**The Politics of Routing**

How Malicious Routing Behaviour Correlates with Freedom

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[DATE]

Declaration

I certify that the material contained in this dissertation is my own work and does not contains unreferenced or unacknowledged material. I also warrant that the above statement applies to the implementation of the project and all associated documentation. Regarding he electronically submitted version of this submitted work, I consent to this being stored electronically and copied for assessment purposes, including the School’s use of plagiarism detection systems in order to check the integrity of assessed work.

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**Abstract.**

In an era of hidden mass surveillance programs that violate human rights, it has become unclear whether a person’s real-world individual freedoms translate into the digital world. The design of the Internet as a global communication network without centralized control, creates challenges for governments who try to restrict freedom of expression. Consequently, governments that suppress individual freedoms tend to exercise tight control over Internet communications to reduce their citizen’s freedom of speech. This report will investigate the distinctions between online and offline freedoms, how different metrics of freedom correlate with nation states and Autonomous Systems (ASes) that participate in malicious routing behaviour and the impacts of their imposed policies.

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Chapter 1

# Introduction

## Chapter Overview

This chapter will explain the reasons for conducting this research and the potential benefits that may come of it. An early approximation of what could be achieved by the report’s aims and objectives will also be laid out. These are dynamic objectives and may be added to or adjusted depending on how the results shape up. The report’s general structure will also be outlined, and each section explained.

## Motivation for Research

Maybe more focused around FOTN = Declining Internet Freedom and infringement on rights by said surveillance schemes (covers monitoring/ censorship/ fear/ etc...). Also outline the connection between mass surveillance and malicious routing… mass surveillance techniques coming under the umbrella term: “malicious routing” + are these policies a driving factor behind rising authoritarianism? (this isn’t about hate-speech laws etc, STOP BEN).

In June 2013, Edward Snowden stole and leaked an estimated 1,500,000 documents exposing the colossal power and capability of intelligence agencies such as the National Security Agency (NSA, US) and their Five-Eyes (FVEY) partners. It was revealed that mass surveillance tools such as “PRISM” [1] and “X-KEYSCORE” [2] provided the capability to collect and search through millions of people’s digital lives. It was also revealed that many Autonomous Systems (ASes) and Internet Service Providers (ISPs) such as British Telecom, Vodafone Cable, Verizon Business, Level 3, Viatel, Global Crossing and Interoute were collaborating with projects such as “TEMPORA” [3] which tapped fibre optic cables and intercepted dataflows. It seemed that the online world was far less private or free than previously realised.

In parallel with the aforementioned revelations, global freedom has been in continual decline for 12 consecutive years [4]. The internet, as an openly accessible and free network, affords freedom of expression, information, religion, identity and trade as laid out by the Human Freedom Index 2018 [5]. Therefore, a decline in internet freedom must be the result of restrictive policies imposed by government, ASes or ISPs. For example, since the Snowden leaks of 2013 and the Investigatory Powers Act of 2016, the UK has dropped 12 places on the Freedom of the Press Index [6]. Restrictions of internet freedom such as these fall under the umbrella term ‘malicious routing’. This report will investigate how these malicious routing policies correlate with an individual’s internet freedom.

## Aims and Objectives

The aims of this report are therefore as follows:

* Determine what it means to have ‘total internet freedom’ and what positive and negative freedoms make up internet freedom.
* Discover the extent to which a correlation exists between a nation’s malicious routing behaviours and the freedom of their citizens.

From the report’s aims, the formal objectives are:

* Form and collect information about each nation’s malicious routing behaviours.
* Analyse and rank nations based on their malicious routing activity.
* Compare each nation’s propensity to engage in malicious routing activity with various measures of their freedom to determine the degree to which they are correlated.
* Consider whether the finding are significant and determine whether propensity to engage in malicious routing activity is a good predictor of freedom.

## 1.4 Report Structure

This report will begin with a review of the relevant existing research surrounding malicious routing. This will help gain a more comprehensive understanding of the current academic reasoning, backgrounds and issues faces in this area of research. The existing research associated with defining and measuring freedom will also be investigated to aid with narrowing the selection of freedom indexes to the most relevant for this topic.

