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Implementation of Time synchronization system using Multi GNSS

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ABSTRACT

This work describes the need for time synchronization. Time is the most critical dimension when multi data processing is to be done in real time system. In an age of internet any real time processing such as bank transactions, purchasing or selling goods online or even a simple e-mail interaction requires time synchronization between two entities. They may be world apart in their geographical location but still needs to maintain a common reference clock/time.

A brief discussion of different time synchronization protocols shall be done. The need for multiple constellations of GNSS for time and position computation is discussed. For an internet connected system, NTP server implementation using GNSS receiver for time synchronization is discussed and the clock accuracy achieved using it.

Key Words - NTP, PTP, Time Synchronisation, GNSS, GPS Time Server

1. INTRODUCTION

Time synchronization is required for application where computing precision is very important. In a network only if all are synchronized can there be effective communication. In an embedded environment where multiple systems are connected to each other and there exist a continuous communication between them then time stamping of each message is required. Under such scenario synchronizing time between these systems is of utmost importance.

Coordinated Universal time (UTC) is the common basis or reference for civil time across the world. All Timing centres synchronize their clock to this reference. Two principal components are used to determine UTC which is TAI and UT1. TAI is the time scale that combines the output of highly precise atomic clocks and UT1 is called as solar clock due to rotation of the Earth [1].

The precision of clocks using different source is shown above in TABLE1. The atomic clock usingcesium is most stable with their frequency stability of the order of 0.0001ppb. However, the price level of such reference clocks is huge and in most of the application cases such high precision clocks are not required or are redundant.

In a distributed system the processing nodes are physically separated and have different clock oscillators or sources that can drift from each other due to aging, difference in temperature etc. So the need for a common time base implies that their clocks should be synchronized periodically to correct that unavoidable drift [5].

Trusted and precise time sources are required in computer networks and Internet for various reasons: time stamps for electronic documents, online transactions, storage and document retrieval, electronic mail, multimedia applications and many others.

Also, the demand for Ethernet as a real-time control network is increasing, as manufacturers realize the benefits of employing a single network technology across the plant. For control and measurement applications, the need of an accurate distribution-wide sense of time is even more stringent than regular applications [4].

Table 1 : Stability of different clock sources

Type	**Stability(in seconds)**
Cesium	up to 10−13
GPS	Around 10−12
Rubidium	up to 10−10
Crystal	up to 10−9

2. TIME SYNCHRONIZATION PROTOCOLS

The different time synchronization protocol accepted internationally is as follows

2.1 NETWORK TIME PROTOCOL

It is one of the oldest and widely used protocols for time synchronization in a distributed network system. It uses UDP/IP (USER DATAGRAM PROTOCOL) for sending the information through internet. PORT123 is dedicated universally for NTP communication between client and the server. Since the interconnected network is generally available and many NTP client software also available freely, there is no need for any additional infrastructure for synchronizing time over the Ethernet. The time offset between the client and the server is computed based on the four time stamps. These four time stamps are as follows Client transmit time stamp(CT) , Server receive (SR), Server Transmit(ST) and Client Receive(CR) . Based on these time stamps the offset is computed at the client end using the following formula

$$\mathbf{O_{cs} = ((SR- CT)-(CR- ST))/2} \qquad \mathbf{(1)}$$

The above expression assumes that the network delay introduced during Client request reaching the Server and Server response reaching the Client is identical.

