Collection of Sensor data in an energy efficient manner using Rendezvous based approach

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***Abstract*—Wireless Sensor Networks (WSN) generally comprises of large number of tiny sensor nodes that can be deployed in larger numbers so that they can de effectively communicated through wireless communication interface. Since the sensor nodes are smaller in size, it can be deployed in larger numbers. Existing approaches involve either single-hop transfer of data from SNs that lie within the MS's range or heavy involvement of network periphery nodes in data retrieval, processing, buffering, and delivering tasks. The main drawback of sensor nodes is that it consumes a huge amount of energy while transmitting the data to its neighbouring node leading to decreased network lifetime. Our proposed System is minimizing the overall network overhead and energy expenditure associated with the multihop data retrieval process while also ensuring balanced energy consumption among SNs and prolonged network lifetime. This is achieved through building cluster structures consisted of member nodes that route their measured data to their assigned cluster head (CH). CHs perform data filtering upon raw data exploiting potential spatial-temporal data redundancy and forward the filtered information to appropriate end nodes with sufficient residual energy, located in proximity to the MS's trajectory.**

***Keywords*—sensor node, mobile sink, rendezvous nodes, cluster head, Base station.**

I. INTRODUCTION

A main reason of energy spending in WSNs relates with communicating the sensor readings from the sensor nodes (SNs) to remote sink. These readings are typically relayed using ad hoc multihop routes in the WSN. A side effect of this approach is that the SNs located close to the sink are heavily used to relay data from all network nodes; hence, their energy is consumed faster, leading to a nonuniform depletion of energy in the WSN. This results in network disconnections and limited network lifetime. Network lifetime can be extended if the energy spent in relaying data can be saved. Recent research work has proved the applicability of mobile elements (submarines, cars, mobile robots, etc.) for the retrieval of sensory data from smart dust motes in comparison with multihop transfers to a centralized element.

A mobile sink (MS) moving through the network deployment region can collect data from the static SNs over a single hop radio link when approaching within the radio range of the SNs or with limited hop transfers if the SNs are located further. This avoids long-hop relaying and reduces the energy consumption at SNs near the base station, prolonging the network lifetime. A large class of monitoring applications involve a set of urban areas (e.g., urban parks or building blocks) that need to be monitored with respect to environmental parameters (e.g., temperature, moisture, pollution, and light intensity), surveillance, fire detection, etc. In these environments, individual monitored areas are typically covered by isolated "sensor islands," which makes data retrieval rather challenging since mobile nodes cannot move through but only approach the periphery of the network deployment region. In such cases, a number of representative nodes located in the periphery of the sensor field can be used as "rendezvous" points wherein sensory data from neighbour nodes may be collected and finally delivered to an MS when the latter approaches within radio range. In this context, the specification of the appropriate number and locations of rendezvous nodes (RNs) is crucial. The number of RNs should be equivalent (neither small nor very large) to the deployment density of SNs. we investigate the use of MSs for efficient data collection from “sensor islands” spread throughout urban environments. We argue that the ideal carriers of such MSs are public surface transportation vehicles (e.g., buses) that repeatedly follow a predefined trajectory with a periodic schedule that may pass along the perimeter of the isolated sensor fields.

The proposed protocol aims at minimizing the overall network overhead and energy expenditure associated with the data retrieval process while also ensuring balanced energy consumption among SNs and prolonged network lifetime. This is achieved through building cluster structures consisted of member nodes that route their measured data to their assigned cluster head (CH). The CHs perform data filtering upon the raw data exploiting potential spatial-temporal data redundancy and forward the filtered information to their assigned RNs, typically located in proximity to the MS’s trajectory. We also introduce a sophisticated method for enrolling appropriate nodes as RNs taking into account the deployment pattern and density of sensor nodes. Last, we propose methods for building adaptable intercluster overlay graphs and techniques for fairly distributing sensory data among RNs and delivering data to MSs in nonintersecting time windows.

II. RELATED WORK

A number of approaches exploiting sink mobility for data collection in WSN have been proposed in recent years. The Mobile sink may visit each Sensor Nodes and gather its data (single-hop communication) **[1]**, **[2]** or May Visit only some locations of the WSN and SN send their data to MS through multihop communication **[3], [4]**. Apparently, since in the first solution only single hop communication is required, energy consumption is minimized, however, at the expense of high data delivery delay. In the second solution, this delay is low but the energy consumption due to multihop communication is rather high.

