Updated with latest news from ITU-T Timing & Synchronization Standardization 10-2018

DEUTSCHE TELEKOM
HIGH ACCURATE TIME DISSEMINATION IN TELECOMMUNICATION NETWORKS

ITSF 2018, Helmut Imlau, 6.11.2018

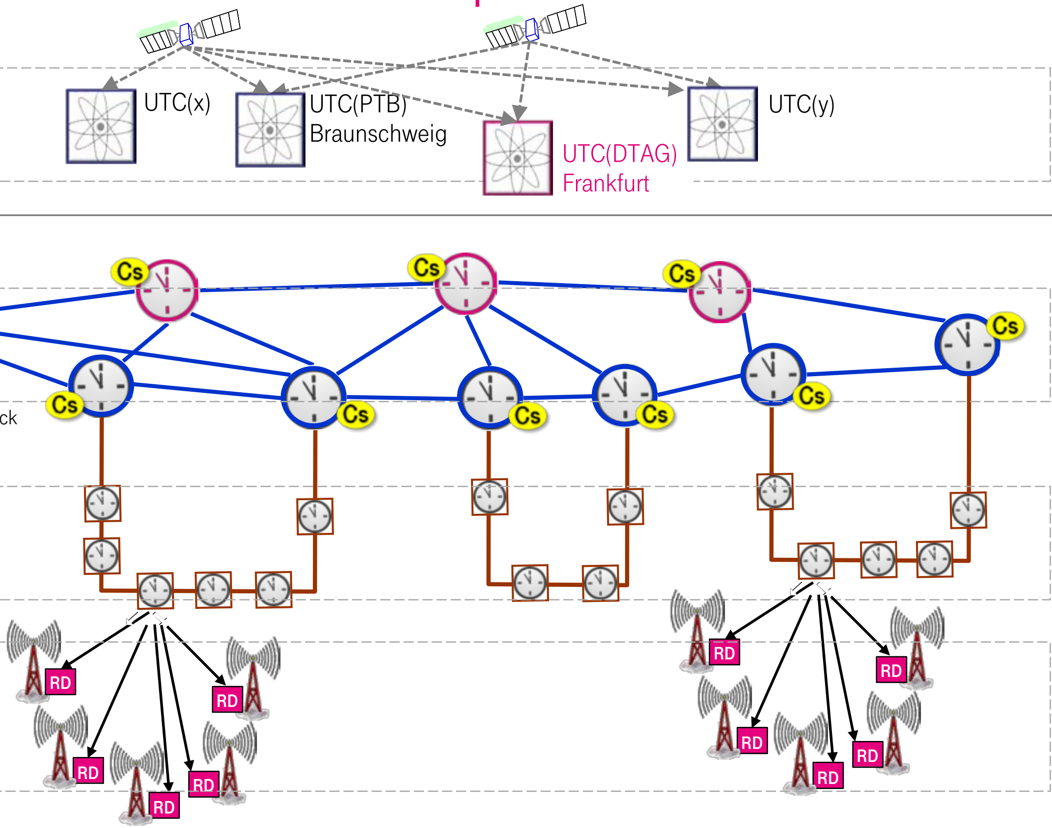
High Accuracy Time Dissemination
Agenda

High Accuracy Time Dissemination
1. Network sync architecture: Example

UTC level (ITU-R)

UTC(k) labs

UTC = Universal Time Coordinated



7/5 Sync supervision

ITU-T Clocks

24/7 Sync production

Core Network
ePRTC, cnPRTC

ePRTC = enhanced Primary Reference Time Clock
cnPRTC = coherent network PRTC

Basis: Mashed Primary Reference Clocks at Core Network level

Aggregation Network
T-BC Class D, PRTC

T-BC = Telecom Boundary Clock

Aggregation Network level supplied by Horse-Shoe architecture

Access Network
T-BC, T-TSC Class C

T-TSC = Telecom Time Slave Clock

Base station supply with synchronization from aggregation nodes

High Accuracy Time Dissemination
2. Network sync architecture
& latest ITU-T recommendations

News from latest SG15 plenary meeting in October 2019:

ITU-T Clocks

Core Network
ePRTC, cnPRTC

ePRTC = enhanced Primary Reference Time Clock
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Aggregation Network
T-BC Class D, PRTC

