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RESEARCH ARTICLE

Approaches for Combating Delay and Achieving Optimal Path Efficiency in Wireless Sensor Networks

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Abstract: ***Wireless sensor networks (WSNs) have gained a lot of interest of researchers because of its wide area of applications. Sensor network has four main performance metrics namely network lifetime, end to end delay, packet delivery ratio and throughput. In recent times a lot of research has been done on extending the lifetime of the network. Many times end to end delay factor is compromised for increasing the lifetime of the network. But in some of the applications like environment monitoring, intrusion detection etc. delay is not tolerable. In this paper we have listed some of the approaches or protocols that are both delay resistant and energy efficient. The aim of this paper is to let the readers aware how to increase the network lifetime without compromising the delay factor. This can be very helpful for the applications which do not tolerate delay in their working.***

Keywords: WSN; end to end delay; energy efficiency; sink mobility; data collection

I. INTRODUCTION

Wireless sensor networks consists of hundreds of sensors nodes which are capable of sensing the environment and sending the data to the base station. These sensor nodes are usually small in size, battery powered and deployed in harsh environments. Once deployed these nodes remain unattended for long durations. It is very difficult or may be impossible to change the batteries or recharge them. So extending the lifetime of the network is one of the main issues of wireless sensor networks. Other issues include limited hardware resources, random deployment of nodes, unreliable environment, diverse applications etc.

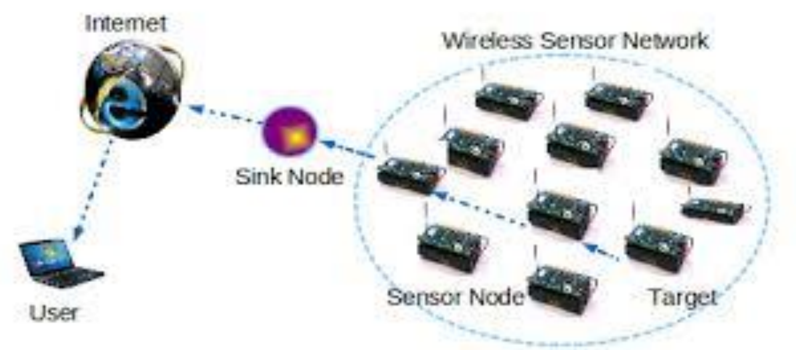


Fig 1: Wireless Sensor Network

Some of the unique advantages of wireless sensor networks are strong adaptability, comprehensive sensing range and high fault tolerance. Major application areas include military applications, health monitoring, space exploration, chemical processing etc. Keeping in mind the importance of wireless sensor networks and its wide range of applications, a lot of research has been done to improve the issues in wireless sensor networks. Lot of work has been done and many doors are left still open. The main performance metrics of WSN are packet delivery ratio, end to end delay, network lifetime and throughput. In this paper the focus will be on two important metrics end to end delay and network lifetime. In earlier times sleep-wake scheduling protocols were developed to increase the network lifetime. These protocols no doubt increases the lifetime of the network but somehow also introduced delay in the network. Here we will list the protocols that minimize the delay with keeping on check the energy efficiency so as to increase the network lifetime. Rest of the paper is organized as follows. In section II literature review to the energy efficient protocols is discussed. In section III some of the latest delay resistant and energy efficient protocols are listed. Section IV gives the conclusion and future work. Section V shows the comparison of all the techniques listed in III.

