A Practical Attack to De-Anonymize Social Network Users

Gilbert Wondracek (Vienna University of Technology)
Thorsten Holz (Vienna University of Technology)
Engin Kirda (Institute Eurecom)
Christopher Kruegel (UC Santa Barbara)

http://iseclab.org

Attack Overview

- Imagine you are a social network user
- Just like any user, from time to time you interact with the social network, add friends, join groups, etc.
- Then, (maybe a week later) you browse evil.com
  - evil.com has no connection to the social network
- Unknown to you, evil.com starts an attack against you, and finds out your social network identity
  - i.e. the data you entered in your profile, name, photo, etc.
- evil.com can even look up more sensitive data from the social network and, for example, say “Hello Gilbert Wondracek”

Attack Overview

- Our aim: Find out the social network identity of website visitors
  - Instead of tracking browsers (cookies, EFF), we track persons
- We leverage information from social networks
  - Attack limited to social network users (hundreds of millions!)
  - Leaked data from social networks and well-known browser attack allow us to compare and find the ID of users
  - All eight social networks that we examined were vulnerable
- Significant abuse potential
  - Ranging from intrusive advertisements to blackmailing
  - Large number of potential victims

Attack Details

Building Block A: History Stealing

- Well-known browser attack
  - Requires only HTML and CSS (Javascript helps, though)
  - CSS allows websites to define style templates (e.g. color, URL for background image) for *visited* / *non-visited* links
- This reveals information about the user's browsing history:
  - Current browsers allow **any** website to ask “Is [URL] in the user's browsing history?” by simply embedding links and comparing the style
  - No exhaustive listing of user's browsing history is possible
    - But no limit on number of asked “questions”
    - Can be done covertly

History Stealing

- Original (ab)use-case of history stealing
  - Spear phishing (targeted attacks): First find out victim's online banking site, then serve “correct” phishing page
- Browser developers paid little attention
  - Mozilla bug tracking list has entries that are 10 years old
  - Security impact deemed too low for sacrificing style feature?
- Browsing history timeout default values
  - 20 days (IE 8), 90 days (Firefox), *Unlimited* (Chrome)

Building Block B: Social Network Specifics

- Web applications have similar structure
  - HTTP GET commonly used for state keeping
    - URLs often contain unique IDs, performed operations, or other sensitive data as parameters:

      `http://sn.com/profile?operation=EditMyProfile&user=12345`
    - We found such links for all social networks that we examined
- Examples from real-world sites:

  Facebook: `facebook.com/ajax/profile/picture/upload.php?id=[UID]`

  Xing: `xing.com/net/[GID]/forums`

  Amazon: `amazon.com/tag/[GID]`

  Ebay: `community.ebay.de/clubstart.htm?clubid=[GID]`

Basic Attack Scenario

Basic Attack Scenario

- De-Anonymization attack
  - Combine history stealing and knowledge of SN webapp layout
  - Lure victim to evil.com
  - User ID of the victim can then be found via history stealing
- Attacking website can simply query for (all) user IDs:

