Design and Implementing of IoT Based Container Operating Management System

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Abstract
This era would be addressed as the Internet of things (IoT) era where millions of devices, sensors, vehicles and humans are connected and reacted together. Using IoT in supply chain management and logistics could be considered as one of the promising IoT applications as it can optimize both cost and operating time. This work proposed a frame work for tracking containers using physical devices as GPS tracker, GSM modem and Internet as connection media to optimize its journey cost and time. The original studied shows that manual system of tracking containers caused many problems such as absence of integrity and efficiency. In case of using the manual data filing system many problems arise such as unfinished ordering request, false requests, vague locations, difficulty in choosing efficient distribution process and assigning tasks to drivers. Also, the wasted time due to checking availability of containers, lost driver looking for the delivery location, delayed updates about container status (available, must empty), unknown container location. This paper proposes a solution that based on IoT to connect and control remotely all the objects involves in container tracking such as GPS tracker, GSM modem with an aid of mobile base application to issues orders in an optimized manner, saving both time and cost. The current work uses a clustering technique to improve distributing and managing construction dumping containers. Automating the process of distributing and monitoring the containers using IoT based solution have many pros such as saving companies' monetary resources, saving employees time, serving customers better.

Keywords: **IoT, logistic management, Clustering Techniques; Mobile Platform; PAM; Google Map; GPS tracker. GPS modem.**

1. Introduction

The recently growth achieved during the last two decades in the field of IoT is going to changes the world face and people way of living. Using IoT you are not only connected with multiple sensors, devices, vehicles or people to collect data but you are able to analyses, interpret, and understand it to change the behavior and the acting way of those objects or things [1].

What is the IoT? Since 1999 the first time when Kevin Ashton mentioned the term "the Internet of Things" [2] many definitions have been formulated such as:

Definition 1: The Internet of Things (IoT) has been defined in Recommendation ITU-T Y.2060 as a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies [3].

Definition 2: "The Internet of Things allows people and things to be connected Anytime, Anyplace, with Anything and Anyone, ideally using Any path/network and Any service [4]."

Due to IoT interconnection and objects communication efficiency, many applications make use of it. These applications fall into three categories, industry, environment, and society [1]. Supply chain management, transportation and logistics [5], [6] and [7], aerospace, aviation, and automotive are some of the industry focused applications of IoT [1]. Telecommunication, medical technology, healthcare, smart building, home and office, media, entertainment, and ticketing are some of the society focused applications of IoT [1] and [8]. Agriculture and breeding recycling, disaster alerting, environmental monitoring is some of the environment focused applications [1] and [9].

Logistics is generally the detailed organization and implementation of a complex operation. In a general business sense, logistics is the management of the flow of things between the point of origin and the point of consumption to meet requirements of customers or corporations. The resources managed in logistics can include physical items such as food, materials, animals,

equipment, and liquids; as well as abstract items, such as time and information [10]. So, we can consider the task of managing and tracking containers for construction and other purposes as one of the logistics management tasks.
Many solutions have been proposed to facile logistic management to achieve profit maximization. Those solutions started by integrating IT with logistic system passing through *E-logistics* that integrates Internet and mobile apps with logistics management systems and finally ended up with integrating IoT with logistic management system [7].

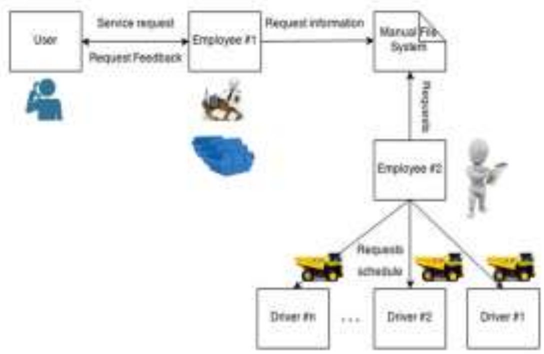

Fig. 1 Manual Containers Tracking System

The current work represents the design and implementing of IoT based container operating management system. The current construction containers in Saudi Arabia suffers from many problems that affect its operating cost and time. The proposed system makes use of IoT to solve that problem, maximize profit and minimize operations time. We can think of IoT as the magical word that combines many technologies such as GPS, GSM, and Wire/ wireless Internet to track and control people or things.
The rest of this papers organized as follows. Section II illustrates the construction containers manual system problems, section III shows the overall architecture of the proposed solution and the scoring algorithm used in the system to optimize the containers path, section IV demonstrate the system results, section V shows the system software and hardware implementation tools and finally section VI shows conclusion.

