DSARMP: DATA SINKING USING ANGLE ROUTING WITH MULTIPLE PARTITION IN WSNS

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ABSTRACT: Data sinking in WSNs using mobile sinks is one of the popular and efficient methods in WSNs. However, the issues associated with zone partitioning and procedures to sink the data greatly affect the network throughput and energy efficiency. We propose an energy efficient Data Sinking based Angle Routing with Multiple Partition (DSARMP). In this paper, both zone partitioning and data sinking are effectively carried out using a unique procedure. The angle based zone partitioning considers the geographical information and sensor node distribution density that greatly helps to fix the location of each sensor node. Simulation results show that there is a remarkable improvement in energy efficiency and data sinking rate when compared to earlier state-of-the Art works..

KEYWORDS: Angle Based Routing, Data Sinking, Distribution Range, Zone Partition, Multipath Partition.

INTRODUCTION

Wireless Sensor Networks are used in a wide range of applications, the design of an efficient Data Sinking techniques is one of the major issues of WSNs. The idea of sink mobility in efficient data sinking has gained wide popularity in most of the recent works. Mobility is achieved by placing the sinks on vehicles, people, and animals and then sent on random trajectories to sink the data [1-5].

Mobile sinks are deployed in many ways to sink data in WSNs. They act as a data observer (Data collector) with optimized power utilization bound to constraint paths [6]. Some of the mobile sinks acts as efficient data sink through single hop transmission with greater energy efficiency in sparsely deployed networks [7-10]. Multiple controlled mobile sinks are used to sink the data with load balancing [11]. Mobile sinks are also used to develop flexible infrastructure that helps to enable specific functionality. Such methods are very essential for energy constrained systems, sparsely deployed networks, delay tolerant networks and security sensitive environment [12-14].

Mobile sinks usually follow Shortest Path Tree (SPT) method in multihop sensor network based on cluster approach. Mobiroute is another popular routing approach followed by mobile sinks in path constrained data collection [15-17].

Motivation

Efficient data sinking is one of the significant issues in WSNs. The network lifetime and energy efficiency are the two major parameters that mainly depends on the efficient data sinking procedures. In earlier works, the path constrained mobile sinks are used to maximize data sinking, but the path selection procedure is not specific. The routing strategy opted to sink the data and method of zone partition is not effective. Thus, it is necessary to device an efficient method of zone partition to carry out energy efficient data collection. Angle based Zone partitioning is one such method, where the network is partitioned based on geographical information and distribution range of sensor nodes.

Contribution

We have designed an effective angle based mobile routing with multiple zone partition to maximize the data sinking and minimize the energy utilization for better network throughput. This protocol is designed with the most important parameters viz., Geographical range g_r, Node distribution density d_n for zone partition, Sub sink queue length Q_L and Data priority P_d for data sinking.

Organization

This paper is organized as follows. Literature survey is presented in section II. Section III gives the concept of background work while section IV defines the problem and objectives. The system and mathematical model along with the proposed algorithm is explained in section V. The detailed performance evaluation is presented at section VI. Conclusions are given in section VII.

LITERATURE SURVEY

Rahul et al., [1] presented a Data sinking approach known as MULES. The MULES collect the data from the sensors which are in close range in sparse sensor networks. The sunk data is sent to wired access points. This method minimizes power consumption in sensors by providing low power transport medium for the sensor data. The limitation of this approach is that the sensors should continuously listen for the presence of MULES.

Sushanth et al., [2] proposed an architecture based on mobility of sinks that are used as forwarding agents to transfer the data from sensors to destination. The forwarding agents collect the data from sensors that are within close proximity and then sent to destination. This approach minimizes energy consumption and communication responsibility of resource constrained sensors. This approach is limited to non real time applications.

Arnab et al., [6] address communication power optimization in randomly deployed distributed sensor networks with a mobile sink on a fixed path. Here, the process of data collection is modeled by a queue with deadlines. The data collector/observer can collect the data if it enters within the sensor range, otherwise there is loss in data. Here, a queuing model is used to identify the combination of system parameters that guarantees adequate data collection with minimum power and equalizes the power consumption at different nodes.

