# OPNT
## Optical Positioning, Navigation and Timing

**Rolling Out Time as a Service (TaaS)**
**ITSF 2019, Nov 5-7**
**Brighton, UK**

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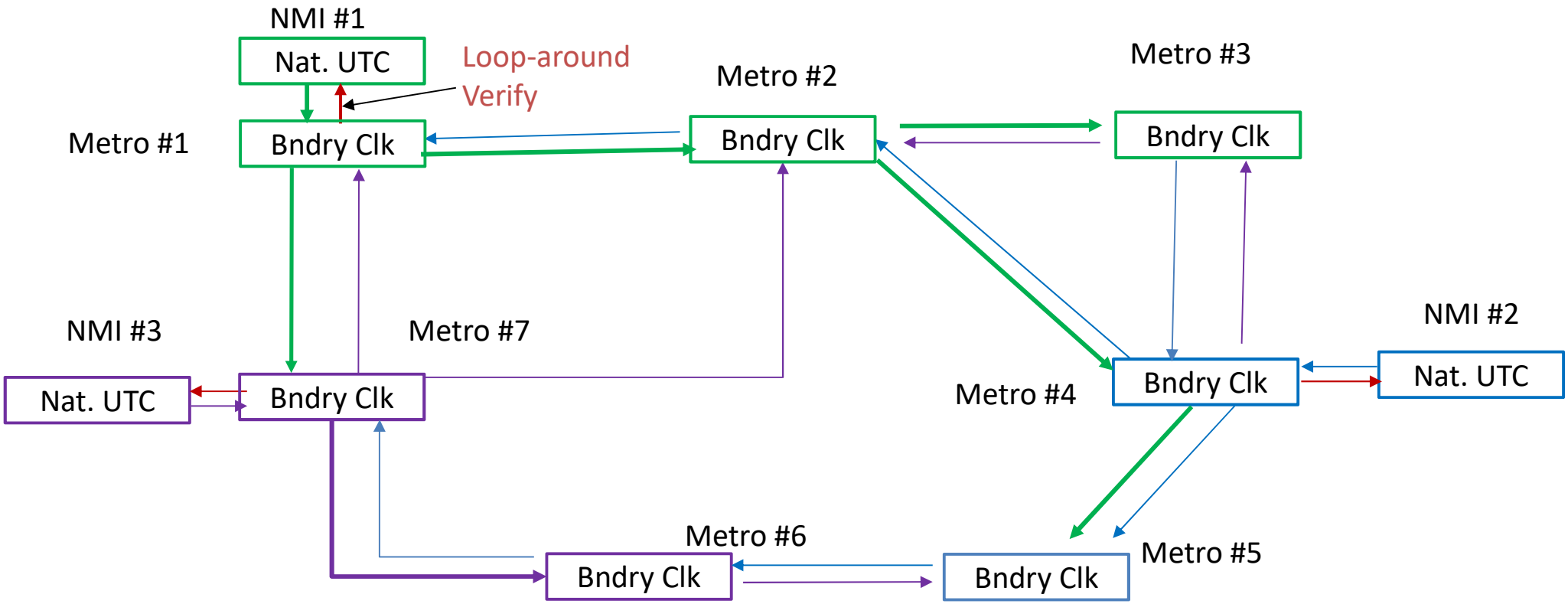
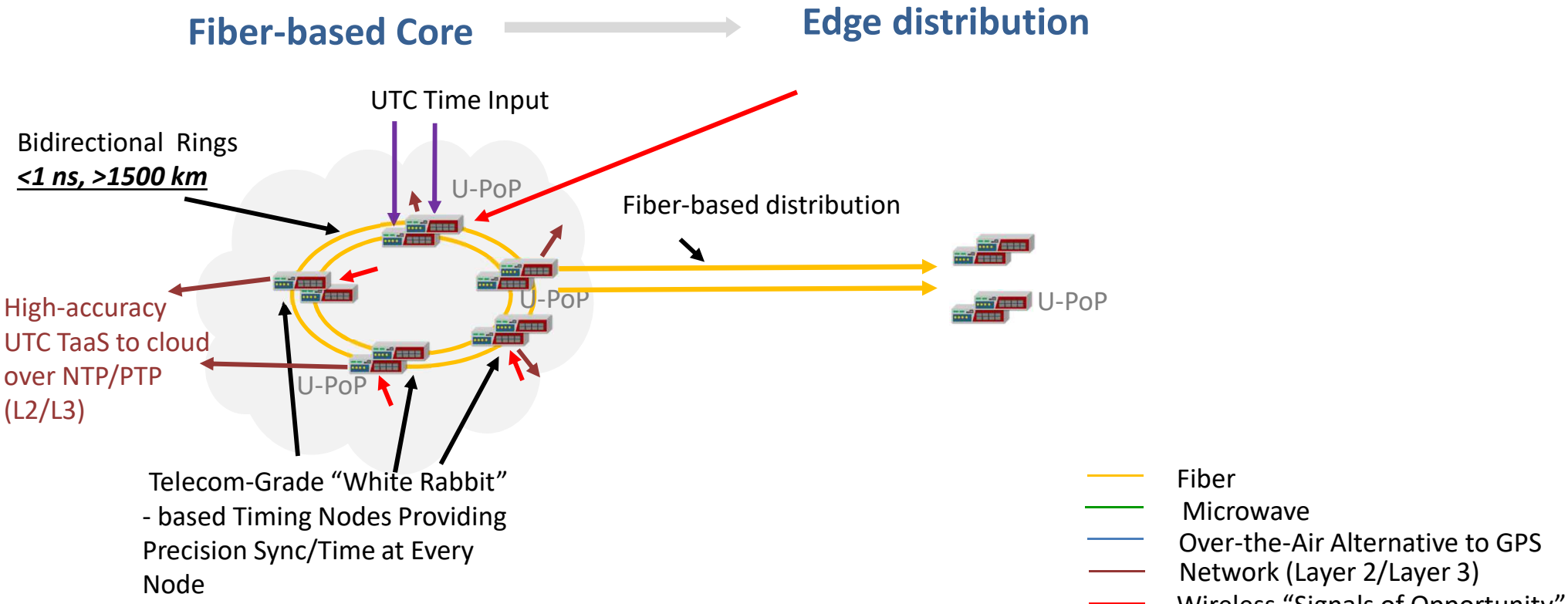
opnt. TIME PROVISIONING

