IoT-Aided Charity: An Excess Food Redistribution Framework

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***Abstract*— A trusted and active community aided and supported by the Internet of Things (IoT) is a key factor in food waste reduction and management. This paper proposes an IoT based context aware framework which can capture real-time dynamic requirements of both vendors and consumers and perform real-time match-making based on captured data. We describe our proposed reference framework and the notion of smart food sharing containers as enabling technology in our framework. A prototype system demonstrates the feasibility of a proposed approach using a smart container with embedded sensors.**

Keywords—Internet of Things (IoT), Sensors, Food Waste Management (FWM), Context, Context-awareness

I. Introduction

In 2016, it's been revealed that 1 in 6 Australians had to deal with food insecurity in the past 12 months [1]. 33% of those who sought food relief were children. Overall, 8% of increase in people who sought food relief is recorded in 2015. Another report has revealed that 795 million of world's population are undernourished [2]. Food insecurity has both physical and psychological impacts on a person's life which could be short term or long term. Tiredness, loss of weight, loss of focus, exposure to illnesses are some of the physical impacts, and stress, loss of confidence, sadness and loss of hope are some of the psychological impacts on a person's life [1]. In contrast, few other studies have released staggering statistics on food loss and waste both locally and globally [3-5].This clearly indicates that if food loss and waste can be managed efficiently, it will have a large impact in reducing the number of people who are undernourished.

Our critical analysis on popular existing non-ICT based systems, ICT based systems and different scenarios has exposed their short comings, strengths and approaches towards dealing in reducing food waste.

This paper proposes a novel approach towards efficient food waste reduction via an IoT enabled dynamic and real-time match-making system which addresses the strengths and shortcomings identified in the above-mentioned analysis. A Smart Food Container/Smart Container containing different sensors is designed to capture real-time context of food donations made available by the vendors[1], to facilitate sharing with consumers[2]. Although the concepts are proposed for the Food Wastage Management (FWM) domain, our approach can be adopted, customized or extended to manage other resources as well.

The structure of this paper is as follows. Section 2 summarizes the strengths and weaknesses of existing ICT based food wastage management systems. The third section describes the overall conceptual architecture of the proposed framework. In the fourth section, we take a deep look into the concept of a Smart Container, a prototype and some results are presented as well. In the final section, a conclusion and future work are presented which foresights the evolution of our proposed system.

II. Related Work

A summary of how ICT has been utilized by some of the popular existing systems is presented in Table 1. This illustrates how different systems have utilized ICT to perform match-making between food vendors and needy consumers, the use of social media and other mechanisms in promoting and building trust in the community, the geographical coverage by each system as well as their approach in deciding the consumers (who should receive the donations).

Table 1 Different ICT usage of analyzed ICT based systems and tools

No	**Covered Geogra-phical Area**	**Trust measur-ing mechani sm**	**Biased consum-er decision**	**Social Media Usage**	**Match making of vendors and consumers based on**
1[3]	AUS	No public data available	No public data	Raise awareness	Location
2[4]	GBR	No public	No	Raise awareness,	Shopping list

[1] Those who supply excess food
[2] Those who consume excess food
[3] Foodbank Local
[4] Foodbank App

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		data available		updates via FB (future)	Location (future)
3[5]	AUS	No public data	No public data	Raise awareness	No public data
4[6]	DEU, NLD, CHE, AUT (more possible)	Referring and contribut-ion statistics	Yes	Raise awareness	Location
5[7]	GBR, NLD (more possible)	Anonym-ous rating	Yes	Raise awareness	Location, food, non-food, wanted
6[8]	USA (North)	Rating Friends	partially	Raise awareness, crowd shipping	Location
7[9]	ITA	Rating removed	partially	Raise awareness	Location
8[10]	Global	Rating, subscript-ion, reviews and Friends	Yes	Authentica-tion and raise awareness	Location, Food category, price, friendship, ownership, availability , subscripti-ons,
9[11]	AUS	Rating	Yes	Raise awareness	Location
10[12]	USA (New England)	No public data available	partially	Raise awareness	Location, Transporta-tion, quality, instruction-s
11[13]	GBR	No public data available	partially	Promotion and raise awareness	Location, food type
12[14]	USA (Chicago & Champai gn)	No public data available	No	Raise awareness	Location, product types, time and schedule
13[15]	USA	Rating, award program, feedback	No	Raise awareness	Location, supply, demand, capacity
14[16]	DNK, GBR, USA, AUS, FRA, DEU, NOR, CHE	Free purchase when a store is introduc-ed	Yes	Raise awareness	Location
15[17]	USA	Volume based discounts , Anonym-ous feedback	No	Raise awareness	Amount, food type, location, time, storage& freezer capacity