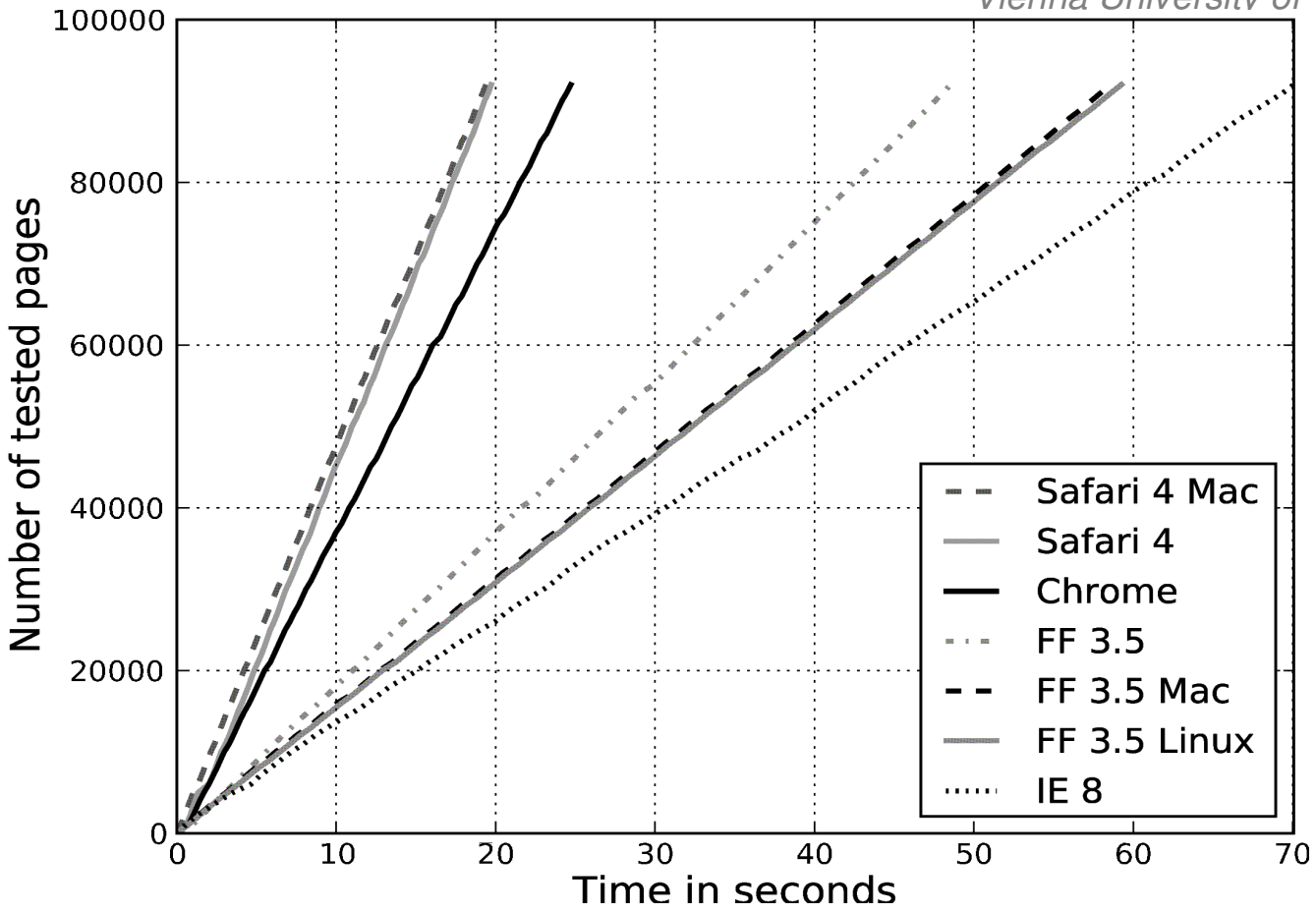
  sn.com/editprofile.html?uid=0

  sn.com/editprofile.html?uid=1

  ...

  sn.com/editprofile.html?uid=[X]
- Look up profile in social network for ID [X]
  - Very unlikely that the URL is in the history if the user is not X

History Stealing Benchmark



Not fast enough...

- Social networks have millions of users
  - This also implies millions of URLs that have to be checked via history stealing
- This would take too long for a real-world attack
  - Web surfers might only stay a few seconds on target site
  - Large scale history stealing can get CPU usage to 100%, sluggish UI response is suspicious
- Basic attack would only work for very small social networks
  - Useless?

Improving the Attack

Building Block C: Groups

- Additional hierarchical layer in social networks
  - Subsets of users with similar interests
    - Examples: “Mercedes Drivers”, “IEEE Members”, “Fans of [x]”
  - Groups can be public / closed
    - Public: Anyone can join (immediately)
    - Closed: Admin has to approve new members
- Group features also use specific hyperlinks for interaction
  - Example: www.sn.com/join_group.php?gid=12345
  - Leaked info → stored in the browsing history again
  - Finding such links in the history is an indicator for membership

Group Member Enumeration

- How can an attacker get information on group members?
- Social networks typically offer member and/or *group directories*
  - Public lists, so that users can find interesting members / groups
  - Group members can usually list the other members in the same group
- An attacker can use this to collect data on groups
  1) Join a group from the directory
  2) List all members
  3) Leave group
  4) Goto step 1
- Eventually, the attacker will know the members of each group

Group Member Enumeration

- Many SN restricts full listing of (group) members
  - Search features can be abused
    - For example, use US census information to enumerate users, works reasonably well (see paper)
- Attacker can use information from the SN itself to reconstruct membership relations
  - Example: Groups shown in member profiles → Attacker can reconstruct the group directory by crawling the public member directory
  - Example: SN that use systematic (numerical) IDs can be “brute-force crawled”
- At the end of the day, attacker gets info on groups again

