HACKING THE BRAIN

Customize Evil Protocol to Pwn an SDN Controller

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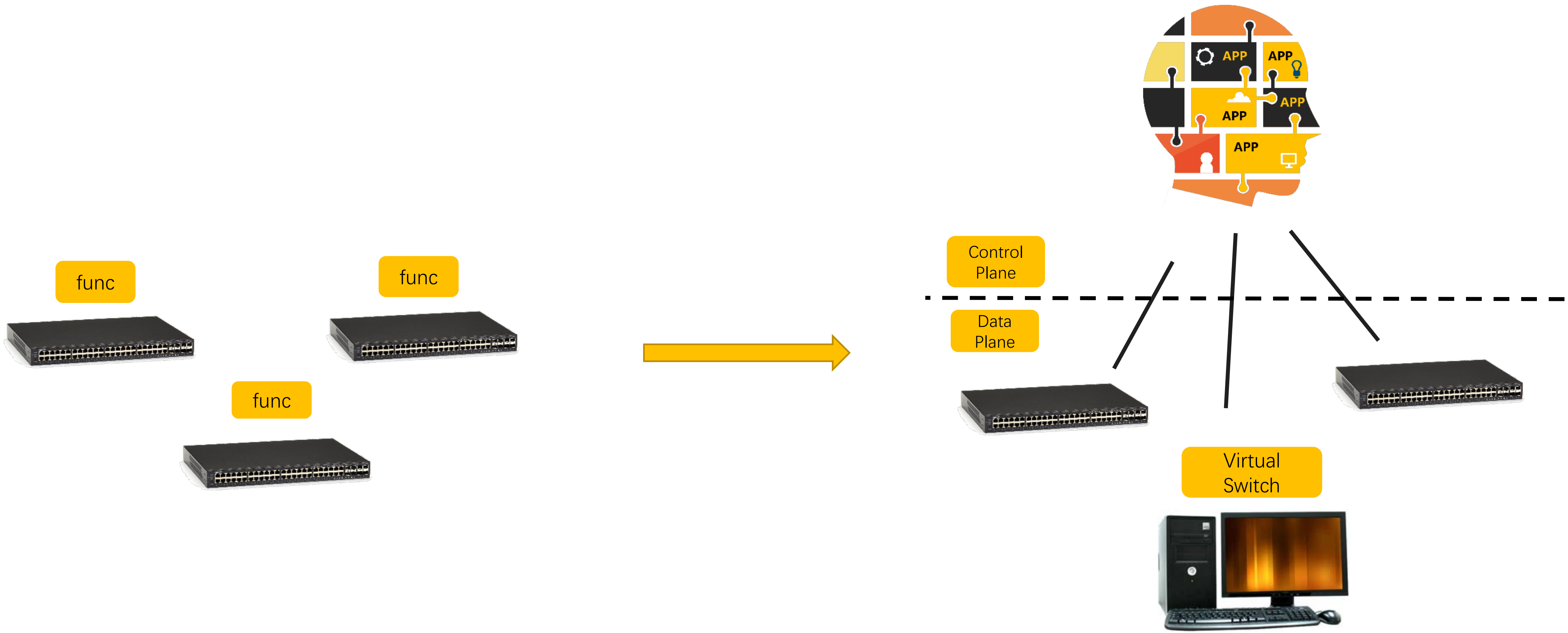
PENNSTATE

What’s SDN?



func

func

func

Control Plane

Data Plane

Virtual Switch

Software-Defined Networking (SDN) is an emerging architecture that decouples the network control and forwarding functions.

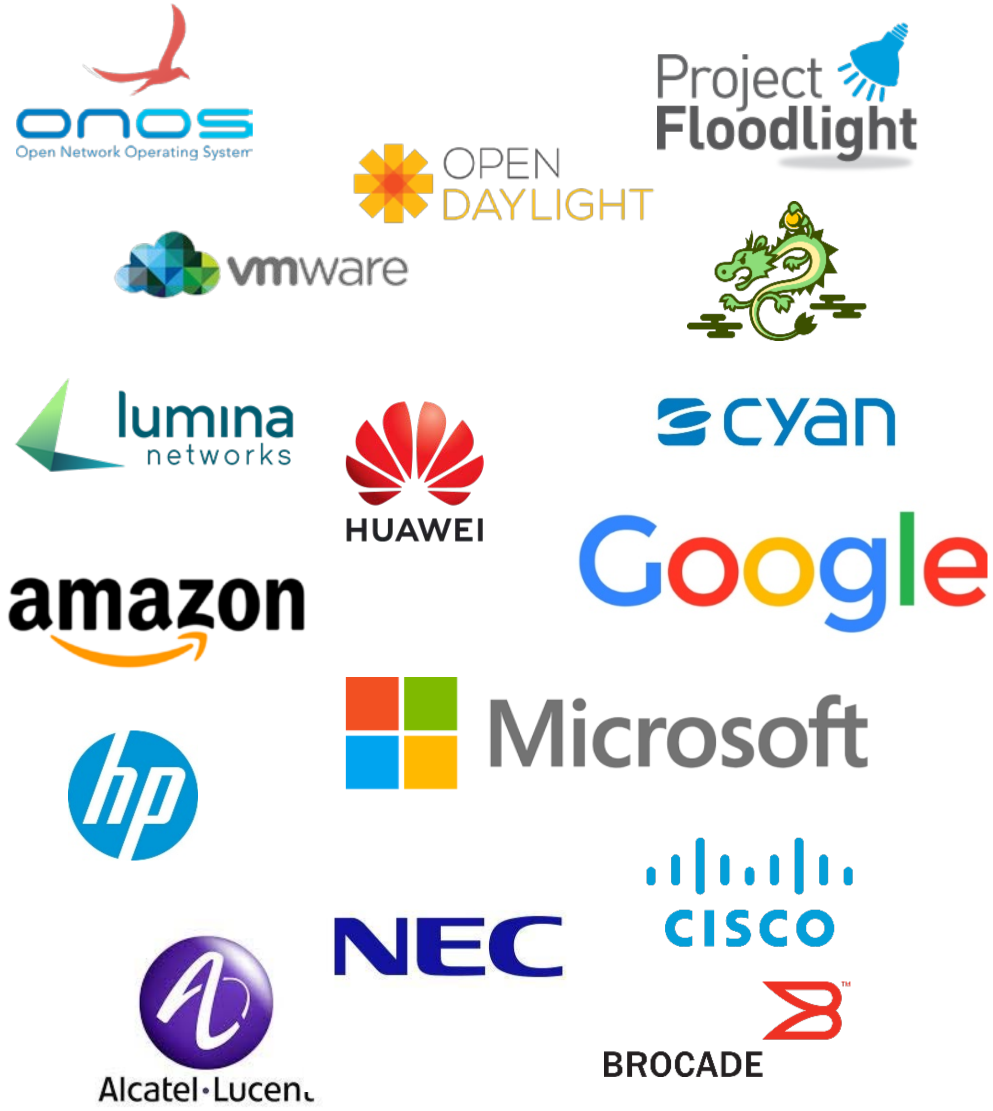
What’s SDN Like Today?

Who are contributing?

- More than 15 popular controllers.
- More than 3000 open source SDN projects.

Who are using?

