PRC:		Primary Reference	Clock
PRTC:		Primary Reference	Time Clock
ePRTC:	enhanced	Primary Reference	Time Clock
cnPRTC:	coherent network	Primary Reference	Time Clock

Deutsche Telekom @ ATIS-NIST WSTS2015

Primary Reference Clocks in Telecommunication Networks
PR(T)C ⇨ ePRTC ⇨ cnPRTC

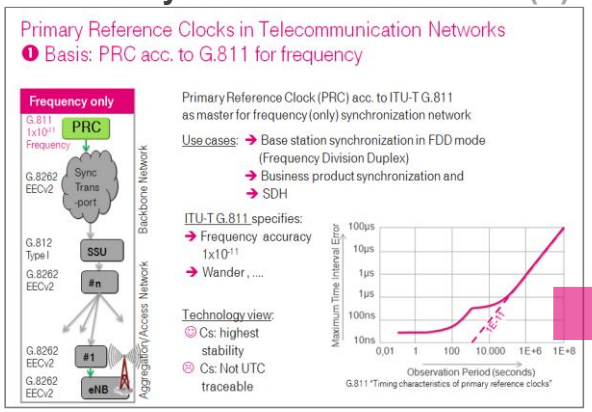
Helmut Imlau, March, 11th 2015

PRC:		Primary Reference	Clock
PRTC:		Primary Reference	Time Clock
ePRTC:	enhanced	Primary Reference	Time Clock
cnPRTC:	coherent network	Primary Reference	Time Clock

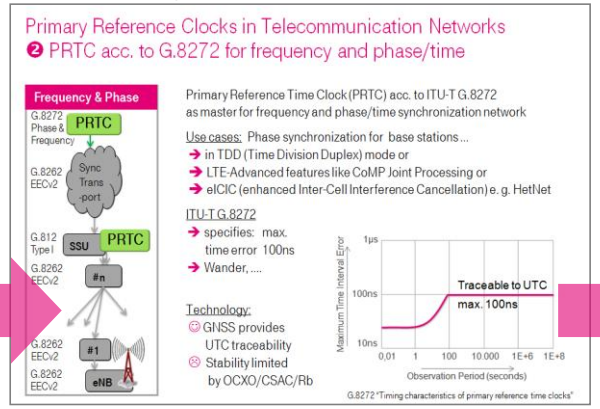
Primary Reference Clocks in Telco Networks

Agenda

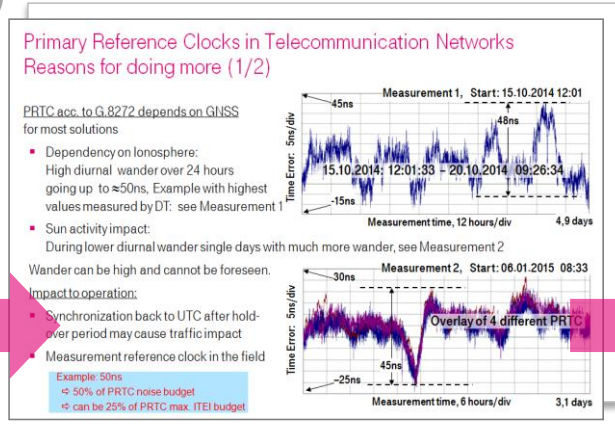
❶ PRC [ITU-T G.811] Primary Reference Clock (1)



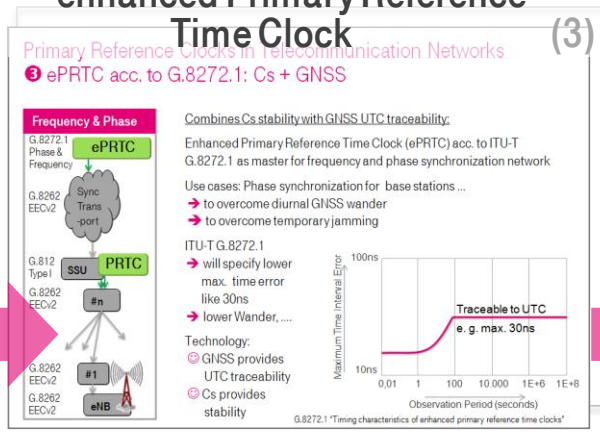
❷ PRTC [ITU-T G.8272] Primary Reference Time Clock (1)



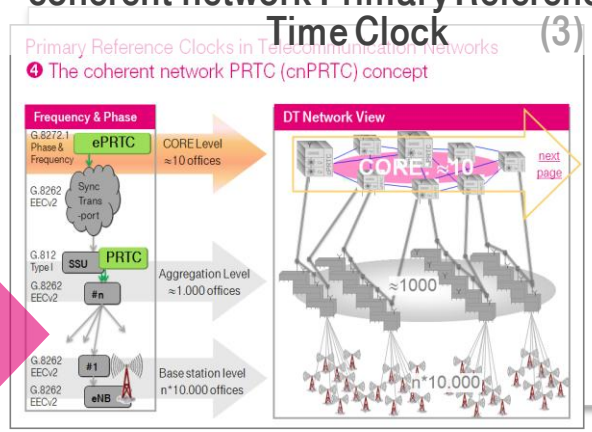
Reasons for doing more (2)



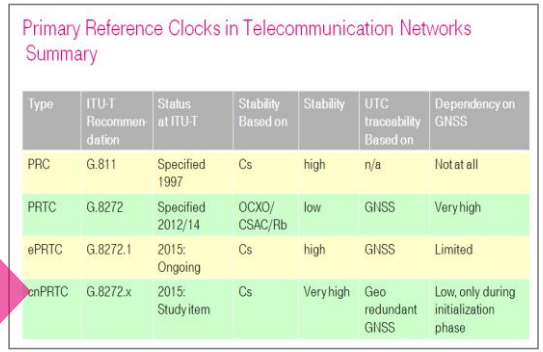
❸ ePRTC [ITU-T G.8272.1] enhanced Primary Reference Time Clock (3)



❹ cnPRTC [ITU-T G.8272.x] coherent network Primary Reference Time Clock (3)



SUMMARY (1)



Type	ITU-T Recommendation	Status at ITU-T	Stability Based on	Stability	UTC traceability Based on	Dependency on GNSS
PRC	G.811	Specified 1997	Cs	high	n/a	Not at all
PRTC	G.8272	Specified 2012/14	OCXO/ CSAC/Rb	low	GNSS	Very high
ePRTC	G.8272.1	2015: Ongoing	Cs	high	GNSS	Limited
cnPRTC	G.8272.x	2015: Study item	Cs	Very high	Geo redundant GNSS	Low, only during initialization phase

