Analysis of BGP Origin AS Changes among Brazil-related Autonomous Systems

Shih Ming Tseng[1], Ke Zhang[1], S. Felix Wu[1], Kwan-Liu Ma[1],
Soon Tee Teoh[2], and Xiaoliang Zhao[3]

[1] University of California, Davis, California, USA
{tsengs, zhangk1, wu, ma}@cs.ucdavis.edu
[2] San Jose State University, San Jose, California, USA, teoh@cs.sjsu.edu
[3] Juniper Networks Inc., xzhao@juniper.net

Abstract. On the inter-domain Internet today, the address prefix origin in our BGP operations has become a major security concern. This critical problem can be stated simply as "Is the originating Autonomous System (AS) authorized to advertise the destination address prefix?" In the long term maybe we will be able to prevent this problem by applying proposed solutions such as SBGP[1] or SoBGP[2]. However, in practical network operations, it is critical to monitor and analyze all the BGP events potentially related to this BGP origin problem. In this paper, we have analyzed OASC (Origin Autonomous System Change) events, generated from the Oregon Route Views [4] archive, related to the Brazil BGP network. Our main focus is on how the Brazil BGP operation has been interacting with the rest of the Internet in the past five years. Also, we provide some possible explanations for OASC anomalies in Brazil.

1 Introduction

As the de facto inter-domain routing protocol, Border Gateway Protocol (BGP) [3] is responsible for discovery and maintenance of paths between distant ASes in the Internet. A BGP route lists a particular prefix (destination) and the path of ASes used to reach that prefix. The last AS in an AS path should be the origin of the BGP routes. We call that AS the *origin AS* of that prefix. A BGP prefix is normally announced by a single origin AS. However, in real BGP operations, for reasons such as multihoming [5], it is quite normal that some address prefixes are fully or partially originated by multiple ASes.

On the inter-domain Internet today, the address prefix origin in our BGP operations has become a major security concern. This critical problem can be stated simply as "Is the originating Autonomous System (AS) authorized to advertise the destination address prefix?" In the long term maybe we will be able to prevent this problem by applying proposed solutions such as SBGP or SoBGP However, in practical network operations, it is critical to monitor and analyze all the BGP events potentially related to this BGP origin problem. In fact, we believe that, without a careful and clear understanding about the OASC

events, it is very difficult to evaluate and justify any preventive solutions claiming to solve the origin AS problem in BGP.

While some of the observed OASC events are indeed due to normal operation, some others might very likely be related to failures, mis-configuration, or even, intentional malicious attacks. Previously, we have defined a set of OASC events [7, 8], and developed a visualization tool to display the events graphically [6]. Ultimately, we would like to tell whether a particular OASC event is normal or abnormal, and furthermore, the explanation for our conclusion.

In this paper, we have analyzed the OASC events, generated from Route Views archive, related to Brazil BGP network. Our main focus is on how the Brazil BGP operation has been interacting with the rest of the Internet roughly in the past five plus years. Comparing to the whole Internet, Brazil ASes have produced slightly lower than average OASC events relative to its network size and address prefixes. Furthermore, we provide some possible explanations for certain OASC anomalous events in Brazil. More specifically, a few Internet-wide OASC storms identified in [6] have impacted Brazil prefixes significantly. Among other OASC anomalies we discovered, most of the Brazil- initiated OASC events in the summer/fall of 2003 were related to a very small number of ASes (such as AS6505 and AS7927), and, likely due to some legitimate reasons such as network re-configuration. Finally, we gave the definition of per-update OASC analysis, which shows very different results from the traditional per-day OASC case.

2 Origin Autonomous System Changes (OASC)

2.1 Definition of OASC

The origin AS number of a IP prefix P at time T_1 is denoted as $f(P, T_1)$ where function f is used to compute the origin AS number. Similarly, $f(P, T_2)$ represents the origin AS number of P at T_2. We define that there is an origin autonomous system change(OASC) event for prefix P between time T_1 and T_2 when $f(P, T_1)$ is not equal to $f(P, T_2)$. For instance, Multiple Origin Autonomous System (MOAS) change [7] is a special type of OASC events. A prefix P has MOAS property when P has two or more origin AS numbers. A MOAS change happens when P has MOAS property at time T_1 or T_2. (i.e. $f(P, T_1)$ or $f(P, T_2)$ contains two or more autonomous system numbers)

An OASC event implies the changes of BGP routing paths. Those changes are possibly caused by legitimate reconfiguration, unintentional mis-configuration or malicious attack. Regardless the causes, an increase in OASC events definitely implies an increase in network instability.

