# 1

# Introduction

## 1.1 The rationale for this book

Wireless communications seems to be an area of frequent and rapid change. New concepts such as updating a Twitter account from a mobile phone arise and become pervasive in less than a year. New devices like the iPhone capture the public imagination within weeks of being launched and in turn change the relationships between the key players in the industry. Satellite navigation seems to be rapidly incorporated into most mobile devices, which themselves are typically replaced within 18 months. Compared with most other industries and consumer products the rate of change is startling. Even in other industries such as the automotive industry, some of the new features such as adaptive cruise control, advanced satellite navigation and collision-control radars are due to advances in wireless technology.

Understanding what is on the 'wireless horizon' – namely what developments are now being considered, developed or trialled – can help make sense of how the wireless world is likely to evolve. This book is about scanning that horizon, identifying the important developments and discussing how they will impact on the world of wireless communications over the next decade or so.

As will be seen in the chapters of this book, simply identifying interesting new technologies is far from sufficient. There have been many 'interesting' new wireless technologies that have failed to live up to their initial promise – mesh wireless networking is one – for a variety of reasons, many of which are not technical. These include the structure of the market, the cost of their provision, the complexity they might entail and, not least, whether they solve a problem that cannot be addressed more readily by other means.

Hence the structure of this book has been divided into two parts. The first looks at new technologies that are 'bubbling'. These are ideas that are being

discussed around the industry, perhaps in academia, research laboratories or conferences. Because the proponents of each idea tend to 'hype' their invention in the hope of getting it widely adopted they are generally relatively easy to spot. Some have been around for many years but have yet to be implemented widely; others are relatively new. The second part of the book looks at application areas such as transport and entertainment and considers the requirements of those sectors. This allows a possible matching between the capabilities of emerging technologies and the needs of particular sectors as well as a discussion of the non-technical barriers that might prevent implementation.

The use of wireless covers an enormous range of activities. This book is mostly concerned with those uses of wireless that affect consumers and change everyday life.

One of the key areas it covers is the cellular phone. This is a large industry involving manufacturers both of infrastructure equipment and of handsets, operators who run the networks and provide service to end users and increasingly applications providers. Of course, there are many associated companies providing a wide range of inputs from chipsets to consultancy and from billing to mast construction.

Another area of increasing importance is the unlicensed use of wireless such as WiFi, Bluetooth and the myriad devices in the home such as garage-door openers. The industry here tends to involve predominantly the manufacturer of the device, although, with wireless embedded in a wide range of goods, the range of manufacturers is equally large.

Wireless is also becoming embedded in many of our possessions including vehicles, computers, toys and so on. All of these manufacturers are affected, and affect, the wireless industry. For example, as we will see, the ability to use wireless in the car changes some of the ways in which it is designed and features that it offers.

This book does not consider wireless in a number of less consumer-focused applications. It does not cover wireless in the military, except where technologies pioneered by the military are now making their way into the commercial world. It does not say much about satellite systems, partly because there is little to say about these (other than that they are steadily improving). Fixed links (or microwave point-to-point links) are not covered, again partly because there is little change expected here and because they are also not direct to the end user. Finally, one of the biggest users of the radio spectrum, radar systems, also does not get a mention, for very similar reasons to the other categories. Actually, with radar systems there is the possibility of using novel designs that would dramatically reduce the use of spectrum without compromising performance, but the speed at which new radars are introduced is so slow and the need for safety case verification so great that the pace of change is glacial.

This book comes at a time when the wireless industry is facing new challenges. For most of the last 25 years wireless has been a dynamic growth industry with companies reporting ever increasing profits and with subscriber numbers rising dramatically. All that has now changed and many companies see declining revenues. Manufacturers have gone into bankruptcy or merged and operators are increasingly looking to mergers to save money. Operators are also facing a challenge from data volumes that have grown dramatically but without much associated increase in revenue. The industry is seeking a technical solution to this problem, but it is more likely that the solution will come from changed value chains, use of smaller cells and an overall change to the landscape of the wireless industry. These issues will be addressed at appropriate points within this book.

