Exploring the Application and Usability of NFC for Promoting Self-Learning on Energy Consumption of Household Electronic Appliances

Vishamlall Ramrecha [1], Girish Bekaroo[1], Suraj Juddoo[1], Aditya Santokhee[1]
[1]Middlesex University (Mauritius Branch Campus), Bonne Terre, Vacoas, Mauritius.

Abstract— **During the past decade, the significant increase in the adoption of consumer electronics has caused a rise in energy demand within the residential and household sectors globally. Since these electronics are dependent on electricity, the impact of these sectors on the environment is also deteriorating and it becomes important to take remedial action. For this, various websites and mobile applications have emerged that provide information to household users on energy consumption of devices and as well as reduction mechanisms. However, since these platforms are limited in various ways in their endeavor to promote self-learning on energy consumption reduction, awareness still remains an important barrier thus giving rise to the need for further investigation on innovative technologies and platforms. Even though Near Field Communication (NFC) could potentially be used, limited work has been conducted in relation to energy consumption of consumer electronics. As such, this paper delves into the application and usability of NFC for promoting self-learning on energy consumption of household electronic appliances through an Android based application called NFC Energy Tracker (NET).**

Keywords— Near-Field Communication, Self-Learning, Energy Consumption, Household Appliances, Usability.

I. INTRODUCTION

It has recently been forecasted that global energy consumption is expected to grow by 48% between the years 2012 and 2040 [1]. This is principally due to the continuously increasing energy demand in various sectors including residential and household sectors [2, 3]. In these sectors, the world has witnessed a massive adoption of technology where there has been widespread adoption of different kinds of consumer electronics including television sets, washing machines, computers and ovens, among others [4, 5]. These household electronics consume electricity and even though considerable improvements have been made to improve their energy efficiency, electricity consumption in household sector kept on increasing during the past decade [6]. The growing concern is that as technology has seamlessly integrated into the everyday life of individuals [7] and that with innovative technologies including Internet of Things, many more such devices are expected to emerge within households thus further adversely impacting the energy needs of the household sector [8]. A recognized approach is for household users to behave in a greener manner by utilizing consumer electronics in a more energy efficient manner [9]. Hence, it becomes important to provide home residents feedback on energy consumption of their different appliances [10]. However, the lack of awareness of household residents on energy consumption of electric and electronic appliances has shown to adversely contribute to inefficient energy use and over-consumption of energy thus also negatively impacting the environment [11].

To address the awareness barrier, different platforms have emerged down the years to provide energy related information about household electronics, especially through information and communication technologies. One of the common platforms involves the use of online published information from websites. Various websites exist that promote self-learning on reduced energy consumption of household electronics including Energy Use Calculator[1], Energuide[2] and Three Actions Projects – Track your Electricity Use[3], among others. These websites provide information on lowering energy costs, accurate measurement of energy use and other energy related content. However, the use of websites for self-learning on energy consumption has various limitations. One of them is reliability of information provided where details displayed on websites could be incorrect or not up-to-date [12]. Moreover, the process of typing the web address and then following various steps to access the required information about an appliance is time consuming and tedious [13]. More recently, with the massive growth in the adoption of mobile phones, various mobile applications emerged for self-learning on energy consumption. Key examples include EnergyLife[4], Amber – Energy Saver and My Power Consumption, available on Play Store. However, key usability issues with mobile applications entail the need for browsing to find the specific appliance before getting appropriate details, thus increasing the time taken for information retrieval. Moreover, many applications require internet connectivity which also poses a potential challenge to information retrieval. With the limitations of these existing platforms for effectively promoting self-learning on energy consumption of household electronics, there is a need for further investigation on innovative technologies and platforms.

