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An Experiment Study for Time Synchronization Utilizing USRP and GNU Radio

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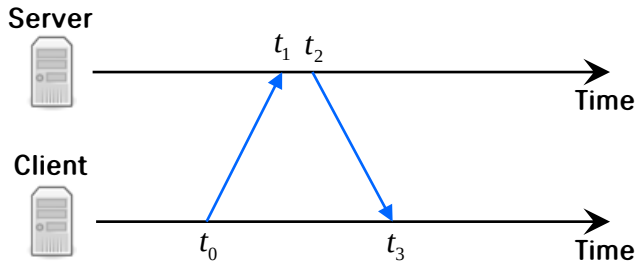
Introduction

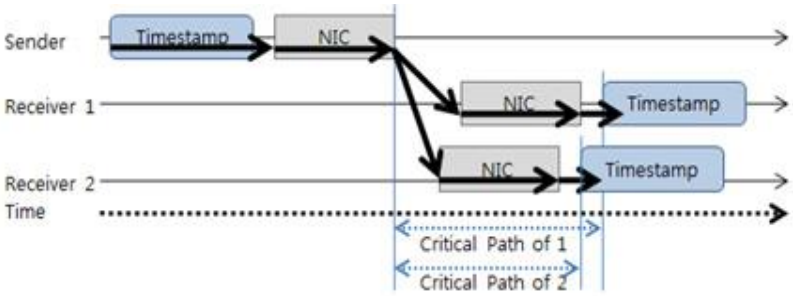
Introduction (1/2)

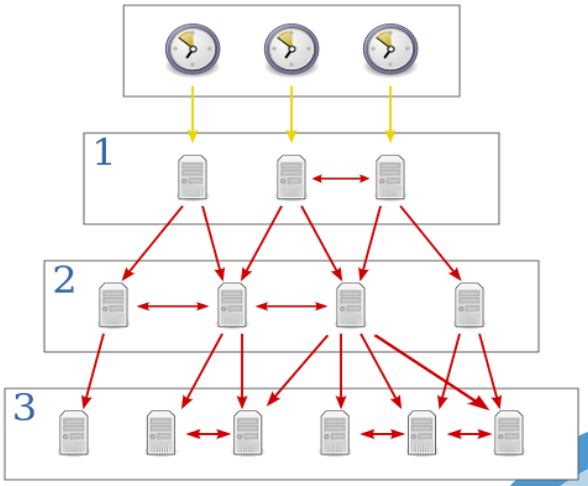
- Time synchronization
  - Core technology in various fields using Internet based network services
    - Geodesy, Weather
    - Defense, GNSS (Global Navigation Satellite System)
    - Finance, Communication, Medical service

Introduction (2/2)

- **Time synchronization method**
  - **Wired time synchronization**
    - NTP (Network Time Protocol)
    - Ethernet
  - **Wireless time synchronization**
    - RBS (Reference Broadcast Synchronization)
    - TPSN (Timing-sync Protocol for Sensor Networks)
    - GNSS