T-BC = Telecom Boundary Clock

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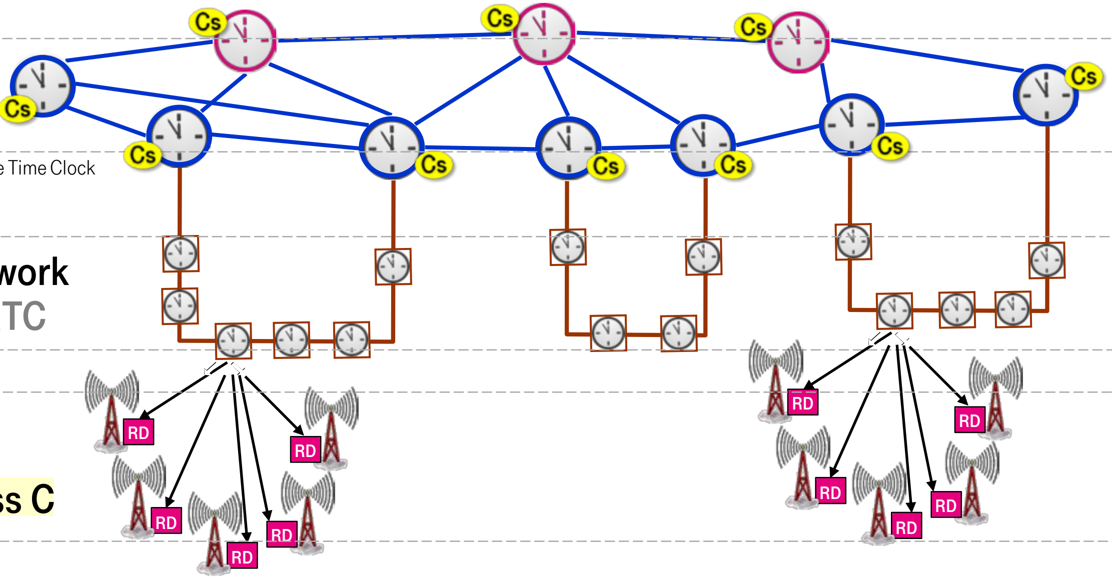

1. New coherent network PRTC architecture (cnPRTC) at G.8275

For cnPRTC functional block diagram
See backup slide .... p. 17

2. New Clock Classes for Telecom Boundary Clock and Telecom Time Slave Clock at G.8273.2:
Class D ($max|TE_L|$=5ns)
Class C ($max|TE|$ =30ns)

For all values: See backup slide .... p. 16

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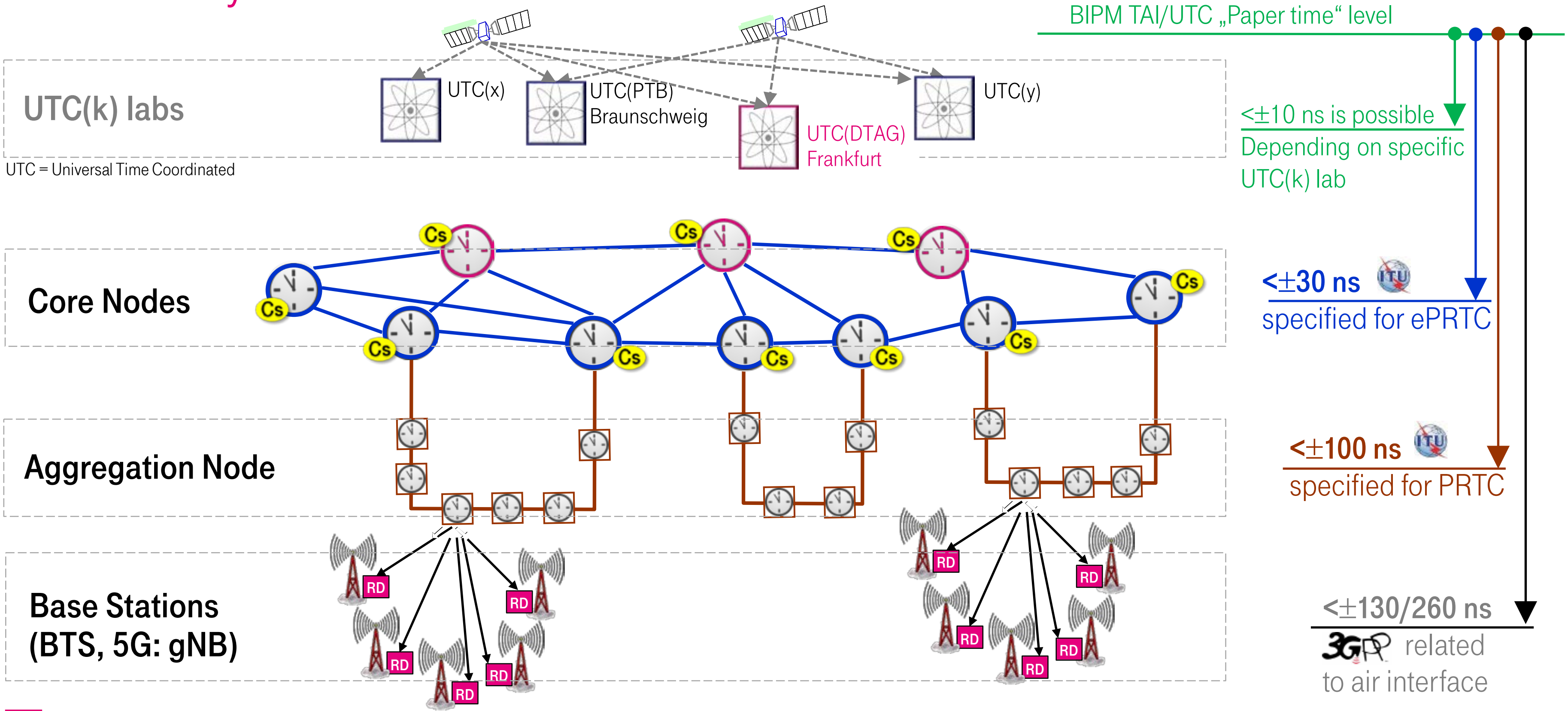
3. Accuracy



