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Some notes on the history of protocol engineering

Gregor v. Bochmann [a,*], Dave Rayner [b,1], Colin H. West [c,2]

[a] School of Information Technology and Engineering (SITE), University of Ottawa, Canada
[b] UK's National Physical Laboratory, Teddington, UK
[c] IBM Zurich Laboratory, Rüschlikon, Switzerland

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ABSTRACT

During the 1970s and 1980s, the first computer communication networks were designed and implemented in the research and commercial sectors. Many of the protocols developed during that time are still in use today. This paper starts by giving an overview of these developments. Then it concentrates on the development of protocol engineering, that is, the methods for the specification of communication protocols and services, the verification of protocols and their implementation and testing. After personal views of the developments in the 1970s, the basic concepts developed at that time are explained. The standardization of Formal Description Techniques in the 1980s is discussed in the following section, as well as the standardization of conformance testing. The purpose of the paper is to show the long way we have come and to suggest that many of the basic concepts have not changed too much during these years, although more detailed aspects have evolved and given rise to new technological developments.

1. Introduction

The FORTE conference, together with its ancestor - the PSTV (Protocol Specification, Testing and Verification) conference, is now in its 30th year, and is now combined with the FMOODS conference which was established in 1996. The authors feel that this is a good occasion to look back to the early times of communication protocols. The purpose of this paper is to provide some of our personal reflections about the early times of protocol engineering in the 1970s and 1980s.

While many new communication protocols were developed during these early times of computer and data communications, some people also became concerned with the question of what methods are best suited for defining protocols, for verifying that they have the desired properties, for developing an implementation (which could be in different hardware/software environments), and for testing a given protocol implementation for conformance with the protocol definition. This preoccupation is reflected in the name of the PSTV conference and has been called "protocol engineering" [23].

In this paper, we first give an overview of the development of computer communications protocols in the 1970s and 1980s. In Section 3, we give then some personal views of the 1970s and explain the basic concepts of protocol engineering that were explored and defined by the research community during those years. In Section 4, we give a short overview of the development of Formal Description Techniques (FDTs) for communication protocols and services, which took place during the 1980s in the context of the standardization of protocols for Open Systems Interworking (OSI). The section also gives an overview of the standardization of protocol conformance testing. The conclusions discuss the impact of these developments on the current technological trends.

* Corresponding author. Tel.: +1 613 562 5800.
E-mail addresses: bochmann@site.uottawa.ca (G.v. Bochmann), dave-rayner@ntlworld.com (D. Rayner), cw@ieee.org (C.H. West).

[1] UK's National Physical Laboratory (Teddington, UK) from 1975 until 2007.

[2] IBM Zurich Laboratory (Rüschlikon, Switzerland) in 1999.

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2. Computer communications in the 1970–1980s

2.1. Initial developments

The 1970s and 1980s were stimulating times for people working in the area of computer communications. In the late 1960s, the first link-level protocols were introduced for remote access, over leased lines, from terminals to host computers. In 1968, Lynch [41] described a protocol with positive and negative acknowledgments which was not fully reliable, as pointed out by Bartlett et al. in 1969 [2]. During the same time, IBM had introduced the Bisync protocol which was used for a long time (a superficial look at its definition seems to indicate that it had similar flaws to the protocol of Lynch).

Then in the early 1970s, a new generation of link protocols was introduced with bit-oriented framing and sequence numbering (initially represented by 3 bits with values from 0 to 7). IBM's SDLC strongly influenced the international standard HDLC developed within the International Organisation for Standardization (ISO). This protocol was used in 1976 by the International Telegraph and Telephone Consultative Committee (CCITT) for their standard network access protocol, called X.25. Note: IBM, at that time, had a dominating market position as computer and software manufacturer, similar to Microsoft in the software domain nowadays.

In the late 1960s, several research projects had been established to experiment with the concept of packet switching. The first two operational packet-switched networks were the ARPANET in the USA and the NPL network at the National Physical Laboratory in the UK. Larry Roberts led the ARPANET team that had the first nodes of a wide area network operating by December 1969. Donald Davies led the NPL team that had the world's first local area network operational by 1970. Donald Davies coined the term "packet switching" in 1966 and co-invented the concept along with Paul Baran of the original ARPANET team. ARPANET is seen as being the forerunner of today's Internet [25]. The French Cyclade network project, led by Louis Pouzin, introduced the concept of an unreliable datagram service at the Network layer over which an end-to-end Transport layer protocol would build a reliable connection-oriented service, sometimes called "virtual circuits" [47]. These concepts were later adopted for the IP/TCP protocol hierarchy of the Internet as we know it today.

During this time, it also became apparent that there needed to be standards for interconnecting different packet-switched networks. Protocols that could be used for this purpose were called Internet protocols. In international group of experts was formed in 1972 under the name INWG[3] which became affiliated with the Technical Committee for Communications Systems (TC-6) of the International Federation of Information Processing (IFIP), as Subgroup 6.1. This group met quite frequently and elaborated a set of Internet protocols which included precursors of IP and TCP, a virtual terminal protocol and others. Gregor Bochmann participated in some of these meetings and had the impression that Vint Cerf from ARPANET and Louis Pouzin from Cyclade were the principal leaders of the group. Towards the end of the 1970s, these IP/TCP protocols were implemented for the interconnection of Ethernets and satellite networks on an international basis, and the original protocols of the ARPANET disappeared.

2.2. Standards for computer networks

At the same time, the common carrier companies and governmental PTT ("post-telephone-telegraph") organizations had realized that standards for commercial packet-switched networks were required and started to discuss possible approaches within CCITT (which later became ITU-T). Following their tradition of telephone network technology, they opted for a network service of reliable virtual circuits. This meant that at the interface between a host computer and the network, there was the requirement of supporting a large number of such circuits with separate flow control. Therefore the interface standard (strictly a "CCITT Recommendation") X.25 that was adopted in 1976 was much more complex than what would be required for providing a datagram service.

During the mid-1970s, there was much polemics concerning the question whether a datagram or a virtual circuit network service would be more appropriate for packet-switched networks. The INWG group had submitted their proposal for datagram and end-to-end Transport protocols to CCITT and tried to convince the PTT experts that their approach was preferable over the virtual circuit approach. However, CCITT stuck to the virtual circuit approach and produced in X.25 a standard network access protocol supporting several multiplexed virtual circuits. Later, a similar standard, called X.75, was defined for the interconnection of different packet-switched networks.

Although the datagram approach had not been adopted by CCITT for the network access protocol standard, discussion continued on whether this technology would be advantageous to be deployed within a network, internally. The Datapac network developed in Canada by Bell-Northern-Research did use internally datagrams with alternative routing. On the other extreme was the French Transpac network which used virtual circuits internally - where each circuit, when established, was allocated to a fixed route. Arguments were related to resilience against different types of hardware faults and resource requirements in terms of memory requirements in the switches (in case of Transpac) and transmission overhead due to lengthy packet headers (in case of datagrams, plus the Transport protocol required for reliability).

2.3. Proprietary computer networking protocols, such as SNA

In the meantime, different computer manufacturers had also started developing proprietary protocols for computer communications. The previous decade had seen batch-

[3] The International Network Working Group (INWG) was created at the ICCC in 1972 and elaborated proposals of protocol standards for network interconnection. This led to the Internet protocols. An account of these developments and the emergence of the Internet as the general networking infrastructure in the 1990s is given in [36]. A few years later, the INWG group became Subgroup 6.1of IFIP TC6 and as such could participate in the discussion on X.25 within the CCITT.