The Internet in Crimea: Changes in Connectivity Revealed by an Analysis of Routing Data

In 2014 the Russian Federation laid claim on Crimea, causing a change of regime and reportedly profound changes in Internet regulation and connectivity on the peninsula. Those changes were evident in our Internet measurements. This report is a summary of a paper presented at the Global Internet Symposium 2020[*1].

3.1 Introduction

Crimea is a peninsula located South of Ukraine and West of Russia. It was previously administered by Ukraine, but the Russian Federation declared its annexation of Crimea in 2014. This caused changes to the way the Internet was wired for an estimated 2.3 million people living in Crimea. Until 2014, access of Crimeans to the rest of the Internet was predominantly handled through Ukrainian networks, held to Ukrainian law and oversight. But since 2014, Crimea has been subject to Russian Internet regulations. Although the Russian government quickly embarked on large infrastructure projects, such as the construction of submarine cables, it took three years for Crimean Internet Service Providers (ISPs) to complete the transition.

We examine and analyze this transition from a perspective on Internet governance, science and technology studies, and network measurements. To gain insight into what the transition was actually like, we combine both a sociological approach—analyzing media reports and information from people in the region—and a science and technology approach—analyzing network measurements. For our network analysis, we propose an AS Hegemony metric based on BGP data to quantify AS (autonomous system, organization that controls routes) dependency. This metric lets us examine changes in network policy in Crimea.

3.2 The Internet in Crimea

First, we gathered information via 45 interviews conducted between December 2017 and May 2018 with relevant actors: ISPs from Crimea and the Ukrainian mainland; journalists and human rights defenders working in the area; members of the Ministry of Communications of Ukraine; and digital security trainers. We also analyzed information communicated via forums and group chats in the regions as well as press reports, all of which elucidated how the infrastructure transitions happened in Crimea between March 2014 and July 2017. Figure 1 also shows these events, which we discuss below.

3.2.1 Background

As a mountainous peninsula, Crimea was heavily dependent on the Ukrainian mainland for supplies, from water and gas to electricity and communications. Russian control of Crimean information infrastructure followed a "soft substitution" model and took about three years. This reflects the fact that the Russian Federation was not able to substitute the necessary services all at once without causing an extended period of service disruptions that would have prompted indignation among the Crimean population.

The geopolitical status of Crimea as a disputed area and the resulting sanctions from the US and the EU drove the development of a gray market for Internet service in Crimea, Lugansk, and Donetsk. Progressive centralization of routing paths and monopolization of the Internet service market in Crimea facilitated control over networks. Consequently, the quality and speed of Internet connections degraded, while the cost of Internet services for end-users increased.

3.2.2 Ukrainian ISPs Left Crimea

Crimea became part of the Russian Federation after a referendum held on March 16, 2014. As a result, the majority of Ukrainian telecommunication companies left the peninsula and Russia acquired Ukrainian Internet and telecommunication infrastructures.

3.2.3 The Kerch Strait Cable

The Russian state-owned telecommunications company, Rostelecom, announced on April 25, 2014 the completion of a 110Gbps submarine link from Russia to Crimea and

*1 Romain Fontugne, Ksenia Ermoshina, Emile Aben. "The Internet in Crimea: a Case Study on Routing Interregnum", Global Internet Symposium 2020. Paris, France. June 2020.

said service will be offered by Miranda Media, Rostelecom's local agent. Miranda Media's main ASN (AS201776) was registered on July 15, 2014 and first seen in BGP as an upstream provider for Crimean networks on July 24. The traffic capacity of the Kerch Strait cable was insufficient, so Ukrainian fiber was kept as a backup option, and one respondent said "routes through Perekop (Ukrainian cable) were cheaper and faster than the undersea connection via Kerch Strait". Crimean providers were reluctant to use the new Kerch Strait cable for speed and quality reasons. Around that time, Crimean World of Tanks[*2] players were among the first to complain about speed loss on dedicated forums, and the price of Internet access in Crimea was raised in 2015.

3.2.4 Internet De/Consolidation

In May 2016, Russia started construction of a second Internet cable that reuses Kerch bridge infrastructure and connects Crimea to an exchange point in Rostov, thus consolidating Crimea's connectivity to Russia. This cable was reportedly first used in July 2017.

