Towards Accurate Optical Fiber Time Transfer for UTC Generation V3

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Outline 1/2

- Recommendation ATFT (draft) to CCTF2015

the BIPM participates actively in these (fibre link etc.) developments, notably by making preparations for exploiting, in time scale realization, clock comparison data issued from new time and frequency transfer methods.

Outline 2/2

- We focus on its use in UTC generation
  - Activities of the UTC laboratories
  - Attainable uncertainty
  - Applications
    - Short-term: validating the new and the most precise-accurate T/F technics
    - Long-term: UTC time transfer, UTC dissemination

TWOTFT=Two-Way Optical-fiber T/F Transfer

- **basic bidirectional**: Very similar to TWSTFT; temperature impact of picoseconds over hundreds km; self-calibration possible;

Close reciprocity $D_{AB} \approx D_{BA}$ in Two-Way time transfer

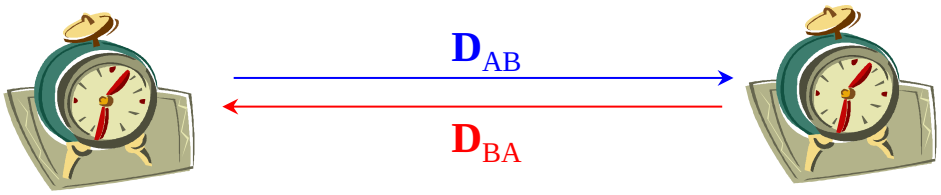


Fig. 1a

- **bidirectional with active delay stabilization**: feedback loop, with self-calibration and the stability of picoseconds

Close reciprocity $D_{AB} \approx D_{BA}$ in Two-Way time transfer

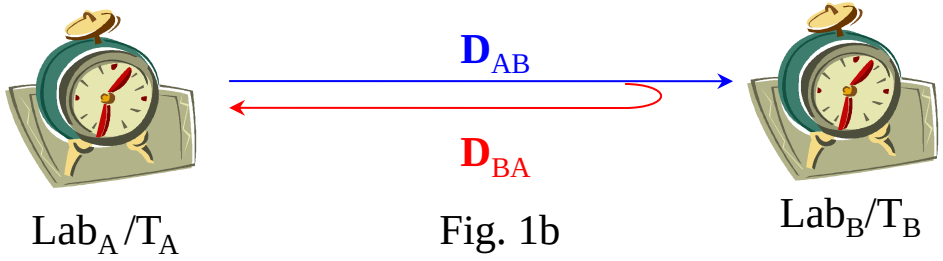


Fig. 1b

Activity in O.F. of the UTC labs/BIPM

- **BIPM Technical Memorandum 253:** > **80 papers,** at least **18** UTC Labs actively involved : PTB, AOS, GUM, IPE, BEV, SP, MIKES, TL, NICT, NMIJ, NIM, INRIM, OP, NPL, NIST, NMIA, VSL and USNO;
- Several operational time/frequency links;
- **AOS-PL, BEV-TP** submit data to BIPM for monthly processing and publications;
- The attainable standard uncertainty < 120~200 ps;
- A study group, Optical fibre link for UTC, created in 2015

