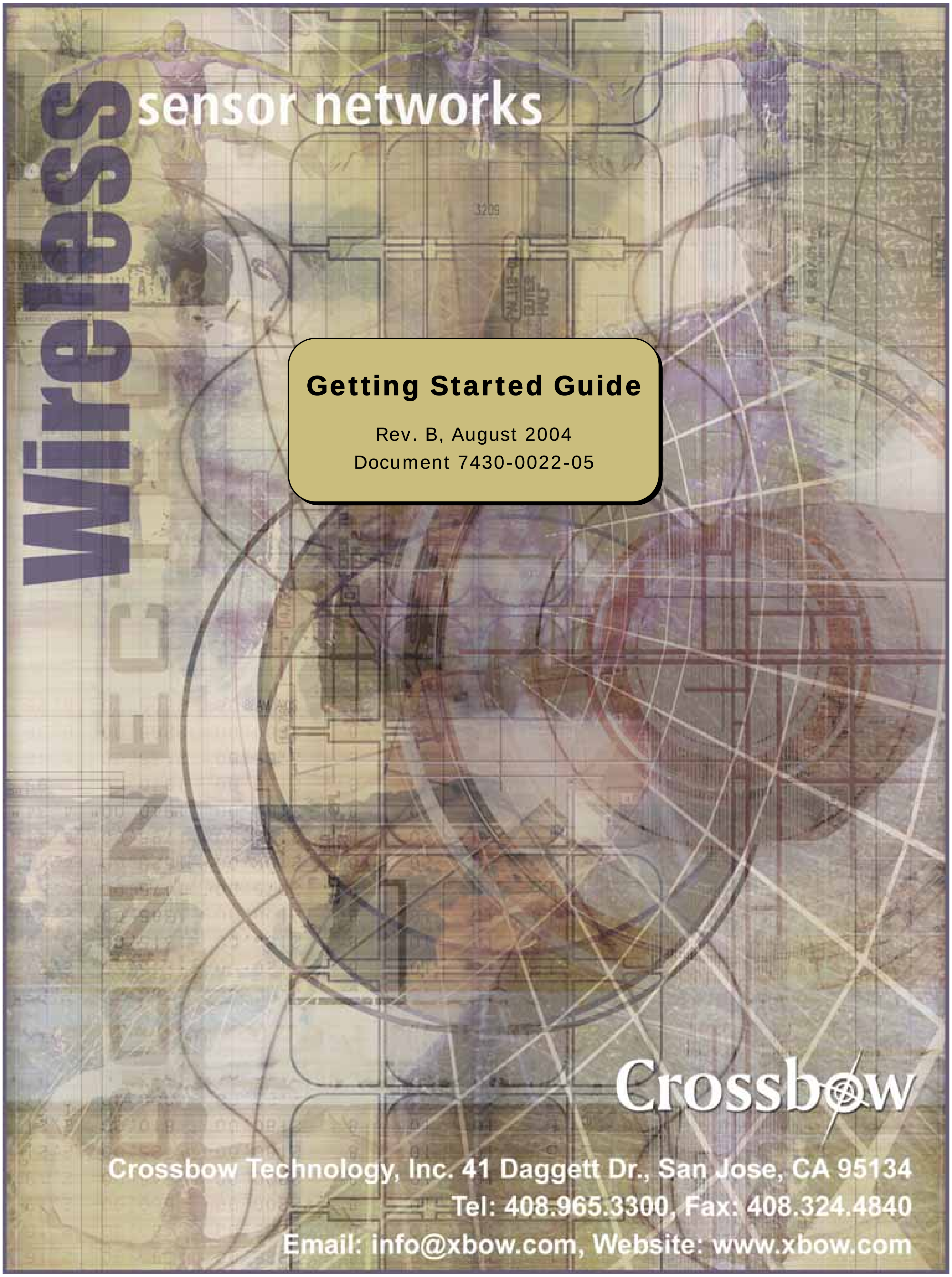

Getting Started Guide

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Crossbow

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About This Document

The following annotations have been used to provide additional information.

NOTE

Note provides additional information about the topic.

☑ EXAMPLE

Examples are given throughout the manual to help the reader understand the terminology.

IMPORTANT

This symbol defines items that have significant meaning to the user

WARNING

The user should pay particular attention to this symbol. It means there is a chance that physical harm could happen to either the person or the equipment.

The following paragraph heading formatting is used in this manual:

1 Heading 1

1.1 Heading 2

1.1.1 Heading 3

This document also uses different body text fonts (listed in Table 1-1) to help you distinguish between names of files, commands to be typed, and output coming from the computer.

Table 1-1. *Font types used in this document.*

Font Type	Usage
`Courier New Normal`	Sample code and screen output
`Courier New Bold`	Commands to be typed by the user
Times New Roman Italic	TinyOS files names, directory names
Arial	Text labels in GUIs

1 Mesh Networking Right Out-of-the-Box

Wireless sensor networks have attracted a wide interest from academia and industry alike due to their diversity of applications. Sensor networks are pervasive by nature; the number of nodes in a network is nearly boundless. Therefore, a key to realizing this potential is multi-hop mesh networking, which enables scalability and reliability. A mesh network is really a generic name for a class of networked embedded systems that share several characteristics including,

- **Multi-Hop—**the capability of sending messages peer-to-peer to a base station, thereby enabling scalable range extension;
- **Self-Configuring—**capable of network formation without human intervention;
- **Self-Healing—**capable of adding and removing network nodes automatically without having to reset the network; and
- **Dynamic Routing—**capable of adaptively determining the route based on dynamic network conditions (*e.g.*, link quality, hop-count, gradient, or other metric).

When combined with battery power management, these characteristics allow sensor networks to be long-lived, easily deployed, and resilient to the unpredictable wireless channel. With mesh networking, the vision of pervasive and fine-grained sensing becomes reality.

Crossbow has developed multi-hop, mesh networking firmware that implements the above characteristics. To help customers try mesh networking, the MICAz, MICA2 and MICA2DOT Motes that come in Crossbow's Basic and Professional MOTE-KITs come preinstalled with a mesh networking application called *Surge_Reliable*. The mesh networking algorithm is based on work by Alec Woo and others at the University of California at Berkeley. The algorithms were extended and improved via a commercial software development and testing process.

We also have a set of PC software tools called *Surge-View*. Included is an enhanced *Surge* graphical user-interface to view the Motes' connectivity, routing statistics, and sensor board data. Furthermore, users can store network performance data into their PCs for post-processing. A second program called *Stats* gives an overall summary of the network health. Another program called *HistoryViewer* allows for manual playback of the network's topology and statistics.

IMPORTANT

This Chapter is geared for the MOTE-KIT Users only. Crossbow's Basic and Professional MOTE-KITs come pre-installed with a mesh networking application called *Surge_Reliable*. If you did not purchase a complete Kit, instead purchased individual boards, please proceed to Chapter 2. The Mote firwmare and PC software are on the *TinyOS Support Tool*s CDROM that comes with wireless the products.

1: Copying Surge-View to a PC

- Insert CDROM into your PC's CDROM drive.
- Copy the folder *Surge-View* and paste into your *C:\Program Files* directory.

2: Getting the Motes Ready

- Install batteries into your Motes, except for the one labeled with "Base" and/or "0".
- Turn on the MICA2 or MICAz Motes using the switch that's on the Mote's PCB. (The MICA2DOTs automatically turn on when the battery is attached.)
- Verify antennas are attached to MICA2 motes.

3: Connecting the MIB510 to a PC

- Connect MIB510 to the serial port of your PC with an RS-232 straight-through serial cable.
- Attach the MICA2 or MICAz mote labeled as "Base_###_0 to the MIB510.

4: Starting the SerialForwarder GUI

- Using Windows Explorer, navigate to the *Surge-View* folder under *Program Files*.
- Double-click on *Serialforwarder.exe*
- When the SerialForwarder window appears, click on "Stop Server."
- Set the COM port number and serial port speed to 57600 in the box under "Mote Communications." An example line is **`serial@COM1:57600`**
- Click on "Start Server."

5: Starting the Surge GUI

- Open a *Command Prompt* window.
- Change the directory to Program Files\Surge-View with **`cd ..\..\Program Files\Surge-View`**
- Type in **`Surge 125`**. (The "**`125`**" is the default group ID.)
- This should invoke the *Surge-View* GUI.

6: Viewing the Results

- The *Network Topology* and *Statistics* windows should appear.
- Wait one to two minutes for the remote nodes to appear.

Figure 1-1. *Flow chart on how to get the Surge-View mesh networking demo running. The "###" in "Base_###_0" will either be 315, 433, 900 or 2400. The "COM#" is the serial port number to which the MIB510 is connected. (Using MIB510 Serial interface board, Serial Cable and PC)*

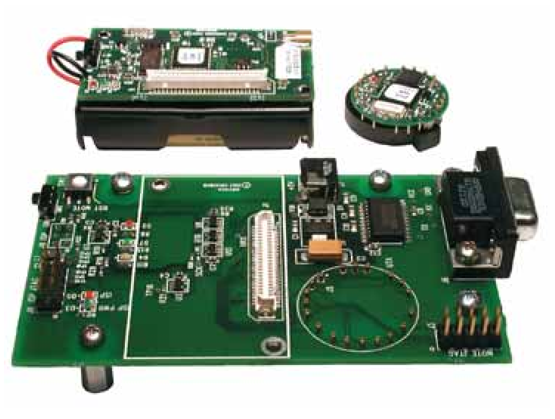
1.1 Installing the Surge-View Folder onto Your PC

- Insert the TinyOS Support Tools CDROM into your PC.
- Using Windows Explorer, open the *Crossbow Software* folder.
- Copy the *Surge-View* folder into your *C:\Program Files* directory.

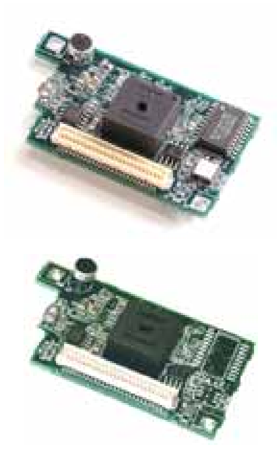
Some of the commands in the Surge-View folder are run by typing in a *Command Prompt* window. You may want to put a shortcut to it (left click on Start>Programs>Accessories, then right click on *Command Prompt*, choose "Create Shortcut") in a convenient location like the desktop or in the Windows® Start Menu.

1.2 Preparing the Sensor Nodes and Base Station

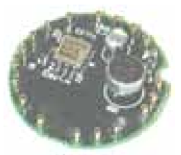
The Motes in your basic or professional MOTE-KIT come pre-programmed with the mesh networking firmware: *Surge_Reliable* and *Surge_Reliable_Dot* for the MICAz, MICA2 and MICA2DOT, respectively. The set of hardware that is used for this application is shown in Figure 1-2 below.



(A)



B) MTS310 and MTS300



C) MTS510

Figure 1-2. *Pictures of the basic hardware used in the mesh networking application. A) In front: MIB510 topside. In back: a MICA2/MICAz and a MICA2DOT both **without** antennas. Antennas **must** be attached to have good radio transmission and reception. B and C) Sensor boards for the MICA2 and MICA2DOT, respectively. The term "sensor node" will be used in this document to mean a MICA2|DOT Mote + sensor board.*

- Install AA batteries and a 3V coin cell in the MICAz/MICA2 and MICA2DOT Motes, respectively. Attach the antennas to the MICAz/MICA2 Motes. Switch the MICAz/MICA2 battery switch to the "ON" position. The MICA2DOTs don't have an "ON/OFF" switch and are automatically powered when the battery is installed.
- Setting up the **base station**: Attach the MICAz/MICA2 Mote labeled "Base_###_0" to the MIB510, where ### refers to the frequency band of your Mote (i.e., 315, 433, 900 or 2400). Supply power to the MIB510 with the AC wall power adaptor. Connect the MIB to your PC's serial port (or USB to serial adaptor) with a straight-through RS-232 cable.

NOTE: The Professional MOTE-KITs come with two MDA500 data acquisition boards. These are circular PCBs populated only with 19 pins. These can be used to make it easier to attach a MICA2DOT to the MIB510. This is done by connecting the 19 female-side of the MDA500 to the 19 male pins on the MIB510. The flexibility of the board and pins of the MDA500 helps to make up for small misalignments between the boards and avoids bending of pins on MIB510.

