Measuring Privacy Threats in China-Wide Mobile Networks

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- Methodology
- Analysis
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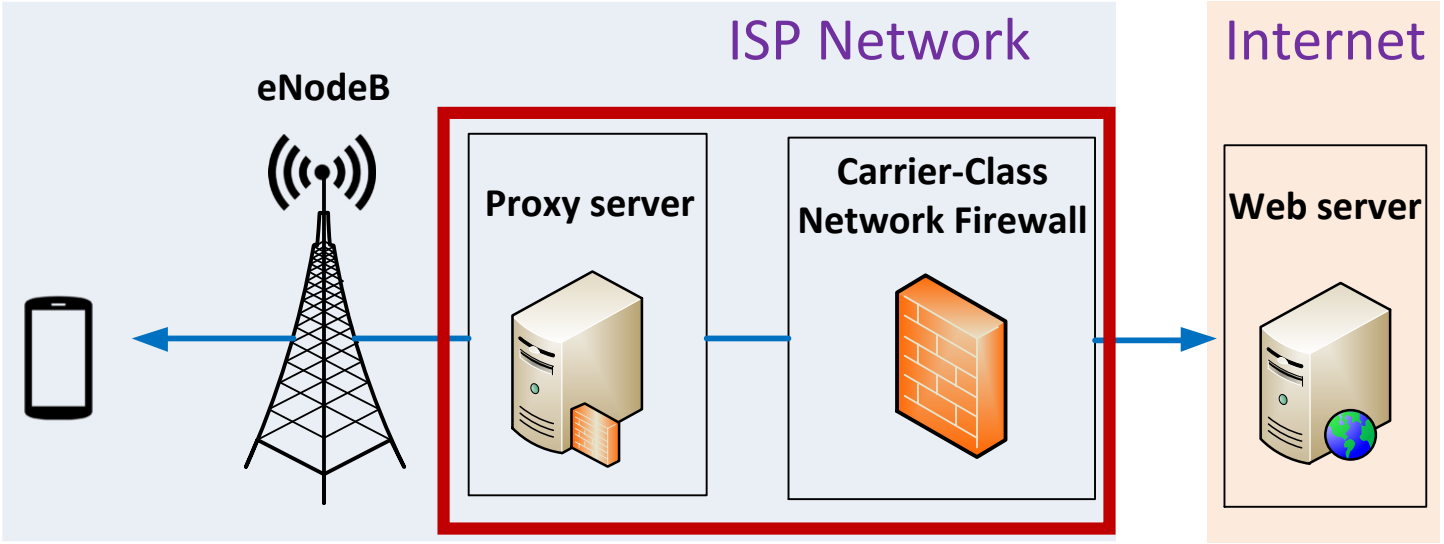
Background

HTTP transparent proxies

- Widely deployed by mobile network operators
  - e.g. cache servers, firewalls, NAT devices…
- Enhance network performance and security [Sherry, SIGCOMM'12]
- Violate end-to-end principle



Examples of HTTP traffic manipulations

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Data usage pop-up

Data plan, Recharge service)

Background

HTTP traffic manipulation

- A core area of free communication online in worldwide [Sherry, SIGCOMM'12] [Weaver, PAM'14] [Chung, IMC'16] [Tyson, WWW'17]
- Some transparent proxies leak private data of users and properties of devices [Weaver, SATIN'11]
- Some transparent proxies are vulnerable to known attacks. [Vallina-Rodriguez, MobiSys'15]

HTTP transparent proxies lead to potential security and privacy issues

Questions To Be Answered

- How is that in China-wide?
- How is that in cellular networks?

Our Goal

- Analyze the manipulation of HTTP traffic by transparent proxies
  - From China-wide
  - In cellular networks

