Industry 4.0

The Industrial Internet of Things

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Alasdair Gilchrist

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*To my beautiful wife and daughter,
Rattiya and Arrisara, with all my love*

About the Author

Alasdair Gilchrist has spent his career (25 years) as a professional techni-
cian, manager, and director in the fields of IT, data communications, and mobile
telecoms. He therefore has knowledge in a wide range of technologies, and
he can relate to readers coming from a technical perspective as well as being
conversant on best business practices, strategies, governance, and compli-
ance. He likes to write articles and books in the business or technology fields
where he feels his expertise is of value. Alasdair is a freelance consultant and
technical author based in Thailand.

About the Technical Reviewer

Ahmed Bakir is the founder and lead developer at devAtelier LLC (www.devatelier.com), a San Diego-based mobile development firm. After spending several years writing software for embedded systems, he started developing apps out of coffee shops for fun. Once the word got out, he began taking on clients and quit his day job to work on apps full time. Since then, he has been involved in the development of over 20 mobile projects, and has seen several enter the top 25 of the App Store, including one that reached number one in its category (Video Scheduler). His clients have ranged from scrappy startups to large corporations, such as Citrix. In his downtime, Ahmed can be found on the road, exploring new places, speaking about mobile development, and still working out of coffee shops.

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Introduction

Industry 4.0 and the Industrial Internet of Things (IIoT) has become one of the most talked about industrial business concepts in recent years. However, Industry 4.0 and the IIoT are often presented at a high level by consultants who are presenting from a business perspective to executive clients, which means the underlying technical complexity is irrelevant. Consultants focus on business models and operational efficiency, which is very attractive, where financial gains and new business models are readily understandable to their clients. Unfortunately, these presentations often impress and invigorate executives, who see the business benefits but fail to reveal to the client the technical abstraction of the lower-layer complexity that underpin the Industrial Internet.

In this book, we strive to address this failure and although we start with a high-level view of the potential gains of IIoT business incentives and models, and describe successful use-cases, we move forward to understand the technical issues required to build an IIoT network. The purpose is to provide business and technology participants with the information required in deploying and delivering an IIoT network.

Therefore, the structure of the book is that the initial chapters deal with new and innovative business models that arise from the IIoT as these are hugely attractive to business executives. Subsequent chapters address the underpinning technology that makes IIoT possible. As a result, we address the way we can build real-world IIoT networks using a variety of technologies and protocols. However, technology and protocol convergence isn't everything; sometimes we need a mediation service or platform to glue everything together. So for that reason we discuss in the middle chapters protocols, software patterns, and middleware IIoT platforms and how they provide the glue or the looking glass that enables us to connect or visualize our IIoT network.

Finally, we move forward from generic IIoT concepts and principle to Industry 4.0, which relates to industry, and there we see a focus on manufacturing. Industry 4.0 relates to industry in the context of manufacturing, so these chapters consider how we can transform industry and reindustrialize our nations.

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Introduction to the Industrial Internet

GE (General Electric) coined the name "Industrial Internet" as their term for the Industrial Internet of Things, and others such as Cisco termed it the Internet of Everything and others called it Internet 4.0 or other variants. However, it is important to differentiate the vertical IoT strategies (see Figure 1-1), such as the consumer, commercial, and industrial forms of the Internet from the broader horizontal concept of the Internet of Things (IoT), as they have very different target audiences, technical requirements, and strategies. For example, the consumer market has the highest market visibility with smart homes, personal connectivity via fitness monitors, entertainment integrated devices as well as personal in-car monitors. Similarly, the commercial market has high marketability as they have services that encompass financial and investment products such as banking, insurance, financial services, and ecommerce, which focus on consumer history, performance, and value. Enterprise IoT on the other hand is a vertical that includes small-, medium-, and large-scale businesses. However this book focuses on the largest vertical

