NAVISP Element 1:
Resilient, Trustworthy, Ubiquitous Time Transfer

FINAL PRESENTATION

Project Implementation and Results
by GMV

Teleconference
November 10th, 2021

INNOVATING SOLUTIONS

Content

Project Objectives

Objectives

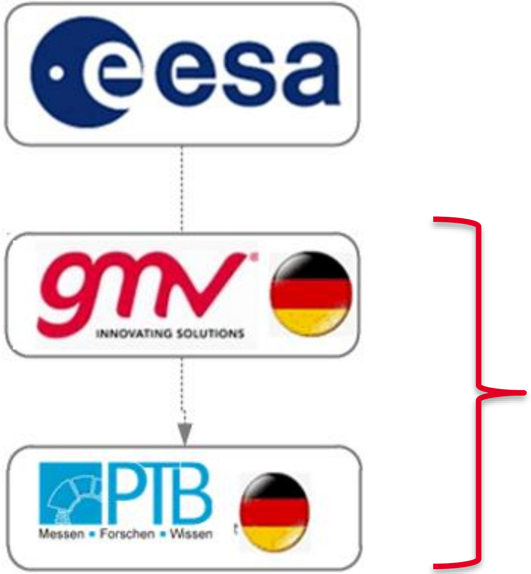
- **This study shall develop innovative effective hybrid solutions of time dissemination, time transfer and synchronizations, combining strengths of GNSS and terrestrial technologies.**

- **Selected solution to be assessed against:**
  - **Use Cases**
  - **Key Performance Indicators**

Project Implementation

Management

Industrial Organisation



Consortium

PTB: its role and its involvement in T&F

- National Metrology Institute, since 1887
- Headquarter in Braunschweig, roots in Berlin where a second site still exists.
- Federal Ministry for Economy and Energy
- 1850 staff, 180 Mio. € budget

Development and operation of atomic clocks

Realization of UTC(PTB) and legal time

Dissemination of legal time, support of industry

International cooperation

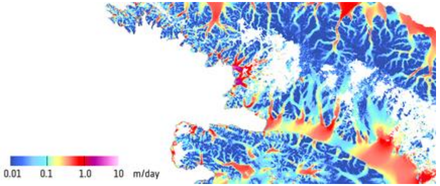
GMV in Germany (GMV GmbH)

