



## Wireless Gateway Appliance Software

Access Tmote wireless sensor modules through Ethernet with Moteiv's Tmote Connect gateway software.

### Product Description

Tmote Connect software allows a Linksys NSLU2 Network Attached Storage device to function as a gateway appliance, connecting Tmote wireless sensor modules to a wired local area network. Each Tmote wireless module connected to a gateway appliance can be remotely administered through a concise web-based graphical user interface. Tmote Connect integrates quickly and conveniently with TinyOS and provides control over remotely connected Tmote wireless sensor modules.

### Key Features

Tmote Connect Software includes:

- Bridging between Tmote wireless networks and Ethernet infrastructure.
- Support for up to 2 Tmote wireless modules per Tmote Connect gateway.
- Bi-directional connectivity for data transfers to and from Tmote wireless modules over TCP/IP sockets.
- Flash reprogramming of Tmote wireless modules remotely using standard in-system programming protocols.
- Integration with TinyOS development system and tools (Both TinyOS 1.x and 2.x).
- Web-based status interface – mote identification, reset, and performance counters.
- Operates in networks with and without DHCP support.
- Field upgradeable for new software features from Moteiv.



\*Tmote Sky modules sold separately

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**DISCLAIMER:** Moteiv provides Tmote Connect software as a replacement for the default software shipped with the Linksys NSLU2 network attached storage unit. By purchasing Tmote Connect from Moteiv, the customer acknowledges that Tmote Connect software voids the Linksys/Cisco NSLU2 warranty. Moteiv, independently from Linksys/Cisco, provides support for Tmote Connect and a supplemental warranty. See page 14 for additional information.

## Setup Information

This section describes how to integrate Tmote Connect into your local area network. Tmote Connect is designed to work both with DHCP and without DHCP. DHCP is preferred for all Tmote Connect installations; whereas non-DHCP operation may be suitable for small installations on private networks.

### Package Contents

- 1 Linksys NSLU2 unit with Moteiv Tmote Connect software
- 1 Ethernet Cable (6ft length)
- 1 110V AC to 5V DC power adapter
- 1 Tmote Connect datasheet (this document)

### Optional Accessories available from Moteiv

- 1 Power-over-Ethernet 802.3af Adaptor Kit
- 2 Moteiv 1 meter USB A-A extension cables

### Connecting Tmote Connect to your network

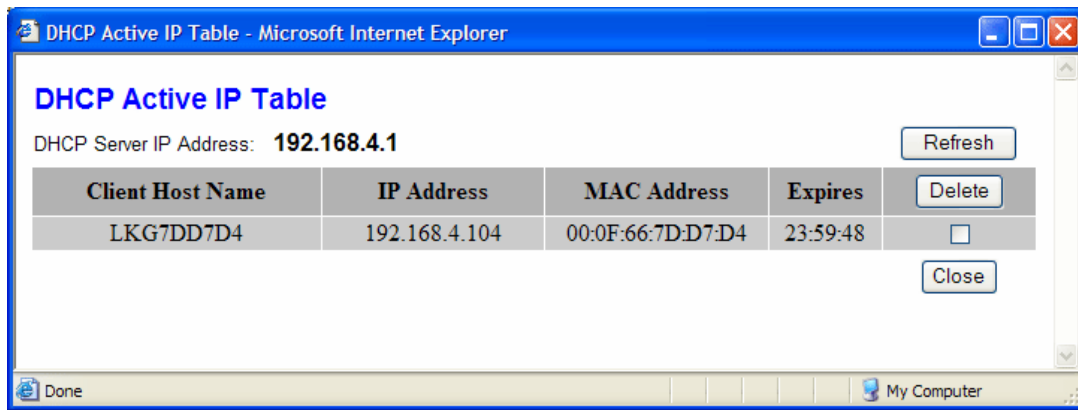
1. Make a note of the Tmote Connect hostname and MAC address found on the bottom of the enclosure. If the label displays a MAC address (00:04:5A:xx:yy:zz, 00:0F:66:xx:yy:zz, or 00:13:10:xx:yy:zz) then the resulting hostname is LKGxxyyzz. If the label displays a hostname in the form LKGxxyyzz, then the full MAC address is the combination of xx:yy:zz with one of the above MAC address prefixes (ie: 00:04:5A:xx:yy:zz).
2. Attach the Tmote Connect's Ethernet port to your hub, switch, or Ethernet outlet with the included Ethernet cable
3. Connect your Tmote Sky modules to the USB ports
4. Attach the Tmote Connect's power port to an electrical output with the included power cord
5. Tmote Connect will automatically power on when the power cord is connected
6. Tmote Connect will run a self test followed by a boot process. When it is ready to be accessed it will beep once.
7. If a Tmote Sky module is connected to the "Disk 1" port, then the Disk 1 LED will be lit; likewise, if a Tmote Sky module is connected to the "Disk 2" port, then the Disk 2 LED will be lit.



