.

4. Security and personal privacy - The IoT in health care should ensure Confidentiality, Integrity, and Availability of patients personal data. Still challenges as of today, while designing an IoT based system are Limited Power, Limited Energy and Limited Memory.

IoT devices are powered by batteries[18]. Transmitting a single bit requires more energy than executing a single instruction. As more and more devices are connecting and communicating with each other, huge volume of data is exchanged. Data aggregation is used to improve the energy efficiency. Smart objects are integrated with agents to facilitate cooperation, global intelligence, and to meet the challenges of IoT.

Mobile agents are autonomous programs[6,7] that transmit their execution state from device to device in networked systems, which provide execution of computational tasks and reduces communication and information processing costs. Mobile agent based data aggregation reduces the power consumption. But the mobile agents may accomplish their task alone. Co-operation in mobile agent makes them powerful. Swarm intelligence is distributed problem solving with a group of agents and it exhibits collective intelligent behavior. Swarm technology provides massive scalability and the ability to easily integrate future, as yet undefined, interfaces and devices. Swarm can drastically reduce

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the costs of application development and deployment, installation, commissioning and maintenance out at the network edge. Swarm intelligent agents are used in data collection, which reduces the cost of integrating remote sensors and devices.

Swarm agents collect data from the devices. But the sensors deliver the same bits of data independent of the application domain, but this data can have distinct purposes in different domains. The understanding ability of machine requires the information which is semantically structured derived from the internet of things. Hence the IoT data should be modeled as ontology.

Light weight semantics are used for metadata to enhance rich sensor data acquisition with the help of the component ontology and semantic mapping[10]. The ontology is the data abstraction of the existing IoT data, and are mapped with the domain concepts and properties. The semantic mapping is to map the raw database schema with RDF of ontology[20].

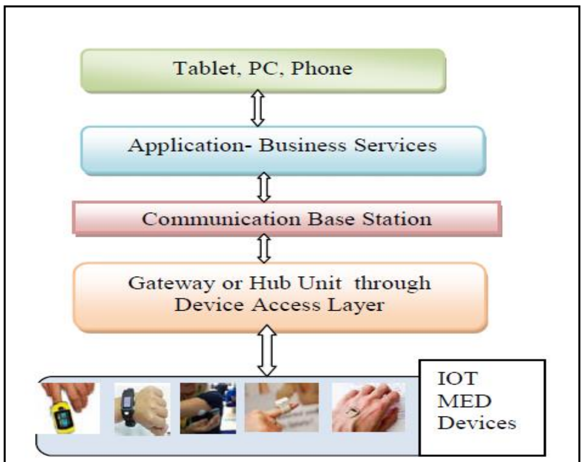

Figure 1. IoT Medical Devices in Smart hospital Scenario

For example, heartbeat can carry an indication of health in the critical care domain or an indication of performance potential in sports or entertainment domain. This example shows that semantic interoperability requires not only sharing of data and concepts, but also positioning them in the specific purpose of the application for their appropriate use. Also from the contextual awareness the heart rate reading should be interpreted as the subject being an adult or infant, at rest or running on a treadmill to allow reasoning about the high or normal heart rate reading.

2. RELATED WORK

Philip's "eICU" medical suit helps the centralized staff of nurses and doctors to monitor the intensive care unit patient's vital signs. QUALCOMM developed a cloud based medical platform 2nd Platform, which communicates the data to the other devices and interoperable with the HIPPA complaint system. Smart Pump Programming has the additional details of drug library and dosage diagnosis. Here the integration of Electronic Health Record[3] details is flowing into the smart pump applications. The prescription values of auto documentation with the event impact data get back from the smart pump program into the hospital management system. Cisco proposes an architectural framework for the IoT enabled eHealthcare. Lei Yu [13] proposes an architecture framework with the business and application service details of middleware. Mervat Abu-Elkheir [19] came out with the IoT data management proposals with the primitives of design.