Expertise

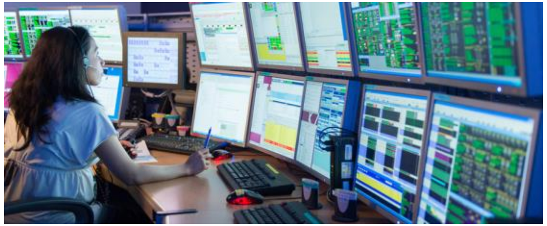
Flight Dynamics

Data Systems

Data Processing



Operations Engineering



SW and product development

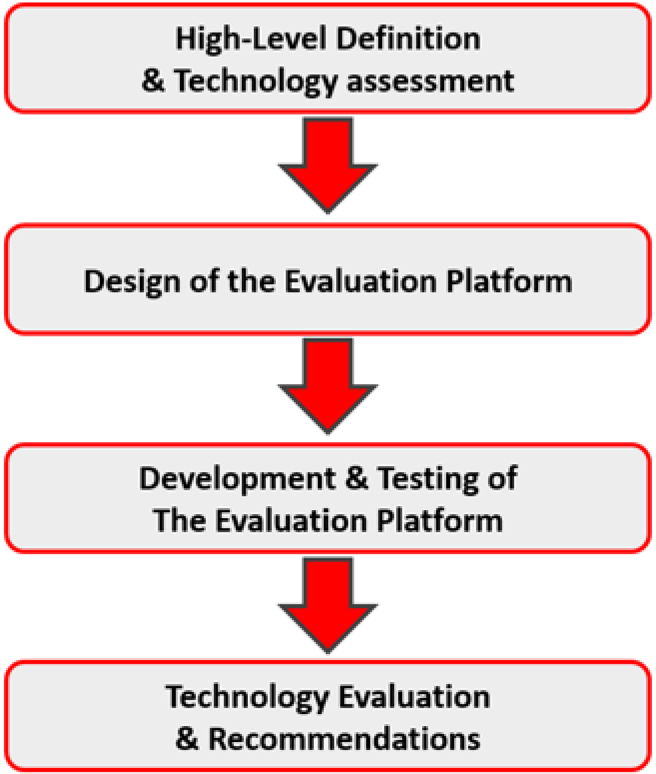
IT & Security

Implementation

Project Implementation

The project is split into 4 tasks:

- **Task 1 = ANALYSIS** *(3 months)*
- **Task 2 = DESIGN** *(4 months)*
- **Task 3 = DEVELOPMENT & DEMONSTRATION** *(5 months)*
- **Task 4 = EVALUATION & CONCLUSION** *(3 months)*



Project Outcome

Task 1 Outcome

ANALYSIS

Concluded by Key Point Meeting 1 held on 30/07/2020

Task 1 Objectives

1. **WHERE: Define Use Cases : Applications/industries where the developed solution could be used – future proof.**

2. **WHY: Analysis of Use Cases against Key Performance Indicators – what are the challenges?**

3. **WHAT: Analyze technologies against Key Performance Indicators/ Use Cases.**

Task 1 Objectives

Key Performance Indicators

- **Cost** effective for future applications (analyzed as CAPEX and OPEX) Low/Medium/High.
- **Ubiquitous** = A technology that is virtually feasible to be employed at any location where the Use Case is to be implemented reasonably.
- **Robustness** = A robust technology withstands effects such as jamming and interference; it includes enough holdover performance in case of failures of one component and is secured against power outages.
- **Secure** = a measure indicating the level of trust a user can have in the timing information provided by a time service.
- **Time accuracy/precision** = defined against Use Cases and their future requirements then evaluated using techniques as defined during the analysis phase in TAM (how we measure).

Summary of Use Cases & challenges

5G and beyond- Network Synchronization

Synchronization of a mobile network base stations vs UTC

Synchronization among network elements is a key ingredient of the operation of a mobile telecommunication network.

Future applications are looking towards the use of 5G, leading to more stringent requirements in terms of timing.

The level of accuracy of 1.5 μs for synchronization to UTC at the end application is well defined and supported by many telecom operators

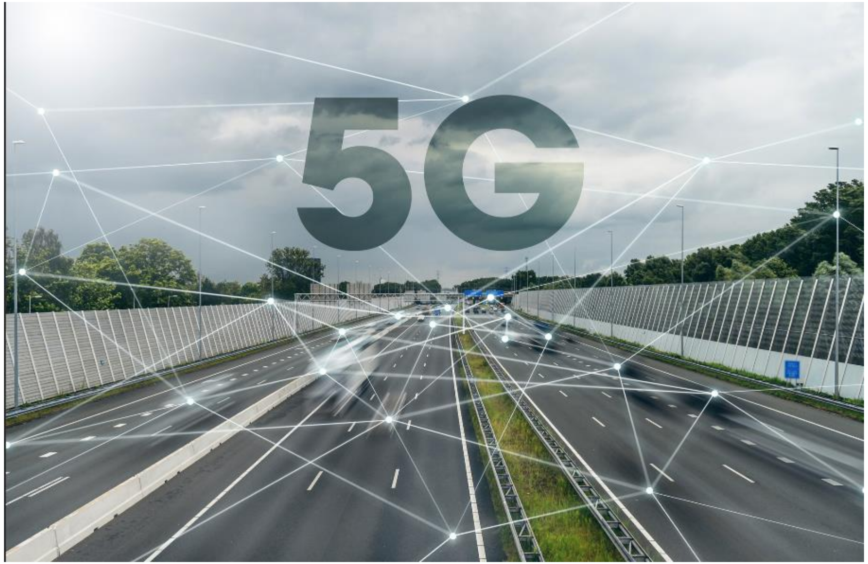
Summary of Use Cases & challenges

5G and beyond- V2X

Relative synchronization between two vehicles (automobiles)

Robustness is key.