- Data Center
- IDC
- Telecom
- …



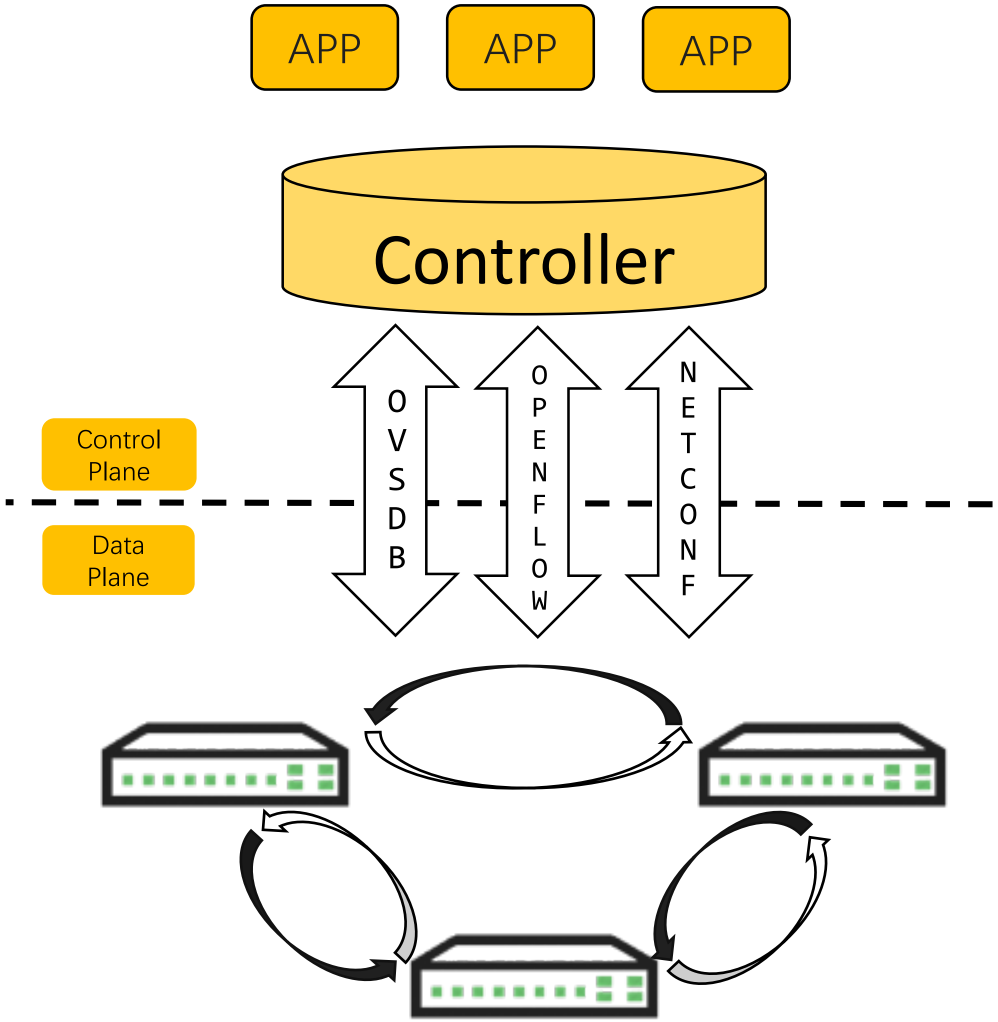
Overview of SDN Attacks

Attack on Control Plane

- Topology tampering
- Control channel flooding

Attack on Data Plane

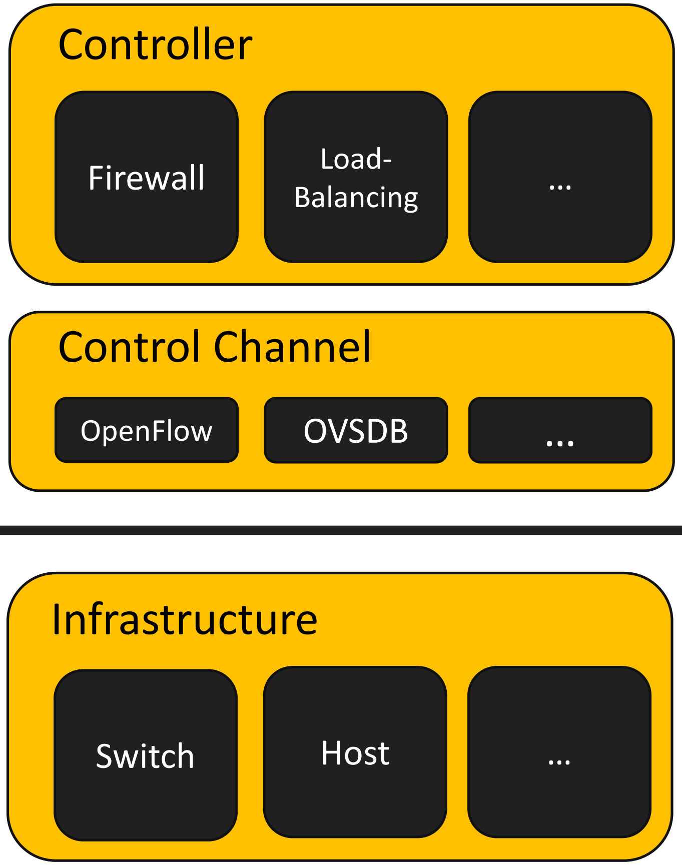
- Switch OS Hacking
- TCAM Flooding



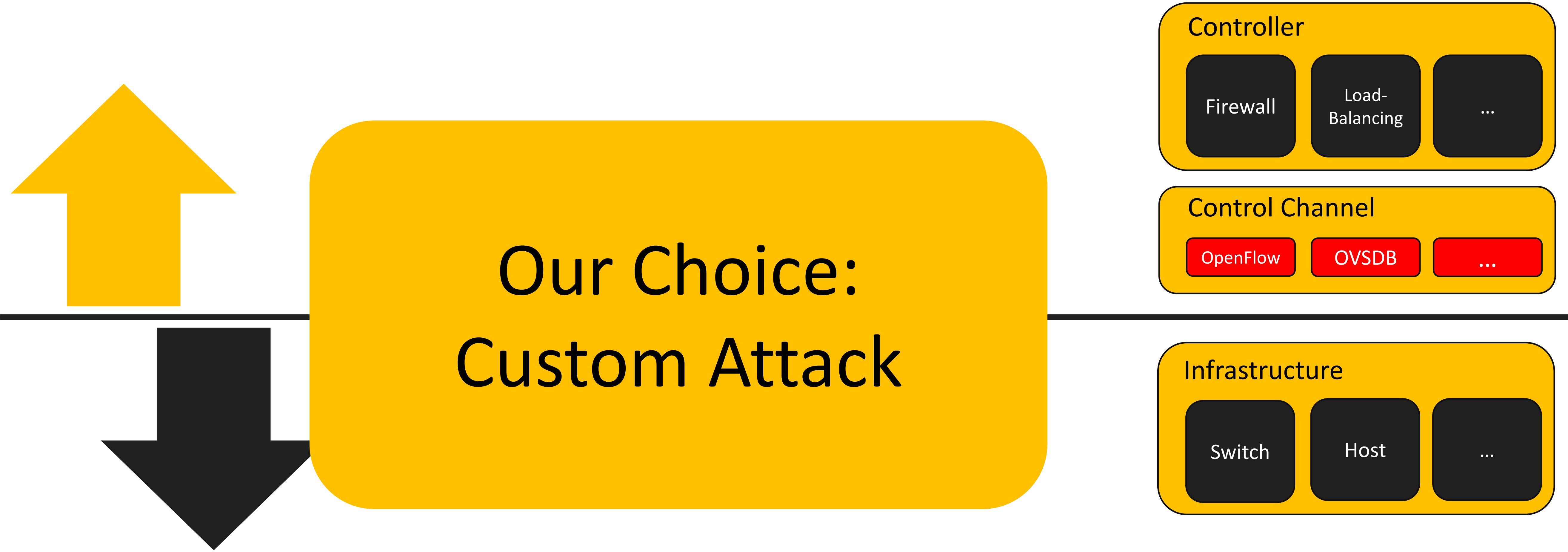
Pwn It Like A Hacker?

Software-Defined Networks

Decoupled Control Plane and Data Plane



Pwn It Like A Hacker?

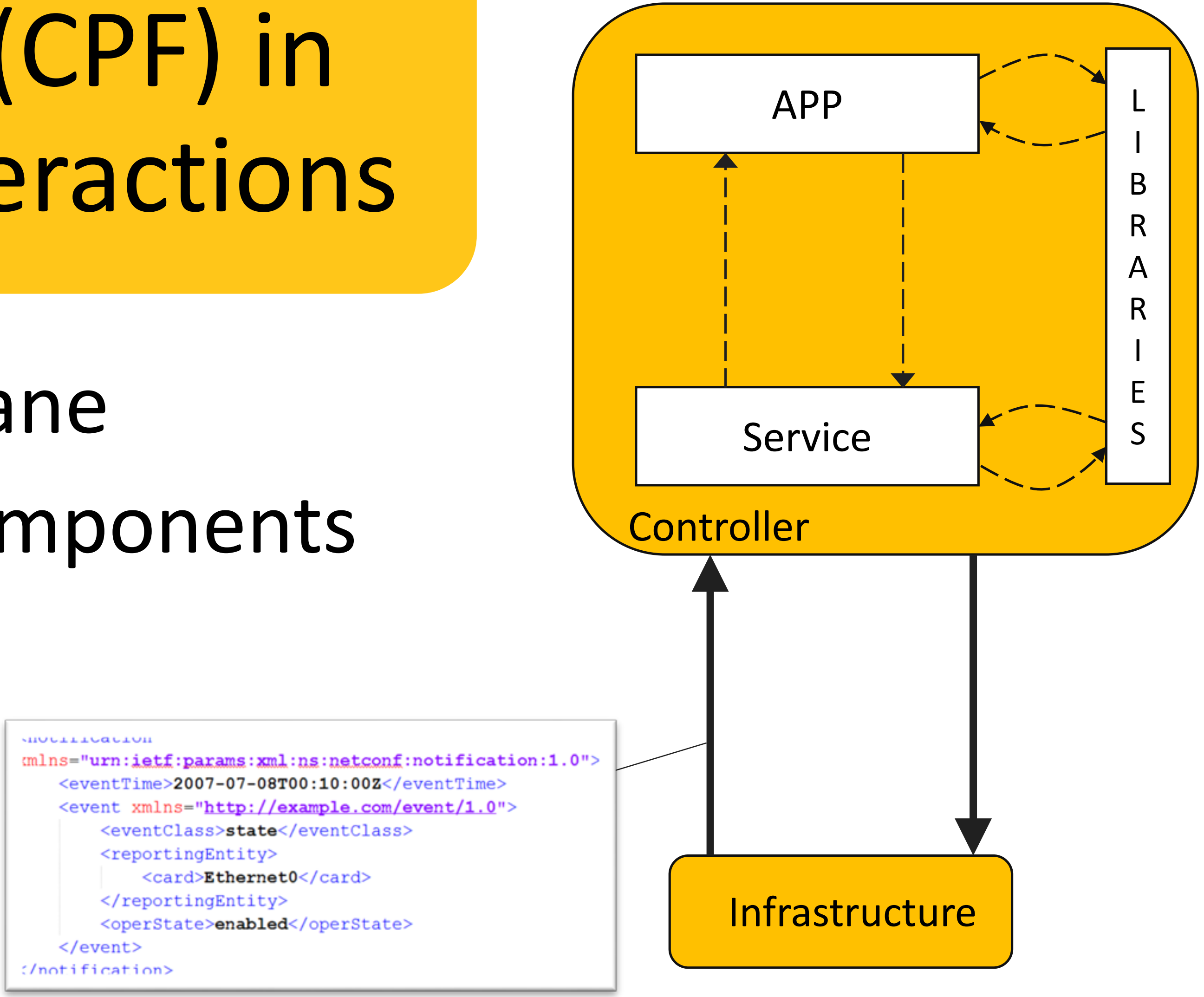


Our Choice:
Custom Attack

Custom Attack

Custom Protocol Field (CPF) in legitimate protocol interactions

- CPF is controlled by data plane
- CPF will be processed by components in the controller



```
<notification
xmlns="urn:ietf:params:xml:ns:netconf:notification:1.0">
    <eventTime>2007-07-08T00:10:00Z</eventTime>
    <event xmlns="http://example.com/event/1.0">
        <eventClass>state</eventClass>
        <reportingEntity>
            <card>Ethernet0</card>
        </reportingEntity>
        <operState>enabled</operState>
    </event>
</notification>
```

