# Time Sync in ITU-T Q13/15: G.8271 and G.8271.1

WSTS - 2013, San Jose

Stefano Ruffini, Ericsson

# AGENDA

- Introduction
- ITU-T G.8271:
  - Scope
  - Status
  - Main Contents
- ITU-T G.8271.1:
  - Scope
  - Status
  - Main Contents

# TIME SYNCHRONIZATION: SCOPE AND PLANS

- ITU-T Q13/15 focusing on this topic after December 2011 (when most of frequency sync aspects were completed)
- The following main aspects are addressed
  - Network Requirements
  - Architecture
  - PTP Profiles
  - Clocks
- The work is tentatively planned to be completed in the 2013/2014 time frame
- Several aspects also involving other SG15 Questions, e.g.:
  - Time sync Interfaces
  - Time sync over access technologies
  - Time sync over OTN

# TIME SYNC: Q13/15 RECOMMENDATIONS

- Analysis of Time/phase synchronization in ITU-T Q13/15:
  - G.8260 (definitions related to timing over packet networks)
  - G.827x series

| | Frequency | Phase/Time | |
|---|---|---|---|
| **General/Network Requirements** | G.8261 | G.8271 | |
| | G.8261.1 | G.8271.1 | G.8271.2 |
| **Architecture and Methods** | G.8264 | G.8275 | |
| | G.8265 | | |
| **PTP Profile** | G.8265.1 | G.8275.1, G.8275.2 | |
| **Clocks** | G.8262 | G.8272 | |
| | G.8263 | G.8273 | |
| | | G.8273,.1,.2,.3 | |

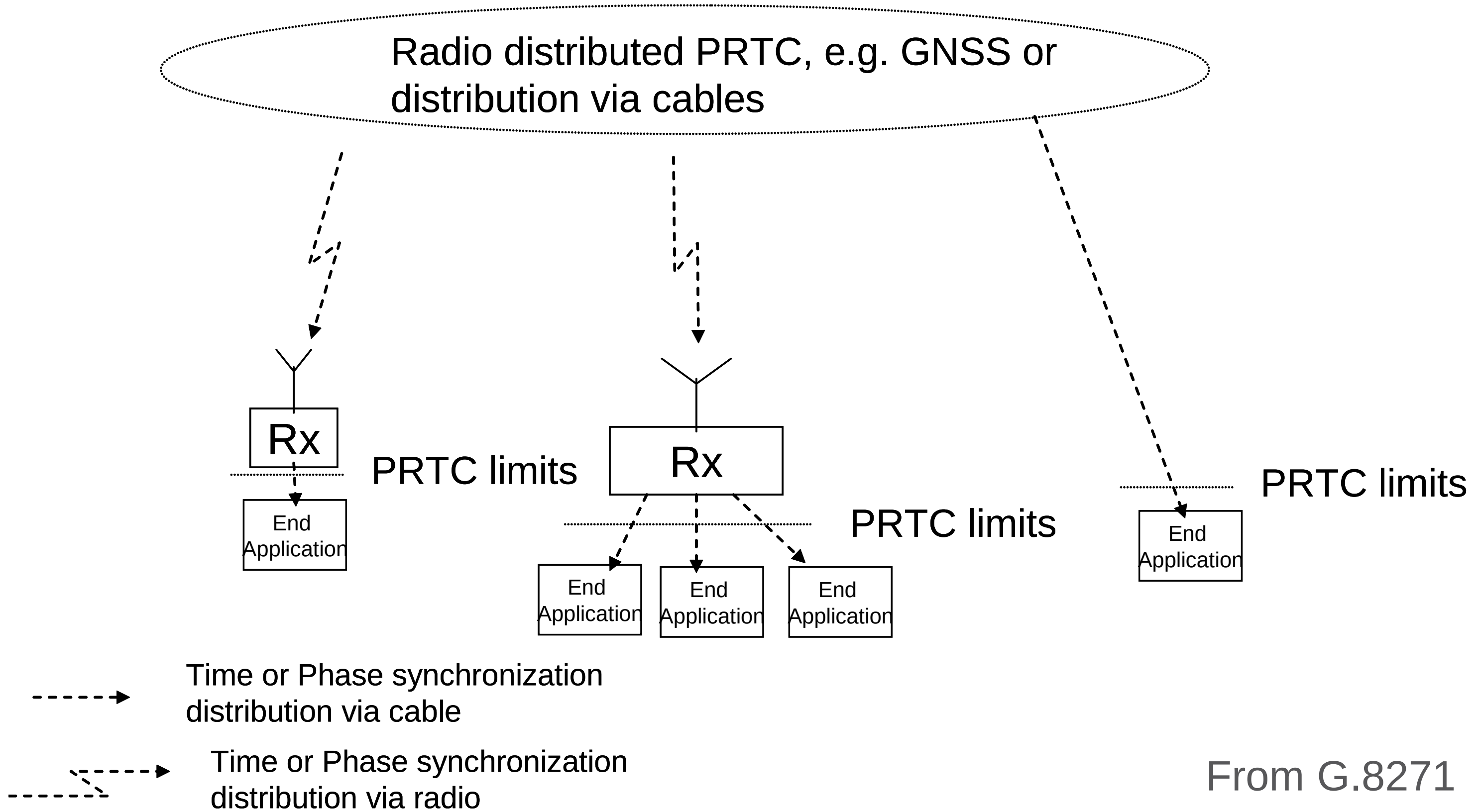
# G.8271: TIME AND PHASE SYNC ASPECTS OF PACKET NETWORKS

- G.8271 scope
  - Time and phase synchronization aspects in packet networks
    - Target applications
    - Methods to distribute the reference timing signals
- It also specifies the relevant time and phase synchronization interfaces and related performance.
  - *Physical characteristics to be moved into G.703 (Q11/15)*
- G.8271 is the first document of the G.827x series to be released (Published in 02/2012)
  - Amendment planned for July 2013 (additional details and alignments with G.8271.1)

# TARGET APPLICATIONS

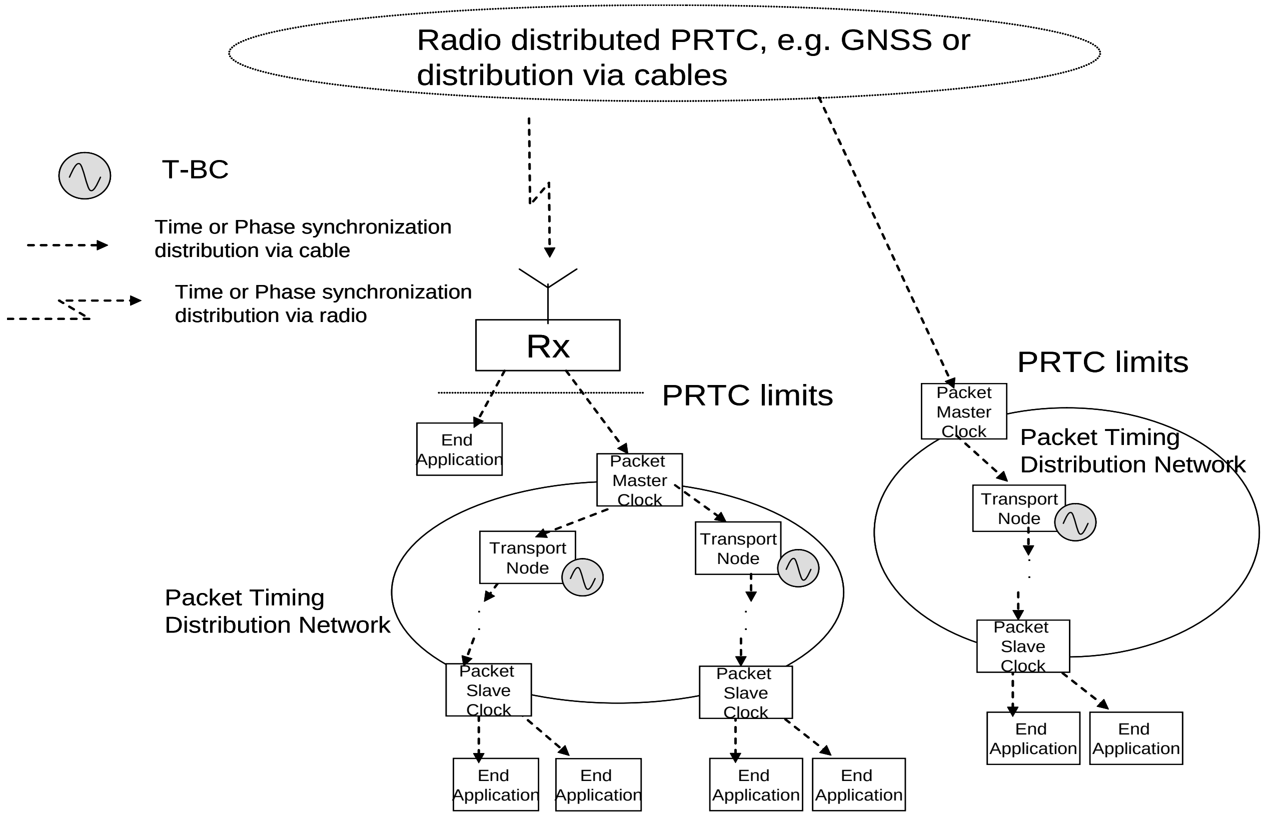
| Level of Accuracy | Time Error Requirement (with respect to ideal reference) | Typical Applications |
|---|---|---|
| 1 | 500 ms | Billing, Alarms |
| 2 | 100 $\mu$s | IP Delay monitoring |
| 3 | 5 $\mu$s | LTE TDD (large cell) |
| 4 | 1.5 $\mu$s | UTRA-TDD, LTE-TDD (small cell) Wimax-TDD (some configurations) |
| 5 | 1 $\mu$s | Wimax-TDD (some configurations) |
| 6 | < x ns (x ffs) | Location Based services and some LTE-A features (Under Study) |

