TSN Evaluation Kit

Quick Start Guide

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1. Overview

Thank you for purchasing the TSN Evaluation Kit. Innovasic appreciates your interest our TSN solution. Please contact us at any time to answer questions, help with set-up, or discuss ideas to make integration easy. Helping get your product to market efficiently and effectively is what our support team does best.

1.1 TSN Evaluation Kit

The Innovasic TSN Evaluation Kit is configured to provide TSN Gateway functionality in order to quickly assess TSN features and capabilities and better understand how TSN works. From there, it is possible to utilize Innovasic's fido5000 Real-time Ethernet Multi-protocol (REM) Switch chip to provide a TSN solution in your product's application. The figure below shows how the TSN Kit architecture relates to a "partitioned" communication architecture and to an "integrated" communications architecture.

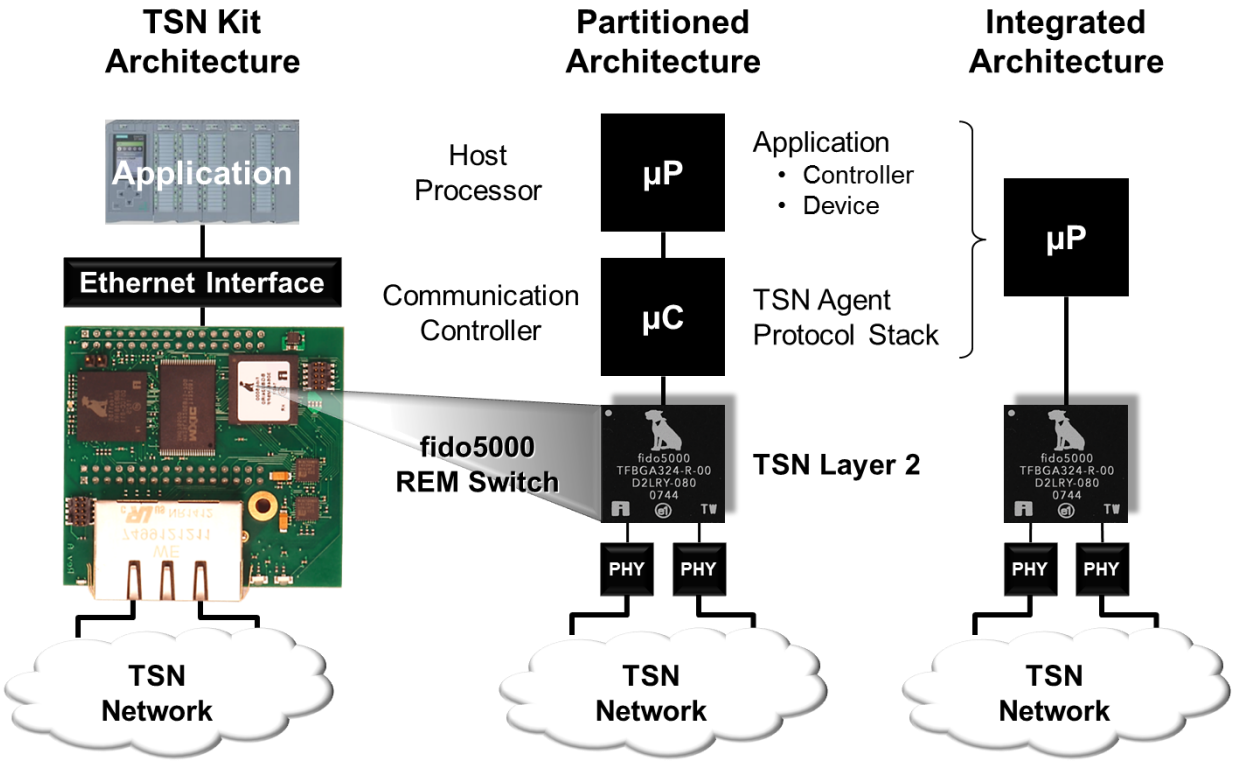


Figure 1- TSN Kit Architecture

Using the TSN gateway functionality allows a non-TSN device to participate in a TSN network without implementing TSN-specific features natively. The TSN gateway has built-in features from the following IEEE specifications:

- 802.1AS, AS-REV – Time Synchronization
- 802.1Qbv – Scheduled Traffic
- 802.1Qci – Ingress Policing
- 802.1CB – Seamless Redundancy
- 802.1Qcc – Stream Reservation Protocol
- 802.1Qbu / 802.3br – Preemption

The TSN gateway comes pre-installed with software that supports 802.1AS, 802.1Qbv, 802.1Qcc, and stream translation. Software updates will be provided to add TSN features and correct any interoperability issues. 802.1Qcc is currently implemented using a webserver, but will ultimately be implemented so the gateway can be configured by a Central Network Controller (CNC),

Network Interface Evaluation Kit Contents:

- 2-port TSN Ethernet Module
- Standard Ethernet Module
- Baseboard with Power Supply
- RJ-45 Ethernet Cable

Figure 2- TSN Kit Contents

1.2 Evaluation Overview

The TSN gateway connects to the TSN cloud as shown in Figure 3 and will synchronize itself with the network using IEEE 802.1AS. In the event there is no master in the TSN network, the gateway can become the master itself. The pre-installed webserver can be used to adjust parameters so the gateway can yield to other masters on the network or force the gateway to become the master on the network.

Once synchronized, the user can define which streams from the standard Ethernet device to translate into the TSN network using the webserver. These streams are "translated" into a format the TSN network can route by tagging the frames with a VLAN tag and assigning a VLAN priority. These streams can then be assigned to queues and then these queues can have "time

windows" assigned to them in order to schedule when the streams can egress onto the network. The assignment of VLAN Priority, queues, and time windows is performed by the using the webserver. An example of how to do this is given as part of this Quick Start Guide.

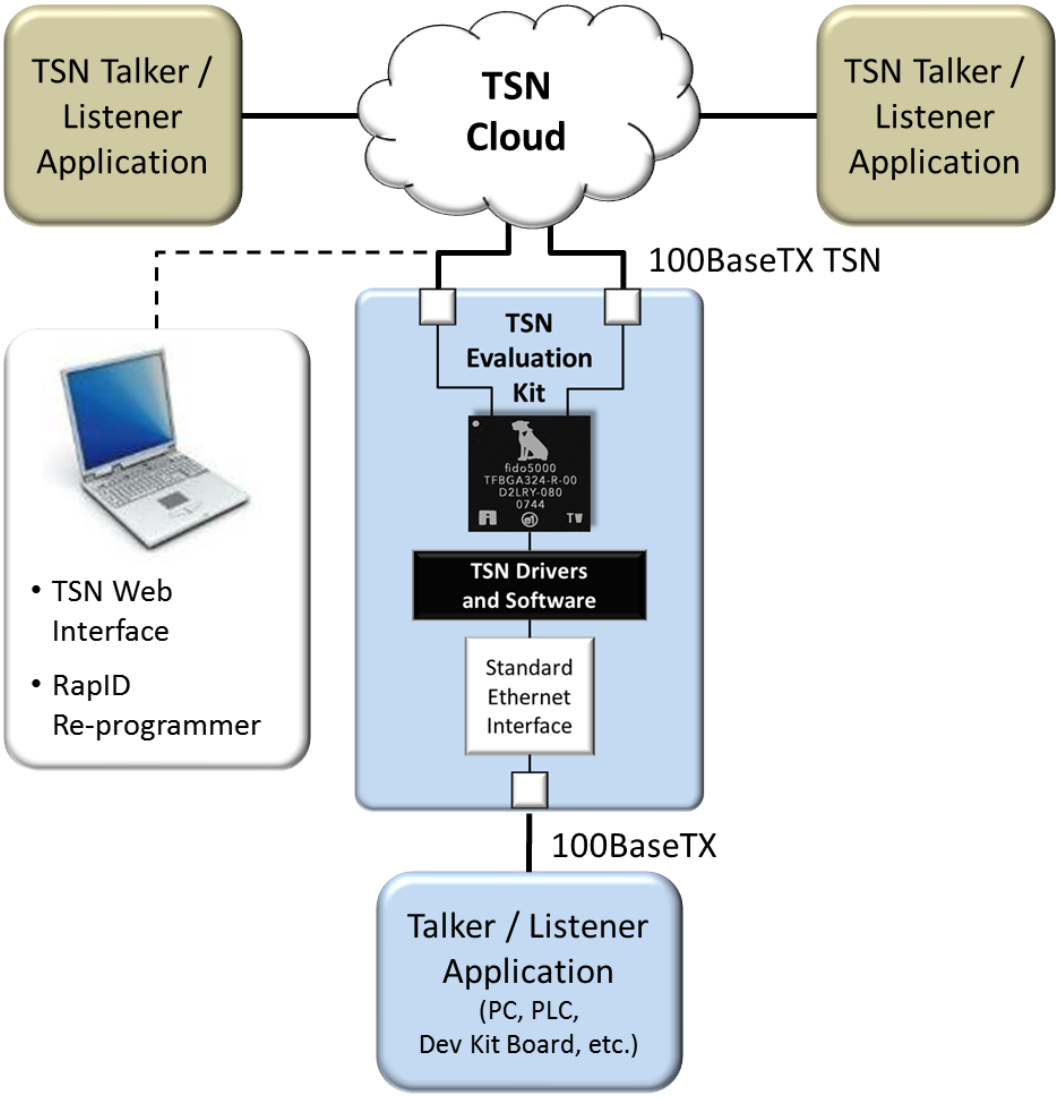


Figure 3- Evaluation Overview

2. Setting up the TSN Evaluation Kit Hardware

This section describes how to setup the hardware provided in the TSN Evaluation Kit so it can be used as a TSN gateway. The next section provides an example of how to connect a standard Ethernet device to a TSN network using the configured TSN gateway. The setup process is simple and should take only a few minutes. From there you can move on to the next section and connect your device to the TSN network. Care should be taken to ensure the modules provided are seated properly and the pins are aligned with the socket.

2.1 ESD and Power Supply Considerations

2.1.1 Electrostatic Sensitive Device

The hardware should be handled in accordance with proper ESD device-handling techniques. Personnel using this board are advised to use their grounding wrist strap to prevent accidental damage to the hardware.

2.1.2 Power Supply and Grounding

A wall adapter power supply is included with your evaluation boards. This supply is 12V, 1A and attaches to the power supply barrel connector. There is also a screw terminal to attach a lab benchtop power supply. For either type of power supply connection, the input voltage to the board must be in the range of 9V to 33V.

2.2 Making the Connections

Setting up the hardware is a simple five step process. Evaluation Kit ships with the correct jumpers installed so there is no need to set any jumpers. There is also no need to set any switches.

Step 1: Connect the Network Interface Module and the Ethernet Personality Module to the Network Interface Baseboard as shown in Figure 3.

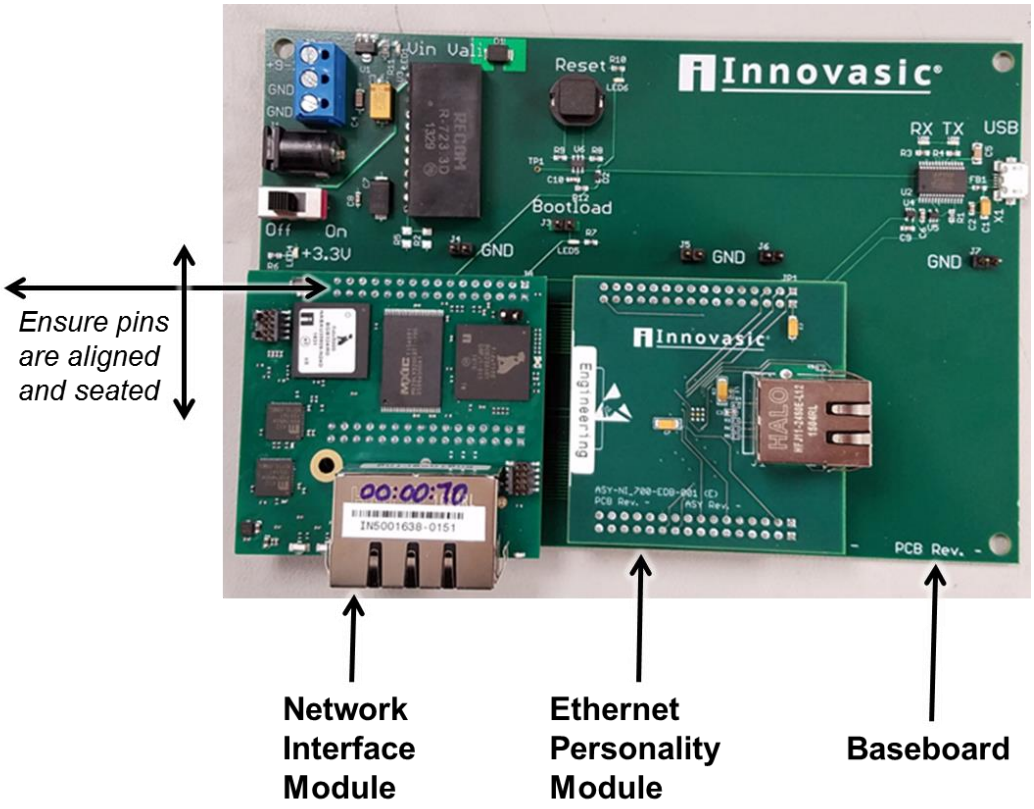


Figure 4 – Baseboard Connections

Step 2: Connect the power cable provided in the kit to the "POWER" port. The detailed location of the power port on the baseboard is shown below. Plug the other end of the power cord into a wall socket.

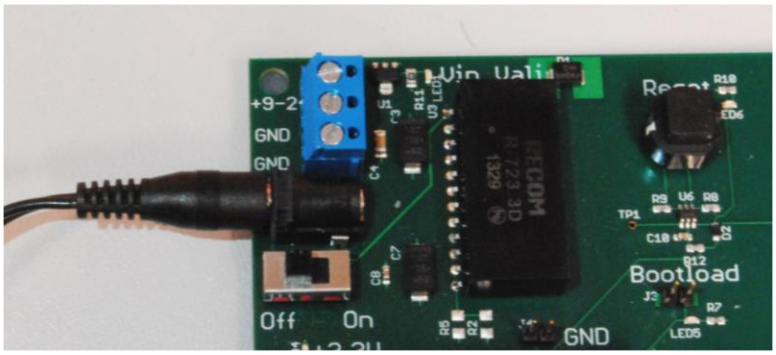


Figure 5 – Power Cable Connection

Step 3: Connect one end of an Ethernet cable to the Ethernet Personality Module on the TSN gateway. Connect the other end of the cable to the standard Ethernet device you want to connect to the TSN network. Please note that this end of the Ethernet cable must connect to a single standard Ethernet device and not a network of devices.

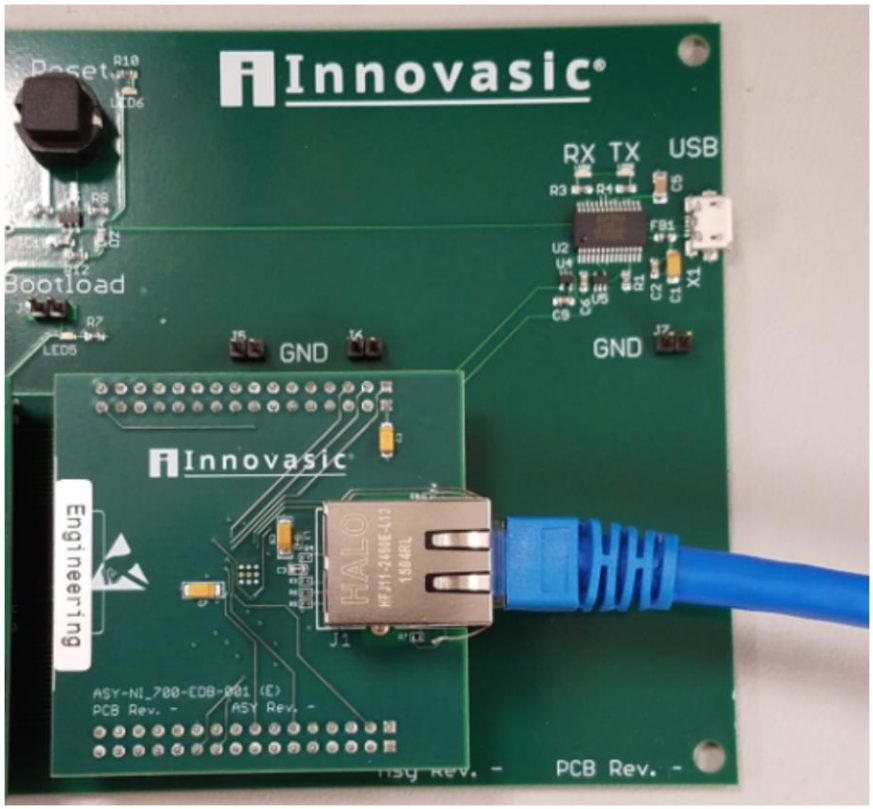


Figure 6 – Ethernet Personality Module Connection

Step 4: Connect one end of an Ethernet cable to either of the RJ45 jacks on the Network Interface module. The detailed location of the RJ45 jacks is shown below. The other end of the Ethernet cable

connects to a TSN Network. The open port on the Network Interface Module can connect to another TSN device or to any other standard Ethernet device.

Figure 7 – TNS Network Connection

Step 5: Apply power to the module by turning the baseboard power switch to the "ON" position. The detailed location of the switch on the baseboard is shown below.

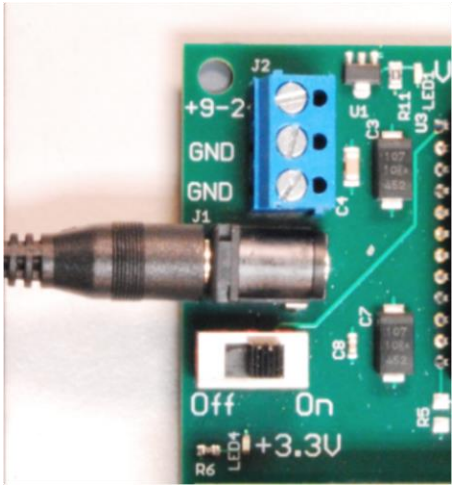


Figure 8 – Power ON Switch location

The resulting setup should look like the picture below.

