

2014



AMPS Protection Manual

TEAM: AMPS COMMUNICATION

Corneliu Turturica, Fahad Alhajeri, Garrett Stauffer, Jorge Rios

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Introduction

This manual is the result of a Fall 2013 – Spring 2014 Senior Design project, titled “AMPS Communication”. The project sought to replace the existing protection scheme with new relays and auxiliary equipment. Schweitzer Engineering Laboratories (SEL) donated all the equipment, and without their support the project couldn’t have happened. All new relays were installed, along with managed switches, a security gateway, data concentrator, automation controllers, and a ruggedized computer to complete the system.

Purpose

The purpose of this manual is to educate the reader on the basic steps to reconfigure the protection equipment for the Analog Model Power System. While this document will not replace the respective instruction manuals, it will provide a comprehensive guide to the equipment in the lab and its initial configuration.

Equipment List

For this project, SEL donated the equipment listed below. Throughout the report, the devices may be identified with their product number.

- SEL 411L – Line Differential Relay
- SEL 351S – Feeder Protection Relay
- SEL 421 – Distance Relay
- SEL 2440 – Discrete Programmable Automation Controller (DPAC)
- SEL 3530 – Real Time Automation Controller (RTAC)
- SEL 2730M – Managed Ethernet Switch
- SEL 3620 – Security Gateway
- SEL 3355 – Ruggedized Computer

Software

For this project, we used the following software:

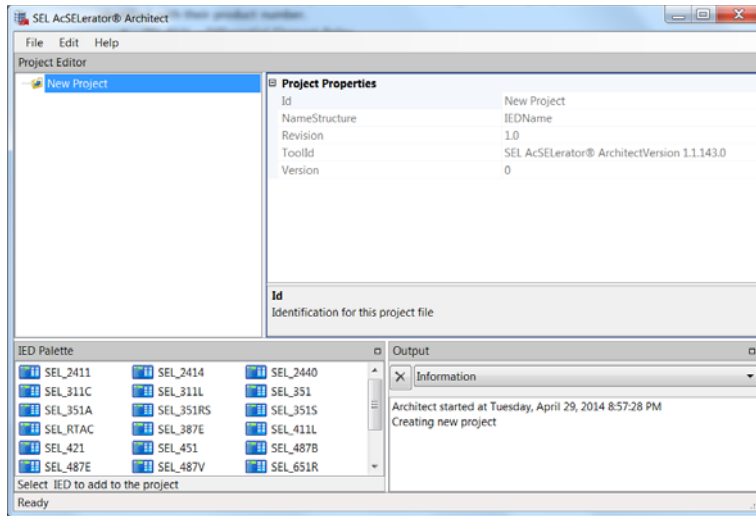
- AcSELerator QuickSet
- AcSELerator Architect
- AcSELerator RTAC
- SEL Compass
- Wireshark (GTK+)

In order to use SEL Compass, a mySEL account is necessary. The lab account is logged in already, to get access to it from your personal computer please contact SEL. SEL Compass is used to download and update any SEL software, manual, or drivers as needed. While Wireshark is not necessary, a version that can understand IEC 61850 standards is very useful in debugging. QuickSet is used for communication with the relays, as well as storing and updating device settings. Architect is used to configure the Generic Object Oriented Substation Event (GOOSE) messaging capabilities of the relays, and creates the Configured IED Description (CID) files that are sent to each device. AcSELerator RTAC is specifically used to program the 3530.

Using Architect (GOOSE Messages)

When Architect is first launched, it will look like figure 1. For new projects, simply start adding devices. To edit the current configuration, open the file "C:\AMPS\Settings\AMPS.selapj" If the configuration is corrupted or maliciously tampered with, contact Dr. Johnson to obtain a copy of the original configuration. Once the project is open, the list on the left will populate with all the devices in the system. By clicking on any of these devices, you can see their current setup and modify it. Changes to the 'Properties' tab must also be made to the port settings of the devices themselves, or the relays will not communicate.

