Network Controller TSNLight Design Documentation

(V1.1)

OpenTSN Open Source Project Team

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Version history

Version	revision time	revision content	Revised file	ID
1.0	**2019.08**	Completed **TSNLight** Controller initial version of	Li Junshuai	**TSNLight1.0** controller
1.1	**2021.05**	**Update** on the version of **TSNLight** line revision, mainly to improve the format line modification	Li Junshuai	

content

1. Overview **of TSNLight**

1.1. Introduction

TSNLight is the control plane function of OpenTSN, which includes topology management,

Functions such as source management, stream management, scheduling management and state management are developed according to the core modules

The basic applications are TSNAnalyzer and TSNSTM.

1.2. Architecture and functions

The overall architecture of TSNLight can be divided into three parts, namely the core service layer, the communication library and the application

user application layer. Among them, in the core service layer, it includes basic modules and basic applications, basic modules

Blocks provide API services for basic applications, which rely on the core service layer and can also provide users with

The application layer provides services; the communication library provides communication between the basic application and the data plane and user applications.

Communication interface; the user application layer can only access the basic application layer through the northbound I/O communication library

The data cannot be accessed to the content of the core service layer.

The overall architecture of TSNLight is shown in the figure below.

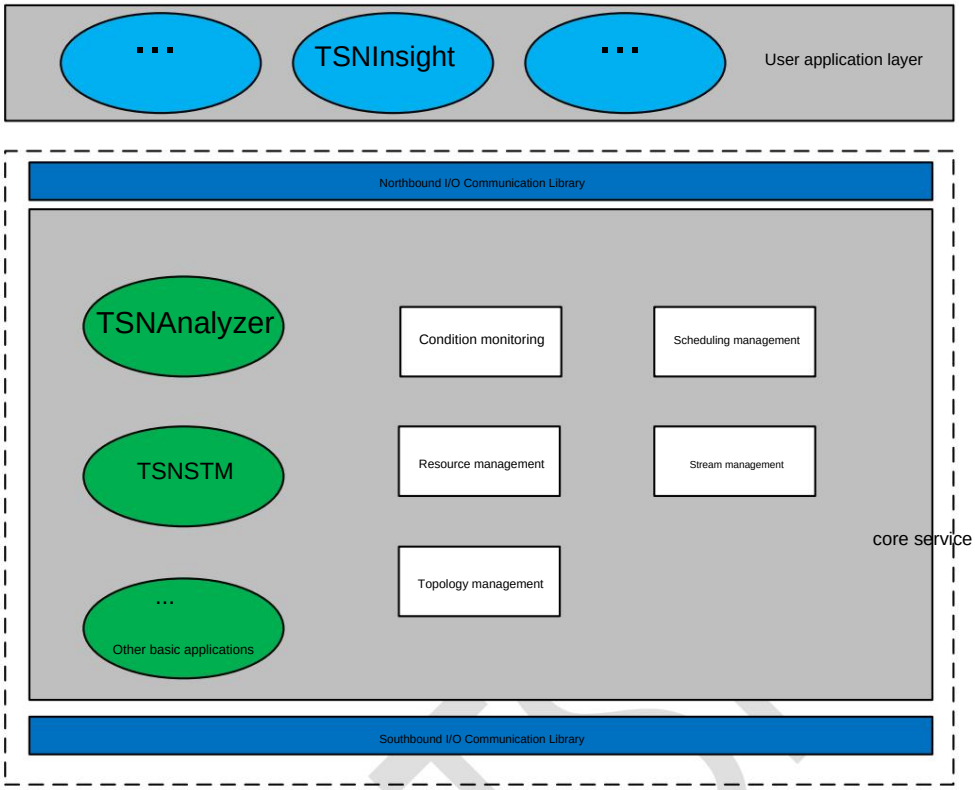

Figure 1-1 Overall architecture of TSNLight

The core service layer includes basic modules and basic applications. The basic modules are mainly used for basic

The application provides API services, including modules such as topology management, resource management, flow management,

Degree management and state management, the basic application includes two modules TSNSTM and TSNAnalyzer

Blocks, mainly for TSN switches and provide basic application services, such as configuring TSN switches

computer, analyze current network traffic, etc.

ÿ Resource management module: manage the bandwidth, queue length, control information, etc. of switching nodes

Resource information, providing APIs related to resource management. Used to initialize resources, provide

Status of resources and updates to resources.

ÿ Topology management module: manages the addresses, identification numbers and connections of switching nodes and end systems

Relationships and other information, and provide APIs related to topology management. Provides the state of the current topology, state

The monitoring judges the current state of all nodes according to the topology information.

