Time transfer characteristics of a WDM-SDH-Based ATM System

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ABSTRACT

NTT will realize a time synchronization network in a new system that provides ATM (Asynchronous Transfer Mode) services. The system transfers ATM cells via SDH (Synchronous Digital Hierarchy) frames that are transmitted over WDM (Wavelength Division Multiplexing) networks. We have finished the initial measurement of the basic characteristics of the system in an experimental environment, and have started a field test, whose purpose is to collect realistic system reliability data for a couple of months. This paper describes time keeping systems in the new ATM network, some initial measurement results such as the time path switching algorithm and its influence on time accuracy, and the time accuracy and stability of the system in the field.

Keywords: time transfer, time synchronization, WDM and SDH

1. INTRODUCTION

NTT is introducing a WDM-SDH based ATM network[1]. The network provides a broadband ATM service that supports conventional interfaces and IP system services. ATM allows highly developed management functions for the network, for itself, and for individual channels. One of the keys to these ATM features is time. ATM systems depend on the reference time synchronized throughout the network to achieve multiple services as ATM connections can be set and released at specified times. The target time accuracy of the referenced time in ATM systems is of the order of microseconds. The most important thing in this category is to hold the desired stability very reliably.

Reference time is transferred to each ATM node as well as reference frequency, and is kept and maintained by new time keeping systems in the ATM network. The kept time is distributed to each function block in the ATM system, so reference time is shared by all functions. We have finished the initial measurements of the basic characteristics of the reference time in an experimental environment, and have started a field test, whose purpose is to collect system reliability data in the field over the period of a few months. The initial test checked time accuracy and time deviation in a simple master-slave configuration of the system. The final field test is to confirm time transfer stability in the multi-linked system configuration that mirrors the actual planned network.

This paper describes time keeping systems in the new ATM network, some initial measurement results such as the time path switching algorithm and its influence on time accuracy, and the time accuracy and stability of the system as discovered in the field.

2. NETWORK CONFIGURATION

The new ATM network consists of three layers: WDM network layer, ATM network layer, and access network layer. Figure 1 shows the total network configuration for the new NTT service. The WDM network layer is a long-haul transmission network based on WDM techniques. The WDM termination points have 2.5Gb/s channel multiplexing and demultiplexing functions. 2.5Gb/s channels within the WDM network layer transfer reference time signals and time information. The ATM network layer is composed of ATM cross-connect systems. Time keeping systems are installed in ATM cross-connect systems. Time is maintained by the SEMF (Synchronous Equipment Management Function) of the ATM cross-connect systems.

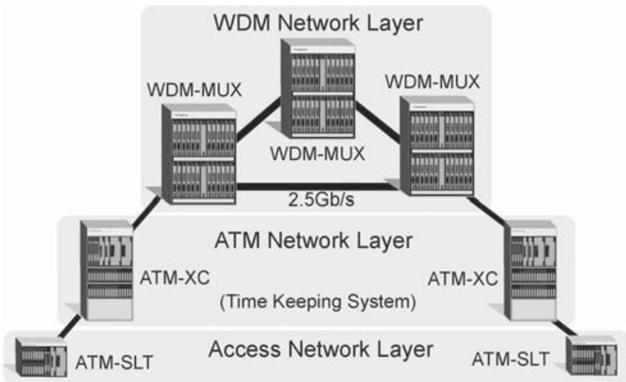

Fig.1-Network configuration for the new service

3. TIME TRANSFER NETWORK

The ATM cross connect systems are connected in a ring network. However the time transfer network is topologically neither a typical star nor a tree-structured master-slave. A ring consists of several ATM cross connect systems, one of which becomes the master node. ATM cross connect A is the master in Fig. 2. The time of the master node is transferred from node to node. One of benefits from the ring configuration is that two time transfer paths can be used; clockwise and counterclockwise. They are called primary and secondary paths. One ring uses both directions for time synchronization without exception to ensure time transfer reliability. Normally the primary path has priority. The time transfer route is node A, C, D, and B in the first ring of Fig. 2. If the primary path fails, the secondary path is used. The time transfer route would then be A, B, D and C. Adjacent rings contact and share some ATM cross connect systems. ATM cross connects C and D are shared by two rings in Fig. 2. In the second ring, the time transfer route is C, F and E in the primary path. All nodes are connected in this manner, and the total network is composed of multiple rings.

