IoT and ANALYTICS for SUPPLY CHAIN

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Abstract - *Internet of Things (IoT) is a network of devices integrating physical and digital worlds together. This study mainly focusses on practical opportunities emerging from Internet of Things (IoT) and its applications to optimize supply chain and logistics tasks introducing transparency and automated networks for the same. This research paper aims at building a custom simulator to better visualize location data, have a control over randomly generated data and build an automated network including several participants in supply chain with the help of several API and cloud-based services. Starting from simple location services tracking plays an important role in overall development of supply chain. It is understood that the IoT infrastructure layer operates by gathering information and communicating it to track the position. Users can select different participants to post and use data and have full access to the interface so they can keep an update about their order. Later if required a pipeline can be created to store data using Amazon Relation Database Service (RDS) and also can be used later as reference for processing and analytics with help of AWS SageMaker. Complex algorithms are in place today which help in taking IoT applications in different supply chains. This paper focuses on building small a solution based on conceptual understanding of IoT, protocols Like MQTT and domain as Supply chain replicating a custom supply chain scenario having specific requirements.*

Keywords*:* IoT - Internet of Things, AWS - Amazon Web Services, SCM- Supply Chain Management, MQTT - Message Queuing Telemetry Transport, GPS - Global Positioning System, RDS - Relational Database Service, API - Application programming interface

1. INTRODUCTION

Today there are millions of goods that need to be transported or monitored on timely basis. Connecting all these goods and people throughout the process of supply chain through IoT creates efficiencies and streamlines processes which in turn saves companies time and money. It is important to track every order placed by the customer and the transportation process carried further. Cloud based services help us overcome some of these problems.

Cloud basically refers to servers accessed over the internet. Some of the leading cloud platforms include AWS, Google, IBM, Microsoft, Watson and many more. Amazon Web Services (AWS) one of the leading cloud platform today offers wide range of services globally out of which one is IoT. Out of which AWS IoT Core supports MQTT, which is a widely adapted protocol to publish or subscribe information. With the help MQTT protocol and several services offered by HERE technologies in this document we tried to accomplish our goal in this paper.

To help developers get familiar to these technologies and services which in turn can enable location in supply chain, this paper demonstrates a simple scenario to showcase the methods of its implementation. It all centers around a company that offers delivery of goods ultimately to the consumers address.

Following is the list of roles that will be involved:

1. Retailer – In simple words provider of the product
2. Consumer – Person who places order and is the last destination in supply chain
3. Delivery Operator – Company used to deliver the goods at a particular address
4. Admin – Where we can track our order on timely basis

The interaction of all these roles forms the base of our supply chain scenario. When an order is placed by a customer from a retailer, the retailers contact's the delivery operator so as to get the product delivered. The retailer is the one who provides the exact location of the customer i.e., where the order has to be delivered.

2. LITERATURE REVIEW

2.1. Internet Of Things (IOT)

Internet of Things (IOT), coined in 1999 by Kevin Ashton was a totally new concept. In the upcoming years with the advancement of technology IOT started being used immensely. In 2006-2008 first European IOT conference was held after which IOT was born. [1]

By the year 2010 there were more connected devices than the population of the world i.e,6.8 billion people were connected to 12.8 billion devices throughout the world which is almost 1.84 devices per person. In the same year IPV6 which is a network layer protocol was launched too.

By 2013 IOT was not just a term but a system of interconnected devices. Since then, IOT has been used widely in our lives. Talking about today IOT holds a position in Gartner Hype Cycle, virtual assistants, smart homes, self-driving cars and many more. [2]

2.2. Supply Chain Management (SCM)

Supply Chain is the process of managing supply chain activities so as to cater the demands of the consumers. The concept of SCM is applied throughout organization not only just to increase operating performance but also to provide more value to our consumers and ultimately create a better organization.

Flows not only involve transformation, movement and storage of goods but also involve the day-to-day flow required for the goods up and down the supply chain.

SCM mainly consists of 5 main stages i.e. [3]

1. Raw Material Supply
2. Manufacturing
3. Distribution
4. Retail
5. Customer

With the advancement in technology Gartner believes that by 2020 most the business will incorporate some element of IOT.

2.3. Position Tracking

All business that includes retailer and consumers there has to transparency maintained while transporting the goods. This helps us in effective utilization of time and cost. This can be achieved by tracking of goods. Hence at this point GPS tracking plays its role. But as our due to the constantly varying position of object it becomes a bit difficult as it requires money and a lot of computational power as tracking of each and every member at each level of supply chain is required. Here's when IOT comes into picture. [4]

So, tracking of any object requires it GPS co-ordinates. Several API are available for this purpose. In order to get the coordinates of the objects Geocoder API is linked using java script and to display the map location API is used. Now the data has to be stored for future reference. So, this is where RDS comes into picture.

