Home Automation Internet of Things: Adopted or Diffused?

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Abstract. The term Internet of Things has become very popular over the past few years. Major tech organizations and manufacturers are dedicating big portions of their focus on developing the foundations of the Internet of Things, including IBM, Cisco, Google, and many others. Most companies are developing tools and applications that are targeted to different industries like: home automation, smart cities, manufacturing, logistics, etc. This study is focused on the Home Automation and how the Internet of Things is disrupting the regular "non-smart" homes we once knew. This research is planned to study the effects of the Home Automation devices and tools currently available in the market and measure how adopted "accepted" they are within the general community. We will also measure how much disruption is it causing to the non-smart home appliances and devices industry, and how is the industry is being reshaped to cater for this newly developed market.

Keywords: Internet of Things · Home automation · Smart homes
Technology disruption

1 Introduction

Connecting every object in our lives through a unified network has been the hype at many of the major technology giants over the past few years to allow different devices to communicate with each other on a common ground. Some of them have taken the lead on creating what later became known as the Internet of Things 'IoT'. The entire idea is simply the presence of tens of objects (things) around us like RFID tags, sensors, mobile phones, home appliances, manufacturing equipment, cars, buses, trains, etc. that can through some common platform communicate, interact & cooperate with each other to reach common goals [1]. One important aspect of the IoT is its impact on different everyday-life and behavior of potential users, on the individual side users are expecting to see technology-based enhancement on assisted living, e-health, home automation, life management, etc. [2]. Such enhancement is expected to make lives easier and more proactive; however, it is disrupting a huge industry on both an individual level as well as on an organization & businesses level. This research is planned to study different theories that assess the adoption and acceptance of the Internet-of-Things on an Individual level and propose a framework that can be used for future technologies.

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2 Literature Review

While the Internet of Things (IoT) has the power to change our world, we are still at the beginning of the transformational journey that will revolutionize the way we live and work for the better. In the next few years, we can expect to see incredible advancements being made by tech giants, such as IBM and other companies. Such enhancement is expected to make lives easier and more proactive; however, it is disrupting a huge industry on both an individual level as well as on an organization & businesses level. The IoT was included by the US National Intelligence Council in the list of six ''Disruptive Civil Technologies" with potential impacts on US national power. The NIC foresees that *''by 2025 Internet nodes may reside in everyday things – food packages, furniture, paper documents, and more"* [3]. The Origins of the Internet of Things go back to merging two terms: Internet and Things, where the 1st one pushes towards a connected oriented vision of the IoT, while the 2nd one focuses on integrating objects into a common framework [2]. When these terms are put together they semantically create: *"a World-Wide network of interconnected objects uniquely addressable, based on standard communication protocols"* [4]. The ITU had a more extensive vision for the IoT, in their report published in 2005 they stated: *"from anytime, anyplace, connectivity for anyone, we will have the connectivity for anything"* [5].

The Internet of Things is expected to enable things "objects" to become active participants in business, information, & social processes where they would be able to interact and communicate among them-selves by exchanging data and information [6]. In an article by the NY Times [7], Mathew Wood, the general manager of product strategy at Amazon Web Services said: *"The idea is turning the world into a smart object that can be continuously improved, and we couldn't be more excited"*. The concept of the Internet of Things is built on 3 main pillars from an object perspective [8]:

1. Be identifiable (anything identifies itself)
2. To communicate (anything can communicate)
3. To interact (anything interacts)

The Internet of Things Paradigm is a mixture of attributes of 3 different paradigms. The first are the Things Oriented visions, where it is about connecting different things to each other or simply offering a connectivity for different objects to communicate, such paradigm is far beyond the simple RFID tags, NFC, or wireless sensors [2]. The European Commission in their latest definition of the Internet of Things reported: *"Things having identities and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environmental, and user contexts"* [4]. On the other hand, the second paradigm is the Internet Oriented visions. According to Gershenfeld et al. [9] the IoT will be integrated with some kind of simplified version of the current Internet Protocol IP, to adapt it to any object and allow these objects to be addressable and reachable from anywhere in the world. Finally, the last paradigm is the Semantic Oriented visions. The idea behind these visions is the number of things "objects" that will connect to the internet in the future will be extremely massive and that will raise issues of how to represent, store, interconnect, search, and organize the information generated by these objects will be very challenging and will require a special IoT storing and communication infrastructure [10]. In their article about how "smart objects" are the backbone behind the Internet of Things concept [11], the researchers define the basics for objects to be considered as smart they would need to:

1. Have a physical embodiment and features
2. Have a minimal set of communications functionalities
3. Possess and unique identifier
4. Associated to at least one name and one address
5. Possess basic computing capabilities
6. May possess means to sense physical phenomena

While Miorandi et al. [8] believes that the Internet of Things in its practical shape should support and enable the following features:

