Building Folkhemmet with the Internet of Things

Final report, Vinnova project 2014-05239
Consumer-facing Internet of Things products: Challenges and opportunities

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Executive Summary

The consumer-facing IoT-product eco-system is on the one hand at the top of the Gartner hype-curve, with a predicted turnaround somewhere between 275–1600 BUSD, and at the same time struggling with a whole range of issues that prevents its growth. The problems can be summarised as follows:

- missing **de facto standards** for communication, wireless connectivity, data, sensors and actuators;
- missing IoT-platforms connecting smart objects without locking consumers and their data into **proprietary** solutions, belonging to big companies, not sharing it between applications and settings;
- missing **use-case infrastructure** providing compelling applications desirable to consumers, beyond creating "Thing +1": that is, everyday objects to which an internet connection is added, without adding much to the utility or user experience;
- requires **new business models**, which in turn often requires completely new business ecosystems to be built. This requires companies and organizations to co-create on a level that has been rare before;
- a lack of **design thinking** to bring out compelling solutions and applications;
- missing **killer interface paradigm** that can go across many different services, domains, situations, as you move between your home, garden, city, public transportation and so on, to make interactions compelling rather than nightmarish;
- lack of **privacy** solutions in existing platforms hindering developments.

These problems can be seen as obstacles or opportunities for the Swedish IoT ecosystem to take on and attempt to tackle in order to unleash its, potentially, huge commercial potential, and bring solutions of relevance to society and consumers. We propose engaging in the following topics.

- **If it is not for all, it is not a revolution:** IoT standards – of various kinds – need to support everyone, including those less affluent, elderly, young, those with illnesses or disabilities.
- **Open data and data standards:** to unleash creativity and bring out compel-ling use cases, open data in structured data standards are required.
- **People in power need to procure and regulate:** we need highly engaged, knowledgeable politicians and industry actors to engage, meet, and bring out the necessary policies, regulations and "first buyer" situations that will drive the development forwards while at the same time protecting consumers and citizens.
- **Interdisciplinary knowledge and training – design thinking:** education to train professionals from many different backgrounds in what IoT offers is needed in order to bring out compelling and relevant IoT solutions.
- **Branding Sweden as an IoT nation:** Swedish standards, values, participatory processes and the overall Scandinavian design model could help place Sweden on the map, once again making Sweden into a testbed and innovation hub in the world.

1. Project goals

The project set out to tackle two goals. First, to map and predict the **size, focus and commercial potential** of IoT for the already existing consumer-product companies as well as consumer-facing IoT startups in Sweden today. Second, to identify **common problems** – be it technologies, toolkits, infrastructure, design competence, creative disruptions in business modelling or spectrum access – for this sector, both from the developer and end-user perspectives.

We saw a great potential in the area as many components are in place for taking the first steps towards strategic leadership in this area. Strong commercial actors (large and small); long experience of research and development where academic and industrial researchers join forces; the Swedish legacy of IT leadership and public transparency (as open data will be necessary); strong tradition of design-led development of high-tech products and services.

To address the goals, we put together a strong consortium, consisting of some of the most forward-looking industrial actors and research centres including Ericsson, Yanzi, Husqvarna Group, IKEA, Sophiahemmet, Boris Design Studio, Ziggy Creative Colony, WeMeMove, BioSync Technology, Twiik, STING, Arvax, Mobile Life, SICS, Wireless@KTH, Uppsala University, IOTAP.

The project focused on IoT for domestic, body-based and games purposes.

2. Background and motivation

As consumers, we are looking for technology that fits with our everyday lives, inside our homes, in our pockets or even on our bodies, not because it makes us more efficient, but because it is **desirable**. Today, we note how consumers have started buying Internet of Things-products. The growth has been spurred by the increasing commercial success of IoT devices – devices such as the Google's Nest, Fitbit, Philips Hue and Belkin WeMo. These devices, and the Internet of Things more broadly, are dependent upon longstanding technical advances in fields such as ubiquitous computing, distributed systems and low power electronics. However the proximate cause that has made these products successful has not been purely technical but innovative design and business models. The Nest worked in a completely different way from earlier thermostats; the Fitbit supported a new type of use; and the Hue and Wemo made use of connected smartphone apps.

Clearly the Internet of Things is not a solely technical endeavour; it is dependent on understanding new uses, user needs and innovative, desirable design, because in spite of its importance in our lives, technology is still frequently frustrating, dehumanizing, or just plain boring. While our everyday life is saturated with technology, our relationship to it is still very far from perfect.

3. Empirical work and joint workshops

Several different empirical studies were completed in the project.

- Thought leader interviews with 25 people from companies such as IBM, Google, Ericsson, Yahoo as well as start-ups (Lewandowski & Mercurio, Appendix 1).

- A study of people's homes, documenting any existence of interactive objects in the home, ranging from entertainment systems to setups for performing work from home (Glöss & Tollmar, Appendix 2).
- An attempt to scope the size of this market (Gullikson, Appendix 3).
- A study of sports applications, determining what is needed to maintain interest in IoT products beyond the novice excitement (forthcoming, more information can be obtained from Jan Markendahl at janmar@kth.se).
- A study of opportunities and challenges of IoT for Health or "Connected Health" (forthcoming, more information can be obtained from Dina Titkova at dina.titkova@biosynctechnology.com).

Apart from regular project meetings, we had two joint work activities in the project.

- A two-day synthesis workshop in August 2015, where all the empirical material was used as a basis for a future scenario exploration. The images illustrating this report are from the synthesis workshop.
- A brainstorming day with Julian Bleecker where we mapped out the future through designing a fictive IKEA catalogue for the year 2040. The fictive catalogue contains e.g. the Unconnected Sofa, a sofa that is extra expensive as it is not connected to the internet (Design Fiction: IKEA catalogue, appended separately).

4. High-level insights gained

Putting all our empirical material alongside the considerable expertise of the project partners, we derived some high-level conclusions.

First, it is clear that Internet of Things is thriving in contexts where there is already a lot of technology integrated with some controlled process, such as in factories, mines or other closed systems. The reason is that the whole infrastructure can easily be put in place, there is no need to rely on non-existent standards for wireless communication protocols or unreliable sensors placed in settings where the companies do not have any control. All the data can be shared as it is a closed system.

The consumer-facing smart products, on the other hand, are still facing difficulties. Let us outline some of the obstacles hindering development, before we discuss a couple of unique Swedish opportunities in the general field of consumer-facing IoT products.

4.1 Obstacles

The project identified several obstacles that need to be removed before consumer-facing IoT products can be launched on a big scale.

4.1.1 De facto standards. First, there is a lack of de facto standards for communication, wireless connectivity, and there are worries amongst industrial actors about unreliable sensors and actuators placed in messy environments, such as the home or city, where they have to interact with technologies of different origins and ages.

4.1.2 Walled gardens. Second, there is a lack of IoT platforms connecting smart objects without locking consumers and their data into proprietary solutions, belonging to big companies, not sharing it between applications and settings.

4.1.3 Compelling use case infrastructure. But what was most often mentioned in our thought leader interviews as well as inferred from our study of people's homes, was the lack of integrated interface solutions and compelling use cases – or as one of our interview subjects expressed it: the lack of a use case infrastructure. As long as this is lacking, actors on the market as well as consumers are not willing to take risks and invest in systems, applications and smart objects that might not deliver what they promise.

Let us develop the complexities of this somewhat. If each smart object you buy for e.g. your home comes with its own mobile app that needs to be installed and managed, using proprietary platforms that do not allow for sharing of data between applications, interesting applications cannot be built and therefore consumers remain reluctant to buy. This in turn makes it doubly hard to create use cases that thrive on data from several different machines or data sources. Without several data streams from different machines or processes in your environment, we will not be able to deliver those compelling use cases. Nobody is interested in a fridge that connects to the internet to tell you that its temperature is within the normal range – the user experience and benefit from this use case is lacking. It is only when all your household machines are connected, streaming their data in a unified format to open platforms that we can create entirely novel applications, such as really controlling energy consumption or other tedious information.

We note the development of HomeKit, HealthKit and similar platform solutions that again will put the main profits with Apple and Google.

The problem of sharing data between applications is particularly true for e.g. biosensor data. If an app can only access either your bicycle data or your FitBit data, but not both, it becomes hard to make new interesting applications thriving on both.

The home is currently the target of most IoT consumer product offerings, yet as was noted, the notion of automating your home is not something most people find necessary or appealing. When it comes to controlling lights (remarked upon as the “sweet spot” for IoT), light switches are more reliable, easy to use, and allow users to control individual lights. The point being that for most, managing light switches is currently not problematic enough, the product offerings may not be compelling enough, or the market may not be mature enough to justify the switch to an IoT setup. One UX design consultant with clients developing consumer IoT products framed the issue with sarcasm, “It’s so hard to turn on my light switch. I can’t do it.”

We end up in a situation where the offered IoT-services and smart objects become quite limited, not really addressing a real need or a delightful interaction. For example, we see many “Things +1”, that is, everyday objects to which an internet connection is added, without adding much to the utility or user experience, such as e.g. an egg minder keeping track of how many eggs you have in your refrigerator.

In addition, each of these smart objects does not add enough value to warrant all the work we have to invest in them – “value-added ≥ maintenance”. That is, smart objects or applications need to convey a perceived value that is higher than the requirements on maintenance, such as upgrading software, dealing with battery consumption or repairing sensors or actuators.

4.1.4 Business models – painful transformations. The problem is often not just the product itself, it is the ecosystem around it. Rather than selling a car, tomorrow’s sustainable business models will primarily innovate new service offerings based on autonomous vehicles in smart environments, where individuals pay for comfort level and distance

rather than today. This (and in owning the platforms that make it happen) is where the big value-added will come.

In addition, consumer product companies like IKEA or Husqvarna take a very high risk if they enter into this domain with the wrong data format, wrong wireless communication protocol, or faulty business model. A sofa from IKEA is used for 10 years and any sensors or actuators placed in it need to come with the same life-span, robustly keeping it up to date (similar to how a Tesla is delivered with a software upgrade once a month through a licensing agreement). It is an entirely different business model to enter such a long-term relationship with a customer instead of selling a product after which the customer relationship is over. On the other hand, if you can enter into a long-term relationship with your customer, you can build loyalty and delightful products with licensing business models – entering into the age of sharing economy. The traditional consumer-product companies are therefore worried that the big telecom- or IT-companies might come in and take over this side of their business, ultimately disrupting their business, reducing them to "hardware" providers – a notably less lucrative role.

4.1.5 Trust & privacy. In some of the scenarios we worked with in the workshop, the risk of a failure for IoT was strongly connected to situations where consumers cannot trust the companies (or governments) with their data. IoT thrives off data, without data there are no services.

Largely, trust is not the main issue from a consumer perspective, but uncertainties around the issue create a lot of hesitation and risk aversion within business.

Legislation is an issue. In many areas, it is unclear what information can be used and how. Other times, data that would be beneficial for society cannot be shared or used.

