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Bogdan FABIAŃSKI*

EMBEDDED SYSTEM OF CRITICAL INFORMATION MANAGEMENT

An example of knowledge transfer from academic research to industry was presented in the paper. IT Integration Platform called *TechLink Bridge* based on the three pillars of innovation was introduced. *TechLink Bridge* system as the result of cooperation of the Poznan University of Technology and Emtel System company was designed as the answer for the market demands. A spatial structure of the proposed main board in terms of external wire and wireless interfaces was shown. The software structure and its particular characteristics as the description of selected communication protocols were introduced. The influence of the development of critical information management to the functionality of the platform was described as the flexibility to manage the information flow was. The future development of *TechLink Bridge* was presented in the end.

1. INTRODUCTION

The genesis of the project dates back to the real market demand for systems integration. Despite a very wide base and a set of standards performing typical tasks of industrial and buildings automation there are very specific needs at the junction of industrial processes and production management, where the commonly used solutions are not optimal or are not available at all. In those cases there is a need to implement a new solution which will precise fit to the execution of a specific task. Modern production processes dominated by automation systems requiring transmission and analysis of very large amounts of data are the difficulties in extracting the critical information that requires an immediate response from those that are normal states of the process. Critical data means a data that indicate a threat to human life or health, and those that may contribute to a major accident that inhibiting the production process.

On the one hand, there is a problem of extracting critical events, and on the other hand, a problem with their appropriate service. It is natural that the process of saving human life is supported by a man, and he is exposed to inefficient operation (due to stress, fatigue, routine). Because of this it was decided to design the platform of critical information detection and its intelligent transmission at the intersection point of multiple interfaces and automation systems to support human activities.

* Poznań University of Technology.

The platform was fully embedded and it was called *TechLink Bridge* (TLB). The first version of the system was introduced in [1], where stability analysis and its integrity control mechanisms were the main topics.

TechLink Bridge is the innovative result of the cooperation of Industrial Control and Electronics Division with Emtel System company. An innovation could be seen in three major aspects:

- conception of market usage – its exceptional quality as an critical information management and propagation platform,
- used production technology (new PCB project, modern, energy-efficient components, unique control algorithms),
- practice implementation as an IT systems integrator platform on the one hand and usage of handy, popular channels of information propagation on the other hand.

The system core was STM32F4 microcontroller. The ARM Cortex-M4 based STM32F4 series is an extension of the STM32 family with high performance. These MCU leverage 90 [nm] production technology and *ART* accelerator to reach the industry's highest benchmark scores for Cortex-M based microcontrollers with up to 225 [DMIPS] / 606 [CoreMark] executing from flash memory at 180 [MHz] operating frequency [2]. The DSP instructions and the floating point unit enlarged the range of addressable applications. 90 [nm] process, *ART* and the dynamic power scaling enabled the current consumption in run mode to be as low as 238 [μA/MHz]. STM32F4 was the result of integration the real-time control capabilities of an MCU and the signal processing performance of a DSP.

2. SYSTEM INNOVATION

2.1. Introduction

As shown in Figure 1, using the available communication interfaces, *TechLink* Brigde mediated the propagation of critical information. There were wired interfaces such as Ethernet, RS-232, RS-485, CAN, which cover most of the communication networks used in industrial practice. In terms of wireless communication there were used: the GSM and ISM (Industrial, Scientific and Medical), FSK (Frequency-Shift Keying) 433 [MHz] band radio. DECT (Digital European Cordless Telecommunications) telephone system could be used by integration with e.g. ASCOM Elise module.

The first practical implementation of the system [1] exposed the weaknesses of the structure. Primarily aimed at – as expected – the use of GSM gateways outwardly with RS-232 resulted in periodic data transmission errors. In spite of the hardware mechanisms of anti-lock, including resetting system, there were possible latencies and data losses, what is unacceptable in human life protect system. Current solution was based on GSM module blended with the PCB design. This allows more complete control and minimizes the risk of transmission errors by significantly shortening the length of data lines. The use of its own design, dedicated PCB removes functional limitation of evaluation board consisted of the shared SDIO interface line (memory card) and RS-232 (GSM gateway). This resulted in the need to run SDIO interface during the read from configuration file and later switch to the RS-232 interface (with permanently lost of SD card access). This prevented the use of an SD card in the ongoing reporting mechanism and use it as an optional "black box" or as a source of data for the analysis in the direction of improving the platform performance. Custom PCB design allowed also to minimize costs and added practical application of industrial interfaces (CAN, RS-485) required additional physical layer systems and electrical isolation.

