
Designing the
Internet
of Things
Adrian McEwen & Hakim Cassimally

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About the Authors

Adrian McEwen is a creative technologist and entrepreneur based in Liverpool. He has been connecting devices to the Internet since 1995—first cash registers, then mobile phones, and now bubble machines and lamps. He founded MCQN Ltd., an Internet of Things product agency and (along with Hakim and others) is co-founder of DoES Liverpool, a hybrid co-working/makerspace that incubates Internet of Things startups in NW England. He is also CTO of Good Night Lamp, a family of Internet-connected lamps. He was one of the first employees at STNC Ltd, which built the first web browser for mobile phones and was acquired by Microsoft in 1999. Adrian concentrates on how the Internet of Things intersects with people's lives and how heterogeneous networks of devices should work together, and lectures and speaks on these issues internationally. You can find him on the Internet at `www.mcqn.net` or follow him on Twitter as `@amcewen`.

For Jean, Les, and Christine, and in memory of Karen.

—Adrian

Despite an education in Italian and English literature, once **Hakim Cassimally** discovered software development, he hasn't looked back. He is a staunch proponent of Perl and was one of the organisers of YAPC::EU 2010 in Pisa. These days, however, he is likely to be writing Python for 3D printers or for civic hacking projects with mySociety.org. He co-founded (with Adrian and others) DoES Liverpool. His website is at `greenokapi.net`.

For my parents. This time I didn't start with the page numbers.

—Hakim

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—Adrian and Hakim

The acknowledgements section was one I never normally paid a lot of attention to, as it was the author thanking a load of people I didn't know. Having written a book, and realised how much help and support are given to the authors, I have a newfound appreciation for this section.

I'd like to thank Hakim for agreeing to join me in the adventure of actually doing the writing. Andy Huntington, Lawrence Archard, and Christopher Pett were all generous with their time and sharing their expertise in areas where I'm only in the early stages of exploring.

For endless encouragement and keeping me sane in the difficult bits, I need to thank my family and friends, especially Francis Irving, Andrew Dixon, Rob Stock, Neil Sowler, Kieran MacCourt, Jen Forakis, Colette MacCourt, Dan Lynch, and Neil Morrin.

And, finally, thanks to Bubblino for helping get me into this mess in the first place.

—Adrian

I tend to at least skim the acknowledgements and knew (in theory) that writing a book was a huge, collaborative effort. Experiencing it firsthand was awe-inspiring. We will almost certainly have forgotten to thank somebody: if that's you, we would love to make it up to you over a beverage of your choice.

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I worked with Greg McCarroll back in 2005. Though I didn't know it at the time, his connected train-aware alarm clock was the first Internet of Things object I ever came across. Greg was a gentleman as well as an innovator, and will be dearly missed.

Thanks, also, to Claire, Lolita, Rumplestiltskin, Sheri My, Wolfie, and Helvetica. Definitely.

—Hakim

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Introduction

A COMPUTER PROCESSOR such as Intel's i486 used to cost around the same as a small car. Nowadays a chip with similar power is the price of a chocolate bar.

When processing power is so cheap, you can afford to put processors in places that you couldn't before—not just a business workstation or a home PC but also a telephone, an electricity meter, a bedside lamp, or a teddy bear. We can make objects intelligent. We can make them think and speak. Pundits have dubbed this "physical computing", "ubiquitous computing" or "ubicomp", or "the Internet of Things". Whatever you choose to call it, we are really talking about making magical things, enchanted objects.

In this book we look at the kinds of computer chips that can be embedded in objects ("microcontrollers" such as the Arduino) and take you through each step of the process from prototyping a Thing to manufacturing and selling it. We explore the platforms you can use to develop the hardware and software, discuss the design concepts that will make your products eye-catching and appealing, and show you ways to scale up from a single prototype to mass production.

WHAT THIS BOOK IS NOT

For starters, this book is not a specific guide to any given microcontroller. Although we look at the Arduino, Raspberry Pi, and other options, this detailed technical information will necessarily date more quickly than the rest of the material in the book. So we are more interested in showing the criteria for evaluating and choosing a platform.

Nor is this book a guide to particular cool projects to make. Rather, we survey some groundbreaking Things but mostly look at the general design principles that will, we hope, encourage you to make something fresh, beautiful, useful, and magical.

Finally, this isn't an academic treatise on the business infrastructure of tomorrow's Internet of Things—technologies such as 6LoWPAN and emerging M2M standards. We are far more interested in how to design, manufacture, and sell consumer-facing Things that will delight *people*.

WHO SHOULD READ THIS BOOK?