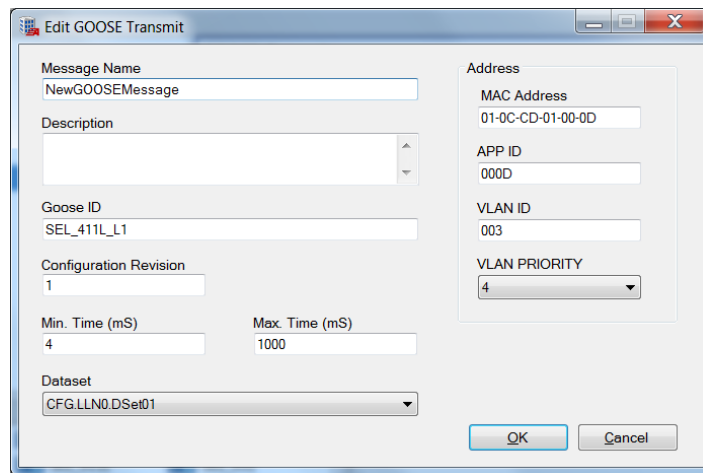
Figure 1. Architect Opening Screen



A GOOSE message contains a single dataset, which can be modified or created under the 'Datasets' tab. Datasets consist of one or more functional constraints, which are defined in IEC 61850. Essentially what this boils down to, is devices have many variables stored in them, called 'Relay Word Bits' by SEL, which contain everything from the status of inputs, to trip commands. These Relay Word Bits all correspond to different constraints as defined by IEC 61850. For example, when setting up the 411L's, there is a Relay Word 'TRIP' that is a 0 normally and a 1 when the device detects a trip condition. This Relay Word corresponds to 'ST.PRO.TRIPPTRC1.Tr.general'. This is documented in the instruction manual for the 411L. By adding these constraints to a dataset, they are automatically transmitted with that dataset.

Figure 2. GOOSE Message Properties

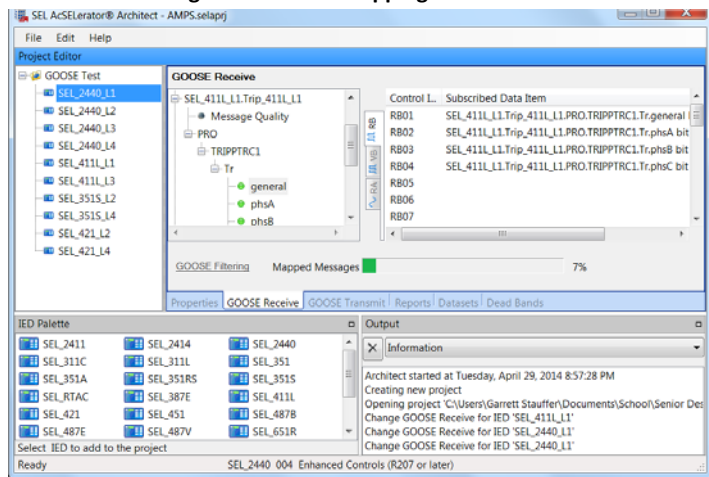
To transmit a dataset, click on the 'GOOSE Transmit' tab and create a new message. A window will appear, like that shown in figure 2. Give it a name and a description, but do not edit the MAC Address and APP ID unless you know what you're doing and know the relevant 61850 specifications. Click on the dropdown menu to change the dataset to the one you previously set up. Make sure that the VLAN ID¹ matches a VLAN with the proper ports as set up in the 2730M. VLAN Priority can vary from 1 to 7, with 7 being the highest priority, suitable for critical control signals. See the 2730M section for information on how this is implemented.



