



RIPE NCC

RIPE NETWORK COORDINATION CENTRE

Internet in Ukraine

Over A Year Of War

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Expectation vs Reality



- Expectation: Rapid destruction of Ukrainian Internet
- Reality: Remarkable resilience

- Why?
- Elements of resilience
 - Distributed/decentralised Internet at multiple levels
 - Humans!



Elements Of Resiliency

Ukrainian End-User Market Overview



- One of the least concentrated markets worldwide
 - Herfindahl-Hirschman index (HHI) based on users per ASN
 - 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
- Update 2023-01-01 : Ukraine at 0.074

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

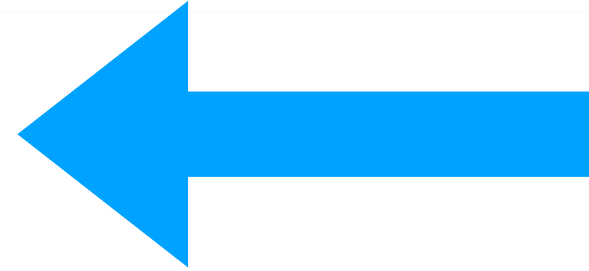
	Country	HHI
1	Brazil	0.018
2	Russia	0.047
3	United States	0.05
4	<u>Ukraine</u>	<u>0.052</u>
5	Lebanon	0.067
6	Singapore	0.069
7	Albania	0.072
8	Guadelope	0.081
9	South Africa	0.083
10	Japan	0.087

Ukrainian Internet Exchanges (IXPs)

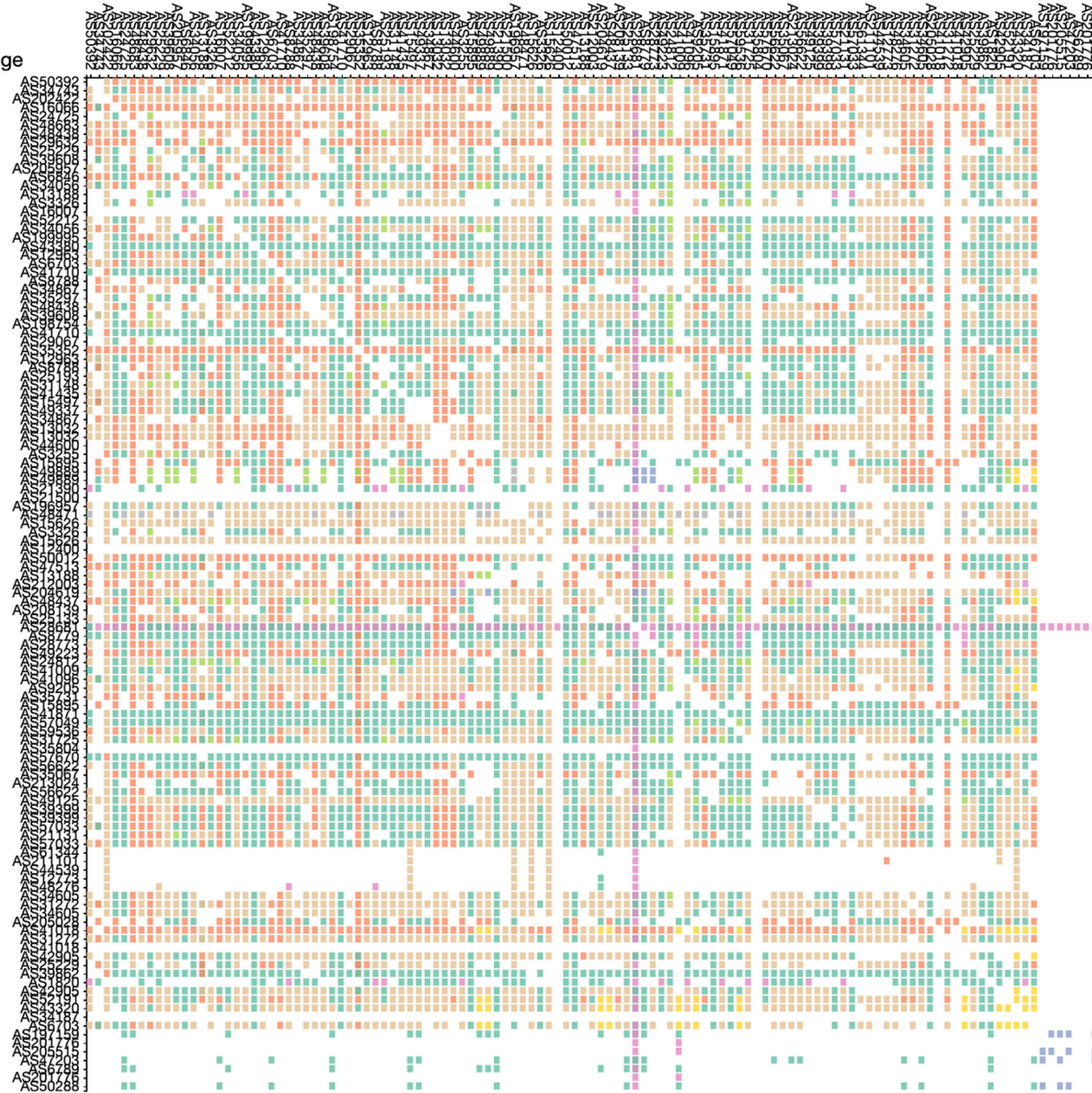


- kremen-IX
- UA-IX
- LVIV-IX-Main
- KM-IX-Main
- IF-IX-Ivano-frankivsk local exchange
- GigaNET Odessa-Odessa local exchange
- GigaNET Kyiv-Global exchange
- GigaNET Kharkov-Kharkov local exchange
- DTEL-IX-PUBLIC
- DN-IX
- Crimea-IX
- CLOUD-IX KIEV
- 1-IX Internet Exchange

Destination (North to South)



13/17 are active between the RIPE Atlas probes in the country



- Mesh between Atlas probes in Ukraine
 - What is between them?
- The majority of these paths are mediated by IXPs (the total of coloured cells)
- Many different IXPs are used, indicating **diversity** in IXPs

People!



