Effective Data Collection using Ferry Node in Wireless Sensor Network

Miss. Nupur R. Banode[1] Mr. Kapil N. Hande[2]
[1]PG Student [2]Assistant Professor
[1,2]Department of Computer Science & Engineering
[1,2]Priyadarshini Bhagwati College of Engineering, Nagpur, India

Abstract— The usefulness of mobile ferries, can be stated by the nodes that transfer the data between other nodes in process of their movement, provides multiple benefits for Wireless Sensor Networks (WSNs). It has been suggested and can evaluate several different approaches and protocols for collecting the data using such ferries from isolated WSN subnetworks for different scenarios. The results of the simulations can be presented, that reveals the effects of the WSN density, ferry speed, node sleep policy and maximum hop limitation on the performance and required resources for the tested protocols.
Key words: Data Collection using Ferry Node, WSN

I. Introduction

The word WSN means wireless sensor networks are a division of adhoc wireless networks certain of a number of sensor nodes deployed over a monitored area. Each sensor node is a low-cost, energy-constrained device which is capable of sensing its environment and does simple processing tasks and then transmits sensed data over the wireless medium towards neighboring sensor nodes. To achieve more complicated data processing, data gathering mechanisms are designed and deployed for powerful data collection at one or a small number of accurately powered sink nodes inside the WSN.

Sink nodes are the nodes that are dedicated nodes that are responsible for collecting composed data and serve as gateways between the sensor network and the wired or wireless network. The applications of sensors may be quite different, data packets want to be aggregated at data sink. The homogeneous networks are the network where sensors are organized into a flat topology, as they need to relay many packets from sensors far away from the data collector. If any of these sensors fail, as a result, other sensors also cannot reach the data collector and the whole network becomes disconnected, but most of the nodes can still survive for a long period. It is not a good idea for a large-scale sensor network, using single static data sink to gather data from all sensors. A mobile data collector is perfectly suitable for applications where, sensors are densely connected and deployed, but some of the sensors may be disconnected and cannot forward data to the data sinks via wireless links.

Mobile data collectors assist as a mobile "data carrier" and links that all are separated to sub networks. The moving paths of the mobile data collector carry out as virtual links between separated sub networks.

In order to provide a scalable data-gathering scheme for large-scale static sensor networks, we employ mobile data collectors to gather data from sensors. Mobile data collector can be a mobile robot or a vehicle equipped with a powerful transceiver, battery, and large memory. The mobile data collector starts a tour from the data sinks, traverses the network, and collects sensing data from nearby nodes while moving, and then returns and uploads data to the data sink. Since the data collector is mobile moving path must be well panned, so that it can move close to sensor nodes, and the network lifetime can be continued.

The network lifetime here can be defined as the duration from the time sensors start sending data to the data sink till the time when a certain percentage of sensors cannot send data to the data sink or either run out of battery due to the failure of relaying nodes. For convenience, we can now use the word mobile collector to denote the mobile data collector.

The mobile ferries (MFs) are the nodes that transfer the data between the remote (isolated) parts of the WSN, in the process of their movement with temporal data storage on-ferry. The most vital difference between the mobile sinks or mobile relays and the MFs is that the relays and sinks usually require full control over their mobility, while the MF mobility does not need to be controlled. The other advantage of MFs is that they can be used to interconnect even distant subnetworks as in Fig. I. The MFs can increase the coverage of the WSN by connecting the sink and isolated subnetworks and improve the energy efficiency.

The major disadvantage of the data transferring using MFs is the communication latency that depends on the mobility pattern, speed and network layout of the MFs.

In the paper, we focus on the MFs scenario and the data collecting from the isolated nodes and subnetworks using an MF. Below we propose several different data collection (DCol) protocols, under which we mean the combination of isolated cluster discovery, connection establishment, routing, and data communication mechanisms.

