

系统设计

Crawler, Typeahead

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Design a web crawler

Dropbox, Google, Turn, Alibaba

Design thread-safe producer and consumer

Google, Amazon, TripAdvisor, Microsoft, Snapchat

Design a Typeahead

LinkedIn, Uber, Hulu

1. Producer consumer pattern
2. How to design distributed web crawler
3. How search engine works
4. How to design Google Suggestion

Interviewer: How to design a web crawler?

How to design a web crawler?

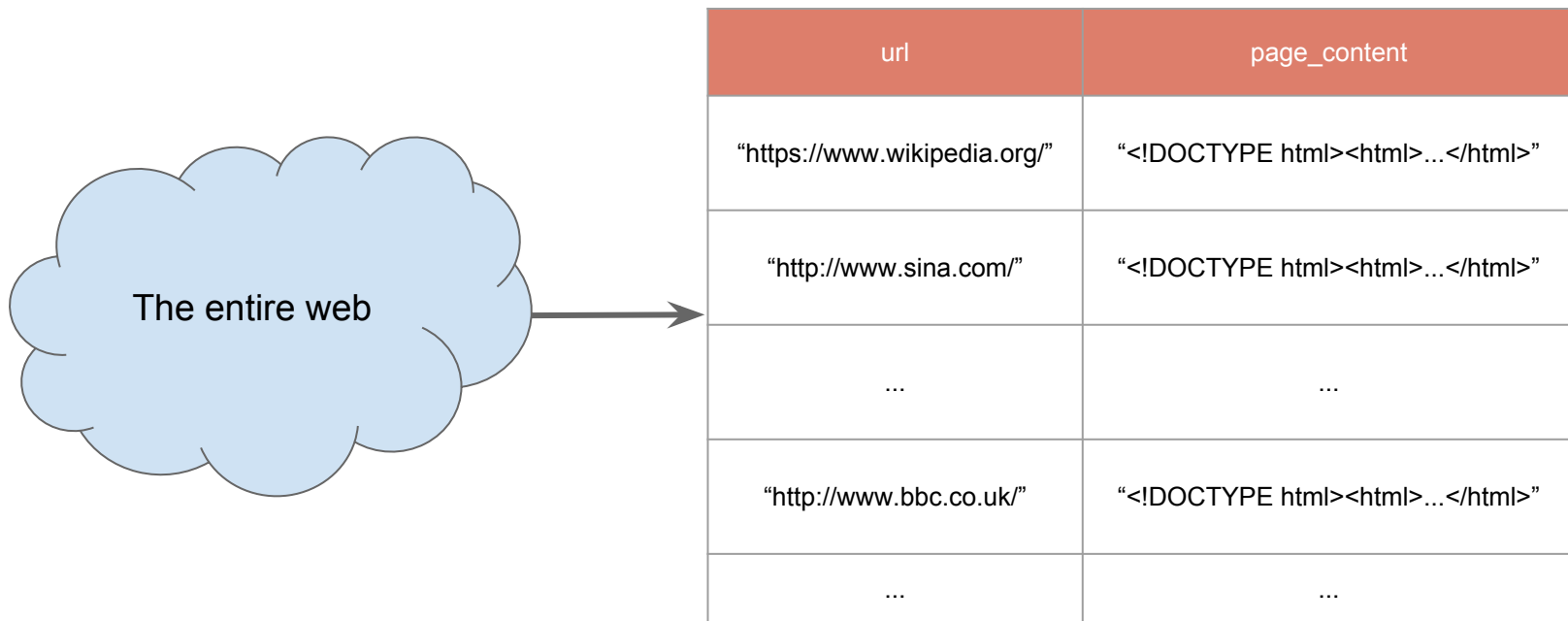
- multi-threading
- system design

What is a web crawler?

- For collecting data/information from the web

Design a web crawler

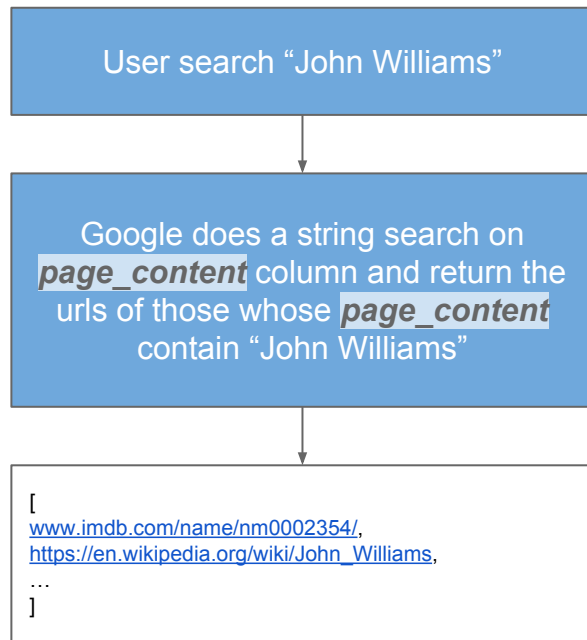
What does Google's crawler do?



Design a web crawler

What does Google use this table for?

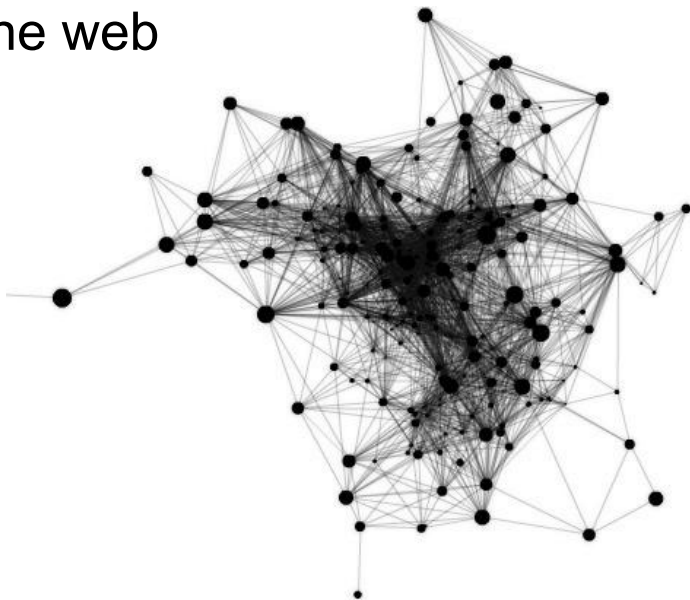
url	page_content
...	...
"www.imdb.com/name/nm0002354/"	"<!DOCTYPE ...imdb ... John Williams ... </html>"
...	...
"https://en.wikipedia.org/wiki/John_Williams"	"<!DOCTYPE ... John Williams ... </html>"
...	...



Design a web crawler

Scenario

Given seeds, crawl the web



Scenario: How many web pages? how long? how large?

1. crawl **1.6m web pages per second**
 - 1 trillion web pages
 - crawl all of them every week
2. 10p (petabyte) web page storage
 - average size of a web page: 10k

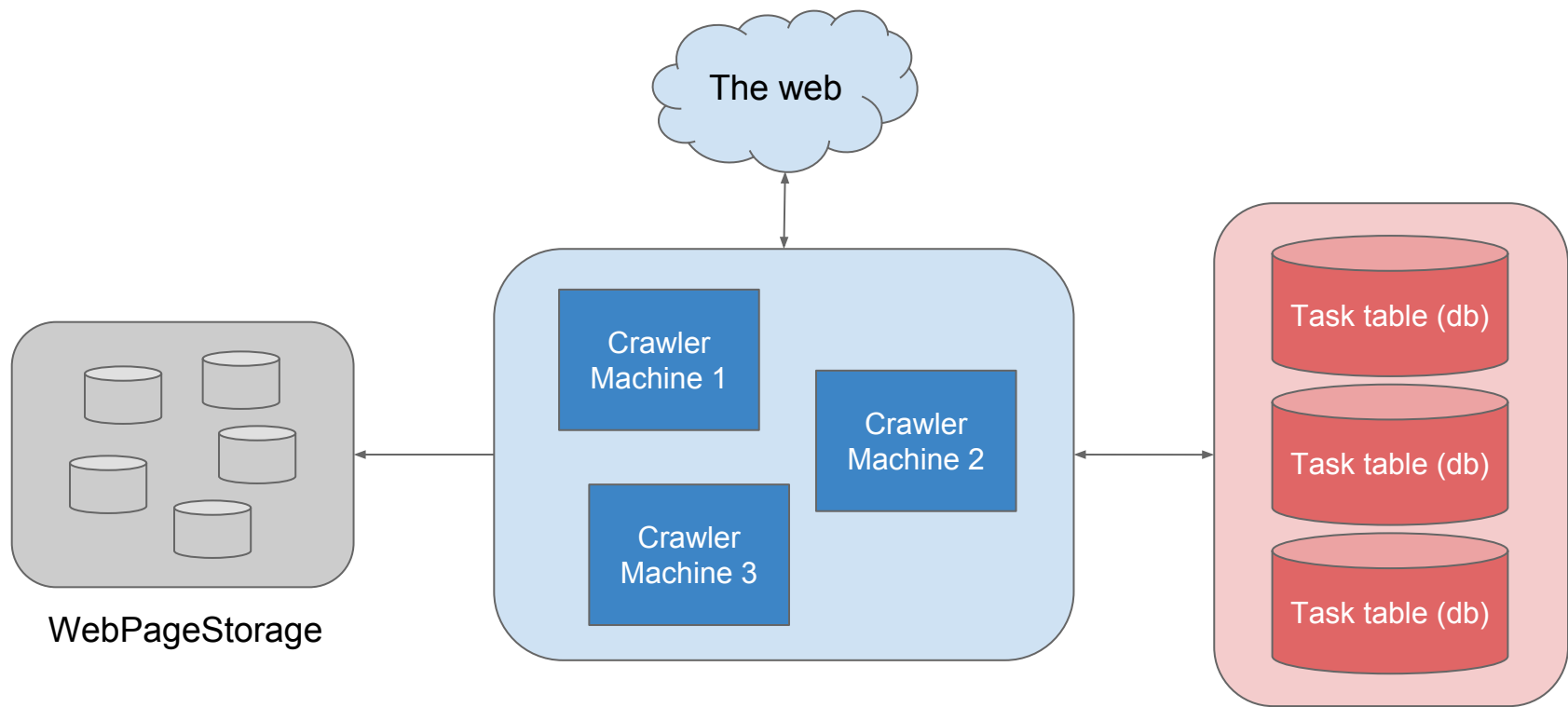
Design a web crawler

Scenario: How many web pages? how long? how large?

