Unit 20: **Network planning**

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1. About this document

This material is part of the course package created for TRICALCAR project. For information on TRICALCAR, please consult the introductory module or, www.wilac.net/tricalcar/. This material was originally written in English as part of the materials developed for the APC project "Capacity Building for Community Wireless Connectivity in Africa" http://www.apc.org/wireless/ The material was updated and adapted to the context of Latin America.

1.1 Intellectual Property Information

1.2 Degree of difficulty

The degree of difficulty of this unit is “basic”.

2. Introduction

This document focuses on the practical implementation of a wireless network in terms of *project planning*, and *budgeting* for equipment. A detailed i*mplementation plan* of a wireless network is necessary to be able to produce a *good and consistent budget*. A good implementation plan should not just consider the physical location of the wireless equipment, or our chosen technology and vendor, but also which are the extra resources needed to get a network up and running.

Sustainability aspects need also to be included in the implementation plan. The budget should also consider backup resources when things “go wrong”. In this unit, we show how being able to make a good implementation plan allows us to produce a good budget in terms of equipment and logistics.

The final cost of the *wireless project* can easily go well above your initial budget if other aspects (not wireless related) are not consider in your planning. When you build wireless networks, you must consider *non-wireless* elements too. It is not about buying the most expensive technology, it is about having a good plan on how to use it.

You will probably sense that most of the content in this unit is pretty obvious, but keep in mind that not forgetting the obvious stuff will make your project run smoothly.

A good and detailed budget will not only show that you master all the technology-related aspects but, but your project management skills as well.

3. Viability study

The project should start with a detailed viability study which includes a practical and technical site survey.

Please see unit *Site Survey for Wireless Implementations* for more information.

4. Implementation Plan

Going from a viability study to the actual implementation requires a detailed, practical-oriented plan, an implementation plan.

4.1 Network topology with Radio simulations

The implementation plan should include a proposed network topology. In the topology, the central hub of the network (assuming a star topology) must be identified. Furthermore, the network might require repeaters to reach all potential clients. Where should these repeaters be placed and how should they be powered?

Designing the topology for a wireless network requires **radio simulations**. If possible, the simulations should be based on the GPS coordinates of the sites and 3D cartography. Software like *Radio Mobile* is a good option for simulating wireless networks.

Radio Mobile is a free software that uses the information from terrain elevation data (digital maps), such as SRTM[1], to compute path profiles between sender and receiver. See unit Outdoor Links Simulation for further information about Radio Mobile.

If GPS data are not available, digital simulations can still be done based on:

1. Knowledge of distances between sites (measured with trip meter)
2. Angles between sites (measured with compass) and
3. At least one landmark in the area that can be identified on a digital map

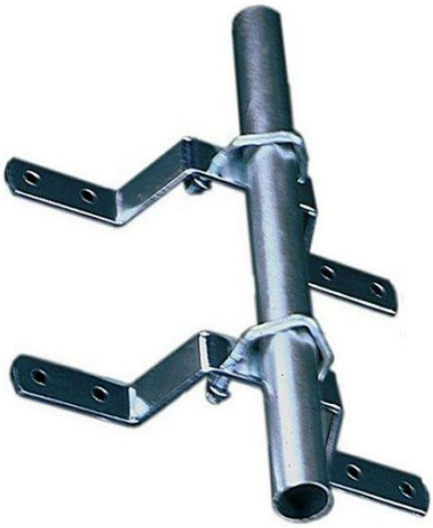
If you can not perform a radio simulation based on any of the above mentioned methods, you can still calculate basic radio link budgets to make sure that the links are functional (assuming LOS and free Fresnel zones). This require that you know the distances between sites and the specifications of the equipment you plan to use.

1. SRTM (Shuttle Radar Topography Mission) is a NASA project that provides free digital topographic data. For Africa, the SRTM images have a precision of 3 arcs of a second (circa 90 meters).

4.2 Practical installation issues

For each client in the network, issues like the following must be considered:

1. Should the equipment be of *indoor* or *outdoor* type? Consider the advantages and disadvantages for each model. Indoor equipment is more cost efficient but might require an external antenna (and RF cable). An RF cable implies signal loss and you must calculate how much you can afford to loose to keep the link functional.
2. How should the equipment be mounted? What tools and materials will be needed for the physical installation. Galvanised steel poles with wall mount brackets are very useful for installation of client devices.



