Light-weight Protocol Simulation for Binary Data Exchange over Heterogeneous Networks

Salah Sharieh[1], Kamran Sartipi[1], Alexander Ferworn[2]
[1]McMaster University, [2]Ryerson University
sharies@mcmaster.ca

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Abstract

This paper presents a protocol for a near –real-time binary data exchange over Ad-Hoc networks, and heterogeneous networks. The protocol was tested with a software simulation and a real fully mobile system which monitors oxygenated hemoglobin (HBO) and deoxygenated hemoglobin (HB) concentration changes in the brain and tissues. The system uses global system for mobile communications (GSM) and Bluetooth networks. The system consists of three parts: a wireless near-infrared light sensor with Bluetooth support, a personal digital assistant (PDA) with Bluetooth and GSM support, and a personal computer (PC) connected to the internet. When the system starts, the sensor connects to the PDA using Bluetooth, and the PDA connects to the PC in the lab using GSM and the Internet. The system packages the acquired data using the protocol described in this paper (LayerPro). LayerPro performance was compared with the hypertext transfer protocol (HTTP). The results show that LayerPro performs better than HTTP when streaming binary data over heterogeneous networks

1. INTRODUCTION

Infrastructure-based networks or non-infrastructure -based networks play an important role in our lives [1]. Wired networks, such as the Internet, provide us with global data access while wireless networks such as the Global Standard for Mobile Communications (GSM) give us mobility. Non-infrastructure-based networks (ad-hoc networks), such as Bluetooth networks, give us the freedom to communicate at no cost, over short ranges [2].

Various types of sensors have been created and used in a wide range of monitoring functions [3]. These sensors can often communicate with each other to create some form of network [4]. Such networks have been used in manufacturing [5], telecommunications [6], security [7] and natural environment monitoring [8].

Most networks and sensors communicate through proprietary protocols. Existing protocols support point-to-point communication between well known device types over the same network type. Currently there is not a well defined protocol for data exchange over heterogeneous networks. This paper introduces a light-weight protocol for binary data exchange over ad-Hoc networks and heterogeneous networks.

The paper is organized into five sections; introduction; related work; proposed protocol; performance evaluation and conclusion and future work.

2. RELATED WORK

Bluetooth devices (short range communication), utilizing the unlicensed frequency of 2.4 GHZ, offer a 10 to 100-meter range and a data transfer rate of up to 1 Mbps [9]. Bluetooth technology offers point-to-point and point-to-multiple-point communication [10]. GSM (wide range communication) is widely used around the world [11]. The introduction of data communication has helped GSM standards become more and more popular. GSM networks use different frequencies for upload and download links, which offer various data transfer rates between the network and the device. The data transfer rates can reach up to 9.6 kbps, which allows the networks to provide basic data services to their users [12] The introduction of General Packet Radio Services (GPRS) – data services to GSM networks – has made it possible to run more varieties of applications than before, at a lower cost and faster speed [13]. GPRS was added on top of the traditional GSM network to allow network operators to offer better data communications. GPRS is a packet-switched communication method in which the communication channel can be employed by other users, unlike other data communication methods, such as circuit-switched data. With GPRS download rates reaching 236 Kbps, and upload transfers can reach up to 118 Kbps. GPRS offers enhanced speed over the traditional GSM network [14].

Currently there are wide varieties of sensor networks used in enterprises performing different tasks ranging from monitoring machine performance and product quality to ensuring workers' safety [15]. Monitoring machines or products on factory floors does not require mobility or wireless connectivity, since everything is in close proximity. Monitoring habitat On the other hand, is not practical for extended periods of time using wired networks without disturbing the surrounding environment. Wireless networks are better for this task.[16]. For example, several wireless sensors can be dropped from the air in different locations, where they can perform data collection about the environment, and then send the data back to a central location using wireless communication. Wireless sensor networks have limited mobility: they are stationary. Mobile wireless sensor networks, however, allow mobile monitoring of conditions and situations that are at least somewhat independent of location and use wireless connections to transmit their collected data [17].

Transmission Control Protocol (TCP) is a reliable protocol used in communications requiring this characteristic. TCP allows two hosts to communicate and exchange data streams and guarantees data delivery. Data packets are delivered in the same order they were sent. In contrast, User Datagram Protocol (UDP) does not provide guaranteed delivery and does not guarantee packet ordering. Selecting which protocol to use for a particular application depends, of course, on the application requirements. These protocols have proven their value and made their way into Bluetooth and GSM networks.

Application level protocols are created to support specific applications. These protocols can run on top of either TCP or UDP protocols. HTTP protocol and LayerPro protocol are examples of such protocols.

3. PROPOSED PROTOCOL

3.1. Protocol Overview

LayerPro (the Protocol) was designed to support fast and reliable data exchange over heterogeneous networks in near-real-time. The protocol name reflects the fact that it can communicate between devices over multi-layered networks with different speeds (e.g. The Internet, GSM, and Bluetooth). It was created to support a mobile system to monitor brain function in near-real-time. Initially, the system used HTTP protocol as a data encapsulation protocol. HTTP protocol is designed to be a request-response protocol to transmit text based data. Therefore, it is unsuitable for fast binary transmission without adding performance overhead.