# Overall Picture of Potential TaaS: Fiber Connections
# NMI to Metro with Redundant Links – Skeleton View





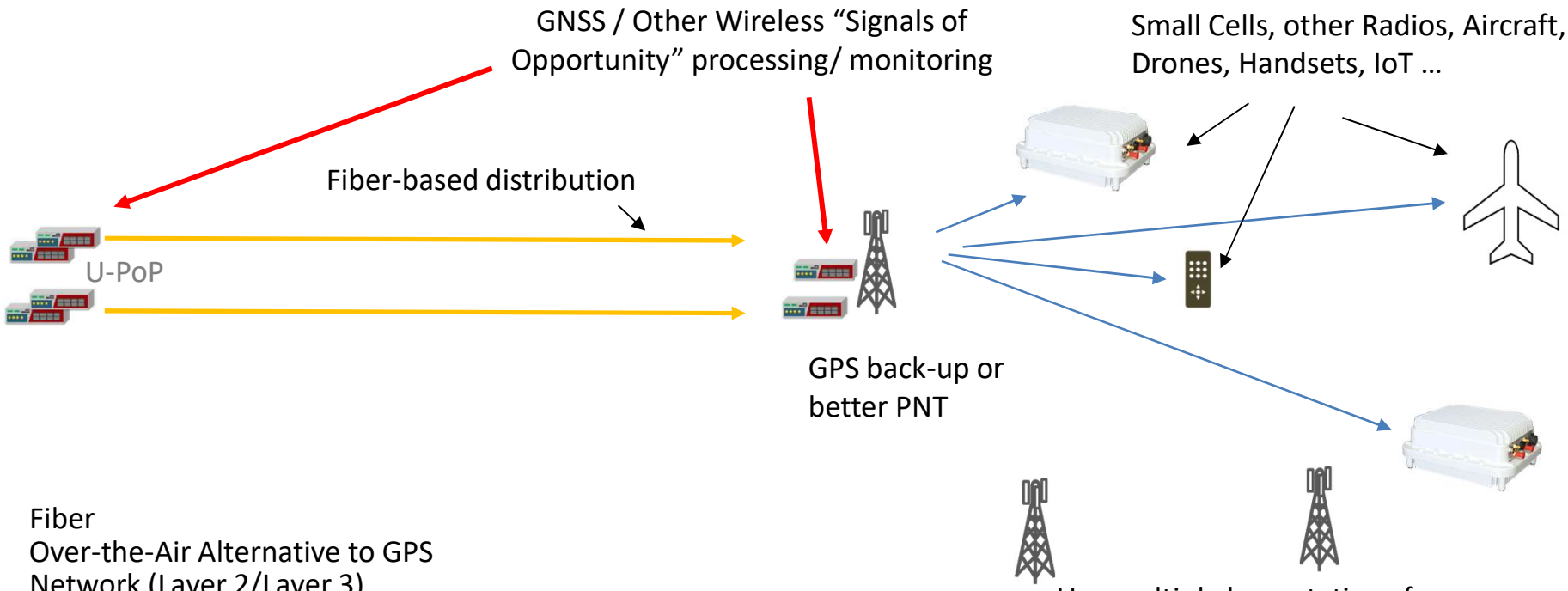
# Overall Picture of Potential TaaS: Core to Edge



