

Cross-Layer Design: A New Paradigm

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Abstract— Deployment of wireless networks requires more efficient protocols and optimal architectures. A new approach which has been attended by the research communities is the cross-layer design (CLD) methodology. Recently, various architectures and models have been proposed by the CLD designers. So far, the work on CLD has focused on problem-based realization and modification of the traditional layered network architectures. In this paper, we review the current works on CLD and propose a new paradigm in CLD. Using the new paradigm; network designers have a solid and comprehensive roadmap for CLD. Unlike the existing CLD approaches, the new paradigm offers a problem-independent model categorizing CLD in four general styles: SSSD, SSMD, MSSD, and MSMD. This classification considers the number of sources and destinations contributing in cross-layer communications. In order to cover all possible CLD models, direct and indirect types is proposed for CLD that specify the cross-layer interactions. Consequently, using the new classifications the CLD concept can be better realized and standardized. Also, the designers would have been organized for new CLDs.

I. INTRODUCTION

Traditional solutions for network design are based on the strict layering architecture. This results in isolation of the protocol design process for all individual layers. Unfortunately, the layering approach is no longer adequate to address designing issues of the next-generation mobile systems. In next-generation mobile systems, a mix of real-time and data traffics are transferred across the wireless shared media [1], [2]. In this context, the most important challenges are due to time varying transmission characteristics of the wireless channel and the dynamic Quality of Service (QoS) requirements. One of the most important solutions for this point is to violate the layered reference model in such a way to achieve higher performance. This approach is generally called cross-layer design. Cross-layer design (CLD) is a new paradigm in the network architecture; it takes into account of dependencies and interactions among layers and supports optimization across layer boundaries. This is unlike the layering approach where the protocols at different layers are considered independently. Layering and cross-layer optimization are tools that should be used together to design highly adaptive wireless networks [2], [3].

There are different CLD proposals in the literature. Researchers have generally introduced various shortcomings of the layered architecture for wireless applications in both Ad-Hoc and Cellular networks, violations to the layered reference

model as well. For example, in [4], substantial performance gains through CLD for real-time video streaming are demonstrated and a new CLD framework is proposed. Authors in [3] discuss relevant challenges of CLD and focus on application-driven CLD for video streaming over wireless networks. They highlight basic concept of CLD from the architectural viewpoint and demonstrate the performance gain achieved by this CLD approach.

In the literature, there are works categorizing CLDs that result in better utilization and management. [5] surveys the various types of CLDs in each layer of the protocol stack. Also, in [2], authors present a brief survey, suggest the definition, discuss the basic types of CLD and categorize the initial proposals in how cross-layer interactions may be implemented. Other CLDs were proposed that are not covered by these categorizations (e.g., [3], [4], [6]). Hence, having a new comprehensive categorization for the cross-layer architectures seems necessary. One solution is to change the design direction toward organizing CLD in order to have a standard CLD rather than problem-based approaches. Consequently, the CLD designers need only be aware of the optimization parameter flows across the protocol layers and not about the target optimization constraints.

This paper presents a new paradigm for the CLD architectural organization. Substantially, the cross-layer approach aims to solve an optimization problem for the network performance. One can consider this optimization as a multi-input multi-output function and represent the whole CLD performance optimization using this function. We propose a CLD model that is based on the number of inputs and output parameter flows from different layers composed of four architectural modes:

- Single Source Single Destination (SSSD),
- Single Source Multiple Destination (SSMD),
- Multiple Source Single Destination (MSSD), and
- Multiple Source Multiple Destination (MSMD).

Using this kind of realization, the analysis problem for network performance becomes more simplified. By simply characterizing the parameters of each layer, contributing in the optimization function, one can clarify the optimum CLD modification for the network architecture design.

The rest of the paper is organized as follows. In Section II, CLD methodology and a survey on the proposals and related challenges are discussed. The new CLD model is presented in Section III. The new classification for cross-layer interactions are presented in Section IV. Section V covers the capabilities of the new model. Finally, we conclude in Section VI.