DNSRelay - Group 24

> *Group Members: Tiantian Li, He Zhu, Tianyi Yang*

Overview

Brief Requirements

Implement a DNS relay that:

- Receives DNS queries from DNS clients and forwards them to a given DNS server.
- Receives DNS responses from the DNS server and forwards them to the clients.

There are 3 different cases we need to handle:

- For domain name included in the local database (e.g., hosts.txt), it sends back the corresponding IP addresses.
- If found, for IP address 0.0.0.0, it sends back "no such name"(reply code=0011).
- For domain name not included in the database, it forwards the query to the DNS server.

Target

One of the targets is to gain a deeper understanding of how the Domain Name System (DNS) works and, specifically, to learn about the process of resolving domain names to IP addresses, which is a fundamental aspect of how the Internet functions.

By implementing a DNS relay in Rust, we will have the opportunity to learn how to work with Rust's syntax and data types, as well as its concurrency model. Rust has a strong focus on safe and efficient concurrency, which makes it a great choice for building network applications such as a DNS relay.

Requirements Analysis

Development Environment

- Operating system: Arch Linux
- Programming language: Rust 1.70.0

Detailed Requirements

On startup, the program should read environmental variables, command line arguments and the local hosts file. It also opens two `UdpSocket`s: one for communicating with clients, one for communicating with upstream DNS server.

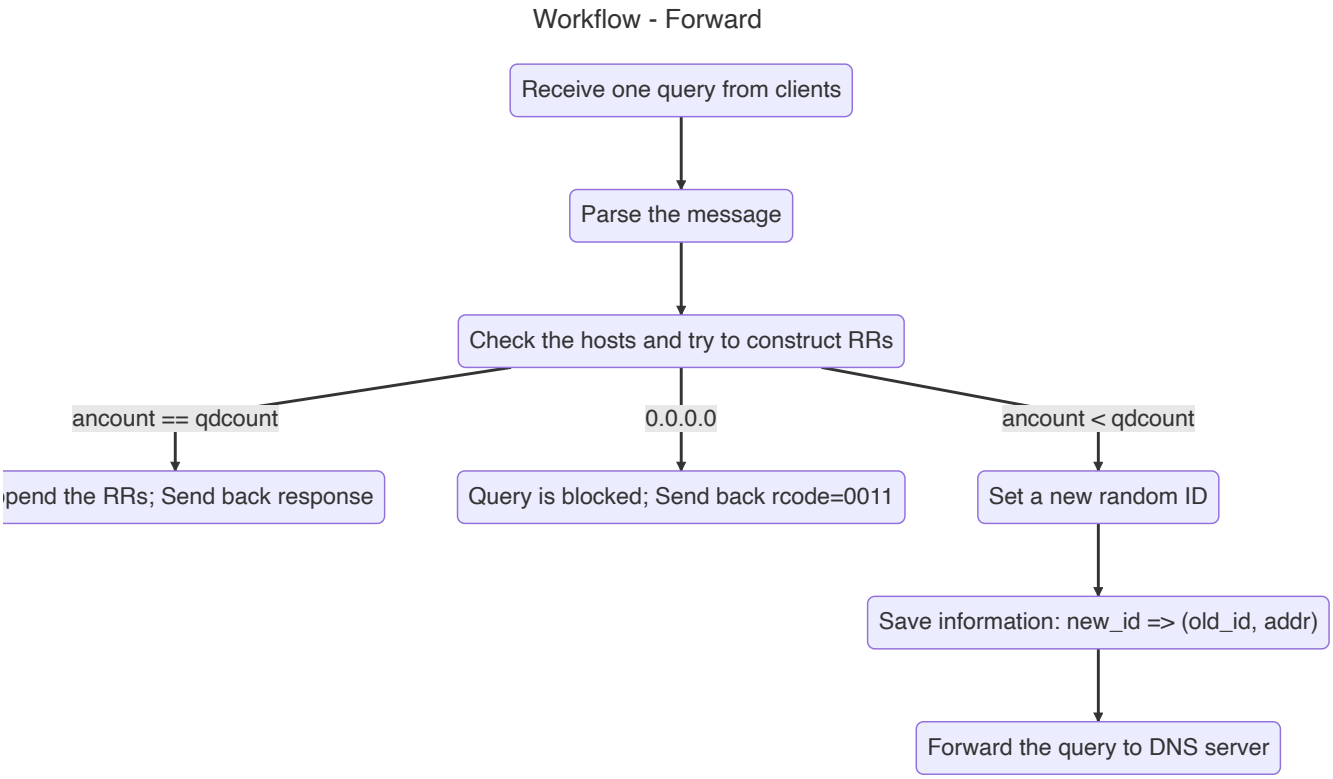
Upon receiving queries from clients, the program parses the packet and extract useful information for further processing. The hosts file is checked for local answer construction and blacklist blocking.