- Setting up the **sensor nodes**: Attach the MTS300 (found in the Basic kit) or MTS310 (found in the Professional kit) to your MICAz/MICA2 Motes. (Professional kit only: If necessary, attach the MTS510 sensor board to each MICA2DOT.) While the Motes for this demo are pre-labeled with numbers, it does not matter which sensor boards you attach to the Mote as long as its of a compatible kind, e.g., MTS310/MDA300 to MICAz; MTS300/310 to MICA2; MTS510 to a MICA2DOT.

1.3 SerialForwarder

The *SerialForwarder* is a program written in Java, and it is used to read packet data from a computer's serial port and forward it over a server port connection, so that other programs can communicate with the sensor network via a sensor network gateway. *SerialForwarder* does not display the packet data itself, but rather updates the packet counters in the lower-right hand corner of the window. Once running, the serial forwarder listens for network client connections on a given TCP port (9001 is the default for MIB510 and 10002 for MIB600), and simply forwards TinyOS messages from the serial port to the network client connection, and vice versa. Note that multiple applications can connect to the serial forwarder at once, and all of them will receive a copy of the messages from the sensor network.

You can startup the *SerialForwarder* in one of two ways:

1. Double-clicking on the file *SerialForwarder.exe* using *Windows Explorer* (right click on "start" on the task bar and navigate to *C:\Program Files\Surge-View*). See Section 1.3.1 for details. **OR…**
2. Typing in a command line in a *Command Prompt* window (found in start>Programs>Accessories). See Section 1.3.2 for details.

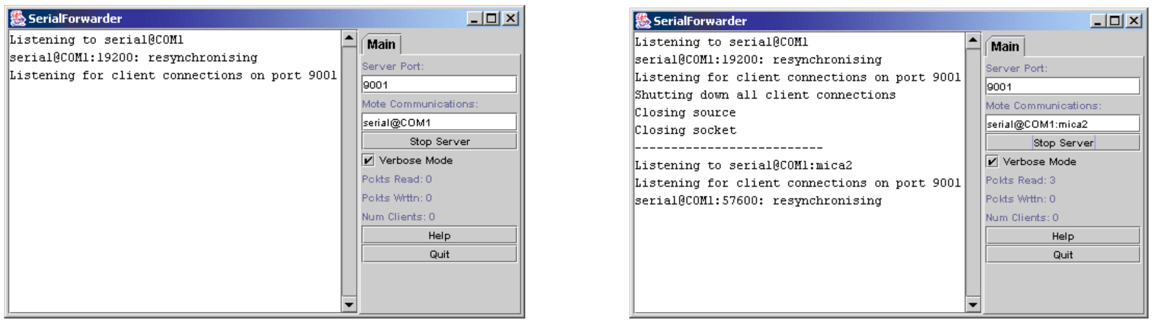
1.3.1 Double-clicking on the file *SerialForwarder.exe* in the *Surge-View* folder

If you used *Windows*® *Explorer* and double-clicked on *SerialForwarder.exe*, then a window with the label **SerialForwarder** screen should appear.

- Check that the **Server Port** is set to 9001.
- Click on **Stop Server** (which then becomes **Start Server**). Edit the text box under Mote Communications to

  `serial@COM<#>:mica2`

  where **<#>** = **`1`**, **`2`**, **`3`**, etc., for serial port COM1, COM2, COM3, etc.
- Click on **Start Server** (which then becomes **Stop Server**).


```
Listening to serial@COM1
serial@COM1:19200: resynchronising
Listening for client connections on port 9001
```
Server Port: 9001
Mote Communications: serial@COM1
Verbose Mode ✓
Pckts Read: 0
Pckts Wrttn: 0
Num Clients: 0

```
Listening to serial@COM1
serial@COM1:19200: resynchronising
Listening for client connections on port 9001
Shutting down all client connections
Closing source
Closing socket
--------------------------
Listening to serial@COM1:mica2
Listening for client connections on port 9001
serial@COM1:57600: resynchronising
```
Server Port: 9001
Mote Communications: serial@COM1:mica2
Verbose Mode ✓
Pckts Read: 3
Pckts Wrttn: 0
Num Clients: 0

Figure 1-3. *Left) The Java application SerialForwarder when it first appears. Right) When you click on "Start Server," it prints what serial port, speed, and port. A third line should include the word "resynchronizing."*

You should see the **Pckts Read** number increase if your MIB510 has an attached MICAz/MICA2 Mote labeled with "Base_###_0" and is plugged into your PC and that you have the remaining Motes installed with batteries and antennas as needed. (The "###" will either be 315, 433, 900 or 2400)

1.3.2 Command Prompt directions

- Start the *Command Prompt* program by going to the Windows® Taskbar and clicking on Start>Programs>Accessories>Command Prompt.
- Change the directory to *C:\Program Files\Surge-View*. If the default directory is *C:\Documents and Settings\[Your User Name]>*, use the following command line.

  ```
  cd ..\..\Program Files\Surge-View
  ```

- Start *SerialForwarder* along with the -comm port information

  ```
  SerialForwarder -comm serial@COM<#>:57600
  ```

  where **<#>** = 1, 2, 3, etc. for serial port COM1, COM2, COM3, etc.

The **-comm** argument tells *SerialForwarder* to communicate over a specific serial port (`COM1` in the example above).

1.4 Running the *Surge* GUI

To run the *Surge* graphical user-interface:

- Start the program *Command Prompt* (if not running) by going to the Windows® Taskbar and clicking on Start>Programs>Accessories>Command Prompt.
- Change directory to the *Surge-View* folder under *C:\Program Files*.

  ```
  cd ..\..\Program Files\Surge-View
  ```

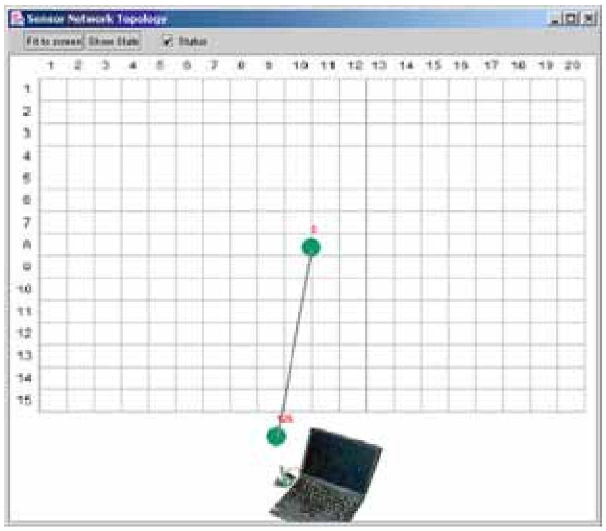
- Type in the command line below:

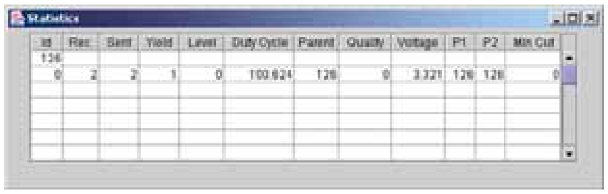
  ```
  Surge 125 > log_filename
  ```

  The "**125**" is the default group ID for your network. Surge will output on the *Command Prompt* window the raw network data. You can write that output to a file. To do this include the "**> *log_filename***" text as shown above, where ***log_filename*** is a user defined file name for the output.

When the application starts, you should immediately see the base node reporting sensor values. Typically after one to two minutes (but could be longer depending on how many nodes you have in the network), the remote nodes should appear as the network topology builds. A solid green line indicates an active data transmission link. A blue line represents a partially active communication link. A red line indicates that the link is no longer active and will soon disappear from the topology view until the link is re-established.

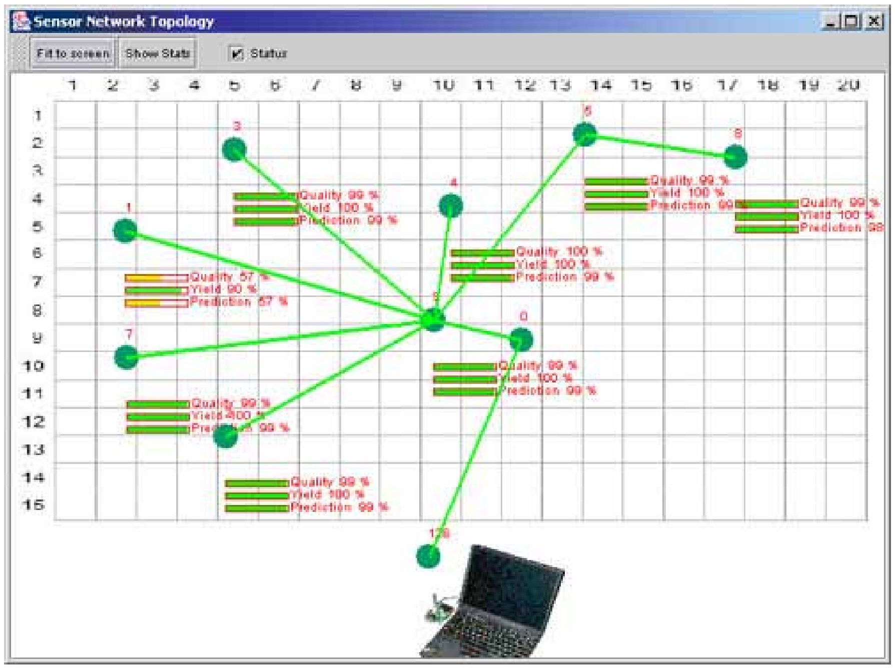
NOTE: The location of the node IDs on the screen does not represent the physical location of the nodes in the neighborhood of the PC.

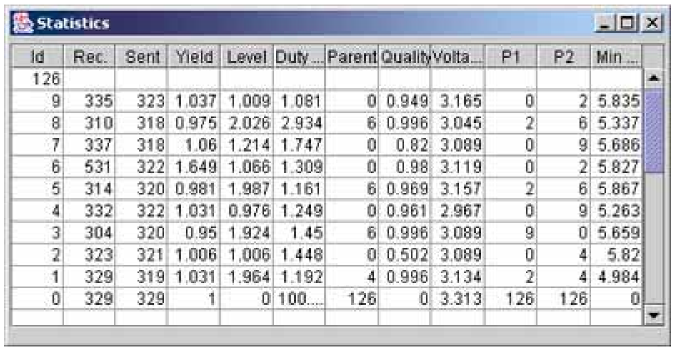




Id	Rec	Sent	Yield	Level	Duty Cycle	Parent	Quality	Voltage	P1	P2	Min Cut
126											
0	2	2	1	0	100.624	126	0	3.321	126	126	0

Figure 1-4. *Network topology and Statistics windows. Initially only the base station Mote as node 0 and host PC as node 126 appear on the Topology window.*





Id	Rec.	Sent	Yield	Level	Duty ...	Parent	Quality	Volta...	P1	P2	Min ...
126											
9	335	323	1.037	1.009	1.081	0	0.949	3.165	0	2	5.835
8	310	318	0.975	2.026	2.934	6	0.996	3.045	2	6	5.337
7	337	318	1.06	1.214	1.747	0	0.82	3.089	0	9	5.686
6	531	322	1.649	1.066	1.309	0	0.98	3.119	0	2	5.827
5	314	320	0.981	1.987	1.161	6	0.969	3.157	2	6	5.867
4	332	322	1.031	0.976	1.249	0	0.961	2.967	0	9	5.263
3	304	320	0.95	1.924	1.45	6	0.996	3.089	9	0	5.659
2	323	321	1.006	1.006	1.448	0	0.502	3.089	0	4	5.82
1	329	319	1.031	1.964	1.192	4	0.996	3.134	2	4	4.984
0	329	329	1	0	100....	126	0	3.313	126	126	0

Figure 1-5. *After a minute, the other Motes will begin to appear. Depending on the number of Motes, the entire network may take several minutes to come on line.*

NOTE: For Professional MOTE-KIT users. The MICA2DOTs have a default transmit rate of once every two seconds. The MICA2s have a transmit rate of once per eight seconds. Therefore, in the "Statistics" window, the "sent" counter for the MICA2DOTs to be about four times the amount as the MICA2s. This will allow you to test how transmission rates affect quality and yield. You can change either the MICA2s or MICA2DOT's transmit rate.

