A RESEARCH REVIEW ON WIRELESS NETWORK ON CHIP

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ABSTRACT:

Network-on-chip (NoC) systems are becoming more popular due to their big advantages when compare with systems-on-chip (SoC). Therefore, an increasing number of researchers and organizations now focus on the study and development of NoC techniques. As a result, so far many achievements have been gained. Furthermore, considering the dominant position of wireless and the weakness of wired communication, people also turn to try to insert wireless links in NoC systems in order to solve the multi-hop problem.

This report gives a brief description of some outstanding developments of NoC and WNoC (Wireless NoC) systems, including some important technique and the achieved results, mainly related to the required hardware and communication protocols. In addition, the report also contains my experiments on NoC and WNoC systems. I use the Booksim simulator to measure their performances and make some comparisons, and then give some analysis and conclusion of those results. At the end the report summarizes the Bus based System Architecture and gives some more developing directions of NoC and WNoC systems.

Keywords: Network-on-Chip(NoC), Bus based System Architecture, Systems on a chip (SoC)

INTRODUCTION

Network on chip or network on a chip (NoC or NOC) is a communication subsystem on an integrated circuit (commonly called a “chip”), typically between intellectual property (IP) cores in a system on a chip (SoC). NoCs can span synchronous and asynchronous clock domains or use unclocked asynchronous logic. NoC technology applies networking theory and methods to on-chip communication and brings notable improvements over conventional bus and crossbar interconnections. NoC improves the scalability of SoCs, and the power efficiency of complex SoCs compared to other designs.

i. NoC: Is an on chip packet based communication system between blocks connected via routers

ii. Today application-specific systems on-chip (SoC) make extensive use of busses as the interconnect infrastructure

iii. However, in recent years research has shown that Network on-Chip (NoC) is likely to replace buses in future SoCs [1–4]
Fig. 1: Bus based System Architecture

Traditionally, ICs have been designed with dedicated point-to-point connections, with one wire dedicated to each signal. For large designs, in particular, this has several limitations from a physical design viewpoint. The wires occupy much of the area of the chip, and in nanometer CMOS technology, interconnects dominate both performance and dynamic power dissipation, as signal propagation in wires across the chip requires multiple clock cycles.

[2] MOTIVATION AND PROPOSED WORK

i. NoCs offer superior performance, power and area tradeoffs as the number of modules increases [1-4].

ii. Bus-based architectures have trouble scaling with increasing number of IP blocks and decreasing geometries

iii. NoC is a far easier-to-scale interconnect, with shorter, unidirectional, point-to-point wires [5]

iv. For QC ASICs NoC reduces interconnect by 30 – 40%
The interconnect for on-chip global communication to provide well-controlled global wire delay and efficient global communication, a packet switched Network-on-Chip (NoC) architecture was proposed by different authors. In this paper, the NoC system parameters constrained by the interconnections are studied. Predictions on scaled system parameters such as clock frequency, resource size, global communication bandwidth and inter-resource delay are made for future technologies.

Wireless NoC’s an innovative solution. As mentioned, if we can decrease the number of hops in a transmission path of a message, we may improve the performance in time latency, power consumption and throughout. By using wireless, the transmission range can increase. Therefore, for the same given transmission distance between two nodes, a message may go through smaller numbers of wireless nodes. Consequently, some approaches worth considering are 3D and photonic NoCs and NoC architectures with multiband RF interconnect (RF-I) transmission lines [11].

The basic idea of these alternative solutions is to insert some kind of express transmitting channels to reduce the latency and power consumption. Although they can improve the performance over that of any traditional NoC system without doubt, there is a lack of an effective technique to implement the hardware components. For example, the design of transmitter, receiver, oscillator and a high reliability integrated light source may be needed. Although CMOS-based technologies have some manufacturing challenges, they still need long physical lines to work as wave guides. Such unsolved problems are the bottleneck in the use of on-chip wireless [2]. So, though such emerging paradigms can improve the performance, especially in latency and power consumption, of the traditional wired NoC system to some extent, they are not matured and still need more study and further research before the new solutions are deployed at a large scale.

That means, people should continue to look for other ways to realize the wireless communication in NoC system. Here we are going to introduce three leading approaches. Their classification is based on the transmission method. They are ultra wide band (UWB) - based WNoC, mm-wave-based WNoC and Carbon nanotube (CNT) - based WNoC system.

