Wired Communication Protocol for Body Sensor Network: A Solution for Sensor Data Acquisition

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***Abstract*—Body sensor networks typically rely on wireless communication technologies, but in large and dense topologies, challenges with material efficiency, cost-effectiveness, and coexistence can arise. Wired communication has the potential to address these issues while preserving wearability and movement freedom, yet wired networks for body sensor networks have been overlooked and under-studied. In this extended abstract, an architecture for a low-power wired body sensor network and an optimized communication protocol for a large number of sensor nodes is proposed. And a proof-of-concept experimental device that demonstrates the feasibility and suitability of our approach for real-time applications is presented.**

***Keywords*—Body Sensor Networks, Sensor Data Acquisition, Body Area Networks, UART, Wired communication**

I. Introduction

Body sensor network (BSN) technology involves the use of small and lightweight electronic sensors that are attached to the body to collect data. These sensors can monitor various physiological parameters such as heart rate, blood pressure, temperature, and movement. They can be embedded in clothing, jewelry, or patches that are applied directly to the skin, allowing for continuous, non-invasive monitoring of health status. BSNs have a wide range of applications in healthcare, sports, and fitness, providing real-time data for personalized interventions and preventative care.

In a typical BSN, nodes are equipped with wireless communication modules that allow data transmission from sensors to a mobile processing unit like a smartphone. However, when there are many densely deployed nodes in a BSN, the circuitry required for individual power sources and wireless communication increases the system's complexity, size, and cost. Additionally, busy locations may have limited wireless bandwidth due to other wireless technologies, which can negatively impact the system's performance. This is especially problematic since wearable devices have limited power budgets.

Wired connections in BSNs have been overlooked due to concerns about restricting movement, but they offer benefits such as low loss, high speed, and a reliable transmission medium. This paper presents an architecture for a wired BSN that optimizes wiring for low-power micro-controllers (MCUs) on the body and proposes a novel protocol for synchronized data acquisition from multiple sensor nodes. The results show that the proposed approach is suitable for real-time applications with at least 26 nodes on a 1.6 m wire bus.

II. Background

Low-power MCUs commonly use communication interfaces such as Inter-Integrated Circuit (I2C), Serial Peripheral Interface (SPI), and Universal asynchronous receiver-transmitter (UART). An overview of these interfaces and their configurations is presented in Table I. I2C is often used to connect nodes on the body [2], [3], but it has limitations on the number of devices and length of the bus due to its open collector output. In SPI and UART push-pull outputs are used to control signal lines. Although typically SPI is slightly faster, UART requires less wiring. Considering the cost and complexity introduced by extra wires, UART potentially is a better fit for wired body sensor networks.

TABLE I
Summary of Wired Micro-controller Communication Interfaces for Body Sensor Network Communication.

Interface	Configuration	Topology	Output	Wires	Baud rate, kBd/s
I2C	Standard	↔Bus	OD/OC	2	100
I2C	Fast	↔Bus	OD/OC	2	400
I2C	Fast+	↔Bus	OD/OC	2	1000
I2C	High Speed	↔Bus	OD/OC	2	3400
I2C	Ultra Fast	↔Bus	PP	2	5000
UART	Address bit	⇆Bus	PP	2^a	460.8^b
UART	Idle frame	⇆Bus	PP	2^a	460.8^b
SPI	Full duplex	⇆Bus	PP	$3{+}N^a$	1000^b
SPI	Daisy-Chain	⇆Line	PP	4	1000^b
SPI	Half duplex	↔Bus	PP	3	1000^b
SPI	Enhanced Daisy-Chain [1]	←Line	PP	2	1000^b

↔ Half-Duplex, ⇆ Full-Duplex, ← Simplex.
OC – open-collector.
OD – open-drain.
PP – push-pull.
N – number of connected nodes.
[a] In half-duplex configuration required wires are one less.
[b] A typical value for currently used low-power MCUs.

III. The proposed solution for data acquisition

The solution is proposed taking into account following factors: optimized wiring, optimized communication overhead and low-power operation.

A. System architecture

The system architecture, depicted in Figure 1, is designed to acquire sensor node data on a personal mobile device using a bus topology. The architecture comprises a multitude of sensor nodes distributed throughout the body, optimized wired connections, a wireless relay node with a centralized power supply, and the mobile device itself, which functions as the platform for data aggregation and processing.