Service: Crawler, TaskService, StorageService

Storage: Use db to store tasks, BigTable to store web pages

Design a web crawler



Design a web crawler

A simplistic news crawler

A simplistic web crawler

A single-threaded web crawler

A multi-threaded web crawler

Dropbox interview question:

Program a web crawler, then make it multi-threaded

How a simplistic news crawler works

- given the URL of news list page
1. Send an HTTP request and grab the content of the news list page
 2. Extract all the news titles from the news list page

A Simplistic News Crawler

Input: URL of the news list page

<http://tech.163.com/it>

A Simplistic News Crawler



Grab the content of the page

```
import urllib2
```

```
url = 'http://tech.163.com/it'
```

```
request = urllib2.Request(url)
```

```
response = urllib2.urlopen(request)
```

```
page = response.read()
```

```
>>> request = urllib2.Request('http://www.baidu.com')
>>> response = urllib2.urlopen(request)
>>> response.read()
'<!DOCTYPE html><!--STATUS OK--><html><head><meta http-equiv="content-type" cont
ent="text/html; charset=utf-8"><meta http-equiv="X-UA-Compatible" content="IE=Edg
e"><meta content="always" name="referrer"><meta name="theme-color" content="#293
2e1"><link rel="shortcut icon" href="/favicon.ico" type="image/x-icon" /><link r
el="search" type="application/opensearchdescription+xml" href="/content-search.x
ml" title="\xe7\x99\xbe\xe5\xba\xa6\xe6\x90\x9c\xe7\xb4\xa2" /><link rel="icon"
sizes="any" mask href="//www.baidu.com/img/baidu.svg"><link rel="dns-prefetch" h
ref="//s1.bdstatic.com"/><link rel="dns-prefetch" href="//t1.baidu.com"/><link r
el="dns-prefetch" href="//t2.baidu.com"/><link rel="dns-prefetch" href="//t3.bai
du.com"/><link rel="dns-prefetch" href="//t10.baidu.com"/><link rel="dns-prefetc
h" href="//t11.baidu.com"/><link rel="dns-prefetch" href="//t12.baidu.com"/><lin
k rel="dns-prefetch" href="//b1.bdstatic.com"/><title>\xe7\x99\xbe\xe5\xba\xa6\x
e4\xb8\x80\xe4\xb8\x8b\xef\xbc\x8c\xe4\xbd\xa0\xe5\xb0\xb1\xe7\x9f\xa5\xe9\x81\x
93</title>\n<style index="index" id="css_index">html,body{height:100%}html{over
flow-y:auto}body{font:12px arial;text-align:center;background:#fff}body,p,form,ul,li{m
argin:0;padding:0;list-style:none}body,form,#fm{position:relative}td{text-align:
left}img{border:0}a{color:#00c}a:active{color:#f60}input{border:0;padding:0}#wra
```

A Simplistic News Crawler

Extract all the news URLs from the news list page

Regular Expression

```
<h3[^>]*><a[^>]*>(.*?)</a></h3>
```


A Simplistic News Crawler

Output: a list of news titles

[

“富士康或将收购夏普交易推迟到下周”，

“美的董事长回应董明珠：怎么能说我们是骗子”，

“终于来了 亚马逊招开发经理打造VR平台”，

...

“Skylake Mac mini?小众用户也想要更强性能”

]

Design a web crawler

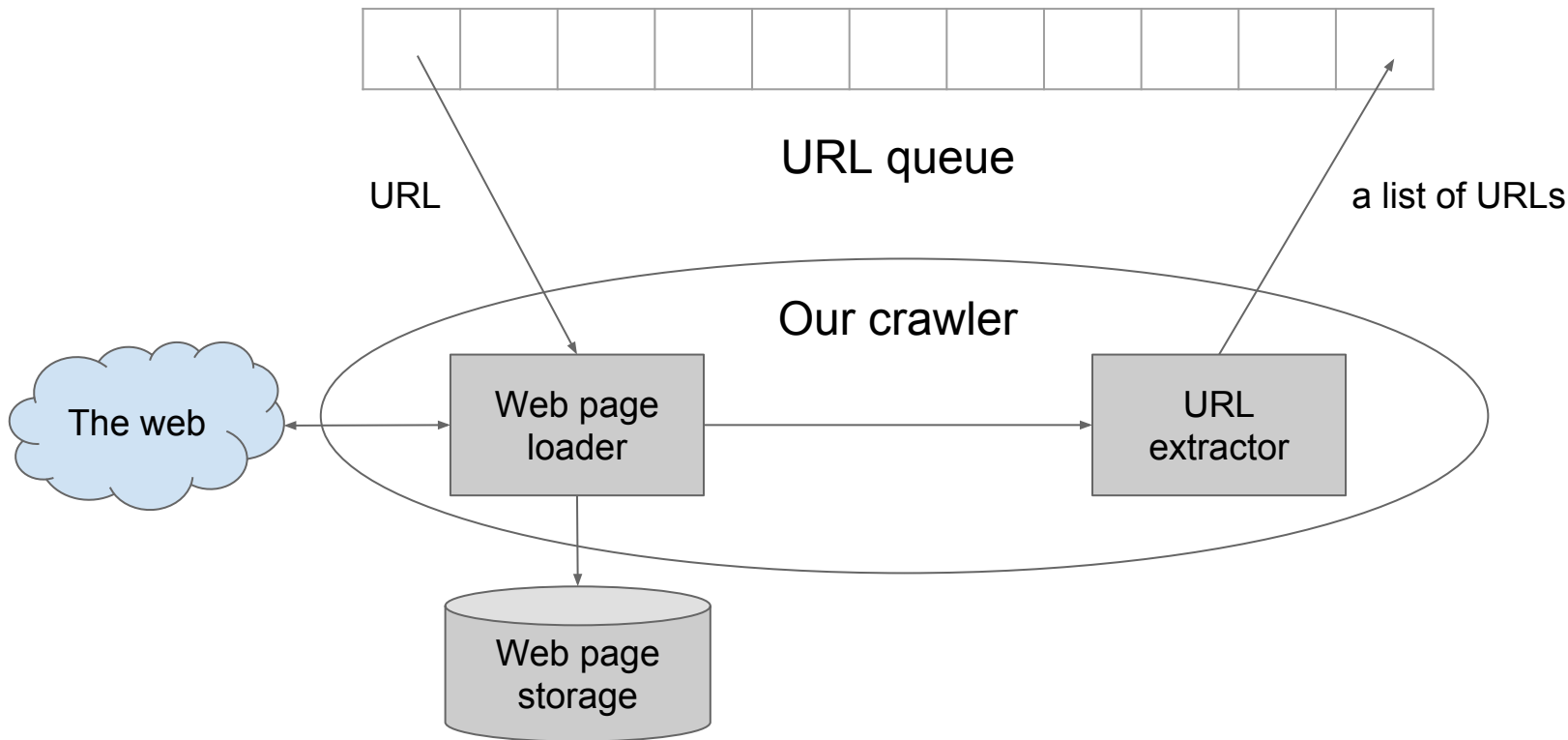
Dropbox interview question:

Program a web crawler, then make it multi-threaded

Input: url seeds

Output: list of urls

A Single-threaded Web Crawler



A Single-threaded Web Crawler



九章算法

```
thread crawler
```

```
    function run
```

```
        while (url_queue not empty)
```

```
            url = url_queue.dequeue()
```

```
            html = web_page_loader.load(url) // consume
```

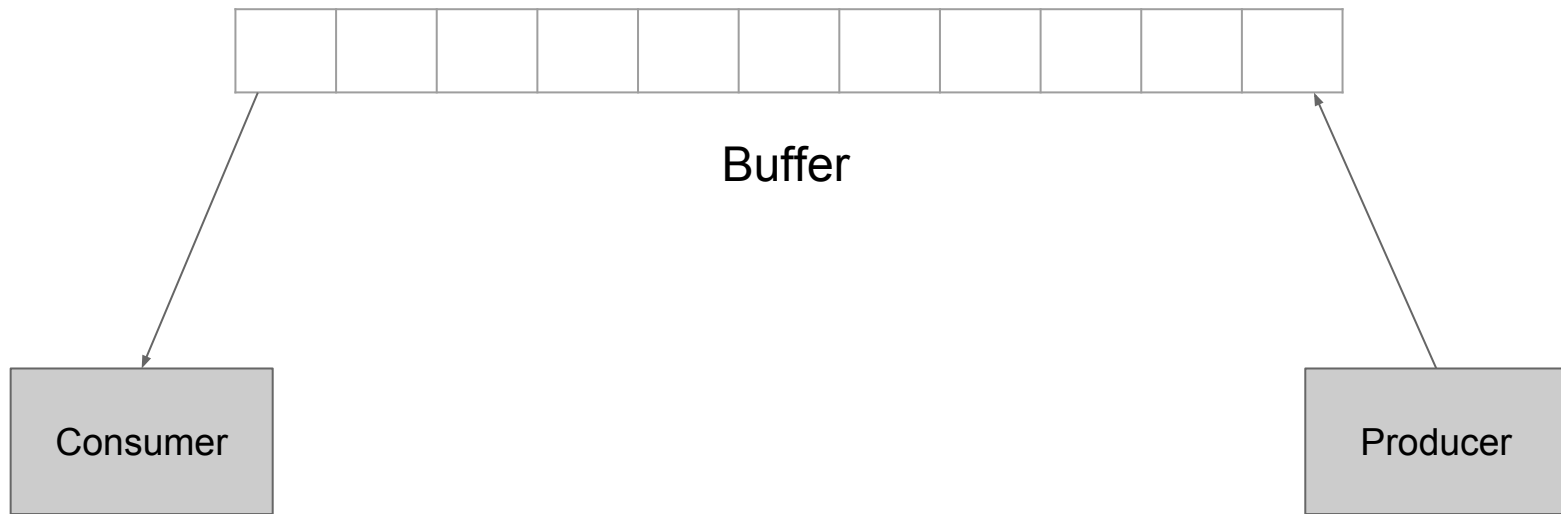
```
            url_list = url_extractor.extract(html) // produce
```

```
            url_queue.enqueue_all(url_list)
```

```
        end
```

