2020
Cybersecurity Insights

NSFOCUS

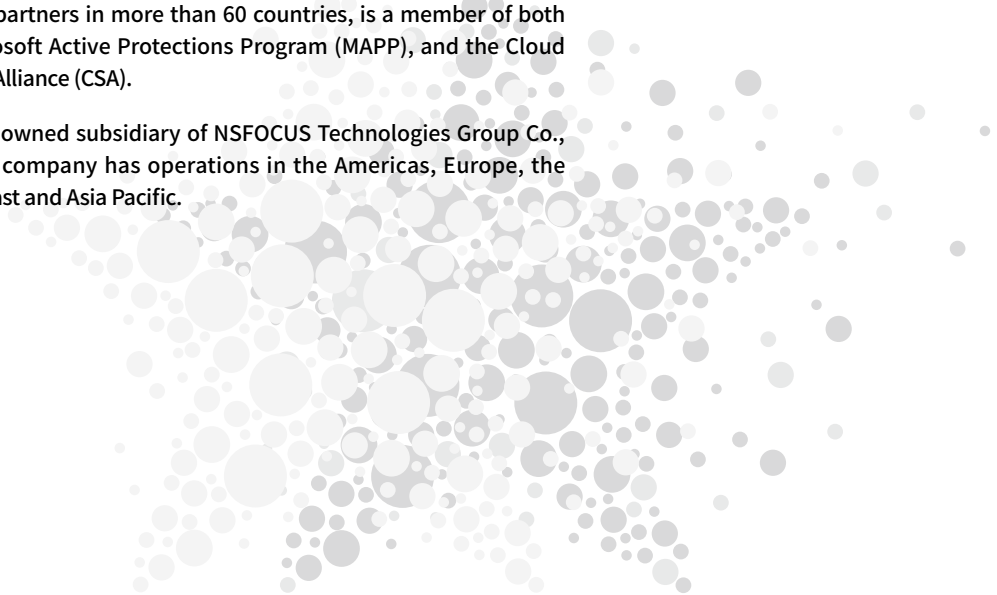
NSFOCUS

About NSFOCUS

NSFOCUS, Inc., a global network and cyber security leader, protects enterprises and carriers from advanced cyber attacks. The company's Intelligent Hybrid Security strategy utilizes both cloud and on-premises security platforms, built on a foundation of real-time global threat intelligence, to provide multi-layered, unified and dynamic protection against advanced cyber attacks.

NSFOCUS works with Fortune Global 500 companies, including four of the world's five largest financial institutions, organizations in insurance, retail, healthcare, critical infrastructure industries as well as government agencies. NSFOCUS has technology and channel partners in more than 60 countries, is a member of both the Microsoft Active Protections Program (MAPP), and the Cloud Security Alliance (CSA).

A wholly owned subsidiary of NSFOCUS Technologies Group Co., Ltd., the company has operations in the Americas, Europe, the Middle East and Asia Pacific.



Special Statement

All data used for analysis has been anonymized and no customer information appears in this report to avoid information disclosure per GDPR.

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Executive Summary

Executive Summary

In 2020, COVID-19 reached almost every corner of the world. Amid this pandemic, security incidents leveraging pandemic-related information streamed in. In the past year, NSFOCUS kept close tabs on hacking activities conducted by crafting pandemic-related trending topics. We noticed that hackers usually incorporated information about the novel coronavirus disease into the kill chain and industry chain of the Internet-enabled underground economy, as demonstrated in the significant increase in social engineering attacks related to COVID-19.

During the past year, national conflicts in the cyberspace against the global geopolitical background kept escalating, with critical information infrastructure becoming a top concern in cybersecurity assurance. NSFOCUS is committed to providing insights into the security of the Internet of things (IoT), industrial Internet, 5G, artificial intelligence (AI), and data.

- NSFOCUS has been continuing to delve into assets and related risks and threats in the IoT and industrial Internet. As for exposure of assets, the actual number of IPv4 and IPv6 assets exposed on the IoT and industrial Internet is updated, and related threats are analyzed from the perspectives of exploits and protocol attacks. Such analysis covers the latest threats of reflection attacks and ransomware attacks.
- 5G-related security is analyzed from the perspectives of incidents, 5G security standard updates, and 5G security risks. Upon a thorough analysis of potential security threats and attack surfaces of the new 5G technology, NSFOCUS makes it clear that a comprehensive defense system is key to cybersecurity.
- NSFOCUS finds that the adoption rate of AI soared during cybersecurity improvement in 2020, mainly resulting from the widespread use of AI for threat detection, malicious execution prevention, and enhancement of security operations. On the other hand, AI provides good opportunities for hackers. Adversarial examples have become the biggest threat facing AI security, followed by backdoor attacks and training data poisoning.
- According to data collected by NSFOCUS about the biggest data breaches around the world, data and privacy disclosure incidents scaled up in 2020, with more devastating impacts that may even disrupt the stability of the whole society.

2

Key Findings

Key Findings

1. Following the outbreak of the COVID-19 pandemic in 2020, cyberattacks leveraging this event have sprawled into every corner of the globe, with an escalating frequency of occurrence. The rapid development of new infrastructure, such as the IoT, industrial Internet, 5G networks, and AI networks, gives rise to new cybersecurity requirements, accelerating transformations in the world's cybersecurity industry.
2. [Vulnerabilities] Compared with 2019, the number of vulnerabilities decreased in 2020. Specifically, CWE-79 (cross-site scripting) vulnerabilities were ranked first in terms of the quantity, Windows MS17-010 vulnerabilities were most frequently exploited in scanning attacks, and web servers were the biggest target because of containing various vulnerabilities, especially those in the Common Gateway Interface (CGI).
3. [Malware] COVID-19 phishing was a trending phrase in the cybersecurity realm in the first half of 2020. Related topics became a convenient bait for malicious email attacks. Variants of Mirai and Gafgyt, the two major IoT DDoS families, were emerging on end, attempting to exploit new vulnerabilities for lateral movement.
4. [Malicious traffic] While the number and traffic volume of distributed denial-of-service (DDoS) attacks decreased in 2020, the bandwidth of such attacks in 5G environments increased, with small-medium attacks overtaking small ones to become the mainstream.
5. [APTs] In 2020, Lazarus and Kimsuky, the two advanced persistent threat (APT) groups from North Korea, were mostly frequently named, followed by APT-C-35, APT32, and Dropping Elephant, three Southeast Asian groups. APT groups showed a new interest in launching attacks by leveraging the pandemic, especially attacks that used COVID-19 information as the decoy. Typical examples of such groups in 2020 include Dropping Elephant (India), APT32 (Vietnam), Operation C-Major (Pakistan), TA505, Sidewinder (India), Lazarus Group (North Korea), and Wizard Spider (Russia).
6. [IPv6 security threats] Education institutions and carriers continued to be the major targets of malicious actors, together receiving over 90% of cyberattacks. Cryptojacking and worms were still the major attack methods used in IPv6 environments. A significant increase was spotted in

exploits targeting IPv6 websites.

