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Simulation of efficient organization of WSN to reduce average delay in data collection process

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Abstract: **Sensor webs consisting of nodes with limited battery power and wireless communications are deployed to collect useful information from the field. Gathering sensed information in an energy efficient manner is critical to operate the sensor network for a long period of time. Energy saving is always crucial to the lifetime of a wireless sensor network. Recently, many algorithms are proposed to tackle the energy saving problem in wireless sensor networks. In these algorithms, however, data collection efficiency is usually compromised in return for gaining longer network lifetime. There are strong needs to develop wireless sensor networks algorithms with optimization priorities biased to aspects besides energy saving. In this paper, a efficient data collection network structure for wireless sensor networks is proposed. The objective of the proposed network structure is to minimize delays in the data collection processes of wireless sensor networks.The proposed network structure is able to increase the number of DCPs per unit time without imposing extra delay on each single DCP.**

Keywords: **Network structure, schedule, data collection duration, WSN**

I.INTRODUCTION

Strong adaptability, comprehensive sensing coverage, and high fault tolerance are some of the unique advantages of wireless sensor networks. Wireless sensor networks consist of large amounts of wireless sensor nodes, which are compact, light-weighted, and battery-powered devices that can be used in virtually any environment. Because of these special Characteristics, sensor nodes are usually deployed near the targets of interest in order to do close-range sensing. The data collected will undergo in-network processes and then return to the user who is usually located in a remote site. Most of the time, wireless sensor nodes are located in extreme environments, where are too hostile for maintenance. Sensor nodes must conserve their scarce energy by all means and stay active in order to maintain the required sensing coverage of the environment.

Wireless sensor networks (WSNs) are in high demand for connecting and monitoring complex engineered systems [1]–[3]. Unlike ordinary target detection applications, WSNs for system monitoring should not only provide snapshots of system states with short delays, but also reduce delays between consecutive data collection processes (DCPs) as to support continuous control monitoring.

In a network with N wireless sensor nodes, suppose the nodes are organized into the delay-aware data collection network structure (DADCNS) using the bottom-up approach mentioned in [4]. Assuming in-network data fusion is feasible, it takes $[\log_2(N + 1)]$ time-slots for a base station (BS) to collect data from all its wireless sensor nodes. The DADCNS is designed for scenarios that a DCP will be invoked occasionally, but once invoked, it should complete within a short duration. A typical example is an event detecting application, in which an event may rarely happen, but once detected, data should be reported to the base station with a minimum delay. The rest of the paper is organized as follows. Section II briefly reviews related work. Section III defines the System architecture, proposed network structure and network organization algorithm. Simulation results are shown in Section IV. Finally, the paper is concluded in Section V.

II. RELATED WORK

Due to the energy constraint of individual sensor nodes, energy conservation becomes one of the major issues in sensor networks. In wireless sensor networks, a large portion of the energy in a node is consumed in wireless communications. The amount of energy consumed in a transmission is proportional to the corresponding communication distance. Therefore, long distance communications between nodes and the base station are usually not encouraged. One way to reduce energy consumption in sensor networks is to adopt a clustering algorithm [1]. The LEACH protocol presented in [1] is an elegant solution to this data collection problem, where a small number
of clusters are formed in a self-organized manner. A designated node in each cluster collects and fuses data from nodes in its cluster and transmits the result to the BS. LEACH uses randomization to rotate the cluster heads and achieves a factor of 8 improvement compared to the direct approach,before the first node dies. Further improvements can be obtained if each node communicates only with close neighbors, and only one designated node sends the combined data to the BS in each round.
Lindsey and Raghavendra proposed another clustering algorithm called PEGASIS[2] (Power-Efficient GAthering in Sensor Information Systems), which is near optimal for this

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data gathering application in sensor networks. The key idea in PEGASIS is to form a chain among the sensor nodes so that each node will receive from and transmit to a close neighbor. Gathered data moves from node to node, get fused, and eventually a designated node transmits to the BS. PEGASIS improves on LEACH by saving energy in several stages.