A Single-threaded Web Crawler

Producer Consumer Pattern



Snapchat: write producer consumer

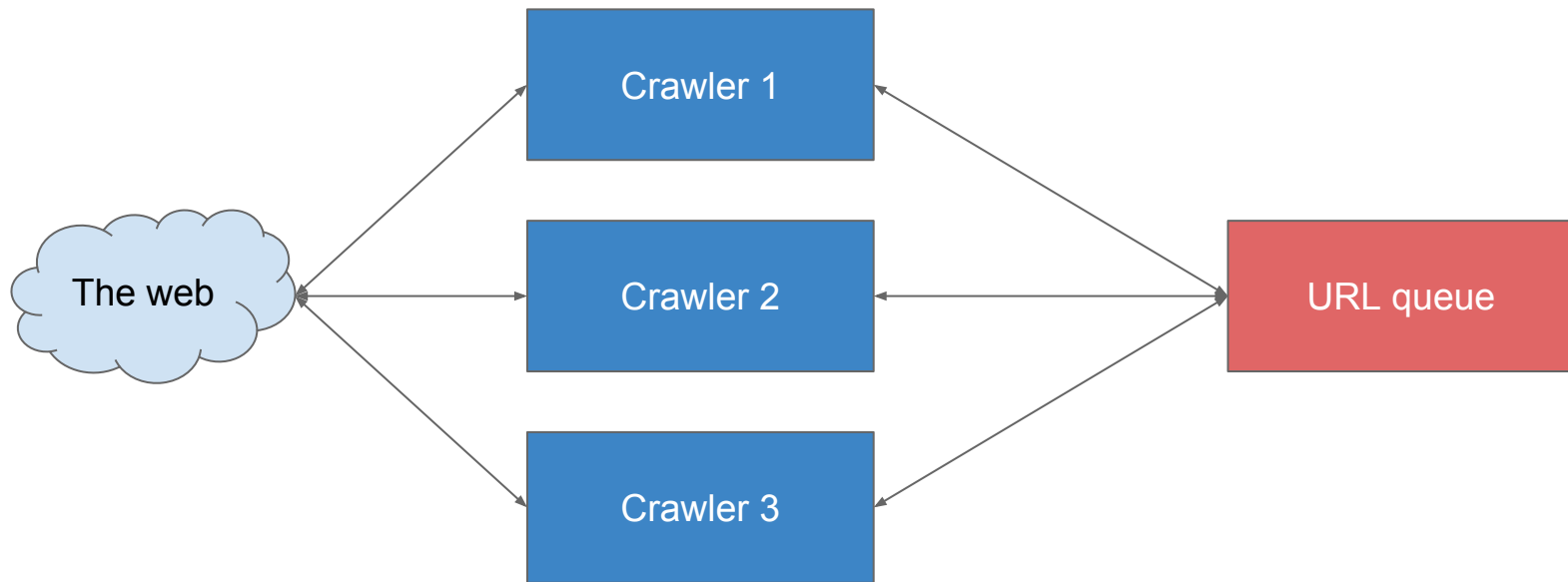
答案见附录

A Single-threaded Web Crawler

What's the problem of single thread?

Too slow?

A Multi-threaded Web Crawler



How different threads work together?

Three approaches:

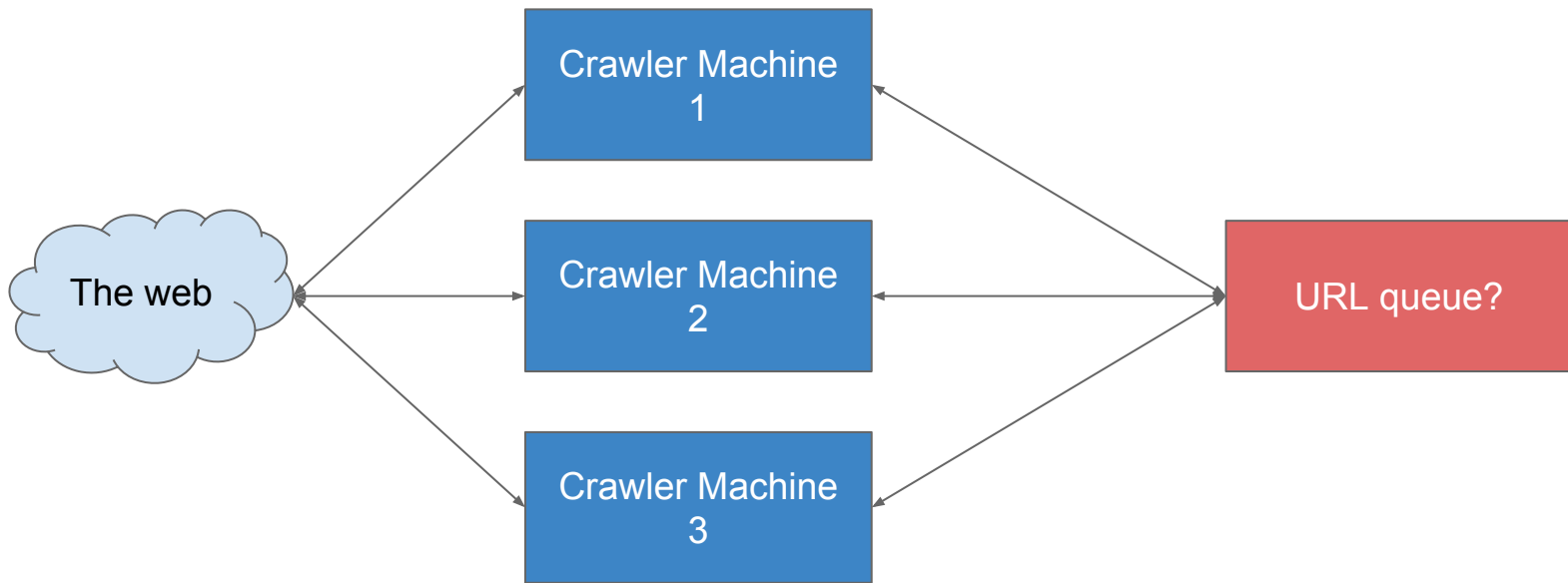
1. sleep
2. condition variable
3. semaphore

However, more threads doesn't necessarily
mean more performance

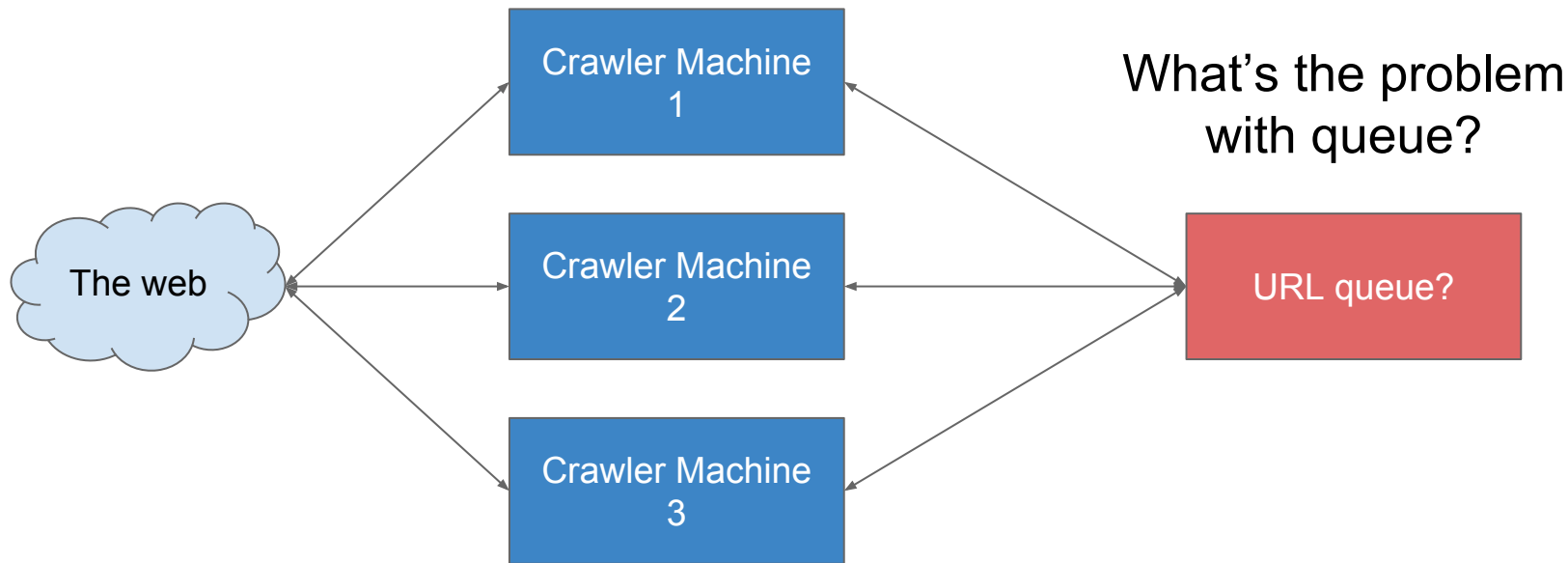
Why?

- context switch cost (CPU number limitation)
- thread (port) number limitation
- network bottleneck for single machine

