POSTER: Wavelength Allocation for Efficient Communications on Optical Network-on-Chip

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***Abstract*—Optical Network-on-Chip (ONoC) is a promising communication medium for large-scale Multiprocessor System on Chip (MPSoC) with advantages in terms of throughput and latency. ONoC can support multiple transactions at the same time on different wavelengths by using Wavelength Division Multiplexing. However, sharing the same waveguide for simultaneous communications leads to inter-channel crosstalk noise due to the short wavelength spacing between optical signals and resonance frequency of the Microring Resonator (MR). This problem impacts the Signal to Noise Ratio (SNR) of the optical signal, which leads to an increase in the Bit Error Rate (BER) at the receiver side. To limit crosstalk noise during communication between parallel application tasks, we propose a strategy to allocate the wavelengths by evaluating the loss induced by spatio-temporal communication conflicts. Simulation results show that the proposed algorithm can significantly reduce the crosstalk of optical signal.**

I. Introduction

Evolution of Multiprocessor System-on-Chips (MPSoC) is moving towards the integration of hundreds of cores. Designing such complex MPSoC is very challenging and, in particular, designing the communication media is one of the most critical part of such systems. A large number of classical Network-on-Chips (NoC) were designed and proposed in the literature, but these NoCs suffer from some limitations due to the electrical interconnect characteristics.

Recent progresses in silicon photonics device manufacturing allow to rely on Optical Network-on-Chip (ONoC) for on-chip MPSoC communications. ONoCs are based on optical waveguides carrying optical signals and optical components allowing to inject or drop optical signals into this waveguide from an electrical interface. This technology offers low latency and high bandwidth properties. The waveguide for payload transmission can be shared by multiple senders and receivers when Wavelength Division Multiplexing (WDM) is used to support multiple transactions at same time. An overview of the architecture used and an example of waveguide sharing are presented in Figure 1. Although simultaneous transmissions can offer high bandwidth, when there are supported by close adjacent wavelengths, it may introduce inter-channel crosstalk noise through different optical switching elements within the network. Due to the non ideal filtering of Micro Resonators (used to inject and eject optical signals into the waveguide,

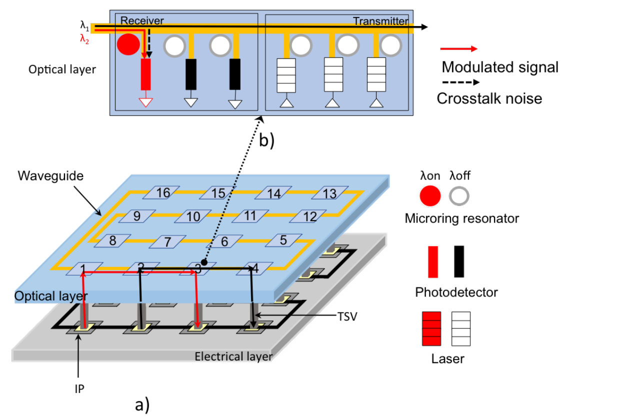

Fig. 1. Architecture Overview: a) 3D Optical Manycore ; b) Optical Network Interface

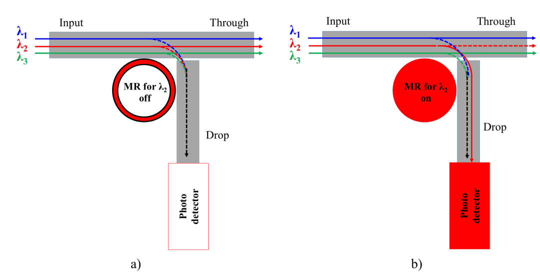

Fig. 2. Analysis of signal dropping by an MR element for a) MR in off-state; b) MR in on-state

see Figure 2), this inter-channel crosstalk leads to an increase of the laser power when a specific bit error rate (BER) is targeted. Thus, it is very important to try to limit the effect of this crosstalk to limit the ONoC power consumption.

II. Wavelength allocation strategy/algorithm

The global objective consists in ensuring a good Signal-to-Noise Ratio (SNR) to offer efficient communications between all the IP cores. For a specific communication on wavelength λ_i, the crosstalk induced by the wavelength λ_j of another communication will be linked to the distance between the two wavelengths. If $\Delta_\lambda = |\lambda_i - \lambda_j|$ is small (the two wavelengths