2.2 The Model of Snapshot Differentiation

A snapshot $S(T_1)$ is defined as a BGP routing table dump at time T_1. Assuming that there is a set of BGP update messages M which occurs between time T_1 and T_2. Hence, the snapshot S(T2) can be obtained after applying BGP update

messages M to snapshot S(T1). The snapshot differentiation(SD) is defined as the difference between $S(T_1)$ and $S(T_2)$.

Per-Day-OASC The per-day-OASC is defined as : T_1 and T_2 has the difference of 24 hours. Consequently, SD of $S(T_1)$ and $S(T_2)$ represents the changes of 24 hours. Also, M represents all of the update messages within the 24 hours duration. As mentioned in section 2.1, $f(P, T_1)$ is computed from $S(T_1)$ and $f(P, T_2)$ is computed from $S(T_2)$. Therefore, a per-day-OASC event of prefix P occurs if and only if $f(P, T_1)$ is not equal $f(P, T_2)$.

Per-Update-OASC The per-update-OASC is defined as: BGP update messages M contains only one BGP update message. Hence, the snapshot S(T2) can be obtained after applying one BGP update messages M to snapshot S(T1). Similarly, for prefix P, a per-update-OASC event occurs if and only if $f(P, T_1)$ is not equal $f(P, T_2)$.

Obviously, per-update-OASC results the maximal level of detail in OASC analysis. However, per-update-OASC also results a huge computational overhead. For instance, it took us about 20 minutes to compute one snapshot based on the Per-Day-OASC model. But, it took us about one week of CPU time to compute all the Per-Update-OASC events of a 24 hours window. I.e., computing Per-Update-OASC is about 500 times more expensive.

Route Views BGP archive shows that (i) there are more then 262 million BGP update messages in total from all connected peers in March 2005 (nearly 100 update messages per second) (ii) there are more than 172,000 prefixes exist in the routing table dump of March 31, 2005. Due to the data complexity and limited computational resources, it might not be feasible to have per-update-OASC analysis by processing all BGP update messages. Instead, per-update-OASC method can be used as an auxiliary for per-day-OASC analysis when detail information is needed.

2.3 Types of OASC

Generally speaking, each OASC event contains five attributes [6]: (i) "$Time$" represents the date and time when an OASC occurs. (ii) "$Type$" represents the OASC event type (iii) "$Prefix$" represents the IP prefix in CIDR format (iv) "$OldAS$" represents a set of origin AS number before an OASC event. (v) "$NewAS$" represents a set of origin AS number after an OASC event.

There are mainly four categories of types of OASC events which are C_{type}, O_{type}, H_{type} and B_{type}. C_{type} event implies that the origin AS number of P is changed. O_{type} event implies a prefix P is announced and previously there is no route to P. B_{type} event implies that a more specific prefix P(e.g. /24 network) is announced with the same origin AS number as the origin AS number of less specific prefix P_{Big}(e.g. /16 network) where P_{Big} exists in routing table and P_{Big} is the smallest prefix which can embrace P. H_{type} event implies that a more specific prefix P is announced but the origin AS number is not the same as the origin AS number of less specific prefix P_{Big}.

In addition, there are up to four sub-types in each category. It comes out that there are twelve types of OASC event in total [6]. i.e. OS, OM, CSS, CSM, CMS, CMM, HSS, HSM, HMS, HMM, BSS and BMM. The abbreviation for each type of event is either in two or three letters. The first letter stands for the main category. The second and third letter which is either S (stands for *single*) or M (stands for *multiple*) means the number of origin AS number in $OldAS$ and $NewAs$. For examples, CSS stands for a C_{type} event and the number of origin AS number in $OldAs$ and $NewAS$ are both one.

