black hat
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Self-Verifying Authentication – A Framework for Safer Integrations of Single-Sign-On Services

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Motivation

- SSO – the "front door" lock for tens of millior
    - E.g., Airbnb.comallows Facebook sign in.
- Many companies provide identity services
    - Provide SDKs (i.e., lock products) for different we
    - Step-by-step instructions to teach programmers
        - E.g., OpenID Connect 1.0 spec, Azure AD dev guid
- But most website programmers are not expe "locksmiths"
    - Imagine that you need to read an installation sheet, drill holes, and install a lock cylinder, knobs and steal plates on your front door
    - Can every average homeowner do it securely?

Security-Critical Logic Bugs are Pervasive

- Numerous studies have shown serious bugs
  - Papers in leading academic security conferences
  - Findings from the Black Hat community
    - E.g., in Black Hat USA 2016 and Black Hat Europe 2016
- Consequences:

Login safety	An attacker can sign into a victim's account
Login intent	A victim can be tricked to sign into an attacker's account (login forgery - CSRF)

- Cloud-API integration bugs are the No.4 cloud security top threat
  - SSO logic flaws are the primary example of this bug category

Attack demos

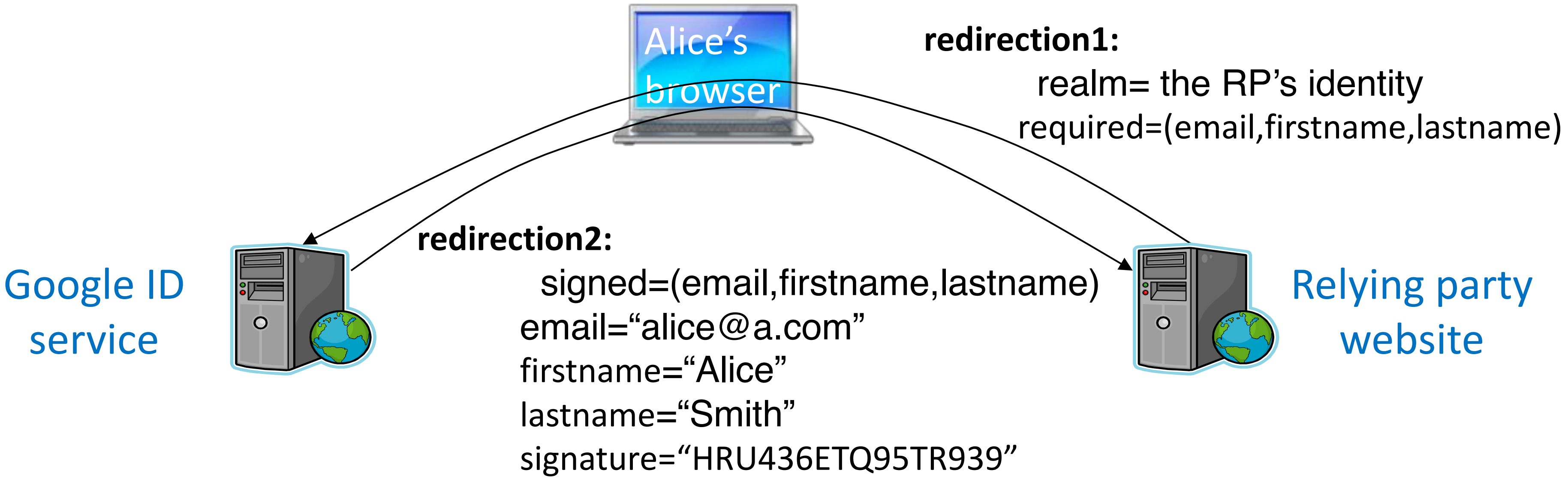
- Demo 1:
  - Microsoft Azure AD library for Node.JS
  - **Login safety violation**: attacker logs into any victim's account
  - Video

- Demo 2:
  - https://web.skype.com
  - **Login intent violation** via request forgery: victim unknowingly login into the attacker's account
  - Video1 Video2