Improved Attack Scenario

1) Preparation step: Crawl the targeted social network, get group and membership data
2) Lure victim to attack website
3) Use history stealing to check for links that indicate group membership
4) For these groups, look up the (crawled) members
5) Reduce the candidate set: Calculate intersection set for the found group members
   - If intersection set is empty (data may be inaccurate, history deleted etc), use the union set (slower, but more reliable)
6) Use basic attack on candidate set
   - Ideally, all but one profile will be eliminated → Success!

Evaluation

Evaluation Overview

- Experiments on real-world social networks
  - In-depth analysis of Xing (about 8 million members)
  - Feasibility studies for Facebook and LinkedIn
  - Checked total of 8 social networks, all vulnerable to attack
- We compared custom / commercial service crawling for group data collection
  - Custom crawler was not hard to implement
    - No countermeasures, group information considered non-critical (unlike profiles)
  - Commercial: 80legs.com, $0.25/million URLs → cheap!
- Controlled and public experiments with volunteers

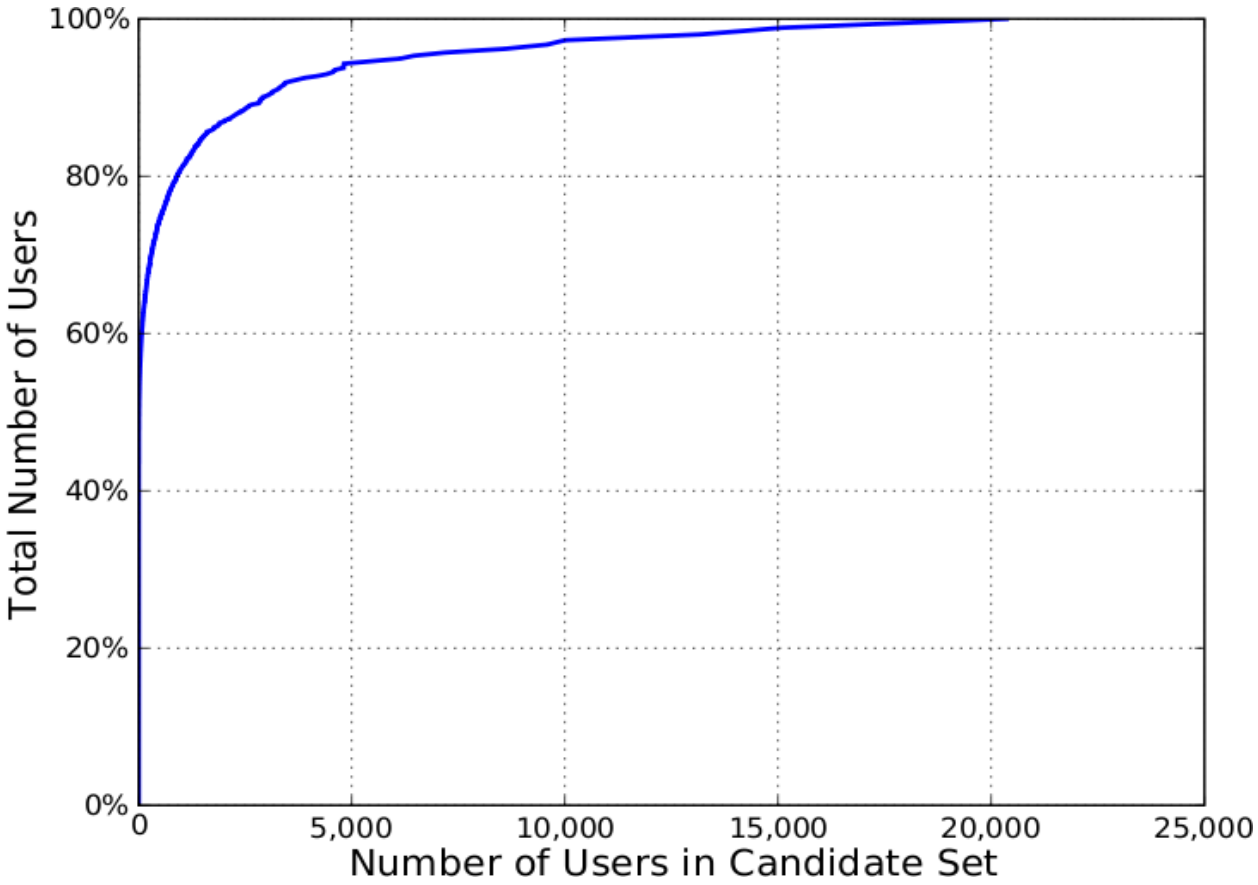
Case Study: Xing

- Xing, popular German social network
  - Business-oriented (people use real names, high value target)
  - Similar to LinkedIn in the US
  - About 8 million members, this moderate size allowed us to rely on lab resources for custom crawling
  - We created a user profile and kept on joining / listing / leaving ***all*** public groups (6,574)
  - Closed groups: We simply asked if we can join
    - 1,306 join attempts, 108 accepted => 404,331 unique members
    - Worked for most large groups (>10^5 members, too hard to maintain?) → important groups for attacker!

Xing Analytical Results

- Recovered 4.4 million membership relations, 1.8 million unique group members (of 8 million total)
  - Complete coverage: Attacker has to check 6,277 groups
  - Only 6,277 URLs to check instead of 8 million
- About 42% of users have a *unique* fingerprint
  - I.e. there is only one user with this configuration of group memberships in the SN
- For 90% of all groups members, the intersection size is below 2,912 users
- Shows that the attack is feasible in real-world settings
