Understanding Latency – A Root Cost and Mitigation Approach

Abstract: Latency has always been a key part of network performance, but recent increases in network bandwidth, router forwarding speed, and end-system computational resources have elevated it to a primary focus for electronic traders, search engines, name-servers, data centers, and home Internet users. Even so, latency has typically been challenging to both measure and to mitigate, largely because previous approaches have addressed symptoms resulting from complex combinations of root causes and because end-to-end interaction delays are a multidimensional combination of these effects. This tutorial presents a comprehensive exploration of latency by focusing on the independent root causes and their associated costs, and exploring mitigations directly focused on those causes. We begin with an analysis of the transaction latency budget and its relation to the communicating parties - whether human or computer, pairwise or group. We explore boundaries of that budget, whether binary or gradated, and the complex ways in which latency costs can be usefully expressed. The root causes of generation, transmission, processing, multiplexing, and grouping are discussed in depth as well as corresponding mitigations of relocation, speed-up, resource dedication, and avoidance. We address these causes and mitigations in the context of examples including ‘bufferbloat’, Internet and big-data search, and protocols specifically aimed at reducing or tolerating latency for a variety of environments including home Internet access, data center operation, high-speed trading, and interplanetary communication. This tutorial also focuses on emerging opportunities for latency reduction that resulted from resource trade-off changes, including reducing component message sizes and a variety of anticipation techniques. Finally, we discuss how to apply these mitigations and new opportunities in both current and future network architectures, including wireless and optical physical layers; packet and circuit systems; location, location-independent, and name-based services; and network management.

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