GPU-Based Simulation of Wireless Body Area Network

Dion Paul
Florida A&M University
Department of Computer and Information Sciences,
Tallahassee, FL 32307-5100
dpaul@cis.famu.edu

Hongmei Chi
Florida A&M University
Department of Computer and Information Sciences,
Tallahassee, FL 32307-5100
hchi@cis.famu.edu

Clement Allen
Florida A&M University
Department of Computer and Information Sciences,
Tallahassee, FL 32307-5100
allen@cis.famu.edu

ABSTRACT
This research work utilizes an NVIDIA GTX 470 graphics processing unit (GPU) in a local workstation to perform model simulations of a wireless body area network (WBAN). A WBAN is a complex system of multiple wireless sensor nodes which are usually deployed on, or in close proximity to a person's body. It is necessary to develop and simulate a WBAN model in order to understand its behavior before real-world deployment. There are several simulators and computing environments that are available to perform this task, but this research project only focuses on WBAN model simulation in MATLAB, using either the CPU only, or the CPU with GPU co-processing. The goal of this project is to gain an understanding of the GPU-based performance of WBAN model simulation. The purpose of this study is to investigate the reliability and suitability of various WBAN model simulations in different computing environments.

Categories and Subject Descriptors
I.6.6 [**Simulation and Modeling**]: Simulation Output Analysis

General Terms
Experimentation, Performance, Reliability

Keywords: GPU, Model, Simulation, Wireless Body Area Network, MATLAB

1. INTRODUCTION
A GPU is a single-chip processor that was originally used to perform the mathematically-intensive computations for creating lighting effects and transforming objects every time a three dimensional (3D) scene is redrawn [1]. GPU computing was pioneered by NVIDIA to lift the burden of compute-intensive tasks from the central processing unit (CPU). Modern GPUs are primarily used together with the CPU for accelerating the performance of general-purpose scientific and engineering applications, and even complex model simulations.

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This research implements a single GPU equipped with general-purpose, programmable, many-core processors to perform simulations in the domain of wireless body area networks (WBANs). WBAN models are developed according to the IEEE 802.15.6 communication standard, and are presented for simulations in different computing environments. These simulations [7] are performed using the CPU, with and without the support of GPU co-processing. Additionally, considerations are implemented to analyze the effect of mobility on model performance. Numerous simulation tools are available to aid programmers in understanding the performance and behavior of WBANs. These tools vary widely in functionality, scalability, accuracy and feedback details. A simulation environment that also utilizes the graphics processing unit (GPU) may benefit from extended capabilities that might assist developers in debugging and optimizing WBAN applications [8].

This paper is organized as following. In Section 2, we present a detailed exploration of wireless body area networks In Section 3 gives an in-depth investigation of GPU computing. Section 4 introduces the health monitoring scenarios considered in this experiment. Section 5 provides an overview of the experimental methodology for performing simulations of the WBAN model. Section 6 reports on the implementation of this work. Section 7 summarizes these research findings.

2. WIRELESS BODY AREA NETWORKS
A body area network, or WBAN, can almost be seen as a subset or derivative of a WSN since they consist of the same components, and similar techniques can be used to address issues faced by both types of networks. The WBAN functions by passing data from a network of embedded or internal sensor to a main station. The main station then fuses data from each sensor, and then sends it to a recipient via the Internet or another external gateway.

WBANs can greatly vary in size and purpose. A small WBAN monitoring an athlete's vitals while exercising may only require a single user. On the other hand, a large healthcare facility may have hundreds of participants, each with his/her sensors reporting to a large central database or program. Embedded and implanted WBANs employ slightly different configurations because they only have one battery charge. Generally, the same basic WBAN issues need to be addressed regardless of purpose or size [2]. Depending on the scenario, a different network topology or other parameters may be modified to maximize the efficiency of the system.

WBANs can greatly vary in size and purpose. Energy efficiency is crucial for WBANs taking advantage of wireless sensors and devices, and can be improved by enhancing the network layers. Security in WBANs is also important since health data is extremely personal, and it is important for users to know their data is secure and only accessible to the appropriate parties. Similarly, message delivery rate and congestion are important issues a WBAN must focus on due to the time critical nature of medical emergencies. WBAN simulation is useful for addressing energy efficiency and security concerns for these wireless sensors and devices.