### Installation on DHCP-enabled networks

If your DHCP server integrates the client hostname into the naming service (Dynamic DNS), the task of finding Tmote Connect on your network is easy – it is simply assigned the hostname LKGxxyyzz that you noted in step 1 of the installation. If your DHCP server does not communicate with the naming service (as is the case with many of the inexpensive consumer gateways) or uses a different naming scheme, you must access your DHCP server's client data. Most DHCP servers, including devices from Linksys and other major manufacturers, provide a mapping table with the IP address and hostname of the connected Tmote Connect device using MAC Addresses.

An example mapping from a Linksys Router is shown below:



### Finding Tmote Connect on your network (for Linux users ONLY)

If you do not have access to the DHCP client data, you can still find the IP address of your Tmote Connect provided you are on the same network. You can discover the IP address of any particular computer connected to the network using `arping` utility from <ftp://ftp.habets.pp.se/pub/synscan/arping-2.05.tar.gz>:

```
arping 00:04:5A:xx:yy:zz
arping 00:0F:66:xx:yy:zz
arping 00:13:10:xx:yy:zz
```

using the MAC address you recorded in step 1 of the installation.

**!** **NOTE:** There are several, slightly varying versions of `arping` available. In particular, `arping` included as part of the `iputils` package does not support pinging using the MAC address. `arping` is only supported on Unix platforms.

### Operation without DHCP

Tmote Connect ships with DHCP support enabled by default, but can operate without it even in moderate size networks. In the absence of DHCP, Tmote Connect emits a series of “double-beeps” to signal that no DHCP lease has been granted. It then attempts to claim address 192.168.1.77. If there is a conflict at that address (for example, another Tmote Connect has already claimed it), the appliance will scan consecutive addresses until it finds an available address and claim it. After the initial connection, you can assign a static IP address to your Tmote Connect, see section “Tmote Connect Upgrades and Management” on page 10.

