Practice of “TSN-IP” over 5G carrier networks

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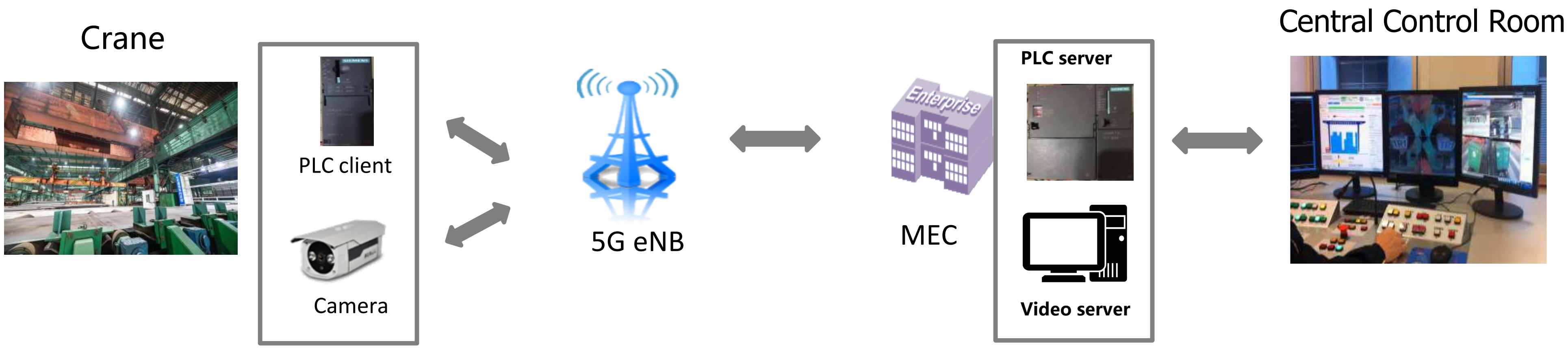
Agenda

- “TSN-IP”: A demo project of using TSN principles over IP carrier networks
- Technical thoughts on TSN techniques for service provider networks

Background

- Vertical industry's demand for carrier network are **upgrading to low delay, high reliability and certainty**.
- Emerging industry scenarios such as remote control, motion control, human-computer interaction and VR/AR require carrier network to **break through the traditional design idea of “best effort".**
- Deterministic network technologies, like **TSN, DetNet(DIP)** and others**,** attracted attention.

