Thirty years later:

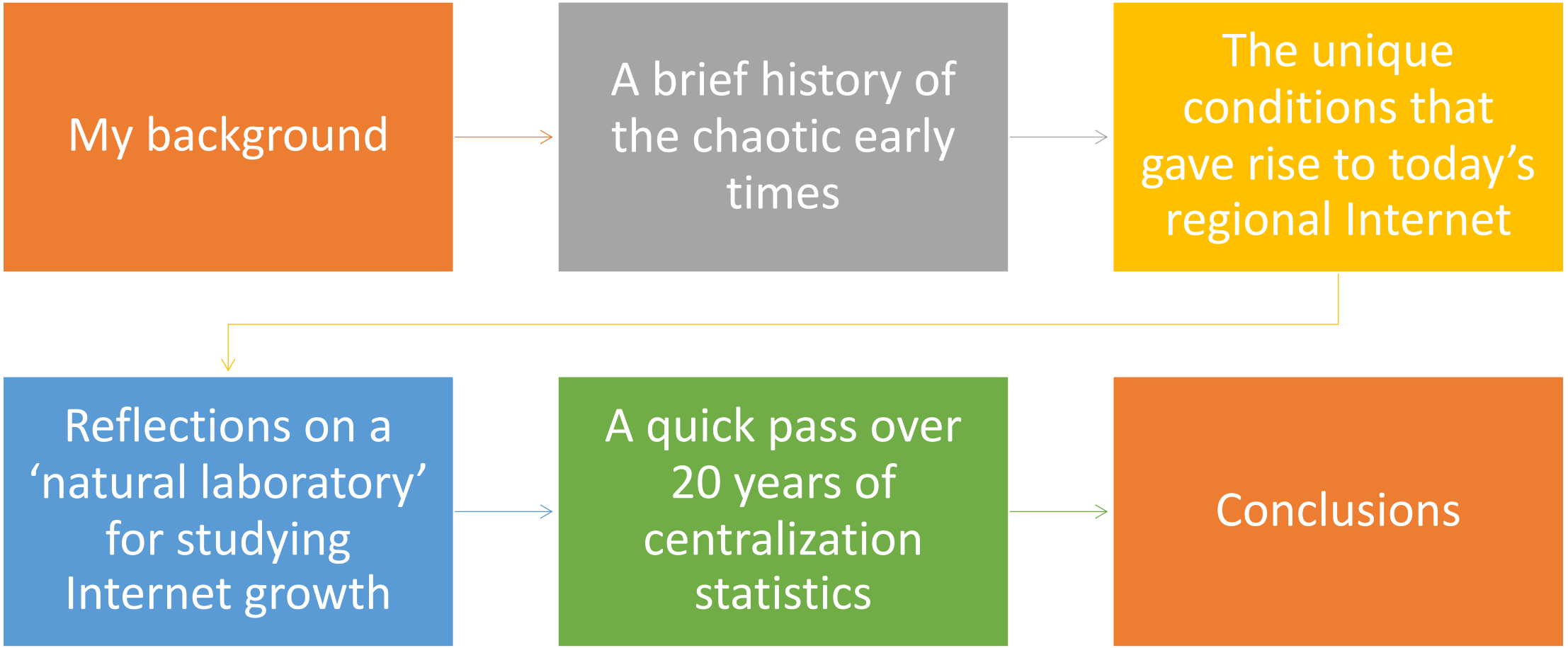
Surveying the Internet of the Former Soviet Union

Jim Cowie

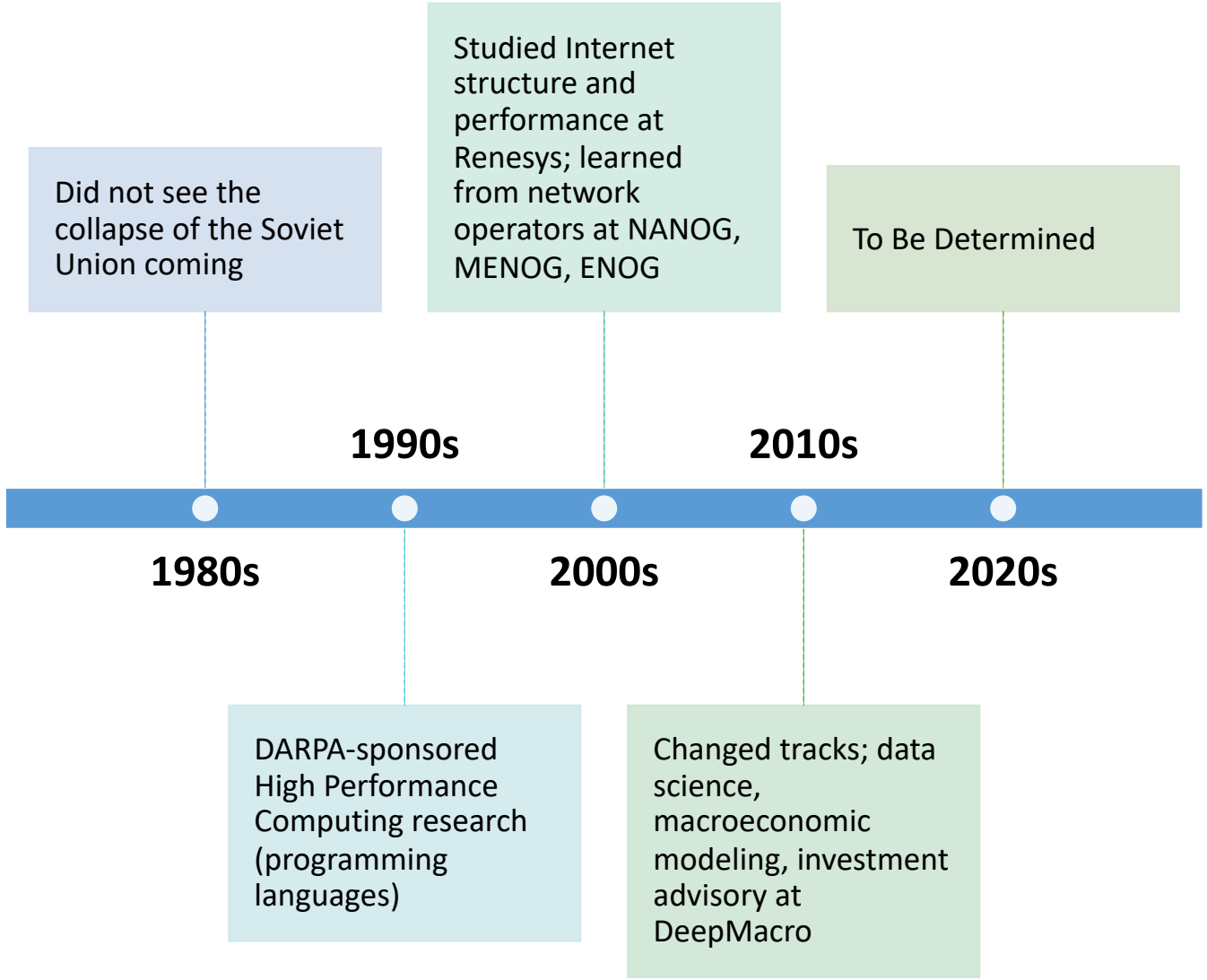
ISOC Tech Talk

11 May 2022

Outline


My background
A brief history of the chaotic early times
The unique conditions that gave rise to today's regional Internet
Reflections on a 'natural laboratory' for studying Internet growth
A quick pass over 20 years of centralization statistics
Conclusions

1. Jim's background



2. Parallel tracks toward today's Internet

1985: Akademset' network for hard sciences collaboration links Moscow, Leningrad, Kiev, Riga, Novosibirsk…

1986: NSFNet

1988: …Tallinn, Vilnius, Minsk, Sverdlovsk

1986-1990: 12th five year plan calls for 1.1M personal computers

March 1990: first T1 line links NSFNet with Europe (Cornell <-> CERN)

August 1990: **Relcom** founded; links Moscow with Helsinki for email

1991: First web server in the US

1991: 70 cities have been linked at speeds up to 9600 baud

August 1991: coup against Yeltsin 'liveblogged' on talk.politics.soviet despite traditional media shutdown; USSR formally disbands in December

1992: ISOC Founded

1992: Sun Microsystems gifts server, known as KremlSun in homage to mythical Kremvax; becomes server for .SU and part of MSK-IX

1992 onward: 'creative recycling' of legacy Soviet infrastructure

3. What happened next?

- Much of Russia's modern Internet structure is determined by the chaos and entrepreneurship of the 1990s and early 2000s.
- The State Property Committee established **Rostelecom** in June 1992, as part of holding company SvyazInvest
- Regional phone companies continued to operate; Rostelecom had sole control of long distance services, and inherited the national legacy backbone
- Rostelecom should have been the all-powerful Russian incumbent provider, but …

“Accidental Decentralization”

A number of serious competitors emerged in this period:

MTS (1994),

Vimpelcom/Beeline (1994)

TransTelekom (1997)

MegaFon (2002)

In Jan 2006, new telecom laws cost Rostelecom their LD monopoly, and ‘mobile’ providers were becoming fixed line competitors as well.

By 2012, however, Rostelecom was finally competing for LTE licenses, and in 2014, was named sole Universal Service Operator for rural Internet services.

