The Resiliency of the Ukrainian Segment of the Internet

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Beginning
Chronicle of the War's Beginning

- Russia's invasion of Ukraine began on February 24, 2022
- Around 5 AM Kiev time, Russian troops launched missile strikes on targets near Kiev, and long-range artillery strikes on Kharkiv.
- Reports of explosions near Odessa, Dnepr, Mariupol, Kramatorsk, Ivano-Frankivsk, Borispol, Ozernyi, Kulbakin, Chuguev, Kramatorsk and Chernobaivka.
- The Russians fired more than 100 missiles - short- and medium-range ballistic missiles, cruise missiles, and sea-based missiles.
- In parallel, a combined ground offensive was launched from three directions along the entire border from Zhytomyr Region (from Belarus) to Luhansk Region and from Crimea.
Russian Missile Strikes in the First Days
Mass Destruction of Civilian Objects
Internet Disruptions in the First Days of War

Confirmed: Significant internet disruption registered in #Ukraine-controlled city of #Kharkiv shortly after huge explosions heard; users report loss of fixed-line service on provider Triolan while cellphones continue to work.

Update: Real-time network data show a significant decline in internet connectivity across #Kyiv, Ukraine since early Thursday, attributed to population exodus and the shuttering of businesses and homes as civilians seek shelter or flee.
Degrading of Fixed Line Services

Customers started switching to mobile services
Initial Assumptions

• Rapid destruction of Ukrainian infrastructure
• Panic among the civilian population, including the staff of telecom operators
• Consistent degradation of the Internet up to complete loss of connectivity
Reality

- Failures of individual nodes did not have a fatal effect on connectivity in the country
- Partial losses of connectivity in the Ukrainian segment were quickly restored
- Telecom operators continued to provide services despite the war
The war develops
First Strikes on the Energy Infrastructure

- Data from the first 24 hours (November 24, 2022)
First Power Interruptions

- Power is an evident bottleneck of the physical Internet infrastructure.
- Power outages led to disruptions of communications service providers.
January: The Scale of Devastation

- Russia destroyed about 10% of Ukrainian energy sector, damaged about half of it (DTEK Group data)
- Ukraine's energy infrastructure: 40 percent of Ukraine's energy infrastructure is out of service (Ukrainian Government)
IODA (Georgia Institute of Technology)

- Hits to the Internet's physical infrastructure are sensitive, but fixes quickly
- Strikes on energy infrastructure are much more extensive, and have a greater impact
- Nevertheless, the industry recovered relatively quickly in each case
- Ukraine's counterattacks repeatedly improve results
RIPE NCC Data

The graph of the visible prefixes numbers/ASNs also clearly reflects the war course:

- Small drop-offs as a result of strikes on cable infrastructure
- Significant dropouts from power system failures
- Unavoidable recovery after
- Counterattacks improve results
- Prolonged fighting in a narrow area along the front line worsens them

https://stat.ripe.net/ui2013/widget/visibility#w.resource=ua
RIPE Atlas probes

• RIPE Atlas is one of the main measurement tools of the RIPE NCC
• These graphs show the change in the total number of RIPE Atlas samples in Ukraine since the beginning of the war
  - Keep in mind that resuming probe operation is often not a priority for operators restoring their operations
Ukrainian Internet Structure by RIS

Ukrainian operators are grey
Foreign ones are pink
Nodes are sized based on their number of direct incoming links

Inter-AS links:
- Stable in grey
- Appeared in green
- Disappeared in red

Nodes:
- Grey for Ukraine-registered networks
- Pink for Russia-registered networks
- Magenta for all other networks

Ookla's glance

- Mobile services are more sensitive to power outages
- Industry continues evolutionary growth despite war
Cloudflare statistics

- The number of requests depends not only on the capacity of operators but also on the number of users
- Migration has a strong impact on this indicator
- It is also possible that the sample of resources behind Cloudflare is not fully representative
Google view: negative trends

- Users activity: Google Web Search (top) and YouTube (bottom)

- The decline in activity:
  - Complete destruction of civilian infrastructure along the line of contact (Bakhmut as the most famous example)
  - Continued migration from the country
Analysis
Ukrainian Market Overview

