Web Communication Analysis of Android Applications

Master Thesis - Final Presentation

Marc-Andrea Tarnutzer
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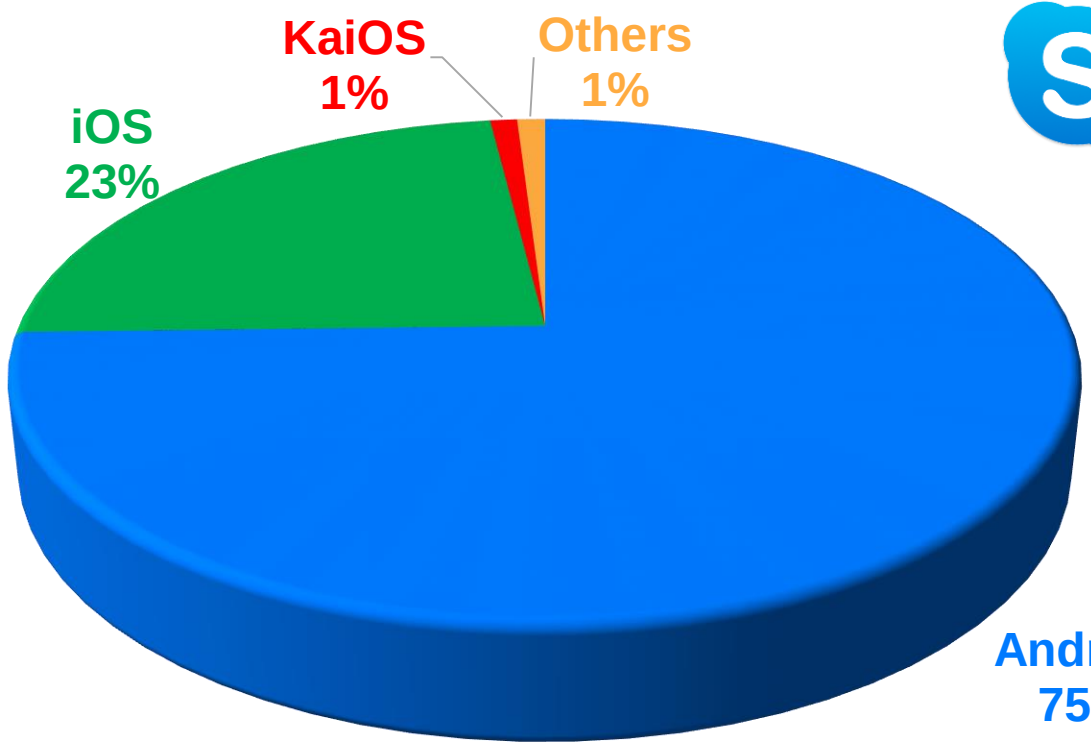
UNIVERSITÄT BERN

Networked Appified World



Web Communication

http://api.snapchat.com/

Request

Response

https://www.admob.com/

Request

Response

Research Questions

RQ1) Prevalent web communication frameworks?

RQ2) Transmitted data?

RQ3) Differences open-source vs closed-source apps?

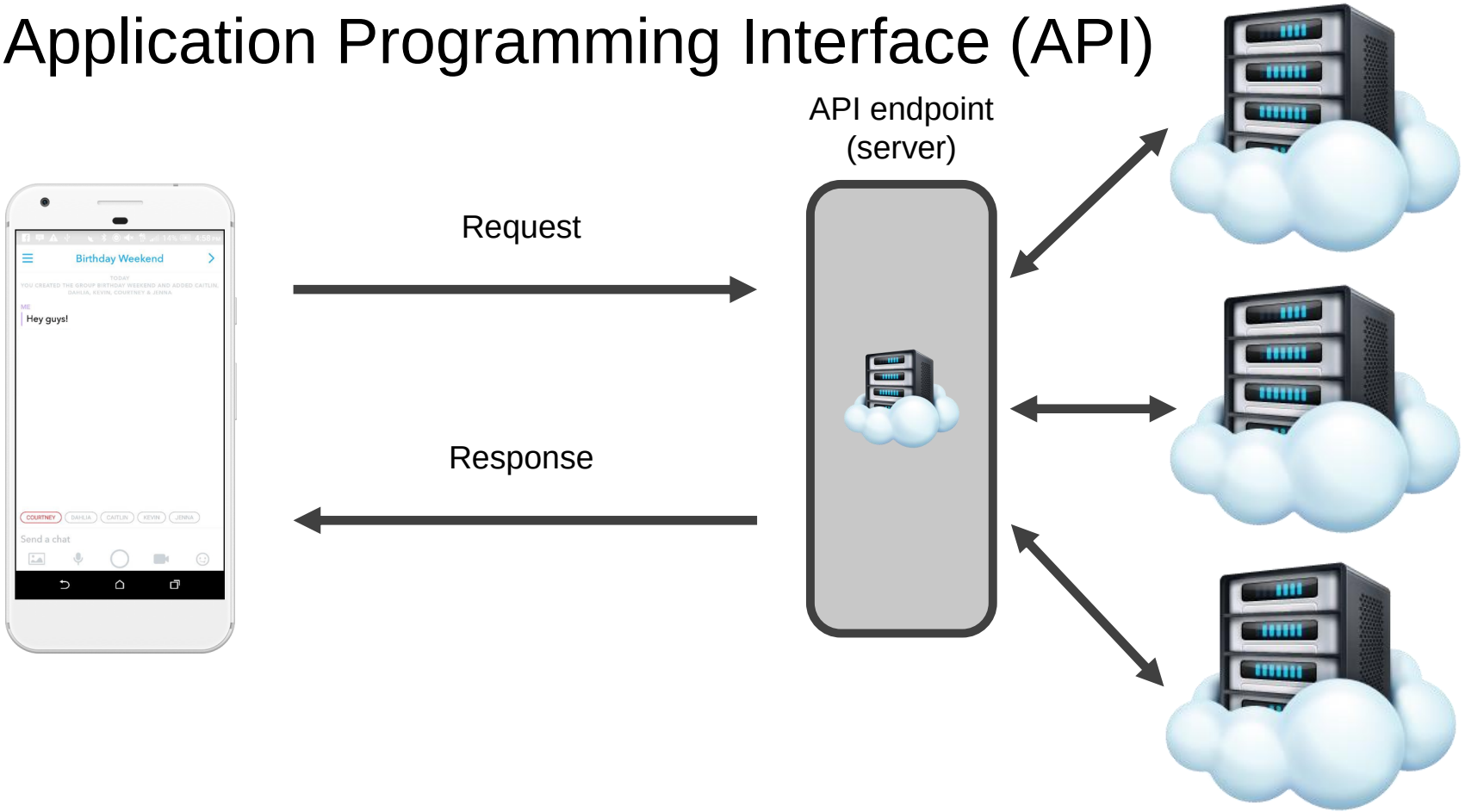
RQ4) Web server configurations?