Wall mounting structure with brackets and pole.

Hose clamps for mounting equipment to a pole.

Figura 1: Pole and wall mounting tools

5. Budget

When the Implementation plan is ready, it is time to work on the implementation budget.

Budgeting can be divided in *hardware budget* and *human resourc*e budget.

5.1 Hardware resources

When preparing a budget for a large wireless network, it is easy to feel overwhelmed with the amount of “site-specific facts” that you need to consider. No site is the same as another and hence the physical

places for installations differ. Therefore, the budget can not be tailor-made for every single site, instead you need to create a set of “kits” that can be applied with flexibility to all situations.

For example, a typical community wireless network normally requires the following four kits, 1) Central Hub, 2) Wireless Repeater, 3) Wireless Outdoor Client and 4) Wireless Indoor Client.

Central Hub (connected to Internet uplink)

1. Radio: Outdoor access point(s).
2. Power: solar or grid. PoE vs. direct power cord feeding.
3. Antenna: Depending on expected coverage area.
4. Mounting: To be mounted in central tower.
5. lightning: Surge protection.
6. Power backup: To be considered (generator, battery backup, solar system etc.).

Wireless Repeater (client of the network or suitable high infrastructure)

1. Radio: Two outdoor units.
2. Power: Solar or Grid. PoE or direct.
3. Antenna: Depending on expected coverage area.
4. Mounting: Pole and wall mount brackets (typically).
5. lightning: Surge protection.
6. Power backup: To be considered (generator, battery backup, solar system etc.).

Wireless Outdoor Client

1. Radio: One outdoor unit.
2. Power: PoE.
3. Antenna: Internal or external sectoral antenna depending on gain and distance.
4. Mounting: Pole and wall mount brackets.
5. lightning: Surge protection.
6. Power backup: UPS .

Wireless Indoor Client

1. Radio: One indoor unit
2. Power: Regular power cord
3. Antenna: Internal or external sectoral antenna with RF cable.
4. Mounting: Pole and wall mount brackets
5. lightning: Surge protection
6. Power backup: UPS

A hardware budget for a wireless implementation requires a lot of thinking. Except for the actual radio and network equipment, there are a set of other items that you should consider.

5.1.1 Electricity

In many developing countries, the demand for electricity is far greater than what the provider of electricity can generate and deliver. This makes the grid power system very unreliable, and blackouts and brownouts occur frequently. The situation in many countries is not stable enough to directly plug electronic equipment into grid powered outlets as the power from unstable grids is fluctuating, which damages electrical equipment.

The solution to unstable power is to add batteries, battery chargers, and inverters to every node in the system. These backup systems are very effective at providing both, surge protection, and a consistent power supply.

The chargers are connected to the electric grid and keep the batteries charged whenever power is available. Inverters continually supply 240V AC to the devices from energy stored in the batteries. In this way, anything plugged into the system is never fed with power straight from the unstable grid. The only part of the system vulnerable to damage from power surges is the battery charger, which is the cheapest part of the system, hence easier to replace than expensive radio equipment.

There are off-the-shelf uninterruptible power supplies (UPS) that use similar systems, called online UPS. These are different from the standard UPS because power is always going through filters and rectifiers. A standard UPS uses line interrupt technology, if a problem is detected; the power switches from the grid to the batteries. The problem with this is that, in many cases, by the time the problem is detected, it is already too late. An online UPS converts the grid alternating current (AC) to direct current (DC), and then rectifies it back to AC. Power in the output plugs of the UPS is never direct from the power grid, and all power problems are blocked by this kind of UPS.

These issues need to be taken into consideration when doing the hardware budget for an implementation.

5.1.2 Electrical grounding and lightning protection

An installation located on top of a roof, or a tower, needs protection against lightning. As lightning is a common enemy to wireless installations, it must be prevented as much as possible. There are generally two different ways in which lightning can damage your equipment: direct and indirect hits.