ÿ Flow management module: manages the flow characteristics of resources that need to be reserved in the current TSN network,

It mainly includes time-sensitive flow and bandwidth-constrained flow, and provides APIs related to resource reservation. resource

The scheduling assignment obtains the current flow characteristics according to the resource reservation module.

ÿ Scheduling management module: According to global resources and topology information, the traffic of reserved resources is adjusted.

Currently, the offline mode is mainly used for pre-resource planning. supply

APIs related to resource scheduling. Calculate the optimal path through topology management and resource reservation, generate

into configuration information.

ÿ Status management module: monitor the current network status, such as time synchronization status,

Current network queue information, etc., and APIs related to status monitoring are provided. According to topology and received

The message judges the current network status of all switching nodes.

ÿ TSNSTM module: Static flow manager, based on the static way to TSN flow and

Non-TSN streams are managed and configured.

ÿ TSNAnalyzer module: Traffic analyzer, lightweight based on Beacon mechanism

Network information collection and management. At the same time, it also provides services for the user application layer, such as

TSNInsight provides accurate hardware timestamps of network status packets, etc.

The modules included in the communication library include the southbound communication I/O library and the northbound communication I/O library, which are used to control the

Communication between the control plane and data plane, control plane and user applications.

ÿ Southbound I/O communication library: used for communication with TSN switches and TSN controllers.

letter, which provides an API to communicate with the FPGA. Mainly used to exchange stanzas by sending messages

point to configure and receive messages to analyze the status. In basic applications, TSNSTM uses

Send messages to this module, and TSNAnalyzer is used to receive messages from this module.

ÿ Northbound I/O communication library: used for communication between the basic application layer and the user application layer,

Provides an API for communication between application layers. TSNAnalyzer is sent to the user application through this module

User layer network status information, including time synchronization and queue status.

The user application layer is mainly oriented to users and provides application services for users, such as visualization interface.

face and so on. Currently only the TSNInsight module is included. It can be further expanded in the future as needed.

ÿ TSNInsight module: a visual interface, which can display the current network synchronization status to users.

status information, flow feature information, TSN switch queue information, etc.

The topology diagram is shown in the figure below, in which TSNSTM and TSNInsight are implemented on the PC.

Now, TSN_Analyzer is implemented in openbox, and each switching node also uses openbox

accomplish.

