Requirements of TinyURL's Design

Understand the requirements and estimations for designing a URL shortening service.

We'll cover the following

Requirements for URL Shortening Design

Let's look at the functional and non-functional requirements for the service we'll be designing:

Functional requirements

- **Short URL generation**: Our service should be able to generate a unique shorter alias of the given URL.
- **Redirection**: Given a short link, our system should be able to redirect the user to the original URL.

- **Custom short links:** Users should be able to generate custom short links for their URLs using our system.
- **Deletion**: Users should be able to delete a short link generated by our system, given the rights.
- **Update**: Users should be able to update the long URL associated with the short link, given the proper rights.
- **Expiry time**: There must be a default expiration time for the short links, but users should be able to set the expiration time based on their requirements.

Quiz

Question

As a design choice, we don't reuse the expired short URLs. Since we don't reuse them, why do we need to delete them from our system?

Show Answer

Non-functional requirements

- **Availability**: Our system should be highly available, because even a fraction of the second downtime would result in URL redirection failures. Since our system's domain is in URLs, we don't have the leverage of downtime, and our design must have fault-tolerance conditions instilled in it.
- **Scalability**: Our system should be horizontally scalable with increasing demand.
- **Readability**: The short links generated by our system should be easily readable, distinguishable, and typeable.

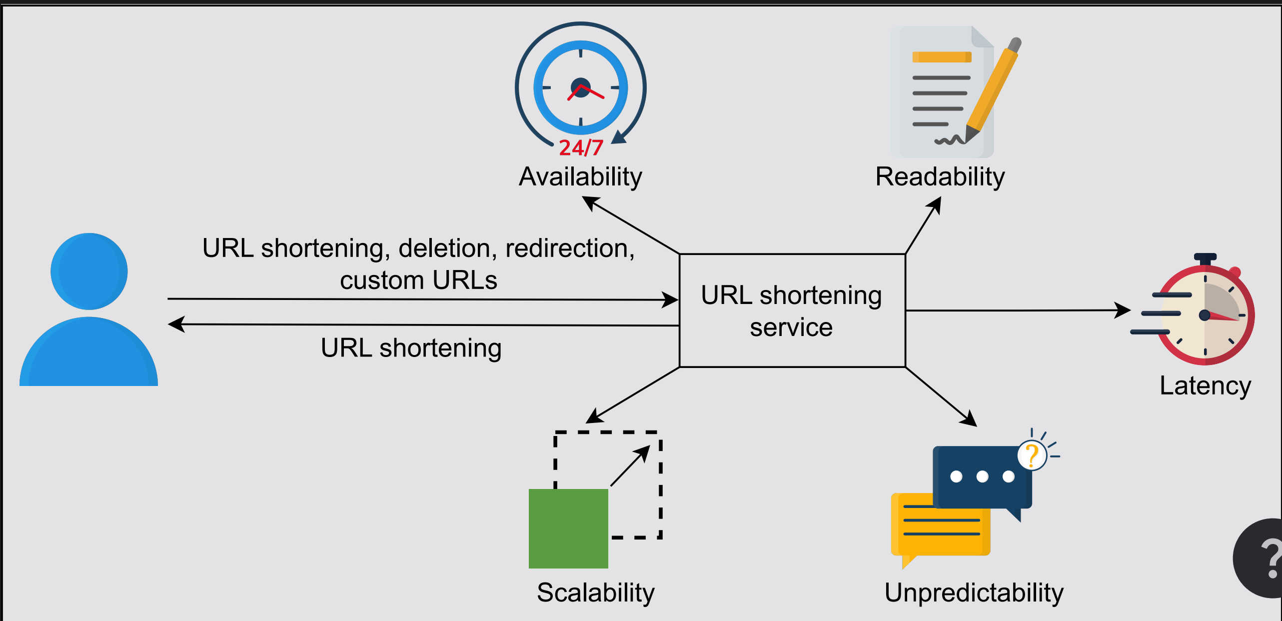
- **Latency**: The system should perform at low latency to provide the user with a smooth experience.
- **Unpredictability**: From a security standpoint, the short links generated by our system should be highly unpredictable. This ensures that the next-in-line short URL is not serially produced, eliminating the possibility of someone guessing all the short URLs that our system has ever produced or will produce.