### USB Extension cables to attach Tmote sky to Tmote Connect

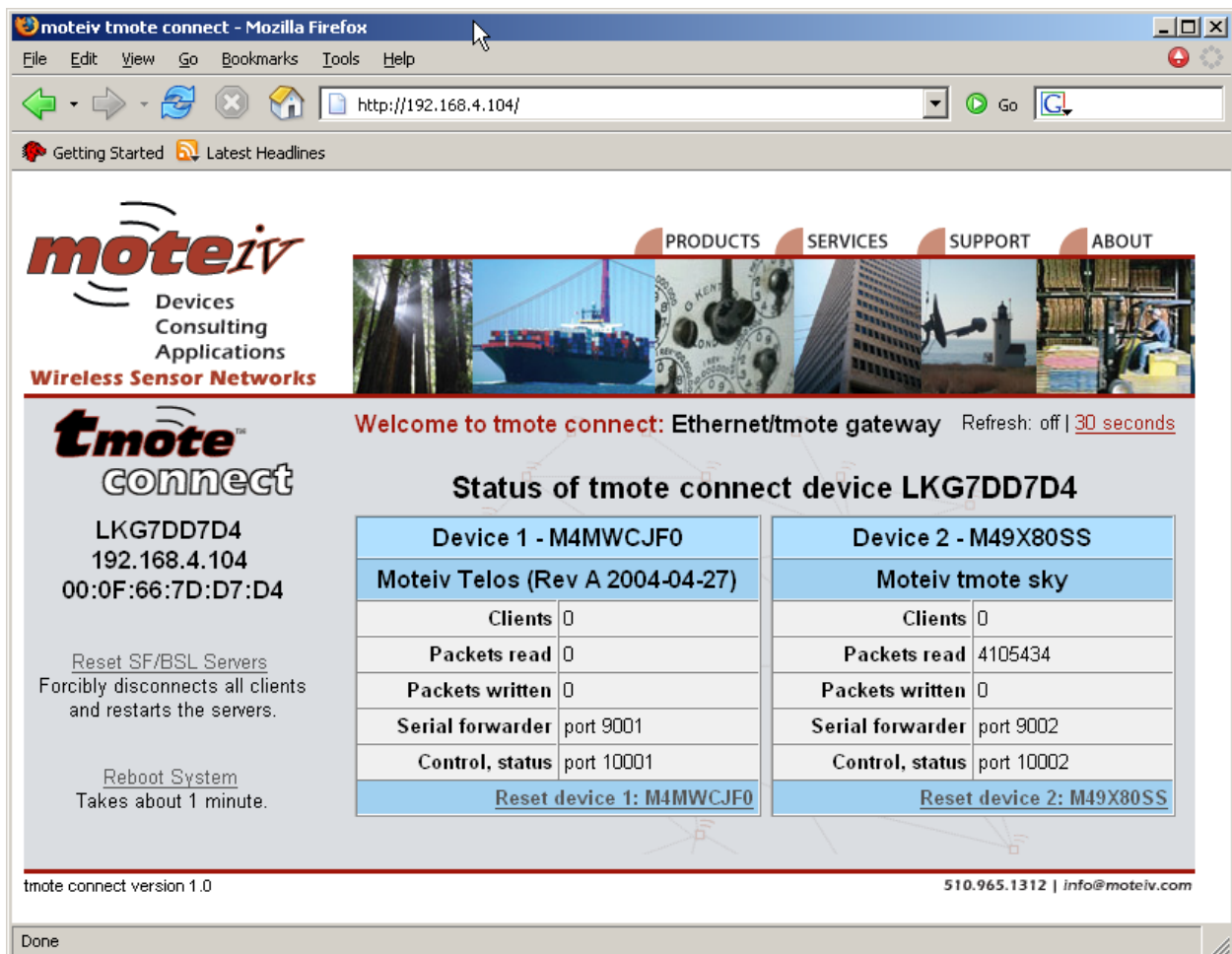
Moteiv sells 1 meter USB A-A extension cables. You can order these cables from <http://www.moteiv.com> or via email at [info@moteiv.com](mailto:info@moteiv.com).

Belkin ([www.belkin.com](http://www.belkin.com)) and DCables ([www.dcables.com](http://www.dcables.com)) provide USB A-A extension cables of varying lengths.

## Accessing Tmote Connect

Tmote Connect can be accessed through a number of interactive or non-interactive interfaces. All of the administrative tasks are accessible through a webpage interface running on port 80. The examples shown throughout this document are based on an interaction with Tmote Connect running at IP address 192.168.4.104; a Telos rev. A is connected to USB port 1 and a Tmote Sky is connected to USB port 2.

## Tmote Connect GUI



Getting Started Latest Headlines

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PRODUCTS SERVICES SUPPORT ABOUT

Welcome to **tmote connect**: Ethernet/tmote gateway Refresh: off | 30 seconds

**tmote connect**

LKG7DD7D4  
192.168.4.104  
00:0F:66:7D:D7:D4

[Reset SF/BSL Servers](#)  
Forcibly disconnects all clients and restarts the servers.

[Reboot System](#)  
Takes about 1 minute.

Device 1 - M4MWCJF0		Device 2 - M49X80SS	
Moteiv Telos (Rev A 2004-04-27)		Moteiv tmote sky	
Clients	0	Clients	0
Packets read	0	Packets read	4105434
Packets written	0	Packets written	0
Serial forwarder	port 9001	Serial forwarder	port 9002
Control, status	port 10001	Control, status	port 10002
<a href="#">Reset device 1: M4MWCJF0</a>		<a href="#">Reset device 2: M49X80SS</a>	

tmote connect version 1.0 510.965.1312 | info@moteiv.com

Done

The Tmote Connect webpage displays the type and serial number of each mote connected to the gateway and information about the gateway itself: hostname, IP address, and MAC address. It also displays information about packets transmitted to or received from each mote and the serial forwarder and control port numbers. By convention, port 900X is the Serial Forwarder port and port 1000X is the control/status port for a mote connected to USB port X. The web interface allows the user to individually reset each mote without breaking established serial forwarder connections, restart the server programs, and to reboot Tmote Connect.

