Consistent Data Synchronization with S7 Communication between several Substations and one Head PLC

S7-1500 / S7-300 / S7-1200 / STEP 7 (TIA Portal)

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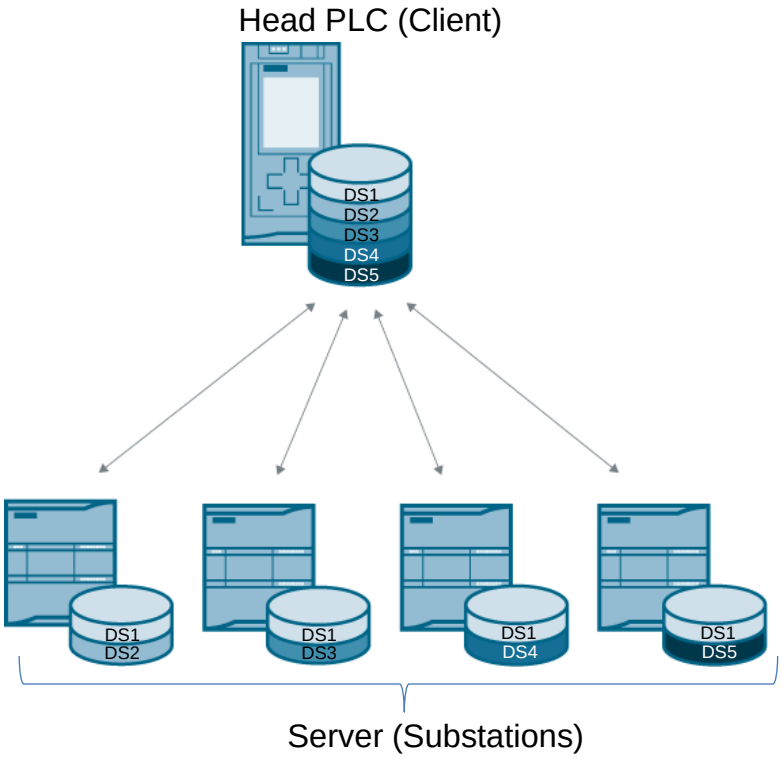
1 Task

Introduction

For central data management in an automation system with several substations, it is often a standard task to cyclically synchronize the data areas between a central head-end station and many distributed substations. One application of a head-end station as a data concentrator, for example, is reducing accesses of pages of a SCADA system to one PLC station only.

The figure below provides an overview of the automation task.

Figure 1-1



Description of the automation task

For consistent synchronization between a central client (head-end) and several servers (substations), blocks are prepared which handle the task using the S7 communication:

- supplying the servers (substations) with data records defined by the user (write synchronization).
- updating predefined data records from the servers (substations) with the client (head-end station) (read synchronization).
- using the write synchronization for synchronizing the system time of the substations with the system time of the head-end station.

Requirements for the automation task

The following requirements are posed to the application.

- The synchronization must be performed in a consistent manner.
- The write synchronization occurs event-triggered from the user program.
- The read synchronization from the servers (substations) to the client (head-end) occurs cyclically.
- The communication occurs via Ethernet using the S7 communication.
- The change of the quantity frameworks of the program (number of servers, size and position of the send or receive data volumes) shall be as simple as possible.
- It shall be possible to employ S7-CPUs of the S7-300/400 and S7-1500 as clients (head-end stations).
- In the application, S7-1200 CPUs are used as servers (substations).
- Programming is preferably performed in SCL.

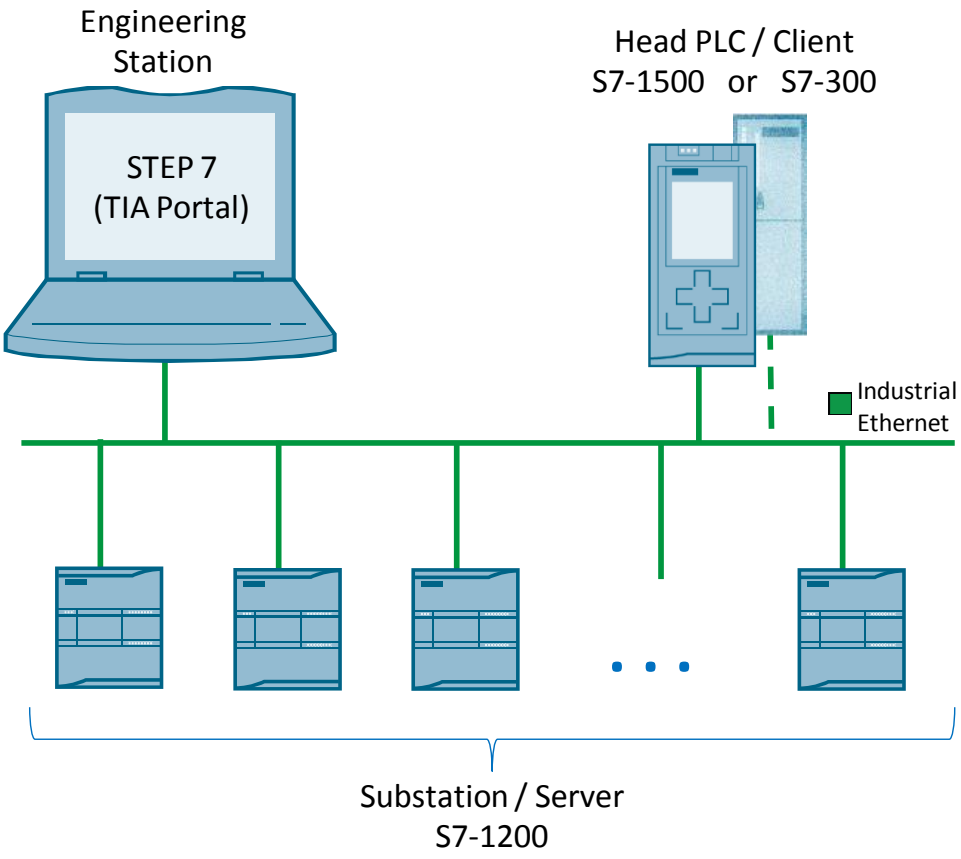
2 Solution

2.1 Overview

Display

The following figure gives a schematic overview of the most important components of the solution:

Figure 2-1



Structure

The structure maps an automation system with one head-end station and several substations, which in this application example are described as client (head-end) and server (substation).

The example component consists of

- one head-end station (S7-1500 or alternatively a S7-300)
- four substations (S7-1200).

Functions

The application example realizes the following functions:

Table 2-1

Function	Description	Quantity framework
Write synchronization (head-end → substation)	On demand, the application synchronizes configurable memory areas of the head-end station (client) with the substations (servers).	Maximal, data ranges of 160 Byte can be synchronized.
Cyclic, read synchronization (substation →head-end)	The head-end station (client) cyclically reads configurable memory areas from the substations (servers) (if new data is pending).	
Clock synchronization	On request, the head-end station (client) transfers the local system time to the substations (server) which can then adopt it.	

The S7 communication is used for synchronization via Industrial Ethernet. The S7 communication via PUT and GET blocks is based on a server-client concept. The server passively stores data which the client can then process via PUT and GET blocks.

Advantages

The solution introduced here offers you the following advantages:

- Configurable size and storage location of the data areas to be synchronized.
- Scalable project for application of more or less than four substations (only dependent on the S7 communication connections maximal available in the head-end station).
- Modular program setup. Both synchronization directions can be used in your applications independently of each other.

Delimitation

This application does not include

- a description of the S7 protocol.
- an introduction into programming with STEP 7 (see \3\).

Basic knowledge of these topics is assumed. Chapter 7.2 gives information on further literature.

Validity

This application is valid for

- STEP 7 as of V15.1
- SIMATIC S7-300
- SIMATIC S7-1200
- SIMATIC S7-1500

2.2 Required hardware and software components

This application was generated with the following components:

Hardware components

Table 2-2

Component	No.	Order number	Note
CPU315-2 PN/DP	1	6ES7315-2EH14-0AB0	Alternatively, another CPU with Ethernet interface from the SIMATIC S7-300 product range can also be used.
CPU1516-3PN/DP	1	6ES7516-3AN01-0AB0	As an alternative, you can also use a different CPU from the SIMATIC S7-1500 product range.
CPU 1212C DC/DC/DC	4	6ES7212-1AE31-0XB0	Alternatively, another CPU with Ethernet interface from the SIMATIC S7-1200 product range can also be used.
SCALANCE X208	1	6GK5208-0BA10-2AA3	Other switches for networking the CPUs can also be used.
PM 190W 120/230VAC	1	6EP1333-4BA00	Other power supplies for connecting the CPUs can also be used.

Note If hardware different from that in the sample project is used, the hardware configuration has to be modified accordingly!

Software components

Table 2-3

Component	No.	Order number	Note
STEP 7 Professional V15.1	1	6ES7822-1..05-..	with Update 2

Sample files and projects

The following list includes all files and projects that are used in this example.

Table 2-4

Component	Note
40556214_S7-Comm_Sync_TiaV15.1_PROJ_V2.1	This zip file contains the STEP 7 project.
40556214_S7-Comm_Sync_DOC_V2.1_en.pdf	This document.

2.3 Performance data

2.3.1 Synchronization speed

Parameters

Performance measurements were performed for an overview of the performance of the application example.

The measured scenarios differ in the following points:

- Type of head-end station
- Number of substations
- program load

Table 2-5 shows the value range of the performance-relevant parameters.

Table 2-5

Parameters	Settings
Type of head-end station	CPU1516-3 PN/DP; CPU315-2 PN/DP
Number of substations	1; 4; 8; 14
Program load in head-end station and substations	6ms; 50ms
Size of the area to be synchronized	160 bytes

Measurement

The write synchronization from a head-end station (client) to several substations (servers) with a parallel performed read synchronization was measured. Start time of the measurement is the incoming trigger for the synchronization. The measurement is terminated after all substations have been synchronized once.

Measurements

Each measuring point in the following diagrams is measured 100 times and then averaged.

