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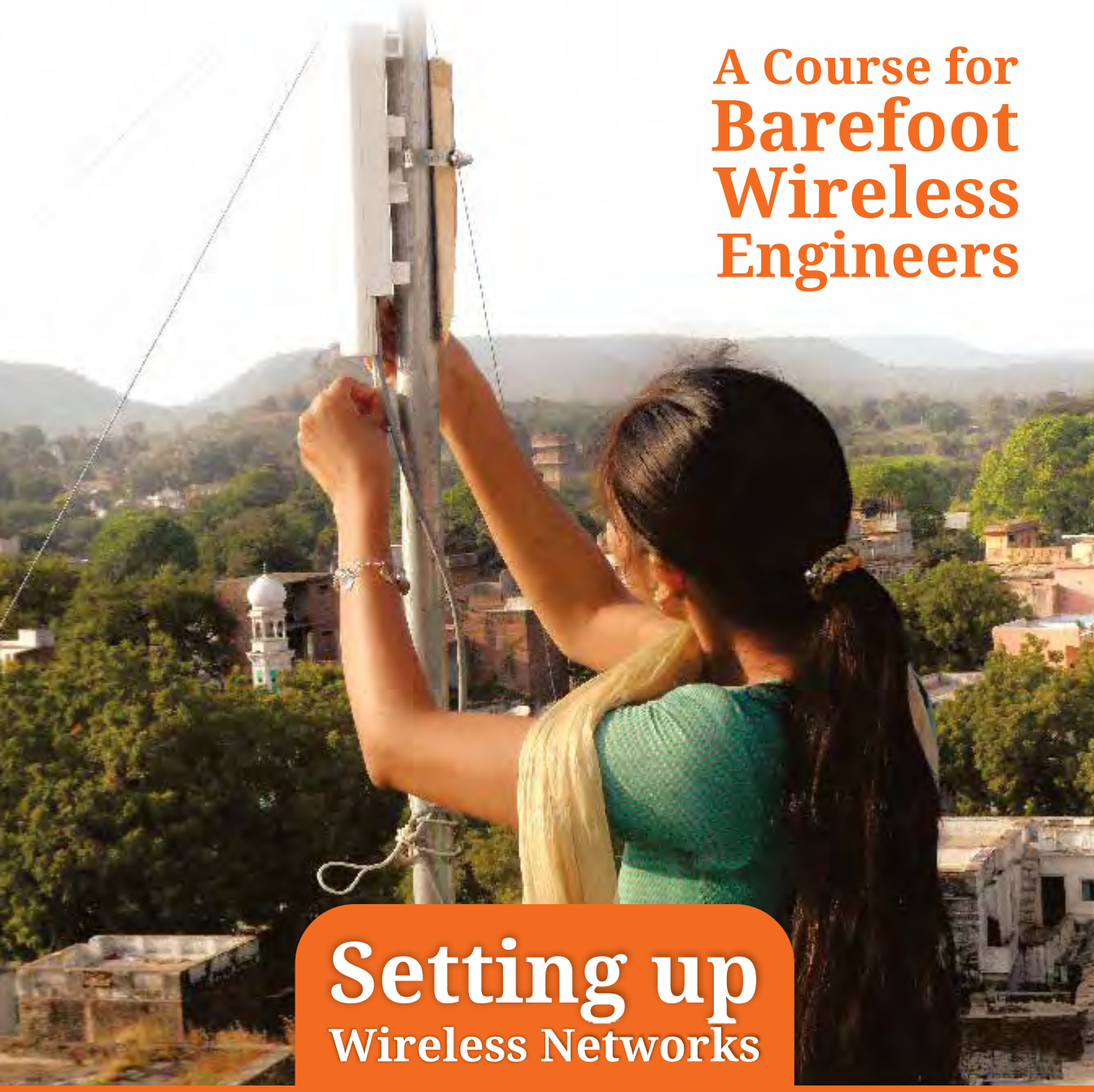
A Course for Barefoot Wireless Engineers



Setting up Wireless Networks

MODULE I

Planning

Copyright

The 'Barefoot Wireless Engineers' course has been developed as part of the collaborative advanced ICT course development project of the Commonwealth of Learning (COL). COL is an intergovernmental organisation created by Commonwealth Heads of Government to promote the development and sharing of open learning and distance education knowledge, resources and technologies.

Digital Empowerment Foundation (DEF), established in 2002, aims to connect unreached and underserved communities of India in an effort to bring them out of digital darkness and equip them with access to information. With the belief 'Inform, Communicate and Empower,' DEF finds sustainable digital interventions to overcome information poverty in rural and remote locations of India, and empower communities with digital literacy, digital tools and last mile connectivity.

This course is intended to be used and shared freely by trainers working in development and civil society organizations such as telecentres, community media organizations and NGOs.

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A COURSE FOR BAREFOOT WIRELESS ENGINEERS

SETTING UP WIRELESS NETWORKS

Module I - PLANNING

Acknowledgements

The Digital Empowerment Foundation wishes to thank the organizations and individuals mentioned below for their contribution to this Self-Study Handbook:

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- Babloo Das
- Aakash Dhakre
- Layak Ram
- Community members

Table of Contents

About this Self-Study Handbook

Setting up Wireless Networks – A Course for Barefoot Wireless Engineers has been produced by the Digital Empowerment Foundation. This course is divided into two parts. The first part covers some basic concepts related to planning the setup of wireless networks such as conducting a location survey and selecting the required hardware. The second part of the handbook covers details of actual installation and maintenance of wireless networks.

HOW THIS SELF-STUDY HANDBOOK IS STRUCTURED?

The course overview

The course overview gives you a general introduction to the course. The information contained in the course overview will help you determine:

- If the course is suitable for you.
- What you will already need to know.
- What you can expect from the course.
- How much time you will need to invest to complete the course.

The overview also provides guidance on:

- Study skills.
- Where to get help.
- Course assignments and assessments.
- Activity icons.
- Units.

We strongly recommend that you read the overview carefully before starting your study

The course content

The course is broken down into units. Each unit comprises:

- An introduction to the unit content.
- Unit outcomes.
- New terminology.
- The core content of the unit with a variety of learning activities.
- A unit summary.
- Assignments and/or assessments, as applicable

Resources

For those interested in learning more on this subject, we provide you with a list of additional resources at the end of this handbook; these may be books, articles or websites.

Your comments

After completing Setting up Wireless Networks we would appreciate it if you would take a few moments to give us your feedback on any aspect of this course. Your feedback might include comments on:

- Course content and structure.
- Course reading materials and resources.
- Course assignments.
- Course assessments.
- Course duration.
- Course support (assigned tutors, technical help, etc.)

Your constructive feedback will help us to improve and enhance this course.

Course overview

WELCOME TO SETTING UP WIRELESS NETWORKS - A COURSE FOR BAREFOOT WIRELESS ENGINEERS

To bring in last mile connectivity for underserved rural and semi-rural areas in India, line-of-sight wireless connectivity is deployed by using low-cost Wireless equipment and the unlicensed frequency spectrum of 2.4 GHz and 5.8 GHz range to create community-operated wireless networks. To further empower the local community, the community members need to be trained in setting up wireless networks themselves.

To view the corresponding video on the course website, you can scan the QR Code displayed here or directly log in to the course website http://lms.defindia.org

Video Duration: 1:40 Minutes

For the purpose of this course, it is assumed that there are three levels at which learners will set up a wireless network. This course is structured to train community members from processes required for Level 1 implementation to processes for Level 3 implementation.

The three levels are:

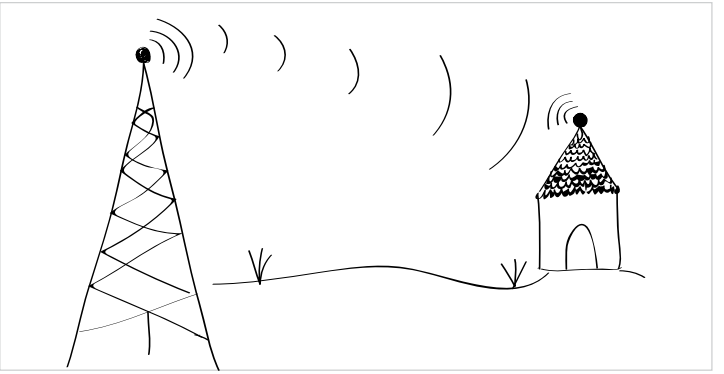


Figure 1 - Level 1, to bring connectivity from the ISP to a single location

Figure 2 - Level 2, to extend connectivity from the single location to another location

Figure 3 - Level 3, to extend connectivity from the single location to multiple locations

SETTING UP WIRELESS NETWORKS - A COURSE FOR BAREFOOT WIRELESS ENGINEERS — IS THIS COURSE FOR YOU?

This course is intended for community members, especially in rural areas of India, who can set up last-mile Internet connectivity for their communities. These members may not have a formal degree in technical areas such as networking or engineering.

Some of the skills that will help you complete this course are:

- Basic knowledge of English
- Using the Internet for Google search or seeing videos
- Installing apps on a mobile phone
- Using a computer
- Downloading and installing software on a computer
- Understanding of common concepts such as the Internet, network, mobile services etc.


Outomes

COURSE OUTCOMES

Upon completion of Setting up Wireless Networks - A Course for Barefoot Wireless Engineers you will be able to:

- **explain** the benefits of a wireless network in bringing connectivity to rural areas.
- **conduct** a location survey before setting up a wireless network.
- **determine** an optical line-of-sight between two points without interference.
- **select** equipment that is suitable for the planned wireless network.
- **prepare** the required agreements and approvals before installing the wireless network.
- **install** the primary infrastructure for a wireless network.
- **install** power backup for the wireless network.
- **establish** maintenance procedures for the wireless network.

Time

TIMEFRAME

What is the expected duration of this course?

60 hours (4 hours per day)

How much formal study time is required?

It is good to have the knowledge of the following

- Basic knowledge of English
- Able to use the Internet for Google search or seeing videos
- Able to install apps on a mobile phone
- Able to use a computer
- Able to download and install software on a computer
- Able to understand the common concepts such as the Internet, network, mobile services etc.

How much self-study time is expected/recommended?

20 hours (4 hours per day)

Study Skills

STUDY SKILLS

As an adult learner, your approach to learning will be different to that from your school days: you will choose what you want to study, you will have professional and/or personal motivation for doing so and you will most likely be fitting your study activities around other professional or domestic responsibilities.

Essentially you will be taking control of your learning environment. As a consequence, you will need to consider performance issues related to time management, goal setting, stress management, etc. Perhaps you will also need to reacquaint yourself in areas such as essay planning, coping with exams and using the web as a learning resource.

Your most significant considerations will be time and space i.e. the time you dedicate to your learning and the environment in which you engage in that learning.

We recommend that you take time now—before starting your self-study—to familiarize yourself with these issues. There are a number of excellent resources on the web. A few suggested links are:

- *http://www.how-to-study.com/*

The "How to study" web site is dedicated to studying skills resources. You will find links to study preparation (a list of nine essentials for a good study place), taking notes, strategies for reading textbooks, using reference sources, test anxiety.

- *http://www.ucc.vt.edu/stdysk/stdyhlp.html*

This is the web site of the Virginia Tech, Division of Student Affairs. You will find links to time scheduling (including a "where does time go?" link), a study skill checklist, basic concentration techniques, control of the study environment, note taking, how to read essays for analysis, memory skills ("remembering").

- *http://www.howtostudy.org/resources.php*

Another "How to study" web site with useful links to time management, efficient reading, questioning/listening/observing skills, getting the most out of doing ("hands-on" learning), memory building, tips for staying motivated, developing a learning plan.

The above links are our suggestions to start you on your way. At the time of writing these web links were active. If you want to look for more go to www.google.com and type "self-study basics", "self-study tips", "self-study skills" or similar.

Help

NEED HELP?

This course is available as a training manual. A companion website for the course is available at the website *http://lms.defindia.org*. You can log in to the course website using your user ID and password.

The course website can be used to download softcopies of this manual, view corresponding videos, upload assignments and attempt the unit assessment online.

Digital Empowerment Foundation (DEF) will provide additional teaching assistance. It is located in House No 44, III Floor, Kalu Sarai, New Delhi - 110017. Any learner can reach out for any query related this handbook and course at given email *defindia@defindia.net.*

Assignment

ASSIGNMENTS

At the end of some units, an assignment may be given to help you practice the concepts learned in this course.

The assignments are optional and can be uploaded to the online course for peer feedback and discussion. These assignments are not graded. However, your submissions are visible to other learners and can be used for discussion and feedback. You can also read and comment on assignment submissions made by other learners.

Ideally, you should work on the assignment immediately after completing the corresponding unit. This will help you practice the concepts covered in the unit.

Assessment

ASSESSMENTS

How many assessments will there be in this course?

There are 20 assessments in this course

Are they self-assessments or teacher-marked assessments?

All of the assessments are self-assessments.

When will the assessments take place?

The assessments can be taken by learner as per their learning pace.

How long will the assessments be?

Assessments will take 1 hour and 40 minutes

How long will learners be allowed to complete the assessment(s)?

Learners are allowed to take 2 hours to complete the assessments

Getting around this Self-Study Handbook

MARGIN ICONS

While working through this Self-Study Handbook you will notice the frequent use of margin icons. These icons serve to "signpost" a particular piece of text, a new task or change in activity; they have been included to help you to find your way around this Self-Study Handbook.

A complete icon set is shown below. We suggest that you familiarize yourself with the icons and their meaning before starting your study.

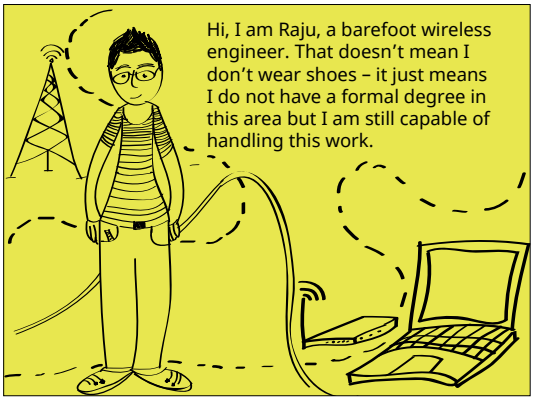
Unit

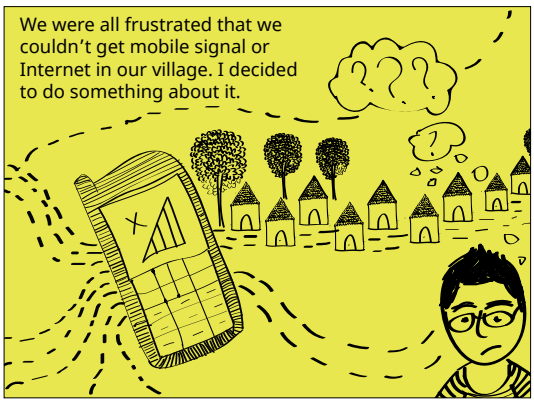
1

Introduction to Wireless Networks

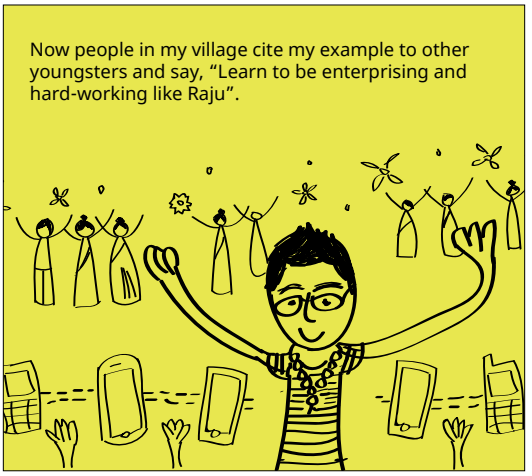
Introduction

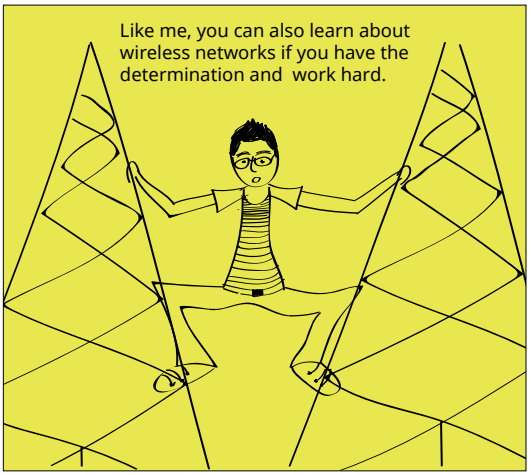
Read the story of Raju, who became barefoot wireless engineer after completing this course.

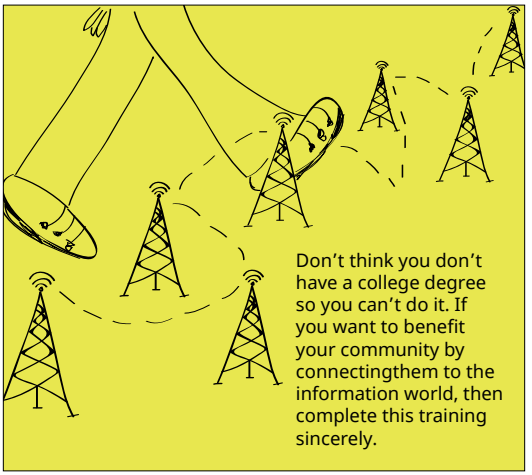


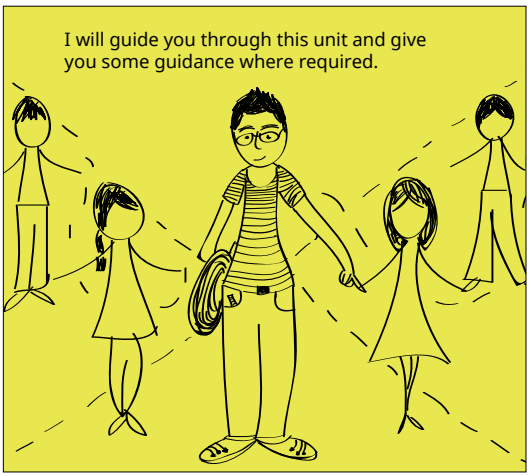



COMPUTER
CENTER
The rest is history...users of my Internet services spread wareness about the benefits of using mobile and internet. More and more people started coming to my centre or use my services.


Now people in my village cite my example to other youngsters and say, “Learn to be enterprising and hard-working like Raju”.


Like me, you can also learn about wireless networks if you have the determination and work hard.


Don’t think you don’t have a college degree so you can’t do it. If you want to benefit your community by connectingthem to the information world, then complete this training sincerely.


I will guide you through this unit and give you some guidance where required.


Good Luck !!!

To view the corresponding video on the course website, you can scan the QR Code displayed here or directly log in to the course website http://lms.defindia.org

Video Duration: 1:30 Minutes

Outomes

This unit will set the context for this course by providing an overview of wireless networks and how they are relevant in day-to-day lives.

