边缘计算
Edge Computing
CONSORTIUM

The Challenges of TSN Testing

汇报人：刘倚昕 Spirent Communications
汇报日期： 2018年11月

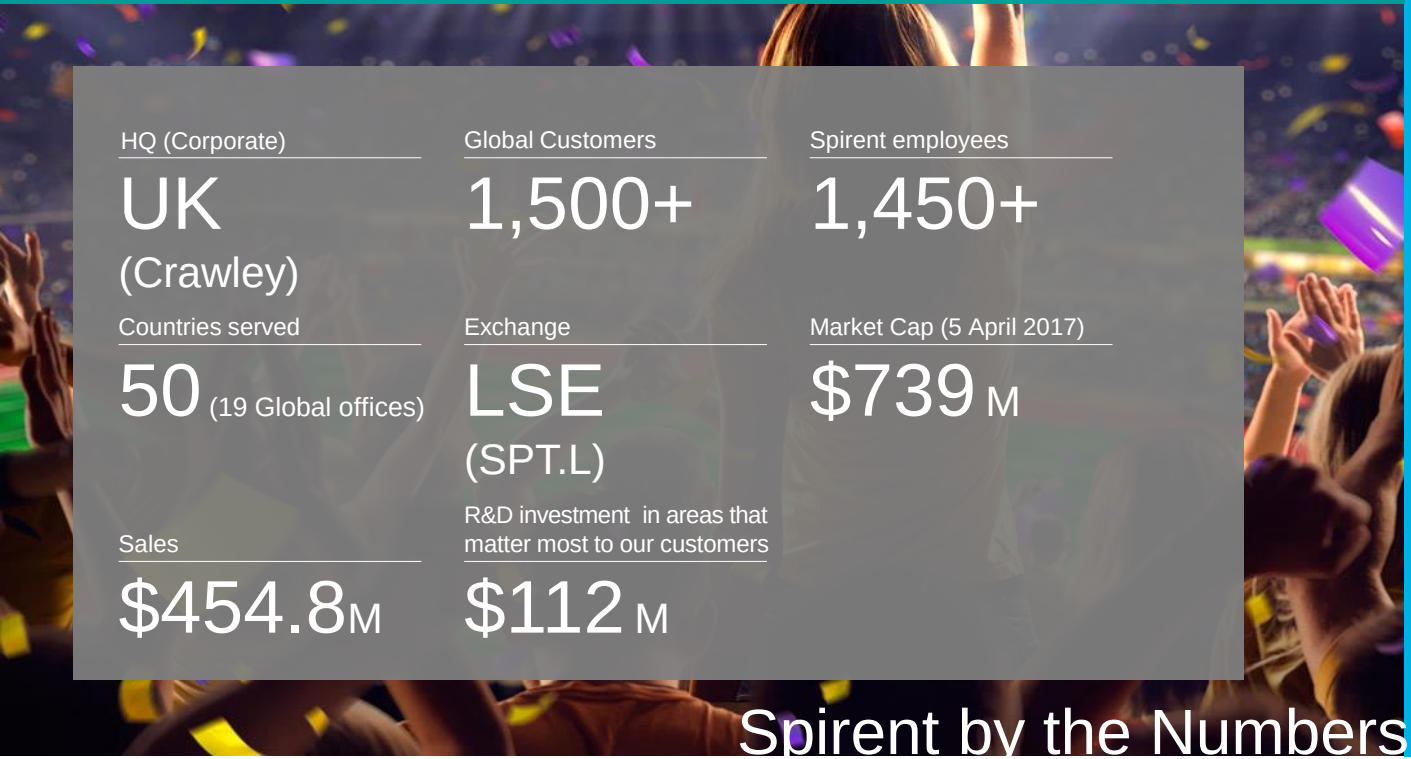
边缘计算 Edge Computing CONSORTIUM

spirent Promise. Assured.

目录

Who is Spirent?

Leader in Communications Test & Assurance Solutions



HQ (Corporate)
UK
(Crawley)

Global Customers
1,500+

Spirent employees
1,450+

Countries served
50 (19 Global offices)

Exchange
LSE
(SPT.L)

Market Cap (5 April 2017)
$739 M

Sales
$454.8M

R&D investment in areas that matter most to our customers
$112 M

- Cloud & Virtualisation
- Networks
  Wireless | Fixed | GNSS | Automotive
- High Speed Ethernet
- Service Assurance
- Cyber-Security

