1. Background

What is d-Mesh?

d-Mesh is a low-cost a wireless upload system for YieldPoint's digital geotechnical sensor products. The system wirelessly enables an array of d-Logger dataloggers and establishes a link with the "nearest" Ethernet Access Point or a WiFi hotspot.

d_Mesh is a battery powered 900MHz wireless mesh technology that can monitor arrays of YieldPoint's instruments connected to YieldPoint's d^4Logger data-loggers. Each wireless mesh comprises a single coordinator and an array of wireless nodes that is self-configuring and potentially self-healing (depending on configuration). The system is designed to be Plug 'n Play building on YieldPoint's "Easy-to-use" d_Logger solution which requires minimal configuration and will operate "out of the box". The 900MHz wireless technology is based on Digi-International's industry leading Xbee 900HP radios. A complete manual for these radios is provided here:

YieldPoint has developed a software solution that enables d^4Loggers to be either (i) remotely downloaded across the wireless mesh, or (ii) autonomously downloaded at predefined regular intervals. A wireless mesh can be deployed in minutes, either as an addition to an existing cluster of d^4Loggers or as part of a brand new system. The mesh radios are low priced (approx. $250-300ea) with one radio required for each d^4Logger which can collect data from 4 YieldPoint instruments. This price-point maintains the telemetry prices much lower than those of the instruments that they monitor. Power for the radios resides in the d^4Logger and all Xbee API packetization is provided by existing d^4Loggers without an upgrade. d_Mesh software is available at no charge on the YieldPoint website.

In building d_Mesh YieldPoint has leveraged the expertise of Digi International Inc., the world's leader in mesh radio communications. Our solution is in no way proprietary, so that interested parties can develop the solution to their own requirements. The radios themselves, operating at 900MHz, have a "proven" LOS range up to 1000m underground. Power consumption is reduced by minimizing the duty-cycle and waking the radios for minimal periods of time when a data download is required.

Where does d-Mesh fit in?

YieldPoint solutions are used for projects with various levels of telemetric capability. Consequently a number of different options are available.

LEVEL 1: Manual readout using the d_Reader which involves a local visit to the instrument.

LEVEL 2: Remote data storage using d^1Logger or d^4Logger. Data is stored at regular intervals but requires a visit and manual upload usually via USB cable.

LEVEL 3: Networked array of d^4Loggers that are accessed from surface using the exising IT backbone usually via Ethernet or WiFi. Either (i) Buffered d^4Logger data can be remotely downloaded using a surface PC or (ii) automatic data upload with auto-polling can be configured with the option to upload data to a file or a Cloud-based SQL database.

d-Mesh radios facilitate the transition for Level 2 to Level 3 for a minimal increase in cost. The radios are modular and can added or removed from an array of loggers as needs dictate. The d-Mesh radio are powered from four(4) D-cell batteries with the d^4Logger.

2. Hardware Components

The radio modem

A 900MHz antenna is provided and may be need to be screwed into the radio module (Figure 2).The d_mesh radio is a small radio modem that connects into the COM port of the d^4Logger (Figure 1). It requires no batteries, and is powered from the d_LOGGER. Radio modules can be used with any d^4Logger and there is no need to provide configuration information. In d_Mesh the same physical hardware is used as an end-node or a router.

When plugged into the d4Logger the Blue LED with begin Flashing on a 1s cycle. This indicates that it is powered and fuctional. The response of the LED is outlined in Table 1.

Configuration of the radio modem.

Each d_Mesh radio comes preconfigured with default setting designed to operate on d_Mesh. The user has the option to change these settings, for example the name of the radio, using Digi-international's X-CTU tool. The is bundles with d_Mesh. The most convenient method of configuring the radio is using the XBEE Config Cable (purchased separately) which can be plugged into the USB port of a PC or laptop computer. Power to the radio from the USB port is indicated by a 1s blinking cycle on the blue LED.

Open X-CTU and under the PC setting tab select the Virtual Com Port (VCP) corresponding to the Xbee Config Cable, COM33 in Figure 3.
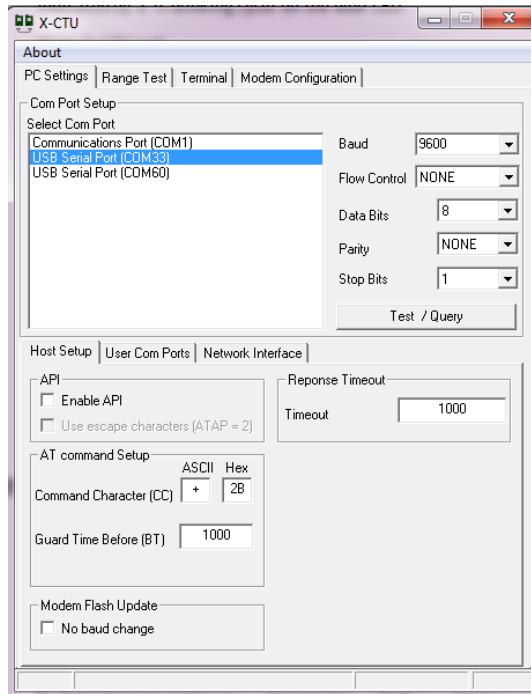
Figure 3: Select the VCP corresponding to the Xbee Config Cable.
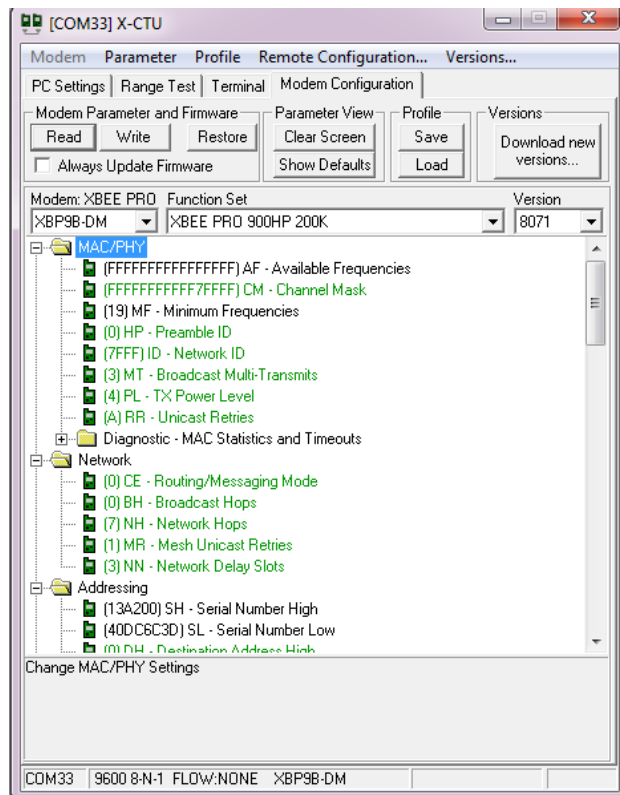