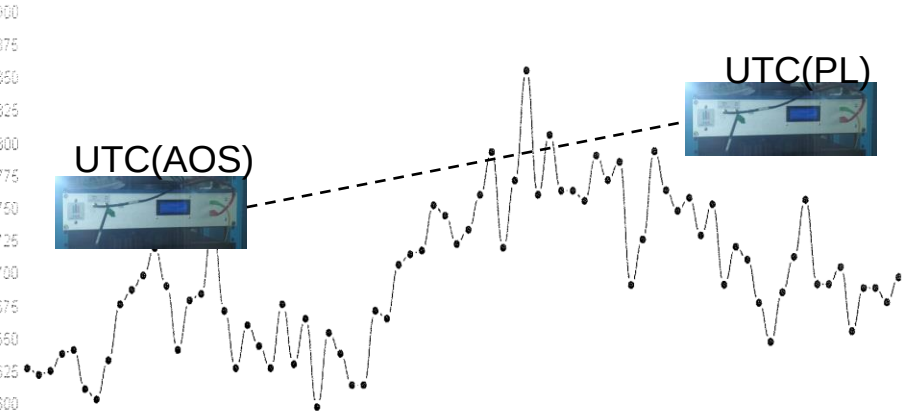
Applications of O.F. in UTC 1/2

- Validation of the new and the most precise technics, such as:
  - **Time link calibration**, Jiang et al. (2015) “Comparing a GPS time link calibration to an optical fibre self-calibration with 200 ps accuracy”, ***Metrologia* 52** *(BIPM-PL-AOS)*
  - **Integer ambiguity PPP**, Petit et al. (2015), “1×10^{-16} frequency transfer by GPS PPP with integer ambiguity resolution”, ***Metrologia* 52** *(BIPM,CLS …)*
  - **Revise Rinex-Shift**, Yao et al. (2015), “A Detailed Comparison of Two Continuous GPS Carrier-Phase Time Transfer Techniques”, ***Metrologia 52*** *(NIST-IAC-BIPM)*
  - **… …**

Applications of O.F. in UTC 2/2

- Future applications and new challenges :
  - Accurate time transfer for UTC generation
    - Configuration of the worldwide UTC network
    - Standardisation of data exchange format and data processing
    - Calibrations
    - Combination with the space based techniques

Fibre link UTC(AOS)-UTC(PL)