A year later in May 2017, the Ukrainian president ordered that access be blocked to Russian platforms such as social media service vk.com, the mail.ru mailing service, and the search engine yandex.ru. On May 31, Crimean users complained about being blocked when trying to access these websites. This was seen as evidence that Crimean ISPs are still connected to upstream Ukrainian networks. Then in summer 2017, the Ukrainian government put pressure on Ukrainian ISPs to stop providing traffic to Crimea (allegedly on July 12, 2017).

3.3 The Transition Viewed Through Internet Measurements

We now look at topological changes in Crimea based on network data. Our analysis focuses on changes in the way ASes operating in Crimea routed traffic before, during, and after the transition.

3.3.1 ASNs in Crimea

As Crimea is a disputed area and the ASN country codes have changed over time (RU, UA, or "Other"), we first need to identify which ASNs were operating from within the peninsula.

We first looked at RIPE Atlas probes[*3] active in Crimea and verified if they corresponded to a commercial ISP using Whois, and we then searched dedicated user forums or official websites of these ISPs. We looked at all the upstream ISPs of these ASNs and identified those located in Crimea. Next, in February–April 2018, a set of network measurements on eight Crimean networks was taken using OONI probe[*4] for Android and iPhone. We also cross-verified this data with the information from forums and interviews to identify ASNs and upstream ISPs.

These efforts identified the biggest upstreams in the area, Miranda Media and UMLC, as well as the two biggest Crimean ISPs, CrimeaCom South and CrelCom. At this point, we had a list of 80 ASNs thought to be in use in Crimea. We combined this with a list of all downstream networks of Miranda Media obtained from BGP data. Finally, we manually checked the combined list and removed three ASNs that were present at Crimea-IX but operated mostly outside of Crimea.

The above steps produced a list of 111 ASNs that were active between 2012 and 2019. This number is surprisingly high, but a closer look at each AS reveals that many are managed by small local businesses or individuals, and about half announce only one or two IPv4 prefixes, usually a /24 or /23.

3.3.2 Network Dependencies

To identify the main transit networks providing Internet to Crimea, we estimated the AS dependency of Crimean networks with BGP data and our AS Hegemony metric[*5]. AS Hegemony, $HASx\,(ASy)$, quantifies the likelihood (value from 0 to 1) of ASy lying on paths toward ASx. $HASx$

*2 An online battle game available worldwide.
*3 A device (https://atlas.ripe.net/) distributed by RIPE, the RIR for Europe, for monitoring the Internet connectivity from the end-user side.
*4 Open Observatory of Network Interface, a tool for checking Internet speed and censorship from the end-user side, available for both Android and iOS.
*5 R. Fontugne, A. Shah, and E. Aben. The (thin) Bridges of AS Connectivity: Measuring Dependency using AS Hegemony. In Proceedings of PAM'18. LNCS, 2018.

(ASy) = 1 means that ASy must be traversed to reach ASx, while values close to 0 mean that ASy is rarely seen on paths to ASx.

We collected data from two RISs[*6] (RRC00, RRC10) and two Routeviews[*7] (RV2, LINX) collectors that account for more than 100 BGP full-feed peers. We then computed AS Hegemony values for all globally reachable ASes on the 15th of each month from January 2012 to December 2018[*8].

To compute AS Hegemony scores for Crimea, we merged results obtained for all origin ASNs located in the area. We obtained AS Hegemony scores for the list of Crimea ASNs compiled in Section 3.3.1 and computed the average. The average AS Hegemony value also ranges from 0 to 1 and conveys network dependency across ASes. Values close to 1 indicate transit ASes commonly seen on paths towards all ASes in the area. Values close to 0 could represent a transit AS that is either rarely seen on paths to all ASes in the area or heavily employed by only a handful of ASes.

As a reference, we also compute the average AS Hegemony for all ASes registered in Ukraine and in Russia (excluding Crimean ASNs) and compare the results.