Liang et al., [7] proposed mobile sinks for sparsely deployed sensors. In this architecture, the multi-hop transmitters of high volume data over the network are converted into single hop transmissions. Transmission scheduling algorithm (TSA) controls the trade-off between the maximization of the probability of successful information retrieval and the minimization of the energy consumption. The efficiency of this algorithm depends on the density of the nodes in a network.

David et al., [11] developed multiple controlled mobile elements (Data Mules) for data collection in sensor networks with load balancing technique. The service of each mobile sink is made available to the sensor nodes based on the load or the density of data. In this work, it is essential to consider the node dynamics at each node to balance the load of the network.

Aman et al., [12] developed intelligent flexible infrastructure for embedded networks to exploit the advantage of mobile components. This work mainly includes adaptive algorithms which are used to control mobility and communication protocol that supports flexible infrastructure and long sleep durations on energy constrained devices. It is advantageous in terms of network lifetime, data fidelity, time synchronization and bandwidth utilization. This technique needs to optimize the communication protocol design for low energy operation.

Arun et al., [15] developed a controllably mobile infrastructure for low energy embedded networks. It reduces the communication energy consumption at the energy constrained nodes and increases the network lifetime. This protocol establishes the short data routes to reduce the data relaying overhead using mobile sinks. This is advantageous in delay tolerant network and sparsely deployed network. The efficiency of this protocol needs to be tested with long term sensor network deployments.

Maria et al., [17] presented an idea of exploiting the sink mobility for maximizing the lifetime of sensor network. A linear programming formulation is adapted to address the problem of the sink mobility and stop over time at the different points in the network that can improve the network lifetime. This work mainly concentrates on improving network lifetime by reducing the energy consumption during data communication. In order to obtain more effective results it is necessary to make more realistic assumptions related to random data generation rates based on moving targets and random network topologies.

Arun et al., [18] introduced mobile element scheduling for efficient data collection in WSNs with dynamic deadlines. The mobile elements are scheduled to collect the data from all the sensor nodes in the network ensuring that there is no buffer overflow at any node.The scheduling algorithm is NP complete and models as ILP Here, the minimum weighted sum first algorithm performs better with minimum computation overhead. Further, this work can be extended with an appropriate approximation algorithm with multiple mobile elements and nodes scalability.

Yayao et al., [19] presented an idea of data harvesting with mobile elements in WSNs. A Partition Based Scheduling (PBS) algorithm is devised to schedule the movements of Mobile Elements

(MEs) in the network. The mobile element collects the data of all possible nodes before data overflow occurs. The PBs provides better performance in terms of minimized data loss rate, required speed and high predictability. Further, it does not handle real time communication events. Arun et al., [20] extended [9] with multiple mobile elements. The vehicle routing problem and time windows have been modified to manage the multiple mobile elements. It shows greater efficiency in data collection when compared with single mobile elements. But the current formulation does not keep track of accountability of energy spent for mobile movements.

Ryo et al., [21] presented improved data delivery latency in sensor networks with controlled mobility. It finds an optimal path of mobile device (data mules) to achieve the minimum data delivery latency and energy consumption at each node. It includes path selection, speed control and job scheduling problems that enables to capture two dimensional data mule scheduling problem. In addition, there is an approximation algorithm that finds near optimal path results with much smaller latency. This work needs to optimize the energy and latency trade-offs.

Guoliang et al., [22] proposed a rendezvous design algorithm to minimize the latency in data collection due to low movement speed of base stations. In this approach, the subset of nodes serves as the rendezvous points that buffers and aggregate data, originating from the different sources and finally transfers to the base station. It balances the network energy saving and data collection delay for both fixed and variable track mobile stations. The selection of rendezvous points should be based on data density.

Rao et al., [23] presented Network Assisted Data Collection (NADC) for data harvesting in WSNs. The balance between energy efficiency and data collection delay is achieved by computing optimum trajectories for a mobile data harvester (MDH). NADC includes completely distributed and network assisted MDH navigation mechanism that helps the sensor nodes to aggregate the data effectively and deliver to the sink. This framework does not address runtime topology changes.

Guoliang et al., [24] proposed an extended work of rendezvous planning in WSN for mobile elements [13]. This work addresses the low movement speed of mobile elements that hinders data intensive sensing applications with temporal constraints. In this approach, a subset of sensor nodes acts as rendezvous points that buffers data from different sources and then sends it to the mobile elements. It minimizes the data collection time with the help of rendezvous point based on RP-CP and RP-UG. This protocol minimizes energy consumption but does not effectively extend the network lifetime.

