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Query Optimization Techniques in Wireless Sensor Network: A Review

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***Abstract*— A Wireless Sensor populated in sensor nodes deployed Network (WSN) could be considered as a scattered data repository which gets in remote locations powered by limited batteries. To retrieve data from these nodes query processing techniques are used. As the applications of WSN are found in remote locations and extreme weather conditions the replacement or recharge of battery is impossible. Henceforth, it is highly required to conserve the battery power in order to increase the network lifetime. Among the sensing, storing, transmitting and receiving activities of sensor nodes, data communication is the most dominant energy consuming activity. Hence query optimization techniques are in huge demand in WSN. This paper presents the prominent query optimization algorithms that are used in WSN to address the issue of energy efficiency. The purpose of this review is to give an overview of the existing literature and research issues in query optimization techniques in WSN.**

Keywords*— *Wireless Sensor Networks, Query Optimization, Genetic Algorithm, Energy efficiency, distributed computing.

I. INTRODUCTION

A Wireless Sensor Network (WSN) [1] may be considered as a distributed database as the sensor nodes continuously capture the data and multiple sensor nodes collaborate to form a network. A sensor network consists of tiny sensor nodes operated on limited battery power and deployed in remote locations like volcanic disruption, earthquake detection system, forest fire detection system etc. The sensor nodes sense environmental parameters like temperature, pressure, humidity, light etc., and transmit to the nearby sensor nodes within their communication range. As these networks are operated in extreme weather conditions and hard-to-reach locations, it is extremely difficult and impossible to replace batteries. Hence, we need to conserve the battery power by optimal utilisation. The sensors perform sensing, receiving and transmission of data to their neighbors. A sensor node expends 80% of power in data transmission hence we need to minimize the data transmission activities to extend the time span of the network. In the process of data extraction the user can submit a query in TinySQL and the network of nodes send the resultant data as shown in Figure1. The TinySQL is the query language used in WSN. The Select statement in TinySQL offers projection, aggregation, Having, Group by clause. The user submits his data requirement in the form of TinySQL queries to the WSN. In WSN, the sink node requires responses from various sensor hubs. The reactions from various sensor hubs are gathered at the sink hub. The primary errand in query handling is to figure a query and query plan at the sink hub. Query processing happens in four stages [5], for example, query decomposition, data localization, global optimization and distributed execution.

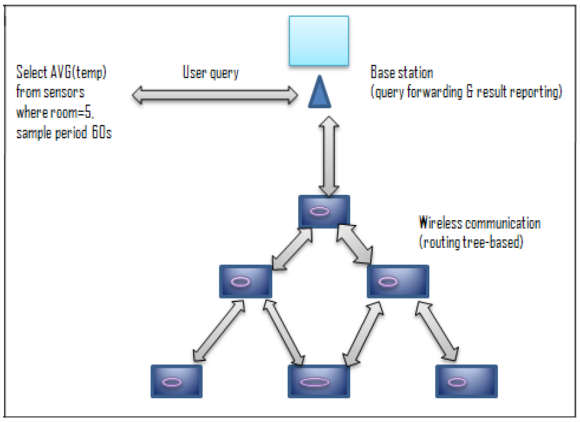

Fig. 1 Query Processing in WSN

II. PROCEDURE FOR QUERY PROCESSING IN WSN

Initially clients present their queries to the base-station At that point the query optimizer of the base-station investigates the query and produces an enhanced query plan. Query streamlining agent chooses the best and productive arrangement for the execution. Code generator produces the

code for the chosen arrangement and interpreter creates executable code for the query. Query at that point spreads to the sensor hubs in the system by means of directing technique. In the wake of getting the query, sensor hubs sense the environment, collect the information and procedure the information as indicated by the query. The pre-prepared information will be submitted back to the sink node. Considering the requirements of WSN, query optimization activity selects the efficient query plan and data processing according to query are the main challenges. Therefore, energy efficient query processing in WSN plays an important role.
As sensor nodes are powered by a battery, they have confined energy; hence it becomes a big challenge in designing routing protocol. The recharge or replacement of the battery is difficult since most of the sensors are remotely placed. Hence we need to conserve the battery power in a WSN through various techniques. One of the network activities is routing that we can devise to diminish energy utilization of sensor hubs and increment the network lifetime. Routing protocols support network lifetime and maintain connectivity between nodes while guaranteeing good performance. A large portion of the analysts concentrated on diminishing the energy utilization of sensor hubs without debasing the nature of WSN framework.

