Grayhill INC.
An ISO-9001 Company

EZCom IP Users Manual

Revision A6

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Section 1. Getting Started

Initialization

When you first remove an EZCom IP radio from it's carton and apply power to it, the radio will boot-up and go through a series of self-tests. After completing the boot process the radio will be ready to receive configuration information. Before the radio can be used to transmit or receive application specific information (network traffic) it must first be configured for the network that it will be used on. All necessary configurations can be done using the Grayhill EZCom-IP Explorer program.

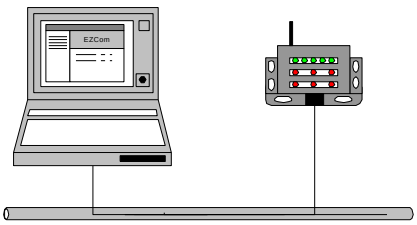
A listing of all the EZCom-IP parameters along with the factory default settings for each parameter is given in Table 1, below. In this first section "*Getting Started*" we will practice configuring some EZCom-IP radios for specific examples. First we will setup a point-to-point link typical of what you may want to institute for a bench test and then we will move on to a more involved example that will demonstrate some of the more advanced features of you EZCom-IP radio. For readers that are looking for a more detailed explanation of specific settings please refer to the Technical Reference section of this manual.

Table 1, Factory Default Settings

Parameter	*Factory Default*	*Comments*
Radio IP Address	192.168.1.1	
Network Subnet mask	255.255.255.0	
Radio Mac Address	******-******	Factory set unique value
Routing Table	None	
Center Frequency	2.442 GHz	Approximately Center of Band

Configuration can be accomplished through a local connection or remotely over the air. A local or direct connection is when an EZCom-IP radio is connected to the local area network where you have the Grayhill EZCom-IP Explorer program running as illustrated in Figure 1. Remote configuration can be accomplished over the air provided that the remote EZCom-IP radio is already set to operate at the same center frequency as the local radio. Remote configuration is discussed in detail in the Technical Reference section of this manual.

Figure 1, Local Connection



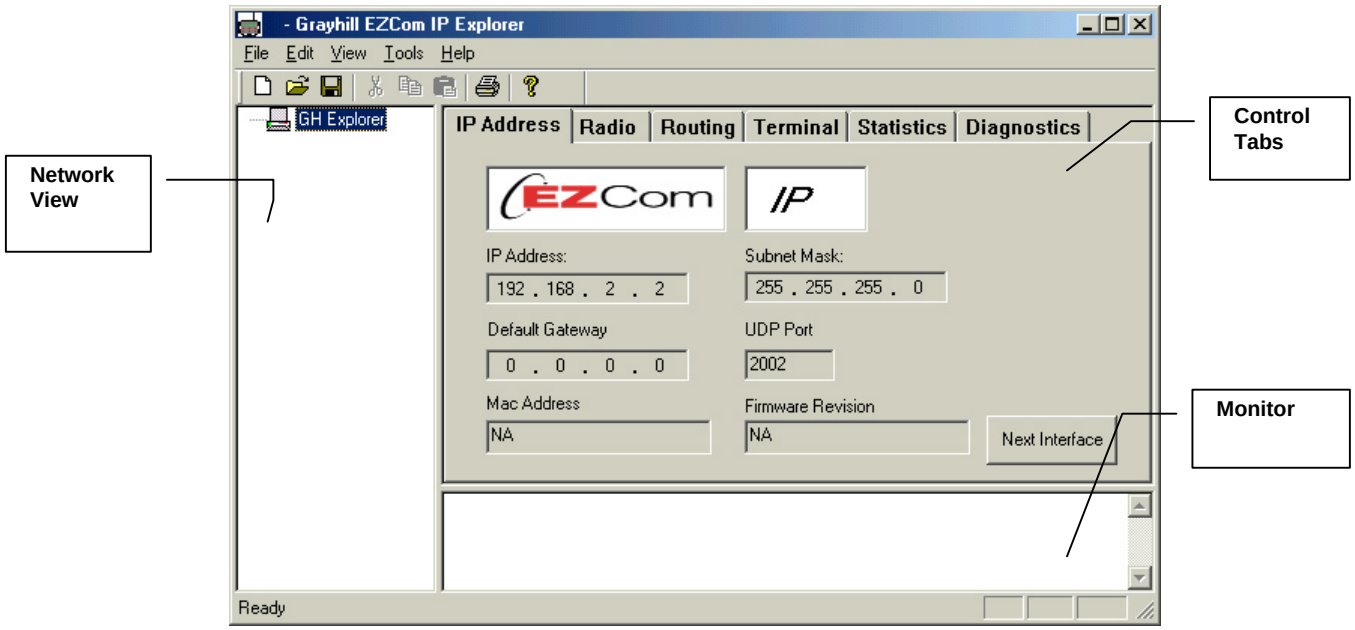
EZCom-IP Explorer Introduction

Before we start on the examples in this section let's take a few minutes to familiarize ourselves with the EZCom-IP Explorer program. If you have not loaded the GH EZCom-IP Explorer program please do so now. The Explorer is a client side program that can be run on any 32 bit Windows based PC. It is designed to communicate configuration and diagnostic information with the EZCom-IP radios either directly attached or via the local area network. The program offers the user a verity of configuration and diagnostic tools. Figure 2, below illustrates the initial screen of the Explorer program. The screen is divided into three main parts;

1. The ***Network View***, which graphically displays the EZCom-IP, radios in the network.
2. The ***Control Tabs*** that can be used to change configuration settings and initiate diagnostic functions.
3. The ***Monitor***, which can be used to observe specific communication events.

When you first start the Grayhill EZCom-IP Explorer your will see a single icon in the *Network View.* This icon represents the computer that is running the GH Explorer program. No other icons appear at this time because the Explorer program must be prompted to go out and find any radios in the network first. If you click on the *Tools* menu and then pick *Find Links* the Explorer will go out and find any EZCom-IP radios on the local network.

Figure 2, EZCom Explorer Window



GH Explorer will then add a radio icon to the *Network View* for each radio it finds on the local network (see Figure 4).

The information in the *Control Tab* window is associated with the icon selected in the *Network View*. As you click on different icons in the *Network View* the information in the *Control Tab View* is updated with the setup values from the object represented by the icon selected. If you select the GH Explorer icon at the top of the window (which is selected by default when you start the program) only the IP address tab is accessible. This is because the GH Explorer icon points to the PC that the program is running on and not to a radio. When you select a radio icon in the *Network View* the information in the *Control Tab* will be downloaded from the radio and displayed in the appropriate tab. If you changing any of the information in the *Control Tab* and click the update button the setup information in the radio pointed to by the icon in the *Network View* will be changed accordingly.

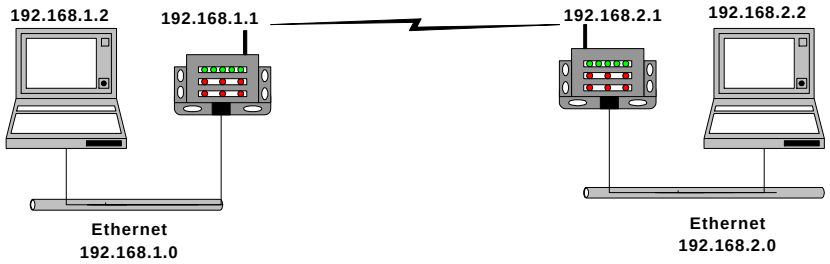
As you can see changing the setup information in a radio is as simple as selecting which radio you want to modify from the *Network View* and then entering the appropriate information in the *Control Tab view.*

Point-to-Point Link Example

In this first example we will set up a point-to-point link between two Ethernet networks. For simplicity we have represented both networks as consisting of one PC and one EZCom-IP radio (router). In reality a point-to-point configuration could be used to connect anything from a single PC and router to a fully developed enterprise network. After we have set up the example we will uses some of the built-in EZCom diagnostic tools to test our setup. After we complete our testing we will try a few simple client server applications that are part of the windows operating system to demonstrate the functionality of the network.

You will need 2 PCs and 2 EZCom-IP radios to fully implement this first example. You may also need to have your operating system CD handy in the event that Windows wants to copy additional files. If you don't have 2 PCs you can still set up the example with only one PC but you will only be able to run the built in diagnostic functions of the EZCom-IP radio you will not be able to run the applications.

Figure 3, Point-to-Point Link



There are 3 basic steps involved in setting up this example: setting the IP addresses on the two PCs, configuring the radios, and setting file share permissions on one of the PCs to allow file access across the network. Table 2 shows each step along with the parameters that need to be setup and the appropriate values.

Table 2, Point-To-Point Setup Parameters

Step	Parameter	Value For PC (A) & Radio (A)	Value For PC (B) & Radio (B)
1. Set PC IP Addresses	IP Address	192.168.1.2	192.168.2.2
	Subnet Mask	255.255.255.0	255.255.255.0
	Default Gateway	192.168.1.1	192.168.2.1
2. Set Radio Parameters	IP Address	192.168.1.1	192.168.2.1
	Subnet Mask	255.255.255.0	255.255.255.0
	Default Gateway	192.168.2.1	192.168.1.1
	Routing Table	Default	Default
3. Set File Share Permissions			File and Print sharing for Microsoft Networks installed

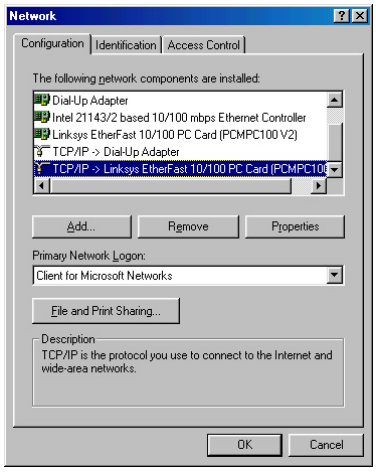
Both PCs must have an Ethernet network interface card or equivalent PCMCIA card installed and both PCs must also have the TCP/IP protocol installed. For information on installing your network interface card see the card manufactures installation instructions. For help installing the TCP/IP protocol, please see the sidebar Windows TCP/IP Set Up on page 13 of this manual.

To get started with this example take a RJ45 Category 5 patch cable and connect one end of it to the Ethernet port on your EZCom-IP radio and connect the other end to an open port on your network hub. If you do not have an existing network you can connect directly to the PC's NIC card or PCMCIA card. Now apply power to the EZCom-IP radio

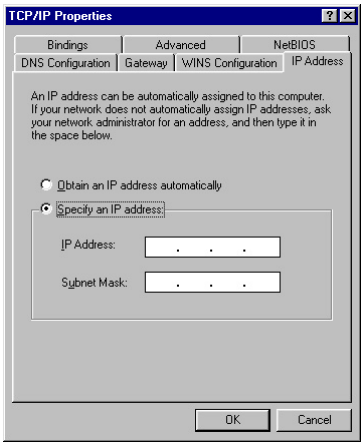
and the PC. After the PC and radio have gone through their normal boot process you should see a green link indicator (see Figure 20, on page 43). If you do not see the green link indicator please follow the steps in the troubleshooting guide for “No Ethernet Link”.

Now that we have a physical connection between the client PC that will be running the EZCom-IP Explorer and an EZCom-IP radio we can begin to setup our first example.

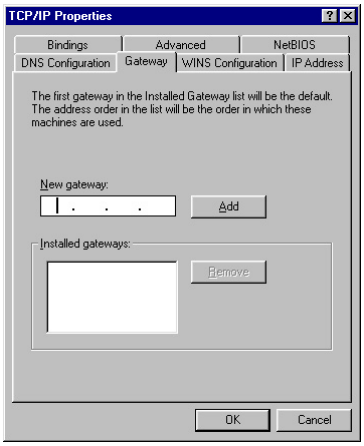
Setting-up The PC’s IP Address



1. Click the **Start** button. Choose **Settings**, Then **Control Panel**.
2. Double-click the **Network** icon. Your Network window should pop up as shown on the right.
3. Select the **Configuration** tab.
4. Highlight TCP/IP (for your network adaptor) under the list of components installed.
5. Click the **Properties** Button. You should now see the TCP/IP properties window below.
6. Select the **IP Address** tab.
7. Make sure the **Specify IP Address** option is selected.
8. Enter the appropriate **IP Address** and **Subnet Mask** (from the setup table on page 6) in the spaces provided.



9. Now select the **Gateway** tab
10. Enter the Default Gateway (again from the setup table) and make sure you click the **ADD** button.
11. Click the **OK** button on the TCP/IP Properties Window.
12. Click the **OK** button on the Network Window.



After clicking the OK button on the TCP/IP properties tab you will be prompted to reboot your computer before theses changes will take effect. Click OK.

The IP Address, Subnet Mask and Default Gateway are now set up on your PC. Repeat these steps using the appropriate setup values for the second PC in the network. You may wish to reopen either one of the properties windows to verify the values match those listed in the example’s setup table.

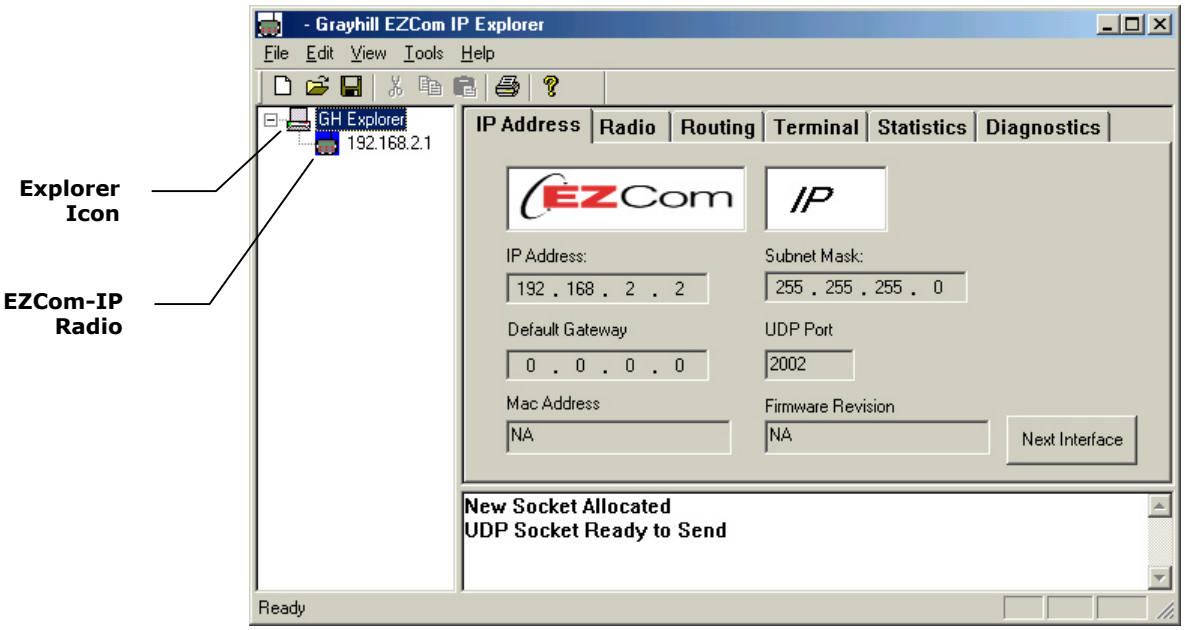
In the next step we will setup the radio parameters for the EZCom-IP radios that will be used in this example.

Setting-up The Radio Parameters

Start the Grayhill EZCom-IP Explorer by selecting “EZCom-IP Explorer” from your PC’s Start/Programs menu. After the program loads select *Find Links* from the *Tools* menu at the top of the explorer main screen. The Searching for Radios dialog box will appear.

Once the searching process is complete press OK to return to the EZCom-IP Explorer main window.

