High-speed Network Time-Transfer using Data-Filtering Method

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Background

- Applications: from document management, patent protection, electronic-commerce to computer forensics.

- Most applications are on Internet.

↓ Demand

Accurate time-transfer techniques on Networks (for commercial time-application users)

Usual methods

- Global Positioning System (GPS) Common-view
  → remote atomic clocks
  – difficult to setup and operate
  Commercial and private users
- Network Time Protocol (NTP)
  → Network environments
  – difficult to receive accurate time
  Network problems

Three distinctive problems

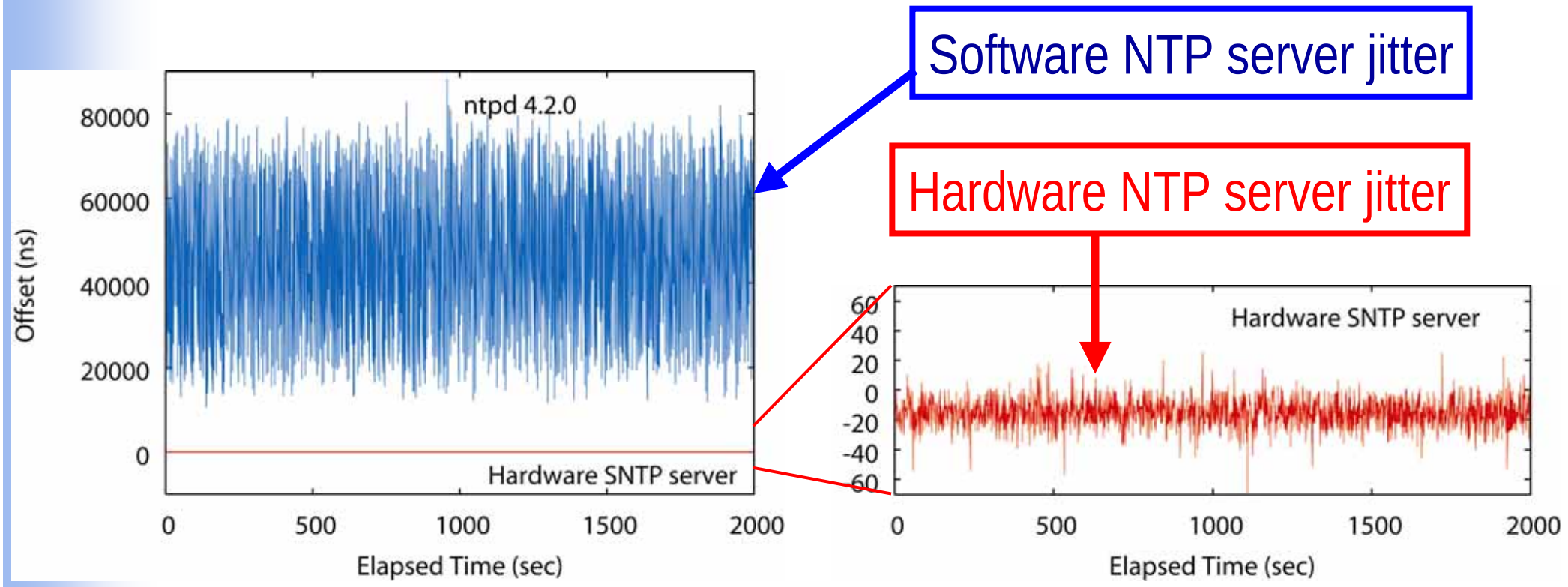
- Software processing
  - Interrupt requests or packet sending delays
- Network time-transfer delay
  - Cross-traffic
- Network condition
  - Internet-links change during long-term operation

Software processing (1)

- Simple-NTP (SNTP) board

Software processing (2)

- SNTP server works at wire-speed of Gb-E
- No server overload and no timestamp jitter greater than transmit clock cycle of Gb-E



