

# **Bahrain's Internet Ecosystem**

**August 2009**

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## Executive Summary

In June 2009, the Bahrain Telecommunications Regulatory Authority (TRA) invited Renesys to perform an initial study of the Bahrain Internet Ecosystem, in order to characterize the current set of observed relationships among the Internet-connected service providers and enterprises within the Kingdom, and measure the stability and growth of the domestic Internet market.

This report combines passive topology data, gathered from the Renesys network of route collectors, with active measurements of each Bahrain network from sites worldwide, and detailed analysis of the routing dynamics of two kinds of disruptive events: a June network outage affecting the King Fahd Causeway, and a February outage affecting the Fiber Optic Gulf (FOG) cable system.

These survey techniques combine to provide a relatively complete description of the ways in which Bahrain's Internet traffic is observed to reach international markets, via Reliance/Flag, Tata, and Emirates Telecom, and helps to characterize the vulnerabilities and potential growth constraints of the Bahrain Internet Ecosystem.

The study's primary observations and conclusions are as follows:

- Bahrain's Internet Ecosystem is one of the richest in the region, for its size.
- Bahrain's current Internet connectivity is adequate, but could be more diverse.
- Significant physical vulnerabilities and bottlenecks exist, but can be routed around.
- Batelco does not offer domestic peering.
- Batelco's customers lack transit alternatives.
- The evolving role of the BIX is unclear.
- The domestic traffic component of Bahrain's market needs more measurement.
- It would be beneficial to promote investment in domestic Internet content.
- Many providers appear to be capacity-constrained in the last mile of connectivity.
- Facility carrier neutrality would increase long-term international transit diversity.

Further details for each of these conclusions, including supporting data and historical analysis, can be found in subsequent supporting sections. Readers who are less familiar with Internet transit engineering may find it useful to begin by consulting Appendix A (“Routing Terminology”) for the definition of key terms.

## Primary Observations and Conclusions

### 1. Bahrain's Internet Ecosystem is one of the richest in the region, for its size.

Bahrain's small population and relatively large number of Internet-connected organizations make it one of the most connected countries in the region, as measured by the number of autonomous systems<sup>1</sup> in operation per capita.

As an emerging Internet market grows, it starts by increasing the number of networks advertised to the world. Growth in this metric corresponds to an increase in the number of enterprises that require dedicated IP address space for their online operations. As the market continues to grow, it begins to increase the number of autonomous systems used to transit those networks. Growth in this metric implies broadening and diversification in the set of competing Internet Service Providers within the market.

Bahrain's rankings for both the number of advertised networks in the global routing table and the total number of autonomous systems providing service to domestic networks are substantially higher than would be expected for the smallest country in the region, indicating that the TRA's push for greater diversification and competition in the domestic market has begun to gather momentum.

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<sup>1</sup> An **autonomous system** is an enterprise that has applied for an Autonomous System Number (ASN) in order to participate in the Internet's routing system. Batelco, BIX, Flag, Google, etc. are all examples of autonomous systems. In order to purchase Internet transit from multiple providers, an enterprise must first apply for Autonomous System status.

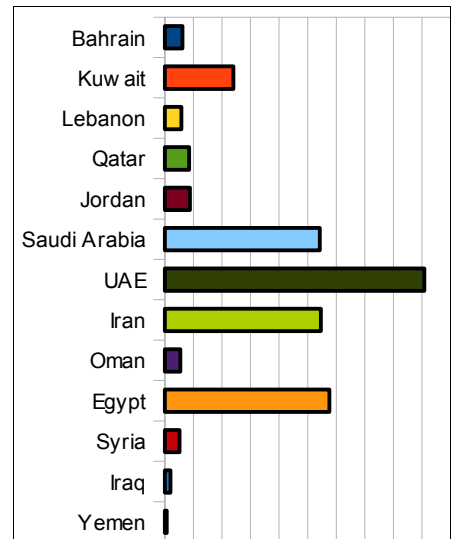
## Regional Rankings (July 2009)

Country	ASNs Per Capita	Networks	ASNs	2008 GDP	Population
<b>Bahrain</b>	<b>1</b>	<b>7</b>	<b>8</b>	<b>12</b>	<b>13</b>
Kuwait	2	5	5	5	10
Lebanon	3	4	3	10	9
Qatar	4	9	10	6	12
Jordan	6	8	7	13	7
Saudi Arabia	7	2	2	1	4
UAE	5	6	6	3	8
Iran	8	3	1	2	2
Oman	9	12	12	9	11
Egypt	10	1	3	4	1
Syria	12	11	11	8	6
Iraq	11	10	9	7	3
Yemen	13	13	13	11	5

At the same time, Bahrain's Internet Ecosystem (the total number of Bahraini network prefixes in the global table) is still very small compared to many of its neighbors. The following chart illustrates the relative size of the regions' Internet ecosystems, as measured by the Renesys Market Intelligence Customer Base Metric.

This metric adds up the network prefixes advertised by all of the providers in each national market, scaling appropriately according to the size of each advertisement in order to estimate the total relative traffic volume. It is useful as a rough comparison of the size and rate of growth of each country's Internet Ecosystem.

In interpreting these rankings, it is also important to realize that Bahrain's autonomous system diversity is only one required element for future growth. Domestic provider diversity must be complemented by carrier diversity (multiple paths to international markets) and access diversity (multiple sources of domestic wholesale access) if the Internet Ecosystem is to deliver maximal benefits to consumers through its expansion in the coming years. Today, neither of these diversity requirements is being adequately satisfied.



## **2. Bahrain's current Internet connectivity is adequate, but could be more diverse.**

Most of Bahrain's major Internet service providers appear to have achieved an acceptable level of route diversity to satisfy short-term needs. In the longer term, the Kingdom needs to continue to build more physically diverse interconnections with the world, and to attract a larger number of international service providers to the domestic marketplace.

Internet connectivity within Bahrain is provided by three primary physical paths: connectivity to Saudi Arabia over the King Fahd Causeway, and dual connectivity to the UAE over the Fiber Optic Gulf (FOG) and FLAG/Falcon cable systems.

Three international service providers (Emirates Telecom, Flag, and Tata) currently offer Internet transit services to Bahrain over these paths to the world's autonomous systems.

- Zain (Vodafone MTC) and the Bahrain Internet Exchange (BIX) both purchase Internet transit directly from Emirates and Tata.
- Batelco purchases transit directly from Flag and Tata.
- Lightspeed now purchases transit directly from Flag alone.
- Mena and 2Connect purchase some direct transit from Tata, and some from the BIX.
- The twelve other autonomous systems in the Kingdom all purchase transit directly from the BIX.

Again, it is important to note the distinction between logical and physical diversity. The carriers that purchase transit from foreign carriers such as Tata or Flag must do so over common fiber that is under contract from a single source. While the contractual relationships for bandwidth are logically “direct” between domestic provider and international carrier, they are at the same time physically dependent on Batelco. Competing domestic providers do not have the infrastructure to perform direct connections to the international market, and in that sense, are not operating fully independently as competing players in the market (see conclusion #10, “Facility carrier neutrality would increase long-term international transit diversity”).

Bahrain's transit arrangements are summarized in the following table, which is current as of August 2009. Note that no autonomous system purchases Internet transit from Batelco (see conclusion #5, “Batelco's customers lack transit alternatives”).

## Internet Transit Relationships Observed in Global Routing Table, August 2009

source: Renesys Market Intelligence™

Customers of...	BIX (AS35019)	Emirates (AS8961, AS8966)	Flag (AS15412)	Tata (AS6453)	Packet Clearinghouse (AS42)	Batelco (AS5416)
Kalaam (AS35443)	✓					
Etisacom Bahrain (AS35457)	✓					
Northstar (AS35546)	✓					
Nuetel (AS35568)	✓					
Viacloud (AS35729)	✓					
BCN (AS41110)	✓					
Ascentech (AS41303)	✓					
RTS (AS42931)	✓					
ICOLPLUS (AS44167)	✓					
Kulacom (AS47380)	✓					
Central Informatics Organization (AS48109)	✓					
Zain (AS31452)		✓		✓		
Mena (AS39015)	✓			✓		
2Connect (AS35313)	✓			✓		
Gateway Gulf (AS44876) <sup>2</sup>	✓				✓	
Lightspeed (AS39273) <sup>3</sup>			✓			
Bahrain Internet Exchange (AS35019)		✓		✓		
Batelco (AS5416)			✓	✓		

2 Inbound traceroutes via PCH to Gateway Gulf end at the London Internet Exchange; true transit not verified.

3 Stopped transiting the BIX on 1 August 2009, began buying transit from Flag.

### **3. Significant physical vulnerabilities and bottlenecks exist, but can be routed around.**

Analysis of Internet outages in 2009 revealed that Bahrain's Internet Ecosystem is subject to significant instability and congestion from disruptions in its physical network connections.

- When connectivity over the Causeway was interrupted at the end of June 2009, the BIX (and providers who rely on the BIX) lost Tata transit. Traffic had to be diverted to Emirates Telecom via the FOG cable. In the case of the BIX, which normally routes the majority of its traffic via Tata, this created temporary network outages and significant congestion until the fault was repaired. Providers who had backup connectivity to Tata, and/or backup transit to Flag (such as Batelco) were much less significantly affected.
- When connectivity over the FOG was interrupted on February 12th, a complementary failure mode prevented the BIX (and providers who rely on the BIX, as well as Zain) from reaching Emirates Telecom. Traffic therefore had to be diverted to Tata over the Causeway. The BIX has more capacity heading west, so the impact was less severe, but lasted longer (nearly two weeks). Again, Batelco had alternative physical transit via the Falcon cable, and was less significantly affected.
- Altogether, the FOG appears to have suffered more than 30 days of reduced capacity in the first half of 2009; this represents a very significant amount of congestion and downtime for the affected providers. Similar events were observed in 2009 on the following dates:
  - Jan 24 – Feb 2, 2009
  - Feb 12-24, 2009
  - Mar 30 – Apr 6, 2009
  - Apr 13–18, 2009
- When the Falcon and/or SMW3/4 cable systems providing data to the region are cut elsewhere (as happened during December 2008, in Egypt), Bahrain loses connectivity along with the entire region. There is no alternative path.

Despite these vulnerabilities, the country's Internet infrastructure as a whole appears to be more consistently stable than many other regional markets, as measured by the percentage of advertised networks that are afflicted by routing problems in an average hour.

All of Bahrain's domestic providers (with the recent exception of Lightspeed, who now buys only from Flag) are now purchasing diverse international transit, either on their own or indirectly through the BIX. This diversity makes it possible to keep traffic flowing (perhaps with increased packet loss and delay resulting from congestion) despite significant damage to the physical infrastructure.



#### **4. Batelco does not offer domestic peering.**

Today, Renesys BGP routing data indicates that Batelco peers with regional providers outside Bahrain, including Qatar Telecom (AS8781) and Emirates Telecom (AS8966), to facilitate settlement-free exchange of regional traffic between their customers. However, they do not peer domestically with the Bahrain Internet Exchange (BIX), nor with the service providers hosted there, and they do not maintain a presence at the Exchange. This is consistent with the routing advertisements that are propagated by BIX and Batelco.

As a result, more than five years after the first Internet Exchange license was granted, it is still not uncommon for Internet traffic between two adjacent buildings to have to leave the country, travel as far as Riyadh or London, traverse a foreign carrier's routers, and return to Bahrain, before arriving at its destination next door.

This creates a significant disincentive for any enterprise that wishes to reach the domestic market (for example, an E-commerce service provider such as a bank) to purchase Internet transit from anyone except Batelco. If they bought transit from the BIX, or from any other domestic provider, they would still be unable to reach the bulk of the domestic market (Batelco's customers) without incurring the additional cost and packet delays of international transit through Tata (PoP in Riyadh) or the Emirates.

#### **5. Batelco's customers lack transit alternatives.**

Most of the country's enterprises still rely on Batelco alone to route their traffic to and from the Internet. Yet, none of Batelco's customers is able to diversify their transit by purchasing a second connection from a competitor, because they all lack autonomous system status. Batelco always advertises its customers' network prefixes directly in its own name, rather than encouraging them to announce their own networks through Batelco as an autonomous system.

It is possible that all of Batelco's customers are entirely satisfied with their Internet transit arrangements through Batelco, and simply do not see the benefits of diversifying their Internet transit by applying for an autonomous system number and purchasing backup service from a second international or domestic provider. The alternative explanation would be that Batelco doesn't sell Internet transit to autonomous systems who are also likely to buy from its domestic or international competitors. Both explanations are consistent with the observed data.

In any case, the fact that Batelco has no autonomous system transit customers at all in Bahrain seems highly unusual given their size, maturity, and leadership position in the domestic market.

For context, there are 108 countries on Earth whose Internet Ecosystem is at least as large as Bahrain's. Of these 108, a total of 97 (nearly 90%) have a largest domestic provider who serves at least one autonomous system customer. The Armenian Telephone Company has ten. Cameroon Telecom and Kyrgyz Telecom each have five. New Caledonia PTT has three, on a remote Pacific island with 250,000 inhabitants. Saudi Arabia's STC has 29. Iran's DCI has 51.

Batelco joins Libya's GPTC, Tunisia's ATI, and Morocco's Maroc Telecom as one of the few most-dominant domestic providers of their nation who have no downstream autonomous system customers at all.

## **6. The evolving role of the BIX is unclear.**

The creation of the BIX in 2005 clearly succeeded in increasing the diversity of Bahrain's Internet ecosystem, by giving companies an alternative to Batelco's existing Internet transit arrangements. And the BIX has arguably succeeded in its original mission: to serve as a single point of convenience for providers to exchange domestic traffic (despite the conspicuous absence of Batelco), to satisfy the monitoring requirements of the Ministry of Culture and Information, and to support the government's lawful intercept capabilities.

However, in the final analysis, Batelco still controls the fiber and ducts over the Causeway, the cable landing stations, and wholesale physical connectivity in general, both domestic and international. This appears to have constrained the growth of the BIX and limited its role.

Instead of becoming a true carrier-neutral Internet exchange, where domestic providers could make deals directly with a large number of international carriers, or a place where all domestic participants could exchange domestic traffic settlement-free, the BIX plays the role of a traditional transit aggregator (service provider), buying a few hundred megabits of wholesale transit from Tata and Emirates over Batelco's wholesale fiber, and selling these services on to BIX members, most of whom are collocated in the same building.

To route around these constraints, Zain, Mena, Lightspeed, and 2Connect have all made the decision to purchase redundant international connectivity, independent of the BIX. 2Connect and Mena both purchase additional Tata transit directly, suggesting that their requirements have outgrown the capacity and/or reliability of the Tata transit provided by the BIX. Zain and Lightspeed have stopped transiting the BIX entirely (Zain in May 2008 and Lightspeed in July 2009) in favor of transit from Tata, Emirates, and Flag<sup>4</sup>.

Physical access to the BIX also appears to be an issue for domestic providers. Many of the

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<sup>4</sup> In this case, "buying transit from FLAG" is something of a misnomer, since all interconnections with FLAG by competing operators must be mediated through a contract with Batelco for physical access to the cable. In other words, the routing tables suggest that a transit relationship exists with Flag, but the contractual relationship is with Batelco.

BIX participants (Kalaam Telecom, Northstar, Lightspeed, iCOL, BCN) have chosen to physically locate their operations in the same building as the BIX, perhaps in order to avoid having to purchase an interconnect through Batelco. Active measurements of the time for packets to reach each of the BIX customer networks suggest that BIX participants who are not present in the same building (e.g., Viacloud, Neutel, 2Connect, Mena, Etisacom Bahrain) can experience significantly higher worst-case delays for their traffic, possibly representing capacity constraints and congestion in their local connection to the BIX.

At the end of July 2009, Gateway Gulf came online in Bahrain as a BIX customer. Their website suggests that they plan to offer a competing carrier-neutral facility solution. However, they are likely to face many of the same challenges that the BIX has had in acquiring international transit and attracting carriers to their peering fabric, especially in light of the limited size of the domestic content market and the resulting international traffic asymmetries.

