Building Automation System Networking Essentials

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Introduction

Connecting to web-based controllers can be an intimidating task. There is always an uneasiness when you think of the steps required to connect your laptop to other field devices. We are often required to connect to JACE panels to make programming changes, software upgrades, or station backups. It is becoming more commonplace to connect to field controllers (rooftop units, Bacnet-enabled sensors, power meters, etc.) through a web browser interface to set its communication parameters. Performing Building Automation System (BAS) work which includes installation, programming, maintenance, service, and upgrades requires this very necessary skill. This article summarizes the key steps in establishing network connections and provides helpful background and terminology to help understand this process.

Key Steps:

1. Determine the Internet Protocol (IP) address, subnet mask, and default gateway of the target device.
2. Connect your laptop to the target device with an Ethernet cable or wirelessly through a wifi router. This may require additional hardware and wires.
3. Set your laptop's network connection IP address, subnet mask, and default gateway accordingly.
4. Verify that the network connection functions.
5. Make the connection with the web browser or controls software.

Photograph 1 – JACE and Network Switch

Background

Most computers and controllers use a binary or base 2 numbering system which is conducive to the use of electrical signals to represent on and off states. This allows them to perform mathematical operations and store data. On and off states in digital circuitry are represented by zeros and ones. A bit is short for binary digit which holds either the value of zero (0) or one (1). A byte is composed of eight bits. A kilobyte is 1024 bytes. A Gigabyte is equal to 1024^3 bytes. A Terabyte is equal to 1024^4 bytes.

Most IP-based building automation system and equipment controllers utilize IPv4 network addressing which uses 32 binary bits to create a unique address on the network. This address is expressed by four octets that are separated by dots or periods. An octet is a binary number based on eight bits as will be explained further. The network address format is not easily or quickly understood in binary form. The decimal equivalent of the octet is typically used to represent the IP address, subnet mask, and default gateway. The IP address represented in Figure 1 equates to a decimal equivalent of 192.168.1.140. Obviously, it is much easier to deal with the decimal format.

11000000.10101000.00000001.10001100

Figure 1

In order to understand how the binary format is converted to the decimal format, a review of the binary numbering system is required. Binary numbers have a base of two and each bit represents an increase in the exponent of the base (two) as indicated by the following figure.

$2^0 = 1$
$2^1 = 2$
$2^2 = 2x2 = 4$
$2^3 = 2x2\ x2 = 8$
$2^4 = 2x2x2x2 = 16$
$2^5 = 2x2x2x2x2 = 32$
$2^6 = 2x2x2x2x2x2 = 64$
$2^7 = 2x2x2x2x2x2x2 = 128$

Figure 2

Any number raised to the power (or exponent) of 0 is equal to 1. Any number raised to the power of 1 is the number itself. With each increase in exponent, the decimal

equivalent doubles in value because it is multiplied by two (2). If the eight (8) bits in the octet are arranged in descending order from the left to the right, we can understand the conversion from the binary representation to the decimal representation.

Binary Form:	1	1	1	1	1	1	1	1
	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	128	64	32	16	8	4	2	1

Figure 3

Each bit in an octet represents a specific power or exponent in the binary number. If the bit is equal to one (1), this means that the value represented by the corresponding power (or exponent) of two contributes to the binary number. If the bit is equal to zero (0), this means that the value represented by the corresponding power (or exponent) of two does not contribute to the binary number. Another way to think of it is that a binary number represents eight columns and each column represents the number two (2) raised to an increasing power (from right to left). If the bit is zero, then that column or power does not contribute to the binary or decimal equivalent of the number.

The summation of the individual bits (columns) in each octet represented by ones (1's) provides the decimal-equivalent of the binary number that is represented. The decimal equivalent represented by Figure 3 is 255. This binary numbering system allows computer processors to utilize 0's and 1's to represent the numbers that we see in base 10 or decimal format. For example, the number 168 in decimal format is equivalent to a binary notation of 10101000 as shown below.

Binary Form: 1 0 1 0 1 0 0 0

Decimal Form: $2^7 + 0 + 2^5 + 0 + 2^3 + 0 + 0 + 0 = 168$

Figure 4 – Decimal Equivalent Example

Likewise, if we wanted to represent the number 140 in binary and decimal forms, it would look like the following.