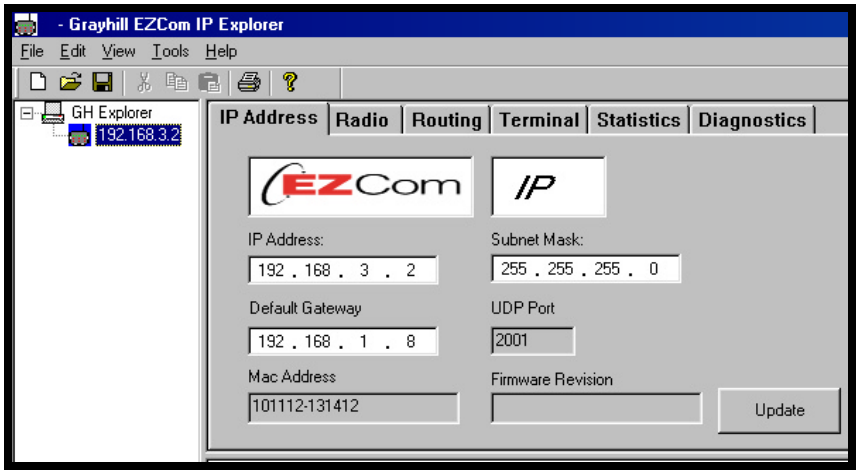
Figure 4, EZCom-IP Explorer After Finding a Radio



The Explorer should now look like the one shown in Figure 4, above. Don't worry if the IP addresses and other data on your screen are not exactly as shown. What is important is that there is an EZCom-IP radio icon below the GH Explorer icon in the *Network View*. Click on the radio icon. The data in the Control Tab window will update to reflect the current settings for the radio you just selected. If the radio you are using is new the settings should look like those listed in Table 1, Factory Default Settings on page 4.

The first *Control Tab* is the *IP Address Tab,* which is shown in Figure 5. On this tab we will set the radio's IP Address, Subnet Mask and Default Gateway. In each of the respective text boxes please enter the appropriate setting from Table 2, Point-To-Point Setup Parameters on page 6. When you are done your IP Address tab should look like the one shown in Figure 5 below.

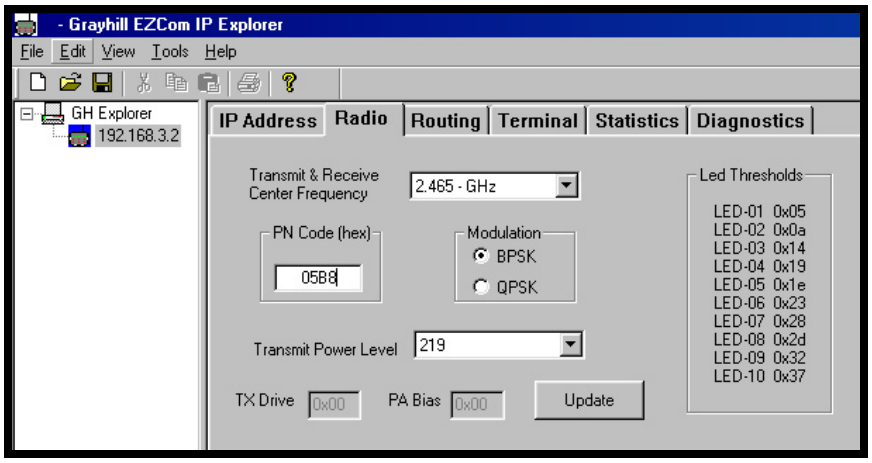
Figure 5, IP Address Tab



Don't worry if you do not fully understand each of the settings that you are about to enter, we will cover each of the settings in more detail in the technical reference section latter in this manual.

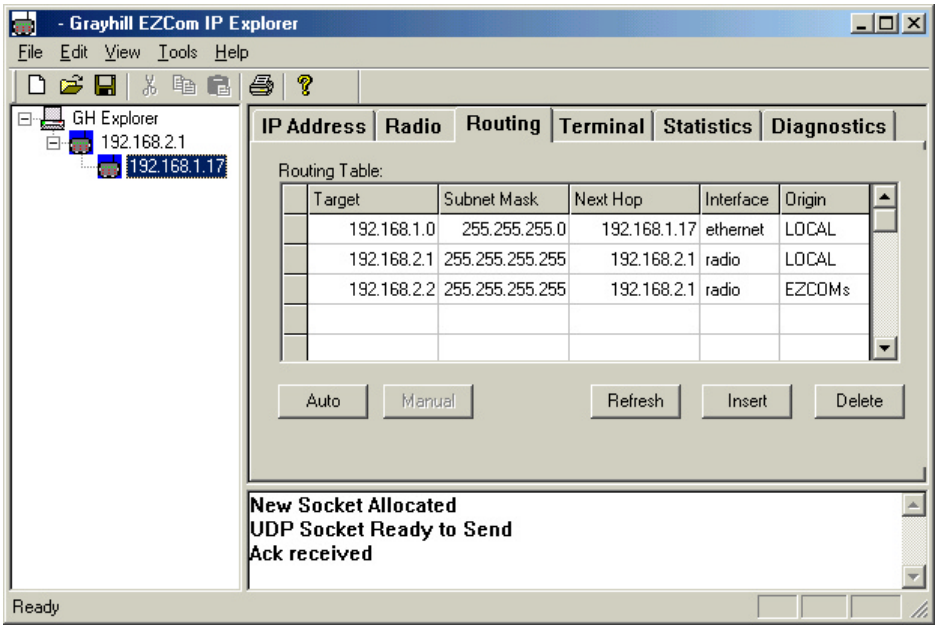
Now click the ***Radio Tab.*** You should not have to change any settings on this tab. All of the factory defaults settings should be fine. You may just want to look over the values and verify that they match those shown if Figure 6. If any of your values are different please change them to match.

Figure 6, Radio Settings Tab



Now click the ***Routing*** Tab. The routing table should contain two entries, which were created automatically by the Explorer program. For our example all routing is actually handled by the Default Gateway setting that we established on the *IP Address Tab*. If there is any other entries in your routing table select them by clicking any where on the row and then click the *Delete* button. Repeat this step for all extra entries. Your routing table should look like the one shown in Figure 7 below.

Figure 7, EZCom-IP Routing Table



Setting Up The Second PC & Radio

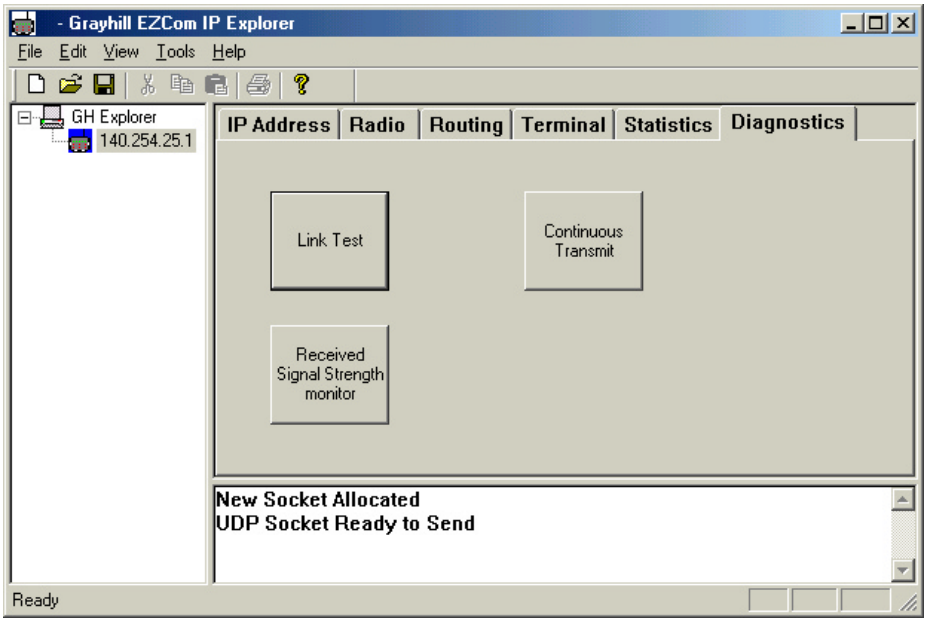
Now that we have completed setting up our first PC and an EZCom-IP radio we will need to repeat the steps we followed with the second PC and radio. For the second PC and radio use the setup information listed in the last column of Table 2 on page 6.

Testing The Radio Link

With both PCs and both radios setup we can now run a few diagnostic test to verify that we first have a link between the radios and then a network connection from one PC to the other. First connect the radios and PCs as shown in Figure 3. Make sure that you connect the radios to the PC with the same subnet ID.

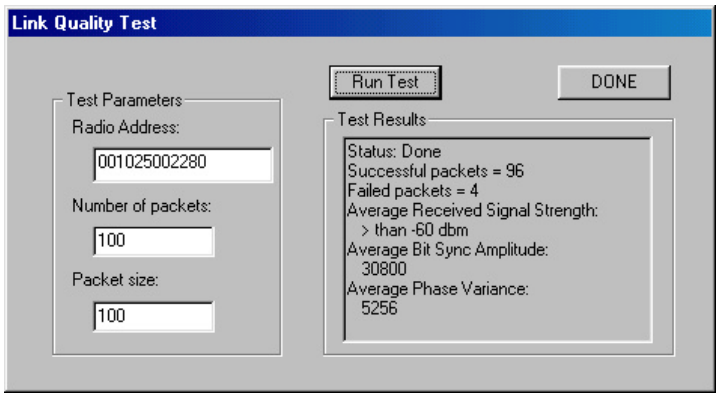
The first test that we will conduct will be a link test. This is to verify that the radios can communicate. This is strictly a radio communications test and none of the network settings are used. Select the *Diagnostics Tab* then click on the Link Test button. The link test dialog box will appear. Enter the Mac Address of the radio you want to link to and click on the *Run Test* button.

Figure 8, Diagnostics Tab



In the Test Results window you will see an announcement that the test is in progress. During a link test packets are transmitted every 50 milliseconds. If you multiply the Number of packets by this interval you can get an idea of how long the test will take. Using the default number of packets the test should take 100*0.05 or just over a half second.

Figure 9, Link Test Dialog



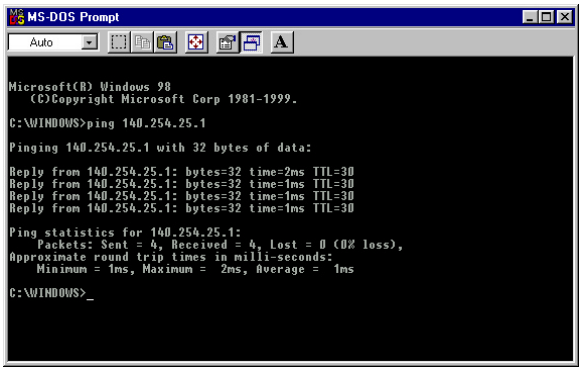
When the Link test is complete you should see the test results in the Link Test dialog similar to the results shown in Figure 9. If your Link Test fails, that is you don't get a large number of Successful packets (typically 90% to 100%), please follow the steps listed in the Troubleshooting guide on page 50.

After successfully running a link test we will now verify that we have a logical network connection from one PC to the other. To accomplish this we will use one of the Windows built in network utilities known as "*Ping*". Actually ping is a member of the TCP/IP protocol suite.

Ping is a simple but very useful utility program, ping sends a special (ICMP) test packet to a designated IP address and then listens for the packet to be echoed back.

Figure 10 shows the output of a ping request. To run the Ping utility program click *Start* then select Programs and click on the MS-DOS Prompt. When the DOS Window opens type the word *ping* along with the IP address of the host that you want to ping and press enter. Ping will then transmit 4 test packets and output the round trip time it takes for each packet to traverse the network. If you are unable to successfully ping the remote PC in this example please follow the trouble shooting procedures on page 51 for "Ping Failed to Respond".

Figure 10, Ping Utility Program



If you have successfully run the link test and ping test you are ready to setup your application to run across the wireless network.

Running our example application

Before we can run an application across the wireless link we must first install the File and Pint sharing for Microsoft Networks service. This service is built in to the Microsoft

Windows operating system and in essence enables the PC it's running on to act as a file and/or print server.

To enable file and printer sharing on your computer

1. Click on the *Start Button* and select *Settings* and *Control Panel.*
2. After the Control Panel dialog box opens double-click the ***Network*** icon.
3. Click **File and Print Sharing**.
4. Select the check box for the "I want to give others access to my files", sharing option. A check mark indicates the feature is activated.
5. Click **OK**.
6. Windows will now install the File & Print Sharing service on your PC. You will be prompted that you must restart your computer before these changes will take effect. Click OK,

After your computer reboots you will need to tell windows which files or folders you want to share on the network. For this example we are going to simply share the entire C drive.

To share The C Drive

1. In **Windows Explorer** or **My Computer**, click the C drive root folder.
2. On the **File** menu, click **Properties**.
3. Click the **Sharing** tab, and then click **Shared As**. Enter the share name "Server Drive". Note: The **Sharing** tab is not visible if you don't have *file and print sharing services* enabled.
4. Click the **Access Type** you want, and, if necessary, enter a password.

Running Our Example Application

Now that we have File and Print sharing setup on our 192.168.2.2 PC we will access the files on this machine from our 192.168.1.2 PC, which is at the other end of our wireless link. The first thing we need to do is to make the Windows operating system on 192.168.1.2 aware of the network connection to 192.168.2.2. Start by:

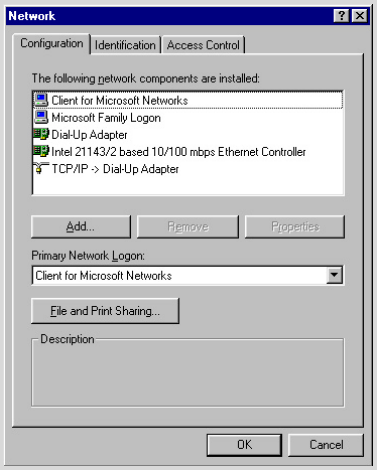
1. Double clicking the **My Computer** icon on your windows desktop.
2. After the My Computer dialog opens, in the **Address Bar** type \\192.168.2.2\.
3. Just below the address bar you will see a dropdown list with the share name "Server Drive". This is the share name we gave to the c drive on 192.168.1.2. Select the **Server Drive** share name by clicking on it.
4. The My Computer window should now be a listing of the files and folders on the 192.168.2.2 c drive. Now click on the Favorites menu and select Add to Favorites.

You can now use the Server Drive just as though it was a hard drive in your 192.168.1.2 PC. Try by copying or accessing any of your data files just as you would if there were on you c drive.

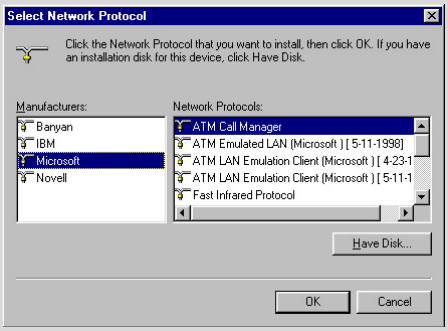
Windows TCP/IP Set Up

Follow these instructions to install the TCP/IP protocol on your PC *only* after a network card has been successfully installed. These instructions are for Windows 95 and Windows 98. For TCP/IP setup under Windows NT or Windows 2000, please refer to your operating system manual.

1. Click the **Start** button. Choose **Settings**, then **Control Panel**.
2. Double-click the **Network** icon. Your Network window should pop up. Select the **Configuration** tab.



3. Click the **Add** button.
4. Double-click **Protocol**.
5. Highlight **Microsoft** under the list of manufactures.



6. Find and double-click **TCP/IP** in the list to the right.
7. After a few seconds you should be brought back to the main Network window. The TCP/IP Protocol should now be listed.
8. Click **OK**. Windows may ask for the original Windows installation files. Supply them as needed (i.e.: D:\win98, D:\win95, C:\windows\options\abs.)
9. Windows will ask you to restart the PC. Click **Yes**.