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Methodology

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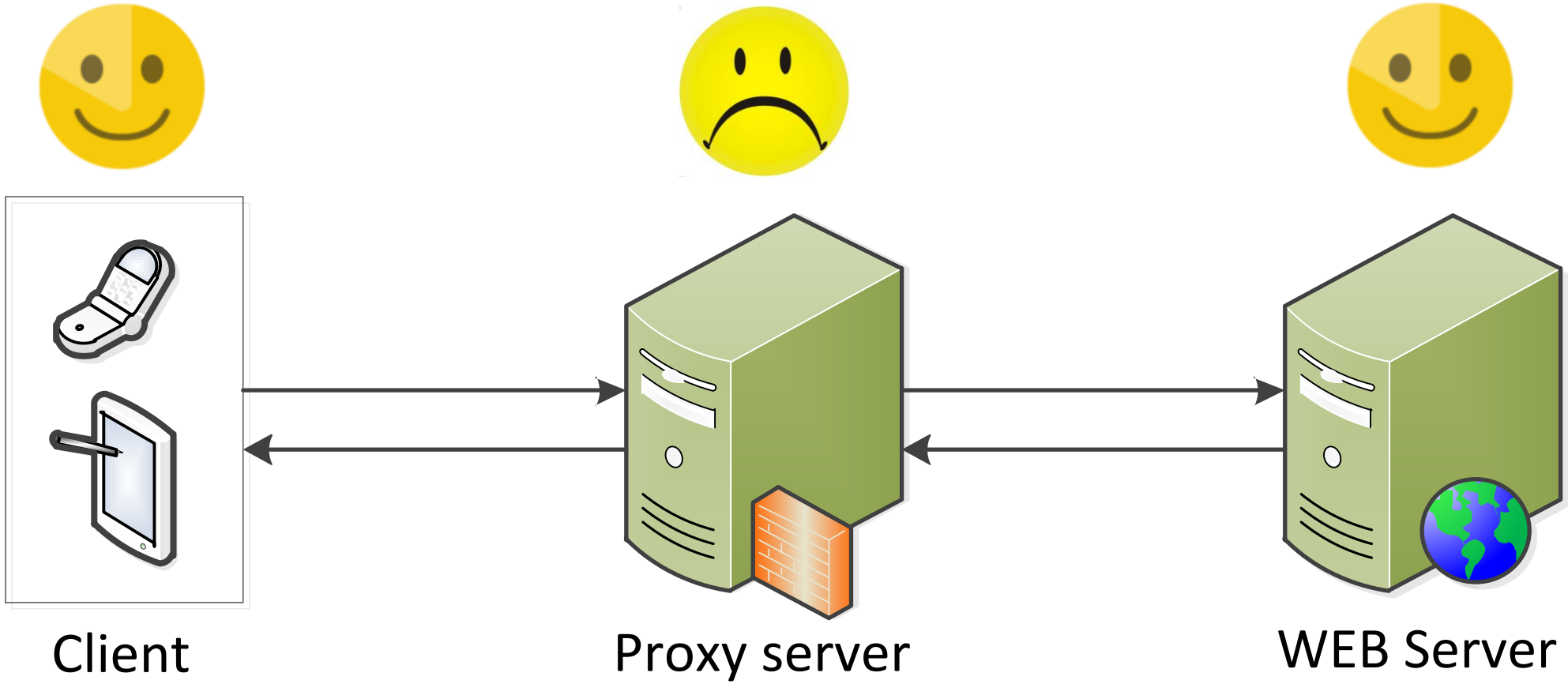
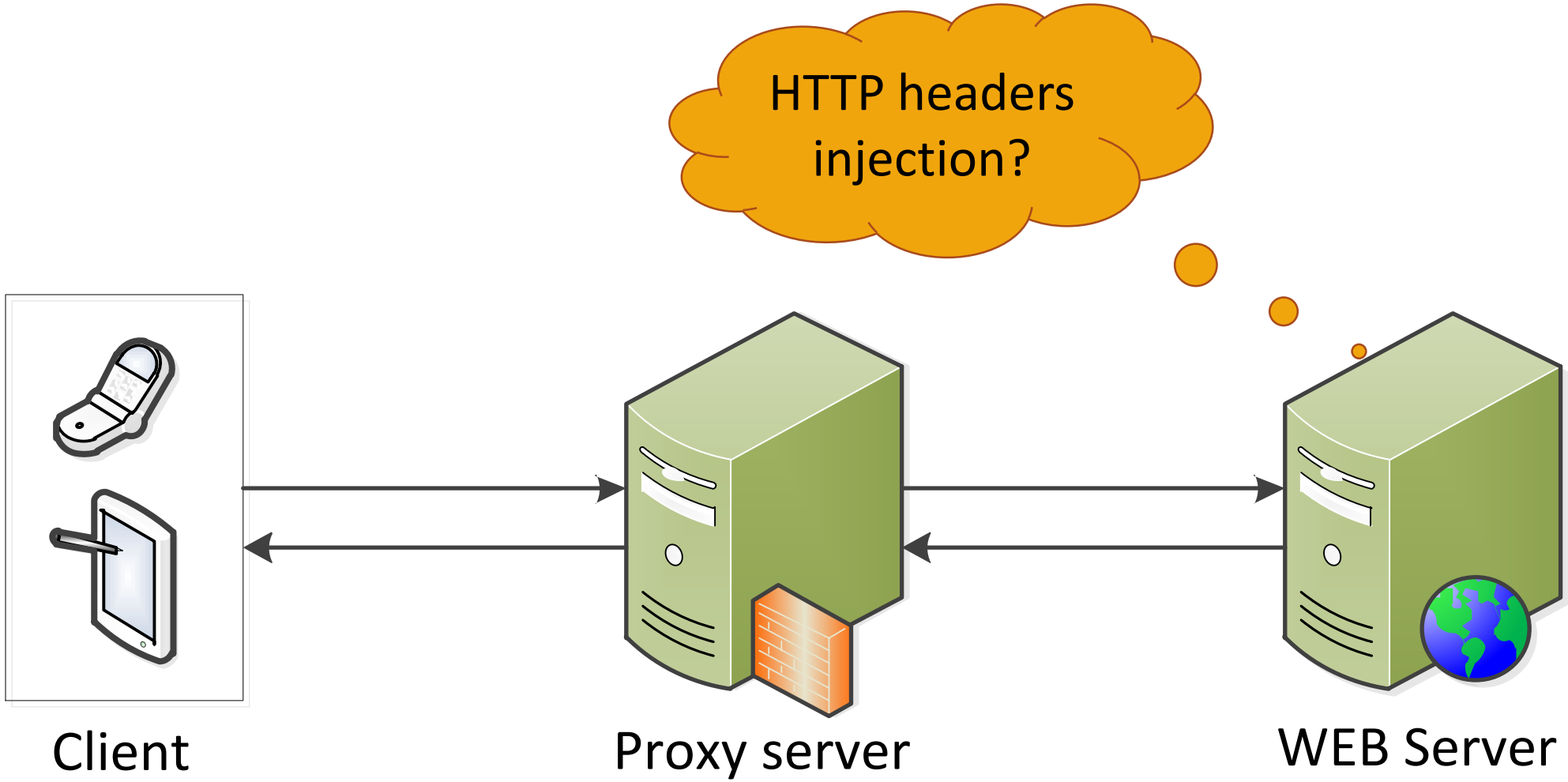
- Identify transparent proxies