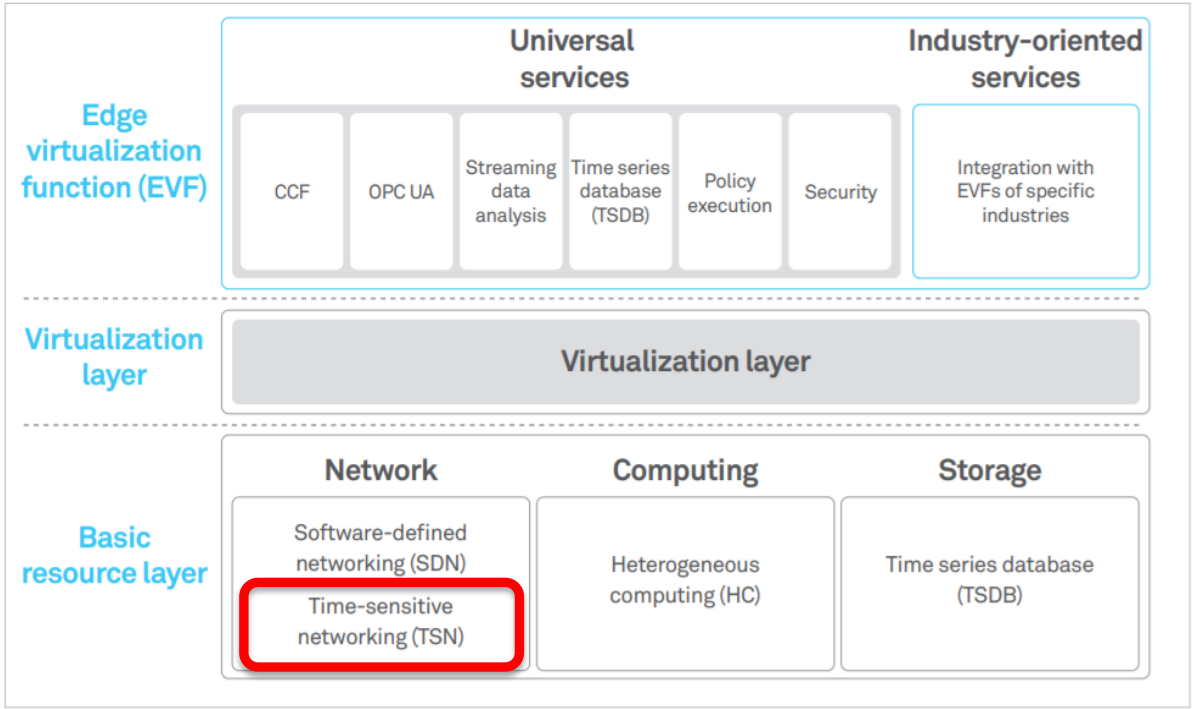
Spirent by the Numbers - 2017

边缘计算
Edge Computing
CONSORTIUM

TSN in Edge Computing

TSN in ECN Architecture

- Ensure determinism;
- Large bandwidth;
- Reliable data transmission;
- Unified management;



TSN Industrial Organizations and Roles

Testbed and Reference Architectures

- Testbeds to evaluate "full stack" and provide feedback to members and liaison organizations
- Application specific architectures to aid in market adoption
- Outbound marketing to create awareness

Application Layers

- Define data models for end-device communication
- Integration of TSN communications and configuration models into application tools
- Application flow for end-node configuration
- Conformance for data models and end node configuration

TSN Transport Interoperability and Conformance

- Define network services needed by market
- Fill gaps in standards to provide interoperable network configuration services
- Conformance of transport and network services
- Establish certification services

Network standards

- Define standard features to provide data plane and configuration plane providing TSN capabilities
- Assure proper operations and backwards compatibility with IT and OT

The challenges of testing TSN

IEEE 802.1 TSN Standards

	Transport	Time Synchronization	Stream Reservation	**Quality of Service**	Redundancy	Security
AVB 802.1BA-2011 The AVB Profile	1722-2011 Media Transport Protocol	802.1AS-2011 gPTP	802.1Qat-2010 SRP	802.1Qav-2009 Credit Based Shaper	-	802.1X-2010 802.1Xbx-2014 802.1Xck
TSN	1722-2016 Adds CAN, FlexRay, LIN + more Audio/Video Transports	802.1AS-Rev Redundant gPTP	802.1Qcc-2018 Enhanced SRP 802.1Qca-2015 Path Control & Reservation	802.1Qbv-2015 Time Aware Shaper 802.1Qbu-2016 & 802.3br-2016 Frame Preemption 802.1Qch-2017 Cyclic Queue Forwarding 802.1Qcr Asynchronous Shaping	802.1CB-2017 Frame Replication & Elimination 802.1AS-Rev Redundant gPTP	802.1Qci-2017 Filtering & Policing 802.1AEcg-2017 (end-to-end) MACSec

TSN Testing Challenge

Traffic Shaping

Traffic Shaping provides the framework for guaranteed data transport with bounded low latency, low delay variation and extremely low loss.