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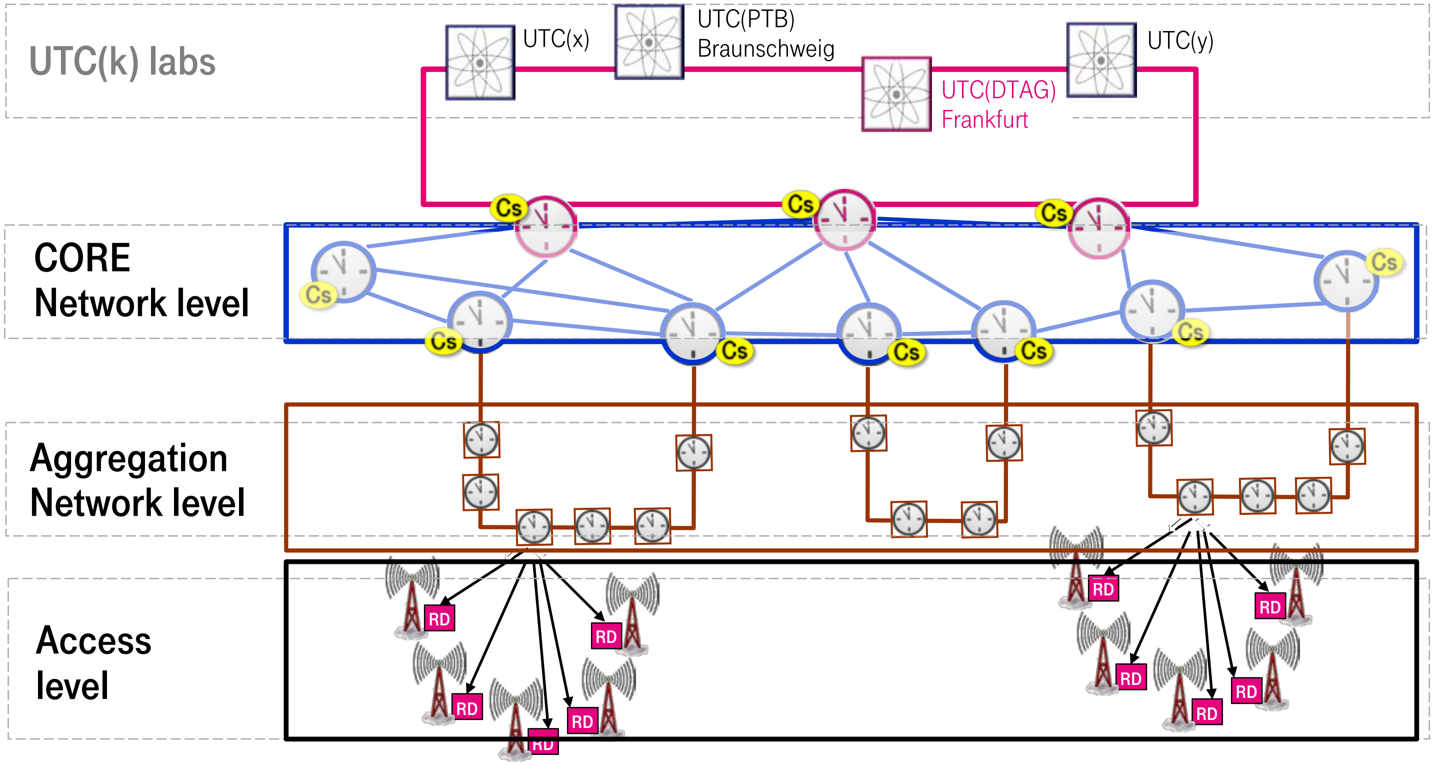
4. Time Transfer at synchronization network