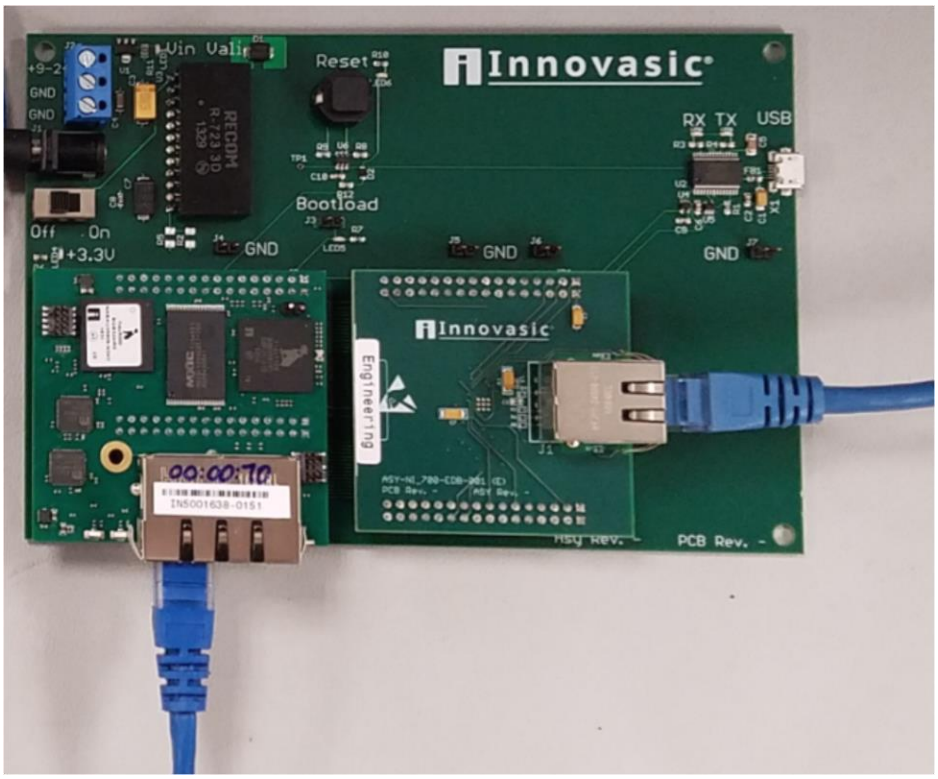


Figure 9 – Assembled TSN Gateway with Connections

3. TSN Network Example

The TSN gateway can bridge any standard Ethernet device onto a TSN network. In order to illustrate how to do this, an example is provided that connects PROFINET Programmable Logic Controller (PLC) to a PROFINET Remote I/O device talking to each other using a TSN network. This example also illustrates standard Ethernet traffic routed across a TSN network using a standard IP camera and a PC. The example setup is shown in the figure below.

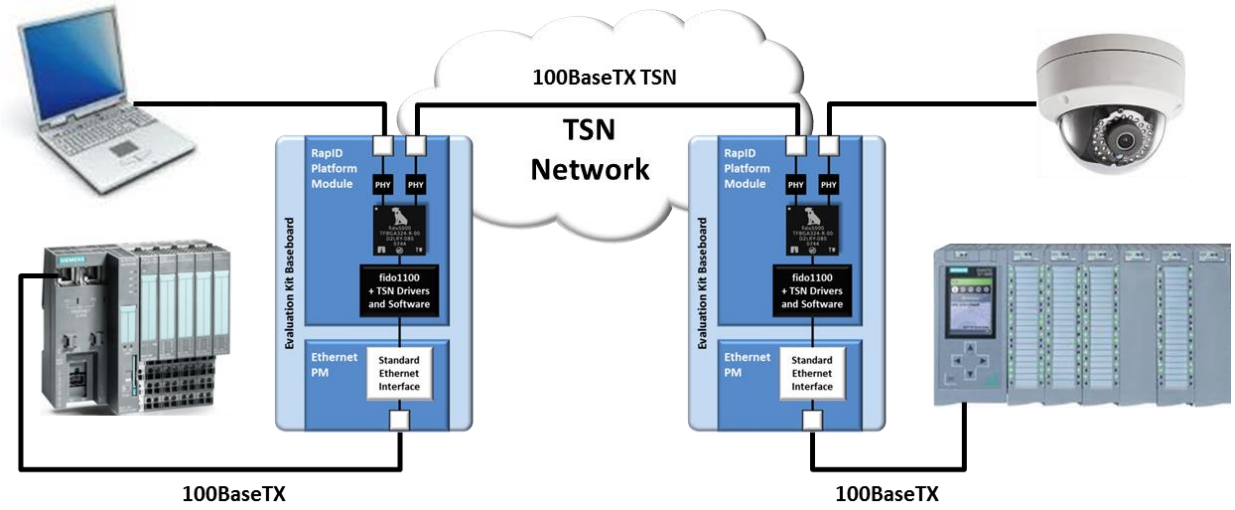


Figure 10 – TSN Network Example Configuration

This example uses the contents of two TSN Evaluation Kits. However, the configuration instructions using the webserver are the same whether you want to set up one device or even two or more devices. The physical connections on the TSN side of the network will be different with just a single device, but again, configuring the ports using the webserver are the same.

3.1 Configuring a TSN Gateway

Using the assembled TSN gateway resulting from the steps described in Section 2, connect a PC to the end of Ethernet cable connected to the two-port Ethernet connector and your standard Ethernet device to the end of the Ethernet cable connected to the single-port Ethernet connector. In this example, we start by connecting the PROFINET Remote I/O device to the TSN gateway. A diagram of how these connections should look is shown in the figure below.

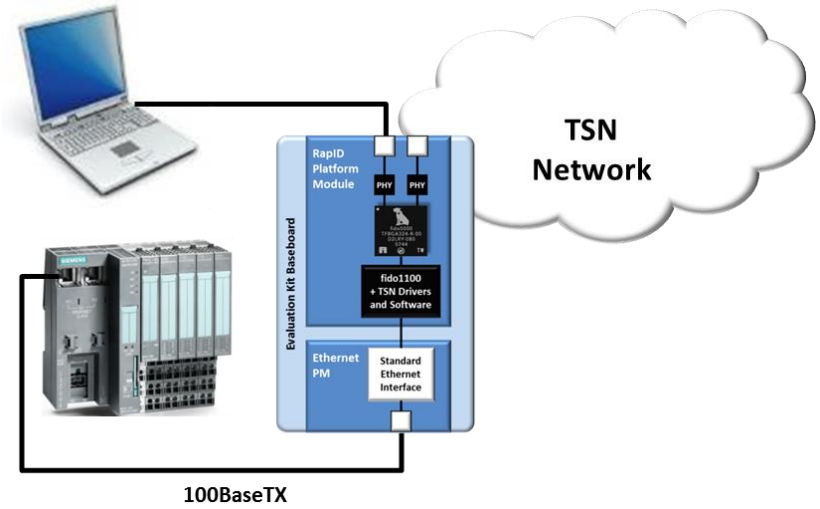


Figure 11 – Connections for configuring a gateway

On your PC, bring up a web browser and type in *192.168.1.1*. This IP Address is the default IP Address and will cause the web browser to display the webpage from the connected TSN gateway as shown below.

Please Note: Because all TSN Gateways ship with the same default MAC address of 12:34:56:78:9A:BC and the same default IP address of 192.168.1.1, only one can be configured on a single network at a time.

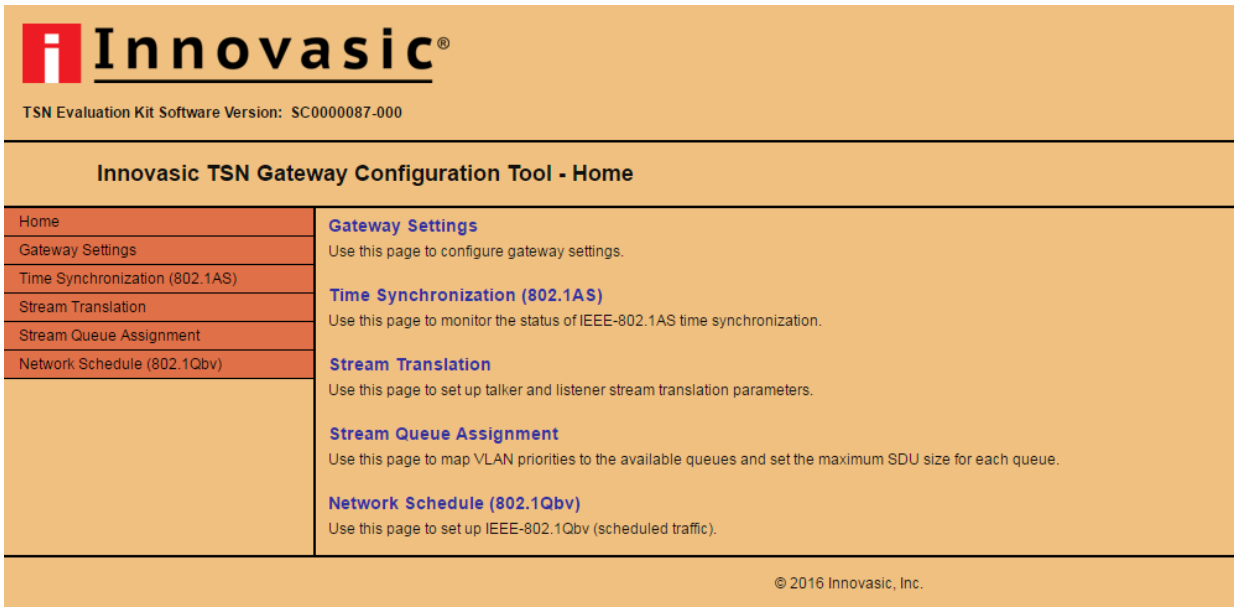


Figure 12 – TSN Gateway Homepage

Please Note: if you are having issues displaying the webpage, please verify your web browser is a version shown in the table below or newer

Browser	Minimum Required Version
Google Chrome	49
Mozilla Firefox	47
Internet Explorer	11
Opera	39
Microsoft Edge	13

Table 1 – Minimum Required Browser Versions

Click on the "Gateway Settings" tab on the left hand side of any webpage to navigate to this page. This webpage is used to setup the IP Address and MAC Address for the TSN gateway as well as setup the MAC address for the standard Ethernet device you wish to connect to a TSN network. The device you are connecting to the TSN network is referred to as the Client and its MAC address is referred to as the Client MAC Address. Click on the "Gateway Settings" tab to navigate to the Gateway Settings page. This page is shown in the figure below.

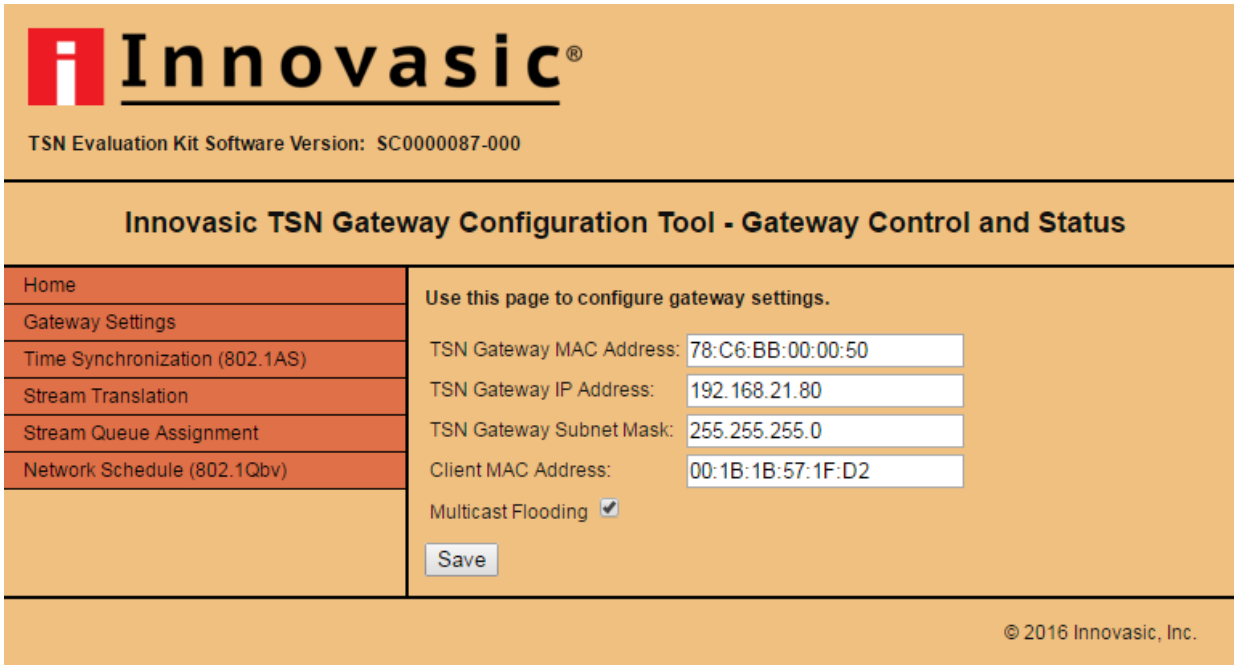
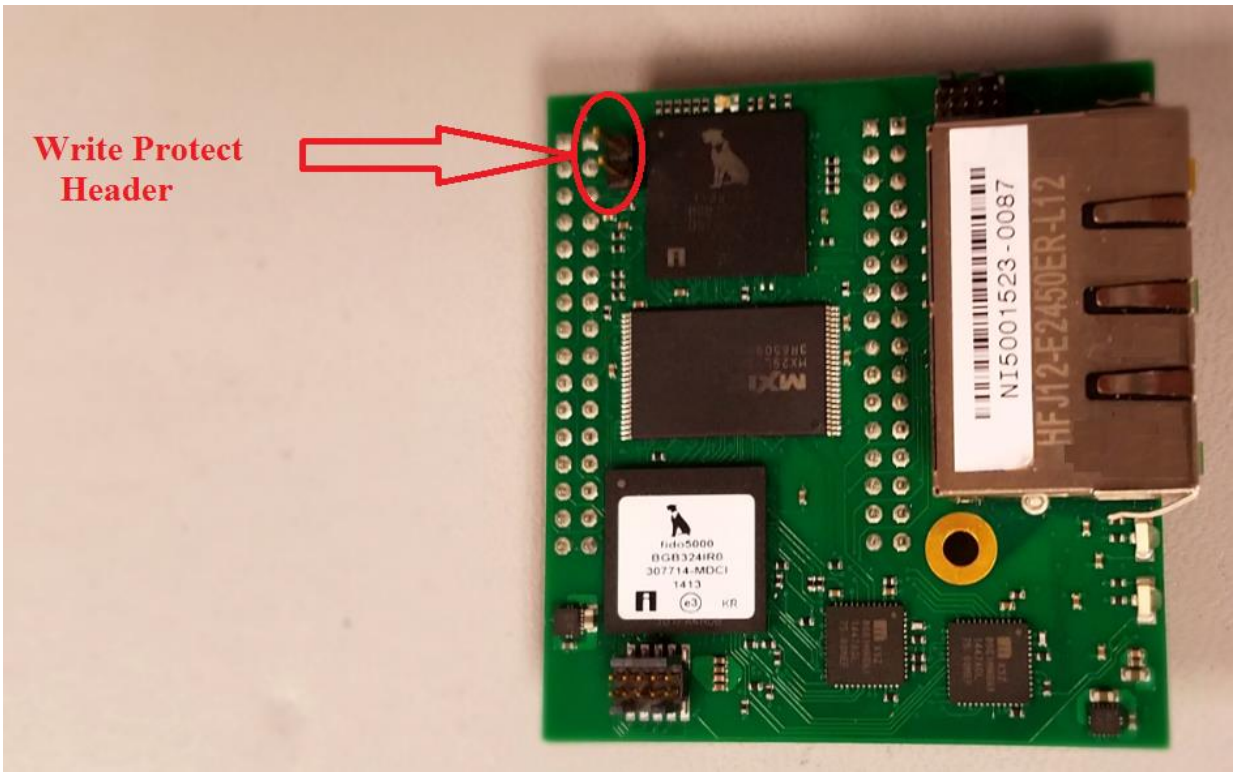


Figure 13 – Gateway Settings Page for TSN Gateway #1

If you wish to change the MAC address of the TSN gateway on your TSN Network, enter a new MAC Address in the "TSN Gateway MAC Address" field. For this example, the MAC Address for the TSN Gateway has been changed to 78:C6:BB:00:00:50.

WARNING: Do not change the value in the "TSN Gateway MAC Address" field to be a Multicast MAC Address. This will cause the device to become inaccessible to a user. A Multicast MAC address has the least significant bit of the first byte set. Hence anything with an odd number for the first byte will be Multicast.

Please Note: if you are changing the MAC address, a jumper must be placed on the write protect header of the TSN Gateway.



Please Note: if you are changing the MAC address, the TSN Gateway will not use the newly assigned MAC address until after it has been power-cycled.

Please Note: if you are using more than one TSN gateway from Innovasic, you MUST provide a unique MAC address for every Innovasic TSN gateway in your network because each TSN Evaluation Kit ships with the same MAC address of 12:34:56:78:9A:BC.

If you wish to change the subnet and / or address of the TSN gateway to meet the needs of your TSN Network, enter a new IP address in the "TSN Gateway IP Address" field.

Please Note: after changing the "TSN Gateway IP Address", you will need to enter that address into your browser in order to get back to the webpages for the TSN gateway.

Find the MAC Address for the device connected to the single-port of the TSN gateway. Enter this MAC address in the "Client MAC Address" field on this page. For this example, the MAC address for the ET200S is shown here in the "Client MAC Address" field as 00:1B:1B:57:1F:D2.

Please Note: Leave the "Multicast Flooding" box checked for now. This option allows the Client to see all Multicast Ethernet frames on the TSN network in the event the Client application needs access to various Multicast Ethernet frames. Unchecking the box allows "fine tuning" of which Multicast Ethernet frames the Client sees.

Click "Save" after entering data in the fields you have changed.

3.2 Verifying Operation of 802.1AS Time Synchronization

Click on the "Time Synchronization (802.1AS)" tab on the left hand side of any webpage to navigate to this page. Most of the fields on this webpage are informational and you can verify the operation of the time synchronization function on the TSN gateway as shown in the figure below. The following describes each of the fields on the webpage.

Sync State, the TSN gateway will report "Synchronized" if it is synchronized to another device that is a better clock source (i.e. a Grand Master) on the TSN network. The TSN gateway will report "Unsynchronized" when it is not synchronized to a master and will report "Grandmaster" if it is providing the master clock source on the TSN network.

Below the "Sync State" status is the status of the two-ports on the TSN side of the gateway. The status of Port 1 and Port 2 are shown and below each port are the following fields:

Port Role: Reports if the port is in "Slave" mode or "Master" mode. If the gateway is not a master, one port will report it is in "Slave" mode while the other port will report it is in "Master" mode. If the gateway is the Grandmaster on the TSN network, then both ports will report they are in "Master" mode.

Port Status: This field reports if the port's connection is "Time Aware" or if it is "Not Time Aware". If there is a connection that can be synchronized then the status is "Time Aware". If there is a connection that cannot be synchronized, the status is "Not Time Aware".

Log Sync Interval: This field allows the user to adjust the rate at which synchronization messages are sent. The value is an integer can range from -5 to +5 which sets the rate between 31.25 milliseconds (2^{-5}) to 32 seconds (2^{5}). It is recommended to leave the value at its default value of -3.

Line Pdelay_Req Interval: This field allows the user to adjust the interval between the Pdelay request messages. The value is an integer can range from -5 to +5 which sets the rate between 31.25 milliseconds (2^{-5}) to 32 seconds (2^{5}). It is recommended to leave the value set at its default value of 0.