Direct hits

Communication towers should be equipped with Franklin rods that are properly grounded at the base of the tower. However, if the lightning do hit the tower (or the equipment), there is very little you can do to save the equipment.

Indirect hits

Induction currents (indirect hits) due to nearby lightning strikes can cause damage to outdoor radio equipment. This can be prevented by using surge protectors to guard vulnerable equipment, and choosing radios that have a higher voltage rating. However, surge protectors do not protect the antenna, only the radio.

5.1.3 Tools

Tools that can come handy during the implementation are, for example:

- Climbing gear, helmet, gloves
- Walkie-talkies, GPS, trip-meter
- Binoculars, blinking lamp or torch, ropes, tape, scissors, a standard tool box.
- Aluminum ladder (light to carry)
- Updated and detailed maps of the area
- Notebook and pens
- Backpack to carry equipment

5.2 Human resources

The human resource of a wireless implementation might be even harder to estimate than the hardware costs. When estimating your work load, remember that things often take more time than expected. You will always find problems: practical, technical, logistical, or problems related to human relationship, that will slow down your work. In the human resources budget remember also to include the following costs: **Local transport and additional expenses.**

5.2.1 Local transport

An implementation project is always in great need of vehicles for local transport. Depending on the size of the team, the equipment, number of sites and distances between them, the number and size of vehicles should be budgeted. Consider also the location of the implementation. Are they easily accessible, or is a 4x4 drive needed? Do not forget to budget for fuel and, perhaps, a guide/driver if you

going places you are not familiar with. Sometimes the installation must be made in national parks or other protected areas that require the company of a ranger, or other security personnel who may have a work schedule different from what you planned.

5.2.2 Additional expenses

Below is a list of additional expenses that could be taken into consideration:

- Accommodation and allowances (if needed)
- Communication (phone calls)
- Administration (a few percent of the total cost for human resources)

6. Licences and permissions

Obtaining the adequate licences and permissions might imply administrative work and financial support.

There are in general two different kinds of permission that are of importance concerning this matter:

- Permission(s) to build a tower or mount an antenna
- Permission (includes licencing) to operate IEEE 802.11

6.1 Mast or tower

If you intend to mount the antenna on the top of a house, or in an existing tower, you must of course contact the owner of the premises for permission. If you intend to establish a new tower/mast, you must ask for permission from the plot owner.

If the tower or the top of the antenna is over a certain height (higher than the average landscape on the location) you must also apply for permission from the authority that regulates the airspace in the country since your implementation might be a danger to helicopters and other low-flying objects.

For further information see unit “Outdoor Installations”.

6.2 Permission to operate IEEE 802.11

To operate data communication in the 2.4GHz or 5,6 Ghz frequency band **may require a licence**. In some countries, the 2.4GHz frequency band does not require a licence, which implies that it is free (of charge) for anyone to operate an IEEE 802.11 network.

Do not assume that what is free in one country should be free and unlicensed in another. Normally, it is the Commission for Communication (or similar) that handles the licenses for this type of communication.

The term “unlicensed” frequency can be misleading. Unlicensed does mean that a radio license is not needed to operate equipment at that frequency, but it does NOT mean that the use of that frequency is unregulated. To say that a frequency band like 2.4 Ghz can be used unlicensed, means that the maximum power output must be no greater than a certain effect (Watt) including the antenna gain.

Permissions to operate IEEE 802.11 varies a lot from country to country depending on the government in power.

Countries like Brazil, Honduras, Nicaragua, Jamaica, Colombia, Mexico, Peru and Venezuela have regulated the free use of the bands at 2.4 GHz and 5.8 GHz, but have limitations for the maximum gain of the antenna as well as for the maximum power transmission allowed. In addition, there may be other constraints, as in the case of Peru, where the free use of the 2.4 GHz band applies only to enclosed spaces or rural and social interest areas.

In some countries like Argentina, Ecuador, El Salvador and Costa Rica, registration is required and there are also power constraints established[2]

In general, there are two types of license for IEEE 802.11 that you can apply for:

- Commercial use (ISPs)
- Private use (closed groups)

If you plan to use the link for a dedicated group only, make sure that you apply for “private use” since the fees for ISPs are normally much higher.