## 1.2 Looking through the rear-view mirror

*Why look backwards?*

Before looking forwards it is informative to look backwards and consider those technologies and applications which have had the greatest impact on wireless communications over the last 10–20 years. This may help us to understand the type of developments that have changed the world and, while the past is not always a good predictor of the future, there are always lessons that can be learnt.

As will be explained, many developments are interlinked. Some make use of the same underlying advances in technology; others are enabled as a result of another development and sometimes form virtuous or self-reinforcing circles. Hence, discussing developments in a logical or chronological fashion is not easy and a different approach is adopted here, namely that of looking at the most important developments and then examining their implications.

*Key changes in communications*

Arguably the biggest development over the last 10–15 years has been the emergence of the Internet as a core component of our everyday life. The Internet has resulted in new models of business, new ways of working, an extraordinary increase in access to information and rapid innovation across the entire spectrum of communications. The original enablers of the Internet are well chronicled and include the work on Arpanet and the development of hypertext and other protocols. From a communications viewpoint, the advent of broadband communications to the home did much to make the Internet a more valuable tool. The broadband revolution itself was broadly enabled by DSL technology, which became possible as a result of improving processing

power within silicon. Widespread access to the Internet on highly standardised platforms then enabled applications such as Facebook to be written in just one format and rapidly adopted. Heavy reliance on the Internet has in turn made it increasingly important to be able to access it even when mobile, driving take-up of mobile data, WiFi connectivity and browsers on mobile phones. We may still be only at the start of this revolution.

Another key development has been the improvement in mobile devices, as epitomised by the iPhone. Part of this has been improvements in the user interface, including touchscreens and more intelligent software, but underlying the change are improvements in component technology, including miniaturisation of cameras, massive increases in memory size and improvements in chip fabrication, enabling multiple wireless technologies to be incorporated into the same device. The iPhone in turn drove changed business models including the success of the applications store. Such concepts had been tried before by mobile operators but failed because they required a very wide range of devices with many different operating systems to be supported and because the user interface often made it difficult to use the applications. The iPhone changed this by offering a single platform with a flexible user interface.

Applications in turn are driving a change in the idea of what a phone is for, leading to changes in the connectivity required. For example, it would have been hard to envisage five years ago phones whose design was centred around updating of social-networking sites. This further increases the attractiveness of wireless connectivity such as WiFi, making it more ubiquitous, making chipsets less expensive and powering another virtuous circle.

Improvements in storage have also driven key developments in entertainment. The CD has increasingly been displaced by MP3 players as their functionality has improved. Of course, this in turn was accelerated by iTunes, which linked device developments with content and helped pave the way for the iPhone. Hard-disc storage has also displaced the video-cassette recorder with the PVR as a mechanism for recording and time-shifting programmes and even the DVD is now under threat as hard discs become large enough to hold archive video material. It is clear that delivery of video content will change over the coming years as these factors play out.

As a separate development, the availability of GPS has driven widespread adoption of satellite navigation and laid the basis for many location-based services.

### *Technical drivers*

The technical drivers that underlie these changes – those that we might have hoped to have predicted 15 years ago – are predominantly related to

storage, processing power, lower-cost and denser chips and better displays and input devices.

Our ability to store data continues to grow by around an order of magnitude every six years. This applies both to hard-disc storage on PCs and in PVRs and to flash-memory storage in portable devices. To put this into perspective, about every 18 years there is a thousand-fold increase in the amount of storage available. This trend has been visible since the mid 1970s and has remained fairly consistent, with slight periods of acceleration and deceleration away from the trend. Predicting this change in storage was relatively easy and some of the implications, such as being able to store an entire music library on a portable device, were known many years in advance. There is no sign that this trend is slowing or reaching any fundamental limits, as will be discussed further in later chapters.

