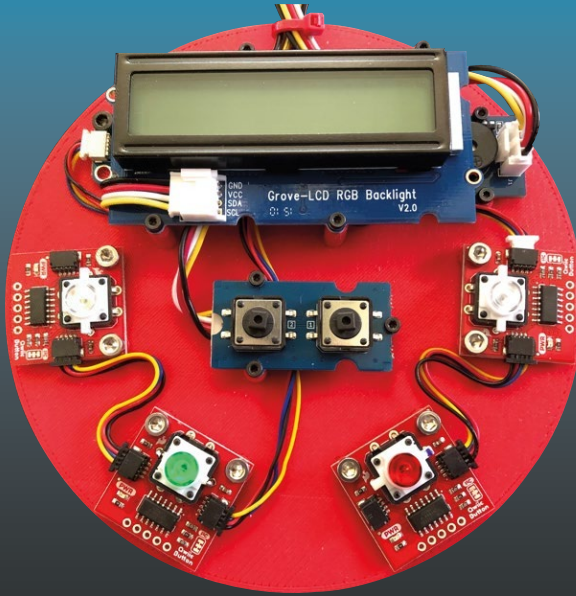


TECHNOLOGY IN ACTION™



# Beginning IoT Projects



Breadboard-less Electronic Projects

Charles Bell

Apress®

# **Beginning IoT Projects**

**Breadboard-less  
Electronic Projects**

**Charles Bell**

**Apress®**

## ***Beginning IoT Projects: Breadboard-less Electronic Projects***

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# About the Author

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# PART I

## Getting Started with IoT

This part begins with an overview of the Internet of Things and then introduces the hardware platforms we will use in the book to learn how to build IoT projects. Platforms include the Arduino and Raspberry Pi. The part also includes tutorials on how to write the software to run on the platforms using the Arduino language for writing sketches and Python for programming on the Raspberry Pi.

## CHAPTER 1

# Introduction to the Internet of Things

Much has been written about the Internet of Things (IoT). Some sources are more about promoting IoT as their latest innovation (that costs more money); other sources seem to suggest IoT is something everyone needs or be left behind in the dust of antiquity.

Fortunately, books and similar media avoid the sales pitch to expand on the science and technology for implementing and managing the data for IoT, while other texts concentrate on the future or the inevitable evolution of our society as we become more connected to the world around us each and every day. However, you need not dive into such tomes or be able to recite rhetoric to get started with the IoT. In fact, through the efforts of many companies, you can explore the IoT without intensive training or expensive hardware and software.

However, most publications<sup>1</sup> assume the reader knows or wants to know how to connect discrete components together to build the hardware from scratch. That means if you'd like to learn more about building

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<sup>1</sup> Including my own books!

Internet of Things (IoT) solutions, but don't have the time or will to learn all of the nuances of electronics and discrete components, you've been left with little recourse.<sup>2</sup> That is, until now.

In this book, we will explore how to build IoT solutions using a series of basic projects without the need to learn the difference between a diode and a resistor. In fact, we will be using two modular platforms that you can connect to your host board without the need to wire anything together!<sup>3</sup> This is accomplished by using a special adapter board/shield for your device that permits you to connect to modules that include sensors, displays, switches, and more!

However, before we get into the details of devices, boards, modules, etc., let's take a moment and learn what the Internet of Things is and what sort of solutions are classified as IoT projects.

## What Is the Internet of Things?

So what is this IoT?<sup>4</sup> I'll begin by explaining what it isn't. The IoT is not a new device or proprietary software or some new piece of hardware. It is not a new marketing scheme to sell you more of what you already have by renaming it and pronouncing it "new."<sup>5</sup> While it is true that the IoT

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<sup>2</sup>Well, there are IoT kits out there that you can use to build specific, simple projects, but not much in the way of help for those that want to take on new projects without spending a lot of time learning enough about electronics to implement the project.

<sup>3</sup>We will discuss advanced uses of the modular components and some simple wiring connections, but nothing that requires prior knowledge of electronics.

