<FPSelect: Low-Cost Browser Fingerprints for Mitigating Dictionary Attacks against Web Authentication Mechanisms>

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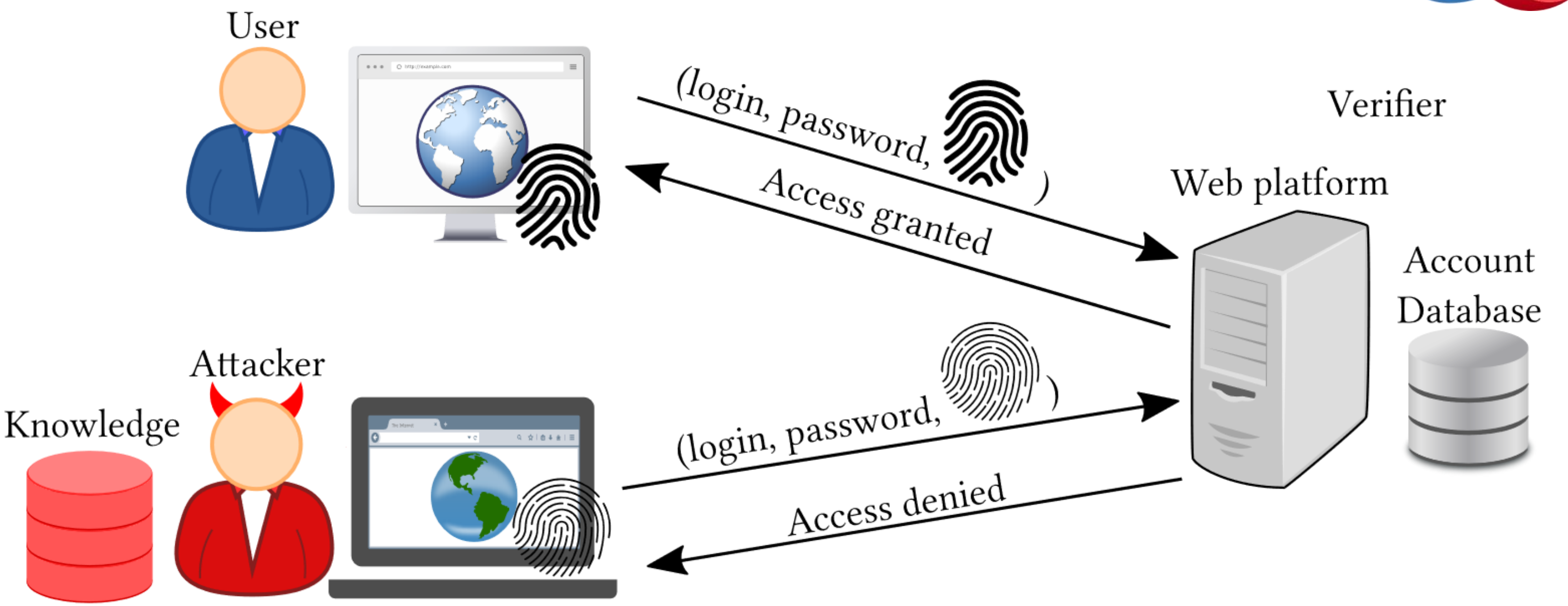
Context

- **Passwords suffer from flaws**
  - Dictionary attacks: common passwords [6] or reuse [16]
  - Phishing attacks: 12.4 million stolen credentials [12]

- **Other authentication factors reduces usability [3]**
  - User must remember, possess, or do something

- **Browser fingerprinting [2, 11]**
  - Collection of browser attributes
  - Depending on the web environment



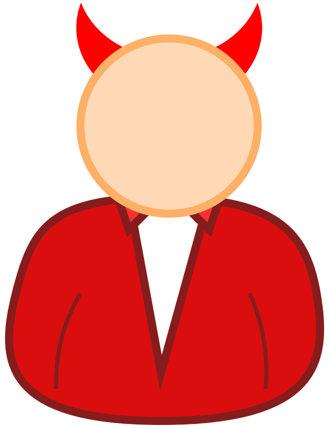
- **Adding an attribute**
  - Helps distinguish browsers
  - Reduces usability
- **Hundreds of attributes are available [2, 11, 13]**
  - Collecting them all is unpractical (e.g., taking too long to collect)
- **Previous works**
  - Use the well-known attributes [2, 11, 15]
  - Iteratively pick attributes [7, 8, 9, 17]
  - Evaluate every possible set [4]