7. [Dark web data breaches] Data breaches in 2020 happened frequently, but with a limited impact, characteristic of less capable attackers. Of all personal information leaked, most was stolen by intercepting mobile texts with pseudo base stations. Therefore, it is recommended that users set the network mode of their handsets to use of 4G or 5G only as a workaround.
8. [IoT] In 2020, top 3 IoT assets exposed on the Internet were routers, VoIP phones, and video surveillance devices. Globally, remote command execution (RCE) vulnerabilities were most frequently exploited in IoT attacks, especially WS-Discovery reflection attacks. Such reflection attacks related to the IoT pose a severe challenge to DDoS mitigation.
9. [Industrial Internet] In 2020, security incidents targeting industrial control systems (ICSs) on the Internet were on the rise. The major threat to ICS environments and operations was ransomware. Of all ICS assets worldwide, those using the Ethernet Industrial Protocol (ENIP) were most exposed, followed by assets using Modbus.
10. [5G security threats] Many countries have raised the development of 5G to the strategic level. 5G security standards are focused on the business security of 5G networks, and 5G security protocols highlight the importance of encryption, mutual authentication, integrity protection, and enhanced privacy and availability.
11. [AI security threats] The major security risks facing AI are from network infrastructure, training data, algorithmic models, and AI application abuses. Adversarial examples are the biggest security threat facing AI systems, followed by backdoor attacks and training data poisoning.
12. [Data security] In 2020, data breaches continued to be a serious issue worldwide. Misconfiguration and hacking were two major contributors to massive data breaches. Most countries have developed data security and privacy laws, urging enterprises and users to raise their awareness of privacy and data protection.

3

Insight into Threats

3.1 Malicious IP Addresses

3.1.1 Distribution of Attacks by Type

According to data collected by NSFOCUS Threat Intelligence (NTI), in terms of attack types[1], spam was ranked first because of involving the largest proportion (48.9%) of malicious IP addresses. Zombies and exploits came in second and third. Besides, about 30% of IP addresses were involved in more than one type of attacks, a bit higher than the percentage in 2019, indicating a minor increase in the resource reuse rate.

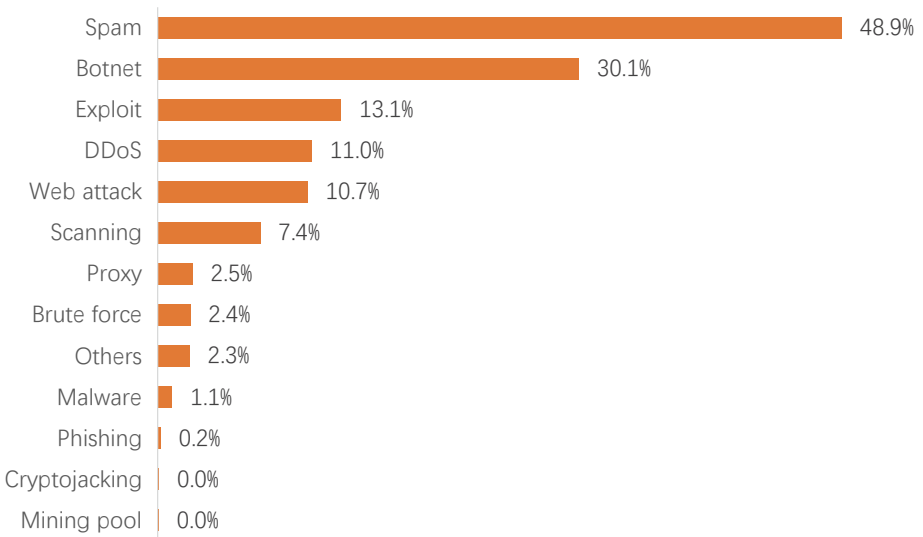


Figure 3-1 Distribution of attacks by type

3.1.2 Geographical Distribution

In terms of the geographical distribution of source IP addresses, China, the USA, India, and Japan were four countries grabbing the top spots.

1 As an IP address may launch more than one type of attacks, the sum of all percentages indicated in the following figure is greater than 100%.