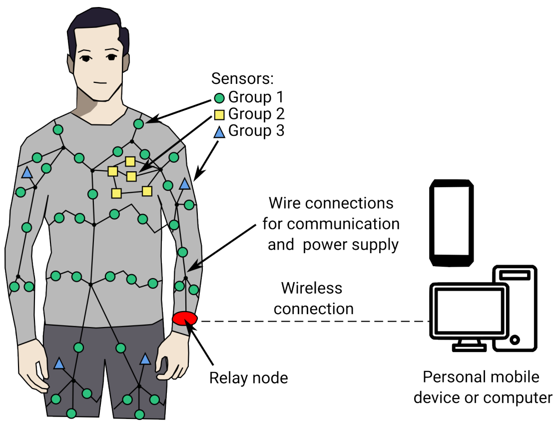

Fig. 1. The overall architecture of the proposed system.

In sensor network bus topologies, both UART Idle and Address bit configurations can be used to address individual nodes and read their data. However, if the network comprises a large number of nodes with the same sampling rate, this approach can result in significant communication overhead and hinder the synchronization of sensor data readings. Therefore, in this paper a new approach is proposed for half duplex bus topologies to address this issue.

B. Protocol

As illustrated in Fig. 2, the new approach for half duplex bus topologies involves grouping sensor nodes and addressing them simultaneously instead of individually. To prevent conflicts, the transmission order and the amount of sensor data to be transmitted are predefined. Additionally, a timeout interval between data frames is introduced to enable recovery if some nodes stop transmitting data for any reason.

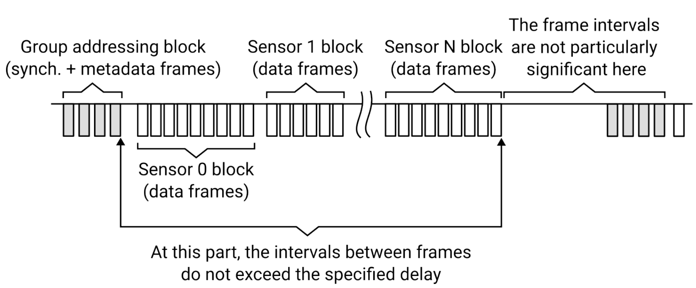

Fig. 2. Frame diagram of the proposed communication protocol.

IV. Experimental setup and results

To demonstrate that the proposed approach is feasible, an experimental setup with 26 sensor nodes was developed. The sensors were connected using 3 wire connections - VCC (positive power supply), GND (ground), and Tx/Rx (UART half-duplex configuration data signal) - over a total length of 1.6 m. Asynchronous communication was established using the following UART frame format: 1 start and stop symbol, 0 parity symbols, 8 data symbols, and a symbol transmission rate of 460800 Bd/s. The communication addressing block was formed by a fixed sequence of six UART frames: [0x55, 0xAA, 0x55, 0xAA, LEN(0-7), LEN(8-15)]. Each sensor's data was transmitted through the wire network using 12 UART frames. Given these communication parameters, the minimum time required to transmit all sensor data, denoted as t_{group}, is:

$$\min\left(t_{group}\right) = 10(6 + 26 \cdot 12)/460800 \approx 6.9 \text{ ms}, \quad (1)$$

which results in the maximum group data rate of ≈ 149.9 Hz.

Using MSP430G2553 MCUs in the sensor nodes, a frame rate of 138.1 ± 0.1 Hz was acheived, which is 92.1% of the theoretical maximum for the settings used."

V. Discussion

This extended abstract proposes a solution for acquiring sensor data from a large network of body sensors in bus topology utilizing only three wire connections (including power supply). The experimental results demonstrate the feasibility of achieving 92.1 % of the theoretical maximum sensor group frame rate (149.9 Hz) for networks with 26 nodes and 1.6 m bus length. The proposed bus topology offers greater flexibility in creating complex physical topologies of sensor nodes while maintaining optimal wiring, compared to the other approaches discussed in this paper. The proposed approach is less susceptible to the effects of parasitic parameters than the I2C protocol, which enables the creation of larger sensor networks. In addition, the proposed protocol utilizes less overhead compared to individual addressing approaches. However, to obtain an accurate estimate of overhead reduction, further investigation is required. While the experimental proof of concept shows that the approach is feasible for real-time applications, additional research is necessary to determine the limits of connected devices and bus physical topologies.

References

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