

Envisioning **Internet of Things** in Indian Context

Design Research Seminar | Report

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Approval Sheet

The research seminar titled '**Internet of Things in Indian Context**' by Sanket Kulkarni, is approved for partial fulfilment of the requirement for the degree of 'Master of Design' in Interaction Design.

Guide 
Co-Guide 
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Abstract

The trend of Internet of Things (IoT) is spreading rapidly and many IoT products are hitting the market. IoT is a futuristic vision of internet in which our daily things along with computers and mobiles will have capacity to connect to internet. It has become popular in developed countries but in developing countries like India, where penetration of ICTs is still under advancement, such products are yet to capture people's attention.

The aim of this project is to carry out a preliminary research study for identifying potential of IoT in India. As IoT products originated in west, their development is based on underlying assumptions which may not be valid in Indian context. As a part of this project, we studied the current state of IoT field and designed India specific IoT concepts. We used these concepts as an ice breaker to have conversation with users in order to understand their concerns and inclinations. Finally, it helped us in coming up directions for further research and refining designed concepts.

At the end of study, we propose new categories for grouping IoT products that are ownership, geography and domain. We also came up with list of common IoT systems and their functions which should be considered while designing IoT ecosystem. Other findings from study indicate that users want to control inference of IoT products in their life. Hence, users preferred PULL approach while using IoT systems. Users preference towards particular IoT product was mainly influenced by its utility and importance of function which it is serving.

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Introduction

Bill Verplank, who coined the term "Interaction Design" along with Bill Moggridge, once said in his interview that the day is not far when everything, we interact with, will have computer inside it or on it [12]. Well, that day is not far.

Currently we use internet for various purposes through computers and mobile phones. The next step for internet is digitally connecting our daily things to each other and to us. This trend is called as Internet of Things. It emerged as a creative application of RFID technology. With time, the definition of IoT has evolved and many other research communities are contributing to it.

However, in India, the internet and mobile computing technologies are still in the process of penetrating the masses, the IoT products are yet receive popularity. The current IoT products are driven by the assumptions, made in western context, which may not be valid in Indian scenario. Hence, there is need to take a step back and recheck the applicability of underlying assumptions.

The aim of this project was to understand the cultural issues related to implementation of IoT in India and to come up with directions for designing IoT products. Finally, using these

direction we designed few IoT products and evaluated their validity by taking user feedback.

The report is divided into two sections. The first section showcases our literature study and review of existing products. In this section we have tried to explain different visions of IoT, architecture of IoT systems, findings from review of existing products and challenges faced by IoT. Moreover, in this section, we propose new dimensions for categorising IoT applications. The second section describes our IoT concepts and user's feedback on them. This section also includes the list of commonly required systems for IoT implementation. Finally, we conclude by specifying design directions and future scope of research work.

Research Process

As IoT field has undergone many developments from research as well as commercial products perspective in last two decades, it was necessary to assess the current state of IoT field. The secondary research involved reading papers, articles, and case studies in order to identify common trends.

The design process followed for this project was different from a typical design project. The main aim of this project was to understand what people overall feel about IoT products and what are their generic concerns. However, understanding IoT and imagining it in Indian context without concrete example or case studies would be difficult for people. Therefore, after doing secondary research, IoT concepts were created before reaching out to users. The researchers were already familiar with Indian context and had broad awareness about the problems faced by target users. Based on their knowledge, many concepts were designed to tackle different problem areas in Home context. Later these concepts were used for initiating conversation with users in order to get concrete feedback from them. Additionally, using participatory design methods, we conducted co-creation sessions with users to solve context specific problems using IoT approach.

Secondary Research

Understanding IoT

Visions

Key Enabling Technologies

SOA Architecture

Challenges

Categorisation of Application Domains

Review of Existing Products

Understanding IoT

Definition

It is hard to say whether a product comes under IoT vision or is just a smarter product. The concept of IoT is often misunderstood as its definition is continuously evolving. Decade ago, its definition considered only use of RFID tags. Now it is broader and points to intelligent and collaborative use of things. These are some definitions of IoT, given by research communities working in this area:

From anytime, anyplace connectivity for anyone, we will now have connectivity for anything - **ITU**, [6]

Things having identities and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environmental, and user contexts- **European Commission**, [6]

A world where things can automatically communicate to computers and each other providing services to the benefit of the human kind - **CASAGRAS consortium**, [6]

Natural enabling architecture for the deployment of independent federated services and applications, characterized by a high degree of autonomous data capture, event transfer, network connectivity and interoperability.
- **Luigi Atzori et al**, 2010, [6]

Understanding IoT

Essential Characteristics

The modern definition of Internet of Things is supported by three characteristics.

Computing, Communication and Identification

It refers to technological ability of IoT products to communicate and identify each other and each other's capabilities.

Distributed Systems

IoT products should be able to work in heterogeneous environment in discrete and distributed manner.

Distributed Intelligence

It states the ability of IoT products to take semantically viable and collectively intelligent decisions in order to achieve a particular goal.

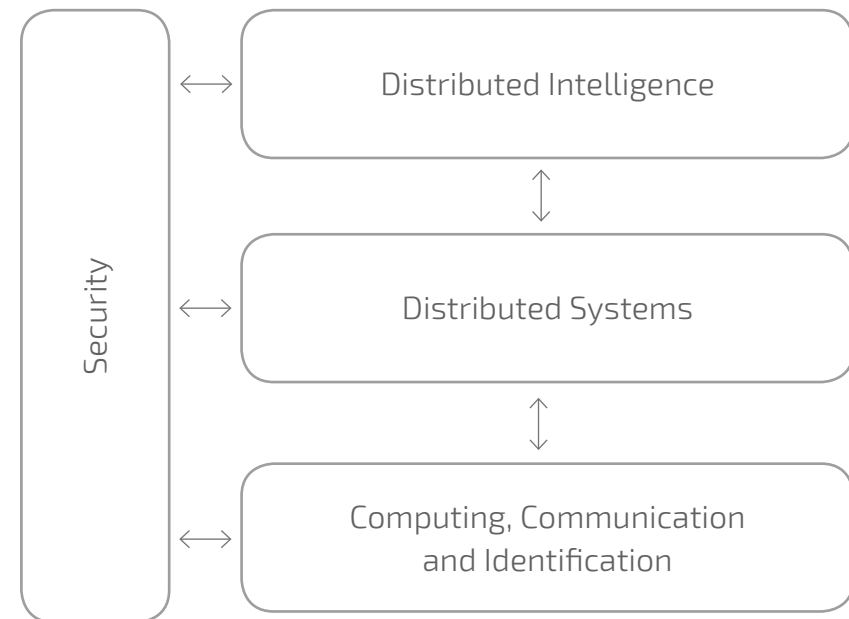


Figure: Taxonomy of Research Areas relevant to IoT [5]

Visions

Researchers from various domains have approached internet of things with different perspectives. The three essential visions, suggested by Luigi Atzori et al [6], which must be studied include thing oriented vision, internet oriented vision and semantic oriented vision.

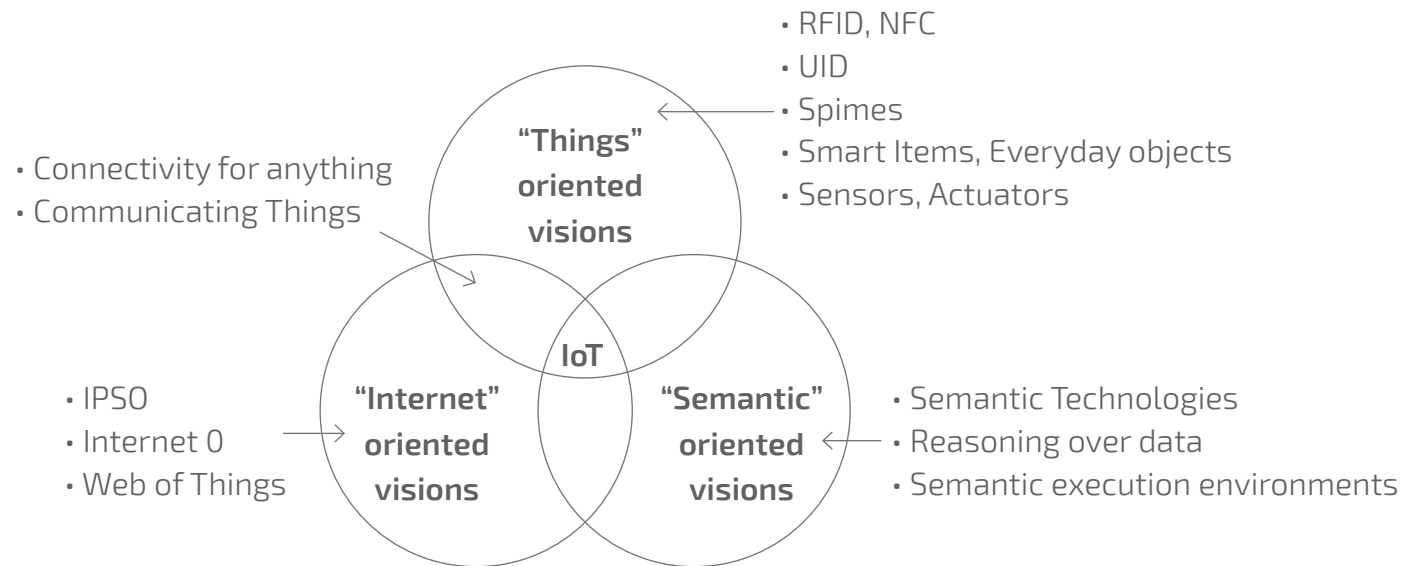


Figure: Visions of IoT [6]

Visions

Thing Oriented Vision

As its name suggests, thing oriented vision focuses on enhancing the intelligence of things. It emphasizes on creating and enhancing technologies and strategies in order to make things capable of handling IoT scenario. It means building things which are context aware and can work collaboratively with other things.

The RFID technology brought the preliminary invention in context awareness technology [2]. Consequently, thing based vision of IoT has come from the RFID research community. The term "Internet of Things" was coined by Kevin Ashton while explaining application of RFID tags for supply chain management [2]. The initial applications of RFID tags were implemented in smaller environments and offered narrow range of functionalities, wherein things were connected through intranet. Applying RFID technology in bigger environments and broader contexts like supply chain management and university campuses [3], researchers realized the need of connecting RFID tagged things through internet. Need of connecting things through internet, raised the issues of assigning unique identification. The EPC (Electronic Product Code) standard was introduced to give

unique identification to each RFID tag across world which is now followed by almost all RFID manufacturers[5]. However, in a heterogeneous scenario wherein things and sensors, which do not use RFID technology (do not use EPC standard), want to be part of network, the issues of standardisation of communication, addressing and identification mechanisms became more complex. Additionally, even though EPC framework considers future scalability of RFID technology, it is not capable of handling billions of non-RFID things and sensor networks which will be connected through internet in the future.

Hence, even though Thing oriented vision started to with application of RFID tags, it now has to consider the broader issues of standardisation of heterogeneous IoT environment.

An extensive thing oriented vision pictures a scenario in which anything can be tracked though space and time throughout its lifetime (concept of "Spime"). Anything will be able connect to anything through wireless technologies. They will have enough memory and processing capabilities for temporary storage of the sensed data, authentication and collaborative decision making.

Visions

Internet Oriented Vision

Internet based vision focuses on communication issues of connecting all things using IP address. Currently most widely used transport layer protocols like TCP are not capable of handling the tremendous amount of traffic that will be generated in futuristic IoT scenario. The length of IP address is not capable of giving unique identifier to everything in the future. Considering the billions of things which will be connected to internet, there is need to redesign the internet architecture and protocols so that new architecture will not only be capable of handling network traffic but also be supportive to exiting systems.

Internet Protocol for Smart Objects (IPSO) is an alliance of more than 500 tech companies working on restructuring and standardisation of IP address and protocols. IPSO plans to use light weight IP stack protocol in the view of 6LoWPAN (IPv6 over low power wireless Personal Area Networks). This assures capability of IP to handle huge number of communicating devices over internet [6].

Also, Web of Things is a standard being developed. It allows embedded devices to provide their services on websites. [9]

Semantic Oriented Vision

Semanatic Oriented Vision asks for meaningful reasoning over collected data and analysis. Even though IoT systems will be able to capture all types of micro data and work collaboratively, IoT systems should be able to take decisions and provide insights which are relevant and meaningful in the working context.

Aspects of IoT related to how to represent, prioritise, order and organize the information comes under semantic vision. In this project, we wish to focus on exploring semantics aspects and constraints in the Indian context for IoT applications.

Key Enabling Technologies

RFID

Radio Frequency Identifier is a circuit in which electricity gets induced due to radio waves, propagated by RFID readers. Upon electricity induction, RFID uses same energy to respond back to reader by emitting a radio wave encoded with its identifier.

RFID tags can be active or passive. Active RFID tags are powered by a battery. Passive RFID tags are powered through radio waves sent by RFID reader.

WSN

Wireless sensor networks are circuits which transmit data collected by sensors through wireless communication like Bluetooth and Wi-Fi [6]. In WSN, there can be multiple discretely located sensors. In such scenario, data is collected at central nodes which have storage capability, called as sinks.

Each discretely located sensor in WSN is powered by a separate battery. The range of data transmission of WSN depends on the technology used by it. Generally, WSNs use Wi-Fi and hence can transmit data over long distance.

RSN

RFID Sensor networks are WSNs which are powered by RFID technology [6]. RSNs harvest power from the radio waves emitted by RFID reader and use this power not only to sense data as well as to transmit it back to reader. The research in the area of RSN is still in its infancy.

	Processing	Sensing	Power	Range (m)
RFID	No	No	Harvested	10
WSN	Yes	Yes	Battery	100
RSN	Yes	Yes	Harvested	3

Figure: Comparison between RFID, WSN and RSN , [6]

SOA Architecture

Amongst different researched architectures [1, 4], Service Oriented Architecture is widely used architecture while implementing IoT systems [6, 11]. Conceptually, SOA is divided into five layers.

Objects Layer

At this layer, objects represent different devices and sensor networks. This layer presents objects at ground level. Objects sense data and perform activities using actuators. Objects using non-compatible technologies can exist together at this layer thereby enabling heterogeneous environment.

Object Abstraction Layer

At this layer, heterogeneity of objects is encapsulated. Objects can be accessed using a common language and procedures.

Service Management Layer

At this layer, one or more functionalities provided by individual objects are combined and offered as services. A service catalogue or repository is maintained at this layer in order to list objects and services provided by them.

Service Composition Layer

At this layer, only visible resources are services not objects. Multiple unit services can be combined into complex services and workflows. Additionally, this layer keeps catalogue of services which are currently available.

Application Layer

At this layer, application utilise exposed services and workflows to perform context specific activities.

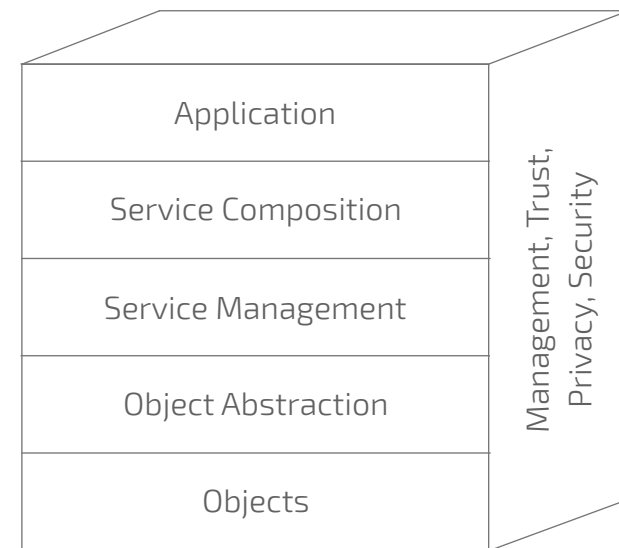


Figure: SOA-based architecture for the IoT middleware, [6]

Challenges

The challenges are divided into three broad categories i.e. technological, political and social challenges.

Technological Challenges

Technological challenges mainly include challenges related to standardisation, networking and security.