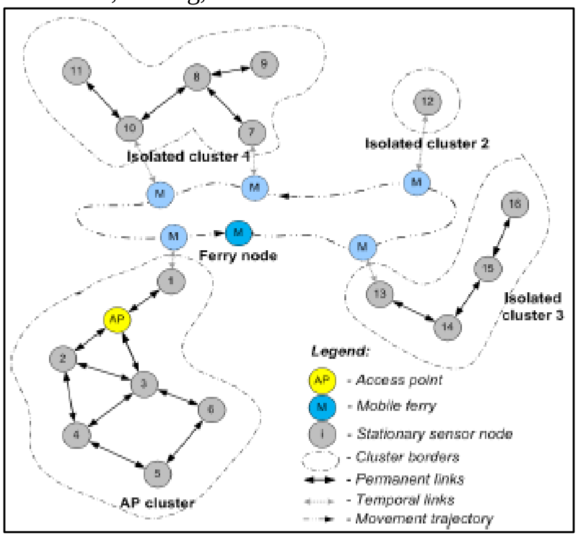

Fig. 1: Example of the WSN with Mobile Ferries.

II. Related Work

In [8] mobile entities called mules were deployed in the environment. Mules picked up data from sensors when they were in close range, buffered it, and dropped it off when within a communication range of wired access points. They used two-dimensional random walk to model the mobility of mules. Both mules and sensors required to have memory capacities as they were buffering data.

In [9] mobile nodes were used in the sensor field as forwarding agents. When a mobile node oved in close proximity to sensors, data is transferred to the mobile node for later depositing at the destination. They used analytical models to understand the key performance metrics such as data transfer, latency to the destination, and power consumption.

In [10], an architecture of a wireless sensor network for a traffic surveillance application with mobile sinks was proposed. All sensor nodes in this architecture were assumed to be located within the direct communication range of the mobile sink. All multi-hop transmissions of high volume data over the network are converted into single-hop transmissions to preserve the energy of the network further.

The authors in [12] used a single ferry to collect data from a circular dense sensors network. They showed that the optimal mobility strategy of the ferry achieved when moving at the border of the sensing area. They divided the area into circles starting from the source. The inner circles forward the data to the outer ones; until the border was reached where the ferry was used to collect the sensed data.

The scheduling of when exactly to send the ferry to collect sensed data from nodes is a quiet complicated task. In [13, 14] authors studied the scheduling problem where the path of the mobile sink was optimized to visit each node in the WSN before its buffer was full. Buffer overflow was used as a trigger to send the ferry to collect data to avoid data loss.

In [17] the authors considered on demand data collection. In this research, sensor nodes broadcast data collection requests when their buffers are about to be full. On receiving such requests, the ferry moves toward the sensor nodes to collect data, and transfer the data to the sink.

In [18] a mobile node was used to help in disseminating data to the sink. It was used to move back and forth along the linear network, and collect data from the individual sensors when it comes within their communication range. The mobile node will then transfer the collected data to a base station. The mobile node was also used to perform other functions, such as data processing, and aggregation, and can also transport messages from the sink to the sensor nodes.

III. Methodology

For investigating the different WSN Dcol methodologies using the MF we have chosen the most general scenario. It is assumed that n static wireless sensor nodes are randomly placed in the area of (x, y) meters and their position is unknown. Each node has N data packets that should be forwarded to the sink node. At random moment of time, single MF approaches the test area and crosses it via some unpredictable route. The mobility of the MF cannot be controlled by the WSN in any way. For increasing the operation time of the WSN, the sensor nodes are allowed to use the low-power sleep mode. The sensors are not synchronized and their sleep schedules are independent.

For such scenario, the main task for the data collecting protocol is the reliable (i.e., without packet losses) data transfer from the sensor nodes to the MF. Unfortunately, the majority of the existing protocols cannot be used for this scenario due to a high level of input data uncertainty.

Therefore, below it has suggested the five protocols for collecting the data from such environment. The first algorithm implements the most basic data collecting protocol for the MF scenario and is similar to the one used e.g., in [17], [18]. This protocol implies the periodic broadcasting of the beacon packet by the MF to advertise its presence to the sensor nodes. The WSN nodes within the communication range of the MF that receive this advertisement, reply with the data packet. To improve the reliability of the communication, it has included in the beacon packet the IDack field that signalizes the sensor node that its previous data packet has been successfully received by MF.

Unlike the first algorithm, the second and the following enable the use of multi-hop forwarding. E.g., for the third algorithm the WSN nodes once finished transmitting all data packets, start to rebroadcast the beacon advertisements and forward the data traffic from the other nodes to the MF. The data from the sensor node to the MF are transmitted via the route with the minimum transmission time for the beacon packet from the MF to this sensor. In case of data or acknowledgement packets collision – the data is rebroadcasted once again after the next beacon.