• One of the least concentrated markets worldwide
  - Herfindahl-Hirschman index (HHI) calculation by Emile Aben (RIPE NCC)
  - APNIC data
  - Correlates with Huawei Cloud HHI calculation (2019)

• No dominant players in the market
  - If an individual network goes down, this has a relatively small effect on the whole network

<table>
<thead>
<tr>
<th>Country</th>
<th>HHI</th>
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<td>Brazil</td>
<td>0.018</td>
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<tr>
<td>Russia</td>
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<tr>
<td>United States</td>
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<td>Japan</td>
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</table>
Hight Fault tolerance

- Diversification among ISPs leads to increased resiliency
- High degree of diversification of the industry in Ukraine for many years ensured its place in the top ten
Interconnection in Ukraine

Green circle = end-user networks serving > 1% of the country’s population

A large ‘gap’ in the circle:

more than half of the Ukrainian end-users networks serve less than 1% of the population

How Ukrainian end-user networks interconnect, as seen from RIPE Atlas
# Ukrainian IXPs

<table>
<thead>
<tr>
<th>Name</th>
<th>Media Type</th>
<th>Country</th>
<th>City</th>
<th>Network</th>
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19 IXPs (1 in Crimea)
Ukrainian IXPs

13 of them are in the tracks between the RIPE Atlas probes in the country

- Each cell here: A path between RIPE Atlas probes in Ukraine
- The majority of these paths are mediated by IXPs (the total of coloured cells)
- Many different IXPs are used, indicating that there is not a single dominant IXP
Our interpretation

- In the Ukrainian segment of the Internet since the beginning of the war, more connections have been lost than gained

+ A significant number of new connections is noticeable

- There is a gradual decrease in the number of connected RIPE Atlas probes.

+ "Waviness" in the graph of connected probes has leveled off recently, indicating a more stable Internet in recent months.

+ The number of working IXPs has remained stable since the beginning of the war
Diversity

- After major strikes on energy infrastructure, it took one-two week almost to regain the quality of service for small and medium-sized ISPs
  - Sadly, major missile strikes occurred every few days, so a full recovery in between was impossible
- However, there were still significant disruptions in the service of major operators all winter long
- Due to the relatively small total share of large operators, the problem did not turn into a catastrophe
Human Factor
Free Internet Access in Bomb Shelters

Despite the drop in revenues, operators have taken on additional social functions.
Operators During the War

• Free internet access in bomb shelters
• Free “national roaming” amongst mobile operators
• Sharing inventory of spare parts
• Repairing emergencies on one operator's network by another operator's teams
• The network restoration right in the middle of the warfare
• The daily heroism of employees
People: ISPs
People: ISPs
People: power companies
Labor feat

- Weekend work
- Work with a break only for sleep
- Workers often slept on the jobsite
Help from Abroad
Starlink proved to be indispensable in several special cases

• Military communications
  - In particular, communication on the combat line

• Communication for government agencies
Starlink

- Communication in the recently de-occupied territories
Keep Ukraine Connected

- An initiative of the Global NOG Alliance
- A platform to collect equipment for the Ukrainian ISPs affected by the war
- The amount of aid already provided exceeds 2 million euros

https://nogalliance.org/our-task-forces/keep-ukraine-connected/
Keep Ukraine Connected
Summing Up
Conclusions

- Obviously, a war does have a huge impact on connectivity
- Diversifying infrastructure dramatically increases its reliability
- There are still bottlenecks to Internet infrastructure - in particular, power provision
- Quick focused help is extremely helpful
  - The Ukrainian army was helped by Starlink
  - Internet service providers were helped by the community
  - Energy companies were helped by many governments
- The key factor remains the people who keep the systems running
Not covered here

• A cyberwar
  - Application-layer cyber attacks in Ukraine rose 1,300% in early March 2022 compared to pre-war levels, according to Cloudflare
  - Major incidents like hacking into a satellite Internet provider’s network

• Re-routing incidents

• Mutual theft of information
  - All personal data of Russians have already been stolen more than three times — Ukrainian CyberAlliance

• Takeovers of Ukrainian companies
Questions

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