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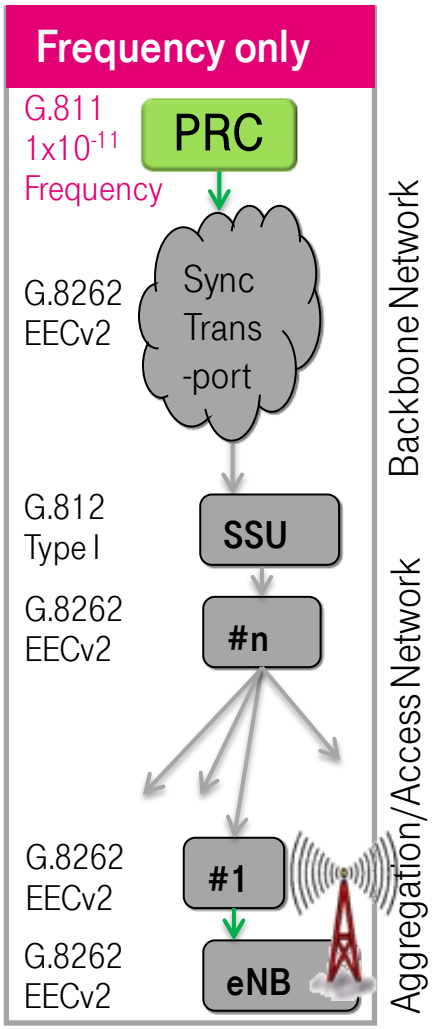
Primary Reference Clocks in Telco Networks
❶ Basis: PRC acc. to ITU-T G.811 for frequency

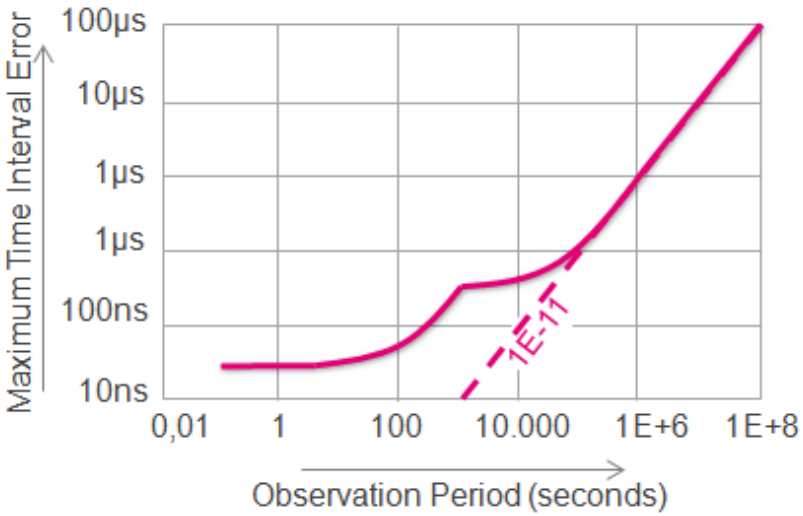


Primary Reference Clock (PRC) acc. to ITU-T G.811
as master for frequency (only) synchronization network

Use cases: ➔ Base station synchronization in FDD mode (Frequency Division Duplex)
➔ Business product synchronization and
➔ SDH synchronization

ITU-T G.811 specifies:
➔ Frequency accuracy $1x10^{-11}$
➔ Wander , ...

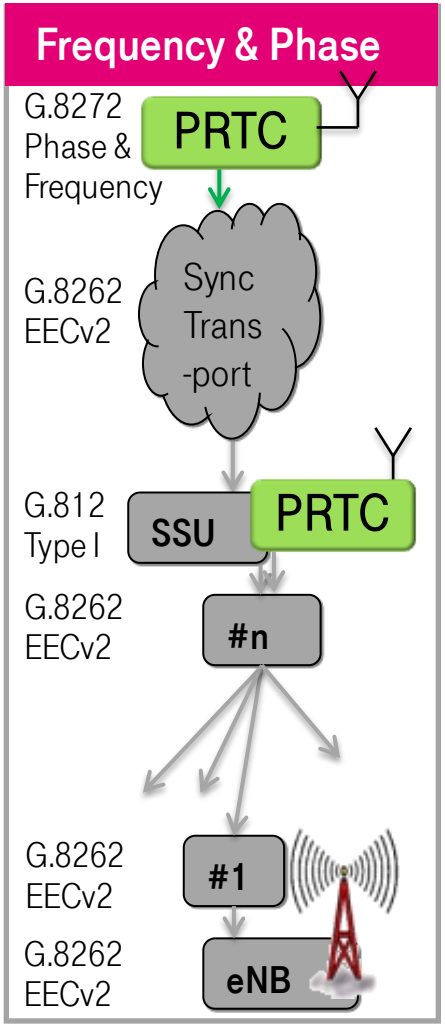
Technology view:
☺ Cs: high stability
☹ Cs: Not UTC traceable



G.811 "Timing characteristics of primary reference clocks"

PRC:		Primary Reference	Clock
PRTC:		Primary Reference	Time Clock
ePRTC:	enhanced	Primary Reference	Time Clock
cnPRTC:	coherent network	Primary Reference	Time Clock

Primary Reference Clocks in Telco Networks
❷ PRTC acc. to ITU-T G.8272 for frequency and phase/time

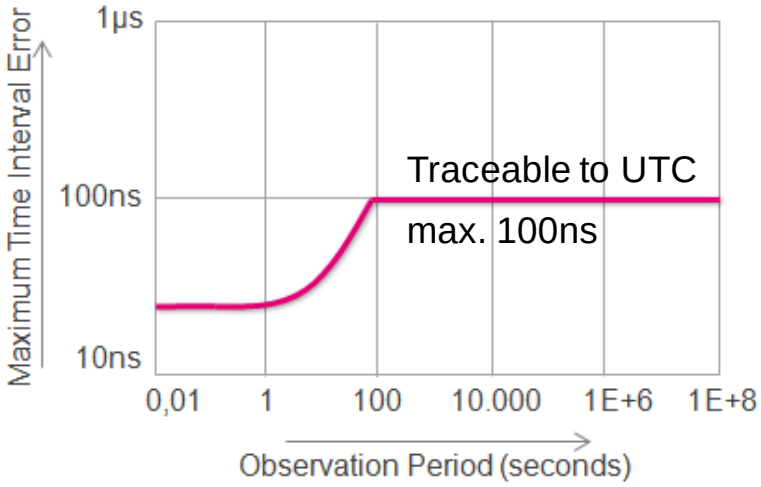


Primary Reference Time Clock (PRTC) acc. to ITU-T G.8272
as master for frequency and phase/time synchronization network

Use cases: Phase synchronization for base stations ...
- ➔ in TDD (Time Division Duplex) mode or
- ➔ LTE-Advanced features like CoMP Joint Processing or
- ➔ eICIC (enhanced Inter-Cell Interference Cancellation) e. g. for HetNet

ITU-T G.8272 specifies:
- ➔ max. time error =100ns
- ➔ Wander as MTIE, ...