Mirela et al., [25] address the issues of data holes near the sink during data collection. The sink is shifted to the high energy dense area in order to avoid the data hole formation. The sink movement is based on the method called hexagonal filing. This approach increases considerably the network lifetime by avoiding data holes around the sinks. The frequency of sink movements from low energy area to higher energy area may penalize the network throughput in sparsely deployed networks.

Jamel et al., [26] presented a survey on routing techniques in WSNs. Eylem et al., [27] introduced Partition Based Scheduling (PBS) proposed to calculate the periodic paths of mobile elements to avoid the data loss at low speed. The PBS is further extended to Multi-hop Route to Mobile Elements (MRME) to support urgent message delivery to mobile elements with minimum delay.

The low mobile device speeds and co-operation among multiple mobile devices need to be addressed.

Kristof et al., [28] proposed restricted flooding to update the paths towards multiple mobile sinks in the network. The mobile sinks collect the data efficiently as the network floods the data from source to sinks, towards minimum energy depletion area. This algorithm has higher time complexity in position updates of mobile sinks and registration of nodes.

BACKGROUND

Most of the existing data collection methods using mobile sinks in WSNs follow different strategies through random paths to maximize data sinking. These strategies are not much effective in increasing network throughput and energy efficiency. In order to overcome this problem, an Efficient Data Collection in WSNs with Path Constrained mobile sinks [32] is designed. A routing algorithm known as Maximum Amount Shortest Path (MASP) with random zone partitioning is implemented. But the procedures used for zone partitioning has not considered geographical information and the node distribution density of the sensor nodes. Moreover, the procedure used for data collection at each subsink is common irrespective of the amount of data collected and priority of data at each sub sink.

PROBLEM DEFINITION

In a given WSN, of *n* randomly deployed nodes, we consider two major steps such as angle based zone partition and data sinking. The first step involves angle based zone partitioning based on Geographical range g_r and Node distribution density d_n. Assumes that if the values of g_r and d_n is less than the stipulated values, the network is partitioned into two zones, with an angle θ_n $(0^\circ < \theta_n < 90^\circ)$ On other hand if the values of g_r and d_n is greater than stipulated values, the network is partitioned into more than two zones, with angles θ_n $(0^\circ < \theta_n < 90^\circ)$. In both the cases, the partition boundary is considered as the trajectories T_n $(1 < T_n < N)$ and assigned with mobile sinks M_{sn} $(1 < M_{sn} < N)$ to each trajectory.
In the second step, the mobile sink M_{sn} traverses along with respective trajectories and collects the data based on the status of decision parameters such as subsink queue length Q_L and priority of the accumulated data P_d at each subsink. The data collected by the mobile sink M_{sn} at each sub sink is based on two conditions such that either queue length of subsink Q_L is greater than threshold value and priority of data P_d is higher or only the highest priority of data P_d is considered.
Jun et al., [29] investigated the issue of load balancing that carefully analyzes the mobility of the sink and considers topology changes due to link breakage and data transfer from source nodes to mobile sinks. This protocol improves the data delivery latency but with loss in reliability.
Yanjun et al., [30] developed a Energy efficient, Delay Aware and Lifetime balancing data collection protocol (EDAL) for heterogeneous WSNs. It generates minimum path cost from all source to the sink with load balancing and packet delay requirements. It is inherently NP-hard problem, and hence the centralized heuristic and distributive heuristic have been developed for large scale networks. Network lifetime for compressive sensing can be further improved.
Fatme et al., [31] developed a low cost disposable mobile relays to reduce the energy consumption of data intensive WSNs. It integrates the energy utilization required by the mobile sinks and wireless transmission. It performs routing without mobility of nodes, topology improvement with newly added mobile nodes and relocation of nodes without checking the topology. This approach incurs synchronization delay.

In our work, we have designed the angle based routing with multiple zone partitioning that considers the geographical information and distribution density of sensor nodes for data sinking. The parameters viz., Geometrical range g_r, Node Distribution density d_n, Sub sink queue length Q_L and Priority of data P_d maximize data sinking and increase energy efficiency in WSNs.