3 OASC Analysis Results for Brazil-related ASes

3.1 Analysis Goals

Our goals are (i) to design a series of OASC analysis methods which can be used to analyze BGP traffic systematically, (ii) to use the developed methods to give the best explanation of certain OASC events related to our target nation which is Brazil in this paper, and (iii) to find the relationship between OASC events and the AS topology of our target nation.

Our interests are to find the best explanation of the following questions: (i) Does Brazil have more OASC event than other countries ? (ii) Have Brazil networks been affected by major OASC storms in the past 5 years ? (iii) Have Brazil generated any OASC events which affected the rest of the world or only itself ?

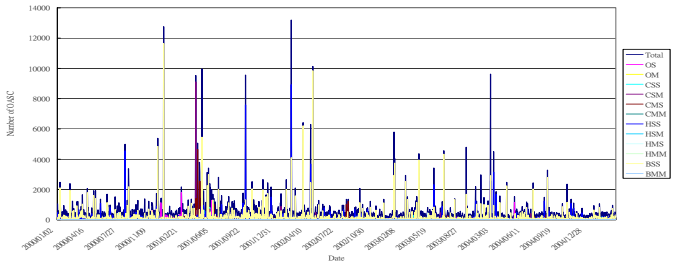
3.2 Autonomous Systems to Country Mapping

Every autonomous system is represents by an AS number. We utilize the Whois server to map every AS number to its registered country. For example, AS6192 (University of California, Davis) is mapped to USA. From Route Views BGP archive and Whois servers, we are able to identify that there are a total number of 246 ASes registered to Brazil.

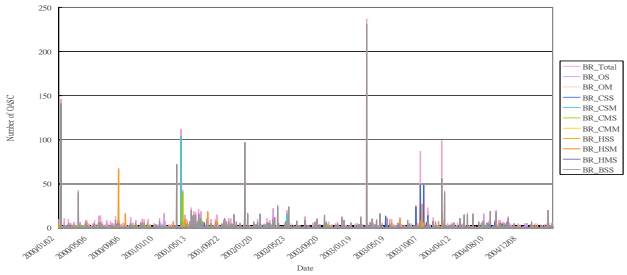
However, Whois servers only keep the most current information. In other words, we are not able to map some ASes due to lack of information. For example, an AS number X, which was registered in country Y in the past but X is currently unregistered and not assigned to any country. Under this kind of circumstances, it is impossible to map X correctly to country Y due to lack of history information. In this paper, the AS to country mapping process utilizes the data from Whois server on April 1, 2005.

3.3 Analysis Results

Route Views BGP archive provides the raw data of BGP traffic from January 1, 2000 to March 31, 2005. When processing BGP raw data, the per-day OASC analysis method is used to as primary tool to examine BGP traffic and per-update OASC analysis is secondary.



(a) World Wide OASC Statistics



(b) Brazil OASC Statistics

Fig. 1. OASC Statistics

The following abbreviations are defined for easy interpretation. (i) A Brazil Autonomous System(AS) is a autonomous system which is associated with Brazil in section 3.2. (ii) The Brazil-related OASC event is defined as a OASC event which involves at least one Brazil AS. (iii) A Brazil-originated OASC event is defined as an OASC event which is generated by a Brazil AS. In summary, a Brazil-originated OASC event is a Brazil-related OASC. But a Brazil-related OASC does not imply a Brazil-originated OASC event.

Compare Brazil-related OASC and Non-Brazil-related OASC As a result from section 3.2, there are 246 Brazil ASes and 33788 non-Brazil ASes. The ratio of Brazil ASes to non-Brazil ASes is 0.728%. In addition, the total number of IP prefixes which have at least one Brazil AS as its origin AS is 1,435 and the nunber of all prefixes is 1,702,077 (BGP routing table of March 30, 2005). The ratio of Brazil prefixes to all prefixes is about 0.84%. In other words, on a per-AS basis, Brazil ASes own slightly more IP prefixes than other countries.

Fig. 1(a) and 1(b) show the number of OASC events in the past 5 years, for the whole Internet and the Brazil Internet, respectively. X-axis represents date and Y-axis represents the number of OASC events per day.