Figure 2-2: 160 bytes, 6 ms program load

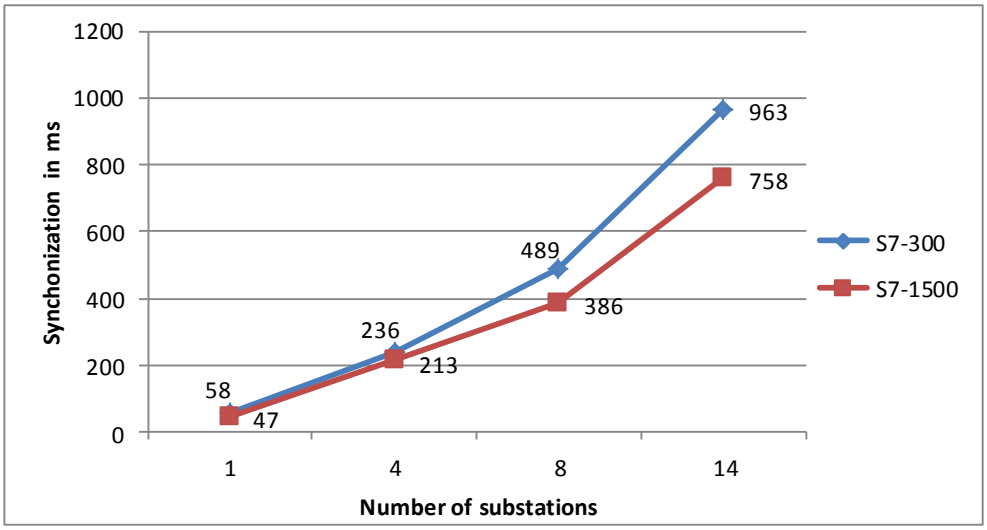
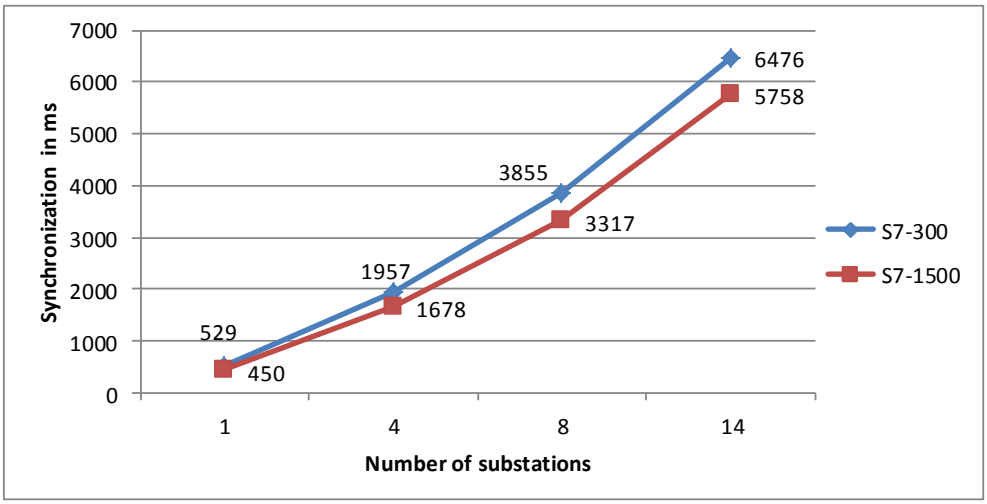


Figure 2-3: 160 byte, 50 ms program load



Observations

The following observations can be derived from the measurement:

- The S7-1500 synchronizes the servers quicker than the S7-300 (for a program load of 50ms and 14 substations to be synchronized, the difference is approximately one second).
- The cycle time increases approximately linear with the number of substations.
- For a lower program load, the synchronization time does not become larger than one second even for 14 substations.

2.3.2 Number of substations

The maximal possible number of substations only depends on the type of the used head-end controller and is available in the technical data.

Table 2-6

Head-end station	Number of connections
CPU 315-2PN/DP (6ES7 315-2EH14-0AB0)	maximal 14 connections for the S7 communication See \8\
CPU 1516-3 PN/DP(6ES7 516-3AN00-0AB0)	maximal 256 connections, 10 of which reserved for ES/HMI/Web See \9\

2.4 Alternative

Open communication

The synchronization of data areas can also be performed via open communication instead of S7 communication.

Differentiation

When using S7 communication, configured connections are accessed which statically assign communication reserves of the communication partners.

When using open communication (TCP/IP, ISOonTCP), the connections can be programmed and established or terminated in the user program.

If you wish to synchronize more nodes than the parallel connections which a CPU can establish, then you need to establish and terminate connections via the open communication (“multiplexing”). In contrast to S7 communication, the open communication provides this option.

Application example

The application example "Data synchronization over open communication between multiple field devices (S7-1200) and a head PLC (S7-1200/ S7-300/ WinAC)" realizes data synchronization with open communication (see \10\).

3 Functional Mechanisms of the Application

This chapter describes the functions of the application.

Chapter 3.1 explains what the terms read and write synchronization refer to.

Chapter 3.2 and 3.3 explain the structure of the user programs of client and server.

3.1 Overview

On request, the application synchronizes memory areas of the client (either an S7-300 or an S7-1500) with four servers.

Data is written cyclically from four servers into memory areas of the client.

The following sections provide an overview over the process of write and read synchronization.

Write synchronization sequence (head-end → substation)

The following figure gives a schematic layout of the write synchronization process of user data from a client with only one server.

Figure 3-1

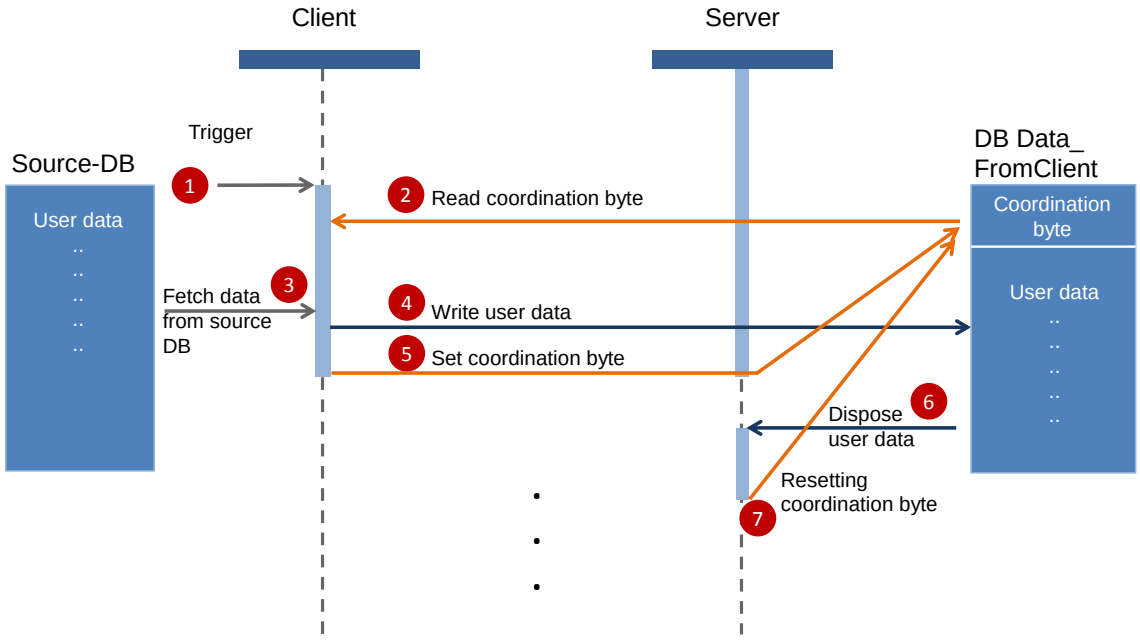


Table 3-1

No.	Process
1	Write synchronization is triggered from the user program.
2	Reading the synchronization byte from the server.
3	If the server indicates that new data exists, the data from the source data block specified by the user are fetched in step 3.
4	The user data is written to specified target data area.
5	The coordination byte is set in order to display the pending of new data.
6	The arrived user data is further processed by the server.

No.	Process
7	The coordination byte is reset by the server when another new data record exists again. The client then starts again with step 1.

Read synchronization sequence (substation → head-end)

The following figure gives a schematic layout of the read synchronization process with only one server.

Figure 3-2

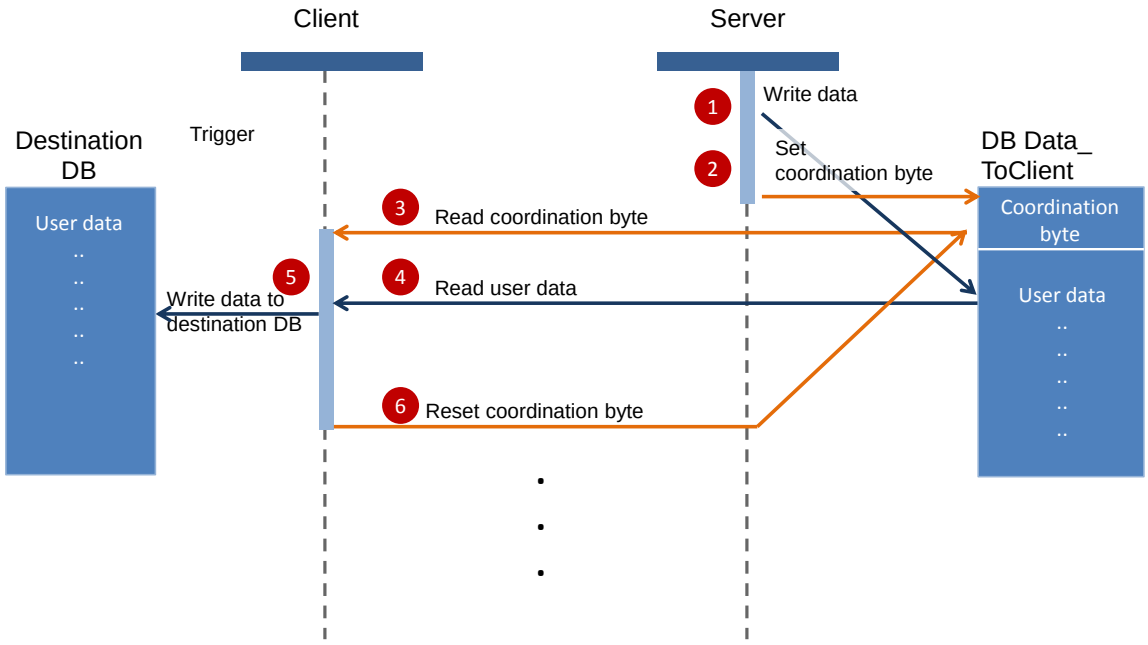


Table 3-2

No.	Process
1	The server writes data for the client into its user data area in DB DataToClient.
2	The server sets the coordination byte in order to inform the client of new data being available.
3	The client reads the coordination byte and evaluates it.
4	The client reads the data from the server and writes it into the receive buffer.
5	The data gets transferred from the receive buffer into the destination buffer.
6	The sever resets the coordination byte.

CPUs in the project

The following S7-CPUs have been configured in the STEP 7 (TIA Portal) project:

- CPU 1516-3 PN/DP (client)
- CPU 315-2 PN/DP (client)
- four CPU 1212 DC/DC/DC (server)

Both clients have the same functionality and can be used alternatively as head-end station.

Functions of the client

As the active part, the central client (either an S7-1500 or an S7-300 station) realizes the synchronization of data areas with the servers. The synchronization is divided into write (see Figure 3-1) and read (see Figure 3-2) synchronization.

For both synchronization types, the user can specify different data areas individually for each server.

The write synchronization is also used to perform a clock synchronization with the servers.

Functions of the server

As the passive part, the server(s) (one or several S7-1200 stations) reacts to the synchronization jobs of the client.