# METHODS: DISTRIBUTED PRTC




From G.8271

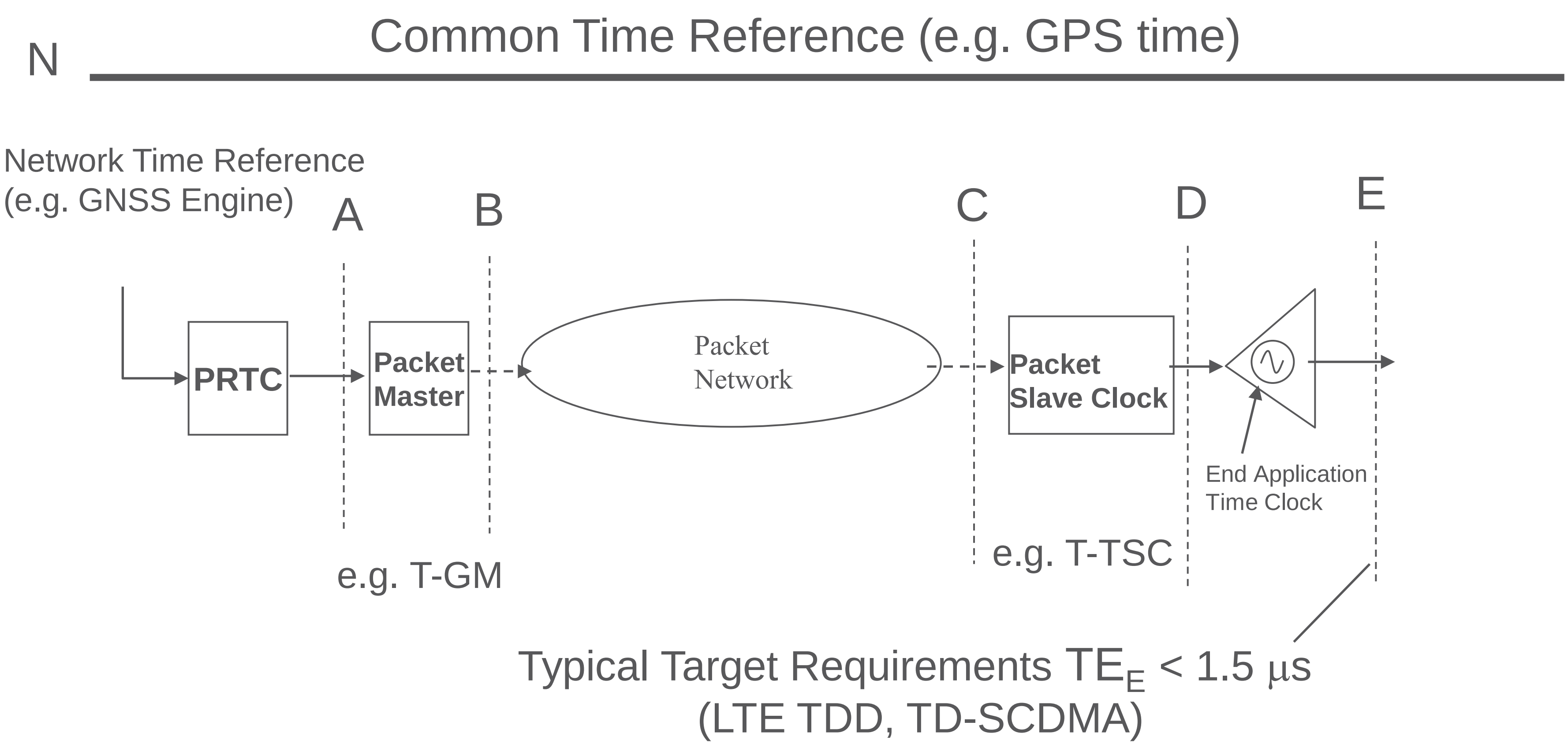
# METHODS: PACKET BASED METHODS




From G.8271

Initial Focus with PTP support (BC and TC) in every node;
New work item with "Partial timing support" recently started

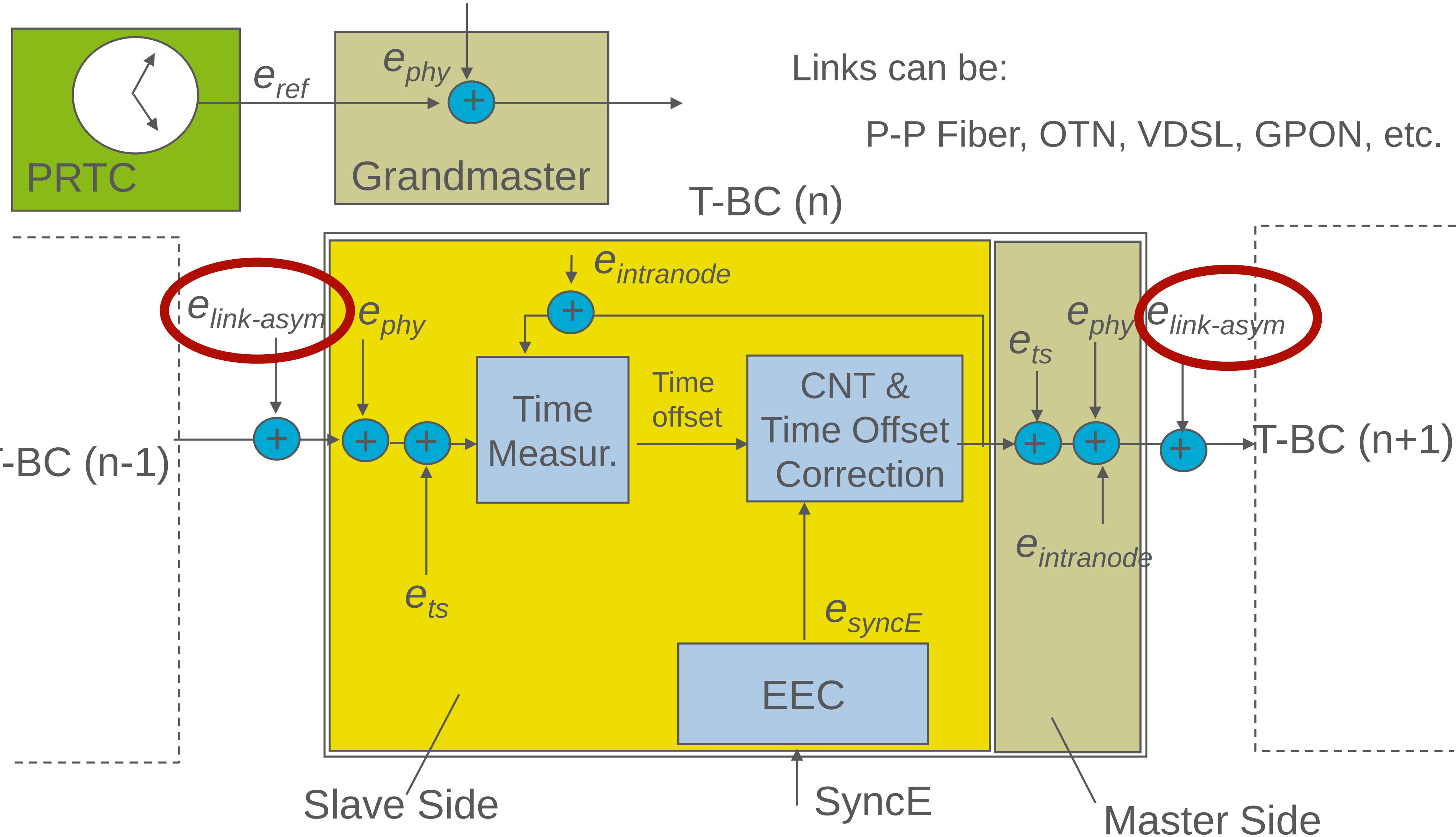
# NETWORK REFERENCE MODEL




**PRTC: Primary Reference Time Clock**
**T-GM: Telecom Grandmaster**
**T-TSC: Telecom Time Slave Clock**

Note: reference model to be moved into G.8271.1

# NOISE SOURCES




Links can be:

P-P Fiber, OTN, VDSL, GPON, etc.

# SOURCES OF ERROR AND TIME ERROR BUDGETING

- Time Error depends on several sources of noises
  - Reference time error (PRTC accuracy), $e_{ref}$
  - Link asymmetry, $e_{link\text{-}asym}$
  - Telecom-BC Internal errors:
    - Local oscillator phase noise, $e_{\varphi}$ (*if PTP used also for frequency*)
    - Frequency reference phase noise, $e_{syncE}$ *(in case of SyncE support)*
    - Phy latency asymmetries, $e_{phy}$ (HW time-stamping);
    - Timestamping granularity, $e_{ts}$
    - Intra-node time distribution, $e_{intranode}$
- Two types of noise
  - **Random noise,** increase with sqrt (N), N number of nodes
  - **“Static” noise** (BC asymmetries and Link asymmetries), increase linearly (N), N number of nodes

# NOISE ACCUMULATION

- Total Error $TE_{TOT}$ is the sum of a constant time error component and a dynamic time error component
  - it is assumed that frequency offset and drift components are not present

