

# The Resilience of the Ukrainian Internet Segment

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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





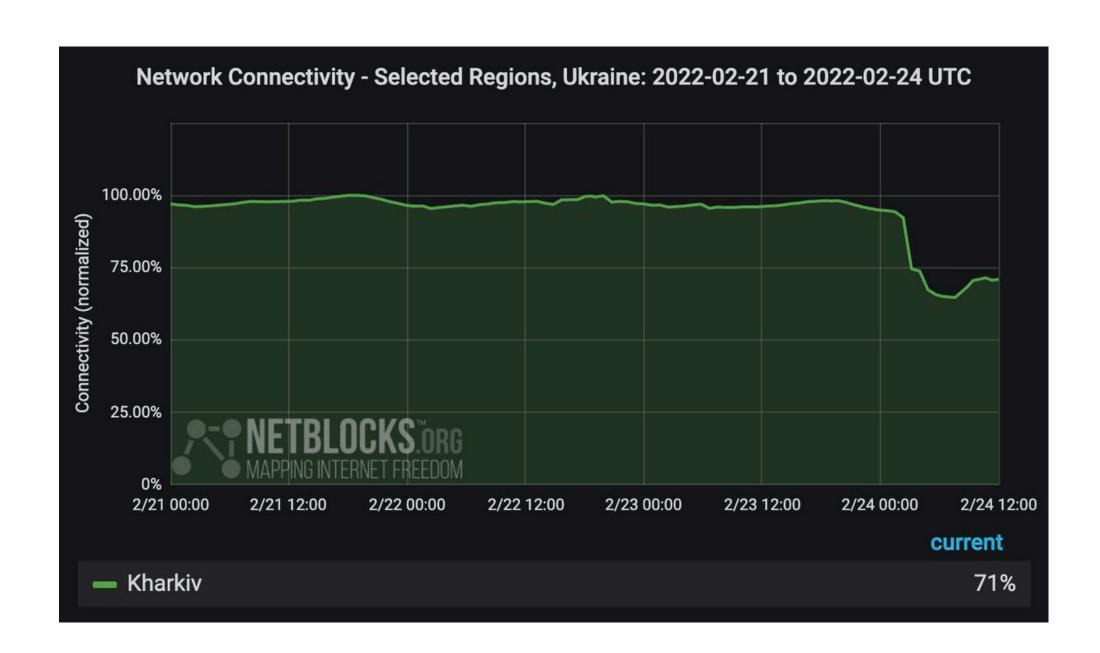


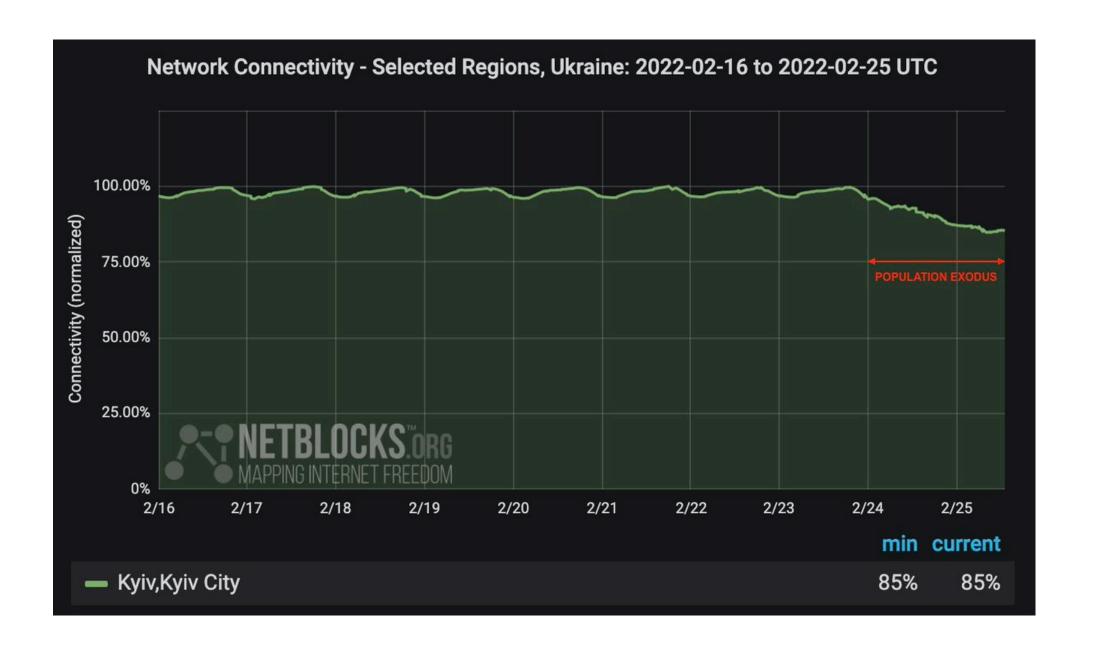


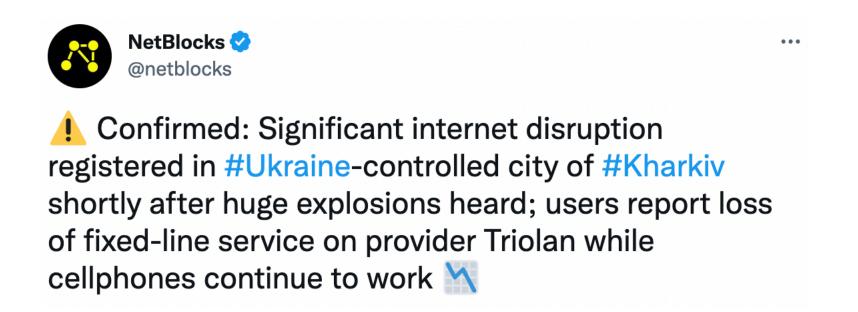


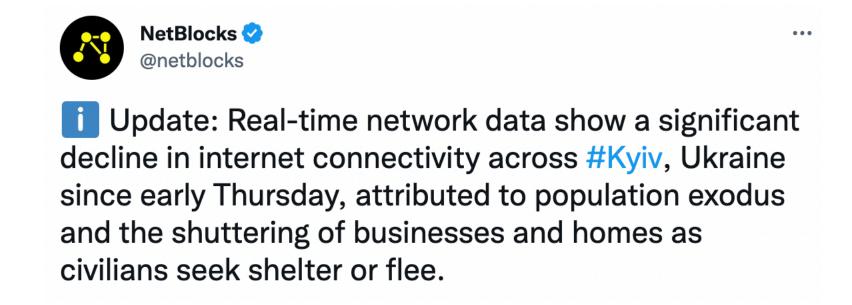
### Internet Disruptions in the First Days of War





