

系统设计第四课

即将开始，小憩片刻



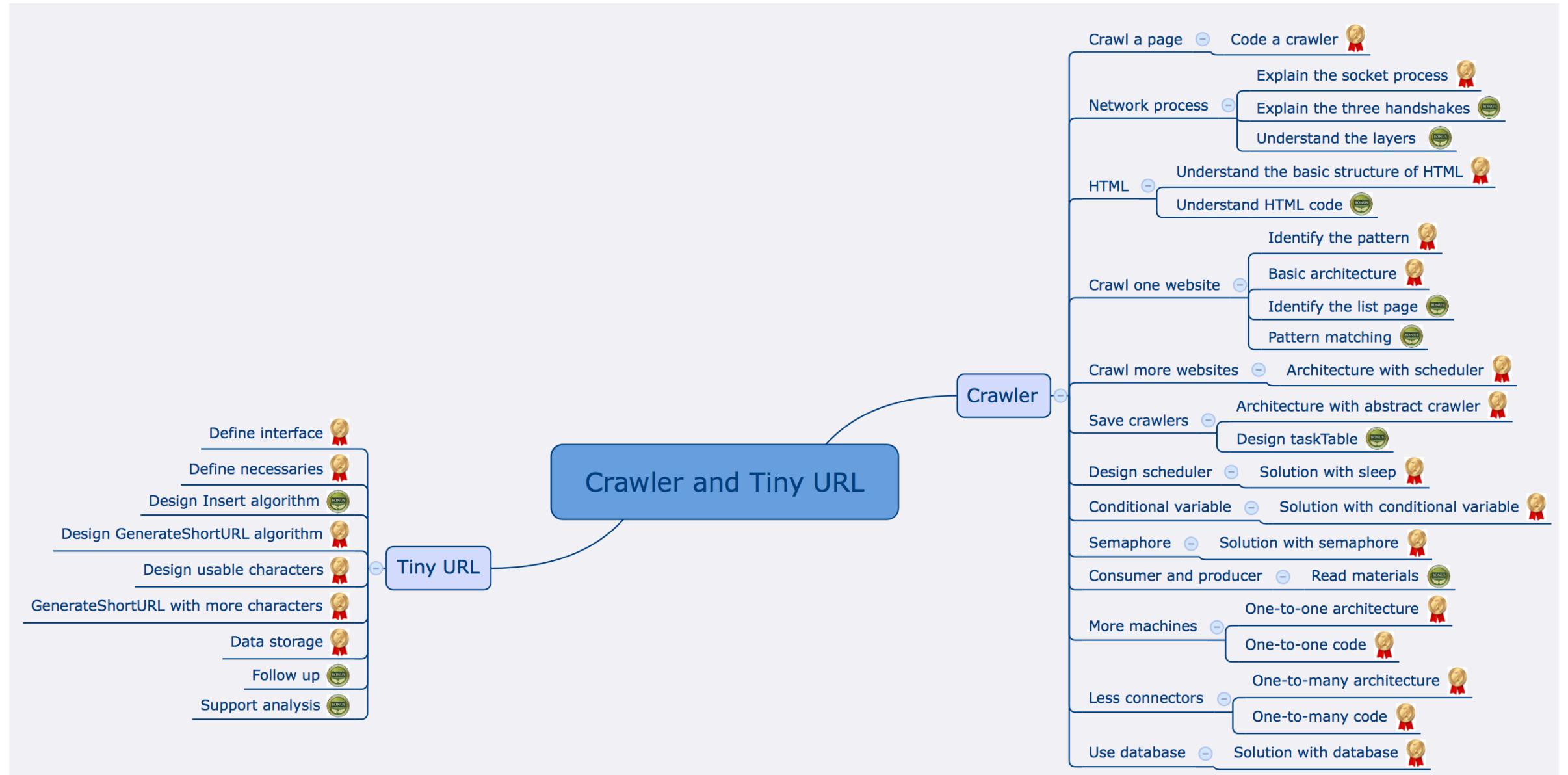
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官网: www.jiuzhang.com

Class3 summary



Divide
&
Conquer

System_Design_4

Web Service and Rate limiter

张无忌

2015-12-05

V3.02

After this class, you can answer

- What happens when you visit www.google.com in your browser?
 - Uber, Two Sigma, Alibaba, Baidu
- How to increase visiting speed of a webpage?
 - Yelp, Alibaba
- Design “秒杀” System?
 - Alibaba, Baidu, Tencent
- Design rate limiter
 - Yelp, Facebook, Google

Part 1

- Visiting

Read More

Book, <http://url.cn/69ymwC>



Alice in Wonderland

Interviewer

- Many users complain that **they cannot use our radio**, please do something!

Interviewer: what is the problem?



Problem definition

- Failure rate
 - = Percentage of users who can't listen to music properly
 - ≈ number of users who fail to play one music / number of total users
- Mission: reduce failure rate



How to identify a customer in a restaurant?





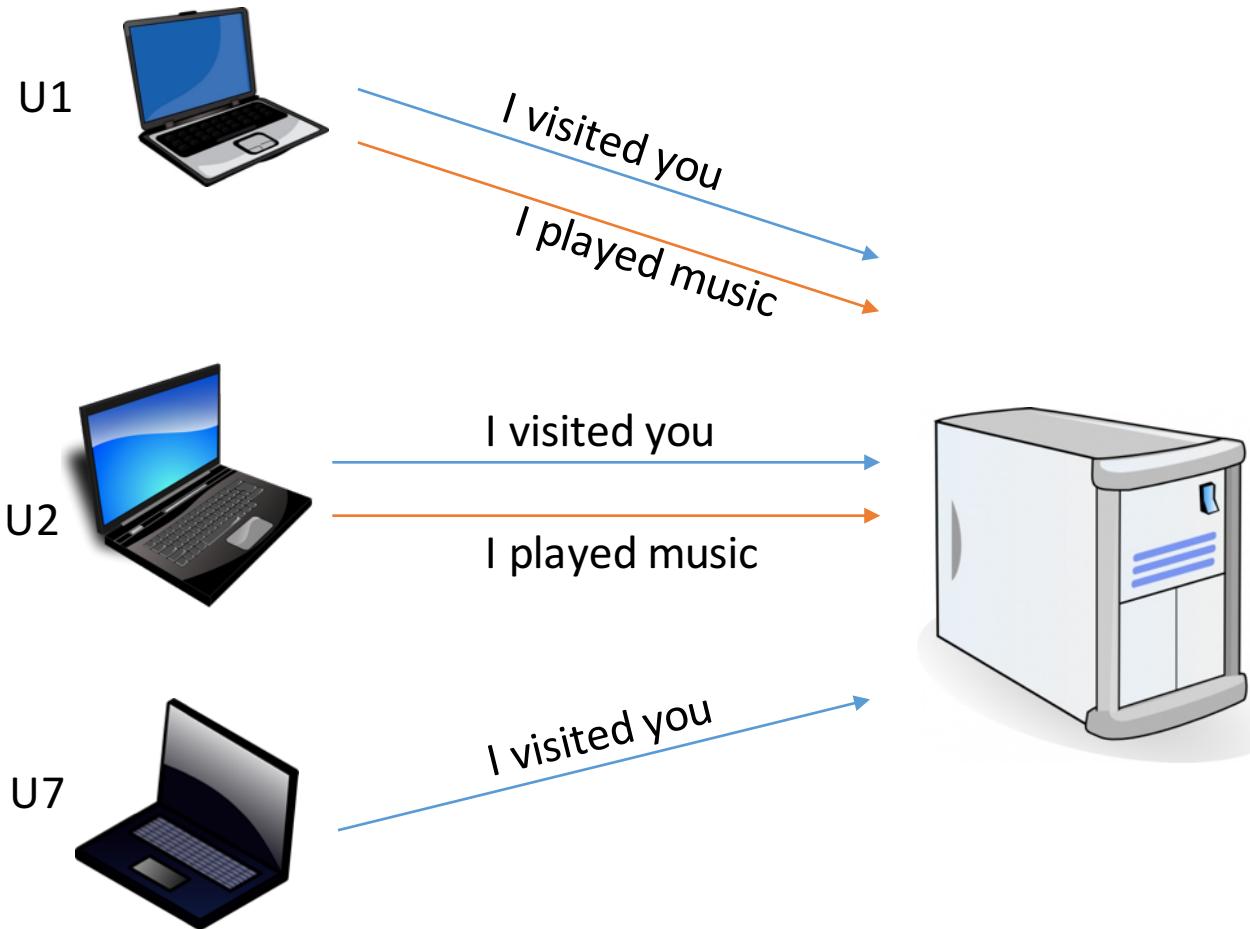
How to identify a user in web server?



[Read More](#)

Expert, <http://url.cn/ekitAe>
Expert/Master, <http://url.cn/YXILcz>

How to collect the data of failure rate (v1)



- Log



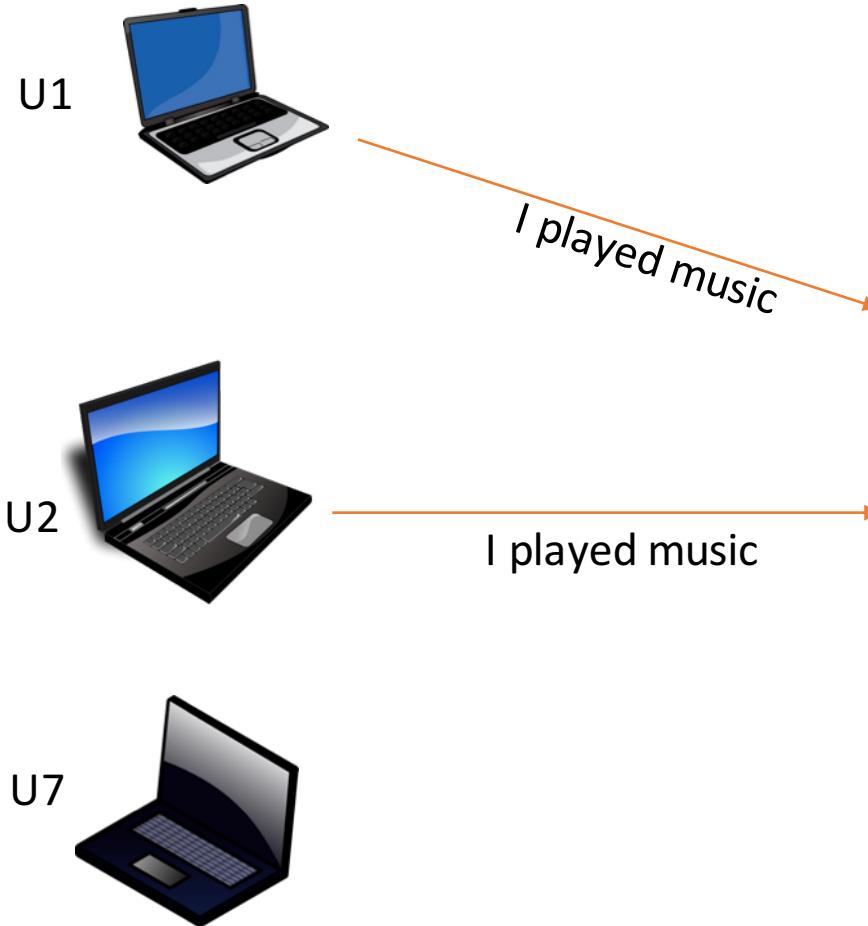
- A user will send a log to server when it visits our website
- A user will send another log to server when it plays music

- $\text{Failure rate} = 1/3$

Read More

Expert, <http://url.cn/bfddpB>
Expert, <http://url.cn/4ffk7f>

How to collect the data for failure rate (v2)



- The server can log automatically when a user visits our website
- A user only need to send a log to server when it plays music

