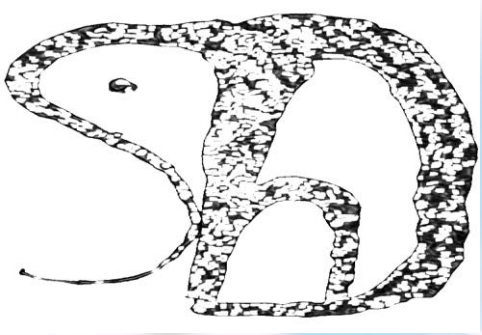
ITSF 2014

The future of Telecom synchronization



white elephant
or
white rabbit

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Agenda

1. History
2. Overview of Synchronization Applications; Requirements and technologies
3. Drivers for a high accuracy sync service
4. Migration to High Accuracy sync network
5. Conclusions

Famous Synchronization quotes

”640ns ought to be enough for anybody”

1. The history of Sync

To predict the future you need to understand the past

"Evolution" of Transport network synchronization
(from internal operation to a service)

Every network consists of nodes and links
Links are synchronous (SDH, PDH, Ethernet, OTN, Base-band modems…)

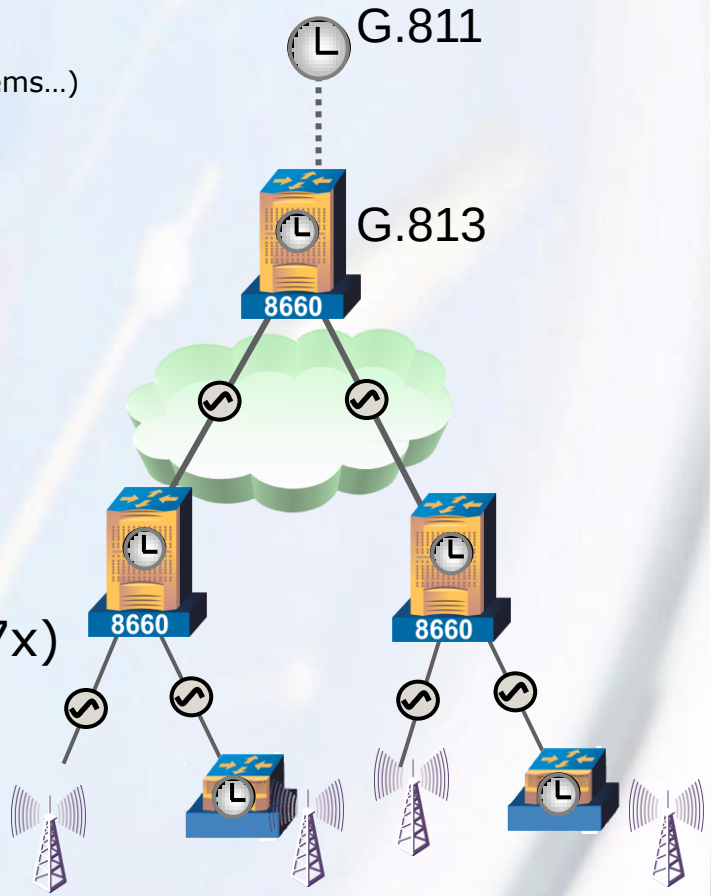
1. Let Clocks appear and synchronize the nodes!

2. Packet rebellion - Down with the clocks!
   Rebels: ATM; Ethernet; OTN

3. Mobile outcry – the clocks are back (G.826x)

4. Clocks transformed – support for Phase (G.827x)

5. **Cross-industry synchronization service**



Synchronization is still becoming a service of the transport network!

Synchronization - Transport Media & Protocol?

Two widely deployed transport media for **sync service**:

1) Radio

- GNSS; (GPS; GLONASS; Beidou; Galileo)
- Eloran (multiple ground stations)
- WWVB; DCF77 (single ground station)

2) Ethernet

- PTP
- SyncE
- White Rabbit (HA1588)

Also IP/UDP/Ethernet encapsulated NTP; PTP… and data

We Need Both! **And all options!**

Reliable, high accuracy synchronization

- Radio waves (end-to-end), but prone to:
  - Fading
  - Interference
  - Jamming
  - Antenna problems

