

of the reception time of the second data 402 recorded by the recording unit 230.

[0066] In step S25, the transmission unit 210 of the master device 200 transmits, as the fourth data 404, data for reporting the corrected value of the reception time of the second data 402 calculated by the correction unit 240 to the time synchronization device 300.

[0067] In step S26, the reception unit 310 of the time synchronization device 300 repeatedly receives the fourth data 404 from the master device 200.

[0068] In step S27, each time the second data 402 are transmitted by the transmission unit 320, the recording unit 330 of the time synchronization device 300 records the transmission time of the second data 402 at the transmission unit 320 by using the slave clock 301.

[0069] In step S28, each time the transmission time of the second data 402 is recorded by the recording unit 330, the correction unit 340 of the time synchronization device 300 generates a random number, and uses the generated random number to calculate a corrected value of the transmission time of the second data 402 recorded by the recording unit 330.

[0070] As will be described below, for calculation of the offset 405, the synchronization unit 350 of the time synchronization device 300 uses the corrected value of the transmission time of the second data 402 calculated by the correction unit 340 as the transmission time of the second data 402.

[0071] In the present embodiment, a communication procedure of sequentially transmitting and receiving the first data 401, the second data 402, the third data 403 and the fourth data 404 one by one is repeated as described above.

[0072] Fig. 5 illustrates operation of calculating the offset 405.

[0073] In step S31, each time the first data 401 are received by the reception unit 310,

$$((T_{s1}' - T_{m1}') - (T_{m2}' - T_{s2'}))/2, \text{ or } T_{\text{offset}} = (T_{m2}' - T_{s2'}) - ((T_{s1}' - T_{m1}') + (T_{m2}' - T_{s2'}))/2 = -((T_{s1}' - T_{m1}') - (T_{m2}' - T_{s2'}))/2.$$

[0081] Example implementation of the master device 200 and the time synchronization device 300 will be described with reference to Fig. 6.

5 [0082] The functions of the reception unit 310 and the transmission unit 320 of the time synchronization device 300 are implemented by a PHY 302 and a media access control (MAC) 303. The PHY 302 and the MAC 303 are hardware included in the time synchronization device 300. Specifically, the PHY 302 is a chip to perform processing on a physical layer in the OSI reference model, and the MAC 303 is a chip
10 to perform processing on a data link layer the OSI reference model. Note that the PHY 302 and the MAC 303 may be integrated on one chip.

[0083] Similarly, the functions of the transmission unit 210 and the reception unit 220 of the master device 200 are implemented by a PHY 202 and a MAC 203. The PHY 202 is a chip to perform processing on a physical layer, and the MAC 203 is a chip
15 to perform processing on a data link layer.

[0084] The functions of the recording unit 330 of the time synchronization device 300 are implemented by a MAC driver 304. The MAC driver 304 is software mounted on the time synchronization device 300. Specifically, the MAC driver 304 is middleware used by an OS 305 to control and operate the MAC 303. The MAC driver
20 304 has a software timestamping function of generating a timestamp by using the slave clock 301.

[0085] Similarly, the functions of the recording unit 230 of the master device 200 are implemented by a MAC driver 204. The MAC driver 204 is middleware used by an OS 205 to control and operate the MAC 203. The MAC driver 204 has a software
25 timestamping function of generating a timestamp by using the master clock 201.

be stored can be changed as appropriate.

[0096] In step S44 in which the master device 200 transmits a Delay_Resp message as a synchronization frame, the time synchronization application 206 generates a synchronization frame that is a Delay_Resp message. The time synchronization application 206 stores, in the synchronization frame, a pair of uncorrected and corrected reception times T_{m2} and T_{m2}' stored in the last column among the pairs of uncorrected and corrected reception times T_{m2} and T_{m2}' stored in the fourth row and the sixth row, respectively, of the correction table 208, that is, the uncorrected and corrected reception times T_{m2} and T_{m2}' of the last Delay_Req message. Upon detecting that the synchronization frame is generated by the time synchronization application 206, the OS 205 activates prioritized interruption to input the synchronization frame prior to other frames to the MAC driver 204. The MAC driver 204 generates a software timestamp at the point when the synchronization frame is input. The MAC driver 204, however, only detects that the synchronization frame is a Delay_Resp message and temporarily holds the generated timestamp in a buffer or the like, and does not feed back the generated timestamp to the time synchronization application 206. Thereafter, the MAC driver 204 inputs the synchronization frame to the MAC 203. The MAC 203 transmits the synchronization frame from the PHY 202.

[0097] In step S54 in which the time synchronization device 300 receives a Delay_Resp message as a synchronization frame, the PHY 302 receives a synchronization frame from the master device 200. The PHY 302 inputs the received synchronization frame to the MAC 303. The MAC driver 304 generates a software timestamp at the point when it detects that the synchronization frame is input to the MAC 303. The MAC driver 304, however, only detects that the synchronization frame is a Delay_Resp message and temporarily holds the generated timestamp in a buffer or

the like, and does not input the generated timestamp to the time synchronization application 306. Thereafter, the MAC driver 304 inputs the synchronization frame to the time synchronization application 306 via the OS 305. The time synchronization application 306 detects that the synchronization frame input from the MAC driver 304 is a Delay_Resp message, and extracts the uncorrected and corrected reception times T_{m2} and T_{m2}' stored in the synchronization frame.

[0098] After step S54, the time synchronization application 306 calculates the offset 405 by using the uncorrected and corrected reception times T_{s1} and T_{s1}' stored in the first row and the third row of the correction table 308 in step S51, the uncorrected and corrected transmission times T_{m1} and T_{m1}' extracted in step S52, the uncorrected and corrected transmission times T_{s2} and T_{s2}' stored in the fourth row and the sixth row of the correction table 308 in step S53, and the uncorrected and corrected reception times T_{m2} and T_{m2}' extracted in step S54. The following calculation formula as described above can be used, but another formula may alternatively be used: $T_{offset} = (((T_{s1} + T_{s1}') - (T_{m1} + T_{m1}')) - ((T_{m2} + T_{m2}') - (T_{s2} + T_{s2}')))/4$, or $T_{offset} = -(((T_{s1} + T_{s1}') - (T_{m1} + T_{m1}')) - ((T_{m2} + T_{m2}') - (T_{s2} + T_{s2}')))/4$.

[0099] Subsequently, the procedure from step S41 to step S44 and the procedure from step S51 to step S54 are repeated.

[0100] *** Description of effects ***

In the present embodiment, since time recorded with use of a software clock is corrected, the time synchronization accuracy of the time synchronization scheme in software-based implementation is improved.

[0101] Second Embodiment

The description of the present embodiment will focus on differences from the