Fig. 2 shows the ratio of Brazil-related OASC to all OASC events where X-axis represents months from January 2000 to March 2005 and Y-axis represents the ratio. The per month average line indicates the ratio of Brazil-related OASC

to all OASC events. Also, cumulative average line shows the average ratio from January 2000 up to the end of a specific month. For instance, per month average is larger than accumulative average in August, September and October of 2003 which means that Brazil had more OASC events than long-term average during those three months. The figure also indicates that the long-term average (accumulative average) is around 0.5% to 0.6% which is smaller than the ratio of prefixes (0.84%) and the number of ASes (0.728%).

Overall, our analysis shows that Brazil has relatively fewer number of OASC events than other countries. However, according to Fig. 2, there were several statistical OASC anomalies. For instance, we can observe spikes on both April and October of 2003.

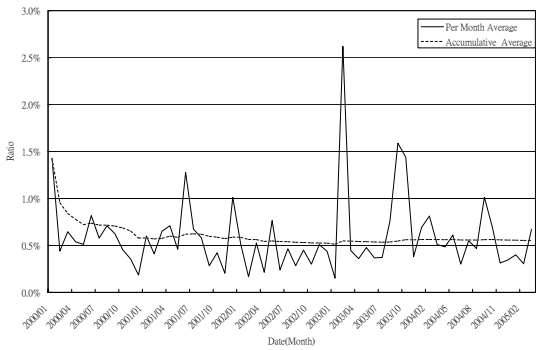


Fig. 2. Ratio of Brazil-related OASC to all OASC

Please note that some OASC events can not be recorded under certain circumstances. For instance, in Fig. 3, BGP router $R1$ makes some changes C on prefix P and the BGP update messages propagate to router $R2$ and $R3$. Based on the current status, $R2$ and $R3$ decide independently if C makes the best route to prefix P. If both $R2$ and $R3$ decide that C does not make the best route to P, the changes C will not be propagated. Hence, peer router PA and PB will not receive C such that C will not be recorded by Route Views. As a consequence, in order to record the changes C, a peer router must be placed near $R1$ to prevent C from being dropped by other BGP routers.

Currently, Route Views has more than 75 peer ASes. Hence, it is highly unlikely that some OASC events are not recorded by any of those 75 ASes. Currently, there is no observation point in Brazil. We can not exclude the possibility that some OASC events closed or within Brazil were not recorded due to aggregation by intermediate routers. In order to record an event before it is neutralized by aggregation, we suggest that a BGP router, which peers with Route Views, should be placed in Brazil.

Fig. 4 is generated by Route Views BGPlay service. The numbers represent ASes and the dash lines represent links. Fig. 4(a) shows the paths from

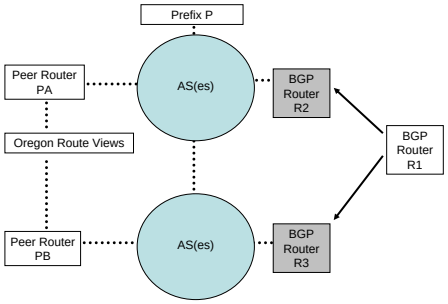
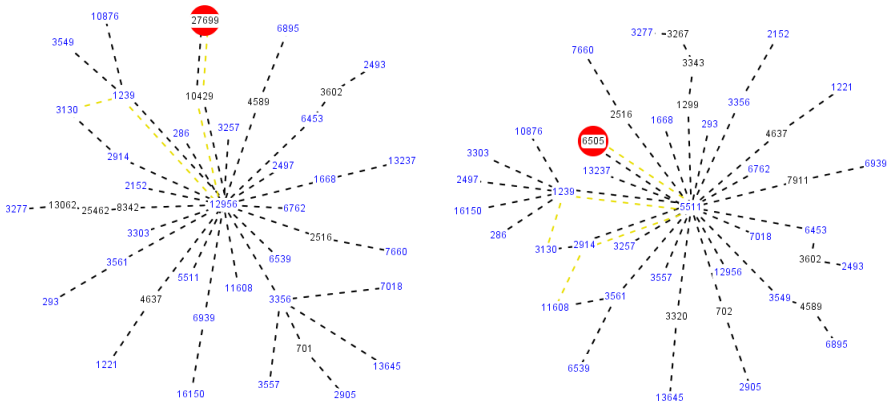


