A Survey on the Various Frameworks Available for Re-Energizing Wireless Senor Networks

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***Abstract*—** Wireless Sensor Networks (WSNs) are finding their applications in different scenarios in our day to day life. However a major problem that our current technology faces these days is the lack of technical knowledge of how these networks can be kept up and functioning to an efficient level. The power consumption and replenishment of sensors deployed in environments for monitoring, has been a challenging factor since decades. Researches on the improvements in the efficiency in the power consumption of WSNs have been going on for quite a while. Premature energy depletion and outdated recharging strategies are some of the major research areas that require improvement in WSNs. In this paper we enumerate the existing technologies and new proposals on the different frameworks that have been designed to enhance the efficiency in recharging Sensors deployed in WSNs.

Keywords-*component; Clustering; Power Efficiency; Recharge; Wireless Sensor Networks; WSN*

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I. INTRODUCTION

Quite a lot of researches are happening on the fields of improvements in the efficiency in the power consumption and recharging of wireless sensor networks (WSN). Early energy depletion and outdated recharging strategies are now some of the major areas that require improvement in the WSNs. There are several constraints mentioned in [1] that create tailbacks in the performance during the recharging and transmission of information across the network. Some of the causes for this is attributed to interferences in the WSNs due to concurrent transmission of data over the same channel by the nodes or also could be because of signal being transmitted in a neighboring network that interferes with the WSN signal transmission. Another reason could be Multipath fading which occurs when the recipient receives the same signal along the line of sight and another replica that is echoed after being echoed by various objects in the environment. Advances in multichannel time synchronized mesh network based on 802.15.4 radios address these problems to a large extent thereby optimizing the transmission process along a physical level. However the improvements at a logical level involve strategies that need to be implemented for efficient communication between nodes through different routing methodologies. This is still in progress. Few of the many breakthroughs in this level shall be discussed in the following sections.

II. BASIC NETWORK COMPONENTS

A. *Base stations or Service Stations (BS):* Sites near sensor networks those are responsible for the distribution and execution of power and maintenance requirements of the WSN.

B. *SenCars:* The vehicles used to carry power in charged batteries from the Service stations to the nodes that require recharging.

C. *Nodes:* These are the sensors that are deployed in an area for monitoring and gathering information from those locations.

D. *Head Node:* The node assigned to each sub area that acts as a gateway between the nodes in that particular area and the nodes of a neighboring area. Usually the node with the highest energy level is selected for this task.

III. LOW ENERGY ADAPTIVE CLUSTERING HIERARCHY (LEACH)

LEACH is one of the first protocols implemented in hierarchical routing which proposed the fusion of data. In LEACH network, the nodes in the network organize themselves into local clusters where one of the node acts as the cluster head. LEACH utilizes randomized rotation of cluster heads to evenly distribute the energy load among the sensors in the network. This is done so that the load doesn't concentrate on a single node and drain it off its power completely. The Cluster head has 2 major responsibilities which are, collection of data and aggregation of data. The aggregation functionality increases the battery life by reducing the energy consumed by frequently sending small data as and when they show up. Each unit of a LEACH protocol is called as a round which is made up of cluster setup stage and steady state storage for the purpose of reducing energy costs [2]. The chart provided in figure 1 details the working of a LEACH Protocol.

The following formula provides the threshold function for node selection in the LEACH protocol:

$$P_i(t) = \begin{cases} \frac{k}{N - k * (r \bmod \frac{N}{k})} & : \quad C_i(t) = 1 \\ 0 & : \quad C_i(t) = 0 \end{cases} \qquad (1)$$

IV. USING THE TEMPLATE

Here k is the number of clusters during each round and N is the number of nodes in the network. Each node becomes a Cluster Head once in N/k rounds; N/k also refers to the cluster size. For each cluster, each sensor has equal chance of becoming the cluster head [2].

Two Level LEACH (TL-LEACH) is an improvement on this model where it has two levels of cluster heads named as primary and secondary respectively [3]. These clusters are rotated randomly so that the energy consumption is evenly distributed amongst the two clusters. This provides an improvement of over 30% of the energy that is consumed during the transfer of data in the network in LEACH.