- U1 visited
- U2 visited
- U7 visited

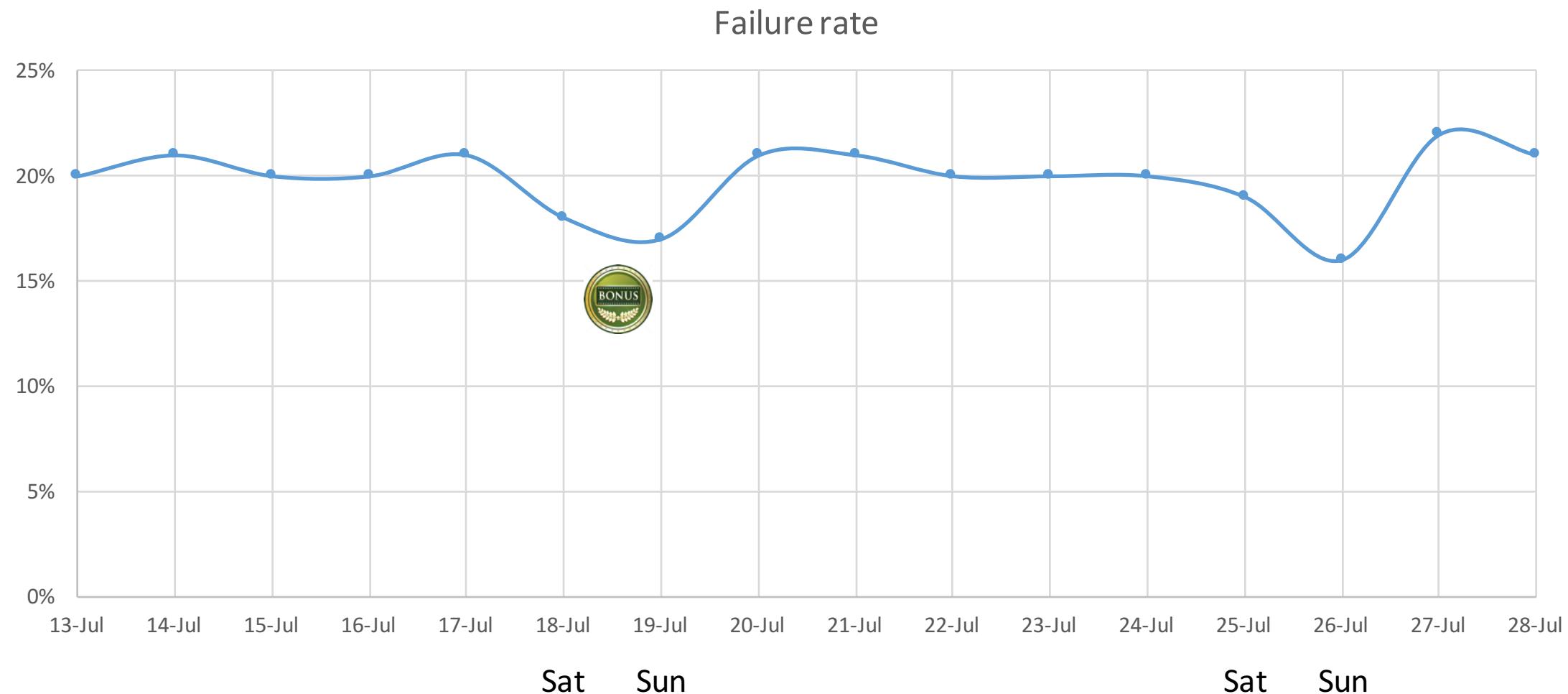
Understand failure rate

- With cookies and logs, we find out

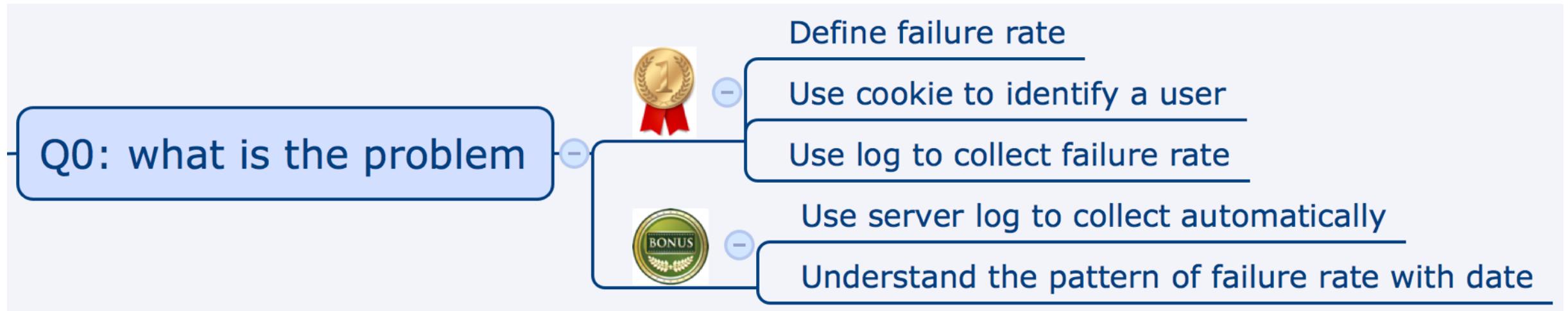
Failure rate = 20%



Understand failure rate with date



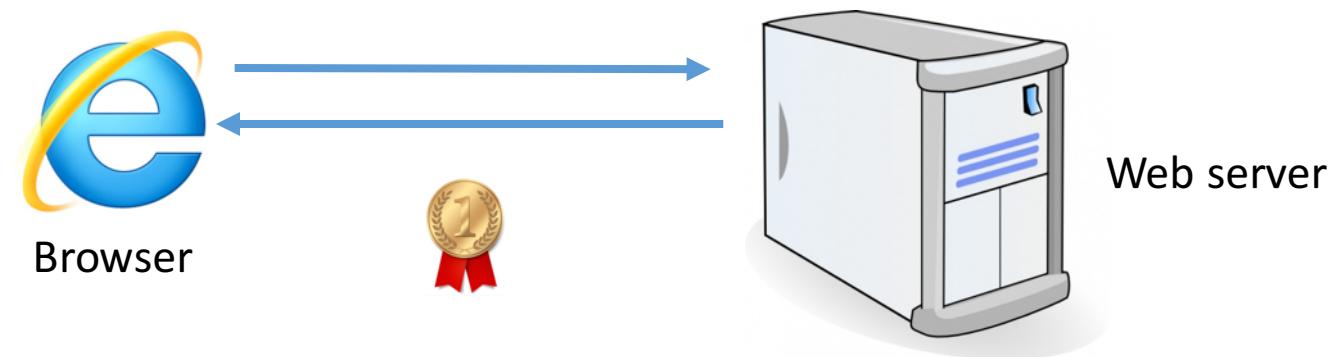
Summary of Question 0 (3+2)



Interviewer: Where is the problem?

Divide
&
Conquer

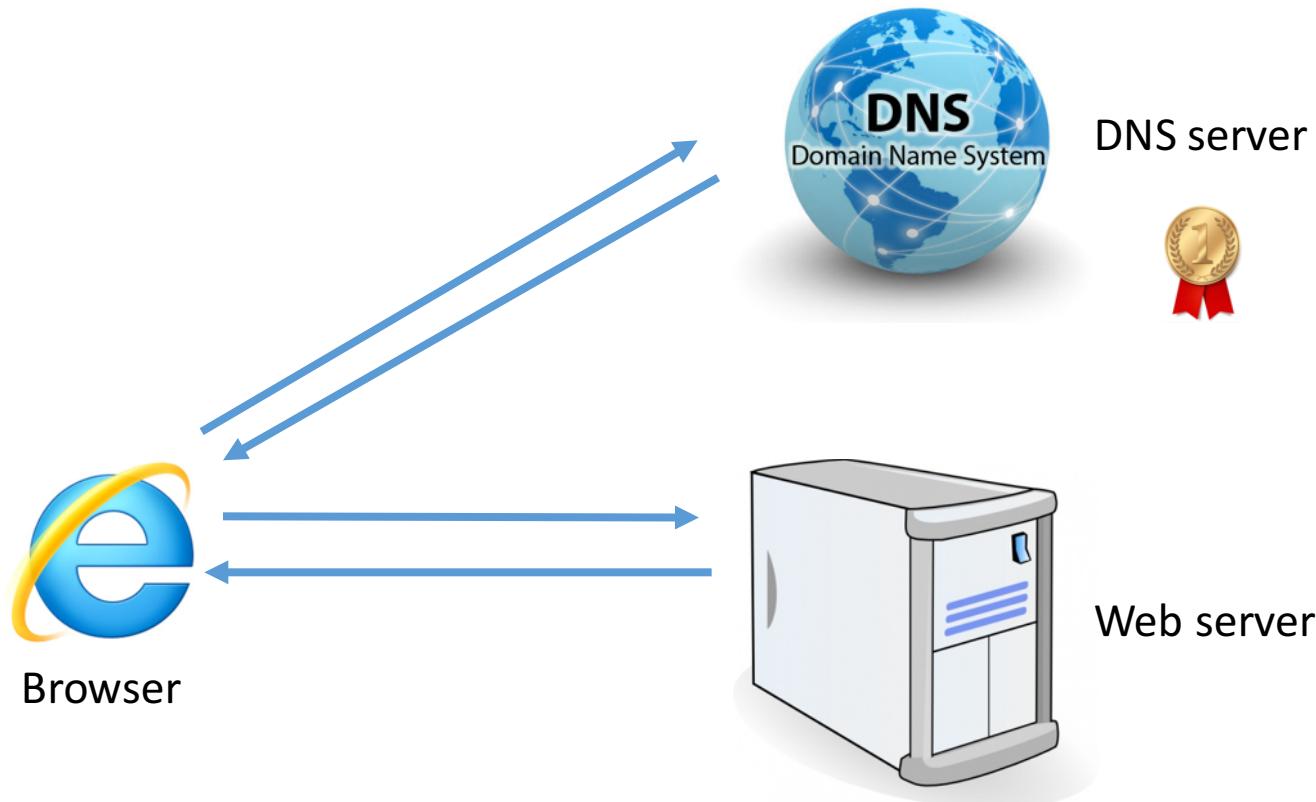
What is the process of playing music (v1)



Read More

Expert, <http://url.cn/XEgh6x>
Master, <http://url.cn/Y1Lv3V>

What is the process of playing music (v2)



Read More

Expert, <http://url.cn/eqCFbY>
Expert, <http://url.cn/bGKraS>
Master, <http://url.cn/7tnaFV>

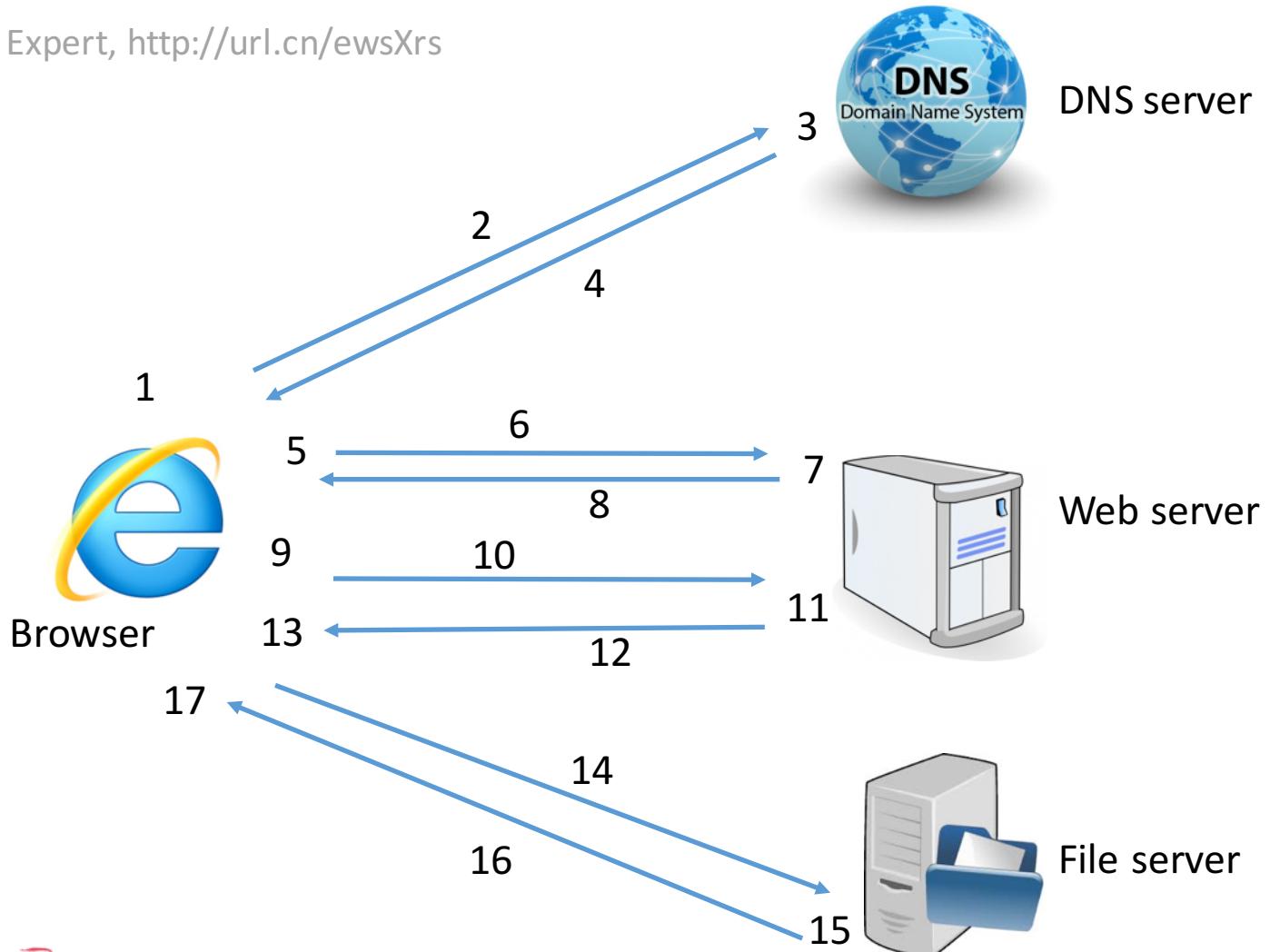
Seeing is believing

- <http://douban.fm>

What is the process of playing music (v3)