Attribute Selection Framework

- The attacker knows a **fingerprint** distribution
  - Submits the **ß-most common** fingerprints

- Example
  - ß=2
  - f_1 and f_2 are submitted
  - The sensitivity is of 4/7

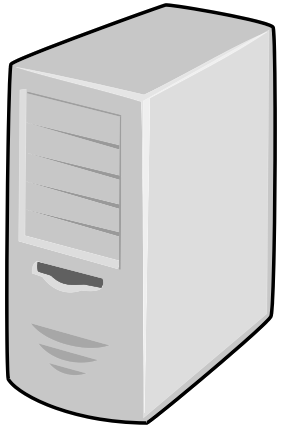
Attacker



F	PMF
f_1	0.40
f_2	0.20
f_3	0.10
f_4	0.10
f_5	0.10
f_6	0.05
f_7	0.05

U	F	Spoofed
u_1	f_2	●
u_2	f_1	●
u_3	f_4	○
u_4	f_2	●
u_5	f_3	○
u_6	f_5	○
u_7	f_1	●

Web platform



- **Verifier has a set *A* of candidate attributes**

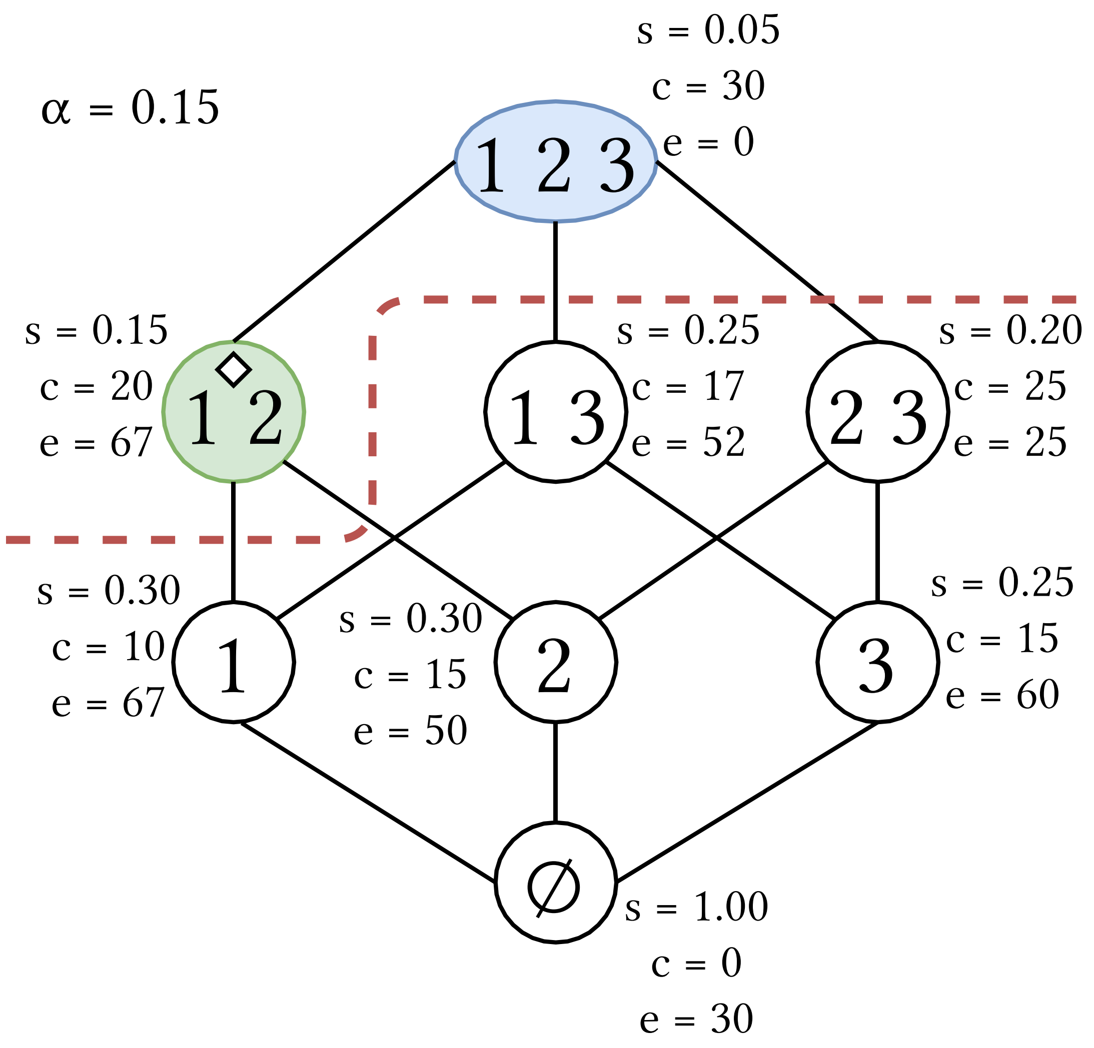
- **Verifier seeks the attribute set**
  - Satisfies a security level *α*
  - At the lowest cost

