A Survey among Network Operators on BGP Prefix Hijacking

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ABSTRACT

BGP prefix hijacking is a threat to Internet operators and users. Several mechanisms or modifications to BGP that protect the Internet against it have been proposed. However, the reality is that most operators have not deployed them and are reluctant to do so in the near future. Instead, they rely on basic –and often inefficient– proactive defenses to reduce the impact of hijacking events, or on detection based on third party services and reactive approaches that might take up to several hours. In this work, we present the results of a survey we conducted among 75 network operators to study: (a) the operators' awareness of BGP prefix hijacking attacks, (b) presently used defenses (if any) against BGP prefix hijacking, (c) the willingness to adopt new defense mechanisms, and (d) reasons that may hinder the deployment of BGP prefix hijacking defenses. We expect the findings of this survey to increase the understanding of existing BGP hijacking defenses and the needs of network operators, as well as contribute towards designing new defense mechanisms that satisfy the requirements of the operators.

CCS CONCEPTS

• **Networks** → **Routing protocols**; **Network management**; • **Security and privacy** → **Network security**;

1 INTRODUCTION

The Internet is composed of tens of thousands of interconnected Autonomous Systems (ASes), which are networks belonging to different administrative entities. ASes use the Border Gateway Protocol (BGP) [16] to advertise address space (as IPv4/IPv6 network prefixes) and establish inter-domain routes in the Internet. BGP is a distributed protocol, lacking authentication of advertised routes. As a result, an AS is able to advertise illegitimate routes for IP prefixes it does not own. These advertisements propagate and "pollute" many ASes, or even the entire Internet, affecting service availability, integrity, and confidentiality of communications. This phenomenon, called *BGP prefix hijacking*, is frequently observed [27], and can be caused by router misconfigurations [1, 2] or malicious attacks [3, 23, 27].

Current defenses are not sufficient. Currently, networks rely on *practical reactive mechanisms* to defend against prefix hijacking, since *proactive mechanisms* such as RPKI [17–20, 26] are fully efficient only when globally deployed[1], and operators are reluctant to deploy them due to associated technical and financial costs [12, 13, 15, 21, 22]. Reactive mechanisms mainly operate in two stages: *detection* (*e.g.,* based on monitoring data) and *mitigation* (*e.g.,* based on local network actions, such as originating BGP advertisements) of the hijack. The speed of the reactive defenses is crucial; even short-lived events can have severe consequences [3]. However, the reality shows that, currently, hijacking events are not quickly mitigated. For instance, back in 2008, a hijacking event affected YouTube's prefixes and disrupted its services for 2 hours [11]. More recently, in Sep. 2016, BackConnect (AS203959) hijacked, at different times, several ASes; the events lasted for several hours [4]. In Jan. 2017, the Iranian state telecom TIC hijacked disparate pornographic websites for more than a day [5]. In Apr. 2017, financial services, like Visa and Mastercard, and security companies, like Symantec, were hijacked by a Russian company for seven minutes [6]. In Aug. 2017, an accidental hijack (route leak) from Google led to a large-scale internet disruption that slowed or blocked access to websites and online services for dozens of Japanese companies for ten minutes [7]. In Dec. 2017, 80 prefixes normally announced by high-profile organizations

[1] Even the accurate measurement of the adoption of the proactive RPKI mechanism is a challenge itself [24].

such as Google, Apple, Facebook, Microsoft and others were wrongly re-routed to a newly assigned Russian AS for several minutes [8].

Survey motivation and contributions. To surpass existing shortcomings and achieve efficient resolution of hijacking events, new defense approaches that fit the needs and requirements of the operators are needed. We launched a survey [10] to increase the understanding of currently used BGP hijacking defenses, and to receive feedback directly from network operators about their needs. We acquired valuable information from this survey that is useful to design defense systems that overcome existing issues in terms of efficiency and deployability.

However, the findings of the survey are more general and can be beneficial for both researchers and operators. Researchers can evaluate the severity of the problem of BGP prefix hijacking as it is seen from the operator community, and investigate new defense mechanisms capitalizing on current operational practices. Operators can be informed about the trends in the BGP prefix hijacking issue and the employed defenses, provide valuable feedback to the network community themselves, and adjust accordingly the way they manage and protect their networks against hijacks.

Structure. In Section 2 we present the questions of the survey, and in Section 3 we discuss the main findings and their implications.

2 SURVEY PROFILE AND QUESTIONS

We launched a survey [10] on network operators' mailing lists, such as NANOG and RIPE. The survey is anonymous and comprises 21 questions studying *(a)* the operators' awareness of BGP prefix hijacking attacks, *(b)* presently used defenses against BGP prefix hijacking, *(c)* the willingness to adopt new defense mechanisms, and *(d)* reasons that may hinder the deployment of BGP prefix hijacking defenses. We received answers from 75 participants operating a broad variety of networks all over the world, working at different positions (engineering, management, etc.).