Read More

Expert, <http://url.cn/ewsXrs>



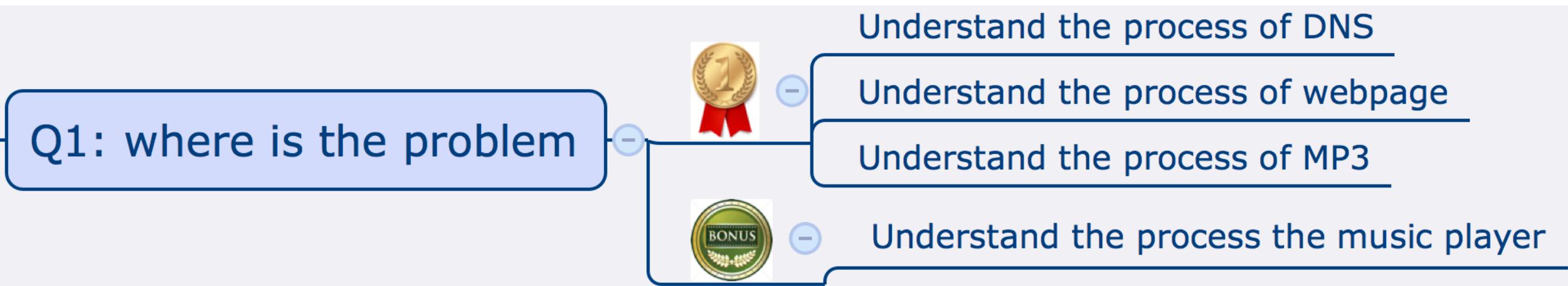
1. Prepare
2. Send DNS request
3. Prepare DNS reply
4. Send DNS reply
5. Process DNS reply
6. Send webpage request
7. Prepare webpage reply
8. Send webpage reply
9. Process webpage
10. Request music player
11. Prepare music player
12. Send music player
13. Process music player
14. Request MP3
15. Prepare MP3
16. Send MP3
17. Play MP3



Where is the problem?

- Failure rate = 20%
= 8% (DNS) + 5% (Web) + 2% (Player) + 5% (MP3)

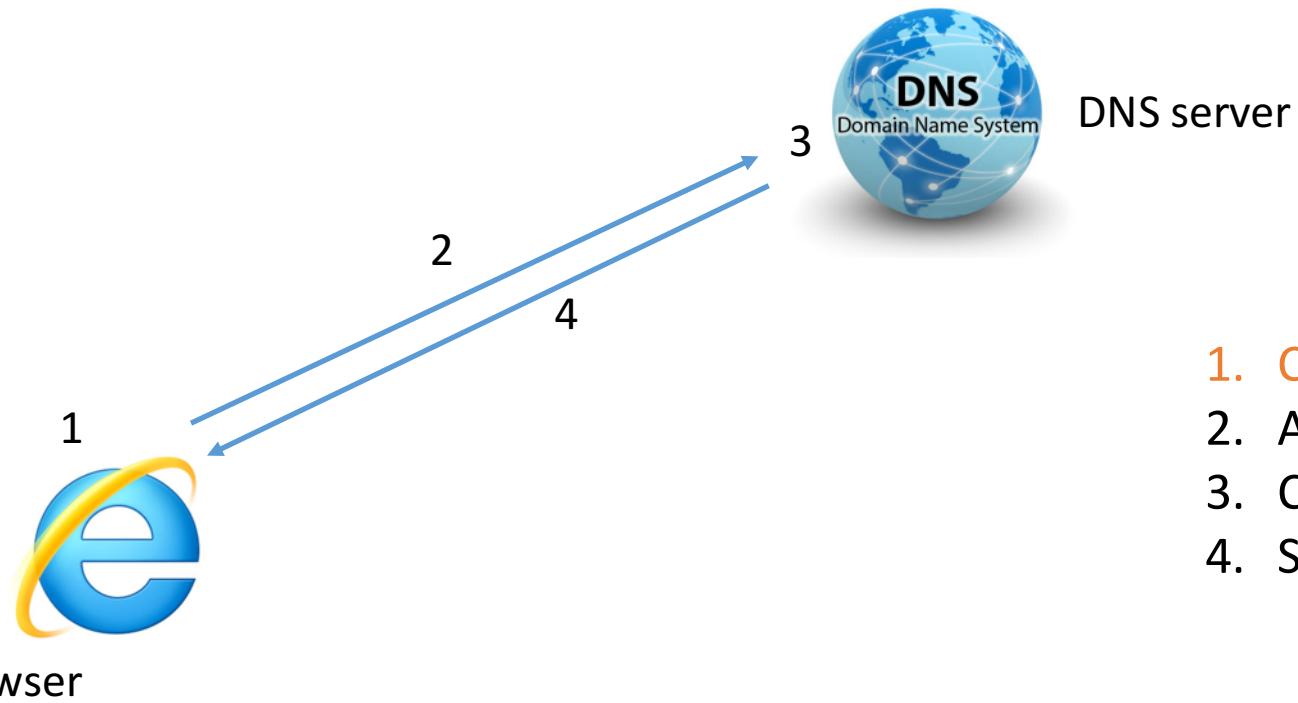
Summary of Question 1 (3+1)



Interviewer: fix the DNS problem

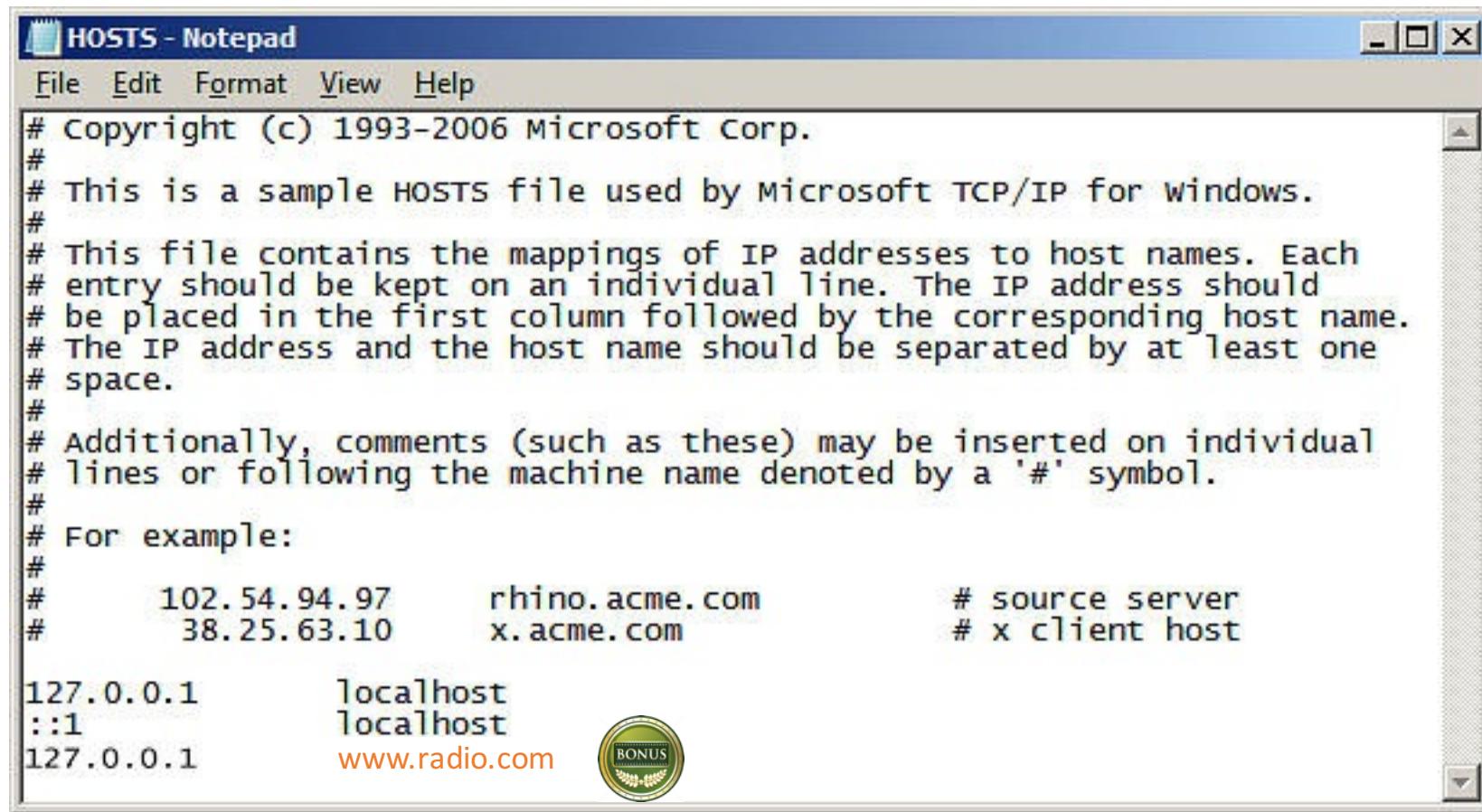
Failure rate	DNS	Web	Player	MP3
20%	8%	5%	2%	5%

Process of DNS



1. Check local Hosts file
2. Ask DNS server
3. Check itself or ask others
4. Send IP address back

Step 1: HOSTS hijack



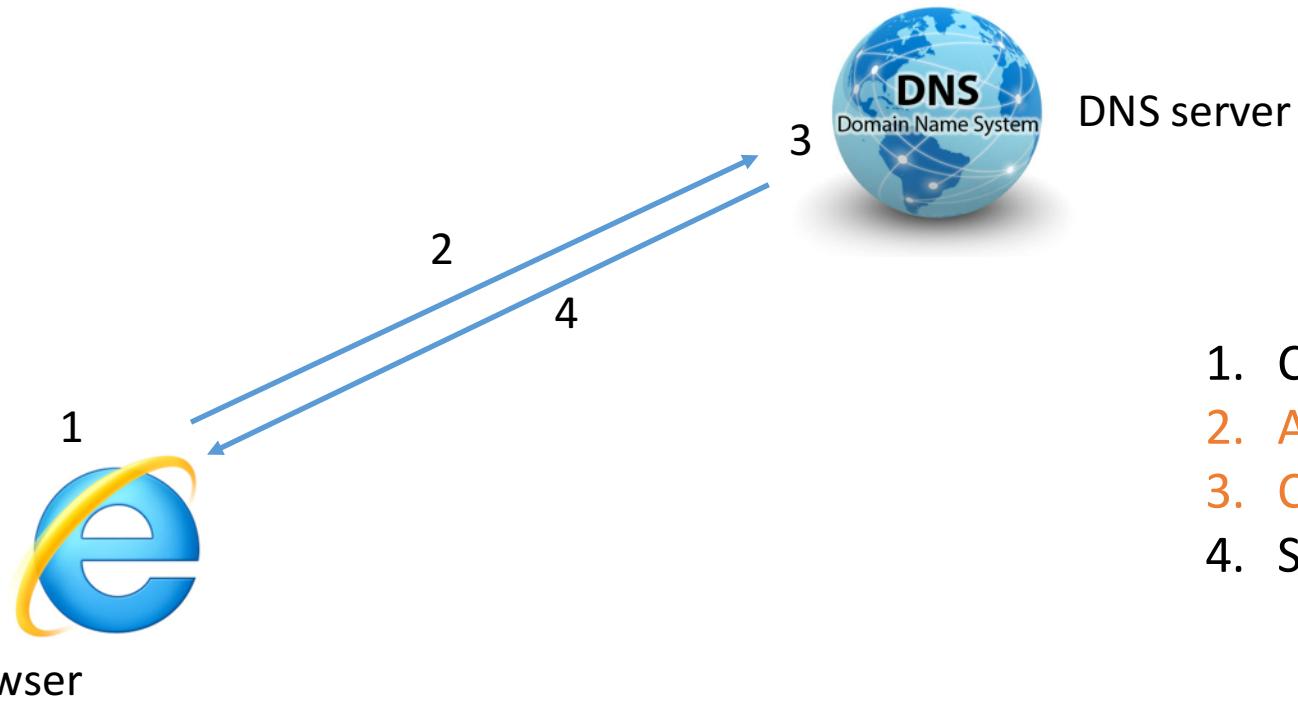
```
# Copyright (c) 1993-2006 Microsoft Corp.  
#  
# This is a sample HOSTS file used by Microsoft TCP/IP for Windows.  
#  
# This file contains the mappings of IP addresses to host names. Each  
# entry should be kept on an individual line. The IP address should  
# be placed in the first column followed by the corresponding host name.  
# The IP address and the host name should be separated by at least one  
# space.  
#  
# Additionally, comments (such as these) may be inserted on individual  
# lines or following the machine name denoted by a '#' symbol.  
#  
# For example:  
#  
#      102.54.94.97      rhino.acme.com      # source server  
#      38.25.63.10      x.acme.com          # x client host  
  
127.0.0.1      localhost  
::1            localhost  
127.0.0.1      www.radio.com
```

Step 1: solution



- Why
 - Some competitors in music industry will hijack the DNS of others when a user installs their software
- Solution
 - Hosts file analysis by our software

Process of DNS



1. Check local Hosts file
2. Ask DNS server
3. Check itself or ask others
4. Send IP address back

Step 2: DNS server analysis by ISP (Internet Service Provider)

ISP	Chinese name	User percentage	Failure rate
CHINANET	中国宽带互联网	58%	1.0%
CHINA169	中国网通	24%	0.9%
CSTNET	中国科技网	7%	93%
UNINET	中国联通	2%	2%
CMNET	中国移动	1%	1.4%
CERNET	中国教育网	1%	0.9%
...

