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Efficient Routing for Energy Harvesting in Wireless Sensing Networks: A Review

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Abstract—WSNs have made possible real-time data aggregation and analysis on an unprecedented scale. Naturally, they have attracted attention and garnered widespread appeal towards applications in diverse areas including disaster warning systems, environment monitoring, health care, safety and strategic areas such as defense reconnaissance, surveillance, and intruder detection. In case of nuclear power plant if any small delay occurs for data forwarding due to any node failure may results in severe disaster. Hence effective Topology Control is required to obtain an energy efficient sensor network even if any node fails. An energy efficient topology control using hybrid bio inspired algorithm based cluster head selection is presented in this work.

Keywords—Clustering in Wireless sensor network (WSN), Cluster, Energy Efficient.

I. INTRODUCTION

A wireless network consisting of a large number of small sensors with low-power transceivers can be an effective tool for gathering data in a variety of environments. In terms of routing protocol, there are two different solutions from existing works. One is flat routing, each sensor node plays the same role and sends their data to sink node directly which always results in excessive data redundancy and faster energy consumption. The other is hierarchical routing. In hierarchical routing, the entire network is divided into several clusters. Each cluster consists of some source nodes and a cluster head [1]. Sensor nodes, referred as source nodes, can gather information from the monitoring region and send the sensing information to their corresponding cluster head [2]. The cluster head is elected from all the sensor nodes in a cluster according to some criteria, and is responsible for collecting sensing data from source nods. After receiving data from source nodes, the cluster head also performs data aggregation to reduce the data size before sending data to the sink, which further reduces the power expended for data transfer [3]. Clustering-based routing algorithms are more appropriate and efficient than flat routing algorithms in WSN. Efficient design and implementation of wireless sensor networks has become a hot area of research in recent years, due to the vast potential of sensor networks to enable applications that connect the physical world to the virtual world. By networking large numbers of tiny sensor nodes, it is possible to obtain data about physical phenomena that was difficult or impossible to obtain in more conventional ways. "A sensor network is a deployment of massive numbers of small, inexpensive, self-powered devices that can sense, compute, and communicate with other devices for the purpose of gathering local information to make global decisions about a physical environment". Unlike their ancestor ad-hoc networks, WSNs are resource limited, they are deployed densely, they are prone to failures, the number of nodes in WSNs is several orders higher than that of ad hoc networks[1][2], WSN network topology is constantly changing, WSNs use broadcast communication mediums and finally sensor nodes don't have a global identification tags. The major components of a typical sensor network are shown in the figure below:

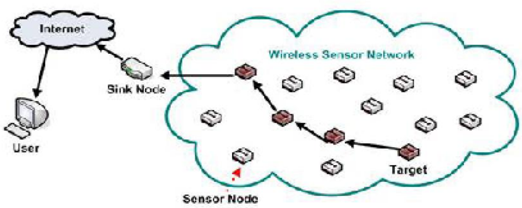

Fig. 1 Architecture of Wireless Sensor Networks

Wireless Sensor Network: A sensor field can be considered as the area in which the nodes are placed.
Sensor Nodes: Sensors nodes are the heart of the network. They are in charge of collecting data and routing this information back to a sink.
Sink Node: A sink is a sensor node with the specific task of receiving, processing and storing data from the other sensor nodes. They serve to reduce the total number of messages that need to be sent, hence reducing the overall energy requirements of the network. Sinks are also known as data aggregation points.
User: The user also known as base station and is a centralised point of control within the network, which extracts information from the network and disseminates control information back into the network. It also serves as a gateway to other networks, a powerful data processing and storage centre and an access point for a human interface. The base station is either a laptop or a workstation.
The following research paper is designed as follows. Section II describes the overall previous research work whereas Section III gives idea of problem formulation. Performance parameter defines in section IV and last but not the least Section V concludes the paper.

II. LITERATURE REVIEW

This section will provide the brief description and highlights the contribution, remarks and factors of the work done by the researchers. Many attempts have been made in the past to achieve the maximum throughput & min energy consumption.