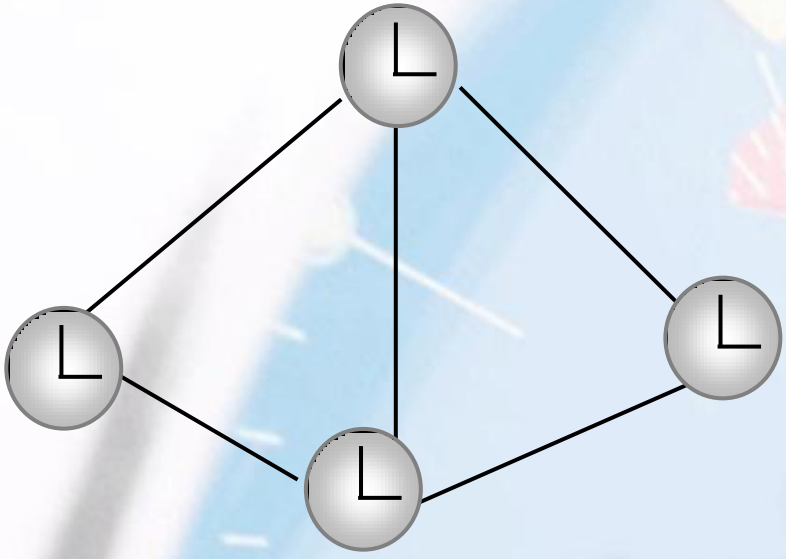
  Using different frequencies helps (GNSS + ELORAN)

- Ethernet (point-to-point fibre) needs:
  - Switches/nodes
  - Topology management
  - Network standards for synchronization

Synchronization Topology

Clocks talk directly to clocks...

(Regardless of Model BC, TC...)



... Anything else impairs performance!

High Accuracy implies full-on-path support

2. Overview of Synchronization Applications; Requirements and technologies

Synchronization Applications

1) Required Accuracy

• TDD		1.5us
• LTE-A	COMP; eICIC	~300ns
• E112	Location services (10m)	~30ns
• CERN; National labs; Google?		**1ns**

- Examples…

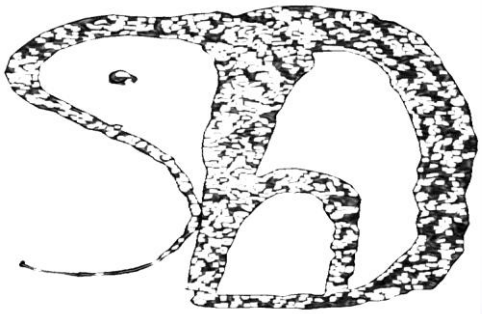
What is the required accuracy of a national; terrestrial; sync network?

Synchronization - Technology and standards

2) Available accuracy/stability

• PTP	timestamp granularity*	~8ns
• GNSS	receiver accuracy	<100ns
• SyncE	re-arrangements	~1us
• White Rabbit	phase measurement	**<1ns**
• Loran/WWVB	receiver accuracy	~30us

* Note: Does not generally increase with increasing Ethernet speeds



ITU synchronization model

- Model equipment (noise generation/transfer)
- Model network (nodes, clock switching)
- Simulate for worst case

\+ defines performance limits

\- "All or nothing"

\- may not reflect reality

Conservative results

PTP synchronization model

- Links are Symmetrical
- Network topology can “self manage”
- As accurate as your implementation

+ Protocol allows high performance

- No performance guarantees

Almost too many features!

Using multiple clocks…

A device can have multiple clocks:

- Local OCXO
- Local GNSS
- Synchronous Ethernet
- Ext clock Input (Rb or Cs)
- Remote PTP master (via local PTP slave)

All the above clock are available in a SFP module!

Non-standard

Three ^ things to do with multiple clocks…

- **Monitor relative stability**
- **Provide time holdover**
- **Ensemble (of multiple clocks)**

