Simulate Real-World IP Networks

Impairments, Delay, Errors, Loss, Optical, Electrical



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Overview

How does GL simulate real-world IP Networks? What is GL's IPNetSim?

- Lab Testing Solution application and automation
- Emulate Full Duplex 1 Gbps and 10 Gbps networks

- Real-world network conditions by imposing impairments
- Multiple streams independently configured





Portable Unit



PacketExpert[™] 10GX Standalone

- 4 x 1 Gbps Optical or Electrical
- 2 x 10 Gbps /2.5 Gbps Optical or Electrical



Hardware Overview



Hardware Overview + Highlights



IPNetSim™ is an optional application available within PacketExpert™ platform (PXN100).

- IPNetSim operates in both multi-stream and single stream mode.
- IPNetSim acts as a bridge between two network segments. As long as the hardware has power it allows frames to flow freely.
- IPNetSim allows users to define up to 16 different streams of traffic. Each of these streams can have its own independent set of impairments applied to them. More to come on streams and exactly how GL defines them.
- IPNetSim is hardware-based...meaning all impairments and timing controls happen at the hardware level.



Hardware Interfaces





Application Overview



Application Overview

- Test Enterprise and Individual-level applications
 - Audio and video streaming (VoIP, IMS, HDT, IPTV)
 - Storage services (Critical Data Access)
 - Cloud and web services
 - > FTP / HTTP
- Simulate backhaul network
 - Static and dynamic networks
 - Satellite + other long delay networks
- Test Quality of Service (QoS) and Quality of Experience (QoE)
- Evaluate the stability of network devices (switches, VoIP Phones, VoIP PBXs, Set-top boxes and VoD Servers.





Stream Overview



Stream Overview





Define Streams in Packet Mode

eam Definition	WAN En	ulation Parameters	Scheduler	L	
		P1 -> P2			
ilter Mode Packet Mode	Raw Mode				
		LS VIP UDP			
Layer (Click to e	dit)	Layer Summary			
MAC VLAN MPLS IP		00-00-00-00-01-01 -> 0 /LAN Id = 0 , VLAN St MPLS Label = 0 , MPLS 192, 168, 1, 11 - 192, 16	00-00-00-00-01 ack = 1 Stack = 1 8.1.16> 192	1-02, Len/Ty 2.168.2.11 -	rpe = XX-XX
		⊙ IPv4 ◯ IPv6			
-Source IP Addr	Fixed (●Range ○ Any			
From	192.168.	1 . 11 To 19	2.168.1.	16	
Destination IP	Address —				
(Fixed (🔾 Range 🔘 Any			
IP Address	192.168.	2 . 11			
			Ар	ply	



Define Streams in Raw Mode

eam Defi	nitio	n	WA	N E	mul	atio	on F	araı	nete	rs	Sc	hed	uler			
P1 -> P2																
ilter Mode																
Packet Mode Raw Mode Offset 26																
Bytes		^	Bv	tes	0		1	2	3	4		5	6	7	,	
Byte 0-7			- '				_;		_			_				
Byte 8-15	5	≣	Va	lue	00	0	0	00	00	01	. 0	2	00	00)	
Byte 16-2	23						_					-				
Byte 24-3	1		Ma	ISK				rF					FF			
Byte 32-3 Byte 40-4	19 17					4.00	alu									
Byte 48-5	5					Ap	ріу									
<	Ĩ S															
)														
Bytes	Va	lue							Ma	ask						
0-7	00	00	00	00	01	02	00	00	FF	FF	FF	FF	FF	FF	FF	FF
8-15	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
16-23	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
24-31	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
32-39	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
40-47	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
10 10						00	00	00	00	00	00	00	00	00	00	00
48-55	00	00	00	00	00	00	00	00	00	00	00	00	00	00		
48-55 56-63	00 00	00 00	00 00	00 00	00 00	00	00	00	00	00	00	00	00	00	00	00
48-55 56-63 64-71	00 00 00	00 00 00	00 00 00	00 00 00	00 00 00	00	00	00	00	00	00	00	00	00	00 00	00 00
48-55 56-63 64-71 72-79	00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00	00	00 00 00 00	00	00 00 00	00 00 00	00 00 00	00 00 00	00 00 00	00 00 00	00 00 00
48-55 56-63 64-71 72-79 80-87	00 00 00 00	00 00 00 00	00 00 00 00 00	00 00 00 00	00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00	00 00 00 00
48-55 56-63 64-71 72-79 80-87 88-95	00 00 00 00 00	00 00 00 00 00 00	00 00 00 00 00 00	00 00 00 00 00 00	00 00 00 00 00 00	00 00 00 00 00 00	00 00 00 00 00 00	00 00 00 00 00	00 00 00 00 00 00	00 00 00 00 00	00 00 00 00 00	00 00 00 00 00	00 00 00 00 00	00 00 00 00 00	00 00 00 00	00 00 00 00 00
48-55 56-63 64-71 72-79 80-87 88-95 96-103	00 00 00 00 00 00	00 00 00 00 00 00 00	00 00 00 00 00 00 00	00 00 00 00 00 00 00	00 00 00 00 00 00 00	00 00 00 00 00 00 00	00 00 00 00 00 00 00	00 00 00 00 00 00	00 00 00 00 00 00	00 00 00 00 00 00 00	00 00 00 00 00 00 00	00 00 00 00 00 00 00	00 00 00 00 00 00 00	00 00 00 00 00 00 00	00 00 00 00 00 00	00 00 00 00 00 00
48-55 56-63 64-71 72-79 80-87 88-95 96-103 104-111	00 00 00 00 00 00 00	00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00	00 00 00 00 00 00 00 00	00 00 00 00 00 00 00	00 00 00 00 00 00 00 00	00 00 00 00 00 00 00	00 00 00 00 00 00 00						