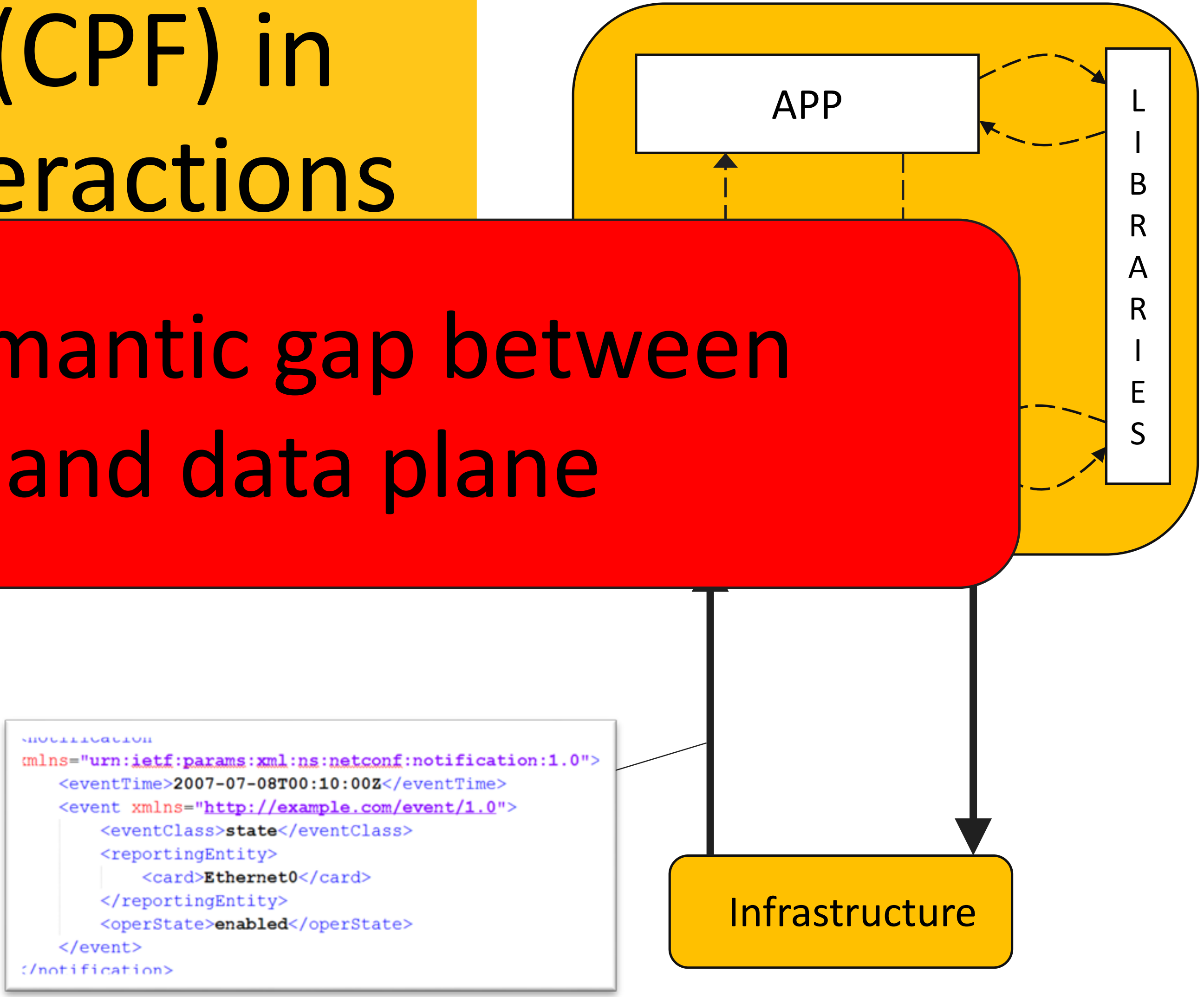
Custom Attack

Custom Protocol Field (CPF) in legitimate protocol interactions

- C
- C

in the controller

CPF results in a semantic gap between control plane and data plane



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    </event>
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```

What Can It Cause?

Execute Arbitray SDN Commands

Steal Confidential Data

Crash/Disrupt Service

Disable Network Function

...

Threat Model

We do NOT assume that hackers can have network access to SDN controllers or SDN applications

Control channel is well protected by SSL/TLS

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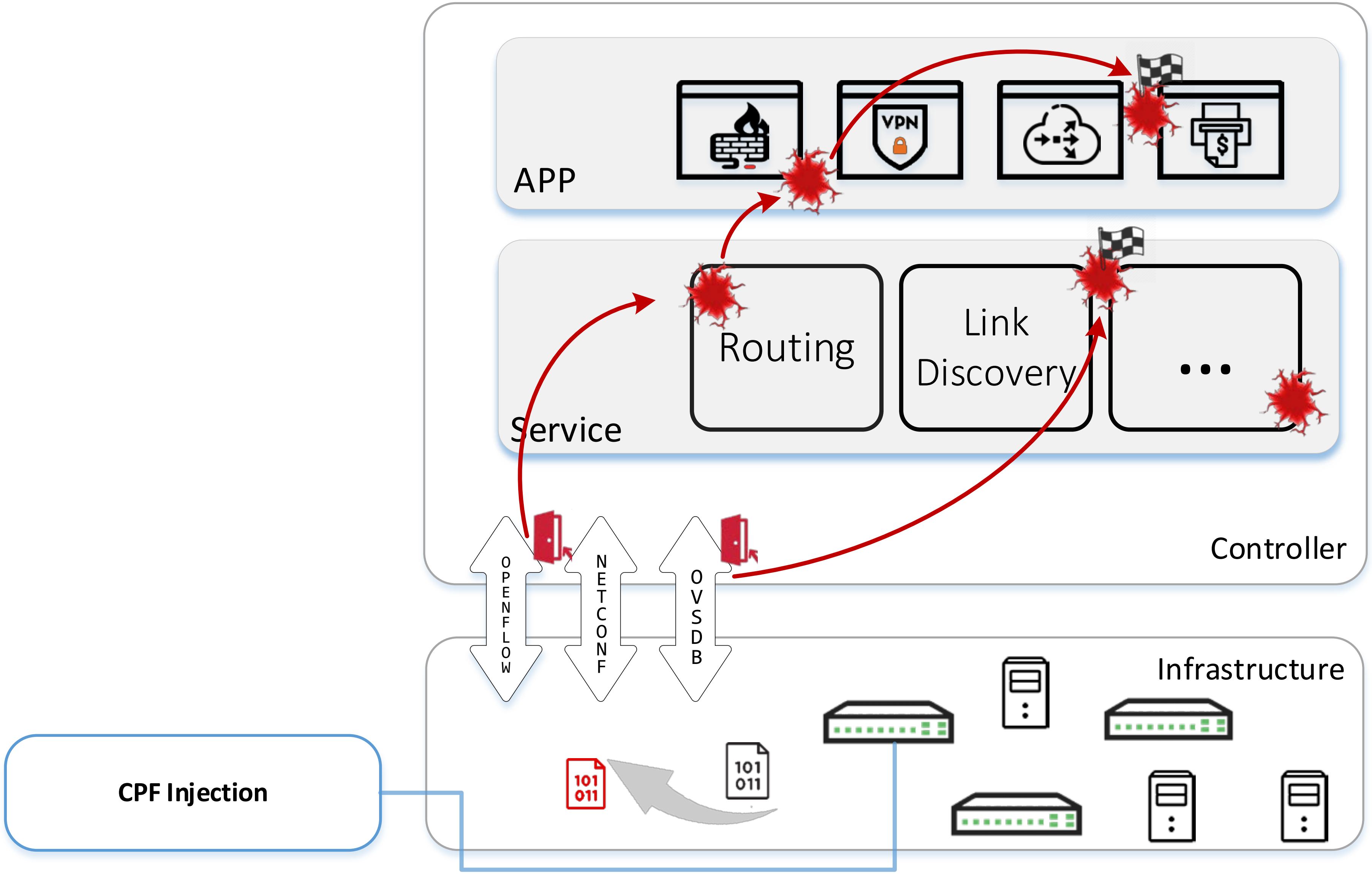
Control channel is well protected by SSL/TLS