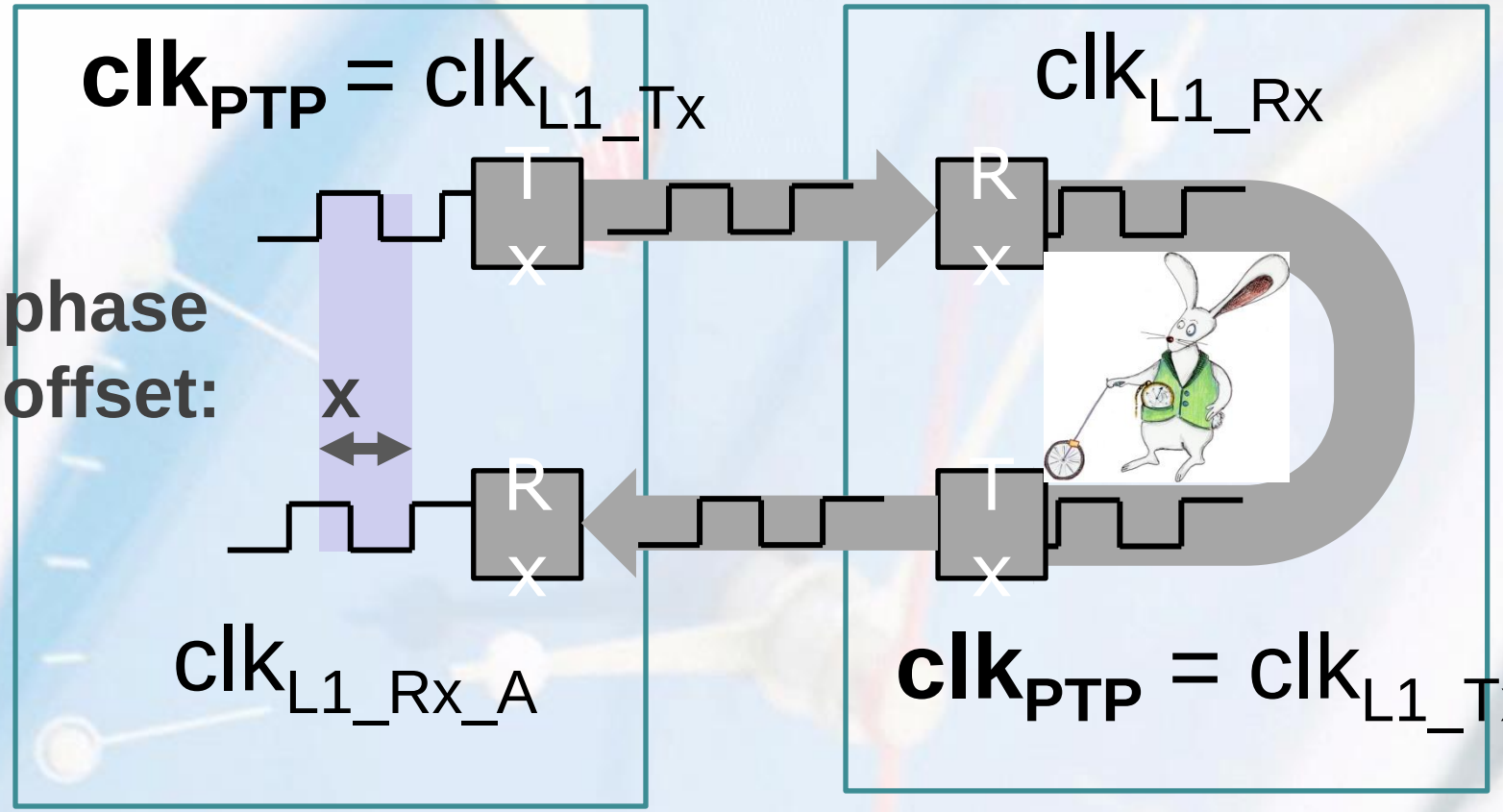
Fits in an SFP... **But not in the standards**

Adding High Accuracy (White Rabbit)