Upon completion of this unit you will be able to:

- Explain the uses of a wireless network
- Describe the features of line-of-sight wireless networks
- Define a wireless network

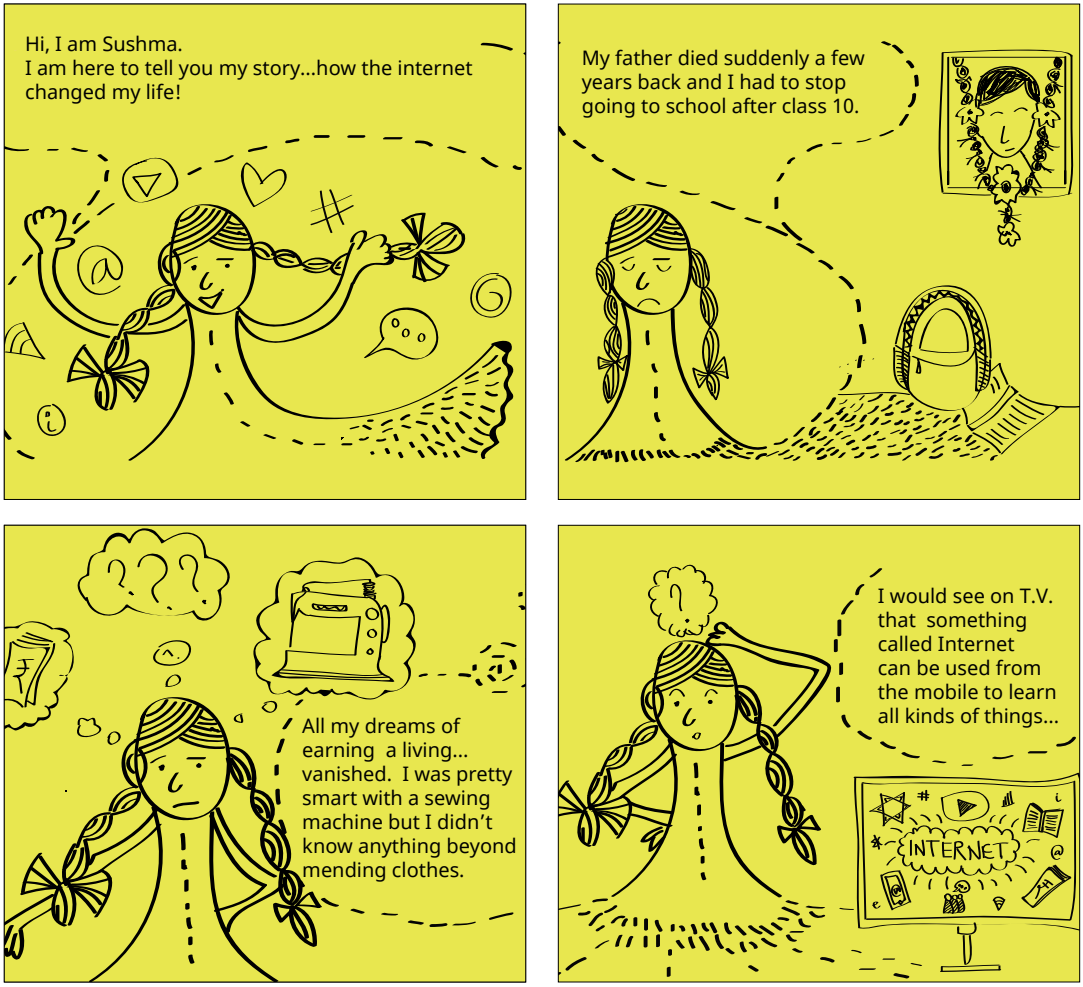
Terminology

Internet:	The biggest communication network of computers. The Internet has millions of smaller domestic, academic, business and government networks, which together carry many different kinds of information. The term is sometimes abbreviated as “the net”.
Line-of-sight:	A way of transmitting a signal between two antennae without obstructions between them
Wireless network:	A connection when no physical wired line is laid between the sender and receiver.

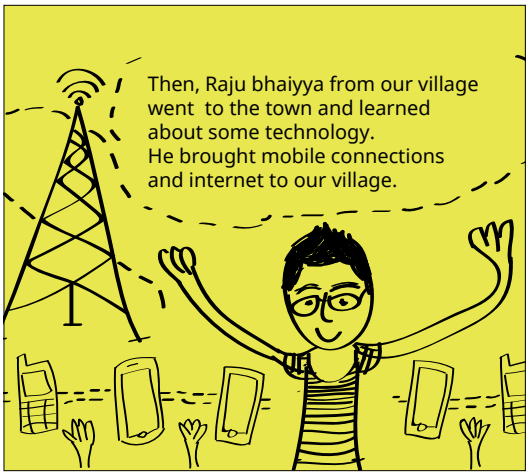
The World of Information

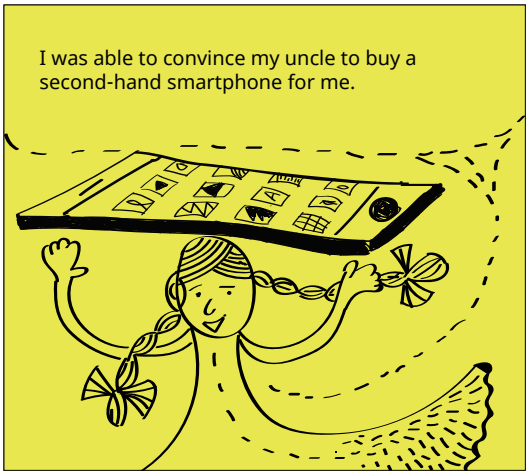
Sushma's Story

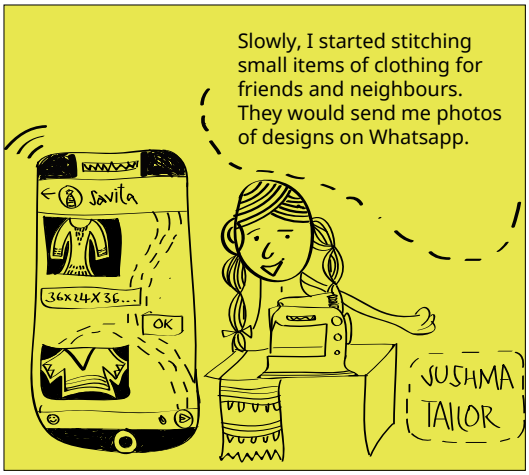
Lets read the story of Sushma, neighbour of Raju, completed this course to become the barefoot wireless engineer



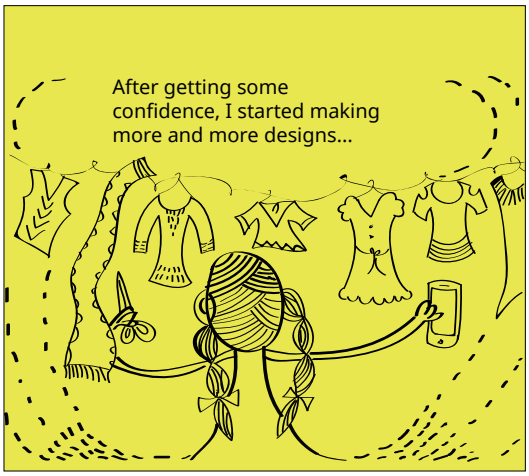

. ...but in our village, even mobile signal was not there, forget Internet!


Then, Raju bhaiyya from our village went to the town and learned about some technology.
He brought mobile connections and internet to our village.

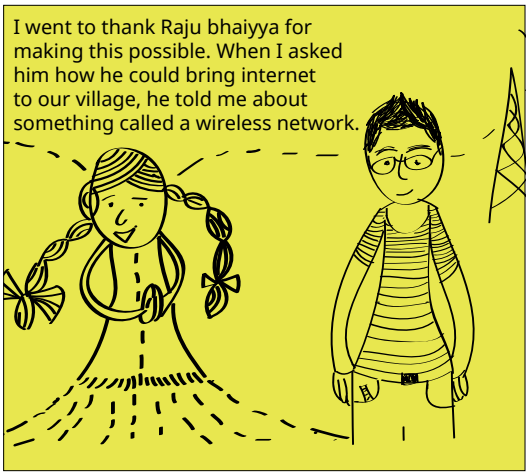

I was able to convince my uncle to buy a second-hand smartphone for me.

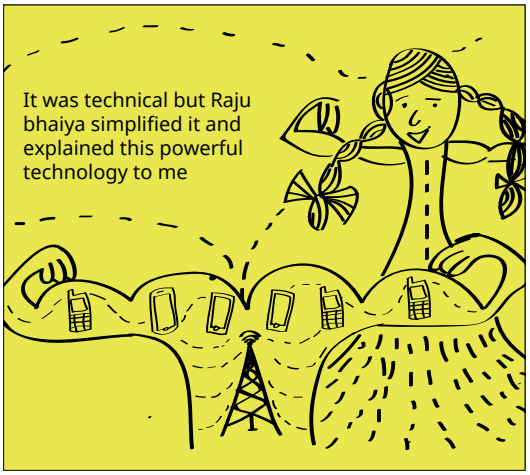

Slowly, I started stitching small items of clothing for friends and neighbours. They would send me photos of designs on Whatsapp.
Savita
36x24x36...
OK
SUSHMA TAILOR

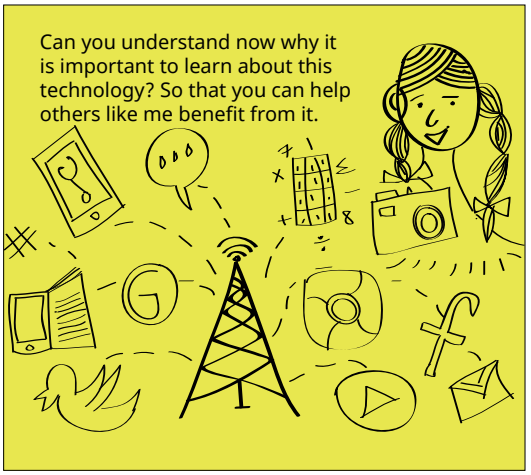

I felt I still had the chance to achieve my dreams...with some help, I learned how to see videos related to stitching.
YouTube
salwar
saree
Blouse


After getting some confidence, I started making more and more designs...


...which is making my work popular and helping me earn a decent amount.
SUSHMA TAILOR


I went to thank Raju bhaiyya for making this possible. When I asked him how he could bring internet to our village, he told me about something called a wireless network.


It was technical but Raju bhaiya simplified it and explained this powerful technology to me


Can you understand now why it is important to learn about this technology? So that you can help others like me benefit from it.


I hope my story inspires you to complete this course and soon become a wireless network engineer.


I didn't know that one man, one tower and this invisible technology could do something so transformational.

To view the corresponding video on the course website, you can scan the QR Code displayed here or directly log in to the course website http://lms.defindia.org

Video Duration: 2:25Minutes

The Power of Information

Information can transform lives by bringing new opportunities and livelihoods to communities. Sushma is just one example of this transformation. Technology is the enabler for bringing information and people together. Whether it is women in self-help groups who are holding video conferences or it is farmers who are sharing videos of best practices, the convergence of hardware, software and the internet has caused an explosion of information.

Unfortunately, Internet penetration levels in India are below the world average; and the penetration level in rural India is even worse. However, deploying traditional communications infrastructure in rural areas which may not have the required threshold of users may not be economically viable for either the service provider or the user. This is where community-owned and community-operated low-cost wireless networks come in.

Wireless Networks

How Mobile Phones Communicate?

While sitting in Chanderi, Madhya Pradesh you get a call on our mobile phone from Kakinada in Andhra Pradesh. How is the call reaching you? Let's understand this in simple terms.

1. A telecom company such as BSNL sets up the mobile tower.
2. Your mobile phone is essentially a two-way radio, consisting of a sending or transmitting component and a receiving component.
3. When you call your friend on your cell phone, your phone converts your voice into an electrical signal, which is then transmitted via radio waves to the nearest cell tower.

4. The network of cell towers then relays the radio wave to your friend's cell phone, which converts it to an electrical signal and then back to sound again. In the basic form, a cell phone works just like a walkie-talkie. The final link is wireless, that is, the signal reaches directly from the cell tower to your phone.

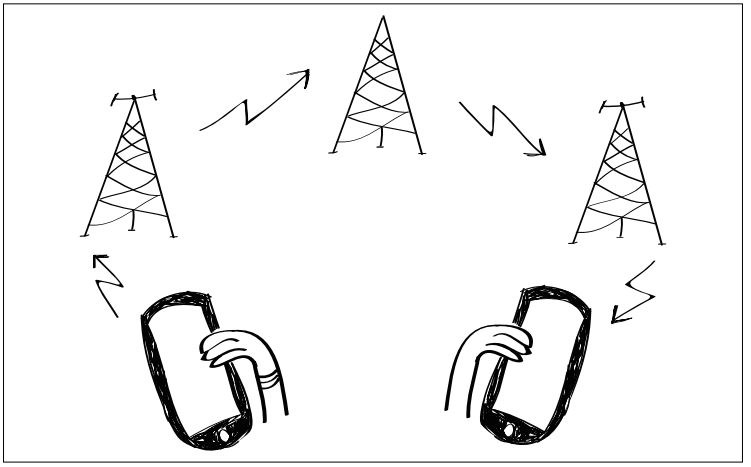


Figure 6: How mobile phones communicate?

This is how the call travels from one mobile phone to the other. But why don't some areas have mobile connectivity? That's because, in such areas, mainstream telecom companies may not be willing to set up cell towers or lay cables as it would not be commercially viable for them

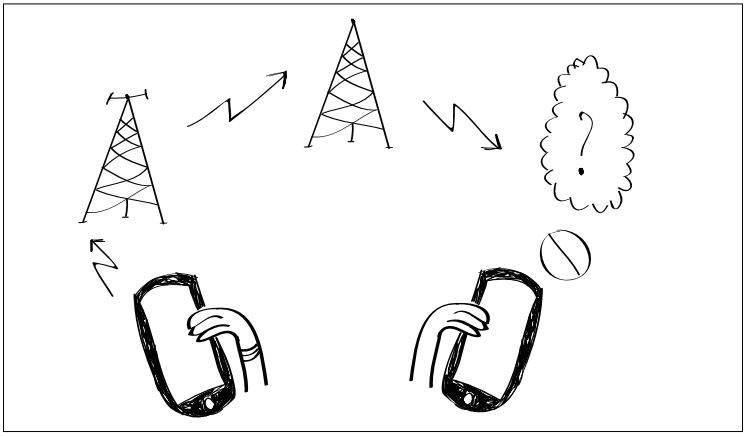


Figure 7: When last-mile connectivity is not present

That's where low-cost, line-of-sight wireless networks come in.

Line-of-sight Wireless Networks

A line-of-sight wireless network is simply a way of transmitting a signal between two antennae without obstructions between them.

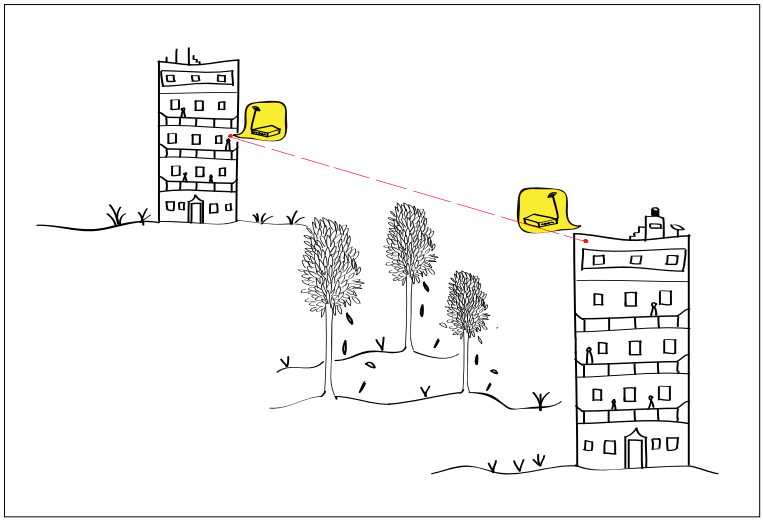


Figure 8: Line-of-sight wireless network

In developing countries, line-of-sight wireless connectivity has emerged as one of the inexpensive technologies to bridge the connectivity gap in remote areas. Thus, in areas where last mile connectivity is missing, such line-of-site wireless networks can be used to bring the signal from the nearest cellular tower to the unconnected area.

In simple terms, a wireless network is defined as a connection without wires. Wireless is the term used to describe when there is no physical wired connection between sender and receiver.

Summary

UNIT SUMMARY

In this unit you learned how being connected to the information world can help shape livelihoods and improve the quality of life. You also learned what a line-of-sight wireless network is. You finally learned how a wireless network can be used to bring connectivity to remote areas.

Assignment

ASSIGNMENT

Uses of the Internet

Amongst your friends or relatives, identify one person who can benefit from using the Internet in their profession or personal life. Write a description of that person's existing challenges and how you think using the Internet can help the person in overcoming these challenges.

Your response should not exceed 300 words. Post your response to the course website. Then, read the responses by other learners and discuss your views using comments. Make sure that you offer constructive feedback and useful suggestions.

Post Assignment Response
http://lms.defindia.org/mod/forum/view.php?id=61

Assessment

ASSESSMENT

Now that you have completed this unit, check your understanding of the concepts learned by responding to the following questions.

You can also take this assessment on the course website.

You can verify your response with the response displayed in the Ideal Responses section.

Question 1: Rajkumari is a 40-year old woman from the Khandela village. She wants to attend training on how to use computers and the Internet. She would like to run a tutorial

centre for the people of Khandela village to train them in English. Given below are some qualities of Rajkumari.

- She has worked as a science teacher in the local school.
- She is fluent in English.
- She has weak eyesight and needs to wear reading glasses.
- She has no prior experience using a computer.
- She doesn't have the finances to buy a computer.

Given these qualities, is Rajkumari is a suitable candidate for learning how to use the Internet?

a. Yes, Rajkumari can learn about computers and the Internet because she has a good knowledge of English.
b. No, Rajkumari cannot learn about computers and the Internet at her age, especially because she has no prior experience.

Question 2: In the image displayed below, does the wireless network represent a line-of-sight network?

a. Yes.

b. No

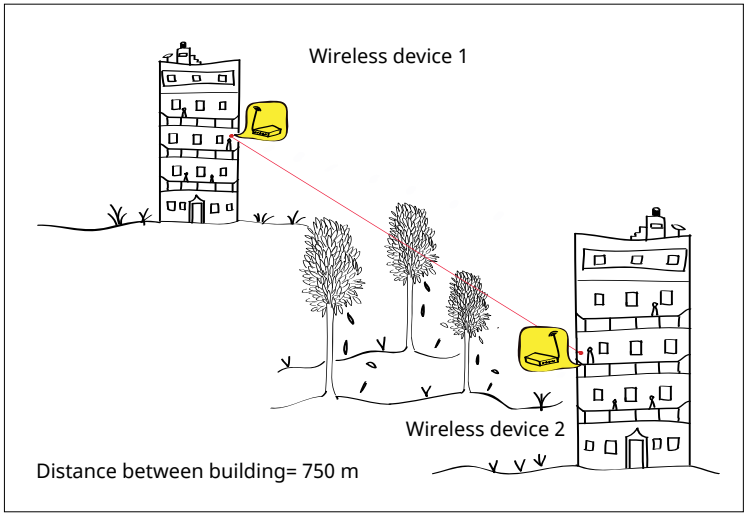


Figure 9: Line-of-sight wireless network

Question 3: Which of the following is an example of a wireless network?

a. A smartphone having Internet connection from BSNL.

b. A laptop computer connected to the BSNL Internet using a cable.

IDEAL RESPONSES

Answer 1: a. Rajkumari can learn about computers and the Internet because she has a good knowledge of English. With hard work and patience, anyone can learn about new technology with guidance and support.

Answer 2: b. This is not a line-of-sight wireless network because a tress is obstructing the signal between the two devices

Answer 3: a. A smartphone having Internet connection from BSNL would be a wireless network as there are no physical cables connecting the device to the network.