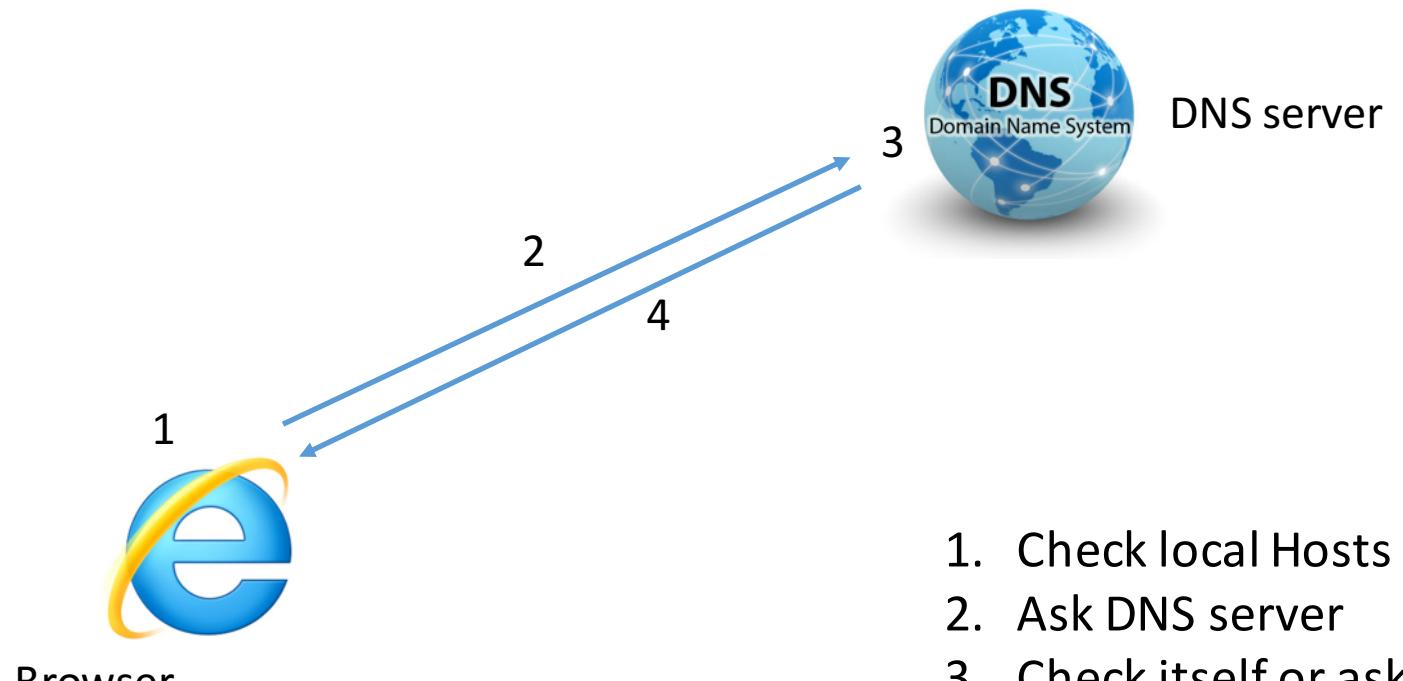


Step 2: solution



- Why
 - CSTNET fails to update our latest DNS after we changed our server address
- Solution
 - Make a phone call

Process of DNS



1. Check local Hosts file
2. Ask DNS server
3. Check itself or ask others (poison from others)
4. Send IP address back (hijacked by middleman)

What happens after fixing DNS?

Scenario	Failure rate	DNS	Web	Player	MP3
Before fixing DNS	20%	8%	5%	2%	5%
After fixing DNS	17%	1%	7%	3%	6%



Why is there still 1%?



- Blocked by company

Company	User percentage	Failure rate
Work_Hard_Company	0.01%	100%
No_Music_Company	0.01%	100%
QQ	0.05%	0.1%
Peking University	0.03%	0.1%

推荐

排行榜

歌单

主播电台

歌手

新碟上架



歌单 •

其实你明知道 回忆里的人是不能去见的

提示

X

由于版权保护，您所在的地区暂时无法使用。

确定

存在

歌曲列表

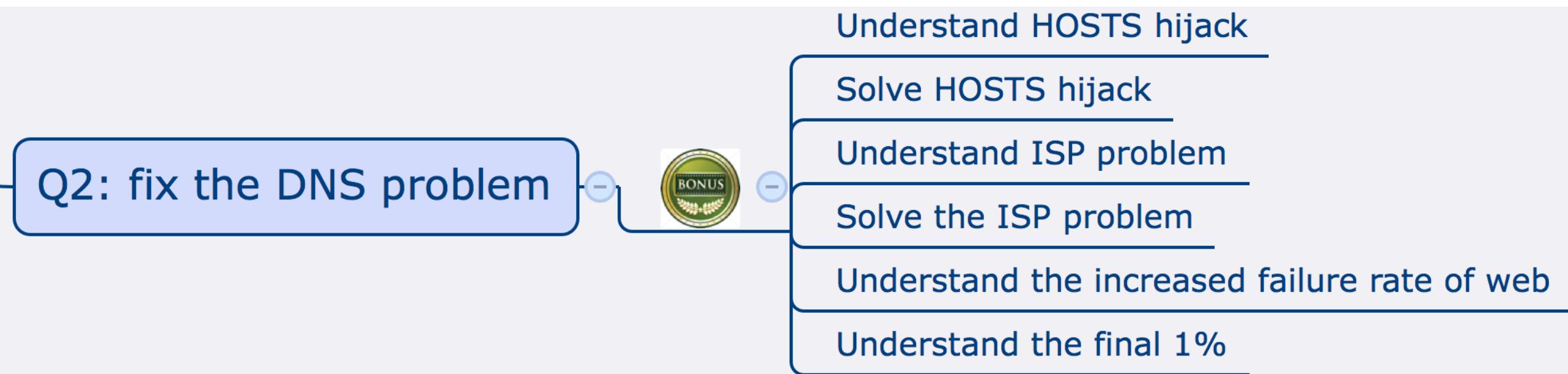
21首歌

 生成外链播放器

播放: 1182496次

	歌曲标题	时长	歌手	专辑
1	 你就不要想起我 	04:40	田馥甄	渺小
2	 寂寞寂寞就好	04:26	S.H.E	2GETHER 4EVE...

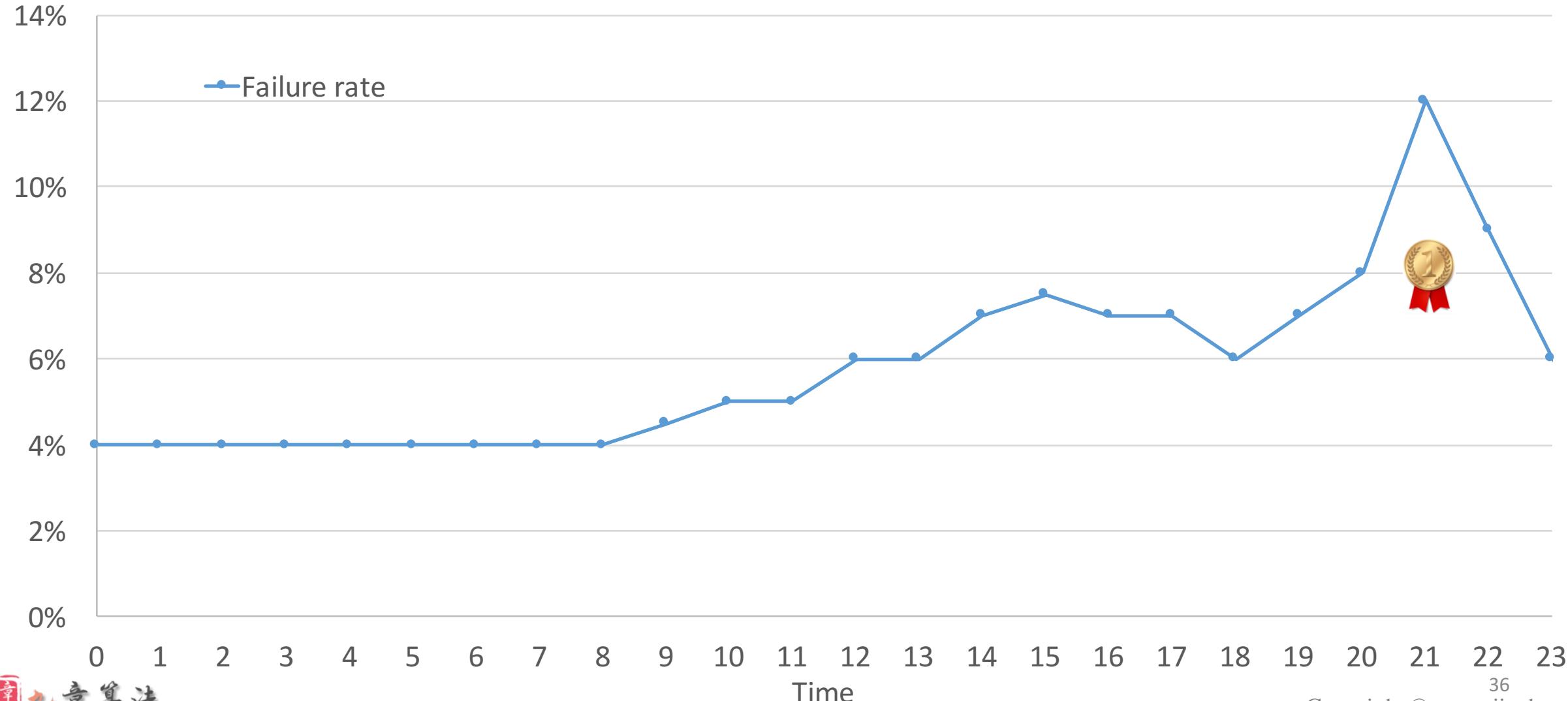
Summary of Question 2 (0+6)