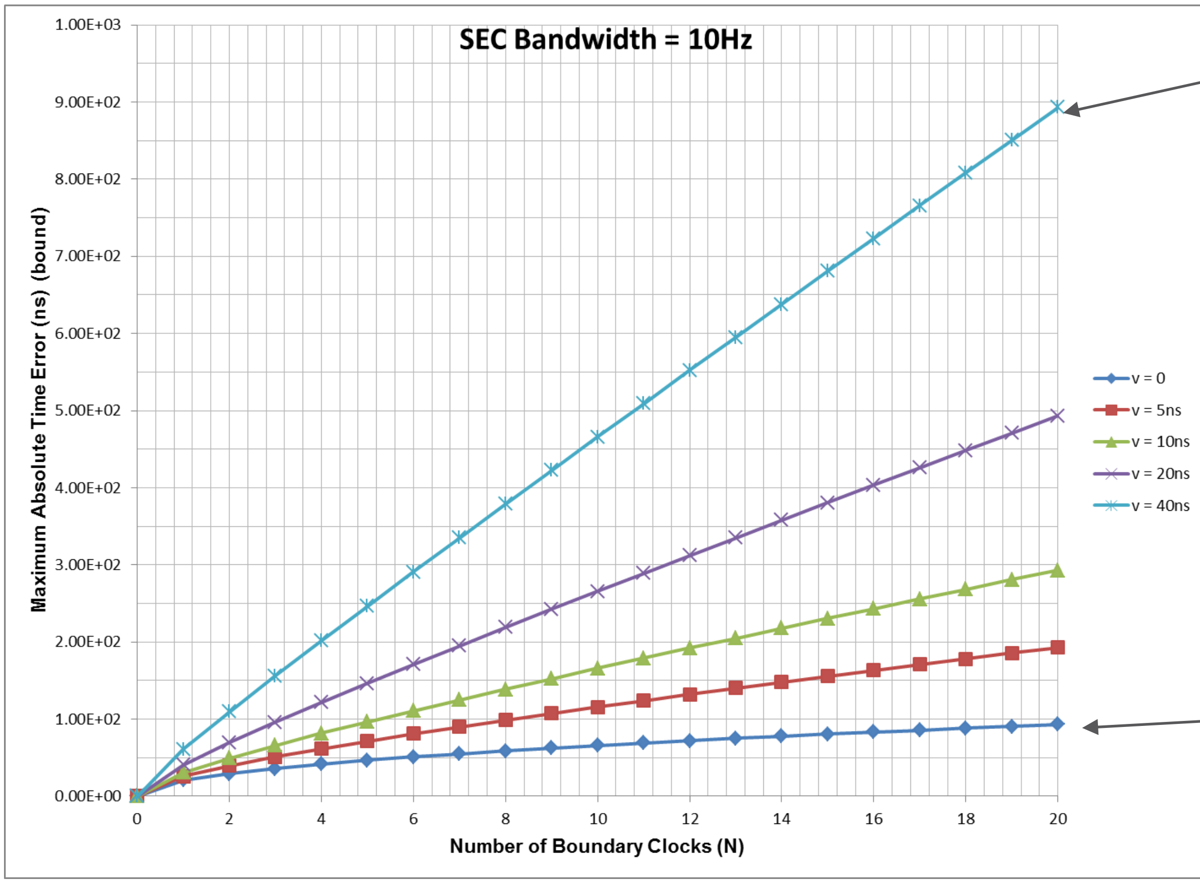
$$\left(\sqrt{M}\right)\cdot TE_{DYNPP} \le TE_{TOT} \le \left(\left(\sqrt{M}\right)\cdot TE_{DYNPP} + M\cdot TE_{CONST} + \Delta_{LINKASYM}\right)$$

$TE_{CONST}$ = absolute value of the constant time error introduced in any clock in the chain
$TE_{DYNPP}$ = peak-to-peak range of the random time error component introduced in any clock in the chain;
$\Delta_{LINKASYM}$ = total link asymmetry component resulting from the interconnection between the clocks in the chain

# EXAMPLE OF TIME ERROR ACCUMULATION

Accumulation of maximum absolute time error over a chain of boundary clocks for different values of asymmetry bias.

The physical layer assist involves SEC/EEC chain with bandwidth 10Hz.




40 ns Time Error due to asymmetry per hop (Constant Time Error)

Source: WD25 (Anue), York, September 2011

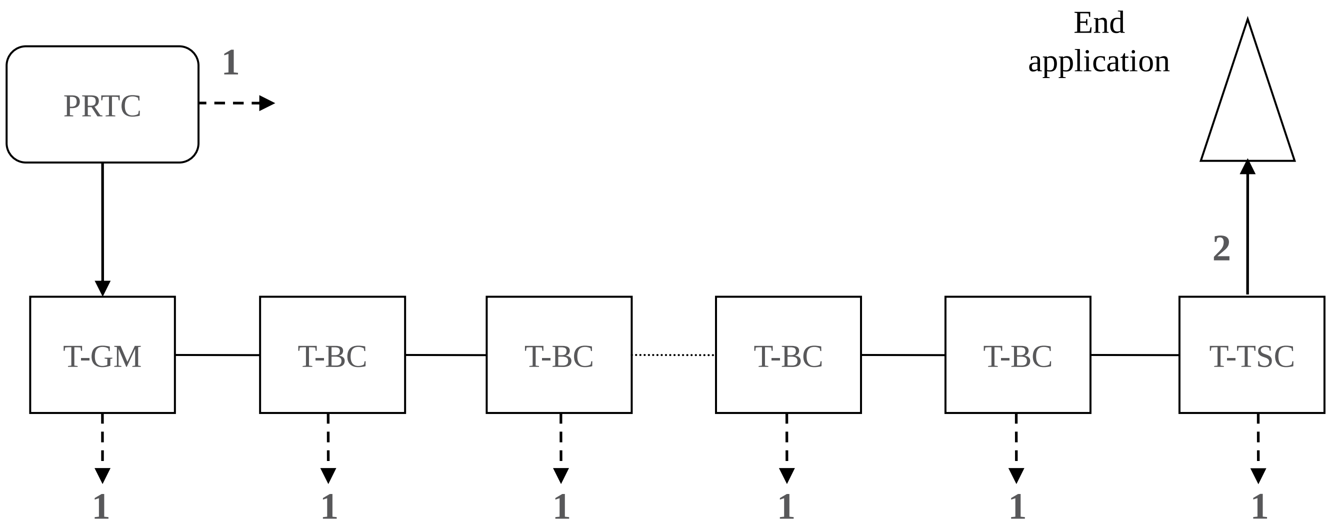
no asymmetry (only Dynamic component)

v = max asymmetry per hop

# ASYMMETRY DUE TO THE TRANSPORT TECHNOLOGIES

- Different paths in Packet networks
  - Traffic Engineering rules in order to define always the same path for the forward and reverse directions
- Different Fiber Lengths in the forward and reverse direction
  - Additional problem: DCF (Dispersion Compensated Fiber)
- Different Wavelengths could be used on the forward and reverse direction
- Asymmetries added by specific access and transport technologies
  - GPON
  - VDSL2
  - Microwave
  - OTN

# TIME INTERFACES




Reference point 1: measurement interfaces
Reference point 2: distribution interface

From G.8271

Specified in G.8271:
- 1PPS V.11 interface
- 1PPS 50Ω phase synchronization measurement interface

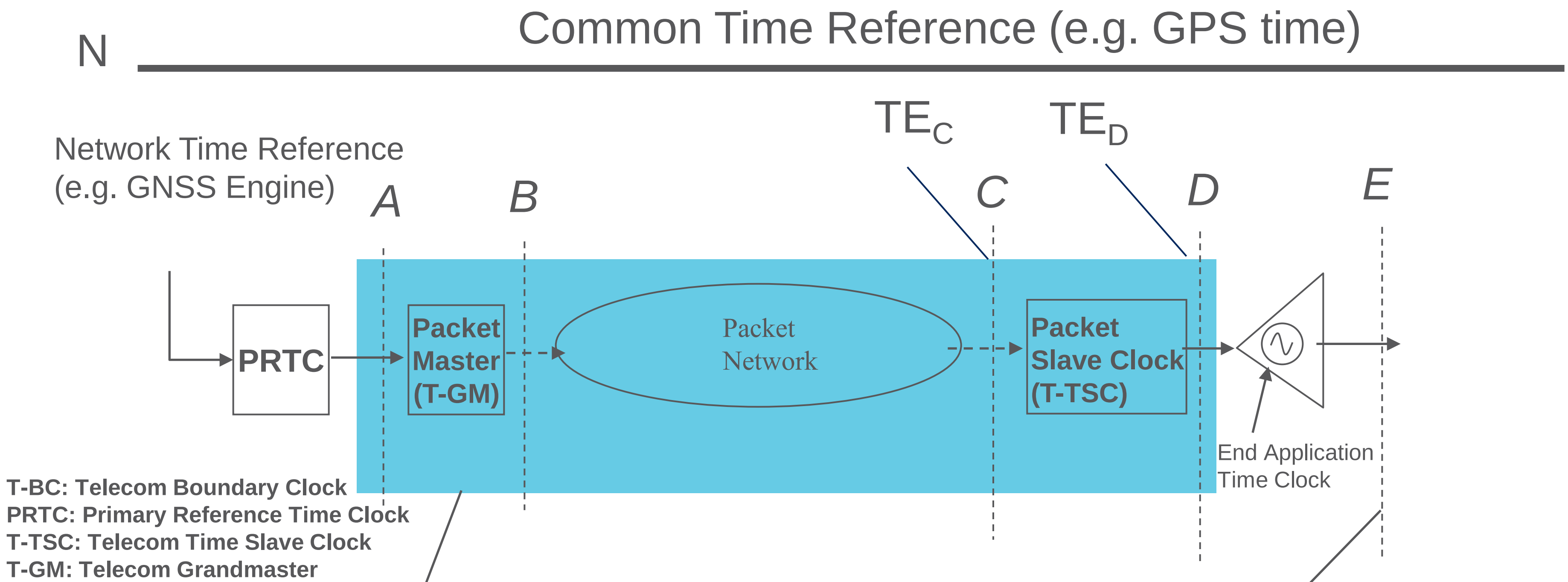
Physical and connector details planned to be included in G.703 (handled by Q11/15)