Web Communication

Background

Application server(s)

Application Programming Interface (API)



REpresentational **S**tate **T**ransfer (**REST**)

- Client-Server Architecture
- Layered System
- Stateless
- Cacheable
- Uniform interfaces
- Code on demand

Data Schemes


```json
{
    "id": 3948292,
    "name": "Miller",
    "first_name": "Bob",
    "address": {
        "street": "Sample Street 1",
        "number": 10
     },
     "married": true,
     "badges": [
        "badge1",
        "badge2" ],
     "social_media": null
}
```


```xml
<?xml version="1.0" encoding="UTF-8"?>
<root>
    <id>3948292</id>
    <name>Miller</name>
    <first_name>Bob</first_name>
    <address>
        <street>Sample Street 1</street>
        <number>10</number>
    </address>
    <married>true</married>
    <badges>badge1</badges>
    <badges>badge2</badges>
    <social_media/>
</root>
```

Common HTTP Request Methods

GET	Retrieve resource	`www.example.com/api/user?id=42`
POST	Create resource	`HTTP body: { "id": 42, "name": "Bob Smith”, … }`
PUT	Replace resource	`HTTP body: {"id": 42, "name": ”Adam Smith”, … }`
PATCH	Modify resource	`HTTP body: { "age": 33 }`
DELETE	Delete resource	`www.example.com/api/user?id=42`

Simplified HTTP Request

1. Request line
2. Request headers
3. Request message body
4. Server status
5. Response headers
6. Response message body

```
PATCH /api/user/20382 HTTP/1.1
Host: someservice.com
Accept: application/json
Accept-Encoding: application/gzip
cache-control: no-cache

{
    "user_name": "Bob"
}
```

Request

```
HTTP 200 No Error
Content-Type: application/json; charset=UTF-8
Access-Control-Allow-Origin: *
Pragma: no-cache
Set-Cookie: PHPSESSID=u45n2me6f0jueflptpjmrvjid4; path=/
Server: nginx/1.14.1
Access-Control-Expose-Headers: Content-Type, X-Requested-With, X-authentication, X-client
Transfer-Encoding: Identity
Referrer-Policy:
Expires: Thu, 19 Nov 1981 08:52:00 GMT
Cache-Control: no-store, no-cache, must-revalidate, post-check=0, pre-check=0
Date: Sun, 31 Mar 2019 15:31:41 GMT
Connection: keep-alive
Vary: Accept-Encoding

{
    "success": true
}
```

Response

RQ1:

Which are the ***prevalent web communication frameworks*** used in mobile apps?

Found Web Communication Facilities
(manual analysis of 160 apps)

HTTP libraries

AndroidHttpClient

OkHttp

AsyncHttpClient (loopj)

Retrofit

HTTP COMPONENTS

Ion

JSON libraries

Gson
github.com/google/gson

org.json
Included in Android

Moshi
github.com/square/moshi

REST Library Support

```
URL url = new URL("http://www.google.ch");
Socket socket = new Socket(url.getHost(), 80);
OutputStream outputStream = socket.getOutputStream();
PrintWriter printWriter = new PrintWriter(outputStream, false);
printWriter.print("GET / HTTP/1.1\r\n");
printWriter.print("Host: www.google.ch\r\n");
printWriter.print("Connection: Close\r\n");
printWriter.print("\r\n");
printWriter.flush();
InputStream inputStream = socket.getInputStream();
InputStreamReader inputStreamReader = new InputStreamReader(inputStream);
BufferedReader bufferedReader = new BufferedReader((inputStreamReader));
int in;
while ((in = bufferedReader.read()) != -1) {
    System.out.print((char) in);
}
bufferedReader.close();
```

without REST library

```
String url = "http://www.google.com";
StringRequest stringRequest = new StringRequest(Request.Method.GET, url,
        new Response.Listener<String>() {
    @Override
    public void onResponse(String response) {
        System.out.print("Response: " + response);
    }
}, new Response.ErrorListener() {
    @Override
    public void onErrorResponse(VolleyError error) {
        System.out.println("Error: " + error);
    }
});
```

with REST library

JSON Library Support

```
String jsonString = "{\"k1\":\"v1\"," +
                    "\"k2\":null," +
                    "\"k3\":9," +
                    "\"k4\":{\"k5\":\"v5\"}}";
```

without JSON library

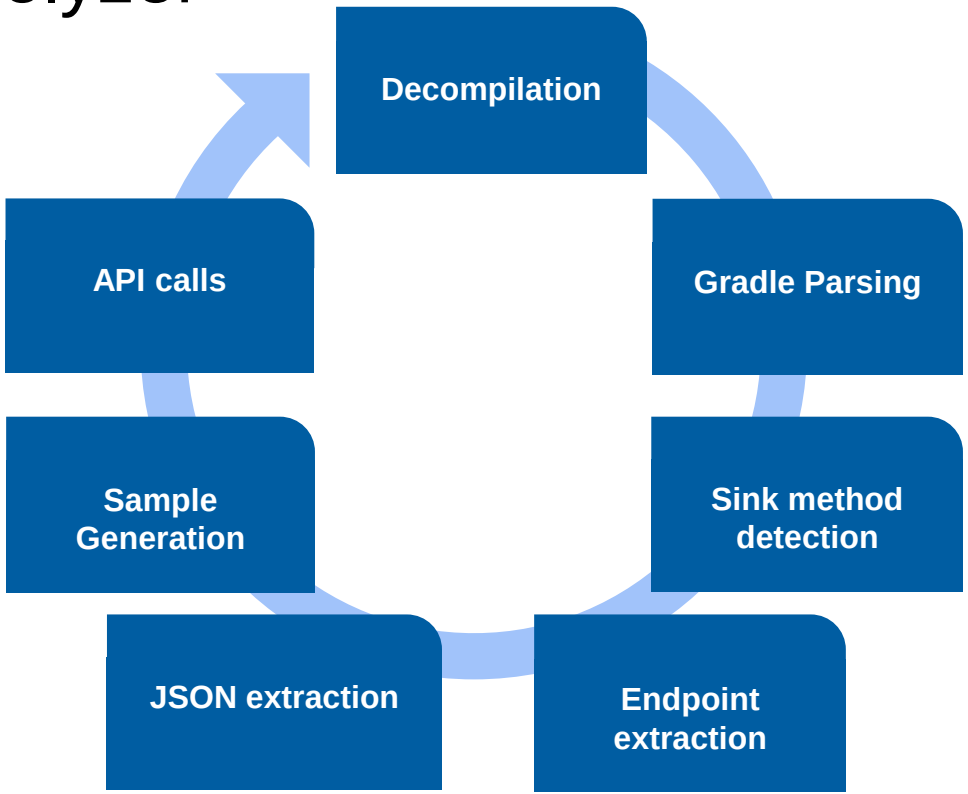
```
JSONObject jsonObject = new JSONObject();
try {
    jsonObject.put("k1", "v1");
    jsonObject.put("k2", JSONObject.NULL);
    jsonObject.put("k3", 9);
    JSONObject jsonObject2 = new JSONObject();
    jsonObject2.put("k5", "v5");
    jsonObject.put("k4", jsonObject2);
} catch (JSONException e) {
    e.printStackTrace();
}
```