Using the relation between **PTP** and **L1** for High Accuracy

White Rabbit
strict relation between L1 and PTP

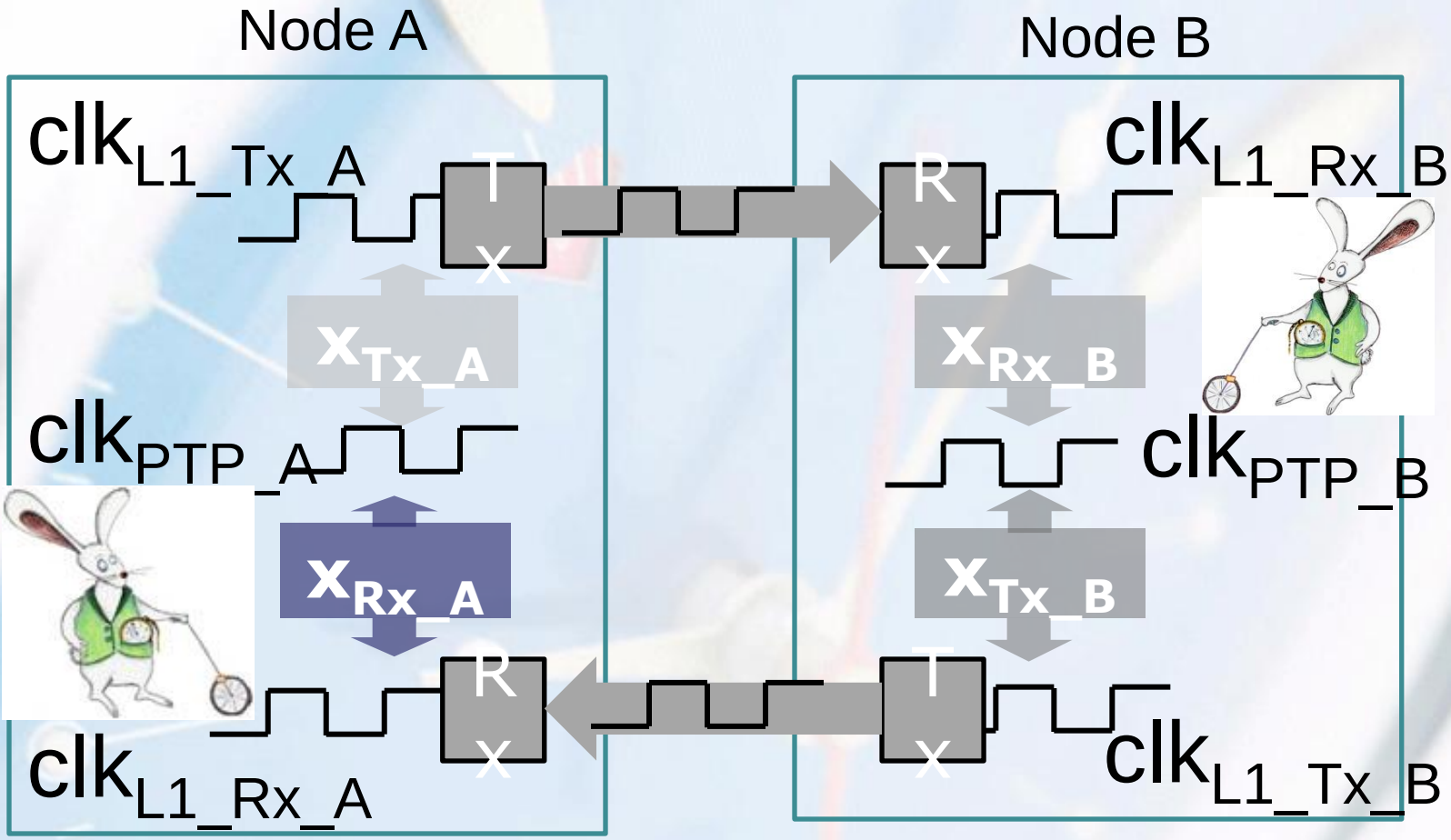
PTP & L1 Master node PTP & L1 Slave node



HA1588

Flexible relation between L1 and PTP

All phase offsets (x's) known and pseudo-constant



3. Drivers for a high accuracy Synchronization service

-Mobile
-E112 (Legislation)
-GNSS support for critical infrastructure (Legislation)

Slides from E112 EC hearing

Enhancing caller location accuracy

- Gap between citizens expectations (5-10 m) and current emergency location solutions
- Currently the emergency caller location accuracy available in EU member states is Cell or sector ID (100m- 40 km)
- Accurate caller location could significantly reduce search cost and contain damage (health, material)
- GNSS based solutions can fill the gap

Slides from E112 EC hearing

The North American E911 Experience

- For the Phase II mandate, A-GNSS has proven to be the technology of choice and is reliable for most outdoor use-cases as well as two-storey residences.

