MTSFB TR 006:2019

TECHNICAL

REPORT

Smart Drive-Through Takeaway Utilizing Wirelessly Powered Passive Tag Automatic Identification for Vehicle Security and Services with Energy Harvesting Capability

Preface

Malaysian Technical Standards Forum Bhd (MTSFB) has awarded Universiti Putra Malaysia (UPM) the Industry Promotion and Development Grant to implement the Proof-of-Concept (PoC) through the Smart Drive-Through Takeaway Utilizing Wirelessly Powered Passive Tag Automatic Identification for Vehicle Security and Services with Energy Harvesting Capability. The duration of this PoC lasts for a period of fifteen (15) months starting January 2018. The PoC is performed at Menate Restaurant, StarParc Point, Jalan Taman Ibu Kota, 53300 Setapak, Kuala Lumpur. The key objective of this PoC is a demonstration case study of the Smart Drive-Through Takeaway (SDT) project. This Technical Report outlines objective, benefit, scope of work, methodology and result analysis.

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Abbreviations

DC	Direct Current
EIRP	Effective Isotropic Radiated Power
EPC	Electronic Product Code
ERP	Effective Radiated Power
GND	Ground
GSM	Global System for Mobile communications
IC	Integrated Chip
IM	Impedance Matching
IR	Infrared
IoT	Internet of Things
ISM	Industrial Scientific and Medical
LoRa	Long Range Wireless
PA	Power amplifier
PLL	Phase-Locked Loop
PoC	Proof-of-Concept
RFID	Radio Frequency Identification
RF-DC	Radio Frequency to Direct Current

SDK	Software Development Kit
SDT	Smart Drive-Thru Takeaway
SOAP	Size Orientation Angle Placement
UHF	Ultra High Frequency
UV	Ultra Violet
VLT	Visible Light Transmission
Wi-Fi	Wireless Fidelity

SMART DRIVE-THROUGH TAKEAWAY UTILIZING WIRELESSLY POWERED PASSIVE TAG AUTOMATIC IDENTIFICATION FOR VEHICLE SECURITY AND SERVICES WITH ENERGY HARVESTING CAPABILITY

1. Introduction

Food preparation, purchasing and delivery is a multi-billion industry. It grows rapidly mainly due to the rapid population migration to the urban and metropolitan area.

There are various choices for food purchasing mechanisms, the conventional approaches based on popularity namely:

a) Eating inside restaurant
b) Takeaway
c) Drive Through or *drive-thru* takeaway.
d) Food delivery

The most popular choice is eating inside the restaurant. This choice is natural due to most of the food venues have their exclusive or shared eating area. This choice, however, one of the most expensive choices due to owner of the food premises need to buy or rent a big area to accommodate the big number of customers if the restaurant becomes very popular. For the customers normally service charges of 10% is applied and in some countries this include extra voluntary “tips” donation. The customers also need to pay for parking their vehicles that can be expensive in certain premium venues or shopping complexes.

The second most popular is takeaway. This choice of food purchasing involve is a call from the customer. The customers still need to park their vehicles and go inside the restaurant premise to collect their ordered foods but the food will be consumed elsewhere for example at the customers’ home or office. The main advantage is that there is no extra charges for extended parking time, no service charges and tips on top of the actual food prices.

The third is the drive-thru takeaway. The customers can ordered the foods upon arrival at the premise but sometimes the queue and the waiting is long for the peak hours. This choice is however is limited for the established big food companies or franchises, namely McDonald’s, KFC and Starbucks. This is due to the drive-thru infrastructure and facility require significant investment in the food premises compound and for metropolitan area this is normally not a viable options for small food companies. According to one report, it adds about one-off additional 50% of the capital investment to the restaurant [1]. This extra cost, however, does not include recurring cost for the additional drive-thru infrastructure and facility maintenance. For certain premium or exclusive area even for the big and established food companies this is not even feasible due to the economic or regulatory reason.

The least popular is food delivery. This unpopularity is mainly due to the significant prices increase with respect to food prices. Reportedly, in US the minimum prices for food delivery is USD8 [2]. This price has to be borne by both the food premises and customers. The limit is that if the order is small i.e. for single or couple of persons, this can represent more than 40% of the food price itself. The reported average profit margin for the food business operator is around 5% this additional delivery cost is very significant and can negatively affect the business owners' profit margin [3]. In addition, there is usually minimum purchase order limit imposed for the customers. Furthermore customer residential or office area can be limited to certain radius e.g. maximum location of 10 km from the food premises. This choice normally only provided by the food giants themselves for examples McDonalds Delivery and Pizza Hut delivery. Recently, however, food delivery has becoming increasingly popular with restaurants and customers due to the introduction of third party delivery services for examples GrabFood, Uber Eats and Food Panda [4]. Thus any restaurant can have their food delivered to the client without establishing and maintaining any of the food delivery vehicles and staff.

1.1 Smart Drive-Thru Takeaway (SDT) Concept

The project is proposing another alternative for food purchasing and delivery that is most affordable and cost-effective compared to the other four conventional food purchasing and delivery choices. It is the hybrid innovation of normal takeaway and drive-thru mechanism. This innovative solution relies on the existence of the unique ID associated with the customer's food orders and vehicle. This unique customer ID is encoded in the passive tag inside customers' vehicles. The order will be delivered to the detected and identified customer upon the customer's vehicle are parked in vicinity of the restaurant premise.

For the case study a new Smart Drive-Thru Takeaway System (SDT) is implemented. Ordering of takeaway foods plus payment activities can be performed online prior to the drive-thru using the customer's smartphone, PC or mobile devices. For demonstration purpose, Me'nate's takeaway foods are ordered online by the registered customers via customers' smartphone. Once the foods are ready, the customers are notified of the location and the exact preferred time for their respective drive-through takeaway pickup. Fair scheduling for the foods pickup is necessary and can be performed in order to optimize the pickup time and avoiding congestion i.e. too many customers queueing like in a conventional drive-through. This queueing must be avoided all cost due to the limited space available in-front of the Me'nate restaurant.

When any of the scheduled customers arrive at the specified time in-front of Me'nate restaurant premise for takeaway pickup, customer vehicle ID is immediately recognized and verified through their system via reader placed strategically close to the pickup location. The foods are then pass to the intended customers without even the customer leaving the vehicle. Delivery of ordered foods can happen seamlessly without ordering, payment and queueing delay. The delay for on-site food ordering and preparation in conventional drive-thru and takeaway can causes the long queue at the existing fast food restaurant drive-thru and takeaway pickup services especially during peak hours or festive seasons. Furthermore, the SDT can help the old people or people with disabilities since it can be very difficult for them to prepare their own drink and food. It can be liberating to have their food delivered to their vehicles since they are not required to enter the premise to collect their purchased food or join the queue. The SDT can provide cheaper and convenient alternative for them to purchase their sustenance. SDT can also help smaller restaurant premises usually do not has budget to cater for proper facility for the old people and people with disability inside their restaurant. SDT also can be a very good solution for food trucks customers to find, purchase and pick-up food from their favourite food truck operators since the trucks are normally mobile and temporary in nature.

1.2 Project site

Me'nate Steak House Restaurant currently has several branch in Kuala Lumpur. Selangor and Johor. The demonstration for the SDT implementation is performed at Me'nate Restaurant Setapak branch located inside StarParc Point, Jalan Taman Ibu Kota, 53300 Setapak, Kuala Lumpur. The picture of the project site is provided by Figure 1(a), 1(b) and 1(c).