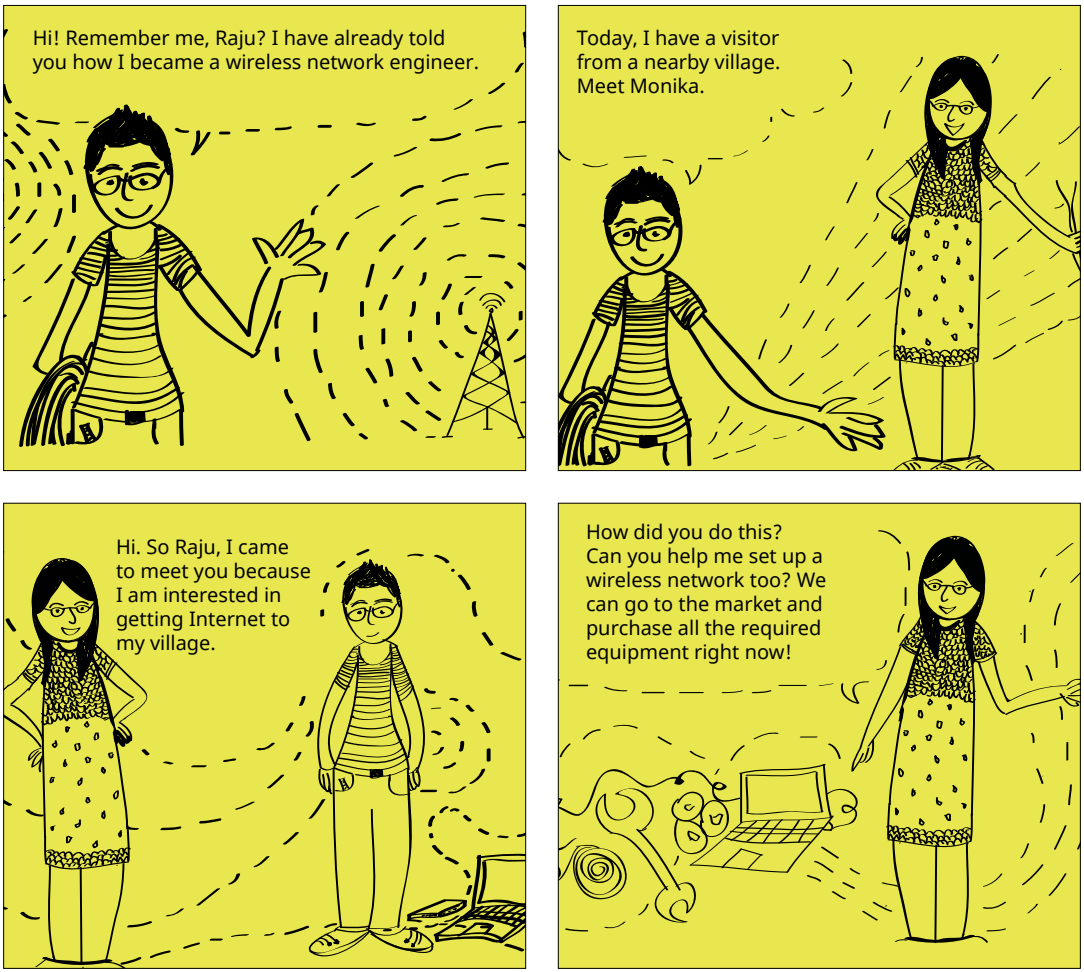
Unit

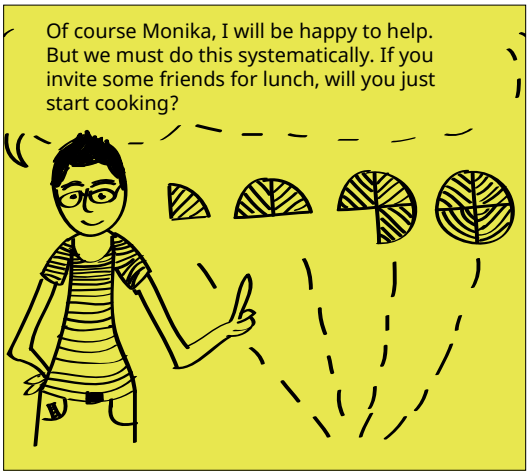
2

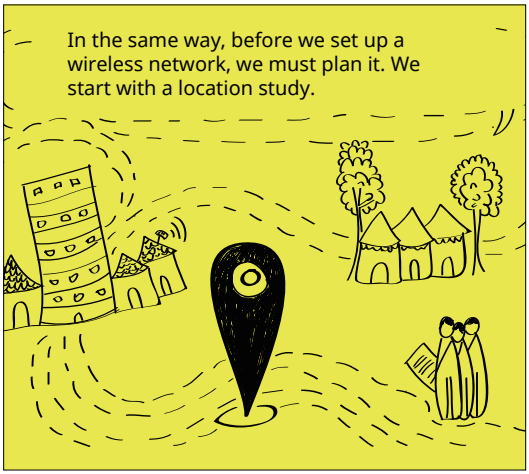
Location Survey

Introduction

Read the story of Monika who needs help of Raju to bring internet connectivity in her village.







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To view the corresponding video on the course website, you can scan the QR Code displayed here or directly log in to the course website http://lms.defindia.org

Video Duration: 1:11 Minutes

The first step toward starting any wireless networking project in a rural or semi-urban area is to conduct a location survey, also known as a feasibility study. The feasibility study is an extensive evaluation of the demographics, location and technical aspects related to the project.

A location survey aims to objectively and rationally uncover:

- The strengths and gaps related to the project (demographic),
- The opportunities and threats as presented by the environment (technical), and
- The resources required to execute the project (technical).

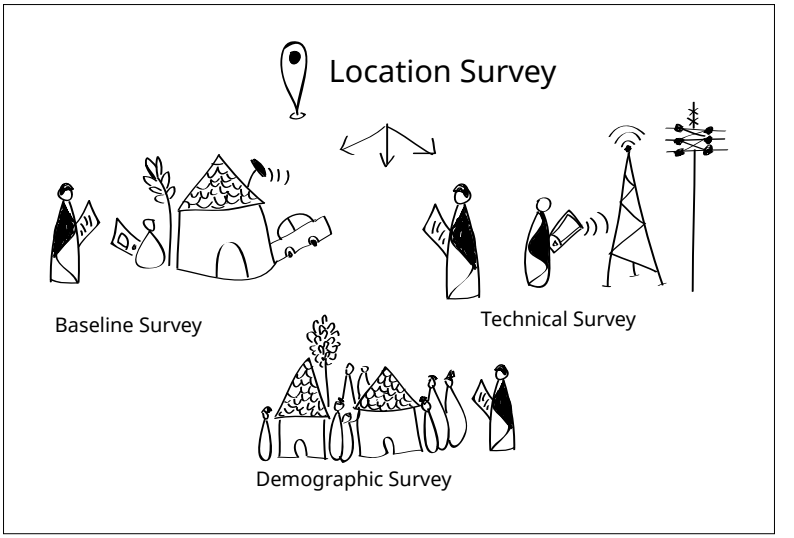


Figure 10: Elements of location survey

Outomes

This unit will cover the need for conducting a location survey and the methods for gathering data for a location survey.

Upon completion of this unit you will be able to:

- Describe the relevance of location survey.
- Differentiate between Demographic, Baseline and Technical survey.
- Conduct a location survey.

Terminology

Demographic survey:	A survey to collect relevant demographic data such as population, gender distribution, age-group distribution, number of households etc.
Baseline survey:	A survey to collect data such as the background of the people, their level of awareness about the Internet and the benefits they can get if they have Internet.
Technical survey:	It helps to understand the getting latitude, longitude, altitude, terrain, power supply and other wdetails required for network planning and Internet infrastructure set up at the chosen location.
Geographical coordinates:	A three-dimensional reference system that locates points on the Earth's surface. To collect geo-coordinates, we collect two coordinate values - latitude and longitude - that measure the angles of a location
LINKPlanner software:	A software that allows modelling of "what if" scenarios based on geography, distance, antenna height, transmit power, and other factors to optimize system performance before purchase
Maverick app:	An Android-based app used to find out the longitude and latitude of a place
MY GPS Coordinates app:	An Android-based app used to find out the longitude and latitude of a placeDemographic Survey

Demographic Survey

In order to understand the user base and establish the need for wireless services, it is a good idea to start with a demographic survey. Demographic information may be obtained from a local governing body such as the Panchayat office or Corporation office. The following information should be obtained:

- The population of the village/Panchayat where services will be provided
- Details of the population such as distribution across genders, age groups, ethnicity etc.
- Number of households in a 5 km radius of the proposed location for installation

This data will help in evaluating the return on investment of setting up the infrastructure for Internet services. Now, recall that there could be three levels at which you could set up a wireless network:

Level 1 – To bring connectivity from the ISP to a single location

Figure 11: Level 1 - Bringing connectivity from the ISP to a single location

Level 2 – To extend connectivity from the single location to another location

Figure 12: Level 2 - Extending connectivity from the single location to another

Level 3 – To extend connectivity from the single location to multiple locations

Figure 13: Level 3 - Extending connectivity from the ISP to multiple locations

A level 1 or level 2 installation would typically mean you are interested in setting up a wireless network for personal use or limited use. This involves bringing Internet connectivity from the nearest Internet Service Provider (ISP) such as BSNL to a house or office. If this is the requirement, then a demographic survey is not required.

A level 3 installation would, however, mean bringing Internet connectivity to a central location in your locality and then distributing it from there to other locations. This could be done in several ways based on the requirements of the community. A demographic survey will help you evaluate if you are likely to have enough customers to justify the cost of setting up this infrastructure.

After a demographic survey, a short survey of the nearby areas should be done to finalize a place to set up the base tower and other infrastructure. It may be necessary to rent a house and get permission from the owner to set up a tower or use a room to keep the networking equipment. Once the house is finalized, the baseline survey and technical survey can be conducted in the nearby areas which the tower will serve.

Example of Demographic Survey for Guna

Here is an example of the demographic data for Guna, a district in Madhya Pradesh.

Area and Population

Guna District is divided into 5 tehsils (administrative division) and has a population of 838926 spread over an area of 6484.63 square kilometres.

Table 1: Area & population of 5 tehsils of Guna district

Name of Tehsil	*The area in Sq. Km.*	*Population*		*Total*
		Male	*Female*	
Bamori	*1575.20*	*54778*	*49270*	*104048*
Guna	*1520.40*	*71633*	*62681*	*134314*
Raghogarh	*1123.77*	*74999*	*65048*	*140047*
Chanchoda	*1149.94*	*74543*	*65412*	*139955*
Aron	*812.75*	*41220*	*35300*	*76520*

Baseline Survey

The baseline survey helps in understanding the background of the people, their level of awareness about the Internet and the benefits they can get if they have Internet.

Some of the information that a baseline survey should gather is:

- **Information about people**
  - Gender/ ethnicity/ age group
  - Educational and professional background
  - Financial background

- **Information about Internet usage**
  - Awareness about the Internet
  - Interest in subscribing for Internet
  - If the Internet used previously – ISP, speed, cost, downtime, technical services
  - If the Internet is being used, what is the purpose? For example, for videos, messaging, music or browser.

- How much are they willing to spend on the Internet? For example, in one survey respondents were willing to spend an average of ₹50 per month.

Refer to the Appendix for a sample baseline survey form. This form is also available on the course website.

Inferences from the Baseline Survey

Once data from the baseline survey is available, it should be analysed to draw conclusions that help you plan the wireless network infrastructure.

Example 1

About 80% of this population is made of farmers. They collect at a central spot every week to watch videos of farming practices and get information on government schemes related to farming.

Inference: You can start Internet services for these farmers at their homes so that they can watch these videos from home any time they want.

Example 2

This population comprises mostly of tribal people who are not willing to spend more than ₹50 per month on the Internet. They make handicrafts and grow spices for livelihood.

Inference: It may take some time to get a return on your investment as income may be low initially.

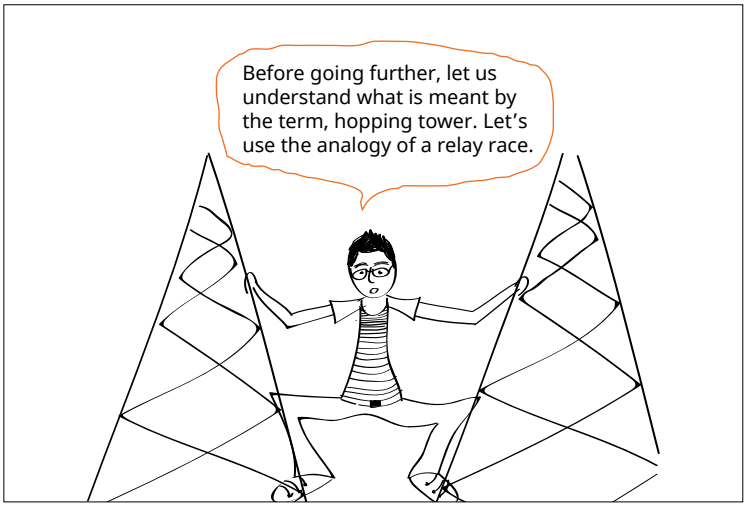
Some of the inferences you can dram from baseline data are:

- Timeline for revenue generation
- Services that can be offered such as Internet connection, wireless hotspot, Internet café, printing etc.
- Plan for scaling the services and infrastructure
- From gender information, ideas for additional services such as dance and music videos for women and farming videos for men
- The estimate for pricing your services

Technical Survey (or Network Feasibility)

The technical survey, also known as Network Feasibility, helps in getting latitude, longitude, altitude, terrain, power supply and other details required for network planning and Internet infrastructure

set up at the chosen location. It will also help us decide whether the tower should be used as a broadcasting tower or a hopping tower that is, to create a point-to-point link between two other locations.



In a 400-meter relay race, the first runner runs for 100 meters and then hands over the baton to the second runner. At that time, the first runner is tired but the second runner starts with full energy. After 100 meters, the second runner too get tired and hands over the baton to the third runner who finally hands over the baton to the fourth runner. So, the baton is relayed from one runner to the other so that the running pace can be maintained.

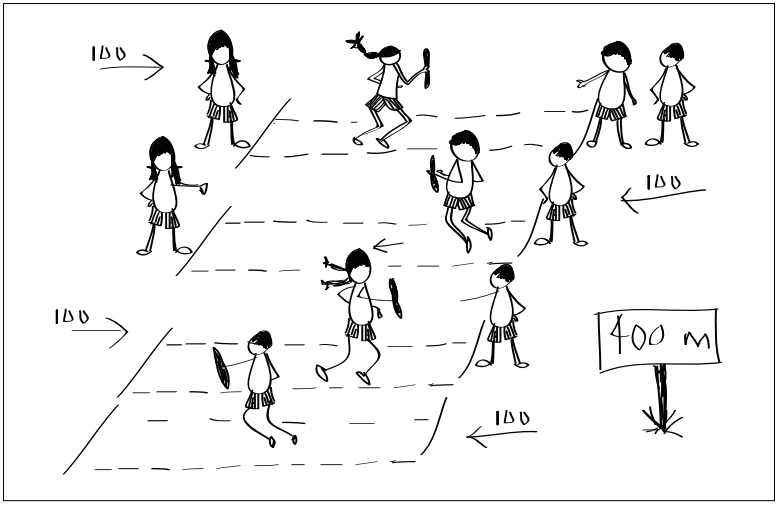


Figure 14: 400-meter relay race

In the same way, hopping towers help relay a wireless signal across long distances. When you need to get a wireless signal from the nearest broadcasting tower to your chosen location, you place a series of towers along the way so that the signal is relayed from the origin to the destination.

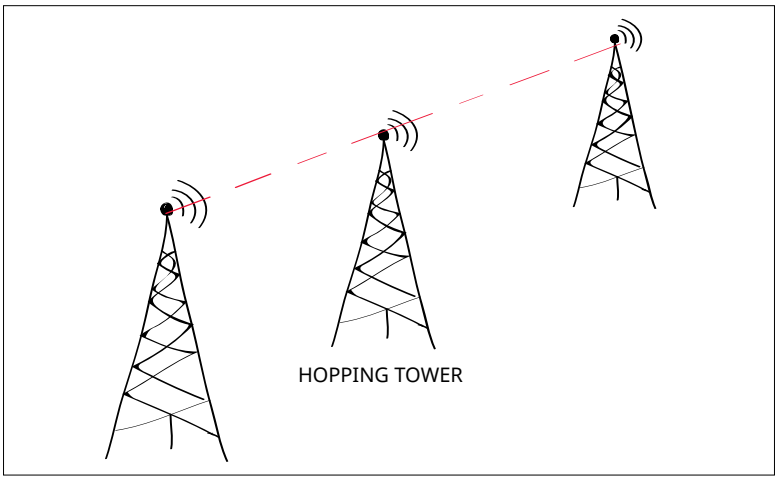


Figure 15: Showing the hopping tower

Now, let's get back to the technical survey. Some information that a technical survey should gather is:

- **Geographic Information**
  - Detailed address of the rented location(s)
  - Latitude and Longitude (for Network Planning)
  - Images of location
  - Height and density of trees nearby
  - The height of nearby buildings
- **Power-Related Information**
  - Electricity supply
  - Voltage fluctuations
- **Nearby ISP (Internet Service Provider) details for leased line connectivity**
  - Find nearby ISPs which can provide leased line connectivity for our Internet setup, from the "India ISP list" available.
  - Name and Class of ISP

- Full Address of ISP office
- Contact Details of ISP office
- Latitude/ Longitude/ Height of tower

Refer to the Appendix for a sample technical survey form. This form is also available on the course website.

Getting Geographical Coordinates of a Location

Getting the location coordinates of a location is one of the key aspects of the technical survey. Location coordinates refer to the longitude and latitude of a place. You may have learned in school that the latitude and longitude help us mark a place precisely on a map.

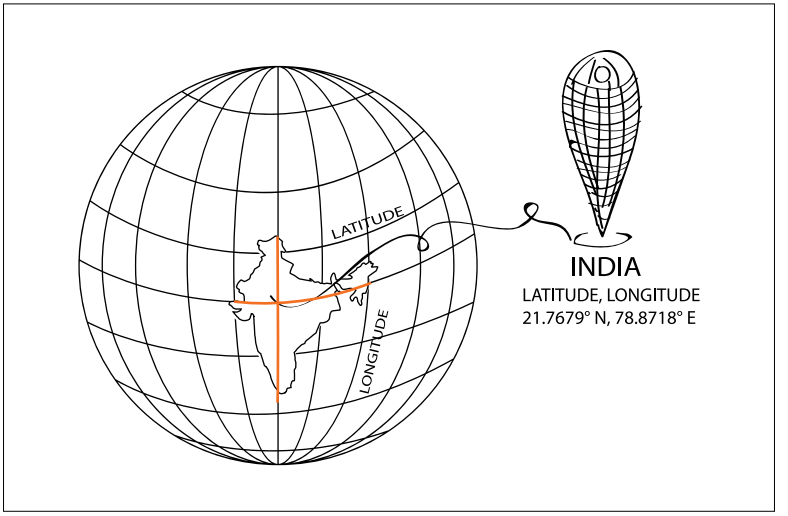
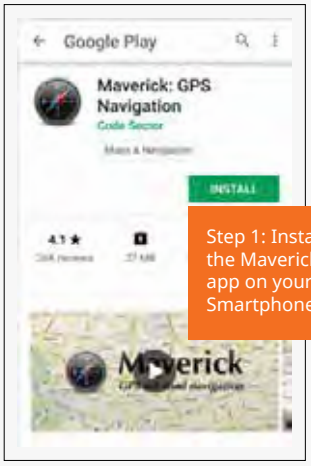


Figure 16: Loation coordinates (Latitude & Longitude)

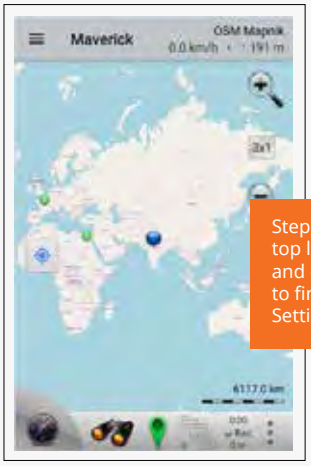
If "Location" i.e. GPS is turned on, in your mobile device, you can collect the coordinates of a location. However, if in any situation, we need to collect only the coordinates and not any other information for that location, then there other applications for the same. In this training, two Android-based apps are recommended – Maverick and My GPS Coordinate. Similar apps can be found for other phones too. You will learn about collecting the geographical coordinates of a location using these two apps.