# G.8271.1: NETWORK LIMITS

- Scope
  - maximum network limits of phase and time error that shall not be exceeded.
  - minimum equipment tolerance to phase and time error that shall be provided at the boundary of these packet networks at phase and time synchronization interfaces.
  - Related Information (HRM, simulation assumptions, etc.)
- Draft Available (WD8271.1ND)
  - Planned for consent in July 2013
- Details on Simulations in G.Supp
  - Planned for 2013

# NOISE (TIME ERROR) BUDGETING ANALYSIS

Focus on Max absolute Time Error




Simulation Reference Model:

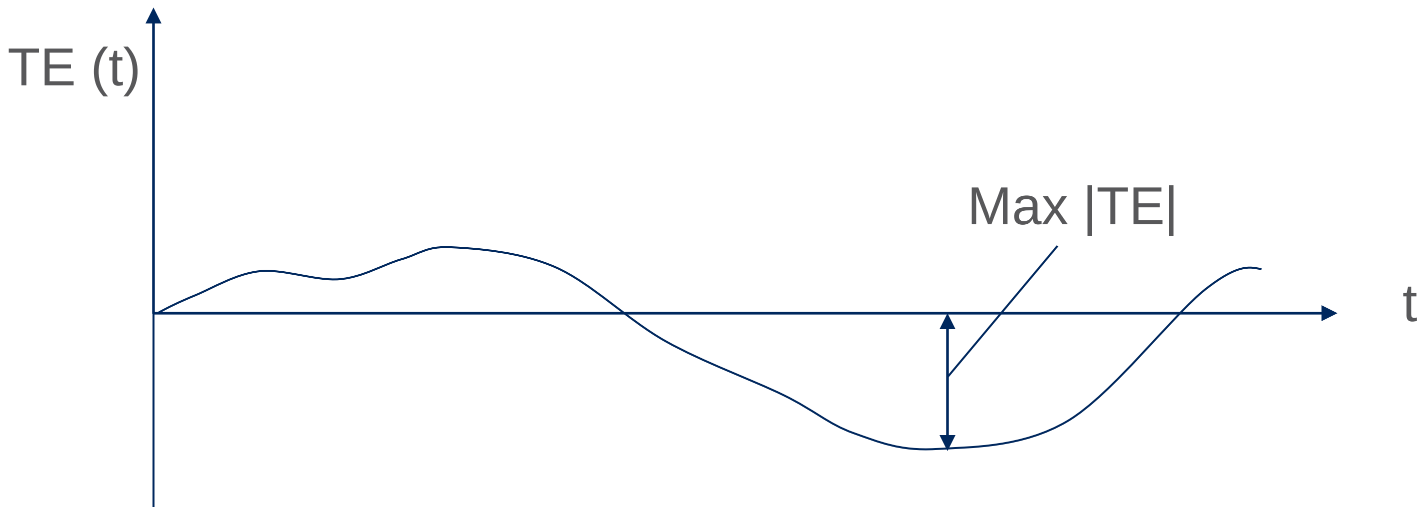
Typical Target Requirements $TE_E < 1.5\ \mu s$
(LTE TDD, TD-SCDMA)

- chain of T-GM, 10 T-BCs, T-TSC
- with and without SyncE support

*Limits in "D" ($TE_D$) applicable only in case of External Packet Slave Clock*

# METRICS FOR NETWORK LIMITS

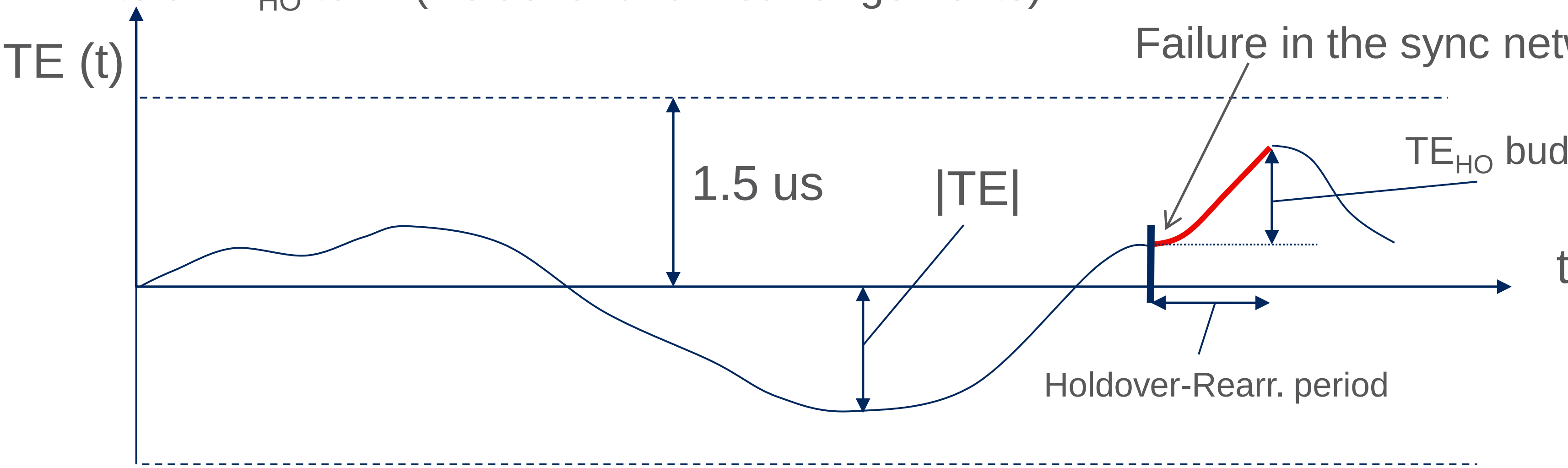
- Main Focus is Max Absolute Time Error (Max |TE|) (based on requirements on the radio interface for mobile applications)
  - Measurement details (measurement duration, tolerance in the measurement, e.g. 6 sigma) need further discussion




- Stability aspects also important
  - MTIE (and TDEV ?)
  - Related to End Application tolerance
- Same Limits in Reference point *C* or *D* !
- Same limits irrespectively if time sync is distributed with SyncE support or not ?

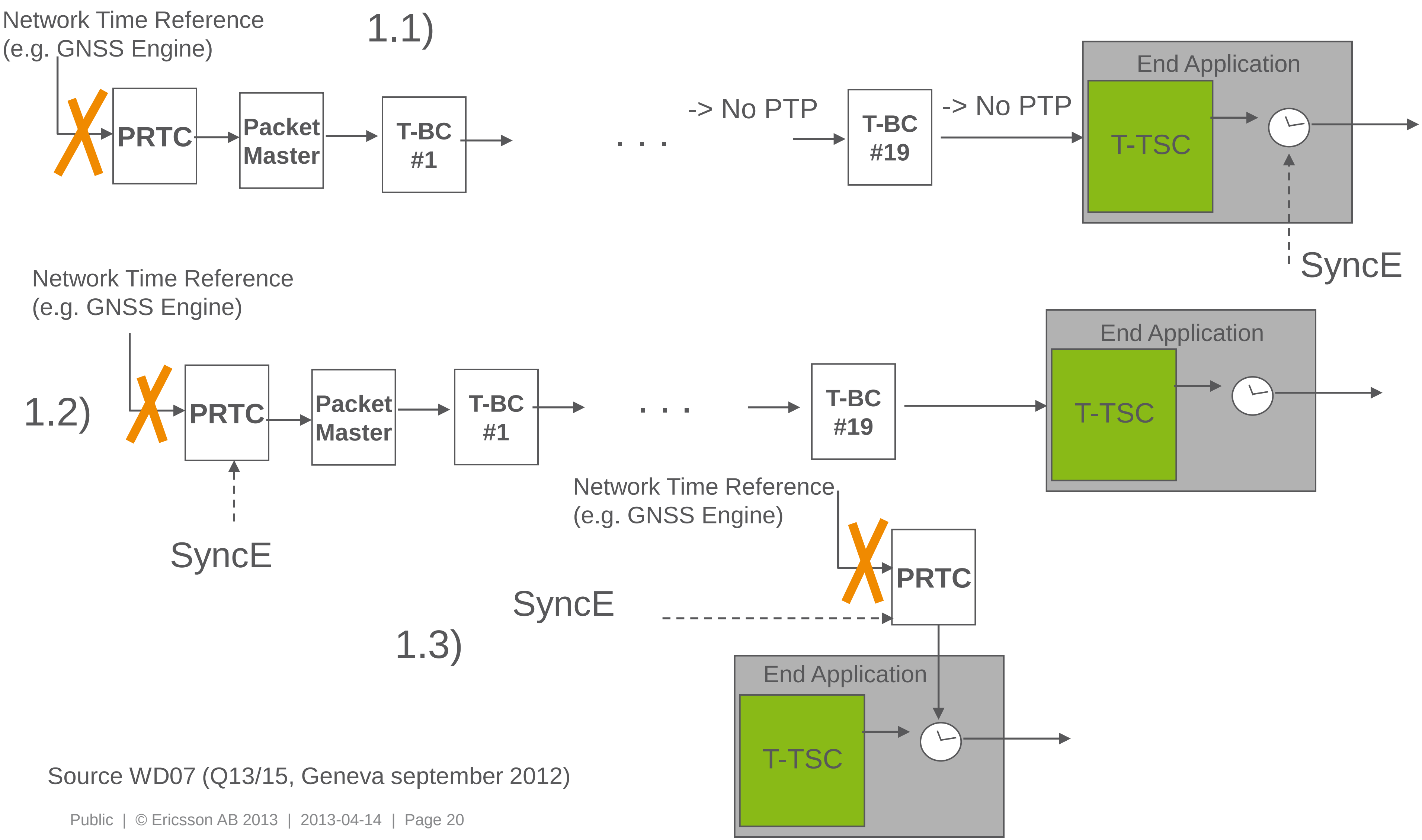
# REARRANGEMENTS AND HOLDOVER

- The full analysis of time error budgeting includes also allocating a suitable budget to a $TE_{HO}$ term (Holdover and Rearrangements)