Fig. 3. Example of Non-recorded OASC

200.160.0.0/17 to all observation points and AS27699(Telecomunicacoes de Sao Paulo) is the origin AS number of 200.160.0.0/17. Similarly, Fig. 4(b) shows the paths from 57.74.160.0/19 and AS6505(Global One Communicaoes Ltda) is the origin AS number. On Apr 1, 2005, we find that there are 29 non-Brazil ASes which are connected to 46 Brazil ASes. Among those 46 Brazil ASes, AS7738 (Telecomunicacoes da Bahia), AS8167 (Telecomunicacoes de Santa Catarina) and AS13591 (MetroRED Telecom Services) have the largest number of connections to non-Brazil ASes. In addition, among those 29 non-Brazil ASes, 17 of them are in USA and the rest are: 2 in Argentina, 1 in Australia, 1 in Canada, 2 in Mexico, 1 in Italy, 1 in Spain, 1 in Switzerland, 1 in Germany, 1 in France and 1 in Uruguay. Please note that those 29 non-Brazil ASes have direct BGP peering sessions to 46 Brazil ASes. This fact implies that there are about 200 Brazil ASes which do not have direct connection across the country's border.



(a) Topology of 200.160.0.0/17 (b) Topology of 57.74.160.0/19

Fig. 4. AS Topology

Non-Brazil-Originated OASC Events Affect Brazil As shown in Fig. 1(b), Brazil was affected by major OASC storms on August 2000 and April 2001. AS7777(Mail Abuse Prevention System LLC) announced a lot of smaller size prefixes (e.g. /30 networks) which was previously owned by other ASes. It results numerous of HSS events. Brazil was one of the victims. Afterward, Brazil was affected again by another OASC storm by AS15412(Flag Telecom). AS15412 announced that it was one of the origin AS number of numerous IP prefixes which was previously own by other ASes. The announcing caused CSM events in every affected prefixes. In other words, the multi-home property was added to those affected prefixes. Those mistakes had been corrected by dropping the paths announced by AS15412. Those fixing(dropping) procedures caused another OASC storm of CMS events. Overall, Brazil network was affected twice (CSM and CMS) by AS15412 in April 2001. Based on our observation, Brazil has not been affected by other major OASC storms after April 2001.

Brazil-Originated OASC Events Generally, we can divide all Brazil-related OASC events into three sub-categories, *Non-BR to BR* , *BR to Non-BR* and *BR to BR*. Brazil-Originate OASC events are caused by Brazil-related AS initialed some changes in origin AS numbers.

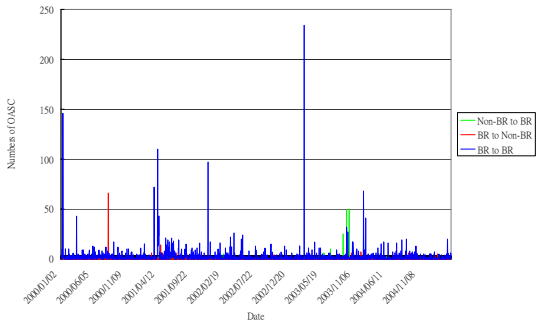
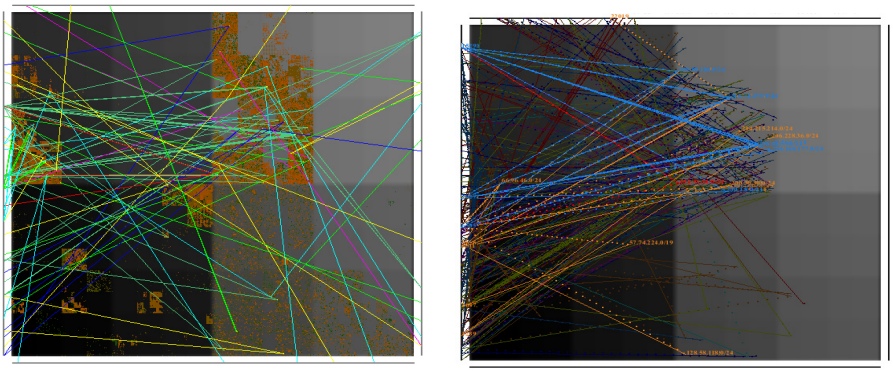