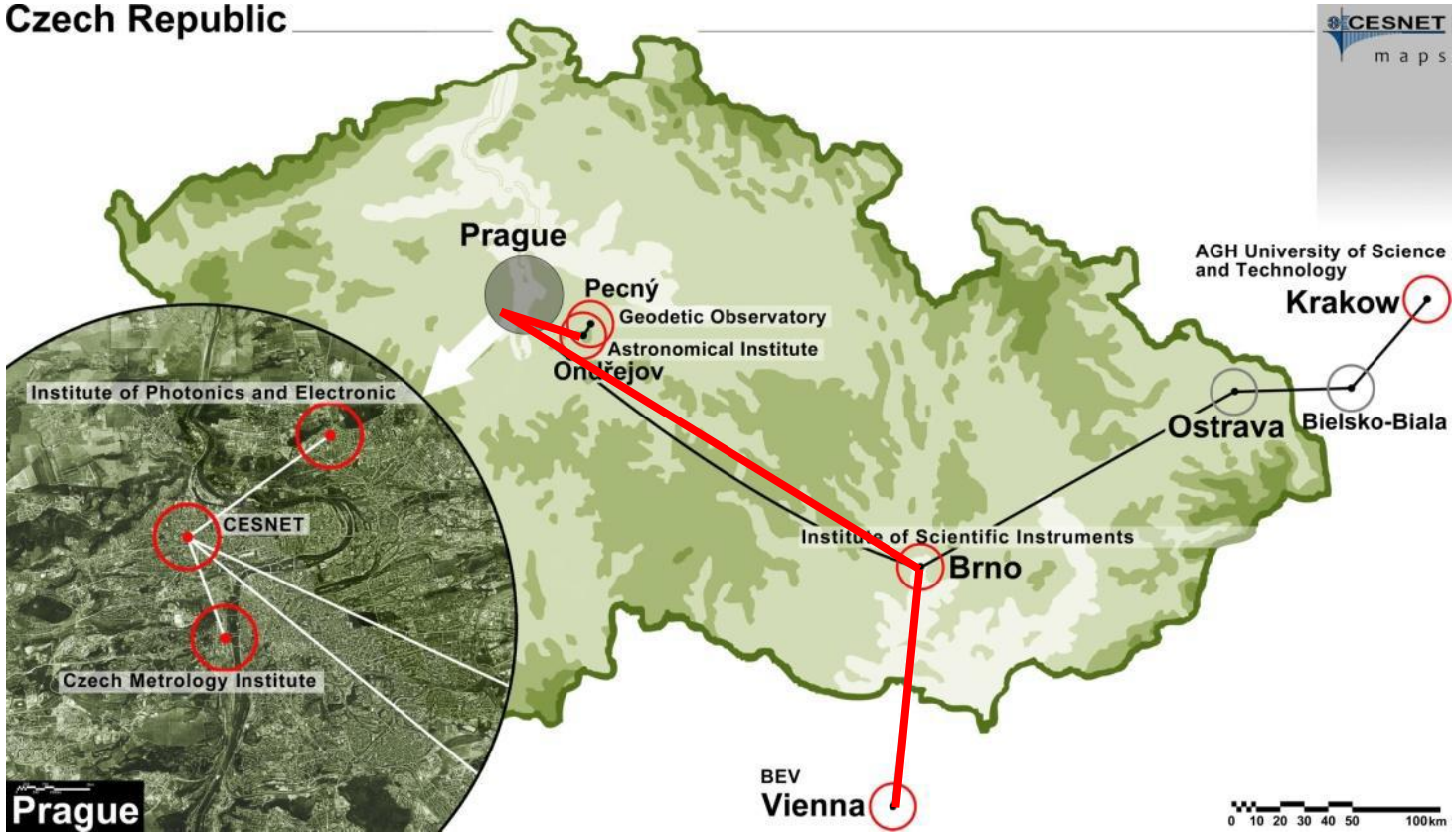


The real-time clock comparison between UTC(AOS) and UTC(PL) through a fibre link, www.optime.org.pl/node/47

420 km baseline 7 amplifiers, permanent operational

Total combined uncertainty **112 ps**

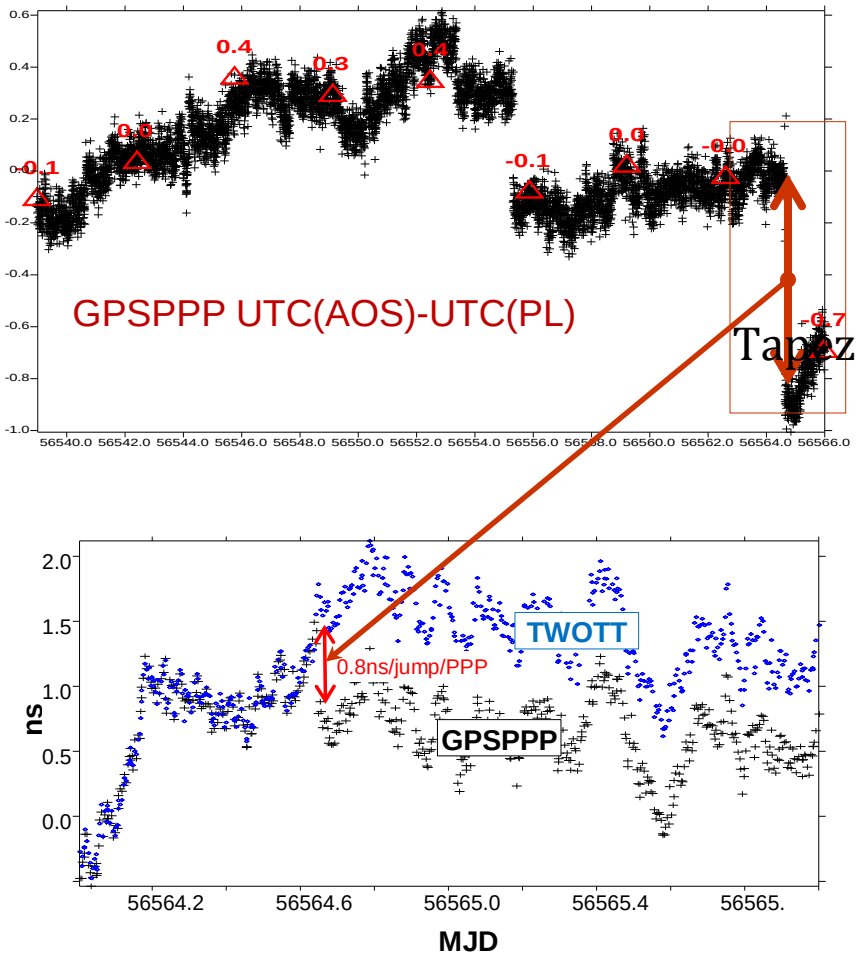
Fibre link UTC(BEV)-UTC(TP)