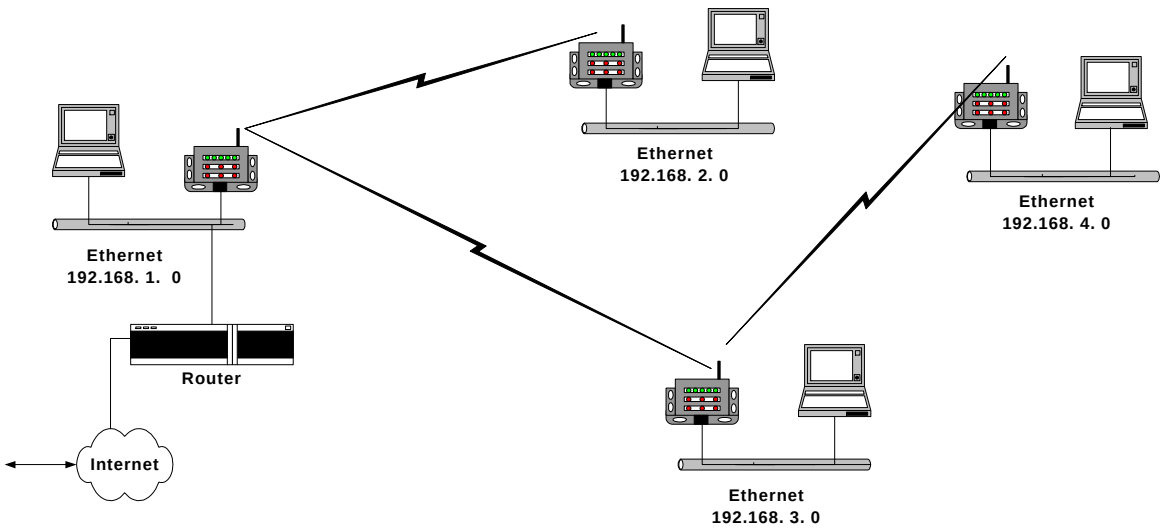
The TCP/IP Installation is complete.

Multipoint Store-&-Forward Example

This second example is designed to demonstrate in detail how to setup and utilize the routing functions available within a TCP/IP network using the EZCom-IP radio. It may not be practical to setup this example because it requires at least 4 EZCom-IP radios, 4 PCs, and a WAND router. Even if you do not setup the example it is beneficial to follow along to develop an understanding of how to setup the different routing aspects of the network.

In our first example we relied on the default Gateway settings for both the PCs and the EZCom-IP radio to handle all of the routing decisions. No routing table entries were made. In this example we will endeavor to more fully illustrate the routing capabilities of the EZCom-IP radio.

Figure 11, Example II Network layout



The first step in setting up this example is to program the IP address and other settings in the EZCom-IP radios. Probably the easiest way to handle this task is to take one PC, which has the EZCom-IP Explorer program installed on it and directly connecting it to each of the radios one after the other. For information and instructions on how to perform the setup tasks from a single point in the network please refer to EZCom-IP Explore documentation on page 44. Table 3, below is a listing of all the settings for both the IP Address Tab and the Radio Tab that need to be set up. Most of these settings are the factory default settings and should already be set.

Table 3, Example II, EZCom-IP Radio Settings

Tab	*Setting*	*Radio A*	*Radio B*	*Radio C*	*Radio D*
IP Address	IP Address	192.168.1.2	192.168.2.2	192.168.3.2	192.168.4.2
	Default Gateway	192.168.1.3	192.168.1.2	192.168.1.2	192.168.3.2
	Subnet Mask	255.255.255.0	25.255.255.0	255.255.255.0	255.255.255.0
Radio	* TX & RX Center Frequency	2.441-GHz	2.441-GHz	2.441-GHz	2.441-GHz
	* PN Code (Hex)	05B8	05B8	05B8	05B8
	* Modulation	BPSK	BPSK	BPSK	BPSK
	* Transmit Att. level	0 dB	0 dB	0 dB	0 dB

* Indicates Factory Default Settings

Once we have the radio settings complete we will need to setup the TCP/IP proprieties for the remaining devices on the four separate subnets. For this example all four subnets

are part of the same network. The IP style network ID is 192.168.0.0 with a subnet mask of 255.255.255.0. Therefore the third byte of the IP address is the subnet ID. The individual subnets are simply identified as (.1), (.2), (.3) & (.4). All of the devices on all four subnets have the same subnet mask 255.255.255.0.

The IP addresses for each of the devices in the network are listed in Table 4 below. If you need help setting the IP addresses on the PCs please refer to Setting-up The PC's IP Address in the first example on page 4. If you need help setting up the IP address of your router please refer to the manufactures instructions.

Table 4, Example II Device IP Addresses

Subnet	*PC*	*EZCom-IP Radio*	*Router*
(.1)	192.168.1.1	192.168.1.2	192.168.1.3
(.2)	192.168.2.1	192.168.2.2	NA
(.3)	192.168.3.1	192.168.3.2	NA
(.4)	192.168.4.1	192.168.4.2	NA

Next we need to establish the routing tables for each of the devices in the network. Before we jump into entering routing table information lets take a moment or two and discuss the routing requirements. If you are uncertain as to what we mean when we are talking about routing tables and default gateways you can refer to EZCom IP Routing on page 40 of this manual.

Subnet (.1) consists of three devices: a PC, a router and an EZCom-IP radio. One port on the router is connected to our subnet and another is connected to the Internet. The primary purpose of the router is to allow Internet access to all of the PCs in our network. Therefore all of the other subnets need to be able to communicate with subnet (.1).

Subnet (.4) as shown in Figure 11, is only able to communicate with subnet (.3) therefore we will need to route subnet (.4) traffic through subnet (.3).

Subnet (.2) can only communicate with subnet (.1) therefore we will have to route any traffic from subnet (.2) to either subnet (.3) or subnet (.4) through subnet (.1).

Since subnet (.2) can only communicate with subnet (.1) we can set the default gateway on subnet (.2)'s EZCom-IP radio to 192.168.1.2. This will cause the radio to forward all packets that are not specifically targeted for devices on subnet (.2) to subnet (.1). In addition to setting the radio's default gateway we also need to set subnet (2)'s PC default gateway to 192.168.2.2. This will direct all datagrams that are not destine for a subnet (.2) device to the radio.

The setup for devices on subnet (.4) are similar to what we just described for subnet (.2). First we need to set the default gateway on the PC to 192.168.4.2 this will direct all data traffic not intended for a device on subnet (.4) to the radio for transmission. Next we need to set the default gateway of the radio to 192.168.3.2. This indicates to the radio that all datagrams arriving from the network should be transmitted to the radio on subnet (.3).

The settings for subnet (.3) are slightly different than subnets (.2) & (.4) because the radio on subnet (.3) can communicate with both subnet (.1) and (.4). First we will set the default gateway on the PC to 192.168.3.2 thus all datagrams not intended for subnet (.3) will be forwarded to the radio for transmission. Next we will have to set the default gateway on the radio to 192.168.1.2 this will handle the bulk of the traffic assuming there is a lot of Internet activity. In addition to the default gateway setting we will also need to add a route to the routing table in the radio to forward subnet (.4) packets to the radio on (.4). Add the following route: (Destination 192.168.4.0, Subnet Mask 255.255.255.0, Next Hop 192.168.4.2). Please refer to the Routing Tab section on page 47 of this manual for specific instructions on how to enter a route in the radios routing table.

Now for subnet (.1), first we will need to set both the PC's and radio's default gateways to 192.168.1.3. This will insure that all packets not specifically addressed to one of our subnets be forwarded to the Internet router. Next we need to add routes to the radio's routing table for all packets destined for one of our subnets. This will entail entering three separate routes as shown in Table 5 below.

Table 5, Routing Table for 192.168.1.2 (EZCom-IP radio)

Destination	Subnet Mask	Next Hope	Interface	Origin
192.168.2.0	255.255.255.0	192.168.2.2	Radio	EZCom
192.168.3.0	255.255.255.0	192.168.3.2	Radio	EZCom
192.168.4.0	255.255.255.0	192.168.3.2	Radio	EZCom

We will also need to add the following routes to the subnet (.1) PC's routing table and to the Internet routers routing table as well. If you are not familiar with the adding a route to your PC's routing table please refer to the sidebar "

The ROUTE Utility Program" on page 31 of this manual. For adding routes to your router please refer to the manufactures instructions.

Table 6, Routing Table for 192.168.1.1 (PC)

Destination	Subnet Mask	Next Hope	Interface
192.168.2.0	255.255.255.0	192.168.1.2	
192.168.3.0	255.255.255.0	192.168.1.2	
192.168.4.0	255.255.255.0	192.168.1.2	

These PC routes were added to direct any datagrams generated by the PC destine for one of our subnets to the radio for transmission. This is necessary because we have already set the default gateway at the PC to 192.168.1.3, which is the Internet router. On all of our other subnets we did not need to make individual route entries because any datagrams that needed to be routed outside the local subnet where handled by the default gateway entry. Subnet (.1) on the other hand has two routers, the Internet router and the EZCom-IP radio.

In summary to setup the network illustrated in Figure 11 on page 14 you would first need to set each device IP address as listed in Table 4 and then you would have to establish the routing tables which are summarized in Table 7.

Table 7 Store & Forward Example Routing Summary

Subnet	Device	Device IP Address	Route Type	Target	Next Hop
(.1)	***PC***	192.168.1.1	Default Gateway	0.0.0.0	192.168.1.3
			Add Route	192.168.2.0	192.168.1.2
			Add Route	192.168.3.0	192.168.1.2
			Add Route	192.168.4.0	192.168.1.2
	Radio	192.168.1.2	Default Gateway	0.0.0.0	192.168.1.3
			Add Route	192.168.2.0	192.168.2.2
			Add Route	192.168.3.0	192.168.3.2
			Add Route	192.168.4.0	193.168.3.2
	Router	192.168.1.3	Add Route	192.168.2.0	192.168.1.2
			Add Route	192.168.3.0	192.168.1.2
			Add Route	192.168.4.0	192.168.1.2
(.2)	***PC***	192.168.2.1	Default Gateway	0.0.0.0	192.168.2.2
	Radio	192.168.2.2	Default Gateway	0.0.0.0	192.168.1.2
(.3)	***PC***	192.168.3.1	Default Gateway	0.0.0.0	192.168.1.2
	Radio	192.168.3.2	Default Gateway	0.0.0.0	192.168.1.2
			Add Route	192.168.4.0	192.168.4.2
(.4)	***PC***	192.168.4.1	Default Gateway	0.0.0.0	192.168.4.2
	Radio	192.168.4.2	Default Gateway	0.0.0.0	192.168.3.2

Section 2. Technical Reference

Introduction

The technical reference section of this manual is intended to develop a basic overview on the subject of network technology, sufficient in detail to explain the routing function of the EZCom-IP radio. It is not intended to be an exhaustive coverage of the subject but it dose burrow in to some detail of the lower level protocols. Although much of what is presented is germane to all forms of network communications, the examples and illustrations are biased toward Ethernet IP applications because it is the underling technology of the EZCom-IP radio.

Many of the subsections that follow are relatively generic in nature and may seem remedial to some readers. The following list describes each section and presents recommendations as to who should read those sections and who can feel free to skip them to focus on the EZCom-IP specific information.

1. ***Protocols And Protocol Architecture*** starts off with a basic introduction to the concept of a protocol stack it then moves on to a general description of the Internet Protocol. If you are already familiar with the idea of a protocol stack you can skip right to the descriptions of the IP protocol. If you are already familiar with the IP protocol also. please feel free to skip this section entirely.
2. ***TCP/IP Communications*** presents an overview of the TCP/IP protocol stack with a detailed description of the IP protocol. The section is divided into four subsections: The Application Layer, The Transport Layer, The Network Layer and The Physical Layer. Having a through understanding of the TCP/IP protocol is not necessary for the application of the EZCom-IP radio. This section is presented for the advanced user. If you are in a hurry you may want to just read the network layer subsection.
3. **Subnetting.** This is a fairly lengthy section that goes into some detail regarding why and how to subnet. Subnetting is one of the more important topics dealt with in this manual. A good understanding of the subject matter will greatly improve your ability to establish large distributed wide area networks. Any one not already familiar with Subnetting and considering using the EZCom-IP radio in a large-scale distributed network should read this material.
4. **EZCom IP Routing** - This section briefly goes through the EZCom-IP routing mechanism. Its brevity is primarily due to the simplistic nature of the routing scheme. Anybody who wants to gain even an intuitive understanding of the EZCom-IP radio should read this section. It will help you maximize the functionality of an EZCom-IP extended network.
5. **Connectors and Indicators**. Briefly introduces you to the indicators on the face of the radio.
6. **EZCom-IP Explorer program** This section goes through all if the menu picks and program dialogs explaining where specific information is entered and where appropriate also offers some guidance as to what should be entered.

Protocols And Protocol Architecture

When computers and/or other data processing devices such as PLC's exchange data, there must be a data path between the two computers, via a communication network. Although, a data path alone is not sufficient to establish communications, more is needed. Typically the following tasks also need to be performed:

1. The source system must inform the communication network of the identity of the desired destination system.
2. The source system must ascertain that the destination system is prepared to receive data.
3. The application on the source system must ascertain that an application on the destination system is prepared to accept the data for a particular use.
4. If the data formats used on the two systems are incompatible, one or the other system must perform a format translation function.

It is clear that there must be a high degree of cooperation between the two computer systems. The exchange of information between computers for the purpose of cooperative action is generally referred to as data communications. Similarly, when two or more computers are interconnected via a communication network, the set of computer stations are referred to as a computer network.

In this discussion of computer networks, two concepts are paramount, Protocols and Protocol Architectures.

A protocol is used for communication between entities in different systems. The terms "entity" and "system" are used in a very general sense. Examples of entities are user application programs, file transfer packages, database management systems, electronic mail facilities, etc. Examples of systems are computers, PLCs, and remote sensors.

In general, an entity is anything capable of sending or receiving information, and a system is a physically distinct object that contains one or more entities. For two entities to communicate successfully, they must "speak the same language." What is communicated, how it is communicated, and when it is communicated must conform to some mutually acceptable conventions between the entities involved. The conventions are referred to as a protocol, which may be defined as a set of rules governing the exchange of data between two entities. The key elements of a protocol are

- Syntax, which includes such things as data format and signal levels.
- Semantics, which includes control information for coordination and error handling.
- Timing, which includes speed matching, and sequencing.

Having introduced the concept of a protocol, we can now introduce the concept of protocol architecture. It is clear that there must be a high degree of cooperation between the two computers. Instead of implementing the logic for this as a single module, the task is broken up into subtasks, each of which is implemented separately. Thus, instead of a single module for performing communications, there is a structured set of modules that implements the communications function. That structure is referred to as a protocol architecture or protocol stack. In the remainder of this section, we will present a simplified protocol architecture. Followed by an introduction to the more complex TCP/IP protocol stack.

A Simple Model

In very general terms, data communications can be said to involve three agents: applications, computers, and networks. The applications execute on computers that can often support multiple simultaneous applications. The computers are connected to the network, and the data to be exchanged is transferred by the network from one computer to another. Thus, the transfer of data from one application to another involves first getting the data to the computer in which the application resides and then getting it to the intended application within the computer.

With this concept in mind, it appears natural to organize the communication task into three relatively independent layers:

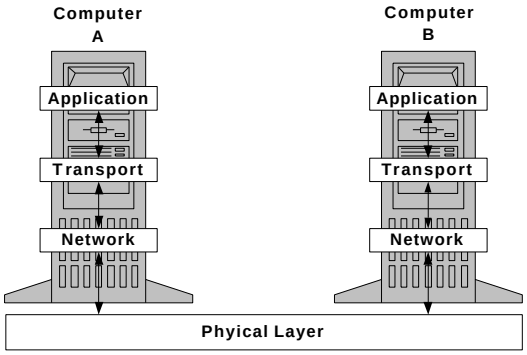
- Application layer
- Transport layer
- Network access layer

The network access layer is concerned with the exchange of data between a computer and the network to which it is attached. The sending computer must provide the network with the address of the destination computer, so that the network may route the data to the appropriate destination. Thus, it makes sense to separate those functions having to do with network access into a separate layer.

Regardless of the nature of the applications that are exchanging data, there is usually a requirement that data be exchanged reliably. That is, we would like to be assured that all of the data arrive at the destination application and that the data arrive in the same order in which they were sent. As we shall see, the mechanisms for providing reliability are essentially independent of the nature of the applications. Thus, it makes sense to collect those mechanisms in a common layer shared by all applications; this is referred to as the transport layer.

Finally, the application layer contains the logic needed to support the various applications. For each different type of application, such as file transfer program, a separate module is needed that is peculiar to that application.

To demonstrate this concept let us trace a simple operation. Suppose that an application, on computer A, wishes to send a message to another application, on computer B. The application on A hands the message over to its transport layer with instructions to send it to a specific application on computer B. The transport layer hands the message over to the network access layer, which instructs the network to send the message to computer B. Note that the network need not be told the identity of the destination application. All that it needs to know is that the data is intended for computer B.



