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Energy Efficient Burst Communication Through Self Adaptive Buffer Allocation For Body Sensor Networks

N. Sangeethapriya[1], R. Sasikala[2] and L.Bharathi[3]
[1.]Department of ECE, Jai Sri Ram College of Engineering, Avinashipalayam, Tiruppur, Tamilnadu, India, e-mail: npriyasangeetha@yahoo.co.in
[2.]Department of IT, K.S.R.College of Technology, Tirunchengode, Namakkal, Tamilnadu, India.
[3.]Depatment of ECE, Excel College of Technology, Komarapalayam, Tamilnadu, India

Abstract

Growing importance in health care and monitoring systems had resulted in greater scope of research nowadays. This had resulted in a rapid surge of interest and motivation in managing patients with neurological disorders and for monitoring of patients with chronic diseases. Human movement monitoring using wireless sensory nodes across the body either at hospitals or at remote locations promises to revolutionize the delivery of healthcare services. These techniques depend on inertial information of the patients for motion analysis. Such actions can help to trigger alarms or diagnose diseases by continuous and complex processing of sensor data from various parts of the body using a Body Sensor Network (BSN). Despite the recent developments and advancements of sensing and monitoring devices, power efficiency and quality of service had left as an open challenge for improvement. This proposal suggests an adaptive energy efficient QoS optimized communication model for monitory and transmitting sensed data to the backend servers periodically. These BSN uses self-adaptive buffers to limit communication to short bursts, decreasing power usage and optimizing the QoS. This project provides a self-adaptive heuristic scheme which is formulated to reduce transmissions among sensor nodes and provide the data at right time for early diagnosis and analysis for health care professionals. Several experimental analysis and simulations are to be done to evaluate the proposed technique for fast allocation of buffers in real-time under various scenarios. The same is to be compared with existing systems as well.

Keywords: Body Sensor Networks, Sensed Data Processing, Burst Communications, Adaptive Buffer Allocation, Buffer resizing, Energy Optimization.

Introduction

A dramatic rise in research interest in power-conscious computing is attributed, in part, to the growing awareness of the greenhouse effect brought about by the exponentially increasing number of computing devices. It is also driven by the impetus to meet the long duration operational requirement of battery-powered sensor networks [1]. Body sensors networks (BSNs) have emerged as a promising computing that enable wearable and mobile healthcare monitoring systems. Such platforms consist of a set of miniaturized sensor nodes which sense physiological and environmental data, initiate actions and trigger alarms during an emergency. BSNs can be used for remote patient monitoring and testing which enables a shift of healthcare from a traditional clinical setting to the home. While these sensors are usually small and cheap, as the network size scales, it is more important to optimize the communication with lower power and buffer usage. This work is motivated by problems arising from power-aware computing in general and by battery-based sensor networks in particular.

A sensor network could be composed of hundreds to thousands of tiny sensor nodes. Each sensor node typically comprises a couple of sensors, memory banks, a radio, and a microcontroller, being equipped with a stripped-down version of the operating system. The sensor node can perform some basic computational tasks such as data measurement, filtering, aggregation, transmission/reception, and packet routing. Once deployed in the patient body, these sensor nodes can self-organize into a perceptive network that enables novel ways to respond to emergencies, habitat monitoring, and around-clock healthcare surveillance. These sensor nodes are required to autonomously operate under harsh conditions for several months, even years, without human intervention and maintenance. In certain cases, battery replacement or recharge may not even be possible. Thus the premise of body sensor networks to detect rarely occurring events or to monitor chronically changing events largely depends on the lifespan of the body sensor network.

In this paper, we propose Self-Adaptive Greedy buffer allocation and scheduling algorithm (SGBAS) for effective utilization of buffers and thereby reduce the energy consumption by scheduling sensed information [1]. The proposed scheme adaptively adjusts buffer length and does not allow the sensors to transmit the same data through the BSN. To estimate the risk of sensing continuity, we exploit an average sensing interval, that is, an average time gap between two consecutive sensing (i.e., sending or receiving a sensed message packet) on a sensor node. By monitoring these sensing intervals, we can estimate how effective is the buffer utilization of the sensor node in sending or forwarding messages. This technique assigns each sensing module a large buffer which is adaptively re-sized to minimize communication cost. Almost all medical monitoring applications require only periodic data [2], real-time sensing are unnecessary. Removing such immediate data-processing deadlines permits energy optimization based on burst transmissions. This is modeled as signal processing as a directed acyclic dependency graph in which forwarding modules use sensed data from nearby sensor nodes for data fusion. Simulation results show that our proposed scheme takes lesser time to reach the sink nodes and reduces the energy requirement up to 78% without any additional overhead.