1.4.1 Changing the background to the Surge UI

The background image displayed in the Sensor Network Topology window can be changed to any jpeg image file. The file called *Surge_background.jpg* is in the *Surge-View\images\* folder. Rename the existing file and then save your own jpeg image file as *Surge_background.jpg*.

1.5 Analyzing Network-data with *Stats*

If you entered in a *log_filename* when starting *Surge* GUI, a colon delimited .txt file is stored onto your disk. This file can be read by a text editor, word processor, or spreadsheet program.

To run the Surge-View interface *Stats.exe*:

- If not active, open a *Command Prompt* window by clicking on Start>Programs>Accessories>Command Prompt
- Change directory to the *Surge-View* folder under *C:\Program Files*

  ```
  cd ..\..\Program Files\Surge-View
  ```

- Run the *Stats* program by piping in ("<") the name you used for log_filename. Optionally you can also write the *Stats* output to file (using ">") and assigning a filename.

  ```
  Stats < log_filename > stats_filename
  ```

  The above command line reads in the file with the network data log and then writes a colon delimited .txt file which can be read by a text editor, word processor, or spreadsheet program.

☑ EXAMPLE—Imported *Stats* Output Turned Into an Excel® File

Node Number	Packets Received	Packets Sent	Success Rate	Parent Changes	Level Changes	Average Level	Duty Cycle	Battery Voltage
1	1211	1270	0.95	140	79	2.26	1.04	3.16
2	1272	1273	1.00	15	8	1.87	1.14	3.12
3	1266	1276	0.99	2	1	2.00	1.31	3.11
4	1275	1277	1.00	8	5	1.86	1.07	2.99
5	1267	1276	0.99	11	3	1.99	1.19	3.19
7	1267	1276	0.99	2	1	2.00	3.10	3.11
8	1255	1276	0.98	5	7	2.89	1.99	3.08
9	1278	1278	1.00	0	1	1.00	1.49	3.19

1.6 Reviewing Network Topology and Yield with *HistoryViewer*

Another way to look at the performance of your wireless network is with the program called *HistoryViewer*. Your data should be a file or subdirectory in the Surge-View folder.

To run the Surge-View interface *HistoryViewer.exe*:

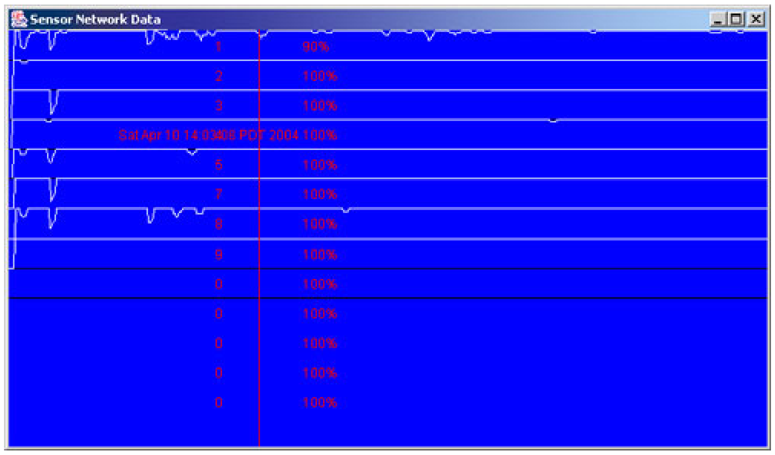
- If not active, open a *Command Prompt* window by clicking on Start>Programs>Accessories>Command Prompt
- Change directory to the *Surge-View* folder under *C:\Program Files*.

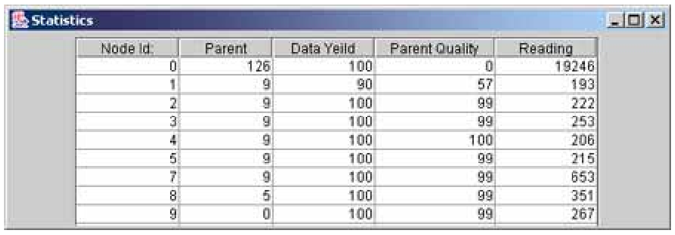
  ```
  cd ..\..\Program Files\Surge-View
  ```

- Type in the following command line. (The "**<**" symbol pipes in the data from the data file *log_filename*.)

  ```
  HistoryViewer < log_filename
  ```

Three windows should appear: a "Sensor Network Topology," a "Sensor Network Data," and a "Statistics" window. In the Sensor Network Data window, use your mouse to move the vertical, red line to examine the statistics and network topology at that date/time.




Statistics

Node Id:	Parent	Data Yeild	Parent Quality	Reading
0	126	100	0	19246
1	9	90	57	193
2	9	100	99	222
3	9	100	99	253
4	9	100	100	206
5	9	100	99	215
7	9	100	99	653
8	5	100	99	351
9	0	100	99	267

Figure 1-6. *Sensor Network Data and Statistics and Topology (not shown) appear when* HistoryViewer.exe *is started.*

2 Installation of TinyOS

This Chapter takes you through the installation of TinyOS 1.1.0, then update to version 1.1.7, and copying of the Crossbow directory, *contrib/xbow/*, on a Windows®-based PC. Installation is required if you want to install firmware on your Motes and/or do firmware development. Following the installation, read Chapter 3 which covers many important programming topics, instructions for compiling and downloading the application firmware into your Motes, and useful programming environment customizations.

2.1 What You Need for Installation

- Crossbow's TinyOS Support Tools CD-ROM
- A Windows®-based PC
  - Operating System: Microsoft Windows® (XP, 2k, NT)
  - 1 GB or more of free space in destination drive
  - 550 MB or more of space in C drive, regardless of destination drive or set the TEMP directory to your destination drive
- Third-party Software
  - WinZip®
  - Adobe Acrobat® PDF Reader
  - Programmers Notepad (available for free at http://www.pnotepad.org/)

2.2 Installing TinyOS 1.1.0, Development Tools, and TinyOS 1.1.7 Updates

NOTE: The installation instructions for TinyOS 1.1.0 are found in *TinyOS Quick Install.htm* found on the CDROM. If you have a previous version of TinyOS or an unsuccessfully installation on your system, you **must** uninstall it. Instructions for this are found in the *Uninstalling TinyOS.htm* on the CD.

Also you **must** install with Administrator privileges. If you don't, the setup will eventually abort but it could leave unwanted files and program registries behind. If you are using Windows NT, you must log on as the "administrator" and not as one who has administrator privileges.

The TinyOS 1.1.0 InstallShield Wizard setup offers the following software packages:

- TinyOS
- TinyOS Tools
- nesC
- Cygwin (An icon for Cygwin will appear on your Desktop when TinyOS 1.1.0 is installed.)
- Support Tools
- Java 1.4 JDK & Java COMM 2.0
- Graphviz
- AVR Tools
  - avr-binutils
  - avr-libc
  - avr-gcc
  - avarice

» avr-insight

2.2.1 Installing TinyOS 1.1.0

Insert the Crossbow *TinyOS Support Tools* CD-ROM into the CD drive of your PC. Open up a window to display the contents of the CD-ROM. Then click on the folder *TinyOS Install/* and then double click on *tinyos-1.1.0is.exe*. After you run on the *tinyos-1.1.0-1is.exe*, the InstallShield Wizard appears and will guide you through the install process. This step may take several minutes (up to an hour).

2.2.2 Updating to TinyOS 1.1.7

Many of the Crossbow applications in the *contrib/xbow/* (See Section 2.2.3 below) directory need to have the updates to TinyOS that have come with the v 1.1.7. As a convenience the TinyOS 1.1.5 RPM is included in the TinyOS Support Tools CDROM. The RPM file name is "tinyos-1.1.7July2004cvs-1.cygwin.noarch.rpm**"** found under *TinyOS Updates* folder.

The instructions are as follows:

- Save your previous work. We recommend making a tarball or copy of your **entire** TinyOS-1.x directory and saving it someplace.
- Copy to a C:\ drive directory of your choice the file tinyos-1.1.7July2004cvs-1.cygwin.noarch.rpm which is in the TinyOS Support Tools CDROM under *TinyOS Updates* folder.
- Install: Open Cygwin by double-clicking on the Cygwin icon on your desktop. Be sure that you have administrator privileges. Then type

  ```
  rpm --force --ignoreos -Uvh tinyos-1.1.7July2004cvs-
  1.cygwin.noarch.rpm
  ```

  in the directory where you saved the rpm. This will take a while (the tinyos package installation includes compiling the java code). TinyOS is installed in /opt/tinyos-1.x.
- You're done! Check the documentation in *opt/tinyos-1.x/doc/index.html* for more information. See "Installing and Updating Packages" if you want to install any optional packages.

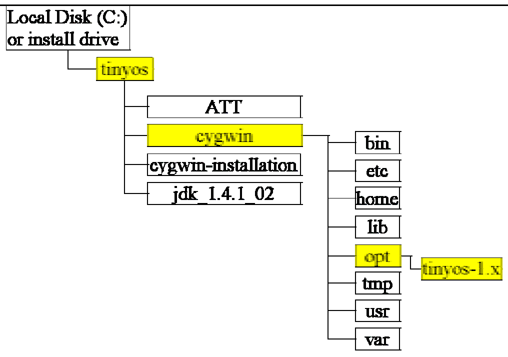
2.2.3 Copy the Crossbow TinyOS Directory (xbow/) into the contrib/ Directory.

Crossbow has developed a number of firmware applications that are not in the main tinyos-1.x/apps/ directory. They are on the TinyOS Support Tools CDROM as a zip file (xbow.tgz) and need to be copied into the *tinyos-1.x/contrib/* directory.

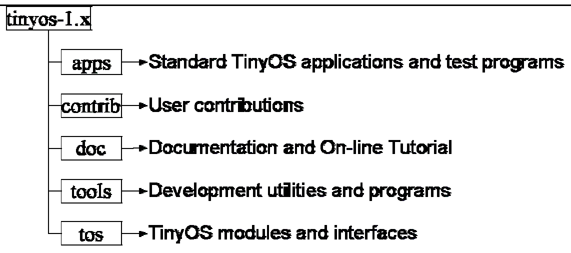
- Verify that a directory called *contrib* exists under the tinyos-1.x directory. That is it is at the same level as the *apps/* directory. If it does not exist, use your Windows® Explorer to create a New Folder and rename it as *contrib*.
- Copy the *xbow.tgz* file in the CDROM under *TinyOS Updates* folder into the *opt/tinyos-1.x/contrib/* directory. Unzip the file there. When complete, you should see a folder (directory) called *xbow* directly under the *contrib* directory.

2.2.4 TinyOS Installation Structure

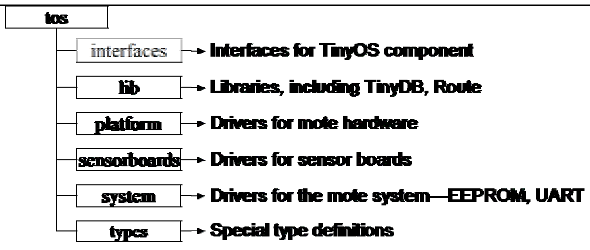
All the TinyOS *apps/, contrib/, doc/, tools/,* and *tos/* directories are located under *<install dir>/cygwin/opt/tinyos-1.x/*. In addition the *Makefile* is in this folder. The environment variables for `TOSROOT` is set to *<install dir>/tinyos-1.x/*. The TinyOS Tutorial is located under *<install dir>/cygwin/opt/tinyos-1.x/doc/tutorial.*



(a) TinyOS top level structure to tinyos-1.x/


tinyos-1.x
apps
Standard TinyOS applications and test programs
contrib
User contributions
doc
Documentation and On-line Tutorial
tools
Development utilities and programs
tos
TinyOS modules and interfaces

(b) tinyos-1.x/ and subdirectories


tos
interfaces
Interfaces for TinyOS component
lib
Libraries, including TinyDB, Route
platform
Drivers for mote hardware
sensorboards
Drivers for sensor boards
system
Drivers for the mote system—EEPROM, UART
types
Special type definitions

(c) tos/ and subdirectories

Figure 2-1. *TinyOS and Subdirectory Map*

IMPORTANT

All the example applications explained in the subsequent chapters are from *tinyos-1.x/contrib/xbow/apps* directory. These are applications developed and thoroughly tested by Crossbow. Crossbow will not support you for the other applications that are found under main apps tree (*tinyos-1.x/apps*)

TinyOS online Resources / Major and MinorReleases

The website for TinyOS is at www.tinyos.net. There you will find the latest news, downloads, and links to the TinyOS user's community, and many other resources. Furthermore, the latest source code can always be downloaded from the TinyOS project page via CVS at SourceForge (http://sourceforge.net/projects/tinyos/). Occasionally TinyOS developers release a convenient-to-install CVS snapshot in the form of an RPM. These are *minor* releases of TinyOS and are posted at www.tinyos.net/download.html.

