Precision Crop Protection Using Wireless Sensor Network

R. Radha[1](✉), Amit Kumar Tyagi[2], K. Kathiravan[3], and G. Staflin Betzy[3]

[1] Department of CSE, Koneru Lakshmaiah Education Foundation, Vaddeswaram, A.P., India
radhupriya@yahoo.co.in

[2] Lingayas Vidyapeeth, Faridabad, Haryana, India
amitkrtyagi025@gmail.com

[3] Department of Information Technology, Easwari Engineering College, Chennai, India
kathirraji@gmail.com, betzy.george93@gmail.com

Abstract. The Wireless Sensor Network (WSN) is a widely developing field which provides many solutions to real-world problems (in various aspects of life). In this paper, monitoring process of the agricultural field by the sensor nodes has been discussed. The sensor node continuously monitors the crop and collects the data, then passes it to the Base station with the help of the Cluster Head (CH). The Cluster head is responsible to collect all the data from the sensor nodes. Collected data passes through multiple cluster heads to reach destination and we create topology among the cluster heads with the help of location information passed by every cluster head along with the data. If more number of shortest paths in the network passes through a cluster head and if it is an Articulation Point (AP) then there is a risk of network partition. So the articulation point must be less in the network, at the same time the between-ness centrality of the cluster head must be more. If cluster head is an articulation point then there will be a huge network failure. To overcome this problem, the cluster head has to be changed dynamically by finding the next between-ness centrality in the cluster region of a network. By using this mechanism, the energy consumption of the network can be reduced, the lifetime of the node can be increased, and the clustering efficiency and throughput is also comparatively increased.

Keywords: Location aware routing · Articulation point · Between-ness centrality · Cluster head

1 Introduction

Today's Wireless Sensor Network (WSN) plays a vital role in the field of agriculture. It is one of the major technologies which are widely used to improve the crop productivity and quality at the lowest cost. A wireless sensor network in an agricultural environment comprises integrated sensors deployed in the area of the farm land. These sensors cooperate with each other to perceive and monitor real-time soil and weather information. Continuous monitoring of the environment is essential to know the status

A. Abraham et al. (Eds.): ISDA 2018, AISC 940, pp. 280–290, 2020.
https://doi.org/10.1007/978-3-030-16657-1_26

or condition of the environment. The monitoring process of the WSN is an important part with which one can get a continuous update of the entire scenario of the application. From the hardware part of the WSN nodes, this work includes all senses environmental conditions to the software interface that displays the monitored data. This monitoring process helps more in the applications such as air pollution monitoring, industrial sewage monitoring, agricultural field monitoring, etc. In this case, for example, an agriculture field has to be monitored in order to help the crop for its healthy growth. The nutrient content of the crop such as water, minerals, soil texture, temperature, micro and macro nutrients is monitored so that the farmers can have a regular update of the crop's conditions and will be able to help the crop to grow in a fertilized manner.

Here, in the monitoring process of the agriculture field, the hardware part of the wireless sensor networks such as the sensor nodes or motes plays an important work of sensing the crop's condition. The sensor nodes are randomly distributed in a field that continuously receives the information from the crop, as the sensors are distributed in a form of clusters, the cluster heads are assigned to each and every region of clusters. In the existing system, the Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol is used to collect the data from the nodes. The Cluster Heads (CH) are responsible to collect the data from the sensor nodes and then it aggregates those data into a single signal to pass the data to the sink. In this process, if a sensor node fails to send the monitored data to the cluster head due to the presence of the articulation points in the network, which will cause network partition and through which the data will not be able to pass on to the farmer. This may mislead the farmer to be ignorant of the issue that has been caused in the particular region and without the knowledge of the farmer, the crops which are planted in that particular area are lost without any proper nutrition.

Hence, remaining of this work is followed as: Sect. 2 discusses literature related to this work. Section 3 discusses our proposed work with topology construction and about needs of articulation point. Then, Sect. 4 discusses the process of cluster head changing. Further Sect. 5 discusses simulation parameters with results and in last, we conclude this work in Sect. 6 in brief.