1 UTC level Time Transfer

2 Core level Time Transfer

3 Core to Aggregation Time Transfer

4 Aggregation to BTS Time Transfer (together with traffic)

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5. Time Transfer Methods: Overview

❶ Optical Time Transfer (OTT), ELSTAB method, not packet based (AGH University Krakow, see ITSF 2016)

Pros & Cons: ☺ Highest performance ☹ Calibration needed, special operational requirements

e2e Performance: <40 ps, during 9 Month, 500 km (Measured by DT)

ELSTAB = ELectronic STABilization

❷ IEEE1588 HA (High-accuracy profile aka. White Rabbit acc. to CERN)

Pros & Cons: ☺ Telecommunication-like (based on special PTP and SyncE), ☹ Calibration needed

e2e Performance: <1 ns

CERN = Conseil Européen pour la Recherche Nucléaire (Geneva)

❸ PTP-FTS with SyncE bi-directional over same fiber

Pros & Cons ☺ Standard PTP-FTS/SyncE acc. to ITU-T makes operation easy

e2e w/o any T-BC: <10 ns (proposed for ITU-T specification)

e2e with T-BC Class D: <70 ns (depending on length of sync chain)

PTP-FTS = Precision Time Protocoll – Full Timing Support from Network

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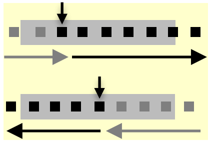
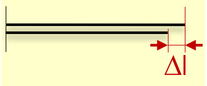
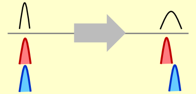
6. To be considered .... (1/3)

Asymmetry: Accuracy of time transfer methods like OTT, White Rabbit and PTP depends on symmetrical delay in both directions, which is impacted by ...

	Relevant for	Issue		Impact, examples
1.	packet methods e.g. over WDM/OTN	Queueing / packet buffer read-out mechanism are not specified, leads different constant Time Error (cTE) after every new start / interruption. Potential solution ⇨ monitoring of FIFO state & controlled buffer read-out.		cTE jumps 10-100 ns
2.	all fiber pair solutions	Fiber asymmetry (different length of both used fibers), leads to constant Time Error, network operator attributable		cTE: 35 ns (Agg. to BTS)
3.	all single-fiber solutions	Different delay for different wavelength due to chromatic dispersion Speed of light at optical fiber = f(wavelength) See separate slide ...		cTE 10 ns/100 km (1605/1615 nm)
4.	all solutions	Smaller impact: Earth rotation related Sagnac effect Depends on going with or against earth rotation		e. g. 0,8 ns (Braun-schweig->Bremen)

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6. To be considered .... (2/3)

Measurement equipment

	Relevant for	Issue			Impact, examples
5.	All measure-ments	Measurement equipment time error can easily superpose time transfer error. Accuracy of measurement equipment, e. g. depending on resolution, to be considered.			
		Examples:			
			Telco SyncE /PTP measurement equipment:	early equipment	1 ... 8 ns
				latest equipment	250 ps
			1pps and 10MHz frequency measurement:	standard counter	20 ps
				high-resolution counter	1 ps

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6. To be considered .... (3/3)

3. **Chromatic Dispersion (CD) in** (ps) [ps/(nm· km)]