IMPORTANT:

There are differences between *major* and *minor* releases of TinyOS. The major releases are strenuously and systematically tested by the TinyOS development team and by Crossbow. We test all applications in the release, run through the applications in the on-line tutorial and *Getting Started Guide* multiple times, and check that the documentation is up-to-date. We also post a list of known issues and problems for TinyOS 1.1.0 at http://www.xbow.com/Support/known-bugs-1_1_0.htm. If your project requires stability, we recommend that you stay with the fully-tested releases.

A *minor* release or CVS snapshot release is very nearly that: a snapshot of the CVS tree in a convenient-to-install package. The intention behind the snapshots is to get the latest code out to developers without requiring developers to maintain a CVS tree. The code in the snapshot releases has generally been in the tree for approximately one month, but that doesn't guarantee that anyone other than the developer tested it. The resulting RPM goes through the TinyOS regression test suite (see regression/). If you'd like the bleeding edge code and don't mind the inherent risks, upgrade to the minor releases as they become available.

We have included the TinyOS 1.1.7 RPM update as described in Section 2.2.2, but please remember that it has not been as thoroughly tested as TinyOS 1.1.0.

2.3 TinyOS PC Tools Verification

A TinyOS development environment requires the use of the avr gcc compiler, perl, flex, Cygwin (if you use windows operating system), and the JDK 1.4.x or above. First, we will check that the tools have been installed correctly and that the environment variables are set. The *toscheck* is a script that will perform these functions.

- Open a Cygwin window by double-clicking on the icon that should be on your desktop.
- Change into the *opt/tinyos-1.x/tools/scripts/* directory and run *toscheck*.

```
cd c:/<install dir>/tinyos/cygwin/opt/tinyos-1.x/tools/scripts
toscheck
```

The last line of the output should be:

```
toscheck completed without error
```

If any errors are reported, make sure to fix the problem.

3 Programing Environment Customization

3.1 Setting Aliases

Once you have successfully installed TinyOS, it is recommended that you setup aliases to commonly used commands and accessed directories. Aliases are to be edited at the bottom of the filed called *profile* which is located in *<install dir>/tinyos/cygwin/etc/*.

- These aliases are useful for quickly changing to commonly used directories while in the Cygwin shell.

```
alias cdtinyos="cd c:/<install dir>/tinyos/cygwin/opt/tinyos-1.x"
alias cdjava="cd c:/<install dir>/tinyos/cygwin/opt/tinyos-1.x/tools/java"
alias cdxbow="cd c:/<install dir>/tinyos/cygwin/opt/tinyos-
1.x/contrib/xbow"
```

NOTE: If the *<install dir>/* is the folder *Program Files*, then you must enter in the text **`Program\ Files`** to correctly handle the space between the two words when changing directories in Cygwin.

These and other alias can be setup to make changing directories and other commands easier. To make your own aliases, use the format as shown in the examples above.

IMPORTANT

All the example applications explained in the subsequent chapters are from *tinyos-1.x/contrib/xbow/apps* directory. These are applications developed and thoroughly tested by Crossbow. Crossbow will not support you for the other applications that are found under main apps tree (*tinyos-1.x/apps*)

3.2 Compiling TinyOS Applications

The new release of TinyOS supports the MICAz, MICA2 and MICA2DOT Mote processor-radio (MPR) hardware platforms. The syntax to type in a Cygwin window for compiling (building) application code is of the form:

```
make <platform>
```

The name to be used for **`<platform>`** can be found in Table 3-1.

Table 3-1. *Listing of Hardware Platforms (**`<platform>`**)*

Processor/Radio Platform	For <*platform*> use
MICAz (MPR2400 series)	**micaz**
MICA (MPR3x0 series)	**mica**
MICA2 (MPR4x0 series)	**mica2**
MICA2DOT (MPR5x0 series)	**mica2dot**

3.3 Programming Boards

The TinyOS development environment supports a variety of programming tools. The supported programmers include:

- The MIB500CA parallel port programming board with serial output.
- The MIB510CA serial port programming board.
- The MIB600CA Ethernet port programming board.
- The Atmel AVRISP.

The standard programming software used in TinyOS is the μ In-System Programmer or UISP. This program, which comes as a part of the TinyOS release, takes various arguments according to the programmer hardware and the particular programming action desired (erase, verify, program, etc.). To simplify using this tool, the TinyOS environment invokes the UISP for you with the correct arguments whenever you issue an **`install`** or **`reinstall`** command. You also need specify the type of device you are using and how to communicate with it. This is done using environment variables.

IMPORTANT

All the apps under *contrib/xbow* use the TinyOS's new make syntax. A detailed explanation of this syntax is provided in Readme file found under *tinyos-1.x/tools/make*. The syntax of typical Make file for these look like below.

☑ **EXAMPLE—The *Makefile* for contrib/xbow apps**

```
# $Id: Makefile,v 1.6 2004/08/06 09:30:24 husq Exp $
XBOWROOT=%T/../contrib/xbow/tos

COMPONENT=TestSensor
SENSORBOARD=mts310

PFLAGS= -I$(XBOWROOT)/interfaces  -I$(XBOWROOT)/system  -
I$(XBOWROOT)/platform/$(PLATFORM) -I$(XBOWROOT)/lib -
I$(XBOWROOT)/sensorboards/$(SENSORBOARD)
include ../MakeXbowlocal
include ${TOSROOT}/tools/make/Makerules
```

New syntax in Makefile

3.3.1 MIB500/Parallel Port Programmers

This is the default programmer device. No additional command line parameters need to be specified when using this programmer.

The default command line entry is **`make mica2 install`**

3.3.2 MIB510/Serial Port Programmers

Append the default command line with **`mib510,com<x>`** where **`x`** is the serial port where the device is attached. Before running this command check you own system to see what ports are available.

☑ **EXAMPLE—Command Line Entry for MIB510**

The command line entry **`make mica2 install mib510,com1`** assumes that the MIB510 is connected to COM1.

◀ **NOTE:** If your computer does not have a DB9 serial port and are using a USB to DB9 serial port converter, you must know what port (COM) number your computer has assigned to the USB port. Use that COM port number when doing the above command. However, there are cases where your computer will issue a COM port number but is not what Cygwin will communicate through. That is, by trial and error you will have to try different numbers for the COM port.

3.3.3 MIB600 Ethernet Programmers

In order to use MIB600 Ethernet programming board, you need to assign an IP address to the device. Every device connected to an IP network must have a unique IP address. This address is used to reference the specific unit. Every TCP connection and every UDP datagram is defined by a destination IP address and a port number

- Install Lantronix device installer (*DeviceInstaller36.zip*) from the CD ROM under *Miscellaneous* folder. This can also be downloaded from http://www.lantronix.com/
- Connect the MIB600 to the network using RJ-45 Ethernet cable and supply power using the power supply that was included in the packaging. Make sure the Power Switch SW2 is in "5V" position.
- Click the Start button on the Task Bar and select Start>Programs>Lantronix>Device Installer>Device Installer. The Device Installer window displays.
- Click on "Search" button and you will see a list of devices that were found with the IP address and corresponding Hardware address.
- Look and match the hardware address of your MIB600 board (eg: 00-20-4A-63-47-31) and select it. Click on "Assign IP" and follow the instructions. Note down the IP address that you assigned.
- Once you have assigned the IP address in order to program a mote use

```
make <platform> install eprb,<IP Address>
```

☑ **EXAMPLE—Command Line Entry for MIB600**

The command line entry **`make mica2 install eprb,192.168.100.123`** assumes that the MIB600 is assigned with IP address 192.168.100.123.

◀ **NOTE:** The programming instructions in this guide assume you are using an MIB510 connected to serial port COM1 using MICA2 platform. If you are using a different COM port number, then simply use that number in the command line. If you are using a different programming board or a different platform, use the appropriate command line explained above.

3.4 Installing TinyOS Applications into a Mote

The programming tools also include a method of programming unique node addresses without having to edit the TinyOS source code directly. To set the node address/ID during program load, the general syntax for installing is:

```
make <platform> re|install,<n> <programmer>,com<#>
```

where ***<programmer>*** the name of the programmer (e.g., for the MIB510CA it would be **mib510,com<*#*>** is the port ID of the host PC to which the programmer is attached,**.<*n*>** is an optional number (in decimal) to set the node ID or address, and ***<platform>*** is the type of Mote processor/radio hardware platform.

The difference between **install** and **reinstall** is explained below.

install.<*n*>—compiles the application for the target platform, sets the node ID/address and programs the device (Mote).

reinstall.<*n*>—sets the node ID/address and downloads the pre-compiled program (into the Mote) **only** and does not recompile. This option is significantly faster.

Assigning a node ID by using "**,<*n*>**" is optional and is discussed further in the next subsection.

3.5 Setting the Group ID and Node Address for the Mote Network

TinyOS messages contain a group ID in the header, which allows multiple distinct groups of Motes to share the same radio channel. If you want to separate multiple groups of Motes that are one the same radio channel, you need to set the group ID to a unique 8-bit value to allow TinyOS to filter out those messages. The default group ID is `0x7d`. You can set the group ID by defining the preprocessor symbol `DEFAULT_LOCAL_GROUP` in a *MakeXbowlocal* file which is located in *tinyos-1.x/contrib./xbow/apps/* directory. Section 3.7 has information about how to edit a *MakeXbowlocal* file. In addition, the message header carries the destination node number, which is a 16-bit value.

IMPORTANT:

Except for decimal numbers **126** (the `TOS_UART_ADDR 0x007E`) and **255** (the `TOS_BCAST_ADDR 0xFFFF`), all other values between 0 and 254 are permissible. The number 0 is **typically** reserved for the base station Mote.

Setting the node address is important when programming Motes for a sensor network (as in Section 6). The node address/ID of your Mote is set when you download the application into the Mote. The command line entry is

```
make <platform> re|install,<n> <programmer>,COM<#>
```

☑ **EXAMPLE—Assigning a node address/ID to a MICA2**

```
make mica2 install,38 mib510,com1
```

The above command line builds an application and downloads to a Mote the firmware and assigns a node ID of 38 via an MIB510 attached to serial port COM1.

3.6 Radio Frequencies

The radio transceivers on the MICA2 and MICA2DOT support multiple frequencies. Units are delivered at a pre-defined base frequencies centered on 315 MHz, 433 MHz, or 916 MHz. The specific values are listed in the Table 3-2 although multiple channels can be programmed within a

frequency band. All of the coefficients for radio tuning are contained in the TinyOS file *CC1000Const.h* located in *tos/platform/mica2/.*
Users must compile in the correct base radio frequency otherwise radio communication will fail. The best and safest way to make sure you're compiling for the correct frequency is to edit the *MakelXbowocal* file (described in Section 3.7 below).
MICAz currently uses IEEE 802.15.4 channel#0 (2.405GHz) and ignores DCC1K_DEF_FREQ.

3.7 The *MakeXbowlocal* File

The *MakeXbowlocal* file was developed by Crossbow to be used with applications within the *contrib/xbow/apps/* directory. It is provided to make it easier for users to change the local group ID, channel (RX/TX frequency) and RF transmission power. It **must** be used with the *CC1000Const.h* file found in *opt/tinyos-1.x/contrib/xbow/tos/platforms/mica2/*. If you added the xbow directory after going through Chapter 2, those files are now available.

