1
Where to Begin

This book was created by a team of individuals who each, in their own field, are actively participating in the ever-expanding Internet by pushing its reach farther than ever before. The massive popularity of wireless networking has caused equipment costs to continually plummet, while equipment capabilities continue to sharply increase. We believe that by taking advantage of this state of affairs, people can finally begin to have a stake in building their own communications infrastructure. We hope to not only convince you that this is possible, but also show how we have done it, and to give you the information and tools you need to start a network project in your local community.

Wireless infrastructure can be built for very little cost compared to traditional wired alternatives. But building wireless networks is only partly about saving money. By providing people in your local community with cheaper and easier access to information, they will directly benefit from what the Internet has to offer. The time and effort saved by having access to the global network of information translates into wealth on a local scale, as more work can be done in less time and with less effort.

Likewise, the network becomes all the more valuable as more people are connected to it. Communities connected to the Internet at high speed have a voice in a global marketplace, where transactions happen around the world at the speed of light. People all over the world are finding that Internet access gives them a voice to discuss their problems, politics, and whatever else is important to their lives, in a way that the telephone and television simply cannot compete with. What has until recently sounded like science fiction is now becoming a reality, and that reality is being built on wireless networks.

But even without access to the Internet, wireless community networks have tremendous value. They allow people to collaborate on projects across wide distances. Voice communications, email, and other data can be exchanged for very little cost. By getting local people involved in the construction of the network, knowledge and trust are spread throughout the community, and people begin to understand the importance of having a share in their communications infrastructure. Ultimately, they realize that communication networks are built to allow people to connect with each other.

In this book we will focus on wireless data networking technologies in the 802.11 family. While such a network can carry data, voice, and video (as well as traditional web and Internet traffic), the networks described in this book are data networks. We specifically do not cover GSM, CDMA, or other wireless voice technologies, since the cost of deploying these technologies is well beyond the reach of most community projects.

Purpose of this book

The overall goal of this book is to help you build affordable communication technology in your local community by making best use of whatever resources are available. Using inexpensive off-the-shelf equipment, you can build high speed data networks that connect remote areas together, provide broadband network access in areas that even dialup does not exist, and ultimately connect you and your neighbors to the global Internet. By using local sources for materials and fabricating parts yourself, you can build reliable network links with very little budget. And by working with your local community, you can build a telecommunications infrastructure that benefits everyone who participates in it.

This book is not a guide to configuring a radio card in your laptop or choosing consumer grade gear for your home network. The emphasis is on building infrastructure links intended to be used as the backbone for wide area wireless networks. With that goal in mind, information is presented from many points of view, including technical, social, and financial factors. The extensive collection of case studies present various groups' attempts at building these networks, the resources that were committed to them, and the ultimate results of these attempts.

Since the first spark gap experiments at the turn of the last century, wireless has been a rapidly evolving area of communications technology. While we provide specific examples of how to build working high speed data links, the techniques described in this book are not intended to replace existing wired infrastructure (such as telephone systems or fiber optic backbone). Rather, these techniques are intended to augment existing systems, and provide connectivity in areas where running fiber or other physical cable would be impractical.

We hope you find this book useful for solving your communication challenges.

Fitting wireless into your existing network

If you are a network administrator, you may wonder how wireless might fit into your existing network infrastructure. Wireless can serve in many capacities, from a simple extension (like a several kilometer Ethernet cable) to a distribution point (like a large hub). Here just a few examples of how your network can benefit from wireless technology.

