Location Services Technology and the Internet of Things

Chapter 1 introduced the Internet of Things (IoT) conceptually. In chapter 2, readers learned of a specific implementation of a Bluetooth low energy (BLE) approach to building location services with recommender features in library book stacks. The BLE beacon approach is only one among several approaches to developing and implementing location services with IoT technology. With the coming maturation of IoT technologies, location-based services in libraries will see increased possibility for service innovation. The maturation and uptake by other industries of IoT-based tools will make additional location-based service innovations possible for library system designers. The future development of consumer-facing IoT tools will have implications for space design in libraries leading toward hyperconnectivity and contextualized services.

IoT innovations will encompass technologies such as near field communication (NFC), radio-frequency identification (RFID), and new Wi-Fi standards. Hardware for IoT systems will move from being a hobbyist concern to a greater mass market and consumer-facing field. Several niche location-based startup companies that leverage sensors within mobile technologies are helping to drive the maturation of IoT technologies. Advances in mobile technology development are also helping to drive IoT systems. These advances include novel modular phones and tablets. In addition to Estimote's example from chapter 2, other startup companies are developing compelling apps and app software development kits (SDKs) in order to leverage new location-based technology.

In this chapter, the ways in which mobile technology can be paired with maturing IoT technology will be detailed, so that examples like those built in chapter 2 can be implemented in library environments with IoT technologies. This chapter will explore the range of technologies that comprise the tool kit for location services. This chapter provides a foundational introduction to several additional IoT technologies that support location-based services, like indoor positioning systems (IPS) with mobile technology.

Near Field Communications (NFC) and Location Services

One way that most of the readers of this report will be familiar with NFC is from the field of mobile payment technology. Within mobile payments, NFC technology has been used to communicate between a phone and a point-of-sale system, where the consumer's mobile phone connects wirelessly to a point-of-sale system that interfaces with a credit card reader. Apple Pay, as one example, is a technology that relies on NFC in order to process payments from the proximity of a user's pay-enabled device. With regard to location services in libraries, NFC could be utilized to tell a user when they are near another NFC-enabled appliance or device. We will explore later in this section why a user would want to know their proximity to other users in a public space, but it bears underscoring that an NFC device could be another user's mobile phone.

Within special libraries and museums, an NFC appliance could be connected to a special collection's installation. These types of NFC-enabled installations are referred to in the IoT literature as "smart" objects. Smart objects and smart devices are foundational in the IoT literature since "most of the things connected to the IoT are actually simple devices that are often referred to as *smart devices*. The devices themselves aren't necessarily smart in and of themselves, but become smart when joined together with other connected devices."[1] For the purposes of this text, we are, by design, referencing the ability and capability of Internet-connected mobile devices that connect or communicate with smart devices.

Specific services for special collections in libraries and museums include receiving information when browsing special collections in buildings—for example, NFC-enabled smart objects or smart displays. Special collections are especially suited for NFC interactions. Consider that users of museums are generally visiting multiple content-rich installations about which they may desire additional information. While museums have offered innovative new ways to engage with objects—like iPhone tours and other mobile audio-based information systems—NFC can provide additional information about the object. In newer mobile devices that run the Android operating system, NFC can be used as a data transfer tool. Therefore, a museum could offer a user the functionality to download additional information about a resource, such as archival photos, archival video, or some other interactive content using NFC. This location-based service is content-rich, a feature that might set a display apart from other traditional displays and museum programming.

The Museum of London is doing exactly this type of programming.[2] The Museum of London NFC implementation allowed users to receive more information about an installation downloaded to their device, offering novel ways to explore and interact. The NFC implementation may also be a faster data transfer and interaction tool when compared to Bluetooth or QR codes for downloading information.

Moving to the more academic services perspective referenced earlier in this section, consider those individuals wishing to form study groups in the library. Traditional group finders in the library did not utilize IoT technology. However, new mobile affordances make finding individuals in a library location easier. This is a desirable service based on previous research into undergraduate students' expectations and needs. The idea for a "Study Buddy" app surfaced during a campus-wide mobile app design competition at the University of Illinois.[3] The Study Buddy app design team was made up of student app designers responding to real student needs of finding people in the library who were in the same courses. One of the problems this addressed for students was the desire to know who was in their course and studying in the library—which was sometimes difficult for students to know in large lecture sessions where opportunities to meet others are not possible. Therefore, an NFC-type ad hoc group formation tool is a desirable service for students.