Maverick App for Android

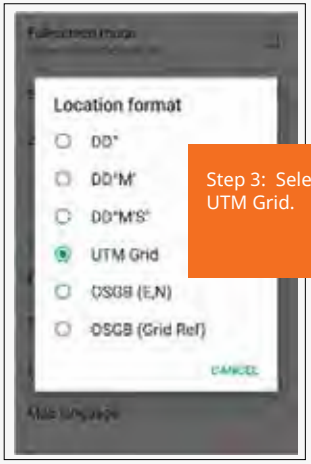
First, let's learn how to configure the Maverick app.



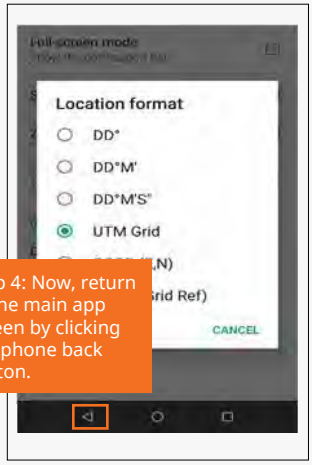
Step 1: Install the Maverick app on your Smartphone.



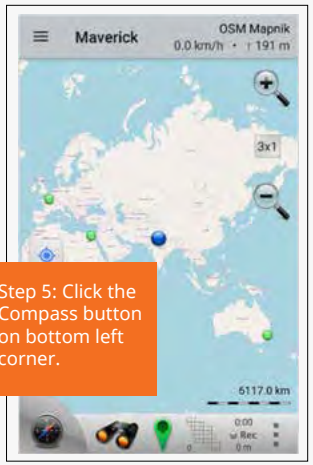
Step 2: Go the top left corner and click menu to find Tools > Settings >



Step 3: Select UTM Grid.

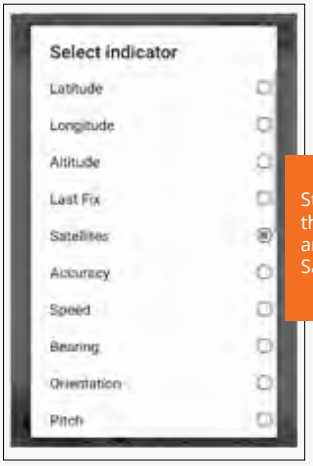


Step 4: Now, return to the main app screen by clicking the phone back button.



Step 5: Click the Compass button on bottom left corner.

Step 6: Flick to come to the screen showing Latitude, Longitude, Altitude etc.



Step 7: Click on the Altitude icon and change it to Satellites.

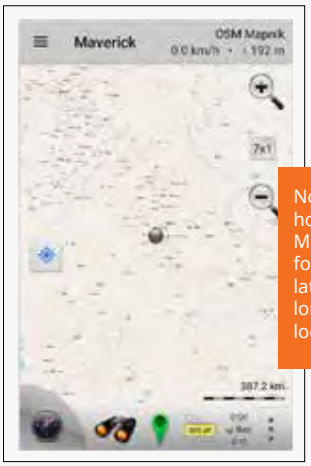
Figure 17: Configuring the Maverick App

To view the corresponding video on the course website, you can scan the QR Code displayed here or directly log in to the course website http://lms.defindia.org

Video Duration: 1:30 Minutes

Using the Maverick App

First, let's learn how to use the Maverick app.



Now, let's see how to use the Maverick app for getting the latitude and longitude of a location.

Step 1: Turn on GPS when you reach the location where you want Internet tower to be put up. If you plan to construct a tower on the terrace of a building, standing on the terrace would give more accurate reading.

Step 2: The "Satellites" icon should show at least 3 or 4 to get accurate value. The more the number of satellites visible, the more is the accuracy of the reading.

Step 3: Note latitude and longitude exactly as shown up to 5 decimals. Note it down along with the name of location where the reading is taken.

Figure 18: Using the Maverick App

To view the corresponding video on the course website, you can scan the QR Code displayed here or directly log in to the course website http://lms.defindia.org

Video Duration: 0:41 Minute

MY GPS Coordinate App

The My GPS app is also available for Android devices and gives precise coordinate up to 3 meters accuracy. Precision is good for proper network planning.

This app is simple and all you need to do is turn on your "Location" and stand in an open space. The app will show you the latest coordinates and also the accuracy. Note down the coordinates in decimal format up to 5 decimal places.

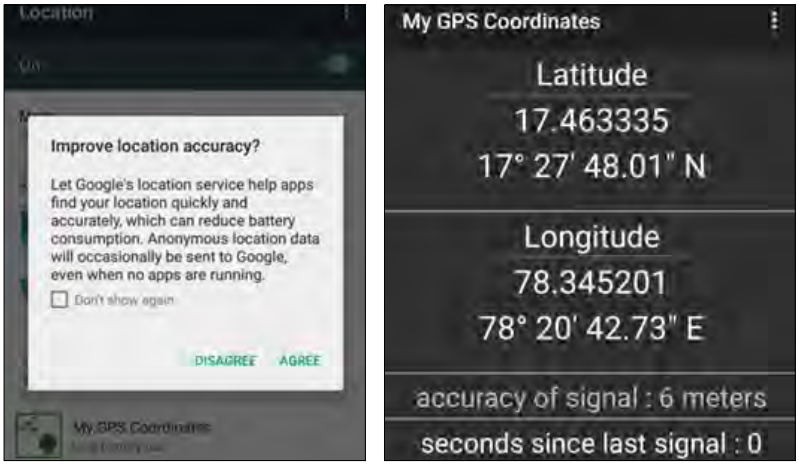
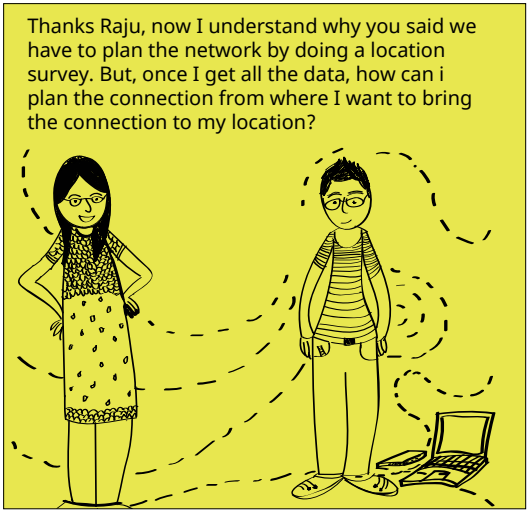
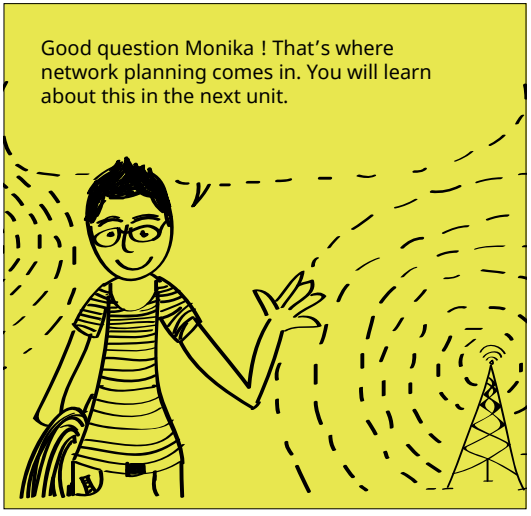


Figure 19: MY GPS Coordinate App





Inferences from the Technical Survey

From the technical survey data, we can draw inferences related to the set-up of the network. For example, if a tall structure such as a building is already present then a tower may not be required. Or, if hopping towers are required based on the distance and terrain. Also, you can estimate the number of various hardware devices and the equipment required. Some inferences you can draw from this survey data are described below.

- Data from this survey allows us to model 'what if' scenarios based on geography, distance, antenna height, transmitting power, and other factors to optimize system performance before the purchase of equipment.
- We can decide whether a tower is required to be specially set up or any existing tall building can be used.
- We can also estimate the equipment volumes (number of devices or length of cables etc.)
- Data from this survey helps us decide whether a direct link can be created between the sending and receiving devices or there is a need for hopping towers.

Example of Technical Survey in Guna

We will take the example of a technical survey which was conducted in Guna district of Madhya Pradesh. The technical survey was conducted to find the strengths and gaps of this area for the implementation of a wireless network in Guna district. The technical survey was conducted in the blocks - Guna, Pohari, Kolaras, Badarwas, Karera, Narwar, Pichore and Khaniyadana.

The results of the technical survey were used to set up the Guna wireless network.

- Except for the Guna district headquarters, most of the blocks did not have seamless internet connectivity.
- In order to connect all blocks of the Guna district headquarters, Guna block was identified as the main broadcasting centre. Since Guna could get true internet bandwidth from any good traditional telecom provider such as Airtel, Tata or BSNL, this was a good choice.
- The district Guna is mostly laid out over a small hill. This was a problem for deployment of a wireless network for the unlicensed band because the unlicensed frequency band (2.4 GHz & 5.8 GHz) cannot cross an obstacle such as a hill. This

frequency only works within line of sight due to the small wavelength. To overcome this problem, a tower was put on the hilltop for connecting two blocks. This provided two advantages - it reduced the requirement for a high tower and there was a decreased loss of the signal. However, the disadvantage was that there was no supply of electricity on top of the hill.

» For the power supply, solar power was used. This decision was based on the survey data that this region had sunlight around 98% days of the year.

» Finally, the best locations were identified for putting a minimum number of towers between the two blocks to connect all 8 blocks of Guna district. For the point-to-point connectivity between two blocks, 5.8 GHz frequency was used.

Summary

UNIT SUMMARY

In this unit you learned how conducting a location survey can provide useful data that will help you set up a profitable wireless network. You also learned about the methods for gathering data using a demographic survey, baseline survey and technical survey.

In addition, you learned how to find out the latitude and longitude of a location using two Android-based apps - Maverick app and MY GPS Coordinates app.

Assignment

ASSIGNMENT

Your Location Survey

This assignment has three parts. Complete all three parts and upload your assignment document to the course website. You may use the assignment template available online for documenting your responses.

Assignment Template
http://lms.defindia.org/mod/resource/view.php?id=44

Part 1: Assume you have to set up a wireless network in your locality. Conduct a demographic survey for the locality and create a summary of the data.

Part 2: Create a baseline survey form that you would use to analyse the requirements in this locality.

Part 3: Pick any two locations which are about 5 or 6 km apart. For each location find out the longitude and latitude.

Post your response to the course website. Then, read the responses by other learners and discuss your views using comments. Make sure that you offer constructive feedback and useful suggestions.

Post Assignment Response
http://lms.defindia.org/mod/forum/view.php?id=62

Assessment

ASSESSMENT

Now that you have completed this unit, check your understanding of the concepts learned by responding to the following questions.

You can also take this assessment on the course website.

You can verify your response with the response displayed in the Ideal Responses section.

Question 1: Which of the following are the aims of the location study? Select the two most suitable options.

a. To objectively uncover the strengths and gaps related to the project.
b. To meet people at the location and advertise your services in the surrounding areas.
c. To plan the resources required to execute the project.
d. To check the weather in and around the area where you would like to set up a network.

Question 2: Monika's village is in a remote area. After conducting a baseline survey, she realizes that most of the residents are retired people such as school teachers, bank employees and government officials. If she plans to charge ₹75 per month for Internet usage, do you think she is likely to find enough customers for Internet services?

a. Yes, because it looks like the residents of her village will have a regular monthly income and may want to use the Internet for communication and entertainment.
b. No, because the residents of her village are mostly retired people so they may be too old fashioned to spend money on the Internet or a smartphone.

Question 3: Which of the following information should be gathered in a technical survey? Select the two most relevant options.

a. Farming practices common to the region
b. Latitude and Longitude of the location
c. The height of nearby buildings
d. Number of households having loans

IDEAL RESPONSES

Answer 1: a, c. Information from the location study should aid in making decisions related to the wireless set up.

Answer 2: a. It is a safe assumption given that there is a lot of awareness and knowledge of the internet and its uses.

Answer 3: b, c. Information that is relevant to setting up a wireless network such as the location and possible obstructions should be gathered in the technical survey.

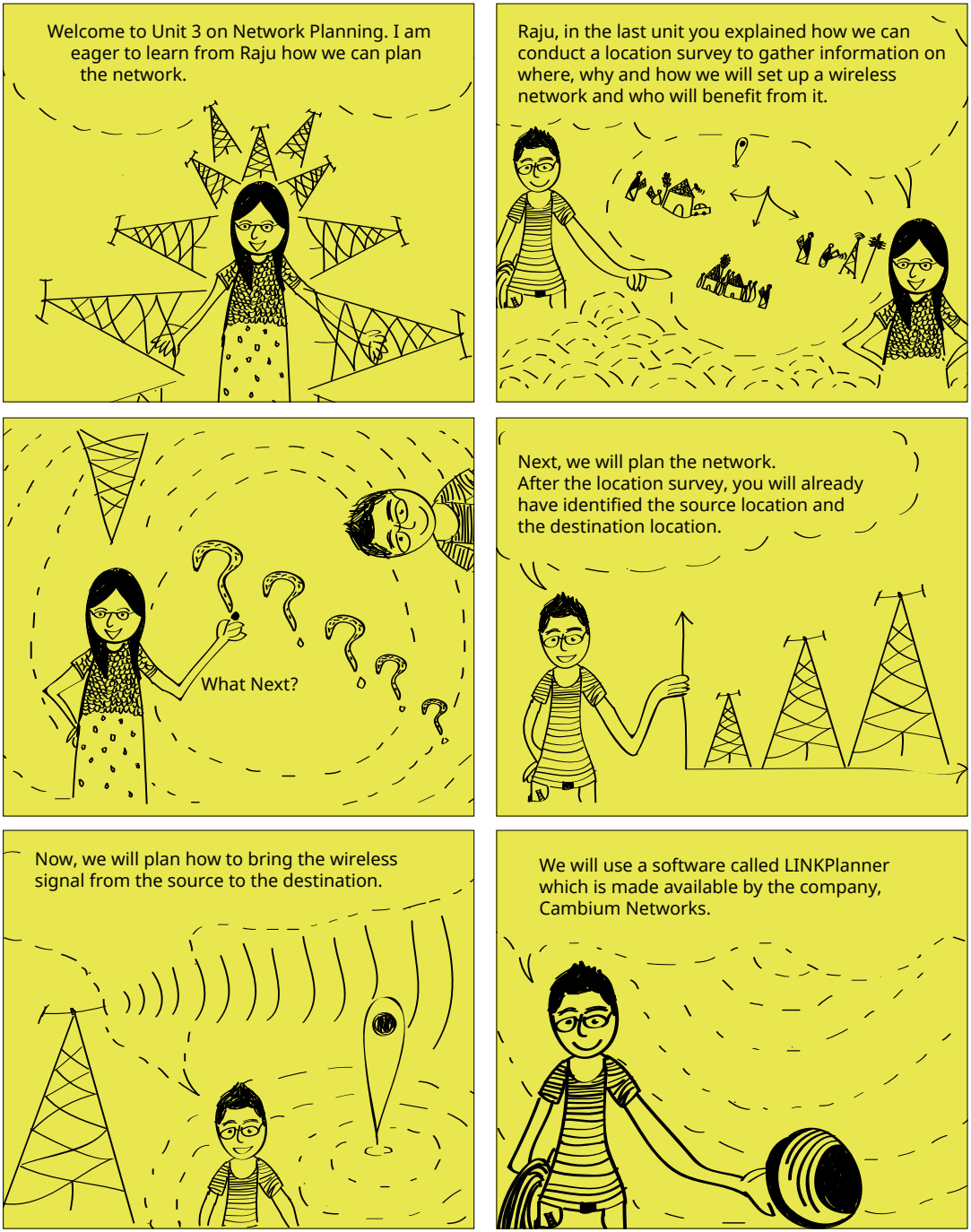
Unit

3

Network Planning

Introduction

Read the story how Monika is learning network planning and how to use LinkPlanner software.



To view the corresponding video on the course website, you can scan the QR Code displayed here or directly log in to the course website http://lms.defindia.org

Video Duration: 0:52 Seconds

Outomes

This unit will provide details of planning a network based on the output from the location survey. Learners will be able to identify the steps for determining an optical line of sight.

Upon completion of this unit you will be able to:

- Define interference.
- Explain why the line of sight is necessary.
- Differentiate between various networking models.
- Create a relay station.

Terminology

Line of Sight	An unobstructed path for wireless signals to travel between buildings or devices.
Interference	A kind of disturbance between two or more networks.
Relay Station	Transmits data between two stations. For example, it can relay the data between the main station and the base station.
Broadcasting Tower	The structure that transmits the data.

Why Network Planning is Required?

What are the Components of a Wireless Network?

When a device sends out a wireless signal, it is called a transmitter. When another device picks up that wireless signal and understands the information, it is called a receiver. In the case of FM radio, there is one transmitter--owned and operated by the radio station--and many receivers that people listen to the station with.

When a device has both a transmitter and a receiver, it is sometimes called a transceiver. Devices such as routers can both transmit and

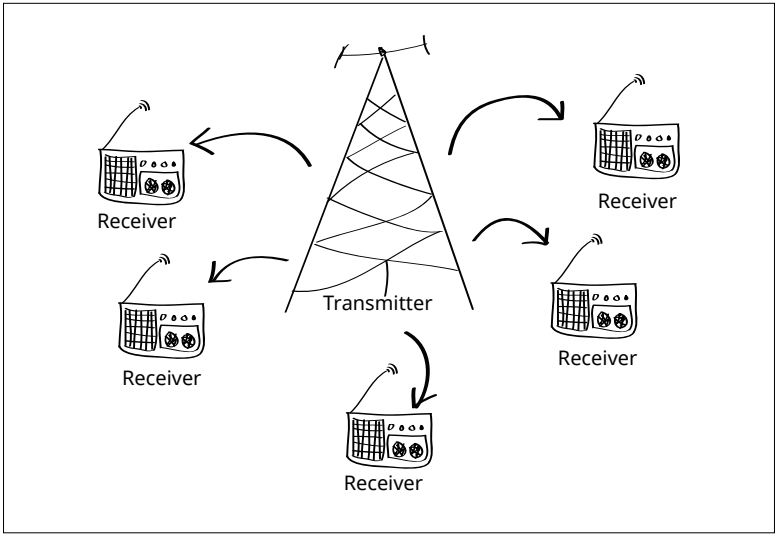


Figure 20: Components of wireless network

receive, which is what makes them useful for building networks. Networks are built with Wireless Routers. Wireless Routers can send, listen to and repeat a signal. They all have direction and strength, meaning that they can broadcast and receive in different directions and at different distances. Broadcast strength varies a lot depending on environmental conditions. You can connect routers either with wires or wirelessly. Buildings, leaves, weather and other wireless signals can all break a connection between two wirelessly connected routers.

Wireless routers have different types of antennas. Some routers will have antennas built in, and sometimes the routers will have a choice of antenna you can attach to the router. There are many specific types of antennas.

Interference and Line of Sight

The term line of sight, often abbreviated as LOS, is quite easy to understand when talking about visible light: if we can see a point B from point A where we are, we have a line of sight. Simply draw a line from A to B, and if nothing is in the way, we have a line of sight.

Interference is one of the most misunderstood terms and phenomenon in wireless networking. When we talk about

interference in wireless networks, it refers to the disturbance between two or more networks.

Interference of this kind is one of the main sources of difficulty in building wireless links, especially in urban environments or closed spaces (such as a conference space) where many networks may compete for use of the spectrum.

When you are planning to establish a wireless network between two or more points, understanding the line of sight is important. There are three main categories of line of sight, the first being full line of sight (LOS) where no obstacles reside between two networks, the next is called Near Line of Sight (nLOS), which includes partial obstruction such as treetops between the two points and lastly Non Line of Sight (NLOS) where full obstruction such as trees, mountain, tall building, etc. between the two points. By determining the specific line of sight conditions in the wireless network area, you can determine the correct type of wireless system/device to install.