¹ Note that this is a hexadecimal value

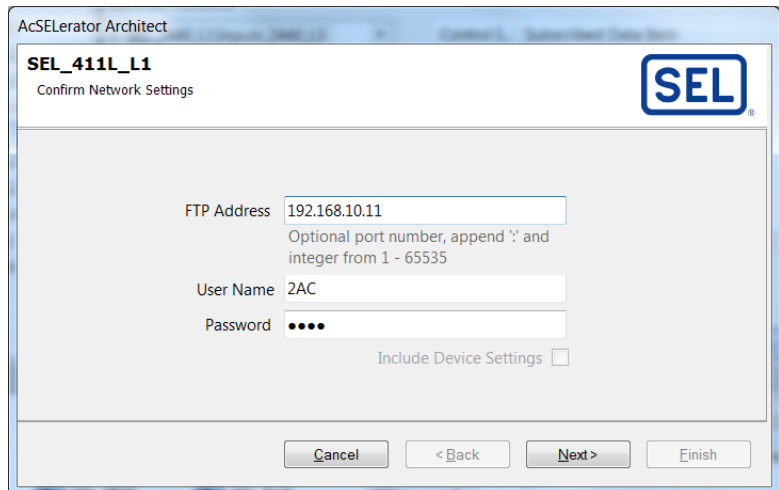
Once the proper message is set up to transmit, select the desired recipient device from the menu on the left. Click on 'GOOSE Receive', and navigate to the device which is transmitting the message you want to receive. By expanding this tree, you can get to the individual values being transmitted. By clicking and dragging variables to the right, they can be mapped to Relay Word Bits inside the recipient device. So, for example, the 411L publishes its trip condition in a GOOSE message which is received by the 2440, which stores it in remote bit 1 (RB01). This is shown in figure 3.

Figure 3. GOOSE Mapping in Architect



After repeating this for every message and device, Architect can automatically create and export the CID files to the devices. This can be done either by right clicking on a device and clicking 'Export CID' and uploading the file to the device later, or directly using the 'Send CID' option. For our project, we exclusively used the send option. By plugging a computer into an enabled port in the back of one of the 2730M's, and configuring the IP address to be on the 192.168.10.0/24² network, these files can be transferred directly via FTP. Right click on the device in question, and click 'Send CID' to get the prompt shown in figure 4. By typing in the IP address of the device, which can be found in Appendix A, and the appropriate credentials, the settings can be transferred. The username is either set in the device settings (initially set to 'AMPS'), or '2AC'. The password is the same as the 2AC password. Sometimes the bottom part of the screen will be cut off; just refer to figure 4 for which button is what. Once the proper CID files are sent to each device, they will automatically start sending GOOSE messages.

Figure 4. FTP Transfer Window



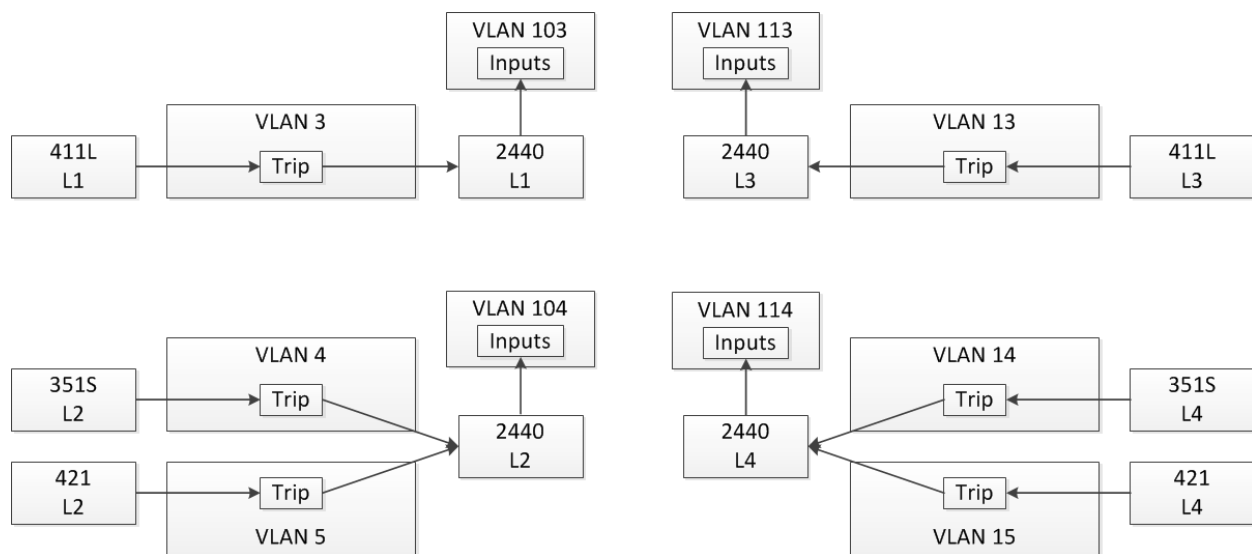
² For information on this notation, refer to Wikipedia's page on 'Classless Inter-Domain Routing' (CIDR)