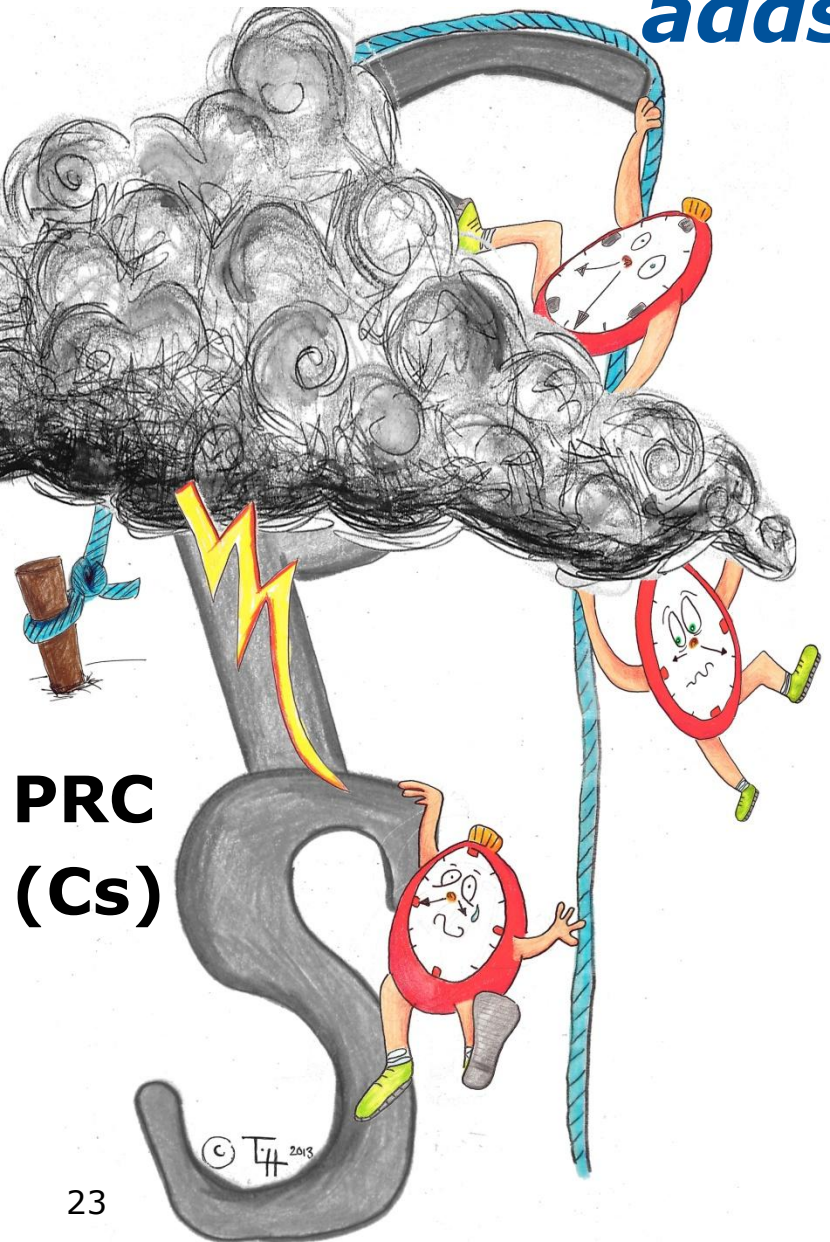
- A-GNSS is not suitable for difficult indoor environments, particularly for determining floor level. 80% of US E911 calls originate indoors.

- In light of technological developments and the fact that 80% of smartphone use is indoors, the FCC is proposing new rules that set accuracy requirements for indoor E911 calls on all three axes.

GNSS is vulnerable…

- *Secure GNSS Synchronization with a back-up.*
- *At least support Time holdover (e.g. 3days)*
- *We could be lobbying for Terrestrial Sync Networks*

Physical layer synchronization adds…



1. Stability - like local Caesium

(Helps in bad weather)