- Holdover Scenarios
  - **Scenario 1**: PTP traceability is lost and and the End Application or the PRTC enters **holdover** using SyncE or a local oscillator
- PTP Master Rearrangement Scenarios
  - **Scenario 2**: PTP traceability to the primary master is lost; the End Application **switches** to a backup PTP reference **with** physical layer frequency synchronization support
  - **Scenario 3**: PTP traceability to the primary master is lost; the End Application **switches** to a backup PTP reference **without** physical layer frequency synchronization support

# ANALYSIS OF TIME HOLDOVER (SCENARIO 1)



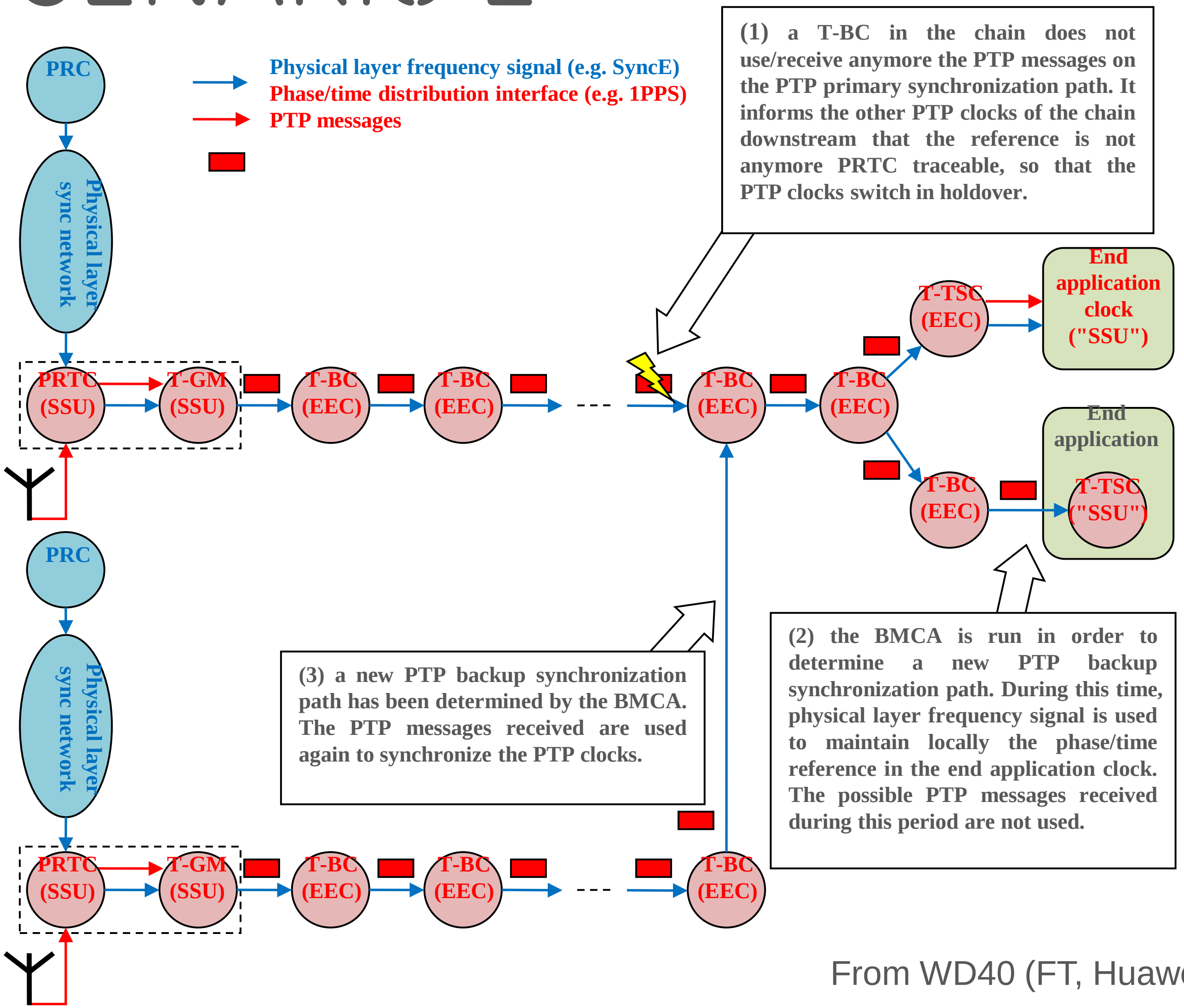

Source WD07 (Q13/15, Geneva september 2012)

# TIME HOLDOVER SCENARIOS

| Protection Scenario | Short Holdover period e.g. 5 min max (e.g. for short Interruptions) | Long Holdover period e.g. 3-8 hours (e.g. for Long Interruptions) | Very long Holdover period e.g. 1-3 days (e.g. for Very Long Interruption) | Available Budget (for 1.5 µs use case) | Considerations |
|---|---|---|---|---|---|
| **1.1** | OK according to simulations, both G.812 Type III in holdover or use of SyncE are applicable | **1,5 us is exceeded** | **1,5 us is exceeded** | values in the order of 400ns can be acceptable | Very long period holdover requires higher budget (e.g. 2us; being discussed with 3GPP) |
| **1.2** | OK according to simulations, both G.812 Type III in holdover or use of SyncE are applicable | **1,5 us is exceeded** | **1,5 us is exceeded** | values in the order of 400ns can be acceptable | Very long period holdover requires higher budget (e.g. 2us; being discussed with 3GPP) |
| **1.3** | OK according to simulations, both G.812 Type III in holdover or use of SyncE are applicable | OK according to simulations, but only with the use of SyncE, not with G.812 Type III in holdover | Should be OK according to simulations (to be confirmed), but only with the use of SyncE, not with G.812 Type III in holdover | values in the order of 1.25 µs can be acceptable* | In general this use case looks ok for all holdover periods when SyncE is used |

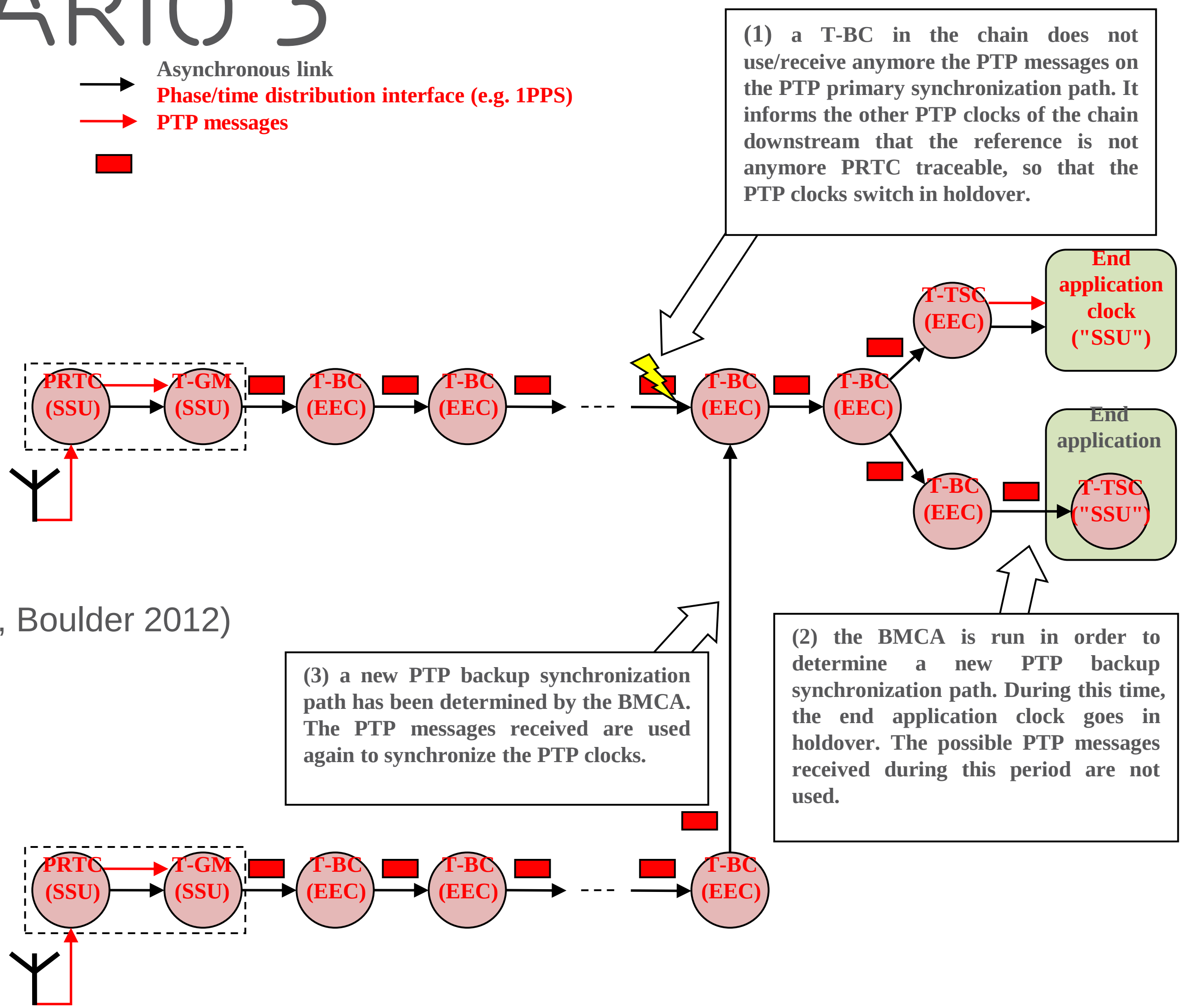
*1.25 = 1.5 – 0.25 ; where 0.25 µs = PRTC accuracy (100ns) + budget of base station (150ns)

