LESSONS LEARNED FROM THE CAPITAL ONE DATA BREACH

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Capital One Data Breach

The Capital One data breach from almost a year ago was one of the most devastating data breaches of all time. A trusted financial services brand, Capital One has been a leader in digital transformation within the banking industry and a sophisticated user of cloud infrastructure. This major cloud data breach serves as a valuable lesson for any organization storing confidential information in the cloud.

Soon after the breach was reported, unwarranted speculation spread on the internet, including suggestions that a single product or a set of professional services could have prevented such an attack. Taking advantage of information that has since become available, Cloudneeti has updated this research note with a technical illustration of the attack and possible ways to prevent such data breaches.

On July 29, 2019, the FBI arrested Paige A. Thompson (also known by the alias "erratic") for allegedly hacking into Capital One databases and stealing the data[1]. CapitalOne disclosed the estimated the data loss at approximately 1 million Social Insurance Numbers of Canadian credit card customers, about 140,000 Social Security numbers and 80,000 linked bank account numbers of the credit card customers[2].

AWS provided their assessment of the incident: "As Capital One outlined in their public announcement, the attack occurred due to a misconfiguration error at the application layer of a firewall installed by Capital One, exacerbated by permissions set by Capital One that were likely broader than intended. After gaining access through the misconfigured firewall and having broader permission to access resources, we believe a SSRF attack was used (which is one of several ways an attacker could have potentially gotten access to data once they got in through the misconfigured firewall."[3]

The criminal complaint[4] and indictment[5] documents provided additional insights. According to the FBI, the following happened.

Timeframe	Activities
January 2019 to July 2019	"Erratic" used TOR (The Onion network) to attempt connections, develop command scripts and other readiness activities. Multiple connections were made to connect to the servers, download pilot files to test out the end-to-end scenarios
April 21, 2019 Data leaked	Capital One's customer information (700 folders worth of data) were posted on the erratic's public GitHub pages IP address of a specific AWS server Code for 3 commands used for the attack 1. **Get Credentials** - First command when executed obtained security credentials known as ****-WAF-Role account (an IAM account) for an elevated role access AWS Web Application Firewall (WAF) 2. **List Buckets** - Second command, when executed, used the security credentials *****-WAF-Role account to list files and folders (aka S3 buckets) 3. **Download files** - Third command, when executed used the *****-WAF-Role account to download files that were accessible by the credentials.
June 26, 2019	"Erratic" shared the collected information casually on a public Slack channel used by a Meetup group to communicate with its members.
July 17, 2019	CapitalOne received an email informing about leaked data  Responsible Disclosure (Shared) <responsiblediscloure@capitalone.com> [External Sender] Leaked s3 data [redacted] Wed, Jul 17, 2019 at 1:25 AM To: "responsiblediscloure@capitalone.com" <responsiblediscloure@capitalone.com> Hello there, There appears to be some leaked s3 data of yours in someone's github / gist: https://gist.github.com[redacted] Let me know if you want help tracking them down. Thanks, [redacted]

Likely Attack Scenario

While the indictment is not specific about the nature of the attack, the following is our best guess regarding the likely steps taken by "erratic" to compromise the data.

STEP 1: Login to the EC2 instance using SSH

It's very likely an EC2 instance was left over from a previous deployment with open SSH access. This was used to perform the SSRF attack.

STEP 2: Discover a weak IAM role

Using the EC2 instance, the attacker must have been able to call the metadata service endpoint from the SSH command prompt something like this
http://169.254.169.254/iam/security-credentials
The endpoint must have returned a role (according to the indictment '*****-WAF-Role')

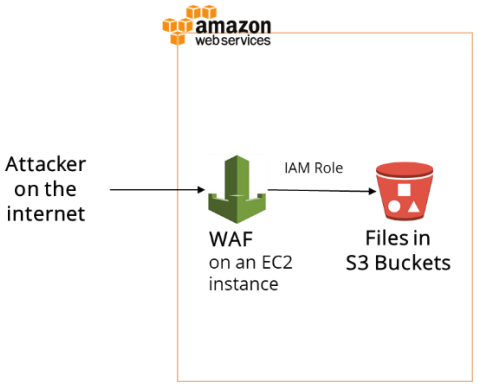
STEP 3: Gain temporary credentials

Using the role name, the attacker then could have queried the specific endpoint to gain access to temporary credentials
http://169.254.169.254/iam/security-credentials/*****-WAF-Role
The above would return the full set of temporary credentials
{
AccessKeyId: "<access key>",
SecretAccessKey: "<secret key>",
}