## **7. The domestic traffic component of Bahrain's market needs more measurement.**

It would be beneficial to evaluate the total volume of Internet traffic that both originates and terminates within the Kingdom (purely domestic traffic), as a fraction of total Internet traffic, taking into account “accidentally international” domestic traffic resulting from the failure of domestic providers to fully interconnect in recent years.

Growth in domestic traffic volumes can serve as a surrogate measurement of the fraction of ICT investment that is 'recaptured' in the domestic market, by building infrastructure that encourages the growth of in-country Web content and online services, rather than the flight to offshore information markets.

## **8. It would be beneficial to promote investment in domestic Internet content.**

As the domestic information market grows, traffic ratios with the outside world become more balanced, enabling lower costs and higher transit diversity over time.

It is likely that Bahrain's relative domestic traffic numbers are actually extremely low, much lower than might be expected, as a result of the relatively slow development of the domestic E-commerce and payment processing industry, and because of the very high demand for Web content and streaming media hosted outside the Kingdom.

Of the top 100 websites identified by Alexa.com as being of interest to Bahrain's consumers (see table, next page), only three actually resolve to IP addresses that are hosted within the Kingdom. Of the rest, most are hosted in the United States (73%), Canada (6%), or Europe (10%).

This is a key stumbling block for many emerging Internet markets, which might be addressed through incentives for (or strategic investment in) the domestic content market. Attracting a

major international content provider to locate a regional data center in the Kingdom, in order to sink traffic requests that would otherwise leave the region and pull content from the US or Europe, would also help significantly.

## Top 100 Websites Accessed by Bahrain Internet Consumers, August 2009

Rank	Site	Primary IP	Country
1	http://google.com.bh	74.125.77.104	US
2	http://live.com	207.46.30.34	US
3	http://youtube.com	64.15.120.233	US
4	http://google.com	74.125.45.100	US
5	http://yahoo.com	209.191.93.53	US
6	http://facebook.com	69.63.176.140	US
7	http://msn.com	207.68.172.246	US
8	http://maktoob.com	74.54.154.48	US
9	http://kooora.com	216.93.181.137	US
10	http://travian.ae	92.51.158.104	DE
11	http://bahrainforums.com	207.210.66.170	US
12	http://blogger.com	74.124.127.191	CA
13	http://tagged.com	67.221.174.30	US
14	http://microsoft.com	207.46.232.182	US
15	http://wikipedia.org	208.80.152.2	US
16	http://4shared.com	208.88.227.170	VG
17	http://gamezer.com	208.43.29.244	US
18	http://flickr.com	68.142.214.24	US
19	http://alwasatnews.com	74.53.119.169	US
20	http://mozook.com	208.43.69.74	US
21	http://indiatimes.com	203.199.93.69	IN
22	http://bp.blogspot.com	unknown	unknown
23	http://bramjnet.com	208.64.26.42	US
24	http://te3p.com	208.43.69.85	US
25	http://3roos.com	72.35.81.133	US
<b>26</b>	<b>http://inetmail.com.bh</b>	<b>193.188.97.108</b>	<b>BH</b>
27	http://dailymotion.com	195.8.215.136	FR
28	http://bdr130.net	89.144.99.81	SA
29	http://wordpress.com	76.74.254.126	US
30	http://akhbar-alkhaleej.com	64.226.254.55	US
31	http://artyria.ae	83.137.113.99	AT
32	http://imdb.com	207.171.166.140	US
33	http://graaam.com	208.43.81.104	US
34	http://jro7i.com	unknown	unknown
35	http://metacafe.com	72.32.120.222	US
36	http://hawaaworld.com	212.162.151.65	SA
37	http://mexat.com	208.115.42.250	US
38	http://0zz0.com	64.15.129.80	CA
39	http://brg8.com	72.46.153.178	US
40	http://clicksor.com	66.48.81.155	CA
41	http://rapidshare.com	195.122.131.14	DE
42	http://ask.com	66.235.120.101	US
43	http://orkut.com	74.125.65.85	US
44	http://g9g.com	75.126.212.102	US
45	http://friendster.com	209.11.168.112	US
46	http://6rb.com	67.205.81.115	CA
47	http://alayam.com	66.132.220.36	US
48	http://conduit.com	98.142.106.40	US
49	http://rediff.com	204.2.177.43	US
50	http://mediafire.com	38.114.196.10	US

Rank	Site	Primary IP	Country
51	http://gulf-daily-news.com	64.226.254.35	US
52	http://jeddahbikers.com	67.225.167.166	US
53	http://shiaoice.com	87.96.162.44	SE
54	http://photobucket.com	209.17.70.11	US
55	http://doubleclick.com	216.73.93.8	US
56	http://jsoftj.com	208.43.78.207	US
57	http://imageshack.us	208.94.2.98	US
58	http://google.co.in	74.125.127.104	US
59	http://zshare.net	216.155.135.202	US
60	http://bing.com	64.4.8.147	US
61	http://jeeran.com	70.98.189.92	US
62	http://bahrainevents.com	174.133.64.106	US
63	http://alwaqt.com	209.51.158.162	US
64	http://m5zn.com	67.220.200.226	US
65	http://classesinternational.com	67.217.100.249	US
66	http://6rbtop.com	72.55.191.190	CA
67	http://arabseyes.com	72.46.153.146	US
<b>68</b>	<b>http://anonymous.com.bh</b>	<b>193.188.112.44</b>	<b>BH</b>
69	http://amazon.com	72.21.207.65	US
70	http://netlog.com	194.60.206.60	BE
71	http://z5x.net	212.187.241.144	GB
72	http://bbc.co.uk	212.58.224.138	GB
73	http://vmn.net	69.50.138.195	US
74	http://myegy.com	92.241.168.97	RU
75	http://bitfight.org	87.106.180.118	DE
<b>76</b>	<b>http://fsupport.gov.bh</b>	<b>89.31.192.194</b>	<b>BH</b>
77	http://paypopup.com	66.48.78.201	CA
78	http://xtendmedia.com	216.39.57.106	US
79	http://bahrain2day.com	208.64.28.98	US
80	http://kaznova.com	75.126.128.130	US
81	http://hihi2.com	208.96.49.204	US
82	http://goal.com	98.129.138.249	US
83	http://hodood.com	72.52.250.71	US
84	http://lakii.com	174.132.118.28	US
85	http://onemanga.com	74.86.48.18	US
86	http://adsbychannel.com	97.74.26.1	US
87	http://adobe.com	192.150.18.117	US
88	http://umm.biz	66.96.248.165	US
89	http://ebay.com	66.135.205.13	US
90	http://maktoobblog.com	70.84.164.202	US
91	http://bo7.net	208.43.247.190	US
92	http://megaupload.com	69.5.88.231	US
93	http://startimes2.com	64.151.87.249	US
94	http://alamuae.com	64.38.59.221	US
95	http://mbc.net	32.107.37.84	SK
96	http://zain.com	72.32.84.240	US
97	http://mininova.org	87.233.147.140	NL
98	http://b4bh.com	174.37.120.248	US
99	http://google.ae	216.239.59.104	US
100	http://google.co.uk	209.85.229.104	US

Source: Alexa (<http://alexa.com/topsites/countries/BH>)

## **9. Many providers appear to be capacity-constrained in the last mile of connectivity.**

Active measurements of packet latency to all of the BIX customers indicated that providers who are not in the same building as the BIX experience significantly higher worst-case latencies for received traffic. This may be the result of congestion and packet loss (due to capacity constraints) in the last mile of leased connectivity between their facilities and the BIX, under peak load conditions. Such constraints would be consistent with the observed lack of alternatives for fixed infrastructure provision within the Kingdom.

## **10. Facility carrier neutrality would increase long-term international transit diversity.**

In future projects to bring connectivity ashore, whether that takes the form of new ducts across the Causeway, new submarine cable landings, or new fiber along the forthcoming Qatar-Bahrain Friendship Bridge, it would be interesting to consider what effect a truly neutral carrier platform would have on the evolution of Bahrain's Internet Ecosystem.

At today's BIX, participants purchase bandwidth directly from the Exchange, at a fixed price, not from the carriers themselves. In a carrier-neutral facility, participants would purchase bandwidth from the carriers, who would establish physical presences in the Exchange and compete to provide service there to operators directly. The Exchange would be responsible for providing space, power, and ports, but not international transit. As multiple international carriers<sup>5</sup> establish a presence at a carrier-neutral Internet exchange, the transit prices paid by operators will tend to be kept low through open competition.

Having such a common Internet exchange point, and subsidizing the interconnection of all domestic providers there, would avoid the necessity of using an international carrier's routers (domestic traffic leaving the country and returning again) to achieve end-to-end connectivity within the Kingdom.

Such a facility could potentially reduce barriers to switching among competing domestic providers, add to the number of international carriers who are available to carry Bahrain's traffic, increase the number of practical transit alternatives for banks and other "critical infrastructure" enterprises, and reduce the cost of Internet access throughout the Kingdom, while greatly increasing the diversity and stability of the Internet ecosystem.

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<sup>5</sup> Emirates, for example, maintains transit relationships with over a dozen carriers; see the transit diversity graphic on page 30.

## Detailed Study

The Renesys historical routing dataset was used to create an objective assessment of the key participants in the Bahrain Internet ecosystem, their relative roles in providing transit to Bahrain's enterprises and citizens, and the dynamics of their interconnections with international providers.

## Methodology<sup>6</sup>

Renesys collects real-time information about the current best routes to every network on earth (over 280,000 globally visible networks at present) from a geographically diverse set of over 300 peer border routers. An average of tens of thousands of route update messages each minute, over seven continuous years of recorded routing history (at 1-second resolution), form a quantitative basis for the objective analysis of Internet connectivity and routing dynamics.



At each moment in history, the Renesys dataset contains a complete set of “best routes” from hundreds of global peers to each of the networks on earth, including routes to approximately 200 globally routed network prefixes located in Bahrain.

<sup>6</sup> For definitions of technical terms used in this section, please consult Appendix A, “Routing Terminology.”

Each route describes an *autonomous system path (ASPATH)* that represents the best known route into the network prefix, in terms of a sequence of network service providers who, through peering and/or transit arrangements, have agreed to carry traffic bound for the given network.

[01:05:08 UTC 25 Jun 2009] 79.171.240.0/24 :: {elided} 7473 8966 35019 39273 30882

*(example of single Renesys ASPATH record)*

For example, this record from the dataset reflects the fact that, in the early morning of June 25<sup>th</sup>, one of the Renesys peers (a customer of Singapore Telecom) believed that the best way to send traffic to Bahrain's Benefit Company BSC was through a chain of providers from Singtel (AS7473), to Emirates Telecom (AS8966), to the Bahrain Internet Exchange (AS35019), to Lightspeed Telecom (AS39273), and finally on to Benefit Company (AS30882), in that order.

From a dataset containing millions of these records, Renesys identifies all the providers who have transit responsibilities for Bahrain's networks, ranks their importance, and catalogs their interconnections with peers, providers, and customers. Particular intervals in time that reflect significant route change events (e.g., damage to the critical physical infrastructure that allows these providers to carry Bahrain's traffic) are examined in order to learn more about how each provider's network reacts, and how their customers fare, under such conditions.

From the patterns of interconnection and change that reflected in the historical global routing dataset, it is possible to infer and validate significant conclusions about the evolving economic relationships of providers and Internet-connected enterprises over time, and thereby identify potential obstacles that might affect the development and stable operation of Bahrain's Internet Ecosystem.

## Organization

The sections that follow provide supporting historical and technical detail for the study's conclusions.

The first section documents the structure of Bahrain's Internet Ecosystem: the detailed network origination, current transit relationships, and historical connectivity of the Kingdom's service providers and enterprises. Internet transit arrangements for Batelco and the Bahrain Internet Exchange (BIX) are specifically emphasized, in order to paint an accurate picture of the critical international transit links upon which the Bahraini economy is vitally dependent.



The next section revisits the Internet routing dynamics surrounding two key events: the June disruption of Internet traffic across the King Fahd Causeway to Saudi Arabia, and the February FOG outage. The connectivity dynamics of these events can be understood in the context of the longer-term historical record of route stability for Bahraini prefixes, and the stability of Bahrain's Internet Ecosystem relative to those of other countries in the region.

Appendix A contains some definitions of technical terms used in this report.

Appendix B summarizes the Renesys Market Intelligence rankings for all of the autonomous systems in Bahrain.

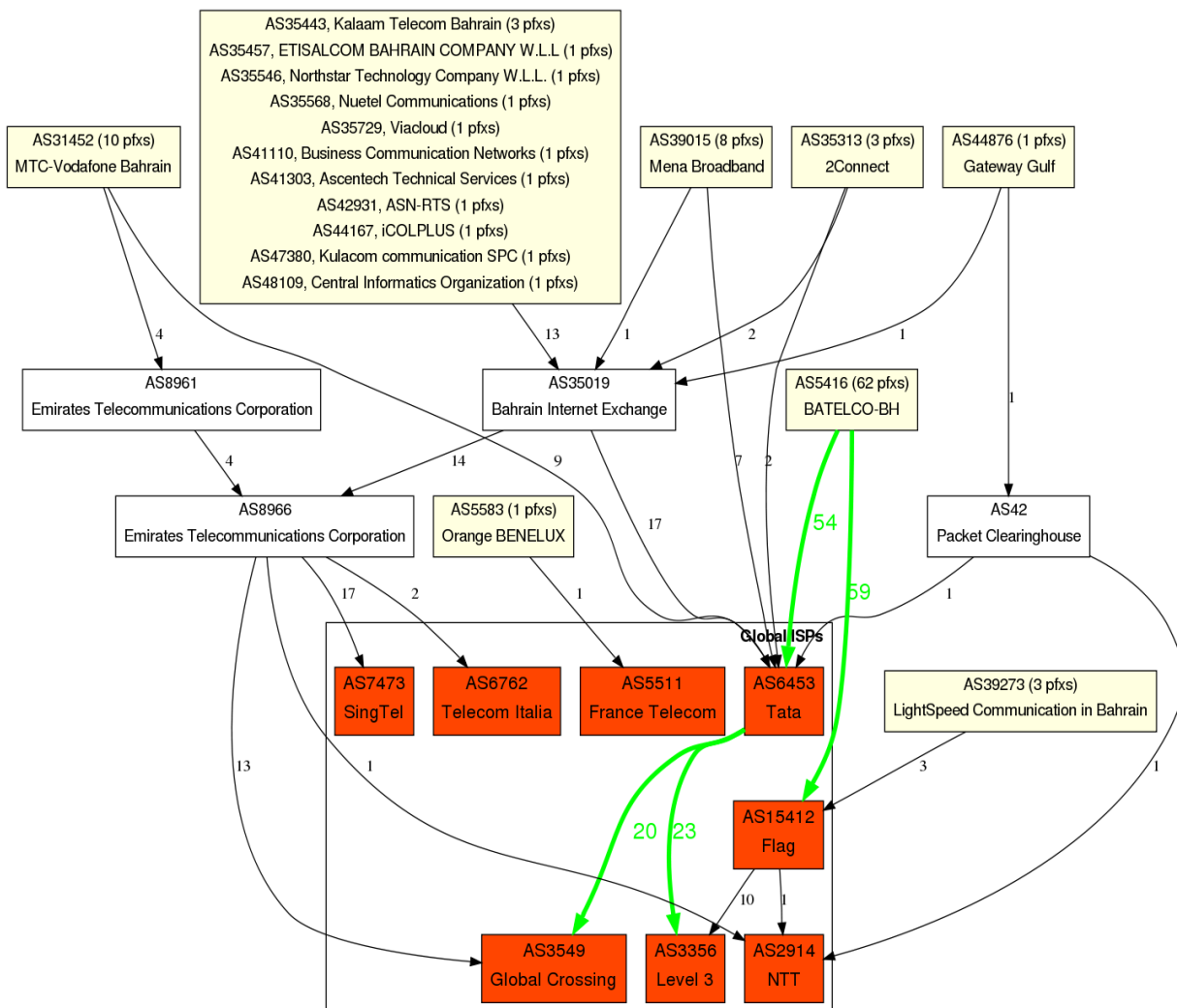
## Bahrain's Internet Service Providers

The following graphic illustrates the transit relationships that support Bahrain's Internet connectivity, as of August 2009.