The fourth algorithm uses the multi-hop multi-route flooding technique that has been suggested for partially-connected WSNs. Once receiving the beacon, the sensor nodes rebroadcast it and start sending data packets. The neighbor nodes that are located closer to the MF (i.e., having less hops) acknowledge, save and forward the packets from the more distant nodes.

The fifth algorithm utilizes the token mechanism. The MF advertises the token, for which the sensor nodes compete. The winner – transmits all its packets to the MF with short delay. In case if the node has no data to transmit, it retransmits the token advertisement further enabling the other nodes to enter the competition. Currently, only one node can hold the token at a time. The “connection lost” timer on the MF ensures network recovery in the case if the token has been lost or if data connections have been broken.

Finally, the Single-Packet Collect (SPC) algorithm tries to collect only a single packet but from each node in the WSN. This protocol is especially useful for the applications that require the “snapshot” of the measurements in the whole WSN and do not care much about the measurements’ history for specific nodes. To the best of our knowledge, this is the first protocol for WSNs that tries to equalize the DCol from different sensor nodes.

For distinguishing the traffic from the other nodes that should be transmitted as soon as possible from node’s own packets, the second buffer (bufferII) has been introduced.

IV. Implementation

Since data transmission can account for up to 70% of the power consumed in typical sensor nodes [20], substantial energy can be reduced by reducing the distance travelled and the amount of data transmitted to the base station.

Distance of the nodes from the base station and inter-node distances can have a high impact on saving nodes’ energy and thus prolonging the network life time which can be defined either as the time for the first node to die, or the time for the last node to die or the time for a certain percentage of nodes in the WSN to die [20]. Moreover, in dense deployments of sensor nodes in a WSN, nodes can cooperate to send data and therefore distribute the consumption of energy between them.

In this paper we propose a ferry-based node ranking clustering algorithm (FNRCA) to collect data from nodes. The difference between this algorithms from the other algorithms is that this algorithm uses a more efficient mechanism to select cluster heads. This is done by measuring the distances, the current energy levels of nodes and calculating the number of rounds that each can be cluster heads for, to maximize the network life time and decrease excessive communication overheads used for electing new cluster heads. In this algorithm, nodes are ranked based on their current energy level (En) and their positions (Dn) with reference to the predetermined checkpoints on ferry's trajectory.

This ranking is used for choosing cluster heads which are also ranked into levels based on their position, Euclidean distance, from the checkpoints on ferry's trajectory. Therefore, each node is assigned a rank Rn (En, Dn) reflecting its readiness for being elected as a cluster head.

The proposed algorithm is shown to be energy efficient because it minimizes the energy used by cluster-heads to reach the BS by using a ferry. In the proposed algorithm, the Base Station (BS) is placed in a fixed position and has unlimited energy. Thus no constraints are assumed with regards to power consumption due to data processing and communication. Also, it is assumed that the ferry dispatches from the base station and go back to it. In addition to that, it is assumed that there are no energy constraints on the ferry. Nodes are distributed randomly based on uniform distribution.

Through the initial step of the algorithm, the BS becomes aware of the locations of all sensor nodes either via collecting their GPS coordinates or any other mechanism. The proposed algorithm is an extension based on our previously published work [7, 8] with node ranking being based on the planned path of the ferry. The steps below give a description of the algorithm and cluster heads' selection process:

1) Similar to the initial step done in [21],[22], [19] each node at the set up phase broadcasts a message of its energy level and location to its neighbors. Therefore, each node sets up a neighbor information table recording the energy levels and positions of its neighbors and broadcast this information to its neighbors. This is conducted by all nodes in the network until information about all nodes in the network is received by the BS. This will provide the BS with a global knowledge of the network.
2) The BS divides the area into smaller partitions called clusters based on the assumed communication range of the nodes.
3) The path of the ferry and checkpoints where the ferry will stop to collect data on its planned trajectory are predetermined by the BS and sent to cluster-heads.
4) Nodes with the highest energy level (En) and least distance (Dn) from the closest checkpoint on the ferry's trajectory in each cluster become a Cluster Head (CH), the first round is completed when cluster heads were chosen in reference to the BS using the NRCA.
5) At each checkpoint the ferry stops to collect gathered sensed data from cluster heads associated with the checkpoint. Gathered data is collected either directly from sensing nodes within these cluster heads communication range or through multi hop forwarding through other cluster heads for out of communication sensing nodes.
6) Dissemination of data from cluster heads to the ferry is triggered by a control message communicated by the ferry to the cluster heads associated with each check point. The time the ferry will stay for at each check point is determined based on several parameters as will be shown later.
7) Cluster heads, which are located closer to the path of the ferry, are referred to as the first level cluster heads. The cluster heads that are located at more distant positions from the path are considered as second level, third level…etc. In order to reach the ferry with the least energy consumption, higher cluster heads' levels transmit to lower cluster heads level.
8) The used energy model for sensing and dissemination of data in our simulation is the same used by 23, 19.

