UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL
INSTITUTO DE INFORMÁTICA
CURSO DE CIÊNCIA DA COMPUTAÇÃO

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Network Monitoring Optimization: Problem, Models and Solutions

Work presented in partial fulfillment
of the requirements for the degree of
Bachelor in Computer Science

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Porto Alegre
December 2018

“If I have seen farther than others,
it is because I stood on the shoulders of giants.”
— SIR ISAAC NEWTON

ABSTRACT

As data traffic grows, service providers are faced with the challenge of how to best use their infrastructure while trying to obtain statistics about their environment. The existing solutions to monitor such networks are no longer effective in these complex environments. An alternative that has been recently emerging as a promising option, allied with programmable networks, is In-Band Network Telemetry (INT), which allows for timely, accurate and fine-grained information retrieval regarding network device state. Although it has the potential to properly handle modern networks, when not employed optimally, INT can lead to high overheads and significant performance degradation. State-of-the-art proposals have focused on devising new monitoring constructs and mechanisms, but have not looked at the problem from an optimization point of view. In this work, we formalize this challenge as an optimization problem, called Network Monitoring Optimization (NEMO) problem, and propose two mathematical models to solve it. The first model is based on a custom approach which aims to cover all programmable device interfaces in topologies while causing minimal overheads. The second model is presented as a generalization of the Vehicle Routing Problem. The results obtained in the model evaluation show that the proposed models can generate solutions that provide accurate and fine-grained information regarding network state while achieving minimal overheads.

Keywords: Computer Networks. In-Band Network Telemetry. Optimization. CPLEX. GLPK. Problem Modeling.

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

VRP	Vehicle Routing Problem
NEMO	Network Monitoring Optimization Problem
GLPK	GNU Linear Programming Kit
INT	In-Band Telemetry
SDN	Software-Defined Networking

CONTENTS

1 INTRODUCTION

Communication networks have continually evolved over the years via the adoption and support of concepts such as Software-Defined Networking (SDN) and network virtualization. Along with the evolution of the networks, there has also been the proliferation of non-elastic applications with stringent resource demands (e.g., telesurgery, smart cities, distributed scientific computation, and virtual reality video streaming). Moreover, there has been a considerable growth in Internet traffic. For example, in 2016 alone, mobile traffic grew 63% and this type of growth is expected to repeat itself in the following years (CISCO, 2017). (CISCO, 2017). This scenario calls for network monitoring to generate information with high accuracy and level of detail.

Network administrators have traditionally relied on tools such as ping, traceroute, NetFlow/IPFIX (PRAS et al., 2009) and SNMP (CASE et al., 1990) to detect network problems. However, traditional tools commonly fail to provide the information needed to detect important network problems (e.g., microbursts in traffic), or collecting accurate information and the required level of detail would generate considerable network overhead. Many efforts (HANDIGOL et al., 2014; ZHU et al., 2015; TILMANS et al., 2018; CHENG; YU, 2017; CHOWDHURY et al., 2014; TANGARI et al., 2017; GUPTA et al., 2017) have contributed to improving network monitoring by optimizing the use of new mechanisms available in the context of SDN. Nevertheless, there is still a gap between the quality of information provided by these mechanisms and that required to offer high performance to non-elastic applications. Furthermore, no work has tried to optimize the use of new mechanisms available more recently in the context of data plane programmability.

In-band network telemetry (BROCKNERS et al., 2017) is a novel monitoring mechanism that emerged in the context of programmable data planes (and networks) and gives better visibility into network state and performance. INT enables packets passing through a network to read and collect information regarding each device in their path. This mechanism achieves unprecedented accuracy and level of detail in monitoring, but may lead to significant network overhead if not applied sensibly. Consequently, it is important to understand the performance impacts involved in carrying out in-band network telemetry and investigate way to minimize these overheads.

In this work, our objective it to enable network administrator to obtain timely, fine-grained and accurate information regarding network state and performance while causing minimal network overhead. We introduce the Network Monitoring Optimization (NEMO) problem, which formalizes the challenge of optimally assigning flows to monitor interfaces while gathering information regarding all used network interfaces and minimizing resource usage. Furthermore, two mathematical models to solve the NEMO problem are provided, together with test results, analysis and comparison between both models.

The work is organized as follows. In Chapter 2, the existing work around network monitoring and INT are discussed. In Chapter 3, we introduce and formalize NEMO. In Chapter 4, two models to solve the NEMO problem are presented, and two lower bound approaches are defined for analytical comparison purposes. In Chapter 5, the testing process is explained, and test results are presented and analyzed. Chapter 6 presents the concluding remarks and describes future work ideas. Extra material is provided in Chapter 7.

2 RELATED WORK

This chapter is organized into two sections. Section 2.1 discusses related works regarding in-band network telemetry, while Section 2.2 discusses proposals that aim to optimize network monitoring.

2.1 In-band Network Telemetry

In recent times, new monitoring techniques have been consistently developed. In this section, we discuss ideas presented by two studies in the context of in-band network telemetry (INT). In INT (KIM et al., 2015) the P4 programming language is used to prototype in-band network telemetry, switches are programmed in order to allow flows to collect network information by embedding network metadata within packets. The procedure of in-band telemetry consists of an ordered set of steps (to be executed per packet):

- Creation of telemetry header
- Embedding of telemetry data to a telemetry header
- Extraction of telemetry data from the packet and its forwarding to a telemetry sink

Tiny packet programs (TPP) (JEYAKUMAR et al., 2014) enables end-hosts to embed tiny programs within packets in order to actively query and manipulate the state of the network. The mentioned works both use INT, but neither approaches the problem from an optimization point of view, in the current work, instead of considering network monitoring as a sole network problem, we interpret it as an optimization problem.

2.2 Network Monitoring Optimization

Our study lies in the context of network monitoring optimization. Multiple works can be found aiming to optimize resource usage while performing network monitoring in the context of Software Defined Networks (SDN) and programmable data planes. However, to our knowledge, no study was done aiming to optimize in-band telemetry from a combinatorial optimization point of view while using exact mathematical models. Using INT, MARQUES; GASPARY (2018), describes the same scenario mentioned in this work, yet instead of formalizing this as an optimization problem, it tries to enhance performance by telemetry orchestration with heuristic algorithms.

NetSight (HANDIGOL et al., 2014) is an extensible platform that captures packet histories, the full packet story while it traverses the network, and enables applications to retrieve such histories. Packet histories help simplifying network diagnosis. To demonstrate how this platform can be used, four applications are available (HANDIGOL et al., 2014): an interactive network debugger; a live invariant monitor; a path-aware history logger; and a hierarchical network profiler. The drawback with this work is that creating a packet history increases both network traffic and network processing, resulting in high network overheads. To improve this, Everflow (ZHU et al., 2015) was designed. Everflow is a system that aims to perform network telemetry in large data center networks. This is done via a "match and mirror" functionality of commodity switches and packet filtering. Therefore, instead of mirroring all packets like NetSight, Everflow limits this via packet filtering. The mentioned approaches use traditional techniques, instead of more sophisticated ones, like INT.

OpenFlow enables applications to obtain flow statistics on a pull-based service. When applications pull information too often, it leads to high network overheads. On the other hand. if applications seldom pull information, the data might not be precise. PayLess (CHOWDHURY et al., 2014) is a monitoring framework for SDNs. It uses adaptive strategies in order to optimize the trade-off between monitoring accuracy, data timeliness, and network overhead. Even though these studies have not used INT, they propose significant overhead-reducing strategies.

In the context of P4 programmable networks, some studies have been recently carried out. UnivMon (LIU et al., 2016) is a flow monitoring framework. It uses estimation algorithms on the control plane and statistics from the data plane in order to compute application-level metrics. Sonata (GUPTA et al., 2017) is a system that provides a query interface which enables applications to perform classic telemetry tasks in an optimized way without worrying about the task implementation. Sonata saves resource usage by running much of the queries within the network switch, at line rate. The aforementioned works provide frameworks which enable applications to perform monitoring techniques in a performative way. Our work, on the other hand, orchestrates flow placement in order to obtain fine-grained and timely data while optimizing resource usage.

3 NEMO: NETWORK MONITORING OPTIMIZATION PROBLEM

In this chapter, we define the Network Monitoring Optimization (NEMO) problem. The NEMO problem arises because in-band network telemetry (INT) may lead to high network overheads if not employed sensibly. It aims to find a flow-to-interface assignment that allows for accurate, timely and fine-grained information retrieval while reducing redundant network monitoring operations. The intent is that, given a solution to the problem, a network administrator can configure each programmable device to embed its telemetry items only into specific flows, minimizing the resource usage and, thus, reducing the network overhead.

In this context, consider a network infrastructure that has a set of programmable forwarding devices D, each with a set I_d of network interfaces. We assume that each interface $i \in I_d$ of each programmable device $d \in D$ has a set of telemetry items that need to be collected by a flow. Furthermore, on top of this network infrastructure, there is a set of active flows F. We assume that each flow $f \in F$ has a fixed telemetry load capacity of Q telemetry sets, which is a constant defined at each problem instance.

As mentioned in Section 2.1, in INT, there are three steps executed per-packet: telemetry header creation, data embedding, and data extraction and forwarding. The main objective of the problem is to gather information from all interfaces being used in a network infrastructure. Since the creation and extraction of telemetry headers are costly operations, they should be minimized. Also, in this work, we assume that whatever flow covers an interface (in this context, cover means a flow collecting telemetry data from an interface), will provide valuable information regarding device state, and the collection by multiple flows does not provide significant benefits. Therefore, one of the main constraints we enforce is that each interface should only be covered by a single flow. Therefore, a desirable solution to efficiently collect telemetry data consists in minimizing the number of telemetry headers created and extracted while collecting only once the telemetry information from each and every interface.

There is, however, a limitation imposed by the P4 programming language which must be taken into consideration. Whenever a flow packet has a telemetry header in its header stack, every interface that processes it will embed its information into the packet. This greatly limits the number of potential solutions to NEMO, since it now needs to coordinate flow placement in order to achieve minimal telemetry header usage. In case a flow was to cover two interfaces that are not sequential in its path, two telemetry headers

Table 3.1: NEMO Objective and Constraints

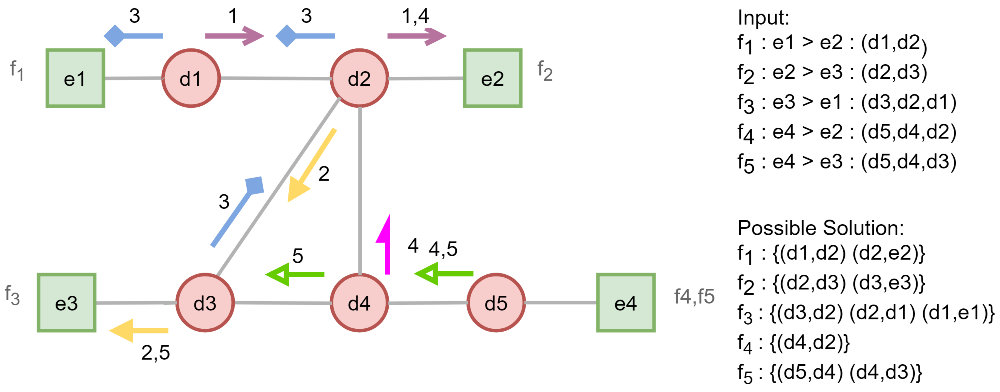
Property
Objective function
Minimize the number of telemetry headers created and extracted
Constraints
Each interface has to be covered by a single flow
The flow telemetry load capacity has to be respected
An interface processing a packet with a telemetry header will embed its information into it

Source: The Authors

would need to be used. The telemetry headers are created by the first interface where a flow collects telemetry information and are extracted by the last interface where the items are collected. Naturally, if a flow does not cover any interfaces, it will not create any telemetry header. To summarize the given information, Table 3.1 provides the objective and constraints previously defined.

To illustrate NEMO, Figure 3.1 is provided. Consider the set of programmable devices $D = \{d_1, ..., d_5\}$. It is important to notice that, in the picture, there are programmable devices, which are represented as circles (e.g., d_1) and endpoints, which are represented as squares (e.g., e_1). Since only programmable devices have telemetry items, set D only contains the programmable devices and not the endpoints, the endpoints are represented in order to improve visualization of flow origin and destination. There are five flows such that $F = \{f_1, ..., f_5\}$ which originate at an endpoint, are routed through a subset of devices from D and terminate at a distinct endpoint, this is, the path of a flow is a sequence of hops, where the first and last elements are endpoints and the middle ones are programmable devices. Therefore, for the mentioned example, we have the following: flow f_1 originates at endpoint e_1, passes through programmable devices d_1 and d_2, and ends at endpoint e_2. Similar information regarding the other flows is located on the right-hand side of the picture. In the picture, interfaces are represented as lines outgoing each device. Furthermore, we also represent interfaces as pairs, where the first element indicates the programmable device that the interface belongs to, and the second element represents the device or endpoint to which the interface is connected via a link in the network (e.g., (d_1, e_1) represents the interface of d_1 connected to endpoint e_1). As mentioned earlier, only the programmable devices need to have their interfaces covered because endpoints do not have telemetry items (e.g., interface (e_1, d_1) does not need to be covered).

Figure 3.1: Example topology



Source: The Authors

In the provided example – considering each flow header being able to carry up to five telemetry sets (i,e,. $Q = 5$) – there are multiple feasible solutions. For instance, the most straightforward solution would be for each interface to embed its information in a fresh telemetry header. This means that, on each interface, a telemetry header is created, some telemetry data is embedded into it, extracted and dispatched via a telemetry report packet to a telemetry sink. Therefore, if there are N active network interfaces, N telemetry headers will be used, one to cover each interface. The problem, however, is that this is not sensible, as it does not aim to minimize the number of telemetry headers created and extracted. Naturally, if each telemetry header was only capable of carrying one telemetry item set (e.g., $Q = 1$), this would be the only feasible solution and, thus, the optimal solution.

Since all interfaces need to be covered, interfaces that only have a single flow passing by it are naturally covered by that flow. On the other hand, interfaces that have more than one flow going through it present the possibility of choice regarding what flow should cover it, this, ultimately, expands the number of possible solutions that are available to the problem.

The example shown Figure 3.1 has three interfaces being shared by multiple flows, thus, there may have many distinct feasible and optimal solutions. On the right hand lower side of the image, one of the feasible optimal solutions is presented. In such solution, flow f_1 covers interfaces (d_1, d_2) and (d_2, e_2); f_2 covers (d_2, d_3) and (d_3, e_3); f_3 covers (d_3, d_2), (d_2, d_1) and (d_1, e_1); f_4 covers (d_4, d_2); and f_5 covers (d_5, d_4) and (d_4, d_3). As explained earlier, the telemetry header is created by the first interface it covers and extracted by the last device where telemetry data was collected. Consequently, a telemetry header would be created for flow f_1 in device d_1 and dispatched in d_2; f_2 creates in d_2 and dispatches in d_3; f_3 creates in d_3 and dispatches in d_1; f_4 creates and dispatches in d_4; and f_5 creates in d_5 and dispatches in d_4.

Table 3.2 presents three optimal solutions to this example instance of the problem. Solution 1 being the one previously discussed. All solutions use all flows and make use of five telemetry headers in order to collect all telemetry items contained in the device interfaces. This means that for this particular instance, the optimal solution value is five telemetry headers.

Table 3.2: Optimal solutions for the example instance with telemetry capacity equal to 5 sets

Flow	Solution 1	Solution 2	Solution 3
1	$\{(d_1, d_2)(d_2, e_2)\}$	$\{(d_1, d_2)(d_2, e_2)\}$	$\{(d_1, d_2)\}$
2	$\{(d_2, d_3)(d_3, e_3)\}$	$\{(d_2, d_3)\}$	$\{(d_2, d_3)\}$
3	$\{(d_3, d_2)(d_2, d_1)(d_1, e_1)\}$	$\{(d_3, d_2)(d_2, d_1)(d_1, e_1)\}$	$\{(d_3, d_2)(d_2, d_1)(d_1, e_1)\}$
4	$\{(d_4, d_2)\}$	$\{(d_5, d_4)(d_4, d_2)\}$	$\{(d_5, d_4)(d_4, d_2)(d_2, e_2)\}$
5	$\{(d_5, d_4)(d_4, d_3)\}$	$\{(d_4, d_3)(d_3, e_3)\}$	$\{(d_4, d_3)(d_3, e_3)\}$

Source: The Authors

If instead of $Q = 5$, the telemetry capacity Q was equal to 2, flow f_3 would not be able to collect all of the telemetry data of the interfaces in its path in a single header, thus, either the telemetry set of the first interface (d_3, d_2) or the last (d_1, e_1) would have to be embedded in a different telemetry header than the other two interfaces. Table 3.3 shows how the solutions adapt to this new constraint. In this scenario, the optimal solution increases from five report packets being generated to six.