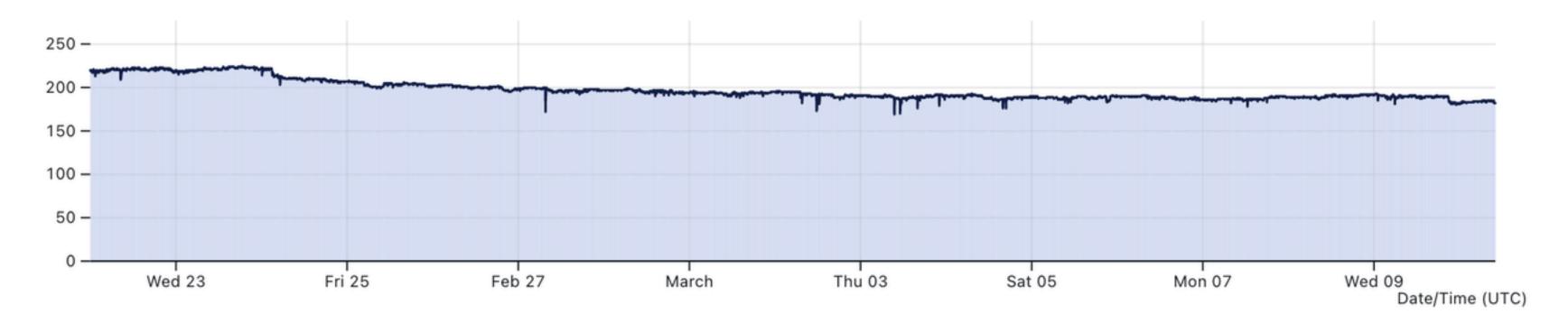






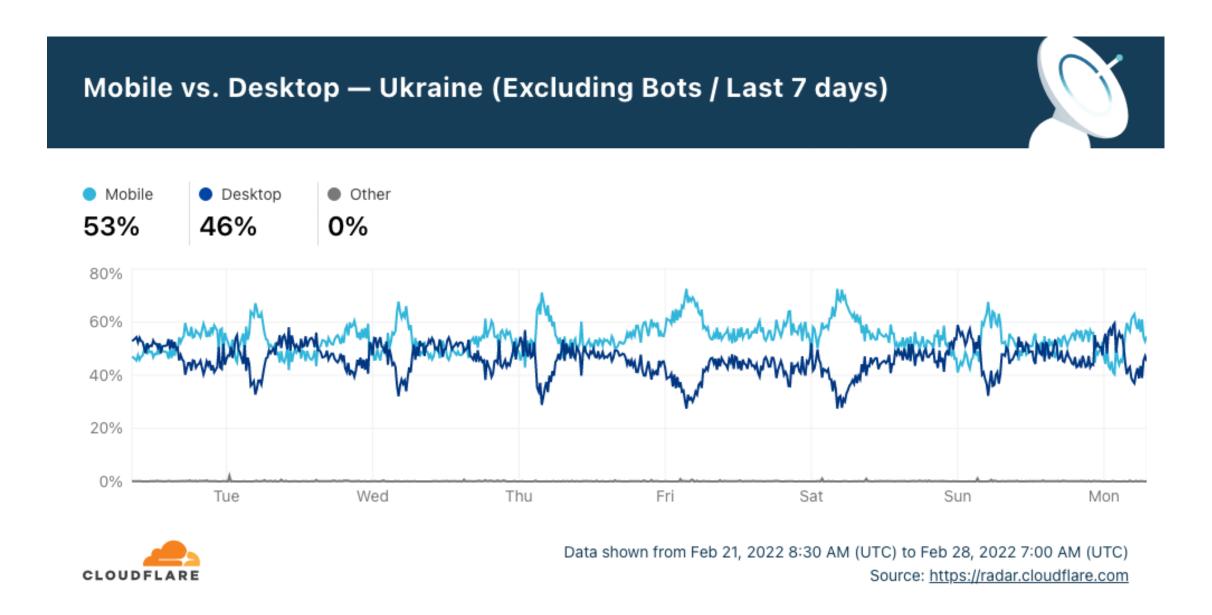
# Degrading of Fixed Line Services





# Connected RIPE Atlas probes

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

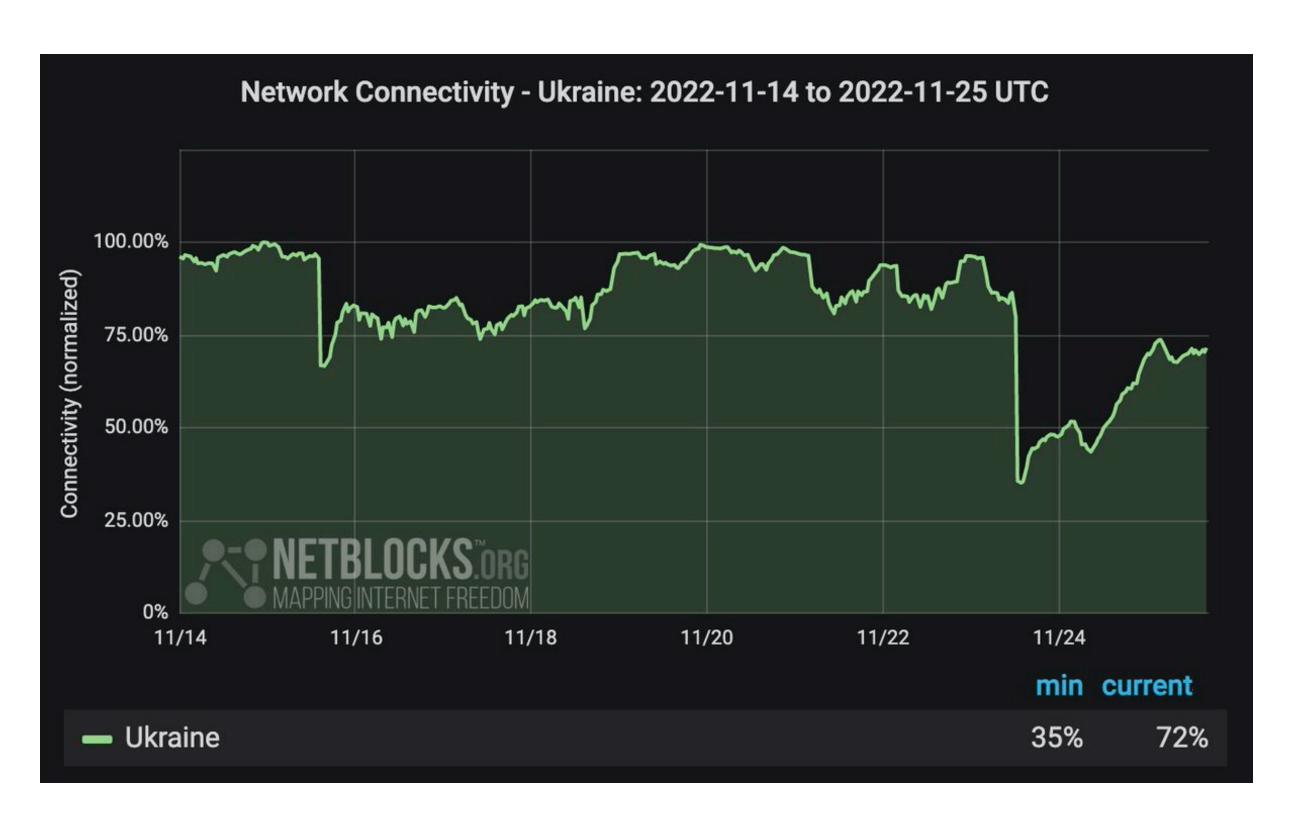


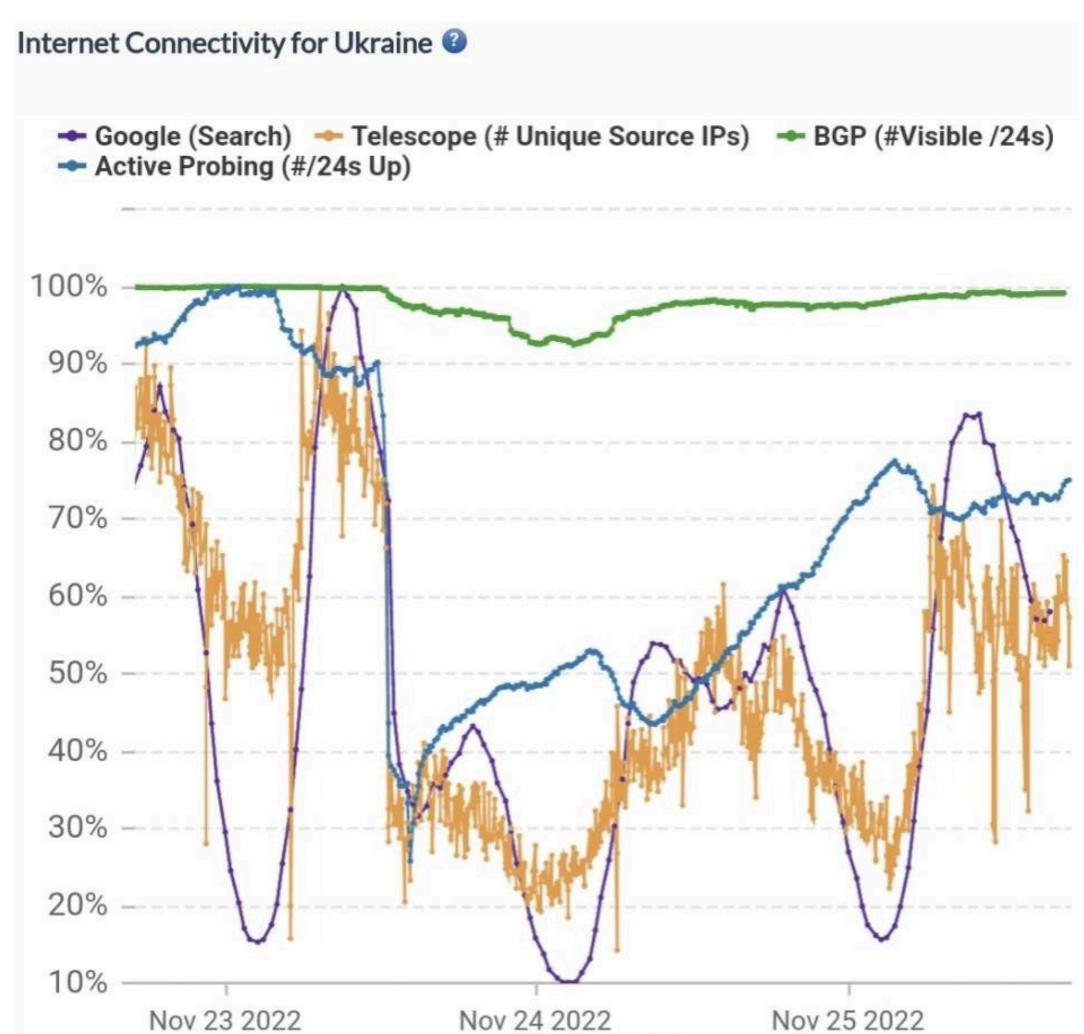
# The war develops

### First Strikes on the Energy Infrastructure



Data from November 24,
 2022

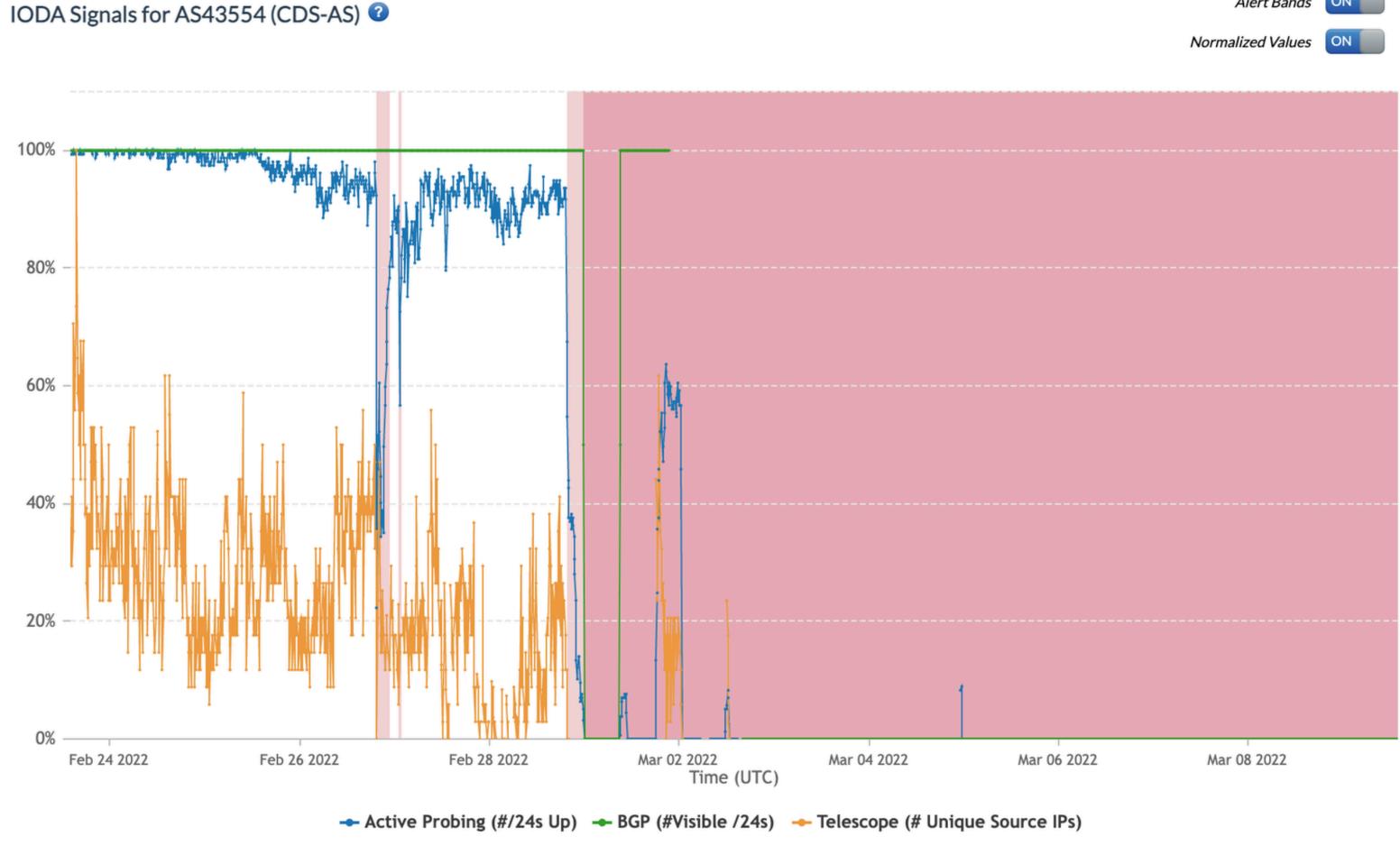




# First Power Interruptions



- Power is an evident bottleneck of the physical Internet infrastructure
- Power outages led to disruptions of communications