Figure 1(a): Project site at Me'nate Restaurant Setapak Branch

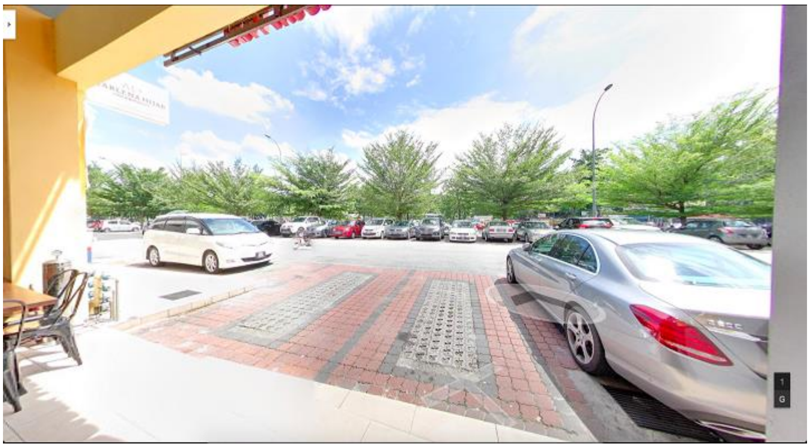

Figure 1(b): Parking area in-front of Me'nate restaurant

Figure 1 (c): Project site with parking entry and exit (bird eye view)

1.3 Smart Drive-Thru Takeaway (SDT) System Overview

SDT is a cyber physical or Internet-of-Things (IoT) system with a combination of hardware and software that creates a dedicated system that is able to take customers' orders, provide payment options, monitor orders, detect customers arrival, alert restaurant staff and help them to perform prompt food in-vehicle delivery. SDT consist of five main components:

a) Dual-band transmitter (hardware)
b) Dual-band passive tag (hardware)
c) Customer order front-end (software)
d) Restaurant staff and manager front-end (software)
e) Passive tag identification back-end (software)

2. Target groups and benefits

SDT is a solution targeting restaurant owners and their customers for cost-effective win-win situation. Essentially it provides the owners with the benefit of a conventional drive-thru without the expensive price-tag of building and maintaining drive-thru facility and infrastructure. It can increase restaurant staff productivity by leveraging on the improvement for food orders accuracy plus secure and convenient in-vehicle delivery based on the passive tag automatic identification. It can also provide more cost effective food purchasing and better customer experiences through online ordering and skipping the dreaded queue at the restaurant even during peak hours at the comfort of inside their own vehicle.

2.1 Me'nate restaurant owner

Specifically SDT has benefits Me'nate restaurant owners in the following items:

a) no expensive up-front investment in drive-thru infrastructure
b) no recurring maintenance for drive-thru facility and infrastructure
c) no extra delivery charges
d) food can be delivered in "fresh-from-the-oven" condition
e) existing parking infrastructure and parking spots for collection can be reserved by the restaurant owner for in-vehicle food collection
f) delivery is not limited to minimum area radius
g) improve the accuracy of the takeaway especially for orders with special dietary constraint
h) significantly reduce customers spending time at premise because orders and payment can be made online

2.2 Me’nate restaurant customers

Specifically SDT has benefits Me’nate restaurant customers in the following items:

a) no extra service charges
b) no extra parking fee (if takeaway is performed in less than 15 minutes)
c) no extra tips (unless voluntarily given)
d) no waiting in congested drive-thru queue during peak hours or festive seasons
e) foods are cooked “fresh-from-the-oven” for timely collection
f) no extra delivery charges
g) delivery is not limited to minimum area radius
h) parking spots close to the premise can be reserved for collection purpose using online booking by the customers from parking operators or municipals.

3. Objectives

The objectives of the project are as follows:

a) To design and develop a new passive tag with energy harvesting capability for vehicle identification.
b) To design and develop a new reader for reading and wirelessly powered the passive tag from a distance of few meters.
c) To evaluate the performances in term of effective identification range, error rate and interference effect to the other nearby wireless standards with varying vehicle’s windscreen tinted film opacity.
d) To implement a case-study of smart drive-through takeaway (SDT) utilizing passive tag embedded inside merchant’s sticker.

4. Scope of work

The scopes of work for the project are as follow:

a) The operating frequency will be in the two main ISM bands namely 919 - 923 MHz and 2.40 - 2.45 GHz.
b) The evaluation of interference will be performed against GSM and Wi-Fi spectral masks, respectively.

c) The detection range will be non-proximity from close range (few centimeters) to a few meters (maximum 10 meters).
d) The designed tag is passive while the reader is active. In order to identify the tag ID, the passive will harvest the energy only from the reader but not from other energy sources for examples battery solar or cellular base stations.
e) For this project only ID will be embedded inside the passive tag (peripheral sensor attachment albeit feasible is for the future feature expansion).

5. Methodology

A passive RFID system consists of two parts, the reader and the tag (transponder). The reader interrogates the tags within its range wirelessly by radiating a high power electromagnetic signal. Passive tag(s) pickup and harvest interrogator's energy to power up its switching circuitry [5]. Then it will backscatter the energy through the antenna in order to modulate the incident signal waveform towards the reader as shown in figure 5.

The reader will pick up the modulated backscattered signal waveform and count its amplitude transitions within a given period to determine the message containing tag's Electronic Product Code (EPC) code for identification (ID).

An Increment in harvested power could be yielded by utilising an extra channel to transmit a secondary energizing signal from the dual-band reader to a dual-band tag. This project investigates this claim through system simulations and real world experimentations.

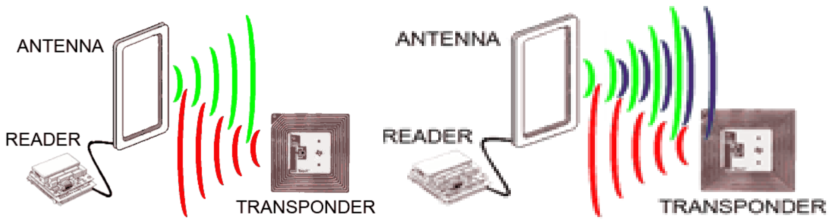

Figure 2: Reader - tag interaction of single Band (left) Vs Dual-Band (right)

The reader will pick up the modulated backscattered signal waveform and count its amplitude transitions within a given period to determine the message containing tag's identification (ID). An increment in harvested power could be yielded by utilizing an extra channel, hence dual-band implementation, to transmit a secondary energizing signal wirelessly from the dual-band reader to a dual-band passive tag.

5.1 System architecture of SDT

The overall SDT system architecture is as shown in Figure 3(a). The passive tag with dual band energy harvester comprises of two sections namely the wireless RF energy harvesting section and RFID section. The more details for passive tag with dual-band energy harvester is as shown in Figure 3(b) and 3(c). The values for the passive tag's resistor, capacitor and Zener diode are 68 Ω, 1 µF and 1.8 V, respectively.

