Non-Invasive method using Contact-less Sensors and Embedded Platform for Monitoring Quality determining factors of Indian Mangoes

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Abstract— **The paper aims at proposing a non-invasive method for monitoring of the quality determining factors of Indian mangoes. The framework shows an IoT architecture in global mango cold chain using edge computing. Positioned at the inside of the reefer container, the system performs the task of sampling physio-chemical data from its integrated sensors and records the dynamic changes in continuous data streams. These records are treated in batches and incase of sensor events, the device triggers an alarm to a remote administration system hosted in Google cloud. GSM (during land transport) and on board Wi-Fi (during sea transport) are used as communication protocols during the phases of the journey. The data generated from the devices have been calibrated with reference to a standard Industry grade meter and compared with other similar systems.**

Keywords— **Sensors, Embedded Platform, Cold chain, IoT protocol, Edge Device**

I. INTRODUCTION

India is the world's largest producer of mangoes in the Global Market [1]. The production have seen a steady growth over the past decades but reports from the International mango trade shows that only 3% of the total volume is exported [2]. The present scenario of exporting mangoes to outer continental markets is largely influenced by the use of Air Freights [3]. However, in recent years the use of Reefer Containers is becoming more common by containerized cargo shipping [4] as the transportation cost is significantly lowered [5]. An effort for container monitoring stacked with perishable foods is made with the help of WSN and IoT [6] due to non-homogeneity of temperature often causing quality deterioration inside the reefer containers [7]. Authors in [8] have shown the use of sensors for monitoring the quality determining factor(s) of frozen consumable perishable items such as milk [9], fresh foods [10], banana [11] and cherry fruit [12] during transportation.

The quality indicators of mangoes depends on its physical appearance and chemical characteristics such as size, shape, skin colour, flesh colour, flavour, sweetness and aroma [13]. During cold transport, they are maintained at optimum temperature conditions for maintaining the shelf life. These indicators is largely influenced by factors such as Temperature, Humidity and Carbon-Dioxide. Tang et al. in [17] proposed a system for monitoring and tracking reefer container with end nodes and coordinator node using zigbee architecture in IoT. The measurement of these indicators doesn't requires high sampling rate, as the rate of change is slow and have a sluggish growth.

Authors in [14] have showed an analytical framework for studying the trade-offs in the quality of the product by introducing the notion, Internet of perishable logistics (IoPL). In IoT Architecture, Edge computing over- comes the limitations of cloud computing in supporting delay-sensitive services [15]. Edge computing devices have a feasible framework that shifts the computational and storage resources towards the edge of the network. The use of embedded non-contact sensors [16], PLC based communication technology for maritime edge computing [19] and NB-IoT driven communication technology in cold chain [20] are some of the non–invasive fruit quality estimation methods in cold chain.

Covering the state of art literature, we proposed a significant contribution towards designing of a prototype performing the task of context extraction from the sensor data with a smart network layout through an automatic selection between Wi-Fi and cellular network. The selection of the sensors and embedded platforms presented in this paper is chosen based on fulfilling the sole requirement of monitoring quality determining factors in a mango cold chain.

II. METHODOLOGY

Freshly harvested mangoes from orchards is taken to pack house where they undergoes several post-harvest treatments as a process for sustaining their shelf-life during transportation. The fruits are later categorized into palettes following its export guidelines [18] and is loaded inside the reefer container of the dimension of 20X8X8 ft. These containers has an air conditioning unit with a preset temperature of 13°C and relative humidity of 90 – 95%. However these quality determining parameters doesn't remains constant throughout the cold chain and the study shows their deviation from a permissible range. Starting from packing to distribution, the export takes place through various modes of the transportation as shown in Fig.1. Transportation via shipment is lengthy in duration thus provokes concerns regarding quality of the mango in Agri-business industry. Shipping giants such as "Maersk", "Mediterranean Shipping Company", and "Orbcomm" etc. has reefer tracking and monitoring systems and provides client service consultancy through real-time container positioning and alert notification. Controlled Atmospheric Containers (CAC) are also used as a transportation medium where the ambient conditions are maintained at a specific threshold level. Other IoT data communication method