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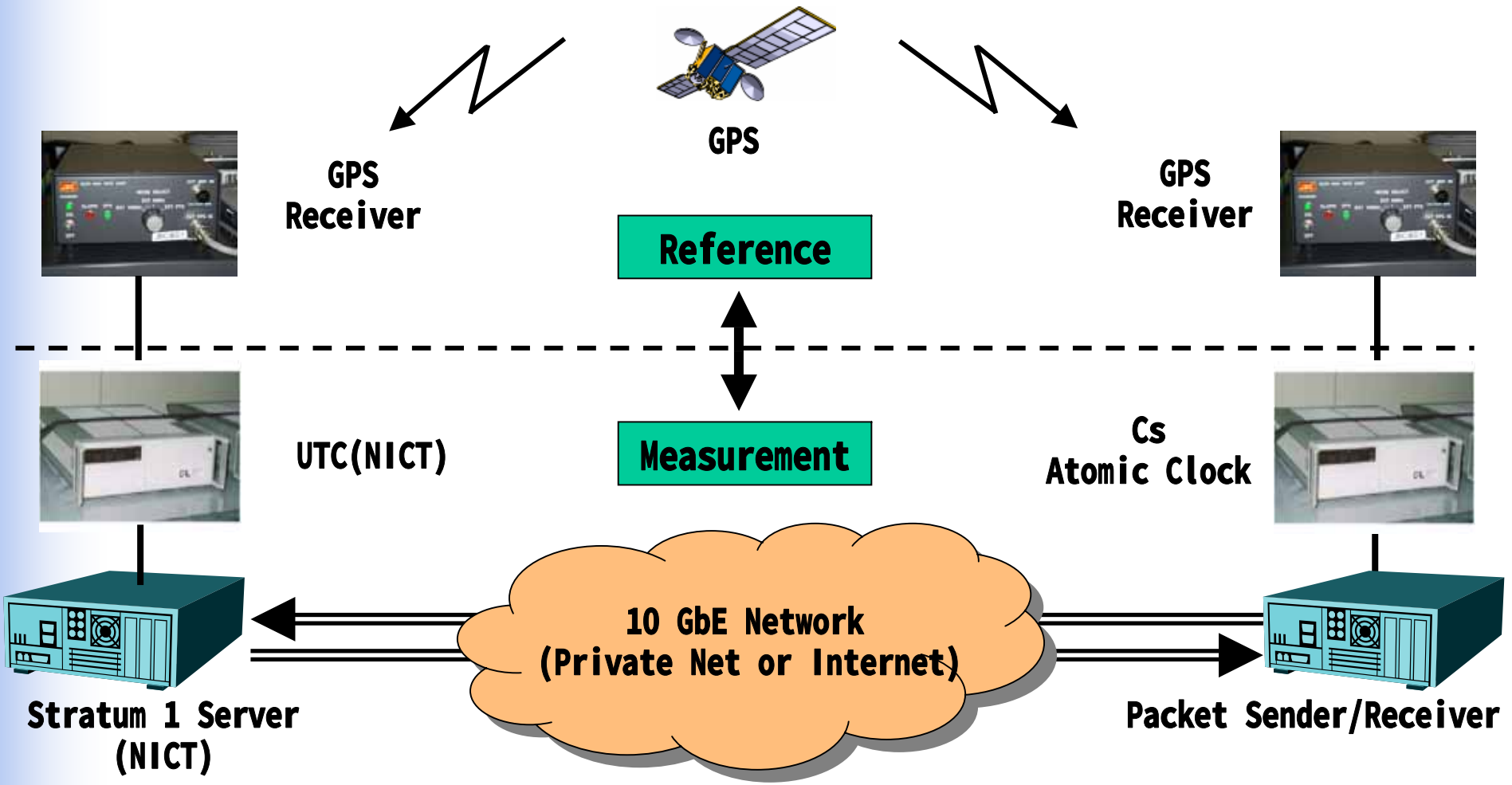
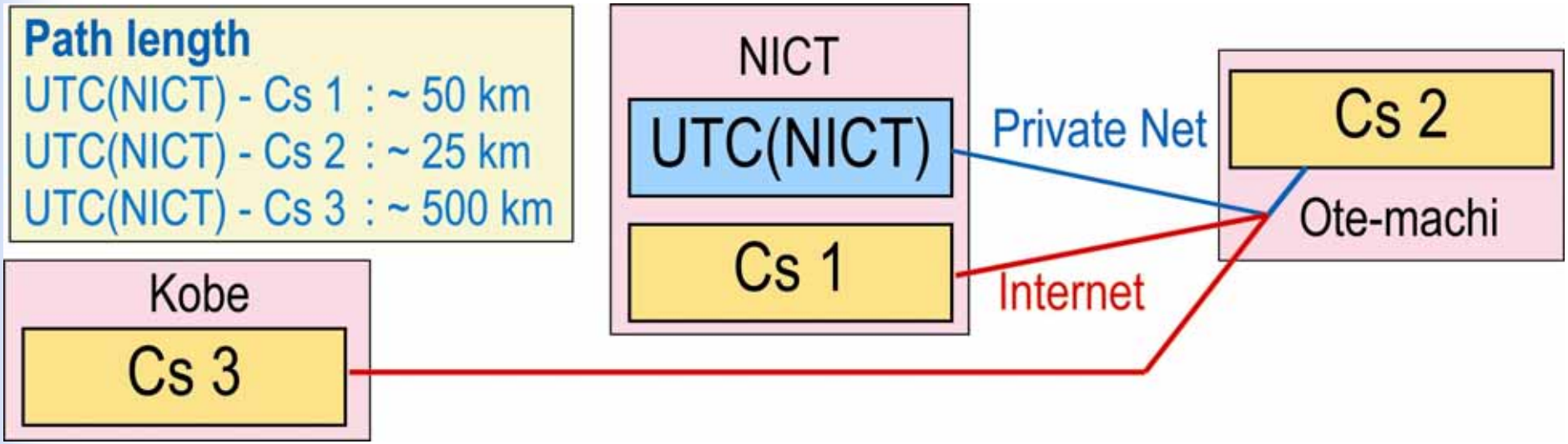
Network time-transfer delay (1)



Block diagram of time-transfer system

Network time-transfer delay (2)

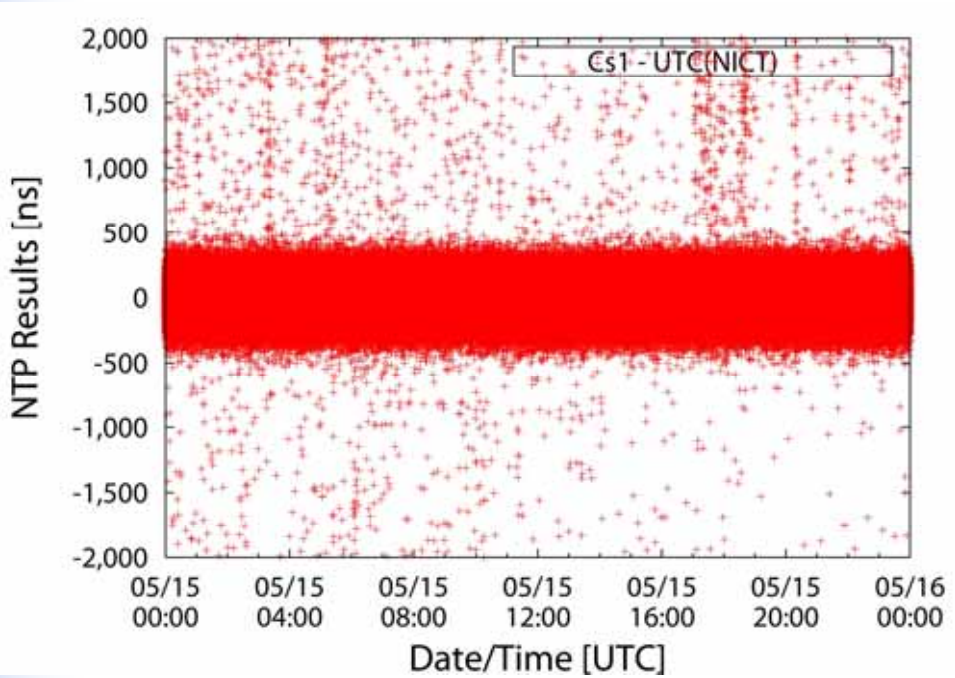
- Network: 10 Gb-E (Internet and private network)
- Between Ote-machi and Kobe: heavy cross-traffic



