Circular economy ecosystem to Recover, Recycle and Re-use F-gases contributing to the depletion of greenhouse gases - LIFE Retradeables

Deliverable: IOT functionalities on the prototype unit

Action C2

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Abstract

This deliverable focuses on an introductory description of the Internet of Things (IoT) functionalities to be applied through the prototype unit, thus enabling the direct transfer of data to the different platforms of the 3R ECOSYSTEM. The IoT technology is considered as the last enhancement functionality to be added to the prototypes before the official production and Europe-wide marketing of a standard version. Subsequently, the F-gas identification & recycling units with IoT functionalities will be included in the Spare Parts portfolio of DENV and DACE and offered to the market through a state-of-the-art e-shop already available. However, due to the fact that the development of the prototype is still ongoing, only an overview of the respective developments to be implemented on the IoT-based device is currently provided.

Contents

1 IoT technology

1.1 Background

The term IoT, originally introduced by Sir Frederick Ashton [(1)], has recently become popular, especially in wireless telecommunications. IoT has brought up many technological advances, so leading to an industrial revolution where all objects in the real and virtual world are connected to every alternative through the Internet. Furthermore, IoT serves as a widely applied digital tool for identification and contactless exchange of information through various technologies used, such as: Radio Frequency Identification (RFID), Near Field Communication (NFC), distributed sensing element networks, short-range wireless communication (such as Bluetooth) and universal mobile accessibility (Wi-Fi hotspots and cellular networks). By constantly exchanging information about modifications detected to their environmental conditions, IoT devices appear fully interactive with external stimuli collaborating as building blocks to create appropriate sensitive areas.

Overall, the increasing involvement of IoT devices and technology in people's lives is supposed to have an absolutely positive impact on their daily routine. This is reasonable since the IoT takes advantage of the following factors:

- **Monitoring**: IoT sensors enable users to monitor conditions like internal and external temperature, humidity, power usage, and more. This provides users with elaborated information regarding their refrigeration systems and usage patterns, resulting in unjust insights into operations and power consumption. Monitoring additionally permits users to remotely assess conditions and manage their system from their mobile phone or laptop. Users can even set alerts when the system reaches critical situations like temperature thresholds and receive immediate notifications on their mobile devices.

- **Increased Efficiency**: The IoT applications can use information from sensors and provide adjustments almost in real-time. This will increase efficiency, reduces prices, and ends up in longer instrumentality life.

- **Predictive Maintenance**: IoT technology provides insights that enable users to schedule maintenance on their units once needed additionally as foresee problems before their systems reach critical conditions. It additionally provides technicians with the information to diagnose remotely and therefore increases system awareness.

[1] Ashton, K. That 'internet of things' thing. RFID J. 2009, 22, 97–114.

2 Upgrading prototype units with IoT

2.1 Basic knowledge

Taking into account the background described above, the final version of the prototype unit will be equipped with a detachable IoT device as an extra feature to promote easy and direct transfer of data to the back-end database which is connected to both platforms of the 3R ECOSYSTEM (Self-certification & Retradeables Marketplace). Basically, it is at the last stage of the development of the prototype when IoT capabilities will be used alongside Daikin's portable Recovery and Recycling unit to facilitate the automatic upload of some key data about the recovery process to the already operational Retradeables database. This data can also be accessible via the marketplace platform. Once the IOT device is coupled with the unit, the entire prototype implementation will be tested in the lab and in the field to verify proper data flow. The F-gas identification and recycling IOT equipment will then be available for sale to the entire European market.

2.2 IoT-based recovery procedures

The different stages of F-gas recovery during which information is captured by the IoT device, are summarized in **Table 1** and illustrated in **Figure 1**, respectively:

Table 1: Overview of IoT-based procedures.

Steps	Short Description
1.a	The user prints the QR code and places it on the installed HVAC-R unit.
1.b	The user scans the QR code printed on the HVAC-R unit with a smartphone camera. The relevant data is sent to the database via the IoT device.
2.a	The user prints the QR code and places it on the recovery bottle(s).
2.b	The user scans the QR code printed on the recovery bottle(s) with a smartphone camera. The relevant data is sent to the database via the IoT device.
3.	Extraction of the refrigerant from the HVAC-R unit. A collection of data is sent to the database via the IoT device (see Section 3 below).
4.	Completion of the recovery process.