   service providers



February 23, 2022 2:05pm — March 9, 2022 2:05pm

# 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)





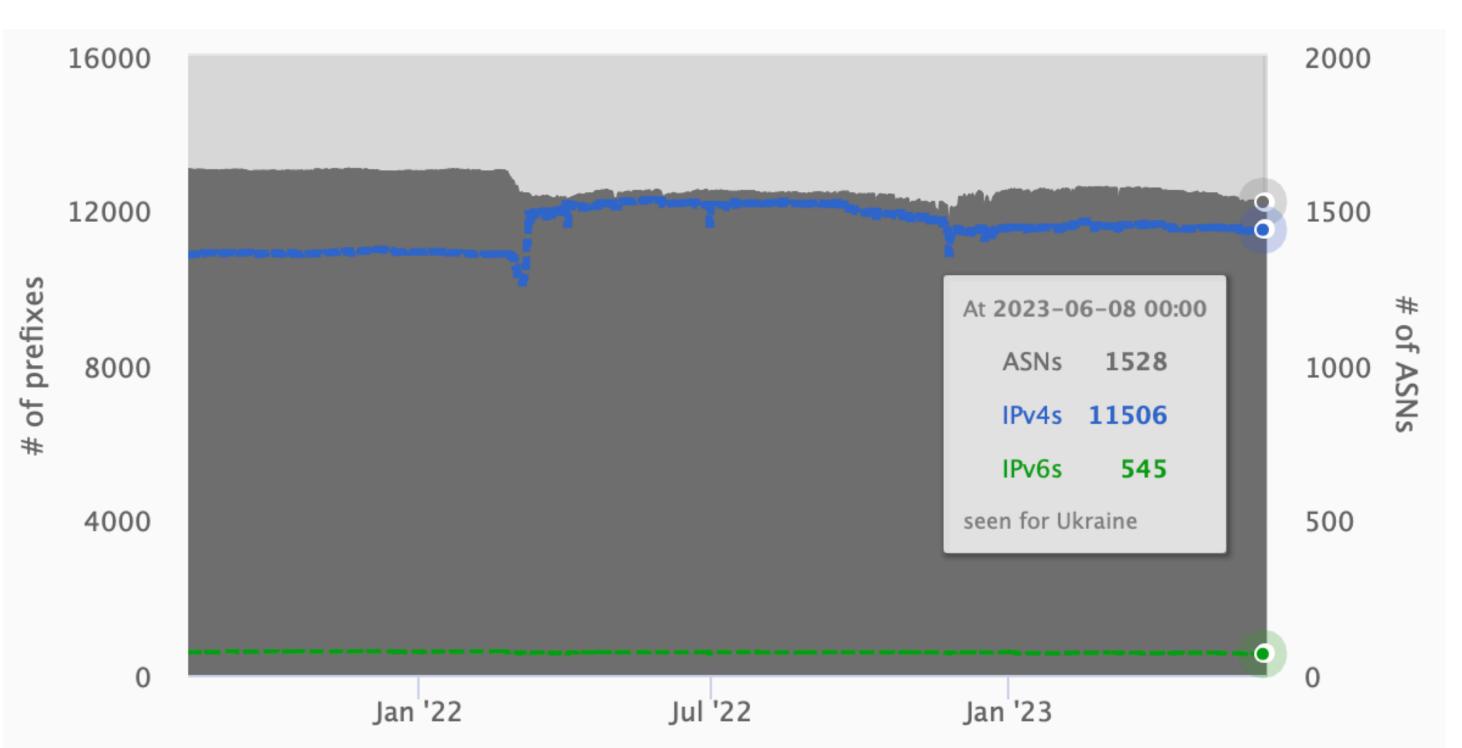
- ✓ Active Probing (#/24s Up)
  ✓ BGP (#Visible /24s)
  ✓ Telescope (# Unique Source IPs)
  ✓ Google (Search)
  - Hits to the Internet's physical infrastructure are sensitive, but fix quickly
  - Strikes on energy infrastructure are much more extensive and have a greater impact
  - Nevertheless, the industry recovered relatively quickly in each case
  - Ukraine's counterattacks repeatedly improve the infrastructural indicators

