

print and be sure that your injector and wireless equipment agree on which pins and polarity should be used for power.

If your wireless equipment doesn't support power over Ethernet, you can still use the unused pairs in a CAT5 cable to carry power. You can either use a **passive POE injector**, or simply build one yourself. These devices manually connect DC power to the unused wires on one end of the cable, and connect the other end directly to a barrel connector inserted in the device's power receptacle. A pair of passive POE devices can typically be purchased for under \$20.

To make your own, you will need to find out how much power the device requires to operate, and provide at least that much current and voltage, plus enough to account for loss in the Ethernet run. You don't want to supply too much power, as the resistance of the small cable can present a fire hazard. Here is an online calculator that will help you calculate the voltage drop for a given run of CAT5 : <http://www.gweep.net/~sfoskett/tech/poecalc.html>

Once you know the proper power and electrical polarity needed to power your wireless gear, crimp a CAT5 cable only using the data wires (pairs 1-2 and 3-6). Then simply connect the transformer to pairs 4-5 (usually blue / blue-white) and 7-8 (brown / brown-white) on one end, and a matching barrel connector on the other.

## Mounting considerations

In many cases, equipment can be located inside a building, provided there is a window with ordinary glass through which the beam can travel. Normal glass will introduce little attenuation, but tinted glass will introduce unacceptable attenuation. This greatly simplifies mounting, power, and weatherproofing problems, but is obviously only useful in populated areas.

When mounting antennas on towers, it is very important to use a stand off bracket, and not mount the antennas directly to the tower. These brackets help with many functions including antenna separation, antenna alignment and protection.

Stand off brackets need to be strong enough to support the weight of the antenna, and also hold it in place on windy days. Remember, antennas can act like small sails, and can put a lot of force on to their mounts in strong winds. When estimating wind resistance, the total surface of the antenna structure must be considered, as well as the distance from the center of the antenna to the point of attachment to the building. Large antennas such as solid dishes or high gain sectorial panels can have considerable wind load. Using a slotted or mesh parabolic, rather than a solid dish, will help reduce the wind load without much affect on antenna gain. Be sure that the mounting brackets

and supporting structure are solid, or your antennas will become misaligned over time (or worse, fall off the tower entirely!)

Mounting brackets must have enough clearance from the tower to allow for aiming, but not too much clearance that the antennas become too hard to reach if any service or maintenance is required.



*Figure 8.1: An antenna with a standoff bracket being lifted onto a tower.*

The pipe on the standoff bracket that the antenna will be mounted on needs to be round. This way the antenna can be pivoted on the pipe for aiming. Secondly, the pipe must also be vertical. If it is being mounted on a tapered tower, the standoff bracket will have to be designed to allow for this. This can be done using different lengths of steel, or by using combinations of threaded rod and steel plates.

As the equipment will be outside for all of its service life, it is important to be sure that the steel used is weatherproofed. Stainless steel often has too high a price tag for tower installations. Hot galvanizing is preferred, but may not be available in some areas. Painting all steel with a good rust paint will also work. If paint is chosen, it will be important to plan a yearly inspection of the mount and repaint when necessary.

## Guyed towers

A climbable guyed tower is an excellent choice for many installations, but for very tall structures a self supporting tower might be required.

When installing guyed towers, a pulley attached to the top of a pole will facilitate the tower installation. The pole will be secured to the lower section already in place, while the two tower sections are attached with an articulated joint. A rope passing through the pulley will facilitate the raising of the next section. After the cantilever section becomes vertical, bolt it to the lower section of the pole. The pole (called a gin pole in the trade) can then be removed, and the operation may be repeated, if required. Tighten the guy wires carefully, ensuring that you use the same tension at all suitable anchoring points. Choose the points so that the angles, as seen from the center of the tower, are as evenly spaced as possible.



