Chapter 15

Correlating Quality of Experience and Quality of Service for Network Applications

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ABSTRACT

There is a significant difference between what a network application experiences as quality at network level, and what the user perceives as quality at application level. From the network point of view, applications require certain delay, bandwidth and packet loss bounds to be met – ideally zero delay and zero loss. However, users should not be directly concerned with network conditions, and furthermore they are usually neither able to measure nor predict them. Users only expect good application performance, i.e., a fast and reliable file transfer, high quality for voice or video transmission, and so on, depending on the application being used. This is true both in wired as well as wireless networks. In order to understand network application behavior, as well as the interaction between the application and the network, one must perform a delicate task – the one of correlating the Quality of Service (QoS), i.e., the degradation induced at network level (as a measure of what the application experiences), with the Quality of Experience (QoE), i.e., the degradation perceived by the user at application level (as a measure of the user-perceived quality) (Ivanovici, 2006). This is done by simultaneously measuring the QoS degradation and the application QoE on an end-to-end basis. These measures must be then correlated by taking into account their temporal relationship. Assessing the correlation between QoE and QoS makes it possible to predict application performance given a known QoS degradation level, and to determine the QoS bounds that are required in order to attain a desired QoE level.

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APPLICATION REQUIREMENTS AND QUALITY OF EXPERIENCE

Applications drive the development of networks. The need to transfer huge amounts of data across long-haul connections drives the increase of network bandwidth. The need for seamless connectivity drives the development of wireless networks. All network applications, including the now ubiquitous e-mail or browsing, require the continuous refining of network technologies. New standards and protocols allow for more reliable and faster data handling. However, the user is the only one who can say whether data is transferred fast enough, or whether the application behaves the way it should.

Consider web browsing. Users may wish that pages are loaded as fast as possible, maybe even instantaneously. This is an *expectation* that depends on user experience, the type of data to be downloaded, etc. A *requirement* in this case is an expectation which is expressed with a time constraint. When browsing the Internet it is desirable that pages are loaded in a couple of seconds. If it takes longer than 10 seconds, the page may no longer be of interest. Therefore, for web browsing, a requirement may be that a web page is loaded in less than 10 seconds.

From the network point of view, each application requires certain delay, bandwidth and packet loss bounds to be met in order to provide a satisfactory performance to users. However, performance evaluation can be done using various metrics, and user satisfaction can have several levels. For example, a user of voice communication can say quality has been “excellent”, “good”, “fair”, “poor” or “bad”, according to a widely used Mean Opinion Score (MOS) as defined in the ITU-T P.800 recommendation (ITU-T, 1996). Usually numbers are associated to these quality levels, on the scale from 5 (excellent quality) to 1 (poor quality) for ITU-T P.800 recommendation. Objective metrics, such as ITU-T P.861 (ITU-T, 1998) or P.862 (ITU-T, 2001), use quality scales as well, but in this case the score will be computed by an algorithm instead of the subjective MOS that is assigned through trials by human observers. For each of the satisfaction levels, an associated set of Quality of Service (QoS) degradation bounds can be determined, and they will represent the requirements of the application under study in order to provide a desired Quality of Experience (QoE) level.

A network application typically implies a data transfer between two end points of a network; data can represent either text and static images in the case of HTTP transfers related to web browsing, binary files in the case of file transfers by the FTP protocol, or video and/or sound for video and voice conferencing.

Based on the time requirements of network applications, two main distinct classes are identified in (Fluckiger, 1995):

- **Real-time or time-critical applications,** that have strict time constraints, such as video or voice conferencing
- **Non-time-critical or asynchronous applications,** for which time constraints are more relaxed, such as file transfers

Note that even in the case of non-real-time applications, there are still some time constraints; for example, if web page loading experiences large delays, the user degree of satisfaction will decrease, therefore delay needs to be taken into account when considering the QoE for such an application.

Based on the type of traffic pattern generated by the application, (Beuran, 2004b) distinguishes between:

- **Elastic traffic applications,** for which the traffic adapts to network conditions (usually this traffic is generated by applications that use TCP/IP as transport protocol)
- **Inelastic traffic applications,** for which the traffic doesn’t adapt to network

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