SEVEN Solutions

When every nanosecond counts

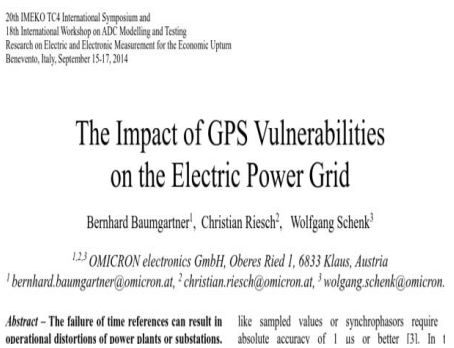
Timing network backup to GNSS

Francisco Girela

www.sevensols.com

- Introduction
- White Rabbit technology
- GNSS backup based on network configuration
  - Plug&play solution for single fiber (bicolor) metro networks
  - Simple calibration for bifibra / bidirectional metro network
  - GNSS assited calibration for long-haul (unidirectional) or unknown networks.

Needs of GNSS backup technologies


20th IMEKO TC4 International Symposium and
18th International Workshop on ADC Modelling and Testing
Research on Electric and Electronic Measurement for the Economic Upturn
Benevento, Italy, September 15-17, 2014

The Impact of GPS Vulnerabilities on the Electric Power Grid

Bernhard Baumgartner[1], Christian Riesch[2], Wolfgang Schenk[3]

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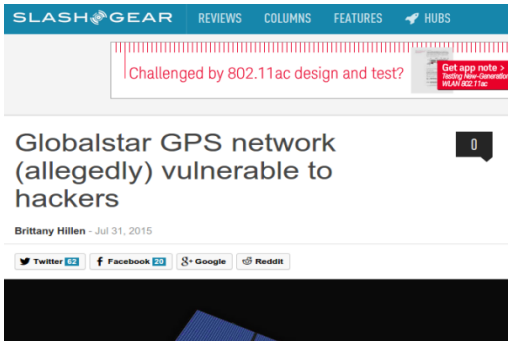
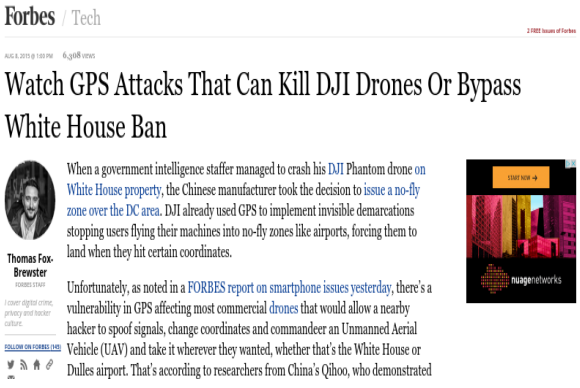
[1] bernhard.baumgartner@omicron.at, [2] christian.riesch@omicron.at, [3] wolgang.schenk@omicron.

Abstract – **The failure of time references can result in operational distortions of power plants or substations.** like sampled values or synchrophasors require absolute accuracy of 1 us or better [3]. In t




Forbes / Tech

6,308 views

Watch GPS Attacks That Can Kill DJI Drones Or Bypass White House Ban

Thomas Fox-Brewster

When a government intelligence staffer managed to crash his DJI Phantom drone on White House property, the Chinese manufacturer took the decision to issue a no-fly zone over the DC area. DJI already used GPS to implement invisible demarcations stopping users flying their machines into no-fly zones like airports, forcing them to land when they hit certain coordinates.

Unfortunately, as noted in a FORBES report on smartphone issues yesterday, there's a vulnerability in GPS affecting most commercial drones that would allow a nearby hacker to spoof signals, change coordinates and commandeer an Unmanned Aerial Vehicle (UAV) and take it wherever they wanted, whether that's the White House or Dulles airport. That's according to researchers from China's Qihoo, who demonstrated

- GNSS backup concept
  - Preserve the network time reference.
  - Dependable GNSS time reference backup.
  - Protection against spoofing and jamming.
  - Time reference monitorization.
- Solutions
  - Holdover clocks
  - eLORAN
  - **Optical fibers networks**

White Rabbit technology

White Rabbit (WR) is a technology born at CERN which achieves sub-nanosecond accuracy in Ethernet based networks. It allows easy deployments of scalable and reliable networks with high accuracy synchronization requirements.

- 10 years of expertise synchronizing large scientific facilities with WR:
  - CERN, GSI, Fermilab, …

- Validated by National Metrology Institutes: NIST, NPL, PTB, OP, VSL, ROA, VTT, RISE, …

- New PTP High Accuracy profile to be released early 2019 will be intensively based on the pre-standard approach White Rabbit.

- More than 8 years of expertise on the White Rabbit technology. Main White Rabbit technology developers.

White Rabbit technology

Easy to integrate
within existing infrastructures (Ethernet, PTPv2).

Deterministic and highly accurate
This allows saving engineering and equipment costs to achieve a global target time budget.

Cost-effective
It compensates dynamically link asymmetries and temperature changes. Easy to deploy, pre-calibration.

Scalable
to long distances & high number of nodes. It supports tree topologies and daisy-chain configurations

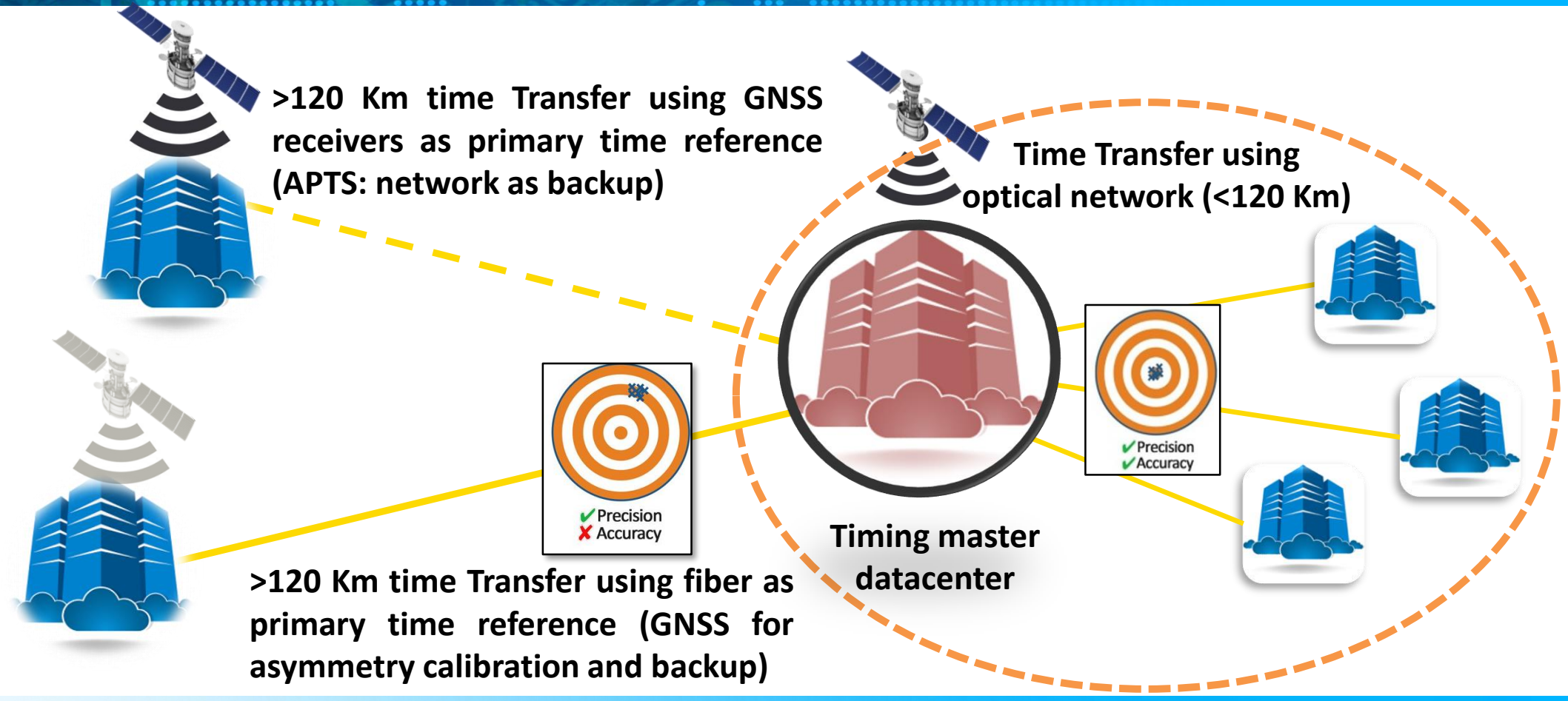
Dependable
It reduces vulnerabilities to spoofing or GPS jamming. Up to 100 km links without on site calibration.

Facilitates new services
Positioning, High Frequency Trading, Time as a Service

Key ideas

- PTPv2 does not provide deterministic time transfer → WR does,
  - It guarantees high precision PPS distribution through all the network.
  - Temperature compensated. Scenarios. Second order drift (<100ps) can be modelled and adjust in most applications if required.
- The asymmetry problem: offset on the PPS signals → Different wavelengths (different group velocities), differences on optical fibers lengths, asymmetries on the amplifiers / DCMs / DWDMs / transponders, etc...
  - The asymmetries can be measured and compensated on most circumstances.
  - For blind situations, a calibrated GNSS receiver is a simple and cost effective solution.
  - Alternatively, we can modify the network adding bidirectional amplifiers (costly R&D approach) or characterize all devices on the network (not always a realistic approach).