For example, in Paraguay for the implementation of a network in the frequency of 2.4 GHz it is required a concession, license or authorisation subject to a one-time payment defined by the National Telecommunications Commission (Conatel); the commercial exploitation service is subject to payment of an annual fee equivalent to a percentage of gross income of the provider[3].

7. Equipment acquisition

The procurement can be done locally (within the country) or by import. The choice should depend on the price, availability and technical support for the equipment.

Another key issue for acquisition is *Delivery time.* This is a factor (unknown in many cases) that can delay a project quite a deal.

2. In the WILAC portal you can find a comparative summary on the management of frequencies of 2.4 and 5 GHz in Latin America http://wilac.net/modules.php?op=modload&name=News&file=article&sid=248&mode=thread&order=0&thold=0

3. Source: http://www.conatel.gov.py/OBTENCIONDELICENCIAS.htm

7.1 Local acquisition

Acquisition of low-tech, heavy and bulky equipment, should always be done locally when it is suitable in terms of price and availability. Since overseas transport is very costly, and normally is charged by weight and/or volume, heavy and bulky equipment should preferable be procured locally.

If satisfactory radio and network equipment is available in the country, it is highly recommended to acquire them also locally. If you experience problems, in the future, with a wireless/network unit, it certainly helps to have the supplier in the country, instead of dealing with shipping faulty units abroad.

If more advanced radio equipment is not available on the local market, it might be necessary to import.

7.2 Import

Rules and regulation for import varies from countries to countries. When you are dealing with larger shipments always contact the *Revenue Authority* in the import country for local information. Other organisations that can be useful to contact are the *Chamber of Commerce* and the *Trade Council*.

Below follows a list of issues that you should bear in mind when importing/exporting equipment:

7.2.1 Pre-shipment inspection

A common procedure is that all imported goods need to go through a so called *pre-shipment inspection,* before the goods leave for export. This does not apply to all countries, so make sure what applies in your country. The pre-shipment inspection, performed in the port of origin, is to confirm the total cost of the items to be imported.

In case that you need a pre-shipment inspection, but no such inspection is done prior to shipment, it needs to be performed at the point of destination, which can be both, time consuming and expensive. Sometimes, it may be a cause of returning the goods.

7.2.2 Proof of origin

Certain countries require at import a so called *Proof of Origin* being issued in the country of export in order to prove the origin of the goods.

Such a proof is normally issued by the Chamber of Commerce, or other authority in the export country, or by the import country's consulate in the export country.

7.2.3 Trading invoice

For all export shipments, a so called trading invoice for the sold goods must be set up. When producing this invoice, the seller must take into consideration the local regulations that are applied in the country of import.

Although all countries have their own regulations about what this invoice should include, there is some basic conventional information that most countries require for customs procedures, such as:

1. Seller and buyers name and addresses
2. Bale id, number of bales
3. Weight (gross and net)
4. Description of goods
5. Quantity
6. Delivery and payment conditions
7. Price per unit
8. Price in total for each type of goods
9. Information about the goods' country of origin

7.2.4 Transport insurance

A transport insurance for the exported goods must be subscribed with an insurance company in either the country of export or import.

7.2.5 Import tax

Most goods are subjects to import duty. The import duty is based on the actual cost and type of the equipment. In most cases, a country keeps a high import tax on goods that are produced locally in the country (to promote the local industry) and a low import tax on goods that are not available within the country.

The value of import fees can range from 0% to 20-30% for different types of goods. For example, in Colombia (2005), import tax of antennas is 15%, while the rate for the broadcasting devices with built-in receivers is 5%.[4]

Make sure that your imported goods are correctly classified in customs by providing a clear description of what each device contains. Pay special attention to equipment like access points, that can both contain a radio transceiver and an antenna. Unfortunately, very often, the customs prefer to apply the highest import tax in case of doubt.

7.2.6 VAT

Furthermore, all imported goods will be a subject to VAT that can vary from a few percent, up to 10-20% in most countries. When the import tax and the VAT are paid, the clearance papers are issued, and the goods can be released from customs. It is preferable to use a clearance agent to ensure prompt clearance of goods. To facilitate the process of clearance, it is better to start the procedure before the arrival of the goods.