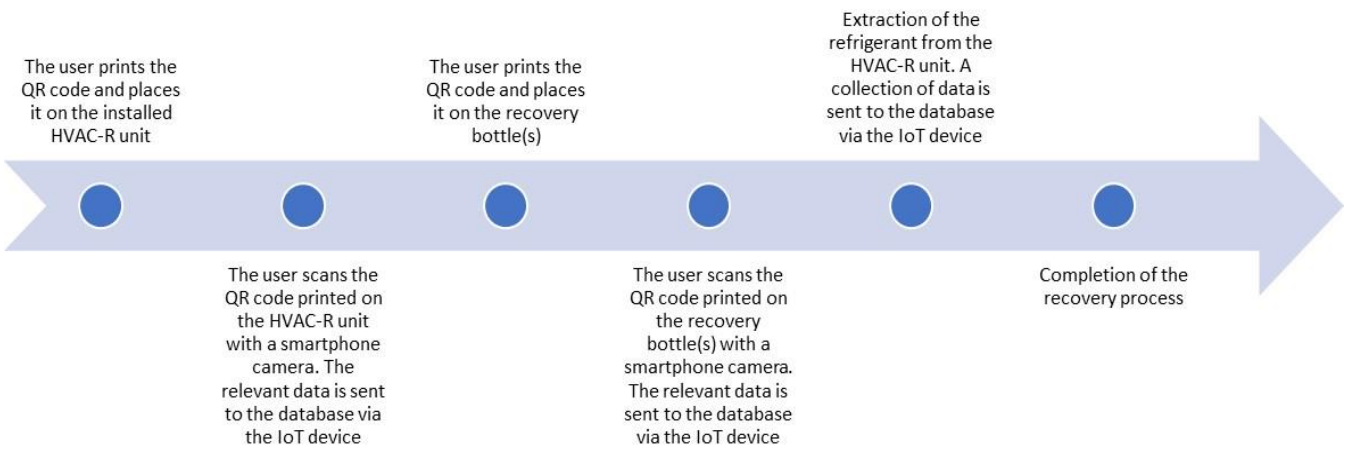

Figure 1: The sequence of the technician's IoT-based activities.

3 IoT device under development

3.1 Key operating principles

A simplified diagram of the **basic operating scheme** of the IoT device under development, including both "inputs" and "outputs", is illustrated in **Figure 2** below:

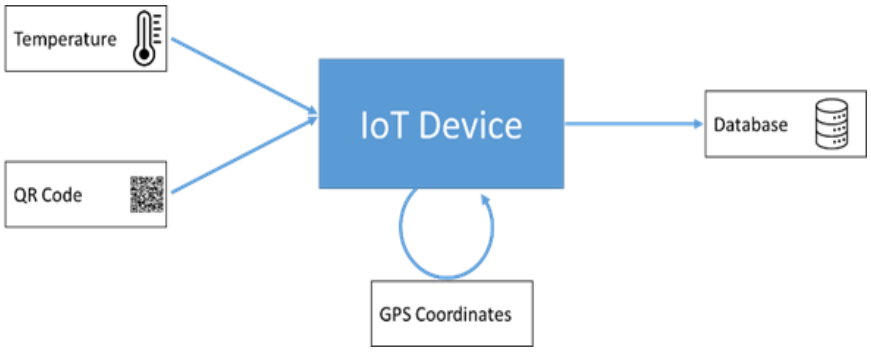

Figure 2: Functionality of the IoT device.

3.2 Functionalities

As shown in **Figure 3**, the following functionalities have been defined to be supported by the IoT device:

1. Connection to the Internet using the mobile network (4G) or WIFI when it is available.

2. Scanning of the QR code that will be printed on the installed HVAC-R unit (via a smartphone camera): The system will be able to scan the unique QR code of the HVAC-R unit. This involves reading a unique identifier (ID) that will be sent to the database thanks to IoT technology.

3. Scanning of the QR code that will be printed on the recovery bottle(s) (via a smartphone camera): The system will be able to scan the unique QR code of the cylinder(s) to be used. This involves reading a unique identifier (ID) that will be sent to the database thanks to IoT technology.

4. Automatic monitoring of the temperature through the suction pipe of the recovery unit: The system will be able to read from the IoT sensor the temperature on the refrigerant pipe. The sensor will be connected to the IoT device using wireless technology (e.g., Bluetooth). This data must be also sent to the database.

5. Automatic tracking of the location of the HVAC-R unit (Global Position System coordinates): The system will trace the HVAC-R unit by reading from the IoT device the GPS coordinates which later must be sent.

