Project IPv6-First

A Case Study in Achieving an 80%+ Native IPv6 SOHO Network

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#apricot2026

APRICOT 2026

APNIC 61

APNIC IPv6 Deployment

The Objective

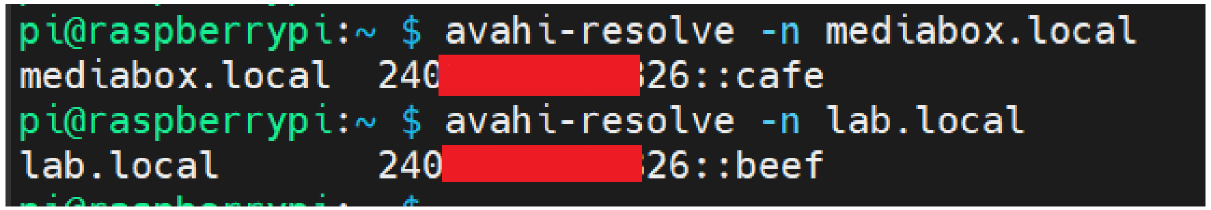
Is a near-native IPv6-first environment achievable today?

- **Goal:** Maximize the native IPv6 traffic ratio on a sophisticated SOHO network.
- **Method:** Data-driven analysis using NetFlow (Akvorado).
- **Challenge:** Identify and remediate residual IPv4 traffic sources without using transition technologies like CLAT (yet).

The Baseline Environment

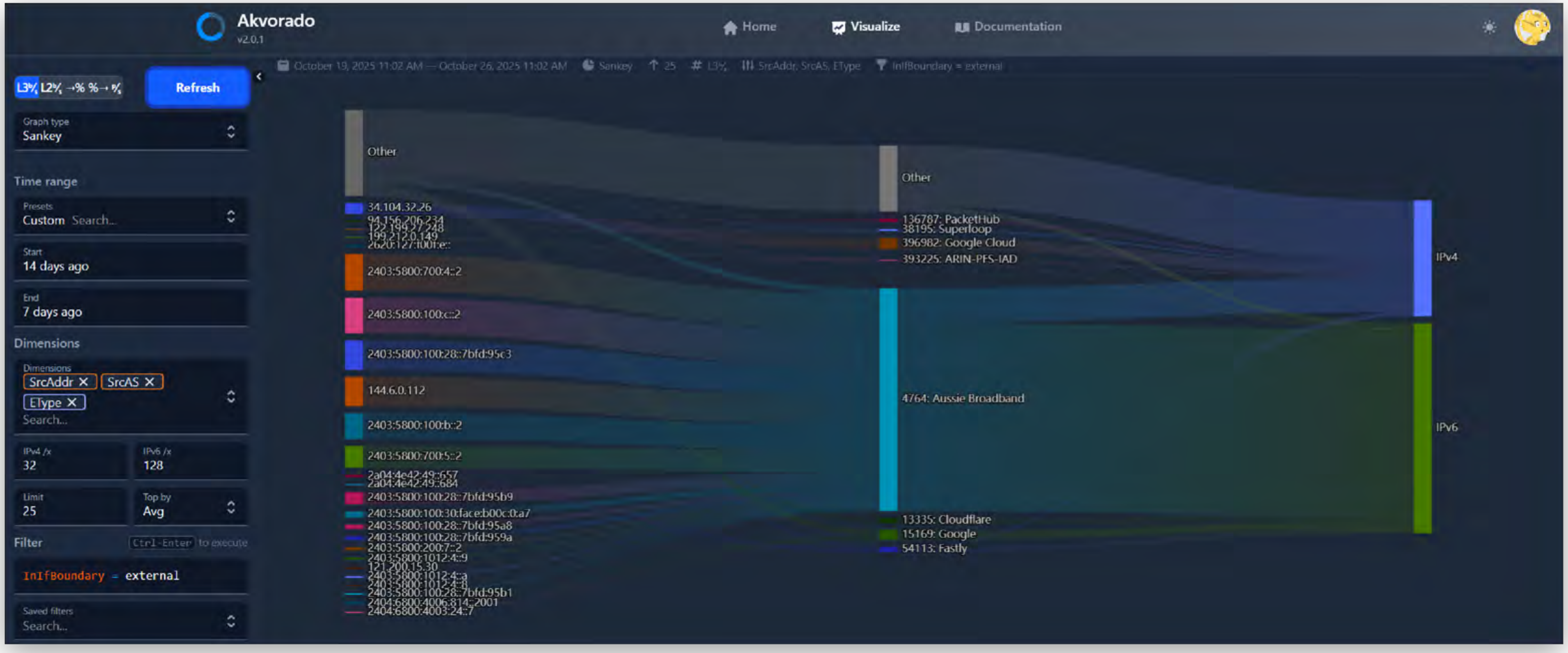
Starting from a robust dual-stack foundation:

- **ISP:** Aussie Broadband (Native IPv6 /48).
- **Gateway:** MikroTik (RouterOS).
- **DNS:** Public DNS Resolver 1.1.1.1
- **Philosophy:** Local services running on planned IPv6 addresses (e.g., `::cafe`, `::beef`).



```
pi@raspberrypi:~ $ avahi-resolve -n mediabox.local
mediabox.local  240[redacted]26::cafe
pi@raspberrypi:~ $ avahi-resolve -n lab.local
lab.local       240[redacted]26::beef
```

Data: The Starting Point



October 19, 2025 11:02 AM — October 26, 2025 11:02 AM · Sankey · ↑ 25 · # L3ᵇ⁄ₛ · SrcAddr, SrcAS, EType · InIfBoundary = external

Graph type: Sankey

Time range
Presets: Custom
Start: 14 days ago
End: 7 days ago

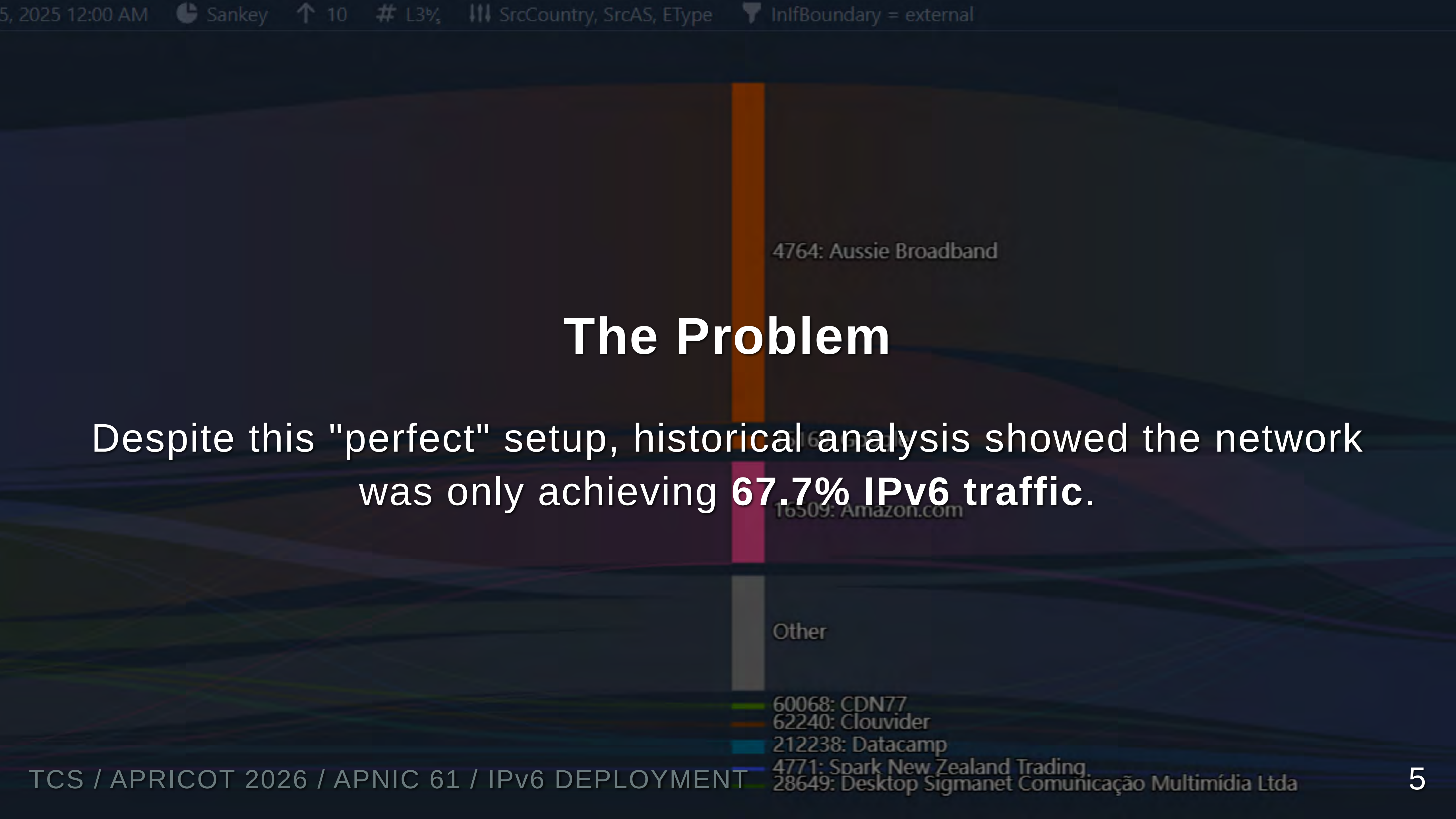
Dimensions
Dimensions: SrcAddr, SrcAS, EType
IPv4 /x: 32
IPv6 /x: 128
Limit: 25
Top by: Avg