Is a function of
- deviation between both used wavelength
- Fiber length

For high accuracy time transfer: CD must be compensated

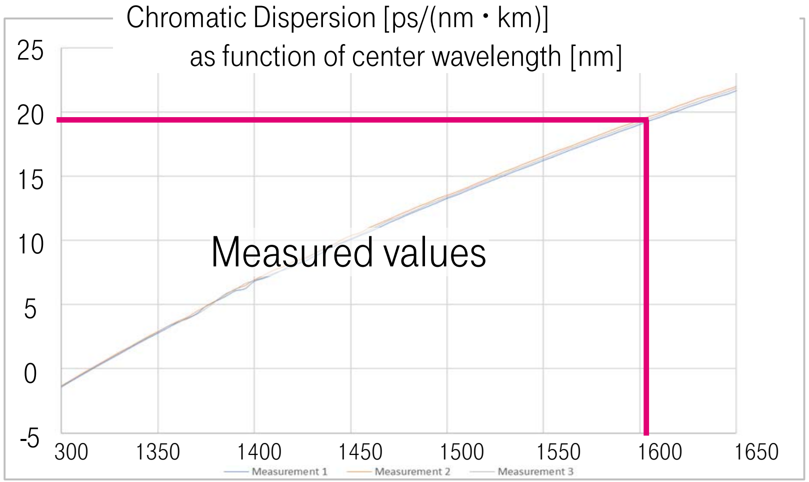
Delay difference Δd per cable length: $\Delta d = CD \times \Delta\lambda \times L$

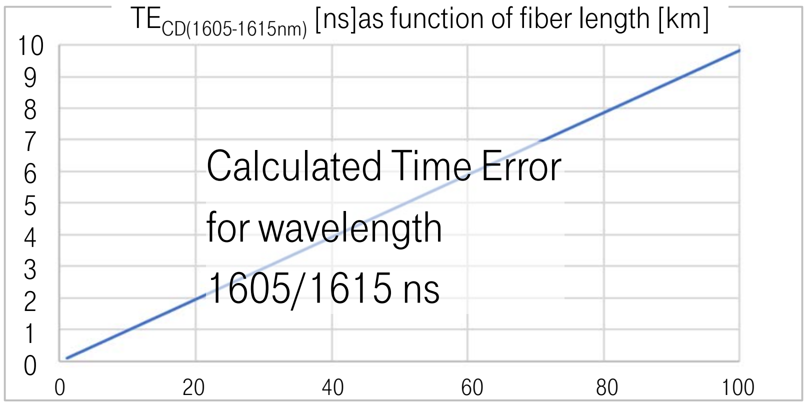
Time Error due to chromatic dispersion: $TE_{CD} = \Delta d/2$

For example:
- Used wavelength: 1605 nm and 1615 nm
- Measured results for CD:

Wavelength [nm]	Chromatic Dispersion CD [ps/nm/km]			
	Measurement 1	Measurement 2	Measurement 3	Average
1605	19,332	19,680	19,470	19,494
1610	19,576	19,905	19,717	19,733
1615	19,867	20,212	19,99	20,023

- Resulting time error is around 10 ns for 100 km





For calculation: see SG15-C0750: "Bi-directional Time Transfer over single fiber: Time Error due to Chromatic Dispersion , Deutsche Telekom / AGH University, 8-19 October, 2018