Katasonov [11], discussed agent-based IoT system architecture, where an agent represents each resource, monitoring and coordinating the resource. G. Fortino, [8,9] presented a multi-layered agent-based architecture for smart objects. Aiello [1] discussed about how agents are used as gateways to access heterogeneous devices and communication protocols in IoT, enabling interoperability, context-awareness and one-to-many communication with centralized group management. Aiello [2] presented Java-based mobile agent framework for SunSPOT where agents are modeled as a multi-plane event-based state machines. Evaluation of the framework with a real-time application for wireless body sensor networks is also provided. Vazquez [23] provides a layered architecture to connect WSN to IoT with Sensors and Actuators layer, Coordination layer and Supervision layer.

Payam introduced [21] the need to share and integrate information between different domains to infer new knowledge. Michele[20] proposed the concept of SWOT framework and introduce the need of reasoning, but do not propose the idea to interlink domain ontologies and rules. Amélie [4] designed the SWOT framework to automatically integrate sensor data with semantics and reason about them by reusing domain knowledge and to provide web services to developers who do not need to learn semantic web technologies. Semantics can be used to enhance data processing such as fusion from multiple data sources and enhance queries and to adapt the results to support different ontological commitments [22].

3. RESEARCH PROBLEM DEFINITION

Automated processing system triggered by events from the IOT devices, the data model plays a major role. As more and more devices are connected and communicated with each other, huge volume of data is exchanged. The data may be structured or unstructured, based on the data, database back end is to be decided. This explosion of data needs to be stored, analyzed with complex data analytic techniques is needed to provide the necessary information for both the patient and doctor. Some of the researchers are focusing on the Agent based data collection. Some give attention to the application framework. Very few are concentrating on the semantic data model.

There is need for end to end to end solution with the energy efficiency for IOT device communications. As data communication is one of the major activities in the IOT medical devices and devices exist with limited battery, energy efficient data collection is required with data preprocessing, analytical, post processing techniques as a architecture framework.

3.1 Research Contributions

The proposed smart patient management system revolves around the meaningful use and analysis of data from IoT devices. The research contributions are as follows

- Swarm agent based data collection - Improve the energy efficiency of the IoT Devices.
- Analytical agent - Analyze and aggregate the data to provide accurate data.
- Semantic Agent - Deliver knowledge as a result to the smart patient monitoring system and to the application layer with the help Ontology mapping and concept level grouping.
- Prediction Module - Patient data are clustered and analyzed with the help of a decision tree and the risk factor is predicted and submitted to the corresponding

practitioner and the approved data to the Mediclaim policy provider and applications.

4. PROPOSED ASIOTH ARCHITECTURE

This work focuses on architecture, process flow, ontology mapping and knowledge base of the smart patient management system enabled with IoT medical devices and also to address some of the challenges in IoT like Scalability, Interoperability, Limited energy and Limited memory.

4.1 Basic Assumptions

All the IoT medical devices can be categorized into medication monitoring, vital sign monitoring, activity monitoring, safety sign monitoring, patient identity and laboratory monitoring. Among them, this work focuses only on the Vital Sign Monitoring.

For the initial study the remote patient monitoring of vital signs is alone considered. The ontology used includes only the concepts and properties of vital signs. In case of the workflows, alert on critical incident alone considered as a use case. Regarding the device management, the battery and energy tracking issues are considered.

For Swarm intelligence the foraging behavior of the honey bees is adapted. The objective of the algorithm is to locate and explore good sites within a problem search space. Many scout agents are sent out, in each iteration. It is always in search of additional good sites which are continually exploited in the local search application.

Design only takes into account the Service Oriented Architecture. In case of network, Wired, Wireless, World Wide Web communication infrastructures are considered. The NOSQL database of unstructured database is considered rather the cloud database. Own Server space for middle tier services, databases and applications are considered rather the cloud based deployment.

4.2 Architecture

The architecture is the logical application framework which contains four layers, namely device layer, communication layer, application layer and user access layer. The layers of this architecture contain four modules

1. Swarm Intelligence Module: 2. Analytical Module: 3. Semantic Module and 4. Prediction module

The introduction of smart objects produces the new data objects. The question is how to sync the well established health care and clinical databases, hospital information systems with the data from the device events. There are standards in data communication to the existing medical databases. So, there is a need for data transformation, data mapping to communicate the data to the external system.