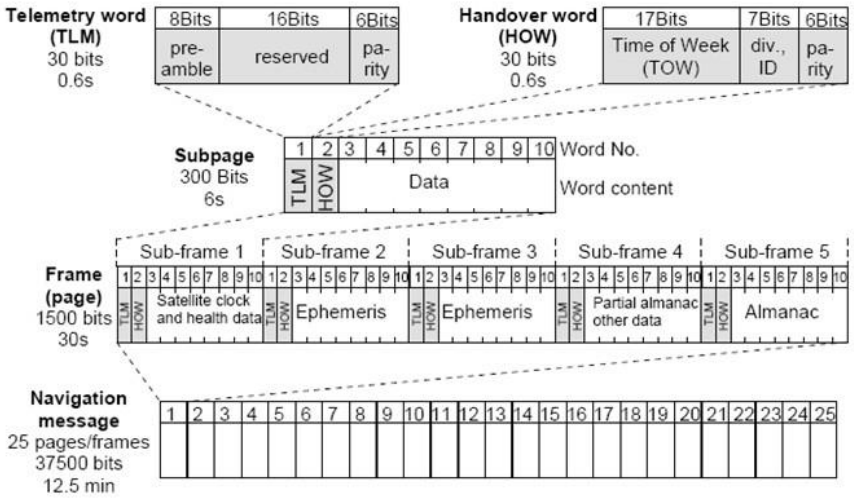


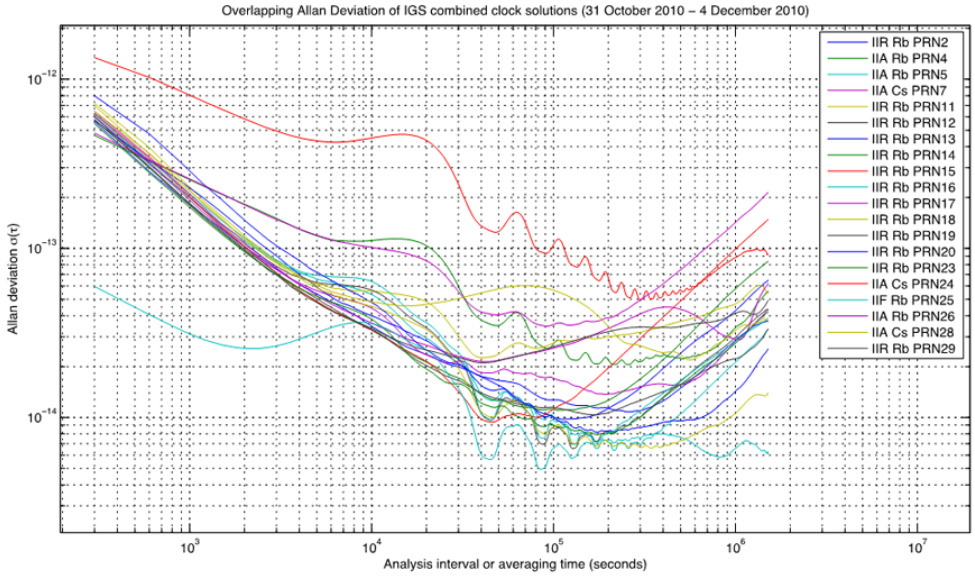




Motivation (1/2)

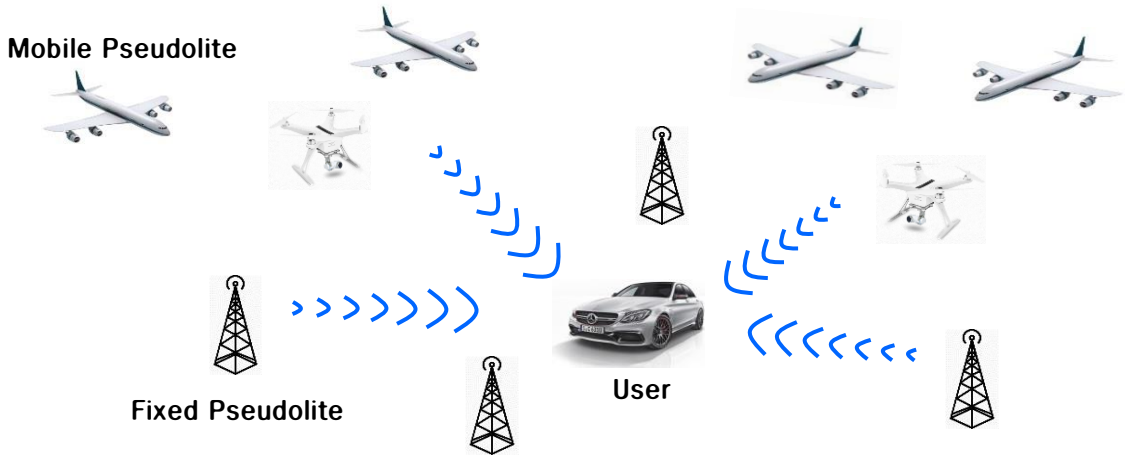
- GNSS time synchronization
  - GNSS navigation message based time synchronization
    - Including signal transmission time information
  - 3~4 Cesium (Cs) & Rubidium (Rb) atomic clocks are mounted in GNSS satellite
    - Highly precise oscillation accuracy





Motivation (2/2)

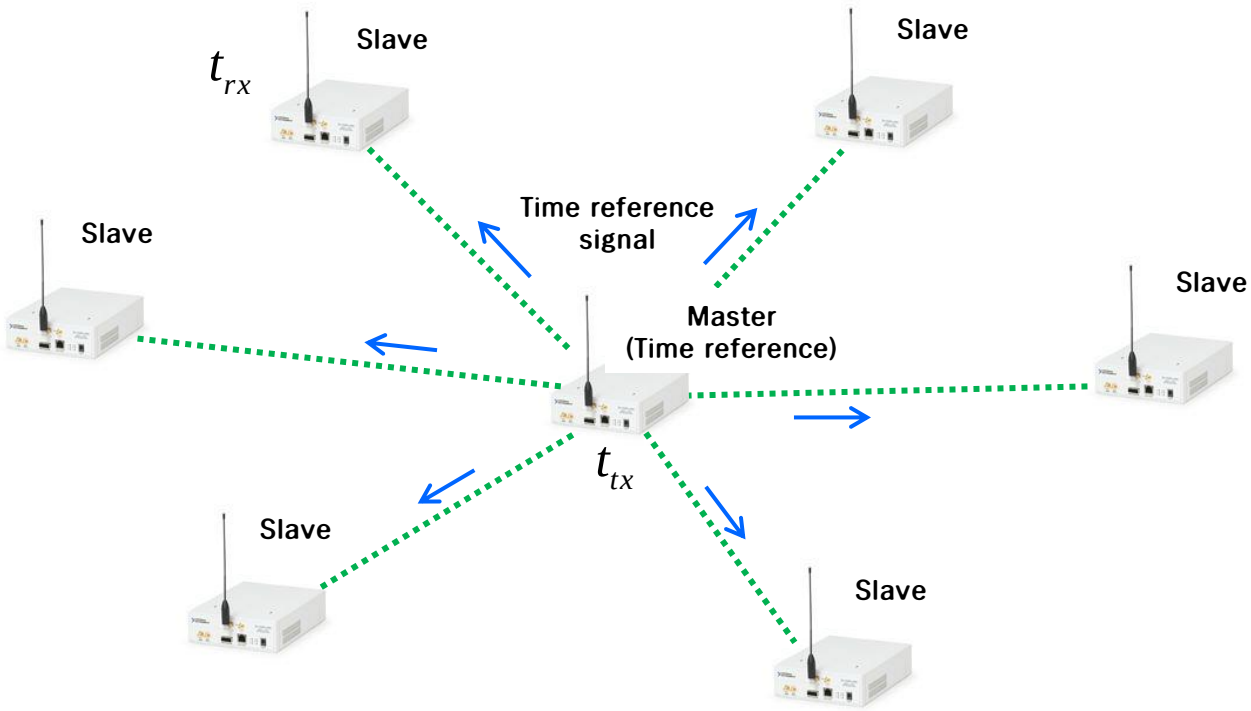
- In case of non-GNSS
  - Standalone positioning utilizing pseudolite
    - Ground-fixed
    - Mobile
  - Separate time synchronization method between pseudolites must be needed
    - TDOA (Time Difference Of Arrival)
      - ✓ Receiver time does not require for synchronize to the transmitters time