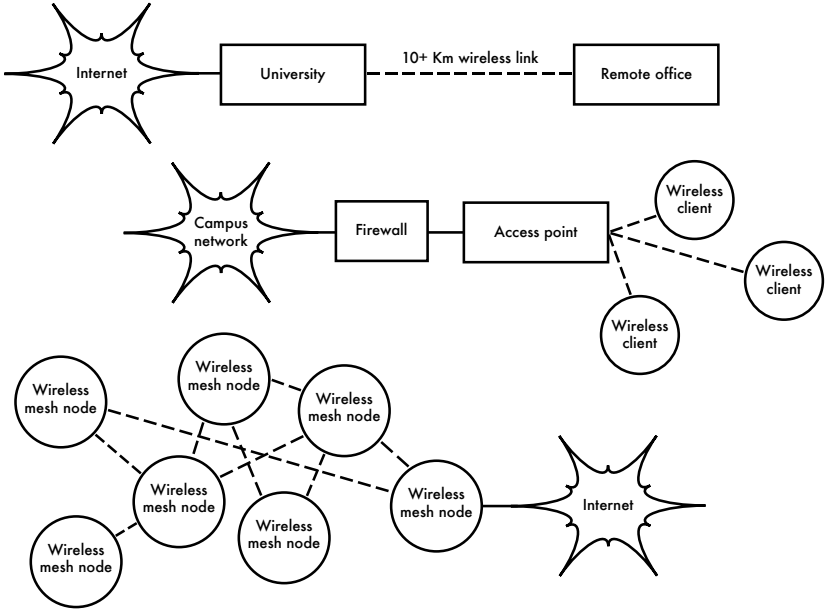

Figure 1.1: Some wireless networking examples.

Wireless networking protocols

The primary technology used for building low-cost wireless networks is currently the 802.11 family of protocols, also known in many circles as ***Wi-Fi***. The 802.11 family of radio protocols (802.11a, 802.11b, and 802.11g) have enjoyed an incredible popularity in the United States and Europe. By implementing a common set of protocols, manufacturers world wide have built highly interoperable equipment. This decision has proven to be a significant boon to the industry and the consumer. Consumers are able to use equipment that implements 802.11 without fear of "vendor lock-in". As a result, consumers are able to purchase low-cost equipment at a volume which has benefitted manufacturers. If manufacturers had chosen to implement their

own proprietary protocols, it is unlikely that wireless networking would be as inexpensive and ubiquitous as it is today.

While new protocols such as 802.16 (also known as WiMax) will likely solve some difficult problems currently observed with 802.11, they have a long way to go to match the popularity and price point of 802.11 equipment. As equipment that supports WiMax is just becoming available at the time of this writing, we will focus primarily on the 802.11 family.

There are many protocols in the 802.11 family, and not all are directly related to the radio protocol itself. The three wireless standards currently implemented in most readily available gear are:

- **802.11b**. Ratified by the IEEE on September 16, 1999, 802.11b is probably the most popular wireless networking protocol in use today. Millions of devices supporting it have shipped since 1999. It uses a modulation called ***Direct Sequence Spread Spectrum*** (***DSSS***) in a portion of the ISM band from 2.400 to 2.495 GHz. It has a maximum rate of 11 Mbps, with actual usable data speeds up to about 5 Mbps.
- **802.11g**. As it wasn't finalized until June 2003, 802.11g is a relative latecomer to the wireless marketplace. Despite the late start, 802.11g is now the de facto standard wireless networking protocol as it now ships as a standard feature on virtually all laptops and most handheld devices. 802.11g uses the same ISM range as 802.11b, but uses a modulation scheme called ***Orthogonal Frequency Division Multiplexing*** (***OFDM***). It has a maximum data rate of 54 Mbps (with usable throughput of about 22 Mbps), and can fall back to 11 Mbps DSSS or slower for backwards compatibility with the hugely popular 802.11b.
- **802.11a**. Also ratified by the IEEE on September 16, 1999, 802.11a uses OFDM. It has a maximum data rate of 54 Mbps, with actual throughput of up to 27 Mbps. 802.11a operates in the ISM band between 5.745 and 5.805 GHz, and in a portion of the UNII band between 5.150 and 5.320 GHz. This makes it incompatible with 802.11b or 802.11g, and the higher frequency means shorter range compared to 802.11b/g at the same power. While this portion of the spectrum is relatively unused compared to 2.4 GHz, it is unfortunately only legal for use in a few parts of the world. Check with your local authorities before using 802.11a equipment, particularly in outdoor applications. 802.11a equipment is still quite inexpensive, but is not nearly as popular as 802.11b/g.