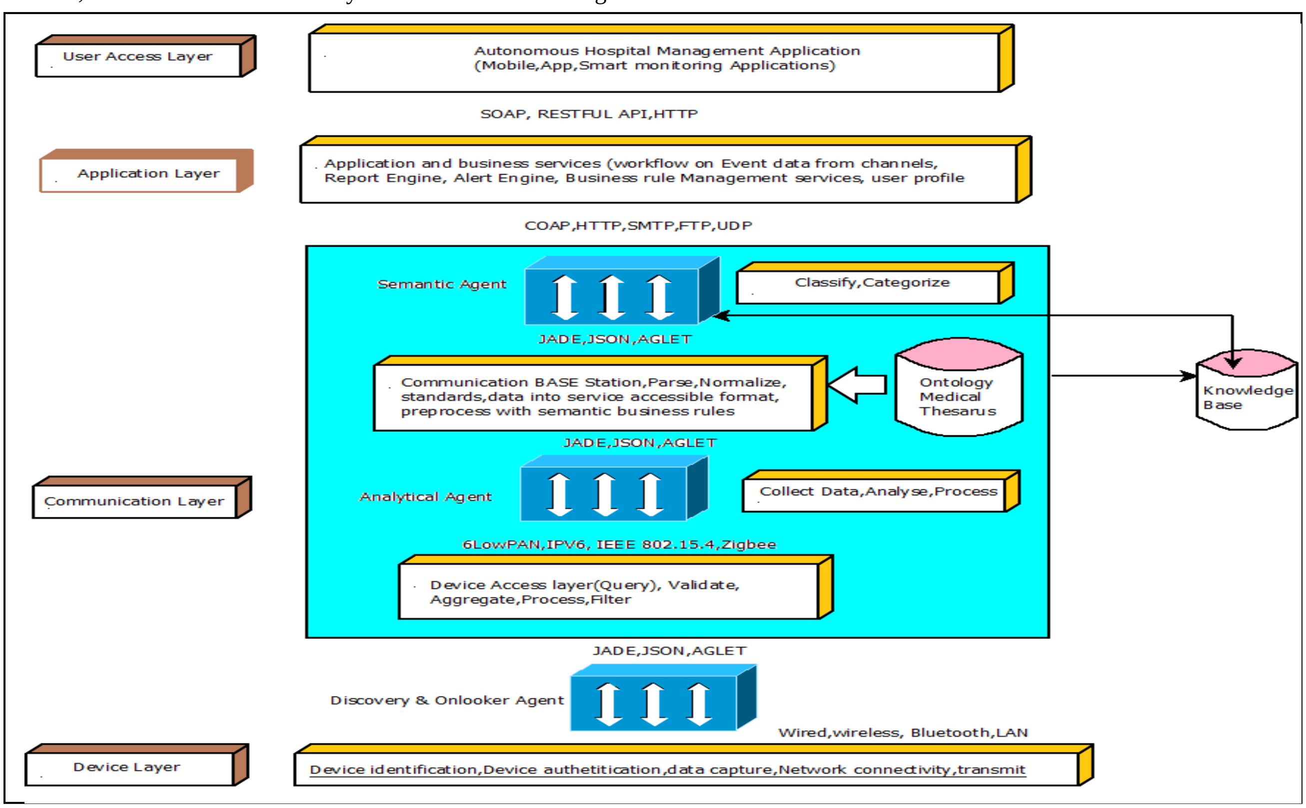

Figure 2. Architecture IoT Medical Devices in Smart hospital Scenario

4.2.1 Device Layer

Device layer is used in data collection from IoT devices. The devices usually had 3 main classes, minimum device of the 8 bit system with the on chip controller and without embedded devices. Mid level devices have the very limited 32 bit architecture, but with the embedded operating system. Most capable devices have the fully capable 64 bit architecture running on a full operating system like Linux. In case of the connectivity, there are numerous connectivity options like LAN or WAN connection with the TCP/UDP connectivity. Zigbee or Mesh radio network, UART serial lines, low power Bluetooth connections, point to point wired links, mobile-network, IPV6 with virtual IPs, WIFI connection are some of the possible connections in the Body Area Network of the HealthCare domain. Device layer includes the swarm intelligence module for data collection and data propagation.