1 ms synchronization to UTC looks like the aim synchronization between vehicles.



Ref: https://www.vodafone.de/business/featured/digitaler-ausblick/autonomes-fahren-mit-5g-v2x/

Summary of Use Cases & challenges

5G and beyond- Factories of the future

Relative synchronization between any two machines within a plant/factory

5G networks offer manufacturers the chance to build smart factories to take advantage of technologies such as continued automation, artificial intelligence, or augmented reality for troubleshooting.

Ubiquitous networking between all components and systems involved in the production chain distributed locally but also across many sites is a key issue.

https://venturebeat.com/2019/04/10/inside-nokias-factory-of-the-future-robots-data-automation-5g-and-even-some-humans/

Summary of Use Cases & challenges

Power Grid

Synchronization of a Synchrophasor Measurement Unit (SMU) vs UTC

Renewable energy: due to the wide-scale connection of decentralized resources.

Future electrical power grids will require real-time capable control and monitoring systems to ensure stability under increasingly complex and challenging conditions

New.siemens.com

Summary of Use Cases & challenges

Financial Markets

Synchronization of timestamps appended to transaction records vs UTC

Legal requirement wrt security to have a synchronization of the business clock for all required operations.

No need for better accuracy to current solutions.

Low cost is not a requirement these are overwritten by strict security requirements.

Ref: https://www.jonesday.com/en/insights/2020/11/fca-consultation-on-new-benchmark-powers

Summary of Use Cases & challenges

Broadcasting Frames Synchronization

Synchronization of broadcasting frames vs UTC

Strong trend in the professional audio/video industry to move toward the use of standard networks instead of analog or special-purpose interfaces in the transport of time-sensitive media, for reasons of flexibility, scalability, and cost.

Synchronized transfer of voice/video is key.

Consolidation of Use Cases (timing reqs)

Use Case ID	Use Case Name	Consolidated Timing performance requirements as per D1 [AD.5]
UC1a	5G and beyond- Network Synchronization	1.5 µs max. time error at any node wrt to UTC
UC1b	5G and beyond- V2X	1 ms to UTC 400-800 ns uncertainty among each other
UC1c	5G and beyond- Factories of the future	100 ns relative synchronization
UC2	Power Grid	1 µs (typical) 100 ns (rare)
UC3	Financial Markets	100 µs
UC4	Broadcasting Frames Synchronization	1 µs

Target: 1 µs

Reviewed Technologies

GNSS: Global Navigation Satellite System (GNSS) is the standard generic term for satellite navigation systems that provide autonomous geo-spatial positioning with global coverage. (i.e.: GPS, Galileo..)

RF Broadcast: Radio Frequency Broadcast.

NTP: The Network Time Protocol (NTP) [RD.8] is a protocol created for internet-based clock synchronization. It is in use all around the world and has been part of most popular operating systems since its creation in the 1980s.

NTP with NTS: The Network Time Security (NTS) [RD.11] provides cryptographic security for the Network Time Protocol (NTP). This enables users to obtain time in an authenticated manner.

PTP: The Precision Time Protocol (PTP) [RD.33] is a protocol created for clock synchronization in local area networks using dedicated protocol-enabled devices.

White Rabbit: The White Rabbit synchronization protocol was developed at the CERN research institute. It is currently being standardized as the high accuracy profile for PTP.

Reviewed Technologies

PPS and 10 MHz: A pulse per second (PPS or 1PPS) is an electrical signal that has a width of less than one second and a sharply rising or abruptly falling edge that accurately repeats once per second. The dissemination of timing signals is via electrical cables (coaxial cables)

DTM: The Dynamic Synchronous Transfer Mode (DTM): is a proprietary technology with server and client running on Nimbra equipment (developed by Net Insight in Sweden). It is designed to provide a guaranteed quality of service for streaming video services but can be used for packet-based services as well.