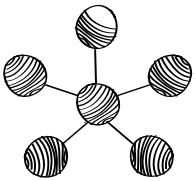
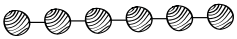
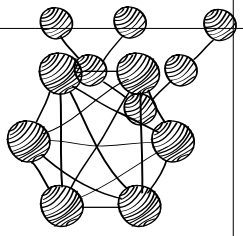
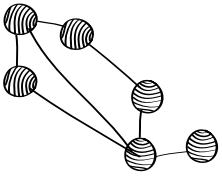
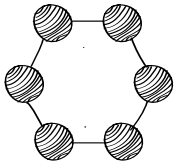
Figure 21: Tower

Towers

One of the methods to establish a line of sight is using towers. A tower is a structure that gives you the height to establish your wireless network. For example, it can be a water tank, the tallest building or any other tall structure that exist in the region. Sometimes, you may have to set-up or build the tower. You will learn more about this in Unit 6.

For planning the locations, we may use different networking models which are ways of arranging routers. Refer to the common types of network topologies relevant to wireless networks displayed below.

Table 2: Common types of network topologies

Topology	*Visual Representation*	*Description*
Star		*Each node is connected directly to a central network hub or concentrator. All data in a star topology passes through the hub before reaching its destination. This topology is common in Ethernet and Wireless LAN.*
Line (or multi-hop)		*A set of nodes connected in a line. Each node is connected to its two neighbouring nodes except for the end nodes that have only one neighbouring node each.*
Tree		*A combination of a bus and a star topology. A set of star-configured nodes is connected to a bus backbone.*
Full Mesh		*A direct link between all pairs of nodes. A full mesh with n nodes requires n (n-1)/2 direct links. Due to its character, it is an expensive topology but very reliable. Mainly used within military applications.*
Partial Mesh		*Some nodes are organized in a full mesh scheme while others are just connected to one or two nodes in the network. Partial mesh topology is less expensive than full mesh but is of course not as reliable since the number redundant links are reduced.*
Ring		*All nodes are connected to one another in the shape of a closed loop so that each node is connected directly to two other devices. Typically backbone infrastructure with optical fibre.*

LINKPlanner for Creating LOS

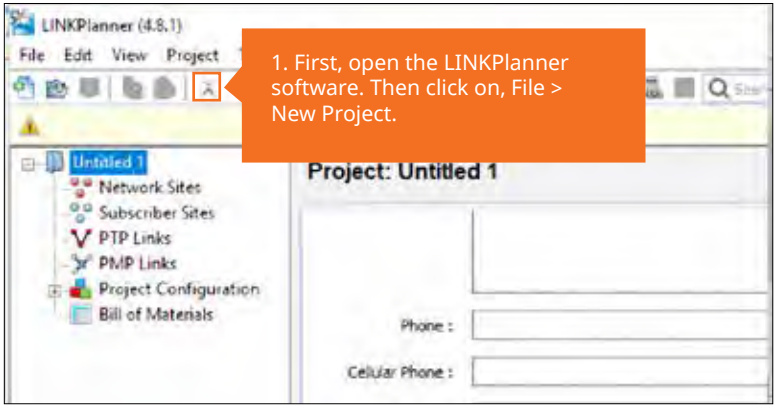
Once we have the coordinates for the transmitting and the receiving location, we need to plan the links between the locations. We recommend a software called the LINKPlanner which can help you plan the links after you input your technical data.

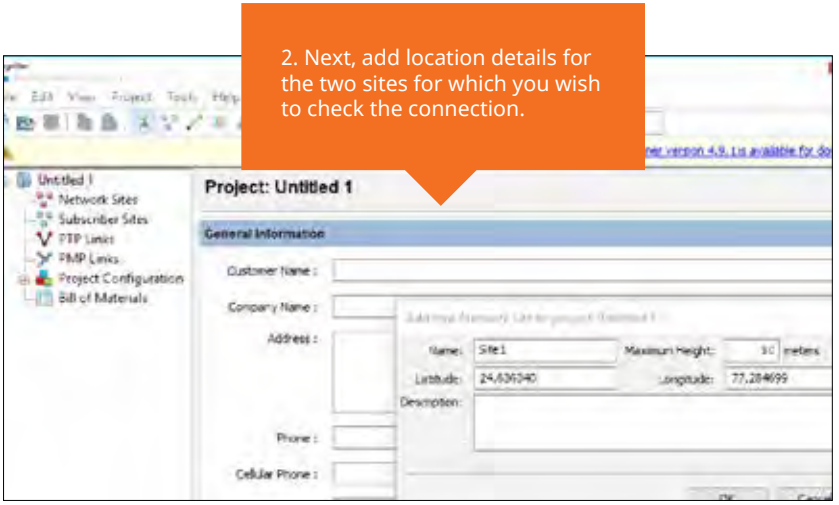
In Wireless networking, a Point-to-Point (PTP) link has to be created between two locations with clear a Line-of-Sight (LOS). This means that if there is no obstacle between the antennas put on top of two towers, then a PTP link can be formed between them.

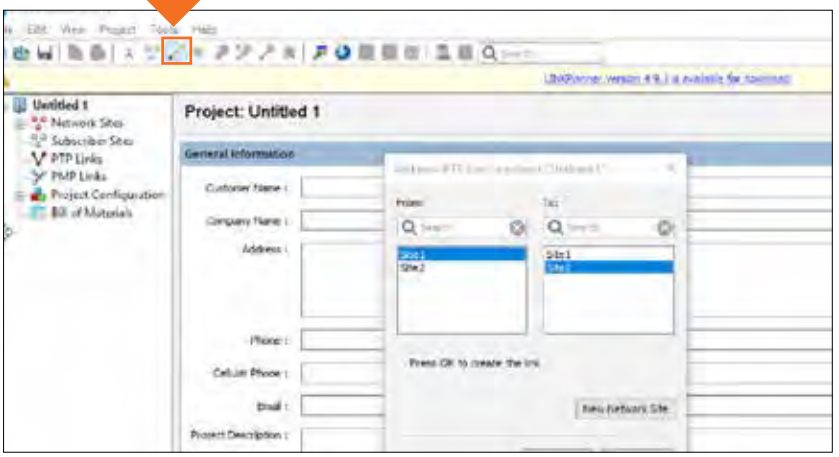
To find out whether there is LOS between two links, we take help of the free software from Cambium Networks called LINKPlanner. It also allows us to play around and change the location, height of towers, antenna power and more to create a link which transmits signal with maximum possible efficiency.

You can download and install LINKPlanner from the Cambium Networks website, **https://www.cambiumnetworks.com/products/management/linkplanner/**

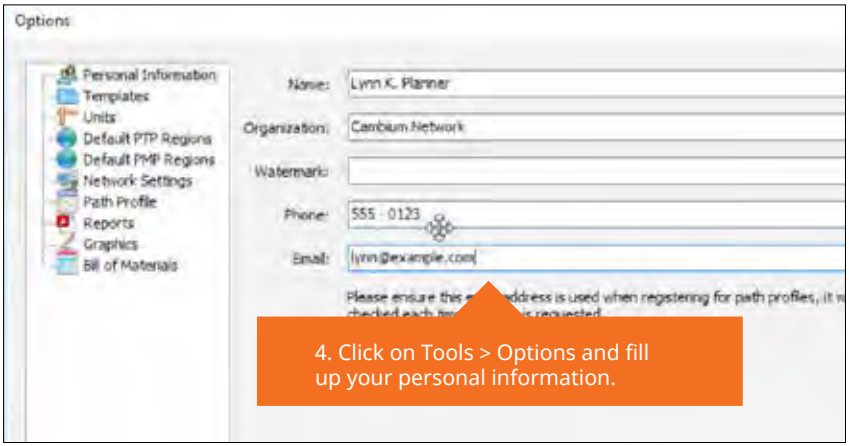
Let's now see how we can use the LINKPlanner software with our data to generate a network plan.

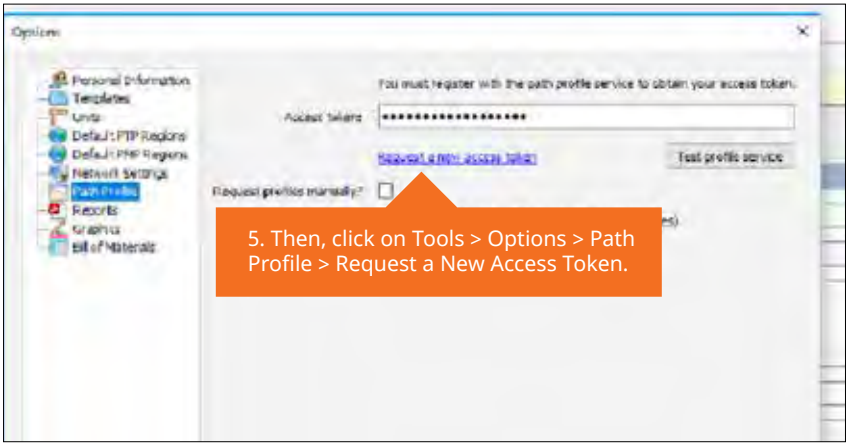


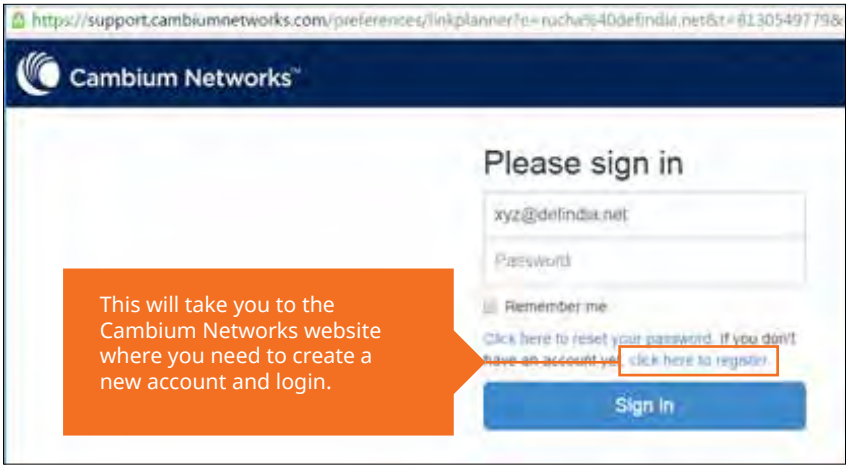


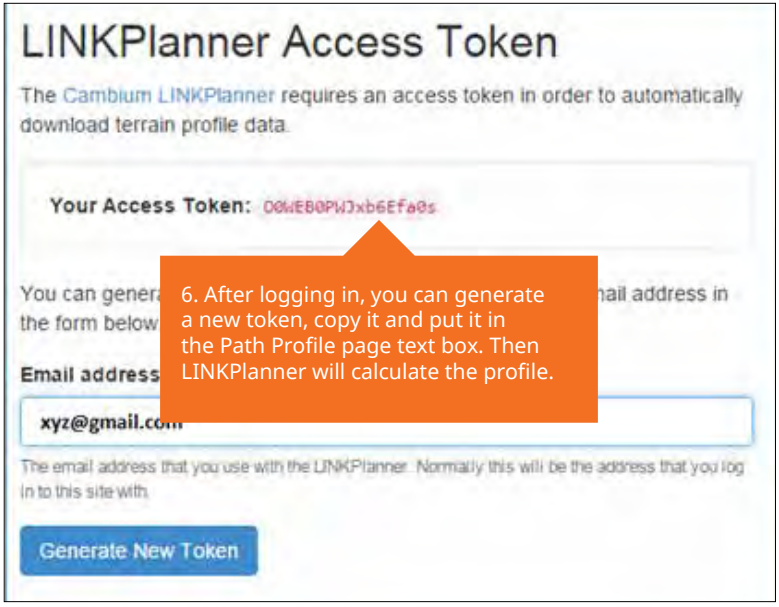


The LINKPlanner will get location altitude and terrain details from Google Earth and show whether the links got connected or not. To get the location profile, some settings need to be done.


Options
Personal Information
Templates
Units
Default PTP Regions
Default PMP Regions
Network Settings
Path Profile
Reports
Graphics
Bill of Materials
Name:
Lynn K. Planner
Organization:
Cambium Network
Watermark:
Phone:
555 - 0123
Email:
lynn@example.com
4. Click on Tools > Options and fill up your personal information.


Options
Personal Information
Templates
Units
Default PTP Regions
Default PMP Regions
Network Settings
Path Profile
Reports
Graphics
Bill of Materials
You must register with the path profile service to obtain your access token.
Access Token:
Request a new access token
Test profile service
Request profiles manually?
5. Then, click on Tools > Options > Path Profile > Request a New Access Token.


https://support.cambiumnetworks.com/preferences/linkplanner?e=rucha%40defindia.net&t=
Cambium Networks
Please sign in
xyz@defindia.net
Password
Remember me
Click here to reset your password. If you don't
click here to register
Sign In
This will take you to the Cambium Networks website where you need to create a new account and login.



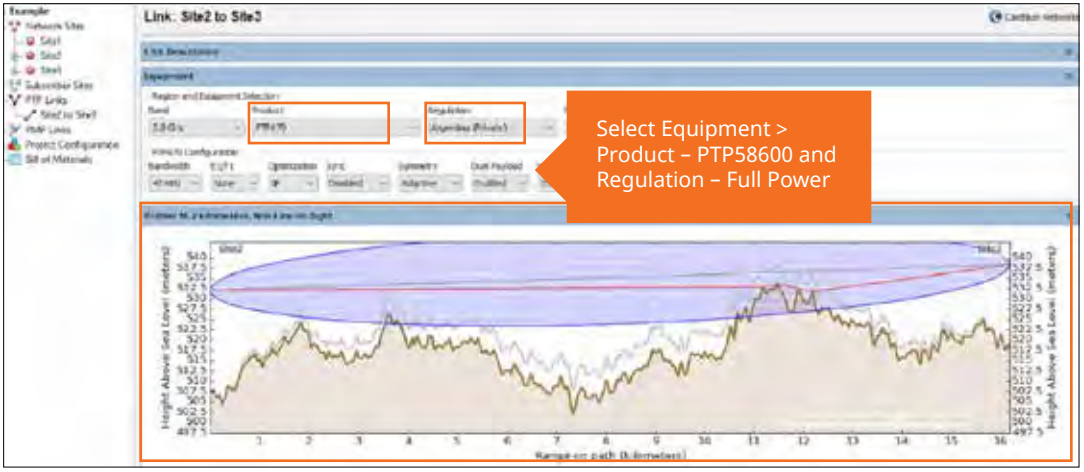
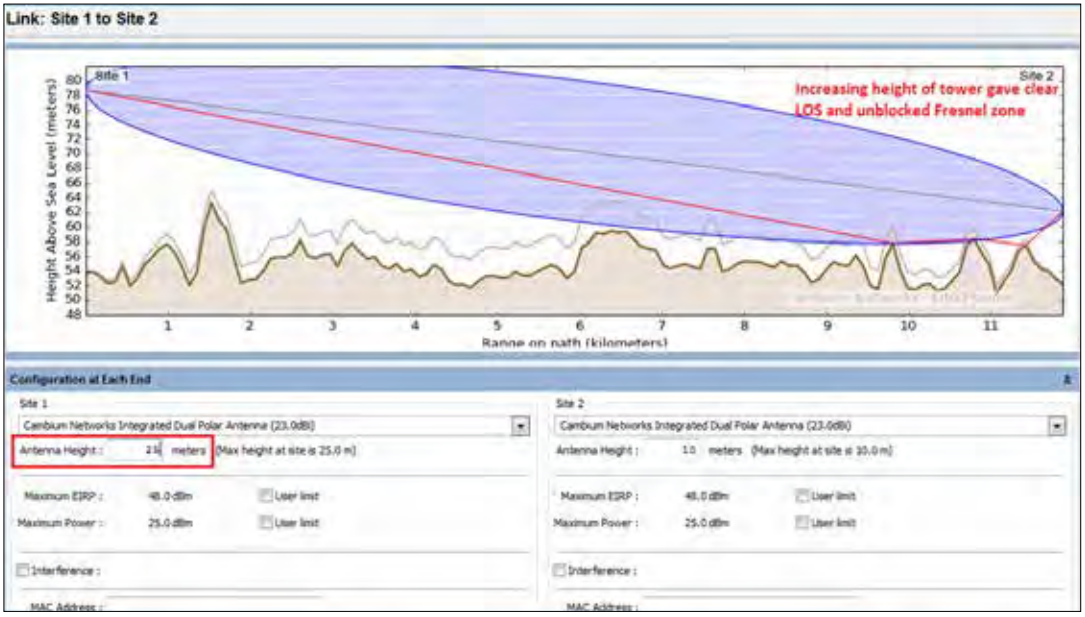


Figure 22: Using LINKPlanner

We can see that the LOS link is not connected properly due to multiple hills acting as obstacles. Here, we have selected Product – PTP58600 because LINKPlanner supports PTP link operating in a licensed frequency band (6 GHz or greater) between two sites. Since the product needs full power, so we have selected "Full Power" in regulation. To learn more about LINKPlanner, refer to the user guide available on the website. **http://unidata.com.ua/epmp/add/files/LINKplanner-4.5.3/link-planner-user-guide-4.5.3.pdf**

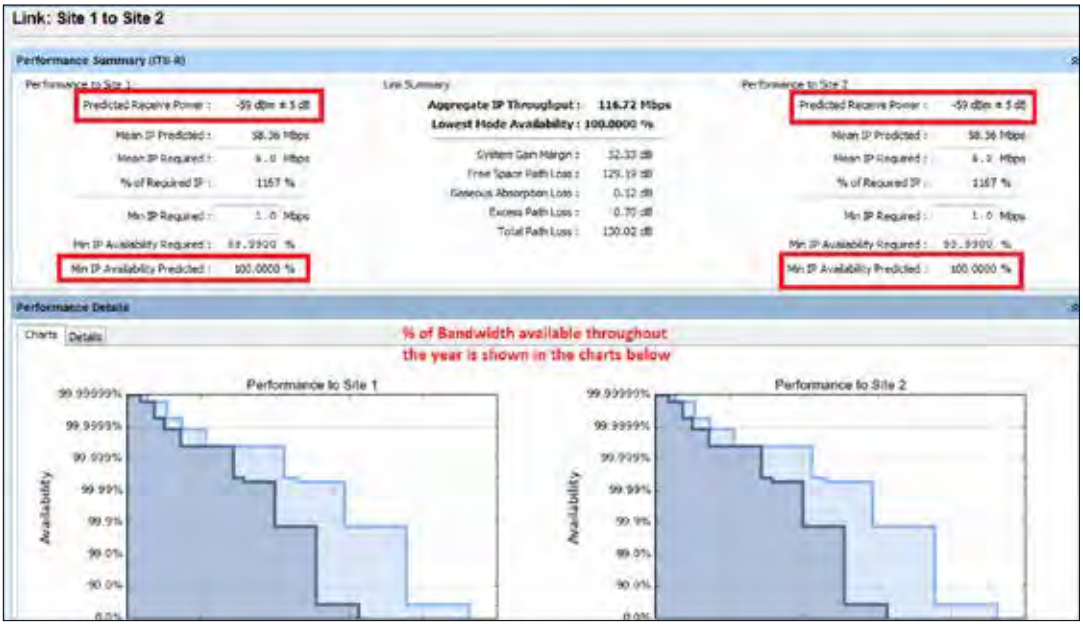
You just learned how you can check the link between two sites using LINKPlanner. In the example you just saw, there are obstacles between the two sites. Let us now see how LINKPlanner can help us plan the LOS around these obstacles.

To overcome obstacles, one solution is to increase the height of the tower.



If we try to increase the height of tower at Site 1 from 10 m to 25 m, we can see that there is clear LOS now. This ensures that maximum power is transmitted from Site 1 to Site 2.

If you scroll down the LINKPlanner screen in the software, you can see the link performance.



