ITSF 2021
A comparison of DTM and Chrony over a home internet link

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Motivation and scope

- DTM over standard Ethernet and IP has been reported to provide sub-microsecond precision and accuracy over long-distance MPLS links:
  - ✓ *Umut Keten, "GPS Independent Time Distribution", International Timing and Sync Forum (ITSF), 4-7 November, 2019, Brighton, UK*
- DTM performance over inexpensive "home internet" links has been little studied
- In this work we analyze a DTM link between two GMV offices in Spain over a Fiber To The Home (FTTH) access
- FTTH speed is 600 Mbps in downlink and uplink
- Price of the FTTH service is around 50 € / month per site
- The two offices are 130 km apart
- Tres Cantos office hosts the DTM server, locked to a UTC-like realization based on atomic clocks
- Boecillo office hosts the DTM client; DTM client time error is measured by means of a calibrated GNSS receiver

UTC scale at GMV

- GMV operates a UTC-like realization in our offices at Tres Cantos near Madrid, Spain
- The time scale is based on very stable atomic clocks: two Passive Hydrogen Masers (PHMs)
- Clocks are daily steered to UTC(PTB) by means of GNSS time transfer
- Local GNSS station delays have been calibrated in common-clock relative to a travelling GNSS station from ROA, the Spanish national time laboratory
- ROA's travelling station can be traced to the latest BIPM's calibration campaign (GPS P1 and P2, Galileo E1 and E5a)
- After initialization, the time scale can survive without GNSS in holdover during weeks, with an error below 10 ns

DTM setup

- DTM server and client run on a Nimbra 390 box by Net Insight
- DTM is treated as a "black box" in this work
- The underlying network does not provide any timing support for the link nor to the network equipment
- The time error at the DTM client is measured against the 1PPS from a calibrated dual-frequency low-cost GNSS receiver
- Calibrated GNSS provides UTC with an error below 5 ns
- The 1PPS from GNSS can be injected into the client Nimbra, which measures its time error autonomously
- Otherwise a Time Interval Counter can be used to measure the difference between the 1PPS from DTM (Nimbra) and the 1PPS from GNSS

NTP setup

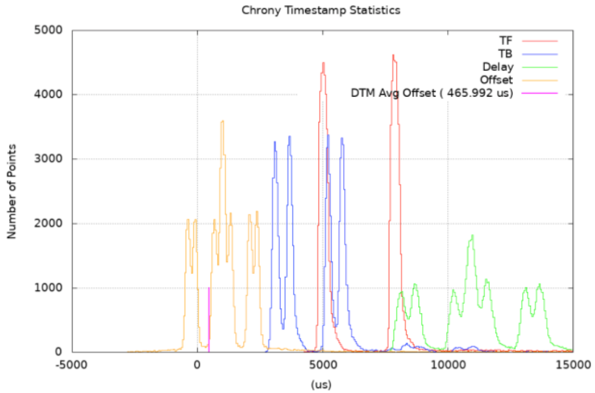
- NTP (Chrony implementation) is used as a “white box” to measure the behavior of the network from the point of view of packet time-stamping
- NTP server and client run on a Raspberry Pi (raspi)
- Both server and client are locked to their local external UTC source to analyze the “true behavior” of the network in absence of clock errors
- The 1PPS from UTC is injected into the raspi through a GPIO pin
- Server raspi (Tres Cantos) is locked to the local UTC time scale
- Client raspi (Boecillo) is locked to the local calibrated GNSS receiver
- The resulting NTP packet time-stamping resolution is limited to a few microseconds due to raspi hardware and OS constraints

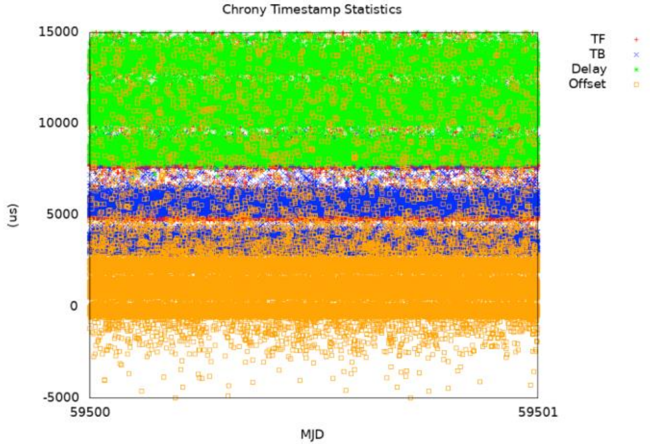
NTP configuration (1/2)