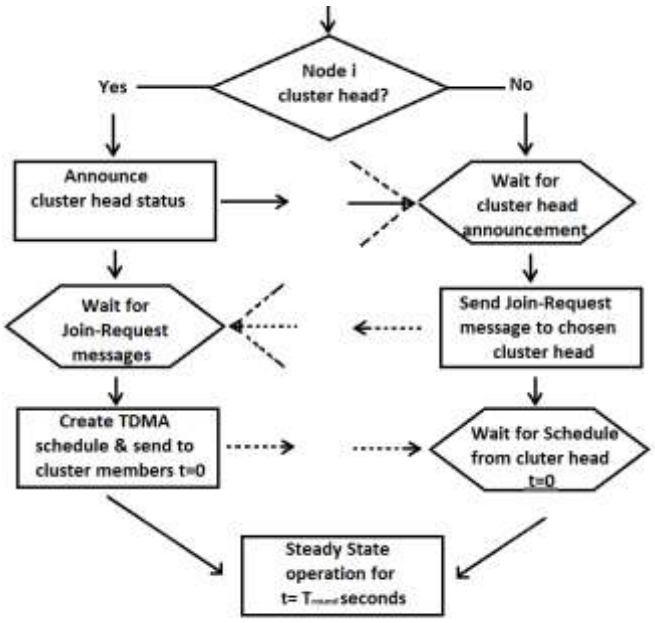


Figure 1: Cluster formation of LEACH protocol [2]

Other improvements on LEACH include LEACH-C protocol, M-LEACH, E-LEACH and V-LEACH [4].

IV. HYBRID ENERGY EFFICIENT DISTRIBUTED CLUSTERING (HEED)

HEED is a clustering method that considers the residual energy in the nodes for forming clusters [5]. Here the node having the highest energy level is selected as the cluster head (CH) node. Cases where the highest residual energy is same, the cost for communication between the nodes is considered to select the cluster head. However it has a slight drawback wherein the energy consumed for round shifting is not considered. However the power dissipated during each round is accounted.

V. ENERGY EFFICIENT CLUSTERING SCHEME (EECS)

EECS is quite similar to the LEACH clustering scheme where the network is divided into a set of clusters. Each cluster contains one cluster head [6] and their interaction with the BS happens in a single hop. But unlike LEACH, cluster formation in EECS is executed by dynamic sizing of clusters based on cluster distance from the base station. So the problem of energy efficiency in cases where the BS is far from the cluster head is resolved here. During the network deployment, the BS sends out a message to all nodes at a fixed power level. From this message, each node is able to calculate the distance to the BS by comparing the transmission signal strength with the received signal strength.

As per the simulation detailed in [6] we can see that EECS is more efficient than the different variations of LEACH and HEED [2][3].

VI. BASE STATION COTROLLED DYNAMIC CLUSTERING PROTOCOL (BCDCP)

BCDCP is a protocol quite similar to a variant of LEACH (LEACH-C) [7]. It has 2 major phases - Setup and Data Communication. As the names suggest, during the cluster formation process (Setup), the base station selects the right candidates from the nodes to be the cluster head. An algorithm is used to split the network into clusters continuously. Messages are aggregated at the cluster heads and sent across to the BS in multiple hops during data communication.

An enhanced version of BCDCP called as EEBDCP has been discussed in [7].

VII. THRESHOLD SENSITIVE ENERGY EFFICIENT SENSOR NETWORK PROTOCOL (TEEN)

TEEN protocol nodes react immediately to sudden changes in the value of a sensed attribute beyond a pre-determined threshold value and are well suited for time critical applications [8]. The process which excludes the threshold value is the same as the one used in LEACH. The method used for cluster formation is also same as LEACH. Hard Threshold value (HT) and Soft Threshold value (ST) are the parameters transmitted by the head nodes once the clusters are formed. Once the data values exceed the HT value, the nodes collect and transmit the data. Once the HT is surpassed, the collection and transmission of data by nodes happen only when they exceed ST. If the data does not exceed HT, the node doesn't transmit any data. And if it doesn't exceed ST, we cannot know about data changes after the default value is passed, especially if the data change is below the threshold value. So it would be tough to determine if the nodes are alive or not and even if the data exceeds both the threshold values, the collected data goes through a process of aggregation by the cluster head node.

VIII. ADAPTIVE PERIODIC THRESHOLD SENSITIVE ENERGY EFFICIENT SENSOR NETWORK (APTEEN)

APTEEN is a hybrid protocol for efficient routing that adapts the advantages in both LEACH and TEEN. It makes use of comprehensive information retrieval [9]. Data transmission in APTEEN follows the threshold value method used in TEEN [8] and the periodic data transmission is done as in LEACH. Such a network enables the user to request past, present and future data from the network in the form of historical, one-time and persistent queries respectively. The threshold value and parameters that include the TDMA schedule count time is transmitted after cluster formation by the CH node to the other network nodes. All nodes communicate the collected data to the CH at the time set by the parameter. But it still has a disadvantage wherein all the nodes of the network are supposed to transmit data in a steady manner.

