Voice over Internet Protocol

Recommendations for Interoperability

Background

To certify DoD VoIP Systems, DoD has developed Appendix 3 to the Generic Switching Center Requirements (GSCR), Defense Switched Network Voice over Internet Protocol (VoIP) Requirements. While Appendix 3 addressed the overall VoIP Systems and Local Area Network (LAN) requirements, it did not address the details that would allow VoIP Systems to be tested independently of the LAN (i.e, currently a VoIP System is tested with each available LAN).

DoD has many heterogeneous networks provided by various network vendors such as Cisco Systems, Foundry Networks and Extreme Networks to name a few. A need to define certain network functions exists so that VoIP Systems could be tested independently of the various LANs. At a minimum, the following network functions have the potential of impacting whether VoIP Systems would be operable over the various networks used within DoD:

a. Class of Service (CoS)

b. Quality of Service (QoS)

c. Redundancy Protocols

d. Routing Protocols

If implemented in an inconsistent manner, the above network functions will impact how well VoIP systems can meet DoD VoIP requirements. A survey (see Appendix 1) of the major vendors that provide network equipment was conducted to see if there was a basic set of network functions that could be supported by all vendors. This document outlines some recommendations that would help ensure that VoIP systems could work over IP networks regardless of the IP vendor providing the network devices.

Class of Service (CoS)

Class of Service (CoS) is a mission-sensitive indication of relative ‘priority’ of an individual application session (e.g., phone call). CoS is determined by end user at time of session origination and is determined solely by mission content. CoS methods used within DoD can be constrained by “class-mark” privileges and authentication. CoS is a classification method only; it does not ensure a level of Quality of Service (QoS), but is the method used by queuing mechanisms to limit delay and other factors to improve QoS.

Common CoS models include the IP TOS (Type Of Service) byte, Differentiated Services Code Point (DiffServ or DSCP) and the Institute of Electrical and Electronic Engineers (IEEE) Inc 802.1p/Q. CoS, or tagging, is ineffective in the absence of QoS because it can only mark data. QoS relies on tags or filters to give priority to data streams.

CoS tagging mechanisms need to be defined at the Open Systems Interconnection Reference Model (OSIRM) Data Link Layer (Layer 2) and Network Layer (Layer 3). Layer 2 CoS tagging is required to ensure that 'information' flows are given an appropriate priority tagging as they enter the lowest level network devices, Ethernet switches. Layer 3 tagging is also required to ensure that these Layer 2 'information' flows are tagged appropriately as they are aggregated in Layer 3 devices, Routers.

The Layer 2 CoS mechanism recommended is IEEE 802.1p. 802.1p adds a 3 bit or 8 possible priority level tag to the Ethernet header. For DoD, the following 802.1p recommendations are provided for VoIP implementations:

The 3 bits (Priorities 0 to 7) be used to map 'information' flows as following:

a. Priority 6 (bits 110) – Network Control & Signaling

b. Priority 5 (bits 101) – Voice Media

c. Priority 0 (bits 000) – Best Effort Data

For vendors that currently 'hard code' 802.1p tags differently than the above, it is further recommended that a one-year time frame be given to implement the recommendation providing that they can identify Network Control & Signaling, Voice Media, and data traffic flows with separate 802.1p tags.

The Layer 3 CoS mechanism recommended is DSCP. DSCP is a six-bit field (0 to 63) in the IP header. For DSCP, the following recommendations are provided for VoIP implementations:

The 6-bit tag be used to map 'information flows' as following.

a. 48 (bits 11000) – Network Control & Signaling

b. 46 (bits 101110) – Voice Media

c. 0 (bits 000000) – Best Effort Data

For Layer 2 to Layer 3 mapping, a one-to-one correlation is expected. I.e.,

a. 802.1p tag 6 mapped to DSCP tag 48

b. 802.1p tag 5 mapped to DSCP tag 46

c. 802.1p tag 0 mapped to DSCP tag 0

3.0 Quality of service (QoS)

QoS is defined as being the collection of technologies that allow applications/users to request and receive predictable service levels in terms of data throughput capacity (bandwidth), latency variations (jitter) and delay (I.e., it refers to the capability of a network to provide better service to selected network traffic). QoS involves giving preferential treatment through queuing, bandwidth reservation, or other methods based on attributes of the packet, such as CoS priority.

Similarly to CoS, the queuing mechanism used to implement QoS must be implemented at both the OSIRM Layer 2 and 3. For both Layers, the following QoS recommendations are provided for VoIP implementations:

A minimum of 3 queues be provide at each egress port for Layer2/Layer 3 devices implemented as follows:

a. Layer 2
   - Highest serviced queue – Network Control & Signaling (802.1p tag 6)
   - 2nd Highest services queue – Voice Media (802.1p tag 5)
   - Lowest serviced queue – Best Effort Data (802.1p tag 0)

b. Layer 3
   - Highest serviced queue – All Signaling (DSCP tag 48)
   - 2nd Highest services queue – Voice Media (DSCP tag 46)
   - Lowest serviced queue – Best Effort Data (DSCP tag 0)

4.0 Redundancy Protocols

Redundancy protocols allow for the ability of one device to act as a backup device for another in the event that one device fails. There are various redundancy protocols, many of which are vendor proprietary. It is recommended that as a minimum all Core network devices support Virtual Router Redundancy Protocol (VRRP). VRRP is an open standard that all vendors support. Since it is quite common for all core devices to be vendor specific, it is also recommended that vendor proprietary redundancy protocols be allowed providing that VRRP is supported.