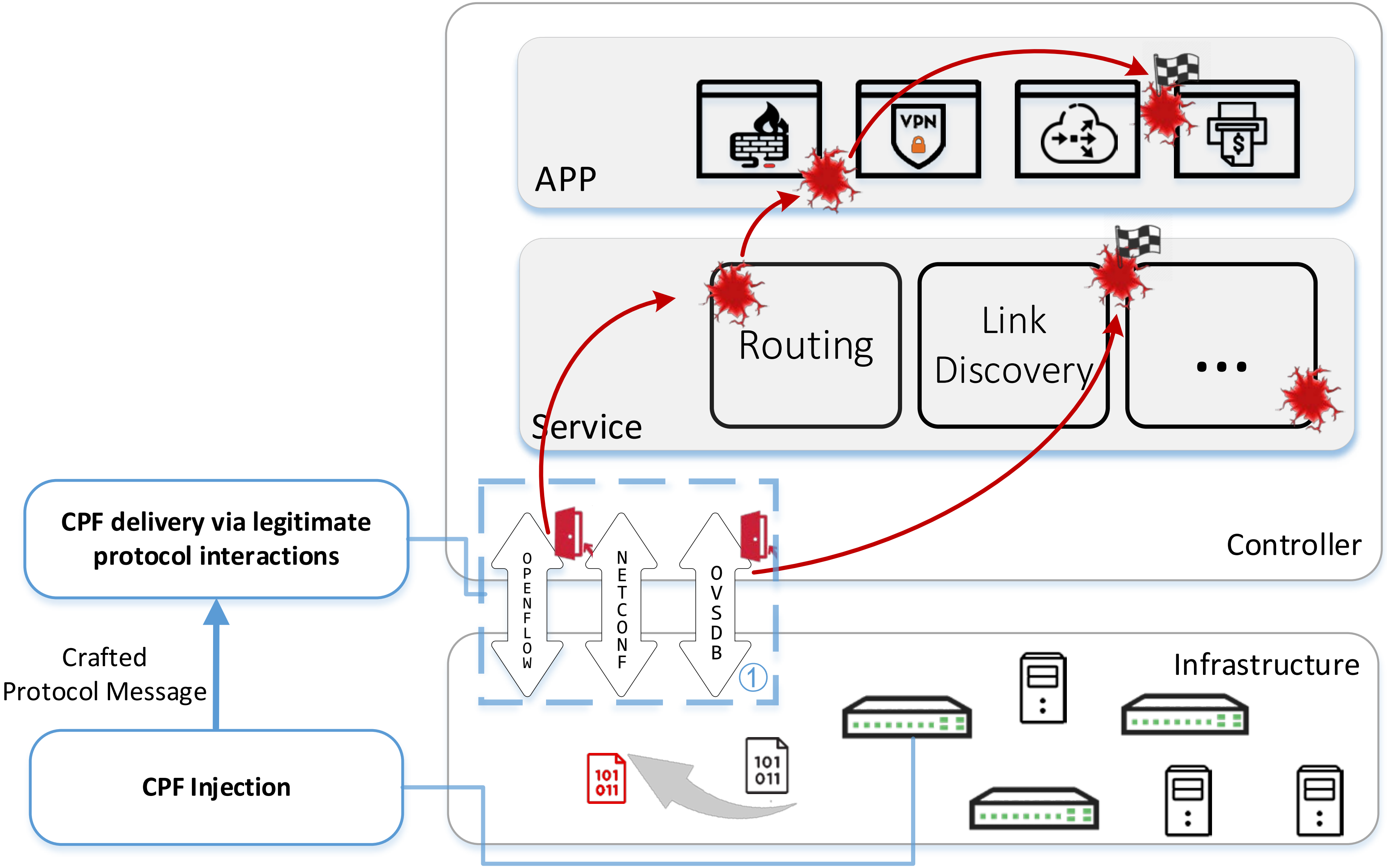
A compromised host[1] or switch[2]

[1] exploitable if the target network is configured with in-band control.
[2] Switches are vulnerable to multiple remote attacks (e.g., Buffer Overflow[CVE-2016-2074]).