Designed synchronization method

Designed method (1/5)

- Time synchronization concept
  - SDR-based time synchronization utilizing USRP, GNU Radio
    - Transmission time : t_{tx}
    - Reception time : $t_{rx,N}$, N is the number of slaves
    - Goal : Minimize $t_{rx,N} - t_{tx}$ (compensated travel time)

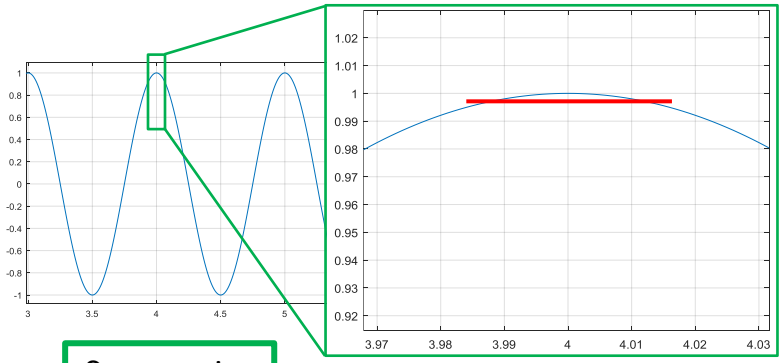


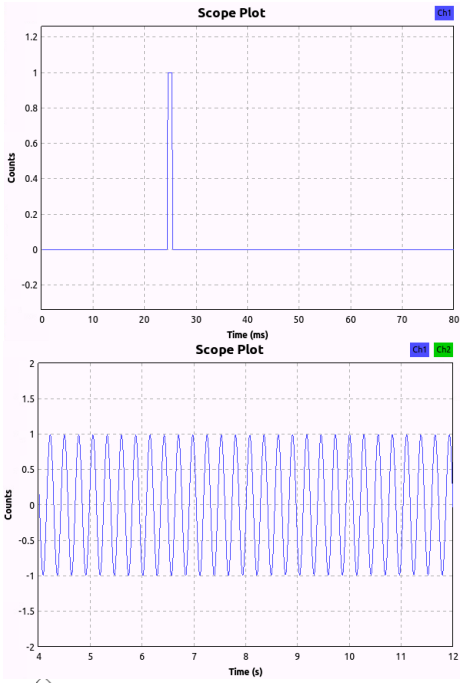
Designed method (2/5)

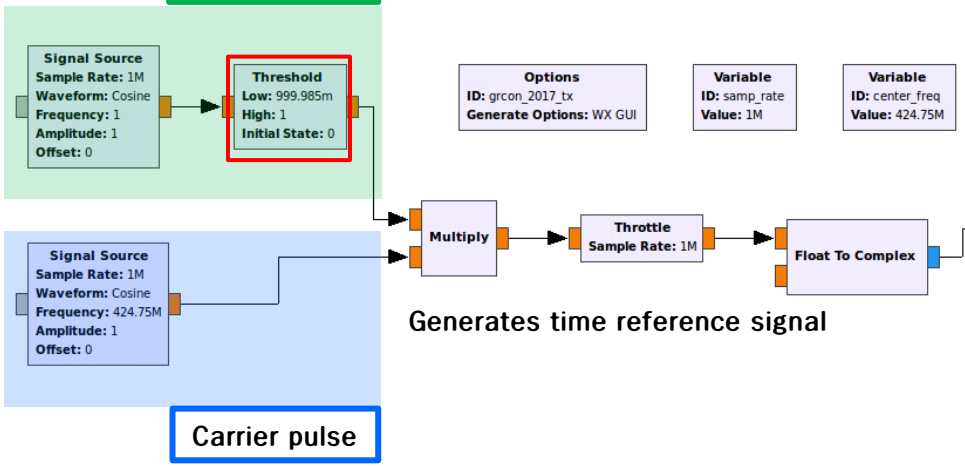
Generation and Transmission of time reference signal

Time Reference USRP(Clock source)