Processing power is a similar story. Moore's Law goes back even further and has been followed with uncanny accuracy over many decades (most probably because it has become a self-fulfilling prophecy). This drives not only enhancements in processors but also increasingly dense integration on chipsets. The result has been that concepts that were overly complex at one point become implementable later. (As an aside, when GSM was standardised in the late 1980s, it was known at the time that it was not possible to implement a portable device with the available technology, but the assumption was that this technology would improve sufficiently to allow portable devices – and it did.) However, as regards wireless, we may be coming towards the end of this trend, more because the battery power available cannot support more powerful processors than because it is not possible to manufacture them. Just as with storage, increased processing power was a very predictable trend.

Better displays and in particular touchscreen displays were more difficult to predict. There are no well-known 'laws' of evolution in display technology, instead there tend to be breakthroughs as new materials are brought into use or new manufacturing approaches enable cost-effective displays. How displays might change in the future is likely to be as much of a key driver as it has been in the past and this is considered further in Chapter 9.

*Application drivers*

While technology can enable new devices, it is the applications they can be used for that result in consumer interest and adoption. As mentioned above, one of the key drivers has been the Internet, which has enabled a wide range of applications including communications of all sorts, on-line purchasing, targeted advertising, information search, information sharing and a range of business connectivity functions. Many of these are things that consumers were

already doing (communicating, purchasing, etc.) but could now be performed more effectively.

On-line purchasing was one of the early Internet applications leading to Amazon and a wave of Internet retailers. At first take-up was slow as consumers persisted in the 'old way' of doing things and because they harboured doubts and concerns about security, payment mechanisms and delivery issues. However, as confidence grew and early adopters told others of their good experiences, adoption grew quickly and moved from the most obvious areas such as book purchase where actually seeing or holding the product was of little relevance to areas such as clothes retailing and grocery shopping. After initially replicating the physical shopping experience, a range of novel services such as 'if you liked that you'll probably like this too' and consumer ratings were added, further increasing the value to end users. Comparison sites sprang up, enabling users to compare prices across a range of vendors. So on-line purchasing started by replicating an existing experience and then evolved to add new services and value.

On-line search was another obvious function to add to the Internet. Initially appearing simply because there was no other way to access the mass of data available on-line, search improved rapidly as clever algorithms were devised to present increasingly useful results. This is an on-going process as researchers seek algorithms that will 'answer questions' rather than just look for matches to search strings. Search broadly replaced either going to a library or asking around a number of colleagues or organisations for access to information. Search often has a similar function to advertising – with search a consumer may be trying to discover products, whereas with advertising a company may be trying to inform consumers about their products. Thus it was an obvious step to link the two together – forming the business model that has driven Google's success. This is now driving fundamental changes in advertising, with spending shifting from traditional media to the Internet in a way that is having knock-on consequences for newspapers, broadcasting and other entities with advertiser-funded revenue models.

Search, advertising and on-line purchasing have fed off one another. Search makes it simpler to compare prices across multiple stores and discover information about products than it would be via 'conventional' shopping. This in turn feeds more on-line purchasing, increasing the value of search and click-through advertising. Internet retailing is often cheaper for the retailer, who no longer needs a physical presence, further increasing the overall attractiveness. With all these self-reinforcing characteristics it is unsurprising that on-line purchasing initially grew slowly but then reached a 'tipping point' where growth accelerated sharply.

However, this evolution is threatening to lessen the value of the original activities. So, for example, search results are becoming less about what can be 'found' and more about what has been paid for by advertisers to be shown to those searching for particular items. In some cases there may be no conflict between these and in others search engines such as Google appear to differentiate between paid-for responses and what has been found. Others try to increase the likelihood of their site being listed by a search engine by modifying parameters of the site to make it more likely that it will be found – tending to favour those with the greatest resources. Perhaps this behaviour might be compared with colonising the West in the USA. The Internet to date has been somewhat like Frontierland with little in the way of rules and much in the way of land-grabs. Once rules start to emerge, then 'Main Street' starts to make its presence felt, increasing the dominance of large organisations and decreasing that of individuals. Quite where this will end is unclear – perhaps with alternative types of search deliberately trying to throw up unexpected and unusual results.

