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Pre-ePTS-Based Nationwide UTC(k) Distribution over Packet Networks for GNSS-Resilient Synchronization

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Workshop on Synchronization and Timing Systems

May 2026

enhanced Partial Timing Support (ePTS)

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Partial Timing Support (PTS):

Assumes partial timing awareness in the network
Limited capability to handle PDV and asymmetry

pre-ePTS:

Operator-driven evolution of PTS

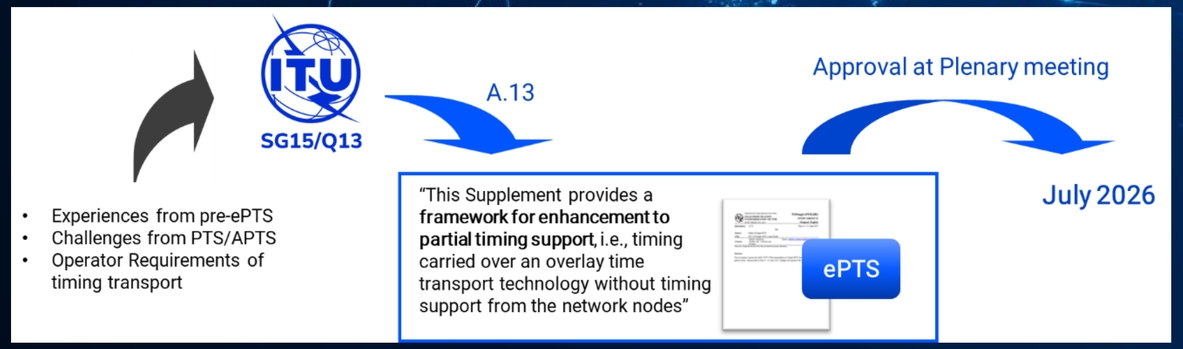
Developed to address:

High PDV in packet networks
Asymmetry and path variability
GNSS-challenged environments
Deployed and validated at national scale

ePTS (ITU-T SG15/Q13 – WD/LD):

Standardization of enhanced timing transport
Defines mechanisms for:
Advanced PDV filtering
Asymmetry mitigation
Network-wide timing accuracy

pre-ePTS → evolved into ePTS (ITU-T SG15/Q13 WD)



LIMITATIONS OF EXISTING PTS

Partial Timing Support (PTS):

Before Pre-ePTS, extensive test campaigns were conducted using PTP distribution aligned with the G.8275.2 profile in preparation for 4G and early 5G deployments. The trials included:

- Standard PTP tests over MPLS backhaul, validating frequency and phase transfer.
- Boundary Clock scenarios under varied topologies and loads.
- Mini-Grandmaster hold-over trials, assessing resilience under GNSS input loss.

Our measured performance for PTS consistently ranged between 10 µs and 100’s of µs, depending on topology and network conditions. While this was acceptable for legacy mobile backhaul, it was insufficient to meet the tighter accuracy requirements of advanced mobile networks. These results underscored the need for a more robust approach, directly motivating the development of ePTS.

Conclusion

- PTS was designed for limited impairments in the network.
- PTS did not fail, it simply was not designed for this environment

This work presents field experience with a pre-standard implementation (pre-ePTS)

Field experience from a nationwide deployment
Operation under real GNSS impairment conditions
Validation through national metrology (TÜBİTAK UME)
This work focuses on operational experience

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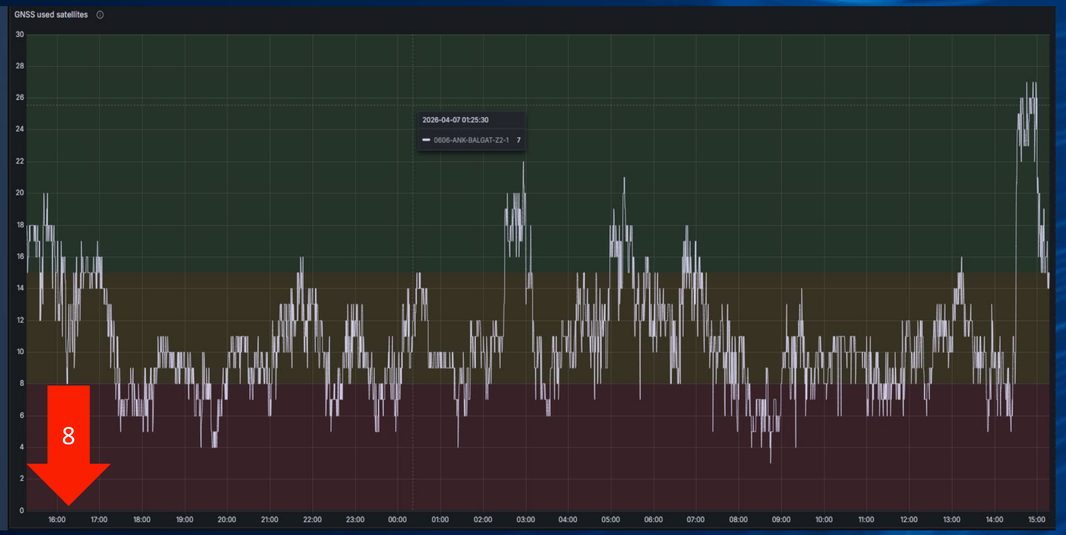
PROBLEM: GNSS IS NOT ALWAYS TRUSTWORTHY

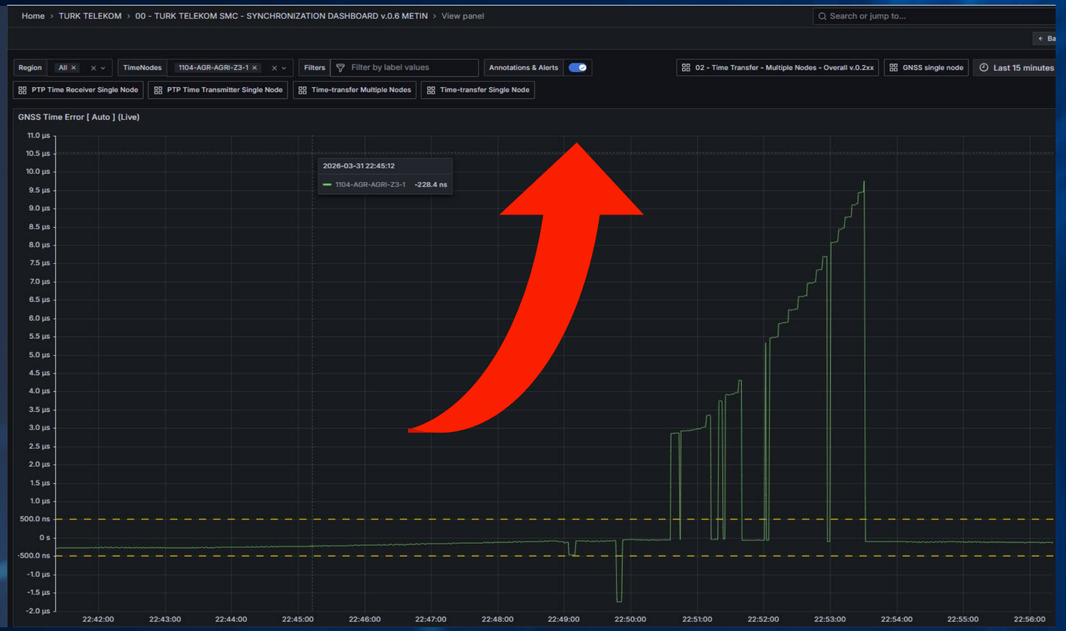
- Up to 28 satellites visible → only 4–9 usable
- Position shift up to 7 km detected
- Time drift and phase distortion observed
- Continuous jamming and spoofing coexistence