#### RIPE NCC Data



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

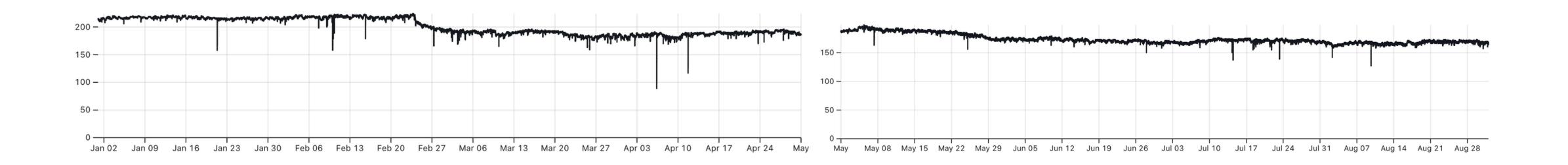
- Small drop-offs as a result of strikes on cable infrastructure
- Significant dropouts from power system failures
- Unavoidable recovery after
- Counterattacks improve results
- Prolonged fighting in a narrow area along the front line worsens them

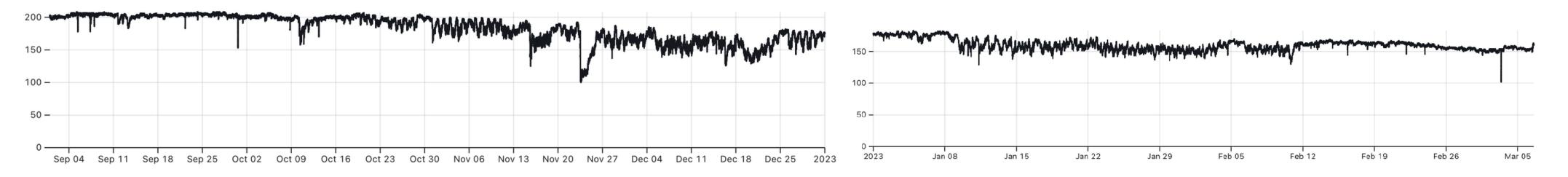


https://stat.ripe.net/ui2013/widget/visibility#w.resource=ua

## RIPE Atlas probes



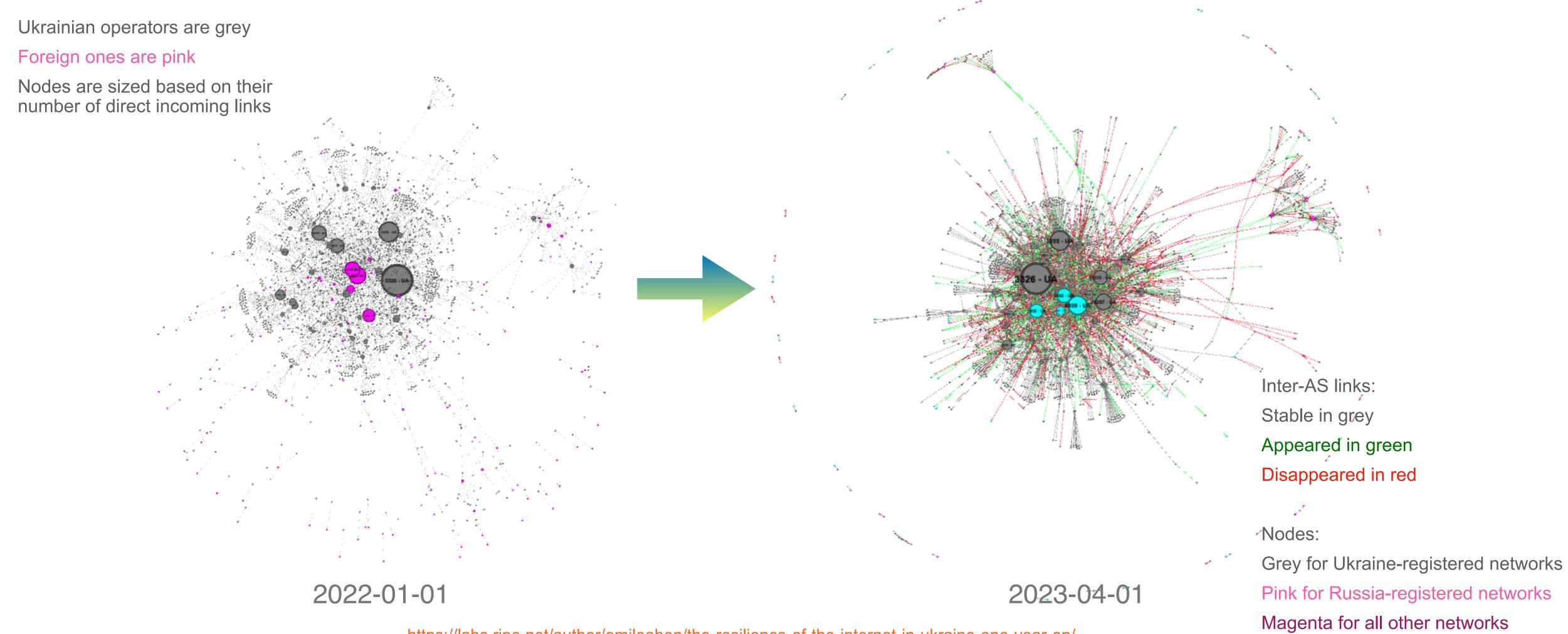




- RIPE Atlas is one of the main measurement tools of the RIPE NCC
- These graphs show the change in the total number of RIPE Atlas probes in Ukraine since the beginning of the war
  - Keep in mind that resuming probe operation is often not a priority for operators restoring their operations