You should ensure that the IP availability is 100%. Here, IP availability is a measure of the bandwidth availability – if the line of sight is clear from both ends, you will get 100% or the full bandwidth applied from the telecom service provider. If there is an obstacle, then IP availability will be less than 100%. Typically, power at the receiver is always lower than the power transmitted.

In this way, we can use LINKPlanner to connect multiple sites together. You can generate two kinds of reports using LINKPlanner.

- **Proposal Report:** It will contain LOS feasibility, with link summary, performance charts, losses and standards, required equipment and other useful information about all links in the network.
- **Installation Report:** It will contain installation notes for all tower sites along with some of the information in the proposal report.

The figure below shows how to generate both reports.

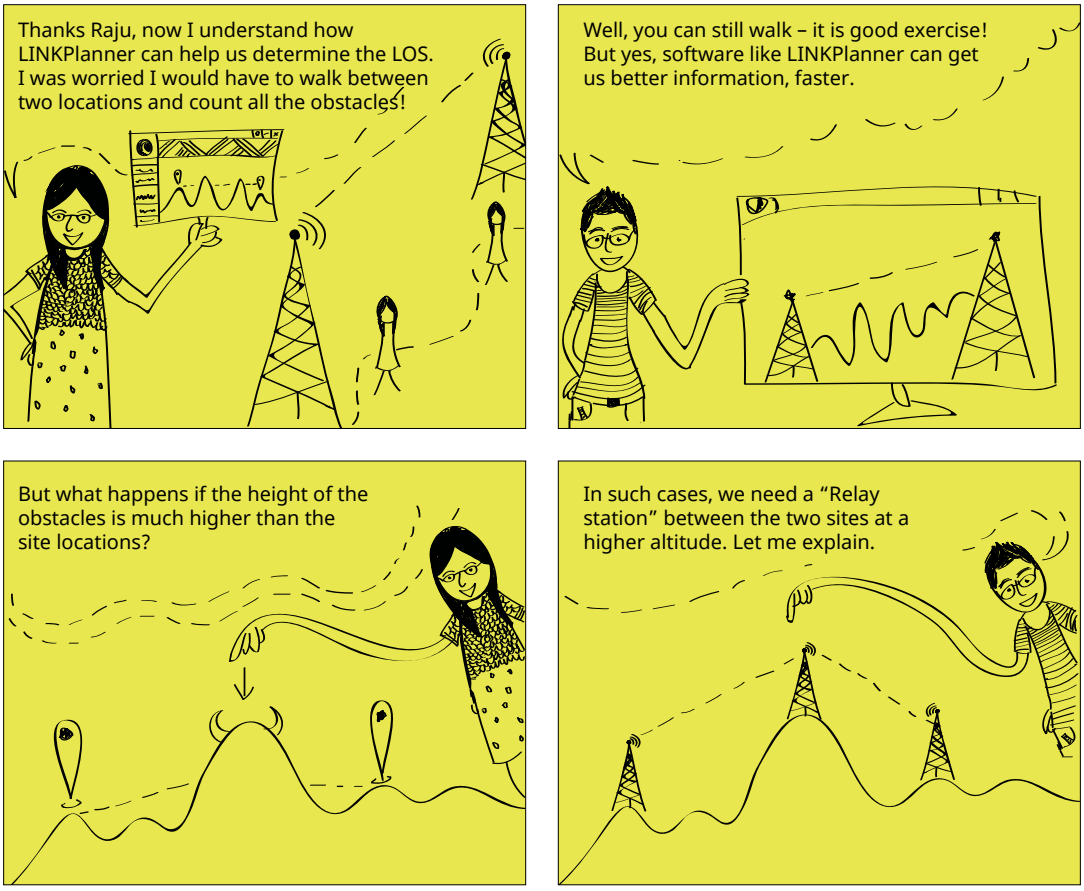
Figure 23: Generating proposal and installation report

To view the corresponding video on the course website, you can scan the QR Code displayed here or directly log in to the course website http://lms.defindia.org

Video Duration: 2:06 Minutes

You can refer to the course website to view a sample report generated by LINKPlanner.

Finding Relay Stations



To view the corresponding video on the course website, you can scan the QR Code displayed here or directly log in to the course website http://lms.defindia.org

Video Duration: 2:25Minutes

Sometimes, even if we increase the height of a tower, it does not help since there are multiple obstacles or the altitude of the obstacles is much higher than the altitude of the site locations. In such cases, we need a "Relay Station" between

the two sites at a higher altitude. Both sites will be connected to this relay station and thus indirectly to each other. We can achieve this by experimenting using Google Earth. Let us learn how to do that.

Google Earth to find Relay Stations between two NLOS Sites

We will see a real example of a setup planned in Hoshangabad, Madhya Pradesh to connect the following sites.

- Bhaura (Main centre+client1)
- Kundi (client1)
- Raipur (client2)

Since Bhaura is the Main Centre where we can get leased line connectivity from an ISP, we need to connect the other 2 centres to this centre in a star formation.

However, if we try to do this using LINKPlanner, we see that there is a mountain range with Bhaura on one side and Kundi and Raipur on the other. So there is no Line of Sight between them.

In the Fig 24, we can see the network links in Red colour show that this link is not possible.

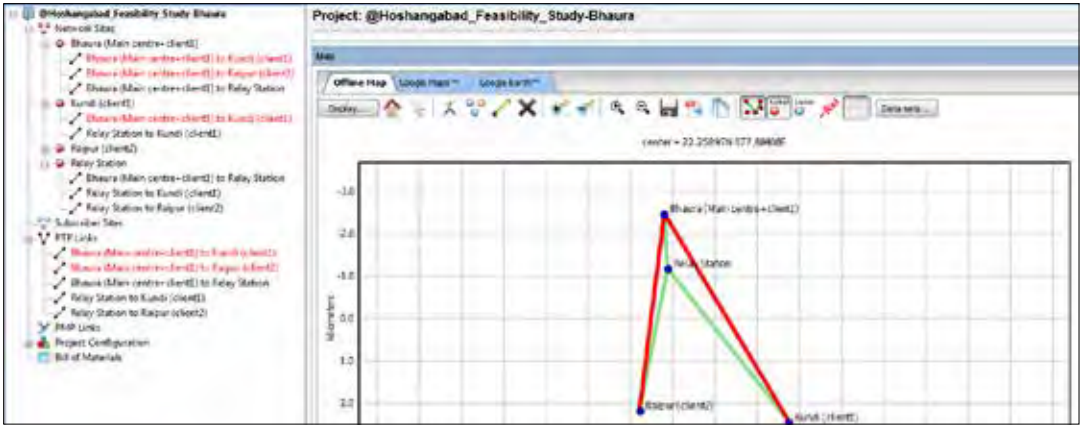


Figure 24: Showing network lines in red color

Let us see how we can understand this from the Link Profile and Performance Charts.

The Link Profile clearly shows that direct LOS is not possible due to a mountain peak of height 430 m above sea level. The Fresnel zone is completely blocked.

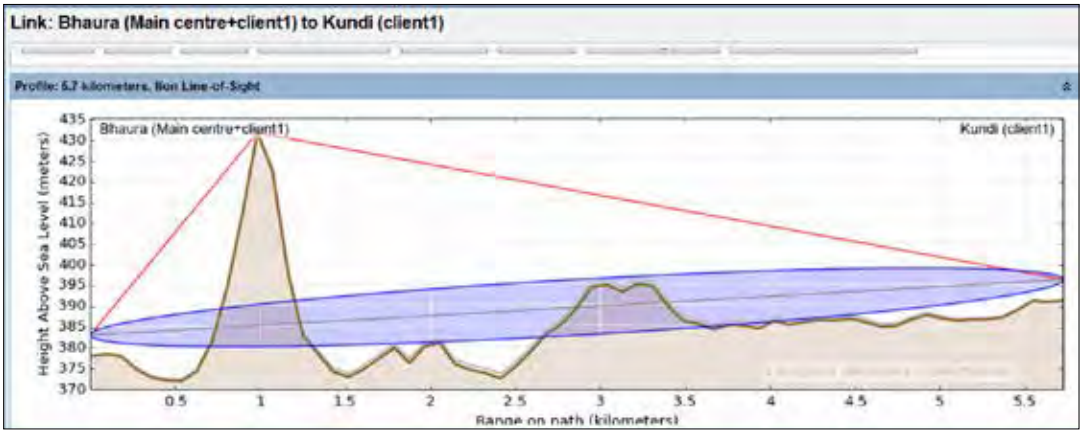


Figure 25: Showing direct LOS is not possible due to a mountain peak

In the given below Fig. 26, we can see that the predicted received power is -92 dBm which is much less than the allowed -70 dBm. The predicted speed is less than 5 Mbps and its available only 3.11% of the times annually.

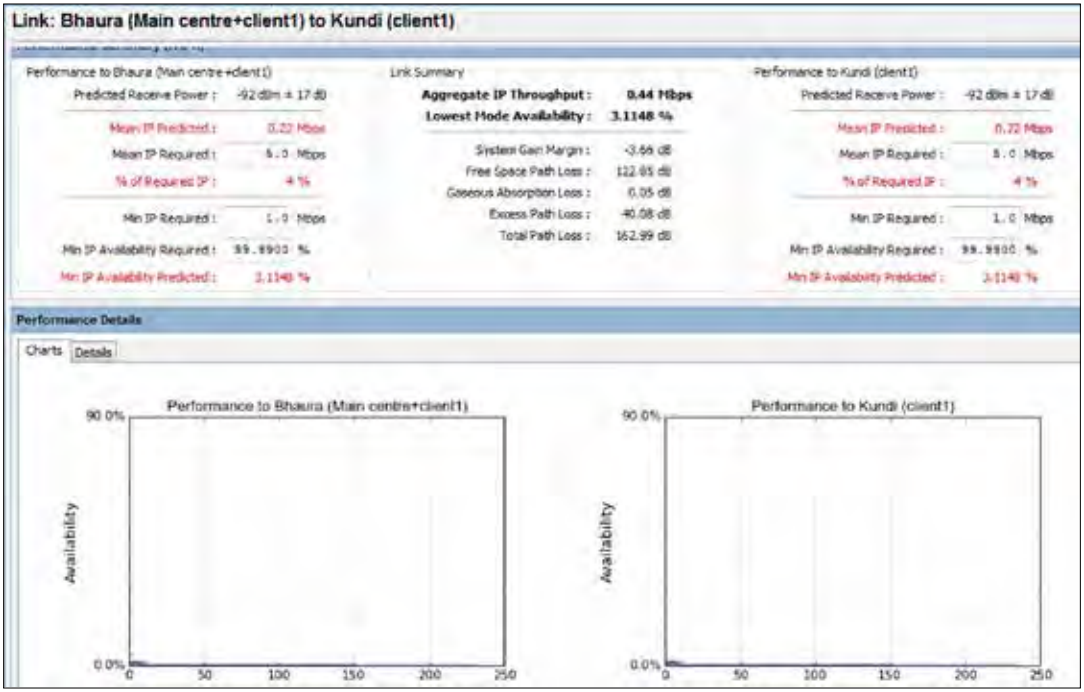


Figure 26: Showing predicted received power is -92 dBm

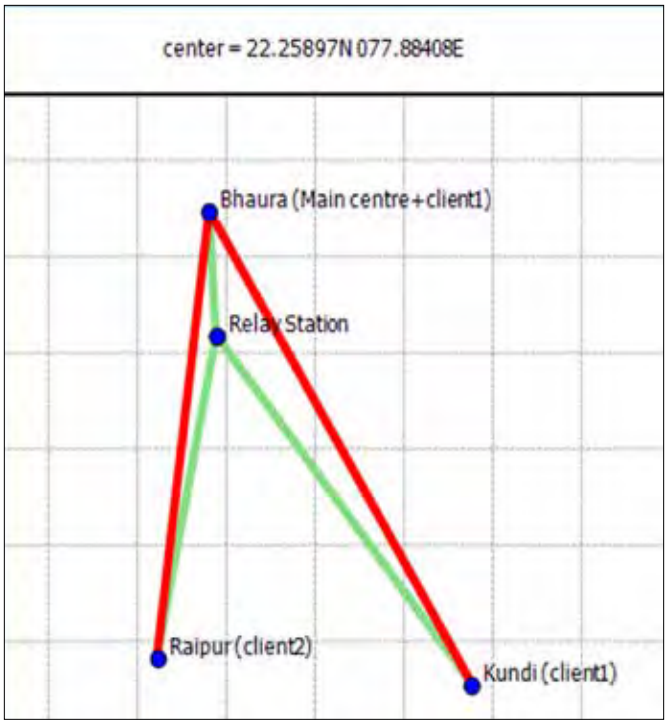


Figure 27: Showing a relay station connecting 3 locations

If we look closely in Fig. 27, we can also see a relay station which connects perfectly to all 3 locations of the centres. We need to do some experimenting on Google Earth to find a perfect spot to set up this Relay Station.

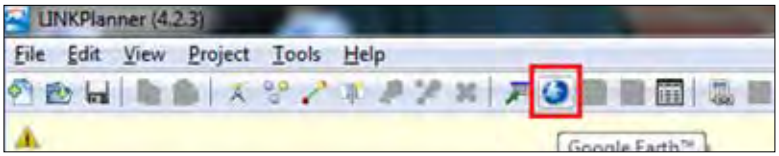


Figure 28: Showing Google Earth icon

Open this project on Google Earth by clicking the Google Earth icon in LINKPlanner menu bar as shown above in Fig 28.

Figure 29 a: Showing red links as broken due to a range of mountains

Figure 29 b: Showing red links as broken due to a range of mountains

The red links between Bhaura and Kundi or Bhaura and Raipur can be seen in Fig. 29 as broken due to a range of mountains (dark colour in the map). Hp 1 and Hp 2 are the highest points on the link (with maximum elevation). On the bottom right corner of Google Earth, we can also see the latitude, longitude and elevation (height above sea level) of any point where the mouse is pointing. This is highlighted in a yellow box in the picture below.

We need to find a Relay station which is:

- Possibly near the mountain range, so that its elevation is higher than that of the client stations
- A building where we can request the owner to set up a tower
- A building which is well-connected by road so that a maintenance person can visit the place easily from town

Thinking of the above 3 aspects, we have found a Relay Station as shown in the diagram. The Fig. 30 shows a zoomed in version of the building we have chosen to be the relay station. It is next to the main road connected to Bhaura. And its elevation is higher than all three client stations – Bhaura, Kundi and Raipur. Now, the main hurdle here is to visit the location, verify whether there actually is a building there as seen in Google Maps and convince the owner to allow us to put up a tower on his building or

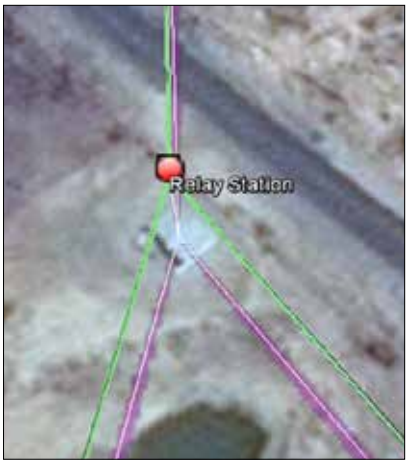


Figure 30: Zoom version of building selected for a relay station

grounds. No tool can help in achieving this! So good luck!

Coverage Area of Broadcasting Tower

The coverage of a wireless signal from the tower is the geographic area where the client device can communicate. Coverage depends on several factors, such as orography (i.e., mountains) and buildings, technology and radio frequency.

The coverage area of Guna's Block

Coverage area of Guna' Block which is covering 5 kilometre of radios base on -80 dBm are showing below in Fig 31:

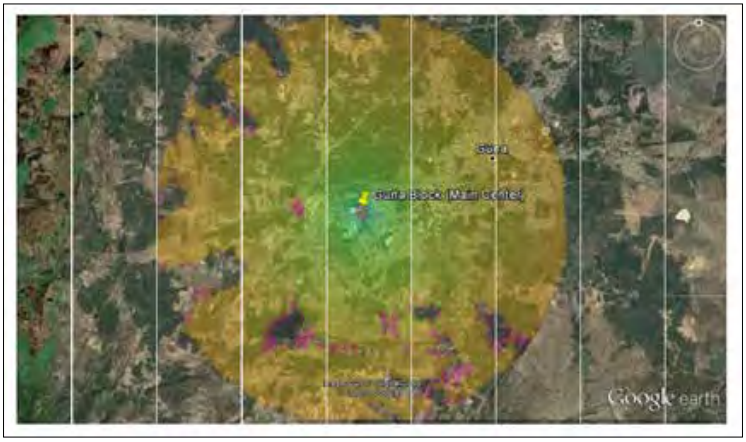


Figure 31: Coverage area of Guna block

Tower Locations and Heights

The network feasibility will enable you to understand the tower height requirements. It will help us understand how to decide which device should be used at what locations and how many do we need.

Let us go through a small example showing a Network Diagram. This example shows a network of 8 Community Information Resource Centres (CIRCs) of DEF. Following are the names of the centres:

Table 3: Tower locations and their height

Centre Name	*Tower Height*
Pradan campus (Main centre)	*32 m*
Raipur	*10 m*
Kamthi	*18 m*
Koylari	*21 m*
Salimet	*15 m*
Kala Akhar	*10 m*
Doudi	*32 m*
Morpani	*21 m*

The 9th tower named BTS belongs to the local ISP from where we have got a leased line of 10 Mbps Internet. The 10th tower named Node1 is a relay station i.e. it's an extra tower we had to set up since Line of Sight was not available between BTS and Pradan Campus and the distance between them was too much.

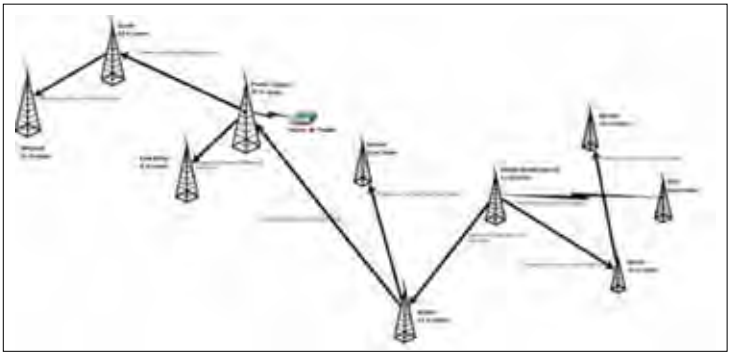


Figure 32: Showing network diagram of Pradan Campus

Each centre is allotted a maximum bandwidth of 2 Mbps. This ensures that no user can get a speed of more than 2 Mbps at any point in time and thus number of users can be accommodated in the 10 Mbps bandwidth available.

Aerial Distance between two towers, locality, population density, whether the terrain is hilly, whether there is dense forest or trees between towers are some points that need to be considered to understand how equipment calculations were done.

Link Summary

In link summary, you will find Name of linked towers, the distance between these two towers (km), Band (GHz), Aggregate Throughput (Mbps), Link Availability, Left Gain (dBi), Left Predicted Receive Power, Right Gain (dBi), Right Predicted Receive Power.

Network Diagram with IP Planning

A Network Diagram with IP planning is a schematic representation of the interactions of various devices on a network along with the IP addresses. A Network Diagram shows the devices that enable a network, such as routers and switches, as well as devices that access the network.