To use it, double-check that the *Makefil*e in your application directory has the following line:

```
include ../MakeXbowlocal
```

By adding this line in your applications *Makefile* will cause the compiler to include the *MakeXbowlocal* file. Below the actual contents of *MakeXbowlocal* and where to make the changes needed to change the local group, channel, RF transmission power, and programmer/COM port number.

☑ **EXAMPLE—The *MakeXbowlocal* File**

```
##########################################################################
#
# MakeXbowlocal - Local Defines related to apps in contrib/xbow directory
#
##########################################################################


##########################################################################
# set Mote group id
# - default mote group  (in makerules) is 0x7D
##########################################################################
DEFAULT_LOCAL_GROUP=0x81
```

Change this to modify your local group ID.

```
##########################################################################
# set radio channel (freq)
#   -Uncomment ONLY one line to choose the desired radio operating freq.
#   -Select band based on freq label tag on mote (916, 433, or 315)
#    (i.e. 433Mhz channel will not work for mote configured for 916Mhz)
##########################################################################
#
# 916 MHz Band
#
# CHANNEL_00 - 903 MHz     CHANNEL_02 - 904 MHz     CHANNEL_04 - 905 MHz
# CHANNEL_06 - 906 MHz     CHANNEL_08 - 907 MHz     CHANNEL_10 - 908 MHz
# CHANNEL_12 - 909 MHz     CHANNEL_14 - 910 MHz     CHANNEL_16 - 911 MHz
# CHANNEL_18 - 912 MHz     CHANNEL_20 - 913 MHz     CHANNEL_22 - 914 MHz
# CHANNEL_24 - 915 MHz     CHANNEL_26 - 916 MHz     CHANNEL_28 - 917 MHz
# CHANNEL_30 - 918 MHz     CHANNEL_32 - 919 MHz     CHANNEL_34 - 920 MHz
# CHANNEL_36 - 921 MHz     CHANNEL_38 - 922 MHz     CHANNEL_40 - 923 MHz
# CHANNEL_42 - 924 MHz     CHANNEL_44 - 925 MHz     CHANNEL_46 - 926 MHz
# CHANNEL_48 - 927 MHz
#
```

For MPR400/500 Motes: uncomment one of the next 24 lines.

```
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_00
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_02
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_04
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_06
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_08
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_10
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_12
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_14
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_16
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_18
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_20
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_22
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_24
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_26
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_28
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_30
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_32
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_34
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_36
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_38
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_40
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_42
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_44
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_46
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_916BAND_CHANNEL_48
#---------------------------------------------------------------------
# 433 MHz Band
#
# CHANNEL_00 - 433.113 MHz     CHANNEL_02 - 433.616 MHz
# CHANNEL_04 - 434.108 MHz     CHANNEL_06 - 434.618 MHz
#
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_433BAND_CHANNEL_00
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_433BAND_CHANNEL_02
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_433BAND_CHANNEL_04
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_433BAND_CHANNEL_06
##--------------------------------------------------------
```

For MPR410/510 Motes: uncomment one of these 4 lines.

```
# 315 MHz Band
#
# CHANNEL_00 - 315 MHz
#
##--------------------------------------------------------
#CFLAGS = -DCC1K_DEFAULT_FREQ=RADIO_315BAND_CHANNEL_00
########################################################
```

For MPR420/520 Motes: uncomment this line.

```
##########################################################################
# Set Radio Power
#  - Radio transmit power is by a value (RTP) between 0x00 and 0xFF
#  - RTP = 0 for least power; =0xFF for max transmit power
#-------------------------------------------------------------------------
#  For Mica2 and Mica2Dot
#  Freq Band:  Output Power(dBm) RTP
#  916 Mhz     -20               0x02
#              -10               0x09
#               0 (1mw)          0x80
#               5                0xFF
#  433 Mhz     -20               0x01
#              -10               0x05
#               0 (1mw)          0x0F
#               10               0xFF
##########################################################################
CFLAGS += -DRADIO_XMIT_POWER=0xFF

##########################################################################
```

Change the hexadecimal value after the "=" to change RF TX power

IMPORTANT: Don’t use Microsoft® Word to edit the file. A recommended text editor is Programmers Notepad which is includes in the CDROM under *Miscellaneous* folder. This is also available for free at http://www.pnotepad.org/.

NOTE: In order to comply with "Biyjacku" (Japanese standard), the Radio Transmit power for the MICA2 must have a PA_POW set to 0x01 in *MakeXbowLocal* file shown above.

4 Introduction to TinyOS and NesC

TinyOS is an open-source operating system designed for wireless embedded sensor networks. It features a component-based architecture which enables rapid innovation and implementation while minimizing code size as required by the severe memory constraints inherent in sensor networks. TinyOS's component library includes network protocols, distributed services, sensor drivers, and data acquisition tools—all of which can be used as-is or be further refined for a custom application. TinyOS's event-driven execution model enables fine-grained power management yet allows the scheduling flexibility made necessary by the unpredictable nature of wireless communication and physical world interfaces.

4.1 TinyOS Programming philosophy

The TinyOS operating system, libraries, and applications are all written in nesC, a new structured component-based language. The nesC language is primarily intended for embedded systems such as sensor networks. NesC has a C-like syntax, but supports the TinyOS concurrency model, as well as mechanisms for structuring, naming, and linking together software components into robust network embedded systems. The principal goal is to allow application designers to build components that can be easily composed into complete, concurrent systems, and yet perform extensive checking at compile time.

TinyOS also defines a number of important concepts that are expressed in nesC. A brief summary is provided here.

Table 4-1. *Description of the Main TinyOS/nesC Concepts*

TinyOS/nesC Concept	Description
Application	A TinyOS/nesC application consists of one or more components, linked ("wired") together to form a run-time executable
Component	Components are the basic building blocks for nesC applications. There are two types of components: *modules* and *configurations*. A TinyOS component can provide and use interfaces.
Module	A component that *implements* one or more interfaces.
Configuration	A component that *wires* other components together, connecting interfaces used by components to interfaces provided by others. (This is called **wiring**.) The idea is that a developer can build an application as a set of modules, wiring together those modules by providing a configuration. Furthermore, every nesC application is described by a top-level configuration that specifies the components in the application and how they invoke one another.
Interface	An interface is used to provide an abstract definition of the interaction of two components. This concept is similar to Java in that an interface should not contain code or wiring. It simply declares a set of functions that the interface's provider must implement—commands—and another set of functions the interfaces' requirer must implement—events. In this way it is different than Java interfaces which specify one direction of call. NesC interfaces are bi-directional. For a component to call the commands in an interface it must implement the events of that interface. A single component may require or provide multiple interfaces and multiple instances of the same interface. These interfaces are the *only* point of access to the component.

NesC also defines a **concurrency model**, based on **tasks** and **hardware event handlers**, and detects **data races** at compile time. When looking at the files in an application directory, you can identify the nesC files because it uses the extension "`.nc`" for all source files—interfaces, modules, and configurations.

4.2 Concurrency Model

TinyOS executes only one program consisting of selected system components and custom components needed for a single application. There are two threads of execution: **tasks** and **hardware event handlers**. Tasks are functions whose execution is deferred. Once scheduled, they run to completion and do not preempt one another. Hardware event handlers are executed in response to a hardware interrupt and also run to completion. Unlike a task, it may preempt the execution of a task or other hardware event handler. Commands and events that are executed as part of a hardware event handler must be declared with the *async* keyword.

Because tasks and hardware event handlers may be preempted by other asynchronous code, nesC programs are susceptible to certain race conditions. Races are avoided either by accessing shared data exclusively within tasks, or by having all accesses within **atomic** statements. The nesC compiler reports potential **data races** to the programmer at compile-time. It is possible the compiler may report a false positive. In this case a variable can be declared with the **norace** keyword. The norace keyword should be used with extreme caution.

4.3 An Example Application: Blink

So far this is all fairly abstract—let's look at a concrete example: the simple test program *Blink* found in */tinyos-1.x/contrib/xbow/apps/Blink/*. This application simply causes the red LED on the Mote to turn on and off at 1 Hz.

Blink consists of two components: a module, `BlinkM.nc` and a configuration, `Blink.nc`. Remember that all applications require a single top-level configuration, which is typically named after the application itself. In this case `Blink.nc` is the configuration for the *Blink* application and the source file that the NesC compiler uses to generate the executable for the Mote. `BlinkM.nc`, on the other hand, actually provides the *implementation* of the *Blink* application. As you might guess, `Blink.nc` is used to wire the `BlinkM.nc` module to other components that the *Blink* application requires.

The reason for the distinction between modules and configurations is to allow a system designer to quickly "snap together" applications. For example, a designer could provide a configuration that simply wires together one or more modules, none of which she actually designed. Likewise, another developer can provide a new set of "library" modules that can be used in a range of applications.

Sometimes (as is the case with `Blink` and `BlinkM`) you will have a configuration and a module that go together. When this is the case, the convention used in the TinyOS tree is that `Foo.nc` represents a configuration and `FooM.nc` represents the corresponding module. While you could name an application's implementation module and associated top-level configuration anything (ncc uses the 'COMPONENT' definition in the application's *Makefile* to find the top-level configuration), to keep things simple we suggest that you adopt this convention in your own code. There are several other naming conventions used in TinyOS code.

4.4 Compiling the *Blink* Application

TinyOS supports multiple platforms. Each platform has its own directory in the *tos/platform/* directory. In this section, we will use the MICA2 platform as an example.

Open a Cygwin window by double-clicking the icon that can be found on your desktop.

- Enter the *tinyos-1.x/contrib/xbow/apps/Blink/* directory using your shell. Compiling and installing *Blink* is a good exercise to make sure that the most basic hardware is working.
- Type **`make mica2`** in a Cygwin window. This should complete successfully and create a binary (.srec) image of your program for the Motes.
- All objects, generated includes, and executables are placed in the *bin* directory for the specific platform, e.g., */tinyos-1.x/contrib/xbow/apps/Blink/build/mica2/*.

You should, of course, observe errors and warnings that arise in building your application. This example should not have any. At the very end, the **`make`** command shows you a piece of the load map that tells you whether your application fits.

4.5 Programming a Mote and Running Blink

To download an application into the MICAz/MICA2 Mote, connect the 51-pin male connector of the MICA2 to the 51-pin female connector on the MIB programming board (see Figure 4-1). To download into a MICA2DOT, connect the female connectors of the MICA2DOT to the male connectors of the MIB's MICA2DOT programming bay located on the "underside" of the MIB programming board (see Figure 4-2).

NOTE: The Professional MOTE-KITs come with two MDA500 data acquisition boards. These are circular PCBs populated only with 19 pins. These can be used to make it easier to attach a MICA2DOT to the MIB510. This is done by connecting the 19 female-side of the MDA500 to the 19 male pins on the MIB510. The flexibility of the board and pins of the MDA500 helps to make up for small misalignments between the boards and avoids bending of pins on MIB510.

WARNING: When programming a MICAz/MICA2 with the MIB510, turn OFF the battery switch. For a MICA2DOT, remove the battery before inserting into the MIB510. The MICAz/MICA2s and MICA2DOTs **do not** have switching diodes to switch between external and battery power.

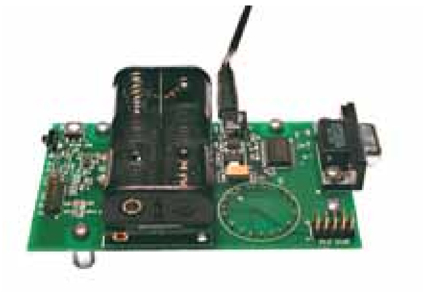


Figure 4-1. *MICAz/MICA2 plugged into top-side of an MIB510.*

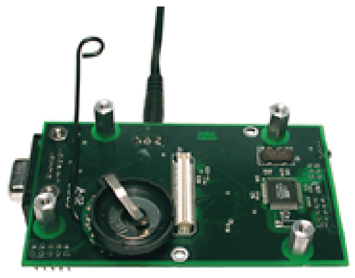


Figure 4-2. *MICA2DOT plugged into bottom-side of an MIB510.*

- Connect your MIB510 Mote programming interface board to the PC using a DB-9 serial straight-through cable to connect the MIB to a serial port on the PC.
- Power the MIB510 by connecting the output plug of the AC wall power adaptor (5 VDC output) to the connector (labeled as J7) on the MIB510. The green LED at location D3 and labeled as "SP PWR" should be on.
- Attach your MICAz/MICA2 Mote to the MIB510 via the 51-pin connector.