- PPS signal







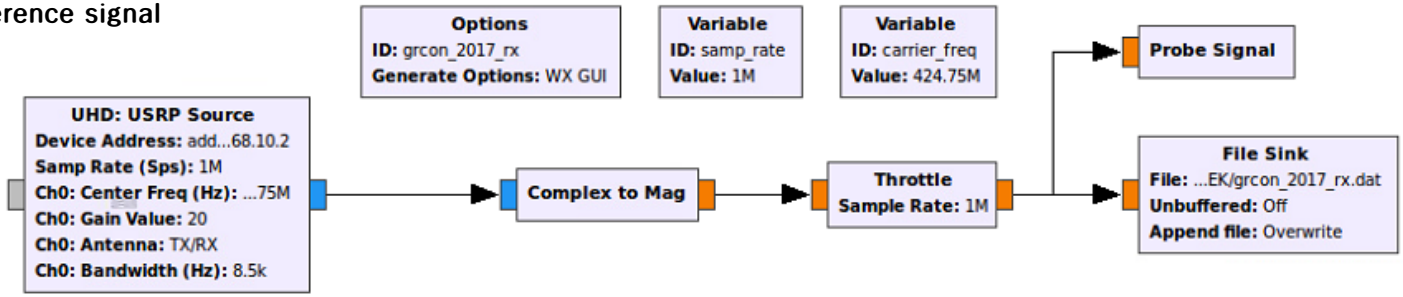
Generates time reference signal

Transmit time reference signal
(PPS signal)

Designed method (3/5)

- **Reception and Detection of time reference signal**
  - Slave USRP
    - Time synchronize to the reference signal

Receive time reference signal



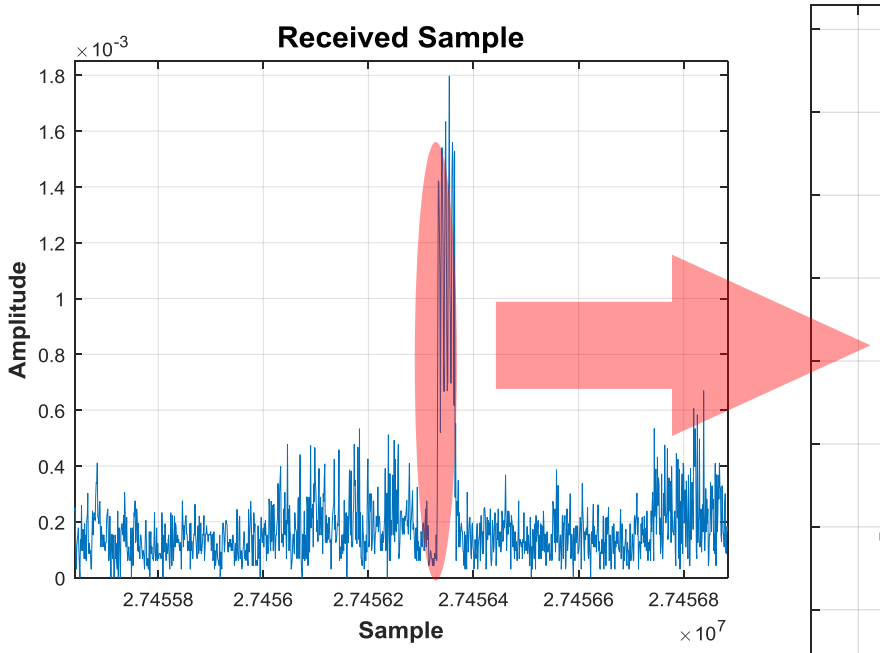

```
##################################################
# Blocks
##################################################
self.probe = blocks.probe_signal_f()
f = open('grcon_2017_rx2.log', 'w')
f.write("Rx2 Logging start\n")
f.close()

def _variable_function_probe_0_probe():
    temp = 0
    while True:
        val = self.probe.level()
        diff_val = val - temp
        print(diff_val)
        temp = val
        f = open('grcon_2017_rx2.log', 'a+')
        if abs(val) > 0.2 and abs(diff_val) > 0.2:
            self.uhd_usrp_source_0.set_time_now(uhd.time_spec_t(0.0),0)
            now_time = "%10.8f\n" % self.uhd_usrp_source_0.get_time_now().get_frac_secs()
            f.write(now_time)
            f.close()
    try:
        self.set_variable_function_probe_0(val)
    except AttributeError:
        pass
```