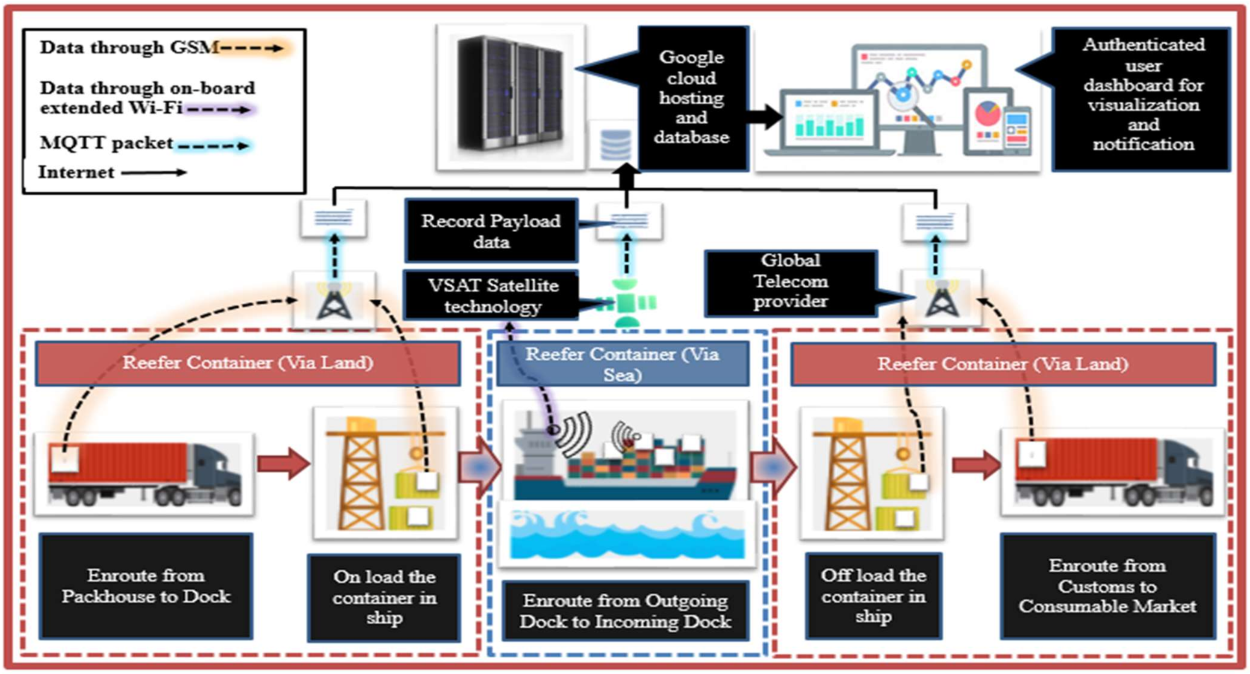

Fig.1 Proposed Architecture

includes the use of LoRa (Low power and long range). The use of LoRa and Lora WAN is not suited for application in multi-area regions due to similar frequency channels. These frequency bands differs from one continent to other. As the global cold chain embraces complex processes, a simple event based data collection scheme with full duplex M2M data communication over MQTT is presented and implemented over an edge device designed around the embedded platform, Raspberry Pi 3B.

III. EDGE DEVICE

A. Hardware Implementation

Power source of 220V AC is acquired through tap-in from the power generated by the D.G sets of the vessel. An AC/DC converter followed by a Buck converter with a 5V DC output is used for powering the edge device and connected peripherals. The sensor used for measuring temperature and humidity is DHT22, a digital, low cost and commercially available sensor. This sensor transmits discrete bits of data having binary levels. The conversion from binary to decimal and ultimately a human readable quantity is processed by the microcontroller. The sensor, Mg811 is used for measuring carbon-dioxide level has an analog output, with moderate cost and commercially available. This sensor responds towards the target gas by returning a voltage signal to the processing unit which is expressed by the microcontroller as a concentration in percentage. The device uses "SIM7600G-H" global version module with a global IoT micro SIM under 4G/LTE network. The SOC Wi-Fi module of the embedded platform makes timely searches for a Wi-Fi network. The device contains all the TCP/IP protocols stacked within the self-contained Wi-Fi module and creates a Wi-Fi link, establishes itself in STATION mode and connects to the router which behaves as an access point, AP. A 2.4GHz USB adapter with SMA connector and -2dBi signal gain antenna is used with the embedded board's SOC Wi-Fi module along with an in-build SMA antenna with the GSM module for better transceiving the signals as shown in Fig.2.