# Overall Picture of Potential TaaS: Edge to Wireless

## Wireless beacon/Wireless monitor/“SUPERGPS”

## Edge distribution



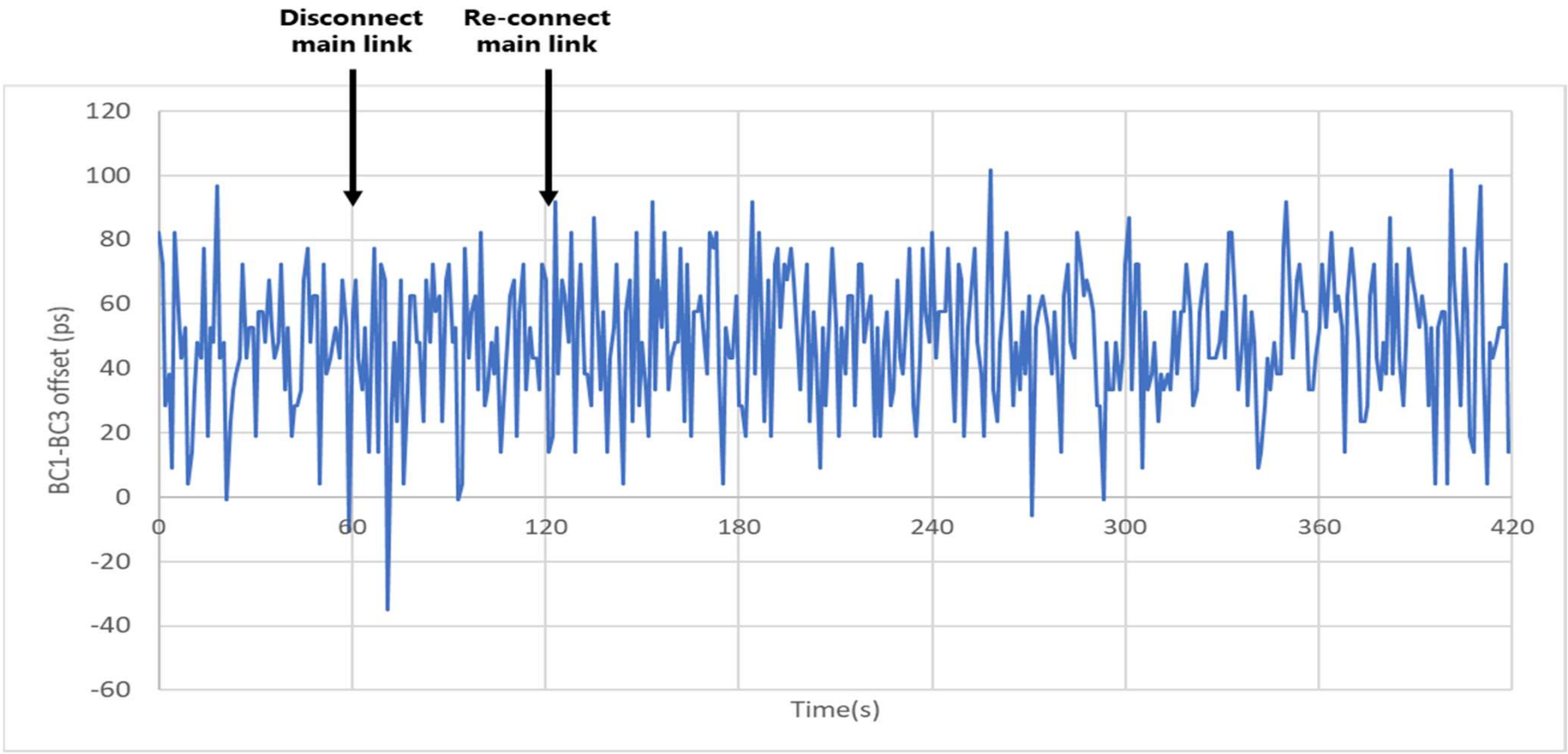
# Rolling Out Time as a Service (TaaS)
# Outline

1. Different transport options in fiber
   – White Rabbit: pros and cons
   – PTPv2 over existing transports: pros and cons
2. Resilience considerations
3. Wireless transmissions: extending the time base into full PNT
4. Reverse Beacon: monitoring the network
5. A new idea: Compliance as a Service (with Blockchain)
6. Conclusions

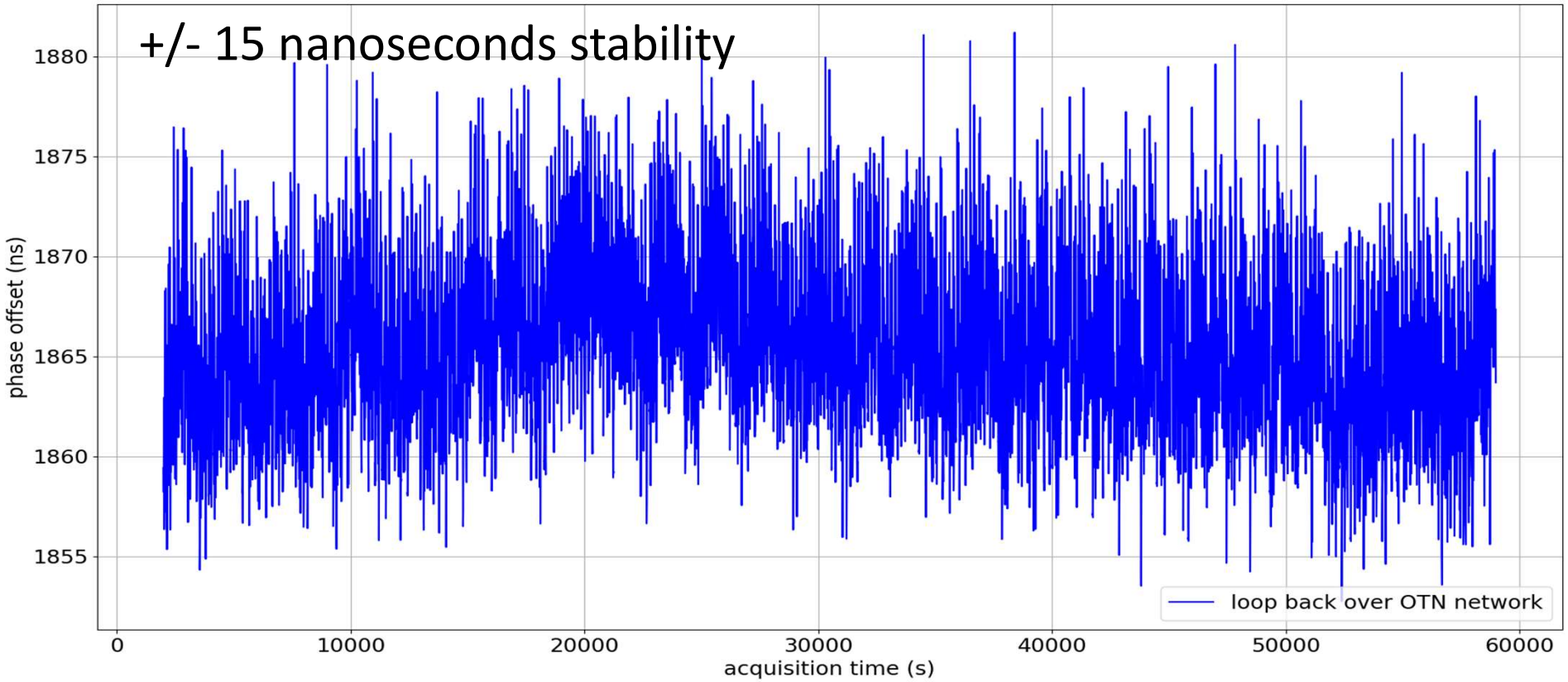
# 1. Different transport options in fiber