One such technology which could potentially be used is Near Field Communication (NFC). NFC is a form of contactless communication between devices (e.g. smartphones

[1] Energy Use Calculator, available at: http://energyusecalculator.com/
[2] EnerGuide, available at: http://www.enerquality.ca/program/energuide-rating-system/
[3] Three Actions Project, available at: http://www.threeactionsproject.org/Actions/Track-Your-Electricity-Use.php
[4] EnergyLife, available at: http://www.energyawareness.eu/beaware/solutions/energy-life/

or tablets) thereby allowing users to place their smartphone over a compatible NFC device or tags to enable transfer of information [14]. Although this technology has been successfully used for various purposes including secure credit transfer among mobile phones [15] and virtual ticketing [16], among others, its application has not been well explored for promoting self-learning on energy consumption of consumer electronics. Furthermore, since mobile applications face various design issues in terms of small screen size, limited connectivity, high power consumption rates and limited input modalities, the way these applications are practically used critically determines the success or failure of such applications [17]. As such, it also becomes important to evaluate the usability of mobile applications to decide if an application is usable and delivers a good user experience. As such, this paper investigates the application and usability of NFC for promoting self-learning on energy consumption of household electronic appliances. In order to achieve the purpose of this paper, an Android based application called NFC Energy Tracker (NET) was designed and implemented, as discussed next.

II. NFC ENERGY TRACKER (NET)

NET aims to promote self-learning on energy consumption of household electronic devices through a mobile application and NFC tags. Android was chosen as targeted operating system for NET because it was recently regarded as the most popular one in the world [18]. In terms of key features of NET, the end user can obtain power and energy related information (e.g. power consumption, energy consumed for a period of time, energy saving practices, etc.) of an appliance by scanning the NFC tag found on the device. A screenshot of the application is depicted in Fig. I which also shows information obtained from a microwave appliance by scanning the NFC tag found on it.

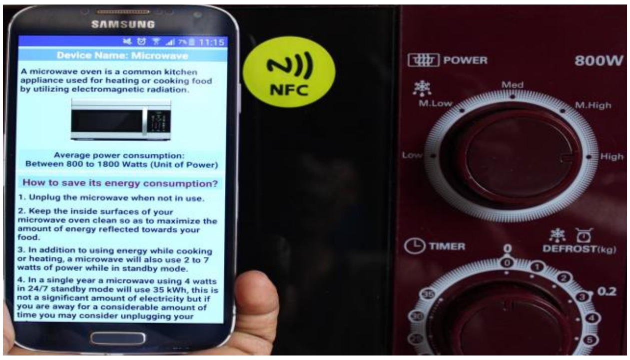

Fig. I - Scanned Information from Microwave

Additionally, NET also allows the end user to obtain the energy consumption of an appliance (values updated every second) while also giving an approximate cost per month. For cost estimates, the end user can edit the price paying per kWh. These features were included so as to better promote awareness on the impacts of not implementing energy saving measures with household appliances. An image of the screen depicting the values obtained related to energy consumption is given in Fig. II. Furthermore, even users who do not possess the relevant NFC tags can utilize NET to obtain similar information. However, in this case, the user has to manually browse and select the appropriate appliance.

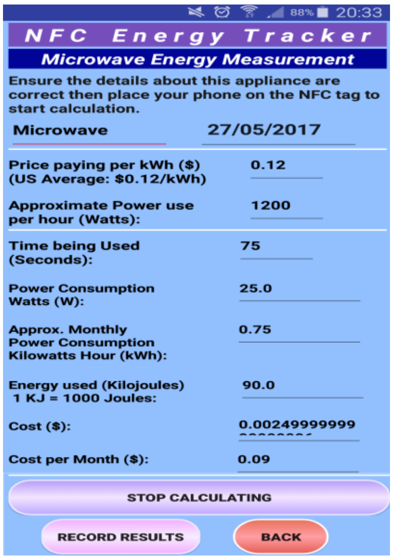

Fig. II - Appliance Energy Consumption

III. EVALUATION

As approach, heuristic evaluation was considered for evaluating the usability of the proposed application and the NFC based approach for promoting self-learning on energy consumption of household electronic devices. This approach was chosen because it is a well-established and popular technique originally proposed by Nielsen [19] while also being cost-effective, fast and helps to identify minor and major issues of applications. Due to their relevance, the following heuristics based on Nielsen's principles [20] were considered to assess NET.