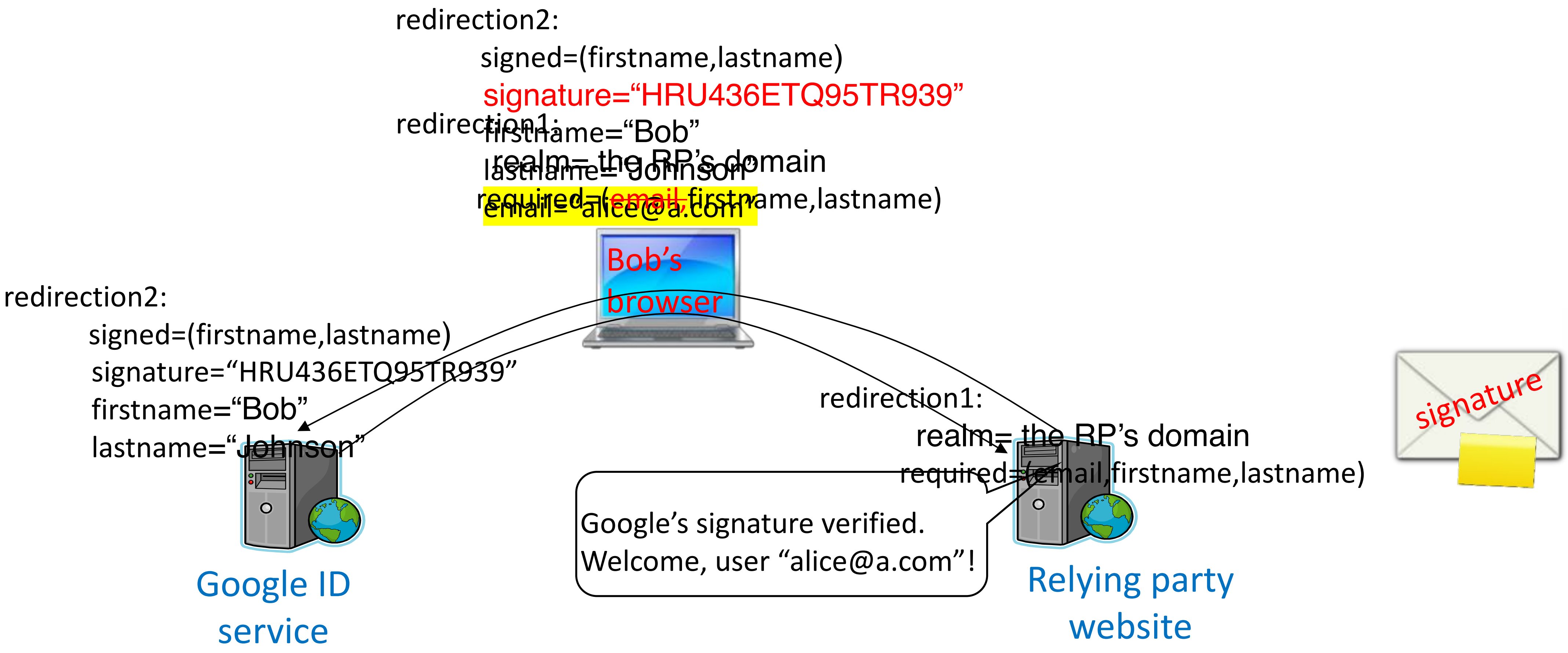
- We have reported many SSO issues to various identity providers and websites.
  - Companies, big or small, make these mistakes.

Example: an SSO bug due to insufficient logic checks using Google ID

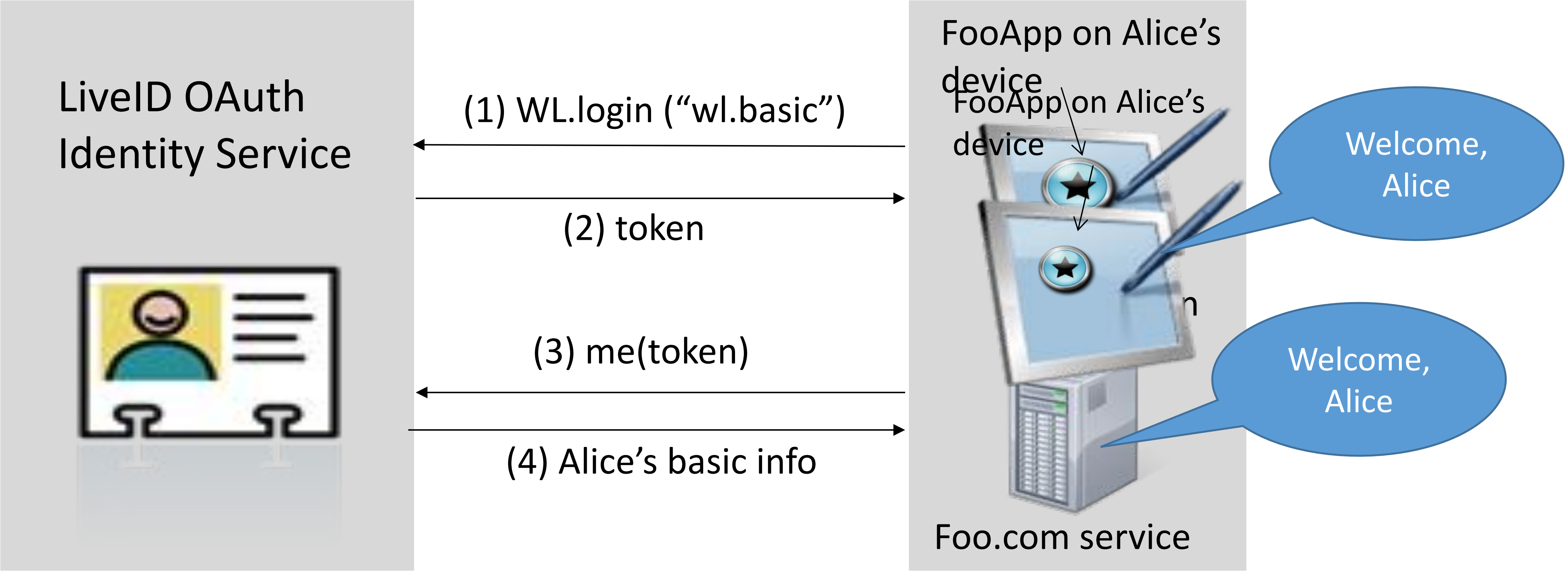
- A simplified illustration of the Google ID protocol
  - In 2012, it was based on Open ID 2.0