Table 3.3: Optimal solutions for the example topology with telemetry capacity equal to 2 sets

Flow	Solution 1	Solution 2	Solution 3
1	$\{(d_1, d_2)(d_2, e_2)\}$	$\{(d_1, d_2)(d_2, e_2)\}$	$\{(d_1, d_2)\}$
2	$\{(d_2, d_3)(d_3, e_3)\}$	$\{(d_2, d_3)\}$	$\{(d_2, d_3)\}$
3	$\{(d_3, d_2)(d_2, d_1)\}\{(d_1, e_1)\}$	$\{(d_3, d_2)\}\{(d_2, d_1)(d_1, e_1)\}$	$\{(d_3, d_2)\}\{(d_2, d_1)(d_1, e_1)\}$
4	$\{(d_4, d_2)\}$	$\{(d_5, d_4)(d_4, d_2)\}$	$\{(d_5, d_4)(d_4, d_2)(d_2, e_2)\}$
5	$\{(d_5, d_4)(d_4, d_3)\}$	$\{(d_4, d_3)(d_3, e_3)\}$	$\{(d_4, d_3)(d_3, e_3)\}$

Source: The Authors

4 MODELS

In this chapter, two models proposed to solve the NEMO problem are presented. It is organized as follows. In Sections 4.1 and 4.2, the two models to solve the problem are presented and in Section 4.3, two lower bounds are described.

4.1 Covering Model Formulation

This section introduces the model we call Covering.

There are three restrictions that have to be ensured when solving the NEMO problem. First, there has to be a way to control which flow covers each interface. Second, the network interfaces need to understand which flows need to create and dispatch the telemetry packets. Third, there has to be a way to control the packet load so that the telemetry capacity constraint is respected. Thus, the Covering model makes use of three sets of decision variables to control each one of those requirements. The GLPK code is available in the Appendix Section.

Table 4.1 represents the variables, parameter, and sets used in the Covering model. The first column indicates which attribute is being referred to and the second column briefly describes its role. Variable c_{df} represents the telemetry load that flow f has when arriving at device d. Variable x_{fi} indicates if flow f covers interface i. Variable y_{df} indicates whether flow f dispatches its telemetry header at device d. To represent the limit of telemetry items that each flow can have at the same time, Q is used, Q should be set at each instance of the problem. Set D represents all the devices within the network. Set F represents all the flows in the network. Set I represents all the interfaces in the network. And, finally, set L is the set that contains the last interfaces of each flow in the network.

Table 4.1: Variable, parameter and set definition for the Covering model

Symbol	Definition
Variables	
$c_{df} \in \mathbb{Z}$	Load of flow f when arriving at device d
$x_{fi} \in \{0,1\}$	Controls whether an interface i is covered by flow f
$y_{df} \in \{0,1\}$	Defines whether flow f dispatches on device d
Parameter	
Q	Value that defines the flow telemetry load capacity
Sets	
D	Devices in the network
F	Flows from the network
I	Interfaces of the network
L	Last interfaces in the network

Source: The Authors

$$\mathbf{min} \sum_{f \in F} \sum_{d \in D} y_{fd} \tag{4.1}$$

$$\mathbf{s.t} \sum_{f \in F} x_{fi} = 1 \qquad \forall i \in I \tag{4.2}$$

$$x_{fi} = 0 \qquad \forall i \in I \backslash f, \forall f \in F \tag{4.3}$$

$$x_{fi} \geq y_{df} \qquad \forall f \in F, \forall i = (d,e) \in I, \forall d \in D \tag{4.4}$$

$$y_{df} \geq x_{fi} \qquad \forall f \in F, \forall i = (d,e) \in L, \forall d \in D \tag{4.5}$$

$$x_{fi} \times Q \geq c_{df} \qquad \forall f \in F, \forall i = (d,e) \in I \tag{4.6}$$

$$y_{df} - x_{fi} \geq -c_{ef} \qquad \forall f \in F, \forall i = (d,e) \in I \tag{4.7}$$

$$(-y_{df} + x_{fi}) \times Q \geq c_{ef} \qquad \forall f \in F, \forall i = (d,e) \in I \tag{4.8}$$

$$c_{df} \leq c_{ef} + 1 + (1 - x_{fi}) \times Q + y_{df} \times Q \qquad \forall f \in F, \forall i = (d,e) \in I \tag{4.9}$$

$$c_{df} \geq c_{ef} + 1 - (1 - x_{fi}) \times Q - y_{df} \times Q \qquad \forall f \in F, \forall i = (d,e) \in I \tag{4.10}$$

$$c_{df} \in \mathbb{Z}^{+} \qquad \forall f \in F, \forall d \in D \tag{4.11}$$

$$x_{fi} \in \{0,1\} \qquad \forall f \in F, \forall i \in I \tag{4.12}$$

$$y_{df} \in \{0,1\} \qquad \forall d \in D, \forall f \in F \tag{4.13}$$

The model's objective function is to minimize the number of report packets sent to telemetry sinks. Since this information is controlled by variable y, the model aims to minimize the sum of the values in variable $y_{df} \forall d \in D, \forall f \in F$.

Constraint set 4.2 verifies that all interfaces have been covered. Constraint set 4.3

determines that a flow can only cover an interface that is part of its path. Constraint set 4.4 ensures that a telemetry header can only be dispatched if an item has been collected at that programmable device, because, if no item was collected, it means that there was no telemetry header in the flow header stack. Constraint set 4.5 ensures that if a telemetry packet has data on the last interface of a flow, then it should dispatch it at such interface. Constraint set 4.6 ensures that the telemetry load capacity is respected. Constraint sets 4.7 and 4.8 ensure that the following behavior is followed:

- If x_{fi} equals 1 and c_{ef} equals 0, it means that the telemetry header was dispatched at device d, therefore y_{df} equals 1
- If x_{fi} equals 1 and c_{ef} is more than 0, it means that the telemetry header was not dispatched at device d, therefore y_{df} equals 0
- If x_{fi} equals 0, then c_{ef} has to be 0 and y_{df} also has to be 0, because there was no telemetry header in the flow header stack (this happens because of the earlier mentioned restriction that if a flow has a telemetry header, the interface will embed its data into the header)

Finally, Constraint sets 4.9 and 4.10 ensure that the following is respected:

- If an item has been embedded in a header and that header was not dispatched, then the load value should increase by 1 to the next hop. Therefore, if x_{fi} equals 1 and y_{df} equals 0, c_{ef} has to be c_{df} plus 1
- If a header is dispatched, the next hop should have load value equal to 0. Therefore, if x_{fi} equals 1 and y_{df} equals 1, c_{df} has to be 0
- If an interface is not covered by a flow, such flow should not have a telemetry header when arriving at this interface. Therefore, if x_{fi} equals 0, c_{df} has to be 0

The variable values obtained from example in Figure 3.1 are shown in Table 4.2. Column *Variable* represents which variable each entry refers to. Column *Flow* identifies the flow. Column *From* indicates the device that owns the interface which is being covered. Column *To* represents the device or endpoint to which the interface is connected via a link in the network. Finally, Column *Device* represents which device each entry refers to. It is important to mention that the table only demonstrates the variables which have the value equal to 1 because showing the whole variable scope would hinder the understanding of the solution.

Looking at the values of variable x, it is possible to see that flow f_1 covers interfaces (d_1, d_2) and (d_2, h_2); f_2 covers (d_2, d_3) and (d_3, h_3); f_3 covers (d_3, d_2), (d_2, d_1) and

Table 4.2: Covering model results from example

Variable	Flow	From	To	Value
x	1	d_1	d_2	1
x	1	d_2	h_2	1
x	2	d_2	d_3	1
x	2	d_3	h_3	1
x	3	d_3	d_2	1
x	3	d_2	d_1	1
x	3	d_1	h_1	1
x	4	d_4	d_2	1
x	5	d_5	d_4	1
x	5	d_4	d_3	1

Variable	Device	Flow	Value
y	d_1	1	1
y	d_3	2	1
y	d_1	3	1
y	d_4	4	1
y	d_4	5	1
c	d_2	1	1
c	d_3	2	1
c	d_2	3	1
c	d_1	3	2
c	d_4	5	1

Source: The Authors

(d_1, h_1); f_4 only covers (d_4, d_2); and f_5 covers (d_5, d_4) and (d_4, d_3).

Since, in this example, we considered that the telemetry load capacity was five (i.e., $Q = 5$), no flow covers more than five interfaces, and all interfaces covered by each flow are sequential, we conclude that each flow only needs to dispatch its items once. Such dispatch should occur on the device of the last interface covered by the flow. So, flow f_1 dispatches on device d_2; f_2 dispatches on d_3; f_3 dispatches on d_1; f_4 dispatches on d_4; and f_5 also dispatches on d_4.

Since most of the groups only have two interfaces in it, most of the load values should be 1 (this is due to the fact that when the flow embeds the data from its last interface, it immediately dispatches the telemetry header, not carrying it forward in its path), that is the case for the second interface for flows f_1, f_2 and f_5. Flow f_4 does not have any value different than 0 in our table because it only covers a single interface. Flow f_3, since it covers three interfaces, arrives with load value equal to 1 in d_2 and load value equal to 2 in $d1$, likewise, if it covered more interfaces, it would increase one-by-one, although never surpassing the limit set by Q.

To calculate the model's objective function value, one needs to sum all values within variable y_{df}. Variable y has value 1 in positions $(d_2, 1)$, $(d_3, 2)$, $(d_1, 3)$, $(d_4, 4)$ and $(d_4, 5)$, therefore the objective value is **5**.

4.2 VRP Model Formulation

This section introduces the model we call VRP.

The second approach is a model based on the Vehicle Routing Problem (VRP). In VRP, there are customers, which have demands, trucks, which have pre-defined paths called routes, and a depot, which has the items that the customers demand. To meet the demands of the customers, trucks need to fetch the items at the depot and then deliver each item to the intended customer. VRP's objective function is to minimize the cost of meeting all customer demands.

In order to formalize NEMO as a generalization of VRP, some analogies need to be defined. In the VRP problem, trucks need to go to the depot in order to start and end their journey, this can be reflected with the creation and dispatch of the telemetry headers to a telemetry sink. In VRP, there is a depot. which is similar to a telemetry sink in our context. Therefore, from now on, the depot will be called device 0 (d_0), so, when a telemetry header needs to be created, this is interpreted as a truck coming from the depot (d_0) and when it needs to dispatch the data, the truck returns to the depot (d_0). The other aspect is the routes that trucks follow. Since, in NEMO, flows have their paths pre-defined, there is no such flexibility. Therefore, we associate each route with the path of an existing flow in the network and fix the route so that it does not change, the only difference is the ability to use partial routes (meaning that if a flow does not cover all interfaces in its path, the route related to that flow would consist of only the covered interfaces, likewise, if a flow needs to use two telemetry headers to cover its interfaces, then it would have two routes) instead of complete ones.

With the former analogies set, the trucks need to cover all the customers while gathering items from the depot. In our adaptation of the VRP, the objective is to minimize the trips that trucks need to perform to the depot, which translates into minimizing the number of telemetry headers created. This models GLPK code is available in the Appendix Section.

Table 4.3 describes the variable, parameter, and sets used in the VRP model. Variable x_{fik} controls if route k from flow f covers interface i. If $x_{fik} = 1$, it means that interface i is covered by route k from flow f. The parameter used in VRP is the same as used in Covering. Likewise, many of the sets used in VRP are the same as used in the Covering model. Differing from it, we have set $I^{+}(d)$ representing all flows leaving device d via an interface. Likewise, $I^{-}(d)$ represents all flows entering device d via an

Table 4.3: Variable, parameter and set definition for the VRP model

Symbol	Definition
Variables	
$x_{fik} \in \{0,1\}$	Controls whether interface i from a flow f is covered by route k
Parameter	
Q	Value that defines the flow telemetry load capacity
Sets	
D	Devices in the network
F	Flows from the network
I	Interfaces of the network
I_0	Interfaces related to router r_0
K	Routes in the network

Source: The Authors

interface. Set I_0 represents the interfaces of device d_0. And, finally, set K is a set that represents all routes, it ranges from 1 to N, where N is the number of flows present in the network.

$$\textbf{min} \sum_{f \in F} \sum_{i \in I_0^+} \sum_{k \in K} x_{fik} \tag{4.14}$$

$$\text{s.t} \sum_{f \in F} \sum_{k \in K} x_{fik} = 1 \qquad \forall i \in I \tag{4.15}$$

$$\sum_{i \in I^+(d) \cup I_0^+} x_{fik} = \sum_{i \in I^-(d) \cup I_0^-} x_{fik} \qquad \forall d \in D, \forall f \in F, \forall k \in K \tag{4.16}$$

$$x_{fik} = 0 \qquad \forall i \in I \backslash f, \forall f \in F, \forall k \in K \tag{4.17}$$

$$\sum_{f \in F} \sum_{i \in I_0^+} x_{fik} \leq 1 \qquad \forall k \in K \tag{4.18}$$

$$\sum_{i \in I} \sum_{f \in F} x_{fik} \leq Q \qquad \forall k \in K \tag{4.19}$$

$$x_{fik} \in \{0,1\} \qquad \forall f \in F, \forall i \in I, \forall k \in K \tag{4.20}$$

Statement 4.14 presents the objective function of the model. As the objective of the model is to minimize the number of telemetry header creation and dispatches, in an analogy to VRP, the objective is to minimize the number of trips to the depot (d_0), therefore, minimize the sum of values in variable $x_{fik} \forall f \in F, \forall i \in I_0, \forall k \in K$.

Constraint set 4.15 ensures that all interfaces are covered. Constraint set 4.16

Table 4.4: VRP model results from example

Flow	From	To	Route
1	d_0	d_1	1
1	d_1	d_2	1
1	d_2	h_2	1
1	h_2	d_0	1
2	d_0	d_2	2
2	d_2	d_3	2
2	d_3	h_3	2
2	h_3	d_0	2
3	d_0	d_3	3
3	d_3	d_2	3
3	d_2	d_1	3
3	d_1	h_1	3
3	h_1	d_0	3
4	d_0	d_4	4
4	d_4	d_2	4
4	d_2	d_0	4
5	d_0	d_5	5
5	d_5	d_4	5
5	d_4	d_3	5
5	d_3	d_0	5

Source: The Authors

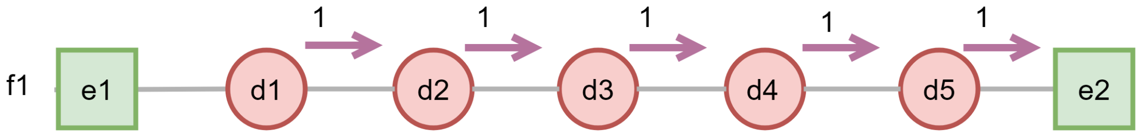
guarantees the flow conservation, meaning that whenever a flow enters a programmable device, it has to exit. Constraint set 4.17 guarantees that an interface can only be covered by a route belonging to a flow that goes through it. Constraint set 4.18 ensures that each route can only contain interfaces that belong to the same flow. Constraint set 4.19 verifies that the telemetry load limit, Q, is respected.

The variable values obtained from example in Figure 3.1 are shown in Table 4.4. It is important to mention that the table only demonstrates the variables which have the value equal to 1 because showing the whole variable set would hinder the understanding of the solution.

Let us consider Table 4.4. One may notice that route 1 covers interfaces (d_1, d_2) and (d_2, h_2); route 2 covers (d_2, d_3) and (d_3, h_3); route 3 covers (d_3, d_2), (d_3, d_1) and (d_1, h_1); route 4 covers (d_4, d_2); and route 5 covers (d_5, d_4) and (d_4, d_3).

In this example, $Q = 5$ was used. From Table 4.4, we see that no route covers more than five interfaces, therefore, each route only needs to create one telemetry header to be able to embed all telemetry data from different interfaces. To dispatch the headers, the routes need to return to the depot. So, after route 1 passes by h_2, it goes back to d_0,

Figure 4.1: Unbounded example topology



Source: The Authors

the same is true for route 2 with h_3, route 3 with h_1, route 4 with d_2 and route 5 with d_3.

As mentioned in the previous paragraph, to ensure that no route has exceeded the telemetry load capacity, one needs to observe the number of interfaces covered by such route and the number of trips to the depot that were made. In Table 4.4, it is observed that route 1 covers 2 interfaces, therefore, it has value 2, which does not exceed the limit set by Q. When checking the other routes, we observe that route 2 has load value 2, route 3 3, route 4 1 and route 5 2. As expected, no route has exceeded its telemetry load capacity.

To obtain the model's objective value, one needs to sum the values in variable x_{fik} which have originated from the depot (d_0). Therefore, route 1 originates in interface (d_0, d_1); route 2 in (d_0, d_2); route 3 in $(r0, r3)$; route 4 in $(r0, r4)$; and route 5 in $(r0, r5)$. Thus, the objective value is **5**.

4.3 Lower Bounds

This section presents two lower bounds for the NEMO problem. The first, Unbounded, utilizes the same model as Covering but without the carrying limitation. This means that restrictions 4.6, 4.7, 4.8, 4.9, and 4.10 were adapted to ignore telemetry load capacity related restrictions. The second is an integer programming relaxation, which we call Relax, of the Covering Model, meaning that all variables now accept fractional instead of only integer values. The section organization is as follows. In Section 4.3.1 we present an example where Unbounded achieves better results than those of Figure 3.1. In Section 4.3.2 we present the output obtained when using the example provided in Figure 3.1 as input for Relax. The GLPK implementations are available in the Appendix.