A Distributed Web Crawler



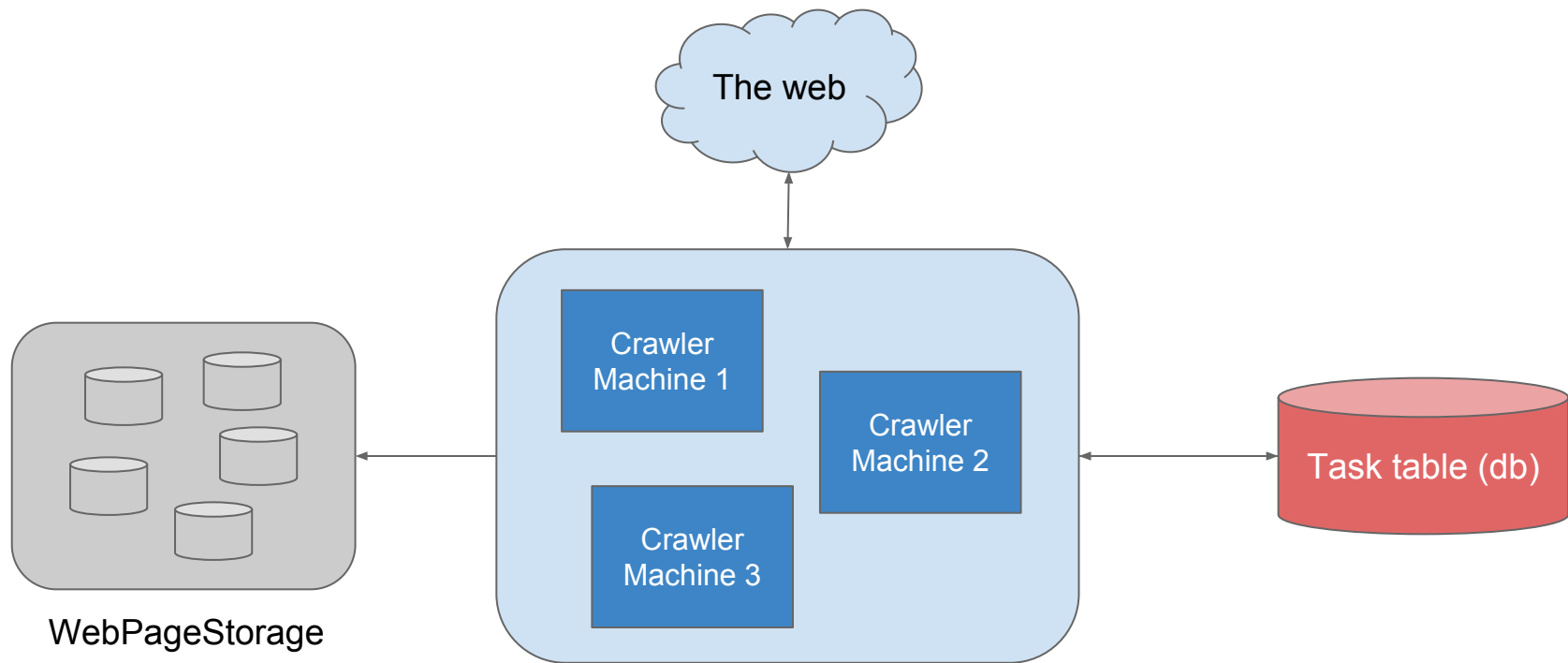
A Distributed Web Crawler



How to design the task table

id	url	state	priority	available_time
1	"http://www.sina.com/"	"idle"	1	"2016-03-04 11:00 am"
2	"http://www.sina1.com/"	"working"	1	"2016-03-04 12:00 am"
3	"http://www.sina2.com/"	"idle"	0	"2016-03-14 02:00 pm"
4	"http://www.sina3.com/"	"idle"	2	"2016-03-12 04:25 am"
...

A Distributed Web Crawler



A Distributed Web Crawler

Now we have a work solution!

Scenario: How many web pages? how long? how large?

Service: Crawler, TaskService, StorageService

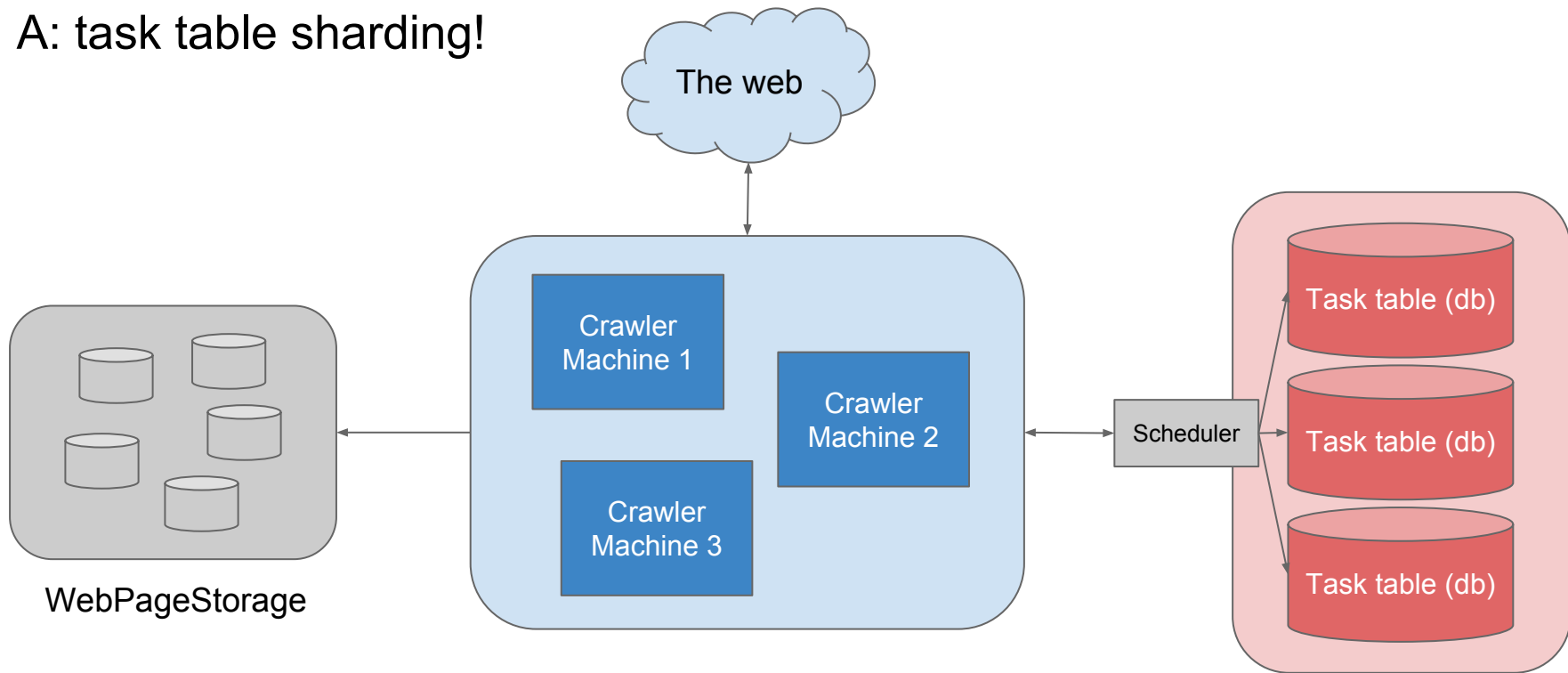
Storage: Use db to store tasks, BigTable to store web pages

Let's see how to scale!

Interviewer: How to handle slow select?

A Distributed Web Crawler

A: task table sharding!



Interviewer: How to handle update for failure?

(i.e. content update, crawl failure)

A Distributed Web Crawler

Answer: Exponential back-off!

success: crawl after 1 week

no.1 failure: crawl after 2 week

no.2 failure: crawl after 4 weeks

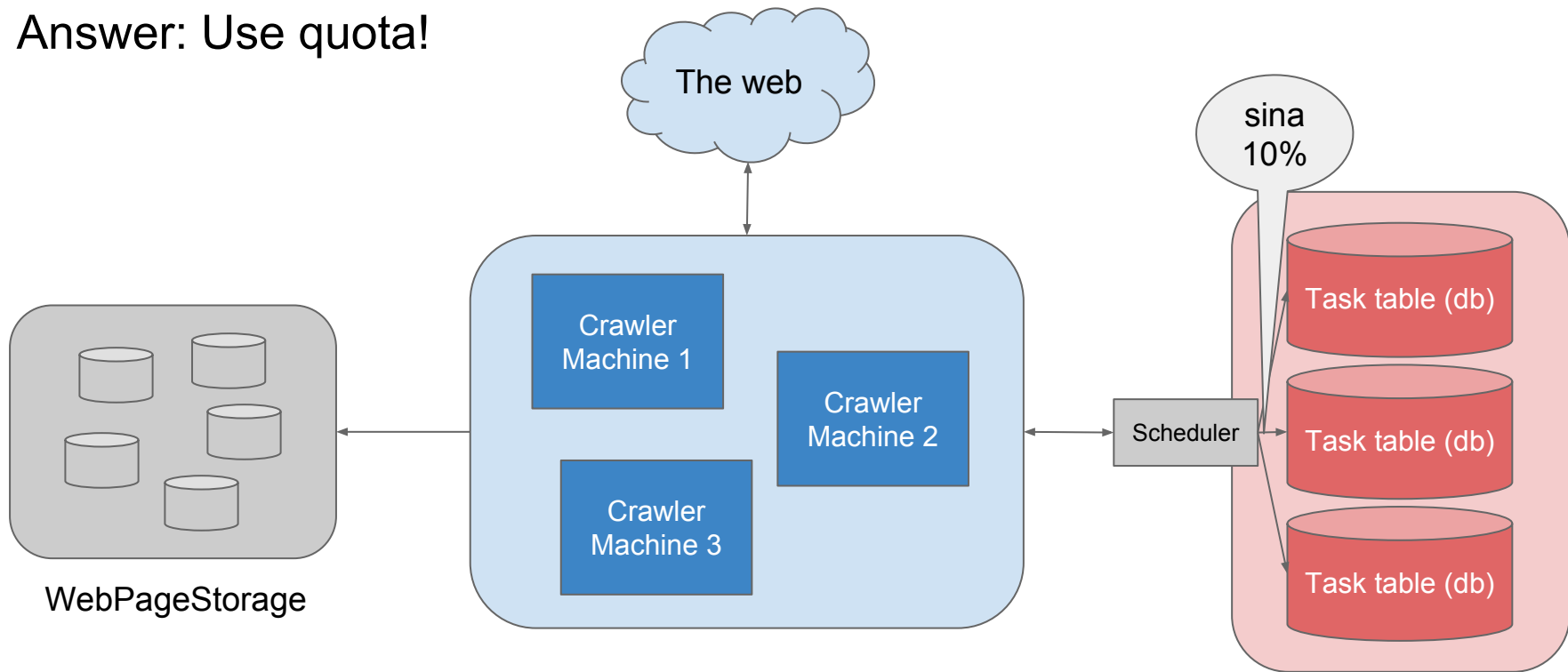
no.3 failure: crawl after 8 weeks ...

Interviewer: How to handle dead cycle?

(Too many web pages in sina.com, the crawler keeps crawling sina.com and don't crawl other websites)

A Distributed Web Crawler

Answer: Use quota!



Scenario: How many web pages? how long? how large?

Service: Crawler, TaskService, StorageService


Storage: Use db to store tasks, BigTable to store web pages

Scale: single -> multi, multi -> distributed, queue -> table, slow select (db sharding), crawl failure/update handle, dead cycle (sina.com -> quota), multi-region

Interviewer: How to design a Typeahead?