4.2.1.1 Swarm Intelligence Module

It has different kinds of agents. The agents follow the well defined rules. Intelligent behavior is the outcome of interaction between such agents. This module mainly used in data collection.

The swarm intelligence module has three dimensions. They are

1. Discovery Agent – To verify the energy level of the nodes and to share the information with onlooker agent.

2. Onlooker Agent- Based on the information shared by the discovery agent decides the path to collect the data.

3. Scout agent – placed on the sink itself, evaluates the quality path.

Discovery Agent

The smart objects read and transmit in the form of OP_CODE, LED, display value of 10-16 binary digit values. The critical health measure devices considered are Pulseoximeter which sense and reports the oxygen saturation level in the blood, blood pressure detector to access the blood pressure, temperature sensor for reading the body temperature, ECG sensor to report the electrical and muscular functions of the heart, glucometer to measure the blood glucose level, airflow sensor for detecting the breathing pattern. Here, the resource or device is registered with the application service, then by application discovery, RESTFUL API, Asynchronous notification the event data are communicated to the smart patient management system.

Table 1. Packet Structure of Discovery Agent

Sink Id	*DA seq No*	*Sensor Id(s)*	*Patient Id*	*Datetime*
Energy Value		*Critical Data*	*Src List(Nbr)*	*Next Hop(n)*
Processing Code(p)		*Estimated distance*		

Sink id and DA Seq No: It is used to identify the DA packet. *Sensor Id and patient Id*: It is used to specify information about sensor and patient. *DateTime*: Date and time of the data collection. *Energy value*: It is used to specify the energy value of the nodes. *Critical data*: It is used to compare the collected data with a threshold. *Src List*: It specifies what sources are visited by DA. *Next hop*: It is an immediate next hop node. *Estimated distance:* It is the distance from current node to the source. An Algorithm for discovery agent shown in Figure 3.

```
Algorithm 1 :Discovery Agent Structure

Initialize network,node,neighbor, routing table
while round < n do
for all t ∈ Nbr(srclist) do
Evaluates the energy of t.
s selects the next hop node n
If s(data) =  critical data then
raise an alarm
round = round + 1
end while
Updating Routing Table.
Energy Broadcasting.
 end if
```

Figure 3. Algorithm for Discovery Agent

Onlooker Agent and Scout Agent

The onlooker agent, a self simulating agent, simulates a number of times. It depends on the quality of the path. The number of cloned onlooker agents would be more, once the nodes have a good amount of energy and produces more data.

Table 2. Packet Structure of Onlooker Agent

Sink Id	*OA seq No*	*Sensor Id(s)*	*Patient Id*	*Datetime*
Energy Value	*Critical Data*	*Src List(Nbr)*	*Next Hop(n)*	
Processing Code(p)	*DATA*			

The scout bee explores the environment to find the food source of flower patch. The Scout bee returns to the hive and inform the forager bees with a special dance called, "waggle dance". If the source is exploited, it has to explore the different food source. In the same way, in the communication system, if the energy is exploited in the route initially chosen by the scout agents, it has to find out the alternative.

```
Algorithm 2:  Onlooker Agent Structure

 While round < n do
for all t ∈ Nbr(srclist) do
collects the data from t.
s selects the next hop node n
If s(data) =  critical data then
raise an alarm
round = round + 1
end while
Updating Routing Table.
end if
```

Figure 4. Algorithm for Onlooker Agent

Critical data: It is used to compare the data with a threshold. *Src List*: It specifies what sources are visited by OA. *Next hop*: It is an immediate next hop node. *DATA*: It is to carry the data. Algorithm for Onlooker agent shown in Figure 4.

Sink id and DA Seq No: It is used to identify the OA packet. Sensor Id and patient Id: It is used to specify information about sensor and patient. *DateTime:* Date and time of the data collection. *Energy value*: It is used to specify the energy value of the nodes.