2 Literature Survey

In the past decade, several researchers have given/discussed their ideas regarding crop protection using several approaches. Abouzar et al. [1] proposed RSSI-based distributed Bayesian localization algorithm based on message passing to solve the approximate inference problem in the sensor networks. But it fails due to require high power efficiency, high computational scalability. Further in [2], Ssu et al. proposed a range-free localization scheme (work with mobile anchor points). Each anchor points equipped with the Global Positioning System (GPS) moves by the sensing field and broadcasts its current position periodically. But it fails due to privacy issues. Further, Chen et al. [3] proposed an analytic localization algorithm via utilizing radical centers. But this scheme also does not work efficiently due to high overhead. Together this in [4], Mahlein et al. proposed a technique, i.e., in this near-range and remote sensing techniques have demonstrated a high potential in detecting diseases and in monitoring crop stands for sub-areas with infected plants. But unfortunately, this technique also fails due to scalability issues.

Later in [5], Han et al. proposed that if the users cannot obtain the accurate location information; the related applications cannot be accomplished. The main idea in most localization methods is that some deployed nodes (landmarks) with known coordinates. The localization algorithms (are two types, i.e., Range-based and Range-free) does not work efficiently due to having high number of unknown nodes in its process. Further, Anisi et al. [6] discussed the energy consumption of the sensor nodes as the main issue. The aim of this paper is to classify and describe the state-of-the-art of WSNs and analyze their energy consumption based on their power sources. This work also fails due to its direct impact on the lifetime of the network. Further in [7], Santos et al. proposed an approach using wireless sensor networks and control system for crop spraying. Through computer simulations, wireless sensor networks is shown to be useful in crop spraying operation to minimize and to control pesticide drift, to improve the quality of application, to reduce environmental contamination and to save time and money. Further, Qing et al. [8] proposed a new distributed energy-efficient clustering scheme for heterogeneous wireless sensor networks (known as DEEC). The simulation results show that DEEC achieves longer lifetime and more effective messages than current important clustering protocols in heterogeneous environments. But, this scheme also fails due to having longer lifetime of nodes.

In [9], Krishnamachari et al. also proposed an approach, i.e., autonomous systems with severe energy constraints (wireless sensor networks are often unattended) and low-end individual nodes with limited reliability. Theoretical analysis and simulation results show that 85–95% of faults can be corrected using this algorithm, even when as many as 10% of the nodes are faulty (a weakness). Further in [10], Rault et al. presented a top-down survey of the trade-offs between application requirements and lifetime extension that arise when designing wireless sensor networks. Further, Sibley et al. [11] presented an extensive field-scale validation testing of the system's Nitrate Extraction and Measurement Sub-Unit (NEMS) in two crop (wheat and carrot) production systems. This approach was not more useful due to its lengthy process. He et al. [12] presents APIT, a novel localization algorithm that is range-free. This scheme performs better when an irregular radial pattern and random node placement are considered. This scheme requires low communications overhead, but could not achieve. Further, Hong et al. [13] discussed a localization algorithm necessary for building small-sized network's position reporting system using wireless sensor network. Unfortunate, this scheme also fails due to having static nature of (using) sensor nodes. Further, Jiang et al. [14] discussed about the monitoring system of an orchid industry (established in Taiwan) which produce large-scale orchid greenhouses to achieve high-precision cultivation of orchids (especially for Phalaenopsis). Wireless Sensor Network (WSN) is an important technology for effectively acquiring environmental parameters (in real-time). However in this, the mobile benches equipped with different sensors used in an orchid greenhouse create a problem of susceptible dynamic network topology. In last in [15] Karbasi et al., the problem of localizing wireless devices (in an ad- hoc network) embedded in a dimensional Euclidean space is considered. But when the positions of the devices are unknown and only local distance information is given, we need to infer the positions from these local distance measurements. This problem is particularly challenging when we only have access to measurements that have limited accuracy and are incomplete.

Hence from above literature, we reached to a conclusion that no approach provides sufficient results. Now next section will discuss our purposed work in detail.