Table1. Literature Review Table

Authors	Paper Title	Research Methodology used	Major Findings	Research prospects
Ahmad Naseem Alvi, Safdar Hussain Bouk, Syed Hassan Ahmed	Enhanced TDMA based MAC Protocol for Adaptive Data Control in Wireless Sensor Networks	Bit map assisted shortest job first based MAC (BS-MAC)	For BS-MAC , Transmission Delay 1st Session :72% 2nd Session :79% 3rd Session :80% 4th Session :85% Data Transmission Efficiency 1st Session :70% 2nd Session :80%	The control overhead and energy consumption is also minimized by introducing the 1 byte short address to identify the member nodes.
Abul Kalam Azad , Mohammad Shah Alam and Shamim Ara Shawkat	LL-MCLMAC:A Low Latency Multi Channel MAC Protocol for Wireless Sensor Networks	A low latency multichannel LMAC protocol, LL-MCLMAC protocol Focus on two algorithm 1. Initial Slot Selection Distance to gateway calculation after a node 2. Receives a control packet	Discrete event simulator OMNet++ with modeling framework Mi-XiM. For 50 Nodes No. of Received Packets : 210 ,220 ,250 ,240 End to End Delay : 13 ,16.5 , 13.5 , 18 sec Energy Consumption : 0.011 , 0.0099, 0.008, 0.001 respectively	A low latency multichannel LMAC protocol, LL-MCLMAC protocol, is presented that exploits the benefits of multiple slots of a channel from multiple channels for wireless sensor networks applications to improve end-to-end delivery latency as well as throughput.

		from any other node.		
Dr.Trilok Chand , Arvind Kakria	Comparative analysis of a contention based (RI-MAC) and TDMA based (ATMA) MAC protocols for Wireless Sensor Networks	Receiver-initiated MAC Advertisement-based Time Division Multiple Access	For 48 Nodes RI-MAC Avg. End to End Delay : 0.7750 sec Packet Delivery Ratio: 97.8 % Average Throughput : 4.79 kbps Average Energy Consumption : 4.83 J ATMA Avg. End to End Delay : 0.6944 sec Packet Delivery Ratio: 98.51 % Average Throughput : 4.77 kbps Average Energy Consumption : 1.36 J	A receiver-initiated asynchronous duty cycle MAC protocol and ATMA, a new TDMA-based MAC protocol for Wireless Sensor Networks using NS2 as the simulation tool.
Imane DBIBIH, Imad IALA, Driss ABOUTAJDINE	ASS-MAC: Adaptive Sleeping Sensor MAC Protocol Designed for Wireless Sensor Networks	ASS-MAC : Adaptive Sleeping Sensor Used NOAH protocol	For 5 Hops Mean Latency: 275 sec. Energy : 11 mJ/Byte Mean Energy : 8 mJ/Byte	The main goal of our contribution, ASS-MAC, is to allow the protocol to be adapted dynamically with different type of applications and especially if there is a high traffic environment.
Dattatray S. Waghole , Vivek S. Deshpande, A.B. Bagvan	Performance Analysis of FMAC Protocol for Reporting Rate in Wireless Sensor Networks	Hybrid FMAC (Federated MAC) is compared with existing protocols like CSMA, TDMA and 802.15.4 MAC Protocols.	Average PDR for FMAC is 54 to 61% better as compare to TDMA, 50 to 90% better as compare to 802.15.4 and 5 to 20% better as compare to CSMA protocol. End-to-End Delay for FMAC varying reporting rate require 48 to 54% less as compare to TDMA , 5	The Paper shows the behavior and performance of FMAC Protocol for different reporting rates.

