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# Systems Security

## COMSM1500

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# Web Security

…continued

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# How would you…

- CCS-based
- Setting: Attacker can get victim to visit his/her website
- Goal: Learn what other website the victim has visited
- Exploit: ???
- Fix: ???

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- Setting: Attacker can get victim to visit his/her website
- Goal: Learn what other website the victim has visited
- Exploit: Link colour (visited/not visited)
- Fix: Lie to JS about this (always say unvisited)

# How would you…

- Cache-based
- Setting: Attacker can get victim to visit his/her website
- Goal: Learn what other website the victim has visited
- Exploit: ???
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- Exploit: Time it takes to load candidate objects (e.g. google map tiles)
- Fix:
  - No-cache client side (slow website ☹)
  - Origin-based cache (seems a good compromise)
  - Maybe non-local cache (company level?)

# How would you…

- Rendering engine
- Setting: Attacker can get victim to visit his/her website
- Goal: Learn what other website the victim has visited
- Exploit: ???
- Fix: ???

# How would you…

- Rendering engine
- Setting: Attacker can get victim to visit his/her website
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- Exploit:
  - Attacker make a copy of target.com/login (when user is logged off)
  - Display login page of victim.com in a frame
  - CCS blur applied on frame
  - Measure how long it takes for the blurring effect to apply (on “real” and copy frame)
  - Difference would indicate if user was already logged in or not
- Fix: ???

# How would you…

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- Setting: Attacker can get victim to visit his/her website
- Goal: Learn what other website the victim has visited
- Exploit:
  - Attacker make a copy of target.com/login (when user is logged off)
  - Display login page of victim.com in a frame
  - CCS shader effect (e.g. blur) applied on frame
  - Measure how long it takes for the blurring effect to apply (on “real” and copy frame)
  - Difference would indicate if user was already logged in or not
- Fix:
  - Apply same-origin policy on shader effect…
  - … prevent possible genuine use cases?

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# Timing attack

The cache example

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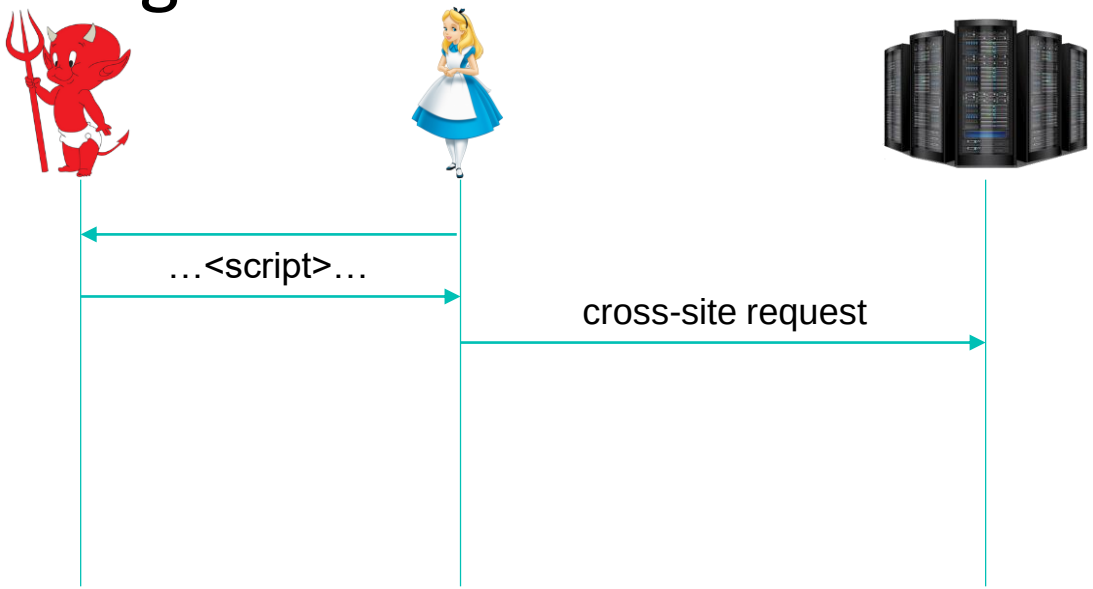
# Timing side-channel



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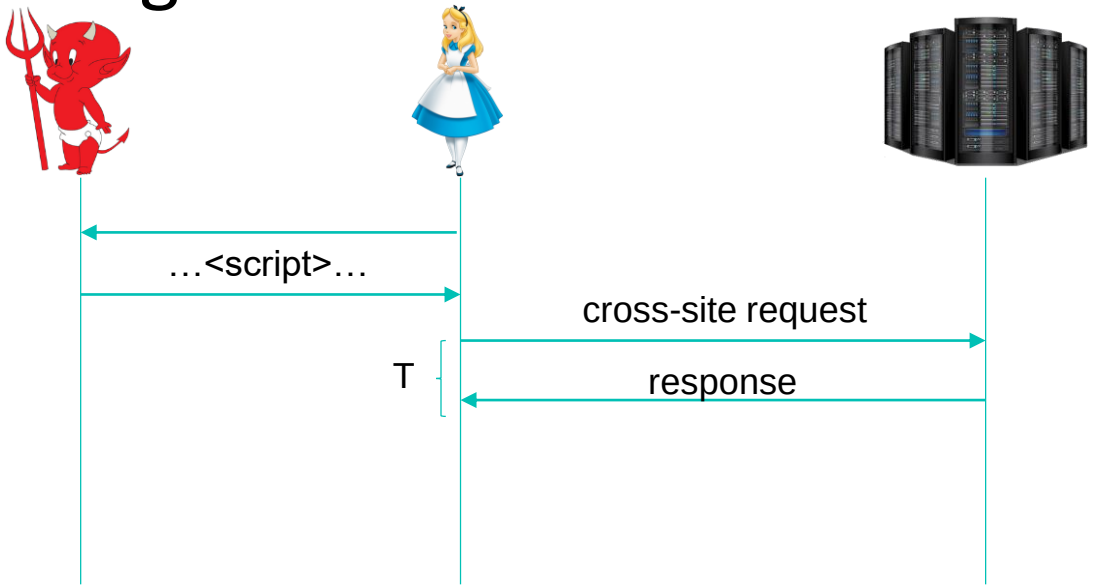

