The Internet of Things (IoT) and Libraries

On Technology and Libraries in the Twenty-First Century

Libraries face profound service challenges in the twenty-first century. Some of the challenges relate to changes in the networked information landscape of the last several decades, including the massive and direct availability of information without mediation of a librarian, the challenges associated with curating and describing massive quantities of data, and the renewed challenges related to library as a place combined with perennial questions about the future of print. The intersection and culmination of several of these effects of networks, spaces, and data are poised to disrupt technologies within libraries as the so-called Internet of Things (IoT). The IoT is comprised of billions of connected devices that usher in a new realm of possibility for library service development and innovation.

Some may be wary of the oncoming IoT development since, in no small measure, libraries are asked to do more with less in an age where technology has not always delivered on an upward rising trend of making operations more streamlined or efficient. The implementation of new technologies can, in some cases, even lead to less stable services in the near term as newer services attempt to scale to demands. Technology disruptions do not always end up with the hoped-for result of service efficiencies. There are times, however, when the technological promise is too profound to ignore. Enter the Internet of Things, the latest evolution of networked computing technology, made possible by the ever-smaller form factors of computers and sensors, the combination of which provides a distinctively different, and somewhat unusual, promise. The IoT encompasses very small computers, directly or indirectly connected and interconnected with the web and everyday objects to provide profoundly innovative levels of monitoring support, device control, service innovation, and, for many, business opportunities.

Defining the Internet of Things

Defining the Internet of Things is a challenge. This challenge is caused in part by the newness of the domain and the many varied services that technologists foresee for the IoT. IoT technologies encompass not just one type of hardware but many kinds of hardware that have existed as unconnected devices. Smart appliances, like networked thermostats or network-accessible “smart ovens” are examples that only begin to scratch the surface of the IoT service possibilities. Several technologists consider the shift to the IoT, where every appliance is networked and has an IP address, as inevitable. The IoT literature goes on to suggest that the IoT will encompass millions of devices linked with the Internet, relating information about environment, logistics, and control systems.[1] Some suggest the IoT will be connected as part of a larger cloud infrastructure that can autonomously collect and produce data about the environment in which it exists. IoT devices are not desktops or mobile devices, but rather computing machines that aren’t traditional end points of use; in other words, the IoT devices do not have traditional interfaces—they are more like probes that gather data.

One reliable source of technology industry reports is Gartner. The company is most likely known to library technologists for its development of the “Gartner Magic Quadrant” research methodology, but illustrative for our purposes is its helpful and more broadly encompassing definition of the IoT. According to a Gartner industry press release on this topic, "The Internet of Things is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment." Noting the economic importance surrounding the IoT, "Gartner said that IoT product and service suppliers will generate incremental revenue exceeding $300 billion, mostly in services, in 2020. It will result in $1.9 trillion in global economic value-add through sales into diverse end markets."[2] The business applications encompass affordances for efficiency, helping to reach out to new or returning customers.[3]

For library purposes in general, and the specific IoT library-based case study contained herein, we will use a working definition of IoT that includes how technologies smaller than traditional computing (laptops and phones) will interact with the physical environment. Since early IoT will necessarily have some overlap with what has come before, our case study will talk about how mobile technologies will interface with IoT architectures—namely, beacons that broadcast a Bluetooth signal that help to provide location awareness to modern-day apps.

Yet it should also be noted that, although mobile devices and applications seem an almost natural initial extension and interface into the IoT, there is no requirement that the IoT must be connected to mobile devices in order to provide service enhancement and novel functionality. In the work *Enchanted Objects,* by David Rose, the author noted that small screens, while enabling profound services through mobile device interfaces, may in fact not be the best way to experience connected objects.[4] Rose noted, "Today we spend most of our technology interaction time staring at little glass slabs, which are positioned right before our eyes and in the center of our focus. This must change. We need to better understand the workings of all five senses so we can involve them more fully."[5] The agenda sketched out by Rose is intriguing, since it speaks to ever more immersive and potentially useful IoT uses—that come untethered. In Rose's perspective, it would make sense to consider the mobile-enhanced IoT environment a transitional state to the more fully encompassing IoT in which devices are less tethered to our control systems of mobile devices, desktops, or servers and act more like the "enchanted objects" described in his IoT vision.

The reason IoT technologies are so hyped today is their promise for a deeper interconnected world and the anticipated benefits that these deeper connections will bring. At least one white paper author has referred to the IoT as "the network of networks" and "the first real evolution of the world wide web,"[6] and in some industries it looks poised to provide even deeper automation than is currently possible with nonconnected infrastructure.