– Devices heterogeneity: The Internet of Things as a technology would be able to connect various kinds of devices if they can communicate on a common interface with other objects "things".
– Scalability: When every object we have is a candidate of being part of the Internet of things many issues raise and must be addressed as early as possible. Naming and addressing, data communication & networking, information management, and service provisioning & management are some of the main ones.
– Ubiquitous data exchange through proximity wireless technologies: Communications limitation and spectrum availability might cause issues when substantial number of things are interconnecting within a certain geographical location.
– Energy-Optimized solutions: Minimizing the energy required for communicating and processing within the "things" is a critical and important aspect.
– Localization and tracking capabilities: Things will connect on low-range frequencies and this would allow physical movement tracking while in range, which would be very beneficial in the logistics & life-cycle management.
– Self-organization capabilities: Networks of the Internet of Things will have to handle hundreds, or thousands of things connected to one or more nodes, and such activity should be managed automatically and autonomously without the need of any human interaction.
– Semantic interoperability and data management: Internet of Things will enable thousands of devices to communicate with each other and for that to happen there must be a standard format of data transmission so various categories of things can understand each other.
– Embedded security and privacy-preserving mechanisms: for humans to trust that things connect to each other and communicate among each other they must have proper security mechanisms and an integrated authentication process before allowing them to communicate.

In their paper about the integration of the Smart Home with Cloud Computing [12] the researchers present the system architecture of the Smart Home that fulfills the requirement of measuring home conditions, processing instrumented data, and has the ability to monitor home appliances. Their system architecture [12] includes those major components:

- Microcontroller-enabled sensors: those sensors measure home conditions, interprets and processes the collected data.
- Microcontroller-enabled actuators: the actuators receives commands transferred by the microcontroller to perform certain actions. Those commands are issued based on the interaction between the microcontroller and Cloud services.
- Database/Data Store: stores data from microcontroller-enabled sensors and Cloud services for data analysis and visualization.
- Server/API layer between the back end and the front end: it would facilitate the received data processing from sensors and storing the data in the database. It also receives different commands from the web client to control the actuators and stores those commands in the database.
- Web application serving as Cloud services: it enables the measurement and visualization of sensor data, and controls devices using a mobile device.

In their paper about classifying the IoT and predicting the future [13] the researchers divide the IoT development into 3 consecutive phases to ultimately reach the perfect IoT vision era, the stages they described are:

- Early stage (1999–2005):
  - This was during the early stages of the idea development of Internet of Things
  - The early outcomes were connecting objects through the RFID transponders through a globally unique Electronic Product Code [14]
- Unit IoT stage (2005–2011):
  - This stage witnessed the decisions made by many governments around the globe to invest into IoT research and development and the agreement that the Internet of Things is going to be a life changer
  - The addition of Sensors on the Internet of Things field added a huge value to the Internet of Things development. Sensors included contact, contactless, and remote sensing methods (sound, light, & electricity sensing)
  - Because industry was leading the development while academic experts were behind, no universal framework of standards was developed at that stage
- Ubiquitous IoT stage (2011-present):
  - This stage will last for at least 35–50 years
  - It could be divided into 3 steps:
    - Step 1 - Industrial IoT: *"Some national standards for industrial IoT will be formulated and cross-field cooperation mechanism will be established. Also, some global industrial standards concerning cross-nation communication, such as global logistics, will emerge at this stage"* [13]
    - Step 2 – National IoT: In this step the national standards of the IoT will be established. These standards along with the regulations will allow countries to internally manage their informational network and resources
    - Step 3 – Global IoT: Cross-national cooperation will be formed, and major changes in people's life styles, ideals, social organization structures, and government functions are expected drastically.

Most of the research conducted on the Internet of Things has focused on the technical issues and consequences of the IoT, but very limited work has been done on the impact of the IoT on the human behavior and interaction. Few researchers have attempted to evaluate the literature of the Home Automation Internet of Things [15] where they evaluated more than 220 articles discussing different aspects of the Internet of Things and they categorized them into 4 different categories:

- Review & Survey Articles: including articles about the applications in intelligent smart homes, and the challenges of IoT based smart homes
- Studies Conducted on IoT apps and their use in smart homes: including articles of evaluation studies, comparative studies, and activities of IoT applications
- Proposals of System design and framework to develop and operate applications: including articles of system design and implementation, module designs and methods, and framework designs
- Report of actual attempts to develop apps

They summarized the conclusions all the reviewed articles and derived 3 major conclusions of the Internet of Things:

1. IoT-based Smart Home Benefits
2. IoT-based Smart Home Challenges
3. IoT-based Smart Home Recommendations

However, almost none of those articles focused on the adoption or behavioral impact and assessment of the Home Automation Internet of Things. There was a mention of user acceptance in one of the articles relating to the healthcare IoT-based Internet of Things, but it was not discussed in details, nor any elaboration on how can we overcome those challenges. As [13] mentioned in their article that academia is trying to catch up with the industry when it comes to the Internet of Things. This is on the main reasons that most the academic research is currently focused on the technical integration and the standardized frameworks of the Internet of Things. Never the less in their paper [16] the researchers created a framework to examine the adoption, usage and impact of the Internet of Things, and created a list of questions that will assess the impact of the Internet of Things on the Individual level, the Organization level, the Industry level, and the Society level. The list of questions they propose on an individual level are:

- Adoption of the IoT by Individuals
  - How will the global proliferation of consumer electronic technologies such as smartphones, wireless devices, and smart wearable devices impact the adoption, usage and impact of the IoT?
  - Who will bear the cost of the IoT-enabled systems? How will costs be shared?
  - What is the availability of easy-to-use individualized big data analytics tools? How will individual use these tools?
  - What will be the impact of the IoT and big data analytics on digital divide issues?
  - To what extend can the dominant current user acceptance theoretical models be used to study the user acceptance of IoT-enabled applications?
- Usage of the IoT by Individuals
  - How will usage of the IoT be influenced by, and influence, views and usage of personal data?

  - Will the IoT open up new security vulnerabilities and who will be subjected to these vulnerabilities?
  - How will individuals make use of the IoT in their daily lives?
- Impact of the IoT on Individuals
  - What are the primary and secondary costs and benefits of using

Just like any now innovation, adoption & diffusion are very critical to its success or failure. No matter how good the innovation is, it will be considered unsuccessful unless adopted [17]. Decision makers of any new innovation should always keep in mind that maximizing the adoption rate is a key element in the success of the product or service. In order to maximize the adoption of new innovations, stakeholders need to understand the factors that contribute in adoption or diffusion of that innovation. In his paper Weber [18] discuss the security and privacy challenges that faces IoT and a major obstacle IoT is currently facing is the lack of governing security regulations, which in his predictions relied solely on the self-regulations of users until a more global regulations are implemented. This indeed is a major challenge to the adoption of IoT at least on the individual level, however with that fear some people are still widely adopting different IoT based devices in their homes without paying much attention to those security and privacy concerns. In their paper [19] the researchers point out that the importance of the non-technical aspect is becoming more important in the development of the Internet of Things as it adds "a new quality" to the technical aspects. They discuss that the current public debate is wither to accept or reject the Internet of Things, so the dilemma of "security versus freedom" and "comfort versus data privacy" [19]. They then elaborate on how privacy concerns can be a barrier of the adoption of the Internet of Things as those smart objects will collect massive amounts of personal data about every step we make during the day, and even a small data breach would have major consequences. In addition, our lives will be heavily dependent on a steady internet connection, and this might be an obstacle in many regions where the internet is not stable enough during the day. To test the privacy vulnerability on the IoT-based home automation devices, the researchers [20] tested 4 different devices and through a simple observation they were able to infer user behavior from encrypted smart home traffic. This privacy concern would have a big impact on the adoption or rejection of IoT-based devices on the home level.

There are many theories that measure the adoption rate of innovation. One of the widely used theories is the Technology Acceptance Model (TAM) introduced by Davis [21] to assess the user adaptation to technology. Venkatesh and Davis extended this model in [22] to examine the user acceptance of Information technology, "The goal of TAM is to provide an explanation of the determinants of computer acceptance that is general, capable of explaining user behavior across a broad range of end-user computing technologies and user populations, while at the same time being parsimonious and theoretical" [22, 23].

In their original model of measuring IS success, DeLone and McLean [24] evaluated the literature extensively and concluded that there are main 6 categories that represent the level of success in information systems, the categories are:

- System Quality: Measures of the Information Processing System Itself
- Information Quality: Measures of Information System Output
- Information Use: Recipient Consumption of the Output of an Information System

- User Satisfaction: Recipient Response to the Use of the Output of an Information System
- Individual Impact: The Effect of Information on the Behavior of the Recipient
- Organizational Impact: The Effect of Information on Organizational Performance

They describe impact as the most difficult to define in a non-ambiguous context. It could be related to the improvement of performance, as well as an indication of better understanding of the decision context [24]. Then they introduced a success measurement model for IS based on an intensive review of the literature. 10 years later DeLone and McLean [25] revisited the model they introduced, they reviewed the literature over the past years and introduced some changes on the original model to include 6 modified categories, including: Information Quality, System Quality, Service Quality, Use (Intention to Use), User Satisfaction, & Net Benefits. There has been multiple attempts to modify the original and updated models introduced by DeLone and McLean, including the model introduced by Seddon [26], where he introduces extra categories to the original model in order to effectively measure the success of IS on different levels. However, all those related models focus on different elements that might not specifically be applicable in the case of IoT adoption on the individual level.