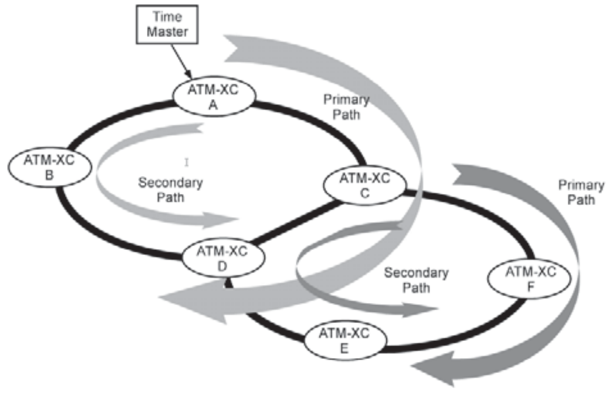

Fig. 2 - Time transfer Network

4. TIME KEEPING AND MANAGEMENT SYSTEM

Each ATM cross connect system uses its internal management function to keep the reference time as shown in Fig. 3. This function offers redundancy since reliability is the most important attribute in time management. ATM cross connect systems can receive reference signals from three networks; the frequency synchronization network, the time synchronization network, and the NTP network. This enables the three kinds of time to be independent and to be independently managed. Time is kept by 6 internal clocks called RTCs(Real Time Clocks). In this configuration, the failure of one type of time does not influence the others, and fault location and system switching can be achieved without interruption.

Reference frequency, which is distributed in the frequency synchronization network, is a basic clock that is used as the time clock for RTC. RTC time is adjusted against the time information from the time synchronization network. Reference frequency is supplied from the external equipment generally called BITS or SANE. BITS can hold reference frequency to within 10^{-12}, even if the reference frequency network fails. Therefore, reference frequency is highly reliable and stable. Even if the time information fails, RTC time in the ATM cross connect system can be kept to within the nanosecond level by these reliable time clocks. NTP is used to backup the reference time network. The NTP network is modified to make the transmission delay constant. This yields maximum time accuracy.