We certainly hope that this book, as a technical publication, will help software engineers, web developers, product designers, and electronics engineers start designing Internet of Things products. Indeed, we cover microcontrollers, electronics, embedded programming, and web APIs, among other technical topics of interest.

The book is also targeted at entrepreneurs, "makers" (designers, artists, craftspeople, and hobbyists), academics and educators, and anyone interested in getting an overview of this exciting upcoming technology. Even if you have little or no technical background in IT, much of the material is accessible to a general reader, and our coverage extends beyond the purely digital to topics in design, ethics, and business.

HOW TO USE THE BOOK

As we mentioned previously, this is not a "how-to" book, so you don't need any particular tools to read along. The more technical chapters do give some suggestions for microcontroller hardware or web development frameworks that you may choose to investigate further in parallel.

We have designed the book to flow from principles through prototyping to manufacture and business considerations, so you *can* certainly read it from cover to cover. However, you may prefer to take alternative paths through the book. Depending on your background and concerns, some chapters may be of greater interest, whereas others you may prefer to skip for now.

Part I, "Prototyping", introduces the Internet of Things and moves onto experimenting and creating your prototype project.

We recommend that all readers start with Chapter 1, "The Internet of Things: An Overview", which describes what the Internet of Things is and why it's happening now, and Chapter 2, "Design Principles for Connected Devices", where we set out a manifesto for consumer-facing Things for humans.

Chapter 3, "Internet Principles", is designed to be an accessible introduction which will be helpful to keep your ideas clear while you are building your Thing and thinking about how it communicates with the world. If you have a background in the Internet and web family of protocols, you can certainly skip this one.

The next chapters will be of most interest if you are planning to build a Thing yourself. To get a better understanding of the field, it is certainly worth reading Chapter 4, "Thinking About Prototyping", for general considerations about technology choices. For the engineer, maker, or technical person responsible for making a device, Chapter 5, "Prototyping Embedded Devices", applies the general principles to specific devices (at time of publication); Chapter 6, "Prototyping the Physical Design", discusses how to build the physical design of your prototype; and Chapter 7, "Prototyping Online Components", describes building the online components as web APIs.

Although many readers will have at least some general knowledge of programming, writing code for the small computers which often power connected devices has its own challenges. Chapter 8, "Techniques for Writing Embedded Code", presents some lessons learned in the trenches and will be useful to makers involved in projects with more complex computational requirements.

Part II, "From Prototype to Reality", moves beyond the world of making and prototyping and looks at what happens when your project meets the real world.

If you are an entrepreneur hoping to make money from your Internet of Things project, Chapter 9, "Business Models", examines business models which go far beyond simply selling devices. Of course, if you *are* planning to sell devices, then moving to manufacture presents a whole new set of problems, such as creating PCBs, sourcing materials, and getting certification, as we discuss in Chapter 10, "Moving to Manufacture".

Finally, technology always changes the world, and not always for the better. We began the book with design principles for making enchanted objects, and Chapter 11, "Ethics", discusses how ethical and moral principles are also essential if we want to keep the enchantment from going bad.

You can find more information about the book and the authors at `book.roomofthings.com` or by following `@aBookOfThings` on Twitter.

PRODUCTION NOTES

They say travel broadens the mind. It also helps you write. Parts of the book were written on a couple of flights, but much more on countless train journeys—mostly between Liverpool and London, but also elsewhere in the UK and in northern Italy. Former transport systems worked, too: the High Line in New York was an excellent venue for writing during an extended visit there early in the book's life.

The rest was written in and around Liverpool. In DoES Liverpool, in my flat by the cathedrals, holed up in Bold St. Coffee, or on the third floor of the majestic Central Library. When the weather permitted, even some down at the Pier Head, overlooking the river Mersey.

The main text was written in Vim in Markdown, on a Sony Vaio laptop running Ubuntu, and then edited in Microsoft Word on Windows on the same laptop.

—Adrian

Before even touching a keyboard, Adrian and I had several long, wide-ranging conversations about the Internet of Things in general and the content we wanted for the book. As I was quite new to the topic, this helped me form an understanding by getting to ask silly questions and challenge assumptions. The discussions helped us to reach a common "voice" for the book. We drafted a chapter together (which eventually became Chapter 4, "Thinking About Prototyping") and then split the remaining chapters evenly in accordance with our interests and knowledge. We have consistently reviewed each other's chapters before submitting them, which has helped maintain that shared voice through the whole process.

My drafts were written in Vim, converted from Markdown using Pandoc, and edited in LibreOffice, originally on an aging ThinkPad and then, when that finally gave up the ghost, on a MacBook Pro. Dropbox was invaluable for sharing the latest version of every document immediately. We wrote blog posts in Markdown, too, and published them with Jekyll.

—Hakim

PROTOTYPING