# ANALYSIS OF DELAYS IN TRANSMITTING TIME CODE USING AN AUTOMATED COMPUTER TIME DISTRIBUTION SYSTEM

**Y. Shan, H. A. Chua, A. M. Kyaw, and J. Levine***
National Measurement Center
Singapore Productivity and Standards Board
1 Science Park Dr., Singapore
E-mail: *time@psb.gov.sg*

*Time and Frequency Division
National Institute of Standards and Technology
Boulder, CO 80303, USA
E-mail: *jlevine@clock.bldrdoc.gov*

*Abstract*

*An automated computer time distribution system broadcasts standard time to users using computers and modems via telephone lines. For users who need traceable time, it is of particular interest to know the uncertainty of time information received. Factors that contribute to transmission delays in a telephone network have been measured and analyzed. The results revealed several dominant factors that contributed to delays – software platform (50% of the delay), transmission speed of time-codes (25%), telephone network (15%), modem and others (10%). The standard deviation of delays is below 20 ms in all cases. The results allow us to estimate that, within Singapore, an uncertainty of about 20 milliseconds is achievable using the system.*

## INTRODUCTION

A service that distributes time – the Automated Computer Time Service (ACTS) – has been set up at the National Measurement Center (NMC) of Singapore Productivity and Standards Board (PSB). The system broadcasts standard time to users via computers, modems, and telephone lines. Users dial the ACTS server to receive time traceable to the national time scale of Singapore, UTC(PSB). The users can in turn run applications that require traceable timekeeping, such as traffic controls, communications, synchronized clocks, etc.

The ACTS system transmits time code in ASCII format. To remove errors due to delays in transmitting codes, the ACTS server has the capability to compute and compensate each transmission delay by first measuring the round trip delay. It then corrects for one-way delay through time code advancement. PSB provides dial-up software on both Windows and DOS platforms to users. This software echoes an On-Time Marker (OTM), which enables the server to compute and compensate delays. Time code transmitted by this service is compatible with that of a similar service provided by the National Institute of Standards and Technology (NIST) [1].

For users who need traceable time, it is important to know the uncertainty of time code received, which is caused by delays when the code travels through various media along the transmission path. A detailed analysis of these delays enables service providers such as PSB to assign an uncertainty to the time code received by the users.

## FACTORS CONTRIBUTING TO DELAYS

In the transmitted time code, there is an On-Time Marker (OTM) denoted by an asterisk (*). OTM serves as a reference point for the time code – time indicated by the code refers to the arrival time of OTM. For

example, if the time code shows 12:34:56, it means that the time is 12:34:56 at the arrival of OTM.

The OTM is delayed in the transmission path as it travels from the server to the user's computer. To compensate for this delay, the ACTS server sends out the OTM a fixed number of milliseconds early. This helps to improve the accuracy. Better results are possible if the users return the OTM to the server. On receiving the returned OTM, the server measures the time it took for the OTM to travel from server to the user and back. It then divides the measured round-trip delay by 2 to get the one-way path delay. This of course assumes reciprocity in the path. ACTS server then advances the OTM by the calculated one-way path delay and sends out the code. If the OTM changes from an asterisk to a hex sign (#), the server is measuring the delay and correcting for it. On receiving the # sign, the user knows that error due to path delays has been removed, and the time received is within a few milliseconds of UTC(PSB). The remaining error is due to the transmission asymmetry and noises.

Figure 1 shows the system used for measuring delays. During the boot-up of the ACTS server, we used a RS232 signal from a Time Code Generator (TRAK model 6460), which is synchronized to UTC(PSB), to automatically set the server time. The system then is operated continuously from a 1pps signal of UTC(PSB). Three main elements contribute to delays in such setups – modems, telephone lines, and computers. Furthermore, the amount of delay also depends on the type of modem and its speed, the location of users, the type of computer used, · software platforms, etc. Delay may also vary depending on the time of day at which transmission takes place.