Free Internet Access in Bomb Shelters



Despite the drop in revenue, operators have taken on additional social functions



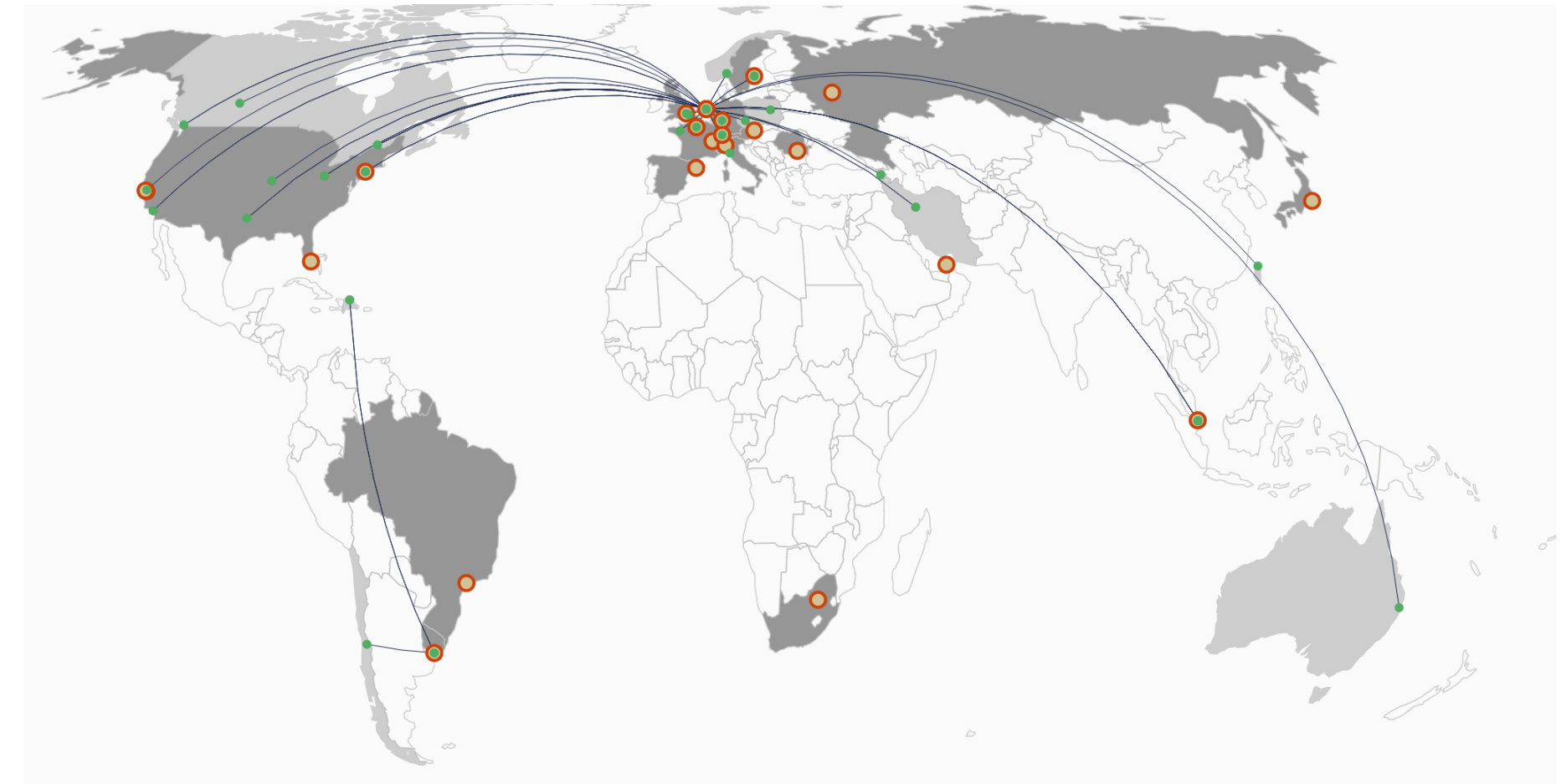


What Network Measurement Data Shows For Ukraine

Our Observation Systems



- RIS
 - Monitors inter-network routing system (BGP)
- RIPE Atlas
 - > 10,000 devices worldwide that monitor local Internet conditions (latency, loss)
- For community, by community





Atlas up/down

Online RIPE Atlas probes in UA

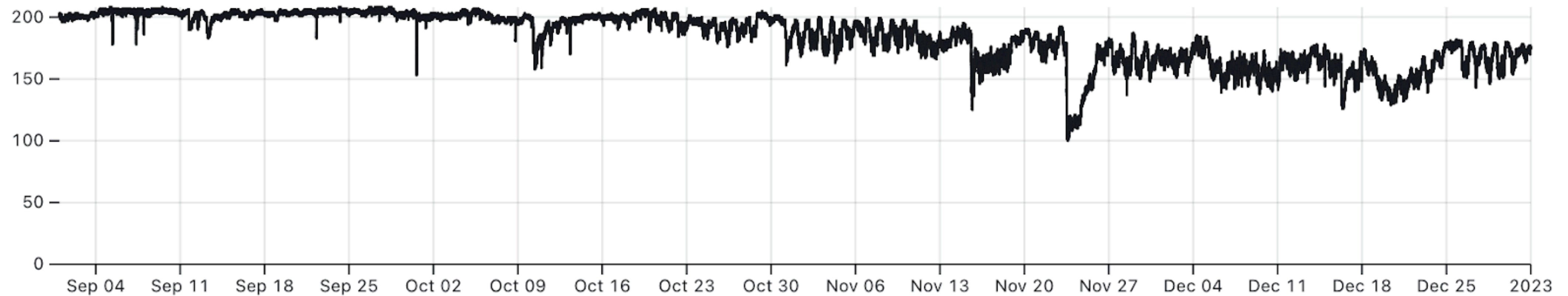


<https://observablehq.com/@ripencc/internet-outages-as-seen-by-ripe-atlas>

Online RIPE Atlas probes in UA



Online RIPE Atlas probes in UA



- 2022-10: Russia starts bombing critical infrastructure
- No power, no Internet

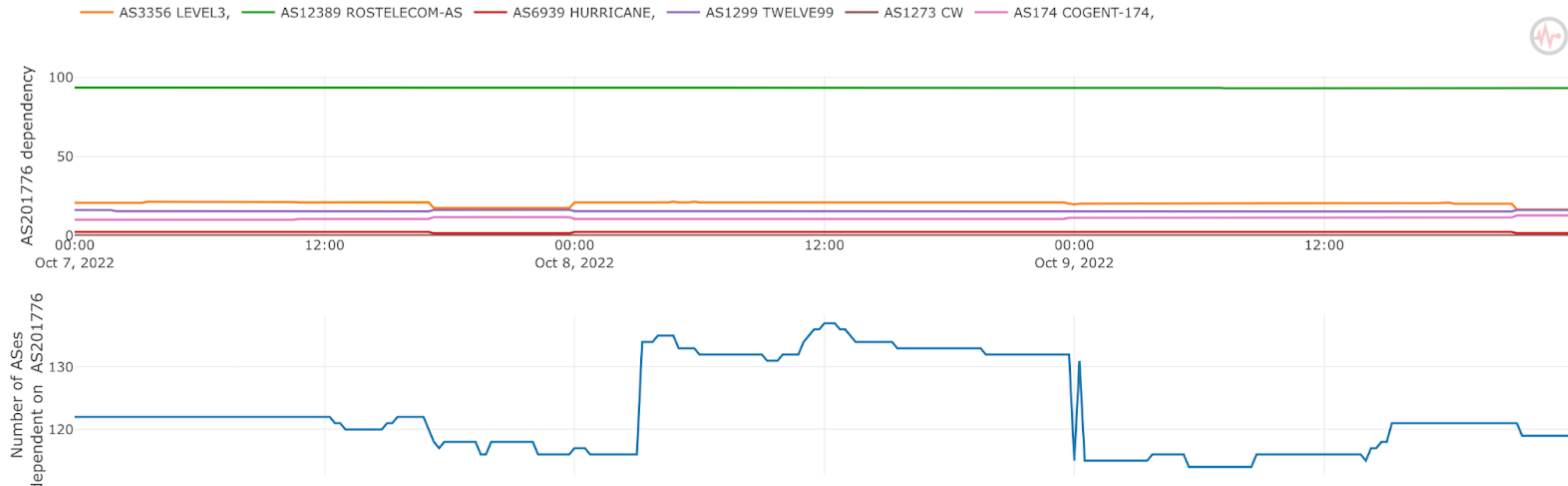


Kinetic warfare and effects on the network

Effects of kinetic warfare



- Notable event: Kerch Bridge Explosion (2022-10-08 03:00 UTC)
- BGP data for **Miranda Media** (from the Internet Health Report)

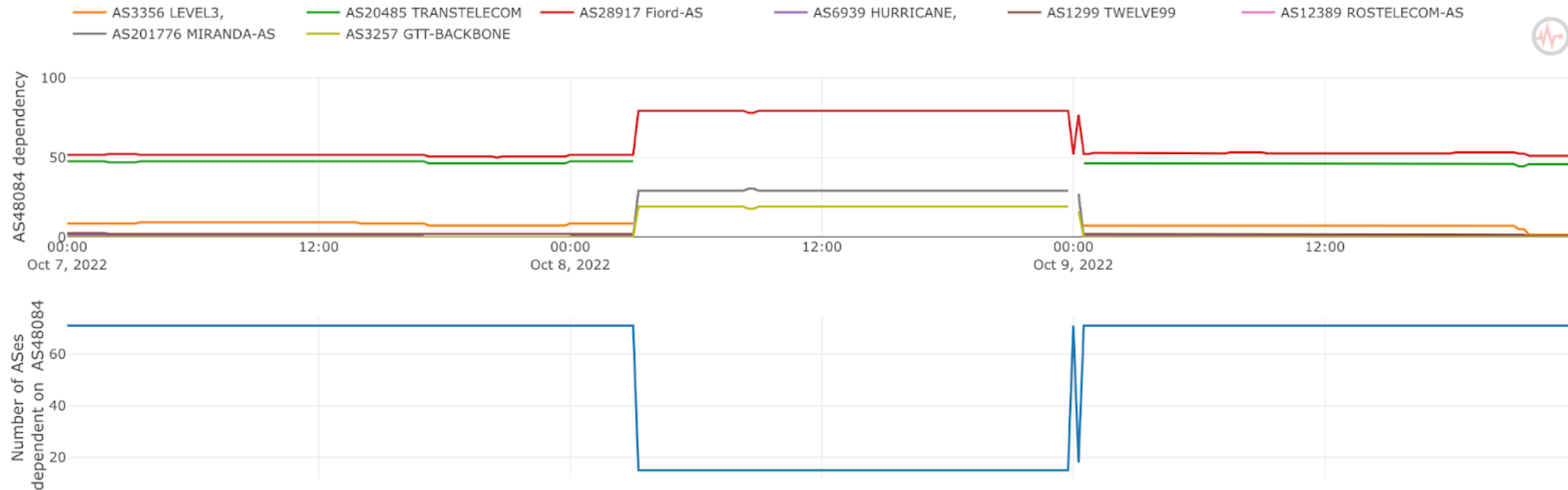


<https://ihr.iijlab.net/ihr/en-us/>

Effects of kinetic warfare



- Notable event: Kerch Bridge Explosion (2022-10-08 03:00 UTC)
- BGP data for **UMLC**