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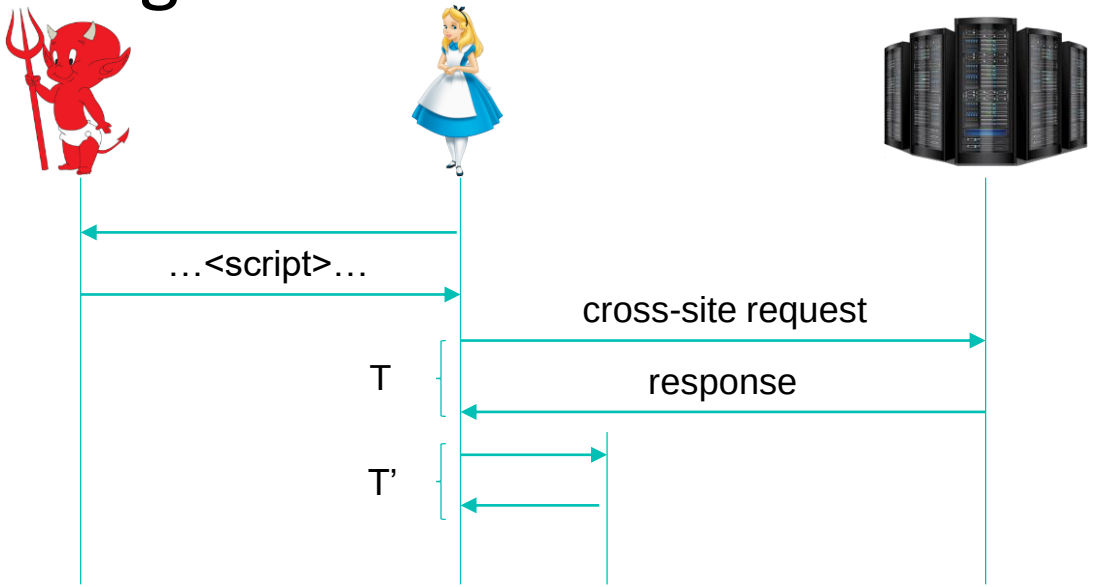


Attacker cannot see the response (same-origin policy), but it can measure delay.

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# How to build more complex query?

Cross-Site Search Attacks

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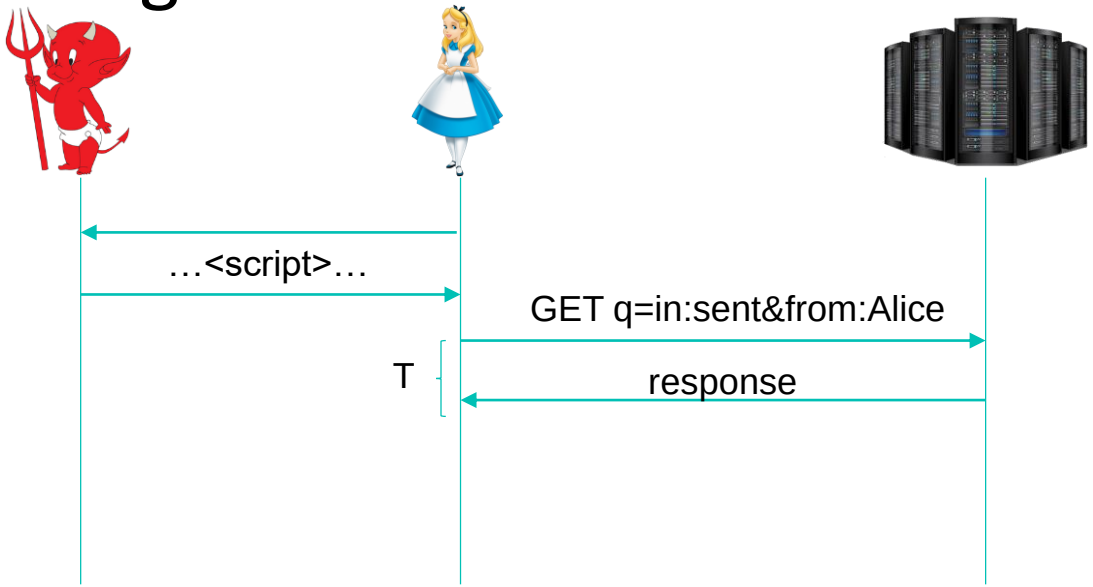
# Timing side-channel



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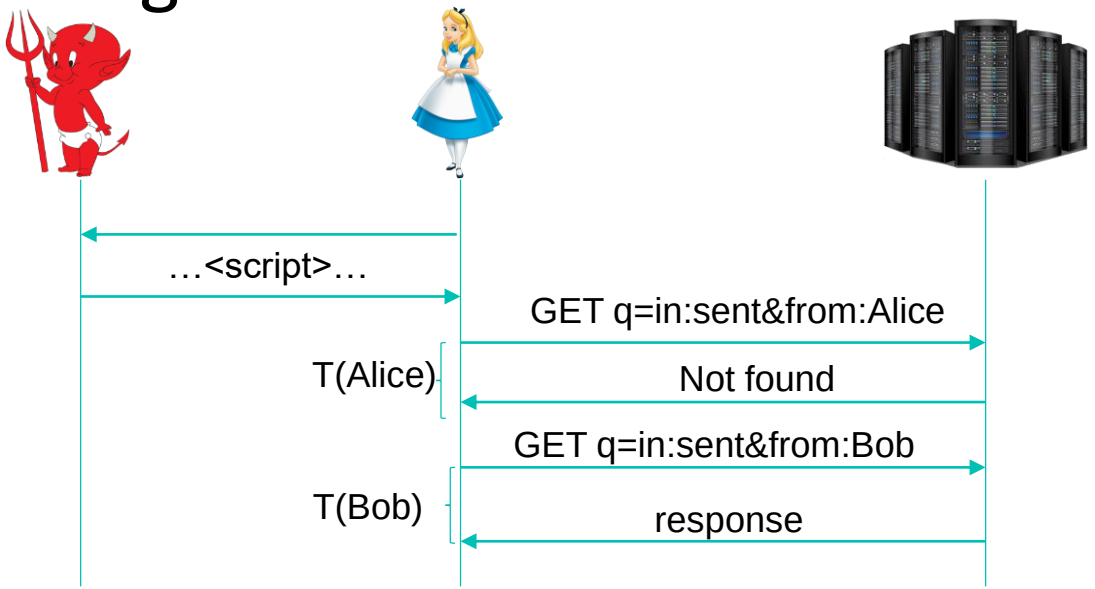
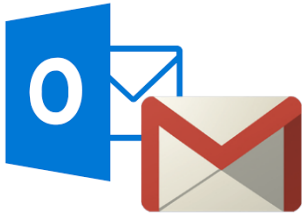



- Is user Alice or Bob?
- Compare:
  - T(Bob)
  - T(Alice)

# What can we learn?

structured data

e-mail content

– Countermeasure to the attacks discussed today are in place on major platforms… however, this was true 3-4 years ago.

