An efficient Spatio-temporal Index for Spatio-temporal query in Wireless Sensor Networks

Don Hee Lee and Kyoung Ro Yoon*
Department of Computer Science and Engineering
Konkuk University
Seoul, Korea
donhlee@dreamwiz.com, yoonk@konkuk.ac.kr

Abstract - Recently, in wireless sensor network related technology that senses various data, spatio-temporal queries for searching necessary data from wireless sensor nodes have been recognized. From sensor node, queries are transmitted and in the process of transmitting the sensed data into the application server, the research about the index processing method for increasing accuracy while reducing the node energy and minimizing query delays have been actively going on. In the existing research, they emphasize the accuracy and sensor node's routing overlooking the energy cost. In this thesis, I propose IR-tree(Itinerary-based R-tree) in order to solve the existing problem of spatial query processing method and for more efficient processing and for the spatio-temporal query that expanded into the domain of time.

Keywords - Itinerary, Spatio-temporal Query, MBR, R-tree

I. INTRODUCTION

As the spatial query, necessary for obtaining necessary data from the wireless sensor network that senses various data, it is recognized as an important area of research. The research for spatio-temporal indexing process method for minimizing node's energy cost and minimizing processing delay by increasing accuracy in the process of transmitting sensing data to server and disseminating query to node have been actively going on.

The advantage of centralized method, a method where all the sensor node's location and sensing information are collected and spatial query is processed in server, is the fact that it is simple. However, because it approaches to all sensor nodes, through wireless transmitting cost, the energy efficiency is very low. Therefore, GR-tree has been researched in order to complement this. The dispersal spatial filtering is performed within network so that it reduces the wireless transmitting cost. GR-tree is formed of a grid based tree so that the spatial query process is possible by spatial indexing that gets saved to wireless sensor node. However, problems are presented as the parent nodes get closer to the BS(Base Station) and the energy consumption is very high. Additionally, when nodes are renewed, the communication cost is much. Meanwhile, the CDQO(Centralization and Distribution Query Optimization) algorithm that processes query aggregation for processing multiple queries simultaneously has been researched but there is a disadvantage because it performs simple spatial centered aggregation that cannot process spatio-temporal aggregation. In order to solve these problems, this thesis is proposing IR-tree.

II. RELATED WORK

Wireless sensor nodes have a small capacity and when data are transferred, the energy consumption is high. Since it is impossible to relocate and recharge many nodes, the lifespan of node can be considered as same with that of battery. The way to obtain sensing data is to collect location. Sensing data through server and processing centralized methods in server is simple. However, there is a disadvantage of low energy efficiency since it approaches to all sensor nodes. Therefore, GR-tree was proposed for complementing this and performing dispersal spatial filtering within network for reducing communication cost.

GR-tree has a problem of high energy consumption as parent nodes get closer to BS. Also, in the case of adding or deleting nodes, the cost for renewing tree is high. On the other hand, CDQO algorithm that processes multi-queries at the same time is based on Quad-tree structure. Before sending off query from BS, query aggregation and routing optimization are performed in the network.
However, the inherent disadvantage of tree structure is the fact that when there is a renewal of nodes, index reconstruction consumption is high. The disadvantage of high energy consumption of parent nodes still exists. When queries are aggregated, it only processes spatial aggregation so that the past, present, and future spatio-temporal aggregation cannot be processed.

Therefore, existing tree structure’s parent nodes have high consumption of energy and get affected by the wireless sensor network’s status change. In order to solve the problems of existing infra-structure method (GR-tree), we are proposing IR-tree. IR-tree’s advantages are the fact that R tree is stable and has the dynamic itinerary. IR-tree forms R tree from root node. Below a certain level, it utilizes itinerary method, a dynamic routing method. Itinerary does not form routing for all queries but it only forms and processes routings for the user queries given temporarily. Also, in IR-tree, when there is query aggregation, it expands from spatial to spatio-temporal and increases the effect of aggregation. The key component to consider during the IR-tree construction is the minimization of the energy cost of the sensor nodes. Also, reducing the loss occurrence rate from data transferring errors needs to be the element for consideration. Lastly, by considering the distribution for sensor nodes and query range area, we are trying construct in order to reduce time for spatio-temporal arithmetic process.

III. IR-TREE DESIGN

When there are queries, the way to approach from itinerary to R tree is to form many local R trees and perform Itinerary routing by targeting root nodes. Since R tree needs to be renewed every time queries are made in itinerary routing, the maintenance cost for R-tree is high and efficiency is low. The overall routing structure, R tree is the upper part of the entire routing structure and the inner part uses by dynamic routing.

1) Index formation

In order to process spatio-temporal query process, search for the closest sensor node from SR(Sensor network Range)'s center point and select it as root node for routing. Next, since the sensor network area is known ahead of time, the center point can be calculated. Each sensor node must select its parent node. In order to pick parent nodes, just like <Fig.1>, broadcast about all the nodes in the communication area about the BM(Build Message). The nodes that received BM broadcast BM again within their radius to all the nodes except the nodes that received BM.

After that, leaf nodes continuously work. When there are 2 parent nodes, select nodes that are close the root nodes. After deciding parent nodes, make MBR (Minimum Boundary Rectangle) among sensors and complete R tree based on the MBR.

2) Query distribution and collect process results

After forming the R tree, when spatio-temporal query arrives at the BS, BS initiate spatio-temporal aggregation about the queries. Spatio-temporal aggregation is an aggregation about space, attribute and time. Time can be at certain point or a certain period of time. After the result of aggregation, the range of query gets deducted. BS distributes QR and itinerary routing level to all the nodes. After, QR gets separated into many Cells and forms Quad-tree. The reason that we form Quad-tree is to reduce the query process time when there is itinerary routing distribution through query process. After that, routing is not formed ahead of time by the itinerary method within each Cell of Quad-tree so that query is processed by temporarily forming the routings in the interest area for the given user query.

3) Index renewal

In IR-tree, when sensor network area is changed, the entire IR-tree is renewed. However, when sensor node is added or removed, IR-tree renews only the certain part of the index level in the upper R tree. Since most of the

*Corresponding author: Kyoung Ro Yoon*
lower Itinerary area is a method to form routings, renewal is unnecessary.

IV. PERFORMANCE EVALUATION

The evaluation of IR-tree is compared with GR-tree, and CDQO algorithm. The evaluation is classified by number of sensor nodes, number of queries, accuracy of query processing size of queries in each field, energy cost, and time of processing queries. <Fig. 3> is the evaluation for performance per nodes. IR-tree had lower accuracy than GR-tree and CDQO but had kept 95%. Typically, the accuracy requires more than at least 90%. IR-tree showed better energy consumption and processing time than GR-tree and CDQO.

Through this, we have proved the excellence of IR-tree that this thesis had proposed.

In BS, the spatio-temporal query aggregation processing time and energy consumption were reduced, the reduced processing time by processing aggregated query by the node distribution of the query region. Also, in the most of the lower level, the renewal index cost has been reduced by processing dynamic routing. However, the accuracy of this research was less than that of the existing research. The accuracy was kept at 95% while the required accuracy is 90%. The future research needs to research about how to process IR-tree’s spatio-temporal arithmetic query about the moving wireless sensor node efficiently that this research could not consider.

CONCLUSION

In this thesis, we analyzed the performance accuracy of the query processing results, energy cost, and query processing time of GR-tree, CDQO algorithm and IR-tree.

REFERENCES