Prediction of Common-View Based Time Differences to Build a Resilient Dissemination System

National Metrology Centre, Agency for Science, Technology and Research (A*STAR), Singapore
Email: shilpa_manandhar@nmc.a-star.edu.sg, meng_yusong@nmc.a-star.edu.sg

***Summary*—This paper discusses the results of predicting the time differences between the two time & frequency labs in Singapore. Results show that the prediction can be achieved for up to 5 hours in advance with an average error of 2.5 ns. The prediction plays an important role to flag out any deviations from the normal clock behavior, which helps the backup (business continuity) lab to perform individually and with similar accuracy as that of the main lab. This will help to prepare for any unwanted conditions that could interrupt the timing services, hence improving the resiliency of the services.**

Keywords—Time & Frequency Transfer; CGGTTS; GPS time transfer; Resilient Time Services

I. Introduction

Various applications that use time & frequency services demand for seamless services without any interruptions [1]. Thus, to maintain resiliency is one of the key focus areas for National Metrology Institutes (NMIs). Many NMIs have more than one time & frequency laboratories developed to provide uninterrupted services [2]. At the National Metrology Centre (NMC) of Singapore, we have one main lab and one backup lab for business continuity being setup to achieve this. The schematic in Fig 1. shows the locations of the labs. There is also ongoing research on building an optical clock and establishing an optical standard link between the two. The architecture will then be able to provide resilient services island wide. At NMC, we are also focusing on the development of prediction algorithms and near real-time time transfer technique [3] which can be helpful in alarming us of any upcoming anomalies and support resiliency of the system.

In this paper, we will present some recent progress in prediction of the time differences between two labs. The results are calculated for various prediction windows. The predicted results are useful to steer the time reference maintained at the backup lab. This helps to run the backup lab individually and will help to create a stable system whereby the labs can support each other while maintaining the timing accuracies.

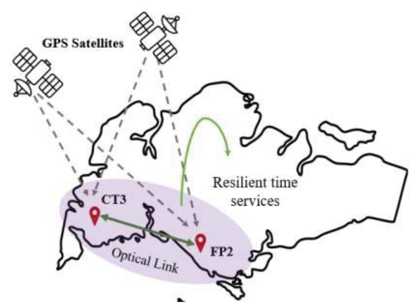

Fig 1: Resilient network for dissemination of precision timing information.

II. Methods

A. Database

For this paper, we have used the data from two labs in Singapore, located at Fusionopolis 2 (FP2) and Joo Koon (ACEZ) for analysis and prediction. The lab at ACEZ has recently been relocated to new site at CT3 shown in Fig. 1. The data from ACEZ was periodically sent to BIPM for calculation of the UTC time, and the hydrogen maser hosted there was steered periodically as per the UTC time information together with an ensemble of Caesium (Cs) atomic clocks. Unlike this the Cs atomic clocks at FP2 are temporarily free running without any feedback and undergoing continuous development.

In this paper, common data (before relocation) from 7 days in 2021 (MJD 59358 – 59364) are used for the analysis and development. The observation data are grouped as per hour.

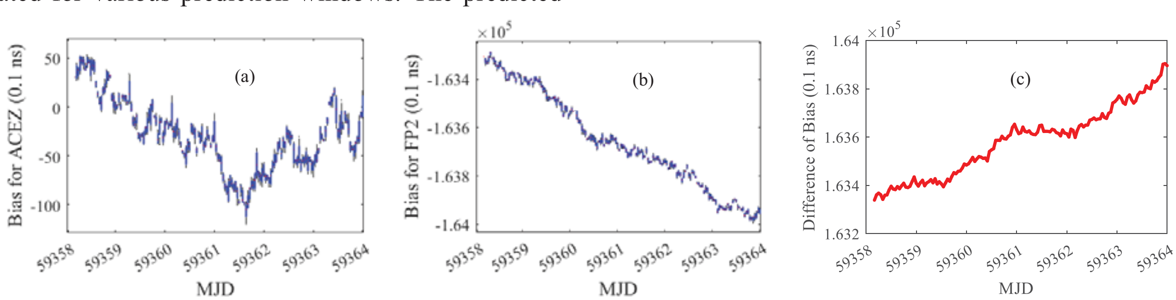

Fig 2: (a) Receiver clock bias for ACEZ (b) Receiver clock bias for FP2 (c) Difference between clock biases of receivers at ACEZ and FP2. All biases are in units of 0.1 ns.