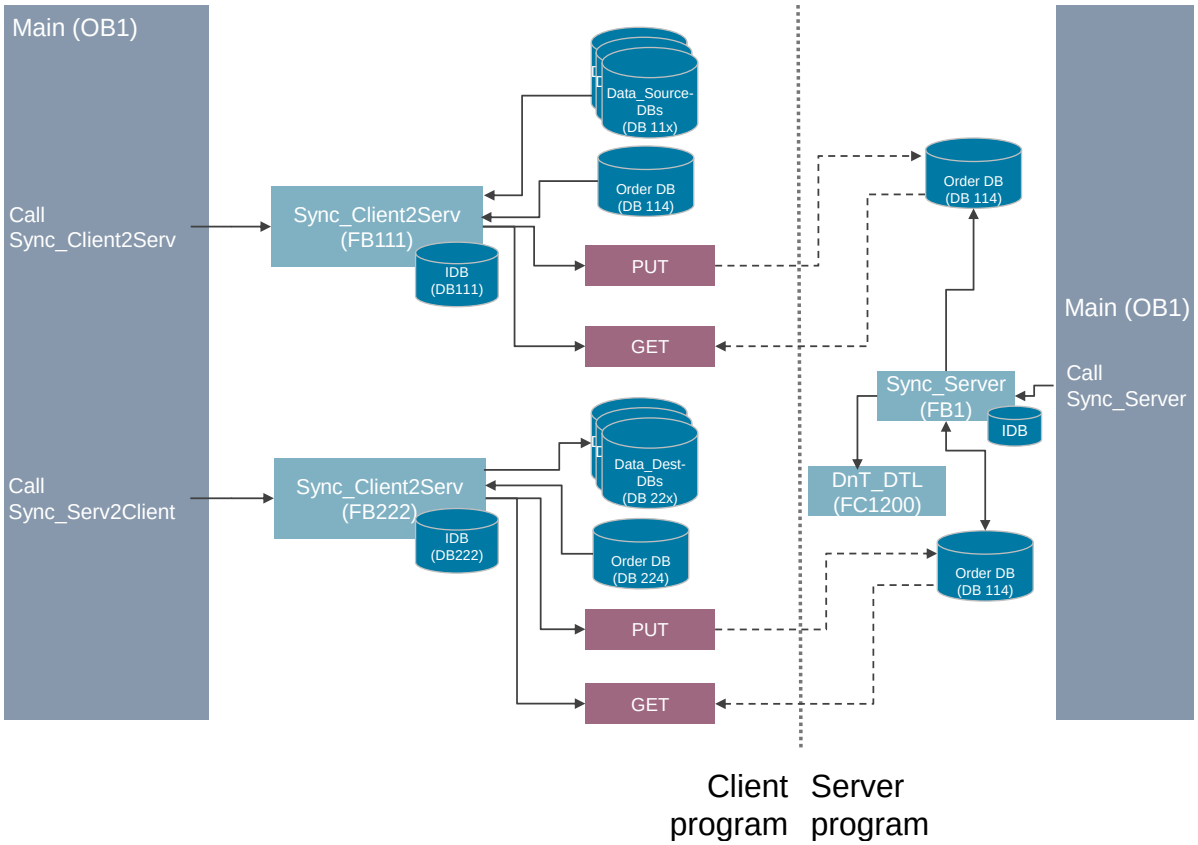
In order for the server program to react to the actions of the client, as well as to ensure data consistency, it must be known which data areas are to be synchronized.

3.2 Description of the program of the head-end station

3.2.1 Program overview

Overview

Figure 3-3



Functions

The following functions are realized in the client:

- upon a request: write synchronization once with the data areas of all servers (see chapter 3.2.2).
- Cyclic read synchronization of data areas (see chapter 3.2.3).
- upon a request: Clock synchronization of the client with the servers.

The read synchronization is performed cyclically, since in the user program of the client (head-end station) it is not known when new data is pending on the servers (substations).

System blocks PUT and GET are used for reading and writing data.

Blocks and instructions of the client

Table 3-3

Element	Symbolic name	Description
OB1	Main	Contains the main program. • Calls up FB Sync_Client2Serv (FB111) and FB Sync_Serv2Client (FB222). • Through the calls, it realizes a synchronization of data areas of the clients with one/several servers.
FB111	Sync_Client2Serv	On request, it synchronizes areas of the client of up to 160 byte size with one/several servers according to the “orders” INPUT. Option of clock synchronization with all servers.
FB222	Sync_Serv2Client	INPUT “orders” defines data areas to be synchronized. If new data is pending at the servers, these data blocks of up to 160 byte size are synchronized with the area specified in the client.
DB1	Param_Main_Call	Data block for supplying the parameters of the function calls in OB Main (OB1)
DB111	Sync_Client2_Serv_DB	Instance DB of FB Sync_Client2Serv (FB111)
DB114	Client2Serv_orders	Definition of the data areas to be synchronized for client to server synchronization.
DB115	Client2Serv_Buffer	Buffer area of the data
DB11x	src_blk_x	A data block with data to be synchronized for one/several servers.
DB222	Sync_Serv2Client_DB	Instance DB of FB Sync_Serv2Client (FB222)
DB224	Serv2Client_orders	Definition of the data areas to be synchronized for server to client synchronization.
DB225	Serv2Client_Buffer	Buffer area of the data
DB2xx	dest_blk_x	A data block with synchronized data from a server.
Instruction	PUT	Writes data to a remote CPU with S7 communication.
Instruction	GET	Reads data from a remote CPU with S7 communication.

Data blocks DB Client2Serv_orders and DB Serv2Client_orders consist of PLC data types which are described in greater detail in chapter 3.4.

Data consistency

If the function blocks of the user blocks have been implemented correctly, the consistency of the data areas to be synchronized is ensured.

Please follow the respective instructions and notes in chapter 6.3.

3.2.2 FB Sync_Client2Serv (FB111): Write synchronization

Overview

FB Sync_Client2Serv (FB111) realizes the write synchronization of the specified data areas on the S7 servers (substations).

On request, the FB performs

- reading and evaluation of the coordination byte of the destination data area.
- writing of new data to the server.

Here, the example program synchronizes the maximal possible 160 bytes of user data.

In order to synchronize data volumes smaller than 160 bytes, please follow the instructions and notes in chapter 6.1.

Parameters of FB Sync_Client2Serv (FB111)

Figure 3-4 shows the parameters of FB Sync_Client2Serv (FB111).

Table 3-4 describes the individual parameters.

Figure 3-4

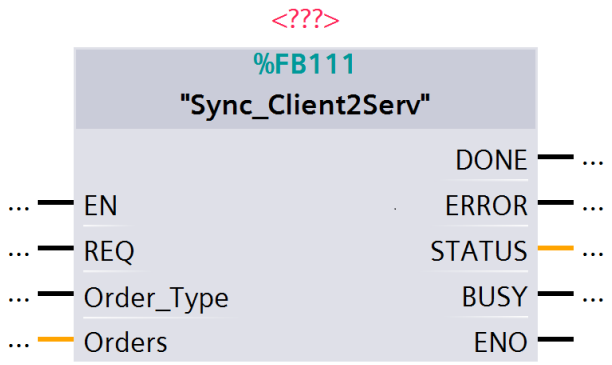


Table 3-4

Parameters	Type	Remarks
REQ	IN: BOOL	Request input: a positive edge triggers the synchronization process.
Order_type	IN: BOOL	Specifies the synchronization job. Order_type=TRUE: system time is sent. Order_type=FALSE: up to 160 bytes of user data are sent to the data area specified through “Orders”.
Orders	INOUT: Client2Serv (see chapter 3.4)	Specifies the synchronization jobs with the servers. Transfers the number of servers to be synchronized, the ID of the connection, the DB number and offset of source and destination, as well as the length of the user data.
DONE	OUT: BOOL	After a successful synchronization run: DONE=TRUE for one cycle
ERROR	OUT: BOOL	After a synchronization run with errors: ERROR=TRUE for one cycle
STATUS	OUT: DWORD	Gives further information on the type of error. STATUS remains pending for one cycle.

Parameters	Type	Remarks
BUSY	OUT: BOOL	Indicates that the block is running a synchronization process

NOTICE	**For the write synchronization the specified length of the data area to be synchronized must be identical for all servers!**

The STATUS output parameter

Table 3-5

Byte	Meaning
Byte 4	Indicates the number of servers the synchronization has failed with.
Byte 3	Instruction at which the error has occurred. • 16#01: GET • 16#02: BLKMOV • 16#03: PUT
Byte 1+2	Indicates the status of the last failed instruction.

Internal sequences in FB Sync_Client2Serv (FB111)

The synchronization task in FB Sync_Client2Serv (FB111) is realized as state machine (Table 3-6).

Figure 3-5

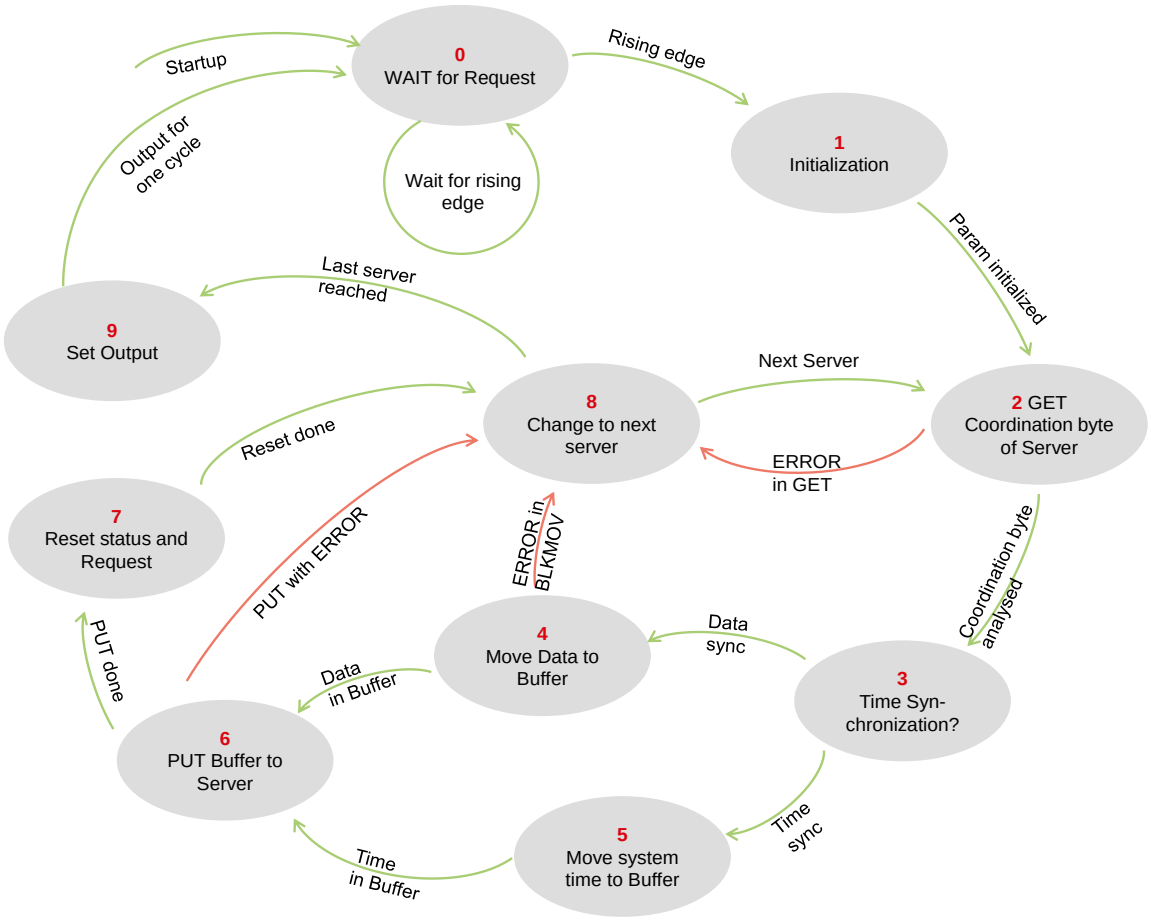


Table 3-6

Step	Instruction
0	Waits for a rising edge at the REQ input.
1	Sets parameters, such as the • request input of PUT = 0. • request input of GET = 1 in order to fetch the coordination byte. • …
2	The received coordination byte is evaluated. The following action is performed depending on the status of the coordination byte: • 16#F0 = Data not yet processed: cancelling the synchronization with this server. • 16#FF = Clock synchronization not yet terminated: cancelling the synchronization with this server. • 16#00 = Server ready to receive data → step 3 For the meaning of the coordination bytes, please refer to Table 3-7.