GNSS backup

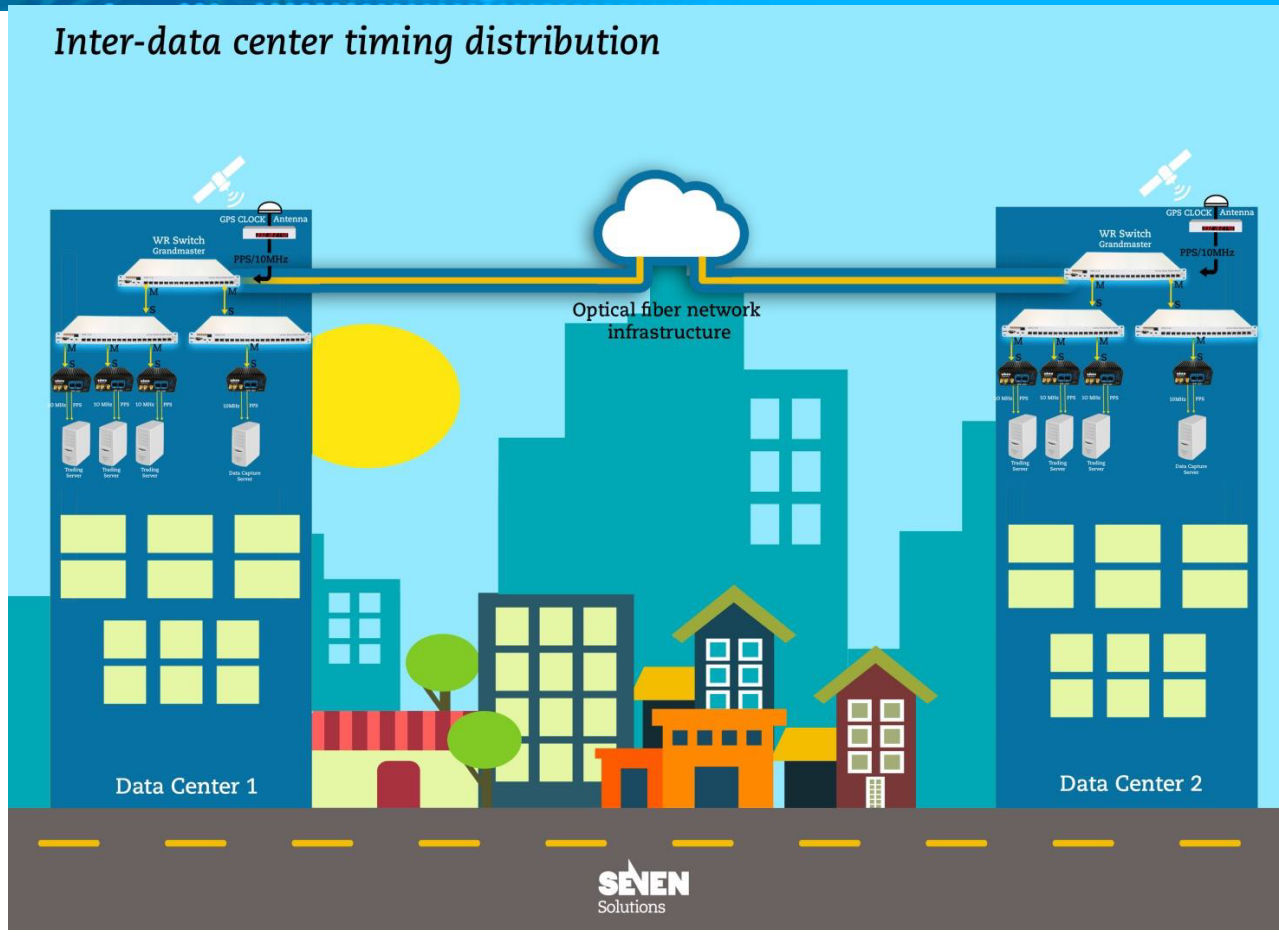

>120 Km time Transfer using GNSS receivers as primary time reference (APTS: network as backup)
Time Transfer using optical network (<120 Km)
Precision
Accuracy
Precision
Accuracy
Timing master datacenter
>120 Km time Transfer using fiber as primary time reference (GNSS for asymmetry calibration and backup)

GNSS backup

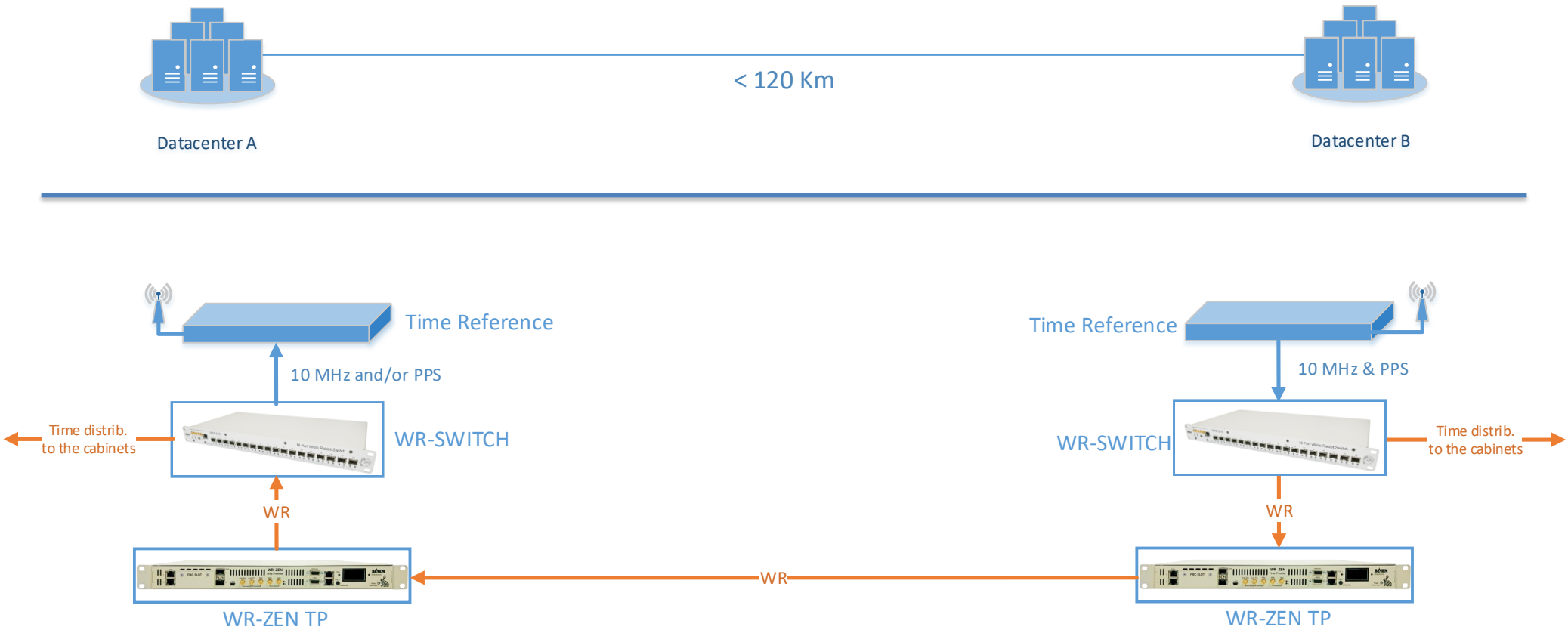
- GOAL: accurate and reliable time transfer over optical fiber networks without modifications (avoid changing the network topology or components).
  - Good performance (not as good as metrologist solutions).
  - Interoperable with standard networks.
- Cases:
  - Bi-color metro links: Pre-calibrated / plug&play.
  - Bi-fiber metro links: Easy calibration procedure based on bidirectional networks.
  - Long-haul links: GNSS assisted calibration.

GNSS backup bicolor

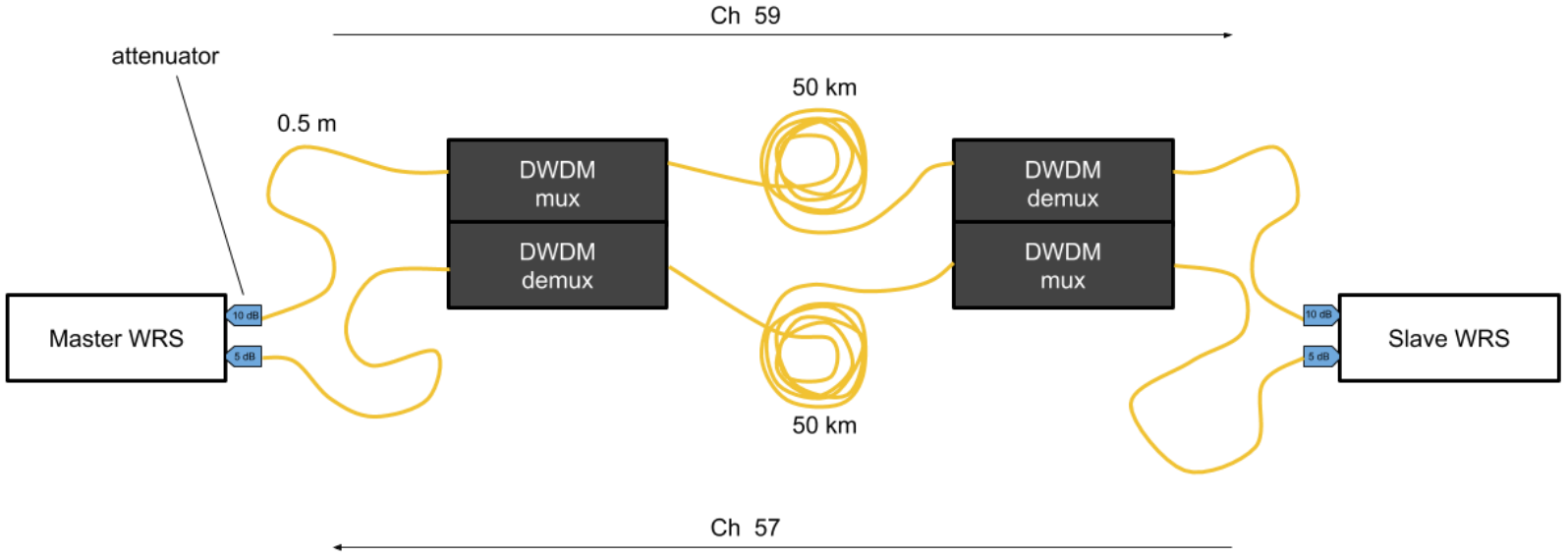
- Sub-nanosecond synchronization using bidirectional optical fiber links.
- Distances up to 120 Km.
- Dedicated or DWDM optical networks channels without amplification.
- Dedicated or data-shared timing channels.