*Figure 8.2: A climbable guyed tower.*

## Self-supporting towers

Self supporting towers are expensive but sometimes needed, particularly when greater elevation is a requirement. This can be as simple as a heavy pole sunk into a concrete piling, or as complicated as a professional radio tower.



*Figure 8.3: A simple self-supporting tower.*

An existing tower can sometimes be used for subscribers, although AM transmitting station antennas should be avoided because the whole structure is active. FM station antennas are acceptable, provided that at least a few of meters of separation is kept between the antennas. Be aware that while adjacent transmitting antennas may not interfere with your wireless connection, high powered FM may interfere with your wired Ethernet cable. Whenever

using a heavily populated antenna tower, be very scrupulous about proper grounding and consider using shielded cable.



*Figure 8.4: A much more complicated tower.*

## Rooftop assemblies

Non-penetrating roof mount antenna assemblies can be used on flat roofs. These consist of a tripod mounted to a metal or wooden base. The base is then weighed down with bricks, sandbags, water jugs, or just about anything heavy. Using such a rooftop “sled” eliminates the need to pierce the roof with mounting bolts, avoiding potential leaks.



*Figure 8.5: This metal base can be weighed down with sandbags, rocks, or water bottles to make a stable platform without penetrating a roof.*

Wall mount or metal strap assemblies can be used on existing structures such as chimneys or the sides of a buildings. If the antennas have to be mounted more than about 4 meters above the rooftop, a climbable tower may be a better solution to allow easier access to the equipment and to prevent antenna movement during high winds.

## Dissimilar metals

To minimize electrolytic corrosion when two different metals are in moist contact, their electrolytic potential should be as close as possible. Use dielectric grease on the connection between two metals of different type to prevent any electrolysis effect.

Copper should never touch galvanized material directly without proper joint protection. Water shedding from the copper contains ions that will wash away

the galvanized (zinc) tower covering. Stainless steel can be used as a buffer material, but you should be aware that stainless steel is not a very good conductor. If it is used as a buffer between copper and galvanized metals, the surface area of the contact should be large and the stainless steel should be thin. Joint compound should also be used to cover the connection so water can not bridge between the dissimilar metals.

## Protecting microwave connectors

Moisture leakage in connectors is likely the most observed cause of radio link failure. Be sure to tighten connectors firmly, but never use a wrench or other tool to do so. Remember that metals expand and contract as temperature changes, and an over-tightened connector can break in extreme weather changes.

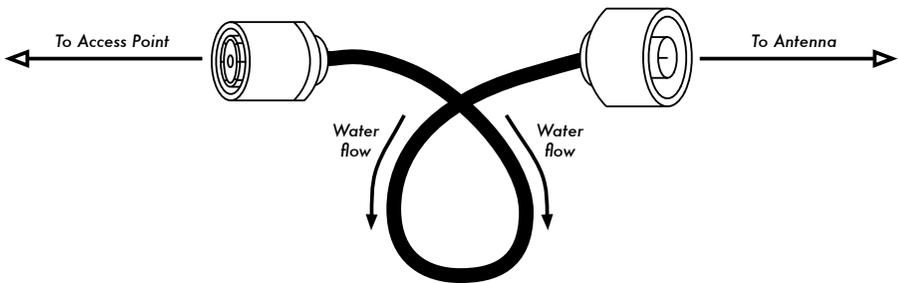


Figure 8.6: A drip loop forces rainwater away from your connectors.

Once tight, connectors should be protected by applying a layer of electrical tape, then a layer of sealing tape, and then another layer of electrical tape on top. The sealant protects the connector from water seepage, and the tape layer protects the sealant from ultraviolet (UV) damage. Cables should have an extra drip loop to prevent water from getting inside the transceiver.

## Safety

Always use a harness securely attached to the tower when working at heights. If you have never worked on a tower, hire a professional to do it for you. Many countries require special training for people to be allowed to work on towers above a certain height.

