ENERGY EFFICIENT SERVICE-ORIENTED ROUTING OF QUERIES IN WIRELESS SENSOR NETWORKS

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Abstract -Wireless Sensor Network (WSN) is a network of few hundred to several thousands of autonomous nodes, which work cooperatively to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants. The main issue of WSN is energy constraint as the node drains faster and the battery is also not rechargeable and replaceable. Analysis on wireless sensor network shows that communication module is the main part which consumes major portion of the sensor nodes energy. Since routing protocols directly access the communication module the design of energy efficient routing protocols is a challenging task. In this paper we propose Energy efficient Service oriented Query Routing (ESQR) scheme to achieve data centric routing of queries with supporting quality of service in Wireless Sensor Networks. The routing scheme works by forming service clusters of the nodes based on three different parameters namely nodes distance to base station, residual energy and service provided by the nodes. The queries are routed through the cluster heads to reach the nodes that can provide the requested service. Simulation results show that ESQR performs better than the other algorithms in most of the cases. Therefore, ESQR is a stable and energy efficient clustering algorithm to be utilized in any real time WSN application. This approach saves energy, extends network lifetime, without duplicating a routing table on each node and improves the latency in routing queries.

***IndexTerms*—WSN,ESQR,SARP,Data-centric, Fuzzy logic, Bootstrapping.**

I. INTRODUCTION

Wireless sensor networks are an alliance of tiny computing nodes that integrate simple processing, storage, sensing, and communication capabilities and open doors to a plethora of applications such as disaster relief, environment control, biodiversity mapping, intelligent buildings, machine surveillance, precision agriculture, medicine and health care, and much more.

A major attribute of nodes in a wireless sensor network (WSN) is that of energy constraint in contrast to nodes in traditional communication networks. To tackle this constraint, the nodes in a wireless sensor network are usually deployed redundantly thereby allowing robustness. One implication of this redundant deployment of nodes in WSNs is that of data centricity. The fact that the user of the network (an originator of a query in our scenario)is more interested in the data requested and less in the identity of the nodes. Data-centric routing protocols were required to address this particular issue in WSNs. Data-centric routing algorithms route the data based on the naming of the data itself than that of the nodes.

In a query routing environment, which is the main focus of our paper, data centric routing of queries allows the user the freedom to simply specify what data they want without the need to specify from which node they want the data.

In this paper, we propose a data-centric query routing protocol called ESQR (Energy efficient Service oriented Routing of Queries) that not only routes queries from base stations to WSN nodes based on the content of the requested data but also tries to minimize the energy expended by the nodes by adjusting the transmission range using the term called competition radius. ESQR also distributes the routing state in a hierarchy of cluster heads instead of centralizing routing state on one or two base stations.

The remaining sections of this paper are organized as follows: in section 2 we review related previous work, in section 3 we present details of ESQR, in section 4 we present evaluation results of our approach and we conclude this paper in section 5.

II . RELATED WORK

A. Service Oriented Query Routing

Abdelmounaam Rezgui and Mohamed Eltoweissy[3,4] developed a service aware routing protocol (SARP) that routes a query based on its semantics from one or more base stations to any node that can provide a response to the query. The key idea in SARP is avoiding flooding the network with the query as this may result in "aimlessly routing". SARP routes queries as follows. First the nodes advertise their sensing and actuation services to their neighbors at bootstrapping time. Any node in the neighborhood learning of the provision of a new service that it doesn't provide further disseminates the advertisement to its neighbors. By the time this first phase of SARP is over, each node will have a service directory indicating which node provides what service or which node is on a path to a node that provides a specific service. When a query is received by a node from a base station the node checks the service requested in the query. If the service can be provided by that node, a response will be provided. Otherwise, the node will have to broadcast the query to its neighbors after checking its service directory to see if at least one of its neighbors can either provide the service or is on a path to a node that provides the service.

SARP has its drawbacks that need to be tackled and which we set out to solve in preparing this paper. Two of SARP's drawbacks arise from the fact that it is a flat based routing mechanism and not a hierarchical one. In such a scheme, the nodes close to the base station will die out quickly as these nodes will be repeatedly used and disproportionately exhausted [5].