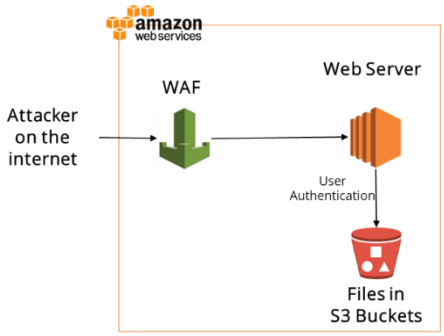
STEP 4: Gain access to S3 buckets by calling AWS S3 list and Sync

CLI commands
$ aws s3 ls
The ls command would list all the S3 buckets accessible using the IAM role
$ aws s3 sync s3://somebucket
The sync command would download all resources from the 'somebucket'

In summary, the most likely root cause of the attack was a poor security architecture design that exposed S3 buckets via AWS WAF/EC2 instance to anyone with an IAM role. While S3 buckets were not exposed to the Internet like many other breaches, an EC2 instance with an excessive IAM role might have been the culprit. The deployed architecture would have looked something like this. It was a trivial step to "compromise" the poorly configured WAF.



A level of indirection, and a lower privileged IAM role might have been a better architecture decision. It would look like this. The attacker would not have unfettered access to S3 buckets.



AWS Components	Predicted Configurations and Usage during the attack
Firewall	A misconfiguration of AWS Web Application Firewall.
	Excessive permissions to an IAM role allowing access to private S3 buckets
IAM role access to S3	"CapitalOne determined that the first command, when executed, obtained the security credentials for an account known as ***-WAF-Role that, in turn, enabled access to certain of Capital One's folders at Cloud Computing Company. (III.A.11)"
SSRF attack using AWS Metadata service	An SSRF attack tricks a server into executing commands on behalf of a remote user, enabling the user to treat the server as a

AWS Components	Predicted Configurations and Usage during the attack
	proxy for his or her requests and get access to non-public endpoints. An EC2 instance was likely used to access AWS metadata service, accessible at http://169.254.169.254. A particularly important function of the metadata service is to provide temporary credentials that give the node access to other AWS services based on a permission policy defined in the instance's IAM role. IAM roles are an alternative to long-lived user access keys and secrets; rather than hard coding an access key into an application's configuration, the application simply requests credentials from the metadata endpoint periodically.
EC2	Exposing unnecessary shell access, probably from a left-over development / staging or a production debugging deployment.
S3 bucket	Capital One determined that the third command (the "Sync Command"), when executed, used the ***-WAF-Role to extract or copy data from those folders or buckets in Capital One's storage space for which the ***-WAF-Role account had the requisite permissions. (III.A.11) Suggests that the attacker had access to 'aws s3 sync' command. i.e. the IAM role used S3 list (e.g. aws s3 ls) and Read access (e.g. aws s3 sync).

Recommendations

AWS Governance Practices

The following AWS governance practices would prevent such attacks:

1. Don't allow EC2 instances to have IAM roles that allow attaching or replacing role policies in any production environments.
2. Clean up unused cloud resources (especially EC2 instances and S3 buckets) left over from prior development or production debugging efforts.
3. Review S3 bucket permissions, policies and access via both automation and manual audits.

4. AWS lists a few basics here https://aws.amazon.com/premiumsupport/knowledge-center/secure-s3-resources/ . Cloudneeti automates 100's of these policies and provides security and compliance views across all AWS accounts.
5. Use CloudTrail, CloudWatch and/or AWS lambda services to review and automate specific actions taken on S3 resources.
6. Periodically review IAM roles

Ensure each application, EC2 instance, or autoscaling group has its own IAM role. Do not share roles across unrelated applications.

Scope the permissions of each role to enable access only to the AWS resources required. The "WAF" role described above did not require access to list S3 buckets "in the normal course of business" (according to the indictment).

If possible, include a "Condition" statement within the IAM role to scope the access to known IP addresses or VPC endpoints.

