Feasibility of S-plane configuration for Shared Radio Units among Mobile Network Operators

Hirofumi Yamamoto¹ᵃ), Keita Takahashi¹, Tatsuya Shimada¹, and Tomoaki Yoshida¹
¹ NTT Access Network Service Systems Laboratories, NTT Corporation
1-1 Hikarinooka Yokosuka-shi, Kanagawa 239-0847, Japan
a) hirofumi.yamamoto.cz@hco.ntt.co.jp

Abstract: With the expansion of 5G mobile network, a large number of installation sites for small cell base stations are required, and the base station needs to be a more compact space.
To solve this problem, we propose an S-plane configuration for the shared radio unit (RU) among mobile network operators.
In addition, we propose the "Flunkey Clock" configuration as the PTP slave function mounted on the shared RU, and the feasibility of this system is verified and explained.

Keywords: Time synchronization, Precision time protocol, 5G mobile, Infrastructure sharing
Classification: Network system

References

[1] MEF Forum,"MEF White Paper Slicing for Shared 5G Fronthaul and Backhaul", Apr 2020
[2] O-RAN.WG4.CUS.0-v03.00 Technical Specification O-RAN Fronthaul Working Group Control, User and Synchronization Plane Specification, Mar 2020.
[3] IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems, IEEE Std 1588™-2008, July 2008.
[4] Precision time protocol telecom profile for phase/time synchronization with full timing support from the network, ITU-T G.8275.1/Y.1369.1, Mar 2020.
[5] Precision time protocol telecom profile for phase/time synchronization with partial timing support from the network, ITU-T G.8275.2/Y.1369.2, Mar 2020.
1 Introduction

A large number of small cell base stations is necessary to expand a 5G service area. In case of that each mobile network operator (MNO) installs base stations respectively, many installation spaces are required, and the limited equipment has become an issue (Fig. 1 (a)). One solution is infrastructure sharing in which MNOs share base stations [1]. As a means of infrastructure sharing, we propose a solution for confined spaces in which a remote radio unit (RU) is shared among MNOs (Fig. 1 (b)).

A shared RU refers to infrastructure sharing facilities that share RUs for each MNO. The shared RU is connected to a distributed unit (DU) for each MNO, and the signals flowing between them consist of a U/C/M/S-Plane (user/control/management/synchronization) [2]. In the S-plane, the IEEE 1588 -2008 Precision Time Protocol (PTP) [3] is adopted as a time synchronization protocol, and it is used to establish the synchronization between a DU and shared RU. The shared RU requires only one synchronous source (sync-source) to prevent radio interference. Therefore, the shared RU requires a sync-source to establish synchronization with any of the MNO’s DUs.

However, there are two issues with this configuration. One is that DUs other than the sync-source DU cannot establish a synchronization sequence (sync-sequence) with the shared RU only by connecting DU and shared RU. Therefore, they stop transmitting a U- and C-plane to the shared RU [2]. The other hand is that if the sync-source DU fails, the shared RU cannot acquire synchronization information (sync-info) from the DU and enters the FREERUN state and stops the RF transmissions of all MNOs [2]. As far as we know, such an implementation configuration of the shared RU to solve these issues has yet to be considered.

In this paper, we propose a S-plane configuration of the shared RU with a master selector. In addition, to reduce the circuit scale, we propose an improved RU configuration in which the shared RU establishes a pseudo sync-sequence between DUs other than the sync-source DU by using a pseudo signal and verify the feasibility of this configuration.

2 Proposal

The proposal S-plane configuration is illustrated in Fig.2(a). The sync-sequence between each DU and shared RU is described as below:
The master selector decides a sync-source from PTP master #1-#N. At this time, assume that #X is determined to PTP master. This letter does not mention PTP master selection methods of the master selector such as best master clock algorithm [3].

Each sync-info extractor receives a sync-info from each PTP master, and sends a sync-info to each time information comparison function. At the same time each sync-info extractor sends a sync-info to each PTP master to establish sync-sequence.

In the time information comparison function, each difference of clock value...
between each PTP master and sync-source is calculated respectively. 
(A4) The only calculation result of the time information comparison function \#X 
is sent to the accuracy correction calculator. 
(A5) The accuracy correction calculator modifies the Timer with differential 
results corresponding to the determined sync-source. 
Fig. 2(a) solves the aforementioned two issues. The first issue is solved by 
mounting the PTP slave function corresponding to all PTP masters in the shared 
RU. The second issue is solved by mounting the master selector. When the sync-
source DU fails, the master selector decides other sync-source and the above 
procedure runs again to prevent the shared RU from entering the FREERUN 
state.