V. EXPERIMENTAL RESULT

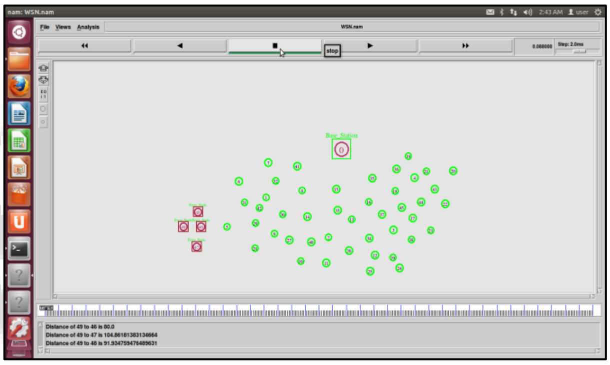

Fig. 2: Adhoc Network of 50 Nodes with 4 Nodes as Ferry Nodes

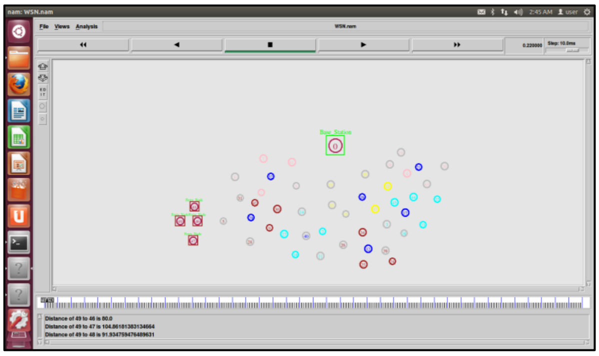

Fig. 3: Formation of Cluster

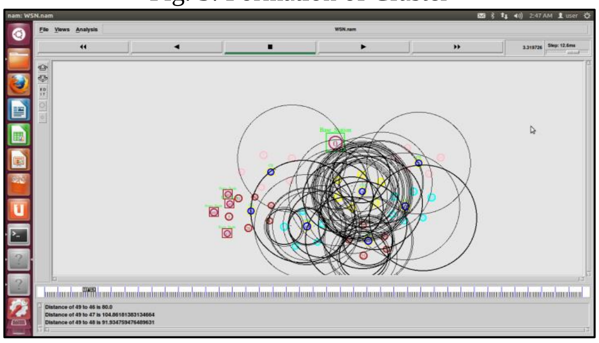

Fig. 4: Nodes Contact With Each Other

Fig. 5: Ferry Node Moving Toward Cluster Head

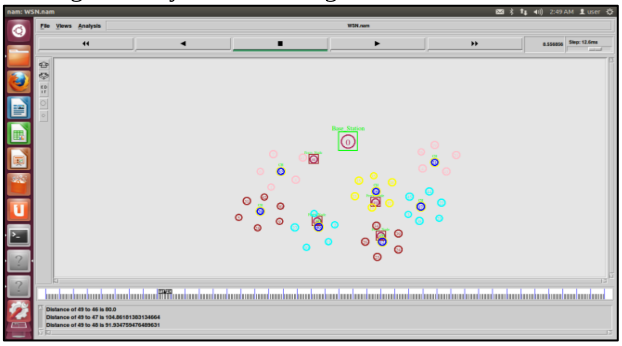

Fig. 6: Ferry Node Collecting Data From Cluster Head

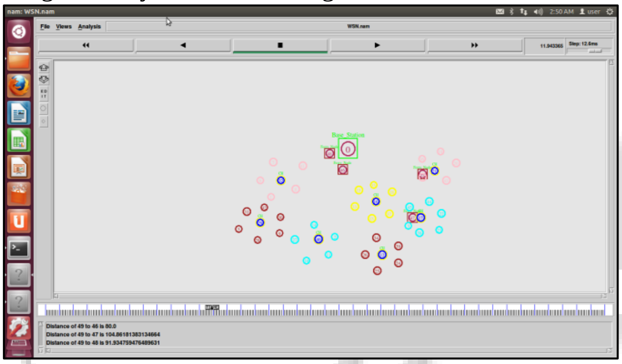

Fig. 7: Ferry Node Transferring Data To The Base Station

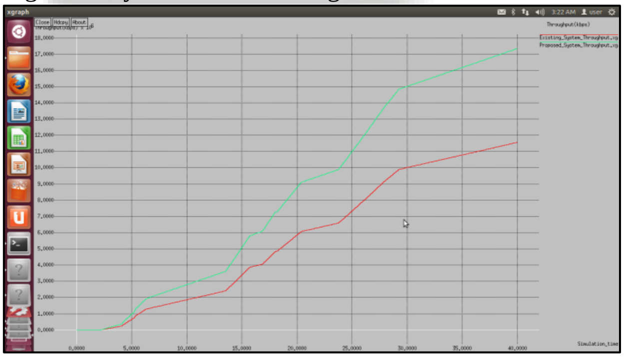

Fig. 8: Comparison Of Xgraph Of Throughput

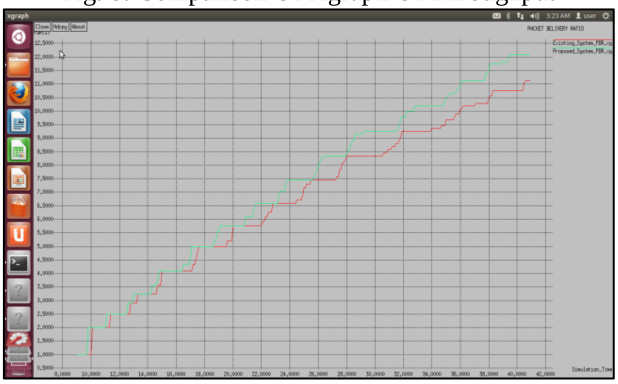

Fig. 9: Comparison Of Xgraph Of Packet Delivery Ratio

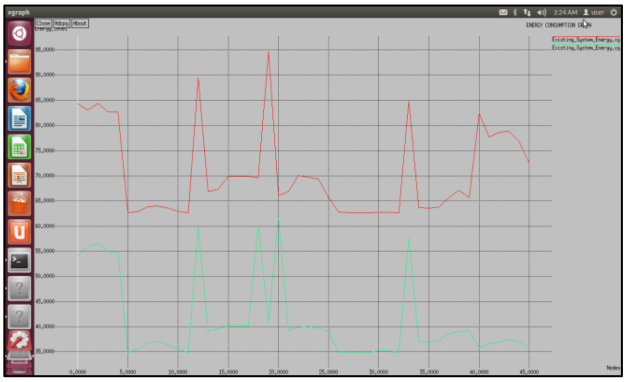

Fig. 10: Comparison of Xgraph of Energy Consumption

VI. CONCLUSION

It can be shown how using mobile ferries can be used for data gathering in WSNs addressing two areas, determining the path of the ferry and the scheduling when to dispatch the ferry to collect data from static sensors. Here it has been presented a classification of mobile ferries, based on the role they play in addition to carrying information. Furthermore, it will show on path planning and scheduling of ferry dispatching in the literature. In addition to that, common challenges in deploying mobile ferries in WSNs were discussed along with many of their possible applications.

The recent progress of using mobile ferries for data gathering in WSNs addressing two areas, determining the path of the ferry and the scheduling when to dispatch the ferry to collect data from static sensors. Here it has been presented a classification of mobile ferries, based on the role they play in addition to carrying information. Furthermore, it is surveyed the existing work on path planning and scheduling of ferry dispatching in the literature. In addition to that, common challenges in deploying mobile ferries in WSNs were discussed along with many of their possible applications.