Network and location

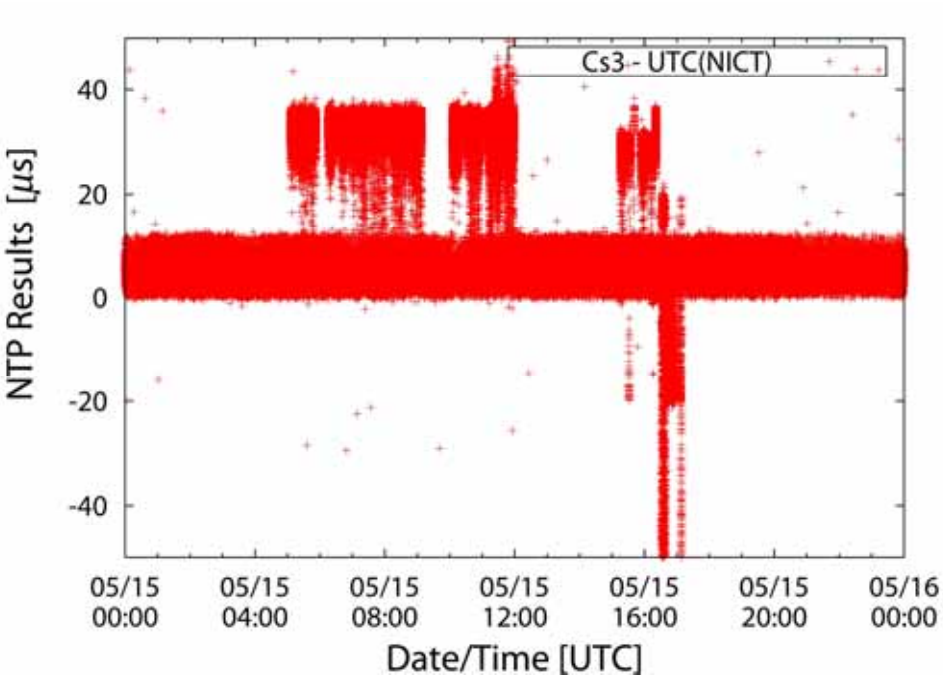
NTP results

Cs 1 & Cs 2 cross-traffic light



Jitter: ~ 1 μs

Cs 3 cross-traffic heavy

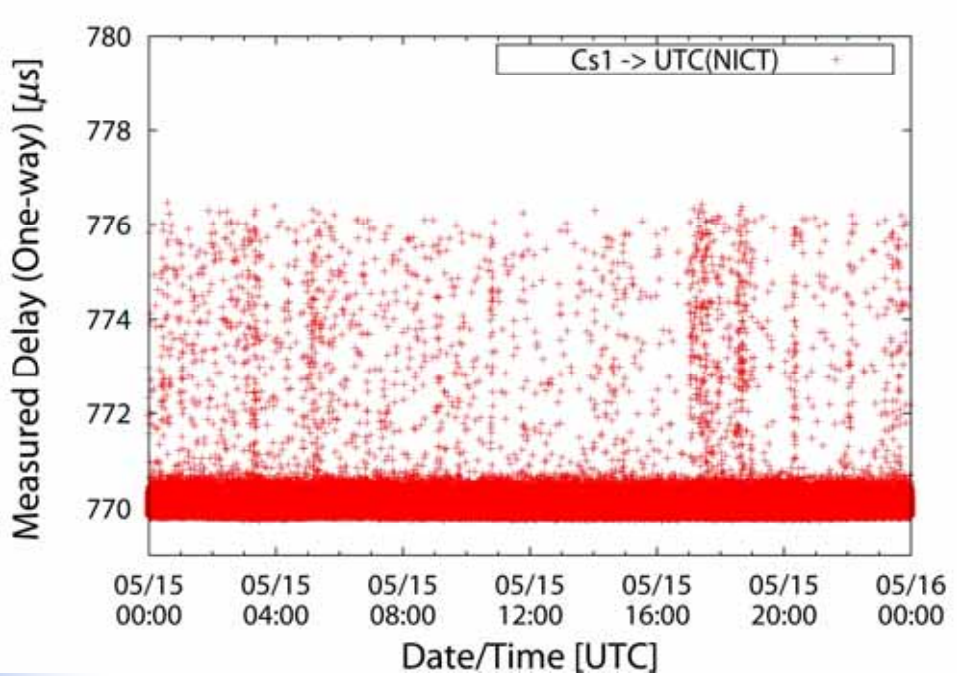


Jitter: > 10 μs

Cannot apply to atomic clock

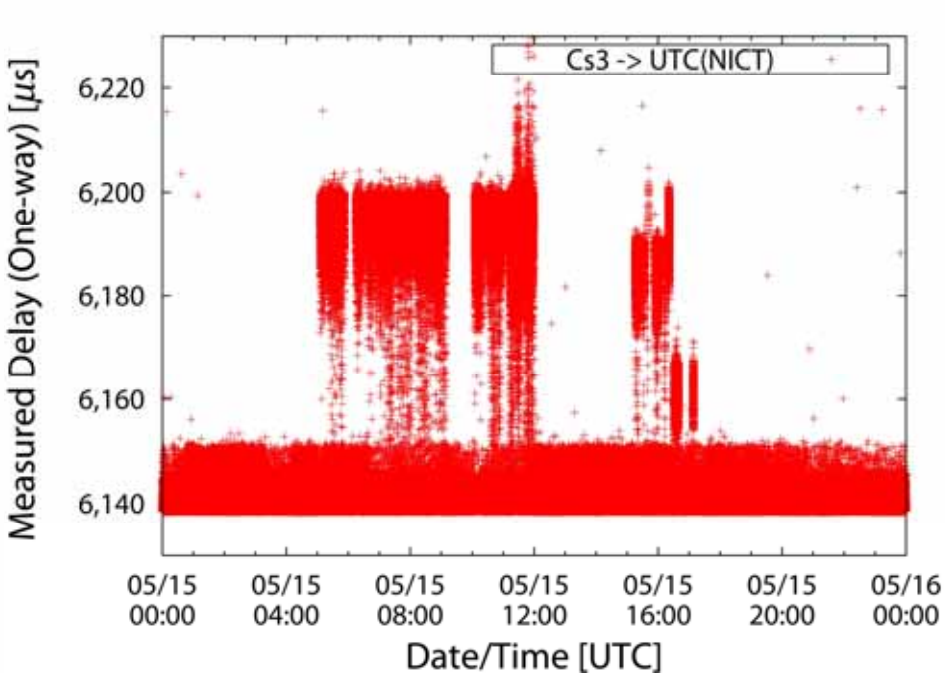