In this competitive environment, a very large number of autonomous systems flourished, and Rostelecom today has a less dominant position in Russia’s Internet structure than might have been expected, given their incumbent legacy.

Russian IPv4 on-net percentages, 2001-2022

Month	Largest provider share		2nd largest		3rd largest	
200105	RTCOMM-AS	22%	BST-AS	14%	RELCOM-AS	10%
200205	RTCOMM-AS	13%	RELCOM-AS	12%	RBNet	8%
200305	TRANSTELECOM	13%	RTCOMM-AS	10%	RELCOM-AS	8%
200405	TRANSTELECOM	19%	RTCOMM-AS	12%	SOVAM-AS	7%
200505	RTCOMM-AS	20%	TRANSTELECOM	18%	SOVAM-AS	8%
200605	TRANSTELECOM	25%	RTCOMM-AS	12%	SOVAM-AS	9%
200705	TRANSTELECOM	23%	RTCOMM-AS	12%	SOVAM-AS	10%
200805	TRANSTELECOM	23%	SOVAM-AS	11%	ROSTELECOM-AS	11%
200905	TRANSTELECOM	19%	ROSTELECOM-AS	15%	SOVAM-AS	10%
201005	ROSTELECOM-AS	18%	TRANSTELECOM	17%	SOVAM-AS	11%
201105	ROSTELECOM-AS	19%	TRANSTELECOM	18%	SOVAM-AS	10%
201205	TRANSTELECOM	19%	SOVAM-AS	17%	ROSTELECOM-AS	17%
201305	ROSTELECOM-AS	17%	TRANSTELECOM	16%	SOVAM-AS	13%
201405	RINET-AS	52%	TI-AS	52%	ROSTELECOM-AS	9%
201505	ROSTELECOM-AS	17%	SOVAM-AS	15%	TRANSTELECOM	15%
201605	ROSTELECOM-AS	20%	SOVAM-AS	12%	TRANSTELECOM	11%
201705	ROSTELECOM-AS	23%	SOVAM-AS	12%	TRANSTELECOM	11%
201805	ROSTELECOM-AS	18%	SOVAM-AS	12%	TRANSTELECOM	12%
201905	ROSTELECOM-AS	19%	SOVAM-AS	12%	TRUENETWORK	11%
202005	ROSTELECOM-AS	15%	SOVAM-AS	12%	TRANSTELECOM	12%
202105	ROSTELECOM-AS	16%	SOVAM-AS	14%	TRANSTELECOM	11%
202205	ROSTELECOM-AS	17%	SOVAM-AS	13%	MF-MGSM-AS	9%

Note that from the start of our BGP routing table history, Rostelecom (fixed line incumbent) doesn't place in the top 3 until 2008, and doesn't take the lead for good until 2015, after the telecommunications law was amended

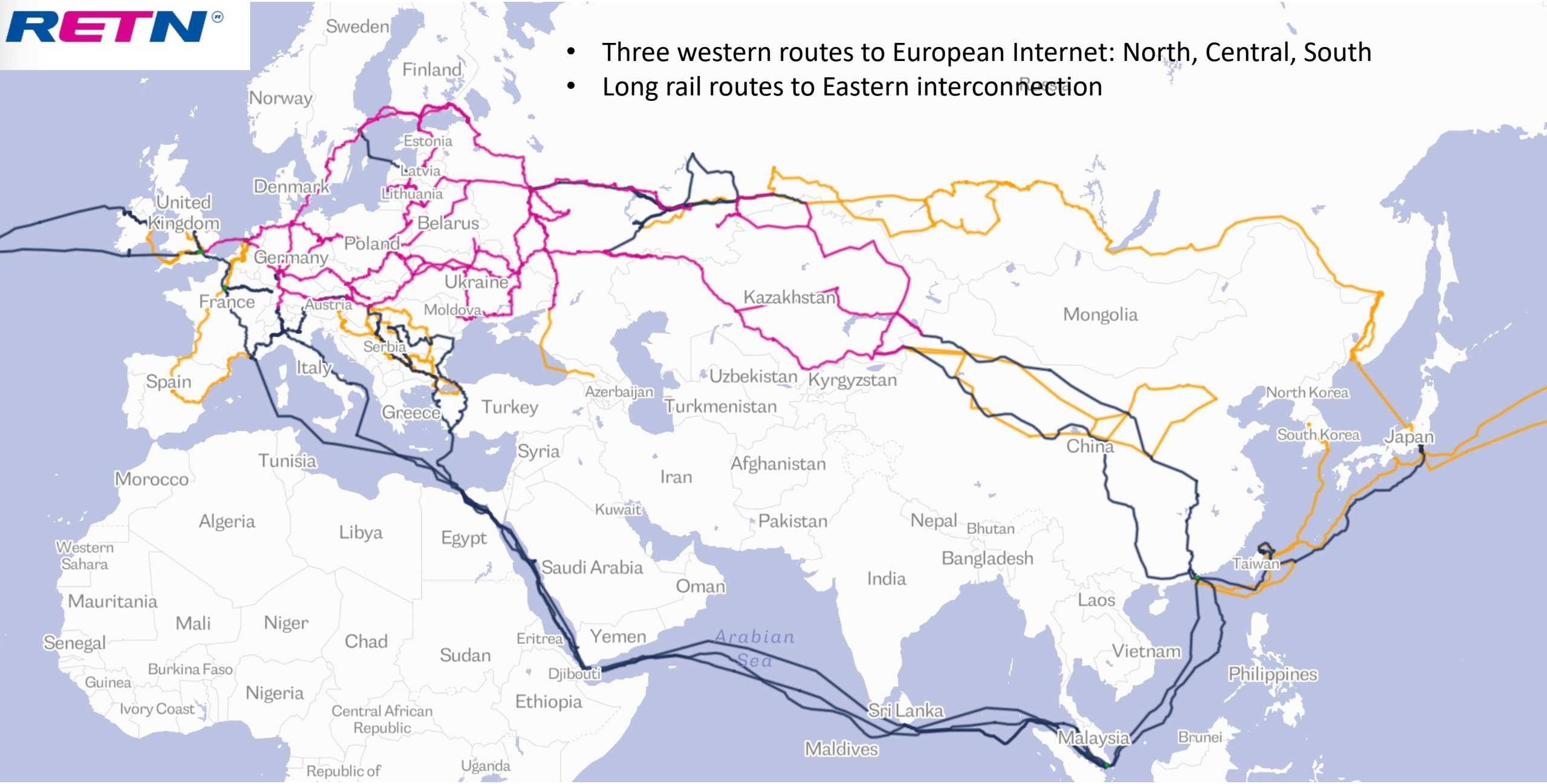
4. Beyond Russia: Regional Differences

- During the Soviet period, the 15 Union Republics were held together by trade networks, centrally planned prices and subsidies, and a common currency
- After the collapse, everything reset. Geography (connections to neighbors) and infrastructure (energy pipelines, rail networks) became the major determinants of the evolution of the Internet
- Diffferent countries reacted differently to the sudden availability of international transit, depending on the role of the national incumbent

Emergent Transit Watersheds

RETN®

- Three western routes to European Internet: North, Central, South
- Long rail routes to Eastern interconnection




RETN
Oslo
Stockholm
Saint Petersburg
Санкт-
Петербург
Northern Route:
Baltic/Scandinavian
Riga
North
Sea
Baltic Sea
Moscow
Москва
Minsk
Минск
Central Route: Belarus
Berlin
London
Kyiv
Київ
Paris
Vienna
Southern Route: Ukraine

Top Foreign providers: Baltics, 2001-2022

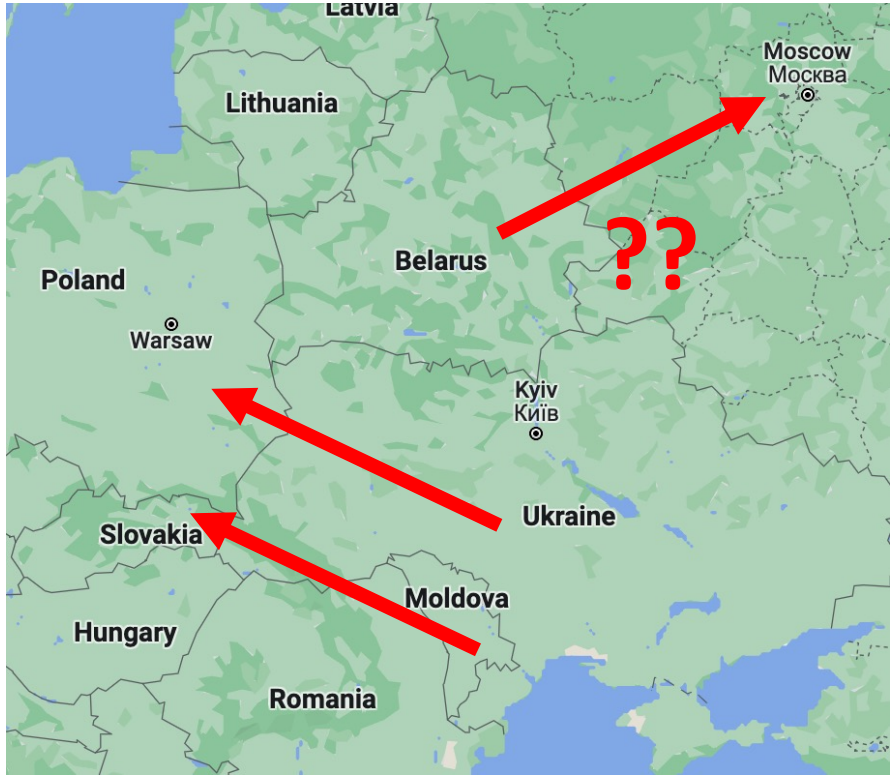
	Lithuania	Latvia	Estonia
200105	TWELVE99	UUNET	FUNETAS
200205	Telia-Lietuva	UUNET	ELISA-AS
200305	TWELVE99	UUNET	TWELVE99
200405	SPRINTLINK	UUNET	SPRINTLINK
200505	TWELVE99	TWELVE99	CITIC
200605	TWELVE99	TWELVE99	CITIC
200705	TWELVE99	TWELVE99	TWELVE99
200805	TWELVE99	TWELVE99	CITIC
200905	TWELVE99	RETN-AS	CITIC
201005	LATTELEKOM	TWELVE99	CITIC
201105	TWELVE99	TWELVE99	NTT-LTD-2914
201205	DTAG	TWELVE99	NTT-LTD-2914
201305	COGENT-174	RETN-AS	NTT-LTD-2914
201405	GTT-BACKBONE	LEVEL3	CITIC
201505	TWELVE99	TWELVE99	TWELVE99
201605	TWELVE99	TWELVE99	CITIC
201705	TWELVE99	TWELVE99	CITIC
201805	TWELVE99	TWELVE99	CITIC
201905	TWELVE99	TWELVE99	TWELVE99
202005	TWELVE99	TWELVE99	TWELVE99
202105	TWELVE99	BITE	TWELVE99
202205	TWELVE99	BITE	TWELVE99