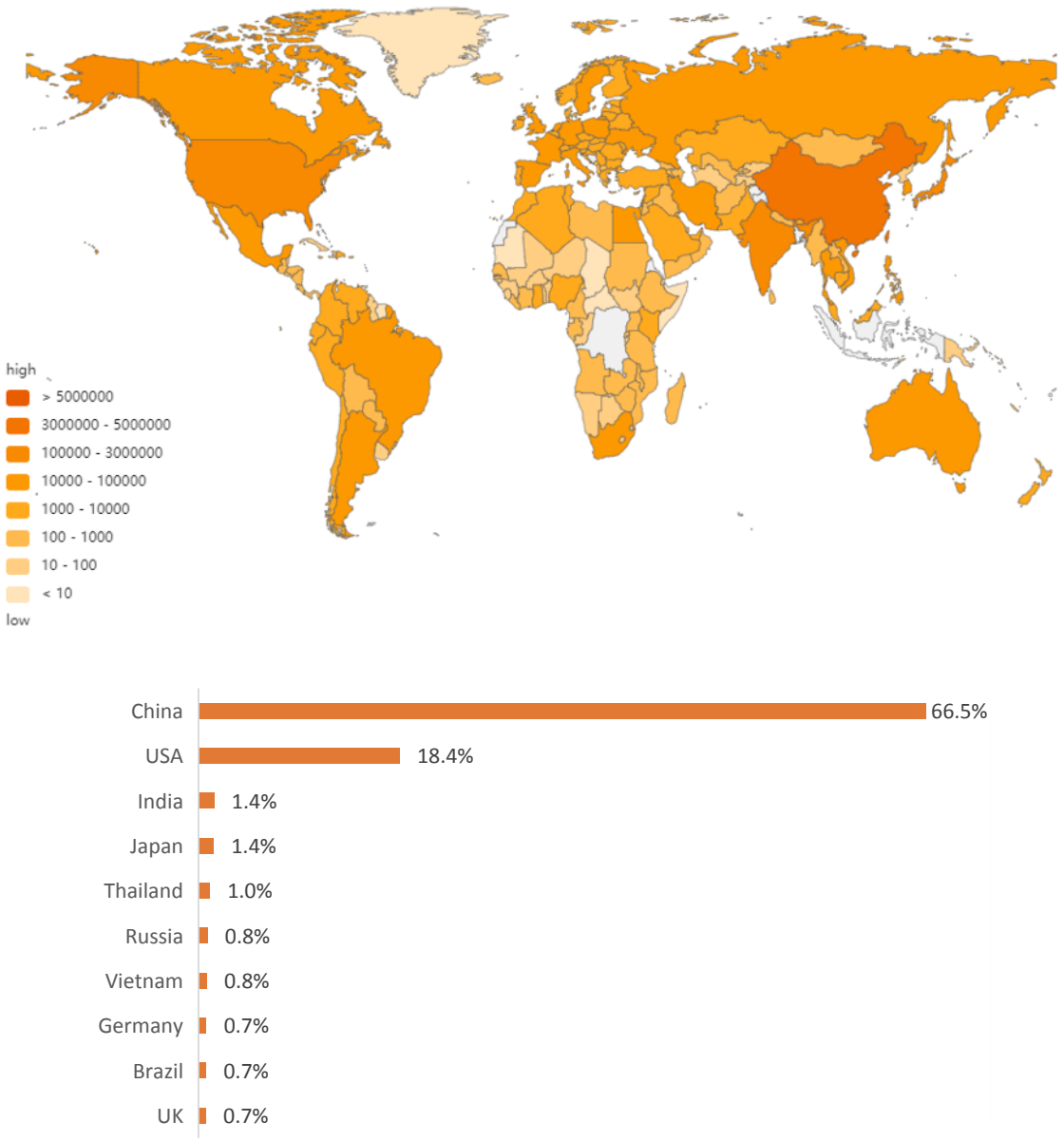


Figure 3-2 Global distribution of attack sources

In terms of the geographical distribution of target IP addresses, China and the USA were two biggest targets, together suffering around 76% of attacks.

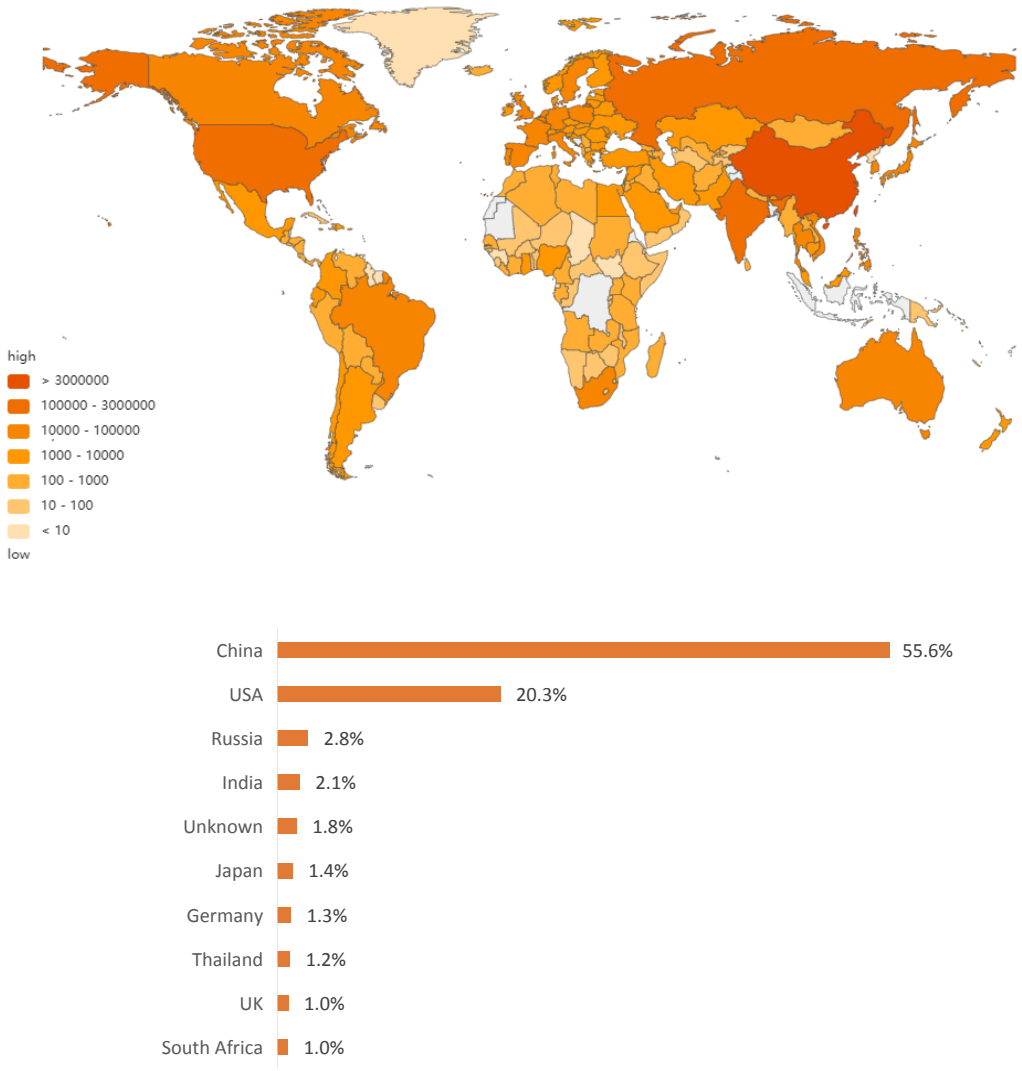


Figure 3-3 Global distribution of attack targets

3.2 Vulnerabilities

3.2.1 Overall Trends

By December 31, 2020, 14,443 vulnerabilities found in 2020 had been added to the National Vulnerability Database (NVD). The following figure shows the annual number of vulnerabilities recorded in the NVD

over a 22-year period from 1999 to 2020. Compared with 2019, the number of new vulnerabilities in 2020 decreased.