3. GPU-BASED SIMULATIONS FOR WBAN

A WBAN simulator imitates the behavior of the wireless network media, in addition to the sensor nodes in the network. Some WBAN simulators present detailed models of the wireless media including effects of obstacles between nodes, while other simulators represent abstract models. Simulations allow researchers to validate WBAN hardware architecture, middleware and power consumption schemes and other software solutions before deployment. The simulation of WBAN models before commercial or private deployment is crucial in reducing the need for remedial actions once the network is in real-world operation [3].

GPU computing involves the use of a graphics processing unit together with a CPU to accelerate general-purpose scientific and engineering applications. Pioneered five years ago by NVIDIA, GPU computing has quickly become an industry standard, enjoyed by millions of users worldwide and adopted by virtually all computing vendors. GPU computing offers unprecedented application performance by offloading compute-intensive portions of the application to the GPU, while the remainder of the code still runs on the CPU. From a user's perspective, applications simply run significantly faster. CPU + GPU is a powerful combination because CPUs consist of a few cores optimized for serial processing, while GPUs consist of thousands of smaller, more efficient cores designed for parallel performance. Serial portions of the code run on the CPU while parallel portions run on the GPU. The latest generation of high-end video cards offers considerable computing power using their 100–200 on-card processors, 0.3–1.0+ GB of RAM, and fast inter-processor communications [1].

This project fuses the complexities of WBAN simulation with the promising application of GPU computing. This is achieved by using specific MATLAB functions to perform behind-the-scenes parallel computations on the GPU during the simulation of the WBAN models [5]. From this perspective, the GPU becomes a co-processor for the host or workstation where the simulations are executed.

4. SCENARIO

WBANs present a fast evolving field of low-power wireless communication. Many researchers and developers devote considerable effort in optimizing appropriate models for understanding the medium access control (MAC) and physical (PHY) layers of these systems. In MATLAB, these complex implementations are achieved by generating a signal power profile (signal variable) using a random set of Weibull distributed numbers which are generated according to best fit to signal statistical distribution around the mean from NICTA's measurements. The initial signal is then manipulated to make its fade depth statistics match those found in NICTA's measurements, and the final signal is adjusted so its mean is equal to the mean specified by input the input parameters [4].

The health monitoring scenarios are based on the use of the WBAN for monitoring the health status of a single user, Pablo. As illustrated in Figure 1, Pablo's simple real-world health monitoring scenario is utilized for simulations of the WBAN model in MATLAB.

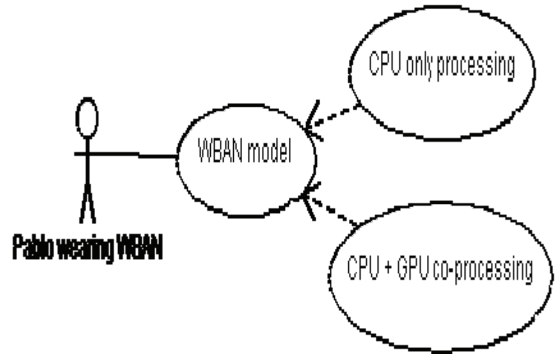

Figure 1: Use case for WBAN model simulation

Even though this research work primarily targets the computation time required to complete the simulation of the WBAN models, it is important to ensure that the simulation output is achieved for each run. These model simulation runs produced output as a plot in MATLAB. Each plot represents a plot of the channel gain in the wireless channel during the specified simulation period. The WBAN models used in this experiment are classified according to the core parameters listed in Table 1.

Table 1: Core parameters of WBAN models

Parameter	Type	Value Range
data rate	Constant	1024 kbps
carrier frequency	Constant	820 MHz
sample rate	constant	1Mhz
receiver sensitivity	constant	-87dBm
simulation time	variable	60 – 30, 000 seconds
relative body velocity	variable	1.5 – 20 km

The MATLAB profiler was used to report the performance of WBAN model simulations for various parameter configurations and computing environments. Performance was measured in terms of computational time required for the model simulation to be completed. This measurement was analyzed from two (2) perspectives – reliability and mobility.

5. METHODOLOGY

This project aims to make a knowledge contribution by verifying whether the GPU co-processing provides a boost in the performance of WBAN model simulations. The selected methodology consisted of three (3) phases – model development, simulation configuration and performance measurement. The performance measurement phase was used to analyze the model simulation runs from the aforementioned perspectives.

5.1 Model Development

The architecture of the WBAN models in this experiment are designed for implementation and simulation in MATLAB, with and without GPU co-processing. The architecture of the WBAN models used in this project also consider the internal partitioning of all nodes and hubs into a physical (PHY) layer and a medium access control (MAC) sublayer.