Ukraine

As shown in Figure 1, the dependencies for Ukrainian ASes are fairly stable from 2012 to 2018. The main changes are the decline of TOPNET and the rise of Blinking Megabit from 2017; information on this transition is publicly available[*9]. These ASes are both owned by Datagroup, so our results show that Ukrainian networks are mainly dependent on Datagroup and UARNET. Other significant dependencies are large international ISPs, such as RETN (EU), Level 3 (US),

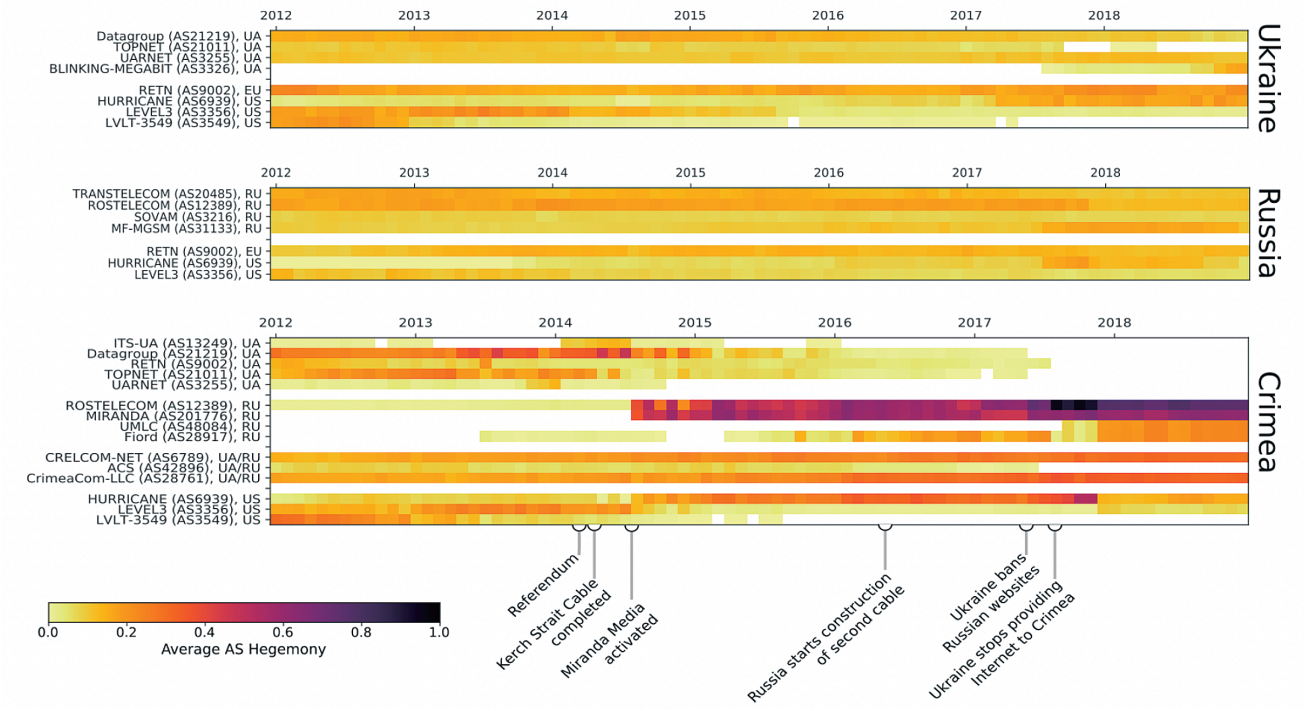

Figure 1: Average AS Hegemony for networks located in Ukraine, Russia, and Crimea. High AS Hegemony scores reveal networks that are central to reach a region.

*6 Routing Information Service, an Internet routing data collection and analysis service provided by RIPE (https://www.ripe.net/analyse/internet-measurements/routing-information-service-ris). RRC00 and RRC10 are two major repositories.

*7 A University of Oregon project that collects BGP routing information and makes it publicly available (http://www.routeviews.org/routeviews/). RV2 and LINX are two major repositories.

*8 Internet Health Report. AS Hegemony REST API. https://ihr.iijlab.net/ihr/en-us/api, 05 2020.

*9 PeeringDB. Topnet, last updated on Sep. 4, 2017 (https://peeringdb.com/net/1157).

and Hurricane Electric (US). Since the RETN network is primarily deployed in East Europe and Russia[*10], this network is observed as a main transit for both countries. Note that RETN was registered in May 2012 with the country code UA but changed to EU in July 2018.