“Stub” autonomous systems, which have no autonomous system customers, are colored yellow; transit autonomous systems are colored white, and international carriers are colored red.

An arrow from provider A to provider B indicates that A purchases Internet transit from B, and the number next to the arrow indicates the number of network prefixes (blocks of IP addresses) that are “transited” via that provider. Observed domestic peering relationships would be represented by lateral arrows; however, no domestic peering between operators was observed.

Paths that typically carry more than 20 network prefixes are highlighted in green. These include Batelco's international connectivity to Flag and Tata, and Tata's transit of Bahraini prefixes via Level3 and Global Crossing.



Renesis Corp. 2009 (c)

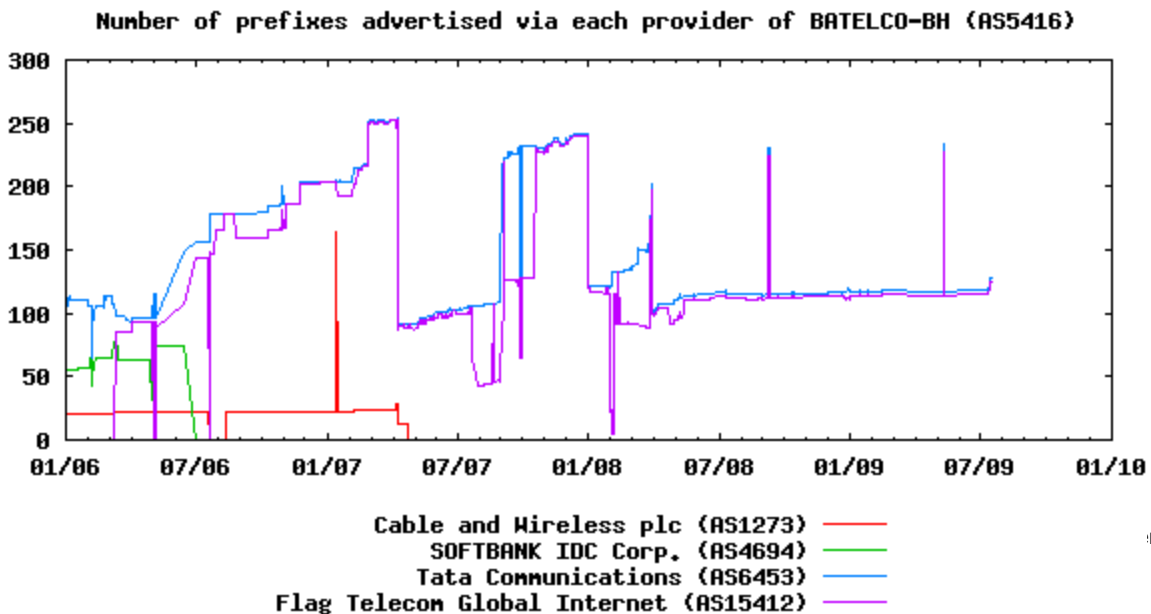
## Bahrain Telecommunication Company (Batelco, AS5416)

Batelco is the national incumbent, and maintains a dominant position in each of the domestic telecommunications markets in which it participates, with the significant exception of multihomed Internet transit. Launched by the government as a Joint Stock Company in 1981, Batelco has weathered the loss of its monopoly in mobile communications to MTC Vodafone (2003), in fixed-line communications to Lightspeed Communications and Kalaam Telecom (2005), and in Internet service provision to the Bahrain Internet Exchange (2005).

Batelco's Internet transit timeline:

- **Jan 2001:** Already buying from Teleglobe (Tata, AS8297 and AS6453) and Savvis (AS3561) when Renesys historical routing data coverage begins.
- **Aug 2002:** Turn down AS8297 as Teleglobe retired the ASN
- **Oct 2003:** Briefly add transit to FLAG (AS15412) before dropping them again in December 2003
- **Jan 2004:** Add transit via Softbank IDC (AS4694; aka Japan Telecom IDC, aka Cable and Wireless IDC) as a heavily prepended (7x) backup route.
- **Feb 2004:** Add Cable and Wireless (AS1273).
- **Jun 2004:** Drop Savvis (AS3561).
- **Mar 2006:** Add transit via FLAG (AS15412).
- **Jul 2006:** Drop Softbank IDC (AS4694).
- **May 2007:** Drop Cable and Wireless (AS1273).
- **Jul 2009:** Continuing transit relationships via Tata (AS6453) and FLAG (AS15412).

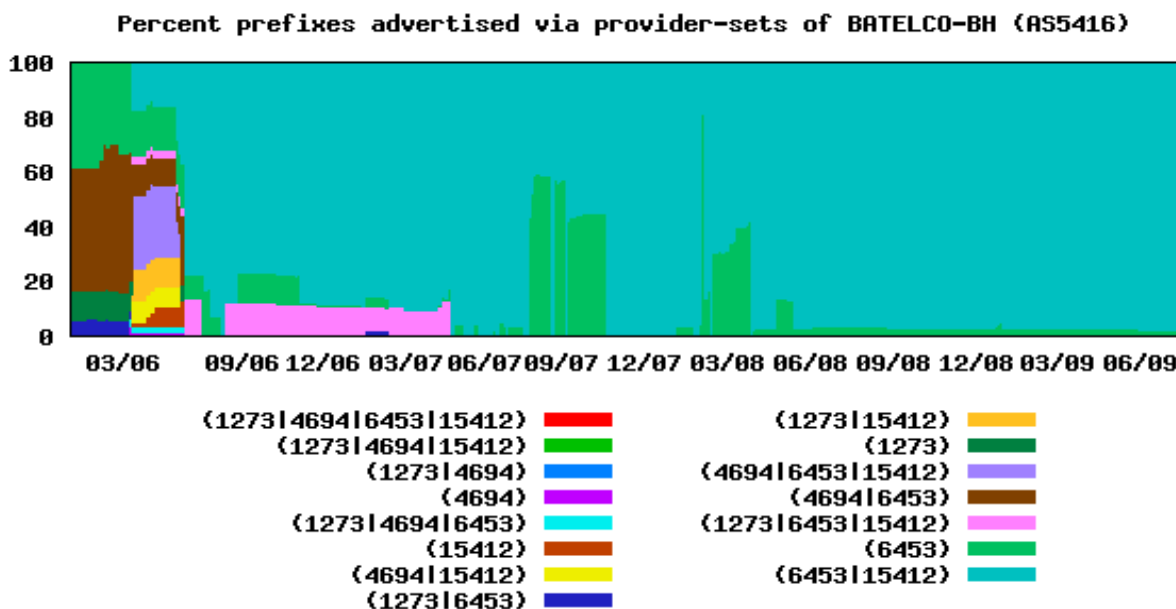
Batelco originated 119 prefixes in the global routing table as of 1 July 2009. Of these, eight were large blocks of /18 and /19, and the remaining 111 were more-specific deaggregates of these blocks ranging in size from /21 to /24. Over the last 18 months, Batelco has consistently advertised almost all of its prefixes to both Flag and Tata symmetrically, with only a few prefixes seen through Tata alone.



B:

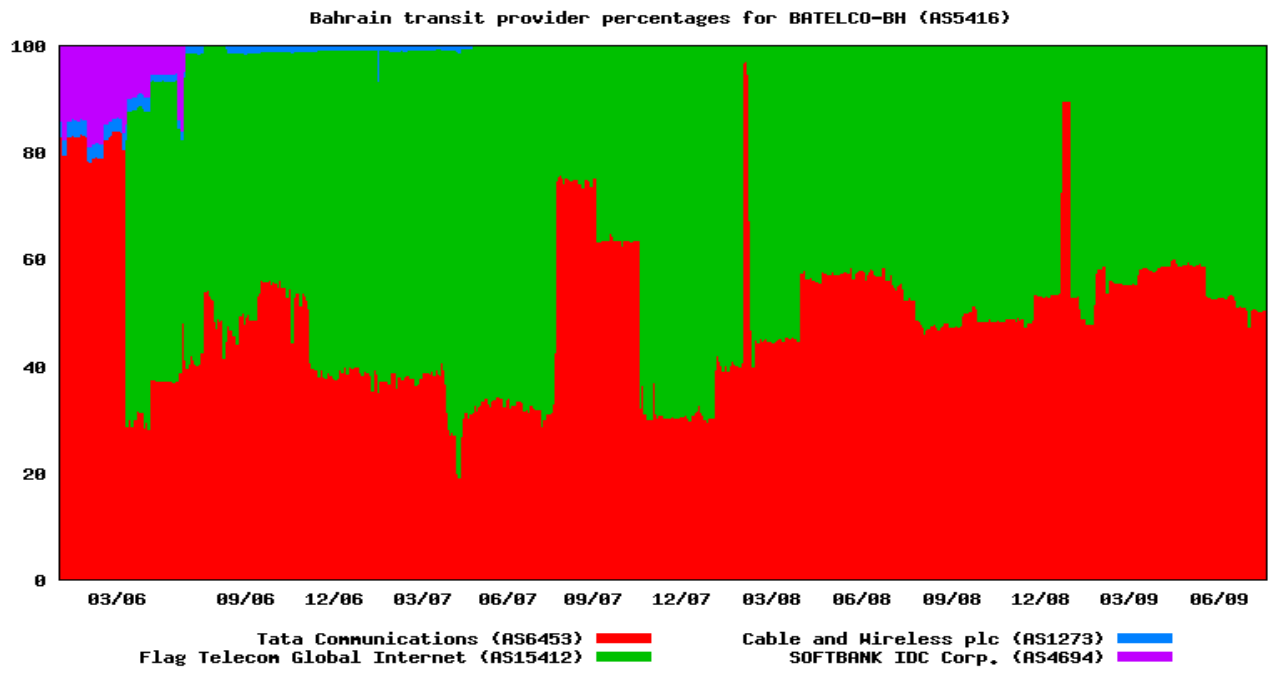
nesys 2009

The number of prefixes announced to both providers took a sharp drop in April 2007, with a smaller drop about a year later, both due to reaggregation of covered /24 more-specific prefixes by Batelco (no net loss of connectivity).



Batelco's advertisements have not always been entirely symmetric between the two providers, however. This plot shows the percentage of Batelco's customer prefixes that appear to have been advertised to different sets of providers – e.g., Flag alone (15412), or Flag and Tata together (15412|6453), Tata alone (6453), etc. In 2007-2008 one can see periods in which 40% to 50% of advertised prefixes were sent to Tata alone (darker green regions above), instead of to both Flag and Tata (lighter teal-colored regions).

Another way to look at Batelco's transit arrangements is by considering the evolution over time of the percentage of Renesys peers that prefer one provider over the other for Batelco's prefix set. The percentage of Renesys peers preferring a Tata route (here, in red) over a Flag route (here, in green) has been fairly stable over time, at a level approaching 50% in 2009 and no evidence of significant, sustained traffic engineering to steer route preference one way or the other.



Since August 2008, with the exception of the December 2008 period, Batelco has clearly attempted to maintain a more even balance between its two providers, with peer selection closely approaching a 50-50 split.

## Bahrain Internet Exchange (BIX, AS35019)

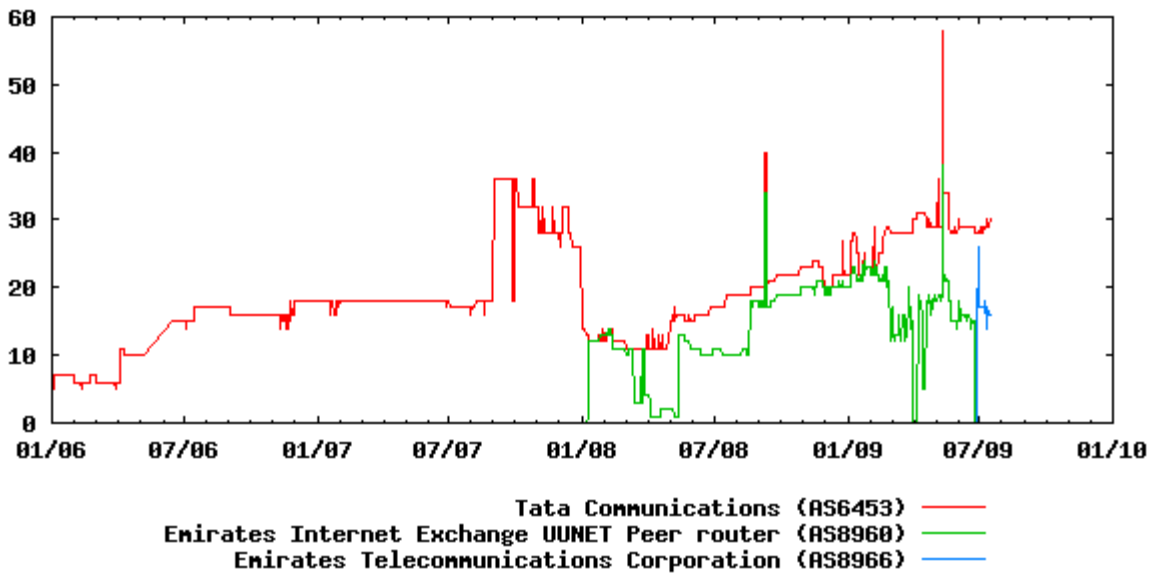
The BIX grew rapidly in its first two years of operation, but growth has since moderated, as shown by the following timeline. Dates of new customer activation represent the first appearance of the customer downstream of the BIX in the global routing table.

BIX Internet transit timeline:

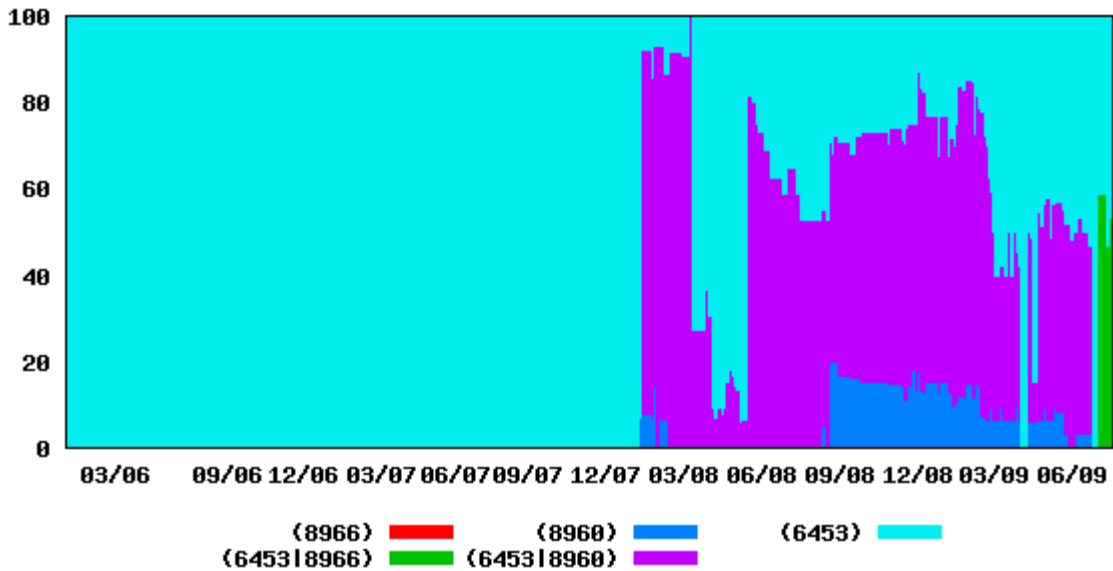
- **Mar 2004:** Internet exchange license granted by TRA.
- **Jun 2005:** BIX comes online, single-homed to Tata (AS6453).
- **Jul 2005:** Kalaam Telecom (AS35443) and 2Connect (AS35313) join. (2Connect will also buy a limited amount of backup transit direct to Tata; see below.)
- **Sep 2005:** Etisalcom Bahrain (AS35457) and Northstar (AS35546) join.
- **Dec 2005:** Viacloud (AS35729) and Mena Broadband (AS39015) join. (Mena will also get transit to Tata; see below.)
- **Jan 2006:** Lightspeed Telecom (AS39273) joins.
- **Feb 2006:** Nuetel(Amwaj, AS35568) joins. Nuetel also gets occasional satellite transit from IABG Teleport (AS29259) from April 2006 through November 2006.
- **Jul 2006:** Ascentech (AS41303) joins.
- **Sep 2006:** BCN (AS41110) joins.
- **Jul 2007:** RTS (AS42931) joins.
- **Dec 2007:** *BIX adds second transit to the EMIX (AS8960).* 2Connect stops using the BIX for transit.
- **May 2008:** Kulacom (AS47380) and iCOLPLUS (AS44167) join. MTC-Vodafone (Zain) also stops using the BIX for transit.
- **Jul 2008:** 2Connect resumes using the BIX for transit.
- **Oct 2008:** Bahrain Central Informatics (AS48109) joins.
- **May 2009:** *BIX adds additional transit from Emirates (AS8966).*
- **June 2009:** *BIX drops first EMIX transit (AS8960).*
- **August 2009:** Lightspeed Telecom (AS39273) stops transiting the BIX, and Gateway Gulf (AS44876) joins.