  - Leveraging groups: Number of potential victims smaller, but still hundreds of millions!

Cumulative distribution of candidate set sizes for set intersection



Controlled Experiment

- Website that implements attack against Xing
  - HTML + Javascript + Ajax for history stealing
  - Feedback form for participants
- 26 volunteers from the authors' Xing contacts
- We could not find any URLs that indicate groups in the browsing history of 11 people
- We successfully de-anonymized 15 / 26 users
  - Group member intersection method worked for 11 users (median size 570 members)
  - Fallback to union set for 4 users (median size 30,013 members, still feasible)

Public Experiment

- A tech report of our attack found its way to the news
  - Mainly German language news, Spiegel, Slashdot, ...
- 9,969 volunteers who participated and completed the experiment on our website
- We found group traces for 3,717 users (37.3%)
- 1,207 users claim they were correctly de-anonymized
  - 12.1% of overall participants!
- No reliable information on background of volunteers
  - Still, we think that this shows that the threat is serious
  - Success rate is high, large amount of people de-anonymized

Mitigation

Mitigation

- Server-side
  - No more HTTP GET parameters with sensitive data
  - Quick fix: Add non-guessable tokens to sensitive URLs
  - We disclosed our attack to Xing, they invited us, now they use links like www.xing.com/net/pri523ba6x/tuwien/
  - Problematic, breaks SEO!
- Client-side
  - Disable browsing history, use safe browsing mode
- Browser-side
  - Same origin policy for style infos, prevent access to style infos on links
  - Upcoming Firefox will fix history stealing (after 10 years of discussion)

Summary

- We presented a novel attack to de-anonymize website visitors who also use social networks
- Social networks are used to collect the ID data
  - Group feature used to identify victims quickly
- Any website can host the de-anonymization code
  - Find traces of groups and user profiles via history stealing
  - Match these traces against data from the social network
- Consequences are severe
  - Hundreds of millions of potential victims
  - Malicious activities limited only by imagination of attacker