For more Chromatic Dispersion details: See backup slide .... p. 18

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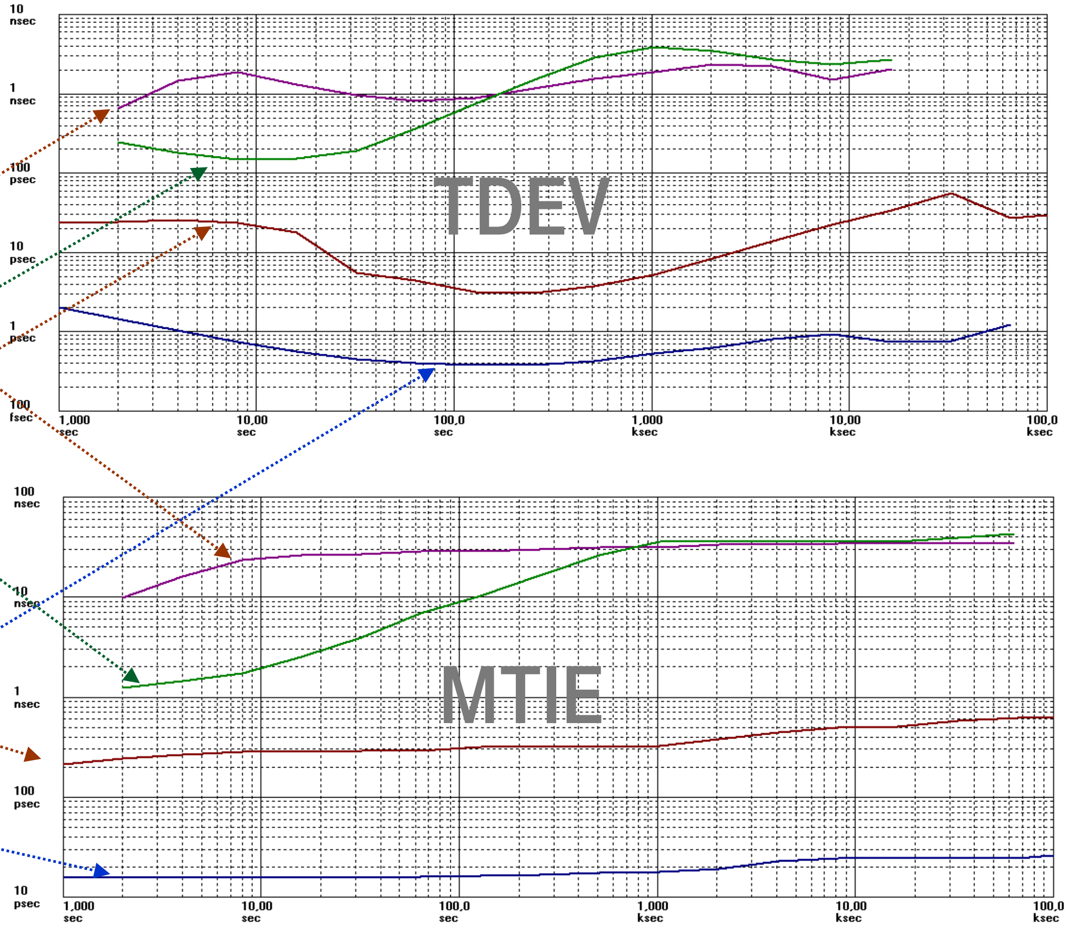
7. Measurement results