4.3.1 Unbounded Example

If we consider Figure 3.1 again, when $Q = 5$, no flow is affected by the telemetry capacity. Therefore, the solution value for the Covering model is the same as the solution

Table 4.5: Solution to Unbounded example

Variable	Flow	From	To
x	1	d_1	d_2
x	1	d_2	d_3
x	1	d_3	d_4
x	1	d_4	d_5
x	1	d_5	h_2

Variable	Device	Flow
y	d_5	1

Source: The Authors

Table 4.6: Solution to Relax example

Variable	Flow	From	To	Value
x	1	d_1	d_2	1
x	1	d_2	h_2	0.2
x	2	d_2	d_3	1
x	2	d_3	h_3	0.2
x	3	d_3	d_2	1
x	3	d_2	d_1	1
x	3	d_1	h_1	1
x	4	d_4	d_2	1
x	4	d_2	h_2	0.8
x	5	d_5	d_4	1
x	5	d_4	d_3	1
x	5	d_5	h_3	0.8

Variable	Device	Flow	Value
y	d_2	1	0.2
y	d_3	2	0.2
y	d_1	3	1
y	d_2	4	0.8
y	d_3	5	0.8
c	d_2	1	1
c	d_3	2	1
c	d_2	3	1
c	d_2	4	1
c	d_1	3	2
c	d_4	5	1
c	d_3	5	2

Source: The Authors

of the Lower bound. Instead, let us consider an example described in Figure 4.1. As can be seen in Table 4.5, the solution value is 1, whereas, when solving it using the Covering model with $Q = 3$, for example, the solution value would be 2. This means that Unbounded provides better solution values when compared with models which operate with low capacity (e.g., low Q).

4.3.2 Integer Programming Relaxation Example

Table 4.6 represents the values obtained when using Relax to find the solutions for the example provided in Figure 3.1. One can observe, by the sum of the values in variable y, that the lower bound found by Relax, is 3. It is able to achieve lower values because multiple routes end up at the same programmable device and with the ability to have fractional values, it combines them to create fewer telemetry packets.

5 EXPERIMENTAL EVALUATION

This chapter presents the computational results obtained. The chapter is organized as follows. In Section 5.1, the test instances and the testing process are described. In Section 5.2, the details and results of the tests are presented. In Section 5.3, we analyze the results presented in Section 5.2 for the Covering Model. In Section 5.4 the results obtained when using VRP are discussed. In Section 5.5, both model results are compared.

5.1 Datasets

All the topologies used are from TopologyZoo (KNIGHT et al., 2011). These are all real wide area networks and they vary in device, interface and flow count. In total, 119 topologies were used, each with five different levels of network activity (represented as flows), totalizing a set of 595 instances.

Each topology provided in TopologyZoo (KNIGHT et al., 2011) has a file describing traffic demands between each pair of programmable devices, this value is given in Mbps. Therefore, in a topology with n programmable devices, $n \times (n-1)$ values are represented. To understand how different levels of network activity influences solution values, five activity variations of each topology were generated. In the first variation, a flow between each pair of devices is generated. In the other four variations, only the flow pairs with the highest traffic demands are used (e.g., the pairs with the highest Mbps demand value). The second variation utilizes only the 80% highest demands. The third, fourth and fifth variations use 60%, 40%, and 20% respectively.

To better understand how the topologies are distributed, in terms of device, interface and flow count, Table 5.1 was generated. Column *Property* identifies what property each row is referring to. Column *Value* refers to the interval in which the values are located in. Column *Quantity* represents the number of topologies within that category. Therefore, it is possible to observe that 202 topologies have between 1 and 50 devices. The remaining rows follow the same approach.

Based on the provided information, we notice that smaller topologies (e.g., $1 \leq |D| \leq 50$; $1 \leq |I| \leq 50$; $1 \leq |F| \leq 100$) are the most recurrent. They represent 32% of all topologies. While larger topologies (e.g., $251 \leq |D| \leq 400$; $251 \leq |I| \leq 500$; $3001 \leq |F| \leq 15000$) only represent 11%. The flow count is usually higher, when compared to the device and interface count, due to the fact that, for each device, there is

Table 5.1: Distribution of topologies

Property	Value	Quantity
I D I	1-50	202
I D I	51-100	190
I D I	101-150	128
I D I	151-250	39
I D I	251-400	33
I I I	1-50	117
I I I	51-100	129
I I I	101-150	103
I I I	151-250	163
I I I	251-500	80
I F I	1-100	105
I F I	101-500	146
I F I	501-1000	107
I F I	1001-3000	139
I F I	3001-15000	95

Source: The Authors

at least one variation of each topology that has $(n - 1)$ flows connecting it, where n is the device count. Thus, the flow count is always higher than the device count.

5.2 Experimental Environment

All tests were performed in a computer with $11GB$ of RAM memory, Intel(R) Core(TM) i7 930 @ 2.80GHz CPU and Linux Ubuntu 18.04 LTS 64 bits operating system.

All models were developed to be compatible with the GLPSOL solver. GLPSOL has a built-in functionality that converts the models developed in its format to the CPLEX format. All tests were performed with the usage of the CPLEX solver. The thread limit was set at four threads, the timeout was set to an hour and the standard cuts were enabled. To solve the linear programming models, the LP solver option of CPLEX was used. The value used for parameter Q was 5. The same configuration was used for all tests. The Covering model tests finished in four days. The VRP model tests finished in seventeen days. Unbounded tests finished in eight hours. Relax finished in five hours.

To showcase the results, Table 7.5 presents the results for the two models and the two lower bounds. To summarize the results, Table 5.2 is provided.

Table 5.2: Solution group results for tests on all instances

$\|D\|$	$\|I\|$	$\|F\|$	Group	#Instances	Covering			VRP			Unbounded			Relax		
					Sol	Time	CPLEX Gap(%)	Sol	Time	CPLEX Gap(%)	Sol	Time	$Gap_v(\%)$	Sol	Time	$Gap_v(\%)$
$1-30$	≤ 25	≤ 12	1	19	5.3	0.0	0.0	5.3	0.1	0.0	5.3	0.0	0.0	3.9	0.0	26.0
		≤ 25	2	15	7.3	0.0	0.0	7.3	0.1	0.0	7.3	0.0	0.0	5.8	0.0	20.9
		$91 \leq$	3	16	7.8	0.0	0.0	7.8	0.3	0.0	7.8	0.0	0.0	7.2	0.0	7.3
	$26 \leq$	≤ 60	4	24	14.0	0.1	0.0	14.0	1.3	0.0	13.9	0.0	0.6	9.8	0.0	30.1
		≤ 90	5	21	13.8	0.1	0.0	13.8	2.1	0.0	13.8	0.0	0.0	10.8	0.0	21.8
		$91 \leq$	6	20	14.6	0.3	0.0	14.6	7.6	0.0	14.6	0.0	0.0	13.1	0.0	9.6
$31-60$	≤ 75	≤ 150	7	21	23.5	0.3	0.0	23.5	55.2	0.0	23.3	0.0	1.0	16.8	0.0	28.5
		≤ 230	8	21	21.0	1.7	0.0	21.0	46.7	0.0	20.9	0.1	0.2	17.7	0.0	15.7
		$501 \leq$	9	22	22.3	1.8	0.0	22.4	309.9	0.3	22.3	0.1	0.0	20.9	0.1	6.3
	$76 \leq$	≤ 325	10	26	33.5	3.5	0.0				33.2	0.1	0.9	22.5	0.0	32.8
		≤ 500	11	24	30.4	9.0	0.0				30.3	0.2	0.3	24.5	0.1	19.6
		$501 \leq$	12	27	33.2	14.2	0.0				33.2	0.3	0.0	27.8	0.1	16.2
$61-90$	≤ 125	≤ 500	13	18	41.5	5.7	0.0				40.9	0.2	1.5	30.4	0.1	26.6
		≤ 800	14	18	35.1	24.8	0.0				34.9	0.4	0.5	32.5	0.2	7.3
		$1201 \leq$	15	18	36.2	10.0	0.0				36.1	0.7	0.3	34.8	0.3	3.8
	$126 \leq$	≤ 800	16	20	54.3	21.9	0.0				53.8	0.4	0.8	36.7	0.2	32.4
		≤ 1200	17	19	46.2	246.0	0.1				45.7	0.8	1.0	38.2	0.3	17.3
		$1201 \leq$	18	20	48.4	323.1	0.4				48.3	1.6	0.2	42.0	0.5	13.2
$91-130$	≤ 195	≤ 1000	19	21	70.0	88.3	0.0				69.5	0.6	0.7	50.0	0.3	28.6
		≤ 1900	20	19	58.4	179.5	0.0				58.3	1.7	0.2	50.8	0.6	13.0
		$2701 \leq$	21	18	57.5	1314.6	1.6				57.5	2.9	0.0	53.6	1.0	6.8
	$196 \leq$	≤ 1800	22	20	71.6	427.8	0.2				71.2	1.5	0.6	53.8	0.6	24.9
		≤ 2700	23	18	66.7	1854.8	1.2				66.4	3.8	0.5	56.8	1.1	14.8
		$2701 \leq$	24	19	64.9	2029.7	1.4				64.9	5.1	0.0	59.3	1.6	8.6
$131 \leq$	≤ 300	≤ 2750	25	18	84.8	1093.8	1.0				83.3	2.8	1.8	69.5	1.1	18.0
		≤ 4300	26	20	75.9	2147.2	1.7				75.5	7.3	0.6	71.3	2.8	6.1
		$15001 \leq$	27	19	80.3	1353.2	0.4				80.2	23.1	0.2	78.9	8.4	1.7
	$301 \leq$	≤ 8000	28	18	146.5	3601.5	12.8				127.6	22.8	12.9	109.7	8.2	25.1
		≤ 15000	29	17	167.7	3377.1	13.3				138.4	77.7	17.5	127.5	22.9	24.0
		$15001 \leq$	30	16	189.5	3299.3	13.1				148.8	352.4	21.5	41.6	14.6	78.0
					54.1	714.3	1.6				50.9	16.9	2.1	40.6	2.2	19.5

Source: The Authors

The column organization of Table 5.2 is as follows. Column $|D|$ represents the interval of the number of programmable devices that each group of instances has. Columns $|I|$ and $|F|$ follow the same concept of column $|D|$, but for interfaces and flows, respectively. For example, if a topology belongs to the first group, it means that it has between one and thirty devices, has twenty-five interfaces or less and has twelve flows or less. Column *Group* presents the group id. Column *#Instances* indicates the number of topologies in each topology group. Columns *Covering Sol*, *Covering Time* and *Covering CPLEX Gap* represent the average, average meaning the sum of the obtained values divided by the number of topologies in such group, of the solution, time and CPLEX gap, the CPLEX gap represents the difference between upper and lower bound solutions found by CPLEX. The VRP and Lower bound columns follow the same concept. Columns Gap_v represent the gap between the solutions found by the Covering model and the Lower Bound. The Gap_v for VRP was not calculated. To calculate the Gap_v, the formula is:

$$Gap_v = 100 \times \frac{CoveringSol. - LowerSol.}{CoveringSol.}$$

5.3 Covering Model Analysis

If we consider groups 1 to 16, all topologies were able to find an optimal solution in, on average, less than a minute. If the scope is stretched to group 27, however, it is noticeable that, even though these larger topologies did not find an optimal solution, the average gap never surpassed 2%. When analyzing the test results individually, in Table 7.5, it is possible to see that this is a consequence of the model finding optimal solutions for many topologies. In the case of group 26, the group that presented the highest gap, out of the twenty topologies, thirteen succeeded in finding optimal solutions, the other seven topologies had gap values of 2.78%, 1.39%, 2.20%, 9.73%, 2.67%, 6.58%, 1.14% and 7.23%. When calculating the average of the values, the average found is 1.7%. Therefore, we can conclude that, even though the model could not find optimal solutions for some topologies, the average gap of the group is low because it found optimal solutions for the majority of the topologies.

When focusing on the bigger topology groups, such as 28, 29 and 30, it is clear that the time average rises drastically. Since the tests were executed with a one hour limit, and the average time nears an hour. This means that almost no topology was able to find an optimal solution and the execution had to be stopped. This is also reflected by the average gap value, which revolves around 13%. Even though these tests were not able to find an optimal solution when comparing the solutions to the solutions provided by the Lower bound, the difference is not too expressive, it averages 17%. This means that the chances of the scenarios of improving the best-known solution were low.

The solution values found by the Covering model are very similar to the values found in the lower bound solutions. When considering solutions found by the Unbounded lower bound, the gap is almost neglectful. In the best case, the optimal solution found by the Covering model is the same as the one found in Unbounded. In the worst case, where the Covering model was unable to find an optimal solution, the solution value found by the Covering model is only 21% higher than the one found by Unbounded. On average, the gap is 2.1%.

Topologies with a higher level of activity take longer to run because there are more flows that the solver has to consider. However, the solution value is lower because, if a flow reaches its carrying limitation, the chances of another flow sharing an interface are higher, so a different flow can cover this interface instead of the same flow creating a new telemetry header. This can be observed in Table 5.2. Groups that have a higher number of flows tend to have a lower solution value than the ones that have a lower number of flows. The only exception to this pattern are topologies located in groups 28, 29, and 30 because the solver reached its execution time limit, therefore it did not reach the threshold where the solution values become lower.

5.4 VRP Model Analysis

In this section, the results obtained by testing the VRP model are discussed. The difference between the results obtained by the Covering model and those obtained by the VRP model is that there are many rows which are empty for VRP. This is because the VRP model presented memory barriers. Since it only uses one decision variable set, and it controls all the different requirements of the problem, the number of variables in this model is much higher than in Covering. So, when trying to generate the linear programming data format, GLPSOL runs out of memory when generating the tree of possible values for the variables and constraints.

When considering the first 9 groups, it is possible to see that most tests succeeded in finding optimal solutions. Furthermore, the time elapsed for the majority of the tests did not surpass one minute. The average gap between the solution found from VRP and the one found by Unbounded is 0.3%, the lowest is 0%, and the highest is 0.8%. Starting from group 10, some topology models were not generated because the computer ran out of memory, therefore, we omitted the data as to not hinder data visualization with partial information. After group 17, no topology was able to execute due to the memory limits.

5.5 Comparison

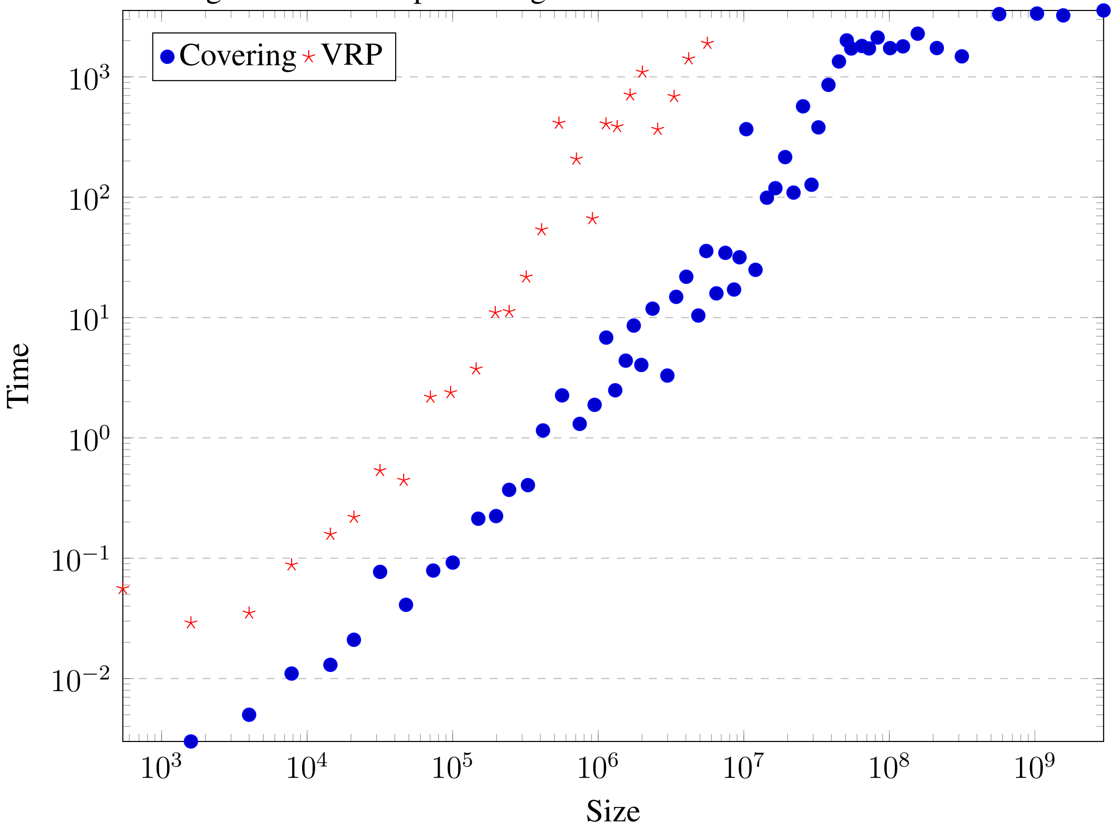
In order to compare both models, two metrics were considered. Since we want to better understand the relation between the topology size to the time taken to run its test, the first metric is the time elapsed running each test. Likewise, we want to know how the gap of the solution found is affected by the topology size, the second metric is the solution gap. In order to have a cleaner visualization of this information, two Plots 5.1 and 5.2 were generated.

