International Journal of Innovation Scientific Research and Review
Vol. 03, Issue, 06, pp.1373-1376, June, 2021
Available online at http://www.journalijisr.com

Research Article

ISSN: 2582-6131

MODBUS GATEWAY DESIGN USING ARM MICROPROCESSOR

[1,*] Semanur KARACA and [2]Dr. Onur AKBATI

[1]Department of Control and Automation Engineering, Yıldız Technical University, Istanbul, TURKEY.
[2]Asst. Prof, Department of Control and Automation Engineering, Yıldız Technical University, Istanbul, TURKEY.

Received 21th April 2021; Accepted 22th May 2021; Published online 30th June 2021

ABSTRACT

Integration of various communication protocols into automation system becomes a necessity for designing a gateway to reduce complexity in network topology. In this study, Modbus RTU / Modbus TCP Industrial Ethernet Gateway design and implementation is presented with ARM Embedded System and FreeRTOS real-time operation system. The Modbus gateway can perform communication with Modbus RTU and Modbus TCP devices over itself. Moreover, the gateway can be adjustable with the user-interface application or messaging interface without user-interface application.

Keywords: Gateway, Industrial Communication, Modbus, Network.

INTRODUCTION

Improvement of technology in automation system, different device technology and communication protocols are introduced. Data transmission speed, compatibility between devices, setup cost and maintenance become crucial with enlarging automation systems. The first remarkable criteria when setup an automation system is communication protocol. There are lots of research and development in industrial communication technologies to improve technical characteristics. For example, the devices use wired connection to support serial communication RS232 and CAN supply only point-to-point communication, low speed and limited transmission distance besides RS485 has supporting up to 32-128 nodes, high transmission speed, over transmission distance, low cost and strong anti-interference. Another wired communication technology is Ethernet is most used communication protocols because of good compatibility and easily connective, data rates is up to reach 10 megabits per second to 100 gigabits per second, including CSMA/CD standard to prevent data-collision [Shuangye Chen *et al.,* 2013], [Li Hui et al., 2013]. Accordingly, MODBUS protocol can support both Serial and Ethernet communication. Modbus RTU is based on serial communication with RS232, RS485 and RS422 psychical layer since Modbus TCP is based on Ethernet TCP/IP protocol [Mihai Postolache, 2017], [Modbus Foundation]. Another research area is connection capacity. Programmable Logic Controllers (PLCs) are capable multiple interfaces, but the main purpose of this devices is implementing data acquisition and processing of data, not for packet processing and protocol handling. The price of PLCs and the time for man-hour to program the PLC functionality is enormous costs to solve complexity in the heterogenous network topologies [ClaudiuChiculita and Mihai Lucian Cristea, 2013]. The research concludes the requirements of gateway.The aim of this study is design and developing a Modbus gateway which is low cost, real-time, more connection capacity, reliable, convenient Serial-Ethernet communication through RS485 serial bus and Ethernet TCP/IP. The main purpose of the design is to make installation and setup the system easier with user interface and messaging interface and the second aim is designing a low cost, reliable and real time system. Since ARM Embedded System, FreeRTOS real time system, Ethernet and Serial line devices are met the target system requirements.This abstract is organized as follows, firstly, the architecture and the system implementations are discussed in Section II, Section III demonstrates our tests and the results, and the Section IV draws the conclusion.