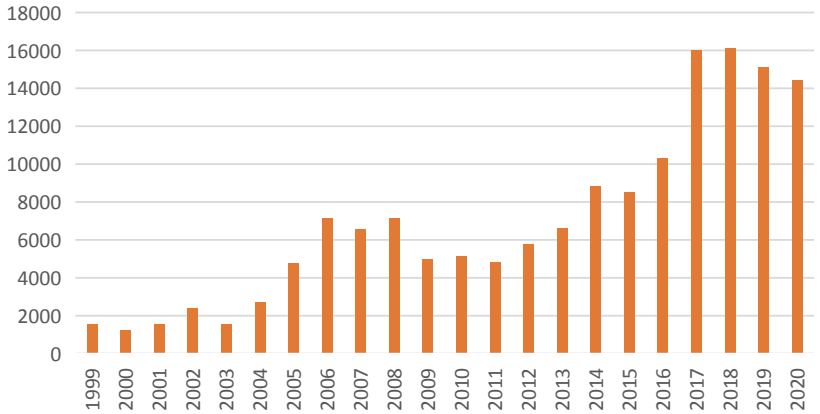


Figure 3-4 Annual number of vulnerabilities from 1999 to 2020

CVSS 3.1 rates vulnerabilities into four levels in terms of the severity: critical (9.0–10.0), high (7.0–8.9), medium (4.0–6.9), and low (0.1–3.9). By December 31, 2021, CVSS 3.1 scores had been assigned to 14,169 vulnerabilities, more than half of which (56.66%) were either critical (14.07%) or high-level (42.59%) ones. These vulnerabilities can be exploited to remotely execute arbitrary commands or code. Some can even allow for remote code execution without requiring user interactions.

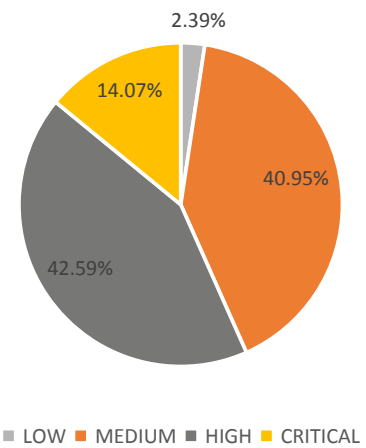


Figure 3-5 Distribution of CVSS 3.1 vulnerabilities

3.2.2 Exploits

Based on data collected by NTI through ongoing monitoring, we picked exploit attacks from alerts logged throughout 2020 and identified top 10 vulnerabilities most frequently alerted, as shown in the following table.

Table 3-1 Top 10 vulnerabilities alerted in 2020

Vulnerability ID	Vulnerability Name	Number of Alerts
ms17-010	Windows MS17-010 Vulnerability Scanning Attack	10,694,163
CVE-2003-0486	phpBB viewtopic.php topic_id Remote SQL Injection Vulnerability	7,413,032
CVE-2016-0800	OpenSSL SSLv2 Weak Encryption Communication Method DROWN Attack Vulnerability	2,991,082
CVE-2005-2678	Microsoft IIS "500-100.asp" Source Code Disclosure Vulnerability	2,119,380
EDB-ID 45978	ThinkPHP 5.x Remote Command Execution Vulnerability	2,076,446
CVE-2015-5311	PowerDNS Authoritative Server DNS TKey Unknown Record Denial-of-Service Vulnerability	1,856,060
CVE-2017-0144	Windows SMB Remote Code Execution Vulnerability (Shadow Brokers EternalBlue)	1,827,316
CVE-2003-0132	Apache HTTP Server Line Feed Memory Leak Denial-of-Service Vulnerability	1,508,481
CVE-2017-5638	Apache Struts 2 Remote Command Execution Vulnerability (S2-045/S2-046)	1,497,304
CVE-2014-6271	GNU Bash Environment Variables Remote Command Execution Vulnerability	836,630

According to data in the preceding table, old vulnerabilities found before 2010 were still frequently exploited in the wild, indicating that a large number of out-of-date software applications and systems were left unpatched on the Internet. We classified exploits found in 2020 and named malformed attacks, trojan attacks, and CGI attacks as the top 3 attack types, as shown in the following figure.

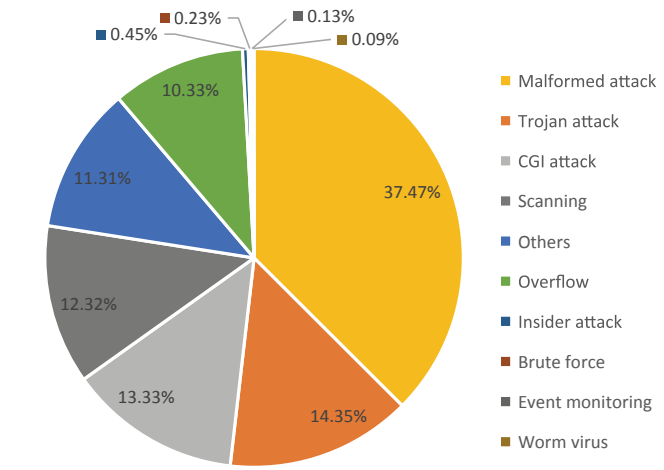


Figure 3-6 Distribution of attack types

3.2.3 Server Vulnerabilities

Server vulnerabilities mainly reside in system services and programs that run on a server to support or deliver network management and actual services. Main server types include the web server, scanning server, Windows server, DNS server, database server, and mail server. Based on NTI's monitoring data, we calculated the percentage of each server type targeted by exploits. As shown in the following figure, web servers were most severely hit, with a percentage of 64.76%.