In addition to the above standards, there are a number of vendor-specific extensions to equipment, touting higher speeds, stronger encryption, and increased range. Unfortunately these extensions will not operate between equipment from different manufacturers, and purchasing them will effectively lock you into that vendor for every part of your network. New equipment and standards (such as

802.11y, 802.11n, 802.16, MIMO and WiMAX) promise significant increases in speed and reliability, but this equipment is just starting to ship at the time of this writing, and availability and vendor interoperability is still uncertain.

Due to the ubiquity of equipment and unlicensed nature of the 2.4 GHz ISM band, this book will concentrate on building networks using 802.11b and 802.11g.

Question & Answer

If you are new to wireless networking, you likely have a number of questions about what the technology can do and what it will cost. Here are some commonly asked questions, with answers and suggestions on the listed page.

Power

- How can I supply power to my radio equipment, if there is no grid power available? **Page 211**
- Do I need to run a power cable all the way up the tower? **Page 250**
- How can I use solar panel to power my wireless node while keeping it online overnight? **Page 217**
- How long will my access point run on a battery? **Page 238**
- Can I use a wind generator to power my equipment at night? **Page 212**

Management

- How much bandwidth will I need to purchase for my users? **Page 65**
- How can I monitor and manage remote access points from my office? **Page 174**
- What do I do when the network breaks? **Page 174, 267**
- What are the most common problems encountered on wireless networks, and how do I fix them? **Page 267**

Distance

- How good is the range of my access point? **Page 67**
- Is there any formula I can use to know how far I can go with a given access point? **Page 67**
- How can I know if a remote place can be connected to Internet using a wireless link? **Page 67**
- Is there any software that can help me estimate the feasibility of a long distance wireless link? **Page 74**

- The manufacturer says my access point has a range of 300 meters. Is that true? **Page 67**
- How can I provide wireless connectivity to many remote clients, spread all around the city? **Page 53**
- Is it true that I can reach a much greater distance adding a tin can or aluminum foil to my AP's antenna? **Page 116**
- Can I use wireless to connect to a remote site and share a single central Internet connection? **Page 51**
- My wireless link looks like it will be too long to work well. Can I use a repeater in the middle to make it better? **Page 77**
- Should I use an amplifier instead? **Page 115**

Installation

- How can I install my indoor AP on the top of a mast on my roof? **Page 249**
- Is it really useful to add a lightning protector and proper grounding to my antenna mast, or can I go without them? **Page 263**
- Can I build an antenna mast by myself? How high can I go? **Page 251**
- Why does my antenna work much better when I mount it “sideways”? **Page 13**
- Which channel should I use? **Page 15**
- Will radio waves travel through buildings and trees? What about people? **Page 16**
- Will radio waves travel through a hill that is in the way? **Page 17**
- How do I build a mesh network? **Page 56**
- What kind of antenna is the best one for my network? **Page 102**
- Can I build an access point using a recycled PC? **Page 143**
- How can I install Linux on my AP? Why should I do so? **Page 152**

Money

- How can I know if a wireless link is achievable with a limited amount of money? **Page 281**
- Which is the best AP with the lowest price? **Page 137**
- How can I track and bill customers for using my wireless network? **Page 165, 190**

Partners and Customers

- If I am supplying connectivity, do I still need service from an ISP? Why? **Page 27**
- How many customers do I need to cover my costs? **Page 287**
- How many customers will my wireless network support? **Page 65**
- How do I make my wireless network go faster? **Page 79**
- Is my Internet connection as fast as it can be? **Page 90**

Security

- How can I protect my wireless network from unauthorized access? **Page 157**
- Is it true that a wireless network is always insecure and open to attacks by hackers? **Page 160**
- Is it true that the use of open source software makes my network less secure? **Page 167**
- How can I see what is happening on my network? **Page 174**

Information and Licensing

- What other books should I read to improve my wireless networking skills? Page 355
- Where can I find more information online? **Page 349,** *http://wndw.net/*
- Can I use parts of this book for my own teaching? Can I print and sell copies of this book? **Yes.** See **About This Book** for more details.