To control this operation, control information, as well as the original user data, must be transmitted. Let us say that the sending application generates a block of data and passes this to the transport layer. The transport layer may break this block into two smaller pieces to make it more manageable. To each of these pieces the transport layer appends a transport header, containing protocol control information. The combination of data and control information is known as a protocol data unit (PDU); in this case, it is referred to as a transport protocol data unit. The header in each transport PDU contains control

information to be used by the peer transport protocol at computer B. Examples of items that may be stored in this header include

- Destination application. When the destination transport layer receives the transport protocol data unit, it must know to whom the data are to be delivered.
- Sequence number. Because the transport protocol is sending a sequence of protocol data units, it numbers them sequentially so that if they arrive out of order, the destination transport entity may reorder them.
- Error-detection code. The sending transport entity may include a code that is a function of the contents of the remainder of the PDU. The receiving transport protocol performs the same calculation and compares the result with the incoming code. A discrepancy results if there has been some error in transmission. In that case, the receiver can discard the PDU and take corrective action.

The next step is for the transport layer to hand each protocol data unit over to the network layer, with instructions to transmit it to the destination computer. To satisfy this request, the network access protocol must present the data to the network with a request for transmission. Once again, this operation requires the use of control information. In this case, the network access protocol appends a network access header to the data it receives from the transport layer, creating a network access PDU. Examples of the items that may be stored in the header include

- Destination computer address. The network must know to whom (which computer on the network) the data are to be delivered.
- Facilities requests. The network access protocol might want the network to make use of certain facilities, such as priority.

With the concept of protocol architecture still fresh in our minds let jump right into the TCP/IP protocol stack because it is this architecture that the EZCom-IP radio supports.

The TCP/IP Protocol Architecture

TCP/IP is the most widely used interoperable network communications architecture in use today. TCP/IP is a result of protocol research and development conducted on the experimental packet-switched network, ARPANET, funded by the Defense Advanced Research Projects Agency (DARPA), and is generally referred to as the TCP/IP protocol suite. This protocol suite consists of a large collection of protocols that have been issued as Internet standards by the Internet Activities Board (IAB).

There is no official TCP/IP protocol model, however, based on the protocol standards that have been developed, we can organize the communication task for TCP/IP into five relatively independent layers:

1. Application layer
2. Host-to-host, or Transport layer
3. Internet layer
4. Network access layer
5. Physical layer

The physical layer covers the physical interface between a data transmission device (e.g., computer or PLC) and a transmission medium or network. This layer is concerned with specifying the characteristics of the transmission medium, the nature of the signals, the data rate, and related matters.

The network access layer is concerned with the exchange of data between an end system and the network to which it is attached. The sending computer must provide the

network with the address of the destination computer, so that the network may route the data to the appropriate destination.

The network access layer is concerned with access to and routing data across a network for two end systems attached to the same network. In those cases where two devices are attached to different networks, procedures are needed to allow data to traverse multiple interconnected networks. This is the function of the Internet layer. The Internet protocol (IP) is used at this layer to provide the routing function across multiple networks. This protocol is implemented not only in the end systems but also in routers. A router is a processor that connects two networks and whose primary function is to relay data from one network to the other on its route from the source to the destination end system. This is essentially what the EZCom IP radio dose.

Regardless of the nature of the applications that are exchanging data, there is usually a requirement that data be exchanged reliably. That is, we would like to be assured that all of the data arrive at the destination application and that the data arrive in the same order in which they were sent. The mechanism for providing this reliability is referred to as the host-to-host layer, or transport layer. The Transmission Control Protocol (TCP) is the most commonly used protocol to provide this functionality.

Finally, the application layer contains the logic needed to support the various user applications. For each different type of application, such as file transfer program, a separate module is needed that is peculiar to that application.

Figure 12, TCP/IP Protocol Stack

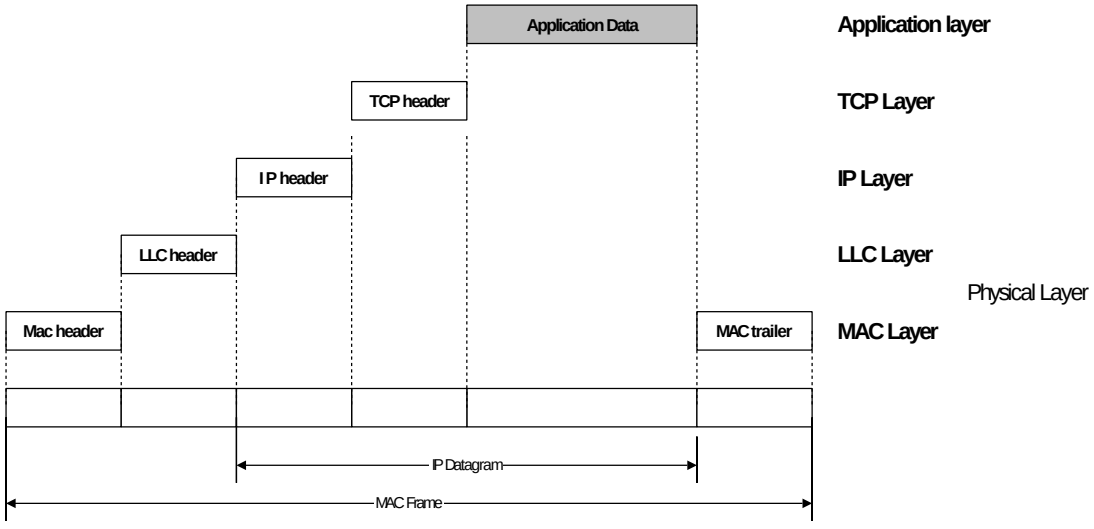


Figure 12, shows how the TCP/IP protocols are implemented in end systems. Note that the physical and network access layers provide interaction between the end systems and the network, whereas the transport and application layers are what is known as end-to-end protocols; they support interaction between two end systems. The Internet layer has the flavor of both. At this layer, the end system communicates routing information to the network but also must provide some common functions between the two end systems.

TCP/IP Communications

The TCP/IP Protocol Stack

In the previous section we introduced the concept of Protocol Architecture and we described the basic structure of the TCP/IP protocol stack. In this section will take a closer look at some of the individual protocols associated with the TCP/IP protocol stack. Most of our attention will be focused on the Internet Protocol (IP) because it is responsible for routing of information on a TCP/IP network. Essentially an EZCom-IP radio is an IP router and as such relies on the IP protocol to implement routing function.

Application Layer

The top layer of the stack is the Application layer. This is not where you find applications such as Word or Excel, but rather where you find NetBIOS and Winsock (the two main networking APIs in the Microsoft network architecture). These components provide services to the actual applications that can call on the network by using these network APIs. As stated, the APIs provide a standard method for programmers to call on the services of the underlying network without having to know anything about it.

Sitting at this layer, you might also add an NCP (Netware Core Protocol) component to enable you to talk with or provide services to the Novell world, or maybe add an NFS component to enable you to work with the Network File System that is popular on the Unix platforms.

Transport Layer

Overview of TCP

TCP is used to provide a connection-oriented delivery service for the higher-level protocols. To do this, TCP must first establish a session with the remote communicating host. It does this by means of a three-way handshake. First the host initiating the communications sends a packet to the other host that contains information about itself and a SYN (or synchronize flag) telling the other host that a session is requested. The other host receives this packet and responds with information about itself—the SYN flag and an ACK (acknowledgment) of the information that it received. Finally the first host ACKs the information it received from the other, and a session now exists between the two systems.

At the end of the communication session, a similar three-way handshake is used to drop the session with the remote host. This ensures that both of the hosts are through transmitting. It closes the session cleanly.

Transmission Control Protocol (TCP)

TCP provides reliable communication between processes that run on interconnected hosts. This Transport layer functions independently of the network structure. TCP is not concerned with routing data through the internetwork; the network infrastructure is the responsibility of the IP layer. TCP on one host communicates directly with TCP on another host, regardless of whether the hosts are on the same network or remote from each other.
In fact, TCP is oblivious to the network. A wide variety of network technologies can be accommodated, including circuit switching and packet switching on local and wide area networks. TCP identifies hosts by using IP addresses and does not concern itself with physical addresses.

The main functions of TCP are:

- Session establishment
- Byte stream communications
- Sliding windows

Session Establishment

Applications using the TCP protocol must be able to open, close, and check the status of sessions to allow them to communicate. To perform this function, TCP uses a three-way handshake. The handshake is important not only to create the session, but also in allowing the hosts to exchange data about their capabilities.

The handshake starts when one host is asked by Winsock to open a connection (or session). A TCP segment is generated to start the session, and the SYN control bit is turned on. This tells the other host that a session is requested. The host also includes in the TCP header the starting Sequence number for this connection and the current window size.

The TCP segment is now sent to the other host, who acknowledges the segment, including its window size. The segment sent to acknowledge the first host also includes the SYN control bit. Finally, the process ends when the first host acknowledges the receipt of the other's segment.

After the hosts have completed their communications, the connection is closed in a similar manner, the difference being that the FIN control bit is set rather than the SYN bit.

Byte Stream Communications

When a connection (session) is established, the upper-layer protocol uses this connection to send data to the other host. The upper-layer protocols do not concern themselves with formatting data to fit the underlying topology, but send the data as a continuous stream.

This process, called *byte stream communications*, means that TCP must have some method for dealing with a large volume of data that has no boundaries. Every byte in a stream is assigned a Sequence number, enabling every byte sent, to be acknowledged. If TCP sent each byte as a single package, this would be unmanageable. TCP therefore bundles the data stream it sends into segments; a segment contains chunks of data.

The TCP header specifies the segment Sequence number for the first byte in the data field, and each segment also incorporates an Acknowledgment number. Because you do not know which byte will be the first in a given segment, you must give each byte a Sequence number. When TCP sends a segment, it retains a copy of the segment in a queue (transmit window), where it remains until an acknowledgment is received. Segments not acknowledged are retransmitted.

When TCP acknowledges receipt of a segment, it relieves the sending TCP of responsibility for all data in that segment. The receiving TCP then becomes responsible for delivering the data in the segment to the appropriate upper-layer process.

Sliding Windows

This is all necessary because of the way the Internet (or your intranet) works. The segments that you send could each take a different route. This might happen because routers can become busy or links could fail. Data must be buffered on the sending host until the remote host has acknowledged it.

The Sliding Window is the buffer that enables byte stream communications, and enables TCP to guarantee the delivery of segments of data. During the session establishment, the two hosts exchange the current size of the receive window. This information is also

included in the TCP header of each and every segment sent. A host that is communicating sets the size of its send window to match the other host's receive window.

If you look at the data being transmitted, you would see a series of bytes. If you overlay a window at the start of the data, you can see that a portion of the data falls into the window. This is the only data with which the TCP layer can work. The window cannot slide (move to cover more data) until all the data currently in the window is sent and acknowledged.

As the data in the window is transmitted to the remote host, the retransmit timer is set for each segment sent. The receiving host acknowledges the segments when its receive window fills to a predetermined amount (in Windows 98 & NT this is two consecutive segments). When the sender receives the acknowledgment, it's transmit window slides past the acknowledged data and the next segments are transmitted.

In the process of moving the data from point A to point B, many things might happen to the segments being transmitted. They could be lost due to congestion at the routers, or could be received out of sequence.

If a packet is lost, the retransmit timer expires on the sending host, the segment is retransmitted, and the retransmit timer is set to two times the original value. This continues until the segment is acknowledged or the maximum number of retries has been made (about 16 seconds). If the data cannot be transmitted, TCP reports the condition and you get an error message.

In a case where the segments are received out of order, the receiving host sets the delayed acknowledgment timer for the segment it did receive, and waits for other segments to arrive. If the delayed acknowledgment timer (hard-coded to 200 ms) expires, TCP on the receiving host sends an acknowledgment for the segment it did receive.

TCP Window Size

You can adjust the size of the sliding window. Great care should be taken in adjusting the window size. If the window size is set too small, only a few packets can be sent at a time. This means that the system transmits the packets and then must wait for acknowledgments. If the size is set too large, network traffic delays the transmission.

You can adjust the TCP window size under:

HKEY_LOCAL_MACHINE\System\CurrentControlSet\Services\TCPIP\Paramters.

The default is 8760, which is tuned for Ethernet. This setting affects only TCP, because UDP does not use a sliding window.

User Datagram Protocol

TCP is a connection- or session-oriented protocol that requires hosts to establish a session, which is maintained for the duration of a transfer, after which the session is closed. The overhead required to maintain connections is justified when reliability is required but often proves to be misspent effort.

User Datagram Protocol provides an alternative transport for processes that do not require reliable delivery. UDP is a datagram protocol that does not guarantee data delivery or duplicate protection. As a datagram protocol, UDP need not be concerned with receiving streams of data and developing segments suitable for IP. Consequently, UDP is an uncomplicated protocol that functions with far less over-head than TCP.

In the following several situations, UDP might be preferred over TCP as a host-to-host protocol:

- **Messages that require no acknowledgment.** Using UDP can reduce network overhead. Simple Network Management Protocol (SNMP) alerts fall into this category. On a large network, considerable SNMP alerts are generated because every SNMP device transmits status updates. Seldom, however, is loss of an SNMP message critical. Running SNMP over UDP, therefore, reduces network overhead.
- **Messages between hosts are sporadic.** SNMP again serves as a good example. SNMP messages are sent at irregular intervals. The overhead required to open and close a TCP connection for each message would delay messages and bog down performance.
- **Reliability is implemented at the process level.** Network File System (NFS) is an example of a process that performs its own reliability function and runs over UDP to enhance network performance.

Network Layer

Both TCP and UDP pass information to the IP layer. This layer is responsible for actually moving the data from one machine on the network (or internet work) to another. The IP layer handles a number of different communication tasks. The IP layer, however, does not guarantee delivery; this is dealt with by TCP. Some of the functions handled at this layer include the following:

- Routing of datagrams
- Resolution of IP addresses to MAC addresses
- Fragmentation and re-assembly of datagrams
- Error detection and reporting

With respect to the EZCom-IP radio this is the most important part of the TCP/IP stack because this is where routing takes place. The EZCom-IP radio processes IP packets just like a PC or other device on the network.

Before we can have a truly meaningful discussion regarding how the Network layer performs it's tasks we need to first develop an understanding of the IP addressing scheme.

Overview of TCP/IP Addresses

To make TCP/IP work, each and every device on a TCP/IP network requires a unique address. An IP address identifies the device to all the other devices on the network. IP addresses are made up of two parts. The first identifies the network ID. This ID is used to route the information being sent to the correct network. The other part of the IP address is the host ID, a unique number that identifies each computer and device on your TCP/IP network.

An IP address is very similar to your street address. If your address is 110 Main Street, the address identifies which street you are on, Main Street. It also identifies your house on that street, number 110. The only difference between a street address and a TCP/IP address is that the street addresses are reversed. If this were a TCP/IP address, it would look like this: Main Street, 110.

How much of the address describes the network ID depends on the type of address you have. Three main classes of addresses exist: Class A, B, and C. A TCP/IP address is, simply put, a 32-bit binary number. Looking at an address as 32 zeros or ones is difficult for humans, so the address is viewed as a dotted decimal address in the following format: 198.53.147.153. In this case, you are on network 198.53.147, and you are host number 153. Each of the four numbers represents 8 bits of the address and is referred to as an

octet or byte. To understand TCP/IP and some of the concepts that make it work, it is important to be familiar with the binary form of the address.

Understanding binary is relatively easy. Look at the number 238, for example. In conventional math, this is two hundred and thirty-eight. Automatically, you see the 2 as two groups of one hundred, the 3 as three groups of ten, and there are eight groups of one. Each of the digits is multiplied by a positional value to make the total. That value is always ten times the value to the right because there are ten different numbers: 0 1 2 3 4 5 6 7 8 9.

Normally, you need only to work with binary numbers that are 8 digits long. Table 8, shows the values for those first 8 positions:

Table 8, Bit Position Values

128	64	32	16	8	4	2	1

In binary, there are only two numbers, 1 and 0. Where the decimal system is a base ten system, the binary system is a base two system. Like the decimal system, the positional values increase. Here, however, they increase by two times the previous value (exponentially). Using Table 8, you should be able to figure out that the binary code 110110 does not represent one hundred and ten thousand, one hundred and ten. Instead, it represents one group of thirty-two, one group of sixteen, no groups of eight, one group of four, one group of two, and no groups of one. That is, 110110 represents the number 54 if you express it in decimal form.