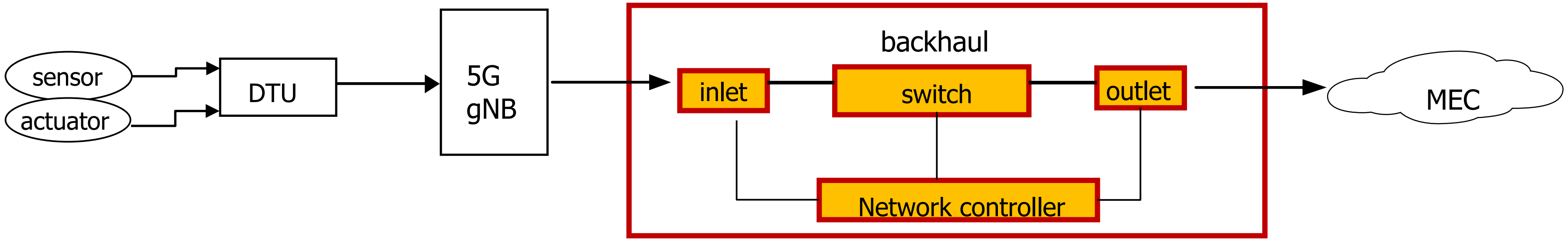


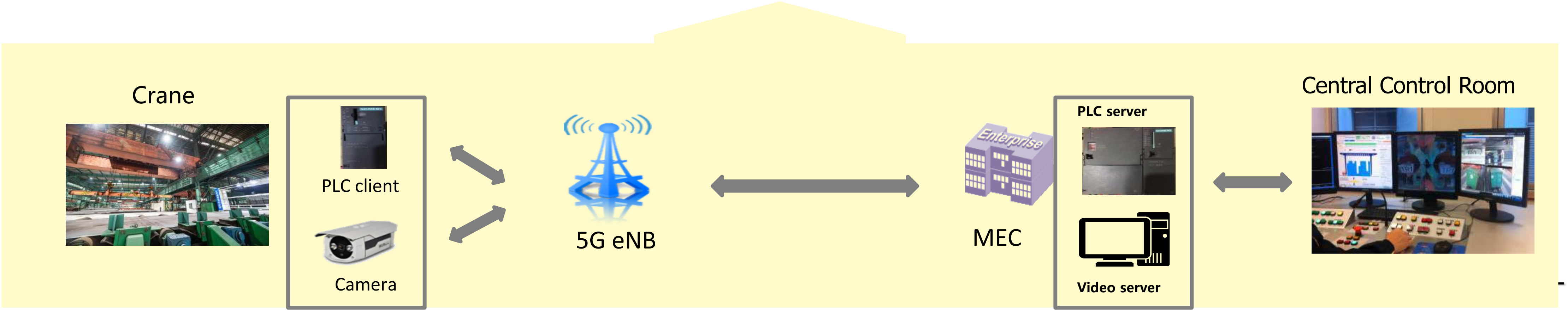
Example: a trial on crane remote control

Services	Indicators			Measured data		
	E2E latency	Bandwidth	Reliability	E2E latency	Bandwidth	Reliability
Control signal	20ms		99.999%	Mini:6ms, Average: 9ms, Max: 18ms		
Surveillance video	60ms	80Mbps			60~120Mbps	

Introduction on “TSN-IP”

- “TSN-IP” is the name of the cooperation project between China Unicom and Huawei, which intends to test the combination of 5G and TSN technologies in order to guarantee required carrier network performance, such as upper bound of delay, stability of required bandwidth, packet loss etc.
- First stage (2021), 5G backhaul network was selected.
- Second stage (2022-), 5G access network, backhaul network and MEC are planned.





Test schema

- **Scenarios**: **factory automation, smart grid, and smart port** are three comprehensive scenarios, including **15 subdivided business scenarios**, such as mobile robot, power distribution automation, advanced metering, intelligent inspection, crane remote control, unmanned collection card, and video surveillance etc.
- **Traffic model**: for the foresaid three comprehensive scenarios, 3GPP TS 22.104 and other related white papers are referred for design of the corresponding traffic models.
- **Traffic construction**: a test instrument is adopted to simulate the desired traffic according to the foresaid traffic models.
- **Test site**: the test is made on 5G test network in Guangdong, "China Unicom Cube-Net 3.0 Greater Bay Area Demonstration Base".

