BY DON ROTOLO,* N2IRZ

Wireless Local Area Network (LAN) Design

This time we'll move toward the practical considerations that need to be considered when building a wireless network. In the past, this column has discussed the design of such a network, but now I want to offer some specific suggestions as to hardware and configuration. We'll also take a look at a great book I recently received, a professional text on site surveying for 802.11 systems.

Some History

Back in the days of numerous packet networks, we used to assemble stacks of Terminal Node Controllers (TNCs) using diode matrix boards or computers with multi-port RS-232 cards to create nodes, which were used as network switches to route connections across the network. Today, we can leverage the equipment available in the commercial sector to perform these functions at a much lower cost. The network model I'm suggesting looks like a wired network but uses wireless bridges to replace the ethernet wires that would normally connect together a number of network switches or hubs. The end result looks and acts much like a wired network.

Get Wired

To build a wired network (fig. 1), we simply run to the computer or office supply store and pick up a wired ethernet switch or hub, which generally costs under $30. A switch uses the full bandwidth available for each single connection, while a hub shares the total bandwidth across all connections. Think of a hub as a radio channel with all users on the same frequency, while a switch is like each user having his or her own frequency, the switch connecting the audio between users as necessary.

We can also connect multiple switches to one another in order to make our wired network larger. I might use a 4-port switch to connect together four 8-port switches, allowing up to 28 computers ($4 \times 8 = 32$ ports, but one port per switch is used to connect back to the 4-port switch, so $32 - 4 = 28$ available ports) to be on the same network at one time. Of course, like any peer-to-peer network, you must know how to find the other computer(s) with which you wish to communicate, and those other computers must be set up to allow such communications.

Going Wireless

We can use consumer-grade wireless devices to replace that piece of wire connecting an 8-port switch to the 4-port switch, resulting in a wireless link. At each network facility, add a wireless router to allow users to connect in, and you have a wireless data network. Yes, it's that simple.

You may have heard the terms *hub, switch, router,* and *bridge* used before (at least if you're a ham you might have!). I already explained what a hub and switch are. A router (which usually also has an integrated multi-port switch) allows you to communicate to another network (such as through a cable or DSL modem). The big advantage of a

*P.O. Box 114, Park Ridge, NJ 07656
e-mail: <n2irz@cq-amateur-radio.com>

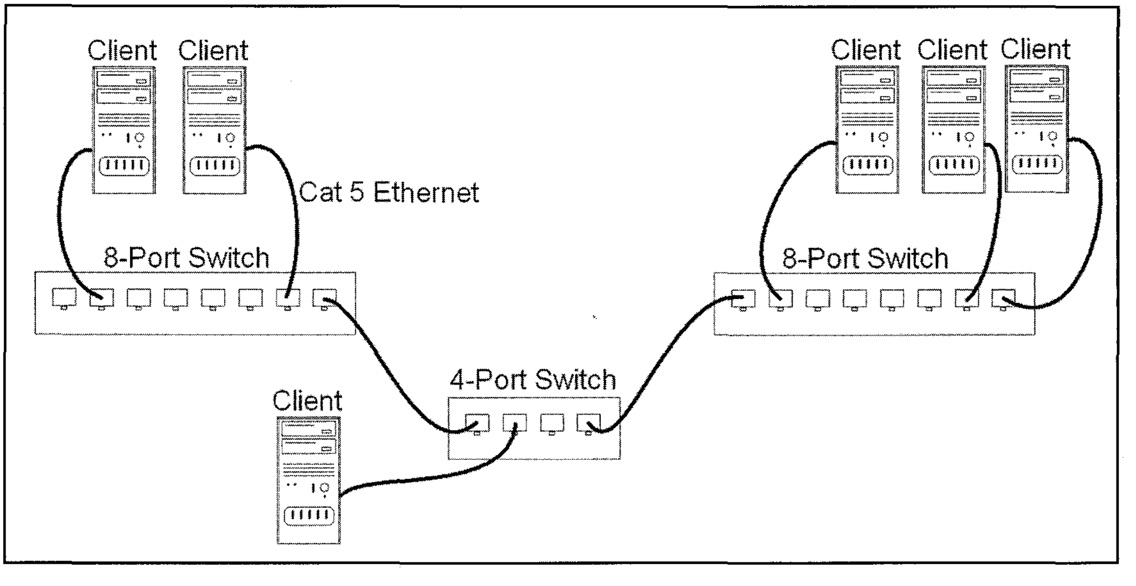

Fig. 1– A typical wired network, with a 4-port switch as its center and two 8-port switches to connect up to 16 client computers (only six are shown for simplicity) together in a wired Local Area Network, or LAN.