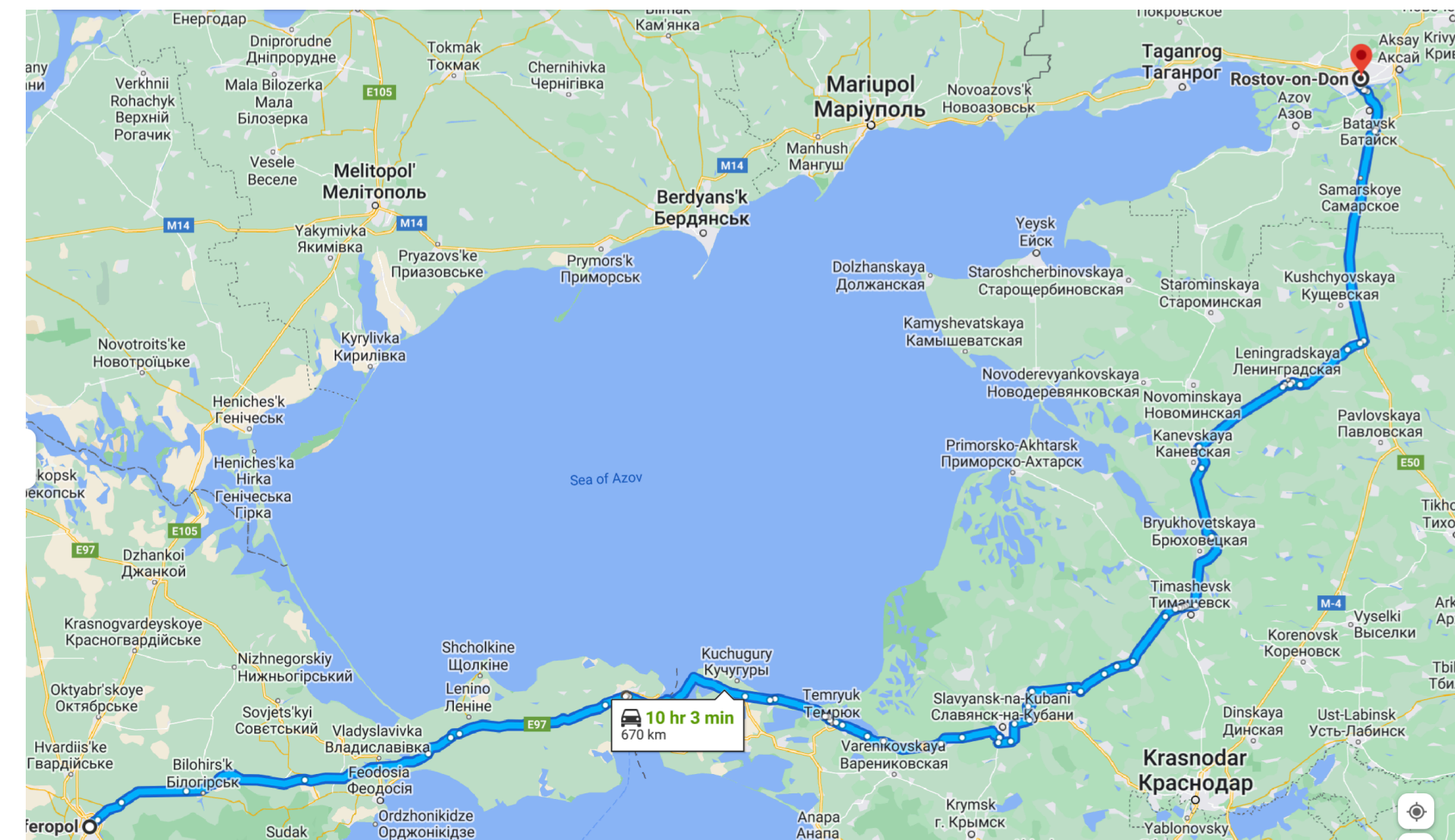
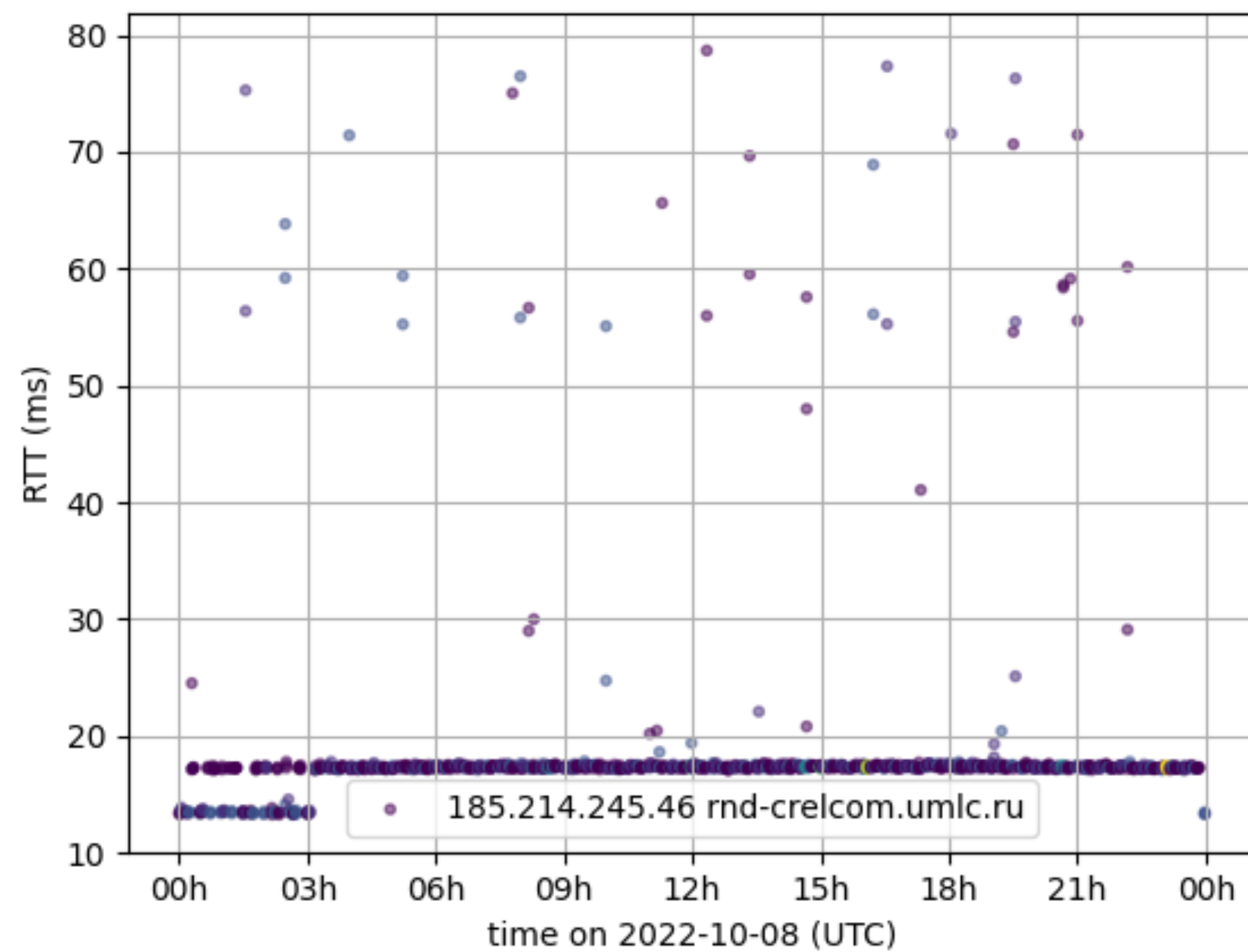


Effects of kinetic warfare



- Notable event: Kerch Bridge Explosion (2022-10-08 03:00 UTC)
- RIPE Atlas traceroutes from Crimea via UMLC