# REARRANGEMENTS: SCENARIO 2




From WD40 (FT, Huawei, Boulder 2012)

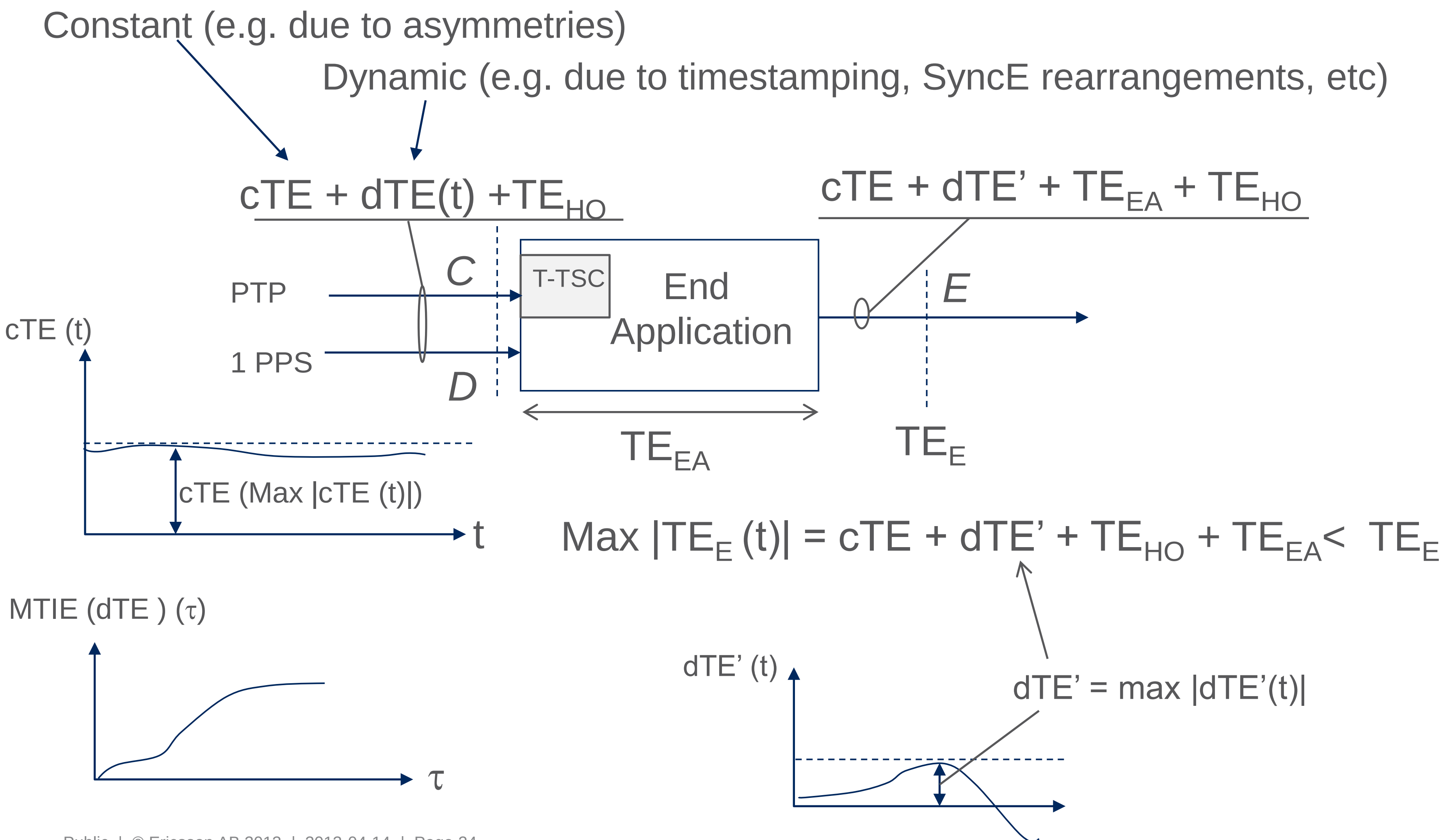
# REARRANGEMENTS: SCENARIO 3




From WD40 (FT, Huawei, Boulder 2012)

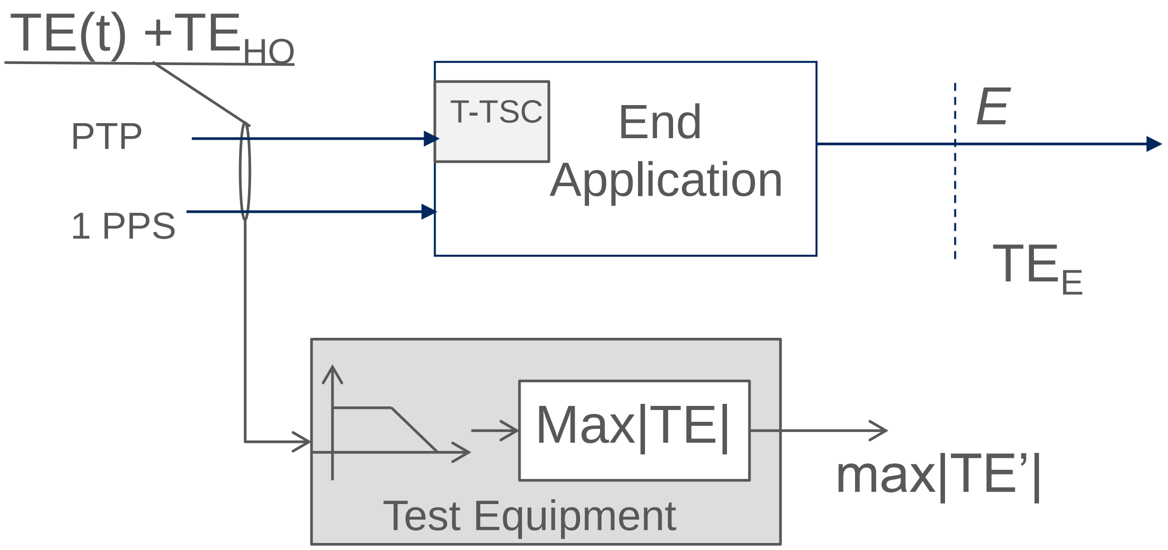
Rearrangements could be controlled within 150 ns assuming the BMCA is quick enough and the Time Clocks allow for fast start up. If this is not possible a higher budget would be required instead.

# HOW CAN WE DEFINE THE NETWORK LIMITS?



# CONSTANT TE OR MAX TE?

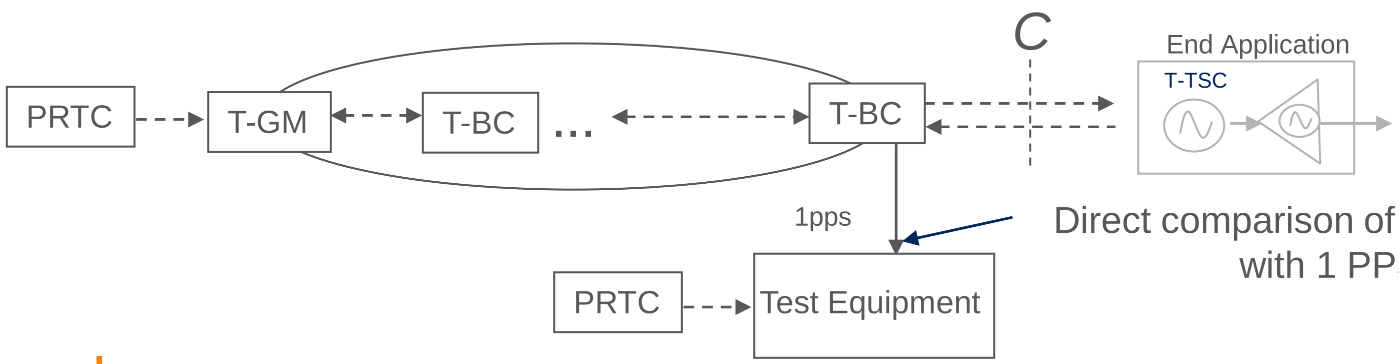
- The Constant Time Error measurement is useful as can be easily correlate to the error sources, however
  - Maybe complex estimator (see G.8260)
  - Different values at different times (e.g. due to temperature variation)
  - Significant tolerance for the error in the measurement may need to be defined
- Alternative approach based on defining max TE (under discussion):
  - The measurement should be done on pre-filtered signal (i.e. emulating the End Application filter, e.g. 0.1 Hz)




$$\text{Max } |TE_E(t)| = \max|TE'| + TE_{HO} + TE_{EA} < TE_E$$

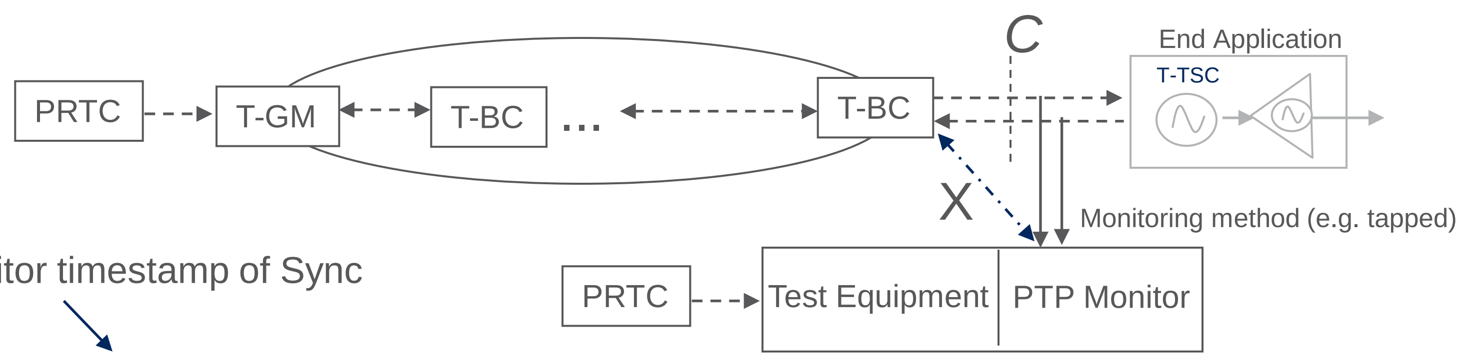
# MEASUREMENT OF NEWTORK LIMITS IN *C*

## Option a




Direct comparison of PRTC Time with 1 PPS

## Option b




Monitor timestamp of Sync

TE = TM2 - T1 – X ≈ TM3 – T4 -X

Sync timestamp (t1)

