Transportation Infrastructure and Systems Research Lab: CAVe-in-a-Box Infrastructure Manual

This manual documents the software and networking setup for the lab's CAVe-in-a-Box. It details issues encountered and provides supplemental notes to the official documentation. For specific details, readers should refer to the original resources, from which screenshots are used throughout this guide. These resources include:

- Cohda Wireless support articles for the MK5 RSU and OBU (requiring a support account).
- Two "CAVe-in-a-Box Instruction Set" manuals from Leidos. The August 2025 version is the most current (with one minor exception that has been noted to Leidos for correction in future versions), while the 2022 version should be referenced for understanding the MK5 RSU's role. Both Leidos documents are available in Teams.

If you encounter any trouble recreating results I have already completed, you can reach me at my personal email: **markus.hoehn07@gmail.com**. For additional support, contact **cavsupportservices@dot.gov**, which I used to fill in many of the gaps and obtain several of the files referenced here. I will include my email exchange in the Teams.

For physical installation, a separate 2022 infrastructure document also available in Teams covers mounting the kit into the travel case. An accompanying construction video is a good reference for the physical/ethernet connections, with both resources containing a few component differences to the lab.

Components

We have the following components for the infrastructure kit:

Figure 1: Windows Tablet (CE1248) managed by K-State and USB-C ethernet adapter.

Figure 2: Econolite Cobalt Traffic Signal Controller

Figure 3: Intel NUC Computer, The “V2X Hub”

Figure 4: Cradlepoint IBR650C-150M-D (no WiFi)

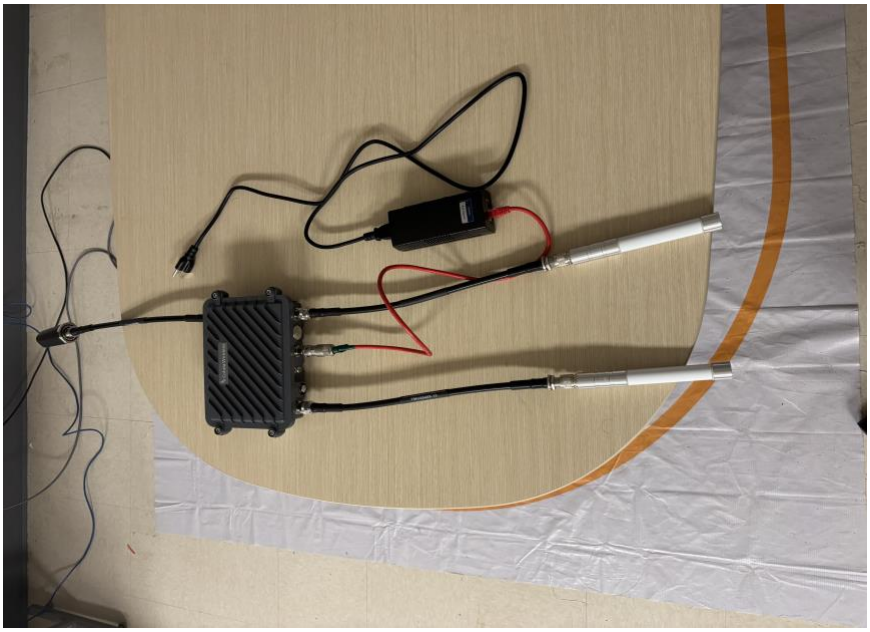

Figure 5: Cohda MK5 RSU with GPS and DSRC antennas connected by N-male to N-female LMR-400 coaxial cables.