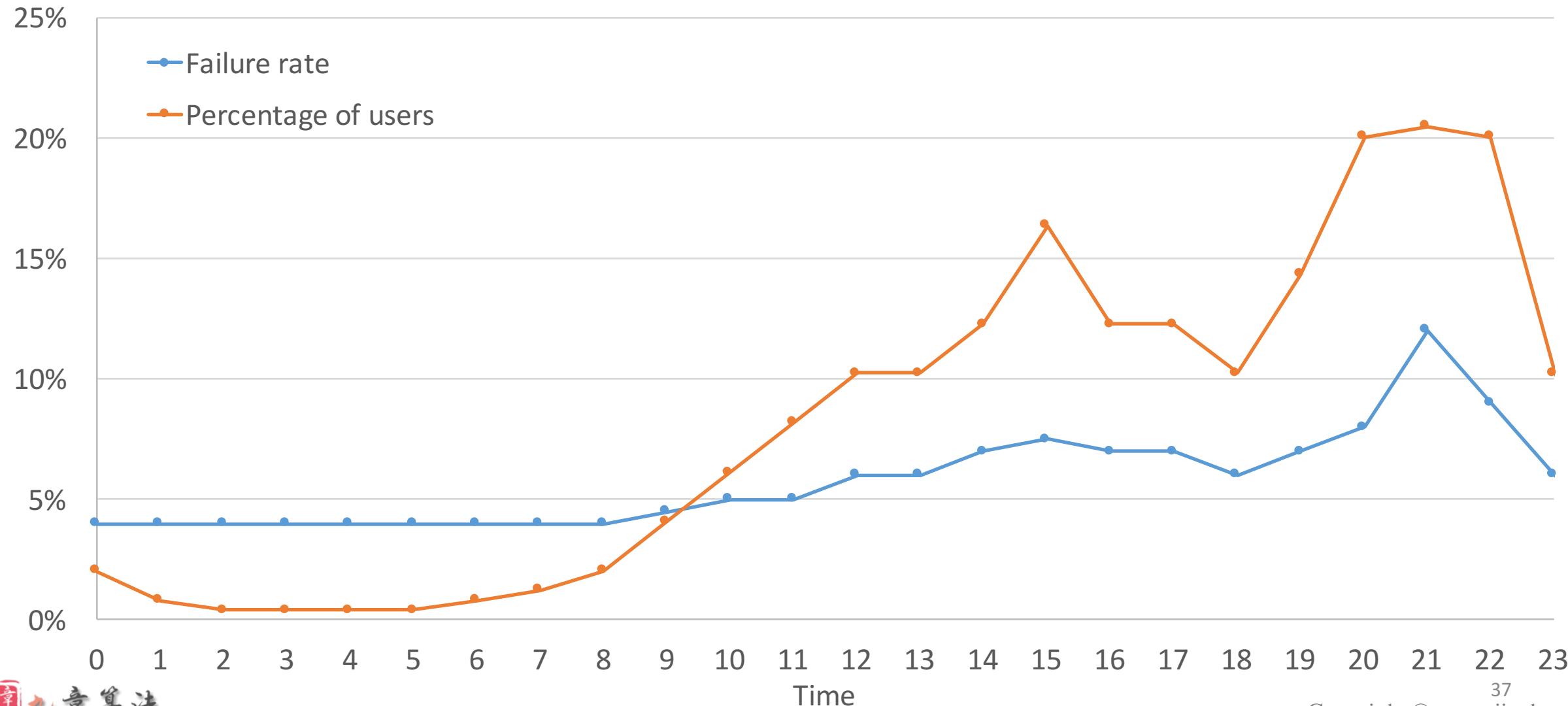
Interviewer: fix the web problem

Failure rate	DNS	Web	Player	MP3
17%	1%	7%	3%	6%

Web failure rate analysis with time



Web failure rate analysis with time and users

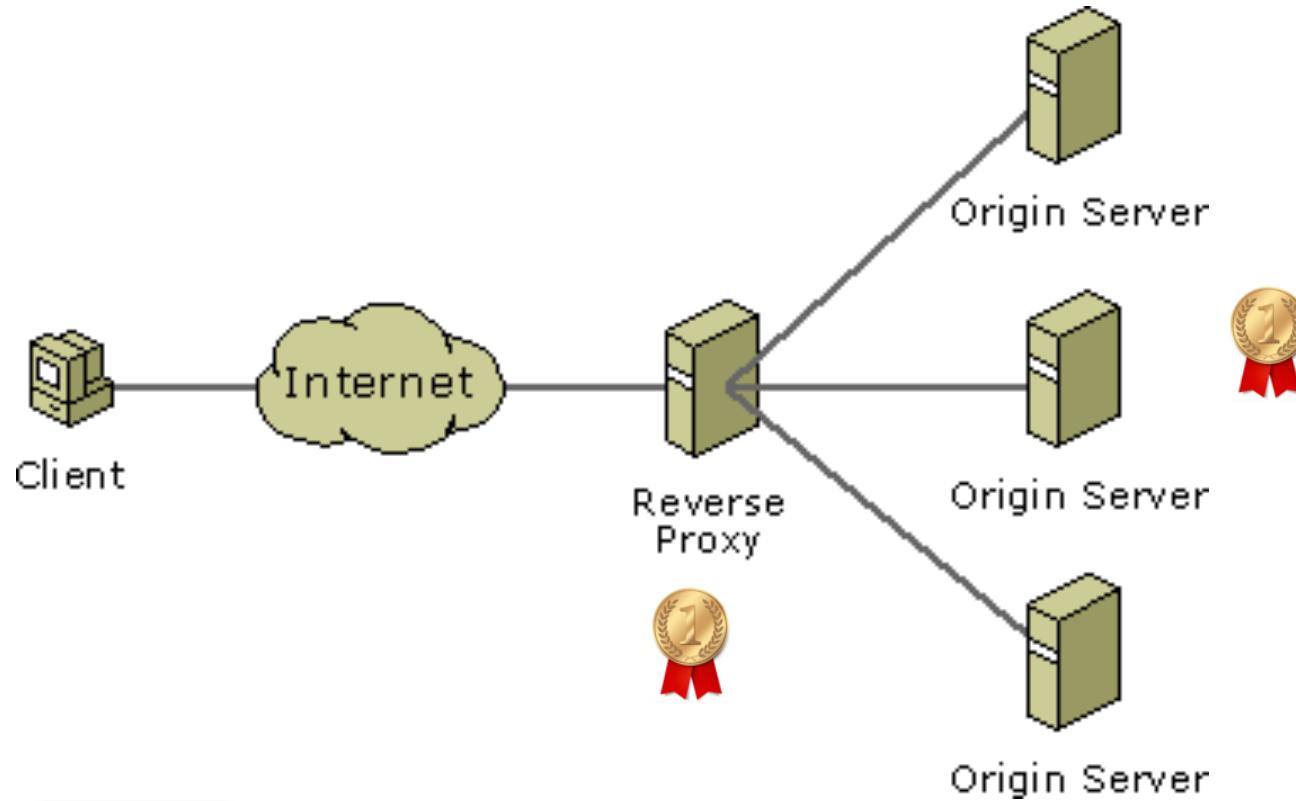


Why?

- With more users, our web server can't handle these requests.



Solution 1: reverse proxy with more servers



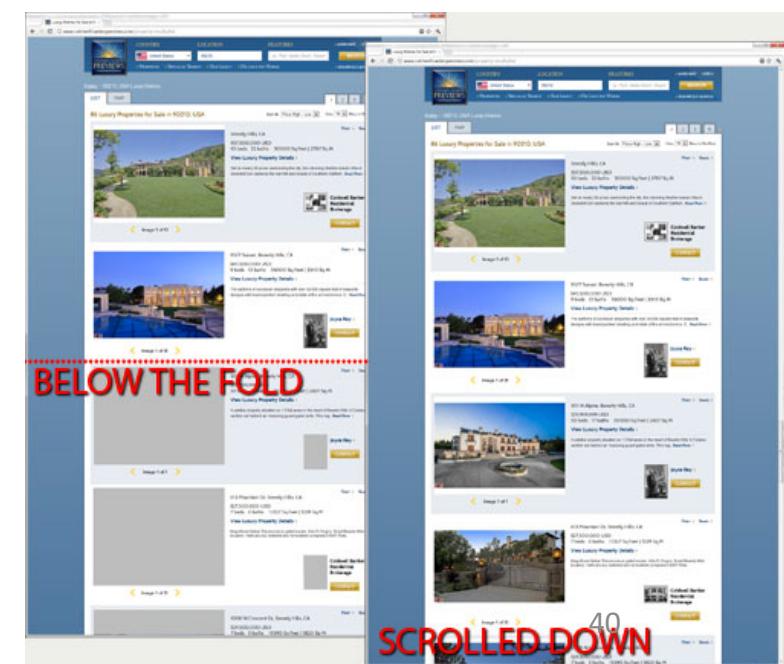
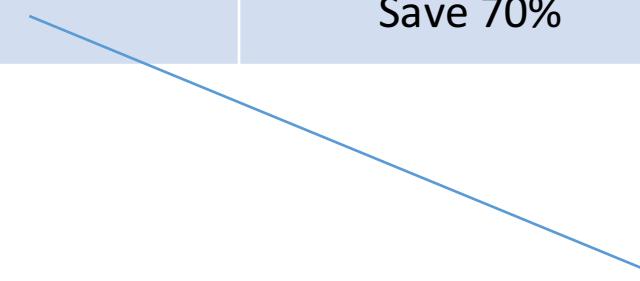
Read More

Novice, <http://url.cn/ccjApK>
Novice, <http://url.cn/dNj6oD>
Expert, <http://url.cn/cO2lbS>
Expert, <http://url.cn/bnLZTx>

Solution 2: reduce the size of webpage



Method	Example	Results
Simplify content	Rewrite JS code	Save 10%
Compress/merge images	From 300dpi to 72dpi	Save 40%
Lazy load		Save 70%

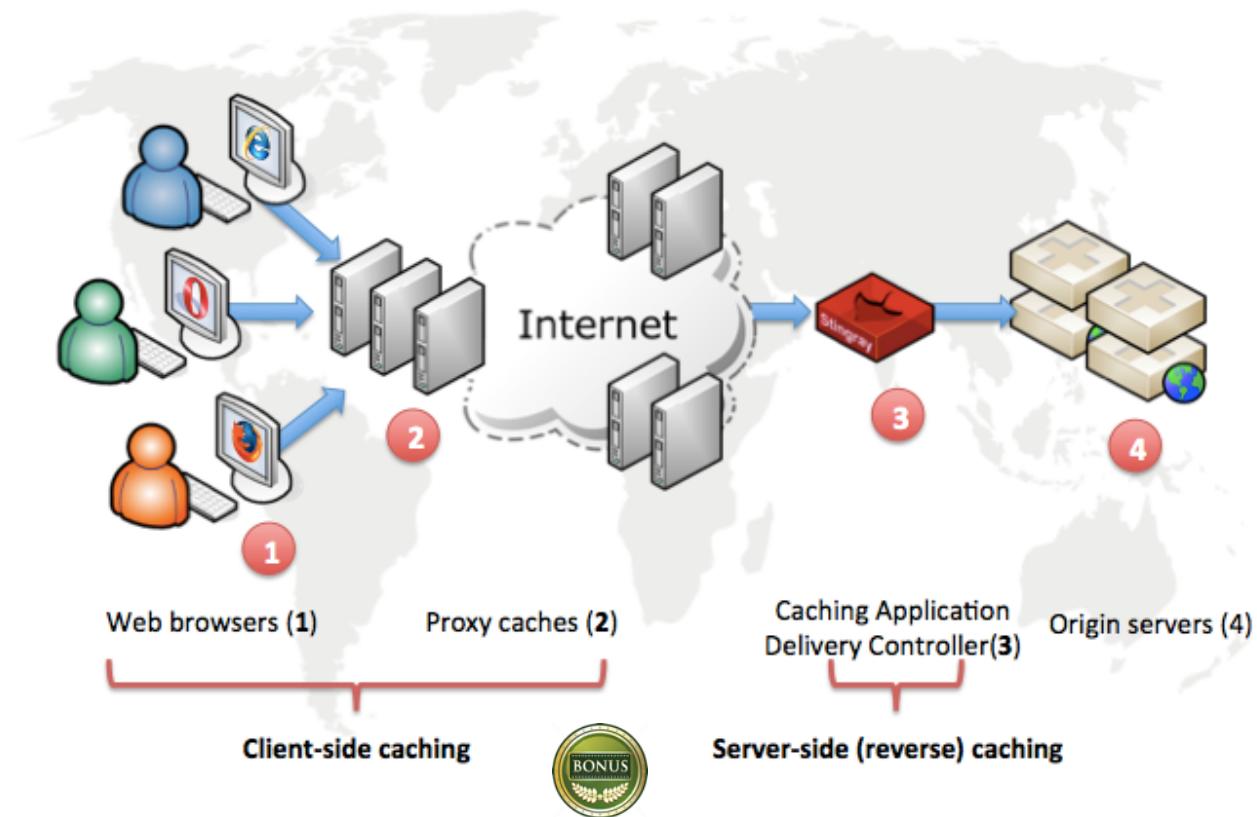


Novice: <http://url.cn/bRZz2M>
Novice: <http://url.cn/dZAjfO>

Read More

Solution 3: more cacheable pages

- Change dynamic webpage into static webpage 



What happens after fixing Web?

Scenario	Failure rate	DNS	Web	Player	MP3
Before fixing Web	17%	1%	7%	3%	6%
After fixing Web	15%	1%	4%	3%	7%

Why is there still 4 percentage?

- Many users will close the webpage as soon as they open it.