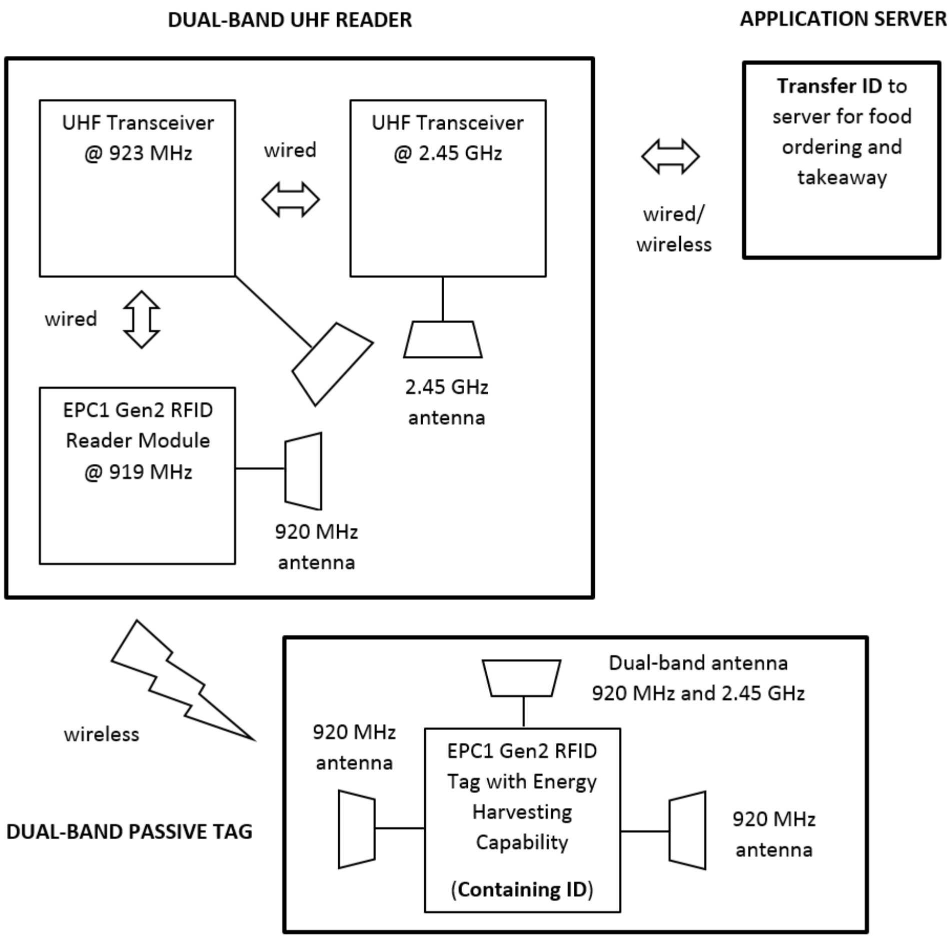

Figure 3(a): System architecture of SDT

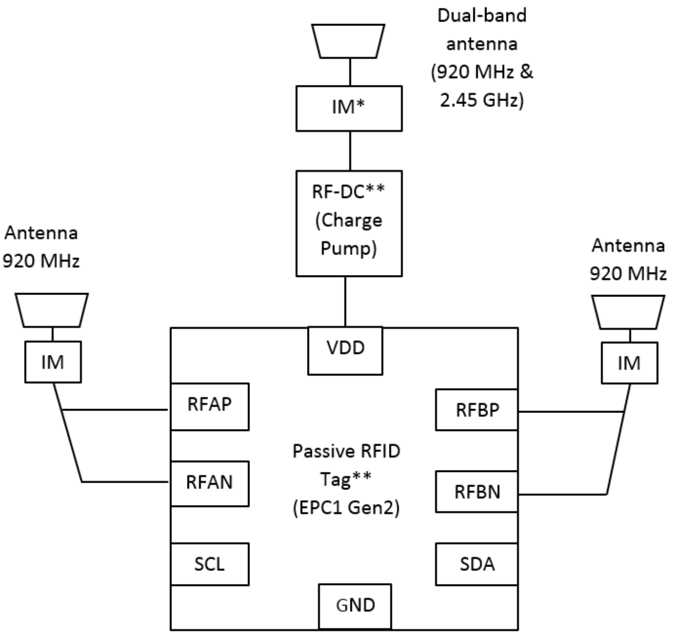

Figure 3(b): Logical configuration for passive tag with dual-band energy harvester

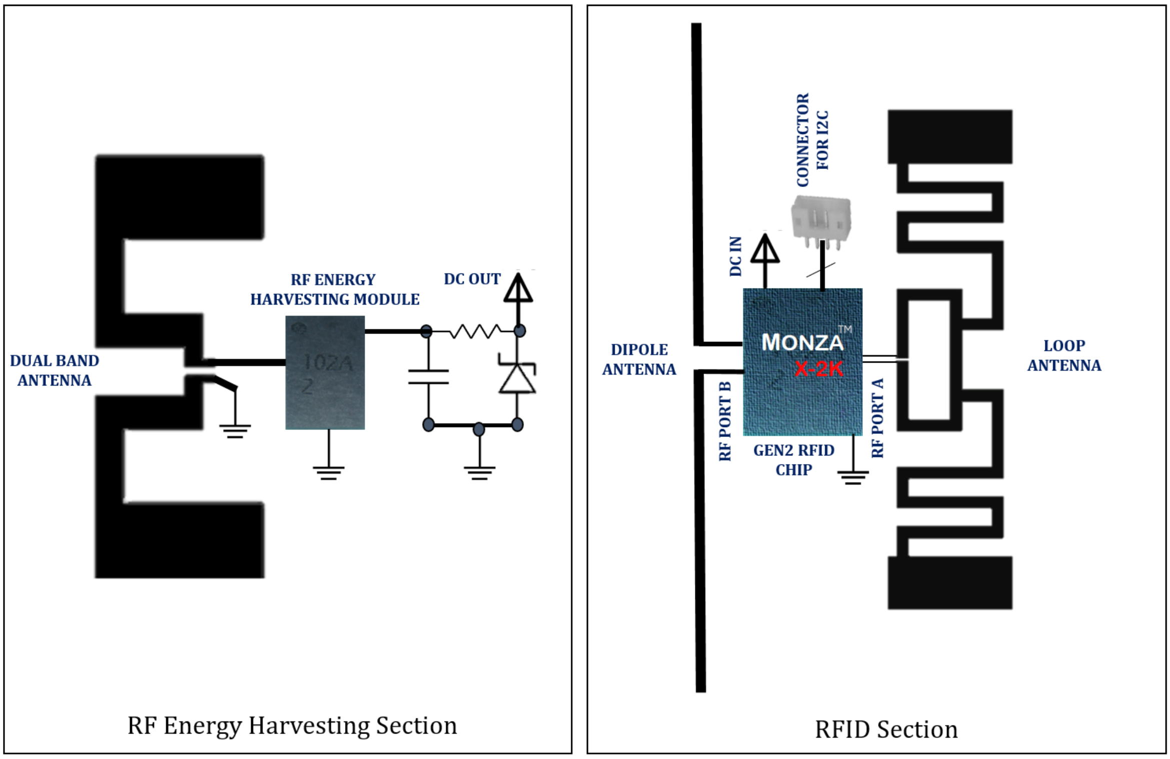

Figure 3(c): Physical circuit configuration for passive tag with dual-band energy harvester

Figure 4(a) and 4(b) illustrate the SDT flow chart for the restaurant's customer registration and on-line ordering respectively.

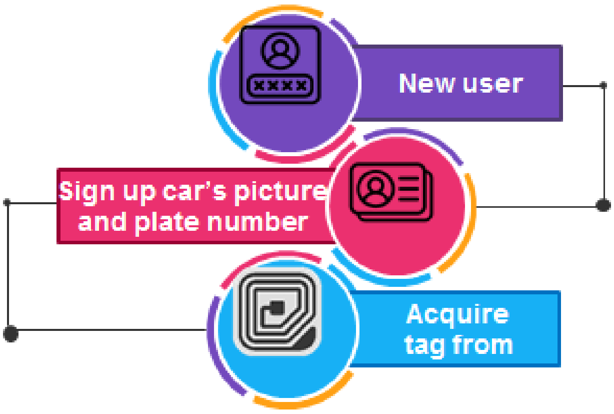

Figure 4(a): Customer registration

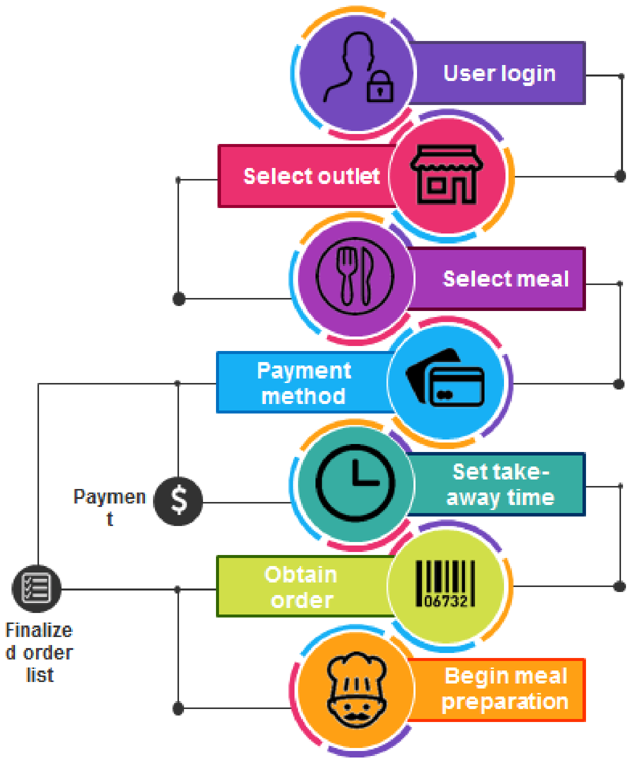

Figure 4(b): Online food ordering

Figure 5(a) and 5(b) illustrate the SDT flow chart for the restaurant's staff front-end for in-vehicle delivery and manager's front-end for new card registration including orders delivery performance monitoring, respectively.