Another drawback of SARP is that it duplicates routing state on each node. While distributing the routing state as much as possible has got advantages in terms of robustness, the fact that all nodes need to store the routing state means a higher use of node memory in the WSN overall. In addition, updates of routing state change will require higher maintenance traffic [6].

We propose ESQR which will solve the fore mentioned drawbacks of SARP by virtue of the fact that ESQR is a hierarchical routing protocol. In addition, we limit the distribution of routing state only to some of the nodes that are nominated as a cluster head from time to time.

There have been substantial amount of research on clustering protocols for WSNs. Most of the clustering protocols utilize two techniques which are selecting cluster-heads with more residual energy and rotating cluster-heads periodically to balance energy consumption of the sensor nodes over the network [7]. These clustering algorithms do not take the location of the base station into consideration. This lack of consideration causes the hot spots problem in multi-hop WSNs. The cluster-heads near the base station die earlier, because they will be in heavier relay traffic than the cluster heads which are relatively far from the base station. To avoid this problem base station distance also considered while forming clusters in ESQR. In order to make wise decisions, it utilizes the residual energy and the distance to the base station parameters of the sensor nodes.

III. ENERGY EFFICIENT SERVICE ORIENTED ROUTING OF QUERIES

Before describing our proposed algorithm in detail, we introduce the characteristics of the system model that we use in our implementations. First, we list the assumptions that we make about the network model.

1. Sensor nodes are deployed randomly 2.All sensor nodes and the base station are stationary after deployment phase 3.Nodes have the capability of adjusting the transmission power according to the distance of the receiver nodes 4.All sensor nodes have the same amount of energy when they are initially deployed 5.Base station need not be located far away from the sensing region 6.All sensor nodes are identical.

ESQR uses content based clusters to hierarchically organize the network. The clusters are formed not just based on energy efficiency but also on similarity of services provided by nodes belonging to the same cluster. This will help in providing an aggregate response to the query if necessary. ESQR has two components which we describe below.

A. Cluster Formation

Fig 1 shows ESQR's cluster formation algorithm that is executed at bootstrapping time and periodically in predetermined time intervals on each node.

ALGORITHM: Cluster Formation

Input: Sensor network with randomly deployed nodes

Output: Service clusters

```
nodeState ← CLUSTERMEMBER
clusterMembers ← empty
myClusterHead ← this
be TentativeHead ← TRUE
Calculate Rcomp using fuzzy if-then mapping
message(ID,Rcomp,resEnergy)
On receiving Message from node N
if this.resEnergy < N.resEnergy then
    be TentativeHead ← FALSE
```



```
    Advertise QuitElectionMessage(ID)
 end if
 if be TentativeHead = TRUE then
    Advertise CandidateCHMessage(ID,service,
     resEne rgy,distance)
    nodeState← CLUSTERHEAD
    On receiving all candidateCHMessage
 For each message
      If this.service is equal of received service
      myClusterHead ← the closest cluster-head
  end if
 Send JoinCHMessage to the closest clusterhead
 On receiving JoinCHMessage(ID) from node N
  add N to the clusterMembers list
 EXIT
```

Fig: 1 CLUSTER FORMATION ALGORITHM

Each node in the network calculates the competition radius based on two parameters that are distance with base station and residual energy. There are nine combinations of competition radius (ie transmission range) are created based on three categorization of both distance and residual energy as shown in table 1. After calculating competition radius each node will broadcast its Residual energy with Node ID.

Distance to Base	Residual Energy	Competition Radius
Close	Low	Very Small
Close	Medium	Small
Close	High	Rather Small
Medium	Low	Medium Small
Medium	Medium	Medium
Medium	High	Medium Large
Far	Low	Rather Large
Far	Medium	Large
Far	High	Very Large

Table1: COMPETITION RADIUS CALCULATION

Each receiving node compares its residual energy with received residual energy. If its residual energy is greater than received residual energy then it will broadcast CandidateCH message. The nodes receiving CandidateCH message selects the cluster head based on the service provided by the node and which is closest to the base station.