4.2 Opportunities

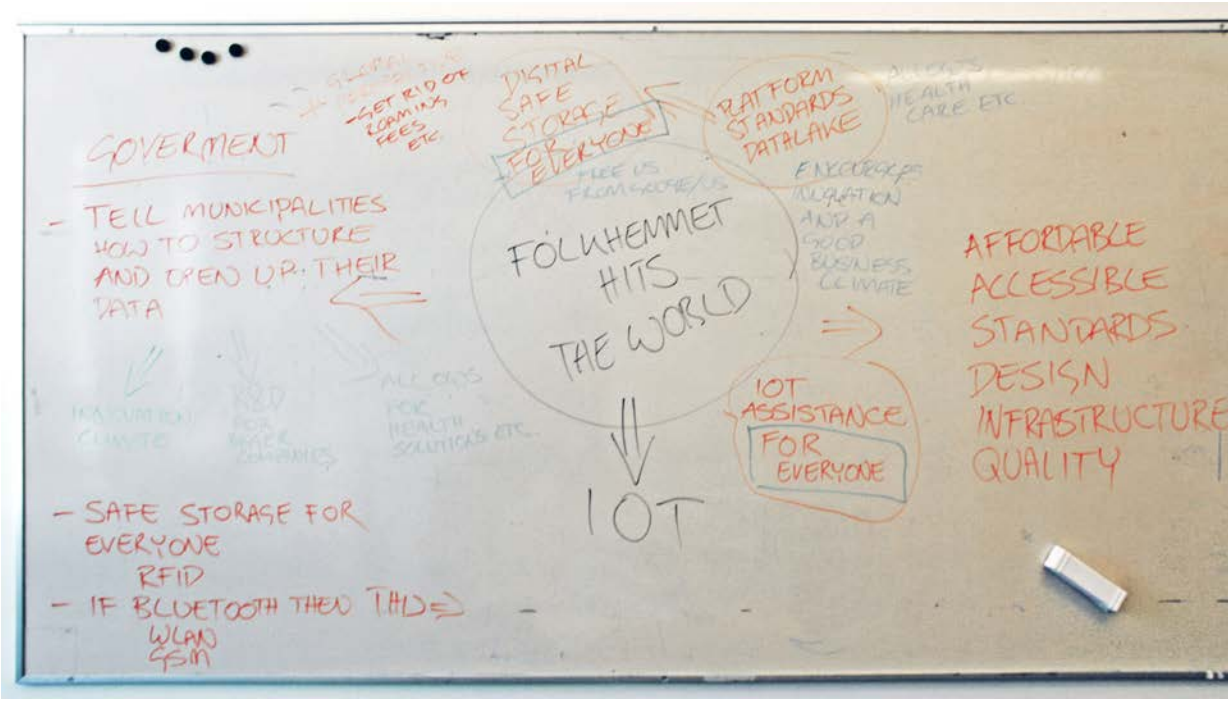
At the same time the hype curve (according to Gartner) for IoT is at its peak. There are estimates saying that this market will have a turnaround of somewhere between 275–1600 BUSD (Gullikson).

While the complexities of the interdependencies of an ecosystem in formation are far beyond what this particular project can tackle, there is a window of opportunity for researching and creating key puzzle pieces that strategically support Swedish industry to focus on a compelling, delightful use case infrastructure for consumer-facing Internet of Things products.

The project identified several interesting opportunities that would be of benefit not only to the commercial market, but also to create for a better society.

4.2.1 Health and wellbeing. Health and wellbeing was identified as a strong market. We can already see a growth in sports and wellbeing applications (Gullikson, Markendahl). We see new opportunities arising focusing on life-long illnesses and life-style related problems. Various forms of IoT, such as sensor-based diagnosis and management, interactive applications supporting movement or meditation, may help in dealing with stress-related illnesses, diabetes, MS, obesity and encourage movement and exercise.

In the project we have done some findings related both to end-user experience as well as to market aspects and potential business models for products and services based on IoT and connected devices for sport and wellbeing. When it comes to solutions and devices linked to market structure and business aspects we can make a number of observations:



Future scenario: Folkhemmet 2.0.

- Current health apps and devices make use of or depend on smartphones.
- For both sport and healthcare applications the telecom industry look into stand-alone devices directly connected by cellular systems.
- The market is very fragmented with a multitude of solutions and devices.
- The end user value varies and depends on the service context.
- There are several business model options (different revenue potential), ranging from selling a device to providing services on top of one or several devices.

4.2.2 A new take on Folkhemmet. A potential market, as of yet unexplored, would be if Sweden showed the way towards a society where IoT is serving all – a new "folkhemmet".

Sweden has a long-standing tradition of participatory influence on technology developments. Democracy on local as well as national level has been driving societal developments. The aims of the society has been to give everyone equal opportunity and provide everyone with reasonable living standards. The IoT development needs to pick up on these values and make sure that the benefits of the digitalisation is for all.

Historically, Swedish industry has benefitted immensely from those goals. When the state required that everyone in Sweden could be reached by telephony and later by broadband, Ericsson and Televerket (Telia) collaborated and created technical solutions that were later exported. The 24/7 principle of how we can reach authorities has pushed municipalities, the health organisation and the state to very early on digitalise many of their services and ways of working, in turn building a strong IT industry in this sector.

In industry, we note how the strong values of designing for "the many" that has governed the development of IKEA enforced highly innovative thinking, shaping their products and solutions to make them affordable.

In general, the Scandinavian design model, forming both aesthetic ideals of the light, easy-to-use, accessible and beautiful, as well as forming strong participatory values, has been of great benefit to shape and brand Sweden and Swedish industry.

Similar values should govern the development of IoT in Sweden: participatory developments, democracy as a strong driving factor, equal opportunities in reaching and benefitting from the digitalisation of society, healthcare, wellness, homes or leisure time activities.

We need to reduce fragmentation and support open platforms to make this happen. IoT solutions need to become affordable and beneficial for all.

4.2.3 Smart Data Layer. As noted above, the real benefits from digitalisation are sometimes only achieved when many objects, services and processes are connected. Only then is it possible to create innovation that go across many different data sources, governing interesting “actuation” in the world. One way of putting a finger on the problem would be to think of it as a smart data layer that many different applications can thrive upon.

A smart data layer requires access to several continuously streaming data sources. It requires orchestration, access to open data, and a uniform way of treating the interaction without relying on a centralised system, owned by one stakeholder. To have any effect, it needs to go across several applications, produced by different stakeholders.

While this may seem utopian, we can compare it with the web- and mobile-based applications. Data is collected both “locally”, for each service on the net, using cookies, location as well as other sensors (such as the gyro and camera in mobiles). Data is also collected across applications, using both proprietary data, but also any open data sources available (see e.g. the open data initiative at Stockholm City Municipality). Translation systems are built on data from the whole web using, e.g. Wikipedia. Predictions of the future or identification of terrorist acts is done through harvesting data from the net, social media and mobile interactions (as in the works by companies such as RecordedFuture).

All this modelling allow these services to silently adapt the interacting for us, filling in fields for us, showing us where we are on a map as well as where a nice restaurant can be found nearby or where the next Uber-taxi will be coming from, placing relevant ads in front of us, proactively adapting the prices of the trips we are planning, placing the systems in the right context for us to use. Obviously, not all of these interactions are benevolent, and strong regulations and policies are needed in order to protect consumers and organisations from crimes and intrusions. But overall, it has made interactions accessible, easy to understand, better integrated with our everyday activities. We need a similar development for the IoT apps and services. If such a smart data layer was available, many applications and smart objects would be better fitted to our everyday practices and thereby easier to use as well as more relevant to us.

5. Recommended actions

To remove some of the obstacles that are currently hindering development in this area, we jointly arrived at the following recommendations.

5.1 If it is not for all, it is not a revolution.

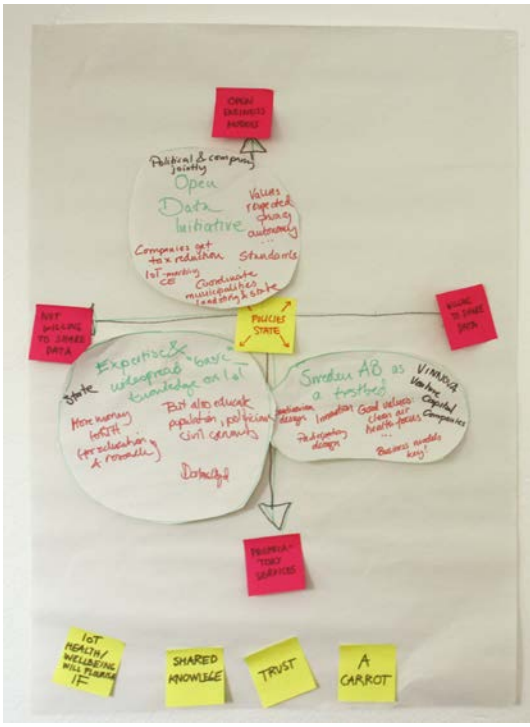
As IoT and the digitalisation of society and industry is potentially disruptive, changing everything from business models to how the government organises its work, it is of key importance that the government provides support for technological equality – if it is not for all, it is not a revolution.

IoT standards – of various kinds – need to support everyone, including those less affluent, elderly, young, those with illnesses or disabilities. This becomes key in any products aimed for consumers. The interfaces must be accessible to many, that is the way upgrades are made, the maintenance, the ways in which they serve us, helping us to save energy in ours homes, improving our healthcare system, or any of the other visions for IoT, must be **usable for all** and also provide **value for all**.

5.2 Open data and data standards.

To unleash creativity and bring out compelling use cases, open data in structured data standards are required. The more data we can make accessible to entrepreneurs, companies and institutions, the more likely it is that we will innovate services of relevance to consumers and citizens. We need to reduce fragmentation and support open platforms. We might even need to regulate against proprietary data solutions when the data is thriving off people who are not getting paid to share it, or when the government is gathering the data. We would like to emphasise that the IoT development is not so much about technological standards as it is data standards.

In addition, data can serve interesting bridging roles. Health data for research as well as for innovative health services creating bridges between consumer facing



Future scenario: Sweden can become a leader in IoT, but it requires coordinated initiatives on open data standards.

products (e.g., smart watches) and the health sector, or within the transport sector and ODB2-connected consumer products in vehicles.

Sweden lacks structured governance for such standards, which should be a given task for authorities such as Transportstyrelsen and eHälsomyndigheten.

5.3 People in power need to procure and regulate.

IoT has the potential of addressing major societal problems – healthcare, wellbeing, efficiency in use of joint infrastructures and (energy) resources, as well as more compelling and aesthetically appealing applications for end-users. But in order to do so, we need highly engaged, knowledgeable politicians and industry actors to engage, meet, and bring out the necessary policies, regulations and "first buyer" situations that will drive the development forwards.

This in turn requires that knowledge on IoT spreads to industry actors as well as politicians and that meeting arenas are created where these discussions can take place. We foresee huge problems with privacy and trust, unless regulations and policies, foreseeing the complexities of these new interactions, can be put in place.

5.4 Interdisciplinary knowledge and training – design thinking.

As discussed above, doing design in this area requires interdisciplinary knowledge. We need to educate more designers (whether engineers, industrial designers, political science, business economics or some other professional background) to work in this complex landscape.

In particular, we would like to emphasis the importance of design knowledge and design research. Design thinking supports investigations of "what may be rather than simply what is". Training in design thinking helps not only those who are professional design practitioners, but anyone aiming to create innovative solutions. In a design-driven process, the exploration of a problem is done through creating many imagined solutions, opening a whole design space, solutions that in turn help us see what the problem really is and what may address it properly. We gain new knowledge via the act of making. This can be applied to problems that are otherwise framed as wicked problems (problems where there is no obvious simple solution).

