

APPLICATION NOTE

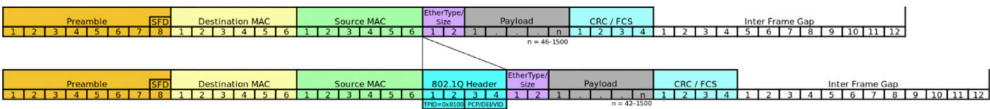
iMX350 RAPTOR® and GOOSE/Multicast Control in Substations

BACKGROUND

61850 based substations use GOOSE and Sampled Value (SV) communications to monitor and control substation devices such as Protective Relays, Merging Units, Phasor Measurement Units and other IEDs. GOOSE/SV messages are based on Layer 2 multicast Ethernet frames and have no Layer 3 component. However, unlike devices and switches in factory automation and other infrastructure applications, IGMP snooping or the use of multicast groups (static/dynamic) has no effect on these Layer 2 multicasts, so IGMP cannot be used for multicast control. Since protective relays generate multicast-based GOOSE messages but cannot respond to switch/router operations controlling multicast groups, VLANs must be used to control the traffic.

Quality of Service parameters can be applied to ensure that the GOOSE/SV messages are handled before all other traffic during conditions of high bandwidth utilization (traffic rates exceeding 70% of the bandwidth available on an Ethernet interface). IEEE 802.1Q VLAN tags also contain priority identifiers, referred to as IEEE 802.1p Priority tags or Class of Service (COS) identifiers. The priority tags support 8 levels/IDs. 0 to 3 are for normal priority levels, 4 to 7 are for high priority levels. The priority can be assigned when the VLAN is created and is attached to all Ethernet frames that are VLAN tagged. If the VLAN is assigned to a port, the administrator also assigns a default priority to that VLAN, ensuring that all frames assigned to that VLAN have the same priority as they move through the network. Below (figure 1.0) is an example of an Ethernet frame with the VLAN/ priority tag and the VLAN Tag format.

Figure 1.0



802.1Q tag format			
16 bits	3 bits	1 bit	12 bits
TPID	TCI		
	PCP	DEI	VID

Tag protocol identifier (TPID)

A 16-bit field set to a value of 0x8100 to identify the frame as an IEEE 802.1Q-tagged frame. This field is located between the Source MAC Address and EtherType fields and is used to distinguish which Ethernet frames have VLAN tags assigned.

Tag control information (TCI)

A 16-bit field containing the following sub-fields:

Drop eligible indicator (DEI)

Identifies the frame as eligible to be dropped under times of extremely high bandwidth utilization.

Priority code point (PCP)

A 3-bit field which references the IEEE 802.1p class of service (CoS) configured by the user and maps to the frame priority level. The PCP code number are from 0 (the lowest) to 7 (the highest) priority.

VLAN identifier (VID)

A 12-bit field identifying the VLAN ID to which the frame is assigned. The hexadecimal values of 0x000 and 0xFFFF (decimal 0 and 4094) are reserved. VLAD ID 1 to 4093 should be used. The reserved value 0x000 indicates that the frame does not carry a VLAN ID and is referred to as a **Priority tag**.

802.1Q/p VLANs and associated priorities are recommended for use with IEC 61850 operations in substation networks.

Switch Function Guidelines- VLANs and priorities

Substation Relays have the following properties:

- GOOSE/SV messages are controlled using switch VLAN functions. The network design of managing these GOOSE based VLANs or “GOOSE VLANs” considers the following:
 - o Single Relays can produce multiple GOOSE messaging groups, which in turn talk to other relays.

- o Each GOOSE group should have its own separate VLAN. Multiple possible VLANs from each relay require that VLAN trunking be enabled at each switch port where a GOOSE relay is attached.
- o A priority level is assigned to the created VLAN ID on the protective relay or IED. The switch will use this to maintain proper QOS for all Ethernet frames assigned to the VLAN.
- o Layer 2 Multicast frames are treated as broadcasts by Ethernet switches. Since relays can produce multiple GOOSE groups, multiple VLANs may be used per device connected to the switch (edge switch). The VLANs serve the purpose of containing the Multicast messages (as they act like broadcast packets) so they do not impact other devices on other VLANs.
- **Switch configuration guidelines:**
 - o For each connected Relay/GOOSE device, enable that port to be a VLAN Trunk.
 - o Higher-level monitoring/SCADA communications need to have VLAN planning as well. Remember that any non VLAN (untagged) communications from devices are automatically placed in the Ethernet switch ports “Native”/Default VLAN (known as the PVID).
 - o If these SCADA devices communicate remotely (outside of the substation) make sure they are routed correctly (using the switches/routers Layer 3 routing functions).
 - o If these SCADA devices communicate locally (within the substation), ensure the Native VLAN (PVID) is used for them also.