Standardisation Challenges

Many research communities have taken efforts in establishing standards for IoT. Some of these standards like EPC and IP are followed world-wide. However, there is no comprehensive framework which supports heterogeneous devices. Hence, there is need to design all-inclusive standardisation framework. An ideal standardisation framework should fulfil following needs:

- Scalable in terms of number of devices which can be connected and identified. [1]
- Supports interoperability. It means framework should enable devices implemented using heterogeneous communication technologies to work together. [1]

- Support simultaneous mobility of sensors and things [6].
- Support multiple device discovery algorithms [1]

Addressing and Networking Challenges

The prime challenge related to addressing and networking is inability of current protocols to handle IoT scenario [6]. Current protocols need to be redesigned in order to handle

- The huge amount of traffic that will be generated in IoT scenario
- Transport of high amount of data that will be generated in IoT scenario [9]
- Better Fault tolerance [9]
- Better Quality of Service support [6]

Challenges

Security Challenges

Security for IoT is a major challenge. In a heterogeneous scenario, it becomes difficult to decide roles of devices in terms of security as devices work at different levels of IoT architecture. Additionally, resource constrained IoT devices are not capable of implementing advanced security mechanisms.

Authentication Challenges

Currently existing security provisions use encryption algorithms to authenticate devices. In order to implement these algorithms, device needs high processing power. IoT devices are low energy devices with limited processing power. Device may not have enough processing capacity to run encryption and decryption algorithms to provide advanced security.

Data Integrity [6]

The passwords used by IoT devices to protect data are short in size (due to their limited processing ability). This poses a high security threat on the integrity of data transmitted by IoT devices.

Privacy Challenges [5, 6]

IoT devices capture lot of person's private information. There is chance that person is not aware about what information is being collected about him/her and how it is being used. Hence, the distribution of generated information needs to be controlled.

Digital Forgetting [6]

The information collected about person should be deleted after it is used. Retaining information without reason and consent is not ethical.

Challenges

Political Challenges

The management and use of data generated by IoT devices raises many political concerns. Some of these concerns are:

- There still exists lot of confusion regarding the ownership of data generated by IoT. Data of substantial commercial or social value can be used without owner's consent.
- IoT will also generate lot of public data, then it becomes a concern who is entitled to use such data and for what purpose.
- It is still not clear that who will govern IoT systems. What is the role of government in controlling unethical use of IoT.

Hence, there is need of a strong and effective ethical and legal framework to handle such issues.

Social Challenges

It is certain that IoT will facilitate our lives and will make it more comfortable. However, this is only one side of coin. The other side includes the negative impacts or side-effects of IoT on our lives.

With so many smart devices around us, the real freedom and privacy that we will have in the future is questionable. IoT things may not operate as we would desire. They will choose what is best for us by analysing our behavioural patterns. In this regard, interaction designers has a big role to play. They need identify the boundary for IoT systems to limit their interference in our social lives.

Review of Existing Products

We choose 36 products to review from wide range of available products. Products were chosen based on their popularity and variety in terms of application areas and strategies.

The review of products was done in two parts. First part includes critical analysis of product's functionalities, interaction design strategies and user interface against Indian context. Findings from first part gave us overall insights about conflicting assumption. Second part of review included mapping of products onto SOA architecture. The second part of review brought out insights related to architectural trends and need gaps.

List of Reviewed Products:

Tennis Racquet	Nike+ FuelBand SE
Sense	Nest
Smart Car	Lab of Things
Dog collar	Wulian Smart Home Wire-
Toothbrush	less LED Dimmer
Baby Onesie	IoT Monitor
Beddit	Cooey
Oven	Spark Core
LG HomeChat system	IOT Series
Mobiplug	Netatmo June
ALLJoyn	Misfit Shine Activity Tracker
SmartThings	The Health Patch
Electric Imp	Sensoria
FitBit	Smart wear
EVERYTHNG	Philips Hue
Belkin Wemo	
Securifi Almond+	
IFTTT	
MagicCast	
Freescale	
Broadcom's WICED™ Sense Kit	
UP	

Review of Existing Products

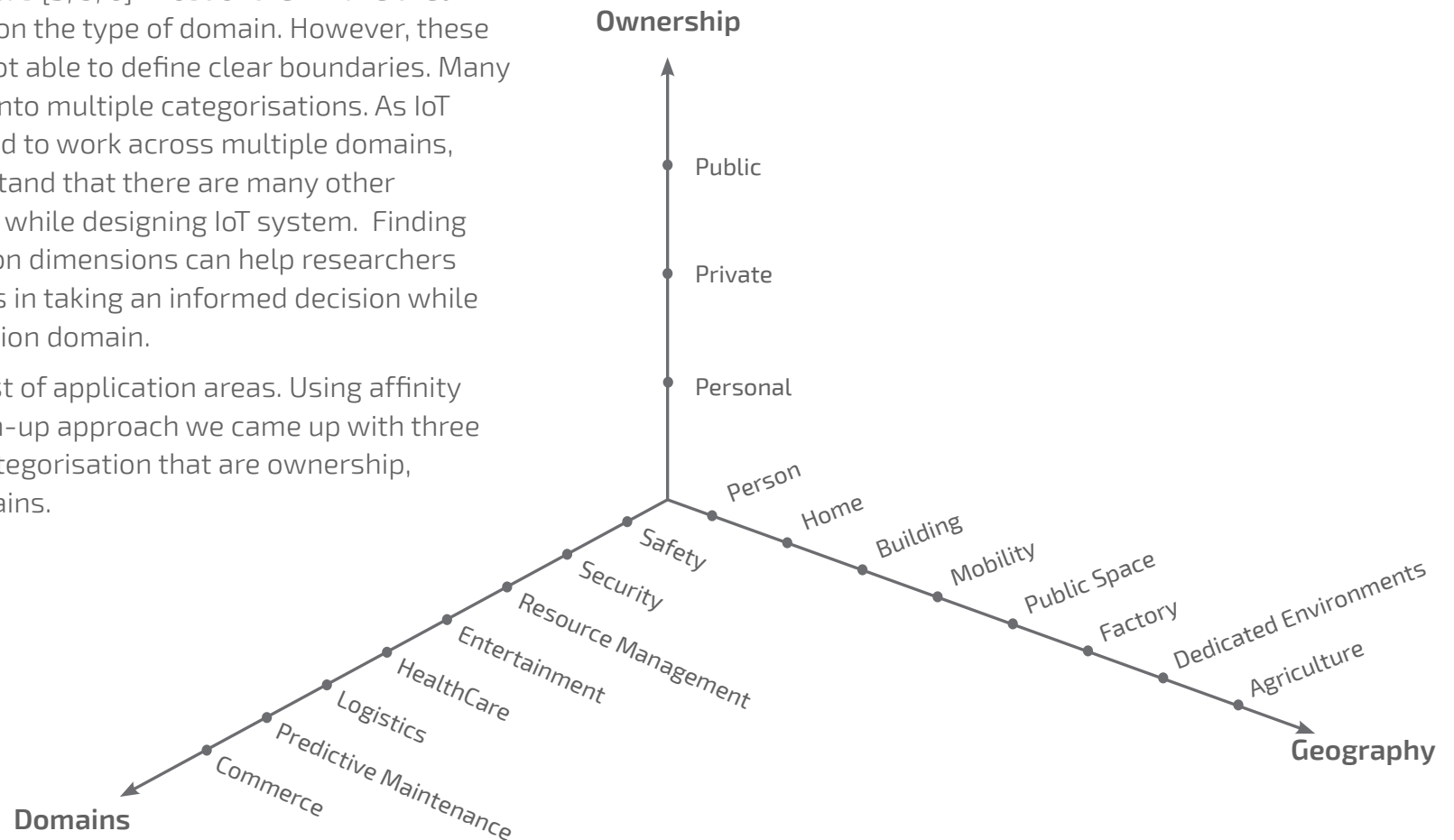
Conflicting Assumptions

- Most of the products are personal products and assume that it will only be used by same user. However, in home or personal use scenario, where sharing is inherent part of tradition, sharing of IoT products in multi-user scenario need to be addressed.
- Most of the products showcase the analysis of data using different types of graphs. However, it is uncertain in India whether users, who are less educated, will be able to understand them and draw some meaningful insights.
- Almost all products assume, there is availability of smartphones, wi-fi router and high speed internet which may not valid in India. While designing IoT products for India, it is necessary to consider resource-constrained environments.
- In India, people are more concerned about the return value while investing into anything. Many products are very costly and address problems which one may not find important. Hence, it is uncertain that people will buy products whose return gains are not significant.
- It is wrong to assume that people will buy new IoT products to replace existing products. For India, to create low-cost products, one strategy could be to create add on products which convert existing products into IoT products.

Categorisation of Application Domains

In the field of Internet of Things, researchers have mentioned many application areas [3, 5, 6]. Most of them have tried to categorise based on the type of domain. However, these categorisation are not able to define clear boundaries. Many IoT applications fall into multiple categorisations. As IoT systems are expected to work across multiple domains, one needs to understand that there are many other dimensions involved while designing IoT system. Finding generic categorisation dimensions can help researchers and products makers in taking an informed decision while choosing an application domain.

We tried to gather list of application areas. Using affinity mapping and bottom-up approach we came up with three dimensions of IoT categorisation that are ownership, geography and domains.



Categorisation of Application Domains

Proposed Dimensions

Ownership

In ownership dimension, we define three levels that are personal, private and public. As its name suggests, products under personal dimension will be owned by a single individual. He/ she might not like to share with anyone. Products under private categorisation are owned by group of people. Applications designed for home or private organization will be considered under this level. Products under personal and private level need to provide means of identification as well as authentication. Products at public level are accessible by everyone. Generally, such products will be government owned e.g. IoT applications in city bus. Products at private and public level have to consider multi-user scenario while designing.

Geography

This dimension deals with scope of IoT products in terms of geographical area. Levels in this dimension start from a person level, home level till the city level. These geographical levels actually represent the nested threshold spaces for human. Our concerns and perspectives in different thresholds are different. To illustrate, we praise our city while debating with a person from other city. However, both of us will praise our state while debating against person from another state. Various IoT applications are designed to cater different geographies or in other words different threshold spaces.

Domains

These are different application specific contexts like healthcare, security and entertainment. To illustrate, a healthcare application can be designed for different ownership and geographical dimensions. To illustrate, a healthcare IoT application with private ownership in a factory has to be designed differently than a healthcare IoT application for family (private) inside home.

Categorisation of Application Domains

Table: Categorisation of Various Application Areas in geographical and domain dimension

	Person	Home	Building	Mobility	Public Space	Office/Business	Factory	Dedicated Environ- ment	Agriculture
Safety	Disaster Management	- Disaster Management - Environmental Monitoring	- Disaster Management - Environmental Monitoring	- Disaster Management - Environmental Monitoring	- Disaster Management - Environmental Monitoring	- Disaster Management - Environmental Monitoring - Employee Safety	- Disaster Management - Environmental Monitoring - Employee Safety	- Disaster Management - Environmental Monitoring - Surveillance	- Disaster Management - Environmental Monitoring - Surveillance
Security	Losses and Thefts	- Surveillance - Losses and Thefts - Perimeter access control	- Surveillance - Losses and Thefts - Perimeter access control	- Surveillance - Losses and Thefts - Perimeter access control	- Surveillance - Losses and Thefts - Perimeter access control	- Surveillance - Losses and Thefts - Perimeter access control	- Surveillance - Losses and Thefts - Perimeter access control	- Surveillance - Hospital Patient Surveillance - Losses and Thefts - Perimeter access control	- Surveillance - Losses and Thefts - Perimeter access control
Resource Management	- Personal Trends - Historial Queries - Search Engine for Things	- Light & Temperature Control - Resedential E-Meters - Enhanced Game Room - Augmented Maps - Search Engine for Things	Light & Temperature Control	- Light & Temperature Control - Smart Parking - Traffic Control - Assisted Driving - Robot Taxi	- Light & Temperature Control - Smart roads - Noise urban Maps - Electromagnetic Field levels - Waste Management - Smart Steet Lights - Potable water monitoring - Air Pollution - Earth Quake early detection - Chemical leakage detection in rivers - Meterological Applications - City Information Model - Augmented Maps - Search Engine for Things	- Light & Temperature Control - Smart Marketing - Flow Optimization - Real Time Inventory - Asset Tracking - Search Engine for Things	- Light & Temperature Control - Tank level monitoring - Silos stock calculation - Industrial Control - Augmented Maps - Search Engine for Things	- Light & Temperature Control - Smart Museum - Search Engine for Things	- Light & Temperature Control - Wine Quality Control - Green Houses - Meterological Applications - Smart Compost
Entertainment	- Infotainment - Social Applications	Infotainment	Infotainment	Infotainment	Infotainment	Infotainment	Infotainment	Infotainment	
HealthCare	- Drug Tracking - Elderly Fall Detection	Ambient Assisted living						- Ambient Assisted living - Hospital Medical Fridges	
Logistics				- Fleet monitoring - Item Monitoring - Ambulance Telemetry - Drug Tracking		Supply Chain Control	- Supply Chain Control - Smart Product Management	Hospital Asset Tracking	Supply Chain Control
Predictive Maintenance		Repairing & Maintenance	Repairing & MaintenanceW		- Repairing & Maintenance - Meterological Applications	Repairing & Maintenance	Repairing & Maintenance	Repairing & Maintenance	
E-Commerce	Payments			Mobile Ticketing	Payments	- Payments - Intelligent Shopping Applications		- Payments - Intelligent Shopping Applications	

Scope

Application Domain

After studying existing application domains through different dimensions, we decided to work on the Home related application for private ownership. We chose to work on IoT solutions for targeting private ownership in order to get insights about the multi-user scenario. The exact application domain was not fixed so as to consider wide variety of problems existing in home environment. Later, it also helped us in understanding users' priorities for different domains.

Target Users

For considering problems and needs, we chose bachelor users and users, living with their family, as our target users.

For bachelor users living together, there is no hierarchy and difference in the role played inside home. On the other hand, for a family, there exists a hierarchy and different roles in terms of responsibilities. Moreover, generally bachelor users are generally reluctant towards taking care of home while family users are concerned about their home. By targeting these two user groups, gave us insights about two different kinds of multi-user scenarios and IoT products will work in such context.

User Studies

User Studies Plan

User Studies Summary

User Studies Plan

Goals of User Study

Evaluation of Generated Ideas

Qualitative

- To understand contextual concerns about the interactions involved in the generated ideas
- To find out the reasons / factors based on which users desire and order ideas relative to each other

Quantitative

- To find most desirable ideas
- To rank ideas in multiple ways based on different factors

Co-Creation Session

- To explore opportunity areas other than generated ideas
- To understand ownership and responsibility dynamics in multi-user context

User Studies Plan

User Studies will be conducted in two ways:

Type 1

- Short Interview, in which users will be only asked to evaluate, rank ideas.
- Expected number of interviews: 4-5
- Each interview is expected last around 15-20 minutes.

Protocol

1. Initially, users were given brief about the project
2. Users were shown one idea at a time and they will be asked for their concerns.
3. **Card Sorting:** After showing all ideas, users were given cards of ideas. They were asked to order ideas in any 3 ways. Later, they were asked to explain criteria for each ordered list.
4. At the end, they were asked to rate each idea in terms of desirability.

User Studies Plan

Type 2

- Co-creation Sessions, in which users were not only be asked to evaluate ideas but also to generate new ideas based on their real problems.
- Each Co-creation Session was conducted with group of users. E.g. with all family members, all room-mates.
- Expected number of Sessions: 2-3 , around 3 users per session
- Each session lasted around 1 hour

Protocol

1. Initially, users were given brief about the project
2. Users were shown one idea at a time and they will be asked for their concerns.
3. **Love & Breakup Letter:** Each participant from the recruited group were asked to write a letter to product/ object they hate most. They were asked to express their feelings through this letter. Every user was asked to read out their letter to everyone. Finally, users were asked to agree to work on certain problems related to only single object / product.
4. **Use of IoT Toolkit to Ideate:** Using this toolkit, users were asked to discuss and envision an IoT product.
5. At the end, they were asked to rate each idea in terms of desirability.

User Studies Plan

What is IoT Toolkit?

IoT toolkit is a set of cards, which can help users to build IoT products and ecosystem. It will consist of following types of cards: Sensor, Service, Connectivity, Devices, Channel, User and Recipe cards. Each cards will consist representative pictures, basic information and fields to fill in.

Sensor Cards: info about majorly used sensors (like motion sensor, GPS, etc.)

Service cards: info about most common services IoT offers (e.g. detecting presence)

Connectivity Cards: Technology using which objects will connect to each other

Device Cards: Mobiles, Laptop, Desktop, Tablet, etc.

Channel Cards: Email, SMS, Mobile Application, Website, etc.