- IEEE 802.1Qav - Forwarding and Queuing for Time Sensitive Systems (FQTSS)
  - Works in conjunction with IEEE 802.1Qat (Stream Reservation Protocol)
  - Defines Credit Based Shaping algorithm, SRP Boundary Detection; bandwidth availability parameters used for reservations and mapping of queues to priorities
  - CBS spaces out frames and reduces bursting and bunching
- IEEE 802.1Qbv - Enhancements for Scheduled Traffic
  - Introduces Time Aware Shaping algorithm via time-based control of transmission gates for the 8 bridge queues
    - Gate states: “Open or Close”
  - Needs synchronization mechanism
  - The schedule is periodic
  - Reduces latency variation and makes latency deterministic for Constant Bit Rate (CBR) traffic

TSN Testing Challenge

Traffic Shaping(continued)

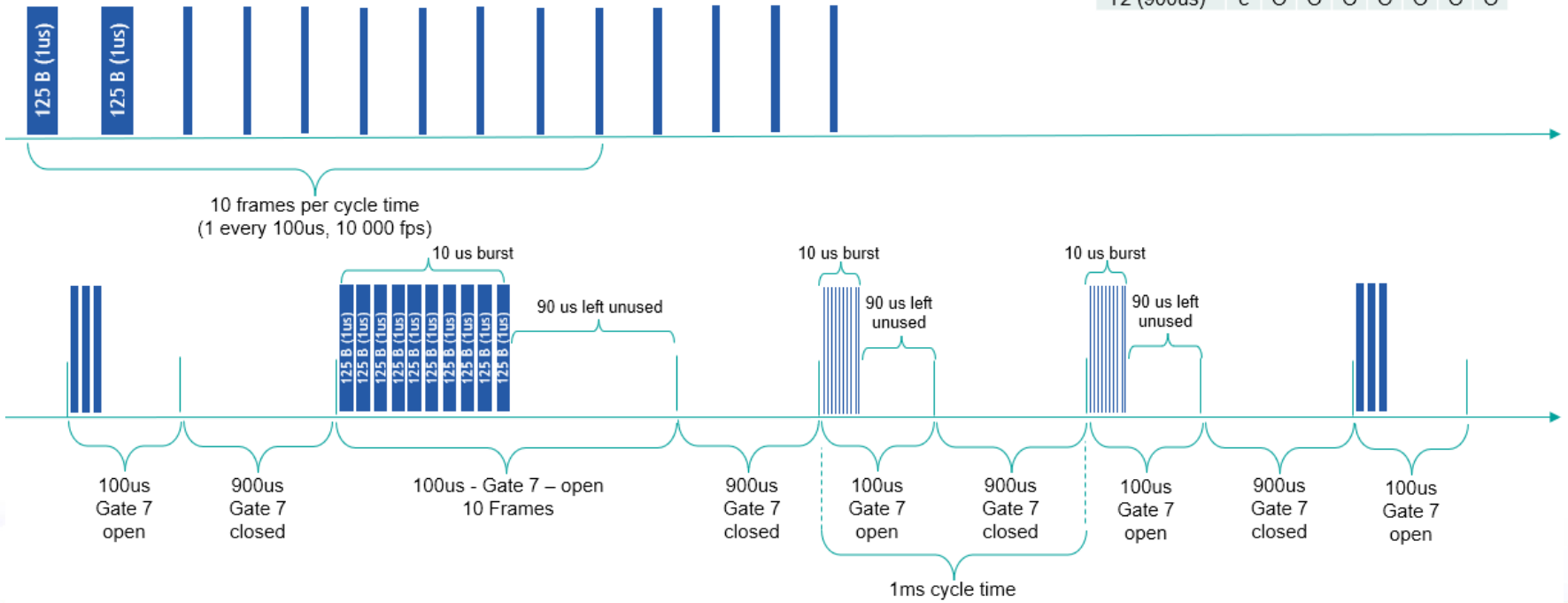
In addition to the traffic shaping standard amendments, **Frame Preemption** standard makes sure that critical time sensitive traffic is not stuck behind other interfering traffic:

- IEEE 802.3br (Interspersing express traffic) & IEEE 802.1Qbu (Frame preemption)
  - Specifies Mac Merge Sublayer for Express and Preemptable traffic
  - Exchange link partner preemption capabilities via LLDP