Design of Self-Adaptive Greedy Buffer Allocation and Scheduling Algorithm

Our system consists of several sensor nodes with varying capabilities (A, B, C, D), each equipped with a buffer modules, processing module and a routing architecture powered by a battery source [3]. The buffer holds the sensed data and the buffer size varies with the type of data being sensed or type of sensor node it is attached with. The processing module takes care of processing the data in the buffer and decides which to send at a time [4]. Each node may be equipped with varying sensors such as temperature, pressure, gyro, accelero, etc. A number of sensor nodes are placed on different parts of the human body. Sensed data obtained by each sensor node is subject to physical action, internal body changes, health issues and further processing.

Our node takes preprocessed data which involves several modules including preprocessing, segmentation, feature extraction, and classification. This processed data is taken to the buffer. Each sensor node makes a local classification decision on the data being available at the buffer.

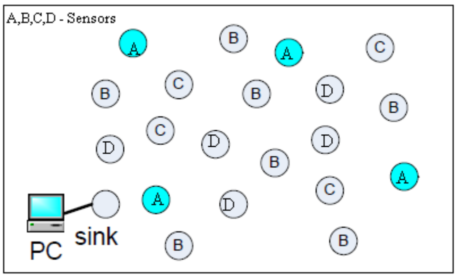

Figure 1: Sample Scenario

A final decision based on the all local data in the buffer is made by a central node. The amount of data that can be stored within buffers is constrained by the available memory of the nodes. Different hardware processing units, including reading (raw sampled sensor data), segmentation, feature extraction and classification produce data blocks of different sizes. Our communication model maintains two types of buffers for each sensor node as follows. A buffer called intra-node buffer in order to enable in-node processing. The data stored in this buffer will be consumed by the next processing unit within the same node [5]. Furthermore, a buffer allocated to a processing unit due to inter-node dependencies is called inter-node buffer. These buffers provide data for consequent dependent units. Inter-node buffers are sized according to the number of actions each link would store. An inter-node link with $X_{ij}^{\omega\eta}$ number of actions allocates a buffer to the source unit and another buffer to the destination unit. When a source unit has more than one outgoing edge, only one buffer is enough to store data for both links. The size of such buffer is adjusted adaptively based on maximum amount of data required to be transmitted among the links. The inter-node buffer is then sized according to the values of X_{ij}^{SS} and X_{ij}^{SF}. However, the maximum required size for a link is decided on the go and it gets self-adapted to accommodate the data generated by this unit. Queue length is an indicator of congestion. For the sake of eliminating effect of quick queue change, the average queue length, instead of real queue length, is used [6]. Packets beyond these queues are handled

Application Layer		
Self Adaptive buffer	QoS Optimization	Burst Communication
EEBC Routing		
IEEE 802.11		
Physical Layer		

Figure 2: System Architecture

separately or dropped. Every arriving packet will be queued in the buffer. Otherwise, a packet should be selected to drop with certain probability depending on the nature of sensed data. Different packets from different sub-nodes are the same priority [9]. This packet scheduling scheme shown below decides them.

Self-Adaptive Greedy buffer allocation and scheduling algorithm (SGBAS):
Input: Sensed local Data, Data from neighbor nodes.

Output: Queue in buffer and forward schedule.

Variables: Queue for local packets, Queue for transit packets, minimum threshold, maximum threshold, current buffer lengths, incoming packet.

Algorithm:
The SGBAS algorithm can be used offline to determine initial buffers associated with different links. This is required at the system startup where dependencies are fixed and defined by the application [7]. In addition to the objective function w and feasible solutions F the algorithm needs an initial feasible solution x_0 as input. An obvious value for x_0 is obtained by initializing every variable x_j to the smallest possible value. This algorithm initializes all xj to 1 at the beginning of the program. In all iteration, the algorithm will increment the variable adaptively with respect to inter and intra node buffers. Each link augmentation allocates some buffer to both processing blocks connected by the link. The objective of adaptive buffer allocation is to reassign buffers based on changes in dependency graph. At each point in time, one or more inter-node links may be removed from the graph and several edges can be added. Since the system is expected to operate in real-time, it is extremely important to quickly decide what the size of each buffer should be considering the QoS factors.

Deletion of an inter-node link makes some memory available on the nodes. The new memory space can be used to assign buffers to the existing or newly inserted links.

However, the optimality of the solution is not guaranteed if only memory of the deleted links is taken into consideration when reassigning buffers [8]. To overcome this problem, this proposal explores certain properties of greedy algorithm which allows to drastically reducing the number of steps for real-time buffer allocation. The key idea is that, by means of information obtained from the static case, the algorithm can restart with a significantly large initial feasible solution and yet achieve the same solution as the static buffer allocation approach with in the QoS limits. To achieve the QoS norms a loop back message is added along with acknowledgement [9].