User Cards: It will contain fields to write down user related features and responsibilities

Recipe Cards (Inspired from IFTTT): It will help users to write triggers and actions.

Blank Cards: users can create their own cards

User Studies Summary

User studies involved interviewing 15 Users, which included 10 male and 5 female users. In total, 4 card-sorting sessions, 1 co-creation session and 3 short interviews were conducted.

Session No.	Age	Gender	Education	Occupation	Living In	Marital Status
1	25	M	M.Tech (Mech)	Student	Hostel - Single Room	Unmarried
	25	M	M.Tech (Mech)	Student	Hostel - Single Room	Unmarried
2	28	M	M.B.A.	Bank Manager	Rented Flat	Unmarried
	26	M	B.E.	Software Engineer	Rented Flat	Unmarried
	25	M	B.E.	Software Engineer	Rented Flat	Unmarried
	27	M	B.E.	Software Engineer	Rented Flat	Unmarried
3	23	M	M.Tech (Elex)	Student	Hostel - Shared Room	Unmarried
	23	M	M.Tech (Elex)	Student	Hostel - Shared Room	Unmarried
	23	M	M.Tech (Elex)	Student	Hostel - Shared Room	Unmarried
4	26	F	M.Des (Visual. Comm.)	Student	Hostel - Shared Room	Married
	24	F	M.Des (Visual. Comm.)	Student	Hostel - Shared Room	Engaged
	25	F	M.Des (Visual. Comm.)	Student	Hostel - Shared Room	Unmarried
5	32	F	C.A.	Business	Owned Flat	Married
6	57	M	M.Com	Service	Owned Flat	Married
7	29	F	C.S.	Service	Owned Flat	Married

Card Sorting



Ideation Session with IoT Toolkit



Love & Breakup Letter



User Feedback on Concepts



Concepts & User Feedback

Letter Box

Refrigerator

Mosquito Killing Machine

Kitchen Jars

Window

LPG Cylinder Regulator

Door Reminder System

Repairing of Things

Chat With Things

Letter-Box

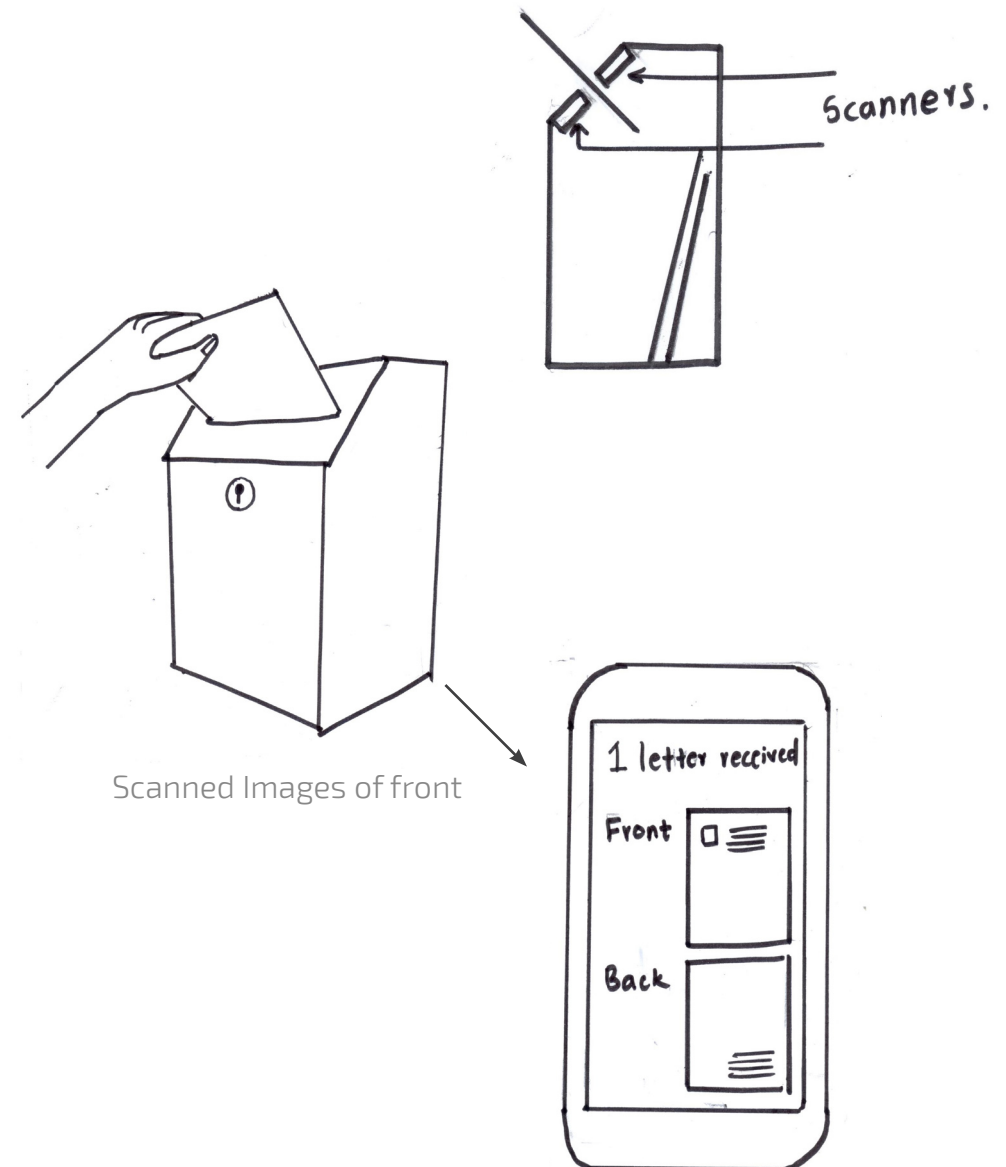
Problem

Due to reasons like "away from home" and forgetting, we may not be able to check received letters. Some important letters might require immediate attention.

Concept

Letterbox can be connected to internet and it can notify user on the arrival of letter.

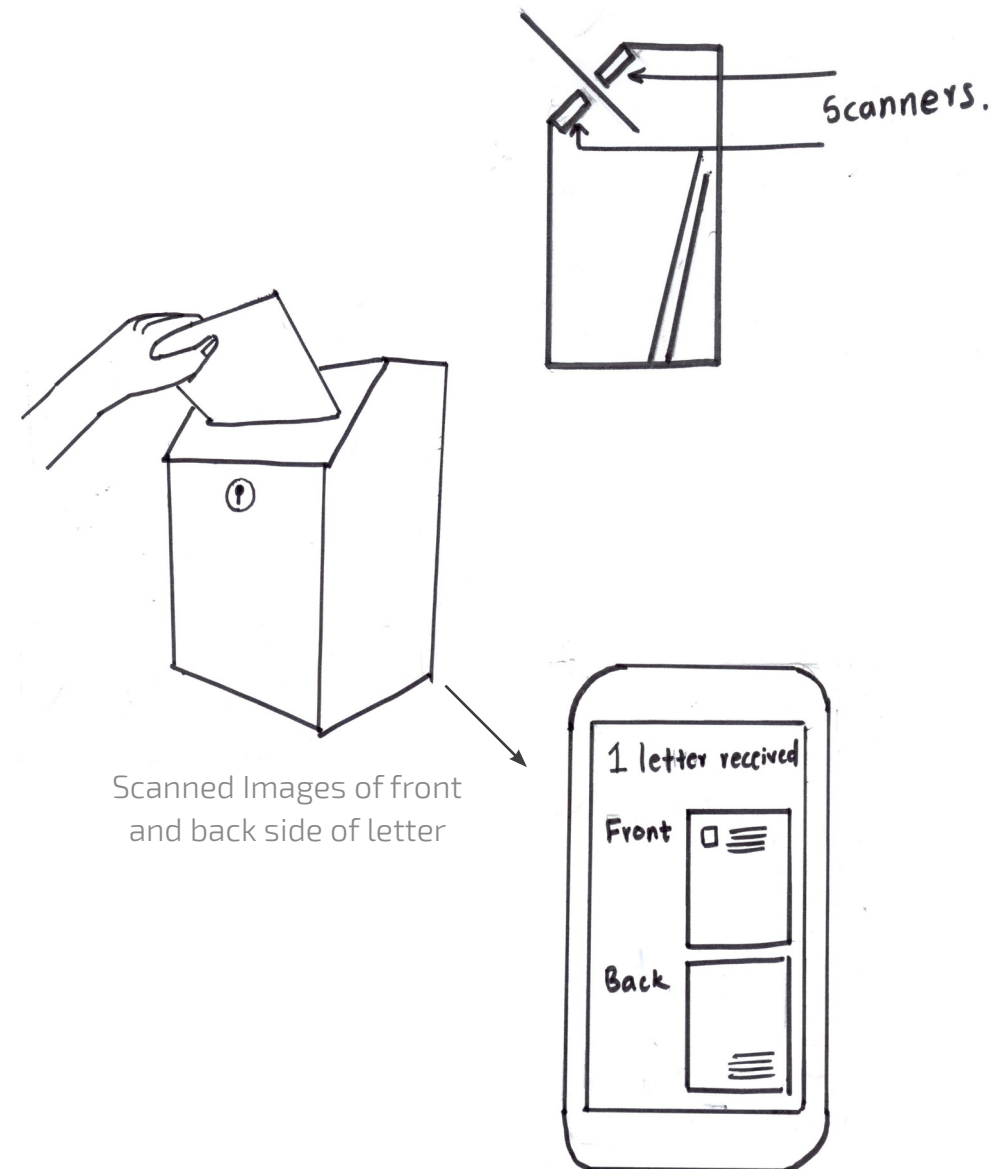
Scanners are placed inside the letterbox at the opening (where letters are put inside). They scan letter from both sides while dropping letter inside. Letterbox will notify user about the delivery of letter and send scanned images to user's smartphone.



Letter-Box

User Feedback

- Users expected letterbox to give notification based on their importance. Some users wanted letterbox not to give notification for promotional letters.
- Many societies visited in user studies had a combined letterbox for all members. Users raised their concerns that how letterbox will come to know receiver and consequently, to whom letterbox will notify.
- Users felt that scanners will not be able to detect letters in the middle if postman puts bunch of letters inside letterbox together.
- The use of physical letters for communication in home context has tremendously decreased due to introduction of new digital communication mediums like email and SMS. Hence, many users didn't feel necessity letterbox.



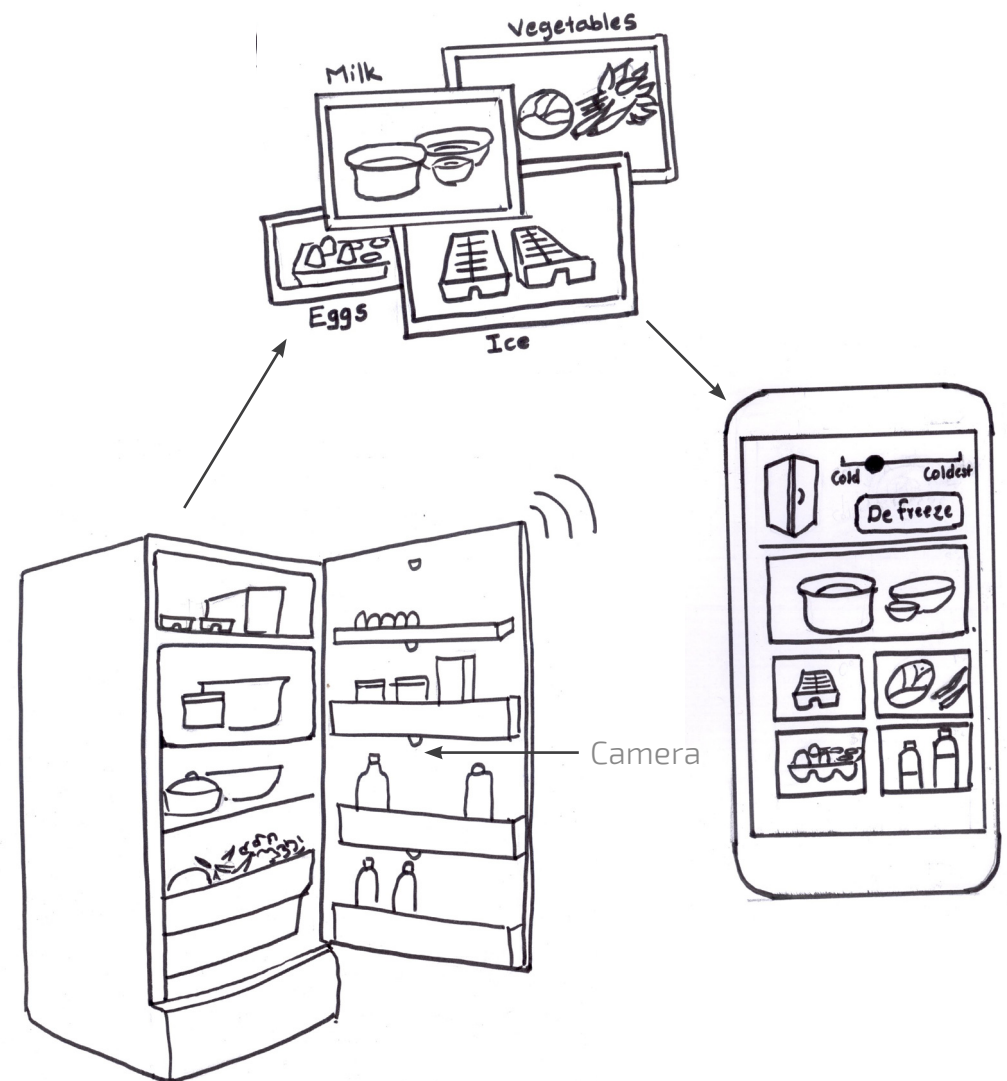
Refrigerator

Problem

When we are away from home and want to make arrangements for food, we may not know how much food is remaining at home. Hence, it becomes difficult to decide things to buy while shopping or ordering food from restaurant.

Concept

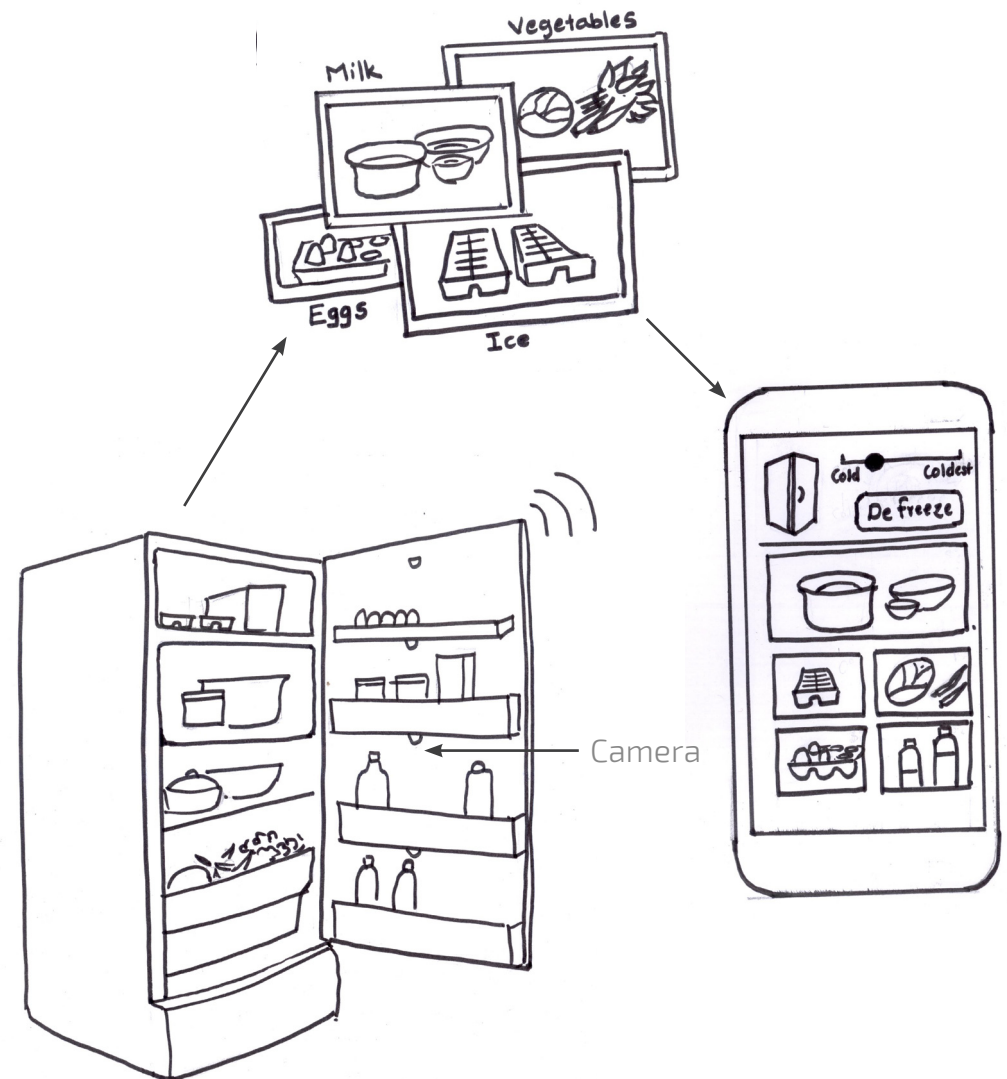
Refrigerator can have multiple cameras placed inside. Upon user's request, refrigerator can click photos of inside and send them to user. Additionally, other operations of refrigerator can be accessed from smartphone like changing temperature, de-freezing.