Log Announce Interval: This field allows the user to adjust the rate for the interval between announce messages. The value is an integer can range from -5 to +5 which sets the rate between

31.25 milliseconds (2^{-5}) to 32 seconds (2^{5}). It is recommended to leave the value set at its default of 0.

Line Delay: This field reports the value of the line delay calculated for the cable length of the network connection. This value is reported in ns. In the event the port is "Not Time Aware" or there is no connection to the port, this value will read zero.

The next four items on the page relate to the best master clock source information.

Best Master Clock ID: This field is the 802.1AS Clock Identity of the Best Master to which the TSN gateway is synchronized.

Best Master Priority1, Best Master Priority2, Best Master Steps Removed: these fields are reported for informational purposes related to the Best Master.

The next three items on the page relate to the local clock source information.

Local Clock ID: This field is the 802.1AS Clock Identity of the TSN gateway since it can be the master to a peer on either Port 1 or Port 2.

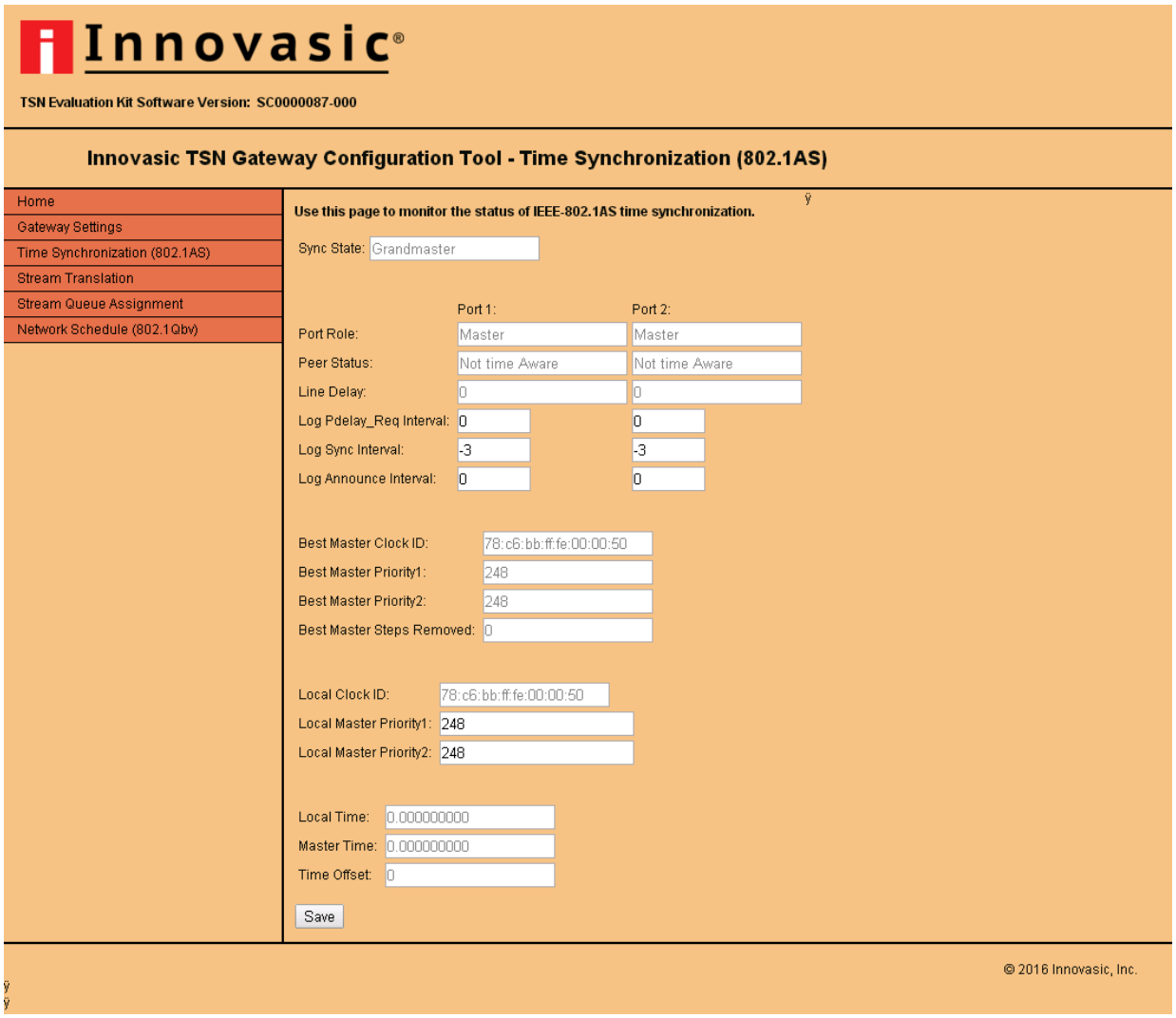


Figure 14 – Time Synchronization Status for TSN Gateway #1

Local Master Priority1, Local Master Priority2: These fields are used in the Best Master Clock Algorithm (BCMA). By adjusting these values up or down you can change the local clock priority relative to the Best Master's clock priority in order to allow the TSN gateway become the Best Master or prevent it from becoming the Best Master.

The last three items on the page report the status of the time.

Local Time: This field is the value of the local time on the TSN gateway.

Master Time: This field is the value of the Best Master's time.

Time Offset: This field is simply the difference between the Local Time on the TSN gateway and the Master's Time. When the TSN gateway is the Master, the offset is 0.

Please Note: If you change the Log Sync Interval, the Local Priority1 or Local Priority2 value, make sure to hit "Save" in order to have the values take effect.

3.3 Setting up Stream Translation

Once you have verified time is working properly on the TSN gateway, the next step is to identify which streams from your standard Ethernet device you want to put into the TSN network. Streams not identified for use in a TSN network are automatically classified as "Best Effort" traffic and are handled just like in any other standard Ethernet network – i.e. these streams will not be able to use any of the features of TSN.

The process by which standard Ethernet frames are converted into a format suitable for use in a TSN network is called "Stream Translation". Click on the "Stream Translation" tab on the left hand side of any webpage to navigate to this page. This page is shown in the figure below.

3.3.1 Talkers and Listeners

When your standard Ethernet device sends Ethernet messages to another device it is referred to as a "Talker". When your standard Ethernet device receives Ethernet Messages from another device it is referred as a "Listener". This is why on the Stream Translation page you see a set of "Talker Parameters" and a set of Listener Parameters".

It is possible to perform Stream Translation for four Talker Streams. It is also possible to perform Stream Translation on a separate set of four Listener Streams. A checkbox is provided on the page to select how many streams you would like to enable for stream translation. Checking the box will highlight the fields that need to be filled out for the Talker Parameters and Listener parameters.

For the four Talker Streams, it is possible to use 5 different "Methods" to identify the streams coming from the Client in order to translate them into the TSN network. The fields in the Talker Parameters section will change based on the Talker Method selected.

The subsections below describe how to setup Talker and Listener Stream Translation starting with the "Talker Methods" used for Talker Stream Translation.

3.3.2 Talker Methods

The five translation methods for identifying Client streams are a unique filter that will match particular Client streams. These methods are identified as:

- Destination MAC Address
- Destination MAC Address AND Priority Code Point of VLAN Tag
- Destination IP Address AND Differentiated Services Code Point (DSCP)
- Destination IP Address AND Protocol and Source Port
- Destination IP Address AND Protocol and Destination Port

The following subsections define the fields looked at for performing the filter match in the stream translation process. If you would like further details on the structure and definition of an Ethernet frame please refer to Wikipedia at the following link:

https://en.wikipedia.org/wiki/IEEE_802.1Q

3.3.2.1 Destination MAC address

This is the default filter and is the method that is used in this example. The Destination MAC address will be the first 6 bytes that follow the Preamble to any standard Ethernet packet.

The structure of the Ethernet frame and the fields used are highlighted in the figure below. The webpage associated with this Talker Method is shown in the figure that follows.

Preamble	SFD	**Destination MAC Address**	Source MAC Address	Ethertype	Payload	32-bit CRC
7 bytes	1 byte	**6 bytes**	6 bytes	2 bytes	46-1500 bytes	4 bytes

Figure 15 – Destination MAC address location in an Ethernet packet

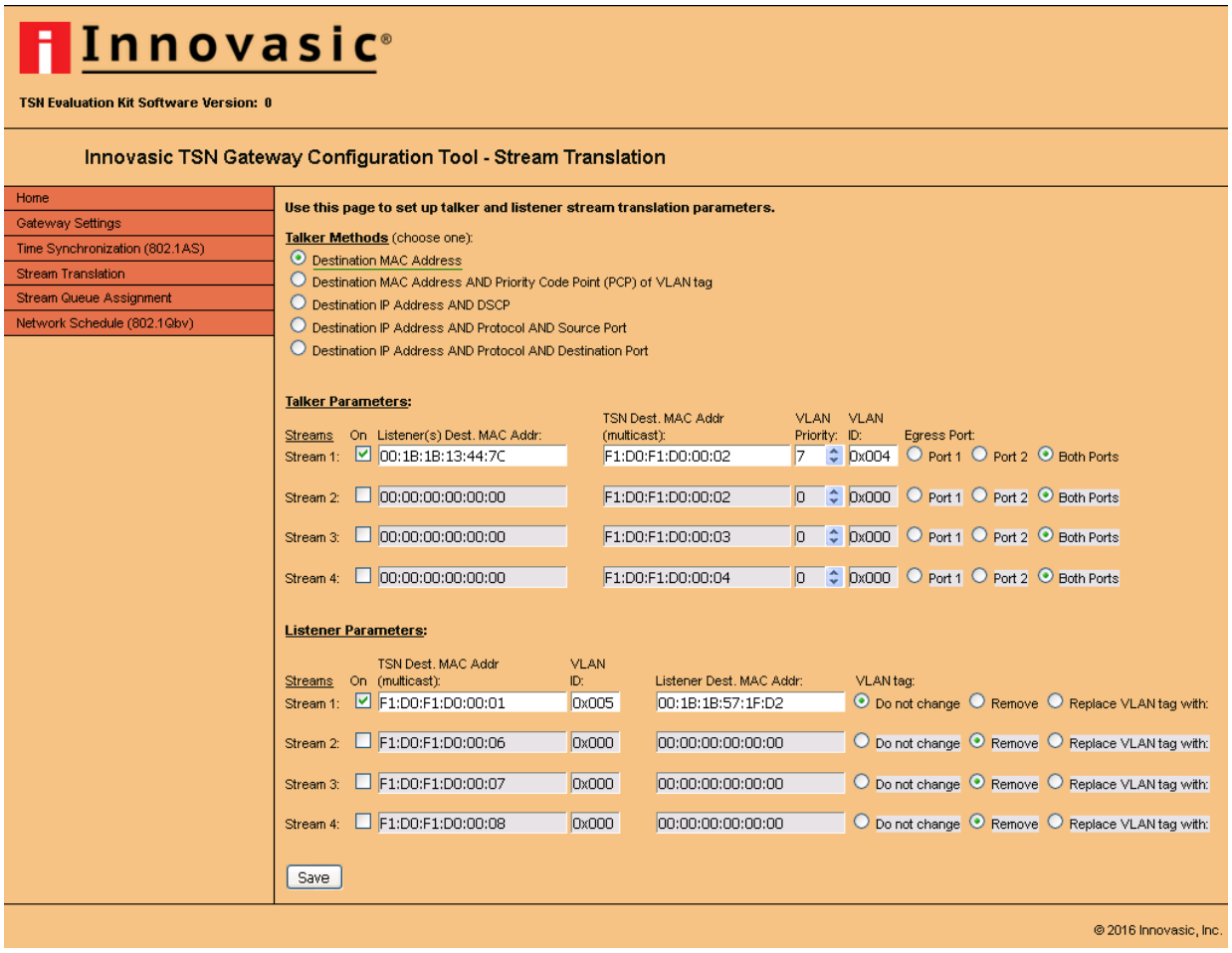


Figure 16 – Stream Translation Page using Destination MAC Address Talker Method

3.3.2.2 Destination MAC address and Priority Code Point of VLAN TAG

Another method is to use the PCP of the VLAN TAG along with the Destination MAC Address to define a stream. The VLAN header is located immediately following the Source MAC Address. The Priority Code Point of the VLAN Tag is 3 bits immediately following the 16 bits for TPID.

The structure of the Ethernet frame and the fields used are highlighted in the figure below. The webpage associated with this Talker Method is shown in the figure that follows.

Preamble	SFD	**Destination MAC Address**	Source MAC Address	**VLAN Tag**	Ethertype	Payload	32-bit CRC
7 bytes	1 byte	**6 bytes**	6 bytes	**4 bytes**	2 bytes	46-1500 bytes	4 bytes

TPID	**PCP**	DEI	VID
16 bits	**3 bits**	1 bit	12 bits

Figure 17 – Destination MAC address and PCP location in an Ethernet packet

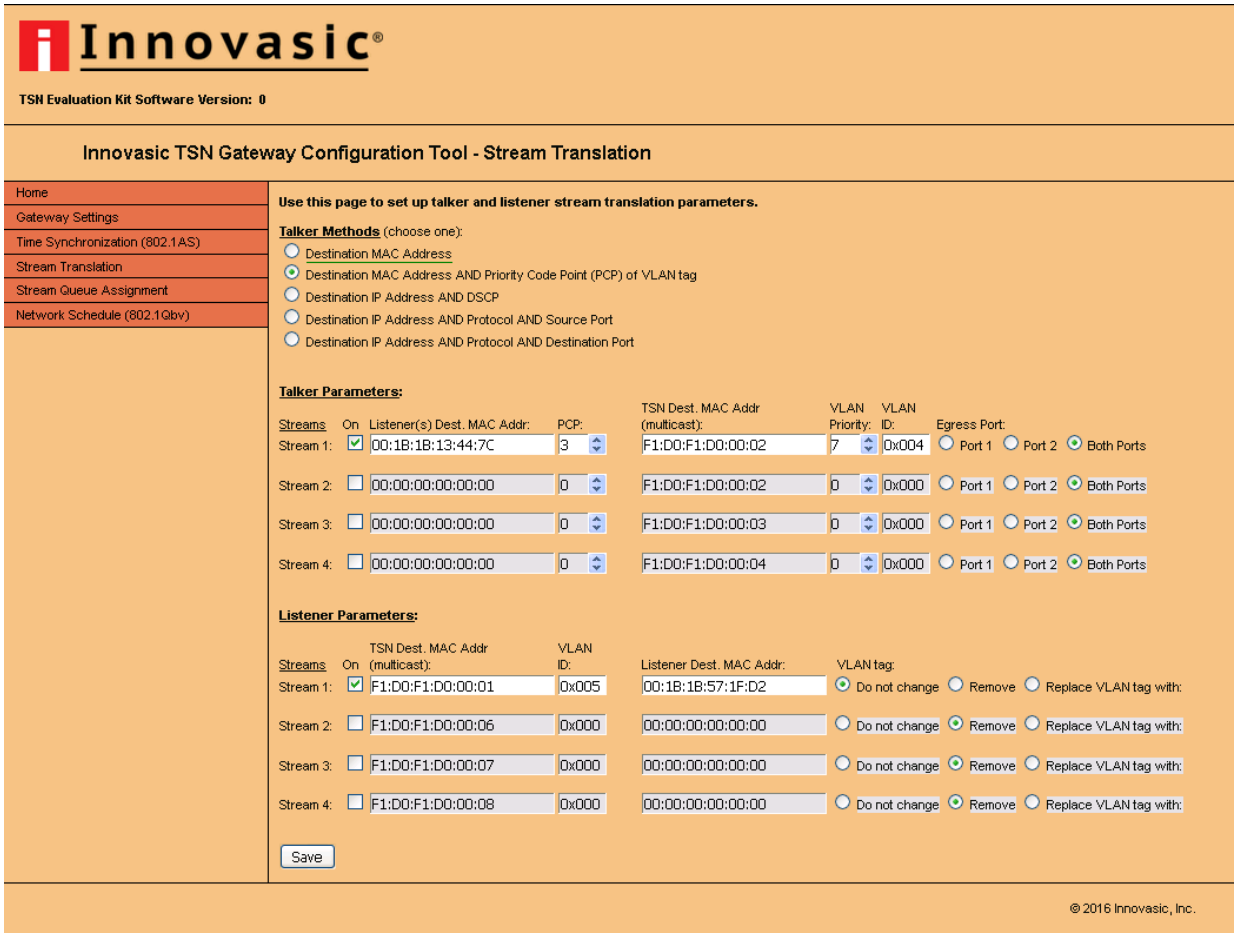


Figure 18 – Stream Translation Page using Destination MAC address and Priority Code Point of VLAN TAG Talker Method

3.3.2.3 Destination IP address and Differentiated Services Code Point

When an Ethernet frame is designated as "IP" in the Ethertype field, an IP Header will immediately follow as the first 19 bytes in the Payload. The Destination IP address is used in conjunction with the Differentiated Services Code Point to define a stream. The DSCP and the Destination IP address can be found as in an Ethernet frame as shown below. The DSCP is the first 6 bits of the second byte in the IPv4 Header. If you would like further details on the structure and definition of an IPv4 within and Ethernet frame please refer to Wikipedia at the following link:

https://en.wikipedia.org/wiki/IPv4#Header

The structure of the Ethernet frame and the fields used are highlighted in the figure below. The webpage associated with this Talker Method is shown in the figure that follows.