A nation’s freedom can be measured in a wide variety of different ways, each resulting in a different freedom index. Before any research is conducted into malicious routing, the report will cover the various definitions of freedom and determine which indexes are most applicable when correlating with malicious routing. The primary index to be considered will be the Freedom House, Freedom of the Net Index [9]. This index will also function as a prediction for the most closely correlated index and will also help determine whether the best predictor of internet freedom is a nation’s propensity to conduct malicious routing activity.

The main section of the report will focus on the technical aspects of malicious routing in defining its component elements, examining the nations that partake in it and finding any correlations with freedom. This will begin by accurately defining what actions and policies malicious routing comprises of. Then a table of nations that partake in malicious routing will be built, holding information about the activities of each nation, as well as a standardised numerical score for each nation based on the amount of malicious routing behaviour that said nation conducts. Once the table has been created and the ranks calculated, it will then be possible to contrast malicious routing behaviour with freedom to determine if any correlations are present.

Depending on the results from the correlations, there may be clear connections between certain kinds of malicious routing behaviour and freedom. This next section will examine trends seen across the data as well as stand-out and edge cases. This will be followed up with the ‘findings’ chapter that will contain a careful analysis of the results and a critical review of the methods used. Finally, the report will end with conclusions based on the research and a discussion of the limitations and lessons learnt, as well as any possible future work.

Chapter 2

# Background Research

## 2.1 Chapter Overview

This chapter will briefly summarise what has been learnt from existing research papers about closely related topics. The focus is on malicious routing, however some papers regarding the definitions of freedom have also been included to help form a better understanding of how the varying ideas of freedom can be combined to create an index.

Due to the nature of this project, some information, such as the Snowden leaks which predominately came from news outlets like The Guardian, will be found outside of academic papers. In such a case, only reputable sources of information will be used.

## 2.2 The Politics of Routing: Investigating the Relationship between AS connectivity and Internet Freedom

This study, conducted by Rachee Singh et al, aims to find a relationship between the level of Autonomous System connectivity within a single country, and that country’s Internet Freedom [7]. A network topology graph was constructed for each nation using a BGP path simulator to compute AS paths that are compliant with routing policy. Features of this graph were then extracted and applied to various machine learning techniques that tried to predict freedom.

In this paper, internet freedom of a nation is measured using the Freedom House, Freedom of the Press Index [8]. However, while closely related in legislation, the freedom of individuals online is fundamentally different from the freedom of the press, since there are fewer social and economic constraints acting on a single internet user. Where the vast majority of the press operate in a profit-driven environment, in which straying from the overton window could damage sales, an individual internet user operating under perceived anonymity is somewhat relieved from such pressures, and therefore is more likely to share nonconforming or illegal material. Therefore, this report will primary focus on measuring internet freedom with the newer and more closely related Freedom House, Freedom of the Net Index [9]. The actual differences between these indexes will be investigated in more detail later in the report.

The study found that, of all the graph’s features, IP density and path length were the best predictors of internet freedom. Their machine learning algorithms were able to predict a nation’s freedom category (Free, Partially Free, Not Free) with a 95% accuracy. I will follow a similar method when defining the features that malicious routing comprises of. It will also make an interesting comparison to see whether the correlations between AS connectivity and internet freedom mirror the correlations between malicious routing and internet freedom.

## 2.3 Nation-State Hegemony in Internet Routing

This paper researches the extent to which various countries are dependent on the United States and other Western nations to connect to popular internet destinations [10]. In general terms, their results show that underserved regions of the globe are dependent on North America and Europe. In some cases, over 85% of traffic from an independent nation was routed through another country such as the United States. However, they also found that by using Region Aware Networking, they were able to route traffic away from these hegemonies with middle to high success rates.

This is significant for this report as it showed that the level of malicious routing that a nation’s citizens are exposed to extends beyond just the country they live in and includes nearby hegemonic nations where traffic is likely to be routed through. It will be worth considering the impact and measurability of this when defining what constitutes as malicious routing. It also brings up the question of whether nations should be judged based on solely their own policies, or whether neighbouring hegemonic entities need to be taken into consideration.