These considerations are reasonably supported by the the ISO/OSI-IEEE 802 reference model, which targets the systems with a data rate range from 75.9 kbps (Narrowband) up to 15.6 Mbps (UWB) [6]. Figure 2 illustrates the architecture of the WBAN model that was developed for use in this experiment.

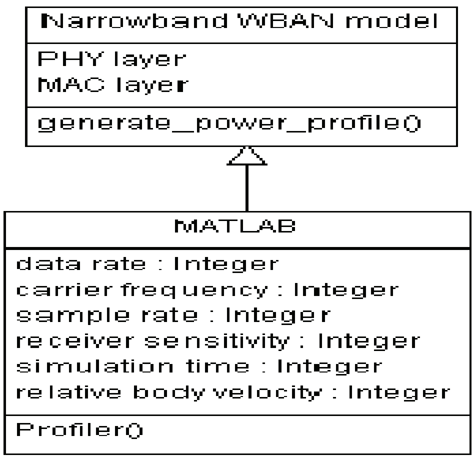

Figure 2: Architecture of WBAN model

The WBAN model parameter is categorized as constant or variable based on whether or not its value is configurable. Each model parameter plays a vital role in accurate representation of the real-time WBAN. The generic WBAN model can also be configured with different parameter values to represent various health monitoring scenarios. The parallel for loop (parfor) implementation in MATLAB was used to offload some of the WBAN model code for the GPU co-processing. This co-processing is performed by MATLAB computational engines or lab workers, and they are identified and reserved with the matlabpool command.

5.2 Simulation Configuration

This experiment utilized simple, yet realistic model parameters to mitigate complex technical issues during simulation. The simulation configuration was premised on the IEEE 802.15.6 communication standard. The IEEE 802.15.6 specifies the guidelines for short range (human body range), low power and highly reliable wireless communication for use in close proximity to, or inside, a human body [4]. The available MATLAB code for this standard was also useful in providing an appropriate environment for simulating the WBAN model. For GPU-based simulations in this experiment, the WBAN model was developed to enable a block of code to execute in parallel on a cluster of GPU-based lab workers. The GPU co-processing was achieved once the pool of MATLAB pool of computational engines (matlabpool) was open, and a specific number of lab workers were also selected. This experiment utilized between 2 – 8 lab workers for GPU co-processing. CPU only processing was performed once the matlabpool was closed, or no workers were selected.

5.3 Performance Measurement

In this phase, the performance of the model was analyzed for Pablo's simulated operation of the WBAN in terms of reliability and mobility. The reliability analysis reported the computation time required to simulate Pablo's use of the WBAN for different simulation periods. Using the same WBAN model for each of ten (10) runs, the simulation time parameter was configured for different values ranging between 60 to 600 seconds (s). The mobility analysis reported the computational times for 10 runs with a fixed simulation time of 60 seconds, and different velocity configuration values within a range of 1.5 km/h to 15 km/h. The MATLAB Profiler was used to collect performance data for each simulation run in this phase.

6. RESULTS

The results of this experiment were useful in understanding the effect of CPU only, versus CPU plus GPU co-processing for WBAN model simulations. The reliability analysis was based on the computation time required to simulate Pablo's use of the WBAN for specific simulation periods ranging from 60 – 600 seconds (s) with a carrier frequency of 820 megahertz (MHz). This data is presented in Figure 3, where each line in the plots of Figure 3 represents the series of simulations completed in MATLAB – either with the CPU only, or with CPU plus GPU lab workers. Each plot point gives the computation time taken for each run with a specific simulation time parameter value.