## Programming Notes

The programming code depends on the `nc` (`netcat`) utility that's widely available on UNIX system. Precompiled versions of `netcat 1.10` for Linux and Cygwin systems can be downloaded from the Moteiv support page at <http://www.moteiv.com/support.php>. Mote programming using Tmote Connect has been fully integrated into the TinyOS build system as of early May 2005. Users running release of TinyOS 1.1.12 or earlier should download the programming rules that allow for programming using Tmote Connect from the above support page. TinyOS 1.1.13 includes native support for Tmote Connect.

Users working with the TinyOS CVS repository from SourceForge, simply run

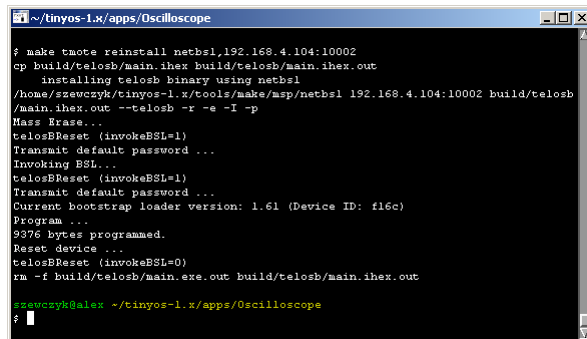
```
cvns update
```

in your `$(TOSDIR)/../tools/make` directory to download the new programming rules.

Once the programming rules have been installed within the TinyOS distribution, Tmote Connect is ready to be used. To compile and install an application onto a particular mote, run:

```
make tmote reinstall,2 netbs1,192.168.4.104:10002
```

The above command will install the program configured for mote id 2 at Tmote Connect module at address 192.168.4.104 on USB port 2. The arguments to `netbs1` can take a form of the standard `IP:PORT` or can be shorthanded to `XX.1` and `XX.2`. The value `XX` will be prefixed with the value of `NETBSL_HOSTPORT_PREFIX`, which defaults to "192.168.1." for a full ip address of 192.168.1.XX; the shorthand port numbers "1" and "2" map to ports 10001 and 10002 used to program each Tmote Connect USB port.

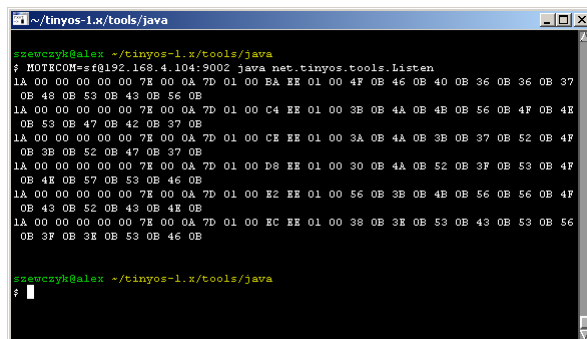


```
~/tinyos-1.x/apps/Oscilloscope
$ make tmote reinstall netbs1,192.168.4.104:10002
cp build/telesh/main.ihex build/telesh/main.ihex.out
installing telesh binary using netbs1
/home/szewczyk/tinyos-1.x/tools/make/asp/netbs1 192.168.4.104:10002 build/telesh/main.ihex.out --telesh -x -e -I -p
Mass Erase...
teleshBreset (invokeBSL=1)
Transmit default password ...
Invoking BSL...
teleshBreset (invokeBSL=1)
Transmit default password ...
Current bootstrap loader version: 1.61 (Device ID: f16c)
Program ...
9376 bytes programmed.
Reset device ...
teleshBreset (invokeBSL=0)
rm -f build/telesh/main.exe.out build/telesh/main.ihex.out

$
```

## Accessing Mote Data

The data connection to motes is provided using the Serial Forwarder protocol used extensively throughout the TinyOS distribution. All TinyOS java applications retrieve the connection information from an environment variable called `MOTECOM`. In our example, to connect listen to packets generated by the Oscilloscope application, run



```
~/tinyos-1.x/tools/java
$ java net.tinyos.tools.Listen
1A 00 00 00 00 00 7E 00 0A 7D 01 00 EA EE 01 00 4F 0B 46 0B 40 0B 36 0B 36 0B 37
0B 48 0B 53 0B 43 0B 56 0B
1A 00 00 00 00 00 7E 00 0A 7D 01 00 C4 EE 01 00 3B 0B 4A 0B 4B 0B 56 0B 4F 0B 4E
0B 53 0B 47 0B 42 0B 37 0B
1A 00 00 00 00 00 7E 00 0A 7D 01 00 CE EE 01 00 3A 0B 4A 0B 3B 0B 37 0B 52 0B 4F
0B 3B 0B 52 0B 47 0B 37 0B
1A 00 00 00 00 00 7E 00 0A 7D 01 00 D8 EE 01 00 30 0B 4A 0B 52 0B 3F 0B 53 0B 4F
0B 4E 0B 57 0B 53 0B 46 0B
1A 00 00 00 00 00 7E 00 0A 7D 01 00 E2 EE 01 00 56 0B 3B 0B 4B 0B 56 0B 56 0B 4F
0B 43 0B 52 0B 43 0B 4E 0B
1A 00 00 00 00 00 7E 00 0A 7D 01 00 EC EE 01 00 38 0B 3E 0B 53 0B 43 0B 53 0B 56
0B 3F 0B 3E 0B 53 0B 46 0B

$
```

```
MOTECOM=sf@192.168.4.104:9002 java net.tinyos.tools.Listen
```