While NFC is a technology that could power an app like Study Buddy, it is not the only piece of technology utilized for this service. An app such as this requires several sets of technologies to come together in order to function. In the case of the Study Buddy app, for example, the app would need to have access to campus locations, be able to manage sessions, and include some type of messaging feature. All of these would need some degree of data persistence, which a database like MySQL could provide. MySQL has been a popular technology component in the past for a variety of library data persistence needs. IoT applications also make use of MySQL software. In the work *MySQL for the Internet of Things,* the author described a process whereby a MySQL server can be installed in a Raspberry Pi node.[4] The author noted that one of the advantages of this system is that "the low cost Raspberry Pi with an attached USB hard drive makes for a very small-footprint database server that you can put just about anywhere. This is great because IoT solutions, by nature and often by necessity, need to be small and low cost."[5] The Raspberry Pi is a favorite among hobbyists for the functionality it enables to accomplishing IoT projects. For those unfamiliar with it, a Raspberry Pi is "a small, inexpensive personal computer. Although it lacks the capacity for memory expansion and can't accommodate on-board devices such as CD, DVD, and hard drives, it has everything a simple personal computer requires."[6] There are several other hardware types that are used in IoT development by hobbyists; these include Arduino boards, among others, but generally fall into the microcontroller set of technology solutions.[7]

Radio-Frequency Identification (RFID) Tags and Location Service

With the incorporation of passive Radio-Frequency Identification (RFID) sensors used as security devices within libraries, the profession may already have a foothold into new IoT location-based services. Most items in libraries that are secured by RFID are secured at the physical item level, something that industries outside of academia and public service functionality are planning to adopt. As Greengard wrote regarding automation and RFID in his work *Internet of Things:* "Inventory and asset tracking technology, often incorporating RFID, identify physical assets or follow them through a supply chain. For more than a decade, retailers have used these systems at the pallet or case level to identify the location of goods in transit. However, retailers and others are now taking RFID to an item level. This makes it possible to build far more robust systems and introduce entirely new features and capabilities."[8] Greengard noted that there may also be implications in terms of value-added services that are developed over the technology with "RFID-enabled badges, smartphone apps using GPS and location aware services, and other tools, mak[ing] it possible to know where a person is at any instant. The technology is widely used in secure facilities and labs, including government offices and military bases with strict authorization or access controls."[9] Note that Greengard's portrait of the world is similar to several other predictions related to smarter infrastructure and location tracking. This future vision intimates some of the mass surveillance concerns that are explored more in depth in chapter 4 on security and privacy.

Note, however, that there are examples of ways in which businesses are able to begin optimizing operations through the use of RFID: "A good example of how sensors and monitoring are changing things is apparent in how Swiss-based multinational oilfield service firm Weatherford uses RFID today. The company is able to gauge the condition of drilling equipment and determine when repairs and upgrades need to take place."[10] At a more library-specific level, consider the environmental areas that need manual reporting when equipment malfunctions—a copier, a scanner, even a personal computer. Consider examples also from larger libraries, which include remote storage areas. Often these high-density remote storage buildings include industrial type technology that could make use of IoT type monitoring tools. Though these types of devices do not yet have RFID-monitoring capabilities, it would be a potential cost-saving measure to see the IoT applied to other types of equipment that libraries own, operate, and maintain—for example, a library with automated shelving units, the type that are designed for high-density shelving. These parts of the library could be equipped with a location-monitoring tool, like RFID, that could record if the equipment was not operating within expected parameters in a given area. This way, shelving systems could be serviced before any breakdowns in equipment occurred.

Wi-Fi Standards and Location-Based Services

Wi-Fi capabilities are getting better over time due to maturing wireless standards. With newer Wi-Fi standards, indoor positioning systems may come integrated into the standard. Indoor positioning services were a novel research area in computer science investigating how to "offer existing Wi-Fi enabled devices a positioning service."[11] With a positioning service in a library building, a library would be better able to support the navigation of complicated or unknown spaces. There is a sustained strand of research in computer science fields on using Wi-Fi as a means to generate indoor positioning services within buildings. The efforts of applied researchers within libraries has also contributed to advancing the functionality of such services. Several early innovators in this area included libraries in Finland and the University of Illinois Library, which used Wi-Fi access points to determine location within a library location.[12] These services were initially designed to support student wayfinding to books.

There are disadvantages to utilizing older Wi-Fi standards for Wi-Fi-only–based positioning services, since these older standards were not developed for indoor positioning services specifically. However, now that smartphones are more common, the demand for indoor locating is greater, and we may expect future versions of Wi-Fi access points to help support indoor positioning services.