Objectives:

1. Efficient data collection through angle based routing with multiple zone partitioning.
2. Increase the network throughput and energy efficiency.

Assumptions:

1. Initially all the sensor nodes have equal amount of energy.
2. All mobile sinks have higher energy compared to other sensor nodes.

SYSTEM AND MATHEMATICAL MODEL

The proposed system model is illustrated in Fig. 1. The system model is divided into seven different phases. The first phase involves the random sensor node deployment. The zone partitioning of the network is carried out during the second phase. The third phase includes the trajectories fixation and mobile sink assignment process.

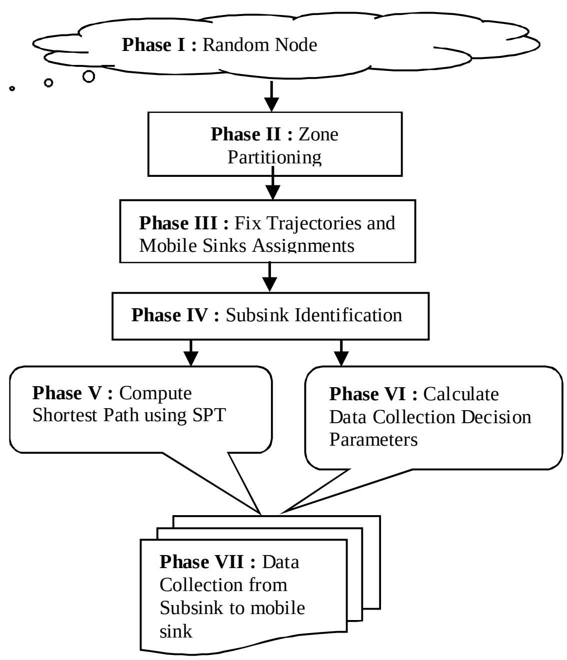

Fig. 1. DSARMP System Model

The sub sink selection is done in the fourth phase. The fifth and sixth phase computes the shortest path and data collection decision parameters. Finally, the data is transferred from sub sinks to mobile sinks in the seventh phase.

Table 1:Zone partition

Function 1: Zone_Partitioning( )

Input: S_{v1} - stipulated value of geographical range,
S_{v2} - stipulated value of node density range,
d_n – node distribution density,
g_r - geographical range, Z_p - Zone Partition,
N_T- number of trajectories, N_M- number of mobile sinks.

Assumption: $S_{v1} = 50000, S_{v2} = 100, Z_p = 0, N_T = 0,$ $N_M = 0$

if $g_r \leq S_{v1}$ && $d_n \leq S_{v2}$ **then**
divide network into zones with angle θ_n and assign a mobile sink M_{sn}
$\boldsymbol{Z_p = 2; N_T = 1; N_M = 1; T_1 = M_{S1}}$
else if $g_r \geq S_{v1}$ && $d_n \geq 100$ **then**
divide network into zones with angle θ_n
($1 \leq n \leq N$) in range of 0° to 90°
then assign
mobile sinks M_{sn} to each
trajectories
$\boldsymbol{Z_p = 4; N_T = 3; N_M = 3;}$
$\boldsymbol{T_1 = M_{S1}; T_2 = M_{S2}; T_3 = M_{S3}}$
end if

The following subsections describe these different phases with their respective mathematical model.

Phase I: Random node deployment.

The sensor nodes are deployed randomly in the area of 10000 sqm.

Phase II: Zone Partitioning (Z_p)

The second phase involves Zone partitioning z_p, based on Geographical range g_r, and Node distribution density d_n in a network. If the value of g_r and d_n is below some stipulated value S_{vi}., The network is partitioned into two zones with an angle θ_n (n=1), within the range of ($0^{\circ} < \theta_n < 90^{\circ}$) and if the value of g_r and d_n is above the stipulated value S_{vi} ,then the network is partitioned into more than two zones with angle θ_n ($1 < n < N$) within the range of ($0^{\circ} < \theta_n < 90^{\circ}$). It can be expressed as

$$Z_p = \begin{cases} p = 2 & if\ (g_r\ \&\&\ d_n) \leq S_{vi} \\ p > 2 & if\ (g_r \&\&\ d_n) \geq S_{vi} \end{cases} \qquad (1)$$

where p is number of partitions and S_{vi} is stipulated values where i = 1 and 2.