If you were to take the 198 from the example address 198.53.147.153, you could express this number as 128+64+4+2 (or 11000110). Remember that each of the 4 numbers represents 8 bits of the address, making up the total of 32 bits.

The most obvious difference between the three main types of addresses is the number of octets used to identify the network ID. Class A uses the first octet only; this leaves 24 bits (or three octets) to identify the host. Class B uses the first two octets to identify the network, leaving 16 bits (two octets) for the host. Class C uses three octets for the network ID, leaving 8 bits (one octet) for the host.

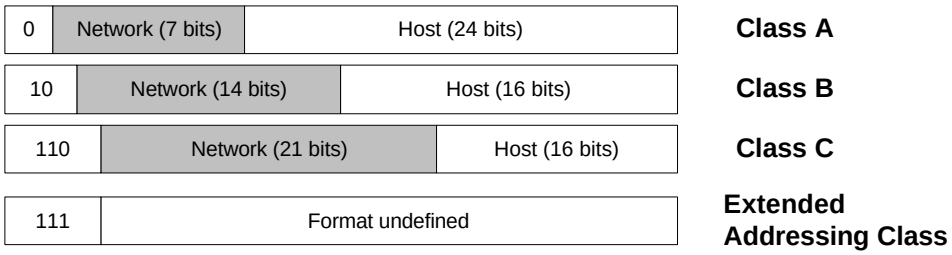
Table 9, TCP/IP Address Classes—First Octet

Class	*Start (Binary)*	*Finish (Binary)*	*Start (Decimal)*	*Finish (Decimal)*
A	00000001	01111111	1	127
B	10000000	10111111	128	191
C	11000000	11011111	192	223

A couple of rules determine what you can and cannot use for addresses. Neither the network ID nor the host ID can be represented by all 0’s or by all 1’s, because each of these conditions has a special meaning. As well, the network with the first octet 127 is used solely for loop back tests.

The classes of networks also differ in how their addresses start in binary. Class A addresses start with 0. Class B addresses start with 10. Class C addresses start with 110. You can tell which class of address a host has by the first octet of its TCP/IP address. Knowing that the first octet represents the first 8 bits of the address, and by knowing the starting bits for the classes of addresses, you can see the first octet ranges for the respective classes in Table 9

Figure 13, IP Address Formats



Because the Class A addresses use only the first octet to identify the network ID, there are a limited number of them (126, to be exact; 127 is reserved). Each of these 126 networks, however, can have many hosts on it: 2^{24} (the remaining 24 bits) hosts minus two (the host IDs that are all 0's and all 1's) equals 16,777,214 hosts on a single network (albeit impossible).

Class B addresses use the first two octets. The first 2 bits, however, are set to binary 10. This leaves 14 bits that can be used to identify the network: 2^{14} possible combinations (6 bits in the first octet and 8 from the second)—16,384 network IDs (because the first two digits are 10, you don't have to worry about an all 0's or all 1's host ID.) Each of those network IDs has 16 bits left to identify the host or 65,534 hosts ($2^{16} - 2$).

Class C networks use three octets (or 24 bits) to identify the network. The first three bits, however, are always 110. This means that there are five bits in the first octet and eight in the other two that can be used to uniquely identify the network ID or 2^{21} possible networks (2,097,152)—each of which has 8 bits for hosts or 254 ($2^{8} - 2$).

Table 10 summarizes all the possible TCP/IP addresses.

Table 10, Address Class Summary

Address Class	*First Octet Start*	*Finish*	*Number of Networks*	*Hosts Each*
A	1	126	126	16,777,214
B	128	191	16,384	65,534
C	192	223	2,097,152	254

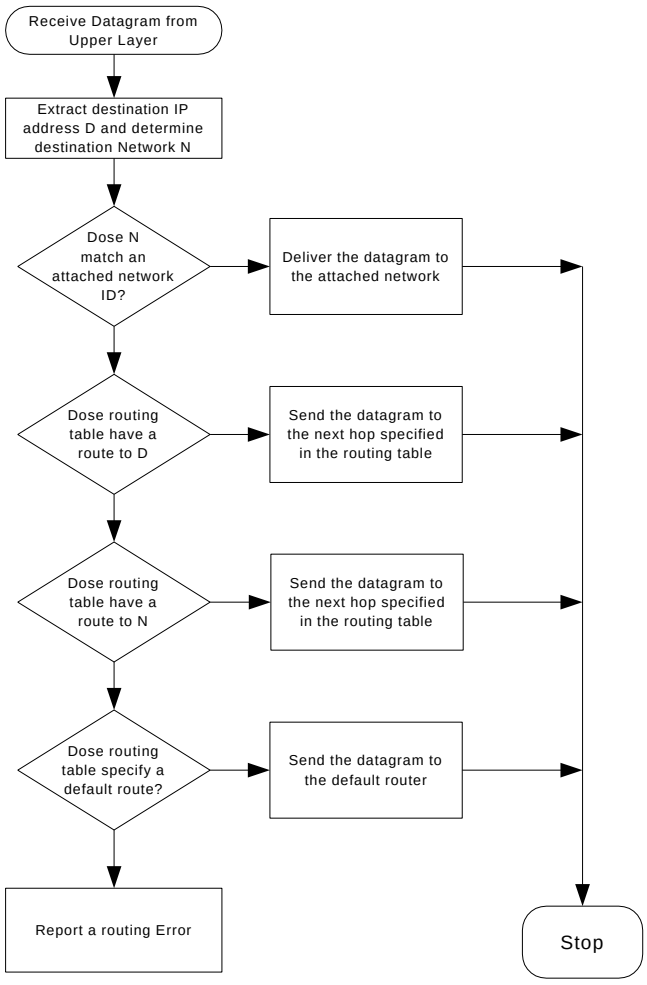
Internet Protocol Routing

When a packet arrives at the IP layer the subnet mask can be used to determine whether the destination host is a local or remote host. First the devices own IP address is ANDed with the subnet mask to extract the network ID for the local network on which the host resides. Then the IP address that IP receives in the pseudo header is ANDed with the subnet mask to determine the designation's network ID. It is important to note that the network ID generated from the ANDing with the local host's subnet mask might be incorrect. If the local host attempting to send the datagram is a Class C host using 255.255.255.0 as the subnet mask, ANDing generates an incorrect address if the remote host is a Class B. This does not matter, however, because the network IDs will not match (remember the first octet differs, depending on the class of network). As you can see, therefore, the subnet mask enables you to extract the network ID. This information is used to see whether the datagram is for the local network. If it is not, the system needs to look at the remote IP address and use the routing table to figure out where to send it.

After the network IDs are known, they can be compared. The only case where they should match is if the two hosts are on the same network. If the host that you are trying to reach is on the same network, the IP layer finds that host and transmits the data to it. If

not, it needs to look for a route to the host. This will be done in the routing table. We will take a closer look at the routing table in just a minute. For now lets look at the logic used to find a route in the routing table first.

Figure 14, IP Routing Logic



As you can see from Figure 14, the IP layer has a very specific logic it uses in determining how a datagram should be routed. This is referred to as the routing mechanism and all IP based devices use this same mechanism. The simplicity of the routing mechanism is part of what makes the IP protocol so attractive and also vary robust. You are probably thinking how can such a simple mechanism be used to route information all over the world as it dose in the Internet. The simplicity comes from the fact that any device on the network only has to know the next hop in the overall routing of any datagram. The strength and complexity of routing datagrams all over the world is attributed to what is referred to as the routing policy. Routing policy is responsible for what is in the individual routing tables. In the case of the EZCom-IP radio the routing policy is completely up to you. All entries in the routing table are entered via the EZCom-IP explore program. This type of routing policy is referred to as static routing. There is a verity of dynamic routing protocols in use today on routers that are part of the Internet but dynamic routing is not currently an option on the EZCom-IP radio.

Routing Table

All devices that use the IP protocol have a routing table, which includes the EZCom-IP radio. In some cases a host's, routing table does not contain much routing information, except for the default gateway (router) address. In this case any packet not on the local network is normally sent to the default gateway. IP on the gateway then looks in its routing table for a route to the remote network. In most cases you will need to have entries in the local host's routing table. In those cases, the table is consulted to find the first hop in the route. The following is an example of a routing table.

Table 11, Active Routes:

Network Address	Subnet mask	Gateway Address	Interface	Metric
0.0.0.0	0.0.0.0	206.51.250.69	206.51.250.69	1
127.0.0.0	255.0.0.0	127.0.0.1	127.0.0.1	1
206.51.250.0	255.255.255.0	206.51.250.69	206.51.250.69	1
206.51.250.69	255.255.255.255	127.0.0.1	127.0.0.1	1
206.51.250.255	255.255.255.255	206.51.250.69	206.51.250.69	1
224.0.0.0	224.0.0.0	206.51.250.69	206.51.250.69	1
255.255.255.255	255.255.255.255	206.51.250.69	206.51.250.69	1

A routing table contains the following five pieces of information:

- **Network Address.** The actual network ID to which the entry describes a route. This is the real network ID, not the one generated earlier when checking, if the host is local or remote.
- ? **Netmask.** The subnet mask that can be used to generate the network ID. The system runs through the table and ANDs the IP address you are trying to reach with each of the netmasks. Then it can compare the result to the Network Address to see whether they match. If they match, a route has been found.
- **Gateway Address.** Where to send the packet if it is a remote network ID to which the computer is sending.
- **Interface.** Which network interface to send the packet from. Normally you only have one network card, and this is the same for all entries. (The exception here is the loopback and multicasting addresses.) In the case of the EZCom-IP radio there are 2 interfaces one that attaches the radio to the local subnet and the other is the radio link to other EZCom-IP radios. You can learn more about this in the EZCom IP Routing section on page 40.
- **Metric.** How far away this network is. This is the number of routers (gateways) that the packet must travel through to get to the remote.

There will often be an entry for network 0.0.0.0 with a netmask of 0.0.0.0. This is the entry for the default gateway and is checked last. If you work it out in binary, you will see that all addresses match this one. Figure 14 summarizes the process that IP uses to determine where it should send the packet.

You can add routes or modify the routing table in your EZCom-IP radio using the EZCom-IP Explorer program. If you need to setup a route or modify one on you PC you need to use the ROUTE utility program included with the windows operating system.

The ROUTE Utility Program

Syntax for the ROUTE command is as follows:

Manipulates network routing tables.

ROUTE [-f] [command [destination] [**MASK** netmask] [gateway] [**METRIC** metric]]

-f Clears the routing tables of all gateway entries. If this is used in conjunction with one of the commands, the tables are cleared prior to running the command.

-p When used with the ADD command, makes a route persistent across boots of the system. By default, routes are not preserved when the system is restarted. When used with the PRINT command, displays the list of registered persistent routes. Ignored for all other commands, which always affect the appropriate persistent routes.

command	Specifies one of four commands
	PRINT Prints a route
	ADD Adds a route
	DELETE Deletes a route
	CHANGE Modifies an existing route
destination	Specifies the host.
MASK	If the MASK keyword is present, the next parameter is interpreted as the netmask parameter.
netmask	If provided, specifies a sub-net mask value to be associated with this route entry. If not specified, it defaults to 255.255.255.255.
gateway	Specifies gateway.
METRIC	specifies the metric/cost for the destination

All symbolic names used for destination are looked up in the network database file NETWORKS. The symbolic names for gateway are looked up in the host name database file HOSTS.

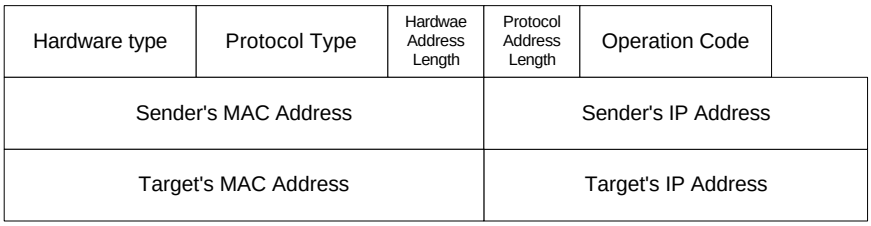
If the command is print or delete, wildcards may be used for the destination and gateway, or the gateway argument may be omitted.

Finding Another Machine's Address

Whether a packet that you are sending is going to a host on your network or to a host on a remote network, the packet is always sent to a MAC address (the hardware address of the network card). The only difference in sending to the local or the remote network is that the address used for a remote network is the address of the router on the local network. Remember that a router is a simple device that connects two (or more) networks; it has a network interface on each network (with an IP address on each subnet) and the IP layer to enable it to route packets between different networks based on the routing table. In the case of a packet going to a remote system, the system finds the MAC address of the default gateway's IP address on the local subnet (see Figure 14).

The resolution of hardware addresses, as previously mentioned, is the responsibility of ARP (Address Resolution Protocol). ARP first checks the ARP cache to see whether it has recently resolved the address. If it has, it can pass that to IP so that the packet can be sent. Otherwise, ARP creates a broadcast packet that is sent on the network (see Figure 15). The packet contains the IP address your system wants to resolve. It also contains the IP address and MAC address of your machine.

Figure 15, ARP Packet



The parts of the ARP packet are as follows:

- **Hardware type,** references which type of hardware is being used to access the network (for example, token ring).
- **Protocol type.** The protocol being used to perform the address resolution. Normally set to 0800 (hex), which is IP.
- **Hardware address length.** Size of the hardware address in bytes. For Token Ring and Ethernet, this is 06 (hex).
- **Protocol address length.** Size in bytes of the address being sought. This is 04 (hex) for IP.
- **Operation code.** Determines what this packet is. Operations include Query and Reply.
- **Sender's addresses.** Both the MAC and IP address. This is added to the target machine's ARP cache, and is used to reply.
- **Target's addresses.** The information being sought. The IP address is known, and the MAC address is returned.

When the ARP packet is broadcast on the network, all the systems receive the packet and pass it up to their own IP layer. ARP sees whether the IP address being sought is its own IP address. If it is, it takes the IP address and MAC address of the other host and adds it to its own table. Then it creates an ARP reply to tell the other system its MAC address. Both systems now know each other's IP and MAC addresses. You should, however, remember a couple of things about the ARP cache: Entries in the ARP cache expire after a short period of time; if the address is not used again, the entry lasts for two minutes; if it is used, it is kept for ten minutes. An entry could also be removed if the cache is getting full—in this case, ARP removes the oldest entries first. You can also add a static entry in the ARP cache. It remains, however, only until the system is restarted.

This might seem a little severe. Entries in the ARP cache, however, are the hardware addresses of the network cards in other hosts. This could very possibly change for a given host, and would (if your entries were permanent) require all the hosts to be updated.

ARP Utility Program

To work with your ARP cache, you can use the ARP command. You can use ARP to displays and modify the IP-to-Physical address translation tables used by the address resolution protocol (ARP).

The following is the help text for the ARP command:

C:\users\default>arp /?

ARP -s inet_addr eth_addr [if_addr]
ARP -d inet_addr [if_addr]
ARP -a [inet_addr] [-N if_addr]

-a Displays current ARP entries by interrogating the current protocol data. If inet_addr is specified, the IP and Physical addresses for only the specified computer are displayed. If more than one network interface uses ARP, entries for each ARP table are displayed.

-g Same as -a.inet_addr Specifies an internet address.

-N if_addr Displays the ARP entries for the network interface specified by if_addr.

-d Deletes the host specified by inet_addr.

-s Adds the host and associates the Internet address inet_addr with the Physical address eth_addr. The Physical address is given as 6 hexadecimal bytes separated by hyphens. The entry is permanent.

eth_addr Specifies a physical address.

if_addr If present, this specifies the Internet address of the

interface whose address translation table should be modified.

If not present, the first applicable interface will be used.

Ethernet Physical Layer

As we have mentioned before the EZCom-IP radio is essentially an Ethernet IP router. It is not necessary to fully understand how Ethernet works to utilize the EZCom-IP radio just as it is not necessary to understand the internal workings of a combustion engine to drive a car. However for those interested there is a description of media access procedure for Ethernet in appendix B. In this section we are will look at the Ethernet MAC frame structure because of it's involvement in the overall routing scheme. We will focus on the IEEE 802.3 standard where there is both a medium access control layer and a physical layer specified.