- White Rabbit: pros and cons
  - White Rabbit (WR) is a combination of a frequency sync, such as Synchronous Ethernet (SyncE) and the Precise Time Protocol packet sync
  - WR can transfer time with sub-nanosecond accuracy across thousands of km
  - This level of accuracy depends on a bi-directional link, and calibrated equipment
  - WR can function at a lower accuracy level, or require more calibration across two uni-directional fibers, but they still must pass a layer 2 frequency sync (like SyncE) coherent with the PTP packets
- PTPv2 over existing transports: pros and cons
  - An experiment reported here at ITSF and at WSTS show sub-100 ns *stability* using PTPv2 over the OTN in the US, with a distance of 200 km
  - Advantage is that this or potentially other systems could be used over existing telecom infrastructure
  - Disadvantage is that it requires calibration initially, or re-calibration if equipment loses power
  - However, re-calibration given multiple calibrated links, could be automatic

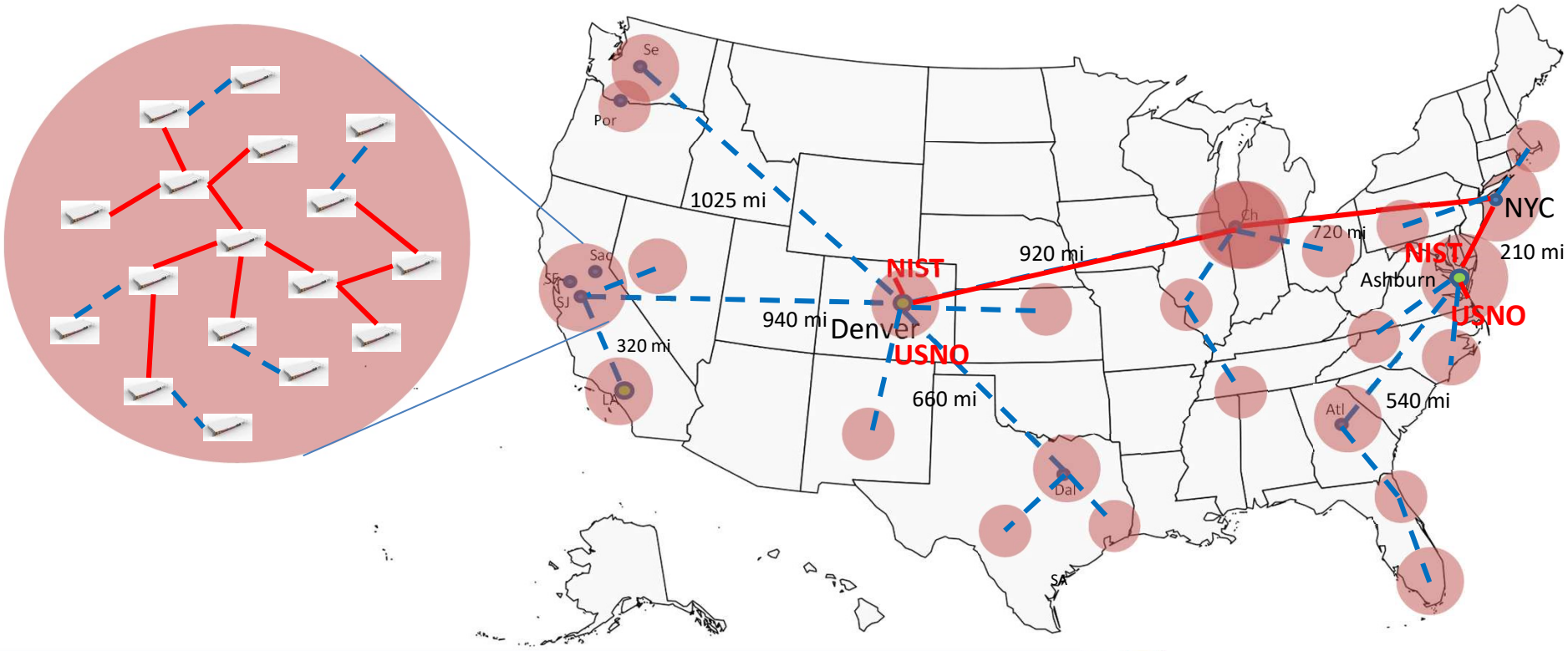
# 135 Miles, Netherlands - Dark Fiber (Calibrated): Accuracy, Stability and resilience