Overall it can be stated that almost all the systems lack the use of IoT in capturing real-time dynamic context data of the donations, and most of them are not context-aware in decision making which results in inefficiencies in food distribution and notifications to consumers about excess food, bias or inaccurate decisions about the distribution of donations. Also, although there have been several attempts in building trust and reputation within the community they lack a trust and reputation building and measuring mechanism which could actively collaborate with a fraud detection and prevention mechanism. Fraud detection and prevention system is an essential part of the system to prevent misuse of donations by several parties as identified via several studies [6-9]. With the knowledge gained via analyzing existing systems a new framework (and architecture) is designed to address the shortcomings of existing systems while building on the strengths they already have.

III. A Proposed Framework

The proposed framework consists of four main components which are Virtual Marketplace, Data Management Engine, Recommendation Engine and Trust, Reputation and Fraud Detection and Prevention Engine. This is illustrated in Figure 1.

A Virtual Marketplace is designed as a platform which facilitates the creation of profiles, registering of requirements and donations, and receiving recommendations. Vendors and consumers can interchange their roles due to the context-awareness of the system and the system not only considers human consumption of surplus food but also other uses such as composting and bio-materials/processing. This is open for all the stages of the Food Supply Chain (FSC).

Data Management Engine handles all the data related operations in the system. This enables coexistence and collaboration between systems by importing profiles and transaction data from existing systems to build and enhance profiles. Furthermore, it can automatically extract data from the web and social media with the consent of users to improve the context knowledge of each user, which prevents users from filling lengthy forms at the registration process. In addition, collection of sensor data is handled by this Engine. Moreover, it handles all the data storing, retrieval and update operations. The four databases store profiles, donations

[5] SecondBite
[6] FoodSharing.de
[7] Olio
[8] Food Cowboy
[9] Bring the Food
[10] RipeNearMe
[11] Neighbour Flavor
[12] Spolier Alert
[13] Plan ZHeroes
[14] Zero Percent
[15] Food Rescue US
[16] Too Good To Go
[17] Go Copia

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related data, transaction history and knowledge gained through analysis for future improvements.

Recommendation Engine handles all the match-making between vendors and consumers. An initial match-making is performed based on the profile and requirements of resources by both parties which is continuously monitored and improved based on real-time data extracted from sensors. This is then sent to Analytics Engine to analyze based on the transaction history and knowledge base. After the analysis, optimized recommendations are sent back to the Recommendation Engine where final matching will occur based on this new knowledge and will be sent to the Virtual Marketplace, which will notify interacting parties. This Recommendation Engine considers both vendor's and consumer's requirements when executing the match-making algorithm which aims to guarantee both parties' requirements are satisfied. Analytics Engine will store the new knowledge gained for future references. Existing systems can use this framework as vendors or consumers to find food relief or post donations on behalf of their clients and the match-making will occur between these systems' users and results will be sent to those systems establishing collaboration between them.

Trust, Reputation and Fraud Detection and Prevention Engine detects fraud and builds trust and reputation based on personal information, domain behavior and transaction information. This will guarantee a trusted and active local community who works efficiently towards reducing and minimizing food waste. This will assist in reducing fraud associated with charities, their staff and consumers which were discussed earlier in this paper.

As the initial phase, a Smart Container is designed to capture context data of the donations via several sensors. This is further described in the next section of this paper.

IV. Smart Food Container

Smart Food Container is a container equipped with state of the art sensors which can automatically capture and transmit the context data of the food donations dropped into it. Food donations dropped into the Smart Food Container will be detected and the information shared on our Virtual Marketplace framework so that consumers can be notified