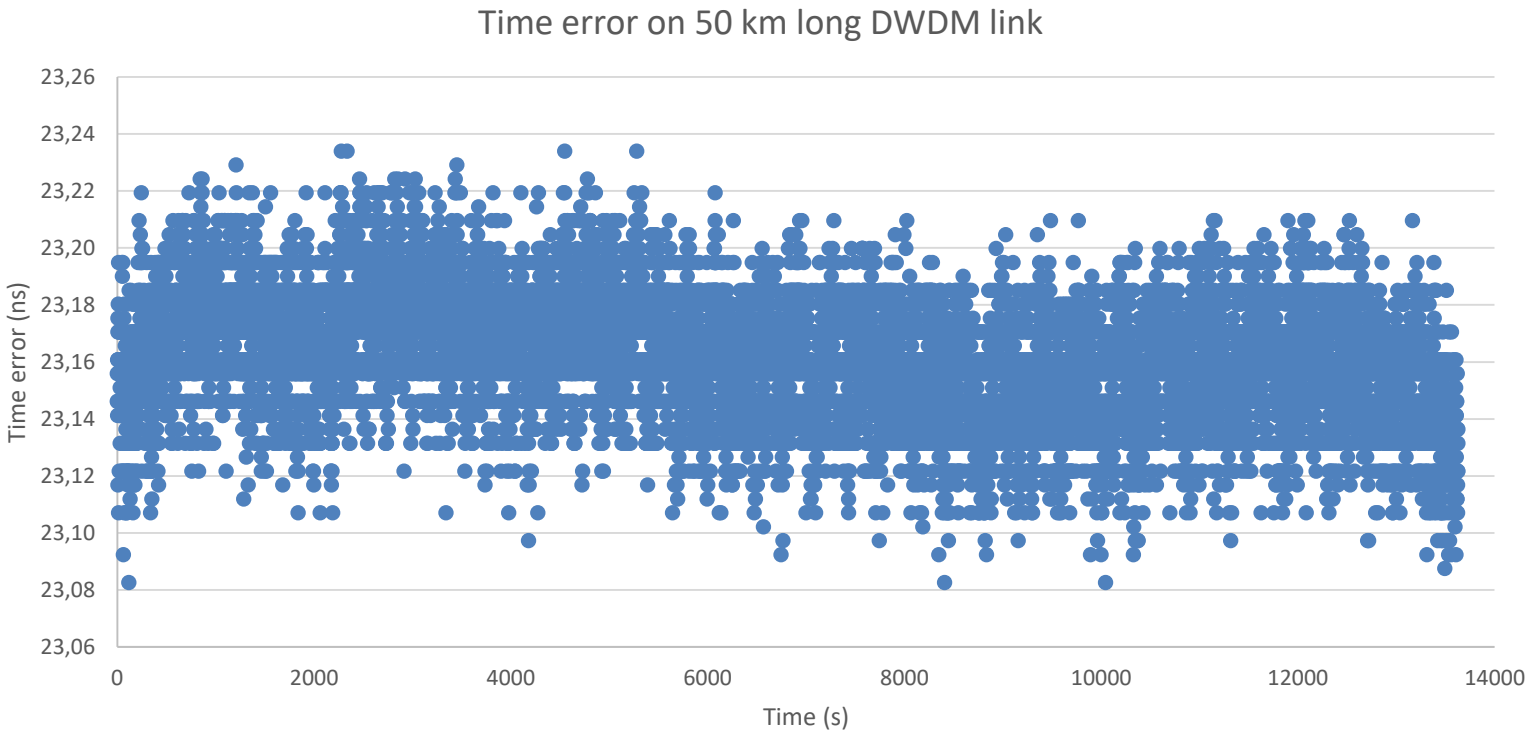
GNSS backup bicolor



- Unidirectional WDM connection through 50 km fiber



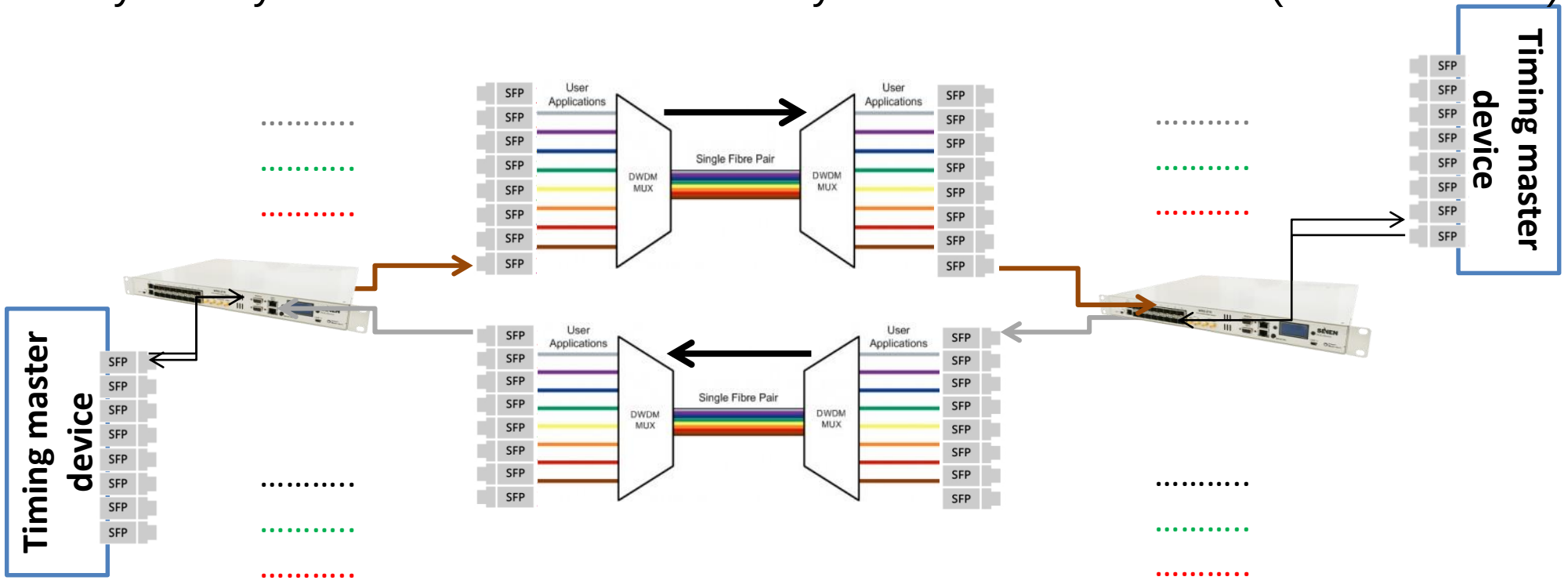
GNSS backup bi-fiber



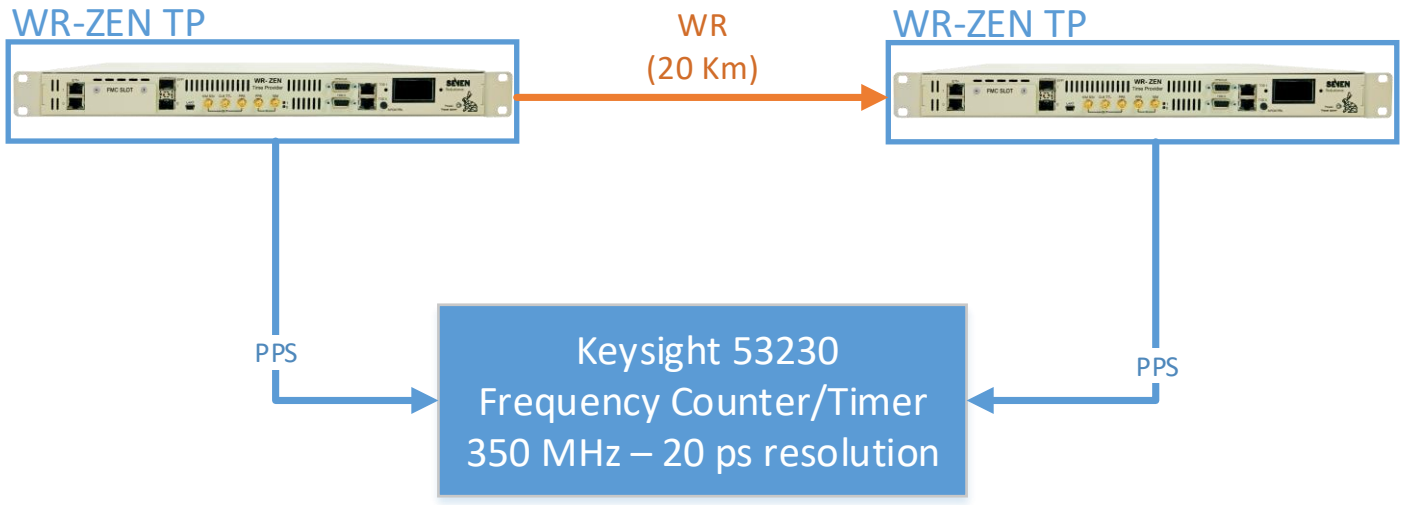
Results provided by the University of Granada with 7Sols equipment.
Further results Will be presented soon.

GNSS backup bi-fiber

- Support for bi-fiber bidirectional WDM networks.
- Asymmetry calibration can be assisted by an additional oscillator (i.e. GNSS-DO).