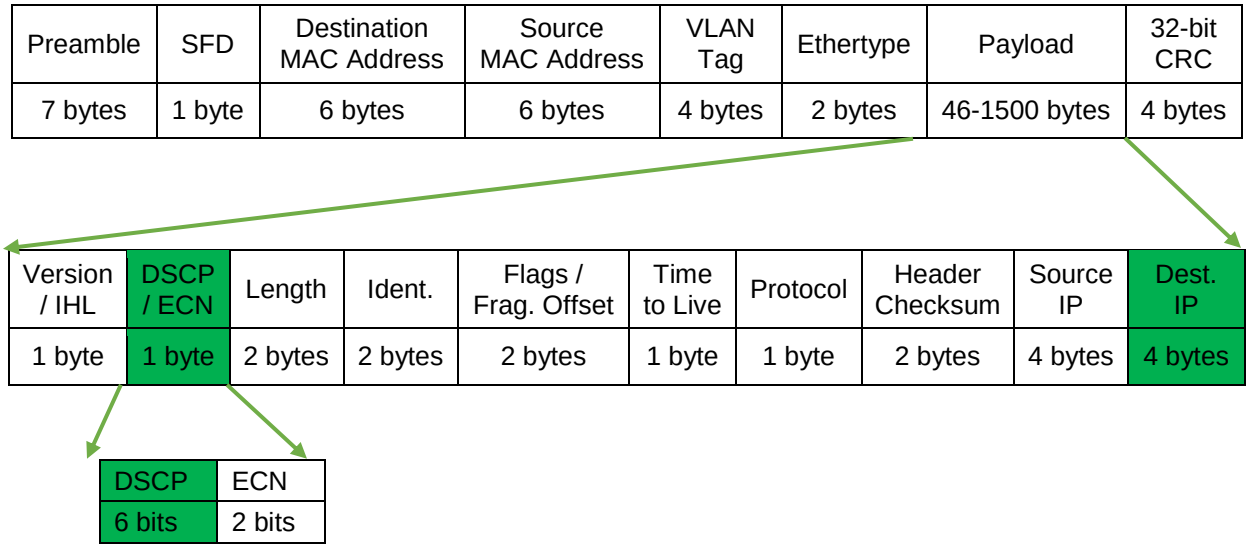


Figure 19 – Destination IP Address and DSCP location in the IPv4 header

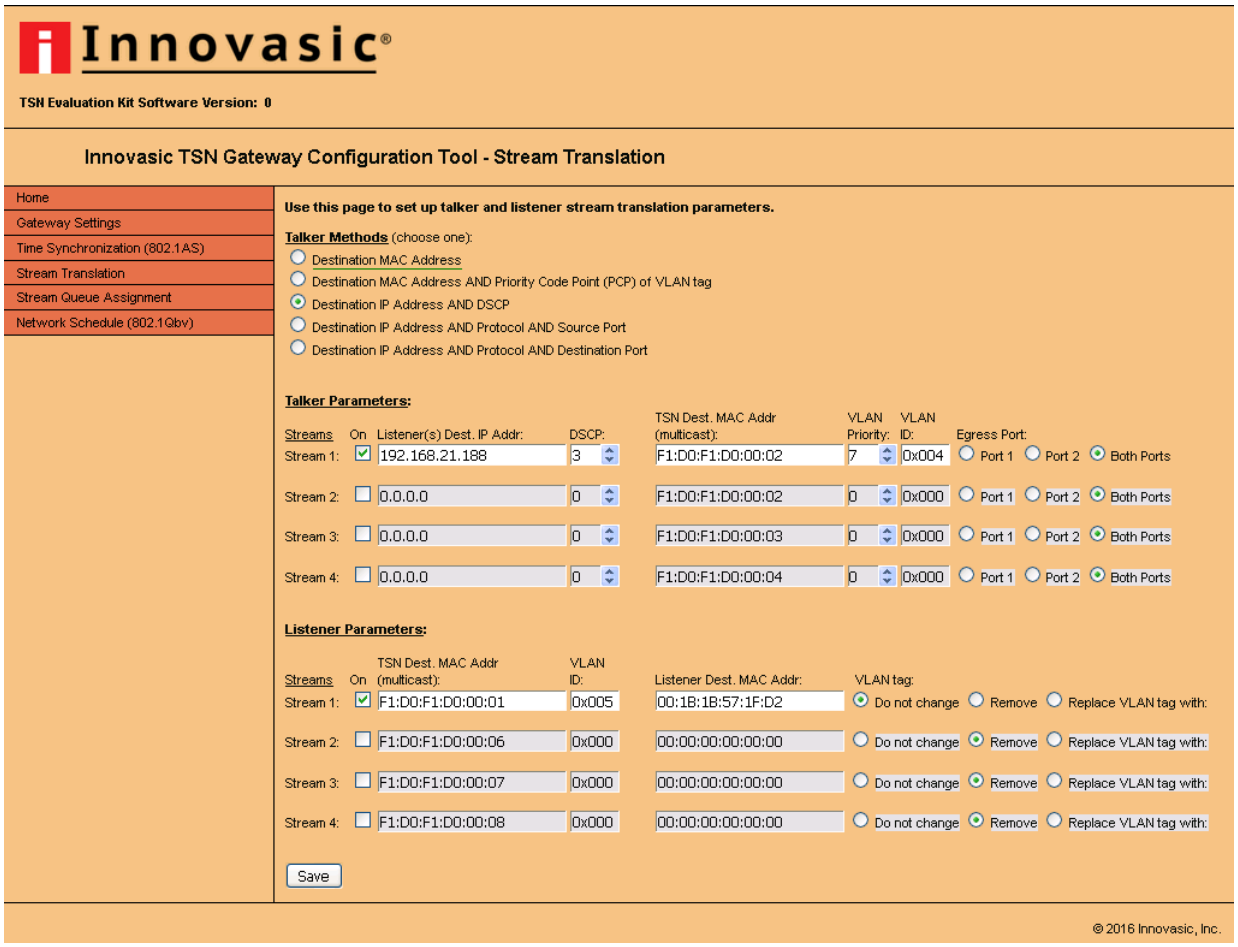


Figure 20 – Stream Translation Page using Destination IP address and Differentiated Services Code Point Talker Method

3.3.2.4 Destination IP address and Protocol and Source Port

When an Ethernet frame is designated as "IP" in the Ethertype field, an IP Header will immediately follow as the first 19 bytes in the Payload. The Destination IP address is used in conjunction with the Source Port in either the TCP Header or the UDP Header to define a stream. The Protocol field in the IP Header defines the protocol, and if the protocol is TCP or UDP, one of these two headers will immediately follow the IP Header. The Source Port is the first 2 bytes in either the TCP or UDP Header. This is shown in the two figures below. If you would like further details on the structure and definition of a TCP or UDP Header in an IPv4 Header within an Ethernet frame please refer to Wikipedia at the following link:

https://en.wikipedia.org/wiki/Transmission_Control_Protocol

https://en.wikipedia.org/wiki/User_Datagram_Protocol

The structure of the Ethernet frame and the fields used are highlighted in the figure below. The webpage associated with this Talker Method is shown in the figure that follows.

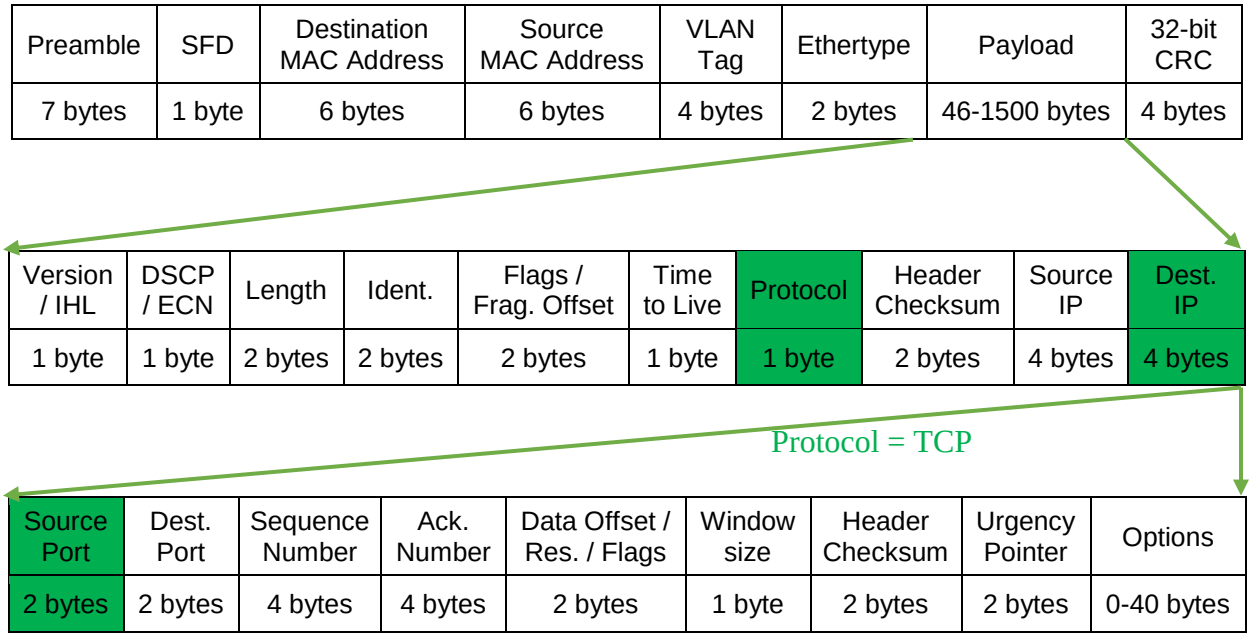


Figure 21 – Destination IP Address, Protocol, and Source Port in TCP Header

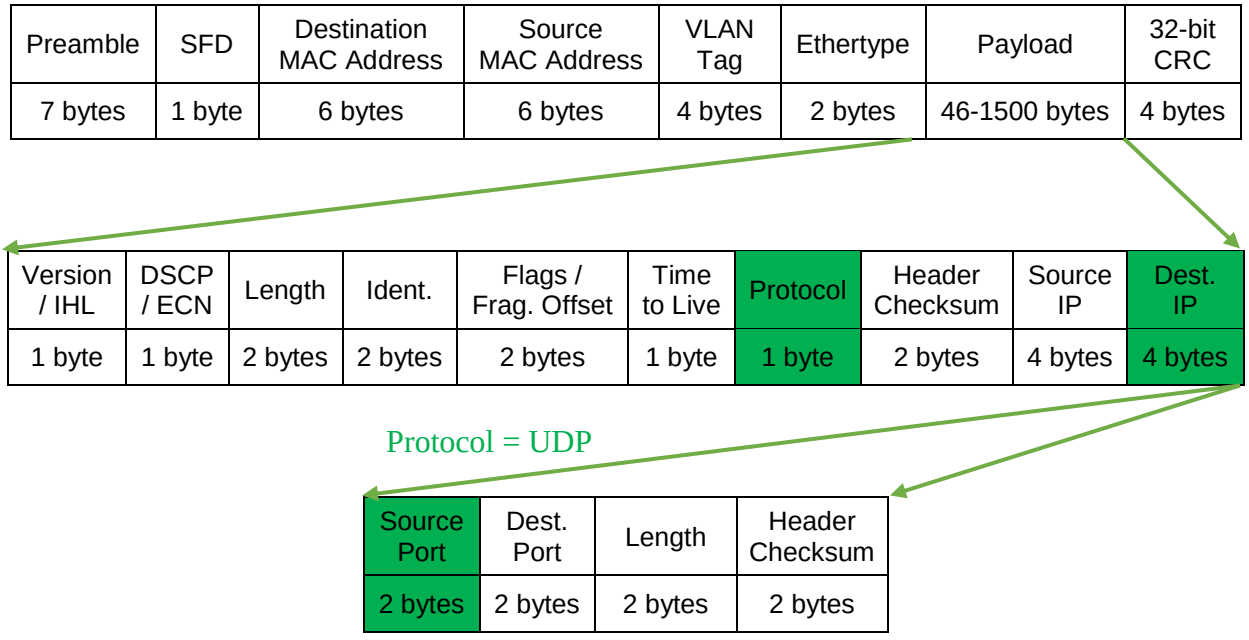


Figure 22 – Destination IP Address, Protocol, and Source Port in UDP Header

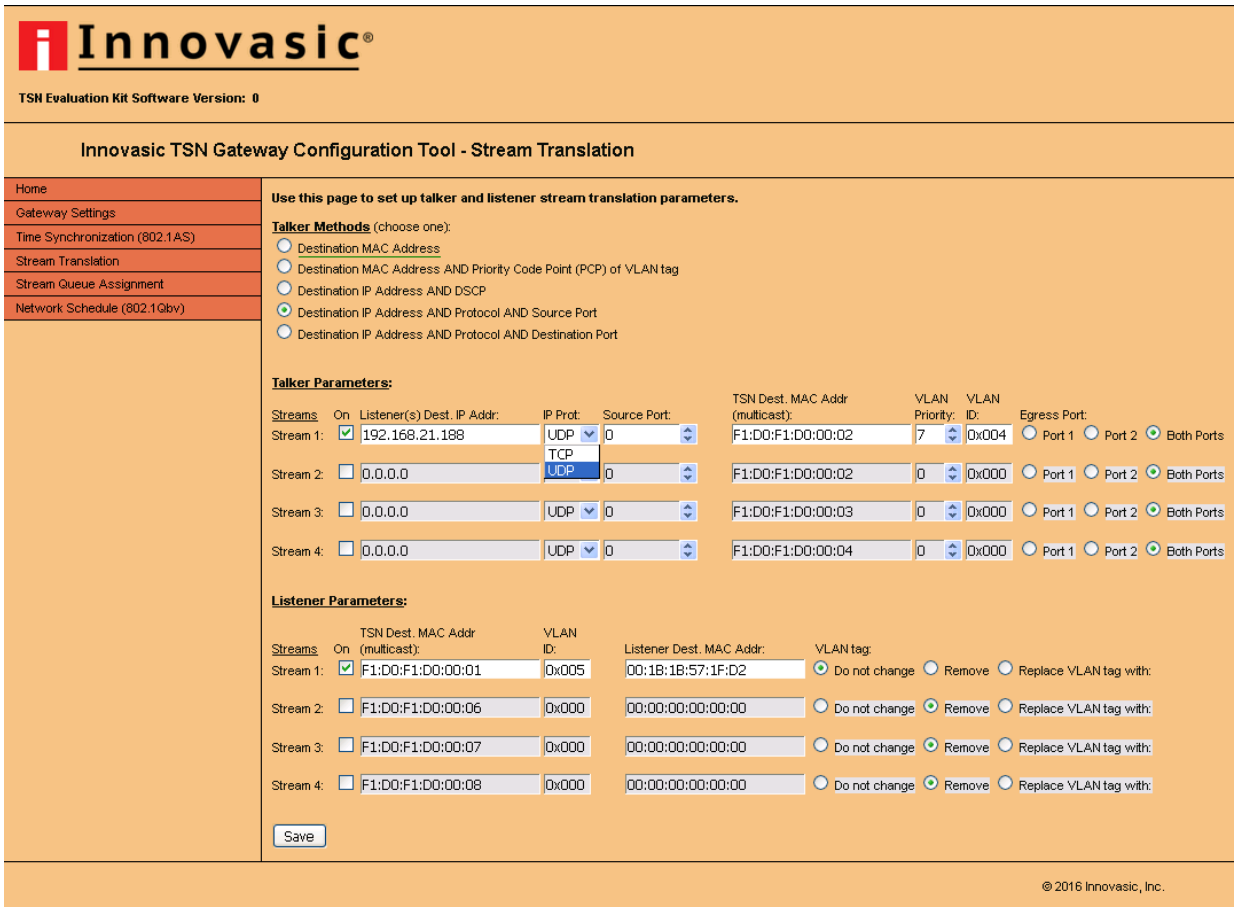


Figure 23 – Stream Translation Page using Destination IP address and Protocol and Source Port

3.3.2.5 Destination IP address and Protocol and Destination Port

When an Ethernet frame is designated as "IP" in the Ethertype field, an IP Header will immediately follow as the first 19 bytes in the Payload. The Destination IP address is used in conjunction with the Destination Port in either the TCP Header or the UDP Header to define a stream. The Protocol field in the IP Header defines the protocol, and if the protocol is TCP or UDP, one of these two headers will immediately follow the IP Header. The Destination Port is the second 2 bytes in either the TCP or UDP Header.

The structure of the Ethernet frame and the fields used are highlighted in the figure below. The webpage associated with this Talker Method is shown in the figure that follows.

