Microprocessors and Microsystems 57 (2018) 76–88

Contents lists available at ScienceDirect

Microprocessors and Microsystems

journal homepage: www.elsevier.com/locate/micpro

Topology generation and performance enhancement based on channel assignment optimization for hybrid wireless NoC with large system size

Jianhua Li*, Han Li, Yongliang Hu, Gaobiao Wu

Institute of Computer Application, Taizhou University, 317000, China

ARTICLE INFO

Keywords:
Wireless Network-on-Chip
Topology generation
Channel assignment optimization
Conflict graph

ABSTRACT

To achieve the efficient topology generation of upper-layer network in hybrid wireless NoC with large system size, a method of topology generation and performance enhancement based on channel assignment optimization is proposed. The method is implemented under certain signal-to-interference plus noise ratio (SINR) and strict resource budget by establishing relevant models of power consumption and interference for hybrid wireless NoC. A communication protocol with low overhead based on weighted conflict graph and two-level wireless token arbitration mechanism is designed for hybrid WiNoC with large system size. The designed protocol could handle channel contention and reduce the waiting time to get access to a wireless channel effectively. It improves obviously the frequency channel utilization. The experimental simulation demonstrates that the resulting topology generated by channel assignment optimization outperforms the conventional counterparts in terms of achievable throughput, power efficiency and latency at the cost of little area overhead.

1. Introduction

Network-on-Chip (NoC) has emerged as an interconnection and communication architecture for the complex SoC paradigm [1]. The NoC has appeared as a good alternative for global interconnects due to their optimized electrical properties, such as better performance in terms of power, delay, bandwidth, and scalability compared to buses and global interconnects [2]. However, the performance limitations such as high latency and power consumption due to planar multihop wired links hinder seriously the further performance enhancement of multicore SoC with the increasing complexity [3]. Recently, by integrating miniaturized on-chip antennas and transceivers, the Wireless NoC (WiNoC) has been proposed as a promising solution to enable intra-chip wireless interconnection and communication with a few tens to a few hundreds of GHz bandwidth [4–6]. Owing to the lower design complexity, higher performance gains in terms of transmission performance and power consumption, the hybrid wired/wireless WiNoC architectures with millimeter-wave interconnects (mWNoC) currently dominate the research in the wireless NoC [7–9]. Nevertheless, the hybrid WiNoC still faces some problems of topology design besides the technological challenges including the design of transceiver components and integration of on-chip antennas.

Firstly, the topology design of hybrid WiNoC suffers from resource limitations such as the total wireless spectrum and available number of sub-channels. For example, in [10], it is demonstrated that only three non-overlapping channels were created with on-chip mm-wave wireless links. There are 24 different frequency channels created through the carbon nanotubes (CNT) antennas for the WiNoC architecture designed with THz/optical frequency range wireless links (THzNoC). Although the THzNoC shows better performance than mWNoC, the performance improvement of hybrid WiNoC with large system size will suffer from the limited number of wireless links depending on the available number of distinct frequency channels. What is more, THzNoC working on 24 wireless channels still faces some challenges in manufacturing, integration, layout and reliability of CNT devices. By contrast, the mWNoC is CMOS-compatible. Similarly, a total of 16 available channels [5,12] is insufficient for the large-scale on-chip wireless network. Secondly, the wireless nodes will cause additional power consumption and area overhead arising from embedding wireless communication components. Subsequently, the topology design of hybrid WiNoC should be implemented under strict physical constraints from the area overhead of wireless nodes (i.e., on-chip antennas, transceivers, etc.). Thirdly, the wireless links encounter channel interference (inclusive of inter-channel interference and co-channel interference), which remains unresolved [11,12] and results in performance limitation in terms of network capacity and data transmission rates [13] in the hybrid WiNoC.