Refrigerator

User Feedback

- Unlike many other concepts, users liked the fact that the interaction with Refrigerator is initiated by Human.
- According to users, photographs will not be able to reveal how much food is remaining inside closed vessels. Moreover, users wanted to know about whether food is in still edible or spoiled, for how many days food is inside refrigerator and expiry date of packaged food items.
- Some users felt that refrigerator is very crowded place. There is high chance that camera will get blocked by some vessel or bottle.
- Many users felt that this functionality will be limited for food items inside refrigerator. The concept does not allow to track food items placed outside of refrigerator.



Mosquito Killing Machine

Problem

People forget to turn off mosquito killing machine. Some users keep it always on for getting away from the efforts of turning machine on and off daily.

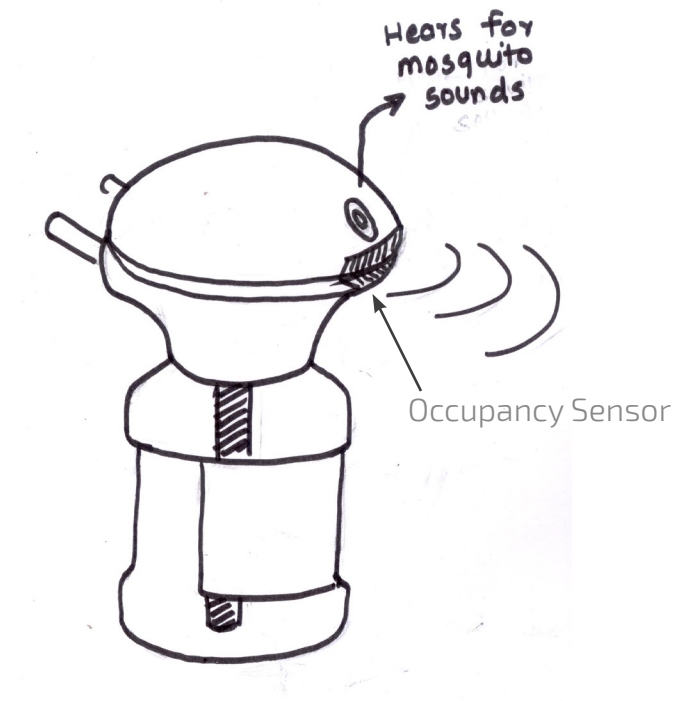
Concept

Mosquito Killing Machine can have people presence sensor or it can access same data from central people presence detection system. By leveraging people presence data, machine can know when to switch on/ off or when to turn on/ active mode.

Mosquito killing machine has a dedicated sensor to detect the presence of mosquitos inside room. Presence of mosquitos can be detected using by the sound frequencies generated by mosquitos.

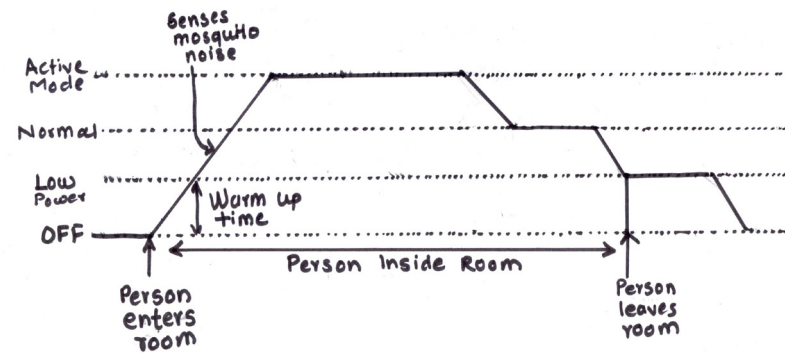
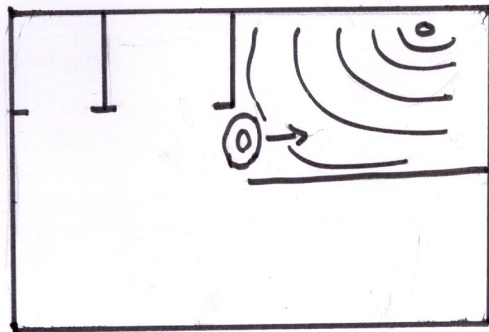
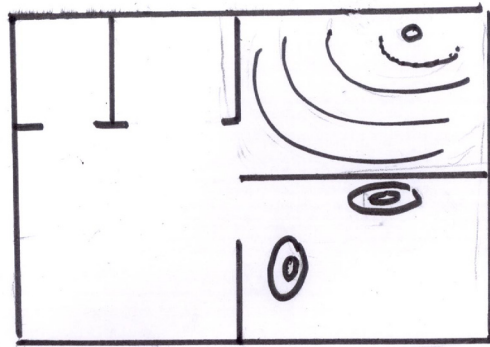
Mosquito Killing Machine uses both of its sensor strategically to achieve balance between its function and low power consumption.

Additionally, mosquito killing machine add refill pack to your shopping list it becomes empty.



Mosquito Killing Machine

Selects mode by sensing presence of people



Condition Map

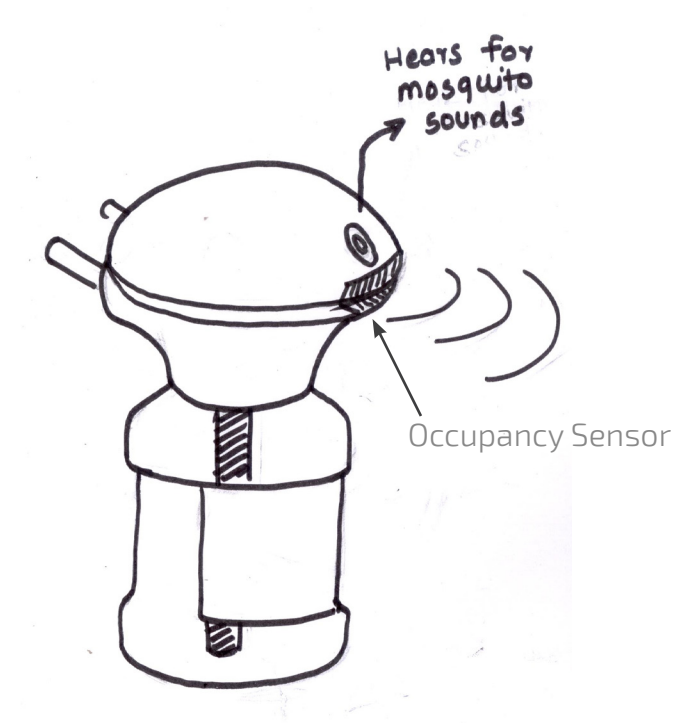


Adds Refill pack to shopping list after its empty

Mosquito Killing Machine

User Feedback

- Users didn't find use of people presence sensor necessary. Mosquito detecting sensor is enough. Even if no one is at home, mosquito killing machine should turn on if it detects mosquito presence.
- Very few users felt that the people presence system can be hacked and illegitimate users will be able to access the location and presence of family members.
- One of common need expressed by users related to shopping is that items should be added to shopping list well in advance. System should be able to predict when stock is going to end by analysing usage patterns.



Kitchen Jars

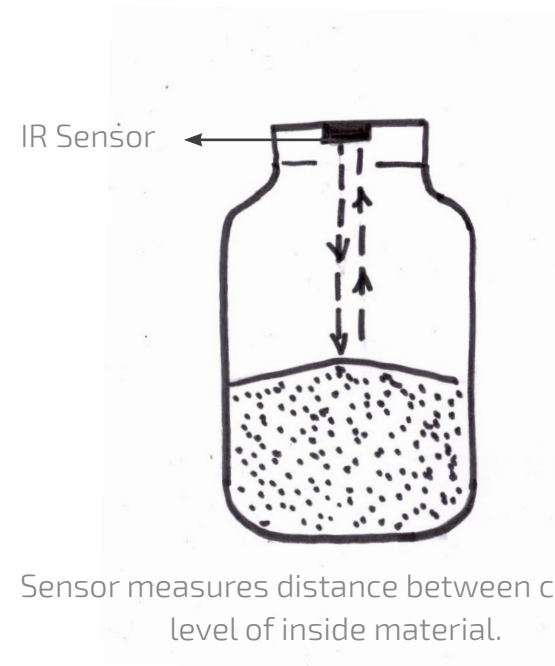
Problem

Many times whenever we go for shopping, we do not know about the remaining stock of food items in home. We end up buying some things extra or less.

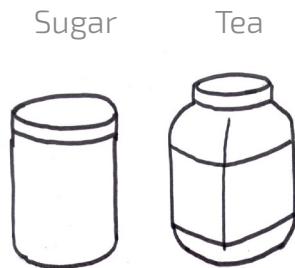
Concept

A distance measuring sensor (IR sensor) can be attached inside lid of jar. Initially, this sensor can be calibrated for full height of jar with empty jar. The material which user is going to put inside jar can be declared through smartphone application.

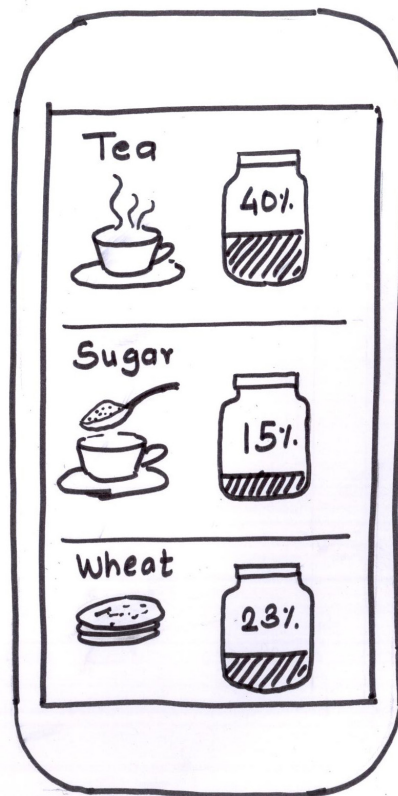
User can attach such sensors inside any jars as per his/her wish. The sensor data is transmitted to mobile phone through Bluetooth or Wi-Fi. User can see the remaining amount of food items while shopping and can take informed decisions.



Kitchen Jars



Sensors inside different bottles can be associated



User Feedback

- Some women strongly stated that they remember about all things in kitchen. Hence, they know which things to buy while shopping. Their knowledge about kitchen represents their control and ownership on the kitchen. Hence, they don't want to get dependent on machine.
- Almost all users asked to represent the remaining amount in kg/gram or in number of days material can last.
- In Indian scenario, the lids of jars might get exchanged or user can decide to put another material in the jar. In all such cases, user is required to manually change the association of jar with new material in IoT system. Users showed reluctance to do such tasks if it needs to be done very frequently.
- Kitchen jar should be able to measure all types of materials including materials like ghee who do not settle down at one level.
- One of the factor affecting perceived usefulness is frequency of usage. Users living with their families stated that they generally go for shopping one a month. Hence, they don't need to know about remaining stock of items in kitchen frequently. Hence, they didn't feel it as useful.

Window

Problem

Window serves many functions in maintaining inside home environment fresh and healthy. We keep window open or close to control the ventilation, light and noise of inside environment. However, as humans we have limitations. We cannot tell by simply looking at air that how much polluted it is. Similarly, we cannot state whether sunlight contains UV rays or not. Hence, there is still scope of improvement in taking more informed decisions about operations of window.

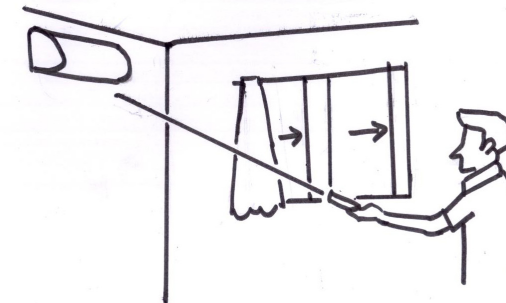
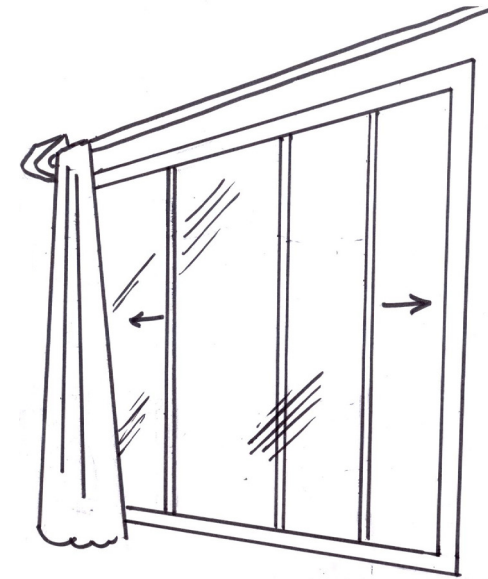
Additionally, function of window is dependent on other devices like A.C. People forget to close window when air conditioning system is turned on.

Concept

Window can have sensors to measure data of inside and outside home environment about noise, humidity, dust, temperature, light and oxygen content. Window will try to maintain the internal home environment as per health standard defined in terms of these parameters.

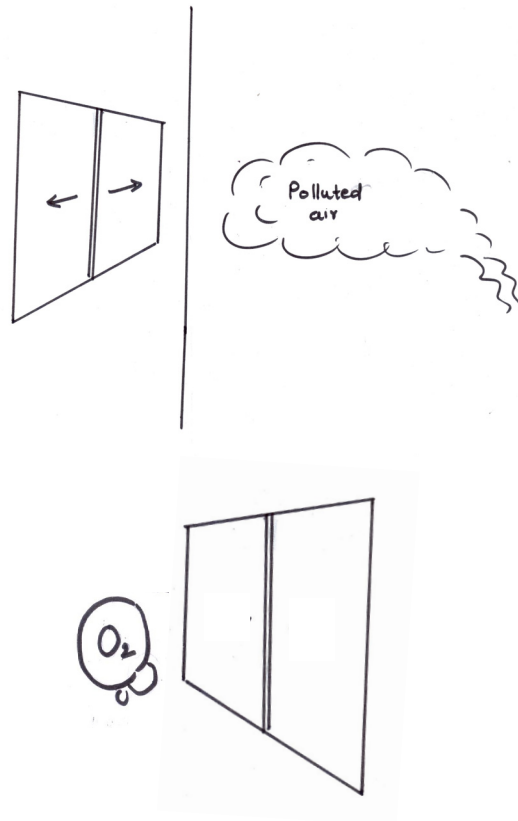
Additionally, window can also detect robbery if someone tries to open window door from outside.

Opening or closing of window and curtains can be triggered by other devices like A.C. through IoT intranet.