Step	Instruction
3	If the Order_type input is • TRUE: clock synchronization → step 5 • FALSE: transferring the user data → step 4
4	It fetches data from the data area defined in DB Client2Serv_orders (DB 114) via BLKMOV and writes the data to the buffer DB Client2Serv_Buffer (DB115). At the end, it sets the request input of the PUT instruction.
5	Reads the system time and writes it to the buffer DB Client2Serv_Buffer (DB115). At the end, it sets the request input of the PUT instruction.
6	• PUT with error → step 8 • PUT without error → step 7 The PUT instruction processes the jobs at the ADDR_x and SD_x inputs in a sequentially rising order. This enables secured sending of firstly, the user data, and secondly, the coordination byte, in one single PUT call. → data consistency
7	Resetting the status for the active server → step 8
8	Changing the server to be synchronized by incrementing "control.number" → step 2 After attempting to synchronize all of the servers once → step 9
9	Sets the output parameters, see Table 3-5. → step 0

Table 3-7 Meaning of the coordination bytes

Value / Direction	16#00	16#F0	16#FF
Client2Serv	Data can be written.	Data not yet processed.	Time not yet synchronized in the server
Serv2Client	No new data pending.	New data → Data can be read.	---

3.2.3 FB Sync_Serv2Client (FB222): read synchronization

Overview

FB Sync_Serv2Client realizes the cyclic read synchronization of the specified data areas with the S7 servers.

The following individual functions are realized cyclically by the client:

- reading and evaluation of the coordination byte in the server.
- fetching the data from the server when new data is available.
- display for the server that the data has been fetched.

Here, data areas with a size of 160 bytes are fetched. For changing the size of the data area to be synchronized, please note chapter 6.1.

Parameters of FB Sync_Serv2Client (FB222)

Figure 3-6

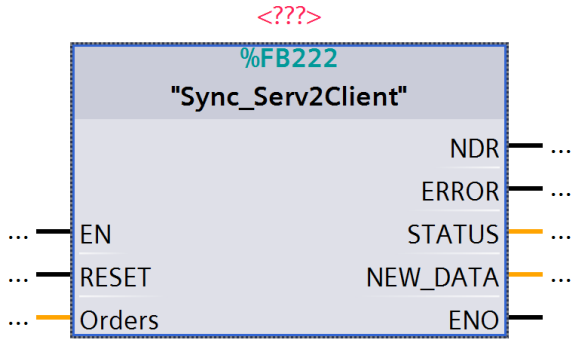


Table 3-8

Parameters	Type	Remarks
RESET	IN: BOOL	If RESET=TRUE, then the block jumps to step 0: initialization (Figure 3-7). For RESET=FALSE, the state machine of the block is running through normally.
Orders	INOUT: Serv2Client (see chapter 3.4)	Specifies the synchronization jobs with the servers. Transfers the number of servers to be synchronized, the ID of the connection, the DB number and offset of source and destination, as well as the length of the user data.
NDR	OUT: BOOL	After a successful synchronization run, indicates NDR=TRUE for one cycle.
ERROR	OUT: BOOL	After a synchronization run with error(s), indicates ERROR=TRUE for one cycle.
STATUS	OUT: DWORD	Gives further information on the type of error. The STATUS output also remains pending for one cycle.
NEW_DATA	OUT: INT	For NDR=TRUE or ERROR=TRUE, it indicates how many data areas were synchronized in one run sequence.

The STATUS output parameter

Table 3-9

Word	Meaning
Byte 4	Indicates the number of servers the synchronization has failed with.
Byte 3	Instruction at which the error has occurred. • 16#01: GET coordination byte • 16#02: GET data • 16#03: PUT coordination byte • 16#04: UBLKMOV data
Byte 1+2	Indicates the status of the last failed instruction.

Internal processes in FB Sync_Serv2Client (FB222)

The synchronization task in FB Sync_ Serv2Client (FB222) is realized as state machine (Figure 3-7).

Figure 3-7

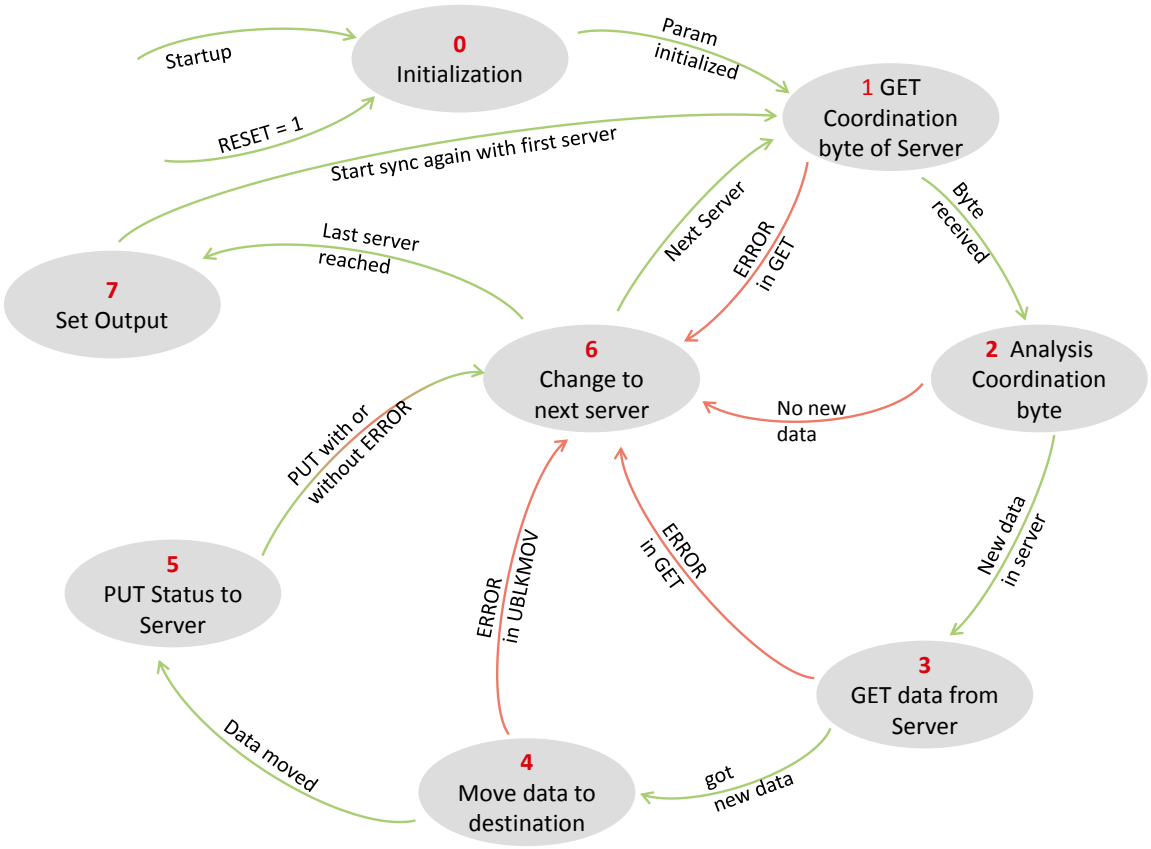


Table 3-10

Step	Instruction
0	Sets parameters, such as the • request input of GET = 0, to create a positive edge. • control.number=1, to mark the first server as active. • …
1	Sets the request input of the first GET instruction in order to read the coordination byte.
2	Analyzes the coordination byte of the server: • 16#F0: new data of the server is pending → step 4 • 16#00: no new data exists → go to next server (step 6) For the meaning of the coordination bytes, please refer to Table 3-7.
3	Fetching the data from the server by setting the request input of the second GET instruction.
4	Defining the coordination byte (16#00) and setting the request input of the PUT instruction in order to write the coordination byte to the server.

Step	Instruction
5	Fetching the data from the buffer and storing it in the destination DB with the UBLKMOV instruction.
6	Changing the server to be synchronized by incrementing “control.number” → step 1 After synchronization has been attempted for all of the servers once, the first server is marked as active → jump to step 7
7	Setting the output parameters → step 1 for a new synchronization run.

3.3 Description of the program of a substation

3.3.1 Program overview

Functions

The server reacts only passively to the synchronization through the client. The PUT/GET blocks are only called up in the client (head-end station), and only the client can determine the end of a write/read process.

The passive server does not contain any active communication blocks and needs to control the coordination of the accesses through the user program.

The following functions have been realized in the user program of the server (substation):

- coordination of the disposal of data by the client (write synchronization with the substation).
- coordination of the supply of data to the client (read synchronization from the substation).
- Setting the system time at a time synchronization job.

A graphic program overview is described in Figure 3-3.

Blocks and instructions in the substation

Table 3-11

Element	Symbolic name	Description
OB1	Main	Contains the main program. • Calls the FB Sync_Serv2Client (FB2) • The call implements a receive logic for the synchronization with the client.
FB2	Sync_Server	Reacts to the synchronization from the client. The information which DBs are synchronized must be transferred to the FB. Any deviation from the example application must be adjusted in the user program (see chapter 6).
FC1200	DnT_DTL	Transforms the Date_and_Time data type into data type DTL.
DB2	Sync_Server_DB	Instance DB of FB Sync_Server (FB2)
DB6	Data_FromClient	Storage location of the data from the client.
DB7	Data_ToClient	Storage location of the data for the client.

3.3.2 FB Sync_Server (FB111)

Overview

FB Sync_Server (FB111) reacts to changes of the coordination byte and ensures smooth synchronization with the client.

For changes and adjustments in the user program, please note chapter 6.

Parameters of FB Sync_Server (FB111)

Figure 3-8

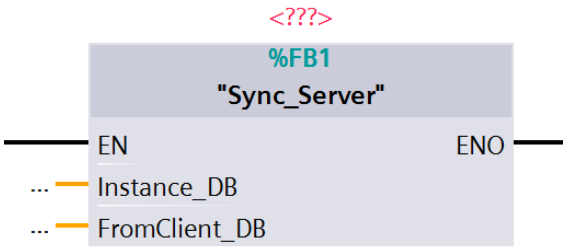


Table 3-12

Parameters	Type	Remarks
Instance_DB	IN: INT	Specifies the number of the instance data block of the FB in order to temporarily store the time in the instance data block during clock synchronization.
FromClient_DB	IN: INT	Specifies the number of the DB Data_FromClient in order to read the time from the data block during clock synchronization.

Reaction to a write synchronization

Figure 3-9

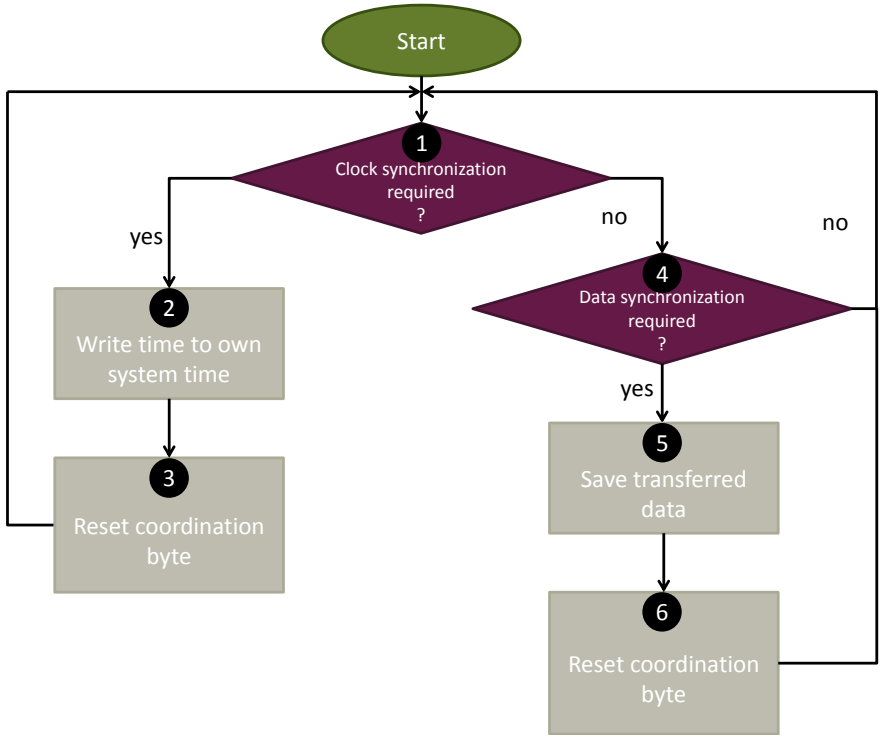


Table 3-13

No.	Instruction
1	If the coordination byte has the value 16#FF, the client has stored the time in the receive buffer.
2	• The received time is transferred to the instance DB. • The time is transformed into data type DTL by data type Date_and_Time. • The time is adopted in the server as the system time.
3	The coordination byte is reset, the synchronization job is terminated.
4	If the coordination byte has the value 16#F0, the client has stored user data in the destination area.
5	The data in the receive buffer can be further processed.
6	The coordination byte is reset so the client knows that the data has been disposed of.