MAC Frame

When an IP datagram is passed down from the network layer to the physical layer it is encapsulated by the physical layer in a MAC frame. Figure 16, depicts the frame format for the 802.3 protocol; it consists of the following fields:

- Preamble. A 7-octet pattern of alternating 0s and 1s used by the receiver to establish bit synchronization.
- A start frame delimiter. The sequence 10101011, which indicates the actual start of the frame and which enables the receiver to locate the first bit of the rest of the frame.
- Destination address (DA). Specifies the station(s) for which the frame is intended. It may be a unique physical address, a group address, or a global address.
- Source address (SA). Specifies the station that sent the frame.
- Length. Length of the LLC data field.
- LLC data. Data unit supplied by LLC.
- Pad. Octets added to ensure that the frame is long enough for proper CD operation.
- Frame check sequence (FCS). A 32-bit cyclic redundancy check, based on all fields except the preamble, the SFD, and the FCS.

Figure 16, IEEE 802.3 frame format.

LEGEND
SFD =Start-frame delimiter
SA = Source address
DA = Destination address
FCS = Frame-check sequence

Routing, Putting All of the Pieces Together

When a packet is received by IP from either a higher-level protocol such as TCP or UDP or from the network interface, The destination IP address is compared to the devices IP address if they match the packet is delivered to one of the higher level protocols. If the IP addresses don't then the routing table is consulted to find a next hop IP address. After the next hop address is identified ARP is used to resolve the MAC address of the device the packet is to be sent to. Then the packet is delivered to the MAC address.

Subnetting

Subnetting is the process of dividing a network into smaller sections or segments; with each segment having it's own IP subnet address. Subnetting is not necessary in all situation, but it will greatly reduce the number of routing table entries that you will have to create and maintain. It will also improve the overall network performance by reducing the time it takes for each radio to lookup a route when forwarding packets.

If you are planning on connecting your network to the Internet (World Wide Web), you must subnet. If you work only with computers in your own organization, you can use any addressing scheme you feel like using, this is called a Private *Network Address Space*. This is the case as well when you use a firewall or proxy server. Although, once again subnetting a set of private network addresses will greatly improve the performance of your EZCom IP radio and reduce the total number of routing table entries required to implement a private wireless network

How Do You Subnet?

Subnetting is usually done only once, and falls into the planning stages of the network. Changing the subnetting scheme after a network is in place generally requires visiting each station and each EZCom IP radio on the network and reconfiguring them.

Determining Your Addressing Needs

You must determine two critical factors when choosing how to subnet your network. First you need to know how many different subnets are needed, and then you need to know the maximum number of hosts required on any one subnet. Remembering that your network will probably grow at some time in the future, you should always design your network so that the growth you expect (and more) can be accommodated.

Some points that you want to consider in planning the subnetting of your network include where your hosts are physically located, and how much network traffic the different types of hosts are going to generate. General guidelines include the following:

- Locate hosts that share time critical data with each other on the same subnet
- Place hosts with heavy network usage on less populated subnets
- Reserve a network ID (subnet) for each EZCom-IP Radio.
- Allow for the most subnets possible-use the desired maximum number of hosts per segment as the limiting factor
- Where possible, put client hosts on the same subnet as the servers they will use

All these help to reduce the load on your EZCom IP routers. You should also plan redundancy into your router scheme, making alternate routes available in case one fails.

Remembering Binary

Because understanding what happens in Subnetting requires an understanding of the TCP, IP address as a 32-bit binary number. We will start with a recap of the IP address in binary form. In the section titled "Internet Protocol Routing" on page 28 we covered how the IP layer uses the subnet mask to determine whether a host is on the local network or a remote network. To do this, the bits in the subnet mask are turned on for the portion of the IP address that represents the network ID. In a class B address, for example, the standard subnet mask is 255.255.0.0, which means all the bits are "on" (1s) for the first two octets. The ANDing process pulls the first 16 bits from the IP address, which is the network ID. Table 12 shows an example of this.

Table 12, Extracting a Network ID Using a Standard Subnet Mask

IP Address	160.16.45.3	10100000	00010000	00101101	00000011
Subnet Mask	255.255.255.0	11111111	11111111	00000000	00000000
Network ID	160.16.0.0	10100000	00010000	00000000	00000000

Throughout this section I have tried to show the dotted decimal form of the IP address in the second column of most of the tables, and the binary form for each of the octets of the address in the remaining columns. This arrangement enables you to see the binary versions of the IP addresses and subnet mask. You will probably find (as most people do) that it is easier to understand the subnet mask if you look at it in it's binary form.

When a network is subnetted, all that happens is that you set two or more extra bits to "on" in the subnet mask. In this way, the IP layer sees more of the hosts with which you are communicating as being on a remote network, including some of the addresses within your organization Table 13, shows a network ID extract using a custom subnet mask.

Table 13, Extracting a Network ID Using a Custom Subnet Mask

IP Address	160.16.45.3	10100000	00010000	00101101	00000011
Subnet Mask	255.255.240.0	11111111	11111111	11110000	00000000
Network ID	160.16.32.0	10100000	00010000	00100000	00000000

Notice that the network ID extract in Table 13, differs from that in Table 12-even though the IP address is the same. This is because extra bits are used to identify the network. In this case, four extra bits are used. Assume, for example, that you are trying to contact a host with an address of 160.16.154.23, as shown in Table 14.

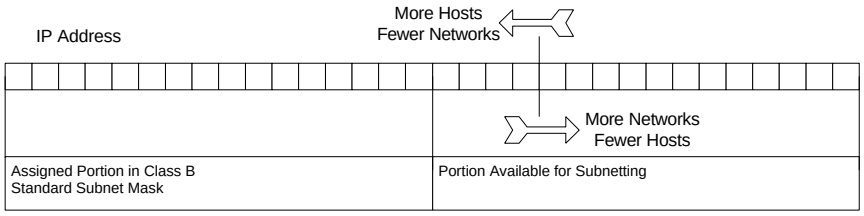
Table 14, Extracting the Target Network ID Using Standard and Custom Masks

IP Address	160.16.154.23	10100000	00010000	10011010	00010111
Subnet Mask	255.255.0.0	11111111	11111111	00000000	00000000
Network ID	160.16.0.0	10100000	00010000	00000000	00000000
Subnet Mask	255.255.240.0	1111111	11111111	11110000	00000000
Network ID	160.16.144.0	10100000	00010000	10010000	00000000

As Table 14, shows, if you use the standard subnet mask, the network IDs match, and your system will know that the host is a local host. If you use the custom subnet mask, however, the network IDs differ, this means that the target host is remote.

Remember that the IP address is a 32-bit binary address with the first part as the network ID, and the remainder as the host ID on that network. Obviously if you use more bits for the network ID (to subnet it), it has fewer for the hosts; you reduce the number of hosts per network (see Figure 17).

Figure 17, More Networks Mean Fewer Hosts Per Network & Vice Versa



Defining Your Subnet Mask

For an IP address to be a remote address, the network portion of the address must be different (in binary) from your own. In the case of subnetting, that means the bits in the portion you are using to subnet have to change. The easiest way to figure out how many bits you need is to write the number in binary. Twelve subnets, for example, would be

1100. It takes 4 bits to write the number 12 in binary. To allow for at least 12 unique binary combinations, therefore, you need to use 4 bits for your subnet mask.

You can add the bits to the standard subnet mask to generate a custom subnet mask. When the bits are added to the subnet mask, all the required bits are set to 1. In the class B example used earlier, it would look like Table 15.

Table 15, Creating a Custom Subnet Mask by Adding Subnetting Bits

Standard Mask	11111111	11111111	00000000	00000000
Additional Bits			1111	
Custom Subnet Mask	11111111	11111111	11110000	00000000

You might want to move the bits you want to use to the beginning of the octet (as shown in Table 15, for example). Because the network ID is always the first part of the IP address, the subnetting bits (which are an extension of the network ID) are always the first bits after the standard mask.

Finding Out How Many Networks, How Many Hosts

As you might have guessed, there are actually more than the 12 subnets required. In fact, four bits generate 16 unique combinations (or 2'). This means that a total of 14 subnets are available, because just like host IDs and network IDs, the subnet IDs cannot be all 0s or all 1s.

Calculating what the subnet mask requires is very simple now. In fact, you have already done it. Table 6.4 shows the custom subnet mask, you can just convert it to decimal 255.255.240.0. You can also figure out how many hosts each subnet will have. Remember that the subnet mask is used to remove the host ID so that only the network ID remains. All the bits that you are masking out (0s), therefore, are used for the host ID.

In this case, the third octet has 4 and the last octet has 8, meaning 12 bits are used for the host ID. The number 2 put to the power of 12 gives you the number of hosts that are supported per subnet. Remember, though, to subtract 2 from the product because the address with all Os is this subnet's ID, and the address with all is 1s the broadcast for this subnet. So 2^2 is 4,096 minus 2 is 4,094 hosts available on each subnet.

Because you always include the bits that you want to subnet with immediately after the standard subnet mask, only certain numbers work for the subnet mask. Obviously 255 and 0 are available-they make up the standard subnet mask. As you saw in the preceding example, you took the 4 bits and put them on the left side of the octet; the rest was padded with 0s. This is the same procedure you follow for all custom subnetting. Table 16 shows all the valid numbers for subnet masks.

Table 16, Valid Subnet Numbers

Bits Used	Octet in Binary	Decimal Value
1	Not valid	Not valid
2	11000000	192
3	11100000	224
4	11110000	240
5	11111000	248
6	11111100	252
7	11111110	254
8	11111111	255

Notice that subnetting on one bit is not valid. This makes sense if you remember that the subnet ID cannot be all 1s or all 0s. Because the only possible subnet IDs with one bit would be a 1 or a 0, you cannot use this.

Subnet IDS

Now that the hard work is done, you can figure out the subnet IDs. By figuring these, you can calculate the valid host IDs for each subnet. Using the same example as earlier, 16

possible combinations exist in the subnetted octet. Looking at them as an entire octet, they can be converted to decimal. This gives you the subnet IDs. Table 17 shows the calculation of subnet IDs using binary.

Table 17 Calculating the Subnet IDs Using Binary

Octet in Binary	Decimal Equivalent	Full Network ID
0000 0000	0	Not Valid
0001 0000	16	160.16.16.0
0010 0000	32	160.16.32.0
0011 0000	48	160.16.48.0
0100 0000	64	160.16.64.0
0101 0000	80	160.16.80.0
0110 0000	96	160.16.96.0
0111 0000	112	160.16.112.0
1000 0000	128	160.16.128.0
1001 0000	144	160.16.144.0
1010 0000	160	160.16.160.0
1011 0000	176	160.16.176.0
1100 0000	192	160.16.192.0
1101 0000	208	1 60.16.208.0
1110 0000	224	1.60.16.224.0
1111 0000	240	Not Valid

Again two values are not valid because they consist of all 0s and all 1s. Looking at Table 17, you might notice that the subnet ID always increases by 16. If you look at the first half of the octet (the part being subnetted), this is being increased by 1 each time, and the 4 other bits are ignored. Therefore you are counting by 16s.

This in fact works for all the possible subnetting scenarios. You always end up counting by the position value of the last bit in the subnet mask. To look at another example, consider what happens if you subnet on 3 bits (see Table 18).

Table 18, Subnet IDs for a Three-Bit Subnet Mask

Octet in Binary	Decimal Equivalent	Full Network ID
000 00000	0	Not Valid
001 00000	32	160.16.32.0
010 00000	64	160.16.64.0
011 00000	96	160.16.96.0
100 00000	128	160.16.128.0
101 00000	160	160.16.160.0
110 00000	192	160.16.192.0
111 00000	224	Not Valid

In this case, the last bit in the subnet mask has a position value of 32. To calculate the subnet IDs, therefore, all you need to do is look at the position value for the last bit in the subnet mask. This is the first valid subnet ID, and the value by which to increment. Table 19 summarizes all the information that you have looked at so far.

Table 19, Table for Calculating Subnet Mask, IDs, and Number of Subnets

Position Value	64	32	16	8	4	2
Subnet Bits	2	3	4	5		
Subnets	22-2=2	23 -2				
Available						
Subnet Mask						
Host Bbits						

Using Table 19, look at a network with the given class B address of 152.42.0.0. In this case, you need at least 28 subnets with a maximum of 300 hosts per subnet (segment). In this case, there is more than one right answer.

Knowing that you need 28 subnets, the obvious answer is to use 5 bits for subnetting-as you can see, that this gives you up to 30 subnets. You might, therefore, use the 255.255.248.0 as the subnet mask. This leaves 3 bits for hosts in the third octet plus the 8 in the last for a total of 11 bits. That works out to 2,046 hosts per segment.

Finding the end of the valid host IDs is also simple. Take the next subnet ID (in the case of the last subnet, use the subnet mask-which is the subnet with all 1s) and subtract 1, as shown in Table 20. This gives you a case where all the hosts' bits are on in the previous subnet. Because this is the broadcast address, you should back up one more to get the last host ID.

Table 20 Finding the Last Host ID by Subtraction

Next Subnet ID	160.16.47.255	10100000	00010000	00110000	00000000
Minus	l	00000000	00000000	00000000	00000001
Broadcast for Previous Subnet	160.16.47.255	10100000	00010000	00101111	11111111
Minus l		00000000	00000000	00000000	00000001
Last Host ID	160.16.47.254	10100000	00010000	00101111	11111110

Finding the host IDs becomes very obvious if you look at it this way, notably in the case of a subnetted class A or B address. You can apply the same math, however, when subnetting a class C address. In this case, it is not so obvious because the numbers are not familiar.

Take 198.53.202.0, for example, as a network address. You want two subnets. You end up with 198.53.202.64 and 198.53.202.128 as the two subnet IDs (subnet mask 255.255.255.192). Following the logic set out previously, the valid hosts are as follows in Table 21:

Table 21 Host IDs for a Subnetted (IP) Address

Subnet ID	Starting Host ID	Last Host ID
198.53.202.65		198.53.202.126
198.53.202.129		198.53.202.190

Finding the end of the valid host IDs is also simple. Take the next subnet ID (in the case of the last subnet, use the subnet mask-which is the subnet with all Is) and subtract 1, as shown in Table 22. This gives you a case where all the host bits are on in the previous subnet. Because this is the broadcast address, you should back up one more to get the last host ID.

Table 22, Finding the Last Host ID by Subtraction

Next Subnet ID	160.16.47.255	10100000	00010000	00110000	00000000
Minus	1	00000000	00000000	00000000	00000001
Broadcast for Previous Subnet	160.16.47.255	10100000	00010000	00101111	1111111
Minus	1	00000000	00000000	00000000	00000001
Last Host ID	160.16.47.254	10100000	00010000	00101111	11111110

Finding the host IDs becomes very obvious if you look at it this way, notably in the case of a subnetted class A or B address. You can apply the same math, however, when subnetting a class C address. In this case, it is not so obvious because the numbers are not familiar.

Take 198.53.202.0, for example, as a network address. You want two subnets. You end up with 198.53.202.64 and 198.53.202.128 as the two subnet IDs (subnet mask 255.255.255.192). Following the logic set out previously, the valid hosts are as follows in Table 23:

Table 23, Host IDs for a Subnetted Class C Address

Subnet ID	Starting Host ID	Last Host ID
198.53.202.64	198.53.202.65	198.53.202.126
198.53.202.128	198.53.202.129	198.53.202.190

EZCom IP Routing

Introduction

Routing is the primary function of an EZCom IP radio. The routing scheme implemented in the EZCom IP radio is modeled after the same routing mechanism used on the Internet. In fact the EZCom-IP radio can be used to route private network or Internet information.

Figure 18 below shows a simplified view of the processing an EZCom-IP radio performs when it receives network traffic. Packetized data or as we will refer to it throughout this discussion, datagrams can arrive at the EZCom IP layer through either the network interface (meaning from the attached Ethernet) or the RF interface (over the air). There is also one other source for datagrams those generated internally by the EZCom kernel, but we will not discussion them in this section.

