Development of Interconnecting SW for Intranets and Fieldbuses

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Abstract: The paper aims at software architectures for intermediate systems with Intranets and wired or wireless Fieldbus-type interconnections. This manuscript communicates a case study founded on a real-world application that demonstrates an alternative contribution to network convergence in software architectures. The approach stems from design experience in both industrial network applications and in metropolitan networking. The case study applies IEEE 1451 standards providing a design framework for applications based not only on IP/Ethernet profile but also on ZigBee/IEEE 802.15.4.

Keywords: embedded system, design system, sensor system, computer communication network, communication protocol, network intermediate system, IP routing, IEEE 1451, network convergence.

1. INTRODUCTION

According to the ISO Open Systems Interconnection (ISO-OSI) vocabulary, two or more sub-networks are interconnected using equipment called as intermediate system whose primary function is to relay selectively information from one sub-network to another and to perform protocol conversion where necessary. A bridge or a router provides the means for interconnecting two physically distinct networks, which differ occasionally in two or three lower layers respectively. The bridge converts frames with consistent addressing schemes at the data-link layer, or medium access and control (MAC) sub-layer, while the router deals with packets at the network layer. Lower layers of these intermediate systems are implemented according to the proper architectures of interconnected networks. When sub-networks differ in their higher layer protocols, especially in the application layer, or when the communication functions of the bottom three layers are not sufficient for coupling, the intermediate system, called in this case as gateway, contains all layers of the networks involved and converts application messages between appropriate formats. An intermediate system represents typically a node that belongs simultaneously to two or more interconnected networks. The backbone network interconnects more intermediate systems that enable to access different sub-networks. If two segments of a network are interconnected through another network, the technique called as tunnelling enables to transfer protocol data units of the end segments nested in the proper protocol data units of the interconnecting network.

The paper deals with the current software architectures for intermediate system for Intranet and small-range wireless interconnections. The next section reviews the basic concepts of supporting resources, namely (1) IP routers as the most important means forming the Internet, (2) industrial network couplers that enable to create hierarchical communication systems as a basis of various -- not only industrial -- applications, and (3) design experience collected by our team in this domain, which influence unsurprisingly the current research. The section 3 dealing with network convergence aims at Ethernet and IP-based industrial networking that offer an application development environment compatible with common TCP/IP settings. It stems from IEEE 1451 family of standards and provides a design framework for creating applications based not only on TCP/IP/Ethernet profile but also on ZigBee. The second part of this section reviews the case study based on an application dealing with pressure and temperature measurement and safety and security management along gas pipes.

2. STATE OF THE ART

Contemporary industrial distributed computer-based systems encompass not only TCP/IP intranets, but also various wired or wireless digital actuator/sensor to controller connections. Those connections usually constitute the bottom segments of hierarchical communication systems that typically include higher-level fieldbus or Intranet backbones. Hence, the systems must comprise suitable interconnections of incident higher backbone and lower fieldbus or wireless segments, which mediate top-down commands and bottom-up responses. While interconnecting devices for wide-spread industrial LANa and fieldbuses are currently commercially available, some real-world applications can demand also to develop various couplers and router extensions either dedicated to special-purpose protocols or fitting particular operational requirements, see (Sveda, et al., 2005).

2.1 IP Routers

Internet/Intranet router architectures have experienced three generations, see e.g. (Keshav, 1997) or (Nguyen and

Jaumard, 2009). The first generation router architecture, sometimes called also as software router, which is based on a monolithic (or centralized) routing engine, appears just as a simple PC equipped with multiple line cards. Such a router is build with one CPU on a control card handling all basic modules such as Routing Engine, Packet Forwarding and Service Engines. The Routing Engine handles a set of routing protocols like IS-IS, OSPF, BGP and MPLS that run all together and interchange routing and switching information. Routing Table Manager is responsible for retrieving the information learned from the different routing protocol modules, making decisions for selecting the best routes and generating accordingly the Best Route Table, which can be used later in forwarding the packets to the corresponding destinations.