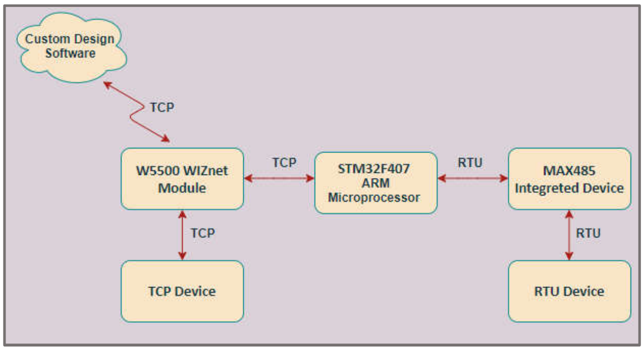


Fig. 1. The illustration of system architecture

SYSTEM ARCHITECTURE AND METHODOLOGY

Modbus protocol services both Serial and Ethernet based connection. It is also openly published, free charge and designed for industrial application. The Modbus gateway make easier communication between devices that are placed in different networks. It is designed to transfer the messages from one port to another and if necessary, to convert the messages from one protocol to another. The hardware of Modbus gateway is built with STM32F407 ARM Microprocessor. It can run up to 168MHz frequency, has 1Mbyte flash memory and supporting up to 15 different communication interfaces. The main communication interfaces for forming Serial and Ethernet communication are USART and SPI. The USART channel of ARM microprocessor is set up for RS485 serial line communication with MAX485 device. MAX485 integrated device is capable of long-distance and bidirectional data transmission up to data rate 2.5Mbps. Ethernet communication is setting up with SPI channel of ARM microprocessor and W5500 WIZnet module. W5500 chip supports Hardwired TCP/IP protocols, SPI Mode 0.3, 10BaseT/100BaseTX Ethernet, auto negotiation, has 8 independent sockets running simultaneously. Figure1 shows hardware implementation of Modbus gatewayandancillary deviceswhich are configured using the database running on the embedded server.The Modbus gateway works as

[*]**Corresponding Author:Semanur KARACA,**
Department of Control and Automation Engineering, Yıldız Technical University, Istanbul, TURKEY.

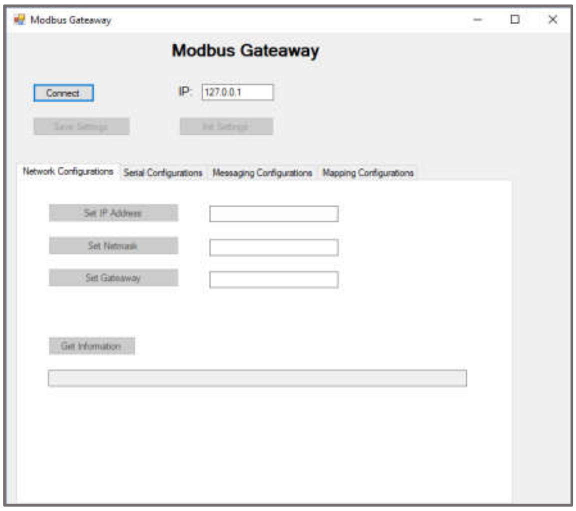
server and the main duty is meeting message demands coming from RTU and TCP devices properly. It gives exception message 10 when misconfiguration that the mapping configuration is not current or overload situation that message buffer is full. Moreover, it gives exception message 11 in such cases message timeout which means device is absent. The other specification is mapping which means Unit ID- Slave ID matching and Unit ID – IP Address matching. This specification is to bring flexibility to find device ID in more complex network and to increase communication nodes. Unit ID-Slave ID matching can be used for accessing TRU devices, besides user can use Unit ID – IP Address matching for accessing TCP devices over the gateway without need router or switching devices. The database is created via STM32F407 flash memory which size 128Kbyte. It is used for storing mapped data list and the gateway Serial and Ethernet connection settings such as IP Address, Net mask, Gateway, Baud Rate, Parity Bit, Stop Bit, Word Length, Response Timeout.