Figure 18, EZCom-IP Routing Mechanism

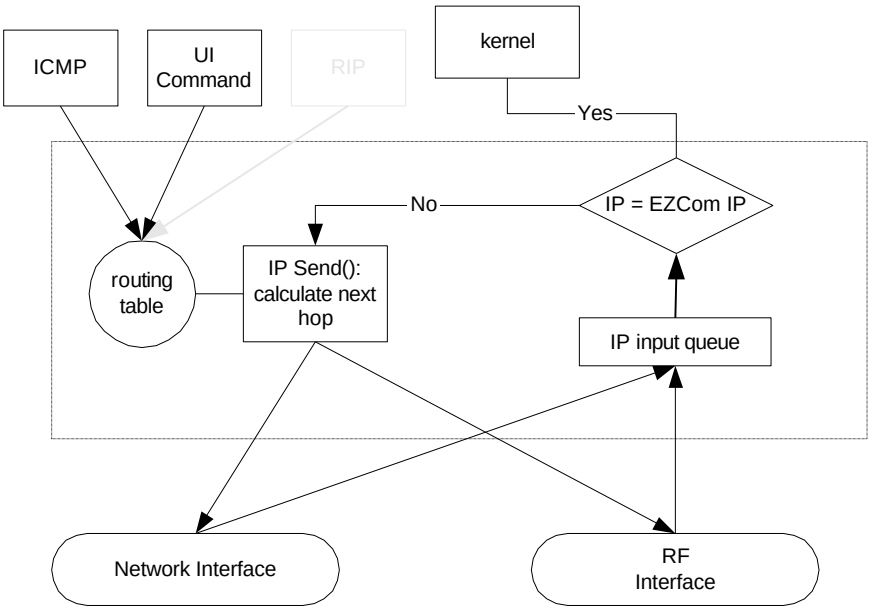


Figure 19, EZCom processing done at IP layer

Conceptually, EZCom IP routing is very simple, an EZCom-IP radio can only receive datagrams from one of two places, the network interface or the RF interface. When a datagram is first received it is placed on the input queue and the destination IP address is compared to the radio's IP address and the standard IP broadcast address. If either of these match the datagram is forwarded to the radio's kernel for further processing. If the IP addresses don't match, the datagram is moved to the IP, *send* routine.

The *send* routine then searches the routing table to determine where the datagram should be sent. We will take a closer look at this process in just a minute. First lets go over the contents of the routing table.

Table 24, Typical EZCom-IP Radio Routing Table

Target	*Subnet Mask*	*Next Hop*	*Interface*	*Origin*
192.168.1.0	255.255.255.0	192.168.1.2	Radio	Local
192.168.4.12	255.255.255.255	192.168.4.1	Radio	

Each EZCom-IP radio has a routing table in memory that it searches each time it receives a datagram to send. Each entry in the routing table contains the following information:

- Destination IP Address. This can be either a complete host address or a network address. A host address has a nonzero host ID and identifies one particular host, while a network address has a host ID of 0 and identifies all the hosts on that network.
- Subnet Mask. This is the subnet mask implemented on the destination network. This is used to ascertain the net ID and the host ID. If the Destination address is a host address the subnet mask will always be 255.255.255.255.
- Next Hop. This is the IP address of a router, or directly connected network. A next hop router is either on the attached network or is another EZCom-IP radio, which we can send datagrams to for delivery. The next hop router is typically not the final destination, but it takes the datagrams we send it and forwards them to the final destination.
- Specification of interface (Ethernet or Radio) the datagram should be passed to for transmission.
- Origin. “

The routing table shown in Table 24 is accessed frequently on a busy radio, this could mean hundreds of times a second but it is updated by the EZCom-IP Explorer program much less frequently. In most systems this will be done once initially when the network is deployed and may never be updated again unless new hardware is added to the network. On other systems where dynamic routing is implemented this could be as frequent as once every 30 seconds.

When a datagram is sent to the send routine the routing table is searched in the following order:

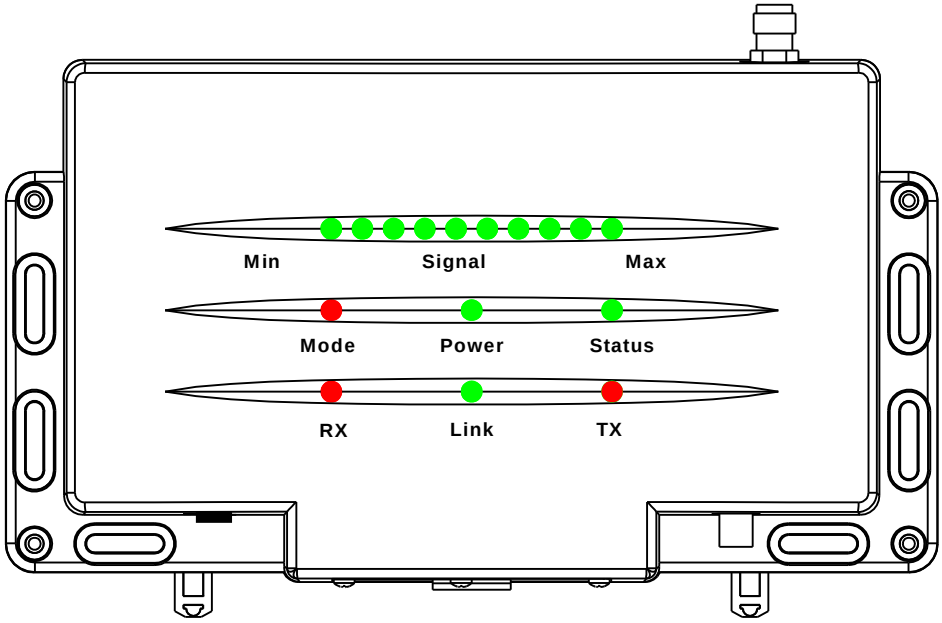
- Search the routing table for an entry that matches the complete destination IP address (matching network ID and host ID). If found, send the packet to the indicated next-hop router or final destination if it is directly connected.
- Search the routing table for an entry that matches just the destination network ID. If found, send the packet to the indicated next-hop router or to the directly connected network interface. All of the hosts on a local Ethernet are handled with a single routing table entry of this type. This check for a network match must take into account the subnet mask.
- Search the routing table for an entry labeled “default.” If found, send the packet to the indicated next-hop router. This is the Default Gateway entry on the IP Address Tab. This entry dose not show up on the Routing Tab

EZCom IP routing is done on a hop-by-hop basis. As we can see from the information stored in the routing table, EZCom IP dose not know the complete route to any destination (except, of course, those destinations that are directly connected via the network or the RF port). All IP routing provides is the IP address of the next-hop router to which the datagram is sent. It is assumed that the next-hop router is really “closer” to the destination. The process of comparing the destination IP address to EZCom’s own IP address and forwarding datagrams in accordance with the information in the routing table is referred to as the routing mechanism. For more information on IP routing please refer to the section titled “Internet Protocol Routing” on page 28 of this manual

Indicators and Connectors

The following indicators are provided on the face of the EZCom-IP radio.

Figure 20, EZCom-IP Indicators



- **Signal** is a series of 10 indicators that represent receive signal strength. When illuminated red indicates uncorrelated signal. Green is correlated.
- **Mode** indicates 1 meg/sec or when green 2 meg/sec.
- **Power** when illuminated indicates power is on.
- **Status** TBD
- **RX** when illuminated indicates data is being received via the radio.
- **Link** when illuminated indicates that an active Ethernet connection exists.
- **TX** when illuminated indicates that data is being transmitted via the radio.

Section 3. Grayhill EZCom-IP Explorer Program

Introduction

The Grayhill EZCom-IP Explorer is a client side program that can be run on any 32 bit Windows based PC. It is designed to communicate configuration and diagnostic information to and from a group of EZCom-IP radios either directly to the local area network or logically attached via the wireless network. The program offers the user a verity of configuration and diagnostic tools.

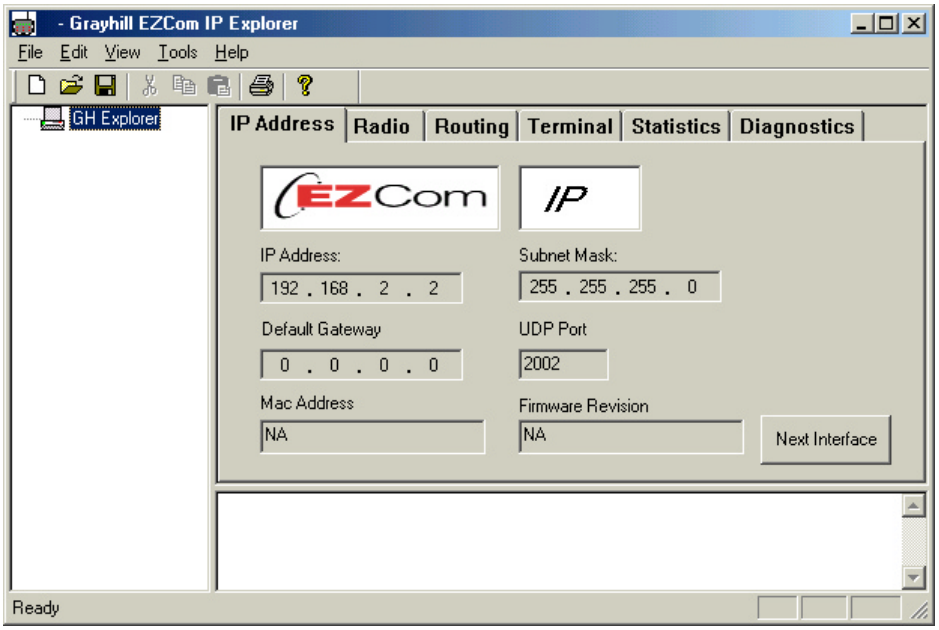
Views

The programs main window is divided into three main parts;

1. The ***Network View*** graphically displays all of the EZCom-IP, radios in a network. By selecting a radio icon in this view you are choosing which radio's settings are displayed and which radio you are linked to for editing setup information and diagnostics.
2. The ***Control View*** contains a series of tabs that are used to display different categories of setup and diagnostic information. By editing the fields on the different tabs you can change many of the radios characteristics. Some of the fields are used to only display specific information. These display only fields can be identified by their grayed background color.
3. The ***Monitor***, which can be used to observe specific communication events.

When you first start the Grayhill EZCom-IP Explorer your will see a single icon in the *Network View.* This icon represents the computer that is running the GH Explorer program. No radio icons initially appear until you instruct the Explorer program to go out and find links. If you click on the *Tools* menu and then pick *Find Links* the Explorer will go out and find any EZCom-IP radios on the local network.

Figure 21, EZCom Explorer Window

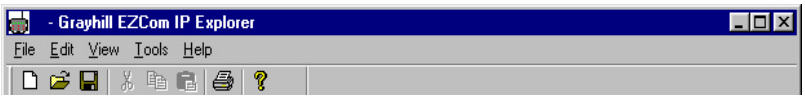


GH Explorer will then add a radio icon to the *Network View* for each radio it finds on the local network.

The information in the *Control Tab* window is associated with the icon selected in the *Network View*. As you click on different icons in the *Network View* the information in the *Control Tab View* is updated with the setup values from the object represented by the selected icon. If you select the GH Explorer icon at the top of the window (which is selected by default when you start the program) only the IP address tab is accessible. This is because the GH Explorer icon points to the PC that the program is running on and not to a radio. When you select a radio icon in the *Network View* the information in the *Control Tab* will be downloaded from the radio and displayed in the appropriate tab. Any information that is changed on the *Control Tab* will cause the setup information in the radio pointed to by the icon in the *Network View*.

As you can see changing setup information in a radio is as simple as selecting which radio you want to modify from the *Network View* and then entering the appropriate information in the *Control Tab view.*

Menus & Tool Bar



There are 5 menu selections across the top of the EZCom Explorer Program

The ***File*** menu currently only supports the Exit command. Click exit only when you are done using the Explorer program. Any setup information that has not been uploaded to the radio by clicking the *Update* button will be lost when you exit the program

The ***Edit*** menu is reserved for future use and is not enabled in this version of the EZCom-IP Explorer.

The ***View*** menu has to selection choices: a Toolbar and a Status bar item. These are used to turn on and off the Toolbar and the Status respectively. A check mark to the left of either choice indicates that the option to view that item is enabled. To change the view option just select the menu item and it will toggle from off-to-on or on-to-off.

The ***Tools*** menu has 4 choices: Options, Find Links, Remote Connect, and Disconnect.

> The ***Option*** menu when selected will cause the option dialog box to be displayed. Here you can adjust how certain features of the Explorer program operate.
>
> The ***Find Links*** menu is used to initiate the search routine for the device selected in the Network View. If the Explorer icon is selected in the Network View, then the search routine will look for any EZCom radios attached to the local Ethernet. If a radio icon is selected the search routine will look for other radios that can communicate with the selected radio. If a radio is found within communications range an icon for that radio will be added to the Network View under the selected item at the time you clicked the find links menu item. The search routine will also add routes to the routing tables to maintain ongoing communications with any radio it finds.
>
> The ***Direct Connect*** menu item is used to manually connect to a specific radio. To use Direct connect you will need to have prior knowledge of a radios IP address. After selecting the Direct Connect menu item you will be prompted to enter the IP address of the radio you would like to connect to. This option is provide to establish a connection without having to use the Find Links command.

The ***Disconnect*** menu item is used to delete a radio from the Network View. When you select Disconnect you are telling the Explorer program that you no longer want to communicate with the radio selected in the Network View. Disconnect only effects the radio selected in the Network view and any other radios that are listed below it. When there are mutable instances of the same radio in the network view you can use Disconnect to delete the unwanted duplicates.

The **Help** menu has two submenu items EZCom Explorer Help and About EZCom Explorer. Neither of which are implemented in this version of the Explorer program.

Control Tabs

There are six control tabs as shown in Figure 22. Each of these tabs is used to access a specific type of information or to control a specific type of action associated with a particular radio. The information on each tab is associated with the object selected in the Network View.

Figure 22, Control Tabs

IP Address Tab

The ***IP Address*** field is used to view or edit a radio's IP Address. The address is presented in dotted-decimal notation with each of the four numbers displayed representing one byte of the 32-bit address. With each of the numbers representing a single byte the legal range for each number is between 0 and 255.

If you have a private network (not connected to the Internet) then you can setup any addressing scheme you want. On the other hand if you are connected to the Internet without a proxy server or other DHCS then you must conform to the Internet addressing requirements.

The ***Sub Net Mask*** field is used to distinguish the network ID and host ID from the radio's IP Address. In short the subnet mask is anded with the IP address to yield the network ID. For a detailed explanation of the subnet mask and help choosing a subnet mask please see the section titled "Subnetting" on page 35.

The ***Default Gateway*** field delineates the next hope IP address that is used by the radio when no route can be found in the routing table for a particular IP address. In other words if the radio receives a packet and there is no routing information in the routing table for that IP address the radio will send it to the device with the IP address from the Default Gateway.

The ***UDP Port*** field defines the port ID used to communicate with the radios operating system. It is a read only field and it can't be changed directly on the IP Address tab. The only time you will need to change this field is if other devices on your network are using the same port number. To change the *UDP Port* setting, click on the *Tools* menu and select *Options*.

The ***Mac Address*** field is a read only field that displays the hardware address of the currently selected radio. This address is factory set and can't be changed. Each radio has a unique hardware address. You will not typically have to use this address except when you are conduction a link test.

The ***Firmware Revision*** field displays the revision level of the currently selected radio. It is important to know the Firmware revisions of your radios when contacting Grayhill for technical support.

The ***Update Button*** is used to upload any changes you have made on the IP Address tab to the currently selected radio. Any change that you make on this tab will not take effect until you click on the Update button.

Radio Tab

The Radio Tab is used to set the operating characteristics for the currently selected radio. There are only three settings that you should ever have to change: the Transmit & Receive Center Frequency, the Modulation type and the Transmit Output Power level.

The **Transmit & Receive Center Frequency** setting controls the radio carrier frequency. This is analogous with changing the station on your car's FM radio. There are 85 station settings ranging from 2418 MHz to 2443 MHz in 1MHz increments. Please note that if you change the carrier frequency you will need to change it on all of the radios in your network. Radios set on different carrier frequencies cannot communicate with each other.