Energy utilization is aggregation of the total energy utilized by each and every sensor hub present in the network when moving and preparing the submitted packet or query. Since sensor nodes are battery powered, they have limitations in energy; hence it becomes a challenge in designing routing protocol. Battery replacement is difficult since most of the sensors are remotely placed. The estimation of energy utilization utilized by sensor hubs is a significant presentation metric in assessing a WSN directing strategy. A proficient routing calculation that can lessen vitality utilization of sensor hubs will build the system lifetime. Routing protocols support network lifetime and maintain connectivity between nodes while guaranteeing good performance. The vast majority of the specialists concentrated on decreasing the energy utilization of sensor hubs without corrupting the nature of WSN framework.

Data storage in WSN [2] can be categorized as centralized (unified) data storage and distributed (appropriated) data storage. In unified methodology [3] a predetermined set of information is normally conveyed from the sensing nodes to a focal database. Clients can query the database by means of some interface given by the framework. The subsequent methodology is appropriated in nature where information is kept on the sensors where the detected information dwells in the sensor hub and the collected information is sent to the sink hub. In the appropriate approach, the information that should be extricated from sensing nodes is controlled by the query remaining burden. The disseminated approach is, hence, not just adaptable to such an extent that queries separate various information from sensor arrangement, and furthermore guarantees productive extraction of just significant information from the sensor organization.

III. Various Query Processing Techniques

A tremendous contrast is seen amongst query processing in conventional databases with WSNs. In conventional databases, the efficient query plan picked by the query optimization agent is the one that requires the least number of disk accesses [4]. Query processing among conventional databases is for the most part inadmissible for WSN. Be that as it may, in WSNs the analyzer picks the query plan which gauges negligible energy cost. Notwithstanding this the thing that matters is because of the natural properties of the sensors establishing the remote system. The hub including a WSN is increasingly inclined to disappointments, has limited memory size, and utilizes tremendous measures of energy for information transmissions, information streaming and so on. As opposed to the customary query processing approach in DBMS, the information is a consistent information stream obtained by a sensor in a WSN. So as to guarantee proficient query processing in WSNs, different asset administrations like-memory, energy, data transmission and so forth ought to be thought of. Query processing methods in sensor systems can be sorted into In-network handling or Base station query handling. These are otherwise called circulated handling or warehousing. Appropriated handling or In-network processing decrease data transferrable costs. Warehousing approach includes information transferring (for processing), to the particular spot midway found outfitted with plentiful energy.

A. Data Aggregation with respect to results obtained from query processing:

Data aggregation targets expanding the time span of the network by lessening information transfers that are repetitive. This particular procedure totals the comparative information detected by different sensor hubs going through a specific hub before arriving at the base station. Information aggregation methods might be characterized into i) chain-structure ii) tree-structure and iii) lattice structure collection [4]. The data might be totaled with the assistance of different accumulation plans like Low Energy Adaptive Clustering Hierarchy (LEACH), Tiny Aggregation (TAG) and so on. The collection might be carried out either by i) Decrementing the information size or ii) transmission without decreasing the information size. The first strategy includes joining and packing the information detected at a specific hub which gets the information from other neighboring hubs previously permitting them to advance toward the base station. In the subsequent technique, the information that is gotten from different hubs is converged at a specific hub which lessens correspondence overheads. Further processing does not happen on the particular consolidated information which is next sent to the sink node.