REFERENCES

[1] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, “Energy efficient communication protocols for wireless micro sensor networks,” in Proc. HICSS, Maui, HI, Jan. 2000, pp. 1–10

[2] W. Zhao, M. Ammar, and E. Zegura, “A message ferrying approach for data delivery in sparse mobile ad hoc networks,” in Proc. ACM MobiHoc, 2004, pp. 187–198.

[3] R. C. Shah, S. Roy, S. Jain, and W. Brunette, “Data MULEs: Modelling a three-tier architecture for sparse sensor networks,” in Proc. IEEE WorkshopSens. Netw. Protocols Appl., 2003, pp. 30–41.

[4] S. Jain, R. C. Shah, W. Brunette, G. Borriello, and S. Roy, “Exploiting mobility for energy efficient data collection in wireless sensor networks”. Norwell, MA: Kluwer, 2005.

[5] D. Jea, A. A. Somasundara, and M. B. Srivastava, “Multiple controlled mobile elements (data mules) for data collection in sensor networks,” inProc. IEEE/ACM Int. Conf. DCOSS, Jun. 2005, pp. 244–257.

[6] J. Luo and J.-P. Hubaux, “Joint mobility and routing for lifetime elongation in wireless sensor networks,” in Proc. IEEE INFOCOM, 2005, pp. 1735–1746.