Technology view:
- ☺ GNSS provides UTC traceability
- ☹ Stability limited by OCXO/CSAC/Rb



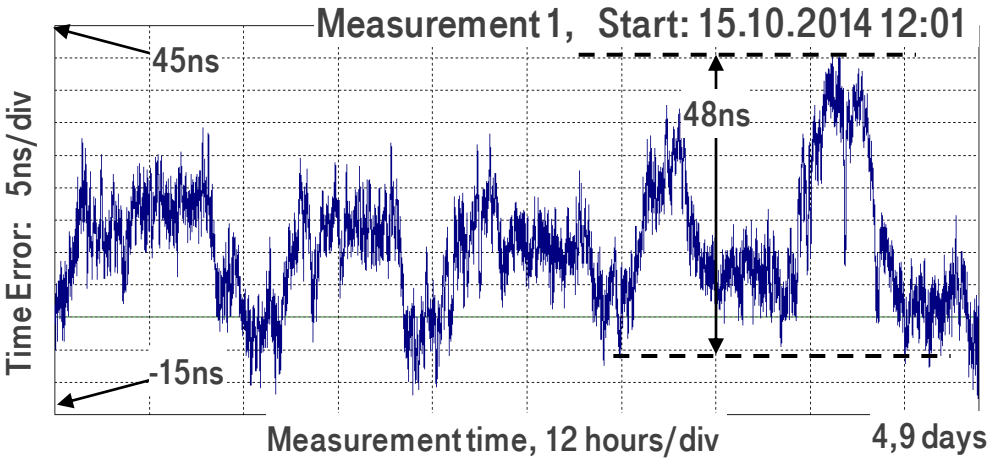
G.8272 "Timing characteristics of primary reference time clocks"

PRC:		Primary Reference	Clock
PRTC:		Primary Reference	Time Clock
ePRTC:	enhanced	Primary Reference	Time Clock
cnPRTC:	coherent network	Primary Reference	Time Clock

Primary Reference Clocks in Telco Networks Reasons for doing more (1/2)

<u>PRTC acc. to G.8272 depends on GNSS</u>
for most solutions

- Dependency on Ionosphere:
  High diurnal wander over 24 hours going up to ≈50ns, Example measured by DT: see Measurement 1
- Sun activity impact:
  During lower diurnal wander single days with much more wander, as example see Measurement 2

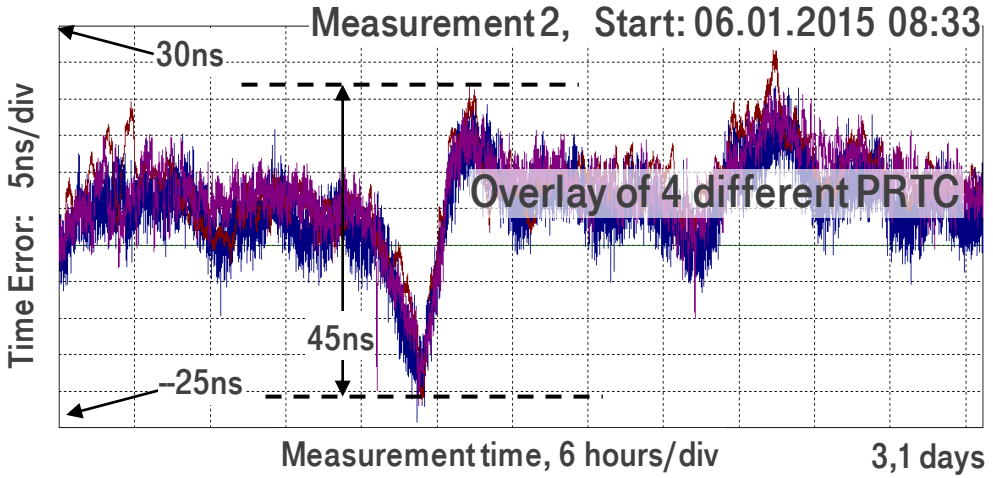


Wander can be high and cannot be foreseen.

<u>Impact to operation:</u>

- Synchronization back to UTC after hold-over period may cause traffic impact
- Measurement reference clock in the field

Example: 50ns
⇨ 50% of PRTC noise budget
⇨ can be 25% of PRTC max. ITEI budget



PRC:		Primary Reference	Clock
PRTC:		Primary Reference	Time Clock
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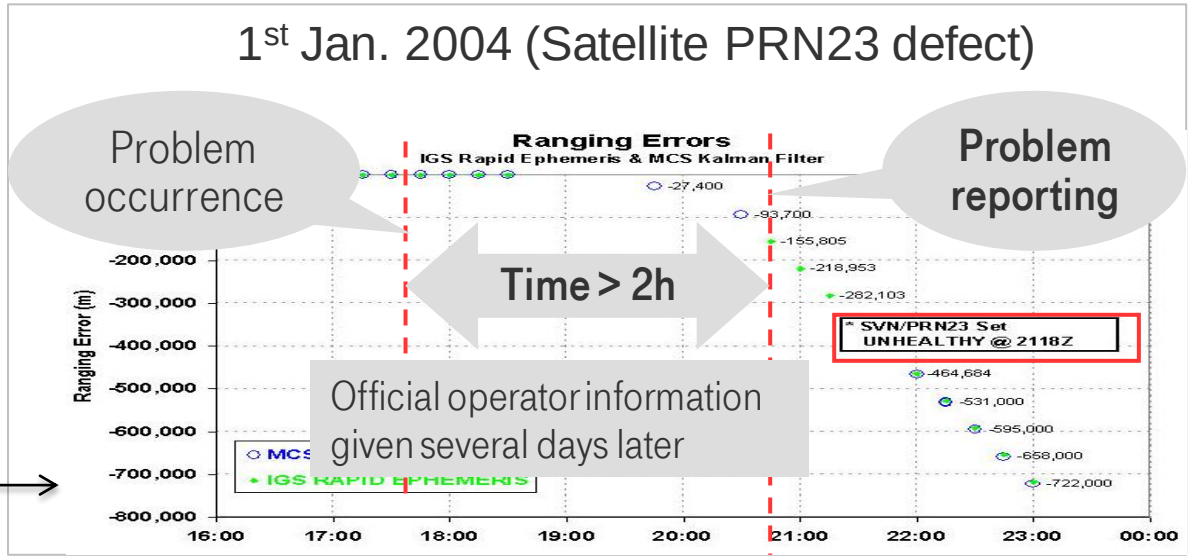
Primary Reference Clocks in Telco Networks Reasons for doing more (2/2)

Hint: On high level mentioned only, please refer
Charles Curry:
Report on GPS Jamming Trials and Criminal Use of Jammers
WSTS2015 (10.3.2015)

GNSS risks

1. GNSS jamming
   - is easy, jammers are available, more and more GNSS tracking applications lead to more and more reasons for GNSS jamming
   - Risk of unintentional jamming
2. GNSS spoofing
   - Get more and more easy
3. Satellite failures (seldom)
   - Like 1.1.2004, please refer DT talk @ITSF2004
   - In general, GNSS satellites are very reliable, but problems can occur. Therefore, using combined GNSS engines in future, like GPS + Galileo would help.