■ **Russia**

Similar to what the Ukraine data show, the dependencies of Russian ASes stay fairly stable. The ASes are dependent mostly on two state-owned ISPs, Rostelecom and Transtelecom, as well as two other major Russian ISPs, MegaFon (AS31133) and SovAm/VimpelCom (AS3216). Also similar to Ukraine, there are dependencies on RETN, Level 3, and Hurricane Electric.

■ **Crimea**

Unlike those for Ukraine and Russia, the AS dependencies of Crimean ASes changed drastically. In 2012 and 2013, there were the same dependencies as in the Ukraine along with dependencies on local Crimean ISPs (CrimeaCom, CrelCom, and ACS) and a weak dependency on Rostelecom. These results reveal the role of local Crimean ISPs as a proxy to larger Ukrainian and international ISPs. 2014 is marked by a significant increase in dependency on a new AS, Miranda Media, and its parent company, Rostelecom.

At that time, numerous AS paths began to feature the same pattern: they originate from Crimea and go through Miranda Media and then Rostelecom. This routing change significantly reduced the number of paths transiting through Ukraine, a trend that continued until mid-2017, after which paths going through Ukrainian ASes were no longer observed. From 2015, another Russian ISP, Fiord, also became a common transit for Crimea, and as with the Miranda Media / Rostelecom pair, from August 2017 Fiord connected to Crimea via UMLC.

In summary, the topology of Crimean networks has evolved to a singular state where paths bound to the peninsula converge on two ISPs (Rostelecom and Fiord) located outside of Crimea. The transition was marked by two major events, the appearance of Miranda Media in 2014 and the end of transit via Ukraine in 2017. We discuss these two phases in detail below.

3.3.3 Appearance of Miranda Media

The appearance of Miranda Media was Russia's first clear step toward consolidating Crimean connectivity. As Figure 1 shows, multiple Crimean ASes switched to Miranda Media as soon as it was made available in 2014. To understand the Miranda Media adoption dynamics, we detail the main AS dependencies of Crimea from July to December 2014.

We found that 55 out of the 78 Crimean ASes that were active in 2014 had a strong dependency on Miranda Media ($H > 0.5$) during 2014. Figure 2 depicts these 55 ASes (left nodes) and their major AS dependencies in 2014 (all other nodes). If an AS depends equally on multiple networks, we take its major dependency to be the closest non-Crimean AS. For example, networks with a dependency of $H = 1$ for CrimeaCom South, Miranda Media, and Rostelecom are classified as Miranda Media.

As of July, the dependencies remained similar to what we had observed for Crimea since 2012, but significant changes came in the following two months with Miranda Media appearing on paths to CrimeaCom South, CrelCom, and ACS customers. Thus, by connecting to central Crimean ISPs, Miranda Media became the main transit network for Crimea in a very short time frame.

From October 2014, however, we observe dependencies on the three Crimean ISPs (Figure 2). These networks were again seen on paths with Ukrainian upstreams instead of Miranda Media. Operators informed us that Ukrainian ISPs were sometimes preferred because of the higher cost and degraded quality experienced with Miranda Media.

Also, a few Datagroup customers switched to Miranda Media every month, and thus Datagroup's Crimean customer count had fallen significantly by the end of 2015.

*10 RETN Network Map (https://retn.net/networkmap/).

In summary, the arrival of Miranda Media and connections to key ISPs had an immediate and significant impact on Internet routing in Crimea. We found, however, that networks had to maintain paths to Ukraine as Miranda Media's capacity was insufficient. Also, about a third of Crimean ASes (23 out of 78 ASes active in 2014, not shown in Figure 2) did not commit to Miranda Media in 2014 and kept their paths going through Ukrainian ISPs.

3.3.4 End of the Transition

Ukraine claimed that it stopped providing Internet connectivity to Crimea in July 2017. To understand connectivity in Crimea before and after this key event, we also investigated AS dependency changes for Crimean ASes in 2017 (Figure 3).

We look at the four ASes that relied mainly on Ukrainian ISPs from January to May 2017 (the four ASes relying on Pitline and TOP NET on the left of Figure 3). At the time, Miranda Media / Rostelecom and Fiord provided Internet to a large fraction of Crimean ASes, but the three main Crimean ISPs (CrimeaCom South, CrelCom, and ACS) still had connections with Ukraine.