In addition, SN should constantly be kept updated about the MS’s current location thereby creating considerable routing overhead. A solution in between is to have SN send first their data to a certain number of nodes(RN) which buffer the received data and send them to MS when MS is within their transmission range **[5]** or when they receive a query from MS asking for the buffered data **[1]**. In the second approach, the MS does not necessarily pass near the RNs and the data Stored at each RN are forwarded to MS by reversing the route of the received Query packet. The works presented in **[6]** and **[7]** are mostly relevant to the research described herein as they are rendezvous-based solutions which both assume MS. In **[7]**, a MS is used to collect data from groups of SN. During a training period, all the WSN edge nodes located within the range of MS routes are appointed as RNs and build paths connecting them with the remainder of sensor nodes.

Those Paths are used by remote nodes to forward their sensory data to RNs; the latter buffer sensory data and deliver them to the MS when it reapproaches in range. The movement of mobile robots is controllable which is impractical in realistic urban traffic conditions. Most importantly, no strategy is used to appoint suitable nodes as RNs while selected RN are typically associated with uneven numbers of SN. In **[6]**, rendezvous-based solutions are presented for variable as well as fixed MS trajectories. The proposed technique assumes full aggregation. Apparently, this is not always possible and thus it is rather a strong assumption. The solution presented for fixed MS track seeks to determine a segment of the MS track shorter than a certain bound such that the total cost of the trees connecting source nodes with RNs is minimized. Note that in both the cases of variable and fixed tracks, knowledge of network topology is necessary and the whole algorithm is performed centrally at the BS.

The large-scale deployment of WSN and the need for data aggregation necessitate efficient organization of the network topology for the purpose of balancing the load and prolonging the network lifetime. Clustering has proven to be an effective approach for organizing the network in the above context. Besides achieving energy efficiency, clustering also reduces channel contention and packet collisions, resulting in improved network throughput under high load. Our clustering algorithm borrows ideas from the algorithm **[8]** to build a cluster structure of unequal clusters. The clustering algorithm in **[8]** constructs a multisized cluster structure, where the size of each cluster decreases as the distance of its cluster head from the base station increases. We slightly modify the approach of **[8]** to build clusters of two different sizes depending on the distance of the CH from the MS trajectory.

Specifically, SN located near the MS trajectory is grouped in small sized Clusters while SN located farther away is grouped in clusters of larger size. The CH near the MS trajectory is usually burdened with heavy relay traffic coming from other parts of the network. By maintaining the clusters of these CH small, CH near the MS trajectory are relatively relieved from intracluster processing and communication tasks and thus they can afford to spend more Energy for relaying intercluster traffic to RN.

Apart from **[6]**, a number of other rendezvous-based solutions that assume variable MS trajectory have been proposed **[10].** These works determine the MS trajectory in such way that certain optimization criteria (e.g., minimum energy consumption for transferring the data to RNs) are met while obeying certain constraints (e.g., the MS trajectory length should be lower than a certain threshold).

A common characteristic of all techniques described above is that the routing structures that carry data from SN to RN are built once and are used without any modification for the whole lifetime of the WSN. Most of these works are centralized approaches that try to minimize an energy related cost function without paying proper attention to the selection of nodes that will serve as RNs. Specifically, they do not take into account the contact time of a RN with the MS during which it can send the buffered data.

Also, there is no special focus on the amount of data the RNs receive from the other nodes of the network. So, a heavily loaded RN that is in contact with the MS for only a short time may not manage to transfer all buffered data and this gradually may lead to buffer overflow or very long delivery delays. Also, they do not examine the proximity of the selected RNs and as a result, frequent collisions could arise due to concurrent transmissions from nearby RNs when the MS is approaching these RNs.Apparently, this considerably reduces the actual data delivery rate to the MS. Note also that many of the previous works provide an on time delivery guarantee by bounding the length of MS trajectory.

The main trade-off that should be considered is between the delivery delay tolerated and the energy consumption due to multihop routing to the RNs. Another issue in all previous schemes is that there is no provision in case that RNs run out of energy. In that case, all SNs that send their data to these RNs cannot send their data to MS any longer. A local or even a global rebuilding of the routing structures may be required in order to bypass dead RNs.

In our work, we deal with all these important issues. We propose a distributed protocol which selects as RNs only nodes with sufficient energy and in close proximity with MS for sufficiently long time. Also, only RNs with no overlapping contact intervals with MS are selected, eliminating so the collisions arising due to concurrent transmissions from nearby RNs. Furthermore, the operation of RNs is well coordinated and the right amount of data is distributed to each RN according to the contact time and data delivery rate of each RN.