SAT. VISIBLE



POSITION DEVIATION

SPOOFING



PROBLEM: GNSS IS NOT ALWAYS TRUSTWORTHY

- Geopolitically unstable regions are heavily impacted by GNSS interference.
- Currently it is a mix and trend is moving to more spoofing then jamming.
- Jamming is easy to mitigate, spoofing is harder and the way that spoofings happen are more intelligent then a few years ago.
- The time shift and location shift accompanied with it starts very slowly and moves slowly. Sometimes the detected drift is not more then ~40ns a day.

The challenge is no longer signal availability; it is signal trustworthiness.

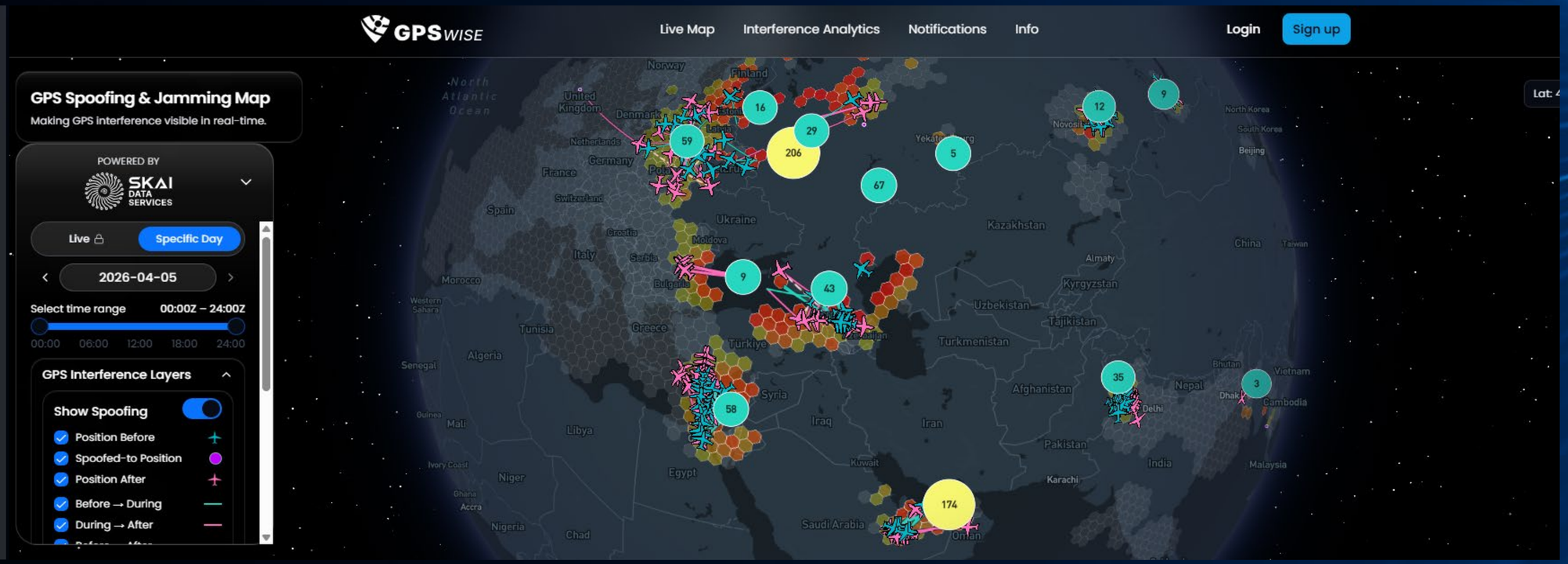
SPOOFING

JAMMING

PROBLEM: GNSS IS NOT ALWAYS TRUSTWORTHY

GNSS requires complementary timing mechanisms in challenged environments.

https://gpswise.aero/map



- Geopolitical instable regions are heavily impacted by GNSS jamming.
- GNSS availability is regionally inconsistent and unreliable
- The above maps only show aerial jamming, jamming affecting terrestrial is not shown.
- Middle East Region: Continuous jamming → GNSS unavailable
- Black Sea Region: GNSS available only ~3 hours/day

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IMPORTANCE OF SYNCHRONIZATION VS GNSS DEPENDENCY

Risks of GNSS

- No SLA
- Weather Conditions
- Dependency on foreign Technology
- Operational limitations
- Cyber attacks: Spoofing and Jamming

Telco	Disruptions in Communication Dependency on foreign technology
Defense	Positioning, Navigation Communication
Energy	Energy disruptions Hard to track disruption location
Broadcasting	Broadcast Disruptions Time dilution
Finance	Financial tracking and logging Loss of trades

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July 25, 2018, 12:00 PM GMT+3

The World Economy Runs on GPS. It Needs a Backup Plan

The small satellite network, which keeps global computer systems from freaking out, is shockingly vulnerable to all kinds of interference.

By Paul Tullis

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Duke Buckner was enjoying his breakfast at the Renaissance Tel Aviv Hotel, looking out on the city marina, on the day that time stuttered. Buckner oversees marketing and business development for Microsemi Corp., an American communications and defense contractor, and he gets a copy of emailed error reports for its equipment. It's rare to get more than one in a given day. But on the morning of Jan. 26, 2016, they flooded his inbox. He forgot about breakfast.

Business

Report estimates cost of disruption to GPS in UK would be £1bn per day

Err, maybe it's time for backup?

