PhD Thesis Proposal Form
China Scholarship Council (CSC)/ENS Rennes
Call for projects 2018

FIELD open

Thesis subject title: Reliable Multi-Technologies Network-on-Chip

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Thesis proposal (max 1500 words):

Since a few years, we are witnessing the emergence of manycore architectures, namely to the implementation of massive parallelism on a single chip. Associated with the shrinking size of the transistors, announced reaching an 11nm technology on 2020 [1], these manycore architectures should reach the integration of thousand of heterogeneous cores allowing huge parallel computation capabilities suitable for High Performance Computing (HPC) and embedded systems. These parallelism capabilities obviously generate an enormous amount of data exchanges. This is the case of deep learning algorithms used in the context of applications which need to adapt their behavior depending on the environnent modifications and/or constraints. Indeed, the implementation of deep learing algorithms leads to large number of transfers between the different cores available in the architecture. To support the transfers, efficient communication media must be implemented in the manycore architectures. In this context, the major bottleneck of such system is shifted toward the communication infrastructures rather than computation capabilities.

While Electrical Network-on-chips (ENoCs) are now a mature interconnection medium, new integration technologies have allowed the advent of silicon photonics and on-chip wireless transmissions. This has given rise to new on-chip interconnection media: Wireless-NoC (WNoC) [2, 3] and Optical-NoC (ONoC) [4, 5]. It seems clear that future systems will have to exploit not only one of these communication infrastructure, but merging two or three of them is probably the best solution to define efficient system.

Moreover, given the shrinking size of the transistors and their increasing number inside a chip, the electronic devices become more and more sensitive to single-event upsets or soft errors. This leads to

faults appearing at runtime, due to electronic perturbations or aging, or during the fabrication process. Thus, error detection and correction mechanisms or autonomic self-test must be integrated in today's architectures [6]. This statement is enforced with the way to associate the different technologies: the network interfaces are becoming the door to access each communication medium, and any fault in these blocks will degrade the performance of the system. This performance degradation is mainly due to high traffic rerouting creating bottlenecks or cluster isolation. We propose to use monitors at runtime to detect faults at block level. The granularity of the block is: electric router, WNI, and ONI.

Considering this context, this thesis aims at defining a reliable Hybrid NoC (HNoC) by associating electrical, optical and wireless technologies. This association targets to take advantage of each technology benefits (e.g. broadcast efficiency for WNoC, long-distance with low latency for ONoC, and low-distance efficiency for ENoC), and to overcome their drawbacks.

The first contribution of these works is to define methods to ensure association between these different technologies and capabilities. These methods will provide new hierarchical interconnection topologies. Moreover, as the use of ONoC and WNoC requires a high rate of data serialization, a pooling of access points can be considered within the network to minimize the area while increasing traffic hotspots.

To efficiently benefit from the HNoC, given that each technology is efficient for one type of communication, and considering that applications running on a system generate various kinds of traffics, the second contribution is the proposition of new routing strategies to route messages along the most efficient medium. The goal is to provide a quality of service to the applications, for instance ensuring latency, throughput, or power consumption. The routing strategy can be tuned on run-time by the operating system given application and context constraints. The strategy will have to consider the use of one medium for each communication, but we will also explore the possibility to allocate several mediums for a communication in order to optimize the global use of the HNoC.

The third contribution of this thesis is the use of monitors at runtime to detect faults at router, Wireless- and Optical Network-Interface levels. To avoid resource wastes caused by disconnecting a whole faulty block, it is important to locate more accurately which part of the block is the faulty one. To address this issue, we will develop new approaches, such as hierarchical online test vectors that can be used as inputs of the temporarily isolated faulty block [6]. This step will allow to characterize the kind of occurred fault: i) temporal (permanent or transient), ii) functional (including performance), and iii) spatial. According to the timing and the user constraints, the fault characterization and location can be done at different granularity levels (coarse, middle or fine grained). Moreover, HNoC capabilities will be used to develop new testing methodologies. These new techniques should benefit from the low latency transmissions or broadcast capabilities given by the ONoCs and WNoCs, respectively. For instance, WNoC can be used to easily update routing tables in the HNoC when a part of the NoC is suspected as faulty (coarse grained detection) in order to bypass this zone, while the ONoC can reduce the loading time of test vectors to determine at fine grain which part is faulty.