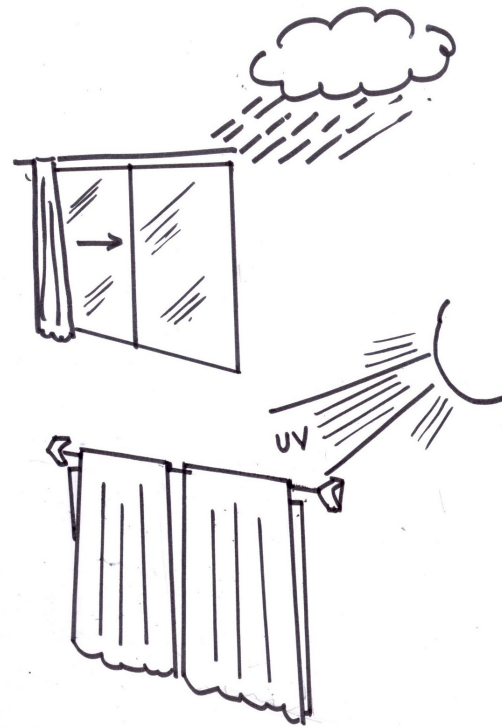


After turning on AC, window is automatically closed

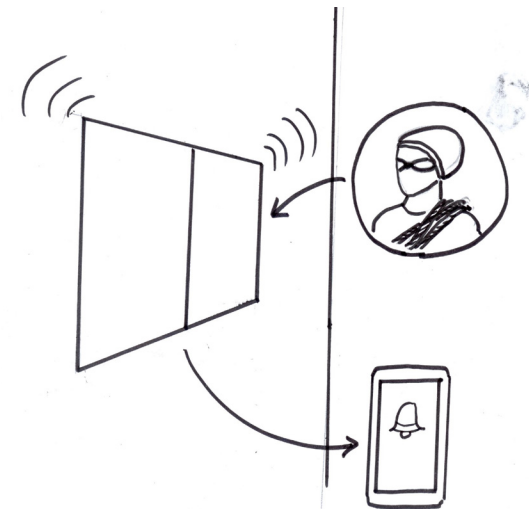
Window



Depending upon quality of air, window can inform user when to keep it open/close



Window can adjust itself depending upon weather conditions

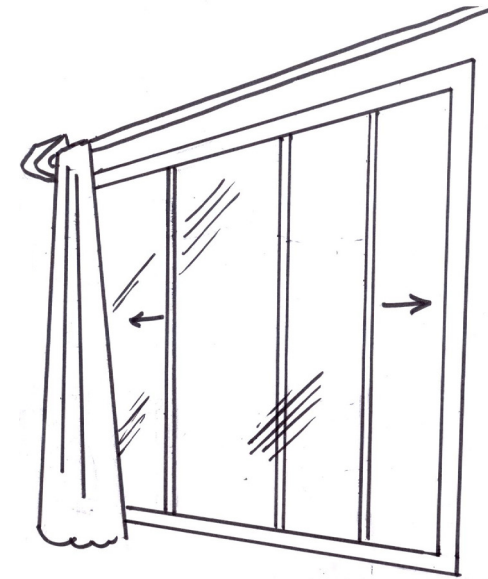


Window can alarm user in case of burglary attempt

Window

User Feedback

- Users felt that window should have automatic as well as manual mode. Even on putting window in manual mode, it should keep giving alerts and suggestions on whether to keep window open or closed.
- People asked that what will happen if inputs from different sensors trigger conflicting actions on window. To illustrate, if light sensor detect very low light and triggers window to open. At the same time, air quality sensor detects there is high pollution and triggers window to close.



LPG Cylinder Regulator

Problem

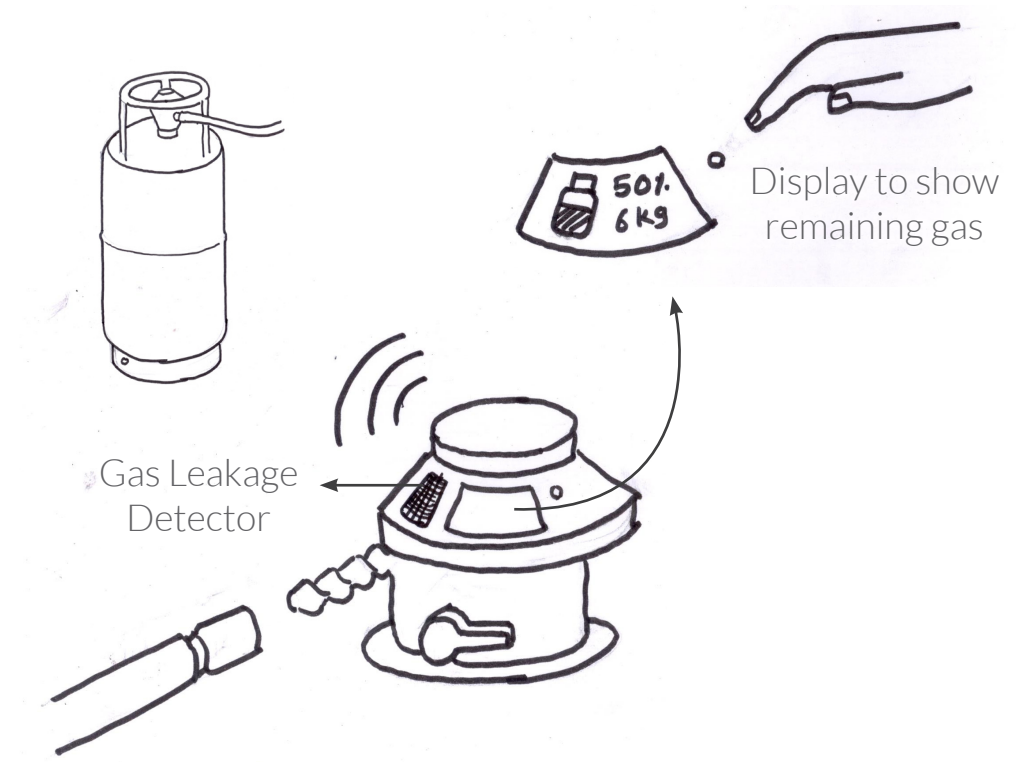
Forgetting to turn off LPG gas stove or pipe leakage can lead to fatal accidents.

Concept

A new LPG cylinder regulator can be designed which has inbuilt sensor to measure gas usage. Gas usage sensor can be used to detect flow LGP gas as well as to find usage patterns of user.

Regulator can have a gas leakage sensor on placed on its body. If gas leakage is detected when no one is present at home (through people presence system), then it can be notified to user through mobile application. User can turn off regulator valve through mobile application. However, functionality of turning regulator valve on is not provided through mobile application. It has to be turned on manually using physical knob.

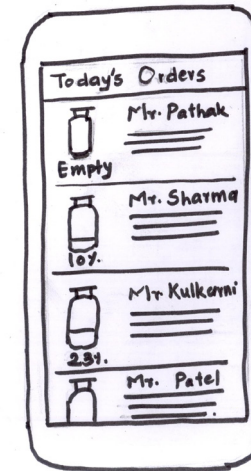
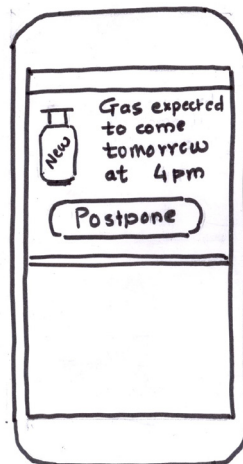
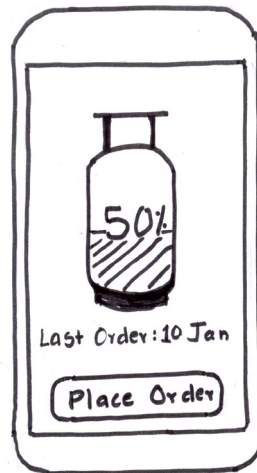
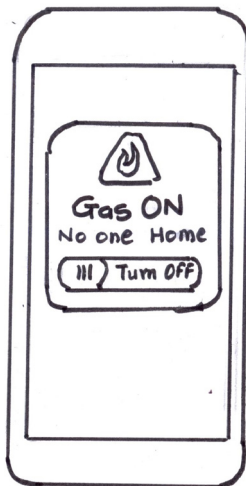
The data collected by regulator can be sent to gas distributing agency. The gas distributing agency can take informed decisions based on this data regarding delivery system. One of such application is gas delivery man can decide to whom to deliver cylinder first based on their emergency and amount of remaining gas.



LPG Cylinder Regulator



Triggered when no one is present inside house



Deliver worker can decide delivery priorities by knowing remaining gas percentage of consumers

LPG Cylinder Regulator

User Feedback

- Generally, people keep gas cylinder under kitchen counter. In order to detect gas leakage as soon as possible, it should be placed near to stove and pipe. Hence, placing it on regulator may not be good idea.
- Users raised lot of concerns related to the logic based on which gas distributor will distribute LPG cylinders. Users stated that their daily usage of LPG should be considered.
- Some users did not agree to use IoT regulator for deciding LPG cylinder delivery priority. They asserted that whoever applies first should get delivery first. In that case, the data from IoT regulator should be used to predicting quantity of LPG cylinders required for an area or region.

Door Reminder System

Problem

We forget many things like car keys, wallet and office files while leaving in hurry. We remember about forgotten things when we are away from home. It also includes important events like open tap, LPG gas on/off, window open/closed and electric iron on/off.

Concept

Door is the threshold space from which we go outside or come inside of house. Hence, it is the best place to remind people about forgotten things and events before leaving house.

Door can have a RFID tag reader and things which you forget can be attached RFID stickers. Association of these stickers with physical objects can be saved in IoT system by user using a mobile application.

The purpose of going outside for person can be detected by the type of bag he/she is carrying along. Depending upon bag, it can also be detected which things to remind.



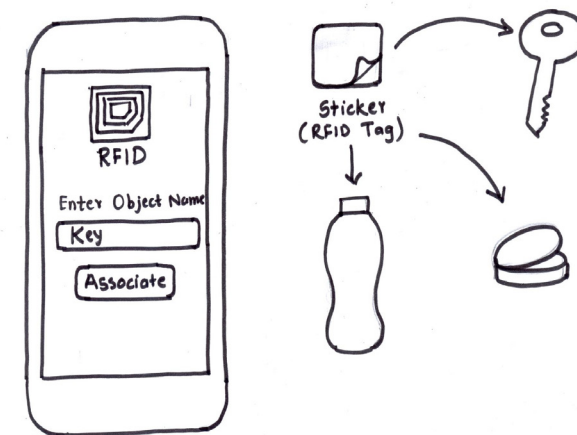
Door scan leaving person for present RFID tags

Door Reminder System

Bag can indicate the purpose of going out. Depending on purpose different things can be checked and reminded

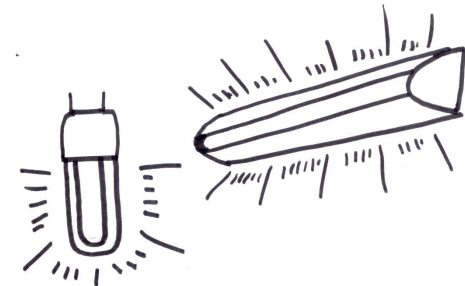
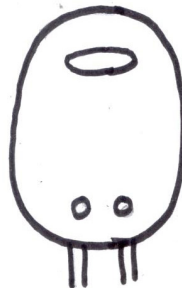
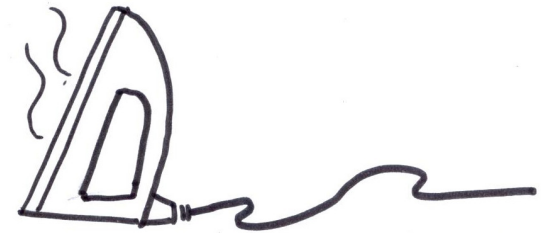
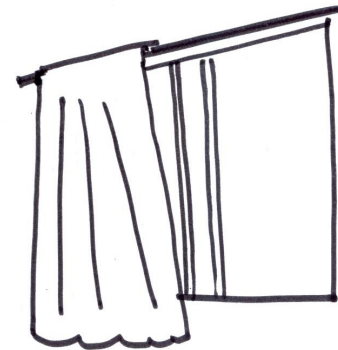
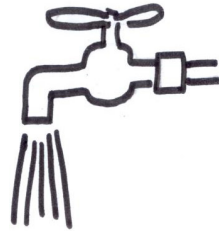


Associate things to RFID tags via smartphone



Door Reminder System

Reminder of different events
before leaving home



Door Reminder System

User Feedback

- User liked the idea of reminding about important events. However, almost all users felt it will result into giving too many notifications. In such case, door should prioritize and order notifications based on their criticality and importance.
- Users had doubts related to how door will know for which purpose they are going outside and which things should be reminded.
- In order to get reminder of events, users felt that they are required to buy IoT system for each type of event and which may be costly.

Repairing of Things

Problem

When things are damaged or need repairing, we need to find invoices and service receipts. It becomes difficult to find bills physically and virtually as many times we forget where we have kept them.

Concept

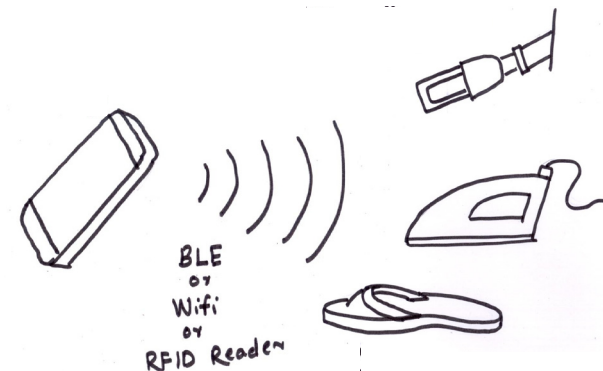
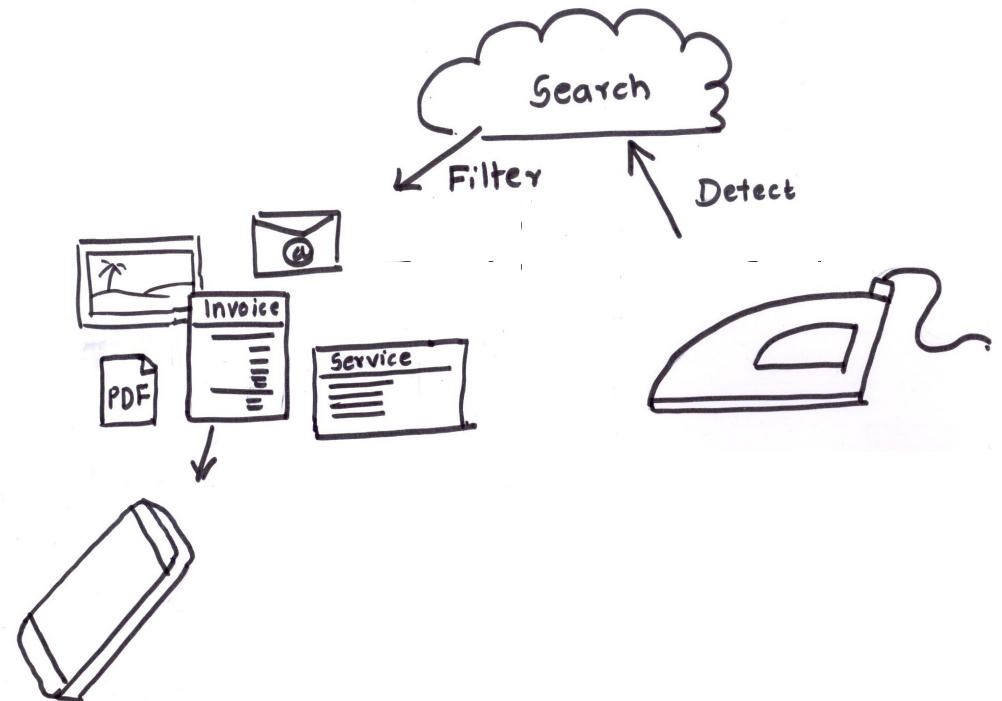
Bills and invoices related to a particular thing can be associated against its RFID. This associations will be saved on the cloud-based server. If received bill or invoice is in physical form, it can be photographed or scanned and can be uploaded on cloud to associate it with thing.

Hence, when required user only has to scan RFID of thing and all documents related to that RFID tag can be retrieved very easily.

Note: Things can have inbuilt RFID tags or externally attached RFID tags. Smartphone with in-built RFID reader can be used to detect these things.

User Feedback

Many users liked this idea of a new way searching that is using things. System should also give information about nearest dealer or service centre.



Chat with Things

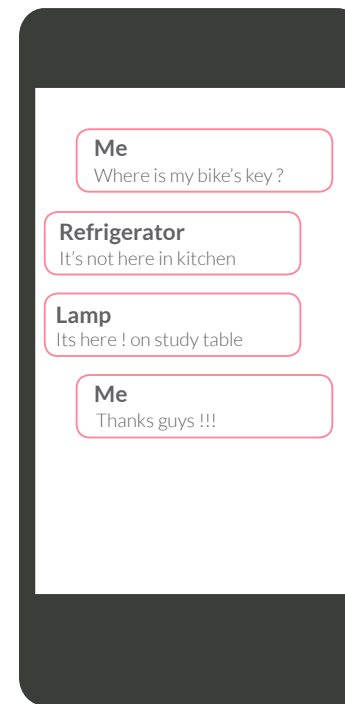
Concept

To make interaction with things more interesting and emotionally meaningful, we can give artificial intelligence to things so that they can have natural conversation with family members.