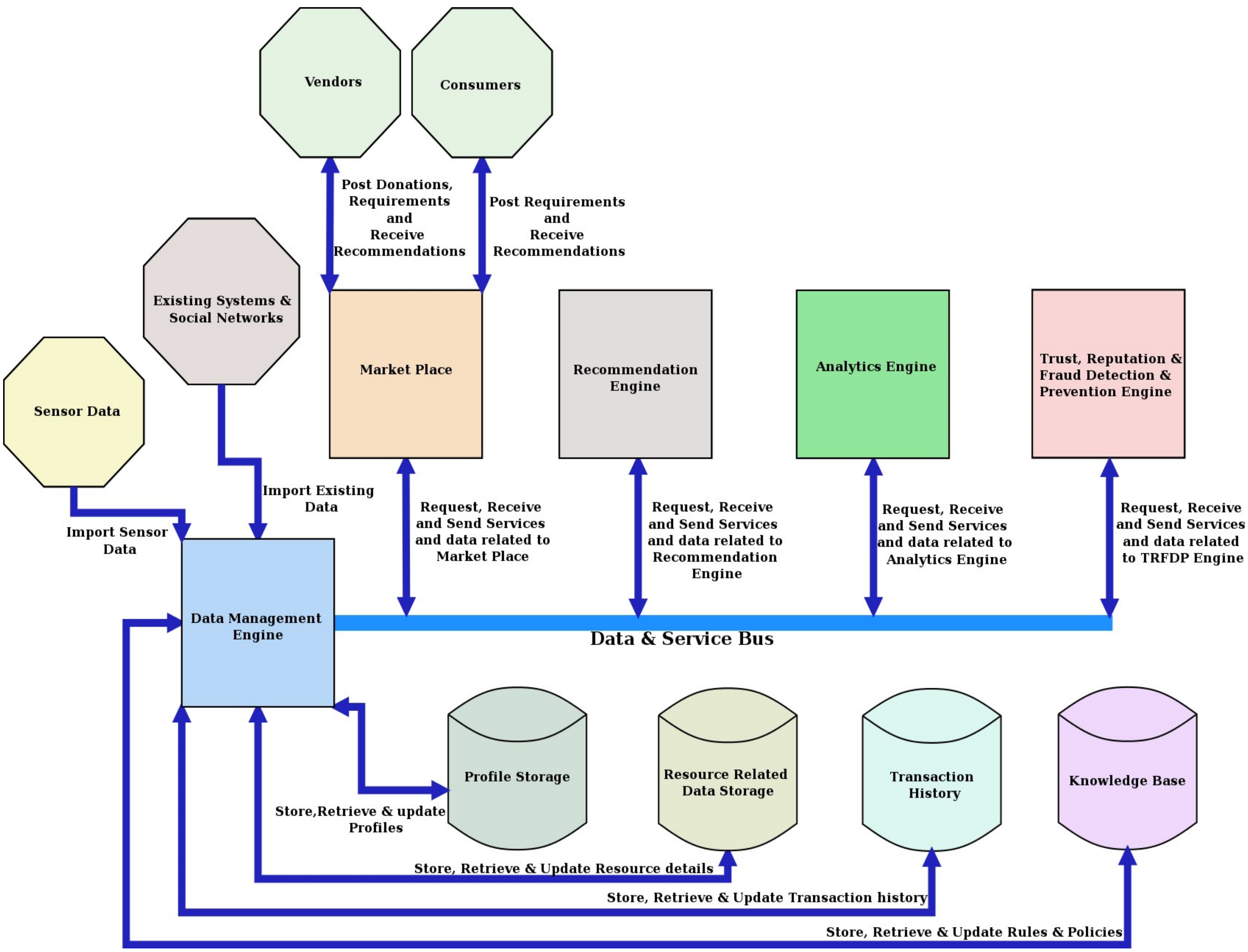

Figure 1 Proposed Conceptual Architecture

and consumers can understand the context of the food available for donation. The idea is to automate the sharing of excess food via such containers- users only need to drop their excess food into the container and the system does the rest.

Our conceptual Smart Food Container contains a distance sensor and a light sensor to detect the opening of the box, a weight sensor to detect that a new item is dropped inside and to calculate the weight of the items inside, a RFID reader to read RFID tags, a temperature sensor to capture the temperature inside, humidity and air pressure sensors, a GPS sensor to locate the Smart Container's location, a camera to capture and identify the food items inside and a WIFI enabled Raspberry Pi (or Arduino), which captures data from the sensors and transmit to the distribution center via internet. Figure 2 illustrates the conceptual Smart Container.

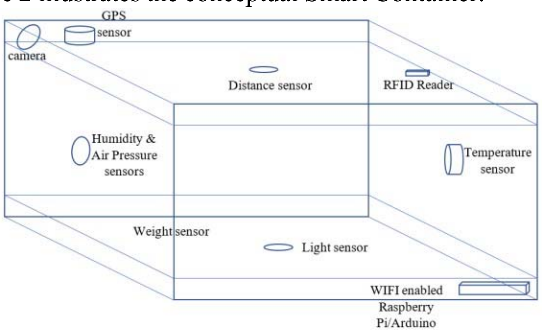

Figure 2 Smart Container

This can be extended to contain several such smart containers inside a larger container as illustrated in Figure 3. Each container can have specific sensors for the type of food items contained in them such as Fresh Produce, Deli, Sea Food and Meat and grocery products. This enables capturing more accurate and specific context data relevant to each type of food item. For an instance, temperature and humidity sensors are essential to detect the temperature of Deli, Fresh Produce and Sea Food and Meat containers to keep the food items edible for a longer period whereas it is of not that importance to the Grocery Products container.