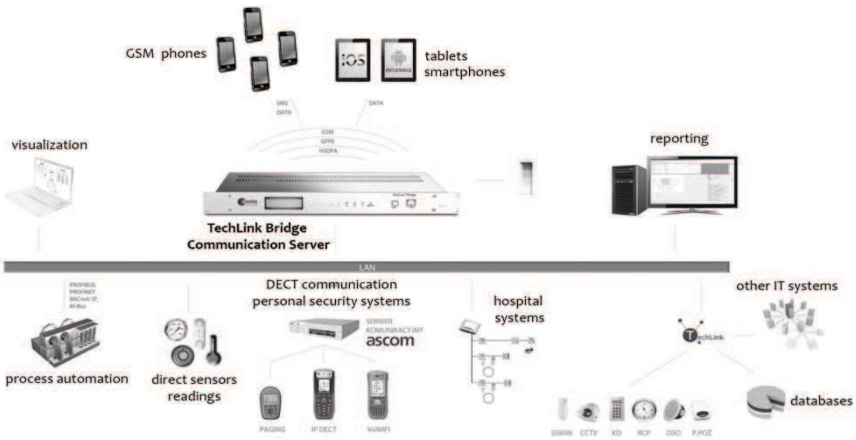

Fig. 1. Integration abilities of TLB and its place in communication network

2.2. Hardware design

From a practical point of view TLB was performed in a compact, standard enclosure mounted in a 19 inch rack. Ethernet interface, USB and HMI (Human Machine Interface) in the form of an alphanumeric display, buttons and LED lights in the front panel as presented in Figure 2. GSM antenna connector and power supply were mounted on the rear of the unit as the another industrial interfaces are.

Fig. 2. TLB v1.0 front panel

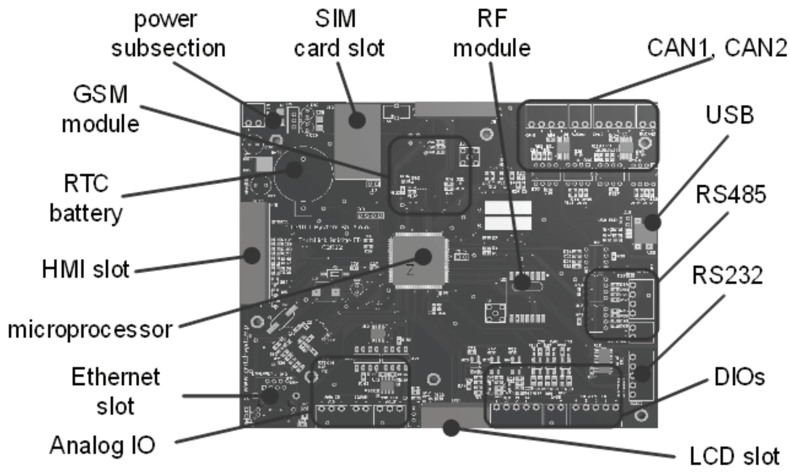

Fig. 3. Spatial distribution of the main elements of PCB

It is very important that low energy consumption attribute makes it possible to implement emergency power system based on a battery with relatively small capacity and an automatic switch when a main power loss. Period of work on battery backup would be much greater than several minutes as for standard PC UPS systems and can reach several hours in practical implementation.

One of the main objectives of the *TechLink Brigde* PCB project was full galvanic isolation of external interfaces, which – as shown in Figure 3 – included two independent CAN interfaces, Ethernet, analog input and output as 10 [V] standard, triple entry, binary inputs and outputs in standard 24 [V], independent RS-232 and RS-485, USB FS. Wireless connectivity was complemented by GSM and RF 433 [MHz] ISM FSK. Internal buses are: RS-232 for communication with the GSM module and the SPI for communication with the RF module. Selected protocols for individual interfaces were described in Section 2.3.

2.3. Software

The core software system based on *FreeRTOS* real-time system [3]. The system allows flexible real-time, simultaneous support for all tasks in the system established by closing within a single thread. In addition, malfunction of one does not result in the suspension of the whole program. Such a system fault tolerance is required in critical events propagation system. Some of the blocks that do not fall within the scope of RTOS perform as interrupt handlers (Figure 4). The basic system clock was called *SysTick* and its role was to clock speeds for the operating system. *UART* communication service (physical layer of the *OpenAT* protocol [4]) demanded immediate access to the data received. *ETHERNET* block controls the data flow from the buffer to the *lwIP* stack [5]. *Real Time Clock* (RTC) functionality was to include the information about the time of the event, alarm messages and setting timestamp interrupt handler (removed from later version as described below). The last two interrupt routines are the communication physical interfaces: SDIO – implementing specialized transmission data protocol with Secure Digital Card (SD) and Universal Serial Bus (USB) as the local communication purposes extension.