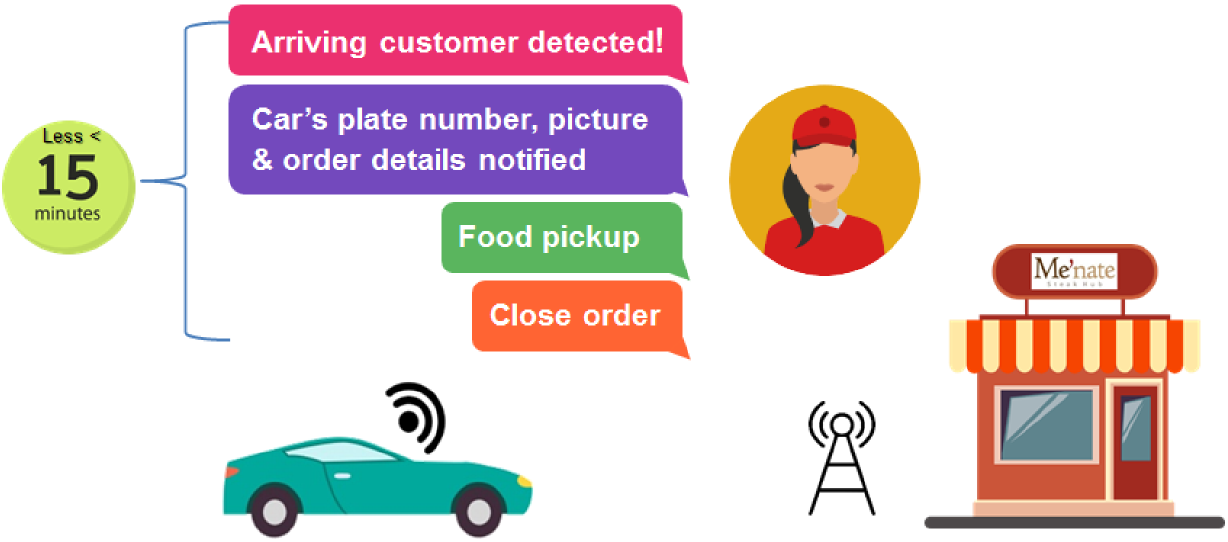

Figure 5(a): Customer arrival detection, notification and in-vehicle delivery time of less than 15 minutes duration

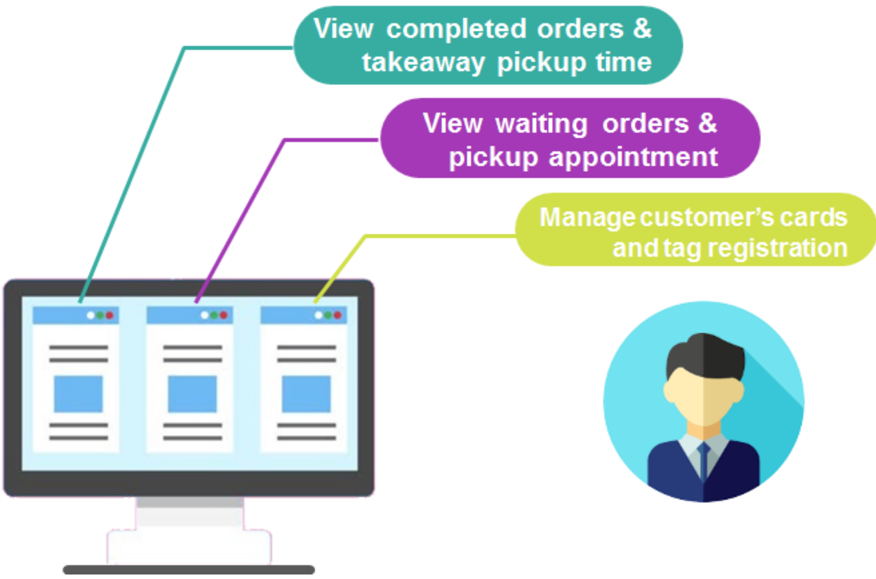

Figure 5(b): Manager back-end for new passive tag registration and activation including orders delivery performance monitoring

5.1.1 Hardware

The first part of the SDT hardware is consisted of RFID reader module with dual-band energy transmitters operating at 920 MHz and 2.45 GHz bands located in-front of restaurant premise near the parking area. The second part of the SDT hardware is consisted of dual-band passive tag located inside the customer's vehicle. These hardware are in compliant with the global standard of UHF EPCglobal Gen2 Specification or better known as EPC Gen2 [6].

5.1.1.1 Dual-band passive tag

A passive tag is mainly composed of three main parts working together: an antenna, RF-DC rectifier, and tag integrated chip (IC) [5]. The rectifier is made of a diode, an element that only allows AC current flow in one direction, and a smoothing/storing capacitor that ensures the energy harvested is within a stable range for at least a minimum acceptable period of time. The passive tag is intended to be read at up to the 10 m distance from the reader located in-front of the restaurant premise. Since there are usually parking spots available in-front of the premise, any parked cars in the designated parking area can be detected by the reader for identification of customer car. The main purpose of introducing energy harvesting capability to the passive tag harvesting is to increase the robustness of the passive tag detection by increasing its read detection distance and sensitivity.

Unlike most of the proposed remote wireless energy harvesting in the literature, this energy harvesting technique is on-demand, directed and temporarily dedicated. These external energy sources are not from opportunistic scavenging of the energy from the environment e.g. telco's base stations, although they also can be harvested if available. Thus it can provide much higher wireless power being harvested and delivered to the passive tag within allowable limits.

According to the data sheet of the Impinj's passive RFID tag chip, typical read sensitivity of the passive tag are as follow [7]:

- when using a single RF antenna port -17 dBm (20 µW)
- when using dual RF antenna ports -19.5 dBm (12.6 µW)
- with DC input -24 dBm (4 µW)

Thus by replacing battery with RF-DC voltage from energy harvester module can get more robust passive tag detection by significantly reducing the minimum power necessary to reflect/back scatter signal for the identification process i..e higher sensitivity. Based on the datasheet, the DC port can be enabled at the voltage range of 1.6 - 3.6 V. Fabricated passive tag with dual-band energy harvester is as shown in Figure 6 and the corresponding details of the circuit components and configurations are shown in Figure 2(b) and 2 (c).