This concept achieves the same by giving ability to humans and things to have conversation through a standard chatting applications (like WhatsApp). In this application, things can answer to the questions posed by family members. Things can log their activities in the chat. Hence, chatting can also act as prime feedback medium in IoT scenario. Additionally, things can also be given tasks in natural language by human.

User Feedback

- Users felt that instead of giving voice to many things separately, they would like to interact with a single central entity.
- Some users did not like the idea of chatting with things because they felt that it will be fake and artificial interaction.



Text Chat



Voice Chat



Common Concerns

Dependency on machines

People expressed their concerns about high dependency on machines and their interference in daily life. People specifically raised such concerns for ideas like door reminder system and kitchen jars, where use of too many sensors was involved and for ideas which were less important in terms of safety.

Too many notifications

Proposed ideas were not alternatives to each other. All ideas can exist together. Hence, when all ideas were presented to users, users felt that in collection users will be pushed with lot of notifications.

As IoT systems altogether will generate many notifications for the user, it is necessary to order, chunk and prioritise notifications based on some criteria. Users suggested some criteria like safety, shopping, urgency and electricity saving.

Whom to notify?

To whom it will notify for shared objects e.g. a car key? In multi-user scenario, how IoT system decides whom to notify?

Some users stated that they can decide responsibilities of each family member beforehand. E.g. ask father to handle letter box alerts. For critical alerts, everyone should be notified e.g. robbery and gas leakage.

Common Concerns

Useful only in “No one home” Scenario

For many ideas like kitchen jar and refrigerator, users felt that they do not intend to use IoT products if someone is present in home. Ideas are useful when no one is present inside home.

Automatic as well as Manual Control

Users felt for all ideas, along with automated working, users should be able to override the system and take manual decisions.

Health issues related to Wireless Communication

Many users got worried about the health issues related to excessive use of wireless communication inside house.

Costly

Users thought that buying IoT system will be very costly

Data Storage

Very few users expressed their concerns about data storage. They were not clear about where the data will be saved.

Commonly Required Systems

People Status System

Things Status System

Semantic Manager

Access Control System

Dashboard and Control Panel

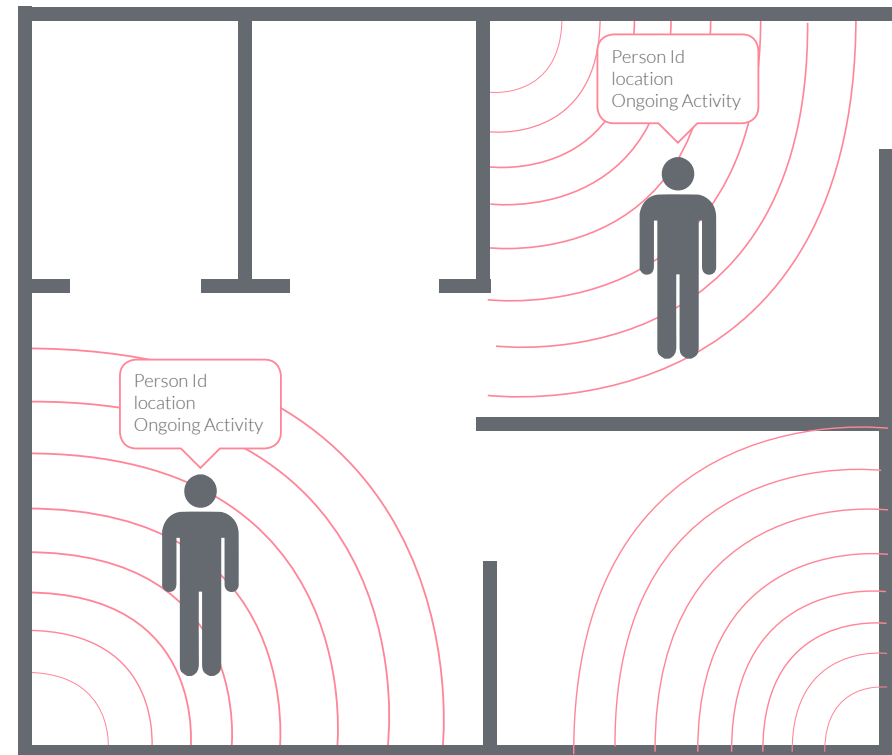
Centralised Notification Manager

Thing- Manufacturer Feedback Sharing

People Status System

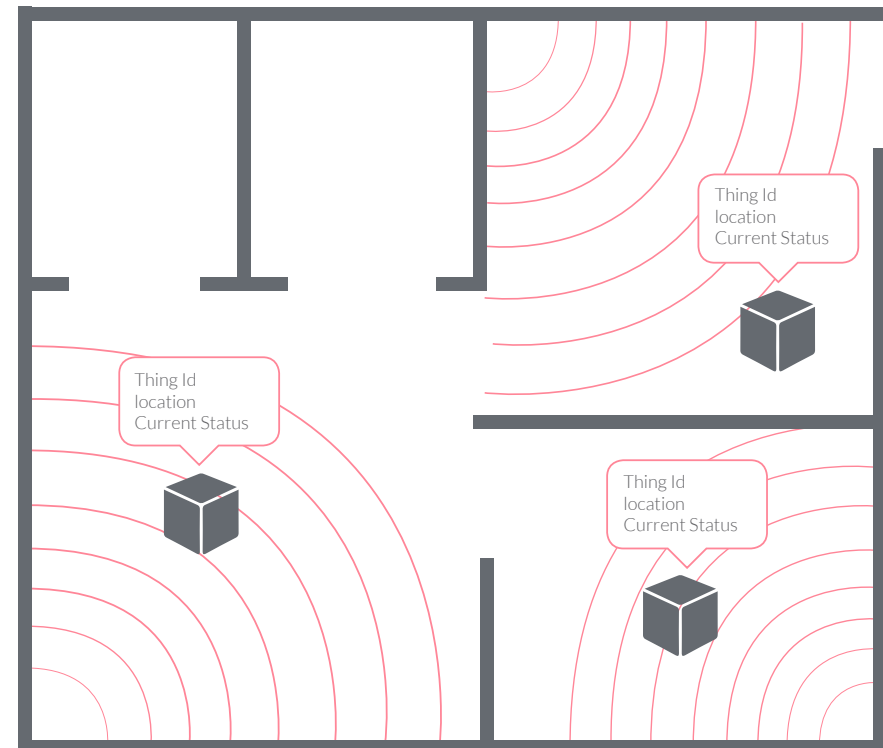
Basic people status system should detect the presence of people inside house and feed that data to other devices or to the central IoT system of home. Advanced people presence system should not only detect their presence but also detect identity of people. Using people detection data, devices can decide their actions in "no one home" scenario or they can personalize their actions to cater specific user.

People status system can be implemented in many ways. Cameras placed inside home can detect people presence as well as identities. Otherwise, motion sensors placed inside each room or RFID tags placed on people themselves can help in presence detection.



Things Status System

The location of things plays important role in IoT scenario. It can help in grouping things by their location. Things in same group can be assigned a common task to complete in collaboration. Location of non-electronic things can be determined by using RFID tag reader. Location of non-mobile electronic things can be located from the location of switch in which they are plugged in. Things status in Wi-Fi network can also help in detecting their course location.

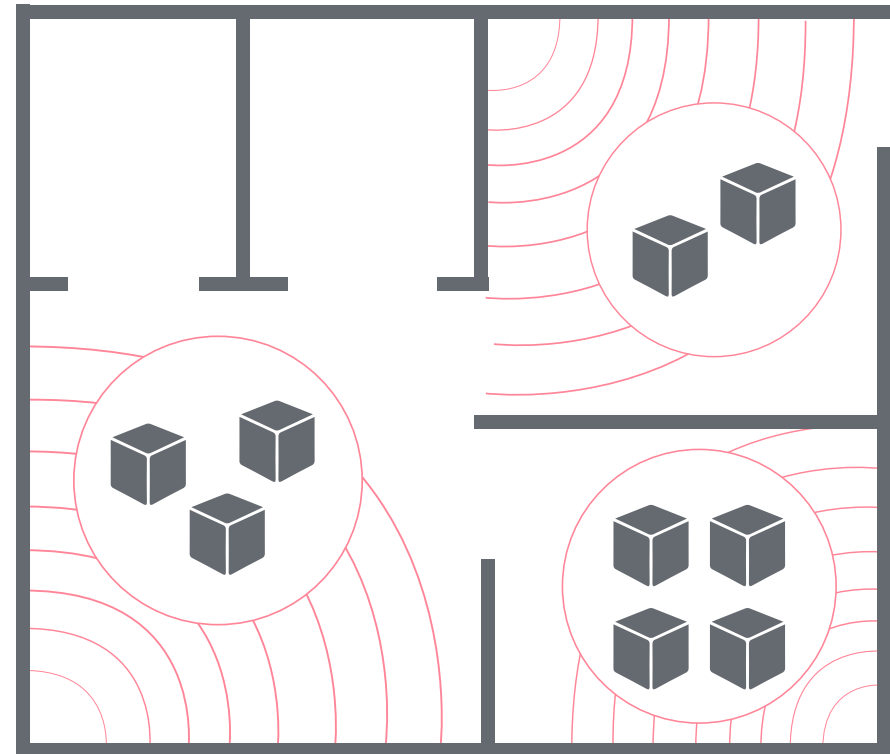
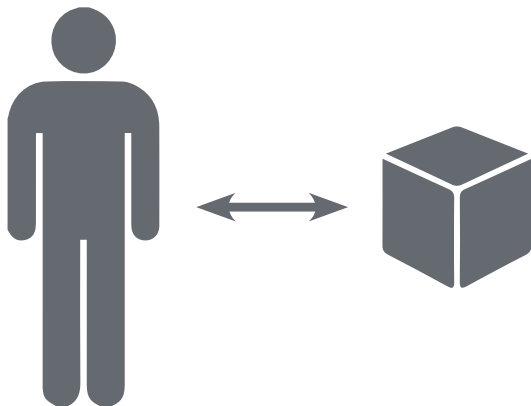


Semantics Manager

The primary function of semantics manager is to apply meaningful rules and context specific logic to the input data from IoT Things in order to trigger desired actions.

IFTTT is one of such generic application which helps users can write conditions for triggering an action in IoT enables thing.

Detect Activities based on People - Thing Interactions



Group things by their location

Access Control System

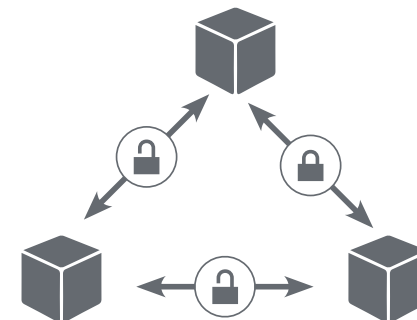
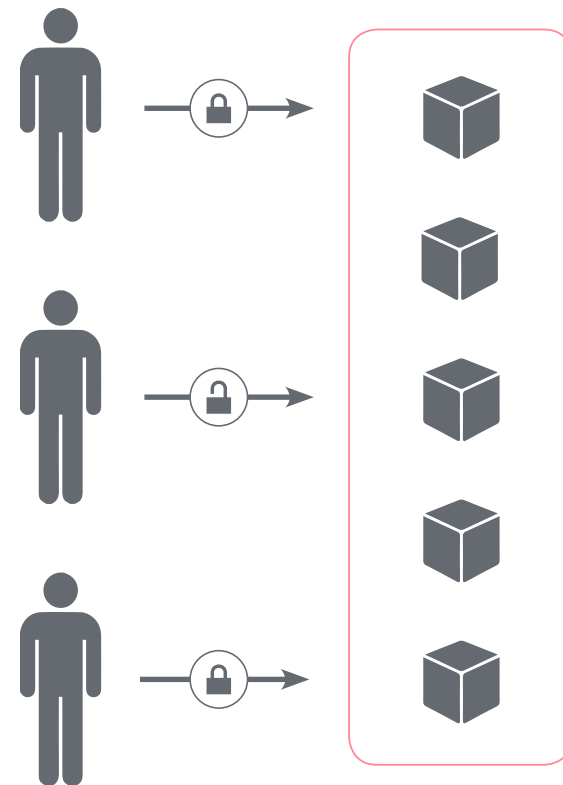
Access Control System works at backend to control the access of humans and things to each other based on their privileges. Its role in IoT scenario is very crucial as it control privacy and security issues. Currently, its scope is limited to controlling digital access of users. Access control system handles two types of communications:

Human – Thing Interaction

Access control system should allow only legitimate users to access things. To illustrate, in a family scenario, access control system can restrict children from accessing critical things like LPG stove, electric iron. Similarly, things in bedroom should not be accessible by guests.

Thing – Thing Interaction

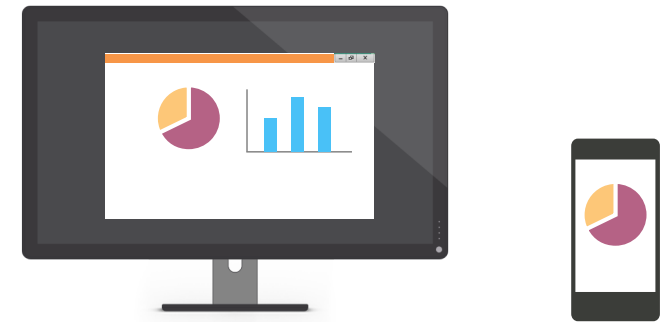
Besides handling human-thing interaction, access control system will also control the interaction between any two things or groups of things. There can be scenario where crucial things like health-care and safety related products cannot share their service or sensors with other things and hence cannot participate in doing tasks which they are not intended to do.



Dashboard and Control Panel

This is the primary interface for the user to get feedback and change the control settings of IoT devices or system. It can be offered in multiple ways like smartphone application, website or physical interface located on thing-itself.

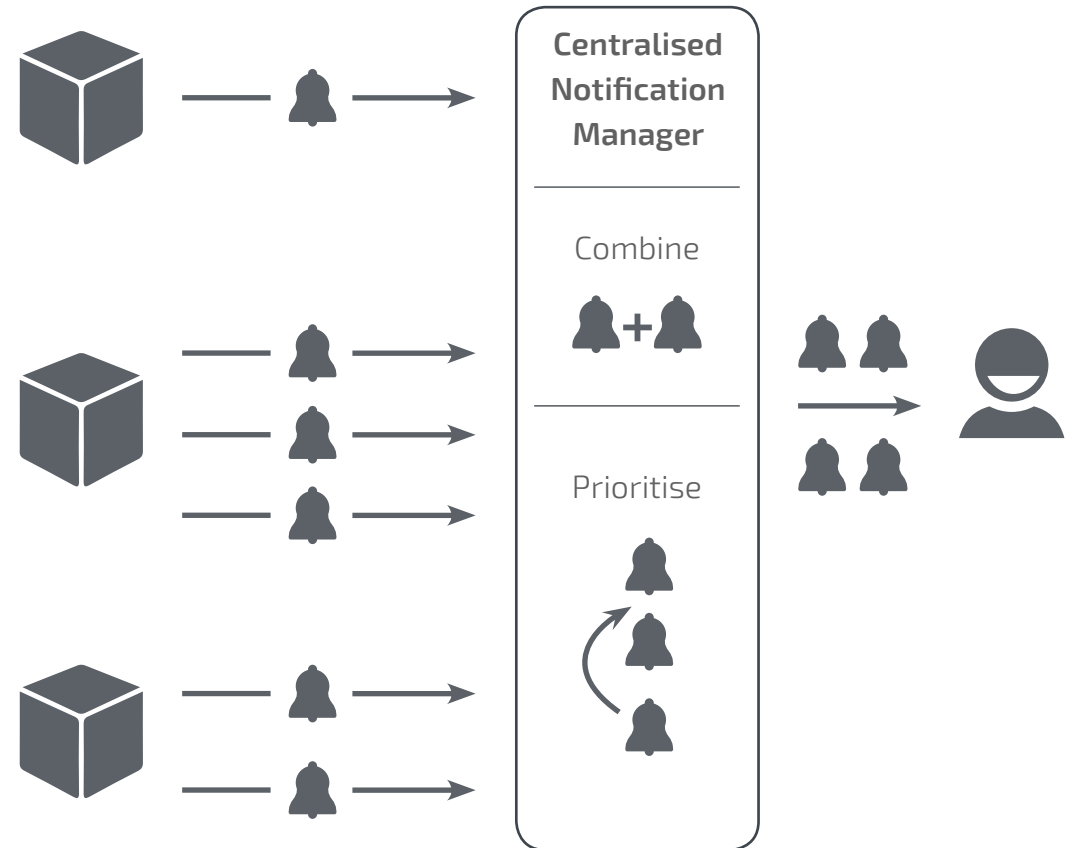
The major challenge for Dashboard and Control Panel design is to have a common interface which can control all IoT devices or to have multiple interfaces for controlling different devices.