The network scheme of the test

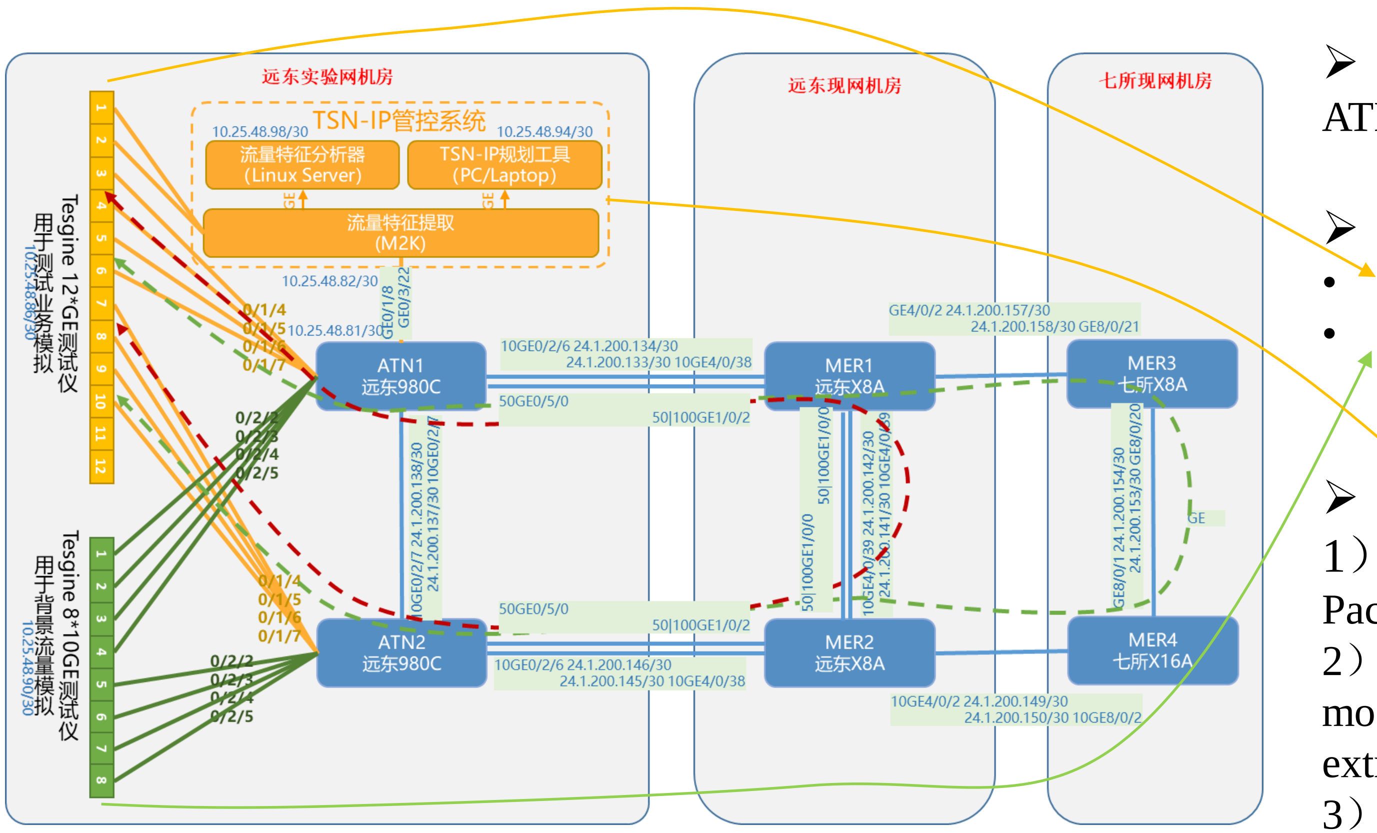


Figure: Network scheme

- ➢ 5G carrier network equipment：

ATN1、ATN2、MER1、MER2、MER3、MER4

- ➢ Test instrument :
  - the 12*GE tester simulates desired traffic
  - the 8 *10GE tester simulates background traffic of the live network.

- ➢ TSN-IP management & control system：

1）Traffic feature extraction (M2K): extract features of Packet by packet.

2） Traffic characteristic analyzer (Linux server): Study and model the traffic characteristics based on M2K traffic feature extraction.

3）TSN-IP planning tool (PC)：complete Network delay queue planning, resource reservation, and delivery these configuration

Traffic construction

- The features of the service traffic output by learning the model match the test service, meeting the requirements of automatic learning of the service traffic model.

序号	Service	Traffic types	Packet length	Num. of packets per burst	Burst period
1	Smart grid	Differential protection	256 Byte	10	833us
2		Power distribution automation	Uplink:800 Byte Downlink:256 Byte	Uplink:10 Downlink：10	Uplink：40s Downlink：40s
3		Advanced measurement	250 Byte	10	40s
4		Power transmission patrolling	1500 Byte	110	33.333ms
5	Smart port	Gantry crane_ control signal	250 Byte	10	6ms
6		Gantry crane_video	1500 Byte	110	33.333ms
7		AGV_video	1500 Byte	110	33.333ms
8		AGV_remote control	250Byte	10	40ms
9		Video surveillance_ single channel traffic	1500Byte	110	33.333ms
10	Factory automa-tion	Motion control	40Byte	10	1ms
11		Controller to controller_ large printing press	1024Byte	10	10ms
12		Controller to controller_assembly line	1024Byte	10	50ms
13		Mobile robot_ motion control	250Byte	10	1ms
14		Mobile robot_ machine control	250Byte	10	10ms
15		Mixed packet	800-1300Byte	10	10ms

Traffic characteristics learning

- Verify the accuracy of traffic feature collection and modeling of "TSN-IP Control System".
- Feature collection and learning of 15 different service traffics in three scenarios of simulated smart grid, smart port and factory automation can accurately obtain traffic characteristics and perform visual presentation.

Figure： business traffic feature extraction and modeling results

Traffic characteristics: Obtain the peak traffic rate, average traffic rate, length, and burst traffic parameters.

The total learning time required for the successful modeling of service traffic characteristics is strongly related to the regularity and periodicity of traffic itself.