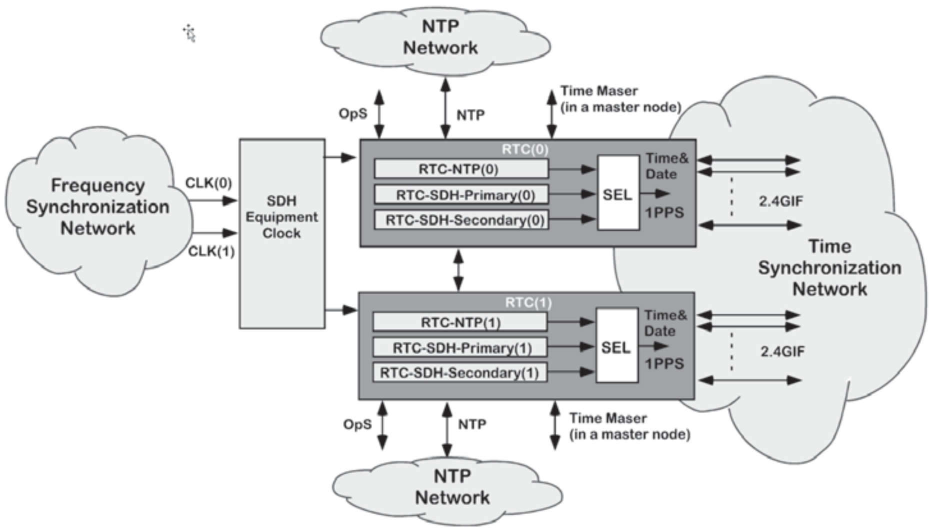

Fig. 3 - Time keeping and management system in ATM-XC

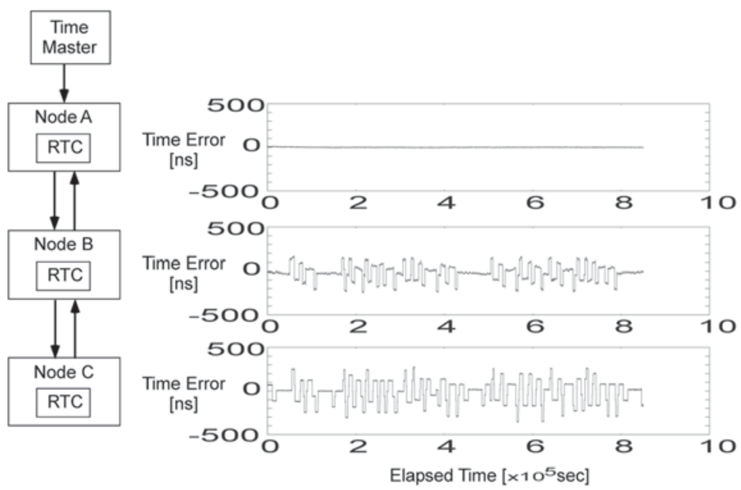

Fig. 4 - Time Stability in a chain of nodes

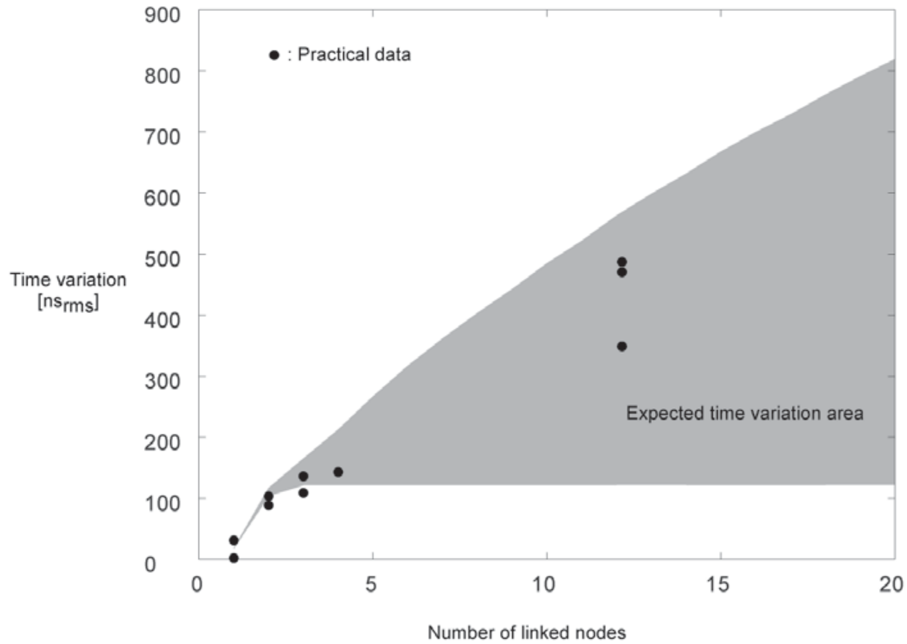

Fig. 5 - Time variation estimation and experimental data

5. TIME ACCURACY AND STABILITY OF CHAIN OF NODES

Reference time is transferred node by node. A detailed evaluation of time performance is important in a chain of nodes, since time errors such as time control resolution accumulate with this topology. Figure 4 shows the time stability as measured at the outputs of three nodes connected in a ring network. The top plot in Fig. 4 shows the master node time stability. The middle plot shows that of the second node directly linked to the master node. The bottom plot is for the third node. Time control resolution is 61ns, so time variation is of the order of hundreds of nanoseconds. The time variation increases with the number of links. The variation of the third node is slightly larger than that of the second node.

Figure 5 shows the time variation expected versus the number of nodes. Black circles plot the data measured in experimental networks. The shaded area indicates the expected time variation. The top line includes the influence of system clock deviation. Ignoring this deviation yields the bottom line. This means that each time clock is perfectly synchronized to the system clock. We expect that the maximum number of nodes so linked will be about 20. Accordingly, normally time variation is expected to be around 600ns.

6. PATH SWITHCING INFLUENCE

An initial measurement test was conducted to confirm the integrity of the time path switching algorithm and its influence on time accuracy. The test network configuration is shown in Fig. 6. The plots in Fig. 7 characterize what happens under time transfer route switching. First, node #3 is synchronized to node #2 by using the primary path. At the elapsed time of around 350 seconds, the primary path fails, and the route is switched to the secondary path. There is a slight jump in time when switching occurs. This is caused by circuit asymmetry. After that, time continues as before. This proves that switching from a primary to secondary path creates no interruption. The primary path is recovered at the elapsed time of 900 seconds, and time of node #3 returns to the original time. Time of node #4 is not influenced by this failure, since the node received reference time from node #2.

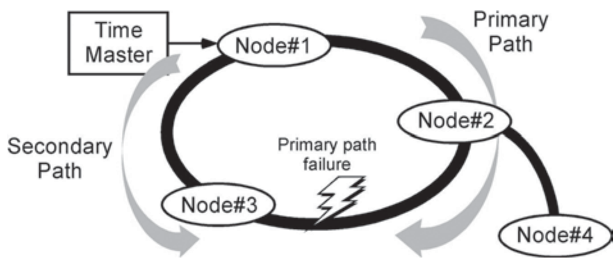

Fig. 6 - Time path switching test network configuration

7. TIME ACCURACY AND STABILITY IN ACTUAL FIELD

The field test examined time transfer stability in the multi-linked system configuration shown in Fig. 8, which basically mirrors the actual planned network. The network for the field test included 12 node with ATM cross connect systems. Time in node #12 was compared to the reference time of the master. Its time change is shown in Fig. 9. The maximum time variation against the master is 500ns to around 1 microsecond. Average time offset is around zero, and time at the end of the 12 node chain does not deviate from the master reference time.