III SYSTEM ARCHITECTURE

The system architecture of the proposed system is shown below

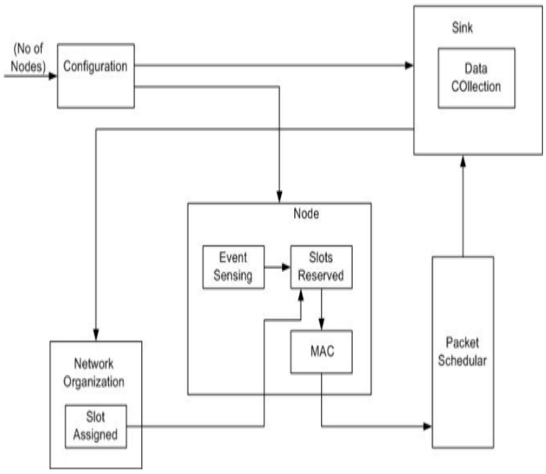

Fig 1: System architecture

System architecture is the conceptual design that defines the structure and behavior of a system. An architecture description is a formal description of a system, organized in a way that supports reasoning about the structural properties of the system. It defines the system components or building blocks and provides a plan from which products can be procured, and systems developed, that will work together to implement the overall system.

Delays among consecutive DCPs can be reduced by modifying the network structure into the one as shown in Fig. 2. A BS is represented by a rectangle, while wireless sensor nodes are represented by circles. Numbers inside the circles are showing the time-slot that a node will transmit its data.
A single DCP will, again, last for 3 time-slots. There will be 2, 3, and 1 nodes involved in data transactions at the first to the third time-slots, respectively (see Fig. 3). Note that not all nodes are involved at the first time-slot, the next DCP (data stream B) can therefore begin at the third time-slot of the current DCP (data stream A). The duration of each DCP remains the same. Furthermore, by having the transmission schedules overlap, it takes only $(q - 1) \times 2 + 3$ to complete q DCPs. Therefore, for $q > 1$, the modified network can complete the same number of DCPs with a shorter time.

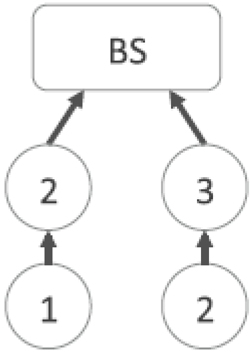

Fig.2. An optimized network structure for consecutive DCPs

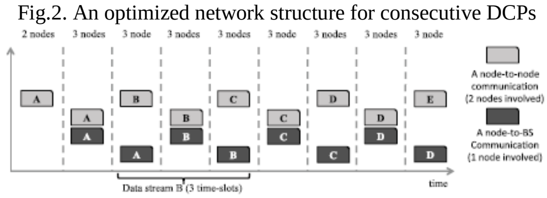

Fig.3.Transmission schedule of the network shown in Fig.2
For the proposed structure let T_{DCP} be the duration of a DCP and $T_{OL} \leq [T_{DCP}/2]$ be the overlapping duration of 2 consecutive DCPs. The duration for q consecutive DCPs (Tq) is expressed as

$$Tq = (q - 1)(T_{DCP} - T_{OL}) + T_{DCP} \qquad (1)$$

For a scenario with $T_{OL} = 0$, Tq is minimized when T_{DCP} is minimized. A minimum T_{DCP} can be achieved when the DADCNS is adopted. In the DADCNS, each node is assigned with a rank ρ. A node i with rank ρ = k may at most connect to k − 1 child nodes with their ρ s ranging from 1 to k − 1.Furthermore, this node i will connect to a parent node with ρ > k. Note that if a DCP is started at time-slot 1, the rank of a node will be equal to the time-slot t for it to communicate with its parent node. Therefore, the node i will receive data packets from its child nodes from the 1st time-slot to the k−1th time-slot, and will make a transmission to its parent node at the kth time-slot. A network with the DADCNS (Bottom-Up Approach) will be organized into several clusters. A cluster with a cluster head (CH) of a rank ρ can accommodate a maximum of $2^{\rho-1} - 1$ cluster members (CMs). By setting $T_{OL} = 1$, the next DCP will begin at the last timeslot (i.e. T_{DCP}) of the current DCP. If the network structure remains unchanged, a node i with $\rho = T_{DCP}$ will need to make a transmission to its parent node (i.e. the BS in this case) at time-slot T_{DCP}. Nevertheless, if node i has a child node with ρ = 1, it will need to receive a data packet simultaneously. Note that to resolve the conflicts, nodes with $\rho = T_{DCP}$ should not connect to nodes with $\rho = T_{OL} = 1$.

Network organization: The network organizing algorithm considers the network as a fully connected network and then constructs the proposed network structure by removing unnecessary edges.