B. *Query Dissemination for processing different queries:*

The client transmits a query to the sink node through a graphical interface. At a point where the sink node gets that query, [5] it contrasts it and the query history. In the event that it is as of now utilized, the base station utilizes the past estimations from its reserve. In the event of ongoing estimation required, the query is set in the dynamic rundown. In a circumstance where the transfer hub gets a query, the Deadline Controller contrasts the query cutoff time and the current time. On the off chance that it seems, by all accounts, to be not exactly the query cutoff time, the exchange will be transmitted to the scheduler. Otherwise, the exchange is prematurely ended. When a hand-off hub gets a query reaction from its child hubs, the query would be expelled from the scheduler. Or else, the transfer hub transmits the query one more time to its child hubs until the affirmation of a reaction is gotten. At the point when the child hub gets the query, it confirms its cutoff time. On the off chance that the exchange has missed its cutoff time, it will prematurely end naturally. Every hub deals with the received queries by being independent with other sensor hubs.

C. *Spatial query processing :*

In-network query processing [6] components utilize the area information to answer an uncommon sort of query called spatial query. In such queries the clients requests are communicated through topographical predicates, for example, "the humidity gathered by hubs in a district" or "the dampness gathered by hubs nearest to a point". Spatial queries are database inquiries upheld by geo-databases. Spatial queries contrast from customary questions in dual primary concerns. To start with, they join geometry information types, for example, focuses and polygons. Secondly, these questions think about the spatial connection among the characterized geometries, for example, a point inside a polygon or a polygon that covers another.Spatial queries processing are analyzed in six stages: Pre-Processing, Forwarding, Dissemination, Aggregation, Sensing and Return.

A skyline query [7] is an intense apparatus for multi criteria information investigation, information mining, and basic leadership. Given an arrangement of information tuples with different properties, a skyline query recovers an arrangement of information tuples, called skyline tuples, to frame a skyline. These skyline tuples are not ruled by some other tuples. Here a tuple x is said to command the other tuple y if x isn't more awful than y on all traits and x is entirely superior to y on somewhere around a single property. Due to the complex and costly features of mobile devices like superior processors, memory, sensors and capacity there is a huge requirement for skyline query processing.

D. *Spatio Temporal Processing:*

One of the traditional data processing techniques [8] that is Spatio-Temporal processing (STP) is a control strategy to expand the nature of the received signals in remote systems. There are a few methods for energy proficient handling of Historical Spatio-Temporal queries, HST. The response to a HST question is framed through the estimations of all sensing nodes situated in the territory taken when the time is being extended. A clear method to answer a HSTquery, called FullFlood, is reaching each system hub. The query originator hub, which could be a random hub in the system, communicates the query to its neighbor hubs, which thus communicate the query to their neighbor hubs, etc, until all hubs have acquired the query. An outcome of broadcasting is that every sensing hub could get a similar query a few times. For single query, a hub forms just the primary query message acquired, disposing of ensuing messages. The query answers are sent back uniquely to the neighbor sensor hub from where the query was first gotten from. To the various neighbor sensor hubs, vacant answers are sent. At the point when the query is acquired, the hub broadcasts the query, chooses the privately put away information pertinent to the query (assuming any), hangs tight for its neighbor sensor hub's answers and unions them with its own, lastly it restores the response to the neighbor sensor hub that it acquired the query from. When the query originator hub gets results from every one of its neighbor hubs, it can give the query result to the client.

E. *Query Request Processing With Cooperative Caching:*

The examination in [9] says, when a lot of query solicitations of simultaneous errands have been changed over into a binary string, which speaks to the arrangement of traits in all lattice cells at a specific time allotment, tactile information are brought from the reserve at sensor hub, or recovered from the system in an ongoing manner, for noting these question demands.

Some applications of WSN require data on a continuous basis. Such time critical military applications as shown in Figure 2 require every sensor node to continuously sense and send data to the base station. Such systems are termed as push-based query processing models. Certaine applications of WSN require only a snapshot of the network data, such queries are intended only to a part of the network or few nodes in the network or maybe complete network data at the moment or based on previous data, such systems are called pull-based systems. In a pull- based system the base station sends a query to the network on need basis. Here the query could be based on already sensed data (historical data) or the current data. Database query engines utilise pull-based or push-based methodologies [10] to stay away from the appearance of information to query administrators. Through queries, data is either pushed from sensor nodes to a gateway, or pulled from the gateway. Hybrid push-pull data dissemination performs better than the pure approaches and offers significant energy savings.