Most importantly, in case that a RN runs out of energy, it is quickly replaced by other available RNs and thus the data transmission to MS is not disrupted as in other rendezvous-based schemes. Also, in contrast to other schemes which use flat network architecture, our approach builds a clustering structure on top of the sensor network. That way, high data aggregation ratios are possible since data from the nodes of the same cluster usually are strongly correlated **[9]** and thus aggregation at each cluster head considerably reduces the data forwarded to RNs. This in turn leads to much lower energy consumption in the WSN and also much less data are buffered at RNs, reducing so the probability of buffer overflows at a RN.

III. DESIGN CONSIDERATION

Mobile sink (MS) are mounted upon public buses circulating within urban environments on fixed trajectories and near-periodic schedule. Namely, sinks motion is not controllable and their routes do not adapt upon specific WSN deployments. Our only assumption is that sensors are deployed in urban areas in proximity to public transportation vehicle routes. Also, an adequate number of nodes are enrolled as RNs as a fair compromise between a small numbers which results in their rapid energy depletion and a large number which results in reduced data throughput.

Sensor nodes are grouped in separate clusters. Raw sensory data are filtered within individual clusters exploiting their inherent spatial-temporal redundancy. Thus, the overhead of multihop data relaying to the edge RNs is minimized. Given that the communication cost is several orders of magnitude higher than the computation cost, in-cluster data aggregation can achieve significant energy savings. A basic assumption in this design is that SN are location unaware, i.e., not equipped with GPS- capable antennae. Also, we assume that each node has a fixed number of transmission power levels.

The four phases are described. The first three phases Comprise the setup phase while the last comprise the steady phase. The setup phase completes in a single MS trip and during this trip, the MS periodically broadcasts BEACON messages which are used by SN for determining a number of parameters important for the protocol operation. In the steady phase, data from SN are routinely gathered to Rendezvous nodes (RN) and then sent to MS. During the steady phase, reselection of RNs and/or local reclustering is performed in case of energy exhaustion of some critical nodes. Most importantly, these operations take place in the background without disrupting the protocol's normal operation.

A. Clustering

The first phase involves clustering of sensor nodes. The large-scale deployment of Wireless Sensor Network and the need for data aggregation necessitate efficient organization of the network topology for the purpose of balancing the load and prolonging the network lifetime. Clustering has proven to be an effective approach for organizing the network in the above context. Besides achieving energy efficiency, clustering also reduces channel contention and packet collisions, resulting in improved network throughput under high load.

The clustering algorithm in constructs a multisized cluster structure, where the size of each cluster decreases as the distance of its cluster head from the base station increases. We slightly modify the approach of to build clusters of two different sizes depending on the distance of the Cluster Head (CH) from the MS's trajectory. Specifically, SN located near the MS trajectory are grouped in small- sized clusters while SN located farther away are grouped in clusters of larger size .The CHs near the MS trajectory are usually burdened with heavy relay traffic coming from other parts of the network. By maintaining the clusters of these CHs small, CHs near the MS trajectory are relatively relieved from intracluster processing and communication tasks and thus they can afford to spend more energy for relaying intercluster traffic to RNs.

B. Rendezvous node election

The Second phase involves rendezvous node election. RN guarantees connectivity of sensor islands with MS. Hence, their selection largely determines network lifetime. RN lie within the range of travelling sinks and their location depends on the position of the CH and the sensor field with respect to the sinks trajectory. Suitable RNs are those that remain within the MS's range for relatively long time, in relatively short distance from the sink's trajectory and have sufficient energy supplies. In practical deployments, the number of designated RNs introduces an interesting trade-off.

A large number of RNs implies that the latter will compete for the networks Wireless channel contention as soon as the mobile robot appears in range, thereby resulting in low data throughput and frequent outages. A small number of RN implies that each RN is associated with a large group of sensors.

C. *Cluster head re-election*

In cluster head re-election, based on node deployment each node sends the cluster head election Packets to its neighbour for electing the Cluster Head. By periodically reelecting the Cluster Head based on higher energy the problem of node failure could be undone. Also by adopting proper strategy of electing proper node as Rendezvous nodes the data could be communicated to the Mobile sink from the Sensor Nodes without any Communication overhead.