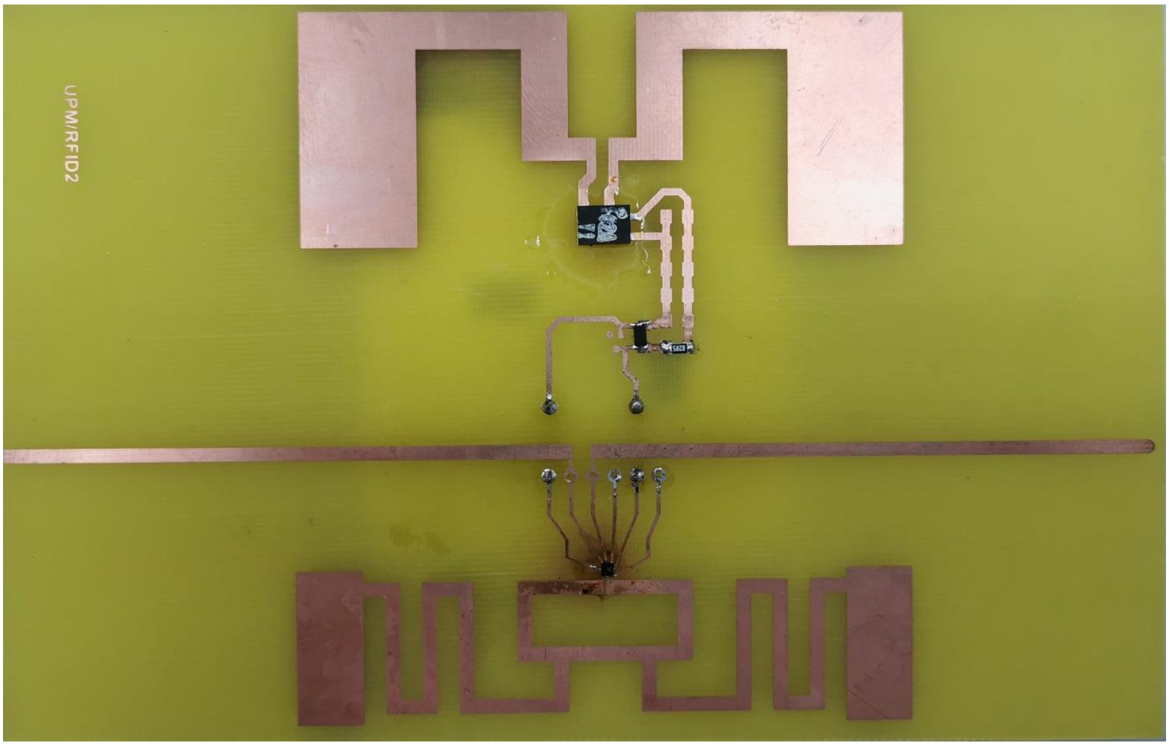

Figure 6: Fabricated passive tag with dual-band energy harvester

5.1.1.2 The RFID reader module with dual-band wireless energy transmitter

RFID reader module is standard based EPC Gen2 reader with dual-band energy transmitter is as shown in Figure 7 and the corresponding antenna configuration being used for the RFID module with dual-band energy transmitter is as shown in Figure 8.

At both 920 MHz and 2.45 GHz frequency bands, the respective Phase-Locked Loop (PLL) is used to generate the RF signal and feed into the power amplifier (PA) input in order to amplify the signal. Both PLL and PA need to be powered accordingly based on the values provided in Table 1. The RFID module does not require PLL or PA since it has its own built-in PLL and PA, including its own power supply connector.

Table 1: Power rating specifications for dual-band wireless transmitter.

Transmitter 1 @ 2.45 GHz	Vdd / V	Idc / A
PLL1	5.5	0.3 - 0.5
PA1	3.3	1.5
Transmitter 2 @ 920 MHz		
PLL2	5.5	0.3 - 0.5
PA2	3.6	0.35

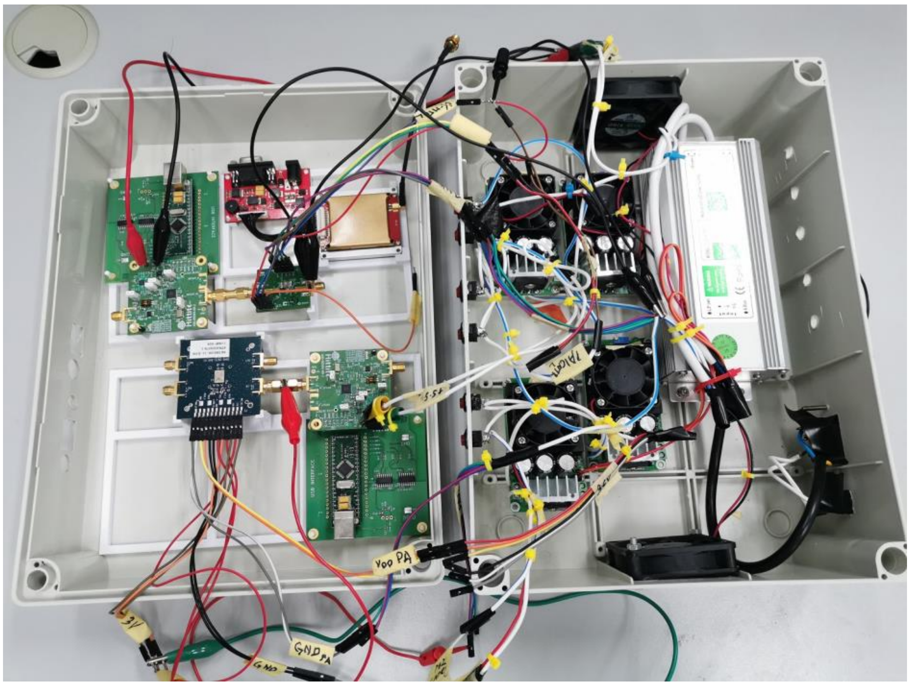

Figure 7: RFID reader module with dual-band energy transmitter inside the outdoor packaging case

Figure 8: Three antenna for the RFID reader (920 MHz), 920 MHz and 2.45 GHz wireless energy transmitter.

5.1.2 Application server

The interfacing and connectivity to RFID reader module is programmed based on the software development kit (SDK) provided by the vendor RFID reader module. The EPC ID that is retrieved from the RFID reader module is then send to the application server hosted in the cloud via the Internet.

5.1.3 Software

SDT software constituted of two main parts namely customer's front-end and staff's front-end. The customer's front-end is used to place order and to monitor his/her orders that have been made. Once the customer login into the web application via PC or smartphone, he/she can then choose to order from specific branch of the restaurant premise, in our case the customer will choose for Menate at StarParc Point. The customer can choose the food from the list of available menu. The customer is then order the desired menu available for this specific branch. After the desired menu has been chosen the customer can proceed to purchasing the food and indicate the type of payment he want to use i.e. online or physical payment at the restaurant. After the complete he will be notified of the time he/she need to collect the food from the premise.

The staff's front-end is used to monitor all the orders that have been made to the specific restaurant premise in this case Me'nate at StarParc Point. It also used to indicate that food collection by the customer has completed successfully. The time different between car being detected upon arrival and food being collected can be used as the performance of the SDT system. In our case the maximum is 15 minutes for the entire time duration the customer entering the StarParc Point complex and leaving the complex. This will make the time different to be much less than 15 minutes. The 15 minute duration is chosen because after 15 minutes the customer will be charged per entry that starts at one hour duration.

Figure 9 shows the pop-up notification for the new arrival. Figures 10 shows the screenshot of new arrival information with the corresponding picture of the customer's car or vehicle and Figure 11 shows the bigger picture for easier recognition. This provides an extra layer of security where not only the vehicle's registration number is known, but the staff can verify that they are dealing with the correct customer. This also make it easy for the staff to quickly and accurately identify the specific vehicle for performing the in-vehicle delivery by looking at the customer's vehicle type (e.g. sedan, SUV, hatchback, van, etc), shape, colour, brand (e.g. Mercedes, Proton, etc) and model (C200, X70, etc). The software stack from the retrieval of the EPC ID from the reader module and the website for front end and backend database connectivity is written using the Java programming language.

