Study on Intelligent Communication Module for Programmable Logic Controller

Sheng Lu[1], Zhong-Jian Cai[1] and Tan Liu[2]

[1] School of Computer Science and Information Engineering, Chongqing Technology and Business University, Chongqing, China

[2] Automation R&D Center, Schneider Electric, Shanghai, China

alanltnew@126.com

***Abstract*-This paper gives a new design for Ethernet/IP Intelligent Communication Modules (EIICM). The new EIICM module not only acts as the network communication module for the PLCs to facilitate the communications between the PLCs and the remote network devices, but also it acts as the CPU of the built-in operation switch to perform the network topology monitoring and maintenance, IGMP Snooping, and switch managing and diagnosing. Furthermore, it acts as an Ethernet/IP and MB/TCP end device to provide implicit and explicit messaging services. In this paper, it focuses on the overall architecture, the functional design and some key techniques of new solution in EIICCM, such as "Structured Message Broker" pattern, "Management-self Adaptable" pattern, and device management method. It has given a new solution for the next generation of Ethernet module for industrial PLC.**

Keywords- *ethernet; intelligent; PLC*

I. INTRODUCTION

Although a wide variety of networks and Ethernet have been used in the manufacturing industry over the past decade [1], the widespread adoption of Ethernet as a standard in other domains (e.g., the internet) has made it an attractive option to consider. The increased network speed and the reduced cost of devices have further heightened interest. The introduction of switched Ethernet has allowed for more deterministic behavior and alleviated many of the concerns about unbounded delays. Ethernet is already being widely used as a diagnostic net-work in manufacturing systems and is making inroads into the control networking domain also[2].

This paper does the research on a new Ethernet/IP intelligent communication module (EIICM) for industrial PLC control. The architecture definition of the EIICM is based on the analysis and evaluations of the advanced product concept alternative solutions documented in PLC research area. It has given the whole decomposed structures (subsystems, components, and tasks) of the EIICM system. And it also has analyzed functionalities, behaviors, and interfaces of the structures relationships and interactions among these decomposed structures. This new design has presented and discussed functional interactions between the EIICM subsystem and its environment, quality properties of the EIICM system (response time, throughput, overload behavior, and scalability), architecture models and diagnosing and configuration of EIICM, etc.

II. EIICM

The goals of the EIICM is to develop the next generation Ethernet/IP communication modules with Modbus interoperability and higher performance for our existing industrial PLCs and to bring traditional Ethernet modules some intelligent abilities. The converged protocol modules significantly increase the interoperability between the largest installed base of industrial Ethernet networks: Ethernet/IP and Modbus/TCP and facilitate our customers to reuse their existing Modbus/TCP devices to reduce cost, time, and risk for deploying and maintaining their network architectures.

The EIICM system implements the new ODVA(Open DeviceNet Vendor Association) CIP(Common Industrial Protocol) specifications Vol. 7, "Integration of Modbus into CIP Architecture". The EIICM system also provides more TR services and higher performance than all the last generation Ethernet/IP products do[3][4]. Therefore, the customers' needs for the converged protocol modules, the competition for introducing the converged protocol modules, the extending of the TR functionalities and increasing performance, and the avoidance of over exposure of old products in the field are the key drivers to initiate the EIICM project.

The EIICM system to be architected in this paper actually plays several roles in the control network. First it acts as the network communication module for the PLCs to facilitate the communications between the PLCs and the remote network devices to realize the system configuration, control, diagnostics, and data collecting and will be designed and implemented based on the existing last products. Secondly it acts as the CPU of the built-in operation switch to perform the network topology monitoring and maintenance, IGMP Snooping, and switch managing and diagnosing. On the third, it acts as an Ethernet/IP and MB/TCP end device to provide implicit and explicit messaging services.