Generally, many of the smart or connected devices that seem to be early IoT technologies communicate with Wi-Fi. Several of the sensors that could collect environmental data—like the Nest Protect smoke alarm system—can leverage Wi-Fi to enable a smart home.[13] The Nest Protect is a "smart monitor that connects to the accompanying smartphone app via Wi-Fi. At the first indication of any problem, you get a friendly heads-up on your smartphone. If things get worse, the Nest Protect flashes red, sounds an alarm, and tells your household what to do, using recorded words instead of the normal beeps. Nest Protect works in conjunction with the Nest thermostat. If Nest Protect detects high carbon monoxide levels, it notifies the Nest thermostat, which then turns off your gas furnace."[14] This is an exemple of how a combination of connected devices can provide location-specific information to a mobile app—but then also act on the information if there is a compelling use case to do so. Similar monitoring of library environments would be compelling in terms on monitoring collections to ensure that proper preservation environments are maintained.

Nest Protect
https://nest.com/smoke-co-alarm/meet-nest-protect/

IndoorAtlas and Location Service

IndoorAtlas is a technology startup that developed a solution for mapping local environments in order to provide indoor positioning services using a smartphone. While not specifically designed for libraries, the service addresses wayfinding and orienting functionality for buildings in general. Studies of users new to a building indicate that wayfinding and navigation to items is a problem area for the physical environment, due in part to stacks arrangement and library-based classification.[15] Specifically, users of spaces may have an information need and have identified a resource, but often struggle from a "last-mile" problem, where they cannot get to the item due to problems with the building and stacks navigation. IndoorAtlas offers a variety of value-added location services for the indoor maps generated by its software.

The IndoorAtlas technology for IPS mapping is original and unique in this area. IndoorAtlas software utilizes the geomagnetism surrounding a building to characterize locations in a room. IndoorAtlas offers a software developer kit (SDK) in order to create several of those value-added services. Utilizing the SDK is a three-step process. The requirements are to first create a venue in the IndoorAtlas web tool, where a floor plan must be provided. Next, the configuration app from IndoorAtlas is used to collect data on the location's unique magnetic map data. Finally, the SDK can be drawn on to add location-based functionality.[16]

Several of the sample use cases described by IndoorAtlas include supporting wayfinding to items in collections. Use cases of IndoorAtlas for installations within special collection or museums include the ability to track users' experiences in a building in real time. This is also a helpful tool if users need assistance within a collection. A common request in book stacks–based browsing is for real-time point-of-need assistance.[17]

Proximity advertising is another area that is drawn from commerce and applicable to museums and library domains. When a user's device is within the proximity of an object, the SDK can allow for interactions based on these proximity triggers. As a key advantage over several of the technologies in this chapter, the IndoorAtlas technology stack does not require additional hardware—it requires only a mobile phone with app capability. The "multi-dot" feature that IndoorAtlas provides would also help to satisfy the Study Buddy example application detailed earlier in this chapter. With multi-dot, students could opt in to sharing their location with others enrolled in their courses in order to form ad hoc study groups in the library. In larger organizations, the multi-dot functionality would enable employees to quickly locate one another.

To summarize the applicability of IndoorAtlas, note that most smartphones and contemporary mobile devices have standard components like a magnometer for their compass apps and to enable GPS.[18] IndoorAtlas takes advantage of the ubiquity of the sensors that everyone carries to make possible a unique and simple way to implement location-based service for library needs of locating, navigating, and wayfinding to known items.

Project Tango Tablet and Location Service

The Project Tango Tablet from Google is a piece of hardware that hints at the future of in-building navigation and indoor positioning services. Several novel technologies are combined that make the Tango an innovator within the IPS realm. Within the Tango Tablet, there are increased sensors for depth, which are not included in contemporary tablets or mobile application phones. Within the Tango Tablet are also infrared emitters and an "infrared camera, which picks up the reflected light. A wide-angle camera adds visual cues about location to the mix. The Tango system also relies on highly accurate accelerometers, gyroscopes and barometers."[19]

The library technologist may wonder how exactly these technologies support location services and location-aware apps. According to Elgan, there are several ways in which the Project Tango Tablets actually improve upon beacons for indoor positioning. With the upgraded types of sensors available in a Project Tango Tablet, a mobile device can more readily determine its location within buildings, so apps can better leverage natural markers in the world around the user.[20] Lenovo has recently announced that the first "Tango-enabled" smartphone is available for purchase.[21] With these new devices, there is an increased expectation among users for location services. Google has demonstrated some new advances in indoor location services recently that make use of the Tango capabilities. Tango developers have worked with partners from Lenovo and the museum industry to create indoor navigation with the Tango's precision sensors for location-based museum guidance and exploration. These features not only include wayfinding and guide tours, but they also implement location-based augmented reality in museums, drawing directional paths onto the real-world environment.[22] It is worth noting that researchers in computer science and engineering control systems extoll the advantages of using vision-based approaches to developing indoor positioning services over other techniques.[23] Vision-based services would be much more possible in devices like Tango tablets.