Filter (Ctrl-Enter to execute)

```
InIfBoundary = external
```

Saved filters: Search...

(Ref: Akvorado Sankey Chart)



The Problem

Despite this "perfect" setup, historical analysis showed the network was only achieving **67.7% IPv6 traffic**.

Methodology: The "Find and Fix" Loop

1. **Establish Baseline:** Analyze destination ports and protocols via Akvorado.
2. **Isolate Laggards:** Identify high-bandwidth applications defaulting to IPv4.
3. **Targeted Intervention:** Reconfigure applications to force IPv6 compliance.
4. **Validate:** Measure the "After" state.

The First Culprit: BitTorrent

Initial Status:

BitTorrent was a significant drag on the network, operating at only **44% IPv6**.

The "Working" Dual-Stack Trap:

- The client was bound to "Any Interface."
- It accepted IPv4 peer connections from trackers immediately.
- **Result:** It defaulted to a suboptimal IPv4 NAT path rather than waiting for superior IPv6 peers.

Results: The Shift

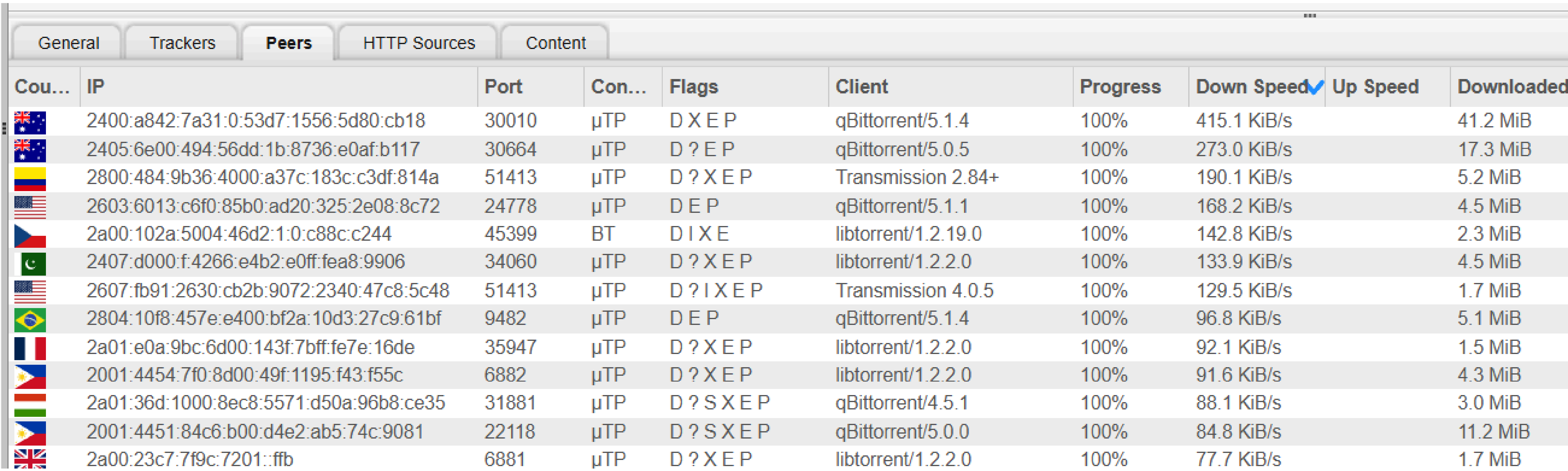
Application Level:

- BitTorrent traffic flipped from 44% to **ALL IPv6**.

Network Level:

- The structural change lifted the entire network's stable operational average from ~67% to **>80%**.

> “ How much would an ISP save on NAT444 at a ratio of 80% ipv6 traffic? ”



Cou…	IP	Port	Con…	Flags	Client	Progress	Down Speed	Up Speed	Downloaded
🇦🇺	2400:a842:7a31:0:53d7:1556:5d80:cb18	30010	µTP	D X E P	qBittorrent/5.1.4	100%	415.1 KiB/s		41.2 MiB
🇦🇺	2405:6e00:494:56dd:1b:8736:e0af:b117	30664	µTP	D ? E P	qBittorrent/5.0.5	100%	273.0 KiB/s		17.3 MiB
🇨🇴	2800:484:9b36:4000:a37c:183c:c3df:814a	51413	µTP	D ? X E P	Transmission 2.84+	100%	190.1 KiB/s		5.2 MiB
🇺🇸	2603:6013:c6f0:85b0:ad20:325:2e08:8c72	24778	µTP	D E P	qBittorrent/5.1.1	100%	168.2 KiB/s		4.5 MiB
🇨🇿	2a00:102a:5004:46d2:1:0:c88c:c244	45399	BT	D I X E	libtorrent/1.2.19.0	100%	142.8 KiB/s		2.3 MiB
🇵🇰	2407:d000:f:4266:e4b2:e0ff:fea8:9906	34060	µTP	D ? X E P	libtorrent/1.2.2.0	100%	133.9 KiB/s		4.5 MiB
🇺🇸	2607:fb91:2630:cb2b:9072:2340:47c8:5c48	51413	µTP	D ? I X E P	Transmission 4.0.5	100%	129.5 KiB/s		1.7 MiB
🇧🇷	2804:10f8:457e:e400:bf2a:10d3:27c9:61bf	9482	µTP	D E P	qBittorrent/5.1.4	100%	96.8 KiB/s		5.1 MiB
🇫🇷	2a01:e0a:9bc:6d00:143f:7bff:fe7e:16de	35947	µTP	D ? X E P	libtorrent/1.2.2.0	100%	92.1 KiB/s		1.5 MiB
🇵🇭	2001:4454:7f0:8d00:49f:1195:f43:f55c	6882	µTP	D ? X E P	libtorrent/1.2.2.0	100%	91.6 KiB/s		4.3 MiB
🇭🇺	2a01:36d:1000:8ec8:5571:d50a:96b8:ce35	31881	µTP	D ? S X E P	qBittorrent/4.5.1	100%	88.1 KiB/s		3.0 MiB
🇵🇭	2001:4451:84c6:b00:d4e2:ab5:74c:9081	22118	µTP	D ? S X E P	qBittorrent/5.0.0	100%	84.8 KiB/s		11.2 MiB
🇬🇧	2a00:23c7:7f9c:7201::ffb	6881	µTP	D ? X E P	libtorrent/1.2.2.0	100%	77.7 KiB/s		1.7 MiB

Local DNS & Happy Eyeballs

The "IPv6-First" success relies on a local DNS stack (Pi-hole + Unbound) that optimizes the **Happy Eyeballs v2 (RFC 8305)** race.