B. CGGTTS Processing

Common GNSS Generic Time Transfer Standard (CGGTTS) is used for processing the receiver biases at each station. Receiver bias is the difference between the receiver clock and the satellite time. For this paper, only Global Positioning System (GPS) satellites are considered so the differences are with respect to the GPS time (GPST). Common-View methodology (i.e., the observations from the common GPS satellites in view) is used to compute the differences between the two stations as shown in eq. 1 below.

$$T_{ACEZ} - T_{FP2} = (Sat_1 - T_{FP2}) - (Sat_1 - T_{ACEZ}) \qquad (1)$$

where T_{ACEZ} and T_{FP2} are the receiver time for stations ACEZ and FP2 respectively and Sat_1 is the GPST for satellite prn 1, which in this case, is the common satellite for both the stations. The results presented in this paper follow this method to get the time difference values.

III. Results & Discussion

A. Biases at the individual stations

Fig. 2 (a) and (b) show the clock offset between the local clock time and the GPST for individual laboratories at ACEZ and FP2 respectively. The units of the measurement are in 0.1 ns. The range of the clock biases for ACEZ is within 10 ns whereas the range of the biases for FP2 is within 16.34 µs for the data used for this paper. Unlike the free running Cs clocks at FP2, the reference time scale at ACEZ is periodically steered. Hence, the receiver differences compared to GPST is much smaller at the ACEZ side.

It can be noticed that the clock bias at FP2 has almost linear trend. This is because the characteristic of Cs atomic clock is such that it drifts slowly with time (good long-term stability). Fig. 2 (c) shows the difference between the biases of ACEZ and FP2. The difference values are very high which is dominated by the free running Cs clocks at the FP2 lab.

B. ARIMA model for time difference prediction

The ARIMA (Autoregressive Integrated Moving Average) model is implemented for the prediction of the time differences. ARIMA is a simple time series forecasting statistical model based on autoregression. Fig. 3 shows the typical results for a random day: MJD 59360. The point at '0' represents the present time. The data in red are the past data that can be used for the prediction. The data in blue are the true data and the data in green are the predicted results. The prediction model was run for using different lengths of the past data and was also tested for different lengths of prediction window.

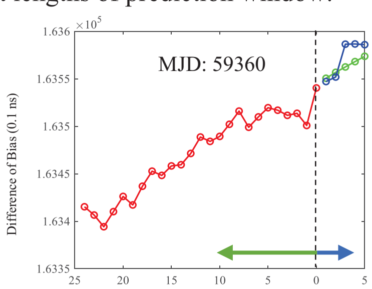

Fig 3: Prediction of biases using ARIMA model

Fig. 4 shows the accuracy of the model for various conditions, which include different lengths of past data and different prediction windows. The accuracy is gauged by calculating the differences between the true values and the predicted values for a given condition. In Fig. 4, the colored curves represent varying prediction windows (in hours), and x-axis is the varying lengths of past data (in hours). As expected, the accuracy decreases as the prediction lead time increases (i.e., wide prediction window). For a prediction window of an hour the accuracy is below 2 ns, but at least 8 hours of past data is required to achieve this accuracy. Increasing the length of the past data beyond 15 hours does not really improve the results much. The results indicate that an accuracy of better than 2.5 ns can be achieved for a prediction window of up to 5 hours. The predicted time differences can be used to steer and safeguard the performance of the backup station.

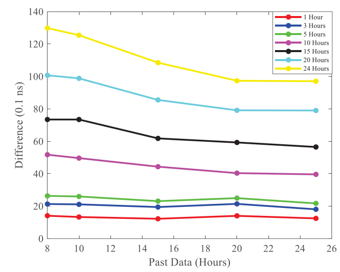

Fig 4: Prediction of time differences when using different length of past data and for different prediction windows [indicated by different colors].

IV. Conclusions

This paper presents the results that discuss the idea of predicting the time differences between two-time labs. The results show that an accuracy of better than 2.5 ns can be achieved for a prediction window of up to 5 hours, which is helpful for timely steering of the backup lab and to build a national resilient system. The research findings will be further improved for implementation at the backup lab when a new hydrogen maser and multi-channel frequency domain measurement system to be delivered in early 2023.

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