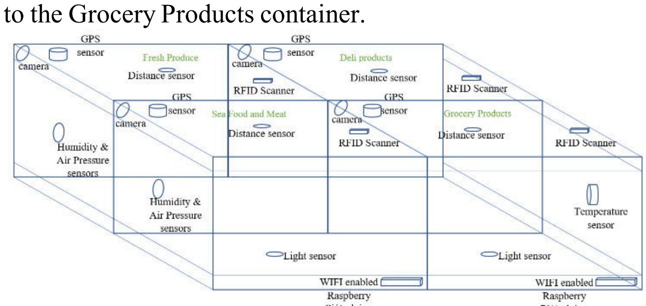

Figure 3 Extended Smart Container

An initial prototype was designed and implemented to prove the concept of a Smart Container. Raspberry Pi Camera and a DHT 11 sensor was used to capture the images of donations, humidity and temperature inside the Smart Food Container. Figure 4 depicts the sensors used for the prototype.

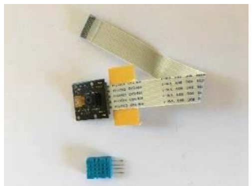

Figure 4 Camera and DHT11 sensor

Figure 5 depicts the top and side views of the prototyped Smart Container.

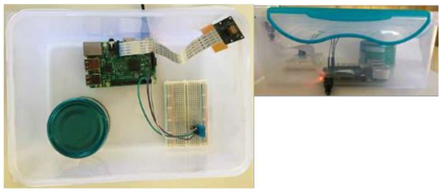

Figure 5 Prototype

Figure 6 is an image of a donation captured by the Raspberry Pi camera. Image processing to identify the items is not considered in the initial prototype.

Figure 6 Donation captured

A client-server architecture is designed using socket programing to communicate between the Raspberry Pi and the Server. An initial test was performed in a local network to prove the concept. Figure 7 illustrates the communication between Raspberry Pi and the server. Sensor readings are performed in 30 seconds intervals and the data is transferred to the server with the time when the data was captured by Raspberry Pi.

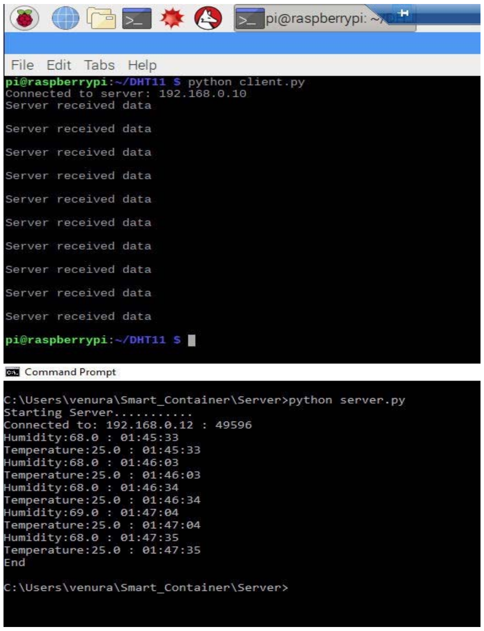

Figure 7 client-server communication

Further tests were performed to check how the environmental variables, humidity and temperature changes over a period of half an hour when the container's lid is open and when it is closed. Readings are performed in 30 seconds intervals as mentioned above and the tests were carried out in an indoor environment.

The first test was performed with the lid of the container opened and the readings were plotted as shown in Figure 8. Humidity has changed at the beginning and has remained steady in the middle and has changed again towards the end. The sensor and the items in the container were directly exposed to the changes in the environment.

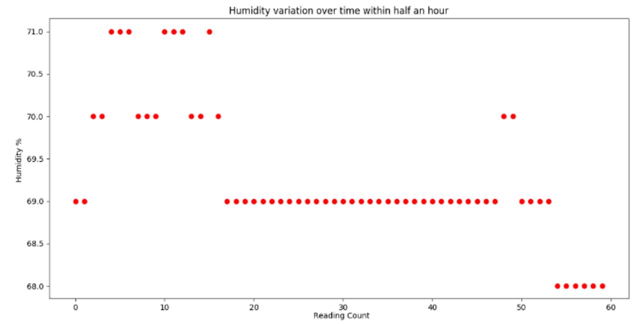

Figure 8 Humidity variation when lid is open

Temperature variations are illustrated in Figure 9. Temperature has remained steady except for a spike during the whole time.