Bing

Search history

Gooooooooooogle
1 2 3 4 5 6 7 8 9 10

relationships
(follows…)

# XS-search basic flow

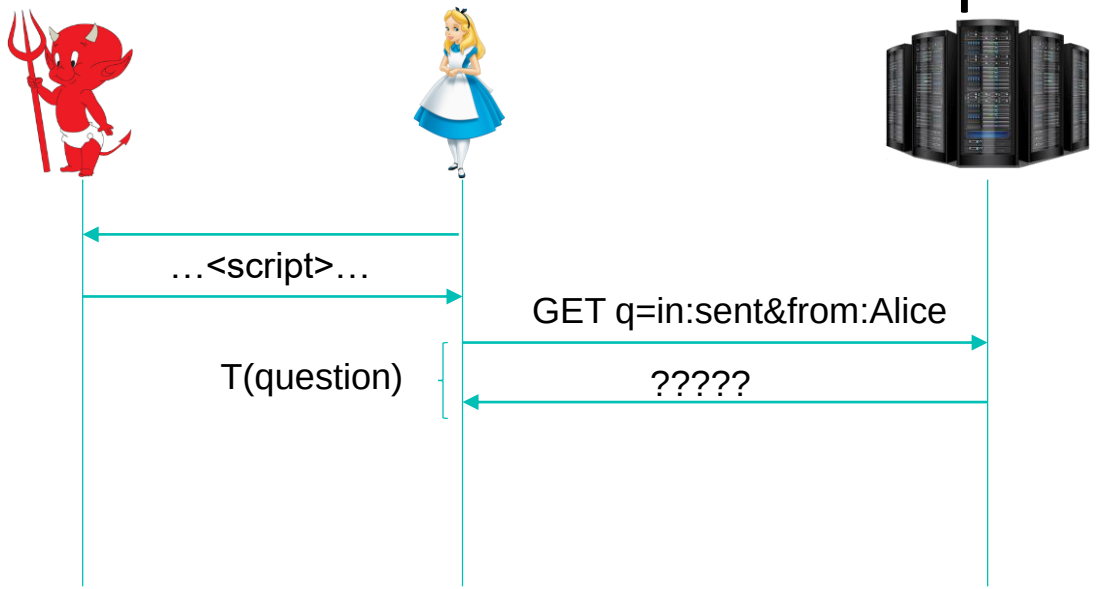
- Goal: find the answer for a boolean question

- Three steps:
  1. Transform the question into a search request
  2. Send search requests and collect samples
  3. Analyse response time -> Answer the question!

# XS-search basic flow – 1st step

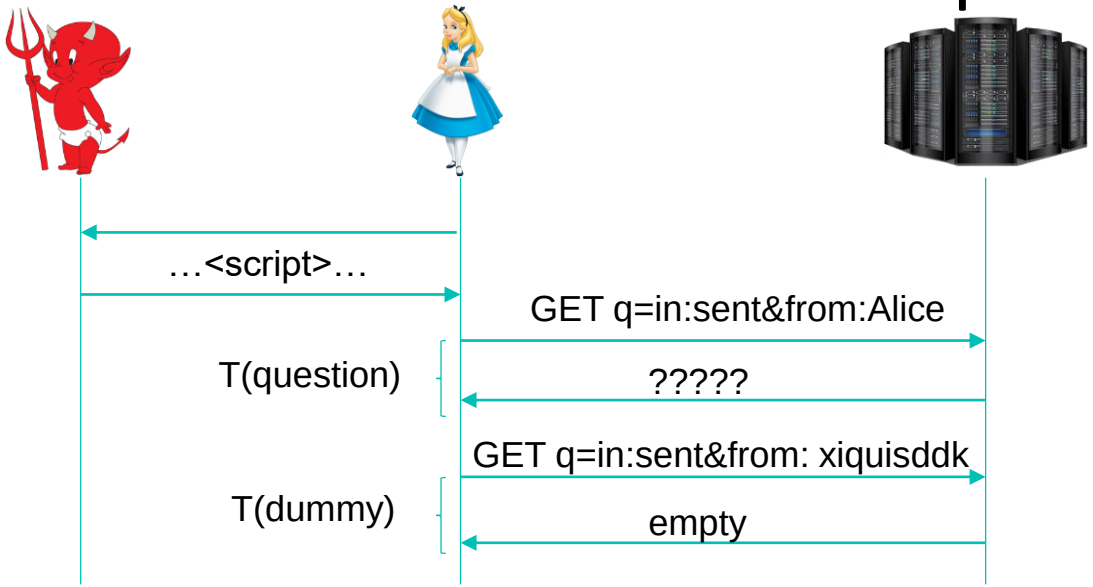
- Is the name of user Alice?
  - in:sent from: Alice
- Is she related to bob@gmail.com ?
  - bob@gmail.com&st=100
- Does Alice have an affair with Charlie?
  - “I love you” to Charlie
- etc…

# XS-search basic flow – 2nd step



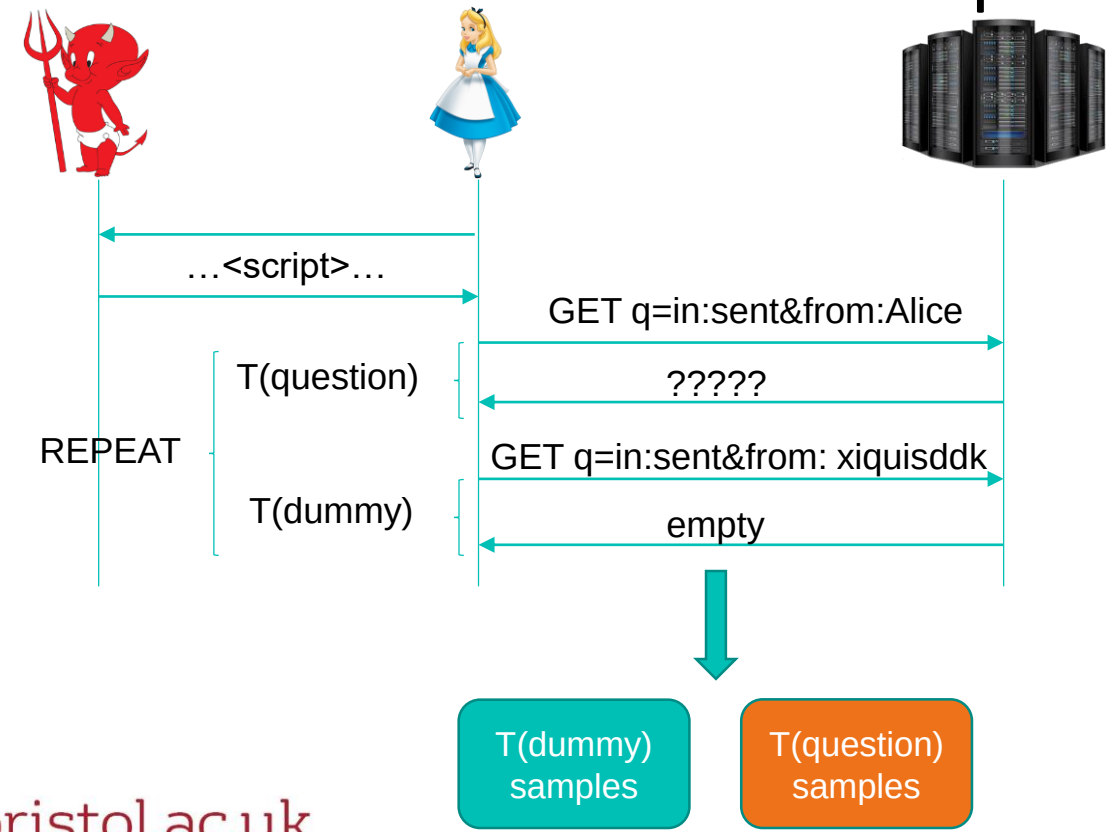

- Send our question
- Is the user name Alice?
  - True: a full response is returned (has some content)
  - False: an empty (short) response is returned