Configuration planning and implementation for SLA guarantee

TSN-IP有界时延承诺方案

SLA保障业务规划总计
6
业务类型 5种 业务隔离 1类

6 service traffics

最大SLA规划预期时延
44.93 ms
对应SLA业务需求时延 50 ms

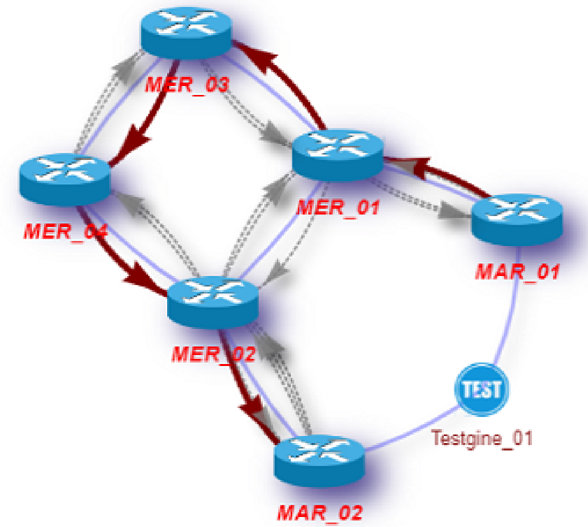
planning Max latency

最小SLA规划预期时延
2.93 ms
对应SLA业务需求时延 3 ms

planning Min latency

最大SLA规划跳数
6 跳
对应SLA规划平均跳数 5 跳

planning Max hops



SLA业务路径规划信息

只显示业务路径信息 No

业务ID	业务类型	平均速率	突发大小	时延需求	时延预期
1	差动保护	24.272593 M	2.56 KB	3 ms	2.93 ms
	0.9ms-0.3ms-0.3ms-0.3ms-0.9ms	MAR_02(Q1)-->MER_02(Q1)-->MER_04(GE8/0/1Q1)-->MER_03(GE8/0/21Q1)-->MER_01(Q1)-->MAR_01			
2	差动保护	24.272593 M	2.56 KB	3 ms	2.93 ms
	0.9ms-0.3ms-0.3ms-0.3ms-0.9ms	MAR_01(Q1)-->MER_01(GE4/0/2Q1)-->MER_03(GE8/0/20Q1)-->MER_04(Q1)-->MER_02(Q1)-->MAR_02			
3	三遥上行	0.0016 M	8 KB	12 ms	9.28 ms
	3.4ms-4.9ms-0.9ms	MAR_02(Q2)-->MER_02(Q1)-->MER_01(Q1)-->MAR_01			
4	三遥下行	0.000513 M	2.56 KB	12 ms	11.88 ms
	4.9ms-4.9ms-2ms	MAR_01(Q2)-->MER_01(Q1)-->MER_02(Q2)-->MAR_02			
5	高级计量	0.000501 M	2.5 KB	50 ms	39.88 ms
	11.6ms-16.6ms-11.6ms	MAR_02(Q3)-->MER_02(Q2)-->MER_01(Q2)-->MAR_01			
6	巡检监控	38.13596 M	165 KB	50 ms	44.93 ms
	3.4ms-9.9ms-9.9ms-9.9ms-11.6ms	MAR_02(Q2)-->MER_02(Q2)-->MER_04(GE8/0/1Q2)-->MER_03(GE8/0/21Q2)-->MER_01(Q2)-->MAR_01			

Compare the effect of “TSN-IP” and DiffServ network

- After the corresponding combination of 15 specific services in the three scenarios of smart grid, smart port and factory automation, **verify the actual SLA guarantee of each test service in the three comprehensive scenarios.**