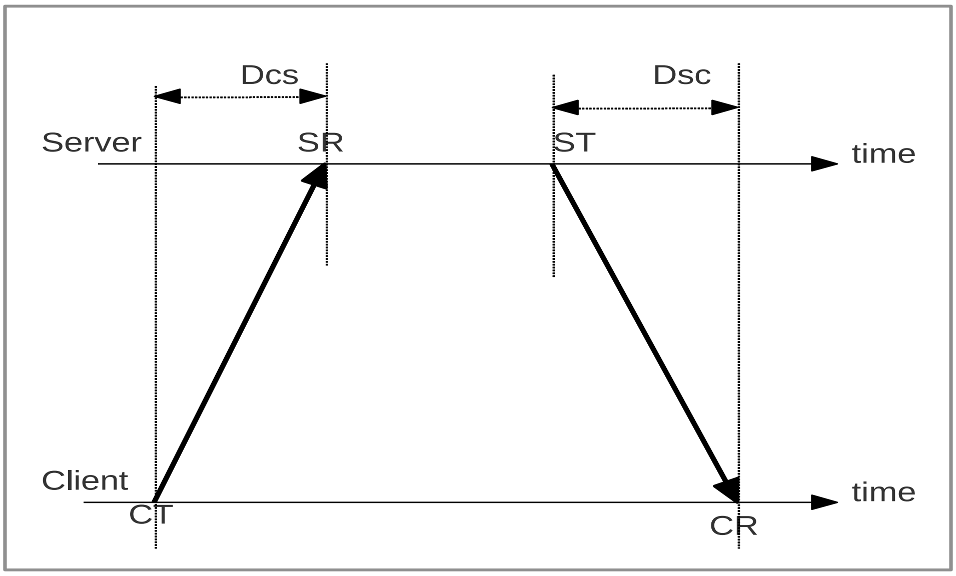

Figure 1:Time synchronizing using NTP

The above **Fig.1** shows the process involved in the NTP architecture. In a Unicast mode of NTP, a client request the server for time sync and time stamps the message with the transmit time. Server on receipt of the request, time stamps it. During reply from the server the transmit time is also added to the message.
The client upon receiving the NTP packet shall compute the offset and network delay.

The architecture for NTP uses a hierarchical model known as stratum. Each server is placed in stratum acts as a time server for the lower stratum. The server located in the root or stratum1 is called as primary server. These primary servers are synchronized to stratum 0 which consist of an atomic clock or standard clock. The maximum level of stratum supported by the NTP is fifteen.

A client can be connected to multiple NTP servers simultaneously and can decide which of the servers to be considered for time synchronization.The client maintains the time information from different time servers and evaluates the time stamp to decide the best server. The one with less distance for synchronization and lower stratum shall be used for setting the clock.

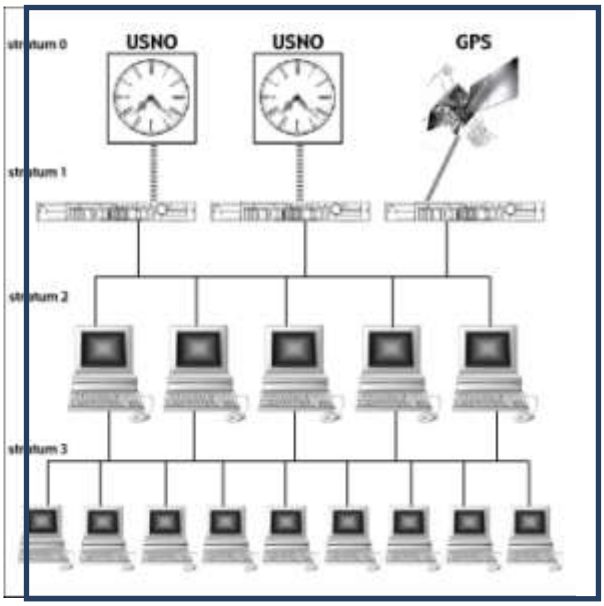

Figure 2:Hierearchy of Stratum in NTP

2.2 IRIG TIME CODES

Inter-range instrumentation group time codes are one of the standard time synchronizing methods employed in Defense or Aerospace application. This standard consists of a family of rate-scaled serial time codes with formats containing up to four coded expressions or words. All time codes contain control functions (CFs) that are reserved for encoding various controls, identification, and other special-purpose functions. IRIG- A has a time frame of 0.1 seconds with an index count of 1 millisecond and contains TOY in days, hours, minutes, seconds, tenths of seconds, and year information in a binary coded decimal (BCD) format and seconds-of-day in straight binary seconds (SBS).

IRIG-B has a time frame of 1 second with an index count of 10 milliseconds. IRIG-D has a time frame of 1 hour with an index count of 1 minute. IRIG-E has a time frame of 10 seconds with an index count of 100 milliseconds. IRIG-G has a time frame of 0.01 seconds with an index count of 0.1 milliseconds. IRIG-H has a time frame of 1 minute with an index count of 1 second.[7]

2.3 PRECISE TIME PROTOCOL

PTP also referred as IEEE 1588 was designed to achieve increased time accuracy over traditional Ethernet based protocols. This protocol implements a master slave relationship for time synchronization between a main grandmaster clock and other clocks in the system.