2730M Configuration

The 2730M is a managed switch, and is configured using the front RJ45 port, Eth F. By connecting to this port with a port on a computer which has DHCP enabled, it will automatically redirect to the 2730M management page. Ignore the security warning and continue to the login page. The username and password can be obtained from Dr. Johnson. By clicking on 'Port Settings' on the left hand side individual ports can be enabled or disabled. 'VLAN Settings' allows VLANs to be configured and edited³. Under 'Global Settings' VLANs can be disabled or enabled en masse. Also, the way that VLAN Priority tags are handled can be configured here as well, to either be strict (sends highest priority messages first) or weighted (sends several high priority messages for every low priority message). Under the 'File Management' tab, the current settings can be exported, old settings can be restored, etc.

For the AMPS, we utilized VLANs to regulate our traffic and decrease latency. During power system events, the latency is critical for controls. However, because of the way GOOSE messages are transmitted, this is also when the most traffic is being sent⁴. By tagging every message with a VLAN, traffic can be forwarded to only the ports that need to receive the traffic, which reduces the number of packets the device has to read. So for example, packets on VLAN 3 (2440 L1 to 411L L1) won't be sent to the 2440 on L2, which only has to read packets sent to it by the 421 on L2, 351S on L2, and all untagged traffic (such as FTP or Telnet). The VLAN configuration can be seen below in figure 5, and by cross referencing with the port information in Appendix A, the port numbers assigned to each VLAN can be decided. VLANs 1 and 2 are reserved, and should not be used.

Figure 5. VLAN Configuration



3620 Configuration

The 3620 can be accessed from anywhere on the University's LAN network. The configuration page can be reached at <https://129.101.221.87> and Dr. Johnson can supply the proper username and password. By clicking on 'File Management' under the 'System' header, new connection directories can be uploaded, and settings can be exported and imported. Under the 'Serial Ports' header, choosing 'Port Mappings' will allow the second method of access for the 3620 to be configured. All the devices that are accessible are listed here, as part of the uploaded connection directory, as well as how they are accessed. By adding a network interface and checking 'master port', this interface can be used to connect to the

³ Note that the VLAN ID entered is in decimal notation

⁴ See Appendix B

3620 remotely. Currently, it is configured to accept SSH communications on port 22. By clicking on 'Password Management' under 'Security', passwords for each device can be automatically changed to a randomly generated password. In practice, we have yet to test this feature. However, the 3620 must be aware of all device passwords if it is to function as a gateway into the other devices.

By using an SSH client, such as PuTTY, and connecting to 129.101.221.87:22 via SSH from anywhere within the University network, the 3620 terminal interface can be reached. The proper login and password can be obtained from Dr. Johnson. Once logged in, the command 'WHO' will list all possible device connections. Then the command 'SElect x'⁵ will connect to device x. Depending on the permissions for the username you have used, the 3620 will automatically enter the password for any access level that you type in that you have permission to access. To return to the 3620 interface at any time, simply press 'Ctrl+W'.

2440 Configuration

The 2440's are configured according to figures 6 and 7. The outputs control the breakers as designated in table 1. For the bottom 2440s, attached to L2 and L4, 125 VDC is attached to mechanical switches that route the voltage to either IN205 or IN206. As indicated in the diagram, these are logically considered enables for the 351S and the 421. At the 2AC access level, the outputs can be pulsed using the command 'CONtrol OUTput OUTxxx [n]' with an optional parameter 'n' for the duration of the pulse, where 'xxx' is the output number (e.g. 'control output out105 6' or 'con out out101'). Please be aware that these settings can and should be altered for future projects and research, and so to obtain accurate information get the settings from the 2440's themselves. This can be done by logging in to the 2440 in question at the ACC level and typing the command 'SHOW Logic'.