IX. ADVANCED REGIONAL CLUSTERING SCHEME USING THRESHOLD DATA SET (ARCT)

ARCT is a protocol based on dynamic clustering that acts on the basis of the cluster and proactive network that transmits at a fixed time [10]. In addition it uses threshold just like in TEEN discussed earlier. Thus it can be categorized as a reactive network just like TEEN. ARCT uses two types of clusters—the regional cluster and the normal cluster. These clusters have different ways to collect data. The regional cluster contains data formed through a comparison of the data collected from adjacent nodes, and after that the head node of the regional cluster acts and transmits the collected data. The normal cluster combines with the nodes that failed to participate in the regional cluster. All the nodes that contain this cluster take part in data collection. The nodes that participate in this cluster increase the energy efficiency using a threshold value table when collecting data.

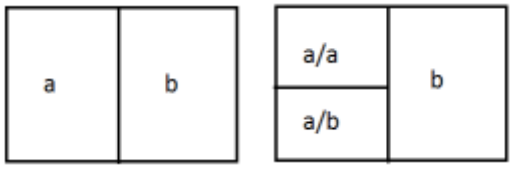
X. ADVANCED REGION CLUSTERING SCHEME (ARCS)

ARCS is a protocol based on a dynamic cluster and proactive network which has been proposed for environmental monitoring [10]. All nodes in the network are assumed to transmit data in a multi hop fashion. Unlike other schemes we have discussed so far ARCS considers more parameters other than the energy levels for forming the clusters. These parameters include sensed value and the altitude of the node. Since the sensor range is considered in this protocol, the distance for communication is much shorter as compared to the usual cases where we use transmission range. The proposal assumes that the sensor range is shorter than the transmission range.

XI. NDN BASED REAL TIME WIRELESS RECHARGING PROTOCOL (NETWRAP)

NETWRAP is a very recent proposition on improving the routing efficiency of a WSN. It makes use of a novel concept called Named Data Networking (NDN) proposed for the internet [12]. In NDN the data being transmitted in the network are referred to with their names rather than using their recipient's address. Communication is initiated from the receiver and has two entities – Interest and Data [11]. As interest messages are communicated from one node to the other, it creates a Pending interest table (PIT) at each node through which it traverses. This further helps in back tracking the path the message needs to take when it needs to get back to the receiver with the data. The forward transmission is based on Forward Interest Base states of the nodes in the network.

The network is divided into hierarchical sub regions and energy information is collected in aggregated forms. Each sub region is given a name and the data is then addressed by the region's name rather than the node address. For instance, say we have a rectangular region divided vertically to two areas 'a' and 'b' (Figure 2(a)). When 'a' is divided horizontally, the 2 new sub areas are named 'a/a' and 'a/b' (Figure 2(b)).



(a) (b)

Figure 2: NDN based division and naming of WSN Networks

After proper assignment of names, a head node is selected for each area. This would be usually the one with the maximum energy level in that area. The SenCars send energy requests to the heads in the top level. The heads send lower level energy interests to its child head in that area and so forth till the bottom most child nodes receive the energy interest messages. On receiving an energy level message a node responds with its ID and energy level. Thu the names of the nodes with low energy levels are aggregated and passed on up the hierarchy directing towards the head node of the respective area. So finally, the top most head node gets this information and passes it on to the SenCar.

The advantages of using NDN based protocol are a handful as discussed below:

Firstly, as compared to existing networks, the number of SenCars used in an NDN network is minimized to a great extent. This has a great impact in reducing the cost incurred in charging the nodes.

Secondly, in old networks the network is assumed to be a static without changes in the topology. However emergency situations may arise where some nodes may face greater load in the network. This makes them to be more accessible by the SenCars. Such emergency situations are considered in the NDN design. Thirdly, as the areas are referred to instead of

individual nodes as discussed earlier, it makes it easier to track a node requiring a recharge.

XII. CONCLUSION

So far we have discussed the various protocols that have been implemented and proposed for improving the life time of WSNs. Some are specific to certain applications and others can be used in general scenarios. Further research needs to be done on finding how the strengths of one protocol can be combined with another and further improve the lifetime of networks they are being applied to. NDN seems to hold a new break through into how WSN can be managed power efficiently. Further research in this sector is quite promising.

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