with JSON library

Jandrolyzer

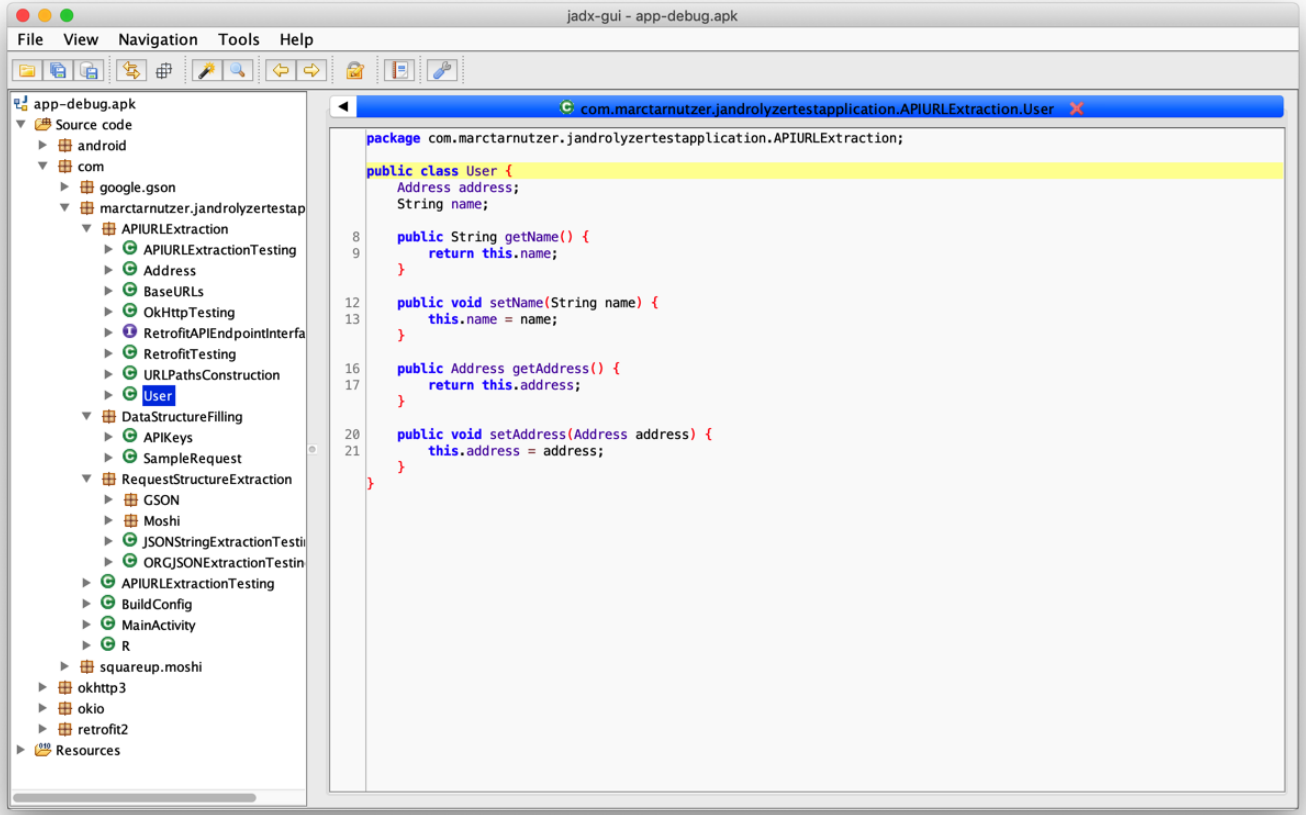
Introduction

Jandrolyzer

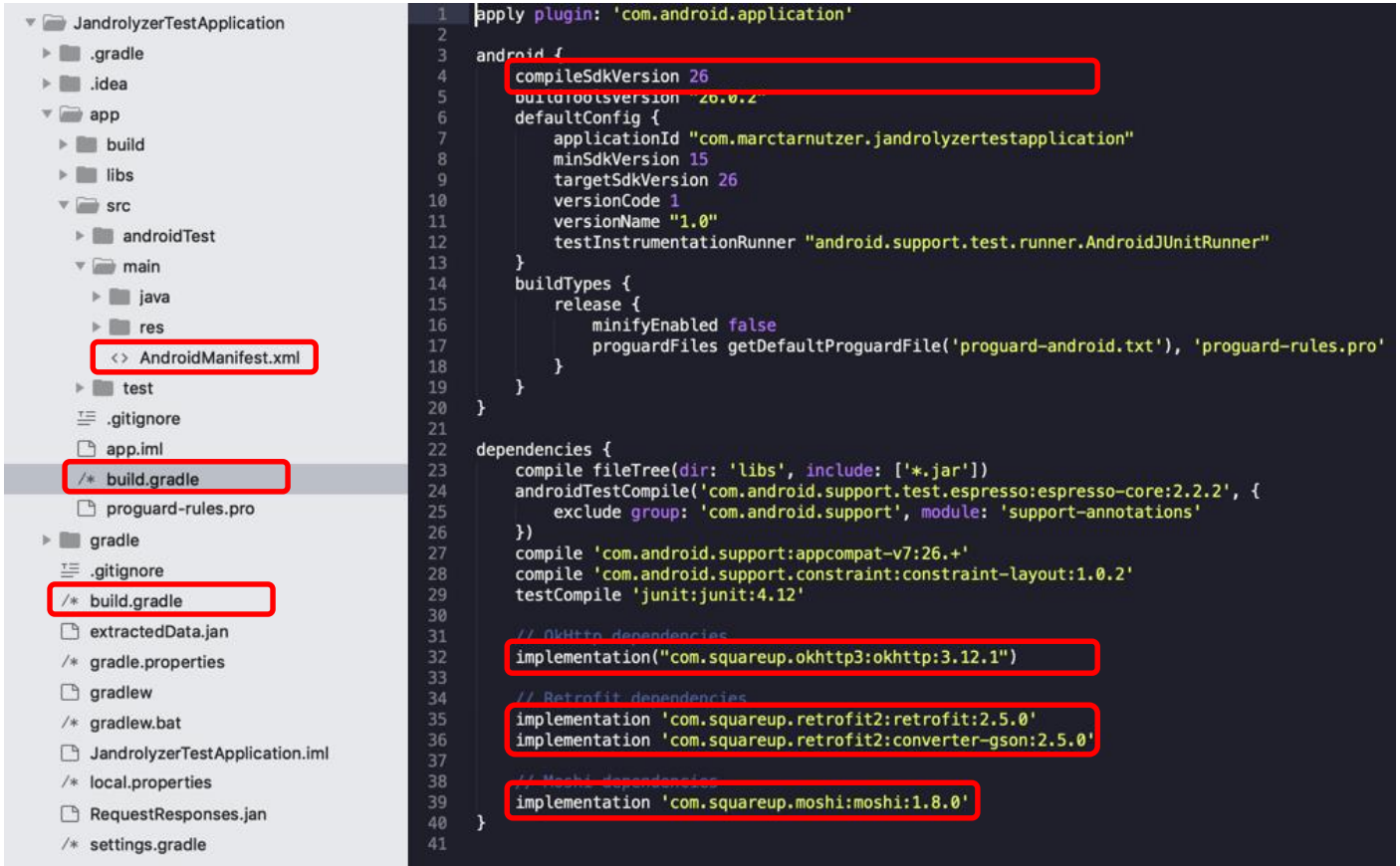


- Java.net
- OkHttp
- Retrofit
- Gson
- Moshi
- org.json

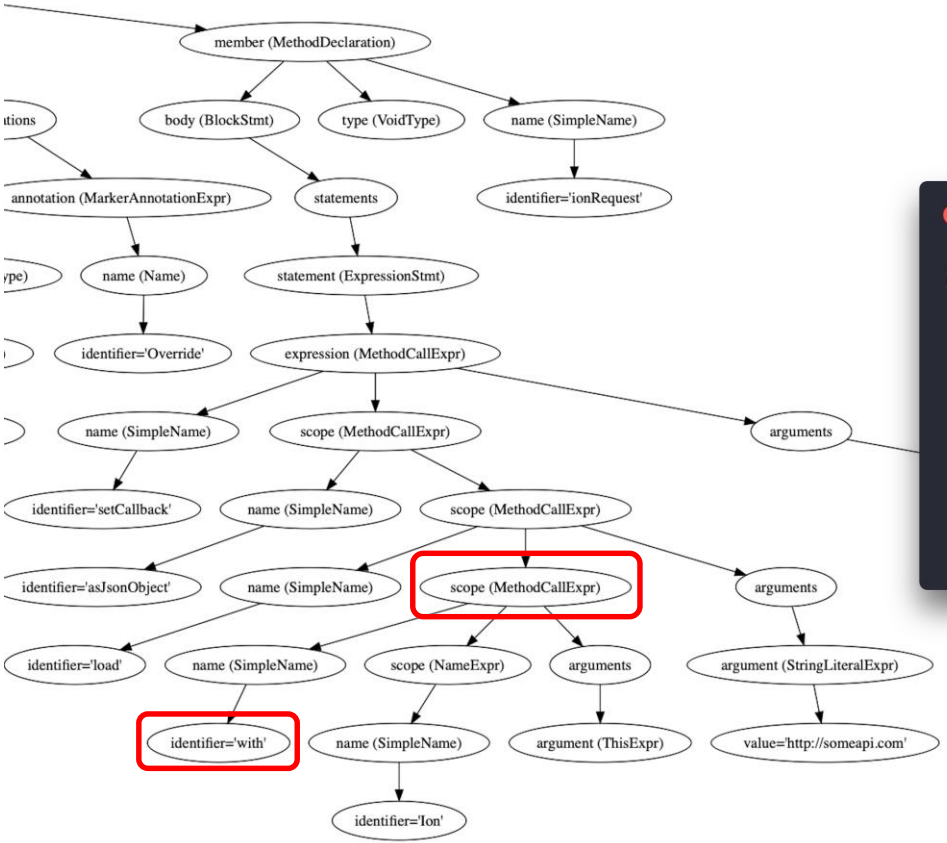
Analysis Step 1 / 7: Decompilation



Analysis Step 2 / 7: Gradle Parsing



Analysis Step 3 / 7: Sink method detection



com.koushikdutta.ion.builder.LoadBuilder

```
Ion with(this)
    .load("http://someapi.com")
    .asJsonObject()
    .setCallback(new FutureCallback<JsonObject>() {
        @Override
        public void onCompleted(Exception e, JsonObject result) {
            System.out.print("Result: " + result);
        }
    });
```

Analysis Step 4 / 7: Endpoint Extraction

interface **implementation**

```
Retrofit retrofit = new Retrofit.Builder()
    .baseUrl("http://retrofiturl.com/")
    .addConverterFactory(GsonConverterFactory.create())
    .build();

RetrofitAPIEndpointInterface rApiInt
        = retrofit.create(RetrofitAPIEndpointInterface.class);
```

http://oldapi.com/api/loadNewsFromOldAPI

http://retrofiturl.com/api/loadUser/<INTEGER>

http://retrofiturl.com/api/loadUsers

http://retrofiturl.com/api/createUser

interface **declaration**

```
public interface RetrofitAPIEndpointInterface {
    @GET("http://oldapi.com/api/loadNewsFromOldAPI")
    Call<Article> loadNewsFromOldAPI();

    @GET("api/loadUser/{id}")
    Call<User> loadUser(@Path("id") int userId);

    @GET("api/loadUsers")
    Call<List<User>> loadUsers(@Query("order") String order,
            @Query("position") String position);

    @POST("api/createUser")
    Call<User> createUser(@Body User user);
}
```

