International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 7 (2018) pp. 4702-4707

Virtual Tier structured Grid based Dynamic Route Adjustment scheme for mobile sink based Wireless Sensor Networks (VTGDRA)

Gaurav Bathla, Rajneesh Randhawa

Department of Computer Science, Punjabi University, Patiala, Punjab, India.

Abstract

Wireless sensor network is one of the emerging fields from past decade for environment sensing and reporting. WSN is expected to be integrated into Internet of Things (IoT) in future trends. Transmission of the aggregated sensed data to Base Station (BS) is termed as routing. This transmission of data is based on limited energy capacity nodes which can neither be charged nor be replaced. So efficient routing scheme is required to be designed which consumes less energy. The sensed data is required to be sent to sink. Sink mobility across the network can be considered as fine strategy to balance the load on the nodes of the network. Proposed scheme virtually divides the network area into four isolated regions (Grids), where each Grid in turn further divided into three tiers based on the distance from the center part of that Grid. After forming the minimum spanning tree among nodes of each Grid, data of each Grid is transmitted to mobile sink node. Proposed scheme proves to have better lifetime with less reconstruction cost than existing techniques.

Keywords: Routing, Grid, minimum spanning tree, Wireless Sensor Networks, WSN.

INTRODUCTION

Wireless Sensor Network (WSN) is a network consists of a large number of Nodes. These sensor nodes (SN) are distributed in some geographical area. WSN's are used where person cannot interfere in the area of interest. Nodes are deployed in hazardous places, flood effective regions, underwater environments [1]. So, in such unreachable area [2] it is also very difficult to deploy the nodes.

In WSN, sensor nodes have limited processing power, communication bandwidth, and storage space. These nodes are equipped with non-chargeable & irreplaceable battery source.

Routing is the main concern which can increase the lifetime of the network [3]. Various techniques have been developed since last decades to find out the ways to increase the lifetime of the network. Among all these techniques clustering is found to be the most effective technique to increase lifetime along with lowering the propagation delay. Various Clustering algorithms are classified based on different criteria to effectively utilise this energy. Among that major criterion are cluster head selections, cluster head properties, clustering process [4, 5, 6].

Clustering technique works by forming the cluster of nodes then identify a cluster head. All sensor nodes needs to send data to the respective CH, which further aggregates [7, 8] the data and send it to the base station or the sink node. In this fashion, all nodes can save their energy by sending data to a lower distance.

Cluster head selection is based on either the probability factor or on remaining energy of the node. In case of probabilistic election, role of CH is to be rotated after each round otherwise node with highest residual energy is elected as CH. Among proposed techniques, lowering the energy consumption is the major task to tackle. Prime objective is to increase the network lifetime by decreasing the energy consumption.

In this paper, a technique based on creating a Grid & then portioning Grid in tiers is proposed and evaluated. This algorithm is divided into three steps Grid formation and partitioning Grid into tiers (static), Grid head selection (dynamic), and routing.

Grid head is selected based on residual energy of the nodes. Node with highest residual energy in top most tier is used to aggregate & transmit data to mobile sink.

The other sections of paper are divided as follows; the next section presents work done so far in the relevant field. The section following the second one proposes VTGDRA scheme about forming the network and data transmission model along with algorithmic routines. The fourth section is the simulation environment and result comparison with existing techniques. The fifth section concludes the paper.

RELATED WORK

Extensive research is going to improve network lifetime for wireless sensor networks. Lifetime can be improved by well designing routing techniques. Data dissemination is done in the network and same can be energy efficient by making the sink node mobile. As sink node moves around the periphery, nearest Grid will transmit the data to sink node. Mobility of sink will save energy of the nodes and can be controlled or uncontrolled. In controlled mobility [9-12], speed and direction of the sink is managed by external observer or as per network dynamics. This paper considers controlled mobility of the sink with a particular speed around the periphery. Subsequent paragraphs highlight some of the existing work done in the relevant field.

Backbone base virtual Infrastructure (BVI) proposed by oh et al. [13] disseminates data in multi hops. It uses HEED [14] for clustering & tries to minimize the number of clusters. One cluster head (CH) is used to keep track the location of mobile sink. Mobile sink registers itself to the CH via agent node.