PRC:		Primary Reference	Clock
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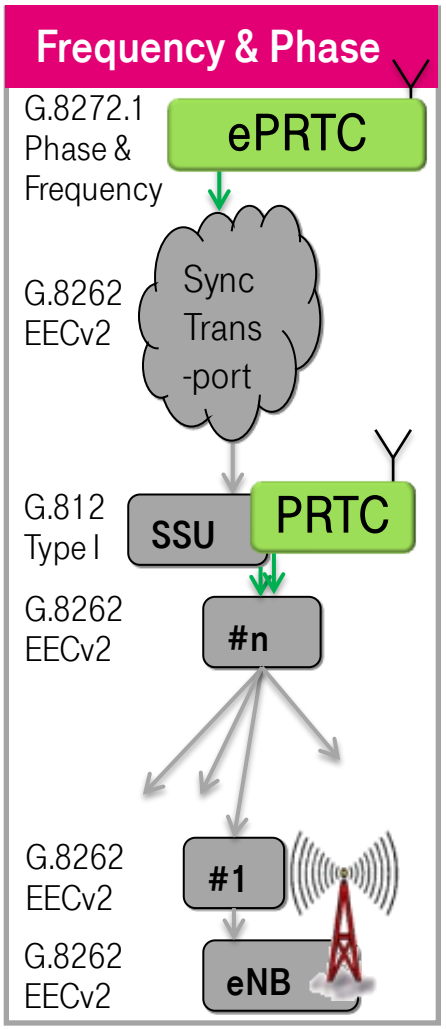
cnPRTC:	coherent network	Primary Reference	Time Clock

Primary Reference Clocks in Telco Networks
❸ ePRTC acc. to ITU-T G.8272.1: Cs + GNSS



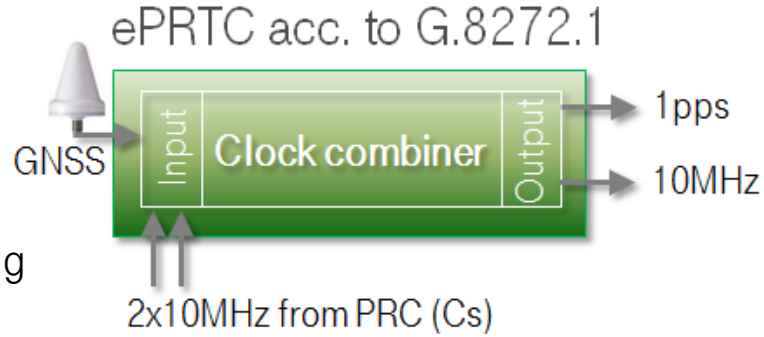
Enhanced PRTC combines Cs stability with GNSS UTC traceability:

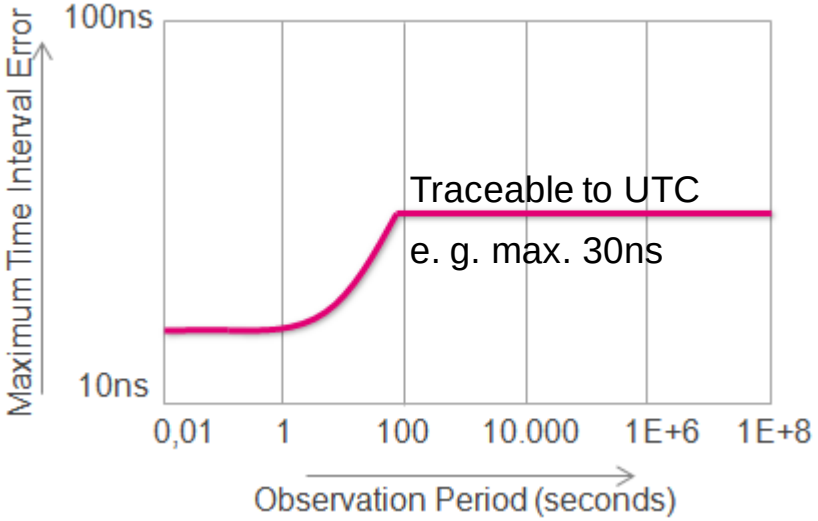
Use cases:

Master for frequency and phase
- ➔ no diurnal GNSS wander
- ➔ to overcome temporary GNSS problems like jamming

ITU-T G.8272.1 will specify:
- ➔ lower max. time error like 30ns
- ➔ lower Wander, ...

Technology view:
- ☺ GNSS provides UTC traceability
- ☺ Cs provides stability





G.8272.1 "Timing characteristics of enhanced primary reference time clocks"