Centralised Notification Manager

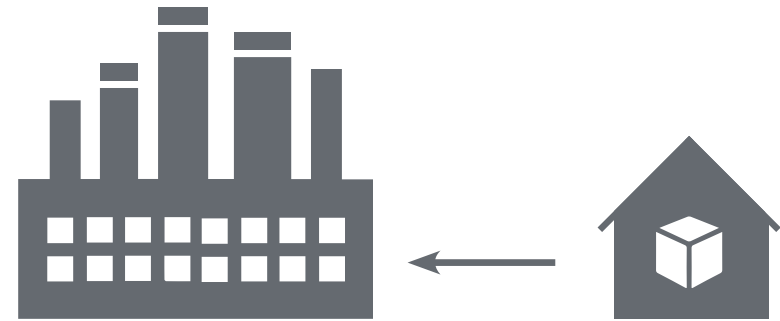
Centralised Notification Manager receives notification from different IoT enabled things. The major function is to prioritise, order, sort and chunk notifications based different criteria like involved risk, urgency, user's preference, chronological, type of alert, etc.

User should be able declare his/ her priorities in Centralised Notification Manager in order to customize it.



Thing- Manufacturer Feedback

Like softwares, with IoT enables physical things, it is now possible to share data related to failures, errors, and usage reports with manufacturer. Using this data, manufacturers can not only provide better customer care service but also improve product by utilizing user's usage patterns.



Other Findings

Findings from Card Sorting

Findings from Co-Creation Session

Comparison of Bachelor and Family Scenario

Desirability Ranking

Findings from Card- Sorting

As users were asked to do open card sort, they arranged cards into using criteria

- Safety
- Purchasing priority
- Needed right now – Not needed
- Automatic vs Manual

Following is the order in which users arranged cards.

Safety

1. LPG Cylinder Regulator
2. Window
3. Door Reminder System
4. Letter Box
5. Kitchen
6. Refrigerator
7. Repairing

Purchasing priority

1. LPG Cylinder Regulator
2. Window
3. Kitchen
4. Refrigerator
5. Door Reminder System
6. Letter Box
7. Repairing
8. Mosquito

Needed right now – Not needed

1. LPG Cylinder Regulator
2. Repairing of Things
3. Refrigerator
4. Kitchen Jars
5. Door Reminder System
6. Letter – box
7. Mosquito Killer Machine
8. Window
9. Chat with Things

Findings from Card- Sorting

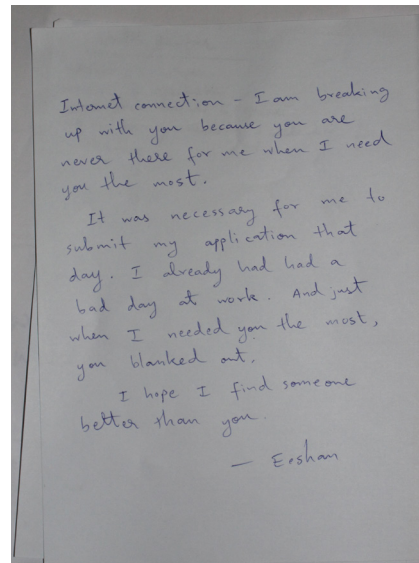
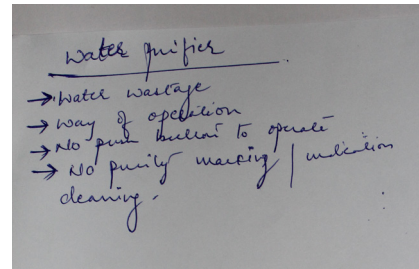
- From these categories we can notice the user's preference towards safety. Even while ordering concepts by "Purchasing Priority" criteria, implicitly they gave preference to safety related products.
- Criteria "Purchasing Priority" and "Needed right not to not needed" suggests user concern towards cost of implementing IoT systems in their houses.
- Even categorisation "Needed right now – not needed" shows that people are aware about the fact that they will not be able to buy all such systems. So users wanted to invest into products which can return significant value as compared to the amount they will invest in.
- Automatic and Manual categorisation also hints towards the inherent need of user's to feel control over IoT products.



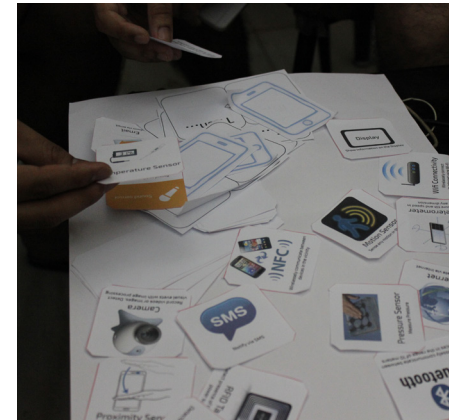
Findings from Co-creation Session

Within the limited tenure of project, we were able to conduct one co-creation session with bachelor users. The session was conducted with the use of IoT Toolkit. Each user was asked to write a love and break-up letter to a household object which he hates most. Users wrote letters to their laptop, internet connection and water purifier. Finally, users decided to design water purifier with IoT vision.

Love & Breakup Letter



Ideation



Findings from Co-creation Session

Following are the features of redesigned Water Purifier:

- Water purifier records everyone's daily water consumption. It also checks actual water consumption against user's water intake requirement as per his gym / exercise schedule. It then prompts user.
- It notifies user via a SMS if tap is leaking.
- It notifies user via SMS when filter tubes need replacement.
- Water purifier also has water cooler inside it.

It is important to notice that while designing Water Purifier, users tried to solve the problem which they were actually facing. Most of proposed solutions were related to improving the feedback which is currently not available. The timing and medium of giving feedback also matters as then it will result into action. Users wanted water purifier to participate in maintain their health i.e. keeping watch on daily water intake. We understand that there is need to conduct more such sessions with both target user groups in order to draw some conclusive insights.



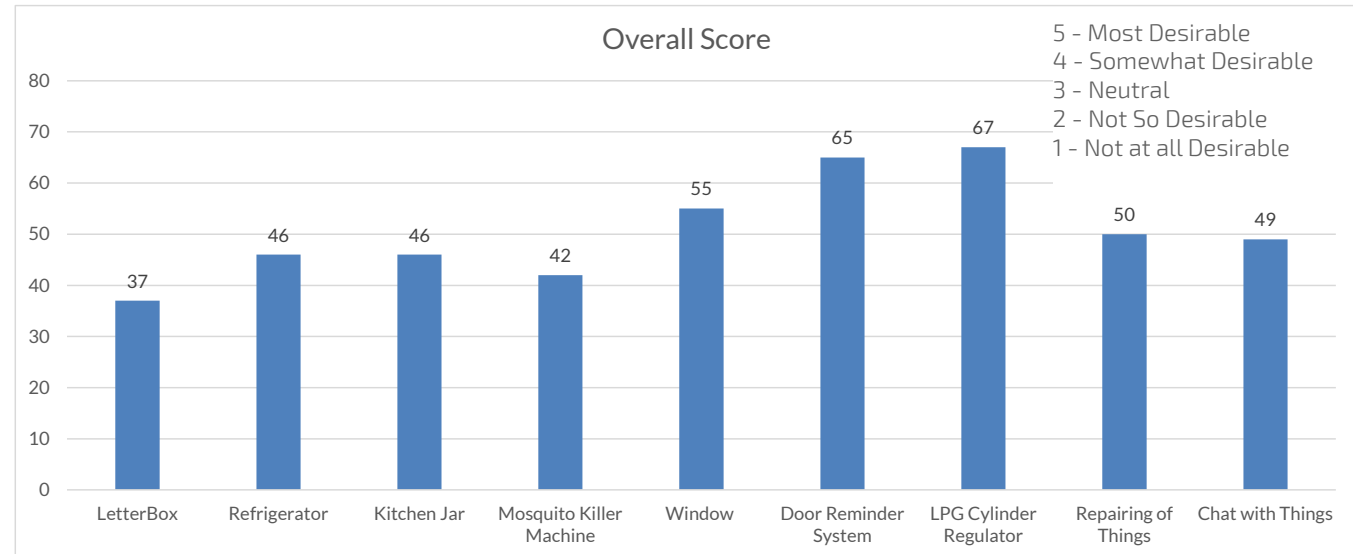
Comparison of Bachelor and Family Scenarios

- Both of type of users gave preference to safety related concepts. However, bachelor users liked concepts of refrigerator and kitchen jars, which were disliked by users living with their family. It could be because bachelor users find it difficult to share responsibility among each other. They want everyone to take equal responsibility. Due to this reason, they find shopping difficult to manage.
- Family users disliked shopping related concepts as they thought machines are interfering too much with their daily life. When asked, unlike bachelor users, family users preferred to distribute responsibilities among themselves. E.g. father would take the responsibility of checking letters, mother would take the responsibility of shopping.
- For concepts like kitchen jars and refrigerator, family users stated that there is no need of such concepts if some other family member is present inside home. However, in case of bachelor users, they found these ideas useful as such concepts can help them to take shopping decisions independently without disturbing their friends.
- In case of bachelor users, everyone expected to get equal privileges and access control. On the contrary, in case of family users, users insisted not bothering elderly and children users for critical responsibilities.
- It is important to note that in case of bachelor users, users wanted to take responsibility of their own things. For shared things like washing machine and refrigerator, they wanted everyone to share responsibility. On other hand, family users felt the collective ownership of all things. Hence, they were ready to full responsibility of managing things.

Desirability Ranking

Ranking

1. LPG Cylinder Regulator
2. Door Reminder System
3. Window
4. Repairing of Things
5. Chat with Things
6. Refrigerator
7. Kitchen Jar
8. Mosquito Killing Machine
9. Letter Box



From desirability rankings, we can see users' clear preference towards safety related concepts. Next set of top ranking concepts were highly desired because of their multi-purpose use. The Mosquito Killing Machine idea got low desirability rating because users didn't find worth investing in it. Both of these trends slightly hint users' preference towards concepts which provide significant value for money. The Letterbox idea got lowest desirability rating because non-use of physical letters in today's world.

Conclusion

It was surprising to notice that very few users raised concerns about their privacy and security. One of the reason behind this could be low fidelity of shown concepts. They were not able to gaze privacy and security related issues associated with them. Hence, it is necessary to conduct more research with high fidelity prototypes. It will be interesting to see how people respond after actually deploying IoT products in their home.

It was clear from user feedback that users are finding too much of inference of machines into their life annoying. Hence, IoT products should be designed with the maximum use of PULL approach. It means that unless necessary and critical, IoT products shouldn't push notifications to user. They get triggered on user's request.

Users showed clear preference towards products which are cost-effective, multi-purpose and have high return value. Hence, one of strategy to design IoT products for India could be to design low cost add-on parts which enable existing products to be part of IoT system.

Before starting to design IoT product, the scope should be defined in terms of three dimensions that are ownership, geography and specific application domain. In case of

multi-ser scenario, it necessary to understand hierarchy of responsibility and users willingness to share responsibilities.

There is need of a centralised system which manages all IoT enabled things. Important functions of such system would be to act as central interface for communicating with humans, to distribute intelligence over things, to take semantically viable decisions, to manage access control and to prioritise notifications and alerts.

While designing IoT products for people from middle and lower income groups, it is necessary to design low cost products which tackle real and important problems of people. People from middle and lower income groups will not be able to make one-time investment to buy big IoT systems. They will buy multiple IoT products over the period of long time. Therefore, building IoT enabled home will be a gradual process. Then it becomes necessary to design an ecosystem of IoT products which can be built bit by bit in any order and still it should deliver maximum collective performance.

