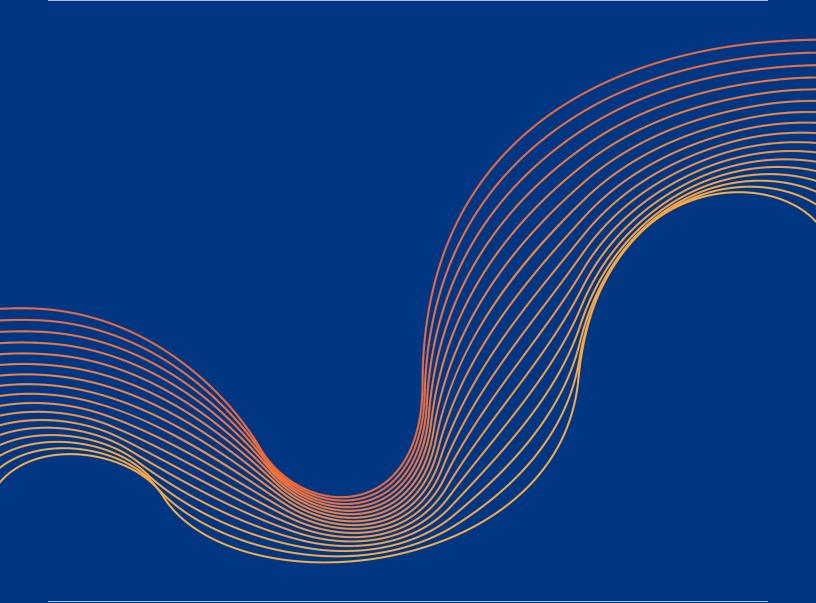
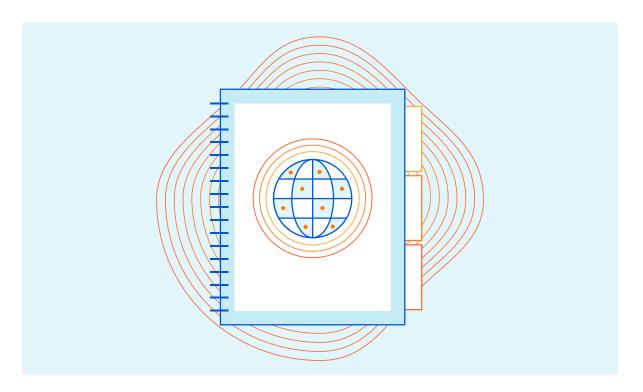


Improving DNS security, performance, and reliability



I. Executive Summary



A website or mobile application is only as fast as its slowest component. How can you ensure that DNS does not become that chokepoint?

When used and implemented properly, DNS can significantly improve an Internet property's security, performance, and reliability. However, the DNS infrastructure is highly vulnerable to a wide spectrum of increasingly common cyberattacks that can degrade performance or bring DNS servers down completely. These attacks, along with rising user expectations around website performance and availability, make it risky for DNS to be a single point of failure.

Achieving robust site security, performance, and reliability requires integrated DNS security and a redundant DNS infrastructure that is optimized for performance. This paper shows how to gain these benefits.

II. DNS security: A weak link in enterprise cybersecurity

The DNS infrastructure in use today was designed in the 1980s, when internet access was restricted to government agencies, scientists, and the military. The system's architects were concerned about reliability and functionality, not security.¹

As a result, DNS servers in the modern world are vulnerable to a broad spectrum of attack types, including spoofing, malware, DNS tunneling, and DoS/DDoS attacks. These attacks are happening more frequently and becoming more costly. According to IDC's 2019 Global DNS Threat Report:

- 82% of organizations suffered a DNS attack in the past two years
- Significant year-over-year increases were reported across all types of attacks, from volumetric to low-signal
- The average cost per attack exceeded \$1 million in 2019, up 49% from the year prior²

Another reason to be vigilant is that DNS attacks are frequently deployed in conjunction with other cyberattacks to distract security personnel from the true target. Verizon estimates that DNS attacks are involved in about one-third of data breaches³.

Types of DNS attacks

There are a variety of DNS attacks. Many are some variant of distributed denial of service (DDoS) attacks, in which so much traffic is sent to a targeted machine that legitimate traffic cannot get through.

Common attack methods include:

- DNS amplification. These attacks use a compromised endpoint to send UDP packets with spoofed IP addresses to a DNS recursor. Each one of the UDP packets makes a request to a DNS resolver, often passing an argument such as "ANY" in order to receive the largest response possible. After receiving the requests, the DNS resolver, which is trying to be helpful by responding, sends a large response to the spoofed IP address. The IP address of the target receives the response and the surrounding network infrastructure becomes overwhelmed with the deluge of traffic, resulting in a denial-of-service.
- DNS water torture. These attacks generate random strings (i.e. random fake subdomain names) to make DNS servers attempt to resolve the IP address for subdomains that don't exist, like xxyyzz.foo.com. As a result, foo.com must respond to the query even when xxyyzz.foo.com does not exist.
- DNS spoofing/cache poisoning: In these attacks, forged DNS data is introduced into a DNS resolver's cache, resulting in the resolver returning an incorrect IP address for a domain.
 Instead of going to the correct website, traffic can be diverted to a malicious machine or anywhere else the attacker desires; often this will be a replica of the original site used for malicious purposes such as distributing malware or collecting login information.

Optimizing DNS for security

Because the DNS threat landscape is so diverse, effectively mitigating DNS attacks requires an integrative security strategy that includes all of the following:



Enable DNSSEC, a set of security protocols that verifies DNS records using cryptographic signatures. By ensuring that a site's signature matches its record, DNS resolvers can authenticate the origin of the data being sent from the DNS server, preventing spoofing.