In interdisciplinary teams (such as the one behind this project) where everyone has sufficient understanding of what IoT is and might offer, design thinking and designerly ways of working can bring out highly innovative and compelling applications and services.

5.5 Branding Sweden as an IoT nation.

We see an opportunity to brand Sweden as an IoT nation. The Swedish standards, values, participatory processes and the overall Scandinavian design model could help place Sweden on the map, once again making Sweden into a testbed and innovation hub in the world.

6. Authors and acknowledgments

This report is the result of the joint work of the following people.

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Appendix 1:
Lacking meaningful products –
IoT and industry challenges

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UNDER REVIEW - not to be shared, spread or cited

Lacking Meaningful Products: IoT and Industry Challenges

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ABSTRACT
Despite over two decades of ubiquitous computing research, involving the development of embedded networked computing systems, the most recent trend in this technologies development, the "Internet of Things" (IoT), is struggling to find a reason to exist in the lives of consumers. Following an extended round of interviews with twenty-five industry IoT professionals in both the consumer and industrial sectors of IoT, we draw attention to design challenges for the industries consumer sector that should be addressed by HCI researchers. We conclude with remarks on how HCI might work toward addressing these issues with the interaction design of the Internet of Things, and work toward clearer, more compelling reasons, for why this technology should be adopted.

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Authors' choice; of terms; separated; by semicolons; commas, within terms only; this section is required.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous; See http://acm.org/about/class/1998 for the full list of ACM classifiers. This section is required.

INTRODUCTION

Why should HCI researchers care about the *Internet of Things* (IoT) when we have a well-established, rich discourse around technologies that capture the system that it describes (ubiquitous computing, context-aware computing, pervasive computing, embodied interaction)?[27,7,1,8,9] Although there are technical distinctions made between IoT and those systems listed above, this research aims to uncover a more subtle difference. By listening to the understandings and concerns of technology industry professionals in their own words, this research aims to ground the challenges of similar HCI research in the fast-paced world of IoT consumer product development.

This is of particular importance to HCI if we are to contribute our decades of related work to the burgeoning market around this technology. HCI is in an advantageous position to address these fundamental issues by engaging with the philosophical underpinnings of technology design. That is to say that the problems facing the consumer oriented Internet of Things are not only technical or practical. There are plenty of researchers (both corporate and academic) working to solve those issues. The problems we discovered through our interviews concern matters of substance. What will we use the Internet of Things for? Will we even find a reason to make use of the Internet of Things? Is an Internet of Things future as it is currently portrayed realistic or even desirable?

These questions are made manifest explicitly (and implicitly) through the technical and practical concerns of those IoT professionals we interviewed. Either by their answers or inability to provide answers to these questions, these individuals that have so much riding on the success of IoT, expose the absence of compelling reasons for why we should surround ourselves with so many networked sensor/actuator computing nodes. There is no absence of practical consideration for how the Internet of Things will be implemented; yet these individuals often struggle to make a compelling case for why our daily lives would be improved by this technology.

Our ultimate aim in this work is to suggest an agenda for research that works toward understanding how this technology could be rendered meaningful. This is no easy task, with no straightforward answer, yet the challenge is clear and present, as the hype around this technology has been peaking on the Gartner hype-cycle for the past two years. Next comes the trough of disillusionment, and until we find appropriate answers to those difficult 'why' questions, the consumer-oriented Internet of Things will struggle to find a reason to exist and our daily lives will go on as they always have without the benefit of all of the hard work put into the technical and practical considerations.

Our research consists of an analysis of interviews conducted with twenty-five IoT professionals within the technology industry in Sweden and the United States. This was followed up with a thematic analysis and coding of the transcribed interviews. Although several major themes emerged through the analysis, this paper focuses on the opportunities for (and barriers to), added value and compelling use cases for IoT. It is through this analysis that we hope to highlight similarities and differences between the UbiComp and IoT

communities, while clarifying or giving reasons for ambiguities that exist within the consumer IoT discourse.

Finally, this article addresses how new directions in design theory and practice could influence the development of IoT objects and their related services, by suggesting new avenues for interaction research and how to design with the materials of IoT in a manner that addresses matters beyond those concerned with the technical and practical details that arise when designing for comfort and convenience.

BACKGROUND/RELATED WORK

The Internet of Things is currently garnering broad investment and interest from various technology industries, agriculturists, manufacturers, retailers, and venture capitalists (i.e. corporate interest). Big industrial actors speak about 50 billion connected devices in 2020—and even if most of those are mobiles and devices used in industrial production, a whole plethora of devices will be surrounding us in our everyday lives if we are going to arrive at 50 billion.

Though most agree that IoT loosely pertains to "connected devices" (i.e. networked embedded computing objects - typically equipped with sensors), the expectation for "connected devices" goes beyond a simple 1-to-1 connection, referring instead to a vast network of devices communicating with each other locally in addition to providing streams of data for the internet to store, process, and provide feedback to those devices (that in turn could be linked to various services). While this has been achieved to a certain extent in various industrial sectors (e.g. agriculture, manufacturing, shipping), the consumer-oriented sector is far from realizing this level of sophistication. There are already numerous articles that provide a broad range of definitions for IoT, so in this paper we will only focus on the understandings of our interviewees. [10,18,24,14,19,12]

There is a broad range of roles to fill in order to realize their sizable predictions. These include (but are not limited to) the design and development of products, data analytics, application software, middleware, firmware, service providing, infrastructure, platform development, security protocols, power supply management, and compatibility protocols.

There has been over two decades of research, both technological and ethnographic, surrounding the topic of ubiquitous computing within HCI. [3,8,11] While this research has operated under the guise of various names (i.e. ambient intelligence, pervasive computing, context-aware computing, embodied interaction etc...) the underlying research discourse has taken two main paths, those concerned with the engineering and technical challenges posed by networked embedded computation, and an extensive exploration of human behavior in various contexts aimed at understanding how computational environments might shape that behavior.[8]

Now that we have a strongly emerging commercialization of the technologies described in much of what has been written of UbiComp in HCI under the heading of the "Internet of Things", it is time to explore the challenges currently faced by those corporate entities in order to better understand how we might address those challenges within the HCI community.

UbiComp and HCI

UbiComp has a long history of envisioning the future as bridging interdisciplinary fields however the focus on design is often lacking [11]. Mark Weiser [26,27]. has contributed to HCI by contradicting the visions that it is not just the technology itself that made ubicomp but also the seams of interaction that bridge the physical and digital. However this seamlessness can easily be critiqued to be unachievable when it comes to actual design, [5].

The primarily visions of UbiComp are similar to the ones within IoT in that they seek to design computers/systems that are, "part of the environment, embedded in a variety of everyday objects, devises and displays" [17]. UbiComp envisions augumenting everyday objects and embedded computational systems in everyday settings to sense, monitor, track and actuate the environments [3,8], while IoT envisions the world of more entangled relations between the digital and physical [20].

Even though the imaginative possibilities of UbiComp are now more than a decade old they might provide the foundations for the Internet of Things [23]. Looking back on the visions of UbiComp it was successful as a research endeavor and creating a technical agenda, however some are critical as to if there has ever been a meaningful bridge between these two successes [3]. Many have argued that UbiComp has mainly been a conceptual project while it operates on a technical level [9].

This is all to suggest that while UbiComp research within HCI provides a wealth of research relevant to IoT, perhaps this literature needs reconfiguring in light of the complex challenges presented by developing actual consumer products for the Internet of Things.

The Internet of Things and HCI

We discovered two literature reviews of IoT products within the ACM digital archives that serve as helpful guides for understanding the current state of product development for HCI audiences. [2,18]

The HCI community is currently developing a discourse around IoT. Even though the UbiComp and IoT visions share similarities and differences,, the primary distinction is the notion of interconnectivity, the potential to make multiple connection and data shared between all objects of the IoT. [25,4].

Much of the research focus has thus been on the fact that objects have increased the level of agency, in particular the distinction between object agency and human agency [16].

Therefore: *In particular, the user of technology can no longer be presumed to be human. We present the concept "social things" as a means of accounting for this kind of agency.* . [20]

Lynch et al modified Atzori et al.'s framework for examining HCI-related efforts within IoT. The framework shows us that efforts are still largely technical and that the focus is mainly around the effort of "things".[6] Even though the framework might help us to understand implications within HCI needed to design for the IoT, there is a clear lack of human-centered focus. [17].

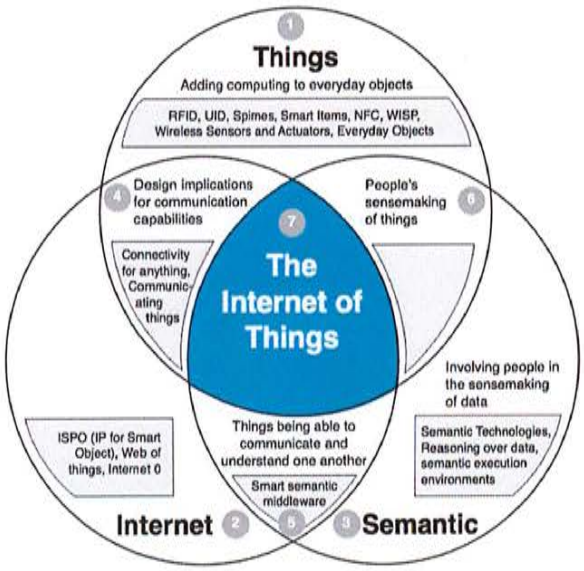

Figure 1: Modified version of Atzori et al.'s (2010) 'Internet of Things' paradigm.

METHOD

This study was originally motivated by an interest in what exactly is meant by the "Internet of Things" as it was not altogether clear due to the numerous and disparate definitions, visions, products, and roles involved. Additionally, the consumer-oriented IoT product sector did not seem to be nearly as thriving as anticipated by the amount of investment and hype. We wanted to know why.

Interviews

For this study we conducted twenty-five semi-structured interviews with professionals in Sweden and the United States that play various roles in developing and designing for the Internet of Things. Those interviewed ranged from those that work for global Fortune-500 companies to consultants for small design firms. The variety of roles represented consisted of product engineers, product designers, technology consultants, computer scientists, managing directors, strategy leaders, UX designers, CIO's, and researchers. It should be noted that most individuals working for larger technology firms (i.e. Google, Yahoo!, Xerox Parc) made the disclaimer that the views expressed in their interviews were their own, and not a reflection of company policies.

Therefore, we will maintain the anonymity of the individuals and their respective employers, but will clearly state the role of the participants in order to better understand their perspectives.

We recruited interviewees by emailing contacts at organizations directly or within the scope of our personal and professional networks. The interviews and recruitment was done iteratively over time. We did not collect any demographic information from our interviewees.

The reason we chose technology industry professionals to interview was motivated primarily by the fact that these are the people who make up the majority of those generating the visions and shaping the discourse around IoT

Of the twenty-five professionals interviewed five were women. The interviews were conducted with each participant individually. Interviews lasted between 60 and 90 minutes. Some were done over the phone others in person. Three IoT related panel discussions were also included in our research data.

Our interviews were structured loosely around a set of questions pertaining to interviewees understanding of IoT:

- What is the Internet of Things?
- How does your work relate to IoT?
- What is your (or your organizations) vision for the Internet of Things?
- What are the greatest design challenges for IoT?
- What core competencies do you look for in hiring new employees for IoT projects?
- What IoT products do you use personally?