## Ukrainian Internet Structure by RIS



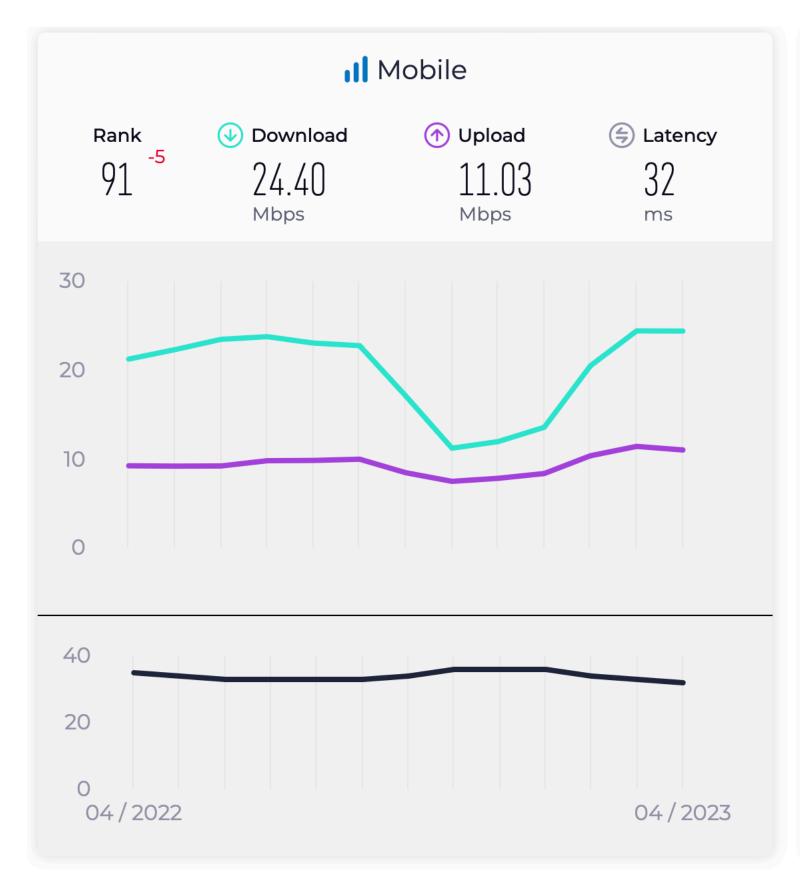


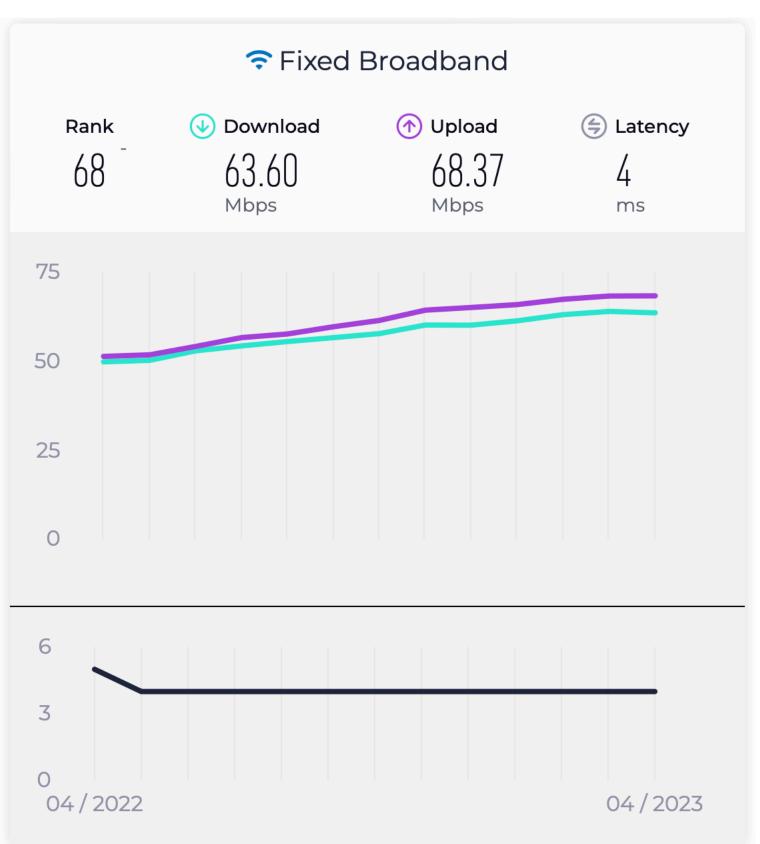
https://labs.ripe.net/author/emileaben/the-resilience-of-the-internet-in-ukraine-one-year-on/

# Ookla's glance



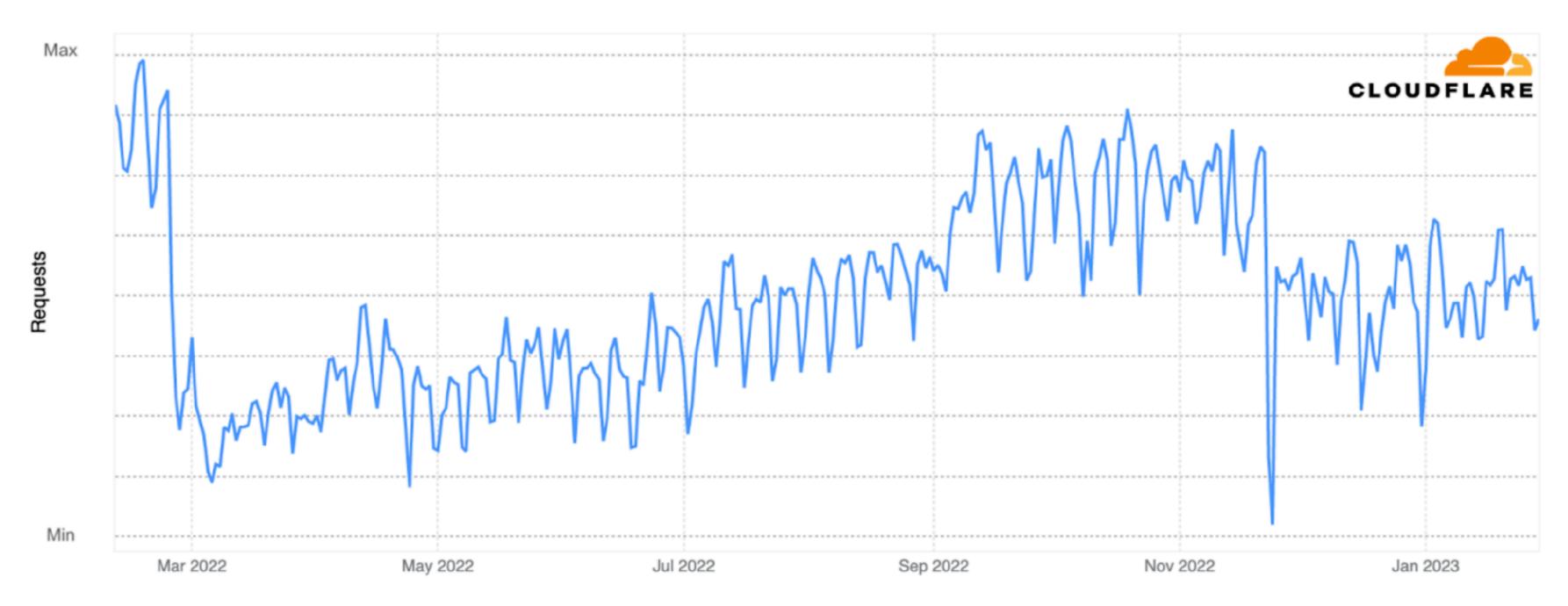
- Mobile services are more sensitive to power outages
- Industry continues
   evolutionary growth
   despite war