RTTs between probe 12571 and 185.214.245.46



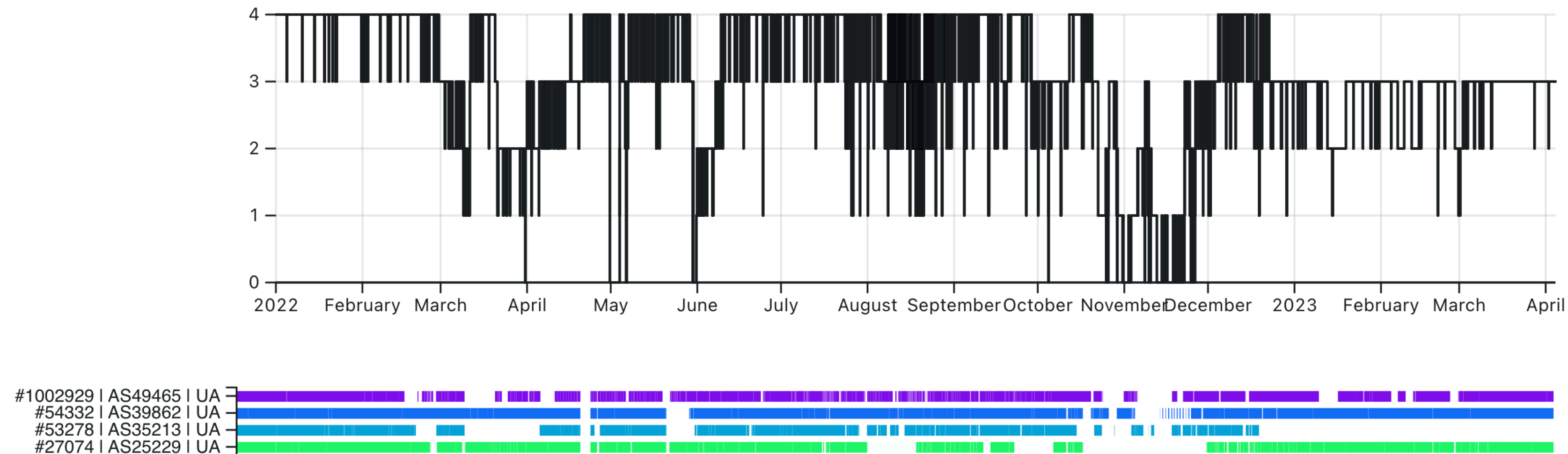


Occupation/ Deoccupation

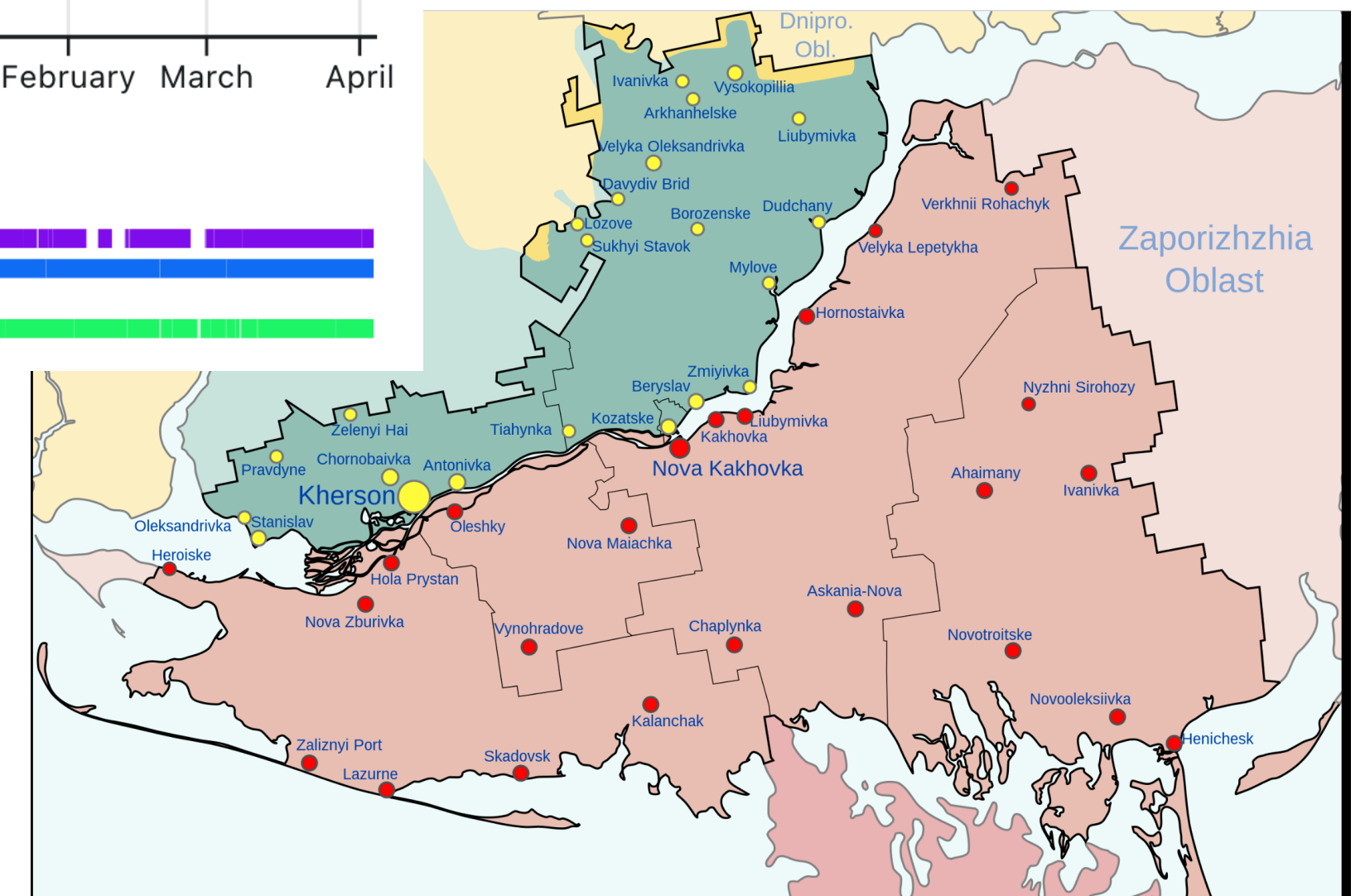
Online probes around Kherson



Probe connectivity



- Probes 50km around Kherson
- Russia-occupied 2 March - 11 Nov

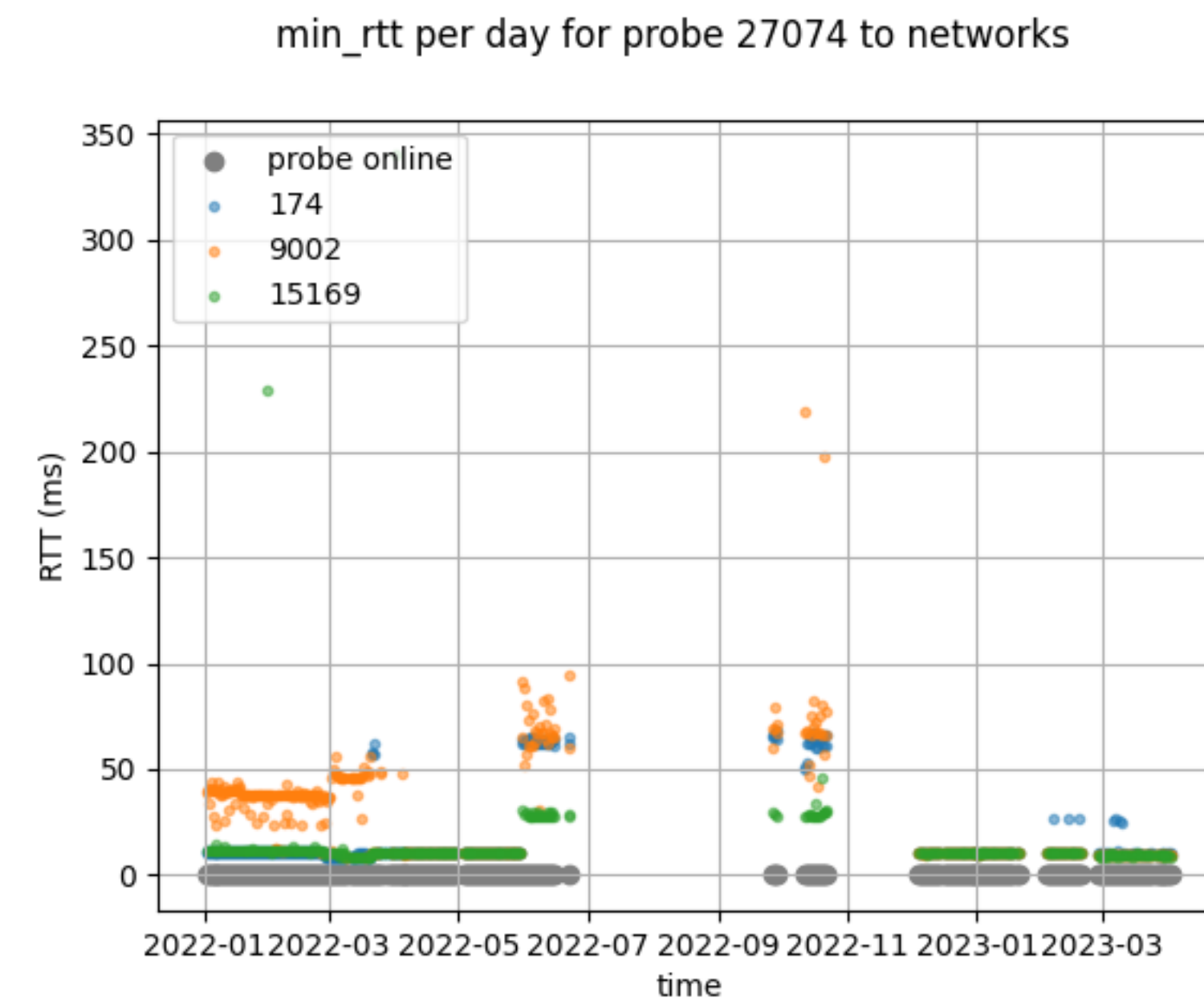