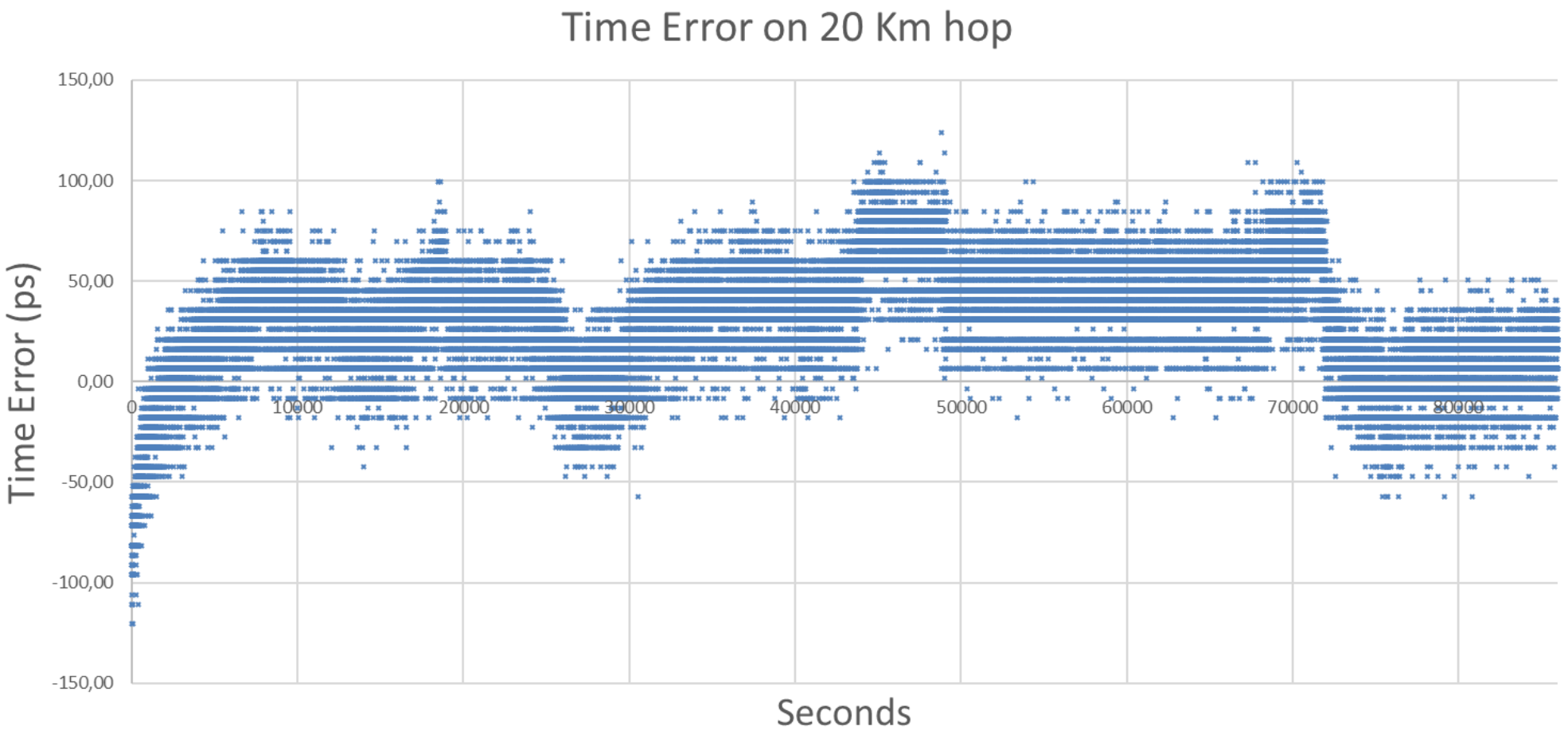


Metro links

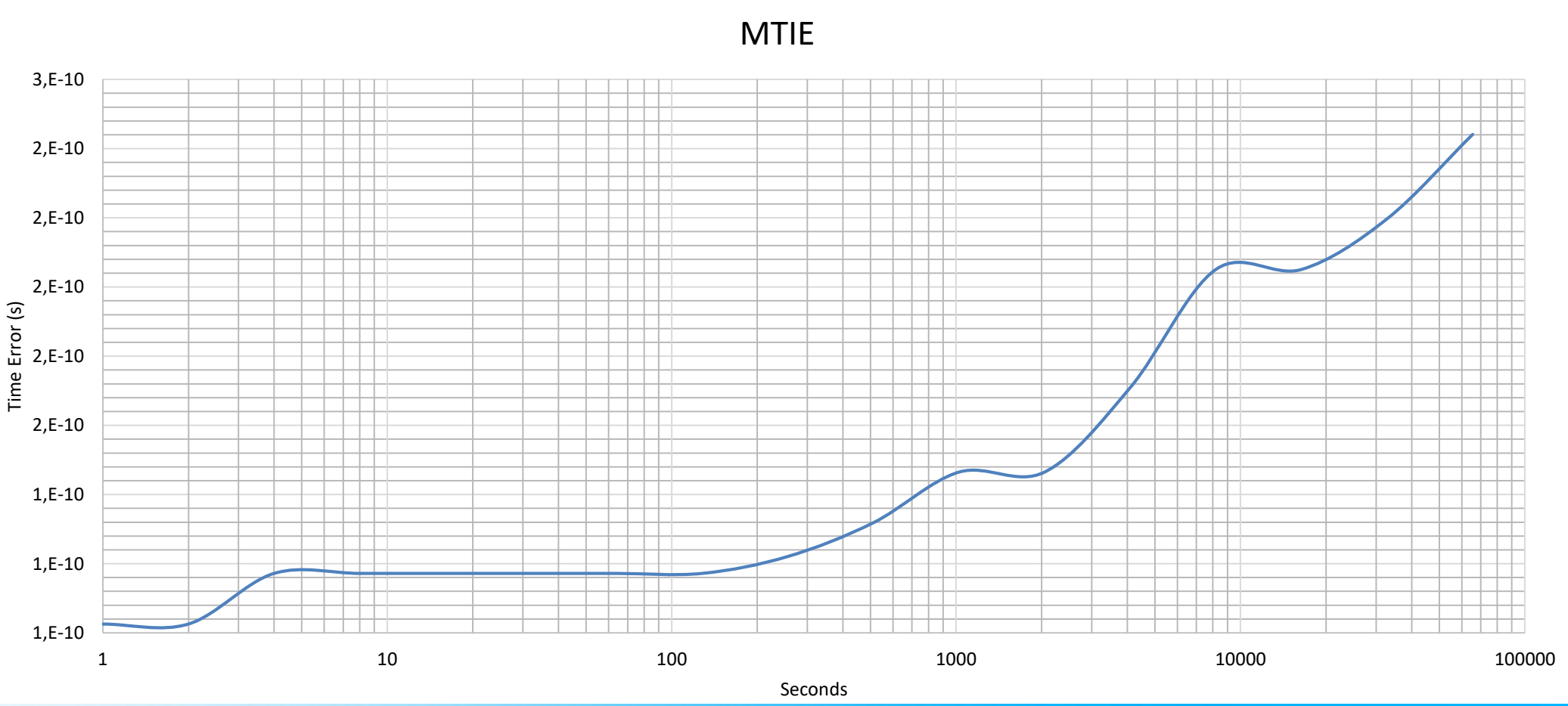


- Lab test
- 24 hours measure
- Sub-nanosecond accuracy and precision

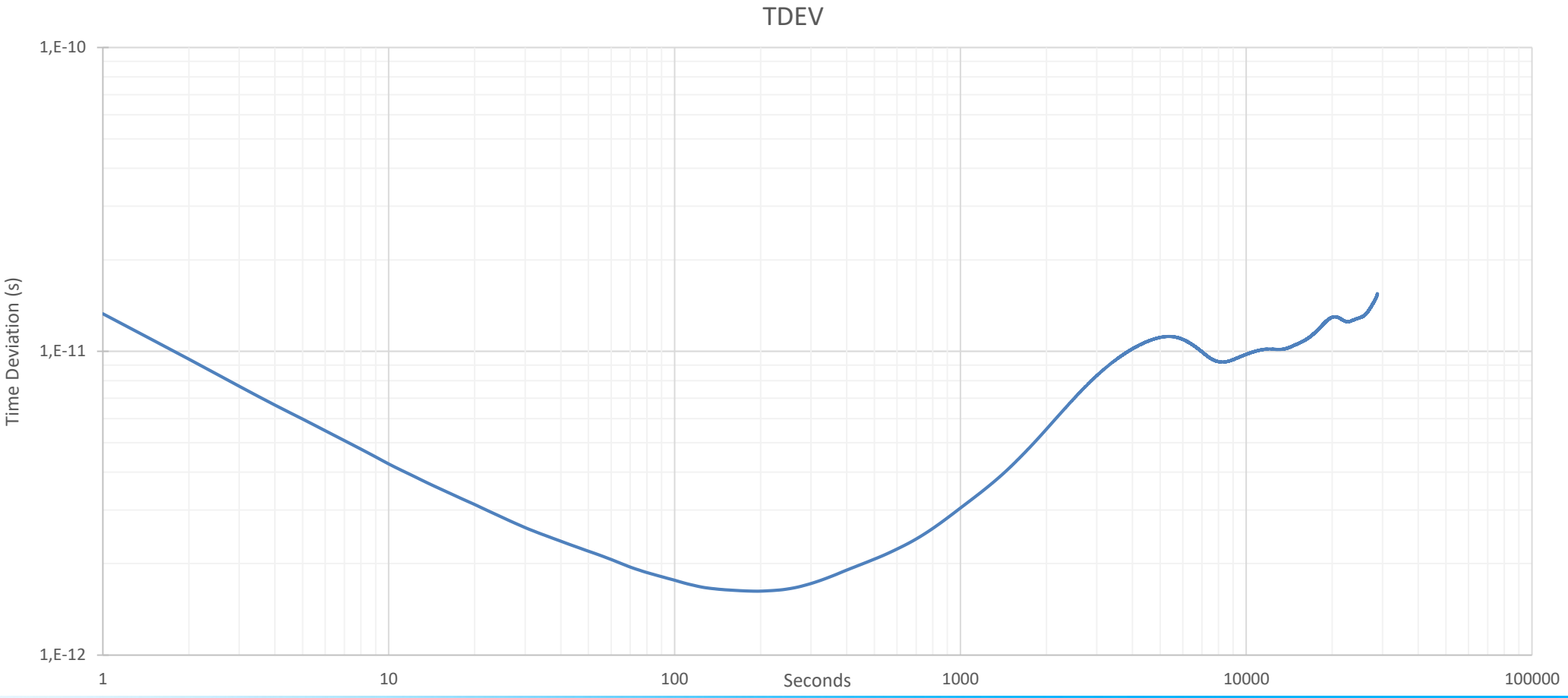
Metro links


Time Error on 20 Km hop
Time Error (ps)
150,00
100,00
50,00
0,00
-50,00
-100,00
-150,00
0
10000
20000
30000
40000
50000
60000
70000
80000
Seconds