Once we get the latitude and longitude at a given point of time the data is subscribed and published by MQTT and stored in a cloud for future reference.

3. PROPOSED SYSTEM MODEL

3.1. Amazon Web Service (AWS)

One of the broadly adopted cloud platform AWS offering various cloud computing solution. There are billions of devices that need to be connected and their data has to stored. AWS offers deep IOT services. AWS IOT Core allows us to connect several AWS services and interact with devices. Some of the services used in this research are:

1. AWS IOT Core
2. AWS IOT Analytics
3. RDS

3.2. Message Queuing Telemetry Transport (MQTT)

MQTT is a lightweight publish/subscribe protocol initially released by IBM in 1999. It possesses many advantages out of which one is bi-directional. It allows messaging between device to cloud and vice versa. In this paper we have used MQTT protocol via AWS IOT Core to publish and subscribe the data. Concepts used include

1. Publish/Subscribe: Publisher publishes the messages and user subscribes to these topics. Subscriber subscribes to these specific topics which relate them.
2. Topics and Subscriptions: Publisher publishes the messages to the topics and subscriber subscribes to these topics to get specific messages.

Architecture of MQTT mainly comprises of 2 components:

1. Client: It could be the publisher or the subscriber and it establishes the connection to the broker.

2. Broker: It controls the distribution of information. Mainly responsible for receiving all messages from publisher, filtering them and then sending the messages to clients.[5]

Figure 1 discusses about the approach followed in this paper and further implementation for future use. With the help of MQTT, web client publishes and subscribes the geo coordinates of the participants in the model. There are two ways to replicate this scenario i.e., hardware or software. If hardware is used the data is sent through IoT gateway to MQTT and then used. In this paper second approach is used i.e., software. By using several API offered by HERE technologies a custom simulator is created and data is published and subscribed by MQTT. Further the data is sent to AWS IoT Core.

Once the data is published in AWS IOT Core it is sent to AWS IoT Analytics. Once the data is sent to AWS IoT Analytics it is filtered and stored for future use. Pipeline receives the data from channel which is then filtered before it is stored in a data store. Amazon SageMaker is a service which provides developers and data scientist the ability to build or train model [6]. Further the data stored can be used to train models.

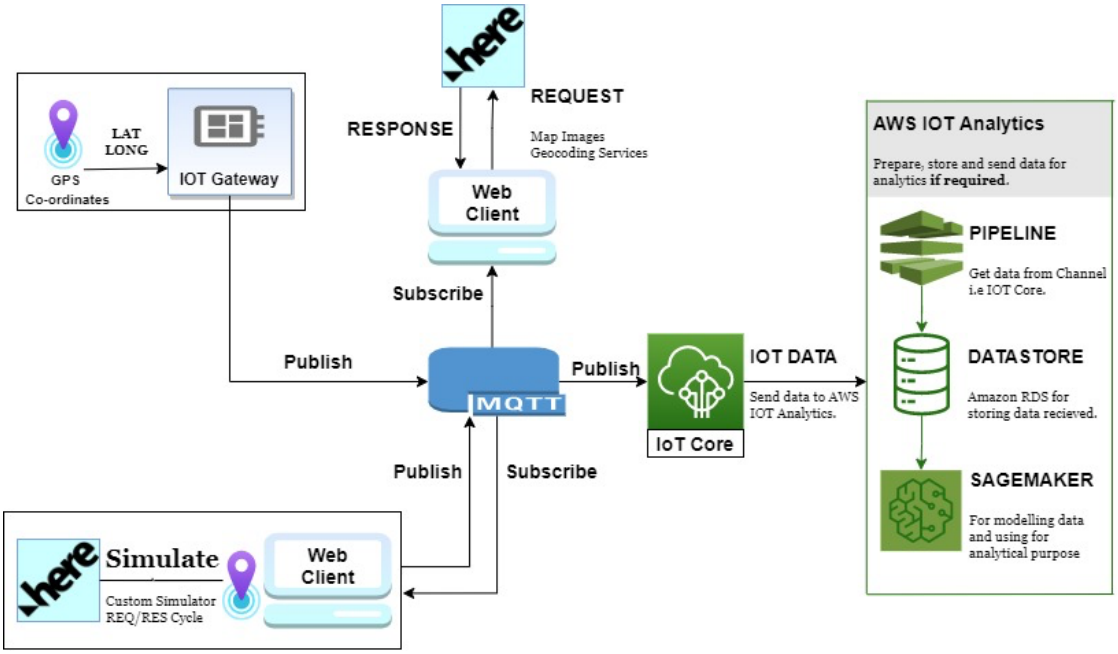

Figure 1 Flow Diagram

4. PROCEDURE AND DISCUSSION

Supply Chain Management is an integral application of IoT. To begin with, a connection is established via web client from here location API to MQTT and AWS IOT endpoint via MQTT with JavaScript. In addition, connections need to be secured by hashing keys, encrypting and decrypting data across endpoints securely and efficiently.