Scandinavian transit readily available.

Foreign providers: Belarus/Ukraine/Moldova

	Belarus	Ukraine	Moldova
200105	MF-AS	SMS-NET	MARLINK-EMEA
200205	MF-AS	SMS-NET	MARLINK-EMEA
200305	AS21166	MARLINK-EMEA	SKYVISION
200405	SPRINTLINK	UTA-AS	SKYVISION
200505	UTA-AS	UTA-AS	DTAG
200605	AS6453	TKTELEKOM-AS	DTAG
200705	SPRINTLINK	LEVEL3	DTAG
200805	AS35422.0	LEVEL3	DTAG
200905	ROSTELECOM-AS	LEVEL3	RTD
201005	ROSTELECOM-AS	RETN-AS	RTD
201105	ROSTELECOM-AS	RETN-AS	RTD
201205	RETN-AS	RETN-AS	RTD
201305	RETN-AS	RETN-AS	AdNet-Telecom
201405	ROSTELECOM-AS	RETN-AS	RTD
201505	ROSTELECOM-AS	RETN-AS	RTD
201605	ROSTELECOM-AS	RETN-AS	RTD
201705	ROSTELECOM-AS	RETN-AS	RTD
201805	TRANSNEFT-TELECOM-AS	HURRICANE	RTD
201905	RASCOM-AS	HURRICANE	RTD
202005	ROSTELECOM-AS	HURRICANE	COGENT-174
202105	RETN-AS	HURRICANE	COGENT-174
202205	TRANSNEFT-TELECOM-AS	HURRICANE	COGENT-174

Despite similar geography on the threshold of Europe, very different connectivity choices. Belarus goes east for Russian transit; Ukraine and Moldova go west for tier1 connectivity.



Foreign providers: Georgia

Month	Top foreign ASN	#2	#3
200105	NETSAT-AS	KPN	AS12497
200205	SMS-NET	SKYVISION	RTCOMM-AS
200305	SKYVISION	SMS-NET	RTCOMM-AS
200405	AS21166	SKYVISION	SMS-NET
200505	SKYVISION	SMS-NET	AS21166
200605	TTNet	PROXIMUS-ISP-AS	SKYVISION
200705	TTNet	ROSTELECOM-AS	Delta-Telecom-AS
200805	TTNet	ROSTELECOM-AS	Delta-Telecom-AS
200905	TTNet	Delta-Telecom-AS	COGENT-174
201005	COGENT-174	Delta-Telecom-AS	TTNet
201105	TTNet	COGENT-174	ROSTELECOM-AS
201205	LEVEL3	BinkNet	Delta-Telecom-AS
201305	LEVEL3	TWELVE99	Delta-Telecom-AS
201405	LEVEL3	Delta-Telecom-AS	TWELVE99
201505	LEVEL3	Delta-Telecom-AS	TWELVE99
201605	SOFIA-CONNECT-AS	TWELVE99	LEVEL3
201705	LEVEL3	SEABONE-NET	SOFIA-CONNECT-AS
201805	TWELVE99	LEVEL3	NTT-LTD-2914
201905	SEABONE-NET	LEVEL3	COGENT-174
202005	COGENT-174	LEVEL3	NTT-LTD-2914
202105	COGENT-174	LEVEL3	Delta-Telecom-AS
202205	LEVEL3	BORUSANTELEKOM-AS	COGENT-174

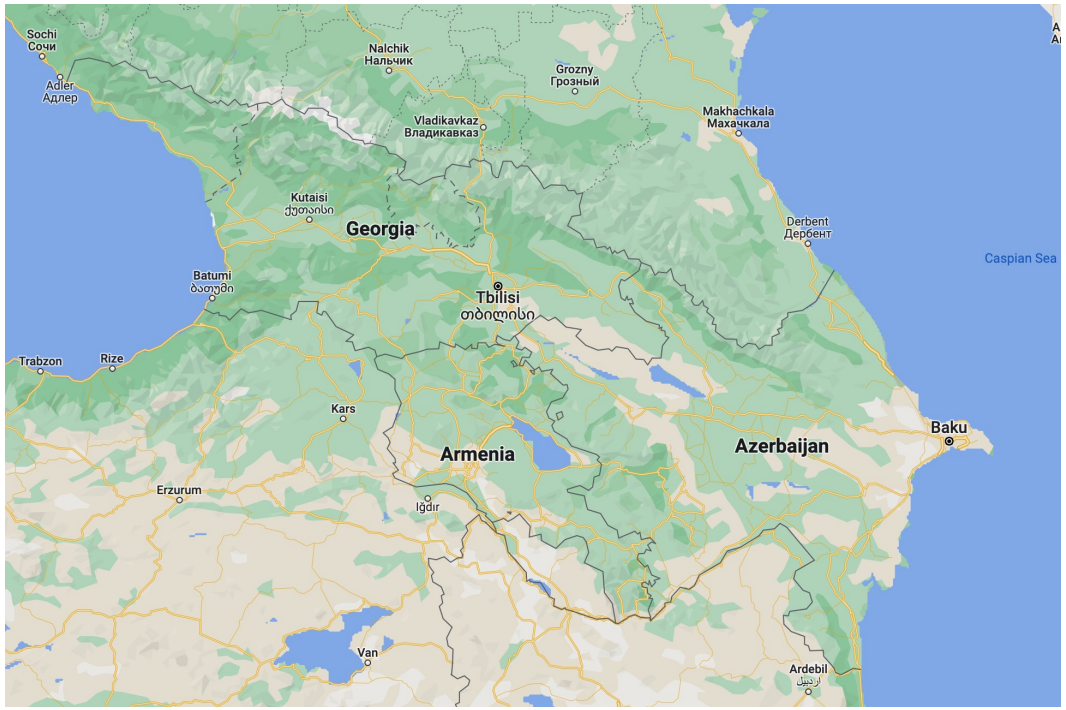
Evolution from satellite (NetSat, 2001) to Turkish (TTNet, 2006), to Azeri (Delta, 2009), to Bulgarian (Sofia Connect, 2016) and global backbone transit (Level3, Cogent, Telia)…

…Thanks to the Caucasus Cable System and east-west energy pipelines.

Foreign providers: Armenia

Month	Top foreign ASN	#2	#3
200105	RTCOMM-AS	TISCALI-UK	AS6453
200205	UKRTELNET	SMS-NET	TWELVE99
200305	RTCOMM-AS	SMS-NET	COLT
200405	SMS-NET	UKRTELNET	COLT
200505	UKRTELNET	SPRINTLINK	AS21166
200605	UKRTELNET	SKYVISION	SPRINTLINK
200705	UKRTELNET	SatGate	SKYVISION
200805	GRT-AS	SatGate	SOVAM-AS
200905	GRT-AS	ROSTELECOM-AS	SOVAM-AS
201005	GRT-AS	ROSTELECOM-AS	CAUCASUS-CABLE-SYSTEM
201105	CAUCASUS-CABLE-SYSTEM	ROSTELECOM-AS	GRT-AS
201205	CAUCASUS-CABLE-SYSTEM	ROSTELECOM-AS	LEVEL3
201305	CAUCASUS-CABLE-SYSTEM	LEVEL3	ROSTELECOM-AS
201405	LEVEL3	CAUCASUS-CABLE-SYSTEM	SILKNET-AS
201505	TWELVE99	CAUCASUS-CABLE-SYSTEM	LEVEL3
201605	TWELVE99	AS6453	ROSTELECOM-AS
201705	SOVAM-AS	TWELVE99	ROSTELECOM-AS
201805	SOVAM-AS	TWELVE99	CAUCASUS-CABLE-SYSTEM
201905	SOVAM-AS	TWELVE99	CAUCASUS-CABLE-SYSTEM
202005	SOVAM-AS	COGENT-174	CAUCASUS-CABLE-SYSTEM
202105	SOVAM-AS	CAUCASUS-CABLE-SYSTEM	LEVEL3
202205	LEVEL3	TWELVE99	AS6453