D. Communication between rendezvous nodes and mobile sinks

The Phase 4 involves communication between RN and mobile sinks**.** The delivery of data buffered to RN to MS. Data delivery occurs along an intermittently available link. Hence, a key requirement is to determine when the connectivity between an RN and the MS is available. Communication should start when the connection is available and stop when the connection no longer exists, so that the RN does not continue to transmit data when the MS is no longer receiving it. To address this issue, we use an acknowledgment-based protocol between RN and MS. The MS, in all subsequent Path traversals after the setup phase, periodically broadcasts a POLL packet, announcing its presence and soliciting data as it proceeds along the path. The POLL is transmitted at fixed intervals Tpoll.

This POLL packet is used by RNs to detect when the MS is within connectivity range. The RN receiving the POLL will start transmitting Data packets to the MS. The MS acknowledges each received data packet to the RN so that the RN realizes that the connection is active and the data were reliably delivered. The acknowledged data packet can then be cleared from the RN cache.

IV. SIMULATION RESULTS

A number of rendezvous-based approaches have been proposed which either assume a fixed MS trajectory or determine that trajectory according to some energy-related optimization criteria. In the simulation tests, we compare our method with the solutions proposed in **[7]** and **[6]** which also assume fixed MS trajectory. In these tests, MobiCluster and the protocols in **[6]** and **[7]** have been extensively evaluated with respect to several performance parameters. First, the three protocols are compared in terms of the network lifetime, the average residual energy as well as the variance of this energy across the network. Then, the protocols are compared in terms of the overall number of outages. Finally, the third group of tests concerns the total generated traffic as well as the network throughput of these protocols.

Next, we present the results for the most representative performance metrics, namely the number of outages, the. In **[6]**, a solution for variable MS trajectory is also presented. In tests of Figs. 1, 2, 3, we considered three cases for the data aggregation carried out in the network. In the basic scenario, the aggregation ratio achieved depends on how early this aggregation is carried out along the routing paths. Specifically, for MobiCluster, we assume that due to strong correlation existing in the data from the same cluster, the high aggregation ratio of (60%= f1) is possible in the CHs. However, for data aggregation carried out along the intercluster paths, the aggregation ratio is only (5%= f2). For the other two protocols, aggregation ratio of 60 percent is assumed only at the two lowest levels of routing trees where due to the proximity of nodes at these levels, high data correlation should be expected. At all other nodes of trees, a 5 percent aggregation ratio is assumed.

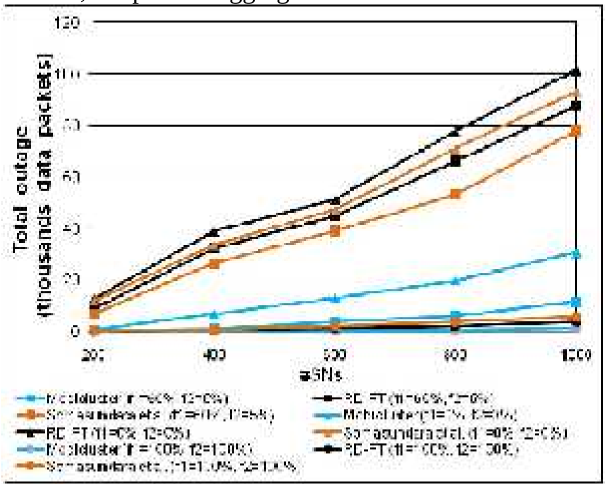

Fig 1 Total outage

Completeness, we also consider the cases of no aggregation (f1, f2=0%) and full aggregation (f1, f2=100%) in the following three tests. Fig. 1 illustrates the overall number of outages. In the basic scenario, the RD-FT protocol performs worse mainly due to the fact that SNs are not fairly distributed to the available RNs (see Fig. 3b) and thus relatively few RNs handle a considerable amount of sensory data. This is further exacerbated in no aggregation case whereas in full aggregation scenario RD-FT is slightly better than **[7]** since in that case the data each RN handles are much fewer and thus the problems above do not arise. Also, contrary to RDFT, the protocol in **[7]** tends to employ a large number of RNs competing for the same wireless channel and hence leading to increased packet collisions. MobiCluster exhibits the best performance in all scenarios because of the more sophisticated selection of RNs; RNs have sufficient time to deliver their data and suffer low Number of collisions since they are well separated spatially.

In Fig. 2, the time of the first SN's energy depletion. In the basic scenario, our protocol involves RNs only for delivering pre-processed data to the sink in contrast to **[7],** where RNs Fig.2 Network lifetime. It receives much data and is also enrolled in data processing and delivering data to the MS. Again, the problem is more severe in RD-FT due to its aforementioned tendency of gathering SNs around few RNs.