Object No	Object	Address (Decimal)	Command Length (Byte)	Read Only (RO), Write Only (WO) or Read/Write (R/W)	Function Codes (HEX)		Default
					Read 0x03 - Read Multiple Bytes	Write 0x10 - Write Multiple Bytes	
1	IP Address	40001	4	R/W	0x03	0x10	192.168.2.20
2	Net mask	40005	4	R/W	0x03	0x10	255.255.255.0
3	Gateway	40009	4	R/W	0x03	0x10	192.168.2.1
4	Baud Rate	40013	1	R/W	0x03	0x10	0
5	Parity Bit	40014	1	R/W	0x03	0x10	0
6	Stop Bit	40015	1	R/W	0x03	0x10	0
7	Word Length	40016	1	R/W	0x03	0x10	0
8	Response Timeout	40017	4	R/W	0x03	0x10	5000
9	Mapped Data List	40021	248	R/W	0x03	0x10	0XFF
10	Save Setting	40025	1	WO	-	0x10	-
11	İnit Setting	40026	1	WO	-	0x10	-

Table 1. Message Register List

Baud Rate		Parity Bit		Stop Bit		Word Length	
DataRate (Mbps)	Address (HEX)	Value	Address (HEX)	Value	Address (HEX)	Value	Address (HEX)
9600	0x00	None	0x00	1	0x00	8 Bits(including Parity Bit)	0x00
19200	0x01	Odd	0x01	2	0x01	9 Bits (including Parity Bit)	0x01
38400	0x02	Even	0x02				
115200	0x03						

User can access and can modify the RTU and TCP devices settings and the database over itself. The message table is used to write the register numbers of each setting. Table 1 and Table 2 show message lists. Another option for the user interface is a custom-design software (GUI) on a computer. The user can set and access all RTU and TCP devices via database running on the gateway. Furthermore, user can send test messages with RTU and TCP devices using FC3 and FC16 function codes via GUI. Figure 2 illustrates the custom design software application.



Modbus Gateaway

IP: 127.0.0.1

Fig. 2. Custom design software on computer

Figure 3 shows the flowcharts of Modbus gateway. TCP connection task is executable SPI bus interface. The device setting message is controlled via #255 Unit ID over the Modbus gateway with using message register table. TCP devices can be accessed over Modbus gateway using Unit ID – IP Address matching. The user is used #248-254 Unit ID for setting up TCP connection. The gateway always controls the mapped data list, gateway message state (busy or done) and message buffer before the message is send. When message state is busy, mapped data list is not configured or message buffer is full, the exception message is sent.RTU connection task is running on USART bus interface. The device state and message queue are controlled before the message is send. Even if the message queue is full or the device state is busy, the exception message is sent.

