Challenges and Opportunities for Smart Homes Deployment in Developing Countries: A Case Study of the User Perspective in Kenya

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Abstract

A smart home refers to a habitation furnished with a communication network, sensors, household devices, and appliances that can be remotely identified, accessed, monitored, and controlled. The objective of this paper is to assess the perception of users of smart homes on the enablers and challenges they face in the deployment of smart homes and seeks to identify opportunities that could be adopted by vendors and manufacturers in meeting a selling point to users. The methodology adopted in this paper is on literature review, observation, and interviews based on a purposive sampling method in data collection where qualitative and quantitative data was collected. The findings from the respondents generally listed several issues as barriers to the adoption of smart homes which include: High cost of ownership of the technology, Inflexibility of devices once installed, Poor manageability, Security, Human Resources, and Power were cited as barriers. The enablers or opportunities listed by smart home technology users include: Spare part sales and repairs, Businesses or vendors need to explore the option of selling devices-as-a-service, businesses need to change their product management approach by giving a free base and then sell their services, Investment into research on devices which can think and act autonomously and Vendors are also encouraged to develop products that motivate interoperability between appliances. The conclusion made was that companies need to shift from a product company mindset to a solution company by embracing technology and evolving towards innovative new business models. The governments in developing countries need to also create an enabling environment to allow exploitation of these opportunities and breaking of barriers that prevent the adoption of this technology. Users of smart homes will therefore get what they want while vendors will create sustainable revenue streams for their firms and establish a deeper and leng-

thier relationship with their customers.

1. Introduction

A smart home refers to a residence furnished with a communication network, sensors, household devices, and appliances that can be remotely identified, accessed, monitored, and controlled, these devices have the capability to provide services and respond to the residents' needs either autonomously or upon user intervention [1]. The smart home technology hinges itself on the Internet of Things (IoT) which is a term that designates a system where objects in the physical domain and sensors attached to these objects are connected to the global computer and related networks. The objects may be able to communicate or are readable, recognizable, addressable, locatable, and/or controllable through the Internet, irrespective of the communication means, they could include things that are non-electronic such as food and clothing. The sensors attached to the objects can use different types of local area connections such as Bluetooth, RFID, NFC, Wi-Fi, and Zigbee. The sensors can also have wide area connectivity to support operations.

Many developing countries have by now taken advantage of IoT technology; from monitoring agricultural production in the field and on transport, healthcare providers tracking the health of outpatients to utility companies using connected meters to check usage.

The unique environment in developing countries is that there is no need for legacy infrastructure hence they can leapfrog in a number of application areas without difficulty unlike developed countries, which must evolve through the phases of technology upgrades and disposal [2]. IoT is a plug-and-play technology unlike legacy systems is well known to be a stop-and-start technology that deals with change in big chunks, is costly to manage, have issues in interoperability, and is not good for employee training. Based on what users understand as a smart home, it may be confusing to get to identify where the opportunities really are in the smart home market in developing countries. The study sought to assess the perception of users of smart homes on their expectations, and challenges and seeks to get some opportunities that could be adopted by users or vendors and manufacturers in meeting a selling point to users.

2. Related Studies

The development of smart devices has experienced exponential growth, notably

two technology companies Cisco and Ericsson have circulated data around the IoT market and the potential in the connected devices. The two companies agree that over 50 billion connected devices will exist by 2020 [3]. The number of smart homes in the world is as shown in Figure 1 below.

The worldwide smart home market is anticipated to grow to USD 246.42 billion by 2025 [5] which shows a huge opportunity for expansion. Global companies like Amazon, Google, and Samsung are entering this vast market providing state-of-the-art services and products to take advantage of the emerging market. Many start-ups are also making efforts to join this very fast developing sector of the economy. These companies are exploring areas of: control and connectivity of devices, personal appliances, facility management, energy management, security applications, comfort and lighting, home entertainment, and home appliances. The growth of these devices is as shown in Figure 2 below.