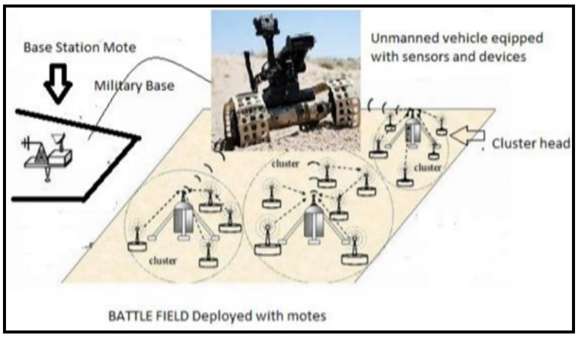

Fig. 2 WSN in Military Applications

F. a)Push based query:

Engine which is also known as the visitor pattern [10] is widely used in streaming systems. Inpush-based query engines, the control stream is switched contrasted with that of pull-based engines. All the more solidly, rather than goal administrators mentioning information from their source administrators, information is pushed from the source administrators to the goal administrators.

b) Pull based query:

Engine which is also known as the iterator pattern [10] is most broadly utilized in pipelining strategies in query engines. The structure of pull-based engines legitimately relates to the iterator configuration structure in object arranged programming. Each query administrator plays out the job of a goal administrator and solicitations information from its source administrator. In a pull engine, this is accomplished by summoning the following capacity of the source administrator and appears as control stream diagrams.

IV. VARIOUS PLANS FOR QUERY PLAN GENERATION

Query optimization diminishes the quantity of queries brought into the sensor network, and accordingly brings down the general traffic and asset use over the network. Query optimization strategies can be applied at various levels (e.g. equipment, programming, information connect directing, working framework etc). They can be classified as static or dynamic. Static optimizations are planned at the arrangement time and stay unaltered. Dynamic optimization gives improvement during runtime concurring the application prerequisite.

A. Base Station optimization:

The primary level optimization is at the base station. It goes about as a channel to diminish copy information accesses from the network and conceals query elements.

B. In-Network optimization:

Base station advancement can't bolster sharing of the normal highlights among queries at the best granularity. Communicate nature of the sensor hubs are not contemplated for the base station enhancement. Sensor hubs can settle on nearby choices and handle the remaining burden with time.

C. Query based methodology :

Query based methodology [4] is one among the broadly acknowledged methodologies for information retrieval as shown in Figure 3. This depends on forming a query to the database for data recovery. The explanation behind its fame is its ease to work with interfaces. The queries given for the data extraction are limited with boundaries while showing the sensed information and performing different total calculations like least, greatest and so on this information. The key attributes of the information sensed in the system are both memory and time. The query dialects face trouble in representing them.