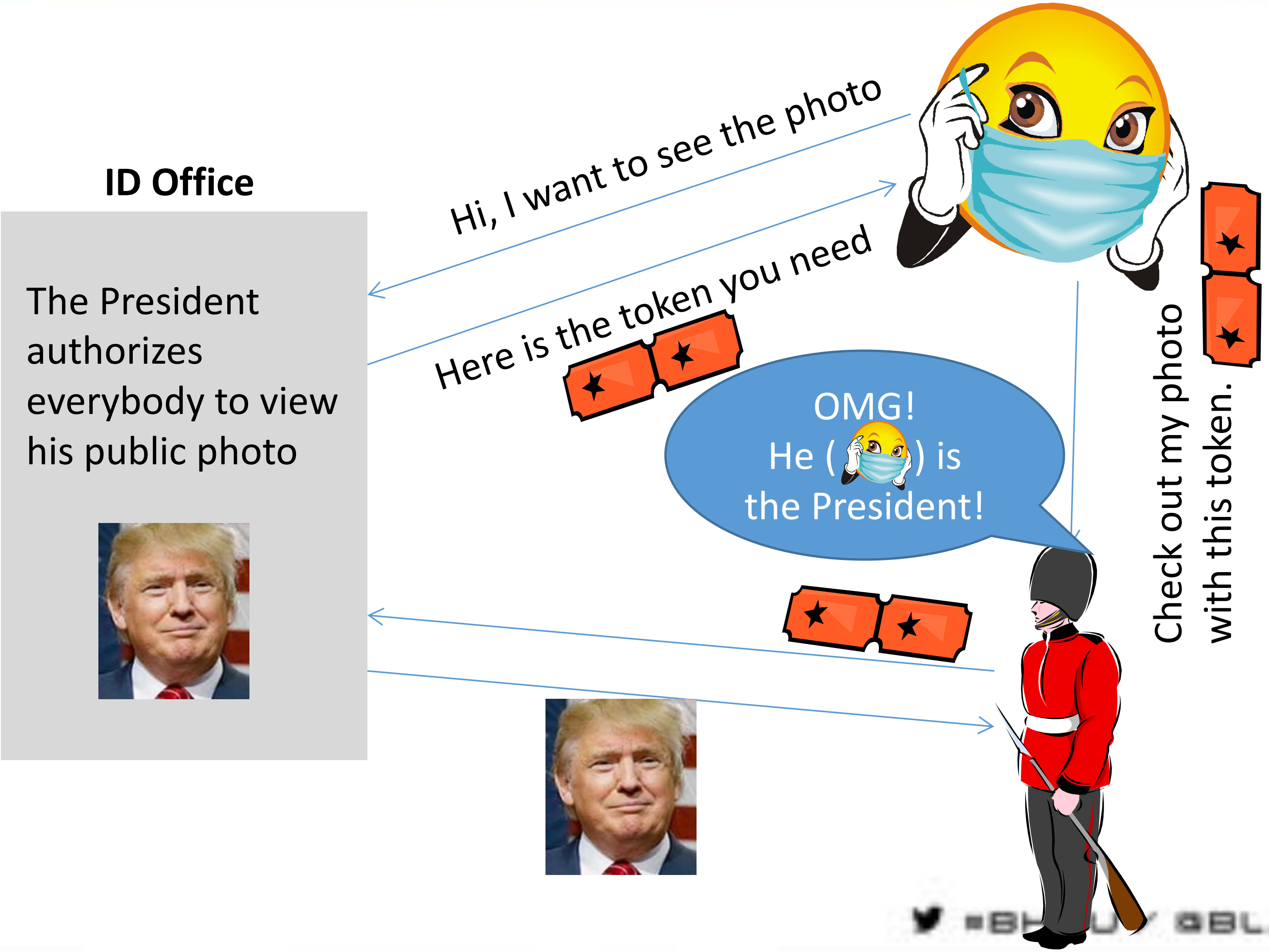
Vulnerability and attack



Example: unintended usage of OAuth 2.0 access token



Confusion about authentication and authorization



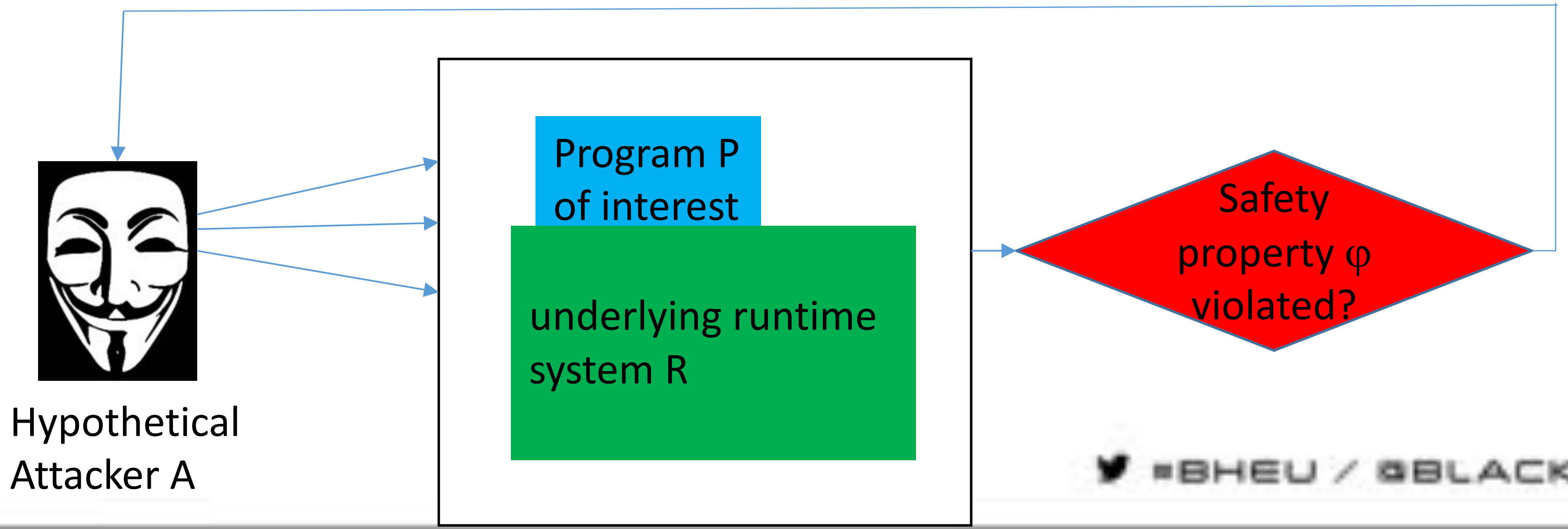
demo

Program verification to prevent logic bugs in SSO

Our verification technology: self-verifying execution (SVX)

