Applications of Low Power Wide Area Network Sensing Devices
(Technical Paper)

A Framework for Emotion and Trust Between Humans and the Internet of Things
(STS Paper)

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Introduction

The Internet of a Trillion Things is coming, and it will increasingly be woven into our daily lives. The interconnection of small computers embedded in everyday objects, known as the Internet of Things, has been growing for more than a decade (Stevenson & Lindberg, 2011). That growth is expected to increase exponentially in the next decade; by 2035 more than a trillion devices are predicted to be connected—more than 100 devices per person on earth (Perry, 2019). Today, the generation entering adulthood has had technology present for a large portion of their lives, but grew up alongside it rather than *with* it. Toddlers are often seen toting iPads, but the future is more immersive than that. As compact, energy efficient, wireless devices mature, they will be integrated ubiquitously into life: smart home, smart car, smart road, smart office, smart grocery, smart park, smart life.

These technologies should improve our day-to-day life by introducing efficiencies, informing decisions, and enhancing communications, but they also stand the risk of instigating a deeply-seated negative human emotion: distrust (Ahmed, Ab Hamid, Gani, Khan, & Khan, 2019). If trust in the Internet of Things is lost, the technology will be rejected in a way which is difficult to recover from, stifling technological progress and the improvements it brings.

Our technical team is researching and prototyping long-range sensors which will operate for years on battery-power using Low Power Wide Area Network protocols. These new protocols are the beginning of what will enable the diverse and proliferated devices that will bring the Internet of Things out of the home and into the rest of the world. As work is conducted on the technology and use-cases, I will be developing a framework for designing devices in a way which will inspire trust and enable optimal human-computer interactions.

Technical Topic

There are tradeoffs with any wireless technology. The largest, and often most important, tradeoff is between range, data rate, and power consumption (Danbatta & Varol, 2019). The further a given signal must transmit, the more power it will require to get that signal to its destination. Similarly, the more information that must be sent, the more power it will take to send. Additionally, higher data rate signals are broken up more quickly by interference and travel shorter distances. AM Radio uses high power to transmit small amounts of data—mono audio at a relatively low quality—long distances, up to 100s of miles. At the high end of data rate lies a Long Term Evolution (LTE) cell tower. Even using high power, LTE towers transmit only a few miles, trading off that range for very high data rate connections to many devices, enabling mobile video streaming and high speed internet (Ayoub, Samhat, Nouvel, Mroue, & Prévotet, 2019). Lastly, Bluetooth is an example of a technology with a focus on low power. Bluetooth devices such as headphones can last for hours on a tiny battery because they have limited data rates—just enough to stream audio—and very short ranges of just tens of feet. Wireless protocols range across the full spectrum of this three-way trade-off, targeting a narrow set of use-cases to provide the best application specific performance (Danbatta & Varol, 2019).

As technology improves, however, the boundaries of this trade-off continue to change (Campbell, Pannuto, & Dutta, 2015). With better designed transmitters, range is increasing at the same power levels. More efficient communication strategies are improving data rates without sacrificing range or battery life. These improvements have opened up a new class of communication protocols known as Low Power Wide Area Networks, or LPWAN. Using an LPWAN chip, a power efficient device can communicate at ranges of 3-10 miles while lasting for years on just a few AA batteries (Kabalcı & Ali, 2019). The trade-off is in the data-rate, but these networks are still easily fast enough to transmit sensor data and could even stream audio. LPWAN technology, in turn, has enabled applications which were not possible just a few years ago. In areas where power is inaccessible, traditional communications such as Wi-Fi are not available, and/or the cost of using traditional cellular networks is prohibitive, LPWAN shines as a new way to connect devices.

Our client, Alarm.com, is a smart home and home security provider. The company partners with security system installers to install intelligent home solutions backed up by Alarm.com's core product, an integrated software platform for home management. Alarm.com has taken notice of LPWAN technology and is interested in how it may present the possibility of expanding their business outside of the home to extend their platform's capabilities in new and exciting ways. Our team will be exploring the technology, generating use-cases, speaking with potential users, then developing and refining prototypes of new sensing devices to pitch to Alarm.com.