<sup>4</sup>[https://en.wikipedia.org/wiki/Internet\\_of\\_Things](https://en.wikipedia.org/wiki/Internet_of_Things)

<sup>5</sup>For example, everything seems to be cloud this, cloud that when in reality nothing was changed.

employs technology and techniques that already exist, the way they are employed, coupled with the ability to access the solution from anywhere in the world, makes the IoT an exciting concept to explore. Now let's discuss what the IoT is.

The essence of the IoT is simply interconnected devices that generate and exchange data from observations, facts, and other data, making it available to anyone you'd like – only yourself or immediate family – or share it with the world. While there seem to be some marketing efforts attempting to make anything connected to the Internet an IoT solution or device (not unlike the shameless labeling of everything “cloud”), IoT solutions are designed to make our knowledge of the world around us timelier and more relevant by making it possible to get data about anything from anywhere at any time.

As you can imagine, if we were to connect every device around us to the Internet and make sensory data available for those devices, it is clear there would be potential for the number of IoT devices to exceed the human population of the planet<sup>6</sup> and for the data generated to rapidly exceed the capabilities of all but the most sophisticated database systems. These concepts are commonly known as addressability and big data, which are two of the most active and debated topics in IoT. But don't worry about these terms – I mention them here for completeness and possibly to pique your interest. You can read more about these issues at your leisure.

However, the IoT is all about understanding the world around us. That is, we can leverage the data to make our world and our understanding of it better.

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<sup>6</sup>We aren't so far away from that now. Think about how many iWatches there are out there – yes, they're IoT devices too!

Before we proceed, let's review some terms that can help us understand the context and subject better. The following are the major terms used in this book:

- *IoT solution*: A complete project that implements the software and hardware to perform one or more tasks
- *IoT device*: The hardware (and associated software) that connects to the Internet sending data to one or more IoT services
- *IoT service*: A product or set of services in the cloud used to process IoT data
- *IoT vendor*: Those businesses that provide services for IoT solutions
- *IoT data*: Data generated from one or more IoT devices such as observations from one or more sensors
- *Knowledge*: The conclusions one can draw from the data once it has been made available in the IoT services (cloud) for review

Now that we know what the IoT is and some terms we use to describe it, let's dive further into what IoT means to us.

## The Internet of Things and You

The best example of a sophisticated IoT device is the human body. It is a complex marvel of ingenious sensory apparatus that allow us to see, hear, taste, and even feel through touch anything we encounter or get near. Even our brains can store visual and auditory events recalling them at will. IoT solutions mimic many of these sensory capabilities and therefore can become an extension of our own abilities.

While that may sound a bit grandiose (and it is), IoT solutions can record observations in the form of data from one or more sensors. Sensors are devices that produce either analog or digital values. We can then use the data collected to draw conclusions about the subject matter. IoT devices can also retrieve information from one device and forward it to another, but let's keep it simple and focus on devices that detect things about the world around us and what that knowledge could do for us.

For example, an IoT device could be connected to a sensor to detect when a mailbox is opened. In this case, the knowledge we gain from a simple switch opening or closing (depending on how it is implemented and interpreted) may be used to predict when incoming mail has arrived or when outgoing mail has been picked up. I use the term predict because the sensor (switch) only tells us the door was opened or closed, not that anything was placed in or removed from the mailbox itself – that would require additional sensors.

When working with IoT projects that include sensors, you should always think about what conclusions you can draw from the data. Sometimes, like the switch in the mailbox, it can be only a few things, which is most often the case. By defining what we can perceive (learn) from the sensor data, we can better understand what our IoT project and its data can do for us.

A more sophisticated example is using a series of sensors to record atmospheric data such as temperature, humidity, barometric pressure, wind speed, ambient light, rainfall, and so forth, to monitor the weather and perform analysis on the data to predict trends in weather. That is, we can predict within a reasonable certainty that precipitation is in the area and to some extent its severity.

Now, add the ability to see this data not only in real time (as it occurs) but also remotely from anywhere in the world, and the solution becomes more than a simple weather station. It becomes a way to observe the weather about one place from anywhere in the world.

This example may be a bit commonplace since you can tune into any number of television, web, and radio broadcasts to hear the weather from anywhere in the world. But consider the implications of building such a solution in your home. Now you can see data about the weather at your own home from anywhere!