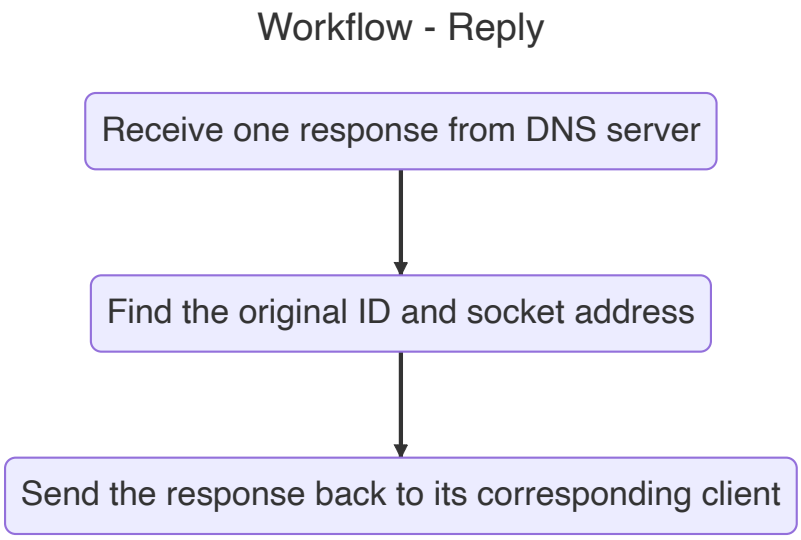
If all questions in the query can be processed without consulting the upstream DNS server, a reply consisting of one or multiple answers is constructed and sent to the clients. Otherwise, the query packet is forwarded to the upstream DNS server.

System Design

Generally speaking, there are two loops running **asynchronously**, namely '**forward**' and '**reply**'. The following diagrams show the their workflows.

Flow Chart





Module Decomposition

The application consists of three parts serving different functionalities:

- `main.rs` - the entry of the program
- `lib.rs` - the business logic, including the two workflows mentioned above configuration reading
- `packet.rs` - the homemade wrappers for DNS packets

Data Structures

Struct `Message` comprises a header, a question, and an answer struct. All three types of struct consist of a mutable reference to a byte buffer and the length of the buffer. Methods such as `get_id()` and `add_entries()` are implemented to manipulate the underlying data.

```
pub struct Message<'a> {
    pub header: Header<'a>,
    pub question: Question<'a>,
    pub answer: Answer<'a>,
}
```

Struct `QuestionEntry` is comprised of an offset, a qname, a qtype and a qclass. It is used to represent the parsed version of entries in the question section.

The offset points to the starting byte of the qname. The qname is the query string. The qtype field is used to specify the type of resource record being requested. Common types include A records (which map domain names to IP addresses), MX records (which specify the mail server for a domain), and NS records (which specify the authoritative name server for a domain). The qclass field is used to specify the class of the resource record being requested. This is typically set to IN, which indicates that the record is part of the Internet class.

```
pub struct QuestionEntry {
    pub offset: usize,
    pub qname: String,
    pub qtype: u16,
    pub qclass: u16,
}
```

Struct `ResourceRecord` contains the information needed to construct the reply packet. It includes a name, a rtype, a rclass, a ttl, a rdlength, and a rdata. The name is stored as a pointer for message compression.

```rust
pub struct ResourceRecord {
    pub name: u16,
    pub rtype: u16,
    pub rclass: u16,
    pub ttl: u32,
    pub rdlength: u16,
    pub rdata: RData,
}

pub enum RData {
    V4([u8; 4]),
    V6([u8; 16]),
}
```