- **Attribute set *C* ⊆ *A***
  - c(*C*): its usability cost (strictly increasing)
  - s(*C*): its sensitivity (decreasing)

$$\arg\min_{C \subseteq A} \{\mathrm{c}(C) : \mathrm{s}(C) \leq \alpha\}$$

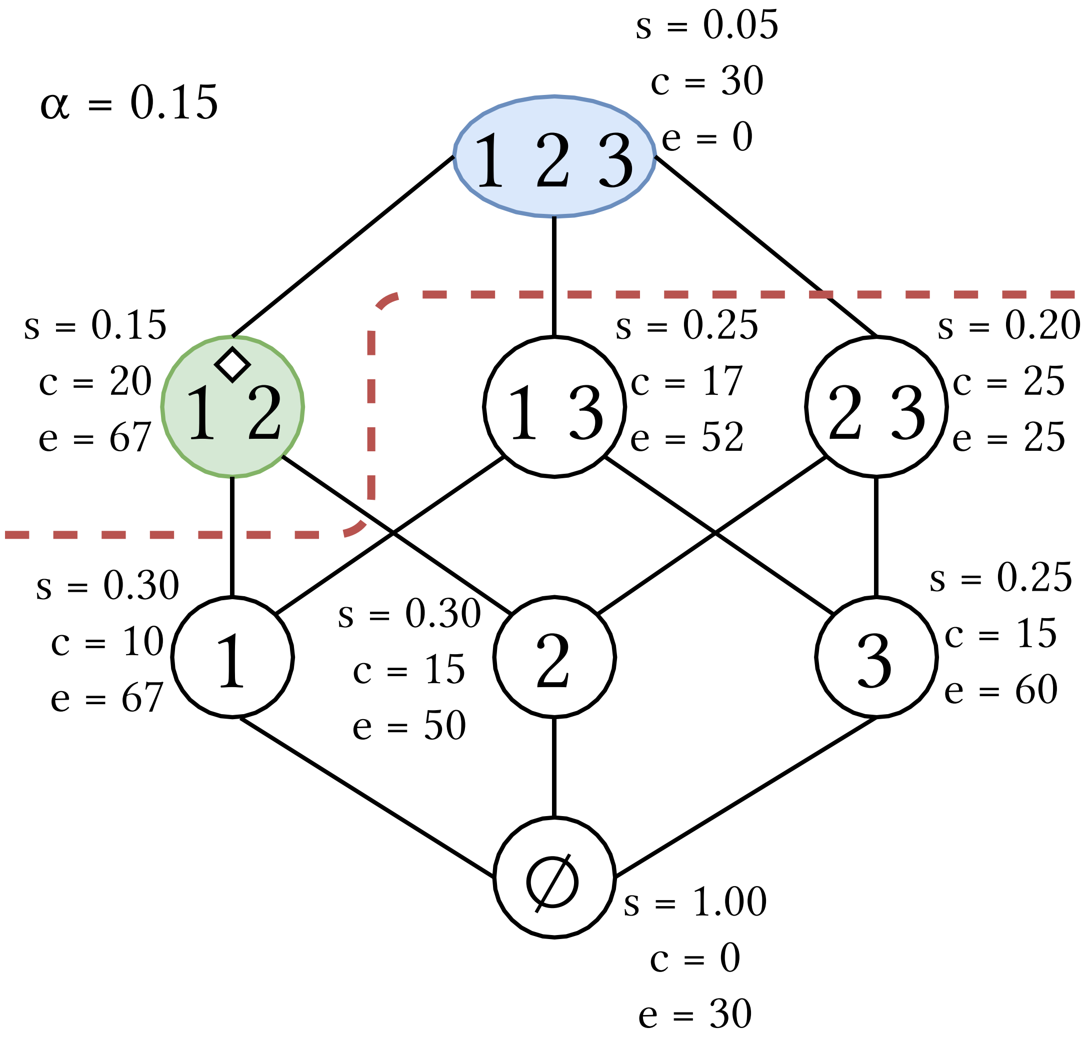
- **Greedy exploration algorithm**
  - Expands by adding one attribute
  - Holds *k*-nodes to expand
  - Partial solutions ordered by the usability gain/sensitivity ratio