- Powered by a 30W PoE+ injector
- Connected via an M12 Ethernet connector

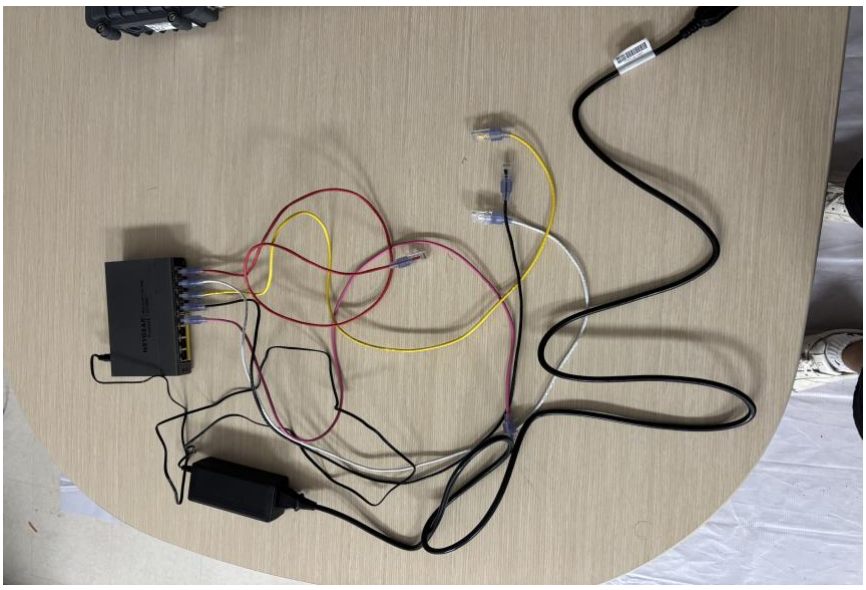

Figure 6: Network Switch and Ethernet Cables
(Note: Do not use the PoE ports for the RSU)

Figure 7: Power Strip

The first step is to plug all components into the power strip using their respective power cables, except for the Windows tablet. For the RSU, this is done through the PoE injector. The Windows tablet has its own charger and should be charged separately.

Next, we move on to the ethernet connections and network setup.

Network Setup

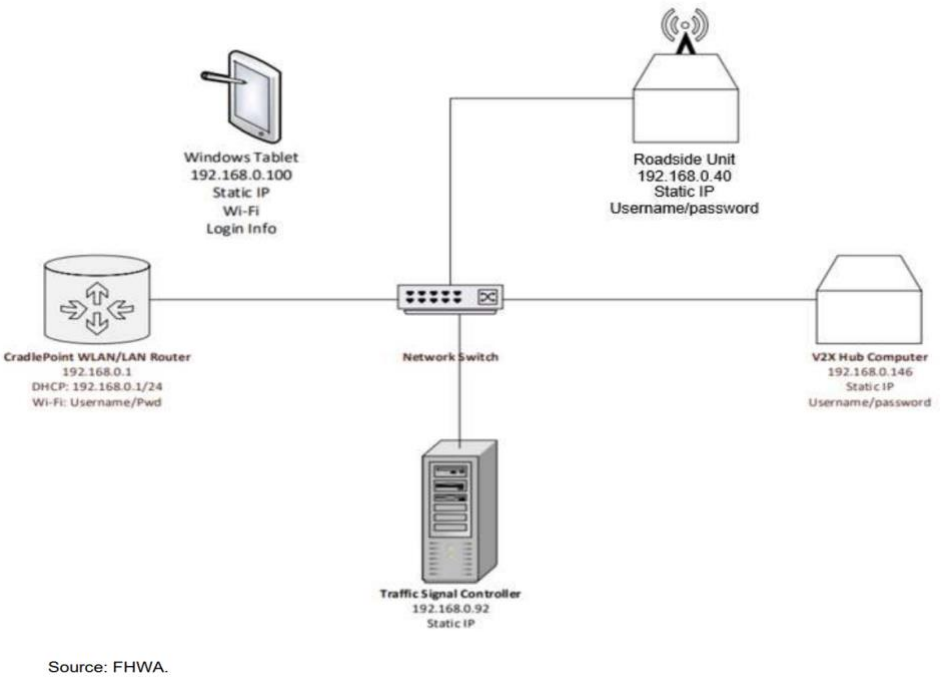

Figure 8: Diagram of CAVe-in-a-Box network configuration.

- Connect the components as shown in the diagram, with one exception: the Windows tablet is connected to the network switch because our Cradlepoint router does not have Wi-Fi capabilities.
- In the router settings, use a DHCP server to assign an IP address to the Windows tablet; however, with K-State IT admin privileges, you can also change this to a static IP.
- For reference, the Ethernet cables are plugged into:
    - The 2.5G port on the Intel NUC
    - The top E-NET1 port of the Traffic Signal Controller
    - The DATA-IN port of the PoE injector for the RSU
    - The LAN port of the Cradlepoint router
    - The USB-C Ethernet adapter for the Windows tablet

To set up the IP networking, plug in a monitor, mouse, and keyboard into the Intel NUC which has Ubuntu 25.04 installed. Set the IPv4 settings as follows:

- **Address:** 192.168.0.146
- **Netmask:** 255.255.255.0
- **Gateway:** 192.168.0.1
- **DNS:** 192.168.0.1

Once on the Intel NUC (current user password: 12345), access the router settings at http://192.168.0.1 and log in with the username **admin** and password **WA223600758141**. Enable the setting in Local IP Networks for the IPv4 DHCP server to pick an IP from the range 192.168.0.100 to 192.168.0.100 (this prevents the need to use K-State IT privileges to configure the static IP for the Windows tablet).