## 2.4 Quantifying Information Exposure in Internet Routing

In close relation to the last paper, this paper measures the extent to which communications between pairs of countries are exposed to other countries [11]. It was found that, even when sending data between physically adjacent countries, there is a high level of information exposure. Typically, even short international paths route through at least 3 separate countries. It was shown that the better connected a country is, the more their information is exposed and there is a trade-off between robustness and information exposure. An important feature when measuring a nation’s internet robustness was the number of independent routing paths between surrounding nations, however it was shown that as the number of paths increases the level of information exposure proportionally increases as well. This is because internet routing is ‘best effort’ and if there are many alternate paths available, then there is a higher chance one of those paths will be chosen.

This is significant for this report because when defining exposure to malicious routing, it will be important to include whether the nation in question has many independent paths. With a greater number of paths to choose from, the likelihood of a packets taking an alternative path increases. If these alternative paths route through a nation that performs malicious routing, then the likelihood that the original data packet could be intercepted or observed increases. To quantify this chance, a function that takes a nation’s proximity with countries that perform malicious routing, and that nation’s number of independent paths will be created. This will then be used as one of the features that makes up malicious routing.

## 2.5 Schengen Routing: A Compliance Analysis

As explored earlier, due to the internet’s best effort approach to packet routing, there is a chance that packets will unnecessarily pass through additional nations before reaching the destination. To try to counteract this, European intelligence agencies developed Schengen Routing. The aim of which is to make sure that when the sender and receiver are both within the Schengen area, their packets are entirely routed within the Schengen area.

This paper [12] investigated weaknesses of Schengen Routing, specifically looking into the compliance of available routes and the amount that any nation uses Schengen compliant routes. The paper found that up to 39.7% of routes within the EU were Schengen compliant and compliance levels for individual countries ranged from 0% to 80%. The choropleth map shown in *figure 1* has been extracted from the report and shows compliance levels by nation within the EU.



Figure 1: Schengen Routing compliance levels from [12]

This legislation helps reduce the exposure to malicious routing. However, this only affects a small proportion of the world, so when quantifying malicious routing, some nations will be subject to unique features that are not applicable to others. Therefore, for this report it may be necessary to assess the impact of legislation such as this for each nation individually.

## 2.6 Politically Motivated DDoS

This paper [13] documents and analyses the reasons behind many of the recent denial of service attacks directed from governments. It documents the nations involved, their expected reasons and the result of the attack.

The records from this paper will be used alongside the DDoSDB [14], a database that records global denial of service attacks, to gauge an idea of the nations involved in orchestrating DDoS attacks. This information will partially represent a nation’s propensity to conduct offensive cyber-attacks. The combined dataset will form one of the features of malicious routing that, alongside the Mirai-like signatures [18] cover the attacking side of malicious routing. The victims of the attacks will also be recorded and will be an important feature in the exposure of other nation’s to malicious routing activity.

## 2.7 Related Work: Freedom Indexes

Measurements of freedom will provide a necessary backbone from which any correlations with malicious routing will be found. There are many various measurements of freedom and freedom indexes available online. For this project, the primary freedom index that will be contrasted is the Freedom on the Net Index 2018 [15]. This is because we predict that malicious routing behaviour will correlate closest with internet freedom.

However, predictions are frequently wrong, therefore other freedom measures listed below will also be analysed.

### 2.7.1 Freedom on the Net 2018

[15] This will be the main index that malicious routing in contrasted with. The index covers 65 countries and 87% of the world’s internet users. It’s divided into 3 main features that are analysed for each country individually:

* **Obstacles to access**

Referring to how difficult it is for an individual to get online.

* **Limits on content**

Referring to top down restrictions on what can and cannot be shared online.

* **Violation of user rights**

Measures legal protections and restrictions on online activity.

### 2.7.2 Freedom of the Press 2017

As used in 2.2 [7], (The Politics of Routing) Freedom of the Press [16] has been used in the past as a good measure of individual freedom and freedom of speech. While it has its limitations, as outlined earlier, its rankings are significantly different from the Freedom of the Net Index and may provide an additional interesting correlation to explore.

