Evaluation of IPv6-only-Capable Iterative Resolvers

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ABSTRACT

This paper introduces an "IPv6-only-Capable resolver" to address the issue of many zones remaining unresolvable due to a lack of IPv6 connectivity in authoritative name servers. The proposed method utilizes NAT64 to transmit packets to IPv4-only authoritative name servers and increases resolution success rates with competitive response times compared to a traditional IPv6-only resolver.

KEYWORDS

IPv6, IPv4, NAT64, DNS resolution, Network performance

1 INTRODUCTION

The global transition from IPv4 to IPv6 is crucial for the Internet's future growth and stability [11], made more urgent by IPv4 address space depletion [5]. Several IPv6 transition technologies, facilitating IPv4-as-a-Service [1, 14, 16] in IPv6-only networks [18], have been created and performance-tested [8, 9, 15, 21]. Yet, DNS faces unique issues [4], with many zones unresolvable in IPv6-only settings due to incomplete DNS delegation chains via IPv6 or absent IPv6 connectivity in authoritative name servers [17]. Our previous experiments [19] have shown that having AAAA records for a domain does not guarantee its resolvability in an IPv6-only environment.

2 IPV6-ONLY-CAPABLE RESOLVER

This paper elaborates on the IPv6-only-Capable Resolver, a mechanism we propose in an Internet-Draft [20]. This is not a new concept, as they are gradually being incorporated in resolution software such as Unbound [7] and BIND [13].

As depicted in Figure 1, the resolver uses NAT64 to transmit packets to the IPv4-only authoritative name server. When encountering an authoritative name server with only an A record, the resolver performs address synthesis, converting the IPv4 address to IPv6. This allows the query to be routed to a stateful NAT64 [2] gateway for further IPv4 packet conversion. Contrary to 464XLAT [10], which relies on the device's operating system for the IPv4 to IPv6 translation and back, our proposed resolver performs the translation within the DNS resolver software, obviating the need for operating system support.

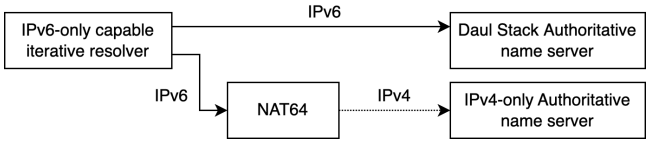

Figure 1: IPv6-only-Capable resolver

While our proposed resolver guarantees higher resolvability regardless of the IPv6 connectivity of the authoritative name servers, it does so at the potential expense of NAT64 overhead [15]. Hence, we conducted experiments to determine whether the benefits of universal resolvability outweigh the costs associated with NAT64 overhead.

3 ANALYSIS AND DISCUSSIONS

3.1 Setup and Methodology

We ran multi-threaded experiments, consisting of 100 iterations each, using the dig command on the top 100,000 domains from the Tranco list [12], and recorded query times and resolution failures. The Tranco list ranks the most popular domains on the Internet. We focused on the top 100,000 domains representing the most commonly accessed websites. Success was determined by receiving a "NOERROR" response, indicating a successful resolution, instead of a "SERVFAIL" error. We tested Unbound in six configurations (Table 1) and deemed a domain resolvable if it succeeded once in 100 attempts for both UDP and TCP [3] connections, using median response times of these attempts for each domain. Unbound with the NAT64 support feature enabled [7] was used as the resolver.

Configuration Name	Protocol	Preferred Protocol
Dual	Dual stack	Default[1]
Dual-prefer4	Dual stack	IPv4[2]
Dual-prefer6	Dual stack	IPv6[3]
IPv6only	IPv6-only	IPv6
Proposed-v6only-capable	Dual stack (via NAT64)	Default
Proposed-v6only-capable-prefer6	Dual stack (via NAT64)	IPv6

Table 1: Overview of resolver configurations

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Configuration Name	UDP	TCP
Dual	99.62%	99.59%
Dual-prefer4	99.62%	99.60%
Dual-prefer6	99.61%	99.60%
IPv6only	72.94%	72.97%
Proposed-v6only-capable	99.49%	99.49%
Proposed-v6only-capable-prefer6	99.49%	99.48%

Table 2: Success rates for different configurations

Our experiments took place in a network setup with the NAT64 gateway located in the same Autonomous System as the resolver, a common scenario for our proposed resolver's operation.