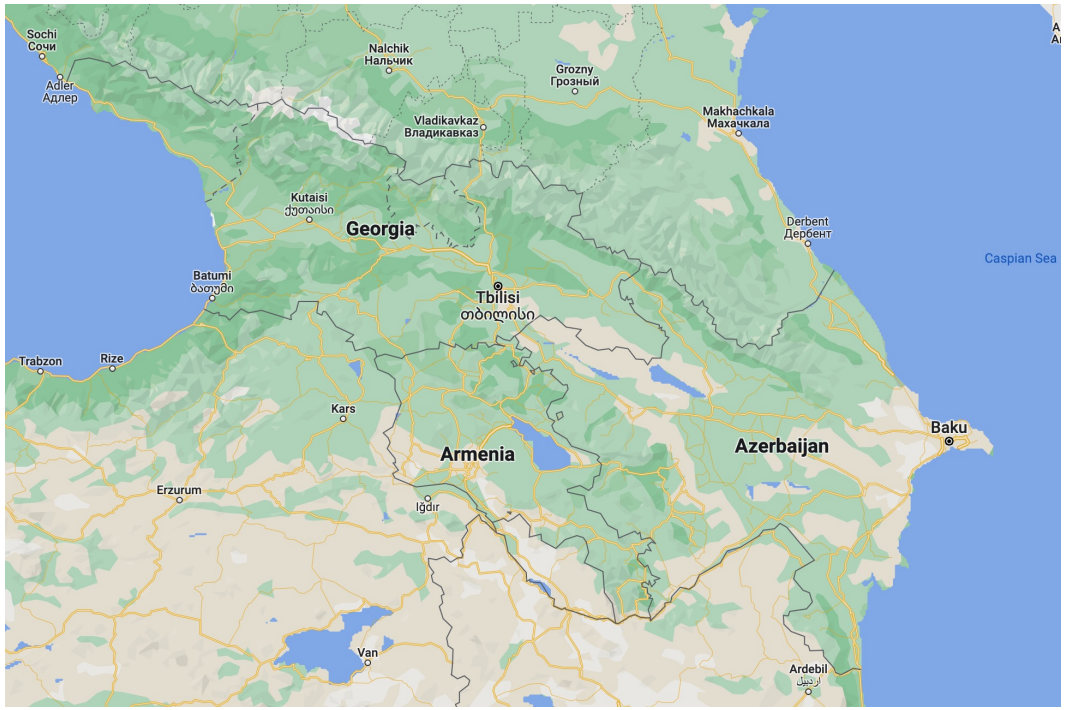
Caucasus Cable System, Georgian, and Russian providers, evolving to tier1 carriers (Cogent, Telia, Level3, Tata)



Foreign providers: Azerbaijan

Month	Top foreign ASN	#2	#3
200105	SOVAM-AS	UUNET	SMS-NET
200205	UUNET	SOVAM-AS	SMS-NET
200305	SMS-NET	ASN-BICS	AS-ISOL
200405	ASN-BICS	SMS-NET	TTNet
200505	TWELVE99	SMS-NET	RADIO-MSU
200605	TWELVE99	RADIO-MSU	AS20535.0
200705	TWELVE99	DTAG	AS20535.0
200805	AS6453	CAUCASUS-CABLE-SYSTEM	TWELVE99
200905	TTNet	ROSTELECOM-AS	TWELVE99
201005	ROSTELECOM-AS	TTNet	GEANT
201105	ROSTELECOM-AS	LEVEL3	CAUCASUS-CABLE-SYSTEM
201205	ROSTELECOM-AS	TRANSTELECOM	GTT-BACKBONE
201305	LEVEL3	ROSTELECOM-AS	TRANSTELECOM
201405	ROSTELECOM-AS	TRANSTELECOM	TWELVE99
201505	ROSTELECOM-AS	TRANSTELECOM	LEVEL3
201605	ROSTELECOM-AS	TRANSTELECOM	NTT-LTD-2914
201705	TRANSTELECOM	LEVEL3	MF-MGSM-AS
201805	MF-MGSM-AS	LEVEL3	TRANSTELECOM
201905	TRANSTELECOM	TWELVE99	NetIX
202005	TWELVE99	LEVEL3	CAUCASUS-CABLE-SYSTEM
202105	NetIX	TWELVE99	LEVEL3
202205	TWELVE99	LEVEL3	NetIX

Russian providers, evolving to tier1 carriers (Cogent, Telia, Level3, Tata) met in Sofia (NetIX)