Figure 5.1 is the plot that shows the relationship between the execution time and size (size is the result of a multiplication of the number of devices, flows, and interfaces) of a topology. On the x-axis, the size is represented and on the y-axis, the time elapsed is represented. Both axes are on a logarithmic scale in order to facilitate data visualization. The circles represent the solutions found when using the Covering model and stars represent the solutions found when using the VRP model.

In general, the Covering model finds optimal solutions faster than the VRP model. From the plot, one can observe that the Covering model finds solutions ten times faster. When the size of the topology is around 10^5, the VRP model runs into memory issues. Therefore, after that, only the Covering model is able to run. Not only small topologies are quick to execute. Any topology that does not provide many feasible solutions also gets executed very fast. That happens because there are not many possibilities to be explored. For example, a topology which only has one flow going through each interface only presents one feasible solution, consequently, it would execute much faster than a topology which has a higher level of network activity, although it will probably have a higher solution value as well. We can confirm this by comparing similar topologies with different levels of activity.

Figure 5.2 is a plot that shows the relationship between the topology size and solution gap. The gap represents the gap values returned by CPLEX which is the difference between the upper and lower bound values found at the end of the execution. If they are

Figure 5.1: Plot representing relation between time and size



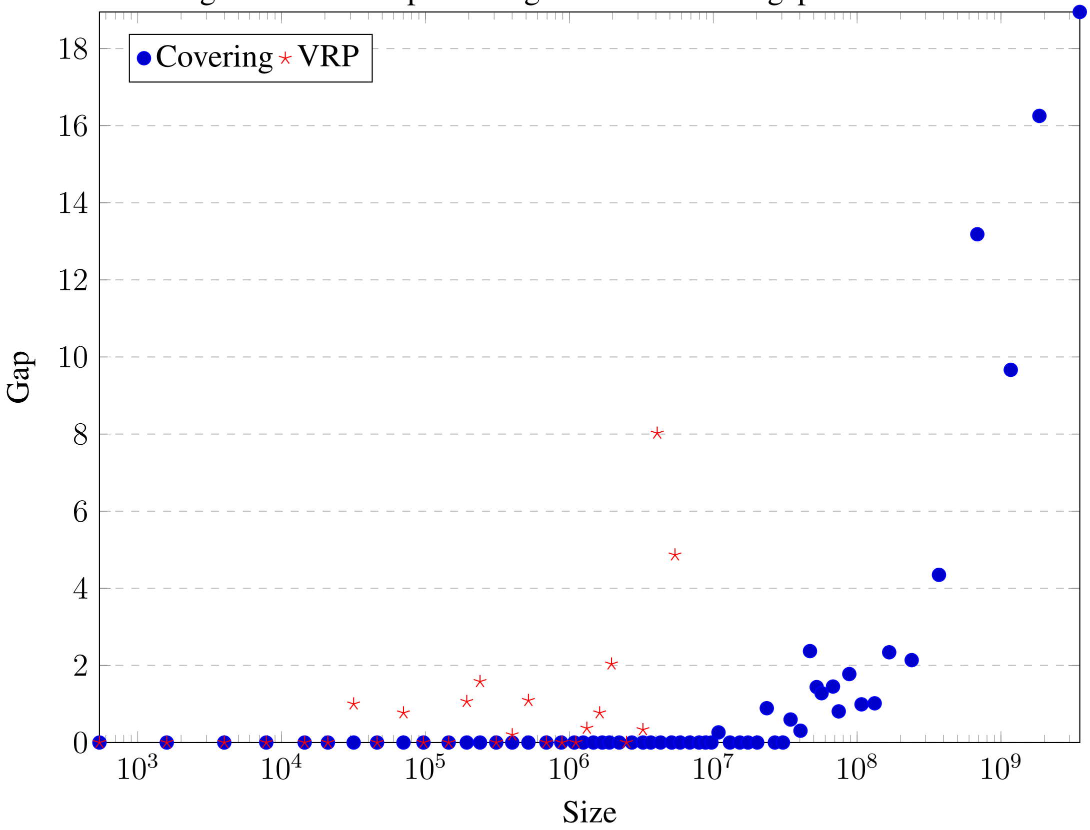
Source: The Authors

the same, the gap is 0 and the solution is optimal. If the values are not the same, the gap is higher than 0, but there is a chance that the solution found thus far is optimal, however, the solver was not able to confirm before timing out. On the x-axis the size is represented and on the y-axis, the solution CPLEX gap is represented. Like the first plot, the size is represented in logarithmic scale in order to facilitate data visualization, circles represent the values obtained by running the Covering model and the stars represent the values obtained when running the VRP model.

In smaller topologies (i.e., size $< 10^4$), both models find optimal solutions. However, when topologies increase in size, VRP starts faltering while Covering still finds optimal solutions, this is observed when the size nears 10^5. When the size reaches 10^7, VRP is no longer executed, however, Covering still finds optimal solutions. As the topologies reach near 10^8 in size, Covering is not able to find optimal solutions anymore.

The reason that the Covering model executes much faster than the VRP model is that of the set of decision variables sets and its constraints. The Covering model has three decision variables each with a specific purpose, while the VRP model has a single decision variable which suits all problem requirements. VRP model also uses a lot of constraints that need to consider the whole variable scope. This greatly increases the tree of possible

Figure 5.2: Plot representing relation between gap and size



Source: The Authors

values which needs to be tested while the Covering model has compact constraints. This, ultimately, leads to the Covering model executing much faster. Therefore, based on the information provided, we conclude that the Covering model is much better for both time and gap aspects. It runs much faster than the VRP model and finds optimal solutions in topologies that the VRP is unable to run.

6 FINAL CONSIDERATIONS

Network monitoring has been the subject of many discussions and proposals in recent years. This is due to the fact that, with recent technology advances, the complexity of accurately diagnosing network events, and the need for more detailed information regarding device state, in a timely manner has risen. In an attempt to efficiently diagnose network events through the usage of in-band telemetry, we introduce the Network Monitoring Optimization (NEMO) problem, which aims to provide optimal packet distribution within flows while obtaining precise and timely information with low network overhead.

We propose two models that represent different approaches to solving the NEMO problem. The Covering model utilizes a straight-forward approach to solving the problem, while the VRP model is a generalization of the Vehicle Routing Problem. Both models can find similar solutions in small topologies (i.e., size < 10^5) but the Covering model runs about ten times faster and uses less memory (in our landscape, the VRP model is unable to execute for scenarios with size > 10^7), where the Covering model still thrives. In big topologies (i.e., size > 10^7) it was not possible to generate the VRP model, because it requires too much memory. Consequently, the Covering model is the best choice when solving any instance of NEMO.

When comparing the solutions provided by the Covering model, for topologies with up to 300 interfaces, against the solutions provided by the Lower bound, we notice that the gaps never exceed 2%. Therefore, solutions provided by the Covering model are very close to the lower bound solutions. In topologies that have more than 300 interfaces, the Covering model was unable to finish in under an hour, therefore, the solutions found are not optimal. In this case, the gaps average 17%.

In the path of formalizing this study, it was possible to notice that there are many related branches that could be explored, for example:

- Usage of metaheuristics to solve the Network Monitoring Optimization Problem;
- Usage of reoptimization. It consists in developing a new model which takes into account existing solutions to solve similar inputs;
- Proof of NP-completeness of the NEMO problem. The initial idea was to include this in this work, but due to lack of time, it was not possible.

All the codes and models utilized for this study are available in the author's GitHub repository (SPANIOL, 2018).

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7 APPENDIX

7.1 GLPK Code Covering

```
# In-band Telemetry Optimization problem
#
# This problem finds the least amount of telemetry data fetch possible that
# gets data from all routers present at a landscape
#
# Authors: Fernando Spaniol, Luciana Buriol, Jonatas Marques, Luciano Gaspary

set S;
# Array of indexes of flows

set V;
# Set that defines what routers are in a network

set F{s in S} within (V cross V);
# All flows in an environment

set Last{s in S} within (V cross V);
# All flows in an environment

set A within (V cross V);
# Set of archs in a network

var C{S,V} >= 0;
# Control the weight that each route is handling

var Y{S,V} >=0, binary;
# Check whether route k dispatches on device V

var X{A,S} >=0, binary;
# Check whether arch A is handled by route K

param q;
# Capacity that each flow can carry at one same time

```

```
minimize groups: sum{s in S, u in V} Y[s,u];
# amount of telemetry submitions

s.t. checkFlow{(u,v) in A}: sum{s in S} X[u,v,s] = 1;
# check if all archs are being covered by a route

s.t. sameFlow{s in S, (u,v) in A diff F[s]}: X[u,v,s] = 0;
# Make sure that a route only takes items from passes through a flow with same index

s.t. deliver{s in S, (u,v) in F[s]}: X[u,v,s] >= Y[s,u];
# A route can only deliver if it collects on that device

s.t. receive{s in S, (u,v) in F[s]}: C[s,u] <= X[u,v,s] * q;
# If a device is not going to collect a flow, it should have never gotten any weight

s.t. weight1{s in S, (u,v) in F[s]}: Y[s,u] - X[u,v,s] >= -C[s,v];
# If a route carries and not delivers, bind the weight, if it carries and delivers, the weight has to be 0

s.t. weight2{s in S, (u,v) in F[s]}: (-Y[s,u] + X[u,v,s]) * q >= C[s,v];
# Limit the capacity of a flow and make it dispatch

s.t. bindWeight1{s in S, (u,v) in F[s]}: C[s,v] <= C[s,u] + 1 + (1 - X[u,v,s]) * q + Y[s,u] * q;
# First bindage of the weight

s.t. bindWeight2{s in S, (u,v) in F[s]}: C[s,v] >= C[s,u] + 1 - (1 - X[u,v,s]) * q - Y[s,u] * q;
# Second bindage of the weight

s.t. dispatchLast{s in S, (u,v) in Last[s]}: Y[s,u] >= X[u,v,s];
# Dispatch the last device

solve;
end;
```

7.2 GLPK Code VRP

```

# In-band Telemetry Optimization problem
#
# Vehicle Routing Problem based approach
#
# This problem finds the least amount of telemetry data fetch possible that
# gets data from all routers present at a landscape
#
# Authors: Fernando Spaniol, Luciana Buriol, Jonatas Marques, Luciano Gaspary

set V;
# Set that defines what routers are in a network

set S;
# Array of indexes of flows

set Z := {0};
# Set that has the base router

set A within (V cross V);
# Set of archs in a network

set K := 1 .. card(A);
# Set that defines the indexes of the routes

set Last{s in S} within (V cross V);
# Dummy to not have to alter the inputs

set F{s in S} within (V cross V);
# All flows in an environment

var X{A union (V cross Z) union (Z cross V),K,S} >=0, binary;
# Check whether arch A from flow F is handled by route K

param q;
# Capacity that each group an handle

minimize groups: sum{v in V, k in K, s in S} X[0,v,k,s];
# amount of telemetry submitions
```

```

s.t. checkFlow{(u,v) in A}: sum{s in S} sum{k in K} X[u,v,k,s] >= 1;
# check if all archs are being covered by a route

s.t. keepFlow{k in K, s in S, v in V}: sum{(a,v) in (F[s] union (Z cross {v}))} X[a,v,k,s] = sum{(v,b) in (F[s] union ({v} cross Z))} X[v,b,k,s];
# This binds the route to go back to the base router

s.t. bindFlow{k in K, s in S, (u,v) in A diff F[s]}: X[u,v,k,s] = 0;
# A link can only be handled by a flow that has it

s.t. oneFlow{k in K}: sum{s in S} sum{(u,v) in (Z cross V)} X[u,v,k,s] <= 1;
# The route only has one group

s.t. weight{k in K}: sum{s in S} sum{(u,v) in A} X[u,v,k,s] <= q;
# limit the weight of each group

solve;
end;
```

7.3 GLPK Code Unbounded

```
# In-band Telemetry Optimization problem
#
# This problem finds the least amount of telemetry data fetch possible that
# gets data from all routers present at a landscape
#
# Authors: Fernando Spaniol, Luciana Buriol, Jonatas Marques, Luciano Gaspary

set S;
# Array of indexes of flows

set V;
# Set that defines what routers are in a network

set F{s in S} within (V cross V);
# All flows in an environment
```

```

set Last{s in S} within (V cross V);
# All flows in an environment

set A within (V cross V);
# Set of archs in a network

var Y{S,V} >=0, binary;
# Check whether route k dispatches on device V

var X{A,S} >=0, binary;
# Check whether arch A is handled by route K

minimize groups: sum{s in S, u in V} Y[s,u];
# amount of telemetry submitions

s.t. checkFlow{(u,v) in A}: sum{s in S} X[u,v,s] = 1;
# check if all archs are being covered by a route

s.t. sameFlow{s in S, (u,v) in A diff F[s]}: X[u,v,s] = 0;
# Make sure that a route only takes items from passes through a flow with same index

s.t. deliver{s in S, (u,v) in F[s]}: X[u,v,s] >= Y[s,u];
# A route can only deliver if it collects on that device

s.t. dispatchLast{s in S, (u,v) in Last[s]}: Y[s,u] >= X[u,v,s];
# Dispatch the last device

s.t. break{s in S, (u,v) in F[s], (v,z) in F[s]}: Y[s,u] >= X[u,v,s] - X[v,z,s];
# Need to dispatch in case the next one is not selected

solve;
end;
```

7.4 GLPK Code Integer Programming Relaxation

```

# In-band Telemetry Optimization problem
#
```

```
# This problem finds the least amount of telemetry data fetch possible that
# gets data from all routers present at a landscape
#
# Authors: Fernando Spaniol, Luciana Buriol, Jonatas Marques, Luciano Gaspary

set S;
# Array of indexes of flows

set V;
# Set that defines what routers are in a network

set F{s in S}, dimen 2;
# All flows in an environment

set Last{s in S}, dimen 2;
# All flows in an environment

set A, dimen 2;
# Set of archs in a network

var C{S,V} >= 0;
# Control the weight that each route is handling

var Y{S,V} >=0;
# Check whether route k dispatches on device V

var X{A,S} >=0;
# Check whether arch A is handled by route K

param q;
# Capacity that each flow can carry at one same time

minimize groups: sum{s in S, u in V} Y[s,u];
# amount of telemetry submitions

s.t. checkFlow{(u,v) in A}: sum{s in S} X[u,v,s] = 1;
# check if all archs are being covered by a route

s.t. sameFlow{s in S, (u,v) in A diff F[s]}: X[u,v,s] = 0;
```

```
# Make sure that a route only takes items from passes through a flow with same index

s.t. deliver{s in S, (u,v) in F[s]}: X[u,v,s] >= Y[s,u];
# A route can only deliver if it collects on that device

s.t. receive{s in S, (u,v) in F[s]}: C[s,u] <= X[u,v,s] * q;
# If a device is not going to collect a flow, it should have never gotten any weight

s.t. weight1{s in S, (u,v) in F[s]}: Y[s,u] - X[u,v,s] >= -C[s,v];
# If a route carries and not delivers, bind the weight, if it carries and delivers, the weight has to be 0

s.t. weight2{s in S, (u,v) in F[s]}: (-Y[s,u] + X[u,v,s]) * q >= C[s,v];
# Limit the capacity of a flow and make it dispatch

s.t. bindWeight1{s in S, (u,v) in F[s]}: C[s,v] <= C[s,u] + 1 + (1 - X[u,v,s]) * q + Y[s,u] * q;
# First bindage of the weight

s.t. bindWeight2{s in S, (u,v) in F[s]}: C[s,v] >= C[s,u] + 1 - (1 - X[u,v,s]) * q - Y[s,u] * q;
# Second bindage of the weight

s.t. dispatchLast{s in S, (u,v) in Last[s]}: Y[s,u] >= X[u,v,s];
# Dispatch the last device

solve;

end;
```