550 km baseline with 7 amplifiers, permanent operational

Tdev 30 ps/20s

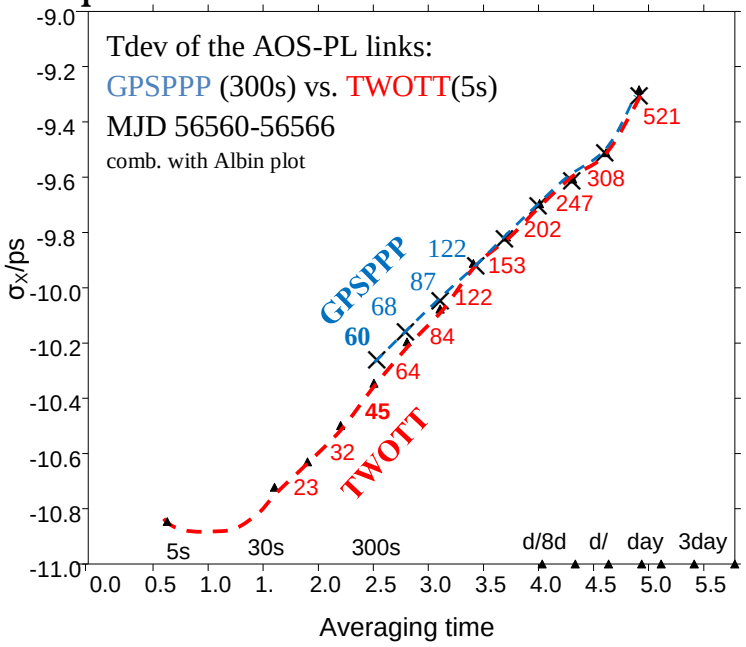
Assess fibre link vs. GPSPPP (jumps) 1/2



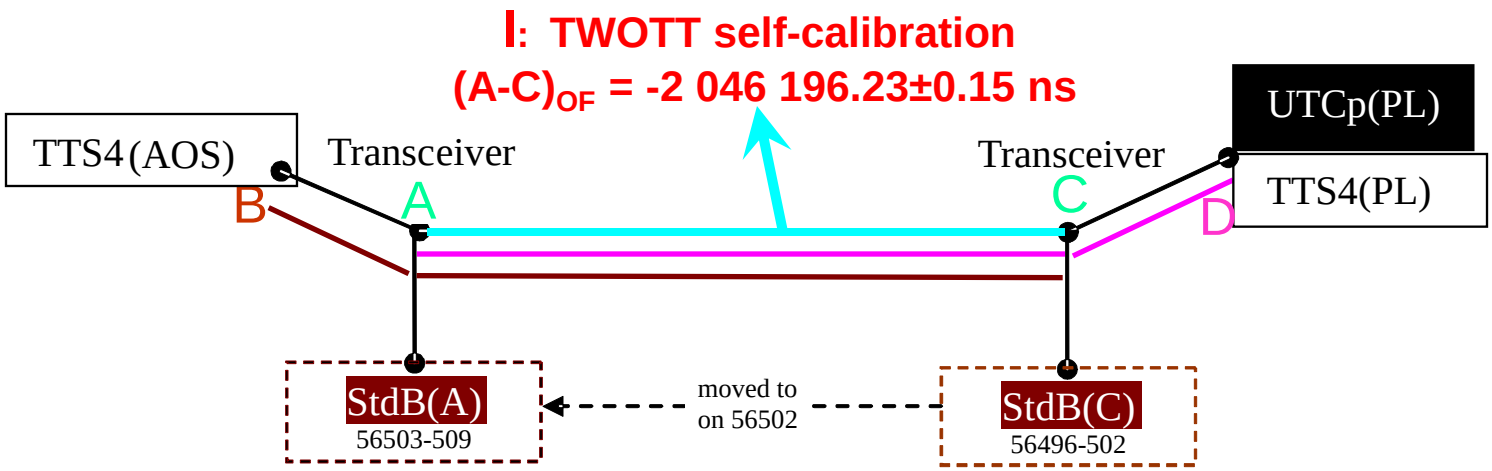
Noises, discontinuities,
drifts and jumps << 1ns.