On the Traffic Signal Controller, navigate from the main menu through **Configuration** → **Communications** → **Ethernet** and set the controller IP as follows:

- **IP:** 192.168.0.92
- **Subnet Mask:** 255.255.255.0
- **Default Gateway IP:** 192.168.0.1
- **Server IP:** 192.168.0.146 (the Intel NUC)

For the RSU, refer to this Cohda Support article for general instructions. For the CAVe-in-a-Box, you can configure the RSU either through the Intel NUC or the Windows Tablet. The IPv4 is already configured; however, if it was factory reset, connect via IPv6 using the last 6 digits of the serial number found on the sticker label on the MK5 RSU (in our case, the last 6 digits are 10C914) to replace the x's in fe80::6e5:48ff:fexx:xxxx. For the ethernet interface enp89s0, you can SSH with:

```
ssh rsu@fe80::6e5:48ff:fexx:xxxx%
```

In our case:

```
ssh rsu@fe80::6e5:48ff:fe10:C914%enp89s0
```

which has the password "rsuadmin." Then run the following commands:

```
fw_setenv static_ip_addr "192.168.0.40"
fw_setenv static_ip_mask "255.255.255.0"
fw_setenv static_ip_bcast "192.168.0.255"
fw_setenv static_ip_gw "192.168.0.1"
fw_setenv static_ip_ns "8.8.8.8"
reboot
```

If this goes wrong (which happened to me when I copied these commands from an email with curly quotes), connect via serial port using another PC (I used a Windows PC in the lab and a custom-built Leidos cable) to resolve the issue. See: Connect MK5 via serial port.

After rebooting you can SSH with the same password "rsuadmin" with:

```
ssh rsu@192.168.0.40
```

You should ping every item from the network diagram from the Windows tablet to confirm the network is working.

V2X-Hub Software and Plugins

Next, you need to install the V2X-Hub on the Intel NUC. Before you begin the installation, you must first connect the NUC to the internet (e.g., using K-State's Wi-Fi). Once you have an internet connection, follow these steps:

- Run the following command in the home directory:

```
git clone https://github.com/usdot-fhwa-OPS/V2X-Hub.git
```

- Change to the V2X-Hub directory:

```
cd V2X-Hub
```

- Checkout the specific commit:

```
git checkout 45c8a0adb097466b55784036ecdebe9a8a6f3004
```

The reason we checkout to that specific commit is that it was the commit the developers made after a GitHub issue I had fixing problems with the V2X-Hub on our specific setup and Ubuntu installation. Between that commit and now, I am having login issues; however, for our purposes, I use that commit which works as intended.

Next, go through the initialization script by following these instructions: V2X-Hub Configuration Instructions. Make sure to select version 7.9.0, as 7.10.0 does not work with that old commit on our Intel NUC. The current username and password match those in the instructions: user: “v2xadmin”, password: “V2xHub#321”.

To see the V2X Hub UI on the Intel NUC, if the Chromium browser is installed, you can run (otherwise the UI won’t load):

```
chromium-browser --ignore-certificate-errors 127.0.0.1
```

I had issues with V2X-Hub working on launch as it was supposed to, so I created a service script to run this bash script on boot which resolves the launch issues:

```
#!/bin/bash
# Navigate to the V2X Hub configuration directory
cd /home/nuc_user/V2X-Hub/configuration
echo "--> Stopping any old V2X Hub services..."
/usr/bin/docker compose down
echo "--> Starting V2X Hub services..."
/usr/bin/docker compose up -d
echo "--> V2X Hub startup process complete."
```

I also created an SSH server so you could access the Intel NUC from the Windows tablet if needed without plugging in a monitor, keyboard, and mouse.