Fig. 5. Brazil-Related OASC Events

Fig. 5 shows all Brazil-related OASC events where X-axis represents date and Y-axis represents number of OASC event. We have the following conclusions by cross reference Fig. 1(b) and Fig. 5. (i) Most of the events in *BR to BR* subcategories are due to the BSS ,CSM and CMS events. Since the BSS events only involve one single AS, the effects were limited. The noticeable CSM and CMS event were caused by AS15412. Also, there are rarely BR to Non-BR events except on August 14, 2000 by AS7777. Those events has been discussed in previously section. (ii) There are a cluster of Non-BR to BR events activities at the end of 2003. We have identified that those series of events are mostly CSS events related to AS6505. The data indicates that a set of IP prefixes previously own by Chile, Colombia and Venezuela ASes had been change to

AS6505. Furthermore, in the past 5 years, AS6505 had involved a total number of 242 OASC events and 147 of them are CSS events. We noticed that among all involved prefixes, most of the origin AS numbers still remain unchanged. Hence, we conclude that if those CSS events are legitimate, our best explanation is that was due to an large scale network aggregation from other countries to Brazil.

Fig. 6 shows the results of per-day OASC analysis and per-update analysis by using ELISHA visualization tool [6]. Fig. 6(b) highlights a small set of OASC events related to AS6505 and AS7927. A CSS (AS7927 to AS6505) event in per-day analysis could probably be more events in per-update analysis. A CSS event could possible be the consequence of two update messages(a withdraw and an announce) or one update message(an announce which replaces the old route). For example, prefix 206.228.36.0/24 was dropped from AS7927(Global One Venezuela) at 5:09am on October 12,2003 and added to AS6505 3 minutes later. The number of per-day and per-update OASC events is compared in Fig. 7. In conclusion, the number of per-update OASC event is greatly larger than per-day OASC and per-update OASC analysis gives more detail. As shown in Fig. 7, per-update analysis has a burst of events on October 9 , 2003 which is not shown by using per-day analysis. We leave the investigation of the burst of events for future research.



(a) Per-Day Analysis (b) Per-Update Analysis(focus on AS6505)

Fig. 6. Visualization of October 12, 2003 OASC events

Summary of Analysis Results We summarize the dates which have more number of Brazil-related OASC events in Fig. 8. We have the following conclusions:

1. The majority of Brazil-related OASC events were due to numerous BSS events (i.e. “self punch a hole”). Those events were only involved with single particular Brazil AS and the origin AS number of most of the involved

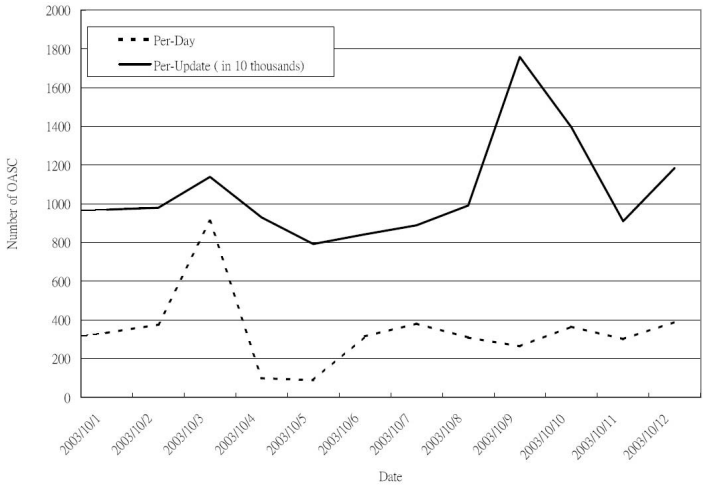


Fig. 7. Number of Per-Day OASC and Per-Update OASC

prefixes remains the same. Hence, we conjecture that those events might be legitimate re-configuration within Brazil.