- *Visibility of the system status*

It is important for a system to keep users always informed on the purpose of a specific layout by providing menu titles, instructions and to have proper feedback when function keys are pressed within reasonable time.

- *Aesthetic and minimalist design*

This heuristic assesses whether layouts are simple, brief, familiar and descriptive.

- *Recognition rather than recall*

This heuristic can help to confirm if a user would have to remember information from one part of the layout to another while browsing across different layouts and to also know if there is visibility of actions made.

- *User control and freedom*

Users often choose system functions by mistake and this heuristic would help confirm if the system has options to leave the unwanted state without having to go through a number of steps.

- *Consistency and standards*

To ensure that the system is consistent by having the same menu structure, consistent fields labels from one screen to another and also meeting proper standards.

In order to collect data on the above heuristics from participants, a questionnaire was formulated which also consisted of key sections pertaining to demographics information of participants, list of tasks, previous experience with NFC technologies, and perspectives on effectiveness of NET for self-learning. Then, participants were recruited and for this, as pointed out by Nielsen [19], useful results can be achieved by non-expert users provided they understand what is being evaluated. As such, non-expert users in the form of students were targeted. Since the evaluation would be involving statistics, Nielsen [21], recommends the recruitment of at least 20 participants in such quantitative study. In all, 22 students from Middlesex University (Mauritius Branch Campus) were asked to carry out the evaluation and following recruitment, ethical considerations were followed with relevant consent forms filled-in. Only participants owning an Android based phone were recruited so that users can personally download and install the developed tool. Also, during the recruitment process, a check was done to ensure that the participants had at least 5 such electronics at home in order to be able to sufficiently utilize NET. Following installation, each user was given a set of properly labelled NFC tags glued on different appliance pictures (to avoid confusion) and brief training was provided. The reason for providing brief training was to improve chances of identifying usability problems, as highlighted in a previous study [22]. Once the participants were briefed and had the relevant tags, 1 week was given as evaluation period for them to utilize the application and perform different tasks including:

- Scan and record average power consumption information from at least 5 devices (e.g. washing machine, television, microwave, refrigerator, iron and computer)
- Start measuring energy consumption of different devices for a period of time.
- Stop measuring energy consumption of specific appliances.
- Record energy results displayed.
- View power and energy related statistics.

After the allocated time, a debriefing session was conducted individually with every participant. In this process, the questionnaire was filled-in by each participant to collect data, which was then input and analyzed statistically.

IV. Results and Discussions

As demographic details, 14 males and 8 females participated in the evaluation representing 63.6% and 36.4% of the total participants respectively. All participants were aged between 15 and 35 years as shown in Fig. III and all were following undergraduate courses.

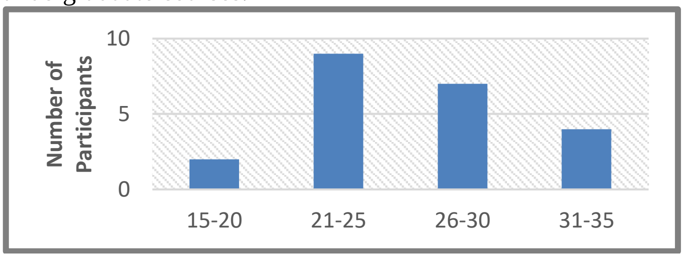

Fig. III– Age Group Distribution

Furthermore, the use of the NFC feature on smartphones was found to be quite low where only 6 among the 22 participants (27.2%) ever made used of this technology. Additionally, none of these 6 participants previously used any NFC based system for learning on energy consumption of electronic appliances. Besides, the most common ways of obtaining appliances energy information were from the television, websites and brochures as shown in Fig. IV.