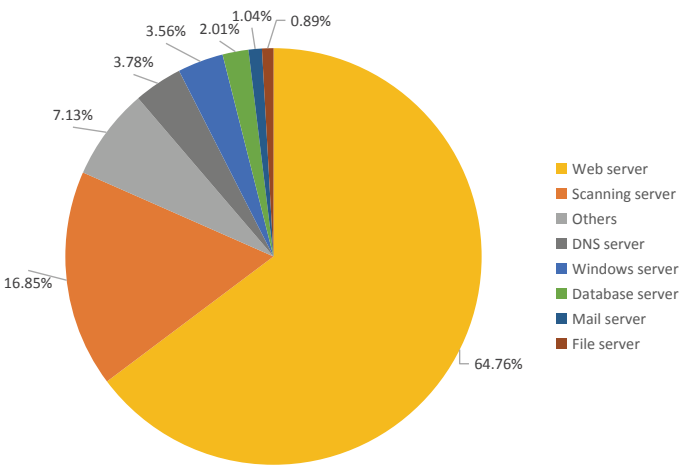


Figure 3-7 Distribution of server types targeted by exploits

Our analysis goes further into specific services, which are ranked in terms of the total number of exploits. As shown in the following figure, CGI is the No. 1 service targeted by the most exploits. CGI vulnerabilities are mainly due to misconfigurations, improper input validation, and boundary condition errors, allowing attackers to leak information, execute code, and perform other operations.

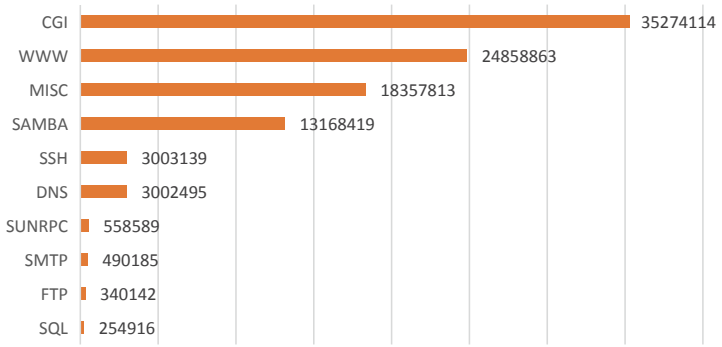


Figure 3-8 Top 10 services targeted by exploits

3.2.4 Application Vulnerabilities

Typical application software types include the browser, Office suite, Flash player, PDF reader, and mobile software. The following figure shows the percentage of each application type in exploits. In actual attacks, browsers are a good point to start and so are favored by attackers, involved in 48.54% of attacks in 2020, which is on a par with the figure in 2019.

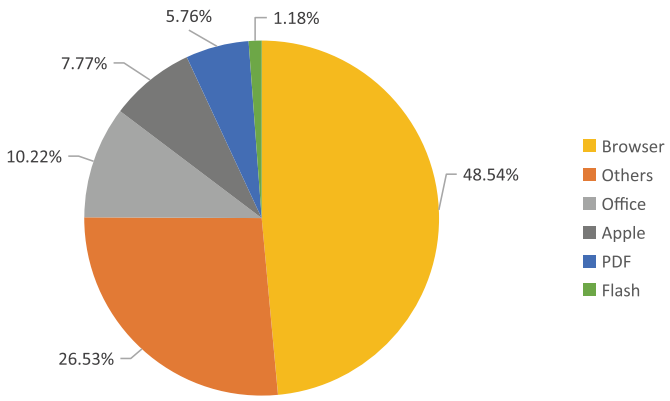


Figure 3-9 Distribution of applications targeted by exploits

From 2018 to 2020, the percentage of Flash vulnerabilities targeted by exploits continuously decreased. The root cause is that Flash-related exploits cannot be achieved independently by SWF files. For the purpose of attacks, Flash must be embedded in browsers, Office software, or PDF files as a plug-in. Besides, Adobe began to phase out the Flash plug-in, and major vendors have adopted measures to block its use. Predictably, exploitation of Flash vulnerabilities will become something only in our memory someday.

3.3 Malware

3.3.1 Impact of COVID-19 on Cybersecurity

The outbreak of the COVID-19 pandemic in early 2020 imposed a tremendous impact on cybersecurity. According to NSFOCUS's observation, "COVID-19 phishing" was a trending phrase in the cybersecurity realm in the first half of 2020. Hacker groups and malware operators around the world all used COVID-19 as a convenient decoy for malicious mail attacks by adding related information in email messages, documents, or even attached images, in hopes of successfully compromising victims by taking advantage of Internet users' sensitivity to such information amid the pandemic.

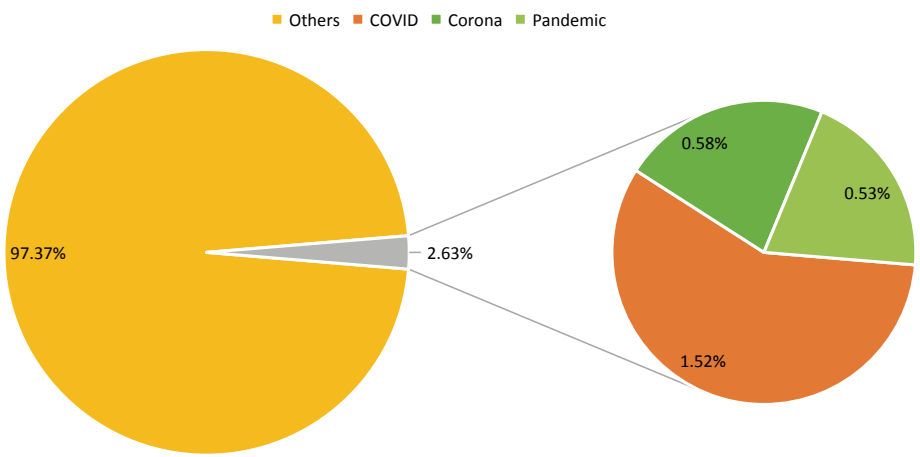


Figure 3-10 Distribution of keywords related to COVID-19 in malicious emails

Of all decoy emails regarding COVID-19 detected by NSFOCUS, most were sent by active trojan families with a global presence, such as Formhook, Emotet, SmokeLoader, NetWire, and Warzone. The

following figure shows an email intercepted by NSFOCUS in March 2020. It was a spearphishing email sent by a malicious email botnet controller against Italian users. The email body is a COVID-19 update from the World Health Organization (WHO) in Italian, and the attachment is a decoy newsletter, which contains the Emotet trojan that will download and execute various malicious programs for privacy theft, keylogging, remote controls, and cryptojacking once executed by the email receiver.