The survey/questionnaire is composed of three parts.

(1) Information about the participants and their organizations. In the first part we ask the participants to provide information about the type (*e.g.,* ISP, CDN) and location of their organization. Fig. 1 presents the results.

(2) Knowledge and Experience with BGP Prefix Hijacking. The second part consists of questions related to the participants' awareness and concern about BGP prefix hijacking, including their experience with past hijacking events on their networks.

(3) Defenses against BGP Prefix Hijacking. The last part asks the participants about (i) the defenses they use (if any)

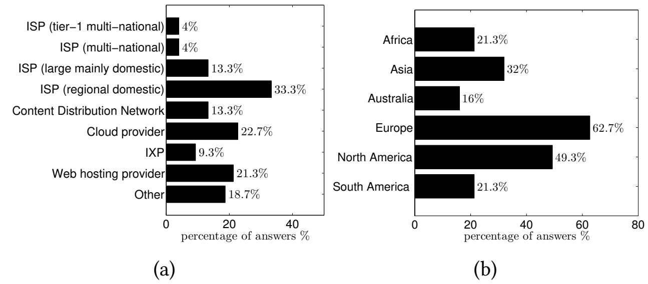


Figure 1: Information about the organization of the participants: (a) terms that best characterize each organization, and (b) continents in which it operates. Note that an organization might be characterized by more than one terms and operate in many continents.

against BGP prefix hijacking, such as RPKI, (ii) how they detect and mitigate a hijacking event affecting their prefixes, and (iii) the characteristics they consider desirable (or not) in a future defense (detection/mitigation) system.

A detailed presentation of the survey questions and answers is provided as supplementary material (also available in [25]).

3 SURVEY RESULTS

We classify the survey findings in 4 categories, which we present in the following sections: (i) evaluation of impact of hijacks (Section 3.1), (ii) general information about current defense mechanisms employed against hijacks (Section 3.2), (iii) specific information on the detection and mitigation stages in today's operations (Section 3.3), and (iv) requirements posed on new mitigation mechanisms (*e.g.,* involving outsourcing defense functionality to third parties), as well as the willingness of operators to adopt them (Section 3.4).

3.1 Impact of Hijacks

BGP prefix hijacking is a real threat and concerns network operators. More than 40% of the operators reported that their organization has been a victim of a hijack in the past. Moreover, the vast majority is concerned about BGP prefix hijacking in the Internet and its potential impact on their own networks. Almost all operators are knowledgeable on the issue of hijacks and the involved mechanisms.

Hijacks have a severe and lasting impact. Operators evaluate the impact of a potential hijack targeting their network (in terms of *duration* and *number of disrupted services*) as shown in Table 1. The vast majority (76%) expects the impact of a hijack to last for a long time (few hours or more), while opinions are divided on whether the hijack will affect a few or many of their services/clients, indicating that

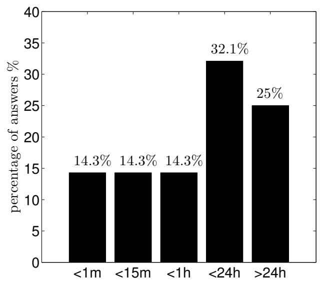
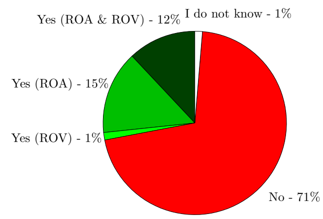


Figure 2: Experience of participants with BGP prefix hijacking events having as victim their organization: duration that the network of the organization was affected by a hijack.



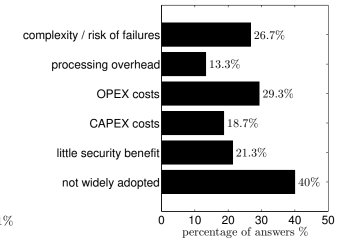


Figure 3: (a) Usage of RPKI in participants' organizations, and (b) main reasons for not using RPKI.

there are concerns both for extended (*e.g.,* route leaks) and limited/targeted (*e.g.,* malicious attacks) hijacks. Moreover, their past experience (Fig. 2) shows that most hijacks indeed lasted long: more than 57% of hijacks lasted more than an hour, while 25% lasted *more than a day*; around 28% are short-term hijacks, lasting a few minutes (14.3%) or seconds (14.3%).