Hurdles of traditional verification approaches

- Why can't I feed my source code P and a property φ into a program verifier, and expect bugs to be found automatically?
- Because program verification is a very challenging task
  - Need to model the runtime system R – hard to be precise
  - Need to model the unknown attacker A – hard to be exhaustive
  - Theorem to prove: if attacker A calls P for infinitely many times, and each time has multiple public APIs, can φ ever be violated?
  - Need to prove by induction (because of the infinite possibilities of executions) – hard to automate.



Basic idea of SVX

- Every actual execution is responsible for collecting its own executed code, and proving that it satisfies φ.

- No need to model the attacker
  - Because every execution is driven by a real user.
- No need to model the runtime platform
  - Because execution happens on the actual platform
- No need for inductive proof
  - Because it only proves “this execution satisfies φ”, not “all possible executions satisfies φ”.

Distributed consensus: comparing integer constants among three websites

Alice.com

```
const int Value=10;
Message grab (Message m1)
```

Message

Untrusted client

Safety property φ:

Whenever conclude(m2) is reached, m2 must represent the website holding the biggest int.

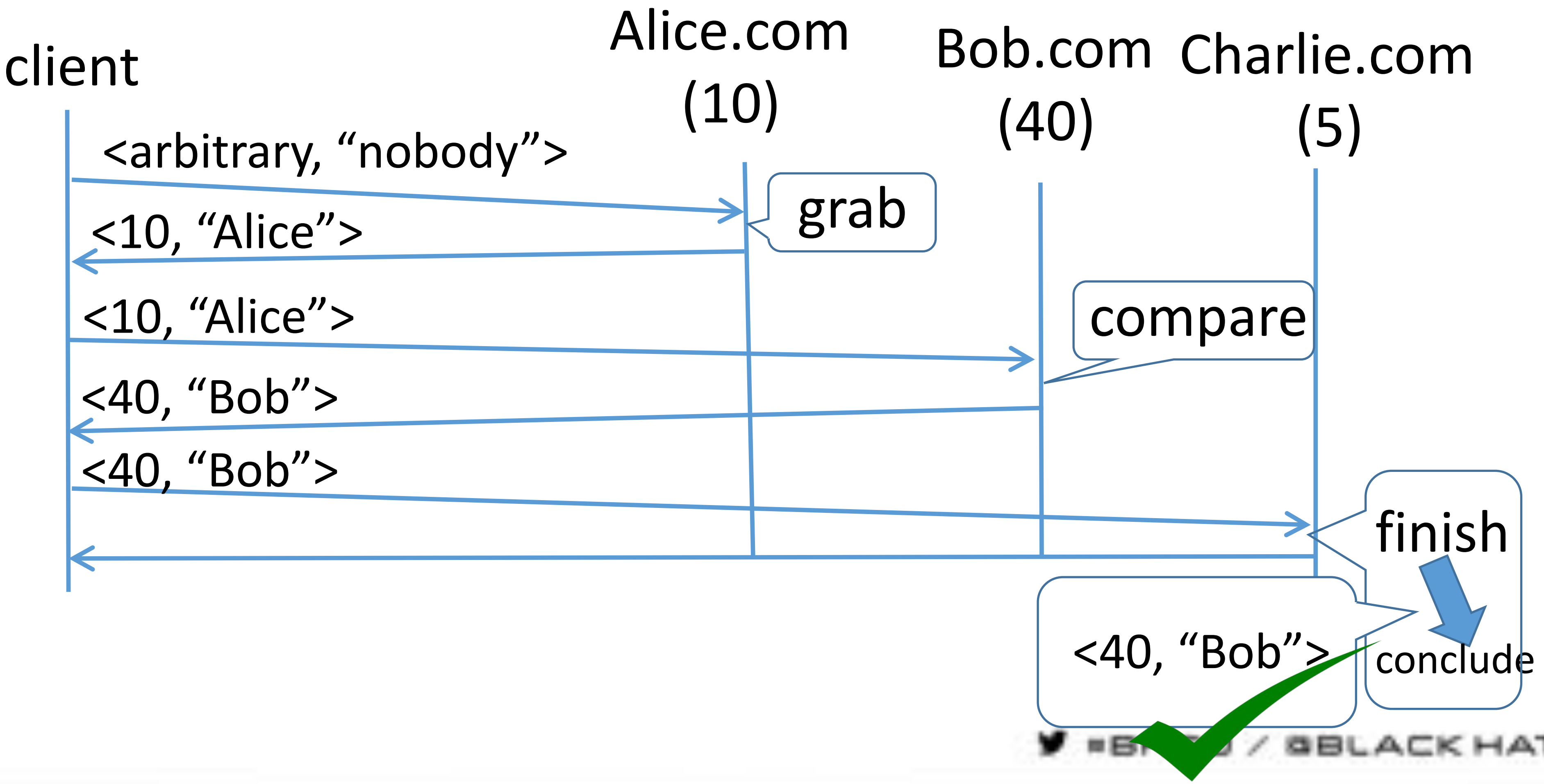
Bob.com

```
const int Value=40;
Message compare (Message m1)
{   ValidateSignature(m1);
    Message m2;
    m2 = <Value, "Bob">;
    m2 = max(m1,m2);
    m2.SignBy("Bob.com");
    return m2;
}
```