Avoid working on towers during strong winds or storms. Always climb with a partner, and only when there is plenty of light. Tower work will likely take longer than you think it will. Remember that it is **extremely** hazardous to work in the dark. Give yourself plenty of time to complete the job long before the sun sets. If you run out of time, remember that the tower will be there in the morning, when you can start on the problem again after a good night's sleep.

## Aligning antennas on a long distance link

To properly align antennas at a great distance, you will need some sort of visual feedback that shows you the instantaneous received power at the antenna feed. This lets you to make small changes to the antenna alignment while watching the feedback tool, ultimately stopping when the maximum received power has been found.

The ideal antenna alignment toolkit consists of a **signal generator** and a **spectrum analyzer**, preferably one of each at both ends of the link. By attaching a signal generator to one end of the link and a spectrum analyzer to the other, you can observe the received power and watch the effect of moving the antenna to various positions in real time. Once the maximum has been found on one end of a point to point link, the generator and analyzer can be swapped, and the process repeated for the other end.

The use of a signal generator is preferable to using the radio card itself, as the signal generator can generate a continuous carrier. A WiFi card transmits many discrete packets of information, switching the transmitter on and off very rapidly. This can be very difficult to find with a spectrum analyzer, particularly when operating in noisy areas.

Obviously, the cost of a calibrated signal generator and spectrum analyzer that works at 2.4 GHz (or even 5 GHz if using 802.11a) is well beyond the budget of most projects. Fortunately there are a number of inexpensive tools that can be used instead.

### Inexpensive signal generator

There are many inexpensive transmitters that use the 2.4 GHz ISM band. For example, cordless phones, baby monitors, and miniature television transmitters all generate a continuous signal at 2.4 GHz. Television transmitters (sometimes called **video senders**) are particularly useful, since they often include an external SMA antenna connector and can be powered by a small battery.

Video senders usually include support for three or four channels. While these do not directly correspond to WiFi channels, they permit you to test the low, middle, or high end of the band.

For 5 GHz work, you can use a video sender in combination with a 2.4 GHz to 5 GHz converter. These devices accept a low power 2.4 GHz signal and emit high power 5 GHz signals. They are usually quite expensive (\$300-\$500 each) but will still likely be cheaper than a 5 GHz signal generator and spectrum analyzer.



Figure 8.7: A 2.4 GHz video sender with an SMA antenna connector.

Whatever you choose for a signal source, you will need a way to display the received power level levels at the other end. While the cost of 2.4 GHz spectrum analyzers is slowly coming down, they still typically cost a few thousand dollars, even for used equipment.

## Wi-Spy

The Wi-Spy is a USB spectrum analysis tool made by MetaGeek (<http://www.metageek.net/>). It features a very sensitive receiver in a small form factor (about the size of a USB thumb drive).



Figure 8.8: The Wi-Spy USB spectrum analyzer

The latest version of the Wi-Spy includes better dynamic range and an external antenna connector. It also comes with very good spectrum analysis software for Windows called Chanalyzer. It provides instantaneous, average, maximum, topographic, and spectral views.

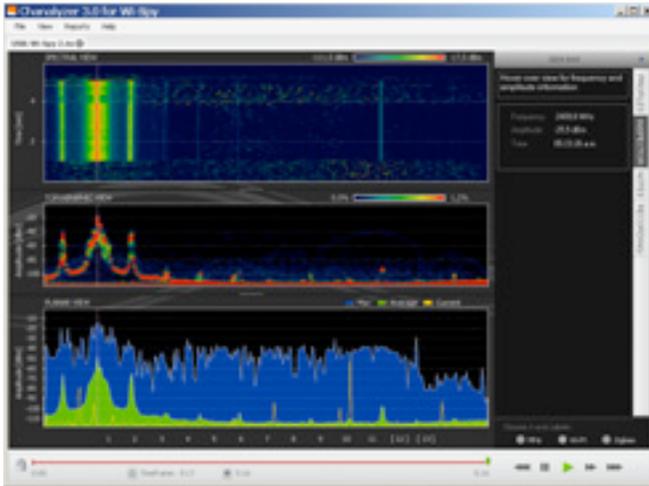


Figure 8.9: The distinctive spiked pattern to the left of the graph was caused by a high power 2.4 GHz television transmitter.