Although all of the interviewees were asked the questions listed above, the interviews often covered topics related to their role and interest in IoT projects and topics. Detailed handwritten notes were kept during each interview. The interviews were all recorded and transcribed.

Synthesis, analysis, and discovering themes

The two interviewers began analysis by going through the audio and transcribed data bottom up, looking for recurrent themes. The most emergent themes were then presented to two senior HCI researchers in a workshop setting. The analysis was then refined a second time with coding of the data into different themes focusing on the challenges and opportunities for IoT.

Although several major themes emerged through the analysis, the following sections focus the challenges that emerged around design and IoT. The process of analyzing the interviews went as follows:

1. Discover general themes
2. Identify design related themes

3. Determine design related themes relevant to HCI

The analysis was coded along three themes:

1. value added (VA)
2. use cases (UC)
3. design thinking (DT)

INDUSTRY DESIGN CHALLENGES FOR IOT

Putting all the interviews alongside one-another, they provided a good understanding of where IoT is thriving and where it is still lagging behind.

It is thriving in contexts where there is already a lot of technology integrated with some controlled process, such as in factories, mines or other closed systems. The reason is that the whole infrastructure can easily be put in place, there is no need to rely on non-existent standards for wireless communication protocols or unreliable sensors placed in settings where the companies do not have any control. All the data can be shared as it is a closed system.

The consumer-facing smart products, on the other hand, are still facing difficulties. There is a lack of de facto standards for communication, wireless connectivity and several interviewees expressed worries about unreliable sensors and actuators placed in messy environments, such as the home or city, where they have to interact with technologies of different origins and ages.

In these interviews we identified several obstacles that need to be removed before consumer-facing IoT-products can be launched on a big scale. For example, we need IoT-platforms connecting smart objects without locking consumers and their data into proprietary solutions, belonging to big companies, not sharing it between applications and settings. At the same time the hype-curve (according to Gartner) for IoT is at its peak.

While the complexities of the interdependencies of an ecosystem in formation are far beyond what the field of HCI/IxD covers, there are some topics, arising repeatedly, where our field has failed to provide key puzzle pieces, as we have not been seeing the full picture of what IoT-industry is trying to tackle. Without considering the complexities of what is happening here, HCI risks lagging behind, not influencing the future lives of many and not taking responsibility for the interactions that IoT-industry will push into the world.

The following sections reflect upon the interviewees design related comments. Particularly how they claim their most challenging issues are primarily of a technical or practical nature, while assumptions about the purpose or added value of these products follow implicitly (or explicitly) from their remarks. These human-centered design challenges are particularly relevant to the HCI community as they involve developing theory and new approaches to the design of ubiquitous systems that are relevant for industry's IoT professionals.

Considering the following sections reflect the discussions we had with our interviewees, we will save references to the relevant literature for the discussion section. Although many of the concerns they raise have been addressed by HCI researchers, we want our analysis to illustrate their struggle with these issues, despite that literature. This could highlight either their lack of engagement with HCI research, or a failure of HCI research to create compelling arguments or robust solutions to their problems. Either way, the following analysis is an attempt to voice the concerns of industry IoT professionals to HCI researchers in order to better understand the gulf that exists between the two. [ref]

The high-level themes are, in short:

- a lack of compelling use cases
- value added by systems need to compensate for the efforts required to maintain them
- the design thinking of IoT professionals reflect technical and practical concerns in addition to making mundane products more desirable

Use Cases?

The next step in analyzing the value theory and practice of the industries IoT sector, reveal their grand historical narratives [22], what current items they consider exemplary use-cases, and how they envision the near-future (and far-flung futures) for how this technology will be used in the everyday lives of consumers.

Historical Narratives

Several interviewees used historical narratives of technologies to explain the lack of compelling use cases for IoT. Most of these mentioned that famously, Alexander Graham Bell is said to have intended the telephone to transmit concerts, lectures, and sermons [ref], not anticipating that people would use it for personal communication. The invention of aluminum production, to plastics, radio, television, the Internet, and social media, are all narratives deployed to divert the conversation away from how IoT might be useful or world changing, given the precedent of so many technologies whose ultimate use was unanticipated. One UX designer paraphrased Marshall McLuhan's trope that the "*Content of the new medium, is derived from the old medium*". Certainly, it could be the case that the purpose of a vast network of connected devices may not emerge until that network is in place, though absent any clear reason to adopt a connected device over another (especially if the connected device costs more or requires a regular service fee) designers and developers will be faced with a chicken-and-egg problem, and speculative, novelty objects will proliferate for kick-starter backers and early adopters.

The Why's of Use-Cases: Rolling out products too early

One design consultant noted that there are three questions he asks of all of his clients that he calls the "*Internet of Why*", "*Why does this create value for your user? Why are these connected experiences or connected features im-*

portant to the overall experience? Why does this create value or improve your business model?" Granted these questions can be answered, his clients are in a better position to engage with the design process. The problem facing most individuals working with companies who are in the early stages of developing an IoT strategy is that they are not sure what services or functionality will be relevant for their business model. The hype of the technology, teemed with the concern for staying relevant is pushing more businesses into expanding their offerings to include IoT products, whether they be services connected to existing IoT hardware platforms, augmenting current products with embedded sensors, or developing new hardware altogether.

Partially due to the preponderance of IoT products seeking funding on Kickstarter, products often attempt to go to market too early without reflection on what makes sense both from a business model perspective or end-user desire/needs perspective. Whereas application software can be rolled out early and updated regularly, physical products for IoT do not share this advantage and thus risk losing large portions of their investment on manufacturing failed products.

As was mentioned earlier, most examples cited by interviewees could be labeled 'domestic' technologies, often with the focus of automating domestic chores with sensors and actuators. Though if these chores are only displaced by a user's need to administrate the system, the chore itself doesn't disappear, it only changes the nature of the work. An automated garden sprinkler system for example, will require some bit of initial setup, but if the network crashes, the sensors fail to detect how dry the soil is, or the sprinklers fail to read the signal from the sensors, the work involved will include not only manually watering the garden, but to maintain the automated system. This mundane example illustrates the complexity involved in introducing technological solutions to work that some might simply enjoy doing (i.e. gardening). Perhaps this introduces another challenge to the automation of domestic life, the desire to engage in activities that reside on the boundaries between work and play.

The Why's of Use-Cases: Tying Services and Flexibility to Smart Objects

One area for use case development involves service design. Service design for IoT involves any native, subscription, or on-demand function provided in addition to (or as a result of) the design of the interactive elements for the hardware or software elements of an IoT product. This begs the question of how to integrate the design of the physical or digital interactive elements with the attached services. Many that we interviewed emphasized the importance of the connection between IoT and services, though the examples they provided were often related to automated diagnostics for faulty products (e.g. troubleshooting the broken washing machine) or resource reallocation (e.g. ordering more detergent when you run out). In other words, service is where many IoT professionals see the most potential value creation, yet the use cases for this aspect are largely unexplored.

One vessel for thought around use cases in Silicon Valley market speak has been the "Killer App". Many of our interviewees would use this term to talk through what potential applications of IoT would convince consumers of the technologies value. For some this was the ability to tether services to physical objects and the actions they afford, others however spoke of customizability, or the ability to put IoT to work doing whatever it is individuals need doing. This appeal to flexibility (or lack of specificity) for consumer IoT products is reflected in many of the current IoT smart home kits, which usually consist of a series of plastic encased sensors and a hub or router. For instance, the SmartThings kit currently includes a water leak sensor, a multipurpose sensor, a motion sensor, an arrival sensor, a power outlet, and a hub. An engineer at a wearables company saw this as analogous with how smartphones have come be adopted, that is, not by virtue of any singular "killer app", but by being flexible enough to allow users to customize their experience.

Home IoT kits and similar products (e.g. Flic: the wireless smart button, littleBits) fall more or less in the category of 'hacks', although their setup and design is more polished than traditional interactive prototyping tools, their use is open to interpretation and seem aimed toward those individuals interested in experimenting with technology. This is an interesting development for IoT, though the use cases for these products are intentionally missing. While it may be exciting to see what interesting purposes people come up with when more accessible tools like these reach the hands of less technologically savvy people, this hands off approach does little to address the underlying issue for those heavily invested in making an IoT world a reality.

Although we spoke to a broad range of IoT professionals, among those working on industrial and consumer facing IoT products alike, both spoke of the current strength and value of industrial applications rather than the consumer-facing ones. It was suggested that measuring and automating responses to those measurements allowed manufacturers, farmers, distributors, and maintenance personnel to increase the efficiency and safety of their processes, automate labor that used to require personnel, permit of greater and more nuanced control, and in some instances allow them to develop entirely new products or services. For example, a managing director at a multinational technology-consulting firm discussed how they helped California vineyard growers create plumper, more consistent top-quality grapes with a higher yield.

Apart from the financial benefits that make adopting IoT technologies attractive for manufacturers, it was also mentioned frequently, especially by those working to find IoT solutions for industrial clients, that the infrastructure for these industries can be more readily adapted to IoT, given organizational cohesion, machinery already equipped with

sensors, the ability to generate large streams of data and draw upon historical data.

This illustrates something of the larger point we are trying to make about the lack of compelling use cases for consumer oriented IoT. The Internet of Things has found a reason to exist in industries where measurements, data analytics, and more broadly, efficiency, are key to the bottom line. This is not to say that consumer IoT products should follow suit by modeling individuals, homes, and cities on manufacturing processes via efficiency, on the contrary, part of what we view as a reason for the slow uptake of this technology by consumers (and thus the lack of compelling use cases) is the assumption that our lives can be better managed by technology for greater efficiency. Although computers, sensors, and large networked data streams may seem to offer solutions for better time management by simplifying or eliminating tasks, this is just the low hanging fruit.

A particular niche that could be filled by HCI researchers lies in the blind spot often obscured by a myopic focus on technological advancement and matters of practical importance prioritized by the technology industry. That is, developing design theory and practice for an IoT that attends to social and cultural life, while addressing the rich inner life of individuals, beyond matters of comfort and convenience, or completing chores. The problems currently being addressed by consumer IoT products are mostly concerned with designing away daily nuisances, or adding novelty to products that already exist as this risks missing those smart objects that address entertainment, and the aesthetics of our homes and cities.

This is not to say that reducing or eliminating tiresome chores through automation is a trivial matter for those that spend large portions of their days attending to those tasks, only that IoT appliance tunnel-vision could obscure the design of potentially more enjoyable experiences. The challenge for designers of IoT is two-fold, first, the interaction paradigm will have to be addressed, secondly, the purpose and use of the products and services will need to be imagined and designed.

Value Added ≥ System Management

Many of the obstacles to achieving a robust IoT mentioned by the interviewees were of a practical nature. Challenges such as the management of power, networks, updates, and security were often central to the discussion of what must be minimized in the design of IoT products. The assumption is that until these challenges are met, consumers will be unwilling to purchase these objects or will quickly abandon them once the novelty has worn off. Implicit in this supposition is that once the practical considerations have been addressed, the Internet of Things will inevitably succeed. That is, ease of use and convenience are currently the main focus for the design of consumer facing IoT things.