- **Pruning methods**
  - Cost higher than the current minimum c_{min} (1)
  - Superset of a node satisfying the threshold or (1)



- **Execution with k=2 and α=0.15**
  - S starts with k-empty sets
  - c_{min} = 20 at stage 2
    - {2, 3} is not expanded
  - {1, 2, 3} is not added to E as it is a superset of {1, 2}

Stage	E	T	S
1	$\{\{1\},\{2\},\{3\}\}$	$\{\}$	$\{\{1\},\{3\}\}$
2	$\{\{1,2\},\{1,3\},\{2,3\}\}$	$\{\{1,2\}\}$	$\{\{1,3\}\}$
3	$\{\}$	$\{\{1,2\}\}$	$\{\}$



- **Usability cost in points**
  - Memory size (10 kilobytes = 10K points)
  - Collection time (1 second = 10K points)
  - Number of changing attributes (1 changing attribute = 10K points)

$$\mathrm{cost}(C, D) = \gamma \cdot [\mathrm{mem}(C, D), \mathrm{time}(C, D), \mathrm{ins}(C, D)]^\intercal$$

C : attribute set
D : fingerprint dataset
γ : cost weights

- **Sensitivity**
  - Measured by the verifier
  - Attacker knows the fingerprint distribution of the protected users
  - Matching function between a submitted and a stored fingerprint

Results

Experimental setup

- **Sample of 30 thousand fingerprints [20, 21]**

- **Verifier and attacker instantiation**
  - Sensitivity thresholds: 0.001, 0.005, 0.015, 0.025 [1, 3, 14]
  - Number of submissions: 1, 4, 16 [5, 18]
  - Explored paths: 1 and 3