There is an excellent free software package for Mac OS X called EaKiu (<http://www.cookwareinc.com/EaKiu/>). In addition to the standard views, it also provides an animated 3D view, and adds support for multiple Wi-Spy devices.

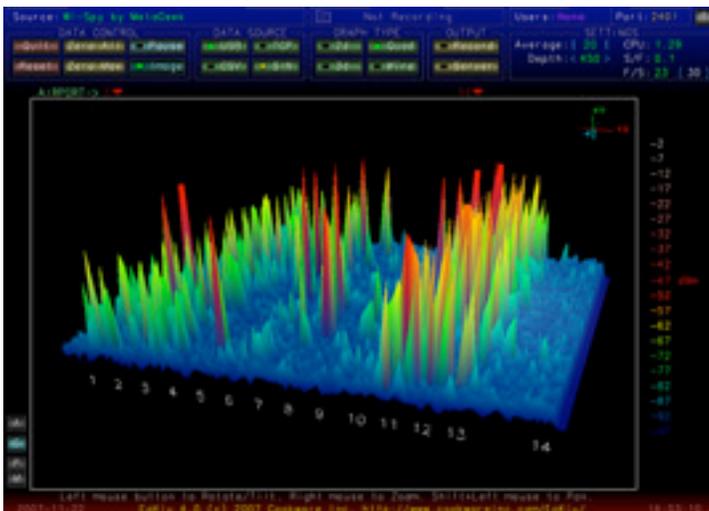


Figure 8.10: EaKiu's 3D view lets you rotate and zoom in on any part of the graph in real time. There is probably a WiFi network on channel 11, with other noise sources lower down in the band.

For Linux users, the Wi-Spy is supported by the Kismet Spectrum-Tools project (<http://kismetwireless.net/spectools/>). This package includes command line tools as well as a GUI built on GTK.

## Other methods

Some wireless routers (such as the Mikrotik) provide an "antenna alignment tool" that shows you a moving bar representing the received power. When the bar is at the maximum, the antenna is aligned. With some routers, you can also enable an audio feedback mode. This causes the router to emit a loud tone, changing the pitch according to the received power.

If you don't have a spectrum analyzer, Wi-Spy, or a device that supports an antenna alignment mode, you will need to use the operating system to provide feedback about the wireless link quality. One simple method to do this in Linux is with a loop that continually calls **iwconfig**. For example:

```
wildnet:~# while :; do clear; iwconfig; sleep 1; done
```

This will show the state of all radio cards in the system, updating once every second. Note that this will only work on the client end of a link. On the access point (master mode) side, you should use the **iwspy** command to collect statistics for the MAC address of the client:

```
wildnet:~# iwspy ath0 00:15:6D:63:6C:3C
wildnet:~# iwspy
ath0      Statistics collected:
00:15:6D:63:6C:3C : Quality=21/94  Signal=-74 dBm  Noise=-95 dBm
Link/Cell/AP      : Quality=19/94  Signal=-76 dBm  Noise=-95 dBm
Typical/Reference : Quality:0   Signal level:0  Noise level:0
```

You can then use a **while** loop (as in the previous example) to continually update the link status.

```
wildnet:~# while :; do clear; iwspy; sleep 1; done
```

## Antenna alignment procedure

The key to successfully aligning antennas on a very long distance link is communication. If you change too many variables at once (say, one team starts wiggling an antenna while the other tries to take a signal strength reading), then the process will take all day and will probably end with misaligned antennas.

You will have two teams of people. Ideally, each team should have at least two people: one to take signal readings and communicate with the remote end, the other to manipulate the antenna. Keep these points in mind while working on long distance links.