3 Proposed System

In order to protect the crop from such issues and problems certain measures has to be taken in such a way that the crops are monitored without any interruption of the articulation point in the network. For this issue, first and foremost using an existing protocol the sink node constructs a topology of an undirected graph and finds the position of all the nodes that are randomly distributed, then it also checks whether if this articulation node exists in the network or not. If yes, then number of data packets forwarded through the articulation node to the sink node. According to the identified articulation points the cluster heads can be changed dynamically. Secondly, using an existing algorithm for the articulation point of the distributed sensor nodes, the evaluation can be obtained from the between-ness of all the neighboring nodes. Here, the shortest path from one vertex of the node to all the other nodes is determined by broadcasting a request packet from source to destination. If the entire shortest path passes through the same edge then it is clear that it is the center node of the network where all the data packets are transmitted to the sink. The center node can also be the Cluster Head (CH), if in case all the data packets are overloaded in the center node. Then next center node can be determined by finding the shortest path as before. Thirdly the cluster head can be changed dynamically with the help of the matrix generated by the previous graph, i.e., drawn. The centrality of the cluster head is determined by calculating the between-ness of the each node in the graph. By evaluating all the centrality of the node in the shortest path of the entire graph, the cluster head can be changed automatically when it faces overload of data packets or if the energy goes low.

3.1 Topology Construction

Topology construction is a mechanism which helps the wireless sensor networks to increase its lifetime and to conserve the energy of the each sensor node. The topology of a sensor network has to be constructed in such a way that the sensor nodes do not face any overheads. Then each node will know its nearby node's position, the same way the next hop node will know its surrounding node positions. For example, consider the undirected graph given below.

The node A knows the position of its neighboring node B and C which are directly connected to it, then the B node knows the position of its surrounded neighboring node D and F. Now the node D will know it's surrounded neighboring nodes B, C, F and G as shown in Fig. 1. The graph is constructed by passing the request message to the destination node as explained in Algorithm 1. The destination node will receive the request message from all the directions of the neighboring nodes. The destination node will wait for certain period of time, until it receives all the request messages. Once the destination receives the request message, it finds the shortest path to the source node in order to send the response message back to the source node. Using these request and response messages the graph is constructed to help the nodes to communicate with the cluster head.

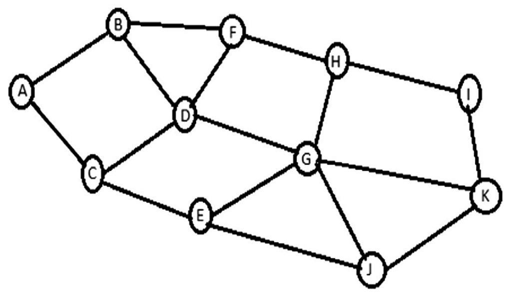

Fig. 1. Topology construction

Algorithm 1: Algorithm for Topology Construction

Step 1: Request packet is broadcasted to all the sensors in the region
RREQ => Broadcast (ID, IP address)
Step 2: The location of each node is identified
Step 3: Once all the request packets reach the destination node, it broadcasts the response packet back to the source node.
RREP => Reverse path (ID, IP address)
Step 4: Based on the RREQ and RREP the topology is constructed.

3.2 Finding Articulation Point (AP)

Once, after the topology of the sensor network is constructed, the articulation points in the network should be identified.

The articulation point is a vertex in the undirected graph that connects the graph mostly at the center part. If this vertex is removed or any failure occurs, there may be a loss of connectivity within the nodes that are directly connected to it. This may cause network partition of the topology constructed. Due to the network partition, the one end of the sensors will not be able to communicate with the other end of the sensors in the region. Using the existing Depth First Search (DFS) algorithm the articulation point is determined as in Fig. 2, the number of shortest paths in the graph is identified, and then the centrality of the each node is examined. The point in the network, which has number of edges passing through the same center point, will be an articulation point or the critical node. All possible shortest paths in the network are identified, then the total number of shortest paths can be determined. After determining the total number of shortest paths, the edges of the each node in the network is evaluated. The between-ness among the nodes in the shortest path is evaluated, i.e., the number of data transmission that passes through the same particular shortest path can be identified. Based on this evaluation the articulation point is determined. The destination node in an adjacency matrix collects the node and edge details of the graph.