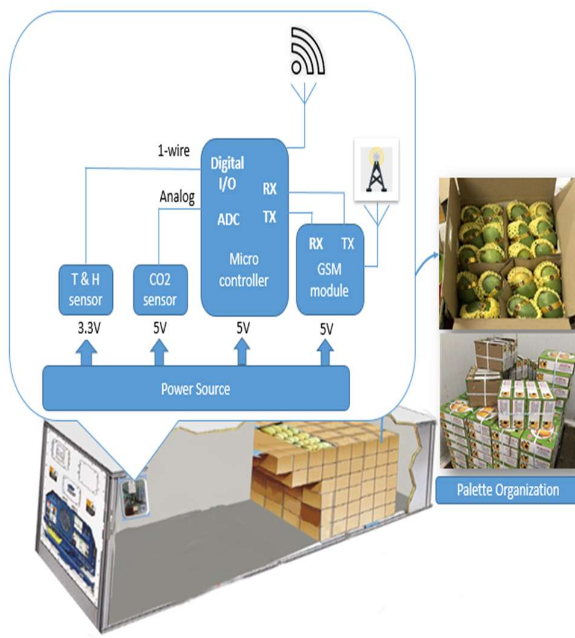

Fig.2 Housing of Edge device inside the reefer container

During different phases of the cold chain transport, under network coverage in both land and sea, we achieved a full scale solution in a single Google Cloud Platform (GCP) starting from data ingestion to display on the UI.

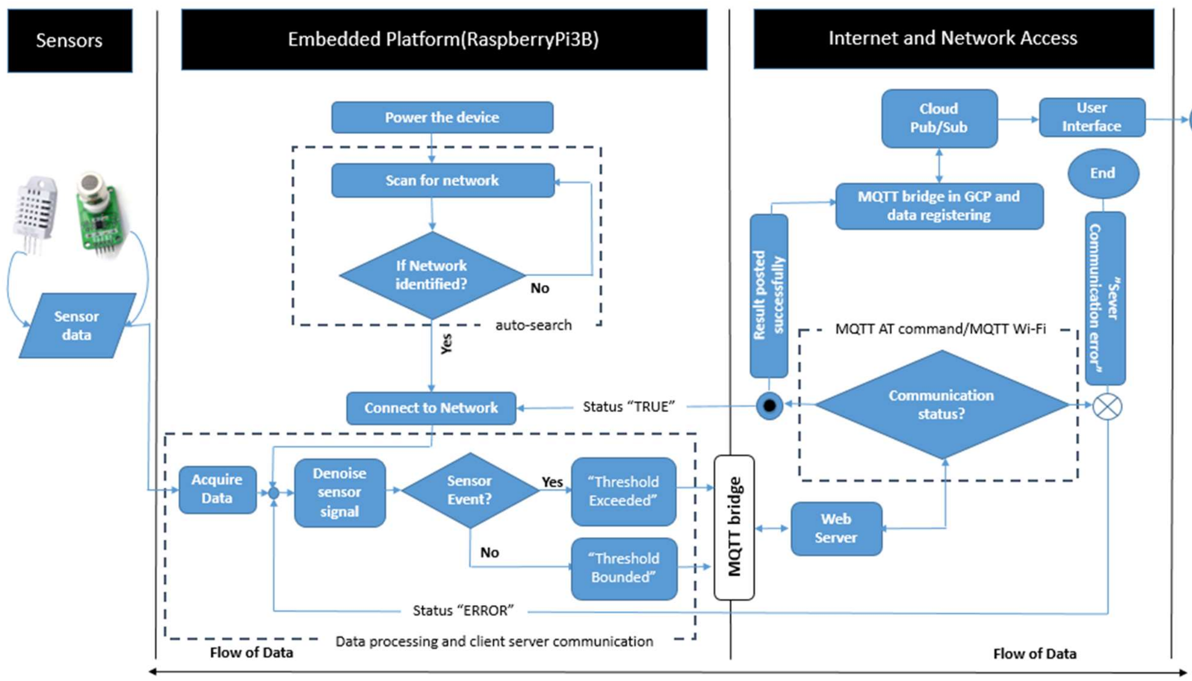

Fig.3 Sequence Diagram

B. *Software Implementation*

RaspberryPi3B is programmed using python in Rasbian OS. The sampling time of the sensors is preset. The microcontroller performs the task of sensing, processing on the sensor signals and accumulation inside the non-volatile memory of the system. The device uploads the data over MQTT server in GCP while publishing over the MQTT Bridge. The data received by the server is recorded in accordance to GST timestamp.

IV. RESULTS AND DISCUSSION

A. *Standardization of the sensors*

Data accuracy is a key component to determine the efficiency of a device. Though there are numerous sensors available, one must decide judiciously the selection of sensors and best suited for the application. The accuracy of the sensors needs to be determined before its continuous simulation for optimizing the performance of the device. The strength of the relationship between two variables of the same data type defines their degree of correlation. For this purpose, we calibrated our devices with reference to a standard meter (Lutron O_2 Meter, O2H-9903SD).
The correlation coefficients is classified into Pearson, Spearman and Kendall's. For evaluating Pearson correlation we assumed that the variables tends to normally distributed and shows linearity. We assumed non-parametric distribution for evaluating Spearman and Kendall's correlation, along with assuming the latter having least ordinal nature. The experimental data is taken from the database for comparing the data estimation accuracy of the device. The results is analyzed using python in Spyder 3.7.0.