# 1330 Miles, US - Standard Telecom Dual Fiber (Uncalibrated): Stability of uncalibrated link



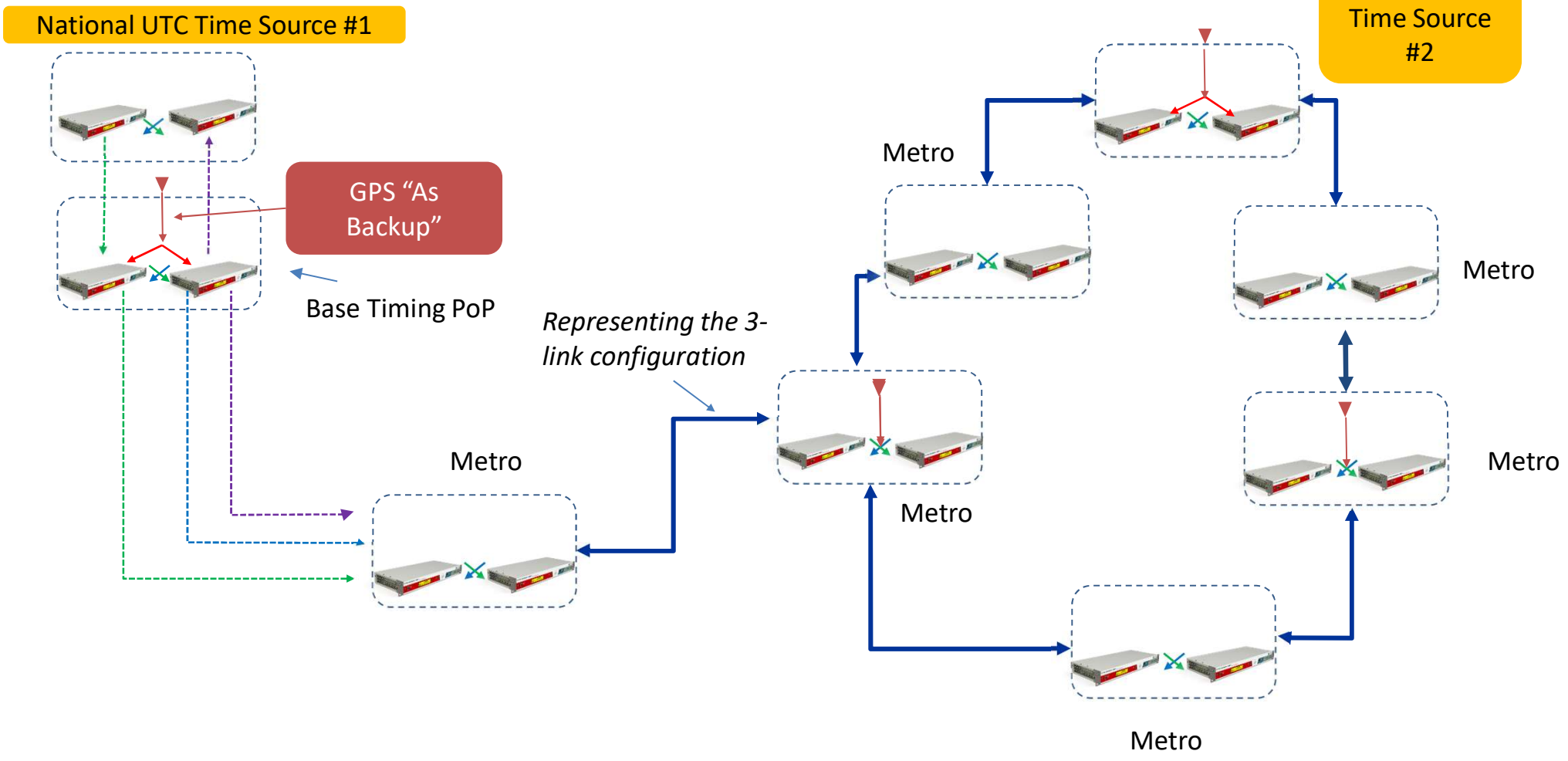
# Potential Local and Long-Distance Densification is the US
# Showing a potential combination of PTPv2 (blue) and the WR links (red)



# 2. Resilience Principles

- Ability to withstand intentional and unintentional anomalies.
- Use of redundancy to detect a timing anomaly and switch to another source.
- Traceability to UTC requires that each source have a documented path to a UTC source.
- Holdover is another option, and requires documenting the expected maximum time excursion during holdover.