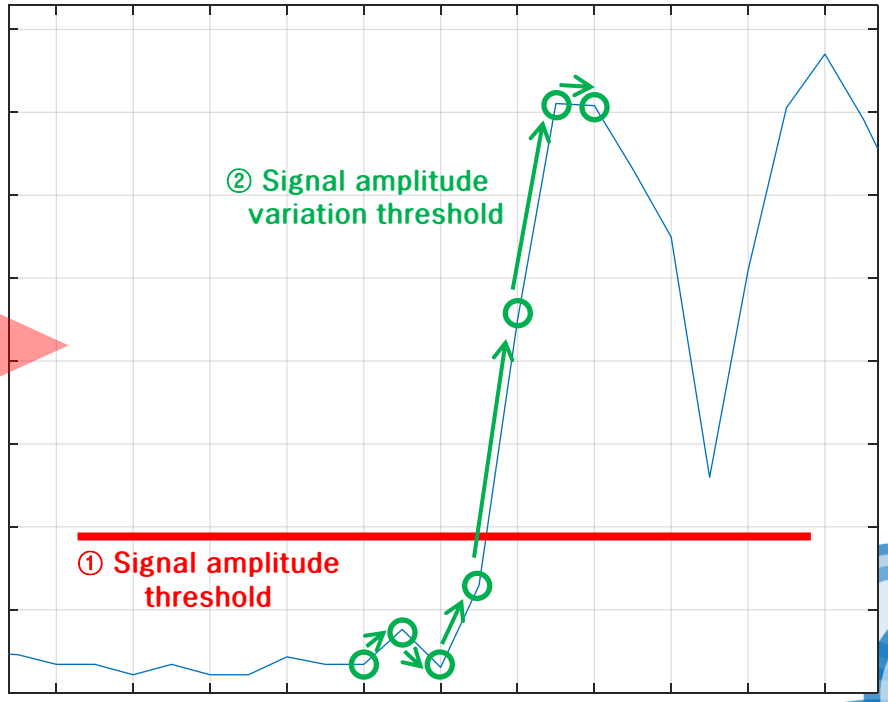
Python based valid signal determination

Designed method (4/5)

Valid signal determination

- Dual threshold method (First sample of rising edge)
  1. Signal amplitude
  2. Signal amplitude variation

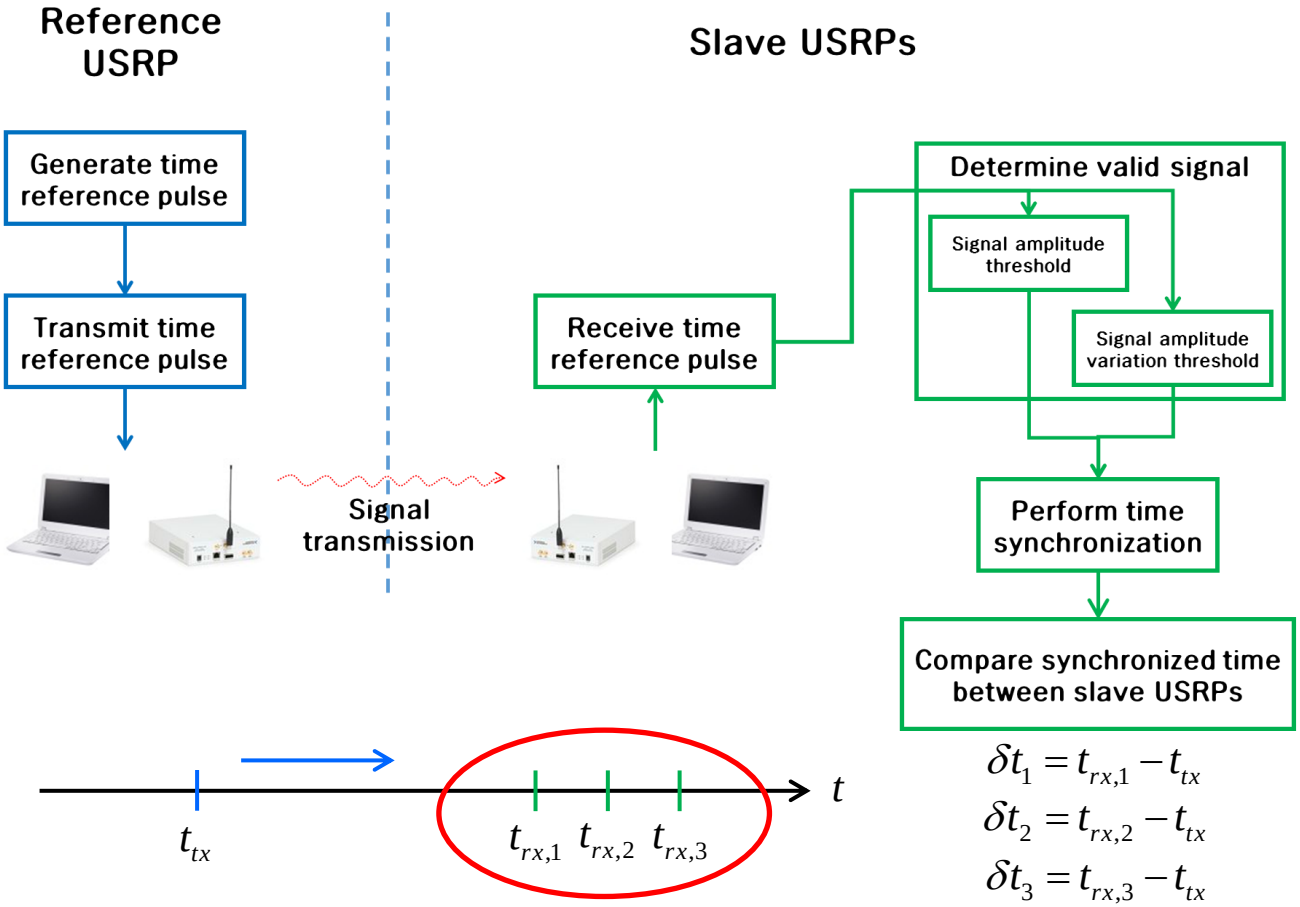




Designed method (5/5)