❸ **PTP-FTS @lab, short cable, OCXO**

Bi-di over WDM, T-GM + 5*T-BC

Wavelength for sync only

PTP-FTS @lab, short cable, Rb

Bi-di over WDM, T-GM + 5*T-BC

Wavelength for sync only

❷ **WR @lab, 300km**

Bi-di over one dark fiber

❶ **OTT ELSTAB @field, 500km**

Bi-di over one dark fiber

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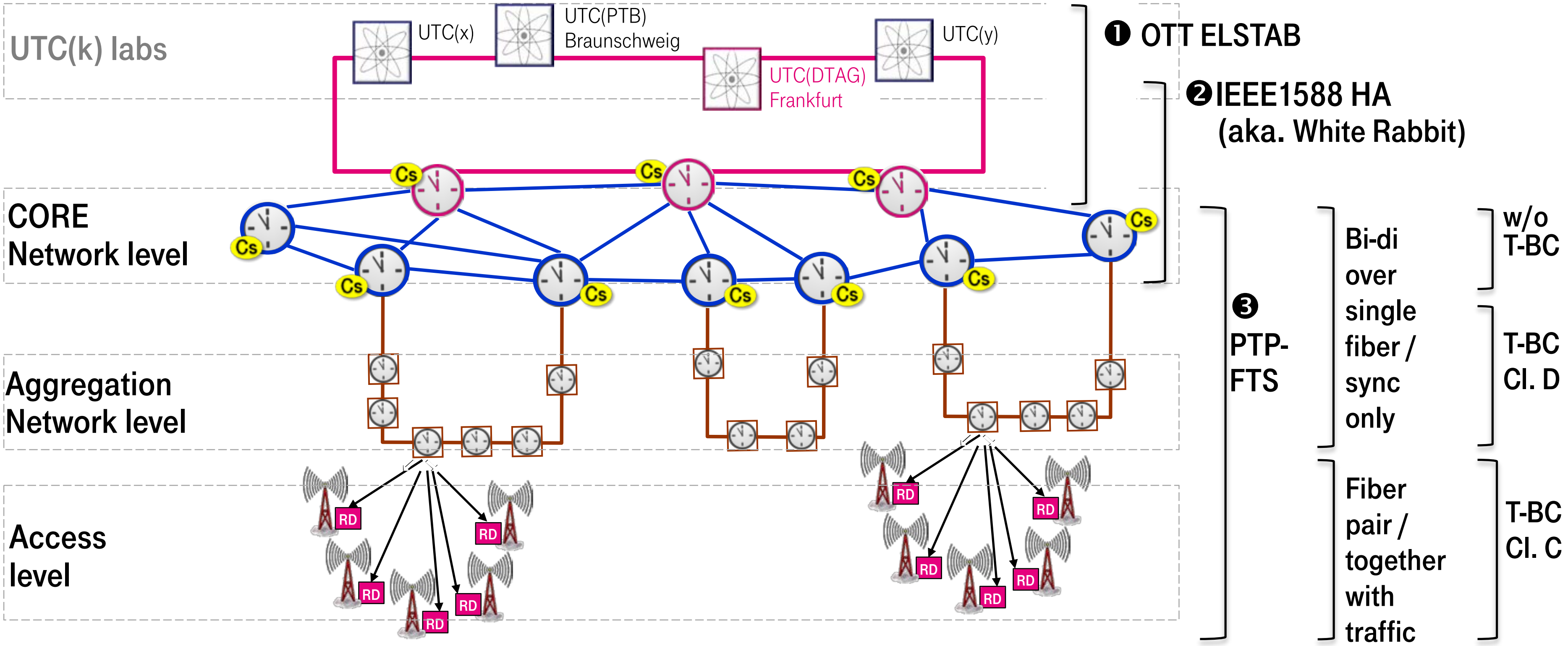
8. Application of Time Transfer Methods and Network Sync Level



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Summary

- There are several candidate technologies for high accurate time transfer.
- Bi-directional operation over the same fiber is a key method to have the accuracy under control.
- Both has to be considered:
  [a] reachable accuracy and [b] operational effort (e. g. for calibration and trouble-shooting).
- Using standardized methods like ITU-T specified PTP-FTS/SyncE makes operations easier.
- With higher operational effort, much better results can be achieved.
- The used method has to be adequate for the needed quality, overshooting is expensive.
- **Based on our network view, we see applications for all three methods:**
  OTT (ELSTAB), IEEE1588 HA (White Rabbit) and PTP-FTS with SyncE.

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- Thank you very much

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Backup

- BACKUP

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T-BC/T-TSC Classes acc. to ITU-T

Updated with latest news from ITU-T Timing & Synchronization Standardization 10-2018

Hints:

New **Class C** specification is fully in-line with old Class A and B, only with stronger values

New **Class D** specification is for new TDM based technology like FlexE and synchronization only equipment

Parameter		T-BC, T-TSC, all values in ns			
		Class A	Class B	Class C	Class D
maxITEI	unfiltered	100	70	30	15 (LL)
$maxITE_L I$	Low-pass filtered	-	-	-	5
cTE (constant TE)		50	20	10*	4 (LL)
dTE_L (MTIE)	constant temp. up to 1.000 sec	40	40	10	3 (LL)
	var. temp. up to 10.000 sec	40	40	FFS	FFS (LL)
$dTE_{L\ (TDEV)}$	constant temp. up to 1.000 sec	4	4	2	1 (LL)
dTE_H	up to 1.000 sec	70	70	FFS**	15 (LL)

(LL)	On the Living List (LL), value is basis for ongoing time error accumulation simulations
FFS	For Further Study
*	Optical module issue to be addressed
**	Expected about 30 ns (anyway less than 60 ns)

