Enhancing the Scalability and Robustness of DNS over QUIC (DoQ) in Heterogeneous Network Environments

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Abstract

This project aims to evaluate and enhance the scalability and robustness of DNS over QUIC (DoQ) in heterogeneous network environments, including mobile and IoT networks. By addressing the unique challenges posed by these environments, such as higher variability in network conditions, resource constraints, and mobility, this research seeks to optimize DoQ's performance and reliability.

The research will involve simulating diverse network environments using tools like NS3 and OMNeT++, conducting extensive performance tests, and developing optimization techniques such as session resumption, 0-RTT, and adaptive congestion control. The expected outcome is a set of practical guidelines and performance benchmarks that showcase DoQ's advantages and propose improvements for its deployment in mobile and IoT networks. This work extends the foundational research on DoQ by addressing its performance in dynamic and resource-constrained environments, providing new insights and solutions for real-world applications.

Objective

Scalability Evaluation:
Assess DoQ's scalability in large-scale deployments within mobile and IoT networks.

Robustness Analysis:
Investigate DoQ's robustness under varied network conditions, including high latency and packet loss scenarios typical of mobile environments.

Optimization Techniques:
Develop and test optimization techniques to enhance DoQ's performance in these heterogeneous environments.

Introduction

Background:
DNS over QUIC (DoQ) has shown promise in enhancing DNS privacy and performance by combining transport and cryptographic handshakes into a single round-trip. This reduces latency compared to traditional DNS over HTTPS (DoH) and DNS over TLS (DoT) [1].

Research Problem:
While DoQ's benefits have been demonstrated in traditional web environments, its performance in mobile and IoT networks, which are characterized by higher variability in network conditions, resource constraints, and mobility, remains unexplored.

Methodology

Experimental Setup:
- Use advanced network simulation tools (e.g., NS3, OMNeT++) to simulate diverse network environments, including 5G, LTE, and IoT networks.
- Deploy measurement tools to collect data on response times, connection latency, throughput, and packet loss rates.

Data Collection:
- Perform tests across multiple mobile and IoT network scenarios, comparing DoQ's performance with DoH and DoT.
- Long-term performance analysis under varied network conditions to gather comprehensive data on DoQ's reliability and scalability.

Solution

1. Session Resumption and 0-RTT Optimization:
Goal: Reduce connection latency.
- Implementing TLS 1.3 session resumption to quickly re-establish connections without a full handshake [2].
- Enabling 0-RTT in QUIC to send data in the first packet, eliminating handshake delays.

Expected Outcome: Faster DNS resolution, especially in high-latency environments.

2. Adaptive Congestion Control Mechanisms:
Goal: Improve performance under varying network conditions.
- Using BBR or Cubic to dynamically adjust data flow based on network conditions [3].
- Switching between congestion control algorithms based on real-time metrics like packet loss and latency.

Expected Outcome: More stable and efficient performance in mobile and IoT networks.

3. Edge Computing Integration
Goal: Reduce latency and improve scalability.
- Deploying DoQ resolvers at edge nodes closer to end-users [4].
- Implementing intelligent load balancing across edge nodes.

Expected Outcome: Lower latency and increased scalability through distributed processing.

Artifact

Scan here to read the foundation paper

This research study builds on the advanced internet architectures and network performance optimization concepts discussed by Prof. Dr. Vaibhav Bajpai. By exploring DoQ in mobile and IoT contexts, this study extends the foundational work and offers practical solutions to real-world networking challenges.

[1]: Kosek, M., et al, "DNS privacy with speed? evaluating DNS over QUIC and its impact on web performance," in *Proceedings of the 22nd ACM Internet Measurement Conference*, 2022, pp. 44–50.
[2]: Rescorla, E., " The Transport Layer Security (TLS) Protocol Version 1.3 ", RFC 8446, 2018
[3]: Langley, A., et al, "The QUIC Transport Protocol: Design and Internet-Scale Deployment," in *Proceedings of the Conference of the ACM Special Interest Group on Data Communication*, 2017, pp. 183–196.
[4]: Iyengar, J., Thomson, M., "QUIC: A UDP-Based Multiplexed and Secure Transport," RFC 9000 , 2021.

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