By Kat Hall 19 Jun 2017 at 08:37 136 SHARE

ands to lose £1bn per day in the event of a major disruption to

GPS WORLD

GNSS POSITION NAVIGATION TIMING

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A day without satellites would affect us all

October 1, 2019 - By Tracy Cozzens 0 Comments Est. reading time: 1:10

You wake up and turn on the TV. Your usual shows aren't airing. You flip on the radio and learn that the Paris and Tokyo stock markets have closed. Back on TV, CNN is trying to use Skype in an attempt to cover what's happening around the world following a solar superstorm.

In a U.S. bunker, the military has lost contact with armed drones flying over hostile areas in the Middle East. Loss of global communication satellites makes it difficult to send commands and surveillance data to soldiers, ships and aircraft, rendering them vulnerable to attack.

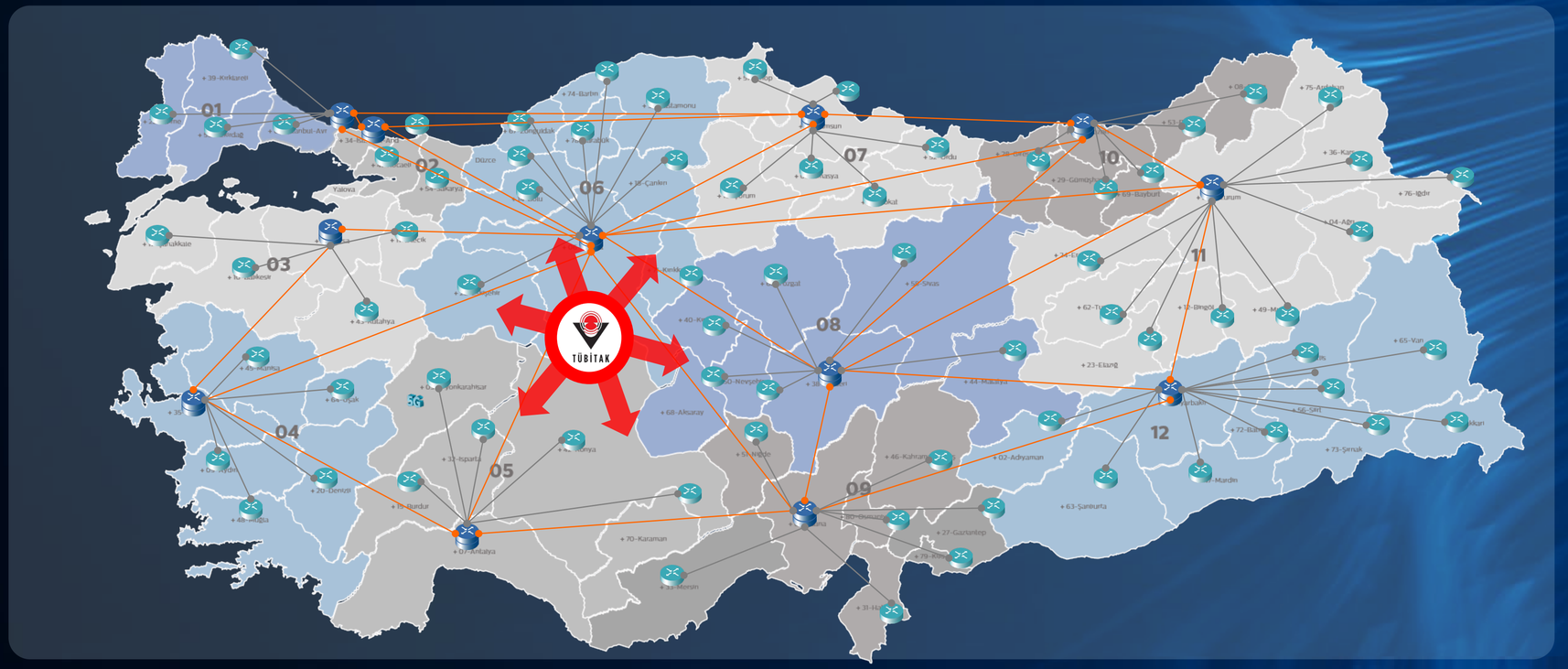
Throughout the day, more challenges arise. First

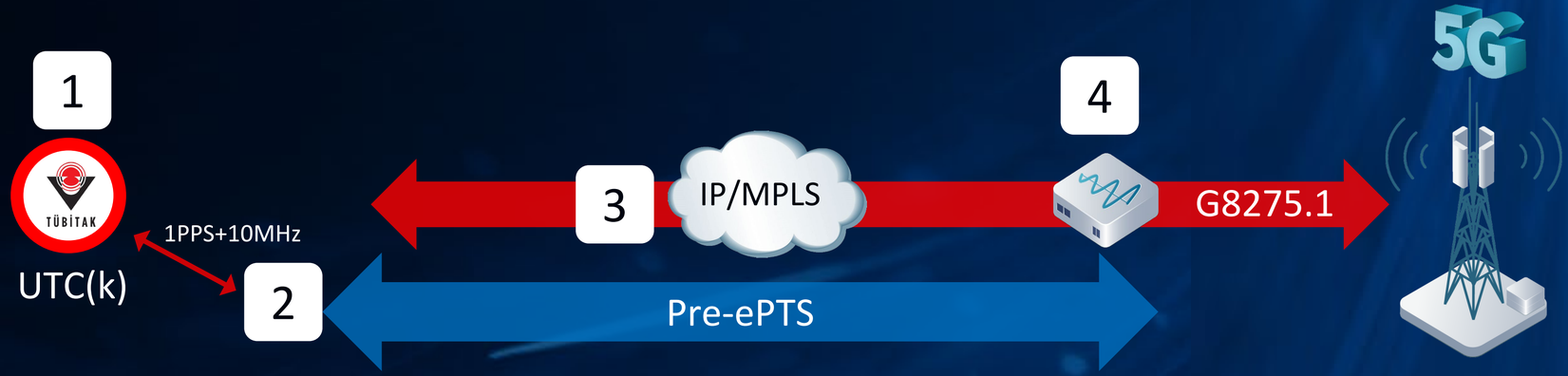
A solar flare in 2015. (Photo: Photo: Solar Dynamics Observatory, NASA)

Pre e-PTS

Time is generated nationally distributed over our infrastructure

1. UTC(k) source: TÜBİTAK UME (BIPM registered)
2. 1PPS+10Mhz is provided by UTC(k) and distribution with Pre-ePTS over packet network (IP/MPLS)
3. No timing support required in packet transport
4. Pre-ePTS hands over at last hop to G8275.1





Pre e-PTS

GNSS is used at selected sites for probing/monitoring

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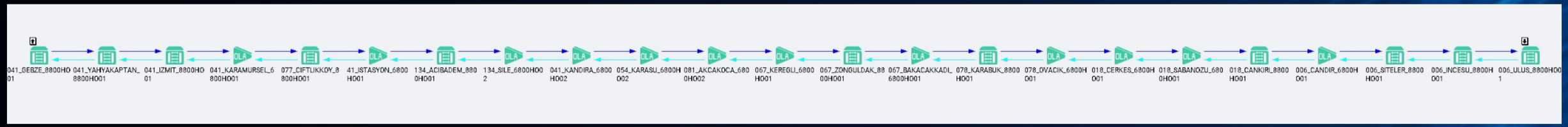
DWDM + MULTI-HOP TRANSPORT

The main time link from Tübitak UME is DWDM, as this is the best we can provide next to dark fiber.