Managing The 'Smart' Home

The home is currently the target of most IoT consumer product offerings, yet as was noted, the notion of automating your home isn't something most people find necessary or appealing. When it comes to controlling lights (remarked upon as the 'sweet spot' for IoT), light switches are more reliable, easy to use, and allow users to control individual lights. The point being that for most, managing light switches is currently not problematic enough, the product offerings may not be compelling enough, or the market may not be mature enough to justify the switch to an IoT setup. One UX design consultant with clients developing consumer IoT products framed the issue with sarcasm, "*It's so hard to turn on my light switch. I can't do it.*"

A business strategist at a digital design consultancy remarked that the added functionality in terms of services or convenience for established products with an IoT 'upgrade' (e.g. lights, thermostats, glasses, refrigerators) must be valuable enough to compensate for any drawbacks, whether that be price, network problems, management issues, or battery life. She emphasized that the problem of managing all of the things within an IoT network, including the setup, charging or powering the device, or any other manual maintenance must be minimal in order for a product to succeed. The value added must justify any of these inconveniences, as it will be increasingly difficult to manage the growing network of objects.

Power Problems and their Workarounds

For example, most mobile phones require charging at least once a day, giving rise to a niche market of portable power solutions, yet mobiles phones remain a central item in people's daily personal effects. What keeps individuals from seeking less power hungry devices? Following the reasoning above, the advantages afforded by smart phones supersede the power limitations and thus solutions for power management proliferate. Of course, portable power only augments the battery life by adding another device to charge and keep track of. These work around types of solutions are sought after and tolerated to the extent that the devices they support remain central to the individuals who use them. It is one thing to make an exception for a smart phone, tablet, or laptop, but when the number of devices to be managed increases, and the value they add becomes less obvious, the less likely individuals will be to adopt.

One of the current complaints with IoT products is that most rely on interaction through a smartphone application or remote control. This is viewed as untenable in the long run as the number of devices to be controlled increases. That is why the consumer-oriented Internet of Things is still considered to be in its infancy, as the visions for IoT often assume a more tacit form of interaction or automation. One strategy to lowering the threshold for interaction involves beacon technologies that can broadcast information such as phone numbers, websites, advertisements, or alerts to be pushed automatically to the smart phone. Though this does

nothing to remove the screen-based paradigm or the notion of the smart phone as the central hub for the Internet of Things. Although most interviewed considered the smart phone as an IoT device, their expectations go beyond this being the center of interaction.

The Ambiguity of Added Value

Part of what contributes to the ambiguity of IoT is exactly the focus on the technical and practical considerations at the expense of designing objects that add clear value above and beyond their non-networked counterparts. This is especially true for IoT 'upgraded' versions of already established products, as most of these appliances in their non-upgraded form have reached a level of sophistication that they require little to no maintenance or setup (e.g. toasters). Yet this is not quite true for their IoT counterparts. One interviewee gave the example of toaster oven printers able to print shared images on bread, "*Is it stupid? That idea? Yes. It's also kind of awesome.*" The problem of missing use cases and compelling visions for these products that go beyond the temporary nature of novelty items will continue to be present even after all of the practical considerations have been met.

New types of interactive products that can take advantage of large streams of data, wireless protocols, and new materials can potentially thrive off the development and dissemination of these more mundane appliances, but we must first develop new visions for alternative ways of living through technology design.

A UX designer working for one of the major global technology firms stated several times that the whole point of user experience design is that it should work toward making our lives easier. For the Internet of Things this means it should work out of the box with as little maintenance as possible. Whether or not you agree that the aim of UX design is to make life easier, if a device doesn't work or requires regular upkeep, chances are those things will not become integral to daily life. Extend this reasoning to the exponential amount of objects predicted for IoT, and it becomes clear that practical limitations must be weighed against functionality during the design of these objects.

DESIGN THINKING

We asked our interviewees about the role of design, specifically how they view interaction design for the Internet of Things. Those with most to say about this were typically UX professionals working on IoT related projects, though engineers, project managers, and corporate IoT researchers often revealed insights relevant to understanding design thinking for IoT. Part of what makes interaction design for IoT particularly interesting is the movement toward less tangible interactions, those interactions that incorporate various environmental sensors and thus include less commonly used interaction modalities. Though tangible interactions should be used to inform certain IoT products, with the amount of automation predicated upon a full fledged IoT, it remains questionable whether or not we can rely on the same interaction paradigms and metaphors going forward into designing sensor rich networked environments.

The Magic of Unloved Objects

When designing an Internet of Things for such mundane products as thermostats and smoke detectors, there exists a tension between not calling attention to these devices unless absolutely necessary and the need to make them interactive, beneficial, and attractive enough to warrant purchasing. One engineer we interviewed working at a major consumer IoT company called these "*unloved objects*" and noted that their design brief is to "*Inject magic into them using the Internet of Things so they appear both magical and marvelous.*" So the challenge is to create an object that can fade into the background (a la calm computing) while also being aesthetically beautiful and interactively robust.

Designing for Failure

Designing for failure was something one of the interviewees noted was important in such a situation as consumer IoT products are currently in. Reliant on stable networks, less than robust relationships between objects (at times due to proprietary constraints), and a lack of attention to human needs and desires from the beginning of the design process are all contributing factors to consider when designing a device for graceful failure. Traditional embedded systems can still be equipped with sensors and actuators but do not always require a network connection to function. IoT products designed to fall back on local connections via bluetooth when they fail to connect to the larger network or cloud, could potentially hedge loss of local functionality. In addition to this one IoT UX designer noted that notifications should be pushed to the user when the Internet connections to IoT products fail. More solutions like this will be necessary to ease consumers into the mess that can result from a consumer IoT in its infancy.

DISCUSSION

The following section engages with the discussions analyzed above by further unpacking the implications for how to proceed given these challenges. Our intention is to broaden to discourse around IoT by introducing industry concerns into the wider discussion around embedded networked technologies within HCI.

Value Added ≥ System Management

In summary, the [value added ≥ systems management] equation reflects at least some of the industry's current design thinking about value for consumer IoT products. Though this consideration may also be used to address practical matters, it should also be extended to include the underlying purpose or functional elements that contribute to or engage with humans in ways that not only address issues of convenience or comfort, but those that recognize societal, cultural, or inter-personal pressures (i.e. the inner-life of individuals). In other words, the why question of "do we really need this?" That is not to say that matters of practical importance cannot address these issues, only that we should be thinking more critically about how IoT might answer the

hard or messy problems related to existential matters i.e. what is the good life, how to live the good life, how will these technologies impact how we think about ourselves and our lives, or how do we want this IoT world to look.

Use Cases?

The 'Everyday'

First, a brief word about the use of the concept of the 'everyday' and the narratives about 'everyday' life emerging through the discourse of both industry and academic research and practice. How we conceive of the 'everyday' broadly impacts the types of designs that eventually shape concepts of the 'everyday' for users. If our notions of the 'everyday' only address the nuisances and frustrations that users face with technologies, we are designing quite narrowly and not for the rich experiences of users.

That is to say that if the types of behaviors created by interacting with IoT technologies assume a concept of the 'everyday' do not address fundamental human needs, desires, or goals, those issues will never be familiarized or practiced enough to include the 'everyday'. For instance, Erving Goffman's 'The Presentation of Self in Everyday Life' deals broadly with the expressions of individuals and the impressions they make within their social order. [13] Goffman's notion of the everyday is markedly different from how industrial IoT professionals address this through design. While Donald Norman's 'The Design of Everyday Things' conceives of the 'everyday' in terms of the design of objects used daily, and bears more relevance for design focused on the practical and cognitive constraints to bear in mind when designing products. [21]

Both of these approaches to understanding the 'everyday' bear relevance for IoT design, though we would make the case that Goffman's personal and social considerations need a closer look when constructing notions of the 'everyday' for consumer IoT products. The risk being that these new type of networked objects and their related services may overlook crucial aspects of how society comes to live and understand the 'everyday'. At least, these questions bear asking when designing and developing products and services for everyday use, "What do we mean by 'everyday'?" and "What do we want 'everyday' to be like?"

In his exploration of the meaning of context in HCI, Paul Dourish, speaking of the ethnographic accounts of technology use writes, "I have been concerned not simply with the empirical contributions of that style of research, but with it's analytical contributions—its central concern with the fact that the orderly nature of everyday conduct is an achievement of social actors, rather than something imposed upon them." [8]

This highlights the current problem with the approach IoT is taking to developing for domestic life. That is, those industry professionals tasked with designing and developing for IoT need to engage with notions of the 'everyday' that acknowledge human agency and the constantly evolving construction of our daily lives and how our agency develops in concert with the agency of those objects and environments that surround us.

Part of the problem facing the search for IoT use cases is that a focus on efficiency and convenience, often underpins an assumption that saving time is the highest value. Of course some chores can be frustrating to complete or remember, but to capture the attention of consumers for the Internet of Things, either these objects must outperform their current 'unintelligent' counterparts, engage people in a manner they find surprisingly pleasant, or render previous tasks irrelevant.

Design Thinking

There seems to be two classes of IoT hardware currently being designed and developed. Those products that serve as +1 IoT upgrades to previously established products (appliances), and those novel products that present new forms of interaction made possible by sensors, actuators, and embedded networked computers (tangibles). Of course, there will be objects that reside somewhere between these two spaces, and it can be expected that IoT appliances will initially dominate the product offerings, but the major challenge is to design new types of objects that introduce novel forms of interaction.

No where else is it clearer than at the Maker Faire, that the design of interactive technologies, particularly for networked sensors, actuators, and computing platforms, is being left up to hobbyists, start-ups, and those not concerned with commercializing products. Although the Maker Faire, and the maker community at large is passionate about these endeavors, at times it seems as if industry developers are passing the design buck to the public.

Disclosing Expectations for IoT Interaction

A crucial aspect of design for the Internet of Things involves the user's expectations for interactive products. These expectations can either be challenged by tangible interactions or more subtle implicit interactions with environmental sensors and actuators. Correspondingly, the result of the interaction can either be rendered explicit or implicit.

Imagine for instance an IoT stapler. This stapler appears undifferentiated from a regular stapler, but is equipped with a sensor for detecting and communicating when something has been stapled and by whom. From the user's perspective it functions exactly like every other stapler they have previously encountered, it staples papers together. Though on the back end the stapler is transmitting data to the supply chain about when, where, and by whom the most staples are consumed.

This suggests that as IoT appliances are further developed and integrated in domestic and work life we will need new signifiers for recognizing the functionality of these products. These could take the form of symbols, labels on products, or perhaps more interestingly, new form factors or

entirely new means of interaction that individuals recognize as networked objects.

CONCLUSION

In Julie Halls book compiled from selections of the UK National Archives 'Inventions That *Didn't* Change the World', she explores the proliferation of domestic and industrial patents submitted during the boom of the industrial revolution. The patents that are discussed are those designed for highly specific purposes that never made it into production, weren't widely adopted, were too absurd to understand, or just didn't work (e.g. flying machines).[15]

Our suggestion is that the current propagation of IoT gadgets serves as an interesting analogue to the explosion of useless inventions during the Victorian era. All it takes is a search for Kickstarter Internet of Things projects to see that we are currently experiencing a similar boom in useless product offerings. We are not suggesting that this is an altogether useless pursuit, as Halls writes of 19th century British inventiveness:

"*In the nineteenth century anyone who had an idea that might solve a problem or speed up a task could come up with a technical solution. Inventors were ingenious, imaginative, sometimes misguided, but, in the unexpected world of Victorian inventions, ever hopeful.*" [15]

It is this sometimes-misguided hope for the promise of realizing their visions for a robust IoT that drives many to pursue this technological path. Although there are countless inventions that never saw the light of day, many have survived, thrived, and blazed the trail for future developments.