II. LITERATURE REVIEW

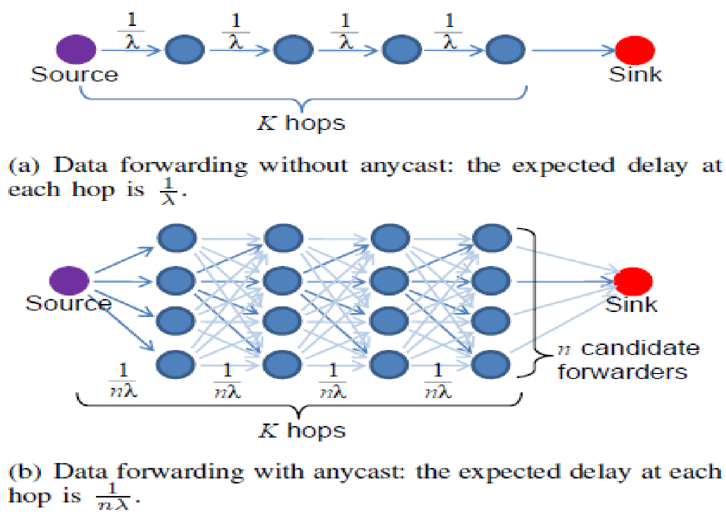
R. R. Choudhury and N. H. Vaidya in [1] listed the algorithms which use the hop-count information to reduce the delay along the routing paths. On demand sleep-wake protocols have been proposed in [3] to increase the energy efficiency by turning off the radios when not required. In [2] authors first proposed a hardware model and then introduced the design of physical layer aware protocols, applications and algorithms that minimizes the energy consumption of the system for wireless sensor nodes.

Solis and Obraczka in [4] studied the impact of timing in data aggregation for wireless sensor networks. They developed a timing model for periodic aggregation known as ‘cascading timeout’ that achieves energy efficiency while maintaining data accuracy and freshness. In [5] a collection tree protocol is proposed which is a gradient based protocol that uses expected transmissions as its routing gradient. Delay-minimized Energy-efficient Data Aggregation algorithm (DEDA) is a distributed, energy-efficient algorithm for collecting data from all sensor nodes with minimum latency. The DEDA algorithm minimizes data aggregation latency by building a delay-efficient network structure. At the same time, it also considers the distances between network nodes for saving sensor transmission power and network energy.

III. DELAY RESISTANT AND ENERGY EFFICIENT PROTOCOLS OR APPROACHES

A. Minimizing Delay And Maximizing Lifetime For Wireless Sensor Networks With Anycast [6]

This paper focuses on event driven sensor networks. In event driven sensor networks main energy consumption sources are communication radios, data transmission and reception, sensors and transmission and reception of control packets. Sleep-wake scheduling can be used to increase the lifetime of the network. In Synchronous sleep-wake scheduling algorithms sensor nodes periodically exchange synchronization information with neighboring nodes. These type of protocols incur additional communication overhead and consume a considerable amount of valuable energy. So this paper uses the asynchronous sleep-wake scheduling protocols in which every sensor node wakes up independently of neighboring nodes for energy saving. This independence of wake-up process however causes extra delay at each node along the path to the sink because each node has to wait for its next-hop node to wake-up before the transmission of data. This delay cannot be accepted in event driven networks which are used for delay sensitive applications that require the event delay to be very small. To minimize the delay anycast packet forwarding technique is used. However anycast forwarding policy applied in isolation do not give the good performance too. So anycast and sleep-wake scheduling used jointly gives the desired results. It directly impacts both end to end delay and network lifetime. This protocol generalizes typical asynchronous sleep-wake scheduling into account for anycast. In this author has assumed that there is a single source that sends out event reporting packets to the sink. Anycast packet forwarding scheme allows nodes to forward the packet to the first neighboring node that wakes up among multiple candidate nodes, such set of nodes called forwarding set. Simulation results showed that the anycast packet forwarding scheme can reduce the event reporting delay and prolong the lifetime of the network employing asynchronous sleep-wake scheduling.



(a) Data forwarding without anycast: the expected delay at each hop is $\frac{1}{\lambda}$.

(b) Data forwarding with anycast: the expected delay at each hop is $\frac{1}{n\lambda}$.

Fig 2: Example of anycast data-forwarding: anycast can reduce the expected one-hop delay and the expected end-to-end delay by n times.