Figure 4: select read from the Modem Configuration tab to display the setting for the d_Mesh modem.

A user-guide for X-CTU is bundled with the software: X-CTU user-guide.

An on-line tutorial for X-CTU is available here:

https://www.youtube.com/watch?v=Boy5asltEJw

and a number of other are available on-line. The default setting for a d_Mesh are shown in Appendix A. Entries in green are Digi International defaults those in Blue have been changed for compatibility with d_Mesh.

Once d_Mesh has been deployed these settings can be modified over-the-air (OTA) from the d_Mesh software using remote AT commands (see below).

3. d-Mesh Deployment – Office network.

d-Mesh is a true mesh network that will auto-configure. It is highly recommended that the user familiarize themselves with the system using an office network. Download d_Mesh from the YieldPoint website:

http://www.yieldpoint.com/dmesh_setup.exe

install the program which also comes bundled with X-CTU (Digi International) and Device Explorer (Tibbo Inc).

In our mesh we will use:

1. A d_Mesh coordinator configured with a local IP address on the office LAN
2. 2 x d^{4}Loggers
3. 2 x d_Mesh modems

To create a very simple mesh:

STEP 1: Connect the d_Mesh Coordinator to the Ethernet.

Note: This device represents a bridge between an Ethernet network and the Xbee mesh. On the Ethernet page it is often referred to as a GateWay and on the d_mesh it is usually referred to as the coordinator.

If PoE is available the solid blue LED will indicate power otherwise the unit can be powered from 110VAC.

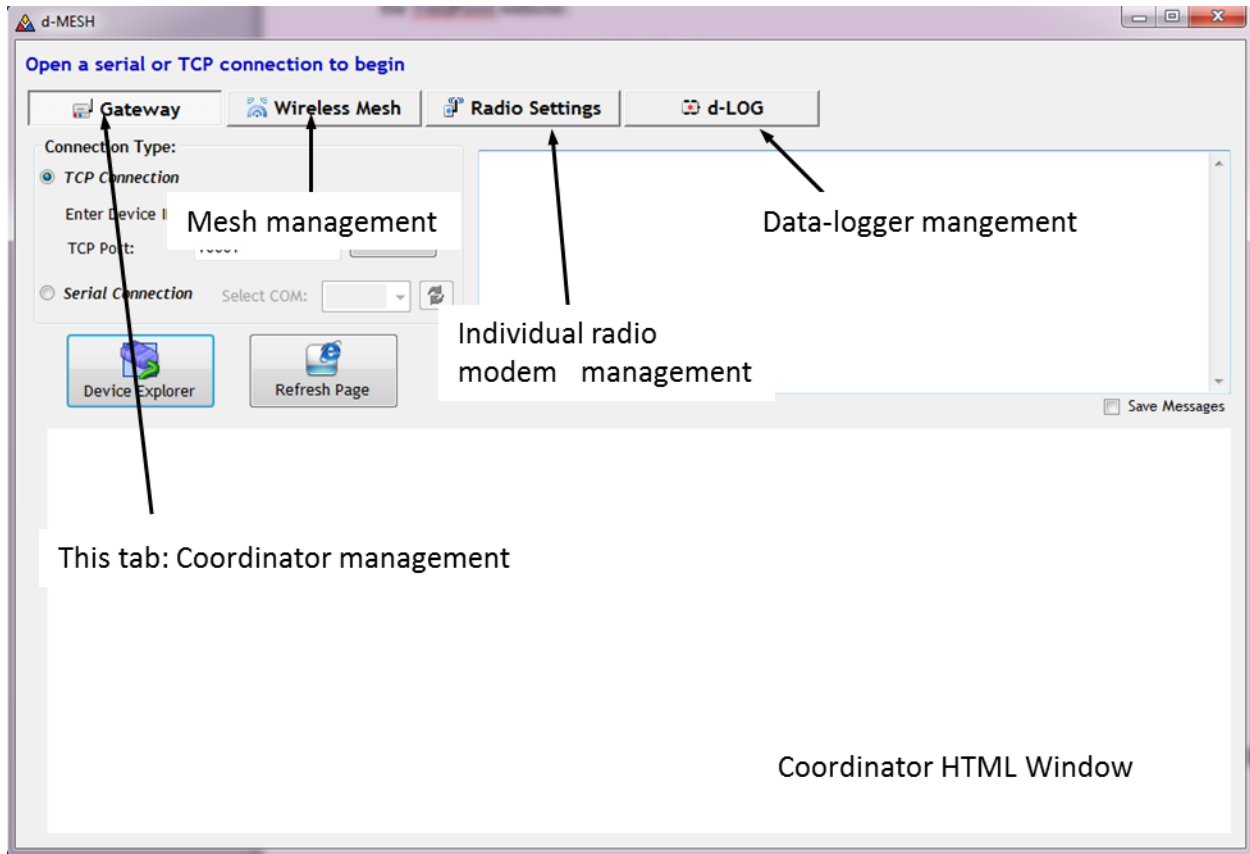**STEP 2:** Open the d_Mesh software. The structure of the software is described in Figure 5.