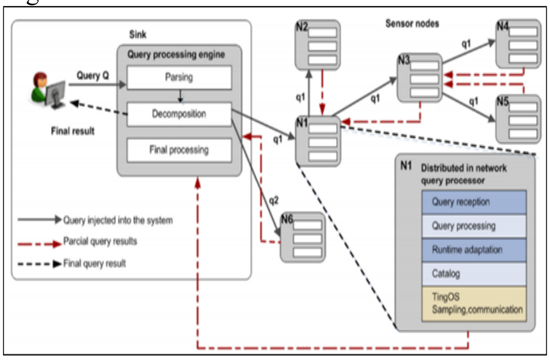

Fig. 3 Query based methodology for Information Retrieval

D. Distributed query plan generation problem (DQPG) :

It is an unpredictable and difficult issue, Honey bee Mating Optimization (HBMO)based DQPG [12] algorithm is introduced which creates a query processing plan, for a given conveyed query, which limits the query proximity cost QPC. This algorithm produces disseminated query plans dependent on the nearby feature of a query plan. Contributions to the algorithm are the connection location network, lot of automaton query plans, most extreme introductory pace of the queen query plan, least passable pace of the queen query plan needed to keep mating flights, the pace decrease plot, measure of the queens query plan (number of query intends to be considered for development), count of mating flights (iterations) to be attempted and the quantity of working drones (arrangement improvement heuristics). In this methodology an underlying populace of honey bees, speaking to the underlying arrangement of drone query plans is arbitrarily created. This underlying populace, that goes about as the input, is tried to be advanced by the HBMO based DQPG algorithm to acquire a predominant quality populace of query plans.

Query Optimization in Distributed databases is a complex issue with confused target works along these lines ground-breaking search algorithms is required for it.

E. Ant Colony Optimization :

Ant Colony Optimization (ACO) [13] is a meta-heuristic, multi specialist procedure that recreates the scavenging conduct of ants for unraveling troublesome NP-hard combinatorial optimization issues. Ants are social bugs whose conduct is coordinated more inclined to the endurance of settlement all in all than that of a solitary individual of the state. A significant and intriguing conduct of an ant colony is its circuitous co-usable foraging process. Ant Colony Optimization depends on the conduct of some ant species. They store pheromone trails on the floor so as to make an ideal way that will be trailed by different ants from the colony.

A hybrid algorithm of Genetic Algorithm and Ant Colony Optimization (GA-ACO) is given in [13] to tackle the issues of optimization of join requesting (just nested circle joins considered) in social repository queries by defeating the weaknesses of the two combined algorithms. Various nature roused algorithms have been proposed to take care of optimization issues.Out of which few are briefed below:

According to the approach in [14] query plans have been generated in view of the commonality of the information needed for answering the query. The Genetic algorithm considers the relations in the FROM clause, the hubs having this information, the likelihood of hybrid (crossover), likelihood of change (mutation) and the pre-indicated number of generations as input, and produces the top-K inquiry plans as yield. Queries need effective processing, which commands formulating of ideal query processing techniques which create productive query processing plans for an appropriate query sent. A proficient query handling plan is required from among all the conceivable query plans. For a noticed crossover and mutation rate, GA approach unites rapidly towards the ideal query processing plans. According to the research of [15] it briefly illustrates a table containing various variables and viewpoints to assess the worth every optimization strategy gives from adaptability to dependability.

According to [16] we present a novel query optimization methodology known as clock stroke event handler for the database reflection of WSNs which comprises different clients. The assessment results show the proposed conspire which essentially diminishes the energy utilization in both single and numerous base station situations.

According to [17] the attainment of least expenses become complex in nature which can be illuminated in polynomial opportunity to accomplish global ideal expense of information transmission by Clonalg algorithm.

In 1975, John Holland had proposed the possibility of Genetic algorithm (GA) [18]. GA is a searching heuristic that emulates the procedure of normal advancement. This heuristic is much of the time used to create helpful answers for optimizing and exploration issue. Genetic algorithms use mutation, selection and crossover operators to give rise to better results.

From the study of Particle Swarm Optimization (PSO) [18] PSOis a vigorous optimization procedure roused from the development and insight of swarms. This methodology includes a lot of possible arrangements (called as particles), being scattered at different focuses in the arrangement space. Every point shows target work esteem, subsequently it has fitness, for its present area. Particles move (fly) in a way that every particle's development is impacted because of the accompanying two factors:

a) The best fitness accomplished by the particle up until this point.

b) The efficient fitness accomplished by a random particle in its area.

In this scenario, we can consider queries as the particles which will travel to different nodes till it reaches the destination node to obtain the user required result.

One of the solutions to address the problem of generation and choice of query plan is nature inspired algorithms. These algorithms have been rendered to tackle various genuine multifaceted issues. Such issues are helped by Bio-inspired algorithms. Artificial Immune System (AIS) [17], is enlivened from the common human immune system. Clonal selection procedure, one of AIS approaches, has been talked about in the examination to create ideal dispersed query plans in appropriated wireless sensor networks.