Quiz

Question

Why is producing unpredictable short URLs mandatory for our system?

Show Answer



Functional and non-functional requirements

Resource estimation

It's better to have realistic estimations at the start. For instance, we might need to change them in the future based on the design modifications. Let's make some assumptions to complete our estimation.

Assumptions

- We assume that the shortening:redirection request ratio is $1:100$.
- There are 200 million new URL shortening requests per month.
- A URL shortening entry requires 500 Bytes of database storage.
- Each entry will have a maximum of five years of expiry time, unless explicitly deleted.
- There are 100 million Daily Active Users (DAU).

Storage estimation

Since entries are saved for a time period of 5 years and there are a total of 200 million entries per month, the total entries will be approximately 12 billion.

$$200\ Million/month \times 12\ months/year \times 5\ years = 12\ Billion\ URL\ shortening\ requests$$

Since each entry is 500 Bytes, the total storage estimate would be 6 TB:

$$12\ Billion \times 500\ Bytes = 6\ TB$$

URL Shortening Service Storage Estimation Calculator

URL shortening per month	200	Million
Expiration time	5	Years
URL object size	500	Bytes
Total number of reques	*f* 12	Billion

ts		
Total storage	*f* 6	TB

Total storage required by the URL shortening service in 5 years

Query rate estimation

Based on the estimations above, we can expect 20 billion redirection requests per month.

$$200\ Million \times 100 = 20\ Billion$$

We can extend our calculations for Queries Per Second (QPS) for our system from this baseline. The number of seconds in one month, given the average number of days per month is 30.42:

$$30.42\ days \times 24\ hours \times 60\ minutes \times 60\ seconds = 2628288\ seconds$$

Considering the calculation above, new URL shortening requests per second will be:

$$\frac{200\ Million}{2628288\ seconds} = 76\ URLs/s$$

With a $1:100$ shortening to redirecting ratio, the URL redirection rate per second will be:

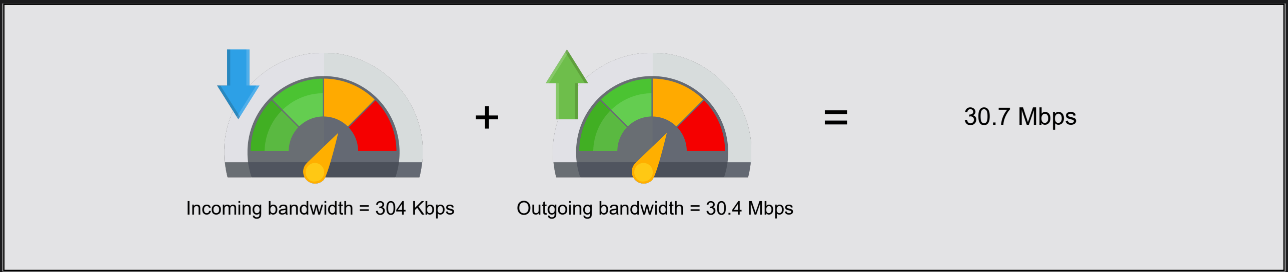
$$100 \times 76\ URLs/s = 7.6\ K\ URLs/s$$

Bandwidth estimation

Shortening requests: The expected arrival rate will be 76 new URLs per second. The total incoming data would be $304\ Kbps$ per second:

$$76 \times 500\ Bytes \times 8\ bits = 304\ Kbps$$

Redirection requests: Since the expected rate would be 7.6K URLs redirections per second, the total outgoing data would be $30.4 Mbps$ per second: $7.6\ K \times 500\ Bytes \times 8\ bits = 30.4\ Mbps$



The total bandwidth required by the URL shortening service

Memory estimation

We need memory estimates in case we want to cache some of the frequently accessed URL redirection requests. Let's assume a split of 80-20 in the incoming requests. 20 percent of redirection requests generate 80 percent of the traffic.