Figure 5: The structure of the d_Mesh Software

STEP 3: Connect to the Gateway

Once connected to the network a d_Mesh coordinate will request a local IP address from The LANs DHCP server. If no DHCP server is reachable (perhaps the device is connected directly to a PC using a X-over cable) then after 30secs the d_Mesh coordinator will assume an IP usually 192.168.1.253.

Once connected to the network the device explorer button can be used to find the network coordinator (Figure 6). It may be necessary to click on the refresh button. Unless visible in Device Explorer a TCP connection will not be established with the coordinator.

To connect enter the IP address assigned to the Coordinator with a TCP Port = 10001 and click "Connect via TCP".Two TCP connections will be established and within 10s the status of the wireless mesh may be returned.

STEP 4: Configuring the gateway using HTML form

Use the HTML page to configure the coordinator lower window to configure the coordinator. It may be necessary to click on the refresh button several times for the page to appear.

Alternatively just browse in any browser to the devices IP address, 192.168.1.88 in our case and the HTML page will load.
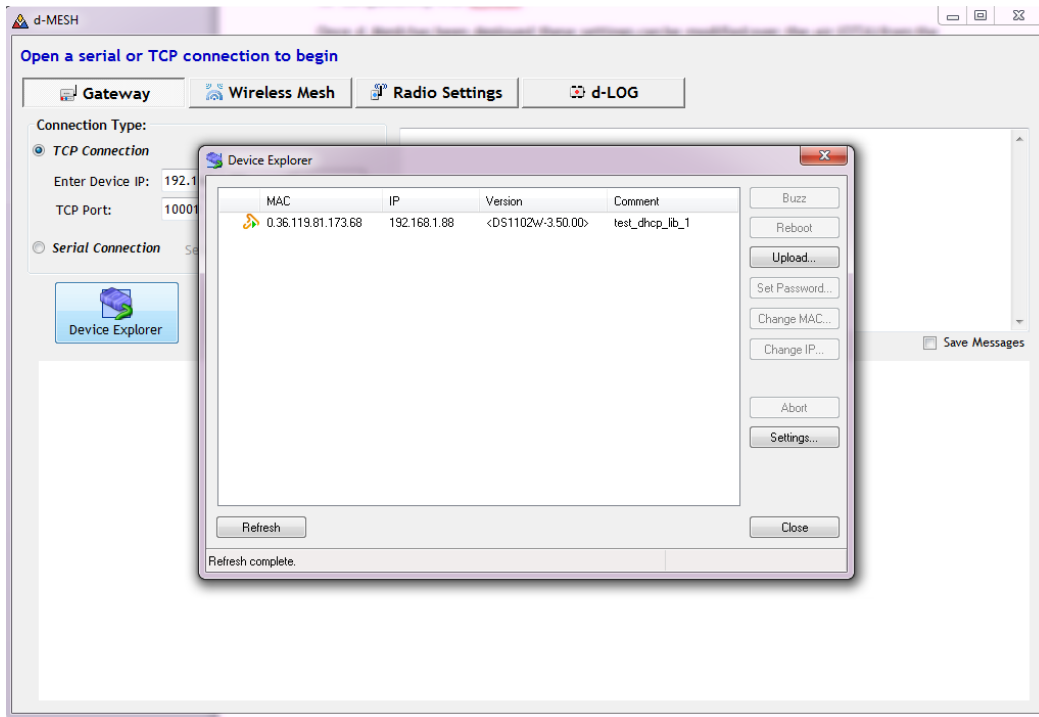

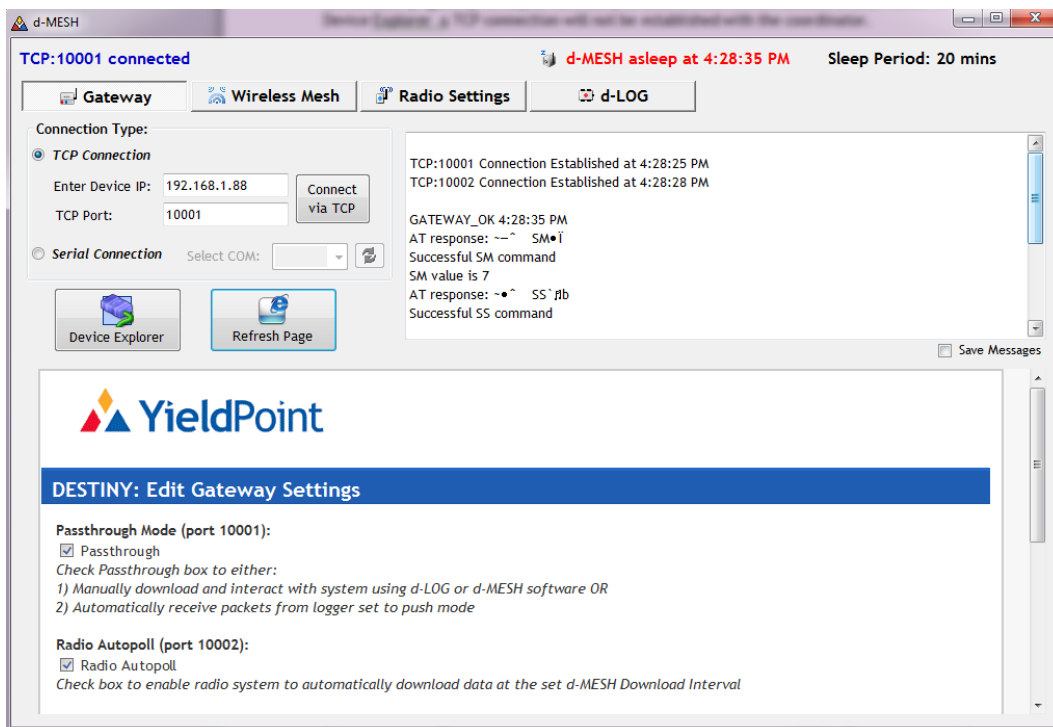**Figure 6:** Using Device Explorer to discover the gateway at IP address 192.168.1.88.