To access it on the Windows tablet, first connect to https://192.168.0.146:19760 in a browser and accept any certificates (otherwise the UI won’t load), then connect to http://192.168.0.146 in a browser as shown in the figure below. The first connection was the necessary step missing in the new Leidos 2025 documentation but present in the 2022

version. I was informed they will/have updated newer documentation to bring that back. Follow the instructions in the figure below to log into the UI

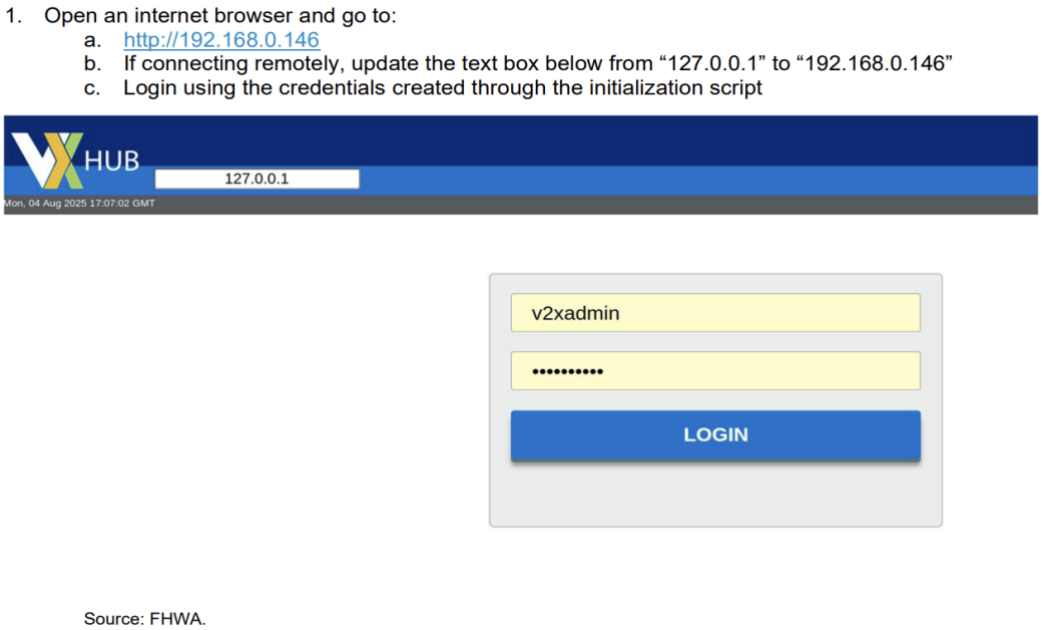

Figure 9: How to access V2X Hub from Windows Tablet

To enable the cw-mon interfaces and set up immediate forwarding on the RSU (to the MessageReceiver plugin on the V2X hub), run the script at this link: Script for RSU Setup via an SSH connection to the new IPv4 address. This script is also included in the Teams.

Since we have already set up the IP, respond with "n" to allow the rest of the script to run. With the CAVe-in-a-Box ready for plugin configuration, the 2025 documentation can be followed practically verbatim. However, for the RSU MK5's role, the 2022 documentation is needed as the 2025 documentation refers to newer RSUs.

- Ensure all main plugins are set up:
  - SPAT
  - MAP
  - Immediate Forward
  - Message Receiver
- This indicates that everything is working.

Here's a link for a map file you can add to your V2X-Hub/configuration/MAP/ path for the plugin to use: Download MAP File. You can do this by accessing the Intel NUC directly and downloading the file or using secure copy and SSH. This file is also included in the Teams.

As of writing this manual, all software and networking is set up as described, and the MAP plugin works. The RSU receives data when the ImmediateForward plugin is enabled on the V2X Hub, which I've confirmed via packets on its wired eth0 interface. The RSU's cw-mon interfaces, however, are not showing received or forwarded traffic as expected, and the SPAT plugin shows no messages from the traffic signal controller. Documentation for the traffic signal controller is available in Teams, as is useful debugging information about the RSU forwarding and interfaces at the end of the email exchange in Teams.

To address the SPAT issue, I have successfully installed and set up Net-SNMP on the Windows Tablet. The tool now works correctly from the command line, referencing the README that came with the installation. I have discovered, however, that the necessary enableSPaT.bat file is not included with the Net-SNMP software itself. This script, I believe, is found in a separate Econolite-EnableSPaT.zip archive. I do not currently have this zip package, but the documentation for enabling SPaT via Net-SNMP, which identifies this archive and explains how to set up Net-SNMP, mentions it is available from Econolite Support. This documentation is also available in the Teams.