of them all, the Industrial Internet of Things, which encompasses a vast amount of disciplines such as energy production, manufacturing, agriculture, health care, retail, transportation, logistics, aviation, space travel and many more.
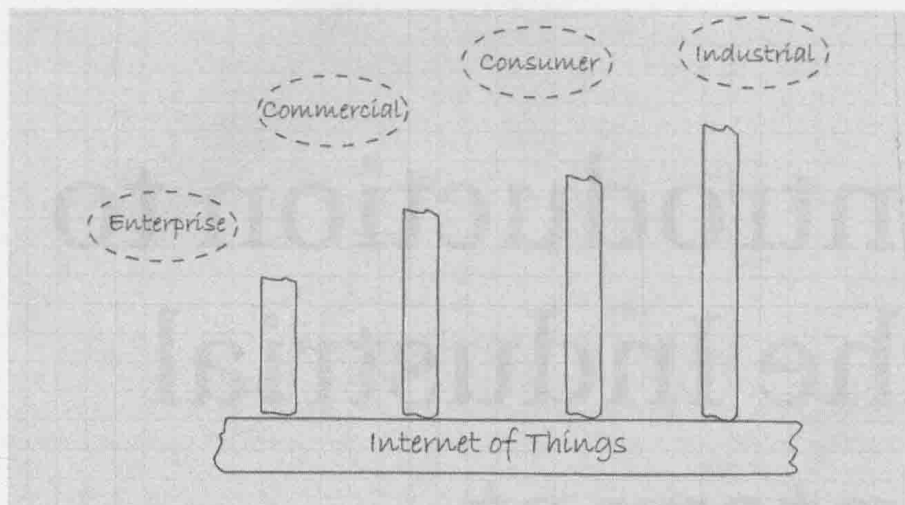
Figure 1-1. Horizontal and vertical aspects of the Internet of Things

In this book to avoid confusion we will follow GE's lead and use the name Industrial Internet of Things (IIoT) as a generic term except where we are dealing with conceptually and strategically different paradigms, in which case it will be explicitly referred to by its name, such as Industry 4.0.

Many industrial leaders forecast that the Industrial Internet will deliver unprecedented levels of growth and productivity over the next decade. Business leaders, governments, academics, and technology vendors are feverishly working together in order to try to harness and realize this huge potential.

From a financial perspective, one market research report forecasts growth of $151.01 billion U.S. by 2020, at a CAGR of 8.03% between 2015 and 2020. However, in practical terms, businesses also see that industrial growth can be realized through utilizing the potential of the Internet. An example of this is that manufacturers and governments are now seeing the opportunity to reindustrialize and bring back onshore, industry, and manufacturing, which had previously been sent abroad. By encouraging reindustrialization, governments hope to increase value-add from manufacturing to boost their GDPs.

The potential development of the Industrial Internet is not without precedence, as over the last 15 years the business-to-consumer (B2C) sector via the Internet trading in retail, media, and financial services has witnessed stellar growth. The success of B2C is evident by the dominance of web-scale giants

born on the Internet, such as Amazon, Netflix, eBay, and PayPal. The hope is that the next decade will bring the same growth and success to industry, which in this context covers manufacturing, agriculture, energy, aviation, transportation, and logistics. The importance of this is undeniable as industry produces two-thirds of the global GDP, so the stakes are high.

The Industrial Internet, however, is still in its infancy. Despite the Internet being available for the last 15 years, industrial leaders have been hesitant to commit. Their hesitance is a result of them being unsure as to how it would affect existing industries, value chains, business models, workforces, and ultimately productivity and products. Furthermore, in a survey of industry business leaders, 87% claimed in January 2015 that they still did not have a clear understanding of the business models or the technologies.

This is of course to be expected as the Industrial Internet is so often described at such a high level it often decouples the complexities of the technologies that underpin it to an irrelevance. For example, in industrial businesses, they have had sensors and devices producing data to control operations for decades. Similarly, they have had machine-to-machine (M2M) communications and collaboration for a decade at least so the core technologies of the Industrial Internet of Things are nothing new. For example, industry has also not been slow in collecting, analyzing, and hoarding vast quantities of data for historical, predictive, and prescriptive information. Therefore the question industrial business leaders often ask is, "why would connecting my M2M architecture to the Internet provide me with greater value?"

What Is the Industrial Internet?

To explain why businesses should adopt the Industrial Internet, we need to first consider what the IIoT actual is all about. The Industrial Internet provides a way to get better visibility and insight into the company's operations and assets through integration of machine sensors, middleware, software, and backend cloud compute and storage systems. Therefore, it provides a method of transforming business operational processes by using as feedback the results gained from interrogating large data sets through advanced analytics. The business gains are achieved through operational efficiency gains and accelerated productivity, which results in reduced unplanned downtime and optimized efficiency, and thereby profits.

Although the technologies and techniques used in existing machine-to-machine (M2M) technologies in today's industrial environments may look similar to the IIoT, the scale of operation is vastly different. For example, with Big Data in IIoT systems, huge data streams can be analyzed online using cloud-hosted advanced analytics at wire speed. Additionally, vast quantities of data can be stored in distributed cloud storage systems for future analytics performed in

batch formats. These massive batch job analytics can glean information and statistics, from data that would never previously been possible because of the relatively tiny sampling pools or simply due to more powerful or refined algorithms. Process engineers can then use the results of the analytics to optimize operations and provide the information that the executives can transform to knowledge, in order to boost productivity and efficiency and reduce operational costs.