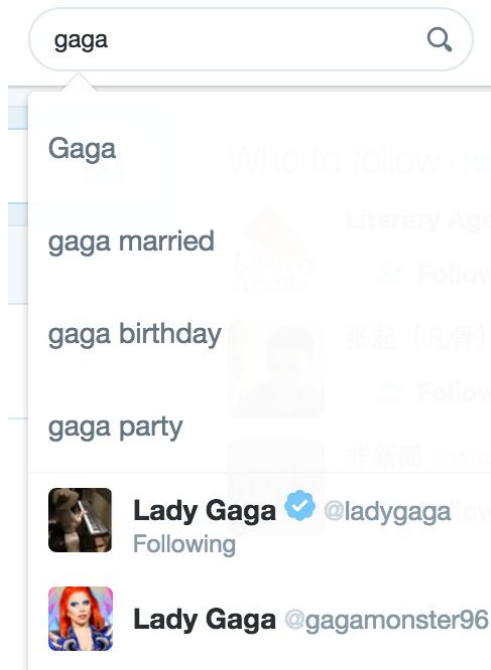
What is Typeahead?



donald	
<div>Google Suggestion</div> <ul style="list-style-type: none">donald trumpdonald duckdonalddonald trump 中文donald tsangdonald sutherlanddonaldsondonald trump poll	

Design a Typeahead

Twitter Typeahead



Design a Typeahead

Google suggestion

- prefix -> top n hot key words

Twitter typeahead

- suggestion + user + hashtag

Design a Typeahead

Google Suggestion

Scenario: prefix -> top n search keywords

DAU (daily active user): 500m

Search: $4 * 6 * 500m = 12b$ (every user searches 6 times, types 4 letters)

$QPS = 12b / 86400 \approx 138k$

$Peak\ QPS = QPS * 2 \approx 276k$

Design a Typeahead



Google Suggestion

Service

What service(s) do we need?

Design a Typeahead



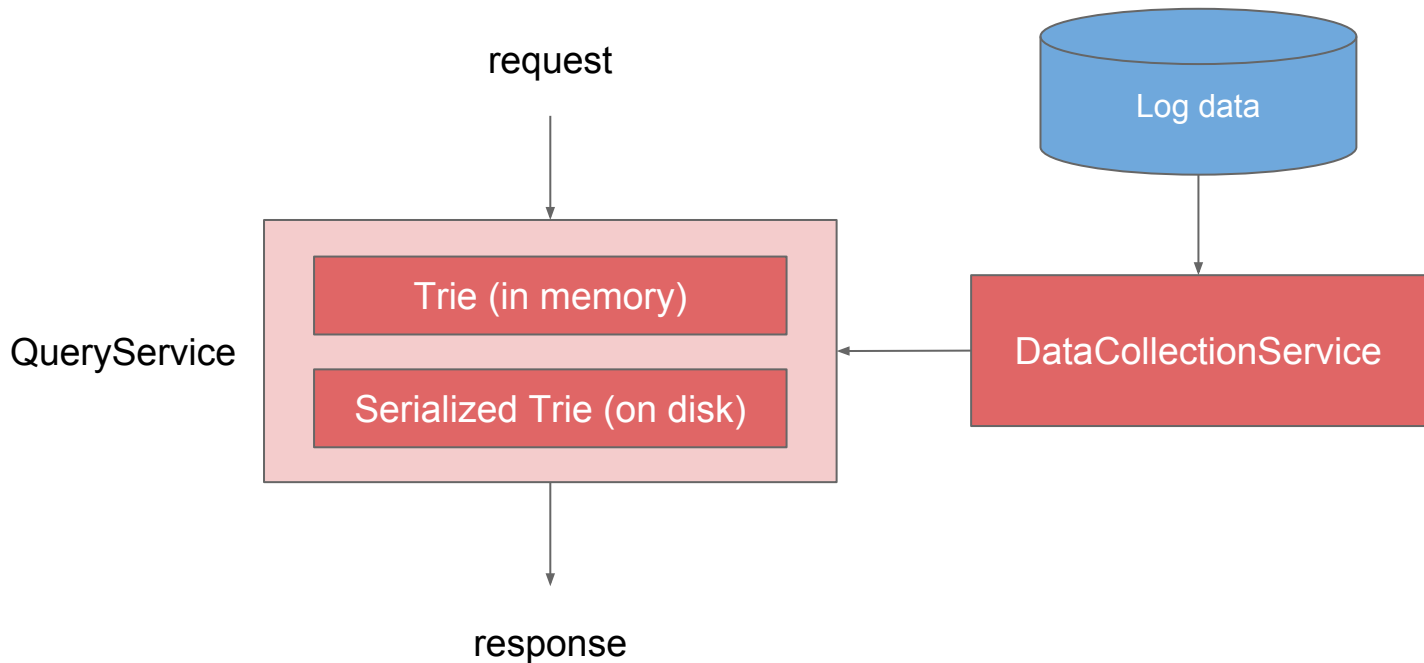
Google Suggestion

Service:

1. QueryService
2. DataCollectionService

Design a Typeahead

Google Suggestion



Design a Typeahead



Google Suggestion

Storage

What storage do we need for QueryService?

Design a Typeahead

Google Suggestion

Storage

1. QueryService

what kind of data

do we need to store?

The naive way

keyword	hit_count
"amazon"	20b
"apple"	15b
"adidas"	7b
"airbnb"	3b
...	...

Design a Typeahead

How to query on the db?

Query payload: { key }

Query SQL:

```
SELECT * FROM hit_stats
WHERE keyword LIKE `${key}%`
ORDER BY hit_count DESC
LIMIT 10
```

keyword	hit_count
"amazon"	20b
"apple"	15b
"adidas"	7b
"airbnb"	3b
...	...

hit_stats

Interviewer: What's the problem with this approach?

Design a Typeahead

```
SELECT * FROM hit_stats  
WHERE keyword LIKE `${key}%`  
ORDER BY hit_count DESC  
LIMIT 10
```

LIKE operation is expensive!

```
WHERE keyword LIKE `abc%`
```

is equivalent to

```
WHERE keyword >= `abc` AND keyword < `abd`
```

Design a Typeahead

To reduce query time

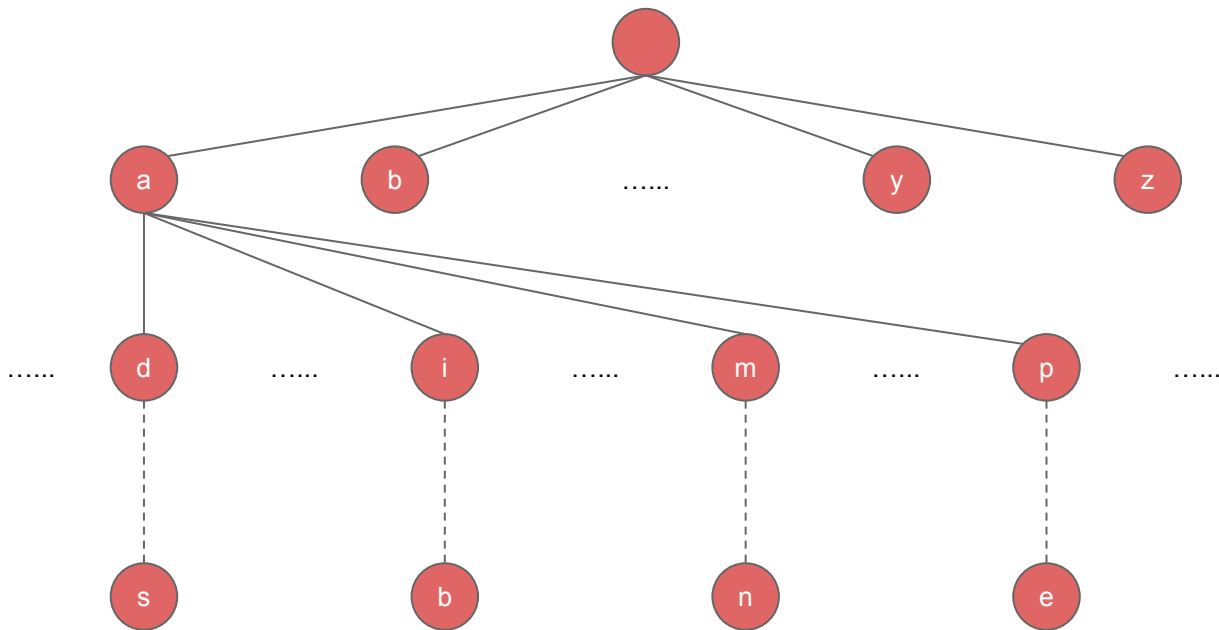
prefix	keywords
"a"	["amazon", "apple", ...]
"am"	["amazon", "amc", ...]
"ad"	["adidas", "adobe", ...]
"don"	["don't have", "donald trump", ...]
...	...

Design a Typeahead



九章算法

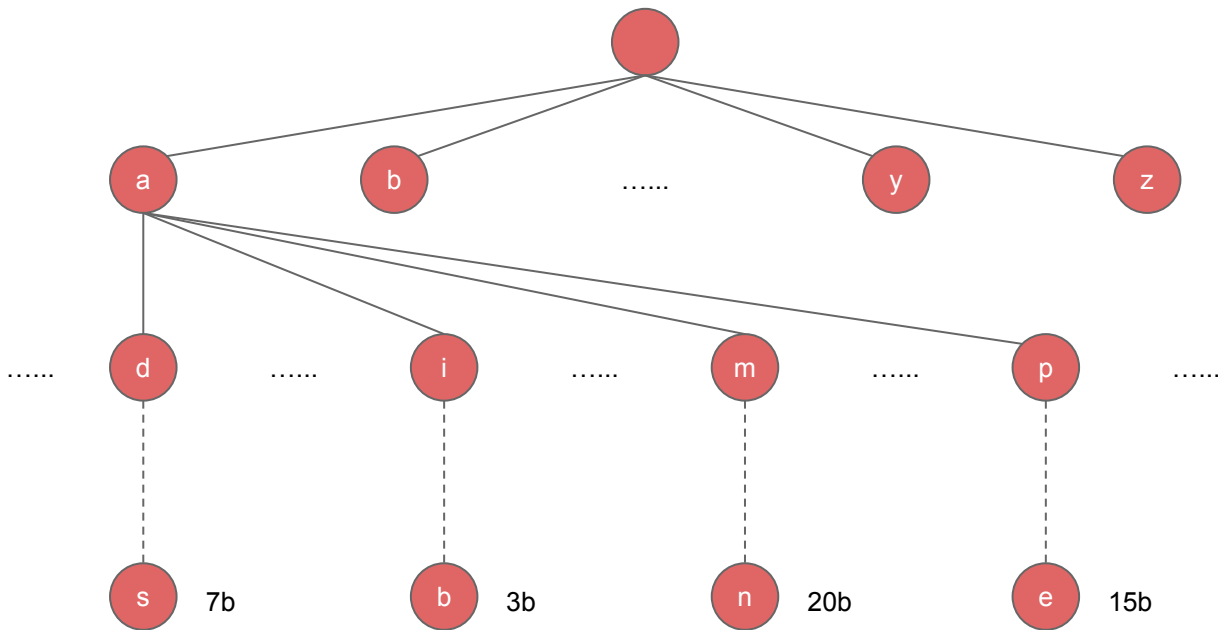
A better way: trie!