Except as noted, all of the BIX members use the BIX as their exclusive source of Internet transit. In this sense, the BIX functions less as an Internet exchange and more as a direct competitor to Batelco for Internet transit aggregation.

Prefixes advertised via each provider of Bahrain Internet Exchange (AS35019)

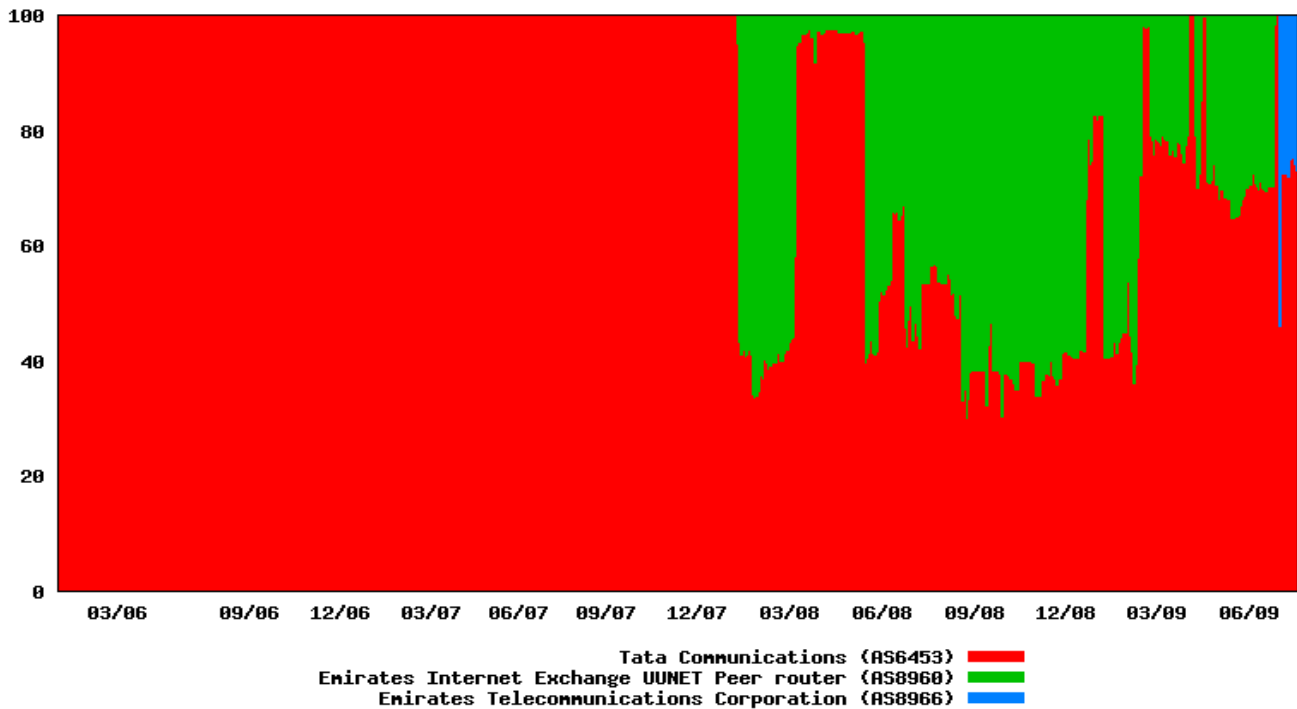


Percent prefixes advertised via provider-sets of BIX (AS35019)



The BIX continues to grow the number of prefixes it announces to Tata, and to a lesser extent, to Emirates Telecom. In 2009, a significant percentage of BIX prefixes (about half) were only visible through Tata (light blue, above); the other half were truly multihomed to Tata and Emirates (purple and green, above). As a result, Tata carries about 75% of the BIX's routes in 2009 (up from 40% in 2008), as shown in the following plot of observed provider preference.

Bahrain transit provider percentages for Bahrain Internet Exchange (AS35019)



## MTC-Vodafone Bahrain (Zain, AS31452)

When MTC arrived in Bahrain in 2003, Batelco was the only choice for Internet transit. For obvious reasons, MTC seems to have chosen to go to some lengths to find alternative sources of transit, including satellite Internet and (in 2006) a connection to the BIX.

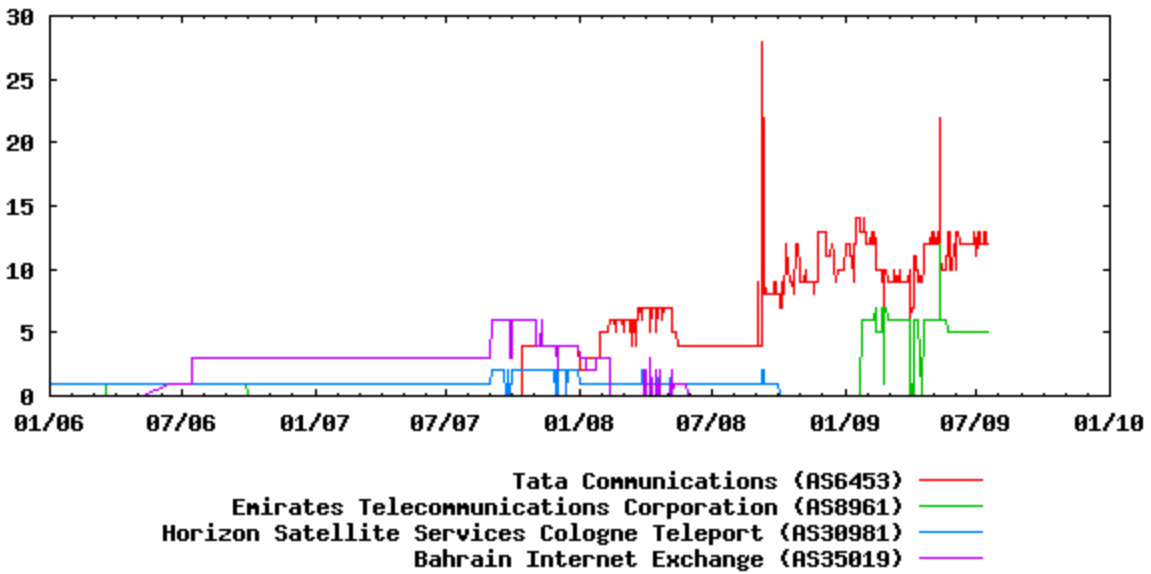
Zain's Internet transit timeline:

- **Aug 2003:** MTC-Vodafone licensed to provide Internet services.
- **Jun 2004:** MTC (AS31452) joins the Internet with satellite transit via Transfer, Ltd (aka Horizon Satellite Services, AS30729).
- **Dec 2004:** Add second, terrestrial transit connection to Emirates (AS8961).
- **Mar 2005:** Add third transit connection via Horizon Satellite Services (AS30981), drop Transfer, Ltd
- **May 2006:** Join the BIX (AS35019) and begin transiting some traffic through them.
- **Oct 2006:** Drop Emirates (AS8961) as a transit provider.
- **Sep 2007:** Add Tata (AS6453) as a transit provider.
- **May 2008:** Stop transiting the BIX entirely, relying on Tata and Horizon for all connectivity.
- **Sep 2008:** Turn off Horizon Satellite Services. Start advertising 62.209.16.0/20 (WiMax) on 8 September.
- **Jan 2009:** Restore transit via Emirates (AS8961).

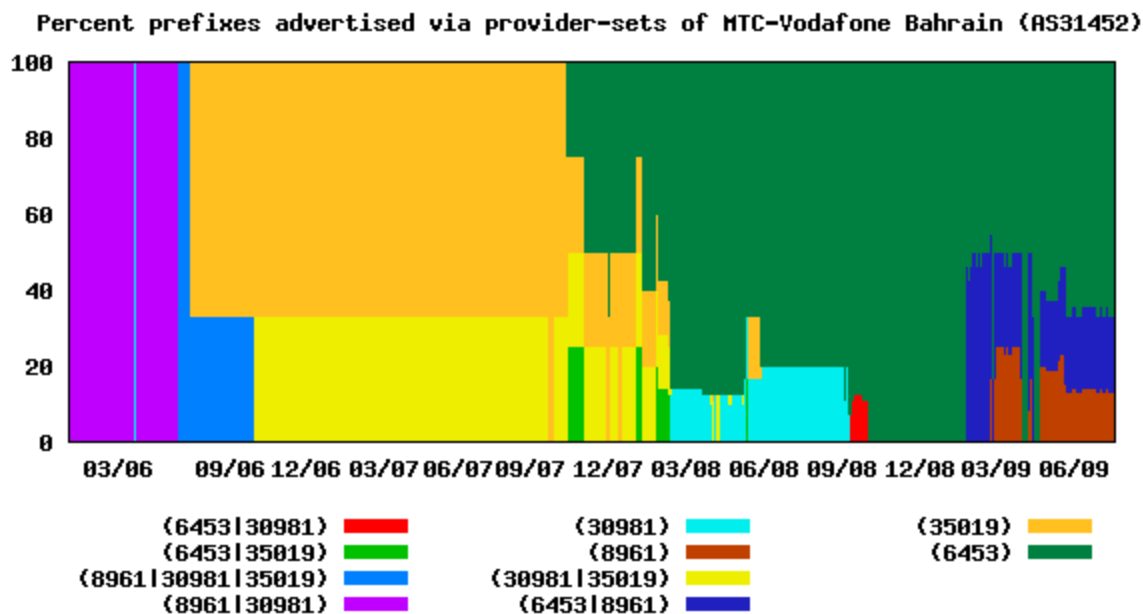


Today, Zain originates 15 network prefixes, making them the second largest domestic provider after Batelco in terms of address space, the fastest growing provider in the Kingdom, and one of only two providers, other than Batelco, who do not have transit from the BIX (the other is Lightspeed).

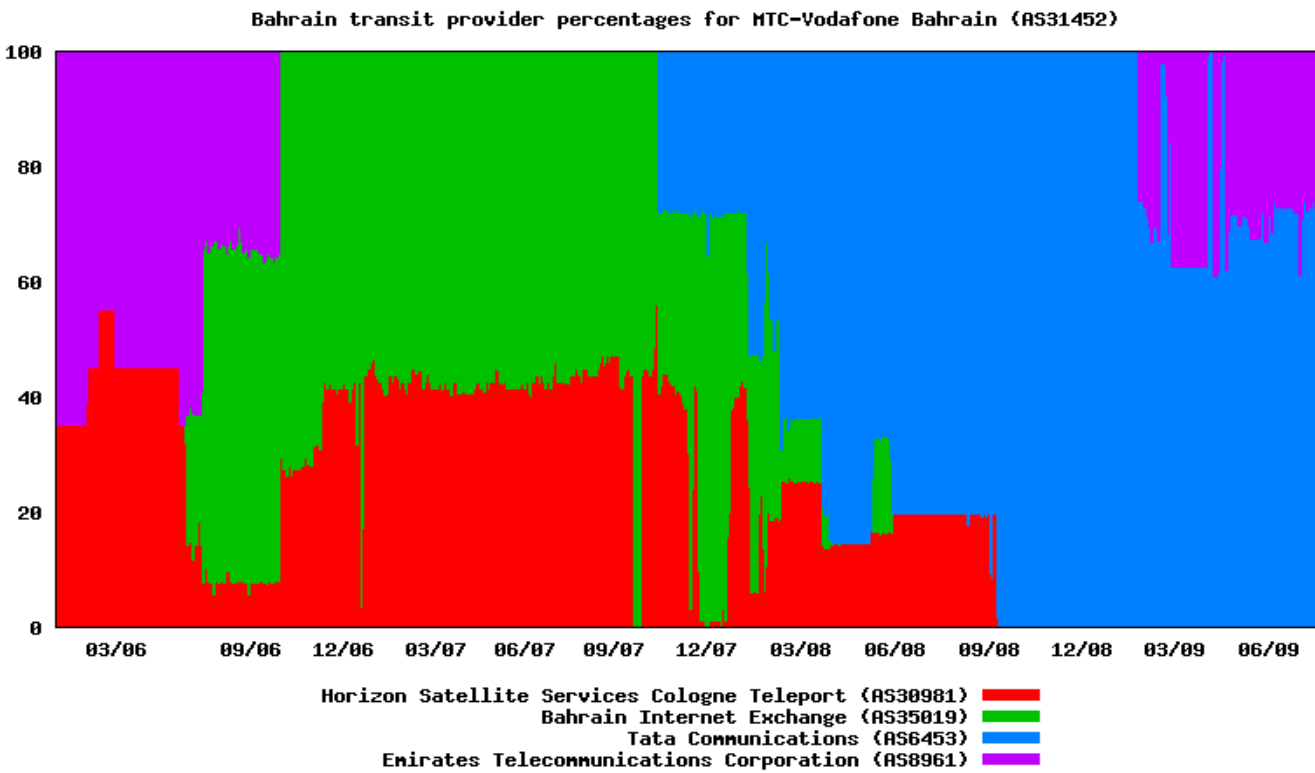
**Number of prefixes advertised via each provider of MTC-Vodafone Bahrain (AS31452)**



Zain relies more heavily on Tata than on Emirates, and announces roughly two thirds of their prefixes through Tata alone (dark green in the following plot), with the balance advertised to both providers (dark blue) or to Emirates alone (dark red).



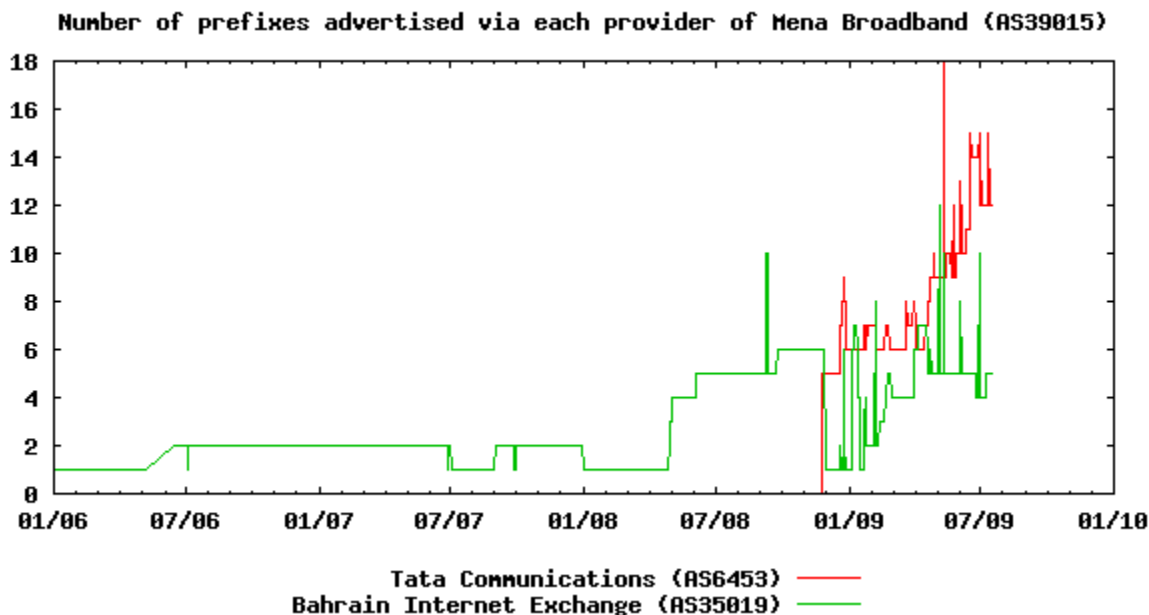
This results in an observed provider preference distribution across the Renesys peerset that heavily favors Tata over Emirates, as shown in the following plot. Nonetheless, some transit diversity is better than none, which was the case from September 2008 through January 2009.