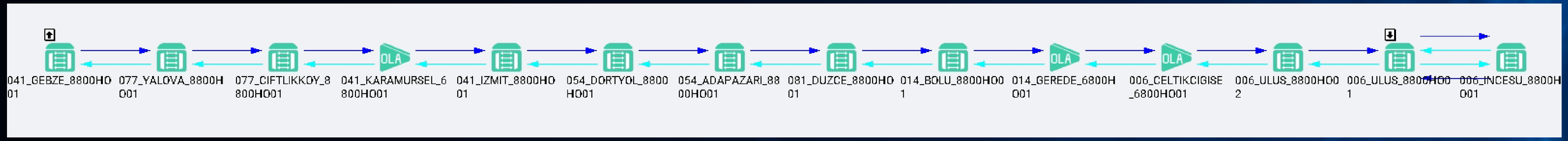
Dark fiber is limited to distance which is the purest form of a transport medium however a dark fiber for distances longer than 80 Km a different transport medium is required.

For this time-transfer purpose we use 2 redundant DWDM links each of 10Gb capacity.

Link 1 (23 hops)



Link 2 (14 hops)



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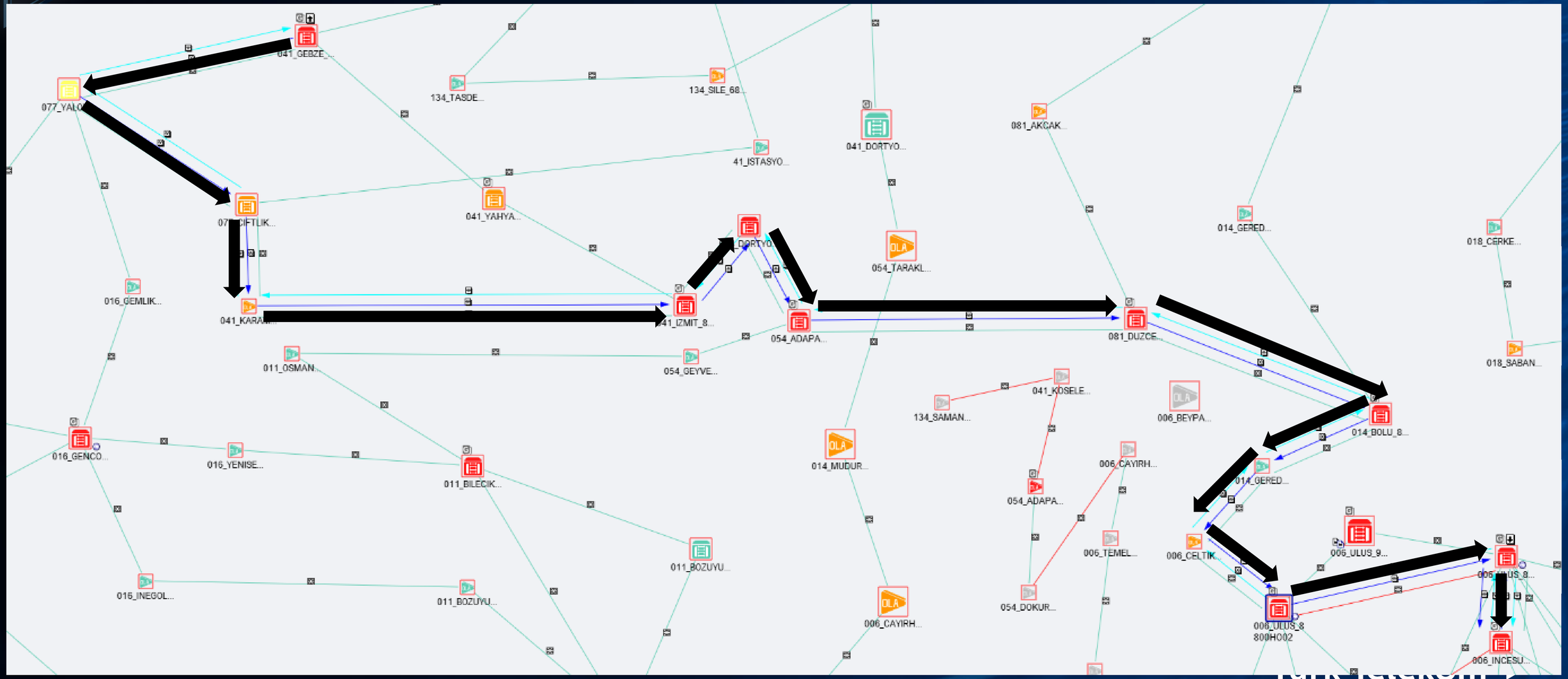
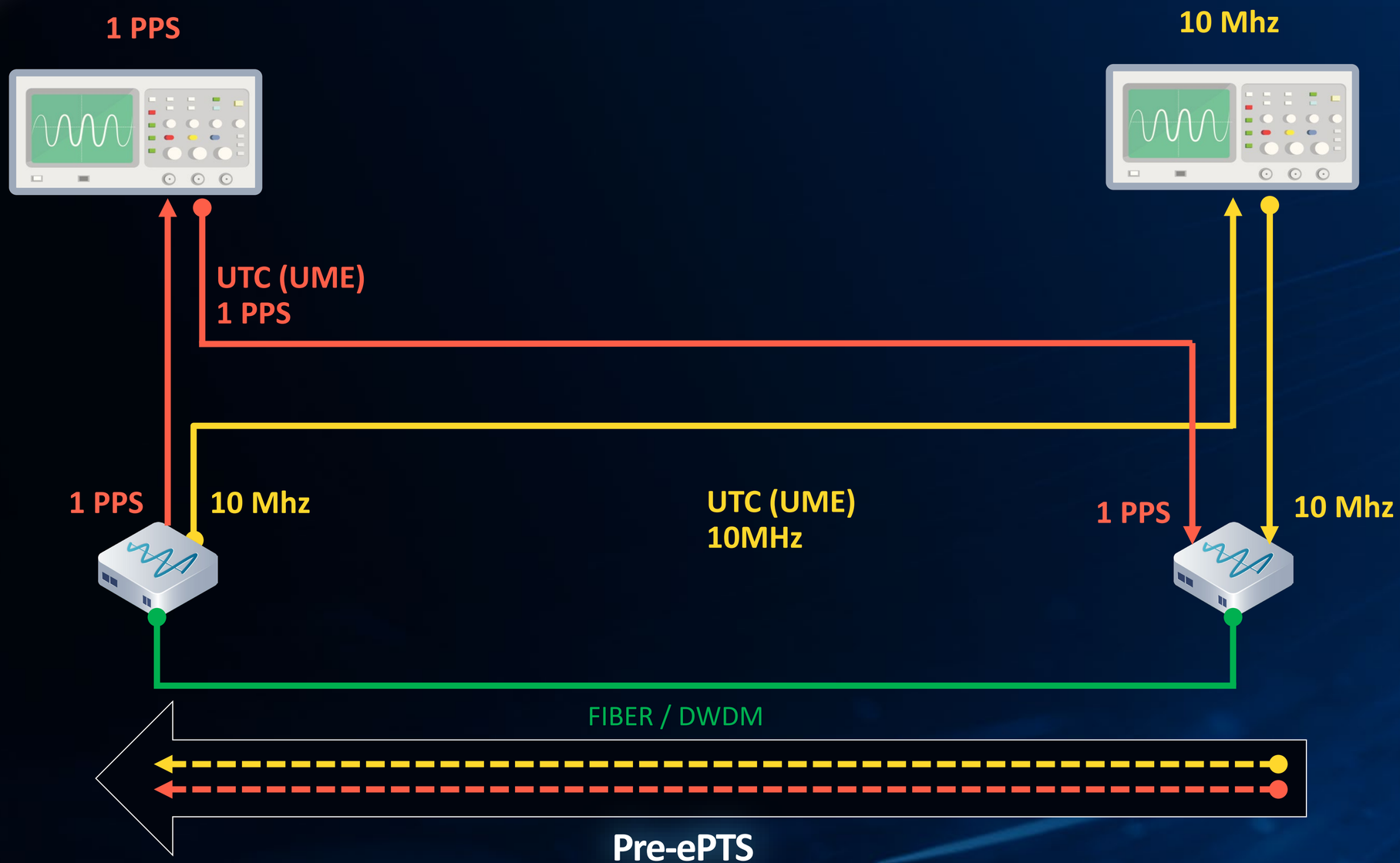
DWDM + MULTI-HOP TRANSPORT