With this syntax we can quickly switch between different Serial Forwarder servers. `MOTECOM` variable can be made persistent for a shell session (e.g. when all connections are made to the same Serial Forwarder server) by executing:

```
export MOTECOM=sf@192.168.4.104:9002
```



## Tmote Connect Advanced Operations

This section describes the Tmote Connect control protocol for **expert** users. The protocol has been engineered for simplicity and readability rather than compatibility with existing standards (like HTTP) or security. All protocol transactions take a form of

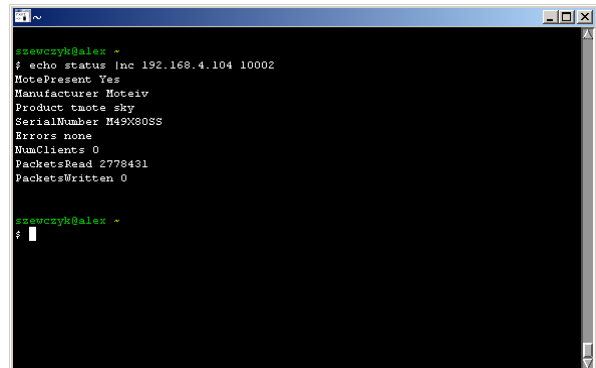
```
Command line
Optional data
Optional trailer
```

After issuing the command, the client reads the response from the socket until the server closes the connection. The examples below use `nc` (`netcat`) utility to show protocols in action. Currently, the following protocol actions are supported:

```
status
quit
msp430-bsl
baudrate
protocol
unfriendly_system_reboot
```

### Status

Various status parameters of the Tmote Connect control server can be obtained by connecting to the Control port and issuing a single line with the word "status". The server returns a sequence key value pairs, each on a separate line. Keys are limited to be a single word, the value begins after the initial space and extends until the end of the line. For example, to access the status of the server at IP address 192.168.4.104 connected to the mote on port 2, we could execute the following command



```
ssawczy@alex ~
$ echo status | nc 192.168.4.104 10002
MotePresent Yes
Manufacturer Moteiv
Product tmote sky
SerialNumber M45X80SS
Errors none
MmciPresent 0
PacketsRead 2778431
PacketsWritten 0
ssawczy@alex ~
$
```

```
echo status | nc 192.168.4.104 10002
```

### Programming Protocol

Tmote Connect's programming protocol is based on `msp430-bsl` application. The command can be issued in the form:

```
echo "msp430-bsl <command-line-switches>" | nc 192.168.4.104 10002
```

Command line switches specify the device type to be accessed and a sequence of actions to perform. When a program is being uploaded to the mote, the above command is to be immediately followed by the program image in the IHEX format. The end-of-file is signified via a blank line. The server responds with a sequence of diagnostic messages that one see as an output from `msp430-bsl`.

The programming protocol supports the following actions:

```
-e, --masserase      Mass Erase (clear all flash memory)
-E, --erasecheck     Erase Check by file
-p, --program        Program file
-r, --reset          Reset connected MSP430. Starts application.
                    This is a normal device reset and will start the program that is
                    specified in the reset vector.
-v, --verify         Verify by file
```

Don't forget to specify "e" or "eE" when programming flash!

The platforms are supported:

```
--tmote              Moteiv Tmote Sky
--telosb             Moteiv Telos rev. B
--telos              Moteiv Telos rev. A
```



**NOTE:** The Tmote Connect software does not auto detect the platform for programming access, so you must specify `--tmote`, `--telosb`, or `--telos`. If the control server responds with "NAK received", the user specified an incorrect platform (e.g. `--telosb` instead of `--telos`, or the platform was omitted altogether).