## METHOD OF MEASUREMENTS

Each of the delay factors mentioned above were investigated individually, while keeping the other influencing factors unchanged as much as feasible. For example, to measure delays of various modems, all connections remained unchanged and dialing was done for the same time. To measure variations in delay over time, we kept the same computer and modems. Measurements were carried out, at the same location, for 51 days from 51330 to 51380 MJD. Server was dialed daily in three blocks – morning, afternoon, and evening. Each block consisted of 10 dial-ups, and each dial-up involved tens of delay measurements and stability calculations. Only the one that satisfied stability criteria of several ms was recorded. Sometimes, the conditions were not identical, but all data and conditions were made comparable.

The total data we collected for the testing are over 12,000 pieces. One piece of data records the advancement or the delay of OTM, either the # or * sign, and the difference between the user's computer time and standard time.

## MEASURED RESULTS AND DISCUSSIONS

In Figure 2, delays of several modems were averaged in three blocks daily. Time code transmission speed was set to 9600 baud. Data were collected from 51330 to 51380 MJD. Dial-up software operated on Windows platform. Figure 2(a) shows the means and standard deviations of 4 modems in the morning block (at around 1000 hours). Figure 2(b) shows the results of the same 4 modems in afternoon block (around 1500 hours). Figure 2(c) is the results of the evening block (around 2200 hours), in which the first two modems are the same as that used in the morning and afternoon blocks. All blocks used similar computers. Other conditions are about the same during the three blocks of measurements. Figures 2(a), (b), and (c) show that delays did not differ significantly among the three blocks. Delay of the first two modems – US Robotic 33.6K and Prolink 14.4K – was around 145 and 125 ms, respectively for morning, afternoon, and evening blocks. Standard deviations were around 15 ms. Capacity of modems, however, has slight influence on the delay. For example, the 14.4K modem was around 125 ms. It went up to 140, 145, and 150 ms for, respectively, 28.8K, 33.6K, and 56.6K modems. In all cases, stability of delays, or standard deviation, stays almost the same at about 15ms.

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Figure 3 shows the diurnal effect on the delay. Measured data came from the same modem, with Windows software ran at a speed of 9600 baud, and DOS software ran at a speed of 1200 baud. The client computer dialed the server 10 times each hour around the clock continuously from 51459 to 51461 MJD. It shows that delays fluctuate between 135 ms and 155 ms for Windows software, and around 108 ms for DOS software. The standard deviations were around 15 ms and 5 ms, respectively. It is apparent that software platforms contributed considerable delays to transmission, while the delays remain largely the same throughout the day.

Figure 4 compares the delays of two client computers – 486-66MHz and Pentium II-233MHz. 486 ran on DOS platform, while Pentium II ran on both Windows and DOS platforms. Each setup was tested at two speeds – 1200 and 9600 baud. Results show hardly any difference in delay between two different client computers. For example, the delay was around 55 ms for both computers when dialing on DOS at a speed of 9600 baud, and around 108 ms when dialing on DOS at a speed of 1200 baud. When the same computer (Pentium II) operated on Windows and DOS platforms, the delays differed significantly. At 9600 baud, delays when operated on Windows and DOS were around 150 ms and 55 ms, respectively. At 1200 baud, the figures for Windows and DOS were around 190 ms and 108 ms, respectively. Standard deviations of DOS system were around 5 ms, while that of Windows were between 10 and 20 ms. Therefore, dialing with DOS software produces smaller, and also more stable, delays.

Next, we investigated different modems. Figure 5 shows delays obtained by different 56.6K modems (commonly found in the current market) at 1200 and 9600 baud, dialed on DOS and Windows platforms. It shows that at 9600 baud, all modems had similar delay, and that was true on both DOS (around 50 ms) and Windows platforms (around 150 ms) . The differences between modems did not exceed 10 ms. At 1200 baud, however, the measured delays spread from 70 ms to 200 ms. DOS software at 9600 baud seems to offer the best solution to users who need an uncertainty of a few milliseconds.