One-way delay results

Cs 1 & Cs 2 cross-traffic light



Cs 1

Cs 3 cross-traffic heavy

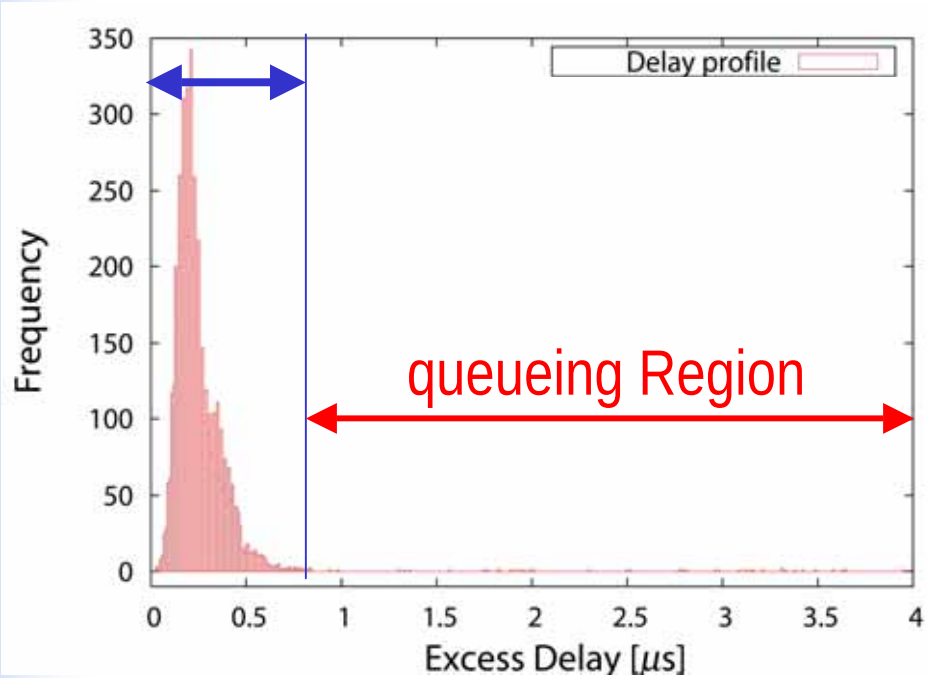


Cs 3

Excess delay → spread by queueing delay

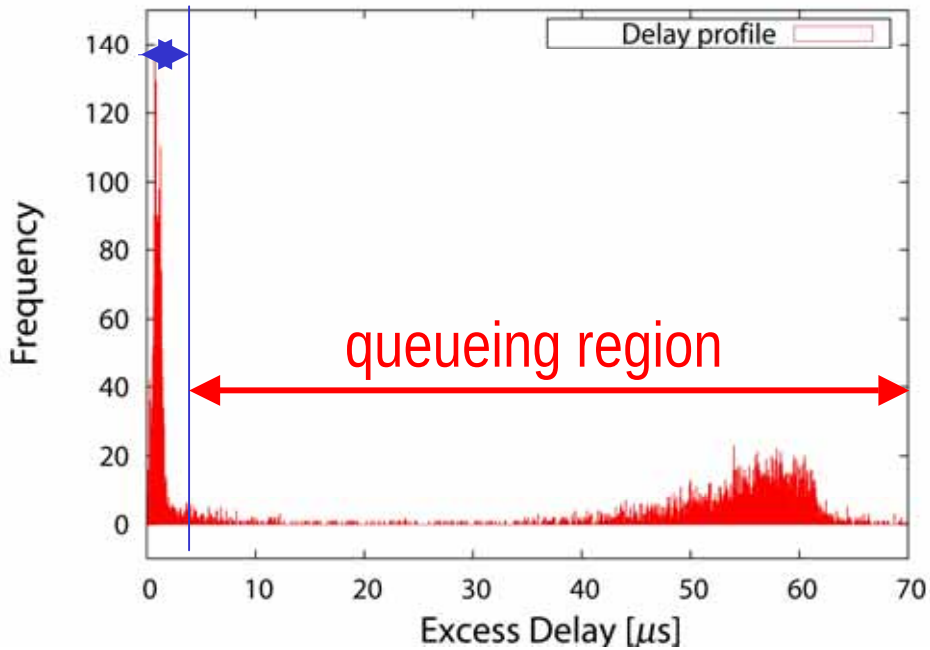
One-way results (delay profile)