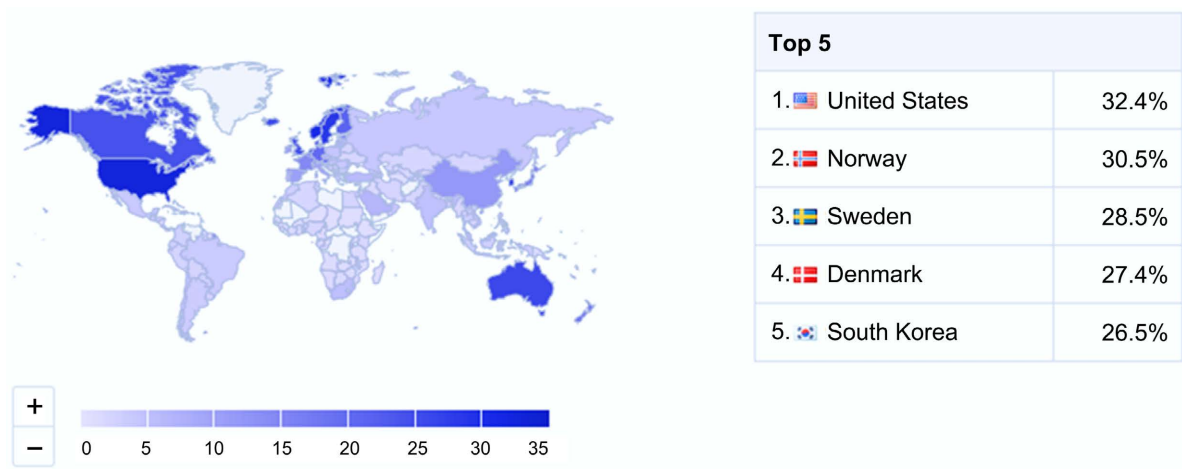| Top 5		
1. United States	32.4%
2. Norway	30.5%
3. Sweden	28.5%
4. Denmark	27.4%
5. South Korea	26.5%

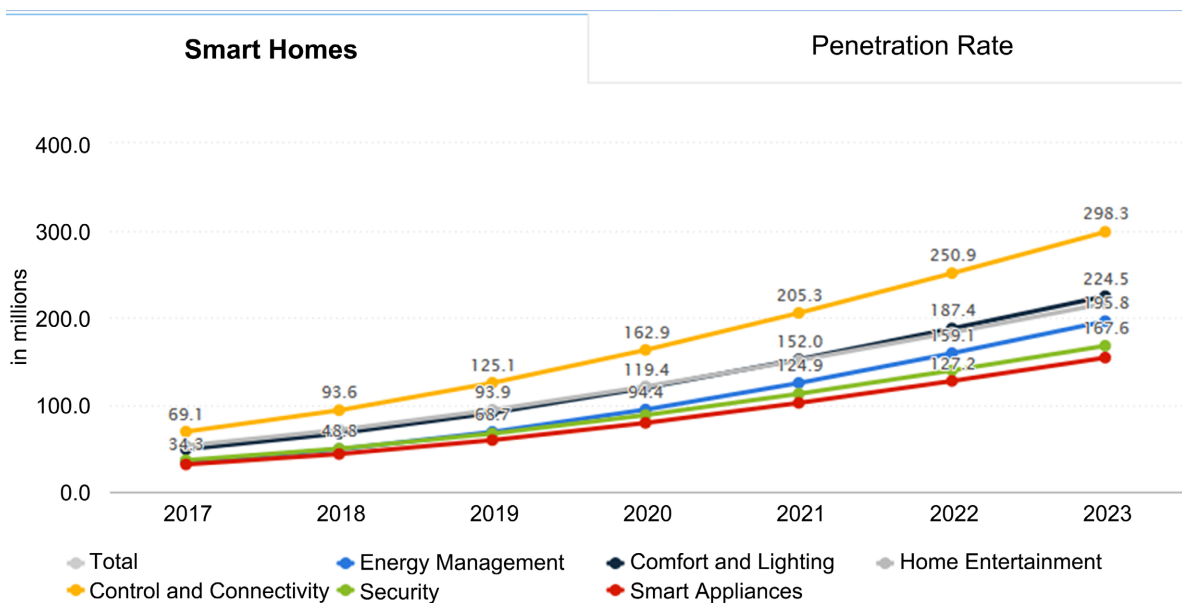**Figure 1.** Distribution of smart homes world wide as of May 2020 [4].