Figure 6. Logic Diagram for L1 and L3

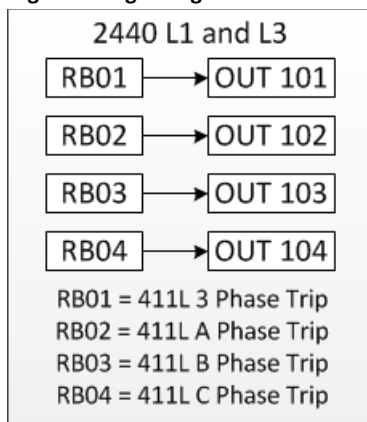


Figure 7. Logic Diagram for L2 and L4 DPACs

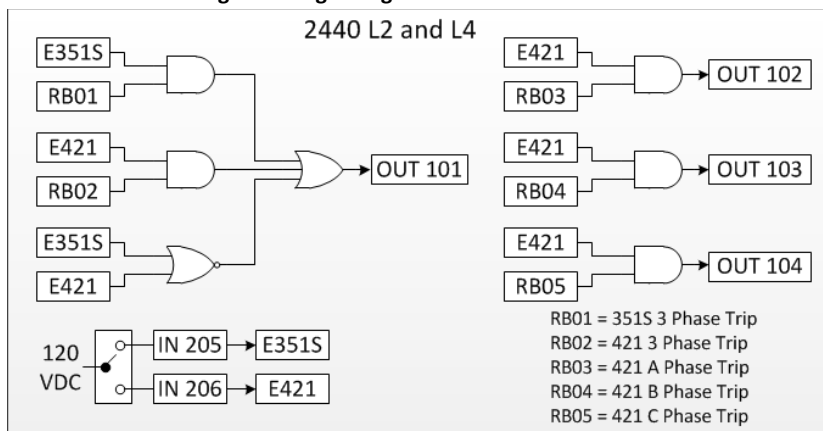


Table 1. 2440 I/O Mapping

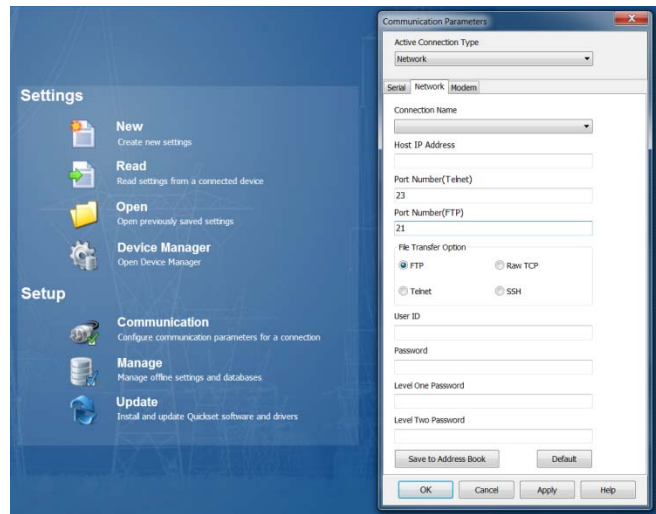
OUT 101	Breaker Three Phase Open
OUT 102	Breaker A Phase Open
OUT 103	Breaker B Phase Open
OUT 104	Breaker C Phase Open
OUT 105	Breaker Three Phase Close
IN 201	Breaker A State (Closed = 1)
IN 202	Breaker B State (Closed = 1)
IN 203	Breaker C State (Closed = 1)

⁵ When using the terminal, only the first three letters of a command are read, so 'sel' is equivalent to 'select'.

Using QuickSet (Device Settings)

QuickSet is capable of connecting to SEL devices over either serial (via a USB adapter or a COM port) or over the network (using FTP, Telnet, or SSH). This can be configured by pressing communications, or on the keyboard pressing 'Ctrl+R'. This can be seen in figure 8. Communications over the network require the computer to be plugged in to the 2730M, with a port configured to be on the 192.168.10.xxx/24⁶ subnetwork. This takes a little setting up, but allows fast connections to any device with no physical changes to the setup. Serial communication is much easier to set up, as you don't even have to go back into the cage, but is slower and must be unplugged and replugged to switch devices. All devices have their front serial port enabled at 19.2 kBaud, 8 data bits, 1 stop bit, and no parity.

