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Task requirement aware pre-processing and Scheduling for IoT sensory environments

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ABSTRACT

In Internet of Things (IoT) sensory environment Wireless Sensor Networks (WSNs) are connected to the Internet through gateways and this gives birth to many real time sensor based applications. Applications from Internet querying for Spatio-temporal information within WSN may require query decomposition. Decomposition of queries may result in tasks having similar functional and Quality of Service (QoS) requirements. Thus pre-processing the tasks results in decreased number of task executions within WSN as compared to executing tasks individually. Moreover prior knowledge of sensor nodes' residual energy can help in deciding if a task can be scheduled for its successful completion. Existing energy monitoring protocols in WSNs incur considerable amount of message traffic and energy. Thus an Energy Monitoring System (EMS) that works on reduced message traffic and yet provide the correct energy information will be of great value. This paper proposes Task Requirements Aware Pre-processing and Scheduling (TRAPS) mechanism comprising a task pre-processor, EMS and scheduler within the gateway. The scheduler allocates the best available sensor nodes to the incoming tasks while meeting their QoS requirement. Task pre-processor and EMS are tested individually to measure the key performance metrics that include number of tasks entering WSN and energy information prediction accuracy respectively. Further the performance evaluation of TRAPS is extended to study its effects on various network parameters. It is found that TRAPS outperforms the findings of recent research on task scheduling in IoT sensory environments in terms of the identified network performance metrics.

1. Introduction

Research in the WSNs has mainly focused on MAC protocol, routing protocol and location management of the sensor nodes. Internetworking between WSN and Internet; and enabling applications to handle the sensed information is going to be the future of ubiquitous computing. Research related to this is divided into two fields. One is the gateway-based which is performed by gateway located between the WSN and the Internet; the other is overlaying-based integration which is performed by overlay networks constructed on either the WSNs or the Internet [19].

In IoT sensory environment, applications on Internet query [1] for a variety of physical quantities in Spatio-temporal domain. Extensive interaction between applications from the Internet and sensors is the next big thing in the era of Internet where smart devices (sensors and RFIDs) will get connected to the Internet [1–4]. Being an advancement in the technology, IoT offers many challenges for researchers in both academia and industry. One of those challenges is to manage WSNs to process queries by Internet applications. For instance, in a simplistic scenario of intense aquaculture, the application on Internet may query for the information about the dissolved oxygen concentration in different parts of the pond. Such a query can be characterized as Spatio-temporal since the oxygen concentration can vary from one part of the pond to the other and may change over time. However, a complex query can have multiple tasks to be executed in WSN. These tasks may have specific functional and QoS requirements. In the above scenario, the required service (oxygen concentration) from the target location and the information bits required are the functional requirements whereas maximum tolerable delay is the QoS requirement associated with the task. Since the given network technology has its own resource constraints, meeting application requirements while carefully managing the constrained resources is the foremost challenge. Grouping of tasks having similar requirements and injecting the selected ones into WSN conserves network resources. Further, scheduling them on the most appropriate sensor nodes leads to their successful completion. Moreover, in IoT

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[1] The term "query" is an abstract used at application level which further decomposed into network level tasks.