The system required continuous fast binary data streaming. After reviewing existing binary protocols and approaches, it was obvious that a new protocol was needed. Performance, reliability with support for a native binary data stream over heterogeneous networks, devices and applications were key requirements for the protocol. The protocol achieved the requirement through minimizing the control data and the number of overall transactions. Moreover, the protocol packet was designed to hold binary data which reduced the data representation overhead and the overall packet size. In contrast, HTTP requires further manipulation to represent binary data and the overall packet becomes larger.

3.2. Protocol Overview

LayerPro encapsulates the acquired data in the form of packets. The packets get sent over any transport layer. Figure 1 show the transport layer used in the system that implemented the protocol. The protocol has a fixed length; it has 36 bytes. It is stateless and supports limited transactions, of the form: open, close and send.

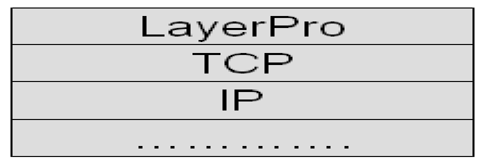

Figure 1: Protocol Layers

3.3. Protocol Packet Format

This protocol has two parts: head and tail (see Figure 2). The head contains 3 bytes representing the transmission sequence number and 1 byte describing the packet type (Data or Control). There are four possible values for the packet type field: 0-data; 1-open; 2; send; 3-close.The tail contains the actual binary data. In this protocol, fixed length is used to determine the end of the packet.

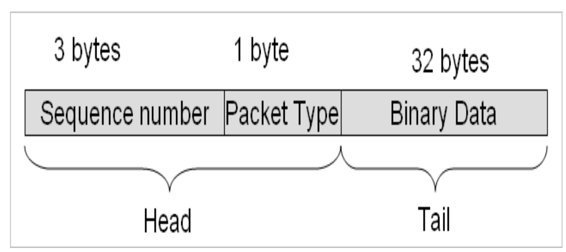

Figure 2: LayerPro Packet Format

3.4. Protocol Transactions and Packet Flow

To start the data streaming, the source system sends an open transaction packet. This transaction packet indicates to the destination system (server) the beginning of a transmission. The sequence number value in the packet head is “00 00 00”; the packet type field contains the open command, and no data in the packet tail. The open transaction packet is followed by a send transaction packet that contains the acquired data from the source (sensor) in the tail, the send command in the packet type and a sequence number in the sequence number field. The close transaction packet indicates to the destination (server) the end of transmission. The packet type field has a close command; the sequence number value in the packet head in this transaction is the last data sequence number with no data in the packet tail. Figure 3 demonstrates these transactions and flow between the source system (PDA) and the destination system (server).

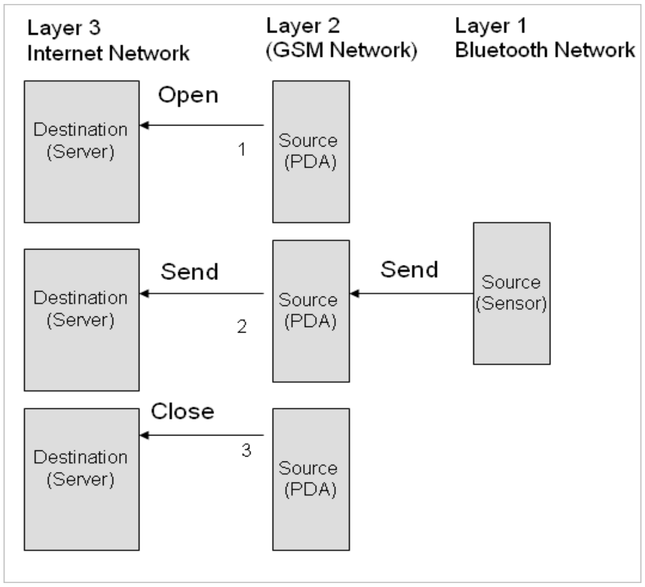

Figure 3: Layer Pro Transactions

4. PERFORMANCE EVALUATION

4.1. Experiment Setup

The system used to test the protocol consists of three main hardware components. The first component is a Bluetooth wireless sensor. The second is a PDA, which is the main controller for the measurement process and the data communication bridge between the sensor and the central computer (Middleware). The third component is a central computer (Server, or Host Computer, or PC) that stores the data for later analysis. See Figure 4 for a full display of the system's architecture.

Two different ranges of communication are used in the developed system. First, the communication between the sensor and the PDA is carried over a Bluetooth network. The maximum signal range between the PDA and the sensor is approximately 10 m (short range). The other range of communication occurs between the PDA and the central computer and is carried over the GSM network (wide range).