6. Recording a specific date and time of each recovery process.

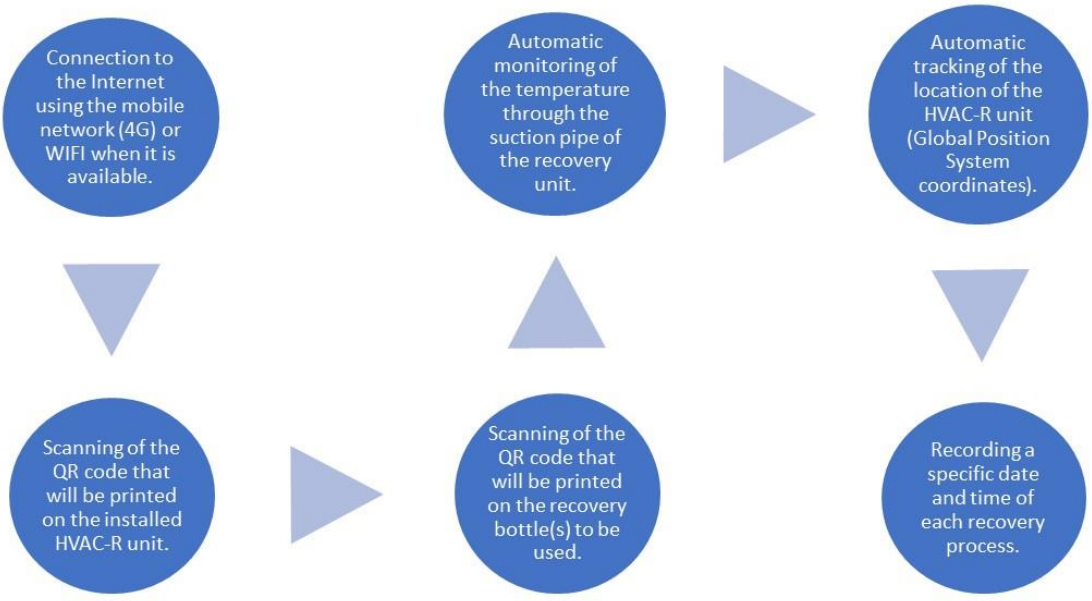

Figure 3: Functionalities to be supported by the IoT device.

3.3 Traceability of refrigerant

Regarding the type of data transmitted from the IoT device to the 3R ECOSYSTEM platforms, this is practically driven by the respective IoT functionalities. Therefore, the uploaded IoT data will include:

- A 1st unique identifier: this has been extracted during the scanning process of the QR code pre-printed and placed by the technician on the installed HVAC-R unit.
- A 2nd unique identifier: this has been extracted during the scanning process of the QR code pre-printed and placed by the technician on the recovery bottle(s)/cylinder(s).
- The collection date: this is the date that the extraction takes place.
- The Global Position system coordinates: these are the coordinates (Longitude and Latitude) of the location of the IoT device. A precision of eight numbers is used with a scale of six where:
    - ✓ Precision is the number of digits in a number.
    - ✓ Scale is the number of digits to the right of the decimal point in a number.

  For example, the number 123.45 has a precision of 5 and a scale of 2.
- The temperature: This is the temperature of the F-gas as it is extracted from the unit using either infrared or Bluetooth technology.

Table 2 shows the complete list of fields that are supposed to constitute the "IoT data" table to be integrated within the existing (back-end) database.

Table 2: Structure of the "IoT data" table.

Characteristics		Required	Data type	Precision	Scale
Installed HVAC-R unit	Id	YES	Unique Identifier		
	QR code id	YES	Character	100	
Recovery bottle(s)	Id	YES	Unique Identifier		
	QR code id	YES	Character	100	
Collection Date		YES	Date Time	3	
GPS Location (Longitude)		YES	Decimal	10	8
GPS Location (Latitude)		YES	Decimal	10	8
Temperature		YES	Decimal	5	2

4 Conclusions

The use of IoT technology to further improve the performance of the prototype unit can reasonably be described as a real upgrade. However, it is rather early to report on this development as the prototype itself has not yet been standardised and laboratory testing on the F-gas composition analyser (the first of the two prototype components) is currently ongoing. However, this does not mean that there is no progress on the IOT device to be attached to the Daikin's Recovery and Recycling unit (the second component of the prototype). The exact utility of the IOT functionalities has been clarified and research is now being carried out to ensure that the finalisation of the prototype unit (estimated between Q1 & Q2 2023) will coincide with that of the IOT equipment, thus providing an integrated solution suitable for commercialisation across Europe.