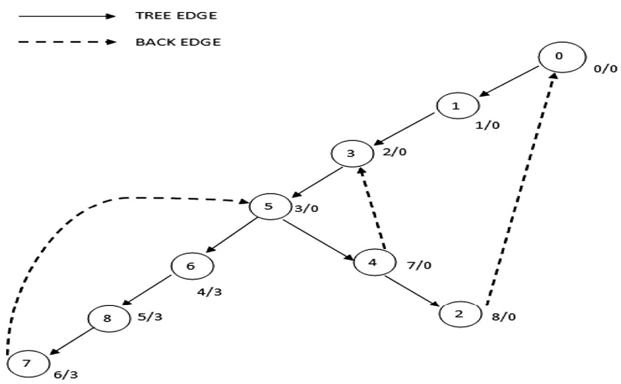

Fig. 2. Finding articulation point using a graph

The graph shows the nodes in a particular cluster region. The articulation point in this graph is found using DFS algorithm with certain conditions such as:

i. The root is an articulation point if and only if it has more than one child.
ii. Any other vertex v is an articulation point if and only if v has some child w such that $low(w) \geq num(v)$.

Here, for node 5, num(v) is 3 and low(w) is 3 which satisfies the condition, $\boldsymbol{low(w) \geq num(v)}$**.** Therefore, **node 5** is an articulation point.

4 Cluster Head Changing

Cluster Head is an important node in each cluster region. The Cluster Head communicates with each and every node in the cluster. CH is responsible for all the nodes in the cluster, so it sends and receives information from each node. It works as a temporary base station in the cluster region, once after it collects the data from the nodes, it sends those data to the sink node. In this process, if the Cluster Head is an articulation point, then it would be at a risk of network partition.

In order to overcome this problem the cluster head has to be changed dynamically using the method of between-ness centrality which is explained in algortihm 2 as in Fig. 3. Between-ness centrality is the measure that determines the vertices in the network that lies in the path of the other vertices. Note that the cluster head must have the

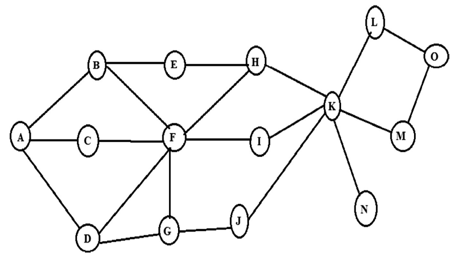

Fig. 3. Dynamic changes of cluster head

higher between-ness centrality. So it will be easy for the other cluster members to communicate with the cluster head. The between-ness centrality of the node is measured using the expression:

$$\mathbf{g(v)} = \sum\nolimits_{s \neq v \neq t} \boldsymbol{\sigma st}(\boldsymbol{v}) \ / \ \boldsymbol{\sigma st}$$

Where $\boldsymbol{\sigma st}$ is the total number of shortest path from the source $\boldsymbol{s}$ to destination $\boldsymbol{t}$**.** And $\boldsymbol{\sigma st}(\boldsymbol{v})$ is the number of paths which passes through the node $\boldsymbol{v}$**.**

Algorithm 2: Algorithm for Dynamic change of Cluster Head

Step 1: Find the between-ness of articulation when the current node is the destination,

Step 2: If the number of nodes uses the same edge to transmit the data packets and if it is an articulation point, change the cluster head or else do not change,

Step 3: To change the cluster head, find out the node which has, the more between-ness centrality excluding the articulation point.

If (BC = AP = 1)
{ "Change Cluster Head" }
Else If (BC = AP ≠ 1) {
"Don't Change Cluster Head" }

Where BC is Between-ness Centrality and AP is Articulation Point.

Step 4: If the cluster head is a destination node, it will be easy for all the nodes to send the data packets.

Step 5: The destination node must not be an articulation point, so the cluster head must be changed dynamically by finding out all the possibility of between-ness centrality in the network.

Hence this section discussed essential work like cluster node changing, etc. needed for our proposed work. Now next section will deal with simulation results.

5 Simulation Parameters and Results

The simulation of this work is carried out with the NS-2 simulator (an open-source simulation tool). The parameters for the simulation are taken as a sample for analyzing the energy consumption of the network to get the throughput of the existing and the proposed system.

The energy parameter is measured using the unit of Joules (J). Each node is measured to determine the energy consumed by them in the network. The same way the clustering efficiency is also determined to know the efficiency of clustering the each region in the network. The efficiency of clustering is measured between the existing and the proposed system. The articulation point is determined by generating the node positions and their required values with the help of NSG 2.1. The parameters (listed in Table 1) are used to get the simulation results more accurately/ performance evaluation of our proposed system.