  Build and install the application firmware:

  Type **`make mica2 install mib510,com1`**.

  If you are using Windows and the install doesn't work, you make need to check the port specified to the UISP.

You should see the upload take place (this may take several seconds) and the red LED should light up every second.

WARNING: Users are strongly advised to use a Crossbow MIB500/510 interface board with an external wall mounted power supply (5 to 7 VDC). If using batteries, check the battery voltage. If the battery voltage is less than 3.0 V the flash memory may not reprogrammed correctly. This can also cause the ATMega128L fuses to be set incorrectly which will defeat any further reprogramming. There have been numerous reported difficulties with programming Motes. These include program failure, flash verification errors, and dead Motes.

For MIB500 Users: If you still get flash verification errors, please refer to the suggestions provided in the application note: http://www.xbow.com/Support/Support_pdf_files/UISPHELP.pdf. Also rebooting your PC you may need to power cycle the MIB500 and hit the reset switch labeled as RSTN at location SW1.

4.6 Generating the Component Structure Documentation

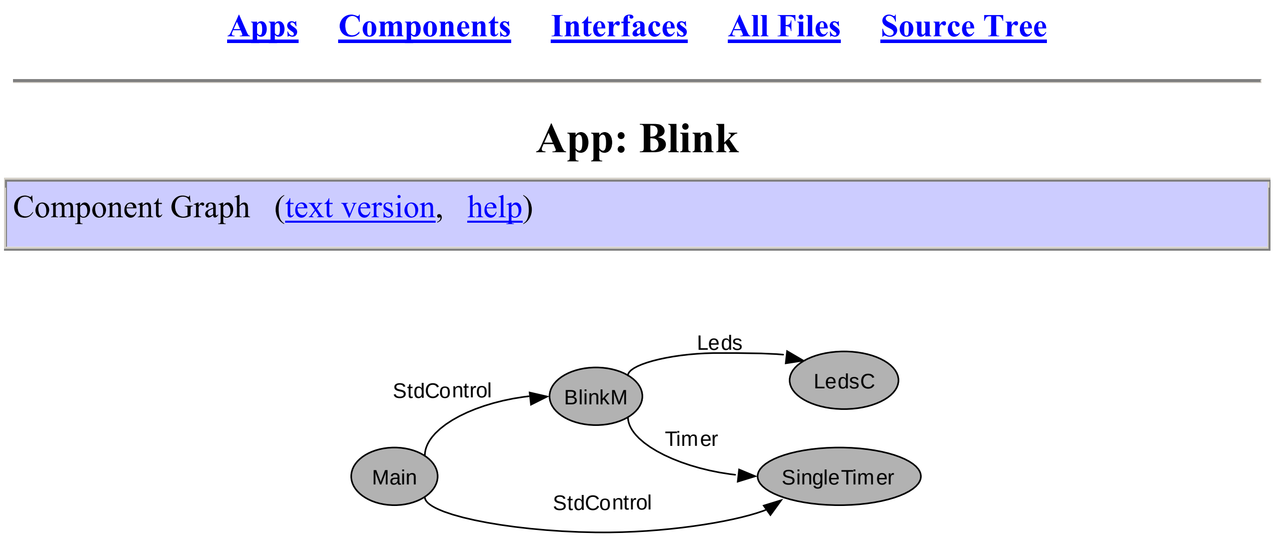
You can view a graphical representation of the component relationships within an application. TinyOS source files include metadata within comment blocks that ncc, the nesC compiler, uses to automatically generate html-formatted documentation.

To generate the documentation, go to the *tinyos-1.x/contrib./xbow/apps/Blink/* directory use the following command:

```
make <platform> docs
```

The resulting documentation will have the filename be generated in the file *docs/nesdoc/<platform>.docs/nesdoc/<platform>/index.html*. This is the main index to all documented applications.

The directory index takes you to an html file that looks like the figure below.



Apps Components Interfaces All Files Source Tree

App: Blink

Component Graph (text version, help)

Browsing through the graphical representation of the component wiring using your mouse is really helpful to understand the overall structure of TinyOS.

4.7 Radio Communications

This Section introduces radio communication. The applications that we will consider are *CntToLedsAndRfm* and *RfmToLeds*. *CntToLedsAndRfm* is a variant of *Blink*. It outputs the current counter value to two output interfaces: the LEDs and the radio communication stack. *RfmToLeds* receives data from the radio and displays it on the LEDs. Programming one Mote with *CntToLedsAndRfm* will cause it to transmit its counter value over the radio; programming another with *RfmToLeds* causes it to display the received counter on its LEDs. (For more details on different component modules, look at Lesson 4 of the TinyOS Tutorial.)

IMPORTANT: If you're using MICA2 or MICA2DOT Motes, you will need to ensure that you've selected a radio frequency compatible with your Motes. *If your Motes do not communicate in this Section, the likely reason is that you don't have your frequency set correctly*. Refer back to Section 3.6 on how to set the radio frequency.

MICAz currently uses IEEE 802.15.4 channel#0 (2.405GHz) and ignores DCC1K_DEF_FREQ.

4.7.1 Sending Messages with CntToLedsAndRfm

- Change your directory to the *CntToLedsAndRfm* directory (using a Cygwin window).

```
cd /opt/tinyos-1.x/contrib/xbow/apps/CntToLedsAndRfm
```

- Attach a MICA2 Mote to your MIB510. Build and install the application.

```
make mica2 install mib510,com1
```

- Remove the MICA2 Mote from the MIB and turn on. Assuming you have batteries in your Mote, you should see a 3-bit binary counter on the Mote's LEDs. And while it is not apparent, it is, of course, transmitting the value over the radio.

4.7.2 Receiving Messages with RfmToLeds

- Attach a second MICA2 Mote.
- Change directory to *RfmToLeds*. Build and install the application.

```
cd ../RfmToLeds
make mica2 install mib510,com1
```

- Remove the MICA2 Mote from the MIB and turn on. If you turn the Mote with *CntToLedsAndRfm*, you will see that the LED counting stops on both Motes.

4.7.3 Radio Transmit/Receive FAQ

There many several reason why you might not be able to communicate. Here are some things to check if you can't get your Motes to communicate with these two applications.

- **Correct radio frequency?** Be sure that you have set the radio frequency (channel) correctly in your *MakeXbowlocal* file.
- **Correct group ID?** Motes on the same channel but different group IDs will not be able to communicate with each other.
- **Base station switch set to transmit only**? If the switch labeled "SW2" is in the "ON" position, the MIB will only transmit but not receive.
- **RF null location?** Move your Mote to a slightly different location or about ± 1m.
- **RF overload?** You may have too many Motes close to each other. Or you may be near a strong RF source such as a major airport or radio transmitters.
- **Antennas installed and correctly oriented?** Motes without antennas will not have much success in transmitting or receiving signals beyond a few cm. Typically you should have your antennas mounted vertically with respect to the ground. In rare cases, the antennas itself may be faulty; try other antennas to see if performance improves.
- **Motes' radio TX/RX range exceeded?** If none of the above apply, you may have to place your Motes closer together. In fact one of the practical uses of these two applications is to do a crude TX/RX site survey. This is done by placing the Mote with *CntToLedsAndRfm* in one location. Move the Mote with *RfmToLeds* until you stop seeing the 3-bit binary count. This would be an approximate distance to for one hop between two Motes.

NOTE: You may have to place the Mote with *RfmToLeds* on a surface and step away since your body is a source of radio interference.

4.8 Learning More About TinyOS and nesC

This section was only a brief introduction to some of the concepts in TinyOS and nesC. An online version of the tutorial for a more complete introduction to TinyOS is at

http://www.tinyos.net/tinyos-1.x/doc/tutorial/

IMPORTANT:

Please note that the tutorial references the applications reference to *tinyos-1.x/apps* found under the main tree. These are public domain applications and Crossbow assumes no responsibility for the support. Hence the support needs to be obtained from TinyOS help group. For more details go to, http://www.tinyos.net/ or e-mail tinyos-help@Millennium.Berkeley.EDU

5 Test Applications and Drivers for Sensor and Data Acquisition Boards

💣 **WARNING:** To use these test applications and drivers, you must update to TinyOS 1.1.7 as described in Section 2.2.2.

This Chapter will help you test your sensor and data acquisition boards. A set of test applications and a corresponding UI called *XListen* are provided to enable user's to do basic testing and verification of their sensor and data acquisition (DAQ) boards. The *XListen* program displays a sensor's or DAQ's output in a Cygwin window. Listed in the Table 5-1 are TinyOS test application and drivers to evaluate your the sensor and/or DAQ board.

Table 5-1. *Test and/or Demo Applications and Drivers for Crossbow's Sensor and Data Acquisition Boards.*

Sensor or DAQ Board	Test/Demo Application	Driver Name
MTS510	XSensorMTS510	mts510
	Surge_Reliable_Dot	
MDA500	XSensorMDA500	basicsb[1]
	Surge_Reliable_Dot	
MTS300/310	Surge_Reliable	mts310
MTS400/420	XSensorMTS400	mts400
MDA300	XSensorMDA300	mda300

[1]basicsb drivers are located in the *opt/tinyos-1.x/tos/sensoboards/* directory, whereas the other drivers are in the *tinyos-.x/contrib/xbow/ tos/sensorboards/* directory.

5.1 Drivers

A driver is a set of software code modules written in nesC which supports the lower level functionality of the sensor board. This is needed by all TinyOS applications. Driver code is typically developed during the sensor board design stage. These drivers should be in the *opt/tinyos-1.x/contrib/xbow/tos/sensorboards/* directory.

IMPORTANT: Follow the instructions per Section 2.2.3 if you have not installed Crossbow's TinyOS subdirectories.

5.2 Test Applications: The *XSensor*-series

The XSensor-series of test applications was developed to quickly and easily test Crossbow sensor and/or data acquisition boards. Furthermore, these applications are a set of well documented code modules which users can modify for their own TinyOS applications.

To install a test application, navigate to *opt/tinyos-1.x/contrib/xbow/apps* and change to the directory that corresponds to the sensor board you want to test. The Mote hardware functionality can be tested in two different ways:

- Over the UART (Universal Asynchronous Receive Transmit): See Section 5.2.1.
- Over an RF (Radio Frequency) link: See Section 5.2.2.

5.2.1 Testing a Sensor Board over the UART

Testing your sensor board over the UART bypasses the need for an RF link. This test is useful if you want to test the sensor board without having to deal with possible radio problems. It also requires only one Mote, and you only have to program the Mote with an appropriate *XSensor* application.

☑ **EXAMPLE—Installing *XSensorMDA500* Test Application for the MICA2DOT**

- Change your directory to the test application.

```
cd tinyos-1.x/contrib/xbow/apps/XSensorMDA500
```

- Attach a MICA2DOT to the bottom side pins on the MIB. Build and install the application to the Mote (with unique node ID other than 0).

```
make mica2dot install,1 mib510,com1
```

  where **`1`** is the node ID

- Read Section 5.3 to run the text user-interface program XListen. Make sure that the switch labeled “SW2” on the MIB510 is on the “OFF” position.

5.2.2 Testing a Sensor Board by Wireless (RF) Link

Testing your sensor board over the RF link requires two Motes. The Mote with the sensor/data acquisition board attached to it will have the test firmware installed. The other Mote will be programmed with an application called *TOSBase* (in */opt/tinyos-1.x/contrib./xbow/apps/*). Assuming you have successfully completed the exercises in Chapter 4, you should be confident about having the frequencies set correctly.

- If you have a sensor node (Mote + sensor board) on the MIB, remove it. Install batteries in it if needed. Make sure the battery switch is in the “ON” position for the MICA2.
- Attach a either a MICA2 or MICA2DOT to the appropriate connector on the MIB.