Methodology

- Identify transparent proxies



Methodology

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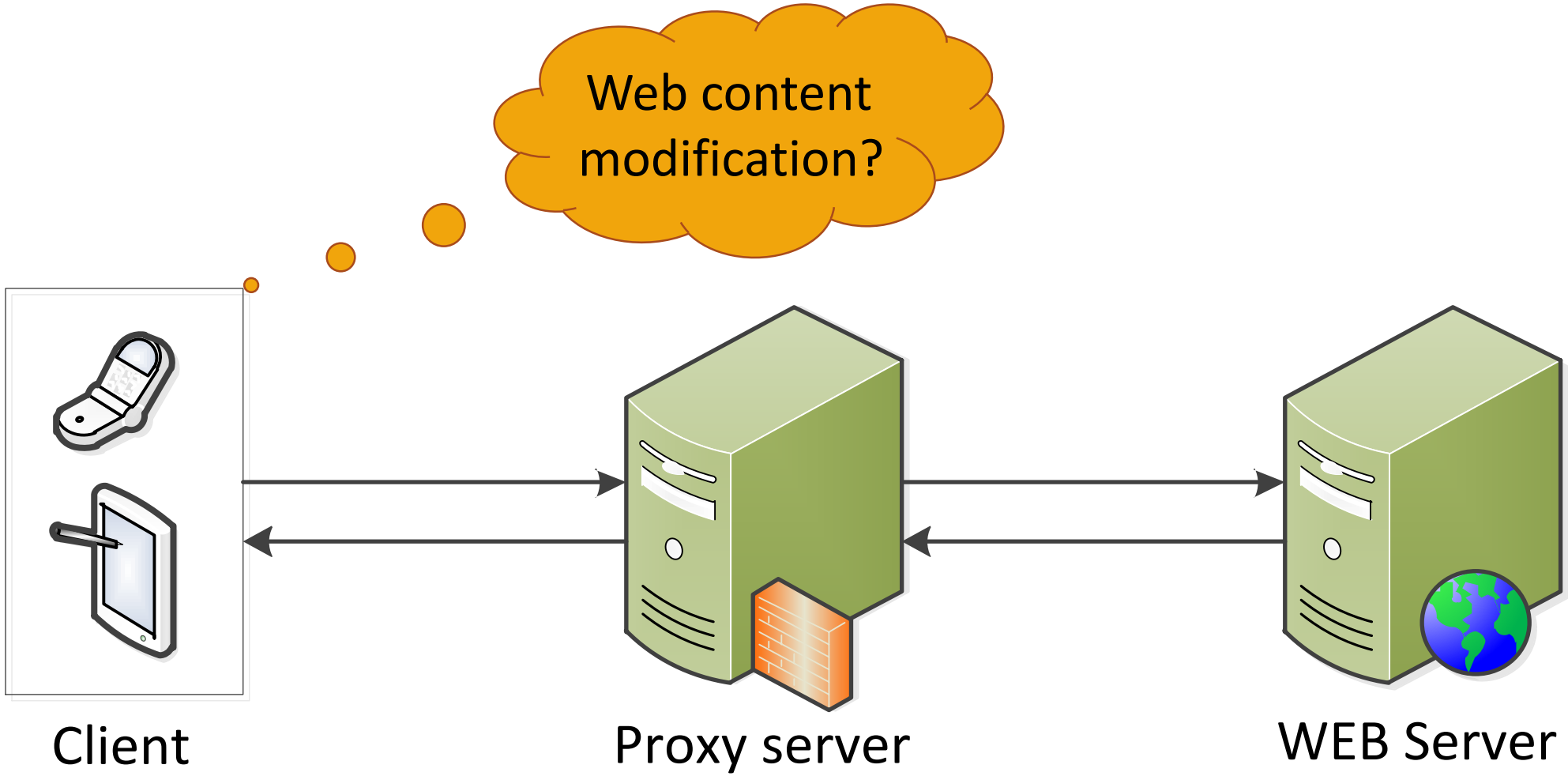
- Identify transparent proxies



Collected Dataset

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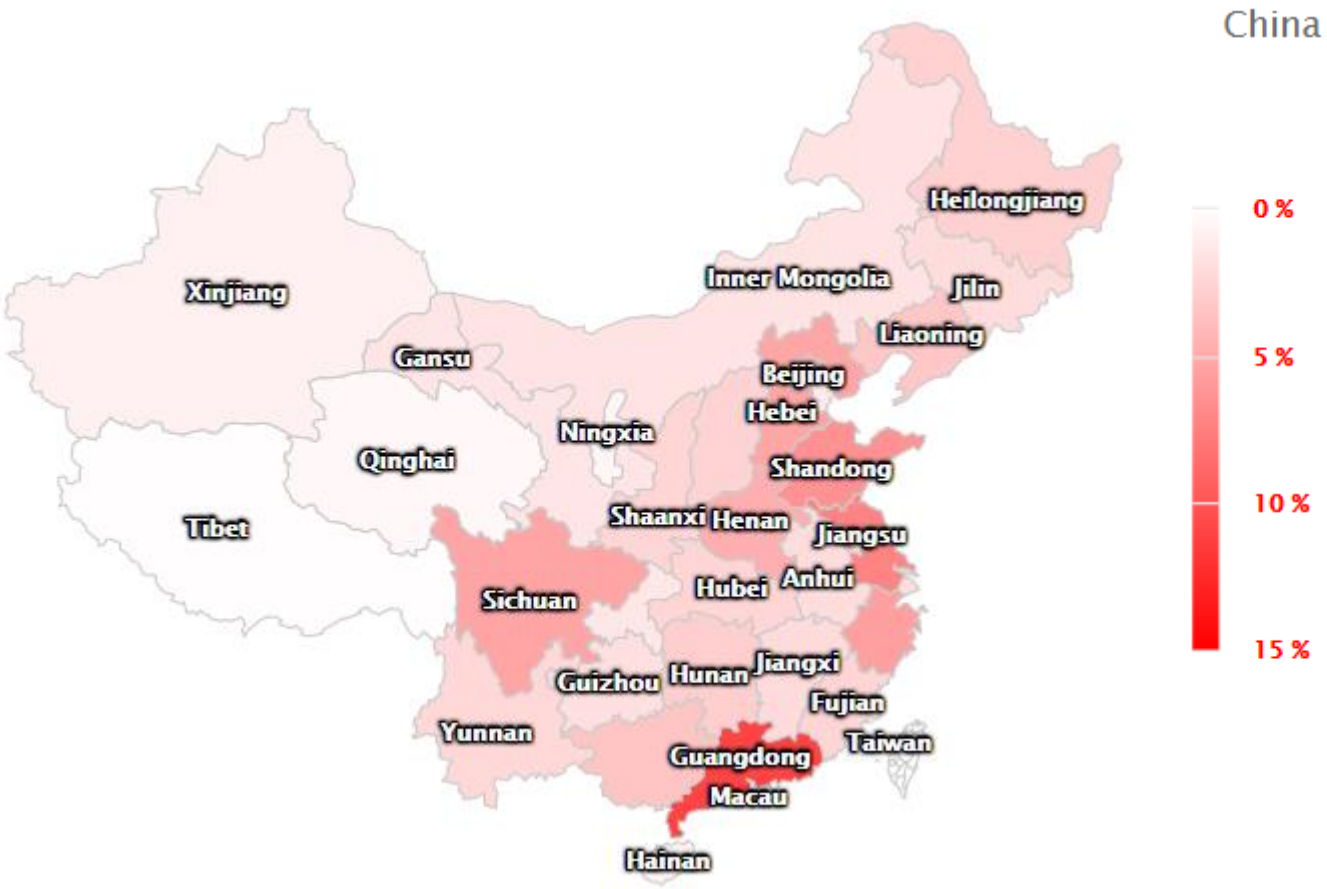
- China-Wide Analysis
  - A mobile network debugging tool of a security software
  - Ethics
    - One-time consent
    - Request our own website
    - Restrict traffic amount
    - Encrypted storage