The sensor has a set of programs developed in the C language required to enable the data acquisition and data transmission. The PDA runs the Java ME program that performs the role of a middleware between the sensor and the host PC. The host PC works as a server and a database server as well. Additionally, the PC is configured with a public IP address to make it accessible through the Internet and to the GSM network. The communication between the PDA and the sensor is bidirectional and the communication between the PDA and the PC is unidirectional– from the PDA to the server.

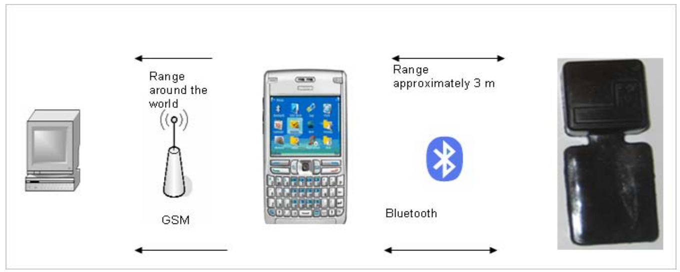

Figure 4: System Architecture

4.2. Experiment Results and Discussion

To validate the protocol's basic functionality more than 100 tests were performed. They were designed to monitor brain functions during smoking outside the lab environment, to collect changes in oxygenation concentration levels in the brain during breath holding and finally to measure the changes in oxygenation concentration levels in the brains of dogs when they are presented with their favorite toys.

The tests were focused on performance, data integrity, availability and the effectiveness of the developed protocol. The system worked in all cases, but different amounts of delay were experienced in the data transmission. The delays vary between 1 to 5 seconds. The delay is impacted by the networks' speed during the time of day the experiments were performed.

The protocol design allows the sending of one packet at a time. This approach reduced the overall packet size which makes it possible to send the data with a very short delay (1 second) most of the time. Whereas the packet size is very small (36 bytes) due to the protocol design, the network bandwidth requirements became very small. Therefore, the system required only a very few resources to transmit the data to the server which makes it possible to transmit the data without data loss despite unpredictable changes in the networks load.

To compare LayerPro performance versus HTTP performance, two version of the system were implemented. The first version implemented LayerPro and the second version implemented HTTP. The results demonstrate that the LayerPro protocol provides better near-real-time binary data transmission than the HTTP protocol. Table 1 shows a sample result compares LayerPro protocol and the HTTP protocol.

Location	Layer Pro Average Delay	HTTP Average Delay
Vaughan	1 second	5 second
Vaughan	1 second	7 second
Vaughan	1 second	5 second
Vaughan	1 second	8 second
Vaughan	1 second	5 second

Table 1 LayerPro Protocol versus HTTP Protocol

The system was tested in two different locations to ensure that the protocol can support true mobility. The test subject was wearing the sensor and carrying the PDA while he was moving around between two cities (Toronto: large city of 5 million people and Vaughan: small city with 0.5 million people). The tests were performed over several days and different times. The combination of location, date and time were necessary to investigate the effect of the mobile network and the Internet load on the quality of the transmitted data during low usage and peak usage of the heterogonous networks. Moreover the location, time and date combination are used to validate how well the protocol can handle the communication during different network loads.

Figure 5 shows a direct comparison between LayerPro and HTTP protocol. From the figure we can see that LayerPro protocol provides better near-real-time binary data transmission than the HTTP protocol. The figure also shows that the network load effect is minimal on LayerPro protocol.

In biomedical applications data integrity is very important. Even one packet dropped sometimes means losing valuable information. Tests also show that all data packet were streamed correctly and in a timely manner.

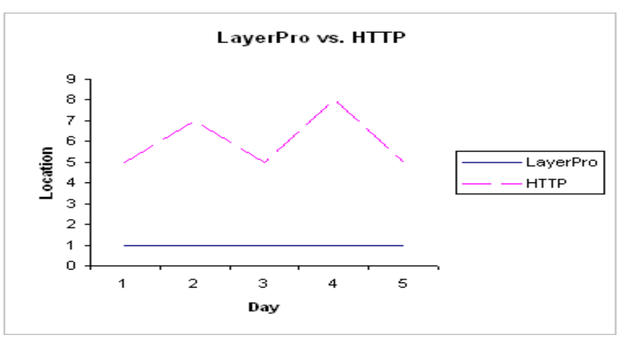

Figure 5: Averages Delays for LayerPro vs. HTTP

5. CONCLUSION AND FUTURE WORK

In conclusion, the proposed protocol provided reliable and fast binary data exchange over heterogeneous networks, devices and applications. The protocol was tested with a fully mobile system to monitor brain functions in real time. The experiments' results show that without employing LayerPro protocol, it would not be possible to stream binary data over the heterogeneous networks using the HTTP protocol and achieve timely and accurate results in the biomedical application used. LayerPro protocol provides better near-real-time binary data transmission than the HTTP protocol. Data transition using LayerPro show that all data packet were stream correctly and in a timely manner. Thus makes the proposed protocol useful for biomedical data streaming.

In the future, it will be necessary to test the protocol with multi-layered networks (more than three layers) and enhance the middleware to support multiple concurrent devices connection with connection pool to increase performance and eliminate the delay.

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