Binary Form: 1 0 0 0 1 1 0 0

Decimal Form: $2^7 + 0 + 0 + 0 + 2^3 + 2^2 + 0 + 0 = 140$

Figure 5 – Decimal Equivalent Example

1. Determine the Address of the Target Device

When a control system is designed, it will already have IP addresses assigned to the major IP-based controllers. These are typically provided on the network riser diagram. As the various controllers are energized and initially commissioned, they will typically have a default IP address, subnet, and default gateway. To change the default IP address, subnet, and default gateway to what you want it to be, we first have to connect using its current network settings. Many controllers, power meters, Bacnet routers, etc. have a web browser user interface that allows us to access the network configuration screens without running any special software. These interfaces will also have a default IP address which must be known beforehand. We enter the controller's IP address in the web browser's address bar and click enter. A user interface screen appears that often asks for a default user name and password which are typically provided on a label or in the equipment literature. Once the address and configuration changes are made, a power cycle is often required in order for them to take effect. For this exercise, we will assume that we want to connect to a controller with an IP address of 192.168.1.140 and subnet mask of 255.255.255.0 with no default gateway.

2. Connect the Laptop to the Target Device

Connecting your laptop to the target device typically occurs by one of these methods:

A. Direct Connection - An Ethernet cable is used to connect the laptop and the target device (controller, Bacnet router, JACE, etc.).
B. Network Switch/Router - The laptop may connect to a network switch or router with an Ethernet cable. The target device is also connected to the same network switch or router. This allows the laptop to connect to several IP-based devices that are on the same network.
C. Wireless Network Router – With a wifi router, the same connections can be made as described above. The only difference is that there is no wire between laptop and wifi router. The wired connection between the wifi router and controller/network completes the laptop to controller loop.

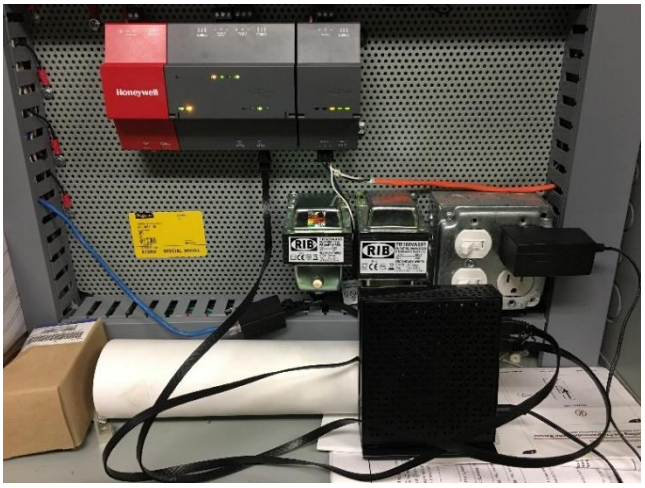
The hardware used to connect your laptop to the controller depends on the how the BAS network is configured. You might connect directly to the controller with an Ethernet cable. This is typically the case when you are configuring or commissioning a JACE or IP controller before it is installed in the field. After it is installed, you may connect to the same device through an intermediate switch. You might also use the direct connect method if you are connecting directly to a rooftop unit controller or Bacnet router to configure its communication settings.

If a network switch or router is available (either in the local control panel or nearby IT closet), connect your laptop to a spare port in the switch/router with an Ethernet cable. If there are no spare network ports, you will have to use a temporary switch or router (used as a switch) to expand the number of devices that can be connected to the BAS network. The network switch shown in Photograph 2 is the Black Box model LGB304A Gigabit Ethernet switch which has five Ethernet ports. It comes with a 120 VAC transformer or it can be powered by your laptop with a 5 VDC USB adapter.

Photograph 2 – Temporary Network Switch

Wireless routers/switches add a new level of mobility and freedom to your testing and commissioning activities. Although it is a "router," we are actually using it as a network "switch." No IP address are assigned (no DHCP) by the router. As long as the laptop is within wifi range, we can update programming, modify graphics, override points, and change setpoints as if you were directly connected to the controller or JACE with an Ethernet cable. The wireless signal range varies by brand and the number of antennas. With a wireless router/switch, you can work where and how it maximizes your comfort and efficiency. You can also take your laptop or other wireless device to the input and output devices that are being tested and directly observe the reaction and verify connectivity. It maximizes the efficiency of the single programmer/technician and reduces the need for a second person to perform point-to-point checkout and calibration work.

The target device is connected through one of the temporary wireless router's **LAN** (Local Area Network) ports. Be sure NOT to use the **Internet** (or WAN-Wide Area Network) port of the wireless router. The WAN port is only used if the router assigns IP addresses to the devices connected to the LAN ports (separate topic). The target device is connected to one of the free LAN ports on the wireless router or panel-mounted network switch.