The master initiates the communication of time synchronization. Unlike NTP, the slave can neither select the master nor be a server for the subsequent clients connected in the network. PTP does the time stamping at the hardware level, where as in NTP it is done in the application layer. Hence the time accuracy achieved by the PTP is of the order of few nano seconds. The disadvantage of using IEEE1588 method for time sync is the requirement of network infrastructure. It requires a dedicated IEEE1588 boundary clocks and transparent switches to achieve the above said accuracy.

3. NEED FOR MULTI GNSS FOR NTP

Generally the GNSS receivers compute position i.e x, y, z using trilateration, considering earth as an ellipsoid in 3D space. The satellites transmit their time and position information continuously. The receiver at any point in globe can receive this information and compute it's position. This demands for at least four satellites to compute x, y, z and the clock biases. Clock bias is the receiver clock offset from the GNSS satellite transmitted time. GPS(Global positioning system) or Navstar GPS satellite transmits GPS time which is not compensated for leap seconds. Currently GPS time is offset by 17 seconds from UTC. The NavIC also transmit time similar to GPS. GLONASS on the other hand transmits time that is aligned to UTC.

This raises the question why position computation algorithms prefer redundant satellites to solve for the four unknowns. Now even though only four satellites are sufficient to solve four unknowns the real time application scenario may be such that these four satellites may be aligned such that the information all satellites provide in less accuracy in x direction. So, redundancy is required to estimate user position accurately which means it is ultimately the geometric distribution of satellites in sky that eventually determines the accuracy achieved. With multi constellation the number of satellite observable increases.

The other parameter that promotes the use of multi GNSS receiver is that fact that most of the GNSS systems are controlled by the military establishment of the respective countries. GALILEO of Europe is considered as the civilian controlled GNSS system. So, if multi GNSS is employed the susceptibility to jamming and spoofing can be reduced considerably to relying on the other constellation that is not jammed/spoofed.

GNSS as a source used in NTP server provides the low cost solution of achieving time synchronization to UTC time.

4. SYSTEM DESIGN

The system architecture of a NTP server using multi GNSS receiver is shown below in **Fig.3**.

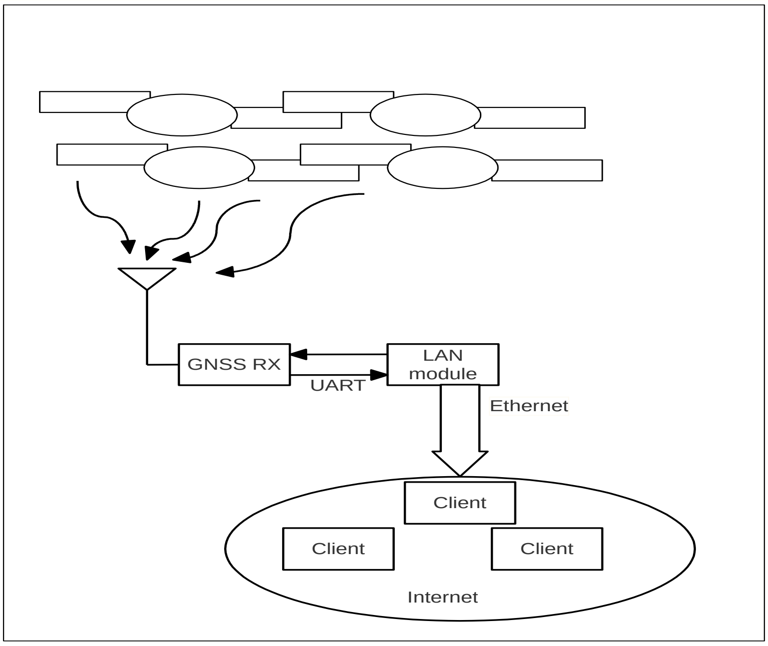

Figure 3: System architecture of GNSS based NTP

The multi GNSS receiver that was used for this work is IG3 receiver module from ACCORD Software and System Pvt ltd. The LAN module is a system on module that houses a SoC that converts serial data to Ethernet. It runs on uClinux OS and provides users to build custom application on it.