References:

- [1] S. I. Association, "ITRS: International technology roadmap for semiconductors." Online, 2015. [Online]. Available: http://www.itrs2.net/itrs-reports.html

- [2] D. DiTomaso, A. Kodi, D. Matolak, S. Kaya, S. Laha, and W. Rayess, "A-WINOC: Adaptive wireless network-on-chip architecture for chip multiprocessors," *IEEE Transactions on Parallel and Distributed Systems*, vol. 26, no. 12, pp. 3289–3302, Dec 2015.

- [3] Y.Chen,X.Ling,andJ.Hu,"A dynamic and low latency wireless noc architecture," in *2015 IEEE 11th International Conference on ASIC (ASICON)*, pp. 1–3, Nov 2015.

- [4] X.Wang *et al*.,"Rpnoc: a ring-based packet-switched optical network-on-chip,"*IEEE Photonics Technology Letters*, vol. 27, no. 4, pp. 423–426, 2015.

- [5] S. L. Beux, H. Li, I. O'Connor, K. Cheshmi, X. Liu, J. Trajkovic, and G. Nicolescu, "Chameleon: Channel efficient optical network-on-chip," in *2014 Design, Automation Test in Europe Conference Exhibition (DATE)*, pp. 1–6, March 2014.

- [6] C. Killian, C. Tanougast, and A. Dandache, "Hybrid fault detection for adaptive noc," *IEEE Embedded Systems Letters*, vol. 5, no. 4, pp. 69–72, Dec 2013.

- Publications of the laboratory in the field (max 5):

- J. Luo, A. Elatanbly, V. D. Pham, C. Killian, D. Chillet, S. Le Beux, O. Sentieys, I. O 'Connor. Performance and Energy Aware Wavelength Allocation on Ring-Based WDM 3D Optical NoC, in "Design, Automation & Test in Europe Conference & Exhibition (DATE) 2017", Lausanne, Switzerland, March 2017

- M. J. Sepulveda, S. Le Beux, L. Jiating, C. Killian, D. Chillet, I. O'Connor, O. Sentieys. Communication Aware Design Method for Optical Network-on-Chip, in "International Symposium on Em- bedded Multicore/Many-core Systems-on-Chip, MCSoC-15", Turin, Italy, Politecnico di Torino, Turin, Italy, September 2015

- J. Luo, C. Killian, S. Le Beux, D. Chillet, H. Li, I. O'Connor, and O. Sentieys, "Channel allocation protocol for reconfigurable Optical Network-on-Chip", Workshop on Exploiting Silicon Photonics for energy-efficient high-performance computing (SiPhotonics) at HiPEAC 2015, Amsterdam, Netherlands, January 19-21, 2015
- C. Killian, C. Tanougast, A. Dandache, "Hybrid Fault Detection for Adaptive NoC", IEEE Embedded Systems Letters (ESL), pp. 69-72, 2013

- C. Killian, C. Tanougast, F. Monteiro, A. Dandache, "Smart Reliable Network-on-Chip", IEEE Transactions on Very Large Scale Integration Systems (TVLSI), Volume 22, Issue 2, pp. 242-255, 2012

- Joint Phd (cotutelle) : NO
- Co-directed PhD : YES

In case of a co-directed or a joint PhD, please detail:

- Partner university name: University of Rennes 1
- Laboratory name and web site:
- PhD co-director (contact person):
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- Provisional duration and timetable of the PhD student's stay at ENS Rennes:
  The PhD student will mainly stay at CAIRN team-project, from INRIA/IRISA laboratories of Rennes, and with some stays at ENS Rennes.
- If previous collaborations with the Chinese co-director/university, please detail:
- Interest of the Joint PhD for the French co-director, for his/her laboratory, for ENS Rennes:
  The student will be welcomed in the CAIRN team-project. Our project-team is currently involved in two Labex projects, one in ONoC in collaboration with INL and Foton (laboratory specialized in photonic systems), and one in WNoC in collaboration with the DIM team from Lab-STICC (with a long experience on the design of miniaturized and fully integrated antennas operating at millimeter wave frequencies). This situation will allow the PhD student to start the presented thesis with all the required technology information while having the possibility to gather expert feedback from each field. Moreover, in the team, we already have a Chinese PhD student working on the ONoC project, which could help to easily integrate the new chinese student in the team.

Date: 15/01/2018

Signature of the PhD director

Name and signature of the Laboratory director