Figure 6. Establishing a Connection in QuickSet



Once a connection has been established, settings can be transferred between the computer and the device. In the folder 'Settings' the current working settings can be found and sent to the device if needed. In order to talk to the device directly, open up the terminal by selecting the 'Communications' menu and then 'Terminal', or press 'Ctrl+T'.

The settings for the devices are all stored in a local database, known as the Device Manager. By default, when QuickSet opens, it asks for a username and password to the database. If basic communication is all you need, or if you do not have the login information from Dr. Johnson, click the cancel button. Otherwise, log in and you can see the device list on the left. This interface manages the settings for each device, as well as the connection information used by the 3620 to connect to the devices. If any changes are made to the IP addresses, passwords, or connection method (e.g. disabling FTP), every device must be updated, and a new connection directory must be sent to the 3620. This can be done either directly in QuickSet, or by generating the file separately and then uploading it using the web interface. This is also where permissions for users on the 3620 are set for each device. By clicking on the 'Permissions' tab for each device, the different access levels granted to each user or user group can be viewed and edited.

Contact

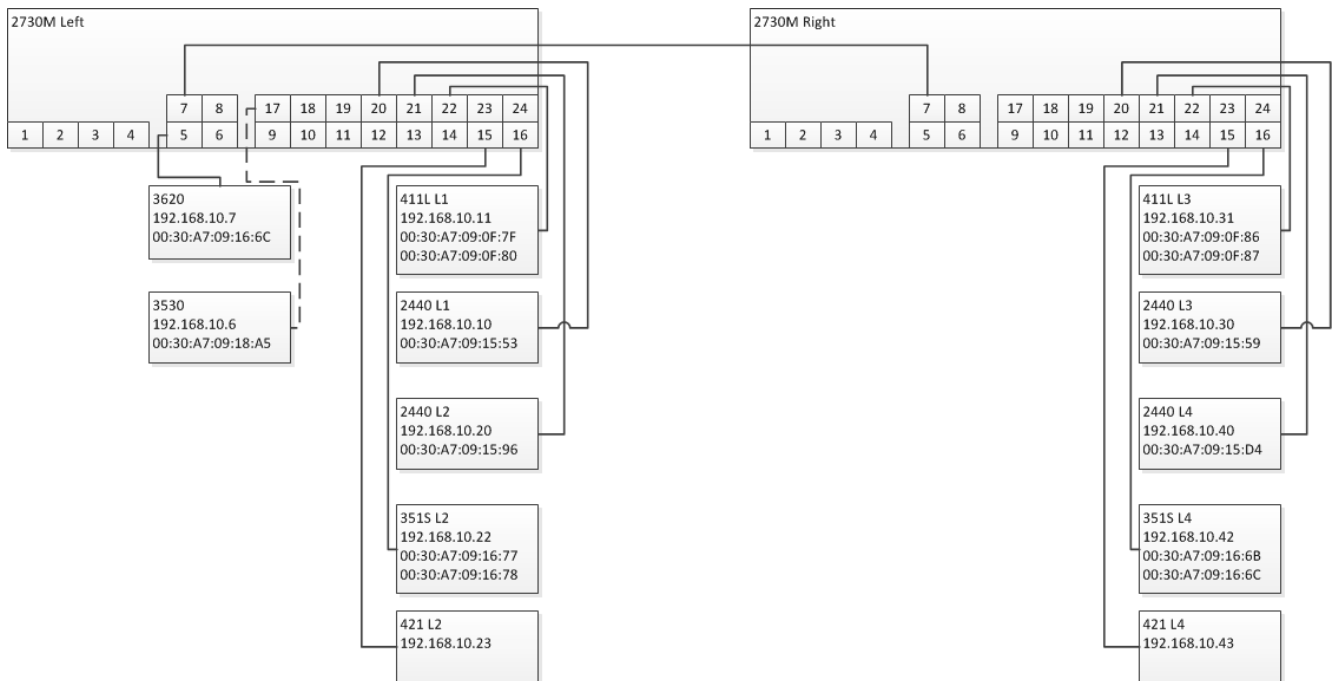
If you need to get ahold of one of the original team members of this senior design project for any reason, feel free to email me at garrettstauffer@gmail.com. Our original mentor was Brian Johnson, and our lead instructors were Amrit Dahal and Touraj Assefi.