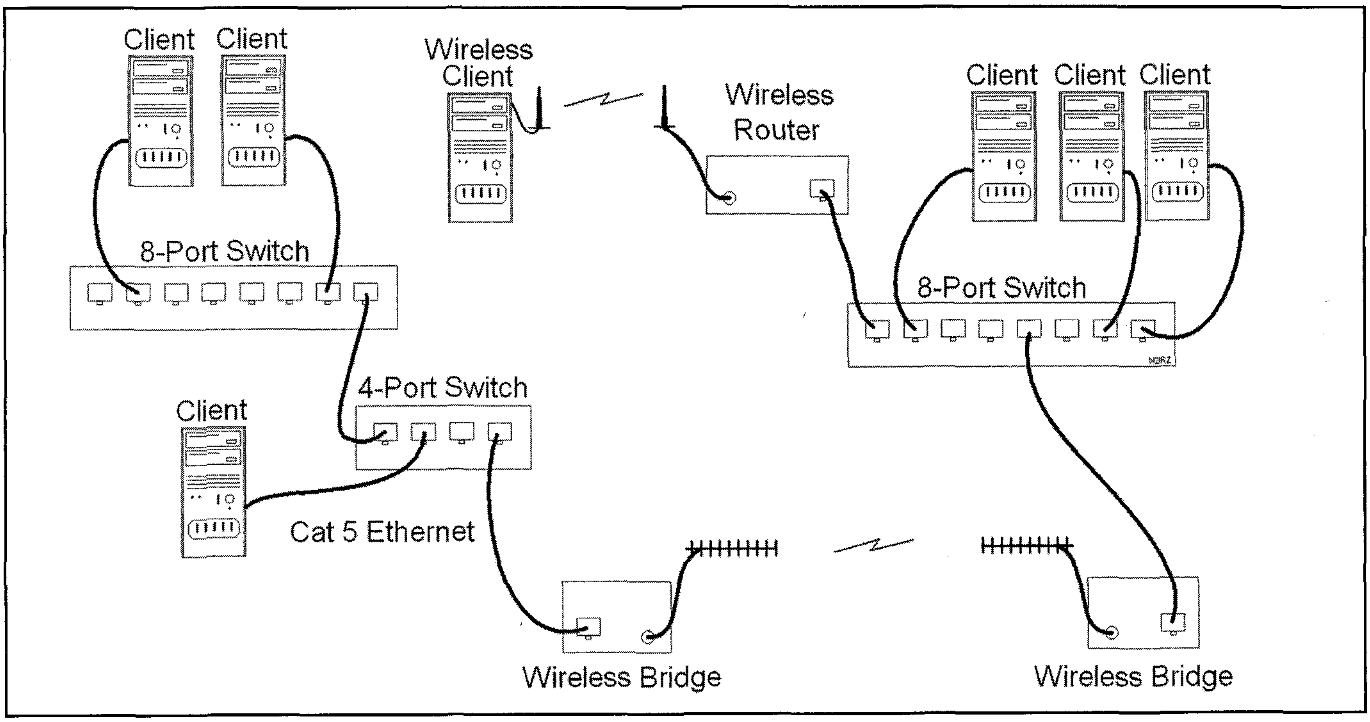

Fig. 2– The same network as in fig. 1, but with one switch connected via a wireless bridge link, as well as wireless router shown providing service to a wireless client. This forms a basic wireless network, which can be expanded as necessary.

router is that it has DHCP; this means it can dynamically assign a TCP/IP address to a user joining the network, which is essential where you cannot or do not want to pre-configure all the network addresses.

A bridge, in contrast, is just a device to extend a network connection. It is completely transparent to the network, just like a piece of wire. Professional-quality wireless bridges can cost a few thousand dollars, but consumer-grade models can be found for under $100 each.

I also want to mention that some wireless routers and access points have a bridge mode, which makes them act like a bridge. If you can find one, it makes a fine alternative to a dedicated bridge. Also, some of the modified firmware available from the resources listed in the sidebar with this article can add bridge capability to some of the really inexpensive consumer-grade wireless routers, making for an even bigger bargain.