Additional options are available. You can access the help screen by specifying `-h` on the command line.

For example, the following command programmatically resets a Tmote Sky mote:

```
echo "msp430-bsl --tmote -r" |nc 192.168.4.104 10002
```

## Resetting the control server

The control server runs within a respawning daemon. Command "quit" will exit the current control server instance, and the respawning daemon will start a new instance.

## Protocol and Baud Rate

Tmote Connect (as of firmware version 1.2.0 and later) supports dynamic setting of the serial protocol and baudrate. The specific protocol can be set with the "protocol" command. Valid options for "protocol" are:

```
auto
tinyos1.x
tinyos2.x
```

When a mote is inserted or reprogrammed, Tmote Connect will automatically try to detect the protocol version running on the connected mote if the "auto" protocol setting is selected. If detection fails, Tmote Connect defaults to `tinyos1.x`. If a specific protocol is specified (such as `tinyos1.x`), the autodetection process will not occur.



The baudrate may also be selected through the command interface. The option specified to the “baudrate” command is any valid baudrate. Specifying “0” (zero) as the baudrate will cause Tmote Connect to autodetect the baudrate based on protocol—in this case, 57600 baud is used for TinyOS 1.x motes and 115200 baud is used for TinyOS 2.x motes. If the baudrate is explicitly set to a number *other* than zero using the “baudrate” command, Tmote Connect will use the specified baudrate regardless of the selected protocol.

The default setting of Tmote Connect is **auto** protocol detection and **auto** baudrate selection. Protocol and baudrate settings are lost when Tmote Connect is rebooted or shutdown.

**!** **NOTE:** Tmote Connect does not gracefully transition clients when a new protocol is chosen. If the protocol is changed from TinyOS 1.x to TinyOS 2.x, all TinyOS 1.x clients will be forcibly disconnected from Tmote Connect.