static region



Cs 1: SD ~200 ns

static region



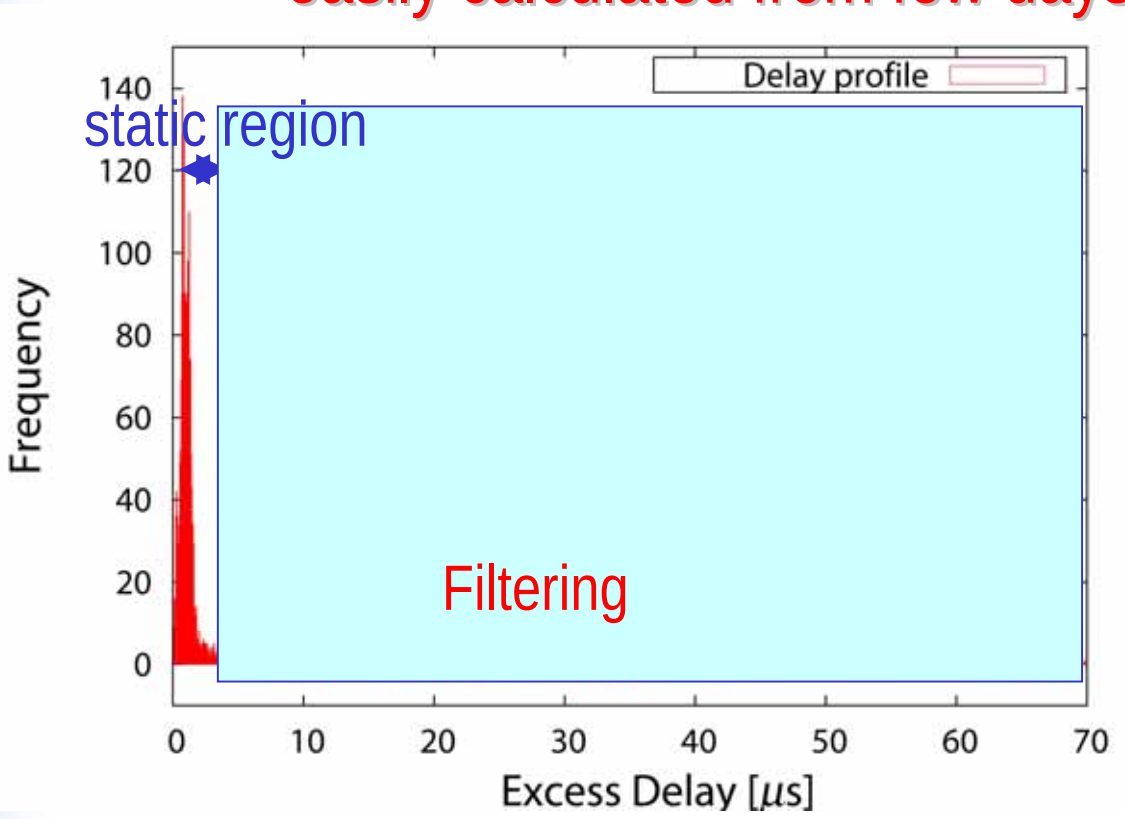
Cs 3: SD ~2,000 ns

Static Region: generated by network equipment
→ independent of cross-traffic

Data-filtering method (1)

- Filtering out queueing region and picking up only static region
- Static region width: depends on network connection

→ easily calculated from few days results



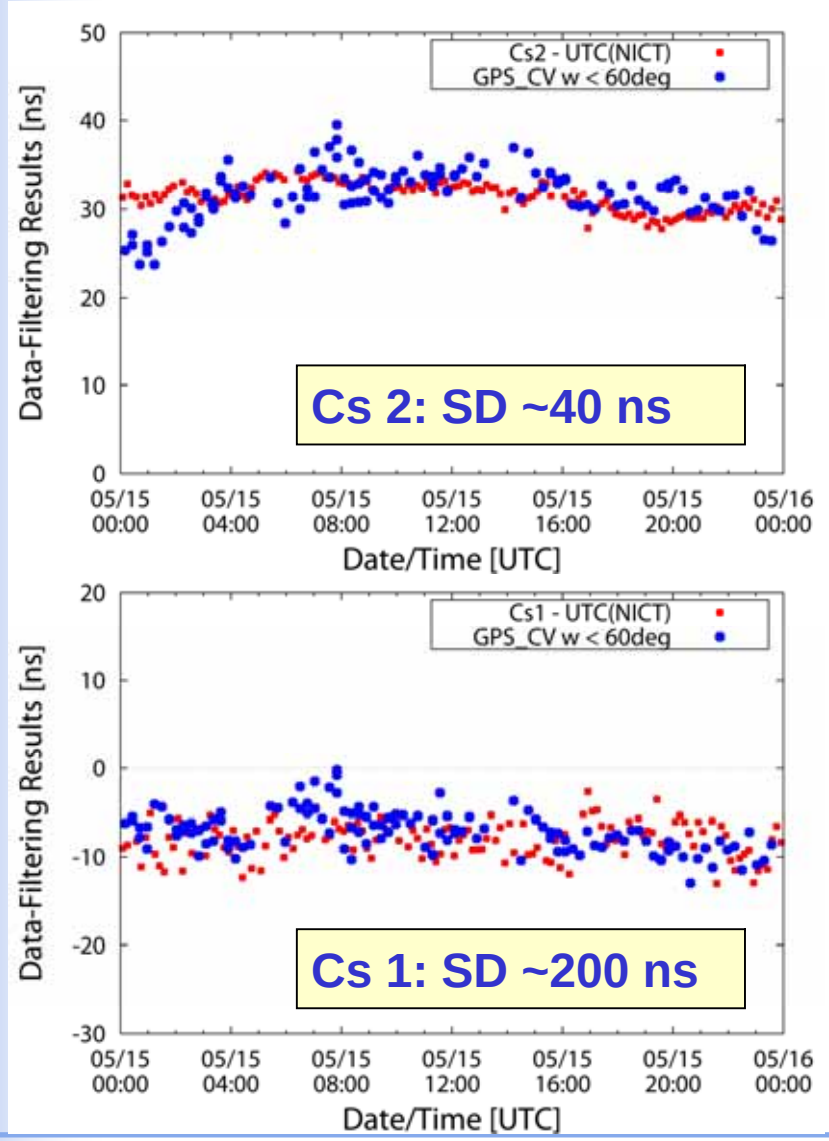
Data-Filtered mean:

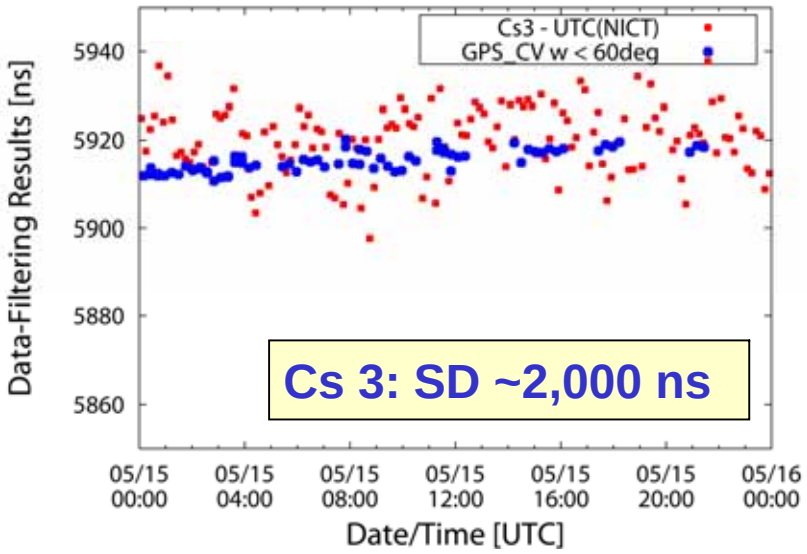
→ calculate every 10 min.

data updated every 10 min.

GPS CV every 13 min.(+3min.)
data updated once / day

Data-filtering method (2)





Data-filtered mean of Cs 1 & Cs 2
equal or better than
GPS CV (ELV > 60deg)

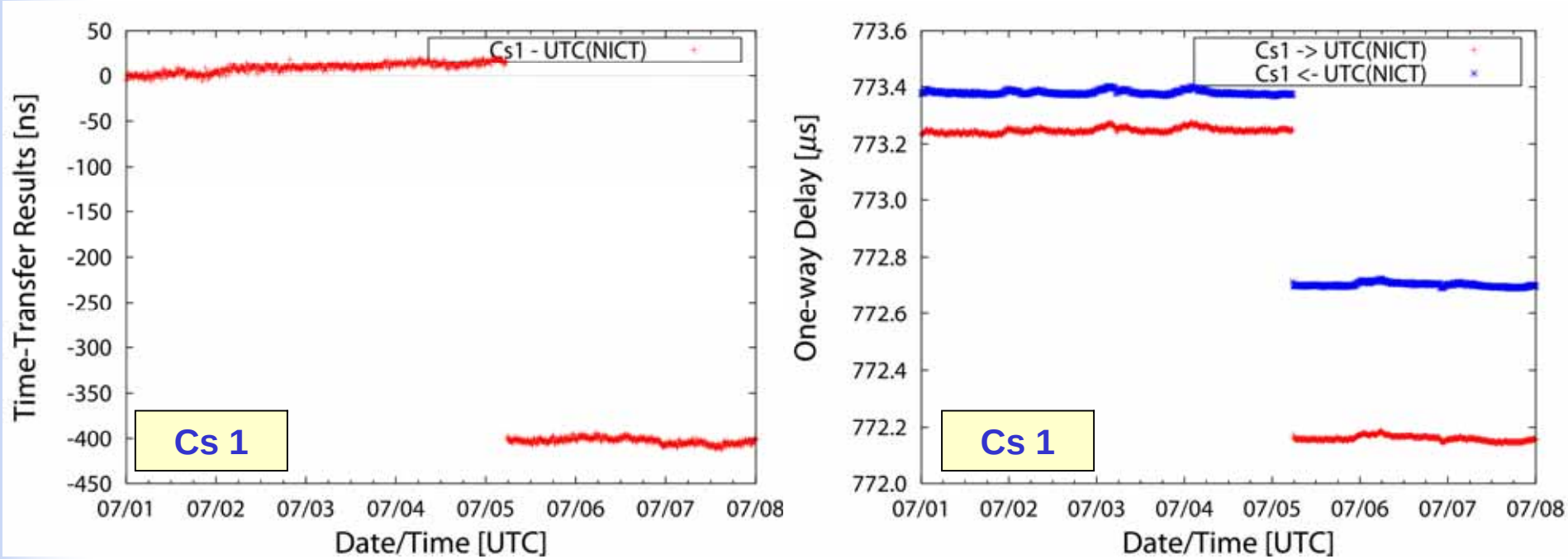
Several statistical methods

Compare SD with data precision of each method

SD all data	Data-filtered mean	All data mean	Minimum few data mean
40 ns	few ns	few ns	10 ns
200 ns	10 ns	20 ns	20-50 ns
2 μs	10-20 ns	200 ns	50-100 ns
4 μs	100-200 ns	200 ns	100-200 ns
10 μs	100-200 ns	1 μs	200 ns