In a cluster-based architecture, often called as the second generation, the Routing Engine modules are distributed on several network communication cards that share an interconnection, usually through a system bus, to operation memory and processor on the control card. Moreover, the network communication cards are equipped with communication controllers implementing physical and data-link layer (L1 and L2) protocols and controlling input and output buffers.

Many current Internet routers, which can provide high speed switching capacity, are built with switching fabrics based on a Banyan or analogous self-routing topology. The Banyan switch fabric transports data from input line controllers to output line buffers according to binary labels derived by a proper trie data structure and related simple rules. In this case, routers are called as of the third generation. More detailed information, namely about the virtual output queued router architecture that appears common nowadays for ISP backbone networks, is provided e.g. by (Nucci and Papagiannaki, 2009).

Not only pure routing, but also additional network services have enriched router functionalities in the past few years, for Internet namely packet tagging, emulating application-level proxies, application-specific packet dropping, performance monitoring, intrusion detecting, and assorted filtering and firewalling. Nevertheless, the routing engine provides the essential part of router functionality. As a software component, the routing engine is used to control the router activities and to build the data forwarding table.

2.2 Industrial Networks Coupling

The following taxonomy of industrial communication and/or control network (ICN) interconnections covers both the network topology of an interconnected system and the structure of its intermediate system, which is often called in the industrial domain as coupler. On the other hand, the term gateway sometimes denotes an accessory connecting PC or a terminal to an ICN. For this paper, the expression “gateway” preserves its original meaning according to ISO-OSI terminology as discussed above.

The first item to be classed appears the level ordering of interconnected networks. A peer-to-peer structure occurs when two or more interconnected networks interchange commands and responses through a bus coupler in both directions so that no one of the ICNs can be distinguished as a higher level. If two interconnected ICNs arise hierarchically ordered, the master/slaves configuration appears usual at least for lower-level networks. The second classification viewpoint stems from the protocol profiles involved. In this case, the standard taxonomy using the general terminology mentioned above can be employed: bridge, router, and gateway. Also, the tunnelling and backbone networks can be distinguished in a standard manner. The next, refining items to be classed include internal logical architectures of the coupler, such as source or adaptive routing scheme, routing and relaying algorithms, and operating system services deployed.

2.3 Design Backgrounds

We launched our coupling development initiatives in the Fieldbus and Internet domains almost concurrently, see (Sveda, 1993) and (Cernohlavek, et al., 1994).

Fieldbus coupling was studied by our research team originally from the viewpoint of network architecture of low-level fieldbuses (Sveda, 1993), (Sveda, et al., 2000). Next interest was focused on real-world applications based on network coupling, such as data acquisition appliance (Sajdl et al., 2003), or wireless smart sensors (Vrba, et al., 2004). And also, the role of Ethernet and TCP/IP attracted our attention as a means of network convergence (Cach, et al., 2003), (Sveda, et al., 2005).

The other branch of our network interconnection initiative covers IP routing. In this case we launched with software router design based on a simple Unix machine (Cernohlavek, et al., 1994) and with creation of a routing domain for academic metropolitan networking (Kania, et al., 1995). The current research initiatives deal with the high-speed IP6 router for optical networks, see e.g. (Korenek and Pus, 2009), and with modelling of dynamically routed IP networks and exploration of their properties such as reachability-based safety and security (Matousek, et al., 2008).

3. NETWORK CONVERGENCE

This section aims at Ethernet and IP-based industrial networking that offer an application development environment compatible with the common TCP/IP settings. The approach stems from IEEE 1451 family of standards and provides a design framework for creating applications based not only on TCP/IP/Ethernet profile but also on ZigBee.

3.1 IP/Ethernet Profile

The attractiveness of Ethernet as an industrial communication bus is constantly increasing. However the concept of the original Ethernet, which was developed during seventies of the last century as a communication technology for office applications, has to face some issues specific for industrial

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