Figure 2. Growth of devices in smart homes and projected growth [4].

Global Comparison—Household Penetration

The major reason why users are still reluctant in adoption of smart homes especially in developing economies include: Market complexity where the smart home market is considered massive and hard to comprehend due to varying customer needs, perceptions and expectations of the smart home. Customers are regularly confused about which devices and components meet their needs and possibility of how to combine them for expansion in future [6].

Many smart home users believe that smart homes are not friendly to their way of life [7]. The main area of concern is the high level of automation is considered problematic that it may make them become lazy over time or that automation of tasks deprive them some experiences.

3. Methodology

The approach to this research problem is observation and a semi-structured approach where seven vendors were visited and a structured random sample of customers who visited the shops were interviewed within the capital city of Kenya (Nairobi). A few of those who had installed devices in their homes were also interviewed on phone. A total of 52 customers were interviewed, of which 38 were male (73.07%) and 14 female (27.93%). The Male respondents seem to be more excited in adoption of smart devices than female. The age of the respondents is as shown in Table 1 below. A range of 10 was chosen since this was observed as sharing the same characteristics in establishment of homes. It was observed that the highest age group interested in smart homes is those between 35 - 44 years at 33.33%, followed by both those of 45 - 54 Years at 27.77%, then 55 - 64 Years at 27.77%, the least is the range of 25 - 34 years at 11.11%. The finding shows that those above 65 years are not interested in smart home solutions or deployments and yet smart homes have advantages of being aging population-friendly.

The study also sought to know the academic level of education of respondents as shown in Table 2 below.

The method used in data collection was interviews and the data collected was qualitative. The questions presented were based on what the customers experience from smart devices and applications in their homes. The anticipated long term experience and barriers to adoption of smart homes. The results from the

Table 1. Age of respondents.

Variable	Frequency	Percentage (%)
25 - 34 Years	3	5.77
35 - 44 Years	16	30.77
45 - 54 Years	25	48.08
55 - 64 Years	8	15.38
Above 65 Years	0	0.00

Table 2. Academic qualifications of the respondents.

Variable	Frequency	Percentage (%)
Primary	0	0.00
Secondary	0	0.00
College	18	34.62
Bachelors Degree	27	51.92
Postgraduate	7	13.46

interviews and observations helped us in triangulation of data with previous related studies.

4. Results

The developing countries' markets have several factors that point to their success in smart homes deployment. These factors are related to the previous studies identified in the previous studies done elsewhere. The central factor identified is on cost of devices and introduction of newer and faster technologies that will handle information processing aspects of IoT [8]. Users identified the following factors as opportunities for smart homes: 1) Deployment of the communication infrastructure where deployment of GSM networks across the country which serves as an enabler of fast deployment of IoT technology. 2) Sensor prices have continued to drop same as the cost of bandwidth hence another pillar to deployment of Smart homes easily. The cost of smartphones has also dropped. 3) With the development of the big data analytics applications, the various connected devices can work faster and data can be processed better and fast. 4) Smartphone penetration in the developing countries has increased and hence the interface for most applications is available to users. 5) Wireless network technologies such as Wi-Fi have become more accessible and cheaper. 6) Device technology has improved such as available alternative energy and ultralow power technologies which have been key enablers to IoT. There are devices currently which can power themselves since they can tap energy from immediate environment.

Customers generally listed several issues as barriers to adoption of smart homes. They include:

1) High cost of ownership of the technology: This includes cost of purchase of devices, installation costs, and operation costs.

2) Inflexibility of devices once installed: Once devices leave the vendor's shop they may not have provisions for upgrades incase of faults or availability of newer software upgrades.

3) Poor manageability of installed devices: Once devices are installed, there is limited manageability since some devices lack interoperability. Vendors also face challenges of message transmission protocols or message and data exchange formats.