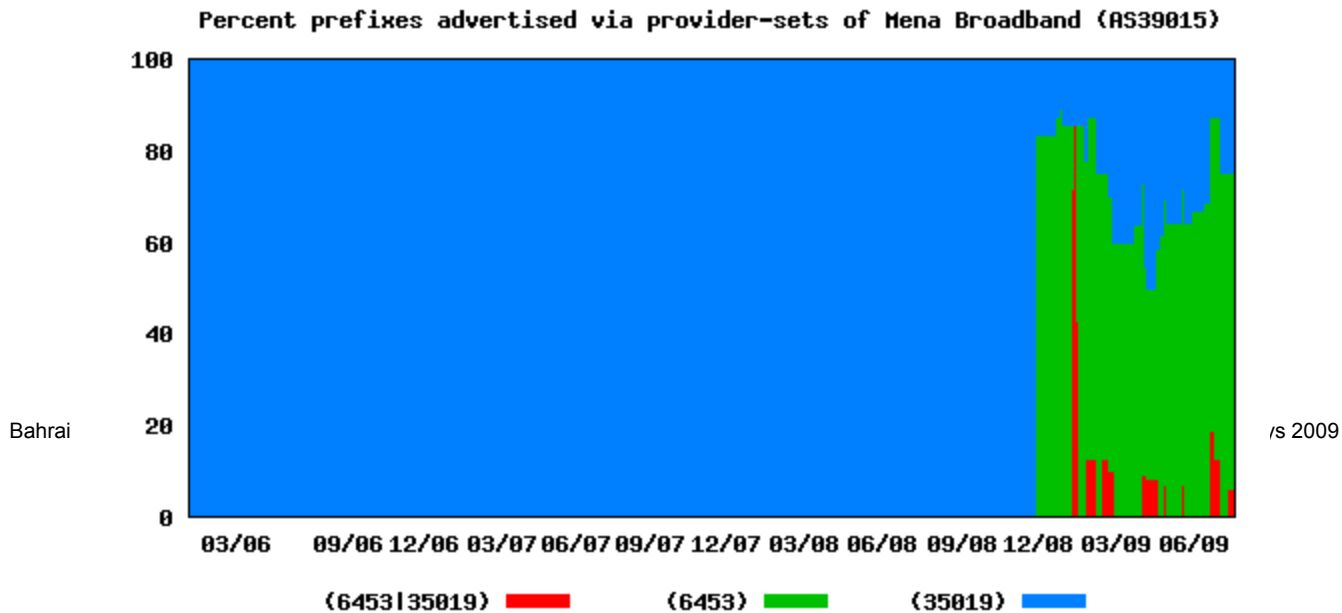
## Mena Broadband (AS39015)

Mena's Internet transit timeline:

- **Nov 2004:** Mena licensed to provide Internet services.
- **Dec 2005:** Join the BIX (AS35019).
- **Nov 2008:** Add second transit connection to Tata (AS6453).



Today, Mena uses an interesting disjoint advertisement policy. About 80% of Mena's prefixes are advertised only through Tata, with nearly all of the remaining 20% advertised through the BIX, and only a few stragglers are seen via both.



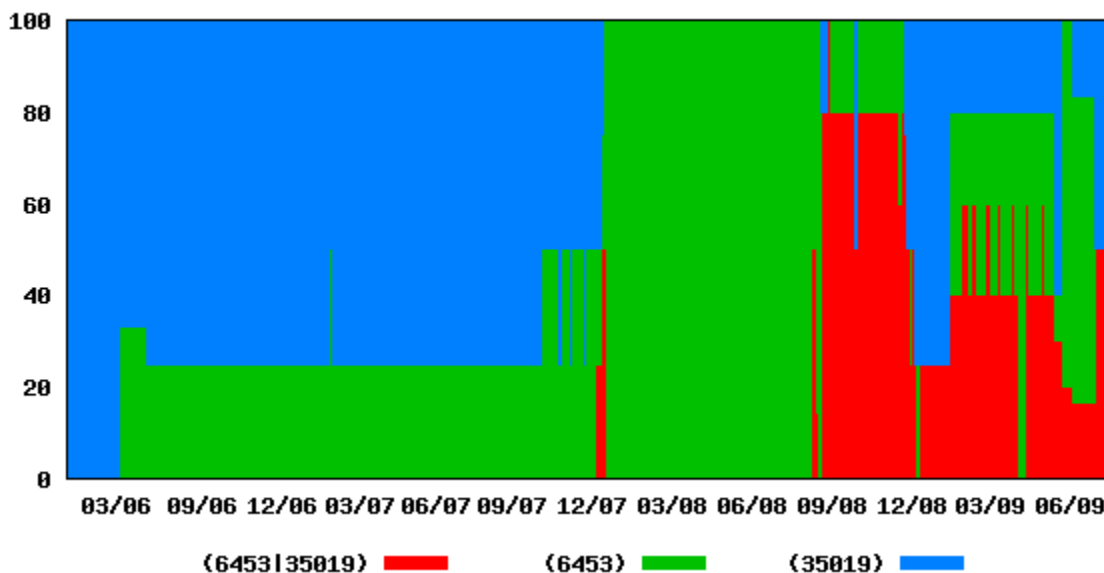
## 2Connect (AS35313)

2Connect's Internet transit timeline:

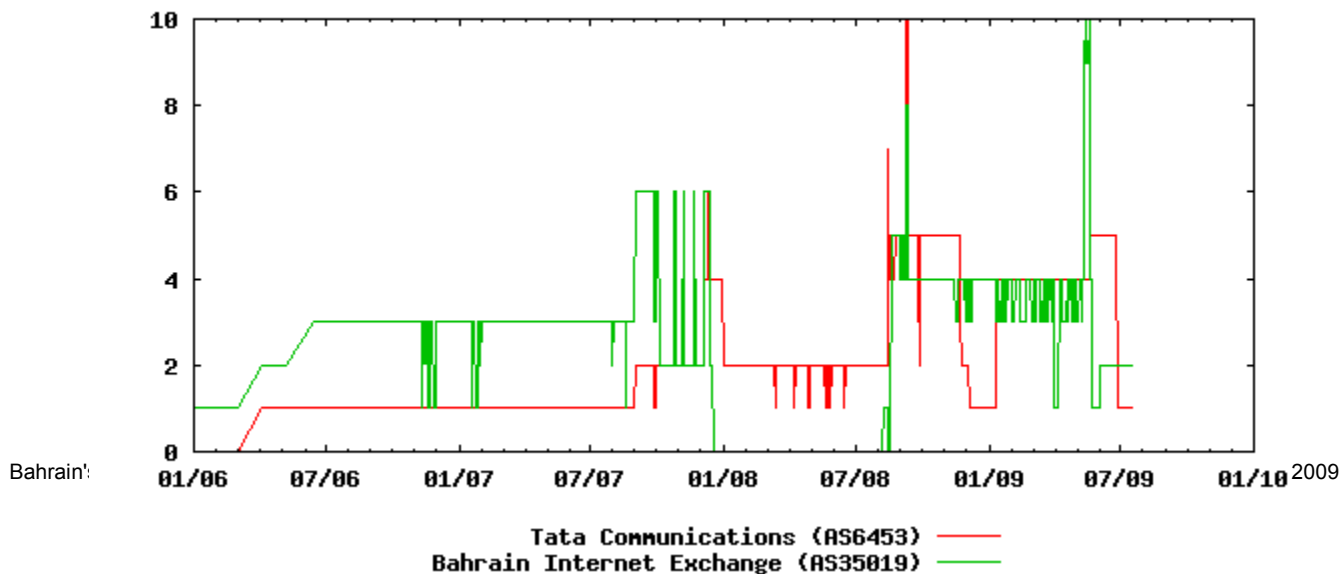
- **Sep 2004:** Licensed to provide Internet services.
- **Jul 2005:** Joined the BIX (AS35019).
- **Feb 2006:** Added a limited amount of direct transit to Tata (AS6453).
- **Dec 2007:** Dropped BIX transit, but still present at the BIX.
- **Jul 2008:** Restored BIX transit.

The reasons for 2Connect's service interruption at the BIX are unclear. For six months in 2008, they appear to have relied on their direct connection to Tata for all Internet transit for their advertised prefixes, as seen in the following two plots.

Percent prefixes advertised via provider-sets of 2Connect (AS35313)



Number of prefixes advertised via each provider of 2Connect (AS35313)



## Lightspeed Communications (AS39273)

France Telecom (via Jordan Telecom Group) elected to take a significant stake in this provider in 2007. Lightspeed is unique among Bahraini autonomous systems, in that it had (until August 2009) two autonomous system customers of its own, yet received all of its transit from the BIX.

Lightspeed's Internet transit timeline:

- **Jan 2006:** Lightspeed comes online at the BIX.
- **Mar 2009:** Start providing transit to The Benefit Company (AS30882)
- **Aug 2009:** Leave the BIX, start buying transit from FLAG alone, and start originating The Benefit Company's address space directly.

Single-homed transit (having a single provider) can be perilous, as it leaves you no alternatives when that provider has a problem. Lightspeed suffered significant instability during the Causeway outage event of June 2009 due to its sole reliance on the BIX, and this may have played some part in their decision to move to FLAG over the next several weeks.

Between 13 July and 15 July 2009, there was transient evidence for Lightspeed connectivity being warmed up via Flag (AS15412), and on 1 August, Lightspeed turned up a more permanent transit connection. They then ceased their advertisement of routes via the BIX, becoming single-homed to FLAG.

Lightspeed had historically transited a single prefix, 57.88.32.0/20, belonging to SITA, on behalf of Orange (AS5583), who used France Telecom (AS5511) as a second upstream. This transit arrangement changed on the day Lightspeed left the BIX, with Lightspeed starting to originate the prefix directly. This has created a strange "multiple origin" situation for the prefix, which appears to originate in both Lightspeed (with Flag transit) and in Orange (with France Telecom transit). Traceroutes into the prefix from outside France Telecom's customer base confirm continued Bahrain transit, but customers of France Telecom are probably unable to reach this network.

The Benefit Company (AS30882) has also received transit from Lightspeed since March 2009, having previously been a VSAT customer of Callsat Telecom (AS24672) since December 2003. When Lightspeed left the BIX on 1 August 2009, the Benefit Company stopped using their ASN, and Lightspeed simply began originating their prefix (79.171.240.0/24) directly. This leaves the Benefit Company unable to purchase Internet transit from a second provider, however, should they decide to become multihomed in the future.

It is unclear whether Lightspeed's overall stability has increased or decreased since the move. Their transit diversity has actually *decreased*, since they are now reliant on a single

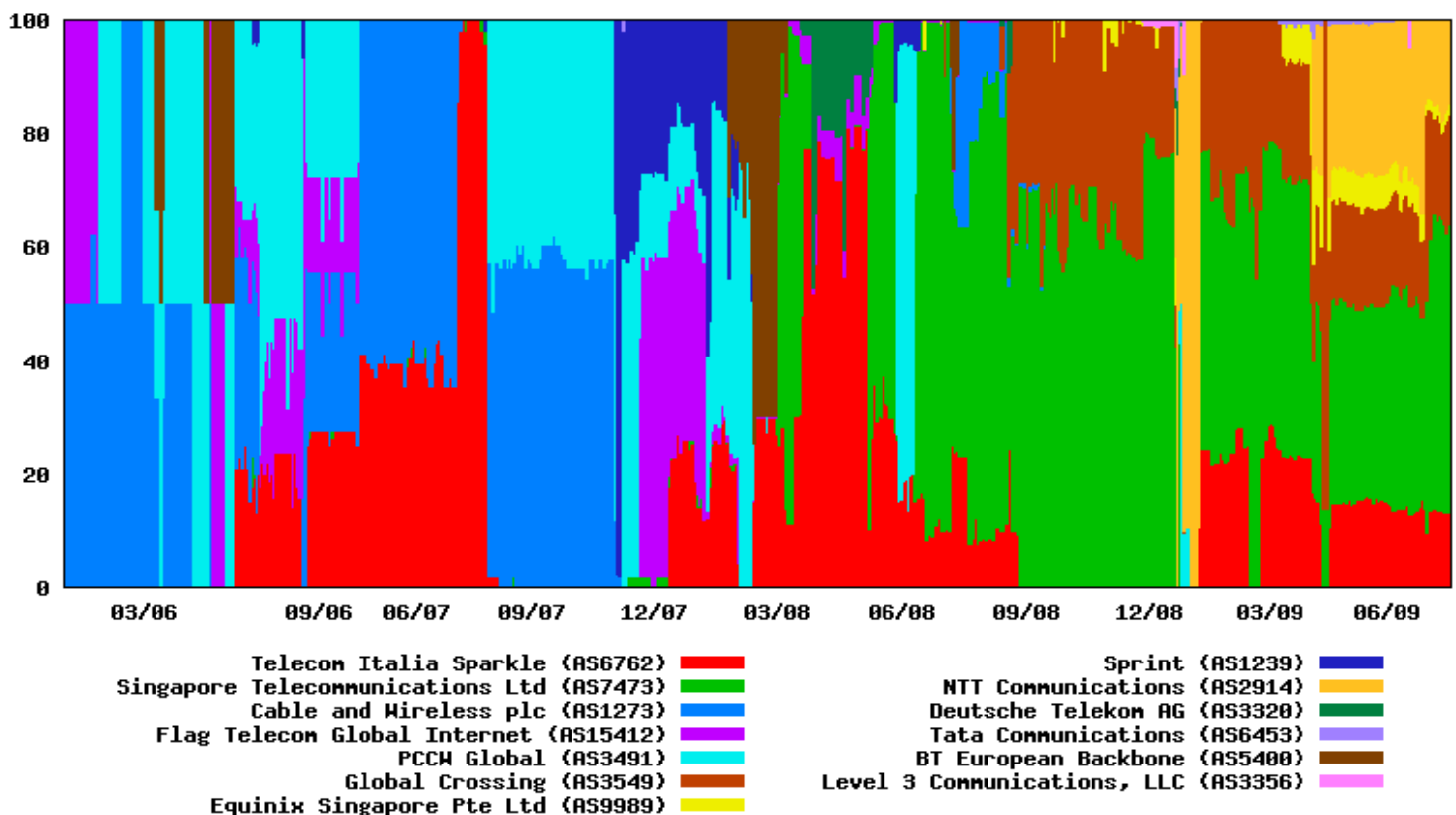
path to Flag, whereas their BIX transit at least had limited physical diversity west to Tata over the Causeway, and south to Emirates over the FOG. It would make sense for Lightspeed to acquire a second connection (probably to Tata for maximum east-west diversity, replicating Batelco's transit strategy).

### Emirates Telecom (AS8966)

While not, strictly speaking, a Bahrain service provider, Emirates serves a key role in the Bahrain Internet Ecosystem as the third key international transit provider, after Tata and Flag.

To appreciate the benefits Emirates reaps as the manager of the SMW-3/SMW-4 cable landings, consider the following plot of transit provider percentages for Bahrain prefixes carried by AS8966. A lot of transit diversity is being put to work on Bahrain's behalf.

Bahrain transit provider percentages for Emirates Telecommunications Corporation (AS8966)



## Routing Dynamics Within the Bahrain Internet Ecosystem

When the physical infrastructure supporting the Internet is damaged, it's possible to gain insight into the affected providers' backup transit relationships and outage mitigation strategies.

