Design and Implementation of Power Communication System SDH Network Simulation Tool Based on EXATA

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Abstract. The power communication system based on synchronous digital hierarchy(SDH) optical transmission technology is an important component to ensure the safety and stability of power network. After years of development, the network has been gradually mature, but it still has many problems, such as the weak structure of the communication network, insufficient network transmission capacity, weak network access and network management. Therefore, it is necessary to do the research and take simulation for the power communication system based on SDH optical transmission technology. The paper builds up the simulation platform of SDH network in power communication system based on the EXATA simulation tools. For SDH device, we implemented functions including multiplexing, demultiplexing and digital cross-connection. And the simulation analysis provides a great theoretical support for constructing equipment models and network topology.

1 INTRODUCTION

Power communication network is the second physical network of modern power network[1]. It is an important infrastructure of power network and an imperative part of power network security[2]. With the increasing complexity of links and the diversity of services, the network's planning and design on experience alone can no longer meet the requirements of the network development. Therefore, a simulation tool is urgently needed for better planning of the communication network. The simulation tool can provide objective and reliable analysis for the network's planning. However, most of existing simulation tools lack the functions of network's planning and data analysis, or they cannot be aimed at the optical transport network scenarios. It is imperative to design a stable and mature power communication simulation tool.

At present, SDH is relatively a mature power communication technology applied in China. SDH optical transmission network has high survive ability, good isolation and recovery capability [3]. It's effective for supporting power communications service.

In this paper, we design a SDH optical transmission network simulation tool for power communication network [4-6]. Referring to (ITU) standards G.707[7], G.783[8], G.784[9]and G.803[10], we implement functions including multiplexing, demultiplexing and

digital cross-connection in SDH device, which is supported by EXATA network simulation tool.

The significance of research SDH network simulation platform is mainly as follows: To analyse and mark the communication network by the research and use of simulation tool; To help operators and maintenance personnel to analyze the causes of network failures and phenomena by the simulation of the tool; Test the new equipment before accessing the grid.

2 Networksimulation technologies

Fig. 1. SDH transmission architecture

The networking technology of SDH is an approach for using SDH infrastructure to provide data services [11-12]. The main block diagram for typical SDH transmission architecture is shown in the figure 1, which is composed with transmitter, terminal multiplexer(TM).

Add/drop multiplexer(ADM), re-generator(REG), digital cross connect(DXC) and receiver. This section will mainly present the delay architecture of network, SDH network elements simulation and the Ethernet over SDH.

2.1 The delay of SDH transmission network

In this paper, we realize a delay measurement from end to end. The end-to-end delay is a one-way delay experienced by packets from transmitter to receiver across SDH transmission network and provides the most basic information regarding the delay performance of the SDH network.

As described in the section, the end-to-end delay is typically composed of four components[13]. According to the SDH transmission architecture, the notations required in the description of the SDH delay calculation formula are defined first as:

t_q : Conversion Delay—dependent upon the optical and electrical signals conversion process, the common optical interface conversion delay is $t_q=5\mu s$;

t_y : Mapping Delay—represent the optical port delay of different 2M to “STM-N”, the common optical interface mapping delay is $t_y=500\mu s$;

t_z : Straight-through Delay—represent the optical port delay of “STM-N” to “STM-N”, the common optical interface straight-through delay is $t_z=300\mu s$;

t_l : Fiber Propagation Delay—dependent upon the fiber span length and speed of light in the fiber, the fiber propagation delay t_l can be calculated from equation(1).

$$t_l = \frac{Ln_1}{c} \quad (1)$$

where L is the length of fiber, n_1 is refractive index of fiber core, commonly optical cable is G.652 cable and $n_1 = 1.48$, C is Light speed and $C = 3 \times 10^5 \text{ km/s}$. So $t_l = 0.005 \text{ ms/km}$.

And can define the SDH delay calculation formula as follows:

$$t = t_l + 2 \times t_y + n \times t_z + 2 \times t_q \quad (2)$$

SDH Network Elements Simulation

SDH transmission network is composed of different types of network elements. The main functions of TM, ADM, and DXC are the multiplexing, demultiplexing and digital cross-connect. Since the REG completes the physical signal enhancement, we perform only the corresponding delay processing and transparent transmission in the simulation process. The most important task of the simulation platform is to design each network element is how to achieve the multiplexing, demultiplexing and digital cross-connect[14].

2.1.1 The realization of multiplexing function

The low-speed line signal is multiplexed to the high-speed line signal, which needs to be mapped, positioned and multiplexed in three steps.

Fig.2 shows how to combine multiple services onto the STM trunk. This is the example of a E1 (2Mbit/s) service in China.

Fig. 2. Multiplexing structure in China flow chart

The multiplexing process is as follows:

The E1 frame is placed into a C-12 Container.

A Path overhead is added and it becomes a VC2 Virtual Container.

Multiple VC-12s are assigned Pointers and become a TUG-2 Tributary Unit Group. The pointers indicate the location of the first byte of each of the Virtual Containers.

Seven of these “TUGs” can be Mapped into a VC3 Virtual Container.

Multiple VC-3 Virtual Containers will be assigned Pointers and placed into an AUG Administration User Group.