Impairments



Traffic Bandwidth

- Traffic which exceeds the stated rate is silently dropped
- UDP Applications will experience data loss
- TCP Applications should adapt via congestion-avoidance algorithms

Stream Definition WAN Emulation Parameters Scheduler					
WAN Stream Type 🔘 Symmetrica	Asymmetrical				
Parameters	P1->P2	P2->P1			
Traffic Bandwidth	10000.00 Mbps	8000.00 Mbps			
Latency	None	None			
Packet Loss	None	None			
Packet Reordering	None	None			
Packet Duplication	None	None			
Logic Error Insertion	None	None			
P1 -> P2		P2 -> P1			
Traffic Bandwidth		Traffic Bandwidth			
10000.000000 Mbps		8000.000000 Mbps 🖌			
<u></u>					



Traffic Bandwidth (Contd.)



 Simulate WAN Applications where Traffic Policing Policies may be in effect, ie Service Level Agreements between Provider and Customer



Traffic Bandwidth (Contd.)



• Simulate QoS settings by setting different bandwidth caps on different ports (or port ranges)



Latency / Jitter

- Apply Static Delay, or a Uniform or Exponential distribution between a minimum and maximum
- Delay a packet up to 500 ms in 1ms increments for 10G ports

Stream Definition	WAN Emulation Parameters	Scheduler					
WAN Stream Type (Symmetrical 💿 Asymmetrical						
Parameters	P1 -> P2				P2->P1		
Traffic Bandwidth	10000.00 Mbps				8000.00 Mbps		
Latency	Random Exp. , 0.	000 msec - 500.000 mse	ec		Random Exp. , 0.000 msec	c - 500.000 msec	
Packet Loss	None				None		
Packet Reordering	None				None		
Packet Duplication	None				None		
Logic Error Insertion	None				None		
P1 -> P2			P	2->P1			
-Latency				-Latency			
O Single Delay	Min	0.000 msec	c 🕶	🔘 Single Dela	ау	Min 0.000 m	sec 💌
🔘 Uniform Distribu	ition Max	500.000 msec	c 🕶	O Uniform Di	istribution	Max 500.000 m	sec 💌
Random Expone	ential Distribution			Random E	xponential Distribution		



Latency / Jitter



Apply a large static delay to simulate backhaul communication (satellite hops, etc.)



Latency / Jitter (Contd.)

	Steady stream of packets
1	
1	Time
	Same packet stream after congestion or improper queueing

- Apply Variable delay (ie, Jitter) to simulate Traffic Shaping policies and/or Network Congestion
- Jitter leads to packet discard (and therefore data loss) in Real Time UDP Applications



Latency / Jitter (Contd.)