1. **Test all equipment ahead of time.** You don't want to fiddle with settings once you're in the field. Before separating the equipment, power everything on, connect every antenna and pigtail, and make sure you can establish a connection between the devices. You should be able to return to this known good state by simply powering on the device, without having to log in or change any settings. Now is a good time to agree on antenna polarization (see **Chapter 2** if you don't understand what polarization means).
2. **Bring backup communications gear.** While mobile phones are usually good enough for working in cities, mobile reception can be bad or nonexistent in rural areas. Bring a high powered FRS or GMRS radio, or if your teams have amateur radio licenses, use a ham rig. Working at a distance can be very frustrating if you are constantly asking the other team "can you hear me now?" Pick your communication channels and test your radios (including the batteries) before separating.
3. **Bring a camera.** Take some time to document the location of each site, including surrounding landmarks and obstructions. This can be very useful later to determine the feasibility of another link to the location without having to travel there in person. If this is your first trip to the site, log the GPS coordinates and elevation as well.
4. **Start by estimating the proper bearing and elevation.** To begin, both teams should use triangulation (using GPS coordinates or a map) to get a rough idea of the direction to point. Use a compass to roughly align the antenna to the desired bearing. Large landmarks are also useful for pointing. If you can use binoculars to see the other end, all the better. Once you have made your guess, take a signal strength reading. If you are close enough and have made a good guess, you may already have signal.
5. **If all else fails, build your own landmark.** Some kinds of terrain make it difficult to judge the location of the other end of a link. If you are building a link in an area with few landmarks, a self-made landmark such as a kite, balloon, flood light, flare, or even smoke signal might help. You don't necessarily need a GPS to get an idea of where to point your antenna.
6. **Test signal in both directions, but only one at a time.** Once both ends have made their best guess, the end with the lowest gain antenna should make fix their antenna into position. Using a good monitoring tool (such as Kismet, Netstumbler, or a good built-in wireless client), the team with the highest gain antenna should slowly sweep it horizontally while watching the signal meter. Once the best position is found, try altering the elevation of the antenna. After the best possible position is found, lock the antenna firmly into place and signal the other team to begin slowly sweeping around. Repeat this process a couple of times until the best possible position for both antennas is found.

7. **Don't touch the antenna when taking a reading.** Your body will affect the radiation pattern of the antenna. Do not touch the antenna, and don't stand in the path of the shot, when taking signal strength readings. The same goes for the team on the other side of the link, too.
8. **Don't be afraid to push past the best received signal.** As we saw in chapter four, radiation patterns incorporate many smaller sidelobes of sensitivity, in addition to a much larger main lobe. If your received signal is mysteriously small, you may have found a sidelobe. Continue sweeping slowly beyond that lobe to see if you can find the main lobe.
9. **The antenna angle may look completely wrong.** The main lobe of an antenna often radiates slightly to one side or the other of the visual dead center of the antenna. Offset feed dishes will seem to be pointing too far down, or even directly at the ground. Don't worry about how the antenna looks; you are concerned with finding the best possible position to achieve the greatest possible received signal.
10. **Double-check polarization.** It can be frustrating to attempt aligning a dish only to discover that the other team is using the opposite polarization. Again, this should be agreed upon before leaving home base, but if a link stays stubbornly weak, a double check doesn't hurt.
11. **If nothing works, check all components one at a time.** Are the devices on both ends of the link powered on? Are all pigtailed and connectors properly connected, with no damaged or suspect parts? As outlined in chapter eight, proper troubleshooting technique will save you time and frustration. Work slowly and communicate your status well with the other team.

By working methodically and communicating well, you can complete the job of aligning high gain antennas in just a short while. If done properly, it should be fun!

## *Surge and lightning protection*

Power is the greatest challenge for most installations in the developing world. Where there are electrical networks, they are often poorly controlled, fluctuate dramatically and are susceptible to lightning. Proper surge protection is critical to not only protect your wireless equipment, but all of the equipment connected to it.