B. SRP-MS: A New Routing Protocol For Delay Tolerant Wireless Sensor Networks[7]

This paper is based on sink mobility. Mobile sink plays a great role in enhancing the lifetime of the network. Traditional energy efficient protocols were based on the concept of clustering. In cluster based protocols a huge amount of energy is used in making clusters and electing cluster heads. So the concept of mobile sink is introduced. Sink is considered to be mechanically driven and can be recharged using external sources, so energy is not a constraint on moving sink. Sink moves on a predefined trajectory and only the nodes which comes under the sensing node of the sink send their data to the sink, other nodes which are not in the sensing range of the sink go to sleep mode and wait till the sink arrives. This technique is suitable for networks which can tolerate some delay.

In this paper authors extended the Stable Election Protocol(SEP)[8] by removing its clustering mechanism and introducing mobile sink. They implemented three different mobility patterns. SS-SRP(squared path within squared region),SC-SRP(circular path within squared region) and CC-SRP(circular path within circular region). Comparison analyses demonstrated that CC-SRP has highest throughput among all techniques whereas SS-SRP has second highest throughput.

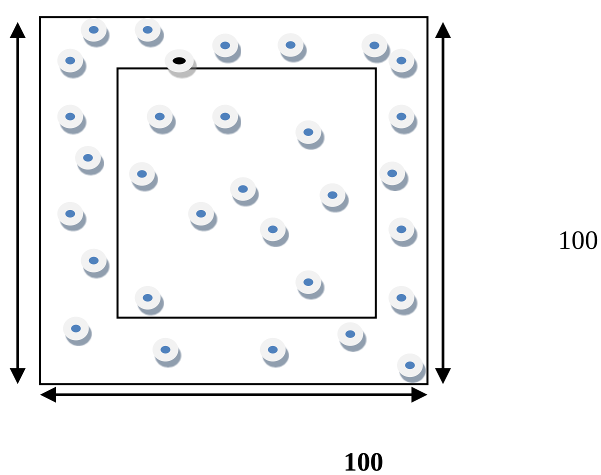


Fig 3: Square trajectory in square region

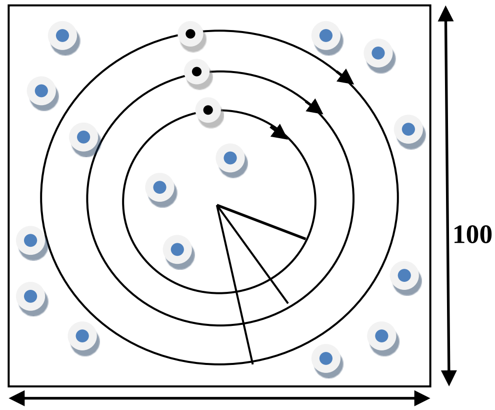


Fig 4**:** Circular trajectory in square region

Simulation results have shown that CC-SRP has significantly prolonged the network lifetime and stability period

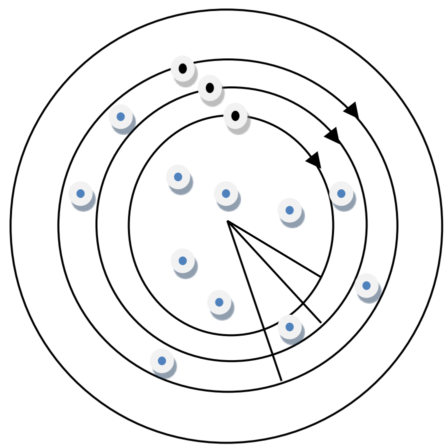


Fig **5:** Circular trajectory in circular region.