Collected Dataset

FOCI '18

- HTTP traffic originates from China-wide mobile networks
- Filter out invalid traffic



Tests	Count
HTTP sessions	33,439
#IP	30,810
Provinces	31
AS	79

Collected Dataset

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- HTTP traffic originates from China-wide mobile networks
- Filter invalid traffic
- Limitation
  - Couldn’t partition the data: cellular vs. wi-fi connectivity

Methodology

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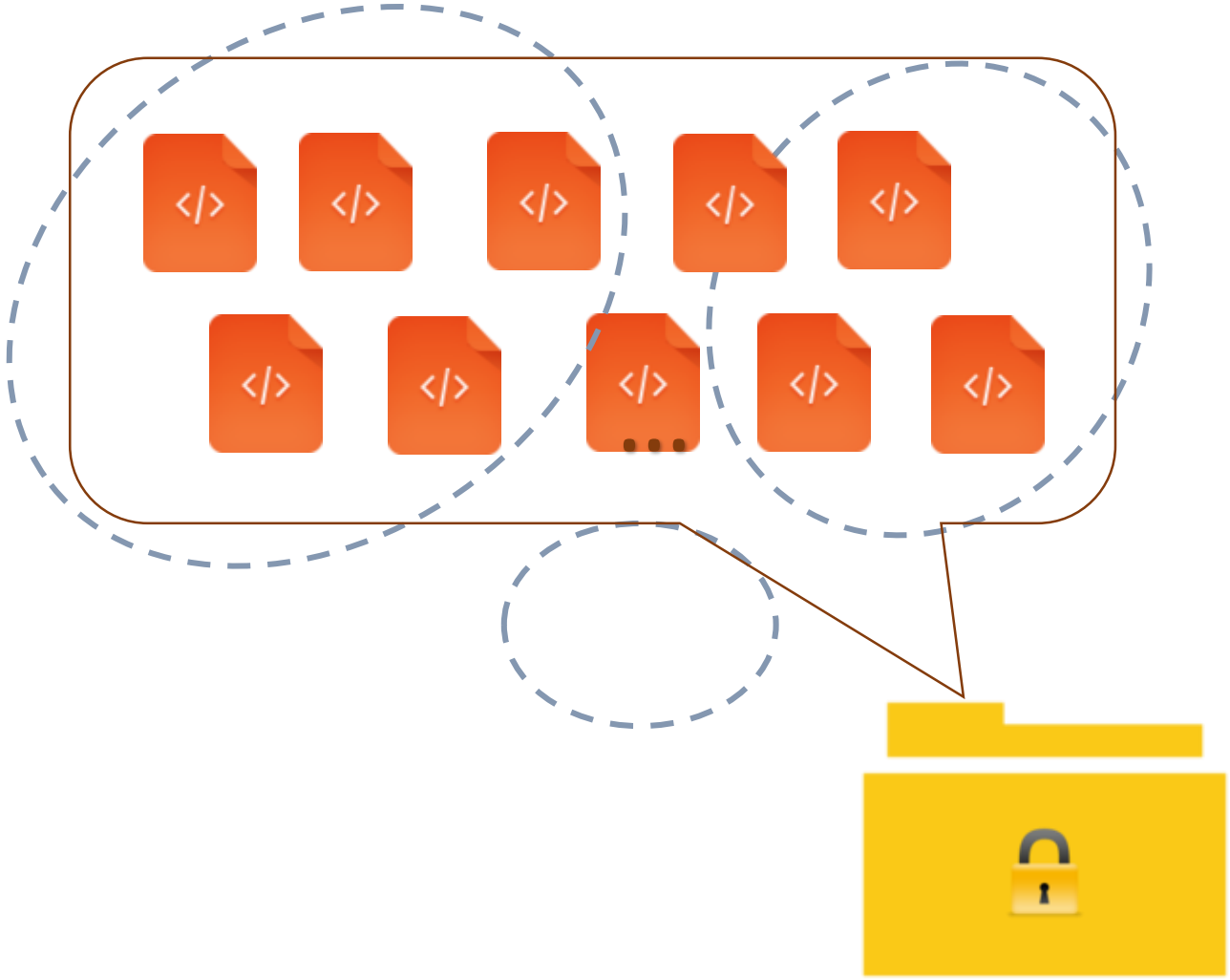
Identify Manipulation