The ambiguities involved in understanding what the Internet of Things is, what its function will be in our daily lives, and what competencies will be required to design compelling products for consumers are at times beneficial due to their openness to interpretation, and at other times frustrating when trying to coordinate shared goals and visions between various actors. The vagueness of the concept and its implementation can lend itself to a variety of interesting developments, and could be seen as an indicator of excitement and interest, though attempting to pin down precisely what is at stake is increasingly difficult. That is why our engagement with industry IoT professionals has been an illuminating experience, particularly because of how confused those at the tip of the IoT spear are as to what they should actually be doing or where this technology is headed.

Despite many proclaiming the inevitability of an eventual IoT saturated world, we have found little reason to currently believe, apart from market analyses involving dropping price-points and the broad interest in technology, that IoT should ever permeate our world in the manner suggested by those corporate visions on display.

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Appendix 2: Folkhemmets IoT

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Introduction

The term “Internet of things” (IoT) has become popular in industry and research to describe changes in all sectors that are related to the enhancement of work processes, leisure activities, public space and many other areas of modern society through connected computational devices. But how do we understand today’s challenges and opportunities for IoT when entering the home environment? How are things connected and more importantly what for? A set of home visits helped us scrutinize everyday practices, challenges and the use of existing technological solutions in order to gain an understanding of how modern families are appropriating technology in their homes and at which points IoT products can support and enhance domestic life further. We use our observations as a starting point to discuss the most important challenges and implications for the design of future IoT.

The data we gathered is very rich and it is a challenging task to filter out relevant observations that point towards potential IoT solutions. However, the purpose of this report is to present an explorative analysis that will sketch some key findings. As a first step, through a gallery of family portraits, we will present a set of examples on how we integrate and use technology in everyday life. In the second step of our analysis we look for repeated patterns across all places we visited.

Methodology

For this study we conducted an ethnographic study and analysis that was building on “family portraits.” These portraits were based on in-depth unstructured interviews and contextual inquiries in eight family homes (of which seven are reported here). In total we interviewed 16 people ranging age 16 to 51. We were able to recruit a wide range of different families, varying in socio-economical status, family status as well as living situations. Four of the here presented families lived in rental apartments (“hyresrätt”) two of them in condos (“bostadsrätt”) and two of them in houses. All families were living in the greater Stockholm or Malmö area.

The ambiguity of the term “Internet of things” in combination with the very explorative outset of the overall project confronted us with the challenge to frame the research with a methodology that could deliver concrete and comprehensible insights of the home as a whole while taking even smaller and potentially important interactions into account. Because at the beginning of our study we had very little idea of how IoT technology is in fact present and apprehended in swedish consumer homes, we designed the methods iteratively, developing the approach throughout the whole research process.

After initial contact we would meet the families for an in-depth interview that would take app. two to three hours. During the interview we let the families guide us through their homes and show us all rooms, concentrating on the function, placement and

meaning of different technologies but also focusing to a great extent on everyday family practices. As part of this families were prompted to describe their daily routines and the things that are involved in them. At the end of the first interview we would hand the family a diary ("trassel- och jubeldagbok") and asked them to write down occurrences during the upcoming weeks that were either negatively disrupting/frustrating or stood out positively. Following up we would visit the families a second time and going with them through the notes in their diaries in order to identify important practices and their meaning for the family's everyday. Data was recorded in form of audio recordings, photos and fieldnotes. For the analysis data was coded and clustered according to emerging themes that became apparent throughout the process. Thereby we focused in particular on three major elements:

Firstly we were interested in practices evolving around the use of technology and how the tie in with family life. We observe different technological artifacts and how they are used either individually by different members of the family but also in social contexts. Secondly we are interested in disruptions and solutions for existing disruptions. Because everyday life does usually not run completely smoothly we are looking for those situations in which practices are interrupted or fail to work. Hereby we are not just looking into practices involving technology, yet we do consider the potential role of technology. Thirdly we are interested in the spatial relationship between home and technology. We are taking a perspective that sees technology not only socially or habitually but also spatially embedded into the domestic environment.

In the following we will present two levels of the analysis. First we will present the emerging themes that we could identify. Thereafter we will discuss the most important potentials and challenges we regard as crucial for understanding IoT at home.

Observations

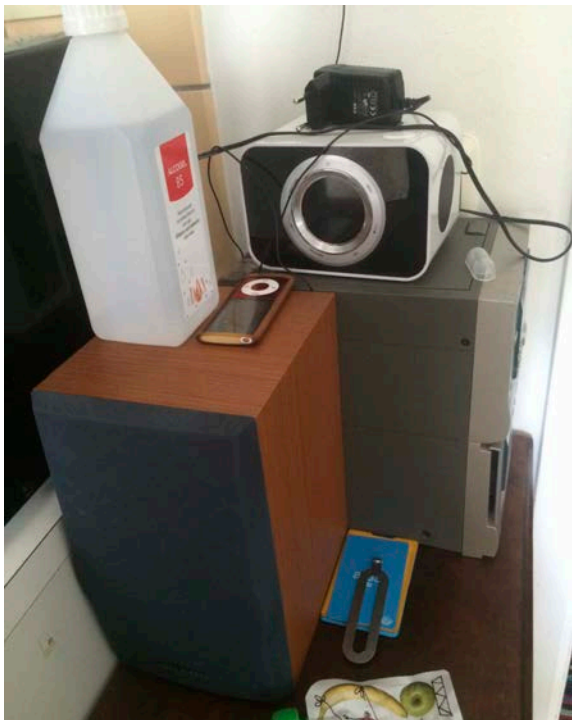
We present the observations in two steps. First we present each family briefly, their home environment and used technology. We seek to characterize each family in terms of their technology use and the way they work as a family. However, these descriptions remain vague to a certain extent and are more meant as an analytical construct in order to show major differences between families. In order to get a closer and more accurate idea of how the different families are managing technology around them, we will hereafter describe some closer observations along more common themes we observed.

Family 1: Organizing new family life

This family of three living in a rental flat in a suburb of Stockholm is dealing with the new situation that their young baby has brought into their everyday life. While the dad, who moved for his wife from Ghana, is focused on adapting to the new cultural environment, the mum is putting large effort on keeping the home and daily life organized with the help of detailed lists and plans. Most important for both of them seem to be their individual laptops.

While she uses hers mainly for work – also in the home – he sits usually in the living room watching the baby and surfing the web, mainly to connect to his home country. Apart from the laptops both are having a cell phone each and a TV in the living room that they use to watch movies together. However, when watching TV on their own they are using their phones or laptops. A separate room serves as the home office but is rarely used as such.

Instead it serves as an additional storage and on the desk they keep the printer. In case something has to be printed they carry the laptop over there and connect via cable. Another technology arrangement is a combination of speakers and iPod in the kitchen that is solely used to listen to radio in the morning.



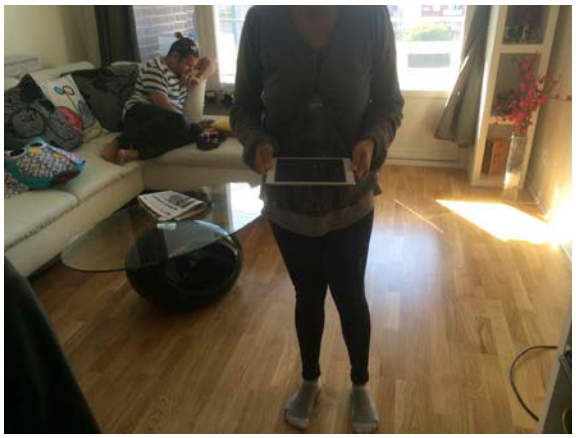
Family 2: Moving

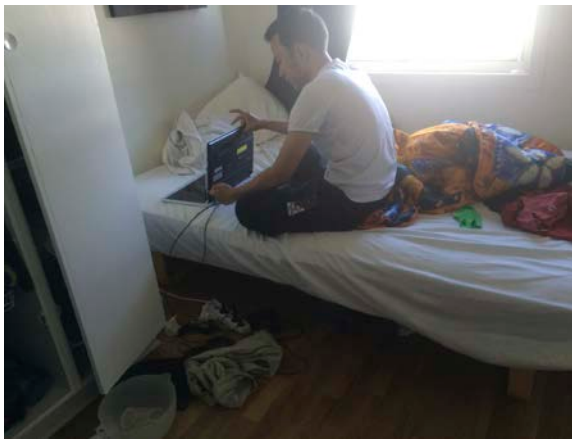
This family has a rather unusual constellation. In the 3-room rental in Malmö live the mother and her son together with the mother's brother. The constellation of this family has been recently disrupted. Because the passing of the mother's husband forced them to relocate to a smaller apartment and they are still in the middle of moving.

The family consists of the mother (in her 40's), her brother and her son (15) from a previous marriage. All three of them are originally from Brazil but moved to Sweden seven years ago.

The brother is looking for a place for himself but at the moment stays on the sofa of his sister. The son is in middle school (högstadiet). To the family belongs also a daughter (22) who just graduated from university and will start working soon. While she has her own student apartment close by, she visits her family frequently (almost every day).

The brother works as a chef in two different jobs. His sister just finished a study circle to become a nurse. The son is just about to finish middle school. Hence, the whole family has very different days. Family life is extremely important for them, they will always gather for dinner and create little family events, such as movie nights or just other friends coming around. Family life often centers around the TV, however, individually they are also watching movies and playing games (in case of the teenage son) on their own devices: The brother on his cellphone, the mom on her tablet and the son on his computer (that his mom has recently taken away as a pedagogical measure).

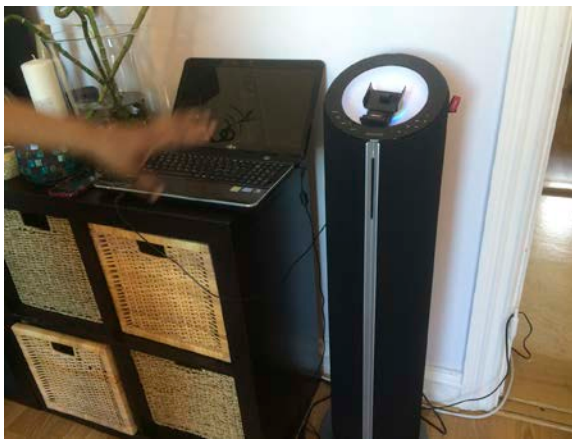


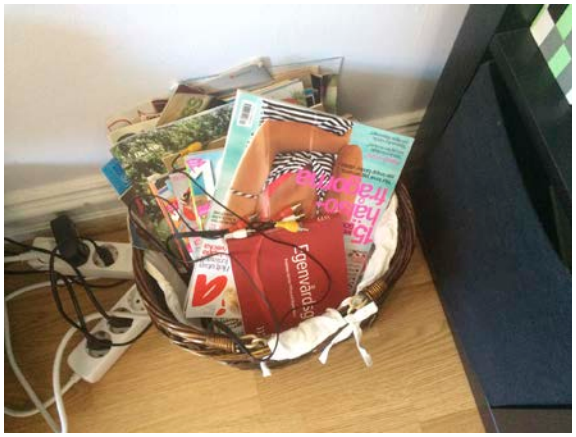


Family 3: Family life between two homes

The family consists of the mom and her three kids: Two sons (17 and 10) and one daughter (12). She shares custody with the father who is living in the same city but in a house. The kids spend one week there and one week with their mother. All of the kids are old enough now to get to school and around on their own now which makes her life much easier because she can go to work without having to wait for them. Nevertheless the mom likes to stay in touch with them during the day via facebook or phone. Usually especially the younger kids would call her after they come home and she would be worried if they didn't. In general life has become much easier for her now that the kids are getting older and can take care of each other. Especially the oldest brother has a great sense of responsibility for his siblings and takes care of them.