We pause here to consider the notion that a deeply interconnected world is not new for those in the information professions, which leads us to ask: what is the departure point from library automation and library mobile apps? There is evidence to suggest that the IoT is comprised of small computer resources that are pervasively connected and directly tied to the cloud. If predictions play out as expected, these very small, pervasively networked computers will increase in quantities far beyond desktop, laptop, or mobile adoption. IoT is the culmination of several forces that include ubiquitous computing (like mobile technologies) manifested in the spread of the smartphone, the processing of data streams by cloud-based infrastructures, and the ever-smaller forms of networked computing components.

Examples of the Internet of Things

So far we have covered the idea of smart objects, which can encompass networked appliances. Networked appliances hold the promise of providing additional functionality, convenience, and overall increased standards of living. Take the refrigerator that can order additional supplies of a prespecified food type when supplies go below a predetermined threshold. Beyond the usual examples of smart home appliances like these, the IoT can literally encompass *anything*, leading some to describe the IoT as the Internet of Everything. As an example of the possibilities for an explosion of connectedness, consider the following examples:

- **Environmental monitoring (smart appliances).** There are several examples of consumer products, like the Nest thermostat, that illustrate IoT technology for the home. These devices, by using user input of temperature preferences, can learn over time the habits of the inhabitants of a house and their heating and cooling preferences in order to optimize the preferred temperature for when the occupants are home. Nest thermostats can be paired and optimized further from a user's mobile device. A mobile app gives the homeowners some ability to control and gather insights about the environment of their home.
- **Smart clothing and smart accessories (wearables)** can send health data to a central server for monitoring heart rate, blood pressure, and similar information. The data could offer predictive analytics into health monitoring. In an article from the Chief Futurist at Cisco, it was noted that within "the next few years, these capabilities will grow profoundly. We'll be able to swallow a pill

that can monitor our digestive tract and intelligently send relevant information to our doctors at the right time and in the context of what we're doing. Expectant mothers will wear 'smart tattoos' to monitor the health and activity of their babies, and send their doctor an early alert when labor begins. We've only begun to scratch the surface of how wearable technology will transform our lives."[7]

- **Hobbyist projects (Raspberry Pi and other small form factor programmable boards).** There are also many hobbyists interested in the IoT space. When we unpack several of the technologies that come into play in the IoT in chapter 3, we will draw on specific programmable microcontroller board examples. But these small computers have the extensibility to have additional peripherals, such as storage and displays, added to them. There are a range of possibilities for hobbyists in the IoT area. In some ways, these have some of the most interesting applications due in part to the flexibility of the devices.
- **Beacons (Bluetooth low energy).** There are some smaller form factor devices that are enterprise-ready; that is, they have graduated from the hobbyist realm and are available off the shelf in the consumer market. In chapter 2, we'll unpack some of the Bluetooth low energy (BLE) possibilities for location services within the IoT, and in chapter 4, we'll discuss the security implications of beacons that provide location assistance to library systems.

Possible Futures of the Internet of Things in Libraries

The IoT is an emerging area, and several possible services and innovations may become available as a result of an increasingly interconnected networked environment. There is speculation over how its various manifestations will impact our lives and the services we can provide within and outside of libraries. One theorist posited that, as a result of implementing the IoT, "a smart planet will evolve, where many of the everyday things around us have an identity in cyberspace, acquire intelligence, and mash-up information from diverse sources."[8] The software components needed to make this happen have not yet been developed since most IoT solutions are hardware-based and not federated into intelligence-gathering networks yet. Kopetz also noted that "the novelty of the IoT is not in any new disruptive technology, but in the pervasive deployment of smart objects."[9] Therefore, it may not simply be a single impact from one IoT technology implementation. Instead, the IoT stands to be a cumulative technology effect due to its pervasive nature.

The hypothetical and supposed IoT benefits to libraries involve issues around how technologists will be able to combine data that might be produced, consumed, or generated from IoT devices to provide innovations in service understanding, which may in fact lead to deeper automation. The data that are produced by inventory control over libraries might in fact help collection developers better understand how users interact with physical spaces.

With regard to the assessment of physical library space, previous to the IoT, there has not existed a good tool kit for knowing what user engagement looked like in collections and in service points at a pervasive level. Beyond assessment, a deeper insight into the actual use of library space will allow libraries to better tell the story of space usage and make decisions based on evidence.

