A probabilistic approach to performance estimation at the un-timed communication abstraction level on system-level design

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System complexity continues to grow according to the well-known Moore's law [3], doubling approximately every two years. In contrast, designer productivity grows at a much smaller rate. The International Technology Roadmap [1] indicates a productivity growth of only 21% (designed transistors/staff-month) in recent years. Figure 1 shows both the complexity and productivity growth. The gap between the complexity and productivity growth in figure 1 is known as the productivity gap.

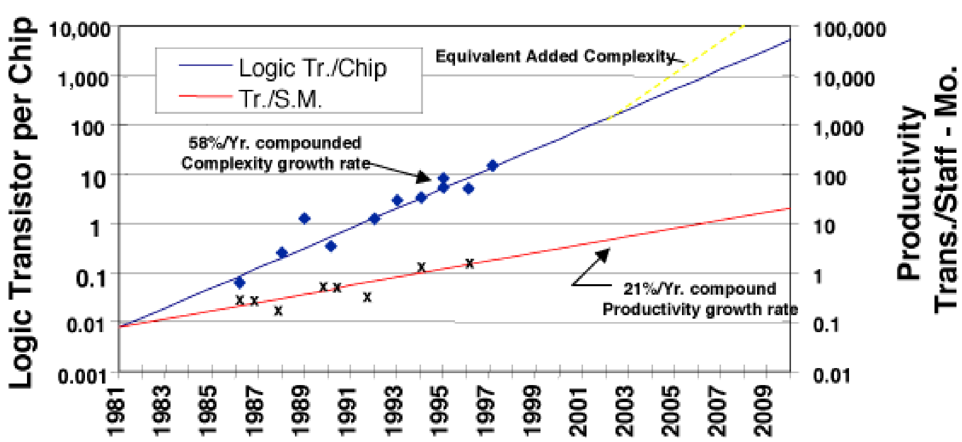

Figure 1: Productivity Gap

System-level design [2], with its abstraction levels and refinement methodologies, is the only solution to the productivity gap. To further improve system-level design it is necessary to include communication modeling and analysis in the higher abstraction levels, but this is difficult due to the lack of communication details at these higher levels. This research addresses this challenge and proposes a random variable based model to overcome the lack of communication details at the higher abstraction levels.

Tools that enable communication modeling and analysis at higher levels of abstraction must: (1) extract the communication architecture details and include them in the abstracted models, and (2) include the dynamic effects of the application traffic on the communication performance evaluation. The proposed model extracts the communication architecture details by way of random variables. Traffic effects are included through simulation. A SystemC-based simulation environment is provided that integrates the random variable based models and the application behavior, to produce the necessary information for communication performance evaluation.

The proposed research impacts three major areas of system-level design, *modeling*, *performance estimation*, and *design space exploration*.

Modeling

This research proposes random variables to model the communication architecture features. In particular this research investigates how to used random variables to model routing and switching protocols at the un-timed communication level of abstraction. A random variable is characterized by its probability distribution. A major challenge in the proposed random variable model is finding the probability distribution that best describes a given routing/switching protocol. Six routing and four switching protocols are studied, and probability distributions are provided for each routing/switching combination, twenty four in total. A random variable whose probability distribution correctly models the combined routing and switching protocols is known as a probability model, or p-timed model.

Performance Estimation

The purpose of the p-timed model is to evaluate different communication architecture features at the un-timed abstraction level. The key to this evaluation is estimation. This research introduces a probabilistic metric as the performance estimator. The probabilistic metric is defined as the probability of collision for a given p-timed model under a traffic pattern. Computing the probabilistic metric is not trivial as most p-timed models don't produces close form probability functions for the collision event. This research investigates different methods for the probability computation.

To simulate the p-timed models with different traffic patterns this research uses a SystemC-based framework. Specifically, this research investigates random, transpose, and hot-spot traffics. The SystemC-based framework subjects the p-timed models to the different traffics and produces the probability metric.

Design Space Exploration

The key to design space exploration is the fidelity of the performance estimates. For the proposed p-timed model, performance is estimated through the probabilistic metric. Fidelity refers to the relation of the estimates when compared to one another, and how this relation holds as the model is refined into an implementation. Unlike traditional estimators, probabilistic metrics cannot be directly compared to each other. Probabilistic metrics are compared through statistics.

This research evaluates different statistics, and investigates how these statistics relate the probabilistic metrics. In particular this research evaluates the statistics of central tendency, standard deviation, skewness, variance, and kurtosis. These statistical relations are validated with different low-level metrics obtained after refinement.

This research presents new models ready to use in system-level design, but more importantly, this research presents how the probabilistic models are derived. This research serves as a guideline for designers to build their own p-timed models, and further improve the un-timed communication models for better communication analysis. Along with the models and modeling guidelines, this research provides new tools for communication performance analysis.

The probabilistic metric combines the proposed p-timed model with the traffic characteristics to produce a communication performance estimator at higher abstraction levels, than any previous research up to date. Using the probabilistic metric, designers can evaluate the communication effects earlier on the design processes. A SystemC-based simulation framework is developed to combine the p-timed models with different traffic patterns, and produce the probabilistic metric.

This document starts by pointing out the productivity gap of figure 1. The proposed random variable based model, and resulting modeling methods and performance analysis tools, form a new system-level design environment through which communication analysis is moved to the higher abstraction levels. This new un-timed communication analysis enables system designer to manage higher complexity, directly resulting in a reduction of the productivity gap.

References

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