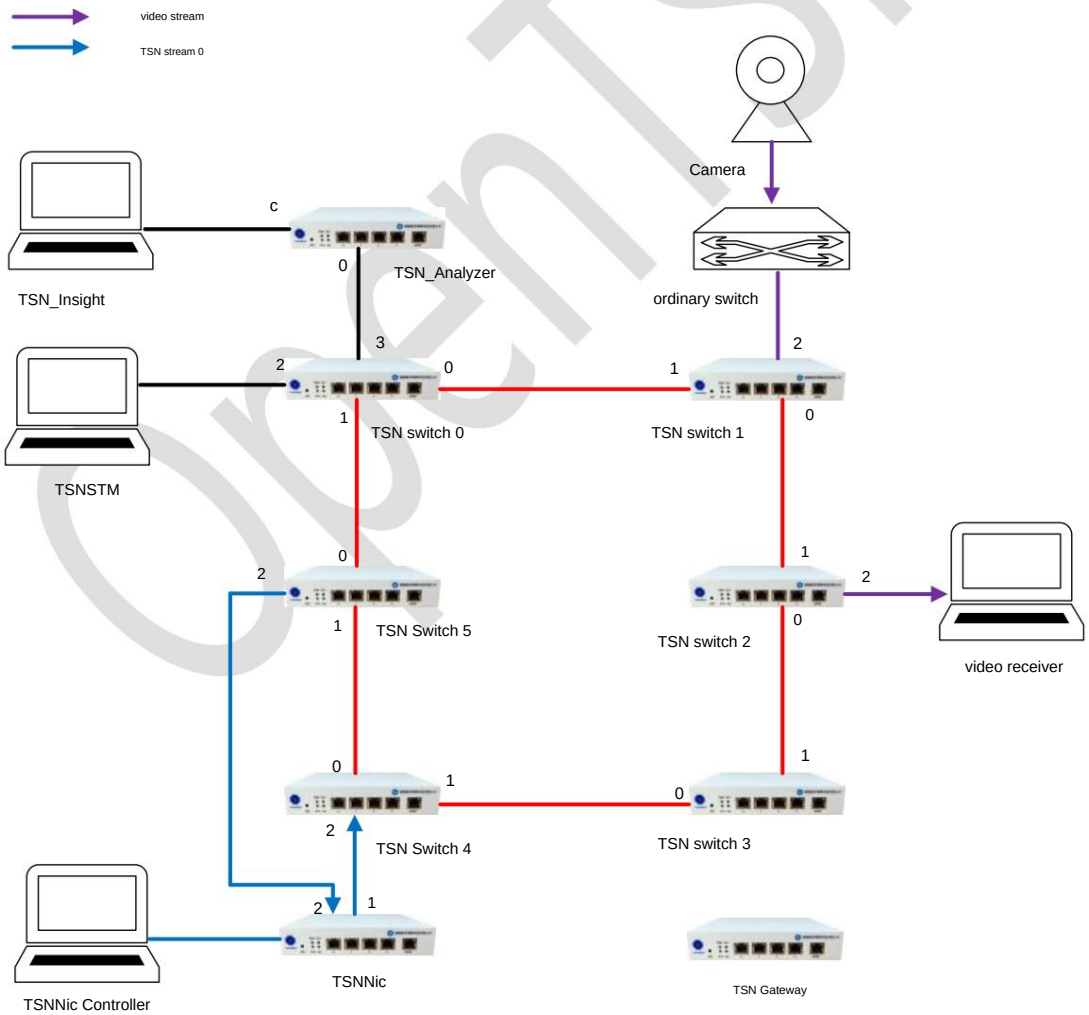

Figure 1-2 Network topology diagram

2. Basic modules of the core service layer

The relationship between each basic module and basic application in the core service layer is shown in the following figure.

The status monitoring module relies on the topology management module, the southbound I/O communication library module and the northbound I/O communication module.

letter library module. The state monitoring module obtains topology information from the topology management module and depends on the south direction

The I/O communication library module obtains PTP messages, and then generates status information via the northbound I/O communication library

The module is sent to the user application layer. The resource scheduling module depends on the resource reservation module and northbound I/O

The communication library module obtains the flow characteristics from the resource reservation module, and then passes the flow characteristics through the northbound I/O

The communication library module is sent to the user application layer.

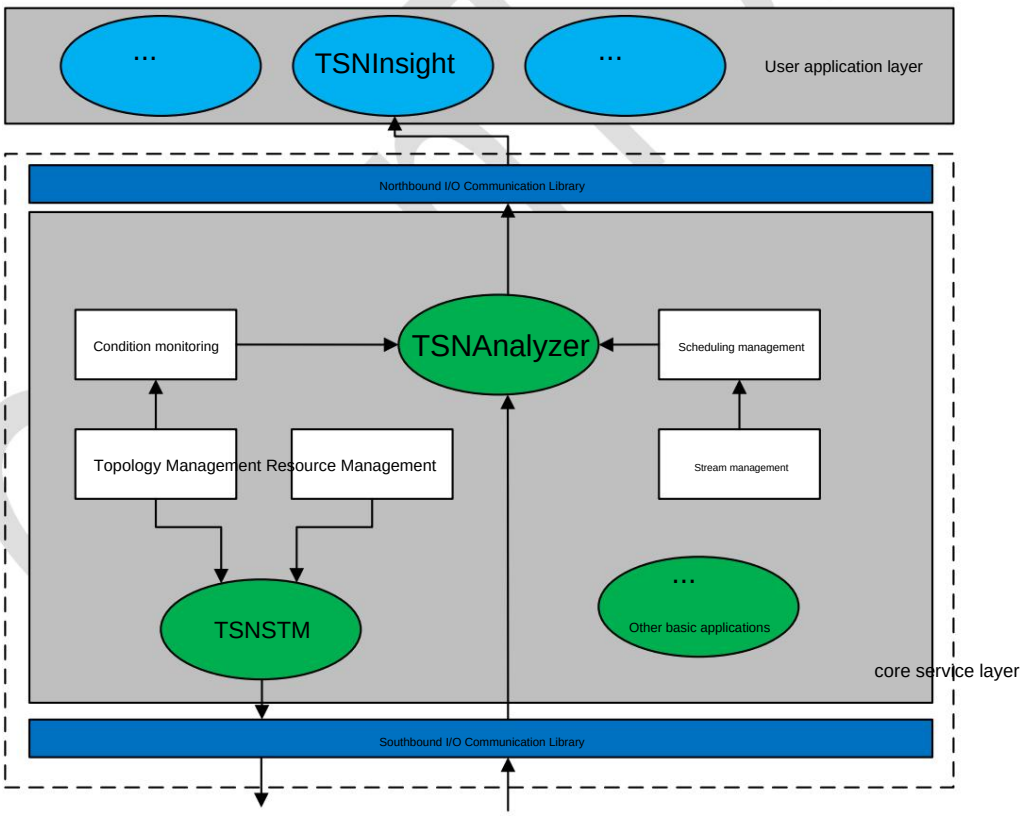

Figure 2-1 Relationship between modules

2.1 Topology Management Module

2.1.1 Functional Description

The topology management module mainly provides the switches and switches in the entire TSN network,

API for managing the connection relationship between switches and hosts. By using a doubly linked list

To save switch and end system properties and connection relationships, read text statically

Perform topology initialization. The APIs provided are topology initialization, insertion of switch nodes, master

It can modify the MAC address of the machine and obtain the properties of the switch node.