### **Fuses and circuit breakers**

Fuses are critical, but very often neglected. In rural areas, and even in many urban areas of developing countries, fuses are difficult to find. Despite the added cost, it is always prudent to use circuit breakers instead. These may need to be imported, but shouldn't be overlooked. Too often, replaceable

fuses are removed and pocket change is used instead. In a recent case, all of the electronic equipment at a rural radio station was destroyed when a lightning strike went through the circuit, without circuit breaker or even a fuse to protect it.

## How to ground

Proper grounding doesn't have to be a complicated job. When grounding, you are trying to accomplish two things: provide a short-circuit for a lightning strike, and provide a circuit for excess energy to be dissipated.

The first step is to protect equipment from a direct or near direct lightning hit, while the second provides a path to dissipate excess energy that would otherwise cause a build-up of static electricity. Static can cause significant degradation to signal quality, particularly on sensitive receivers (VSATs for example). Providing the short-circuit is simple. The installer simply needs to make the shortest path from the highest conductive surface (a lightning rod) to the ground. When a strike hits the rod, the energy will travel the shortest path and thus by-pass the equipment. This ground should be able to handle high-voltage (i.e. you need thick gauge wire, like 8 gauge braided copper).

To ground the equipment, mount a lightning rod above the equipment on a tower or other structure. Then use a thick gauge conductive wire to connect the rod to something that itself is well grounded. Underground copper pipes can be very well grounded (depending on their depth, the moisture, salinity, amount of metal and organic content of the soil). In many sites in West Africa, pipes aren't yet in the ground, and previous grounding equipment is often inadequate due to ill-conductive soil (typical of seasonally arid, tropical soils). There are three easy ways to measure the efficiency of your ground:

1. The least accurate is to simply plug a good quality UPS or power strip into the circuit that has a ground detect indicator (a LED light). This LED is lit by energy that is being diffused to the ground circuit. An effective ground will dissipate small amounts of energy to the ground. Some people actually use this to pirate a bit of free light, as this energy does not turn an electrical counter!
2. Take a light socket and a low-wattage bulb (30 Watts), connect one wire to the ground wire and the second to the hot wire. If the ground is working, the bulb should shine slightly.
3. The more sophisticated way is to simply measure the impedance between the positive circuit and the ground.

If your ground is not efficient you will need to bury a grounding stake deeper (where the soil is more moist, has more organic matter and metals) or you need to make the ground more conductive. A common approach where there

is little soil is to dig a hole that is 1 meter in diameter and 2 meters deep. Drop in a highly conductive piece of metal that has some mass to it. This is sometimes called a **plomb**, which literally means lead but can be any heavy piece of metal weighing 50 kg or more, such as an iron anvil or steel wheel. Then fill the hole with charcoal and mix in salt, then top with soil. Soak the area, and the charcoal and salt will diffuse around the hole and make a conductive area surrounding your plomb, improving the efficiency of the ground.

If radio cable is being used, it too can be used to ground the tower, though a more resilient design is to separate the ground for the tower from the cable. To ground the cable, simply peel back a bit of cable at the point closest to the ground before it goes into the building, then attach a ground cable from that point, either by soldering or using a very conductive connector. This then needs to be waterproofed.

## Power stabilizers & regulators

There are many brands of power stabilizers, but most are either digital or electromechanical. The latter are much cheaper and more common. Electromechanical stabilizers take power at 220V, 240V, or 110V and use that energy to turn a motor, which always produces the desired voltage (normally 220V). This is normally effective, but these units offer little protection from lightning or other heavy surges. They often burn out after just one strike. Once burnt, they can actually be fused at a certain (usually wrong) output voltage.

Digital regulators regulate the energy using resistors and other solid state components. They are more expensive, but are much less susceptible to being burnt.