## Restarting Tmote Connect device

On rare occasions, there may be a need to restart the Tmote Connect device. For those rare occasions, the control interface supports the “unfriendly\_system\_reboot” command. This command takes no arguments, cannot be revoked or cancelled, and produces a single line of output confirming that the reboot will take place. Once you issue this command, Tmote Connect should be available within a minute.

```

$ echo status |nc 192.168.4.104 10002
MotePresent Yes
Manufacturer Moteiv
Product tmote sky
SerialNumber H49X008S
Errors none
NumClients 0
PacketsRead 97496
PacketsWritten 0

$ echo quit |nc 192.168.4.104 10002
quitting

$ echo status |nc 192.168.4.104 10002
MotePresent Yes
Manufacturer Moteiv
Product tmote sky
SerialNumber H49X008S
Errors none
NumClients 0
PacketsRead 116
PacketsWritten 0

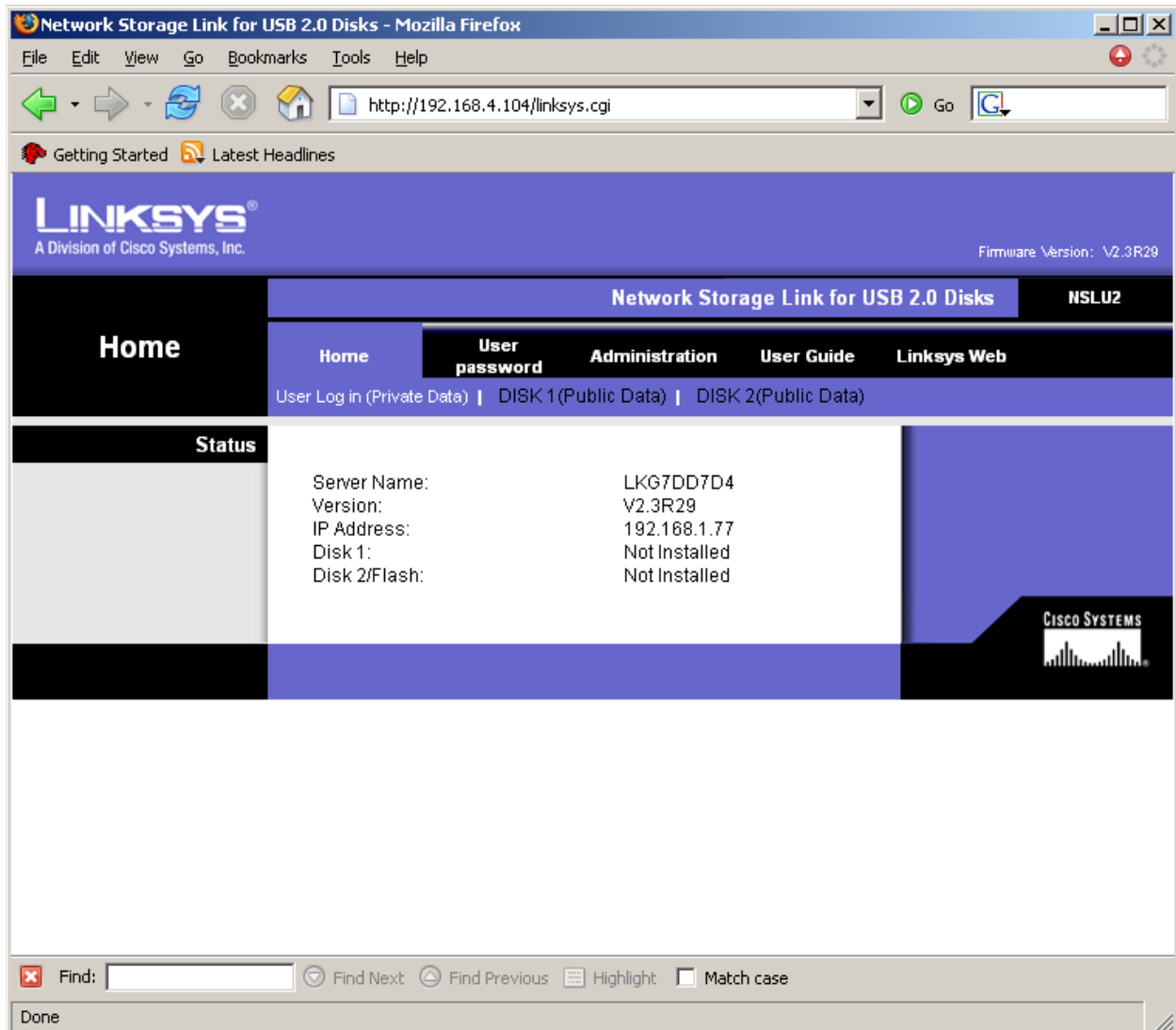
$
  
```

## Tmote Connect Upgrades and Management


This section describes how to manage and upgrade Tmote Connect software with new software provided by Moteiv. Tmote Connect offers a web-based management console. The gateway hardware and the management software was created by Linksys, all troubleshooting questions regarding the operation of Tmote Connect must be directed to Moteiv Support ([support@moteiv.com](mailto:support@moteiv.com)). Linksys does **not** provide support services for the NSLU2 units loaded with Tmote Connect software.

### Managing Tmote Connect

Tmote Connect management interface is located under `linksys.cgi` page in the top level directory. The top-level page describes the basic properties of the device.



The “Administration” tab is useful for administering Tmote Connect network properties. It is password protected; by default access is granted to user “admin” with password “admin”. The “Administration” tab offers the ability to switch between DHCP and fixed IP addresses, change the hostname and workgroup information, as well as access status information.

