Robust, eco-Friendly, on-Demand Bin (ReDbin)

An Internet-of-Things based household-waste container for future smart cities

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Abstract*—This concept paper discusses the need for a new household waste management system and presents a comprehensive literature review of research that concerns the production of high-tech refuse bins. In particular, The paper uses this literature review to argue the case for a new type of high-tech refuse-bin called ReDbin, for which we present an architectural model, comparing it to two other notable approaches, Big Belly and BURBA. Finally we describe our plans for future work.** ***Keywords-component; Internet of Things; ubiqutous computing; Wireless, RFID+, smart cities; environmental impact, waste collection and management.

I. INTRODUCTION

The Internet of Things (IOT) refers to the use of Internet Protocol (IP) networks to form a universal network of interconnected computational "things" (objects that include embedded networked computers) that can communicate with their neighbours to achieve a common goal [5]. Underpinning the success and the adoption of the IoT are increasingly advanced pervasive communication technologies such as short-distance wireless sensor networks (WSNs) or infrared sensors supported by new communication frameworks for the IoT such as machine-to-machine communications (m2m) that use client-server protocols such as Message Queue Telemetry Transport (MQTT) or the Constrained Application Protocol (CoAP) from the Constrained Resource Environments (CoRE) IETF group. The Radio Frequency Identification (RFID) standard (and the more recent RFID+), have contributed enormously to the emergence of IoT based applications related to tracking. The OpenBeacon[1] project is a good example of an open platform for active RFID applications providing an always-on, reliable, on-demand, cloud-based service, which serves as building blocks for this new paradigm, enabling rapid development of vast applications. Furthermore, the advent of tiny but powerful electronic processing units, such the Raspberry PI [2], Arduino [3], BuzzBoards [4] and recent trends in DIY electronics, such as makespace[5], have provided the tools to foster mass creativity in the Internet-of-Things (which, incidentally, was referred to as embedded-Internet devices back in early days [4]).

[1] http://www.openbeacon.org/
[2] http://www.raspberrypi.org/
[3] http://www.arduino.cc/
[4] http://www.FortiTo.com
[5] http://makespace.org/

The Internet-of-Things is a 'hot topic' that is rapidly being integrated into almost every facet of human life leading to it being dubbed, the "Internet-of-Everything". For example, it is seen a step towards creating future smart cities, a market that is forecast to net some $14.4 trillion from 2013 to 2022, according to a white paper published by CISCO [6], a major global player in the area. Another example of the potential of this area is emergence of the, so-called, Internet-of-Cars [6] which brings the concept of massive connectivity's into to transport systems. While many areas are set to benefit from blending real world applications with IoT technology, there is one area, the management of our household waste, that is yet to exploit the full potential of this technology which is somewhat surprising since the impact of household waste on the environment is massive [1]. This paper seeks to address this shortcoming by discussing and introducing "ReDbin", an Internet-of-Things based smarter, "Robust and eco-friendly on-demand bin" that provides self-managing interactive services for managing our household waste.

II. HOUSEHOLD WASTE

Research published in 2013 [8] indicated that the UK government has been invested a lot of resources in tackling household waste issues. The environmental impact that household waste caused is said to have been enormous. For example the greenhouse gas emissions associated with household waste from UK homes alone accounted for approximately the equivalent of 17 million tons of CO_2, and it was suggested that the carbon saving of preventing all avoidable household waste in 2012 is similar to taking one in four cars off the road [8].

Different strategies and measures have been adopted to limit the production of household waste. For example research published by WRAP [7] revealed that in 2007 a staggering 8.3 million tons (22% of purchases) of the food and drink brought into homes in UK was being thrown away. This resulted in a "social issue" which prompted experts and various organisations to launch various awareness programs in a bid to highlight the problem (unnecessary waste) as well as to deliver the key message (negative environmental impact). The campaign was subsequently echoed by various local UK authorities to

[6] http://www.internetofcars.org.uk/

provide more guidance particularly on food labeling. Such collaborations with food providers has been seen as one of the key preventative measures and was a direct result of the publication of report "*Counting the Cost of Food Waste: EU Food Waste Prevention*" published by the House of Lords European Union Committee [7], which highlighted 15m tons of food is wasted in the UK alone each year. Subsequently supermarkets in the UK have been accused of behaving irresponsibly, encouraging their customers to buy more than they require by regularly offering "*buy one get one free*" offers. While much effort has been made to reduce household waste, to-date, very little attention has been paid to the equipment (eg bins) that are used in homes to hold the waste until its collected and disposed of,.