Reaction to a read synchronization

Figure 3-10

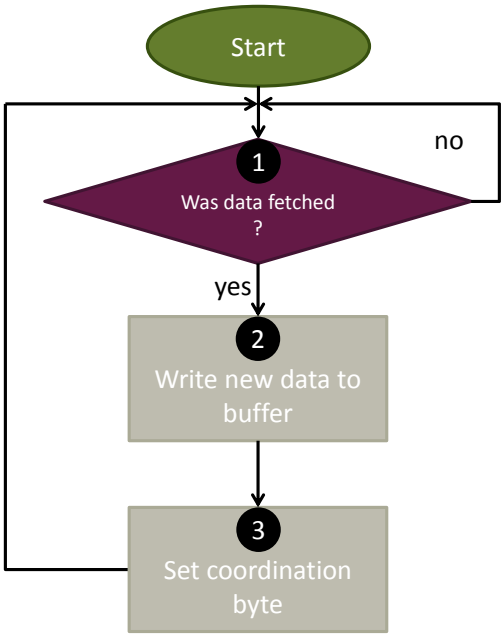


Table 3-14

No.	Instruction
1	If the coordination byte has the value 16#00, the client has already fetched the data from the send buffer.
2	New data can now be written to the send buffer.
3	The coordination byte is set to 16#F0 in order to inform the client of new data being available.

3.3.3 Data consistency in the server

Definition

The term data consistency refers to the data, which is synchronized between client and server, being transferred in a correct state.

Data inconsistency can occur if two processes asynchronously access the same storage area. One possible scenario is that the clearly faster read access "overtakes" the write access, resulting in the read data consisting of old and new values, which makes them inconsistent.

Requirements

Communication with PUT and GET functions is considered uncoordinated communication, since the server cannot directly react to the jobs of the client. Communication with BSEND and BRCV enables inquiring whether data can still be sent or received. In contrast, the PUT and GET functions require a coordination of the accesses in the user program.

Actions

Access in the user program is controlled via the "coordination byte". Its exact meaning, as well as measures for maintaining the data consistency of the program, is available in chapter 6.3 and 6.4.

3.4 The PLC data types

Overview

The following PLC data types are used in the user program of the client (head-end station):

- "order"
- "Client2Serv"
- "Serv2Client"
- "Any_struct"

This chapter describes the structure and usage of the data types.

PLC data type “order”

Figure 3-11 shows the structure of PLC data type “order”. The PLC data type is used by PLC data type Serv2Client as well as Client2Serv and maps a synchronization job with the server.

Figure 3-11

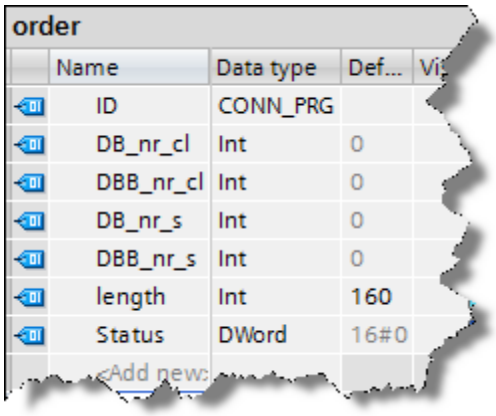


Table 3-15

Name	Remarks
ID	ID of the configured S7 connection. Available in the network view of the TIA Portal in the “Connections” tab. Local connection name / Local end point / Local ID (hex) S7_Connection_50 / S7-1500 [CPU... / 100 S7_Connection_51 / S7-1500 [CPU... / 101 **Note!** The ID is specified in the network view as a hexadecimal value.
DB_nr_cl	Indicates the number of the data block in the client whose data is to be synchronized.
DBB_nr_cl	Indicates the byte offset of the data to be synchronized.
DB_nr_s	Indicates the number of the data block in the server whose data is to be synchronized.
DBB_nr_s	Indicates the byte offset of the data to be synchronized.
length	Specifies the length (in bytes) of the data to be synchronized. Maximal size of the user data: 160 bytes. **Note!** For write synchronization, the specified length must be identical for all of the servers.
Status	If an error occurs during the synchronization with the server, the status of the instruction is stored here, until a successful synchronization run resets the value to 16#0.

NOTICE	**PUT and GET cannot access optimized data blocks!**

PLC data type “Client2Serv”

PLC data type “Client2Serv” contains all relevant information for the client on the write synchronization with the servers.

Figure 3-12

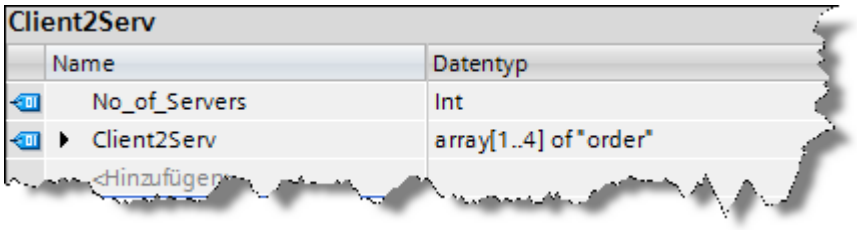


Table 3-16

Name	Remarks
No_of_Servers	Contains the number of servers to be write synchronized.
Client2Serv	Array of PLC data type “order”. An array element is used for each server to be synchronized. The size of the array should correspond to the value of the “No_of_Servers” variable.

In the S7-1500 CPU, a data block can be generated directly from PLC data type “Client2Serv” and then be interconnected at the “Orders” input of FB Sync_Client2Serv.

PLC data type “Serv2Client”

PLC data type “Client2Serv” contains all relevant information for the client on the read synchronization with the servers.

Figure 3-13

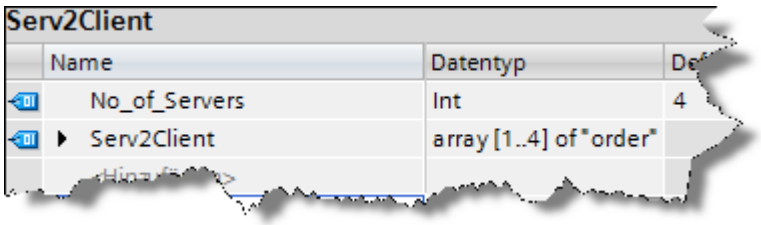


Table 3-17

Name	Remarks
No_of_Servers	Contains the number of servers to be read synchronized.
Serv2Client	Array of PLC data type “order”. An array element is used for each server to be synchronized. The size of the array should correspond to the value of the “No_of_Servers” variable.

In the S7-1500 CPU, a data block can be generated directly from PLC data type “Serv2Client” and then be interconnected at the “Orders” input of FB Sync_Serv2Client.

In the S7-300 CPU, the PLC data type is inserted in a data block and then interconnected at the “Orders” input of FB Sync_Serv2Client. A direct interconnection of the complete DB, as in the S7-1500 CPU, is not possible for a S7-300 CPU.

PLC data type “Any_struct”

PLC data type “Any_struct” maps the structure of the anypointer and is used in the project as AT construct at ANY variables.

This enables assigning or modifying the anypointer more comfortably. The structure of the anypointer is available in the manual \7\.

Differences in PLC data types with an S7-300 CPU as the client

1. The S7-300 does not use data type CONN_PRG but INT (Figure 3-11)
2. In the S7-300 CPU, the PLC data type is inserted in a data block and then interconnected at the “Orders” input of FB Sync_Client2Serv. A direct interconnection of the complete DB, as in the S7-1500 CPU, is not possible for a S7-300 CPU. (Table 3-18)

Table 3-18

	S7-1500	S7-300
Client2Serv_ orders	Client2Serv_orders Name / Data type Static No_of_Servers: Int Client2Serv: array[1..4] of "order"	Client2Serv_orders Name / Data type Static Client2serv_orders: "Client2Serv" No_of_Servers: Int Client2Serv: Array[1..4] of "order"
Mapping	%DB114 "Client2Serv_ orders" — Orders	P#DB114.DBX0.0 "Client2Serv_ orders". Client2serv_ orders — Orders

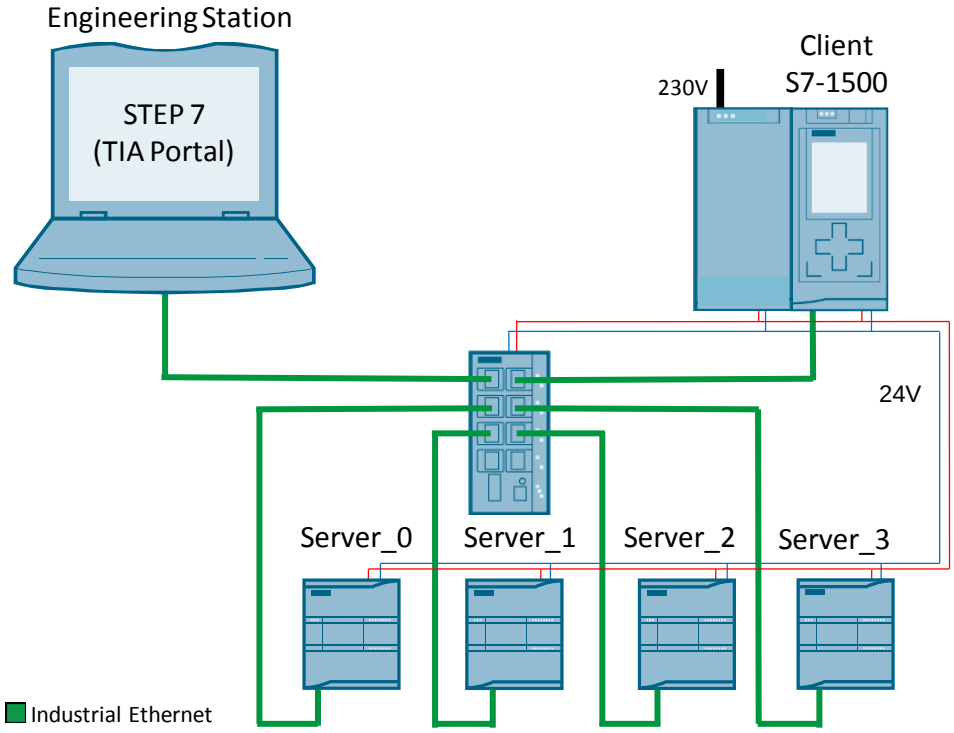
4 Startup of the Application

4.1 Hardware configuration

Overview

The figure below shows the hardware configuration of the project with S7-1500 as a client.

Figure 4-1



The table below describes the procedure for the hardware configuration of the project.

Please observe the regulations for the configuration of an S7 station.

Hardware configuration of the SIMATIC S7-CPUs

Table 4-1

No.	Instruction	Remarks
1.	Insert the power supply and the CPUs into the respective rack	Rail for • S7-300: e.g. 6ES7390-1AE80-0AA0 • S7-1500: e.g. 6ES7590-1AF30-0AA0 • S7-1200: DIN top-hat rail
2.	Mount the switch onto a top-hat rail.	
3.	Wire the CPUs with the power supply.	Mind the correct polarity!
4.	Connect your CPU with the switch via Ethernet cable.	