Figure 7: Making the connection; Connect via TCP

Figure 8: Setting up the Gateway IP using a browser.

In most cases, to ensure a stable TCP connection over time, the gateway should be assigned a static IP address. To do this click on the **CLICK HERE TO SET DHCP OR EDIT IP ADDRESS**. A second HTML page will load in which the appropriate PI information is input. Uncheck the DHCP enabled checkbox.

After clicking on SUBMIT the current HTML page will become unresponsive and it will be necessary to reload page using the newly assigned IP address.

STEP 5: Setting up the Gateway/Coordinator functionality.

The Gateway can be configured to run in a number of different modes.

1. Passthrough Mode simply forces the coordinator to output any commands from the Ethernet port to the Associated Xbee modem.
2. Radio Autopoll cause the Coordinator to run an automated download routine which involves (i) a Node discovery, then for each logger discovered (ii) a logger wake-up and connection, and (iii) a data download for each logger.
3. Push Mode outputs the data downloaded during autopoll to a TCP Port (10009). This takes place only when Radio Autopoll is checked
4. SQL Mode pushes the data retried during autopolling to YP's SQL database. This takes place only when Radio Autopoll is checked.

After connecting to the Coordinator via TCP on the Gateway tab the gateway will attempt to open two ports(10001 and 10002) and respond with:

TCP:10001 Connection Established at 11:58:01 AM

TCP:10002 Connection Established at 11:58:04 AM

On the Wireless mesh tab, the former is used for all gateway traffic and is displayed in the upper window, the latter for mesh related messages and is displayed in the lower window.

GATEWAY_OK 11:58:10 AM

GATEWAY_OK 11:58:20 AM

GATEWAY_OK 11:58:30 AM

The heatbeat on the Gateway will repeat every 10seconds as long as the TCP connection can be maintained.
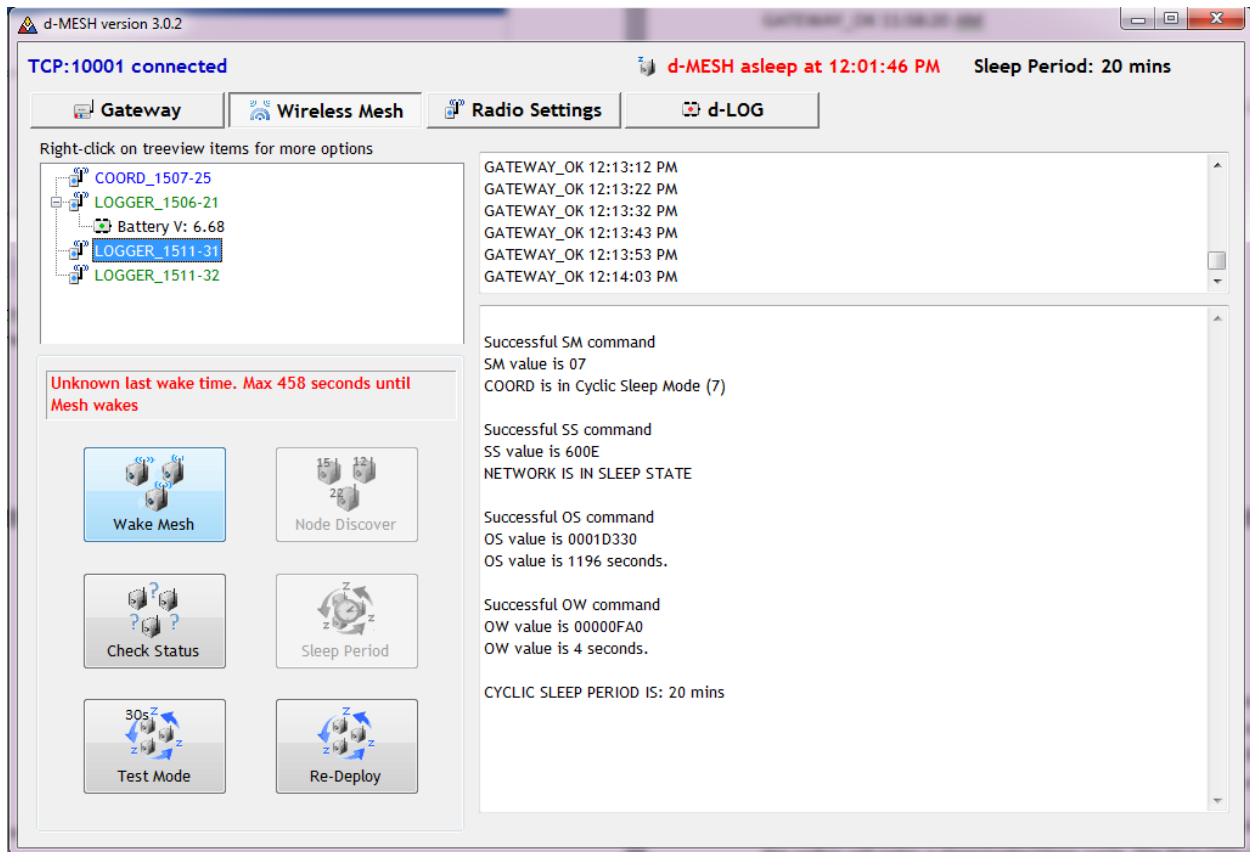
STEP 6: Configure the wireless modem.

Each wireless modem should be factory preconfigured to work automatically within a mesh. To check the configuration connect the Radio to an Xbee->USB cable. Then Launch X-CTU from the Radio Settings Tab.

Determine which virtual COM port(VCP) the Xbee radio is associated with by plugging and unplugging and restarting X-CTU. The VCP that disappears when the Xbee USB cable is unplugged from the computer is the assigned port.