Therefore, we simply replace the wires between the switches in our

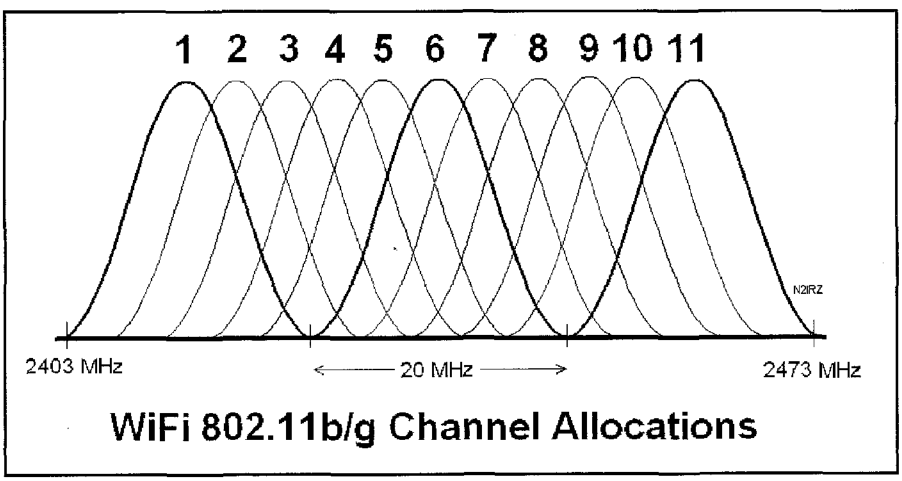

Fig. 3– WiFi 2.4-GHz channel allocations. Note that only channels 1, 6, and 11 do not overlap. Channel 6 is a common default and tends to have a lot of Part 15 activity, so it should be avoided where possible.

wired network with a pair of wireless bridges, and off we go. Add some user access via a wireless router, and we have the high-speed wireless network shown in fig. 2.

Reducing Interference

We need, however, to take actions to eliminate interference. With multiple RF devices operating on 2.4 GHz, some interference can be expected. It should go without saying that co-located RF devices need to be on different channels, but we must also use standard RF diversity techniques to minimize or eliminate interference. Note that only WiFi channels 1, 6, and 11 do not overlap (see fig. 3).

FM repeaters use expensive duplexers, which are very sharp but efficient filters, to eliminate interference between the output and input frequencies. This should also work on 2.4 GHz, but duplexers are expensive and need to be tuned. More simply, one can merely separate the antennas sufficiently, especially if they are directional Yagis. Pointing the Yagis in different directions helps a lot, as does physical separation and shielding them from one another (a window screen works well). Placing vertically-polarized omnidirectional antennas as far as possible from one another vertically—one above the other on a tower, for example—is also effective.

Equipment

Equipment is much less of an issue. A Google search for wireless router revealed many choices, such as the LinkSys WET54G for under $90, or the Trendnet TEW-430APB for around $40. Of course, the Cisco Aeronet 1400 can be had for a mere $3200—a good choice for a large corporation more interested in range, reliability, and throughput than cost.

Speaking of range, the consumer-grade (meaning inexpensive) models are usually in the 10- to 30-milliwatt power range (10–15 dBm), while more expensive units can have 200 mw (23 dBm) output. If power becomes an issue, find a bi-directional amplifier (BDA), which is a quick (but not necessarily cheap) way to get into the watt range. I found many 1-watt BDAs in the under-$200 price range, but an amplifier isn't always necessary.

However, what we save on output power can sometimes be made up by antennas. Once nice thing about big antennas is that they hear better, too. On 2.4 GHz, "big" is a relative term, with

Resources

<www.dd-wrt.com>: A website offering open-source alternative firmware for various wireless routers, some of which can greatly enhance networking functionality to professional standards.

<http://www.dd-wrt.com/wiki/index.php/WDS_Linked_router_network>: Detailed step-by-step instructions on how to create a wireless backbone link between multiple access points that are part of the same wireless network.

<http://www.oreilly.com/catalog/wirelesscommnet2/>: Information on the book *Building Wireless Community Networks,* 2nd Ed., by Rob Flickenger (2003, 182 pages, ISBN 0-596-00502-4), a well-known and well-written how-to book.