[7] A. Kansal, A. Somasundara, D. Jea, M. Srivastava, and D. Estrin, "Intelligent fluid infrastructure for embedded networks," in Proc. ACM MobiSys, 2004, pp. 111–124.
[8] W. Liang, P. Schweitzer, and Z. Xu, "Approximation algorithms for capacitated minimum forest problems in wireless sensor networks with a mobile sink," IEEE Trans. Comput., to be published.
[9] F. Bai, K. S. Munasinghe, and A. Jamalipour, "A novel information acquisition technique for mobile-assisted wireless sensor networks," IEEE Trans. Veh. Technol., vol. 61, no. 4, pp. 1752–1761, May 2012.
[10] Vasilescu, K. Kotay, D. Rus, M. Dunbabin, and P. Corke, "Data collection, storage and retrieval with an underwater sensor network," in Proc.ACM SenSys, 2005, pp. 154– 165.
[11] A. Somasundara, A. Ramamoorthy, and M. B. Srivastava, "Mobile element scheduling for efficient data collection in wireless sensor networks with dynamic deadlines," in Proc. IEEE RTSS, Dec. 2004, pp. 296–305.
[12] Chongqing Zhang , Binguo wang , Shen Fang , Zhe Li , " Clustering Algorithms for wireless sensor networks using spatial data correlation ", International conference on information and Automation , pp-53-58 ,june 2008.
[13] Zhikui chen , Song Yang , Liang Li and Zhijiang Xie , " A clustering Approximation Mechinism based on Data Spatial Correlation in Wireless sensor Networks ", Proceedings of the 9th international conferenses on wireless telecommunication symposium -2010.
[14] S. Basagni, A. Carosi, and C. Petrioli, "Controlled vs. Uncontrolled mobility in wireless sensor networks: some performance insights," Proc. IEEE Vehicular Technology Conference (VETECF'07 Fall), Mar. 2007, pp. 269–273, doi:10.1109/VETECF.2007.70.
[15] R. C. Shah, S. Roy, S. Jain, and W. Brunette, "Data MULEs: modeling a three-tier architecture for sparse sensor networks," Proc. IEEE Workshop on Sensor Network Protocols and Applications (SNPA'03), IEEE Press, May 2003, pp. 30–41, doi:10.1109/SNPA.2003.1203354.
[16] T. Chen, T. Chen, and P. Wu, "Data collection in wireless sensor networks assisted by mobile collector," Proc. IFIP Wireless Days (WD'08), IEEE Press, Nov. 2008, pp. 1–5, doi:10.1109/WD.2008.4812895.
[17] M. Zhao and Y. Yang, "Data gathering in wireless sensor networks with multiple mobile collectors and SDMA technique sensor networks," Proc. IEEE Wireless Communications and Networking Conference (WCNC'10), IEEE Press, Apr. 2010, pp. 1–6, doi: 10.1109/WCNC.2010.5506199.
[18] H. Jun, W. Zhao, M. H. Ammar, E. W. Zegura, and C. Lee, "Trading latency for energy in densely deployed wireless ad hoc networks using message ferrying," Ad Hoc Netw., vol. 5, no. 4, May 2007, pp. 444–461, doi:10.1016/j.adhoc.2006.02.001.
[19] G. Anastasi, M. Conti, E. Gregori, C. Spagoni, and G. Valente, "Motes sensor networks in dynamic scenarios: an experimental study for pervasive applications in urban environments," International Journal of Ubiquitous Computing and Intelligence, vol. 1, no. 1, Apr. 2007, pp. 9–16, doi:10.1166/juci.2007.002.
[20] A. Kansal, A. A. Somasundara, D. D. Jea, M. B. Srivastava, and D. Estrin, "Intelligent fluid infrastructure for embedded networks," Proc. International Conference on Mobile Systems, Applications, and Services (MobiSys '04), ACM, 2004, pp. 111–124,doi:10.1145/990064.990080.
[21] S. Gao, H. Zhang, and S. K. Das, "Efficient data collection in wireless sensor networks with path-constrained mobile sinks," IEEE Transactions on Mobile Computing, vol. 10, no. 4, Apr. 2011, pp. 592 –608, doi:10.1109/TMC.2010.193.
[22] A. Somasundara, A. Kansal, D. D. Jea, D. Estrin, and M. B. Srivastava, "Controllably mobile infrastructure for low energy embedded networks," IEEE Trans. Mobile Computing, vol. 5, no. 8, Aug. 2006, pp. 958–973, doi:10.1109/TMC.2006.109.
[23] Salarian, H.; Chin, K.; Naghdy, F. An energy efficient mobile sink path selection strategy for wireless sensor networks. IEEE Trans. Veh. Technol. 2014, 63, 2407–2419.
[24] Konstantopoulos, C.; Pantziou, G.; Vathis, N.; Nakos, V.; Gavalas, D. Efficient mobile sink-based data gathering in wireless sensor networks with guaranteed delay. In Proceedings of the 12th ACM international symposium on mobility management and wireless access (MOBIWAC 2014), Montreal, QC, Canada, 21–26 September 2014; pp. 47–54.
[25] Somasundara, A.; Ramamoorthy, A.; Srivastava, M. Mobile Element Scheduling for Efficient Data Collection in Wireless Sensor Networks with Dynamic Deadlines. In Proceedings of the 25th IEEE International Real-Time Systems Symposium, Lisbon, Portugal, 5–8 December 2004; pp. 296–305.
[26] Gu, Y.; Bozdag, D.; Brewer, R.; Ekici, E. Data Harvesting with Mobile Elements in Wireless Sensor Networks. Comput. Netw. 2006, 50, 3449–3465.
[27] Chen, T.-C.; Chen, T.-S.; Wu, P.-W. Data collection in wireless sensor networks assisted by mobile collector. In Proceedings of the 1st IFIP Wireless Days, Dubai, United Arab Emirates, 24–27 November 2008; pp. 1–5.
[28] Liang, H.; Zhuang, Y.; Pan, J.; Xu, J. Evaluating on-demand data collection with mobile elements in wireless sensor networks. In Proceeding of the 2010 IEEE 72nd Vehicular Technology Conference Fall (VTC 2010-Fall), Ottawa, ON, Canada, 6–9 September 2010; pp. 1–5.
[29] Jawhar, I.; Ammar, M.; Zhang, S.; Wu, J.; Mohamed, N. Ferry-based linear wireless sensor networks. In Proceedings of the 2013 IEEE Global Communications Conference (GLOBECOM), Atlanta, GA, USA, 9–13 December 2013; pp. 304–309.
[30] Alnuaimi, M.; Shuaib, K.; Alnuaimi, K.; Abdel-Hafez, M. Performance analysis of clustering protocols in WSN. In Proceedings of IFIP/IEEE WMNC2013, Dubai, United Arab Emirates, 22–24 April 2013.
[31] Anastasi, G.; Conti, M.; di Francesco, M.; Passarella, A. Energy conservation in wireless sensor networks: A survey. Ad Hoc Netw. 2009, 7, 537–568.
[32] Raghunathan, V.; Ganeriwal, S.; Srivastava, M. Emerging Techniques for Long Lived Wireless Sensor Networks. IEEE Commun. Mag. 2006, 44, 108–114.