The Power of 1%

However, an interesting point with regard to the Industrial Internet is what is termed the power of 1%. What this relates to is that operational cost/inefficiency savings in most industries only requires Industrial Internet savings of 1% to make significant gains. For example, in aviation, the fuel savings of 1% per annum relates to saving $30 billion. Similarly, 1% fuel savings for the gas-fired generators in a power station returns operational savings of $66 billion. Furthermore, in the Oil and Gas industry, the reduction of 1% in capital spending on equipment per annum would return around $90 billion. The same holds true in the agriculture, transportation, and health care industries. Therefore, we can see that in most industries, a modest improvement of 1% would contribute significantly to the return on investment of the capital and operational expenses incurred by deploying the Industrial Internet. However, which technologies and capital expenses are required when initiating an IIoT strategy?

Key IIoT Technologies

The Industrial Internet is a coming together of several key technologies in order to produce a system greater than the sum of its parts. The latest advances in sensor technologies, for example, produce not just more data generated by a component but a different type of data, instead of just being precise (i.e., this temperature is 37.354 degrees). sensors can have self-awareness and can even predict their remaining useful life. Therefore, the sensor can produce data that is not just precise, but predictive. Similarly, machine sensors through their controllers can be self-aware, self-predict and self-compare. For example, they can compare their present configuration and environment settings with preconfigured optimal data and thresholds. This provides for self-diagnostics.

Sensor technology has reduced dramatically in recent years in cost and size. This made the instrumentation of machines, processes, and even people financial and technically feasible.

Big Data and advanced analytics as we have seen are another key driver and enabler for the IIoT as they provide for historical, predictive, and pre-scriptive analysis, which can provide insight into what is actually happening inside a machine or a process. Combined with these new breed of self-aware and self-predicting components analytics can provide accurate predictive maintenance schedules for machinery and assets, keeping them in produc-tive service longer and reducing the inefficiencies and costs of unnecessary maintenance. This has been accelerated by the advent of cloud computing over the last decade whereby service providers like AWS provide the vast compute, storage, and networking capabilities required for effective Big Data at low cost and on a pay-what-you-use basis. However, some risk-adverse companies may prefer to maintain a private cloud, either on their own data centers or in a private cloud.

Why Industrial Internet and Why Now?

To comprehend why the Industrial Internet is happening today, when its tech-nologies have been around for a while, we need to look at legacy system capabilities and inefficiencies.

One assumption is that the complexity of industrial systems has outpaced the human operator's ability to recognize and address the efficiencies, thus making it harder to achieve improvements through traditional means. This can result in machines operating well below their capabilities and these factors alone are creating the operational incentives to apply new solutions.

Furthermore, IT systems can now support widespread instrumentation, monitoring, and analytics due to a fall in the costs of compute, bandwidth, storage, and sensors. This means it's possible to monitor industrial machines on a larger scale. Cloud computing addresses the issues with remote data storage; for example, the cost and capacity required to store big data sets. In addition, cloud providers are deploying and making available analytic tools that can process massive amounts of information. These technologies are maturing and becoming more widely available, and this appears to be a key point. The technologies have been around for a while and have been adopted by IT—cloud adaptation and SaaS are prime examples of this. However, it is only recently that industrial business leaders have witnessed the stability and maturity of solutions, tools, and applications within these IT sectors reach a level of confidence and lessen concerns.

Similarly, the maturity and subsequent growth in networks and evolving low-power radio wireless wide area networks (WWAN) solutions have enabled remote monitoring and control of assets, which previously were simply not economical or reliable enough. Now these wireless radio networks have reached a price point and a level of maturity and reliability that works

in an industrial environment. Together these changes are creating exciting new opportunities when applied to industrial businesses, machines, fleets, and networks.

The decline in the cost of compute, storage, and networks is a result of the cloud-computing model, which allows companies to gather and analyze much larger amounts of data than ever before. This alone makes the Industrial Internet an attractive alternative to the exclusive M2M paradigm.

However, the Industrial Internet has its own issues, which may well act as severe countermeasures to adoption. These are termed *catalysts* and *precursors* to a successful Industrial Internet deployment.

Catalysts and Precursors of the IIoT

Unfortunately, there are several things an IIoT candidate business simply must have in place before embarking on a serious deployment, discussed in the following sections.

Adequately Skilled and Trained Staff

This is imperative if you expect to benefit from serious analytics work as you will certainly need skilled data scientists, process engineers, and electro-mechanical engineers. Securing talent with the correct skills is proving to be a daunting task as colleges and universities seem to be behind the curve and are still pushing school leavers into careers as programmers rather than data scientists. This doesn't seem to be changing anytime soon. This is despite the huge demand for data scientists and electro-mechanical engineers predicted over the next decade. The harsh financial reality is that the better the data analytical skills, the more likely the company can produce the algorithms required to distil information from their vast data lakes. However, this is not just any information but information that returns true value, aligned to the business strategy and goals. That requires data scientists with expert business knowledge regarding the company strategy and short-medium-long term goals. This is why there is a new C-suite position called the Chief Data Officer.