4.2.2 Communication Layer

Communication layer includes two modules to perform process, aggregate, validate, normalize and preprocess the data with semantic rules. The data from IoT are to adhere the Continuity Care Document medical record standard. The strategies that governs data normalization automatically map local content to terminology standards and translate data between standards are required to eliminate the ambiguity of meaning in clinical data. Clinical data vendors and health care information systems follow the standard like SNOMED CT. The data interchange format from device layer could be the XML or JSON. TinyDB, Cougar, SINA, Dsware, MILAN, Mires are some of the database options for storing the internal data. The middleware and application services could be event triggered, application driven or service oriented. The communication protocol options vary from IEEE 802.15.4e (standardized for Medical Body Area Network), BTLE, 2G-3G, LTE, Zigbee protocol to CoAP.

4.2.2.1 Analytical Module

Analytical Module is having an agent specialized in processing, analysis and aggregating the data. This agent can combine different sensing technologies that provides heterogeneous data and provide more accurate information to the upper layer services.

Table 3. Packet Structure of Analytical Agent

Sensor Id(s)		*Patient Id*	*Datetime*
Energy Value	*Critical Data*	*Src List(Nbr)*	*Next Hop(n)*
Proc. code (p)	*DATA*		*Previous value(pr)*

Figure 5 shows the workflow and the algorithm of the analytical agent. This module is to communicate this information gained from the devices in this layer, apply the necessary data transformations and serve them to the layer 3 and the structure of analytical agent is shown in Table 3.

```
Algorithm 3: Analytical Agent Structure

The source node begin to send its data packets to the destination
hop-by- hop.
for all t ∈ Nbr(srclist) do
while round < n do
If s(data) =  critical data then
raise an alarm
else
if s(data) !=pr
Aggregates s(data)
s→ DB // s sends the packets to DB
end for
round = round + 1
end while
Updating Routing Table.
Energy Broadcasting.
 end if
```

Figure 5. Algorithm for Analyticl Agent Structure

4.2.2.2 Semantic Module

It uses metadata to enhance rich sensor data acquisition with the help of the component ontology, concept level grouping and semantic mapping.

In Figure 6 explains the process flow of the smart patient monitoring system. It involves the standardizing of the medical record structure, business rules to map to the destination information system record structure without losing the meaning. The monitoring system and to the application layer with the help Ontology mapping and concept level grouping. Semantic interoperability is sharing of concepts by communicating its representation leads to appropriate interpretation. The Semantic

Ontology Mapping

The ontology has the potential of supporting not only correct interpretation of sensor data, but also ensuring its appropriate use in accordance with the purpose of a given IoT application.

The ontology of the smart patient monitoring system describes the observation data of the IoT devices. The raw observation data are stored in the NOSQL database without any semantics. Then the data is mapped into the RDFs vocabularies or OWL ontologies in Table 4. The database is transformed into knowledge base by mapping the table into classes and the columns in the table into the properties. The classes and the property provide precise

module includes an agent called semantic agent. Semantic agent delivers knowledge as a result to the smart patient.

Table 4. Properties of Ontology

Property Name	Explanation
Observation property	Points to the specific quality of the feature of interest
Observed By	Points to a sensor which produce the observation data
hasLatitude	Points to the latitude of the sensor
hasLongitude	Points to the longitude of the sensor
hasUnit	Points of the measuring unit
hasDate	Points to the date when the observation is measured
hasTime	Points to the Time when the observation is measured

Ontology based medical thesaurus available to recognize the disease from the symptoms of the patients, which diagnose the diseases from the reported clinical data of the patient. Patient id, sensor id details along with the diagnosed values are stored in the knowledge base. This diagnosis, need the practitioner's approval before the treatment. Semantic Agent clustered the readings and the clustered values are passed to the medical practitioner. They confirm the diagnosis of the diseases as a clinical disease.