Testings and Results

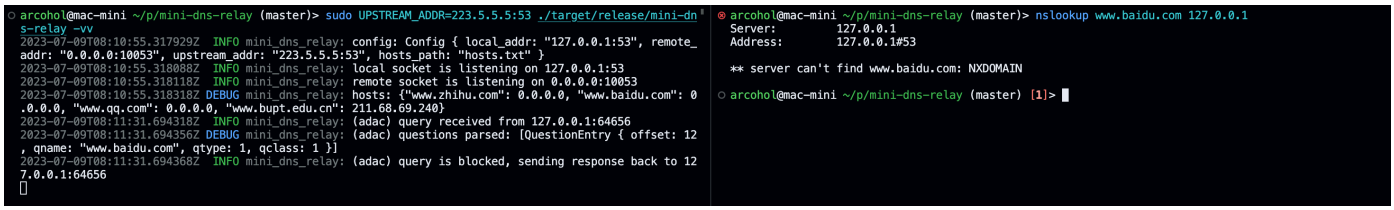
Sample hosts file:

```
# ./hosts.txt
0.0.0.0 www.baidu.com www.zhihu.com www.qq.com
211.68.69.240 www.bupt.edu.cn
```

1. Blacklist

As shown in the `hosts.txt`, `www.baidu.com` is blocked with an address of `0.0.0.0`.

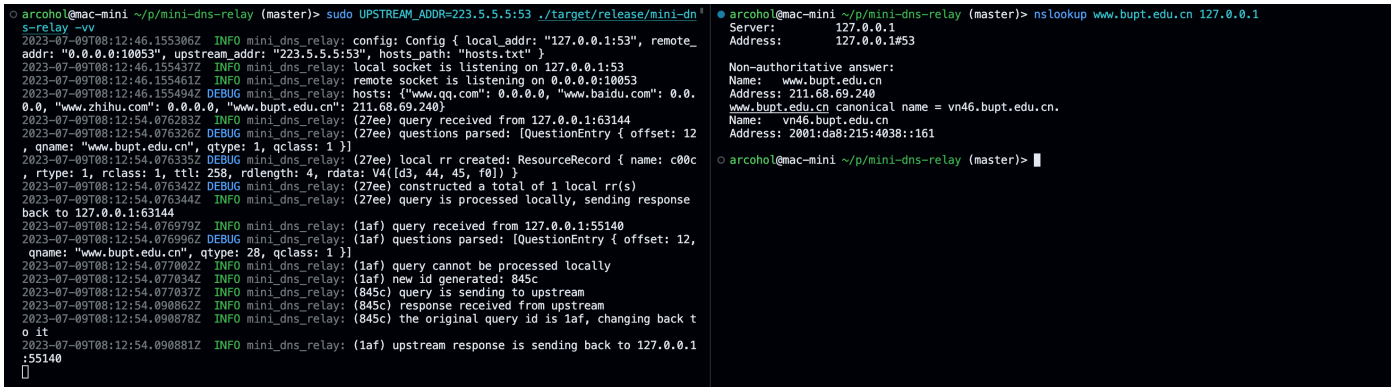
The program responded with a `NXDOMAIN`, indicating that the domain does not exist.



2. Local Record Matching

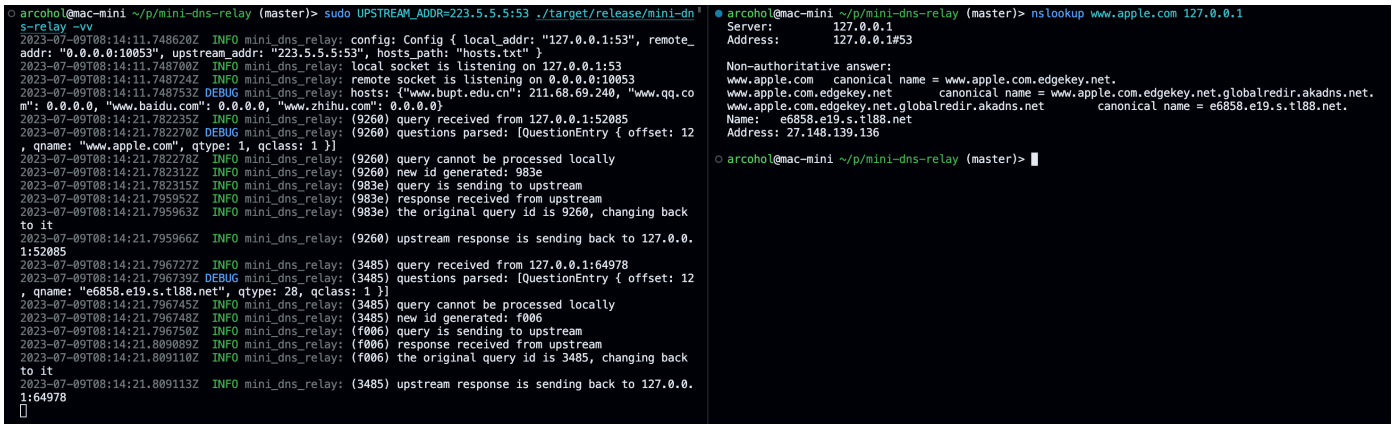
`www.bupt.edu.cn` exists as an entry in hosts.txt, so the relay server successfully constructed a local resource record and returned the recorded A answer `211.68.69.240`.