- NTP is configured to exchange packets every second
- The client NTP log is processed
- The NTP log provides the Delay and the Offset of the link every second
- Packet Time Forward (TF) and Time Backward (TB) are calculated from Delay and Offset as:
  - ✓ TF = T2 – T1 = Delay/2 + Offset
  - ✓ TB = T4 – T3 = Delay/2 - Offset
- TF, TB, Delay and Offset are plotted in the form of daily time series and histograms

NTP configuration (2/2)

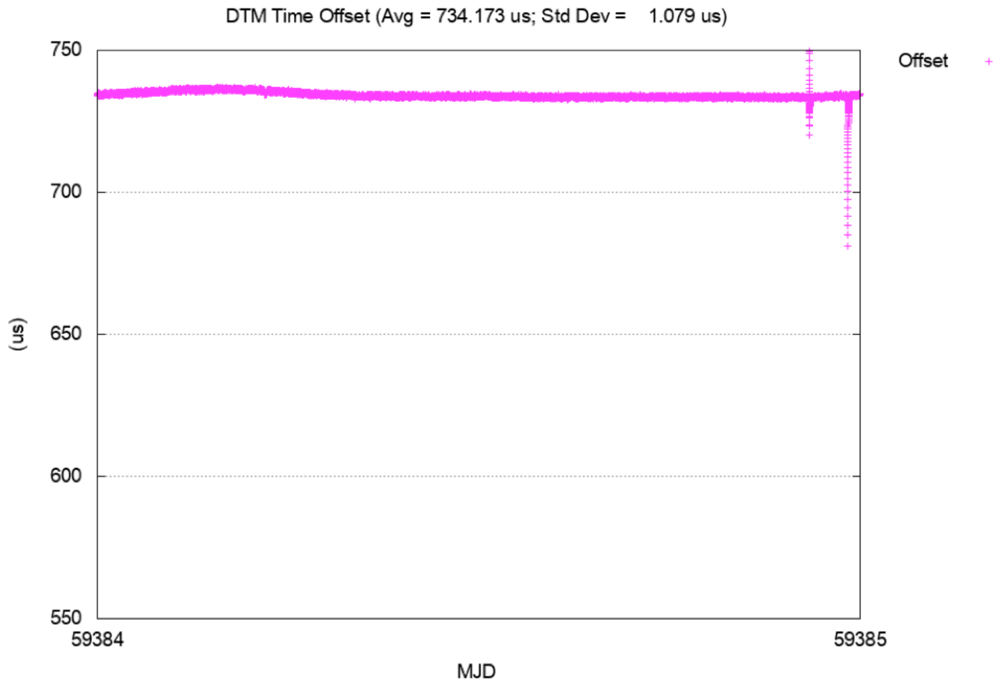
- NTP histograms show the number of forward and backward paths (or routes)
- Two forward paths are seen in the example (red peaks)
- Four backward paths are seen in the example (blue peaks)
- The peaks are wide, which indicates a high time jitter
- In addition packets seem to follow the different forward and backward paths randomly in time, as shown by the time series
- The link is also highly asymmetrical as indicated by the orange peaks (Offset) in the histogram
- Fortunately the network behavior is stable over days… until a network reconfiguration happens
- The conclusion is that this FTTH scenario is quite challenging for an accurate and precise time transfer via packet exchange