2. The Problem of distributing and Tracking Containers

Description of Existing Manual Method
Fig. 1 shows the current used manual system in Saudi Arabia for distributing and tracking containers. This system depends mainly on a human in receiving operation requests, issuing orders for drivers and constructing journey paths.

This scenario followed by the current manual system results in the following problems:

- Vague locations.
- Unfinished request.
- False requests.
- Wasted time in checking the availability of containers.
- The absence of availability, efficiency, and integrity in the user manual data filing system.
- Difficulty in choosing efficient distribution process and assigning orders to drivers.
- Wasted time in case of the lost driver.
- Delayed updates on the current status of each container (available, must empty … etc.).
- Unknown containers locations in case of theft or moved containers.

Because of these problems, the current work proposed an IoT based solution as described in section III.

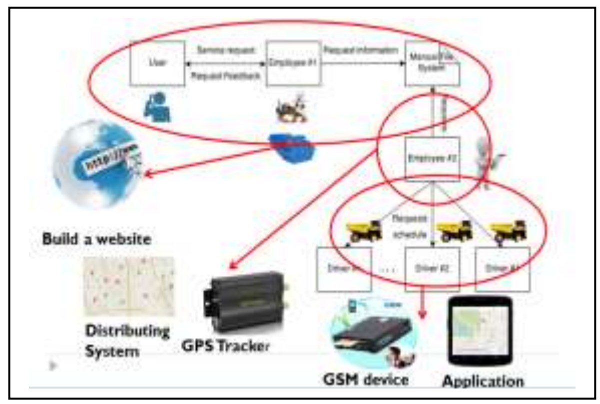

Fig. 2 Proposed System framework

3. The Proposed IoT based Solution for Solving Tracking Containers Problem

3.1 System Component

The system general architecture shows in Figure 2. The system main component is a Web-based application to receives orders from customers. Where each customer should provide the required details information about the location of source, destination, required container size, if he needs this service once or for a period, if customer needs to hire the container for a period of time shall the drivers pick it daily to empty it and back to customer or each specific period. On the other side, each drive has a mobile app to receive his daily schedule and detect his location. For each container, we attach GSM modem and GPS tracker to detect container specific location.

1. *GSM Modem*

"A GSM modem is a specialized type of modem which accepts a SIM card, and operates over a subscription to a mobile operator, just like a mobile phone. From the mobile operator perspective, a GSM modem looks just like a mobile phone." [11]. Figure 3 shows a GSM Modem. GSM modems allow different computing devices to communicate over the mobile network, and it can be used for sending and receiving SMS and MMS messages. SMS client-server software must be existing to send and receive messages. It can be downloaded along with GSMCOMM library [12].

The two updating methods; GSM modem and mobile application are used in the proposed solution.

Fig. 3 GSM Modem

2. Tracking

GPS tracker is used to monitoring containers locations in the proposed solution. This tracker device is using GPS (the Global Positioning System) to find the exact location of any objects it is attached to, was it a vehicle, person, or anything else at regular intervals. Locations data records can be stored inside the tracking device until later retrieval, or it can be transferred to an internet-connected computer or a central-location database, using a satellite, radio, cellular (GPRS or SMS), or modem implanted in the device. The retrieved locations data can be displayed on a backdrop map, both in real time and when analyzing the tracking results later, by using GPS tracking software. Smartphones with GPS capability have data tracking software suitable for this job. The function of the GPS tracker is done by the GPS module that receives the GPS signal and calculates the coordinates [13]. Figure 4 shows GPS Tracker Device.