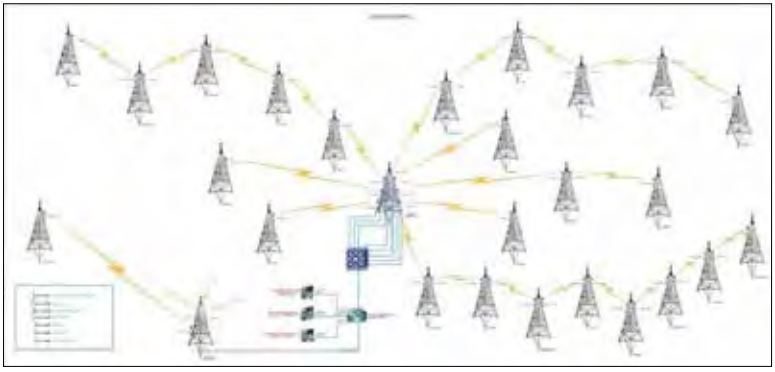


Figure 33: Guna network diagram with IP planning

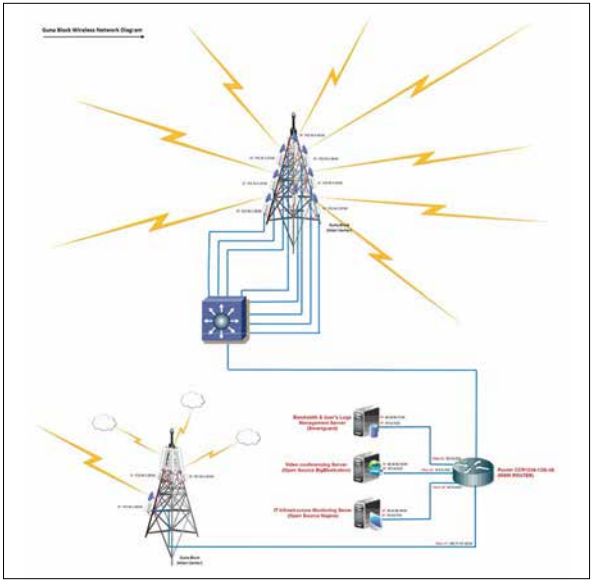


Figure 34: Network diagram with IP addresses

Summary

UNIT SUMMARY

In this unit, you learned about interference and creating a line of sight to remove interference. You learned about some of the common types on network models – Star, Line (or multi-hop), Tree, Full Mesh, Partial Mesh and Ring. You saw how the LINKPlanner software can be used to check the link between two sites and plan a line of sight around any obstacles. You also learned how relay stations can be can be planned using Google Earth.

Assignment

ASSIGNMENT

Your Link Planner Reports

Select any two sites of your choice which are not more than 10 km apart. Using the LINKPlanner software, generate a Proposal Report and an Installation Report and upload these to the course website.

Read the responses by other learners and discuss your views using comments. Make sure that you offer constructive feedback and useful suggestions.

Post Assignment Response
http://lms.defindia.org/mod/forum/view.php?id=63

Assessment

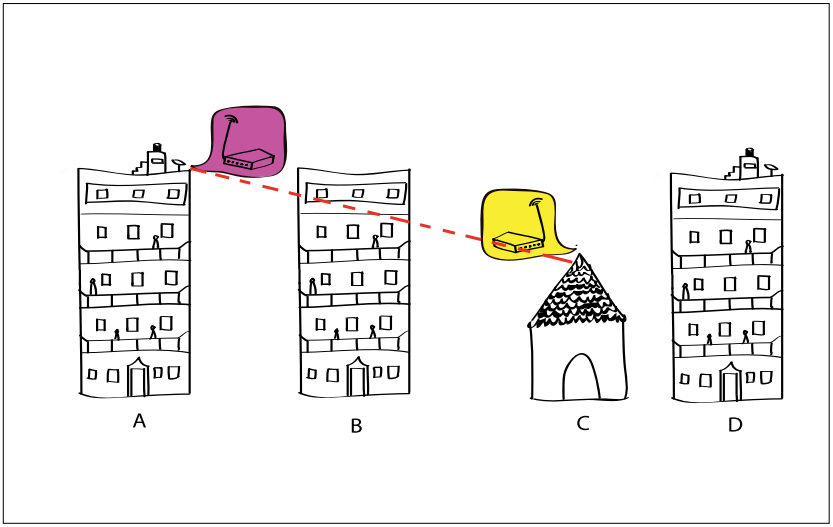
ASSESSMENT

Now that you have completed this unit, check your understanding of the concepts learned by responding to the following questions.

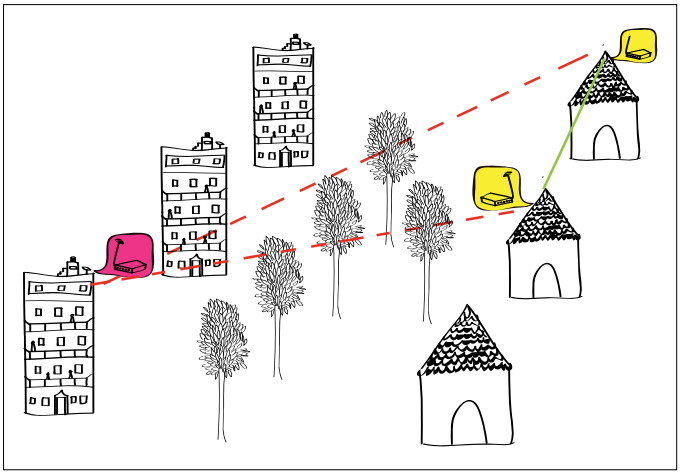
You can also take this assessment on the course website.

For each of the scenarios described below, draw the response in your notebook. Then, verify your response with the response displayed in the Ideal Responses section.

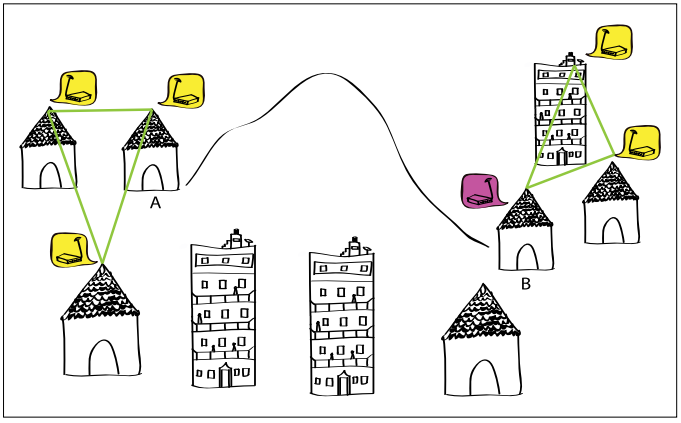
Scenario 1: In the image displayed below, you are required to create a network connection between A and C. However, building B is obstructing the line of sight. How will you establish the required connection?



Scenario 2: In the image displayed, some of the buildings do not receive a proper signal as it is blocked by trees. How will you ensure the signal is not blocked?

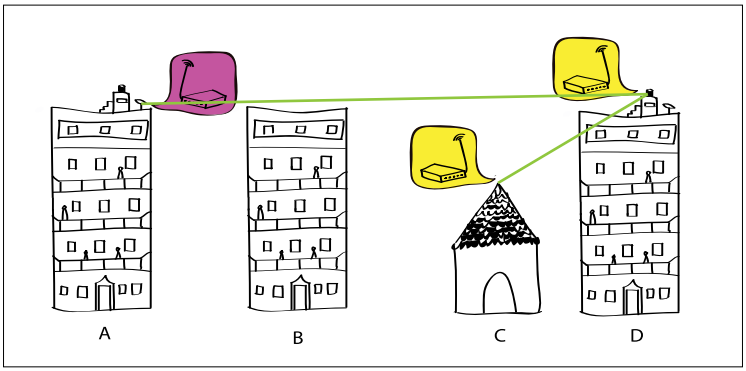


Scenario 3: In the image displayed below, buildings A and B need to be linked. However, a hill obstructs the line of sight. How will you ensure a line of sight is established?



IDEAL RESPONSES

Scenario 1: A relay router can be added to building D to act as a relay between A and C.



Scenario 2: The routers on the buildings can be raised using poles to increase their height above the treeline.

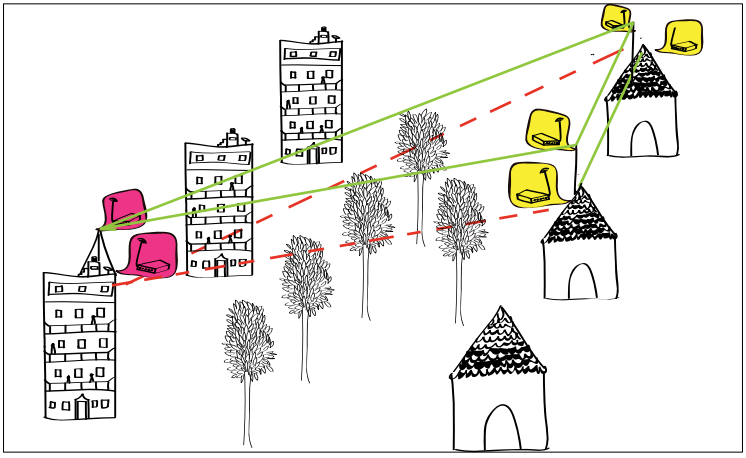
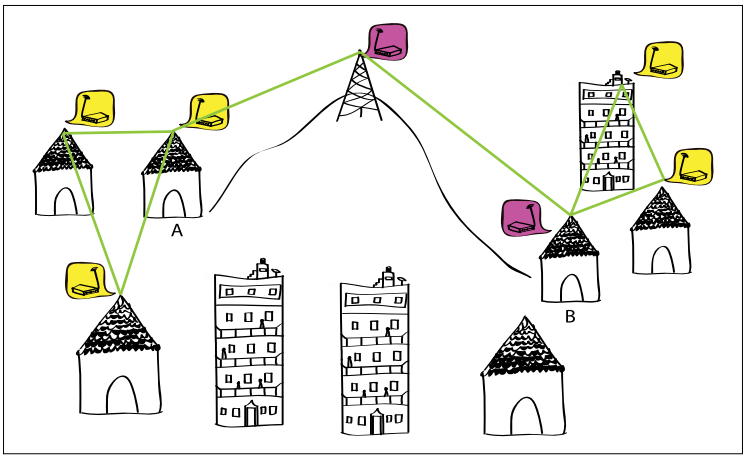
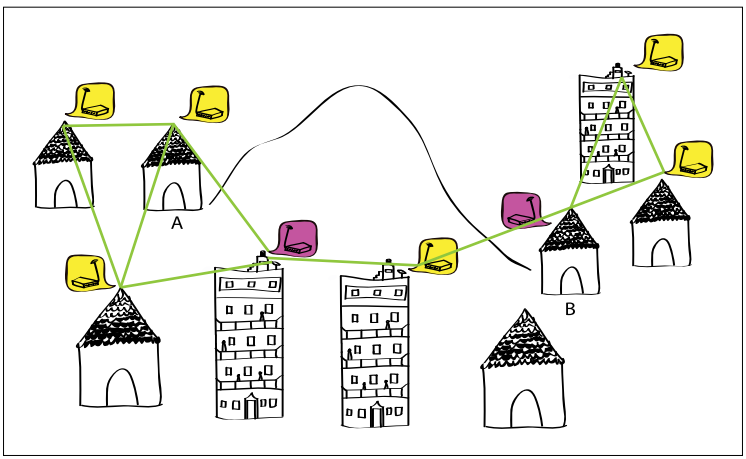


Figure 45

Scenario 3: If possible, a tower can be put on top of the hill.



Or, alternately relay routers can be set up on other buildings.



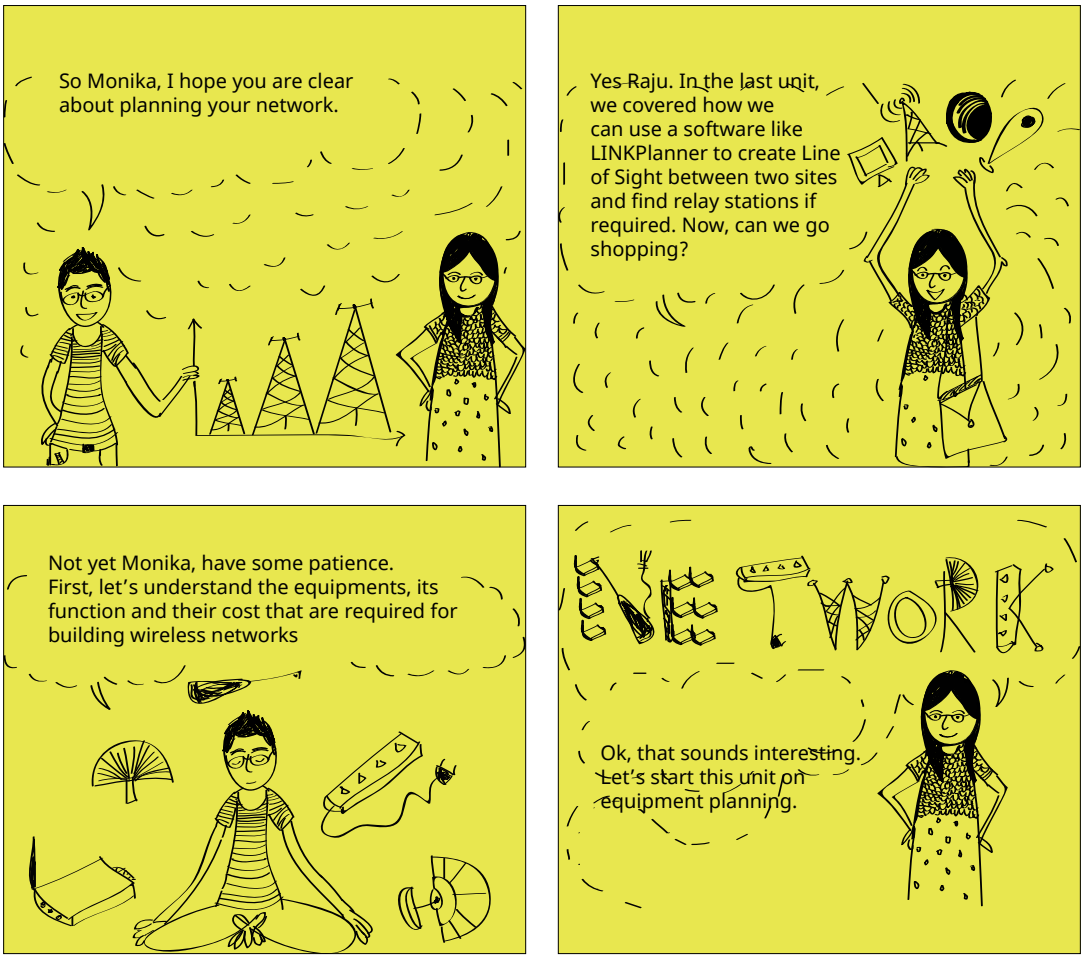
Unit

4

Equipment Planning

Introduction

This is the story of Monika learning about planning of equipments.



To view the corresponding video on the course website, you can scan the QR Code displayed here or directly log in to the course website http://lms.defindia.org

Video Duration: 0:41 Seconds

Outomes

Once the location survey and networking planning are complete, the next step is to plan for the required equipment. This unit will cover details of some common equipment used while providing the learner with guidance on situations in which they can be used.

Upon completion of this unit you will be able to:

- Explain why an inventory is required.
- Choose appropriate devices based on the setup.
- Select suitable tower infrastructure if required to establish a line of sight.

Terminology

Router	A device that analyses the content of data packets transmitted within a network or tow another network.
Access Point	A device that allows wireless devices to connect to a wired network using Wi-Fi or related standards
Client Premises Equipment (CPE)	A radio device that can be mounted on rooftop of a consumer's home/ shop in order to provide the Internet connectivity.
Antenna	Equipment that converts electrical signals to radio waves.
Radio device	In radio communications, a radio receiver, also known as a receiver, wireless or simply radio is an electronic device that receives radio waves and converts the information carried by them to a usable form.
Power-over-Ethernet (PoE)	Systems which pass electrical power along with data on Ethernet cabling.

In the previous units, you learned about some devices such as routers and antennas. Now, let us look at all types of equipment that are used in building wireless networks in general.

In this handbook, you will find a list of suggested tools and equipment for wireless installations. It includes many common hands- and power tools that you may already have or may be able to borrow. So, do not feel that you have to purchase these tools.

Some items are also listed as optional — these may make some installations easier but are not mandatory. There is also a list of some wireless routers and mounting kits, but you should pick one based on the specific installation you are performing.

When buying equipment for a wireless network, you should think about three basic criteria:

- What do you want to do?
- What is your budget?
- What equipment is available?

Once you have answered these questions, the next step is to select the required equipment from various products.

There are five criteria for selecting products –

- Robustness
- Price and availability
- Power consumption
- Environmental friendliness
- Support for your system

Definitions of Common Equipment

Let's go over descriptions of some common equipment and their functions briefly.

Router

Routers determine whether the source and destination are on the same network or whether data must be transferred from one network type to another. This requires encapsulating the data packet with routing protocol header information for the new network type.

Access Points

Most wireless networks are made using access points - devices that host and control the wireless connection for laptops, tablets, or smartphones. If you use Wi-Fi in your home or office, it is most likely through an access point. An access point is sometimes a stand-alone device that bridges between a wireless and wired (Ethernet) network or is part of a router. Access points can cover a range of areas with a wireless signal, depending on the power of the device and the type of antenna.

An access point is similar to a person on stage, addressing an audience or crowd - they are providing the information for everyone else. Those audience members can ask questions of the person on the stage, and receive a response.

Antenna

It converts electrical signals to radio waves. It is normally connected to a radio transmitter or radio receiver and is the interface between the electrical signals in the radio, and the movement of the signals through the air.

Types of Equipment

Now, let us look at all the types of equipment that are used in building wireless networks in general. The most common devices, equipment and tools that we frequently use in small and large wireless setups are listed below. This list will give you a brief idea about the functions of each device. If you would like to learn more, please use the Internet to look up the latest models of each of these devices and study their features.

Table 4: Wireless networking devices

Device	Model Name of device (if applicable)	Description
Advanced Router 	Mikrotik Routerboard RB 450G	5-port Gigabit Ethernet router with Winbox management utility. Used to configure IP addresses, DHCP, Hotspot (for user management), Firewall and more features of the network
Advanced Router 	Mikrotik Router CCR1036□12G□4S	Cloud Core Router has 4 SFP ports, 12 Gigabit Ethernet ports, serial console and a USB port. Used for Dynamic routing, hotspot, firewall, MPLS, VPN, advanced quality of service, load balancing and bonding, real-time configuration, monitoring and more
Wireless Router 	D-Link N150 Wireless Router	Wireless Router for home or small-sized networks with 1 WAN port, 4 LAN ports

Wireless Access Point 	TP-Link TL-WA7210N: 2.4GHz 150Mbps Outdoor WAP	Used in WISP CPE solutions and long distance wireless network solutions. Has up to 500 mW wireless transmission power and a built-in 12dBi dual-polarized antenna which provides an efficient way to pick up and maintains a stable signal for a wireless network connection ranging multiple kilometres.
Antenna/ Client Premises Equipment (CPE) 	AirGrid M5: 5GHz CPE Technology	23dBi Grid Antenna 5GHz CPE 24vdc POE 300mW, 150 Mbps throughput is a complete antenna and 802.11a/n radio system
Antenna 		27 dB Integrated P2P antenna
Sector Antenna 	Ubiquiti Airmax 2.4GHz 15dBi 120 degree Sector Antenna	Directional antenna with a sector-shaped radiation pattern. Three such antennae is used to broadcast the Internet at 360 degrees on a broadcasting tower.
Radio device 	5.8 GHz RB411R Radio	RouterOS Level-3 and 100mW 802.11b+g radio, used to transmit/receive 5.8 GHz signals across long distances.

Radio device 	2.4 GHz RB411AH Radio	RouterOS Level-4 license. Used to transmit/receive 2.4 GHz signals across long distances.
Radio device 	RB 433L	Used for an outdoor sector AP installation or local AP (Level4 license)
Layer-2 Ethernet Switch 	D-Link Switch 16-port	DGS-1016D 16-Port 10/100/1000 Switch
Wireless Access Point 	MikroTik BaseBox 2GHz MiMO 1000mW Access Point	MIMO-compatible outdoor Wireless device which is fitted with antenna typically for long distance wireless links (getting Internet from BTS)
Parabolic Dish Antenna 	Mikrotik mANT30 5GHz 30 dBi Dual Polarity Parabolic Dish antenna	Specially designed to use with BaseBox, but can be used with other pole-mounted wireless devices also.
Power-over-Ethernet (PoE) 	Power-over-Ethernet (PoE)	An adapter used to carry electricity along with data over an Ethernet cable up to wireless access points. It allows for long cable lengths.