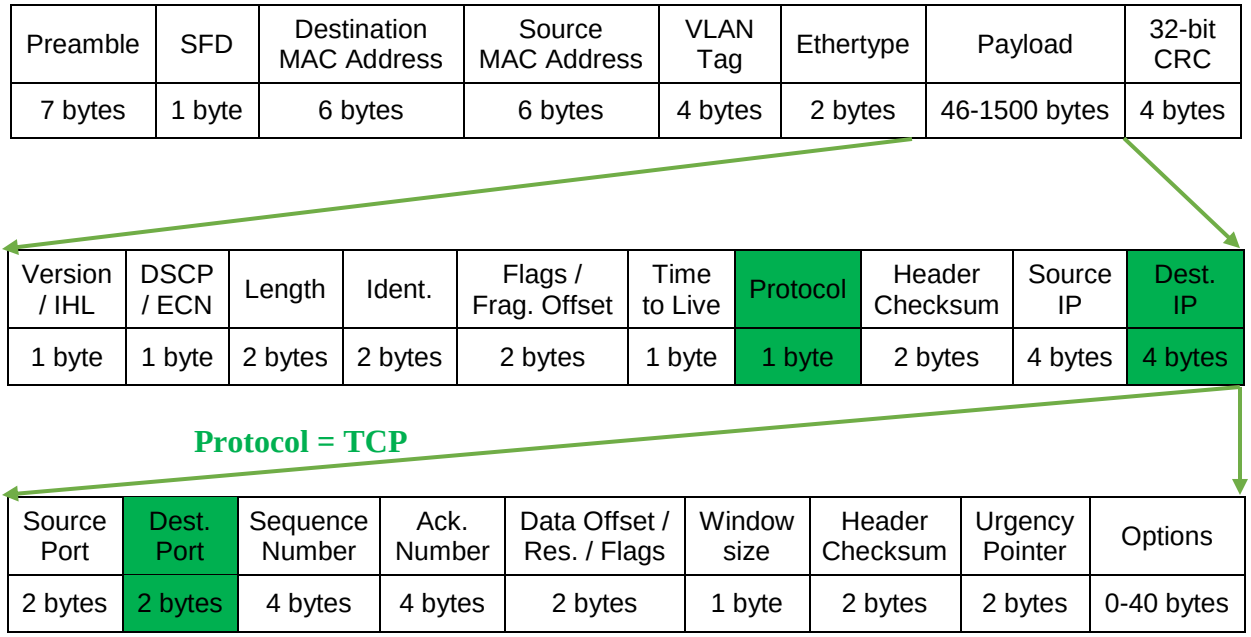


Figure 24 – Destination IP Address, Protocol, and Destination Port in TCP Header

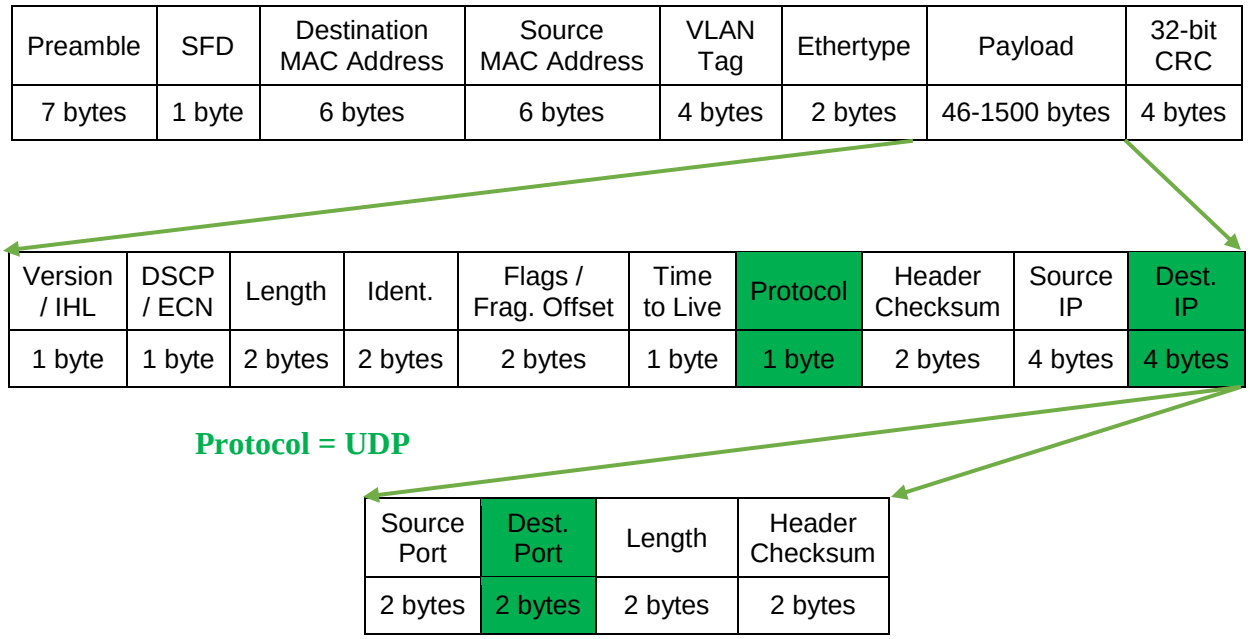


Figure 25 – Destination IP Address, Protocol, and Destination Port in UDP Header

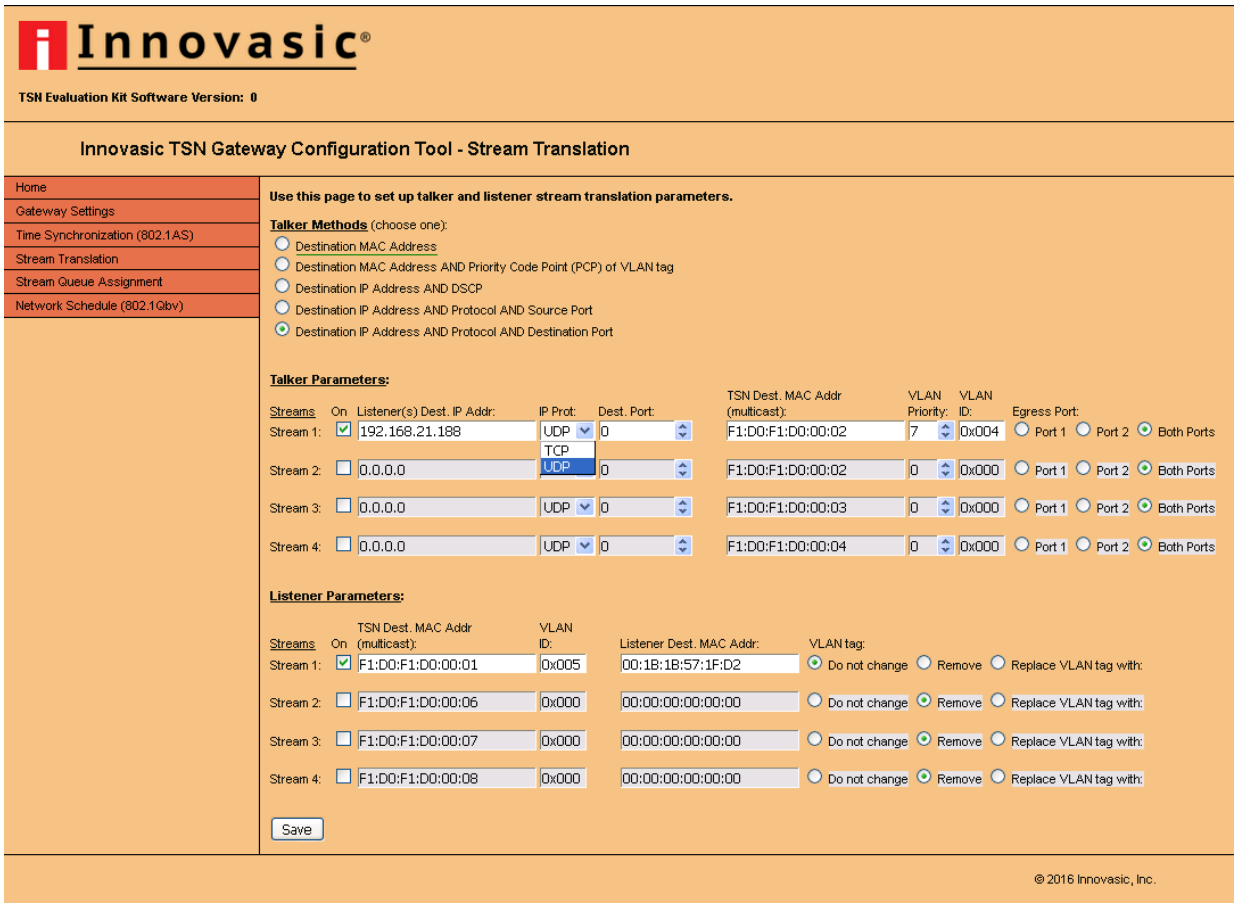


Figure 26 – Stream Translation Page using Destination IP address and Protocol and Destination Port

3.3.3 Using Listener Parameters

Listener Parameters are used to identify the Ethernet messages to be received from the TSN Network. These parameters are in the section below the "Listener Parameters" on the Stream Translation webpage. Notice that there are no "methods" by which to do this. You simply use the TSN multicast address and the VLAN ID of the stream you want to receive from the TSN Network. In the case of this example, we know the stream coming from the "Talker" we want to "Listen" to is 01:F1:D0:00:00:**02** (note that this is a different multicast address than we used for the Talker stream used in the section above). You will see this address in the "TSN Dest. MAC Addr. (multicast)" field under "Listener Parameters" in the figure in the previous section.

We also must supply the Destination MAC address of the Listener. Since the Listener is the Client in this case, it may seem redundant to enter the MAC address of the Client. However, it is possible to have a connection with in the Client that requires a multicast address so this field is provided for that situation. In the case of this example, we simply enter the MAC address of our Client which is 00:1B:1B:57:1F:D2.

The end result will be that any TSN stream with a Destination MAC of 01:F1:D0:00:00:02 and VLAN ID of 0x001 will "untranslated" into a stream with the Destination MAC address of 00:1B:1B:57:1F:D2 and sent to the Client

You can also select how you want to change the VLAN Tag in the "untranslated" stream headed to the Client. It is possible to not change the tag, remove it, or replace it with something else. The purpose of these options is to ensure the VLAN tag is properly handled in VLAN unaware devices or if a device has a specific VLAN tag requirement. In this case, we have chosen to not change the VLAN tag and pass it on as is.

3.4 Assigning Streams to Queues

Once you have defined the streams for the client to send to listeners in the TSN network, you assign these streams to queues so the streams can be scheduled at particular times on the network. Click on the "Stream Queue Assignment" tab on the left hand side of any webpage to navigate to this page. The queue assignment is made by selecting the VLAN Priority of the stream and "checking" the queue you want that VLAN Priority assigned to. This is shown on the webpage in the figure below.

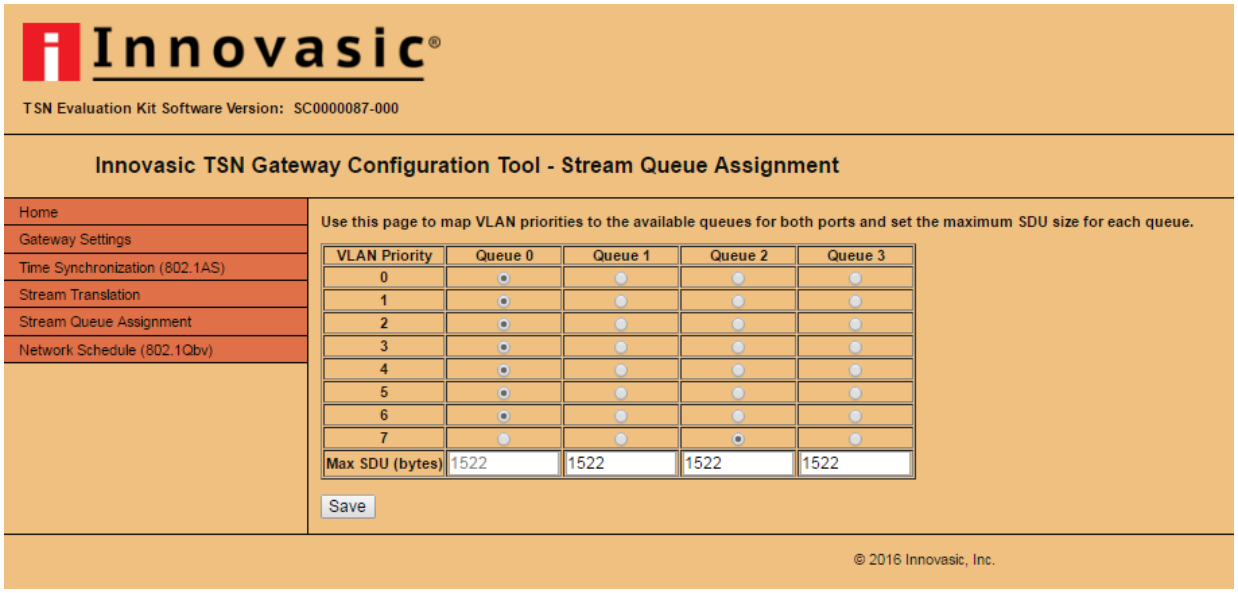


Figure 27 – Stream Queue Assignment for TSN Gateway #1

For this example, VLAN Priority 7 has been assigned to Queue 2 and all other VLAN Priorities are assigned to Queue 0.

Please note: Queue 0 is the "Best Effort" queue. This means that all traffic that does not have a VLAN tag and considered "Standard Ethernet" gets automatically mapped to Queue 0. So for this example, all traffic that is not VLAN Priority 7 gets queued together with the "Best Effort" traffic. This is also why any standard Ethernet device is compatible with a TSN network – traffic that cannot be mapped to a particular VLAN Priority is simply classified as "Best Effort" traffic.

The next step is to assign a schedule to the queues.

3.5 Assign Queues to a Schedule

Click on the "Network Schedule (802.1Qbv)" tab on the left hand side of any webpage to navigate to this page. The schedule is off by default. It must be enabled to activate the schedule. Make sure to "check" the box labelled "Scheduled Traffic Enabled" when you want the defined schedule active on the network. This is shown on the webpage in the figure below.

Setting the schedule is done by defining "windows" within a "Base Period". The default for the "Base Period" is 20ms. You can enter whatever Base Period you want and the resolution is in nanoseconds. For this example, we will set up four windows within the 20ms Base Period. The windows are defined as:

1. Window 1 (Entry 0) – 0 to 5ms
2. Window 2 (Entry 1) – 5ms to 10ms
3. Window 3 (Entry 2) – 10ms to 15ms
4. Window 4 (Entry 3) – 15ms to 20ms

The next step is to assign queues to these windows. This is done by "checking" the box under the queue you want assigned to that window.

Please note: Queue 3 must be enabled at least once during the Base Period. This is because the 802.1AS messages for synchronization are assigned to this queue automatically by the gateway software.

In the figure below you can see the queues have been assigned to the windows as follows:

1. Window 1 (Entry 0) – 0 to 5ms: Queue 0
2. Window 2 (Entry 1) – 5ms to 10ms: Queue 1
3. Window 3 (Entry 2) – 10ms to 15ms: Queue 2
4. Window 4 (Entry 3) – 15ms to 20ms: Queue 3

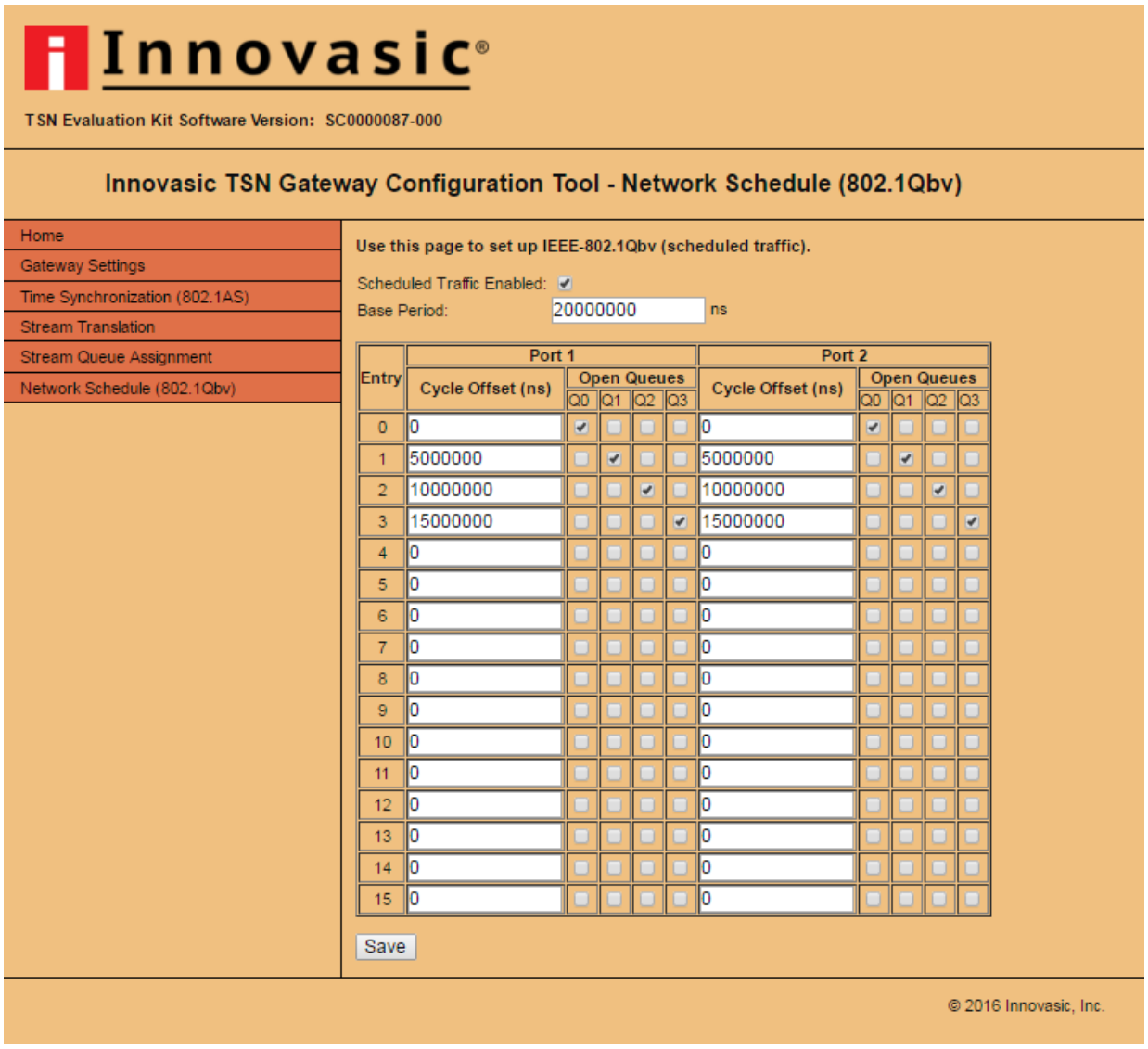


Figure 28 – Network Schedule for TSN Gateway #1

The assignment of these queues in this example is arbitrary. There may be specific reasons to setup faster cycle times and have multiple queues enable at the same time.

3.6 Setting up A Second TSN Gateway

Now that we have one TSN gateway configured we can configure a second one for the purpose of passing schedule traffic back and forth between two standard Ethernet devices. Using a second TSN gateway from another TSN Evaluation Kit, we make the connections as shown in Figure 10 to connect the PROFINET PLC to the TSN Network. The IP Camera is connected, but there is no additional setup since those streams will be handled as “Best-Effort” traffic.

The figures that follow show the configuration of the TSN gateway. Starting with the "Gateway Settings" page, the gateway has been configured with a different TSN Gateway MAC Address, TSN Gateway IP Address, and the Client MAC Address. Compare this webpage with the setting for the ET200S gateway in Figure 13.

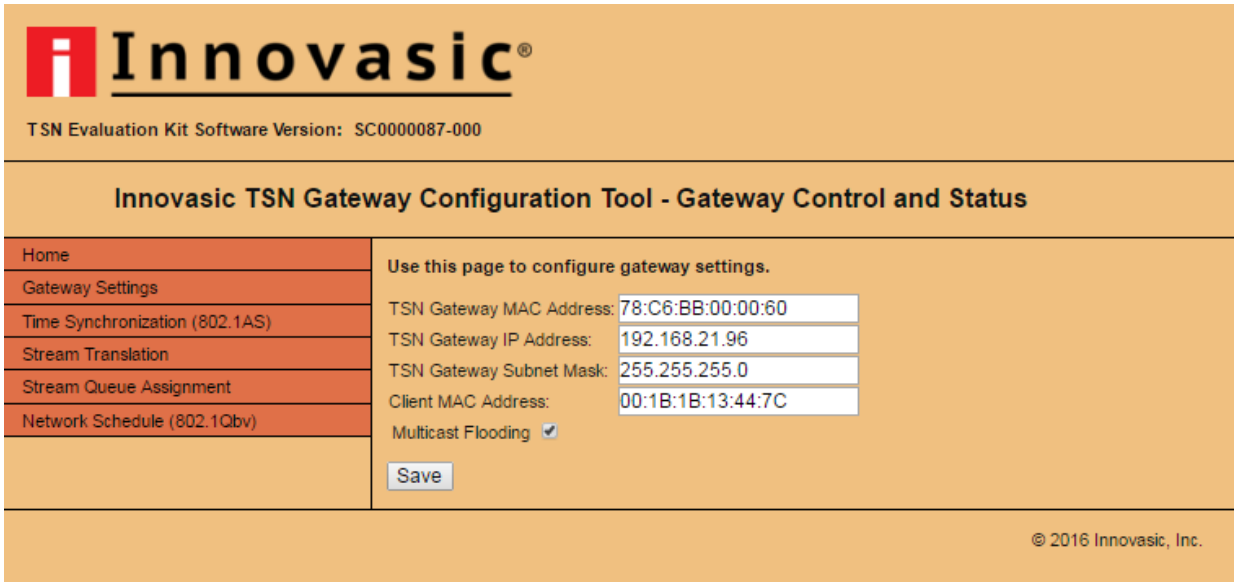


Figure 29 – Gateway Settings Page for TSN Gateway #2

The Time Synchronization status for TSN gateway #2 is shown in the figure below. Notice that this gateway is synchronized and that Port 1 is a Slave and Port 2 is a Master. Port 1 is also "Time Aware" whereas Port 2 is "Not Time Aware". This makes sense for our setup because port 1 of this gateway is acting as a slave to the other gateway and is synchronized with it. Compare this webpage with the setting for the ET200S gateway in Figure 14.

Please note: The LED on the Network Interface board on this second gateway is flashing yellow. This means that the gateway is a Slave. The LED on the other gateway is flashing red and this means that gateway is the Grandmaster.