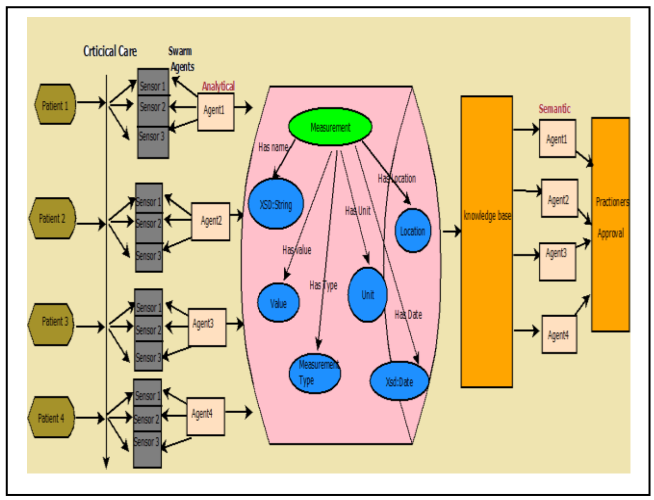

Figure 6. The Process flow of the smart patient monitoring

descriptions of the critical care data by integrating the domain knowledge of the smart patient monitoring system. The interoperability is achieved by structuring with semantics of the raw data.

Concept level Grouping

Semantic agent collects the data from the knowledge base and group the data into clusters based on the sensor id's. For example, there are $p_1 \ldots p_n$ patients , $s_1 \ldots s_n$ sensors and m clusters

S_1.cluster={ P_1. S_1 U P_2. S_1 U P_3. S_1 ………...P_n.S_1}
S_2.cluster= { P_1.S_2 U P_2.S_2 U P_3.S_2 …………P_n.S_2}
S3.cluster= { P_1.S_3 U P_2.S_3 U P_3.S_3 …………P_n.S_3}
…………..
S_m.cluster= { P_1.S_m U P_2.S_m U P_3.S_m ………P_n.S_m}

Figure 7 . Workflow of Concept level grouping

Table 5: Predicted values for Diabetics

A1c %	*Avg Blood Glucose (Mg/dl)*	*Degree of control*	*Health Risk*
<= 6	*135*	*Very Excellent*	*Very low*
7	*170*	*Excellent*	*Low*
8	*205*	*Good*	*Good*
9	*240*	*Fair*	*Medium*
10	*275*	*Poor*	*High*
11	*310*	*Very poor*	*Very high*
>=12	*345*	*Extremely poor*	*Extremely high*

Then the grouped data are transferred to the particular practitioner's approval shown in Figure 7. For example, if S_i sensor is for Glucose level monitoring for in patients, then S_i clustered data is submitted to diabetician approval and if it is a sensor for heart beat, then submitted to the cardiologist and so on.

4.2.3 Application Layer

The middleware and application services could be event triggered, application driven or service oriented. The communication protocol options vary from IEEE 802.15.4e (standardized for Medical Body Area Network), BTLE, 2G-3G, LTE, Zigbee protocol to CoAP.

The application layer provides the following services 1.Medical device observation services, 2. Web notification services 3. Sensor or actuator alert services.

4.2.3.1 Prediction Module

The sensor clusters of communication layer are analyzed with the help of a decision tree and the risk factor is predicted and submitted to the corresponding practitioner and to the Insurance company for the approval of new mediclaim policy.

Suppose if sensor s1 is for glucose level monitoring, then the s1 cluster is used to predict the possibility of diabetics for a particular patient using the percentage level of A1C test. The A1C test is a blood test that provides information about a person's average levels of blood glucose, also called blood sugar, over the past 3 months. The A1C test result is reported as a percentage. The higher the percentage, the higher a person's blood glucose levels have been. A normal A1C level is below 5.7 percent. Within the prediabetes A1C range of 5.7 to 6.4 percent, the higher the A1C, the greater the risk of diabetes. Those with prediabetes are likely to develop type 2 diabetes within 10 years, but they can take steps to prevent or delay diabetes.

The HBA1C is calculated using

$$HbA1c = (46.7 + Plasma\ Glucose) / 28.7$$

The range of A1C values and the possibility of predicted diabetics is given in Table 5 and its decision tree is in Figure 9.

4.2.4 User access Layer

User can access the services of the smart patient monitoring system through mobile, app and smart monitoring applications.

The following is the algorithm for data processing in IoT enabled patient monitoring applications. Algorithm 4 represents the overall performance of the smart patient monitoring system.