The YieldPoint Factory default settings are shown in Appendix 1. Each of the radios

Step 7: Start the Wireless Mesh
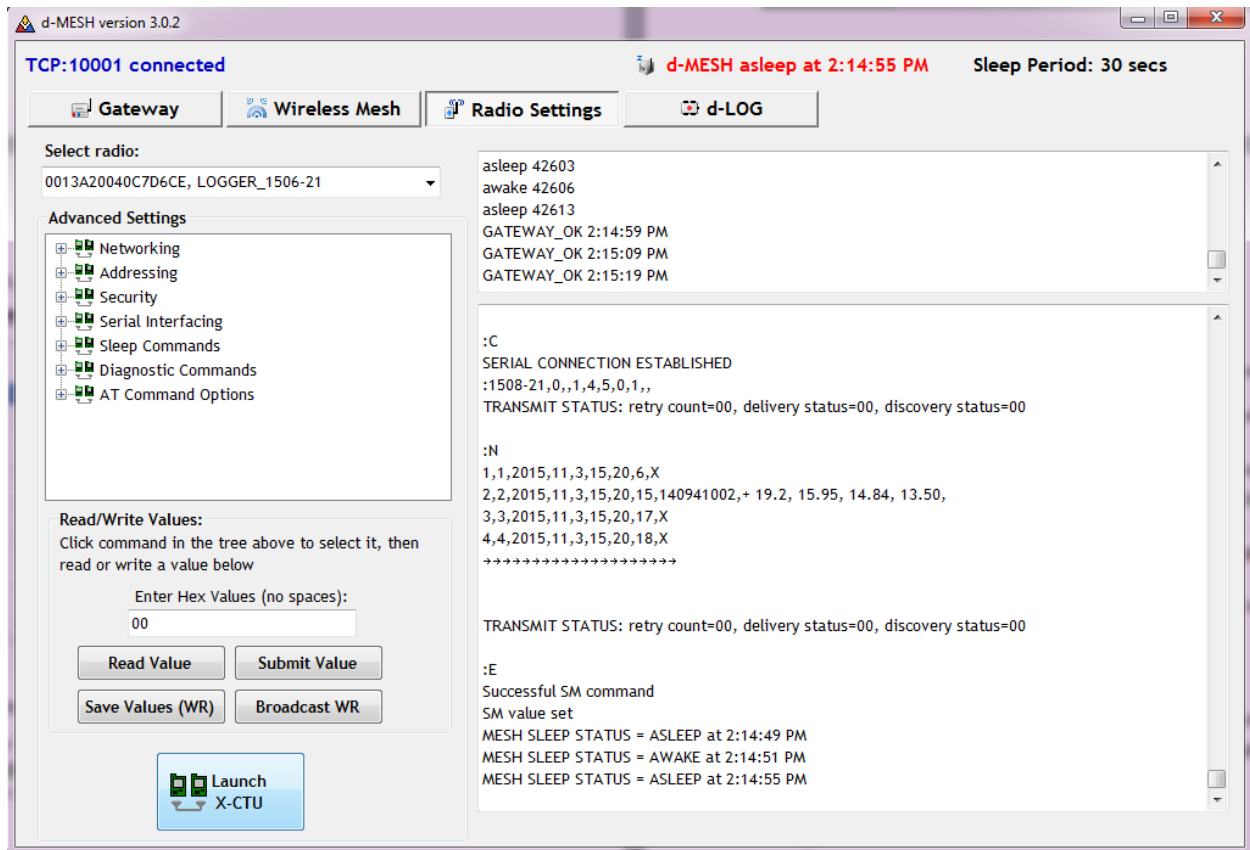
After having configured the Coordinator, and checked that each wireless modem is properly configured it is now time to start the wireless mesh. Simply make sure the coordinator is powered and connect each wireless modem to a d4logger COMMs Port (Important; Make sure the d4Logger has batteries). The Blue LED in the Radio modems will Flash on a 1sec cycle.

After approximately 30secs after being switched on, the wireless mesh will self-configure and the radios will enter a sleep/wake/sleep cycle. The blue LEDs on the modems will flash on a 1sec cycle when the loggers are awake and turn off when the mesh is asleep. In the d_Mesh software under the Wireless Mesh tab the mesh Sleep status will be reported as follows.

****

MESH SLEEP STATUS = AWAKE at 2:48:21 PM

MESH SLEEP STATUS = ASLEEP at 2:48:24 PM

MESH SLEEP STATUS = AWAKE at 2:48:51 PM

MESH SLEEP STATUS = ASLEEP at 2:48:54 PM

MESH SLEEP STATUS = AWAKE at 2:49:21 PM

****

The 30s cycle (27secs asleep and 3secs awake) is referred to a TestMode and is suitable for configuring up the mesh.

d-mesh operates using Digi International's Digimesh protocol. DigiMesh has only one node type. As a homogenous network, all nodes can route data and are interchangeable. There are no parent-child relationships. All can be configured as low-power / battery powered devices. Digimesh operates on a synchronous sleep cycle so that all nodes on the mesh sleep and wake in unison. As a result when the mesh is asleep and all the nodes are in low power mode, it is impossible to send messages across the mesh. Hence it is necessary to wake the mesh

Step 7a: Wake the Mesh

To wake the mesh click the Wake mesh Button on the Wireless mesh tab. If the wake button os not present click the Check status button to find out if the mesh is already awake. 10secs before the mesh wakes d_Mesh will beep every second to alert the user. The mesh will wake with te associated message:

****

Sending Sleep Mode = 0 broadcast to modems when d-Mesh wakes up

MESH SLEEP STATUS = AWAKE at 3:09:51 PM

Wake coordinator

Successful SM command

SM value set

****

The mesh will now remain indefinitely awake.