From the perspective of low-power design, by improving network connectivity of hybrid WiNoC, it is quite effective to increase network capacity and reduce communication power consumption with positive relation to average hop count. There is no doubt that the fully

* Corresponding author.
E-mail address: ljh2007@tzc.edu.cn (J. Li).

https://doi.org/10.1016/j.micpro.2018.01.004
Received 29 August 2016; Received in revised form 30 December 2017; Accepted 23 January 2018
Available online 31 January 2018
0141-9331/ © 2018 Elsevier B.V. All rights reserved.

connected wireless network in the upper layer of hybrid WiNoC could achieve the least hop count and lowest communication power consumption. Despite all this, it will cause increasing in the number of wireless links sharing the same frequency channel due to the limitation of available number of wireless channels. For example, in the case of hybrid WiNoC system with 12 wireless links working on the above-mentioned three non-overlapping channels, there will be four wireless links sharing the same frequency channel on average. However, the wireless links working in the interference range will interfere with each other if they are on the same frequency channel [14]. That is to say if two links are within the interference range of each other, they can transmit or receive simultaneously only if they use different channels. Similarly, owing to the low parallelism arising from link interference [13], the performance improvement in transmission delay and throughput will be limited in the certain degree for hybrid WiNoC. From the perspective of low-interference design, we should decrease the number of wireless links sharing the same frequency channel to reduce network interference [13], which in turn results in lower network connectivity. Thus it will increase the power consumption of hybrid WiNoC. It can be seen that power consumption and network interference interact with each other: the more connectivity is achieved, but the more interference is induced. However, by reasonable wireless link placement and channel assignment (CA) under limited number of wireless channels, it is possible to properly increase the number of wireless links, and at the same time reduce power consumption and link interference [15].

An mWNoC architecture, which can accommodate single or three simultaneous frequency channels resulting in further improvement of overall performance, is designed by optimizing the wireless interfaces (WIs) under the constraints that a single hub (namely, wireless router, WR) could have a maximum of one WI (denoted as MOWI) and each WI in the network is assigned one of the three channels [11]. Owing to those design constraints, there will be only maximum of one WR working on particular frequency channel at any given instant of time. That is to say, each node has maximum of one simultaneously transmitting wireless links at a time. It is unreasonable to improve the overall performance especially for the hot wireless nodes. Furthermore, the WIs sharing the same channel form a cluster and a simple token passing protocol as the arbitration policy is used to handle co-channel contention and interference in the mWNoC, but it does not scale well with an increase in the number of wireless nodes, and the excessive wireless links sharing the same frequency channel will cause higher token returning period [16] and lower parallelizability between the links for hybrid WiNoC with large system size. As illustrated in [17], for a 64-core system, WiNoC uses twelve WIs in total with four WIs operating on each of the 3 wireless channels. As can been seen in Fig. 1a, each WR has only a single WI assigned one of the three channels (channel $c1$, $c2$ and $c3$) in the mWNoC for a 36-core system. There are three clusters and each cluster is formed by 3 WIs sharing the same channel. It is observed that it has at most 3 simultaneously transmitting wireless links over different channels at a time for any size mWNoC, such as link $l_{(1,2)}$, $l_{(6,7)}$ and $l_{(3,5)}$ (or link $l_{(1,2)}$, $l_{(6,8)}$ and $l_{(4,5)}$), concurrently. The $l_{(1,\ 2)}$ is defined in Section 3.1.