Whenever mobile sink moves in the cluster; it is the responsibility of CH only to establish a connection with the sink. Root node being frequently used for route adjustment drains out much faster compared with rest of the nodes.

HexDD[15] (Hexagonal cell-based Data Dissemination), creates hexagonal grid structure to transmit data to multiple mobile sinks. Sink data query will be replied by the nodes in center of the cell. When query reaches to the cell with relevant data, reverse path is adopted for sending reply to the sink node. Sink movement is informed to centre as well as border nodes along with routing information. This information causes high energy loss especially when sink is moving at high speed.

Authors in [16] proposed a circular cluster based routing technique VCCSR (virtual circle combined straight routing) in which mobile sink circulates in the sensor field. This mobile sink communicates with cluster head nodes present at the border leading short distance communication & transmission of network data to sink at lower cost. Although this scheme reduces route reconstruction cost but unable to distribute load evenly on nodes of the network.

MESS [17], is based on pacing heterogeneous nodes in terms of storage at equal distances in the field of interest. Mobile sink passes a query message to the nodes in the network by flooding approach. Appropriate nodes containing the reply packet to the query revert to mobile sink. Similar approaches were also defined in [18, 19] for data collection by mobile sink. They were also relying on frequently used nodes which in turn drain out much faster.

Quadtree data dissemination [20], divides the network area into four quadrants. it defines few set of Rendezvous Points (RP) for data collection which are near to centroid of quadrant. Mobile sink collects data from RP. These RP's being most frequently nodes so depletes much faster, resulting in shorter network lifetime.

TTDD [21] also constructs virtual grid structure in which mobile sink disseminates the query packet & that is reverted by the sensor node. GCA [22] proposed hexagonal cellular based structure for handling sink mobility. It prevents flooding of packets for sink location information. Header nodes communicate with mobile sink for query reply. However due to expiry of time to live value of packets there is increase in latency & number of dropped packets.

VGDRA [23] was the Grid structure routing protocol which divides the network in virtual grids based on number of nodes in the network. CH in every cluster transmits data in chain based approach to mobile sink via another CH. It tries to minimize the packet transmission for sink location update by sending packets to selected CHs only.

MVGDRA proposed on [24] is also mobile sink based virtual grid routing scheme based on [23]. This scheme selects cluster head on the basis of remaining energy of the nodes. Nodes with highest energy were appointed as CH & transmit data only based on occurrence of event (event driven approach).

VTGDRA SCHEME

This section discusses the construction of Virtual grid environment for the proposed scheme which is based on virtually dividing the network region into several square shaped regions (Grids) based on number of nodes present in the region. This scheme is inherent from [23] with some changes for computation of number of Grids. Numbers of Grids (K) to be formed are calculated as given in equation

$$z=n/K \qquad \text{-------(1)}$$

Where, n is the number of deployed nodes, $12 \leq z \leq 25$.

This variation is just because one cannot adhere to condition for 4 Grids for 100 nodes & 9 Grids for 101 nodes. Value of z can be set as per the requirement in the application scenario. The construction of VTGDRA is shown in figure1.

Grid Head Rotation: Grid head is selected based on the energy of the node & tier number. Node with highest energy in the tier1 is selected as head node that will transmit the aggregated data to Mobile sink node. This role of Grid Head is on rotation basis. As this head node depletes energy below threshold, role of head is assigned to other node in same tier (if available), otherwise to a node in next tier. This process of rotation is repeated to distribute load evenly to all nodes in the network. When all nodes deplete energy below threshold, new threshold is defined & same process is repeated for Grid Head rotation.

Sink Detection: Sink node, being resource opulence node, is considered to move around the periphery of the region of interest. Each head node will transmit the data to mobile sink when sink is near to boundary of the region. About sharing the location of mobile sink, TDMA schedule is shared among all the nodes of the network. As the sink approaches near to the grid, data of the concerned grid is aggregated and transmitted by Grid Head to Sink.