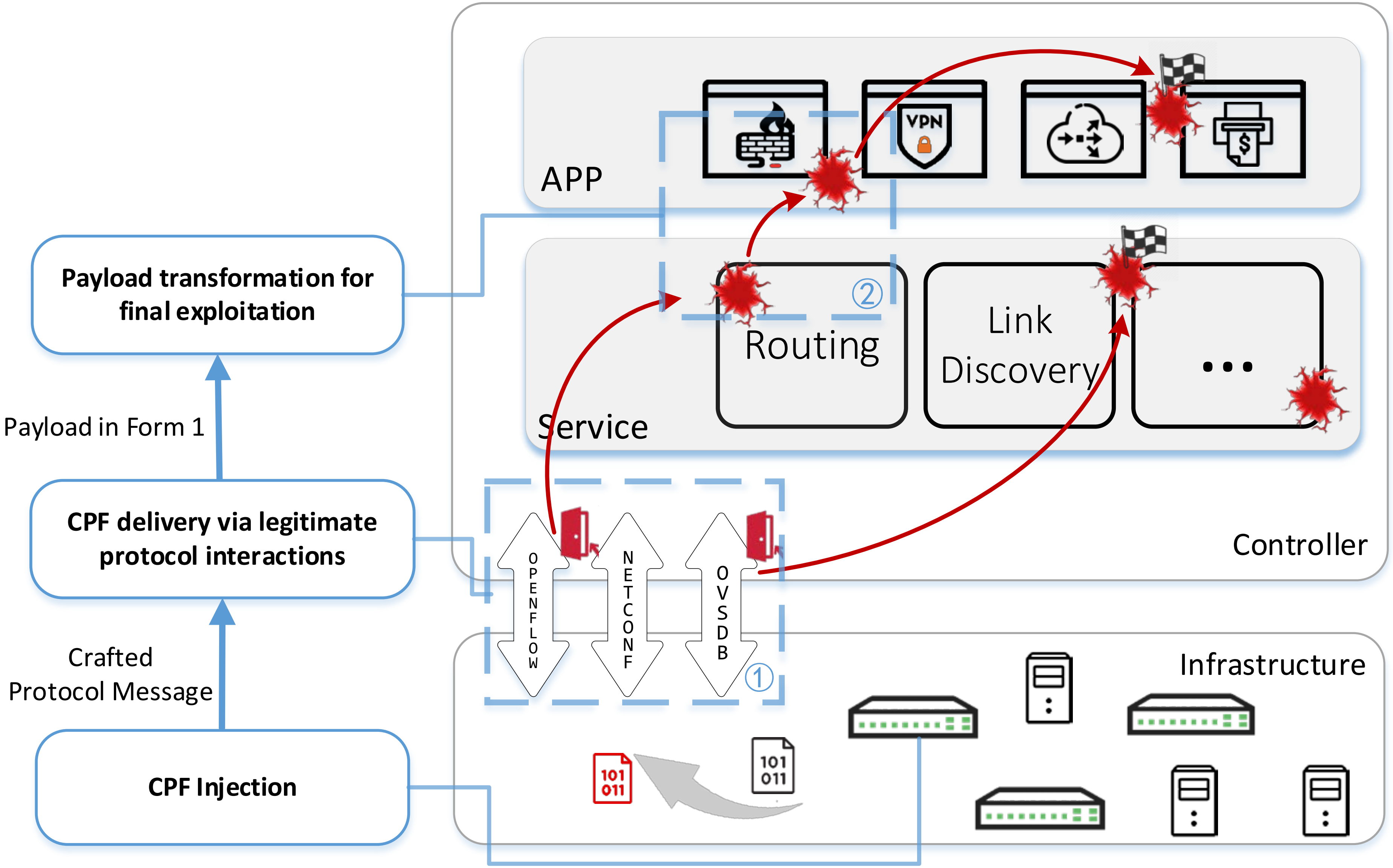
Attack Workflow



Attack Workflow



Attack Workflow



Payload transformation for final exploitation

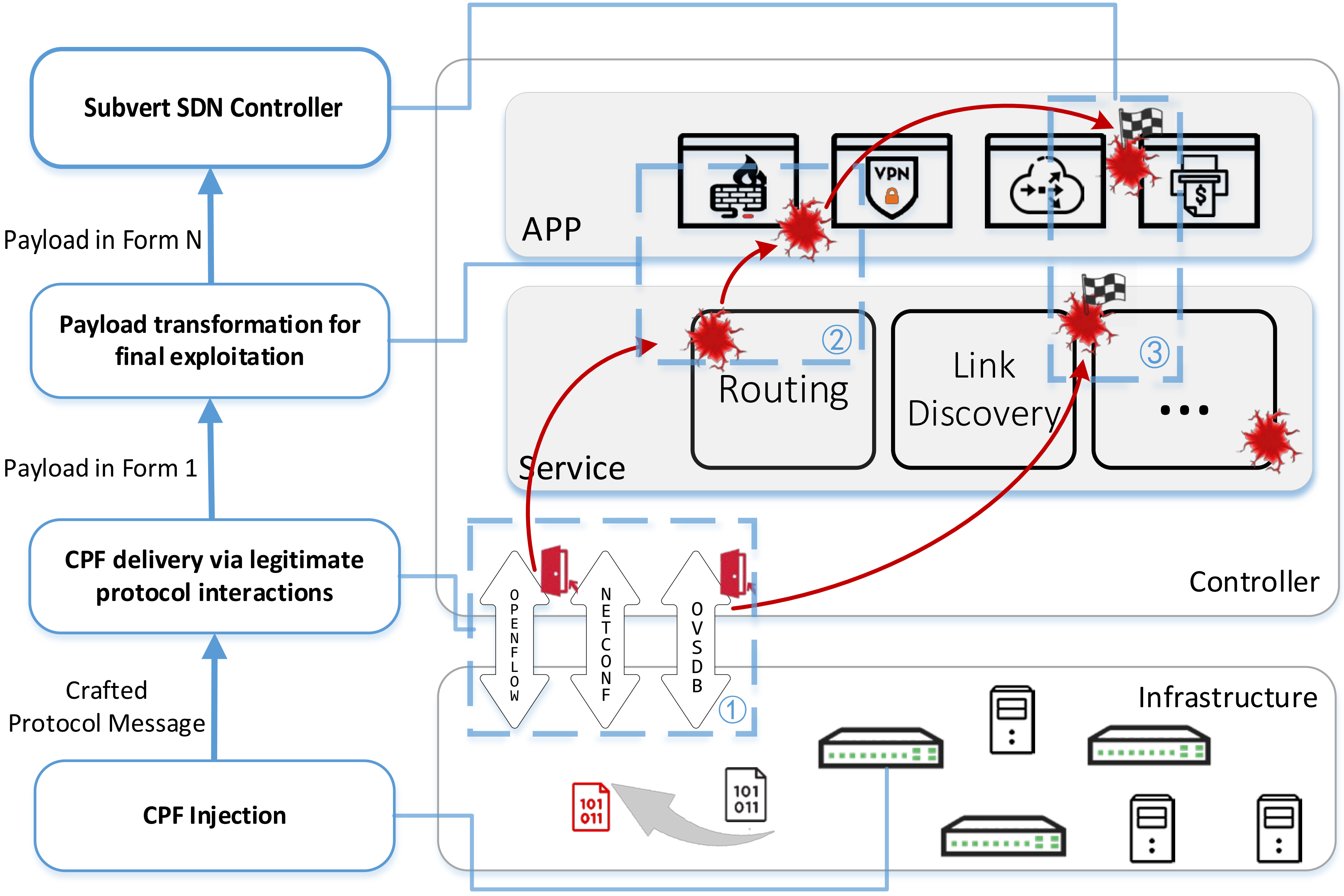
Payload in Form 1

CPF delivery via legitimate protocol interactions

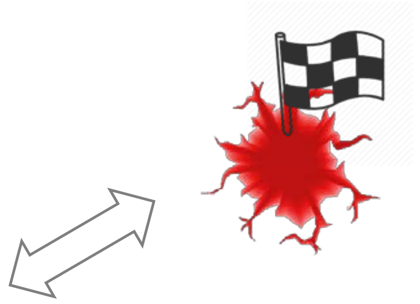
Crafted Protocol Message

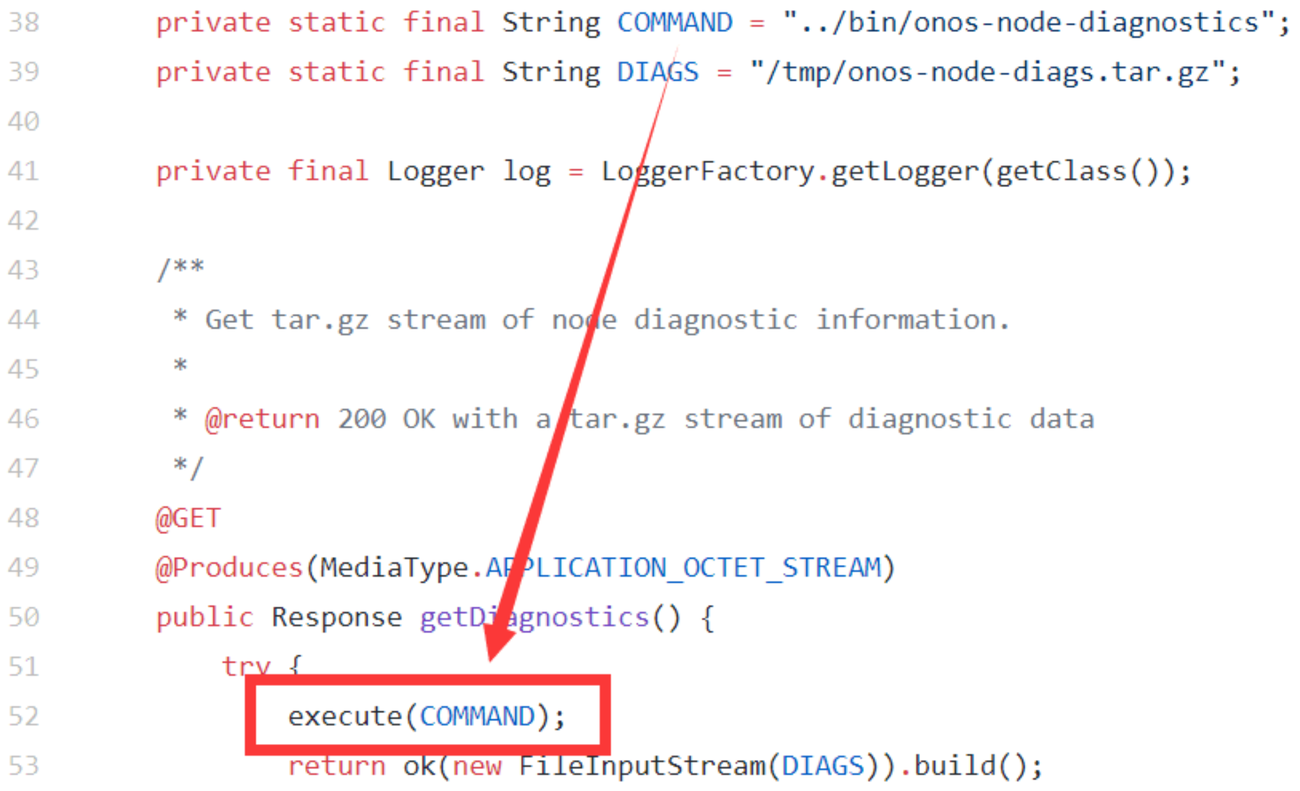
CPF Injection

Attack Workflow



Hack Something Real!



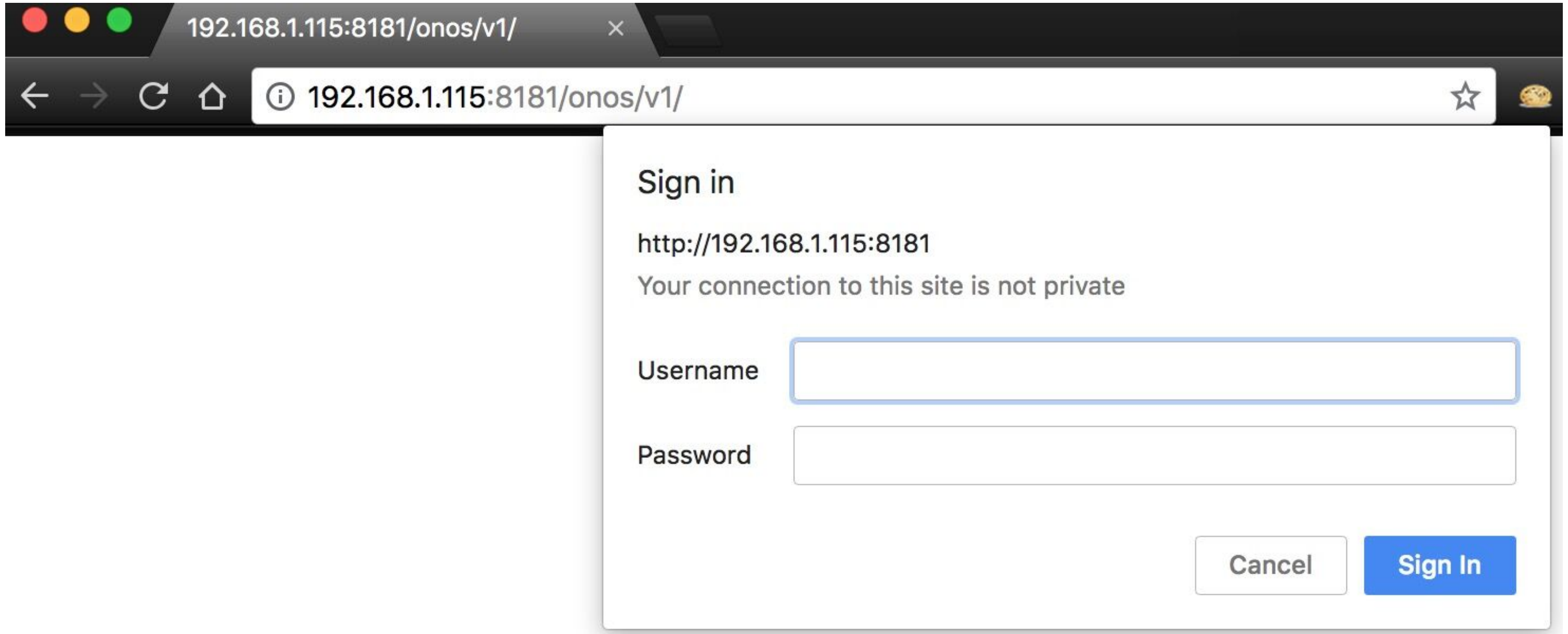


```
    private static final String COMMAND = "../bin/onos-node-diagnostics";
    private static final String DIAGS = "/tmp/onos-node-diags.tar.gz";

    private final Logger log = LoggerFactory.getLogger(getClass());

    /**
     * Get tar.gz stream of node diagnostic information.
     *
     * @return 200 OK with a tar.gz stream of diagnostic data
     */
    @GET
    @Produces(MediaType.APPLICATION_OCTET_STREAM)
    public Response getDiagnostics() {
        try {
            execute(COMMAND);
            return ok(new FileInputStream(DIAGS)).build();
```

Hack Something Real!