A report published by CMS Cameron McKenna LLP on "*Waste Management in Central and Eastern Europe*" [1] revealed that a huge investment in waste infrastructure had taken place in Western Europe which has driven changes in the nature and structure of their waste management system. While most of the changes highlighted in the report have been associated with the disposal of waste (landfill) and support for creating recycling facilities (beyond the scope of this paper), one of the changes concerned the mandatory separation of waste, an approach we argue could hugely benefit from the IoT based technology which, as yet, remains to be exploited. The report also revealed that in EU, a staggering 502kg of household waste was generated on average per person in 2010. This figure serves a good indicator and reflects on the scale of the problems such as various barriers and obstacles, in terms of household waste collection. Separate collection of waste streams is still in its infancy, but forms part of the overall costs of meeting the EU standards, are estimated to be at least €370 million.

What does waste collection involve? As indicated in the report [1], tasks range from 'the collection, through transport and recovery, to disposal of waste, including the supervision of such operations, the after-care of disposal sites, and actions taken as a dealer or broker'.

A report published by the Department for Environment Food & Rural Affairs on "I*ncineration of Municipal Solid Waste"* in 2013 [2] revealed that a decrease of household waste (food and drink) production has been evidenced from the waste collected by local authorities. The report also highlighted that despite the reduction, the "*total amount of household waste in the UK was around 7.0 million tons in 2012, and two thirds of those were collected by local authorities, of this, most was collected at the doorstep/kerbside*" [2]. The current arrangement is that it is the responsibility of either the District or the Borough Council's waste collection authority (and their partners) to manage residential waste disposal. In terms of waste collection, it is the responsibility of the resident [3], to take the initiative and place their bins outside their building prior to the arrival of the collection vehicle. In other words, the collection vehicle only collects those bins that are placed outside the building. Although there are a diversity of collection strategies across Europe, it has been suggested that collection systems are likely to go through phases of change that may be dominated by the need to make cost savings [3]. However, the final report to European Commission's Directorate for the General Environment on "*Costs for Municipal Waste Management in the EU*" [3] provides a different view of the collection system in which different types of waste play a major role (Figure 1)

Figure1 Stylised Representation of Collection System [3].

As a result, the study [3] concluded that the cost for collection is relative to the types of waste collected.

Normally the collection vehicles work in a scheduled manner, whereby household waste is collected at a regular and period time (e.g. a particular morning every week). The waste will then be collected for treatment later.

Clearly, the current household waste collection arrangement introduces a few problems: (1) placing too much initiative on the resident (who is a tax payer and, thus, both funds the service as well as being an end user of the service) (2) causes inefficiencies, for example some of the bins placed outside the building do not require emptying but as the driver is unaware of this, it contributes to the unnecessary generation of greenhouse gas via wasted energy. In addition, some bins that do need emptying may be missed if, for example the resident forgets to place them outside. (3) The collection trucks cause traffic congestion as often the vehicles are on the road during morning peak hours or moving through busy areas of town, and can even cause accidents. Thus we argue that a more eco-friendly, efficient way of collecting different types household waste household waste is needed for future smart cities.

III. THE REDBIN

A. Related work

Currently there are two relevant ventures in this area. The first is called "Big Belly[8]" trash-can (Figure 2), an all-in-one waste and recycling collection system which is in the process of being commercialized . The Big Belly trash-can has different components able to provide services via "apps". It is network-enabled, works in real-time and can work as a standalone system or be coupled with similar trash-can to form a "collection system".

[7] http://www.publications.parliament.uk/pa/ld201314/ldselect/ldeucom/154/154.pdf

[8] http://bigbellysolar.com/

Figure2 Big Belly Trash can.

The second venture is an EU Framework 7 funded project called "BURBA[9]", a consortium of 9 members. The project seeks to optimize waste management systems by using RFID tags and LBS (Locations Based Service). The project also proposed a bin called IWAC (Intelligent Waste Container). The bin usage is tightly associated with users through the use of RFID (e.g. for access and control). The waste collection is optimized via the data collected from IWACs.