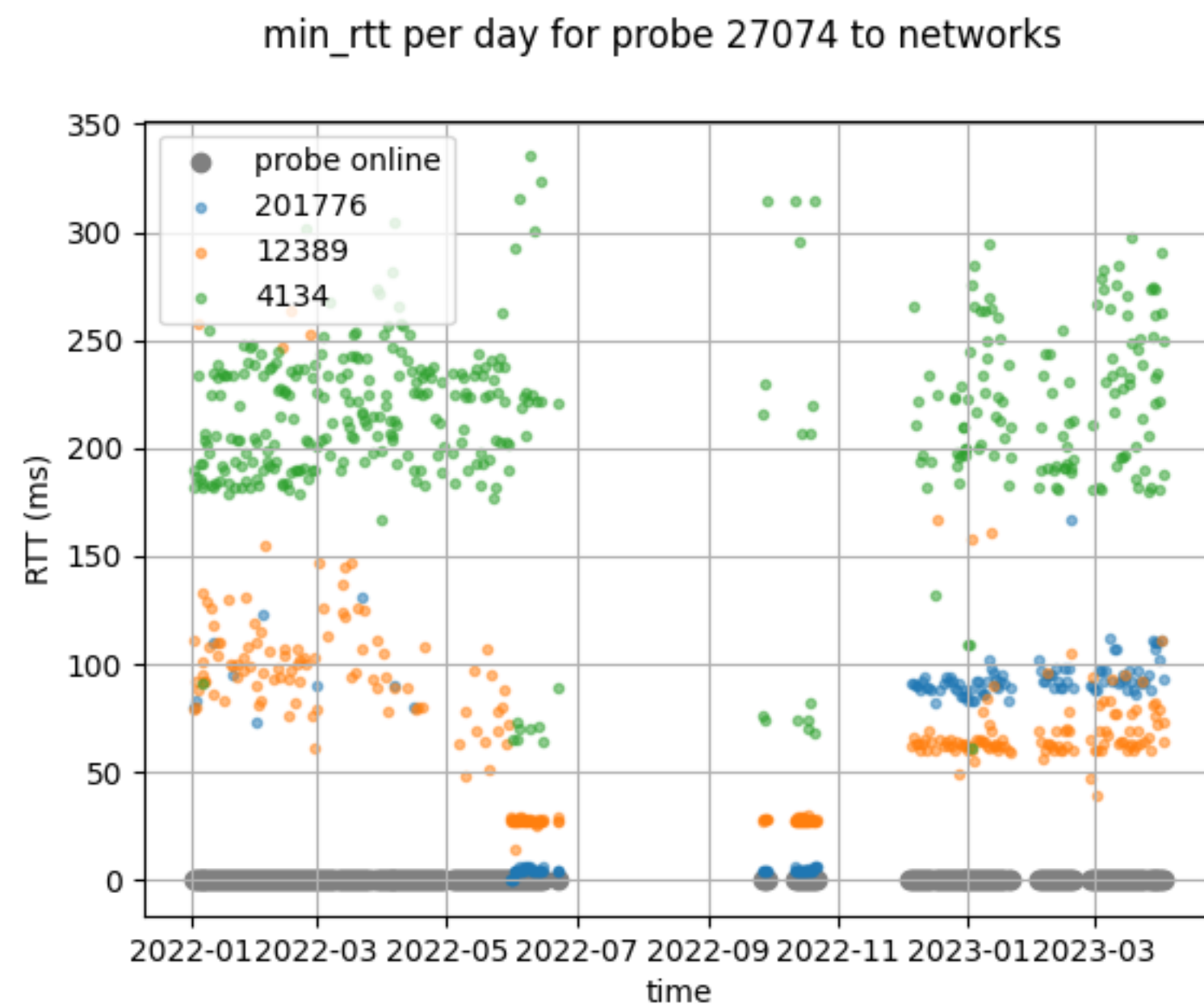


Source: https://en.wikipedia.org/wiki/Russian_occupation_of_Kherson_Oblast

Latencies from Kherson to Internet



- Very different RTT profiles during the occupation
- Lower RTTs to Miranda Media, Rostelecom and China Telecom
- Higher RTTs to Cogent, RETN, Google





