Simulation of Real Home Healthcare Sensor Networks Utilizing IEEE802.11g Biomedical Network-on-Chip

Iyad Al Khatib
Dept. of Microelectronics & IT
Royal Institute of Technology
Stockholm, Sweden
iyad@imit.kth.se

Axel Jantsch
Dept. of Microelectronics & IT
Royal Institute of Technology
Stockholm, Sweden
axel@imit.kth.se

Mohammad Saleh
Dept. of Microelectronics & IT
Royal Institute of Technology
Stockholm, Sweden
mohsaleh@kth.se

ABSTRACT

This paper presents a wireless biomedical Network-on-Chip (NoC) platform utilizing 54Mbps IEEE802.11g inter-NoC links for healthcare applications in home-care sensor-networks. NoC is a nano-technology microelectronic chip that consists of several processing-cores and sensors that are interconnected to form an ultra-fast on-chip network of distributed computing systems. BioNoC is a biomedical NoC designed to serve medical applications. A BioNoC is a basic block for future medical sensor networks. Patient mobility adds the need for a wireless BioNoC link in home healthcare. We concentrate on the wireless BioNoC for chronic diseases and sleep disorders as a component in a healthcare sensor-network utilizing the fastest wireless local-area-network technology available in the market, namely IEEE802.11g. One of the challenges is to enable the wireless BioNoC sensor network to converge to medical decision and warning within an acceptable time limit for critical life cases, especially when more than one BoiNoC are interconnected. We use a defined mechanism to enable many BioNoCs to interact together. The advantages of this mechanism are: the ability to connect different wireless BioNoCs in a scalable manner, increasing biomedical computational capabilities, and wireless BioNoC interoperability. We simulate a specific application of wireless interconnected BioNoCs utilizing IEEE802.11g in a home care medical sensor-network for patients suffering from apnea. Our simulations show a millisecond convergence time for the protocol for biomedical applications in case of a medical warning.

Categories and Subject Descriptors

C.2.1 **Network Architecture and Design**

General Terms

Algorithms, Performance, Design, Experimentation, Human Factors.

Keywords

Wireless Sensor Networks, biomedical application, healthcare, IEEE802.11g, Network-on-Chip, BioNoC.

1. INTRODUCTION

The demand for higher computational speeds, lower power consumption, and patient mobility in healthcare applications are continuously increasing. The NoC technology is a solution [1] for this demand mainly when used as a component in a sensor-network. NoC is made of a large set of on-chip microelectronic processing-cores and sensors that are interconnected to form an ultra-fast nano-technology network of distributed computing systems [2]. Biomedical NoCs or BioNoCs provide a solution to a growing healthcare set of needs. In order for many BioNoCs to communicate (whether with a wire or wireless protocol), we use the definition of NoC as an autonomous system (NAS) in a sensor network [3]. In healthcare, there is an increase in the number of biomedical equipment used at home, but current biomedical devices lack the ability to provide large-scale analysis, simulations and computations at the patient's location. Today's home healthcare progression is becoming a predominant form of healthcare delivery [3]. In this paper we focus on the wireless BioNoC based platform utilizing the fastest market-available wireless-local-area-network protocol (IEEE 802.11g) for one medical scenario of patients suffering from apnea, which is the most prevalent of all sleep disorders and a life-threatening condition. The monitoring of sleep apnea patients includes measuring the apnea-hypopnea index (AHI), breathing frequency, as well as the oxygen low point or destruction index (DI), which are biomedical parameters that are looked upon in this paper as just numerical values of interest to simulations. We simulate a home-care environment for apnea-patient monitoring and care using an IEEE 802.11g wireless BioNoC sensor network.

2. OVERVIEW OF WIRELESS BIONOCS

A Wireless BioNoC is a Network-on-Chip with medical sensors and processing cores that support wire and wireless communications. In this investigation we use the IEEE 802.11g as the wireless protocol that is used by the wireless BioNoCs for a home-care sensor network.

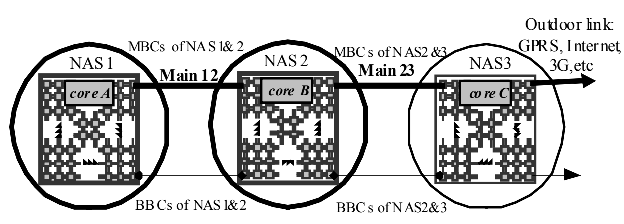

Figure 1. Interconnected BioNoCs. The MBC is Main Border Core. The BBC is a Backup Border Core. The Main and Backup links are wireless links utilizing the IEEE 802.11g. NAS stands for NoC Autonomous System, representing a self-governed-and-administered BioNoC.