Photograph 3 – Temporary Wireless Network Switch

An inline Ethernet coupler is occasionally required when there is not enough slack to connect this cable directly to the temporary switch or wireless router. The coupler is placed on the end of the Ethernet cable that originally connected the JACE to the existing BAS network. The other end of the coupler is connected to the temporary switch by an Ethernet cable. Another Ethernet cable connects the JACE LAN port to another free port in the temporary network switch or wireless router. With this temporary configuration, the existing BAS network is still intact and your laptop is now connected to the BAS network either wired or wirelessly. Photograph 3 shows an Ethernet coupler that is used to connect the blue Ethernet cable (that is normally connected directly to the JACE) to the temporary network switch.

Photograph 4 – Inline Coupler & USB to RJ45 Adapter

With increasing frequency, laptops are manufactured without network ports. If this is the case with your laptop,

you will need to acquire either a USB to RJ45 adapter or a USB-C to RJ45 adapter depending on what type of USB connections your laptop has. When it is connected to your USB port, it automatically adds a local network connection to your list of available networks. This network connection can then be configured as required. Even if your laptop has an Ethernet port, these adapters allow you to add additional local network connections to your laptop. This allows you to connect to multiple controllers on different networks without disconnecting, changing adapter properties, and reconnecting.

3. Configure the Laptop Network Connection

In order to communicate with controllers that utilize the Transmission Control Protocol/Internet Protocol (TCP/IP) each computer and controller requires a unique IP address. The address assigned to each device, must be within the same "network" which is defined by both the IP address range and its subnet mask. For example, if you want to connect to a controller with an IP address of 192.168.1.140 and subnet mask of 255.255.255.0, your laptop IP address would be assigned the same subnet mask and the first three octets of the IP address would be the same. The final octet must be between 1 and 254 and not coincide with any other device address already on that network.

If 192.168.1.250 was selected, you would then go the network connection properties page and assign this IP address to your laptop's network connection. It is typically safer to select an IP address that is high in the range to avoid conflicts. I like to use 250. Type **ncpa.cpl** in the Windows search field and the available network connections will appear.

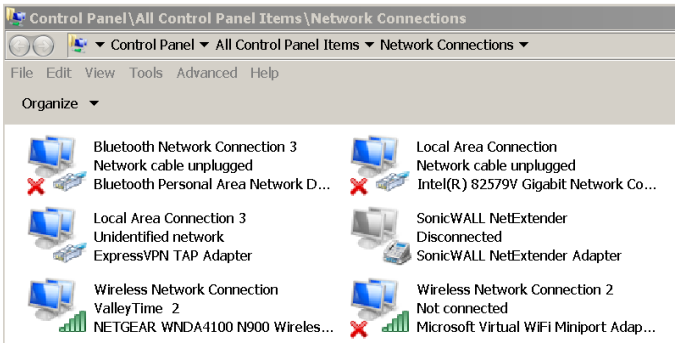


Figure 6 – Network Connections

Double-click the wired or wireless connection that you plan to use to connect to the target device. This action opens the dialogue box for this device (See Figure 7).

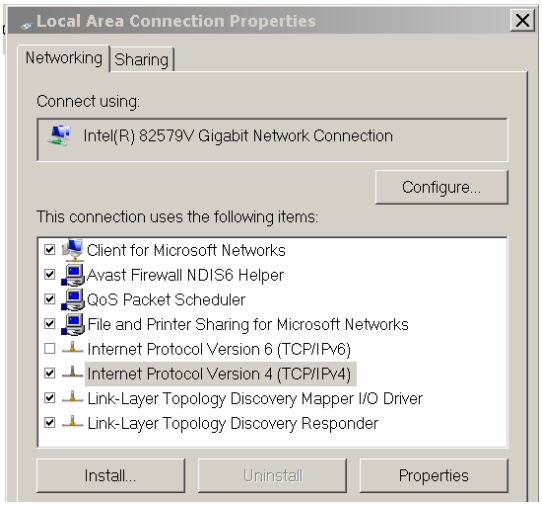


Figure 7 – Network Connection Properties

Select the Internet Protocol Version 4 and click **Properties** to enter to define how the laptop's network connection acquires its IP address. If the target device or network is capable of automatically assigning IP addresses, then you would select **Obtain an IP address automatically**. Dynamic Host Configuration Protocol (DHCP) is a service that automatically assigns IP addresses to connecting devices. This is a commonly-used IP addressing tool when the IP addresses are used on a temporary basis.