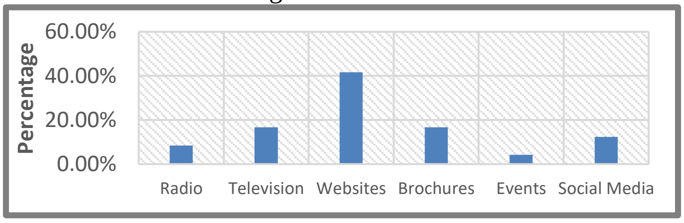

Fig. IV - Method for obtaining energy information by participants

Amongst the methods given in Fig. IV, 17 participants (77.3%) agreed that these were not much effective and highlighted the need for more innovative technology for improving awareness on energy consumption of appliances. The results for the heuristics analyzed are given in the next sections.

***Heuristic 1:* Visibility of the system status**

The majority of the participants agreed that all layouts began with a title with a score of 4 out of 5. However, some participants found error messages quite confusing with a score of 3.3. This was because the default Android toast functionality was used which provided a standard font different from the font used in the application. Since every button pressed had some seeable feedback, it got a score of 4.4. The review checklist is compiled in Table I.

#	Review Checklist	Avg. Score
1.1	Does every display begin with a title or header that describes screen contents?	4.0
1.2	Do menu instructions and error messages appear in the same place(s) on each menu?	3.3
1.3	Is there some form of system feedback when function keys are pressed?	4.4
	Average score:	**3.9**

Table I - Visibility of system status

***Heuristic 2:* Aesthetic and minimalist design**

Most of the participants approved that field labels and data entry screens such as when editing the Wattage and price paying per kWh of an appliance were simple, clear and descriptive which got received a score of 4.2. On the contrary, an average score of 3.1 was received for menu titles as it was quite confusing for 27.3% (6 participants) of the evaluators. The summarized information for this heuristic is given in Table II.

#	Review Checklist	Avg. Score
2.1	Are field labels brief, familiar, and descriptive?	4.2

2.2	Does each data entry screen have a short, simple, clear, distinctive title?	4.2
2.3	Are menu titles brief, yet long enough to communicate?	3.1
	Average score:	**3.8**

Table II – Aesthetic and minimalistic design

Heuristic 3: Recognition Rather than Recall

There has been mixed reviews about the grouping of items. Some participants did not understand the headings between different layouts. According to the participants, a more proper title could be considered for some layout which looked complex. The color coding and separation of different subtopics of the application were appropriately done which the majority of the participants agreed with a score of 4.1. The results are compiled in Table III.

#	Review Checklist	Avg. Score
3.1	Have items been grouped into logical zones, and have headings been used to distinguish between zones?	4.0
3.2	Have zones been separated by spaces, lines, color, letters, bold titles, rules lines, or shaded areas?	3.8
3.3	Is color coding consistent throughout the system?	4.1
	Average score:	**4.0**

Table III – Recognition rather than recall

Heuristic 4: User control and freedom

According to participants, stopping calculation of energy consumption was easily carried out as a dedicated visible button was implemented. There was also an issue concerning character edits in specific fields where participant accessing the calculation of the energy measurement layout were confused whether there was a need to enter some information before starting the calculation process. As improvement, the fields that allowed character edits could be filled with another color. The review checklist is compiled in Table IV.

#	Review Checklist	Avg. Score
4.1	Can users cancel out of operations in progress?	4.2
4.2	Are character edits allowed in data entry fields?	3.0
4.3	If users can go back to a previous menu, can they change their earlier menu choice?	3.6
	Average score:	**3.6**

Table IV - User Control and Freedom

Heuristic 5: Consistency and standards

Participants did agree that menu choice structure have items that match specific menu title. Also, the task structure was relevant to the menu structure and the layout title was given a short and easy name to understand thus yielding an average score of 4.2. Additionally, field labels were consistent in different layouts to also obtain an average score of 4.1. Results for consistency and standards are given in Table V.