Synchronize time between USRPs

Operational flow



Experiment

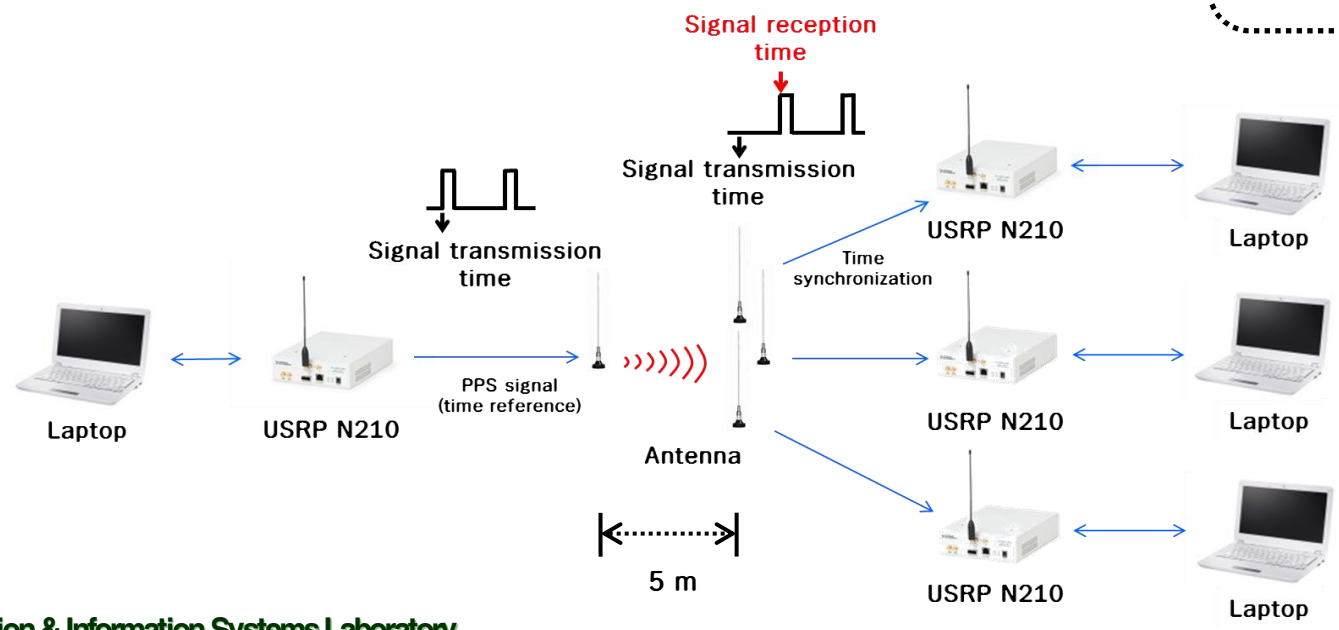
Experiment (1/4)

Experiment configuration

- Experiment equipment
  - USRP N210 (rev.4 : SBX) : 4 EA
  - Laptop PC : 4 EA
  - UHF antenna : 4 EA
- Carrier frequency : 424.75 MHz
- Sampling rate (f_s) : 1 Msps (Mega Samples per second)

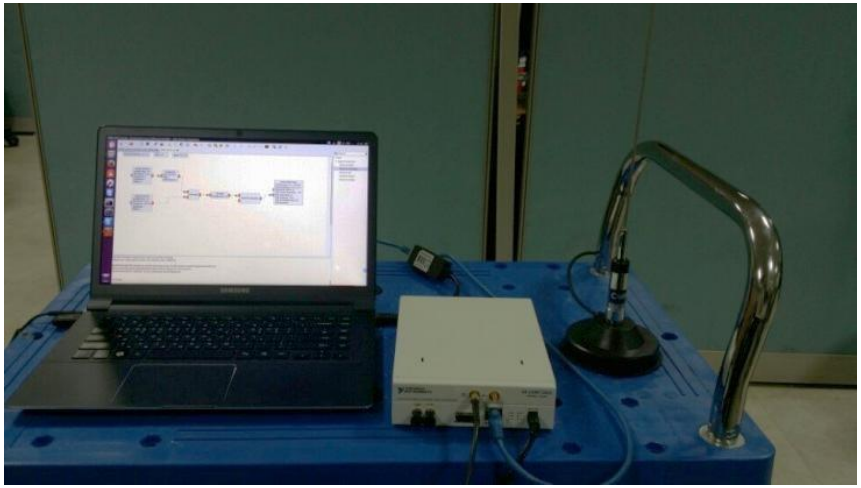
$$T_s = \frac{1}{f_s} = 10^{-6} \text{ sec}$$