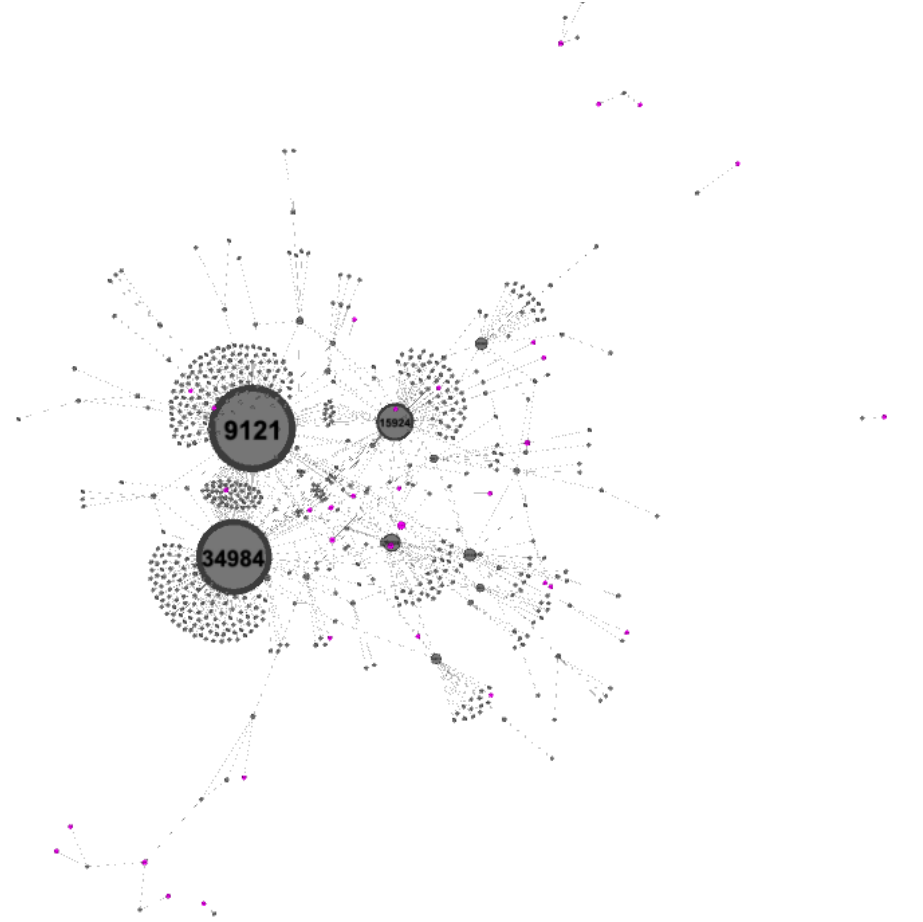
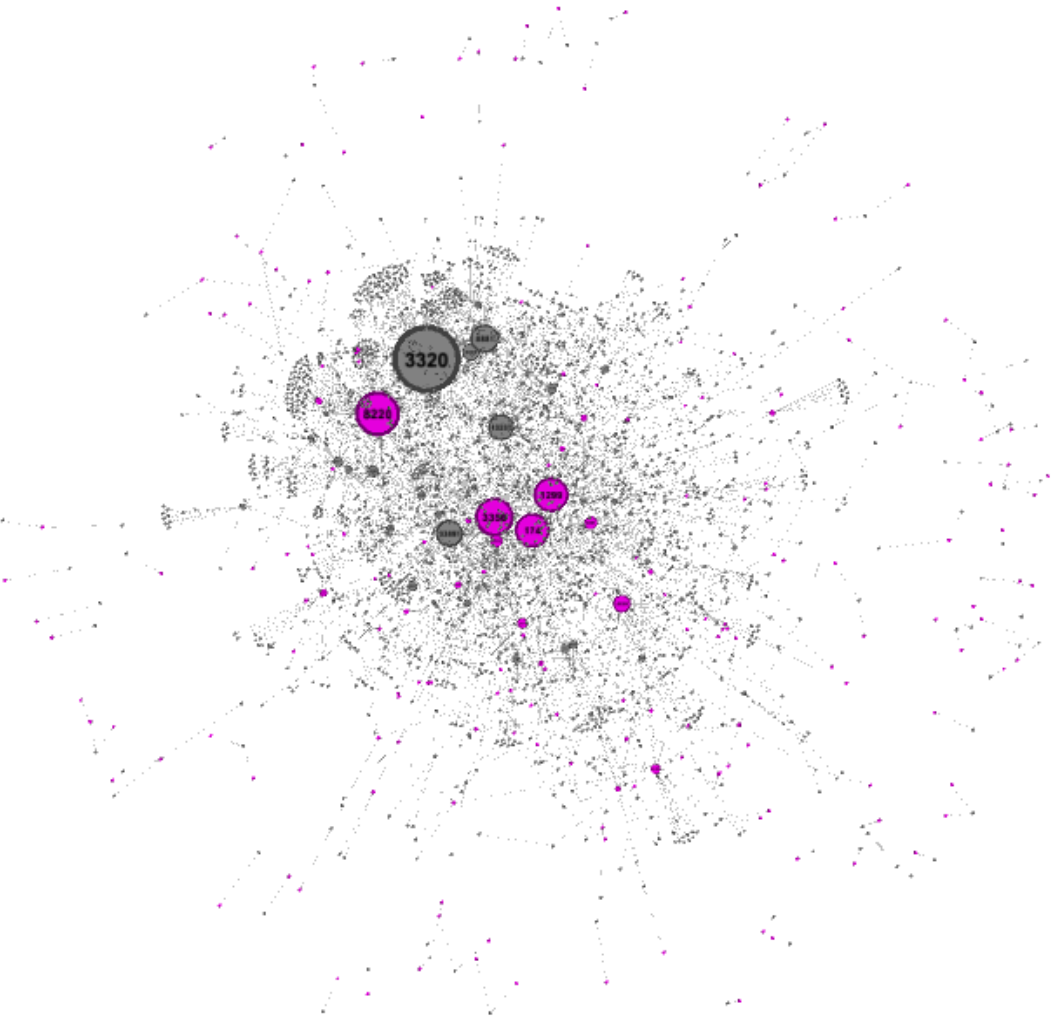
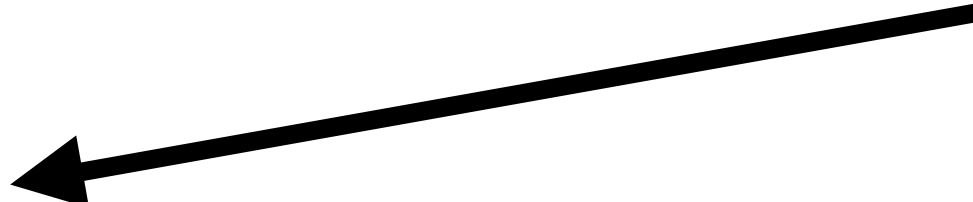
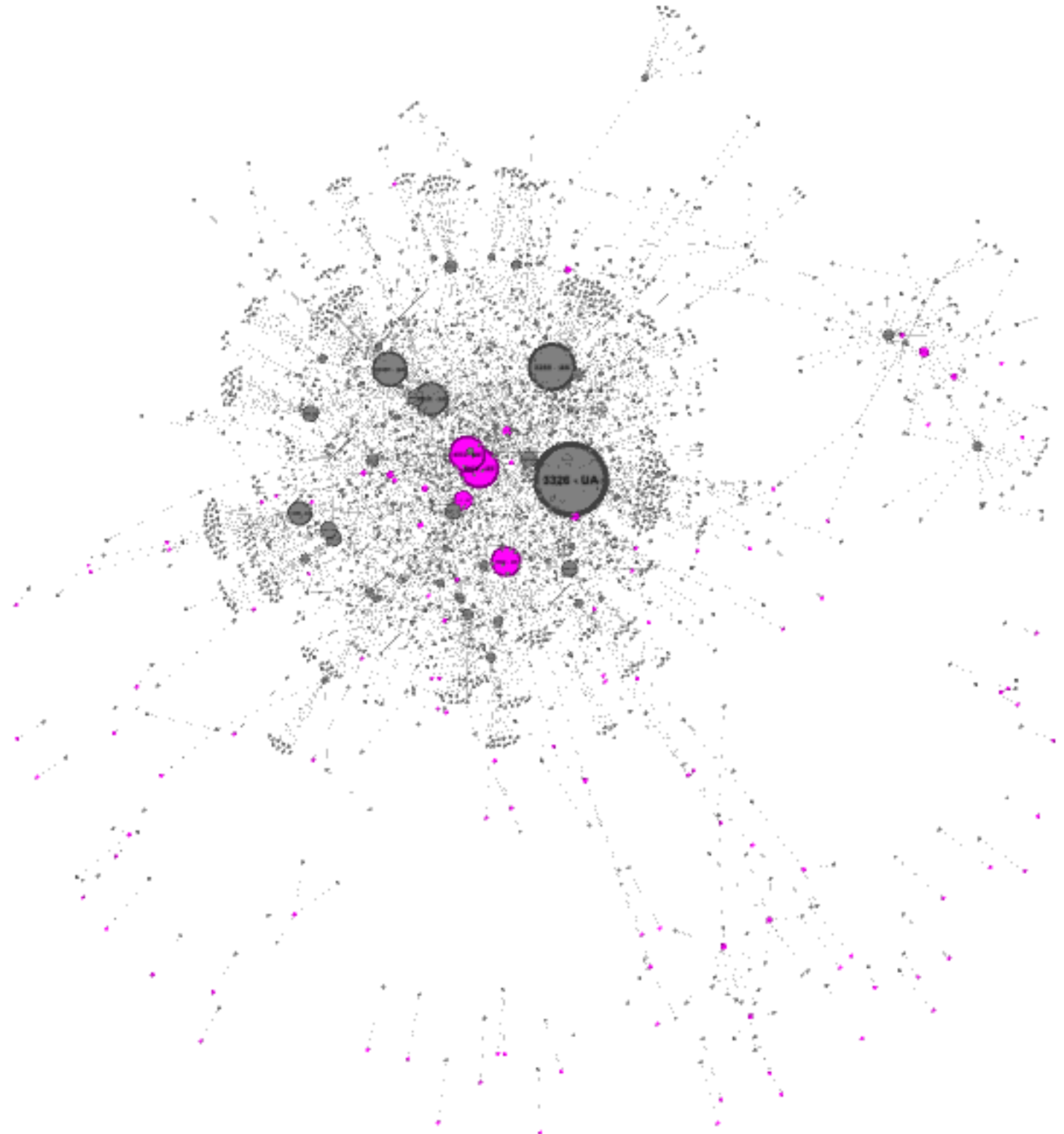
Country Internet Graph Effects

Complexity Of Internet Transit Graph



Which country is which?

Choices: UA,DE,TR



- Size: in-degree
- Color:
 - Domestic (grey)
 - Intl. (pink)

How Is the Ukrainian Internet different now?