3.2 Performance Evaluation and Analysis

3.2.1 Resolution Success Rates: Table 2 presents varied resolution success rates. Dual stack resolvers (dual, dual-prefer6, dual-prefer4) attained 99.6% rates for TCP and UDP, while the IPv6-only configuration showed lower rates of 72.9%, implying IPv4 reliance. The proposed IPv6-only-Capable resolver configuration (v6only-capable and v6only-capable-prefer6) achieved 99.5% rates for both protocols. Although slightly lower than dual configurations, these rates show substantial improvement over the traditional IPv6-only resolver, suggesting potential for a smooth IPv4 to IPv6 transition.

3.2.2 Resolution Query time: For UDP, as in Figure 2(a), IPv6only configuration had the shortest median resolution time (103ms), but many queries ended prematurely as seen in its low success rate. The proposed v6only-capable resolver showed slightly longer median times (141ms for Proposed-v6only-capable and 123ms for Proposed-v6only-capable-prefer6), which are competitive with the dual stack configurations (115ms to 143ms).

TCP inherently has higher resolution times due to its connection-oriented nature, as depicted in Figure 2(b). The proposed v6only-capable resolver configurations produced median times (2823ms for Proposed-v6only-capable and 2721ms for Proposed-v6only-capable-prefer6) that remain competitive with the dual configurations, which ranged from 2583ms to 2783ms.

3.3 Discussion and Future Work

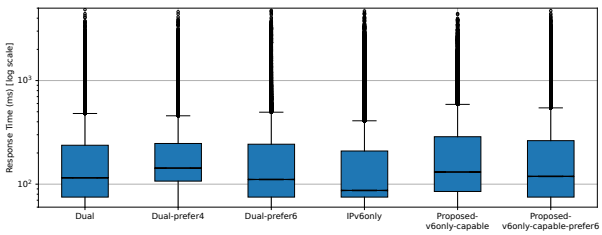
Our study shows that the proposed resolver resolves 30% more domains than the traditional IPv6-only method, with only a minor increase in response time. This suggests the potential to address DNS resolution challenges in IPv6-only networks with NAT64. Although response times may vary depending on network topology, speed, and NAT64 translator performance, the overall positive results from our experiments give us confidence in the efficacy of the proposed IPv6-only-Capable resolver.

Furthermore, we have observed that the choice of preferred protocol has an impact on resolution response times. The default algorithm in Unbound, which adapts to network conditions based on past response time data [6], may lead to unpredictable outcomes. Considering the faster speeds offered by the IPv6 network, prioritizing IPv6 over IPv4 emerges as a logical choice.

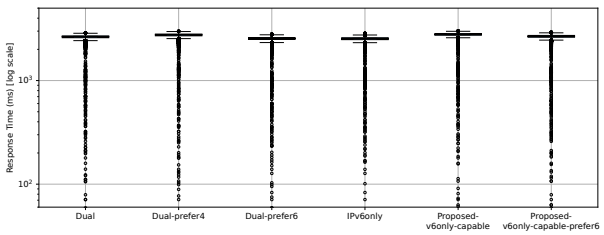
In future work, we aim to widen our experiments' scope to include diverse network locations and conditions. By incorporating further performance metrics, such as traffic overhead, resource utilization, and reliability, we can provide a more comprehensive evaluation. We also plan to conduct an in-depth comparison with 464XLAT. This will delve into aspects like efficiency, speed, resource usage, reliability, and ease of implementation, offering valuable insights into the strengths and potential areas for enhancement of our proposed resolver. Assessing the impact of NAT64 placement within the network topology could be another worthwhile avenue for exploration.

Collectively, these efforts promise to contribute significantly to the broader community as we navigate the IPv4 to IPv6 transition.

[1]The default protocol preference is determined by Unbound's algorithm based on past Round-Trip Time (RTT) data.
[2]When IPv4 is preferred, Unbound will use the IPv4 address first if available.
[3]When IPv6 is preferred, Unbound will use the IPv6 address first if available.



(a) UDP



(b) TCP

Figure 2: Name Resolution Response Times (log scale)

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