Figure: **TSN-IP SLA guarantee effect** in smart grid scenario

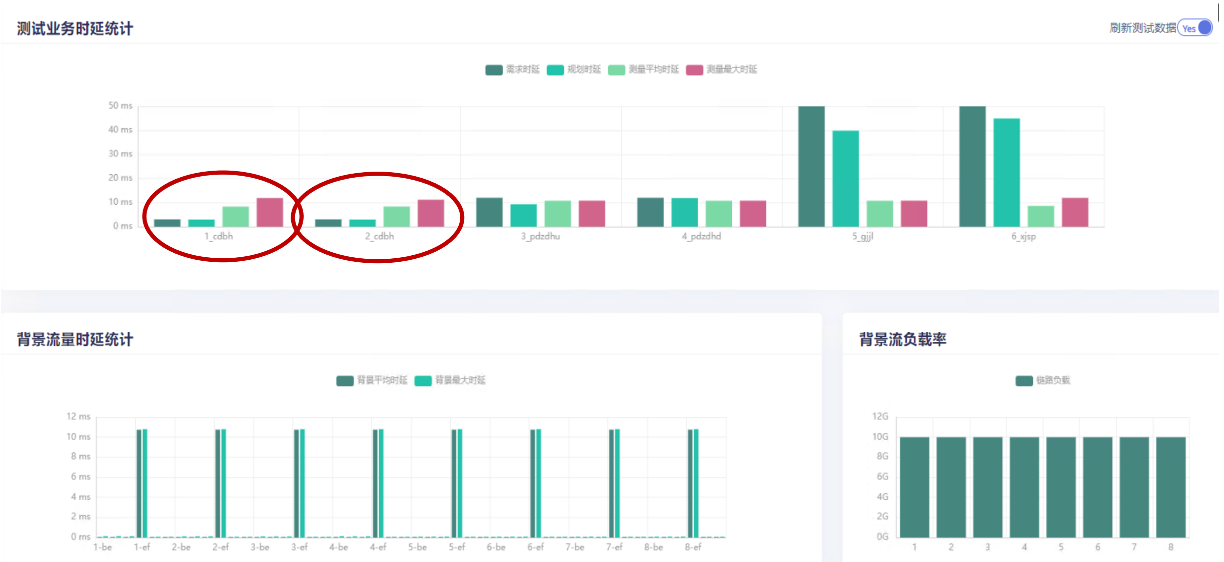


Figure: SLA guarantee effect of **traditional QOS services** in smart grid scenario

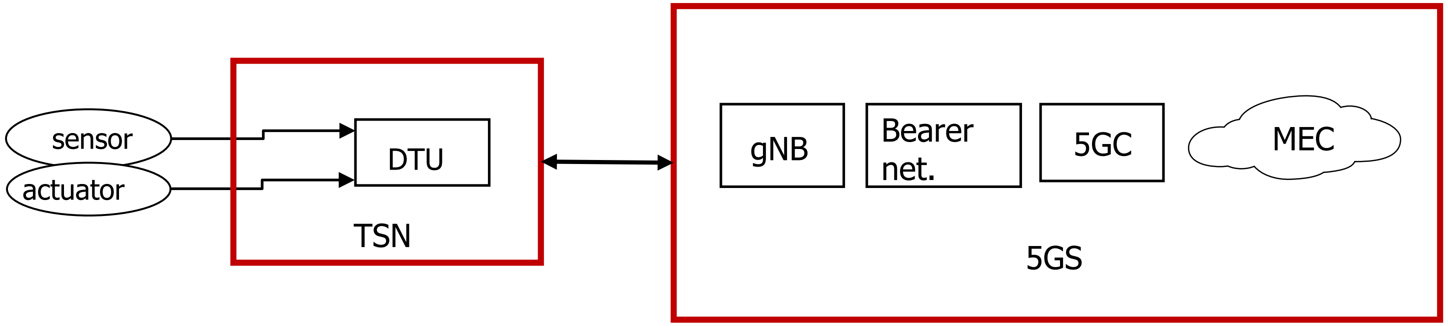
- “TSN-IP”： The **maximum service delay is always lower than the required delay** and the planned delay, ensuring the boundedness of the delay**. Differentiated delay guarantee effect among services**; In the case of background traffic congestion and instantaneous traffic burst, the upper delay bound can be guaranteed.
- Legacy DiffServ Network： In the case of background traffic congestion and sudden increase of services, **the delay values of all services are close**, and there is no guarantee of segmentation and differentiation among different services. In addition, packet loss occurs, and **some services cannot meet the required delay.**

Summary

Lessons learned:

- In actual industry applications, if industry customers cannot accurately describe their service characteristics, **"Traffic characteristics learning" provided by "TSN-IP" can automatically extract and learn traffic characteristics to obtain quantitative description of service traffic**, laying a foundation for service SLA guarantee.
- Under the condition of independent network light load, the "TSN-IP" can effectively **guarantee the upper bound of delay and bandwidth** for the identifiable traffic, **meet the different network requirements of different services in 5G carrier network**, and provide desired SLA guarantee.