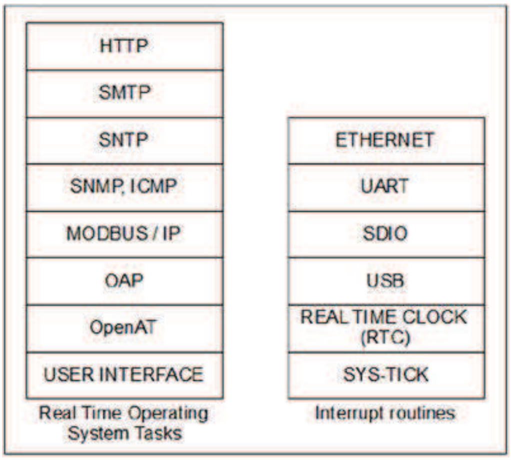

Fig. 4. TLB software architecture

The basic functionality of the operating system was operation of the ethernet application layer protocols. In terms of operation, TCP/IP stack based on *lwIP* library, completed by the author's implementation of the following protocols: ICMP (Internet Message Control Protocol) [6], SNTP (Simple Network Time Protocol) [7] and MODBUS/IP [8].

SNTP allowed to synchronize the system time with the available NTP servers on the network. ICMP was required for testing the integrity of the nodes in the IP network. Via MODBUS protocol it became possible to integrate with sensors of physical quantities. Other application level protocols were: SMTP (Simple Mail Transfer Protocol) and HTTP (Hypertext Transfer Protocol).

SMTP [9] with some authentication methods implemented (*auth login*, *auth plain, CRAM-MD5*) [10] allowed the use of a very popular and convenient way of communication which was electronic mail (e-mail). SMTP is a useful protocol for sending information about the reports, balance sheets and statements for some period of time. An additional advantage is the storage of information on independent mail servers.

There is a work underway on implementing TLS (Transport Layer Security). In practice, less and less mail servers allow to authentication on the unencrypted link.

Transport Layer Security (TLS) and its predecessor, Secure Sockets Layer (SSL), are cryptographic protocols that provide communication security over the Internet. TLS and SSL (belonging to the presentation layer ISO / OSI model) encrypt the segments of network connections at the Application Layer for the Transport Layer, using asymmetric cryptography for key exchange, symmetric encryption for confidentiality, and message authentication codes for message integrity [11][12].

The last of the listed protocols HTTP was used in the remote system upgrades. By implementing an appropriate structure of the code, main program could be loaded via the Internet and regular web browser. Mechanisms to protect against unauthorized access to the platform and errors in the main program transfers were developed (respectively: authentication login form and special verification code).

The general principles of critical information logic flow could be modified according to the end-user demands. However, the system users lists, reaction times, devices (for example: DECT or IP network elements) or definitions of system alarms were variables that could be modified. Users were configured in the groups, and the specified group are called for the definition of an alarm in the cycle of escalation information. The configuration of the logic flow of information can be identified with a multi-dimensional array in which the value of "1" means an open channel, and "0" closed one. Multidimensional array in practice was broken into a number of smaller two-dimensional so that it was possible to modify at the level of intuitive configuration text file (based on XML format).

The new implementation of critical events (alarms) management based on a set of variables that defined the state of each alarm. Separated alarm thread was inserted into RTOS and the real-time, parallel alarms management was possible. A simple dead-time periods was implemented to filter interferences. The use of dead-times made possible prioritization of alarms. An alarm with a higher identification number when arrived during the period of dead-time of a lower priority alarm removed the second one from execution list). This mechanism allows to eliminate multiple entries of alarm propagation that are dependent on each other and always occurs in pairs.

3. SUMMARY

In the introduction genesis of the article was brought closer. IT Integration platform called *TechLink Bridge* based on the three pillars of innovation was introduced. TLB system as the result of cooperation of the Poznan University of Technology and Emtel System company was designed as the answer for the market demands.

A spatial structure of the proposed main board in terms of external wire and wireless interfaces was shown. The software structure and its particular characteristics as the description of selected communication protocols were introduced.

In the nearest future it is planned to design the binary analog inputs/outputs expansion module capable to cooperate with the internal CAN network distributed systems. Later, a sensor module of basic physical quantities based on wireless communication with very low energy consumption would be introduced. The original TLB system is subject to constant evolution with successive implementation of industrial protocols (*Powerlink*, *Profibus*, *Profinet*).

TechLink Bridge, its conception of use, develop and functionality supported by real implementations have been awarded the elimination for the final stage of the *iWielkopolska* competition organized by the Marshal Office of the Wielkopolska Region [14].

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