• Increased Latency causes TCP applications to spend increasing amounts of time idling while waiting for ACKs from the far side, thereby throttling throughput



Packet Loss

tream Definition WAN Emulation	on Parameters Scheduler	
WAN Stream Type 🔿 Symmetrical	 Asymmetrical 	
Parameters	P1->P2	P2 -> P1
Traffic Bandwidth	10000.00 Mbps	8000.00 Mbps
Latency	Single Delay, 100.000 msec	None
Packet Loss	10.000 %	20.000 %
Packet Reordering	1 out of 10 packets	1 out of 20 packets
Packet Duplication	1.000 %	5.000 %
Logic Error Insertion	10^-2	10^-5
P1 -> P2 -Packet Loss O Single Packet O Burs	st Packets	P2 -> P1 Packet Loss Single Packet Burst Packets
Min 5 Frames Max 10 Rate WARNING: For PacketLoss rate less t 0.099%, only rates which are mul 0.002 are allowed Periodic Rand Rate 10.000	Frames han tiple of om %	Min 5 Frames Max 10 Frames Rate WARNING: For PacketLoss rate less than 0.099%, only rates which are multiple of 0.002 are allowed Periodic Random Rate 20.000 %

• Randomly drop from 0.01% to 100% of all Packets in the stream



Packet Loss (Contd.)



• Real Time UDP Applications are resilient to minor loss, but vulnerable to heavy loss



Packet Loss (Contd.)



• TCP Applications are vulnerable to even very minor loss rates as every loss results in retransmissions and reduced window sizes.



Packet Reordering

- Reorder 1 out of every X packets.
- Set a minimum time in ms to hold the reordered packet
- Set a maximum time in ms to hold the reordered packet

tream Definition WAN Emulation Parameters Scheduler					
WAN Stream Type 🔘 Symmetri	cal 💿 Asymmetrical				
Parameters	P1->P2		P2->P1		
Traffic Bandwidth	10000.00 Mbps		8000.00 Mbps		
Latency	Single Delay, 100.000 ms	ec	None		
Packet Loss	10.000 %		20.000 %		
Packet Reordering	1 out of 10 packets		1 out of 20 packets		
Packet Duplication	None		None		
Logic Error Insertion	None		None		
P1 -> P2 Packet Reordering Periodic ORan Reorder 1 packet out of 10 Delay Offset	dom packets	P2 -> P1 Packet Reorder P Reorder 1 pack Delay Offset	ing eriodic Random et out of 20 packets		
⊙ Time ○ Frames	s v 10 ms	⊙ Ti Min 0	ime Frames		



Packet Reordering (Contd.)



• When a packet is out-of-order, TCP behaves exactly as though the preceding packets are lost resulting in duplicate ACKs, retransmissions and window reduction



Packet Reordering (Contd.)



• TCP Selective Acknowledgement (SACK) can mitigate this issue by letting the receive side Acknowledge OOO packets.



Packet Duplication

- Randomly duplicate from 0.01% to 100% of all Packets in the stream
- Emulate WAN applications where multiple paths are possible and Load Balancing may be present

Parameters	P1 -> P2	P2 -> P1
Traffic Bandwidth	10000.00 Mbps	8000.00 Mbps
Latency	Single Delay, 100.000 msec	None
Packet Loss	10.000 %	20.000 %
Packet Reordering	1 out of 10 packets	1 out of 20 packets
Packet Duplication	1.000 %	5.000 %
D1 > D2		P2 > P1
CDuplication		Cuplication
Rate WARNING: For Duplication rat than 0.099%, only rate are multiple of 0.002 are Periodic Priodic F Rate 1.000	e less s which e allowed Random %	Rate WARNING: For Duplication rate less than 0.099%, only rates which are multiple of 0.002 are allowed Periodic Random Rate 5.000 %



Packet Duplication (Contd.)



- Duplication can be fatal in broadcast situations (i.e, broadcast storm)
- Similarly dangerous in multicast applications where small network misconfigurations can have disproportionately large consequences
- Watch out for this in multipath Spanning Tree networks



Logic Error Insertion

- Insert a single bit error every 10^-X frames (-1 <= X <= -9)
- Use byte offsets to target particular parts of a frame

Stream Definition WA	N Emulation Parameters Scheduler Symmetrical Symmetrical			
Parameters	P1->P2	P2 -> P	1	
Traffic Bandwidth	10000.00 Mbps	8000.00	Mbps	
Latency	Single Delay, 100.000 msec	None		
Packet Loss	10.000 %	20.000	%	
Packet Reordering	1 out of 10 packets	1 out of	20 packets	
Packet Duplication	1.000 %	5.000 %	5	
P1 -> P7		P2 -> P1		
CLogic Error Insertion -		-Logic Error Inserti	on	
Rate	Periodic 🔘 Random	Rate	● Periodic ○ Randor	n
Packet Error Rate 1	0^ -2	Packet Error Ra	te 10^ -5	•
Bytes Offset	Beginning of frame	Bytes Offs	et 15	Beginning of frame
Bytes Offset 1	End of frame	Bytes Offs	et 20	End of frame
		L		



Logic Error Insertion (Contd.)