Follow-up research direction:



Agenda

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Multiple TSN shapers coordination

Suggestion 1: Gradually update service provider network with TSN capable devices and make most advantages out of existing QoS/A-synchronized Profiles;

Profile	Shapers	Advantages	implementations
Synchronized	TAS/CQF	Low latency / Jitter control	New TAS Devices + gPTP
A-synchronized	ATS/TBS/Priority	Bounded latency	Existing QoS Devices
	mCQF	Bounded latency / Jitter control	N/A

Challenge 1: Network controlling tools need to support QoS/TSN resource calculation and provisioning.

Application areas

Latency Guaranteed

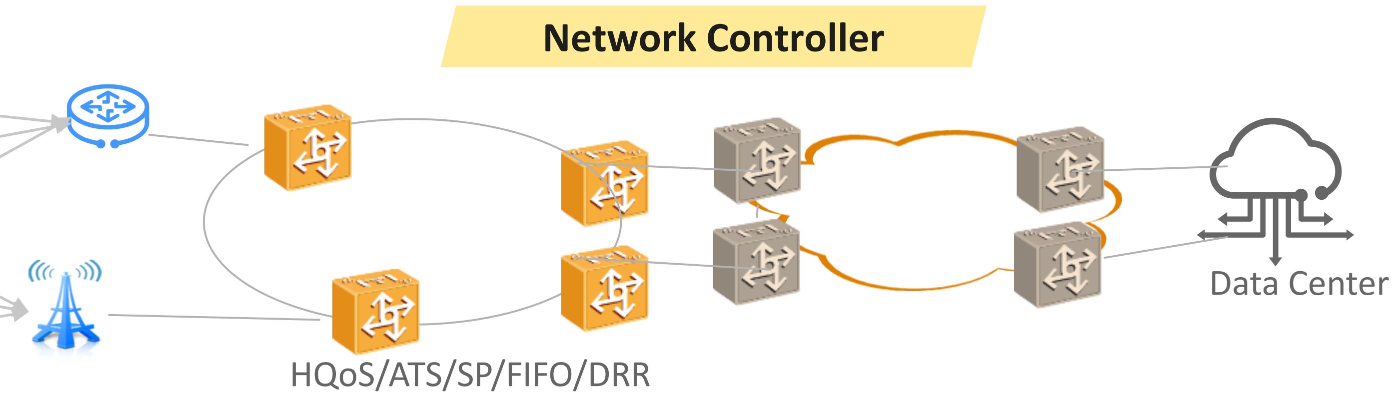
- Service 1 ~ 2ms
- Service 2 ~ 20ms

Bandwidth Guaranteed

- Service 3 ~ 20 Mbps
- Service 4 ~ 50 Mbps

Connection services

- Service 5
- Service 6



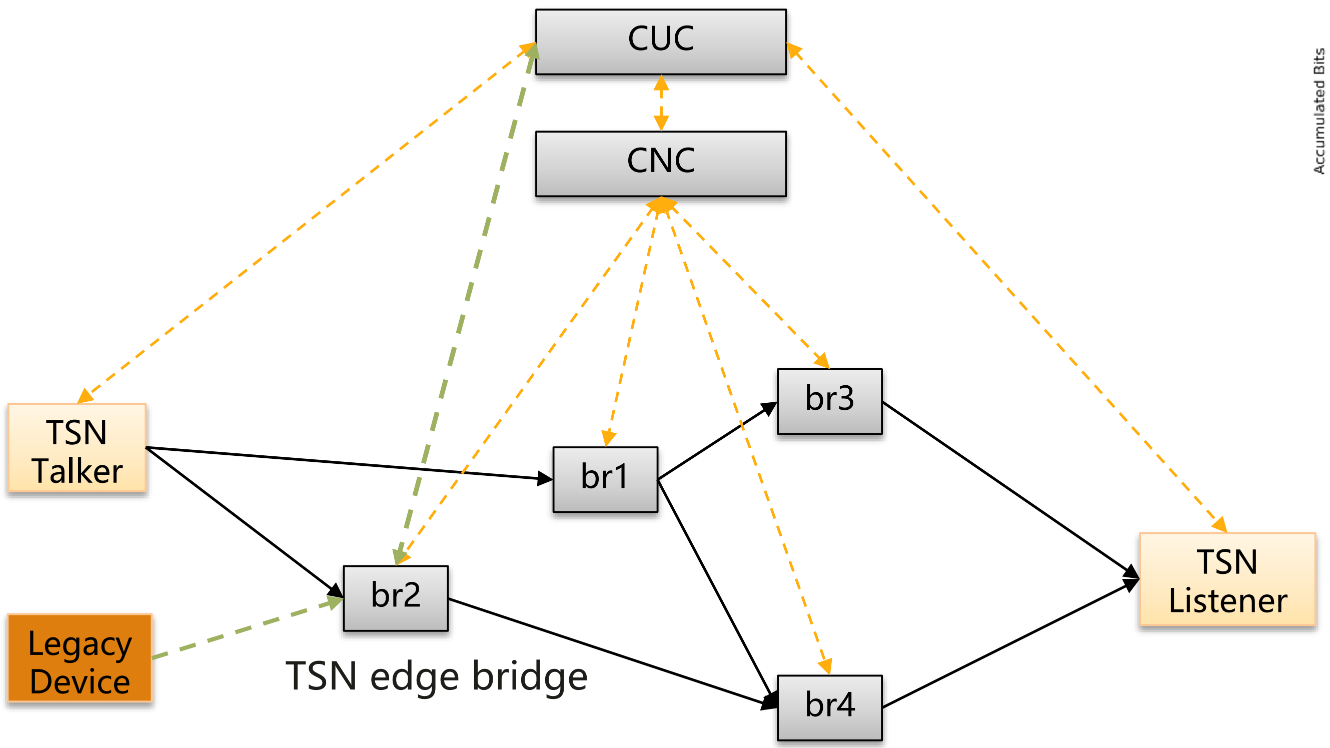