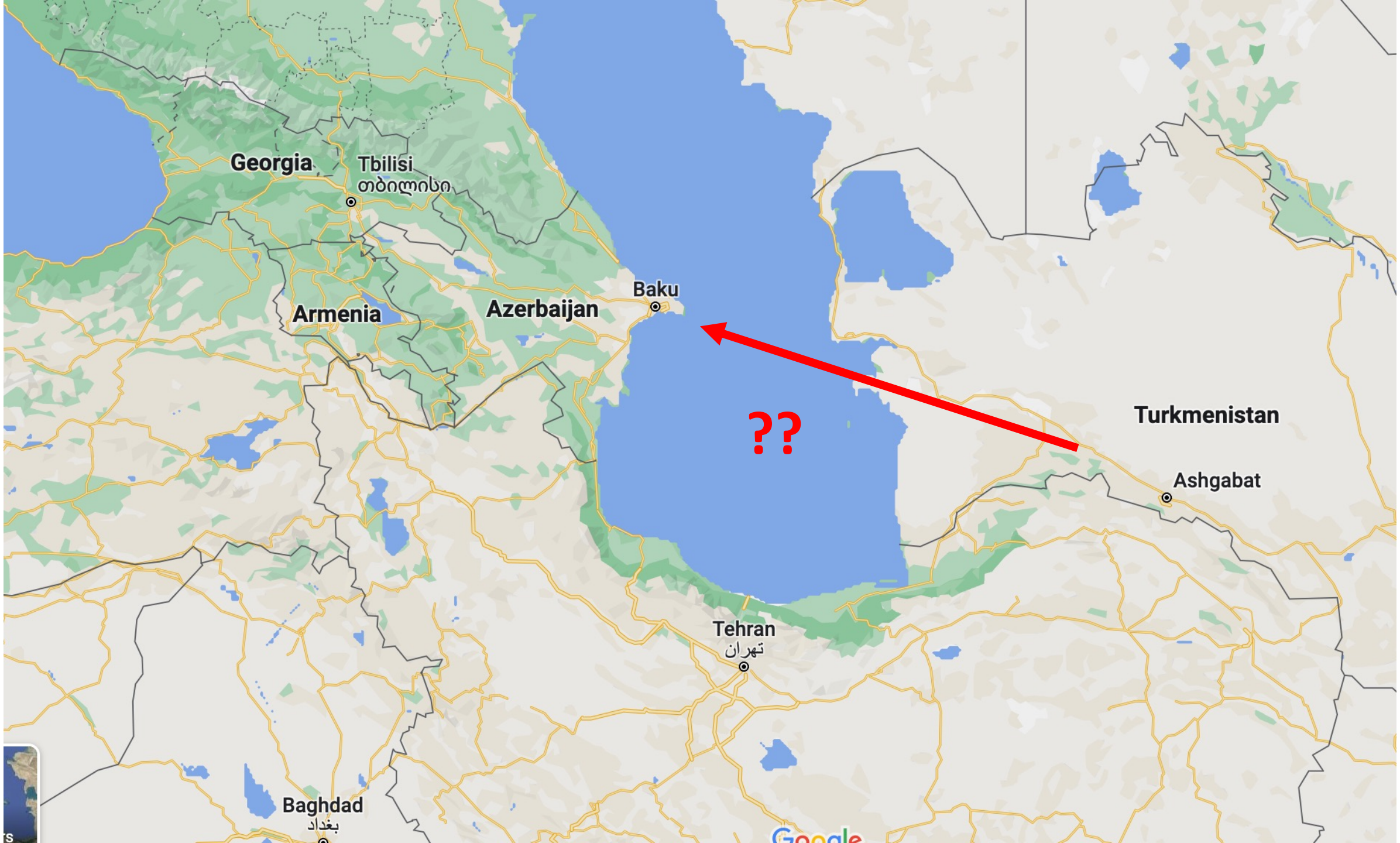


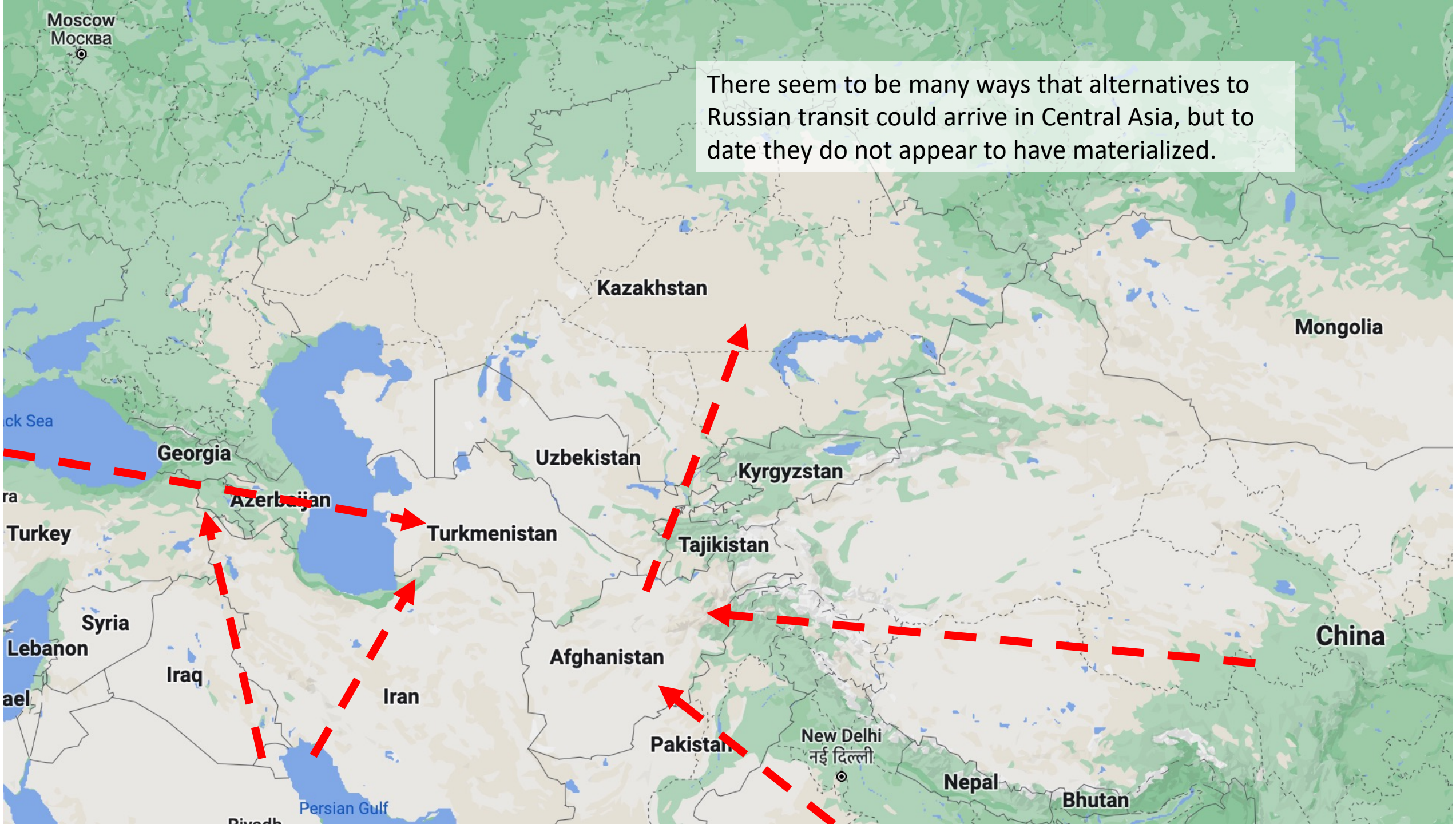
Top Foreign Providers: Central Asia

	Kyrgyz Republic	Kazakhstan	Uzbekistan	Tajikistan	Turkmenistan
200105	WOLKEE-AS	ROSPRINT-AS	BSKYB-BROADBAND-AS	KPN	Level3
200205	AS20535.0	TSF-IP-Core	Gascom-Net	AS2820.0	ROSPRINT-AS
200305	RELCOM-AS	EQUANT-ASIA	CHINANET-BACKBONE	SNR-RO	ROSPRINT-AS
200405	RTCOMM-AS	EQUANT-ASIA	AS29059.0	AS2820.0	ROSPRINT-AS
200505	KAZTELECOM-AS	NEWSKIES-AS-AP	KAZTELECOM-AS	AS2820.0	SATISNET-AS
200605	RTCOMM-AS	SPRINTLINK	ROSTELECOM-AS	SATISNET-AS	SATISNET-AS
200705	GTS-BACKBONE	TRANSTELECOM	KAZTELECOM-AS	SATISNET-AS	SATISNET-AS
200805	KAZTELECOM-AS	TRANSTELECOM	KAZTELECOM-AS	SATISNET-AS	DCI-AS
200905	KAZTELECOM-AS	TRANSTELECOM	SOVAM-AS	SOVAM-AS	SatGate
201005	KAZTELECOM-AS	ROSTELECOM-AS	iTelecom	SOVAM-AS	SatGate
201105	KAZTELECOM-AS	TRANSTELECOM	ROSTELECOM-AS	KTNET	ROSTELECOM-AS
201205	TTI-NET	TRANSTELECOM	ROSTELECOM-AS	SOVAM-AS	AS6453
201305	Prime-Telecom-AS	TRANSTELECOM	ROSTELECOM-AS	DINET-AS	AS6453
201405	SOVAM-AS	SOVAM-AS	ROSTELECOM-AS	IHOME-AS	TTNet
201505	SOVAM-AS	TRANSTELECOM	ROSTELECOM-AS	KAZTELECOM-AS	KAZTELECOM-AS
201605	KVANT-TELECOM	ROSTELECOM-AS	ROSTELECOM-AS	AS8449-ELCAT	KAZTELECOM-AS
201705	TNS-Plus-Core	ROSTELECOM-AS	KAZTELECOM-AS	AS8449-ELCAT	AS6453
201805	KVANT-TELECOM	MF-MGSM-AS	MF-MGSM-AS	TTC-AS	AS6453
201905	TNS-Plus-Core	KVANT-TELECOM	MF-MGSM-AS	TTC-AS	ROSTELECOM-AS
202005	TRANSTELECOM	KVANT-TELECOM	KVANT-TELECOM	TTC-AS	ROSTELECOM-AS
202105	SOVAM-AS	KVANT-TELECOM	HURRICANE	TTC-AS	ROSTELECOM-AS
202205	TNS-Plus-Core	MF-MGSM-AS	reacom	SOVAM-AS	Delta-Telecom-AS

Moving away from satellite is good, but nearly all of the remaining transit for Central Asia is Russian.

How does Turkmenistan have Tata and Azeri transit?


Georgia
Tbilisi
თბილისი
Armenia
Azerbaijan
Baku
??
Turkmenistan
Ashgabat
Tehran
تهران
Baghdad
بغداد


There seem to be many ways that alternatives to Russian transit could arrive in Central Asia, but to date they do not appear to have materialized.
Moscow
Москва
Kazakhstan
Mongolia
Georgia
Azerbaijan
Uzbekistan
Kyrgyzstan
Turkey
Turkmenistan
Tajikistan
Syria
Lebanon
Iraq
Iran
Afghanistan
China
Pakistan
New Delhi
नई दिल्ली
Nepal
Bhutan
Persian Gulf

5. A Quick Tour of Regional Structure

Internet ecosystems in which consumers and enterprises have more good choices are plausibly more resilient and faster-growing

Indeed, we can see this playing out in the last 20 years of centralization metrics for the new countries that emerged from the collapse of the Soviet Union, at the birth of the Internet

Ground truth: two primary sources

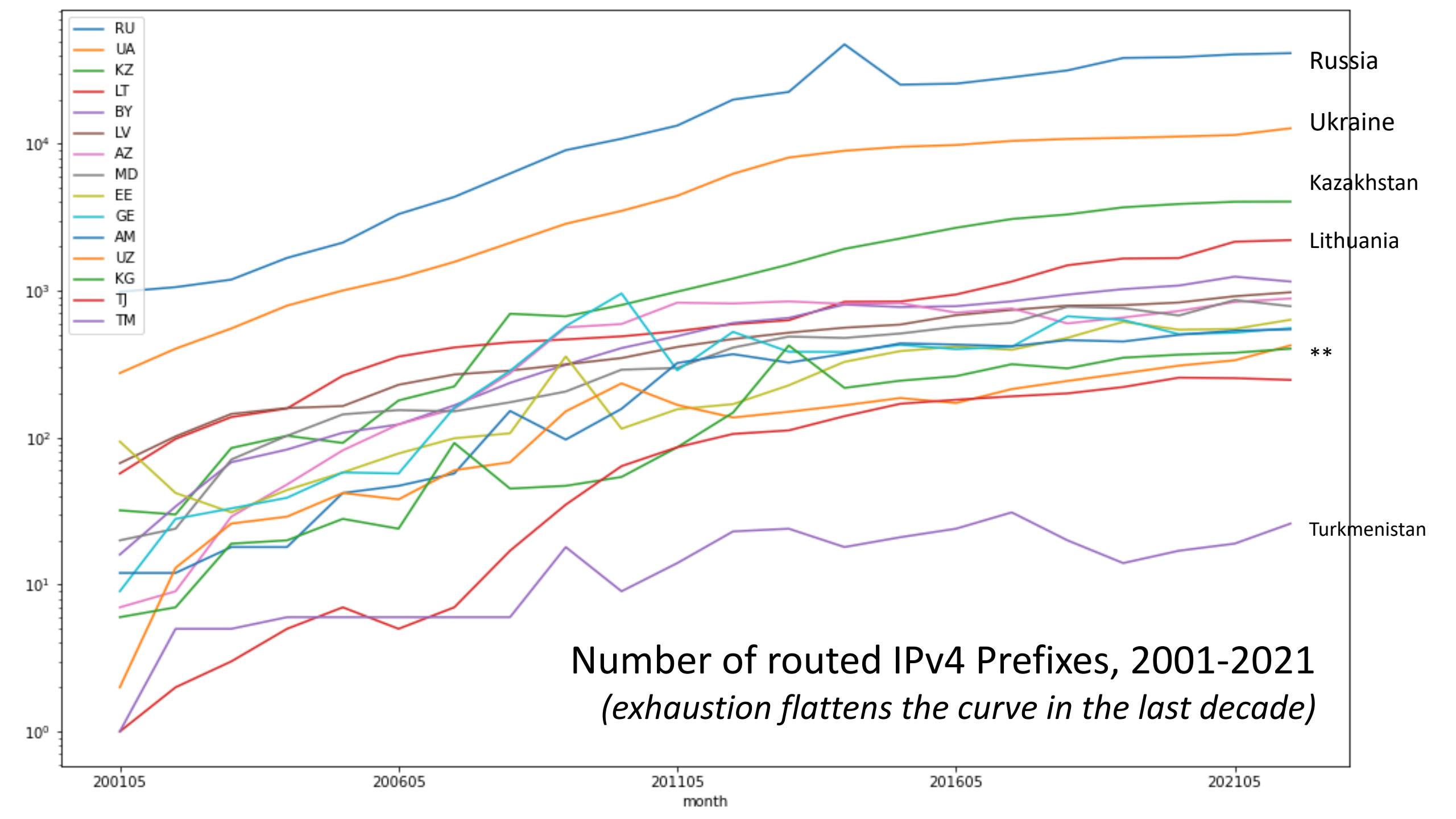
The RIPE database of autonomous systems and networks, to establish where small ranges of IP addresses believe they are (or were)