- Webpage modification
- HTTP headers injection

Methodology

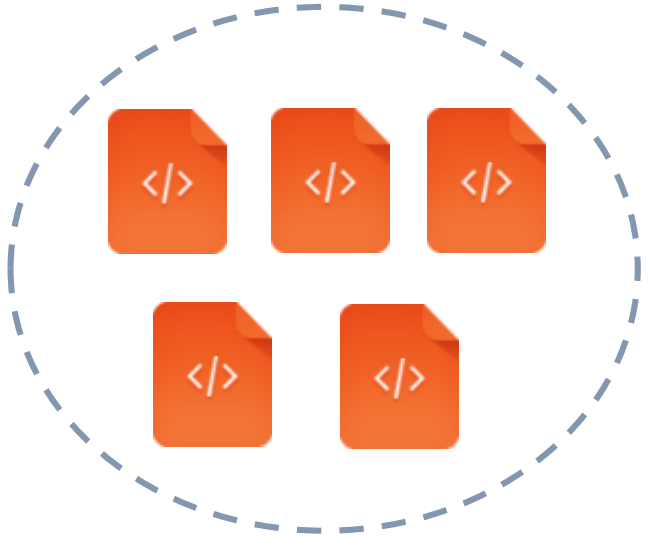
Identify Manipulation

- Webpage modification
  - Hierarchical clustering
  - Classify the similar pages



Methodology

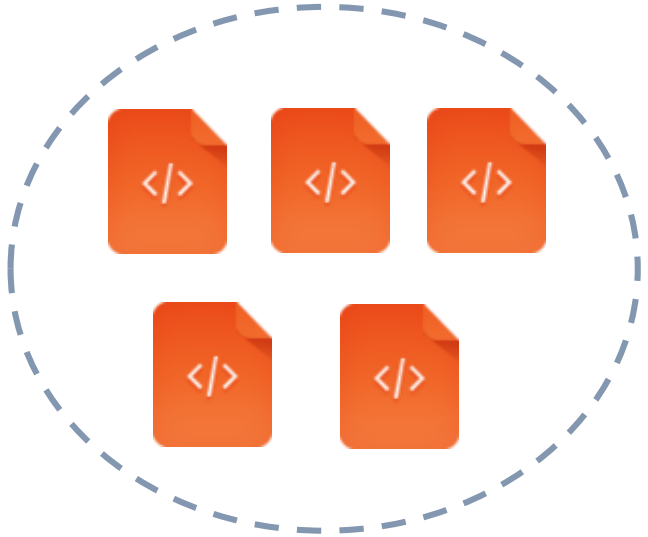
Identify Manipulation



- Webpage modification
  - Hierarchical clustering
  - Classify the similar pages
  - Inspecting sample pages from each cluster manually

Methodology

Identify Manipulation



- Webpage modification
  - Hierarchical clustering
  - Classify the similar pages
  - Inspecting sample pages from each cluster manually
- HTTP headers injection
  - Jaccard distance between original headers set and captured ones

$$J(A,B) = \frac{|A \cap B|}{|A \cup B|}$$

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Scale of Traffic Manipulation

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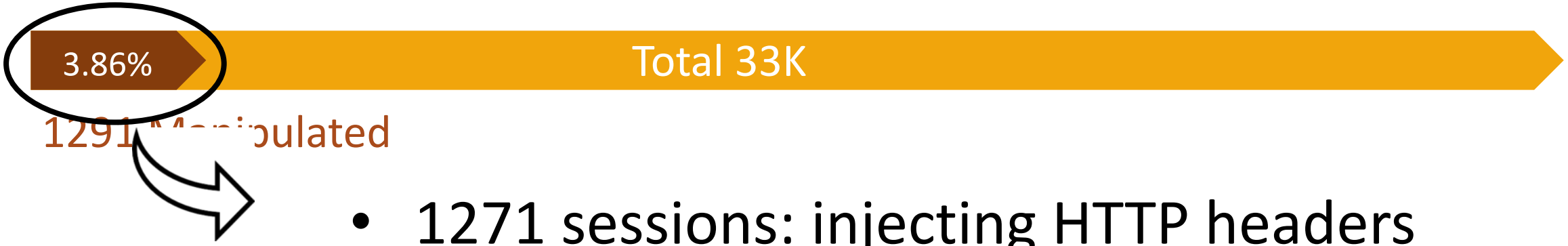
- HTTP session



  - 1271 sessions: injecting HTTP headers
  - 22 sessions: modifying web contents

- IP address

451 Manipulated

Scale of Traffic Manipulation

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Geo-Distribution (451 IPs in 30 provinces)

Top 8 Provinces

Province	# Session
BJ	229
HB	135
JS	135
JL	75
HN	69
SD	67
GD	46
SX	44

Scale of Traffic Manipulation

AS-Distribution

- From three major mobile operators (China Telecom, China Unicom and China Mobile)

TOP 5 ASes

AS	#Session	ISP
4134	257 (19.9%)	China Telecom
4837	202 (15.6%)	China Unicom
9809	128 (9.9%)	China Mobile (GD)
4808	114 (8.8%)	China Unicom (BJ)
56046	111 (8.6%)	China Mobile (GD)

Scale of Traffic Manipulation

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Network Operator

- Top 12 operators related to HTTP traffic manipulation.
- 90% manipulated traffic are found in networks of the top 3 ISPs.