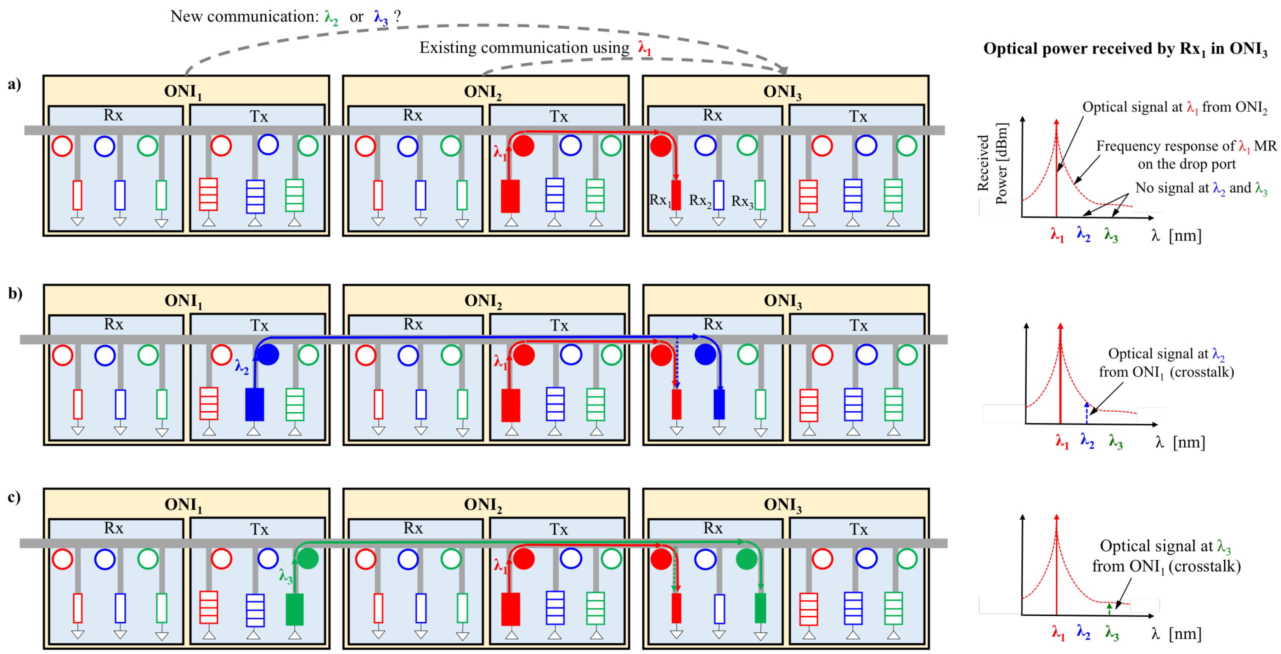

Fig. 3. a) Example of communications to ensure on a shared waveguide ; b) Crosstalk on wavelength λ_1 induced by wavelength λ_2 ; c) Crosstalk on wavelength λ_1 induced by wavelength λ_3.

are close in frequency), the crosstalk is high. Conversely, if Δ_λ is high, the crosstalk is less important and can be neglected. Considering the hypothesis that a specific BER is targeted to ensure communications, it is therefore important to select wavelengths with the largest Δ_λ for simultaneous communications. This effect is briefly presented in Figure 3.

The global strategy of our algorithm is divided into three steps: 1) to evaluate the crosstalk, we first find all the communications with conflict; 2) these conflicts are then sorted by their impact level on the crosstalk; 3) based on this sorted list of conflicts, the wavelengths of all couples of communications in conflict must be chosen by spacing the wavelengths as much as possible.

Step 1: To extract the conflicts between all the communications of the application, we define a communication graph, $OCG = G(\mathcal{C}, \mathcal{E})$ as a directed graph. Each vertex $C_{i,j} \in \mathcal{C}$ represents the communication between cores p_i and p_j on one wavelength $\lambda_{i,j}$. Each edge $E_{C_{i,j},C_{k,l}} \in \mathcal{E}$ defines the overlapped relationship between $\lambda_{i,j}$ and $\lambda_{k,l}$. An edge between two nodes $C_{i,j}$ and $C_{k,l}$ exists if temporal and spatial conflicts for these two communications appear simultaneously. The edge direction represents the source of the optical signal that introduces crosstalk noise to the detected signal. The weight $WE_{C_{i,j},C_{k,l}}$ of edge $E_{C_{i,j},C_{k,l}}$ corresponds to the crosstalk introduced by the communication $C_{k,l}$ on the communication $C_{i,j}$.

Step 2: The weight of an edge represents the crosstalk impact of one wavelength on another wavelength during a communication. This impact is similar to the SNR without considering all the noise from all the other wavelengths but just by considering another specific wavelength. This approach enables the estimation of the crosstalk by considering two wavelengths used for two communications in conflict. In this case, the higher the weight, the higher the SNR.

Step 3: The edges are extracted in order from the previous list, and, for each edge $E_{C_{i1,j1}C_{k1,l1}}$, concerning the communications $C_{i1,j1}$ and $C_{k1,l1}$, the crosstalk is evaluated by allocating each possible wavelength. For each possible wavelength allocation, the crosstalk induced by the other wavelengths in conflict is computed. The allocation that produces the smallest crosstalk, i.e. the highest SNR value, is then chosen and a new edge is then extracted from the list SL until SL contains no more edge.

III. Conclusion

This short paper briefly presents a strategy for the management of wavelength allocation in the context of Optical Network-on-Chip which limits as much as possible the inter-channel crosstalk between different parallel communications. Indeed, without any specific wavelength management, this inter-channel crosstalk leads to a reduction of the communication SNR. However, we show that this crosstalk can be reduced if the wavelengths are correctly chosen.

Thus, the proposed algorithm explores the wavelength allocation and produces a solution from the knowledge of all the communications of an application. The result is a solution that minimizes the local crosstalk for each conflict of couple of communications. he wavelength allocation produced by our algorithm is a sub-optimal solution, but the results show that the crosstalk is generally near the optimal solution.