TABLE I. PERFORMANCE EVALUATION FOR DATA ACCURACY

Device data Acquisition phases	**Sensor's Parameters**	**Correlation Coefficients**		
		Pearson	Spearman	Kendall
GSM	Temperature	96.41%	92.48%	86.17%
	Humidity	98.34%	98.39%	90.49%
	Carbon dioxide	72.33%	66.48%	57.26%
Wi-Fi	Temperature	96.57%	92.58%	86.33%
	Humidity	98.39%	98.72%	90.60%
	Carbon dioxide	79.74%	73.72%	63.45%

B. *Event data*

The quality of the mangoes varies with its shelf life which in turn depends on the ambient conditions inside the reefer container. The shelf life can be preserved upto a point when these factors are bounded within certain limits. In an ordinary reefer container used in an Indian mango cold chain, these parameters cannot be controlled and tuned with optimized settings. In depth visualization of these factors vs. time, gives agricultural scientists a prediction regarding the quality of the fruit. Hence it is necessary to keep track of the estimates where they crosses an upper and lower bounded thresholds. Whenever the sensor data crosses either of the limits, the edge device treats these data packets as sensor events as shown in Fig. 4(a, b).

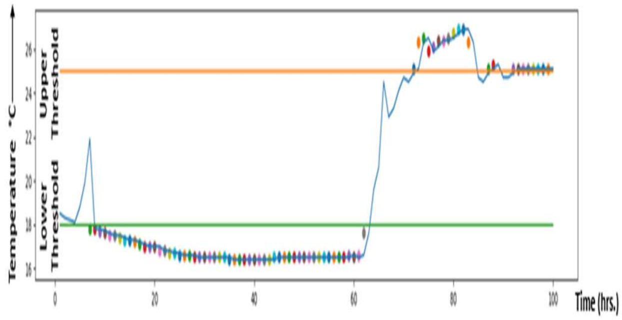

Fig.4 (a) Time-Temperature profile with dots representing the threshold exceeded data

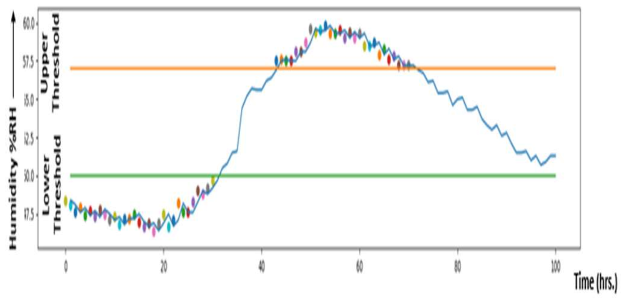

Fig.4 (b) Time-Humidity profile with dots representing the threshold exceeded data

C. *Comparison with similar devices*

In this section, we made a survey of the devices used for reefer container monitoring stacked with perishable fruits and compared their features with ours.

TABLE II. COMPARISION WITH OTHER EXISTING SYSTEMS

Parameters	**Device Reference**			
	Reefer container monitor using PLC [20]	Fresh fruit supply chain sensing[16]	NB-IoT drives Intelligent cold chain[21]	Proposed system
Sensors	Temp., Humidity, Heat Sensing	Temp., Humidity, Biosensor	Temp., Humidity, Light, Position	Temp., Humidity, CO2
GPS tracker	Terrestrial Marine	Terrestrial	Terrestrial	Terrestrial Marine
Event data and Alarm	Voyage Status, Device Status, Display ON-deck	Alarm text to carrier driver	Real time monitor through App	Unbounded data given as alert through GCP
Wireless Network Protocol	Satellite Transmit	GSM	NB-IoT	GSM Wi-Fi IEEE 802.11 a/b/g/n
Topology	VSAT Star topology	Cellular topology	Cellular topology	Cellular, Star topology
Transport domain	Inland, Marine	Inland	Inland	Inland, Marine
Energy consumption	High	Low	Low	Low
Installment cost	High	Low	Low	Low

V. CONCLUSION

We reviewed the quality indicating factors of Indian mangoes and the non-invasive methods to estimate these factors. We reviewed the current trends in association with edge device used for the purpose of reefer container for tracking and monitoring. An edge device prototype is shown which can efficiently perform the task of remote sensing from inside of the reefer containers and notify the sensor events as an alarm. Since no such electronic nose sensors are available to predict the quality of mangoes in real time, this work can be extended by deploying a computationally modified edge device which will be able to estimate the shelf life of the mangoes at the edge of the network and dynamic pricing with an addition of block chain technology in cloud for a transparent mango cold chain network.

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