600Km of DWDM This is not a lab setup, this is live network transport.



TÜBİTAK UME VALIDATION

Metrology-grade measurement results



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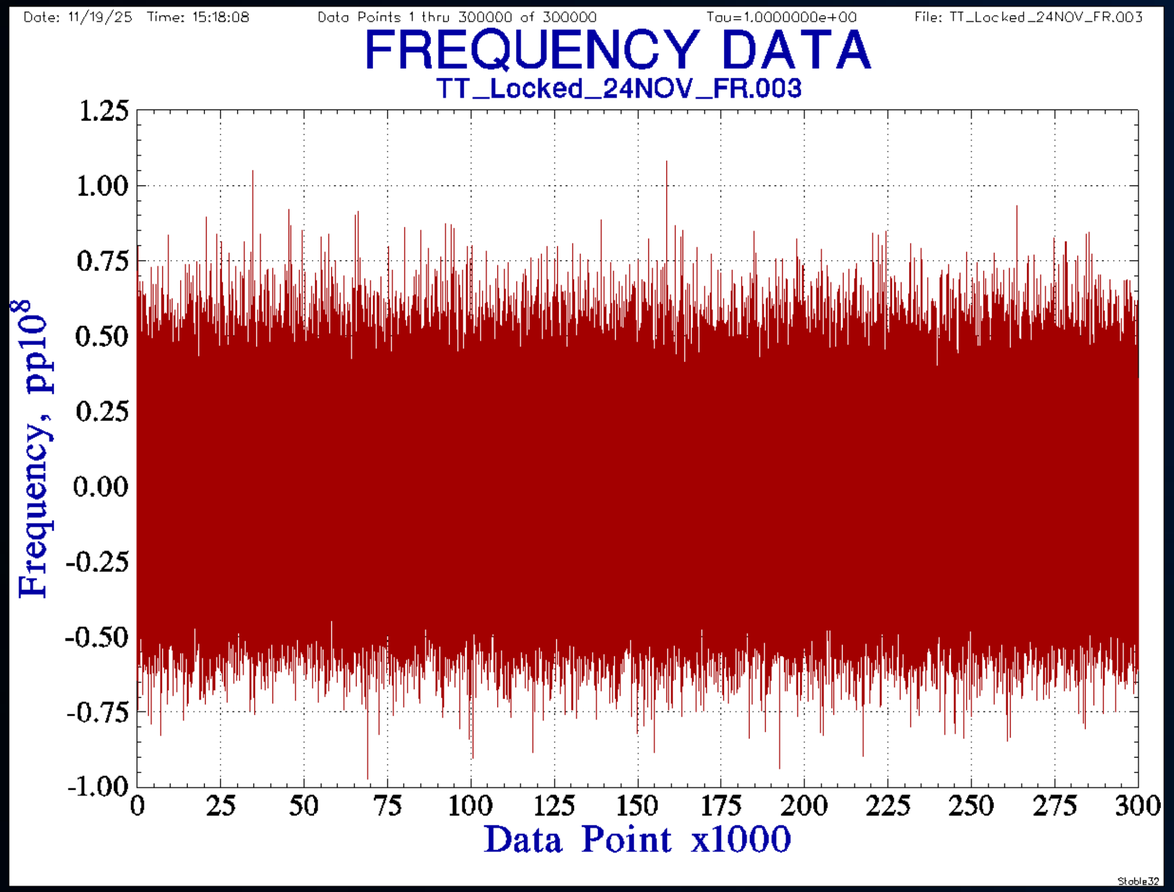
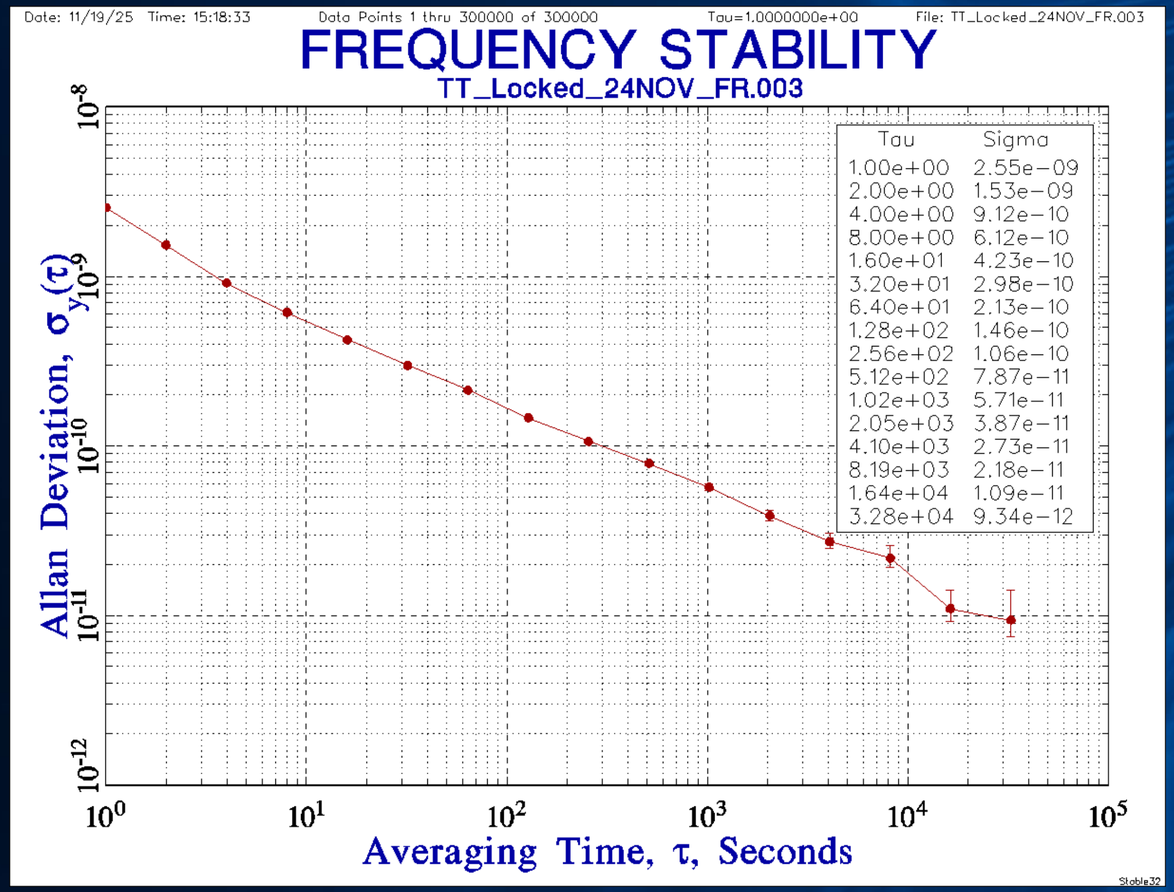
TÜBİTAK UME VALIDATION