III. GENERAL ARCHITECTURE

A. deployment diagram

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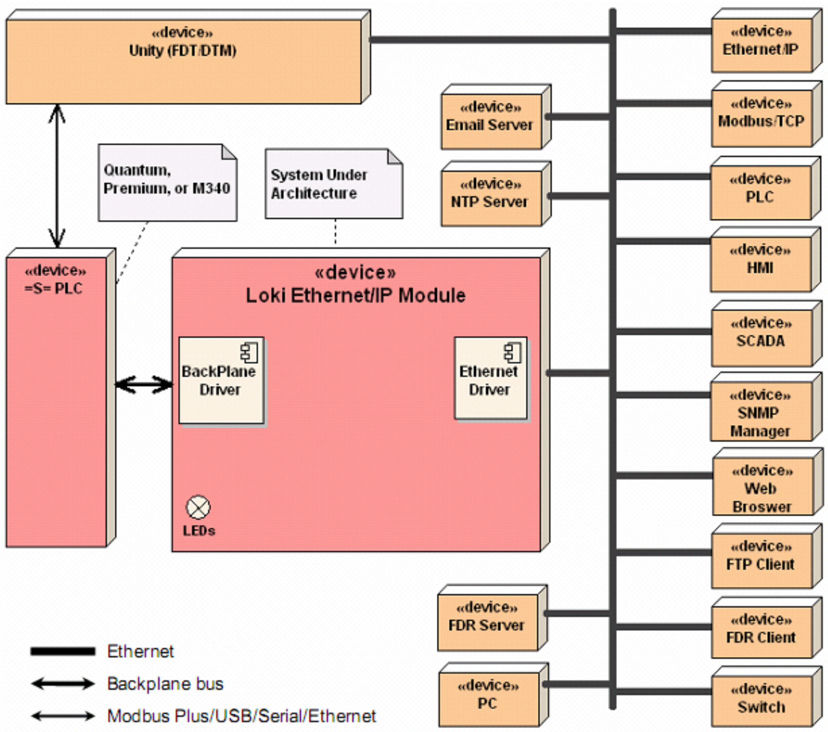

Figure 1. The general architecture of the EIICM in the converged protocol control

Figure 1 shows the general architecture of the EIICM system in an Ethernet/IP and MB/TCP converged protocol control network system. This control network system consists of the controllers (PLCs), networking communication modules (EIICM), configuration and diagnostic engineering tools (Unity, HMI, and SCADA), PC, Switch, and various kinds of devices from different vendors with different network protocol applications. In this control network system, the EIICM system connects to its PLC through a back plane bus which is platform dependent and to the network through its Ethernet port.

B. Functional design

Functionally, the EIICM system is designed to provide the following primary services as shown in Figure 2.

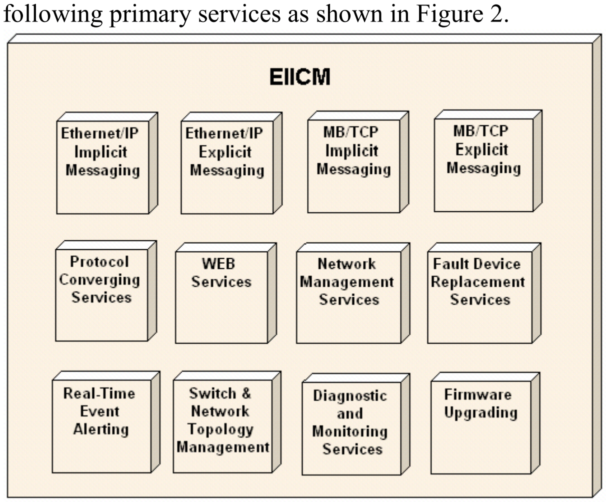

Figure 2. The primary services of EIICM.

The detailed intelligent functionalities are as follows.

1)Protocol Converging Services

The EIICM system receives and acquires data and converts them into a format the targets (PLC or MB/TCP devices) of the data can use. For example, converting the Ethernet/IP message to MB message to facilitate the remote Ethernet/IP device access the PLC Modbus Registers; converting the MB message into Unitel message to facilitate the remote MB/TCP devices to access the Premium PLC; and converting the Ethernet/IP message to MB/TCP message to facilitate the user application to send the EIP explicit messages to the remote MB/TCP devices[5].

2)WWW interface and Network Management Services

The EIICM system hosts a Web server and Web pages to allow the user to perform web diagnostic and web monitoring. The EIICM system allows the users to perform networking management activities[6].

3)Fault Device Replacement Services

The EIICM system provides the FDR (Fault Device Replacement) services to facilitate the fault device replacement and reset.

4)Real-Time Event Alerting

Under certain event conditions, the EIICM system signals the assigned persons through SNMP traps and LED for them to react to the events[7].

5)Network Topology Management

The EIICM system acts as the CPU of its embedded switch to perform the network topology monitoring and maintenance, IGMP snooping, and switch control.

6)Diagnostic and Monitoring Services

The EIICM system allows the users to diagnose, monitor, and troubleshot the system and performs analysis. Besides the provided functionalities as addressed above, the EIICM system are also easy to be scalable.

The EIICM system collect and send the IO data (a mixture set of Ethernet/IP and MB/TCP IO devices) simultaneously at the user specified RPIs and exchange the IO data with the PLC periodically (driven by PLC). This is the real-time aspect of this control network system.