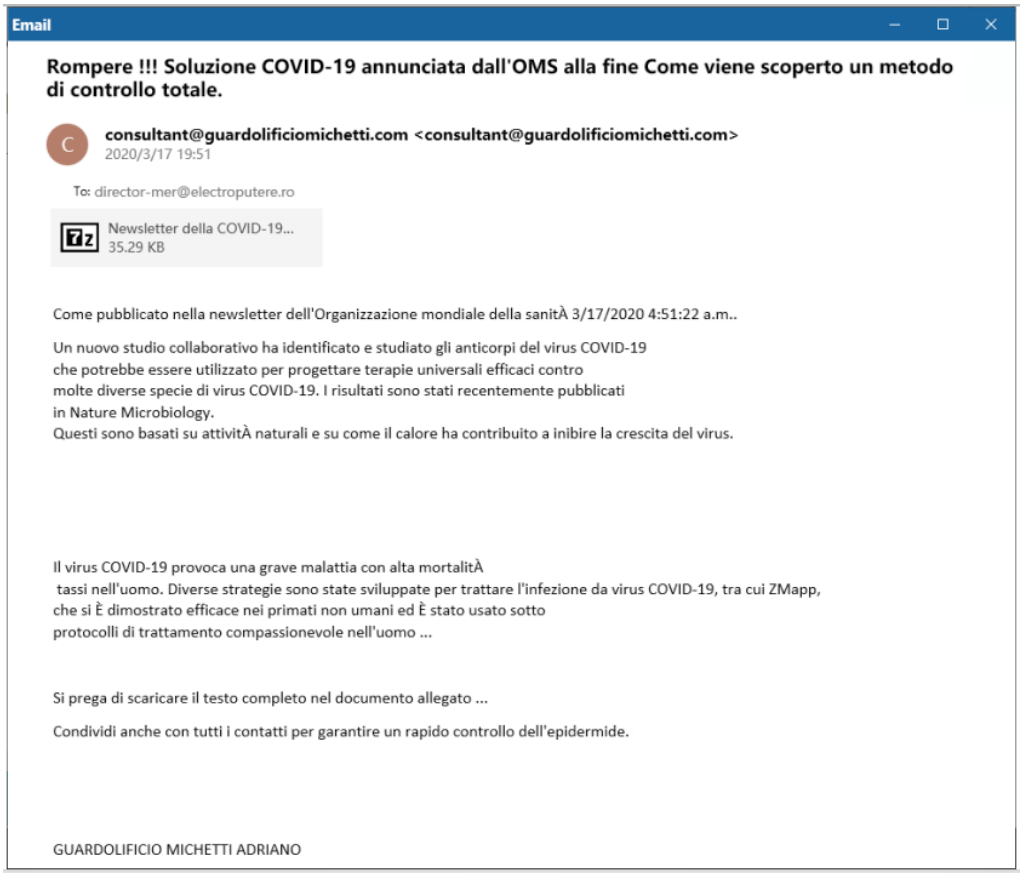


Figure 3-11 Emotet's spearphishing email leveraging COVID-19 in March 2020

3.3.2 Email Trojans

3.3.2.1 Emotet banking trojan

We performed clustering analysis of some suspected malicious emails and identified major threat

types. According to our data, Emotet was still the most dangerous email trojan in the world in 2020. Of all emails alerted, 13% were connected to the Emotet trojan.

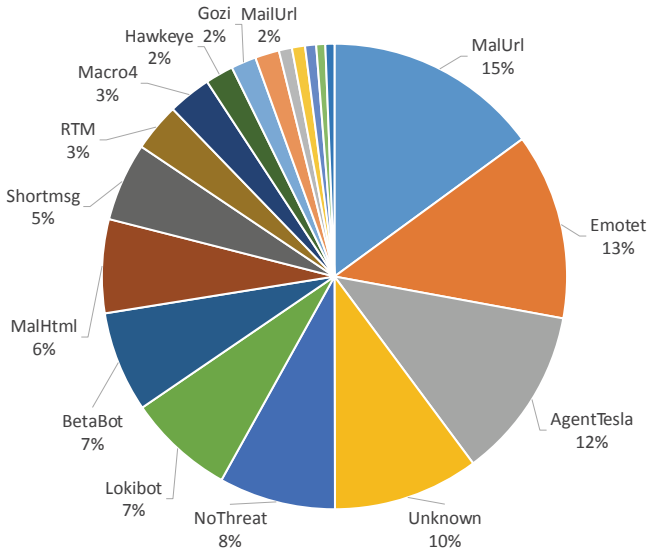


Figure 3-12 Distribution of trojans responsible for malicious email activities in 2020 Q2

The Emotet family, first spotted in 2014, is a banking trojan mainly propagated via spam to infect Windows hosts and compromise users' email accounts for theft of important personal financial information.

Emotet underwent a major change in its operation model in 2020. Besides using COVID-19 information to trap users, the Emotet team started cooperation with the QBot operator, as demonstrated in the crazy delivery of the QBot program through its email network after August. By far, NSFOCUS has discovered up to eight types of mainstream trojan programs that Emotet is bound with, including banking trojans, spyware, ransomware, and DDoS trojans.

3.3.2.2 Agent Tesla banking trojan

Agent Tesla was the email trojan that grew fastest in the number of victims in 2020. According to the analysis, this trojan appeared in over 12% of all emails alerted, overtaking Lokibot to become the second largest email trojan.

As a typical spyware trojan, Agent Tesla of major versions can steal credentials stored in various browsers, user information in FTP client applications, host keystroke records, and texts in Windows programs. They can also regularly take desktop screenshots of the controlled hosts and then deliver such screenshots to the attacker's email address. During the process, C&C communications are done via the Simple Mail Transfer Protocol (SMTP).