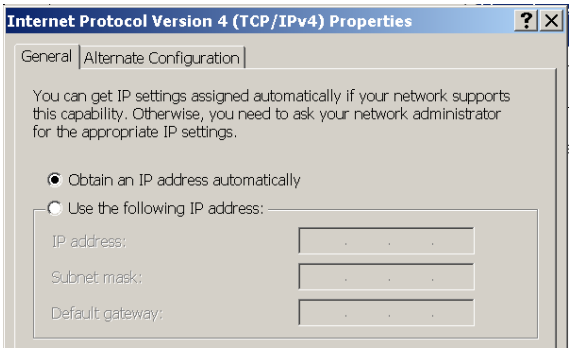


Figure 8 – DHCP Option

When connecting to network devices that do not automatically assign IP addresses, a static IP address will be required. Static IP addresses must be manually configured. Click the **Use the following IP address** option and enter the IP address, subnet mask, and gateway (if required) that the laptop will use to communicate with the target devices. Typically, the default gateway address is left blank unless it is required. Click **OK** and close the local network or wireless network connection properties window. Also be sure to click the **Close** button on the network connection properties window to be sure that the updated network connection values are updated.

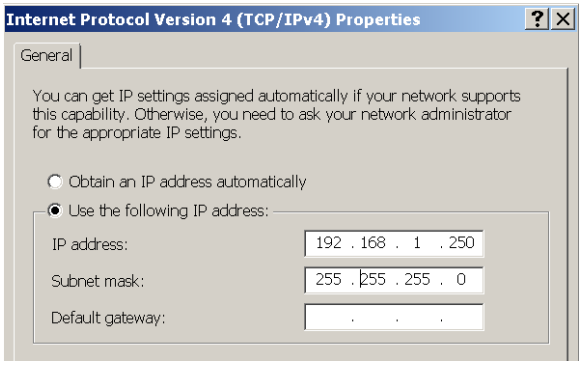


Figure 9 – Static IP Settings

To verify that your computer has been assigned the new address parameters, open a command prompt window in Windows by typing **cmd** in the search bar. This will open a DOS or command prompt window with a command line. At the prompt, type **ipconfig** and the properties of the available network adapters will be provided. The IP address of the network connection that you changed should be updated.

```
Ethernet adapter Ethernet:

   Connection-specific DNS Suffix  . :
   IPv4 Address. . . . . . . . . . . : 192.168.1.250
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Default Gateway . . . . . . . . . :
```

Figure 10 – Typical IPCONFIG Results

4. Verify Communication

Once the correct IP address of the laptop has been confirmed, it is time to verify that it is able to communicate with the target device. The most common way to do this is to use the ping command. Type cmd in the Windows search field to open a command prompt window. Type **ping 192.168.1.140** and your laptop will send for four packets of data to the target device and record the time it takes to respond. If the two devices are on the same network and there are no conflicts, the ping requests will be acknowledged by four successful replies. In addition, a summary of the test results will be provided.

```
C:\Users\Valentine>ping 192.168.1.140

Pinging 192.168.1.140 with 32 bytes of data:
Reply from 192.168.1.140: bytes=32 time<1ms TTL=128
Reply from 192.168.1.140: bytes=32 time<1ms TTL=128
Reply from 192.168.1.140: bytes=32 time<1ms TTL=128
Reply from 192.168.1.140: bytes=32 time<1ms TTL=128

Ping statistics for 192.168.1.140:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms
```

Figure 11 – Successful Ping Request Results

If the ping is unsuccessful, then the two devices are not on the same network or there may be an address conflict. The issue is typically caused by one or more of the following: Incorrect IP Address, Incorrect Subnet Mask, Incorrect Default Gateway, or incorrect cable type. Verify the target IP address, subnet, and default gateway. Then verify that your laptop is correctly configured with the **ipconfig** command. Update as necessary and retest the connection with the **ping** command.

```
Pinging 192.168.1.140 with 32 bytes of data:
Request timed out.
Request timed out.
Request timed out.
Request timed out.

Ping statistics for 192.168.1.140:
    Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),
```

Figure 12 – Unsuccessful Ping Request Results

The ping command is also very useful when you have to restart a JACE controller. Type **ping 192.168.1.140 /t** and it will continuously ping the IP address until **CTRL+C** is depressed. When the JACE platform has started, the JACE will respond to the ping request. This is an easy way to know when the platform connection has been reestablished during a power cycle.

5. Use the Web Browser or Controls Software

At this point, we have a laptop that can successfully ping the target device. This means that whatever software package we run will be able to communicate through TCP/IP. These skills are applicable when you want to connect to a JACE controller with the Niagara workbench software or browse the BAS graphics (on the JACE). Many equipment controllers come with a web browser user interface to change the default IP, subnet, and default gateway. This same interface may also be used to configure the MS/TP address and device identification. In order to connect these controllers to the BAS, we often have to change the communication parameters of the equipment controllers.

Conclusion

BAS networking can be frustrating, especially when it does not go correctly. Be patient. With a little practice, you will quickly become adept at making data connections to IP-based devices. We don't have to be Information Technology professionals, but we are required to know enough to connect our controls laptop to a variety of controllers, computer, servers, and JACE panels out there in the field. Practice is the key.