<http://www.linksysinfo.org/portal/forums/showthread.php?t=47118>: A guide to setting up WDS (Wireless Distribution System) on the LinkSys WRT54G/GS routers. The website <linksysinfo.org> is not related to LinkSys (a division of Cisco, Inc.), but is a valuable site for networkers.

<http://www.sveasoft.com/>: A company offering firmware replacements for popular routers, allowing them to function as wireless LAN components.

<http://www.sparcotech.com>: One of many distributors of professional WiFi gear.

<http://www.fab-corp.com>: Fleeman, Anderson, and Bird, also known as FAB, is another distributor of wireless gear.

most actually being quite small for their gain. Also, small can mean inexpensive. For example, MFJ sells its Model 1800 16-element WiFi beam Yagi, with 15 dBi gain, for under $30—and it weighs only 2.9 ounces. Directional antennas are good choices for backbone (also called "backhaul") links. For user ports, Comet sells a 2.4-GHz vertical omnidirectional antenna, Model GP-24, for about $150, which boasts about the same gain as the MFJ Yagi. A 21-dBi parabolic grid antenna can be had for under $80.

Wireless routers and access points are plentiful and cheap, with the local office-supply store having one or another on sale weekly for under $30. Access points are not as common, but are readily available in various power ranges. For example, a quick search of the web found a D-Link Model DWL-G700AP access point for under $40, but it has only 32 mw transmit power. A NetGear WG102, with 100 mw power, sells for about $130, and a pro-quality 2611CB3 from Netgate, with 200 mw power, but limited to 802.11b speeds, costs $100.

Wired equipment, such as switches, are plentiful, cheap, and widely available. Every few weeks a D-Link 4-port switch goes on sale for under $8 after a mail-in rebate. My local Staples store has a LinkSys switch for about $25. Just remember that you really don't want a wired router in most cases, unless you expect to provide internet access. If you do want to, the best way to save your license is to limit access to only certain websites by using a proxy server, a computer running software that controls access. If your local schools have internet access, it is likely through a proxy server.

Legal Aspects

One point about antennas, wireless, and the law: If you intend to run your entire network under Part 15, you need to learn about, understand, and comply with the rules. In particular, there are limits on output power and allowable antennas, and you're not allowed to modify the equipment. Under Part 97, however, we have a different set of rules, allowing a free selection of antennas, increased power limits, and ability to modify equipment (such as swapping out antenna connectors), but at the "cost" of having to identify at least every 10 minutes, and ensuring that your network cannot be accessed by Part 15 (non-ham) users.

We've just seen how we can use consumer-grade WiFi gear to build a high-speed wireless network. Our understanding of RF comes in handy, since we can select antennas and manage power levels. The biggest advantage is out ability to run all this under Part 97, allowing the use of antennas, amplifiers, and other gear to design a high-performance network that our Part 15 cousins can only dream about.

The last part, that of really designing a network as opposed to throwing some aluminum into the air to see what happens, has been covered before, but will be revisited sometime in the future.

FIRST

As I have remarked in this column before, as the winter solstice approaches we tend to become just a little bit kinder to one another. An organization I'm involved with, FIRST (For Inspiration and Recognition of Science and Technology), uses the guise of a serious robotics competition to help high school kids learn about teamwork, cooperation, and "gracious professionalism." If you've never heard of FIRST, I urge you to go to its website (www.usfirst.org) and find a local team.

FIRST has over a thousand teams building serious robots to perform a specific task, with a common kit of parts, and each team has only six weeks to design, build, and test its robot before shipping it off to a regional competiton. The competition and six-week build season starts with the kickoff on January 6, 2007 and I am 100% certain that any team you contact will welcome your involvement, whether a single visit, once a week for a few hours, or seven days a week for six weeks. Your reward will be the grateful students who will truly appreciate your knowledge and experience as they approach a design challenge that is "the hardest fun ever."

As is traditional for my last column of the year, I want to use a bit of space to wish everyone the very best of health, happiness, and prosperity in the coming year. All many of us ever want is peace in our day, and so I offer my hopes for each and every one of us. I also thank everyone who has taken the time to write to me with comments, suggestions, ideas for future columns, and yes, even complaints. We're used to two-way communications, and this column isn't any different. Until next time . . .73, Don, N2IRZ