2. Optional High Accuracy - White Rabbit achieves sub-nanosecond

Good for normal operation
Good for Time Holdover
Cost efficient solutions

4. Migration to High Accuracy synchronization network

HA1588 - Three in one

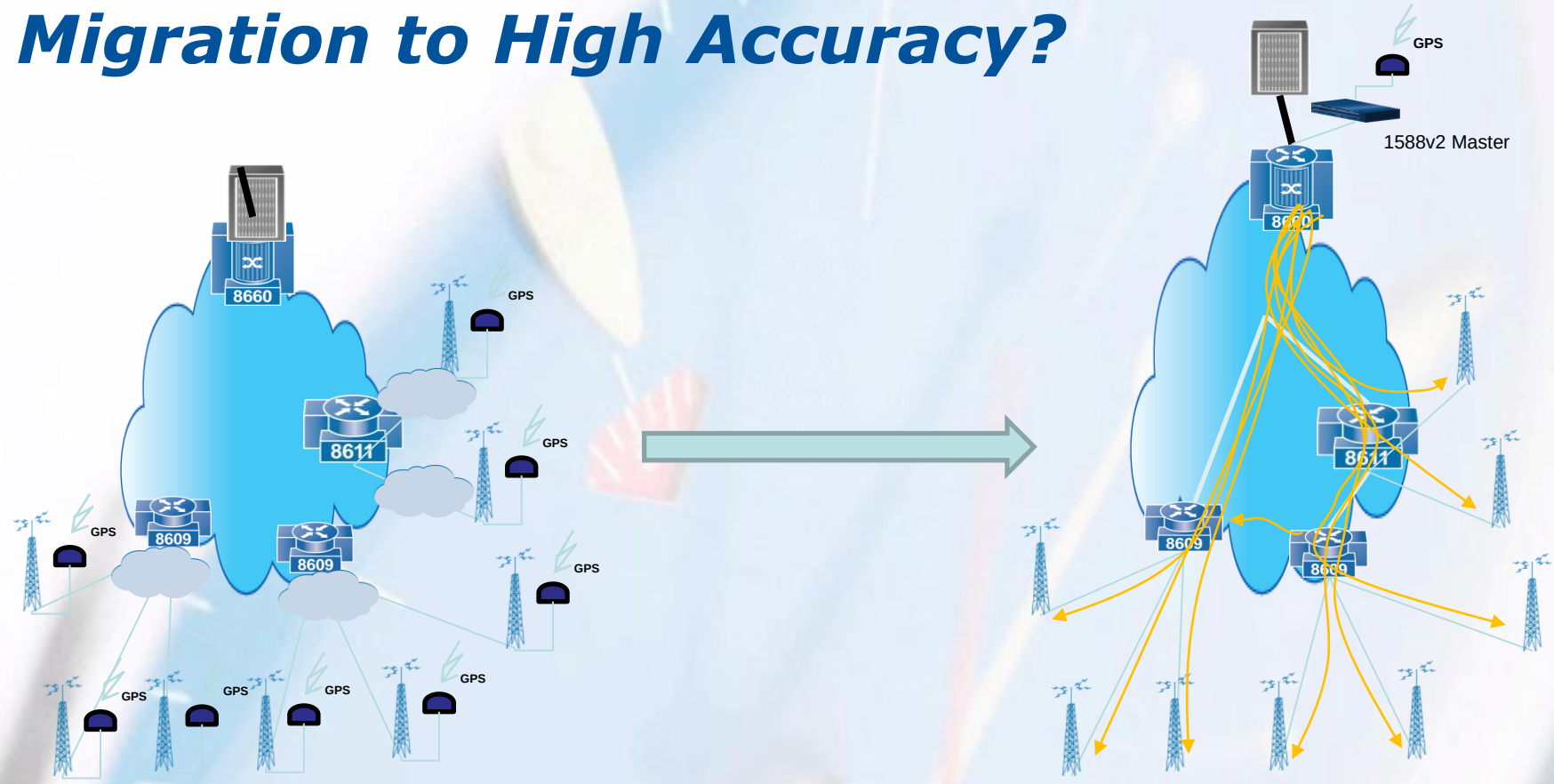
PTP

SyncE

White Rabbit

Co-ordinated by IEEE Ha1588?

Migration to High Accuracy?



GNSS low in network
Failures localized
Time holdover via Rb, PTP, Eloran

GNSS high in network
Back-up via network
Time distribution service
Physical Layer (HA1588)

Short term and longer-term

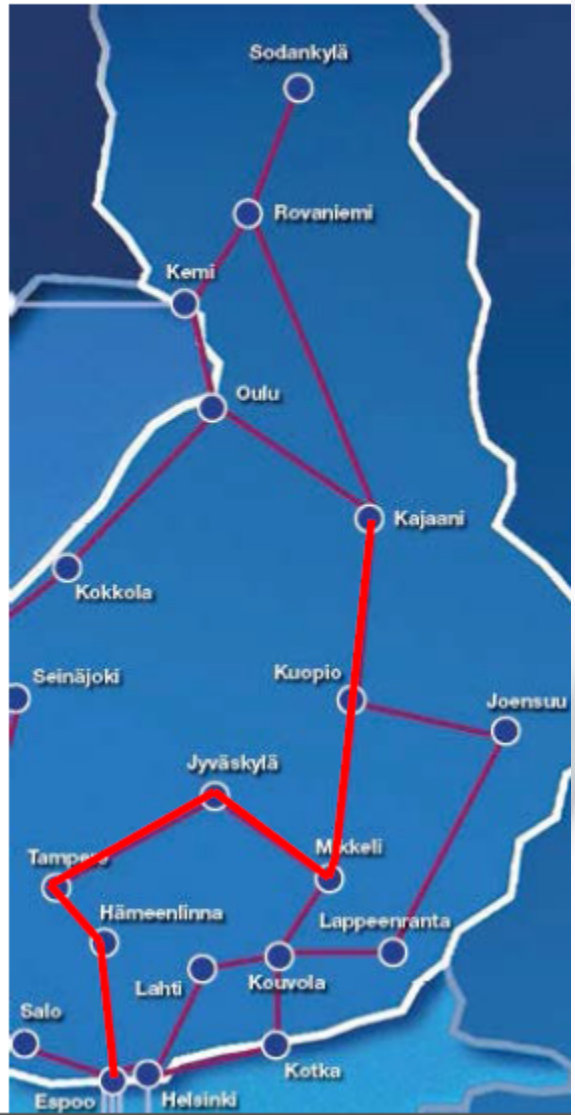
1. Use and enhance current standards
   - ITU-T optimized for mobile
   - SyncE (Freq) and PTP (Time) standards