Capture traffic specification for performance management

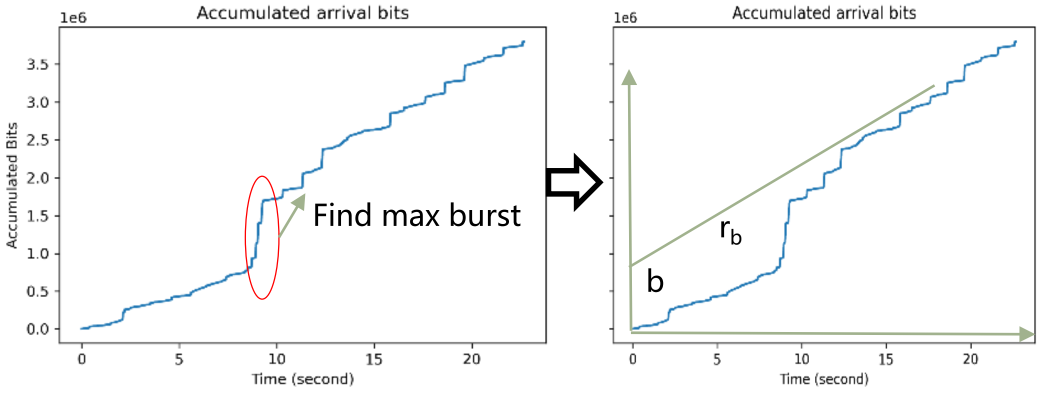
Suggestion 2: Traffic characteristic is key factor in network performance management. Either end stations announce its traffic characteristic or network devices learn/check traffic as "proxy" end stations.

TSPECs	Standard	Attributes	Applicable area
TSPEC 1	Defined in 802.1Q-2018 Clause 35.2.2.84 Tspec	MaxFrameSize, MaxIntervalFrames	Periodic traffics
TSPEC 2	Defined in 802.1Qdd D0.5 Clause 99.4.3.6 Talker Announce attribute	Committed rate Committed burst size	Bursty traffics
TSPEC 3	N/A	Distributions(normal, Poisson), variance, expected value , Modulated Markov process	Meeting/Surveillance Video traffics

Back Compatible TSN – Support Legacy Industrial End Stations

- TSN edge bridge learns traffic feature from legacy industrial devices and help setup TSN data path between legacy device and TSN listener as a proxy.