Although the routing data themselves do not indicate which physical paths are in use, events like these give important clues about which physical paths are used by each service provider to carry network traffic in and out of the country, making it possible to infer which providers are using which physical resources.

This section explores the detailed Internet routing dynamics surrounding two key outage events in 2009: a problem with the Fiber Optic Gulf (FOG) cable in February 2009, and a problem with Internet traffic over the King Fahd Causeway in late June 2009.

Our conclusions can be summarized as follows:

### **Problems on the King Fahd Causeway result in difficulty reaching Tata.**

- The worst impacts of a Causeway cut fall on providers who have no alternative path to Tata over the FOG or Falcon cables, which appears to include Mena, Zain, BIX, and 2Connect; that is, everyone but Batelco.
- Batelco shifts traffic to their FLAG connection, and to what appears to be an alternative Tata connection, over the Falcon cable.
- Everyone else shifts traffic to their Emirates connections (if they have one), which presumably becomes very congested. The BIX, in particular, relies heavily on Tata for the majority of its transit, and becomes capacity-constrained when the Causeway goes out.

### **Problems with the FOG cable result in difficulty reaching Emirates.**

- This represents the complementary outage --- it becomes difficult or impossible for the BIX and Zain to reach Emirates Telecom, and they shift their traffic to Tata over the Causeway.
- Again, Batelco is less impacted, because they continue to access FLAG over the Falcon cable. They do appear to lose their Emirates peering, which may or may not have a significant impact on enduser experience.
- This is by far the most common failure mode for the Bahrain Internet Ecosystem; four separate multiday events have been identified so far in 2009 that could plausibly be described as FOG outages.

The following sections provide a detailed analysis of the route dynamics of each event that

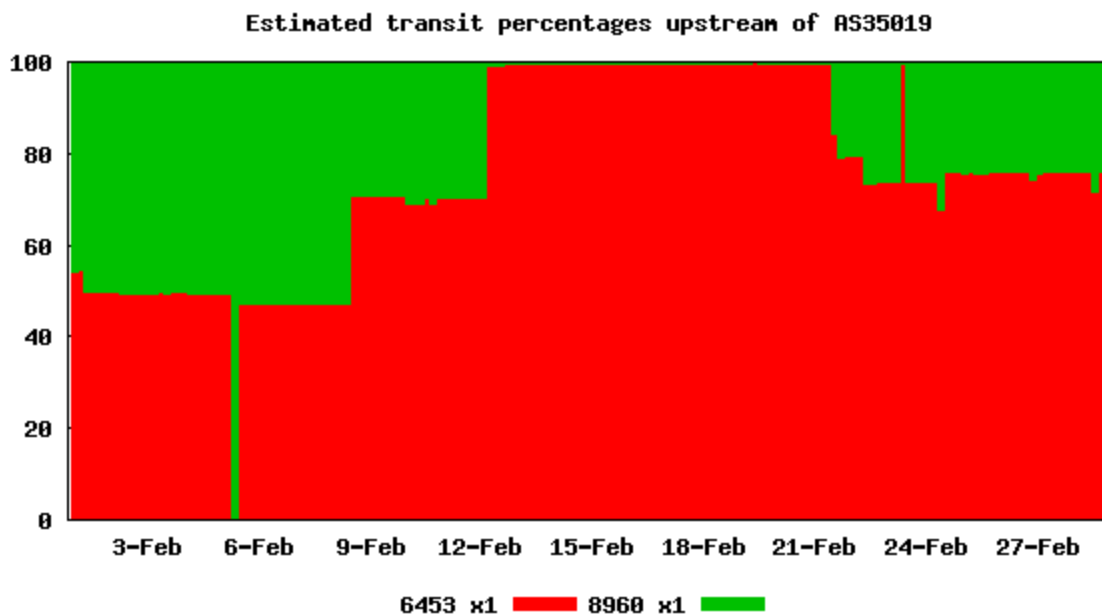
supports these conclusions. The final section examines the longer historical record of route stability in Bahrain, to provide additional context.



## FOG event of 12-25 February 2009

When the Fiber Optic Gulf (FOG) cable suffers an outage, the visible impacts on the global routing table are fairly modest, because of the relatively low number of affected network prefixes and their multihomed transit. However, because the FOG carries something like a third of the BIX's available transit, and a significant fraction of Zain's transit as well, its failures result in significant congestion on the surviving international transit paths.

Compounding these problems, a typical FOG outage appears to last for days, rather than minutes or hours, while repair crews are dispatched to splice the break.

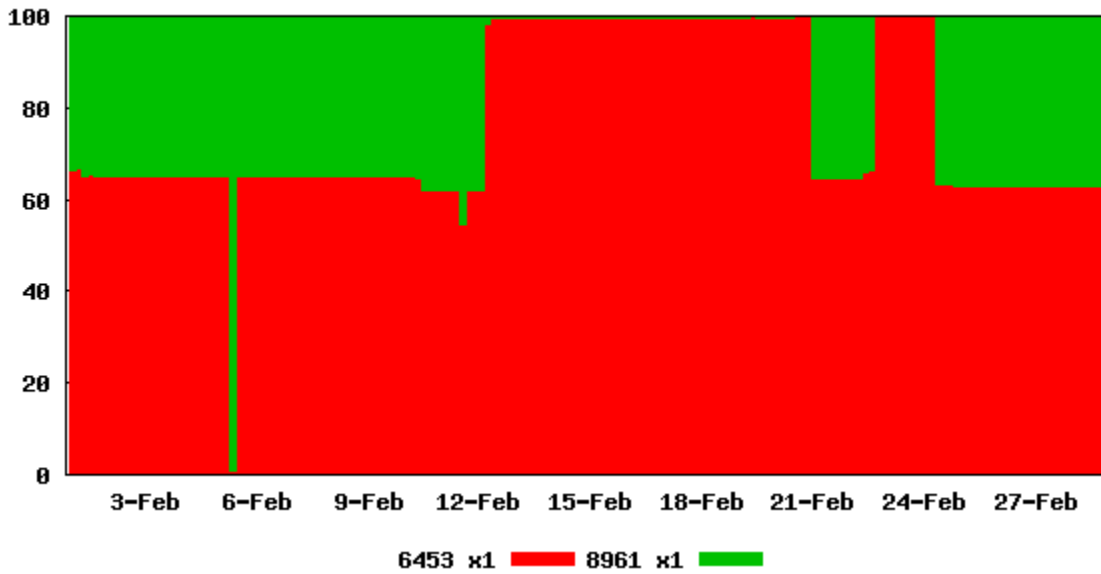


Looking at the timeseries of peer preference for Bahrain autonomous systems during the month of February, one can see the Bahrain Internet Exchange (AS35019) shift away from Emirates (AS8961) to Tata (AS6453) just after midnight on 12 Feb 2009, and stay that way for almost 2 weeks.<sup>7</sup>

Simultaneously, Zain (AS31452) experiences a very similar shift in peer preference from Emirates (AS8960) to Tata (AS6453).

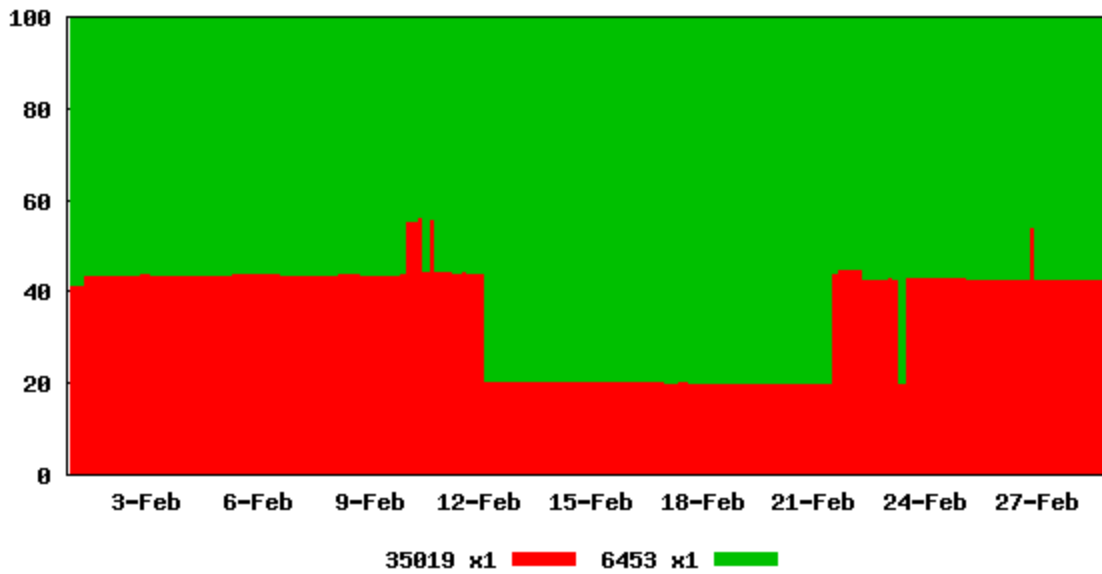
<sup>7</sup> Here, "6453x1" and "8960x1" reflect the fact that the BIX advertises prefixes to Tata and Emirates with itself prepended only once (the normal case; i.e., with ASPaths containing "6453 35019" or "8960 35019"). Longer prepends are also possible, as will be seen in succeeding slides, and indicate an undesirable backup path. An "x10" (ten times prepended path; for example, "15412 5416 5416 5416 5416 5416 5416 5416 5416 5416") would be a very undesirable path, indeed.

Estimated transit percentages upstream of AS31452

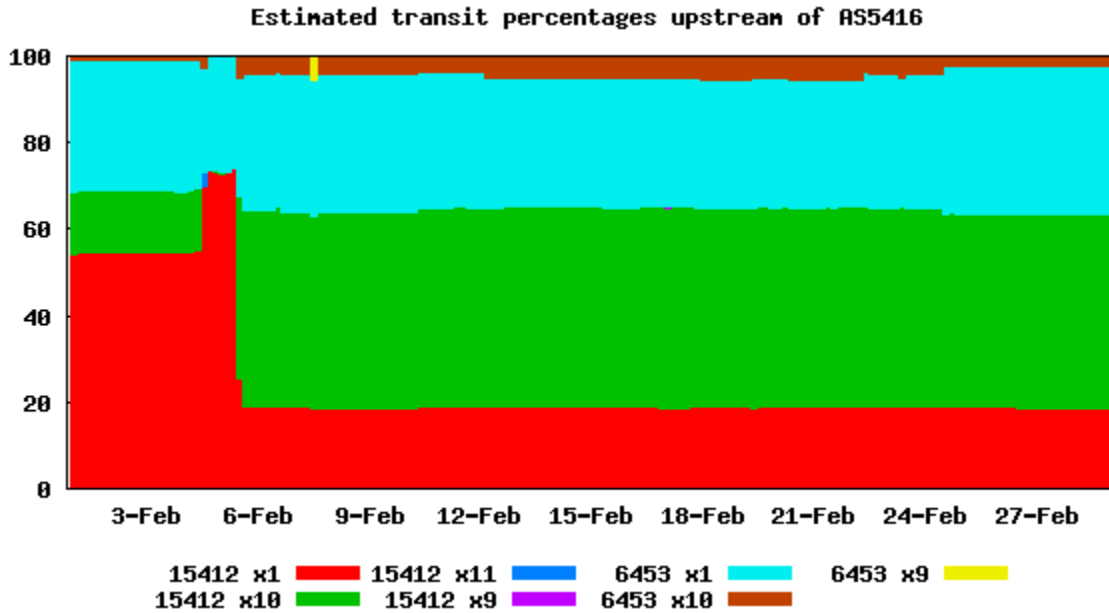


Very shortly after the onset of this event, one can also observe 2Connect's (AS35313) direct connection to Tata being chosen by a larger percentage of the world, compared to its BIX transit, which is presumably suffering significant congestion.

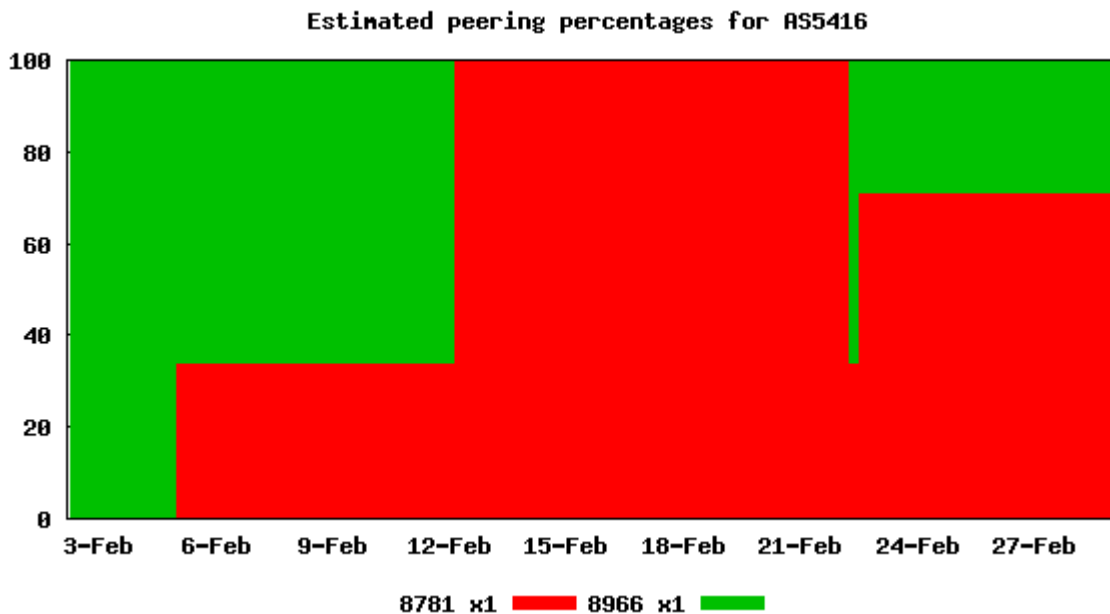
Estimated transit percentages upstream of AS35313



Batelco's transit preferences seem largely unaffected by the event, since they have transit to FLAG on the unaffected Falcon cable. They do exhibit some modest increase in their transit via less-preferable (10x prepended) paths to Tata, but most of their routes are untouched.



However, Batelco's international **peering** mix changes significantly, as they, too, appear to lose connectivity with Emirates (AS8966):



All of these visible effects (BIX's Emirates transit, Zain's Emirates transit, Batelco's Emirates peering) revert to more normal levels on February 24<sup>th</sup>, presumably when the FOG returns to service.