Step 7b: Conduct a Node Discover

Once the mesh is awake Node Discover (Wireless Mesh tab) will search for all modems that are present on the mesh. Clicking the button which will become active once the mesh is awake will return a list such as that shown below:

****

RADIO DISCOVERED: 0013A20040E47F97, COORD_1507-25 RSSI=0

RADIO DISCOVERED: 0013A20040C7D6CE, LOGGER_1506-21 RSSI=40

RADIO DISCOVERED: 0013A20040D66DF8, LOGGER_1511-31 RSSI=40

RADIO DISCOVERED: 0013A20040DC6C34, LOGGER_1511-32 RSSI=40

****

Four radios are present on the mesh: the coordinator, COORD 1507-25 and 3 Logger nodes LOGGER_1506-21, LOGGER_1511-31 and LOGGER_1511-32. The number beginning 0013A200 represents the hardware address of the Xbee modem. The RSSI (Received Signal Strength Indicator) indicates the signal strength between adjacent nodes. This value, converted to decimal and *made negative*, is the signal strength from -40 to -100 dBm. The more negative the signal strength (in dBm), the weaker the signal. Therefore, -50 dBm is better than -60 dBm. In our experience values between -40dB and -55dB provide reliable service.

Step 7c. Set a period of 10 Minutes

In TestMode the mesh is awake for 27seconds then asleep for 3 seconds which equates to duty cycle of 10%. At this rate the 4 D-cell batteries will drain after 3 days. Increasing the Sleep period to 10mins reduces the duty cycle to approximately 0.5% meaning the batteries will last for around 2months. The disadvantage of a longer Sleep period related to the "latency" of the system, in other words the average wait-time for the user before the mesh awakens.

Resetting the Sleep Period only takes effect when the mesh is put back to sleep. An extra sleep/wake cycle may be required to see the change take effect.

Step 8: Manual download from a d4Logger over the Wireless Mesh.

Once the mesh is awake and the Coordinator is set for PassThrough Mode, the d-LOG Tab allows the user to conduct a regular d_LOG session.

The steps are as follows:

(i)   Select the radio Node from the drop down menu: ***Select Wireless Logger***, in our case LOGGER 1506-**
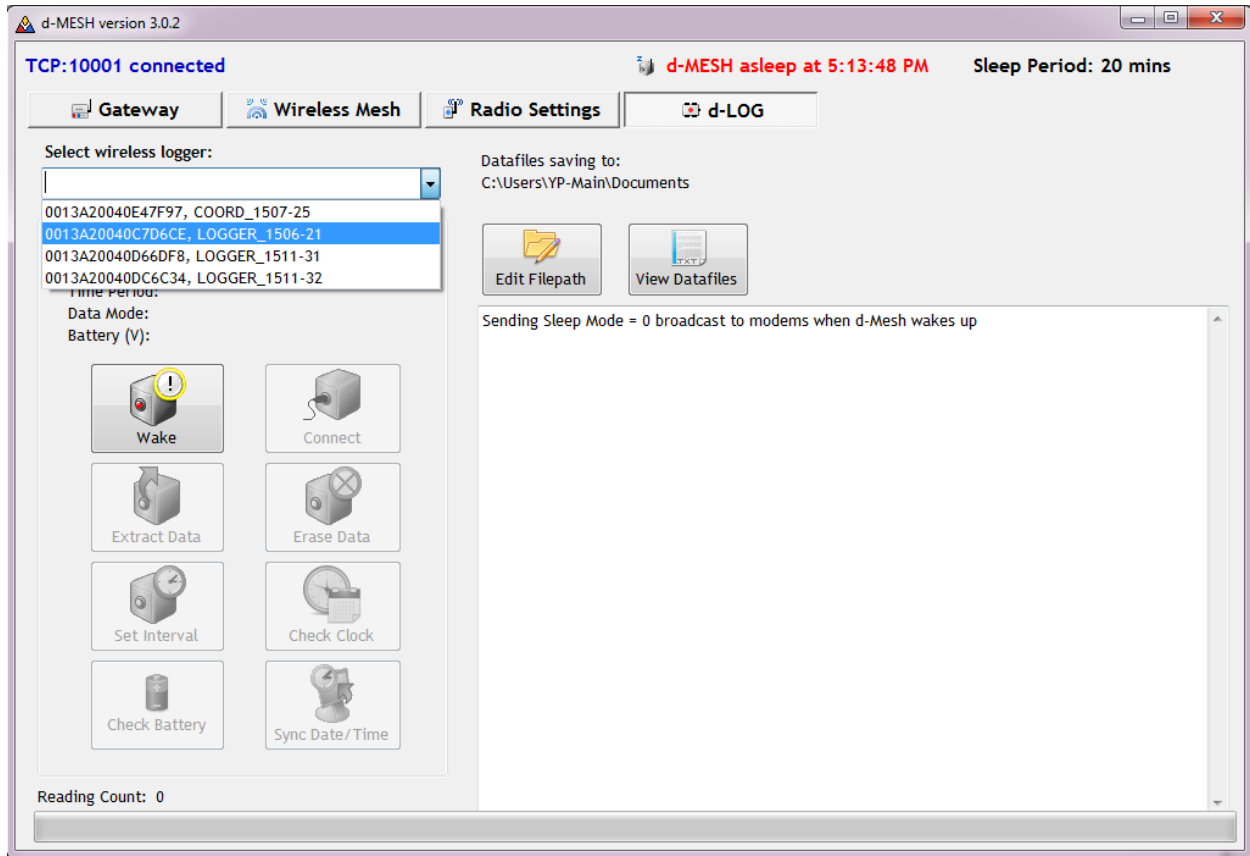
(ii)   Click the Wake button to wake the Logger (not to be confused with waking the mesh). A successful transmission will be followed by:

TRANSMIT STATUS: retry count=00, delivery status=00, discovery status=00

whereas an unsuccessful transmission will be followed by:

TRANSMIT STATUS: retry count=01, delivery status=25, discovery status=02

(iii)   Connect to the Logger

TRANSMIT STATUS: retry count=00, delivery status=00, discovery status=00

:C
SERIAL CONNECTION ESTABLISHED
:1508-21,0,,1,8,5,0,1,
TRANSMIT STATUS: retry count=00, delivery status=00, discovery status=00

:B
  668
Battery (V): 6.68

(iv) Then the usual d_Log operations can be executed 9See the d4Logger manual. For example a data download will give.