Figure 2.0 - Example of VLAN/GOOSE group use in Substation

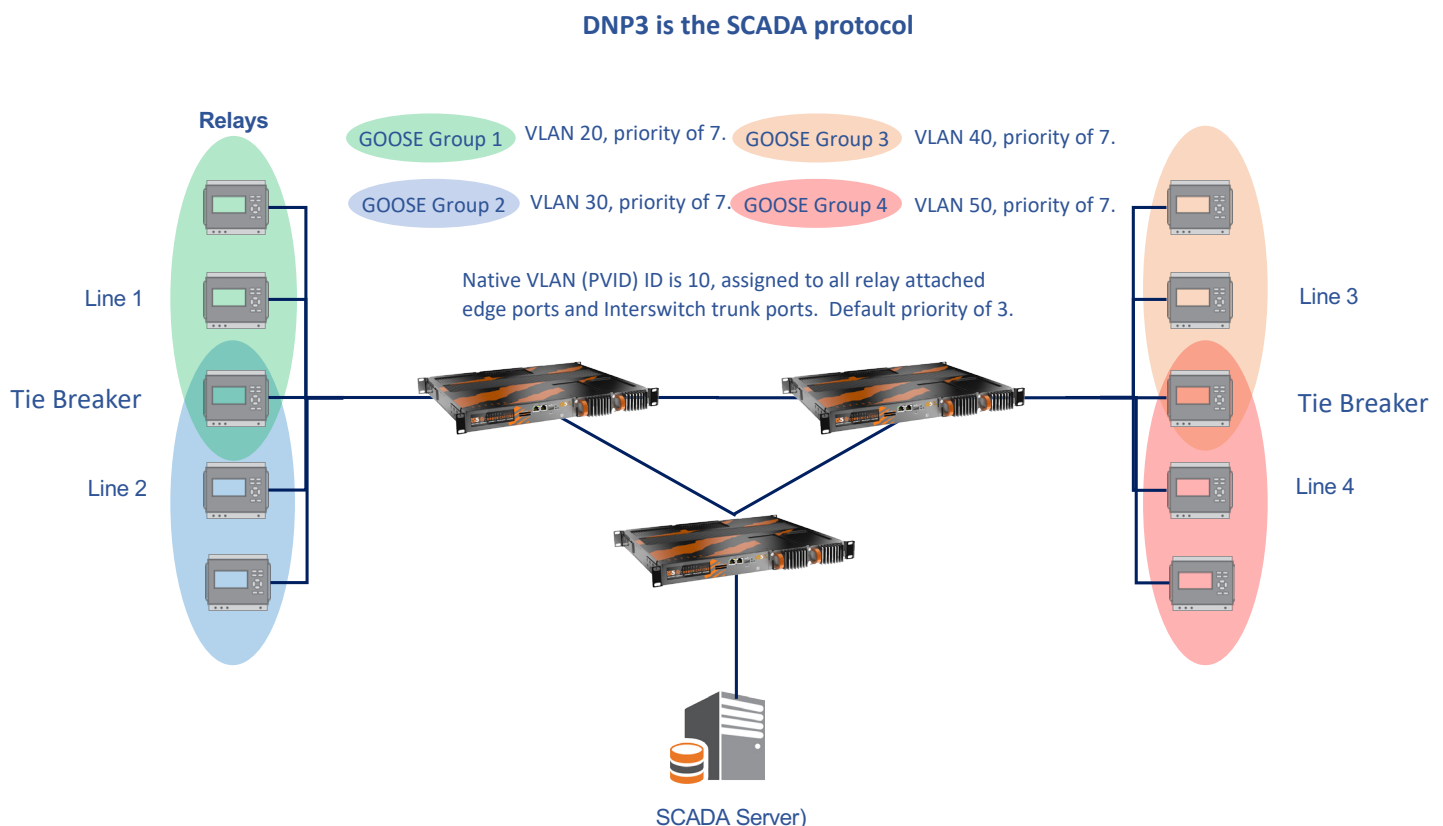
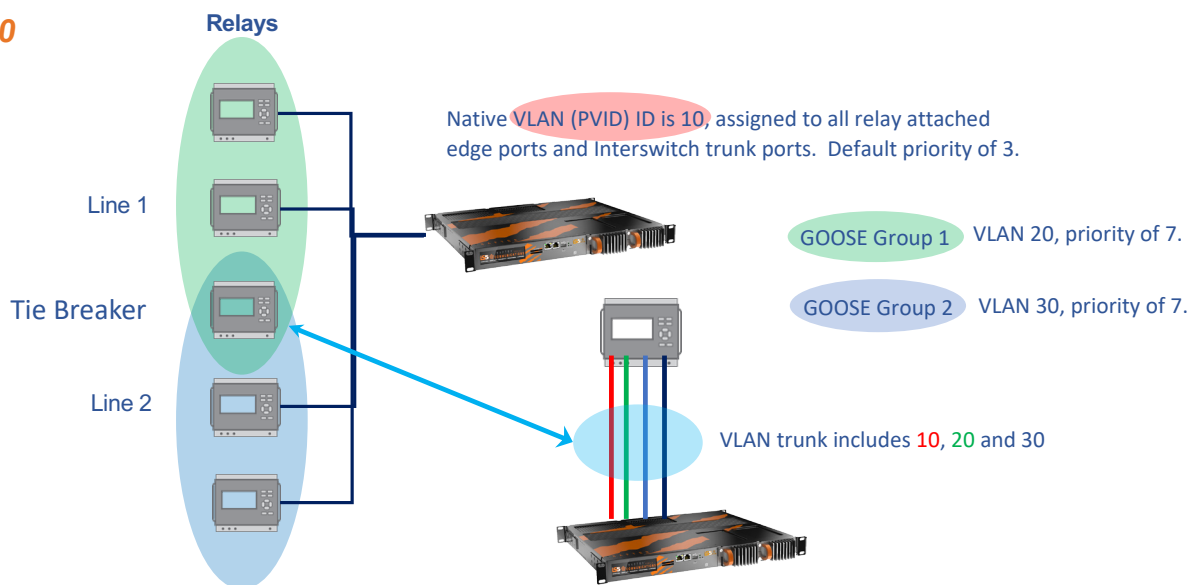