3.2 The Working Scenario

The working scenario starts when customers provide orders through Web-based application then the system feed these data to the scheduling algorithm (CWSP-PAM) [15] the data contains other constraints like a number of available drivers, available containers number and size of each and permitted working time to satisfy orders. The usual working hours to transfer containers starts from 12 a.m to 5 a.m. all daily orders should be scheduled during this period. Then after generating driver's daily schedules through scheduling algorithm, the system sends each driver his schedule to start his journey on time. The schedule could be updated at any time. Finally, the system stats tracking containers and rivers path to update with any change.

Figure 4 GSM/GPRS/GPS Vehicle Tracker TK104 [14]

3.3 Distribution Clustering Technique:

The original algorithm, Cluster Partitioning Around Medoids (PAM) was modified by using the shortest path between any node and others [15]. The CWSP-PAM (Clustering with Shortest Path-PAM algorithm), proposed algorithm, starts by dividing the orders locations into clusters based on specific criteria. Determining the minimum cost and time which fulfills each situation constraints is done by the system as well. After that, each driver will be responsible for one cluster of the resulted ones. Testing the modified algorithm shows its efficiency and flexibility in solving the problems raised in the process of distributing construction dumping containers and managing its renting and retrieving process.

In this system's distribution part, clustering technique [15] is used to develop an algorithm for distribution of the containers. Figure 5.1-3 show flowchart of the developed CWSP-PAM algorithm. The idea of the CWSP-PAM algorithm is based on PAM algorithm after modifying the PAM distance function to satisfy the desired path constraints.

First, some inputs must be provided (the company location, all orders locations, dumping locations and number of drivers available on this specific day). Then, start scheduling all orders to get the total potential cost, which is the total time needed to complete all orders of this day. For doing this, the nearest drop off point (if there any) from the company must be found, adding its cost to the total cost and marking it as finished. Next, looking for the least cost point from unmarked points in the cluster - which is one cluster in the beginning - after that checking its type (drop off, emptying, pick up point/order).

If it is a drop-off point and the driver already has a container, checking if the size is available -from the previous point- then summing the point cost to the total cost. Marking the point as finished. If the driver doesn't have a container or the required size is not available, just going back to the company to get the needed size, so the total cost is summing the point cost plus the time from the current point to the company. After that, marking this point as finished.

If it is an emptying point and the driver has a container, summing its emptying cost and the time from current point to this point, then adding it to the total cost. Then, marking this point as finished. In case the driver doesn't have a container or the size is not available, summing its emptying cost * 2 and the time from current point to this point, then adding it to the total cost. Marking the point as finished.

If it is a pick-up point and the driver doesn't have a container, summing its pick up cost and the time from current point to this point then adding it to the total cost. Marking the point as finished.

If the driver has a container and it is not the desired size, the driver must return to the company first to change the container, summing the cost from current point to company to the total cost.

After that, repeating the process until all points in the cluster are marked as finished. Then, dividing the total cost of working hours of the day to get a minimum number of drivers needed to complete all orders. Minimum_number_of_drivers = total cost / working hours per day.

Afterwards, comparing the Minimum_number_of_drivers with the number of available drivers entered by the user. If Minimum_number_of_drivers is less than available drivers, running PAM algorithm, with the shortest path using Minimum_number_of_drivers as k, must be done. Then repeat scheduling process for each cluster until making sure all clusters fulfills the driver working hours.

If Minimum_*number_of_drivers* is greater than available drivers, the user has to add more drivers or delay some orders and run the algorithm again.

After that, comparing each cluster's total cost with driver working hours. If the total cost of all clusters is equal or less than driver's working hours, the algorithm stops. If not, adding more drivers should be done and running the process again.

