

CREATIV: Stochastic Processing Calculus: A New Methodology for Advanced Semiconductor Manufacturing and Data Center Networking

PIs: J. G. Dai (Georgia Tech), B. Lin (UCSD), J. Xu (Georgia Tech)

This CREATIV project aims to integrate expertise across the two traditionally separate disciplines of *manufacturing* and *networking* in order to bring about transformative research that will have substantial impact in both communities. This effort brings together the team of PI Dai from the manufacturing and operations research community and PI Lin and PI Xu from the networking community to tackle the challenges set forth in this proposal. In particular, this research will be driven *concurrently* by two distinct applications, one in *advanced semiconductor manufacturing*, and the other in *data center networking*. Whereas previous work on wafer fab scheduling has largely focused on throughput maximization and mean cycle time minimization, emerging business models in semiconductor manufacturing are requiring foundries to provide delivery guarantees to customers. In networking, emerging warehouse-scale data centers are *virtualized* to house many cloud computing applications simultaneously. These virtualized data centers employ multipath routing architectures to alleviate communication bottlenecks and server load-balancing to enable the scaling of distributed applications. In these environments, network performance guarantees are becoming essential.

A unifying framework for modeling and analyzing problems in both application domains is the stochastic processing network model, which provides a powerful abstraction for a diverse range of real-world applications, including manufacturing systems, service systems, communication networks, and computer systems. The central contribution of this work will be a new mathematical foundation that we call *Stochastic Processing Calculus* that will allow us to reason about and provide performance guarantees in stochastic processing networks. In particular, we plan to investigate the problems of *delivery guarantees* in semiconductor manufacturing and *network performance guarantees* in virtualized data centers as concurrent drivers in our research so that our investigations into the two application domains can inform each other to bring about new solutions that might not be imagined otherwise.

Intellectual Merit: The intellectual merit of our proposed research stems from its integration across multiple disciplines and the potentially transformative nature of the problem. In particular, this project contributes to the CREATIV goals in the following ways:

- This project synergistically combines concepts in stochastic processing networks from the manufacturing and operations research community with concepts in network Quality-of-Service (QoS) from the networking community to develop a new unifying mathematical foundation called Stochastic Processing Calculus that will allow us to reason about whole new classes of problems in both fields.
- This project brings together researchers from two communities that rarely interact. We envision new interdisciplinary communities will emerge from this work in virtualized manufacturing and networked enterprise systems.
- Our research effort is concurrently driven by two traditionally separate application areas. Rather than tackling each problem separately, this research will bring about an integrated approach to produce new methodologies and analytical tools that can unify the two application domains.
- As the manufacturing and networking communities have often in the past looked at problems from very different perspectives, asking different questions, we believe this interdisciplinary research will lead us to raise new fundamental questions and interesting new directions for research.
- In addition to a unifying mathematical foundation, this research is potentially transformative in that it will bring about new ways of thinking about problems in both communities. For example, our initial ideas on wafer fab virtualization have been inspired by our insights into concepts from data center virtualization. Similarly, new data center computation models share many similarities with manufacturing problems. We believe new ways of thinking about data center problems will arise based on insights from the manufacturing field.

Broader Impact: The broader impact of our proposed research lies in part in the diverse range of economic sectors that can benefit from this research, including manufacturing, service, and information technology. New innovations in any of these sectors will have enormous societal benefits by solving problems that can improve the quality of life in substantial ways. Broad dissemination of results through publications will expedite knowledge transfer within the academic community and between academia and industry. Research and education will be integrated through new curriculum that will empower future generations with new ways of thinking. Because the proposed interdisciplinary research brings together background knowledge and domain understanding from two traditionally separate fields, it would be very difficult for a typical panel from each program (NeTS or MES) to properly review this work, in part due to a lack of expertise in one area or vastly different perspectives in one area vs. the other. In addition, this research is high-risk in nature because of the complexity of the abstraction models considered. Finally, the PIs have no other current or pending proposals that deal with the subject matter described in this proposal.