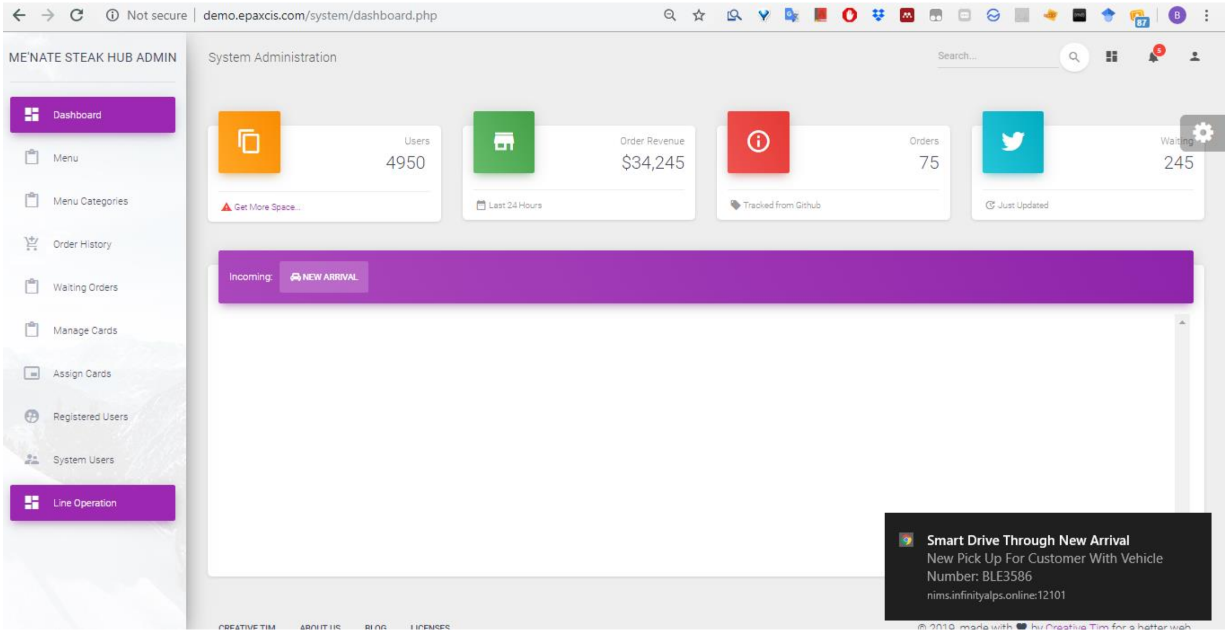

Figure 9: Pop-up notification for the new arrival

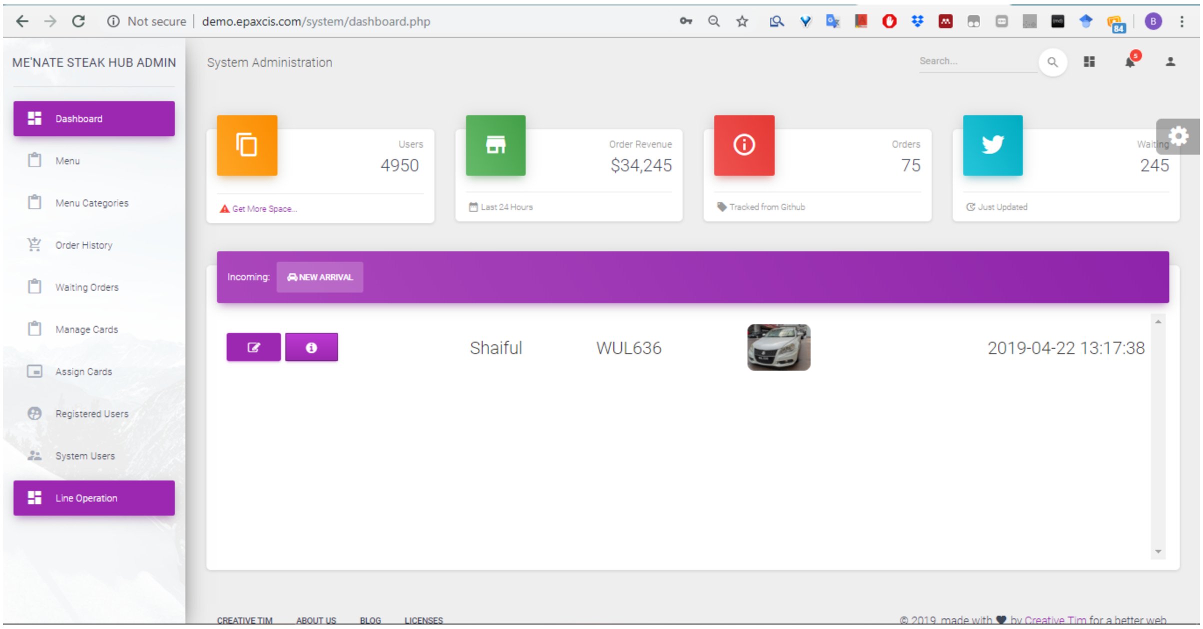

Figure 10: New arrival info with the corresponding picture of the customer's car

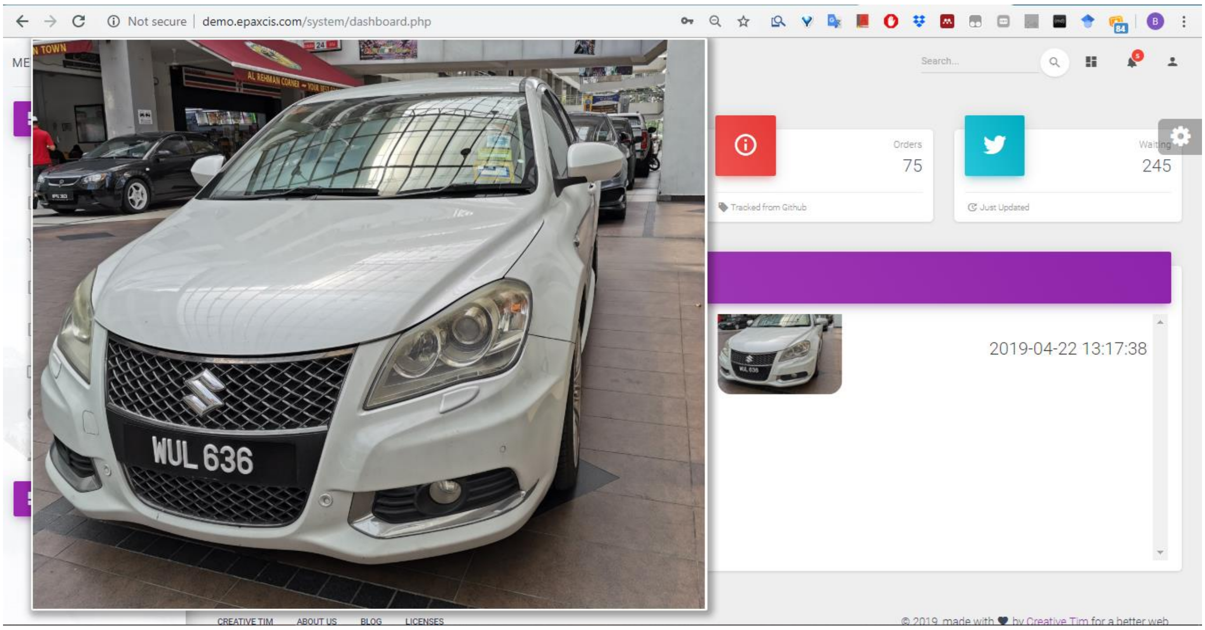

Figure 11: High definition image to help identify the car awaiting order delivery

5.1.4 SDT system interference monitoring

The proposed and implemented system operate in the ISM bands at 920 and 2.45 GHz [8,9]. The main concern of these wireless transmissions for the ISM bands is the potential interference with nearby wireless frequency spectrum bands (inter-spectrum) and the interference within ISM frequency spectrum bands itself (intra-spectrum). The interference is tested on the two main of operating frequency namely 919 - 923 MHz (RFID reader module at 919 MHz and at 923 MHz energy source) and 2.40 - 2.45 GHz (2.45 GHz energy source).