1. **The "Resolution Delay" (50ms):**
   - **Standard:** RFC 6724 sees to it that all `AAAA` records are ranked first.
   - **Local Edge:** Unbound resolves in **microseconds**. The `AAAA` record never arrives "late," so the browser never defaults to IPv4 during lookup.
2. **The "Connection Head Start" (~250ms):**
   - Because the IPv6 address is available instantly, the OS starts the IPv6 connection immediately.
   - It waits **~250ms** before attempting IPv4.
   - **Result:** IPv6 runs unopposed for a quarter of a second.

Key Takeaway: Local DNS resolution removes any "latency penalty" from the race, ensuring IPv6 is not just **preferred**, but mathematically **destined** to win.

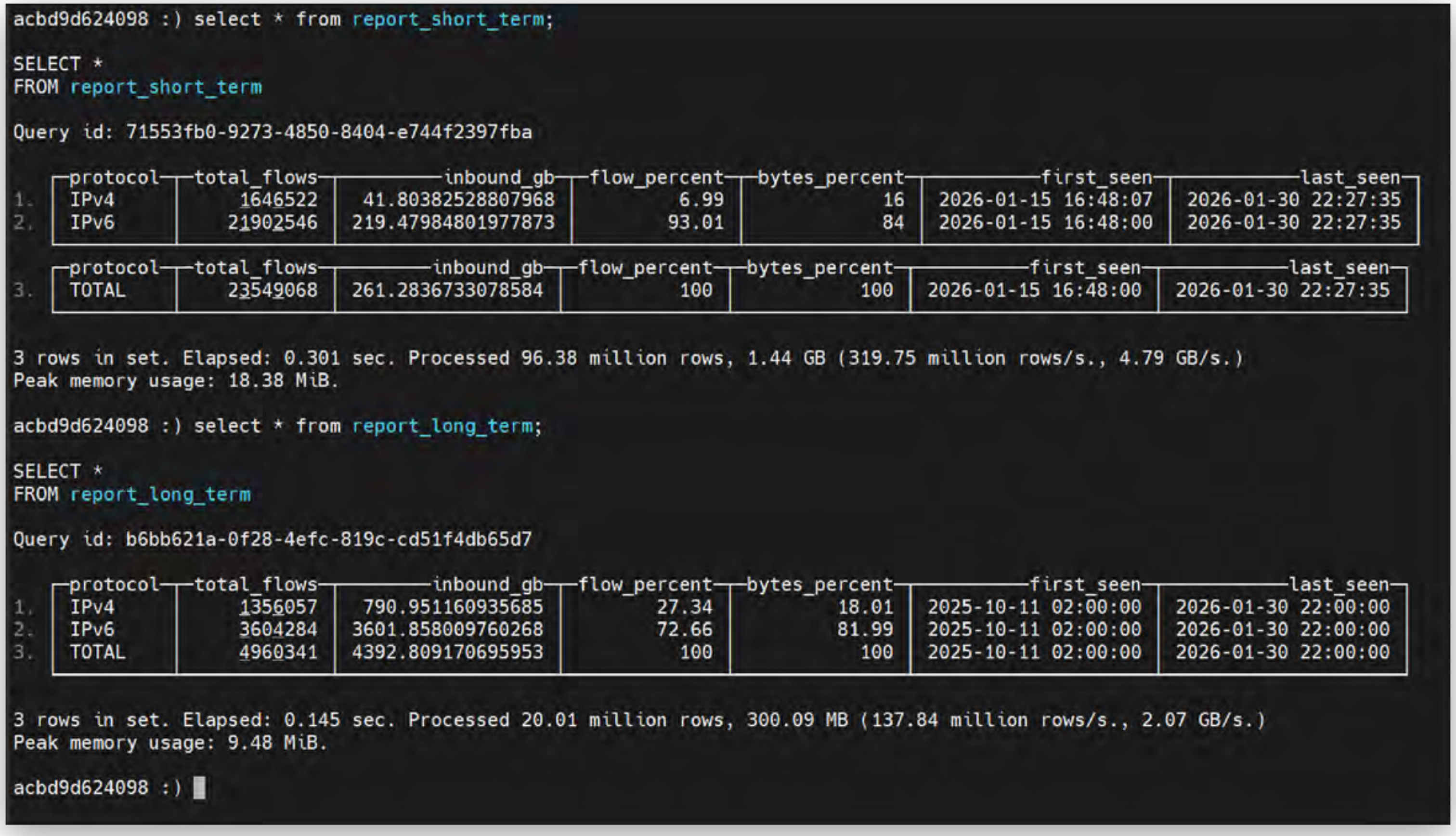
Update: Breaking the 90% Barrier

Recent SQL analysis (Dec 7 – Dec 22, 2025) shows continued optimization has pushed the network even further.