Evaluation

This section shows the effect of the proposed scheme on energy usage, by showing the average residual energy of all sensor nodes over a simulation time of 50 seconds when there are variable flows (such as from Sensor A, B, C, D) with periodic transmissions. Each sensor node initially has 100joules. The energy consumption for packet reception, transmission and processing (which includes adaptive resizing and scheduling) is reset to 0.022, 0.016 and 0.142watts/sec, respectively. The various simulation parameters used are shown below in table 1. We use NS2 simulator to evaluate the proposed scheme with the Body Sensor Network performing various experiments.

Table 1: Simulation Parameters

Parameter	**Value**
Transmission range	2.5m
Initial energy	100 joules
Idle power	0.0012 watt
Sleeping power	0.0001 watt
Transmitting power	16.0mW
Receiving power	22.0mW
Processing power	142.0mW
Bandwidth	1 mbps
Area	15m*15m
Carrier sense threshold	3.22 m
Rx threshold	1.565m

As time increases by, SGBAS consumes energy exponentially due to periodic sensing by various types of sensors. When there is a single flow, energy consumption by BSN nodes are noted and the same is evaluated with more flows of periodic sensing. The results show that there is enough stability in energy consumption. The same is evaluated with increase in sensor nodes. Due to the shortest hop-path policy in routing the sensed data to sink, the intermediate nodes rarely change irrespective of sensor deployment density. In the absence of buffering scheme, each sensor is required to send its local data to the neighbor sensor on occurrence of every sensing there by to reach the destinations possibly the sink. This results in 231 transmissions per node during 50 seconds of system operation. Table I shows difference between the SGBAS and greedy buffer allocations for two configurations. The end-to-end delay is analyzed to evaluate the time complexity of SGBAS. The results confirm the quickness of the protocol over greedy algorithms.

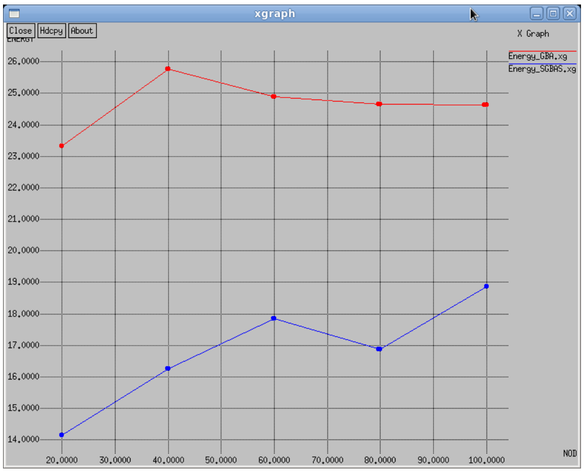

Figure 3: Energy Consumption

Table 2: Energy Consumption Comparison For Experiment1

No. of Sensors	**Average Energy Consumption(J)**	
	GBA	SGBAS
20	23.3225	14.1632
40	25.7552	16.2539
60	24.8826	17.8586
80	24.6554	19.8586
100	24.6228	21.8586

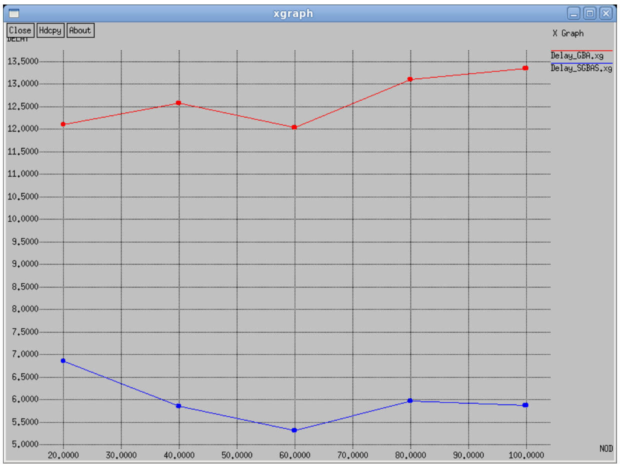

Figure 4: End-to-End Delay

Table 3: End-To-End Delay Comparison For Experiment1

No. of Sensors	**Average End-to-End Delay(10^-6 s)**	
	GBA	SGBAS
20	12.1084	6.85872
40	12.5853	5.86157
60	12.0417	5.32473
80	13.0941	5.96680
100	13.3403	5.87954

Conclusion

In this paper, we propose a Self-Adaptive Greedy buffer allocation and scheduling algorithm (SGBAS) to reduce the number of transmissions over the BSN networks. The scheme uses self-adaptive buffer scheme to effectively handle packets and schedule them in queues. It ensures minimum end-to-end data transmission delay for the light weight data while exhibiting reduction of energy consumption. Experimental results show that the proposed SGBAS scheduling scheme has better performance than the existing GBA and Multilevel Queue Scheduler in terms of the average end to end delay and energy requirements.

As scope for future developments, one can envision to reduce processing over head and save bandwidth as well. Further the proposed scheme to be analyzed and evaluated with other network parameters too. We would also validate the simulation result using a real test-bed

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