Monitor timestamp of Delay Request

Delay Resp timestamp (t4)

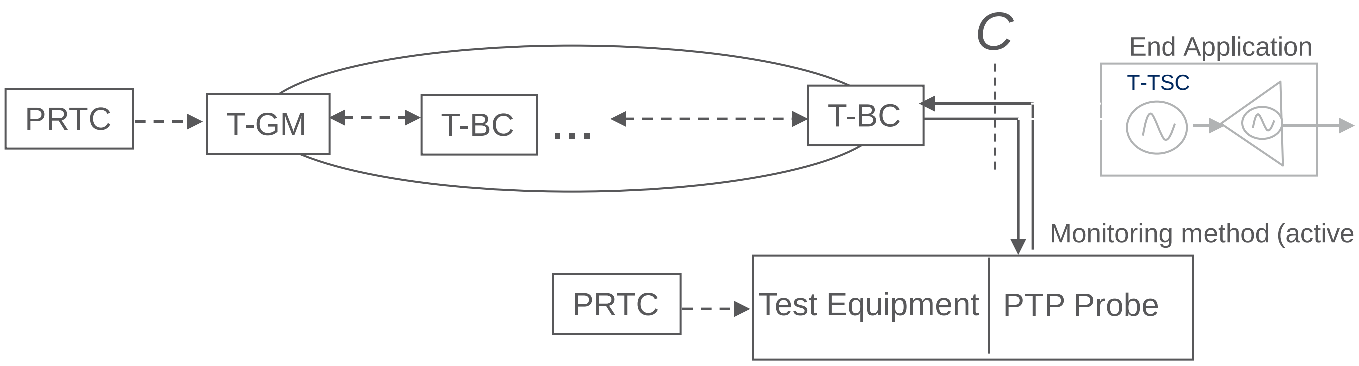
In alternative the 4 timestamps could be used:

TE = (TM2 – T1 – T4 + TM3)/2

# MEASUMRENET OF NEWTORK LIMITS IN C

## Option c

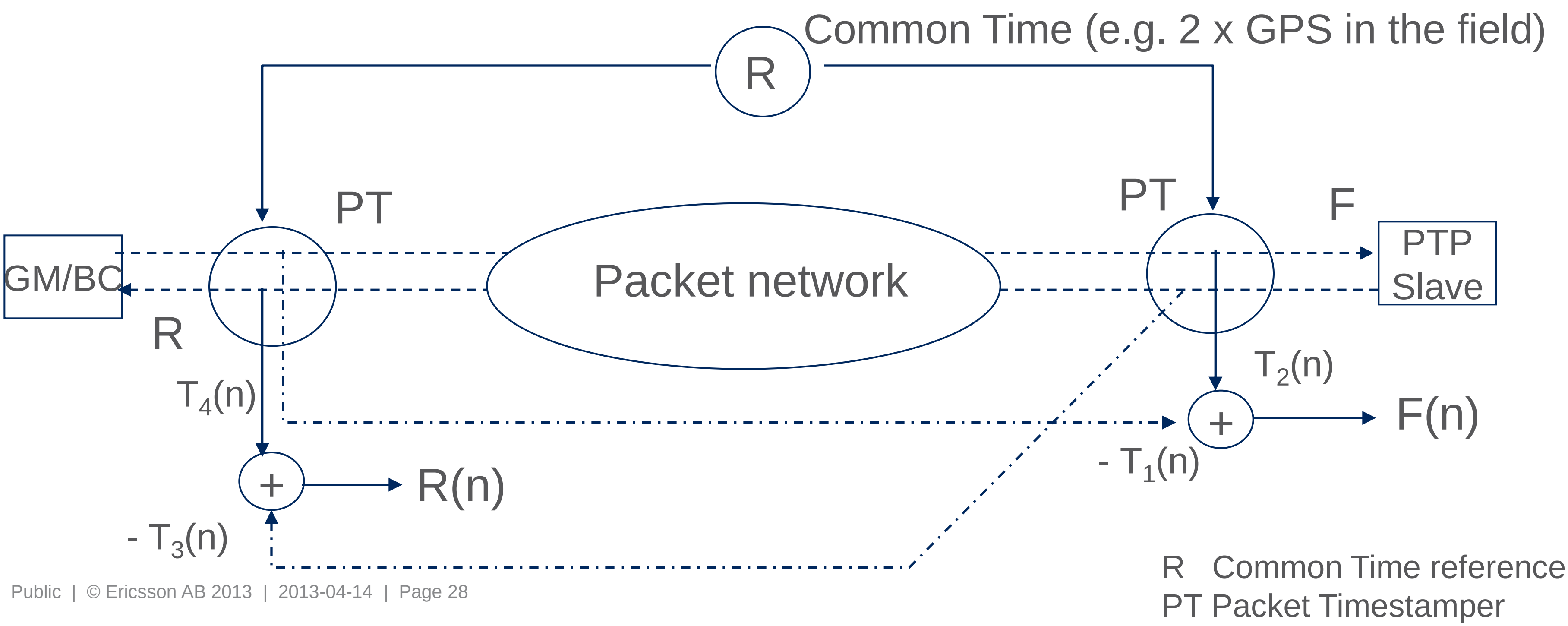
from the two-way PTP flow via an active measurement probe
(e.g. prior to the start of the service, or connecting the active monitor to a dedicated port of the T-BC).




$$TE = (T2 – T1 – T4 + T3)/2$$

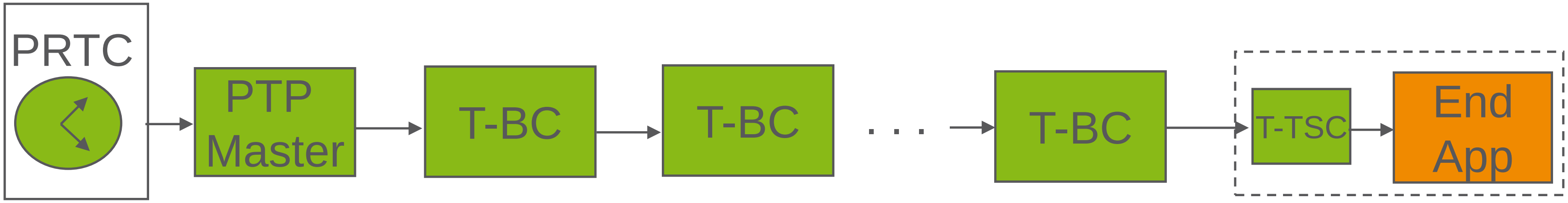
# MEASUREMENT OF NETWORK PERFORMANCE IN PARTIAL SUPPORT?

- Not defined yet; similar measurement set up as defined for PDV
- Synchronous Set up is required (need to evaluate transit time of each packet)
- Two-way packet flow must be monitored (*Forward Packet Delay* and *Reverse Packet Delay*)
- Two–way metrics have been proposed (e.g. minTDISP)



# SIMULATIONS: REFERENCE CHAIN WITH BC IN EVERY NODE

- Removal of PDV and asymmetry in the nodes by means of IEEE1588 support (e.g. Boundary Clock in every node).