2. Combine SyncE with PTP (coherency)
   - Add characterization of physical layer to PTP
   - Extend characterization of physical layer:
     - Frequency tractability with coherency
     - Stability characterization
     - Loop-timing identification
     - Bi- or mono- directional fibres (White Rabbit)

Not just in wonderland…

White Rabbit time-transfer experiment between Espoo and Kajaani in Finland

- Status:
  - White Rabbit link between MIKES and CSC sites in Espoo is operational and under evaluation (1PPS transfer).
  - Grandmaster clock is synchronized to UTC(MIKE) and feeds a WR-switch at the CSC Espoo site. All other links will be connected to this switch.
  - Alien wave link (all-optical underground link) has been established between MIKES sites at Espoo and Kajaani (fibre length ~900 km, with a number of unidirectional amplifiers).
  - GPS-PPP time transfer link is being set-up between MIKES sites at Espoo and Kajaani to evaluate the link performance.
  - Once proper operation of the link is verified, a 5071A Cs-clock will be transferred to Kajaani to aid in link evaluation.



Not just in Finland…

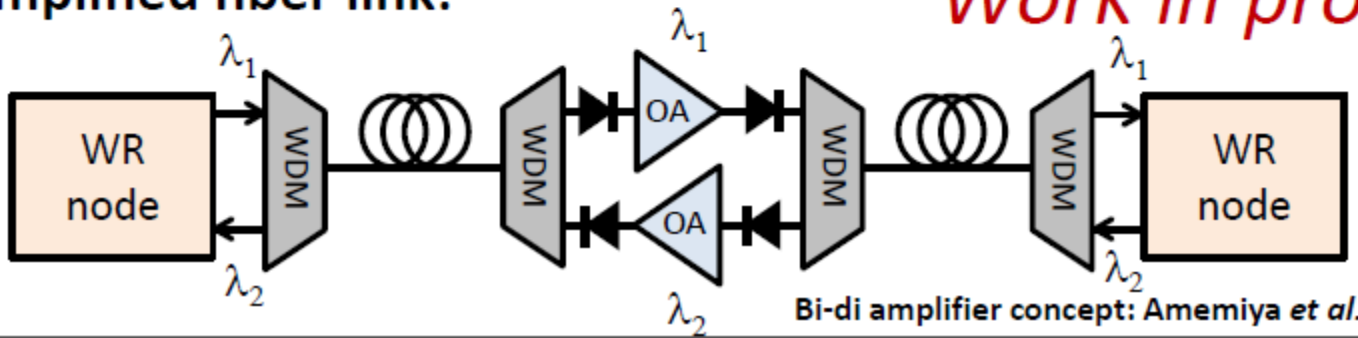
Netherlands: 120 km installed fiber link (2)

- Aim: use WR equipment for long-haul dissemination of Cs clock signals:
  - **Time**: UTC(VSL) — accuracy < 0.1 ns
  - **Frequency**: unit Hz — 13-14 digits relative accuracy

- Application: optical frequency measurements of atoms and molecules for **tests of fundamental physics**, and **searches for 'new physics'** (time-varying fundamental constants etc.)

Amplified fiber link:

Work in progress…



Bi-di amplifier concept: Amemiya *et al.*, IEEE FCSE (2005)