Organization	QTY	Organization	QTY
China Mobile	524	Beijing Founder Broadband Network	3
China Unicom	325	Shanghai Anchang Network Security	2
China Telecom	317	ZhengZhou GIANT Computer Network	2
CNISP-Union Technology (Beijing)	15	Beijing flash newsletter cas telecommunication	1
Zhejiang Taobao Network	8	BeiJing New-Billion Telecom Technology	1
BeiJing Guoxin bilin Telecom Technology	4	Beijing yiantianxia Network Science&Technology	1

Dataset Analysis

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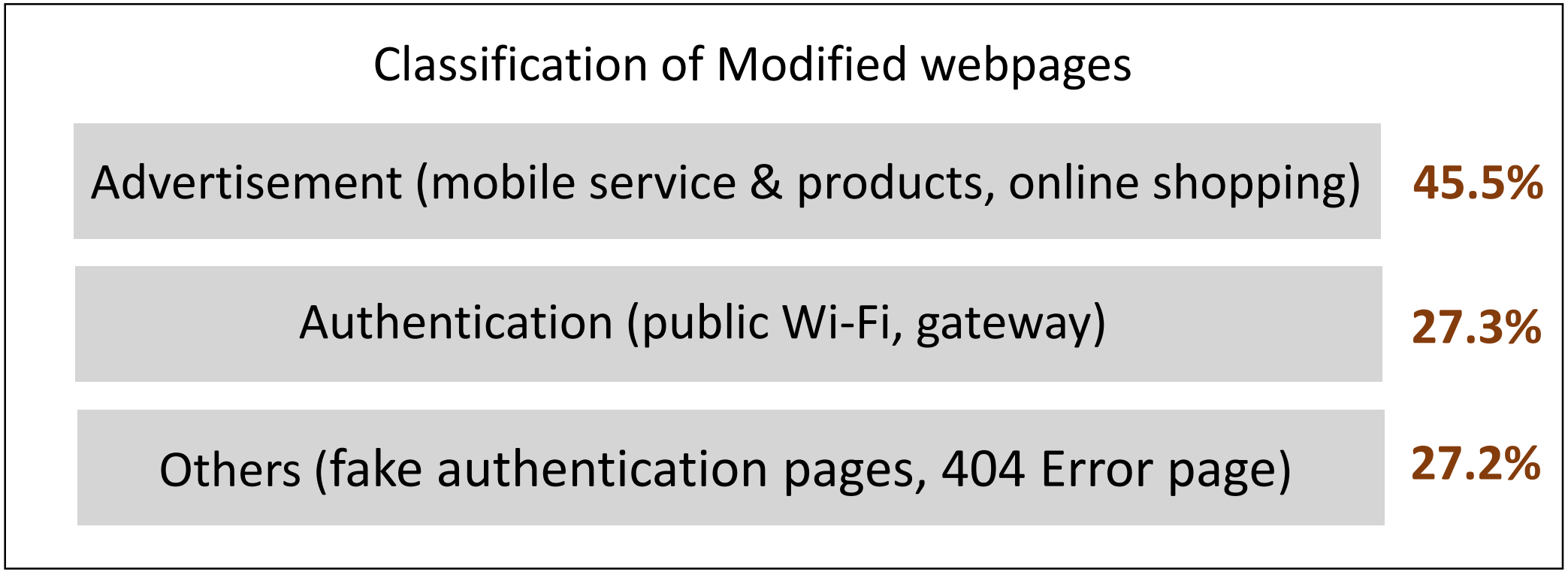
Modification of HTML Contents

- 22 modified web pages from 30K samples



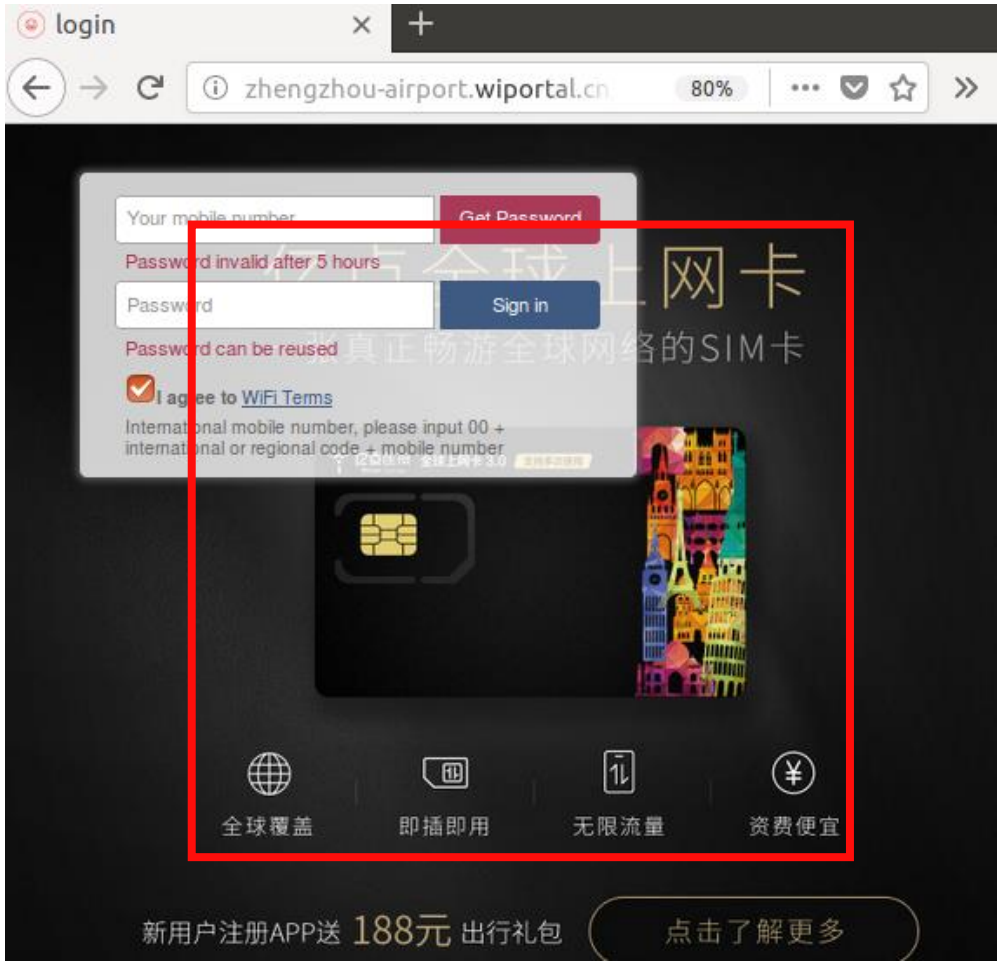
1. Advertisement (10 of 22)