- **Matching function** $\sum_{a \in A} f[a] \approx^{a} g[a] > \theta$

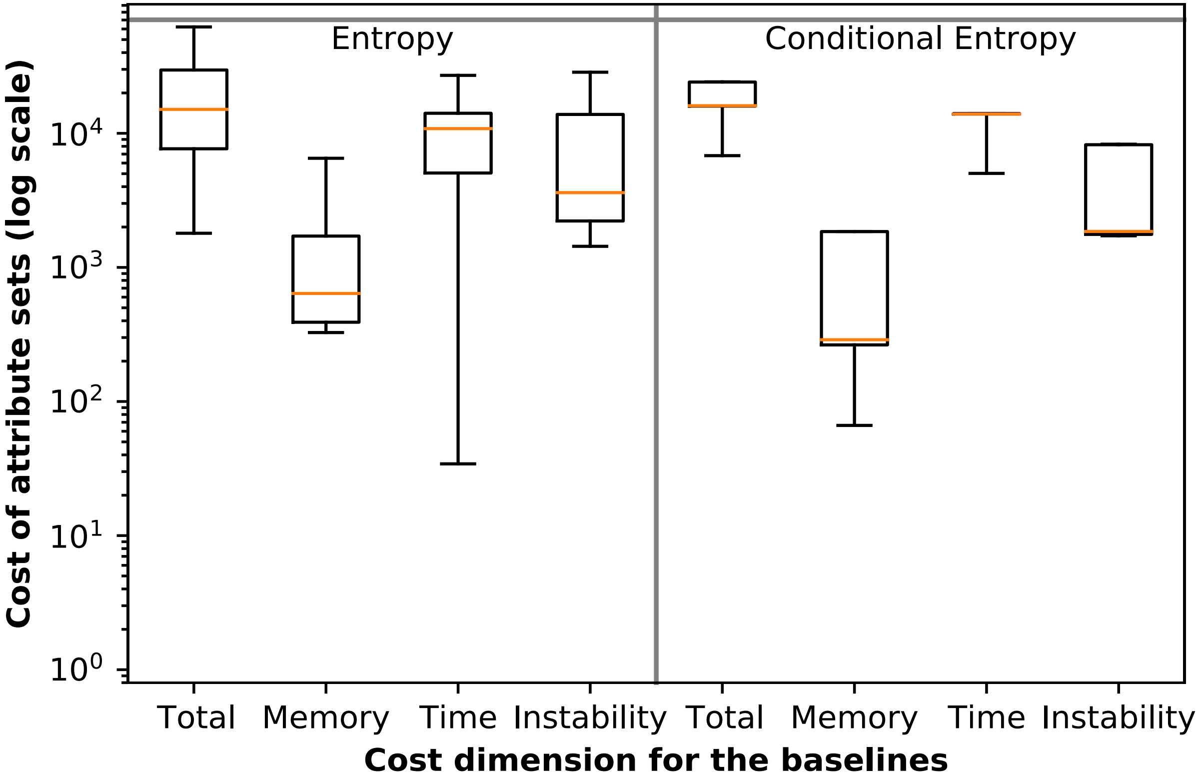
f, g : submitted and stored fingerprint

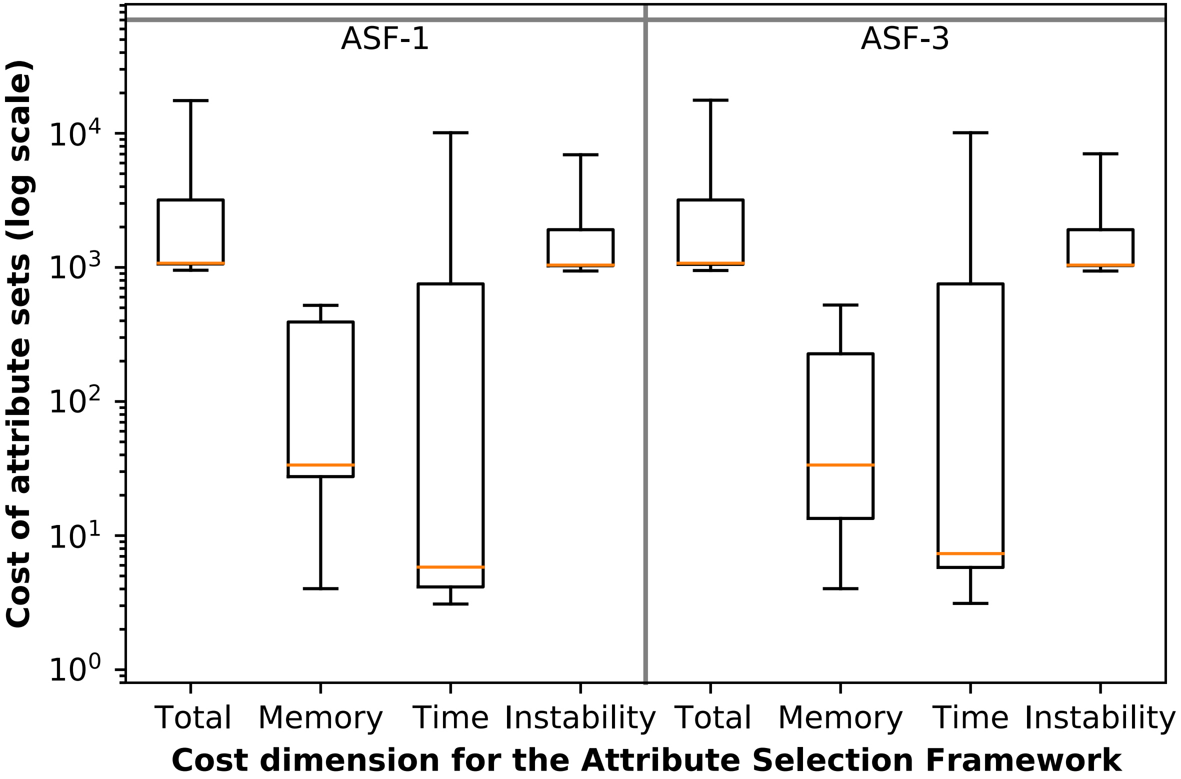
$\approx^{a}$: 1 if a is sufficiently similar between f and g, else 0

θ : matching threshold A : the attributes used

- **Compare FPSelect results with the baselines**
  - Entropy [8, 9]
  - Conditional entropy [7]

Usability Cost Results





A solution for **9** among the **12** cases, due to unreachable sensitivity threshold.