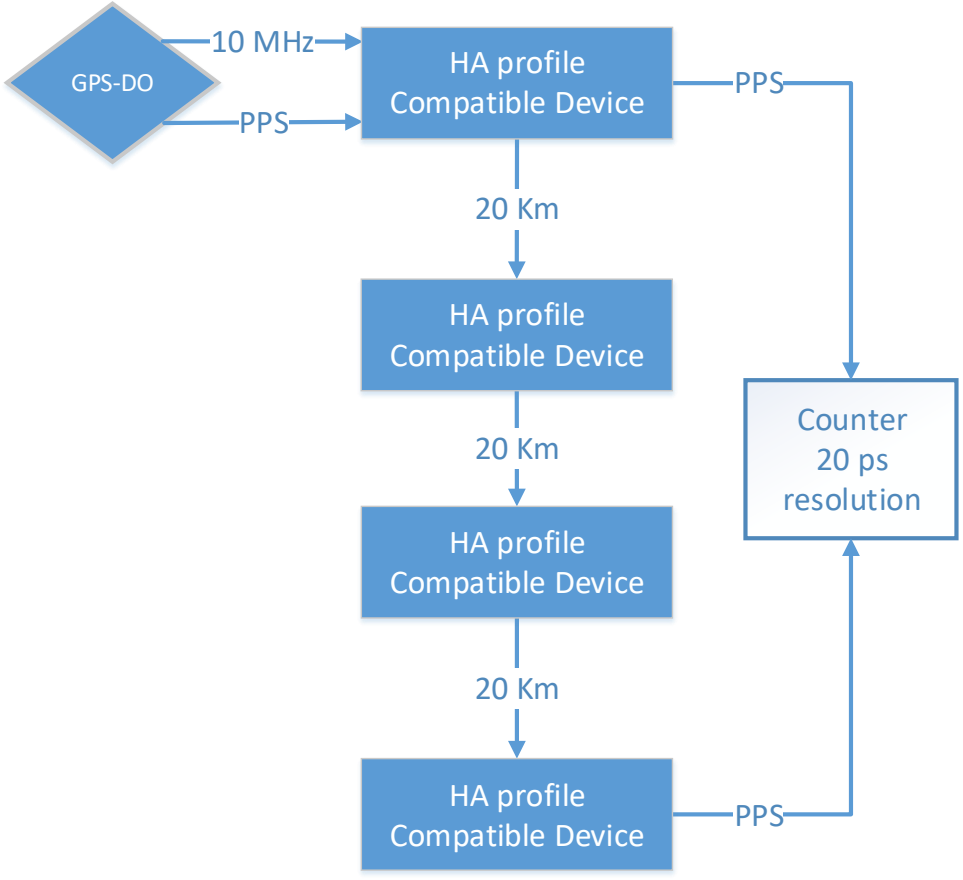
Metro links


MTIE
3,E-10
2,E-10
2,E-10
2,E-10
2,E-10
2,E-10
1,E-10
1,E-10
1,E-10
Time Error (s)
1
10
100
1000
10000
100000
Seconds