# XS-search basic flow – 2nd step



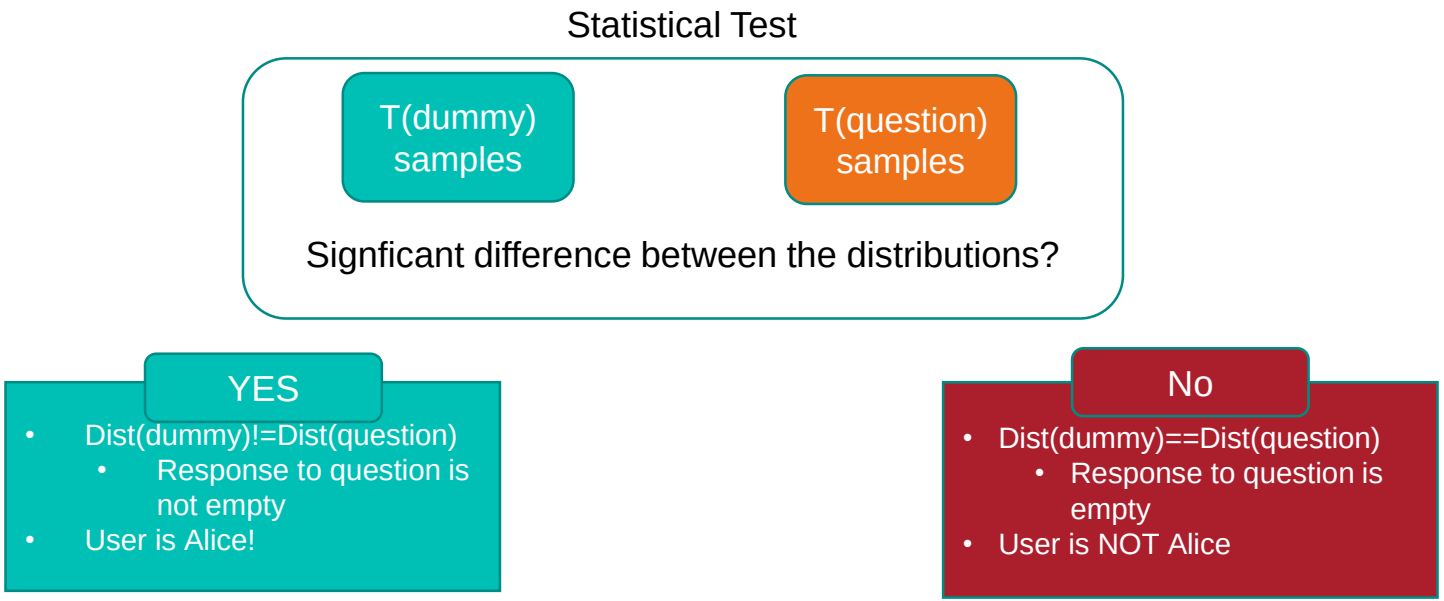

- Send a dummy request
- Is the user name xiquisddk?
  - Expected to be false

# XS-search basic flow – 2nd step




- Send a dummy request
- Is the user name xiquisddk?
  - Expected to be false

# XS-search basic flow – 3rd step



# Practical timing attacks: challenges

- Delays depends dynamically changing factors: congestion and concurrent request on client and server
- Minimal time
  - Exploit even short visit of urers
- Minimal number of requests
  - Avoid detection and blocking
    - e.g. server anti-DOS defenses

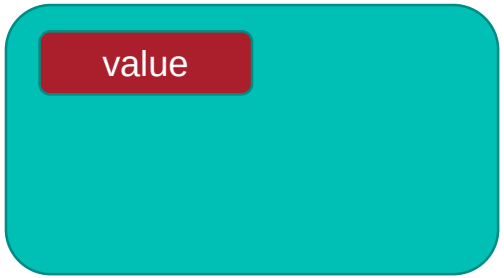
# Solution: response inflation!

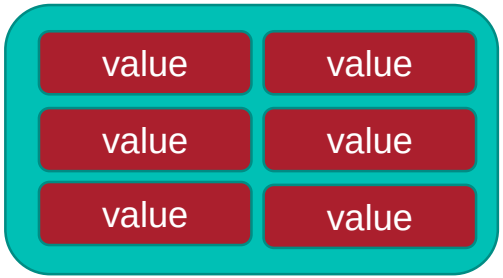
- Idea: make it easier to distinguish between empty and full response
- Increase the difference in size between the two
- Larger difference in size -> larger difference in time

# Response inflation

- Search requests have many parameters
- Some are reflected in the response as a function of the number of results

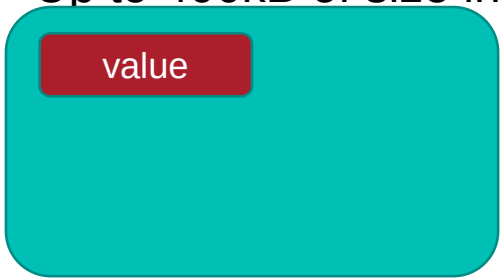
https://example.com/search?reflected_parameter=value

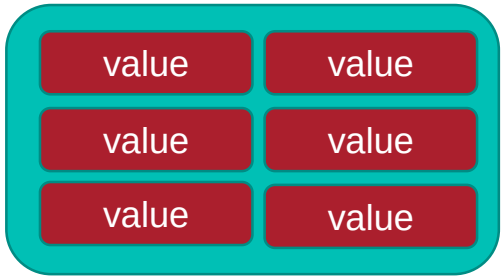


# Response inflation

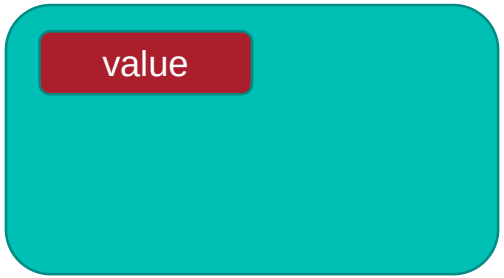
- Send very long string as reflected parameter
- In Gmail used to be the query itself
  - Appear once for each entry (50 max per default)
  - Can be inflated to 8kB
- Up to 400kB of size inflation!

