Cross-Layer-based Adaptive Congestion and Contention Controls for Accessing Cloud Services in 5G IEEE 802.11 Family Wireless Networks

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Cross-Layer-based Adaptive Congestion and Contention Controls for Accessing Cloud Services in 5G IEEE 802.11 Family Wireless Networks*

Ben-Jye Chang[1] and Shin-Pin Chen

Abstract—The big-data cloud services accessed through 4G LTE-A and 5G WiFi networks need extremely high-speed and highly reliable transmission. **However**, it exhibits a critical issue that of inconsistently executing congestion control for the global end-to-end connection and contention control for the local wired/wireless links. **For instance**, in the transport layer (Layer 4 or L4), the reliable TCP adopts ACK-based congestion control to determine the congestion window (denoted by L4_CWND) for the global E2E connection; **but**, the link layer (Layer 2 or L2) adopts the Truncated Binary Exponential-based (TBE) access control to determine the contention window (denoted by L2_CW) for the local wireless link. **Clearly**, the congestion and contention control mechanisms for the global end-to-end connection and the local wireless link should cooperate tightly and consistently, but the existing congestion control and contention control are separately operated at different layers. This paper thus proposes a Cross-layer-based Adaptive Congestion Control (namely CACC) for the connection-based transport layer and the link-based media access layer. CACC aims to determine L4_CWND for the end-to-end congestion control, and then sends the cross-layer L4 congestion state to L2 to determine L2_CW_Max and L2_CW consistently. Numerical results demonstrate that CACC outperforms the compared approaches in L2 goodput, L2 collision probability, L2 contention delay, L2 fairness, L4 goodput, L4 fairness, and L4_friendliness. Furthermore, the claims of the determined L4_CWND and L2_CW are supported by mathematical analyses.

***Keywords*—Big-data transmission, cloud computing, 5G WiFi, Cross layer, MAC Contention Window, TCP Congestion Window, congestion control**

I. INTRODUCTION

Recently, in the cloud computing era, the massive big-data access transmits between user devices and cloud servers [1]-[3]. The cloud servers provide two types of services: the Map-Reduce computing and the massive remote storage. The big-data is frequently accessed through the high speed wireless mobile networking [3]. Certainly, to improve the performance of cloud services, the critical issue of using inconsistent congestion control and contention control at different layers should be addressed efficiently. The related studies are reviewed below.

1.1. The critical issues of inconsistent network congestion control of different layers

The network congestion problem significantly affects the quality of service (QoS) of cloud computing services, and thus it becomes one of the most critical issues that should be solved effectively.

The existing protocols of network congestion can be classified into two types: 1) the global end-to-end-based congestion control [4]-[10] and 2) the local link-based congestion control [11]-[19]. Note that the layer-based protocols are performed individually and independently, and thus adjust (e.g., increase or decrease) the congestion window inconsistently and asynchronously. An inaccurate congestion control results in sending more data segments in a heavily congested network, which leads to some drawbacks: causes the network more congested, increases transmission delay, yields more lost packets, etc.

Additionally, IEEE 802.11 WiFi family is the main wireless network in the world. For instance, to increase the data rate up to gigabit per second, IEEE 802.11ac [20][21][42] adopts several key technologies: 1) 256 QAM as the Adaptive Modulation and Coding (AMC) scheme [22][23], 2) 8x8 MU-MIMO with beamforming to increase the number of streams, 3) using 5 GHZ frequency bands, 4) 400 ns short guard interval (SGI), 5) 80 MHz channel bandwidth, etc. In 5G WiFi, the contention-based random access mechanism similarly works as the congestion control. When the L2 link loading is high, the total number of contentions in L2 increases significantly. As a result, the collision probability is increased and the maximum contention window (denoted by CW_Max, i.e., L2_CW_Max) is also increased. Note that the determination of the L2 contention window (L2_CW) is independent from the L4 congestion control (L4_CWND).

For instance, Fig. 1 shows the big-data transmissions in cloud computing, in which the L4 congestion window of the global end-to-end connection and the L2 contention window of the local wireless link access are operated independently. The

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