Metric	Long Term (Oct-Dec)	Short Term (Dec 7-22)
Total Flows	3.3M	28.1M
IPv6 Bytes %	81.19%	**90.74%**

“ The network is now operating as an effectively IPv6-Native environment. ”

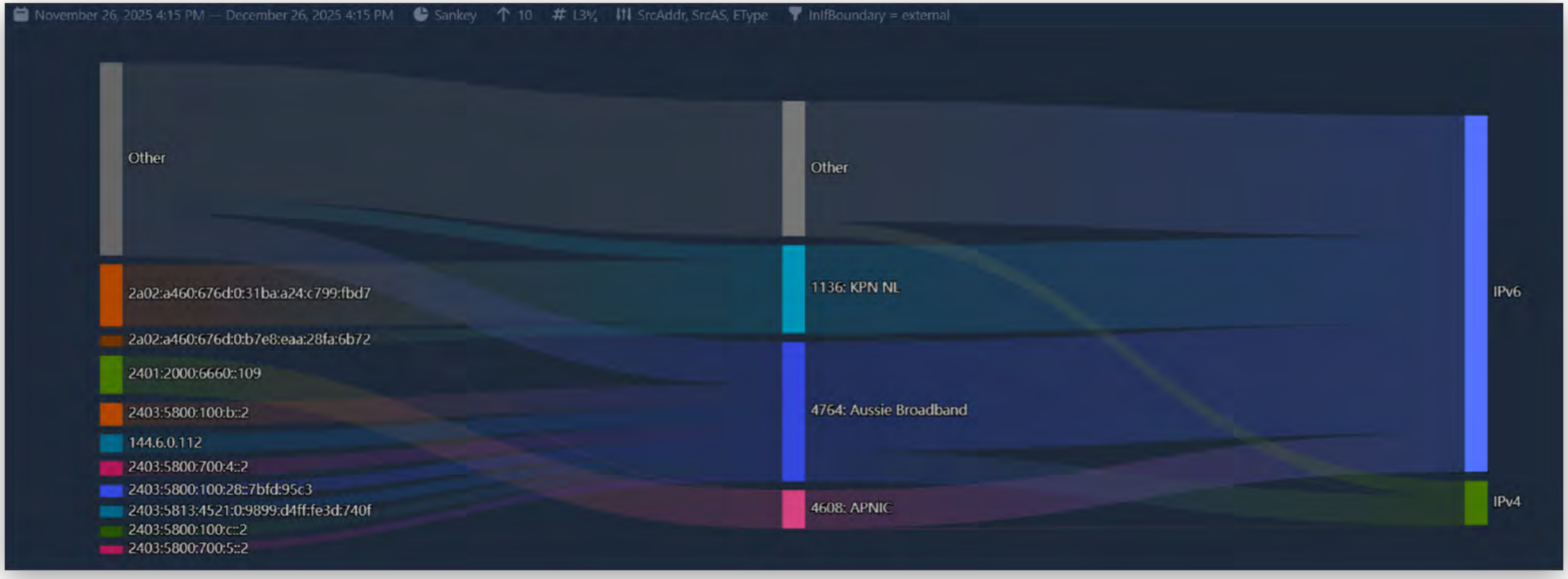
Storing the Data



```
acbd9d624098 :) select * from report_short_term;

SELECT *
FROM report_short_term

Query id: 71553fb0-9273-4850-8404-e744f2397fba

   ┌─protocol─┬─total_flows─┬──────────inbound_gb─┬─flow_percent─┬─bytes_percent─┬──────────first_seen─┬───────────last_seen─┐
1. │ IPv4     │     1646522 │   41.80382528807968 │         6.99 │            16 │ 2026-01-15 16:48:07 │ 2026-01-30 22:27:35 │
2. │ IPv6     │    21902546 │  219.47984801977873 │        93.01 │            84 │ 2026-01-15 16:48:00 │ 2026-01-30 22:27:35 │
   └──────────┴─────────────┴─────────────────────┴──────────────┴───────────────┴─────────────────────┴─────────────────────┘
   ┌─protocol─┬─total_flows─┬─────────inbound_gb─┬─flow_percent─┬─bytes_percent─┬──────────first_seen─┬───────────last_seen─┐
3. │ TOTAL    │    23549068 │  261.2836733078584 │          100 │           100 │ 2026-01-15 16:48:00 │ 2026-01-30 22:27:35 │
   └──────────┴─────────────┴────────────────────┴──────────────┴───────────────┴─────────────────────┴─────────────────────┘

3 rows in set. Elapsed: 0.301 sec. Processed 96.38 million rows, 1.44 GB (319.75 million rows/s., 4.79 GB/s.)
Peak memory usage: 18.38 MiB.

acbd9d624098 :) select * from report_long_term;

SELECT *
FROM report_long_term

Query id: b6bb621a-0f28-4efc-819c-cd51f4db65d7

   ┌─protocol─┬─total_flows─┬─────────inbound_gb─┬─flow_percent─┬─bytes_percent─┬──────────first_seen─┬───────────last_seen─┐
1. │ IPv4     │     1356057 │   790.951160935685 │        27.34 │         18.01 │ 2025-10-11 02:00:00 │ 2026-01-30 22:00:00 │
2. │ IPv6     │     3604284 │  3601.858009760268 │        72.66 │         81.99 │ 2025-10-11 02:00:00 │ 2026-01-30 22:00:00 │
3. │ TOTAL    │     4960341 │  4392.809170695953 │          100 │           100 │ 2025-10-11 02:00:00 │ 2026-01-30 22:00:00 │
   └──────────┴─────────────┴────────────────────┴──────────────┴───────────────┴─────────────────────┴─────────────────────┘

3 rows in set. Elapsed: 0.145 sec. Processed 20.01 million rows, 300.09 MB (137.84 million rows/s., 2.07 GB/s.)
Peak memory usage: 9.48 MiB.

acbd9d624098 :) 
```