GPS CV (ELV > 60deg) ~ 10 ns

Long-term operation



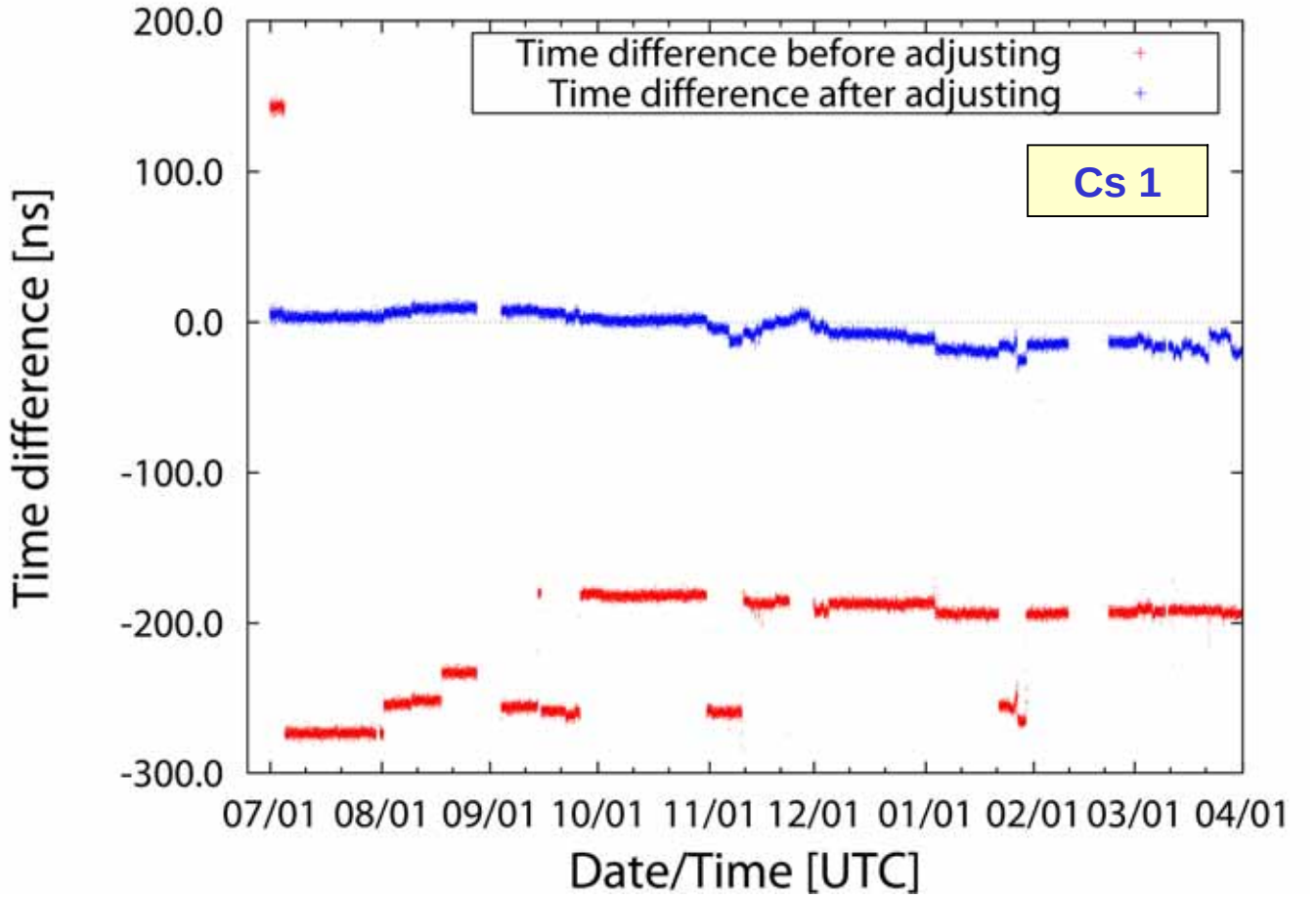
Data-offset → Network-link changed
usually offset time is different for up-link and down-link

Link-change problem

Evaluating data-offset

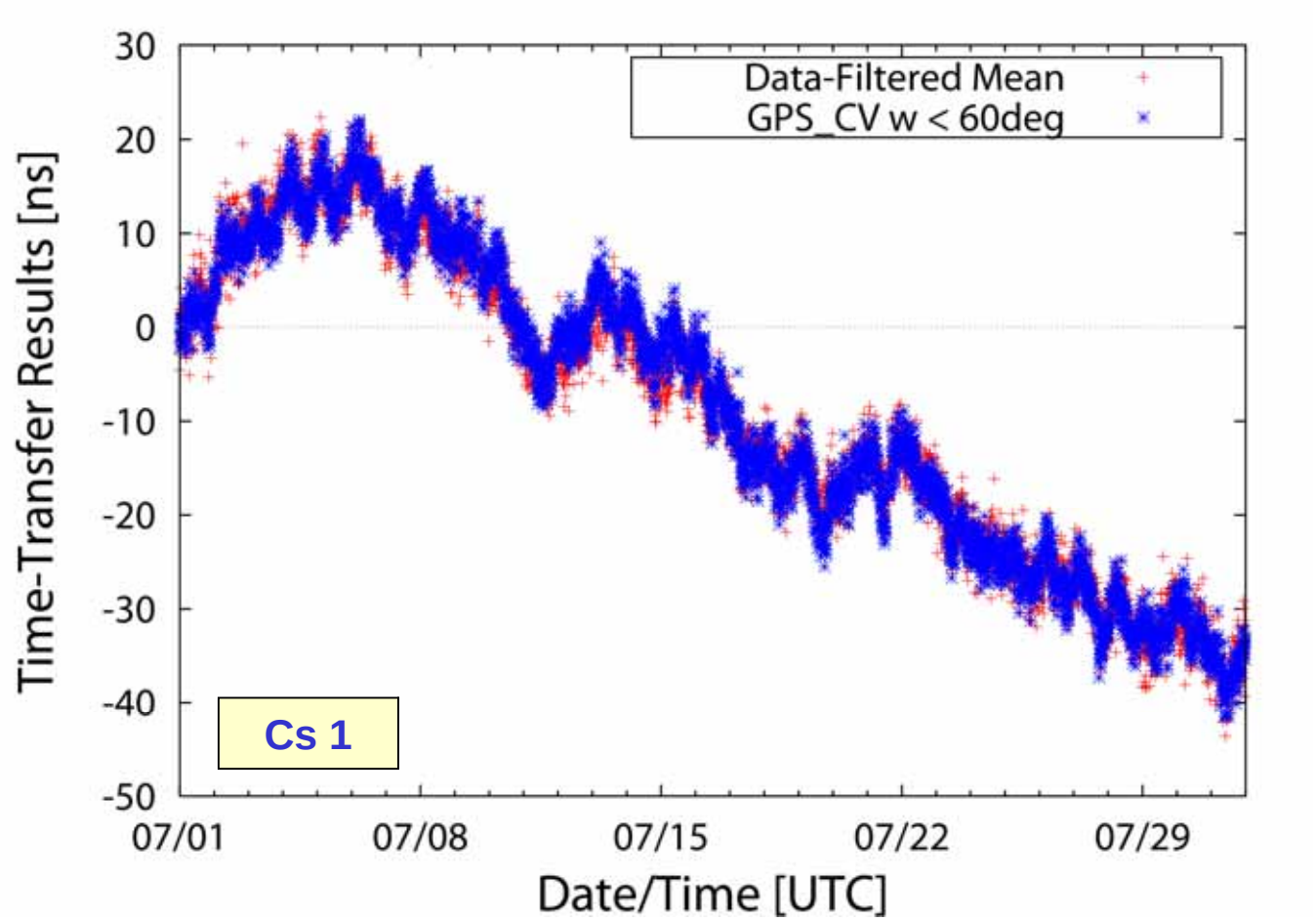
- Premise
  - Data sequence: almost linear for limited length
  - Before calculation: determine number of data lengths for linear prediction for up-link and down-link & available data area (error-bar)
- Calculate data-error for sampled mean data
  - If an error occurs successively more than twice, evaluate data-offset so that error is minimized