The RIPE RIS archive of diverse BGP routing table views from eight selected collection points:

rrc00 (Amsterdam+, 2001-)	rrc14 (Palo Alto, 2005-)
rrc06 (Tokyo, 2002-)	rrc16 (Miami, 2008-)
rrc12 (Frankfurt, 2004-)	rrc19 (Johannesburg, 2016-)
rrc13 (Moscow, 2005-)	rrc23 (Singapore, 2017-)

What would we like to learn here?

- **Internet structure/policy** are visible in the historical routing data
- Determine certain **key metrics** – how many autonomous systems (ASNs)? How many announced IP address blocks (prefixes)?
- Examine their **interconnection** – how many ASNs have connectivity to foreign providers? Are there ASNs that are centrally important to domestic connectivity? To international connectivity?
- Which **foreign providers** are in use, and what can we infer about paths that traffic takes?
- What is the big picture that emerges – **'watersheds' of connectivity**?


RU
UA
KZ
LT
BY
LV
AZ
MD
EE
GE
AM
UZ
KG
TJ
TM
10^4
10^3
10^2
10^1
10^0
200105
200605
201105
201605
202105
month
Russia
Ukraine
Kazakhstan
Lithuania
**
Turkmenistan
Number of routed IPv4 Prefixes, 2001-2021
(exhaustion flattens the curve in the last decade)

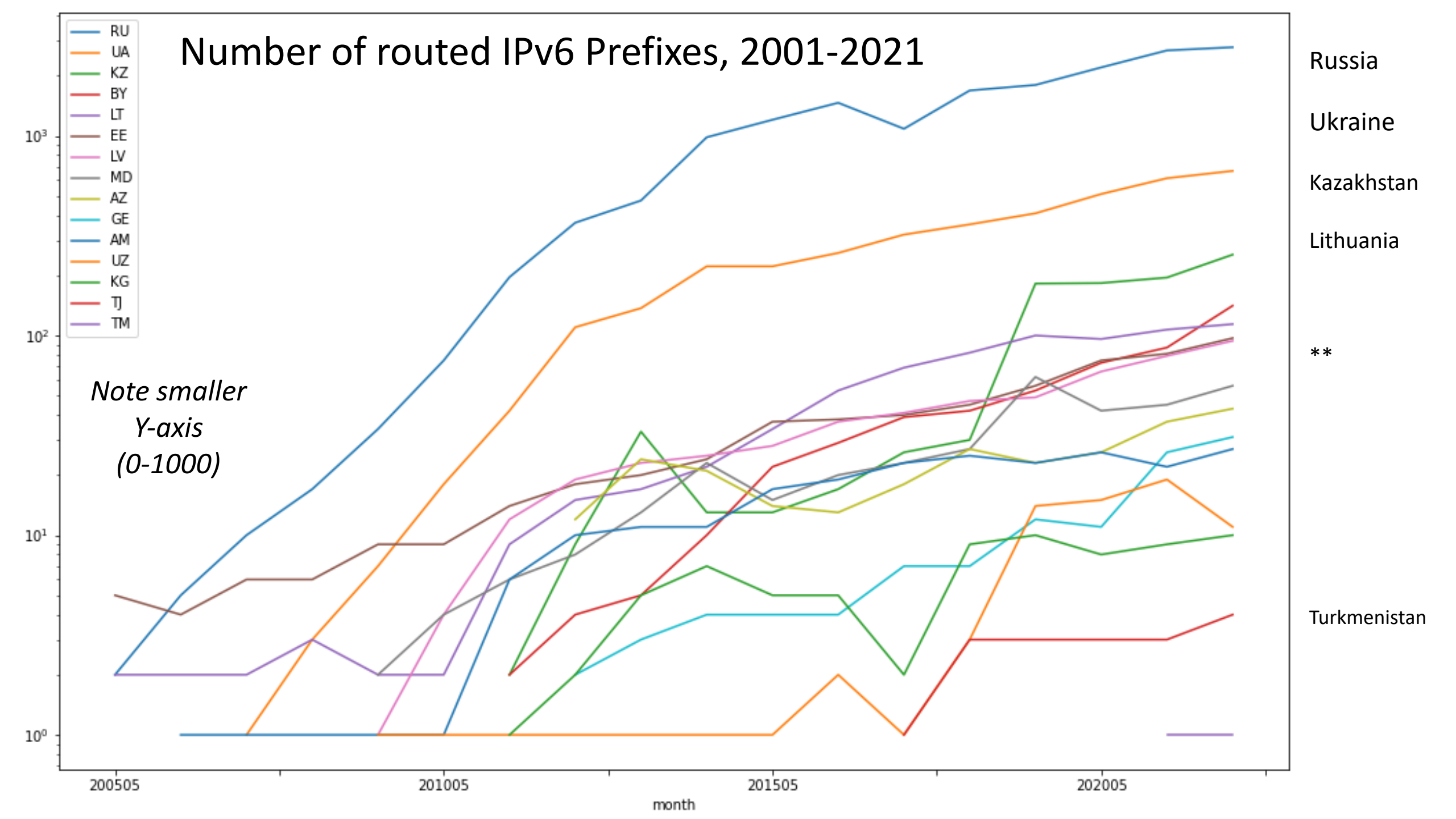
Number of routed IPv4 prefixes, 2001-2022

month	RU	UA	KZ	LT	BY	LV	AZ	MD	EE	GE	AM	UZ	KG	TJ	TM
200105	983	275	32	57	16	67	7	20	94	9	12	2	6	1	1
200205	1057	403	30	98	34	102	9	24	42	28	12	13	7	2	5
200305	1190	553	85	138	68	145	29	71	31	33	18	26	19	3	5
200405	1672	791	103	158	83	159	48	103	44	39	18	29	20	5	6
200505	2124	1003	92	264	108	164	82	144	58	58	42	42	28	7	6
200605	3321	1220	179	356	123	229	123	154	78	57	47	38	24	5	6
200705	4347	1570	223	411	166	269	157	151	99	160	57	60	92	7	6
200805	6272	2116	697	445	236	286	274	174	107	285	152	68	45	17	6
200905	9043	2854	669	466	313	315	563	206	357	574	97	151	47	35	18
201005	10816	3492	799	489	407	348	593	290	115	958	157	234	54	64	9
201105	13296	4422	985	530	491	414	829	298	156	287	322	167	86	86	14
201205	19964	6245	1210	592	603	469	818	410	169	525	370	137	148	106	23
201305	22527	8060	1507	629	653	518	846	487	227	384	324	150	424	112	24
201405	47468	8961	1926	841	804	560	813	477	328	383	372	166	218	140	18
201505	25248	9527	2266	844	774	588	823	511	388	428	438	186	244	170	21
201605	25650	9805	2680	942	784	681	709	567	416	400	430	172	262	181	24
201705	28325	10457	3076	1154	847	740	757	605	396	415	419	214	316	191	31
201805	31559	10785	3304	1489	940	791	599	778	478	670	461	243	296	200	20
201905	38368	10969	3693	1655	1025	797	657	760	614	632	451	274	350	221	14
202005	38838	11193	3892	1667	1084	831	728	678	543	506	501	309	367	256	17
202105	40576	11470	4029	2155	1246	917	838	864	550	518	535	336	378	254	19
202205	41334	12740	4038	2209	1154	975	885	784	634	556	546	424	403	247	26

Double In ~2yrs

Double In ~10yrs?