Test transmission gate operation

Cycle Time = 1ms

	7	6	5	4	3	2	1	0
T1 (100us)	O	c	c	c	c	c	c	c
T2 (900us)	c	O	O	O	O	O	O	O

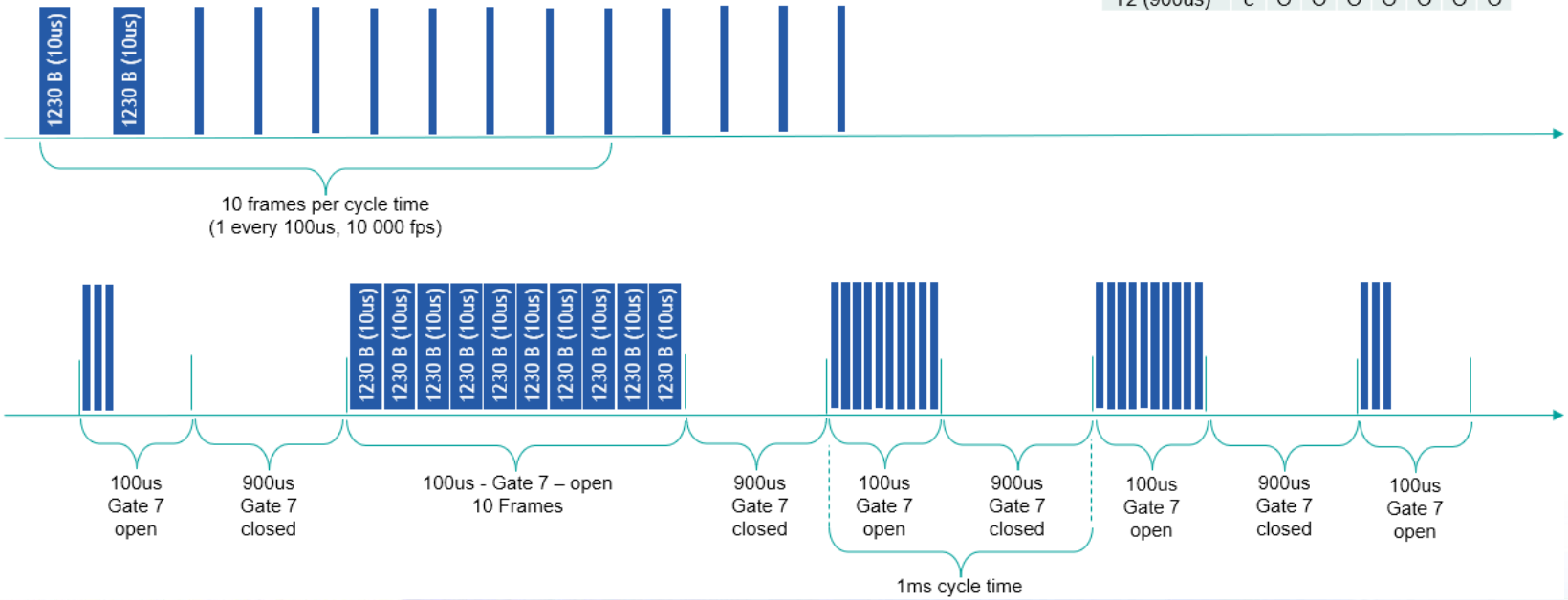


Test gate-close operation

The frames fill completely the gate duration

Cycle Time = 1ms

	7	6	5	4	3	2	1	0
T1 (100us)	O	c	c	c	c	c	c	c
T2 (900us)	c	O	O	O	O	O	O	O



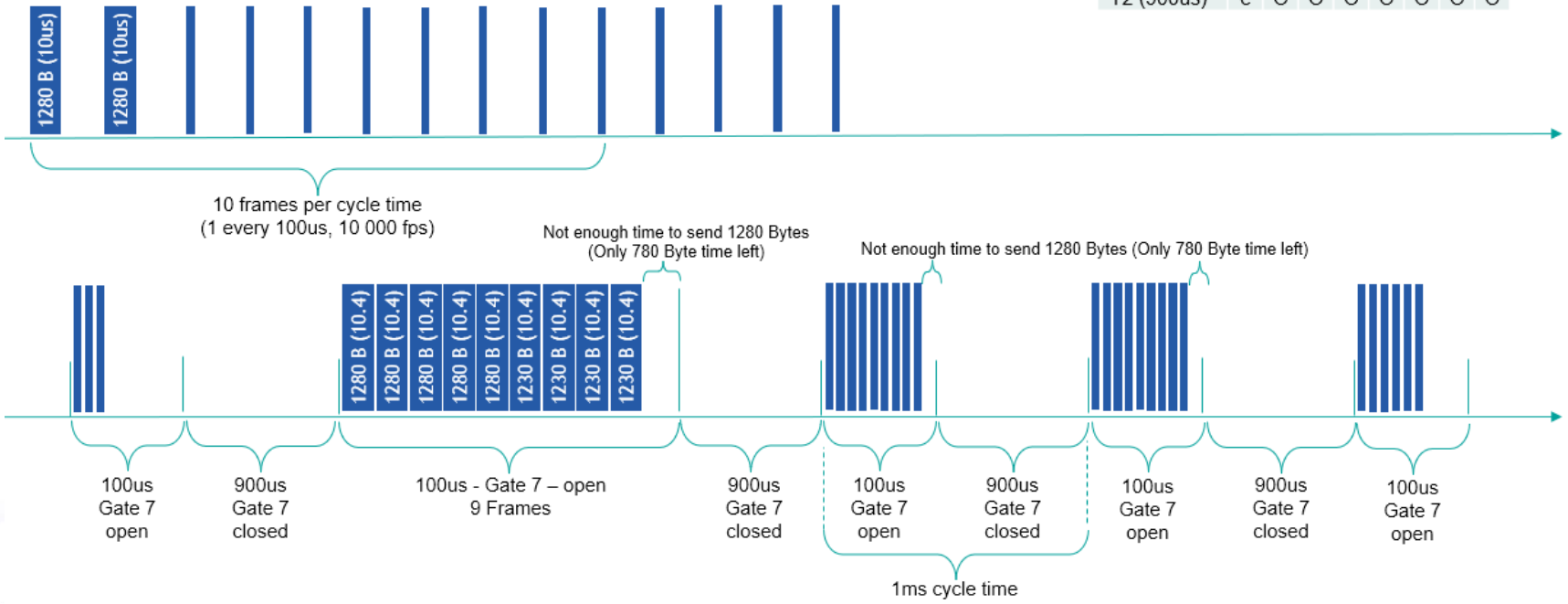
Test gate-close operation

Verify the guard band is enforced

Test solution must send traffic at precise PTP time!