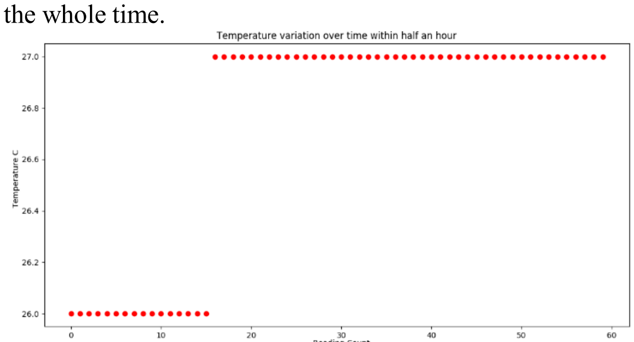

Figure 9 Temperature variation when lid is open

The next experiment was performed when the lid was closed. Apart for the initial changes, humidity has remained steady during the half an hour. With the lid closed it has provided a controlled or stable level of humidity for the items within the container. Figure 10 illustrates the results of humidity variations over time.

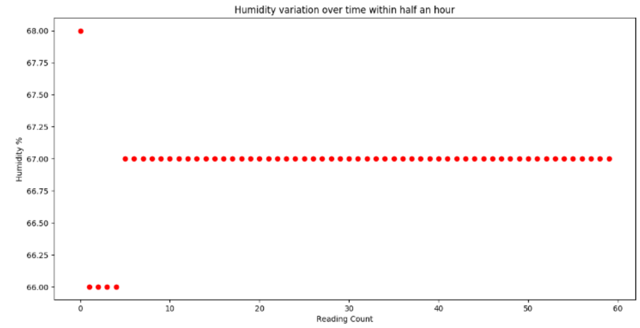

Figure 10 Humidity variations when lid is closed

Figure 11 illustrates the temperature variations when the lid is closed. As with the previous experiment when the lid was open, temperature inside the container has remained steady. These experiments have provided an initial insight into the potential environments these Smart Containers and their food items will be exposed to. Different environments provide different challenges in preserving the quality of food items. Different thresholds can be set to safe guard the food quality by identifying the type of food and the environments they are exposed to. These readings from the sensors provide real-time dynamic context-data about the environments the food is exposed to. For an instance, thresholds can be set for both temperature and humidity levels for a certain food item/ donation and sensors will monitor the environment and issue warnings if the temperature and humidity levels are not within the required thresholds. This allows the users to take actions when necessary and food items remain edible for their maximum usage period and prevents wastage via constant monitoring and reporting.

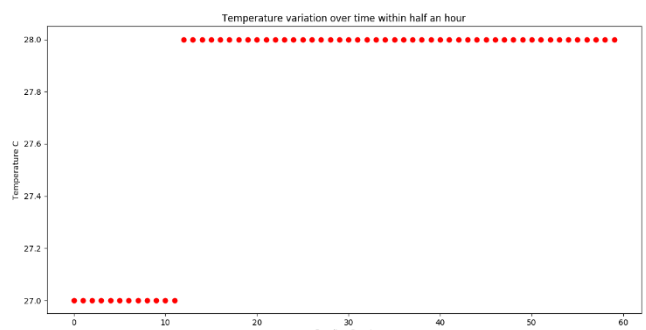

Figure 11 Temperature variations when lid is closed

We have shown that a wide range of events and conditions related to the food container can be tracked – automating the process of updating consumers about food available for donation. We imagine thousands of such food containers made available for people who would like to donate food and the smart food container will be the device to "link" into our proposed framework.

V. Conclusion and Future Work

This paper proposed an IoT based novel, real-time and dynamic framework to efficiently distribute excess food

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which would otherwise end up in waste lands. This framework addresses the weaknesses identified in the existing systems as well as maintains the strengths they have. The concept and an initial prototype of a Smart Food Container was introduced. Although current focus is on the excess food these can be used to identify the best environment for non-excess food as well as for other resources for donation.

Weight, GPS, Air pressure, Light and RFID readers will be added to the Smart Container in the next phase of the implementation. This will enable to gather more accurate context-data about the Smart Food Container's environment, including actions taken with the food and the condition of the food. Ultimately these allows real-time, dynamic, intelligent and context-aware match-making between the vendors/food items and consumers. In the future, drones (on land or flying) can also pick up such excess food from the Smart Food Containers and help deliver them to matched consumers.

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