3.1 Ultra Wide Band (UWB) Based WNoC System
At the transmitter port, UWB-based interconnection uses Gaussian monocycle pulse (GMP) generator to produce an ultra-short pulse so as to realize an extremely low power spectral density (PSD). The modulation model used for the transmitted pulse can be pulse position modulation (PPM) or bi phase modulation (BPM). In addition, by using modulation techniques...
for channelization and separation of users, for example, time-hopped PPM (TH-PPM) and direct sequence coding, multiple access capability can be provided [7]. For the received port, it is made up of a wideband low-noise amplifier (LNA), a correlator that consist of a multiplier and integrator, an analog-to-digital converter (ADC) and synchronization circuits. It should be mentioned that for the wireless NoC architecture, an ADC including comparator and inverter has been developed [4]. In this way, the performance bottleneck for the receiver can be avoided.

3.2 A mm-Wave WNoC System
Another type of architecture used in WNoC uses millimeter-wave interconnections [8]. In order to achieve as much power gain for small area overhead as possible, a kind of zig-zag antenna [5] is proposed. The data transmission process will also include modulator/demodulator, serializer/de-serializer and amplifier. The modulation type used in this architecture is on-off-key (OOK) modulation requiring the specific modulator and demodulator [5]. Other hardware includes low noise amplifier (LNA), which consists of a two-stage cascade amplifier with shunt-peaked load. The serializer/deserializer (SERDES) devices are implemented with an oscillator block and multiplexer (MUX). Also needed is a single pole double throw switch (SPDT), which can switch between the transmitting and receiving modes of the transceiver. For this type of WNoC system, the structure can be divided into two levels: several nodes form a subnet and several such subnets will form the whole WNoC system. Each subnet connects to another subnet through either wired or wireless communication. Within a subnet, a node will connect to another node through wired interconnect. Therefore, the whole WNoC system is a hierarchical architecture with two levels. A shortcoming of this type of WNoC system is that due to the structure of the antenna and the simple communication protocol, all communication channels work at the same frequency. In a single-channel link there is only one wireless communication at a time to avoid interference. In other word, though there are many wireless links in the WNoC system, only one can be functional while others are in a rest state, which does not sound too efficient.

3.3 Carbon nanotubes (CNT) based WNoC
Carbon nanotubes (CNT) have proven to be a much better selection for use as antennas for WNoC [40]. Some recent researches have shown that a single CNT can be used to make several kinds of circuit components, such as antennas, modulator/demodulator [8], and transmitter [3]. CNT is developed by a chemical vapor deposition (CVD) method. In the fabrication process, a localized heater is applied to avoid the preexisting CMOS layers being damaged due to the high temperature CVD. The frequency range of CNT antenna can get to terahertz (THz) level, which has been investigated both theoretically and experimentally [8]. If the frequency range is in THz, the size of antenna will be small enough so that the area overhead will be small.

when the operating frequency is so high, the power dissipation of this type of antenna is quite low [3]. the multiband laser source can help the CNT antenna to be assigned different frequencies in one communicating channel. The Table 1 compares the UWB, mm and CNT based WNoC systems. On the down side, a CNT-based WNoC system not readily deployable as it needs more investigation. It though has apparent advantages than the other two options mentioned.
This section introduces a general architecture of a WNoC system including the topology/structure, wireless link insertion and transmission protocol. We provide a summary of design topologies, communication protocols and routing schemes. Given that there are many existing options, in this and in later chapters, I will describe some of the most popular ones according to my recent study.

4.1 Structure and Topology

In WNoC systems, the wireless link is a key component without any doubt. In general, according to the combination of wired and wireless links in a system, the structure can be divided into two types. One type is with pure wireless links for data transmission between nodes and the other type contains both wired and wireless links. I should point out that, a link whether wired or wireless mentioned here only refers to the data transmission channel. Other connections, for the control channel and channel arbitration, are not considered.

4.1.1 Structure of a Pure Wireless NoC System

Such type of systems mainly depend on UWB transmission. Every data channel between nodes is wireless (not considering the control link since that does not work on data transmission). Therefore, if the range of the wireless link is long enough, a node can connect to any other node in the system by wireless directly, which means every data transmission will be completed without intermediate hopping. In this condition, the system is formed as a fully-connected network.

However, in a single frequency system (or because the wireless source has limited bandwidth), a problem arises with the increase of transmission range: a fully-connected network also implies each node will use more links, which will lead to greater channel arbitrations. As a result more latency will be introduced. Additionally, it costs more area overhead for more reserved wireless nodes. Therefore, a key point in the pure wireless WNoC system is at the best transmission range according to several factors, which include the topology, number of nodes, injection load and routing algorithm.