Commitment to Innovation

A company adopting IIOT has to make a commitment to innovation, as well as taking a long-term perspective to the IIoT project's return on investments. Funding will be required for the capital outlay for sensors, devices, machines, and systems. Funding and patience will be required as performing the data capture and configuring the analytics' parameters and algorithms might not result in immediate results; success may take some time to realize. After all,

statistical analysis does not always return the results that you may be looking for. It is important to ask the correct questions. Data scientists can look at the company strategy and align the analysis—the questions of data pools—to return results that align with the company objectives.

A Strong Security Team Skilled in Mitigating Vulnerabilities in Industrial and IT Networks

This is vital, as the IIoT is a confluence of many technologies and that can create security gaps unless there is a deep understanding of the interfaces and protocols deployed. Risk assessments should reveal the most important assets and the highest risk assets and strategic plans developed to mitigate the risk. For example, in a traditional industrial production factory the machines that produce the products such as lathes that operate on programmable templates contain all the intellectual and design knowledge to construct the product. Additionally, security teams should enforce policy and procedures across the entire supply chain.

Innovation and the IIoT

Proponents of the Industrial Internet refer to it as being the third wave of innovation. This is in regard to the first wave of innovation being the industrial revolution and the second wave the Internet revolution. The common belief is that the third wave of innovation, the Industrial Internet revolution, is well under way. However, if it is, we are still in its infancy as the full potential of the digital Internet technology has yet to be realized broadly across the industrial technology sectors. We are beginning to see intelligent devices and intelligent systems interfacing with industrial machines, processes, and the cloud, but not on an industry-wide scale. Certainly, there is not the level of standardization of protocols, interfaces, and application that will undoubtedly be required to create an IIoT value chain. As an example of this, there is currently a plethora of communication and radio protocols and technologies, and this has come about as requirements are so diverse.

In short, no one protocol or technology can meet all use-case requirements. The existence of diverse protocols and technologies makes system integration within an organization complex but with external business partners, the level of complexity can make integrating systems impractical. Remember that even the largest companies in the world do not have the resources to run their own value chains. Therefore, until interfaces, protocols, and applications are brought under some level of standardization, interconnecting with partners will be a potentially costly, inefficient, and possibly an insecure option.

Intelligent Devices

We are witnessing innovation with the development of intelligent devices, which can be new products or refitted and upgraded machinery. The innovation is currently directed toward enabling intelligent devices. This is anything that we connect with instrumentation, for example, sensors, actuators, engines, machines, components, even the human body, among a myriad of other possible items. This is because it is easy and cost effective to add instrumentation to just about any object about which we wish to gather information.

The whole point of intelligent devices in the Industrial Internet context is to harvest raw data and then manage the data flow, from device to the data store, to the analytic systems, to the data scientists, to the process, and then back to the device. This is the data flow cycle, where data flows from intelligent devices, through the gathering and analytical apparatus before perhaps returning as control feedback into the device. It is within this cycle where data scientists can extract prime value from the information.

Key Opportunities and Benefits

Not unexpectedly, when asked which key benefits most IIoT adopters want from the Industrial Internet, they say increased profits, increased revenue flows, and lower operational expenditures, in that order. Fortunately, using Big Data to reap the benefits of analytics to improve operational processes appears to be akin to picking the low hanging fruit; it's easily obtainable. Typically, most industrial companies head straight for the predictive maintenance tactic as this ploy returns the quickest results and return on investment.

Some examples of this are the success experienced by Thames Water, the largest fresh-drinking water and water-waste recycler in the UK. It uses the IIoT for remote asset management and predictive maintenance. By using a strategy of sensors, remote communication, and Big Data analytics, Thames Water can anticipate equipment failures and respond quicker to any critical situation that may arise due to inclement weather.

However, other industries have other tactical priorities when deploying IIoT, one being health and safety. Here we have seen some innovative projects from using drones and autonomous vehicles to inspect Oil and Gas lines in inhospitable areas to using autonomous mining equipment. Indeed Schlumberger is currently using an autonomous underwater vehicle to inspect sub-sea conditions. The unmanned vehicle travels around the ocean floor and monitors conditions for anything up to a year powered only by wave motion, which makes deployment in remote ocean locations possible, as they are both autonomous and self-sufficient requiring no local team support.