The kitchen is the family space. Here everything runs together. The eldest son spends a lot of time here cooking. The mum often sits her with her tablet or laptop and works. The upper floor belongs to her children. Usually they gather in their eldest brother's room, which is the largest. While the brother does not seem to have much say in who gets to come in, the younger siblings are very particular about their spaces not to be entered. The youngest son really wants to move upstairs to his brother's room. And while the brother is fine with this, the mum has her doubts if he is old enough to be in the room there. The living room seems to be sparely used, except for family evenings that involve a movie. However, those are happening not very often. Usually the mother would sit here when watching TV. In this family technology is used for entertainment and games and for school work. While there is a wide range of technology arrangements – TV and game console both in living room and kids room, stereo connected to mom's laptop and a frequent use of tablet and mobile phones – the family is not very aware of things. Everything has been arranged and is just part of the everyday flow.

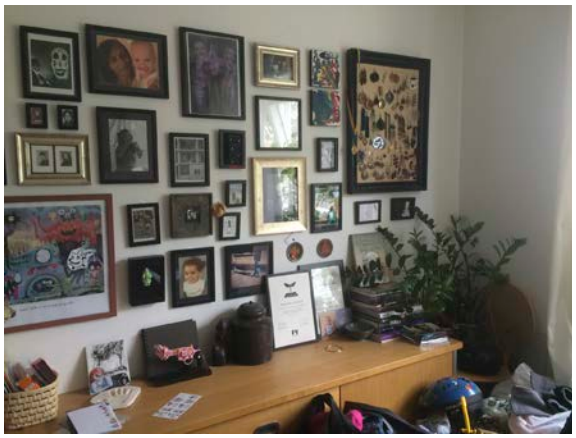




Family 4: Artistic teacher

Family 5 is a mother and her 6-year old son. They live in a part of Malmö that is close to the centre. While she shares custody with the father, the son spends most of his time with her, also because his daycare and now school is closer to her place. She works as a French teacher in middle school and really enjoys her work as a teacher even though it is sometimes tricky to combine it with taking care of her son. Many times she tells me she is just really tired after bringing him to bed, so her personal hobby fall a bit short. But now with the upcoming holidays she has a lot of "projects" she wants to finish, just as picking up painting again, sorting her storage and sewing curtains.

They are eating dinner together before she will bring him to bed. Afterwards she is often so tired that she will just lay on the bed and read or watch movies on her phone. She has two laptops, both provided by her employer but the older one is solely used for her son to watch DVDs because none of the other devices in the house have a DVD-drive. She proudly points out that she does not own a TV and instead has decorated the wall with photos and her own paintings. The newer laptop is used only for school work and usually placed in the kitchen. Additionally her employer provides an Ipad that she does not use at home (she considers it as "dirty" from all the pupils touching it). However, her son will use it regularly to play Minecraft.



Family 5: Close to nature

This family lives in a suburb of Stockholm in a two-story flat (bostadsrätt). Because of the green way the apartment is planned and the very green and idyllic environment, it gives much more the feeling of a row-house with a quite street outside where the kids can play. The family consists of 6 people, but not all live in the house permanently.

Permanently in the apartment live mother, father, son (8) and daughter (5). From a previous marriage the father has two almost adult sons (16 and 21). The eldest son has severe physical and mental disabilities and depends on constant care. He cannot really walk or stand and always has a personal assistant. Because the apartment with its stairs is not very disability-friendly, he spends most of the time with his mother. His younger brother prefers to stay with his mother too since he has got a room there on his own and most of his things are there.

The mother works as a freelancing garden planner, the father in a management position in a company, even though he originally trained as a sculptor and a lot of his art is still in the house. While there is not much ICT used in this family's house, she says, she is the "techie" in the house, usually taking care of IT stuff. However, she cannot really remember when she had taken care of anything, except for stuff with her computer and the printer that serves her own business. None of the younger kids have phones yet. The father has a laptop at work, but often comes home without and then just watches TV or reads. Digital technologies are not so often used as entertainment. One exception is the eldest brothers' room that has a TV as well and is used mainly when the two older brothers are living with them.

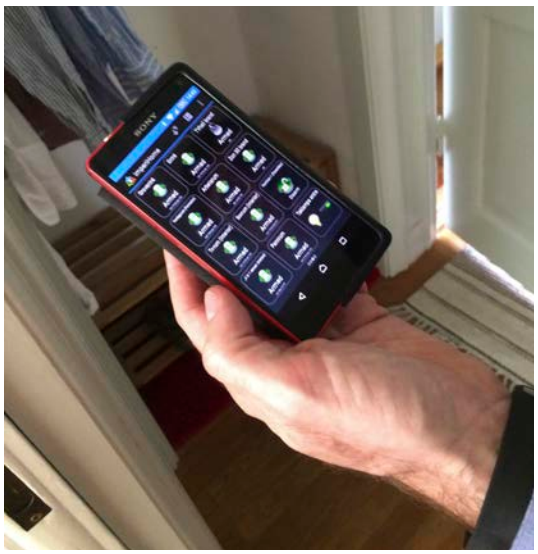
Family 6: Passionate “techie”

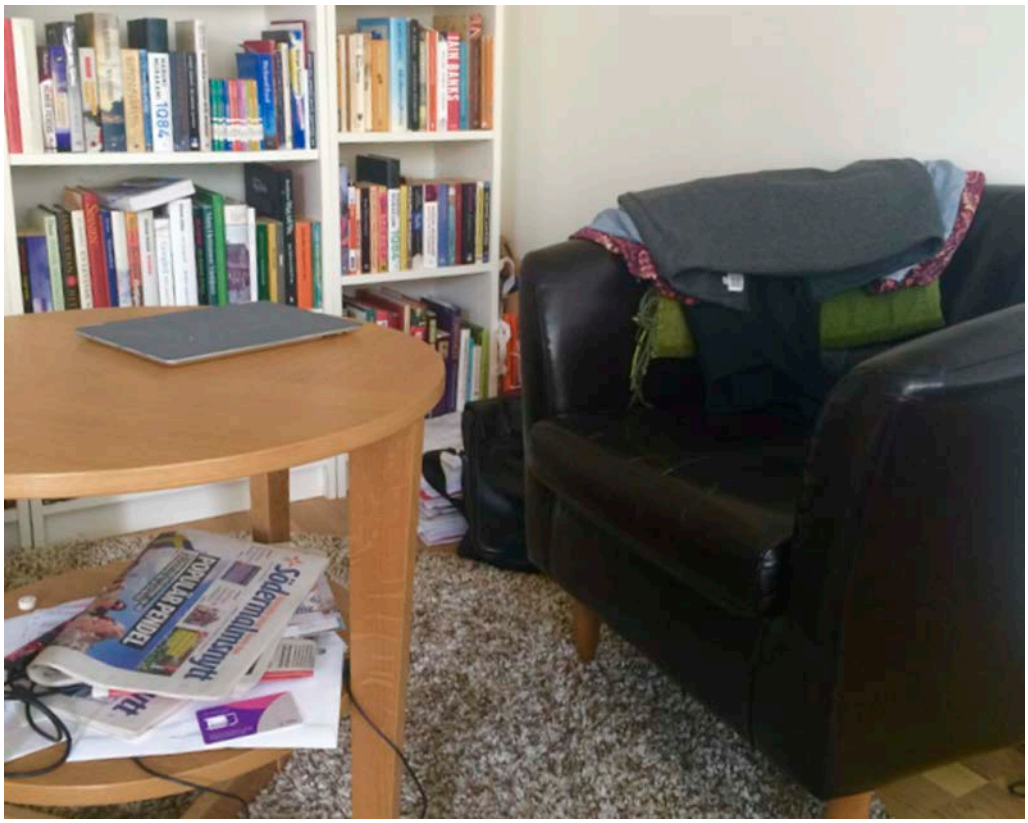
This family of 4 lives in a “villa” suburb of Stockholm in a two story house with garden. Both parents have a business related background and work in leading positions in big companies. They have one daughter (10) and one son (8), both in elementary school. The house is fairly big and well equipped. They moved here before their kids were born, because they always liked the area. In addition the family has a summer house in the archipelago.

Both parents have full-time jobs and work until app. 5pm. The older daughter will be sometimes alone at home after school while the son will stay at school until his parents are home. The kids are spending a lot of time upstairs in their rooms and doing their own things. Both have their own computers/tablets that they tend to not use too often. They also watch TV up there.

After the kids are in bed around 8 or 9pm the parents often relax, usually in the living room, where they watch TV or SVT play. Both of the parents have often work they brought home and they will work on it on their laptops. This family is fully equipped with technology and the father spends a lot of energy into finding a technical solution for everything.

Both kids have mobile phones and tablets provided by their schools. The parents have tablets and computers from work as well as mobile phones. Furthermore they have an iPad (the first model), these to listen to music. The family has two TVs, one upstairs for the kids, solely connected to a DVD player. The TV in the living room is connected to a lot of different devices: Stereo, apple TV, d-link boxee, Wii, xBox, digital receivers as well as to the Internet. Media are stored in the basement on a server. Instead of buying music, the father has together with his friends started a micro-peer sharing. This means they all copied their music on his server, this way they all have access to a very wide range, without having to buy or illegally download anything. Digitalised are also the alarm system and the entrance door locks as well as most lights on the ground floor.





Family 7: Newly single

This family consists of a mother and her two sons (16 and 17) living with her half of the time. They live in a 4-room apartment in one of the central parts of Stockholm since one year. The mother just quite recently separated from her husband. The couple sold their house and both bought their own apartments and are now sharing custody. However, the older son often decides himself where he stays when. The oldest son is not living with the family anymore since he is studying in another city.

The mom works full-time at a tech company. The two sons living with her are both attending school. While the boys spend a lot of time in their rooms (often playing computer), the mother has different areas in the kitchen/living room as well as the balcony. However, dinner they have together at the kitchen table and they do also sometimes watch TV together.

The use of electronics seems to be mostly divided in this house, with the mum mostly using the TV while both boys have their own electronic equipment. While on some occasions they watch TV together, the thing mostly shared is the radio in the kitchen. The mother uses mainly both – the tablet and laptop – for private activities such as surfing and watching movies. While the tablet is often used at an armchair (close to where it is charged), the laptop is mainly placed at the kitchen table. As opposed to the tablet it also serves for more complicated matters, such as paying bills or taxes.

Repeating patterns

The gathered data showed a very heterogeneous image of everyday family life with each family showing their own routines, social rituals, and strategies to face everyday challenges. It became very apparent that computing technology has already become an ubiquitous element in family homes, but also that its integration into the home comes in very diverse and often to the researchers unexpected ways. Thereby the grade of technology usage and range of devices differs widely. However, instead we found common themes around family homes. Thus instead of structuring our observations along the technologies used, we present those areas that were most recurrent in our observations and those that showed the highest degree of technology use.