	Mikrotik 18POW Low power 18V-1A Power Supply	Used as a Power supply for Mikrotik router devices
	CAT6 Cable (Drum) (1 drum = 300 m wire)	Category6 cable – high-performance UTP cable to transmit data up to 10/100/1000 Mbps over 100 m and 10 Gbps over shorter distances
	RJ-45 connectors	Used as a connector for Ethernet network cables.

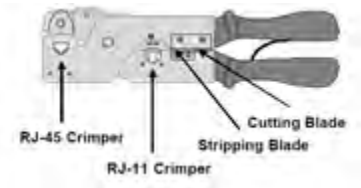
Table 5: Additiona devices/Ssoftware

Device/Tool	Model Name	Description
Routerboard management utility 	Winbox	Software to manage the Mikrotik Routerboard OS

Inverter 	Mikrotek, Luminous (Exide/ Amaron battery)	For Power backup; especially at the main centre where leased line Internet is incoming or for a broadcasting tower
UPS 	Mikrotek, Luminous (Exide/ Amaron battery)	For Power backup; especially at the main centre where leased line Internet is incoming or for the broadcasting tower
Solar Panel 	Mikrotek	Used as the main or alternative source of electricity in places with power problems
Server	Dell Server	Used for storing the data and managing the client
Server 	Windows 2008 Server	

Server Rack 	D-Link	For safe storage of servers, routers and other devices.
Bandwidth & User's Logs Management Server 	Smartcard	Used in large networks for traffic, network and user monitoring and bandwidth management and more services
Video conferencing Server 	Open Source BigBluebutton	Used for video conferencing and presentations in local area networks
IT Infrastructure Monitoring Server 	Open Source Nagios	Monitors all applications, services, operating systems, network protocols, systems metrics, and network infrastructure

Tools

Device/Tool	Description
	Screw Driver
	Wrench
	Pliers
	Crimping Tool

	Extension Cords
	Hammer
	LAN Wire
	Laptop

Equipment Calculations

In the previous units, you learned how to conduct a feasibility study and gather various requirements and data. Now, let's see how we can use that data to determine the equipment we will need to use.

Let us go through an example showing a network diagram. This will help us understand how to decide which device should be used at what locations and how many do we need.

The example below shows a network of 8 Community Information Resource Centres (CIRCs) of DEF.

Table 6: CIRC Centre names along with tower height

Centre Name	Tower Height
Pradan campus (Main centre)	32 m
Raipur	10 m
Kamthi	18 m
Koylari	21 m
Salimet	15 m
Kala Akhar	10 m
Doudi	32 m
Morpani	21 m

The 9th tower named BTS belongs to the local ISP from where we have got a leased line of 10 Mbps Internet. The 10th tower named Node1 is a relay station i.e. it's an extra tower we had to set up since Line of Sight was not available between BTS and Pradan Campus and the distance between them was too much.

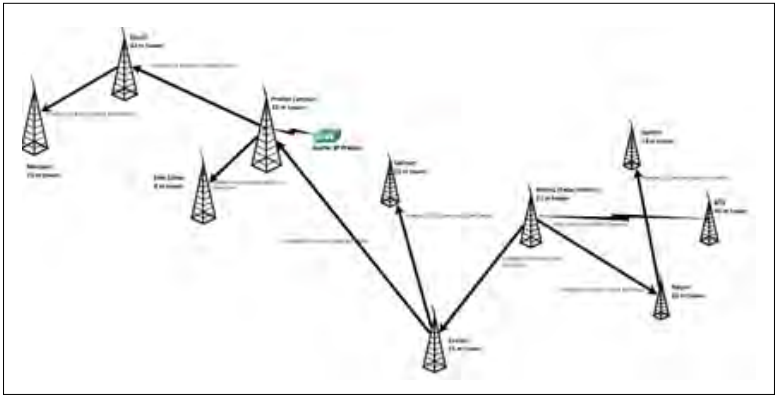


Figure 40: Network diagram of 8 CIRC s of DEF

Each centre is allotted a maximum bandwidth of 2 Mbps. This ensures that no user can get a speed of more than 2 Mbps at any point in time and thus number of users can be accommodated in the 10 Mbps bandwidth available.

Aerial Distance between two towers, locality, population density, whether the terrain is hilly, whether there is dense forest or trees between towers are some points that need to be considered to understand how equipment calculations were done. Note the following points:

Main Link @ Node1:

Distance between BTS and Node1 (Relay Station) is about 8-10 km with clear LOS. However, the terrain between these two towers is hilly with a forest in between. Since this is the most important link through which the Internet will be served to the whole network, this setup needs to be as robust as possible.

Hence, a 27 dB Integrated P2P antenna along with BaseBox was used here. Also, an Inverter UPS is a must since we do not want power cuts or voltage fluctuations to shut down the complete network or affect it adversely.

For **small links of around 2 km as well as long-distance links of 7-10 km** with very clear LOS, AirGrid M5 antenna was used if the signal could be maintained at no less than -70 dB or SNR could be 40 dB.

Koylari:

In this centre, the incoming Internet has to be distributed to more

than 1 centre. (1 incoming, 2 outgoing P2P links). Also, since the centre is also a CIRC centre, people will be using the Internet at the centre too.

To manage these tasks of distributing Internet at the location as well as carrying it forward, a Layer 2 Ethernet Switch would be needed. A D-Link Wireless router would be needed to distribute the Internet at the centre. The configuration will look as shown below:

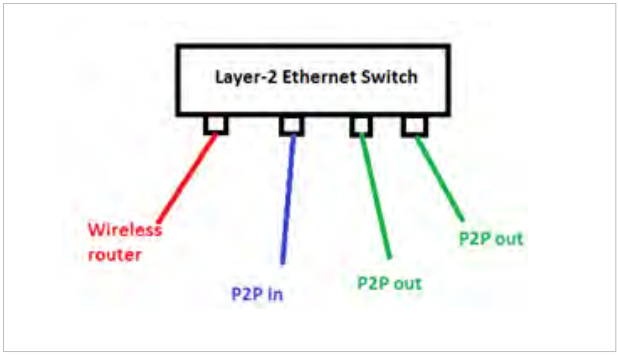


Figure 41: Example of ethernet switch

Pradan (Main Centre):

a. An Ethernet switch as described above is required here too since the centre has 3 PTP links as well as the management router.

b. Since Pradan campus is the main centre and the safest place, the management router Mikrotik RB 450G has been kept here. It should have been kept at the initiating centre connected to the BTS (Node1). However, due to electricity, safety and security issues, the main router was not kept there.

c. Also, the router is serving the local network (a network of the 8 CIRCs). Even if the Internet goes down from the BTS side, the local area network will keep running.

d. A server rack at this centre would be useful to store multiple devices safely.

How many Ethernet switches needed?

For all centres with more than 1 PTP link and a CIRC centre where Net is to be distributed, a switch will be needed. Apart from Node1, Koylari and Pradan, Raipur and Doudi are 2 such centres.

PoE/Adapters:

They are not very robust in nature. It is best to keep 2 per radio device. We do not want the network to go down because a small inexpensive device like adapter got damaged.

Wire length required?

A radio device is put at the topmost point on a tower to maintain the best Line of Sight possible. It will require 2 wires for the PoE. The length of both wires may not be same as tower height. As only one wire goes to the device and the other wire goes from POE LAN port to the switch. A few more metres should be added for the wires to reach the centre room where the router or CPE is kept.

1 drum of CAT6 cables typically contains 300 m wire. At least 2-3 drums would be required for a network of this size.

Power Calculations

It is common knowledge that the use of any electronic equipment requires electricity or power. Depending on the equipment used, we have to decide on aspects such as the:

- A power source (AC or DC etc.)
- Voltage (220/100 volts, 9/6 volts etc.)
- Amperes of current (50 amps, 75 amps etc.)

It is really important that the power supply matches the voltage of the device. Two types of power supply devices can be used to ensure continuous power supply to the network.

1. Inverter UPS

Any inverter UPS from a reputed company like Mikrotek or Luminous with 500 Watts power and Exide Battery of 100 AH can be used. An Inverter UPS is a must at the centre where a leased line is coming in. This will help you to measure the stage of charge of the battery.

A sealed lead-acid battery of 12V provides different voltages depending on its state of charge. When the battery is fully charged in an open circuit, the output voltage is about 12.8 V. The output voltage lowers quickly to 12.6 V when loads are attached. As the battery is providing constant current during operation, the battery

voltage reduces linearly from 12.6 to 11.6 V depending on the state of charge.

A sealed lead-acid battery provides 95% of its energy within this voltage range. If we make the broad assumption that a fully loaded battery has a voltage of 12.6 V when "full" and 11.6 V when "empty", we can estimate that a battery has discharged 70% when it reaches a voltage of 11.9 V.

These values are only a rough approximation since they depend on the life and quality of the battery, the temperature, etc.

Table 7: State of charge, voltage & volts per cell required

State of Charge	12V Battery Voltage	Volts per Cell
100%	12.7	2.12
90%	12.5	2.08
80%	12.42	2.07
70%	12.32	2.05
60%	12.2	2.03
50%	12.06	2.01
40%	11.9	1.98
30%	11.75	1.96
20%	11.58	1.93
10%	11.31	1.89

2. Solar Panels

Solar panels can be used in places where power cuts are a problem and sufficient solar energy is available for most of the time in the year. Power calculations shown below are rough.

Consider the Centre "Node1" which has 3 PTP links and 1 Ethernet switch. The radio devices of 24 V used in each PTP link consume about 2 Watts of power, whereas a switch consumes around 5 Watts. The total wattage of all devices comes to 11 Watts.

Any solar panel which supplies power of more than 11 Watts can be used. Typically, 50 Watts solar panels available in the market are affordable and useful.

Arrangements for Tower

In Unit 2, we had conducted the technical survey to identify whether a tower is needed or we need to establish the tower-alike infrastructure. A tower is the tallest structure that may exist at the location such as a water tank, a tall building or any other telecom/ internet service provider (ISP). You also need to familiarize yourself with the rooftop of the tallest building before you climb up to know what you are dealing with and be prepared. You can draw a layout plan or map to use as a reference.

Figure 42: Examples of towers

Your decision to establish a tower will depend on the following scenarios:

Scenario 1: You are setting up a wireless network for your own use

If you are bringing the internet for your purpose, then you don't need to establish the tower. You can also establish a pole of 5 feet on the roof-top of your house or build the small side brick infrastructure and establish the pole.

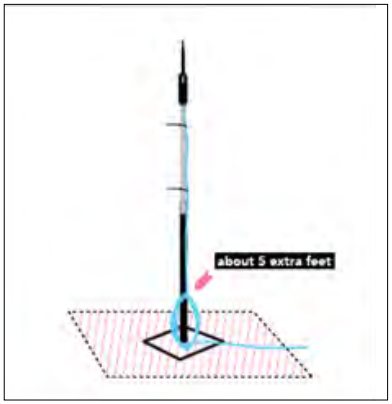


Figure 43: Example of a rooftop pole

Figure 44: Example of a pole with support instead of a tower

Make sure that you provide enough support to the pole as displayed in the image below.

When running cabling, be careful not to deform the cables with fasteners. For example, zip ties installed too tightly or incorrect staples can damage the cable. Be aware of the cable's bend radius - bending a cable too much can cause damage. If running a cable through a wall, use a grommet and reinforce the cable when running it over an edge. For example, you can reinforce it with multiple layers of electrical tape or something similar. If installing outdoors on high points like rooftops, the best practice is to use shielded cables and connectors, as well as a lightning arrestor.

Figure 45: Example of a Shielded Cable

Scenario 2: You are setting up a wireless network for your own use and for distributing internet further

If you are bringing the internet from the last point where the internet service provider has provided internet connectivity, then a tower-like infrastructure is recommended. For this, a tower comprising three pipes of 10 feet welded with criss-cross supports is recommended. The criss-cross supports make the tower self-sustainable and strong enough to bear the load of wind.

These tubular legs and bracings can be economical, especially when the stresses are low enough to allow relatively simple connections. Towers with tubular supports may be less than half the weight of angle towers because of the reduced wind load on circular sections.

Figure 46: Example of a tower made with pipes and welded supports

However, the extra cost of the tube and the more complicated connection details can exceed the saving of steel weight and foundations. This kind of tower also allows you to use multiple transmitters and receivers. You will learn the details in Unit 6.

Summary

UNIT SUMMARY

In this unit, you learned about commonly used equipment and tools for setting up and establishing a wireless network. You also learned how equipment can be selected based on various scenarios and requirements. Finally, you learned about selecting and establishing the required tower structure for your wireless network.

Assignment

ASSIGNMENT

Your Equipment Planning

Imagine you are setting up a wireless network at your home. Respond to the following questions and post your responses to the course website.

Part 1: Evaluate the mounting and power options in your house.

a. Does the building have power nearby? How can power be provided?
b. Are there places to safely mount the equipment?

c. What kind of roof does the building have? Is the roof safe to work on?
d. Are the windows tinted with glass that blocks wireless signals?

Part 2: Evaluate the Wireless Networking Potential in your house.

a. What are the tallest buildings in the area?
b. How many stories/floors does a building have?
c. What buildings have a good line of sight to other buildings?
d. Are there hillls, trees or inaccessible buildings that block line of sight?

After posting your responses read the responses by other learners and discuss your views using comments. Make sure that you offer constructive feedback and useful suggestions

Post Assignment Response
http://lms.defindia.org/mod/forum/view.php?id=64

Assessment

ASSESSMENT

Now that you have completed this unit, check your understanding of the concepts learned by responding to the following questions.

You can also take this assessment on the course website.

You can verify your response with the response displayed in the Ideal Responses section.

Question 1: Access points are:

a. Trees or tall structures that can be used to place routers, transmitters and receivers.
b. Devices that host and control the wireless connection.
c. Software that allows you to configure your devices.

Question 2: The equipment displayed in the Fig 46 is a:

a. Solar panel
b. Wireless access point
c. Parabolic dish antenna

Figure 46

Question 3: Identify the equipment mounted on the tower displayed in the Fig 47:

a. Three sector antennas and one parabolic dish antenna
b. Three Power-over-Ethernet (PoE) adapters and one router
c. Three Client Premises Equipment (CPE) and one sector antenna

Figure 47

IDEAL RESPONSES

Answer 1: b

Answer 2: c

Answer 3: a

Appendix

SAMPLE FORM: BASELINE SURVEY (W4C)

Guidelines for Survey Interview:

1. Please note that the questionnaire below is addressed to an individual respondent only.
2. Make sure that all answers are given by the respondent and nobody else on his/her behalf.
3. Note that interviews should not be conducted in groups.
4. Before starting the interview, introduce yourself and ask if the respondent is willing to spare half an hour for the survey. If not, request for another appointment at a suitable time.
5. All the * marked questions are compulsory. They HAVE to be answered.
6. Try to get clear responses. Avoid writing 'NA' for relevant questions. Find alternative ways to get the answer.
7. Make sure you are familiar with all questions in the survey before you conduct the survey

Section A - Interview Information

Date *	automatic
Interviewer Name? *	

Section B - Respondent Information

Name *						
Category *	Student	Working	Unemployed	Housewife	Other (Please specify)	
Occupation * (if employed)		Labourer	Shopkeeper	Business	Teacher	Other
Mobile/Phone Number						
Email Address	Below 15	16 - 30	31-50	Above 50		
Gender *	Male	Female				
Age group*	Below 15	16 - 30	31-50	Above 50		
Ethnicity						
Financial Background of Family	Lower class	Middle Class	Upper Middle Class	Higher Class		

Section C: Respondent: Technology-related Information

Digital Devices at home/office	Laptop/ Desktop	Smartphone	None	Other (Please specify)
Have you taken any Computer training before?			Yes	No
What content are you interested in?	Agriculture	Livelihood	Employment	Education
	Banking	Business	News	Health
	Entertainment	Govt. schemes	Online banking	Filling forms
	Booking tickets	Email/ Facebook	Work-related	Other
What services are you interested in?	Information Services (Govt. Schemes, Banking, Employment etc.)	Basic Digital Services (Scanning, Printing, Photocopying)	Advanced Digital Services (Ticket booking, Online applications)	Computer Training
	Internet Café	Vocational Training	Other (Please specify)	

Section D: Internet Usage Information

Are you aware of the Internet?	Yes	No
If yes, then ask the following questions		
If no, then exit the form		
Do you use an Internet connection from any ISP at home/office?	Yes	No

If yes, then ask the following questions								
1a	Mode of use*	Broadband on Computer			Mobile Internet		Dongle	
1b	Which ISP? *	BSNL	Airtel	Vodafone	Reliance	Tata Indicom	Other (Please specify)	
1c	Average Internet speed in your Service plan? *	256 Kbps	512 Kbps	1 Mbps	2 Mbps	4 Mbps	10 Mbps	Other (Please specify)
1d	Monthly cost? *	< 500 per month	Between 500 and 1000 per month		Between 1000 to 1500 per month		> 1500 per month	
1e	Problems faced during Internet use?*	Slow connection	Connection lost many times		No problem			
1f	How much downtime do you suffer for Internet use during a day? (hrs.) *		No downtime	1-2 hrs	2-5 hrs		>5 hrs	
1g	Are you satisfied by the technical support provided by ISP? *				Yes		No	
1g.1	If no, then why not?*				Service is slow		Problem is not solved properly	

If no, then ask the following questions					
1a	Do you visit the Internet Cafe? *	Yes		No	
1b	Are you interested in getting our Internet connection at home/ office/business? *	Yes		No	
1b.1	How much are you willing to pay for high-quality Internet service? (Rs.) *	< 500 per month	Between 500 and 1000 per month	Between 1000 to 1500 per month	> 1500 per month

SAMPLE FORM: TECHNICAL SURVEY

Section A - Geographic Location

State Name *	Assam						
District Name *	Nalbari						
Block Name *	Barbhag	Barkhetri	Borigog Banbhag	Madhupur	Tihu	Paschim Nalbari	Pub Nalbari
Village Name *							
Pincode *							
Take a picture of the house *							
Collect the GPS coordinates of the household*	Latitude (x.y°)	Longitude (x.y°)		Altitude (m)		Accuracy (m)	
Describe the region as:	Flat	Hilly		Mountainous			
Height of trees nearby	< 5 m	11		to 10 m	11- 20 m	>20 m	
How densely are trees located?	Lightly dense	Moderately dense		Highly dense			
Height of buildings nearby	< 5 m	11		to 10 m	11- 20 m	>20 m	

Section B: Power Related Information

1	What is the daily duration (in hrs.) of electricity supply in your home/office where you want Internet?		
2	Are there long power cuts during school hours?	Yes	No
3	Is the voltage supply for electricity consistent or fluctuating?	Consistent	Fluctuating
4	Is any power back up available during power outages/failures?	Yes	No
4.1	If yes, then for how many hours does it last?		
5	Has earthing been done for the home/office building?	Yes	No

Section C: ISP Details for Leased Line Connectivity

Name of ISP*				
Class of ISP	A	B	C	
Full Address of ISP office*				
Contact Details of ISP office				
Collect the GPS coordinates of the ISP office*	Latitude (x.y°)	Longitude (x.y°)	Altitude (m)	Accuracy (m)
Height of the Tower (m)*				

Setting up Wireless Networks – A Course for Barefoot Wireless Engineers has been produced by the Digital Empowerment Foundation. This course is divided into two parts. The first part covers some basic concepts related to planning the setup of wireless networks such as conducting a location survey and selecting the required hardware. The second part of the handbook covers details of actual installation and maintenance of wireless networks.

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