C. A Delay-Aware Data Collection Network Structure For Wireless Sensor Networks [8]

In this paper authors proposed a delay-aware data collection network structure to minimize the delay in the data collection processes of wireless sensor networks. Two network formation algorithms namely top down and bottom up approaches are designed to construct the proposed network structure in a centralized and a decentralized approach. The algorithms operate between data link layer and the network layer. The algorithms formed networks with minimum delays in the data collection process. Also algorithms tried to keep the transmission distance among wireless sensor nodes at low values in order to limit the amount of energy consumed in communications.

Top-down approach

The top-down approach is a kind of centralized control algorithm. In this approach, the base station is assumed to have the coordinates of all sensor nodes in the network. The whole approach is going to be executed at the base station. At the end of the optimization process, the base station will instruct the sensor nodes to establish the essential data links and form the appropriate network structure.

The proposed network structure can be constructed according to the following algorithm.

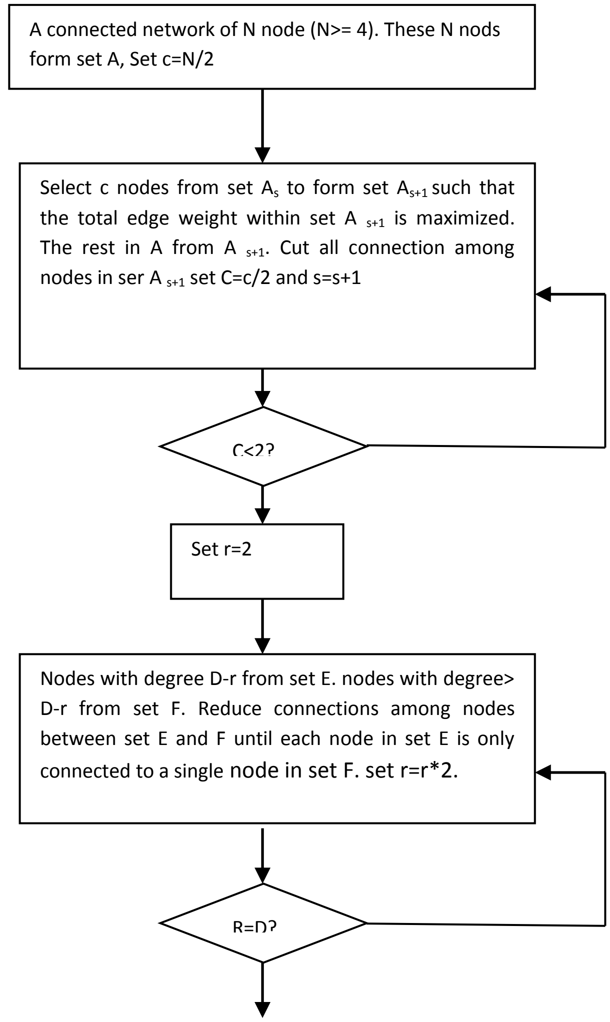


Fig 6: Network formation of the proposed network structure using centralized top-down approach (n>=4).

Bottom up approach

The operation of the bottom-up approach is to join clusters of the same size together. It can be implemented in either centralized or decentralized fashion. Specifically, a decentralized bottom-up approach can be described as follows.

1) Each node is labeled with a unique identity and marked as level. The unique identity will only serve as an identification which has no relation with sensor nodes' locations and connections. For a cluster of nodes, its value is equal to $\log_{2i}$. Within each cluster, one node will be elected as the subcluster head SCH. In the bottom-up approach, a SCH can only make connection (i.e., setup a data link) with another SCH of the same level. Since there is only 1 node in each cluster, all nodes begin as SCH (0). The dimensions of the terrain (t_x, t_y) are provided to the sensor nodes before deployment.
2) Each SCH performs random back off and then broadcasts a density probing packet (DPP) to its neighboring SCHs which are within a distance of m.
3) Each SCH will do a random back off and then broadcast an invitation packet (IVP) to its neighbors within m. The IVP contains the level and the identity of the issuing SCH. A SCH will estimate the distances to its neighboring SCHs using the received signal strength of the IVPs received.
4) Once they are connected, the two SCHs and their belonging level- clusters will form a composite level cluster. One of the two involved SCHs will become the chief SCH of the composite cluster. The chief SCH will listen to the communication channel and reply any CR from lower levels with a rejecting packet (RP). When no more CR from lower levels can be heard, the chief SCH will start to make connection with other SCHs of the same level.