Whenever possible, use a digital regulator. They are worth the added cost, and will offer better protection for the rest of your equipment. Be sure to inspect all components of your power system (including the stabilizer) after lightning activity.



# 9

## Troubleshooting

How you establish the support infrastructure for your network is as important as what type of equipment you use. Unlike wired connections, problems with a wireless network are often invisible, and can require more skill and more time to diagnose and remedy. Interference, wind, and new physical obstructions can cause a long-running network to fail. This chapter details a series of strategies to help you build a team that can support your network effectively.

### *Building your team*

Every village, company or family has individuals who are intrigued by technology. They are the ones found splicing the television cable, re-wiring a broken television or welding a new piece to a bicycle. These people will take interest in your network and want to learn as much about it as possible. Though these people are invaluable resources, you must avoid imparting all of the specialized knowledge of wireless networking to only one person. If your only specialist loses interest or finds better paying work somewhere else, they take the knowledge with them when they go.

There may also be many young and ambitious teenagers or young adults who will be interested and have the time to listen, help, and learn about the network. Again, they are very helpful and will learn quickly, but the project team must focus their attention on those who are best placed to support the network in the coming months and years. Young adults and teenagers will go off to university or find employment, especially the ambitious youth who tend to want to be involved. These youth also have little influence in the community, where an older individual is likely to be more capable of making decisions that positively affect the network as a whole. Even though these indi-

viduals might have less time to learn and might appear to be less interested, their involvement and proper education about the system can be critical.

Therefore, a key strategy in building a support team is to balance and to distribute the knowledge among those who are best placed to support the network for the long term. You should involve the youth, but do not let them capitalize use or knowledge of these systems. Find people who are committed to the community, who have roots in the community, who can be motivated, and teach them. A complementary strategy is to compartmentalize functions and duties, and to document all methodology and procedures. In this way, people can be trained easily, and substituted with little effort.

For example, in one project site the training team selected a bright young university graduate who had returned to his village. He was very motivated and learned quickly. Because he learned so quickly, he was taught more than had been foreseen, and he was able to deal with a variety of problems, from fixing a PC to rewiring Ethernet cable. Unfortunately, two months after the project launch he was offered a government job and left the community. Even a better salary could not keep him, since the prospect of a stable government job was too appealing. All of the knowledge about the network and how to support it left with him. The training team had to return and begin the training again. The next strategy was to divide functions, and to train people who were permanently rooted in the community: people who had houses and children, and were already employed. It took three times as long to teach three people as it took to train the young university grad, but the community will retain this knowledge for much longer.

Though this might seem to suggest that you should hand-pick who is to be involved, that is not often the best approach. It is often best to find a local partner organization or a local manager, and work with them to find the right technical team. Values, history, local politics, and many other factors will be important to them, while remaining completely unfathomable to people who are not from that community. The best approach is to coach your local partner, to provide them sound criteria, make sure that they understand that criteria, and to set firm boundaries. Such boundaries should include rules about nepotism and patronage, though these rules must consider the local situation. It may be impossible to say that you cannot hire kin, but it is best to provide a means of checks and balances. Where a candidate is kin, there should be clear criteria and a second authority in deciding upon their candidacy. It is also important that the local partner is given this authority and is not undermined by the project organizers, thus compromising their ability to manage. They will be best able to judge who will work best with them. If they are well educated in this process, then your requirements should be satisfied.

Troubleshooting and support of technology is an abstract art. The first time you look at an abstract painting, it may just look to you like a bunch of random paint

splatters. After reflecting on the composition for a time, you may come to appreciate the work as a whole, and the “invisible” coherence becomes very real. The neophyte looking at a wireless network may see the antennas and wires and computers, but it can take a while for them to appreciate the point of the “invisible” network. In rural areas, it can often take a huge leap of understanding before locals will appreciate an invisible network that is simply dropped into their village. Therefore, a phased approach is needed to ease people into supporting technology systems. The best method is involvement. Once the participants are chosen and committed to the project, involve them as much as possible. Let them “drive”. Give them the cable crimper or keyboard and show them how to do the work. Even if you do not have time to explain every detail and even if it will take longer, they need to be involved physically and see not only what has been done, but how much work was done.