In most cases,
Caused by GPSPPP

Tapez une équation ici.



Valid GNSS Calibrator with TWOTT over A-C



II: GNSS $(A\text{-}C)_{PL_{TTS4}}$ = (A-D)-(C-D) = -2 046 195.368 ns

GNSS $(A\text{-}C)_{AOS_{TTS4}}$ = (B-C)-(B-A) = -2 046 195.958 ns

} **-2 046 195.663 ns**

➔TWOTT-GNSS Calibration = I – II = **0.57±0.79 *ns***

Consideration of its future Application in UTC

1) Standard data format
2) A new configuration and a new algorithm ?

TWOTFT data format ← ITU-R TF.1153-4 format

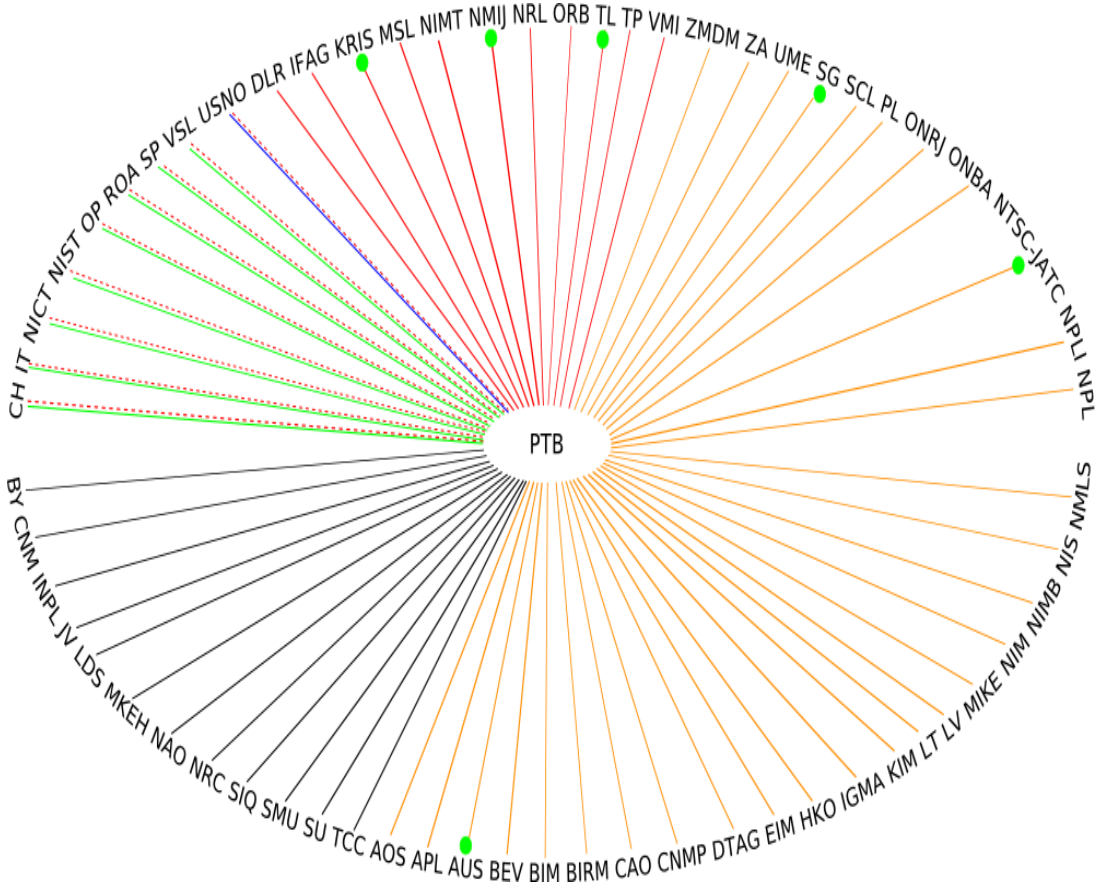
```
* TOPTB56.150 (TWLABOMJ.DDD ➔ TOLABOMJ.DDD)
* FORMAT     01X
* LAB        PTB
* REV DATE   2011-08-03
* ES   PTB01 LA: N  52 17 49.787      LO: E  10 27 37.966   HT:   143.41 m
* REF-FRAME ITRF
* LINK   14 fibre: Dark Channel          Length: 420.00 Km    Amplifiers: 7
*           OPTICAL-TX: 1552.1500 nm RX: 1552.1550 nm
*           MODEM: Dedicated hardware    SIGNAL: 1 PPS on square wave
*           Link Stabilization:  YES
* LINK   16 fibre: AAA Network           Length:  72.00 Km    Amplifiers: ?
*           OPTICAL-TX: 1542.1000 nm RX: 1542.1500 nm
*           MODEM:  SATRE 037            SIGNAL: PRN, 20 Mcps
*           Link Stabilization:  NO
* CAL   xxx TYPE: CAL 141 METODE     MJD: 55760  EST. UNCERT.:    1.5    ns
* CAL   213 TYPE: CAL 142 O.F.Self   MJD: 55769  EST. UNCERT.:    0.112X ns
* LOC-MON   NO