And the AUG will be placed in the STM Frame. The Pointers are used to locate individual 2 meg streams in the STM Frame

In order to simulate this process, this paper designs the flow chart when the program works, as shown in Fig.3.

Fig. 3. Multiplexed flow chart

2.1.2 The realization of demultiplexing function

To demultiplex high-speed line signals to low-speed line signals, it is necessary to analyze the rates before and after demultiplexing and decompose the low-speed signals according to the interpolation rules when multiplexing. Demultiplexing is the inverse of multiplexing. In order to simulate this process, the low-speed signal packets sent to the next node as shown in Fig.4.

Fig. 4. Demultiplexing flow chart

2.1.3 Digital cross-connect function to achieve

The digital cross-connect function converts the rate of the input signal to the rate of the output port. Therefore, after receiving the data packet, it needs to determine whether it needs to perform rate conversion or not, and directly go to the multiplexing program. This function achieves the multiplexing process from “STM-m” to “STM-n” ($m < n$). In order to simulate this process, this paper designs a flowchart of the program, as shown in Fig.5.

Fig. 5. Digital cross-connect flow chart

2.2 EoS (Ethernet Over SDH)

In view of the rapid growth of data services, the traditional SDH system urgently needs to expand IP services. The Ethernet over SDH (EoS) is a more realistic and efficient method of IP delivery and has become the focus of technical research rapidly.

Here is the implementation of EoS based on GFP protocol[15]. GFP aims to improve device interactive ability and improve mapping performance with a low-complexity adaptation mechanism. The goal is to standardize the mapping process as a synchronization technique. Firstly, Ethernet frames transmitted in the local area network are encapsulated into GFP frames (standardized in ITUT recommendation G.7041/Y.1303 [16]). The process includes the following steps:

- Receive Ethernet MAC frame, and calculate the length;
- Determine the value of the PLI field in the GFP header and generate the corresponding HEC byte;
- Determine the value of the Type field and its corresponding HEC byte ;
- Determine the value of each item in the Extension Header;

All bytes after the SFD (Start Frame Delimiter) are used as GFP payloads in the Ethernet MAC frame ;

X43 + 1 polynomial scrambling code is applied to the static payload of GFP (including Payload Header) [17].

Secondly, the GFP frames are mapped into SDH frames that can be transmitted between SDH devices, then point-to-point transmission is performed through the SDH transmission lines[18].

3 Simulation results

This section presents results from an experimental performance evaluation of EoS services scenarios. Figure

3.1 gives the structure of the wide-area stability control system. In the wide-area stability control system, a wide-area measurement system (WAMS) consists of three main parts: Phasor Measurement Unit (PMU), Phasor Data Concentrator (PDC), and communication system. A PDC gathers data from several PMUs and rejects bad data. Communication system of WAMS is responsible for data delivery between PMUs and a PDC or multiple PDCs. The WAMS not only monitors the operation status of the power network in real-time, but also meets the requirements of wide area in space and synchronization in time. Sub-stations communicate through the already built SDH and EoS network directly. Firstly, it accesses to the provincial master station, then accesses to the core network. The whole structure of the system is flat and hierarchical that can greatly reduce the delay time.

After single point fault detection or multiple-point fault detection, PMU communicates through SDH and EoS in uplink transmission, transmitting the fault information to the dispatch center. Dispatch center locates and analyzes the fault, then it issues control order to the executive master station. The executive master station implements an operation for failure recovery then cuts off the faulty link eventually to maintain the stability of the entire wide-area system.

Fig. 6. The structure of wide-area stability control system based on SDH and EoS

This paper uses software called EXATA to build the simulation system. The EXATA communications simulation platform is a network emulator. It uses a software virtual network (SVN) to digitally represent the entire network, the various protocol layers, antennas, and devices. The following operations are the simulation process:

Configure each node model including the internal node type and the network topology of the network in detail.

Configure link properties like bandwidth, delay and packet loss rate.

Customize simulation time, specify file name and generate EXATA scene simulation file.

Start the simulation platform.

The statistical display module reads the configuration parameters and shows the services scene topology. The module displays the services delay, delay jitters and packet loss rate.

According to the actual situation, adjust the link delay and bit error rate as well as the data transmission rate of the switching device port.

Get status information of network.

Here is the simulation results as shown in table 1.

Table 1. Simulation results

EoS Services Application	Delay(ms)	Delay Jitters(ns)	Packet Loss Rate
1	0.537	70.93	0
2	1.975	82.11	0.09
3	4.413	70.76	0.17
4	1.975	56.00	0.09
5	5.350	51.44	0.09
6	3.100	40.56	0.09
7	7.600	49.33	0.09
8	4.380	62.89	0.09
9	4.225	96.11	0.09
10	5.350	91.44	0.09

4 Conclusions

This paper comes up with a new design proposal of SDH optical transmission network simulation platform for power communication network. This system realizes the simulation, statistics display and other multi-module information highly integrated, shared, simulation dynamic visualization. Flexible operation and easy to set up an operation, fundamentally improved the working efficiency and technical level of the power operators. It provides a convenient tool for the safety and reliable operation of power communication network, which has good social and economic benefits.

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