In the same way, but perhaps on a smaller scale, we can build solutions to monitor plants to help us understand how often they need water and other nutrients. Or perhaps we can monitor our pets while we are away at work. Further, we can record data about wildlife in our area to better understand our effect on nature.

## IoT Is More Than Just Connected to the Internet

So, if a device is connected to the Internet, does that make it an IoT solution? That depends on whom you ask. Some will say the answer is yes. However, others (like me) contend that the answer is no unless there is some benefit from doing so.

For example, if you could connect your toaster to the Internet, what would be the benefit of doing so? What knowledge would you gain? It would be pointless (or at least extremely eccentric) to get a text on your phone from your toaster stating that your toast is ready given that it only takes a couple of minutes to complete. In this case, the answer is no. However, if you have someone – such as a child or perhaps an older adult – whom you would like to monitor, it may be helpful to be able to check to see how often and when they use a device like a toaster so that you can check on them.<sup>7</sup> That is, you can use the data to help you make decisions about their care and safety.

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<sup>7</sup>Toasters and toaster ovens have appeared in the top five most dangerous appliances in the home. Scary.



Allow me to illustrate with another example. I was fortunate to participate in a design workshop held on the Microsoft campus in the late 1990s. During our tour of the campus, we were introduced to the world's first Internet-enabled refrigerator (also called a smart refrigerator).

There were sensors in the shelves to detect the weight of food. It was suggested that, with a little ingenuity, you could use the sensors to notify your grocer when your milk supply ran low, which would enable people to have their grocery shopping not only online but also automatic. This would have been great if you lived in a location where your grocer delivers, but not very helpful for those of us who live in rural areas.<sup>8</sup> While it wasn't touted an IoT device (the term was coined later), many felt the device illustrated what could be possible if devices were connected to the Internet.

Thus, being connected to the Internet doesn't make something IoT. Rather, IoT solutions must be those things that provide some meaning – however small that benefit is to someone or some other device or service. More importantly, IoT solutions allow us to sense the world around us and learn from those observations. The real tricky part is in how the data is collected, stored, and presented. We will see all of these in practice through examples in later chapters.

IoT solutions can also take advantage of companies that provide services that can help enhance or provide features that you can use in your IoT solutions. These features are commonly called IoT services and range from storage and presentation to infrastructure services, such as hosting.

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<sup>8</sup> However, given the COVID-19 stay-at-home orders in many places, this idea may have come back into practicality.

## IoT Services

Sadly, there are companies that tout having IoT products and services that are nothing more than marketing hype – much like what some companies have done by prepending “cloud” or appending “for the cloud” to the name. Fortunately, there are some good products and services being built especially for IoT. These range from data storage and hosting to specialized hardware and sophisticated data analysis and visualization.

Indeed, businesses are adding IoT services to their product offerings, and it isn’t the usual suspects, such as the Internet giants. I have seen IoT solutions and services being offered by Cisco, AT&T, HP, and countless start-ups and smaller businesses.

You may be wondering what these services and products are and why someone would consider using them. That is, what is an IoT service, and why would you decide to buy it? The biggest concerns in the decision to buy a service are cost and time to market.

For example, if you want to use IoT in your organization but your developers do not have the resources or expertise and obtaining them will require more than the cost of the service, it may be more economical to purchase the service. However, you should also consider any additional software or hardware changes (sometimes called retooling) necessary in the decision. I once encountered a well-meaning and well-documented contracted service that permitted a product to go to market sooner than projected at a massive savings. Sadly, while the champions of that contract won awards for technical achievement, they failed to consider the fact that the systems had to be retooled to use the new service. More specifically, it took longer to adopt the new service than it would to write one from scratch. So instead of saving money, the organization spent nearly twice the original budget and was late to market. Clearly, you must consider all factors.

Similarly, if your time is short or you have hard deadlines to meet to make your solution production-ready, it may be quicker to purchase an IoT service rather than create or adapt your own. This may require

spending a bit more, but in this case, the motivation is time and not (necessarily) cost. Of course, project planning is a balance of cost, time, and features.