Metro links

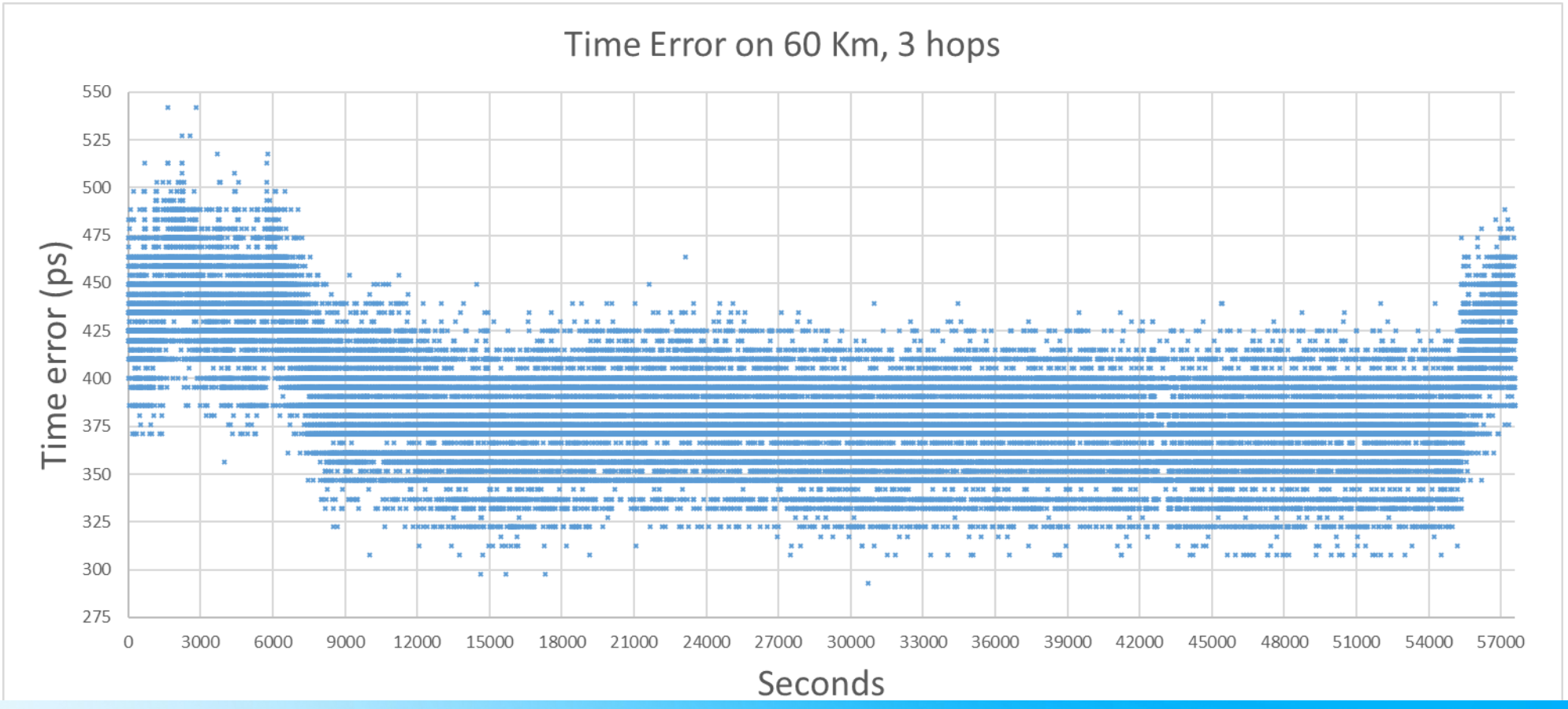

TDEV
1,E-10
1,E-11
1,E-12
Time Deviation (s)
1
10
100
Seconds
1000
10000
100000

Metro links

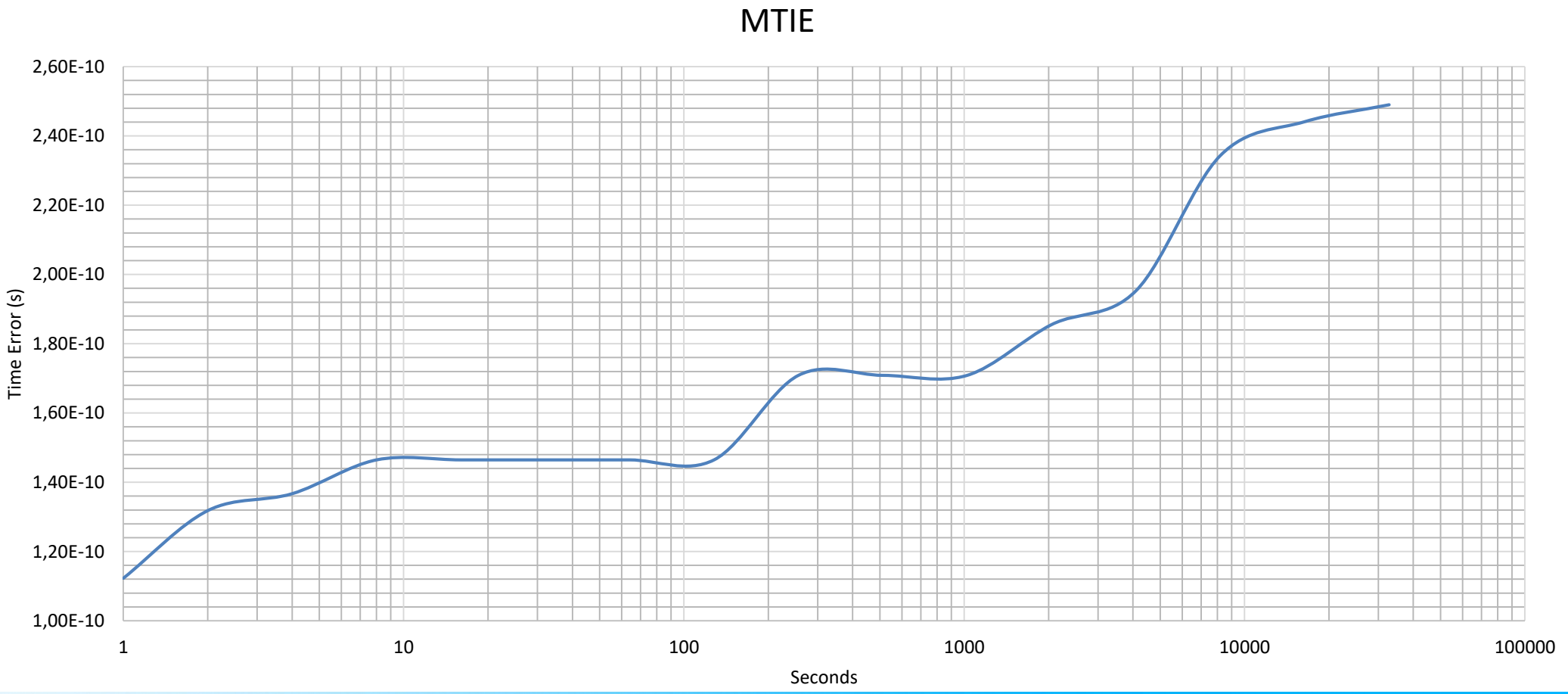


16 hours

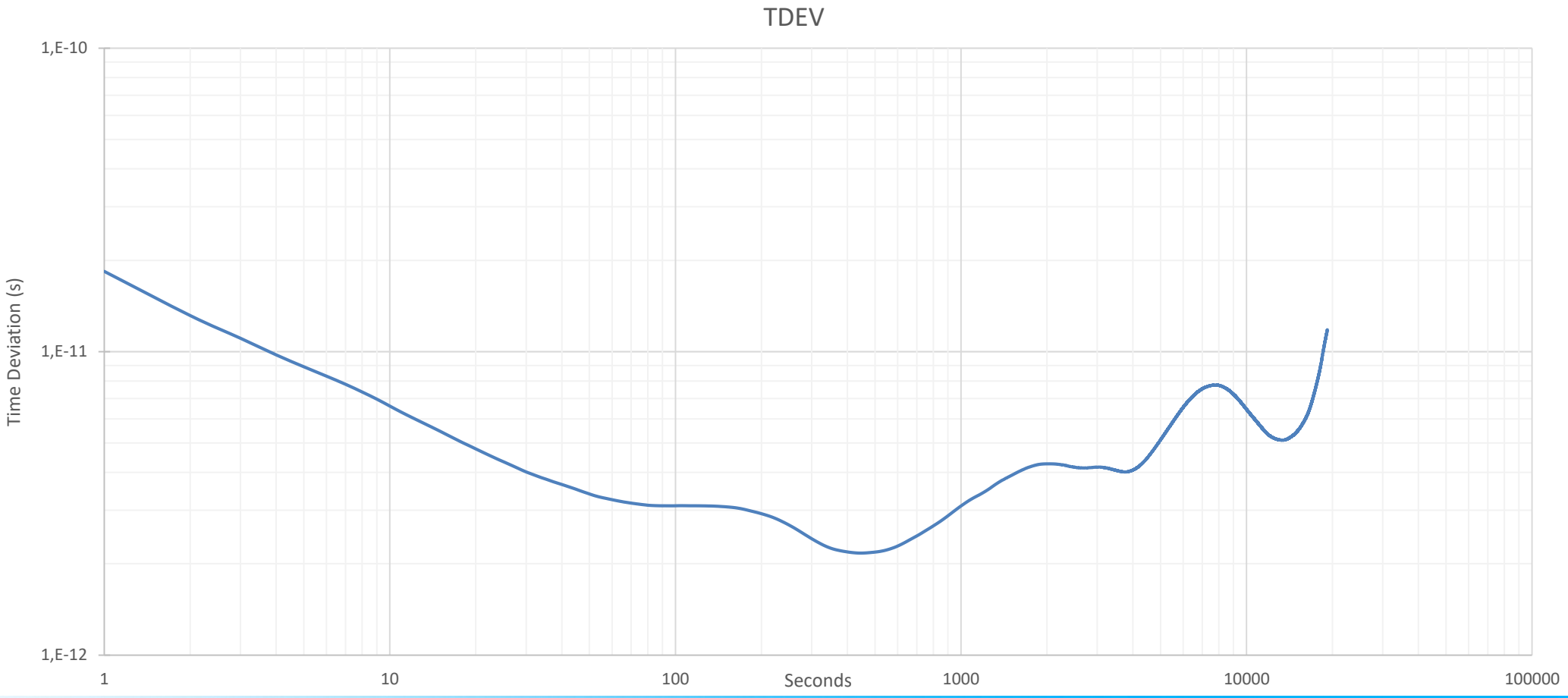
Metro links


Time Error on 60 Km, 3 hops
Time error (ps)
550
525
500
475
450
425
400
375
350
325
300
275
0
3000
6000
9000
12000
15000
18000
21000
24000
27000
30000
33000
36000
39000
42000
45000
48000
51000
54000
57000
Seconds

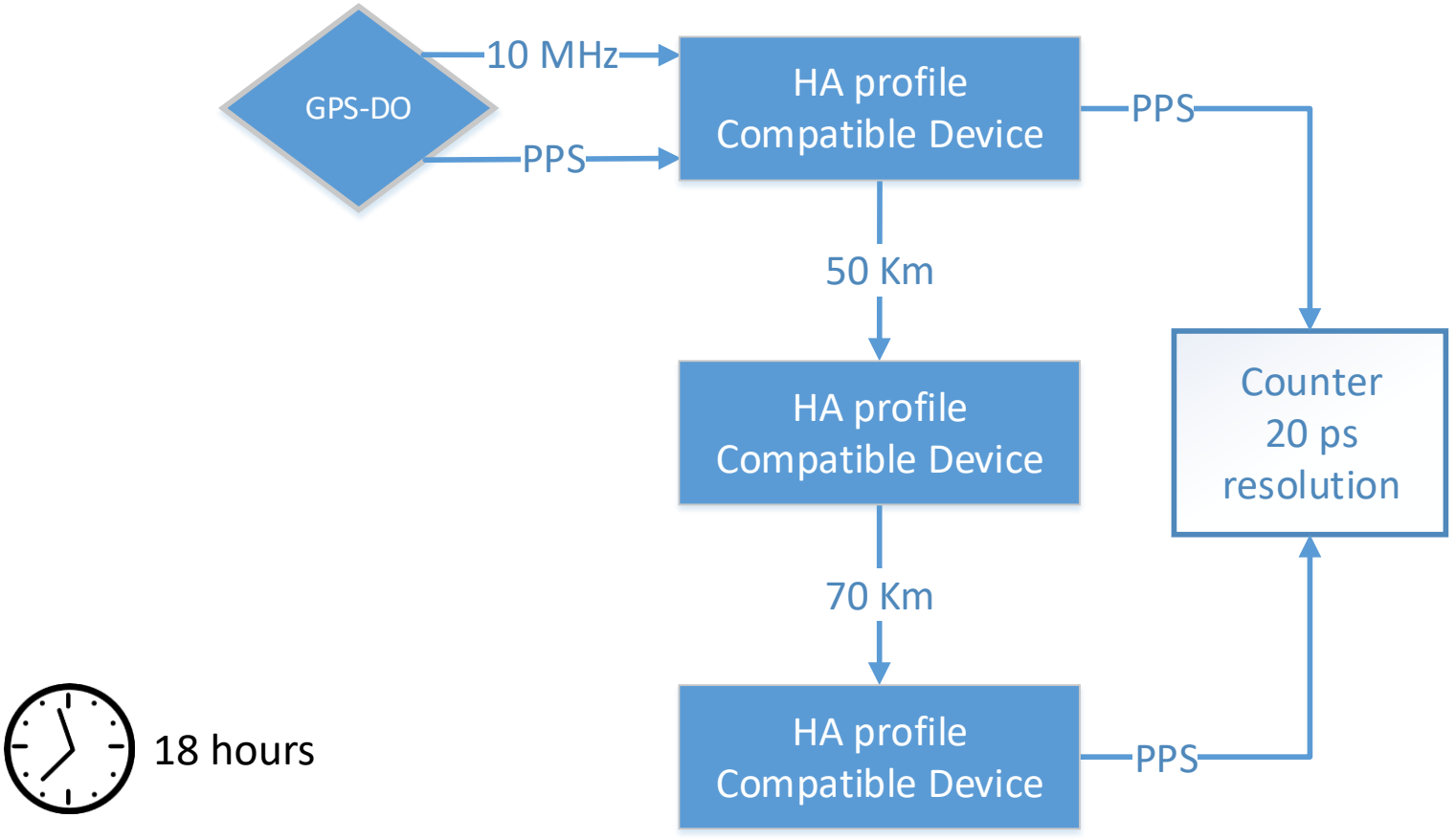
Metro links


MTIE
Time Error (s)
2,60E-10
2,40E-10
2,20E-10
2,00E-10
1,80E-10
1,60E-10
1,40E-10
1,20E-10
1,00E-10
1
10
100
1000
10000
100000
Seconds