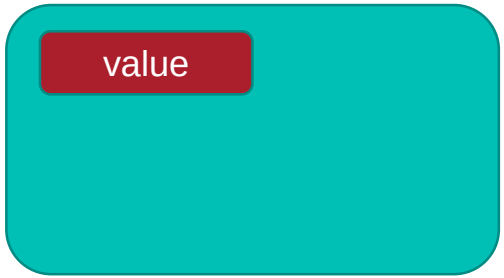


# Response inflation

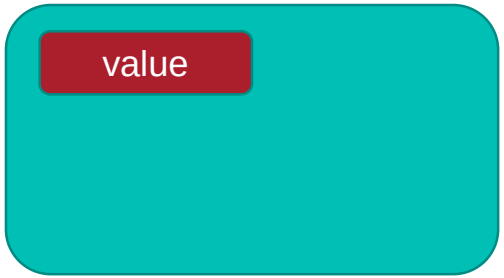
- What if there is no reflected parameter available?
- Empty or full have nearly identical size.

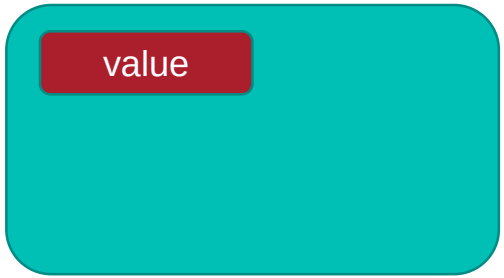


# Response inflation

- What if there is no reflected parameter available?
- Empty or full have nearly identical size.
- Computational inflation (use expense query)
  - dummy: in:sent&from:xiquisddk&hasnot:{rjew+...+iqejh}
  - question: in:sent&from:alice&hasnot:{rjew+...+iqejh}



# Avoiding detection

- Classical timing attack:
  - Attacker send request directly to the server several time to do the measurement
- serviceWorker.cache (local caching)
- Browser-based timing attack
  - Load from the server once
  - Do the statistical analysis based on cache return time

# Avoiding detection (limitation)

- Measure affected by:
  - Classic: network delay, server processing time, browser processing time
  - Browser-cache: browser processing time

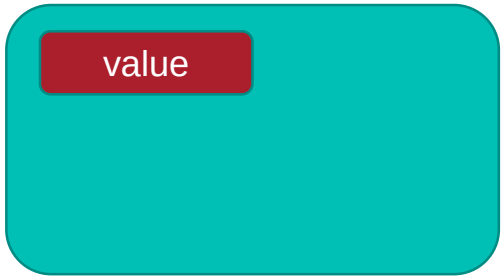
- Can be used to differentiate between:
  - Classic: large/small resources; long/short processing time
  - Browser-based: large/small resources

# Optimized Multiple Terms Identification

- Term from a list of candidate terms
  - e.g. list of family name / given name combination
- Classic divide and conquer
  - from:michael+OR+dan+OR+.... Up to the URL limit
- Identify each term individually
  - e.g. first name then given name
- Demo https://www.youtube.com/watch?v=9wgLbUet5Wk
  - 2000 entries dictionary

# What if inflation is not possible?

- Barely no difference between full or empty
- The attacker can manipulate the target by making the value appear several time?
  - e.g. e-mail (anyone can send you an e-mail)



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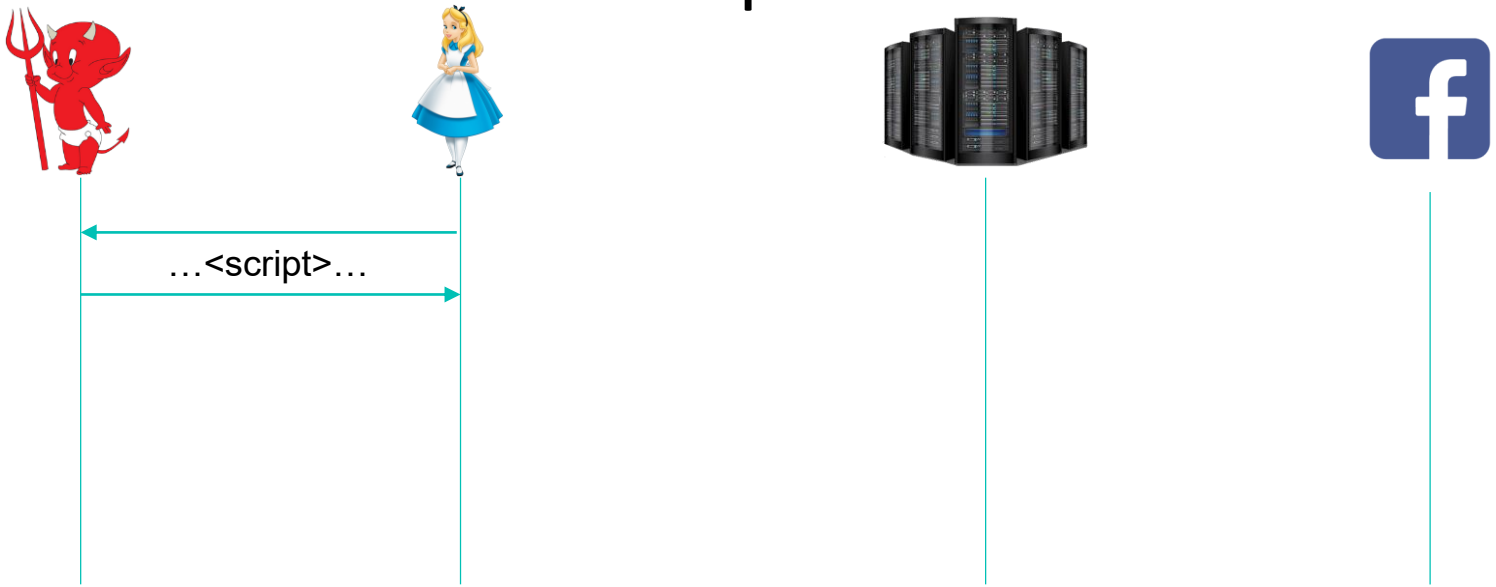