The data structure of the topology management module is also divided into ring and star mode, and star mode is more efficient than ring mode.

In the shape mode, the contents of the forwarding table and the TAP port are added.

2.2 Resource Management Module

2.2.1 Functional Description

Resource management is the management of schedulable resources for all TSN switch devices. TSN

The schedulable resources of the switch device mainly include bandwidth resources, CQF resources and current configuration

information, etc. The resource management operations mainly include resource initialization, acquisition of device resources,

Update device resources, update configuration information, etc. About the schedulable resources of the device and the

The management operations are described in detail as follows:

(1) Equipment resources: including bandwidth resources, CQF resources and current configuration information.

a) Bandwidth resources: Bandwidth resources are mainly used for bandwidth reservation traffic scheduling, but

It should be considered that TSN traffic also consumes bandwidth resources.

b) CQF resources: used for time-sensitive traffic to identify the usage of CQF queues.

c) Configuration information: used to save the configuration information of the current device. main direction

direction, token bucket rate tb_rate, token bucket bucket depth tb_B, and host's mac

Address, if it is a star topology, you need to configure the forwarding table.

(2) Resource management: It mainly includes resource initialization, acquisition of equipment resources, and update of equipment resources.

source, update configuration information.

a) Resource initialization: Initialize the resources of each device at the beginning, mainly

is to assign the total bandwidth and total CQF queue length.

b) Obtain device resources: obtain the current resource usage of the device.

c) Update device resources: Provide an interface for updating device resources, which can be accessed through bandwidth or

CQF changes to update the resource state of the current device.

d) Update configuration information: Provide an interface for updating configuration information, which can be based on the configuration information

changes to update the current configuration information.

The API provided by the resource management module mainly includes device resource initialization and bandwidth resource query.

query and update, CQF resource query and update, current configuration information update and other functions.

In a ring topology, there are 4 queues in each TSN switch node, where the first two

The first queue is the CQF queue, which is used to store the TSN flow; the third queue is the bandwidth reservation queue,

Used to store bandwidth reservation flow; the fourth queue is Best-effort queue, used to store Best

effort traffic. Scheduling resources include bandwidth resources and CQF resources

In a star topology, each switch node is divided into ports, and each port has

Four queues, the first two queues are CQF queues, the third queue is a bandwidth reservation queue,

The fourth queue is the Best-effort queue.

2.3 Stream Management Module

2.3.1 Functional Description

The main function of the flow management module is to read the characteristic information of the resource reservation flow and save it.

It mainly includes flow features.

Stream feature information is read statically through text, and then stored in the data structure, other modules

The block obtains the flow characteristic information by accessing the data structure, which facilitates the scheduling of the flow. in

The flow feature information includes two kinds of flows (time-sensitive flow and bandwidth reservation flow).

It contains characteristics such as mac address, priority, packet size, and delay. The bandwidth reservation flow is mainly

The included feature is the size of the reserved bandwidth.

The flow feature module mainly describes the characteristics of time-sensitive flow and bandwidth reservation flow, and the reservation management

The module mainly obtains the user's requirements for the flow by reading the document, and initializes the current resource preset.

Schedule.

2.4 Scheduling Management Module

2.4.1 Functional Description

The main function of the scheduling management module is to perform traffic flow according to the flow resource reservation table information.

Scheduling and resource allocation. It mainly includes path calculation, traffic sorting, time slot scheduling, bandwidth

There are five modules for scheduling and resource configuration.

The scheduling management module obtains the initial resources of the device according to the resource management, and schedules according to the resources

Get stream feature information. The workflow is to first calculate how each flow should be based on the flow characteristic information.

The best path traversed, generate path information, and then sort the flow according to the characteristics of the flow,

And schedule time-sensitive traffic according to the length of the CQF queue,

Finally, the switching nodes are configured and the global resources are updated.

(1) Path calculation module: calculate the path of each flow according to the topology and flow feature information switch path.

(2) Traffic sorting module: convect traffic according to conditions such as path, number of packets, bandwidth, etc. Sort by quantity.

(3) Time slot scheduling module: according to the available CQF queue length for each time slot Schedule TSN unicast streams.

(4) Bandwidth scheduling module: According to the available link bandwidth, the bandwidth reservation flow is schedule.