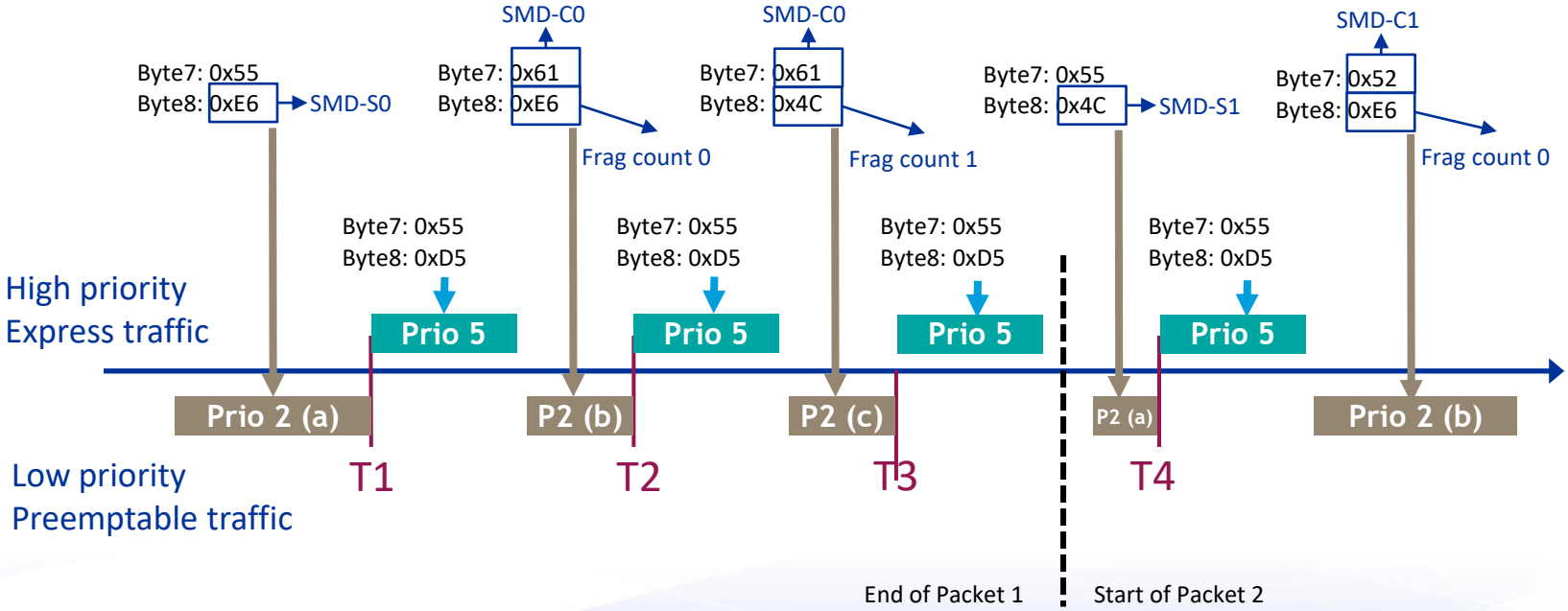
Cycle Time = 1ms

	7	6	5	4	3	2	1	0
T1 (100us)	O	c	c	c	c	c	c	c
T2 (900us)	c	O	O	O	O	O	O	O



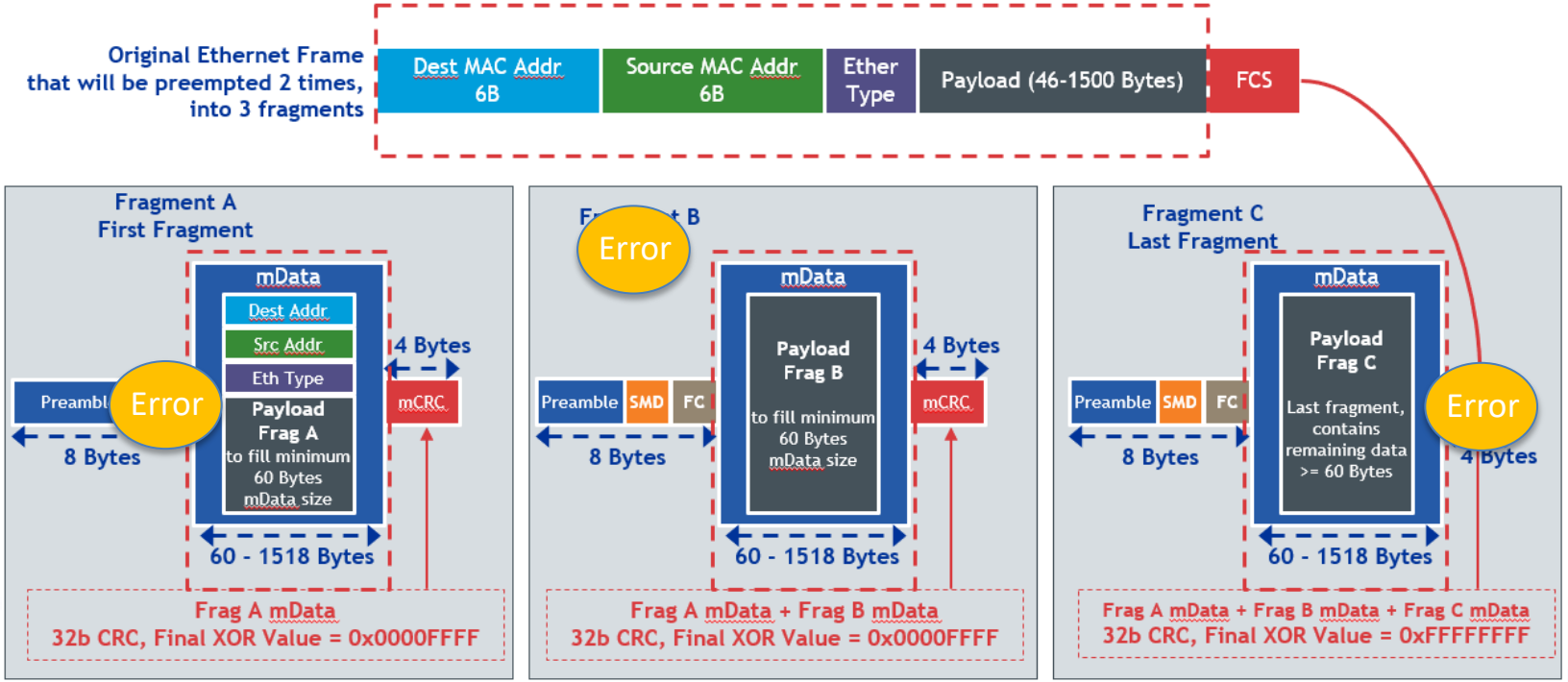
Reduce guard band for cut-through

Using frame preemption (802.1Qbu-2016 & 802.3br-2016)