4. Decree 4341, 2004

7.2.7 Homologation

Many countries require communication equipments to be *homologated* in the country where they are to be used. Homologation procedures usually entail that prior to the import trade, the seller of the equipment, or the local dealer deliver a sample of the equipment to the respective authority, or a designated laboratory in order to be tested, and to ensure it is operating according to regulations. This procedure can be bypassed in some countries that accept as valid the homologation made in the country of origin, or for equipments operating in bands that do not require a licence. It is recommended that you find this out these details before ordering imports.

8. Implementation phase

When the equipment has been procured and delivered, it is finally time for the implementation phase. By this time, you should already have the required licences. The implementation plan should be completed and include detailed instructions for implementation on each site. Also, all tools needed for implementation should be procured or leased at this point.

This section discusses a few practical issues that concern the implementation phase.

8.1 Weather

In countries around the equator, in areas of low altitude above sea level, temperature can rise to 40° C (in the shadow) and heavy rains can fall for weeks. It is therefore a good idea, to plan well the time of the year when the installation will take place.

Installations in towers should be avoided during rainy seasons with frequent lightning. Also, the hottest seasons should be avoided since metallic towers become an unpleasant place to work on.

The heat can also cause problems with overheated radio equipment. In most cases when this happens, the overheated part must be turned off and allow to cool off, and start working again once it is back within the appropriate operating temperature range. However, repeated overheating will wear down the equipment and shorten the life time of the radio. Any outdoor mounted equipment need to have an operating temperature range up to 70°C. Simple (self-made) cooling systems can also be installed outdoors to cool down equipment by using the surrounding air flow.

When planning for the actual implementation you should consider the weather conditions for that time of the year. In countries around the equator, you typically want to avoid the hottest season and the rain periods, while in Europe for example, you rather avoid the cold and wet winter.

8.2 Team members

This might sound trivial, but make sure that your team has the necessary expertise before the day of the implementation. If equipment needs to be mounted in a tower or a high mast, some experience in climbing could be useful. Also, mounting antennas on poles might involve some welding skills.

Obviously, knowledge in radio communication and networking is needed.

9. General advice about contracts

The whole wireless implementation will require a number of contracts between you and the suppliers. There are some critical issues that should be considered when working out a contract with a supplier. Special attention must be paid to the following issues.

- In contracts with suppliers of equipment, make sure that there is a clause for "delivery time" with fair conditions for you. Some hardware may need to be imported, and delivery can be delayed. A delay on the delivery of the tower, for example, will have a negative impact on your time schedule leading to additional expenses due to equipment or labour that you have already ordered for the implementation.
- In contracts with the suppliers, make sure that there is a clear statement about transportation of the purchased equipment. In the case of transporting a tower to the site, a 4x4 can not do it!
- Double-check the conditions for returning equipment that, for some reason, fail to work properly. Who pays the transport? How fast will the faulty unit be replaced?
- If the contract includes implementation of any kind, make sure that testing is included and evaluate the proposed testing methods.
- In general, be careful when making financial agreements with currency other than the local. If the agreements are done in USD, and your local currency suddenly drops compared to the USD after signing the contract, you might end up with a far higher bill than first expected.

10. Quality assurance

Quality assurance is the process of evaluating, testing and measuring the overall project performance to verify that the project satisfies the requirements set up in the contract.

Depending on whether you are the consultant or you are the client, there are certain issues that you should focus on. As a consultant, what can you guarantee to your client in terms of performance, quality and sustainability? As the client, what do you demand from the consultant in terms of performance, quality and sustainability? These questions need to be carefully addressed in the contract to avoid

future conflicts. To assure a certain level of quality, you need to agree on *what* quality are we referring to in that specific case, and *how* can it be measured.

For a wireless link the following parameters can be measured as indicators of a certain level of quality:

1. Uptime
2. Jitter
3. Throughput
4. SNR
5. Packet loss
6. Duplicates of packets
7. Round-trip time

Defining the exact method of measuring the specific data is of outmost importance.

The measurements should be done several times under different weather and load conditions. For example, a dry sunny day compared to a humid rainy day will change your measurements of the SNR. Also, measures taken during a weekend can differ from the ones taken during the week.