7.5 Result Table

Table 7.1: Result table

Instance Name	$\lvert D\rvert$	$\lvert I\rvert$	$\lvert F\rvert$	Covering			VRP			Unbounded			Relax		
				Sol	Time	CPLEX Gap	Sol	Time	CPLEX Gap	Sol	Time	Gap_v	Sol	Time	Gap_v
zoo_7_3	5	6	3	3	0.01	0.00	3	0.04	0.00	3	0.00	0	2	0.00	33.33
zoo_7_5	7	9	5	4	0.01	0.00	4	0.05	0.00	4	0.00	0	3	0.00	25.00
zoo_7_7	7	9	7	4	0.01	0.00	4	0.04	0.00	4	0.00	0	3	0.00	25.00
zoo_8_12	8	13	12	6	0.01	0.00	6	0.06	0.00	6	0.01	0	4	0.00	33.33
zoo_8_9	8	12	9	6	0.01	0.00	6	0.28	0.00	6	0.00	0	4	0.00	33.33
zoo_9_6	7	10	6	6	0.01	0.00	6	0.05	0.00	6	0.00	0	3	0.00	50.00
zoo_10_12	10	14	12	5	0.01	0.00	5	0.12	0.00	5	0.01	0	5	0.00	0
zoo_10_16	10	14	16	5	0.01	0.00	5	0.07	0.00	5	0.01	0	5	0.00	0
zoo_10_20	10	14	20	5	0.01	0.00	5	0.04	0.00	5	0.01	0	5	0.00	0
zoo_10_4	7	8	4	3	0.01	0.00	3	0.05	0.00	3	0.01	0	3	0.00	0
zoo_10_8	8	11	8	4	0.01	0.00	4	0.24	0.00	4	0.01	0	4	0.00	0
zoo_11_12	9	14	12	6	0.01	0.00	6	0.13	0.00	6	0.01	0	4	0.00	33.33
zoo_11_6	10	11	6	5	0.01	0.00	5	0.13	0.00	5	0.00	0	4	0.00	20.00
zoo_12_12	11	15	12	6	0.01	0.00	6	0.06	0.00	6	0.01	0	5	0.00	16.66
zoo_12_18	10	15	18	5	0.02	0.00	5	0.16	0.00	5	0.01	0	4	0.00	20.00
zoo_12_24	12	19	24	6	0.09	0.00	6	0.22	0.00	6	0.01	0	6	0.00	0

zoo_12_30	12	19	30	6	0.02	0.00	6	0.24	0.00	6	0.01	0	6	0.00	0
zoo_12_6	8	11	6	5	0.01	0.00	5	0.29	0.00	5	0.00	0	4	0.00	20.00
zoo_12_9	11	15	9	8	0.01	0.00	8	0.02	0.00	8	0.00	0	5	0.00	37.50
zoo_13_12	9	15	12	6	0.01	0.00	6	0.28	0.00	6	0.01	0	4	0.00	33.33
zoo_13_17	12	18	17	5	0.01	0.00	5	0.05	0.00	5	0.01	0	5	0.00	0
zoo_13_33	13	18	33	6	0.02	0.00	6	0.23	0.00	6	0.01	0	6	0.00	0
zoo_13_9	10	13	9	7	0.01	0.00	7	0.13	0.00	7	0.01	0	4	0.00	42.85
zoo_14_17	14	19	17	7	0.01	0.00	7	0.12	0.00	7	0.01	0	7	0.00	0
zoo_14_25	13	21	25	6	0.01	0.00	6	0.16	0.00	6	0.01	0	6	0.00	0
zoo_14_33	14	22	33	7	0.03	0.00	7	0.40	0.00	7	0.01	0	7	0.00	0
zoo_14_42	14	22	42	7	0.03	0.00	7	0.65	0.00	7	0.01	0	7	0.00	0
zoo_14_9	10	13	9	4	0.01	0.00	4	0.24	0.00	4	0.01	0	3	0.00	25.00
zoo_15_15	13	21	15	11	0.01	0.00	11	0.05	0.00	11	0.01	0	5	0.00	54.54
zoo_15_45	15	21	45	7	0.03	0.00	7	0.49	0.00	7	0.01	0	7	0.00	0
zoo_16_12	11	13	12	5	0.01	0.00	5	0.03	0.00	5	0.01	0	5	0.00	0
zoo_16_23	14	21	23	8	0.02	0.00	8	0.10	0.00	8	0.01	0	6	0.00	25.00
zoo_16_34	16	25	34	9	0.04	0.00	9	0.38	0.00	9	0.01	0	8	0.00	11.11
zoo_16_45	15	24	45	7	0.04	0.00	7	0.45	0.00	7	0.01	0	7	0.00	0
zoo_16_56	16	25	56	8	0.05	0.00	8	0.54	0.00	8	0.02	0	8	0.00	0

zoo_17_29	16	37	29	29	0.03	0.00	29	0.43	0.00	29	0.00	0	13	0.00	55.17
zoo_18_15	14	23	15	15	0.02	0.00	15	0.28	0.00	15	0.00	0	7	0.00	53.33
zoo_18_29	14	20	29	8	0.02	0.00	8	0.16	0.00	8	0.01	0	7	0.00	12.50
zoo_18_43	16	25	43	10	0.04	0.00	10	0.37	0.00	10	0.01	0	7	0.00	30.00
zoo_18_57	17	26	57	10	0.04	0.00	10	0.79	0.00	10	0.01	0	8	0.00	20.00
zoo_18_72	18	28	72	10	0.07	0.00	10	1.36	0.00	10	0.02	0	9	0.01	10.00
zoo_19_15	13	18	15	8	0.01	0.00	8	0.04	0.00	8	0.01	0	6	0.00	25.00
zoo_19_18	16	21	18	10	0.01	0.00	10	0.06	0.00	10	0.01	0	7	0.00	30.00
zoo_19_29	16	23	29	10	0.02	0.00	10	0.16	0.00	10	0.01	0	7	0.00	30.00
zoo_19_57	18	30	57	12	0.05	0.00	12	1.08	0.00	12	0.02	0	9	0.00	25.00
zoo_19_72	18	30	72	12	0.06	0.00	12	1.19	0.00	12	0.02	0	9	0.01	25.00
zoo_20_17	13	17	17	7	0.01	0.00	7	0.04	0.00	7	0.01	0	6	0.00	14.28
zoo_20_18	15	17	18	6	0.01	0.00	6	0.06	0.00	6	0.01	0	6	0.00	0
zoo_20_25	13	18	25	6	0.01	0.00	6	0.08	0.00	6	0.01	0	6	0.00	0
zoo_20_33	14	20	33	7	0.02	0.00	7	0.14	0.00	7	0.01	0	7	0.00	0
zoo_20_36	19	26	36	11	0.02	0.00	11	0.21	0.00	11	0.01	0	9	0.00	18.18
zoo_20_42	14	20	42	7	0.02	0.00	7	0.19	0.00	7	0.01	0	7	0.00	0
zoo_20_44	18	22	44	7	0.03	0.00	7	0.38	0.00	7	0.01	0	7	0.00	0
zoo_20_54	19	27	54	9	0.07	0.00	9	0.40	0.00	9	0.01	0	9	0.00	0

zoo_20_55	19	27	55	10	0.09	0.00	10	0.37	0.00	10	0.02	0	9	0.00	10.00
zoo_20_72	19	27	72	9	0.07	0.00	9	0.80	0.00	9	0.02	0	9	0.01	0
zoo_20_9	10	14	9	7	0.01	0.00	7	0.02	0.00	7	0.01	0	5	0.00	28.57
zoo_20_90	20	29	90	10	0.06	0.00	10	0.83	0.00	10	0.02	0	10	0.01	0
zoo_21_54	17	24	54	8	0.03	0.00	8	0.40	0.00	8	0.02	0	8	0.00	0
zoo_22_110	22	32	110	11	0.08	0.00	11	1.20	0.00	11	0.02	0	11	0.01	0
zoo_22_22	22	30	22	16	0.01	0.00	16	0.14	0.00	16	0.01	0	12	0.00	25.00
zoo_22_36	19	28	36	13	0.05	0.00	13	0.24	0.00	13	0.02	0	9	0.00	30.76
zoo_22_44	22	32	44	15	0.04	0.00	15	0.48	0.00	15	0.01	0	11	0.00	26.66
zoo_22_66	19	26	66	10	0.40	0.00	10	0.71	0.00	10	0.02	0	8	0.01	20.00
zoo_22_72	20	29	72	10	0.08	0.00	10	0.96	0.00	10	0.02	0	10	0.01	0
zoo_22_88	22	47	88	19	0.11	0.00	19	2.47	0.00	19	0.02	0	11	0.01	42.10
zoo_22_90	20	29	90	10	0.04	0.00	10	0.85	0.00	10	0.03	0	10	0.01	0
zoo_24_105	24	39	105	13	0.14	0.00	13	2.56	0.00	13	0.02	0	12	0.01	7.69
zoo_24_132	24	39	132	13	0.17	0.00	13	3.62	0.00	13	0.03	0	12	0.02	7.69
zoo_24_27	18	27	27	14	0.02	0.00	14	0.14	0.00	14	0.01	0	8	0.00	42.85
zoo_24_32	20	26	32	13	0.02	0.00	13	0.17	0.00	13	0.01	0	7	0.00	46.15
zoo_24_53	23	36	53	15	0.03	0.00	15	0.54	0.00	15	0.01	0	11	0.01	26.66
zoo_24_79	24	38	79	12	0.04	0.00	12	1.08	0.00	12	0.02	0	12	0.01	0

zoo_25_32	18	25	32	10	0.02	0.00	10	0.33	0.00	10	0.01	0	9	0.00	10.00
zoo_25_63	22	39	63	15	0.07	0.00	15	0.97	0.00	15	0.02	0	10	0.01	33.33
zoo_26_125	26	49	125	18	0.39	0.00	18	2.84	0.00	18	0.04	0	13	0.02	27.77
zoo_26_130	26	43	130	13	0.12	0.00	13	6.02	0.00	13	0.04	0	13	0.02	0
zoo_26_156	26	50	156	18	0.60	0.00	18	6.71	0.00	18	0.04	0	13	0.02	27.77
zoo_26_32	19	31	32	12	0.02	0.00	12	0.26	0.00	12	0.01	0	7	0.00	41.66
zoo_26_63	24	43	63	21	0.06	0.00	21	1.64	0.00	21	0.01	0	11	0.01	47.61
zoo_26_65	22	37	65	12	0.07	0.00	12	1.45	0.00	12	0.03	0	10	0.01	16.66
zoo_26_94	24	44	94	18	0.21	0.00	18	2.24	0.00	18	0.03	0	11	0.01	38.88
zoo_28_109	27	39	109	14	0.11	0.00	14	2.46	0.00	14	0.03	0	13	0.01	7.14
zoo_28_145	27	38	145	13	0.10	0.00	13	4.10	0.00	13	0.03	0	13	0.02	0
zoo_28_182	28	41	182	14	0.15	0.00	14	5.07	0.00	14	0.04	0	14	0.02	0
zoo_28_37	28	33	37	14	0.02	0.00	14	0.67	0.00	14	0.01	0	14	0.00	0
zoo_28_42	22	34	42	10	0.10	0.00	10	2.01	0.00	9	0.02	10.00	9	0.00	10.00
zoo_28_48	21	33	48	11	0.04	0.00	11	1.05	0.00	11	0.02	0	8	0.00	27.27
zoo_28_73	28	41	73	19	0.09	0.00	19	1.57	0.00	19	0.02	0	14	0.01	26.31
zoo_29_109	28	47	109	14	0.33	0.00	14	4.79	0.00	14	0.04	0	14	0.02	0
zoo_29_145	26	45	145	13	0.29	0.00	13	15.08	0.00	13	0.04	0	12	0.02	7.69
zoo_29_182	28	47	182	14	0.24	0.00	14	18.96	0.00	14	0.05	0	14	0.02	0

zoo_29_37	21	32	37	11	0.04	0.00	11	0.73	0.00	11	0.01	0	7	0.00	36.36
zoo_29_73	26	45	73	14	0.11	0.00	14	1.36	0.00	14	0.02	0	12	0.01	14.28
zoo_29_84	26	41	84	11	0.27	0.00	11	15.96	0.00	11	0.03	0	11	0.10	0
zoo_30_126	28	46	126	13	0.17	0.00	13	9.94	0.00	13	0.04	0	13	0.02	0
zoo_30_168	29	47	168	14	0.35	0.00	14	11.37	0.00	14	0.06	0	14	0.02	0
zoo_30_210	30	48	210	15	0.35	0.00	15	34.93	0.00	15	0.13	0	15	0.03	0
zoo_30_42	19	31	42	12	0.03	0.00	12	0.61	0.00	12	0.01	0	8	0.00	33.33
zoo_30_48	23	36	48	14	0.04	0.00	14	0.67	0.00	14	0.02	0	11	0.00	21.42
zoo_30_84	27	45	84	12	0.10	0.00	12	4.02	0.00	12	0.03	0	12	0.02	0
zoo_31_144	30	47	144	15	0.29	0.00	15	6.91	0.00	15	0.10	0	14	0.02	6.66
zoo_31_48	26	43	48	15	0.08	0.00	15	1.39	0.00	15	0.02	0	11	0.01	26.66
zoo_32_126	30	45	126	16	0.63	0.00	16	4.77	0.00	16	0.04	0	15	0.02	6.25
zoo_32_144	32	56	144	19	1.26	0.00	19	13.07	0.00	19	0.04	0	16	0.02	15.78
zoo_32_168	30	46	168	16	0.42	0.00	16	4.04	0.00	16	0.04	0	15	0.02	6.25
zoo_32_192	32	56	192	19	1.56	0.00	19	19.86	0.00	19	0.05	0	16	0.03	15.78
zoo_32_240	32	57	240	19	1.53	0.00	19	28.71	0.00	19	0.07	0	16	0.03	15.78
zoo_32_42	24	31	42	14	0.04	0.00	14	0.43	0.00	14	0.01	0	10	0.00	28.57
zoo_32_48	26	39	48	14	0.06	0.00	14	0.66	0.00	14	0.02	0	11	0.01	21.42
zoo_32_84	28	39	84	17	0.12	0.00	17	1.29	0.00	17	0.02	0	13	0.01	23.52

zoo_32_96	27	49	96	16	0.22	0.00	16	3.63	0.00	16	0.03	0	12	0.02	25.00
zoo_33_55	28	56	55	28	0.03	0.00	28	1.05	0.00	28	0.01	0	14	0.01	50.00
zoo_34_109	34	73	109	33	0.12	0.00	33	6.01	0.00	33	0.03	0	17	0.02	48.48
zoo_34_163	33	57	163	22	0.61	0.00	22	10.34	0.00	22	0.05	0	16	0.02	27.27
zoo_34_217	33	54	217	17	0.37	0.00	17	151.58	0.00	17	0.15	0	16	0.03	5.88
zoo_34_272	34	80	272	35	1.99	0.00	35	31.78	0.00	35	0.08	0	17	0.04	51.42
zoo_34_55	26	45	55	13	0.27	0.00	13	17.45	0.00	12	0.03	7.69	9	0.01	30.76
zoo_35_123	32	59	123	18	0.58	0.00	18	28.26	0.00	17	0.04	5.55	14	0.02	22.22
zoo_35_184	35	51	184	19	0.36	0.00	19	14.37	0.00	19	0.06	0	17	0.03	10.52
zoo_35_62	27	36	62	16	0.08	0.00	16	1.56	0.00	16	0.02	0	11	0.01	31.25
zoo_36_123	32	47	123	14	0.18	0.00	14	80.79	0.00	14	0.05	0	14	0.02	0
zoo_36_184	34	49	184	16	0.27	0.00	16	50.38	0.00	16	0.11	0	16	0.03	0
zoo_36_185	35	68	185	21	4.78	0.00	21	17.51	0.00	21	0.07	0	17	0.03	19.04
zoo_36_245	36	63	245	24	0.25	0.00	24	22.17	0.00	24	0.07	0	18	0.04	25.00
zoo_36_306	36	53	306	18	0.43	0.00	18	160.44	0.00	18	0.30	0	18	0.06	0
zoo_36_62	32	49	62	24	0.05	0.00	24	1.21	0.00	24	0.01	0	15	0.01	37.50
zoo_36_69	26	40	69	13	0.11	0.00	13	1.12	0.00	13	0.02	0	13	0.01	0
zoo_37_69	25	40	69	16	0.14	0.00	16	1.24	0.00	16	0.03	0	9	0.01	43.75
zoo_37_76	33	60	76	20	0.08	0.00	20	3.14	0.00	20	0.02	0	14	0.01	30.00