- Services of mobile operators

Finance & stock service

Products of online shops

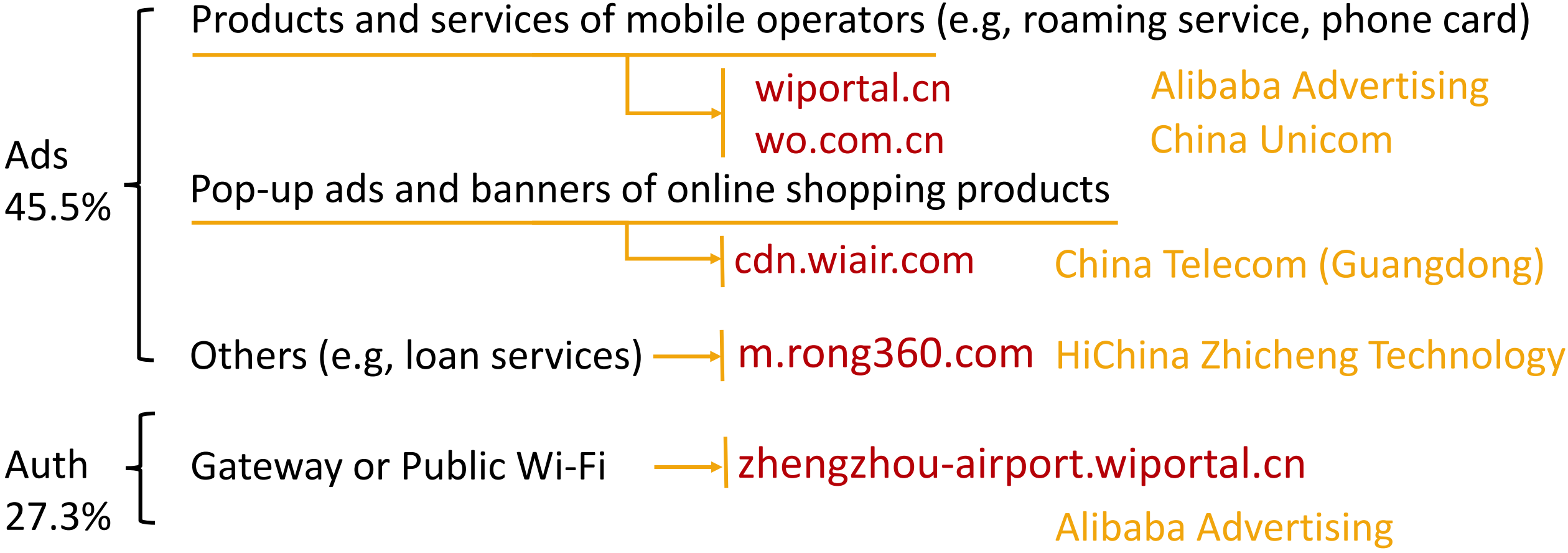
2. Authentication (6 of 22)



Dataset Analysis

Modification of HTML Contents

- Who is behind the modification? (22 modified web pages)



Dataset Analysis

Modification of HTTP Headers

- 1,271 HTTP sessions are injected with 43 types of headers
- These headers embed privacy data of users or devices
  - Location
  - IP address
  - Device serial number (e.g., IMEI)
- 3 categories
  - Identify users
  - Track users
  - Specials types

Dataset Analysis

Modification of HTTP Headers

- Headers for identifying mobile users (11 kinds in total)

Header	Type	Organization	Count
x-IMEI*	IMEI	ChinaMobile (GD)	12
x-IMSI*	IMSI	ChinaTelecom, ChinaUnicom	6
x-up-calling-line-id	Phone #	ChinaTelecom (SH, SN, QH, SC, XJ, GS, BJ, SD, LN, YN, NM, ZJ, AH), ChinaMobile (GD), ChinaUnicom (BJ, JL, LN)	50
X-Nokia-CONNECTION_MODE	Connecting mode	ChinaMobile (GD)	11
x-up-bear-type	Communicating Type	ChinaMobile (GD), ChinaTelecom(BJ, SH, SX, QH, SC, XJ, GS, YN), ChinaUnicom (BJ, NM)	122
x-huawei-NetworkType*	Communicating Type	ChinaUnicom, ChinaTelecom	6

Dataset Analysis

Modification of HTTP Headers

- Headers for tracking mobile users (9 kinds in total)

Header	Type	Organization	Count
X-Forwarded-For	Client IP	Farahoosh Dena, ChinaMobile (GD, SD), ChinaTelecom(SH, SX, SC, QH, XJ, GS), PT Telkom, ChinaUnicom (JL, LN, XJ)	139
X-Nx_remoteip*	Client IP	ChinaTelecom (QH, SC)	3
x-huawei-NASIP*	Gateway configuration	ChinaUnicom	5
x-source-id	Gateway configuration	ChinaUnicom (JL, LN), ChinaMobile (GD), ChinaTelecom (SH, SN, QH, SC, XJ, YN, NM, JS)	62
Cdn-Src-Ip*	Client IP	CNISP-Union, ChinaUnicom (LN)	24