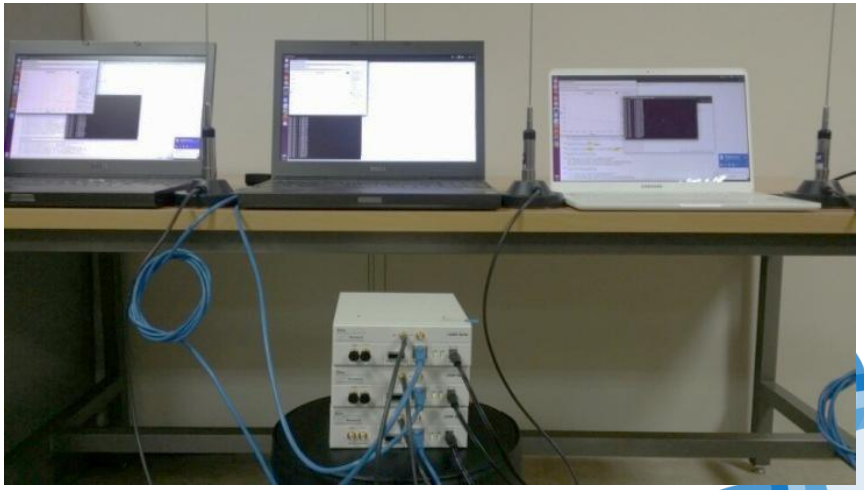
$$r_s = T_s \times c = 300 \ m$$



Experiment (2/4)

- **Experiment configuration**
  - Reference USRP
    - Generation and transmission a time reference signal during 10 minutes
  - Slave USRPs
    - Confirmation of the time synchronization accuracy by comparing the signal reception time of USRPs
      - Mean, Standard deviation of synchronized time

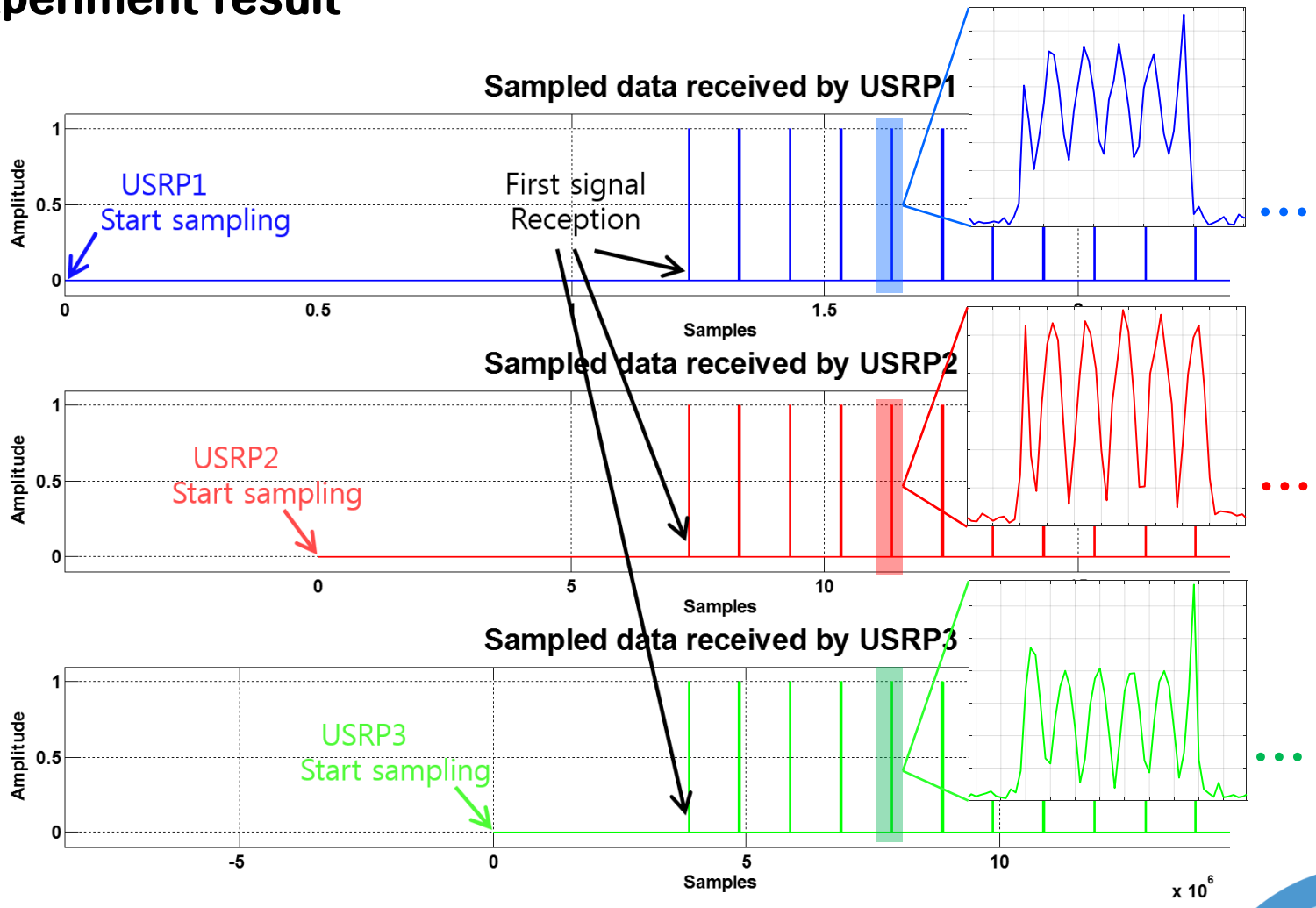




Distance(clock source ⇔ slave) : 5 m

Experiment (3/4)

