A Model-Based Approach to Designing QoS Adaptive Applications

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As part of the DARPA MoBIES program, we have been developing a model-based approach for designing adaptive Quality of Service (QoS) in distributed applications. We have developed a prototype modeling tool, the Distributed QoS Modeling Environment (DQME), that captures some of the essential elements of dynamic QoS adaptation, including mission requirements, observable and controllable parameters, controllers, system dynamics, and adaptation strategies. The DQME modeling tool combines the domain-specific modeling capability of the Generic Modeling Environment (GME) with the runtime QoS adaptation mechanisms of the Quality Objects (QuO) middleware framework. DQME clearly separates the design of the QoS concerns of applications from the functional concerns. Integrated code synthesis tools facilitate code generation and model refinement. To demonstrate its capabilities in designing QoS adaptive applications, we have applied DQME to two distributed real-time embedded (DRE) applications: a signal analyzer and a multi-UAV surveillance and target tracking system.

The capture and classification of digital signals is an important part of military communications and of signal intelligence (SIGINT). A typical signal analyzer is built from a set of elementary signal processing operations, which often include parameters whose values can affect the quality of the signal classification. As part of our participation in MoBIES program, we used the DQME modeling tool to design an automated parameter tuner for improving signal classification. The parameter tuner augments a signal analyzer design with a search space controller driven by a utility function based on correct classification. It tunes parameters by automatically tweaking parameter values in a systematic way and evaluating the utility of the signal analyzer with different parameter values over a set of representative signals with known ground truth. We also developed a code generator that synthesizes the runtime controller code. The tool feeds the optimal parameter values back into the design model at runtime to refine the design.. We have applied the parameter tuning tool to the design of three signal analyzers and achieved improved signal classification in all of them. In addition, the automated parameter tuning exercise has the side effect of providing increased understanding of how individual parameters contribute to signal analysis.

In another application of the DQME tool and as part of a capstone demonstration for the DARPA PCES program, we are evaluating DQME's suitability to model representative DRE systems by modeling the end-to-end QoS adaptation for a multi-UAV surveillance and target tracking application. The QoS adaptation in the PCES capstone demonstration requires system-wide coordination of multiple streams of surveillance and target tracking data as well as local enforcement of resource allocations, in order to meet collective mission requirements. We are applying DQME to design these multi-layer, distributed QoS adaptation strategies in the capstone demonstration and are writing code generators to synthesize runtime adaptation code from the model. With DQME, we are aiming to simplify the design of end-to-end and coordinated QoS behaviors, synthesize QoS control code, and support the evolution of QoS designs through the modeling environment. This work is ongoing and is not without significant challenges, but shows promises for facilitating the design and top-down construction of DRE applications and helping us to mature and evaluate the usefulness of DQME.

This talk will introduce the DQME tool, describe the technology underlying it, and describe the two DRE domains to which it has been applied, three signal analysis case studies and the PCES multi-UAV surveillance and target tracking capstone demonstration.