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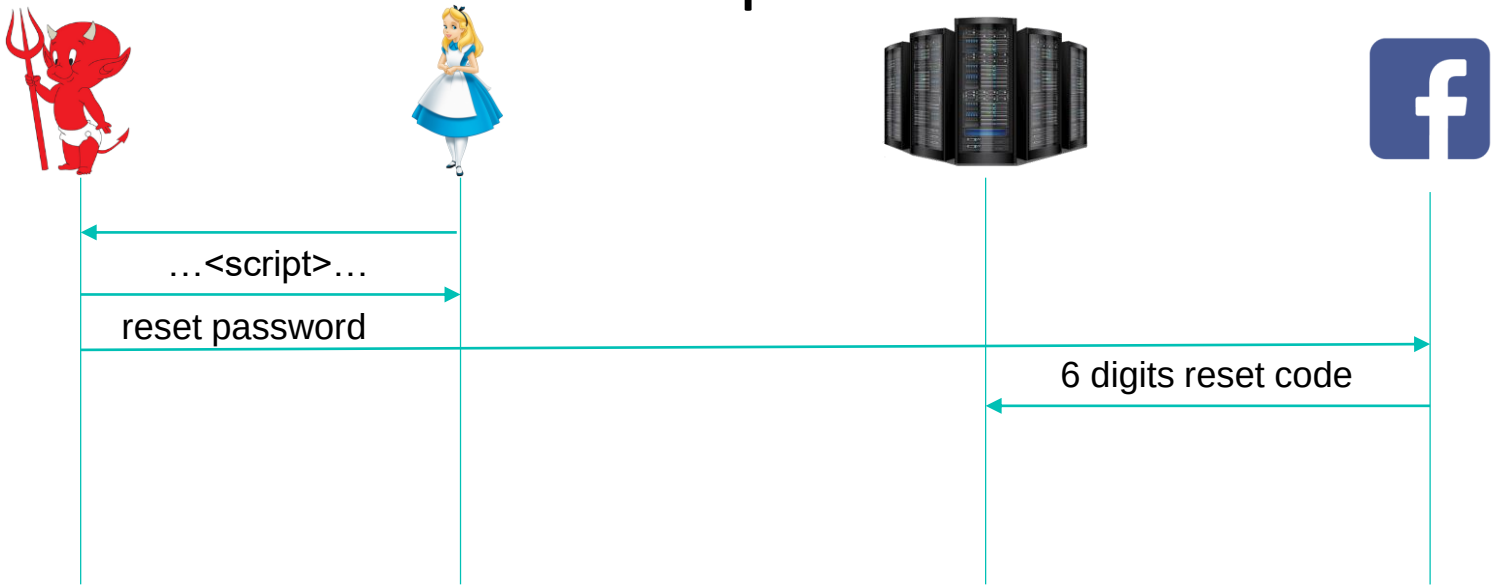

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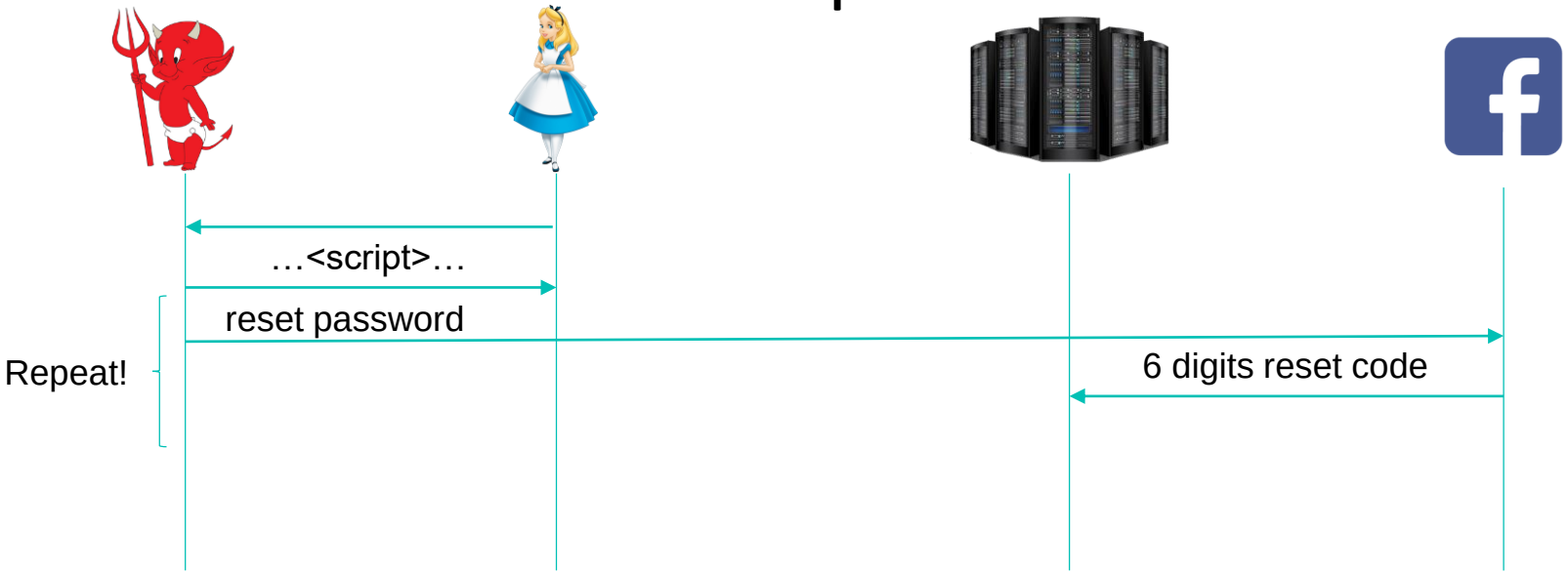

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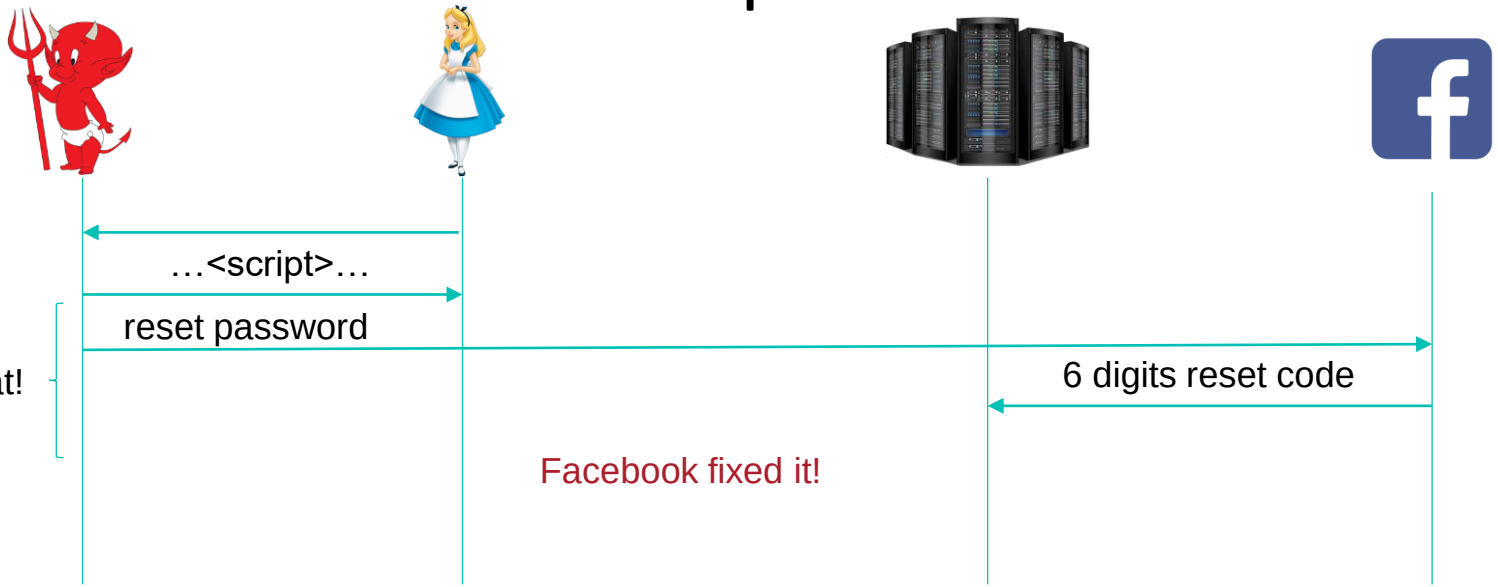