PRC:		Primary Reference	Clock
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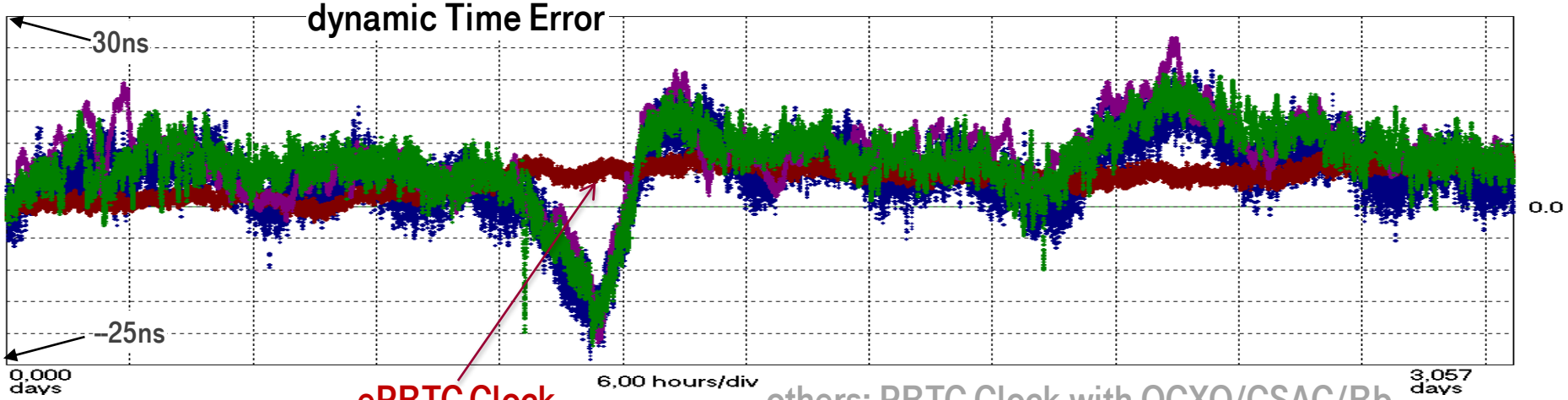
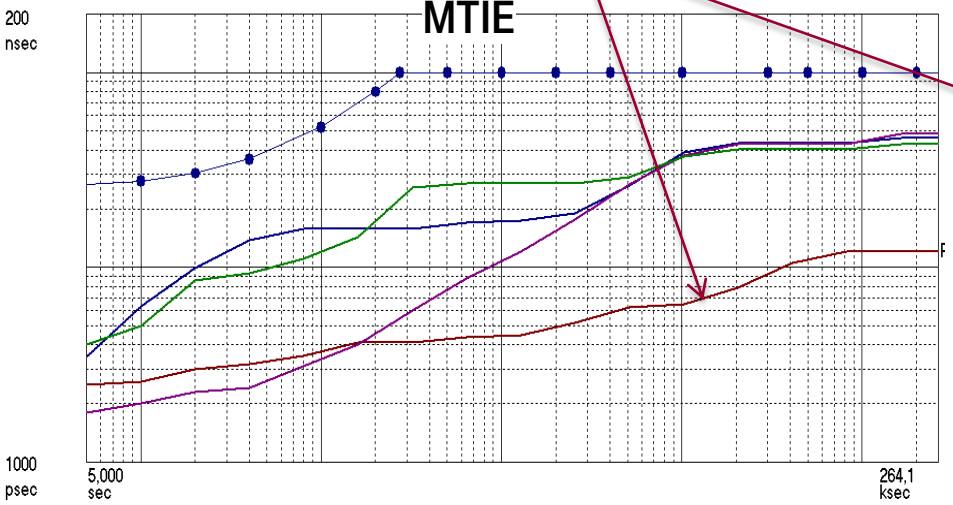
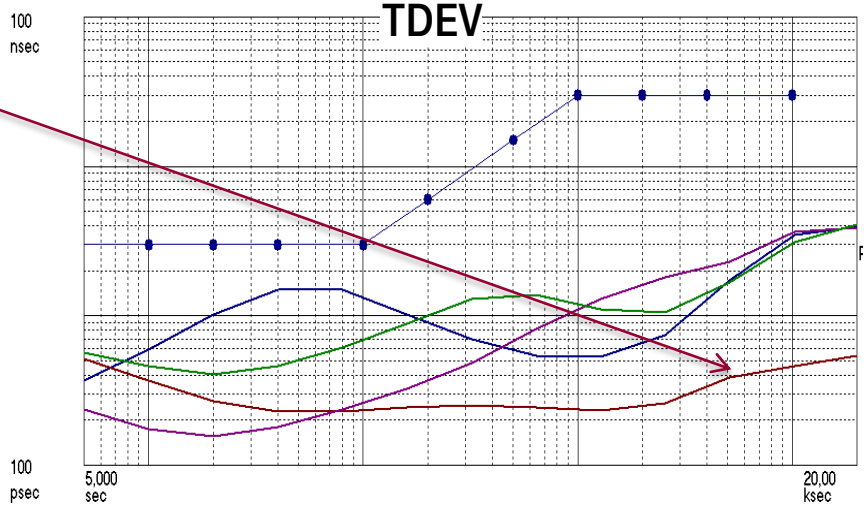
Primary Reference Clocks in Telco Networks
❸ ePRTC Clock combiner acc. to ITU-T G.8272.1: Results