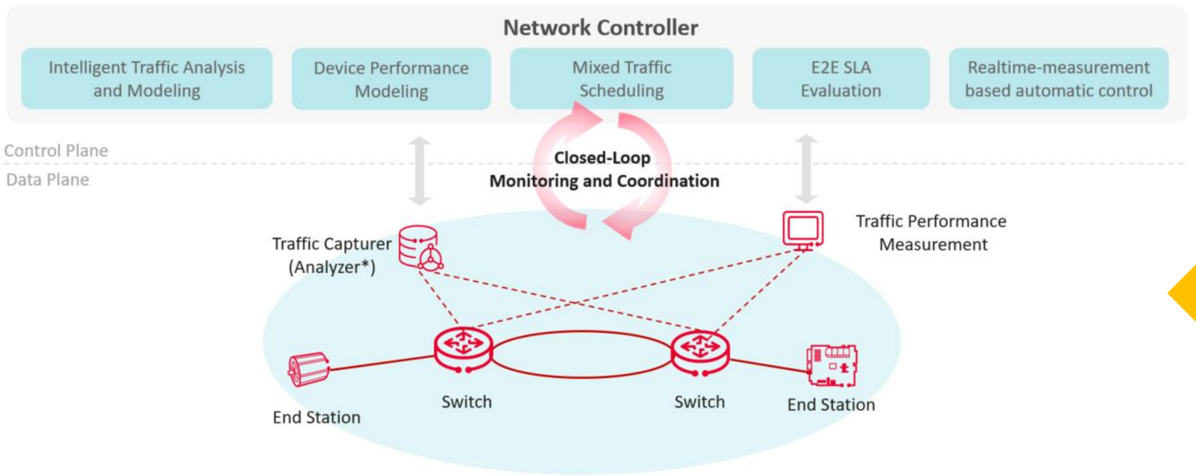


A traffic fitting example

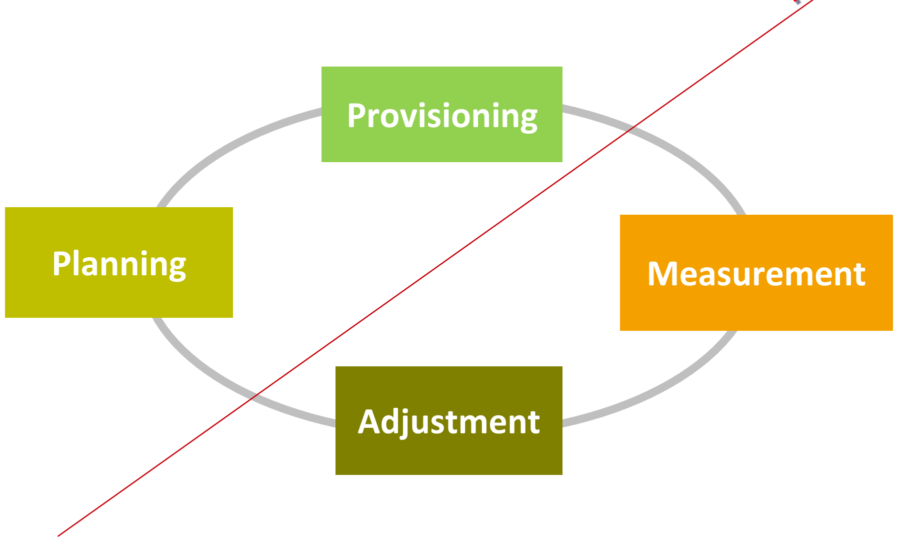
By netflow (RFC 3954) similar approach, TSN bridge could collect statistics for Layer 2 field, like MAC addresses, VLAN IDs and packet and byte counts, timestamps, Type of Service etc. , derive traffic specification in network device to check and learn traffic specifications from legacy end devices.

Closed-loop monitoring and coordination for time critical applications

- Differential Performance KPIs – Multiple levels of Latency, Jitter requirements
- Reliability – Packet Loss Ratio
- Robustness – Self adaptive on not-prefect real world exceptions (clocking shift, interference traffics)
- Evolution – Supporting gradually update existing QoS switch/router with TSN Switch/Routers
- Application driven networks – Coordinate with app-aware indicators



Defined in IEEE TSN



Closed-loop monitoring and coordination for critical applications (time sensitive, highly reliable services)

Thank you!

Test steps

Traffic construction according to traffic models

By test instrument

Traffic characteristics learning and configuration planning

On management & control system (network controller)

Configuration implementation to guarantee the SLA

On switches

Compare the effect of "TSN-IP" and traditional network

On management & control system (network controller)