Approaching “peak v4”


Number of routed IPv6 Prefixes, 2001-2021
RU
UA
KZ
BY
LT
EE
LV
MD
AZ
GE
AM
UZ
KG
TJ
TM
10^3
10^2
10^1
10^0
Note smaller Y-axis (0-1000)
200505
201005
201505
202005
month
Russia
Ukraine
Kazakhstan
Lithuania
**
Turkmenistan

Number of routed IPv6 prefixes, 2001-2022

month	RU	UA	KZ	BY	LT	EE	LV	MD	AZ	GE	AM	UZ	KG	TJ	TM
200505	2	0	0	0	2	5	0	0	0	0	0	0	0	0	0
200605	5	0	0	0	2	4	0	0	0	0	1	0	0	0	0
200705	10	1	0	0	2	6	0	0	0	0	1	0	0	0	0
200805	17	3	0	0	3	6	0	0	0	0	1	0	0	0	0
200905	34	7	0	0	2	9	1	2	0	0	1	1	0	0	0
201005	75	18	0	0	2	9	4	4	0	0	1	1	0	0	0
201105	196	42	2	2	9	14	12	6	0	0	6	1	1	0	0
201205	367	110	9	4	15	18	19	8	12	2	10	1	2	0	0
201305	474	137	33	5	17	20	23	13	24	3	11	1	5	0	0
201405	983	222	13	10	22	24	25	23	21	4	11	1	7	0	0
201505	1203	222	13	22	34	37	28	15	14	4	17	1	5	0	0
201605	1463	259	17	29	53	38	37	20	13	4	19	2	5	0	0
201705	1084	320	26	39	69	40	41	23	18	7	23	1	2	1	0
201805	1686	360	30	42	82	45	47	27	27	7	25	3	9	3	0
201905	1797	409	182	53	100	56	49	62	23	12	23	14	10	3	0
202005	2200	511	183	73	96	75	66	42	26	11	26	15	8	3	0
202105	2676	613	195	87	107	81	79	45	37	26	22	19	9	3	1
202205	2776	667	254	141	114	97	94	56	43	31	27	11	10	4	1

!!

Autonomous Systems w/IPv6 Transit

	RU	UA	LT	LV	BY	MD	EE	AM	AZ	GE	KZ	UZ	KG	TJ	TM
200405	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
200505	2	0	2	0	0	0	5	0	0	0	0	0	0	0	0
200605	5	0	2	0	0	0	6	1	0	0	0	0	0	0	0
200705	11	1	2	0	0	0	11	1	0	0	0	0	0	0	0
200805	27	3	3	0	0	0	12	2	0	0	0	0	0	0	0
200905	44	19	2	1	0	4	19	1	0	0	0	1	0	0	0
201005	89	27	3	8	0	14	19	3	0	0	0	2	0	0	0
201105	183	54	13	18	3	17	24	9	0	0	4	2	1	0	0
201205	256	83	20	30	5	21	28	13	13	2	7	2	2	0	0
201305	386	116	32	36	5	16	27	13	6	5	17	1	4	0	0
201405	510	141	38	41	22	34	34	14	29	18	25	2	7	0	0
201505	607	153	40	44	23	33	35	31	31	16	26	2	4	0	0
201605	673	175	53	51	26	38	38	36	14	18	31	3	10	0	0
201705	720	201	52	51	30	34	43	39	33	19	35	2	7	1	0
201805	761	222	62	55	35	38	47	43	34	22	27	4	14	3	0
201905	844	252	75	68	44	53	57	49	39	34	29	13	16	3	0
202005	907	325	109	91	82	70	63	71	57	57	28	13	17	3	0
202105	975	362	113	110	92	85	73	74	71	67	45	20	17	3	1
202205	977	362	118	108	86	82	77	75	70	59	45	16	15	3	1

Estonia and Lithuania have the longest history, but in the last two years, all fifteen former republics have at least some participation in the global IPv6 routing table!

“Could it happen in your country?”

Renesys (2012) proposed a rule of thumb for judging the risk of national-scale Internet disconnection

A “cross-border” Internet provider is one that demonstrates the ability to exchange traffic with a foreign provider

We can count these adjacencies in the routing table. Every country should have at least 40 such ‘cross-border’ relationships to feel reasonably resistant to large-scale disconnection.

‘Cross-Border’ IPv4 ASNs, 2001-2022

month	RU	UA	LT	EE	LV	KZ	MD	BY	GE	AZ	AM	KG	TJ	UZ	TM
200105	219	89	19	16	15	9	10	5	7	5	11	5	1	2	4
200205	219	130	24	17	22	10	10	11	8	5	11	4	2	3	1
200305	265	172	24	17	24	17	11	15	13	6	11	7	3	5	1
200405	294	198	24	19	25	20	14	22	12	8	12	8	6	7	1
200505	401	206	24	20	28	23	17	23	12	6	14	7	6	5	1
200605	526	230	30	25	34	33	30	25	15	3	12	9	3	8	1
200705	642	281	41	29	43	44	37	27	14	3	13	10	3	5	1
200805	769	336	43	34	50	53	50	31	19	4	18	12	6	8	1
200905	861	314	54	36	52	39	54	33	17	6	12	11	9	11	1
201005	997	332	60	47	56	42	58	33	24	8	10	16	10	17	1
201105	1100	342	66	50	63	39	56	36	27	9	14	16	8	19	3
201205	1206	344	68	53	72	48	48	40	26	16	19	10	10	16	3
201305	1263	376	73	66	63	56	48	40	29	14	17	13	9	28	4
201405	1306	386	77	78	62	49	41	26	25	12	15	18	12	33	5
201505	1306	387	74	81	63	60	33	30	28	10	14	17	11	30	4
201605	1343	424	85	92	73	61	35	26	31	7	11	16	10	25	7
201705	1312	503	79	94	76	62	35	26	24	9	14	17	12	23	7
201805	1314	535	82	93	91	71	34	25	26	10	18	19	5	26	6
201905	1387	581	100	112	97	82	32	28	31	10	21	19	6	32	6
202005	1427	682	123	112	97	77	41	36	27	15	21	15	8	32	6
202105	1401	674	140	121	104	69	50	41	33	17	19	13	12	14	7
202205	1360	660	160	134	109	62	58	44	32	28	23	15	12	6	4

40+: Resistant to Disconnection

10+: Low Risk of Disconnection

3-9: Significant Risk of Disconnection

1-2: Severe Risk of Disconnection

“Provider dominance?”

Measure the number of IPv4/IPv6 prefixes in the routing table that are transited by a given provider.

Divide by the total number of IPv4/IPv6 prefixes that are originated in the given country.

The rough ‘BGP market share’ of the top provider should certainly be less than **70%**, and probably less than **40%** in a diverse economy.

Think of this as the percentage of a country’s address space that can be filtered by a single phone call….

Baltics: Provider Dominance, 2001-2022

	Lithuania: Top provider	share
200105	Telia-Lietuva (AS8764)	45%
200205	Telia-Lietuva (AS8764)	23%
200305	Telia-Lietuva (AS8764)	53%
200405	Telia-Lietuva (AS8764)	59%
200505	Telia-Lietuva (AS8764)	57%
200605	Telia-Lietuva (AS8764)	51%
200705	Telia-Lietuva (AS8764)	55%
200805	Telia-Lietuva (AS8764)	49%
200905	Telia-Lietuva (AS8764)	49%
201005	Telia-Lietuva (AS8764)	41%
201105	Telia-Lietuva (AS8764)	37%
201205	Telia-Lietuva (AS8764)	45%
201305	Telia-Lietuva (AS8764)	36%
201405	Telia-Lietuva (AS8764)	45%
201505	Telia-Lietuva (AS8764)	47%
201605	Telia-Lietuva (AS8764)	44%
201705	Telia-Lietuva (AS8764)	39%
201805	Telia-Lietuva (AS8764)	50%
201905	Telia-Lietuva (AS8764)	47%
202005	Telia-Lietuva (AS8764)	50%
202105	Telia-Lietuva (AS8764)	39%
202205	Telia-Lietuva (AS8764)	38%

	Latvia: Top provider	share
	LATTELEKOM (AS6747)	42%
	LATTELEKOM (AS6747)	39%
	LATTELEKOM (AS6747)	43%
	LATTELEKOM (AS6747)	48%
	TELIALATVIJA (AS5518)	27%
	LATTELEKOM (AS6747)	35%
	LATTELEKOM (AS6747)	36%
	LATTELEKOM (AS6747)	21%
	Baltcom-Fiber-AS (AS35254)	23%
	LATTELEKOM (AS6747)	21%
	ASGLBLCOM (AS42979)	20%
	TELIALATVIJA (AS5518)	18%
	APOLLO-AS (AS12578)	23%
	APOLLO-AS (AS12578)	24%
	APOLLO-AS (AS12578)	26%
	APOLLO-AS (AS12578)	27%
	APOLLO-AS (AS12578)	26%
	APOLLO-AS (AS12578)	29%
	APOLLO-AS (AS12578)	26%
	APOLLO-AS (AS12578)	24%
	APOLLO-AS (AS12578)	22%
	APOLLO-AS (AS12578)	23%