(5) Resource configuration module: It includes two functions: (1) According to resource scheduling Configure the switch and end system according to the configuration result; (2) Update the global resource data.

At present, only the flow characteristics are obtained through the scheduling management module, and then the flow characteristics are passed through The northbound I/O communication library is sent to the TSNInsight application.

2.5 State Management Module

2.5.1 Function description

The main function of state management is to detect network state, which is composed of state table and state management module. become.

The network status includes the time synchronization status and queue information of each switching node. through the pair The received PTP message is analyzed to obtain the synchronization state, and received in each round The message sent by the slave clock will be compared with the master clock reported by the round, so as to judge

In this round, the time deviation between the slave clock and the master clock is used to calculate the synchronization state of the network. queue letter

The information provides the queue status of each switching node at that moment.

The workflow of the state management module is to receive the PTP report sent by the southbound I/O communication library.

Then, according to the topology management module, it parses the PTP report reported by the corresponding switch.

Finally, the generated status information is sent to the user application through the southbound I/O communication library.

(1) Status table: maintain each round of PTP reports reported by hosts and switches through a singly linked list

Clock synchronization information and node status in the text.

(2) State management module: It mainly provides PTP message processing and state table traversal functions.

a) PTP message processing: The PTP message contains each TSN switch and TSN end system

The transparent clock accumulated by the system transmission packets. The header of the FAST packet containing the PTP packet contains

Receive timestamp. Each can be obtained by subtracting the received timestamp from the accumulated transparent clock

The sending time of the TSN node message. In addition, if a PTP packet reported by a node is received,

It means that the state of the node is the running state.

b) State table traversal function: traverse each node in the state table regularly, each round

If the received PTP message times out, the synchronization result of this round will be reported to the controller. every round

Report the number of packets equal to the number of switches received.

3. Communication library

The communication library includes the southbound communication I/O library and the northbound communication I/O library, of which the southbound communication I/O

The library is used for the communication between the basic application and the data plane, and the northbound communication I/O library is used for the basic application

Communication between the application and the user.

3.1 Southbound Communication I/O Library

3.1.1 Functional Description

The southbound communication I/O library mainly provides TSN controller and switch communication functions, including Southbound protocol message related APIs and message I/O operation related APIs are divided into two parts.

Southbound communication message I/O operation supports two communication methods, one is to use libnet to Execute the package libpcap for receiving, another way is to use the FAST lib library for receiving and Send message. Therefore, users can decide according to their own needs whether the running environment of the application is in the The PC side is still on the FAST platform. The current libnet construction and distribution used by the TSNSTM module To send messages, the running environment needs to be on the PC side, and the TSNAnalyzer module uses the FAST lib The library receives messages, and the running environment needs to be on the FAST platform.

The southbound protocol message uses the extended PTP message to carry the TSN controller to the TSN handover. Configuration information delivered by the switch and network status information collected.

The API provided by the southbound communication I/O library module mainly includes the construction and reception of PTP messages, Configure functions such as the end-system MAC address, switch transmission direction, and token bucket parameters.

There are currently two types of topologies, ring topology and star topology. The content is not the same, there are TAP function switches and forwarding tables in the star.

3.2 Northbound Communication I/O Library

3.2.1 Functional Description

The northbound I/O communication library mainly provides the communication function between the core service layer and the user application layer. Thus, the data of the control layer is presented to the user. Including APIs related to northbound protocol packets and northbound

APIs related to message I/O operations.

The implementation mechanism of northbound message I/O operation is based on the TCP socket communication method, providing The API has socket initialization, message sending and other functions.

Northbound protocol packets are encapsulated with JSON by using a custom Northbound packet structure. In the form of packet data, it carries network status clock synchronization information, flow feature information, traffic Switch queue information, etc. The provided API has functions such as constructing northbound packets.

4. Example application

For each module of the controller, multiple applications can be designed. The currently developed basic The basic application modules include TSNSTM and TSNAnalyzer two basic application modules and TSNInsight top-level application module.

4.1 TSNSTM Design

4.1.1 Overall Architecture

The currently designed TSNSTM only has the function of configuring the network, so it uses The module has three modules: global resource management, topology management and southbound communication IO library.

TSNSTM analyzes the topology in the network according to the topology management module, and can give the network The switch in the switch assigns the mac address of the host connected to the switch for traffic forwarding. and Obtain the global resource status according to the global resource management, so as to configure the switches in the network resource information. All configuration functions need to be sent to the network through southbound communication IO, The currently used southbound communication IO uses libnet to send packets. The specific functions of each module See detailed module design.

The structure diagram of TSNSTM is shown below, in which the green part is used by TSNSTM

to the module.