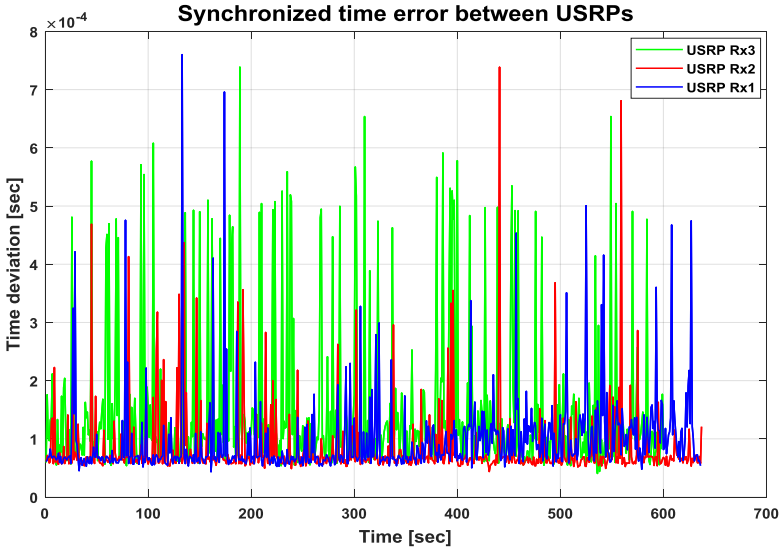
- Experiment result



Experiment (4/4)

Experiment result

- Uses a low-precision time reference signal compared to a method that provides very precise & stable clock pulses
  - 2.5 ppm (USRP) vs 0.0001~0.001 ppb (atomic clock)
- Heavily influenced by processing speed of host PC
- Synchronized-time error
  - From tens to hundred microseconds



Unit : μ sec

	USRP Rx1	USRP Rx2	USRP Rx3
Mean	96.64	83.21	144.98
Standard deviation	69.94	64.28	126.99

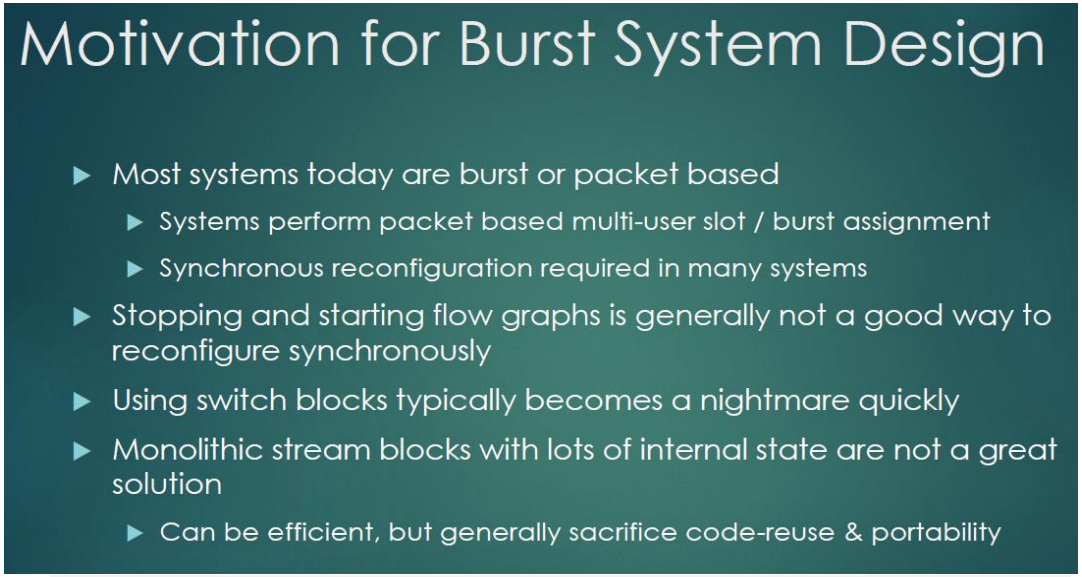
Conclusion with Future work

Conclusion

- Designed and implemented a simple PPS-based time synchronization method utilizing USRP and GNU Radio as an initial study of SDR-based time synchronization
- Generated a USRP-based separate clock source instead of a GNSS-based clock source
- Although accuracy deteriorates, it was confirmed that the time synchronization between USRPs can be achieved within a certain error range
- Evaluated the feasibility of time synchronization scheme by GNU Radio based algorithm
  (signal generation, transmission, reception, and processing)

Future work (1/2)

- **Code optimization & host performance improvement**
  - Time synchronization accuracy is affected by the efficiency of source code
    - TSB(Tagged Stream Block) & PDU(Message Connection) (C++ API)
    - Reduction of synchronous time
  - Time synchronization accuracy is affected by host computer performance in terms of sampling rate



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Future work (2/2)

- **Increasing sampling rate**
  - Reduction of time interval between samples
    - Improves time-axis resolution
    - More precise time synchronization can be achieved
- **Precise detection method**
  - In case of long-distance time synchronization (> 1km), the received signal amplitude will be highly-attenuated
  - Detection algorithm for highly-attenuated signal should be designed
- **PRN code & matched filter**
  - Cross-correlates with predetermined information
- **Message-based time reference signal**
  - More accurate synchronization can be possible

THANK YOU

Q&A