The reason for choosing IEEE 802.11g is the relatively high speed that this technology provides. We use the 54 Mbps bit rate as the transmission rate in the home healthcare sensor-network of BioNoCs.

3. ENVIRONMENT SIMULATIONS

We ran a NAS topology simulation (using C++) for a biomedical home healthcare scenario, which we borrowed from biomedical scenarios using wireless Main and Backup links (with µs delays for IEEE802.11g transmissions at 54Mbps). The scenario for the apnea patient is shown in Figure 2. The patient wears two BioNoCs (1 & 2) that are interconnected via an IEEE802.11g channel, and BioNoC 2 interconnects to the Wall BioNoC (decision maker for warning) via a different channel.

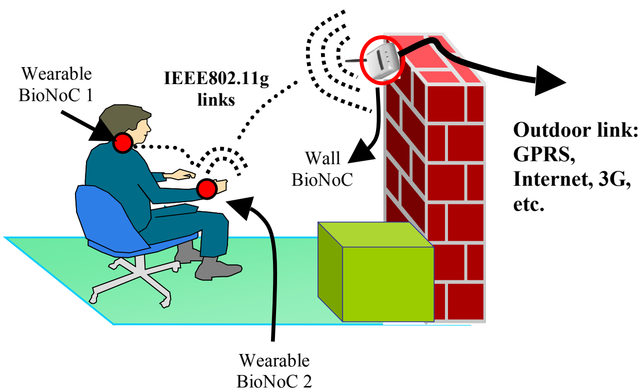

Figure 2. Apneic patient with three wireless BioNoCs: one on the head (Wearable BioNoC1), one on the hand (Wearable BioNoC2), and the Wall BioNoC, which has a wall power connection and an outdoor communication link.

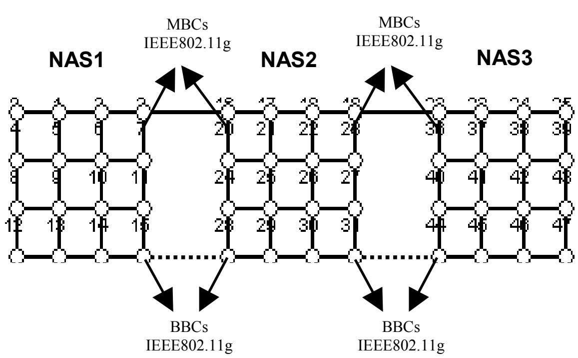

Figure 3. Wireless BioNoCs simulation environment. The numbers over the nodes reveal the hardware address of each core of the 16 cores of the BioNoC. The MBCs and the BBCs run IEEE802.11g at 54Mbps with OFDM modulation.

The Wall BioNoC is responsible for warning decisions since decision calculations consume a lot of power, and it is the only BioNoC in the scenario that is not self-powered (power connected to the wall). The Wall BioNoC is connected to the outside (to a care-center or hospital) via an outdoor communications link (Internet, 3G, or GPRS, etc). The topology of our simulated scenario of BioNoCs is shown in Figure 3. We run the scenario of interest to our project on apneic patients treatment looking for only two biomedical parameters set in the BioNoC simulator *parameters-file*: AHI and DI. AHI and DI are considered as random numerical values in the simulations by taking into consideration their physical limits. For example a value of DI below 70 would require an alarm to be sent to the hospital as it shows a severe lack of oxygen. These two parameters are sensed every hour for patients with high level of suspicion and the average is calculated every 24 hours. Accordingly the simulation is Run with three BioNoCs (Figure 3). Our simulations showed that the NoC discovery time is in milliseconds for the wireless link example of 54Mbps IEEE802.11g as shown in Table 1. The response time of the system was satisfactory from a medical point of view (Table 1).

Table 1. BioNoC simulation results for apneic patient with AHI and DI sensors of the environment shown in Figure 2.

Convergence time (ms)	Information units (# of messages)	Node of Alarm signal
41.71	1220608	1; BioNoC1
40.66	1220608	12; BioNoC1
41.30	1220608	13; BioNoC1
31.35	1220608	17; BioNoC2
30.57	1220608	30; BioNoC2

4. CONCLUSION

The paper presented an IEEE802.11g BioNoC sensor-network for healthcare with remote monitoring of patients suffering from apnea as a life threatening sleep disorder. We simulate a platform of two wearable wireless BioNoCs and a wall BioNoC. Simulations show a convergence-to-warning time that is relatively short (ms). The convergence time is satisfactory to take counter apnea measures and give audio and light warning signals to the patient.

5. REFERENCES

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