ePRTC Clock

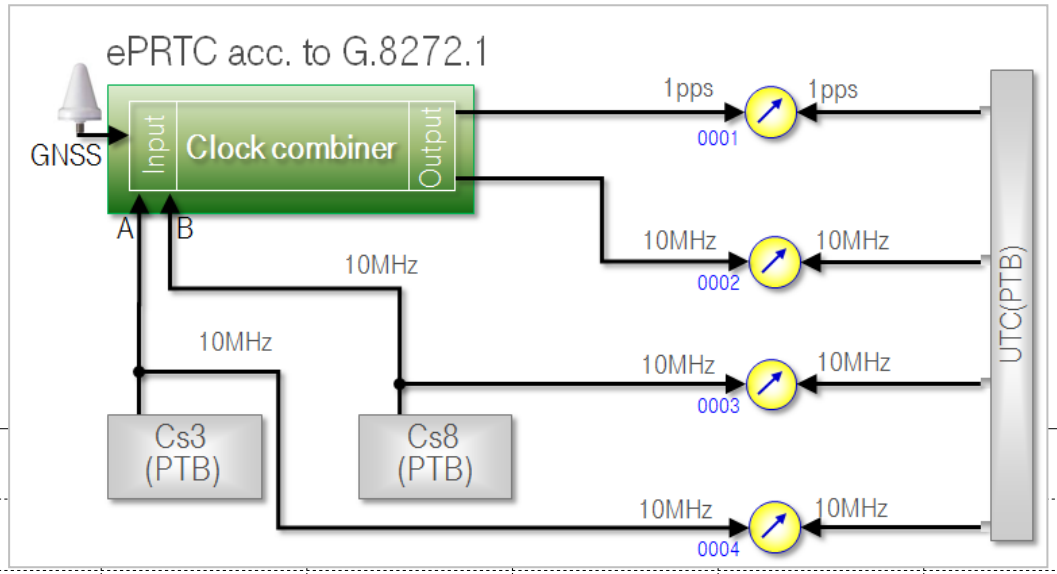
others: PRTC Clock with OCXO/CSAC/Rb



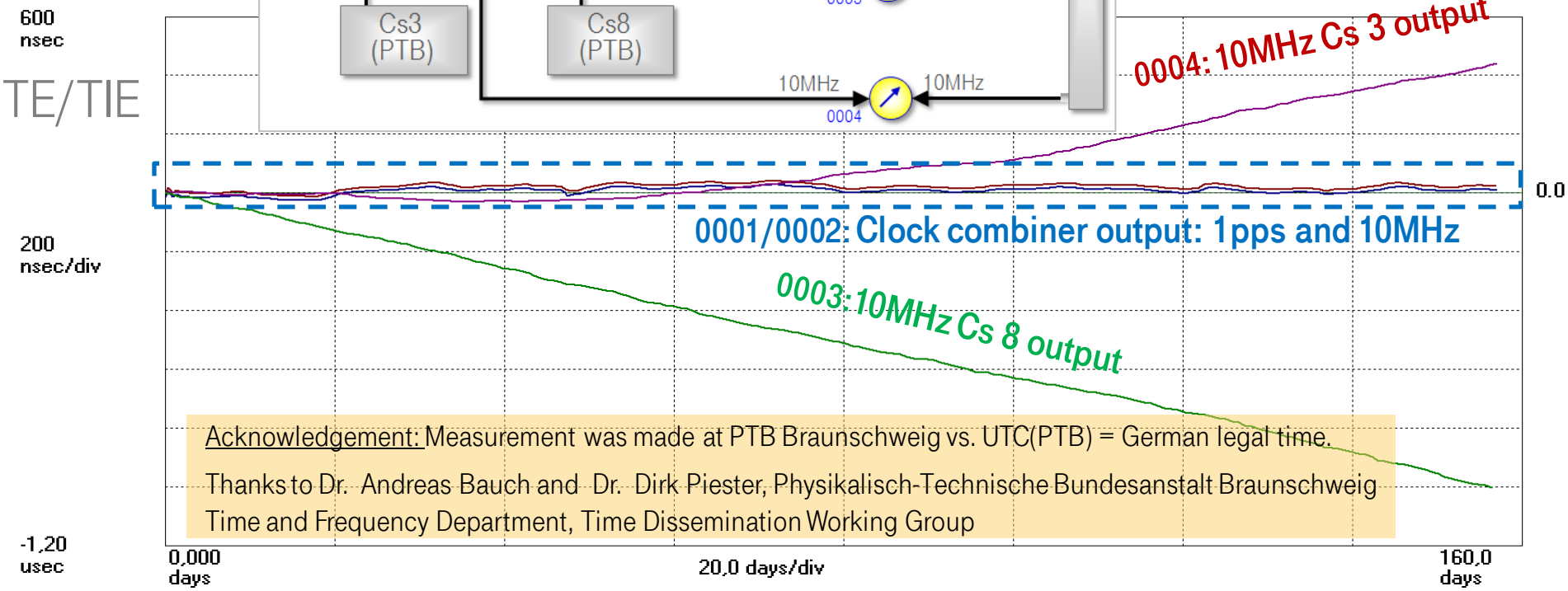


Primary Reference Clocks in Telco Networks
❸ ePRTC Clock combiner acc. to ITU-T G.8272.1: Results

Setup



TE/TIE



Acknowledgement: Measurement was made at PTB Braunschweig vs. UTC(PTB) = German legal time.

Thanks to Dr. Andreas Bauch and Dr. Dirk Piester, Physikalisch-Technische Bundesanstalt Braunschweig Time and Frequency Department, Time Dissemination Working Group

PRC:		Primary Reference	Clock
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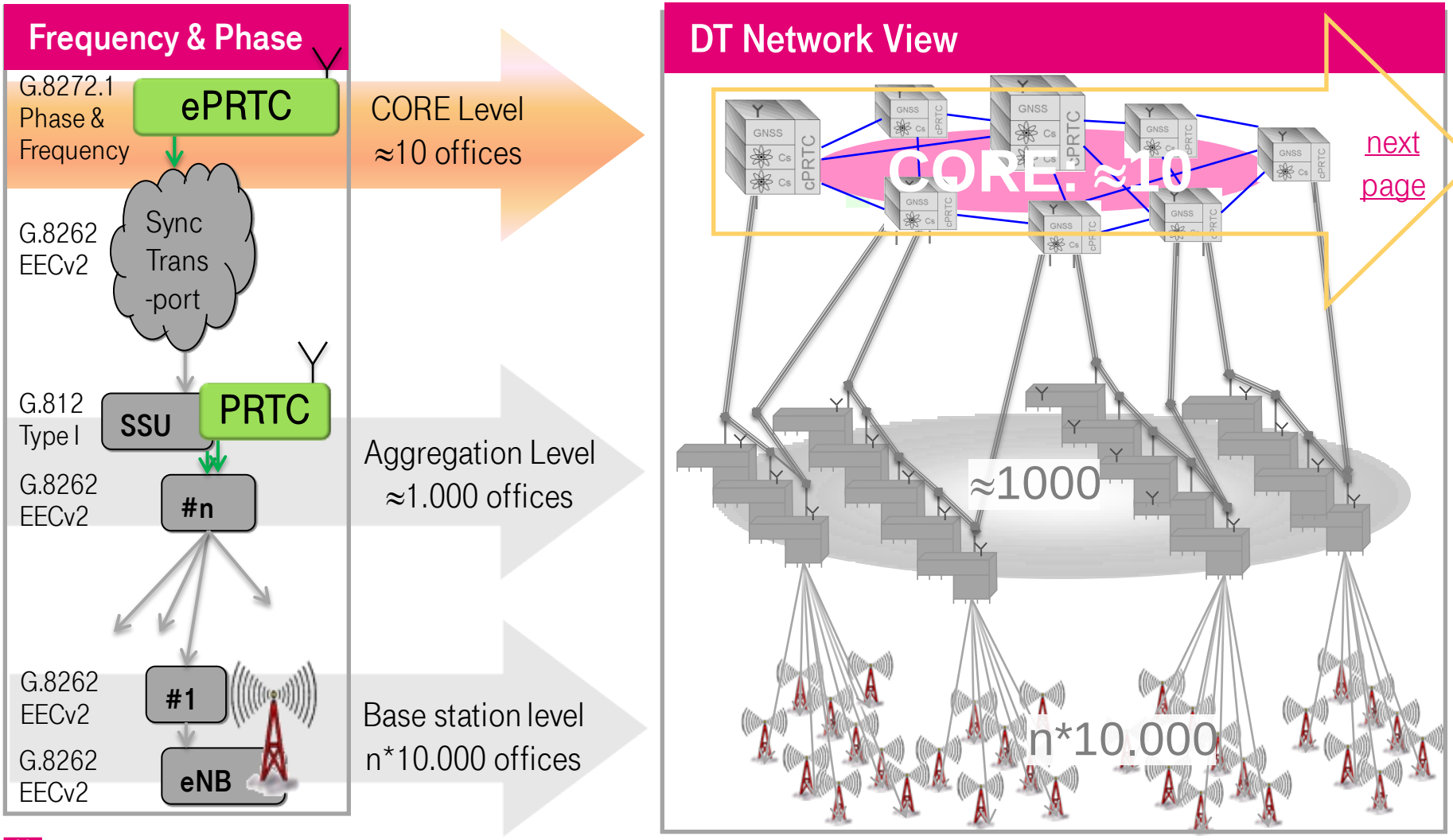
Primary Reference Clocks in Telco Networks