The last test involved dialing the server from various parts of Singapore. Figure 6 gives the locations of client computer, while Figure 7 shows the measured delays. There was no noticeable correlation between measured delays and dialing locations. Telephone connections in Singapore are randomly distributed, and each connection does not exceed three exchanges island wide (around 680 square meters). Assuming the worst delay of 10 ms at one exchange, the total delay caused by the telephone network would be 30 ms at most.

CONCLUSION

The dominant factor contributing to delays is the software platform, which makes up about 50% of the total. Dial-up software on DOS has smaller delay and is more stable. Speed of transmission contributes about 25% of delays, and 9600 baud offers the best connection. About 15% could be caused by the telephone network. Modems may put in another 5% of delay, depending on the type and capacity, with the rest comes from unknown factors such as noise. The smallest delay of 50ms is achievable with the system running on DOS platform at 9600 baud. The largest delay is about 200ms on Windows platform at 1200 baud. Standard deviations for operating under DOS and Windows platform are 5 and 20 ms respectively. These standard deviations are an estimate of the uncertainty of the system after correcting for the delays.

REFERENCES

[1] J. Levine, M. Weiss, D.D. Davis, D.W. Allan, and D.B. Sullivan, "*The NIST Automated Computer Time Service*," Journal of Research of the National Institute of Standards and Technology, vol.94, no.5, Sep.-Oct. 1989.
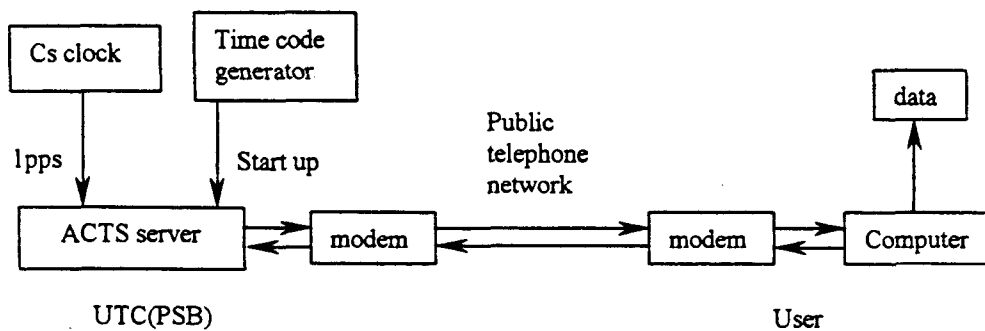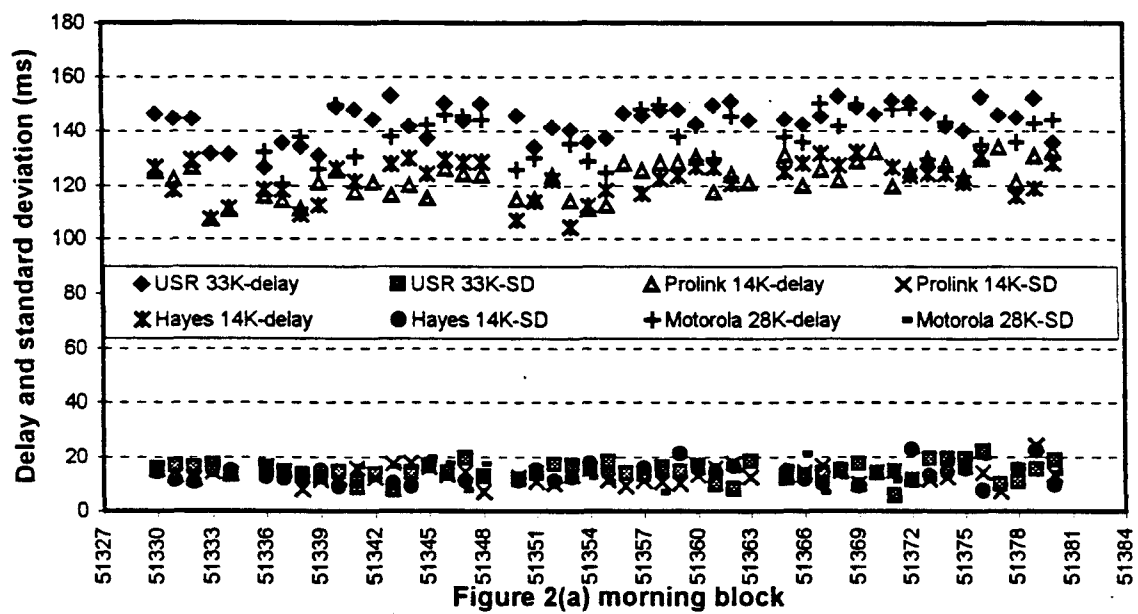
Figure 1.The system setup for delay measurement