No.	Instruction	Remarks
5.	Connect your power supply with the electricity-supply system (230V AC)	
6.	Also connect your engineering station with the switch via Ethernet cable.	

4.2 Configuring the hardware

IP addresses used

The subnet mask used is 255.255.255.0.

Table 4-2

CPU	IP address
S7-300	192.168.0.252
S7-1500	192.168.0.253
Server_0	192.168.0.6
Server_1	192.168.0.7
Server_2	192.168.0.8
Server_3	192.168.0.9

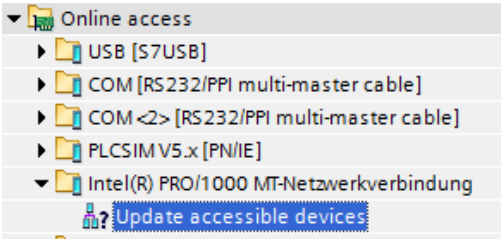
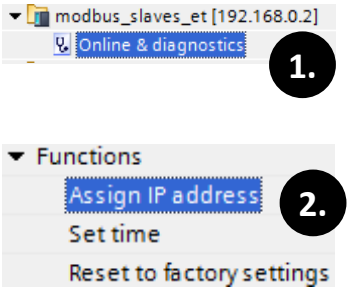
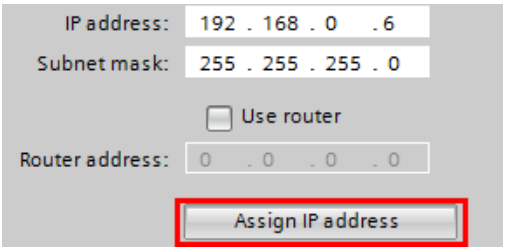
Adjusting the IP address of the S7-1500 CPU

Table 4-3

No.	Instruction	Remarks
1.	On the display of your S7-1500 CPU, you navigate to the “Set IP addresses” item: “Settings > Addresses >X1 (IE/PN) > IP address”	In the display you can navigate via the directional pad and the “OK” and “ESC” button.
2.	Set the IP address of the S7-1500 used in the example project (192.168.0.253).	

Adjusting the IP address of the S7-300 and S7-1200 CPUs

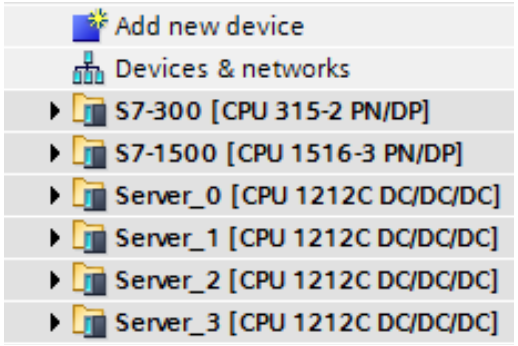
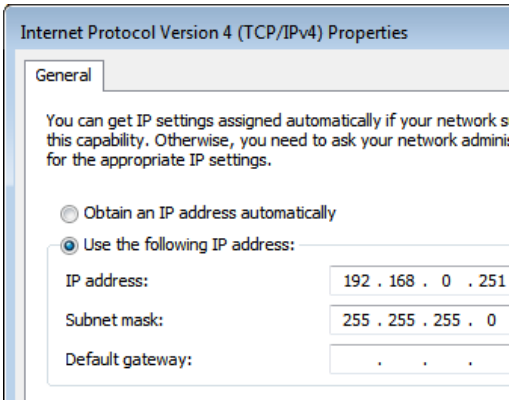
Table 4-4

No.	Instruction	Remarks
1.	Start the TIA Portal in the project view. Search for “Nodes accessible online”. To this end, navigate to “Project Tree> Online Access> [Your_Ethernet_Adapter]> Update accessible devices”. Your S7-CPUs are now recognized.	
2.	The procedure is identical for all CPUs: Now navigate to “[Your_S7CPU]> Online & diagnostics”. In the graphical area of “Online & diagnostics”, select “Functions> Assign IP address”.	
3.	Assign the IP address used in the project for each CPU (see inspector window of the device view). Confirm the action with “Assign IP address”. Your Engineering station successively assigns the IP addresses to the individual stations.	

4.3 Opening and loading the STEP 7 project

The following table shows you how to open the STEP 7 project and load it to the CPU.

Table 4-5

No.	Instruction	Remarks
1.	Unzip the TIA Portal project (see Table 2-4) into a local folder on your PC and open it.	
2.	Make sure that your engineering station is located in the same subnet as the S7 CPU. Example: IP address: 192.168.0.251 Subnet mask: 255.255.255.0	
3.	Use the “Load to device” button to load the configuration individually into each CPU. • S7-300 or S7-1500 • Server_0 • Server_1 • Server_2 • Server_3 After the download, a message appears, informing that the download process has been completed successfully.	
4.	Now you can monitor the plant as described in chapter 5.	

5 Operating the Application

5.1 Monitoring the application

Monitoring

The user program of client and server generates data for program overview and error diagnosis.

These data can be read individually, for example from the instance DBs.

For better clarity, a watch table, which enables an overview of the state of the program, was created in the client as well as in the servers.

The watch tables can be adjusted to your requirements

Overview_Client watch table

The watch table makes statements about the statue of the user program of the client. Additionally, you can control your program via the watch table, unless the control has been realized by an additional logic in the user program.

Table 5-1

Variable	Data type	Remarks
*.P_REQ	BOOL	Request input for FB Sync_Client2Serv (FB111)
*.P_TIME	BOOL	Time input for FB Sync_Client2Serv (FB111)
*.P_ERROR	BOOL	Error output of FB Sync_Client2Serv (FB111)
*.P_STATUS	DWORD	Status output of FB Sync_Client2Serv (FB111)
*.G_NDR	BOOL	NDR output of FB Sync_Serv2Client (FB222)
*.G_New_Data	INT	New data output of FB Sync_Serv2Client (FB222)
*.coord	BYTE	Coordination byte client to server
*.Client2Serv_Buffer[0]	BYTE	First buffer byte of the user data
*.coord	BYTE	Coordination byte server to client
*.Serv2Client_Buffer[0]	BYTE	First buffer byte of the user data
*[1].Status	DWORD	Status of the client to server synchronization with Server_0.
*[2].Status	DWORD	Status of the client to server synchronization with Server_1.
*[3].Status	DWORD	Status of the client to server synchronization with Server_2.
*[4].Status	DWORD	Status of the client to server synchronization with Server_3.
*[1].Status	DWORD	Status of the server to client synchronization with Server_0.
*[2].Status	DWORD	Status of the server to client synchronization with Server_1.
*[3].Status	DWORD	Status of the server to client synchronization with Server_2.
*[4].Status	DWORD	Status of the server to client synchronization with Server_3.

Overview_Server_x watch table

The watch table makes statements on the statue of the user program of the server.

You can adjust the watch table as you wish.

Table 5-2

Variable	Data type	Remarks
*.Coordination_Byte	BYTE	Coordination byte of the client to server synchronization
*.buffer[0]	BYTE	First byte of the user data
*.buffer[1]	BYTE	Second byte of the user data
*.Coordination_Byte	BYTE	Coordination byte of the server to client synchronization
*.buffer[0]	BYTE	First byte of the user data
*.buffer[1]	BYTE	Second byte of the user data

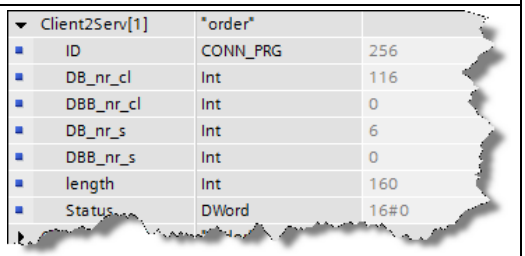
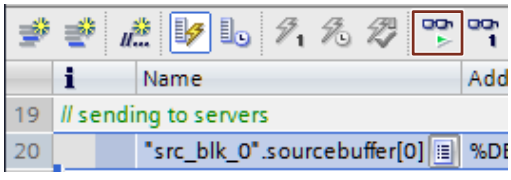
5.2 Scenario A: write synchronization of data

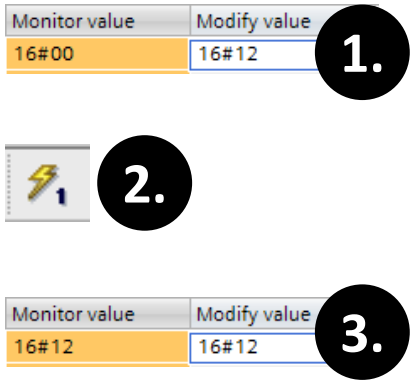
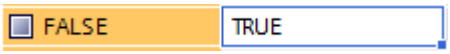
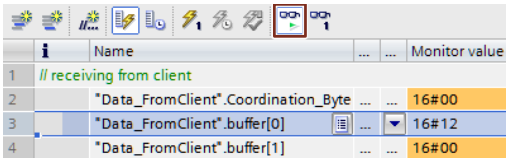
Scenario

This chapter describes the procedure for synchronizing a data area of the client with the data area of the server. In addition, it describes how the process is monitored.

Instruction

Table 5-3

No.	Instruction	Remarks
1.	Start the example project as described in chapter 4.	
2.	Verify the parameters of the first job in DB Client2Serv_orders (DB114)	
3.	Open the "Overview_Client" watch table and press the icon "Monitor all".	

No.	Instruction	Remarks
4.	Control the value of the variable "src_blk_0".sourcebuffer[0] (line 20) to any value, for example: 16#12. Then control the value to transfer it to the CPU.	
5.	Create a positive edge of the “Param_Main_Call”.P_REQ variable via the variable table as well. This triggers the synchronization process, and the jobs of DB "Client2Serv_orders" (DB114) are processed.	
6.	Go to Server_0 of the project. In Server_0 you open "Overview_Server_0" watch table and press the icon "Monitor all". The content of the buffer[0] has changed after successful transfer to the value specified in the client.	

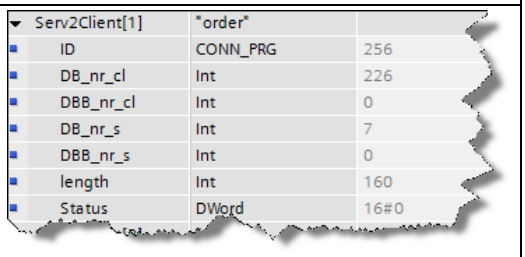
5.3 Scenario B: read synchronization

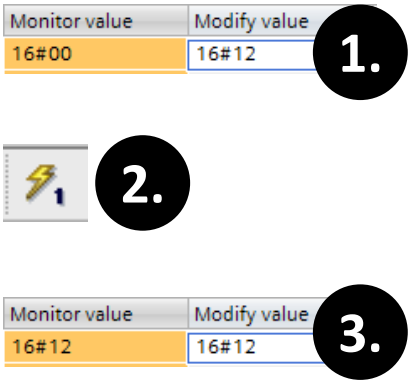
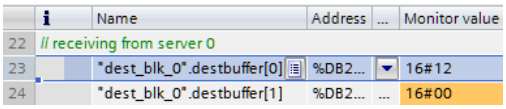
Scenario

This chapter describes the procedure for synchronizing a data area of a server with the data area of a client. In addition, it describes how the process is monitored.