Table 1: WNoC system parameters.

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4.1.2 Structure of Hybrid Wireless NoC System

Recent literature [9], [2], [5] recommend hybrid WNoC more than the pure WNoC. One reason is the limitation of the frequency band. Another major reason is the efficiency and necessity for transmission between two short-distance nodes. Because the most valuable characteristic of wireless communication is that it can decrease the number of hops in a long range transmission, if there is none or just a few hops between two nodes, the benefit of wireless is not so great over the wired transmission. Other reasons, such as the device area overhead and device integration, are also significant. In a hybrid Wireless NoC system, by designing a good combination of the wireless and wired links and suitable system structure, one can alleviate the above problems.

The most popular structure of the hybrid wireless NoC is a kind of hierarchical structure. The whole system is divided into several subnets, which can be considered as the bottom level. Each subnet always contains less than 40 nodes (often the number of nodes in each subnet will be 8, 16 or sometimes 32). The distance, which is treated as the number of hops, between nodes within same subnet is short since a subnet can be called a 'small-world". Typically, in the 'small-world", the average path length is no larger than $\log N$, where $N$ is the number of nodes, and this make the topology so interesting for efficient communication with minimum resources [7], Therefore, applying this feature, nodes in subnet are connected by wires only, which is both efficient in communication and saved the wireless resource. There is a hub in each subnet, whose function is to connect to other subnets through both wireless and wired channels. The topology of the subnet can be 2-D mesh, ring or star-ring, which can be 2 by 4, 4 by 4 or 4 by 8. The top level is made up of all of the subnets. As mentioned above, communication at the top level is wireless or wired and hubs in the subnets are the connection points. Due to the limited resource of wireless which will be discussed later, the neighboring subnets are connected by wire. The topology at this level is always ring, which means all subnets are arranged in a circle and in every subnet nodes are arranged in 2-D mesh, ring or star-ring.

[5] Factors and Parameters

The performance of an NoC/WNoC system mainly contains the throughput, latency and energy consumption. There are many factors that act such parameters.

Factor topology determines the connecting form of the system. Additionally, the size, or in other words, the number of nodes, can be set in the topology factor. For mesh or torus topologies, we always use an $N \times N$ network. To be more specific, we can also set the number of nodes that share a single router in the topology. Last but not least, for some kinds of topologies, such as mesh and torus, there is even a probability of link failure, which can also affect the performance.

Injection rate is the rate at which packets are injected into the simulator. In other words, injection rate is added to tell the simulator how many packets to inject per simulation cycle per nodes on an average. If the rate is too high, which means in practice there is a high injection of data into the WNoC/NoC system, the latency will become huge.

Flow control is another factor that should be considered. It refers to the number of virtual channels [16] per physical channel and the depth of each virtual channel; the unit is it. Such factors can relate to the latency and throughput of a system. Routing algorithm is another key
aspect. For instance, if the router itself is deadlock-free, which means it can use the virtual channels freely, the latency will be smaller; if we have to partition the virtual channel to avoid the deadlock, there must be some additional latency introduced.

[6] CONCLUSION
As a promising technique, NoC systems have been a hot topic of study by many researchers and organizations in recent times. Such researches cover from the system-level down to the device-level and numerous achievements have been reported. Considering the problems of multi-hop communication and improve the performance of a large NoC system, the idea of inserting wireless links offers a potential solution. Therefore, our study of wireless network-on-chip (WNoC) systems is timely. Comparing with an NoC system, although a WNoC system has much improved performance, the techniques for WNoC are not so mature as they are for NoC systems. Still, NoC is the dominant research area. Notably however, there is an increasing number of studies on WNoC systems and the relevant techniques for them are becoming available, gradually.

REFERENCES

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Author[s] brief Introduction

E G Satish is a Computer Science Engineer, presently working as an Assistant Professor in the Department of Computer Science & Engineering of Nitte Meenakshi Institute of Technology (NMIT)Banglore..He pursued his B.E from Sapthagiri College of Engineering,Bangalore and M.Tech from M.S.RamaiahInstitute of Technology,Bangalore. Currently He is trying to utilize his abilities and Knowledge in the field of Wireless Sensor Networks,Network on Chip (NoC) and Bussiness Intelligence.

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