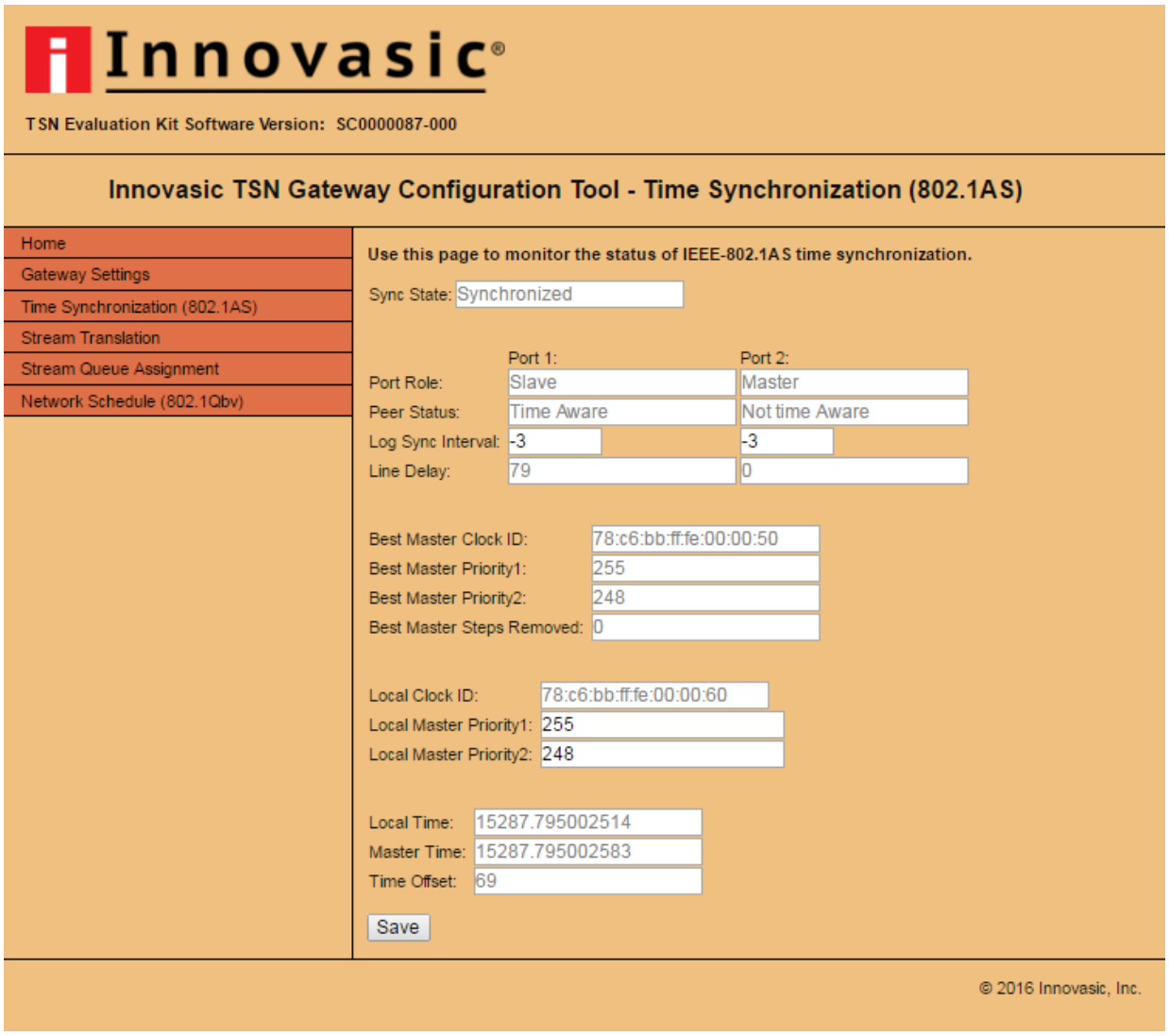


Figure 30 – Time Synchronization Status for TSN Gateway #2

The Stream Translation setting for TSN gateway #2 is shown below. Compare this webpage with the setting for the ET200S gateway in Figure 35. Notice that we use the same Talker Method as TSN gateway #1, but this is not a requirement. You can use whatever method is supported by the standard Ethernet device connected.

For the Talker Parameters we use the MAC address of the ET200S because this is the device that we want the PLC to talk to. We use the "TSN Dest. MAC Addr" setup on TSN gateway #1 in the Listener Parameters because this is the multicast stream we want the ET200S to listen to. For the Listener Parameters we use the "TSN Dest. MAC Addr" setup on TSN gateway #1 in the Talker Parameters because this is the multicast stream we want the PLC to listen to.

A summary of the Stream Translation mapping follows the webpage figure below.

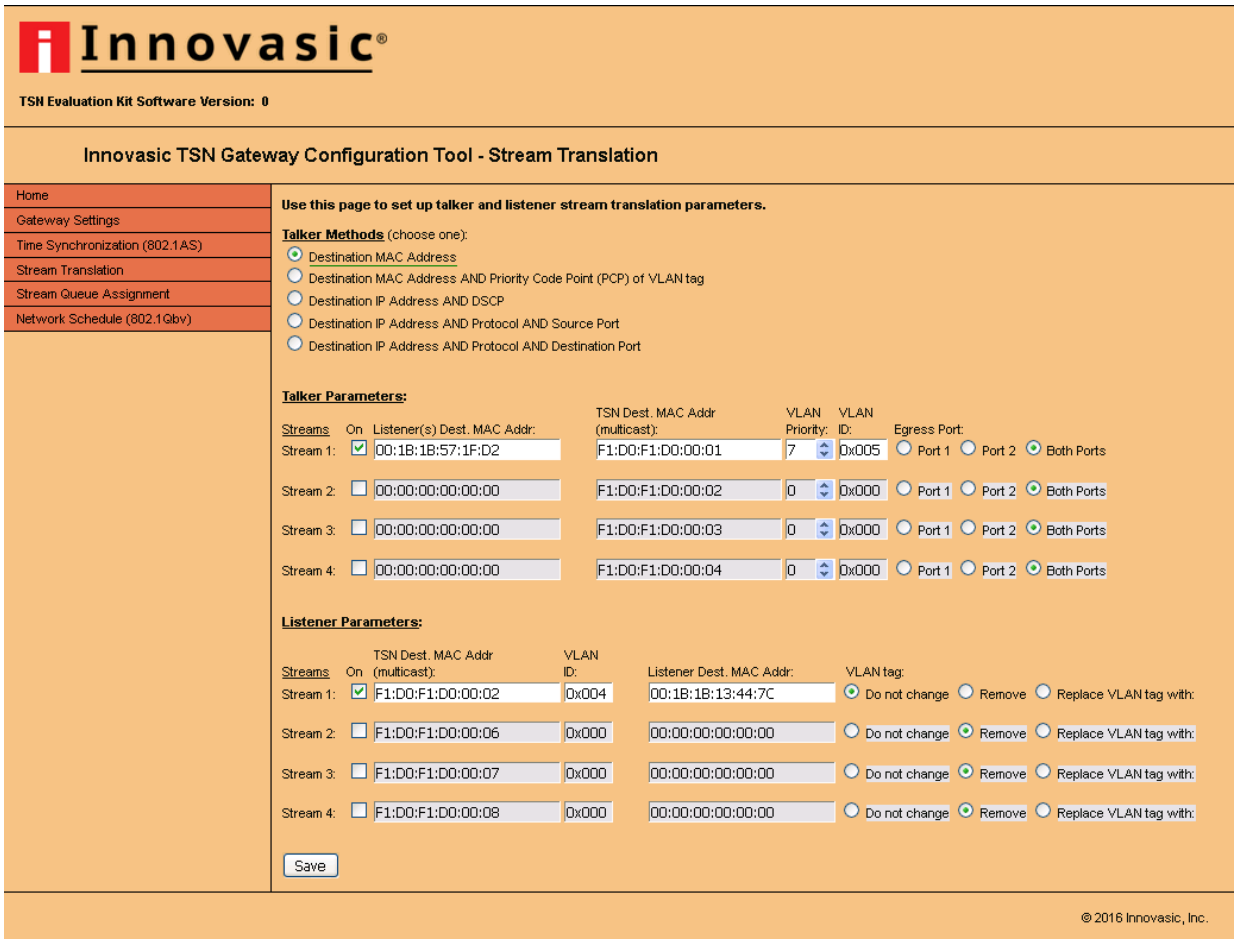


Figure 31 – Stream Translation Page for TSN Gateway #2

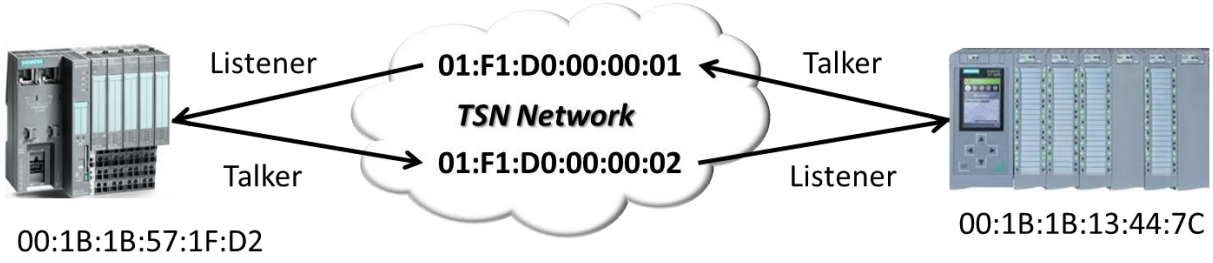


Figure 32 – Stream Translation Mapping

The Stream Queue Assignment for TSN gateway #2 is shown in the figure below. Here we mapped the VLAN Priority to Queue 2 just like we did for TSN gateway #1, and all the other priorities are mapped to Queue 0 along with the Best-Effort traffic. This assignment is arbitrary and we could have picked any other queue. Compare this webpage with the setting for the ET200S gateway in Figure 27

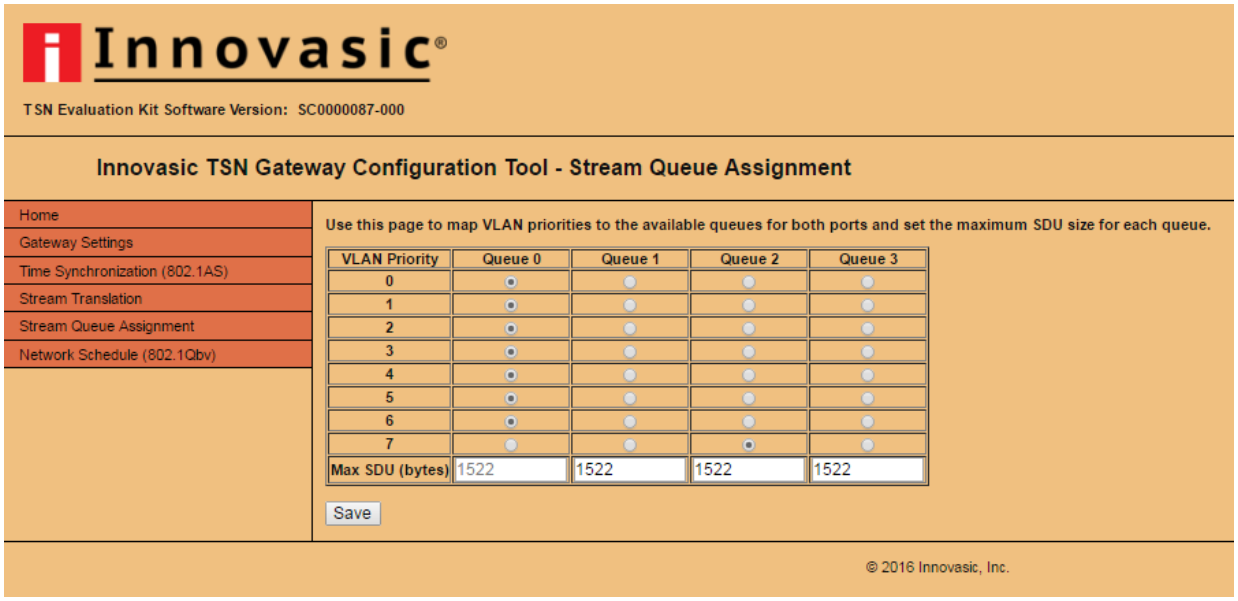


Figure 33 – Stream Queue Assignment for TSN Gateway #2

The Network Schedule for TSN gateway #2 is shown in the figure below. The Base Period and schedule windows are the same for TSN gateway #1. This is to ensure that frames can traverse the network without getting queued downstream. It was also done to emulate the cyclic nature of synchronized Industrial networks like PROFINET IRT. In reality you can setup whatever schedule you like to meet the update rate, latency, and jitter requirements for your network.

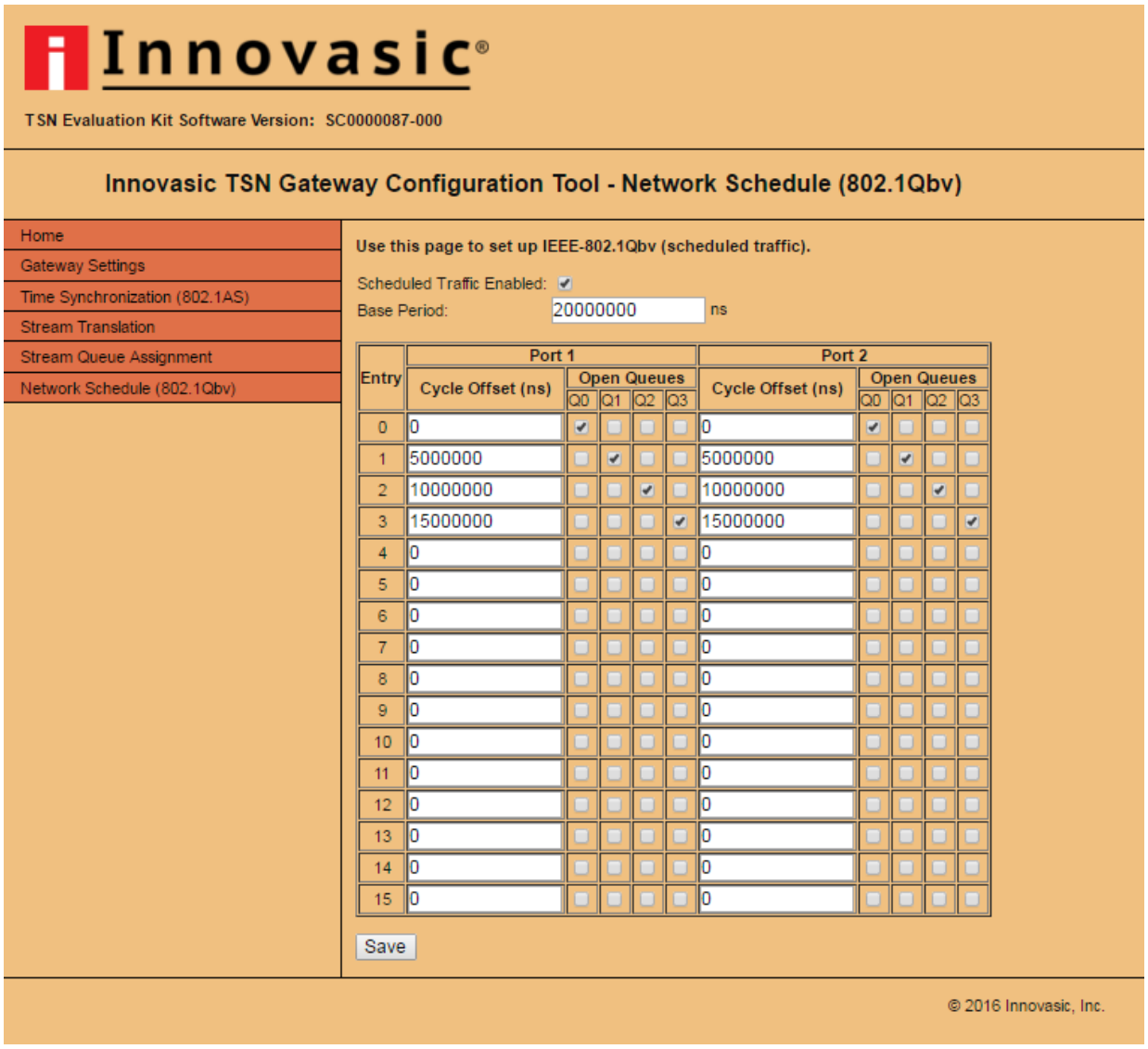


Figure 34 – Network Schedule for TSN Gateway #2

3.6.1 Using Talker Parameters

Talker Parameters are used to identify the Ethernet messages to be sent over the TSN Network. Select one of the methods described in the previous section and fill out the fields to match the criteria of the frames you want to perform stream translation on. In the case of this example, the Destination MAC method is used and the Destination MAC of the device the Client wants to ”Talk” to is entered in the field below the “Listener(s) Dest. MAC Addr.” heading. This allows the TSN gateway to identify streams with the supplied Destination MAC.

Next, enter a “TSN Dest. MAC Addr.” into the field below this heading. This can be any multicast address and Innovasic has chosen to use 01:F1:D0:00:00:**01** for this example (“**01**” is

bolded to distinguish it from the address we will use for the Listener stream later on). The VLAN Priority and VLAN ID fields also need to be filled out.

Please Note: The usable range for VLAN ID is 0x003 through 0xFFE. This is because IEEE8-2.1 Q-2011 lists 0x000 through 0x002 and 0xFFF as reserved.

In this example, we have chosen a VLAN Priority of 7 and a VLAN ID of 0x004. The end result will be that any stream with a Destination MAC of 00:1B:1B:13:44:7C will be translated into a stream with the Destination MAC address of 01:F1:D0:00:00:01 and a VLAN ID of 0x004 with at VLAN Priority of 7.

You can also select which port to send out the translated stream onto the TSN network. Which port you choose depends on your topology, but it doesn't hurt anything to send it out both ports if you are unsure. In this case, we have chosen to send the translated stream out both ports.