The whole network flows both high frequency small size IO data and low frequency large size configuration data, diagnostic data, monitoring data, and other explicit messaging data with many different network protocols. The EIICM system is able to handle varying loads. At a minimum, the EIICM system is capable of handling 12,000 IO packets per second under the condition of 100% pure IO packets traffic. Furthermore, the EIICM system is also able to handle loads that exceed this minimum[8][9].

IV. STRUCTURED MESSAGE BROKER SOLUTION

Actually the EIICM will be constituted of multiple interacting and message transaction oriented subsystems performing message processing and transferring. In our design, we define a Structured Message Broker as shown in Figure 3 to address the message transaction relationship among different subsystems inside the EIICM system and provide design guidance for the subsystem design and implementation.

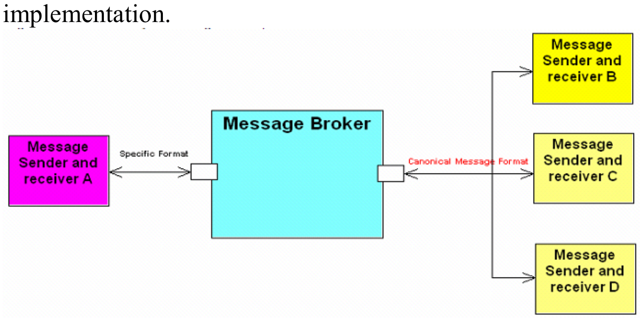

Figure 3. Structured Message Broker.

The message broker usually performs message processing, message transaction, message transformation from one format to another format, message filtering, message storing and queuing, message delivering, message translating, and message coding. The message broker pattern makes the message sender and receiver decoupled each other to facilitate the modifiability. The structured message format (or enterprise data model) makes new components or systems easily to be integrated and increase the integration capability and modifiability. But each message sender and receiver may need to transform the message format between the structured message format and its specific message format[10].

This Structured message broker architecture pattern is created by combining the traditional known " broker" architectural pattern and the enterprise data model.

In the traditional known "broker" architectural pattern, all the message transformation is performed inside the message broker which needs to every sender's and receiver's message formats, decreasing modifiability and resulting in low performance of the message broker.

In this design, we use the structured message broker architecture pattern to figure out the message storage capability, message transaction path, message transaction performance, message quality, optimum message transaction architecture, and optimum component design.

The first application of the structured message broker architecture pattern in this architecture design is given to the whole EIICM control network system architecture. Conceptually the structured message broker architecture is also applicable for addressing the event handling mechanism as shown in Figure 4 which is actually included into this architecture design.

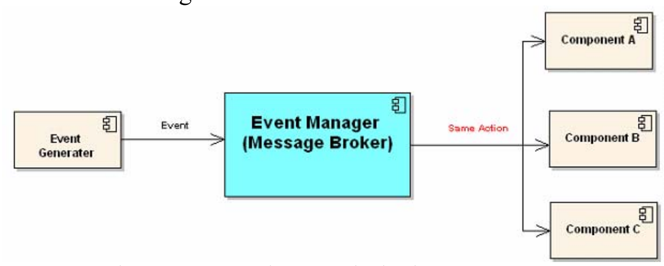

Figure 4. Structured message broker in event manager

In fact, the structured message broker architecture pattern can be applied to any identified subsystems in the EIICM system internal system. We have fully used the structured message broker architecture pattern in the EIICM architecture design to address the message transaction architecture among the subsystems.

V. INTELLIGENT NETWORK MANAGEMENT

A. *"Management-self adaptable" Pattern*

The "Management-self adaptable" pattern specified and adopted in this design addresses two architectural design problems:

1) How to integrate (hook up) new subsystems into the existing system (EIICM system).

2) How to perform the same set of operations systematically on those interacting subsystems with different interfaces.

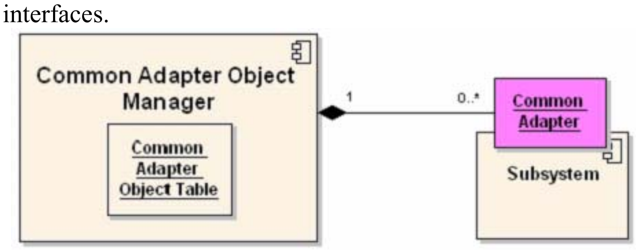

Figure 5. The "Manager-Adapter" Pattern

At the system start-up time following a powered on or reset, a system management function is needed to initialize, configure, and start all the internal subsystems. Even at run time, all these subsystems (components) may need stopping, running, or resetting at the same time under certain conditions (events).