Figure 2(a) morning block

Figure 2(b) afternoon block
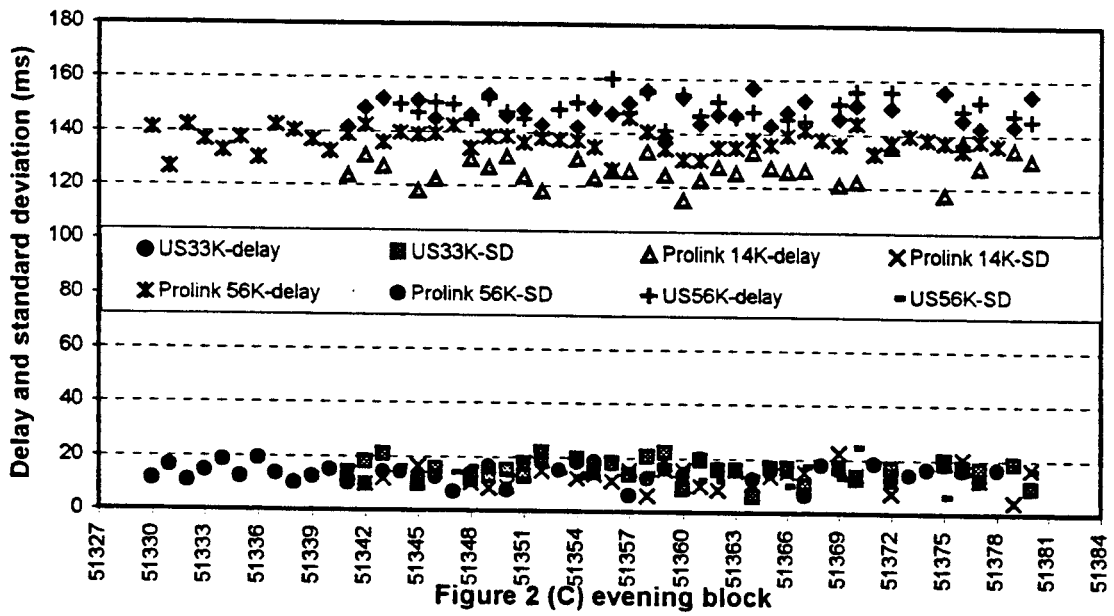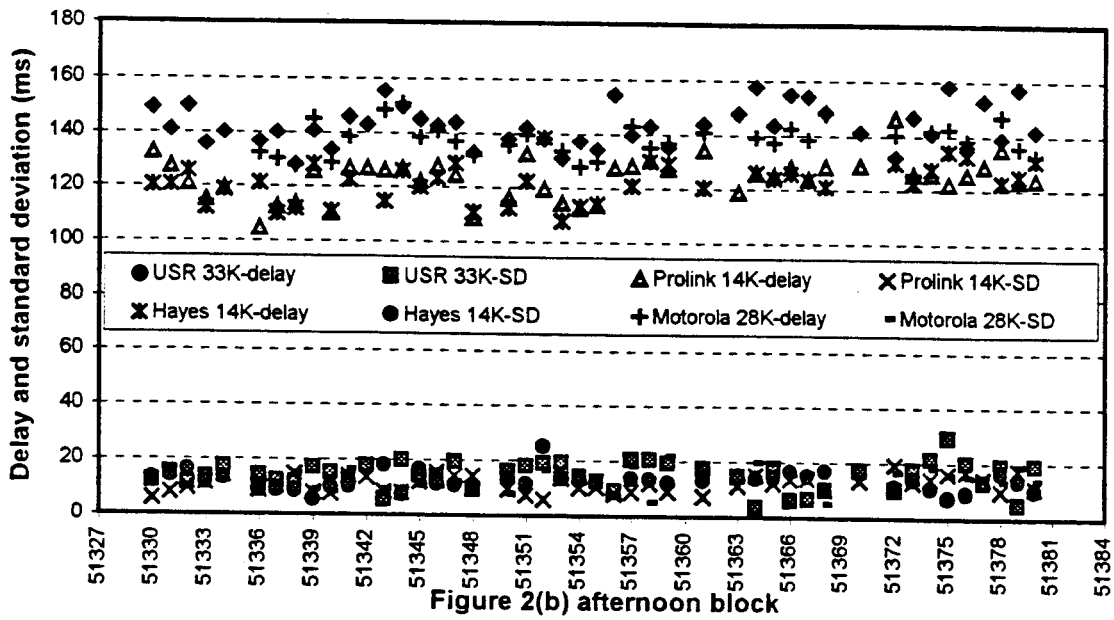