Summary of Question 3 (6+5)

Analyze failure rate with time

Understand the web server problem

Understand proxy

Add more servers

Reduce the size of webpage

Change dynamic page into static

Analysis failure rate with time and users

Compress/merge images

Lazy load

Understand three caches

Explain the last 4% failure rate



Q3: fix the web sever problem



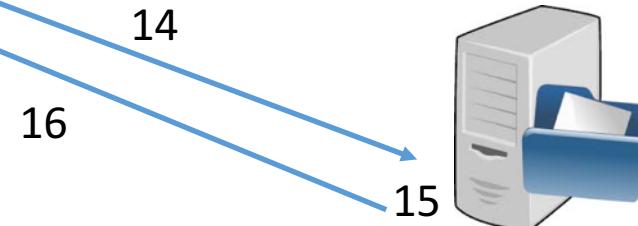
Interviewer: fix the MP3 problem

Failure rate	DNS	Web	Player	MP3
15%	1%	4%	3%	7%

Process analysis



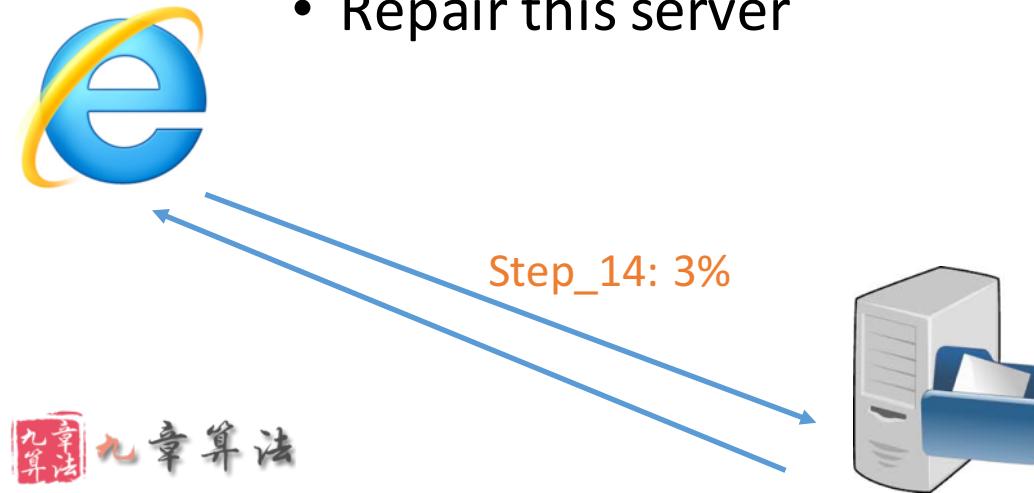
17



Steps	Possible failure point	Failure rate
13	Fail to send the request	0%
14	Network error	3%
	Timeout	0.01%
15	Fail to establish connection	0.01%
	Fail to find MP3 file	1%
16	Network error	0.01%
	Timeout	1%
17	Fail to play	1%
Unknown	???	1%

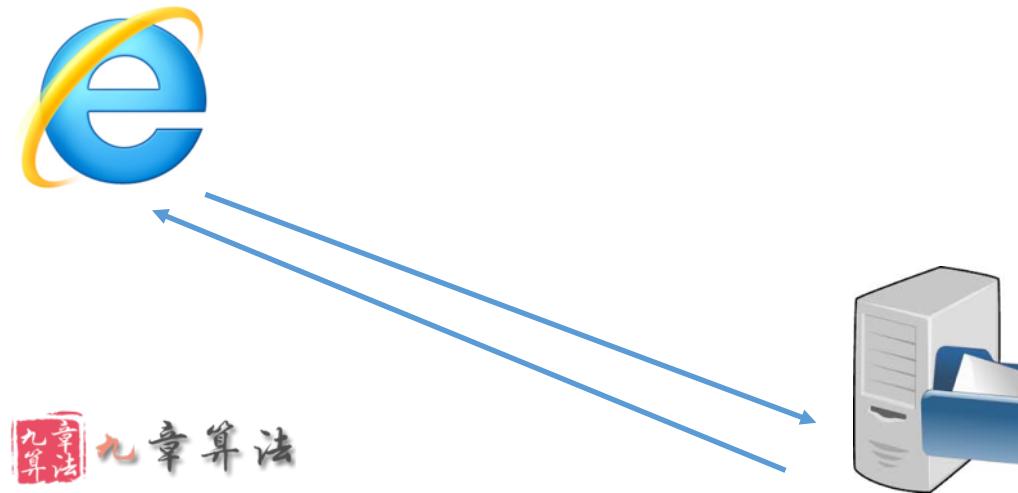
Fix step14 with network error

- Analysis
 - Check the URL of failed MP3 address
 - They are pointing to an unknown IP address
 - Oh, this server has failed without anyone knowing it!
- Solution
 - Remove this server
 - Repair this server



Fix step15 with failing to find MP3 files

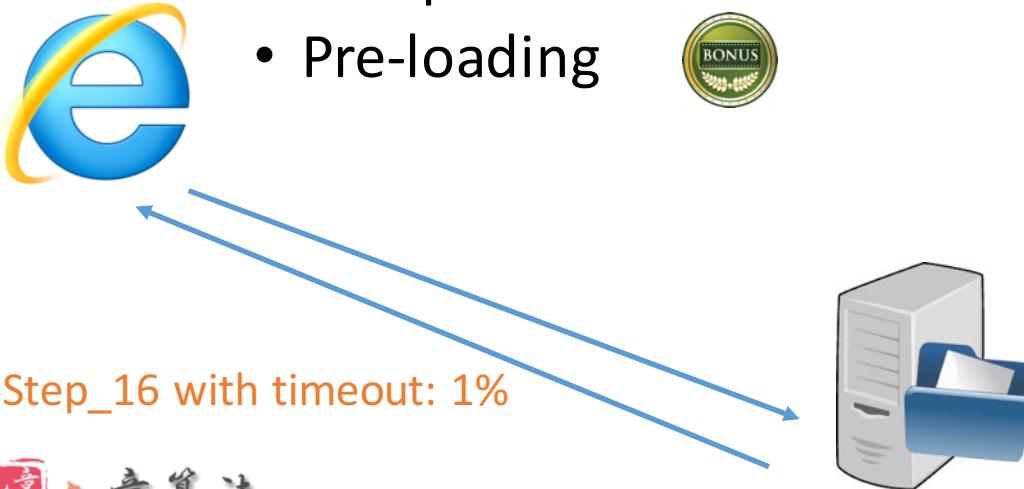
- Analysis
 - Some MP3 servers have more errors than others
 - The reason is that an MP3 address can only be used for 5min to avoid unlimited download from Xunlei
 - But it will fail if MP3 server and Web server have a large time gap
- Solution
 - Sync the clock between servers every 10min



Fix step16 with timeout

- Analysis
 - MP3 files are relative large
 - It will timeout if network speed is low

- Solution
 - Optimize CDN 
 - Compress MP3 with lower bitrate
 - Pre-loading 



Content Delivery Network

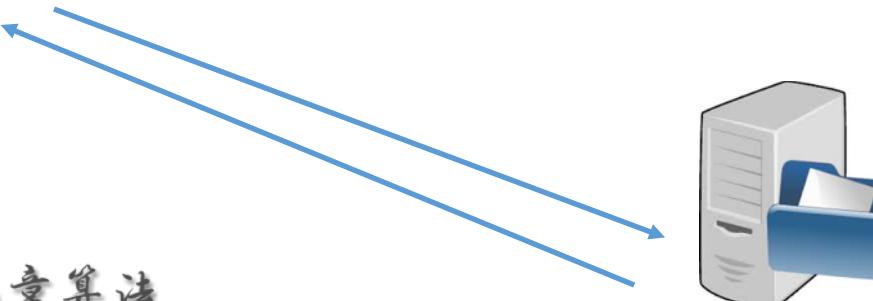


Fix step17 with failing to play

- Analysis
 - Some files cannot be played
 - Finally, we find that it comes from audio transcoding process
- Solution
 - Fix the bug in audio transcoding codes
 - Re-transcoding the bad files



Step_17 with failing to play: 1%



The unknown problem with 1%

- Analysis
 - Many users close the webpage as soon as it opens
 - The unknown problem happens if they close the webpage when it is loading an MP3 file



What happens after fixing the MP3?

Scenario	Failure rate	DNS	Web	Player	MP3
Before fixing MP3	15%	1%	4%	3%	7%
After fixing MP3	10%	1%	4%	3%	2%

Summary of Question 4 (5+5)

Understand failure in step 14

Understand failure in step 15

Understand failure in step 16

Understand failure in step 17

Fix timeout with CDN

Fix step 14 failure

Fix step 15 failure

Fix step 16 failure

Fix Step 16 failure

Understand the unknown problem



Q4: fix the MP3 problem



一休さん



Interviewer: fix the player problem

Failure rate	DNS	Web	Player	MP3
10%	1%	4%	3%	2%

What is the problem?

- Analysis
 - Many users' versions of flash players are too low
 - Many iOS devices cannot play flash!!!
- Solution
 - Develop HTML5 player



Read More

Master: <http://url.cn/SLedbA>

What happens after fixing the flash?

Scenario	Failure rate	DNS	Web	Player	MP3
Before fixing flash	10%	1%	4%	3%	2%
After fixing flash	8%	1%	4%	1%	2%

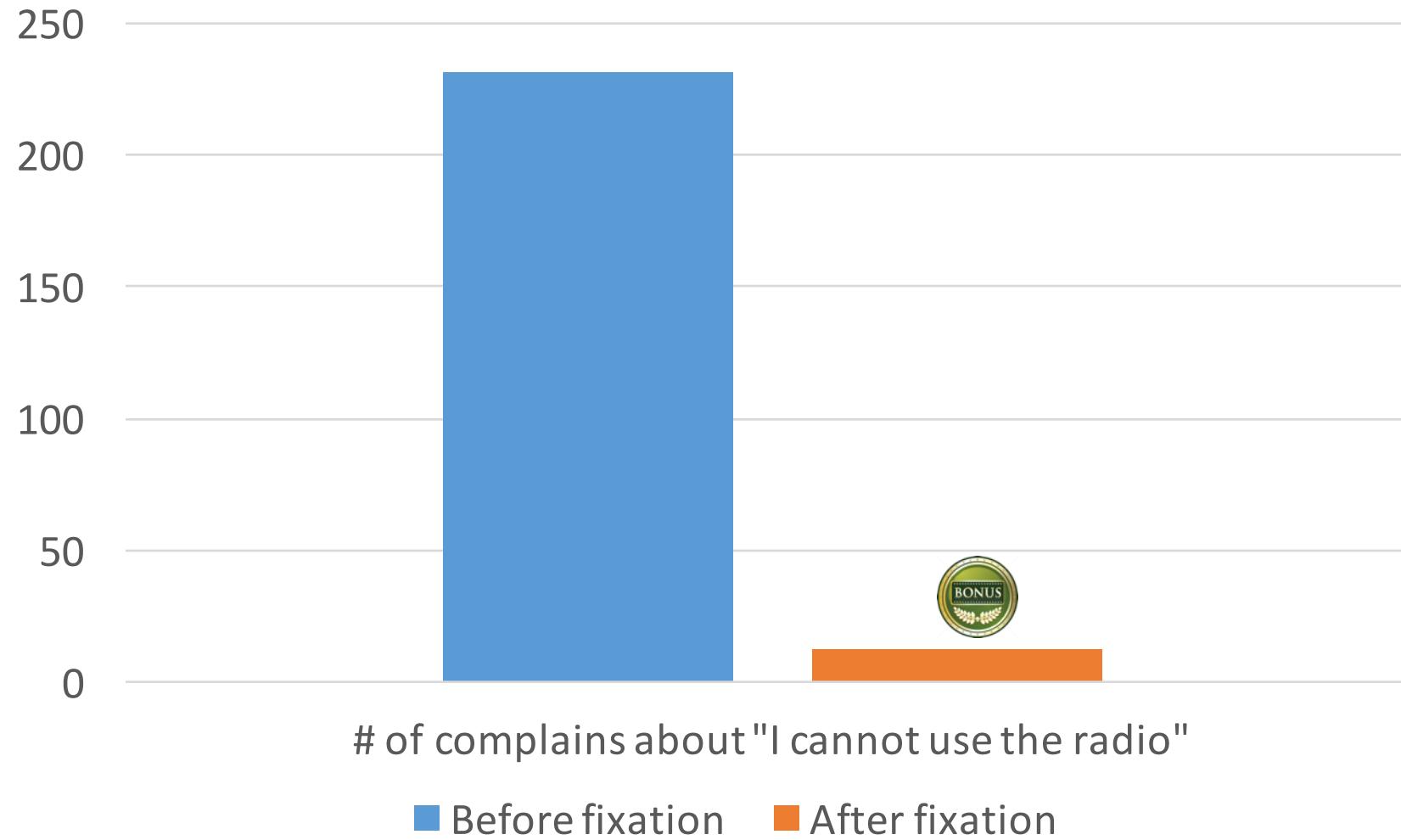
Summary of fixation

Scenario	Failure rate	DNS	Web	Player	MP3
Original scenario	20%	8%	5%	2%	5%
After fixing DNS	17%	1%	7%	3%	6%
After fixing WEB	15%	1%	4%	3%	7%
After fixing MP3	10%	1%	4%	3%	2%
After fixing flash	8%	1%	4%	1%	2%

Interviewer

- How to make sure that you have solved the problem?

Measure number of daily complains



Interviewer

- Will this fixation increase our daily active users?

Can we measure the number of daily active users directly?