Look inside preemption

Verify fragment sequence/SMD/mCRC…



TSN Testing Challenge

Ensure smooth transition from design to deployment

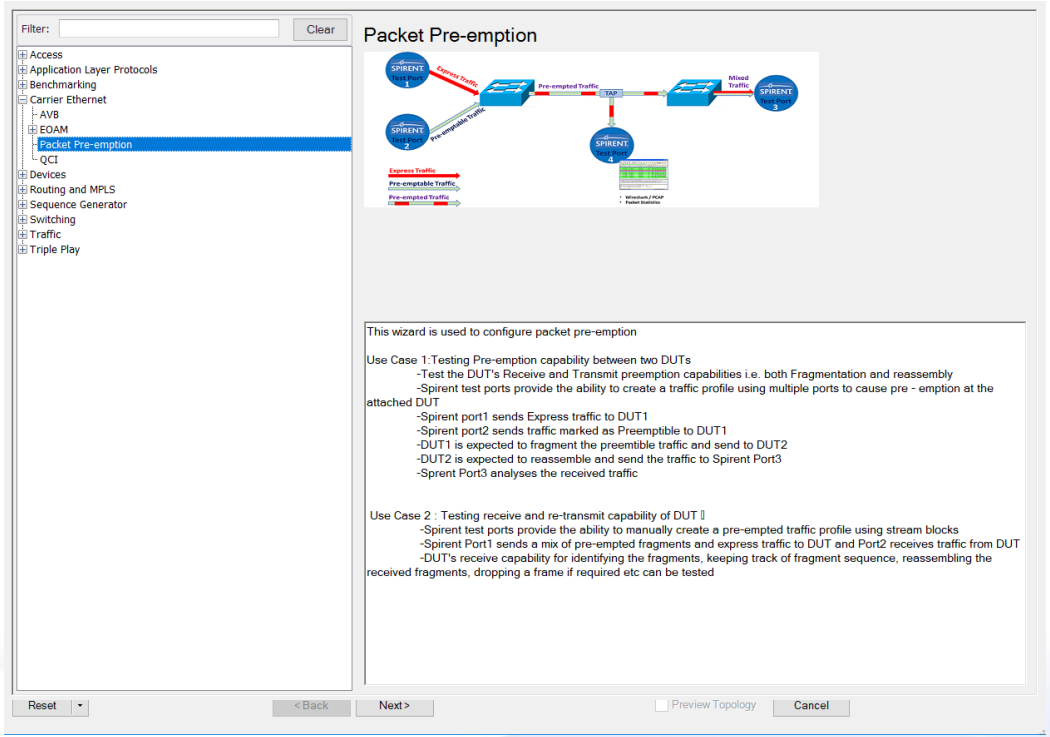
- Ability to test against emulated real-world configurations
  - **Precisely scheduled traffic**
  - Mixed traffic profiles (different classes and priorities)
  - Mixed topology of TSN and non-TSN compliant elements
- Performance measurements
  - Under heavy data plane or control plane (protocol messages) traffic load
- Conforming to the standards
- Testing for resiliency and reliability
  - Negative testing