Appendix - IoT Toolkit

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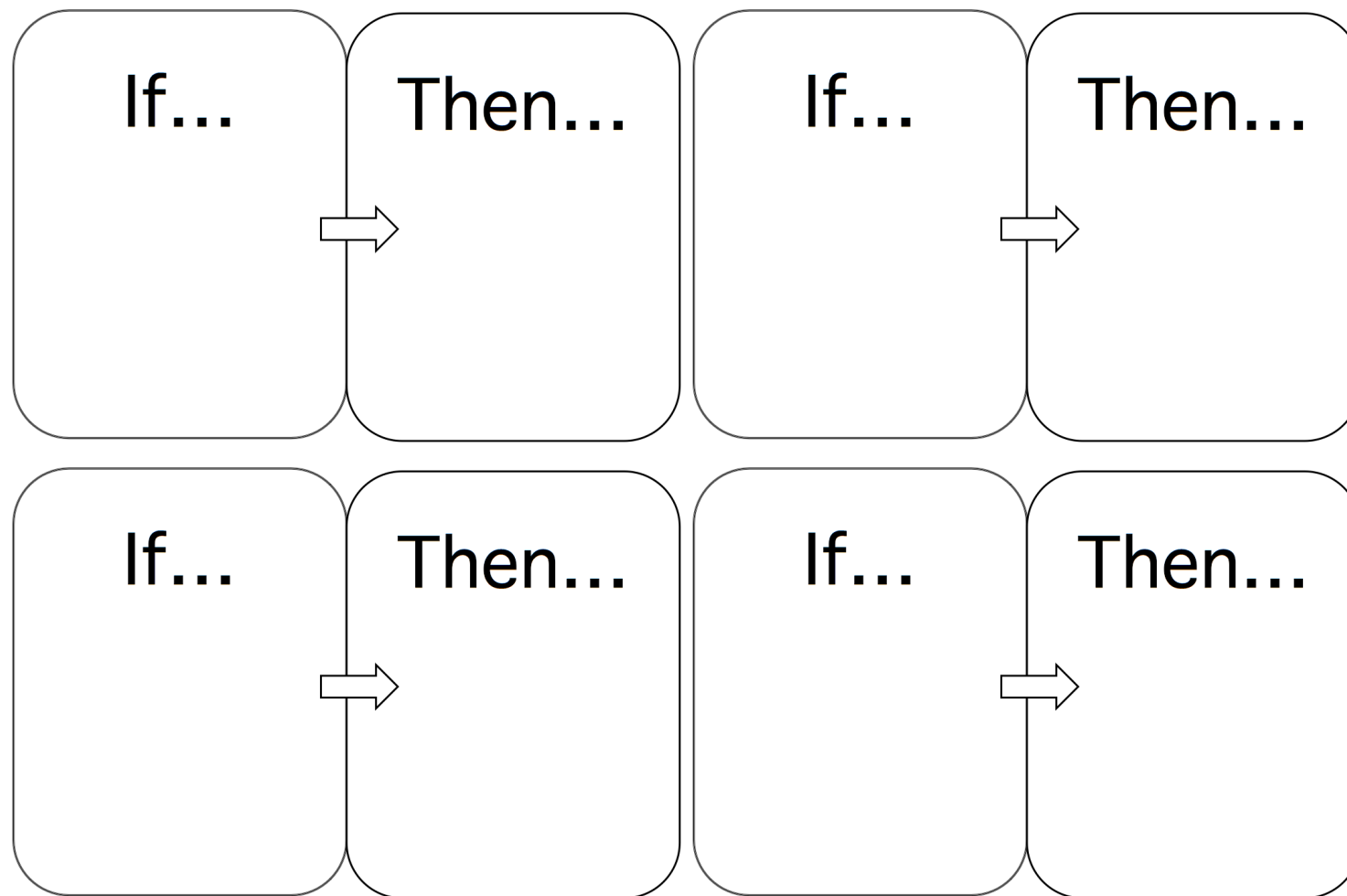
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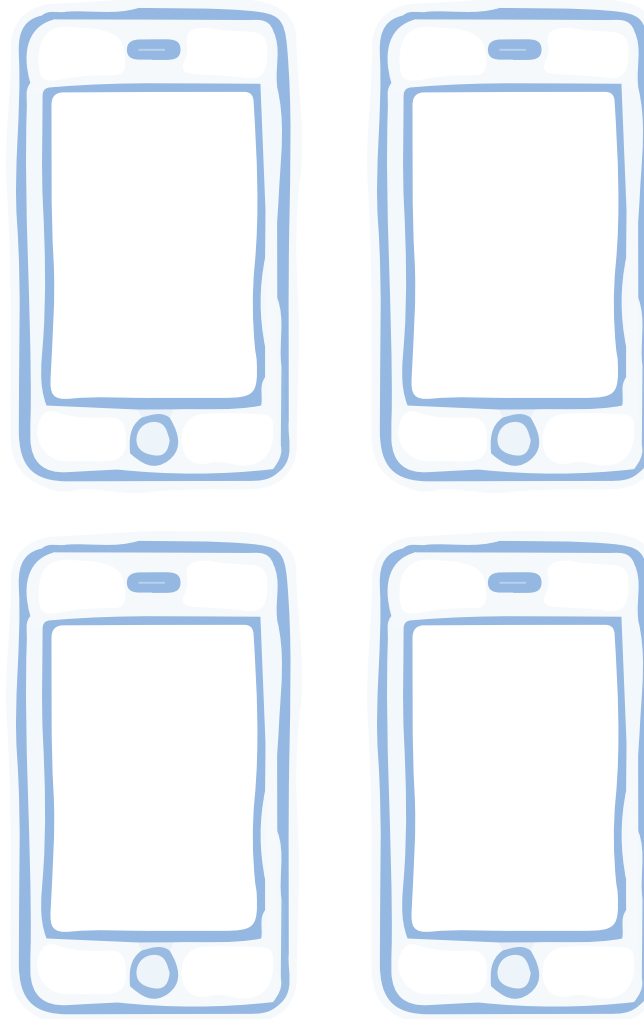
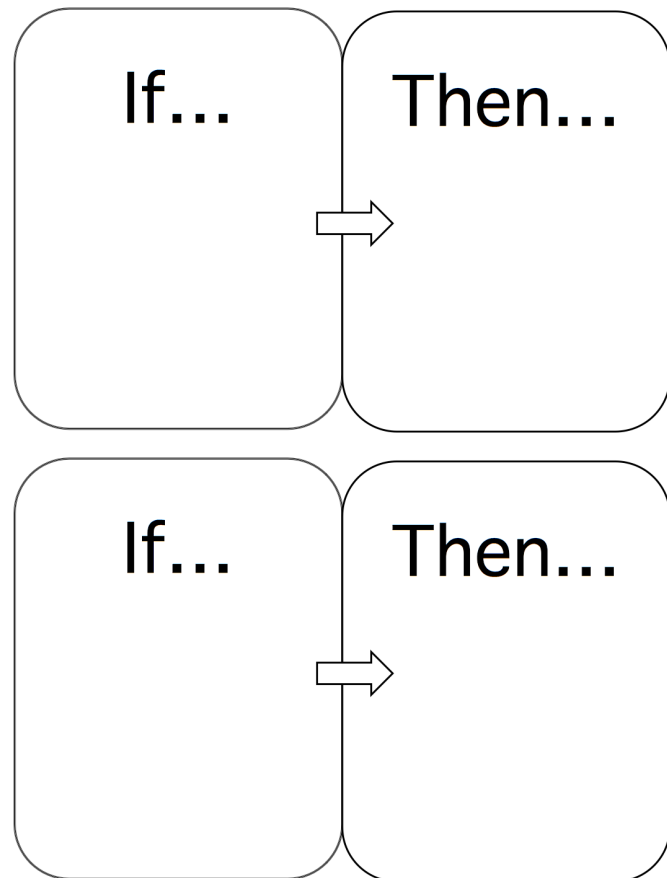
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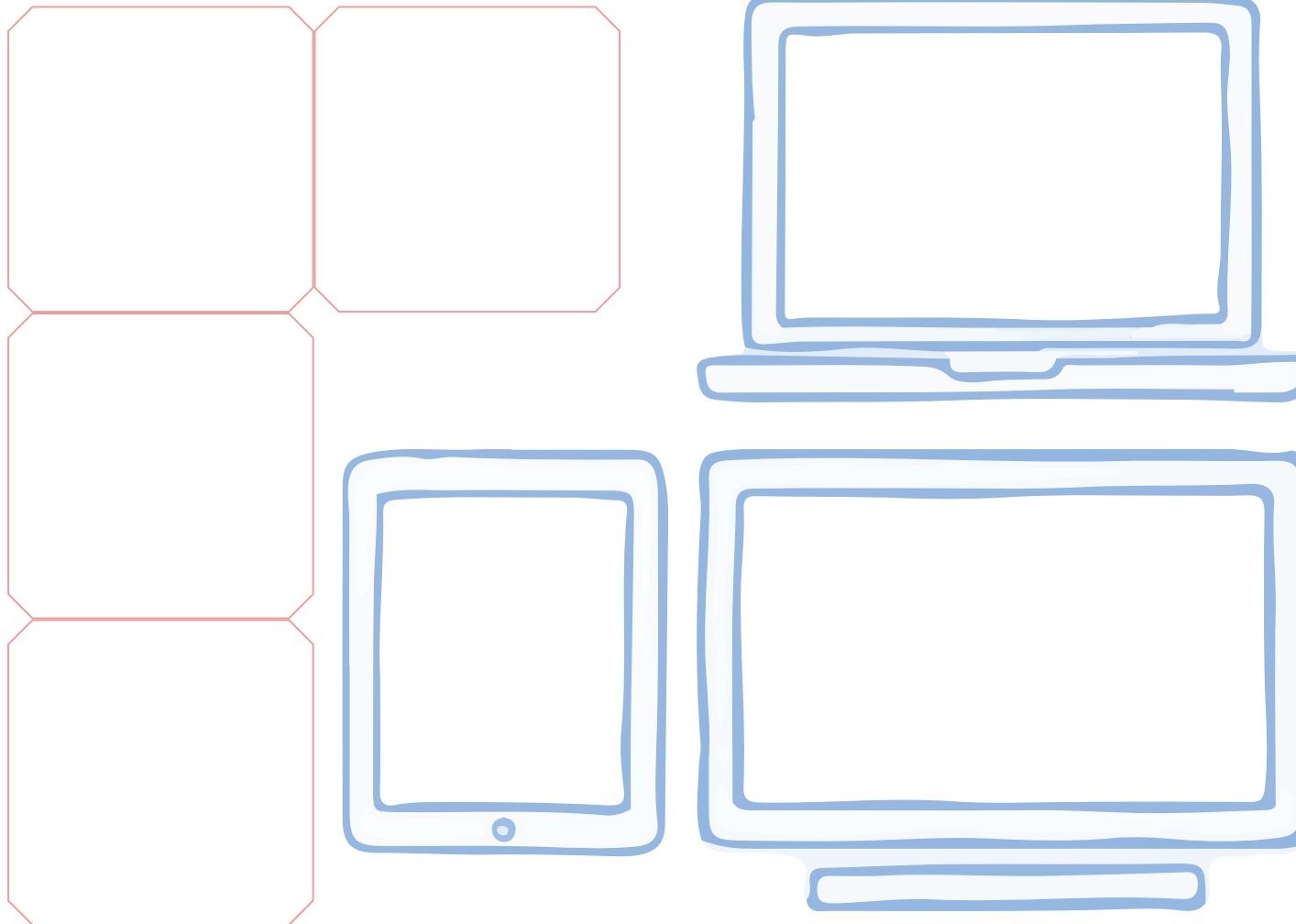
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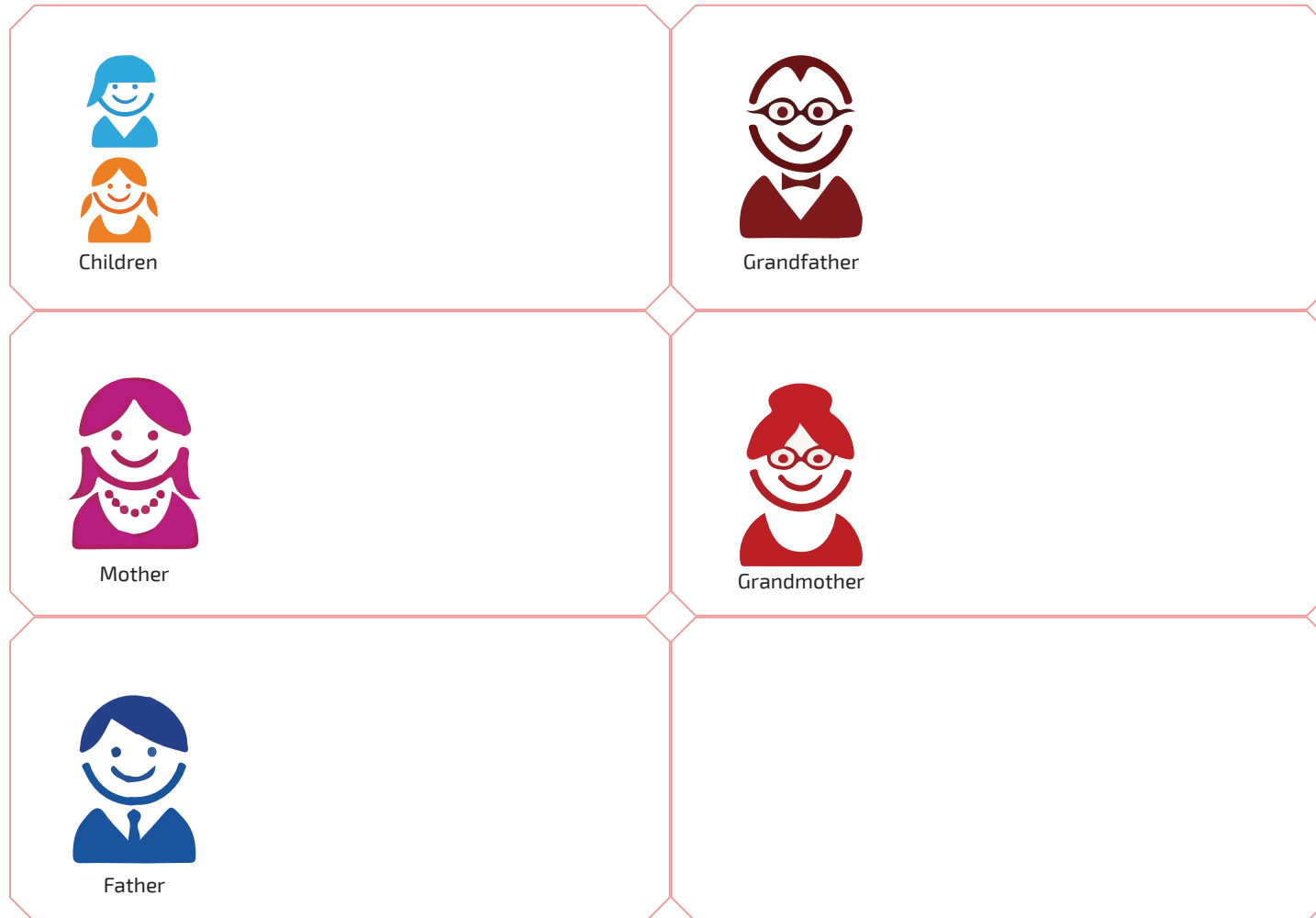
Appendix - IoT Toolkit

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Appendix - IoT Toolkit

For image sources refer to Page No:79



References

1. Michele Zorzi et al, From Today's Intranet of Things to a future Internet of Things: A wireless and Mobility related view, 2010
2. Kevin Ashton, That 'Internet of Things' thing, 2009
3. Evan Welbourne et al, Building the Internet of Things using RFID, 2009
4. Lu Tan & Neng Wang, Future Internet: The internet of Things, 2010
5. Daniele Miorandi et al, Internet of Things: Vision, Applications and Research challenges, 2012
6. Luigi Atzori et al, The internet of things: A survey, 2010
7. Melanie Swan, Sensor Mania! The internet of things, wearable computing, objective metrics, and the Quantified Self 2.0, 2012
8. A. Dohr et al, The Internet of Things for Ambient Assisted Living, 2010
9. Friedemann Mattern and Christian Floerkemeier, From the Internet of Computers to the Internet of Things, 2010
10. Gerd Kortuem et al, Smart Objects as Building blocks for the Internet of Things, 2010
11. Dominique Guinard et al, Interacting with the SOA-Based Internet of Things: Discovery, Query, Selection, and On-Demand Provisioning of Web Services, 2010
12. An interview with Bill Verplank - Johnny Holland
<http://johnnyholland.org/2010/12/an-interview-with-bill-verplank/>

References

Sense - <https://sen.se/store/mother/>
Smart Car - <http://www.openautoalliance.net/#about>
Dog collar - <http://www.whistle.com/>
Toothbrush - <http://www.kolibree.com/shop/product/>
Baby Onesie - <http://mimobaby.com/>
Beddit - <http://www.beddit.com/>
Oven - <http://www.dacor.com/Discovery-IQ.aspx>
LG HomeChat system - <http://www.lg.com/uk/support/>
Mobiplug - <http://www.mobiplug.co/press/>
AllJoyn - <https://www.alljoyn.org/>
SmartThings - <http://smartthings.com/>
Electric Imp - <http://electricimp.com/product/>
FitBit - <http://www.fitbit.com/home>
EVERYTHNG - <http://www.evrythng.com/about-us/>
Belkin Wemo - <http://www.belkin.com/us/wemo>
Securifi Almond+ - <http://www.securifi.com/almondplus>
Sensoria - <http://www.engadget.com/2014/01/02/sensor-socks/>
Broadcom's WICED™ Sense Kit - <http://www.broadcom.com/products/wiced/sense/>
Spark Core - <http://www.hackster.io/daniel0524/building-a-wifi-outlet>
IOT Series - <http://www.aceheattech.com/elstein-iot-screw-heaters.html>
Lab of Things - <http://www.lab-of-things.com/>
IoT Monitor - <http://www.codenize.com/products/internet-of-things-monitor>

Cooley - <http://cooley.co/#features>
IFTTT - <https://ifttt.com/>
UP - <https://jawbone.com/up>
Nike+ FuelBand SE - <https://secure-nikeplus.nike.com/plus/>
Nest - <https://nest.com/>
Netatmo June - <http://www.netatmo.com/>
Misfit Shine Activity Tracker - <http://misfit.com/>
The Health Patch - <http://www.vitalconnect.com/>
MagicCast - <http://www.innopiatech.com/>
Philips Hue - <http://www2.meethue.com/en-xx/>

References

IoT Toolkit Images

Blood Pressure - www.omron-healthcare.com/eu/en/our.../blood-pressure-monitoring

Temperature Sensor - en.wikipedia.org/wiki/List_of_temperature_sensors

Motion Sensor - findicons.com/search/motion-sensor

Bluetooth - logos.wikia.com/wiki/File:Bluetooth_logo.png

Cardio Pulse - www.iconarchive.com/tag/heart-beat

Gestures - hwd3d.com/blog/everything-by-doing/

Pressure Sensor - <https://www.tekscan.com/product-group/test.../pressure-indicating-film>

Email - <https://konversationagent.wordpress.com/>

Family Icon - findicons.com/search/cartoon

RFID Reader - www.dehaatechnology.com/

Industry Display - en.wikipedia.org/wiki/Seven-segment_display_character_representations

IVR - en.wikipedia.org/wiki/Automated_attendant

Microphone - www.aocmonitorap.com/v2015/upload_files/function_icon/

Desktop, Laptop and Mobile Wireframe - tech-kid.com/iphone-5-wireframe.html

Mobile Gesture - <https://play.google.com/store/apps/details?id=com.rpmmeter&hl=en>

RFID Tag - en.wikipedia.org/wiki/Radio-frequency_identification

If Then card - www.teachingchallenges.com/2013_03_01_archive.html

Gas Leakage Sensor - <https://www.sparkfun.com/datasheets/Sensors/Biometric/MQ-6.pdf>

Accelerometer - developer.android.com/reference/android/hardware/SensorEvent.html

Speaker - www.thefreedictionary.com/Side+speaker

Blood Pressure - <https://play.google.com/store/apps/details?id=com.szyk.myheart&hl=en>

Camera - www.iconarchive.com/tag/computer

Desktop - www.flaticon.com/

NFC - www.ntelos.com/product-details/Samsung-SCH-r760-Silver

SMS - en.wikipedia.org/wiki/Short_Message_Service