B. Query Routing

ALGORITHM: Query Routing
Input: specifying the query with required service
Output: Query routed to the node which is providing requested service

1. When a query is received at regional cluster head
   a. Examine query to determine which region the query belongs to.
   b. IF query belongs to same region as the receiving regional cluster head
      i. Examine the service requested by the query
      ii. If itself can provide the service then routes the query
   c. ELSE (query belongs to another region)
      i. Compute a waiting time t =1/RSSI of the concerned regional cluster head.
      ii. Listen for the rebroadcast of this same query by other regional cluster heads until 't' expires
      iii. IF query is broadcast by another regional cluster head before the expiration of time t DO NOTHING
      iv. ELSE broadcast query upon the expiration of t
2. When query is received at service cluster head:
   a. IF aggregate is required respond directly to regional cluster head using maximum transmission power level
   b. ELSE broadcast query using maximum transmission power level so that it is received by any one node providing that service currently not sleeping.

Fig 2: QUERY ROUTING ALGORITHM

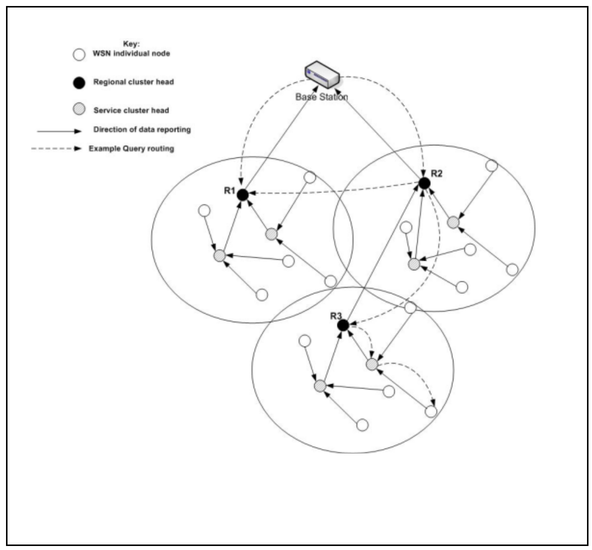

Fig 3: CLUSTER FORMATION SCENARIO

In the example scenario for Fig. 3, the query is destined to region 3. Hence, once the query reached R1 and R2, which one of regional cluster heads R1 or R2 should further broadcast the query is determined by our algorithm (Fig 2) based on a waiting time computed as a reciprocal (multiplicative inverse) of the received signal strength indicator (RSSI) from R3. The RSSI figure of R3 at R1 and R2 was established during cluster formation time.
In our example in Fig. 1, the RSSI from R3 was higher at R2 than at R1. Hence, R2 – not R1-

broadcasted the query since R1 had to wait a longer time based on the fore mentioned computation (i.e. 1/RSSI) and thus learned while waiting that the query had already been broadcasted by R2 earlier.

When the query reaches a service cluster head, we provide for the possibility of further broadcasting the query to a specific node based on the destination node's schedule. Alternatively, the service cluster head can respond directly with an aggregated data by reporting the data back to the regional cluster head. The regional cluster head further broadcasts it using the maximum transmission power to either directly deliver it to the base station or through another regional cluster head.

IV. EVALUATION OF ESQR

A. ENERGY CONSUMPTION

In this section, we present the results of the experiments that we have done to evaluate our algorithm. We compare our clustering algorithm ESQR with LEACH and CHEF. The algorithm is evaluated using WSN simulator to simulate LEACH, CHEF, and ESQR for different WSN configurations. Experimental results have shown that our algorithm performs better than LEACH, and CHEF.