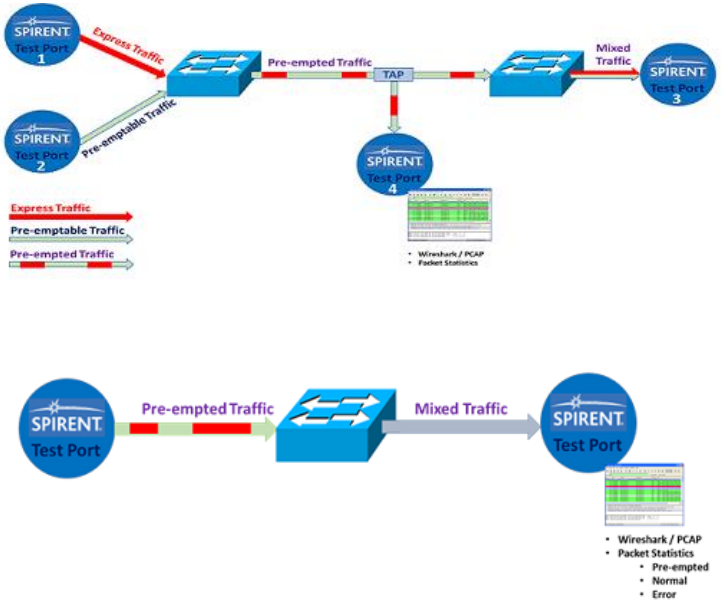
The Right Toolset

TSN traffic simulation

Spirent TestCenter

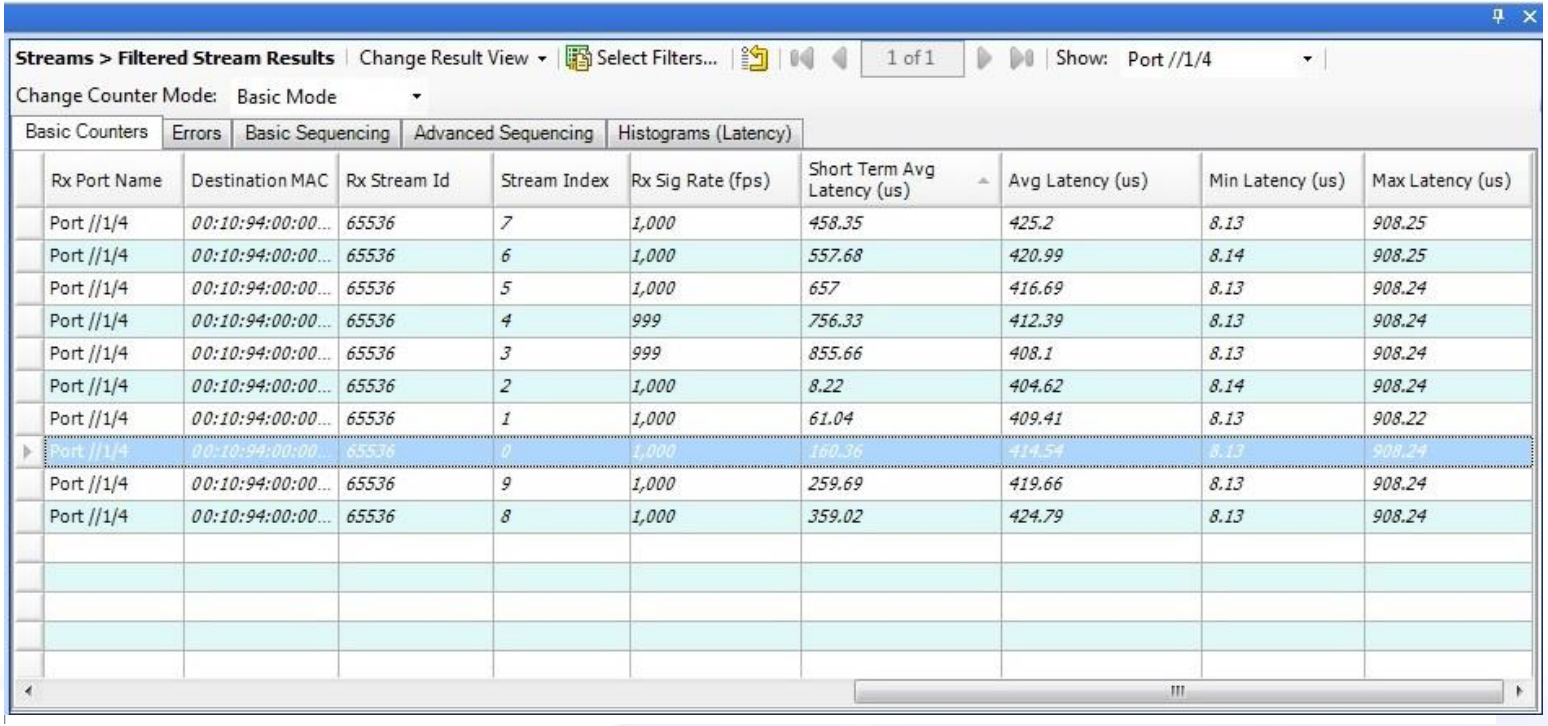
Wizards





TSN traffic simulation

Spirent TestCenter



Streams > Filtered Stream Results | Change Result View | Select Filters... | 1 of 1 | Show: Port //1/4

Change Counter Mode: Basic Mode

Basic Counters | Errors | Basic Sequencing | Advanced Sequencing | Histograms (Latency)

Rx Port Name	Destination MAC	Rx Stream Id	Stream Index	Rx Sig Rate (fps)	Short Term Avg Latency (us)	Avg Latency (us)	Min Latency (us)	Max Latency (us)
Port //1/4	00:10:94:00:00...	65536	7	1,000	458.35	425.2	8.13	908.25
Port //1/4	00:10:94:00:00...	65536	6	1,000	557.68	420.99	8.14	908.25
Port //1/4	00:10:94:00:00...	65536	5	1,000	657	416.69	8.13	908.24
Port //1/4	00:10:94:00:00...	65536	4	999	756.33	412.39	8.13	908.24
Port //1/4	00:10:94:00:00...	65536	3	999	855.66	408.1	8.13	908.24
Port //1/4	00:10:94:00:00...	65536	2	1,000	8.22	404.62	8.14	908.24
Port //1/4	00:10:94:00:00...	65536	1	1,000	61.04	409.41	8.13	908.22
Port //1/4	00:10:94:00:00...	65536	0	1,000	160.36	414.54	8.13	908.24
Port //1/4	00:10:94:00:00...	65536	9	1,000	259.69	419.66	8.13	908.24
Port //1/4	00:10:94:00:00...	65536	8	1,000	359.02	424.79	8.13	908.24

TSN conformance verification

TTsuite - TSN

Invalid Fragment Count	Reject a fragmented frame where the first continuation fragment has a non-zero Fragment Count
	Reject a fragmented frame where the fragments are received out of order
	Reject a fragmented frame where one fragment is missing
	Reject a fragmented frame where more than one fragment is missing (2 missing fragments)
	Reject a fragmented frame where the Fragment Count is not incremented (remains constant)
	Reject a fragmented frame where the Fragment Count has an invalid value (e.g. 0xAB)
Invalid SMD-C	Reject a fragmented frame where the continuation fragments have SMD-C values different than expected based on the SMD-S value from the initial fragment
	Reject a fragmented frame where the 5th continuation fragment has SMD-C values different than expected based on the SMD-S value from the initial fragment
	Reject a fragmented frame where a continuation fragment has an invalid SMD-C value (e.g. 0xAB)


边缘计算
Edge Computing
CONSORTIUM
THANKS!