Entertainment and family life

The most prevalent use of technology and where we could observe the most **connected** technology is the area of home entertainment. An important element of most living rooms was some sort of arrangement for watching television, playing video games or streaming movies from the computer or other devices. Popular arrangements included a TV that was connected to a laptop in order to view movies from there. The connection was made in most cases with the help of a cable and only in one case functioning fully wireless. Thereby the conventional TV program is very often not longer received via cable, families more and more rely on streaming services. Notably most families would call the streaming through TV station services such as SVT play also “watching TV.” However, unlike we had earlier expected, entertainment was not solely centered around this setting. Instead people had their own individual settings in which they would relax during their spare time, usually involving a tablet or their phone. In that their was a clear spatial and material boundary between individual spare time and social gathering.

Depending on how many members the family had this could mean that there were many different places and arrangements for entertainment in a single home. For instance an extra TV setting for the kids, a certain placement for tablet and phone to be used close to the charger or individual computers and tablets in the kids room. Those individual settings were usually maintained individually, thus there was connection between the involved digital devices.

Challenges and disruptions

One of the foci of our analysis was disruption. We looked in particular at those practices that were interrupted or not working properly. One of the first things that became apparent is that technology is not a large interrupter and even though not all set ups would work flawlessly the families would usually not regard it as particularly challenging to deal with these disruptions. In other situations a particular flaw was just accepted as such and in a way integrated into practices. One of the most prevailing examples in our observations has been the way families are dealing with the countless cables in their apartments. Cables that were not in use were often not thrown away but usually stored in a particular box, even when storage space was scarce. Cables in use, in particular in more advanced settings, would often not be hidden but instead

In general we could observe that families would not fully make use of the connectivity and the full technological function that devices could offer them. We noted that each family has problems, some more severe, while others a bit easier, to handle and bridge

the continuous shift in devices, cables, chargers and make them work together and to provide continuous services.

But those problems that were most demanding in daily life were usually connected to few other issues in the house. Firstly, raising the children and organiz-ing everyday around them was a major challenge for most families. From new-born babies to teenagers about to finish school, each age presented the parents with individual challenges but also experiences. Thereby we got the impression that those practices were constantly changing with the kids growing older. Families with kids seem to be in a constant change of adapting daily practices to whatever requirements their kids have at the time. Tied to this is the constant need of keeping things in order and stored. The biggest challenge reported by most families is the lack of storage. In addition to this lots of energy is spent on arranging daily routines such as pick-ups and preparing meals. This keeps the family home in a constant state of adjustment. Therefore families need the things around them to function and in case of disruption they will think of fixes or discard non-functional things.

Strategies and fixes

When it comes to using technology, most families work quite flexible and are very quick with solving problems around digital devices. Computers, tablets and mobile phones are arranged around daily practices in a way that they can be quickly replaced by one another. In one example a mother and her son describe how they bought tickets for the son's trip to Portugal, which was a very big thing for them (and only possible because she got a big tax refund). First both of them were planning on doing this together with the help of the tablet computer – device described as being optimal for sharing. However, when things got more complicated – the desired flight was not easy to get hold of – the mother switched to her own computer and handled it individually. In this example both technologies complemented each other in form and function, accommodating both the need for the social experience as well as the need for functional interaction. When looking at those ways of interacting it becomes apparent that disruptions that have a heavy impact are usually not caused by technology but instead by changes in social arrangements. Thus adding functions to technologies – such as increased functionality – will only in few cases directly affect the problem at hand. Instead it is a process of constant negotiation through which families are handling their daily practices.

Discussion

From repeated pattern like this we will, in the last step, present some emerging trends that hopefully spark new ideas and discussions.

The digital farmer kitchen

We see a transition from old to new technology and behaviour, generating new hot spots in the home that serve a multipurpose of social and technology functionality. This we call the digital farmer kitchen because – just as a farmer kitchen – these hot spots fulfil several (and often unexpected) purposes and are at the same time under constant arrangement. And just like the digital farmer kitchen, things can get messy on the way. We have shown that practices in the home are constantly underlying disruptions and at the same time new solutions or just quick fixes. This indicates a new use of the physical space at home and the way materials are arranged with each other. This also means that technology is

often not used in a way than the designer has originally thought of it. This dynamic needs to be represented in IoT on different levels. IoT needs to support mobility where stuff moves around and can be used in different context. Dynamic and smooth reconfiguration is also needed to enable an easy handling. Moreover, in order to make IoT useful and wanted in different context a responsive design can handle these dynamics.

Stuck in between

Maintaining the home, and then in particular technology, is an ongoing project that balancing between working, semi- and not-working states. None of the homes we visited were in a state of being “finished.” And while the vision of IoT conveys an ideal of perfection and neatness integration, this vision runs diametral to the reality of the family home. So with many technological solutions, families remain “stuck in-between”. While they acquire part of the technology, the necessary set-up remains an unreachable utopia. This clearly points toward important tasks for the design of IoT in terms of compatibility and user friendliness. At this point IoT is mostly for the tech-savvy and requires constant attention/configuration. The lack of usability and standards badly hurt the user experience and trust of IoT. Driving these issues is hence an important task where industry and research needs to act together.

Digital memories

And finally, the last emerging trend is referred to as “Digital memories”. This touch on how we value, preserve and store some things, while others get discarded, and sometime digitalized.

IoT needs to co-exist and proxy with old technology that’s been appropriated into the home and everyday life. Furthermore, these trusted and appropriated devices are kept rather then transfer bulky data to new platforms. IoT needs here also clear and understandable ways to deal with trust and privacy to be added to existing platforms.

Conclusions

IoT in homes needs to show a clear value and benefits, that are well designed and crafted into IoT solutions. The design should focus on solving concrete everyday routines and challenges rather than add gadgets-features. Finding a good balance between aesthetics and usability is most likely a key differentiator in the current IoT wave.

These insights comes from understanding technology appropriation. Design has to function even when individual solutions looks very different. User decisions is mostly based on things and routines that are working well in the domestic environment, and support an understanding of the home as in progress. For this there yet have to be convincing use-cases that combine the “messiness” of everyday family routines that are constantly under construction with the clean and homogenous vision of IoT solutions.

Last, and fundamentally, making IoT accessible from a both technical and economical perspective for everyone is a key driver. Finding affordable but still well designed IoT is a challenge that’s doable but can be accelerated with industry and research partnerships.

Taking this together we are argue for Folkhemmets IoT. The base of the Folkhem vision is that the entire society ought to be like a small family, where everybody contributes. The IoT development needs to pick up on these values and make sure that the benefits of the digitalisation is for all. Long term visions for Folkhemmets IoT should be developed by mixing research, companies and organizations ideas and goals into participatory and democratic developments to give everyone equal opportunity and provide everyone with the benefits IoT for increase digital living standards.

Appendix 3: Market potentials

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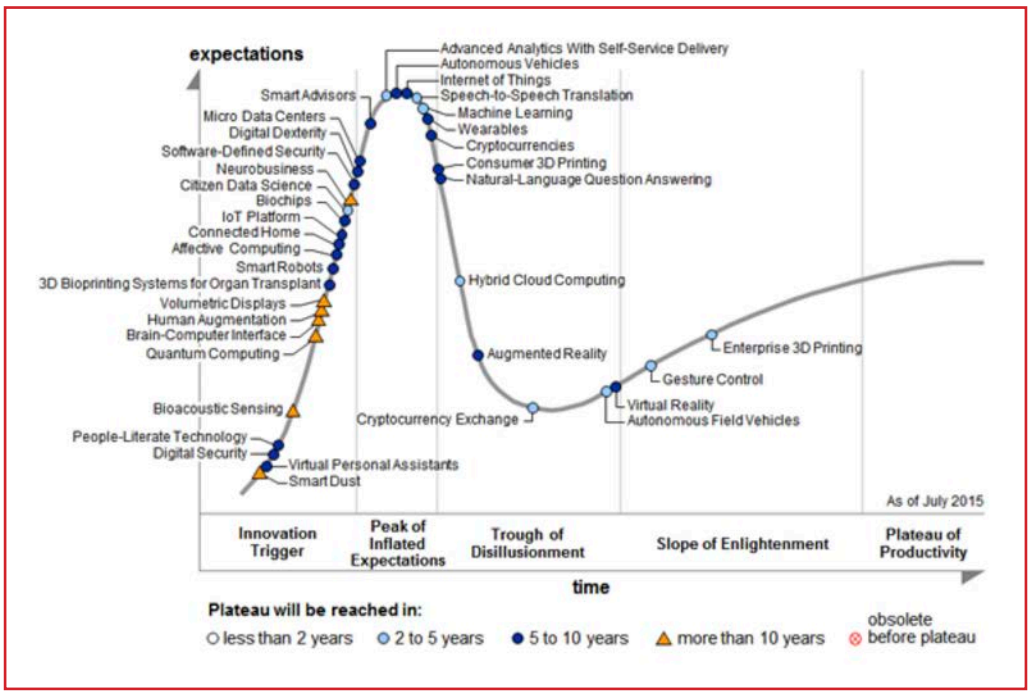
Introduction

The majority of the available surveys and reports related to IoT applications and opportunities relates to B2B applications and a traditional way approaching a business opportunity. It seems to be a natural projection from the M2M initiatives made in the early 2000 century. When searching for surveys and reports related to B2C IoT applications and opportunities, most of the available material is overestimating the market potentials and underestimating the complexity and time in taking value adding products and services to the consumer market.



Gartner hype curve from 2015. Internet of Things at the top.

Findings

To be able to assess the true market potentials for consumer IoT, it is essential to be able to address some key components that impact the ability to make a better and more accurate estimation of the true market and the critical success factors. Key components to succeed with this effort are the following.

- A big picture vision related to IoT and its relation to ongoing macro trends.
- Intelligent IoT products based on real perceived user value.
- Proven business models were consumers are prepared to spend money either on an IoT product or IoT services with a clear added value to the consumer.

With a deeper analysis into what is commonly labeled Consumer Wearables the projections are optimistic and forecasts on growth exceeding Smartphones and Tables by 2020

(Morgan Stanley, Blue Paper, Nov 2014). The main challenges reaching these growth targets are thus.

- Current business qualification models and company silos slows down the growth potentials.
- Bigger companies do not dare to invest in intelligent IoT products due to an unclear ROI, verified user value and supportive business models.
- Lack of agreement related to standards is an obstacle and slows down the growth.

All these factors and the decisions makers' traditional view on executing investments and the associated business, constitute severe obstacles in leveraging on Consumer IoT opportunities existing today.

What can be done to accelerate growth?

The potentials related to Consumer IoT applications are extensive, but so are also the height and number of obstacles and pitfalls for execution. Possible way of managing the pitfalls and hence be able to leverage on available market growth opportunities are the following.

- Verifying market size, user values and business models with technology driven product and service development as a compliment to the traditional consumer driven development.
- Companies need to take a position and acknowledge IoT, set an initial busi-ness model add IoT intelligence to the product assortment and let the market adjust based on value and willingness to pay.
- Companies need support and end users' guidance in creating a roadmap for the future IoT evolution, comprising opportunities and obstacles for different market segments related to degree of fragmentation, maturity, stakeholders in the value chain, user values and cases, and current product/service offering.