Then, calculating the distance between all points and calculating the initial point cost which is the time needed for the point to be done depending on the order type (pick-up cost, emptying cost and drop off cost). After that, running PAM algorithm with the number of available drivers as a number of clusters and the orders of the day. Finally, computing the total cost for each cluster to be sure it satisfies the driver's working hour.

Unsupervised learning is the main reason for using clustering technique. Discovering a new set of groups and categories which are of interest in themselves is the goal of [16]. The idea of clustering is dividing the data set into collections based on some measure of interest differs according to the introduced scenario. One common measure of interest is the sum of squares of the direct Euclidean distance between the cluster centers and the objects they belong to. Still, the use of direct Euclidean distance has its drawbacks in many situations [17]. Some criteria must be used in clustering, to determine if two objects are similar and belong to the same cluster/group or not. Distance measures and similarity measures are two types of methods used mainly to estimate this relationship in clustering [16]. To determine the matching or mismatching between any two pairs of items, distance measures are used basically for this purpose. The distance between two instances xi and xj is donated as d(xi,xj).

Clustering Problem is defined as follows [18]:

• Assuming a data set D = {d1,d2,…,dn} of tuples and an integer number k, the "*Clustering Problem"* here is to define a mapping $f : D \rightarrow \{1, .., k\}$ where every di is assigned to one cluster Cj, 1<= j <= k.

• A *Cluster*, Cj, contains specifically those tuples assigned to it; that is, $Cj = \{di \mid f(di) = Cj, 1 \le i \le n, \text{ and } di \in D\}$.

The proposed system CCDMS (Construction Containers Distribution and Management System) consists of 5 large processes, which are ordering, distribution, scheduling, updating and tracking processes of containers. Description of the existing manual systems is described in section 2. In section 3, the original Pam algorithm is fully described. Section 4 discusses related work to the proposed

PAM Algorithm

K-medoids algorithm is another name for the PAM (Partitioning Around Medoids) algorithm. Basically, it represents a cluster with a medoid. At the start, the inputs are the needed clusters numbers and a random set of k items/objects, which is at the same time, the set of medoids. For each step, all non-medoids items from the input dataset will be examined one after another to see if they are more suitable to be medoids. Which means existing medoids might be changed if the algorithm determines there is a better candidate. By examining all combination of medoids, non-medoids objects, the combination that improves the overall quality of that clustering will be chosen by the algorithm. The measure of interest here is the summation of all distances from a non-medoid object to the medoid of their cluster. An item is mapped to the cluster in which its medoid is the closest to it (minimum distance or "direct Euclidean" distance between the objects and the cluster's center they belong to). The original PAM algorithm [18] is shown in Figure 6.