NOTE: Unlike most other TinyOS applications, the MICA2DOT can be used as a base station Mote. This applies only for the XSensor-series test applications. It is important to use the proper baud rate which is discussed in Section 5.3.2 below.

- Change your directory to the *TOSBase* directory which is in /opt/tinyos-1.x/contrib./xbow/apps/.

```
cdapps
cd TOSBase
```

- Build and install the *TOSBase* to the Mote (with node ID 0).

```
make mica2dot install,0 mib510,com1
```

- Read Section 5.3 to run the text user-interface program *XListen*. Make sure that the switch labeled "SW2" on the MIB510 is on the "OFF" position.

5.3 User Interface: *XListen*

The user interface is a PC-based tool used to view sensor data. *XListen* is a Cygwin C console program written in C that receives RS232/radio packets from the Mote and converts to engineering units. *XListen* is used only to verify that the sensor board is working properly. It is not a sensor network program. This program is located in */opt/tinyos-1.x/contrib/xbow/tools/src/xlisten*. By default, you must be that src/ directory to run Xlisten. To run *XListen* from anywhere in the Cygwin shell, do the following in a Cygwin shell:

- **`cd /usr/local/bin`**
- **`ln -s /opt/tinyos-1.x/contrib/xbow/tools/src/xlisten/xlisten.exe xlisten`**

  The source code for *Xlisten* is in the */xbow/tools/src/xlisten/* directory for user modification and editing.

5.3.1 Help List for XListen

XListen has many modes of operation that can be controlled by passing command line parameters. Help on finding the commands for *XListen* can be found by typing in **`xlisten -?`** in a Cygwin window (see the text output below).

```
$ xlisten -?
xlisten Ver:$Id: xlisten.c,v 1.12 2004/08/05 01:35:35 mturon Exp $
Using params: [help]

Usage: xlisten <-?|r|p|x|c|d|q> <-b=baud> <-s=device>
   -? = display help [help]
   -r = raw display of tos packets [raw]
   -p = parse packet into raw sensor readings [parsed]
   -x = export readings in csv spreadsheet format [export]
   -c = convert data to engineering units [cooked]
   -l = log data to a database or file [logged]
   -d = debug serial port by dumping bytes [debug]
   -b = set the baudrate [baud=#|mica2|mica2dot]
   -s = set serial port device [device=com1]
   -h = specify header size [header=offset]
   -q = quiet mode (suppress headers)
   -v = show versions of all modules
```

5.3.2 Baud rate: -b=[baudrate]

This flag allows the user to set the baud rate of the serial line connection. The default baud rate is 57 600 bits per second (bps) which is compatible with the MICAz/MICA2. The desired baud rate must be passed as a number directly after the equals sign with no spaces in between, i.e., **`–b=19200`**.

Optionally, a product name can be passed in lieu of an actual number and the proper baud will be set, i.e., **`–b=mica2dot`**. Valid variable are in

Table 5-2. *Valid variables and baud rates for the –b option*

Mote	Baud Rate	Variable
MICAz/MICA2	57600	mica2
MICA2DOT	19200	mica2dot

5.3.3 *Serial port: –s=port [serial]*

This flag gives the user the ability to specify which COM port or device *XListen* should use. The default port is /dev/ttyS0 or the UNIX equivalent to COM1. The given port must be passed directly after the equals sign with no spaces, e.g., **`–s=com3`**.

5.3.4 *Raw data values: –r*

Raw mode displays the actual TOS packets as a sequence of bytes as seen coming over the serial line.

☑ **EXAMPLE—Raw text output with `xlisten -r`**

```
$ xlisten -r
xlisten Ver:$Id: xlisten.c,v 1.7 2004/03/23 00:52:28 crossbow Exp $
Using params: [raw]
/dev/ttyS0 input stream opened
7e7e000033000000c8035f61d383036100000000e4510d610000000080070000d4b5f577
7e00007d1d8101060029091e09ef082209e7080b09b408000000000000000000000000100
7e00007d1d81020600f007de07da07d507c306470654050000000000000000000000000100
```

Examining the second line from the output example above, the values are interpreted as:

Packet Byte Name	Example	Notes
TOS Header = `7e00007d1d`		
UART Addess	`7e00`	
Type	`00`	
Group ID	`7d`	Default
Data Payload = `8101060029091e09ef082209e7080b09b40800000000000000000000`		
sensorboard_id	`81`	MDA300
packet_id	`01`	
node_id	`06`	
reserved	`00`	
Data	`29091e09ef082209e7080b09b408000000000000000000000`	Depends on sensorboard_id and packet_id. In this case it is the raw ADC values for an MDA500.

Table 5-3. *The TinyOS files that define this data packet.*

TinyOS file	Information
tos/types/AM	TOS_msg header
contrib/xbow/tools/src/xlisten/xsensor.h	Xbow sensor packet
contrib/xbow/tools/src/xlisten/boards	Sensor/DAQ board specific data payloads

5.3.5 *Cooked data values: –c*

Cooked mode converts the raw sensor readings within a given packet into engineering units.

☑ EXAMPLE—Raw text output with `xlisten –c –b=mica2dot` on a MICA2DOT programmed with *XSensorMDA500*.

```
$ xlisten -c -b=mica2dot
xlisten Ver:$Id: xlisten.c,v 1.7 2004/03/23 00:52:28 crossbow Exp $
Using params: [baud=0x000e] [cooked]
/dev/ttyS0 input stream opened
MDA500 [sensor data converted to engineering units]:
  health:    node id=6
   battery:    volts=3163 mv
   thermistor: resistance=10177 ohms, tempurature=24.61 C
   adc chan 2: voltage=1258 mv
   adc chan 3: voltage=1001 mv
   adc chan 4: voltage=893 mv
   adc chan 5: voltage=939 mv
   adc chan 6: voltage=875 mv
   adc chan 7: voltage=850 mv
```

5.3.6 *Quiet Mode: –q*

This flag suppresses the standard *XListen* header which displays the version string and parameter selections.

5.3.7 *Exporting Data Readings: –x*

Export mode displays raw analog to digital converter (ADC) values as comma delimited text for use in spreadsheet and data manipulation programs. The user can redirect the screen output of *XListen* by using a "**`> log_filename`**" to write file. Later that log_filename can be read by Microsoft® Excel to build charts of the information.

☑ EXAMPLE—Printing to screen (standard output) with `xlisten –x` on a MICA2DOT

```
$ xlisten -b=mica2dot -q –x
51200,24323,54113,899,97,0,58368,3409
6,193,518,409,328,283,296,298
6,194,517,410,330,292,310,300
6,194,518,409,329,286,309,288
6,194,517,411,331,287,297,300
6,194,516,413,335,288,301,287
```

5.3.8 Debugging: –d

This flag puts *XListen* in a mode so that it behaves exactly like the TinyOS raw listen tool (*opt/tinyos-1.x/contrib/xbow/tools/src/raw_listen.c*). All other command line options except **–b** (baud rate) and **–s** (UART serial port) will be ignored. This mode is mainly used for compatibility and debugging serial port issues. Individual bytes will be displayed as soon as they are read from the serial port with no post-processing. In most cases **-r** (raw ADC readings) is equivalent and preferred to using debug mode.

5.3.9 Display Options

The **-r**, **-p**, and **-c** flags are considered display options. These can be passed in various combinations to display multiple views of the same packet at once. The default display mode when *XListen* is invoked with no arguments is **-r**.

☑ EXAMPLE—Output with `xlisten –r –p -c`

```
$ xlisten -b=mica2dot -r -p -c
xlisten Ver:$Id: xlisten.c,v 1.7 2004/03/23 00:52:28 crossbow Exp $
Using params: [baud=0x000e] [raw] [parsed] [cooked]
/dev/ttyS0 input stream opened
7e7e000033000000c8035f61d383036100000000e4510d61000000000080070000d4b5f577
7e00007d1d01010600c200050293014401210135012f0122010000000000000000000100
mda500 id=06 bat=00c2 thrm=0205 a2=0193 a3=0144 a4=0121 a5=0135 a6=012f a7=0122
MDA500 [sensor data converted to engineering units]:
   health:     node id=6
   battery:    volts=3163 mv
   thermistor: resistance=10217 ohms, tempurature=24.53 C
   adc chan 2: voltage=1246 mv
   adc chan 3: voltage=1001 mv
   adc chan 4: voltage=893 mv
   adc chan 5: voltage=955 mv
   adc chan 6: voltage=936 mv
   adc chan 7: voltage=896 mv
```

5.4 Example Output from *XSensorMTS400*

```
$ xlisten -r -p -c -b=mica2 -s=com1
xlisten Ver:$Id: xlisten.c,v 1.9 2004/04/08 01:35:35 crossbow Exp $
Using params: [baud=0x1001] [raw] [parsed] [cooked]
com1 input stream opened

7e0000201d860101007d019803bf1aaccc1eabe3aacad090686545a30000000002e50100
mts420 id=01 battery=017d humidity=0398 temp=1abf
intersema calibration words(1..4) = ccac,ab1e,aae3,d0ca
intersematemp=6890 intersemapressure=4565
taosch0=00a3 taosch1=0000 accel_x=0200 accel_y=01e5
MTS420 [sensor data converted to engineering units]:
   health:       node id = 1
   battery:              = 3287 mv
   humidity:             = 31 %
   Temperature:          = 28 degC
   IntersemaTemperature: = 28 degC
   IntersemaPressure:    = 1007 mbar
   Light:                = 28.059999 lux
   X-axis Accel:         = 583.333313 mg
   Y-axis Accel:         = 81.218269 mg
```

NOTE: When connected to the computer via serial COM to UART, GPS data was not available, so non-GPS sensor data readings are shown above. In order to receive/display the GPS data you must uncomment #define MTS420 line in sensorboardApp.h file found under *tinyos-1.x/contrib./xbow/apps/XSensorMTS400*

5.5 Example Output from *XSensorMTS510*

```
Crossbow@wireless_dev /opt/cvs-src_tinyos-1.x/contrib/xbow
$ xlisten -r -p -c -b=mica2dot -s=com1
xlisten Ver:$Id: xlisten.c,v 1.9 2004/04/08 01:35:35 crossbow Exp $
Using params: [baud=0x000e] [raw] [parsed] [cooked]
com1 input stream opened
7e0000201d020105008303f401030255015401540154015501000000000000000000000100
mts510 id=05 light=0383 acc_x=01f4 acc_y=0203
       sound[0]=155 sound[1]=154 sound[2]=154 sound[3]=154 sound[4]=155
MTS510 [sensor data converted to engineering units]:
   health:     node id=5
   light:        =899 ADC counts
   X-axis Accel: =-0.016129 g
   Y-axis Accel: =0.114754 g
```

5.6 Example Output from *XSensorMDA300*

```
$ xlisten -r -p -c -b=mica2dot -s=com1
xlisten Ver:$Id: xlisten.c,v 1.9 2004/04/08 01:35:35 crossbow Exp $
Using params: [baud=0x000e] [raw] [parsed] [cooked]
com1 input stream opened
7e0000811d01010400c100e1014001fa00d500fa00ee00b8000000000000000000000100
Mda300 id=04 bat=00c1 thrm=01e1 a2=0140 a3=00fa a4=00d5 a5=00fa a6=00ee a7=00b8
MDA300 [sensor data converted to engineering units]:
   health:     node id=4
   battery:    volts=3183 mv
   thermistor: resistance=8874 ohms, tempurature=27.53 C
   adc chan 2: voltage=995 mv
   adc chan 3: voltage=777 mv
   adc chan 4: voltage=662 mv
   adc chan 5: voltage=777 mv
   adc chan 6: voltage=740 mv
   adc chan 7: voltage=572 mv
```

5.7 Example Output from XSensorMDA500

```
$ xlisten -r -p -c -b=mica2dot -s=com1
xlisten Ver:$Id: xlisten.c,v 1.9 2004/04/08 01:35:35 crossbow Exp $
Using params: [baud=0x000e] [raw] [parsed] [cooked]
com1 input stream opened
7e0000811d01010400c100e1014001fa00d500fa00ee00b8000000000000000000000100
mda500 id=04 bat=00c1 thrm=01e1 a2=0140 a3=00fa a4=00d5 a5=00fa a6=00ee a7=00b8
MDA500 [sensor data converted to engineering units]:
   health:     node id=4
   battery:    volts=3183 mv
   thermistor: resistance=8874 ohms, tempurature=27.53 C
   adc chan 2: voltage=995 mv
   adc chan 3: voltage=777 mv
   adc chan 4: voltage=662 mv
   adc chan 5: voltage=777 mv
   adc chan 6: voltage=740 mv
   adc chan 7: voltage=572 mv
```

6 Surge Multi-hop Networking Application

The TinyOS-1.1.0 release and later include library components that provide ad-hoc multi-hop routing for sensor network applications. The implementation uses a shortest-path-first algorithm with a single destination node (the root) and active two-way link estimation. The data movement and route decision engines are split into separate components with a single interface between them to permit other route-decision schemes to be easily integrated in the future. Use of the multi-hop router is essentially transparent to applications (provided they correctly use the interface).

