Dynamic Optimization for Wireless Sensor Network Based On Markov Decision Process

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***Abstract* - Wireless Sensor Network are network of autonomous nodes used for monitoring an environment. Sensor node tunable parameter enables WSN designer to specialize a sensor node to meet application requirement, but however parameter tuning is a challenging process that requires designer expertise. This paper says about an automated MDP based methodology to prescribe optimal sensor node operation to meet application requirement and adapt to changing environment stimuli using a heuristic policies and polices iteration on the methodology.**

***Keywords* - MDP(MarkovDecisionProcess),Wireless Sensor Network,DVFS2(dynamic voltage, frequency scaling and sensing),Dynamic Optimization.**

I. INTRODUCTION

Wireless Sensor Network is widely used in variety of application domains including military, health, ecology, environment, industrial automation, civil engineering, traffic control. There exists previous work related to DVFS and several initiatives towards application-specific tuning were taken. Nevertheless, literature presents no mechanisms to determine an optimal dynamic tuning policy for sensor node parameters in accordance with changing application requirements. To the best of knowledge, propose the first methodology to address WSN dynamic optimizations with the goal of meeting application requirements in a dynamic environment very challenging. One critical design challenge involves application requirements such as lifetime, reliability, throughput, delay(responsiveness)etc. MDPs are characterized as sequential decision making problems that involve choosing actions, making observations of the system, and then modifying these actions based on the new information. The nature of these problems makes it possible to propose solution approaches even when the dynamics of the system (e.g., cost of decisions, probability distributions of random disturbances in the system, etc.) are unknown. The main contribution in paper is :

A. Dynamic optimization based on MDP gives an optimal policy as DVFS2 and specific optimal sensor node parameter for WSN lifetime.
B. Can adapt to changing application requirement and environment stimuli.

II. RELATED WORK

There are lot of research in dynamic optimizations but mostly they are focus the processor memory(cache) in computer system, where they can provide valuable insight into WSN dynamic optimizations they are not directly applicable to WSN due to different design spaces ,Platform particular and a sensor nodes design constraints.

Little previous work exists in the area of application specific tuning and dynamic profiling in WSNs. Sridharan [1] obtained accurate environmental stimuli by dynamically profiling the WSN's operating environment, however, they did not propose any methodology to leverage these profiling statistics for optimizations. Tilak. [2] investigated infrastructure (referred to sensor node characteristics, number of deployed sensors, and deployment strategy) tradeoffs on application requirements.

The application requirements considered were accuracy, latency, energy efficiency, fault tolerance, good put (ratio of total number of packets received to the total number of packets sent), and scalability. However, the authors did not delineate the interdependence between low-level sensor node parameters and high-level application requirements. Kogekar et al. [3] proposed an approach for dynamic software reconfiguration in WSNs using dynamically adaptive software. Their approach used tasks to detect environmental changes (event occurrences) and adapt the software to the new conditions. Their work did not consider sensor node tunable parameters. Kadayif et al.5] proposed an automated strategy for data filtering to determine the amount of computation or data filtering to be done at the sensor nodes before transmitting data to the sink node. Unfortunately, the authors only studied the effects of data filtering tuning on energy consumption and did not consider other sensor node parameters and application requirements. Marr'on etal. [4] presented an adaptive cross-layer architecture TinyCubus for TinyOS-based sensor networks that allowed dynamic management of components (e.g. ,caching, aggregation, broadcast strategies) and reliable code distribution considering WSN topology. TinyCubus considered optimization parameters (e.g., energy, communication latency, and bandwidth), application requirements (e.g., reliability), and system parameters(e.g., mobility).

The system parameters selected the best set of components based on current application requirements and optimization parameters. Vecchio [6]discussed adaptability in WSNs at three different levels: communication-level (by tuning the communication scheme), a Several papers explore DVFS for reduced energy consumption. proposed real-time dynamic voltage scaling (RT-DVS) algorithms capable of modifying the operating systems' real-time scheduler and task management service for reduced energy consumption..[7] proposed a technique for adjusting supply voltage and frequency at runtime to conserve energy.

Their technique monitor program's instruction-level parallelism (ILP) and adjusted processor voltage and speed in response to the current ILP. Their proposed technique allowed users to specify performance constraints, which the hardware maintained while running at the lowest energy consumption. Application-level and hardware-level (by injecting new sensor nodes). There exists previous work related to DVFS and several initiatives towards application-specific tuning were taken. Nevertheless, literature presents no mechanisms to determine an optimal dynamic tuning policy for sensor node parameters in accordance with changing application requirements. To the best of knowledge, we propose the first methodology to address WSN dynamic optimizations with the goal of meeting application requirements in a dynamic environment.