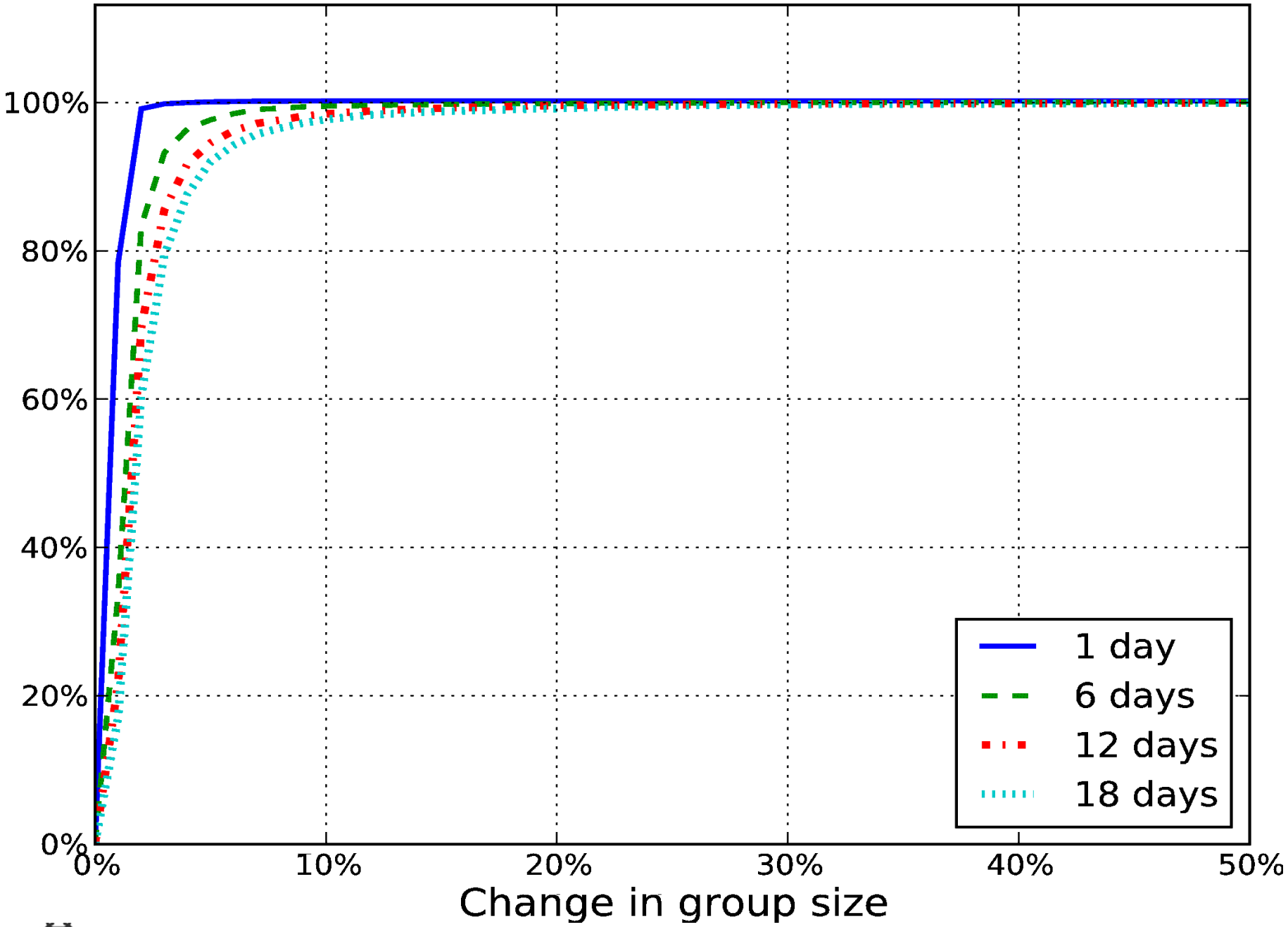
Summary

- Existing anonymity techniques (e.g., onion routing, TOR) are evaded
- The necessary effort for preparing and conducting the attack is relatively low
- High de-anonymization rate in experiments
  - Implemented for Xing
  - Facebook, LinkedIn, MySpace & Co. also vulnerable
  - Can be generalized to other websites that generate sparse datasets (Ebay, Amazon are vulnerable too)

Thank you!

Responsible Disclosure

- We contacted Xing, LinkedIn, and Facebook
- Asked consent of users in experiments
  - Volunteers only, made clear what happens
- Consulted legal department of our university
  - Similar duties like an IRB in US universities


100%
80%
60%
40%
20%
0%
0%
10%
20%
30%
40%
50%
Change in group size
1 day
6 days
12 days
18 days

Feasibility: Facebook / LinkedIn

- Same data collection principle (join / list / leave)
- Facebook: We stopped our custom crawler after obtaining about ***43 million*** unique users
  - 3 weeks of non-stop crawling → our machines were never banned / slowed down
- Commercial service
  - Facebook's group directory (public, but huge) was downloaded for $18.47 → 7.4 million files, 39,156,580 group IDs
  - For other networks (LinkedIn), we used it to brute-force enumerate all active groups (3 million page requests)
- Shows that attack is possible, more details in paper