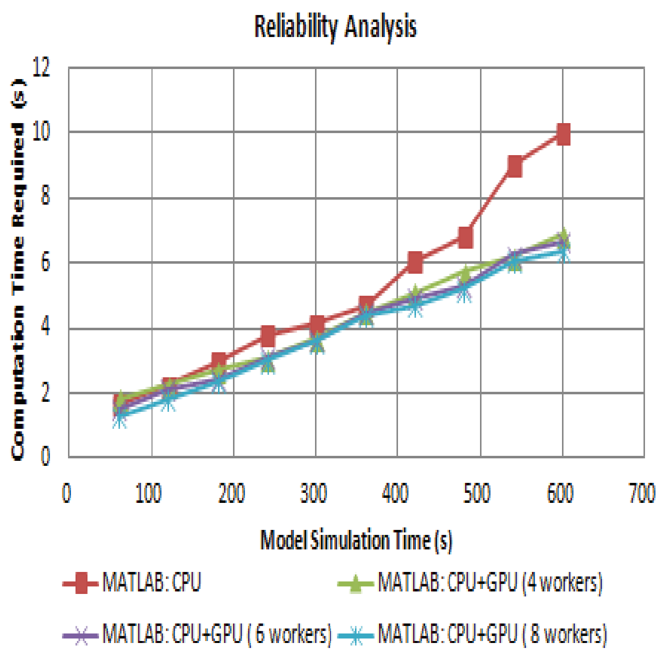

Figure 3: Reliability Analysis of WBAN model simulation

Each line in Figure 3 represents the series of simulations completed in MATLAB – either with the CPU only, or with CPU plus GPU lab workers. This plot data suggests that less computation time is required when an increasing number of MATLAB workers are used. This suggests better performance when the GPU is used as a co-processor in the simulation of the same WBAN model.

The mobility analysis was used to simulate Pablo's use of the WBAN for a fixed simulation period of 60 seconds, with increasing parameter values of the relative body velocity as he goes from walking to light jogging. This data is presented in Figure 4.

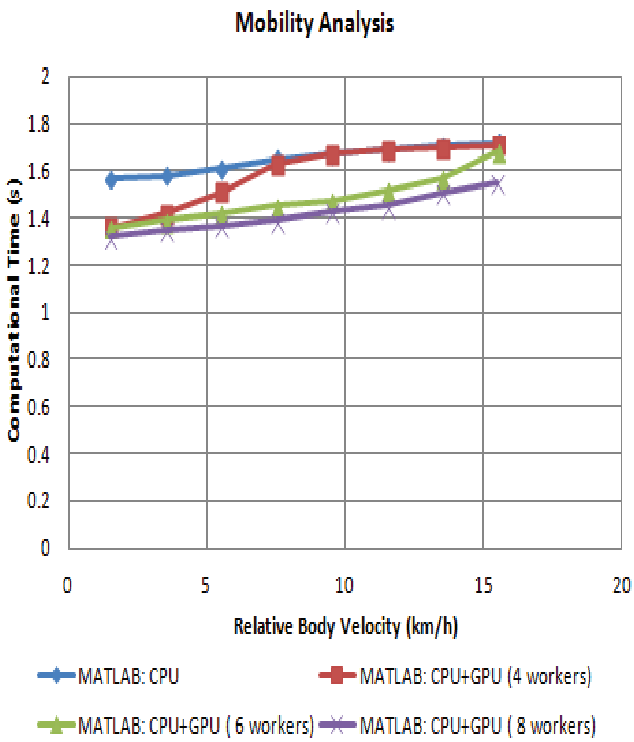

Figure 4: Mobility Analysis of WBAN model simulation

This data also suggests that there is a minor increase in computation times as the relative body velocity parameter is incremented for each simulation run. The GPU-based MATLAB models simulated with more workers performed better than the ones with fewer workers because of the computational boost provided by the additional MATLAB compute engines (workers). The suitability of the GPU-based MATLAB models for mobility analysis is validated by the fairly smaller computational time required for WBAN simulations with the GPU, than those done without it (CPU-only). Similar research in

7. CONCLUSIONS

This simulation experiment presented a methodology for developing and simulating WBAN models in MATLAB, using the simulation using the CPU only, or with GPU co-processing. This experiment proposed and verified that CPU with GPU co-processing achieves better performance for WBAN simulation, than those done using the CPU only. Additionally, it was verified that an increase in GPU resources (MATLAB workers) contributes to an increased performance in most cases.

The reliability of GPU-based WBAN model simulations in MATLAB was validated by their superior performance to those done without the GPU. For example, a WBAN model with a simulation time value 600 seconds requires approximately 6 seconds for computation using the CPU plus eight (8) GPU lab workers. The same model requires approximately 10 seconds for computation when performed using the CPU only. This experiment also verified that these models are also suitable for mobility analysis. WBAN model simulation in MATLAB is premised on the use of MATLAB classes and functions to perform computations on a dataset of randomly generated numbers. These computations are well suited for GPU co-processing since the intensive portions of the code can be processed in parallel, instead of exclusively in series via the CPU only.

8. ACKNOWLEDGMENTS

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