For inter-spectrum interference, the effect of the RFID transmitter operation and the energy harvester on the existing wireless communication signals from the GSM based stations and Wi-Fi gateways. In Malaysia the standard operating frequency for GSM communication system are at the frequency ranges of 880 - 915 MHz and 925 - 960 MHz, for the upper and lower bands, respectively [8]. For intra-spectrum interference, an additional a new low power and long range wireless (LoRa) node operating at 922.6 MHz is placed in proximity of the SDT system for testing the worst case scenario.

Please note that normally the LoRa signal reception at the SDT system is much lower due the long distance from the gateway/base station, and the low power of LoRa transmitter (maximum 500 mW EIRP/ERP). Hence the interference will be very unlikely with the signal sent by the LoRa gateway or base station. All the spectrums signals are monitored using a spectrum analyser that covers the frequency of interests namely at 920 MHz and 2.45 GHz.

5.1.5 Wireless transmission quality through vehicle tinted films

Four types of off-the-shelf tinted films were bought from tint film shop at Putrajaya applied to car windows, with different type of opacity and characteristics are shown in Figure 11. The wireless transmitter and the receiver are used to measure the attenuation resulting from the tinted films obstruction.

(a) Tint 1 Window

(b) Tint 2 Window

(c) Tint 3 Window

(d) Tint 4 Window

Figure 11: Tinted Films with different type of characteristics and opacity

6. Result analysis

The detection of 10 meters distance has been achieved without using the energy harvesting. By using energy harvesting feature, the detection of more than 10 meters can be achieved with higher robustness with improved 3-dimensional (3D) rotation as shown in Table 2. Since the RFID tag detection is bound by Size, Orientation, Angle and Placement (SOAP), and the fact that the range detection ability has been improved together with robust variable orientation is a bonus introduced by the system to the conventional RFID passive tag system.

Table 2: Read range with energy harvesting power fixed at 1.1 W @ 923MHz

RFID Reader Power @ 919MHz (watts)	Range Without Energy Harvesting (m)	Range With Energy Harvesting (m)	Contribution of Energy Harvesting
0.5	0.7	2	Increase Range
1	4	6	Increase Range
1.5	6	7	Increase Range
2	10	10.5	Improve 3D Orientation

Based on the spectrum analyser measurement there is no interference for both inter and intra spectrum with the other wireless systems, in this case with GSM and LoRa systems, respectively. Figure 12 shows spectrum analyzer's output for the monitoring of inter-spectrum interference. Please note that there are three sources of wireless signal at 919 MHz, 923 MHz and 2.4 GHz. There is no sign of interference with the lower or the upper GSM bands that stops at 915 MHz and starts at 925 MHz, respectively.

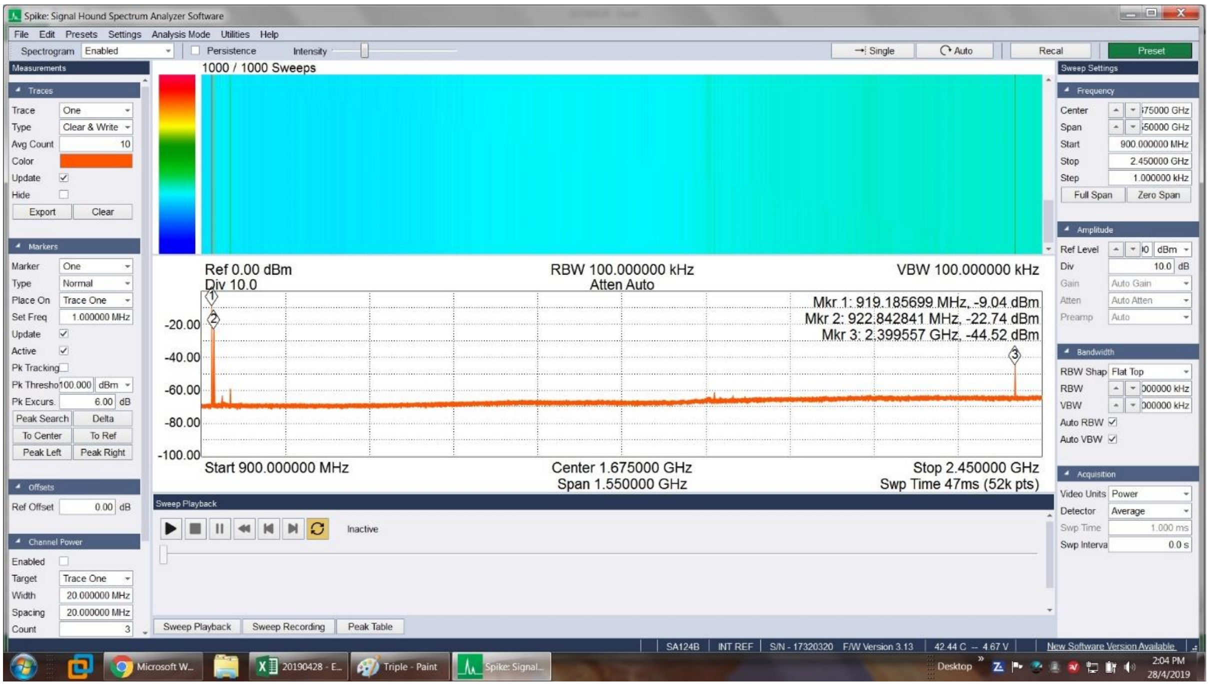

Figure 12: Spectrum analyser output for the monitoring of inter-spectrum interference (with GSM and Wi-Fi)

Figure 13 shows spectrum analyser output for the monitoring of intra-spectrum interference. Please note that this is the worst case since it is at the same frequency, at a very close distance that between the reader and the LoRa node or gateway. Thus, when the RFID reader module and energy harvester are brought in the proximity there is interference if the frequency band is overlapped. This only happened if RFID reader or the harvester operated in the same exact frequency. For LoRa the recommended operating frequency is 922.6 MHz in Malaysia. Since they are meant to be used in the same ISM frequency bands between 919 MHz and 923 MHz, it is best to avoid operating at the exact same frequency [8]. Since both RFID and LoRa standards are meant for two separate and extreme cases i.e. very short Vs Very long distance, this interference can be easily systematically mitigated and prevented for most of the times and situations.