### 2.7.3 The Human Freedom Index (*updated for 2018*)

This index [17] focus’ on overall freedom of a nation’s citizens, taking over 100 features divided into personal and economic freedoms. It will be interesting to compare the results from this very broad index, with the more specific indexes mentioned above. It may also provide an interesting analysis to try to find the single feature from this index that correlates best with malicious routing propensity.

## 2.8 Related Work: Data Logs

### 2.8.1 Bad Packets Report (Ongoing)

The Bad Packets Report [18] scans for packets that resemble the original Mirai source code. This is possible because Mirai’s TCP sequence numbers will equal the value of the target’s IP address. The report records the source nation, IP and AS of Mirai-like packets and publishes them online. This information will be extrapolated along with Mirai Botnet activity to produce an indicator of the offensive malicious routing taking place inside any given nation. Unfortunately the accessible historical data only dates back to September 2018 so the comprehensiveness is somewhat limited by its short time frame however it still gives a good indication.

### 2.8.2 Mirai Botnet Activity (Data from Jan 2017 – Jan 2019)

Similarly to 2.8.1, this dataset holds information on Mirai activity. Instead of recording instances of Mirai-like source code, it instead records all the IP interfaces observed as part of Mirai-like botnets between 2017-2019. Due to the larger time frame, this dataset is far more comprehensive than 2.8.1 and there are not any empty areas.

### 2.8.2 BGPMON (Ongoing)

BGPStream [19] records hijacks, leaks and outages in BGP. The service records the length of the outage and the AS that it occurred in. It’s intended for network engineers to work around outages, however it will also be useful for this report since the affected nations are also recorded. This information will aid in calculating the exposure to malicious routing, although it must be noted that not all BGP outages stem from malicious intent.

### 2.8.3 Routing Dependencies (Jan 2019)

As was explained in the Information Exposure paper [11], highly interconnected ASes have an increased chance of accidently exposing data to other ASes in different nations, even when the two end points are within the same host nation. This can be due to the service in use being dependent on infrastructure that is physically located in another country. For example, accessing Facebook in Mexico routes requests to Facebook’s data centre in the US, thus exposing the data to the American mass surveillance programs. Whether the data is actually compromised during flight is another matter entirely, however for this paper it will not be considered due to limited research in that area.

Data can also be exposed through the internet’s best effort approach to packet forwarding at the network level, where packets may be forwarded through routes that traverse other nations, despite the two end points being located in the same host nation. For example, data travelling from London to Manchester is frequently routed through Amsterdam because both links are of similar speed and latency. In the past, this has sometimes been favourable for intelligence agencies such as the NSA (US) who were legally allowed to intercept data packets travelling across US borders. A technique called Boomeranging was used to encourage packets to be forwarded across borders even when it was not necessary, thus allowing them to be intercepted.

Whenever data packets cross an international border, there is a chance that they’ll be intercepted The specific nation they pass through is also important in determining the chance of interception. The Routing Dependencies Dataset gives the fraction of paths that traverse another country, as a list of all nations that data travelled through. To make this very large dataset more useful, a list of nations that perform surveillance of data in any regard will be compiled. For each nation in the Routing Dependencies Dataset, the percentage of paths that traverse nations that perform surveillance will then be compiled. This will create a more compact dataset that records the fraction of paths that traverse through nations who might intercept them. By then summing the paths together, the total exposure to surveillance programs will be calculated for each nation.

### 2.8.4 –

Chapter 3

# Freedom

## 3.1 Chapter Overview

This chapter will begin by looking into the problems associated with defining freedom for both a nation and for an individual. The gradual decline in worldwide freedom will then be explored, including a brief overview of the Chinese model of censorship as well as the difficulties this creates when trying to define malicious routing. Following this, the freedom indexes that will be used to correlate with malicious routing will be outlined and their necessity for this report will be explained.

## 3.2 Defining Freedom

The issue of defining whether one has true freedom is a philosophical question that we still do not have definite answer to. It is such that two individuals in the same situation could give different answers when asked about it. Freedom is as much down to the individual’s perception of whether they are free, as it to the physical, social and economical constrains acting upon them.