Design a Typeahead

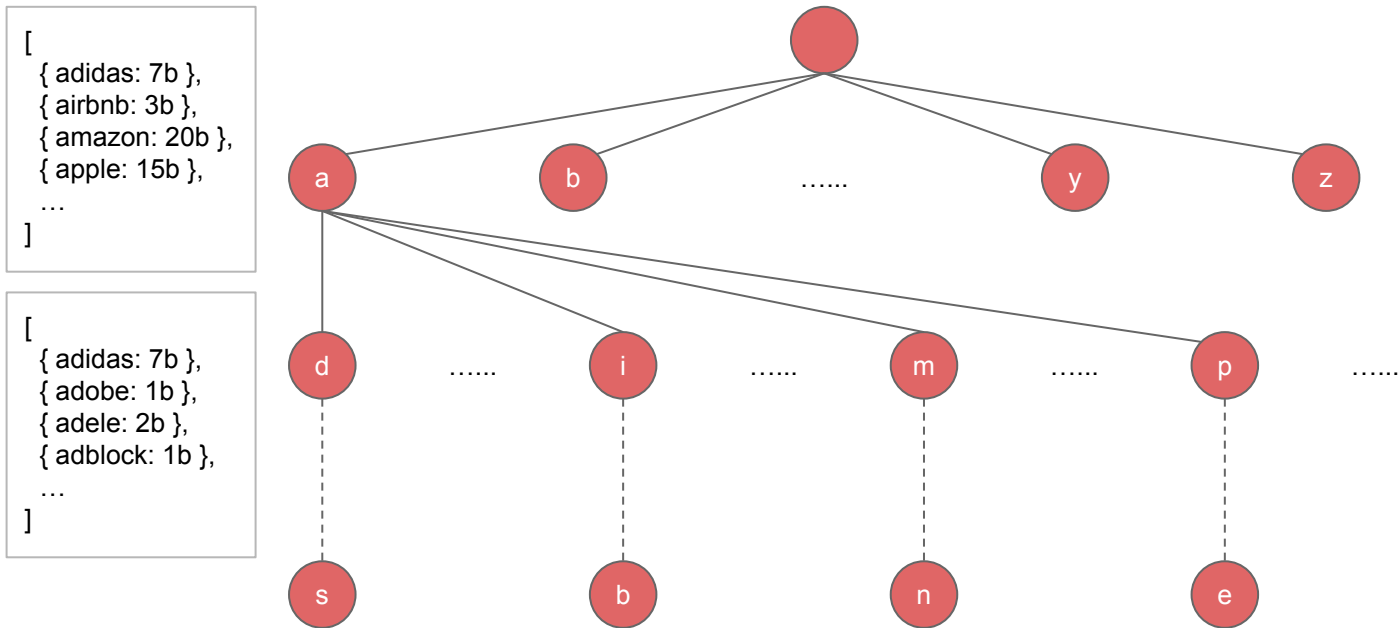
We can store search count at node, but it's slow

keyword	hit_count
"amazon"	20b
"apple"	15b
"adidas"	7b
"airbnb"	3b
...	...



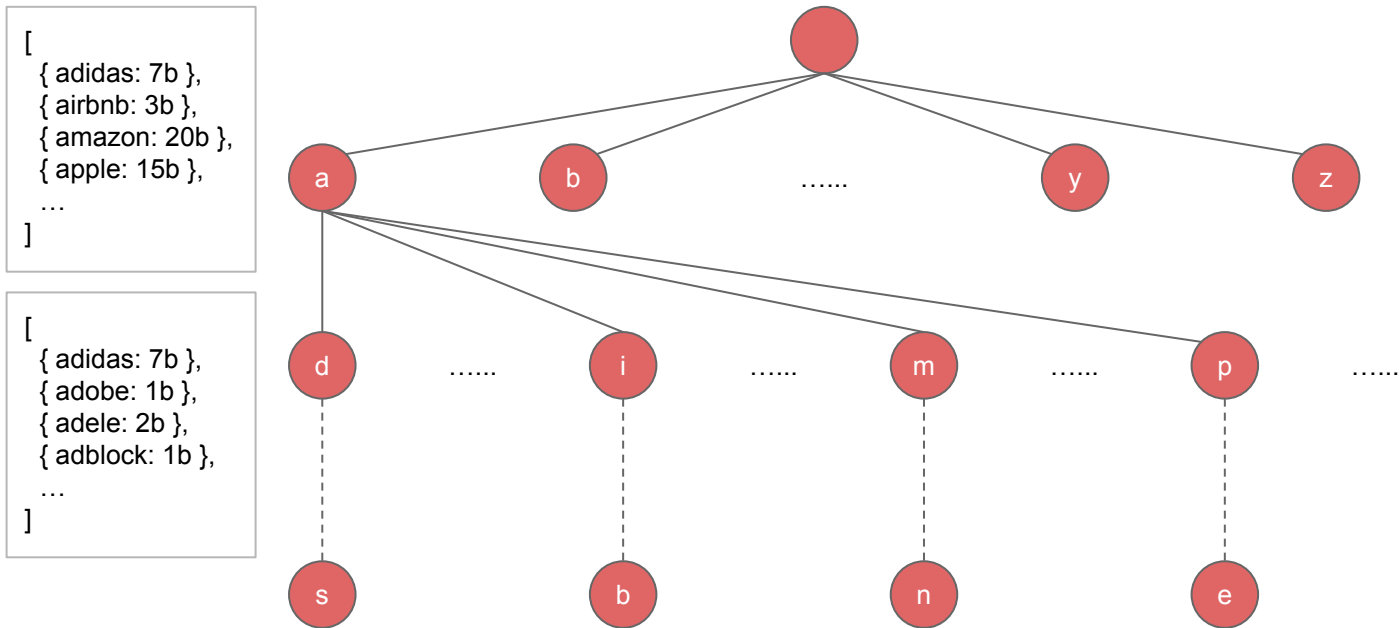
Design a Typeahead

Instead, we can store the top n hot key words, search becomes $O(\text{len})$



Design a Typeahead

How to we add a new record ({adb: 3b}) to the trie? See demo



Design a Typeahead



Google Suggestion

Storage

What storage do we need for DataCollectionService?

Interviewer:

Where does raw data
come from?

keyword	hit_count
"amazon"	20b
"apple"	15b
"adidas"	7b
"airbnb"	3b
...	...

Design a Typeahead

Where does raw data come from?
(i.e. What does DataCollectionService do?)



A diagram showing a Google search bar icon with an arrow pointing down to the 'keyword' column of the 'log data' table.

user	keyword	timestamp
xxx	"amazon"	1463379797
yyy	"apple"	1463379797
zzz	"adidas"	1463379798
kkk	"amazon"	1463379799
...

log data

group by keyword

keyword	hit_count
"amazon"	20b
"apple"	15b
"adidas"	7b
"airbnb"	3b
...	...

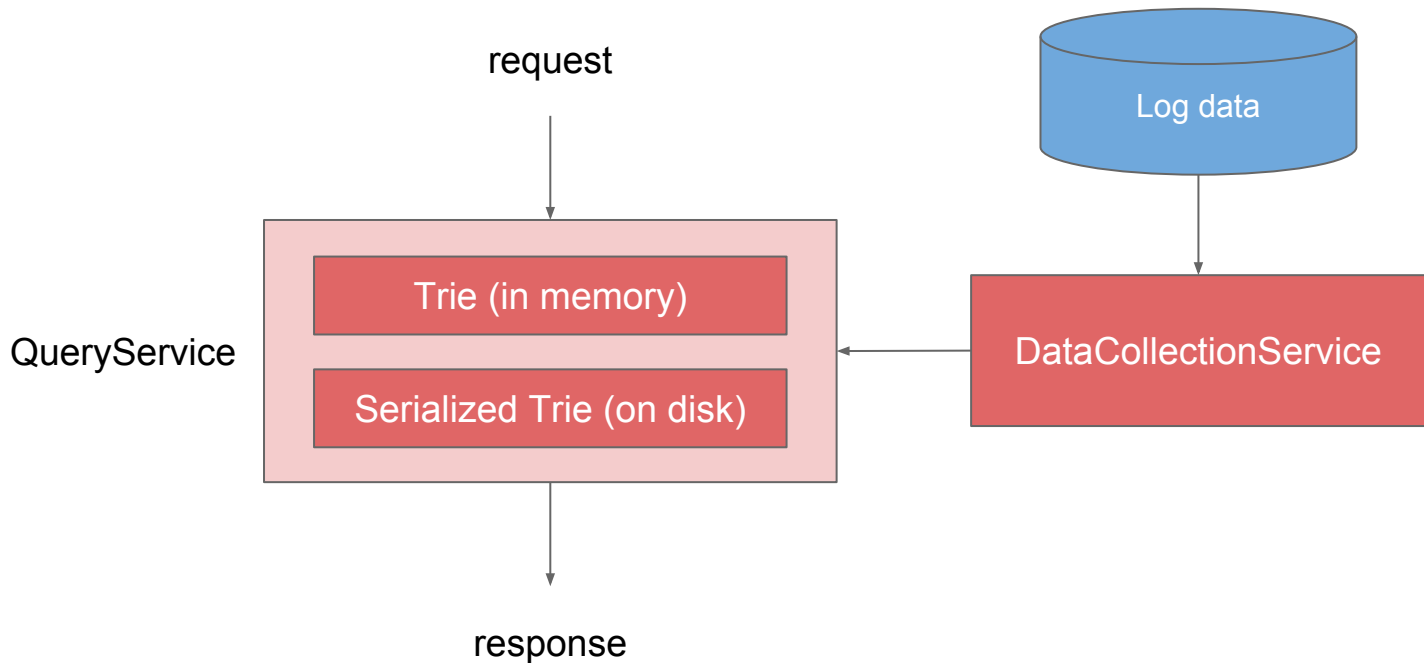
Google Suggestion

Storage

1. QueryService: in-memory trie along with disk serialization
2. DataCollectionService: BigTable

Design a Typeahead

Google Suggestion



Now we have a work solution!

Interviewer: How to qualify this system?