However, in the other two scenarios, no and full aggregation, all protocols achieve the same aggregation level and thus our protocol does not have a clear advantage over the other protocols in this regard. Nevertheless, the superior performance of the protocol in these scenarios is due to reclustering and the enrolment of different RNs when existing CHs or RNs, respectively, get Short of energy. In the other two protocols, the routing structures do not change and thus the energy of SNs near the sink trajectory is rapidly falling resulting in shorter lifetime. Also, further energy savings are gained in our protocol due to unequal clustering and the less frequent packet collisions in the communication of RNs with MS. Unequal clustering balances the traffic load and hence the energy consumption across the network whiles fewer collisions due towel separated locations of RNs in Mobicluster lead to fewer retransmissions and hence low-cost communication of RNs with MS.

Last, as in fig 3, the protocol achieves reduced average energy consumption compared to the other two protocols. For the basic scenario, this is due to clustering and the higher aggregation ratio achieved. In all other cases where the aggregation ratios are the same for all protocols, the higher residual energy levels of our protocol are attributed to the same factors as those mentioned above. the execution of reclustering as well as the use of different RNs when needed, the use of unequal clustering and also the sophisticated selection of RNs. Finally, notice that RD-FT performs better than **[7]** in full aggregation case, since the minimum spanning tree is ideal for this case.

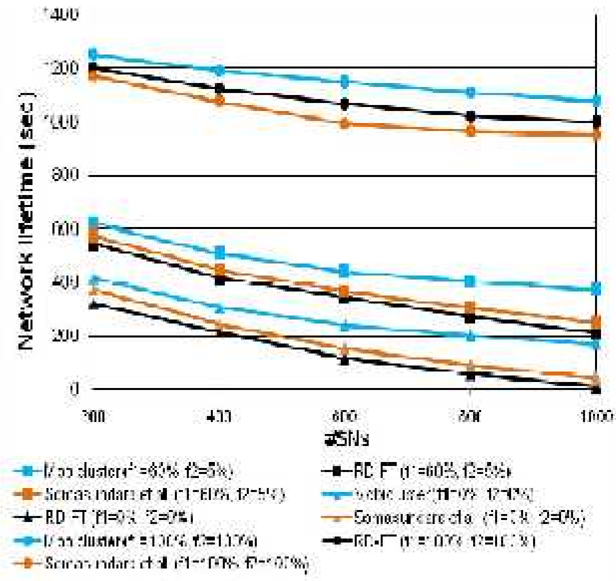

Fig 2 Network lifetime

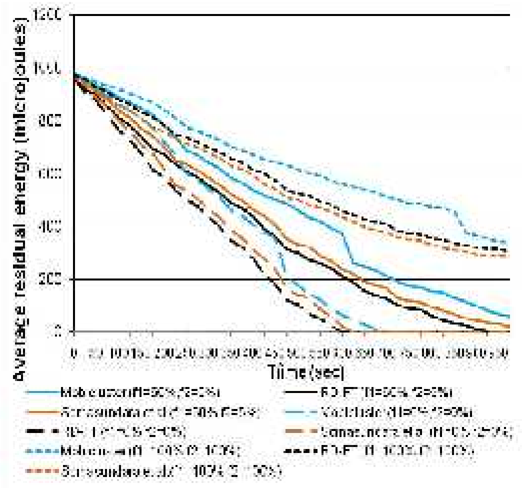

Fig 3 Average Residual Energy

V. CONCLUSION

In this paper we propose a protocol that aims at minimizing the overall network overhead and energy expenditure associated with the multihop data retrieval process while also ensuring balanced energy consumption among SN and prolonged network lifetime. This is achieved through building cluster structures consisted of member nodes that route their measured data to their assigned cluster head (CH). CHs perform data filtering upon raw data exploiting potential spatial-temporal data redundancy and forward the filtered information to appropriate end nodes with sufficient residual energy, located in proximity to the MS's trajectory.

Although cluster head reduces the energy consumption in a sensor network, there are chances for the cluster head node to fail due to heavy overload. To avoid the failure of each and every cluster head, cluster head re-election is done. Thus, by periodically re-electing the cluster head based on maximum energy, the problem could be solved leading to increased network lifetime and minimum network overhead showing a significant increase in the energy-loss ratio in a sensor network.

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Fig 2:Network Lifetime

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