# UTC-Based Redundant, With GPS Backups



# Resilience

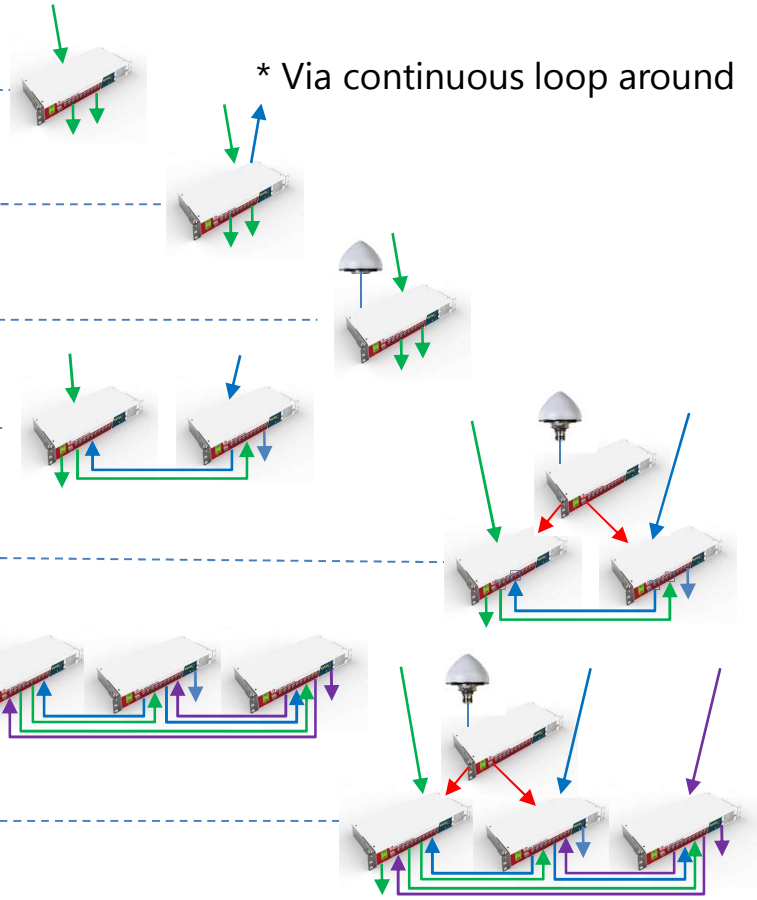


Increasing Resilience

Increasing Expense

| | Hard Fault Detection | Soft Fault Detection | Hard Fault Resilient | Soft Fault Resilient |
|---|---|---|---|---|
| Single Link, w/o GPS | Y | | | |
| Dual link over same infrastructure, w/o GPS | Y | Y* | | |
| Single Link, w/ GPS | Y | Y | Y | |
| Dual link over separate infrastructure, w/o GPS | Y | Y | Y | |
| Dual link over same infrastructure, w/ GPS | Y | Y | Y | Y |
| Triple link over separate infrastructure, w/o GPS | Y | Y | Y | Y |
| Triple link over separate infrastructure, w/ GPS | Y | Y | Y | Y |

* Via continuous loop around



# TaaS Model:
# Monthly Price Matching Performance Required

## Rough Comparisons and Sample Use Cases

| SLA-Based Accuracy to "Base" -> | <1 ms | <100 us | <10 us | <1 us | <100 ns | <10 ns | <1 ns | <250 ps |
|---|---|---|---|---|---|---|---|---|
| **Relative to "Global Base"** | $ | $ | $$$ | $$$ | NA | NA | NA | NA |
| **Relative to "GPS plus National UTC Base"** | $ | $ | $$ | $$$ | $$$ | $$$$ | $$$$$ | NA |
| **Relative to "Intra-Region GPS UTC Base"** | $ | $$ | $$ | $$ | $$ | $$$ | $$$$ | NA |
| **Relative to "Intra-Metro GPS UTC Base"** | $ | $ | $ | $ | $ | $$ | $$ | $$$ |
| **Relative to "City-Core Base"** | $ | $ | $ | $ | $ | $$ | $$ | $$$ |