Metrology-grade measurement results 10MHz





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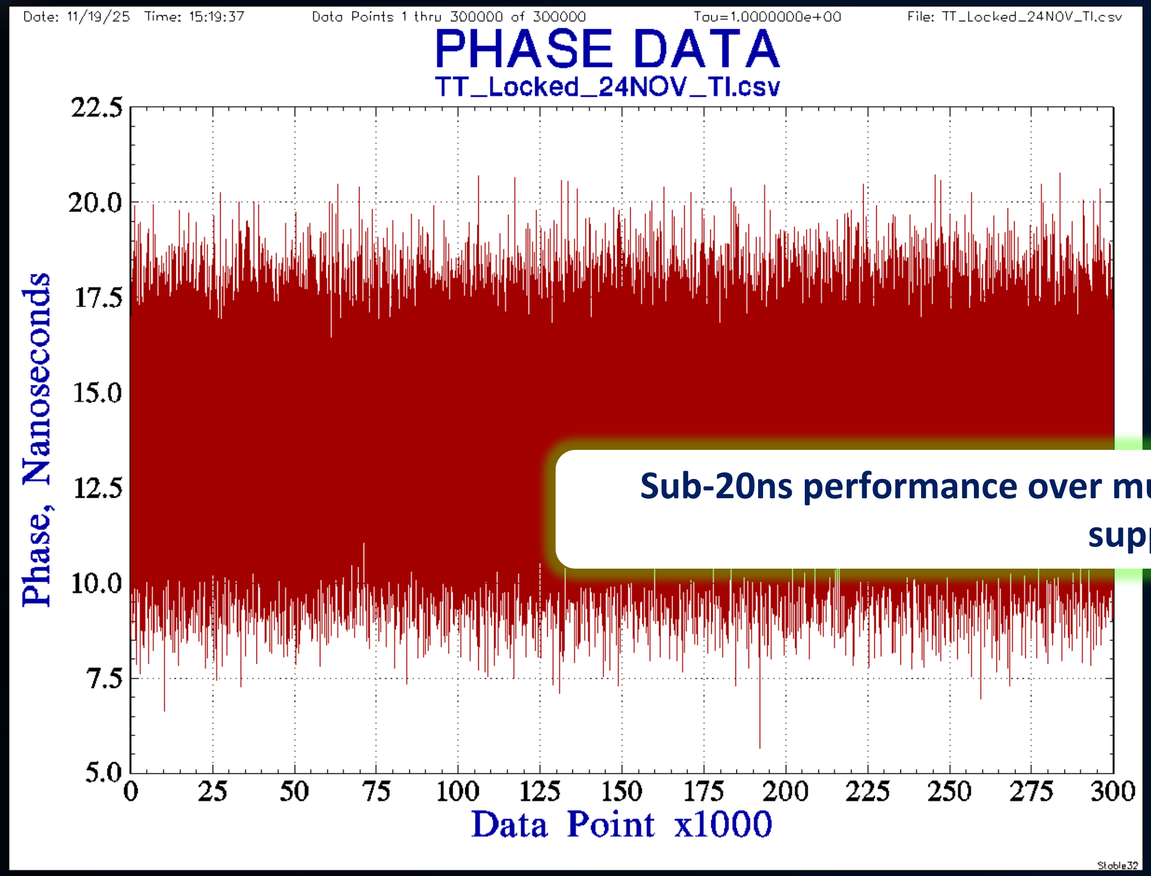
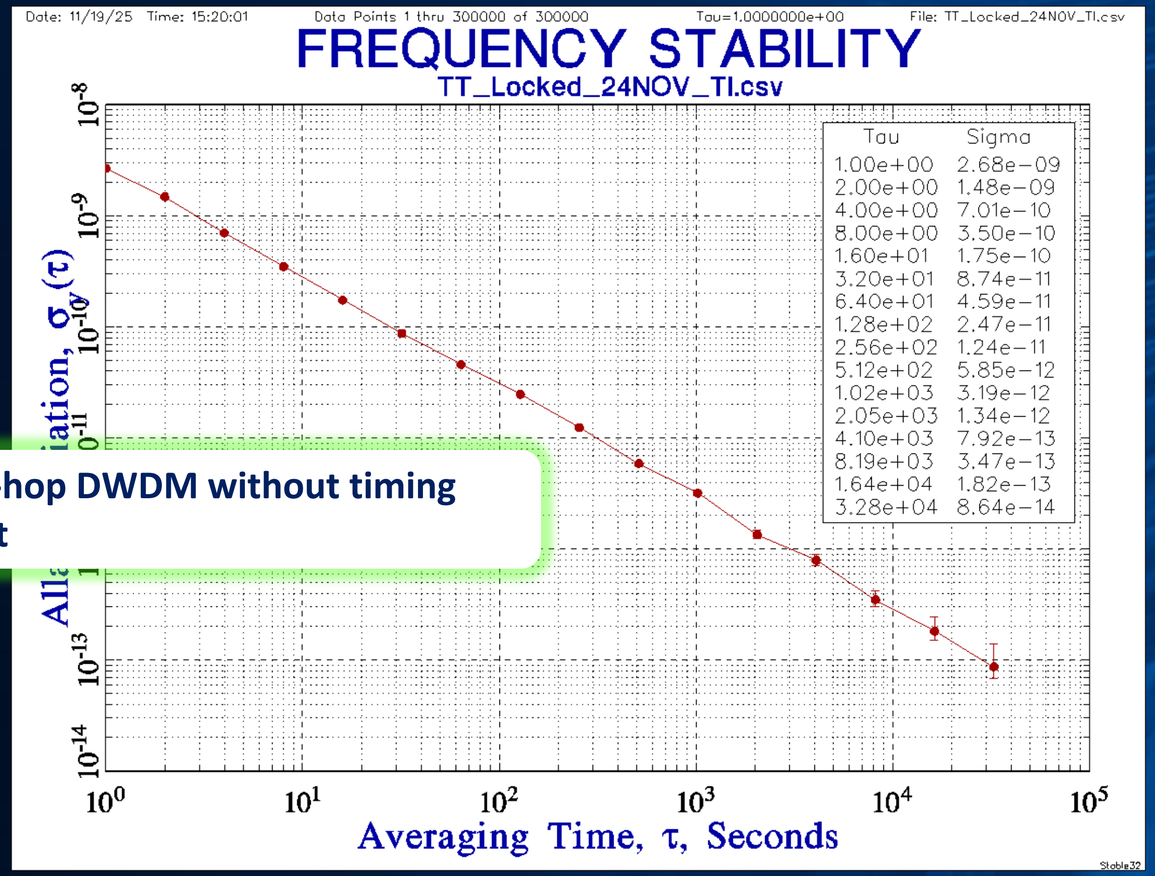
TÜBİTAK UME VALIDATION