6.1 How does Surge Multi-hop network work?

Crossbow's mesh networking resides as a software component in TinyOS. Typical applications that run on the Motes use several different software components—*e.g.*, sensor components, data logging, and more. If the application is going to use mesh networking, it will link in the *MultiHopRouter* software component. The implementation of the *MultiHopRouter* component found in Crossbow's TinyOS contribution directory includes some significant performance upgrades, and it is a state-of-the-art mesh networking algorithm.

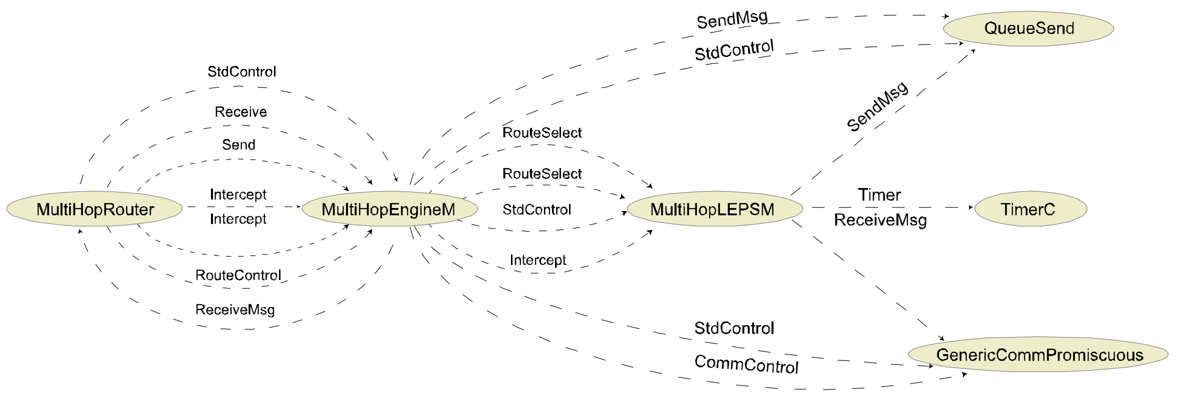


Figure 6-1. *A Graphviz representation of the TinyOS application Surge_Reliable and Surge_Reliable_Dot.*

The *MultiHop* router component automatically transmits link quality estimates, publishes distance estimates, performs optimal route selection and forwards multi-hop data traffic. Pictured in Figure 6-1, the routing component is divided into two major pieces: the *MultiHopEngineM* and the *MultiHopLEPSM* component. Additionally, it uses the *QueueSend* component, the *TimerC* component and the *GenericCommPromiscuous* component to properly perform its duties. The *MultiHopEngineM* component implements the core forwarding and sending function of multi-hop routing. Once a parent has been determined, the *MultiHopEngineM* properly receives updates and transmits the data packet on towards its final destination. Upon receipt of a Multi-hop packet, the *MultiHopEngineM* forwards the packet if and only if it was directly addressed to the node via the packet addressing mechanism. If so, the engine uses the *MultiHopLEPSM* to select the next hop destination and updates the packet by using the *RouteSelect* interface. Once the *MultiHopLEPSM* has updated the fields of the multi-hop packet, the packet is handed to the *QueueSend* for transmission as soon as possible. The

QueueSend is a simple component that will accept multiple transmission requests and perform the actual transmissions as the channel allows.

The data movement and route decision engines are split into separate components with a single interface between them to permit other route-decision schemes to be easily integrated in the future. Use the *MultiHopRouter* is essentially transparent to applications (provided they correctly use the interface).

Use of the multi-hop library component is mostly transparent to the application. Any application that uses the `Send` interface can be connected to this component to achieve multi-hop functionality. One limitation of multi-hop, however, is the aggregate data rate. Applications should maintain average message frequency at or slower than one message every two seconds. Higher rates can lead to congestion and/or overflow of the communication queue.

6.2 Programming Motes with Surge

To program additional MICAz (Section 6.2.2) or MICA2 (Section 6.2.23) Mote with *Surge_Reliable* and additional MICA2DOTs (Section 6.2.4) with *Surge_Reliable_Dot* you'll need to install TinyOS 1.1.0 and then the TinyOS 1.1.7 RPM update onto your PC.

NOTE: The programming instructions below assume you are using an MIB510 connected to serial port COM1. If you are using a different COM port number, then simply use that number in the command line. Remember, the Mote chosen as the sensor network base station must be installed with a ***<nodeid>*** of 0 (zero).

6.2.1 Copying the xbow directories from the CDROM

Follow the instructions per Section 2.2.3 if you have not installed Crossbow's TinyOS subdirectories.

6.2.2 Installing Surge_Reliable on MICAz Mote

The key to building *Surge_Reliable* in TinyOS 1.1.7 for the MICAz is to make certain the *Makefile* in that application's directly uses the new *Makerules*.

- Edit Makefile to uncomment the corresponding line for MICA2 as shown below.

```
COMPONENT=Surge
SENSORBOARD=micasb
#TINYSEC=true

# For MICA2 and MICA2DOT
# PFLAGS+= -I../../tos/platform/mica2 -I../../tos/CC1000RadioAck -
I../../tos/lib/ReliableRoute -I%T/lib/Queue -I%T/lib/Broadcast -
I%T/lib/Attributes

# For MICAZ
# PFLAGS+= -I../../beta/tos/lib/CC2420RadioAck -
I../../beta/tos/platform/micazack -I../../tos/lib/ReliableRoute -
I%T/lib/Queue -I%T/lib/Broadcast -I%T/lib/Attributes

include ../MakeXbowlocal
include ${TOSROOT}/tools/make/Makerules
```

TINYSEC for Network security

For MICA2 Motes: uncomment this line

For MICAz Motes: uncomment this line

- Open a Cygwin window.
- Change directory to the *tinyos-1.x/contrib/xbow/apps/Surge_Reliable*.

```
cd /opt/tinyos-1.x/contrib/xbow/apps/Surge_Reliable
```

- Build the application.

```
make micaz
```

- Download (flash) the MICAz with the application. Be sure to attach the MICAz Mote on the MIB510 before typing in this command.

```
make micaz reinstall,<nodeid> mib510,COM<#>
```

where **<*nodeid*>** is the node address you want that Mote to be and **<*#*>** is the serial port number to which the MIB510 is connected. Repeat this step for as many Motes you need to have programmed.

NOTE: The TINYSEC variable in the above Makefile sets the network security for MICA2 motes. The MICA2DOTs currently do not support this feature. Hence it is important that you comment out this line when using MICA2DOTs in the MICA2 network. Otherwise, MICA2DOTs won't be able to join the network!

6.2.3 Installaing Surge_Reliable on MICA2 Motes

- Edit Makefile to uncomment the corresponding line for MICAz as shown above.
- Open a Cygwin window. Change directory to the *tinyos-1.x/contrib/xbow/apps/Surge_Reliable.*

```
cd /opt/tinyos-1.x/contrib/xbow/apps/Surge_Reliable
```

- Build the application.

```
make mica2
```

- Download (flash) the application into a MICA2: attach a MICA2 Mote into the 51-pin connector on the MIB510.

```
make mica2 reinstall,<nodeid> mib510,COM1
```

- Repeat until you have installed all the MICA2 Motes.

6.2.4 Installing Surge_Reliable_Dot on MICA2DOT Motes

- Open a Cygwin window. Change directory to *tinyos-1.x/contrib/xbow/apps/Surge_Reliable.*

```
cd /opt/tinyos-1.x/contrib/xbow/apps/Surge_Reliable_Dot
```

- Build the application.

```
make mica2dot
```

- Install the application into a MICA2DOT: attach a MICA2DOT Mote into the 19 pin connector on the MIB510.

```
make mica2dot reinstall,<nodeid> mib510,COM1
```

The **`<nodeid>`** should be **never** be 0 for a MICA2DOT and needs to be different than the numbers you gave for the MICA2s.

6.2.5 *Changing the Transmit Rate in* Surge_Reliable *or* Surge_Reliable_Dot

You can change the tranmsit rate of the Motes running *Surge_Reliable* or *Surge_Reliable_Dot* Below is the portion of *Surge.h* located in both the *Surge_Reliable* and the *Surge_Reliable_Dot* directories. Specifically, change line 33 which has the variable "`INITIAL_TIMER_RATE`." The number represents time in milliseconds. In that line, the transmit rate is determined by multiplying 1024 by some integeter value greater than or equal to two.

☑ **EXAMPLE—Part of the *Surge.h* file in *Surge_Reliable_Dot/***

```
 * This file is distributed under the terms in the attached INTEL-LICENSE
 * file. If you do not find these files, copies can be found by writing to
 * Intel Research Berkeley, 2150 Shattuck Avenue, Suite 1300, Berkeley, CA,
 * 94704.  Attention:  Intel License Inquiry.
 */


enum{
    INITIAL_TIMER_RATE = 1024 * 2,
    FOCUS_TIMER_RATE = 1000,
    FOCUS_NOTME_TIMER_RATE = 1000
};
```

Change the "2" in line 33 to another number. (Try "8".)

6.3 Running Surge-View GUI

Follow the instructions provided in Chapter 1 of the guide to run the GUI to visualize the network topology.

7 Warranty and Support Information

7.1 Customer Service

As a Crossbow Technology customer you have access to product support services, which include:

- Single-point return service
- Web-based support service
- Same day troubleshooting assistance
- Worldwide Crossbow representation
- Onsite and factory training available
- Preventative maintenance and repair programs
- Installation assistance available

7.2 Contact Directory

United States:	Phone:	1-408-965-3300 (8 AM to 5 PM PST)
	Fax:	1-408-324-4840 (24 hours)
	Email:	techsupport@xbow.com
Non-U.S.: refer to website		www.xbow.com

7.3 Return Procedure

7.3.1 Authorization

Before returning any equipment, please contact Crossbow to obtain a Returned Material Authorization number (RMA). Ask for technical support and be ready to provide the following information when requesting a RMA:

- ▸ Your name, company/institution name
- ▸ Sales or invoice number
- ▸ Address
- ▸ Telephone, fax, email
- ▸ Part number (usually an 8 to 10 digit number)
- ▸ Serial number
- ▸ Installation or receipt date
- ▸ Failure date
- ▸ Fault description

7.3.2 Identification and Protection

If the equipment is to be shipped to Crossbow for service or repair, please attach a tag TO THE EQUIPMENT, as well as the shipping container(s), identifying the owner. Also indicate the service or repair required, the problems encountered, and other information considered valuable to the service facility such as the list of information provided to request the RMA number.

Place the equipment in the original shipping container(s), making sure there is adequate packing around all sides of the equipment. If the original shipping containers were discarded, use heavy boxes with adequate padding and protection.

7.3.3 Sealing the Container

Seal the shipping container(s) with heavy tape or metal bands strong enough to handle the weight of the equipment and the container.

7.3.4 Marking

Please write the words, "***FRAGILE, DELICATE INSTRUMENT***" in several places on the outside of the shipping container(s). In all correspondence, please refer to the equipment by the model number, the serial number, and the RMA number.

7.3.5 Return Shipping Address

Use the following address for all returned products:

Crossbow Technology, Inc.
41 Daggett Drive
San Jose, CA 95134
Attn: RMA Number (XXXXXX)

7.4 Warranty

The Crossbow product warranty is one year from date of **shipment**.