			to 10% less as compare to CSMA and 802.15.4 respectively.	
Md. Mahedee Hasan, Amit Karmaker , ShafikaShowkat	COASYM-MAC: A Cooperative Asymmetric MAC Protocol for Wireless Sensor Network	Asymmetric MAC Protocol Link Symmetric Relay Selection	OMNeT++ simulator Avg. Energy Consumption : 0.27 J Packet Ratio : 90 % Avg. Delay : 0.24 sec.	A significant number of MAC protocols have been proposed that offer cooperative communication in wireless sensor network.
Md Mustafa Kamal, ShafikaShowkat Moni,	MX-MAC: A Multichannel Based Low Latency Asynchronous MAC Protocol For Wireless Sensor Networks	Multichannel Asynchronous X-MAC Markov Model of Mx-MAC	For 20 Packets Latency : 0.2 ms For 30 nodes Total Energy Loss : 0.2 J	The key intention of our algorithm is to extend the life span of the WSN by reducing latency and energy loss.
Tatsuhiro Kawaguchi, Ryo Tanabe, RyoheiTakitoug,	Implementation of Condition-Aware Receiver-Initiated MAC Protocol to Realize Energy-Harvesting Wireless Sensor Networks	ENRI-MAC protocol Energy-Neutral Receiver-Initiated Mac(ENRI-MAC) enables every sensor to autonomously decide its own intermittent interval based on both the available energy from the energy harvester and the number of communicable sensor	Packet possession probability : For Node 1 : 0.89 For Node 2 : 0.11	It is noteworthy that our system can be used with any kind of EH supplies such as radio-frequency signals and is remarkably low-cost since we only use general devices on the market
Ananda Kumar K S Balakrishna R	Comparative Analysis of Delay and Throughput using IEEE 802.11 and Receiver Centric-MAC Protocol in Wireless Sensor Networks	Novel approach RC-MAC protocol	Throughput : 133.63 PDR : 0.499 End to End Delay : 2031.70 Enhancement of Throughput :2.4 % End to End Delay : 94.08 %	These parametric measures are evaluated using IEEE 802.11 and RC-MAC protocols for calculating the performance, using NS 2.35 simulator with constant number of sensor nodes in wireless sensor networks.
Hyungkeun Lee and Hyukjoon Lee	Modeling and Anaysis of an Energy-efficient MAC Protocol for Wireless Sensor Networks	A new energy-efficient MAC protocol, RIX-MAC, based on asynchronous duty cycling and receiver-initiated scheme	For 18 Nodes Throughput : 500 bytes/node Avg. Delay : 1 sec Energy Consumption : 320000 mJ	We also calculated energy consumption using separating cycle period as TX/RX duration. Our analysis model is validated by comparing it with the results of NS-2 simulation
Hyungkeun Lee , Inhye Park	Performance of a Receiver-initiated MAC Protocol with Aggregation for Event-	A proposed MAC protocol based on RIX-MAC with exploiting data	Avg. Throughput : 160 Delay : 2.8 %	Energy saving has been a research issue for wireless sensor networks since the

	driven Wireless Sensor Networks	aggregation. Data aggregation is performed when at least two data frames exist in the queue and aggregation is allowed at once in a cycle to prevent the starvation of other senders when multiple senders		lifetime of networks is critical. RIX-MAC is designed to minimize energy consumption, without sacrificing latency, by using short preambles and enabling senders to predict a receiver's wakeups.
RendyMunadi , AndiniEksiSulistyorini, FebliaUlfah Fauzi S ,	Simulation and Analysis of Energy Consumption for S-MAC and T-MAC Protocols on Wireless Sensor Network	S-MAC protocol and T-MAC protocol.	Energy of T-MAC protocol is 25% more efficient than the one in SMAC protocol. Energy consumption of T-MAC protocol based on various duty cycle values is 10% more efficient than the one of S-MAC protocol.	The result of this research can be used as a guidance to get a protocol which is efficient and effective in using the energy consumption for wireless sensor network.
S.Lavanya , Dr. S. Prakasam,	MAC Protocols For Reduced Power consumption In Intra Cluster Design For Wireless Sensor Networks	MAC protocols, Techniques for Reduced Power Consumption 1. Periodic sleep/listen patterns 2. Adaptive listening 3. Collision avoidance 4. Overhearing avoidance 5. Message Passing	Mathematical Calculation given for Energy consumed by a cluster member energy spent by cluster head	The Intra-Cluster communication is discussed in detail stating the algorithm and the total energy involved in power consumption. It states how adaptive duty cycle protocol helps in reducing the power consumed
A. Rajasekaran and V. Nagarajan	Adaptive Intelligent Hybrid MAC Protocol for Wireless Sensor Network	Time Adaptive Hybrid MAC A. CSMA Mode B. TDMA Mode C. Hybrid Mode D. Data Transmission	Throughput : 50% Packet Delivery Ratio : 55%	The sink node will receives the BEACON message from each node. Sink node will identify the zone
Abdul Razaque , Khaled Elleithy	Scalable and Energy Efficient Medium Access Control Protocol for Wireless Sensor Networks	SE-MAC SE-MAC reduces the communication delays, channel delays and control delays. Handoff Process for QoS and Scalability	SE-MAC Energy : 0.8 J MAC protocols Energy : 0.64- 0.70 J when increasing the No. of aggregations. SE-MAC has saved 9.8-15% more energy resources than other MAC protocols.	The small-sized packets save more time that could be good choice for improving the QoS in case we require to send small amount of data over the WSNs.