Figure 2 (C) evening block

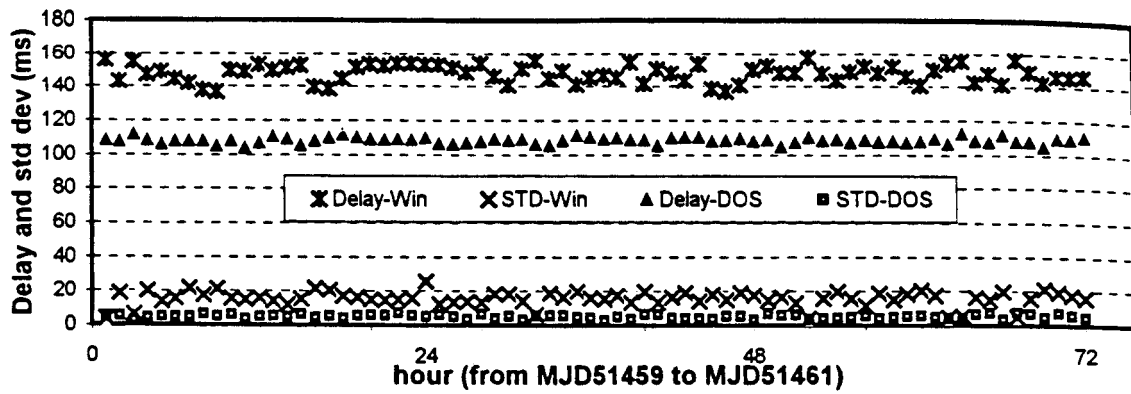Figure 2. Long-term variations in transmission delays

Figure 3. Diurnal variations in transmission delays
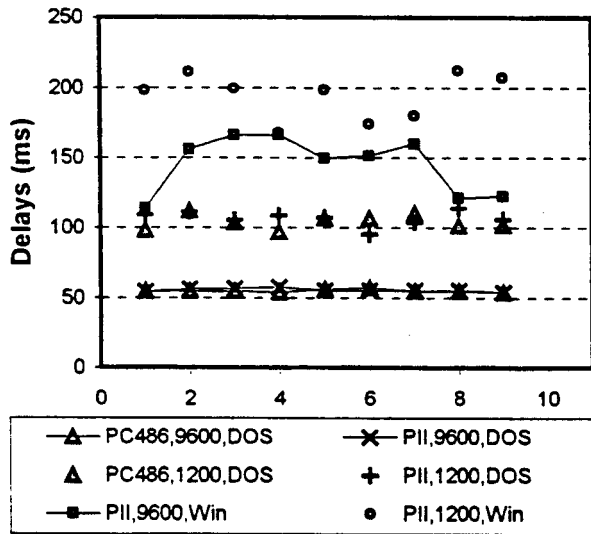