⁶ For information on this notation, refer to Wikipedia's page on 'Classless Inter-Domain Routing' (CIDR)

APPENDIX A. NETWORK CONFIGURATION

The IP and MAC addresses are connected according to the diagram below. Note that ports 1 – 4 are not populated, 5 – 8 are Gigabit connections, and 9 – 24 are 100 Megabit connections. The standards used to pick the IP addresses were set for no reason other than clarity. The devices are attached to the same port on both sides (e.g. both 421's are port 15), and the IP address is set based on the line and device (.1x for L1, .2x for L2, etc. and .x0 for 2440, .x1 for 411L, etc.). All devices use a 24 bit subnet (255.255.255.0) with a subnetwork of 192.168.10, with the exception of the 3620, whose additional port is configured for access to the University LAN, at 129.101.221.87/16.

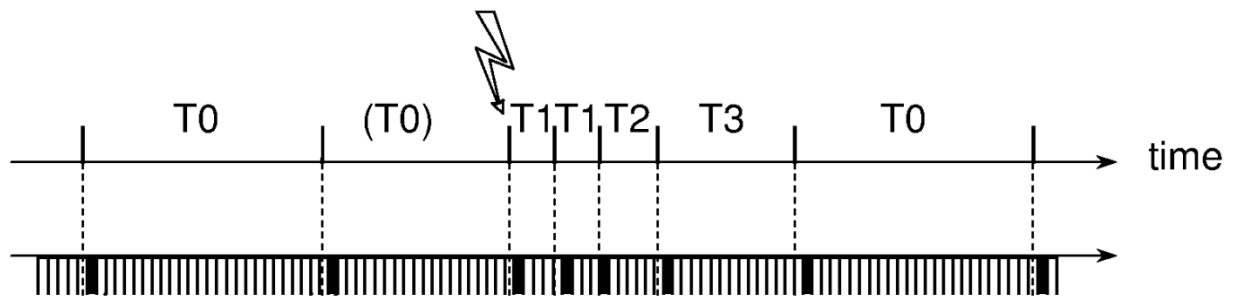
Figure 7. 2730M Port Configuration



APPENDIX B. GOOSE RETRANSMISSION

GOOSE messages use a publisher-subscriber system to transmit messages. Devices that are broadcasting messages do not know who, if anyone, is subscribed to the messages that they are publishing. Each message is given a unique multicast MAC address, and devices use this MAC address to identify which messages to read. Because the communication is strictly one way, there is no acknowledge to tell if the message went through or not. To address the issue of possible dropped packets, GOOSE messages are retransmitted every fixed unit of time. Any time one of the values in the message changes, the device enters a burst mode and rapidly transmits the message several times, gradually slowing down until it is back to its steady state rate of transmission. This is seen in figure 10. In the diagram, an event interrupts the usual waiting time T_0 . After this, the message is retransmitted after a time of T_1 , then again after T_1 , then at T_2 , and lastly at T_3 before it goes back to being transmitted every T_0 . Because an event tends to change many variables at one time, several messages will be entering this burst mode at the same time, leading to congestion at the most critical time for latency. The way this is handled is described in the section '2730M Configuration'.

Figure 8



APPENDIX C. ADDITIONAL REFERENCES

Additional diagrams and references are available on the 3355 computer in the lab, at C:\AMPS\Manuals\ and at C:\AMPS\Diagrams\. If for some reason there is an issue with the computer, there is an additional hard drive with Dr. Johnson that should work, and there is also a shell built in to the 3355 which can be used without a hard drive for rudimentary functions.