Algorithm 4: Structural Decomposition and Data Validation of Data Remanence from IoT Medical Devices

Input:IOT_MED: Devi={ IOT_MED_Reading, Patient},i=1..n
For Every event of the Device (Devi) € IoT_MED **Do**
 Begin
 Authenticate Device
CreateDatabaseconnection(con)
InsertSmartDataObject(Devi)
ExecuteQuery(con)
Discovery agent and onlooker agent Triggers Transmission
Then
CreateRootNode(Devi)
Refer Device Definition, Business Rule from Database(con)
Add SmartDataObjectTag in EXI XML()
Get Attribute() and AttributeValue()
Validate Data for Device(Min, Max Range)
If Data > Max Range then Raise an alarm
else
 Create EXIXML ChildNode for all attributes()
Create EHC Record in EXIXML format()
Analytical Agent analyze data
If Check or Validation fails **Then**
Follow the Fallback Action as per workflow configuration
 EndIf
 Normalize the EHC Record() as per standard(con)
Semantic agent Check for Datatype, Dataformat, Correcttimestamp, SemanticAnnotation, from Device Standards Described in ontology medical Thesaurus (con)
 Process the EHC Record (Message Composition, Content Categorization, Message Filtering, Data Aggreation, Parsing)
Analyze the EHC Record for Prediction Model, Pattern Definition, Frequency Tracking
On the Fly Data Transformation(Source, Target) using semantic Agent from Knowledgebase(con)
Repackage EHC Record into Target Data Model() for practitioner's Approval
Identify Network connection
Transmit EHC Record in the Protocol transmission format
End

Figure 8 : Algorithm for Data Validation

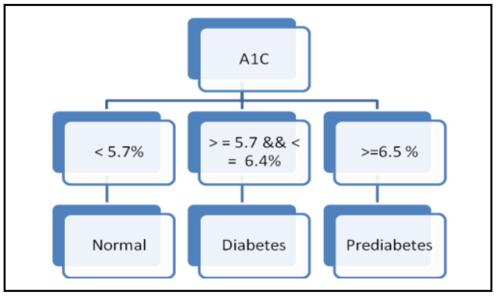

Figure 9 :Decision tree Diabetics prediction

5. RESULTS AND DISCUSSION

Usually, the system classifies the data as level1, level2, level3 (where the level1 – simple entry or sensed data – the raw data, level2 – classified and categorized data, level3 – inferences, statistics, counts). So, the data model also should have the layers with the unification is aimed at. In case of the agent based data collection in bedside monitoring or on the critical care, the range of data generates the event which is captured in Figure 10.

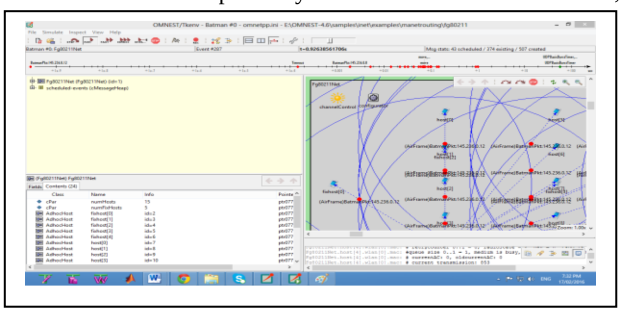

Figure 10. Agent based data collection in OMNEST

In an implementation scenario, we have to create our own channel and define the fields of data communication from the channel. Define the data set as per the definition. The reaction could be the custom HTTP POST or GET. Figure 11 indicates the Quality Of Service(QOS) parameters observed in the network simulation.

The predicted values of the diabetic patient in the critical care, are captured in Figure 12.

The end to end solution of swarm intelligence based data collection, data validation, data classification, semantic data analysis and prediction of data and analysis of data for inferences is covered with this proposed architecture and algorithms with the data models and validation conditions.

IoT devices in the smart health care form the network of devices. This network of devices communicates the health care data among them. This paper proposes a swarm intelligent agent based

data collection mechanism and architecture with the energy efficient communication as the devices survive with the limited battery. To infer from the collected data, the data are classified, semantically grouped, ontological mapped, inferences are generated with the treasures connectivity and the inferences are communicated for decision rather the raw data.