STL: From [orolia.com]: "STL, or Satellite Time and Location, is a low earth orbit satellite-based time reference. It uses the Iridium constellation of satellites to deliver a burst signal specifically designed for position, navigation, and timing applications. The technology was developed by Satelles and is being delivered commercially in partnership with Orolia, the parent company of Spectracom."

Tech:	GNSS				Radio				NTP				NTP+NTS				PTP				WR				PPS				STL				DTM			
KPI / UC	Robustness	Security	Ubiquity	Accuracy	Robustness	Security	Ubiquity	Accuracy	Robustness	Security	Ubiquity	Accuracy	Robustness	Security	Ubiquity	Accuracy	Robustness	Security	Ubiquity	Accuracy	Robustness	Security	Ubiquity	Accuracy	Robustness	Security	Ubiquity	Accuracy	Robustness	Security	Ubiquity	Accuracy	Robustness	Security	Ubiquity	Accuracy
UC1a	PC	C	C	C	PC	C	PC	NC	C	NC	C	NC	C	C	C	NC	C	PC	C	PC	C	PC	C	C	C	C	PC	C	C	C	PC	PC	C	C	C	PC
UC1b	PC	C	PC	C	N/A				PC	NC	PC	PC	PC	C	PC	PC	N/A				N/A				N/A				C	C	PC	C	N/A			
UC1c	PC	C	PC	C	PC	C	PC	PC	C	NC	C	PC	C	C	C	PC	C	C	PC	C	C	C	PC	C	C	C	PC	C	C	C	PC	C	C	PC	PC	C
UC2	PC	C	C	C	PC	C	PC	PC	C	NC	C	NC	C	C	C	NC	C	PC	NC	C	C	PC	NC	C	C	PC	NC	C	C	C	PC	C	C	PC	NC	C
UC3	PC	NC	PC	C	PC	NC	PC	C	C	NC	C	NC	C	C	C	NC	C	PC	PC	C	C	PC	PC	C	N/A				C	C	PC	C	C	PC	PC	C
UC4	PC	C	PC	C	PC	C	PC	C	C	PC	C	PC	C	C	C	PC	C	C	PC	C	C	PC	NC	C	N/A				C	C	PC	C	C	C	PC	C