Figure 3.0



You can also create a MAC Address filter that focuses on the destination MAC Address for the created GOOSE group. There is an official MAC Address range defined within the IEC 61850 communications standard. The table below shows the defined GOOSE/SV MAC Address ranges.

IEC 61850 GOOSE Multicast MAC Address Range	01-0C-CD-01-00-00 to 01-0C-CD-01-1-FF (512 addresses)
IAC 61850 Sampled Values Multicast MAC Address Range	01-0C-CD-04-00-00 to 01-0C-CD-04-1-FF (512 addresses)

A default QOS level can be defined and assigned to an interface providing a higher level of importance to the destination GOOSE MAC Address. The priority can be set to ingress (inbound) or egress (outbound) from any physical Ethernet port the GOOSE group participating relay is attached to. A configuration example based upon the example network shown below follows at the end of this document.

If the user desires to focus the QOS features more finely on a set of MAC Addresses, they can use a Layer 2 filter within the ACL feature. Below is an example.

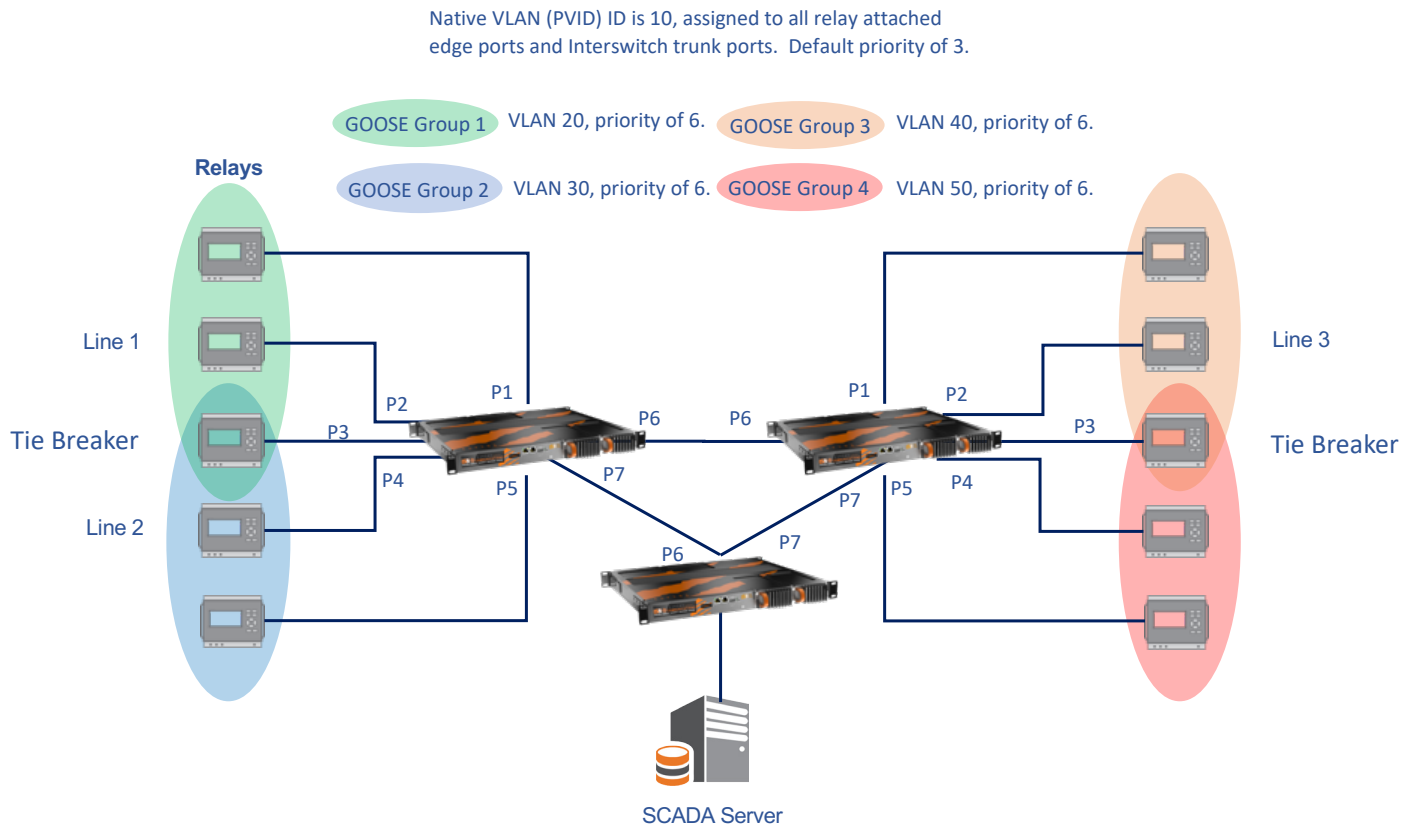
Use of Layer 2 Classifier/Filter with the GOOSE defined destination Multicast MAC Address.

A supplemental way to provide QOS service based upon a specific MAC Address (Source or Destination) is provided by using a classifier. This is a special type of Access Control List (ACL) and can be Layer 2 (MAC Address) or Layer 3 (IP Address) based. Because GOOSE and Sampled Values use an L2 Multicast MAC Address for the destination and there is currently no L3 addressing within the Ethernet frame, the creation of an L2 classifier/filter based on the multicast destination MAC Address is possible. A classifier is created to identify any data that is to be handled in a specific way by the Ethernet switch. In this case, we are ensuring that these designated multicast groups are assigned a higher level of importance or Quality of Service.

Below is an example of a small substation and the associated L2 filter configuration:

Figure 4.0

DNP3 is the SCADA protocol



This example is for an L2 classifier for GOOSE Group 1 with destination multicast MAC Address of 01:0c:cd:01:00:01. It assigns the classifier to VLAN 20 (GOOSE Group 1) and assigns the highest QOS level (8). GOOSE Group 1 includes relays connected to port 1-3 on Switch #1.