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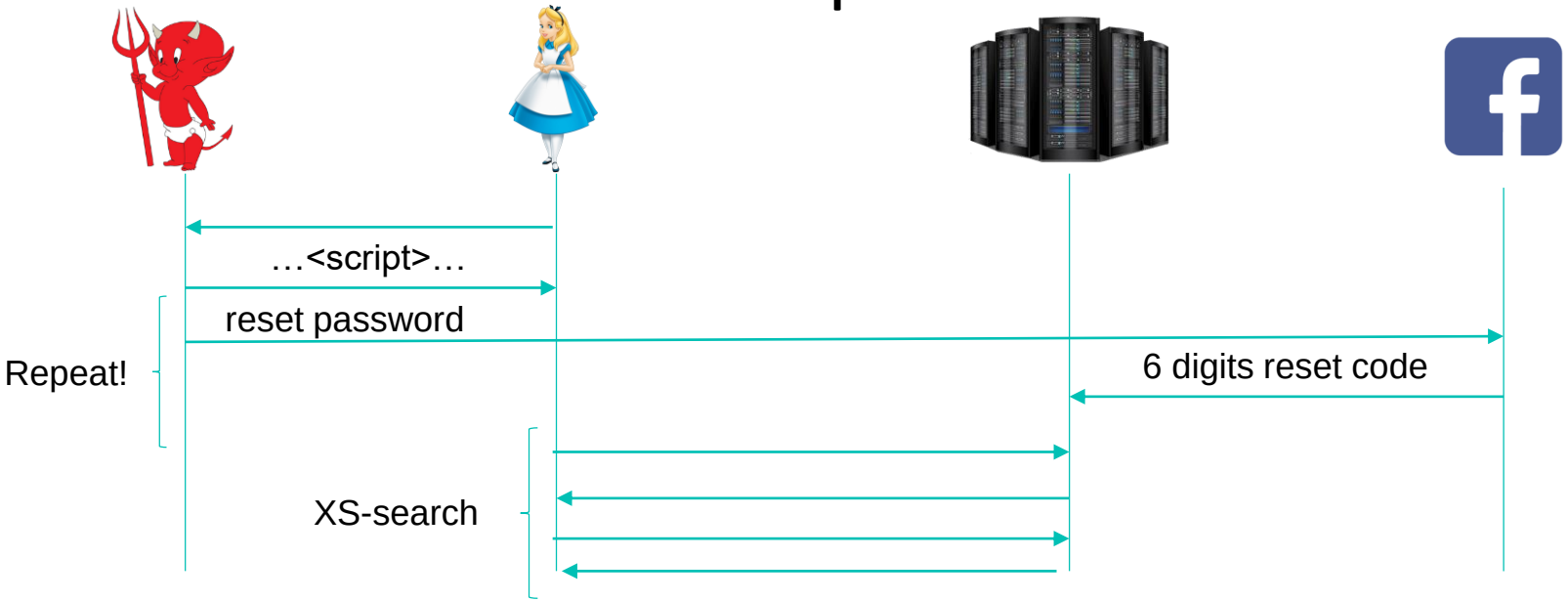

# Problem?

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  - e.g. send the same code multiple time
- What if there is no vulnerability?

# Problem?

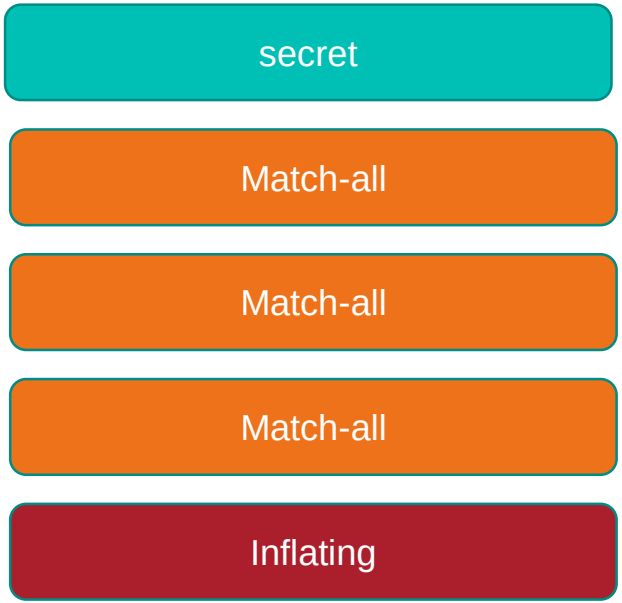
- Rely on a vulnerability in the target service
  - e.g. send the same code multiple time
- What if there is no vulnerability?
- Vocabulary
  - M: maximum number of entry in a response
  - Match-all record: a record that matches all possible entries
  - Inflating record: a match-all record that significantly increase the message size

# Solution

- Attack process
  - Part 1
    - Plant one match-all inflating record
    - Plant M-1 match-all record
    - Reset the password (or whatever)
  - Part 2
    - Perform XS-Search