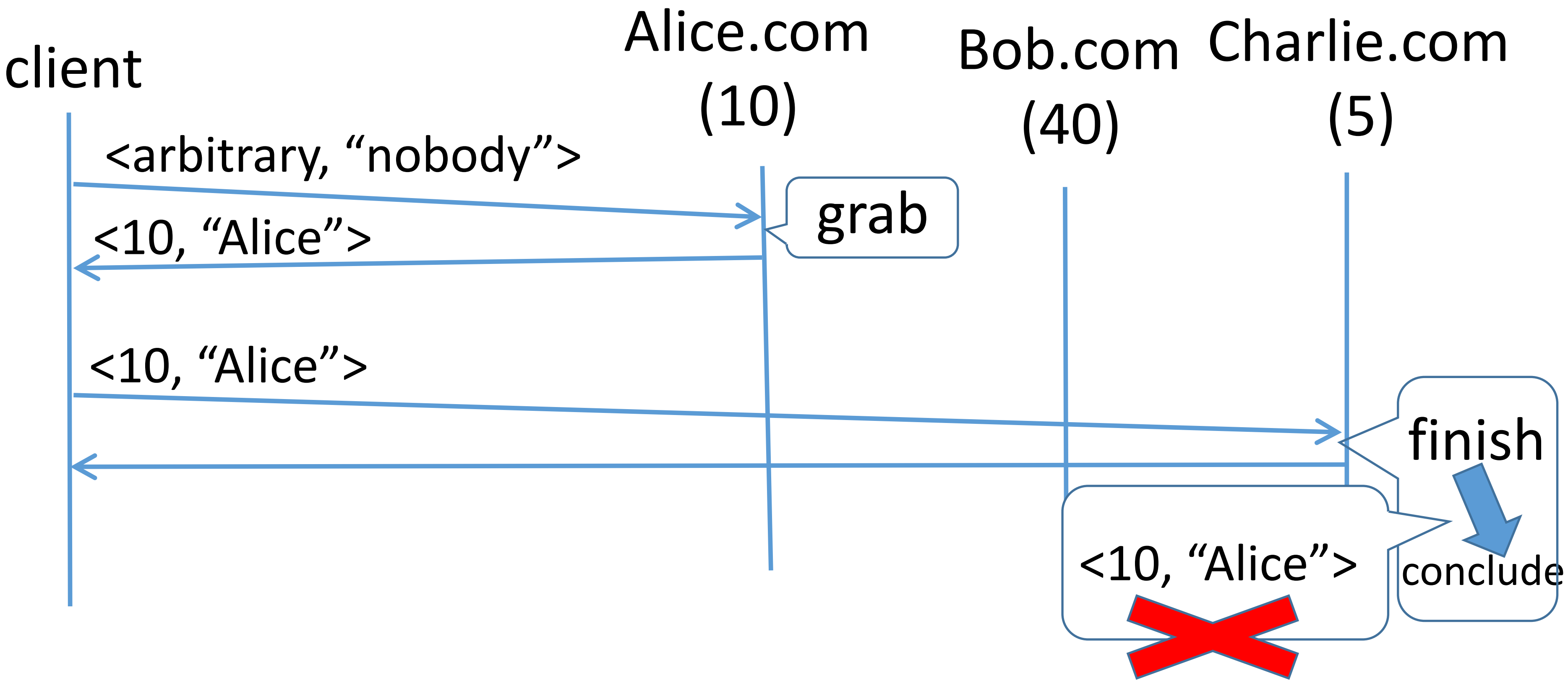
Charlie.com

```
const int Value=5;
Message finish (Message m1)
{   ValidateSignature(m1);
    Message m2;
    m2 = <Value, "Charlie">;
    m2 = max(m1,m2);
    conclude(m2);
    return m2;
}
```