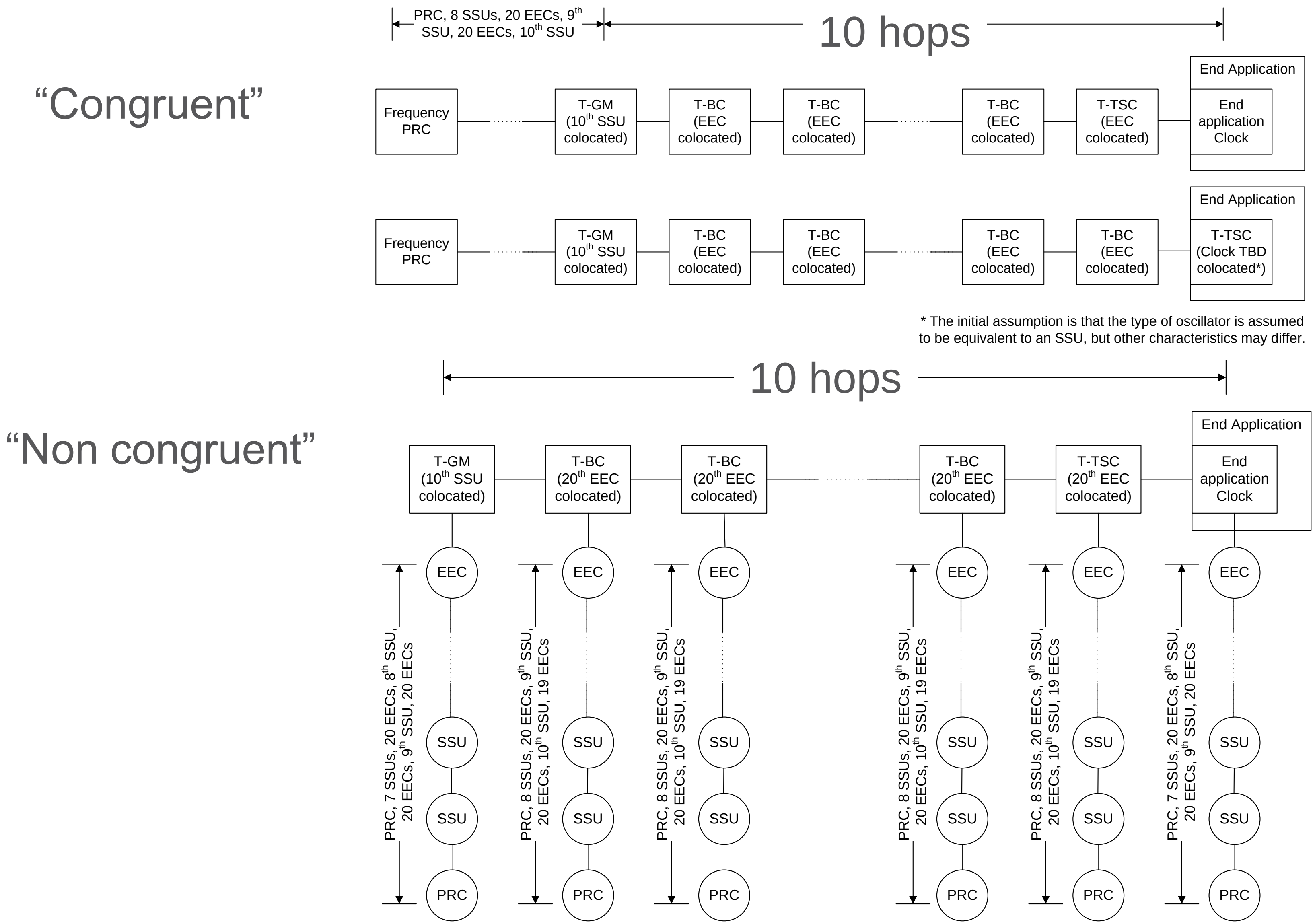

PRTC : Primary Reference Time Clock

T-BC: Telecom - Boundary Clock

T-TSC: Telecom Time Slave Clock

- Ideally the full support can provide very accurate timing, however several sources of errors still remains:
  - Simulations have analysed the “Dynamic Component” during normal conditions and during rearrangements; with and without SyncE
  - Considerations on the “Constant Component” are made separately
- Simulations with partial timing support will require the definition of new HRMs (in G.8271.2)

# SIMULATION MODELS: WITH SYNCE SUPPORT

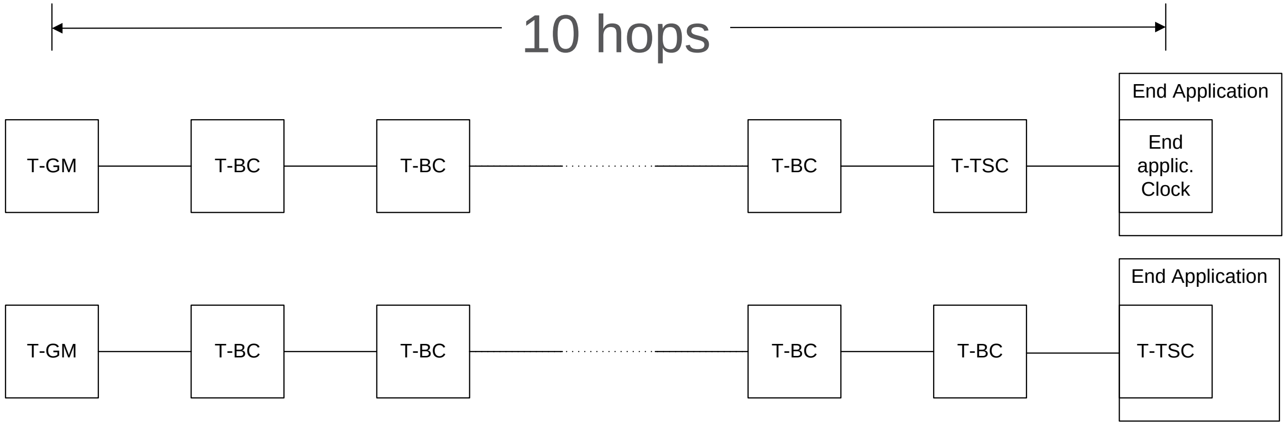





From G.8271.1

# SIMULATION MODEL WITHOUT SYNCE

› Initial Assumptions:
 – a clock resulting in noise generation that is no worse than the noise accumulated along the SyncE chain.
 – Temperature variation profile to be defined.
 – Holdover another important parameter to be defined.

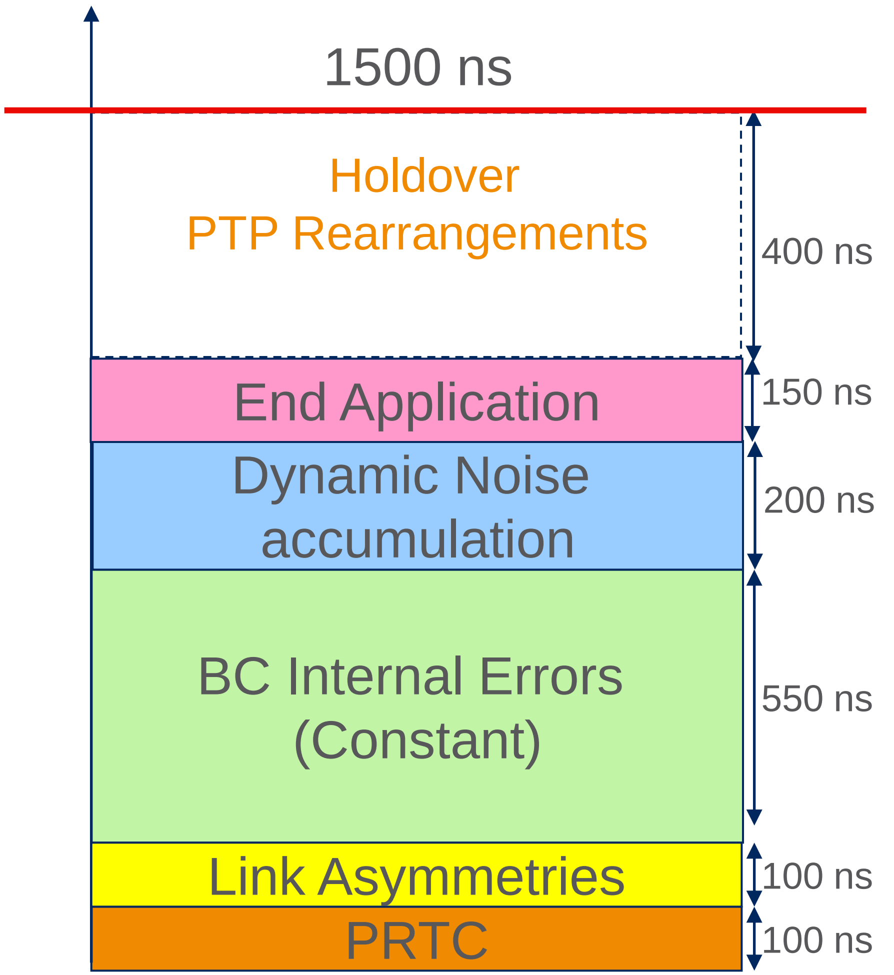



From G.8271.1

# SIMULATIONS RESULTS AND TIME ERROR BUDGETING

## Budgeting Example (10 hops)

- Dynamic Error (dTE)
  - Several simulations have been performed using HRM with SyncE support
  - The most challenging scenarios are related to ring rearrangements in SyncE network.
  - It looks feasible to control the max |TE| in the 200 ns range
    - physical layer signal shall be rejected after the physical layer transient is detected
  - It is assumed that the nodes in a PTP chain without syncE should be designed in order to accumulate similar level of noise. Otherwise the End Application shall filter it
- Constant Time Error (cTE)
  - Constant Time Error per node: 50 ns
  - PRTC (see G.8272): 100 ns
  - End Application: 150 ns
  - Rearrangements: 400 ns (one of the main examples)
  - Remaining budget to Link Asymmetries



# PARTIAL TIMING SUPPORT

Definition Recently agreed:

- packet-based method with full timing support to the protocol level from the network: Packet-based method (frequency or time-phase synchronization) requiring that all the network nodes on the path of the synchronization flow implement one of the two following types of timing support:
  - termination and regeneration of the timing (e.g. NTP stratum clocks, PTP boundary clock);
  - a mechanism to correct for the delay introduced by the network node and/or the connected links (e.g. PTP transparent clock).
- packet-based method with partial timing support to the protocol level from the network: Packet-based method (frequency or time-phase synchronization) where not all of the network nodes on the path of the synchronization flow implement timing support.

*HRM will have to be defined in order to develop related requirements*
*It was agreed to start a new document for that (G.8271.2)*

# SUMMARY

- G.8271 and G.8271.1 provide the fundamentals for Time synchronization: methods, network requirements
  - G.8271 consented in 2011; G.8271.1 and G.8271 Amendment planned to be consented in July 2013.
- Some important points have been agreed or being finalized:
  - Same limits irrespectively if T-TSC embedded in a Base Station or not
  - Control of SyncE noise using SSM (need for filtering in the End Application being discussed)
  - Need for Stability requirements (via MTIE/TDEV?)
  - Max TE or Constant TE?
- The budget for the Time sync Holdover and Rearrangement is a key parameter in the noise budgeting analysis
- Static (Constant) noise must be shared between links and network equipments
- Analysis of Partial Timing Support require the definition of new simulation models and new HRMs (in 8271.2)

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