Being the client, you should carefully read the specifications of the equipment so that you are certain that the specified hardware is suitable for your network implementation. Make sure that the equipment you get is the one you paid for. Check labels and compare the specifications. You should also make sure to include in the contract the period of time during which the implementation guarantees a certain level of performance.

Do not forget to include a paragraph for quality assurance in the contract:

- Specify WHICH parameters to measure and HOW to measure them
- Measurements should be done over a period of time reflecting changes in the environment.

11. Conclusions

In summary, you do not need to be a genius to plan and budget for a wireless implementation. You do need to be one step ahead and always think in terms of "what if?". Having a good implementation plan from the beginning will save you lots of trouble (and money) at the end of the project.

A wireless implementation does not only imply costs in wireless equipment. Do not oversee the costs of bringing Internet and electricity to the place, applying for licences, providing lightning protection, transporting the equipment and yourself to the site(s) and all the other small things you might need, such as climbing gear, testing equipment, binoculars, walkie-talkies, ropes, maps etc.

A budget on its own is not a good plan. But a good plan has a good and detailed budget.

The five main issues you should remember from this unit can be summarised as:

1. You do not need to be a genius to plan and budget for a wireless implementation, just be realistic and a bit "pessimistic".
2. A good implementation plan from the beginning will save you lots of trouble and money at the end of the project.
3. Do not forget that the hardware budget includes more than radio and networking equipment. The budget must also include bringing Internet and electricity to the site, obtain licenses, ensure lightning protection, transport equipment and people, and making sure that all necessary tools are available.
4. Do not forget factors that are out of your control, such as delivery time and weather conditions.
5. A budget on its own is not a good plan, but a good plan has a good and detailed budget.

12. Exercises

12.1 12.1 Exercise 1: Budgeting and planning a Point-to-Point (PtP) wireless link

The Rainbow Foundation which has recently established an elementary school on the island of Curricuta, in Sunland, contact your NGO to request technical assistance. They need to install a wireless link with the mainland to provide Internet access for Curricuta's Elementary School.

Your task is to plan and budget (in terms of equipment and human resources, not finding the value in a

currency) the implementation of a PtP wireless link between the mainland and Curricuta's Elementary School.

Consider that there may be many solutions to the problem. You should have the ability to work in different scenarios and present them to your client. Describe each stage with its advantages and disadvantages including hardware and human resources.

To accomplish this task, the following information is provided:

The Curricuta island is sited 7 km from Sunland's mainland. Between Curricuta island and the mainland (halfway, and in line-of-sight), another island, the island of the Pirate is located at an average height of 50 m above sea level.

The Internet connection on the mainland is located on the roof of a three-story office building. On the roof, there is a mast (vertical) 5 meters high which can be used to install equipment. The base of the flagpole is 50 metres from the Internet connection, which is inside the building. On the third floor there is electricity available.

The only construction on Curricuta island, with the exception of the huts, is the Elementary School situated near the shore (0 m) facing mainland. The highest point on the island (70 m) is 200 metres from the Elementary School. Curricuta is not connected to the power grid of the mainland, thus there is no access to electricity in the island.

The soil of the island is composed of dirt and sand and has a dense vegetation with wildlife (harmless to humans, though).

Sunland is a country located at latitude 0. Tropical and electrical storms are very common, so the weather is hot and humid.

To complete the exercise, you should discuss the following 10 points:

1. Who are the major stakeholders in the project? What key people could be contacted for support?
2. What factual and technical information is needed as the starting point of the project?
3. What technical information on the existing infrastructure do you need?
4. What physical infrastructure do we need in the place prior to the connection?
5. Design the budget to provide Internet connection in the place where the Elementary School is located. Keep in mind the following points:
    - What kind of technology should we use?
    - What are the infrastructure and equipment needed?
    - What human resources do we require?

6. Budgeting to provide energy to the site installation on Curricuta island.
7. Budgeting to implement the real link between the two points.
8. Budgeting of licenses and permits required to operate the network (take your country as an example).
9. Budgeting maintenance and quality assurance of the implementation for one year.
10. What might fail? What is the biggest risk of the project? Risk Analysis.

13. Intellectual property information

Intellectual Property Rights

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