So what are some of the IoT services available? The following lists a few that have emerged in the last few years. It is likely more will be offered as IoT solutions and services mature:

- *Enterprise IoT data hosting and presentation:* Services that allow your users to develop enterprise IoT solutions from connecting to managing and customizing data presentation in a friendly form, such as graphs, charts, and so forth.
- *IoT data storage:* Services that permit you to store your IoT data and get simple reports.
- *Networking:* Services that provide networking and similar communication protocols or platforms for IoT. Most specialize in machine-to-machine (M2M) services.
- *IoT hardware platforms:* Vendors that permit you to rapidly develop and prototype IoT devices using a hardware platform and a host of supported modules and tools for building devices ranging from a simple component to a complete device.

For the hobbyist or enthusiast, you may not need such sophistication. Rather, you may need only a place to store or display your data. In those cases, there are IoT vendors that provide such products (some free, from fee-based) using relatively simple-to-configure features. Two such examples include Microsoft Azure (<https://portal.azure.com>) and ThingSpeak for IoT Projects (<https://thingspeak.com/>). We will see ThingSpeak in action later on in book.

Now that you know more about what IoT is, let's look at a few examples of IoT solutions to get a better idea of what IoT solutions can do and how they are employed.

## A Brief Look at IoT Solutions

Recall an IoT solution is simply a set of devices designed to produce, consume, or present data about some event or series of events or observations. This can include devices that generate data, such as a sensor, devices that combine data to deduce something, devices or services designed to tabulate and store the data, and devices or systems designed to present the data. Any or all of these may be connected to the Internet.

IoT solutions may include one or all of these qualities, whether it is combined into a single device such as a web camera; used as a sensor package and monitoring unit, such as a weather station; or used as a complex system of dedicated sensors, aggregators, data storage, and presentation, such as a complete home automation system. Figure 1-1 shows a futuristic picture of all devices – everywhere – connected to the Internet through databases, data collectors or integrators, display services, or other devices.



**Figure 1-1.** *The future of IoT – all devices, everywhere*<sup>9</sup>

Let's take a look at some example IoT solutions. The IoT solutions described in this section are a mix of solutions that should give you an idea of the ranges of sizes and complexities of IoT solutions. I also point out how some of these solutions leverage services from IoT vendors.

## Sensor Networks

Sensor networks are one of the most common forms of IoT solutions. Simply stated, sensor networks allow you to observe the world around you and make sense of it. Sensor networks could take the form of a pond monitoring system that alerts you to water level, water purity (contamination), or water temperature or detects predators or even turns on features automatically, such as lighting or fish feeders.

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<sup>9</sup><https://pixabay.com/en/network-iot-internet-of-things-782707/>

If you, or someone you know, have spent any time in a medical facility, it's likely that a sensor network was employed to monitor body functions, such as temperature, cardiac and respiratory rates, and even movement. Modern automobiles also contain sensor networks dedicated to monitoring the engine, climate, and, even in some cars, road conditions. For example, the lane warning feature uses sensors (typically a camera, microprocessor, and software) to detect when you drift too far toward lane or road demarcations.

Thus, sensor networks employ one or more sensors that take measurements (observations) about an event or state and communicate that data to another component or node in the network, which is then presented, in some form or another, for analysis. Let's take a look at an example of an important medical IoT solution.

## Medical Applications

Medical applications – including health monitoring and fitness – are gaining a lot of attention as consumer products. These solutions cover a wide range of capabilities, such as the fitness features built into the Apple Watch to fitness bands that keep track of your workout and even medical applications that help you control life-threatening conditions. For example, there are solutions that can help you manage diabetes.

Diabetes is a disease that affects millions of people worldwide ([www.diabetes.org](http://www.diabetes.org)). There are several forms, the most serious being type 1 ([www.diabetes.org/diabetes-basics/type-1/?loc=db-slabnav](http://www.diabetes.org/diabetes-basics/type-1/?loc=db-slabnav)). Those afflicted with type 1 diabetes do not produce enough (or any) insulin due to genetic deficiencies, birth defects, or injuries to the pancreas. Insulin is a hormone that the body uses to extract a simple sugar called glucose, which is created from sugars and starches, from blood for use in cells.