Table 1: "How severe do you consider the potential impact of a BGP prefix hijacking against your network?"

	no impact	~min.	~hours
few services/ clients	0%	9.3%	28.0%
many services/ clients	0%	9.3%	48.0%

3.2 Defenses against Hijacks

RPKI deployment is limited. In accordance with previous studies [14], most of the network operators (71%) answered that they have not deployed RPKI as a proactive defense mechanism in their networks (Fig. 3(a)); very few (12%) use the full functionality of RPKI (Route Origin Authorisation - ROA and Route Origin Validation - ROV). There are various reasons for this, as shown in Fig. 3(b); deployment lags mainly due to RPKI's *limited adoption* and *little security benefits*, but also due to the increased *CAPEX and OPEX costs*, and increased *complexity* and *processing overhead* associated with the protocol mechanisms. Therefore, about 60% of the operators replied that they resort to other mechanisms and practical defenses to protect their networks against BGP hijacks.

Practical defenses include route filtering, extensive peering, and de-aggregation. The responses to the (optional) question of what other defense mechanisms are used by networks are shown in Fig. 4. The majority of the participants, *i.e.,* 17 networks (among those who provided answers for this optional question), use *route filtering* as a proactive defense to protect their own and their customers' prefixes from being hijacked. *Route filtering* is implemented in various ways (based on their answers) including for example: prefix origin (e.g., from IRR records) or AS-path filtering; filtering at edge routers (with customers/peers) or route servers (at IXPs). Less popular approaches are *anycast* (2 answers) and *prefix de-aggregation* (4 answers). Finally, 5 operators (from CDNs or tier-1 networks) mention that they peer with many other networks extensively; this helps them protect their networks from hijacking events (*i.e.,* by reducing their impact).

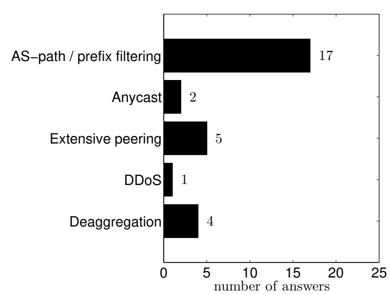
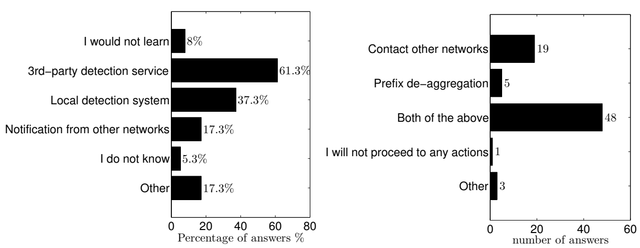


Figure 4: Practical defenses –other than RPKI– used by some networks (60% of participants) against BGP hijacks.

3.3 Detection and Mitigation of Hijacks

Hijack detection mainly relies on third parties. The majority of networks (61.3%) use a third party detection service, which notifies them about hijacking incidents against their prefixes, as shown in Fig. 5(a). BGPmon [9] is the most popular detection service among the answers in our survey. The satisfaction of operators from third parties generally varies a lot; some use them because they are satisfied and others because there are no alternatives (*e.g.,* it is not possible to develop their own detection service)[2]. Moreover, 17.3% of networks also practically rely on third parties, since they expect to get notified about a hijack by receiving notification from colleagues, clients, mailing lists, etc. In total, 78.6% of the networks rely on third parties for the detection of hijacks against their prefixes. About one third of the networks have deployed a local hijack detection mechanism (*e.g.,* by monitoring the disruption of their services)[3]. Finally, a non-negligible percentage of 8% would probably not learn about a hijack.



(a) (b)

Figure 5: Detection and mitigation of hijacking events. How network operators (a) *learn about* and (b) *mitigate* hijacking incidents against their prefix(es).

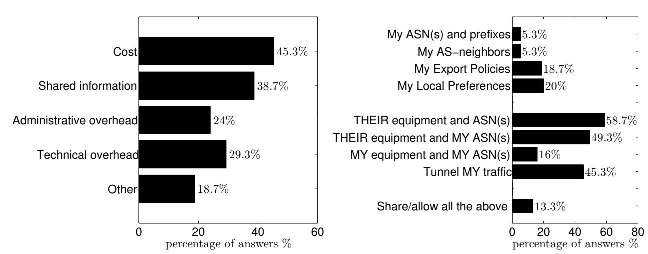
Mitigating through de-aggregation and contacting other networks. Asking operators what would be the countermeasures they would take to mitigate a prefix hijacking[4] (see Fig. 5(b)), the majority (62.7%) responded that they would announce more specific prefixes (de-aggregation) and contact the offending network (i.e., the hijacker) or its providers. 5.3% would follow *only* the former approach (de-aggregation) and 25.3% *only* the latter (contacting other operators). This indicates that although de-aggregation is not widely used currently (see Fig. 4), operators still find it a good solution and are willing to proceed to similar actions after a hijacking event –affecting their networks– has taken place.