The "Management-self adaptable" design pattern (as shown Figure 5) is captured from the conceptual commonality of the design solutions for hooking up and performing the same set of operations on the subsystem (component) in some current network products. In the "Management-self adaptable" pattern model:

1) Each subsystem is wrapped with a Common Adapter object which provides a set of uniform and standard interfaces.

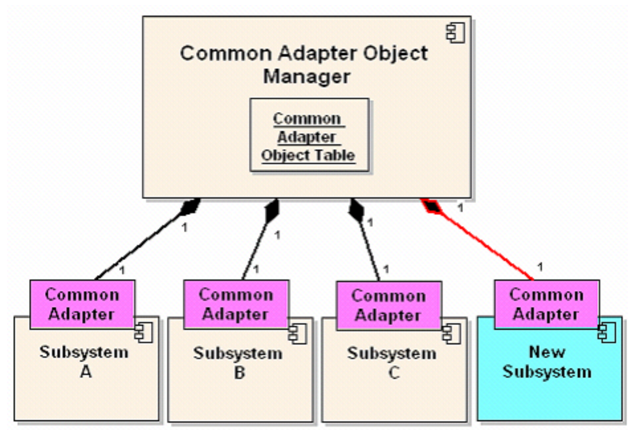

Figure 6. Hook up new subsystem with the "Manager-Adapter" Pattern

2) The Common Adapter Object Manager maintains a Common Adapter object table and allows the user to add a Common Adapter object (hoop up subsystems as shown in Figure 6).

3) The Common Adapter Object Manager performs the same set of operations on the subsystems through the standard interfaces their adapters provide.

B. *Device management*

The Device Management is the first application subsystem component to function when the EIICM system is powered on or reset. It takes over the control from the initialization routine and initializes, configures, and starts all of the other application subsystem components and brings the EIICM system up[11].

The Device Management subsystem acts as the "Common Adapter object Manager" in the "Management-self adaptable" Pattern model. Figure 7 shows the architectural component structure of the subsystem management design pattern. In this case, the "Common Adapter object" is the "Component" object. The Device Management subsystem maintains a "Component" table and controls and manages the other subsystems through the "Component" table.

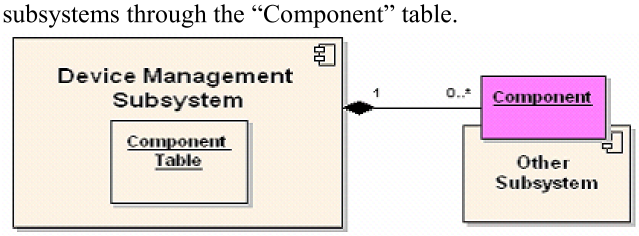

Figure 7. Component structure of the subsystem management design pattern

The Device Management subsystem interacts with the Host Interface subsystem for reading the configuration data from the PLC; interacts with file system for reading and storing the configuration data; interacts with the FDR Client for configuring the IP address, and interacts with the other components for distributing the configuration data, delivering the event, and reading the diagnostic data. In particularly, the Device Management subsystem needs to interact with the EIP Stack subsystem to synchronize the IP configuration information and with IO Management subsystem to perform IO operations to show the system's state and error status. The Device Management subsystem should be standard and platform independent.

VI. CONCLUSION

This paper has a discussion and research on the new design of intelligent Ethernet management system for industrial PLC. It supposes a new design of Ethernet/IP Intelligent Communication Modules (EIICM) for the next generation of PLC, including the overall architecture and the functional design and some key techniques of new solution, such as "Structured Message Broker" pattern, "Management-self Adaptable" pattern, and device management method.

As a communication module for the PLC, the EIICM system can transport the message through it as a switch does and communicate with many different devices. As an Ethernet/IP and MB/TCP end device, the EIICM system is able to originate the message requests and provide response services and must be compliant with the ODVA specification. As a switch CPU, the EIICM system not only manages the switch but also allows the users to configure, control, and diagnose the switch. Most modules of the system (PLC, IO devices or other optional modules) are configured by the top layer tool.

All the devices and modules in the network perform their functions in parallel and individually but some extent of synchronization is also needed in the system. There are many concurrent tasks running in each device and module. In general, the characteristics of this EIICM control network system are: Ethernet/IP and Modbus/TCP converged, distributed, event-driven, real-time data transfer, heavy workloads, and concurrency.

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