8. CONCLUSION

Optical fiber offers extremely high time synchronization capability, especially for the time accuracy requirements of the order of micro to nanoseconds. Fixed network time transfer has the advantages of performance, reliability, and of course cost. The current role of time is just time stamping; however, time will become an essential part of the basic network functions. NTT will open the new system having the accurate time keeping function just described for service by 2003.

Reference

Node#12node

Node#1node

[1] M. Kihara, T. Hiramatsu, S. Maruyama, and K. Hisadome :"Time Synchronization Network for WDM-SDH-Based ATM Service System", the 15th EFTF, pp. 219-222, 2001

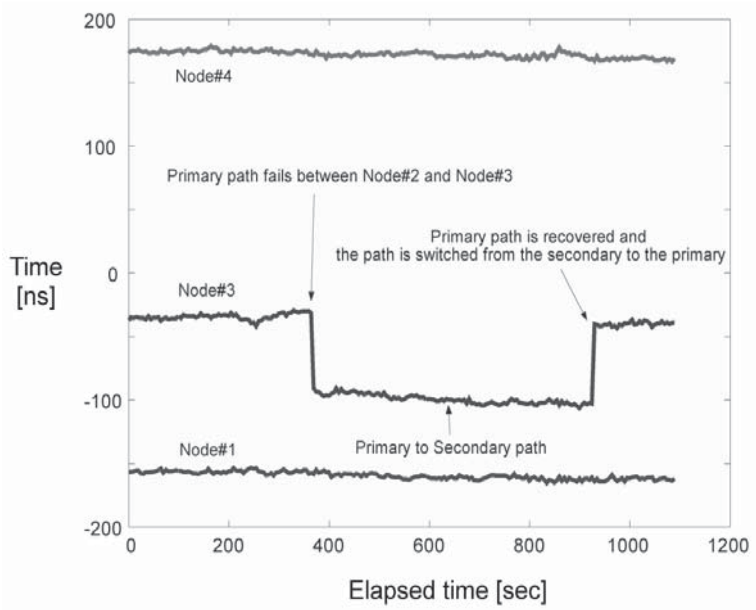

Fig. 7 - Time charactersitics of the switching between primary and secondary paths

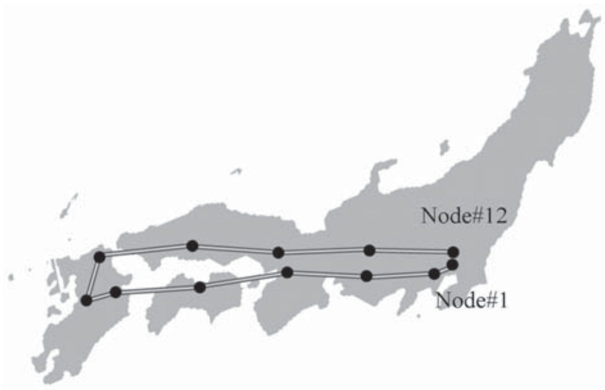

Fig. 8 - The Practical Network for the New Service Time synchronization Nodes

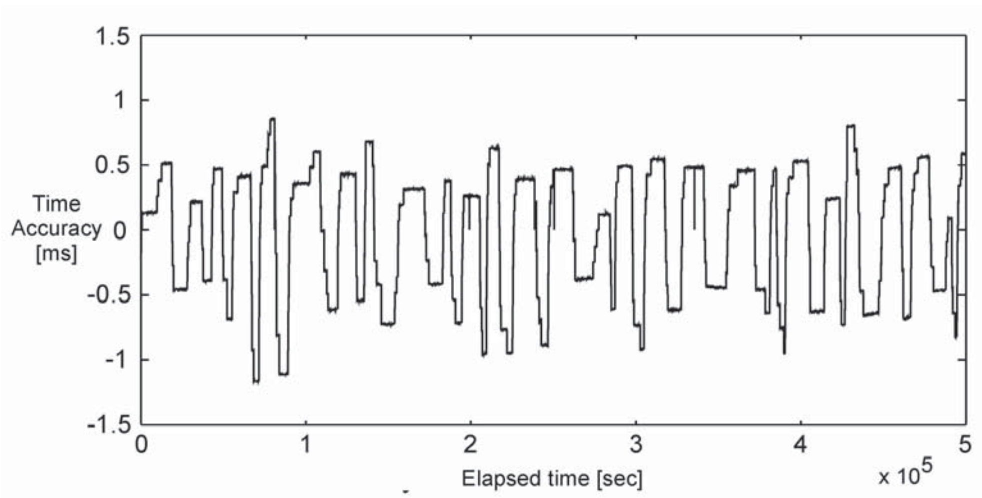

Fig. 9 - Time transfer accuracy and stability in the multi-linked field test configuration