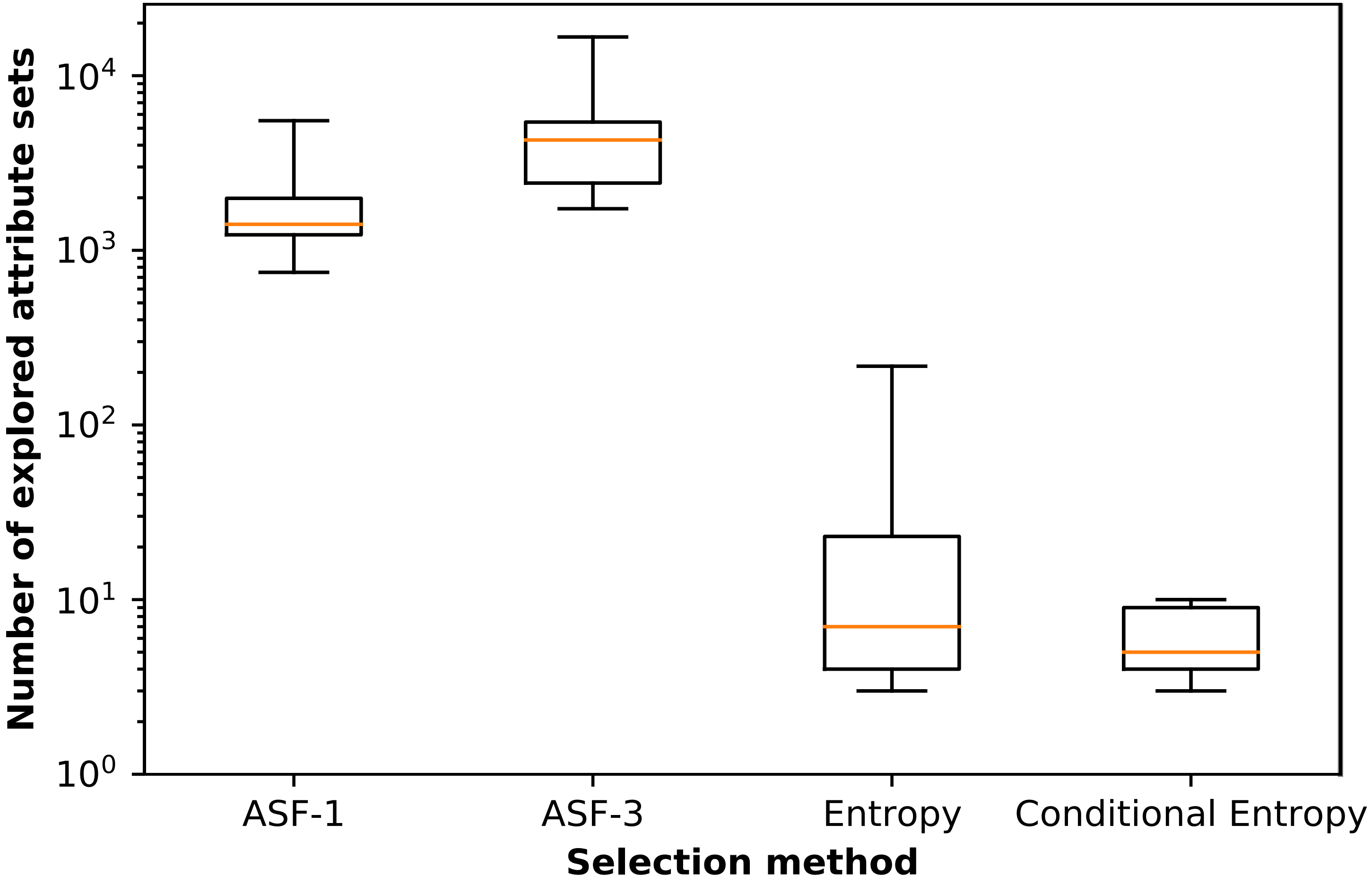
The fingerprints are, on average, up to

- **97 times smaller**
- **3,361 times faster** to collect
- with **7.2 times fewer changing** attributes

Computation Cost

- ASF-1: **three orders of magnitude** more attribute sets than the **baselines**

- ASF3: **three times** more attribute sets than **ASF-1**



Conclusion

- **FPSelect: attribute selection framework**
  - Possibility space as a lattice
  - Greedy exploration algorithm
  - Fingerprints of lower cost than the baselines
  - Higher computation cost
- **Future works**
  - Attackers with targeted knowledge
  - Other experimental settings (browser population, measures)

Thank You

Any question ?

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