#### 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

#### Top 10 least concentrated markets for end-user per network (ASN)

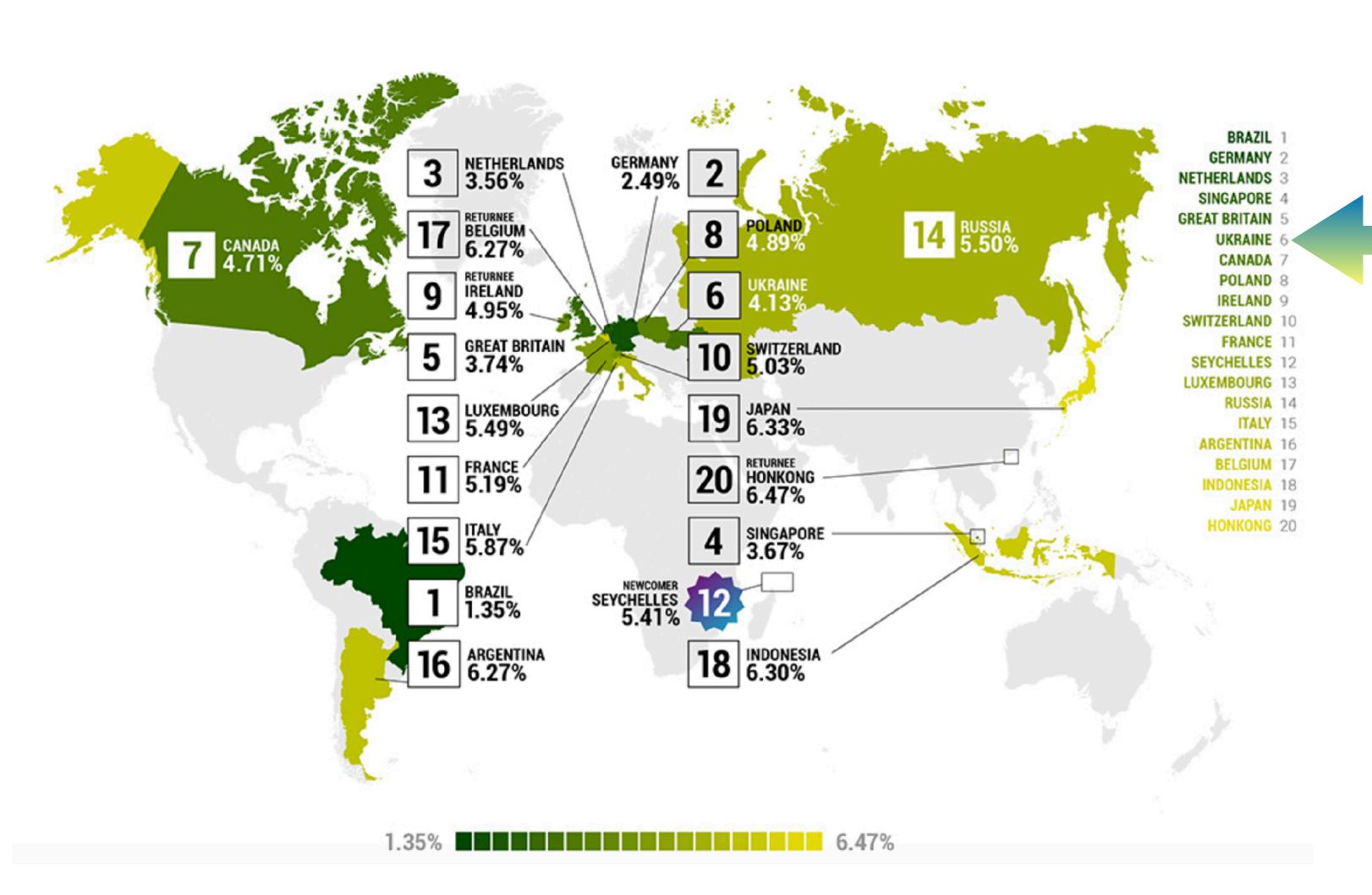
Country		нні	
1	Brazil	0.018	
2	Russia	0.047	
3	United States	0.05	
4	Ukraine	0.052	
5	Lebanon	0.067	
6	Singapore	0.069	
7	Albania	0.072	
8	Guadelope	0.081	
9	South Africa	0.083	
10	Japan	0.087	