zoo_38_137	34	56	137	16	0.39	0.00	16	37.44	0.00	15	0.05	6.25	15	0.02	6.25
zoo_38_205	36	58	205	17	0.40	0.00	17	99.42	0.00	17	0.15	0	17	0.03	0
zoo_38_273	38	60	273	19	0.54	0.00	19	77.96	0.00	19	0.18	0	19	0.05	0
zoo_38_342	38	60	342	19	0.61	0.00	19	80.32	0.00	19	0.21	0	19	0.06	0
zoo_38_69	32	54	69	27	0.06	0.00	27	1.69	0.00	27	0.02	0	15	0.01	44.44
zoo_39_152	35	71	152	25	0.46	0.00	25	15.47	0.00	25	0.09	0	15	0.02	40.00
zoo_39_228	37	75	228	23	1.33	0.00	23	24.75	0.00	23	0.08	0	17	0.04	26.08
zoo_40_152	38	56	152	23	0.17	0.00	23	9.67	0.00	23	0.04	0	18	0.02	21.73
zoo_40_228	40	60	228	20	0.28	0.00	20	14.47	0.00	20	0.06	0	20	0.03	0
zoo_40_304	40	60	304	20	0.18	0.00	20	25.99	0.00	20	0.08	0	20	0.05	0
zoo_40_380	40	61	380	20	0.45	0.00	20	51.64	0.00	20	0.10	0	20	0.06	0
zoo_40_76	30	43	76	21	0.08	0.00	21	1.14	0.00	21	0.02	0	12	0.01	42.85
zoo_42_168	36	60	168	20	0.77	0.00	20	93.17	0.00	20	0.06	0	16	0.03	20.00
zoo_42_185	40	56	185	22	0.51	0.00	22	11.03	0.00	22	0.10	0	18	0.03	18.18
zoo_42_252	41	74	252	23	3.90	0.00	23	230.47	0.00	23	0.17	0	20	0.04	13.04
zoo_42_336	42	76	336	24	3.78	0.00	24	143.87	0.00	24	0.12	0	21	0.06	12.50
zoo_42_420	42	76	420	24	4.10	0.00	26	894.37	0.00	24	0.15	0	21	0.08	12.50
zoo_42_84	35	58	84	22	0.20	0.00	22	5.03	0.00	22	0.04	0	15	0.02	31.81
zoo_43_168	38	65	168	20	2.97	0.00	20	32.07	0.00	20	0.07	0	17	0.03	15.00

zoo_43_252	42	76	252	26	1.44	0.00	26	38.20	0.00	26	0.09	0	21	0.04	19.23
zoo_43_336	39	75	336	23	3.14	0.00	23	41.69	0.00	23	0.11	0	18	0.06	21.73
zoo_43_420	42	78	420	23	1.70	0.00	23	374.33	0.00	23	0.24	0	21	0.07	8.69
zoo_43_84	37	60	84	22	0.16	0.00	22	3.61	0.00	22	0.03	0	17	0.02	22.72
zoo_43_93	40	65	93	25	0.11	0.00	25	10.49	0.00	24	0.03	4.00	18	0.02	28.00
zoo_44_102	34	58	102	17	0.60	0.00	17	698.83	0.00	16	0.04	5.88	12	0.02	29.41
zoo_44_185	40	69	185	22	0.98	0.00	22	50.78	0.00	21	0.13	4.54	19	0.03	13.63
zoo_44_277	42	76	277	22	6.30	0.00	22	50.83	0.00	22	0.10	0	20	0.05	9.09
zoo_44_369	43	79	369	24	6.17	0.00	28	887.73	0.00	24	0.14	0	21	0.07	12.50
zoo_44_462	44	81	462	25	20.32	0.00	38	1346.27	0.00	25	0.32	0	22	0.09	12.00
zoo_44_93	34	62	93	21	0.26	0.00	21	9.26	0.00	20	0.04	4.76	13	0.02	38.09
zoo_45_102	32	68	102	42	0.10	0.00	42	5.67	0.00	42	0.03	0	23	0.02	45.23
zoo_45_185	43	63	185	24	0.55	0.00	24	15.16	0.00	24	0.06	0	21	0.03	12.50
zoo_45_277	44	69	277	24	6.15	0.00	24	26.18	0.00	24	0.08	0	22	0.04	8.33
zoo_45_304	45	72	304	24	1.05	0.00	24	36.52	0.00	24	0.09	0	22	0.05	8.33
zoo_45_370	44	69	370	22	1.22	0.00	22	56.25	0.00	22	0.11	0	22	0.06	0
zoo_45_462	44	69	462	22	0.95	0.00	22	123.03	0.00	22	0.14	0	22	0.08	0
zoo_45_93	40	57	93	27	0.10	0.00	27	4.35	0.00	27	0.03	0	19	0.02	29.62
zoo_46_102	41	54	102	23	0.13	0.00	23	4.54	0.00	23	0.03	0	19	0.02	17.39

zoo_46_203	42	65	203	22	16.79	0.00	22	141.29	0.00	22	0.17	0	20	0.04	9.09
zoo_46_205	44	69	205	25	1.58	0.00	25	14.35	0.00	25	0.06	0	21	0.03	16.00
zoo_46_304	42	64	304	20	1.68	0.00	20	359.91	0.00	20	0.12	0	20	0.06	0
zoo_46_405	45	69	405	22	1.61	0.00	26	1380.91	0.00	22	0.18	0	22	0.08	0
zoo_46_406	46	69	406	23	1.09	0.00	23	77.19	0.00	23	0.14	0	23	0.07	0
zoo_46_506	46	72	506	24	2.57	0.00	32	3601.28	7.69	24	0.37	0	23	0.10	4.16
zoo_47_111	42	79	111	29	0.13	0.00	29	7.93	0.00	29	0.04	0	20	0.02	31.03
zoo_47_331	46	72	331	24	1.89	0.00	24	35.53	0.00	24	0.09	0	22	0.05	8.33
zoo_48_111	46	72	111	33	0.14	0.00	33	4.73	0.00	33	0.03	0	22	0.02	33.33
zoo_48_120	37	57	120	18	0.56	0.00	18	8.83	0.00	18	0.04	0	17	0.02	5.55
zoo_48_221	42	84	221	27	0.95	0.00	27	35.59	0.00	27	0.08	0	19	0.04	29.62
zoo_48_331	45	85	331	26	3.40	0.00	26	130.56	0.00	26	0.11	0	21	0.06	19.23
zoo_48_441	45	87	441	24	13.15	0.00	24	206.42	0.00	24	0.17	0	21	0.08	12.50
zoo_48_442	48	70	442	24	0.81	0.00	24	96.18	0.00	24	0.13	0	24	0.08	0
zoo_48_552	48	93	552	28	63.19	0.00	28	380.36	0.00	28	0.43	0	24	0.10	14.28
zoo_50_120	41	57	120	21	0.22	0.00	21	4.07	0.00	21	0.04	0	20	0.02	4.76
zoo_50_240	49	74	240	28	0.71	0.00	28	27.87	0.00	28	0.07	0	24	0.04	14.28
zoo_50_360	46	69	360	22	8.88	0.00	22	242.71	0.00	22	0.15	0	21	0.07	4.54
zoo_50_361	50	77	361	28	1.46	0.00	28	80.87	0.00	28	0.11	0	25	0.06	10.71

zoo_50_480	49	79	480	25	27.10	0.00	25	339.97	0.00	25	0.33	0	24	0.09	4.00
zoo_50_481	50	78	481	25	1.15	0.00	25	192.81	0.00	25	0.25	0	25	0.08	0
zoo_50_600	50	78	600	25	2.42	0.00	25	202.52	0.00	25	0.32	0	25	0.10	0
zoo_52_130	44	74	130	21	0.71	0.00	21	215.15	0.00	21	0.07	0	18	0.03	14.28
zoo_52_260	51	79	260	35	0.93	0.00	35	25.05	0.00	35	0.08	0	25	0.04	28.57
zoo_52_390	48	83	390	23	9.72	0.00	26	1755.47	0.00	23	0.18	0	22	0.08	4.34
zoo_52_394	52	81	394	27	3.44	0.00	27	132.85	0.00	27	0.13	0	26	0.07	3.70
zoo_52_520	51	86	520	26	33.90	0.00	64	2388.18	0.00	26	0.37	0	25	0.11	3.84
zoo_52_523	52	81	523	26	1.50	0.00	26	82.81	0.00	26	0.16	0	26	0.09	0
zoo_52_650	52	91	650	29	31.93	0.00	44	3601.60	3.33	29	0.49	0	26	0.14	10.34
zoo_54_141	46	71	141	31	0.23	0.00	31	13.54	0.00	31	0.05	0	20	0.03	35.48
zoo_54_152	45	80	152	21	1.97	0.00	21	3600.59	6.35	19	0.07	9.52	17	0.03	19.04
zoo_54_281	53	96	281	39	0.86	0.00	39	34.33	0.00	39	0.09	0	26	0.06	33.33
zoo_54_421	54	104	421	39	2.13	0.00	39	94.32	0.00	39	0.15	0	27	0.09	30.76
zoo_54_423	53	82	423	28	17.72	0.00	28	323.96	0.00	28	0.23	0	26	0.08	7.14
zoo_54_561	54	104	561	37	8.42	0.00	37	205.55	0.00	37	0.20	0	27	0.12	27.02
zoo_54_564	54	84	564	27	0.91	0.00	27	322.01	0.00	27	0.32	0	27	0.10	0
zoo_54_702	54	104	702	37	36.15	0.00	37	242.31	0.00	37	0.27	0	27	0.16	27.02
zoo_55_152	36	51	152	17	0.26	0.00	17	16.33	0.00	17	0.08	0	17	0.02	0

zoo_55_281	53	82	281	31	1.10	0.00	31	34.42	0.00	31	0.10	0	26	0.05	16.12
zoo_55_303	47	86	303	27	5.00	0.00	27	3602.00	3.70	26	0.12	3.70	20	0.07	25.92
zoo_55_421	54	86	421	27	1.68	0.00	27	198.90	0.00	27	0.16	0	27	0.08	0
zoo_55_562	53	84	562	26	2.93	0.00	26	302.55	0.00	26	0.21	0	26	0.11	0
zoo_55_702	54	86	702	27	2.84	0.00	38	667.85	0.00	27	0.28	0	27	0.14	0
zoo_56_152	45	72	152	23	0.59	0.00	23	164.89	0.00	23	0.06	0	19	0.03	17.39
zoo_56_303	50	73	303	26	0.53	0.00	26	35.01	0.00	26	0.10	0	24	0.05	7.69
zoo_56_454	53	94	454	27	42.60	0.00	38	2818.17	0.00	27	0.34	0	25	0.11	7.40
zoo_56_605	56	99	605	29	16.57	0.00	51	880.72	0.00	29	0.36	0	28	0.14	3.44
zoo_56_617	56	85	617	28	2.29	0.00	28	159.27	0.00	28	0.25	0	28	0.13	0
zoo_56_756	56	99	756	29	24.46	0.00	44	3601.99	12.12	29	0.37	0	28	0.18	3.44
zoo_57_325	54	109	325	39	1.71	0.00	39	55.95	0.00	39	0.15	0	25	0.07	35.89
zoo_58_163	56	109	163	53	0.19	0.00	53	26.76	0.00	53	0.06	0	27	0.03	49.05
zoo_58_325	54	88	325	31	1.60	0.00	31	53.14	0.00	31	0.11	0	26	0.06	16.12
zoo_58_487	58	119	487	39	3.57	0.00	39	107.98	0.00	39	0.29	0	29	0.11	25.64
zoo_58_649	58	117	649	36	44.84	0.00	94	1442.13	0.00	36	0.46	0	29	0.15	19.44
zoo_58_650	58	95	650	30	18.13	0.00	30	211.54	0.00	30	0.24	0	29	0.13	3.33
zoo_58_812	58	120	812	36	23.54	0.00	39	3115.16	0.00	36	0.59	0	29	0.19	19.44
zoo_59_174	47	79	174	33	0.42	0.00	33	16.48	0.00	33	0.05	0	19	0.03	42.42

zoo_59_348	54	80	348	29	1.41	0.00	29	105.46	0.00	29	0.17	0	25	0.07	13.79
zoo_60_174	38	59	174	23	0.26	0.00	23	13.79	0.00	23	0.05	0	18	0.03	21.73
zoo_60_348	55	92	348	32	0.78	0.00	32	53.90	0.00	32	0.12	0	27	0.07	15.62
zoo_60_350	58	83	350	37	0.55	0.00	37	43.69	0.00	37	0.11	0	28	0.07	24.32
zoo_60_351	59	87	351	39	0.57	0.00	39	33.95	0.00	39	0.10	0	29	0.07	25.64
zoo_60_522	58	92	522	34	4.49	0.00	34	109.13	0.00	34	0.21	0	28	0.10	17.64
zoo_60_524	59	87	524	34	8.31	0.00	34	94.90	0.00	34	0.17	0	29	0.10	14.70
zoo_60_527	59	87	527	30	0.89	0.00	30	75.27	0.00	30	0.16	0	29	0.09	3.33
zoo_60_696	60	97	696	35	5.17	0.00	35	352.48	0.00	35	0.28	0	30	0.15	14.28
zoo_60_715	59	87	715	29	1.69	0.00	29	159.25	0.00	29	0.26	0	29	0.16	0
zoo_60_720	60	89	720	30	1.12	0.00	30	246.13	0.00	30	0.25	0	30	0.14	0
zoo_60_870	60	97	870	35	3.57	0.00	35	796.25	0.00	35	0.36	0	30	0.19	14.28
zoo_61_174	42	85	174	37	0.40	0.00	37	16.09	0.00	37	0.06	0	17	0.03	54.05
zoo_61_372	54	92	372	26	44.57	0.00	33	3602.17	17.24	24	0.17	7.69	23	0.09	11.53
zoo_62_186	51	81	186	23	1.55	0.00	24	1640.23	0.00	23	0.08	0	22	0.04	4.34
zoo_62_558	61	100	558	32	8.57	0.00	32	146.96	0.00	32	0.37	0	30	0.11	6.25
zoo_62_744	62	102	744	31	2.12	0.00	34	1206.62	0.00	31	0.52	0	31	0.16	0
zoo_62_745	60	100	745	29	5.93	0.00		3601.69	57.35	29	0.43	0	29	0.18	0
zoo_62_930	62	102	930	31	3.08	0.00	31	544.56	0.00	31	0.51	0	31	0.20	0

zoo_63_595	61	92	595	30	41.70	0.00	31	1433.65	0.00	30	0.29	0	29	0.13	3.33
zoo_64_199	58	88	199	34	0.46	0.00	34	134.87	0.00	34	0.09	0	26	0.04	23.52
zoo_64_348	54	114	348	46	2.45	0.00	46	72.29	0.00	46	0.18	0	24	0.08	47.82
zoo_64_397	61	91	397	32	2.74	0.00	33	3600.87	3.12	31	0.18	3.12	29	0.08	9.37
zoo_64_522	57	132	522	54	5.83	0.00	54	402.78	0.00	54	0.22	0	28	0.13	48.14
zoo_64_595	63	111	595	38	10.40	0.00	38	284.64	0.00	38	0.28	0	31	0.14	18.42
zoo_64_696	58	136	696	55	12.72	0.00	55	389.36	0.00	55	0.31	0	28	0.18	49.09
zoo_64_793	63	96	793	31	3.73	0.00	71	3601.99	20.51	31	0.64	0	31	0.18	0
zoo_64_870	60	141	870	55	18.94	0.00				55	0.43	0	30	0.24	45.45
zoo_64_992	64	99	992	32	4.88	0.00	78	3610.05	25.58	32	0.64	0	32	0.23	0
zoo_65_212	56	97	212	41	0.57	0.00	41	37.73	0.00	41	0.09	0	25	0.04	39.02
zoo_65_634	65	118	634	42	4.53	0.00	42	547.99	0.00	42	0.27	0	32	0.14	23.80
zoo_66_1056	66	120	1056	39	43.04	0.00				39	0.78	0	33	0.26	15.38
zoo_66_212	58	91	212	37	0.35	0.00	37	29.30	0.00	37	0.09	0	29	0.04	21.62
zoo_66_423	64	111	423	43	2.52	0.00	43	91.14	0.00	43	0.17	0	31	0.10	27.90
zoo_66_634	65	119	634	38	24.13	0.00	38	395.53	0.00	38	0.30	0	32	0.15	15.78
zoo_66_635	62	105	635	29	11.30	0.00	70	3602.57	9.37	29	0.51	0	29	0.15	0
zoo_66_845	66	120	845	39	9.62	0.00	95			39	0.38	0	33	0.21	15.38
zoo_66_846	66	118	846	38	16.24	0.00		3618.01	2.56	38	0.74	0	33	0.20	13.15

zoo_66_847	65	109	847	33	7.26	0.00	33	0.47	0	32	0.21	3.03
zoo_67_225	59	110	225	37	1.57	0.00	37	0.10	0	26	0.05	29.72
zoo_68_1122	68	133	1122	38	3427.86	2.63	38	1.21	0	34	0.31	10.52
zoo_68_225	51	97	225	32	1.01	0.00	32	0.11	0	22	0.04	31.25
zoo_68_449	62	123	449	36	5.33	0.00	36	0.32	0	28	0.12	22.22
zoo_68_673	63	126	673	36	72.28	0.00	36	0.52	0	29	0.17	19.44
zoo_68_897	67	131	897	37	269.01	0.00	36	0.61	2.70	33	0.24	10.81
zoo_69_238	55	92	238	25	50.02	0.00	22	0.19	12.00	20	0.06	20.00
zoo_70_1190	70	114	1190	35	6.91	0.00	35	1.42	0	35	0.35	0
zoo_70_238	67	102	238	46	0.52	0.00	46	0.08	0	32	0.05	30.43
zoo_70_252	61	101	252	31	5.04	0.00	30	0.14	3.22	25	0.06	19.35
zoo_70_476	67	106	476	35	13.93	0.00	33	0.25	5.71	32	0.11	8.57
zoo_70_714	66	109	714	31	10.29	0.00	31	0.76	0	31	0.20	0
zoo_70_953	70	110	953	35	3.80	0.00	35	0.43	0	35	0.23	0
zoo_71_1190	70	104	1190	35	6.51	0.00	35	0.71	0	35	0.34	0
zoo_71_238	63	86	238	41	0.99	0.00	40	0.09	2.43	29	0.05	29.26
zoo_71_477	67	95	477	36	1.69	0.00	36	0.22	0	32	0.12	11.11
zoo_71_719	70	103	719	37	2.51	0.00	37	0.36	0	35	0.20	5.40
zoo_71_953	70	103	953	36	3.24	0.00	35	0.47	2.77	35	0.27	2.77