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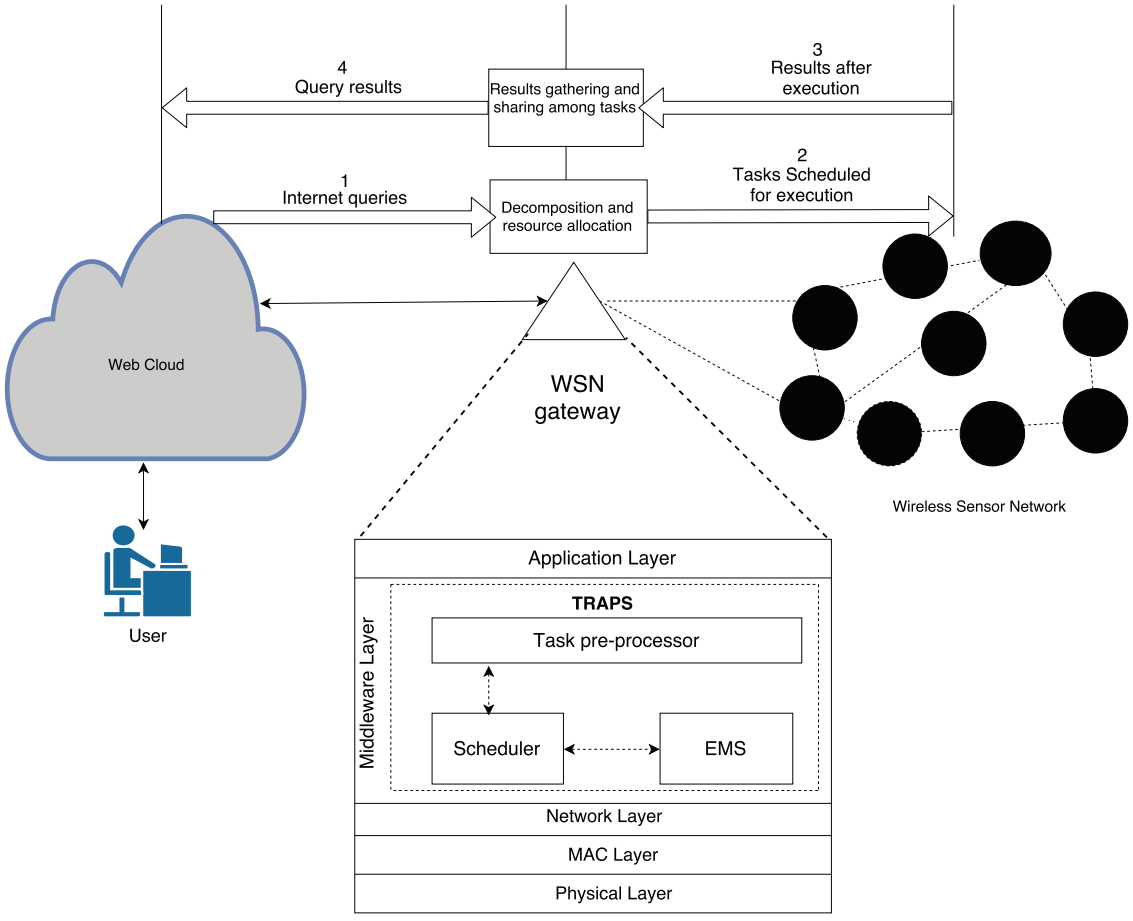

Fig. 1. Proposed WSN gateway design.

scenario, downstream traffic dominates the regular upstream traffic which is not the case in standalone WSNs. Effective resource management to increase network lifetime, fulfilling QoS requirements of incoming tasks and most importantly efficient scheduling of tasks to avoid execution redundancy and reduce the resulting inter-node communication are the key issues in such scenario. To meet the above requirements, this paper proposes an enhancement in the existing gateway architecture by introducing a task pre-processor and energy monitoring system. Fig 1. depicts the functional architecture of such a gateway. Efficient gateway design is an established research problem in distributed computing where various resource management techniques have been proposed. The research related to scheduling of tasks in WSNs [5–8] primarily focus on selecting suitable nodes to satisfy the QoS requirements.

TRAPS in the gateway (Fig. 1) consists of a task pre-processor module (responsible for gathering the requirements of incoming tasks and further classifying the tasks based on their requirements), an EMS module (for monitoring the residual energy of sensor nodes) and a scheduler module (to schedule the tasks). We propose a concept of Critical Covering Tasks (CCT) set that represents the subset of a group of tasks sharing similar spatial requirements. Subsequently, leader(s) are selected from each CCT set and scheduled to be serviced by sensor nodes. This reduction in the number of tasks has a direct consequence on network parameters. The decision for selecting potential sensor node from a set of nodes is based on its sensory capability and residual energy. The scheduler maintains the location and capability of sensor nodes in the network while EMS provides residual energy information. The EMS is designed around providing energy information of nodes with no message exchange in the network.

Rest of the paper is structured as follows. Section 2 discusses the related work. Section 3 describes the problem formulation. The mechanism design and correctness of its modules is discussed in Sections 4 and 5 respectively. Experiment design and evaluation of the overall system is presented in Section 6 followed by the conclusion and future scope in Section 7.

2. Related work

Task scheduling is an established research area in parallel and distributed computing paradigm. IoT offers different set of challenges in this context. Task scheduling in IoT sensory environment requires minimizing the resource consumption since it consists of constrained devices such as sensors and RFIDs. Thus any mechanism developed for such environments should complement to the existing mechanisms for increasing network lifetime and reducing inter-node communication. Moreover such mechanisms should also be light weight. The energy management system proposed in [5] for efficient duty cycling of sensor nodes focuses on selecting critical sensors for a given task on the basis of their residual energy levels. In their work, a new concept of Quality of Information (QoI) aware sensor to task relevancy is proposed to measure the sensory capabilities of sensor nodes against tasks' QoS requirements. Moreover energy management decision is made at run time in order to ensure the fairness in task distribution. Task transition is modeled using Discrete Time Markov Chain (DTMC) which models the changes in the incoming tasks in order to wake up corresponding sensor nodes.

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