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**Faculty of Computers and Information Sciences**

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# Performance Analysis and Enhancement of Optical Interconnection Networks for High Performance Supercomputers

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*This thesis is dedicated to my mother, i really can't describe you in a book. To the memory of my father. I really miss you, but I know that you are happy of this progress of my life. I always pray for you. Thanks to my brother, sister and my future wife. Without all of you, i could not complete that work.*

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# Abstract

Recent advances in the manufacturing of nano-photonic devices and optical networks on chip together with advanced optical routing can enable heterogeneous HPC systems of more than 1000 cores to efficiently perform terascale computing.

In this work, a Wavelength Division Multiplexed Photonic Network-on-Chip (WDM-PNoC) is proposed to replace the conventional electrical Network-on-Chip (NoC) of the homogeneous HPC systems and will be simulated on an IBM Blue Gene/q compute chip as a case study. The proposed WDM-PNoC is intended to reduce the performance limitations of homogeneous HPC systems and provide significant low latency, high bandwidth, and low power dissipation. A WDM-PNoC architecture for optical routing and switching is modeled and developed using a customized version of the PhoenixSim simulator. The proposed models are based on recent advancement in nano-photonics device fabrication, architecture design, CAD optimization and include on-chip optical light sources and modulators, photodetectors, buffers, switches, couplers, optical waveguides, and on-chip WDM devices.

Through a series of simulations, the efficiency of the proposed system is studied in terms of power and energy consumption, data transmission latency and throughput. Moreover, the design parameters of a commercial IBM Blue Gene/q compute chip were used to compare the overall system performance using its current conventional electrical architecture with WDM-PNoC architecture under synthetic random traffic with different loads. The proposed

architecture reduces the overall energy consumption by approximately 40% compared with the electronic one, and achieves an average decrease in end-to-end delay of approximately 60%, meanwhile it remarkably exceeds the offered throughput of the current commercial system.

An enhanced WDM-PNoC model is proposed by including an enhanced WDM-PNoC architecture, which reduces the overall energy consumption by approximately 40% when it is compared with the static WDM-PNoC without negatively affecting the end-to-end delay. The results also show the performance superiority of the proposed enhanced WDM-PNoC.

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