Analysis Step 5 / 7: JSON Extraction

```java
public void sampleReq() {
    String id = "AAAABBBBCCCC";
    updateUser(id);
}

private void updateUser(String id) {
    JSONArray jsonArray = new JSONArray();
    jsonArray.put("badge1");
    jsonArray.put("badge2");

    JSONObject jsonObject = new JSONObject();
    try {
        jsonObject.put("user_id", id);
        jsonObject.put("VIP", true).put("score", 1);
        jsonObject.put("badges", jsonArray);
    } catch (JSONException e) {
        e.printStackTrace();
    }

    ...
}
```

```json
{
    "user_id":"AAAABBBBCCCC",
    "VIP":true,
    "score":1,
    "badges":[
        "badge1",
        "badge2"
    ]
}
```

Analysis Step 6 / 7: Sample Generation

extracted **URLs & JSON**

```
https://someservice.com/api/registerDevice?api_key=<STRING>

{
    "device_id": "AAAABBBBCCCC",
    "api_key": "<STRING>"
}
```

extracted **variables**

```
{"refreshToken":["REFRESHTOKEN"]}
{"accessToken":["ACCESSTOKEN"]}
{"apiKey": "APIKEY"]}
{"id":["userId"]}

...
```

Jaro-Winkler similarity: 0.8944…

final **result**

```
https://someservice.com/api/registerDevice?api_key=APIKEY

{
    "device_id": "AAAABBBBCCCC",
    "api_key": "APIKEY"
}
```

Analysis Step 7 / 7: API Calls

```
https://api.com/path
https://api.com/path2
http://someservice.com/some/path
http://someservice.com/api/users
http://otherservice.com/api/news

...
```


```
{"k":"v","k2":91,"k3":null,"k4":9}
{"test":10}
{"name":"test"}
{"address":{"street":"sample street","number":118},"name":"Bob"}

...
```

RQ2:

What ***data*** do mobile apps transmit through web communication channels?

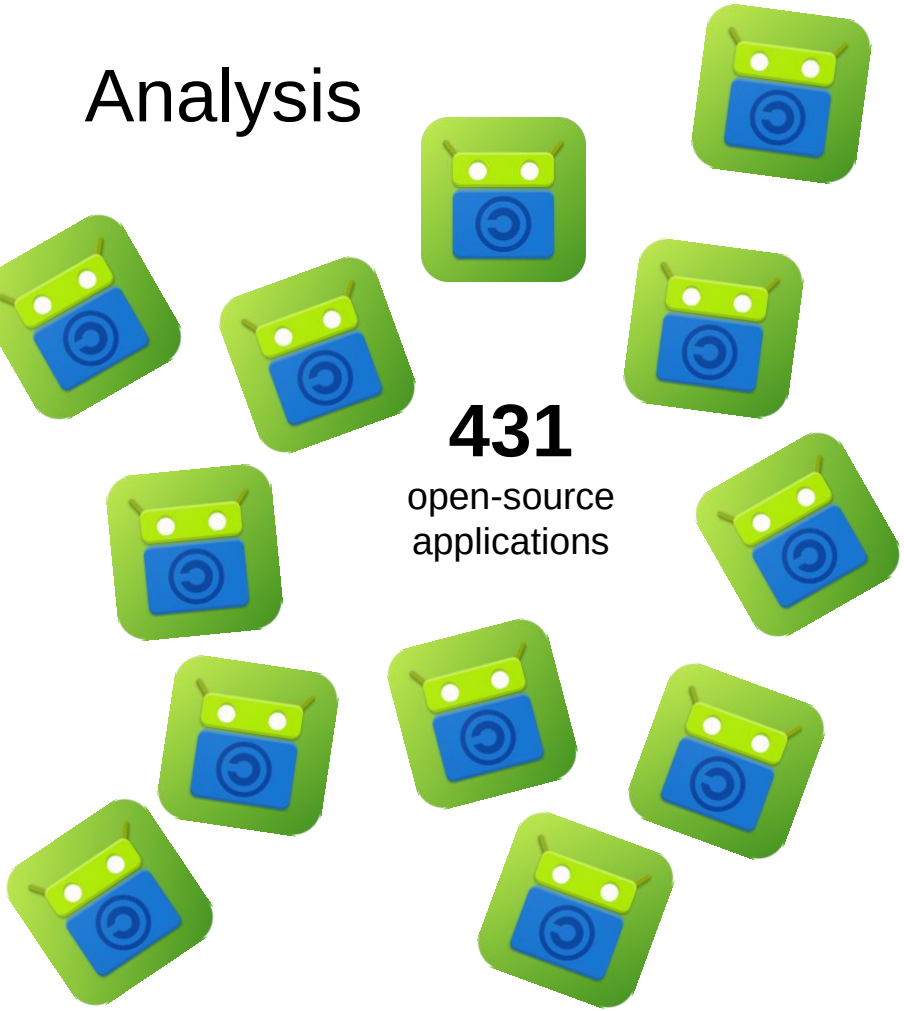
RQ3:

What are the ***differences*** between open-source and closed-source apps in regard to web communication?