III. ISSUES IN CLUSTERING TECHNIQUE

We have basically three issues in WSN clustering.

1. **Distance:** Distance between nodes plays a crucial role. As distance between the nodes increases the number of nodes in a cluster decreases and it may lead to higher consumption of energy.
2. **Energy:** Energy efficiency has been known as the most important issue in research of wireless sensor networks. The energy consumption within a cluster can be reduced by decreasing the number of transmitting messages. Lesser the energy consumption leads to the longer lifetime of network.
3. **Density:** The increase in sensors density may overload the network. Such overload might cause latency in communication and inadequate tracking of events.

IV. CLUSTERING PARAMETER

In WSNs clustering algorithms, it is worth reporting on some important parameters with regard to the whole clustering procedure in WSN.

1. Number of clusters (cluster count): In most recent probabilistic and randomized clustering algorithms the CH election and formation process lead naturally to variable number of clusters. In some published approaches, however, the set of CHs are predetermined and thus the number of clusters is preset. The number of clusters is usually a critical parameter with regard to the efficiency of the total routing protocol.

2. Intracluster communication: In some initial clustering approaches the communication between a sensor and its designated CH is assumed to be direct (one-hop communication).However, multi-hop intracluster communication is often (nowadays) required, i.e., when the communication range of the sensor nodes is limited or the number of sensor nodes is very large and the number of CHs is bounded.

3. Nodes and CH mobility: If we assume stationary sensor nodes and stationary CHs we are normally led to stable clusters with facilitated intracluster and intercluster network management.

4. Nodes types and roles: In some proposed network models (i.e., heterogeneous environments) the CHs are assumed to be equipped with significantly more computation and communication resources than others. In most usual network models (i.e., homogeneous environments) all nodes have the same capabilities and just a subset of the deployed sensors is designated as CHs.

5. Cluster formation methodology:

In most recent approaches, when CHs are just regular sensors nodes and time efficiency is a primary design criterion, clustering is being performed in a distributed manner without coordination.

6.Cluster-head selection: The leader nodes of the clusters (CHs) in some proposed algorithms (mainly for heterogeneous environments) can be pre assigned.

7. Algorithm complexity: In most recent algorithms the fast termination of the executed protocol is one of the primary design goals. Thus, the time complexity or convergence rate of most cluster formation procedures proposed nowadays is constant (or just dependent on the number of CHs or the number of hops).

8. Multiple levels: In several published approaches the concept of a multi-level cluster hierarchy is introduced to achieve even better energy distribution and total energy consumption (instead of using only one cluster level).

V. Conclusion

The hierarchical cluster structures facilitate the efficient data gathering and aggregation independent to the growth of the WSN, and generally reduce the total amount of communications as well as the energy spent. We have found that the some energy efficient algorithms increase the network lifetime. Although every effort has been made to provide complete and accurate state of the art survey on energy efficient clustering algorithms.

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