Wireless Network-on-Chips as Autonomous Systems:

A Novel Solution for Biomedical Healthcare and Space Exploration Sensor-Networks

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***Abstract*—We present a Network-on-Chip (NoC) platform supporting wired and wireless connectivity and propose its novel inter-NoC communication mechanism as a solution to the ever-growing demand for complex computations in sensor networks of biomedical healthcare, medical emergency scenarios, and space exploration applications. NoC is a low-cost single nano-technology microelectronic chip with negligible weight and volume, low power consumption, and very high computational capabilities. NoC is made of a large set of on-chip processing-cores and sensors that are interconnected to form an ultra-fast network of distributed computing systems. We focus on NoC as a component in a sensor network. Our approach is novel in that it makes NoC internal resources partially transparent and accessible from outside. The proposed inter-NoC communication protocol allows many individual NoC based components such as sensors and processing units to collaborate in a standardized but flexible way. One challenge will be to enable the interaction between many NoCs since one NoC may not have enough capacity to render all the computations of a complex application. We introduce the notion of NoC as an Autonomous System (NAS). Since a common protocol is required to establish multi-NoC interoperability, we define a mechanism to enable many NASs to interact together. A key result is a novel protocol for external NoC communications. The advantages of this mechanism are manifold, ranging from the ability to connect multiple different NoCs in a scalable manner, increasing computational capabilities, and NoC compatibility. We illustrate these concepts with a concrete biomedical application of a BioNoC platform for patients with chronic diseases and sleeping disorders as we are also investigating some space exploration scenarios.**

Keywords- Sensor network; network-on-chip; wireless; autonomous system; biomedical healthcare; space exploration

I. INTRODUCTION

As the demand for computational speeds in medical and space applications is continuously increasing, the scaling down of microelectronic technology provides Network-on-Chip (NoC) as a solution. However, the number of computational devices on one NoC may not be enough. For instance, the high computational nature of modern biomedical, bioinformatic, and space applications started requiring the use of a large number of distributed computational systems that are of high speed, small volume, low weight and low power consumption [1]. These applications depend on medical or environmental parameters that are sensed over large periods of time. The recorded parameters are processed and analyzed for fast decision making especially in life critical situations. NoC forms a basic block for the solution [2], but not the whole solution. Therefore, the interconnection of many different NoCs will be needed to provide the required platform with a satisfactory capacity. Today, with the advances in bio-sensors, computing and communications, applications in the home healthcare are becoming a predominant form of healthcare delivery. In addition, home-care ensures continuity of care, reduces hospitalization costs, and enables patients to have a quicker return to their normal life styles. Figure 1 shows an example of a home-healthcare wireless sensor network as part of a remote monitoring system of patients with apnea (chronic disease), which is the first wireless BioNoC sensor solution we are developing.

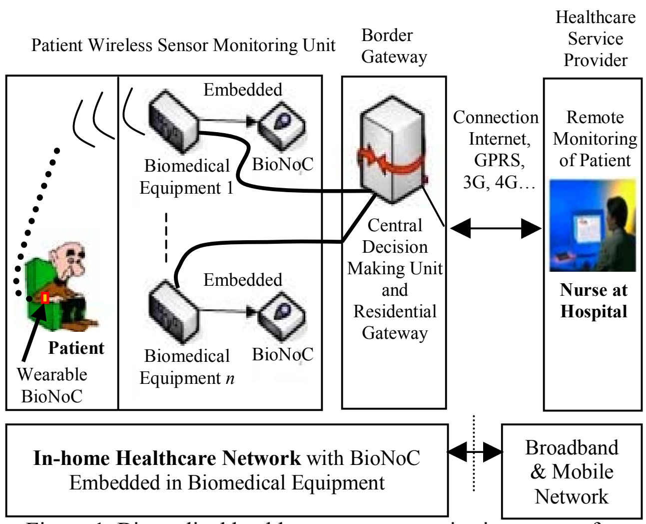

Figure 1. Biomedical healthcare remote monitoring system for patients of chronic diseases and sleep disorders. The system utilizes BioNoC at the home site of the system. Two types of BioNoCs are used: wearable wireless BioNoCs and those embedded in the biomedical equipment station.

The future market for NoCs will lead many vendors to realize the need to connect diverse NoCs, which are built for different purposes. This will only be achieved if there was a standard external NoC communication protocol and set of policies implemented on all interconnected NoCs. We introduce the notion of the NoC as an Autonomous System (NAS), by which we define two main classes for NoC communications: Intra-NoC and Inter-NoC. Intra-NoC or Internal NoC Protocol (INoP) deals with internal NoC data transfer via internal routing and switching. Inter-NoC communications and protocols define the rules and policies used by a NoC to interact with other NoCs, whether being of the same type and vendor or being of a different type and vendor. This paper introduces an External NoC communication protocol, ENoP.