The data are validated for accuracy of the device range and for thecompleteness of system operation. Based on the pattern of the data retrieved, the prediction of medical measures is possible.

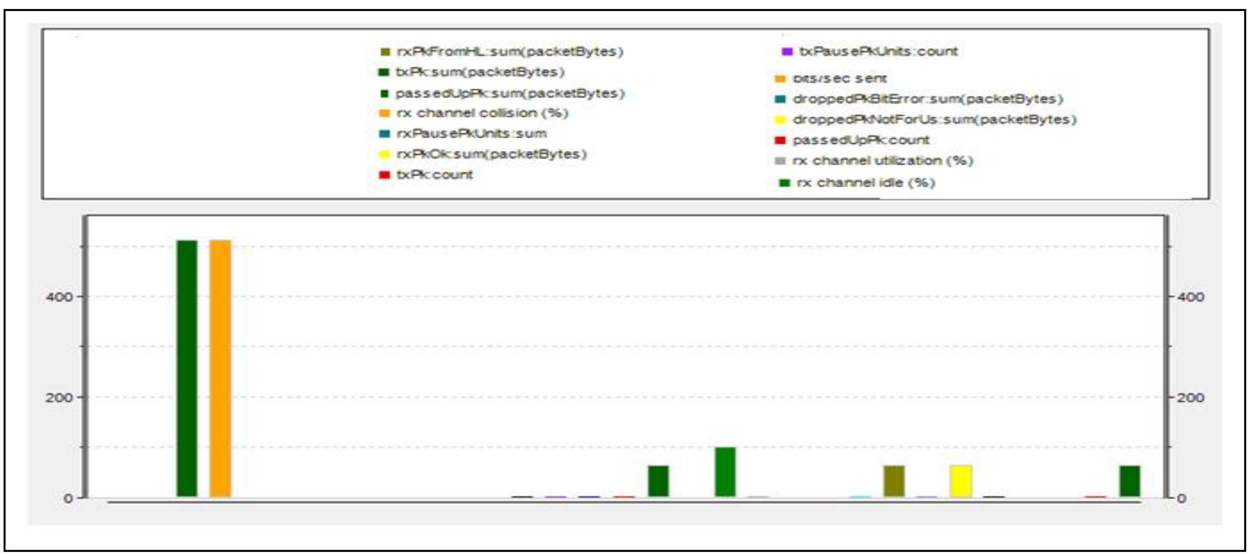

Figure 11. IoT Device Communication - Quality of Service Parameters Observed

6. CONCLUSION

This paper focuses on the general approach and procedure for the IoT enabled autonomous smart patient management system with the following technological avenues, Device selection, interoperability, data mapping & data transformation, data validation & data cleansing, ontology mapping and concept level grouping by means of analytical agent and semantic agent and process flow configuration for event driven workflows, architecture and infrastructure selection details. This paper aims at the sensor IoT devices for the health care domain, it could be extended with the actuators. The challenge of limited battery in the devices needs the routine check or replacement of batteries by the power management framework. The quality processes prescribed a scheduled routine or procedure to check the validity of the device working principles. The lab management, operational care, outpatient treatment, doctor appointments, room allocation, staff-administration, interdepartmental operations are some of the planned future use cases to get implemented as part of the system. The data generated out of the real time devices result in the huge volume of data which needs the cloud and big data analytics platform.

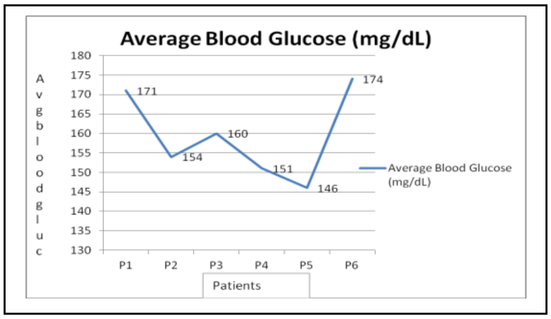

Figure 12. Predicted values of the diabetic patient

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