A Hierarchical Trade-off Assessment Model and the Systematic Evaluation of Networked Systems

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In this abstract, a hierarchical trade-off assessment model for networked systems is presented that constructs from the perspectives of systematic objectives, network component requirements, along with multiple quality of service (QoS) dimensions. The primary goal of this conceptual hierarchical trade-off assessment model is to provide a QoS evaluating mechanism for the networked systems.

In general, there is no lack of efforts in developing concepts and methods of QoS in networked systems (Lee, 1999; Xiao, 1999; Smirnov, 2001). The model proposed is mainly derived from ISO software quality model (ISO/IEC, 1997). Considerations from network component performance and end users' preferences are taken into account as well. The framework facilitates hierarchical tradeoff through the semantically rich software oriented objective attributes and sub-attributes, technical network components, and QoS metrics measurements. It enables to give guidance on the qualities current networked systems run, and the tradeoffs the networked systems are willing to make under various activities.

A series of objective attributes and sub-attributes is borrowed from ISO software quality model. The first level of attributes contains Functionality, Reliability, Availability, Efficiency, Serviceability, and Fairness, selectively adapted from ISO software quality model, other relevant Service Level Agreements (SLA), and end user oriented considerations. The second level deals with apportioning sub-attributes, mapping with six main attributes respectively.

To reflect the network level requirements and appropriate impact of multiple network components and services on the overall networked systems characteristics, the third level of the assessment model introduces common network components, such as routers, switches, links, services, and nodes, under each sub-attribute.

In practice, the operational characteristics of the networked system are directly measured by the lower performance metrics. Metrics such as delay, jitter, loss, throughput, and utilization are fundamental to performance comparison. Within this theoretical QoS assessment model, these lower level performance metrics are combined with the high level objective and the middle level technical components to explicitly evaluate the actual systemic conditions.

Within this multi-dimensional hierarchical structure, partially illustrated in Figure 1, the first three levels of the attributes are normally in non-numeric and non-uniform qualitative order. Even for the lower performance metrics, because many dimensions are involved, it is very difficult to express preferences against each other. In order to formulate a quantitative

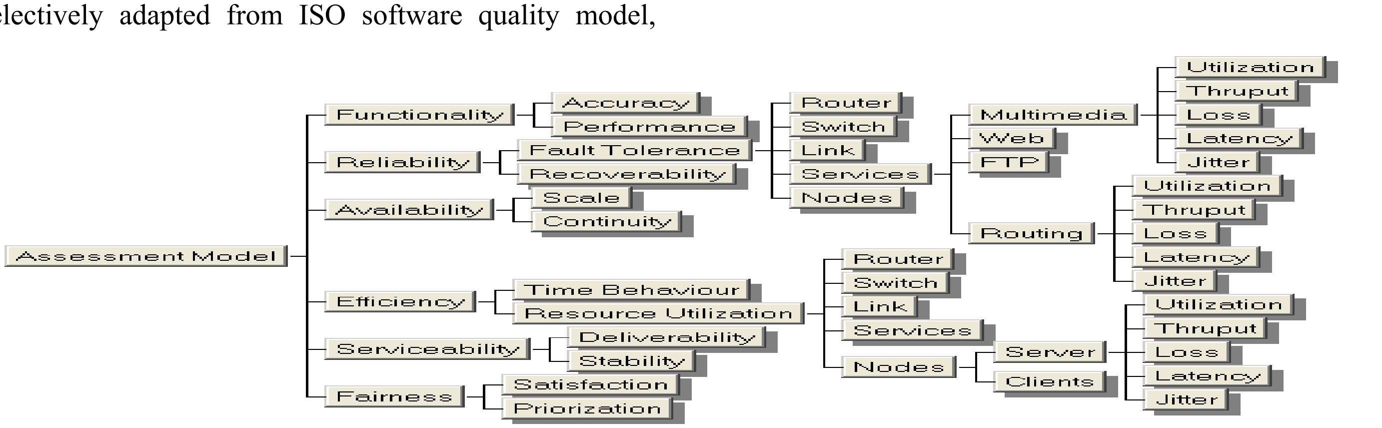

Figure 1. A Hierarchical Trade-off Assessment Model

numeric mapping, Quality Index is defined as a weighted sum in the assessment model. The main issue regarding how weights are assigned is solved by adapting Analytical Hierarchy Process (AHP) (Saaty, 1994; Fahmy, 2001). For the first three levels, basic decision model, in which alternatives are compared against each other under the criterion, is used. Due to the large number of lowest level QoS metrics criteria, ratings decision modelred (ExpertChoice, 2000), as absolute measurement model, is used at the lowest level to compare the measured performance values with the assigned sets of intensities.

The assessment model allows system administrators, along with end users, to define fine-grained objective requests easily for multi-dimensional complex QoS comparisons. Furthermore, by introducing the hierarchical abstraction of relevant multi-dimensional points, which maps qualities to indices in a uniform way, and by the mathematical modeling of QoS tradeoff and multi-dimensional attributes tradeoff, this model transforms the QoS assessment problem into a combinatorial comparisons which ultimately enables to quantitatively measure and evaluate QoS of networked systems in a systematic perspective.

To examine its practical performance and usefulness, experimental studies are conducted in simulation, using network simulator ns-2 (ns-2, 2001). Several scenarios are evaluated and compared.

A central question in evaluating this QoS assessment model is the factual accuracy of the model. Quality Index, the weighted sum of hierarchical multi-dimensional comparisons, is used to categorize systematic network conditions into a normalized numeric expression.

It can be concluded from the experimental study that for a given topology, the response curve is reflecting the conditions changed due to the simulated fault activities. For instance, the management quality index increases as the critical components' performance present well. Furthermore, it is noticed that even for relatively small mismatches between the conventional performance metrics and proposed index, it is quite acceptable to use the proposed quality index to reflect the overall system performance. That is, the preliminary evaluation found that the quality index is consistent across studies.

A sensitivity analysis shows that factors which influence the quality index include the comprehensiveness of network resources, the range of different objectives and sub-objectives covered within a given area. Perhaps more significantly, the AHP oriented tradeoff technique turns out to be very scalable and robust as the number of resources increases.

Because the data available reflects the condition of the system as a whole, index data can be used to reason about how the state of the entire system changes or is likely to be changed over time. These detailed evaluations provide practical insight into which of this model can be used online in real-time systems. The Index benefits the network administrators and end users by providing clear and consistent information regarding QoS and associated network health.

In summary, the study shows that such assessment model is highly useful. It applies quality concepts and methods to the area of networked systems, including measuring present level of quality, deciding a desired goal and actions, and measuring progress. By Measuring quality and relevant criteria, such model bridges the gap between higher objective and lower performance metrics, being implied with an aggregate perspective to quantitatively measure QoS in a systematic perspective, and to analytically plan and allocate resources.

There could be an issue needed to be determined in future, in terms of computational complexity. In general, AHP is considered easy to use by pair comparisons, and pair comparisons involve huge matrix computations. To the simplification of simulation, experimental analysis is carried out in post-simulation data processing rather than on-line execution. How such an algorithm could be implemented within a real-time environment needs to be exercised. However, the author believes that the fast improvement of the processing capabilities makes it possible to eliminate the processing bottleneck thereby reducing the computational cost.

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