While it is possible to measure physical, social and economic constraints on freedom, it is very difficult to gather data on an individual’s perception of their own freedom. Even if such an extensive dataset were to exist, it may not even be helpful since our own standards and past experience feed into our perception of whether we are free. It is for this reason that citizens in both Pyongyang and San Francisco *might* answer “I am free” to the question of perceived freedom.

This problem translates almost exactly over to the digital world and the question of internet freedom. However, it is far beyond the scope of this report to try to provide correlations with perceived freedom, online or in the real world. Therefore, only the quantitative measures of freedom will be used. By using many individual quantitative measures of freedom such as analysing labour market regulation or the integrity of the legal system, a hypothetical perfectly free state can be envisaged from which all real nations can be compared. This paper will use publicly available freedom indexes that rank nations’ freedom scores using quantitative means.

## 3.3 Declining Freedom & China

According to the Freedom of the Net index [15], internet freedom has been in constant decline since 2010. In particular, in 2018 the report points to Facebook’s data exposure scandal involving Cambridge Analytica, security breaches affecting voters in democratic countries and the spread of false rumours and propaganda as reasons for the decline.

The consistently worst abuser of internet freedom is China, but worryingly 36 countries sent representatives to attend Chinese training and seminars on internet and information management. It has also recently been revealed that the Chinese censorship model extends beyond simple mass surveillance and censorship through bans. In her book: “*CENSORED* Distraction and Diversion inside China’s Great Firewall”, author Margaret E. Roberts [20] answers the question “Why do governments attempt to control information when these controls are easily circumvented”? Through past short term ‘crackdowns’ on circumvention methods like VPNs the Chinese government has shown that it has the capacity to make the firewall less permeable but at the current time choses not to. Instead a more complex marriage between social engineering and computer science is being experimented with.

### 3.3.1 Social Engineering as a means to an end

Is social engineering on the internet a more effective method of control than technologically engineered solutions such as mass surveillance? Generally speaking, when a nation conducts malicious routing such as mass surveillance or censorship, their end goal is an improvement to the perceived stability of their nation. However, attempts at censorship, especially on a large scale such as the internet, are almost always imperfect and the spread of information continues regardless, albeit usually at a slower pace or only within specific clued in circles. Given time however, information (especially in the form of ideas or ideology) can resurge, only to need to be repressed again. The diagram below outlines an issue with imperfect censorship over extended periods of time, as experienced by governments around the world:



The Chinese government fully understand this problem and rather than try to perfect their censorship technology, they’ve instead begun to explore ways to reduce the heavy-handedness of the censorship on the general population whilst simultaneously further expanding their control on information.

This is being done through three main methods: fear, flooding and friction [21]. The most simple of which: fear, simply means to threaten punishments towards those who express dissident opinions online. Recently in China, these laws have become more draconian with citizens being arrested for singing the national anthem in a distorted way on public livestreams [22]. Flooding involves not actually removing the dissident opinions, but instead attempting to drown them out in a sea of pro-government or contradictory comments or links. This makes it very difficult or too time consuming for the average onlooker to find the original information that they were looking for. Friction is the most complex of the three and is defined by Roberts as “increasing the cost, either in time or money of access or spread of information”. This plays off the impatience of human nature through techniques such as making problematic websites take longer to load and making the messaging app WeChat lag in places where protests are taking place. The government are aware that the most politically engaged citizens will find ways around this but rely on the fact that the majority of people simply will not be bothered to take the extra steps.

The degree of success of these social engineering policies on population control is far beyond the scope of this paper. It would require an entirely separate study to gauge their impacts and whether they would even be relevant for this report. For this reason, while it is definitely important to note their significance, policies such as these will not individually be assessed in terms of their relation to malicious routing behaviour. Instead, a boolean umbrella category will record whether citizens of any given nation are exposed online social engineering policies from their own government.