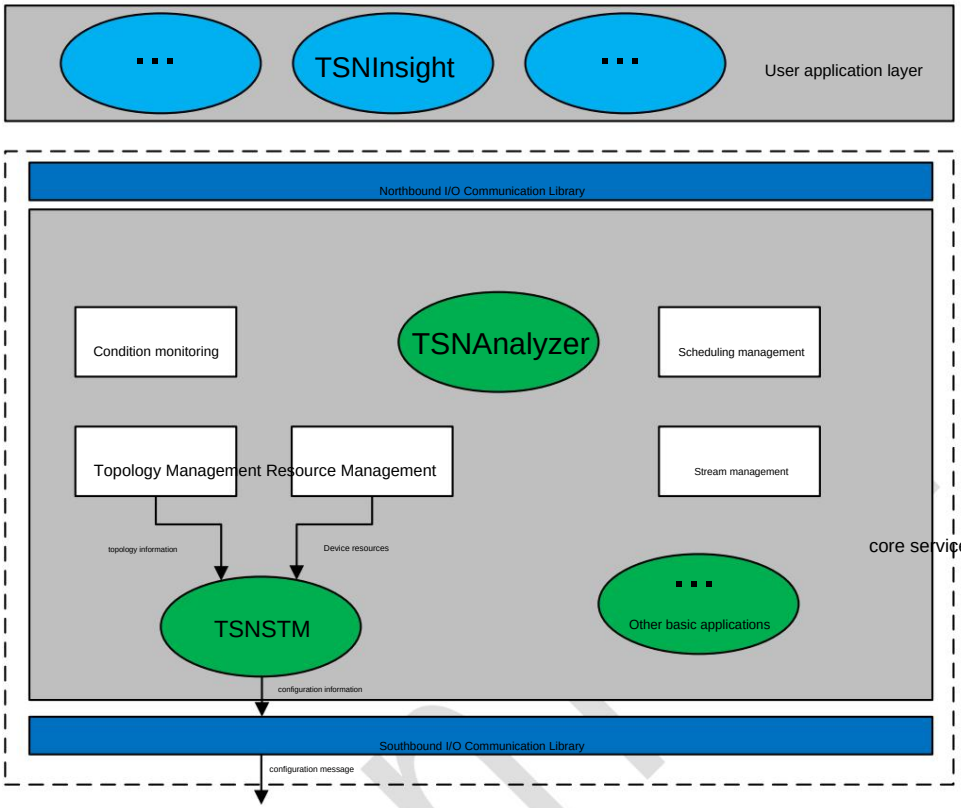

Figure 4-1 TSNSTM structure diagram

At present, the main modules used by TSNSTM are resource management, topology management and southbound I/O.

The communication library module, in which the status of the device resources is obtained in the resource management module, such as obtaining the device

The transmission direction of the backup device, the bucket depth of the token bucket, the rate at which the token is generated, and the size of the time slot, etc.

Obtain topology information in the network in topology management to configure all switching nodes,

Then, the configuration information is generated according to the resource scheduling allocation module, through the southbound I/O communication library module

Generate a PTP message, mainly fill in the content of the configuration field, and then send it to the

in the network.

4.2 TSNAnalyzer Design

4.2.1 Overall Architecture

TSNAnalyzer is a traffic analyzer, mainly used to analyze traffic, including time traffic and other traffic to synchronize information between. The main function currently implemented is the time synchronization The traffic is analyzed, and the switching node sends a message to the TSNAnalyzer at the same time, through the Timestamps of received packets in TSNAnalyzer to calculate their arrival time, then Then analyze the time deviation between each slave clock and the master clock according to the transparent clock. state, the current synchronization state can reach below 50ns.