Nationwide Cyber-Forensics

Global Financial Mkts

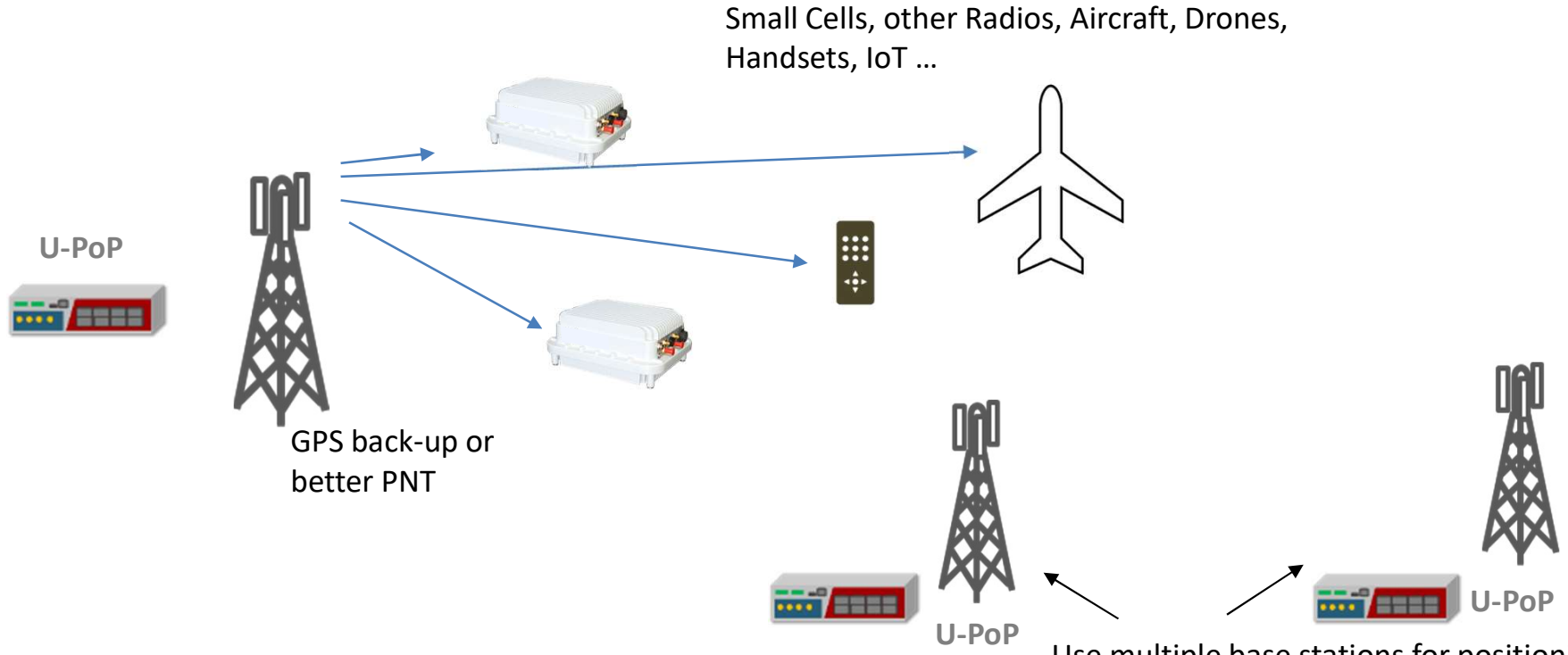
Critical Infrastructure

5G/Indoor/US 911

Autonomous vehicles

# 3. Wireless PNT based on Terrestrial Time

## Wireless beacon/Wireless monitor/"SUPER GPS"




Over-the-Air Alternative to GPS  U-PoP  UTC Point of Presence

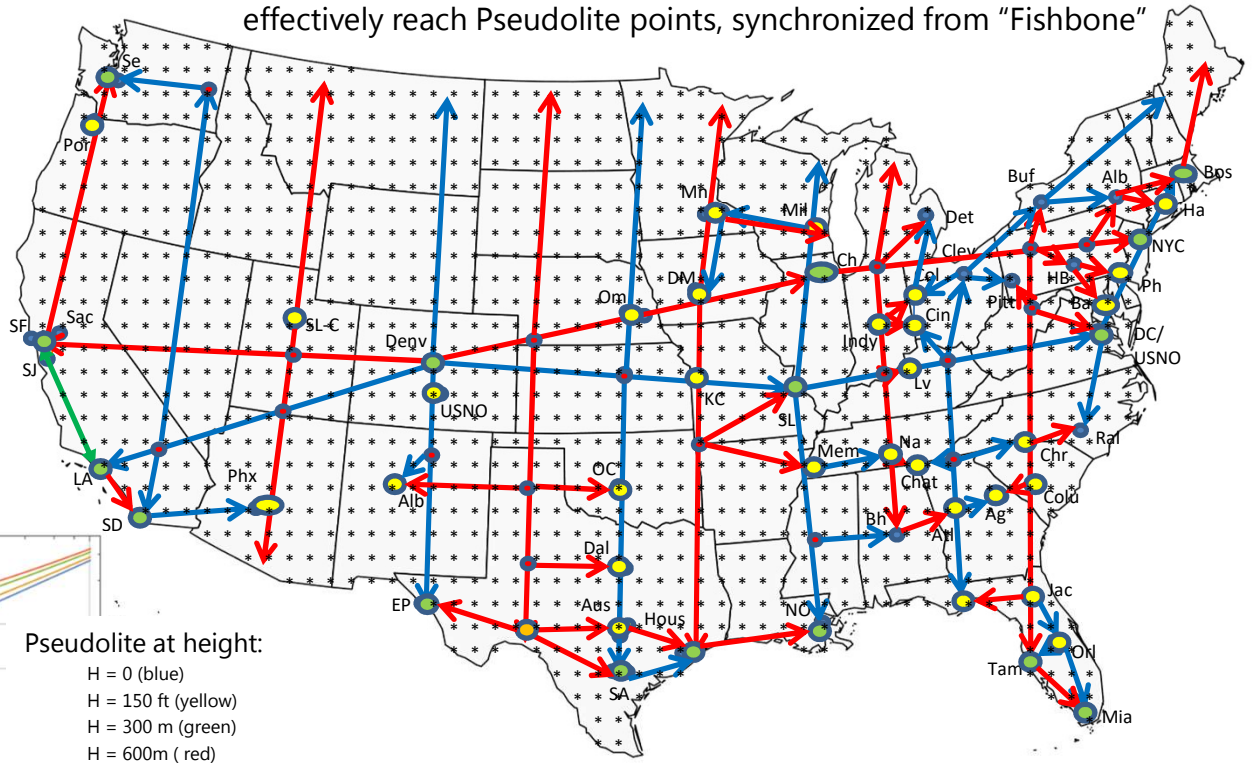
# US Terrestrial Positioning System

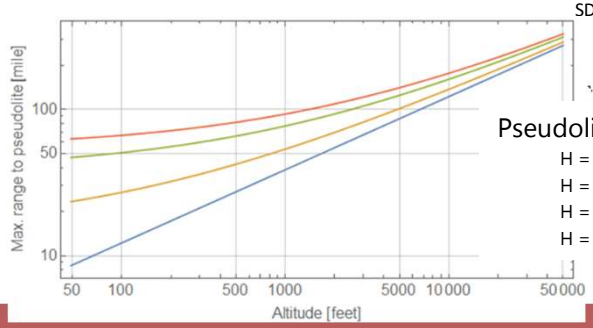
## With Full Wireless Visibility, Trilateration Grid

Combination of fiber and terrestrial-based wireless to cost-effectively reach Pseudolite points, synchronized from "Fishbone"

*e.g. supporting > 650 ft altitude, radio separation as function of radio height (H) is:*

- *31 mi at H = 0ft*
- *47 mi at H = 150ft, 1400 sites*
- *78 mi at H = 300m/984ft, 620 sites*
- *110 mi at H = 600m/1967ft, 260 sites*