STS Topic

The technology used in our daily lives is transforming from a simple tool for accomplishing work to something much more profound which is intrinsically connected to our emotional state. In 2011, surveyed users spent an average of 46 minutes a day using their mobile devices. By 2015, that number had risen to 2 hours and 54 minutes ("Growth of Time Spent on Mobile Devices," 2015). Walking around on any given day, it is easy to see the enormous number of users interacting with their smartphones. More difficult to see is the growing number of interactions which people have with Internet of Things devices. These interactions may be passive, such as one's thermostat detecting their departure and adjusting the temperature to save energy, or intentional interactions, such as asking a smart home speaker what the weather will be like before picking an outfit for the day. Whereas a phone is often central to a given moment, the Internet of Things lies in the periphery and can affect a person in subtle but impactful ways (Montag & Diefenbach, 2018).

Today, the Internet of Things remains slightly out of reach, and perhaps under-useful, for the average consumer. Prices will continue to drop, technology will continue to improve, and the smart home will become just as common as the smartphone. As the Internet of Things grows in the home and overflows into our cities and workplaces, its presence will eventually affect every person who lives in a modernized society (Gudur, Blackler, Popovic, & Mahar, 2013). Any device which is useful to us today stands the chance of becoming internet-connected, and many new use cases will arise which we would never consider today (Ashford, 2014). Behind this wave of growth will be startups, new companies filling the spaces, but also the technology companies we know today: Apple, Google, Amazon, Facebook. Backing the hardware will be more big players: the telecommunications companies. Internet Service Providers such as Charter, Cox, and Comcast and cellular providers such as AT&T, Verizon, and Sprint. Finally, linked to both the consumers and the large companies will be the governments which will inevitably need to step in to regulate certain aspects of IoT devices and perhaps entire segments of the business such as smart cities (Lo & Campos, 2018).

To analyze these interactions, I will be using Actor-Network theory and the theory of technological momentum. Some scholars argue that Actor-Network theory does not account for pre-existing structures, instead assuming that everything is actively emerging from relationships

(Whittle & Spicer, 2008), but the addition of technological momentum analysis will allow me to fill in those gaps. Additionally, to deal with the lack of determinism in Actor-Network theory, I will be tightly scoping the components of the network to deal specifically with the user-device interaction in a home setting—the area which requires among the highest trust (Coughlan et al., 2012). This narrow scope will allow me to manage the number of connections and pull out meaningful conclusions. I will be using technological momentum to investigate the overarching societal players; big companies, government, and long lasting physical hardware are slow moving entities which are resistant to change but can absorb and sustain a new idea if it fits well. With these two theories, I will be able to analyze both fast and slow interactions and the way in which people adopt new technology into their lives.

Research Question and Methods

How can Internet of Things devices be designed, integrated, and managed in a way which inspires trust in users? I will be developing a framework which can serve to guide companies to success and proposing a complementary set of regulatory restrictions which will serve to protect consumers from abuses by technology firms. Previous works have analyzed the issue of trust, but have primarily focused on how a person can determine whether or not to trust a device rather than how companies can design and sell the devices (Xia, Xiao, Zhang, Hu, & Cheng, 2019), (Fritsch, Groven, & Schulz, 2012). Using historical examples of pairs of similar technologies in which one failed and one succeeded, I will examine their differences to find issues where human trust may have played a role. A policy analysis of both US laws and regulations and foreign governments' rule concerning Internet of Things devices will inspire my policy suggestions and show me where gaps exist. And a wicked problem framing will help me better assemble evidence and understand why this is such a difficult problem. These techniques will be paired with the STS research frameworks mentioned above.

Conclusion

By the end of this academic year, my capstone team will present one or more Low Power Wide Area Network sensors which will provide a valuable addition to Alarm.com's current line-up of home sensors by offering a meaningful expansion from the company's current market of home security into other markets which can benefit from the software platform Alarm.com is known for. To address some of the potential problems brought by a growing Internet of Things, I will also present a framework for how companies can develop Internet of Things devices in a trustworthy way and how the government can regulate the companies which find their way into our daily lives through the Internet of Things.

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