Table 1. Simulation parameters

Parameters	Values
Simulation Round	500
Network Size	100 × 100
Number of nodes	350
Initial node power	0.5 J
Nodes Distribution	Uniform Distribution
Data Packet size	4000 bits
Energy dissipation (Efs)	10 * 0.000000000001 J
Energy for Transmission (ETX)	50 * 0.000000000001 J
Energy for Reception (ERX)	50 * 0.000000000001 J

5.1 Energy Consumption of Node

The energy consumption is the amount of energy that is consumed during any process of mechanism; the energy may be of any kind in the system. Here in this work, the energy is considered from the number of nodes present in the region of each cluster. The graph is plotted in order to measure the energy consumption of each node in the network. Using approximately 350 nodes for sample analysis, Fig. 4 shows that our proposed approach is more energy saving in compare to existing approaches.

5.2 Clustering Efficiency

Clustering is the process of grouping the objects of the same or similar kind. The efficiency of clustering in the network is determined by the number of sensors in the network. Hence, our approach shows high clustering efficiency in compared to existing approaches as represented in Fig. 5.

5.3 Draining Speed

Due to the energy consumption of the nodes in the network and the task performed by the nodes, the energy of the each sensor drains faster. This draining speed in the network is calculated by the number of sensors present in the network. Figure 6 shows that our proposed approach achieves low draining speed with comparing of existing approaches.

5.4 Evaluation of Alive Node Count

The number of alive nodes is counted based on the number of nodes present in the network. During the transformation of the data between nodes, it is necessary to check whether the node is alive or not. The nodes which are alive send messages to the neighboring nodes to intimate that it is still alive. Figure 7 shows that in our proposed approach, alive node count is more efficient when compared to the existing system. The alive node count is accurate.

5.5 Network Life (with respect to time)

Network Life-time is an important component for a network. If the life of a network is more, it will be highly reliable and will also have good performance level. Figure 8 shows that the network life-time for our proposed approach is more when compared to the existing approaches.

5.6 Throughput Evaluation

The throughput is a measure of the transmitting rate of data from the source to the direction. Figure 9 shows that our proposed approach achieves a higher throughput than existing approaches. Hence, this section provides several results (in detail) with discussing several parameters used in our proposed work. Now next section will conclude this work in brief with some future enhancement.