3.4 New Mitigation Mechanisms

The survey results show that the main practices that networks currently use for hijack mitigation comprise prefix de-aggregation and contacting other networks (Fig. 4 and 5(b)). Since these approaches have some important shortcomings, *e.g.,* de-aggregation is not efficient when a /24 prefix is hijacked (due to upstream filtering), and contacting network operators is usually done manually and thus adds significant delay to the mitigation process, we ask the network operators about their willingness to deploy new mitigation mechanisms, as well as what desired characteristics these mechanisms should possess.

We first ask them about their willingness to outsource functions related to the detection and mitigation of hijacks to a third party, in order to enhance their defenses. 61% of the operators are not willing to proceed to such outsourcing practices. This shows that a potential mechanism should not be entirely based on outsourcing, since this would not be acceptable by many networks. Flexible approaches that could be operated in two modes, *i.e.,* self-operated and outsourced, could be promising, since a significant percentage of 39% does not reject the possibility to outsource such functions.

The reasons for the operators' reluctance to outsource are given in Fig. 6(a), where the associated (high) cost and the need to share private information about their network are the main factors. Administrative and technical overhead may also prevent outsourcing. This is a first indication about the characteristics of a potential defense system: low cost, privacy-preserving, and easy to operate and manage.



(a) (b)

Figure 6: Outsourcing prefix hijacking mitigation. (a) Main factors that would affect the decision *not to* outsource prefix hijacking mitigation. (b) Assuming a fully trusted outsourcing organization, the information/control (if any) that operators are still *not* willing to share/allow.

[2]This variation can be observed in the following examples from the detailed answers in our survey:
"pretty happy with it", "no issues so far", "it works fine [..], but is relatively limited", "I hate it", "It's ok", " it seems to work quite well the few times I have needed it", "Better than nothing, but a lot of false alerts", "It rules!", "It is very noisy because it does not know a damn thing about IXP route servers", "Not great".

[3]Among the "other" answers, a high percentage of answers relates to the observation of –or, reception of complaints about– disruption in their services.

[4]Note that for this question, we provided the choices, based on the answers received in a preliminary version of our survey; operators could have answered in a different way if this was a completely open question.

More specific results about what would be the information/control that they would *not* be willing to share/allow with an outsourcing organization, are given in Fig. 6(b). As it can be seen, most of them are willing to share information about their prefixes and AS-neighbors (95%), as well as their routing policies (80%). A smaller percentage would allow BGP announcements to be controlled or implemented by the outsourcing organization.

Finally, according to operators, the importance of different characteristics that a hijack defense system should have, is shown in Fig. 7, where the rightmost characteristics are considered of the highest importance. The speed and effectiveness of the mitigation stage, as well as the self-operability and low cost and management overhead, are the highest-ranked characteristics. Moreover, the detection stage is required to generate few false positives, which indicates the need for high levels of detection accuracy.

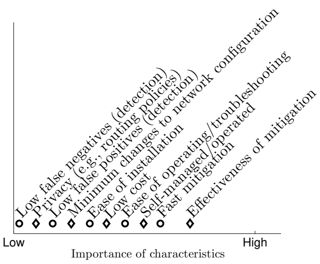


Figure 7: Importance of characteristics of a defense system according to network operators.

4 CONCLUSION

In this work, to increase community understanding of existing BGP hijacking defenses and the needs of network operators, we presented the results of a survey of 75 network operators around the world.

Through the survey, we verified our intuition that BGP prefix hijacking is a real threat and concerns the vast majority of network operators; in fact, hijacks can have a severe and lasting impact on their own networks. In the context of combatting such hijacks, operators can use proactive or reactive techniques. On the one hand, proactive mechanisms, such as RPKI, have gained extremely little traction for multiple reasons, including limited adoption and high cost and complexity of deployment. On the other hand, practical reactive defenses such as contacting other networks, route filtering, extensive peering and prefix de-aggregation are usually preferred methods to mitigate hijacks; however, each has its own significant limitations, ranging from very slow mitigation speeds (*e.g.,* contacting other operators) to inefficient mitigation (*e.g.,* de-aggregation for /24 prefixes).

In terms of detection, we observe that operators mainly rely on third parties, such as BGPmon. However, the level of satisfaction varies wildly across operators. Moreover, most of them are reluctant to perform similar outsourcing for the mitigation of the hijacks themselves; in fact, there are mixed feelings about the kind and amount of information they would be willing to disclose to the third party, as well as the involved costs and technical and administrative overhead. The speed and effectiveness of the mitigation stage, as well as the self-operability and low cost and management overhead, are of paramount importance; moreover, the detection stage is required to generate few false positives, mandating high levels of detection accuracy. The findings of this survey could inform the design and implementation of new concepts and methodologies, as well as more secure inter-domain routing protocols in general.

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