Together, all of this “Emirates avoidance” creates an event signature that can be used to look for similar events over the previous 12 months, in order to judge the stability of the FOG cable relative to other routes out of the Kingdom. Indeed, the routing tables show evidence of virtually identical events on the following dates, which exhibit the same kinds of abrupt shift in peer preference away from Emirates for Bahrain routes:

- **Jan 24 - Feb 2, 2009**
- **Feb 12-24, 2009**
- **Mar 30 – Apr 6, 2009**
- **Apr 13–18, 2009**

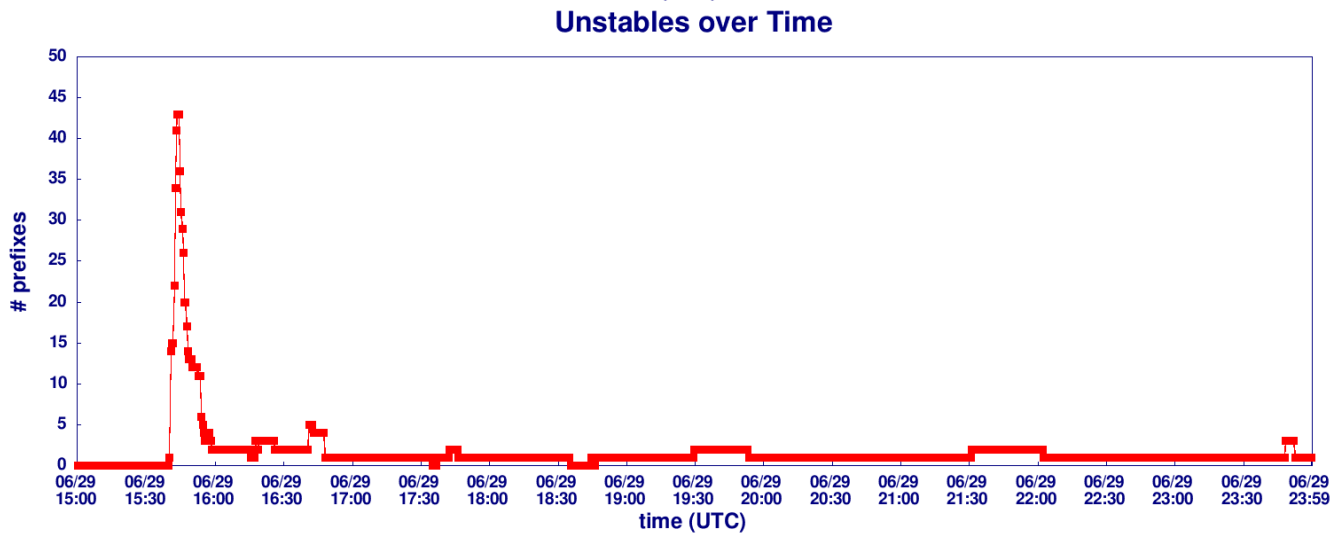
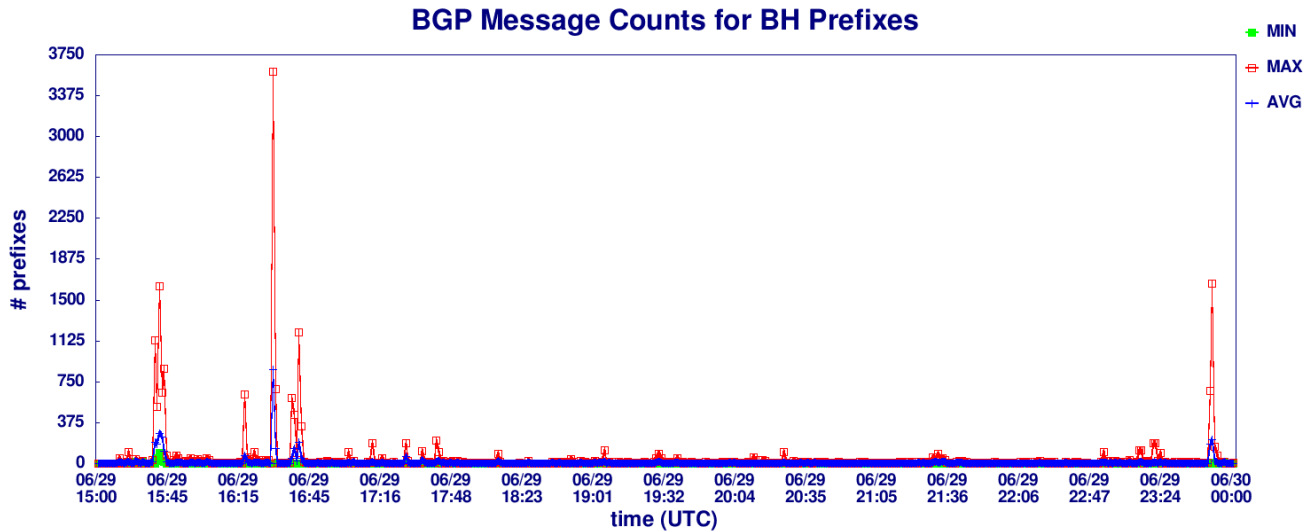
These seem to correlate with reports of FOG disruptions from the media and bloggers in the region.

Altogether, the **FOG appears to have suffered more than 30 days of reduced capacity in the first half of 2009**; this represents a very significant amount of congestion and downtime for the affected providers.

By comparison, the FALCON cable was largely unaffected (except for the December 2008 event in Egypt, which impacted the entire region), and connectivity problems over the King Fahd Causeway appeared to be limited to a single event on 29 June 2009, which the next section examines in more detail.

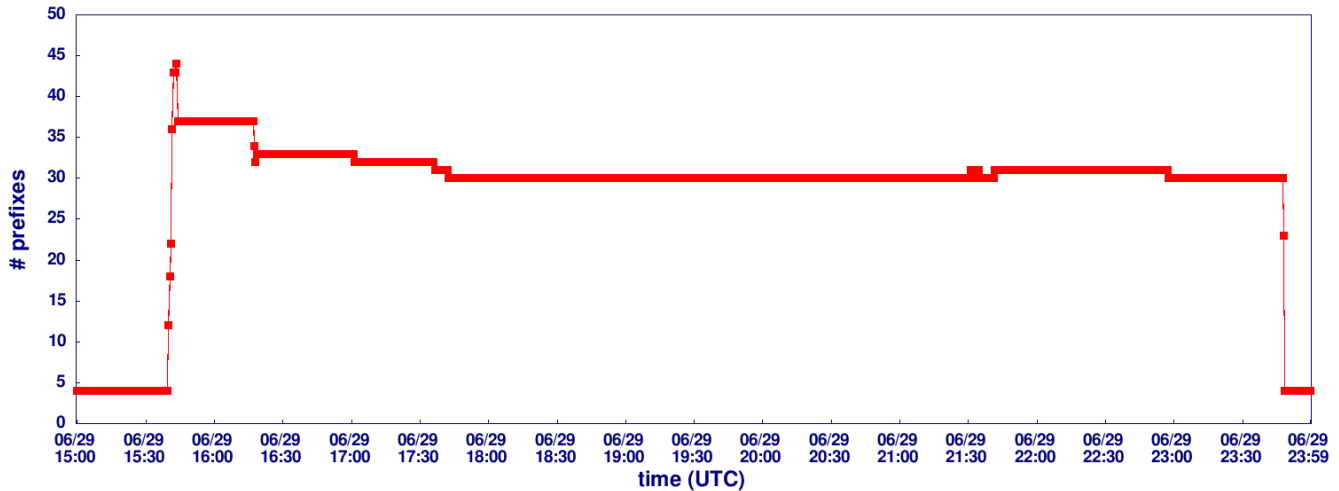
## Causeway event of 29 June 2009

At 15:39 UTC on 29 June, physical network connections across the King Fahd Causeway to Saudi Arabia were disrupted, causing the rapid onset of route change messages for a diverse set of Bahrain network prefixes that relied on Tata transit.



The rapid increase in the arrival rate of BGP route change messages was indicative of a significant rise in the number of unstable and outaged Bahrain prefixes, across a range of providers.

## Outages over Time



The event's dynamics consisted of three periods of particularly intense activity:

- **Initial outage: between 15:39 and 15:43 UTC**

About 40 prefixes suffer outages (39 prefixes) and instability (43 prefixes). The most impacted organizations in terms of affected prefix count were Mena Broadband (AS39015), Bahrain IX (AS35019), and MTC Vodafone/Zain (AS31452). These prefixes were routed mostly via Tata (AS6453).

Seven prefixes from Mena Broadband come back at the end of this period. These prefixes were using Tata (AS6453) for routing before this event. After the event they started using Bahrain IX (AS35019) en route to Emirates Telecom (AS8966) on what looks like a backup route. Namely, a lot of paths looked like this: (... 8966 35019 39015 39015 39015 39015)

Note how AS 39015 is 4 times prepended, indicating that Mena is exercising a less-desirable backup route through the BIX in an attempt to maintain connectivity.

During this period Batelco (AS5416) also experienced significant instability. They lost their main connection to Tata (AS6453) and failed over to backup cables to both Tata (AS6453) and Flag (AS15412), as suggested by the presence of routes where AS5416 is prepended 7 times to AS6453 and 10 times to AS15412.

- **Additional adjustment: between 16:17 and 16:41 UTC**

Five more prefixes that were routed via Tata-BIX (6453-35019) find their way to Emirates Telecom (AS8966); e.g., paths change from (... 6453 35019 ...) to (... 8966 35019 ...).

Approximately 80 prefixes routed via Batelco (AS5416) moved from Tata (AS6453) to Flag-Reliance (AS15412) during this period. In doing so, several backup routes (with

prepends) were selected, but in the end Batelco's most desired routes (with no prepends) were selected.

At this point, the outages are effectively over, even though 26 more-specific prefixes (from Zain, Mena, Lightspeed, 2Connect, etc.) remain unreachable; in each case, less-specific covering prefixes remain visible in the global routing table.

- **Restoration: Between 23:47 and 23:49 UTC**

The 26 more-specific prefixes come back online, finding restored routes via Tata (AS6453).

From these patterns, one can conclude that when the Causeway cable was cut, interrupting connectivity to Tata's Riyadh POP, the ISPs that had Tata connectivity via the BIX (AS35019) managed to reestablish connectivity after some delay. In some cases connectivity was reestablished after 5 minutes, in some other cases after 1 hour.

Bahrain IX (AS35019) also uses Tata (AS6453) as its main provider. However they also have Emirates Telecom (AS8966) as a second provider, which they used as much as possible during the cable cut.

Batelco (AS5416) also has two providers: Tata (AS6453) and Flag-Reliance (AS15412) and they were able to use them well to protect their Internet connectivity.

Like the BIX, Zain (AS31452) fell back to its Emirates Telecom (AS8961) connection.

Mena Telecom reverted to a heavily prepended (less desirable) BIX route, and took advantage of the BIX's redundancy.

Because Batelco appears to have both east- and west-facing connectivity to Tata, they were probably able to maintain something closer to a "normal" traffic balance during the event.

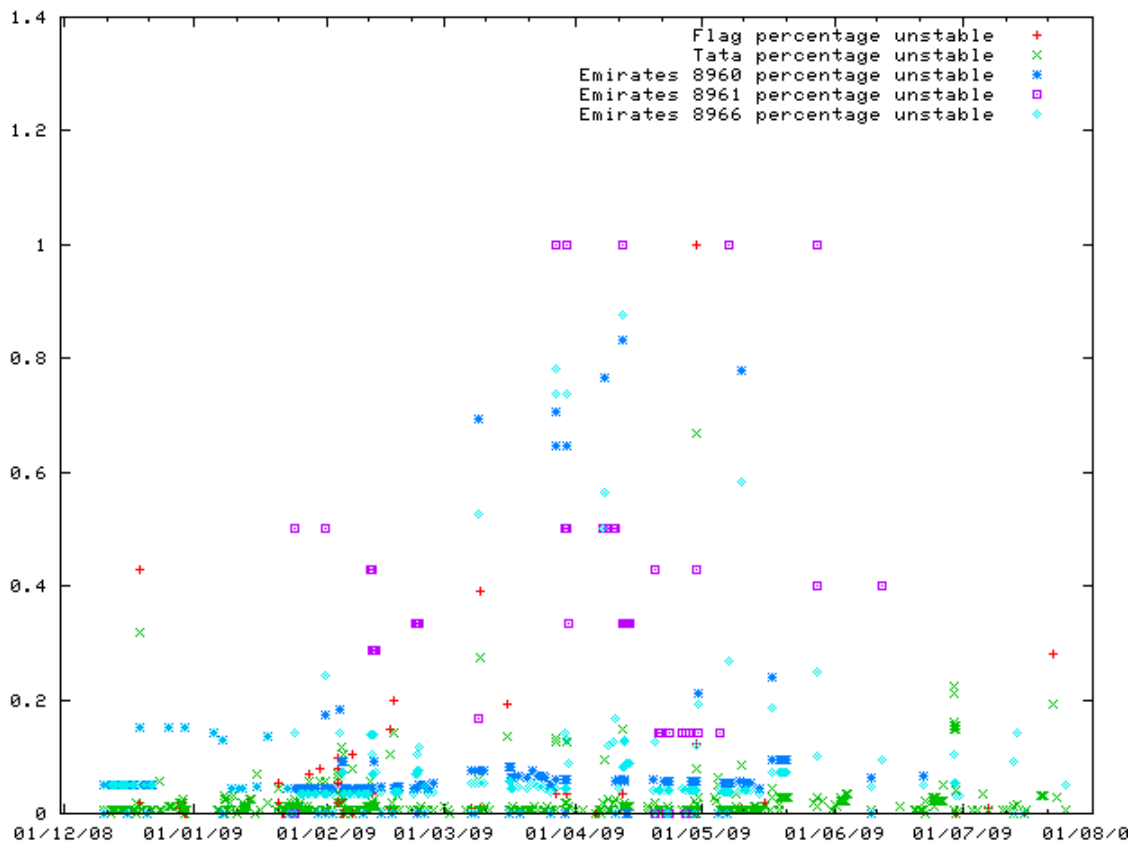
## ***Stability Timeseries for Bahrain and Regional Markets***

How common is this kind of significant route change event? To get a sense of the background level of instability in the Kingdom, Renesys gathered statistics about the percentages of routes affected by similar events over the preceding seven months.

Renesys computes standard metrics for Internet instability, based on the number of prefixes affected (at a specified level of impact), normalized by the total size of the Internet ecosystem. In this way, one can build up a picture of the very largest events affecting a given set of prefixes, and objectively compare different groups of prefixes (companies, transit relationships, or countries) head-to-head. When filtered through methodologies like 95<sup>th</sup>-percentile sampling, these kinds of statistics can form the basis for long-term measurement of proposed strategies for transit diversification and mitigation of worst-case transit scenarios.

The following plot shows, for each hour between 15 December 2008 and 15 July 2009, the percentage of Bahrain networks carried by each international provider that were significantly impacted by route instability or outage. A “significantly impacted” network prefix is defined as having been subject to either a period of unavailability due to route withdrawal, or three or more route shifts observed in at least six 30-second sample windows during the hour.