- NO!
 - The number of daily users depends on so many different factors

One day retention rate



$$= \frac{\text{The number of users visited in both day}_x \text{ and day}_{x+1}}{\text{The number of users visited in day}_x}$$

Today's visitor = {U1, U3, U7, U9, U10}

Tomorrow's visitor = {U2, U3, U9,}

Today's one day retention rate = 2/5

Solution: compare retention rate

	One day retention rate
Before fixation	45%
After fixation	46%

Conclusion: our fixation can increase daily active users a little

Summary of Question 5 (0+3)

Fix the player problem

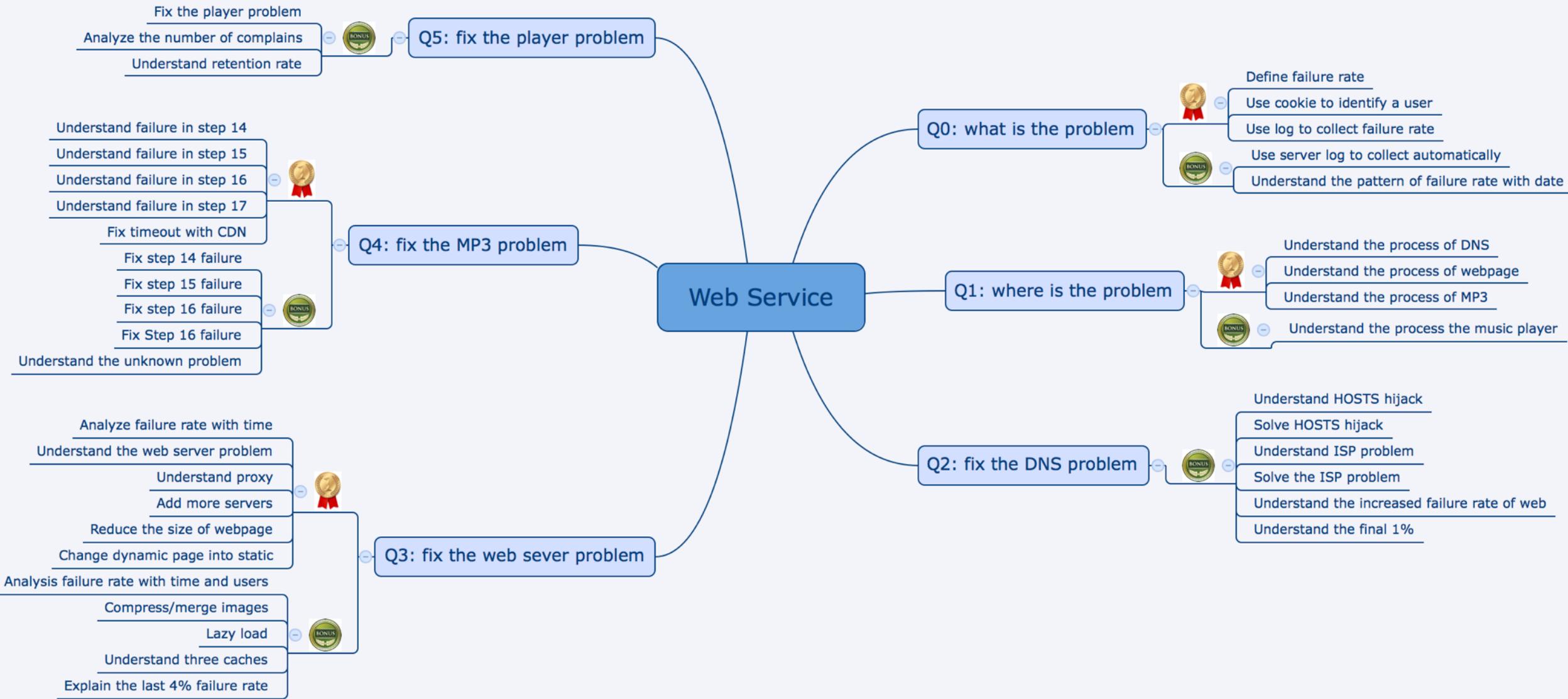
Analyze the number of complains

Understand retention rate



Q5: fix the player problem

Summary of Part 1



Part 2 Rate limiter

[Read More](#)

Novice/Expert, <http://url.cn/80Ylun>

Master, <http://url.cn/dVVjyr>

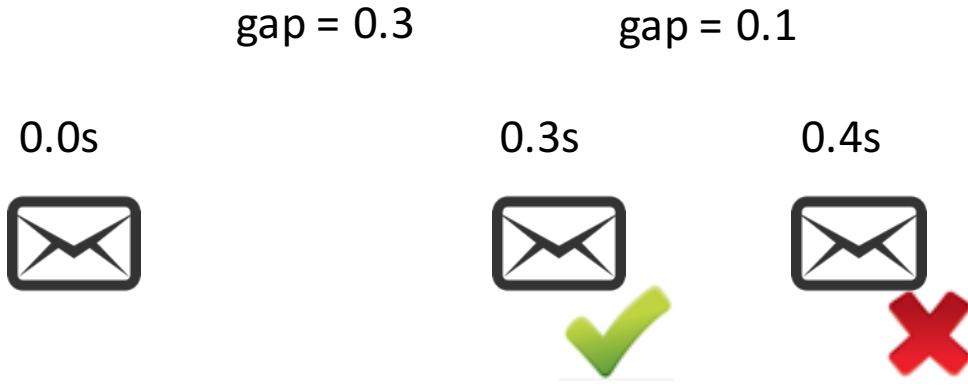
Master, <http://url.cn/c5KSaU>

Interviewer: Limit QPS = 5

Algorithm of gap



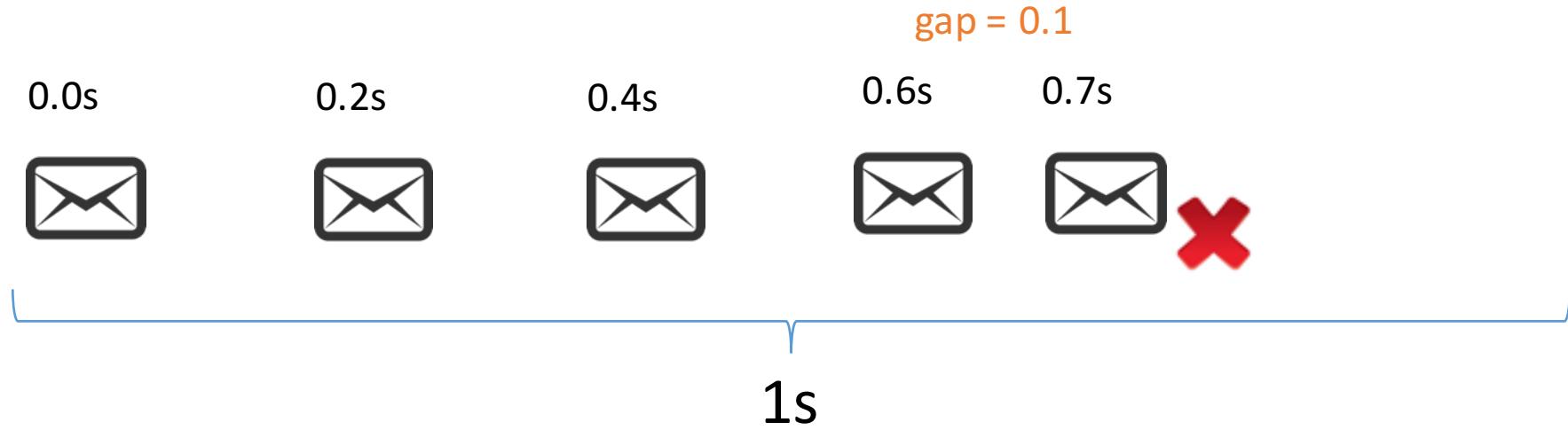
Make sure: the gap between two requests $\geq 1/5$



Acquire()

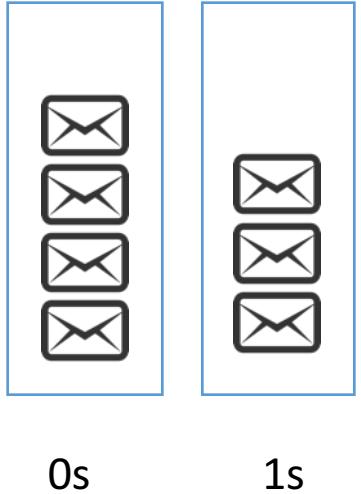
```
If ( now - mLastTime >= 0.2 )
    mLastTime = Now;
    Return True;
Else
    Return False;
```

Bad case



Interviewer: How to limit 5 requests
in every 1 second?

Algorithm of time-bucket



Acquire()

```
s = GetCurrentSecond();  
If ( mCounter[s] >= 5 )  
    Return False;  
Else  
    mCounter[s]++;  
    Return True;
```

Interviewer: Do it with database

Algorithm of time-bucket with Database



Acquire()

s = GetCurrentSecond();

counter = Database.Get(s);

If counter != NULL AND counter >= 5

 Return False;

Else

 Database.Increase(s, 1);

 Database.Expire(s, 1);

 Return True;

Read More

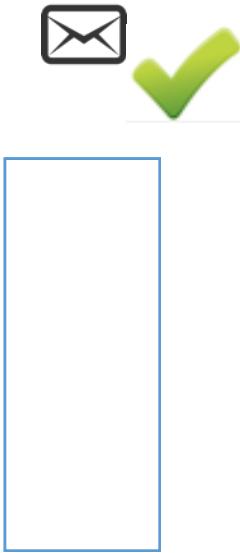
Expert, <http://url.cn/bC1Nvd>

Expert, <http://url.cn/cxdYo3>

Master, <http://url.cn/blbLsr>

Interviewer: Save space without database?

Algorithm of one-bucket

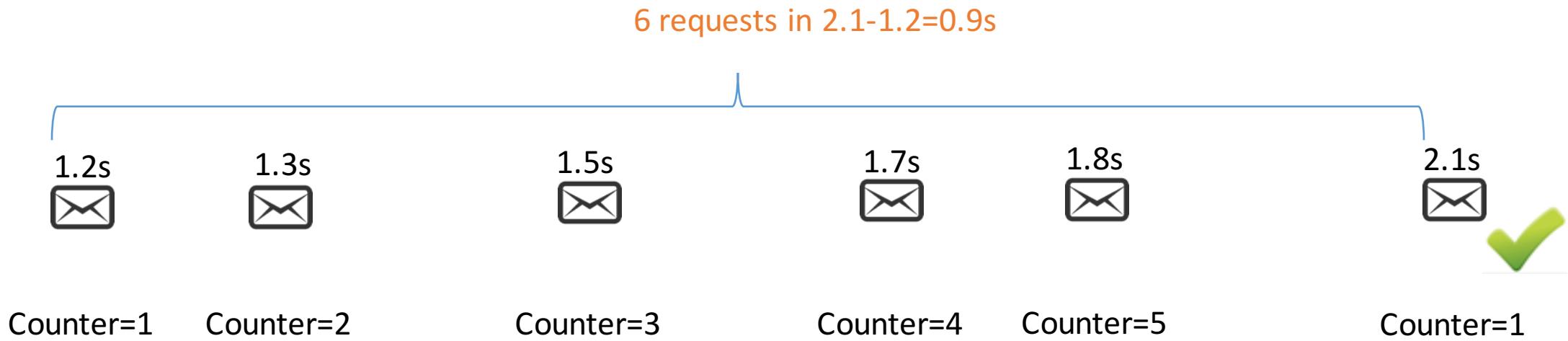


Acquire()

```
currentSecond = GetCurrentSecond();
If ( currentSecond != mPreSecond )
    mCounter = 0;
    mPreSecond = currentSecond;

    If ( mCounter >= 5 )
        Return False;
    Else
        mCounter++;
        Return True;
```

Bad case



Interviewer: How to limit 5 requests in any one second?

Algorithm of requestList



$2.1 - 1.2 = 0.9$

$1.9 - 0.8 = 1.1$

0.8s
 requestList[0]

1.2s
 requestList[1]

1.3s
 requestList[2]

1.5s
 requestList[3]

1.7s
 requestList[4]

1.9s
 requestList[5]

2.1s

Acquire()

```
currentTime = GetcurrentTime();
prefifthTime = mRequestList[ mRequestList.size() -5];
```

If(currentSecond - prefifthSecond >1)

```
mRequestList.append(currentTime);
```

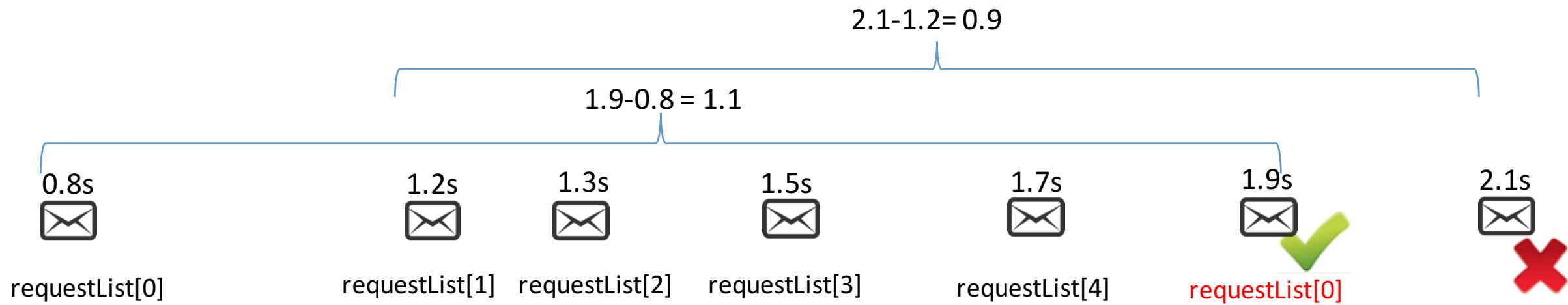
Return True;

Else

Return False;

Interviewer: How to save space?