In January 2017, CrimeaCom South relied on Fiord (H = 0.8) and Ukrainian ISP WNET (H = 0.07, not shown in Figure 3). In the months that followed, a few paths went through Miranda Media, and paths through WNET stopped completely on May 23. Then at 08:00 UTC on July 19, all paths suddenly started going through Miranda Media (H = 1.0).

ACS relied equally on Dataline (not shown in Figure 3) and Miranda Media from January to June. On June 5, Dataline disappeared from ACS's paths, being replaced by CrimeaCom South. And from June 2017, ACS followed the same changes as CrimeaCom South.

In early 2017, CrelCom relied mainly on Russian networks Fiord (H = 0.65) and Miranda Media (H = 0.25) but later had two drastic routing changes. In February, almost all paths to CrelCom began transiting through Rostelecom (H= 0.95). Then at 11:30 UTC on July 19, 2.5 hours after CrimeaCom South switched entirely to Miranda Media, all paths to CrelCom also began transiting via Miranda Media. At the time, Fiord was no longer being used in Crimea and the Miranda Media / Rostelecom pair

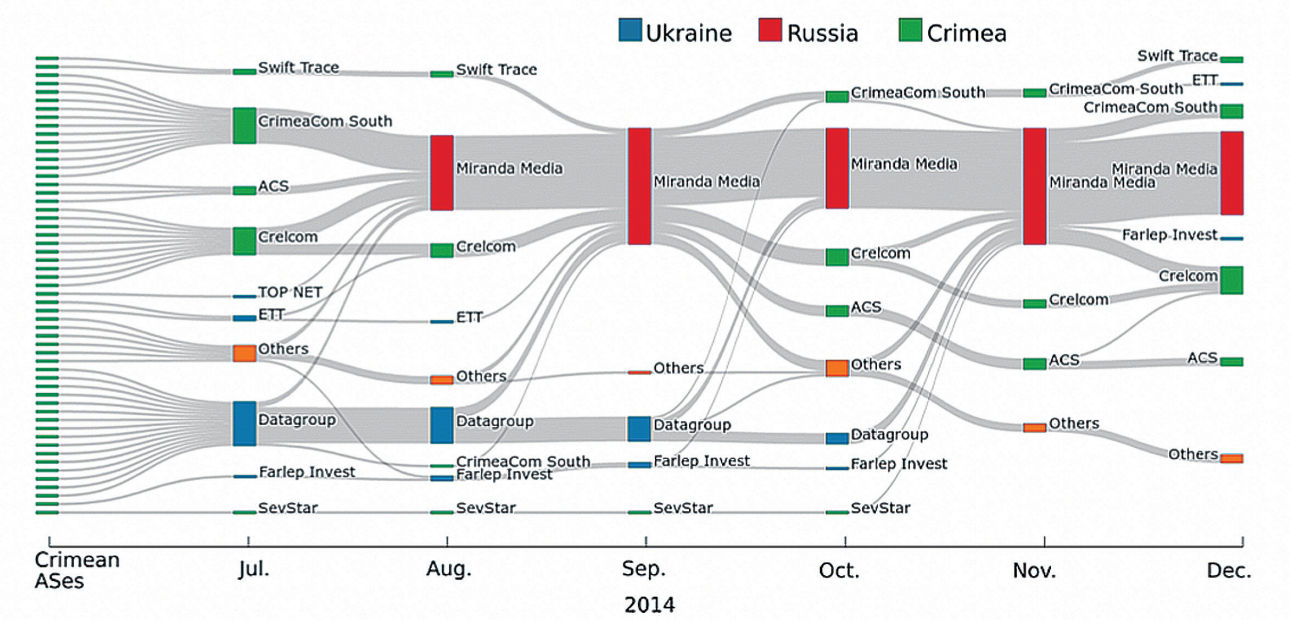

Figure 2: Adoption of Miranda Media
Main dependencies of Crimean ASes from July to December 2014. Left nodes represent Crimean ASes, other nodes are the main dependencies of Crimean ASes at different points in time. Only the highest dependencies are shown. In the case of a tie, the closest AS to Crimea is selected.

was dominating Crimean connectivity (Figure 3, August 2017).