The AAAA query which cannot be processed locally is forwarded to the upstream.



3. Upstream Forwarding

`www.apple.com` was not found in the hosts. Therefore, the program forwarded the packet to upstream DNS server. After receiving the reply from the upstream, the server forwarded the response back to the client.



Conclusion and Future Improvements

The implementation of a DNS relay is a challenging and rewarding project that provides a valuable learning experience in network programming. Through this project, we have gained a deeper understanding of the Domain Name System (DNS) and how it facilitates internet communication by resolving domain names to IP addresses.

Our implementation of the DNS relay in Rust allowed us to learn and improve our skills in this modern systems programming language. Rust's features and focus on safe and efficient concurrency made it an excellent choice for building a network application such as a DNS relay.

Throughout the implementation process, we faced a number of challenges, including working with DNS queries and responses. However, through a methodical approach to problem-solving and careful consideration of system design, we were able to overcome these challenges and produce a functional and reliable DNS relay

server.

There are several possible future improvements that can be employed in this system. For example, a fast and reliable caching system can be implemented so that the network consumption for upstream link can be greatly reduced. It could be very tricky as this involves cache time design, and possibly recursive searching. We decided to not include a cache in this system because we think a unreliable cache is pretty much redundant and may cause a significant drop of performance.

Overall, this project has provided us with valuable experience in network programming, Rust development, and system design.

Contribution

Tiantian Li:

- Business Logic Design: Tiantian played a crucial role in the design phase of the project, contributing to the development of the overall business logic architecture. He was responsible for analyzing the requirements and designing the high-level structure of the DNS relay server.
- Concrete Implementation: Tiantian took charge of implementing the business logic of the DNS relay server, translating the design into actual code. He was responsible for writing the core functionality of the server, including handling DNS queries, forwarding requests, and managing local RR construction. He was also responsible for implementing the server in a non-blocking manner.

He Zhu:

- Business Logic Design: He Zhu actively participated in the business logic design phase, collaborating with the team to brainstorm ideas and propose solutions. He provided valuable insights and contributed to shaping the overall architecture of the DNS relay server.
- Program Testing: He Zhu took the lead in testing the server implementation thoroughly. He designed and executed comprehensive test cases to verify the functionality, performance, and resilience of the DNS relay server. His meticulous testing approach helped identify and rectify potential bugs and vulnerabilities, ensuring the server's robustness.

- Report Writing: He Zhu also played a significant role in documenting the project. He contributed to the writing of the final report, including describing the system architecture, outlining the testing methodology, and discussing the results. His clear and concise writing style helped present the project in a comprehensive and organized manner.

Tianyi Yang:

- Business Logic Design: Tianyi actively participated in the business logic design discussions, providing valuable inputs and suggestions. He contributed to the overall architecture design of the DNS relay server, ensuring that the system met the specified requirements.
- Program Testing: Tianyi collaborated with He Zhu in executing the testing phase. They worked together to design and execute test cases, evaluate the server's performance under various scenarios, and identify potential issues. Tianyi's analytical skills and attention to detail were instrumental in ensuring the server's stability and reliability.
- Report Writing: Tianyi actively contributed to the report writing process. He collaborated with the team to gather and organize information, wrote sections of the report, and ensured that the document maintained a consistent style and structure. Tianyi's ability to synthesize complex information into a coherent narrative greatly contributed to the final report's quality.