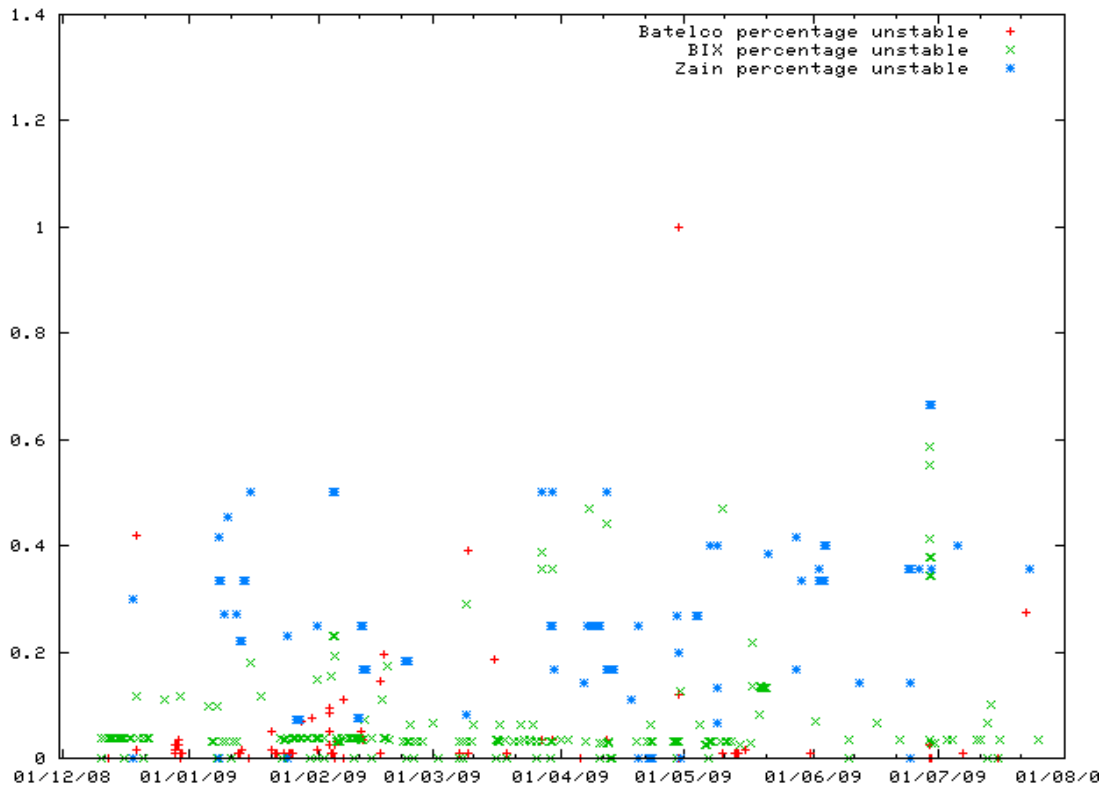




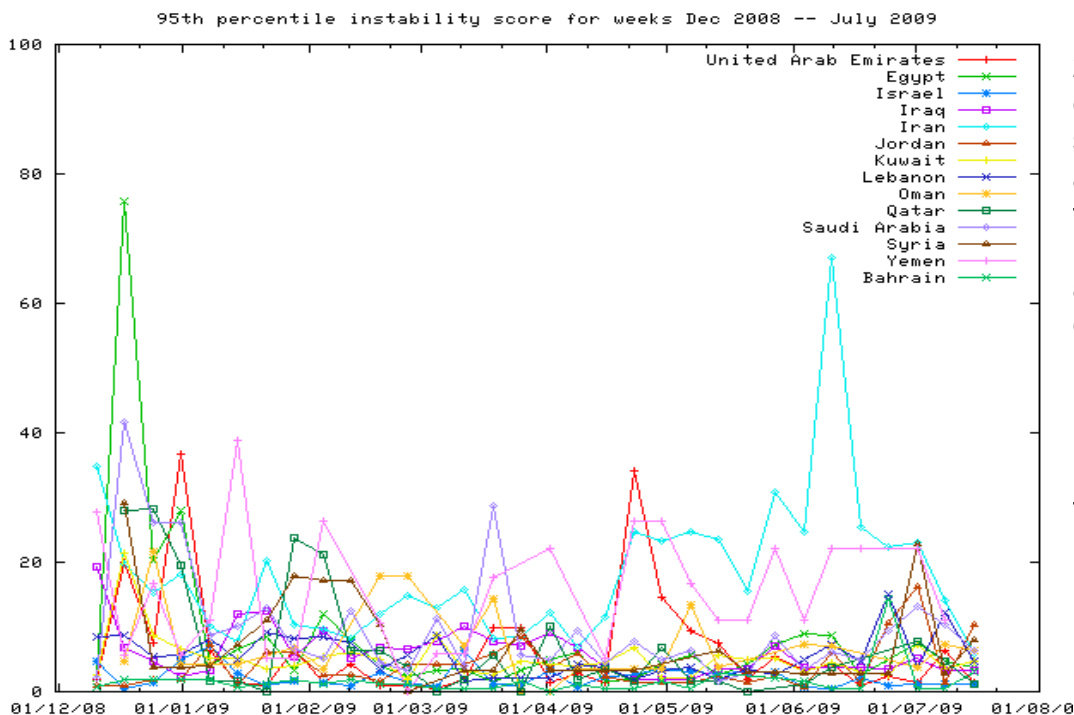
Vertical stacking of points suggests that instability is highly correlated across these providers (reasonable, given the fact that they share significant amounts of common fiber inbound to Bahrain). Flag and Tata are more stable, on a percentage basis, with only rare excursions above 20%. The various Emirates Telecom connections are less reliable, with impacts of 40% or more making an appearance in selected hours during the Spring and Summer of 2009.

By performing the same analysis on the three largest providers with international connectivity (Batelco, BIX, and Zain), one can conclude that Batelco's prefixes are most stable, and that the BIX and Zain both have more common (but still rare) worst-case hours with up to 50% of their routes experiencing significant impacts due to route instability. Again, vertical stacking visually illustrates the fact that BIX, Zain, and to some extent Batelco share common outage modes due to their common dependence on common fiber connections to the Emirates.

It is important to note that each visible point here represents a single hour, out of more than 5000 hours in the survey window, and that these worst-case instabilities are therefore very rare events.



The following two plots apply a 95<sup>th</sup> percentile filter to a week of hourly stability data for the nation-scale prefix sets of each of the countries in the region. This plot is hard to read because of the amount of data represented, but one can see clear patterns of correlation among countries, as well as specific per-country events.

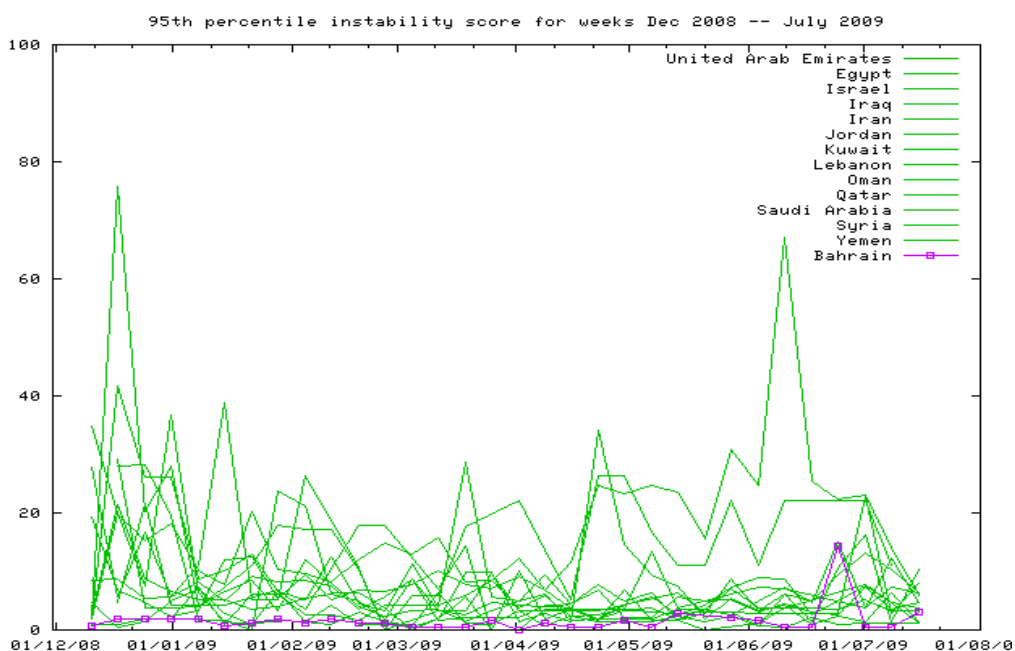


In particular, the 2008 Egyptian cable cut can be seen on the left as a consistent burst to 60%-80% impact in Egypt (green) and other countries.

Iranian instability leading up to and immediately after the June elections is visible in light blue on the right.

Isolating the line corresponding to Bahrain's 95<sup>th</sup> percentile instability indicates that Bahrain's networks consistently experience **less significant route instability** than that experienced in other countries in the region.

The causeway event at the end of June is, indeed, the most significant Bahrain's Internet Ecosystem



Bahrain event visible in this timeseries.

## Latency Measurements for Key Bahrain Providers

As an experiment in active measurement, Renesys performed 51,615 traceroutes to Bahrain Internet prefixes from data centers in California, London, Tokyo, and Amsterdam over a one-week period in July. Each trace provides a sequence of hop latency data, indirectly measuring the incremental latency from the entrance of one provider's network to the entrance of the next (e.g., by combining subsequent intraprovider hops and subtracting the time from the traceroute source to the provider entrance). This gives a rough estimate of the latency (in milliseconds) for traversal and handoff for each path into the country, and for each interprovider hop within the country. Each hop was measured at least 150 times, and most were measured over 500 times.

**Transit Latencies Observed in Traceroutes (milliseconds, 95<sup>th</sup> percentile)**  
July 14-23, 2009

<b>ASN provider</b>	35019 BIX	5384 Emirates	15412 Flag	6453 Tata
<b>ASN customer</b>				
5416 Batelco			202.77	326.64
30882 Benefit Co				
31452 Zain		28.6		358.44
35019 BIX		154.85		340.34
35313 <b>2Connect</b>	<b>85.25</b>			367.89
35443 Kalaam	19.73			
35457 <b>Etisacom BH</b>	<b>991.65</b>			
35546 Northstar	4.38			
35568 <b>Nuetel</b>	<b>19.13</b>			
35729 <b>Viacloud</b>	<b>33.87</b>			
39015 <b>Mena</b>	<b>31</b>			332.87
39273 Lightspeed	17.03			
41110 BCN	7.28			
41303 <b>Ascentech</b>	<b>16.02</b>			
42931 <b>RTS</b>	<b>188.65</b>			
44167 iCOLPLUS	12.79			
47380 Kulacom	4.68			

Measurements can be directly compared *within* columns (i.e., across the customers of a given transit provider), but not *across* columns, because of variations in the intraprovider latency between providers. One should also not add measurements across columns to estimate

total worst case latency (e.g., for Etisalcom BH, 991ms from the BIX “plus” 340ms from BIX to Tata) because the two measurements may reflect *different* 95<sup>th</sup> percentile events. The distribution of 95<sup>th</sup> percentile delays (i.e., 95% of the measured hop latencies were no greater than this value, in milliseconds) suggests three observations.

First, the closely similar worst-case latencies across Tata's network suggest that Tata's network is relatively uncongested, reflecting delays that are almost entirely lightspeed-related (e.g., based on the average physical distance to an entry point to Tata's network), not volatility resulting from contention for network resources under load.

Second, the very different worst-case latencies experienced by BIX and Zain at Emirates suggest that BIX may be experiencing congestion on its own network, multiplying the worst-case latency significantly.

Finally, it appears that providers who are not in the same building as the BIX (represented in the table in **boldface**) experience *significantly higher worst-case latencies* for received traffic. One can theorize that providers are probably capacity-constrained in the last mile of leased connectivity between their facilities and the BIX, resulting in higher congestion and packet loss under peak load conditions than that experienced by providers resident in the same building.

## Appendix A. Routing Terminology

Internet routing has developed its own terminology over time, which may not be familiar to the non expert. This section provides context for some of the terms used in this report.

- **Prefix (or “network”)**: a sequence of IP addresses that an enterprise may use to identify machines that it attaches to the Internet (computers, routers, etc.)
  - *Example: 77.92.160.0/19, which is a contiguous block of 8 million IP addresses belonging to Rawabi Telecommunications and Software.*
- **Border Gateway Protocol (BGP)**: the software protocol used to establish Internet connections between different organizations.
- **Autonomous System**: An organization that has applied for an Autonomous System Number (ASN), in order to be allowed to advertise its own prefixes in the global routing table.
  - *Example: Batelco (ASN 5416), or the BIX (ASN 35019).*
- **Border Router**: networking equipment deployed at the edge of an organization's network, in order to establish connections to other organizations by exchanging BGP messages with them.
- **Advertise (or “Announce”) a Prefix**: An organization that wants other people to be able to reach its prefixes must **announce** them to its transit providers and peers. It does this by configuring its border routers to send BGP messages describing networks it knows how to reach, and listen for BGP messages that announce other people's networks.
- **Path to a prefix, ASPath**: each BGP announcement contains an **autonomous system path**: a sequence of one or more autonomous systems who passed on the announcement, representing the “best path” to the announced prefix.
  - *Example: a BGP announcement containing the ASPath “7473 8966 35019 39273 30882” indicates that the best path to the prefix goes from Singtel (AS7473), to Emirates Telecom (AS8966), to the Bahrain Internet Exchange (AS35019), to Lightspeed Telecom (AS39273), and finally on to Benefit Company (AS30882), in that order.*
- **“Having a Route”**: when a router hears another router announce a path to a prefix, it enters it into its routing table, and is then said to “have a route” to that prefix. If the

new route is an improvement over its existing route, it will re-announce that improved route to all of its other neighbors. Amazingly, a new or improved route to any prefix generally propagates to all of the routers worldwide through re-announcement within 15 seconds.

- **Transit, Transit Provider:** When an autonomous system signs a contract to carry another enterprise's traffic to and from the global Internet, it is serving as a Transit Provider (i.e., "selling transit" to the other party).
  - *Example: FLAG (AS15412) and Tata (AS6453) both sell transit to Batelco.*
- **Singlehomed, Multihomed:** if an autonomous system has only one transit provider, they are said to be singlehomed. If they have more than one transit provider, they are multihomed. Multihoming significantly reduces the risk of having Internet instability and outages, because if one provider has a problem, traffic can transparently fail over to the other provider.
  - *Example: Lightspeed is singlehomed to FLAG (AS15412). 2Connect is multihomed to the BIX (AS35019) and Tata (AS6453).*
- **Peering:** when two autonomous systems agree to exchange traffic between their customers, instead of each having to pay a transit provider to carry that traffic between them, they are said to be peering. If no money changes hands, it's **settlement-free peering** (the usual case).
  - *Example: Batelco (AS5416) and Emirates Telecom (AS8966) peer with each other at the EMIX. Traffic between a Batelco customer and an Emirates customer changes hands "for free," rather than being sent to a paid transit provider, such as FLAG. Most Bahrain autonomous systems (other than Batelco) peer with each other at the BIX.*
- **Reachable, Unreachable (or "Outaged"):** If a router has a route to a given prefix, that prefix is **Reachable** from its perspective; if it no longer has a route, the prefix is **Unreachable**. When a network prefix becomes unreachable (that is, it is no longer being announced to any transit provider), it is no longer connected to the Internet.
- **Instability:** When the routes to a prefix change very quickly (often because a physical link is very congested, or "flapping" in and out of service), the prefix is said to be unstable. A route to it may exist, but traffic may not be flowing smoothly because link quality is poor.
- **Global Routing Table:** the ideal routing table consisting of all the known "best paths" to all of the prefixes on earth, from all of the border routers on earth. Renesys builds an approximation of this ideal global picture by connecting to hundreds of organizations' border routers and synthesizing a continuous map of their routes at one-second granularity.



## Appendix B. Service Provider Rankings: Bahrain

The Renesys Market Intelligence service ranks autonomous systems according to the number and size of the network prefixes whose traffic they carry into a given geographic region.

The July 2009 Retail Customer Base rankings are reproduced below. “Retail transit” of a prefix is defined as origination of that prefix, or transit on behalf of an autonomous system who originates that prefix. Because Tata/Teleglobe (AS6453) provides direct transit to the originated prefixes of both Batelco and the BIX, they top the retail rankings.

The ranking changes in the second column indicate whether the given provider has gained or lost ground in the previous month, relative to the other ranked enterprises. Because Bahrain's market is relatively small, all BGP-connected enterprises (including enduser autonomous systems, as well as service providers) are visible in the top 25 rankings.

Customer Base: Retail – Bahrain				?
1		☆ Teleglobe Inc. AS 6453		
2		★ BATELCO-BH AS 5416		
3	+1	★ MTC-Vodafone Bahrain AS 31452		
4	-1	★ Bahrain Internet Exchange AS 35019		
5		☆ Flag Telecom Global Internet AS 15412		
6		☆ Emirates Telecommunications Corporation AS 8961		
7		☆ Mena Broadband AS 39015		
8	+2	☆ LightSpeed Communication in Bahrain AS 39273		
9	-1	☆ Business Communication Networks AS 41110		
9	-1	☆ ASN-RTS AS 42931		
10	-1	☆ 2Connect AS 35313		
10	+1	☆ ETISALCOM BAHRAIN COMPANY W.L.L. AS 35457		
11	+1	☆ Viacloud AS 35729		
11	+1	☆ Orange Business Services (formerly Equant) AS for BENELUX AS 5583		
11	+1	☆ Northstar Technology Company W.L.L. AS 35546		
12	+1	☆ Kalaam Telecom Bahrain AS 35443		
13	+1	☆ Kulacom communication SPC AS 47380		
13	+2	☆ WoodyNet AS 42		
13	+1	☆ Ascentech Technical Services AS 41303		
13	+1	☆ Central Informatics Organization AS 48109		
13	+1	☆ iCOLPLUS AS 44167		
B. 13	+1	☆ Gateway Gulf AS 44876		
13	+1	☆ Nuetel Communications AS 35568		
14	+2	☆ 754th Electronic Systems Group AS 1733		
15	+2	☆ DoD Network Information Center AS 27064		
15	+2	☆ DoD Network Information Center AS 5237		
15	+2	☆ The Benefit Company B.S.C. (C) AS 30882		