According to the research done in [21] to identify a direct way from the query originator hub to a hub that is situated at the focal point of query's spatial window, GreedyDF algorithm utilizes a greedy technique. The query originator advances the query to its neighbor found nearest hub, which thus advances the query to its neighbor nearest hub, etc. The GreedyDF algorithm utilizes few messages; however it doesn't ensure that a routing way to a hub in the query's spatial window will be initiated. Greedy based routing strategies for location based directing in adhoc networks have appeared to almost ensure conveyance for dense network graphs, yet doesn't function appropriately every now and again for scanty network graphs.

According to the study of [22] query optimization issues are addressed by stressing the implication aware cooperation in the sensor networks. Rather than diving straight to the solid activities, (for example, information sensing, filtering, total, and storing) and connecting examples of sensor information, concentration is around the effect of suggestion and the technique to use it, so the aggregate energy expenditure of query processing is limited. This methodology is named as EE-QPS (Energy-Efficient Query Processing among heterogeneous sensor systems).

In a query based remote sensor network, most of the queries perhaps are sent to a particular hub and a hotspot issue arises and rapidly expends the energy of the particular hub. The traffic flow near the neighboring area of that node is also influenced by the hotspot. To solve the hotspot problem, [23] illustrates two specialists setting algorithms, distance-based agent selection (DAS) and greedy-based agent selection (GAS) to moderate the traffic stream close to hotspot.

The study in [24] proposes Minimum Hot-Spot (MHS), a distributed algorithm that makes a reasonable query directing tree associating all hubs in the system. First the methodology of this issue being separated per tree profundity is talked about and afterward deciding the base conceivable correspondence cost expected to develop a tree.

The study in [25] reviews and explains the procedures of a familiar algorithm, Naive-k for top-k query assessment which registers the appropriate response in bottom up approach in one pass over the network.

Real Time Query Scheduling (RTQS) in [26] is intended to accomplish high information efficiency and separated query latencies through organized simultaneous clash free transmission planning. The received methodology depends on utilizing two parts: an organizer and a scheduler. Two regular RTQS algorithms: Non-preemptive Query Scheduling (NQS) and Preemptive Query Scheduling (PQS) are discussed further in [26].

According to the study of [27] one methodology in WSN preparing, interprets the WSN as a disseminated database, and the handling job infused into hubs for execution is the assessment of a query evaluation plan (QEP). In this methodology, clients indicate required information necessities as decisive queries, which the framework, called a sensor network query processor (SNQP), orders into optimized QEPs for infusion into the WSN. Through occasional assessment, a flood of outcomes is sent back to the clients by means of the base station.

Sensor Network query processing (SNQP) [28] is one of the method that utilizes query and WSN over that it is to be run, to think of a energy proficient Query Evaluation Plan (QEP) that distributes processing inside the assortment of QEP sections to the hubs inside the WSN.

V. Open Research Issues

Several challenges need to be addressed and further examination is required in WSNs. A portion of the open exploration issues for WSNs that can be fathomed utilizing Machine learning and Artificial intelligence (AI) are listed out as follows:

1) To distinguish the flawed sensor hubs from the network.
2) To identify irregularity in the network.
3) To find ideal cluster heads in the system.
4) Efficient various objectives tracking for versatile WSNs.
5) To distinguish an occasion from the perplexing sensor information.
6) To conjecture the measure of vitality (energy) to be reaped inside a particular time period in the network.
7) To predict the network lifetime in WSN.

VI. Conclusion

Taking into account the above study, it is presumed that however there are a lot of data extraction methods, in WSN, every single method has its merits and demerits. Query based methodology is the highest mainstream in light of its usability and its capacity to render a large portion of the data requirements in WSN. To battle the natural imperatives of restricted energy and transfer speed, query processing and transmission optimization are the fundamental zones of study. Query optimization techniques and different procedures have been examined in this paper. These procedures can be utilized by the client as indicated by necessity of use and resources accessible.

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