❹ The coherent network PRTC (cnPRTC) concept



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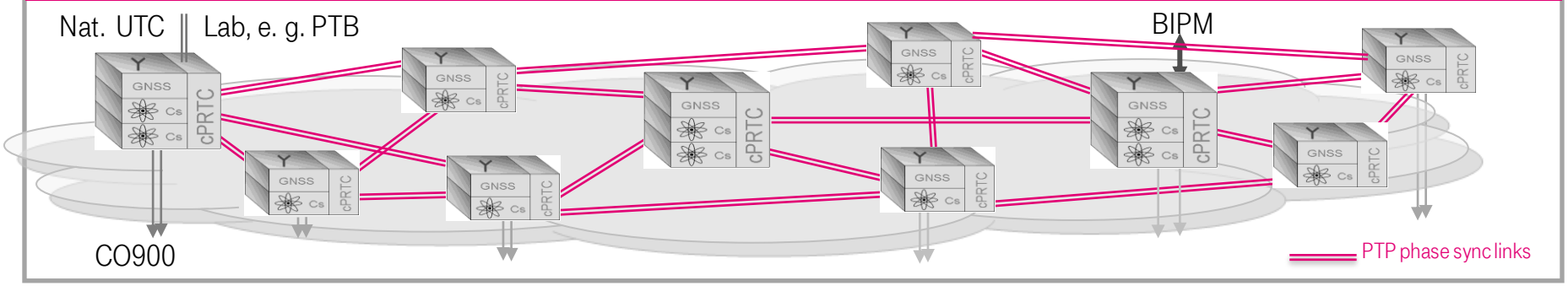
Primary Reference Clocks in Telco Networks
❹ The coherent network PRTC (cnPRTC) concept

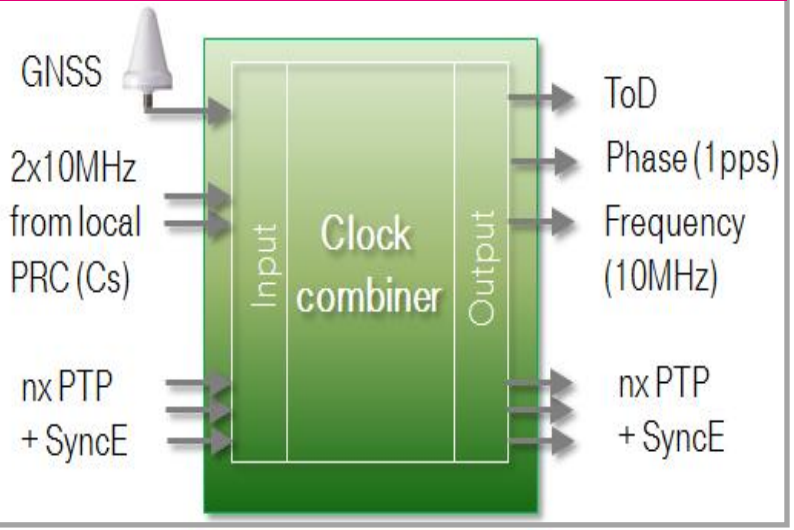
Network View: All CORE location with cnPRTC functions, mashed with SyncE + PTP



System view: One cnPRTC function consists of ....

- .... one ePRTC Clock combiner acc. to G.8272.1
- + additional SyncE + PTP links providing time, phase and frequency from and to neighborhood CORE locations
- For PTP links:
  GNSS based asymmetry compensation can be used
- Adequate calculation and steering algorithm to generate frequency, phase and time
- Optional: UTC/BIPM monitor system using UTC(DTAG)

BIPM = Bureau International des Poids et Measures



PRC:		Primary Reference	Clock
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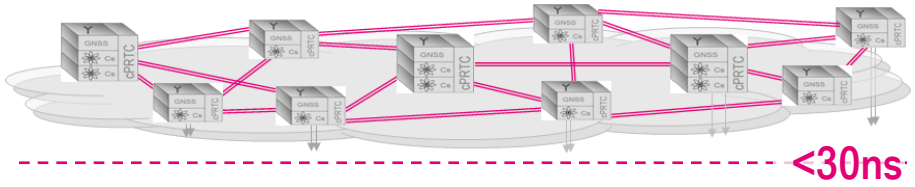
Primary Reference Clocks in Telco Networks
❹ The coherent network PRTC (cnPRTC) concept

cnPRTC advantage:

- Uniform UTC traceable network sync quality @ CORE level
  - ➔ as basis for all services with frequency, phase and/or ToD supply



- Per design:
  - ➔ max|TE| <30ns, very stable ⇨ at entire CORE network
  - ➔ no noise impact from GNSS
- Failure tolerance:
  - ➔ After initial synchronization fully GNSS independent, if needed
  - ➔ Jamming, spoofing and GNSS shutdown would not be a risk anymore (Definition of the second is based on Cs)
- Performance Management:
  - ➔ Monitored acc. to BIPM procedures with UTC(DTAG)
  - ➔ may be combined with optical fiber based UTC lab connections

PRC:		Primary Reference	Clock
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Primary Reference Clocks in Telco Networks Summary

Type	To be used for	ITU-T Reference		Stability		UTC traceability	
		No.	Status	Based on	Quality	Based on	Risk
PRC	Frequency only	G.811	Specified 1988/97	local Cs	high	n/a	n/a
PRTC	Frequency and phase	G.8272	Specified 2012/14	in-build OCXO/ CSAC/Rb	lower	local GNSS receiver	high
ePRTC	Frequency and phase	G.8272.1	2015: Ongoing	local Cs	high	local GNSS receiver	limited
cnPRTC	Frequency and phase	G.8272.x	2015: New study item	Geo redundant Cs	very high	Geo redundant GNSS receiver	low, only during initialization

- PRC+PRTC=ePRTC
- mashed geo redundant ePRTC ⇨ cnPRTC

PRC:		Primary Reference	Clock
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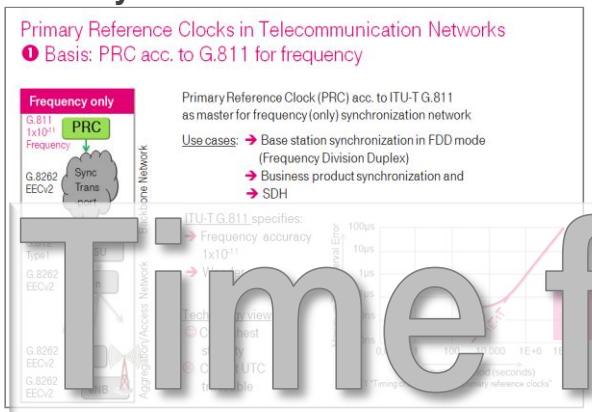
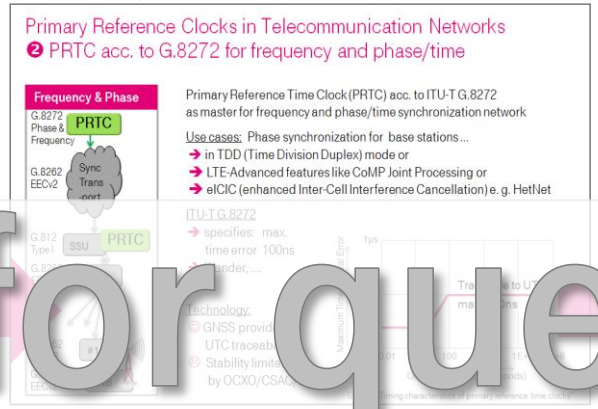
Primary Reference Clocks in Telco Networks Agenda