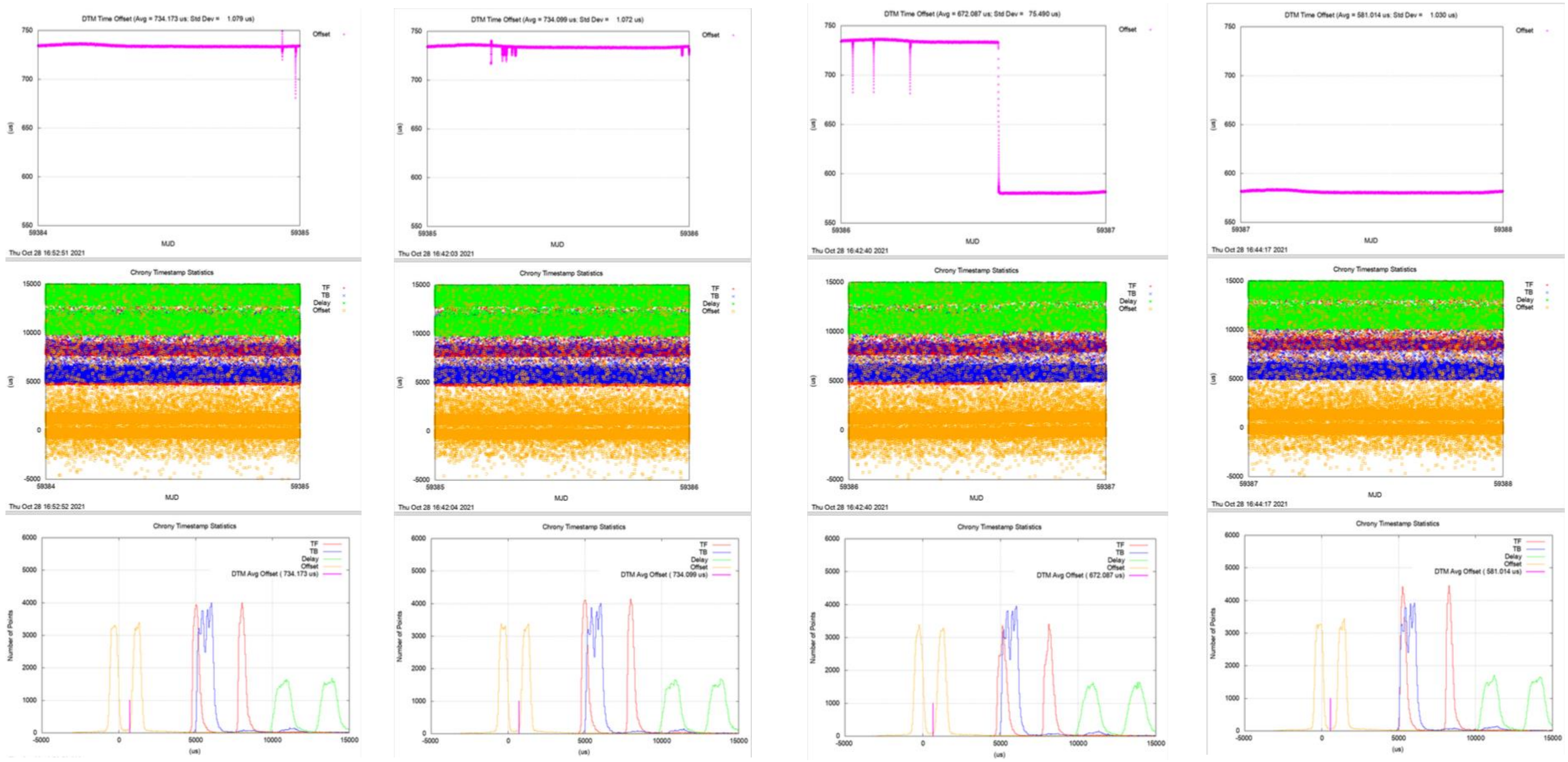


DTM results

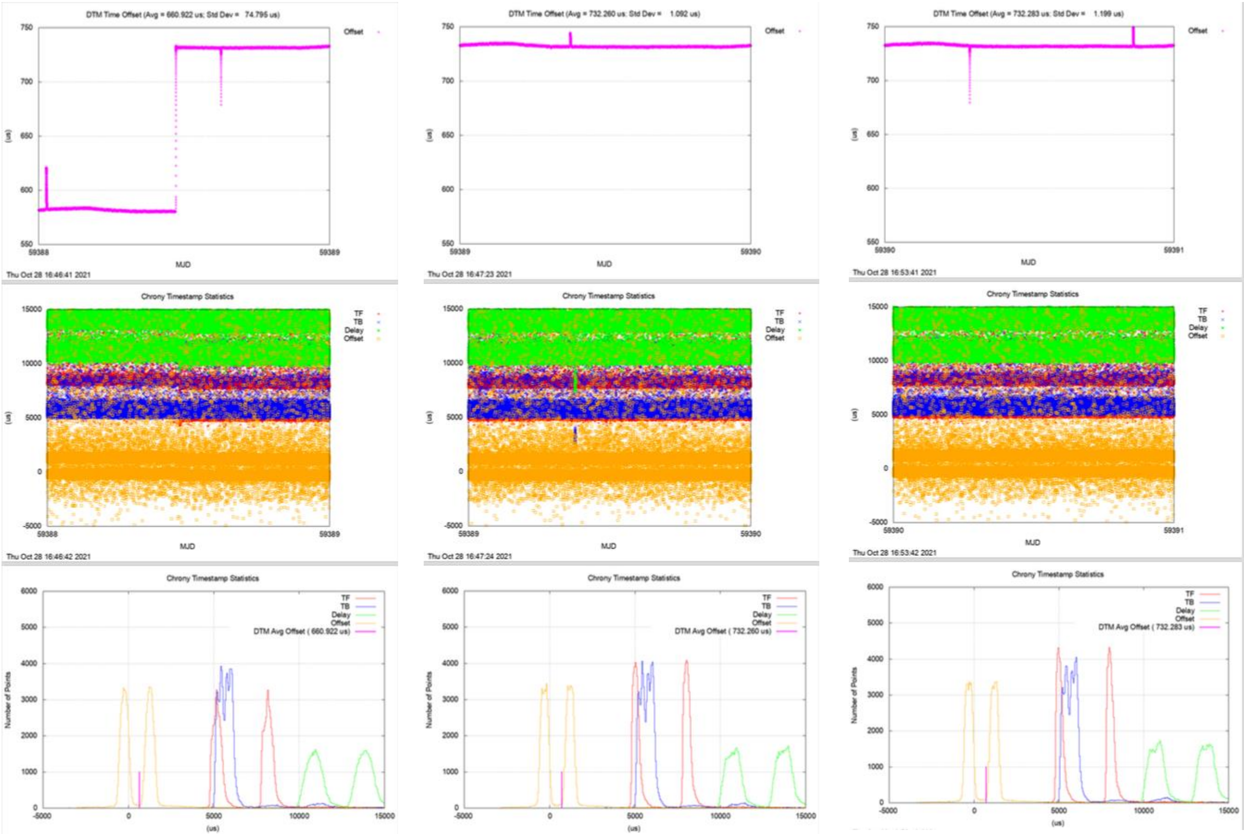
- The DTM time error on the client shows in general a large offset at the millisecond level
- Such large offset is unavoidable over FTTH due to network delay asymmetry
- However the offset is constant between network reconfigurations (i.e., during several days)
- Stability within a day is very good, at the microsecond level
- The short-term jitter is well below the microsecond (typically 300 ns at 1-sigma)
- Repeatability of the mean daily offset is at the level of 100 ns



One-week analysis (June 19-22, 2021)