The scientific method is taught in virtually all western schools. Many people learn about it by the time they reach high-school science class. Simply put, you take a set of variables, then slowly eliminate those variables through binary tests until you are left with one or only a few possibilities. With those possibilities in mind, you complete the experiment. You then test to see if the experiment yields something similar to the expected result. If it did not, you recalculate your expected result and try again. The typical agrarian villager may have been introduced to the concept, but likely will not have had the opportunity to troubleshoot complex problems. Even if they are familiar with the scientific method, they might not think to apply it to resolving real problems.

This method is very effective, although time consuming. It can be sped up by making logical assumptions. For example, if a long-running access point suddenly stops working after a storm, you might suspect a power supply related problem and thus skip most of the procedure. People charged with supporting technology should be taught how to troubleshoot using this method, as there will be times when the problem is neither known nor evident. Simple decision trees or flow charts can be made that test these variables, and try to eliminate the variables to isolate the problem. Of course, these charts should not be followed blindly.

It is often easier to teach this method using a non technological problem first. For example, have your student develop a problem resolution procedure on something simple and familiar, like a battery powered television. Start by sabotaging the television. Give them a battery that is not charged. Disconnect the aerial. Insert a broken fuse. Test the student, making it clear that each problem will show specific symptoms, and point the way as to how to proceed. Once they have fixed the television, have them apply this procedure to a more complicated problem. In a network, you can change an IP address, switch or damage cables, use the wrong SSID, or orient the antenna in the wrong direction. It is important that they develop a methodology and procedure to resolve these problems.

## Proper troubleshooting technique

No troubleshooting methodology can completely cover all problems you will encounter when working with wireless networks. But often, problems come down to one of a few common mistakes. Here are a few simple points to keep in mind that can get your troubleshooting effort working in the right direction.

- **Don't panic.** If you are troubleshooting a system, that means that it was working at one time, probably very recently. Before jumping in and making changes, survey the scene and assess exactly what is broken. If you have historical logs or statistics to work from, all the better. Be sure to collect information first, so you can make an informed decision before making changes.
- **Is it plugged in?** This step is often overlooked until many other avenues are explored. Plugs can be accidentally (or intentionally) unplugged very easily. Is the lead connected to a good power source? Is the other end connected to your device? Is the power light on? It may sound silly, but you will feel even sillier if you spend a lot of time checking out an antenna feed line only to realize that the AP was unplugged the entire time. Trust me, it happens more often than most of us would care to admit.
- **What was the last thing changed?** If you are the only person with access to the system, what is the last change you made? If others have access to it, what is the last change they made and when? When was the last time the system worked? Often, system changes have unintended consequences that may not be immediately noticed. Roll back that change and see what effect it has on the problem.
- **Make a backup.** This applies before you notice problems, as well as after. If you make a complicated software change to a system, having a backup means that you can quickly restore it to the previous settings and start again. When troubleshooting very complex problems, having a configuration that “sort-of” works can be much better than having a mess that doesn't work at all (and that you can't easily restore from memory).
- **The known good.** This idea applies to hardware, as well as software. A **known good** is any component that you can replace in a complex system to verify that its counterpart is in good, working condition. For example, you may carry a tested Ethernet cable in a tool kit. If you suspect problems with a cable in the field, you can easily swap out the suspect cable with the known good and see if things improve. This is much faster and less error-prone than re-crimping a cable, and immediately tells you if the change fixes the problem. Likewise, you may also pack a backup battery, antenna cable, or a CD-ROM with a known good configuration for the system. When fixing complicated problems, saving your work at a given point lets you return to it as a known good, even if the problem is not yet completely solved.