In 2020, Agent Tesla demonstrated a higher level of diversity than previous years in terms of the kill chain. For example, some samples attempted to have themselves downloaded by using documents that contained such vulnerabilities as CVE-2017-11882 and CVE-2017-8570; some samples disguised themselves as applications with a document icon, usually an AutoIt executable. All samples should go through a multilevel drop procedure. The payload at each level uses garbage code, open-source code, code obfuscation, antivirus, or other adversarial methods to improve the rate of survival.

3.3.2.3 Maze ransomware

The inundation of phishing emails with epidemic information as the decoy contributed a lot to the spread of ransomware. An example of such ransomware is Maze, a new variant that has attracted much attention for its extensive impact and high-profile marketing. The main difference between Maze and previous mainstream ransomware families is that its developer tends to add new adversarial methods in new versions and write defiant text messages for victims to read, as a response to security professionals' analysis and disclosure. This deviates a lot from the common understanding that ransomware usually lies in wait for the chance to attack.

The Maze creator maintains several websites, including newsmaze.net, mazedecrypt.top, and corresponding dark web pages, and calls the ransomware "Maze support system" on these web pages, claiming that it can "help detect security issues." On these websites, Maze updates victim information and parts of stolen files in real time and threatens that it will release these files if the ransom fails to be paid on time. Maze also declares that some other ransomware families, such as SunCrypt, REvil, and LockBit, have joined to work under the new operations model.

The following figure shows a threat message displayed on Maze websites, indicating that a website has been attacked and 5% of the stolen data has been published.

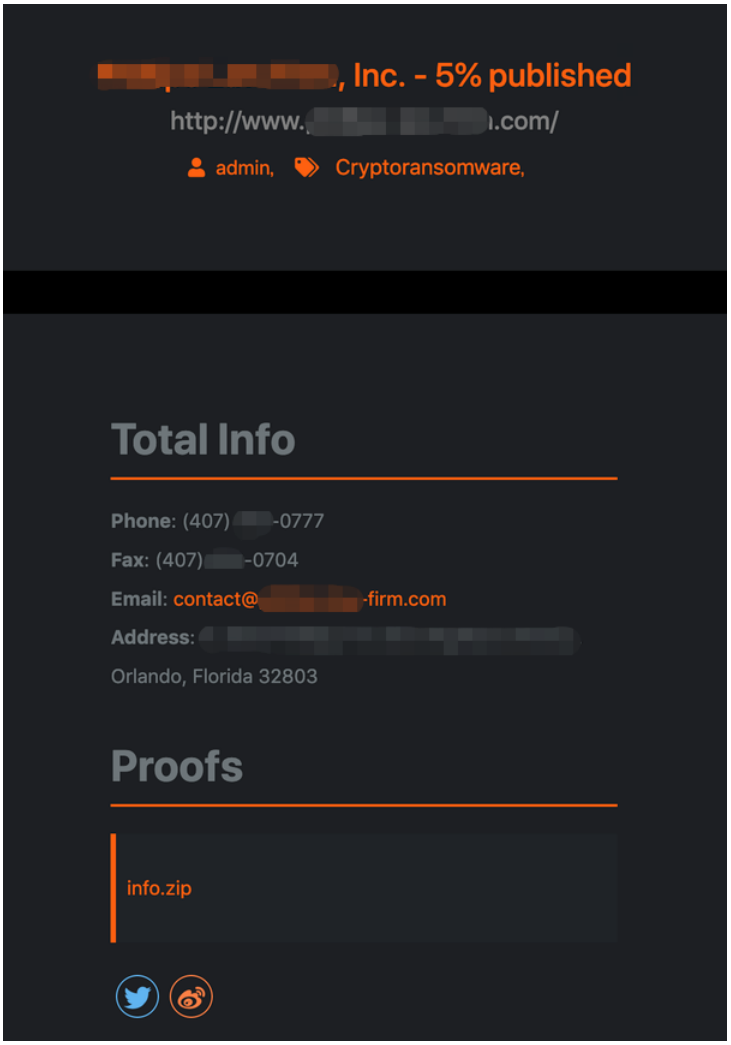


Figure 3-13 Victim information published on Maze websites

In early November, the Maze ransomware group announced on the dark web that "the project is closed". Currently, it is unclear whether this announcement was some kind of smokescreen. A sure thing is that the wicked operation model of combining extortion with data leaks, a typical model adopted by Maze, will be copied by more ransomware families in future.

The following figure shows Maze's announcement made in November.

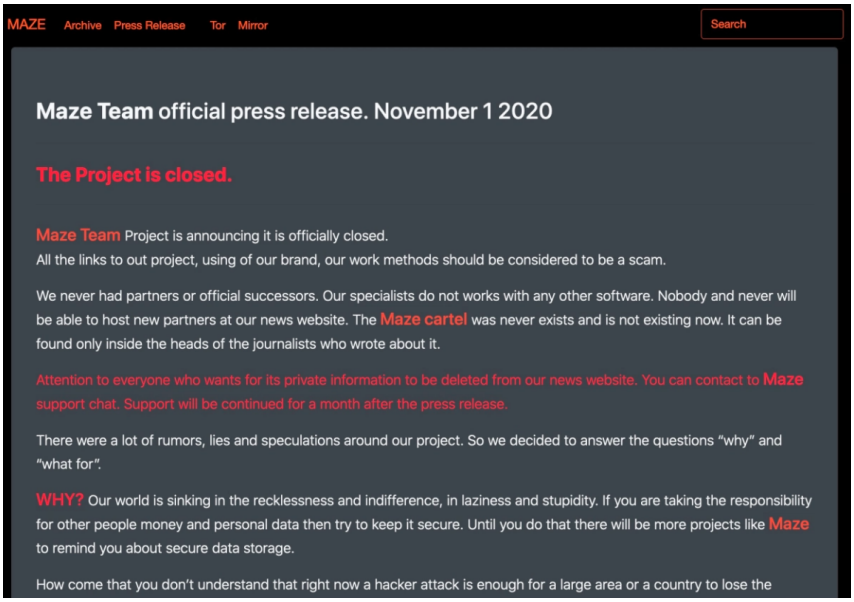


Figure 3-14 The Maze team's announcement

3.3.2.4 BitRAT

In the past few years, as TinyNuke, Gozi, and other remote access trojans (RATs) have their source code disclosed on the Internet, hackers can develop new RATs at a greatly reduced cost. In 2020, Warzone, BitRAT, and other malware families that use the hidden virtual network computing (hVNC) feature, the core of TinyNuke, gained popularity on hacker forums, becoming new favorites of malicious email attackers.