	BURBA	BIG Belly	ReDbin
Location Based Service	x		x
RFID	x		
sensor monitoring	x	?	x
container positioning	x		x
recycling		x	x
realtime data		x	x
navigation	compass based app		google map
power	?	Solar	Solar
WIFI		x	x
GPS	x	x	x
Cloud based			x
Mobile Apps	x	x	x
Web tools	x	x	x
Reporting	x	x	x
email	x	x	x
SMS	x		x
collection process optimisation	x	x	x
bin sends messages automatically	x	x	x
routes optimasation		x	x
incooperate with local traffics		x	x
incooperate local weather			x
Tracking progress		x	x
service/repari management system			x
self-alarming system			x
remote access			x

Figure3 Comparison of BURBA, BigBelly and ReDbin

B. *Proposed Architural Framework*

In our work the main focus of the research is to address the problem of inefficiency in waste collection and ultimately contribute to cost saving, increase users' satisfaction and reduce negative environmental impact (via optimizing collection). We have proposed an architecture framework (ReDbin) to cater for smart, robust, eco-friendly, on-demand and more efficient collection systems. The paper assumes households are network-connected in the smart cities.

The basic architecture framework deals with issues (1) network and sensors connectivity, (2) sensing, (3) security, (4) mobility and (5) data management. System design will take users' interactions and experience into account.

[9] http://88.32.124.85/BURBA/jburba/

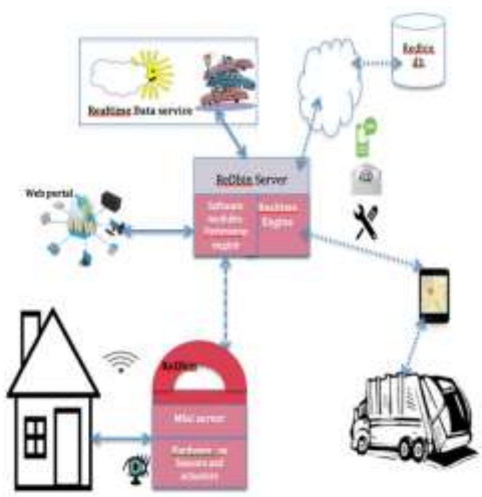

Figure3 The high-level ReDbin Architecture Diagram

At a higher level, the systems consist of (1) network-enabled mobile container called ReDbin, a robust, eco-friendly, on-demand "smart bin" containing embedded networked sensors that facilitates the holding and sorting of different types of household waste. The ReDbin features an in-built self-managing system capable of performing self-diagnostics and informing the authorities whenever it needs emptying or servicing. In addition the ReDbin can act as a "guardian" for the house owners by monitoring the boundary of the property to detect abnormal activities (eg. intruders). The ReDbin can be configured to appropriate actions if such scenarios occur. Furthermore, the ReDbin has security system built-in and can be accessed remotely. (2) A management system hosted in local Collection authority send and receives ReDbin messages.

The ReDbin works with IPv6 enabled local Personal Area Network. The functionalities include:

1. Capacity to hold and sort different types of household waste
2. A self-management capability that can inform the appropriate authorities whenever it needs empty, serving etc.
3. An ability to advertise its position to the collection team
4. An alarm system that can summon assistance if it was taken outside the dedicated area (to prevent vandalisation)
5. A means to measure waste usage for analysis
6. Support for environmental monitoring such as gathering weather or pollution data or detection of activities such lack of activity (a problem with an older person) or unusual activity (security breach), or traffic flow (if bin is near road).
7. Provision of secure remote access.
8. Access via a user-friendly GUI.
9. Solar powered to avoid negative environmental impact.

The support remote collection management systems functionalities include:

1. Prioritized collection (based on bin-status reports)

2. Calculation of best path/routes by in-cooperating with local traffics and weather data (seeking maximize number of bins collected and minimise journey overheads)
3. Routes mapping and monitoring
4. Link to appropriate partners for service/repair

C. *Future Work*

The next stage is to develop a proof-of-concept prototype to advance the RedBin concept. A business case will be developed to support our proposal. We will also identify potential partners including business and trials partners such as local councils and authorities.

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IV. Conclusion

We have presented a comprehensive literature review of the work related to management of household waste, identifying two significant technology ventures that aim to provide a more eco-friendly approach to waste management. The studies have shown that although considerable resources are expended on recycling and reducing household waste production, very little attention has been paid to optimizing waste collection. There is a genuine need for a new robust, eco-friendly and on-demand refuse bin system that is sustainable in the long term and that will achieve a standard of user experience that will prompt widespread user acceptance. The two main contributions of this concept paper were the literature review of IT applications to waste management and a system-level computational model (RedBin) for a holistic Intelligent Environment based solution to domestic waste management. In particular, we have proposed the creation of a city wide eco-system that integrates home-based and city-wide technology, empowering the citizen, to create a more efficient approach waste management. We look forward to reporting on this work in coming conferences.

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