Since the redirection requests per second are 7.6 K, the total would be 0.66 billion for one day. $7.6\ K \times 3600\ seconds \times 24\ hours = 0.66\ billion$

Since we would only consider caching 20 percent of these per-day redirection requests, the total memory requirements estimate would be 66 GB.

$$0.2 \times 0.66\ Billion \times 500\ Bytes = 66\ GB$$

URL Shortening Service Estimates Calculator

URL shortening per month	200	Million

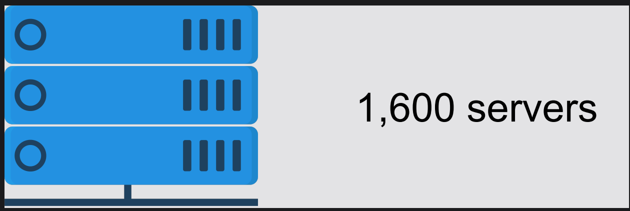
URL redirection per month	*f* 20	Billion
Query rate for URL shortening	*f* 76	URLs / s
Query rate for URL redirection	*f* 7600	URLs / s
Single entry storage size	500	Bytes
Incoming data	*f* 304	Kbps
Outgoing data	*f* 30.4	Mbps
Cache memory	*f* 66	GB

Number of servers estimation

We adopt the same approximation discussed in the Back-of-the-Envelope Calculations to calculate the number of servers needed: the number of daily active users and the requests handling limit of a server are the two main factors in depicting the total number of servers required. Recall that a typical server can serve 64,000 requests per second (RPS). Considering our assumption of using daily active users as a proxy for the number of requests per second for peak load times, we get 100 million requests per second. Then, we use the following formula to calculate the number of servers:

$$Servers\ needed\ at\ peak\ load = \frac{Number\ of\ requests/second}{RPS\ of\ server}$$

$$Servers\ needed\ at\ peak\ load = \frac{100\ million}{64,000} = 1562.5 \approx 1.6K\ servers$$



The number of servers required for the URL shortening service

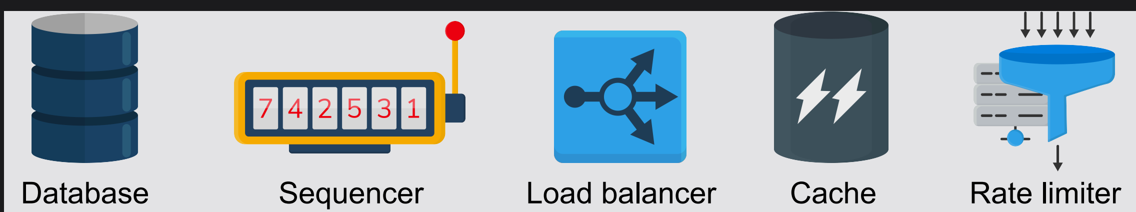
Summarizing estimation

Based on the assumption above, the following table summarizes our estimations:

Type of operation	Time estimates
New URLs	76/s
URL redirections	7.6 K/s
Incoming data	304 Kbps
Outgoing data	30.4 Mbps
Storage for 5 years	6 TB
Memory for cache	66 GB
Servers	1600

Building blocks we will use

With the estimations done, we can identify the key building blocks in our design. Such a list is given below:

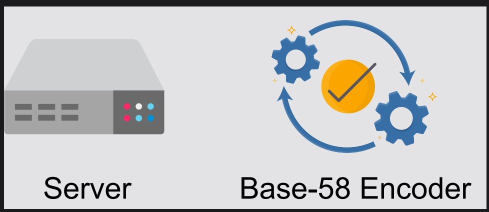


Building blocks in high level design

- **Database(s)** will be needed to store the mapping of long URLs and the corresponding short URLs.
- **Sequencer** will provide unique IDs that will serve as a starting point for each short URL generation.
- **Load balancers** at various layers will ensure smooth requests distribution among available servers.
- **Caches** will be utilized to store the most frequent short URLs related requests.
- **Rate limiters** will be used to avoid system exploitation.

Besides these building blocks, we'll also need the following additional components to achieve the desired service:

- **Servers** to handle and navigate the service requests along with running the application logic.
- A **Base-58 encoder** to transform the sequencer's numeric output to a more readable and usable alphanumeric form.



Components in high level design