Selected Technologies

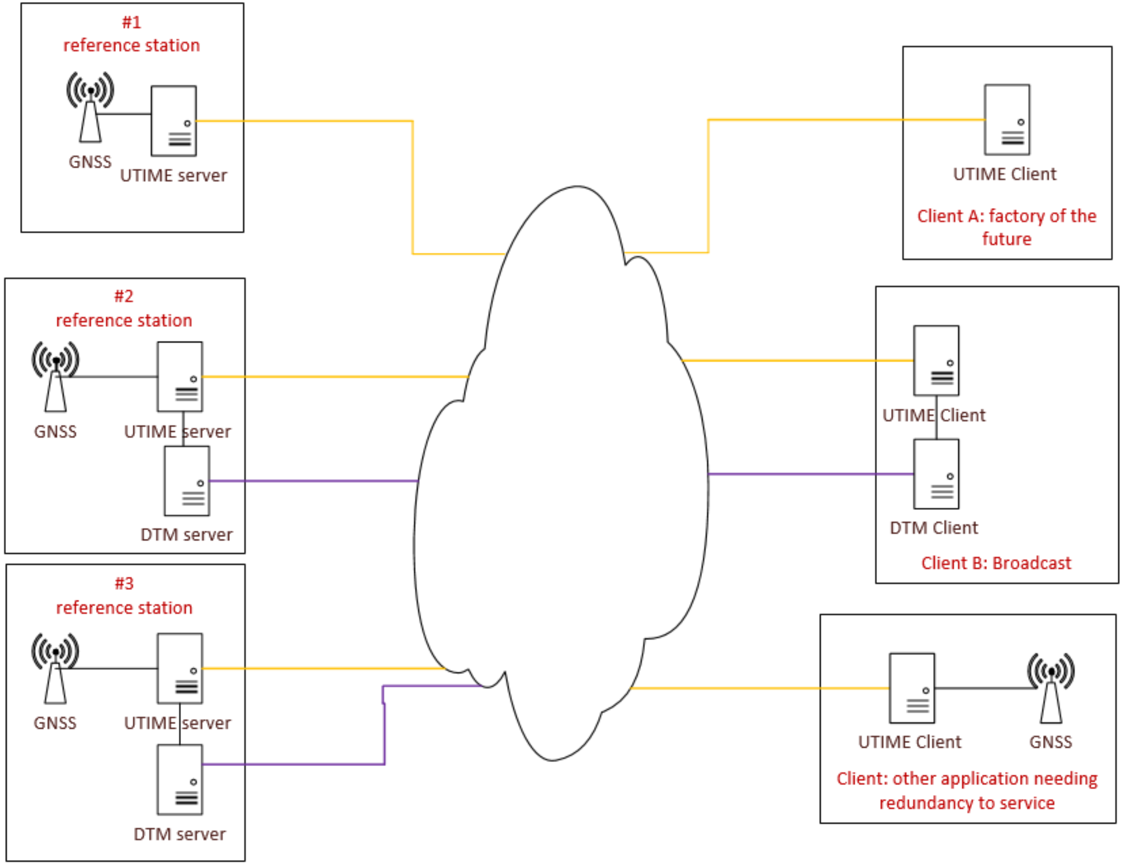
- **STL Solution: "**The combination of Orolia's SecureSync time server and the STL signal provided by Satelles delivered extremely accurate timing indoors and underground, as compared to Coordinated Universal Time (UTC). This solution for resilient timing is available for commercial and civil government applications worldwide, to help protect national critical infrastructure and to deliver precise timing"

- Mix of technologies – solution named **UTIME Solution:**
  - **GNSS**
  - **NTP + NTS**
  - **DTM**

UTIME Solution Concept

- Smart combination of **GNSS** timing from a sparse network of low-cost, multi-frequency GNSS stations, and time distribution over general-purpose terrestrial networks.

- Time distribution should be based on alternative techniques such as **enhanced NTP+NTS** and **DTM** that can work over commercially-available networks.



Scenarios to be tested

- **Open sky:** set-up “out of a building”, with no interference to GNSS signal (i.e.: roof top)
- **Light indoor:** set-up “inside a building or at least a shelter”, antenna possibly in unfavourable location (i.e: indoor near window)
- **Obstructed open sky:** similar to light indoor, understood as GNSS reception affected by multipath and restricted field of view e. g. in canyons
- **Deep indoor:** understood as inside building with no outside access (i.e.: server room…).

Task 2 Outcome

DESIGN

Concluded by Design Concept Review held on 24/11/2020 & 15/12/2020

Task 2 Objectives

- **Design implementation of Test Bed + design of UTIME prototype receiver**

- **Definition of tests to be carried out:**
  - STL tests at GMV premises.
  - UTIME tests at GMV premises using DTM for time distribution.
  - UTIME tests with PTB client against UTC reference.

STL Solution

SecureSync®

Time and Frequency Synchronization Platform

SecureSync’s: Internal precision time-keeping via oscillator:

- Standard Oscillator: OCXO
- Optional Oscillators: **TCXO**, Low Phase Noise OCXO (LPN OCXO),Rubidium (Rb), Low Phase Noise Rubidium (LPN Rb)