Once the zone partition is completed, the trajectories are proportionally fixed along with angle partitions and the mobile sinks M_{sn} ($1 \leq M_{sn} \leq N$) are assigned. The algorithm for zone partitioning is presented in Table 1.

Table 2. Subsink Identification

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Function 2: Subsink_Identification( )

Input: m – number of nodes in a network, N_T- number of trajectories in a network , N_M- number of mobile sink in a network, M_Sn – number of mobile sink, n – number of mobile sinks.

Case 1:   if N_T = 1 then
            for each node i to m do
                broadcasts message from M_Sn
                    if node i receives messages then
                        Sub_s = node_i
                    end if
            end for
          end if
Case 1:   if N_T = 3 then
            for each i=1 to n do
                for each M_Si to m do
                    broadcasts message
                    for each i to m do
                        if node i receives messages
then
                            Sub_s = node_i
                        end if
                    end for
                end for
            end for
          end if
```

Table 3. Algorithm: *DSARMP* Algorithm

Algorithm : DSARMP Algorithm

Step 1: Random node deployment
Step 2 : Perform network partition
__Zone_Partitioning( )__
Step 3: Identifies the subsinks around the trajectories
__Subsink_Identification( )__
Step 4: Compute shortest path from all event generated sensor nodes to subsinks
Step 5 : for each Sub_s 1 to n **do**
If(Q_L > t_h && P_d = 1) or (P_d = 1)
transfer data from sub_s to mobile sink M_{sn}
end if
end for
Step 6: Forward packets from sub sink to mobile sink

Phase III: Trajectory Fixation and Mobile Sinks Assignment

Once the network is partitioned with angles based on geographical range, g_r and node distribution density, d_n, the trajectories are fixed at respective positions at different angles. Then each trajectory T_n is assigned with mobile sinks M_{Sn}. The procedure is illustrated in Table1.

Phase IV: Subsink Identification

This phase involves the identification of subsinks around the trajectories by broadcasting the messages to the one-hop away sensors from the trajectories. This can be represented as

$$Sub_s = node\ i\ (1 < i < n) \qquad (2)$$

Phase V: Shortest Path Computation

This phase describes the shortest path computation from source node to the subsink. It is carried out by using shortest path tree method. It helps to transfer the data from source node to subsink with minimum time cost.

Phase VI: Compute Decision Parameter for Data Collection

This phase involves the computation of decision parameters for efficient data collection. It describes the method of data collection from subsinks Sub_S, based on two decision parameters known as sub sink queue length Q_L and priority of data P_d. The Q_L represents the amount of data collected and the P_d represents the priority of accumulated data at each subsink. The mobile sink M_{sn} collects the data from subsinks on two situations based on the status of Q_L and P_d as follows. The subsink identification is depicted in Table 2.

(i) The mobile sink collects the data from subsinks when the value of Q_L is greater than some threshold value t_h and with highest data priority P_d.

(ii) Mobile sinks collects the data only when the value of P_d is higher.

The last phase of the system design involves data transfer from subsinks to mobile sinks. These steps are illustrated in the algorithm (Table 3), which describes the steps involved in zone partitioning and data sinking.

SIMULATION AND PERFORMANCE ANALYSIS