A month later, on August 22, 2017, UMLC began providing connectivity to Crimea. At first, UMLC was only connected to CrelCom in Crimea and Fiord in Russia. We measure about 20 Crimean ASNs with paths going through CrelCom, UMLC, and Fiord at the time. Fiord came back by the end of 2017 as a major provider to Crimea via ULMC (see also Figure 1). UMLC was subsequently connected directly to other Crimean ASes but seemed to use Fiord exclusively as upstream provider, thus forming the UMLC / Fiord pair depicted in Figure 1.

So in 2017, we observe routing changes that lead to a particular topology with a choke point composed of two pairs: Miranda Media / Rostelecom and UMLC / Fiord (Figure 3). This topology is substantially different from the diverse connectivity observed before August 2014 (Figure 2).

This report has examined network topology changes made visible by our AS Hegemony metric based on BGP routing information. We have made public the tools and datasets we developed in the course of this research. Details of our AS Hegemony metric of Internet dependencies can also be found in other papers referenced herein[*11,*12].

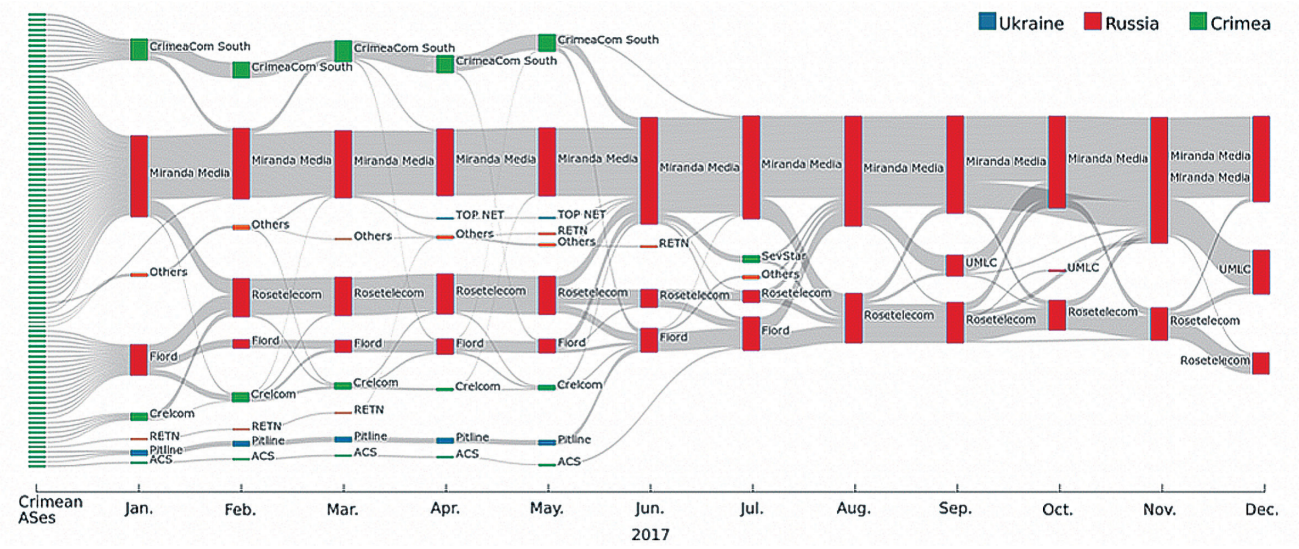

Figure 3: End of the Transition
Main dependencies of Crimean ASes in 2017. Left nodes represent Crimean ASes, other nodes are the main dependencies of Crimean ASes at different points in time. Only the highest dependencies are shown. In the case of a tie, the closest AS to Crimea is selected.

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*11 Tools and datasets: Internet Health Report. AS Hegemony REST API (https://ihr.iijlab.net/ihr/en-us/api), 05 2020. Internet Health Report. Measuring as-dependency of a country (https://github.com/InternetHealthReport/), 05 2020.

*12 References: R. Fontugne, A. Shah, and E. Aben. The (thin) Bridges of AS Connectivity: Measuring Dependency using AS Hegemony. In Proceedings of PAM'18. LNCS, 2018.