	Estonia: Top provider	share
	EENet-AS (AS3221)	56%
	ESTPAK (AS3249)	19%
	ESTPAK (AS3249)	35%
	ESTPAK (AS3249)	34%
	ESTPAK (AS3249)	34%
	ESTPAK (AS3249)	33%
	ESTPAK (AS3249)	34%
	ESTPAK (AS3249)	30%
	RGNET-SEA (AS3130)	72%
	ESTPAK (AS3249)	27%
	ESTPAK (AS3249)	26%
	ESTPAK (AS3249)	25%
	ESTPAK (AS3249)	29%
	ESTPAK (AS3249)	22%
	ESTPAK (AS3249)	18%
	PAGM-AS (AS198068)	17%
	ESTPAK (AS3249)	17%
	ESTPAK (AS3249)	17%
	?? (AS8728)	20%
	ESTPAK (AS3249)	18%
	ESTPAK (AS3249)	19%
	ESTPAK (AS3249)	20%

BY/UA/MD Provider Dominance, 2001-2022

	Belarus: Top provider	share
200105	BELPAK-AS (AS6697)	69%
200205	BELPAK-AS (AS6697)	41%
200305	BELPAK-AS (AS6697)	32%
200405	BELPAK-AS (AS6697)	40%
200505	BELPAK-AS (AS6697)	42%
200605	BELPAK-AS (AS6697)	66%
200705	BELPAK-AS (AS6697)	73%
200805	BELPAK-AS (AS6697)	75%
200905	BELPAK-AS (AS6697)	76%
201005	BELPAK-AS (AS6697)	76%
201105	BELPAK-AS (AS6697)	84%
201205	BELPAK-AS (AS6697)	80%
201305	BELPAK-AS (AS6697)	82%
201405	BELPAK-AS (AS6697)	72%
201505	BELPAK-AS (AS6697)	63%
201605	BELPAK-AS (AS6697)	55%
201705	NTEC (AS60280)	47%
201805	NTEC (AS60280)	53%
201905	NTEC (AS60280)	51%
202005	NTEC (AS60280)	49%
202105	NTEC (AS60280)	49%
202205	NTEC (AS60280)	49%

Ukraine: Top provider	share
UARNET-AS (AS3255)	16%
UARNET-AS (AS3255)	12%
UKRTELNET (AS6849)	16%
UKRTELNET (AS6849)	38%
UKRTELNET (AS6849)	44%
UKRTELNET (AS6849)	18%
Datagroup (AS21219)	13%
ETT-AS (AS35320)	15%
UARNET-AS (AS3255)	12%
UARNET-AS (AS3255)	13%
TOPNET (AS21011)	16%
TOPNET (AS21011)	20%
TOPNET (AS21011)	16%
TOPNET (AS21011)	13%
UKRTELNET (AS6849)	13%
UKRTELNET (AS6849)	13%
TRIOLAN (AS13188)	15%
TRIOLAN (AS13188)	15%
TRIOLAN (AS13188)	14%
Datagroup (AS3326)	16%
TRIOLAN (AS13188)	14%
UKRTELNET (AS6849)	25%

Moldova: Top provider	share
?? (AS8923)	48%
?? (AS8923)	44%
?? (AS9152)	49%
?? (AS9152)	46%
MOLDTELECOM-AS (AS8926)	30%
MOLDTELECOM-AS (AS8926)	45%
MOLDTELECOM-AS (AS8926)	23%
MOLDTELECOM-AS (AS8926)	31%
MOLDTELECOM-AS (AS8926)	28%
STARNET-AS (AS31252)	28%
MOLDTELECOM-AS (AS8926)	30%
STARNET-AS (AS31252)	30%
STARNET-AS (AS31252)	21%
MOLDTELECOM-AS (AS8926)	28%
MOLDTELECOM-AS (AS8926)	36%
MOLDTELECOM-AS (AS8926)	36%
MOLDTELECOM-AS (AS8926)	34%
ASN-OMD-FNO (AS25454)	35%
ASN-OMD-FNO (AS25454)	28%
MOLDTELECOM-AS (AS8926)	37%
MOLDTELECOM-AS (AS8926)	30%
MOLDTELECOM-AS (AS8926)	32%

Caucasus Provider Dominance, 2001-2022

	Georgia: Top provider	share	Armenia: Top provider	share	Azerbaijan: Top provider	share
200105	AS12497.0	22%	TELECOM-ARMENIA (AS12297)	28%	AET-AS (AS13099)	57%
200205	GRENA-AS (AS20545)	39%	TELECOM-ARMENIA (AS12297)	26%	AZT-AS (AS8814)	33%
200305	Geonet-AS (AS21214)	36%	AM-NETSYS-AS (AS21104)	38%	AZERONLINE (AS15723)	58%
200405	Geonet-AS (AS21214)	38%	AM-NETSYS-AS (AS21104)	33%	Delta-Telecom-AS (AS29049)	54%
200505	Geonet-AS (AS21214)	22%	TELECOM-ARMENIA (AS12297)	31%	Delta-Telecom-AS (AS29049)	63%
200605	CAUCASUS-CABLE-SYSTEM (AS20771)	28%	AS16190 (AS16190)	27%	Delta-Telecom-AS (AS29049)	97%
200705	CAUCASUS-CABLE-SYSTEM (AS20771)	48%	TELECOM-ARMENIA (AS12297)	26%	Delta-Telecom-AS (AS29049)	97%
200805	CAUCASUS-CABLE-SYSTEM (AS20771)	38%	AS16190 (AS16190)	46%	Delta-Telecom-AS (AS29049)	93%
200905	SILKNET-AS (AS35805)	75%	MTS-ARMENIA-AS (AS41965)	55%	Delta-Telecom-AS (AS29049)	95%
201005	SILKNET-AS (AS35805)	73%	MTS-ARMENIA-AS (AS41965)	38%	Delta-Telecom-AS (AS29049)	97%
201105	SILKNET-AS (AS35805)	43%	TELECOM-ARMENIA (AS12297)	29%	Delta-Telecom-AS (AS29049)	98%
201205	CAUCASUS-CABLE-SYSTEM (AS20771)	59%	GNC-ALFA (AS6682)	30%	Delta-Telecom-AS (AS29049)	96%
201305	CAUCASUS-CABLE-SYSTEM (AS20771)	39%	TELECOM-ARMENIA (AS12297)	27%	Delta-Telecom-AS (AS29049)	94%
201405	CAUCASUS-CABLE-SYSTEM (AS20771)	39%	TELECOM-ARMENIA (AS12297)	23%	Delta-Telecom-AS (AS29049)	89%
201505	CAUCASUS-CABLE-SYSTEM (AS20771)	35%	UCOMINT (AS8932)	46%	Delta-Telecom-AS (AS29049)	94%
201605	CAUCASUS-CABLE-SYSTEM (AS20771)	41%	UCOMINT (AS8932)	35%	Delta-Telecom-AS (AS29049)	86%
201705	CAUCASUS-CABLE-SYSTEM (AS20771)	37%	UCOMINT (AS8932)	34%	Delta-Telecom-AS (AS29049)	86%
201805	SILKNET-AS (AS35805)	53%	TELECOM-ARMENIA (AS12297)	28%	Delta-Telecom-AS (AS29049)	78%
201905	SILKNET-AS (AS35805)	48%	UCOMINT (AS8932)	29%	Delta-Telecom-AS (AS29049)	79%
202005	CAUCASUS-CABLE-SYSTEM (AS20771)	42%	TELECOM-ARMENIA (AS12297)	36%	Delta-Telecom-AS (AS29049)	81%
202105	CAUCASUS-CABLE-SYSTEM (AS20771)	36%	TELECOM-ARMENIA (AS12297)	36%	Delta-Telecom-AS (AS29049)	78%
202205	SILKNET-AS (AS35805)	40%	UCOMINT (AS8932)	36%	Delta-Telecom-AS (AS29049)	76%

Central Asian Provider Dominance, 2001-2022

	Kyrgyz Republic	Kazakhstan	Uzbekistan	Tajikistan	Turkmenistan
200105	33%	31%	50%	100%	100%
200205	42%	26%	84%	50%	100%
200305	68%	49%	65%	33%	100%
200405	55%	38%	51%	40%	100%
200505	28%	41%	59%	42%	100%
200605	45%	37%	79%	60%	100%
200705	70%	31%	94%	57%	100%
200805	47%	71%	69%	52%	100%
200905	36%	57%	73%	57%	100%
201005	46%	61%	65%	50%	100%
201105	36%	65%	70%	51%	92%
201205	46%	50%	92%	62%	95%
201305	65%	54%	87%	59%	91%
201405	37%	50%	83%	49%	83%
201505	39%	55%	88%	55%	85%
201605	44%	49%	89%	55%	83%
201705	40%	50%	91%	54%	80%
201805	29%	39%	91%	95%	75%
201905	40%	40%	92%	97%	57%
202005	33%	40%	91%	78%	70%
202105	34%	38%	97%	79%	73%
202205	38%	37%	98%	76%	77%

Trend is improving in KG, KZ; worrisome in UZ, TJ; improving but still highly concentrated in TM (numbers are small)

Conclusions

We have barely scratched the surface for centralization studies, using the countries that emerged from the USSR collapse as a natural laboratory

Accidents of history played a part – in particular, the 10+ years of evolution in the Russian Federation during which there was no coherent incumbent force opposing entrepreneurial innovation

Geography is clearly a primary determinant of Internet ecosystem health (Caucasus Cable System, Baltic interconnection with Scandinavia, Ukrainian interconnection with Poland+Czech Republic) but **not** the whole story

Next steps: study content placement (local hosting, remote hosting, local caches of remote content) and router-level, rather than ASN-level, path diversity

Thank you!