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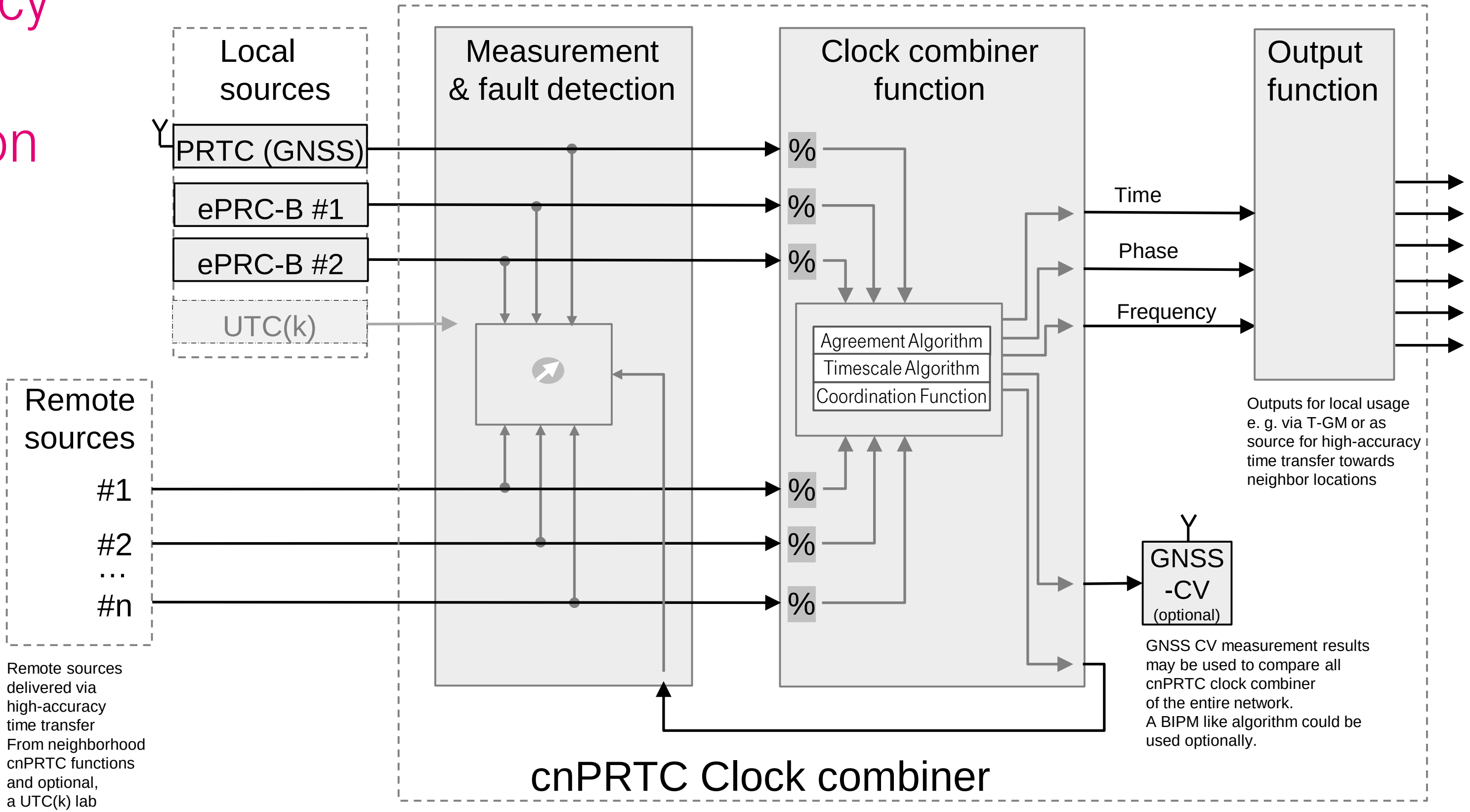
cnPRTC functional model



Remote sources delivered via high-accuracy time transfer From neighborhood cnPRTC functions and optional, a UTC(k) lab

Outputs for local usage e. g. via T-GM or as source for high-accuracy time transfer towards neighbor locations

GNSS CV measurement results may be used to compare all cnPRTC clock combiner of the entire network. A BIPM like algorithm could be used optionally.

% A specific weight range is given to the specific input. Weight range of local sources is higher than remote sources by configuration. Due to specific measurement results, weight can be automatically adjusted. In case of problems, the specific input can be squelched.

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Background information: Chromatic Dispersion

Chromatic Dispersion:

Speed of light at optical fiber depends on wave length due to:

- Material Dispersion:
  refractivity depends on wavelength

- Waveguide Dispersion:
  Depend on refractivity index relationship between optical core and fiber jacket (cladding),
  Longer wavelength goes more into fiber jacket with less refractivity: Longer wavelength = faster

Both components can compensate each other.

Defined as pico seconds per nanometer wavelength delta and km fiber length: ps/(nm·km).

Microsoft Word-Dokument

For calculation: see SG15-C0750:
"Bi-directional Time Transfer over single fiber: Time Error due to Chromatic Dispersion ,
Deutsche Telekom / AGH University,
8-19 October, 2018