	2022-01-01	2023-04-01	Diff
Number of UA ASNs	1781	1677	-110 (-6.2%)
Foreign upstream ASNs	112	99	-13 (-12%)
Country of Registration for Foreign upstream ASNs (Top 5)	RU 48 US 10 NL 8 GB 8 PL 6	RU 21 US 13 PL 10 NL 9 DE 7	
Domestic links	2055	1936	-119 (-5.8%)
Intl. upstream links	662	600	-62 (-9.4%)

- Decrease in ASNs / transit links
- Decrease in international upstream ASNs
 - Primarily Russia
 - almost exclusively connecting occupied territories (Donbas, Crimea)
 - Transits that play an important role
 - Hurricane Electric (AS6939)
 - Cogent (AS174)
 - WNET (AS1820)
 - RETN (AS9002)

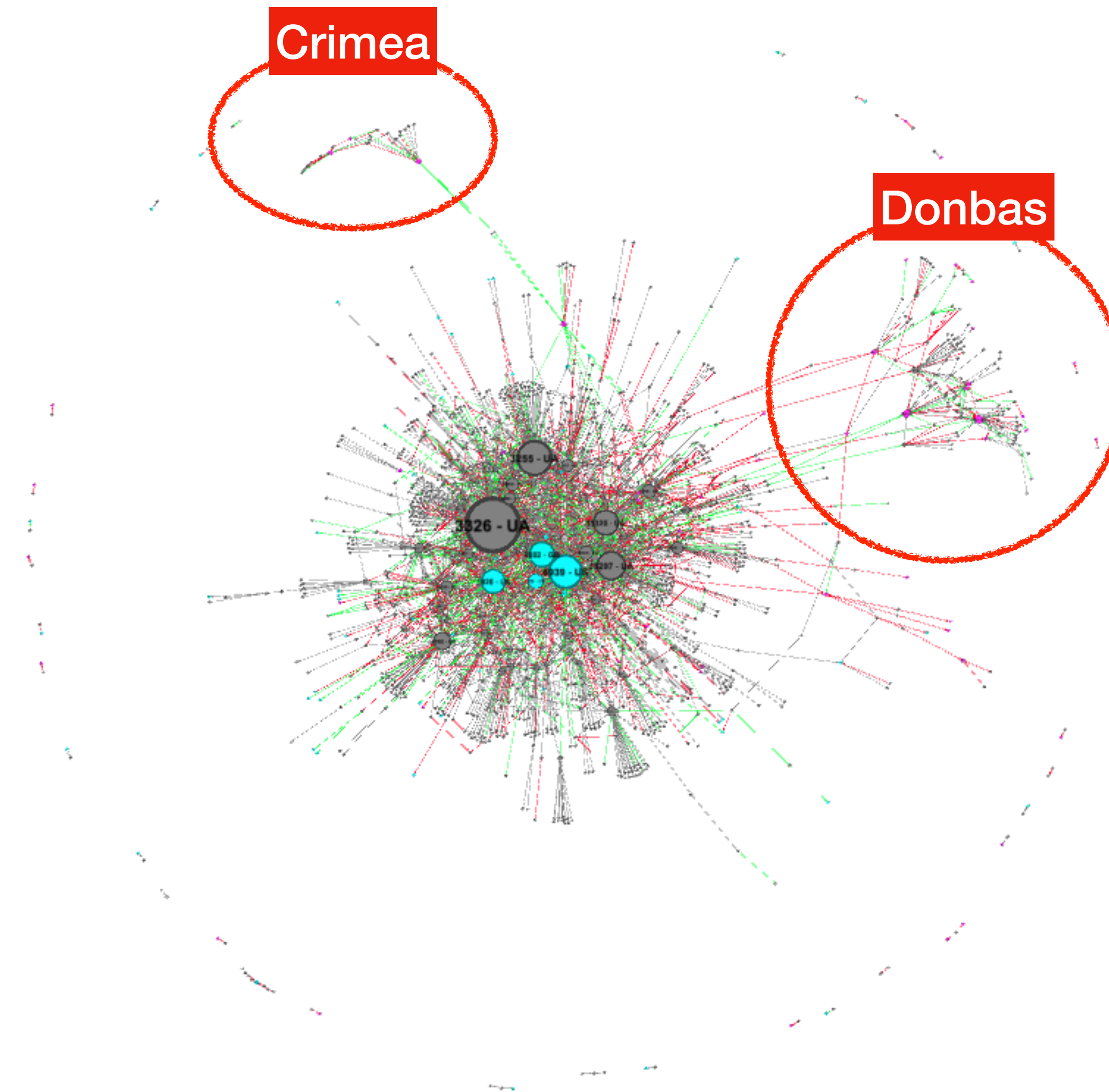
Poland (for comparison)



UA	2022-01-01	2023-01-01	Diff
Number of UA ASNs	1781	1677	-104 (-5.8%)
Foreign upstream ASNs	112	93	-19 (-17%)
Country of Registration for Foreign upstream ASNs (Top 5)	RU 48 US 10 NL 8 GB 8 PL 6	RU 23 US 13 PL 10 DE 7 NL 7	
Domestic links	2055	1887	-168 (-8.2%)
Intl. upstream links	662	599	-63 (-9.5%)

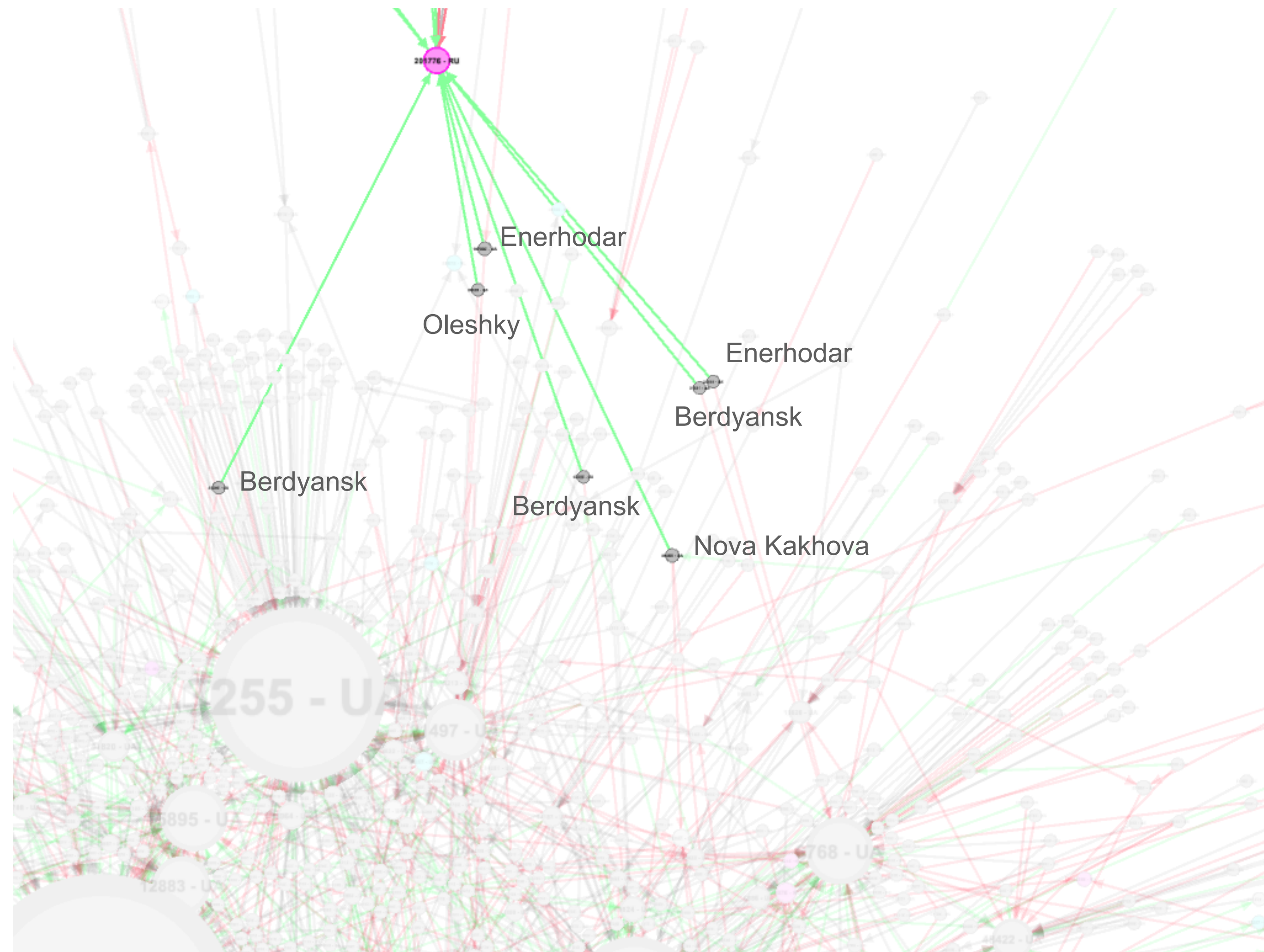
PL	2022-01-01	2023-01-01	Diff
Number of UA ASNs	2140	2115	-25 (-1.1%)
Foreign upstream ASNs	59	52	-7 (-12%)
Country of Registration for Foreign upstream ASNs (Top 5)	US 17 DE 7 GB 6 UA 4 RU 4	US 18 GB 5 RO 4 UA 4 DE 4	
Domestic links	2753	2795	+42 (+1.5%)
Intl. upstream links	699	544	-155 (-22%)