II. NoC as an Autonomous System

We look at the NoC as a *self-governing* system with its private internal policies that are designed and implemented by the manufacturer. We call this system the NoC *Autonomous System* (NAS). Figure 2 shows a general NoC that can be connected to another NoC via two links. These lines are connected to two Boundary Cores (BCs) inside the NAS.

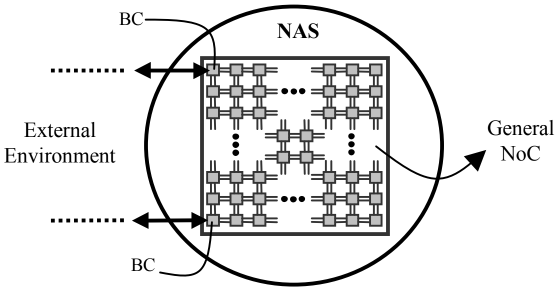

Figure 2. NoC as an autonomous system (NAS). BCs Run the ENoP on the external NoC link and INoP on the internal link.

A *core* is a set of internal NoC components physically connected to serve a set of services. We define a unique hardware address for each NoC (NHA_x, where x is an index reflecting the NAS number), which may also reflect the vendor. We define two general types of communications (Figure 4). The first type is when a specific core p, wants to interact with a specific core q. The other scheme is when a core p wants to interact with some application in some NAS. In the first example, core *p* of NAS4 wants to interact with some *Service,* S10, on *core q* of NAS2. The source address will then be the internal address of *p* associated with NHA_4. The destination address is pointed to from the larger entity to the smaller entity as: NAS2.Core(q).S10. In this way, no mixing of addresses occurs even though two processors *p* and *q* may have the same internal addresses inside their respective NoCs. In the second type of communications, a sending core needs to just know the address of the NAS, where the application resides. *Core p* as a sender will then just need to point to the destination as application A1 in NAS1 (NAS1.A1). It is then the job of the ENoP on the Border Core of the NAS receiving the messages to deliver them to the INoP, which routes them to the core running the application.

III. ENoP Principles

The following are the defined ENoP principles:

1. NAS Neighbor discovery (NND)
2. NoC Authentication (NoA)
3. Message Format Agreement (MFA)
4. Global NAS Timing and Synchronization (GNTS)
5. NAS topology discovery (NTD)
6. External routing information exchange rules

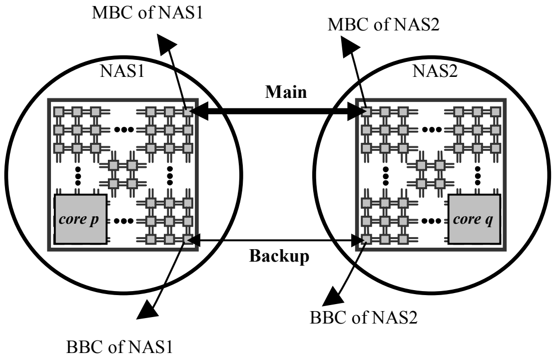

Figure 3. Two NASs interconnected via a Main and Backup links (wired or wireless) that utilize Main Border Cores (MBCs) and Backup Border Cores (BBCs). The ENoP makes the choice on which connection will be the Main and which will be the Backup.

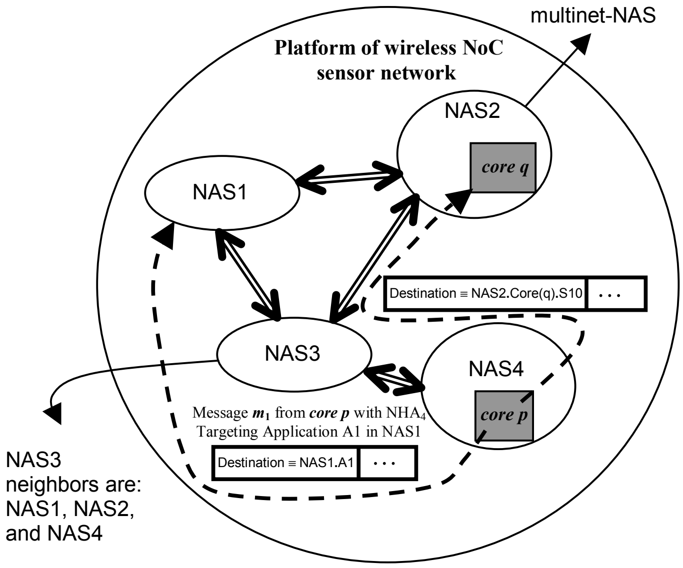

Figure 4. Topology of NASs in a sensor network example.

IV. Conclusion

We present a novel approach for inter-NoC communications in wireless NoC-based sensor-networks as a solution for complex computational needs of applications in biomedicine and space-exploration in order to overcome the anticipated problem of NoC heterogeneity and interoperability.

References

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