#	Review Checklist	Avg. Score
5.1	Does the structure of menu choice names match their corresponding menu titles?	4.3
5.2	Does the menu structure match the task structure?	4.2
5.3	Are field labels consistent from one data entry screen to another?	4.1
	Average score:	**4.2**

Table V - Consistency and Standards

Overall, an average score of 3.9 was obtained for the different heuristics analyzed thus highlighting the overall good usability of NET. Most participants also found the application easy, simple and user friendly as the responses varied mostly between Strongly Agree and Agree. Additionally, participants agreed that there were no major inconsistencies while using the application and considered that regular and occasional users would also like to use the application. Furthermore, Moreover, 90.1% of participants agreed or strongly agreed that the application effectively helped them understand energy consumption of their household electronics where the most significant advantage was instant information retrieval. The NFC based approach provided a means for end users to obtain energy related information on electronics without the need for surfing and browsing through a long list of appliances. The same group mentioned to be willing to use the application in the future for getting energy related information on their appliances. However, some limitations of the NET and the NFC based approach were also highlighted:

- *Compatibility issues*

During the experiment, only participants having NFC-enabled Android smartphones were chosen. As such, NET would not be compatible with phones that are not NFC enabled thus impacting adoption. Moreover, some type of NFC tags may not be compatible with different kinds of smartphones [23] thus also impacting overall acceptance.

- *Need for customized NFC tags*

The major limitation of the approach was identified to be the need for customized NFC tags for every appliance in the household in order to obtain correct information. Without such tags, users would not be able to obtain energy information about appliances thus hindering self-learning. Furthermore, although NET could be used without the use of NFC, only 31.8% participants mentioned the application would be helpful to obtain energy related information but the process will be lengthy with the need for browsing for specific device. Additionally, with the low cost of NFC tags and the widespread adoption of smart phones, most participants strongly agreed that manufacturers of appliances could integrate such tags in their devices thus providing energy related information through mobile applications.

- *Specificity of NFC tags*

According to the participants, specificity of NFC tags was highlighted as another limitation of the approach being investigated for obtaining power and energy information of appliances. There are many brands and models for each appliance and NET only provides average power and energy values for compliant appliances rather than specific values for each brand and model. As such, power and energy information should be made specific to the device to improve accuracy of information given to the end user.

V. Conclusions

This paper explored the application of NFC for promoting self-learning on energy consumption of household electronic appliances through the implementation of an Android based application entitled NFC Energy Tracker (NET). Through the use of NET, end users can obtain power and energy related information (e.g. power consumption, energy consumed for a period of time, energy saving practices, etc.) of an appliance by scanning the customized NFC tag found on the device. The usability of the application was evaluated using the heuristic evaluation approach involving 22 participants to also obtain insightful information from participants on the NFC based approach for promoting self-learning on energy consumption of household appliances. In the experimentation results, an average score of 3.9 was obtained thus highlighting the good overall usability of the tool. Moreover, 90.1% of participants highlighted that the application effectively helped them understand energy consumption of their household electronics and also expressed the willingness to use NET in the future. As such the NFC could potentially be exploited by manufacturers of appliances to integrate such tags in their devices to effectively provide energy related information to the end users. As future works, large scale deployment of NET is envisaged following further effort on addressing the identified key limitations including compatibility issues, need for customized NFC tags and specificity of NFC tags.

VI. References

[1] EIA, "Consumption and Efficiency," Energy Information Administration, 2016. [Online]. Available: http://www.eia.gov/consumption/. [Accessed 20 Apr 2017].

[2] World Nuclear Association, "World Energy Needs and Nuclear Power," 20 Apr 2017. [Online]. Available: http://www.world-nuclear.org/information-library/current-and-future-generation/world-energy-needs-and-nuclear-power.asp.

[3] S. Syngellakis, Waste to Energy, Wit Press, 2014.