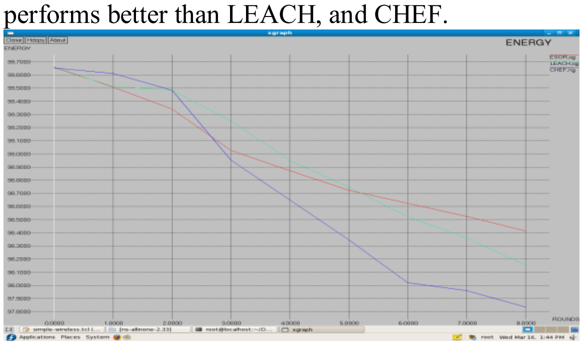

Fig 4: Energy graph for scenario 1

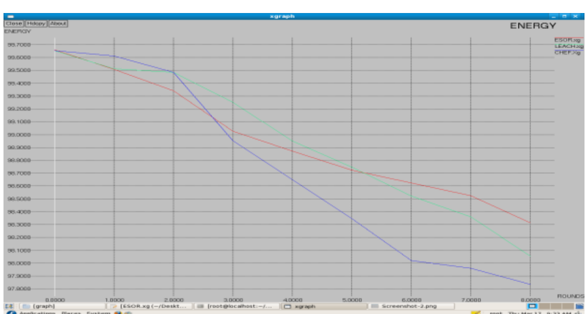

Fig 5: Energy graph for scenario 2

In order to evaluate our proposed algorithm, we consider two different scenarios. The area of deployed WSN is same for all scenarios and is 200x200 m. In the first scenario, the base station is located at the center of the WSN. In the second scenario, the base station is outside of the WSN. In each round of the scenarios, first, clusters-heads are elected and then clusters are formed. Afterwards, each ordinary node forwards a certain bits of data to its cluster-head. Each cluster-head aggregates the received data and forwards it to the base station. The experimental results are shown for both of the scenarios where the energy consumption is less for ESQR to eight rounds of cluster head election shown in the fig 4 & 5.

V. CONCLUSION

In this paper, we have proposed Energy efficient **S**ervice oriented query **R**outing algorithm for WSNs, namely ESQR. The main objective of our algorithm is to route the queries based on the service requested by the query with minimum energy consumption to prolong the lifetime of the WSN. To achieve this goal, we have mostly focused on assigning proper cluster-head competition ranges to sensor nodes. ESQR adjusts the cluster-head radius values considering energy and distance to the base station parameters of the sensor nodes.

ESQR routes queries to their destination based on their contents in order to allow users specify their queries without having to specify the destination of the query which is usually desirable in a WSN. This data centric routing of queries is achieved in a power efficient manner in ESQR since the network is organized as service clusters and a much longer life span for the network. The routing state in ESQR is distributed to a group of regional and service cluster heads to improve overall memory consumption and maintainability of the routing state instead of duplicating it on each and every node in the network.

We have shown that our proposed algorithm has a better performance compared to LEACH and CHEF considering the simulation results. The total remaining energy level of ESQR at a certain round is higher than all the other algorithms. As a result of these experiments, we conclude that ESQR is a stable and energy efficient clustering algorithm for WSNs.

ESQR algorithm is designed for the WSNs that have stationary sensor nodes. As a future work this can be extended for handling mobile sensor nodes.

VI. REFERENCES

[1] Seifu Tatek Yazhy and Seung-Kyu Park, "Hierarchical Service-Oriented Routing of Queries in Wireless Sensor Networks", Proceedings of the 2nd International Conference on Interaction Sciences, November 24-26, 2009.

[2] Hakan Bagci and Adnan Yazici, "An Energy Aware Fuzzy Unequal Clustering Algorithm for

Wireless Sensor Networks" IEEE conference on Fuzzy Systems,pp.1-8,September 2010.

[3] Rezgui A, Eltoweissy M, μRACER, "A Reliable Adaptive Service-Driven Efficient Routing Protocol Suite for Sensor-Actuator Networks", IEEE Transactions on Parallel and Distributed Systems, vol. 20, no. 5, pp. 607-622, May 2009.

[4] Rezgui A, Eltoweissy M, " Service-Driven Query Routing in Sensor Networks", In 31st IEEE Conference on Local Computer Networks pp.649-655, Tampa, Florida, USA, 14-16 November 2006.

[5] Wendi R. H., Anantha C, and Hari B, "Energy-Efficient Communication Protocol for Wireless Microsensor Networks", Proceedings of the 33rd Hawaii International Conference on Systems Sciences, Maui, Hawaii, January 2000. pp. 1-10.

[6] Konrad I, Maarten V, "On Hierarchical Routing in Wireless Sensor Networks ", In Proceedings of the Eighth ACM/IEEE International Conference on Information Processing in Sensor Networks (IPSN 2009), IP Track. San Francisco, California, USA. April 2009. pp. 133-144.

[7] C. Li, M. Ye, G. Chen, and J. Wu, "An energy-efficient unequal clustering mechanism for wireless sensor networks ",in IEEE International Conference on Mobile Adhoc and Sensor Systems Conference, 2005, p. 8.