5.0 Routing Protocols

Routing protocols are protocols developed to share routing information amongst the network devices. It is recommended that DoD IP network core devices support the Open Shortest Path First (OSPF) routing protocol to ensure interoperability at the core layer. OSPF is an open industry standard supported by the major IP network vendors. To ensure overall interoperability at the core layer, it is also recommended that core devices support Border Gateway Protocol (BGP).

6.0 Summary

The above network recommendations, if implemented on each IP network, will allow for a common set of functions that will support VoIP Systems. The recommendations create a baseline set of rules that allow for independent VoIP Systems to work over any vendor's IP networks. The goal of setting these rules is to create a test environment that does not require that every VoIP System be tested with the multitude of IP networks that exist in DoD.

The recommendations provided above cover the four major network functions, CoS, QoS, redundancy and routing that impact the viability of VoIP. While other functions may impact whether a VoIP System works, they are addressed within the local implementation for which requirements are provided (GSCR Appendix 3).

In summary, a base set of three Layer 2 CoS tags (6, 5 and 0) re required to identify as a minimum the network control & signaling, voice media and data traffic flows. Once these Layer 2 Ethernet flows reach the IP network layer, they must be mapped to appropriate Layer 3 (DSCP) tags. For DoD, VoIP implementations, DSCPs 48,46 & 0 are allocated for network control & signaling, voice media and data traffic flows, respectively. To ensure a minimum ability for redundancy and routing, VRRP, OSPF and BGP are recommended for redundancy and routing protocols.

In the long term, as convergence merges voice, video and data traffics, additional CoS/QoS mechanisms will have to be defined to allow for the prioritization and servicing of each type of traffic flow.

Appendix 1

Table 1. Vendor Survey of Core Network Devices

Vendor	Recommendations	Cisco Systems	Extreme	Foundry
Layer 2 CoS	802.1p / tag # - signaling /6 - voice /5 - data /0	***802.1p/ tag #*** ***- voice /5*** ***- signal /3*** ***- data /0***	***802.1p/ tag #*** ***- voice /7*** ***- signal /5*** ***- data /0***	***802.1p/ tag #*** ***- voice /7*** ***- signal /4*** ***- data /0***
Layer 2 QoS	Total queues (3) - PQ (3) - signaling (highest) - voice (medium) - data (lowest)	***Total queues (3)*** ***PQ (1)*** ***- media & signal mapped to 1 PQ*** WRR (1) CBWFQ (1)	***Total queues (8)*** ***CQ (8)*** ***- media & signal mapped to 1 or more queues***	***Total queues (4)*** ***SPQ*** WFQ WRR
Layer 3 CoS	DSCP -Data /0 - Voice /46 - Signal /48	***DSCP*** ***- Voice /46*** ***- Signal /56***	***DSCP*** ***- Voice*** ***- Signal***	DSCP
Layer 3 QoS	Total queues (3) - PQ (3) - signaling (highest) - voice (medium) - data (lowest)	***Total queues (3)*** ***PQ(1)*** ***- media & signal mapped to 1 PQ*** WRR (1) CBWFQ (1)	***Total queues*** ***CQ (8)*** ***- Voice & signal mapped to 1 or more queues***	Total queues (4) SPQ WFQ WRR
Redundancy Protocols	VRRP	***HSRP*** VRRP GLBP	***ESRP*** VRRP	VRRP VRRPE MRP VSRP
Routing Protocols	BGP OSPF	BGP OSPF ***EIGRP*** IGRP RIP	BGP ***OSPF***	BGP RIP OSPF

Table 1. Vendor Survey of Core Network Devices (continued)

LEGEND:

AF	– Assured Forwarding	IGRP	– Interior Gateway Routing Protocol
BGP	– Border Gateway Protocol	LAN	– Local Area Network
C2LAN	– Command & Control LAN	Mgmt	– Management
CBWFQ	– Class Based WFQ	MRP	– Metro Ring Protocol
CoS	– Class of Service	OSPF	– Open Shortest Path First
CQ	– Custom Queuing	PQ	– Priority Queuing
CS	– Class Selector	QoS	– Quality of Service
DE	– Discard Eligible	RIP	– Routing Information Protocol
DMLT	– Distributed MultiLink Trunking (Nortel)	SMLT	– Split Multi-Link Trunking (IEEE Draft)
DSCP	– Differentiated Services Code Point	SPQ	– Strict Priority Queuing
EF	– Expedited Forwarding	VRRP	– Virtual Router Redundancy Protocol
EIGRP	– Enhance IGRP	VRRPE	– Enhanced VRRP
ESRP	– Extreme Standby Routing Protocol	VSRP	– Virtual Switch Redundancy Protocol
GLBP	– Gateway Load Balancing Protocol (Cisco Pr)	WFQ	– Weighted Fair Queuing
HSRP	– Hot Standby Routing Protocol	WRR	– Weighted Round Robin
IEEE	– Institute of Electrical & Electronics Engineers, Inc.		

NOTES:

1. Items highlighted in bold and italicized show the vendors current implementations at JITC.

2. For the Spherical Communications/Foundry Test no layer 3 routing was implemented.

Table 2. Class of Service Classifications

Standard	Length (bits)	Possibilities	Implementation
IEEE 802.1p	3	8	0 – Vendor unique 1 – Vendor unique 2 – Vendor unique 3 – Vendor unique 4 – Vendor unique 5 – Vendor unique 6 – Vendor unique 7 – Vendor unique
DSCP	6	64	56 – Control 48 – Control 46 – EF 40 – Express Forwarding 32 – Class 4 24 – Class 3 16 – Class 2 8 – Class1 0 – Best Effort

LEGEND:

DSCP	– Differentiated Services Codepoint
IEEE	– Institute of Electrical & Electronics Engineers, Inc
IEEE 802.1p	– Layer 2 (Ethernet Header) Priority Tagging