## 3.4 Freedom Indexes

### 3.4.1 Freedom on the Net

[15] The Freedom House’ Freedom of the Net Index analyses the level of digital authoritarianism across 65 nations. The term digital authoritarianism comprises of the difficulty for an individual to get online, the restrictions on digital content and the restrictions on online activity. The report found that 20% of internet users have free access, 33% have partially free access and 34% do not have free access. One of the benefits of this report is that Freedom House publishes a summary for each country individually, listing some of the principal components that made up their value judgement. Of course it would be wrong to assume that they had perfect knowledge of all events for each specific nation, however their choice to omit the proposal and passing of articles 11 and 13 for European nations calls into question the bias of the writers. Apart from this, the index does seem to cover most of the major worldwide issues affecting freedom of the net and for this reason will be the primary index used to correlate against a nation’s malicious routing behaviour.

### 2.7.2 Freedom of the Press

[16] The Freedom House’ Freedom of the Press Index, which has been used by papers in the past as a closely related measure of internet freedom will also be used in this report to compare results with past research. As mentioned earlier in the report, while closely related in legislation, the freedom of individuals online is fundamentally different from the freedom of the press, since there are fewer social and economic constraints acting on a single internet user. Where the vast majority of the press operate in a profit-driven environment, in which straying from the overton window could damage sales, an individual internet user operating under perceived anonymity is somewhat relieved from such pressures, and therefore is more likely to share nonconforming or illegal material. [REPETITION]

### 2.7.3 The Human Freedom Index

Fraser Institute’s [17] Human Freedom Index is a very comprehensive index recording the level of freedom for 162 nations over more than 100 features. Unlike with the previous two indexes, this index is not specific to a certain kind of freedom, however it shares generalised versions of internet freedom and freedom of the press. It will provide an interesting analysis to compare these features with the dedicated indexes to see if any differences are significant enough to impact our results. It will also be useful to compare the individual features of this freedom index with the propensity to conduct malicious routing index. This will help to determine whether any single feature has a significant correlation greater than the freedom of the net correlation.

Chapter 4

# Malicious Routing

## 4.1 Chapter Overview

This chapter will focus on formally defining malicious routing and determining the important features that will create the malicious routing index. Then, the methodology to compare and correlate the indexes will be explained in depth. The correlations will then be calculated and the results will be shown. During this chapter some important distinctions will be made, including the relationship between nations and their ASes, as well as the difference between a nations propensity to conduct malicious routing versus the level of exposure that a nation’s citizens have to malicious routing.

## 4.2 What is Malicious Routing

* Offensive cyber / Monitoring / Censorship
* Will analyse the combined offensive/defensive to look at the exposure to malicious routing from the perspective of a citizen in a given nation.

In the most general sense, malicious routing refers to predatory routing policies and behaviours conducted at a national level. The measurement of malicious routing will be from the point of view of the individual living in a given nation and will try to answer the question: “To what degree is an individual citizen of a given nation exposed to malicious routing?”.

To answer this, the external forces acting upon the nation and by extension the ASes and citizens as well as the policies and actions of the nation itself will be considered. For the citizen’s home nation (…)

## 4.3 Nations and Autonomous Systems

Autonomous Systems always have a home nation however can operate across borders in some cases. They are also in most cases forced to abide by and implement changes based on the laws of the nation in which the primarily operate. A significant proportion of the datasets used in this report record data per AS, not per nation. However, for this report, it would be impractical to analyse each AS so instead ASes will be grouped by their host nation. This allows for citizens to be logically grouped by nation instead of roughly grouped by their use of certain ASes. By extension, allowing exposure to malicious routing can be calculated on a per nation basis.

By indexing by nation, comparisons with legislation, policies, ideology and levels of freedom dramatically simplify the process of analysis and finding correlations. It is important to note however, that this simplification process will come with a minor loss to precision of the exact groups being affected by malicious routing.

## 4.4 Methodology

1. Collecting data

2. Reformatting and condensing collected data sets.

3. Ranking the condensed data and producing a single value judgement.

4. Correlation / Rank analysis

## 4.5 Correlations

Sample text

Chapter 5

# Trends and Impacts

## 5.1 Chapter Overview

Sample text

## 5.2 Policy

Sample text

## 5.3 Case Studies

Sample text

Chapter 6

# Findings

## 6.1 Chapter Overview

Sample text

Chapter 7

# Conclusions

## 7.1 Chapter Overview

Sample text

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