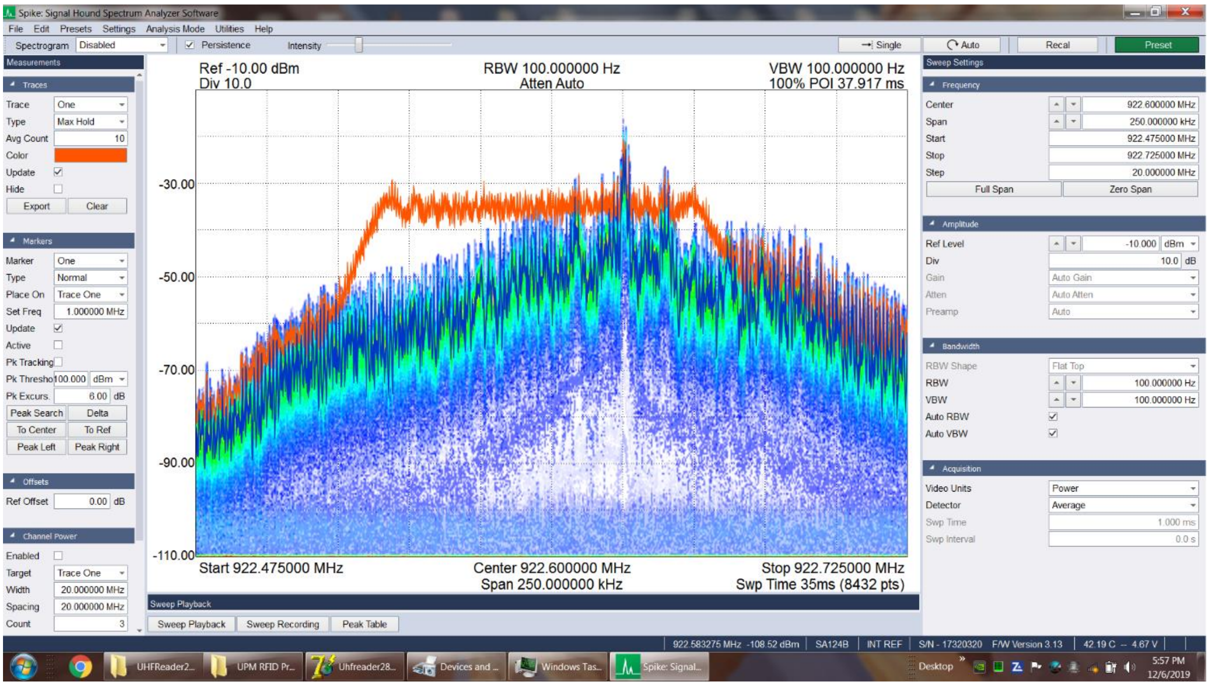

Figure 13: Spectrum analyser output for the worst case of intra-spectrum interference at a very close one meter distance in-between RFID tag and LoRa node (RFID in red).

Wireless transmission attenuation over various vehicle tinted films opacity and characteristics is provided in Table 3.

Table 3: Windows with different tinted films wireless signal attenuation measurement

Transparency	**Tint 1**	**Tint 2**	**Tint 3**	**Tint 4**
UV / %	100	100	52	100
VLT / %	63	50	47	30
IR / %	97	83	54	33
RF Loss @ 920 MHz / dB	1.66	0.51	15.39	6.36

As can be seen from Table 3, window with tint film 3 has the worst attenuation value of about 15 dB while window with tint film 4 is the second worst with attenuation value of about 6 dB. On the other hand, window with tint film 2 has most acceptable attenuation value of about 0.5 dB while window with tint film 3 has attenuation value of about about 1.6 dB. These windows 2 and 3, can be very transparent for the wireless signal transmission for the purpose of passive tag detection. I can also be concluded that the standard transparency parameters, e.g. UV, VLT and IR,that are being used for characterizing the tint films are useless for any indication of wireless signal transmission transparency. This is due to the fact that tint films application is targeting light frequency spectrum not wireless frequency spectrum. Since both are operating at different frequency spectrums, their physical properties are different. The different in attenuations property is not based on the tint films light spectrums transparency (e.g. UV, VLT, IR) standards but rather on the arbitrary content of the metallic component inside the tint films. This category of tint films with metallic content probably cater for the different market segment. It probably for those who want additional strength to their vehicle windows to protect their vehicles against the act vandalism or random incidents (e.g. stones cracking the windows) that can happen while driving or parking their vehicles.

The performance of the overall identification system for smart drive-thru takeaway (SDT) application has been measured. Furthermore the effect of vehicle windscreen property is compared for the effective of the identification in the real world in-vehicle scenario. In addition, the interference level with other wireless transmission nearby (inter-spectrum) or inside (intra-spectrum) of the unlicensed ISM bands. The main challenge is that of the maximum allowable power transmitted of RFID reader/transmitter in ISM band is limited to 2W for Effective Radiated Power (ERP) or Effective Isotropic Radiated Power (EIRP) [8]. The easiest way for increasing range is to increase the power of the RFID reader module and/or harvester but the wireless power can be over the allowable limit. This new proposed approach of having extra (i.e. dual-band channel property) of on-demand and dedicated energy harvester, as opposed to only a single source (i.e. single band property) can significantly improve the range and the robustness of the passive tag detection.

The second challenge is that by nature the wireless signal transmission is being significantly reduced for propagation through metal. For vehicles, the transmission happen over the windscreen or side windows screens since the other parts of the vehicle are mainly made from metallic structures. In hot and tropical country such as Malaysia, tinted films are popular in order to reduce the heat from the sun. For the various vehicles windscreen tint films properties, the most critical property is its metallic content. Since for the vehicle accessory company that sell and install tint films this information is not readily available. For the off-the-shelf vehicle tint films installation, the most common characteristics or parameters that are being considered and measured are the ultra violet (UV), visible light (VLT) and infrared (IR). From the test and measurement that have been carried out, apparently these the typical parameters are not indicative of the performance of the wireless transmission for in-vehicle passive tag identification.

It is envisioned that wireless power energy transmission system will be very popular in the future if there is a reliable technique to harvest the energy either from dedicated, on-demand or opportunistic. The multi-band can be one of the approaches to increase the reliability of the wireless power transfer but still in compliant with the wireless power transmission limitation.

7. Conclusion

SDT is an IoT system with a combination of hardware and software that creates a dedicated system that is able to take customers' orders, provide payment options, monitor orders, detect customers arrival, alert restaurant staff and help them to perform prompt food in-vehicle delivery. The SDT project has been successfully completed and demonstrated. The demonstration for the case study and proof-of-concept (PoC) was performed on **22nd April 2019** at Menate Restaurant at StarParc Point in Setapak Kuala Lumpur. During the demonstration, customer's vehicle has been correctly identified and the ordered transaction has been completed and successfully delivered to the customer. This entire takeaway collection by the customer is completed within the proposed 15 minutes limit thus the customer is not required to pay for the parking spot. The two-factor verification for the customer's vehicle identity using the unique vehicle identification to vehicle's registration number mapping, coupled with visual inspection of the vehicle provide a secure, trustworthy and convenient in-

vehicle food delivery. SDT with location tracking feature can be a very good solution for the food truck operators and their customers due to food trucks mobility and temporary nature.
The dual-band configuration for the energy harvesting at reader and energy transmitter provides more energy to the passive tag within the allowable limit of power transmission. These external energy sources are not from opportunistic scavenging of the energy from the environment e.g. telco's base stations, although they also can be harvested if available. Thus it can provide much higher wireless power being harvested and delivered to the passive tag within the allowable limits. This proposed energy harvesting technique is on-demand, directed and temporarily dedicated. This results in an increased read distance range and more robust detection due to the higher sensitivity. From the spectrum analysis and measurement there is no significant interference with nearby wireless frequency band either inter (e.g. GSM) or intra (LoRa) spectrum for normal operation. The mitigation step is to select different operating frequency for the RFID reader, energy transmitter and LoRa when co-existing since both RFID and LoRa are using 920 MHz ISM bands. The vehicle tinted films can be a problem for the reliable detection of passive tag being placed inside the vehicle because since their main parameters are catering for light transmission instead of wireless transmission. The proposed SDT system can also work perfectly with the standard off-the-shelf EPC Gen2 RFID passive tag for the vehicle identification. The dual-band passive tag with energy harvesting capability is a bonus feature to allow more robust detection off passive tag without the need for battery.

Annex A
(informative)

Frequency Bands and Maximum Power [8]

Item	Frequency Bands	Maximum Power
1.	13.553 MHz to 13.567 MHz	100 mW EIRP
2.	433 MHz to 435 MHz	100 mW EIRP
3.	869 MHz to 870 MHz	500 mW EIRP
4.	919 MHz to 923 MHz	2 W ERP
5.	2400 MHz to 2500 MHz	500 mW EIRP

Visible Light Transmission (VLT) Explanation [10]

VLT %	Category	Lens Tint	Suitable for
80 - 100%	0	None or Very Light Tint	For aesthetic, fashion, or comfort purposes or for use during night time
43 - 80%	1	Light Tint	Weak levels of sunlight
18 - 43%	2	Medium Tint	Average to low levels of sunlight
8 - 18%	3	Dark Tint	For use in strong sunlight, including intensified light which is reflected off water or snow
3 - 18%	4	Very Dark Tint	For use in exceptional levels of strong sunlight (not suitable for drivers and road users)

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