### Hight Fault tolerance



2022 Map of IPv4 Top 20 Fault Tolerant Countries

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

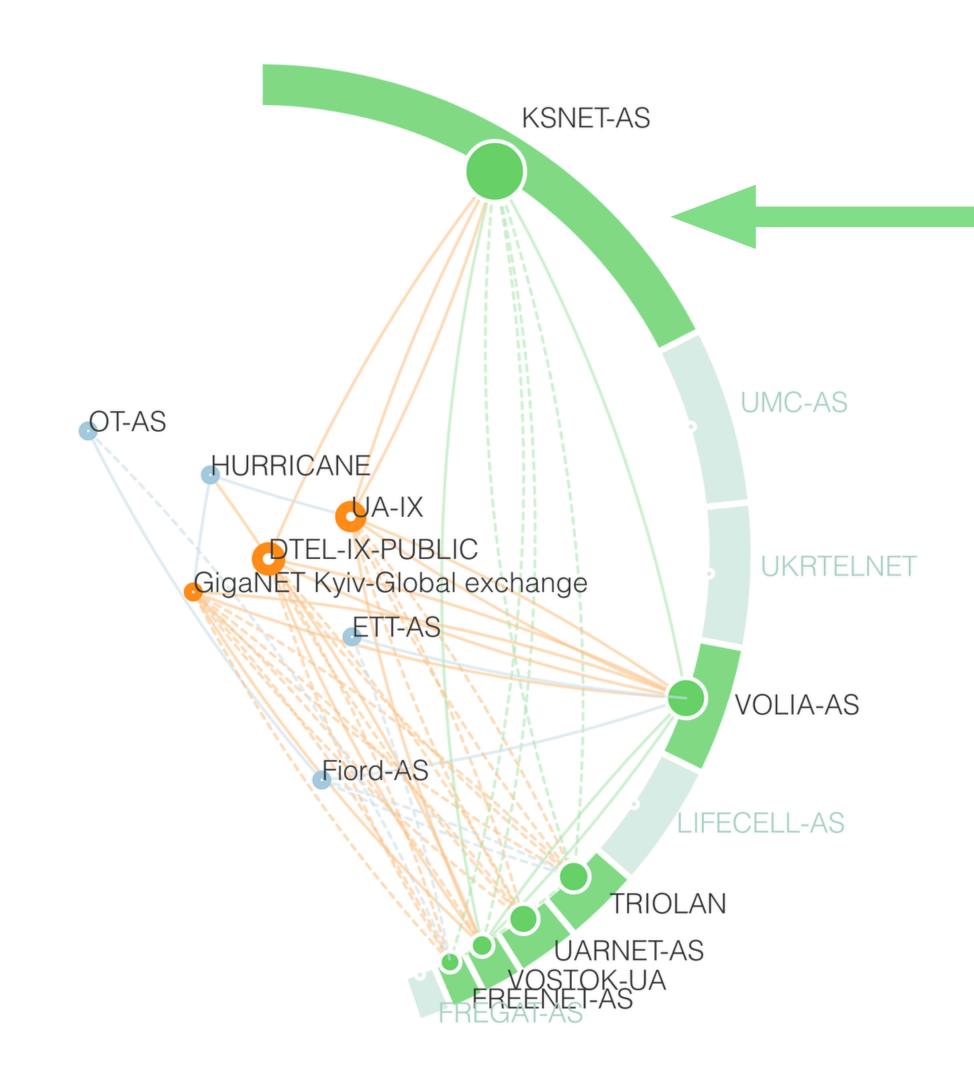


#### Interconnection in Ukraine





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



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

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

#### Ukrainian IXPs



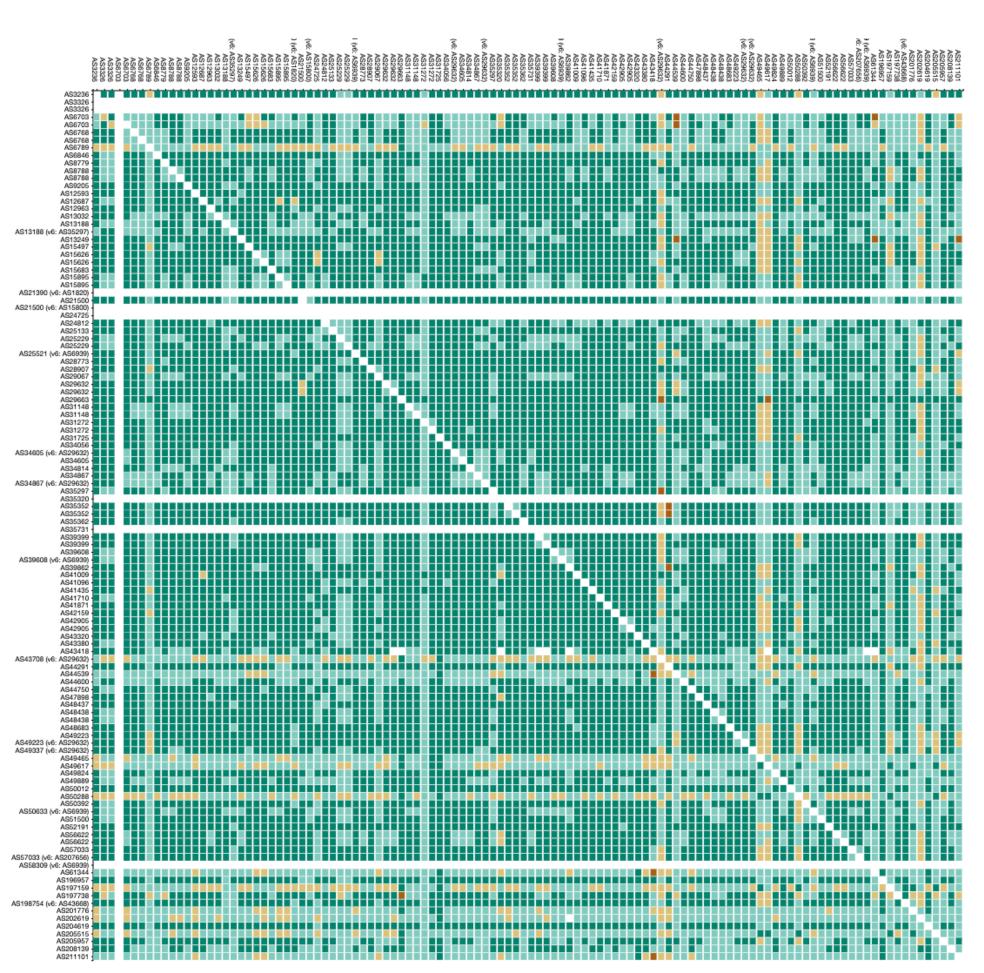
Name	Media Type	Country	City	Network
GigaNET Kyiv Giganet Internet exchange network	Ethernet	UA	Kyiv	174
DTEL-IX Digital Telecom Internet Exchange	Ethernet	UA	Kiev	166
<u>UA-IX</u> Ukrainian Internet Exchange	Ethernet	UA	Kiev	128
PITER-IX Kiev PITER-IX Kiev	Ethernet	UA	Киев	66
1-IX Internet Exchange 1-IX Internet Exchange	Ethernet	UA	Kyiv	39
GigaNET Odessa GigaNET Odessa local exchange	Ethernet	UA	Kiev	11
CLOUD-IX KIEV CLOUD-IX KIEV	Multiple	UA	Kiev	10
GigaNET Kharkov GigaNET Kharkov local exchange	Ethernet	UA	Kharkov	9
<u>_VIV-IX</u> _viv Internet Exchange	Ethernet	UA	Lviv	9
I <u>F-IX</u> IVANO-FRANKIVSK INTERNET EXCHANGE	Ethernet	UA	Ivano-Frankivsk	8
CLOUD-IX KHA	Multiple	UA	Kharkov	6
Crimea-IX Crimea-IX	Ethernet	UA	Simferopol	6
MESH-IX Mesh Internet Exchange	Ethernet	UA	Mariupol	5
RUDAKI-IX RUDAKI INTERNET EXCHANGE	Ethernet	UA	Kyiv	5
Kherson Traffic Exchange Kherson Traffic Exchange	Ethernet	UA	Kherson	4
kremen-IX	Ethernet	UA	Kremenchuk	3
<u>DN-IX</u> Donetsk Internet eXchange	Ethernet	UA	Donetsk	2
KM-IX Khmelnitskiy Internet Exchange Point	Ethernet	UA	Khmelnitskiy	2
SerinIX IX SerinIX Internet Exchange	Ethernet	UA	Kiev	1



19 IXPs(1 in Crimea)

#### Ukrainian IXPs

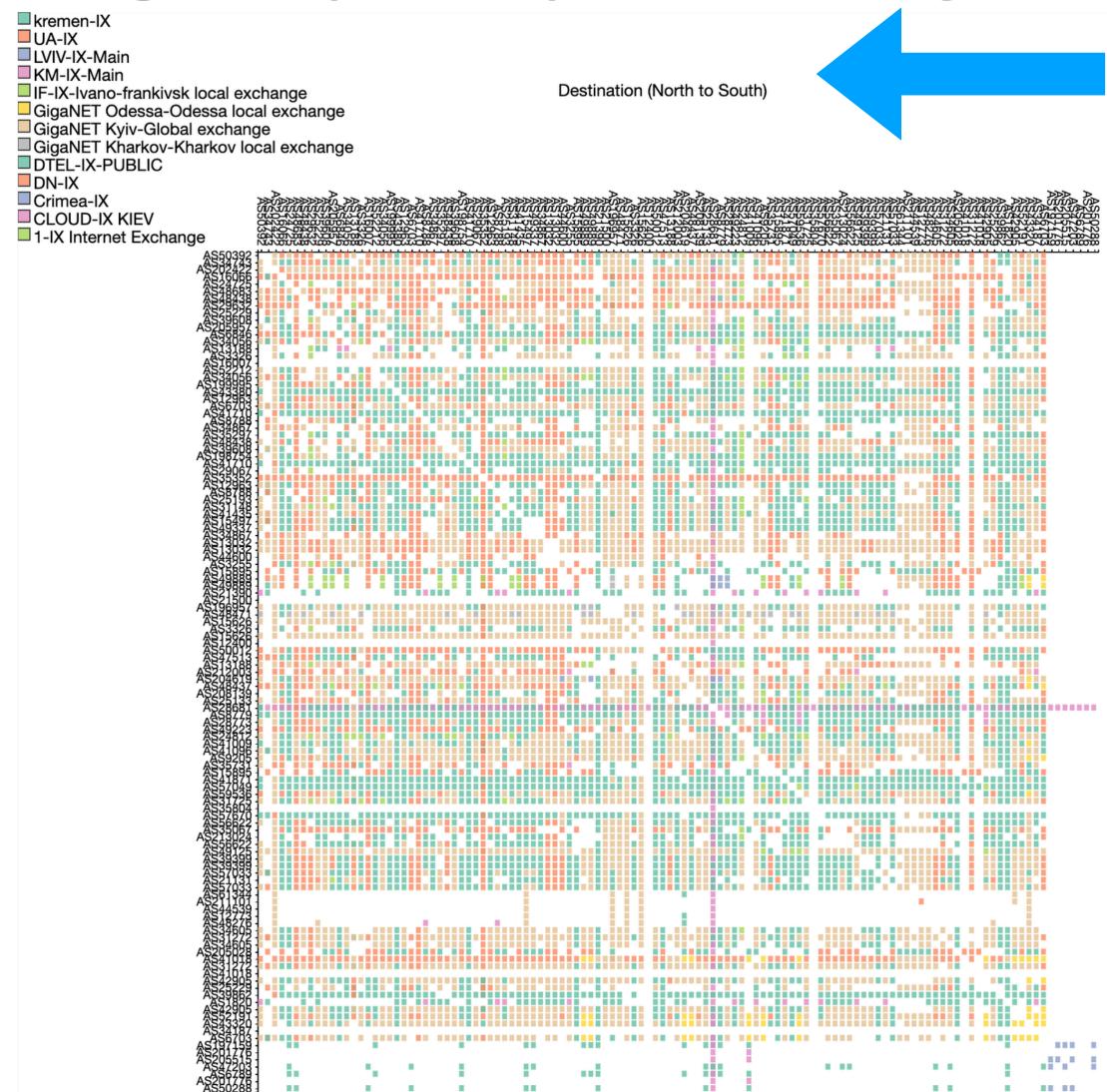




- Each cell here: A path between RIPE Atlas probes in Ukraine
- The majority of these paths are mediated by IXPs (the total of coloured cells)
- Many different IXPs are used, indicating that there is not a single dominant IXP