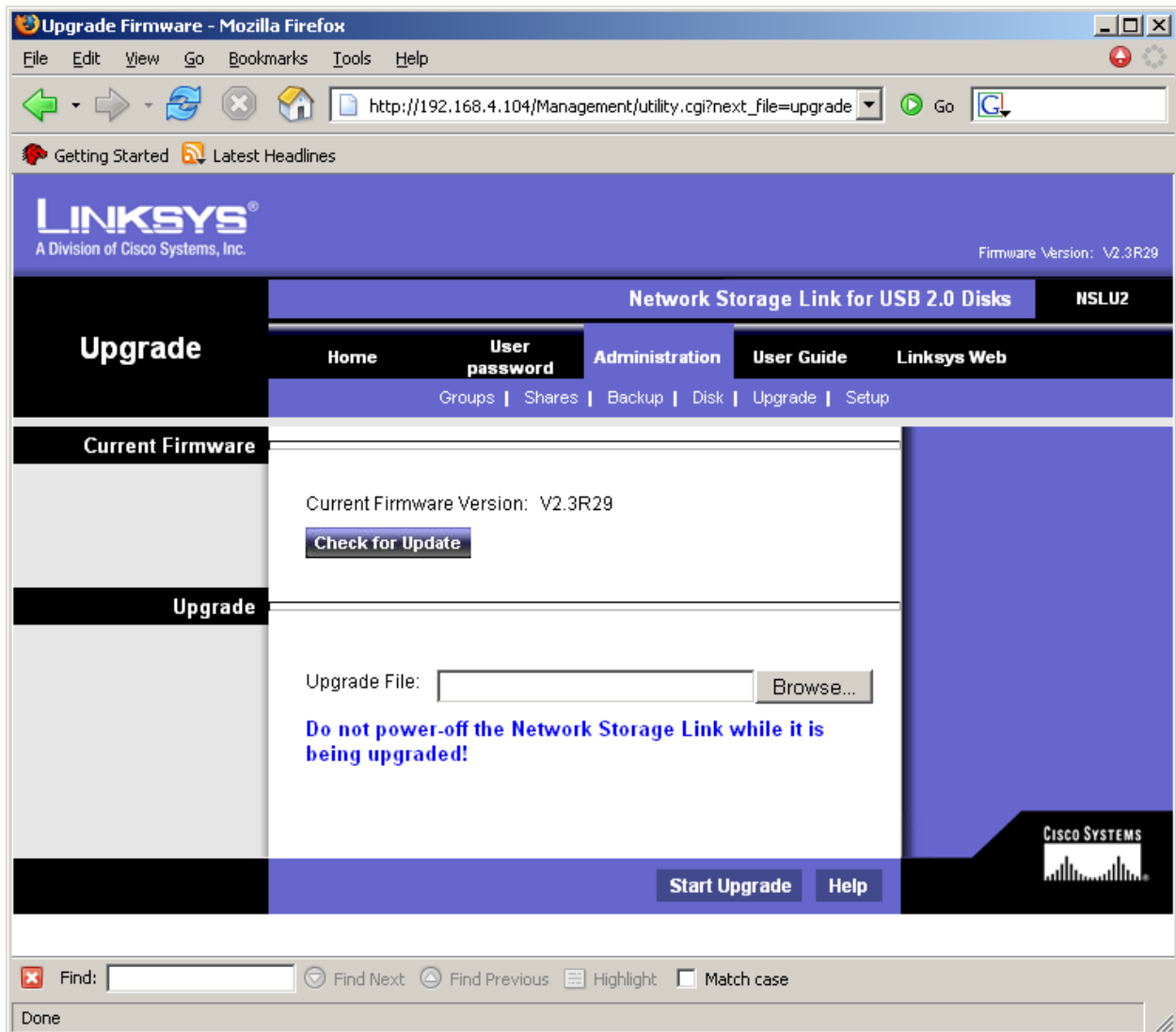
 **NOTE:** By using Tmote Connect software on the Linksys NSLU2 device, the NSLU2 no longer acts as a network attached storage unit. Network attached storage functionality (such as disk status information, user and group management, and UPnP) are not supported by Tmote Connect software.

(continued on the next page)

## Upgrading Tmote Connect

You can access Tmote Connect upgrade page by going to Administration>Advanced>Upgrade tab in the Linksys management interface. Do not press the “Check for upgrade” box. Instead, download software from <http://www.moteiv.com/> to your local drive, and install it using the upgrade utility. The typical installation takes under 5 minutes. After clicking the “Start Upgrade” button, do **not** power-off the unit while it is being upgraded.

The Linksys “Current Firmware Version” text may not change; however, the Tmote Connect software revision is displayed on the main status webpage of the Tmote Connect unit.



## General Information

### Known Limitations

Tmote Connect software does not support certain capabilities of the Linksys/Cisco NSLU2 unit. Below is a short list of unsupported capabilities:

- USB 2.0 High-speed devices
- USB hubs
- USB 802.11 wireless adapters
- USB storage
- File sharing protocols are not supported

### Document History

Revision	Date	Notes
1.0	2005/05/18	Initial Release
1.0.1	2005/12/28	Updated for Tmote Connect software version 1.0.2 Updated software description, principles of use, and contact information Tmote Connect automatically powers on when power is applied
1.0.2	2006/02/06	Updated contact information
1.2.0	2006/12/12	Added additional protocol support (TinyOS 1.x and TinyOS 2.x) Updated data for firmware 1.2.0+, updated pictures and disclaimer

### Address Information

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