• Cellular and WiFi links are very prone to bit errors (as well as latency and bandwidth issues)



Application Examples



VoIP

#	Stream Name						
2	RTP	Stream Definition	WAN Emulation Parameters	Scheduler			
3	Data	L					
			P1 -> P2	Mirror >>			
		UDP	5060> 5060				

Configure SIP packets to be completely unimpaired

#	Stream Name								
2	RTP	Stream Definition	WAN Emulation Pa	rameters Scheduler					
3	Data	WAN Stream Type 🔿 Symmetrical 💿 Asymmetrical							
		Parameters	P1 -> P2	P1 -> P2 Manual					
		Traffic Bandwidth	1000.00 Mbps	100.00 Mbps					
		Latency	None	None					
		Packet Loss	None	None					
		Packet Reordering	None	None					
		Packet Duplication	None	None					
		Logic Error Insertion	n None	None					



#

3

# Stream Name							
2 RTP	Stream Definition WAN Emulation Parameters Scheduler						
3 Data	P1->P2 Mirror >>						
	Mode ● Packet Mode ■ MAC VLAN ■ MPLS ■ IP ■ UDP						
	Layer (Click to edit) Layer Summary						
	UDP 1000 - 5000> 1000 - 5000						

• Apply loss and jitter to RTP streams

RTP	Stream Definition	WAN Emulation Parameters	Scheduler
Data	WAN Stream Typ	e O Symmetrical Asymmetrica	1
	Parameters	P1 -> P2	P1 -> P2 Manual
	Traffic Bandwidth	1000.00 Mbps	1000.00 Mbps
	Latency	Random Exp. , 0 - 120 ms	Random Exp. , 0 - 120 m
	Packet Loss	2.000 %	2.000 %
	Packet Reordering	None	None
	Packet Duplication	None	None
	Logic Error Insertio	n None	None



#	Stream Name					
1	RTP	Stream Definition	WAN Emulation Parameters	Scheduler		
3	Data		P1 -> P2	Mir	ror >>	
Packet Mode Raw Mode						
			N MPLS IP UDP			
_		Layer (Click to e	edit) Layer Summary			

• Set an SLA style bandwidth cap on Data

Name						
	Current De Circle - MAN Emulation Decomptore					
	Stream Definition	WAN Eliiulauon Fai	ameter2	Sched		
ua -	WAN Stream Type O Symmetrical Asymmetrical					
	Parameters	P1 -> P2	P1 ->	P2 Manua		
	Traffic Bandwidth	200.00 Mbps	200.	200.00 Mbps None		
	Latency	None	None			
	Packet Loss	None N		ne		
	Packet Reordering	None	None			
	Packet Duplication	None	None			
	Logic Error Insertion	None No		ne		





Communications



- Determine how your application will behave under expected (and unexpected) network conditions
- Determine what codecs you should use, what jitter buffers, etc.



TCP Over Wireless



- TCP was first described in an IEEE paper written in 1974
- Ethernet was first standardized by the IEEE in 1983
- The first GSM Network went online in 1991





• Loss in a TCP application leads to duplicate ACKs, which lead to retransmissions





- TCP assumes that Loss is due to Congestion
- When Loss occurs TCP automatically cuts throughput to avoid congestion





- TCP uses a Sliding Window mechanism to limit how many unacknowledged bytes can be transmitted before the sender is forced to idle
- High Latency links slow ACKs, cause forced idle, and limit throughput





- When a client moves between cells handoff will cause Loss
- TCP will interpret this as Congestion and cut throughput even if the exact same amount of bandwidth is still available (even if more bandwidth is now available)!





- TCP has Retransmission Timeout mechanism that attempts to track the RTT of the connection
- If Latency suddenly increases (ie cell handoff), this can easily cause Timeouts to trigger, immediately cutting throughput to the minimum!



THANK YOU!