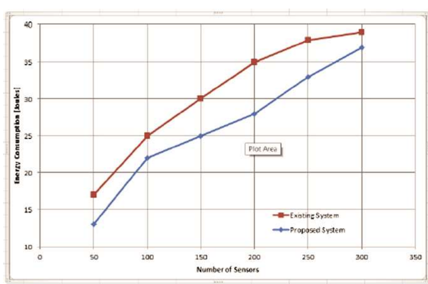

Fig. 4. Measure of energy consumption

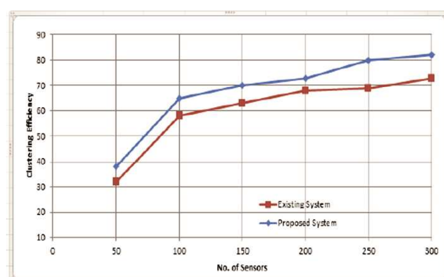

Fig. 5. Measure of clustering efficiency

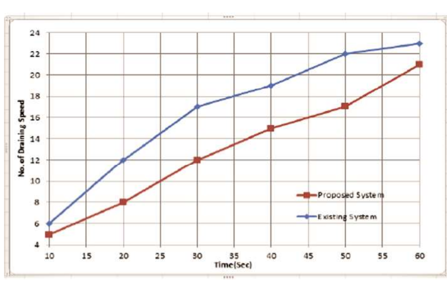

Fig. 6. Draining speed evaluation

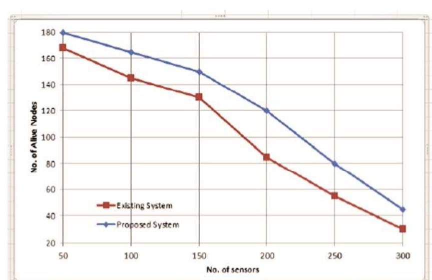

Fig. 7. Evaluations of alive nodes

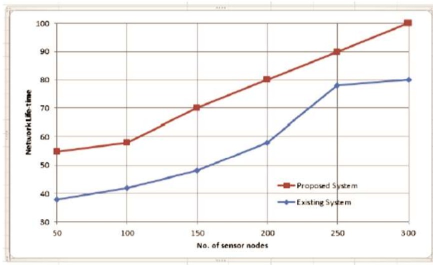

Fig. 8. Network life-time

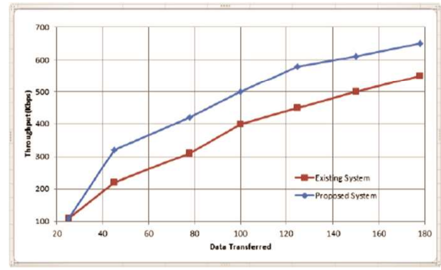

Fig. 9. Throughput evaluation

6 Conclusion and Future Work

This work constructs a topology to reduce the energy consumption and to improve the capacity of the sensors. The articulation points in the network are determined in order to prevent the network partition, and then the between-ness centrality of the network is determined. Finally, the Cluster Head (CH) of the each cluster region is changed dynamically to overcome the problem of network partition. Also our proposed approach reduces the energy consumption, including improves the clustering efficiency, life-time, and throughput of the network. The future work can be considered in certain issues such as reducing the draining speed of the nodes in the network; also can consider improving the throughput ratio even more.

References

1. Abouzar, P., Michelson, D.G., Hamdi, M.: RSSI-based distributed self-localization for wireless sensor networks used in precision agriculture. IEEE (2016). https://doi.org/10.1109/twc.2016.2586844
2. Ssu, K.-F., Ou, C.-H., Jiau, H.C.: Localization with mobile anchor points in wireless sensor networks. IEEE Trans. Veh. Technol. **54**(3), 1187–1197 (2005)
3. Chen, Y.-C., Deng, D.-J., Chen, Y.-S.: Localization Algorithm for Wireless Sensor Networks. Springer, New York (2014)
4. Mahlein, A.-K., Oerke, E.-C., Steiner, U., Dehne, H.-W.: Recent advances in sensing plant diseases for precision crop protection. Springer (2011)
5. Han, G., Xu, H., Duong, T.Q., Jiang, J., Hara, T.: Localization algorithms of wireless sensor networks: a survey. Springer (2011)
6. Anisi, M.H., Abdul-Salaam, G., Abdullah, A.H.: A survey of wireless sensor network approaches and their energy consumption for monitoring farm fields in precision agriculture. Springer (2014)
7. Santos, I.M., da Costa, F.G., Cugnasca, C.E., Ueyama, J.: Computational simulation of wireless sensor networks for pesticide drift control. Springer (2014)
8. Qing, L., Zhu, Q., Wang, M.: Design of a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks (2006). https://doi.org/10.1016/j.comcom.2006.02.017

9. Krishnamachari, B., Iyengar, S.: Distributed Bayesian algorithms for fault-tolerant event region detection in wireless sensor networks. IEEE Trans. Comput. **53**(3), 241–250 (2004)
10. Rault, T., Bouabdallah, A., Challal, Y.: Energy efficiency in wireless sensor networks: A top-down survey. Elsevier (2014)
11. Sibley, K.J., Astatkie, T., Brewster, G., Struik, P.C., Adsett, J.F., Pruski, K.: Field-scale validation of an automated soil nitrate extraction and measurement system. Springer (2008)
12. He, T., Huang, C., Blum, B.M., Stankovic, J.A., Abdelzaher, T.: Range-Free Localization Schemes for Large Scale Sensor Networks. ACM, San Diego (2003)
13. Hong, S.-H., Kim, B.-K., Eom, D.-S.: Localization algorithm in wireless sensor networks with network mobility. IEEE Trans. Consum. Electron. **55**(4), 1921–1928 (2009)
14. Jiang, J.-A., Wang, C.-H., Liao, M.-S., Zheng, X.-Y., Liu, J.-H., Chuang, C.-L., Hung, C.-L., Chen, C.-P.: A wireless sensor network-based monitoring system with dynamic converge cast tree algorithm for precision cultivation management in orchid greenhouses. Springer (2016)
15. Karbasi, A., Oh, S.: Robust localization from incomplete local information. IEEE/ ACM Trans. Networking **21**(4), 1131–1144 (2013)