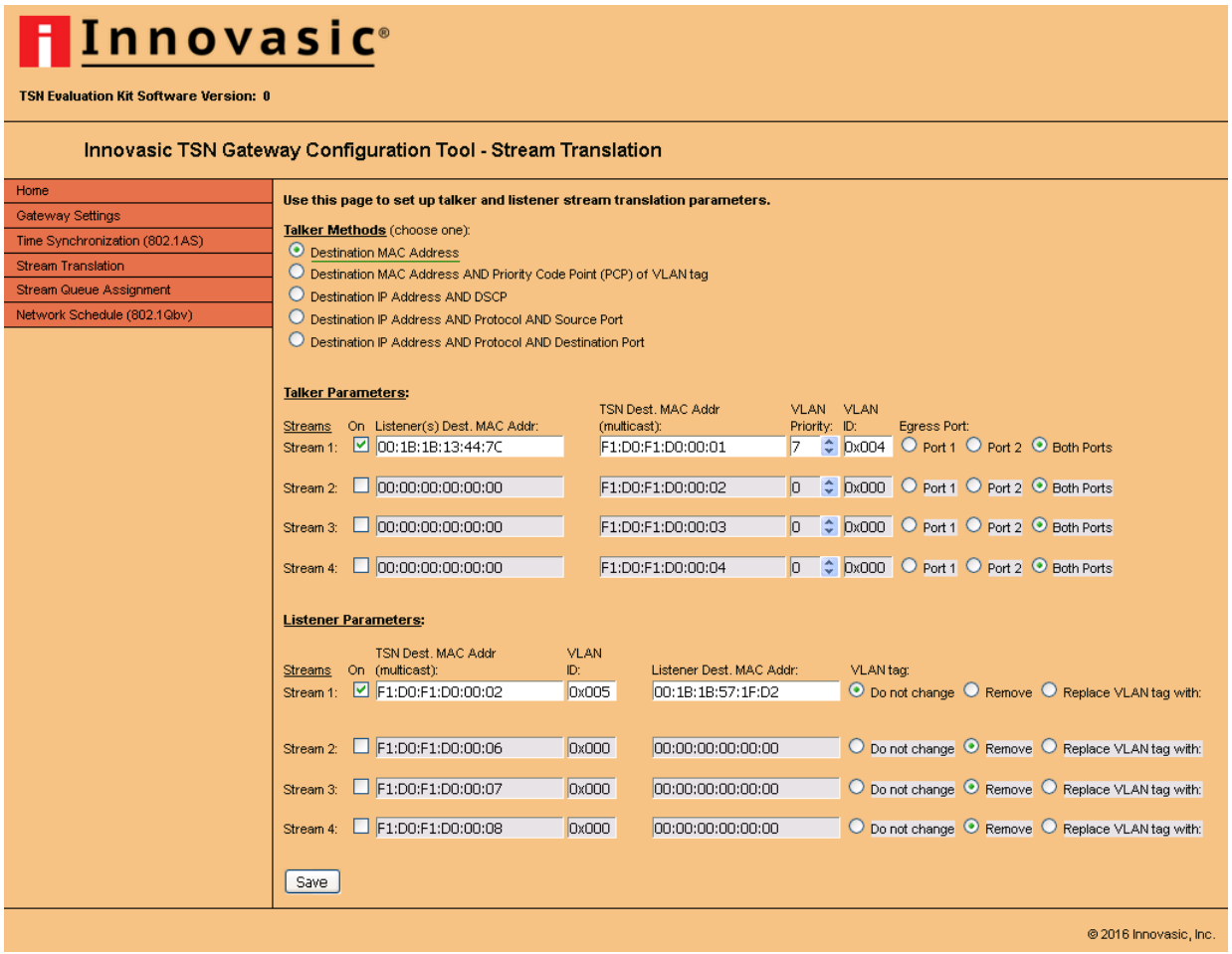


Figure 35 – Stream Translation Page for TSN Gateway #1

3.7 Verifying Scheduled Traffic

Once you have implemented the Network Schedule, you can verify the schedule has been implemented using features in Wireshark. First have a Wireshark capture running with a tap in between the devices. Stop the Wireshark capture by clicking on the red square as shown below:

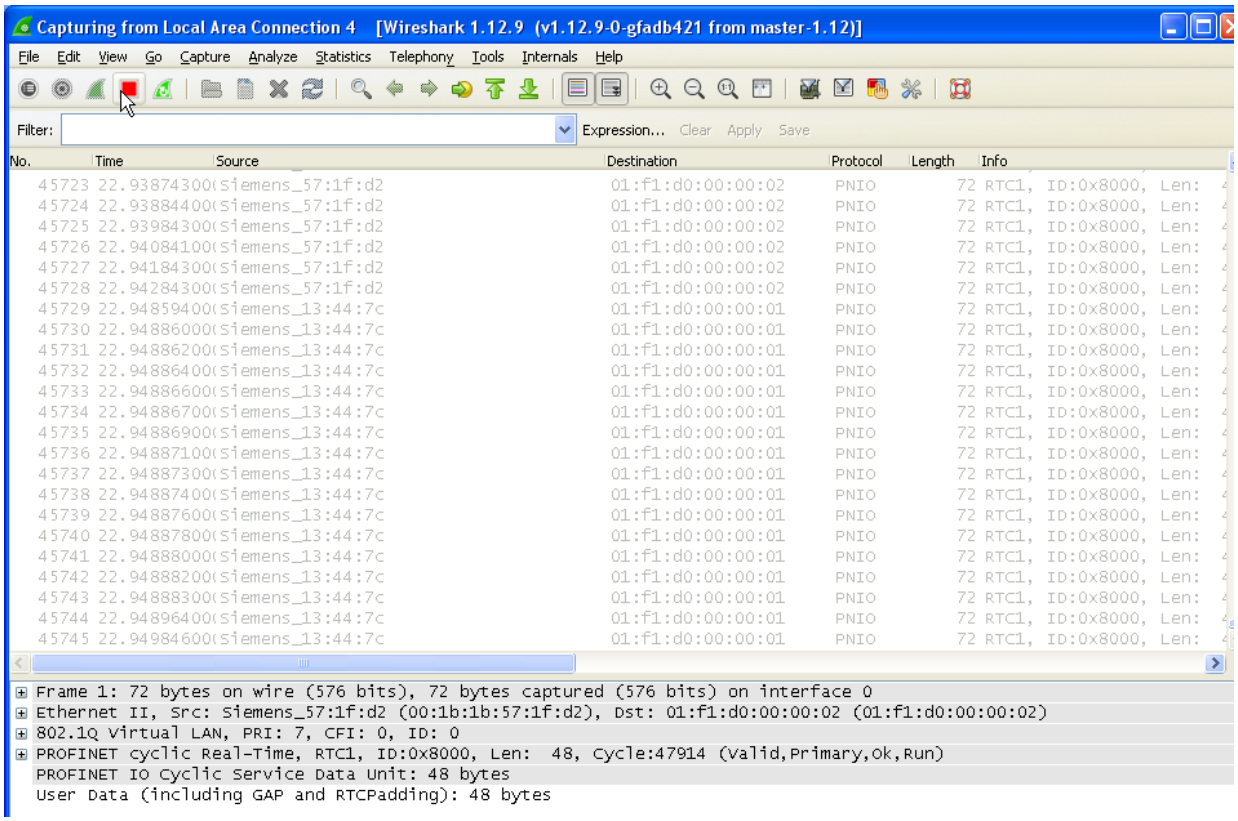


Figure 36 – Wireshark Capture

Navigate to “Statistics/I/O Graph”.

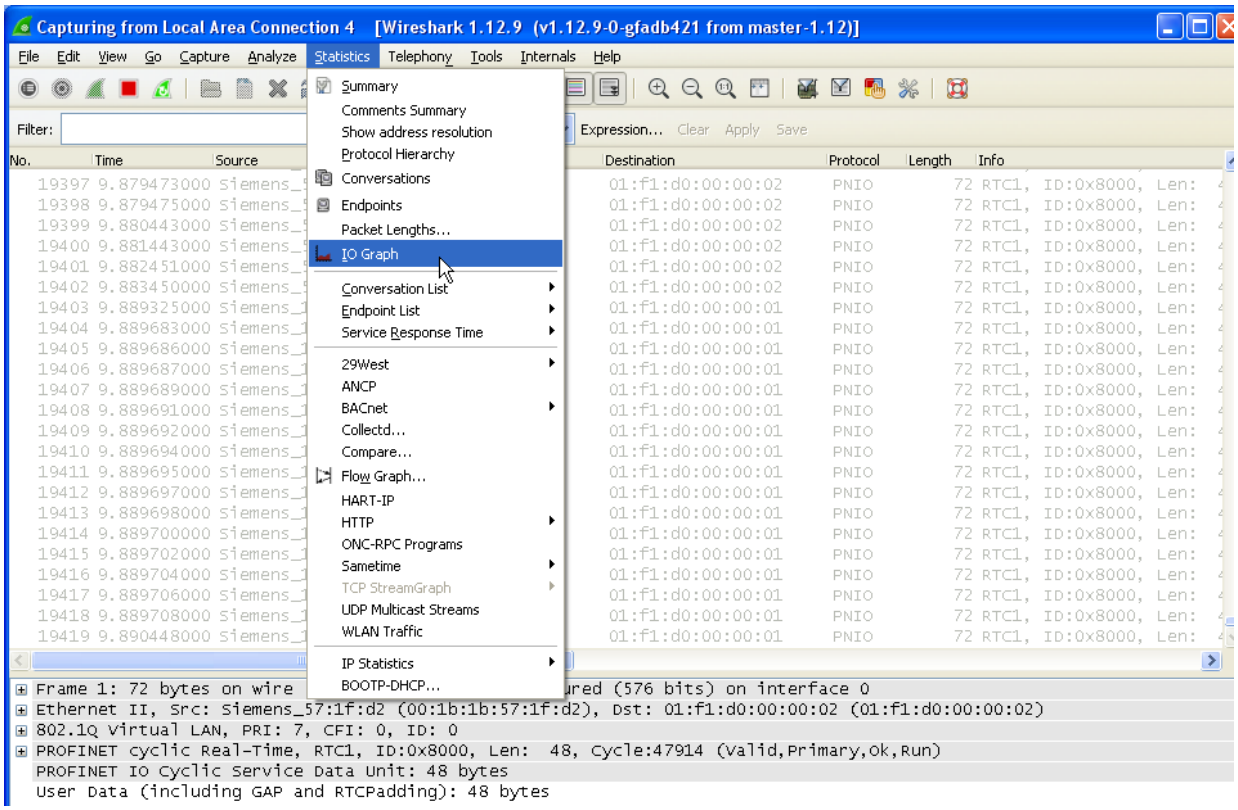


Figure 37 – I/O Graph Selection

Enter the destination MAC address as a filter for each of the I/O Graphs. For this example the MAC addresses used were the Multicast Addresses for the listener/talker streams. Change the

style to FBar and the Tick Interval to 0.001sec. This will then show something like the screen in the figure below.

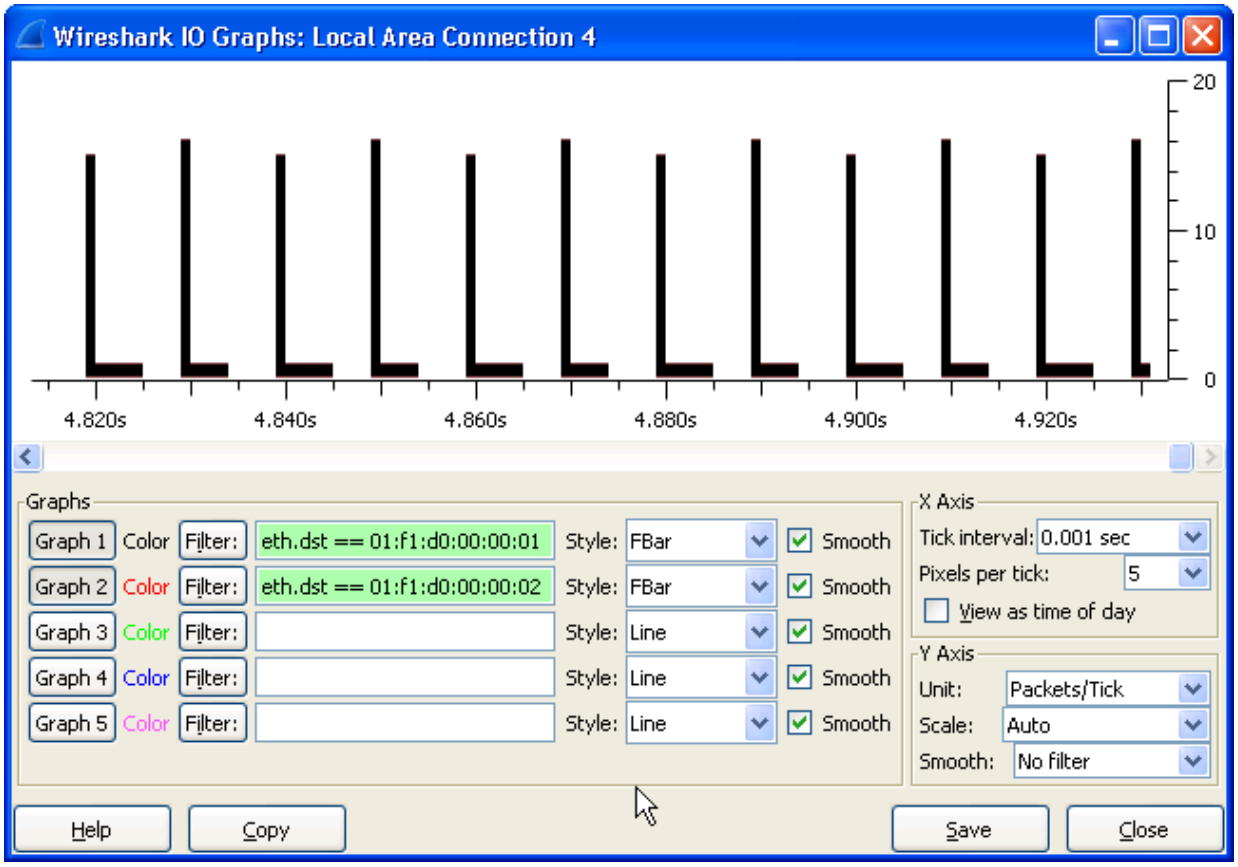


Figure 38 – Wireshark Graph of the example schedule

Because we have the same schedule for both of the streams and these streams were placed in the same queue, both colors depicting the streams may not be displayed. This is the case in the figure above. One way to see both streams is to place them into different schedule windows.

This is shown in the figure below. The stream for the TSN gateway #2 was changed from what was originally implemented in Figure 34 to the schedule below.

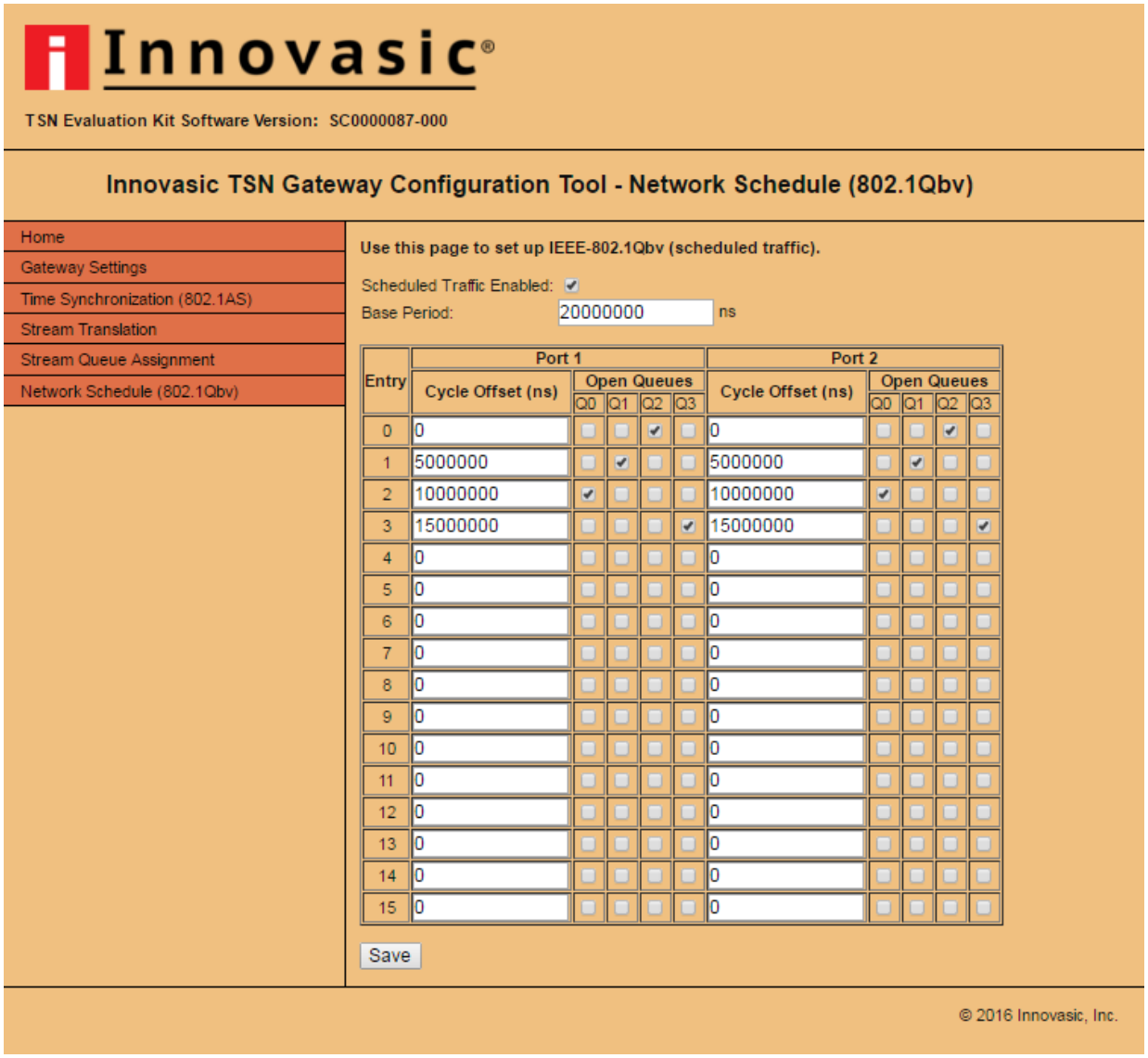


Figure 39 – Modified Schedule for TSN Gateway #2

After modifying the schedule according to the figure above, the traffic has moved to the different schedule windows. This can be seen in the figure below for 01:F1:D0:00:00:01 (shown in black)

and 01:F1:D0:00:00:02 (shown in red). Using Figure 28 and Figure 39 you can verify the traffic shown in black is separated from the traffic in red by 10ms.