The expected protocol flow

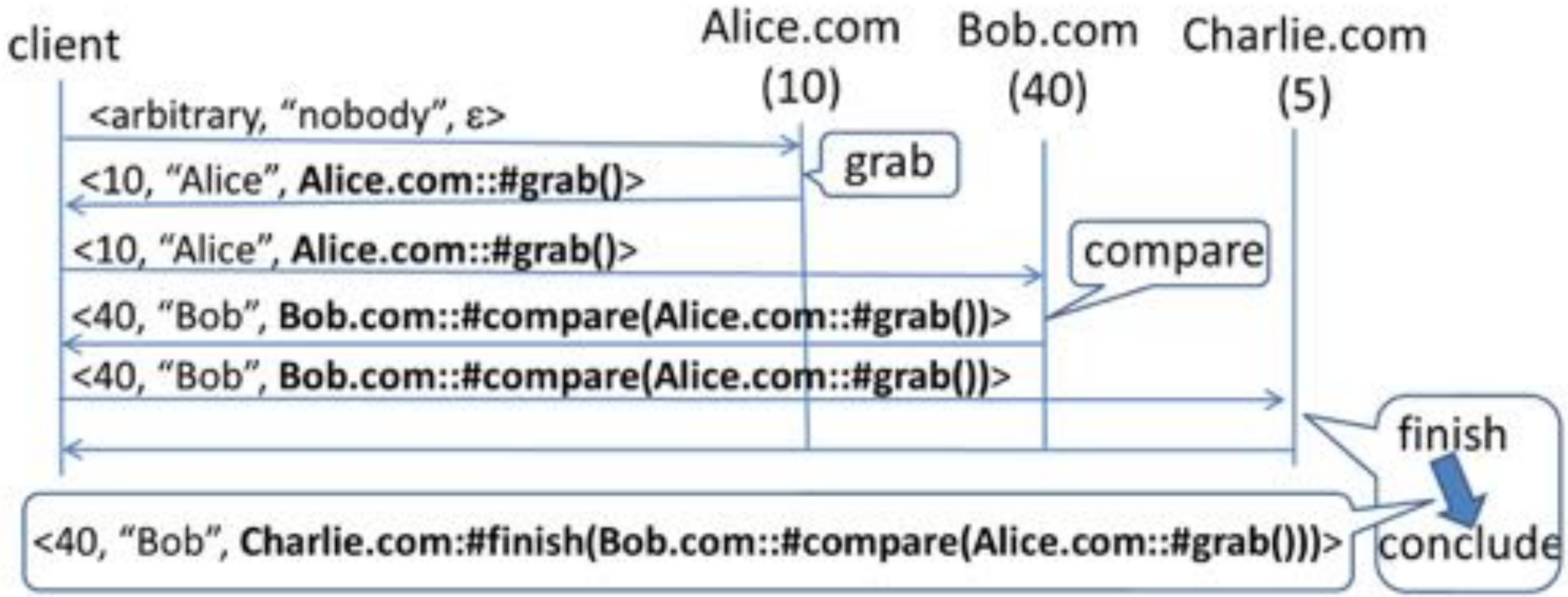


The system is vulnerable!



How SVX works

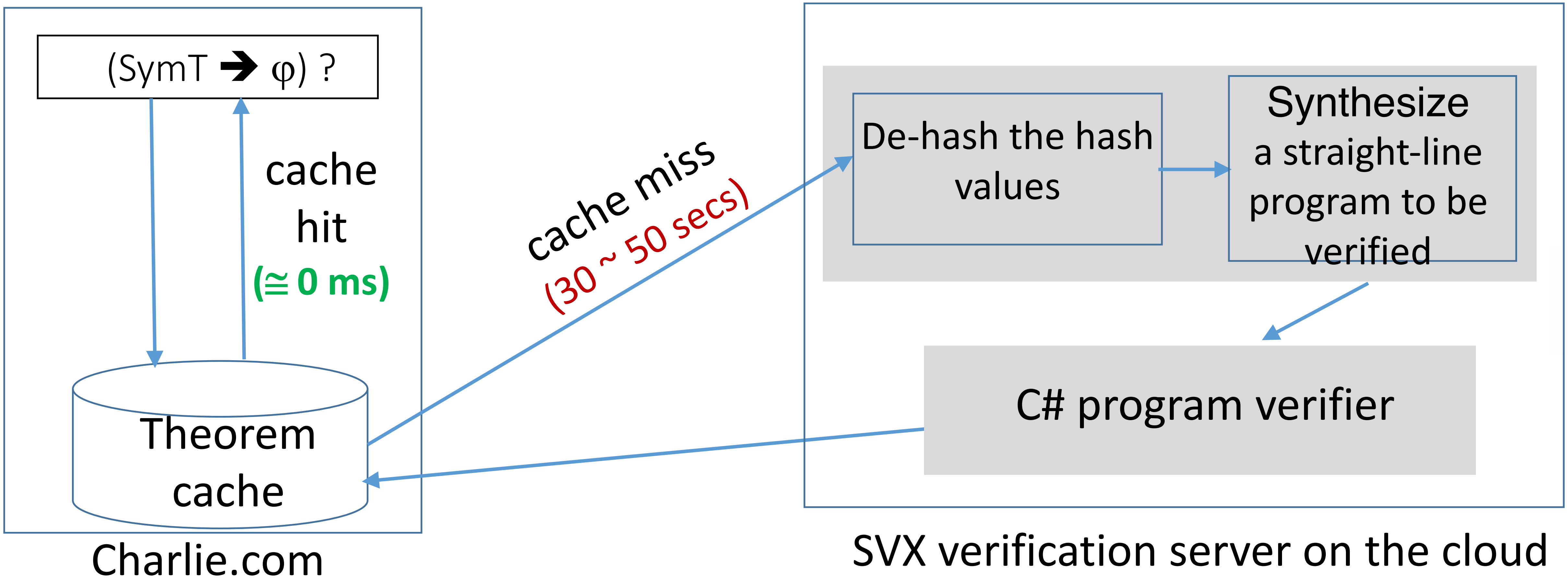
- Attach a field, namely *SymT (Symbolic Transaction)* onto every message.
- #grab, #compare and #finish are a compact representation of the executed code of these methods.



Verifying an execution

- Method conclude() calls a program verifier to prove:
  The final SymT $\rightarrow \varphi$
  - Charlie.com:#finish(Bob.com::#compare(Alice.com::#grab())) $\rightarrow \varphi$, the execution is accepted.
  - Charlie.com:#finish(Alice.com::#grab()) $\nrightarrow \varphi$, the execution is rejected.
- Note that the program verification is symbolic (only about code). The concrete values are ignored.
  - A middle ground between offline symbolic verification and runtime concrete checking.
- SVX's performance overhead is near-zero
  - Because the theorems can be cached.
  - All normal executions should hit the cache.

