

Chapter 9

CORM: A Concern-Oriented Approach and Model to Computer Network Design

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ABSTRACT

Designing future computer networks dictates an eclectic vision capable of encompassing ideas and concepts developed in contemporary research unfettered by today's operational and technological constraints. However, unguided by a clear articulation of core design principles, the process of network design may be at stake of falling into similar pitfalls and limitations attributed to current network realizations. This chapter presents CORM: a clean-slate Concern-Oriented Reference Model for architecting future computer networks. CORM stands as a guiding framework from which several network architectures can be derived. CORM represents a pioneering attempt within the network realm, and to the author's knowledge, CORM is the first reference model that is bio-inspired, accounts for complex system characteristics, and applies a software engineering approach to network design. Moreover, CORM's derivation process conforms to the Function-Behavior-Structure (FBS) engineering framework, which is credited to be applicable to any engineering discipline for reasoning about, and explaining the process of design.

INTRODUCTION

Current research in computer networks is at a critical turning point. The research community is endeavoring to devise future network architectures that address the deficiencies identified in present network realizations, acknowledge the need for a trustworthy IT infrastructure, and

satisfy the society's emerging and future requirements (Clark, 2010). Considering the lessons from the past, and evaluating the outcomes and contributions of contemporary research literature, the community concluded that the advent of a trustworthy future Internet cannot be achieved by the current trajectory of incremental changes and point solutions to the current computer networks, but rather more revolutionary paths need to be

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explored (Clark, 2010; Feldmann, 2007). Proposed network architectures need to be grounded on well-articulated design principles that account for network operational and management complexities, embrace technology and application heterogeneity, regulate network inherent emergent behavior, and overcome shortcomings attributed to present network realizations.

Present computer network realizations are the outcome of incremental research efforts and endeavors exerted during the inchoative stage of computer network design. Back then, the aim was to interconnect architecturally disparate networks into one global network. Such inter-network connection was achieved through the introduction of the Transmission Control Protocol (TCP) (Cerf, & Kahn, 1974). TCP was introduced as a flexible protocol that sustains inter-process communication across networks, while hiding any underlying inter-network differences. TCP was later split into TCP and IP leading to the derivation of the layered Internet TCP/IP suite. As such, the TCP/IP suite defined the Internet system, which was regarded as a vehicle to interconnect diverse types of networks. However, the astounding success of the TCP/IP suite in interconnecting networks resulted in adopting the TCP/IP suite as the de facto standard for inter-computer communication within a single network, as well as across multiple networks. An initiative that undermined the need for independent research efforts addressing the requirements and specifications for internally designing computer networks. Focusing primarily on interconnection, TCP/IP networks possessed intelligence at the network edges, while regarding the network core as a “dump forwarding machine,” thus introducing the end-to-end (E2E) design principle; a fundamental principle for TCP/IP networks (Saltzer, Reed, & Clark, 1984). Influenced by TCP/IP-layered architecture and the E2E design principle, network designers and protocol engineers conformed to a top-down design strategy as the approach to architect networks. Moreover, with the introduction of the layered OSI model,

the top-down layered approach in network design and protocol engineering was emphasized further, in spite of the fact that the OSI was primarily developed as an “Interconnection Architecture,” i.e. an architecture facilitating the interaction of heterogeneous computer networks rather than an architecture for building computer networks (Zimmermann, 1980).

Despite the outstanding success of its realizations, we argue that the Internet-layered model was deficient in representing essential network aspects necessary for network design and subsequent protocol engineering. First, the traditional “cloud model” derived from the E2E principle abstracts the Internet layout as core and edge, thus it fails to express the network topological, social, and economical boundaries. Second, resource management as a function is absent from the Internet-layered model. Consequently, network designers and engineers introduced several point solutions to handle resource-management functions such as admission control, traffic engineering, and quality of service. Third, the Internet-layered model prohibits vertical function integration, thus it hinders the efficient engineering of performance aspects that need to span several layers. A requirement that was accentuated when operating in wireless environments, and resulted in numerous proposals for cross-layer designs. Finally, the Internet-layered model does not express network behavior nor allow for its customization according to context and requirements. A deficiency that led to two undesirable effects. First, IP-based networks exhibit a defining characteristic of unstable complex systems— a local event can have a destructive global impact (Greenberg, et al., 2005). Second, lack of support for mobility, security, resilience, survivability, etc., which are considered main features for a pervasive trustworthy infrastructure.

In response to observed computer network liabilities, research efforts have sprouted a plethora of architectural proposals aiming to overcome shortcomings evident in computer network realizations. Two main approaches can be identified. The

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