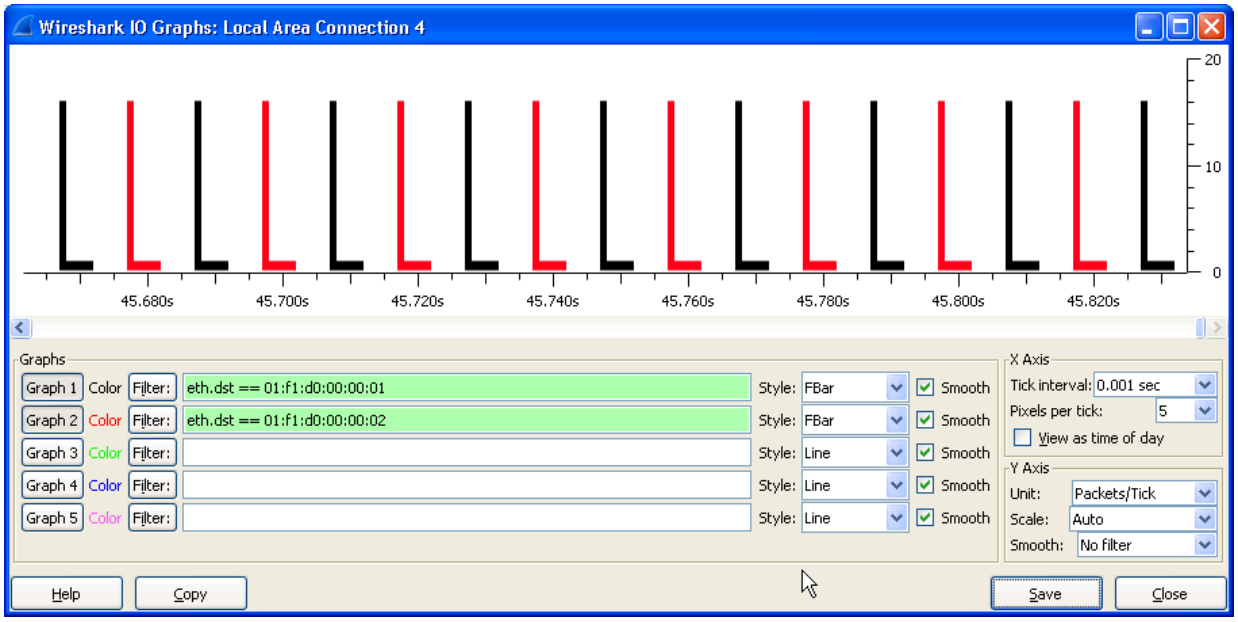


Figure 40 – Wireshark Graph of the modified schedule

3.8 Using the TSN gateway in any TSN Network

This concludes the example for setting up the TSN gateway. With the settings available in the webserver on the TSN gateway, it is possible to configure the gateway of any TSN network requirements where that network is utilizing 802.1AS and 802.1Qbv.

As new TSN features are added or there are updates to existing TSN features, check with Innovasic to get the new software. Details for updating the software for the TSN gateway to enable these new features or updates are provided in Appendix A.

4. Revision History

The table below provides the sequence of revisions to document IA221160923.

Date	Revision	Description	Page(s)
October 17, 2016	00	Initial Release	NA
November 16, 2016	01	Added LED behavior, updated screenshot, added a field for AS description, added a note about only configuring one gateway at a time.	11, 14-15, 46-47
November 22, 2016	02	Added a warning about changing the TSN Gateway's MAC address to Multicast.	13

5. Appendix A – Updating the TSN Gateway Software

The TSN Gateway Kit comes loaded with the latest TSN Gateway application software and firmware at the time of shipment. It is advised that the user update the TSN Gateway application software and firmware as necessary. The latest release of the TSN Gateway application software and firmware can be found at Innovasic's Developer Portal.

To get the most recent software, refer to the picture below and perform the following steps:

1. Log In to the Developer Portal
2. Click on the Network Interface tab on the left-hand side
3. Click on the “Software for Network Interface” sub option
4. Click on the Download button below “TSN Gateway REM Switch Network Interface Software”
5. Agree to the Terms and Conditions

Developer Portal

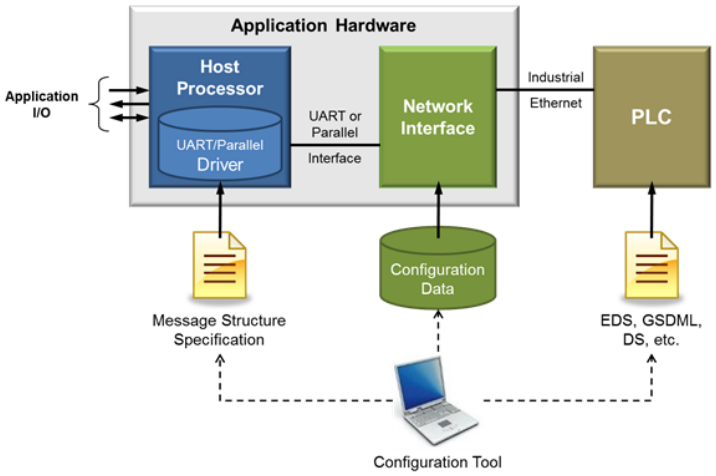
Logout / Return to Portal

- Developer Portal Overview
- Network Interface
- Network Interface with REMS
  - Embedded Design for Network Interface with REMS
  - Software for Network Interface with REMS
  - Documentation for Network Interface with REMS
  - Tools for Network Interface with REMS
- Network Interface with DLR
- PROFIBUS Network Interface
- fido5000 REM Switch
- fido2100 DLR Switch
- Developer Solution
- Request a Schematic Review
- Certification Support
- Ask An Engineer
- Update My Profile
- White Paper Downloads
- Information Series

Software for Network Interface with REMS

Software for the Network Interface with REM Switch module is provided by Innovasic and resides on the flash chip. Whether you are using the Network Interface with REM Switch as a module or an embedded design, there are no license fees or royalties. Software integration with a host processor is also easy. Messages passed between the host processor and Network Interface follow a standardized definition when using either the UART or 16-bit parallel interface. This interface simplifies transmission of cyclic data, acyclic data and alarm data. Example C-code is provided to minimize integration effort on the host processor.

An overview of the host software development process is shown below. Please refer to Network Interface Design Integration Guide which is provided with the evaluation kit and in the Network Interface with REM Switch Tools section of this portal for assistance with the software files you download from this page.



The current version of the software package for the *Network Interface with REM Swtich* is available to download from the Download column on this page.

EtherNet/IP REM Switch Network Interface Software	Download
Profinet IRT REM Switch Network Interface Software	Download
Modbus/TCP REM Switch Network Interface Software	Download
EtherCAT REM Switch Network Interface Software	Download
TSN Gateway REM Switch Network Interface Software	Download

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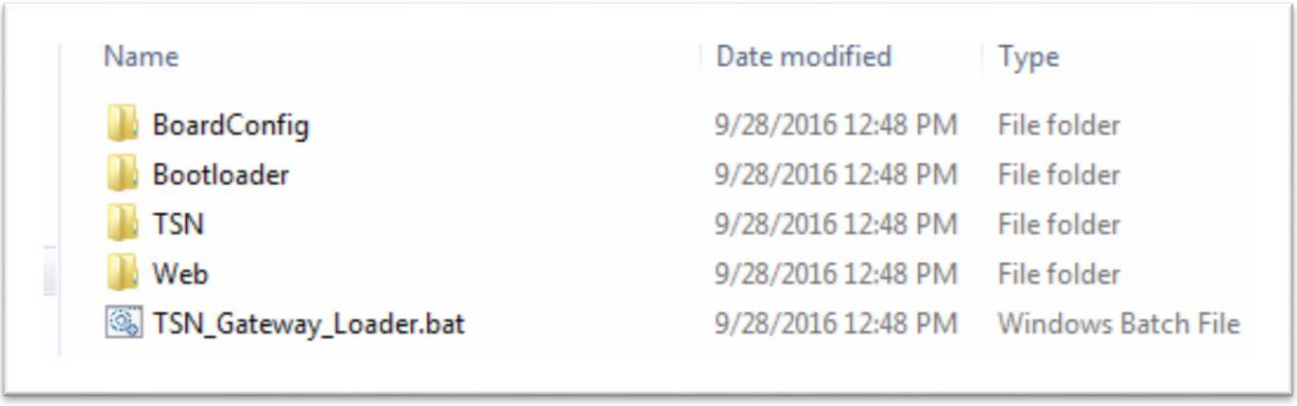
5635 Jefferson Street NE, Suite A, Albuquerque, New Mexico 87109 USA
+1.505.883.5263 or 1.888.824.4184 (US Toll Free) or support@innovasic.com

Once you have downloaded the TSN Gateway software, the directory structure should appear as shown.

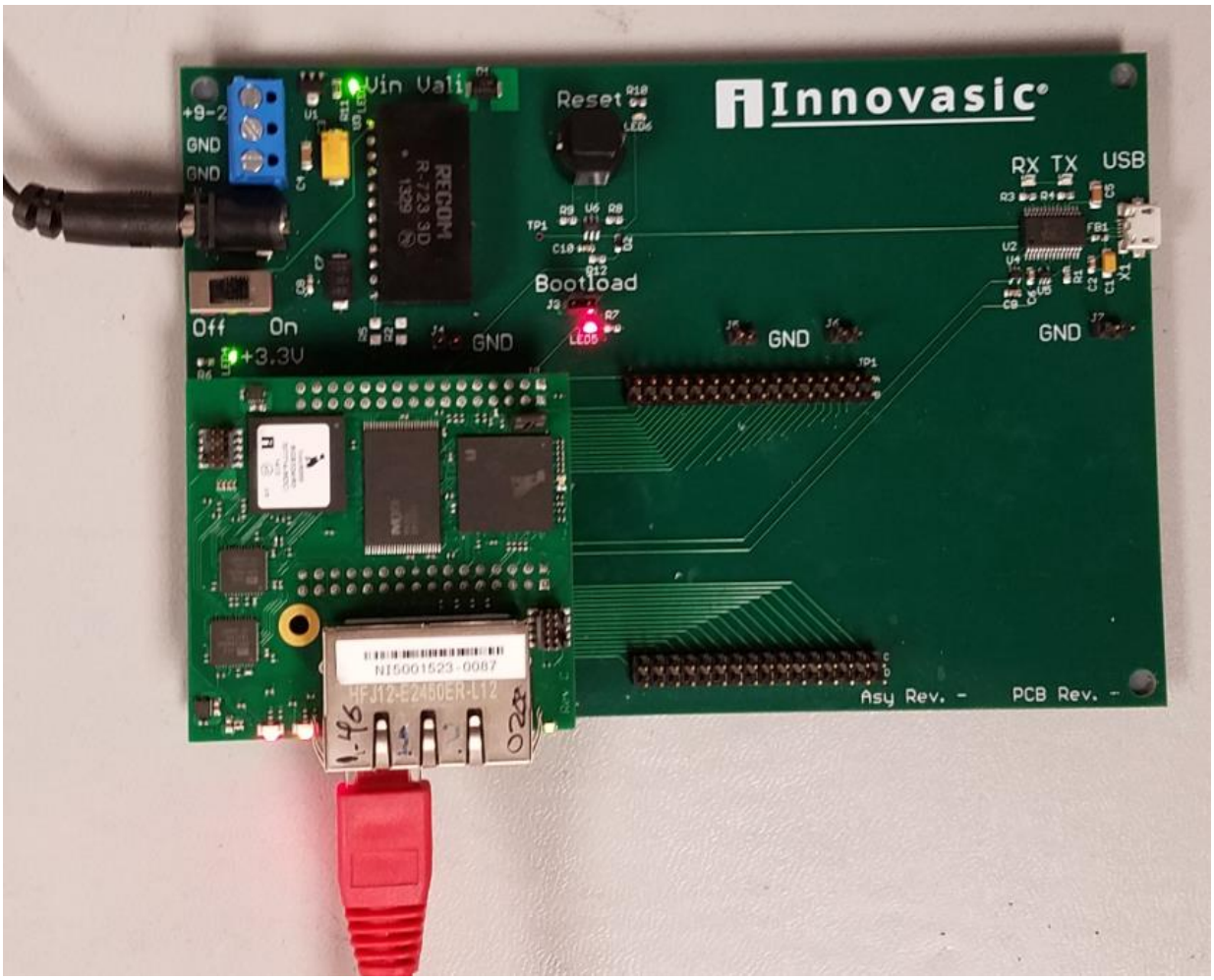


The files that need to be loaded with the Ethernet bootloader and their locations in the zip file are shown in the following table:

Table 2 – Load File Names

File	Location
TSN_Gateway.load	TSN
sfs_data.load	Web
sfs_bat.load	Web

The Ethernet Bootloader is used to program a module with a given .load file. The following instructions show an example of how to update the software using the Ethernet Bootloader.



- First install a jumper on the bootloader header of Innovasic's baseboard.
- Verify that a TFTP server is running on your PC (A sample TFTP server is provided in the "Tools and Docs" download from Innovasic's website).
    - Make a note of the IP address being used by the TFTP server, in this example it will use 192.168.21.100.
- Then create a static arp table entry using a command prompt.
    - The arguments for the arp table entry are the MAC address of the module and the IP address you wish to assign the module.
    - All of Innovasic's modules are preloaded with a default MAC address of 12-34-56-78-9A-BC.
    - The IP address for this example will be 192.168.21.105

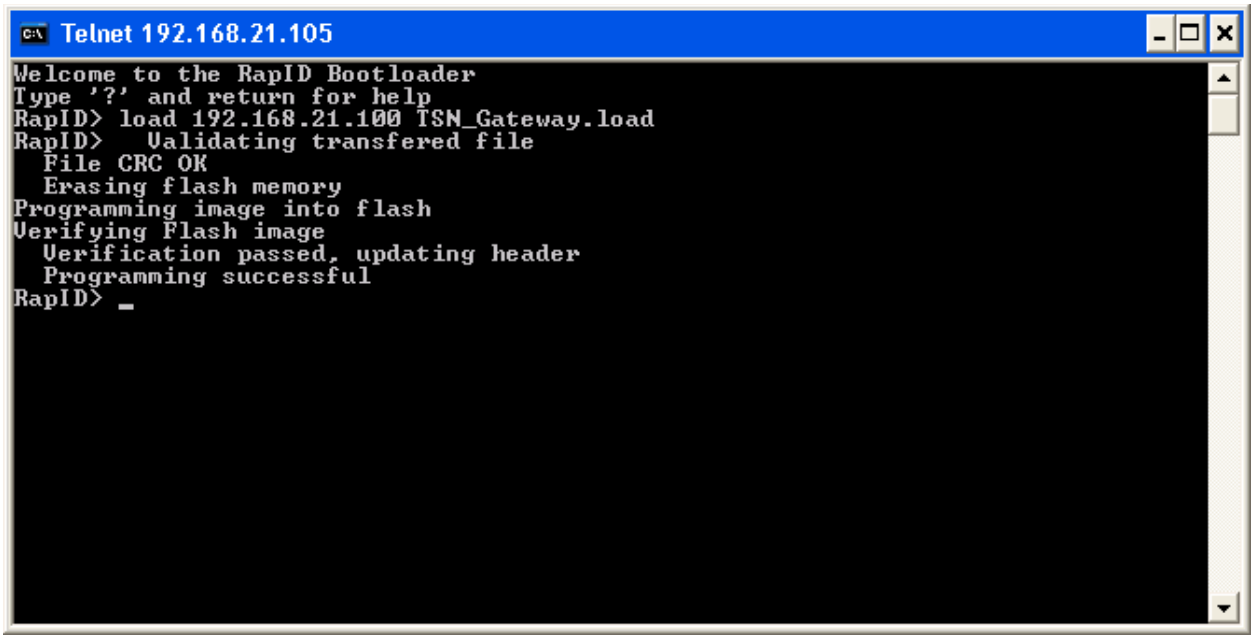
  - From a command line enter the command arp –s 192.168.21.105 12-34-56-78-9A-BC and press enter (Note the IP Address is arbitrary and the only constraint is that it needs to be on the same subnet as the NIC you are using on your PC).
  - Enter the command arp –a and verify the MAC and IP address are present in your arp table.

- Ping the module by typing ping 192.168.21.105
  - The first ping will time out followed by 3 successful pings.
- Establish a telnet session with the module.
  - Type “telnet 192.168.21.105”

You have now accessed the Ethernet bootloader. Load each of the software components by means of the load command

  - Type “load 192.168.21.100 TSN_Gateway.load
  - Type “load 192.168.21.100 sfs_data.load
  - Type “load 192.168.21.100 sfs_bat.load

The bootloader will display the following success message after successfully loading any of the .load files.



Your module has now been updated with the most recent version of the TSN Gateway software.

6. Appendix B – Behavior of the RapID Platform LEDs for the TSN Gateway

The TSN Gateway has LED behavior that is specified according to the following image and tables.

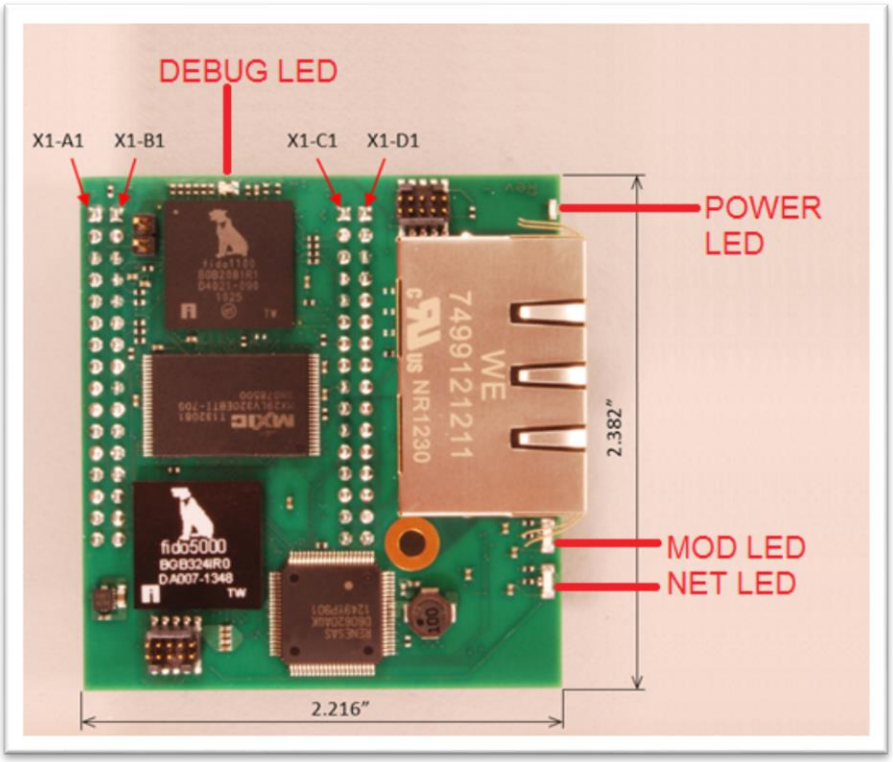


Table 3 – Behavior of LEDs

MOD LED	System Status
Off	Not Participating in a gPTP network
Steady Red	Participating in a gPTP network as a grandmaster
Steady Green	Participating in a gPTP network not as a grandmaster
Flashing Green	Standby (waiting to enter Run Mode. Only seen at power-up or reset)

NET LED	System Status
Off	No Stream Translations have been Configured and scheduled traffic is not enabled
Steady Red	At least one Stream Translation has been configured
Steady Green	Scheduled Traffic has been enabled
Steady Yellow	At least one Stream Translation has been configured and Scheduled Traffic has been enabled

Debug LED	System Status
Off	The system is not in run mode
Flashing Red	The system has entered run mode

7. For Additional Information

The Innovasic Support Team is continually planning and creating tools for your use. Visit http://www.innovasic.com for up-to-date documentation and software. Our goal is to provide timely, complete, accurate, useful, and easy-to-understand information. Please feel free to contact our experts at Innovasic at any time with suggestions, comments, or questions.

Innovasic Support Team
5635 Jefferson St. NE, Suite A
Albuquerque, NM 87109 USA

(505) 883-5263
Fax: (505) 883-5477
Toll Free: (888) 824-4184
E-mail: support@innovasic.com
Website: http://www.Innovasic.com

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