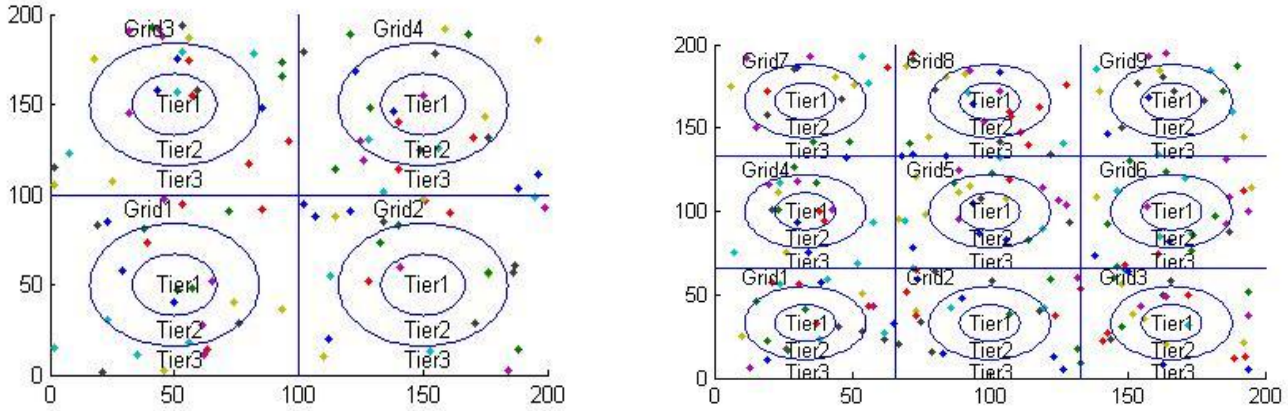

Figure 1. Virtual Grid Structure for different number of nodes (a) 100 nodes (b) 200 nodes

Network Model and characteristics

This section provides detail of network structure, radio model, Network Characteristics and algorithms of the proposed technique.

Network Structure

Network structure illustrates the arrangement of the nodes in the network. Proposed scheme divides the network in virtual partitions based on equation (1). Based on number of nodes, grids are formed for the network region as shown in figure 1. After forming the clusters, nodes in each cluster are connected in form of minimum spanning tree. This scenario is shown in figure 2. Each Grid contains one head node which aggregates & transmits data of the network to mobile sink node. The process of data transmission is explained in Algorithm section.

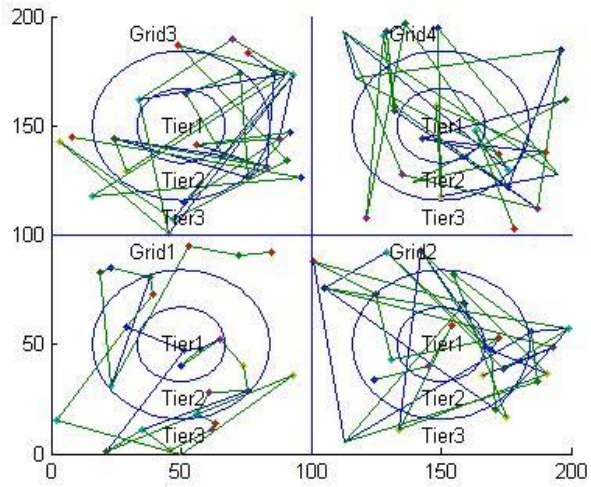

Figure 2. Data gathering in individual Grids

Radio Model

For simulation of proposed technique, first order radio model is considered consisting of transmission, receiving cost over the distance d for the packet of size k is referred from [25]. The radio has power control & energy dissipation can be set as per requirement. The amplification energy can be set depending on the distance between the communicating nodes. The radios can be turned off to save battery power and to avoid receiving of unintended transmissions.

Network Characteristics

i. All nodes are randomly deployed in the area of interest.
ii. Network area (Grid) is equally partitioned based on the number of nodes as per the detail.
iii. Nodes in each Grid are isolated from nodes of other Grid.
iv. Each node is linked with one Grid only and remains static after deployment.
v. In each Grid, nodes are divided into different tiers based on the distance from central part of the Grid.
vi. Each node is capable of transmitting data to any other node in the network.
vii. Each node is aware of its location in the field.
viii. Sink will keep on moving at periphery of the network at a constant speed. Nodes of the network transmit data to BS as per TDMA schedule.
ix. All nodes of a Grid are connected in form of Minimum Spanning Tree.

Algorithms

This section describes step by step procedure for network set up, proposed structure construction and packet reporting phase as per detail given below.