The demand in higher education for evidence-based decision making has never been stronger. While there has been much study by ethnographic researchers who collect qualitative data about what students do in spaces and would like to do in spaces, a deep understanding calls for real quantitative use data about library spaces. There is an actively funded Knight Foundation Project, Measure the Future, which is utilizing IoT technologies for supporting spaces assessment. The Measure the Future project intends to produce hardware and software solutions that will provide a "Google-Analytics-style dashboard for your library building: number of visits, what patrons browsed, what parts of the library were busy during which parts of the day, and more. Measure the Future is going to make that happen by using simple and inexpensive sensors that can collect data about building usage that is now invisible. Making these invisible occurrences explicit will allow librarians to make strategic decisions that create more efficient and effective experiences for their patrons."[10]

Mobile Technology, Location-Based Service, and the Internet of Things

Given the technological challenges, how do libraries respond to the IoT strategically and with impact? In this guide, written for the library generalist and those with an interest in technology, we explore a case study of an IoT implementation that makes possible location-based recommendation services in an undergraduate collection, discuss other approaches to providing location-based services, and also give serious consideration to the privacy and security issues associated with such novel technology. The implementation discussed in chapter 2 utilizes commercially available IoT technologies (i.e., proximity beacons deployed in a grid system) in combination with existing mobile device affordance for Bluetooth-based indoor locating.

It is the IoT as it exists today (when this text was written). An implementation of IoT location recommenders may be substantially different one or two years from today, though.

In chapter 2, we explore how mobile technologies can be paired with beacon signals in their environment in order to build an indoor positioning system. Most of us encounter this capability when we connect to Wi-Fi in public spaces like cafés or libraries. We are also familiar with the Global Positioning System used by our phones. Software that delivers real-time directions to our point of interest has generated high service expectations for functionality based on location. With these high expectations, we have found from our iterative tests in the library that students expect real-time location guidance within a building. These studies coincided with new technology startups that have made available technology that made such location-based services possible. In chapter 3, there will be additional attention paid to some of the other approaches that make location services in libraries possible. Several of those technologies include near field communication (NFC) and new Wi-Fi standards. Chapter 4 covers security and privacy considerations for IoT in general and as they relate to personalized location-based services specifically. This open area includes development of securing middleware—that is, the components that comprise and facilitate the interactions among mobile applications and IoT hardware.

As we conclude this introductory chapter, several factors are worth noting. The report, as we have started to suggest, is not only for technology specialists in libraries. The work is intended to be understandable to the library generalist. Therefore, those for whom the IoT is new are encouraged to read on, especially if they have not given the IoT much thought previously. Each chapter can be read individually as well; therefore, while chapter 2 introduces a case study that raises several privacy considerations, if you are so inclined and motivated, you could go straight to chapter 4 to read about securing and ensuring privacy within the IoT. This work was a wide learning experience for the author, and it is hoped that it can be a learning experience for the reader as well.

Notes

1. Ladan Davarzani and Mark Purdy, "The Internet of Things Is Now a Thing," *Stanford Social Innovation Review* 13, no. 4 (Fall 2015): 8–10.
2. Gartner, "Gartner Says the Internet of Things Installed Base Will Grow to 26 Billion Units by 2020," news release, December 12, 2013, http://www.gartner.com/newsroom/id/2636073.
3. The Economist Intelligence Unit, *Assessing Enterprise Readiness for the Internet of Things: Executive Summary* (London: Economist Intelligence Unit, 2016), http://www.eiuperspectives.economist.com/sites/default/files/Assessing-enterprise-readiness-for-the-internet-of-things.pdf.
4. David Rose, *Enchanted Objects: Design, Human Desire, and the Internet of Things* (New York: Scribner, 2014), 17–21.
5. Ibid., 157.
6. Dave Evans, *The Internet of Things: How the Next Evolution of the Internet Is Changing Everything, white paper* (San José, CA: Cisco Internet Business Solutions Group [IBSG], April 2011), 4-5, http://www.cisco.com/c/dam/en_us/about/ac79/docs/innov/IoT_IBSG_0411FINAL.pdf.
7. David Evans, "Beyond Things: The Internet of Everything, Explained in Four Dimensions," *Impact X* (blog), Huffington Post, September 24, 2013, updated January 23, 2014, http://www.huffingtonpost.com/dave-evans/cisco-beyond-things-the-interne_b_3976104.html.
8. Hermann Kopetz, *Real-Time Systems: Design Principles for Distributed Embedded Applications* (New York: Springer, 2011), 321.
9. Ibid., 307.
10. Measure the Future homepage, accessed July 25, 2016, http://measurethefuture.net/.