Probably the largest and least predicted growth area has been social networking. This started with sites such as Friends Reunited and YouTube but really took off with the advent of Facebook and MySpace. It found yet another direction with Twitter. Unlike retailing and search, these were applications with little parallel in the pre-Internet world, making them much harder to predict. Many appear to have emerged and become highly successful in very short periods of time, partly because of the ease with which applications can be downloaded and people become members, often without needing to spend any money. At the moment there appears to be no end in sight to the social-networking phenomena, although some are wondering whether users will tire of constantly updating their Facebook entry or reading multiple tweets.

Most of these applications proved themselves on fixed networks, initially on PCs connected by wires and low-speed modems to the Internet, but, as the applications proved their value in a fixed environment, users started to want to access them when mobile as well. Mobile search is especially valuable as it can be linked to location. Accessing social-networking sites from a mobile is seen as increasingly important, with some mobiles being designed around this functionality. On-line purchasing is heading in new directions with wireless – for example the ability to wirelessly purchase an e-book for download to a reader. Computers are increasingly wireless, with WiFi providing the final connection for many even if the main connection to the building is via wires. So understanding the applications that are successful on wired systems may provide some guidance as to applications that are likely to expand to wireless – fixed search expanded slowly but steadily to mobile search. However, not all

fixed applications go mobile, some take many years if not decades to make the transition and mobility brings additional functionality that can change some applications.

*Linking the two*

Apparent from reading the section on technologies and then that on applications is how unrelated they appear. Understanding the technology drivers would appear to be of little use in determining which applications would emerge and, equally, looking at the key drivers for the applications reveals little about the technological changes needed. That explains the reason for looking at both in this book rather than trying to predict the future from the evolution of technology or an idea for a new application.

Many of the applications discussed had long been forecast – for example the dot-com bubble of 2000 was based on the idea that on-line retailing would change the way that we shop. In retrospect, many of the forecasts were broadly correct in their magnitude but optimistic in their timing. Some of the discussion above about the virtuous spiral of growth of inter-related services suggests why this might be. Applications are based on a very complex inter-related 'eco-system' that includes manufacturers, operators, other service providers and, importantly, the early adopters and advocates amongst the end users. For example, for location-based services manufacturers need to build easy-to-use GPS location systems within the handset, operators need to provide a framework for location-based services, entities like mapping companies need to produce appropriate offerings, Google needs to provide location-enabled search and early adopters and key influencers need to be enthusiastic about the service in order to convince others to adopt it. The relationships among all these players are complex, with some positive- and some negative-feedback loops. Models of such situations show how dramatically different outcomes can be achieved with relatively little change in inputs, and 'tipping points' are often observed. The complexity is not helped by the tendency of those in industry to look optimistically at the services they are working on, and for analysts to prefer reports with positive rather than negative outcomes.

The existence of tipping points – values of particular input variables at which the prediction of the model suddenly shifts from no growth to the hockey-stick – makes it almost impossible to predict accurately the success of such services. The chances are that most will be predicted to be successful for many years during which they will languish and then suddenly, for reasons that might not even be apparent, or appear of little relevance, they will take off rapidly. All we can do is learn from the models as to what behaviours would be most likely to result in success; but actually we know this already – to be successful all

elements of the service launch must be near-perfect. The technology must work, the service must be easy to use, the pricing must be attractive and the marketing must attract the right early adopters, who must be deeply impressed. If any one element is not quite right it could be enough to prevent the service succeeding. That much is common sense. The difficulty, as always, is for all the companies to work together in a way that is competitive but collaborative, and that embraces standards but allows competitive differentiation. This is very hard – the incentives for individual organisations are rarely such that they work together well. What tends to happen is that individual elements slowly get solved and, when the last one falls into place, the service takes off.