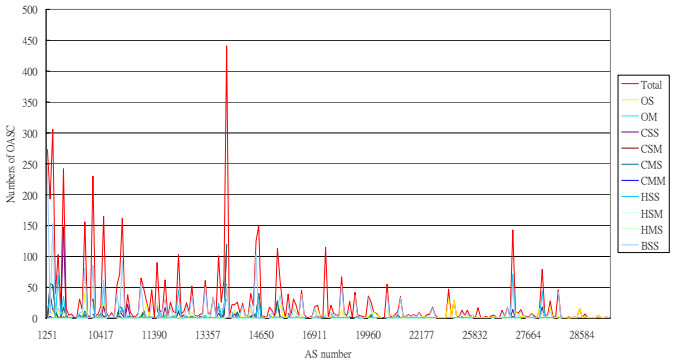
2. Brazil network was affected by the HSS OASC storm (i.e. "being punched a lot of holes") generated by AS7777 in August 2000 and CSM/CMS OASC storms (i.e. "prefixes being hijacked ") generated by AS15412 in April 2001.
3. The HSS events on October 16, 2003 might be legitimate because most origin AS number of involving prefixes remains the same.
4. The CSS (i.e. "ownership changed") events on August, September and October of 2003 were all involving AS6505 (Global One) in Brazil.
5. On October 10 2003, AS10429 (Telefonica Empresas) and AS27699 (Telecomunicacoes de Sao Paulo) in Brazil were involved in 27 HSS events. This is extremely unusual, while the rest of the world had only 287 events on that day, as Brazil had 27 events ($\sim 10\%$). Furthermore, we find a series of CSS and HSS events on October 27, 28 and 29, 2003. Among those events, most of the origin AS number remains the same. Hence, it might possibly be a series of re-configuration activities between AS10429 and AS27699.
6. Fig. 8(c) shows that AS13878 (Diveo do Brasil Telecomunicacoes Ltda), AS2715 (Fundacao de Amparo a Pesquisa do Estado de Sao Pau), AS1251 (Fundacao de Amparo a Pesquisa do Estado de Sao Pau), AS6505 and AS8167 (Telecomunicacoes de Santa Catarina) have involved a relatively larger number of OASC events among all Brazil ASes. We conclude that the number of OASC events related to an AS is not necessary proportional to the connectivity of the AS itself.
7. AS13878 has numerous of CSM and CMS events in the past 5 years. Among those AS13878-related OASC events, the origin ASes of those prefixes were changed back and forth frequently. There have been more than fifteen sets of prefixes having a similar pattern. For instance, the origin ASes of 200.9.219.0/24

Date	Total	OS	OM	CSS	CSM	CMS	CMM	HSS	HSM	HMS	BSS	Note
2000/01/12	146	5	0	0	0	0	0	0	0	0	141	AS2715
2000/03/16	43	1	0	0	0	0	0	2	0	0	40	AS10429
2000/08/14	68	0	0	0	0	1	0	66	0	0	1	AS7777
2001/03/21	72	0	0	0	0	0	0	0	0	0	72	AS14571
2001/04/06	112	0	0	0	104	0	1	1	0	0	6	AS15412
2001/04/10	42	4	0	0	0	37	0	0	0	0	1	AS15412
2001/04/12	43	2	0	0	0	41	0	0	0	0	0	AS15412
2001/12/07	97	0	0	0	0	0	0	0	0	0	97	AS17379
2002/04/05	26	2	0	0	0	0	0	0	0	0	24	AS13495
2003/02/26	237	3	0	0	0	0	0	3	0	0	231	AS1251
2003/08/24	26	0	0	24	1	1	0	0	0	0	0	AS7993(CL) to AS6505(BR)
2003/09/09	87	23	0	49	0	0	0	8	0	0	7	AS7984(CO) to AS6505(BR)
2003/10/06	27	0	0	0	0	0	0	27	0	0	0	AS27699
2003/10/12	50	0	0	49	0	0	1	0	0	0	0	AS7927(VE) to AS6505(BR)
2003/12/31	99	10	0	15	1	1	0	16	0	0	56	AS11097
2004/03/04	42	1	0	0	0	0	0	1	0	0	40	AS8167