Design a Typeahead

How to qualify this system?

Key metric: response time

Bottom line: result quality

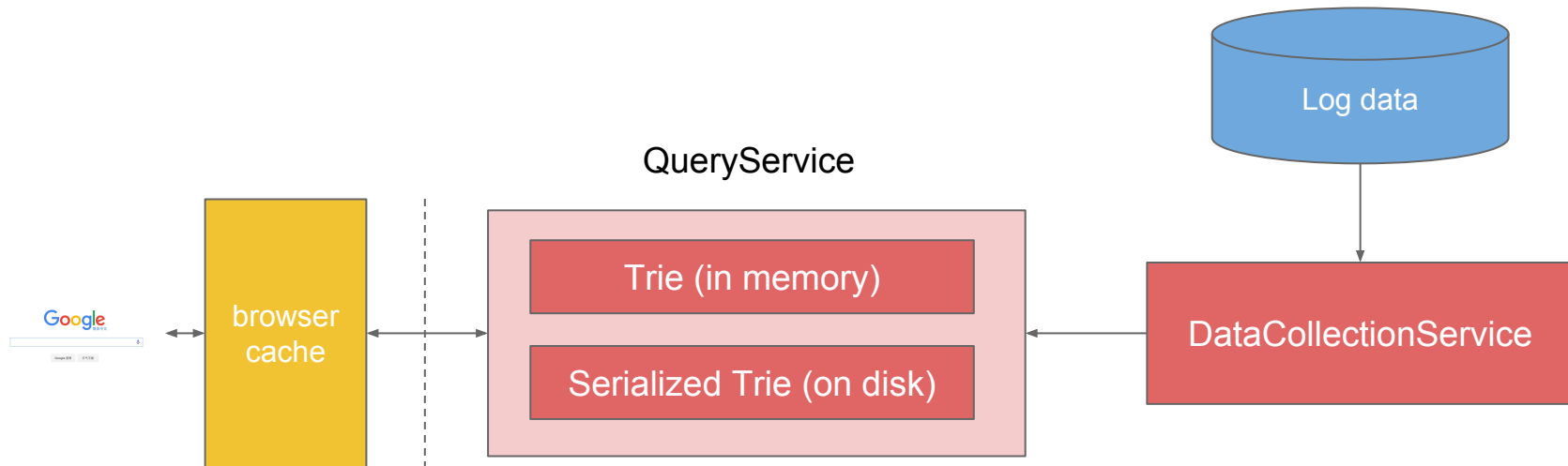
Interviewer: How to reduce response time

How to reduce response time **in front-end (browser)**

1. cache result
2. pre-fetch

Design a Typeahead

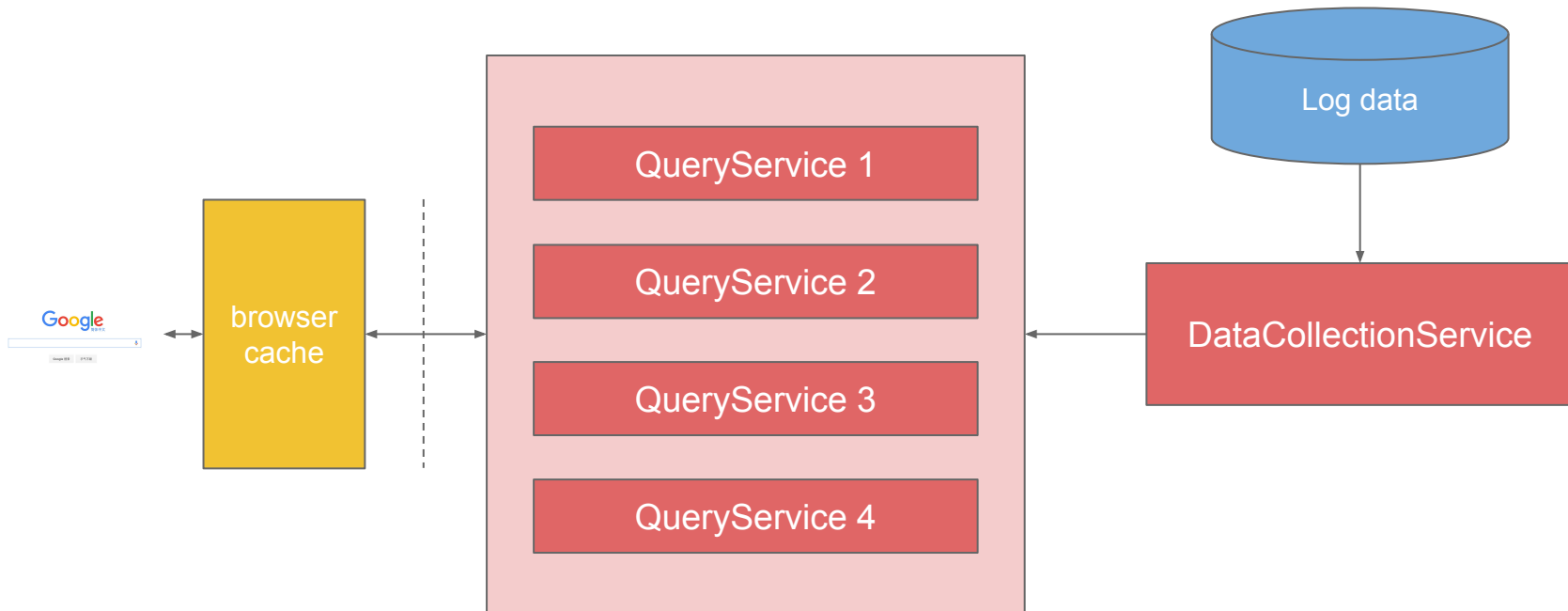
How to reduce response time **in front-end**



Interviewer: What if the trie gets too large for one machine?

Design a Typeahead

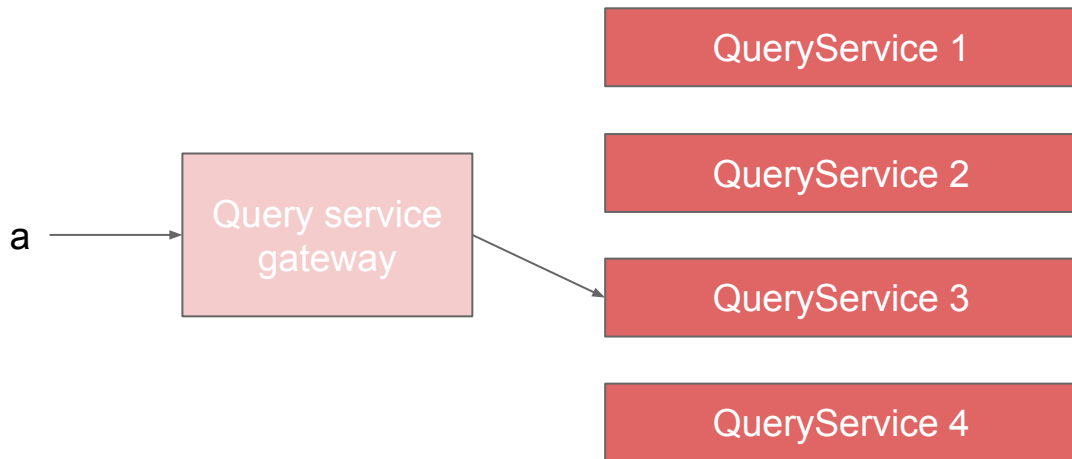
What if the trie gets too large for one machine



Design a Typeahead

How is trie stored across multiple machines?

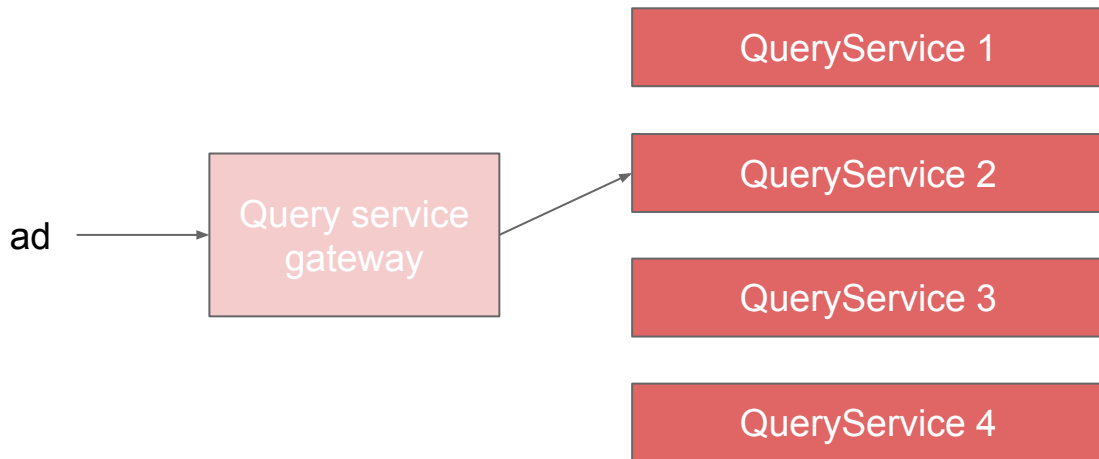
We use consistent hashing to decide which machine a particular string belongs to.



Design a Typeahead

How is trie stored across multiple machines?

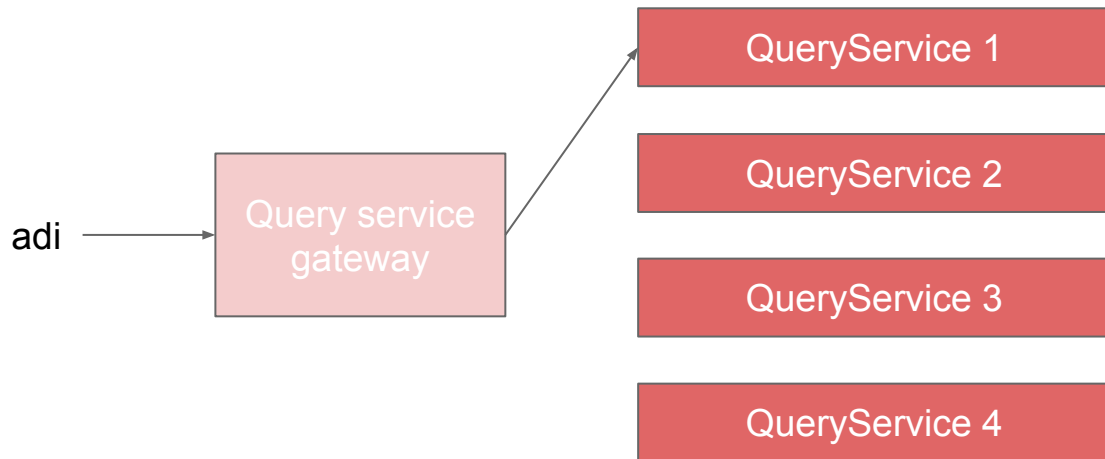
We use consistent hashing to decide which machine a particular string belongs to.