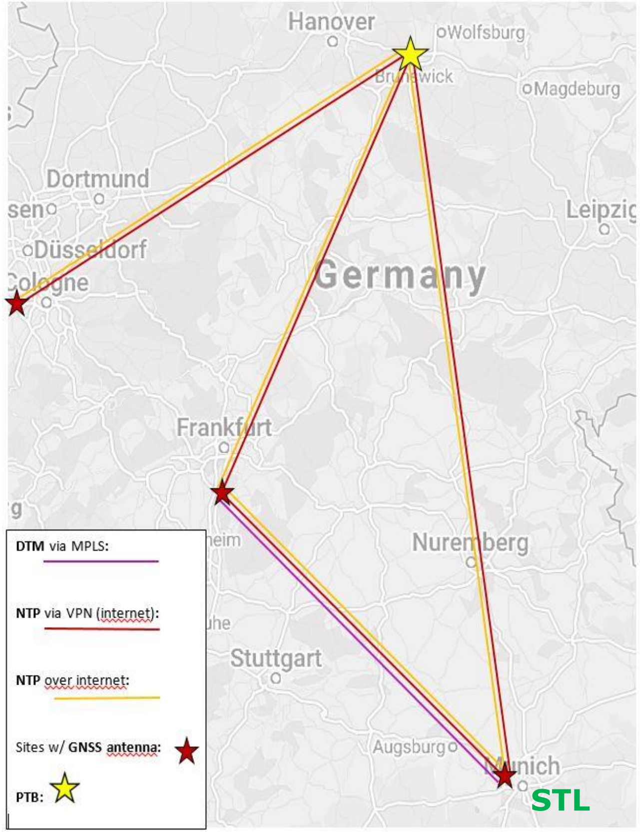
System Performance

See option card descriptions for additional performance specifications.

10 MHz Frequency Output:

	TCXO	OCXO	Low Phase Noise OCXO	Rubidium	Low Phase Noise Rubidium
Accuracy (average over 24 hours when GPS locked)	$1x10^{-11}$	$2x10^{-12}$	$1x10^{-12}$	$1x10^{-12}$	$1x10^{-12}$
Medium Term Stability (without GPS after 2 weeks of GPS lock)	$1x10^{-8}$/ day	$5x10^{-10}$/ day	$2x10^{-10}$/ day	$5x10^{-11}$/ month ($3x10^{-11}$/ month typical)	$5x10^{-11}$/ month ($3x10^{-11}$/ month typical)

Test-Bed deployement



Sites:	UTIME Hardware			Network connections		
	GNSS reference station ★	UTIME receiver configuration	DTM	MPLS (by PlusNet)	Dedicated Internet (Plusnet TBC) configured as either: VPN	Standard Internet
Gilching (GMV office)	✓	**Server** +client(*)	✓	✓	✓	
Darmstadt (GMV office)	✓	**Server**	✓	✓	✓	
Jülich (Jülich Forschungszentrum)	✓	**Server**	✗	✗	✓ *Note: different operator*	
Braunschweig (PTB office)	✗	**Client**	✗	✗	✓	

1 **STL** device with TCXO oscillator located @ Gilching GMV office

https://www.fz-juelich.de/portal/DE/Home/home_node.html

UTIME Receiver Unit – Prototype (server/client)