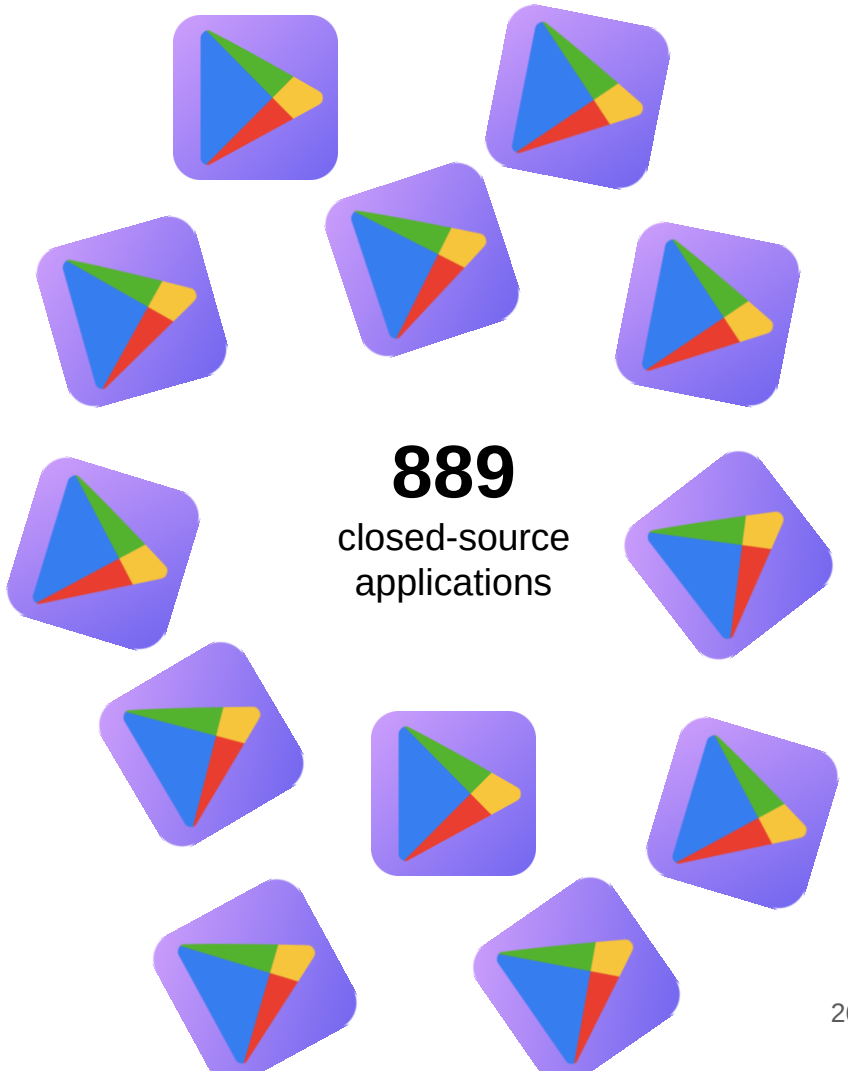
Jandrolyzer

Results

Analysis



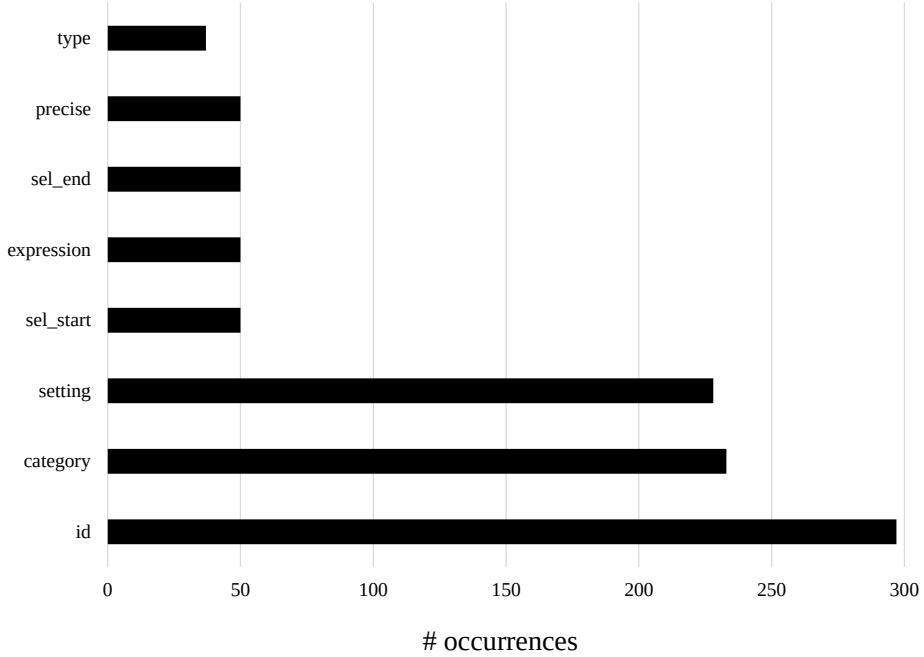
431
open-source
applications



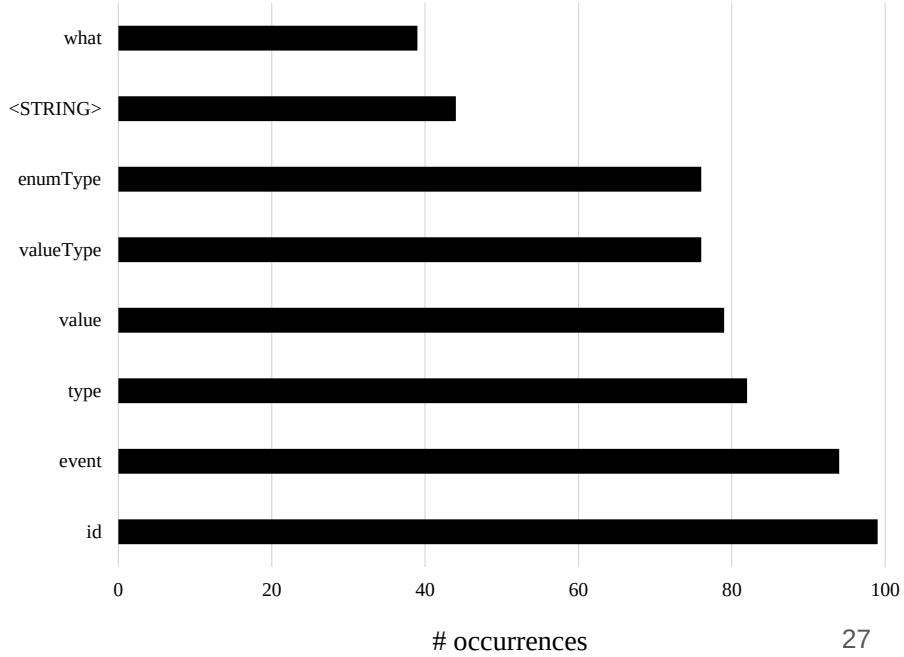
889
closed-source
applications

Top Query and JSON Keys

open-source projects

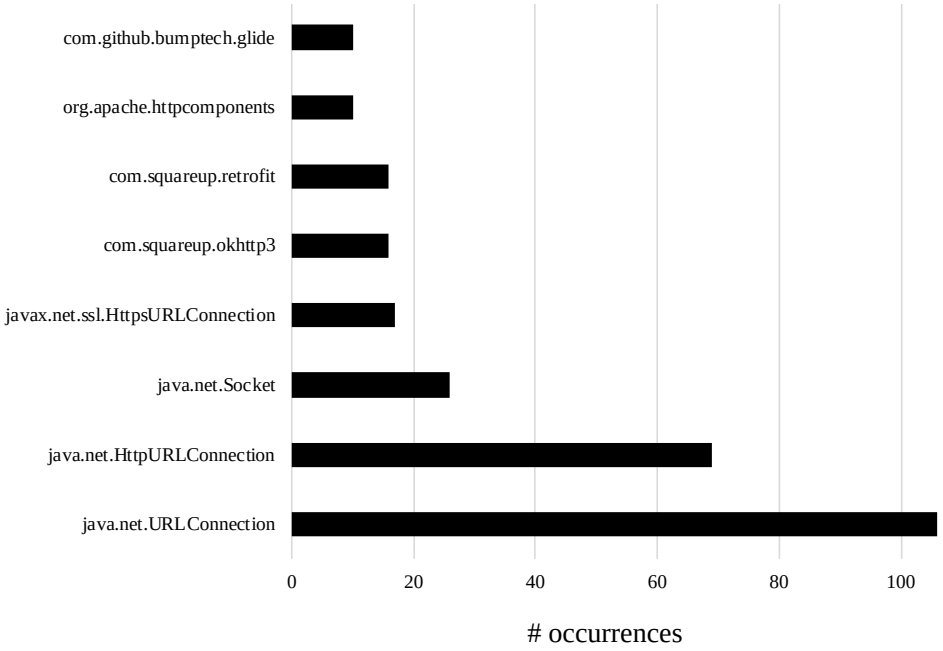


closed-source projects

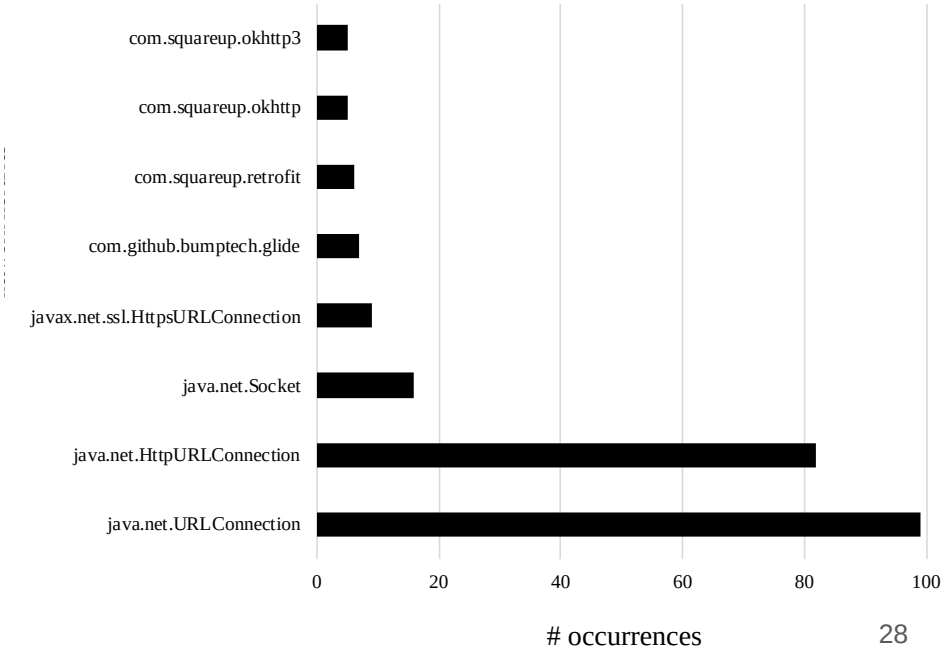


Library Usage

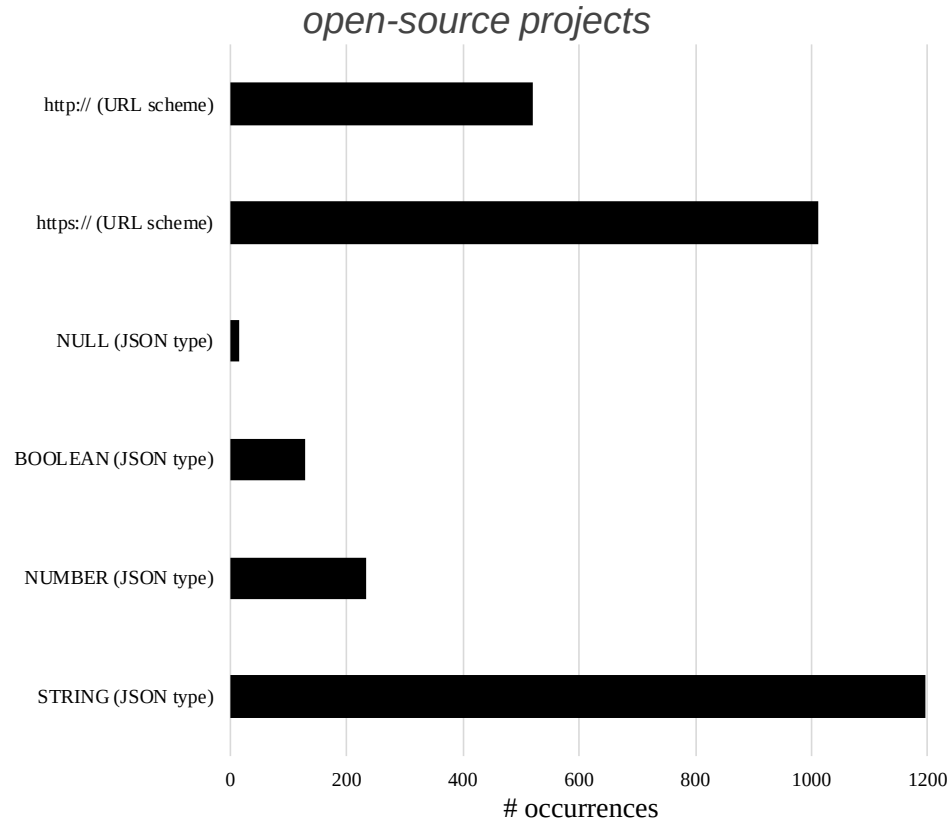
open-source projects

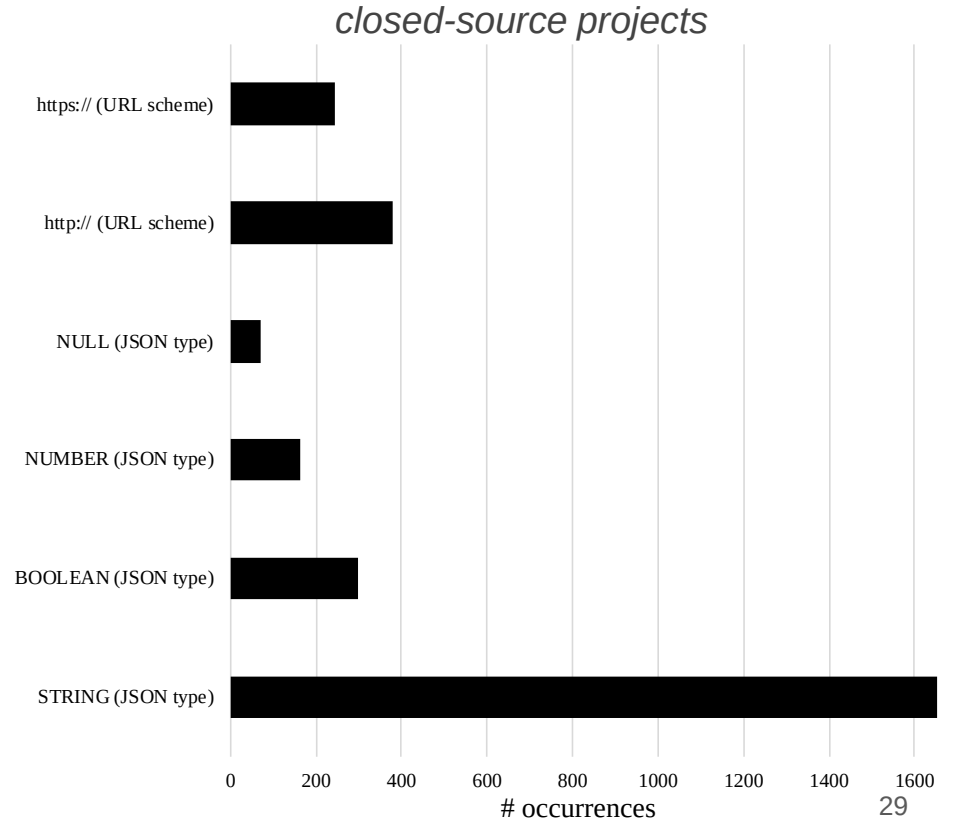


closed-source projects



JSON Types and URL Schemes





RQ4:

What configurations apply to ***API endpoint servers*** found in the wild?

Endpoint Server Analysis – What We Found

Outdated server software with known security vulnerabilities