192.168.1.115:8181/onos/v1/

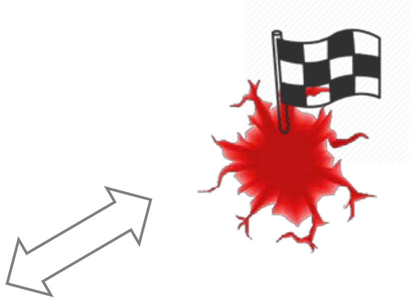
Sign in

http://192.168.1.115:8181

Your connection to this site is not private

Username

Password



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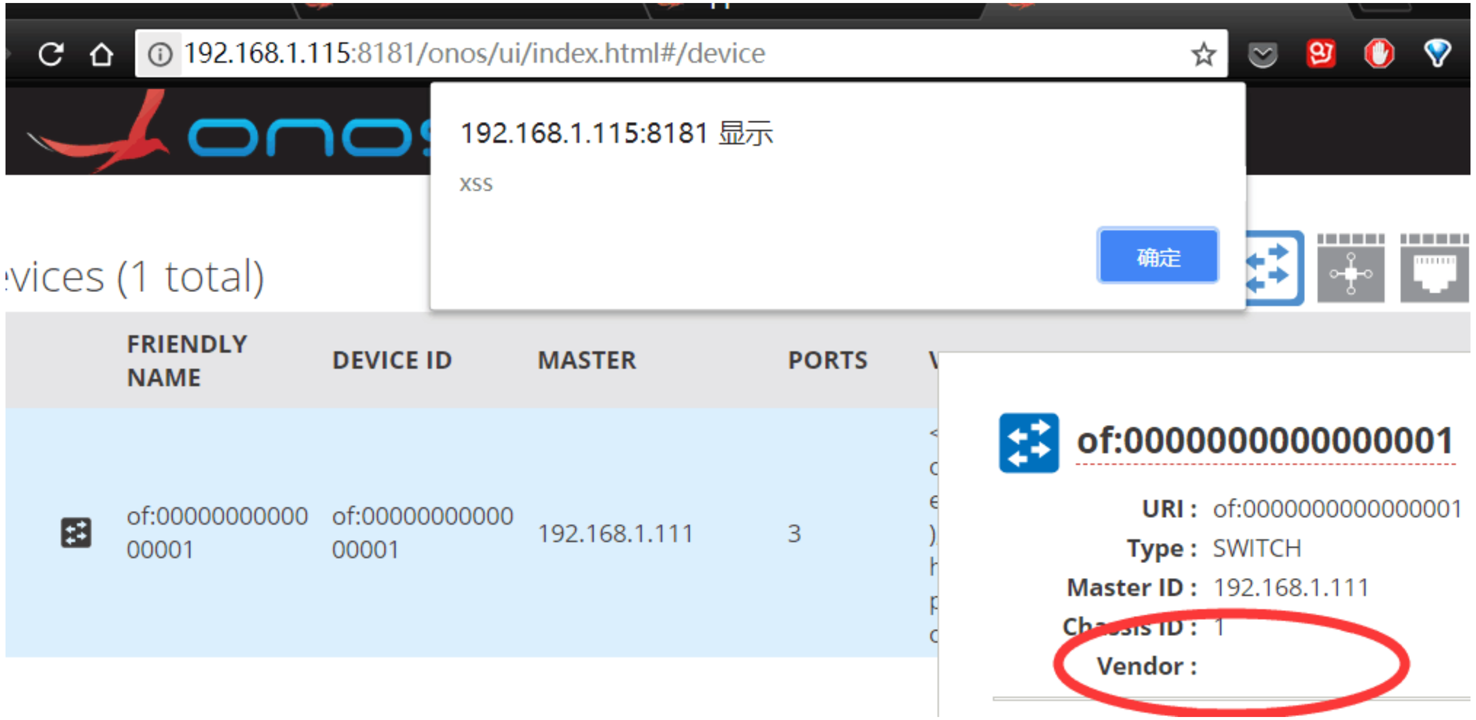


192.168.1.115:8181/onos/ui/index.html#/device

192.168.1.115:8181 显示

xss

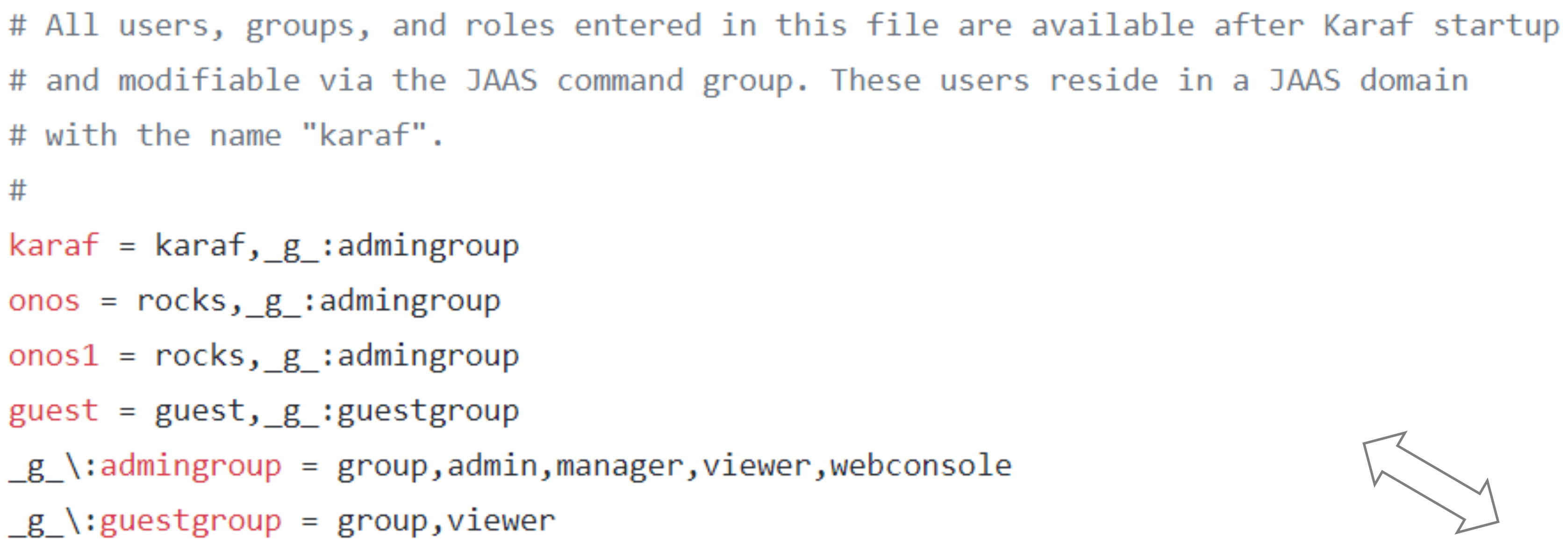
vices (1 total)

	FRIENDLY NAME	DEVICE ID	MASTER	PORTS	V
	of:0000000000000001	of:0000000000000001	192.168.1.111	3	

of:0000000000000001

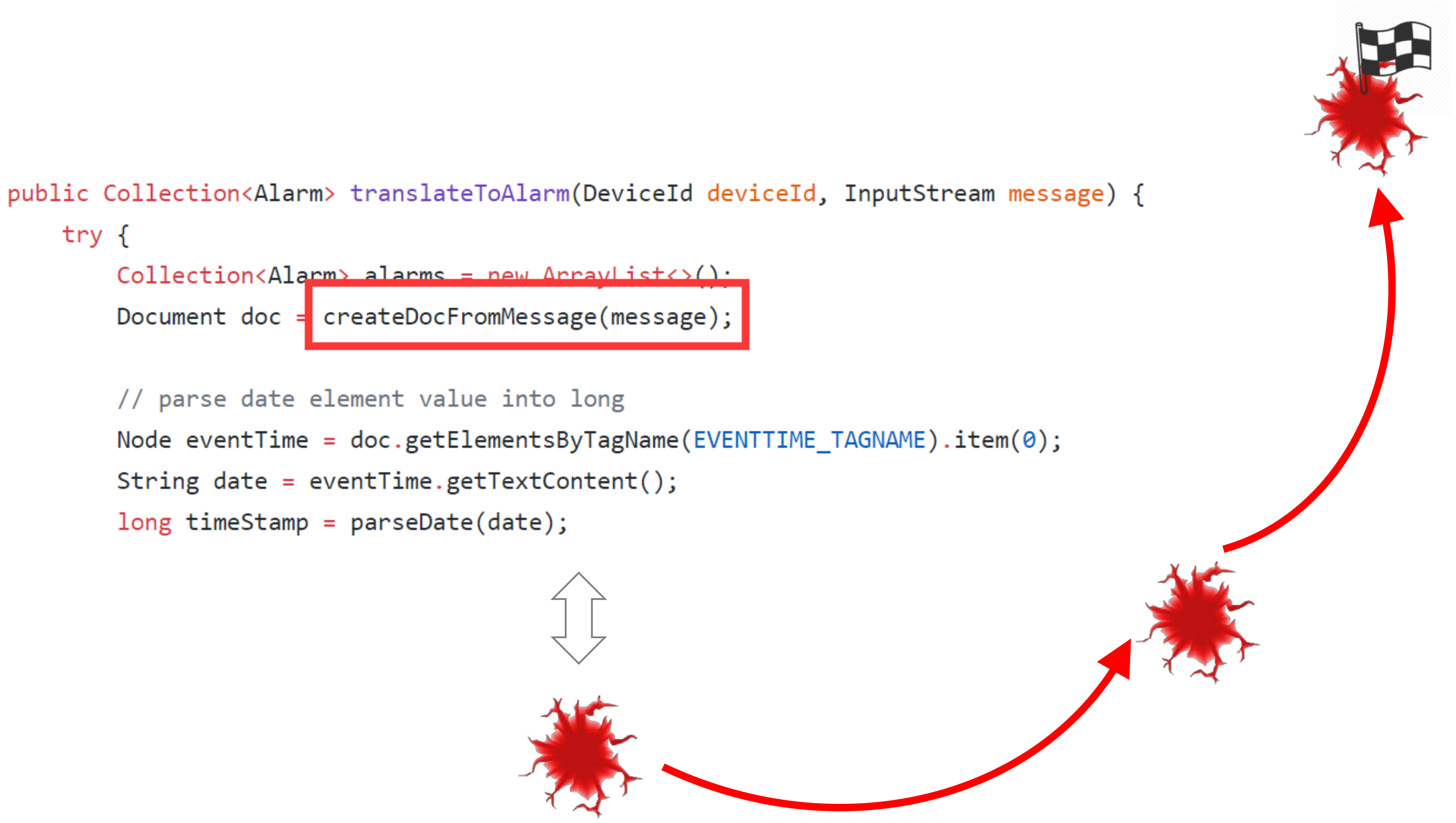
URI : of:0000000000000001
Type : SWITCH
Master ID : 192.168.1.111
Chassis ID : 1
Vendor :