4) Security: Smart home users are not confident on the security of the data generated and sent by devices, there is concern also on how to remedy vulnerabilities once security faults are established. There are also issues of network reliability which compromises availability of services. Issues of connectivity on fluctuating network signals also exist. The fear for over privileged smart applications such as those which ask users to use camera, device locations or access contact list is scaring some users.

5) Human Resources: This is a challenge which users have to get specialists for each of the devices used. For example, get a technician to fix a smart Television then get another to fix air conditioning appliances.

6) Power: A source of reliable power is a major challenge to users in most developing economies. Backups are an option however most users do not have a budget allocated to it.

Solutions to these barriers are proposed in Table 3 below.

Table 3. Proposed solutions to barriers to adoption of smart homes.

Challenge	Proposed Solution
High cost of ownership of the technology	Governments can give incentives to citizens who adopt smart devices used in homes such as Tax reliefs for smart devices.
Inflexibility of devices once installed	Use of open architectures and vendors designing devices which can allow for Over the air (OTA) updates through GSM networks or otherwise this will create a flexible ecosystem of devices in the smart home. There is need to adopt advanced, intelligent products that are at the lead of IoT technology which will not need immediate upgrades or updates.
Poor manageability of installed devices	With the extensive mobile coverage, it is feasible to implement Machine to Machine solutions based on GSM which will simplify management of devices. The devices have also continued to fall in prices and increase in memory, this is an opportunity to develop software which can reduce user effort in management of devices. Sensor data are generally useful in the environment where they are collected. It would be anticipated that building local segments which utilize the data will reduce the load having to queue it over the Internet to the central servers. Development of an efficient interoperability framework that is scalable and evolvable enough to support the ever increasing number of things shortly to be connected to the internet
Security	Vendors and resellers should allocate budgets to research on security vulnerabilities and how to overcome them. Standardization of devices will also contribute to uniform solutions to security problems. The aspect of privileges can be grouped together and only essential service permissions to the applications be requested once.

Continued

Human Resources	Training of more IoT technicians and availability of support services to user offered by vendors or partnerships would help in bridging this gap. Technical IoT practitioners can share experiences and move the IoT technology further. Architects and civil Engineers should include provisions for automated solutions installation when designing and building homes.
Power	Allocation of budgets to other secondary sources of clean energy such as solar and wind power apart from power backup installations. For instance, many IoT nodes require a very small amount of power, so some small low cost solar panels would be ideal to power them. Deploying cheap energy harvesting sensors would also be an easier way to resolve this issue.

Generally some of the issues raised by users need policy makers to understand the benefits they can gain from the explosion of data coming from IoT networks [8].

5. Opportunities

There are numerous opportunities derived from interaction with smart home users which we discuss in this section.

Spare part sales and repairs of smart home devices which break down or are vandalized. For example, Smart locks accessories such as battery holders, PCB motherboards for smart locks, square shafts, smart lock motor modules, smart lock cards, fingerprint module replacements, key covers, and WIFI gateways range from US dollars 10 to 70 [9].

Businesses or vendors need to explore the option of selling devices-as-a-service. Customers are continuously looking for a way of not owning electronics whose technology is continuously changing. Customers have opted to sign a monthly service agreement that provides for product use from vendors. This business model meets customer needs as well as generates predictable revenue for the business.

There are opportunities for businesses to change their product management approach by giving a free base and then selling their services, for example, a home monitoring base station may be installed for "free," but services that send alerts such as burglar alarms, and smoke detection alarms are billed.

More consumers want devices that can think and act by themselves. For example, a smart meter that not only updates them when electricity tokens run low but also makes token purchasing on their own when prices are at a minimum. This motivates more investment in device intelligence by vendors.

Vendors are also encouraged to develop products that motivate interoperability between appliances. Development of middleware that will offer integration of transactions where businesses can innovate payment solutions especially when

purchases are initiated by multiple devices and can be managed in a central place.

There is an opportunity to explore devices that learn user behaviour such as preferences, movements, and attitudes. This will lead to the innovation of devices that make users more comfortable.

Conflicts of Interest

The authors declare no conflicts of interest.

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