AWS Configurations

If the following AWS cloud resource configurations were followed, the attack would have been prevented:

1. **AWS IAM:** Ensure least privileged IAM instance roles are used for AWS resource access from instances.
2. **AWS IAM:** Ensure IAM policies are attached only to groups or roles
3. **AWS S3:** Ensure AWS S3 buckets do not allow public READ access
4. **AWS S3:** Ensure AWS S3 buckets do not allow public READ_ACP access
5. **AWS S3:** Ensure AWS S3 buckets do not allow public WRITE_ACP access
6. **AWS S3:** Ensure S3 buckets do not allow FULL_CONTROL access to AWS authenticated users via S3 ACLs
7. **AWS S3:** Ensure that Amazon S3 buckets access is limited only to specific IP addresses
8. **AWS S3:** Ensure S3 buckets do not allow READ access to AWS authenticated users through ACLs
9. **AWS S3:** Ensure S3 buckets do not allow FULL_CONTROL access to AWS authenticated users via S3 ACLs

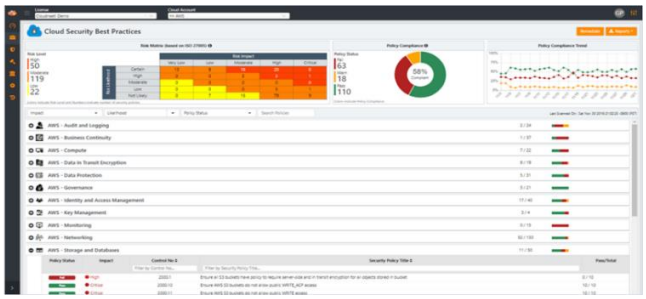
10. **AWS S3:** Ensure all S3 buckets have policy to require server-side and in transit encryption for all objects stored in bucket
11. **AWS Networking:** Ensure no security groups allow ingress from 0.0.0.0/0 to port 22
12. **AWS Networking:** Ensure Application Load Balancer (ALB) with administrative service: SSH (TCP:22) is not exposed to the public internet
13. **AWS Networking:** Ensure no security groups allow ingress from 0.0.0.0/0 to port 22 (SSH)
14. **AWS Networking:** Ensure no security groups allow ingress from 0.0.0.0/0 to port 3389 (RDP)
15. **AWS - Audit and Logging:** Ensure S3 bucket access logging is enabled on the CloudTrail S3 bucket
16. **AWS - Audit and Logging:** Ensure CloudTrail is enabled in all regions
17. **AWS - Audit and Logging:** Ensure CloudTrail trails are integrated with CloudWatch Logs
18. **AWS - Audit and Logging:** Ensure the S3 bucket used to store CloudTrail logs is not publicly accessible
19. **AWS - Monitoring:** Ensure a log metric filter and alarm exist for CloudTrail configuration changes.

The above list of configurations is only for illustration purposes. For an exhaustive list, contact us at www.cloudneeti.com.

These configurations can be part of manual deployment documentation or, ideally, be part of the Infrastructure as Code (IaC) automation within DevOps pipelines. It would prevent these misconfigurations from getting into production in the first place. A cloud security posture management solution like Cloudneeti could be used by Cloud Ops or DevOps team to continuously validate their security posture in pre-production and production environments.

Auto-remediation

The next level of defense would be auto-remediation of misconfigured resources. Cloudneeti also provides an integrated policy driven framework to auto-remediate resources that deviate from the defined security policies. Refer our documentation on: AWS auto-remediation



Conclusion

The industry was understandably shocked by the sheer scale of the attack against one of the most trusted brands operating on one of the most secure infrastructures. There are several lessons to be learned.

Misconfiguration can cause catastrophic losses and the Capital One experience is only one of many known cases. We anticipate seeing more breaches at companies who have not kept up with the pace of change in their cloud environments and have not implemented adequate cloud security and compliance assurance.

Cloudneeti is convinced that the critical flaws that enabled such a devastating breach can be avoided when organizations deploy tools to enforce continuous compliance with cloud security best practices.

About Cloudneeti

Cloudneeti automates security and compliance in the cloud, delivering continuous visibility and enforcing adherence to the most comprehensive set of security policies and compliance frameworks.

Contact Cloudneeti

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[1] Seattle Tech Worker Arrested for Data Theft Involving Large Financial Services Company

[2] Information on the Capital One Cyber Incident

[3] Amazon Letter to Senator Wyden RE Consumer Data

[4] Department of Justice - complaint document

[5] Department of Justice - indictment document