#### 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
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# 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



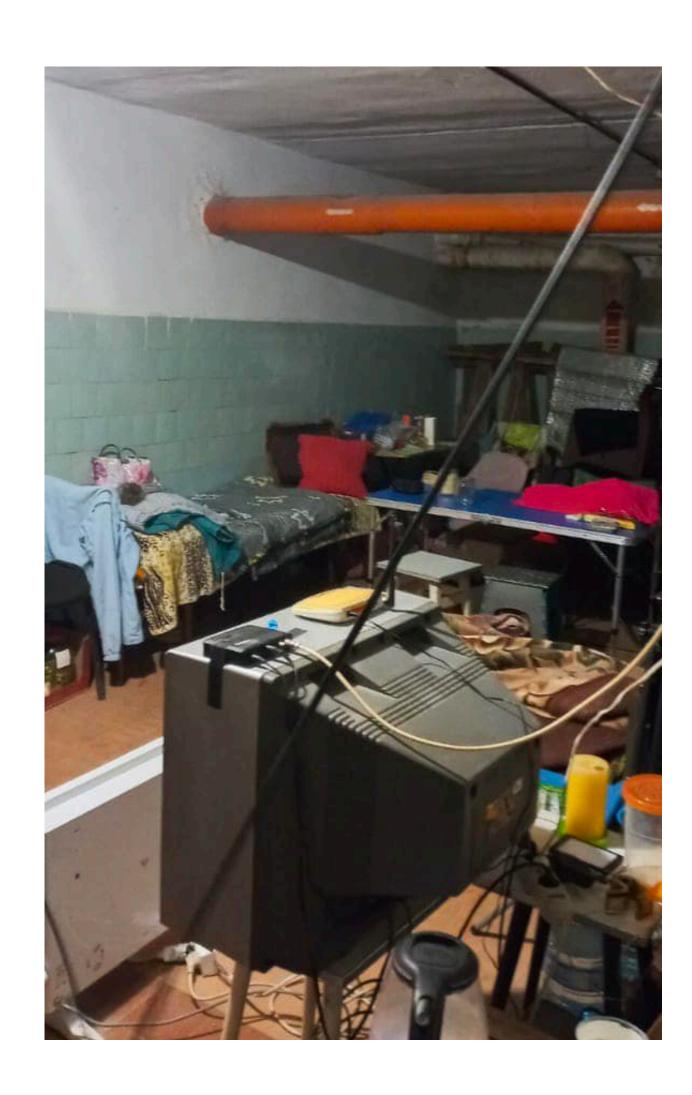
- After major strikes on energy infrastructure, it took one-two week almost to regain the quality of service for small and mediumsized ISPs
  - Sadly, major missile strikes occurred every few days, so a full recovery in between was impossible
- However, there were still significant disruptions in the 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



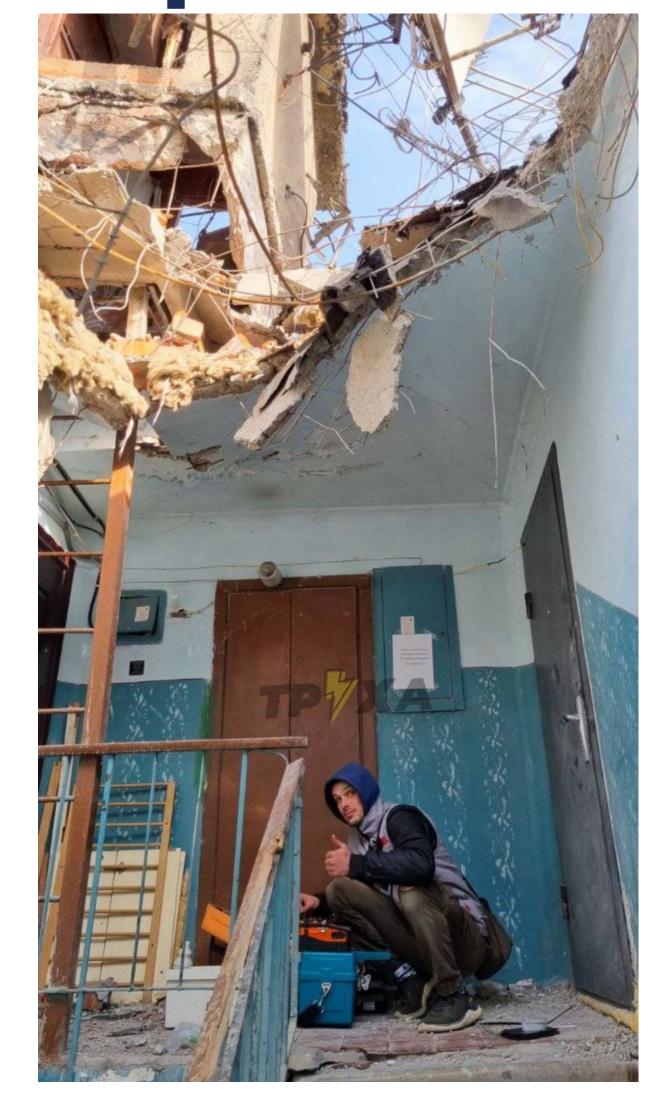
# Operators During the War



- 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



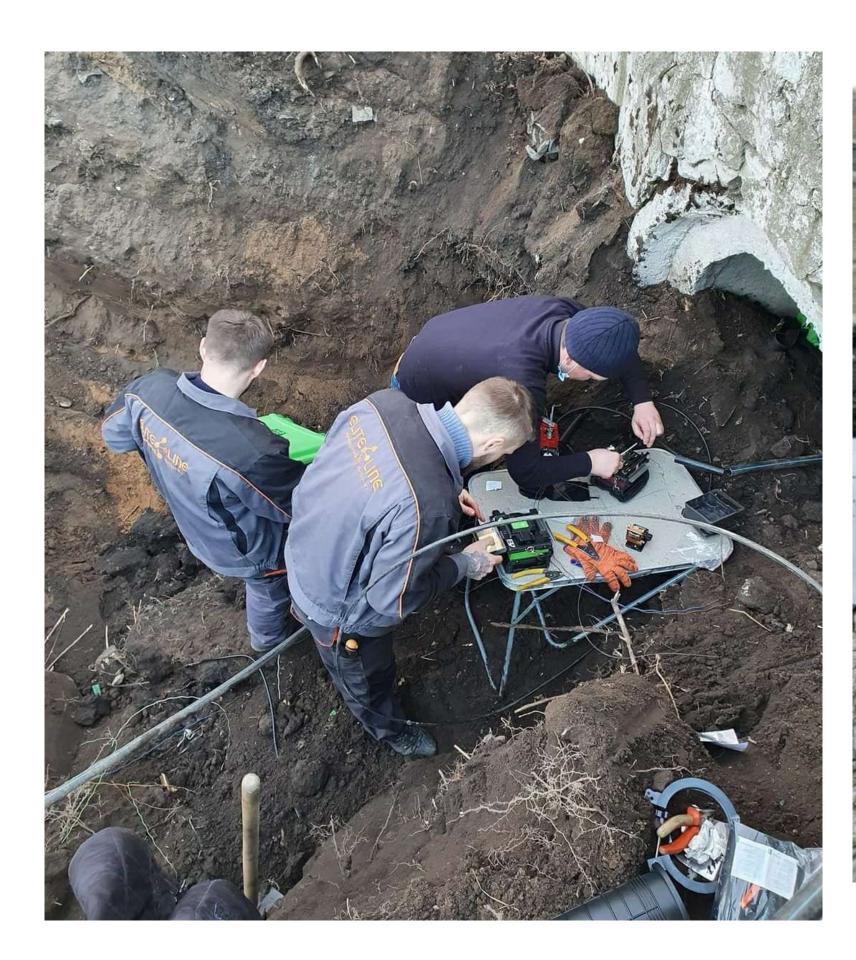






# People: ISPs









# People: power companies











#### Labor feat



- Weekend work
- Work with a break only for sleep
- Workers often slept on the jobsite



# Help from Abroad

#### Starlink





# 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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