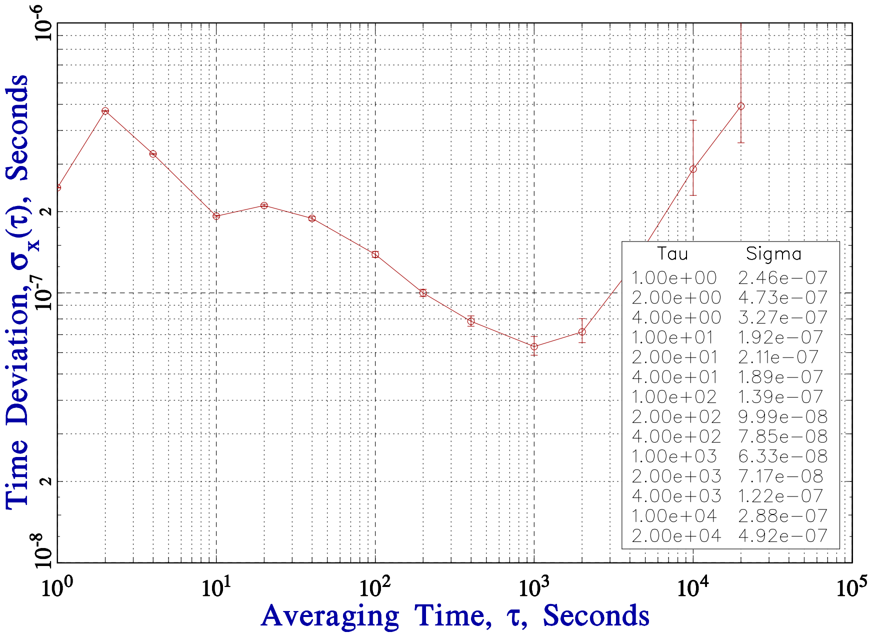


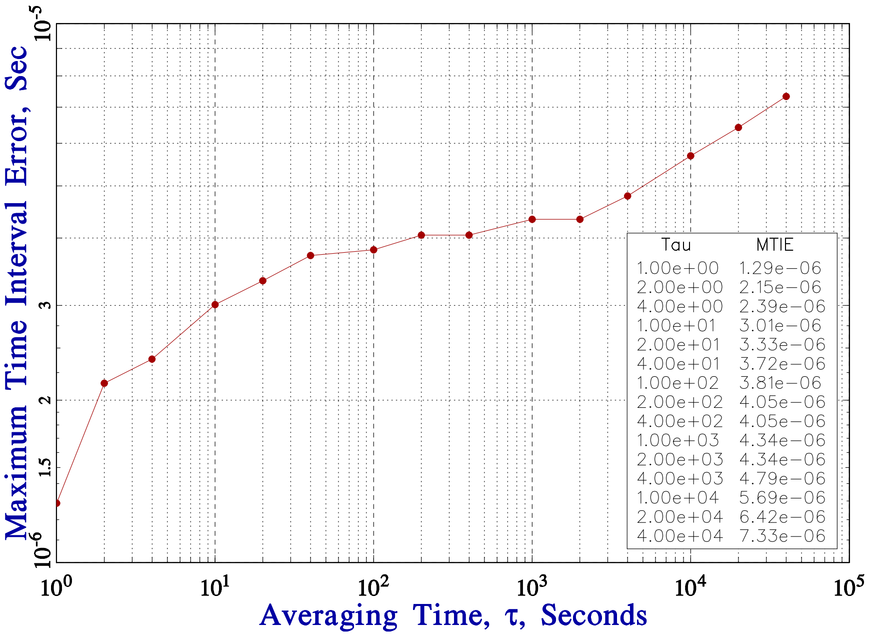
One-week analysis (June 23-25, 2021)



Summary			
Day	**Offset (us)**	**StDev (us)**	**Jitter (us)**
19	734.2	1.1	0.3
20	734.1	1.1	0.3
21		*jump*	
22	581.0	1.0	0.3
23		*jump*	
24	732.3	1.1	0.3
25	732.3	1.2	0.3

TDEV and MTIE for a typical day (June 22)





Conclusions and outlook

- DTM and NTP are complementary techniques for analysis of time transfer over IP networks
- DTM time transfer over FTTH can be stable over several days at the sub-microsecond level
- A large time offset at the millisecond level is unavoidable due to intrinsic FTTH network delay asymmetry
- Jumps in mean offset do occur every several days due to network reconfiguration
- Possible repeatability of mean offsets would open the door to the identification of different “calibration profiles”
- A new experimental Nimbra firmware for “auto-calibration” in case of network reconfiguration is currently being evaluated
- **There is no guarantee that FTTH maintains such behavior, and a different FTTH service provision might result in a different DTM performance**
- For predictable performance, better rely on MPLS or equivalent

Thank you

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