Configuring L2 Classifier

To configure a Layer 2 Filter:

Enable Port 1 (Switch #1)

```
iS5comm# configure terminal
iS5comm(config)# interface gigabitethernet 0/1
iS5comm(config-if)# no shutdown
iS5comm(config-if)# end
```

Configuring VLAN and assigned port (Switch#1)

```
iS5comm#configure terminal
iS5comm(config)# vlan 20
iS5comm(config-vlan)# vlan active
iS5comm(config-vlan)#ports gigabitethernet 0/1-3 untagged gigabitethernet 0/1-3
iS5comm(config-vlan)#name "GOOSE Group 1"
iS5comm(config-vlan)#end
```

```
iS5comm(config)# interface range gigabitethernet 0/1-3
iS5comm(config-if)# no shutdown
iS5comm(config-if)# switchport pvid 20
iS5comm(config-if)# end
```

Enable Port 1 (Switch #1)

```
iS5comm# configure terminal
iS5comm(config)# qos enable
iS5comm(config)#end
```

Create an access control list (ACL) filter for A specific VLAN packet on port 1.

```
iS5comm# configure terminal
iS5comm(config)# mac access-list extended 1020
iS5comm(config-ext-macl)# permit 01:0c:cd:01:00:01 any vlan 20 priority 8
```

 In the permit command, the parameter "priority" is mandatory.

```
iS5comm(config-ext-macl)# end
```

Assign filter ID to Physical port.

```
iS5comm(config)# interface gigabitethernet 0/1
iS5comm(config-if)# mac access-group 1020 in
iS5comm(config-if)#end
iS5comm(config)# interface gigabitethernet 0/2
iS5comm(config-if)# mac access-group 1020 in
iS5comm(config-if)# end
iS5comm(config)# interface gigabitethernet 0/3
iS5comm(config-if)# mac access-group 1020 in
iS5comm(config-if)# end
```

Create a class map and enter the Class-Map Configuration Mode.

```
iS5comm(config)# class-map 20
iS5comm(config-cls-map)#
```

Configure the match criteria for the class map with the criteria specified by the access list 1020 (already configured earlier as all packets for VLAN 20).

```
iS5comm(config-cls-map)# set class 8
iS5comm(config-cls-map)# match access-group mac-access-list 1020
iS5comm(config-cls-cmap)# end
```

Create a policy map to associate with the class map already created.

```
iS5comm(config)# policy-map 20
```

– Map the class to the policy map created, for a specific port.

```
iS5comm(config-ply-map)#set policy class 8 interface gigabitethernet 0/1 default-priority-type none
iS5comm(config-ply-map)#set policy class 8 interface gigabitethernet 0/2 default-priority-type none
iS5comm(config-ply-map)#set policy class 8 interface gigabitethernet 0/3 default-priority-type none
```

The CLASS value is used to link the policy and class map

```
iS5comm(config-ply-map)#exit
```

Save any configuration changes

iS5comm#wr startup-config

To view the configuration details:

iS5comm# show access-lists mac 1020

Extended MAC Access List 1020

Filter Priority : 8

Ether Type : 0

Protocol Type : 0

Vlan Id : **20**

Destination MAC Address : 01:0c:cd:01:00:01

Source MAC Address : 00:00:00:00:00:00

In Port List : Gi0/1, Gi0/2, Gi0/3

Out Port List : NIL

Outer EtherType : 0

Service Vlan : 0

Service Vlan Priority : None Customer Vlan Priority : None Packet Tag Type : Single-tag Filter Action : Permit

Redirect Port List : NIL

TrafficDistField : Unknown

Sub Action : NONE

Sub Action Id : 0

Status : Active

CONCLUSION

IEC61850 GOOSE and Sample Values messages can be controlled and prioritized using IEEE 802.1Q VLANs and utilizing the priorities identified within IEEE 802.1p priority tags to make certain that the GOOSE and SV data is given the highest priority under high bandwidth utilization. The VLANs make sure that the Layer 2 multicasts that GOOSE and SV use are contained to only within the VLAN they are tagged for and do not flood out to the rest of the Ethernet switched network. Adding additional Priority classification with the Layer 2 classifiers described in this document reinforce the priority of this data and enforce the transmission of the data under high utilization connection conditions.

ABOUT iS5 COMMUNICATIONS INC.

iS5 Communications Inc. ("iS5Com") is a global provider of integrated services and solutions, and manufacturer of intelligent Industrial Ethernet products. Our products are designed to meet the stringent demand requirements of utility sub-stations, roadside transportation, rail, and industrial applications. iS5Com's services and products are key enablers of advanced technology implementation such as the Smart Grid, Intelligent Transportation Systems, Intelligent Oil Field, and Internet of Things. All products have the ability to transmit data efficiently without the loss of any packets under harsh environments and EMI conditions.



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