In addition, we propose Fig. 2(b) which is called the “Flunkey Clock” 
configuration as an improved shared RU configuration from the perspective of 
the circuit scale compared with Fig. 2(a). The PTP slave function shown in 
Fig. 2(a) can be replaced with a switch and a pseudo signal generator. The master 
selector instructs the switch to connect interface (IF) and sync-info extractor 
corresponding to sync-source DU, and procedures (A1)-(A5) are conducted. On 
the other hand, the master selector instructs the switch to IF and pseudo signal 
generator corresponding to DU other than sync-source DU. And DU other than 
sync-source DU establish a sync-sequence with pseudo signal generator by using 
the pseudo signal as sync-info.
The pseudo signal generated by pseudo signal generator is discussed as follows. 
Fig. 2 (c) shows the Flunkey Clock frame format. The first 4 octets of the 
common header of the PTP message are defined as a specific value indicating 
“Delay_Req”. In ITU-T G. 8275.1 [4]/2 [5], when the field value specified by the 
PTP clock in the PTP profile is beyond the permissible range, a pseudo value is 
inserted into a mandatory field to update the local data, considering that the 
information is unnecessary for establishing a sync-sequence. In addition, among 
the delivery parameters from the PTP master specified in [2], the domain number 
and unicastFlag fields, which are permissive values of the RU, should be values 
that agree with those of the PTP master. In this improved shared RU 
configuration, if sync-source DU fails, the master selector decides new sync-
source and switch to connect a new sync-source DU. It is not necessary to 
conduct a new sync-sequence.

3 Verification, Results and Consideration
To confirm the feasibility of the Flunkey Clock configuration, we evaluated the 
sync-sequence and some performances using the measurement system shown in 
Fig. 3 (a). First, a frame shown in Fig. 2 (c) was output from the pseudo signal 
generator, and a response packet from the PTP master was then captured using 
the port mirroring function of the L2SW. Fig. 3 (b-1) shows the capture results. 
Using the pseudo signal specified by the Flunkey Clock configuration, it was 
confirmed that the PTP master recognized the Delay-Req frame and responded 
with a Delay-Resp frame. Thus, the pseudo signal showed that the sync-sequence 
of the PTP master was working correctly.
(a) Test configuration

(3) Send pseudo signal
(2) Switch slave
(2) Traffic Generator
(5) Switch slave
(6) Capture device
(7) Port mirror
(1) Send PTP Slave conventional signal

(4) Whether to respond to Delay Resp
(8) Time & frequency synchronization system
(6) Comparison of T1/T4 Time Error

(b) Test results

| No. | Time     | Source          | Destination      | Protocol | Length Info |
|-----|----------|-----------------|------------------|----------|-------------|
| 7758 | 120.95671 | 192.168.4.100   | 192.168.4.101    | PTPv2    | 118 Announce Message |
| 7759 | 120.95672 | 192.168.4.100   | 192.168.4.101    | PTPv2    | 96 Sync Message         |
| 7760 | 120.95673 | 192.168.4.100   | 192.168.4.101    | PTPv2    | 95 Delay Resp Message     |
| 7761 | 120.95674 | 192.168.4.100   | 192.168.4.101    | PTPv2    | 803Sync Message          |
| 7762 | 120.95675 | 192.168.4.100   | 192.168.4.101    | PTPv2    | 803 Sync Message          |
| 7763 | 120.95676 | 192.168.4.100   | 192.168.4.101    | PTPv2    | 803 Sync Message          |
| 7764 | 120.95677 | 192.168.4.100   | 192.168.4.101    | PTPv2    | 803 Sync Message          |
| 7765 | 120.95678 | 192.168.4.100   | 192.168.4.101    | PTPv2    | 803 Sync Message          |
| 7766 | 120.95679 | 192.168.4.100   | 192.168.4.101    | PTPv2    | 803 Sync Message          |
| 7767 | 120.95680 | 192.168.4.100   | 192.168.4.101    | PTPv2    | 803 Sync Message          |
| 7768 | 120.95681 | 192.168.4.100   | 192.168.4.101    | PTPv2    | 803 Sync Message          |
| 7769 | 120.95682 | 192.168.4.100   | 192.168.4.101    | PTPv2    | 803 Sync Message          |

(b-1) Sequence of PTP master and pseudo signal proposed in the “Flunkey Clock” configuration

(b-2) Synchronization accuracy (T1/T4 Time Error) of conventional PTP slave

(b-3) Synchronization accuracy when switching from the pseudo signal to conventional PTP slave

Fig. 3. Test configuration and results
Second, to confirm that the PTP master operation is not affected by the pseudo signal specified by the Flunkey Clock configuration, we measured the synchronization accuracy of only conventional PTP slaves (T1/T4 Time Error [3]) and that when switching from the pseudo signal to conventional PTP slaves, and compared these results. In Fig.3 (b-2) and (b-3), the T1/T4 Time Error accuracy includes the offset value and fluctuation by inserting the L2SW into the measurement system to capture the sequence between the PTP master and slave. As a result, we confirmed that there was no difference between the synchronization accuracy of the PTP master port to the conventional PTP slave (the maximum, minimum, and average values of |T1/T4 Time Error| are 3.9, 3.4, and 3.6 µs, respectively, in Fig.3 (b-2) and the same in Fig.3 (b-3)) and that the pseudo signal has no effect on the PTP master. From the verification result of these two points, the feasibility of the pseudo signal generated by the “Flunkey Clock” configuration was shown.

4 Conclusion
To solve the problem of sharing RU facilities, we proposed an S-plane configuration for the shared RU among MNOs, which is resistant to faults of the DU selected as the sync-source of the shared RU. We also propose the "Flunkey Clock" configuration to reduce the circuit scale and more easily implements the S-plane configuration. In our verification test, the proposed methods demonstrated that the sync-sequence works by using the “Flunkey Clock” configuration for the PTP master that is not selected by the shared RU, and we confirmed that the PTP slave can be replaced by the pseudo signal generator.