## 1.3 Learning from previous predictions

The previous section looked back at the most important developments in communications and related areas in the last 10–15 years. That is relatively easy to do with hindsight, but might we have predicted these developments had we been writing this book in 1995? The only way to really tell is to look at some predictions made in the past and ask how accurate they were. Actually, this turns out to be somewhat difficult to do. There are many sources of such predictions and they are all somewhat different, so a different result will be achieved depending on the source.

Even more difficult is that many predictions make use of scenarios. Scenarios, on the face of it, represent a very sensible approach to forecasting. There are some variables that appear just too difficult to predict, such as whether mobile TV will take off. It seems better, then, to model a range of scenarios, often representing extreme cases. This would work well if all the scenarios, or almost all, pointed to a similar outcome. For example, if 4G were needed under all reasonable scenarios, then the analysis would have demonstrated strongly that its emergence was nearly certain. But in the communications sector this very rarely happens. Instead, the 'status quo' scenario shows that no new networks or technologies are needed while the 'wireless-data explodes' scenario shows that networks will need a sixty-fold increase in capacity or more. Effectively, scenarios demonstrate that in order to make a bet on the future you have to pick a particular scenario. Sadly, the forecasters who use scenarios rarely do. They simply present their set of scenarios and leave it for the reader to select their preferred one.

So in this section we discuss a set of predictions that we made in 2000 when we authored a book entitled *The Future of Wireless Communications* [1]. After a detailed look at the key drivers, the book made specific predictions as to how the world of wireless communications would look in 2005, 2010, 2015 and 2020.

We published another book in 2006, this time entitled *Wireless Communications: The Future* [2]. This also made specific predictions about 2011, 2016, etc. The predictions in these books were made taking a range of factors into account, including network modelling, an understanding of trends such as 'Moore's Law', a look back of up to 20 years to understand the pace of change, assessment of standards currently being developed and input from six 'gurus' as to their views and predictions from experts in specific areas such as screen technology.

In 2000 we predicted that by 2010 homes would become wireless hotspots, with dedicated home networks probably using the Bluetooth technology. Most homes would be connected via broadband with data rates in the region of 10 Mbits/s. Mobile phones, or by that time 'communicator devices', with a wide range of functionality would work with these home networks. Allowing phones to work in the home and office would bring a need for work–life differentiation that would be solved by re-direction functions in the network that reformatted, forwarded or sent incoming messages to message boxes according to circumstances and preferences. We thought that video communications would start to become used, making up about 2% of calls.

We predicted that people would communicate more readily with machines using speech recognition and that machines would increasingly communicate with each other. Networks would have packet-based cores and we thought that public WiFi hot spots would become commonplace.

Most of these appear about right. Homes have deployed wireless nodes, albeit WiFi rather than Bluetooth. Handsets can work on in-home WiFi networks, although this functionality is not yet widely deployed, more because it has not been in the interest of cellular operators to see this happen rather than due to technical reasons. Broadband connections are available to homes and data-rate requirements are somewhere in the region of 10 Mbits/s, although they are not always met. IP cores are well established in cellular networks and public W-LAN hotspots are ubiquitous in buildings in cities.

Some predictions proved over-optimistic. 'Re-direction functions' whereby messages would be intelligently re-routed have not occurred because they have proven overly complex; instead users have made use of different communications mechanisms to handle different message priorities. The prediction that speech recognition would be 'solved' by 2010 and would become the way in which people interacted with machines, rather than using keyboards, appeared entirely plausible in 2000 given the rapid progress that had been made in the late 1990s. However, this progress slowed and it proved very difficult to get accuracy up from around the 98% mark to the near-100% level needed to make it useful. Speech recognition is still making slow progress and is finding more applications, especially where the vocabulary it needs to recognise can