1. 10 A 5V **Power supply:** Traco Power TXL 050-05S

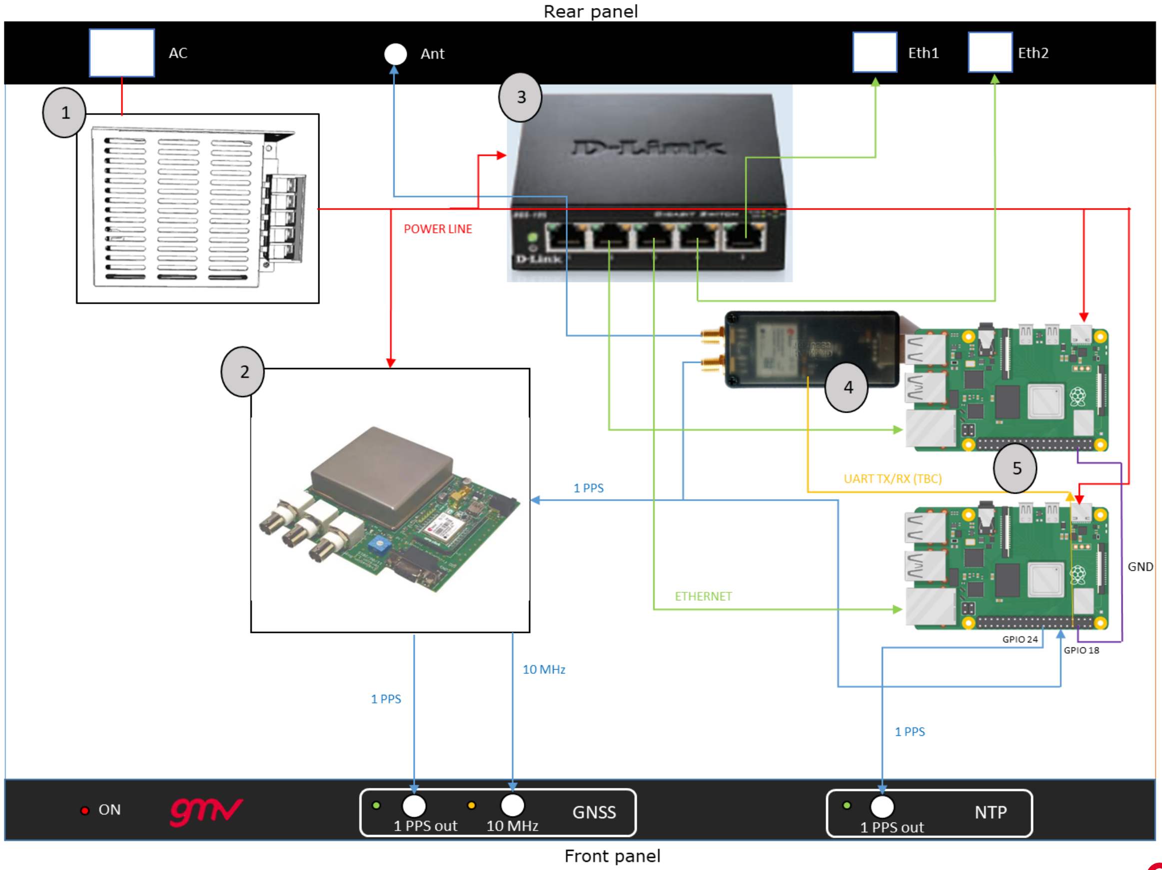
2. Oscillator GPSDO: IQD IQCM-200 with evaluation board

3. GE **switch** Quality of Service: D-link DGS-105

4. GNSS receiver: U-BLOX ZED F9T

5. 2 **Single Board Computer**: Raspberrypi 4 Model B 4 GB

6. TW7972 Triple-band **GNSS Antenna + L-Band:**



UTIME – Nimbra 390 DTM – Net Insight

DTM over IP/Ethernet using copper UTP or Fiber cable at 1 GbE

1 PPS and 10 MHz signals from DTM time transfer synchronization

Time Error value for DTM interfaces against a reference timing signal

UTIME Software Elements

- Linux kernel patched with RT Prempt version for improving Operating System latency
- NTP/NTS server and client using Chronyd implementation
- NTP algorithm to improve Asymmetric network delay
- Getting 1 PPS output from NTP
- GUI interface

https://chrony.tuxfamily.org/

chrony

Introduction
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Introduction

chrony is a versatile implementation of the Network Time Protocol (NTP). It can synchronise the system clock with NTP servers, reference clocks (e.g. GPS receiver), and manual input using wristwatch and keyboard. It can also operate as an NTPv4 (RFC 5905) server and peer to provide a time service to other computers in the network.

It is designed to perform well in a wide range of conditions, including intermittent network connections, heavily congested networks, changing temperatures (ordinary computer clocks are sensitive to temperature), and systems that do not run continuosly, or run on a virtual machine.

Typical accuracy between two machines synchronised over the Internet is within a few milliseconds; on a LAN, accuracy is typically in tens of microseconds. With hardware timestamping, or a hardware reference clock, sub-microsecond accuracy may be possible.