Metrology-grade measurement results 1 PPS





Tau	Sigma
1.00e+00	2.68e-09
2.00e+00	1.48e-09
4.00e+00	7.01e-10
8.00e+00	3.50e-10
1.60e+01	1.75e-10
3.20e+01	8.74e-11
6.40e+01	4.59e-11
1.28e+02	2.47e-11
2.56e+02	1.24e-11
5.12e+02	5.85e-12
1.02e+03	3.19e-12
2.05e+03	1.34e-12
4.10e+03	7.92e-13
8.19e+03	3.47e-13
1.64e+04	1.82e-13
3.28e+04	8.64e-14

Sub-20ns performance over multi-hop DWDM without timing support

Minimum (ns)	Maksimum (ns)	Avg (ns)	Standart Deviation (ns)
5,66	20,77	13,75	2,24

Allan Deviation:

- Stable over long averaging intervals
- Comparable to high-precision systems

CONCLUSION: SYNC TO INFRASTRUCTURE

1. GNSS Resilience

- Reduced reliance on GNSS through resilient terrestrial timing
- Resistant to spoofing and jamming

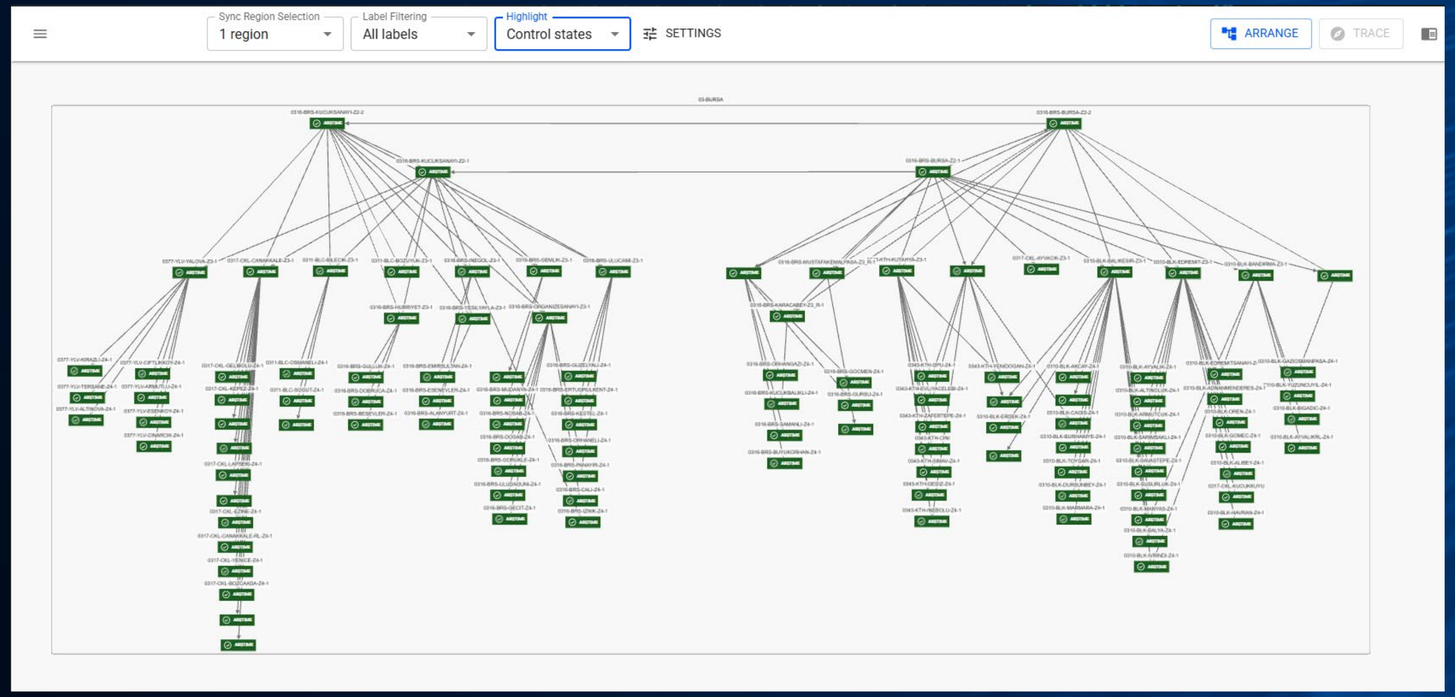
2. Operator-Scale Deployment

- Works over existing IP/MPLS + DWDM
- No need for full timing support

3. National Time Infrastructure

- Unified time for telecom, finance, energy
- Cross-operator synchronization possible

Sample of one region



We are not just synchronizing our network anymore.

We have built a national time infrastructure with a single purpose: Reliable Sync