Instruction

Table 5-4

No.	Instruction	Remarks
1.	Start the example project as described in chapter 4.	
2.	Verify the parameters of the first job in DB "Serv2Client_orders" (DB224)	

No.	Instruction	Remarks
3.	Open the "Overview_Server_0" watch table. Control the value of the “Data_ToClient.buffer[0]” variable (line 7) to any value, for example: 16#12. Then control the value to transfer it to the CPU.	
4.	Go back to the client. Open the "Overview_Client" watch table. Monitor all variables. The content of the variable "dest_blk_0".destbuffer[0] has changed after successful transfer of the data to the value specified in the server.	

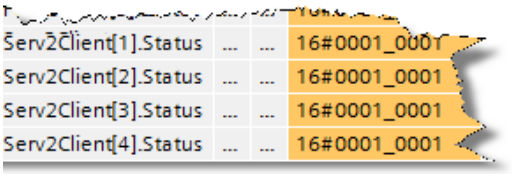
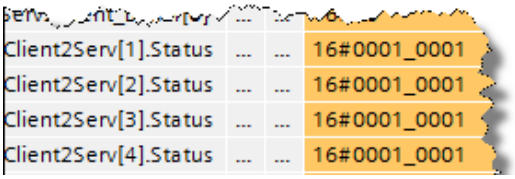
5.4 Scenario C: error message for disconnected cable

Scenario

This chapter describes the behavior of the program if the connection from the client to the servers has been terminated, e.g. due to wrong cabling.

Description

Table 5-5

No.	Instruction	Remarks
1.	Start the example project as described in chapter 4.	
2.	Pull the Ethernet cable which connects the client CPU with the server CPUs.	
3.	Open the "Overview_Client" watch table. The cyclic read synchronization should already have written the status 16#0001_0001. Meaning: • First word: the first instruction has failed. • Second word: the status of the error of the failed instruction is 16#0001	 One trouble shooting option for status 16#0001 that is mentioned in the Help on the GET instruction in the TIA Portal, is to check the wiring.
4.	Create a positive edge of the “Param_Main_Call”.P_REQ variable via the variable table. This triggers the write synchronization process, and the jobs of DB "Client2Serv_orders" (DB114) are processed.	
5.	Due to the fact that the jobs cannot be processed correctly, the states of the write synchronization are also assigned with value 16#0001_0001 as a result. For the respective meaning, see no 3.	

6 Changes at the Project

Overview

If you want to make changes to the STEP 7 (TIA Portal) project, this chapter provides you with support.

The following adjustments are documented.

- Changing the data areas to be synchronized.
- Adding a further slave.
- Ensuring data consistency in the server.
- Expanding the function of the coordination byte.

6.1 Changing the data areas to be synchronized

Overview

On request, the example application places 160 bytes from DB116 of the client into the DB6 of the servers.

From DB7 of the server, 160 bytes are placed into the following DBs:

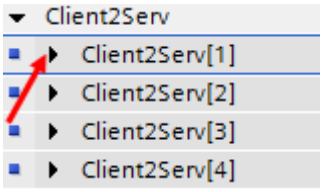
- from Server_0 into DB226
- from Server_1 into DB227
- from Server_2 into DB228
- from Server_3 into DB229

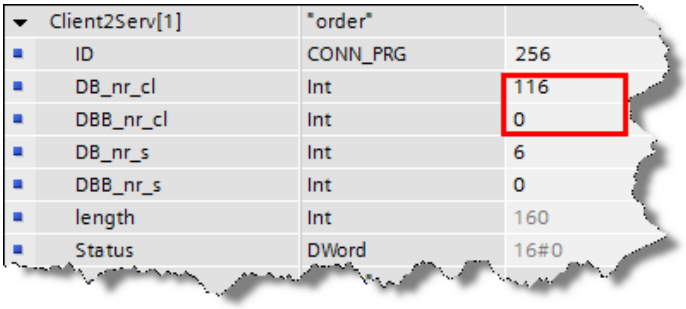
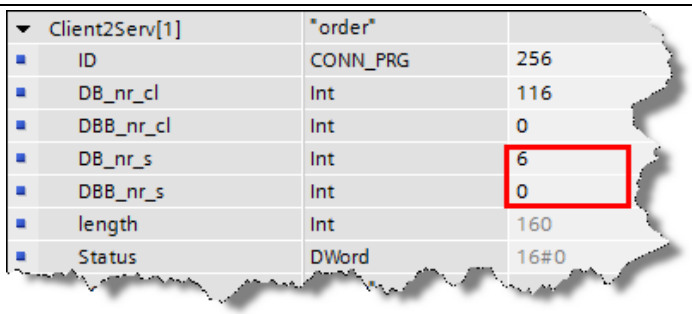
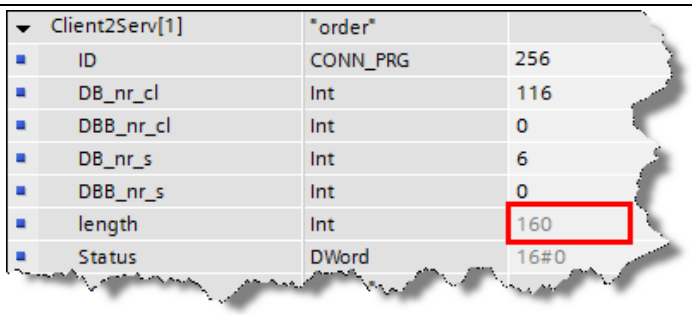
If you wish to change these source and destination areas, please follow the instructions in this chapter.

The procedure is described successively, first for the client, and then for the server side.

Procedure in the client for write synchronization

Table 6-1

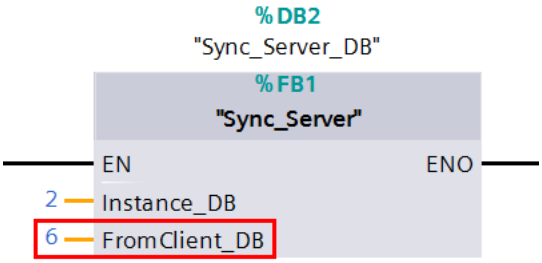
No.	Process	Remarks
1.	Open PLC data type "Client2Serv".	
2.	Open the job you wish to change.	

No.	Process	Remarks
3.	Adjust the number of the client DB and its offset. • DB_nr_cl specifies the DB in the client from which 160 bytes are read. • DB_nr_cl specifies the byte offset from which on the data is read.	
4.	Adjust the number of the server DB and its offset. • DB_nr_s specifies the DB in the server to which the data is written. • DB_nr_cl specifies the byte offset from which on the data is written.	
5.	You can also specify the length of the data area to be synchronized in byte. Note that a maximum of 160 bytes can be synchronized.	
6.	When reducing the length of the area to be synchronized, you need to also reduce the buffer in DB Client2Serv_Buffer (DB115) to this size.	**Notice!** The buffer in DB Client2Serv_Buffer (DB115) is used by all of the jobs. For the write synchronization, the length parameter therefore needs to have the same value for all of the jobs!
7.	Make sure that the DB specified in “3.” exists on the client.	
8.	Download your user program to the CPU again and restart the CPU.	

Procedure in the server for write synchronization

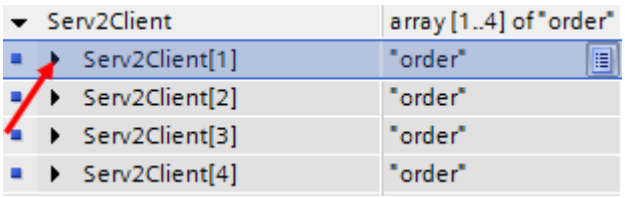
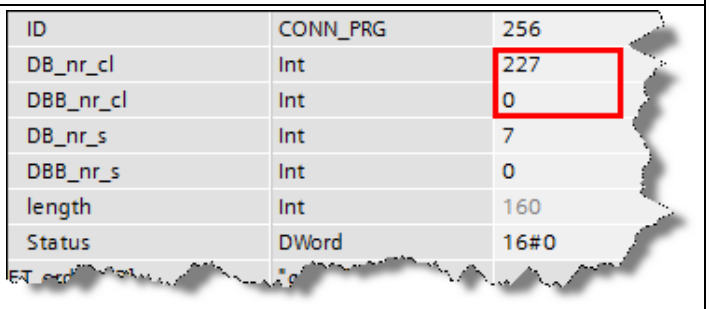
Table 6-2

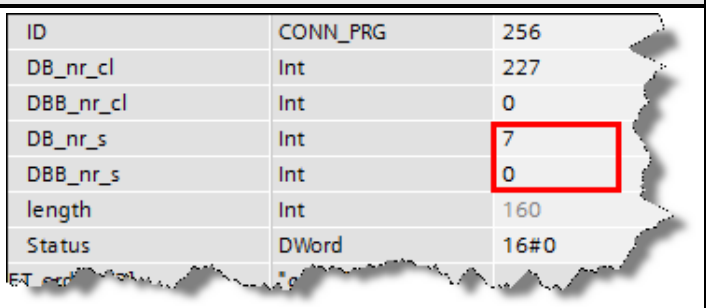
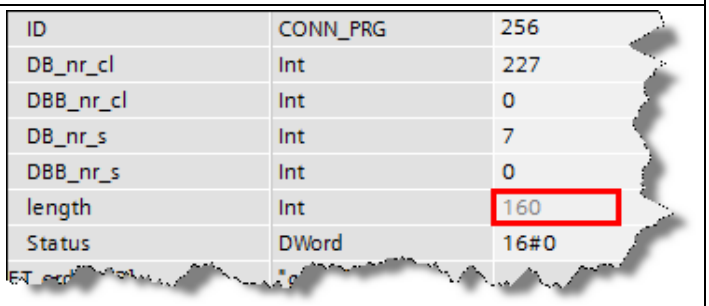
No.	Process	Remarks
1.	Create a DB with the data block number specified under no 4 in Table 6-1 and the symbolic name “Data_fromClient!”.	

No.	Process	Remarks
2.	Add an array named “buffer” and the offset “DBB_nr_s” and the length “length” (from Table 6-1 under no 4) to the data block.	
3.	Open the OB Main (OB1).	
4.	Adjust the call of FB Sync_Server (FB1), by specifying the number of the DB created in “1.” at the FromClient_DB input.	
5.	Download the user program to the CPU and restart the CPU. With the next synchronization request on the client station side, the newly defined data areas synchronized	

Procedure in the client for write synchronization

Table 6-3

No.	Process	Remarks
1.	Open the DB Client2Serv_orders.	
2.	Open the job you wish to change.	
3.	Adjust the number of the client DB and its offset. • DB_nr_cl specifies the DB to which the 160 bytes are written. • DB_nr_cl specifies the byte offset from which on the data is written.	

No.	Process	Remarks
4.	Adjust the number of the server DB and its offset. • DB_nr_s specifies the DB from which the data is read. • DB_nr_cl specifies the byte offset from which on the data is read.	
5.	You can also specify the length of the data area to be synchronized in byte. Note that a maximum of 160 bytes can be synchronized.	
6.	Make sure that the DB specified in “3.” exists.	
7.	Download the DB to the CPU and restart the CPU. With the next synchronization request, the newly defined data areas synchronized	

Procedure in the server for read synchronization

Table 6-4

No.	Process	Remarks
1.	Create a DB with the data block number specified under no 4 in Table 6-1 and the symbolic name “Data_toClient”.	
2.	Add an array named “buffer” and the offset “DBB_nr_s” and the length “length” (from Table 6-1 under no 4) to the data block.	
3.	Download the DB to the CPU and restart the CPU.	