Hack Something Real!



```
# All users, groups, and roles entered in this file are available after Karaf startup
# and modifiable via the JAAS command group. These users reside in a JAAS domain
# with the name "karaf".
#
karaf = karaf,_g_:admingroup
onos = rocks,_g_:admingroup
onos1 = rocks,_g_:admingroup
guest = guest,_g_:guestgroup
_g_\:admingroup = group,admin,manager,viewer,webconsole
_g_\:guestgroup = group,viewer
```

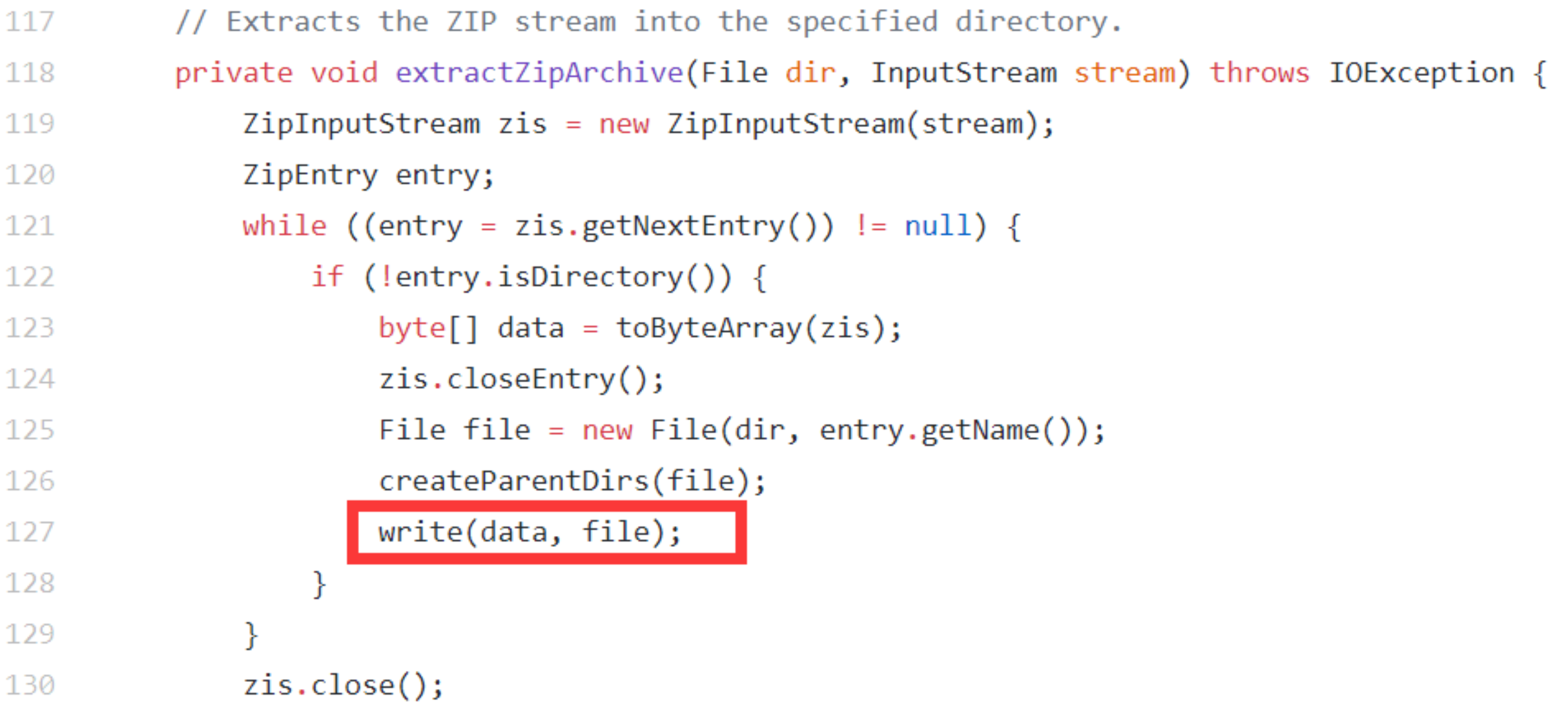
Hack Something Real!



```
public Collection<Alarm> translateToAlarm(DeviceId deviceId, InputStream message) {
    try {
        Collection<Alarm> alarms = new ArrayList<>();
        Document doc = createDocFromMessage(message);

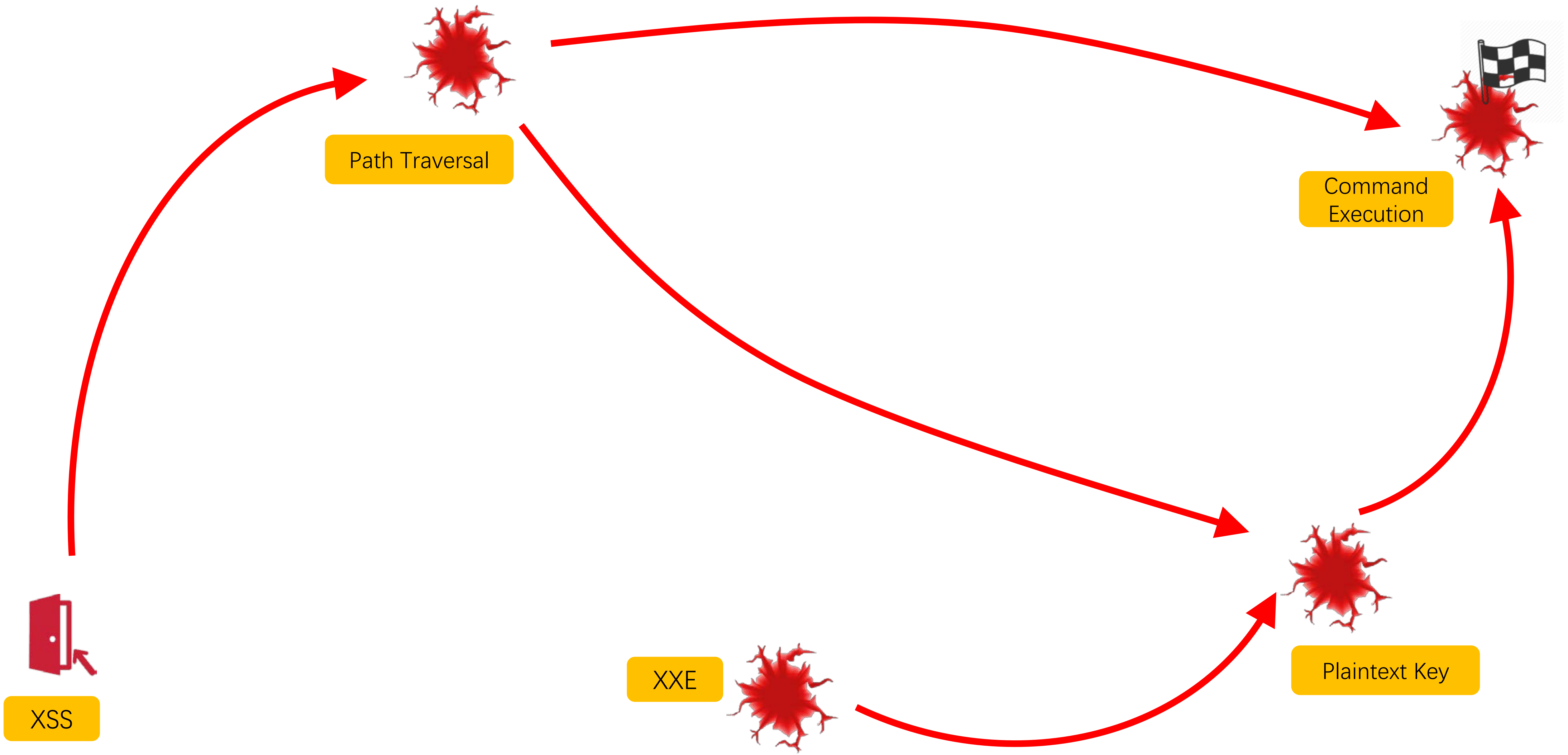
        // parse date element value into long
        Node eventTime = doc.getElementsByTagName(EVENTTIME_TAGNAME).item(0);
        String date = eventTime.getTextContent();
        long timeStamp = parseDate(date);
```

Hack Something Real!



```java
// Extracts the ZIP stream into the specified directory.
private void extractZipArchive(File dir, InputStream stream) throws IOException {
    ZipInputStream zis = new ZipInputStream(stream);
    ZipEntry entry;
    while ((entry = zis.getNextEntry()) != null) {
        if (!entry.isDirectory()) {
            byte[] data = toByteArray(zis);
            zis.closeEntry();
            File file = new File(dir, entry.getName());
            createParentDirs(file);
            write(data, file);
        }
    }
    zis.close();
```

Hack Something Real!