Implement multilayered DDoS mitigation, including traffic filtering measures such as rate limiting, allowlisting/blocklisting IP addresses, and connection tracking to block malicious requests while allowing legitimate traffic through. In addition to enhancing security, mitigating DDoS attacks will also improve reliability and performance by preventing malicious traffic from overwhelming DNS servers.



Deploy DNS firewalls (also known as DNS filtering and DNS blocking) to block access from known malicious domains.



Enable DNS logging. In addition to warning you if a hacker is trying to tamper with your DNS servers, DNS logging provides visibility into issues with DNS queries or updates.



Force HTTPS. Requiring browsers to always load websites over HTTPS prevents domain spoofing by authenticating each site with an SSL/TLS certificate.



Use multi-node resolution. This means handing off the DNS lookup process to different servers — often with different vendors or different networks — to create redundancy in case of an attack.

III. DNS performance: A potential weak link in website performance

When users access a web asset, their devices query a DNS resolver that maps the asset's domain name to its IP address, then sends the correct IP address back to the device. Each time a user accesses a new page in their browser, it must perform at least one DNS lookup; many pages load assets from more than one domain, which requires several lookups. This process is called DNS resolution, and the time required to resolve each requested domain quickly adds up. This is why optimizing DNS resolution speed is crucial to achieving low latency.

Not all DNS providers are optimized for resolution speed. A slow DNS provider could take over 120 milliseconds to resolve each DNS query.⁴ The fastest DNS providers will resolve queries in under 20 milliseconds; Cloudflare DNS, for example, resolves queries in under 12 milliseconds on average.⁵

- Today's web users demand that digital assets load instantaneously. Even small issues can have a noticeable impact on engagement and conversion rates.
- Increased site latency as small as 100-400 milliseconds has a measurable impact on consumer behavior⁶
- Just one additional second of load time can cause conversions to drop by 7%⁷
- About half of mobile users expect apps to respond in two seconds or less⁸
- Google uses page speed as a ranking factor for both desktop and mobile search⁹

Optimizing DNS for performance

Here are some steps you can take to ensure high performance in a marketplace where every millisecond matters.



Use global geolocation-based routing. Every 100 miles of geographic distance between end users and digital resources adds about 0.82 milliseconds of latency,10 so it's important to geo-steer visitors to DNS infrastructure that is located in their part of the world.



Determine an optimal time to live (TTL). TTLs indirectly control DNS resolver caching. Low TTLs can degrade performance but can aid DNS-based load balancing. High TTLs improve performance but can cause users to be directed to a cached server that has since gone down. Since so many factors are involved, there is no universal optimal TTL value.



Use anycast. Look for a DNS provider that uses anycast, which enables multiple, globally distributed DNS nameservers to advertise the same IP address. This improves DNS resolution speed and also provides seamless DNS failover protection.

Move your DNS to the Network Edge





IV. DNS reliability: Redundancy prevents downtime

Left unchecked, latency issues result in the worst-case scenario of your website going dark altogether. The costs of downtime are high: one study found that the average per-minute cost of a data center outage is USD \$8,851.¹¹

The goal for any business must be nothing less than 100% uptime. While that may sound lofty, it's achievable if organizations use a multi-pronged approach centered on redundancy.

Optimizing DNS for reliability

Performance and reliability are like the head and the neck; they are closely connected. one cannot exist without the other. All of the measures you take to improve reliability will also enhance performance. For example, using dual DNS providers improves page load times because resolving nameservers will default to the fastest DNS provider.

- Use a multi-DNS approach. In a single-provider DNS setup, all users are answered by that provider's nameserver set, leaving sites vulnerable to provider outages. Alternatives include:
 - Dual (primary/secondary) DNS providers. Adding a second DNS provider doubles
 the number of nameserver sets that are available for those domains. If the authoritative
 provider is unavailable, query traffic is automatically routed to the backup nameserver set.
 - Hidden Primary. In this model, the authoritative server is not visible to the public Internet, and is often hidden behind a firewall. Its DNS records are replicated to the secondary DNS server, which responds to requests.
 - Primary-Primary. In this model, both servers are visible to the public Internet.
- Cloud-based DNS. Few organizations have the in-house resources and expertise to manage their own DNS servers.
- Nameserver segmentation. Some DNS providers cluster many or even all of their customers
 in the same nameserver record. If one customer suffers a DDoS attack, all of their "neighbors"
 are severely impacted. Make sure your DNS provider segments their network so that only a
 small number of customers share nameserver records.
- A very large, global network of DNS nodes. Your provider's DNS network should include a large number of globally distributed DNS nodes, so if one node fails, traffic can be routed to any of the remaining nodes. A global network also allows for geo-steering, which improves performance.
- **Global and local load balancing.** In addition to ensuring that no one server is overloaded, if a server does fail, a load balancer redirects traffic to the remaining servers.

V. Conclusion

A few milliseconds of load time can make or break your user experience and conversion rate. Website performance and reliability hinge on DNS resolution speed, but DNS servers are extremely vulnerable to a wide variety of cyberattacks. Ensuring a secure, high-performance DNS infrastructure with 100% uptime requires an integrated approach to security, reliability, and performance.

VI. How Cloudflare can help

Cloudflare offers an enterprise-grade authoritative DNS service that's reflective of many of these best practices, offering the fastest response time, unparalleled redundancy, and advanced security with built-in DDoS mitigation and DNSSEC. To learn more and speak to a member of our team, visit www.cloudflare.com/dns/.

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