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NOMENCLATURE

N	No. of nodes in a network.
T_{DCP}	Duration of a single data collection process.
T_q	Duration of q consecutive data collection processes.
T_{OL}	Overlapping duration of data collection processes.
ρ	Rank of a node.
S,U,L	Sets of nodes.
$\Phi(\rho)$	No. of nodes in the proposed structure with their ranks = ρ.

A flow chart of the network organizing algorithm is shown below

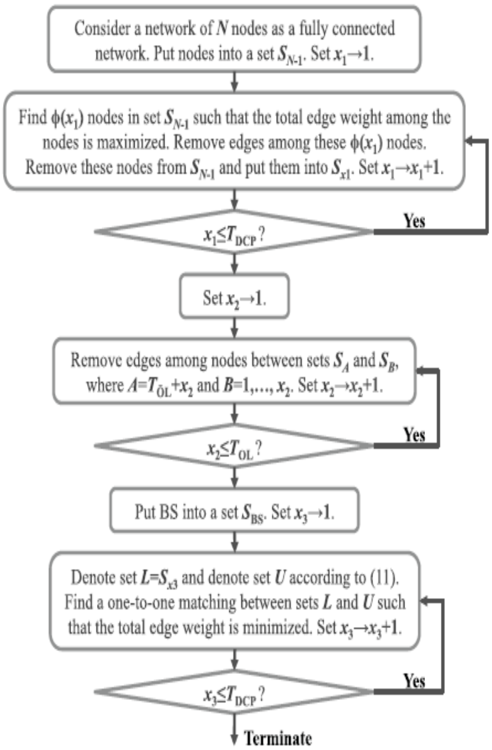

Fig. 4. A flow chart of the network organizing algorithm.

IV. SIMULATIONS

Computer simulations were conducted to evaluate the performance of the proposed network structure. The proposed network structure was compared with the DADCNS and the commonly adopted MC2HS . For fair comparisons, all network structures under test will form networks with multiple clusters. For the DADCNS, the bottom-up approach will be used for network construction. For the MC2HS, multiple 2-hop clusters (i.e. CM→CH→BS) will be formed.

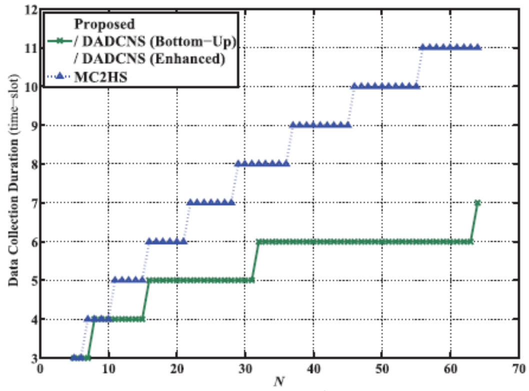

Fig.5.Data collection durations (DCDs) of networks with the proposed network structure, the DADCNS (Bottom-Up), the DADCNS (Enhanced), and MC2HS.

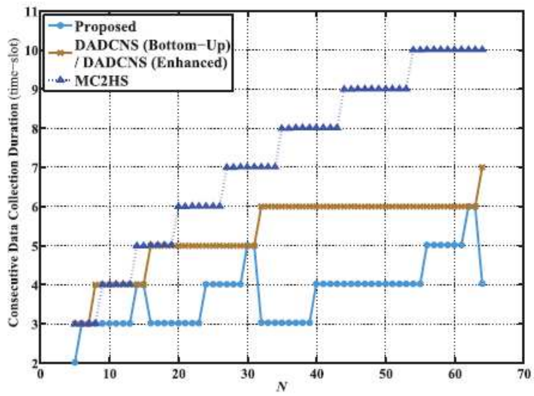

Fig.6.Consecutive data collection durations (CDCDs) of networks with the proposed network structure, the DADCNS (Bottom-Up), the DADCNS (Enhanced), and MC2HS. The datasets of DADCNS (Bottom-Up) and DADCNS (Enhanced) are overlapping.

V.CONCLUSION

In this paper, a efficient network structure and its formation algorithm is proposed for wireless sensor networks to reduce delay in data collection processes. The proposed structure can complete more data collection processes within the period of time without any degradation on the duration of a single data collection process. Simulation results show that the proposed network formation algorithm reduces energy consumption of the whole network. The proposed network structure can greatly reduce the data collection time and is highly suitable for applications that require rapid data collection.

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