The IG3 receiver sends a special time message other than the standard NMEA 0183 messages. This time message is in binary format consisting of hour, seconds and nano seconds field. On receipt of this message the LAN module updates its system time every second.Upon every NTP request the system time is used for time stamping (SR and ST).

There are two threads that run constantly i.e ACTIME thread, NTP thread. The flow chart of the same is shown below in Fig 4

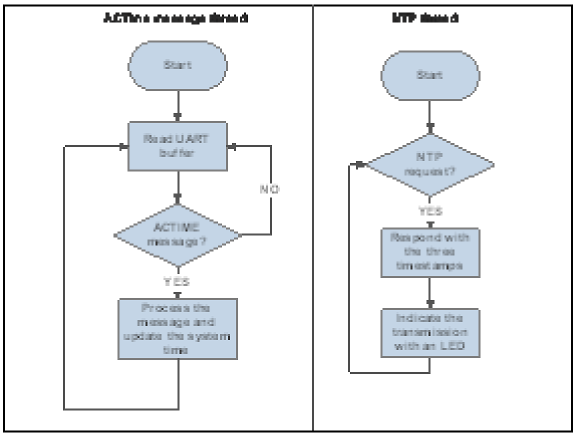

Figure 4:ACTime message and NTP thread

5. RESULTS

For testing the system for performance of time synchronization, it was connected to a network with the server IP address set as 192.168.3.217. A computer system with Windows 7 operating system present in the same network is installed with custom NTP client software. In the same network the another computer system with Red Hat Enterprise Linux 6 version operating system is also used to log the time offset observed periodically from the our NTP server.

To measure the relative offset, Google's NTP server is set as the primary reference source at the client. The time measurement then observed of our server is with respect to the time.google.com. The hardware setup is as shown in the below **Fig.5**.

Figure 5: Hardware setup

The client was setup to send request to the time server once every eight seconds. The logged data is analyzed for offset and network delay. The data was logged for two trials and the results are averaged. The average offset and delay during the two days of test is as mentioned in TABLE 2.

The graph of offset variation during Trial1 and Trial2 is shown in **Fig.6** and **Fig.7**.

Table 2: Average Offset and network delay

	Trial1	Trial2
Average Offset	-7.8ms	-10.2ms

Average Delay	0.925ms	0.925ms

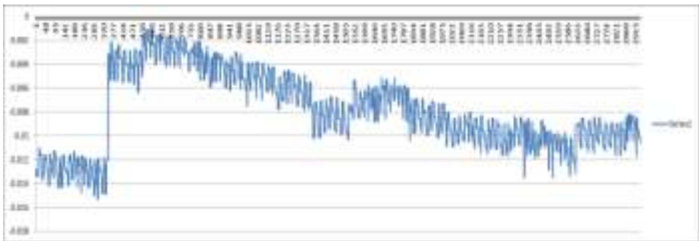

Figure 6:Offset variation, Trial 1

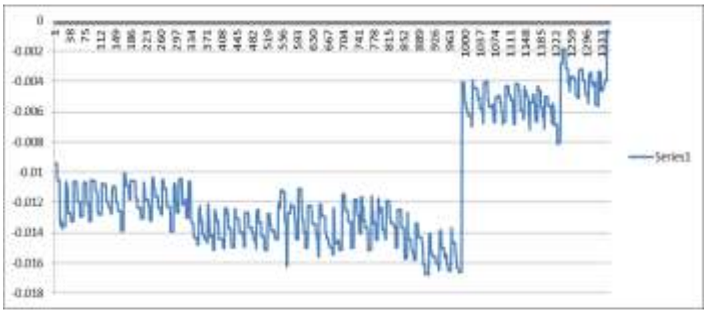

Figure 7:Offset Variation, Trail 2

6. CONCLUSION

NTP time server was implemented using GNSS receiver. The receiver was set to provide position with all constellations i.e. GPS, GLONASS and NAVIC. The average number of satellites used for time and position computation during the entire test was around twenty. The antenna was placed in just outside the window with limited view of the sky.

The processing time variation was not captured during the implementation. Only the time data propagation delay from the receiver to the LAN module was compensated for time updating. The average offset in time that was observed at the client was -10ms. The reference for comparing the offset value was Google time server (time.google.com).

7. AKNOWLEDGEMENTS

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