

APPLICATION NOTE

iMX350 RAPTOR[®] and GOOSE/Multicast Control in Substations

BACKGROUND

IEC 61850 based substations use GOOSE and Sampled Value (SV) communications to monitor/ 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 make sure that the GOOSE/SV messages are handled before all other traffic during conditions of high bandwidth utilization (traffic rates in excess of 70% of capacity). IEEE 802.1Q VLAN tags also contain priority identifiers, referred to as IEEE 802.1p Priority tags or Quality of Service (QOS) identifiers. The priority tags support 8 levels/IDs. Levels 0 to 3 are for low priority traffic, 4 to 7 are for high priority traffic. The priority can be assigned by the switch when the incoming frame contains no VLAN tags by assigning the tags to the Native VLAN (the base VLAN ID assigned to an Ethernet port to which all untagged Ethernet frames are automatically inserted). If the VLAN is assigned to a port, the administrator also assigns a default priority to that VLAN, making sure that all frames that are assigned to that VLAN have the same priority as they move through the network. Below is an example of an Ethernet frame with VLAN/priority tag and the VLAN Tag format. The first Ethernet frame example shows an untagged frame, and the second shows a tagged frame with the additional 4 bytes/octets inserted into the frame.

Figure 1.0

 Preamble
 FSTD
 Destination MAC
 Source MAC
 Ether/spice
 Phyload
 CRC//FCS
 Inter Frame Gap

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 Preamble
 SFD
 Destination MAC
 Source MAC
 802.10 Header
 Ether/Fise
 Peyload
 CRC/FCS
 Inter Frame Gap

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		802.1Q Header format							
Octets		8	7	6	5	4	3	2	1
1 2	EtherType	0x8100 (as per 802.1Q)							
3	Contont	Priority			DEI	VID (upper 4 bits)			
4	Content	VID (lower 8 bits)							

Priority - A 3-bit priority for this frame. If multiple frames are ready to transmit, the oldest frame with the highest priority is sent.

Drop eligible indicator (DEI) - Indicates if the frame can be discarded if congestion is detected.

VID - A 12-bit field specifying the VLAN to which the frame belongs.

IEC 61850 requires GOOSE/SV transmitted from devices to contain a VLAN Header. However, the use of VLAN by 61850 differs significantly from the typical use in office environments.

Switch Function Guidelines - VLANs and priorities

Substation Relays have the following properties:

- GOOSE/SV messages are controlled using switch VLAN functions. The intent is to have the network deliver messages only to the devices which have subscribed to the message. The network design for managing these GOOSE based VLANs or "GOOSE VLANs" considers the following:
 - Single relays can produce multiple GOOSE messaging groups. A GOOSE message group contains a unique GOOSE name and is transmitted with a VLAN header.
 - The relays may also produce a non-GOOSE message containing no VLAN headers.
 - A single relay can consume an arbitrary number of GOOSE message groups independent of those produced.
 - Each GOOSE message group should have its own separate VLAN. These multiple VLANs from each relay will require that VLAN trunking be turned on at each switch port that has an attached GOOSE relay. This is because non-trunking (edge) ports may only be programmed to emit messages from a single VLAN.
 - A priority level is assigned to the message group. The switch will use this to maintain proper QOS for all Ethernet frames.
 - Layer 2 Multicast frames are treated as broadcasts by Ethernet switches. Since relays can produce multiple GOOSE groups, multiple VLANs should be used per device connected to the switch (edge switch). The VLANs serve the purpose of containing the Multicast messages (they act like broadcast packets) so they do not impact other devices.

- Switch configuration Guidelines:
 - For each connected relay/GOOSE device, enable the egress port to be a VLAN Trunk and configure the ingress port to not add any VLAN information.
 - Configure egress ports to emit all frames for which the device has subscribed.
 - 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 switches "Native"/Default VLAN (known as the PVID).
 - Configure each egress port to ensure that the default VLAN tag is stripped from ports to which 61850 devices are attached. This is important because devices expect "normal" messages to be received as untagged frames.
 - If these SCADA devices communicate remotely (outside of the substation) make sure they are routed correctly (using the Switch/Routers Layer 3 routing functions).
 - If these SCADA devices communicate locally (within the substation) then make sure the Native VLAN (PVID) is used for them also.





DNP3 is the SCADA protocol

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 suggested GOOSE/SV MAC Address ranges.

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

A default QOS level can be defined and assigned to an interface VLAN ID 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 below network example is included 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 (Access Control List) 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 (Unicast Source or Multicast Destination) is provided with the use of a classifier. These can be Layer 2 (MAC Address) or Layer 3 (IP Address) based. Because GOOSE and Sampled Values use a L2 Multicast MAC Address for the destination and there is currently no L3 addressing within the Ethernet frame, the creation of a L2 classifier/filter based on the multicast destination MAC Address is possible.

DNP3 is the SCADA protocol

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



Figure 3.0

SCADA Server

This example is for a 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 that are 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

Enable QoS (Switch #1)

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

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

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

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)# interface gigabitethernet 0/3 iS5comm(config)# interface gigabitethernet 0/3 iS5comm(config-if)# mac access-group 1020 in 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.

Scomm(config-ply-map)#set policy class 8 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

While IEC 61850 GOOSE multicast data cannot be controlled utilizing standard network Multicast control mechanisms such as IGMP, it is possible to use Virtual LANs (VLANs) to control where the GOOSE multicasts are allowed. This prevents the GOOSE data from travelling to end devices that have no need to see that data but can allow the needed GOOSE data to the end points that need it.

As an added benefit, the embedded priority structure within 802.1Q VLANs prioritizes the GOOSE data (if the priority tags in the VLAN IDs are used and set appropriately) to maintain high priority over other data that utilizes the same data pathways. As a further enforcement of creating priority structure for GOOSE data, special filters can be created to enforce higher transfer priority for GOOSE data.

ABOUT iS5 COMMUNICATIONS INC.

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