4.1. Tracking of Delivery Operators

Figure 2 represents a scenario including web client having map images from HERE location-based API. Once user is logged in as one of the delivery operators from the drop down, as Transport Vehicle marker corresponding to the specific vehicle will be displayed. The marker is loaded on map pointing to specific geo-coordinates with custom images, draggable behavior is introduced. Where upon dragging the marker, the location can be controlled and changed and the pop-up bubble displays the geo-coordinates respective to the location of marker. As the location of the marker is updated the geocoordinates are published under specific topics via MQTT to AWS IOT Core where the data can be stored for tracking and further use.

In figure 2 the left side of screen displays delivery operator as Transport Vehicle 3. Upon changing the coordinates, the updated data is published in real time via MQTT to AWS IOT MQTT BROKER and stored for further use.

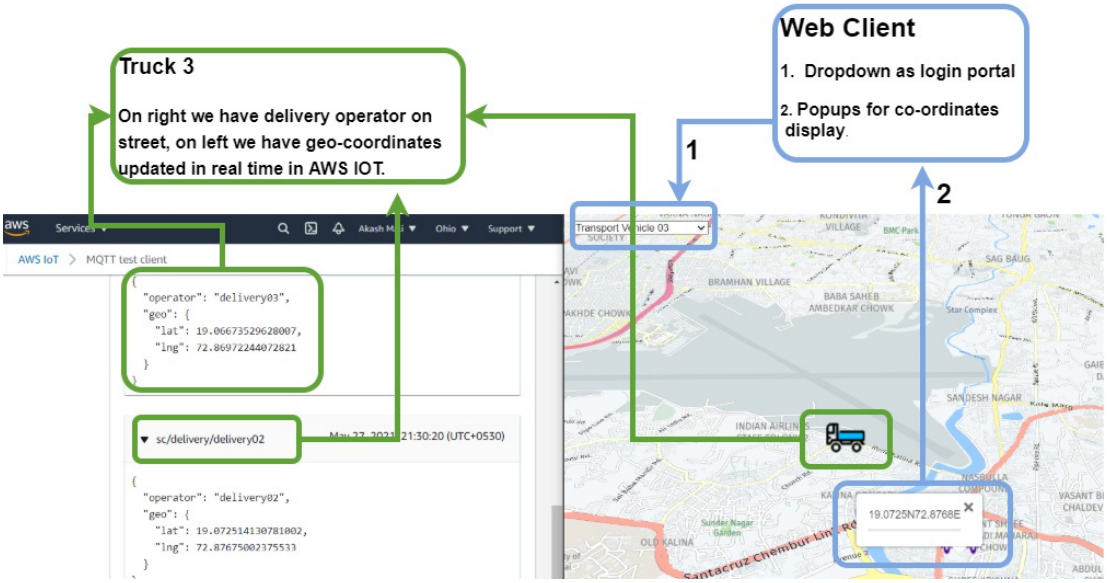

Figure 2. Transport Window

4.2. Tracking and Placing an Order

Once the tracking of the delivery operators is activated, user needs to set up the retail shops with the procedure same as the one for the delivery operator. Here comes a limitation for retailers that draggable behaviors for them would be available only once as the shop residence has to be assigned. After the retailers are set to a fixed location the next in chain comes the consumers. Consumers are set the same way as retailers with same permissions and behaviors.

These behaviors also include geocoder services like converting latitude and longitude to street addresses. Once the consumer is active, they are redirected to new window where they can see the active retailers around the city and place the order from them. After order is placed a random order id is generated and the data along with coordinates and street address of consumer and

retailer is published in real time to AWS IOT via MQTT and subscribed under a specific topic for different types of data posted. Once the user subscribes to this data in retailer's login and the retailer gets aware that it has a consumer and accepts the order, retailer is able to see his consumer in his login as in figure.
Simultaneously same data is subscribed under delivery operator's login and nearest vehicle picks up the order. For the vehicle to pick up the order we use an algorithm wherein we get the geo coordinates of the retail shop and find the differences of latitude and longitude of retail shop with respect to delivery drivers on the map. The nearest delivery operator picks up the order, immediately its published to AWS IoT as a status update and customer is notified about the delivery operator.