TRANSMIT STATUS: retry count=00, delivery status=00, discovery status=00

:N
1,1,2015,11,4,11,10,6,X
2,2,2015,11,4,11,10,15,140941002,+ 19.1, 15.95, 14.84, 13.51,
3,3,2015,11,4,11,10,25,1508116003,• 18.5,+ 19.7,+ 16.8,+ 19.0,+ 19.3,+ 17.3,+ 19.8,+ 18.8,+ 18.1,+ 19.6,+ 18.6,
4,4,2015,11,4,11,10,29,X
5,1,2015,11,4,11,15,4,X
6,2,2015,11,4,11,15,13,140941002,+ 19.1, 15.97, 14.84, 13.51,
7,3,2015,11,4,11,15,24,1508116003,+ 18.5,+ 19.7,+ 16.8,+ 19.0,+ 19.3,+ 17.3,+ 19.8,+ 18.8,+ 18.1,+ 19.6,+ 18.6,
8,4,2015,11,4,11,15,27,X

Thereafter the same process can be repeated for other loggers on the mesh.

The above process is an example of using d_Mesh in PassThrough mode. At the end of your session remember to put the d4Logger back to sleep on the wireless mesh page.
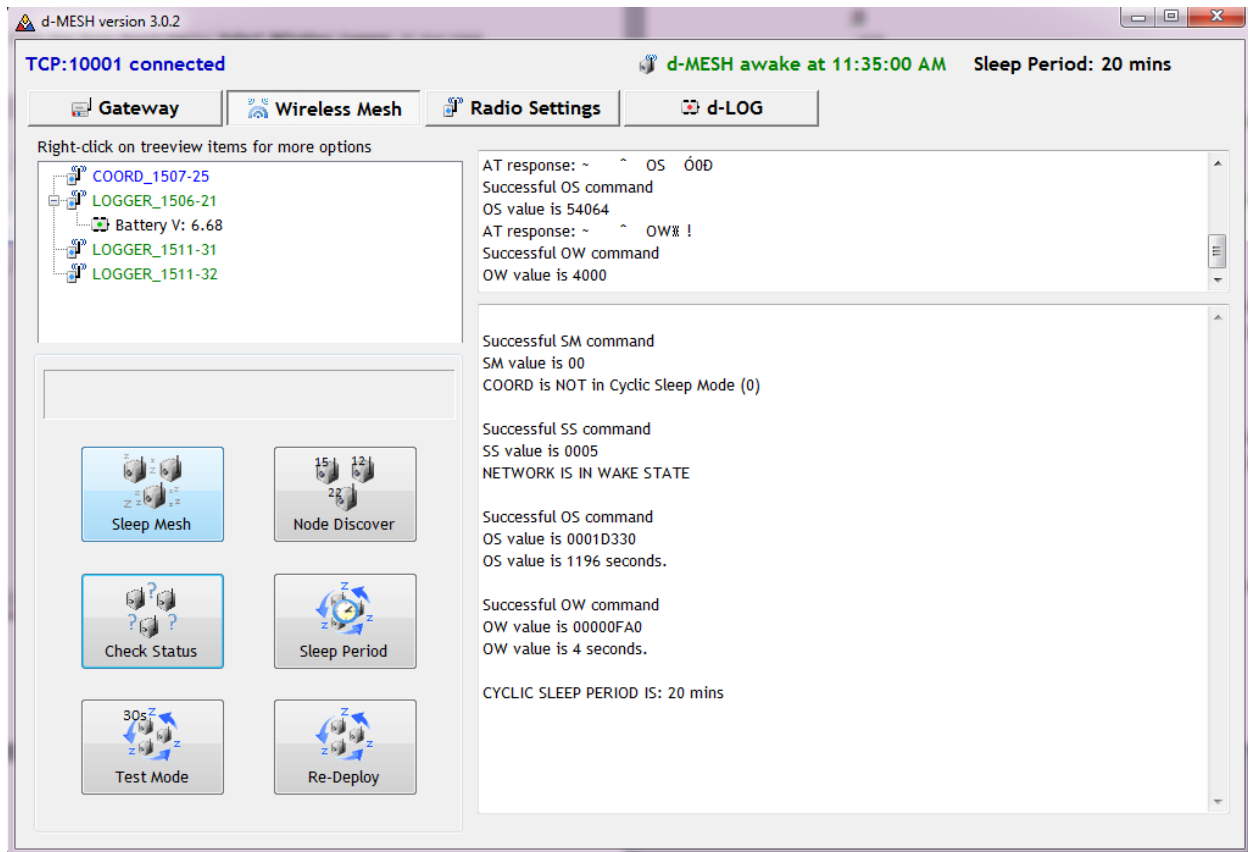
Step 8: Radio AutoPoll Mode

Radio Autopoll mode can accomplish the same functionality as Step 8 above but on a schedule automated with when the logger wakes up. To enable Autopoll check the box in the HTML form on the Gateway Tab. The Autopoll process will be reported on Port 10002.

The sequence followed by Autopoll routine is:

(i)   Wait for mesh to wake. The radio sends a sleep status command when it wakes.
(ii)   Suspend the cyclical sleep status of the wireless mesh
(iii)   Node discovery: Discover the array of radios on the mesh.
(iv)   For each radio discovered:
            (a) Wake the radio (W)
            (b) Connect to the radio (:C)
            (c) If readings exist on the radio download them (:N)
            (d) If download is successful erase data on radio (:E)
(v)   Set the radio mesh back to sleep.

Operations such as Syncing the time on the Logger, Setting the Reading Period of the logger (not to be confused with the mesh wake up period) and other operations need to be conducted using a manual session.