(web server daemons, language parsers & interpreters)

Web views using HTTP protocol
(unprotected communication)

Disclosures of server configuration
(internal error message leaks, …)

Freely accessible APIs
(which are intended for private use)

Hardcoded sensitive information
(API keys and other credentials)

Shell commands in request body (!)
(does not need any further explanations)

Jandrolyzer

Demo

Future Work

Jandrolyzer improvements

more {speed, library support, strategies}

More comprehensive static analyses

more applications, security-related investigations

More comprehensive dynamic analyses

accurate server assessments (OS, web server, programming languages)
+ server port testing (by using default passwords)

Conclusions

Decompilation with JADX (great tool, obfuscation, etc.)

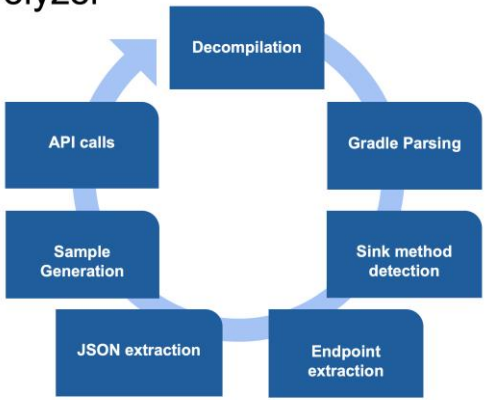
JavaParser (great tool, memory problems, symbol resolving bugs, etc.)

Open-source vs. closed-source apps (transmitted data, libraries, security, ads)

Outdated software in the wild

Implementation variations

Jandrolyzer



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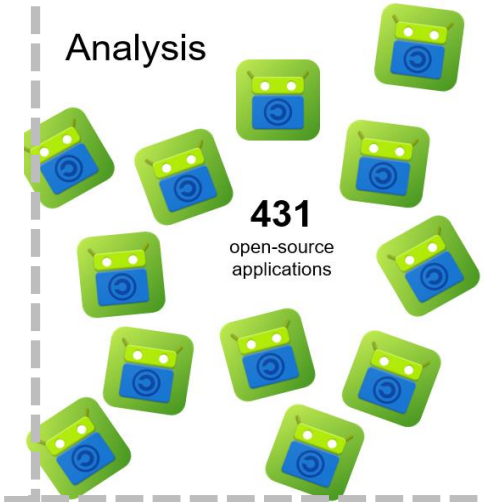
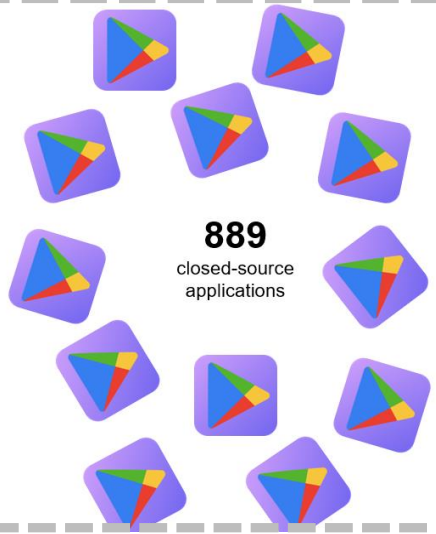
Analysis





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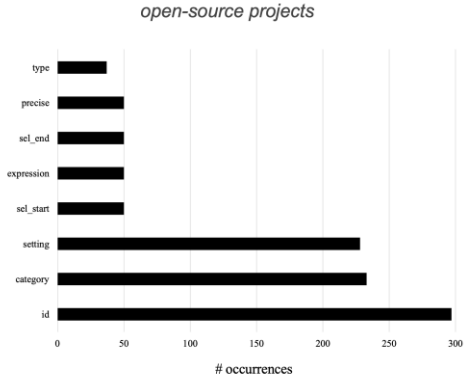

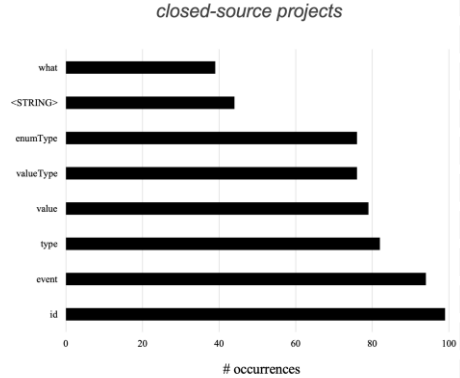

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