Figure 3 represents a customer window where order can be placed from respective retailers around the city. To be specific in figure order is placed from retail 2. As soon as the customer places an order from a retailer, customer is notified with order id, delivery operator (which delivery operator will deliver the product) and a confirmation message. Once the order is placed customer location will be visible in retailer's login as well. The key part is the data of the location, order id and street address (under sc/delivery topic) will be generated and visible in AWS IoT Console along with the status update and Delivery operator information under the topic status.

Figure 3. Customer/Retail Window

4.3. Admin Window

Tracking data is essential to keep transparency and efficient management in Supply Chain. In this window all topics can be subscribed to which data is published for various participants such as delivery operator, retailer and consumer. So, once the order is placed by the customer and accepted by the retailers, delivery operator will be responsible for the transportation and to

maintain transparency the movement can be constantly monitored. In addition to which order status for every specific order can be accessible.

4.4. Data Use

Once the generated data is passed to AWS IoT Analytics, pipelines are created for cleaning and storage purpose. The data is stored to a relational database which can further be used for processing, predictive analysis, monitoring and many more.

5. API AND SERVICES REQUIRED

5.1 HERE API

Here provides many API services. In this paper with the help of some of its services a short supply scenario was implemented. Some of the API which were used are as follows:

5.1.1. Geocoder API

It is a rest API which that allows us to

- Forward Geocoding – Allows to obtain geocoordinates for address
- Reverse Geocoding – Allows to obtain address for a geocoordinate
- Landmark Geocoding – Allows to obtain geocoordinates for known landmarks [6]

5.1.2. Maps API

Here Map API offers great features some of which are efficient map rendering, Geocoding, Routing and many more. Map API for JavaScript is a collection of different types of modules. Some of the modules used in the paper are:

- Core (mapsjs-core.js) – It contains the core functionality for rendering maps
- Service (mapsjs-service.js) – It supports tile retrieval in map
- Ui (mapsjs-ui.js + mapsjs-ui.css) – It adds a set of pre-built cross browser UI components [7]

5.2. AWS IoT Core

AWS IoT Core is a platform where we can connect IoT devices to AWS Cloud without the need to provision or manage servers. Publish and subscribe to messages is one of its capabilities that is used in this paper. The message broker securely transmits messages to and from IoT devices. Other capabilities include

- Mirror Device State
- Build Alexa Built-in devices cost-effectively at scale
- Connect and manage LoRaWAN devices [8]

5.3. AWS IoT Analytics

AWS IoT is a fully full-managed service which makes it easy to operationalize sophisticated analytics on huge volumes of data without worrying about the complexity required to build an IoT analytics platform. Key Features include

- Collect - Device data is collected in a variety of formats.
- Process - Messages with external sources are transformed
- Store - Data is stored for analysis in time-series data store
- Analyze - Using several pre built model and SQL commands predictions are made
- Build – Analytics and report help to build the system

Some of the components of AWS IoT Core used in this paper are mentioned below:

- Channel – It collects all the data from MQTT topic and archives the raw and unprocessed messages before publishing it to a pipeline
- Pipeline – It consumes messages provided by channel and enables the user to process the messages before storing it in a data store. The processing steps, named activities perform various transformations in the messages such as filtering, removing messages based on attribute value and many more
- Data store – It is not just a database but a scalable and quarriable repository of messages. For messages coming from different devices and locations we can have multiple data stores. The processed messages are stored in AWS S3 bucket which can be managed by the user.

Once the data set is created by retrieving the data from data store the data can be used for future purpose by the user.[9]

6. CONCLUSION

IoT is the key technology used in Industry 4.0. One of the areas that has benefitted the most with the development of IoT is Supply Chain Management (SCM) through new technologies such as sensors, data storage, decision making tools etc. In this paper we successfully implemented a small supply chain scenario where we built a transparent and efficient network of various participants in supply chain and automated flow for a predefined supply chain scenario. On the conceptual understandings of MQTT, IoT and Cloud we created algorithms and helper functions for our project using various APIs which included location publish and subscribe to and from cloud, location tracking, converting geocoordinates to street addresses and many more, also built a custom simulator to generate location data, have a better control over our data generated, and visualize data in location in best possible manner. Lack of sharing of any information at every level in supply chain can hinder the growth of supply chain as so this paper demonstrates that how IOT can enhance Supply Chain Management with a use case built with utilizing various APIs, tools and services.

7. ACKNOWLEDGMENT

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