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

Xueqin Jia, China Unicom
Tongtong Wang, Huawei Technologies

IEEE 802.1 TSN, March 2022
Agenda

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

<table>
<thead>
<tr>
<th>Services</th>
<th>Indicators</th>
<th>Measured data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E2E latency</td>
<td>Bandwidth</td>
</tr>
<tr>
<td>Control signal</td>
<td>20ms</td>
<td></td>
</tr>
<tr>
<td>Surveillance video</td>
<td>60ms</td>
<td>80Mbps</td>
</tr>
</tbody>
</table>
“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".
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.

<table>
<thead>
<tr>
<th>序号</th>
<th>Service</th>
<th>Traffic types</th>
<th>Packet length</th>
<th>Num. of packets per burst</th>
<th>Burst period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Smart grid</td>
<td>Differential protection</td>
<td>256 Byte</td>
<td>10</td>
<td>833us</td>
</tr>
<tr>
<td>2</td>
<td>Smart grid</td>
<td>Power distribution automation</td>
<td>Uplink:800 Byte Downlink:256 Byte</td>
<td>Uplink:10 Downlink: 10</td>
<td>Uplink: 40s Downlink: 40s</td>
</tr>
<tr>
<td>3</td>
<td>Smart port</td>
<td>Advanced measurement</td>
<td>250 Byte</td>
<td>10</td>
<td>40s</td>
</tr>
<tr>
<td>4</td>
<td>Smart port</td>
<td>Power transmission patrolling</td>
<td>1500 Byte</td>
<td>110</td>
<td>33,333ms</td>
</tr>
<tr>
<td>5</td>
<td>Smart port</td>
<td>Gantry crane_control signal</td>
<td>250 Byte</td>
<td>10</td>
<td>6ms</td>
</tr>
<tr>
<td>6</td>
<td>Smart port</td>
<td>Gantry crane_video</td>
<td>1500 Byte</td>
<td>110</td>
<td>33,333ms</td>
</tr>
<tr>
<td>7</td>
<td>Smart port</td>
<td>AGV_video</td>
<td>1500 Byte</td>
<td>110</td>
<td>33,333ms</td>
</tr>
<tr>
<td>8</td>
<td>Smart port</td>
<td>AGV_remote control</td>
<td>250Byte</td>
<td>10</td>
<td>40ms</td>
</tr>
<tr>
<td>9</td>
<td>Smart port</td>
<td>Video surveillance_single channel traffic</td>
<td>1500Byte</td>
<td>110</td>
<td>33,333ms</td>
</tr>
<tr>
<td>10</td>
<td>Factory automation</td>
<td>Motion control</td>
<td>40Byte</td>
<td>10</td>
<td>1ms</td>
</tr>
<tr>
<td>11</td>
<td>Factory automation</td>
<td>Controller to controller_large printing press</td>
<td>1024Byte</td>
<td>10</td>
<td>10ms</td>
</tr>
<tr>
<td>12</td>
<td>Factory automation</td>
<td>Controller to controller_assembly line</td>
<td>1024Byte</td>
<td>10</td>
<td>50ms</td>
</tr>
<tr>
<td>13</td>
<td>Factory automation</td>
<td>Mobile robot_motion control</td>
<td>250Byte</td>
<td>10</td>
<td>1ms</td>
</tr>
<tr>
<td>14</td>
<td>Factory automation</td>
<td>Mobile robot_machine control</td>
<td>250Byte</td>
<td>10</td>
<td>10ms</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>Mixed packet</td>
<td>800-1300Byte</td>
<td>10</td>
<td>10ms</td>
</tr>
</tbody>
</table>
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.

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.

Figure: business traffic feature extraction and modeling results
Configuration planning and implementation for SLA guarantee
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.

- **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.

---

**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.
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

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

<table>
<thead>
<tr>
<th>Profile</th>
<th>Shapers</th>
<th>Advantages</th>
<th>implementations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synchronized</td>
<td>TAS/CQF</td>
<td>Low latency / Jitter control</td>
<td>New TAS Devices + gPTP</td>
</tr>
<tr>
<td>A-synchronized</td>
<td>ATS/TBS/Priority</td>
<td>Bounded latency</td>
<td>Existing QoS Devices</td>
</tr>
<tr>
<td></td>
<td>mCQF</td>
<td>Bounded latency / Jitter control</td>
<td>N/A</td>
</tr>
</tbody>
</table>

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
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.

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

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

1. Traffic construction according to traffic models
   By test instrument
   Traffic characteristics learning and configuration planning
   On management & control system (network controller)

2. Configuration implementation to guarantee the SLA
   On switches

3. Compare the effect of "TSN-IP" and traditional network
   On management & control system (network controller)