III. DYNAMIC OPTIMIZATION BASED ON MDP

A typical WSN topology where application requirements and environmental stimuli change dynamically. The sensor field consists of randomly scattered sensor nodes forming an Adhoc network. Sensor node that collect information about observed phenomena using attached sensor &transmit collect data to sink node. Relay that collected data to the application manager via an arbitrary computer communication network and they relay the information of application requirement and updates these requirement. Each sensor nodes possess a set of tuneable parameter, which the sensor node can specialize according to the application requirements.

In this methodology consists of three logical domains: the application characterization domain, the communication domain, and the sensor node tuning domain.

The application characterization domain refers to the WSN application's characterization/specification. In this domain, the application manager defines various application metrics which are calculated from (or based on) application requirements. The application manager also assigns weight factors to application metrics to signify the weightage or importance of each application metric. Weight factors provide application managers with an easy method to relate the relative importance of each application metric. The application manager defines an MDP reward function which signifies the overall reward (revenue) for given application requirements. There exists previous work related to DVFS and several initiatives towards application-specific tuning were taken. Nevertheless, literature presents no mechanisms to determine an optimal dynamic tuning policy for sensor node parameters in accordance with changing application requirements.

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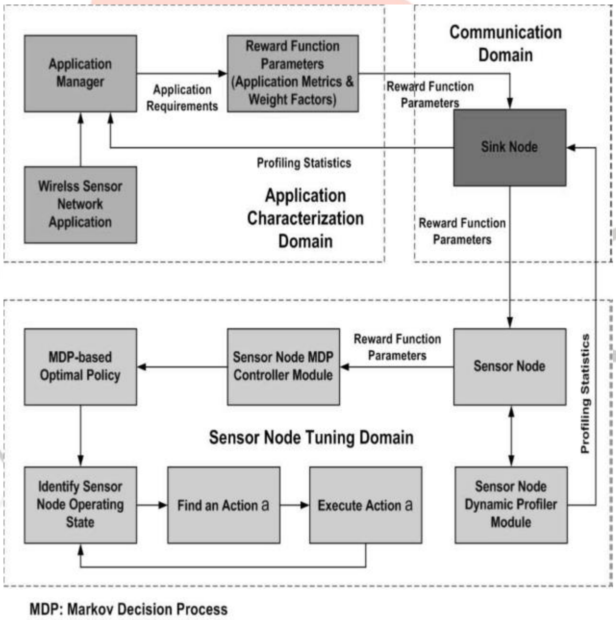


Fig 1

The application metrics along with associated weight factors, represent the MDP reward function parameters. The communication domain contains the sink node and encompasses the communication network between the application manager and the sensor nodes (Figure 1). The application manager transmits the MPD reward function parameters to the sink node via the communication domain, and the sink node in turn relays that information to the sensor nodes. The sensor node tuning domain includes the sensor nodes which each contain an MDP controller module which implements our MDP-based tuning methodology. After a sensor node receives reward function parameters from the sink node through the communication domain, the sensor node invokes the MDP controller module. The MDP controller module calculates the MDP-based optimal policy. The MDP-based optimal policy prescribes the optimal sensor node actions to meet application requirements over the lifetime of the sensor node. The sensor node identifies its current operating state, determines an action 'a' prescribed by the MDP-based optimal policy, and subsequently executes action 'a'. Proposed MDP-based dynamic tuning methodology can adapt to changes in application requirements Whenever application requirements change, the application manager updates the reward function(and/or associatedparameters to reflect the new application requirements. Upon receiving the updated reward function, the sensor node revoke's MDP controller module and determines the new MDP-based policy to optimally meet the new application requirements. MDP-based dynamic optimization methodology reacts to environmental stimuli via a dynamic profiler module in the sensor node tuning domain. The dynamic profiler module monitors environmental changes over time and captures unanticipated environmental situations not predictable at design time. The dynamic profiler module may be connected to the sensor node and profiles the profiling statistics when triggered by the WSN application. The dynamic profiler module informs the application manager of the profiled statistics via the communication domain. After receiving the profiling statistics, the application manage revaluates the statistics and possibly updates the reward function parameters. This revaluations process may be automated, thus eliminating the need for continuous application manager input. Based on these received profiling statistics and updated reward function parameters, the sensor node MDP controller module determines whether application requirements are met or not met. If application requirements are not met, the MDP controller module revokes the MDP-based optimal policy to determine anew operating state to better meet application requirements. This feedback process continues to ensure that the application requirements are met in the presence of changing environmental stimuli. A reliability reward function that can encompass the reliability aspect of WSN since sensor nodes are often deployed in unattended and environments and are susceptible to failures.