Dataset Analysis

Modification of HTTP Headers

- Special header
  - Compromised *Content-Type*
    - The value of 2 sessions have been modified to probes of a vulnerability (Struts2, CVE-2017-5638).
    - OGNL codes

Dataset Analysis

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Modification of HTTP Headers

- Special headers
  - Compromised *Content-Type*

- whoami
- nMaskCustomMuttMoloz
- …

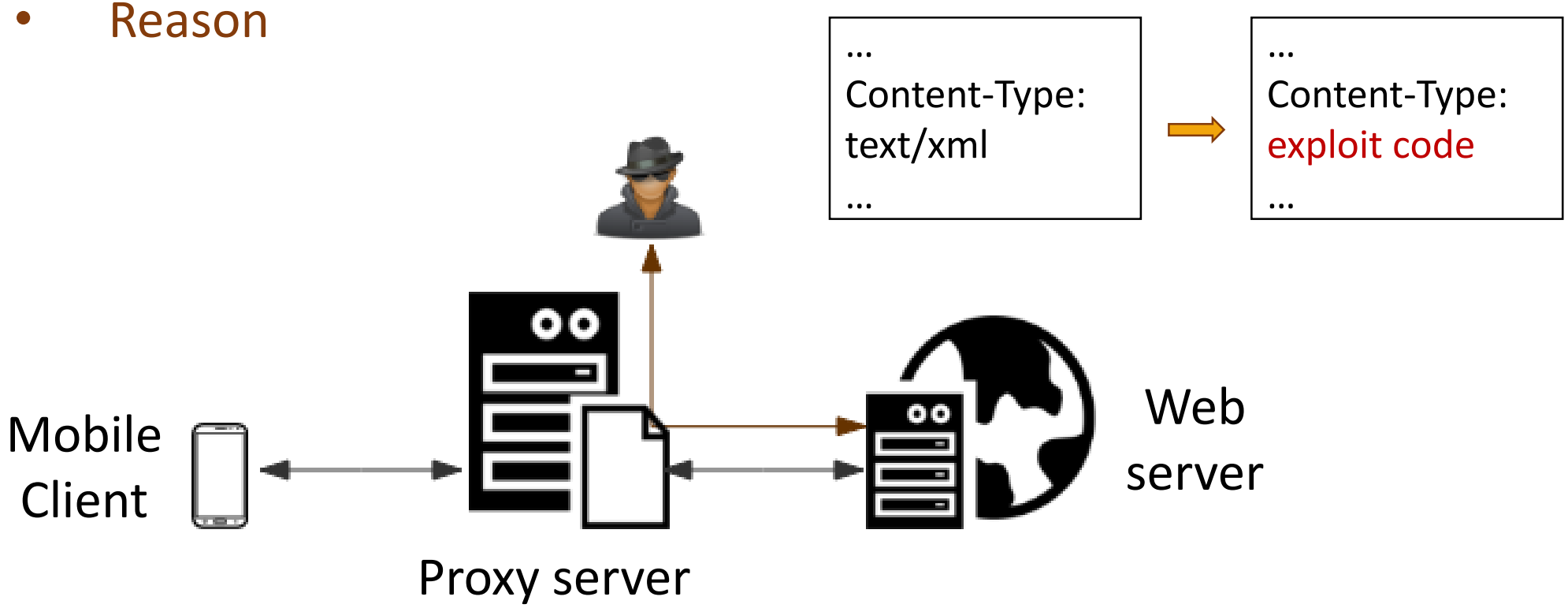
```
def exploit(url, cmd):
    payload = "%{(#_='multipart/form-data')."
    payload += "(#dm=@ognl.OgnlContext@DEFAULT_MEMBER_ACCESS)."
    payload += "(#_memberAccess?"
    payload += "(#_memberAccess=#dm):"
    payload += "((#container=#context['com.opensymphony.xwork2.ActionContext.container'])."
    payload += "(#ognlUtil=#container.getInstance(@com.opensymphony.xwork2.ognl.OgnlUtil@class))."
    payload += "(#ognlUtil.getExcludedPackageNames().clear())."
    payload += "(#ognlUtil.getExcludedClasses().clear())."
    payload += "(#context.setMemberAccess(#dm)))."
    payload += "(#cmd='%s')." % cmd
    payload += "(#iswin=(@java.lang.System@getProperty('os
    payload += "(#cmds=(#iswin?{'cmd.exe','/c',#cmd}:{'/bin/bash','-c',#cmd}))."
    payload += "(#p=new java.lang.ProcessBuilder(#cmds))."
    payload += "(#p.redirectErrorStream(true)).(#process=#p.start())."
    payload += "(#ros=(@org.apache.struts2.ServletActionContext@getResponse().getOutputStream()))."
    payload += "(@org.apache.commons.io.IOUtils@copy(#process.getInputStream(),#ros))."
    payload += "(#ros.flush())}"

    try:
        headers = {'User-Agent': 'Mozilla/5.0', 'Content-Type': payload}
        request = urllib2.Request(url, headers=headers)
        page = urllib2.urlopen(request).read()
```

Payload += “(#cmd=‘%s’).” % cmd

Dataset Analysis

Modification of HTTP Headers

- Special headers
  - Compromised *Content-Type*
    - Reason



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Conclusion

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Contribution

- A measurement study on
  - manipulation of HTTP traffic by transparent proxies
  - in cellular network from China-wide

HTTP traffic manipulation

- 3.86% of collected HTTP traffic are modified
- Two ways
  - web contents modification
  - HTTP headers injection

Conclusion

Motivations of manipulating HTTP traffic

- Advertising
  - E.g., ads injected to web pages
- Malicious behaviors
  - E.g., exploit code
- User tracking or identifying
  - E.g., user-related and device-related headers

Conclusion

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Future work

- Exact location of traffic manipulation
  - TTL limited requests
- In-path vs. on-path injections

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