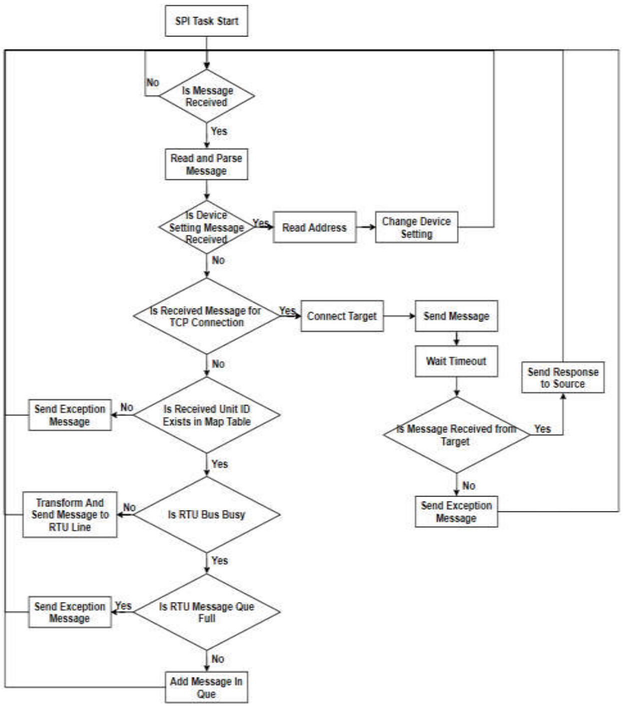


Fig 3. (a) TCP communication task

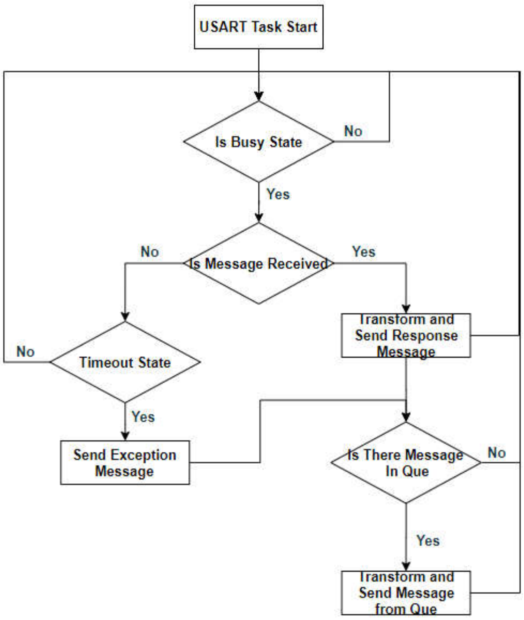


Fig 3. (b) RTUcommunication task

GUI task is executable over TCP connection. There are three main specifications of the system. The first one is that user can get current information of the Modbus device such as network configuration, serial configuration,and mapped data list. Another specification is being set device configuration like serial line, network line and mapping configuration. User must save each configuration change with save setting button. User can turn back to default setting with init setting button. Moreover, user can send test messages RTU and TCP devices using FC3 and FC16 function codes.

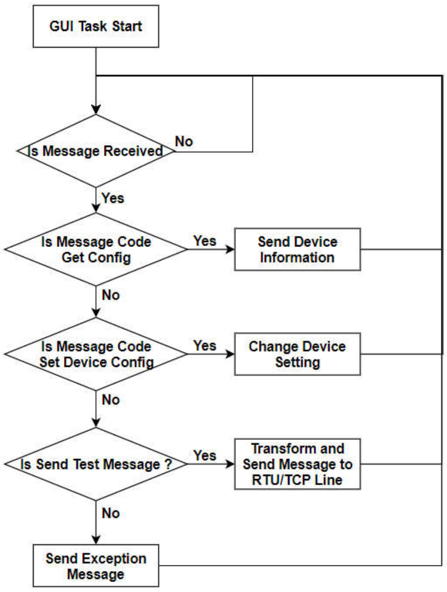


Fig 3. (c) GUI task

Fig.3. The flowcharts of the Modbus gateway.

SYSTEM TESTS

The Modbus gateway is tested via different RTU and TCP devices being found in market. The test procedure is implemented orderly that is indicated in flowcharts. 2 devices can be connected to RTU network lines of gateway without any connection loss or slowdown in connection speed. 2 devices can be connected to TCP network line over the Modbus gateway. The performance seems as good as RTU network line. Power consumption is drawn in system operation. Arm µC's draws different currents at different frequencies. System frequency can be set at 168 MHz / 3mA without effecting system performance. MAX485 integrated device draw current in order of µA, so their effects to power consumption can be ignored. W5500 WIZnet module draws >100 mA current when it transmits data. Table 3 illustrates power consumption of existing system.

Device Name	Current
W5500 WIZnet Module	132 mA
MAX485 Integrated Device	300 µA
Arm Microprocessor	168 MHz / 3mA

Table 3. Nominal current consumption

CONCLUSION

This study presents the design and the implementation of a Modbus gateway that has low cost, real-time application, convenient article in the communication technologies area. The system has monitoring and controlling capabilities via custom design software and over itself. The novel design is to establish connection with TCP devices over the Modbus gateway and to change and access the device setting via message address. Unlike the similar systems, employed embedded server makes the maintenance costs almost zero, the system cost is low since low profile-high quality equipment (such as MAX485 device, W5500 WIZnet module and ARM µC, etc.) are used in the design.The next step of this study includes extending communication line with wireless technology.

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