Theorem cache and verification server

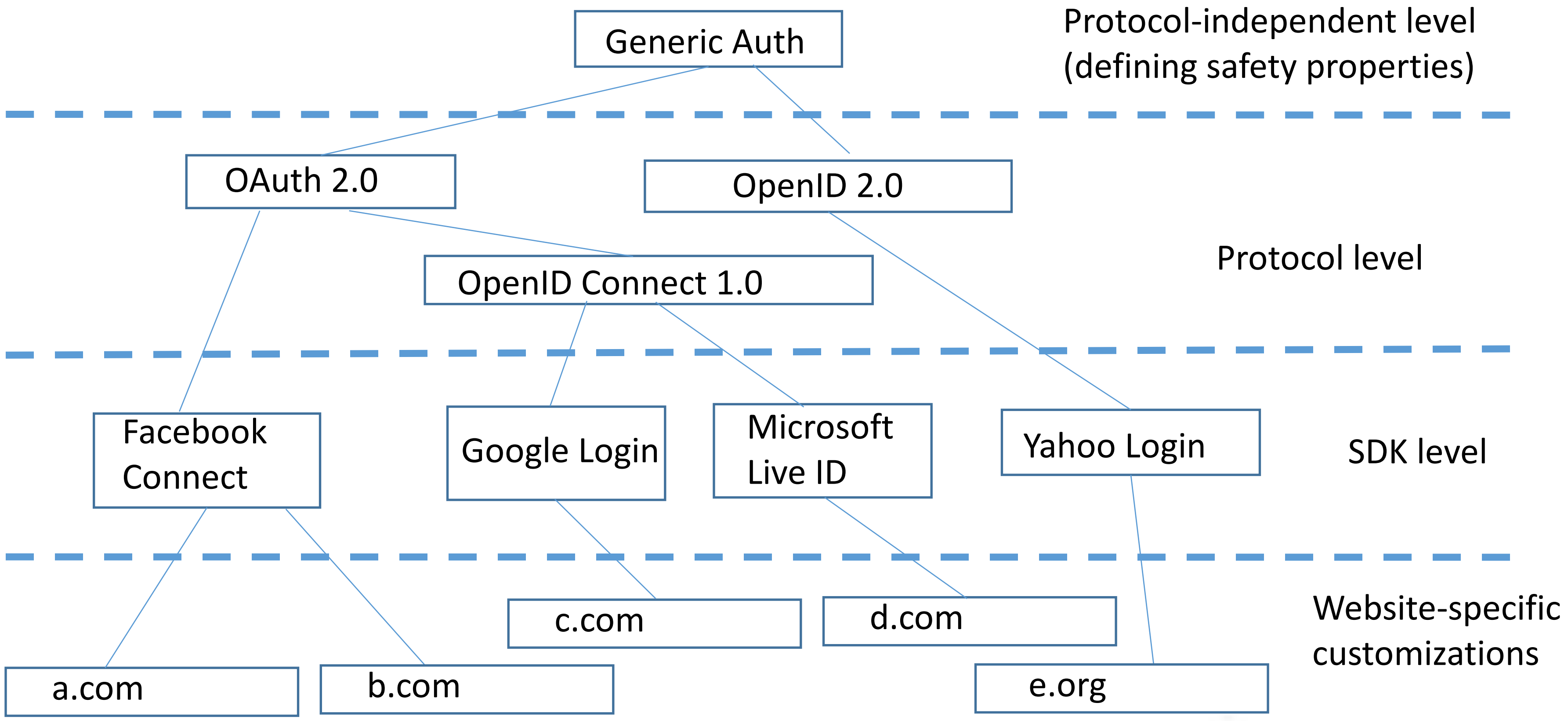


Our open-source project: SVAuth

Safer SSO integration solutions based on SVX

The SVAuth framework: SVX with OO

- Defines “login safety” and “login intent” properties at the base class level.
- Every concrete implementations are guaranteed to satisfy the base class level properties!



A decades-old problem in verification

- Liskov Substitution Principle (LSP) tries to ensure that
  - If a property is true for the base class, then it holds for all derived classes.

```
class Rectangle {
   int height, width;
   virtual int GetHeight() {return height;}
   virtual int GetWidth() {return width;}
   virtual void SetHeight(int x) {height=x;}
   virtual void SetWidth(int x) {width=x;}
}
```

```
class Square: Rectangle {
   override void SetHeight(int x)
        { height=x;
          width=x;  }
   override void SetWidth(int x)
        { height=x;
          width=x;  }
}
```

```
void foo(Rectangle r) {
      int w=r.GetWidth();
      r.SetHeight(3);
      Assert(w==r.GetWidth());
}
```