The *DSARMP* protocol is simulated using NS2 simulator. The results of the simulation are depicted in terms of network throughput, energy efficiency, data collection rate and network lifetime. Our simulation setup includes 200 sensor nodes which are randomly deployed and distributed over the area of 1000*1000mts.

Performance Metrics

The following performance metrics are considered in our *DSARMP* algorithm.

(a). ***Energy Efficiency (EE):*** It is defined as minimum amount of energy utilization to transmit a packet from source to sink.

(b). ***Data Sinking Rate (DSR):*** It is defined as number of packets that can be collected by the sink per unit of time.

Performance Analysis

Table 4 is listed with simulation parameters and their values.

Table 5 illustrates the comparison values of energy efficiency and data collection rate of DSARMP with MASP, SPT and Static sink. These values are depicted as shown in Fig. 2 and Fig. 3. Fig. 2 shows the comparison values of energy efficiency of our protocol DSARMP with MASP, SPT and Static sink. The static sink algorithm consumes much higher energy compared to other three algorithms which uses mobile sinks. The MASP and SPT exhibit almost the same level of energy consumption throughout the simulation with different number of node deployments (200-300 nodes). Whereas DSARMP consumes lower energy with same number of nodes deployment. This is due to zone partition based on more precise parameters i.e., geographical range g_r and node distribution density d_n.

Fig. 3 illustrates the data collection rate of our proposed protocol DSARMP with MASP and SPT. It is observed that DSARMP exhibits much higher data sinking when compared to MASP and SPT. It is due to the impact of the data collection method based on the parameters sub sink queue length Q_L and priority of the data P_d. The DSARMP achieves about 55% higher data sinking rate when compared to other two protocols.

CONCLUSIONS

Mobility of sink plays a key role in maximizing the data sinking in WSNs. The main issues associated with efficient data sinking is energy efficiency. We have proposed and implemented an efficient method of data sinking to carry out zone partition and data sinking. The angle based zone partition routing sinks the data more efficiently with the help of decision parameters *viz.*, geographic range g_r, node distribution density d_n, queue length Q_L of the sub sinks and priority P_d of the accumulated data. Simulation result shows that our algorithm successfully improves the energy efficiency and data sinking rate when compared to earlier state-of-the art work. Further, it can be extended for more delay sensitive and large scale WSNs.

Table 4. Simulation Parameters

Parameter	**Values**
Network Size	1000m * 1000m
Number of nodes	300
Node Distribution	Random
Initial Energy	1J
Data Packet Size	64 bits
Location of sink node	Based on zone partition
Simulation time	20000s

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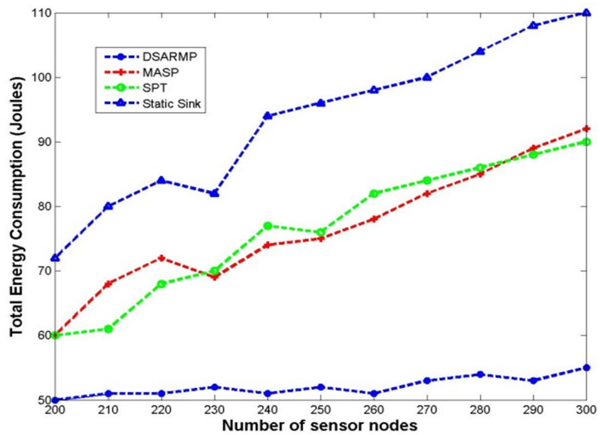

Fig. 2. Energy Efficiency (EE)

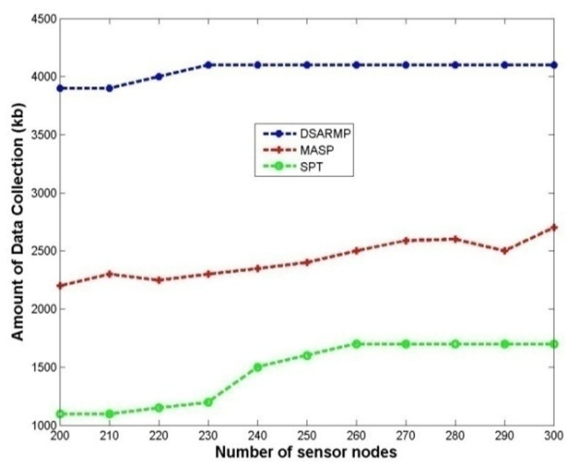

Fig. 3. Data Sinking Rate (DSR)

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Table 5: Comparison Values of Energy Efficiency and Data Sinking Rate

Number of Nodes	Energy Efficiency (EE) In joules				Data Sinking Rate (DSR) in kbps		
	DSARMP	MASP	SPT	SS	DSARMP	MASP	SPT
200	50	60	60	72	3900	2200	1100
210	51	68	61	80	3900	2300	1100
220	51	72	68	84	4000	2250	1150
230	52	69	70	92	4100	2300	1200
240	51	74	77	94	4100	2350	1500
250	52	75	76	96	4100	2400	1600
260	51	78	82	98	4100	2500	1700
270	53	82	84	100	4100	2590	1700
280	54	85	86	104	4100	2600	1700
290	53	89	88	108	4100	2500	1700
300	55	92	90	110	4100	2700	1700

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