Recent advances in Android software are going to make development for Tango devices easier and more accessible. According to a recent presentation by Tango engineers, Unity engine integration for the devices will make it easier for developers to incorporate augmented reality–type features into mobile services. Features that are being demoed in museums include functionality that provides for step-by-step indoor navigation by overlaying waypoints onto the physical environment through the cameras viewfinder screen.[24]

Modular Smartphones and Location-Based Service

The modular smartphone concept is related to the Project Tango. A modular phone is a mobile device that has components or modules that can be swapped out and upgraded by the end user.

Note that several of the technologies discussed in this chapter could be pluggable as added components into future modular devices, e.g. an RFID module, a Bluetooth module, a Wi-Fi radio, or even an upgraded camera module to support location services.

Since modular devices may include more than one camera, it may be possible to implement a more compelling vision tool if stereoscopic fields of vision are possible. Current vision-based tools on smartphones actually suffer from only having one forward-facing camera. Depth perception would be possible with a modular phone with two cameras.

Other modular affordances of phones that will support IoT features include sensors, which could be plugged into the phone, so that environmental data that could be collected would expand to include more than what is available on current phones. As an example, current smartphones do not have the ability to read passive RFID, the technology in use within many library settings. However, with a future modular phone, an RFID module could be added to the phone so that as users navigate the collection space, they would be able to learn more about a library collection that included RFID. If items are in their correct location, then the phone would be able show the user where they are located in the stacks. As mentioned earlier in this work, once a location can be inferred, recommendations could be provided to the user, based on their interest. Rather than viewing a map on a screen, the future modular phone could have a way to project its display—either projecting a map or simply projecting an arrow that's overlaid into the physical environment and points to the location of a similar or recommended item. A module of projection capability like the Pico Projector may be feasible for this use case. Such projection capabilities are available in a new modular line of phones, the Moto Z, which includes a small projector as an add-on module.[25]

On the staff facing side, an RFID enabled modular device could support collection maintenance –e.g. staff walking through the stacks could learn which books are out of order with the wave of a modular phone. This would help optimize traditional shelf reading, but at the same time, in larger library systems, it would be possible to optimize operations by knowing where shelving staff are located. By knowing their location, a colleague or user could route them to pick up requested items in real time. This would help get books to patrons quicker. And the data routed through the system could help optimize the ways that items are queued for shelving and pick up.

Library Vendors and Location Services

Library vendors are beginning to get involved in the IoT space by way of Bluetooth beacon implementations for mobile enhanced location services. As an example of one vendor, consider the new product Beaconstac offering location services in book stacks.[26] According to the June 2016 issue of *American Libraries Magazine*, "Beaconstac uses mobile beacon technology to deliver personalized information to patrons based on their library account and location. To use Beaconstac, a digital beacon location must be set by a staff member at a specific location within the library."[27] This is similar to the system described in chapter 2. Note, however, the Beaconstac would be the company holding data about where a user is in the building. Some libraries may want to host such a solution internally so as to not compromise confidentiality or privacy of library users. Any library using a service such as this should attempt to make it clear what data third parties are collecting, if data are to be collected by third parties.

Summary of Location Service Technologies

To summarize several of the key points and technologies reviewed in this chapter, the technologies that make up the IoT are in some sense already implemented. Therefore, the contemporary IoT is about leveraging new iterations of technologies that are increasingly part of the Internet. Those iterations include feature-rich Wi-Fi, RFID, and NFC. Each of these technologies has its pros and cons when choosing to implement IoT services. As we have seen, hardware is an atomic component of the IoT, but mobile technologies with increased capabilities and functionality make implementing location services easier. This is due to the fact that phones like the Lenovo Tango phone will come with a set of sensors that make hardware-based location services unnecessary. The Lenovo Tango phone is officially known as the Lenovo Phab 2 Pro—the 'phab' moniker indicates that it is a hybrid/crossover device, whose size is between that of a phone and a tablet. In summary, there is not a one clear path towards IoT location services. Each of these technologies must be evaluated in the context of a home institution, development priorities, and technology goals.

Notes

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