(Ref: Clickhouse SQL Analysis confirming >90% IPv6 Netflow ratio)

Visualizing the Data


November 26, 2025 4:15 PM — December 26, 2025 4:15 PM Sankey 10 L3%, SrcAddr, SrcAS, EType InIfBoundary = external

(Ref: Akvorado Sankay Charts)

Macro vs. Micro: Validating the Data

My SOHO network mirrors global adoption curves, suggesting that **~80%** is the current "natural limit" for standard dual-stack implementation.

Context	IPv6 Ratio	Status
Germany (National)	**66.67%**	Strong legacy infrastructure drag
My Network (Baseline)	**67.70%**	Default configs favoring IPv4
India (National)	**78.90%**	Mobile-first / Greenfields architecture
France (National)	**79.23%**	Aggressive ISP migration
My Network (Optimized)	**79.20%**	Active deprecation of IPv4 paths
My Network (Dec '25)	**90.74%**	**The "IPv6-Native" Frontier**

Key Insight:

We can manually achieve today what the global internet would naturally reach in ~5 years.

Defining the "IPv4 Floor"

The remaining ~10% of IPv4 traffic is irreducible without CLAT/NAT64. It consists of:

1. **Legacy IoT:** Ring cameras (IPv4-only video upload).
2. **Legacy Web Services:**
    - Amazon.com (Main retail site).
    - GitHub.com (Main site, though assets are v6).
3. **ISP Infrastructure:** Aussie Broadband caching/accelerators.

> “ Or we can wait for these services to deploy ipv6 … ”

DNS-Aware Dynamic EAM "The Idea"

Standard 464XLAT double-translates traffic (IPv4 → IPv6 → IPv4).
For the "Ring Camera" problem (IPv4 device → IPv6 API), we can do better.