6.2 Adding a further server

Overview

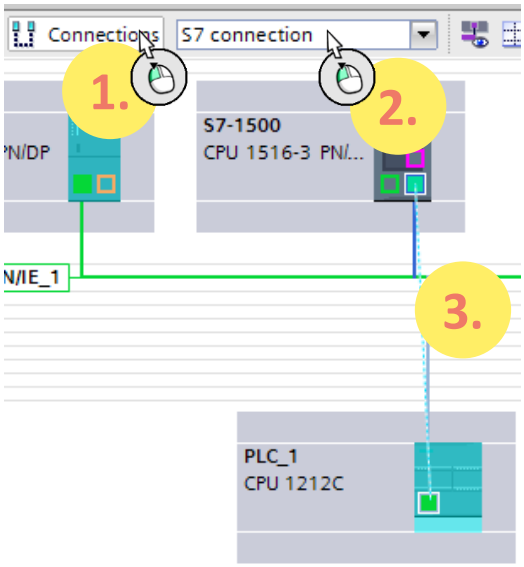
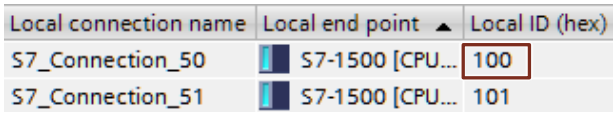
For adding a further server to the project, the following steps need to be realized:

- Adding a new CPU to the project.
- Configuring an S7 connection
- Adjusting the user program of the client (head-end station).
- Create the user program of the newly added server (of the substation).

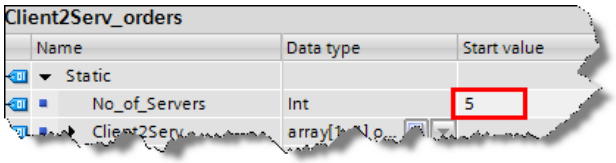
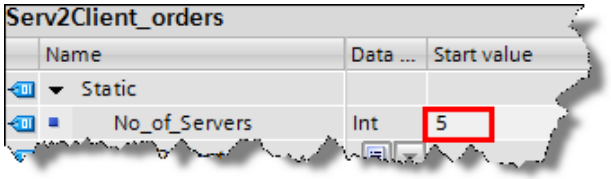
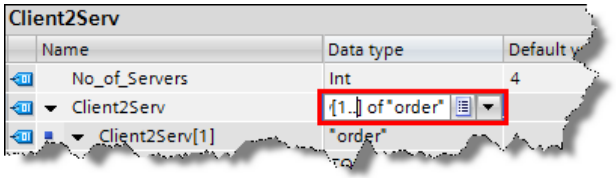
Follow the instructions of the table below.

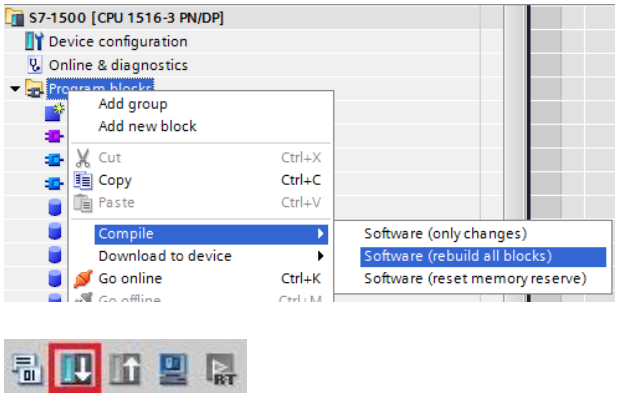
Procedure on the server side

Table 6-5

No.	Process	Remarks
1.	Add a further S7-1200 to your project via “Add new device”.	
2.	Go to “Network View”. Add an S7 connection between the newly added CPU and the already existing S7-300 or S7-1500.	
3.	In “Connections”, you memorize the local ID in the S7-300/S7-1500 of the newly created connection.	
4.	Copy the blocks of another server to the program block folder of the newly added S7-1200.	

Procedure on the client side

No.	Process	Remarks
1.	Go to the “program blocks” folder of your client and open DB Client2Serv_orders (DB114)	
2.	Increment the No_of_Servers parameter by 1.	
3.	Now open DB Serv2Client_orders (DB224)	
4.	Increment the No_of_Servers parameter by 1.	
5.	In the “PLC data types” folder you open data type “Client2Serv”	
6.	Increase the PUT_orders array by 1.	
7.	For the start values of the parameters you enter the following data: • ID from Table 6-5 no 3. • DB_nr_cl = 116 • DBB_nr_cl :=0 • DB_nr_s = 6 • DBB_nr_s =0	
8.	Add a data block into your project with an array of 160 byte size.	
9.	Repeat steps 9 to 11 for data type “Serv2Client” with the following data: • ID from Table 6-5 no 3. • DB_nr_cl = number of the DB from no 10 • DBB_nr_cl :=0 • DB_nr_s = 7 • DBB_nr_s =0	

No.	Process	Remarks
10.	Compile and load the configuration and the user program to the CPUs. Now the client synchronizes data with the added server. For adjusting the data area to be synchronized, please note chapter 6.1.	

6.3 Ensuring data consistency in the server

Data consistency

Data inconsistency can occur if two processes asynchronously access the same storage area.

A practical possibility in this example is the server attempting to access a data area with a simultaneous write access by the client to this data area.

This chapter describes how the data consistency is ensured on the server side.

Write synchronization

If the client performs a write synchronization of a data area with a server, it verifies the first byte of the buffer before sending new data.

If this byte has the value 16#00, new data can be written to the server.

In the user program of the server, the following procedure is recommended and partly already implemented:

Table 6-6

No.	Instruction
1.	Regularly query the coordination byte in DB "Data_FromClient" for the status 16#F0 (before you call the FB "Sync_Server").
2.	If new data has arrived, you save this data to a buffer or process it directly (before you call the FB "Sync_Server").
3.	The FB "Sync_Server" resets the coordination byte to 16#00 so the client can send data again.

Read synchronization

If the client performs a read synchronization of a data area with the server, it verifies the first byte of the buffer before reading the data.

If this byte has the value 16#F0, new data is pending in the server.

In the user program of the server, the following procedure is recommended and partly already implemented:

Table 6-7

No.	Instruction
1.	Write your user data to DB "Data_ToClient".
2.	The FB "Sync_Server" set the coordination byte to value 16#F0 and the client resets it to 16#00 after it has received the data (permanent transfer).
3.	Regularly query the coordination byte in DB "Data_ToClient" for status 16#00 (before you call the FB "Sync_Server"). If the byte has this value, the client has fetched the data and you can start again with no 1.

6.4 Expanding the function of the coordination byte

Overview

The coordination byte is used in order to coordinate the communication between client and server.

If you are adding a further coordination function into your program, this chapter describes where in the program you need to make adjustments.

Values of the coordination byte

In this example application, the coordination byte can take on 3 states. Table 6-8 describes the values the coordination byte can take on and their meaning from the point of view of the client.

Table 6-8

Value / Direction	16#00	16#F0	16#FF
Client2Serv	Data can be written.	Data not yet processed.	Time not yet synchronized in the server
Serv2Client	No new data pending.	New data → Data can be read.	---

Expanding the values in the client

In order to react to different specific values than those in Table 6-8, you need to add further options to the evaluation. Concretely, this means that you need the already existing IF instruction by further ELSIF options.

For FB Sync_Client2Serv at the following position of the code:

Figure 6-1

```
2: //step2: get coordination byte from the server
   // depending on the coordination byte: send data or go to next server in order list
      #control.g_req:= 1; //start GET
   IF #view.G_NDR THEN //data arrived
     #control.g_req:= 0;
     IF "Client2Serv_Buffer".coord = 16#00 THEN //server is ready to receive data
        #control.step := 3; //goto step3
      ELSIF  "Client2Serv_Buffer".coord = 16#F0 THEN //server is not ready to get data,
                                                     //data not yet handled
        #Orders.Client2Serv[#control.number].Status := 16#000000F0; //save status
        #view.no_new_data := #view.no_new_data +1;//data not accepted from server
        #control.step:=8; //go to step8: next server in order list
      ELSIF  "Client2Serv_Buffer".coord = 16#FF THEN //server is not ready to get data,
                                                     //time sync is not yet finished
        #Orders.Client2Serv[#control.number].Status := 16#000000FF; //save status
        #view.no_new_data := #view.no_new_data +1;//data not accepted from server
        #control.step:=8; //go to step8: next server in order list
      ELSIF
      END_IF;
```

add code

For FB Sync_Serv2Client at the following position of the code:

Figure 6-2

```
2: //step2: analyse coordination byte
    IF "Serv2Client_Buffer".coord = 16#F0 THEN //new data in the server available
      #control.step := 3; //goto step3
    ELSIF  "Serv2Client_Buffer".coord = 16#00 THEN //no new data in the server available
      #Orders.Serv2Client[#control.number].Status := 16#00010028; //save status
      #view.no_new_data := #view.no_new_data +1;//no new data in server available
      #control.step := 6; //goto step6: change server
    ELSIF

    END_IF;
```

add code

7 Appendix

7.1 Service and support

Industry Online Support

Do you have any questions or need assistance?

Siemens Industry Online Support offers round the clock access to our entire service and support know-how and portfolio.

The Industry Online Support is the central address for information about our products, solutions and services.

Product information, manuals, downloads, FAQs, application examples and videos – all information is accessible with just a few mouse clicks:
support.industry.siemens.com

Technical Support

The Technical Support of Siemens Industry provides you fast and competent support regarding all technical queries with numerous tailor-made offers – ranging from basic support to individual support contracts. Please send queries to Technical Support via Web form:
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You will receive optimum support wherever you are with the "Siemens Industry Online Support" app. The app is available for Apple iOS, Android and Windows Phone:
support.industry.siemens.com/cs/ww/en/sc/2067

7.2 Links and literature

Table 7-1

No.	Topic
\1\	Siemens Industry Online Support https://support.industry.siemens.com
\2\	Link to this entry page of this application example https://support.industry.siemens.com/cs/ww/en/view/40556214
\3\	Manual "SIMATIC STEP 7 Basic/Professional V15.1 and SIMATIC WinCC V15.1" https://support.industry.siemens.com/cs/ww/en/view/109755202
\4\	Manual "CPU-CPU Communication with SIMATIC Controllers" https://support.industry.siemens.com/cs/ww/en/view/78028908
\5\	Manual "Communication with SIMATIC" https://support.industry.siemens.com/cs/ww/en/view/25074283
\6\	Manual "SIMATIC System Software for S7-300/400 System and Standard Functions - Volume 1/2" https://support.industry.siemens.com/cs/ww/en/view/109751826
\7\	Manual "SIMATIC Programming with STEP 7 V5.5" https://support.industry.siemens.com/cs/ww/en/view/45531107
\8\	Technical data "CPU315-2 PN/DP, 384 KB" https://support.industry.siemens.com/cs/ww/en/pv/6ES7315-2EH14-0AB0/td?dl=en
\9\	Technical data "CPU 1516-3 PN/DP, 1MB Prog., 5MB Data" https://support.industry.siemens.com/cs/ww/en/pv/6ES7516-3AN01-0AB0/td?dl=en
\10\	Application example "Data synchronization over open communication between multiple field devices (S7-1200) and a head PLC (S7-1200/ S7-300/ WinAC)" https://support.industry.siemens.com/cs/ww/en/view/39040038

7.3 Change documentation

Table 7-2

Version	Date	Modifications
V1.0	01/2009	S7 communication via the integrated S7-300 CPU interface (task A) and via an S7-300 CP (task B)
V1.1	02/2010	Supplementation in chapter 2.3: S7-1200 data transmission
V1.2	08/2010	Changing the task in deterministic data exchange via S7 communication (task A)
V2.0	06/2013	Deleting task B and more flexible design of task A: configurable synchronization areas
V2.1	08/2019	Error elimination + update to TIA Portal V15.1