Algorithm of fixed requestList



Acquire()

```
currentTime = GetcurrentTime();  
If( currentTime - mRequestList[mPtr] >1 )  
    mRequestList[mPtr] = currentTime;  
    mPtr = (mPtr+1)%5;  
    Return True;  
Else  
    Return False;
```

Follow up

- How to save space with 10^9 query per hour?
 - Batch queries
- How to support multiple threads?
 - Lock
- How to support limiter on users?
 - <uid, requestList>
- How to support query with different quotas?
 - acquire(quota)

Algorithm of Token Bucket



Space complexity $O(1)$

Read More

Expert, <http://url.cn/cxmNy2>

Expert, <http://url.cn/TaEtSw>

Expert, <http://url.cn/dWlSB3>

Green card

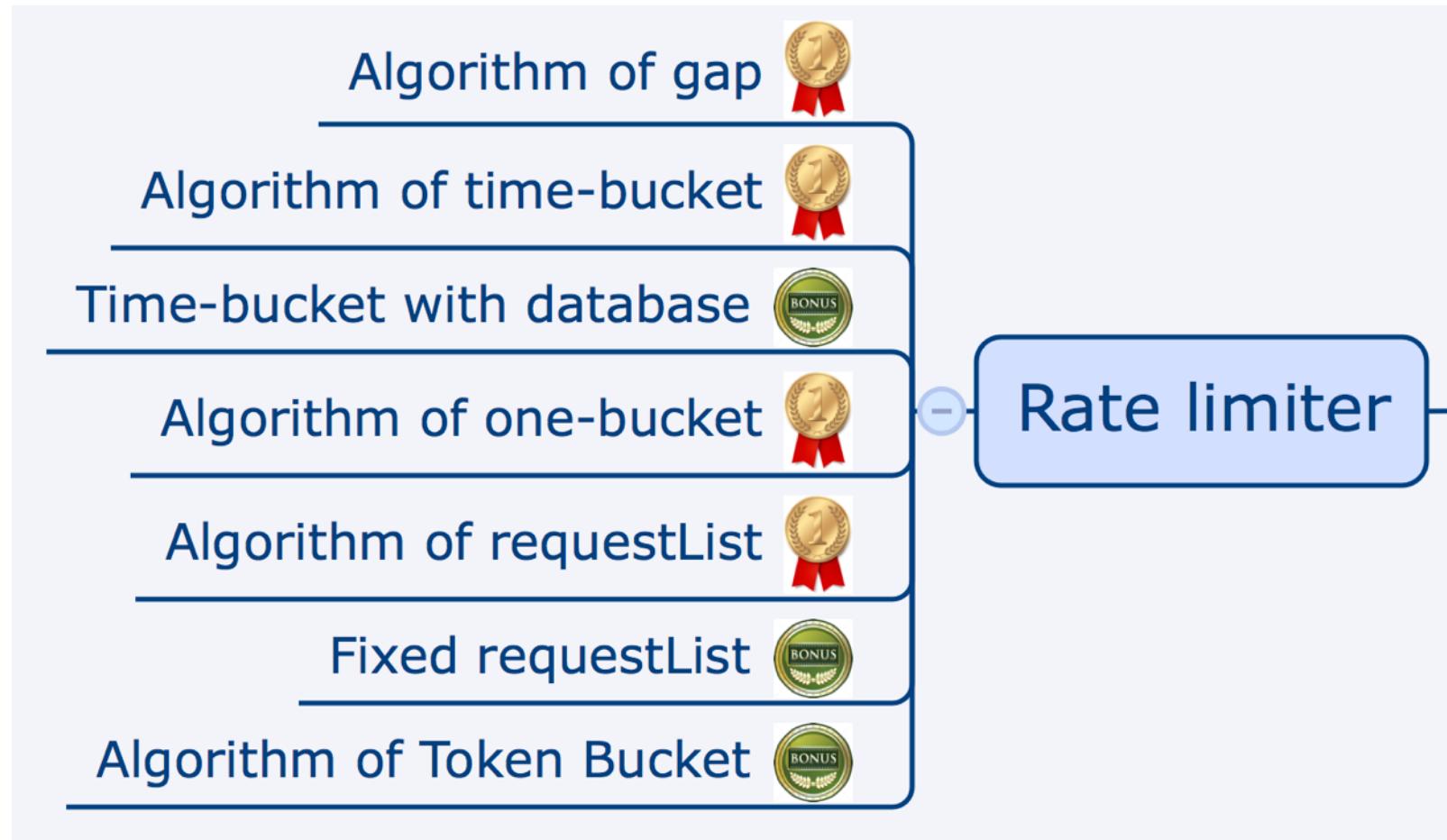
1 green card per 0.2s

Green card

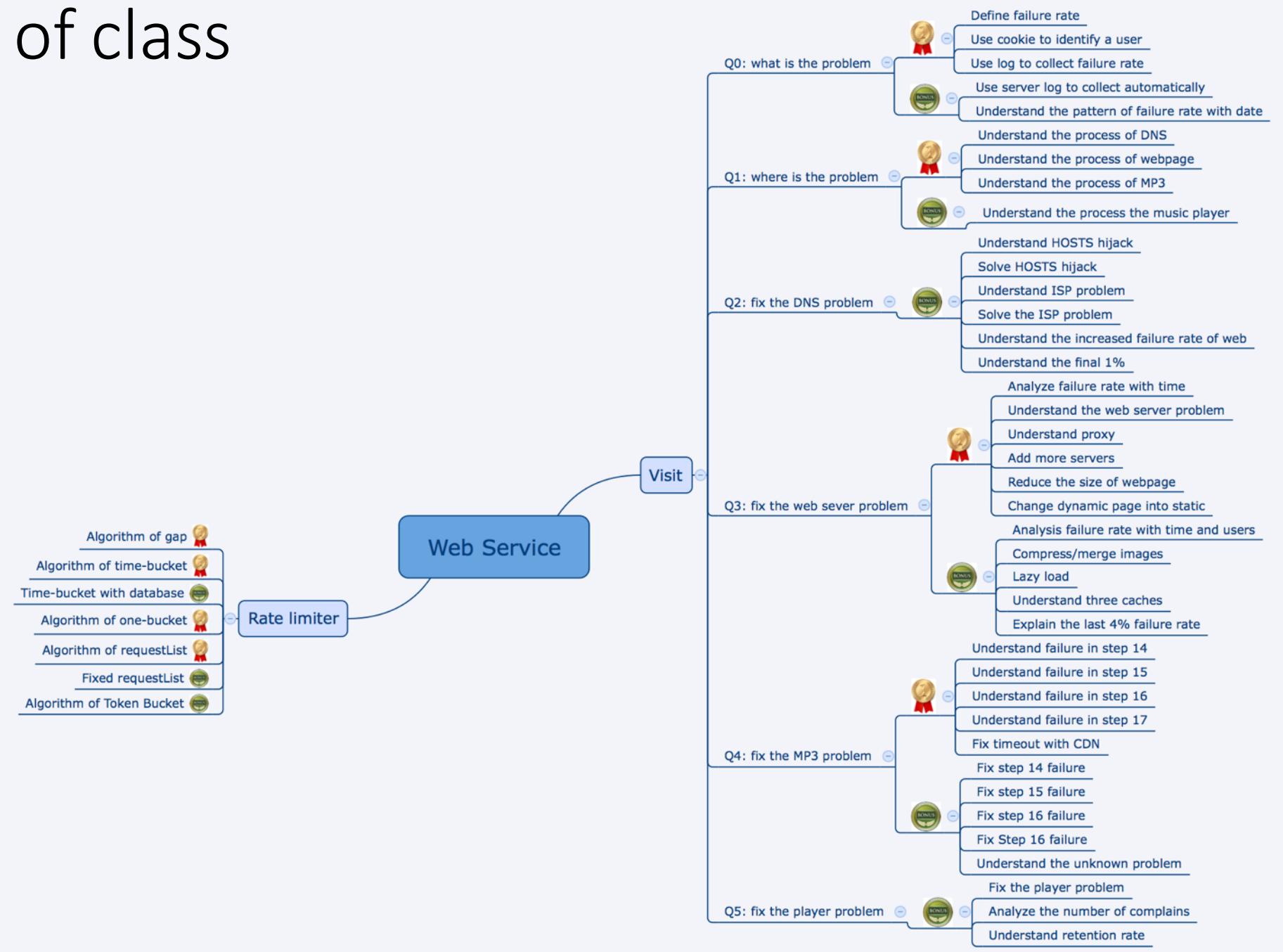
Green card



Summary of Part2 (4+3)



Summary of class



Keyword

- Failure rate
- DNS
- HTTP
- Cookie
- Web server
- ISP
- Proxy
- Compression
- Lazy load
- Cache
- CDN
- Rate limiter
- QPS
- Counter
- Expire
- Request list
- Token bucket

One more thing



[Read More](#)

Novice, <http://url.cn/WaKqHR>

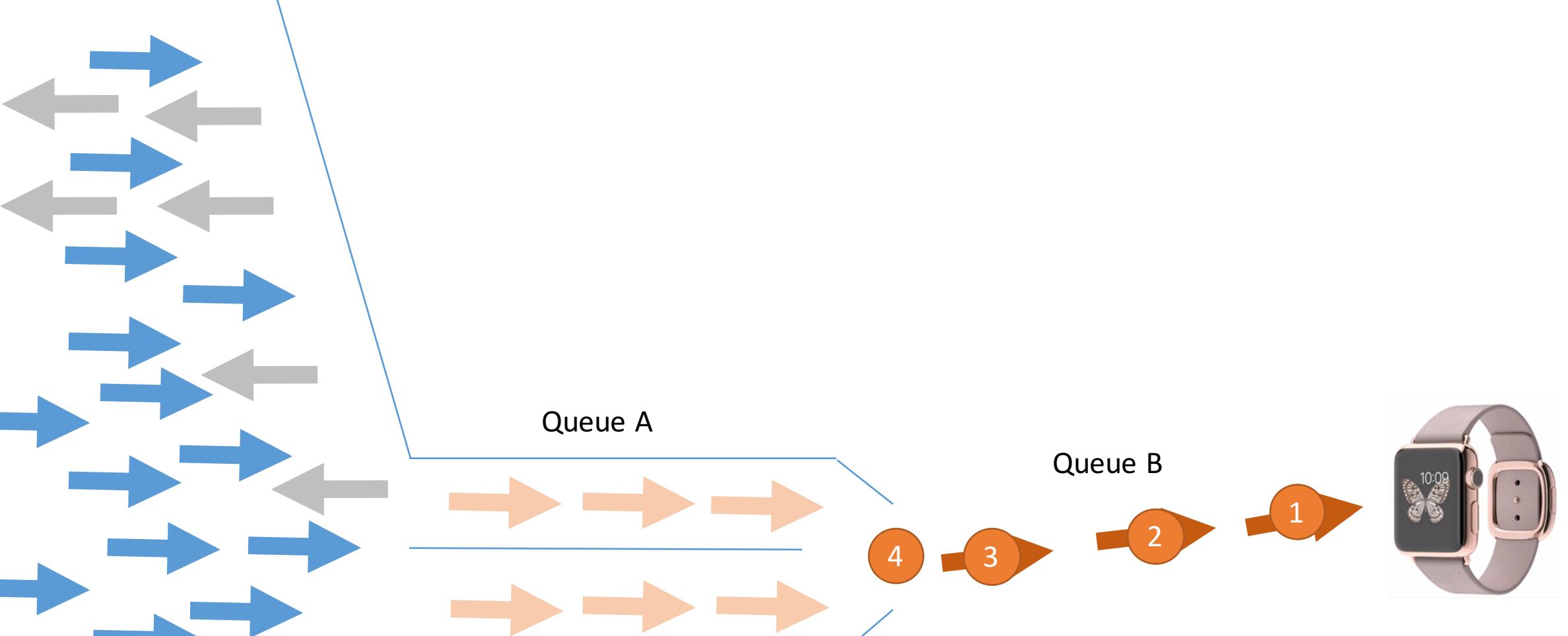
Novice, <http://url.cn/dd88AI>

Novice, <http://url.cn/fRH9hi>

Expert, <http://url.cn/aw3MJe>

Expert/Master, <http://url.cn/cTJ5aP>

Master, <http://url.cn/ZfSCTT>



How to Queue A



How to Queue B



Key point

- How to reduce traffic
 - Reduce page size: no image
 - Cache more: static page
 - Proxy: batch, connection
 - Limit request: JS, balancer
- How to Keep It Simple, Sweetie
 - No DB: memory + log
 - No lock
- How to isolate itself
 - New server
 - Asynchronous
- How to defend
 - IP
 - CAPTCHA

Lottery



Homework: design 12306



<http://www.jiuzhang.com/qa/107/>

[Read More](#)

Expert, <http://url.cn/UgpSk7>
Expert, <http://url.cn/7paBUZ>
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To 

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