Two programs are included in chrony, chronyd is a daemon that can be started at boot time and chronyc is a command-line interface program which can be used to monitor chronyd's performance and to change various operating parameters whilst it is running.

Task 3 & 4 Outcome

DEVELOPMENT & DEMONSTRATION

EVALUATION & CONCLUSION

Concluded by Final Review held on 23/09/2021

STL Results/Analysis summary

Tests carried out:

- **Deep Indoor**
- **Open Sky**
- **Light Indoor**
- **Obstructed Sky**

- The equipment location (STL coverage) could affect to the final operation and impact directly to the ubiquity and timing performance indicators – with low visibility of satellites making it hard to synchronize properly – a better oscillator would improve the holdover.

- The robustness and security performance indicators are fullfilled by design and we didn’t note any issue during the measurements

UTIME Results summary

Tests carried out:

- DTM over MPLS and FTTH were successful showing time synchronization within the 1 us target.
- NTP/NTS over MPLS and FTTH were partially successful providing accurate time transfer however not to the target 1us.
- Security tests were partially successful: NTS vulnerability tests being successful, however holdover and delay attacks were not detected in a timely manner (within the target accuracy).

UTIME Data Analysis Summary: conclusion

- Accuracy performance offered by DTM over MPLS and FTTH meets the requirements and it is under the 1 us Time Error against UTC.

- The results of DTM over FTTH points that those networks could provide good characteristics with almost the same results than with MPLS. *Note specific to Germany.*

- NTP operation over FTTH presents a large time offset (unavoidable network delay asymmetry) these can be reduced through filtering and further improvements.

Project Conclusion

Overall Conclusion

- The main conclusion is that it is possible to achieve sub-microsecond accurate time distribution over several hundred km using packet-exchange network technology (DTM) over relatively inexpensive and commercially available end-to-end network links (MPLS) and without "network engineering".

- Cheaper options over FTTH could be implemented by developing specific improvements (filters, AI for network characteristics/calibration….).

- UTIME project could be further develop as NAVISP Element 2 project: to provide improvement for commercialization.

Way Forward

Technology Roadmap

- GMV is currently developing a suite of products and services under the WANtime trademark. Our intention is to develop a commercial product based on the UTIME receiver, after some modifications. The name for such product will be WANtime receiver.

The *WANtime receiver*

NAVISP Element 2 project - as continuation

Develop upon Element 1 prototype through Element 2 project:

Providing Improved Techniques for Ubiquitous, Resilient Accurate time synchronization

- Migration to new hardware platform improvement of clock (precise cristal clock), hardware timestamping
- Enhancement of NTP algorithm with advanced filtering capabilities
- Implementation of Artificial Intelligence to characterise and compensate inherent Network errors.

NAVISP Element 2 project - as continuation

Time-to-market and Costs

- The time-to-market of the upgraded WANtime receiver could be one year for the production of a few first prototype units for selected users. The calibration of the NTP link offset would still be based on the local GNSS in this product version.

- The estimated development cost of this version, including manpower and materials would be around 100 k€.

NAVISP Element 2 project - additional

- A proposed method to mitigated the remaining time offset of the client side for NTP and DTM is using GNSS or other satellite systems as LEO navigation systems. Calibration through single LEO satellite ("CalSat") could set an accuracy below 100 ns.

- The final product with LEO satellite calibration capabilities would require a much longer development time, including a previous feasibility study.

Net Insight – Press Release

- Net Insight has signed a collaboration agreement with Turkish telecom operator Türk Telekom relating to 5G synchronization (within the framework of the collaboration agreement, SEK 55 million relates to product development, and around SEK 25 million will be an initial). -> reduce cost & speed up rollout for 5G.
- "There is a large total market for 5G synchronization with an estimated future annual value of over **USD 1 Bn**," commented Crister Fritzson, CEO of Net Insight.

https://investors.netinsight.net/pressrelease/?ddpr=83e63740-2d92-4740-a24a-3528156ef0bd/

Thank you

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