* COMMENTS  unit in 0.1 ps
*
--- data body proposition (I)
* EARTH-STAT  LI  MJD  STTIME NTL        TW          DRMS SMP ATL     REFDELAY      RSIG  CI S    CALR     ESDVAR   ESIG TMP HUM PRES
* LOC    REM          hhmmss  s          0.1ps       0.1ps      s     0.1ps         0.1ps          0.1ps      0.1ps    0.1ps   C  %  mbar
 PTB01  TIM01 14 56150 000400 119   265739347023X 1226X 120 119  0000000040870X 0020X 999 9 999999999  1035000X 2800X  12  98 1013
 PTB01  PTB01 14 56150 000700 119   266718670995X 2491X 120 119  0000000040870X 0020X 999 9 999999999  1035000X 2800X  12  98 1013
 PTB01  OCA01 14 56150 001000 119   264311268059X 1497X 120 119  0000000040870X 0020X 999 9 999999999  1035000X 2800X  12  98 1013
 PTB01   IT02 14 56150 001300 119   264702466195X 1937X 120 119  0000000040870X 0020X 213 1   479209X  1035000X 2800X  12  98 1013
 PTB01  ROA01 14 56150 001600 119   260338922342X 2520X 120 119  0000000040870X 0020X 217 1   298673X  1035000X 2800X  12  98 1013
```

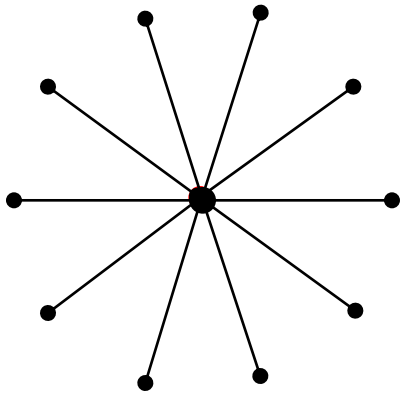
It is suggested adapting the **ITU TWSTFT** data format for **TWOTFT** (SATRE):
-All the data exchanges, processing, calibrations, and the related methodology and software can be kept almost the same;
-This will save huge time and man powers and speed up its applications (BIPM Tsoft);
-Adapted header
-Open points: Rcd 0.1 ps, Sagnac corr.