Effect of adjusting data-offset(1)



Compare with time-interval counter results

Effect of adjusting data-offset(2)

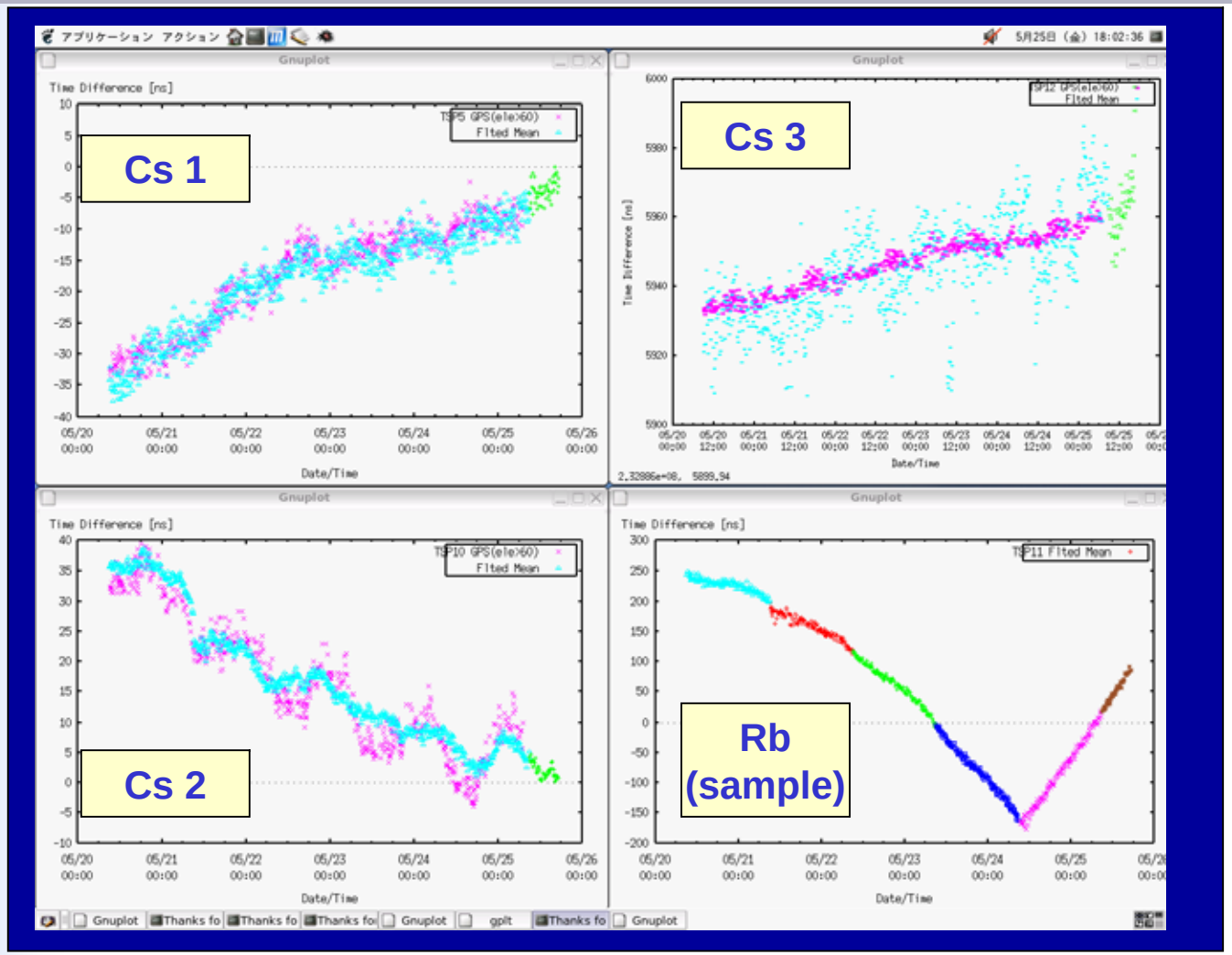


Almost same as high-accuracy GPS CV

Adjusting data-offset

- Effective
  - Network-link simply changed
- Unacceptable
  - Network suspended for long periods

Example of Real-time operation



Cs data

Purple: GPS CV

Cyan : D-F mean
(until yesterday)

Green : D-F mean
(real-time data)

Operation table for Cs1, Cs2, Cs3 and Rb

Summary of uncertainties

- Software processing
  - Developed Simple-NTP (SNTP) board
- Network time-transfer delay
  - Developed Data-filtering Method
- Network condition
  - Adjusted data-offset for up-link & down-link

Accurate time-transfer is available on high-speed Internet