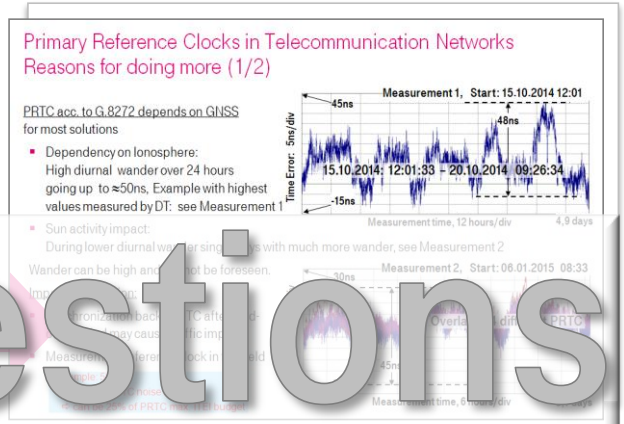
❶ PRC [G.811] Primary Reference Clock



❷ PRTC [G.8272] Primary Reference Time Clock

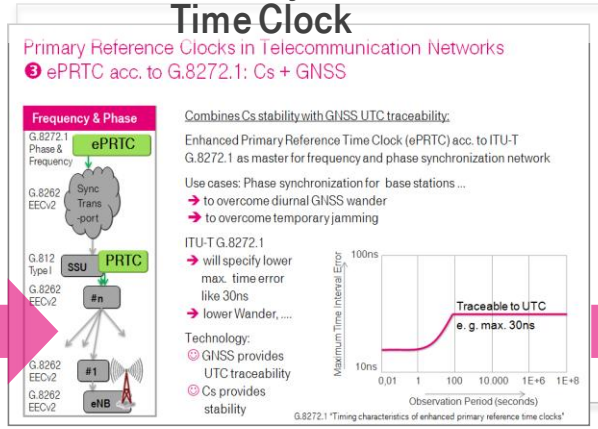


Reasons for doing more

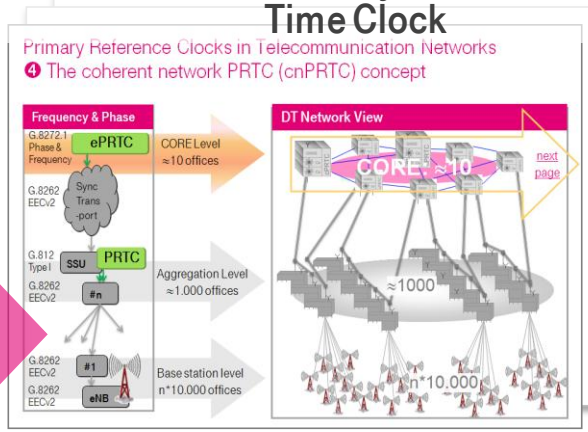


Time for questions

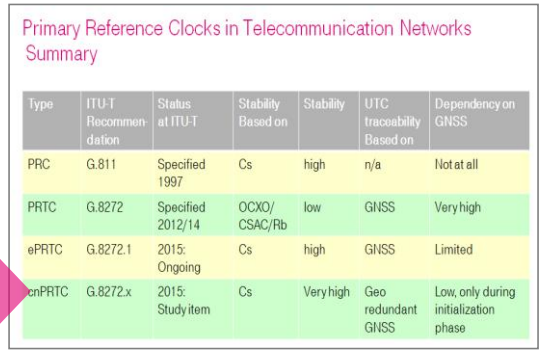
❸ ePRTC [G.8272.1] enhanced Primary Reference Time Clock



❹ cnPRTC [G.8272.x] coherent network Primary Reference Time Clock



SUMMARY



Type	ITU-T Recommendation	Status at ITU-T	Stability Based on	Stability	UTC traceability Based on	Dependency on GNSS
PRC	G.811	Specified 1997	Cs	high	n/a	Not at all
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cnPRTC	G.8272.x	2015: Study item	Cs	Very high	Geo redundant GNSS	Low, only during initialization phase

Primary Reference Clocks in Telco Networks
Acknowledgment

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Acknowledgment

Thank you very much for the good cooperation during of a PRTC ensemble prequalification versus UTC(PTB) locally in Braunschweig

- **Dr. Andreas Bauch** *)
- **Dr. Dirk Piester**

Physikalisch-Technische Bundesanstalt Braunschweig
Time and Frequency Department, Time Dissemination Working Group

Tasks of PTB:

Operation of an atomic clock ensemble, Generation of UTC(PTB) and legal time for Germany, Time transfer using TWSTFT and GPS, Dissemination of legal time (DCF77, telephone service, ntp)

*) Head of Time Dissemination Working Group

Primary Reference Clocks in Telco Networks Abbreviations

PRC:		Primary Reference	Clock
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- 1 PPS — 1Pulse per Second
- APSC — Assisted Partial Timing Support Clock
- BIPM — Bureau International des Poids et Measures (Paris)
- CoMP — Coordinated Multi-Processing Transmission and Receiving
- CSAC — Chip-Scale atomic Clock
- cnPRTC — coherent network PRTC
- Cs — Cesium atomic clock
- DCF77 — Radio transmitter station identification code, given by ITU, “D” for Deutschland (long-wave transmitter for dissemination of legal time Germany, 77,5MHz)
- eICIC — enhanced Inter-Cell Interference Cancellation
- eNB — envolved NodeB (LTE basestation)
- EEC — Ethernet Equipment Clock
- FDD — Frequency Division Duplex
- GNSS — Global Navigation Satellite System
- GPS — Global Positioning System
- HetNet — Heterogeneous network (macro – small cell overlap)
- ITU — International Telecommunication Union
- ITU-T — ITU - Telecommunication Standardization Sector
- MTIE — Maximum Time Interval Error
- NTP — Network Time Protocol
- OCXO — Oven-Controlled Crystal Oscillator
- OTA — Over-The-Air (Synchronization)
- PRC — Primary Reference Clock
- PRTC — Primary Reference Time Clock
- PRTCe — PRTC ensemble
- PTB — Physikalisch-Technische Bundesanstalt Braunschweig
- PTP — Precision Time Protocol
- Q — Question (ITU-T, Q13 = Timing & Synchronization)
- Rb — Rubidium atomic clock
- SDH — Synchronous Digital Hierarchy
- SG — Study Group (ITU-T)
- SSU — Synchronization Supply Unit
- SyncE — Ethernet Physical Layer Synchronization
- TDD — Time Division Duplex
- TWSTFT — Two-Way Satellite Time and Frequency Transfer
- UTC — Universal Time Coordinated
- UTC(PTB) — Universal Time Coordinated (Physikalisch-Technische Bundesanstalt Braunschweig)
- UTC(DTAG) — Universal Time Coordinated (Deutsche Telekom AG)
- UTC lab — BIPM registered official time lab contributing UTC
- WD — Work Draft (acc. to ITU-T rules)