IV. MDP METHODOLOGY ON WIRELESS SENSOR NETWORK

The state space for our MDP-based tuning methodology is a composite state space containing the Cartesian product of sensor node tuneable parameters' state spaces. We define the state space S as:

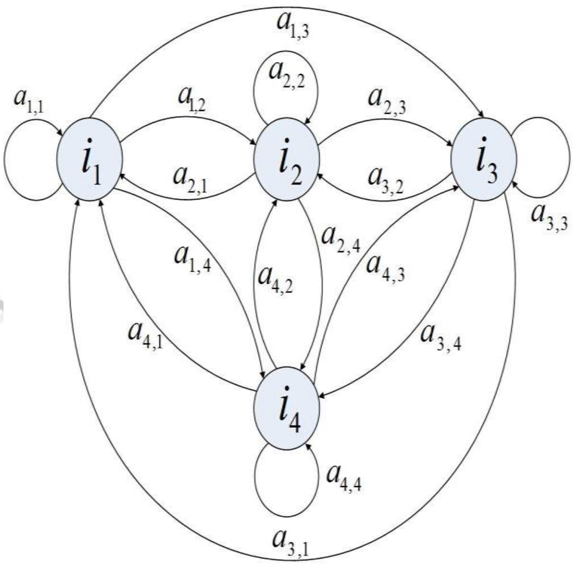
$s=s\times s2\times..\times\ldots\times s1:|s|=I]$

where × denotes the Cartesian product, M is the total number of sensor node tunable parameters, Sk denotes the state space for tunable parameter k where k ∈ {1, 2, . . . ,M}, and |S| denotes the state space S cardinality (the number of states in S).The tunable parameter k's state space (k ∈{1, 2, . . . ,M}) Sk consists of n values:

$Sk = \{sk1 , sk2 , sk3 , . . . , skn\} : |Sk| = n$

where |Sk| denotes the tunable parameter k's state space cardinality (the number of tunable values in Sk). Sis a set of n-tuples where each n-tuple represents a sensor node state s. Each state si is an n-tuple, i.e.,si = (v1, v2, . . . , vM) : vk ∈ Sk. Note that some n-tuples in S may not be feasible (e.g., all processor voltage and frequency pairs are not feasible) and can be regarded as do not care tuples. Each sensor node state has an associated power consumption, throughput, and delay. The power, throughput, and delay for state si are denoted by pi,ti, and di, respectively. Since different sensor nodes may have different embedded processors and attached sensors, each node may have node specific power consumption, throughput, and delay information for each state.

MDP-based dynamic tuning methodology for WSNs is highly adaptive to different WSN characteristics and particulars, including additional sensor node tunable parameters Furthermore, our problem formulation can be extended to form MDP-based stochastic dynamic programs. Current MDP-based dynamic optimization methodology provides a basis for MDP-based stochastic dynamic optimization that would react to changing environmental stimuli and wireless channel conditions to autonomously switch to an appropriate operating state. This stochastic dynamic optimization would provide a major incentive to use an MDP-based policy for parameter tuning that can determine an appropriate operating state out of a large state space without requiring large computational and memory resources.



Consider the following four fixed heuristic policies for comparison with MDP policy:

- A fixed heuristic policy πPOW which always selects the state with the lowest power consumption.
- A fixed heuristic policy πTHP which always selects the state with the highest throughput.
- A fixed heuristic policy πEQU which spends an equal amount of time in each of the available states.
- A fixed heuristic policy πPRF which spends an unequal amount of time in each of the available states based on a specified preference for each state.

V. RESULT

Compare the performance of proposed MDP-based DVFS2 optimal policy ¶ ˆ(¶_MDP) with several fixed heuristic policies using a representative WSN platform. MDP-based policy is sensitive to accurate determination of parameters, especially average lifetime, because inaccurate average sensor node lifetime results in a suboptimal expected total discounted reward. The dynamic profiler module measures/profiles the remaining battery energy (lifetime) and sends this information to the application manager along with other profiled statistics which helps in accurate estimation of nodes. Estimating using the dynamic profiler's feedback ensures that the estimated average sensor node lifetime differs only slightly from the actual average sensor node lifetime, and thus helps in maintaining a reward ratio.

VI. CONCLUSION AND FUTURE WORK

This paper present the application-oriented dynamic tuning methodology for WSNs based on Markov Decision Processes. MDP-based optimal policy tunes sensor node processor voltage, frequency, and sensing frequency in accordance with application requirements over the lifetime of a sensor node. Proposed methodology is adaptive and dynamically determines the new MDP-based optimal policy whenever application requirements change (which may be in accordance with changing environmental stimuli). Compared MDP-based optimal policy with four fixed heuristic policies and conclude that our proposed MDP-based optimal policy out performs each heuristic policy for all sensor node lifetimes, state transition costs, and application metric weight factors.

Future work includes enhancing MDP model to incorporate additional high-level application metrics as well as additional sensor node tunable parameters. In addition, we will enhance sensor node tuning automation by architecting mechanisms that enable the sensor node to automatically react to environmental stimuli without the need for an application manager's feedback.

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