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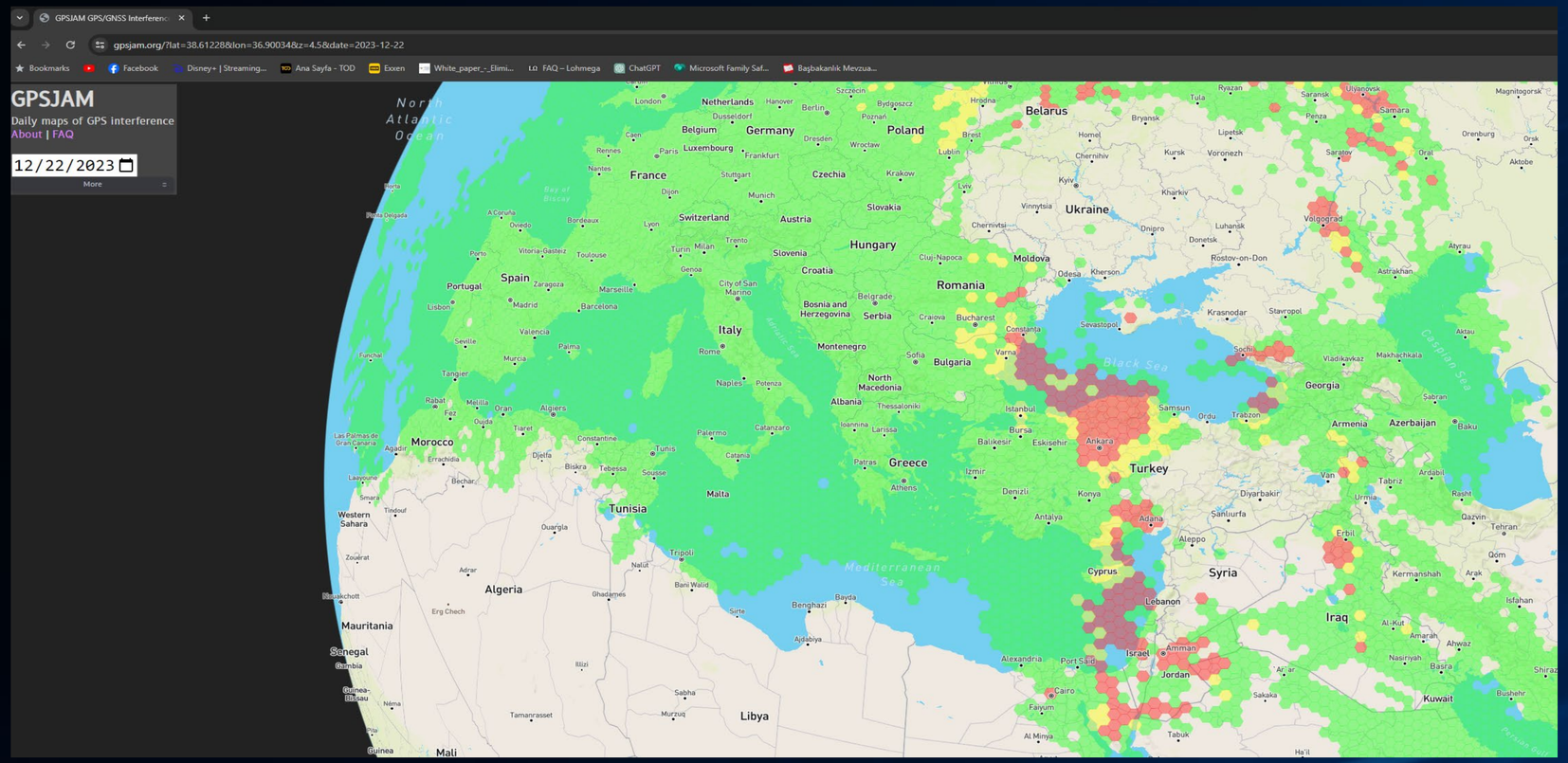
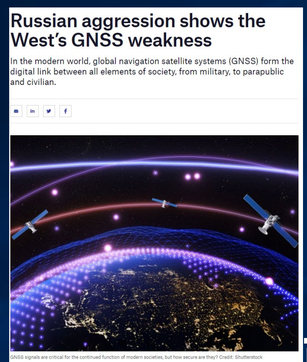
WHY THIS MATTERS

- Satellite-based synchronization services are not consistently reliable in all regions.
- In many locations, intensive jamming and spoofing activities are actively observed.
- These effects are particularly prominent in border areas with ongoing jamming and spoofing activity.
- Satellite systems can be bound to restrictions or service denial.





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Pre-ePTS to ePTS

- Türk Telekom is actively contributing to the development of enhanced Partial Timing Support (ePTS) within ITU-T SG15/Q13, currently progressing as a Working Document and Living Document.
- The deployed synchronization network represents a large-scale, nationwide time distribution infrastructure, designed for GNSS-resilient operation.
- The performance of ePTS is validated by TÜBİTAK (Metrology institute of Turkey.) measurements.

Thank You

Pre-ePTS-Based Nationwide UTC(k) Distribution over Packet Networks for GNSS-Resilient Synchronization

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