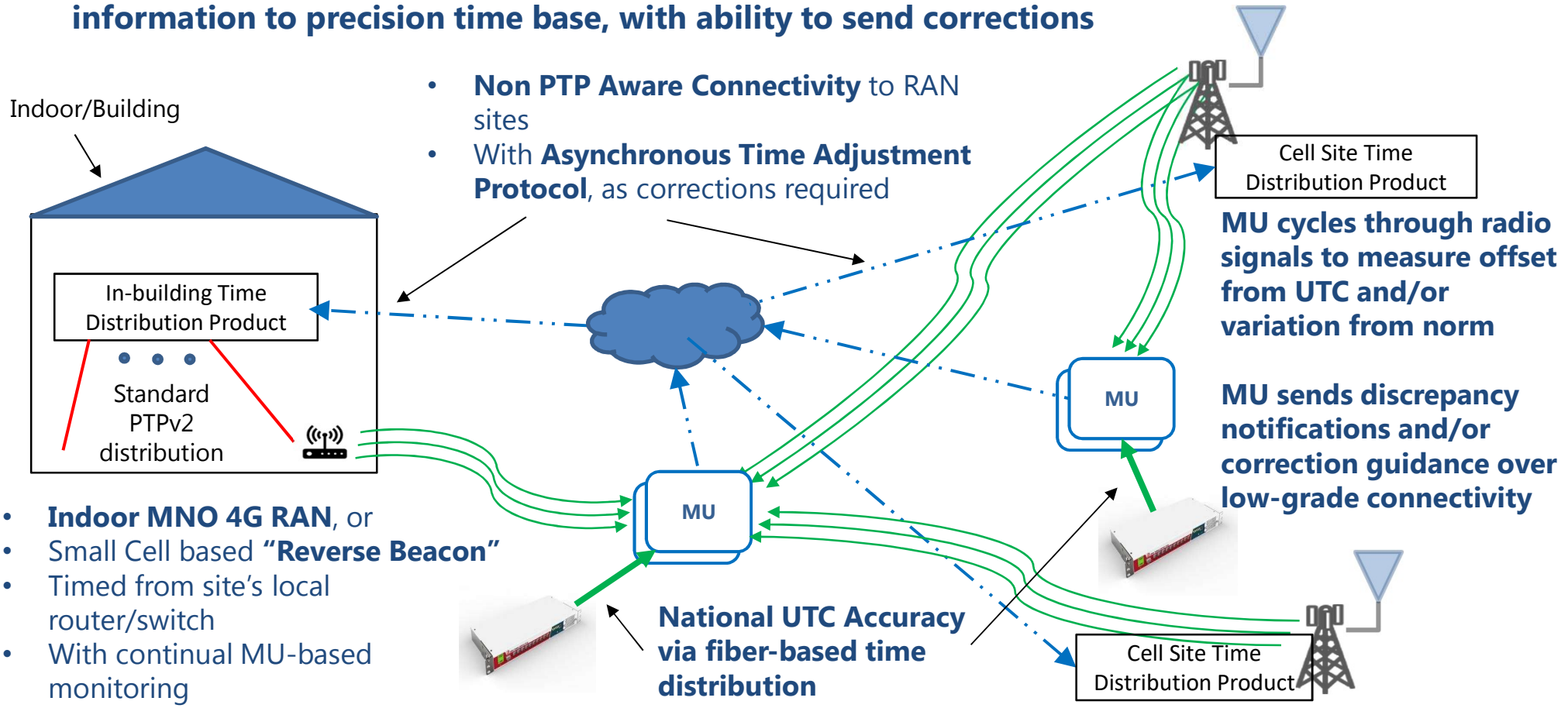




Pseudolite at height:

- H = 0 (blue)
- H = 150 ft (yellow)
- H = 300 m ( red)

# 4. Wireless Monitoring, Correction, and "Reverse Beacon"

**Monitoring Unit (MU) continually compares RAN's embedded time information to precision time base, with ability to send corrections**




- **Non PTP Aware Connectivity** to RAN sites
- With **Asynchronous Time Adjustment Protocol**, as corrections required

**MU cycles through radio signals to measure offset from UTC and/or variation from norm**

**MU sends discrepancy notifications and/or correction guidance over low-grade connectivity**

- **Indoor MNO 4G RAN**, or
- Small Cell based **"Reverse Beacon"**
- Timed from site's local router/switch
- With continual MU-based monitoring

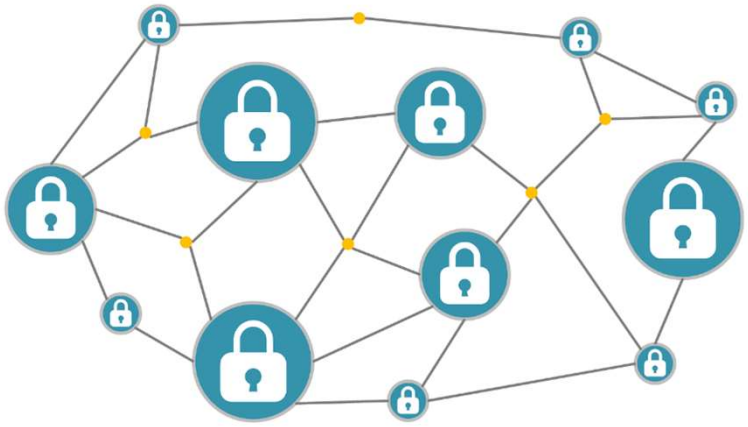
**National UTC Accuracy via fiber-based time distribution**

# 5. Blockchain and Compliance as a Service

**From U. Cambridge: DLT Conceptual Framework**

A DLT system is a system of electronic records that

i. enables a network of independent participants to establish a consensus around
ii. the authoritative ordering of cryptographically-validated ('signed') transactions. These records are made
iii. persistent by replicating the data across multiple nodes, and
iv. tamper-evident by linking them by cryptographic hashes.
v. The shared result of the reconciliation/consensus process - the 'ledger' - serves as the authoritative version for these records.



# Using DLT/Blockchain for Timing Verification and Compliance as a Service

- **Store calibration and verification of accuracy in a blockchain system**. Ensure both veracity and availability.
  - This would provide security against both incidental and intentional distortion of data.
  - It also would allow sharing the data with regulators and customers who might want a way of checking the veracity of the data.
- **Add customers' own timestamps of measurements** to the blockchain system.
  - In finance or electric power, give access to regulators
  - The entity running the timing network could provide **Compliance as a Service:** demonstrate compliance with any timing requirements.

# Conclusions

- Time over fiber:  White Rabbit vs PTPv2
- Resilience considerations
- Wireless transmissions:  extending the time base into full PNT
- Reverse Beacon:  monitoring the network
- Compliance as a Service (with Blockchain)

# Overall Picture of Potential TaaS: Core to Edge

## Fiber-based Core → Edge distribution → Wireless beacon/monitoring/ "SUPERGPS"