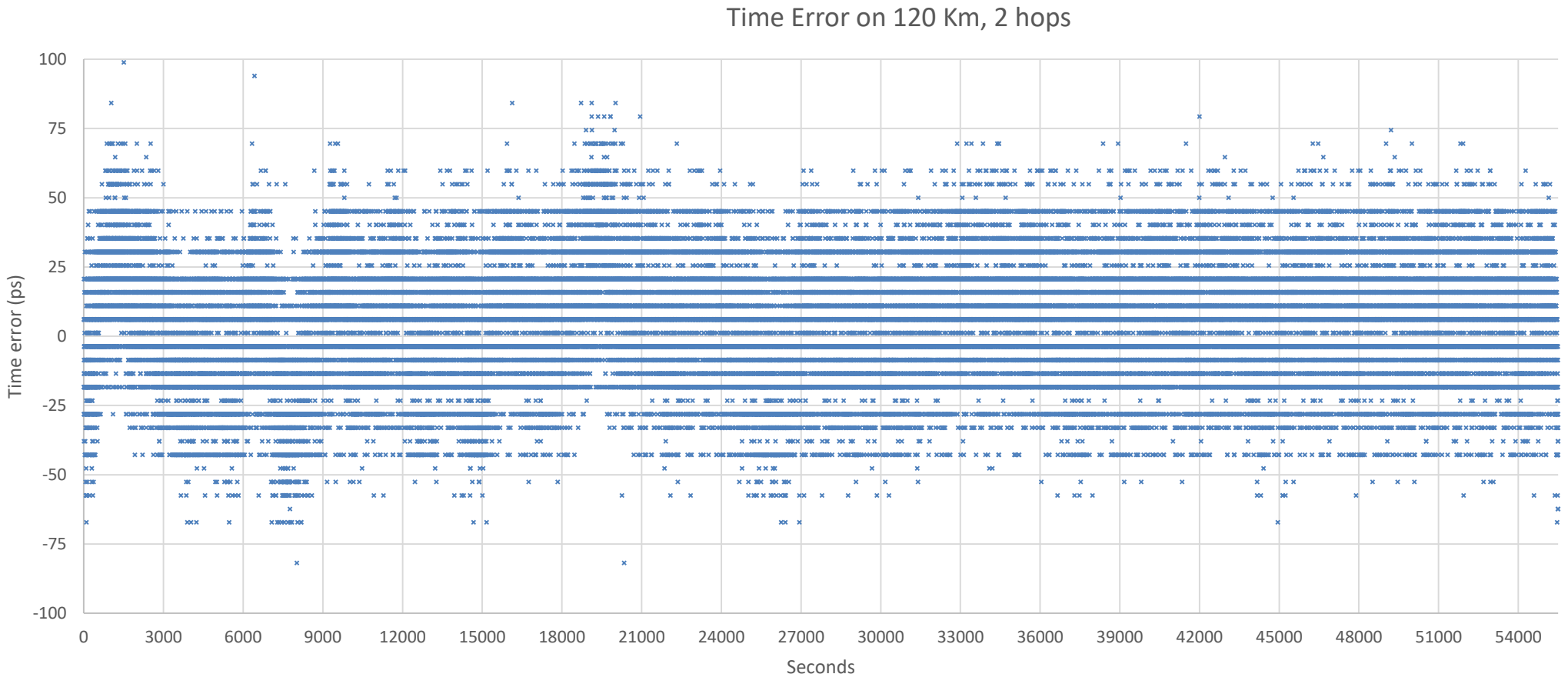
Metro links


TDEV
1,E-10
1,E-11
1,E-12
Time Deviation (s)
1
10
100
Seconds
1000
10000
100000

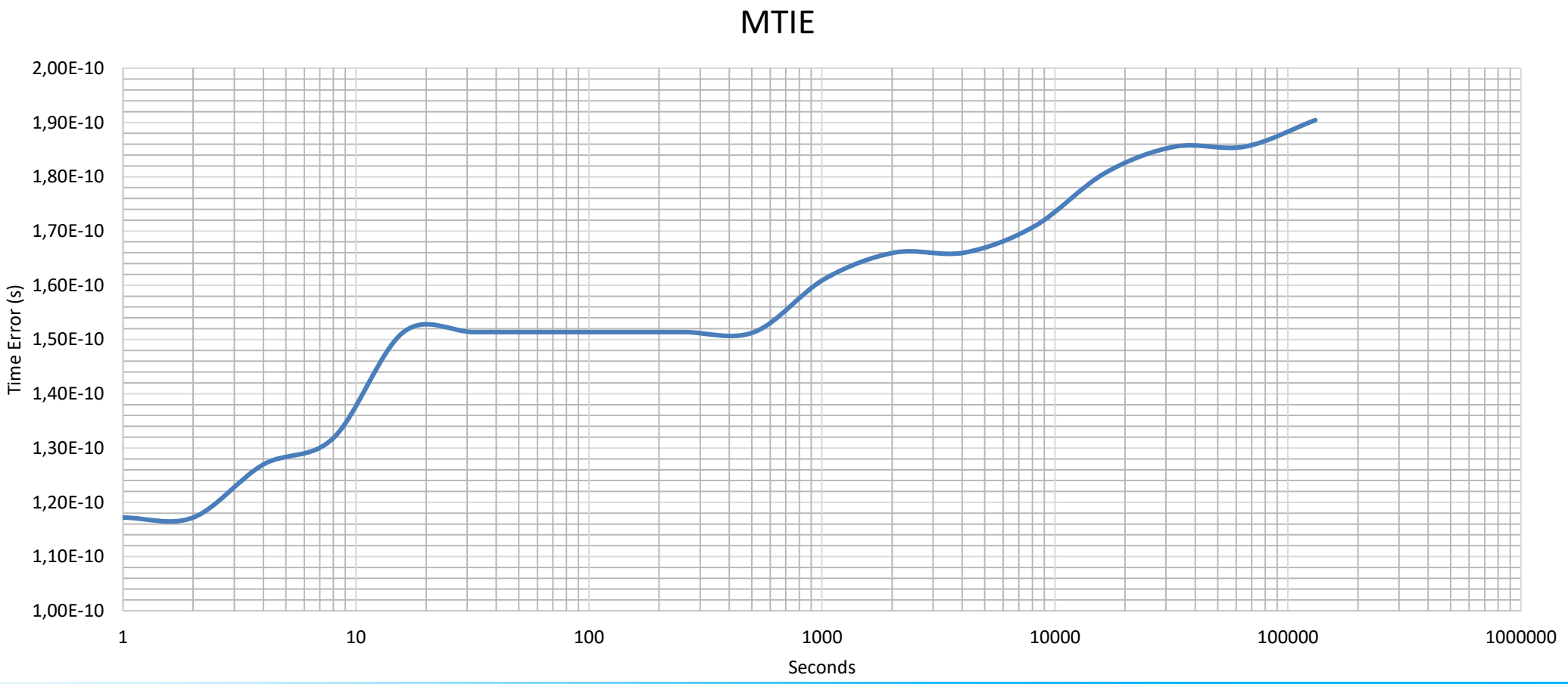
Metro links


GPS-DO
10 MHz
PPS
HA profile
Compatible Device
PPS
50 Km
HA profile
Compatible Device
70 Km
HA profile
Compatible Device
PPS
Counter
20 ps
resolution
18 hours

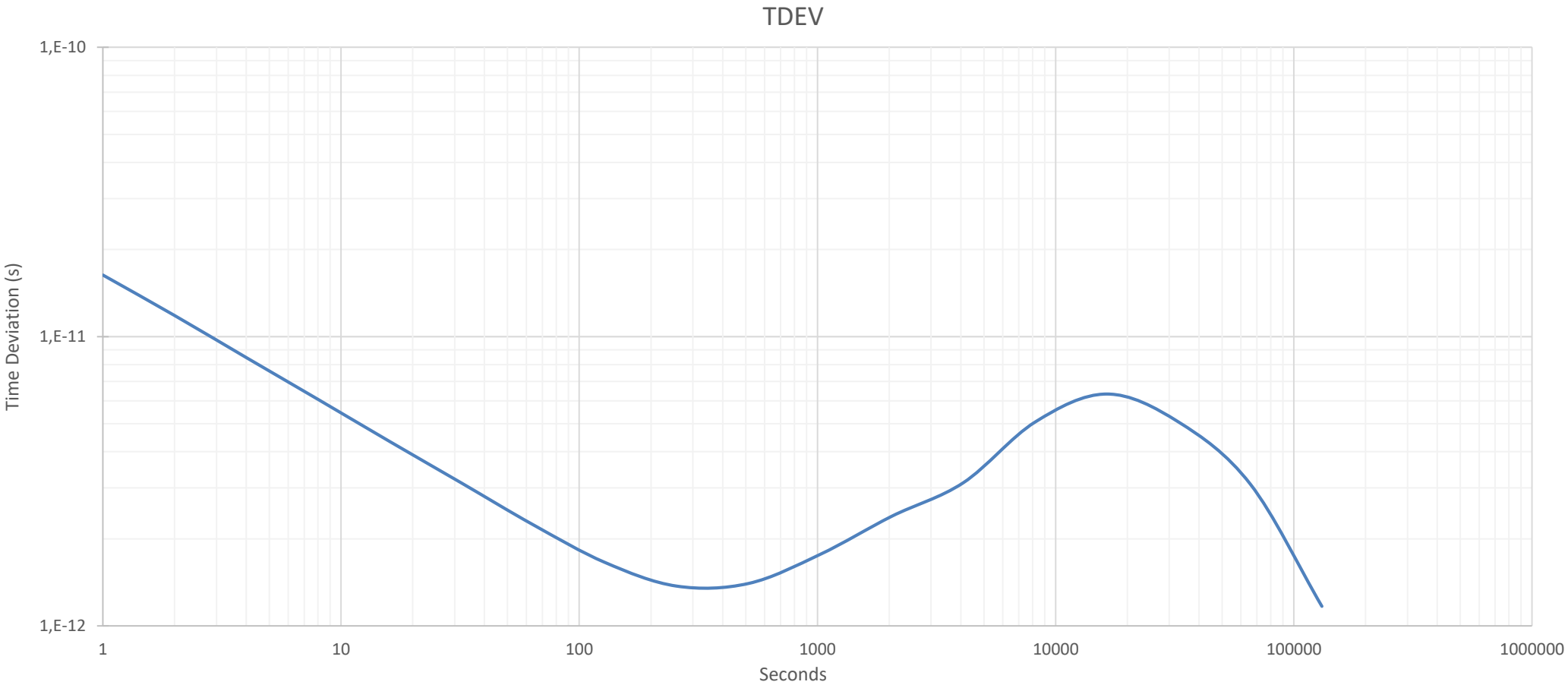
Metro links


Time Error on 120 Km, 2 hops
Time error (ps)
100
75
50
25
0
-25
-50
-75
-100
0
3000
6000
9000
12000
15000
18000
21000
24000
27000
30000
33000
36000
39000
42000
45000
48000
51000
54000
Seconds

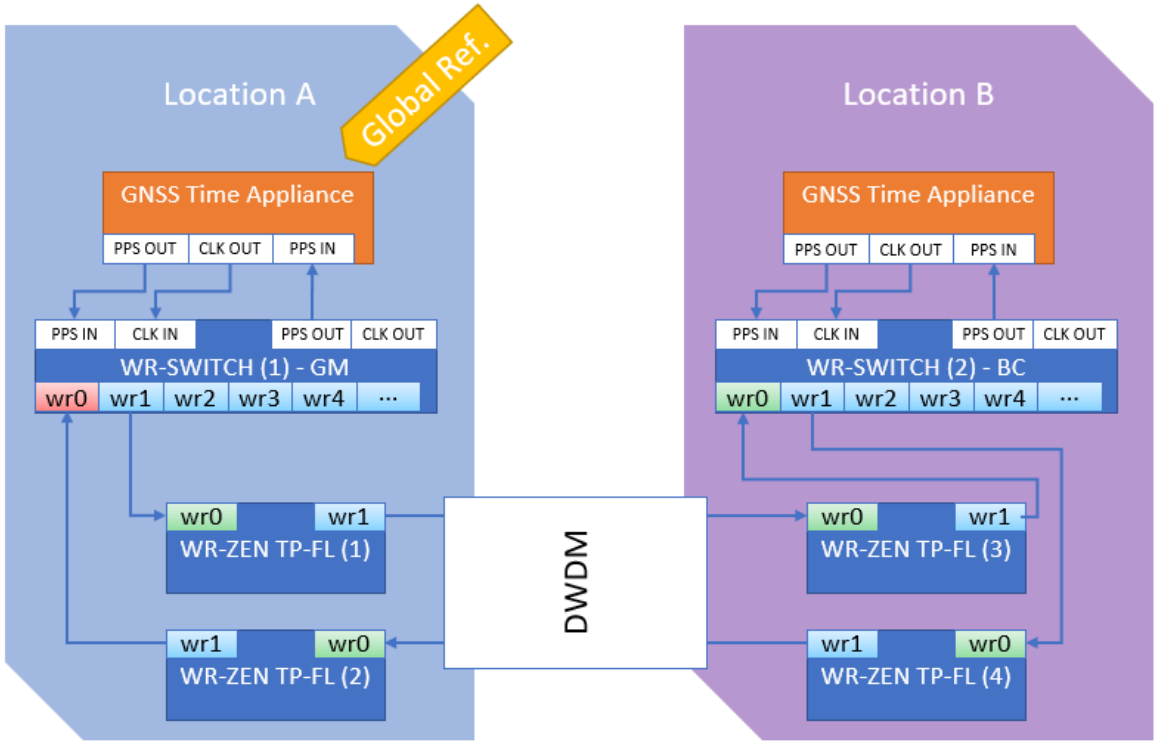
Metro links


MTIE
2,00E-10
1,90E-10
1,80E-10
1,70E-10
1,60E-10
1,50E-10
1,40E-10
1,30E-10
1,20E-10
1,10E-10
1,00E-10
Time Error (s)
1
10
100
1000
10000
100000
1000000
Seconds