One of the most successful theories is the Diffusion of Innovations framework introduced by Everett Rogers in 1962, where he defines diffusion as a process in which innovation is communicated through certain channels over time among members of a social system [27]. He explains that there four main elements in the diffusion of new ideas [27]:

1. The innovation: Why do certain innovations spread more quickly than others? While others fail without real adoption of the general public.
2. Communication channels: The process by which participants create and share information with others to reach a mutual understanding.
3. Time: It is involved in 3 different ways:
   a. Innovation-decision Process: "*Is the mental process through which an individual (or other decision- making unit) passes from first knowledge of an innovation to forming an attitude toward the innovation, to a decision to adopt or reject, to implementation of the new idea, and to confirmation of this decision*" [27]
   b. Innovativeness of the adopter: *"Is the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than other members of a social system"* [27]
   c. The rate of adoption: *"Is the relative speed with which an innovation is adopted by members of a social system"* [27]
4. The social system (context): It is the set of interrelated units that are engaged in mutually solve problems to accomplish a common goal.

He then defines five main factors that influence adoption of an any new innovation:

- Relative Advantage: The degree to which an innovation is seen as better than the idea, program, or product it replaces.
- Compatibility: How consistent the innovation is with the values, experiences, and needs of the potential adopters.
- Complexity: How difficult the innovation is to understand and/or use.

- Triability: The extent to which the innovation can be tested or experimented with before a commitment to adopt is made.
- Observability: The extent to which the innovation provides tangible results.

In his book, Rogers [28] encourages researchers in the field of diffusion to consider additional attributes that could be important in a specific situation of a specific innovation. He defines 5 major stages that a decision regarding an innovation usually goes through before it is accepted or rejected (Fig. 1):

– The Knowledge Stage: when the individual learns about the existence of innovation and searches for information about the innovation.
– The Persuasion Stage: when an individual form a favorable or unfavorable attitude towards an innovation without directly making a decision about adopting or rejecting the innovation.
– The Decision Stage: when the individual chooses to adopt or reject a specific innovation, however the user would try the innovation before adopting or rejecting it.
– The Implementation Stage: would the innovation be applicable to put in practice? During this stage the innovation could lose some of its features to meet the user's requirements during the implementation.
– The Confirmation Stage: when the individual seeks support for his decision, either by accepting or rejecting the innovation.

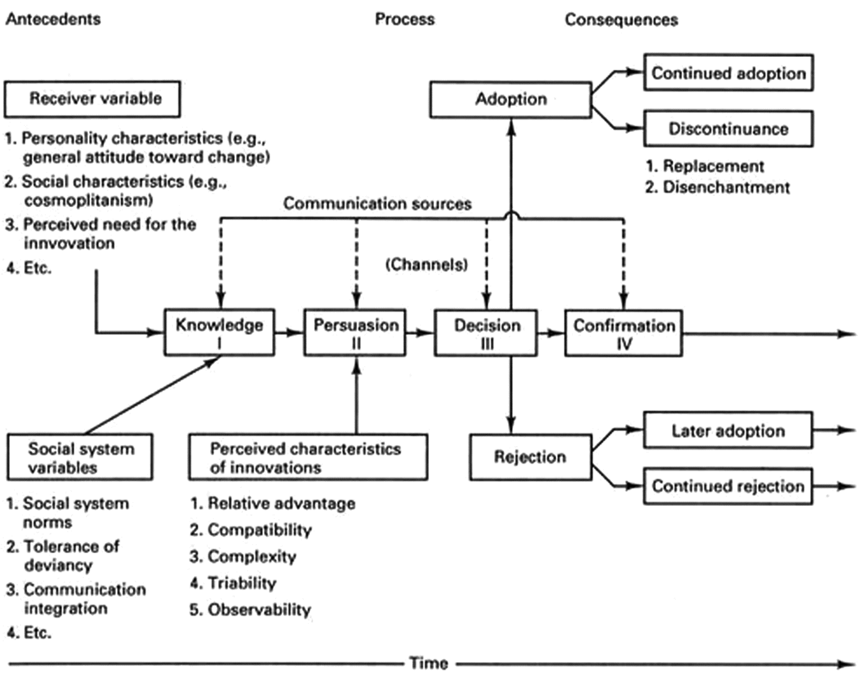

Fig. 1. Conceptual model introduced by Rogers [29]

3 Current Stage

Our objective in this research is to investigate different adoption theories and test their attributes on the Internet-of-Things adoption on the individual level to see which of the theories or mixture of theories is applicable and then introduce a new framework that can be applied on different levels of the Internet-of-things.

We are currently in the 1st stage where we are exploring different theories and preparing for collecting data based on those different theories, the plan is to have the analyzed data ready to be presented at the conference.

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