Design a Typeahead

How is trie stored across multiple machines?

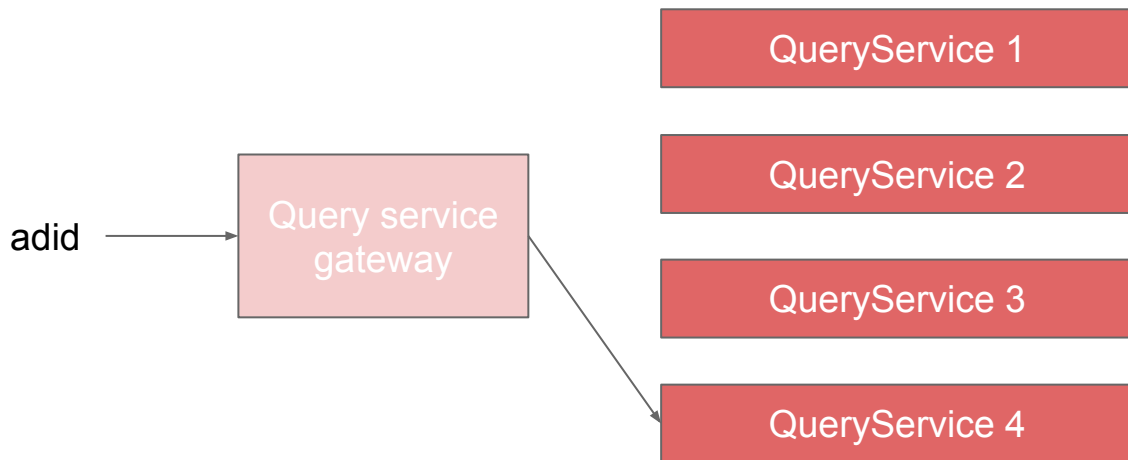
We use consistent hashing to decide which machine a particular string belongs to.



Design a Typeahead

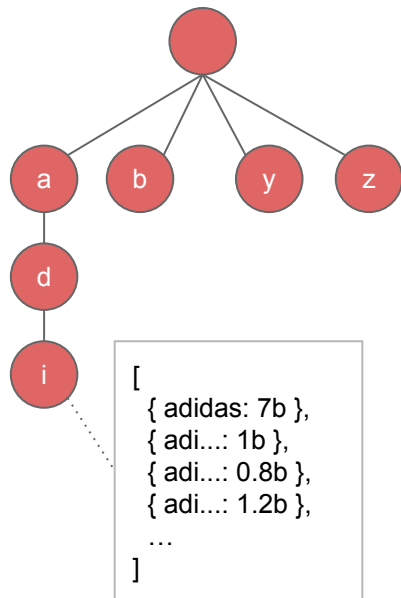
How is trie stored across multiple machines?

We use consistent hashing to decide which machine a particular string belongs to.

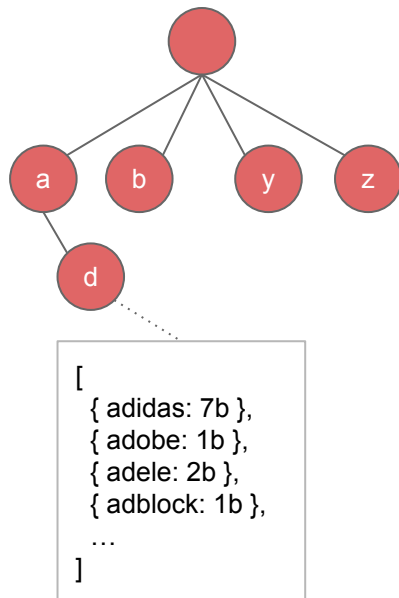


Design a Typeahead

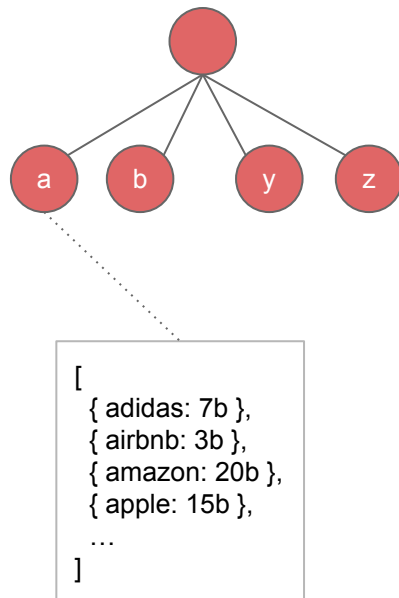
QueryService 1



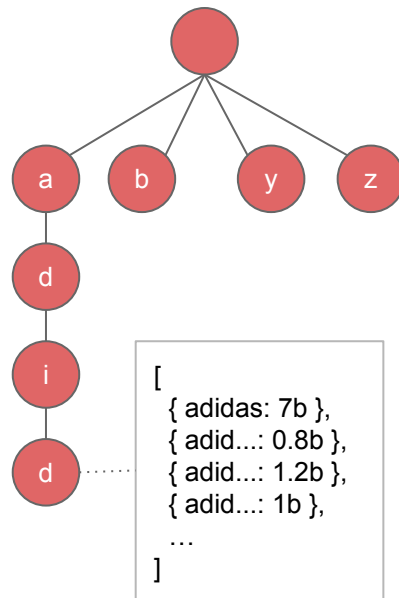
QueryService 2



QueryService 3



QueryService 4

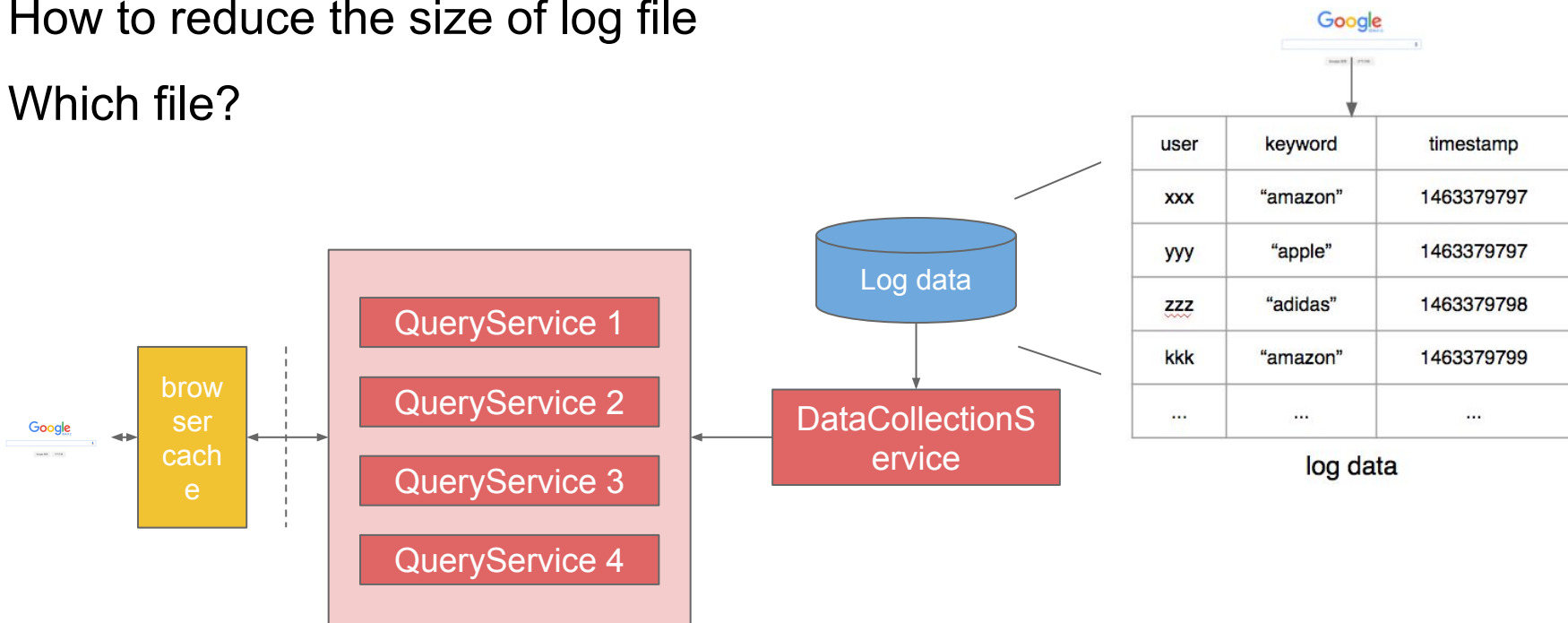


Interviewer: How to reduce the size of log file?

Design a Typeahead

How to reduce the size of log file

Which file?



Design a Typeahead

How to reduce the size of log file

Why do we need to reduce the size of it?

Because all we need is this table on the right and we have to go through 20b log entries just to get “amazon -> 20b”!

Plus, storing 20b log entries costs a lot of money.

keyword	hit_count
“amazon”	20b
“apple”	15b
“adidas”	7b
“airbnb”	3b
...	...

How to reduce the size of log file

How? Probabilistic logging!

Log with $1 / 1000$ probability (the number depends on the system need), i.e. every time we're about to log one hit of “Amazon”, we get a random number from $[1, 1000]$. We log only if the random number we got is 1.

- Say over the past two weeks “Amazon” was searched 1 billion times, with $1 / 1000$ probability we will log only 1 million times.
- For a term that's searched 1000 times (say “cholecystitis”), we might end up logging only once or even zero times.

课后练习

- <http://www.lintcode.com/en/problem/url-parser/>
- <http://www.lintcode.com/en/problem/implement-trie/>
- <http://www.lintcode.com/en/problem/trie-serialization/>
- <http://www.lintcode.com/en/problem/typeahead/>
- <http://www.lintcode.com/en/problem/webpage-crawler/>

自学材料

- http://www.codeguru.com/cpp/sample_chapter/article.php/c13533/Why-Too-Many-Threads-Hurts-Performance-and-What-to-do-About-It.htm
- <http://agiliq.com/blog/2013/10/producer-consumer-problem-in-python/>



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