zoo_72_1008	72	119	1008	37	7.01	0.00	36	0.98	2.70	36	0.29	2.70
zoo_72_1010	71	116	1010	37	8.44	0.00	37	0.54	0	35	0.26	5.40
zoo_72_1260	72	119	1260	36	11.16	0.00	36	1.14	0	36	0.38	0
zoo_72_252	70	105	252	44	0.75	0.00	44	0.09	0	34	0.05	22.72
zoo_72_255	70	115	255	49	1.33	0.00	49	0.20	0	34	0.06	30.61
zoo_72_504	68	113	504	35	97.33	0.00	34	0.69	2.85	33	0.13	5.71
zoo_72_506	71	113	506	37	3.45	0.00	37	0.22	0	35	0.12	5.40
zoo_72_756	69	113	756	33	5.04	0.00	33	0.46	0	33	0.19	0
zoo_72_765	70	114	765	36	60.32	0.00	36	0.52	0	34	0.19	5.55
zoo_73_1065	72	118	1065	36	10.64	0.00	36	0.52	0	35	0.27	2.77
zoo_73_267	58	109	267	38	0.97	0.00	38	0.12	0	26	0.06	31.57
zoo_73_533	68	113	533	38	26.48	0.00	38	0.33	0	32	0.13	15.78
zoo_74_1065	74	167	1065	69	14.73	0.00	69	0.74	0	37	0.32	46.37
zoo_74_1075	74	116	1075	37	4.20	0.00	37	0.47	0	37	0.25	0
zoo_74_1332	74	116	1332	37	6.34	0.00	37	0.55	0	37	0.31	0
zoo_74_267	69	107	267	57	0.42	0.00	57	0.09	0	33	0.06	42.10
zoo_74_533	74	160	533	74	2.29	0.00	74	0.26	0	37	0.14	50.00
zoo_74_799	73	160	799	66	7.21	0.00	66	0.38	0	36	0.22	45.45
zoo_74_800	74	121	800	38	6.85	0.00	38	0.52	0	37	0.20	2.63

zoo_75_282	65	110	282	37	2.63	0.00	35	0.12	5.40	30	0.07	18.91
zoo_76_1125	76	128	1125	39	55.85	0.00	39	1.30	0	38	0.32	2.56
zoo_76_1126	76	115	1126	38	5.20	0.00	38	0.58	0	38	0.30	0
zoo_76_1406	76	129	1406	39	38.35	0.00	39	0.83	0	38	0.41	2.56
zoo_76_282	73	107	282	54	0.71	0.00	54	0.10	0	35	0.06	35.18
zoo_76_563	74	125	563	40	103.63	0.00	39	0.34	2.50	36	0.14	10.00
zoo_76_844	76	128	844	41	6.13	0.00	40	0.43	2.43	38	0.24	7.31
zoo_76_846	76	115	846	40	21.84	0.00	40	0.40	0	38	0.21	5.00
zoo_78_1185	77	140	1185	44	133.49	0.00	44	1.00	0	38	0.48	13.63
zoo_78_1482	78	142	1482	45	167.46	0.00	45	2.93	0	39	0.60	13.33
zoo_78_199	42	107	199	50	0.38	0.00	50	0.07	0	20	0.04	60.00
zoo_78_297	58	97	297	32	5.78	0.00	31	0.25	3.12	23	0.08	28.12
zoo_78_397	56	139	397	63	1.85	0.00	63	0.20	0	27	0.10	57.14
zoo_78_593	73	129	593	40	85.97	0.00	40	0.39	0	34	0.21	15.00
zoo_78_595	63	152	595	63	4.76	0.00	63	0.30	0	31	0.16	50.79
zoo_78_793	64	158	793	61	9.37	0.00	61	0.39	0	32	0.23	47.54
zoo_78_889	77	137	889	43	106.48	0.00	41	0.90	4.65	38	0.32	11.62
zoo_78_890	77	126	890	41	29.36	0.00	41	0.42	0	38	0.23	7.31
zoo_78_891	78	128	891	43	30.75	0.00	42	0.48	2.32	39	0.23	9.30

zoo_78_992	64	159	992	61	22.46	0.00	61	0.54	0	32	0.30	47.54
zoo_79_328	64	102	328	43	1.41	0.00	43	0.12	0	27	0.07	37.20
zoo_79_624	64	130	624	44	6.14	0.00	44	0.31	0	30	0.16	31.81
zoo_80_1248	80	162	1248	52	127.71	0.00	52	1.58	0	40	0.41	23.07
zoo_80_1560	80	163	1560	52	143.51	0.00	52	1.07	0	40	0.53	23.07
zoo_80_312	54	110	312	38	2.10	0.00	37	0.12	2.63	22	0.07	42.10
zoo_80_936	72	144	936	45	142.84	0.00	45	0.88	0	36	0.26	20.00
zoo_82_1315	82	152	1315	55	105.34	0.00	55	0.72	0	41	0.38	25.45
zoo_82_1640	82	158	1640	61	68.83	0.00	61	0.93	0	41	0.50	32.78
zoo_82_656	79	137	656	56	5.90	0.00	56	0.31	0	38	0.17	32.14
zoo_82_984	82	144	984	54	15.28	0.00	54	0.50	0	41	0.26	24.07
zoo_84_1033	84	167	1033	54	47.88	0.00	54	1.15	0	42	0.33	22.22
zoo_84_1377	84	169	1377	51	175.76	0.00	51	2.07	0	42	0.46	17.64
zoo_84_1722	84	169	1722	50	3602.84	8.90	50	2.94	0	42	0.59	16.00
zoo_84_345	75	135	345	54	1.22	0.00	54	0.20	0	36	0.09	33.33
zoo_84_689	81	157	689	57	6.17	0.00	57	0.36	0	39	0.20	31.57
zoo_86_1084	80	126	1084	39	11.47	0.00	39	1.03	0	39	0.35	0
zoo_86_1445	84	127	1445	41	13.09	0.00	41	1.37	0	41	0.47	0
zoo_86_1446	86	130	1446	43	35.17	0.00	43	0.72	0	43	0.40	0

zoo_86_1806	86	134	1806	43	15.22	0.00	43	2.36	0	43	0.63	0
zoo_86_362	75	118	362	42	2.08	0.00	41	0.18	2.38	35	0.10	16.66
zoo_86_723	75	117	723	35	23.58	0.00	34	0.47	2.85	34	0.22	2.85
zoo_86_724	84	148	724	47	22.75	0.00	47	0.66	0	41	0.22	12.76
zoo_88_1135	88	147	1135	49	38.39	0.00	49	0.60	0	44	0.33	10.20
zoo_88_1514	88	147	1514	45	53.28	0.00	45	0.80	0	44	0.44	2.22
zoo_88_1518	88	131	1518	44	11.37	0.00	44	0.75	0	44	0.41	0
zoo_88_1892	88	147	1892	45	48.77	0.00	45	1.10	0	44	0.56	2.22
zoo_88_379	66	101	379	43	1.49	0.00	43	0.13	0	22	0.08	48.83
zoo_88_757	88	146	757	56	3.93	0.00	56	0.35	0	44	0.21	21.42
zoo_88_758	88	129	758	53	6.51	0.00	53	0.51	0	44	0.19	16.98
zoo_89_396	67	124	396	37	54.37	0.00	35	0.31	5.40	26	0.11	29.72
zoo_89_792	83	153	792	49	65.54	0.00	48	0.94	2.04	39	0.28	20.40
zoo_90_1188	83	156	1188	50	120.56	0.00	48	0.79	4.00	38	0.40	24.00
zoo_90_1584	88	172	1584	57	192.32	0.00	56	2.27	1.75	43	0.60	24.56
zoo_90_1980	90	174	1980	56	441.30	0.00	56	2.05	0	45	0.76	19.64
zoo_95_1297	87	154	1297	46	584.03	0.00	45	2.24	2.17	40	0.60	13.04
zoo_95_1729	92	160	1729	48	252.92	0.00	48	4.09	0	45	0.76	6.25
zoo_95_433	83	145	433	49	37.68	0.00	47	0.43	4.08	38	0.16	22.44

zoo_95_865	84	146	865	42	69.60	0.00	41	1.14	2.38	38	0.34	9.52
zoo_95_904	90	135	904	44	61.45	0.00	44	1.09	0	43	0.28	2.27
zoo_96_1188	84	135	1188	44	70.03	0.00	43	0.82	2.27	39	0.40	11.36
zoo_96_1354	91	143	1354	43	128.77	0.00	43	1.77	0	43	0.46	0
zoo_96_1355	89	161	1355	48	388.08	0.00	48	2.36	0	42	0.52	12.50
zoo_96_1585	88	144	1585	47	143.23	0.00	47	1.30	0	43	0.61	8.51
zoo_96_1806	95	176	1806	54	160.11	0.00	54	3.61	0	47	0.74	12.96
zoo_96_1807	95	150	1807	47	20.63	0.00	47	1.43	0	47	0.69	0
zoo_96_1980	90	146	1980	48	105.87	0.00	48	1.99	0	45	0.77	6.25
zoo_96_2256	96	153	2256	48	36.57	0.00	48	4.02	0	48	0.90	0
zoo_96_396	78	117	396	41	4.36	0.00	40	0.19	2.43	34	0.11	17.07
zoo_96_452	82	143	452	52	12.26	0.00	50	0.34	3.84	36	0.16	30.76
zoo_96_792	82	131	792	45	33.63	0.00	45	0.47	0	38	0.29	15.55
zoo_96_903	91	163	903	54	50.53	0.00	53	1.00	1.85	43	0.36	20.37
zoo_98_1412	96	214	1412	73	129.58	0.00	73	1.69	0	47	0.56	35.61
zoo_98_1881	98	216	1881	73	330.38	0.00	73	2.52	0	49	0.77	32.87
zoo_98_2352	98	218	2352	73	700.84	0.00	73	3.50	0	49	1.00	32.87
zoo_98_471	84	178	471	70	2.35	0.00	70	0.25	0	37	0.15	47.14
zoo_98_942	95	206	942	70	36.78	0.00	70	0.63	0	46	0.36	34.28

zoo_99_491	92	161	491	59	5.01	0.00			58	0.37	1.69	42	0.16	28.81
zoo_100_1470	99	184	1470	57	744.07	0.00			57	2.42	0	49	0.60	14.03
zoo_100_1960	99	183	1960	55	3603.06	5.97			55	1.70	0	49	0.88	10.90
zoo_100_2450	100	187	2450	57	3600.77	10.53			57	4.18	0	50	1.07	12.28
zoo_100_980	92	169	980	52	56.58	0.00			51	1.09	1.92	43	0.37	17.30
zoo_101_510	87	151	510	49	47.14	0.00	3622.03	6.12	46	0.55	6.12	37	0.18	24.48
zoo_102_1020	97	174	1020	54	144.91	0.00			52	1.20	3.70	46	0.41	14.81
zoo_102_1530	98	172	1530	49	571.65	0.00			49	2.57	0	47	0.61	4.08
zoo_102_2041	102	177	2041	55	125.71	0.00			55	1.78	0	51	0.86	7.27
zoo_102_2044	101	154	2044	55	1115.91	0.00			55	1.60	0	50	0.71	9.09
zoo_102_2550	102	180	2550	55	309.57	0.00			55	5.65	0	51	1.07	7.27
zoo_102_510	97	141	510	69	2.01	0.00			69	0.23	0	51	0.15	26.08
zoo_104_1061	100	168	1061	60	12.68	0.00			60	0.60	0	48	0.33	20.00
zoo_104_1592	104	179	1592	55	196.70	0.00			55	1.06	0	52	0.56	5.45
zoo_104_2121	104	179	2121	56	43.04	0.00			56	2.05	0	52	0.74	7.14
zoo_104_2652	104	179	2652	55	55.67	0.00			55	1.85	0	52	1.01	5.45
zoo_104_531	101	167	531	70	3.43	0.00			70	0.28	0	50	0.16	28.57
zoo_106_1103	99	206	1103	70	146.03	0.00			70	1.11	0	47	0.46	32.85
zoo_106_1654	101	218	1654	68	268.45	0.00			68	2.84	0	48	0.74	29.41

zoo_106_1655	104	181	1655	59	208.87	0.00	59	1.61	0	51	0.66	13.55
zoo_106_2205	105	230	2205	74	3036.33	2.45	74	4.12	0	52	1.08	29.72
zoo_106_2206	104	181	2206	58	155.76	0.00	58	3.06	0	51	0.93	12.06
zoo_106_2756	106	232	2756	73	871.70	0.00	73	6.94	0	53	1.39	27.39
zoo_106_552	90	168	552	65	4.95	0.00	64	0.33	1.53	38	0.19	41.53
zoo_108_1145	108	189	1145	66	17.45	0.00	66	0.72	0	54	0.41	18.18
zoo_108_1146	104	185	1146	63	22.60	0.00	63	0.73	0	50	0.40	20.63
zoo_108_1717	108	191	1717	61	103.71	0.00	61	2.25	0	54	0.66	11.47
zoo_108_1718	108	189	1718	61	210.35	0.00	61	1.29	0	54	0.65	11.47
zoo_108_2289	108	190	2289	58	3600.55	4.13	58	2.96	0	54	0.92	6.89
zoo_108_2290	108	191	2290	58	3600.14	4.74	58	2.76	0	54	0.92	6.89
zoo_108_2862	108	191	2862	58	1721.64	0.00	58	4.53	0	54	1.20	6.89
zoo_108_573	100	168	573	67	13.80	0.00	67	0.32	0	48	0.17	28.35
zoo_109_594	103	175	594	75	3.22	0.00	75	0.33	0	49	0.18	34.66
zoo_110_1188	109	190	1188	67	23.20	0.00	67	0.80	0	54	0.46	19.40
zoo_110_1189	100	198	1189	62	359.98	0.00	61	1.18	1.61	45	0.59	27.41
zoo_110_1782	107	210	1782	68	3607.23	3.06	67	2.80	1.47	52	0.92	23.52
zoo_110_1783	109	191	1783	63	206.28	0.00	63	1.81	0	54	0.68	14.28
zoo_110_2376	106	212	2376	64	3603.79	4.30	64	5.60	0	51	1.22	20.31

zoo_110_2380	110	194	2380	59	1566.30	0.00	59	3.36	0	55	0.98	6.77
zoo_110_2970	110	218	2970	66	2522.01	0.00	66	7.85	0	55	1.62	16.66
zoo_110_594	106	180	594	73	3.64	0.00	73	0.35	0	52	0.19	28.76
zoo_110_595	96	174	595	60	12.01	0.00	60	0.61	0	44	0.27	26.66
zoo_111_616	101	176	616	73	5.14	0.00	73	0.33	0	48	0.19	34.24
zoo_112_1232	112	196	1232	76	19.20	0.00	76	0.80	0	56	0.45	26.31
zoo_112_1848	112	195	1848	61	213.02	0.00	61	1.37	0	56	0.74	8.19
zoo_112_2464	111	195	2464	59	162.47	0.00	59	3.29	0	55	1.01	6.77
zoo_112_2465	112	197	2465	60	141.39	0.00	60	1.92	0	56	1.07	6.66
zoo_112_3080	112	197	3080	60	730.45	0.00	60	2.46	0	56	1.31	6.66
zoo_112_616	110	180	616	76	6.88	0.00	76	0.37	0	54	0.21	28.94
zoo_114_1278	114	199	1278	71	72.51	0.00	71	0.95	0	57	0.50	19.71
zoo_114_1916	111	194	1916	59	128.97	0.00	59	1.79	0	54	0.77	8.47
zoo_114_2553	114	200	2553	62	3601.87	1.61	62	3.52	0	57	1.09	8.06
zoo_114_3192	114	200	3192	61	1762.97	0.00	61	5.35	0	57	1.39	6.55
zoo_114_639	108	185	639	79	3.00	0.00	79	0.35	0	51	0.21	35.44
zoo_116_1323	116	202	1323	74	23.20	0.00	74	1.05	0	58	0.52	21.62
zoo_116_1984	115	200	1984	63	449.96	0.00	63	2.52	0	57	0.80	9.52
zoo_116_2645	115	229	2645	71	1820.01	0.00	71	4.19	0	57	1.20	19.71