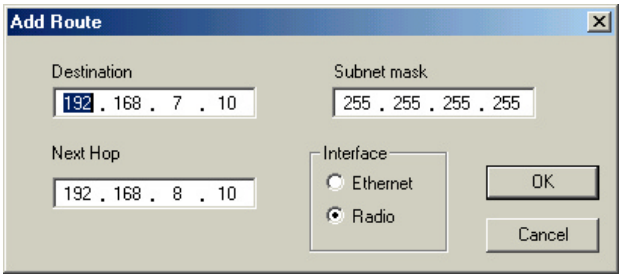
If you are planning to operate more than one network in the same geographic area and want them to operate independently you will need to set the carrier frequencies at least 17 MHz apart from each other this is due to the broadband nature of the EZCom spread spectrum radio.

The **Modulation** setting controls the type of modulation used to encode your data onto the carrier frequency. There are two different choices BPSK, which stand for Binary Phase Shift Keying and QPSK, which stands for Quadrature Phase Shift keying. There are two factors associated with the difference between the two modulation types. The primary factor is the rate at which data is transferred across the radio link. If you select BPSK the basic data rate will be 1 mbps and QPSK is 2 mbps. The other factor is the minimum receive threshold. With QPSK you need 3 dB more receive signal strength to achieve the same link quality as BPSK.

The **Transmit Output Power** level control is provided so that you can turn down the radio's transmitting power. You may want to reduce the output when you are operating in an indoor environment or when you are operating collocated independent networks. You will also have to reduce the output power 1 dB for each 3 dB of antenna gain you have above 6 dB to remain compliant with the FCC ISM band regulations

Routing Tab

The Routing Tab is used to view and/or edit a particular radios routing table. The information in the routing table controls how datagrams are routed throughout the network. The routing table looks like a miniature spreadsheet with each row representing an individual route. The columns of the spreadsheet represent the separate fields that need to be filled out for each route. There are five columns: *Target, Subnet Mask, Next Hop, Interface* and *Origin*.



You can't edit the fields directly in the spreadsheet. To enter a new route you will need to click the *Insert Button.* This will open the Add Route dialog as shown on the right.

To add a new route, enter the *Destination* IP address first. This can be either a Host address or a Network address. A Host address is the destination address for a specific device. A Network address represents all the devices on a network or subnet. After you enter a Destination address you will need to enter the *Subnet Mask*.

The form of the *Subnet Mask* is dependent on the type of destination address entered in the previous step. If the destination address is a host address then the subnet mask will always be 255.255.255.255. On the other hand if the destination address is a network address the subnet mask will be the mask implemented on the destination network. It is important that you use the subnet mask from the destination network and not from the source network unless of course they are the same.

Next enter the *Next Hop* IP address. This will always be a Host address that identifies a router that will forward the datagram onto or at least towards it's final destination. Please keep in mind that routers come in all shapes and sizes, a PC can also act as a router if it forwards datagrams, an EZCom-IP radio is a router as well. The last entry necessary to add a new route is the selection of an Interface. This is the interface that the datagram being routed will be sent out of to the next hop. The EZCom-IP radio only has two interfaces, the Ethernet port and the radio antenna port. If the next hop router is another EZCom-IP radio then the interface will be "Radio" and if the next hop router is another router on the wired network then the interface will be "Ethernet". Please note that if you have two EZCom-IP radios on the same subnet and you want to forward between them you should use "Ethernet" as the interface. This will reduce the local radio traffic and improve overall network performance.

As the final step click on the OK button and your new route will be displayed in the routing table.

If you wish to edit an existing route you will need to first select the route that you want to edit by placing the mouse pointer over any part of the row containing the specific route and clicking it once. After the row is selected click the delete button. This will remove the route from the routing table; them click the insert button and proceed as described for adding a new route.

Clicking the Delete Button will delete the highlighted route from the routing table of the currently selected radio. Please be careful because this operation is immediate you will not be asked if you really want to delete this item.

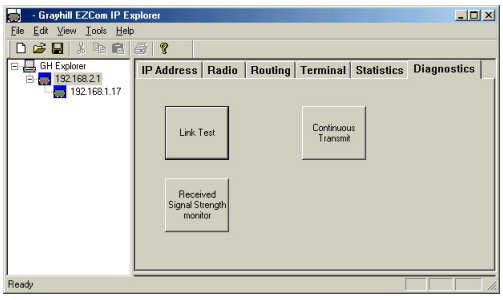
Statistics Tab

When you select the statistics tab you will initially see both the Session and the Cumulative IP statistics for the currently selected radio. Each radio in an EZCom-IP network maintains a set of statistics that can be reviewed to determine the operating condition of the radio. The statistics are divided into two categories IP statistics and Link statistics. The IP statistics are used to keep track of packet errors and packet throughput information. The Link statistics are used to keep track of transmission errors and radio throughput information. You can switch between the two by clicking on the appropriate option button on the Statistics Tab.

For both types of statistics both session and cumulative information is maintained. Session information is presented in the second column and cumulative information is in the third column. You can reset either the set if statistics by clicking the Session Rest or Cumulative Rest buttons.

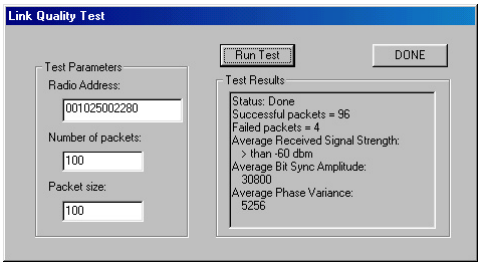
Diagnostics Tab

There are three diagnostic functions accessible from the Diagnostics Tab: Link Test, Continuous Transmit and Received Signal Strength. You can initiate any one of these functions by simply clicking on the appropriate button.



The **Link Test** can be used to verify the quality of communications between two radios. To use the link test function first select the radio that you want to initiate the link test, from the Network view. Then Click on the ***Link Test*** button, this will bring up the Link Test dialog as shown below.

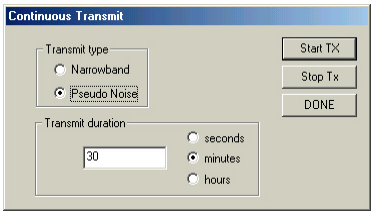
Now enter the Mac Address of the radio you want to link to and click on the *Run Test* button. You can find the MAC address for any radio in the IP Address tab of EZCom Explorer program. Please remember the information in the IP Address Tab is for the currently selected radio in the Network View. After clicking the run test button, in the Test Results window you will see an announcement that the test is in progress. During a link test packets are transmitted every 50 milliseconds. If you multiply the Number of packets by this interval you can get an idea of how long the test will take. Using the default number of packets the test should take 100*0.05 or just over a half second.



When the Link test is complete you should see the test results in the Test Results dialog. similar to the results shown in Figure 9. If your Link Test fails, that is you don't get a large number of Successful packets (typically 90% to 100%), please follow the steps listed in the Troubleshooting guide on page 50. Click on the DONE button to dismiss the Link Quality Test dialog.

The Receive Signal Strength monitor

The ***Continuous Transmit*** function is used to tell the currently selected radio to begin transmitting a test carrier. This is an advanced test feature typically only used by trained RF technicians during the instillation of a wide area network to make path loss measurements and other FCC required measurements. You can select between a narrow band carrier or a wideband pseudo noise carrier. You can also set the transmit duration from 1 second to 24 hours.



Section 4 Troubleshooting Guide

LED Activity

If you encounter difficulty using and/or installing your EZCom-IP product, the error may be related to various causes:

- Out-of range situation, which prevents the EZCom-IP radio from establishing a wireless connection with the network.
- Configuration mismatch, which prevents the EZCom-IP radio from establishing a wireless connection with the (correct) network.

The starting point to troubleshoot problems with your EZCom-IP radio is looking at the LED activity on the radio.

	Description/Action	***Color***	***Indicates***
Power LED	Continuous	Green	Radio is powered on.
Transmit			
Receive LED			
Signal Strength			
Ethernet Link	Continuous	Green	Radio and Ethernet are communicating

No Ethernet Link indicator.

Some possible causes for this problem are:

1. One of the devices is not turned on. Make sure both devices are “ON” and appear to be powered up.
2. The patch cable is defective; try using a different patch cable.
3. One of the devices has a bad Ethernet port: if you have a spare device try substituting it.

Link Test Failed

The link test is designed to test the radio communications between two radios. If a link test fails there are many possible reasons. The following steps may help to isolate the problem.

1. On the Radio Tab of the EZCom-IP Explorer program verify that both radios are set on the same carrier frequency, Modulation type and that both are using the same PN code. If any of these settings are different the two radios will not be able to communicate with each other.
2. View the TX LED on the face of the radio that is initiating the link test and verify that it is periodically flashing. This will confirm the right radio is selected and that it is indeed trying to link with the remote (or other) radio.
3. If you are using an external antenna check that the antenna cable is connected at both ends and that the connections are at tight. If you have a VSWR meter check the match of the complete cable and antenna assembly. You should get a reflection ratio measurement of less than 2:1 or an efficiency match of better than 90%. If your VSWR is greater than 2/1 or efficiency is less than 90% you will

need to isolate and correct the mismatch. Typically poor VSWR readings are caused by poorly installed cable connectors. Some times if there is a Polyphaser used for lightning suppression they can go bad and cause a poor VSWR.

4. If the 2 radios are separated by a large distance say a few miles or more try running a link test to a closer in radio or possibly a spare radio if one is available. If the link test works after reducing the separation between the radios look for one of the following.
    a. If directional antennas are used verify they are aimed correctly. The higher the antennas gain the more critical is the alignment.
    b. Look for obstructions in the line of sight path between the antennas. Obstructions such as trees and buildings can greatly reduce the rang of you EZCom-IP radio. If obstructions are noted try raising the antenna height to get over the obstructions.

Ping Failed to Respond

When Ping fails it indicates that there is no logical connection between two IP Addresses. There are a few things that can be done to isolate the cause of the problem. Due to the variety of different network configurations it is hard to present a step-by-step troubleshooting procedure that will work for every instance. Therefore what is presented below is a list of different techniques that can be used to isolate the problem.

- First try to Ping the EZCom-IP radios on the local subnet, then try to Ping the radio across the wireless link. This should help to localize the problem.
- If you can't Ping the local radio check to make sure both the host and the radio link LEDs are illuminated if necessary check to see that both IP addresses are correct.
- If you can't Ping the radio across the wireless link you may consider running a link test to verify the radio communications.
- It may be necessary to Ping in the opposite direction to localize the problem.
- You can also Ping other devices on the network to verify the local host is operating properly.

Appendix A. Ethernet (CSMA/CD)

The most commonly used medium access control technique for bus/tree and star topologies are carrier-sense multiple access with collision detection (CSMA/CD). The original baseband version of this technique was developed by Xerox as part of the Ethernet LAN. The original broadband version was developed by MITRE as part of its MITREnet LAN. All of this work formed the basis for the IEEE 802.3 standard.

It is easier to understand the operation of CSMA/CD if we look first at some earlier schemes from which CSMA/CD evolved.

Precursors

CSMA/CD and its precursors can be termed random access, or contention, techniques. They are random access in the sense that there is no predictable or scheduled time for any station to transmit; station transmissions are ordered randomly. They exhibit contention in the sense that stations contend for time on the medium. This is true for both wired and wireless side of an Ethernet LAN.

The earliest of these techniques, known as ALOHA, was developed for packet radio networks. However, it is applicable to any shared transmission medium. ALOHA, or pure ALOHA as it is sometimes called, is a true free-for-all. Whenever a station has a frame to send, it does so. The station then listens for an amount of time equal to the maximum possible round-trip propagation delay on the network (twice the time it takes to send a frame between the two most widely separated stations) plus a small fixed time increment. If the station hears an acknowledgment during that time, fine; otherwise, it resends the frame. If the station fails to receive an acknowledgment after repeated transmissions, it gives up. A receiving station determines the correctness of an incoming frame by examining a framecheck-sequence field. If the frame is valid and if the destination address in the frame header matches the receiver's address, the station immediately sends an acknowledgment.

A frame may be invalid due to noise on the channel or because another station transmitted a frame at about the same time. In the latter case, the two frames may interfere with each other at the receiver so that neither gets through; this is known as a collision. If a received frame is determined to be invalid, the receiving station simply ignores the frame.

ALOHA is as simple as can be, and pays a penalty for it. Because the number of collisions rises rapidly with increased load, the maximum utilization of the channel is only about 18%.

To improve efficiency, a modification of ALOHA, known as slotted ALOHA, was developed. In this scheme, time on the channel is organized into uniform slots whose size equals the frame transmission time. Some central clock or other technique is needed to synchronize all stations. Transmission is permitted to begin only at a slot boundary. Thus, frames that do overlap will do so totally. This increases the maximum utilization of the system to about 37%.

As you can see both ALOHA and slotted ALOHA exhibit poor utilization. Both fail to take advantage of one of the key properties of both radios and wired LANs, which is that propagation delay between stations is usually very small compared to frame transmission time. Consider the following observations. If the station-to-station propagation time is large compared to the frame transmission time, then, after a station launches a frame, it will be a long time before other stations know about it. During that time, one of the other stations may transmit a frame; the two frames may interfere with each other and neither gets through. Indeed, if the distances are great enough, many stations may begin

transmitting, one after the other, and none of their frames get through unscathed. Suppose, however, that the propagation time is small compared to frame transmission time. In that case, when a station launches a frame, all the other stations know it almost immediately. So, if they had any sense, they would not try transmitting until the first station was done. Collisions would be rare because they would occur only when two stations began to transmit almost simultaneously. Another way to look at it is that a short delay time provides the stations with better feedback about the state of the network; this information can be used to improve efficiency.

The foregoing observations led to the development of carrier-sense multiple access (CSMA). With CSMA, a station wishing to transmit first listens to the medium to determine if another transmission is in progress (carrier sense). If the medium is in use, the station must wait. If the medium is idle, the station may transmit. It may happen that two or more stations attempt to transmit at about the same time. If this happens, there will be a collision; the data from both transmissions will be garbled and not received successfully. To account for this, a station waits a reasonable amount of time, after transmitting, for an acknowledgment, taking into account the maximum round-trip propagation delay, and the fact that the acknowledging station must also contend for the channel in order to respond. If there is no acknowledgment, the station assumes that a collision has occurred and retransmits.

One can see how this strategy would be effective for networks in which the average frame transmission time is much longer than the propagation time. Collisions can occur only when more than one user begins transmitting within a short time (the period of the propagation delay). If a station begins to transmit a frame, and there are no collisions during the time it takes for the leading edge of the packet to propagate to the farthest station, then there will be no collision for this frame because all other stations are now aware of the transmission.

The maximum utilization achievable using CSMA can far exceed that of ALOHA or slotted ALOHA. The maximum utilization depends on the length of the frame and on the propagation time; the longer the frames or the shorter the propagation time, the higher the utilization.

With CSMA, an algorithm is needed to specify what a station should do if the medium is found busy. The most common approach, and the one used in IEEE 802.3, is the 1- persistent technique. A station wishing to transmit listens to the medium and obeys the following rules:

1. If the medium is idle, transmit; otherwise, go to step 2.
2. If the medium is busy, continue to listen until the channel is sensed idle; then transmit immediately.

If two or more stations are waiting to transmit, a collision is guaranteed. Things get sorted out only after the collision.

Description of CSMA/CD

CSMA, although more efficient than ALOHA or slotted ALOHA, still has one glaring inefficiency: When two frames collide, the medium remains unusable for the duration of transmission of both damaged frames. For long frames, compared to propagation time, the amount of wasted time can be considerable. This waste can be reduced if a station continues to listen to the medium while transmitting. This leads to the following rules for CSMA/CD:

1. If the medium is idle, transmit; otherwise, go to step 2.
2. If the medium is busy, continue to listen until the channel is idle, and then transmit immediately.

3. If a collision is detected during transmission, transmit a brief jamming signal to assure that all stations know that there has been a collision and then cease transmission.
4. After transmitting the jamming signal, wait a random amount of time, and then attempt to transmit again. (Repeat from step 1.)

An important rule followed in most CSMA/CD systems, including the IEEE standard, is that frames should be long enough to allow collision detection prior to the end of transmission. If shorter frames are used, then collision detection does not occur, and CSMA/CD exhibits the same performance as the less efficient CSMA protocol.