Ukraine 2022-01-01 vs 2023-04-01



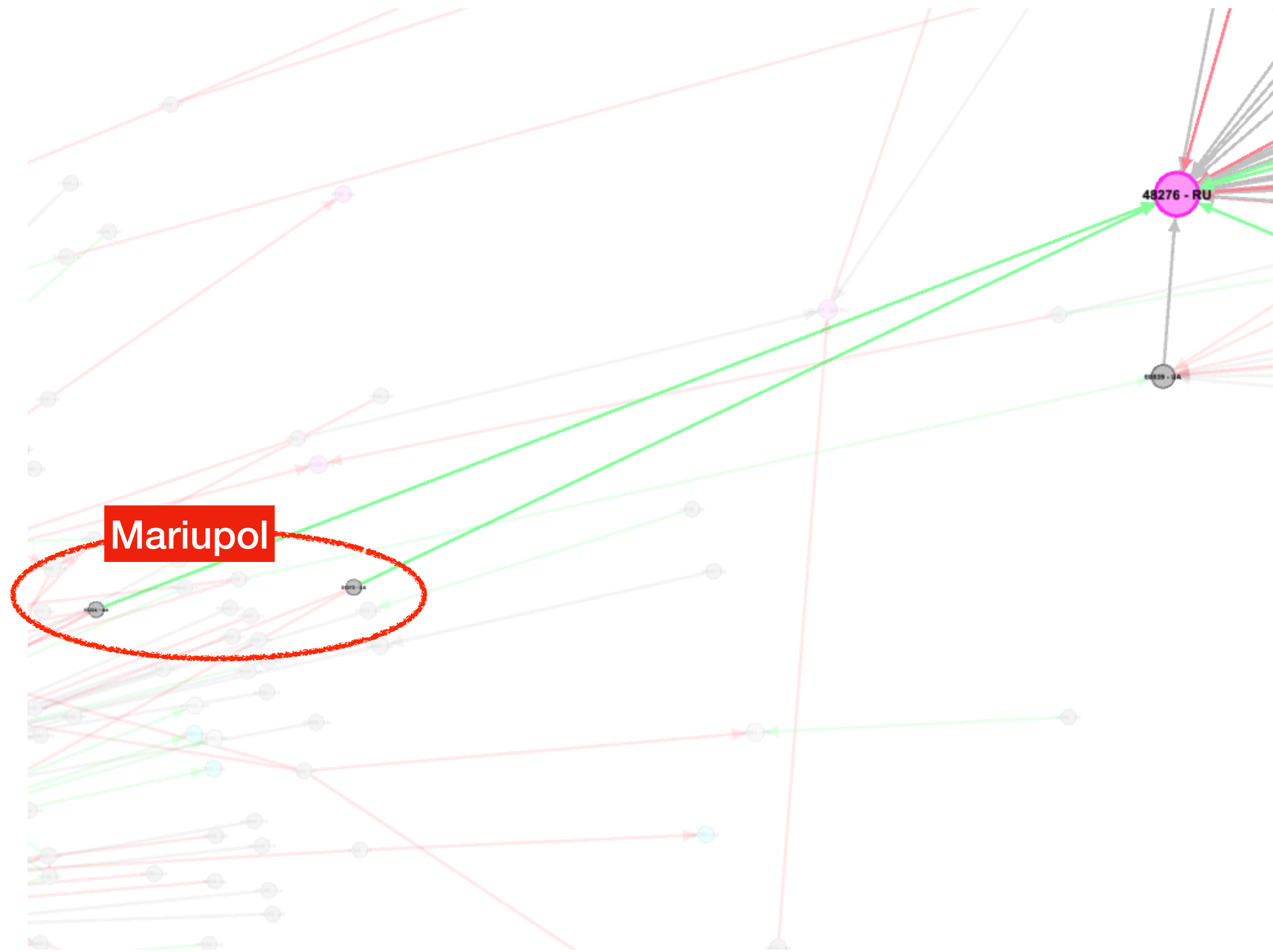
- Edges
 - grey (both)
 - red (gone)
 - green (new)

2022-01-01 vs 2023-04-01: Miranda Media



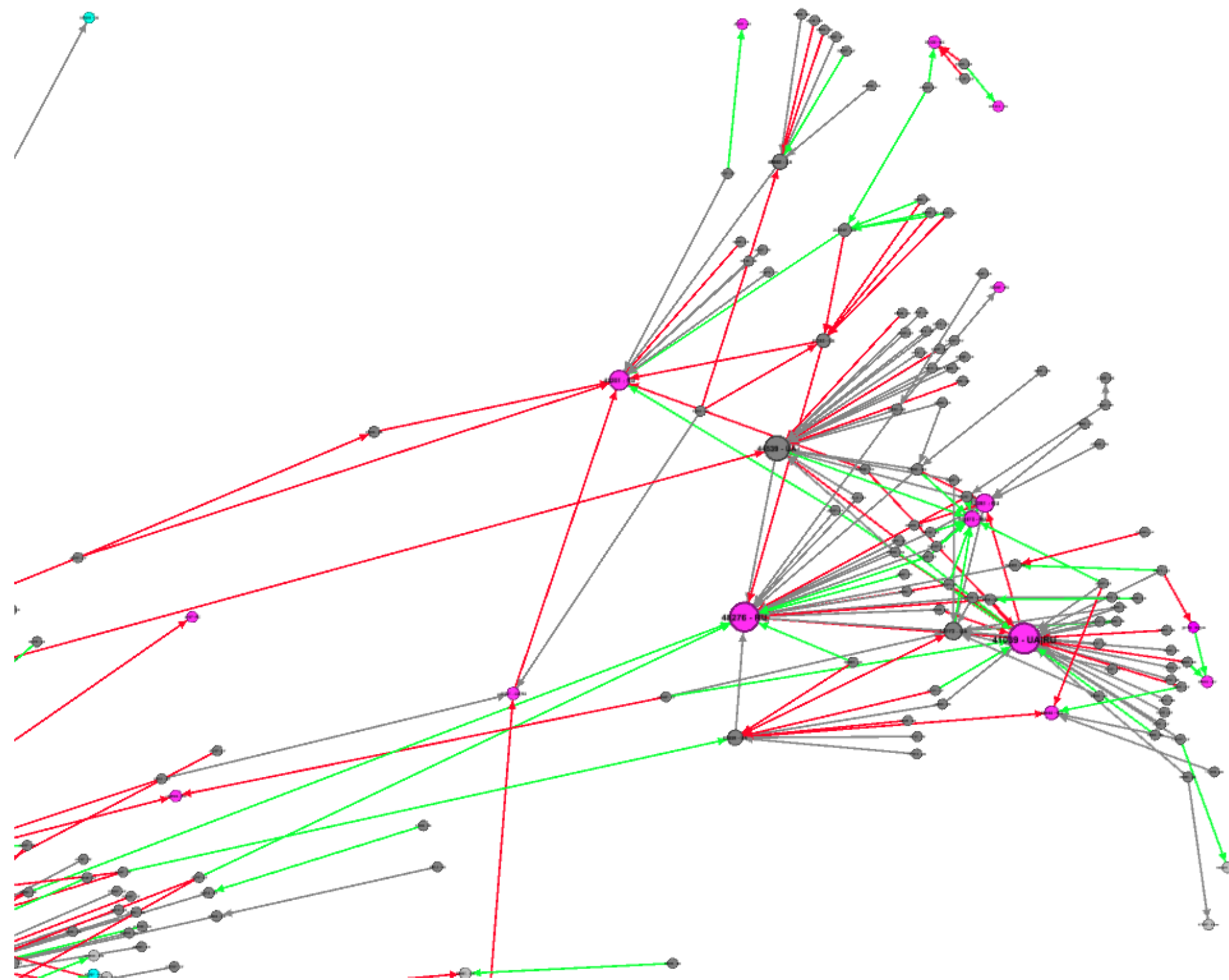
- AS201776 (Miranda Media)
- Provide connectivity to occupied territories north of Crimea (Kherson and Zaporizhzhia oblast)
- Routes via Crimea

2022-01-01 vs 2023-04-01: Mariupol



- Networks in Mariupol disconnected from main Ukraine Internet
- Moved to Donbass transit IPSvyaz

2022-01-01 vs 2023-04-01: Donbas



- Russian upstreams
 - IPSvyaz
 - Level-MSK
- Not connected to “main UA” for transit

Conclusion



- Internet in Ukraine is remarkably resilient
 - Distributed/decentralised at multiple levels
 - Heroism
- Observations
 - Slow - not rapid - decline of connectivity
 - Power infrastructure attacks and other kinetic warfare having its effects
 - International connectivity changes
- Concerns
 - Electricity
 - Equipment
 - Humans



Questions



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