The overall block diagram is shown in the following figure

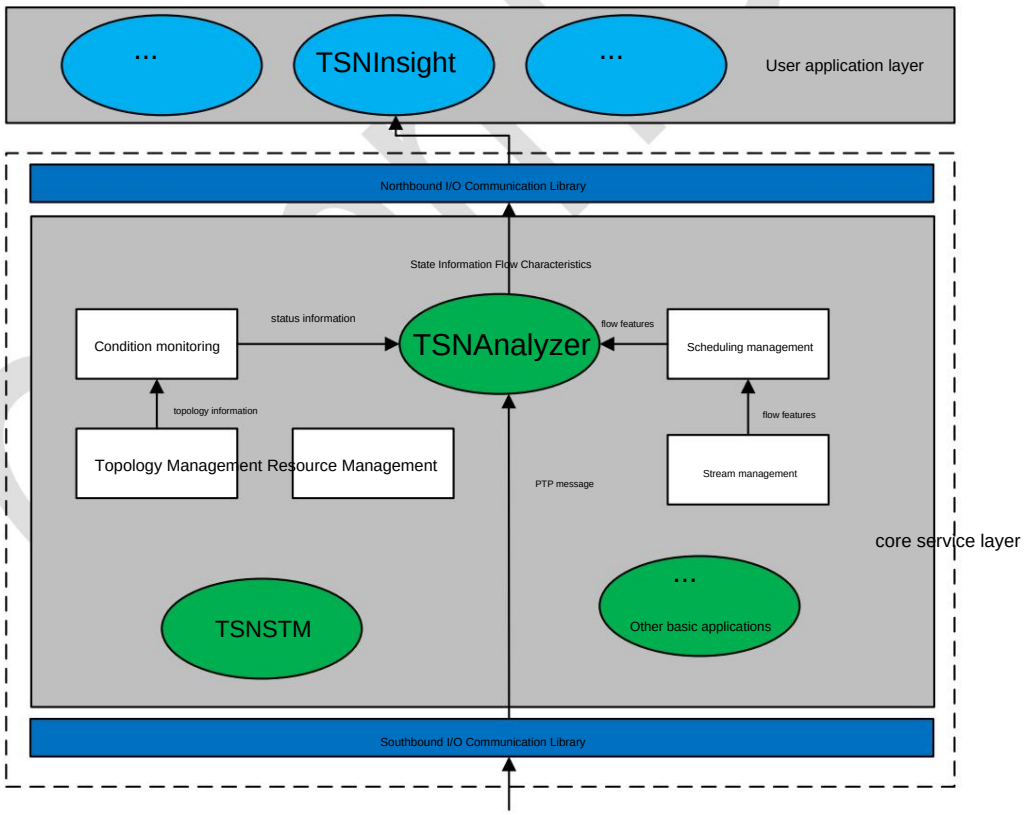

Figure 4-2 TSNAnalyzer structure diagram

Among them, in TSNAnalyzer, the modules used include the southbound I/O communication library, Source scheduling allocation, topology management, resource management, resource reservation, status monitoring, and northbound I/O

Communication library module. Among them, the message is received in FAST through the southbound I/O communication library, and the

The callback function of the receiving thread UA is processed, and it is analyzed whether it is a PTP message or other message.

The PTP message is parsed by the state monitoring module, and then analyzed according to the topology management module.

The status of the outgoing network is then sent to the visualization application through the northbound I/O communication library. resource

The scheduling allocation module can read the flow characteristics from the resource reservation module, and obtain it in the resource management module

The current resource status, and then the allocation scheduling (currently this part has not been implemented, only in the resource

The source scheduling allocation module obtains the flow characteristic information, and then transmits the flow characteristic information through the northbound I/O communication.

information base to the visualization application).

4.3 TSNInsight Design

TSNInsight is to display the synchronization status, that is, part of the user application layer.

Communicate with this part through the northbound communication I/O library of the control part to obtain the network status (same as the

step status and queue information).

The main function of TSNInsight is to display, according to the

Status information is displayed on the interface by using Qt. The main information displayed is static

Display, including topology information and flow feature information, dynamic display including global clock synchronization and

Switch queue information.