DESTINY: Edit Gateway Settings

Passthrough Mode (port 10001):
☑ Passthrough
Check Passthrough box to either:
1) Manually download and interact with system using d-LOG or d-MESH software OR
2) Automatically receive packets from logger set to push mode

Radio Autopoll (port 10002):
☑ Radio Autopoll
Check box to enable radio system to automatically download data at the set d-MESH Download Interval

Push Mode (port 10009):
☑ Push Mode
Check Push Mode to automatically push data to a socket from loggers

SQL Mode:
☑ SQL Enabled
Check SQL Enabled to upload data to sql database when using radio system or leave unchecked to disable

d-MESH Download Interval (seconds): 100

DHCP is currently enabled

SUBMIT

CLICK HERE TO SET DHCP OR EDIT IP ADDRESS

Step 8: Uploading data to an SQL database.

It is possible to upload the data to YieldPoint's SQL database service or any other SQL database.

Example plots for a range of instruments installed at YieldPoint can be observed at:
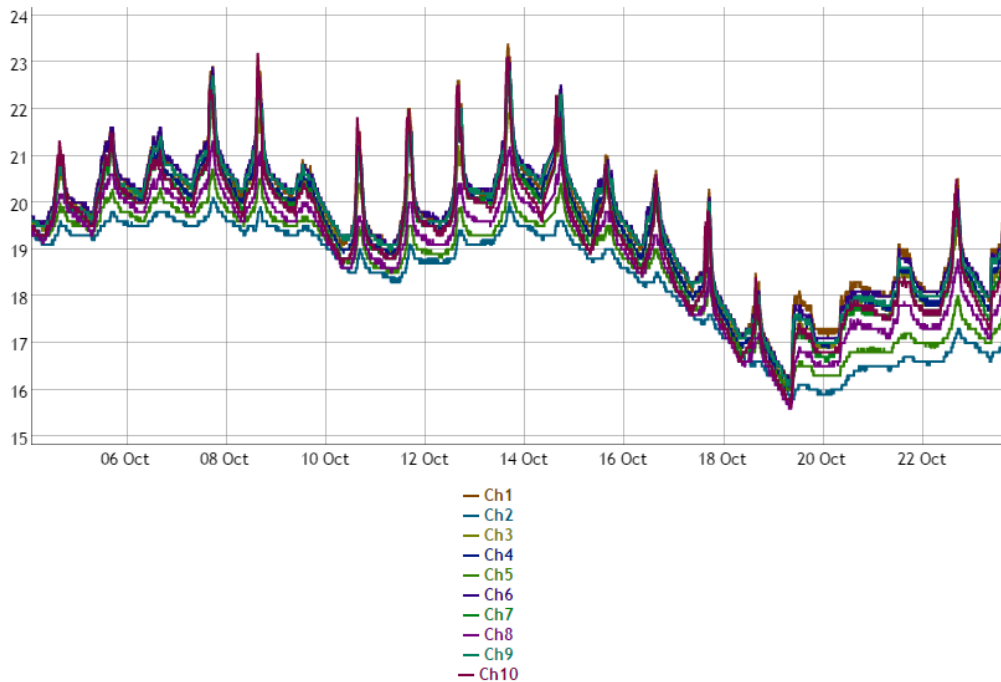
www.yieldPoint.com/data

user: user

Pw: password

The detailed plot for a d10Temp thermos-array is shown in the following figure.
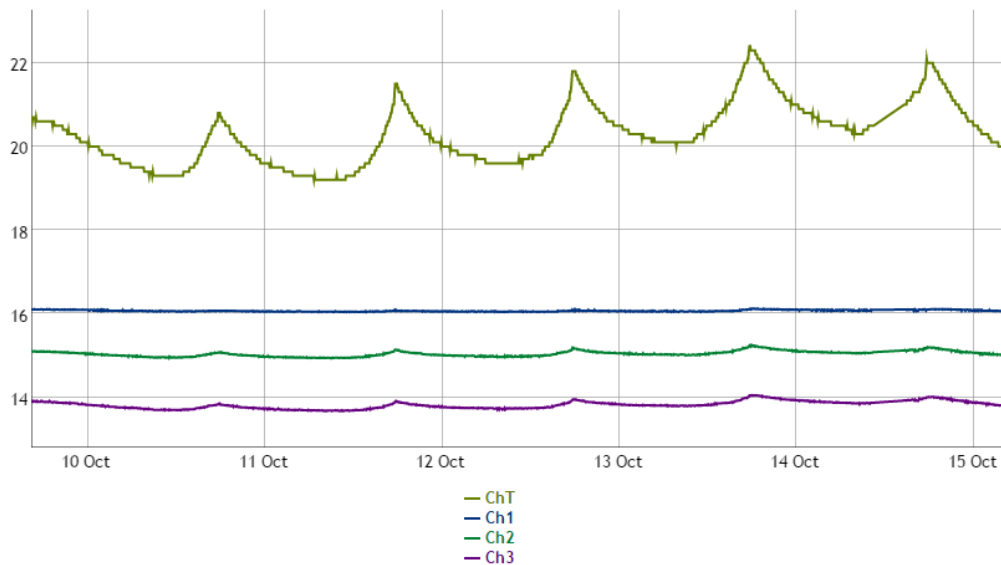
Contact YieldPoint Inc. for details.

Sensor 1508116003

— Ch1
— Ch2
— Ch3
— Ch4
— Ch5
— Ch6
— Ch7
— Ch8
— Ch9
— Ch10

*Select an area of the graph with the mouse to zoom in. Double-click graph to zoom back out.

▲ YieldPoint

Sensor 140941002

— ChT
— Ch1
— Ch2
— Ch3

*Select an area of the graph with the mouse to zoom in. Double-click graph to zoom back out.

The plot above shows the output from a 1.5m long 3-point borehole extensometer between 9th and 15th of October 2015. This particular instrument has been continually submerged in a water column for 15months (see below). It is located in room that faces west and consequently the diurnal temperature fluctuation reach a peak around 6:00pm each afternoon. Since the extensometer is free to expand and contract in the water (*i.e.* is ungrouted) small thermally induced deformations can be observed (<200microns). Notice furthermore that the blue line represented which is 0.5m from the head, moves less than the green line ,1.0m, and the purple line , 1.5m, as must occur if the thermal strain is constant along the probe.