Metro links

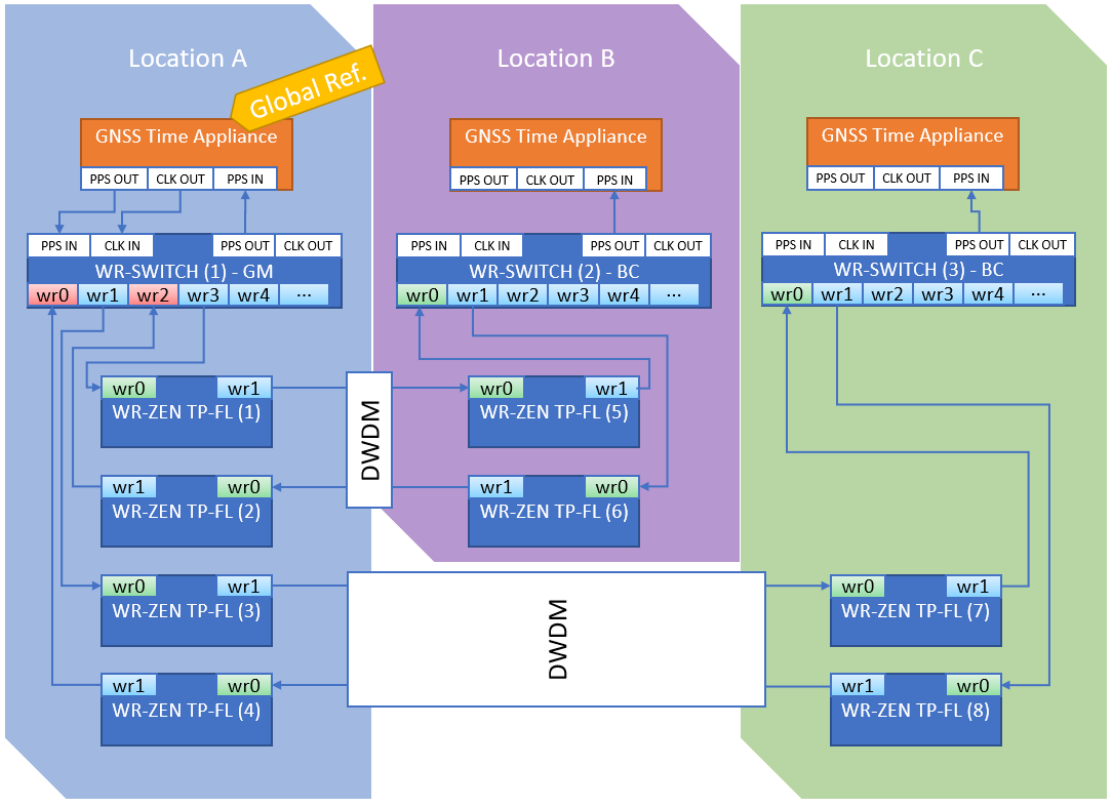

TDEV
1,E-10
1,E-11
1,E-12
Time Deviation (s)
1
10
100
1000
10000
100000
1000000
Seconds

- Point to point GNSS backup topology



GNSS backup example topology

- Triangle GNSS backup topology



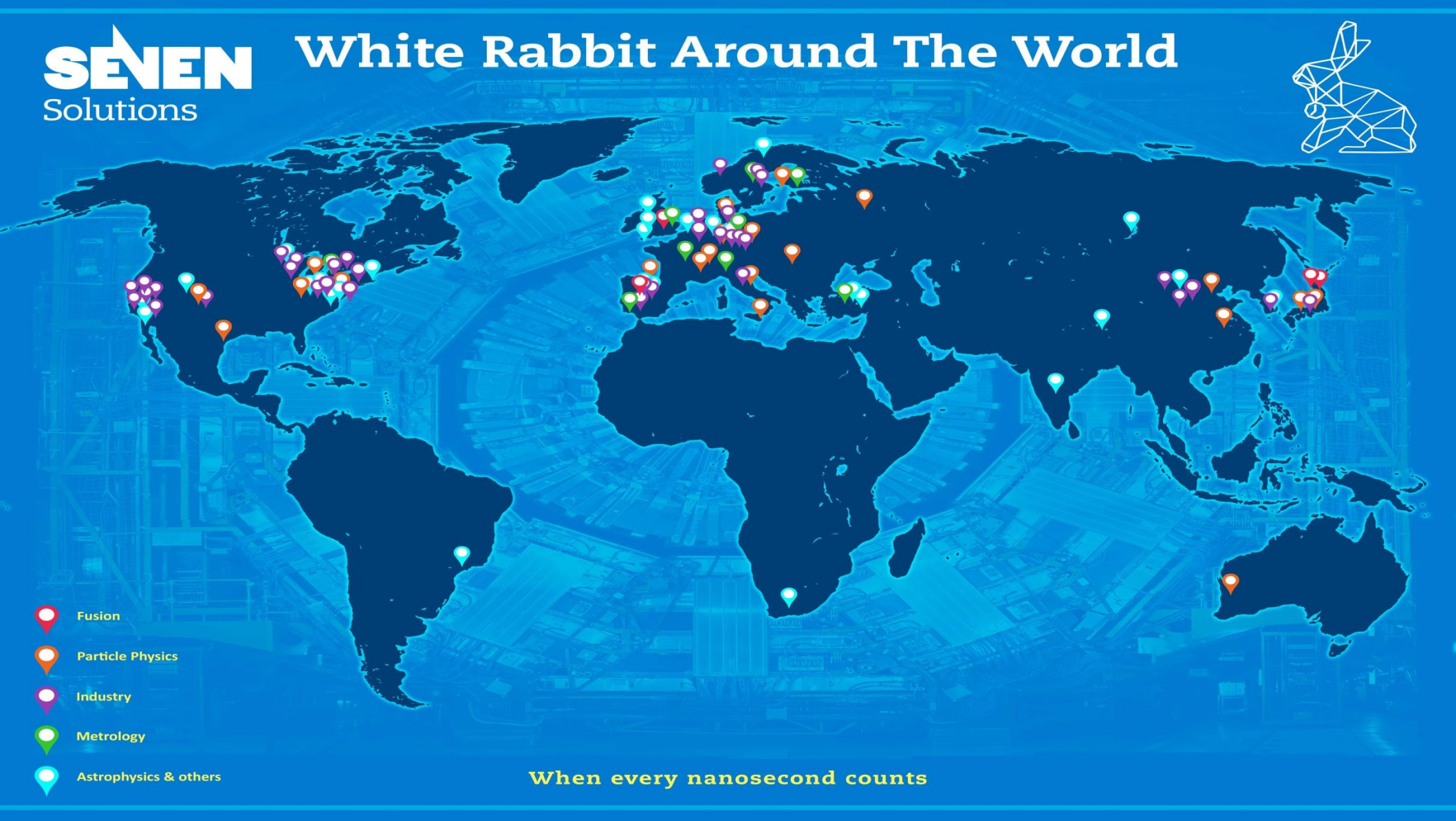
Long-haul link calibration using GNSS (GPS) receivers

- Based on calibrated GNSS (GPS) receivers with up to 5-10ns of the box time transfer capabilities. After deployment, 1ns can be achieved by metrological techniques. An UTC traceable solution.

- PPS differences at the final location can be monitored and annotated on the device. In case of GNSS reference failure, the PPS output from the device can be directly used.
  - Day/night or temperature changes can be learn at run-time.

SEVEN Solutions

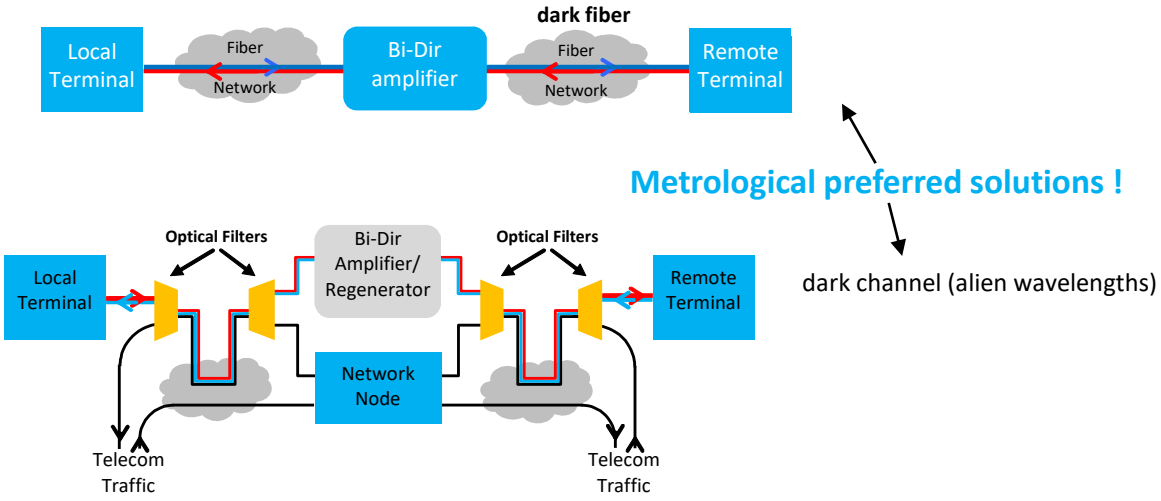
White Rabbit Around The World



When every nanosecond counts

Comparison with other high accuracy solutions

- **Metrological time transfer solutions** achieves ultra-high performance but require dark fibers or dark channels with bidirectional amplifiers. Examples:



- Our solution is **packet based.** Full performance is only possible by full WR on path support but equipment is interoperable with PTPv2.
- Furthermore, our solution is compatible with optical telecom networks (unidirectional)