A unique standard format for all the TWOTT approaches

The UTC network configuration 1/2

Present structure based on GNSS and TWSTFT links



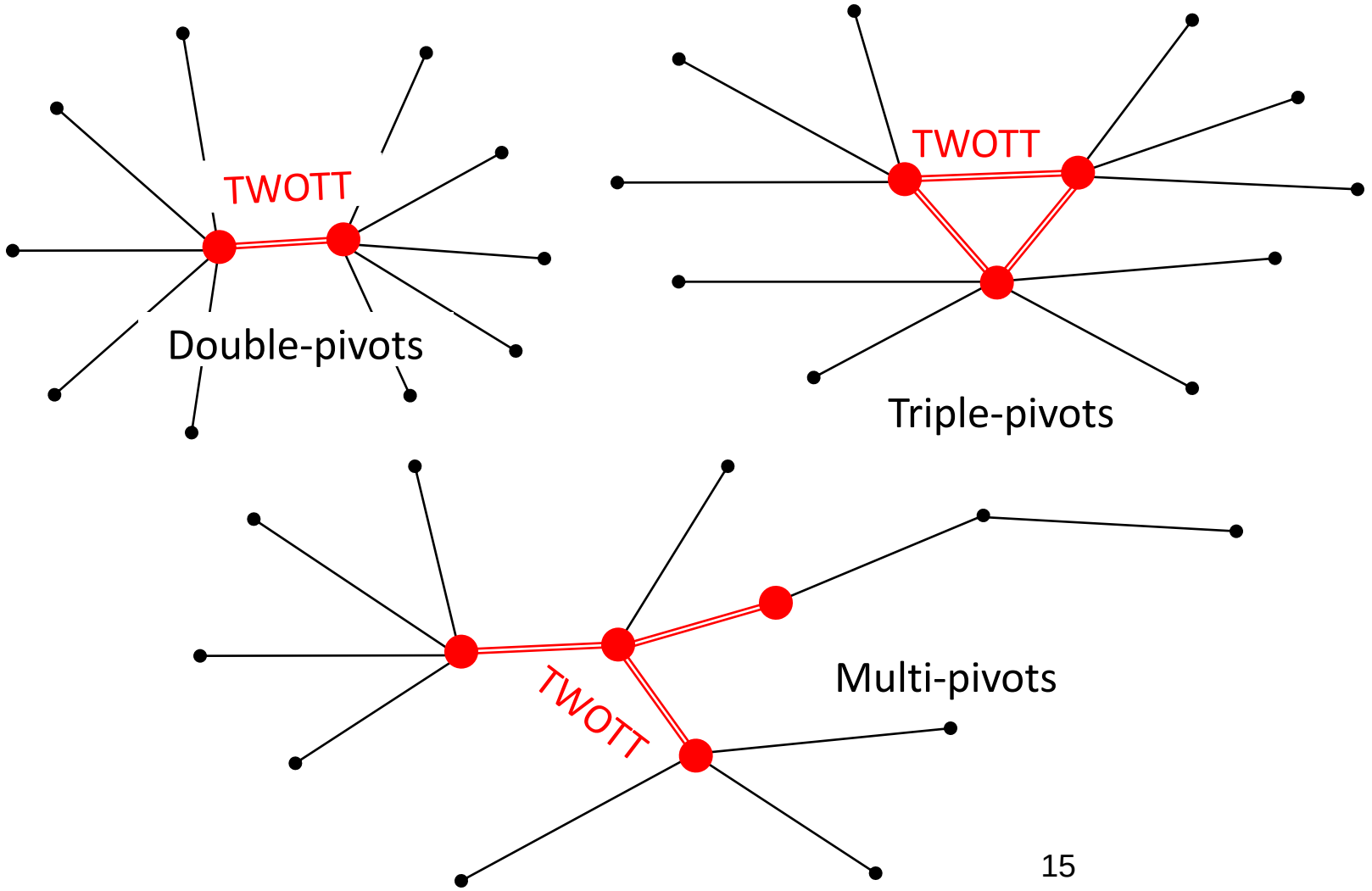


Unique pivot

The new UTC network configuration

2/2

*with the **TWOTT** links ➔ comb. U=0.1 ns negligible*



Thanks

for your attention

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