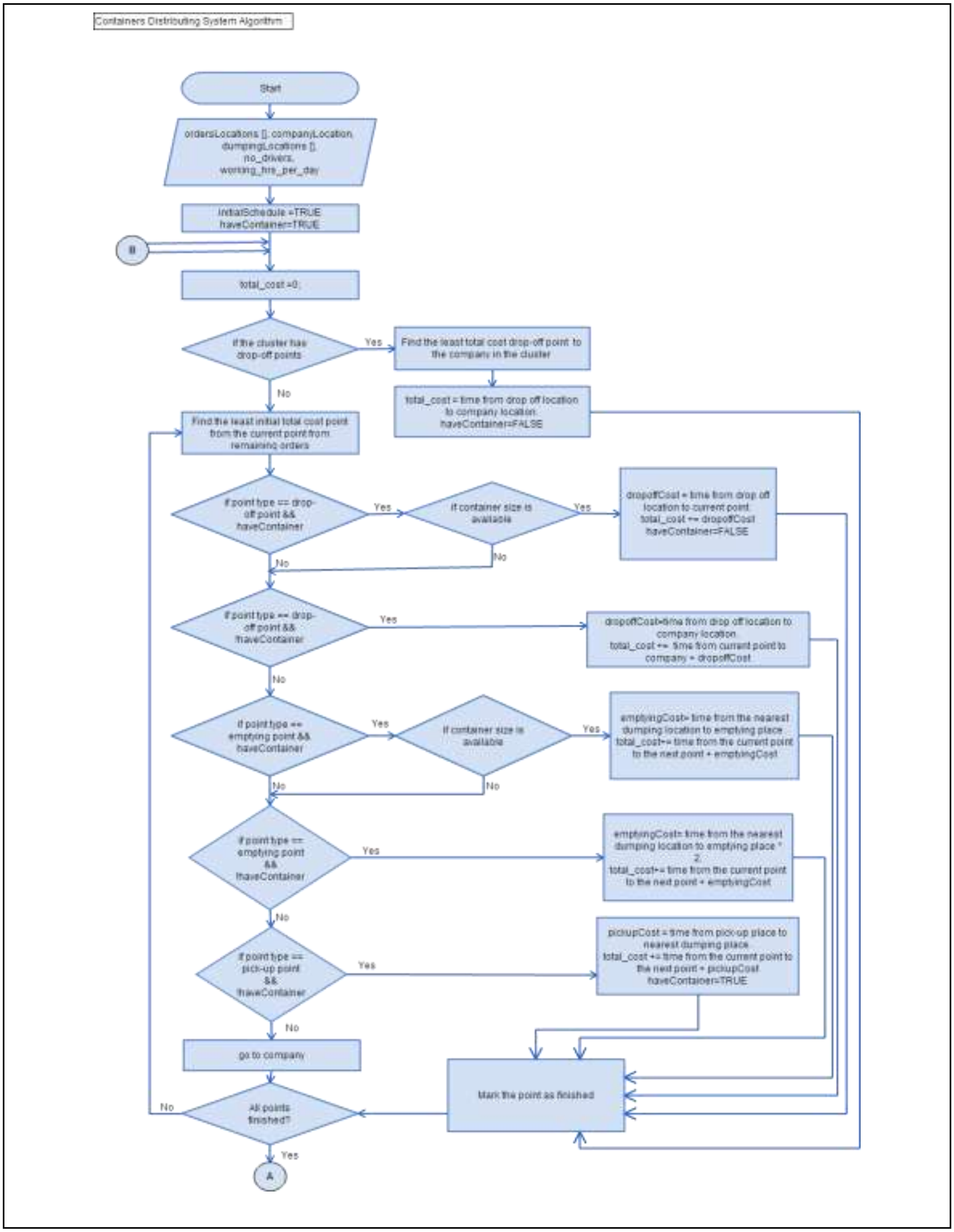

Fig. 5 Algorithm CWSP-PAM

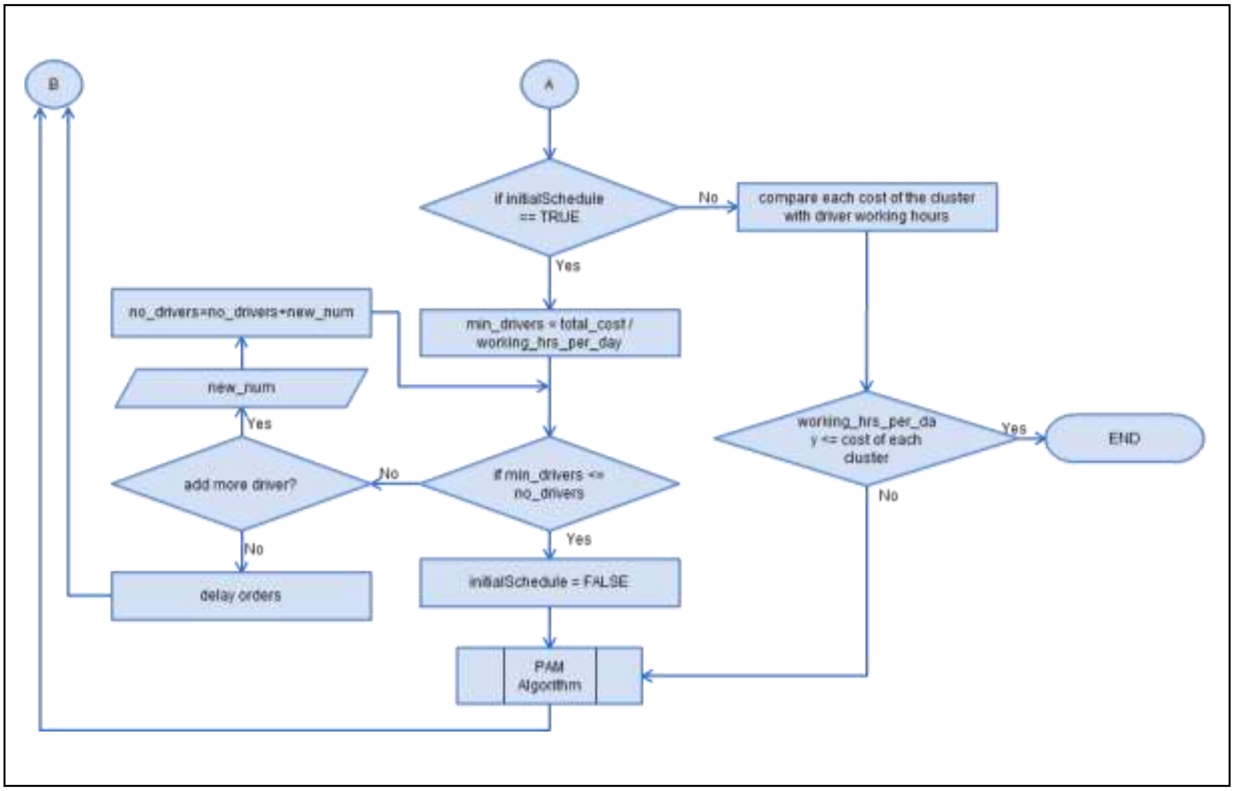

Fig. 5 algorithm CWSP-PAM (continue)

We are assuming here, that C_i is the cluster represented by medoid di. Assuming di is a current medoid, of Ci, and we want to determine whether it should be swapped with a non-medoid object dh. This swap will be done only if the total effect to the cost (summation of the distances to cluster medoid's) represents an enhancement. We use C_{jih} to be the cost changes for an item d_j connected with swapping medoid di with non-medoid dh. The considered cost is the change to the sum of all distances from items to their clusters' medoids. The equation of the total impact to quality by a medoid change TC_{ih} is given by:

$$TC_{ih} = \sum_{j=i}^{n} C_{jih} \qquad (1)$$

3.4 Scheduling

The following step is the scheduling process. After getting the results of the CWSP-PAM clustering algorithm, each cluster will be ready with its arranged orders list and then assigned to its driver.

Algorithm PAM
Input:
D = {d1,d2, d3, ……….., dn} // set of items
A // adjacency matrix showing distance between items.
k // wanted clusters numbers.
Output:
C // set of clusters.
Original PAM Algorithm:
Arbitrarily select k medoids from D;
repeat
For each dh, not a medoid do
For each medoid di do
Compute square error function TCih;
Find i, h where TCih is the smallest;
If TCih < 0 then
Replace medoid di with dh;
Until TCih >= 0;
For each di ∈ D do
Assign di to Cj where dis(di , dj) is the smallest over all medoids;

Fig. 6 PAM algorithm

3.5 Updating

Updating system data can be done in many ways. Such as; entering new data record through system's interface, filling a form to automatically update specific data record, using GSM modem or mobile application connected to the system.

4. System Implementation

In this section, the used software and hardware mentioned followed by screenshots from the implemented system for customer, employee, and drivers.

4.1 Hardware

GSM/GPRS/GPS Vehicle Tracker TK104 [14], was used to test tracking containers locations function. It is a long standby real-time GPS Tracker ideal for cars, trucks, vehicles, and other purposes. It has a base with a strong magnet to attach it to the vehicle body. Figure 4 shows the GPS tracker TK104 pack.