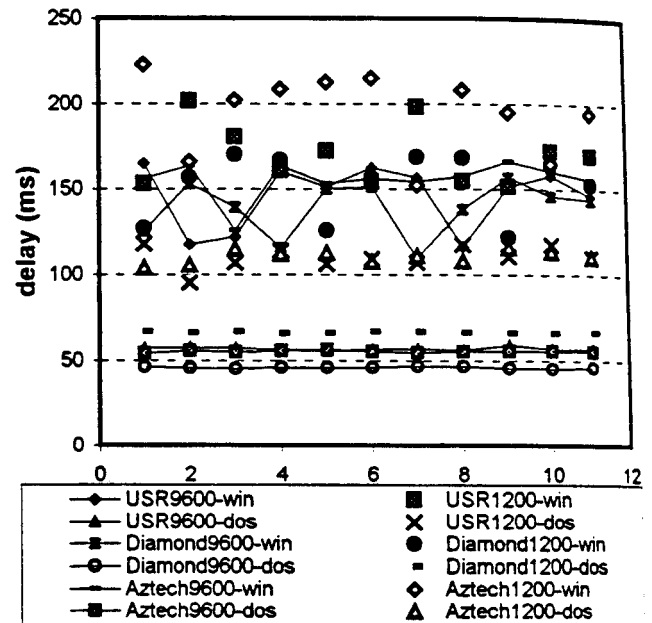Figure 4. Transmission delays of different client computers and platforms



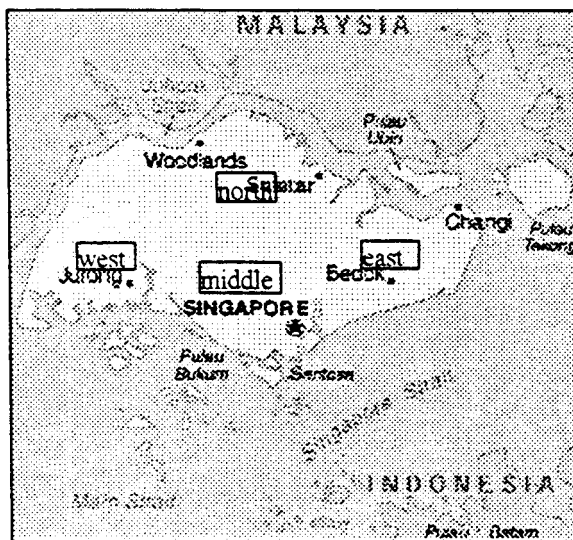Figure 5. Transmission delays due to different modems and speeds
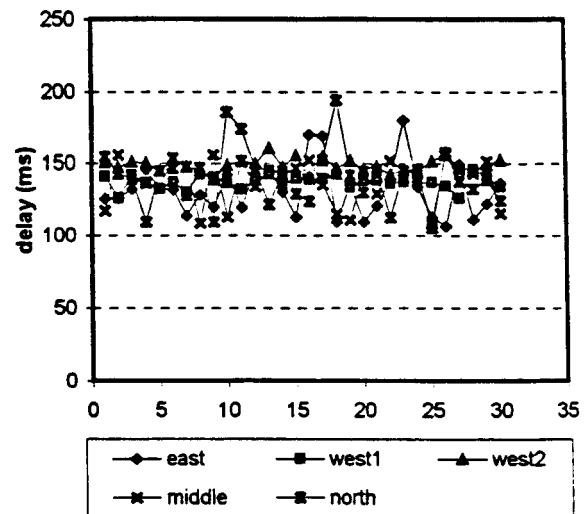


Figure 6. Locations of client computers



Figure 7. Transmission delays at different locations

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