Initialization phase :

i. Disperse all nodes randomly in area of interest.
ii. Assign node_id, to every node for identification purpose.
iii. Divide the region virtually into number of Grids as per detail in equation 1.
iv. In each Grid, assign tier id to node based on distance from center of the Grid. Nodes near to center will be part of tier1 & farthest will be in tier3.

v. Construct minimum spanning tree among the nodes of each Grid (Nodes of other Grids should be kept isolated).

Virtual Structure construction:

i. Disperse nodes in the field of interest.
ii. Assign Grid Id to every node based on the location of the node.
iii. for every Grid
   a. Based on distance from center of Grid, assign tier id to every node.
   b. Create minimum spanning tree among the nodes of the tree, transmission cost shall be considered as cost of the edge between two vertices.
   c. Maintain this tree structure until all nodes are alive, along with rotating the role of Grid head.
   d. As soon as a node is died, discard the node from network and recreate the Minimum spanning tree.
   e. Scenario of a grid with node connection as MST is depicted in Figure 3.

Packet reporting phase :

i. Each Grid of the network will transmit data to mobile sink as per the TDMA schedule.
ii. During the start phase of the network operation, a node from tier1 will be elected to transmit network aggregated data to mobile sink.
iii. Same sender node will keep on transmitting aggregated data to sink until energy[sender]>threshold.
iv. When all nodes from tier1 have energy<threshold, node with highest energy in next tier will be elected as sender node.
v. Same process is repeated for the nodes of next tier.
vi. When energy of all nodes goes below threshold, new threshold is defined and same process is repeated from tier1 nodes.

SIMULATION & RESULTS

The performance comparison of the proposed VTGDRA scheme in contrast to the conventional VGDRA, BVI, HexDD, VCCSR scheme through simulations is presented in this section. The parameters set up for simulation are depicted in Table1. Here sink is not fixed and is assumed to be in motion around the periphery of the network. A node is considered to be dead when it is not able to transmit or receive data from the environment. These parameters are referred from [23].

Table 1. Simulation Parameters

Parameter	**Value**
Transmission and Receiving energy	50nJ/bit
Amplification Energy for free space	10pJ//bit/m2
Amplification Energy for multi path	0.0013pJ/bit/m4
Nodes initial Energy	0.001J
Packet Size	8 bits
Number of nodes	100 to 400
Network Size	100*100 to 200*200
Base Station	Mobile Sink

Network lifetime

Lifetime of the network is time from start of the operation till the network report data to sink. Stable period is the time when all nodes are doing their task. Lifetime comparison of the proposed technique with existing ones is depicted in figure4. As it is clear from the figure that proposed scheme produces better results w.r.t. existing techniques.