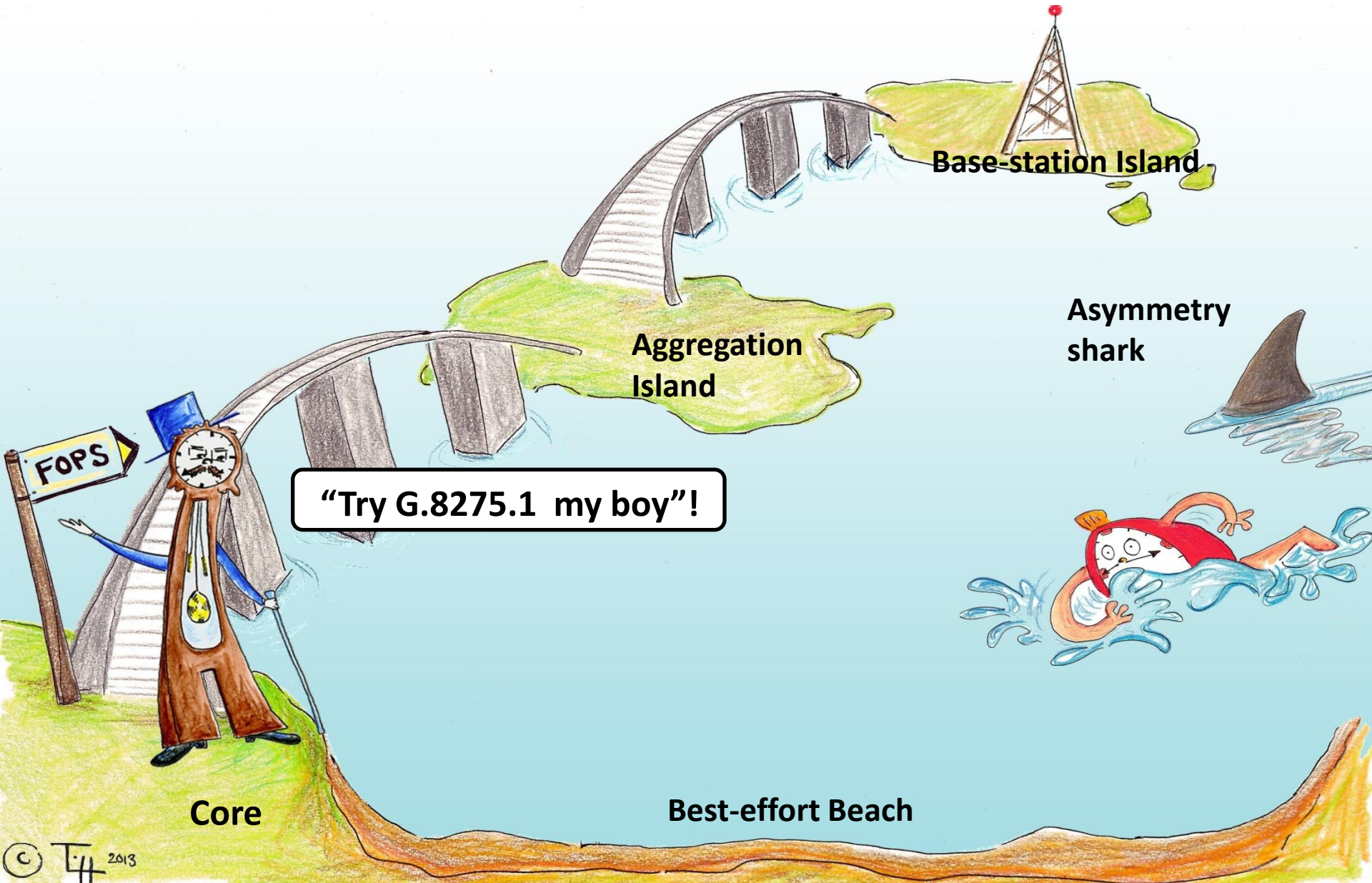
4. Conclusions

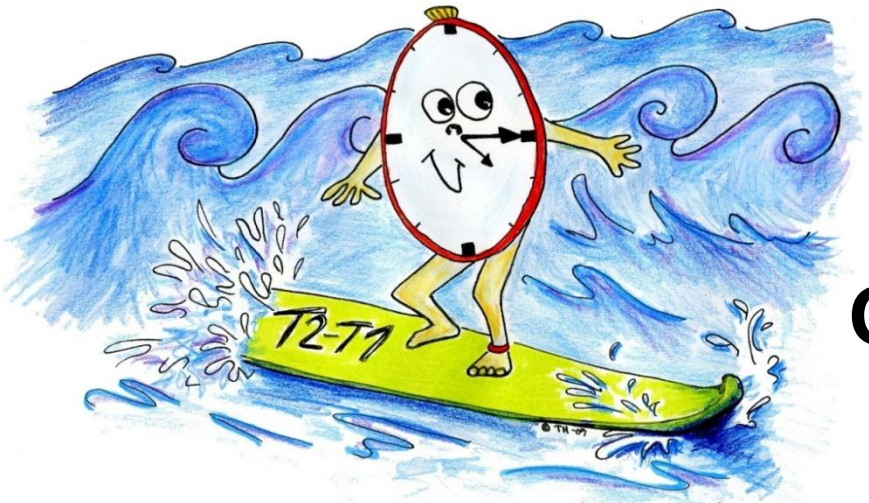
1. Physical layer (Ethernet) is key to:
   - High stability (SyncE+)
   - High Accuracy (White Rabbit)

2. Future Synchronization network
   - Terrestrial; Multi-vendor; Time-service
   - High accuracy (better than GNSS)
   - Legislation for critical infrastructure/E112

3. Future GNSS receivers with “Eloran” backup

Balancing Risk and cost





Selecting the right wave improves packet clock performance

Thanks!

Questions ?