# Solution

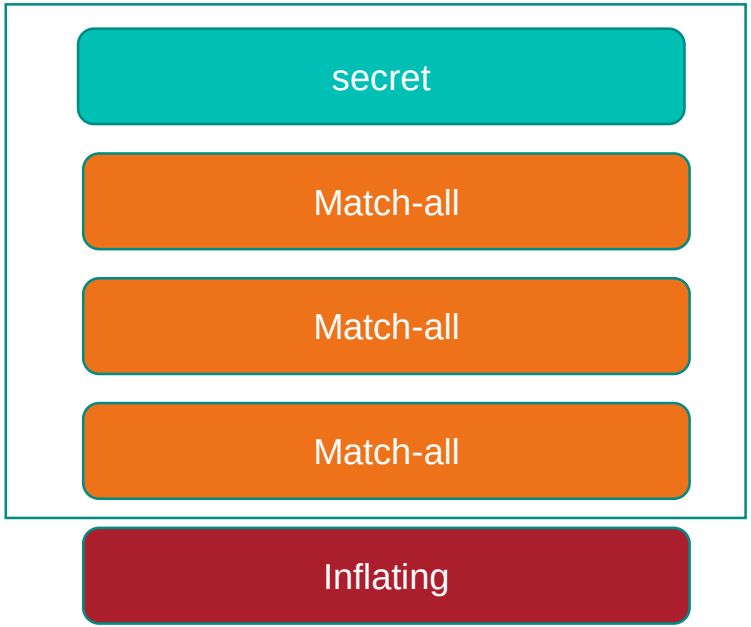
M=4



# Solution

query = secret

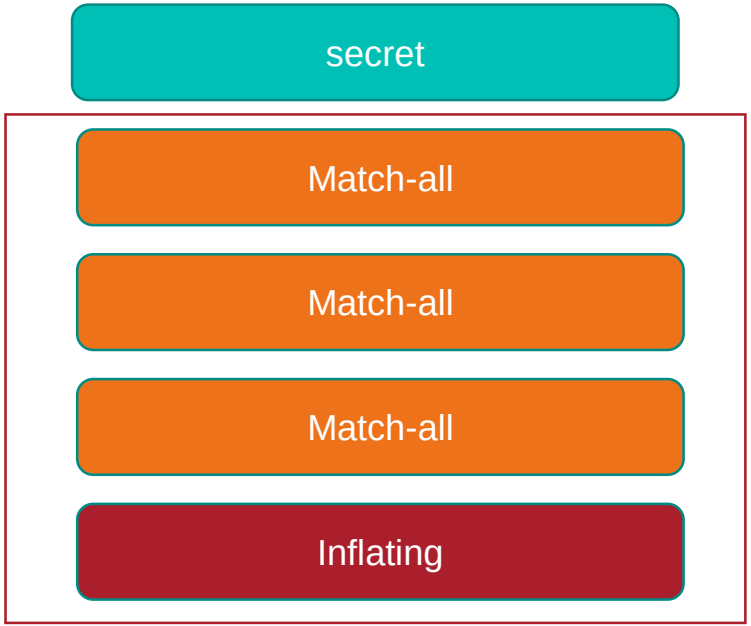
M=4



# Solution

query != secret

M=4



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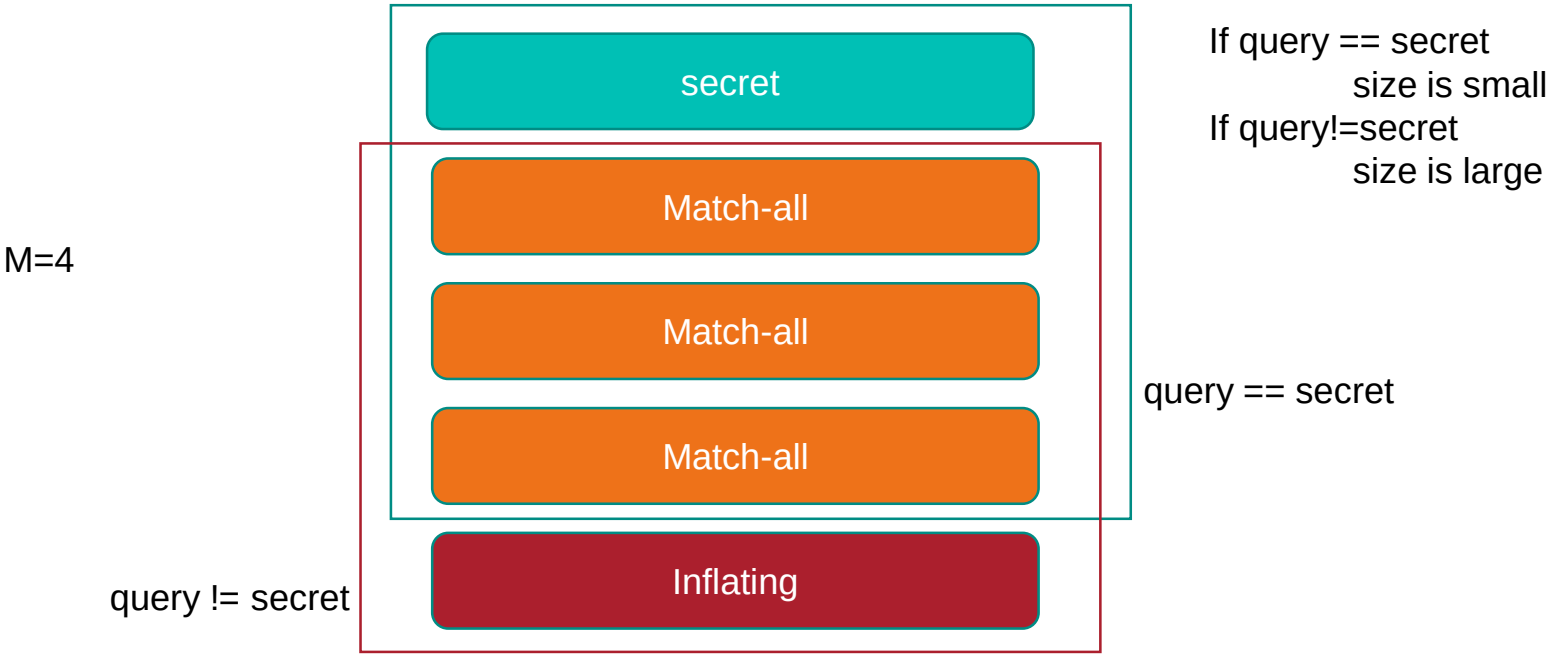
secret
Match-all
Match-all
Match-all
Inflating
M=4
query != secret
query == secret
If query == secret
size is small
If query!=secret
size is large

# Checkout papers on github

- Read the papers it is useful for exams!

# Solutions?

- Don’t allow external queries
  - Does not work for a large class of applications
- Reduce query expressivity
  - Has impact on usability/utility of a system
- Rate limit query
  - Attacker can go around this using browser cache (as we have seen)
- Detection?
  - Attack detection is an active area of research, but it is difficult

# Timing attack outside the web

- You should read about it ;)
- Active area of research in crypto
- UNIX Login (to identify existing users)
- On GPU (they are not only used for gaming)
- etc…

# Conclusion

- Even program with no vulnerability can be compromised
- Timing attacks are an example of side channel attacks
  - They leverage implementation properties to extract secrets
- Side channel attacks are an active area of research
  - Power
  - Electromagnetism
  - etc…
- They do not always have easy fix

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# Thank you

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