The Prototype: Unbound + Jool (SIIT)
I am proposing a dynamic extension to **RFC 7757 (EAM)**:

1. **Detect:** Daemon monitors local DNS (Unbound) for `A` + `AAAA` pairs.
2. **Map:** Dynamically populates the SIIT translator table.
3. **Result:** Legacy IPv4 devices connect **directly** to IPv6 APIs.

> **Impact:** This removes the "Vendor Negligence" traffic (e.g., Ring) from the IPv4 floor without waiting for firmware updates.

A Call to Action

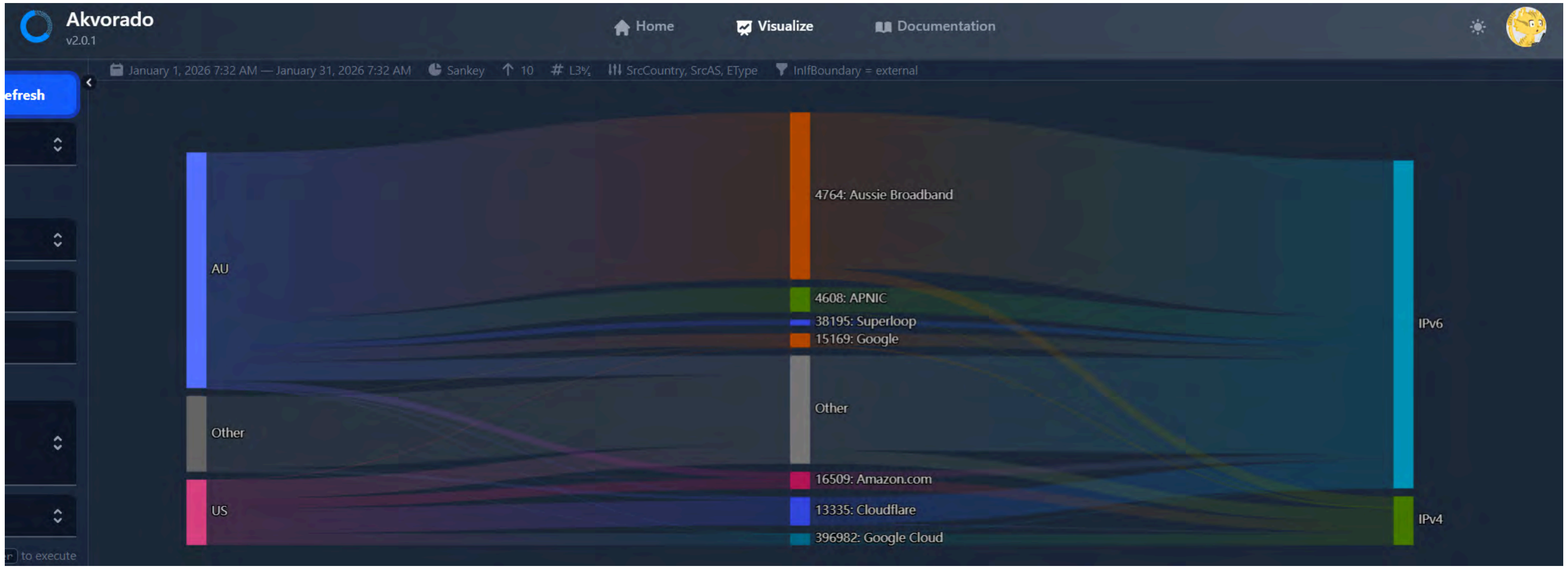
We need 464XLAT on more platforms, including PLAT and CLAT on Mikrotik.

📢 We Need Your Voice

Support Feature Request **#263487** to bring native 464XLAT to RouterOS.

forum.mikrotik.com/t/feature-request-464xlat/263487

January 2026 Data



January 1, 2026 7:32 AM — January 31, 2026 7:32 AM · Sankey · 10 · L3% · SrcCountry, SrcAS, EType · InIfBoundary = external

Acknowledgement

https://vaibhavbajpai.com/publications-by-year.html

The research and validation research of Prof Vaibhav Bajpai.

https://scholar.google.com.au/citations?user=ksAaiuUAAAAJ&hl=en&oi=ao

“ So, yes, we can live without ipv4 ... ”

https://bit.ly/3L4clnw