4.2 Software Tools

The system consists mainly of the following parts work together, exchanging data to achieve system target:

1. For customers: Website to let customers register, manage profile, submit orders.
2. For drivers: Mobile application to send orders list, and truck drivers.
3. For Employee: server-side application to run finding path algorithm, receive orders and assign privilege and tracking drivers and containers and finally update orders if needed.

The following list is the used software tools:

- Eclipse, JAVA IDE
- NetBeans, JAVA IDE
- Microsoft Visual Studio 2010
- SQL server 2008 R2 developer
- Google Maps JavaScript API v3 [19]
- JSON [20]
- Android studio [21]
- Google Maps Android API v2 [22]
- Photoshop
- CSS
- XML in android studio layout editor [23]
- JavaScript

Figure 7 shows customer registration screen followed by figure 8 which is the registration confirmation email to complete the registration process. Figure 9 shows how a customer could manage his orders and profile. He can submit, modify or delete orders.

Fig. 7 Create new account page.

Fig. 8 Activation email.

Fig. 9 Manage Customer Profile and Orders

For company employee, their main function is to view and approve order as shown in figure 10. The employee could also assign privilege as shown in figure 11 and manage container. The employee with "Manage Container" privilege can add a container or edit current containers Figure 12. For drivers, each one of them should download the application on his own mobile, run it and login with a given ID and password (figure 13). After that, he should select one of the options current schedules, update status or help as shown in figure 14.

Fig. 11 Assign Privilege

Fig. 10 Manage orders screen

Figure 12 Manage Container page

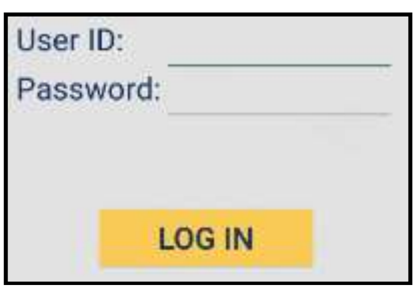

Fig. 13 Drivers login screen

Fig. 14 Drivers Options

Fig. 15 Scheduling orders of the drivers

Fig. 16 The point after clicking update button in update activity

5. Testing Algorithm Results

The proposed system passed through a unit test for each module to ensure that each function works correctly with the desired output. The unit test included testing the CWSP-PAM algorithm. CWSP-PAM algorithm was tested along the way to determine how efficient it is and if there is any possibility for more improvement. After converting CWSP-

PAM to C# language, the Google Distance Matrix method was added to get real-time between locations (orders). The CWSP-PAM has tested again with various sets of orders, to ensure its accuracy and its goal. CWSP-PAM goal is to minimize and optimize the distributing process. For this reason, a comparison was set between the CWSP-PAM and Scheduling with PAM to ensure that purpose. Figure 17 show the number of order versus the average number of hours per driver. This figure shows the average number of hours per driver is increase using PAM because calculating the number of hours using the Euclidian distance with is not applicable due to the existence of streets which make driver to go in a length route increasing the work hours.
The results show that using CWSP-PAM retrieve more accurate result than using PAM. Because PAM Algorithm uses the direct distance between two points which is not applicable in real life, while CWSP-PAM uses the real routes retrieved from Google Maps between points. Figure 18 shows a map after dividing it into clusters using (CWSP-PAM) algorithm.

Fig. 17 Scheduling Results.

Fig. 18 Map divided into clusters

The system also passed through integration test and usability test. Integration test shows that all of the system components work together correctly. The usability test results show that the users can use it easily.

6. Conclusion

This paper presents the design and implementing of construction container scheduling and tracking system based on IoT. The proposed system aims to replace the existing used manual system in Saudi Arabia as it solves many problems faced the manual system and reducing time, organize picking and distributing containers schedule in a proper way which results in maximizing profit. The current system connects customers through a web application, drivers through mobile app and containers trough GSM modem and GPS tracker to achieve efficient object communication. The system used CWSP-PAM algorithm in the scheduling modules. The daily schedule could be updated and modified at any time base on any change in the demand of users or administrators. The testing results show a promising result.

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