Evaluation

5 popular SDN Controller

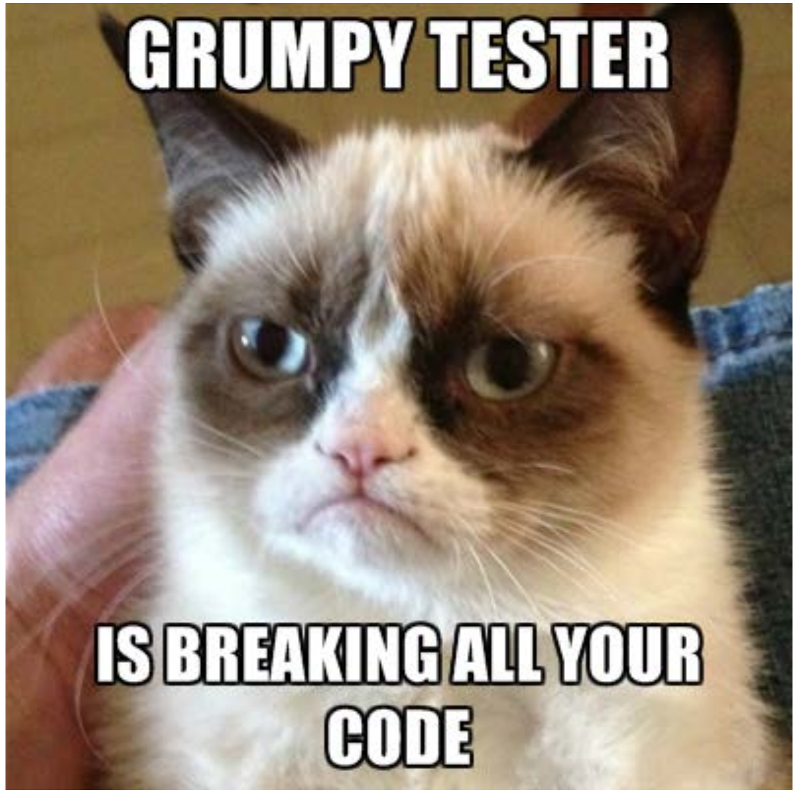
- Three open source projects (White-box)
- Two commercial products (Black-box)

54 apps

- Analyze 12 protocols
- Identify 476 dangerous function calls

19 zero-day vulnerabilities

- Construct 24 sophisticated exploit chains



Impact Analysis

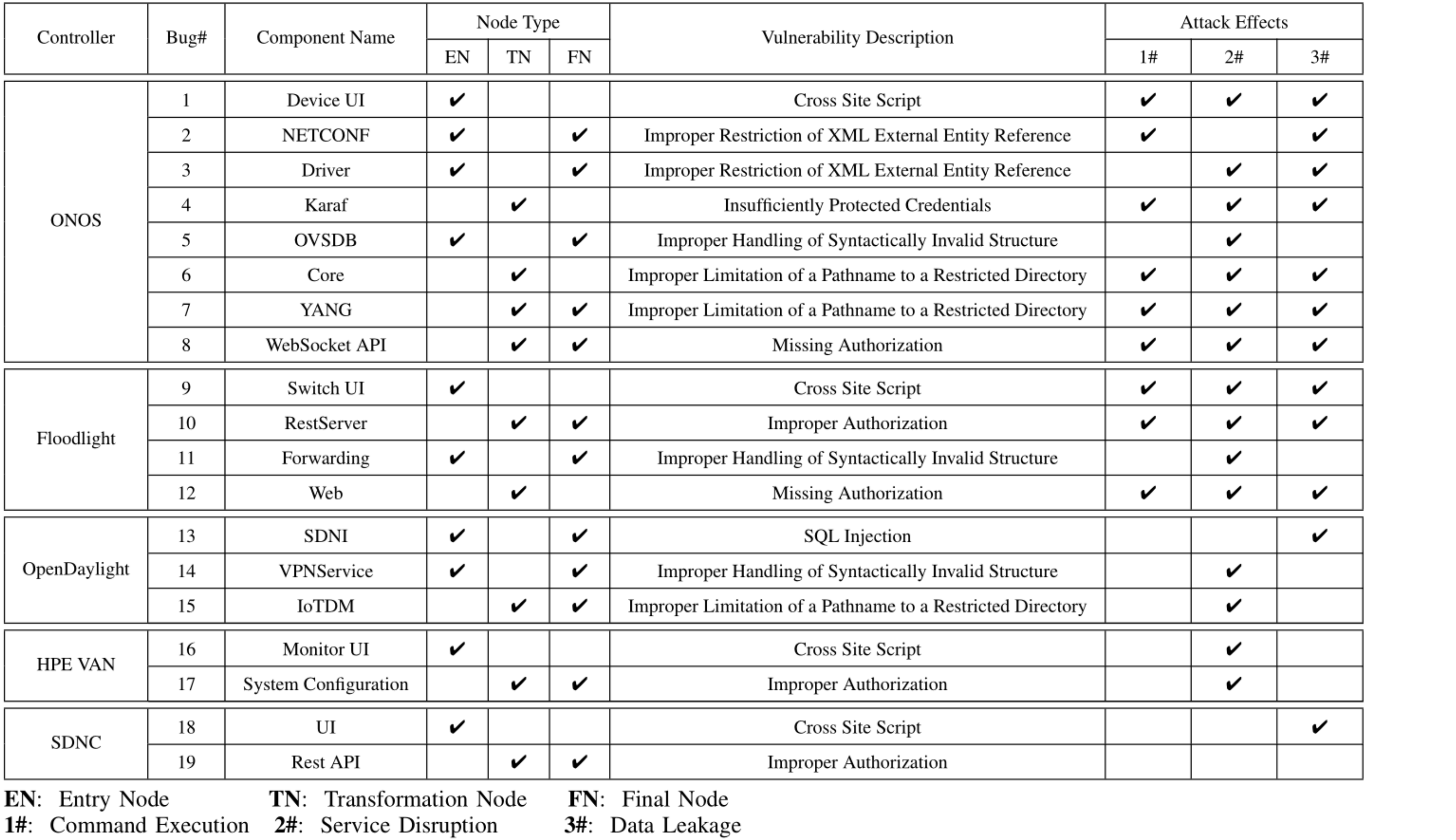
Get System Shell (1 of them)

Execute Arbitray SDN Commands (5 of them)

Steal Confidential Data (7 of them)

Crash/Disrupt Service (11 of them)

0day Profile



Controller	Bug#	Component Name	Node Type			Vulnerability Description	Attack Effects		
			EN	TN	FN		1#	2#	3#
ONOS	1	Device UI	✔			Cross Site Script	✔	✔	✔
	2	NETCONF	✔		✔	Improper Restriction of XML External Entity Reference	✔		✔
	3	Driver	✔		✔	Improper Restriction of XML External Entity Reference		✔	✔
	4	Karaf		✔		Insufficiently Protected Credentials	✔	✔	✔
	5	OVSDB	✔		✔	Improper Handling of Syntactically Invalid Structure		✔	
	6	Core		✔		Improper Limitation of a Pathname to a Restricted Directory	✔	✔	✔
	7	YANG		✔	✔	Improper Limitation of a Pathname to a Restricted Directory	✔	✔	✔
	8	WebSocket API		✔	✔	Missing Authorization	✔	✔	✔
Floodlight	9	Switch UI	✔			Cross Site Script	✔	✔	✔
	10	RestServer		✔	✔	Improper Authorization	✔	✔	✔
	11	Forwarding	✔		✔	Improper Handling of Syntactically Invalid Structure		✔	
	12	Web		✔		Missing Authorization	✔	✔	✔
OpenDaylight	13	SDNI	✔		✔	SQL Injection			✔
	14	VPNService	✔		✔	Improper Handling of Syntactically Invalid Structure		✔	
	15	IoTDM		✔	✔	Improper Limitation of a Pathname to a Restricted Directory		✔	
HPE VAN	16	Monitor UI	✔			Cross Site Script		✔	
	17	System Configuration		✔	✔	Improper Authorization		✔	
SDNC	18	UI	✔			Cross Site Script			✔
	19	Rest API		✔	✔	Improper Authorization			

EN: Entry Node **TN**: Transformation Node **FN**: Final Node
1#: Command Execution **2#**: Service Disruption **3#**: Data Leakage

Demo

ONOS Remote Command Execution

Conclusions

The first attack that can remotely compromise SDN software stack to simultaneously cause multiple kinds of attack effects in SDN controllers.

The data-plane-based attack surface is actually significantly larger than what has been discovered.

Service-logic-free vulnerabilities in the controller could be exploited in unexpected ways to conquer the difficulty brought in by pre-defined protocol interactions.

Thanks!

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