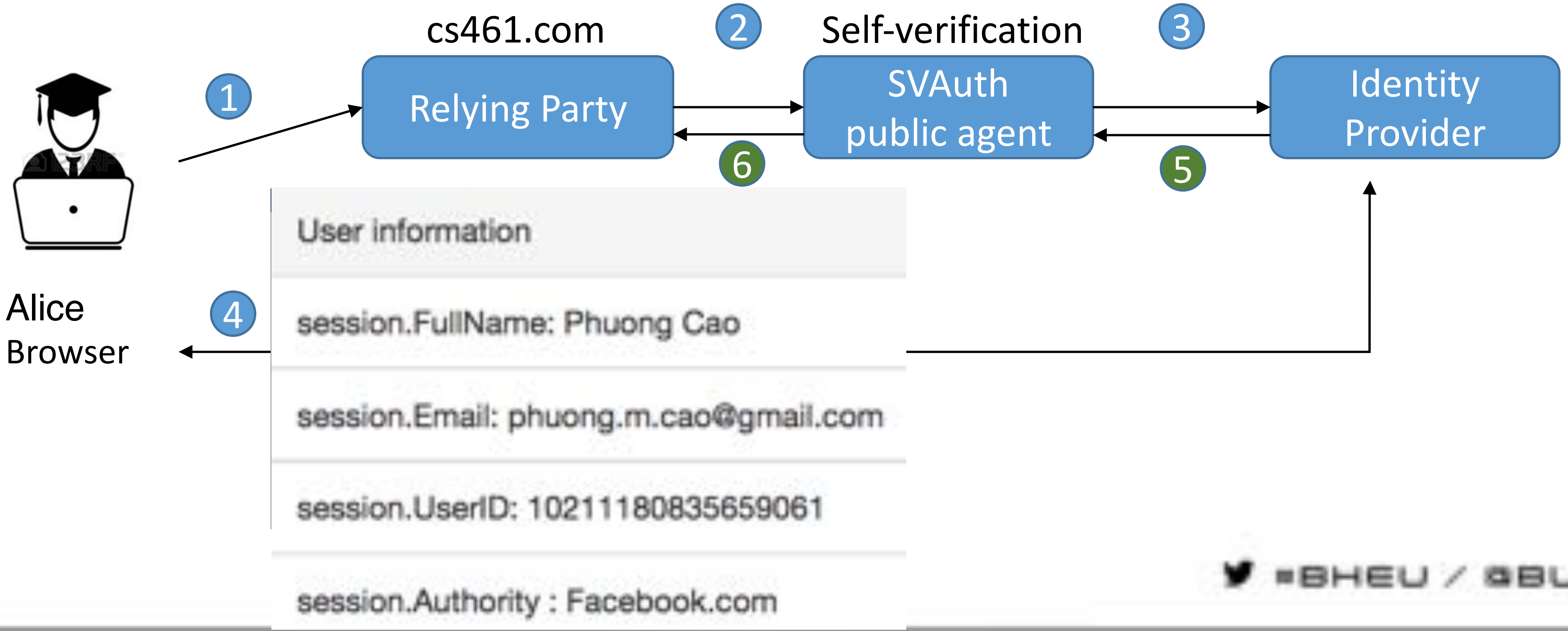
For SVX, there is not confusion

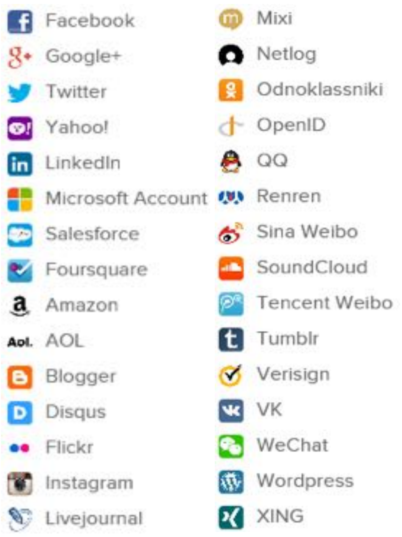
```
Rectangle r = new Rectangle();
Assert(foo(r));
```

```
Rectangle r = new Square();
Assert(foo(r));
```

How does SVAuth work?

- SVAuth consists of an **agent** and an **adapter**
  - Agent: public agent, organizational agent or localhost agent
  - Website developer picks an agent, and sets its endpoint in the SVAuth config file
  - Copy the adapter folder onto the website





Why adopting SVAuth?

	Traditional Oauth SDKs	SVAuth
Oauth protocol	X Need some understanding of Oauth protocols	V **Don't need to know anything about SSO protocols.**
App registration	X Register an app for each identity providers	V **Don't need to register apps for each identity provider**
App secret	X Manage app secrets	V **Don't have to manage app secrets**
Oauth SDK	X Import and update Oauth SDKs for each language	V **Use only basic cryptographic primitives, no external dependencies**
Security issues	X Do you trust Oauth SDKs and Oauth framework?	V **Organizations can run their own version of SVAuth agent**

SVAuth demo

Adopting SVAuth on your website -- extremely simple

Start login flow by redirecting to public agent "***http://authjs.azure.com:3020/***login/Facebook"

Listen for the user's identity information on "/SVAuth/adapters/py/RemoteCreateNewSession.py"

User information
session.FullName: Phuong Cao
session.Email: phuong.m.cao@gmail.com
session.UserID: 10211180835659061
session.Authority : Facebook.com

Start the session

```python
@app.route('/start', methods=['GET'])
def start():
    """
    Start the login flow by contacting the remote svauth agent
    """
    token = init_token()
    return redirect(START_URL.format(token, RELYING_PARTY))


@app.route('/SVAuth/adapters/py/RemoteCreateNewSession.py', methods=['GET'])
def remote_create_new_session():
    """
    Retrieve an authentication code from public agent
    Request user profile from svauth public agent
    Populate user profile to current session
    """
    resp = request_user_profile(request.args.get("authcode"))
    validate_user(resp)
    populate_user_profile(resp)
    return redirect("/")
```

Our experience

- Current status
  - Support 7 SSO services and 3 languages (ASP.NET, PHP and Python)
  - Will support more.
- Integration with real-world applications
  - MediaWiki (8 lines of code changes)
    - Used by a Microsoft Research internal website.
  - HotCRP (21 lines of code changes)
  - CMT (10 lines of code changes)
- Open source, available on GitHub
  - Project repo: https://github.com/cs0317/SVAuth
  - Sample code: https://gist.github.com/pmcao/22d1c6f04ebd662c4baf83d7a6d1e9dd
  - Live demo: http://svauth-python-adapter.herokuapp.com/

Black Hat Sound Bytes

- Most website programmers are not experienced “locksmiths”
  - Installing an SSO lock securely on a website is not easy.
  - SSO security bugs are pervasive. Even big companies make mistakes.
  - The problem is well known in the security community.
- Self-verifying execution (SVX)
  - It is a “locksmith” built into a lock product.
  - The locksmith watches how the lock is opened, and asserts if it is logically sound.
- SVAuth – Open-source SSO framework based on SVX
  - Please adopt SVAuth on your websites
  - Or, join the project to improve the code.
  - Let’s fundamentally address the SSO security bugs.