4.3.1 Overall Architecture

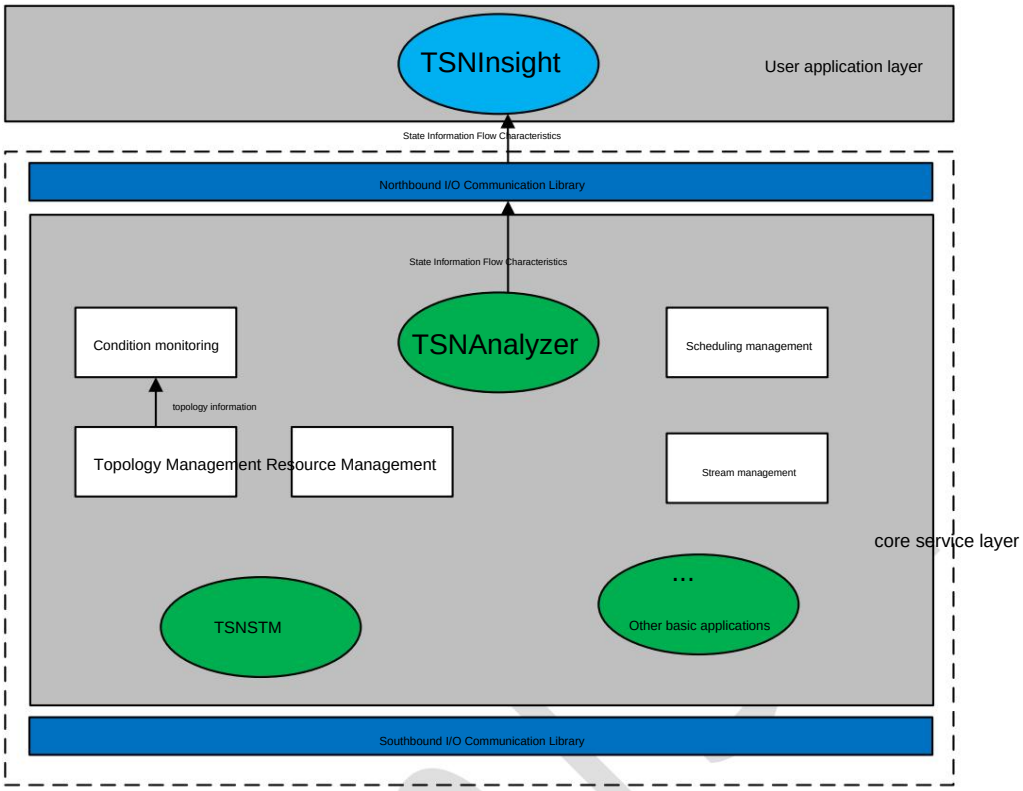

Figure 4-3 TSNInsight structure diagram

The overall architecture of TSNInsight is shown in the figure above, in which TSNInsight is mainly

Obtain the information of TSNAnalyzer in the basic application layer from the I/O communication library, including network status

information and flow characteristic information, among which the network status includes clock synchronization status and queue information, which can

It reflects whether the network is synchronized or not, and the information of the queue usage.

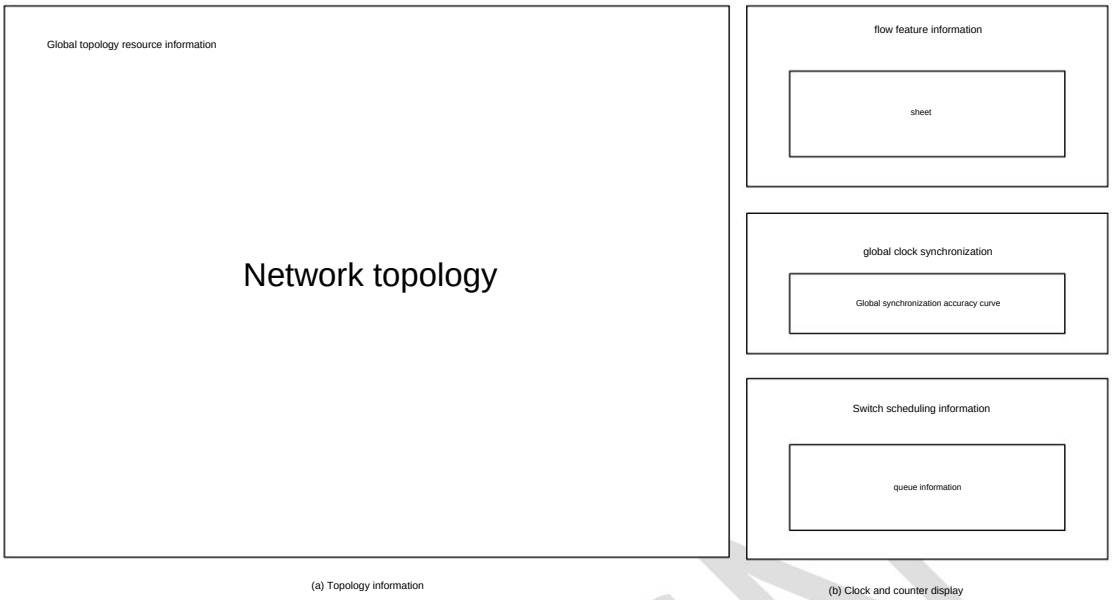

Figure 4-4 Display effect

Figure a shows the topology information, showing the sw_id of the switch, and the host connected to the switch type, resource information includes CQF queues, bandwidth resources, etc., and displays the global time The deviation of synchronization and the deviation of each switching node from the master clock.

Figure b shows the flow characteristics information, including the flow characteristics of TSN flow and bandwidth reservation flow, The source MAC, destination MAC, etc. are shown respectively, and the TSN flow also includes the time period, The maximum delay, etc., the bandwidth reservation flow includes the resources that occupy the bandwidth; the global clock synchronization shows The difference between each switching node and the master clock is displayed in the form of dynamic polylines, and Also shows the polyline of the maximum deviation from the master clock; the switch scheduling information shows the individual teams The usage of the column, each exchange node in the ring has only four queues, and the star is based on the end-to-end The ports are divided, and each port has four queues.