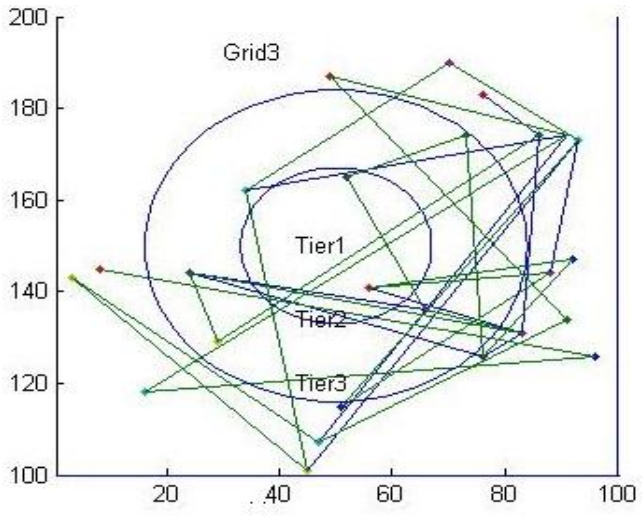

Figure 3. Minimum spanning tree construction among nodes of the Grid

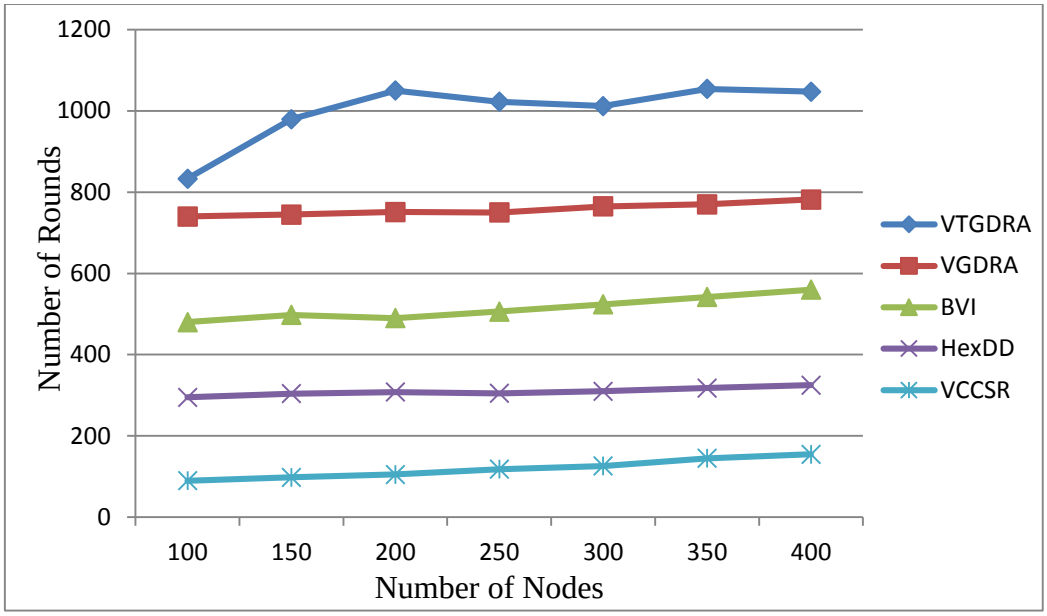

Figure 4. Lifetime comparison of VTGDRA with existing techniques

CONCLUSION

Proposed Virtual Tier structured Grid based Dynamic Route Adjustment (VTGDRA) routing scheme works on dividing the network area into Grids based on number of nodes in area of interest. Each Grid is isolated of other one, thus dividing the network area into isolated components. This isolation in turn makes the network more reliable because failure of one zone does not affect the working of other. Also, this scheme is based on TDMA schedule, so each node transmits as per their schedule saving their battery life. Only one node (Grid Head) transmits data of Grid to the sink and role of Grid Head changes as node's energy goes below threshold. By virtue of this load is evenly distributed on all nodes of the network, so increasing network stable lifetime. In terms of lifetime of the network, simulation reveals improved performance of proposed scheme (VTGDRA) w.r.t. existing schemes.

REFERENCES

[1] Cerulli, R.; De Donato, R.; Raiconi, A. Exact and heuristic methods to maximize network lifetime in Wireless sensor networks with adjustable sensing ranges. Eur. J. Oper. Res. **2012**, 220, 58–66.

[2] Han, R.; Yang, W.; You, K. MB-OFDM-UWB Based Wireless Multimedia Sensor Networks for Underground Coalmine: A Survey. Sensors **2016**, 16, 2158.

[3] Huang, J.; Duan, Q.; Xing, C.C.;Wang, H.G. Topology Control for Building a Large-Scale and Energy-Efficient Internet of Things. IEEE Wirel. Commun. **2017**, 24, 67–73.

[4] Abbasi, A.A.; Younis, M. A survey on clustering algorithms for wireless sensor networks. Comput. Commun. **2007**, 30, 2826–2841.

[5] Tyagi, S.; Kumar, N. A systematic review on clustering and routing techniques based upon LEACH protocol for wireless sensor networks. J. Netw. Comput. Appl. **2013**, 36, 623–645.

[6] Sucasas, V.; Radwan, A.; Marques, H.; Rodriguez, J. A survey on clustering techniques for cooperative wireless networks. Ad Hoc Netw. **2016**, 47, 53–81.

[7] Heinzelman,W.B.; Chandrakasan, A.P.; Balakrishnan, H. An application-specific protocol architecture for wireless microsensor networks. IEEE Trans. Wirel. Commun. **2002**, 1, 660–670.

[8] Afsar, M.M.; Tayarani-N, M.H. Clustering in sensor networks: A literature survey. J. Netw. Comput. Appl. **2014**, 46, 198–226.

[9] B. Nazir and H. Hasbullah, "Mobile sink based routing protocol (MSRP) for prolonging network lifetime in clustered wireless sensor network," in *Proc. Int. Conf. Comput. Appl. Ind. Electron. (ICCAIE)*, Dec. 2010, pp. 624–629.