5) If a RP is received, a SCH will send a CR to its next nearest neighbor in its database. If such neighbor does not exist, the SCH will increase its. The SCH will then broadcast a CR using the new. Upon receiving the CR, a SCH of the same level will grant the request if it is still waiting for a CR.
6) If no connection can be made within a period of time, either all neighbors of the same level are unavailable or all CRs have been rejected, the SCH will increase its and broadcast the CR again. This process repeats and the SCH will make connection with the base station directly. The above processes continue until no more connection can be formed.

The performance of the proposed network structure is compared with a multiple-cluster two-hop network structure, a single-chain network structure, a minimum spanning tree network structure, and a collection tree network structure. Simulation results have shown that the proposed network structure most efficient in terms of data collection time among all the network structures mentioned above.

D. EDAL: an Energy-efficient, Delay-aware and Lifetime-balancing Data collection Protocol for Wireless Sensor Networks[9]

In this paper, EDAL, an Energy-efficient Delay-Aware Lifetime-balancing protocol for data collection in wireless sensor networks, has been proposed which is inspired by recent techniques developed for open vehicle routing problems with time deadlines (OVRP-TD) in operational research. EDAL is formulated by treating energy cost in transmitting packets in WSNs in a similar way as delivery cost of goods in OVR, and by treating packet latencies similar to delivery deadlines. To reduce its computational overhead, authors introduced both a centralized meta-heuristic based on tabu search [10], and a distributed heuristic based on ant-colony gossiping, to obtain approximate solutions. Designs of this algorithm also take into account load balancing of individual nodes to maximize the system lifetime. Finally, the algorithm has been integrated with compressive sensing, which helps reduce the amount of traffic generated in the network. To evaluate EDAL, authors implemented both the centralized heuristic (C-EDAL) and the distributed heuristic (D-EDAL) and compared their performance in terms of network lifetime, selected nodes, and packet delay, with and without the integration of compressive sensing, to two selected baselines. EDAL has achieved its goal to generate routes that connect all source nodes with minimal total path cost, under the constraints of packet delay requirements and load balancing needs. The lifetime of the deployed sensor network is also balanced by assigning weights to links based on the remaining power level of individual nodes. Simulation results proved that compared to baseline protocols, EDAL achieves a significant increase on network lifetime without violating the packet delay constraints.

IV. CONCLUSION AND FUTURE SCOPE

In this paper we have listed the protocols which are both energy efficient and delay resistant. In the traditional protocols one of this parameter is compromised against the other. But the need of the hour is protocols or approaches which are both energy efficient and gives minimum end to end delay. So the future scope can be seen as algorithms which have minimum data collection latency at the same they provide extended network lifetime. Most of the energy of the network in wireless sensor networks is consumed in the communication process. So by minimizing the transmission distance between the nodes we can achieve both the purposes, short distance will consume less energy and will lead to delay minimization. In the future delay and energy consumption can be decreased by using a technique in which every node will have information of neighbors parameters, and its work load and traffic level , it adjusts its data rate by sending its neighbors data rate to avoid congestion and its sends packet to best neighbor so delay , energy spent is reduced and congestion will be avoided.

V. COMPARISON

Table1
Comparison of above mentioned techniques

S. NO.	Approach	Energy efficiency	Delay
1.	Minimizing delay and maximizing lifetime for WSN with anycast(6)	High	Very low
2.	SRP-MS	Very high	Average

3.	Top down approach	High	low
4.	Bottom up approach	Very good	low
5.	EDAL	High	low

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