We can predict that the cluster will grow larger because of enormous number of WIs assigned the same channel for a 512-core system or larger system. However, according to previous research work in wireless mesh networks [14], the architecture of multi-radio with multiple channels assigned to every wireless router nodes could enable multiple transmissions or receptions concurrently. By using the channel assignment optimization (CAO), the neighboring wireless links assigned to different channels can carry traffic free of interference, so that it can dramatically reduce the transmission delay and improve the network throughput up to several-fold advancement [15]. Subsequently, it is very attractive to implement the topology design based on CAO while deploying multiple WIs (multi-WI) to the WR. Fig. 1b shows the WiNoC topology with multi-WI based on channel assignment optimization. It can be seen that the maximum number of simultaneously transmitting wireless links at a time is up to six links in the optimal topology (i.e., $l_{(1,2)}$, $l_{(3,4)}$, $l_{(7,8)}$, $l_{(2,3)}$, $l_{(8,9)}$ and any one link working on channel $c3$). The average token returning period will also decrease due to the existing more parallel links. Correspondingly, the frequency channel utilization will be improved greatly as frequency reuse at a time. Furthermore, each WR with a single WI has maximum of one simultaneously transmitting wireless links at a time (e.g., only $l_{(1,2)}$ for hot node wr_1 in Fig. 1a). The wr_1 is defined in Section 3.1. By contrast, each WR with multi-WI could have multiple transmitting wireless links simultaneously at a time (e.g., $l_{(1,2)}$, $l_{(2,5)}$ and $l_{(2,9)}$ for hot node wr_2 in Fig. 1(b)). Fig. 1c shows the structure of wr_3 with two wireless input/output ports (WI1 and WI2), and the number of WIs depends on the number of wireless channels and the location of WR.

According to the analysis mentioned above, the reasonable and valid channel assignment appears particularly important to design hybrid WiNoC with low interference and high parallelism between links. So far, no effort has been made to design the low interference and high parallelism WiNoC with large system size, and it is a somewhat challenging topic and seldom studied. Therefore, we propose a design method based on optimal wireless link placement and channel assignment under limited wireless resources to generate high-performance topology for hybrid WiNoC with large system size.

Major contributions of this paper are as follows:

(1) We establish mathematical analysis models of power consumption

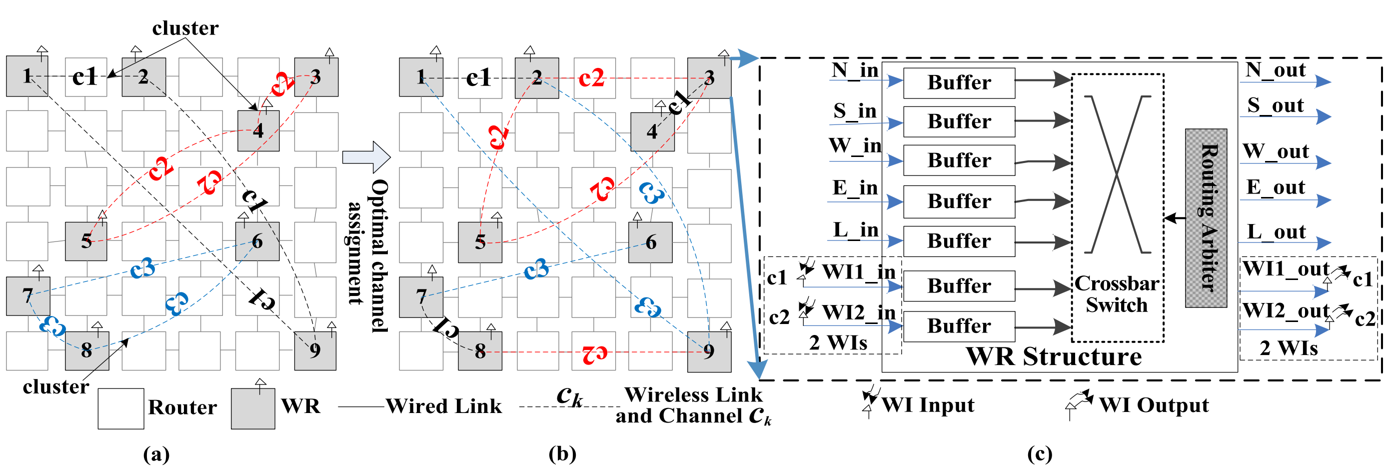

Fig. 1. Topology for a 36-core system and the WR structure of hybrid wireless NoC: (a) mWNoC topology with single WI. (b) WiNoC topology with multi-WI based on channel assignment optimization. (c) WR structure.

Download English Version:

https://daneshyari.com/en/article/6885921

Download Persian Version:

https://daneshyari.com/article/6885921

Daneshyari.com