(a) Large Number of Brazil OASC

Date	Percent	World_Total	BR_Total	BR_OS	BR_CSS	BR_CSM	BR_CMS	BR_CMM	BR_HSS	BR_BSS	Note
2000/03/16	9.21%	467	43	1	0	0	0	0	2	40	AS10429
2001/03/21	12.68%	568	72	0	0	0	0	0	0	72	AS14571
2001/06/02	8.91%	202	18	0	0	0	2	0	1	15	AS10733
2002/04/05	9.42%	276	26	2	0	0	0	0	0	24	AS13495
2003/02/26	8.06%	2940	237	3	0	0	0	0	3	231	AS1251
2003/08/24	19.85%	131	26	0	24	1	1	0	0	0	AS7993(CL) to AS6505(BR)
2003/10/06	8.60%	314	27	0	0	0	0	0	27	0	AS10429(BR) to AS27699(BR)
2003/10/12	12.85%	389	50	0	49	0	0	1	0	0	AS7927(VE) to AS6505(BR)

(b) High Ratio (Brazil to World)



(c) Brazil OASC Statistics (Per AS number)

Fig. 8. Summary of Brazil OASC Anomaly

(a Brazil prefix) were changed back and forth 16 times totally in three months (April, June, July of 2000), based on the Per-Day-OASC analysis. Unfortunately, we are not able to find any reasonable explanation of those CSM and CMS events. This phenomenon certainly causes negative effects on network stability.

4 Remarks

Origin AS Changes are global signals generated by the Internet BGP operations, intentionally or unintentionally. To analyze and diagnosis these causally related signals is the focus of our work here. We took the Brazil BGP network as the target domain and applied various techniques in trying to develop a systematic approach to decode the signals in depth.

As results, we have mixed news: good news, bad news, and unclear news. For the good news, we found that the Brazil BGP network is relatively stable compared to the rest of the Internet in OASC. And, even among the observed OASC events, we currently believe that most of them are legitimate. On the other hand, our bad news is that, not only Brazil has been hit by the OASC storms in the Internet, but also, in October 2003, a small number of Brazil-related ASes introduced unusually significant amount of OASC events into the Internet. Finally, due to the expensive CPU resources to compute the per-update OASC results, while we can observe a much greater details, we have very limited amount of per-update OASC information available. For instance, we observed a clear anomaly in 2000 for the prefix 200.0.219.0/24 and AS13877 on a per-day basis, but without a good explanation. We believe that the potential to explain OASC anomalies with the per-update OASC information is very significant.

References

1. S. Kent, C. Lynn, and K. Seo. Secure Border Gateway Protocol (S-BGP). *IEEE JSAC Special Issue on Network Security*, 2000.
2. J. Ng. Extensions to BGP to Support Secure Origin BGP. http://www.ietf.org/internet-drafts/draft-ng-sobgp-extensions-00.txt, October 2002.
3. Y. Rekhter and T. Li. Border Gateway Protocol 4. RFC 1771, July 1995.
4. The Route Views Project. http://www.antc.uoregon.edu/route-views/.
5. P. Smith. Bgp Multihoming Techniques, 2002. http://www.nanog.org/mtg-0110/smith.html.
6. S. Teoh, K.Ma, S. Wu, D. Massey, X. Zhao, D. Pei, L. Wang, L. Zhang, , and R. Bush. Visual-based anomaly detection for bgp origin as change events. 14th IFIP/IEEE Workshop on Distributed Systems: Operations and Management, 2003.
7. X. Zhao, D. Pei, L. Wang, D. Massey, A. Mankin, S. Wu, and L. Zhang. An Analysis BGP Multiple Origin AS(MOAS) Conflicts. In *Proceedings of the ACM IMW2001*, Oct 2001.
8. X. Zhao, D. Pei, L. Wang, D. Massey, A. Mankin, S. Wu, and L. Zhang. Dection of Invalid Routing Announcement in the Internet. In *Proceedings of the IEEE DSN 2002*, June 2002.