zoo_116_2646	116	202	2646	62	217.42	0.00	62	4.34	0	58	1.15	6.45
zoo_116_3306	116	203	3306	62	2485.19	0.00	62	3.75	0	58	1.45	6.45
zoo_116_662	108	185	662	74	4.70	0.00	74	0.36	0	53	0.22	28.37
zoo_117_1370	113	195	1370	67	49.33	0.00	67	1.28	0	55	0.54	17.91
zoo_117_685	112	193	685	77	8.36	0.00	76	0.48	1.29	53	0.24	31.16
zoo_118_1369	116	203	1369	70	56.58	0.00	70	1.71	0	57	0.56	18.57
zoo_118_1370	117	203	1370	72	35.37	0.00	72	1.29	0	58	0.53	19.44
zoo_118_2053	117	205	2053	65	3600.24	4.31	65	2.02	0	58	0.88	10.76
zoo_118_2054	116	202	2054	64	196.69	0.00	64	3.05	0	57	0.86	10.93
zoo_118_2737	117	205	2737	63	3600.52	4.76	63	4.35	0	58	1.20	7.93
zoo_118_2738	118	208	2738	64	3600.88	4.30	64	2.41	0	59	1.21	7.81
zoo_118_3422	118	208	3422	64	3628.76	4.69	64	5.41	0	59	1.56	7.81
zoo_118_685	111	188	685	76	3.54	0.00	76	0.48	0	53	0.24	30.26
zoo_120_2833	120	209	2833	66	1075.36	0.00	66	2.22	0	60	1.26	9.09
zoo_120_3540	120	209	3540	65	3600.78	4.23	65	2.97	0	60	1.71	7.69
zoo_121_2929	119	206	2929	63	2517.97	0.00	63	4.87	0	58	1.30	7.93
zoo_122_1464	115	208	1464	59	1691.09	0.00	57	1.59	3.38	54	0.81	8.47
zoo_122_2196	122	211	2196	69	495.73	0.00	69	1.62	0	61	0.97	11.59
zoo_122_2197	122	212	2197	68	3578.52	1.93	68	3.09	0	61	0.96	10.29

zoo_122_2930	121	210	2930	65	3044.50	2.31	65	4.33	0	60	1.34	7.69
zoo_122_3660	122	212	3660	66	3617.53	6.06	66	3.27	0	61	1.73	7.57
zoo_122_732	116	189	732	76	4.24	0.00	76	0.48	0	56	0.26	26.31
zoo_123_2196	115	209	2196	57	3600.25	1.75	56	5.43	1.75	54	1.28	5.26
zoo_123_2929	121	216	2929	61	1288.10	0.00	61	7.68	0	60	1.79	1.63
zoo_123_3660	122	218	3660	61	281.96	0.00	61	8.50	0	61	2.30	0
zoo_123_732	105	191	732	55	563.60	0.00	52	1.24	5.45	45	0.38	18.18
zoo_124_1513	121	179	1513	74	123.32	0.00	74	1.03	0	59	0.54	20.27
zoo_124_2269	123	183	2269	64	3600.88	2.73	64	2.19	0	61	0.86	4.68
zoo_124_3025	124	187	3025	63	106.45	0.00	63	2.21	0	62	1.26	1.58
zoo_124_3782	124	187	3782	63	129.52	0.00	63	3.32	0	62	1.58	1.58
zoo_124_757	120	179	757	90	3.68	0.00	90	0.41	0	58	0.26	35.55
zoo_129_3332	128	215	3332	73	391.57	0.00	73	5.81	0	63	1.61	13.69
zoo_129_833	125	200	833	88	35.53	0.00	88	0.70	0	60	0.32	31.81
zoo_130_1665	128	208	1665	81	128.42	0.00	81	1.32	0	63	0.68	22.22
zoo_130_2496	128	214	2496	76	124.29	0.00	76	2.60	0	64	1.10	15.78
zoo_130_4160	130	220	4160	74	1315.09	0.00	74	4.71	0	65	2.09	12.16
zoo_131_1716	124	199	1716	65	223.43	0.00	65	1.40	0	59	0.68	9.23
zoo_132_2574	130	217	2574	68	3604.78	2.94	66	6.05	2.94	64	1.14	5.88

zoo_132_3432	130	217	3432	65	293.07	0.00	65	6.10	0	64	1.62	1.53
zoo_132_4290	132	221	4290	67	198.75	0.00	67	4.86	0	66	2.10	1.49
zoo_132_858	120	192	858	89	8.62	0.00	89	0.50	0	56	0.30	37.07
zoo_134_1769	118	207	1769	58	1148.57	0.00	57	3.55	1.72	53	0.99	8.62
zoo_134_2653	127	221	2653	68	683.15	0.00	67	6.82	1.47	60	1.66	11.76
zoo_134_3542	133	233	3542	68	1589.69	0.00	68	12.28	0	66	2.36	2.94
zoo_134_4422	134	234	4422	69	551.15	0.00	69	12.29	0	67	3.21	2.89
zoo_134_885	114	203	885	66	224.24	0.00	65	1.17	1.51	50	0.45	24.24
zoo_136_1823	133	221	1823	77	748.24	0.00	75	2.85	2.59	66	0.87	14.28
zoo_136_2734	131	216	2734	67	3602.92	2.83	67	4.71	0	64	1.32	4.47
zoo_136_3645	136	226	3645	69	1120.03	0.00	69	7.37	0	68	1.92	1.44
zoo_136_4556	136	227	4556	68	325.93	0.00	68	9.50	0	68	2.50	0
zoo_136_912	120	191	912	73	19.68	0.00	73	0.77	0	56	0.35	23.28
zoo_137_939	129	231	939	91	7.98	0.00	90	0.68	1.09	61	0.41	32.96
zoo_138_1877	135	252	1877	80	116.85	0.00	80	2.97	0	66	0.94	17.50
zoo_138_1879	137	210	1879	84	143.86	0.00	84	1.47	0	68	0.95	19.04
zoo_138_2817	138	262	2817	73	3150.09	0.00	73	4.92	0	69	1.58	5.47
zoo_138_2841	137	213	2841	72	216.54	0.00	72	4.30	0	68	1.47	5.55
zoo_138_3755	138	262	3755	70	2735.88	0.00	70	9.52	0	69	2.26	1.42

zoo_138_3823	138	216	3823	74	95.14	0.00	74	6.37	0	69	2.04	6.75
zoo_138_4692	138	262	4692	70	3600.45	1.43	70	9.95	0	69	2.79	1.42
zoo_138_948	134	206	948	91	8.57	0.00	91	0.67	0	67	0.42	26.37
zoo_140_1933	125	215	1933	64	3600.17	3.15	62	4.61	3.12	58	1.19	9.37
zoo_140_2898	129	225	2898	61	1935.73	0.00	61	7.84	0	60	2.03	1.63
zoo_140_3864	140	241	3864	72	1704.57	0.00	72	9.87	0	70	3.13	2.77
zoo_140_4830	140	241	4830	71	3619.78	1.41	71	16.42	0	70	3.66	1.40
zoo_140_966	108	190	966	53	1073.41	0.00	50	1.25	5.66	45	0.48	15.09
zoo_144_1989	139	202	1989	84	3600.09	2.09	84	2.09	0	68	0.83	19.04
zoo_144_2983	141	208	2983	72	3602.19	2.78	72	3.75	0	70	1.33	2.77
zoo_144_3988	142	212	3988	72	3600.34	1.39	72	5.88	0	71	1.86	1.38
zoo_144_4970	142	212	4970	71	54.72	0.00	71	4.90	0	71	2.46	0
zoo_144_994	141	198	994	93	6.08	0.00	93	0.59	0	70	0.38	24.73
zoo_146_1052	117	210	1052	61	328.23	0.00	60	1.83	1.63	48	0.51	21.31
zoo_146_1988	138	279	1988	89	132.12	0.00	88	2.02	1.12	67	1.10	24.71
zoo_146_2982	140	289	2982	86	3600.31	2.20	85	6.23	1.16	69	1.75	19.76
zoo_146_3979	141	300	3979	89	3600.32	9.73	89	9.03	0	70	2.51	21.34
zoo_146_4970	142	302	4970	90	3600.63	9.84	89	10.88	1.11	71	3.29	21.11
zoo_146_994	126	245	994	89	13.40	0.00	89	0.85	0	57	0.48	35.95

zoo_147_1081	132	214	1081	72	624.94	0.00	68	1.34	5.55	60	0.54	16.66
zoo_148_1081	143	252	1081	96	52.73	0.00	94	0.96	2.08	70	0.53	27.08
zoo_148_2161	146	268	2161	86	771.15	0.00	85	3.97	1.16	72	1.20	16.27
zoo_148_3241	145	216	3241	75	3600.40	2.67	72	5.57	4.00	71	3.45	5.33
zoo_148_3242	148	276	3242	81	3600.44	6.58	80	8.02	1.23	74	1.92	8.64
zoo_148_4321	148	277	4321	78	3600.37	2.55	77	9.74	1.28	74	2.80	5.12
zoo_148_5402	148	277	5402	76	3601.47	2.63	75	19.02	1.31	74	3.72	2.63
zoo_164_1329	164	245	1329	123	15.78	0.00	123	0.91	0	91	0.61	26.01
zoo_164_2657	164	246	2657	102	9.68	0.00	102	2.29	0	82	1.23	19.60
zoo_164_3994	163	245	3994	88	3601.45	1.14	88	3.32	0	81	1.94	7.95
zoo_164_5317	164	247	5317	82	87.72	0.00	82	4.89	0	82	2.65	0
zoo_164_6642	164	247	6642	82	67.04	0.00	82	7.17	0	82	3.39	0
zoo_166_2792	147	243	2792	70	3600.24	7.23	69	6.70	1.42	64	2.82	8.57
zoo_168_1395	154	251	1395	77	1303.12	0.00	75	2.31	2.59	72	1.18	6.49
zoo_168_4191	161	261	4191	80	1321.66	0.00	79	11.76	1.25	77	5.21	3.75
zoo_168_5580	167	269	5580	85	723.75	0.00	85	30.05	0	83	10.05	2.35
zoo_168_6972	168	271	6972	86	1057.66	0.00	86	34.81	0	84	12.30	2.32
zoo_176_1362	146	236	1362	79	223.67	0.00	76	2.53	3.79	67	0.87	15.18
zoo_176_1534	149	243	1534	67	3600.65	7.16	62	6.45	7.46	61	1.92	8.95

zoo_176_2723	156	262	2723	86	1127.84	0.00	85	6.10	1.16	74	2.12	13.95
zoo_176_3067	165	260	3067	78	718.40	0.00	77	7.77	1.28	77	5.51	1.28
zoo_176_4085	162	274	4085	83	154.92	0.00	83	10.09	0	79	3.41	4.81
zoo_176_4597	166	263	4597	79	1243.14	0.00	78	26.22	1.26	78	8.22	1.26
zoo_176_5445	165	281	5445	88	1033.17	0.00	88	17.19	0	82	4.82	6.81
zoo_176_6127	174	271	6127	86	676.94	0.00	86	21.47	0	86	10.74	0
zoo_176_6806	166	282	6806	88	711.51	0.00	88	27.14	0	83	6.33	5.68
zoo_176_7656	176	273	7656	88	541.42	0.00	88	54.26	0	88	17.36	0
zoo_183_1675	158	258	1675	73	3600.18	5.46	67	6.42	8.21	66	2.60	9.58
zoo_183_6703	179	280	6703	87	1527.59	0.00	87	53.84	0	87	14.51	0
zoo_184_3349	171	270	3349	80	1131.66	0.00	79	8.72	1.25	79	5.57	1.25
zoo_184_5023	172	273	5023	80	1724.93	0.00	80	29.51	0	80	9.91	0
zoo_184_8372	184	285	8372	92	962.58	0.00	92	51.33	0	92	40.04	0
zoo_220_11990	220	403	11990	125	3604.59	8.40	123	94.40	1.60	110	19.94	12.00
zoo_220_2398	185	341	2398	107	3600.28	5.32	99	6.68	7.47	81	2.20	24.29
zoo_220_4798	208	374	4798	113	3600.54	5.09	113	10.03	0	99	5.59	12.38
zoo_220_7197	210	381	7197	115	3602.64	9.87	111	35.44	3.47	101	11.01	12.17
zoo_220_9592	219	400	9592	123	3601.75	7.53	122	52.58	.81	109	13.57	11.38
zoo_224_2534	188	359	2534	109	3607.45	1.83	105	6.77	3.66	80	2.19	26.60

zoo_226_10128	223	432	10128	137	3651.21	16.52	125	79.34	8.75	110	13.59	19.70
zoo_226_12656	226	436	12656	135	3601.94	11.85	129	108.15	4.44	113	20.74	16.29
zoo_226_5064	214	410	5064	126	3600.69	16.06	117	18.16	7.14	101	5.59	19.84
zoo_226_7597	224	427	7597	127	3601.14	6.89	124	41.56	2.36	111	9.36	12.59
zoo_250_12402	246	411	12402	125	3603.10	1.60	125	101.82	0	121	24.99	3.20
zoo_250_15500	250	418	15500	129	3602.22	1.71	129	465.89	0	125	30.61	3.10
zoo_250_3103	217	369	3103	114	3600.36	8.90	103	12.96	9.64	96	5.06	15.78
zoo_250_6206	237	400	6206	120	3600.81	6.67	116	38.53	3.33	112	13.65	6.66
zoo_250_9312	243	410	9312	123	3601.10	2.44	122	69.25	.81	118	18.65	4.06
zoo_254_12830	253	384	12830	128	1388.26	0.00	128	32.49	0	126	15.02	1.56
zoo_254_16002	254	386	16002	127	1953.04	0.00	127	76.99	0	127	16.61	0
zoo_254_3209	252	377	3209	187	3604.21	0.95	186	4.63	.53	133	2.86	28.87
zoo_254_6424	251	380	6424	155	3602.56	1.65	154	10.08	.64	124	5.70	20.00
zoo_254_9711	253	384	9711	142	3601.16	2.24	142	15.94	0	126	9.83	11.26
zoo_290_12533	282	502	12533	155	3602.86	11.06	144	95.68	7.09	137	28.80	11.61
zoo_290_16733	287	510	16733	159	3616.35	8.10	150	197.95	5.66	143	39.49	10.06
zoo_290_20880	290	518	20880	167	3804.75	11.53	152	471.84	8.98			
zoo_290_4180	254	458	4180	138	3600.60	14.06	125	20.12	9.42	112	6.46	18.84
zoo_290_8359	268	480	8359	142	3601.77	9.19	133	54.36	6.33	124	17.69	12.67

zoo_298_13242	285	517	13242	163	3602.67	13.46	150	156.30	7.97	136	29.51	16.56
zoo_298_17653	293	529	17653	163	3602.50	10.34	155	141.87	4.90			
zoo_298_22052	298	536	22052	165	3617.28	8.48	161	372.87	2.42			
zoo_298_4411	277	489	4411	161	3600.59	10.66	147	37.31	8.69	128	7.70	20.49
zoo_298_8842	285	506	8842	214	3601.07	34.50	149	53.12	30.37	136	17.22	36.44
zoo_306_14006	305	499	14006	182	3602.66	13.87	171	71.97	6.04	152	34.84	16.48
zoo_306_18706	302	500	18706	180	3603.44	15.42	164	143.46	8.88			
zoo_306_23256	306	508	23256	177	3602.60	11.22	167	235.46	5.64			
zoo_306_4666	285	459	4666	182	3600.74	2.27	179	13.52	1.64	135	6.22	25.82
zoo_306_9309	295	477	9309	174	3601.07	12.36	166	40.47	4.59	144	14.75	17.24
zoo_316_14934	301	512	14934	159	3602.33	8.28	152	117.88	4.40	144	40.20	9.43
zoo_316_19883	311	526	19883	177	3627.98	12.53	158	382.30	10.73			
zoo_316_24806	316	537	24806	184	3622.90	12.46	165	505.98	10.32			
zoo_316_4973	267	456	4973	205	3600.90	44.49	121	23.13	40.97	112	8.71	45.36
zoo_316_9927	287	488	9927	487	3601.01	73.13	135	68.92	72.27	130	22.08	73.30
zoo_317_11345	270	428	11345	137	1941.78	0.00	136	107.77	.72	132	28.16	3.64
zoo_317_15150	271	434	15150	135	3633.09	0.74	135	196.74	0	133	61.51	1.48
zoo_317_18906	276	441	18906	141	3625.05	1.42	140	352.52	.70	138	58.91	2.12
zoo_317_3790	228	371	3790	112	3600.45	7.33	103	21.26	8.03	95	6.92	15.17

zoo_317_7571	249	406	7571	190	3601.03	39.36	117	47.15	38.42	113	18.79	40.52
zoo_394_15448	371	642	15448	641	3601.58	72.55	187	123.48	70.82			
zoo_394_23194	382	665	23194	256	3615.34	26.85	192	522.75	25.00			
zoo_394_30895	388	674	30895	231	3660.49	16.56	198	1448.66	14.28			
zoo_394_38612	394	684	38612									
zoo_394_7736	361	603	7736	286	3601.03	38.85	187	52.11	34.61	170	16.18	40.55