[4] T. Crosbie, "Household energy consumption and consumer electronics: The case of television," *Energy Policy,* vol. 36, no. 6, pp. 2191-2199, 2008.

[5] G. Bekaroo, C. Bokhoree and C. Pattinson, "Impacts of ICT on the natural ecosystem: A grassroot analysis for promoting socio-environmental sustainability," *Renewable and Sustainable Energy Reviews,* vol. 57, pp. 1580-1595, 2016.

[6] A. De Almeida, P. Fonseca, B. Schlomann and N. Feilberg, "Characterization of the household electricity consumption in the EU, potential energy savings and specific policy recommendations," *Energy and Buildings,* vol. 43, no. 8, pp. 1884-1894, 2011.

[7] M. Weiser, "The computer for the 21st century," *Scientific american,* vol. 265, no. 3, pp. 94-104, 1991.

[8] J. Gubbi, R. Buyya, S. Marusic and M. Palaniswami, "Internet of Things (IoT): A vision, architectural elements, and future directions," *Future generation computer systems,* vol. 29, no. 7, pp. 1645-1660, 2013.

[9] K. Peattie, "Green consumption: behavior and norms," *Annual review of environment and resources,* vol. 35, pp. 195-228, 2010.

[10] H. He and S. Greenberg, "Motivating Sustainable Energy Consumption in the Home," University of Calgary, 2008.

[11] S. Greenberg, "Motivating Sustainable Energy Consumption in the Home," April 2009.

[12] SHRM, "Social Media: What are the advantages and disadvantages of social networking sites? What should we include in a policy?," 2012. [Online]. Available: https://www.shrm.org/resourcesandtools/tools-and-samples/hr-qa/pages/socialnetworkingsitespolicy.aspx. [Accessed 5 Jun 2017].

[13] Purch, "Top 10 Usablity Problems Found in Websites," 10TopReviews, 2017. [Online]. Available: http://www.toptenreviews.com/business/articles/trust-in-a-website/. [Accessed 2 March 2017].

[14] NFC, "Near Field Communication," Near Field Communication, 2017. [Online]. Available: http://nearfieldcommunication.org/. [Accessed 10 May 2017].

[15] D. Monteiro, J. Rodrigues and J. Lloret, "A secure NFC application for credit transfer among mobile phones," in *IEEE 2012 International Conference on Computer, Information and Telecommunication Systems (CITS),* 2012.

[16] S. Ghìron, S. Sposato, C. Medaglia and A. Moroni, "NFC ticketing: A prototype and usability test of an NFC-based virtual ticketing application," in *IEEE First International Workshop on Near Field Communication*, 2009.

[17] R. Harrison, D. Flood and D. Duce, "Usability of mobile applications: literature review and rationale for a new usability model," *Journal of Interaction Science,* vol. 1, no. 1, p. 1, 2013.

[18] Network World, "Android now the world's most popular operating system," Network World, 2017. [Online]. Available: http://www.networkworld.com/article/3187011/mobile-wireless/android-is-now-the-worlds-most-popular-operating-system.html.. [Accessed 28 May 2017].

[19] J. Nielsen, "Enhancing the explanatory power of usability heuristics," in *Proceedings of the SIGCHI conference on Human Factors in Computing Systems*, 1994.

[20] J. Nielsen, "10 Usability Heuristics for User Interface Design," Nielsen Norman Group, 1995.

[21] J. Nielsen, "How Many Test Users in a Usability Study?," *Nielsen Normal Group,* 4 June 2012.

[22] J. Castillo, H. Hartson and D. Hix, "Remote usability evaluation: can users report their own critical incidents?," in *CHI 98 conference summary on Human factors in computing systems*, 1998.

[23] V. Kostakos and E. O'Neill, "NFC on mobile phones: issues, lessons and future research," in *Fifth Annual IEEE International Conference on Pervasive Computing and Communications Workshops*, 2007.