[10] T. Banerjee, B. Xie, J. H. Jun, and D. P. Agrawal, "Increasing lifetime of wireless sensor networks using controllable mobile cluster heads," *Wireless Commun. Mobile Comput.*, vol. 10, no. 3, pp. 313–336, Mar. 2010.

[11] W. M. Aioffi, C. A. Valle, G. R. Mateus, and A. S. da Cunha, "Balancing message delivery latency and network lifetime through an integrated model for clustering and routing in wireless sensor networks," *Comput. Netw.*, vol. 55, no. 13, pp. 2803–2820, Sep. 2011.

[12] Kinalis, S. Nikoletseas, D. Patroumpa, and J. Rolim, "Biased sink mobility with adaptive stop times for low latency data collection in sensor networks," *Inf. Fusion*, vol. 15, pp. 56–63, Jan. 2014.

[13] S. Oh, E. Lee, S. Park, J. Jung, and S.-H. Kim, "Communication scheme to support sink mobility in multi-hop clustered wireless sensor networks," in *Proc. 24th IEEE Int. Conf. Adv. Inf. Netw. Appl.*, Apr. 2010, pp. 866–872.

[14] O. Younis and S. Fahmy, "HEED: A hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks," *IEEE Trans. Mobile Comput.*, vol. 3, no. 4, pp. 366–379, Oct. 2004.

[15] Erman, A. Dilo, and P. Havinga, "A virtual infrastructure based on honeycomb tessellation for data dissemination in multi-sink mobile wireless sensor networks," *EURASIP J. Wireless Commun. Netw.*, vol. 2012, no. 17, pp. 1–54, 2012.

[16] T.-S. Chen, H.-W. Tsai, Y.-H. Chang, and T.-C. Chen, "Geographic convergecast using mobile sink in wireless sensor networks," *Comput. Commun.*, vol. 36, no. 4, pp. 445–458, Feb. 2013.

[17] B. Tang, J. Wang, X. Geng, Y. Zheng, and J.-U. Kim, "A novel data retrieving mechanism in wireless sensor networks with path-limited mobile sink," *nt. J. Grid Distrib. Comput.*, vol. 5, no. 3, pp. 133–140, 2012.

[18] E. B. Hamida and G. Chelius, "A line-based data dissemination protocol for wireless sensor networks with mobile sink," in *Proc. IEEE Int. Conf. Commun.*, May 2008, pp. 2201–2205.

[19] J.-H. Shin and D. Park, "A virtual infrastructure for large-scale wireless sensor networks," *Comput. Commun.*, vol. 30, nos. 14–15, pp. 2853–2866, Oct. 2007.

[20] Z. H. Mir and Y.-B. Ko, "A quadtree-based data dissemination protocol for wireless sensor networks with mobile sinks," in *Proc. Personal Wireless Commun.*, 2006, pp. 447–458.

[21] H. Luo, F. Ye, J. Cheng, S. Lu, and L. Zhang, "TTDD: Two-tier data dissemination in large-scale wireless sensor networks," *Wireless Netw.*, vol. 11, nos. 1–2, pp. 161–175, Jan. 2005.

[22] X. Chen and M. Xu, "A geographical cellular-like architecture for wireless sensor networks," in *Proc. Mobile Ad-Hoc Sensor Netw.*, 2003,pp. 249–258.

[23] Khan, Abdul Waheed, Abdul Hanan Abdullah, Mohammad Abdur Razzaque, and Javed Iqbal Bangash. "VGDRA: a virtual grid-based dynamic routes adjustment scheme for mobile sink-based wireless sensor networks." *IEEE sensors journal* 15, no. 1 (2015): 526-534

[24] Kaur, Navpreet, and Ashwani Kumar Narula. "MVGDRA: Modified Virtual Grid based Dynamic Routes Adjustment Scheme for Mobile Sink-based Wireless Sensors Networks." (2017).

[25] Xin Liu, Quanyu Wang and Xuliang Jin, "An Energy-efficient Routing Protocol for Wireless Sensor Networks", Proceedings of the 7th World Congress on Intelligent Control and Automation June 25 - 27, 2008, Chongqing, China, page 1728-1733.