BitRAT first spotted in the third quarter typically represents the current trend of RAT creation. Usually, BitRAT is delivered by, for example, executing scripts in a form, a not very complex method. Besides, such delivery involves only a few levels and the RAT will execute immediately upon delivery.

BitRAT is a multi-purpose trojan that supports remote desktop, video recording, audio recording, agent communication, keylogging, cryptojacking, process and file control, and credential theft. However, it was a rough product pieced together, with core code borrowed from open-source projects, including its hVNC feature derived from TinyNuke, audio recording from WAVE, as well as video recording implemented via the OpenCV API.

In the future, BitRAT may make its kill chain more complicated by reference to the Warzone trojan and enter into a phase of fast expansion. These general-purpose RATs, represented by Warzone and BitRAT, will engage in price wars because of delivering similar functions in a foreseeable future when malicious emails carrying the trojans will also experience a fast growth.

3.3.3 IoT Botnet Families

3.3.3.1 Mirai/Gafgyt

Because of their particularity in the use of network resources, IoT devices are always a magnet that attracts various DDoS trojans. Over time, Mirai and Gafgyt, two major DDoS trojan families, have grabbed the lion's share of compromised IoT devices. The two families, by virtue of their open-source code, ease of use, high scalability, and cross-platform capabilities, have been popular among hackers, especially young ones.

According to NSFOCUS's statistics, the activity of Mirai varied greatly from month to month in 2020. In the third quarter when the botnet was the most active, 5987 nodes were added to the botnet on average each month. In contrast, the Gafgyt botnet was relatively stable, with 2186 nodes added on average each month.

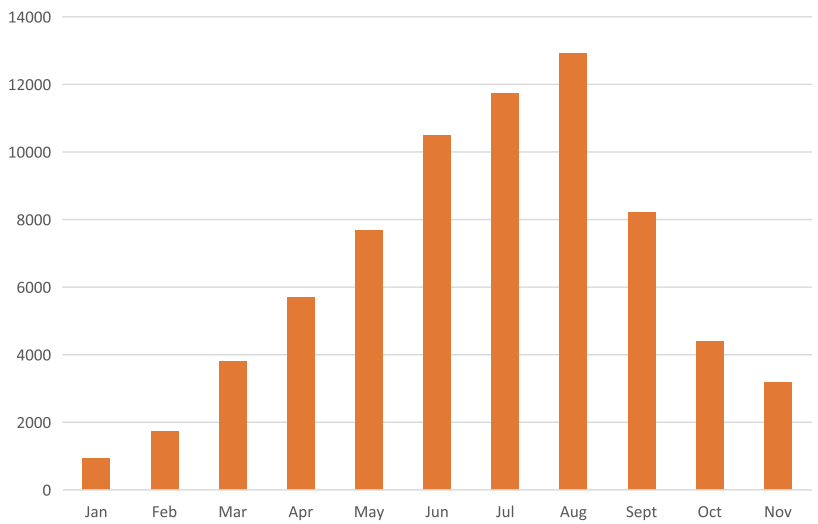


Figure 3-15 Monthly increase in active nodes of Mirai

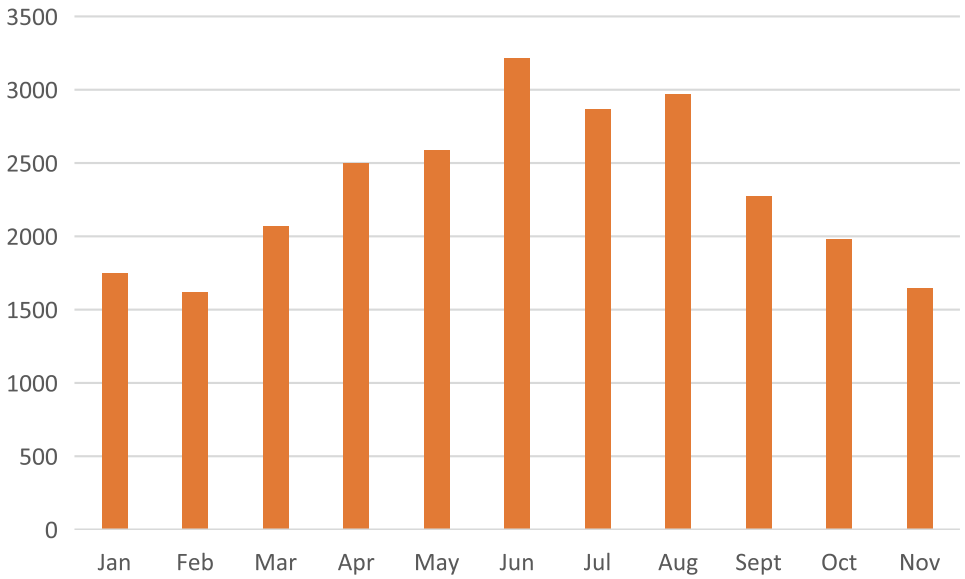


Figure 3-16 Monthly increase in active nodes of Gafgyt

Because of their easy access, Mirai and Gafgyt have built up huge user bases, which in turn, stimulates hackers to work relentlessly on development of more variants. Inspired by the new Mirai variant Echobot that emerged at the end of 2019, many new variants in 2020 chose to carry exploit payloads. We find that, as far as Mirai is concerned, the variant craziest about exploits in 2020 was fetch, which carried up to 56 different exploit payloads targeting vulnerabilities in a wide range of IoT devices from different vendors. Other variants, such as dark (29), Toaster (21), and Loligang (19), also made aggressive attempts to exploit new vulnerabilities for lateral movement. Some Mirai/Gafgyt variants even carried suspected 0-day vulnerabilities, showing some IoT botnet operators' capabilities of discovering vulnerabilities.

The following figure shows exploit payloads of the fetch trojan.

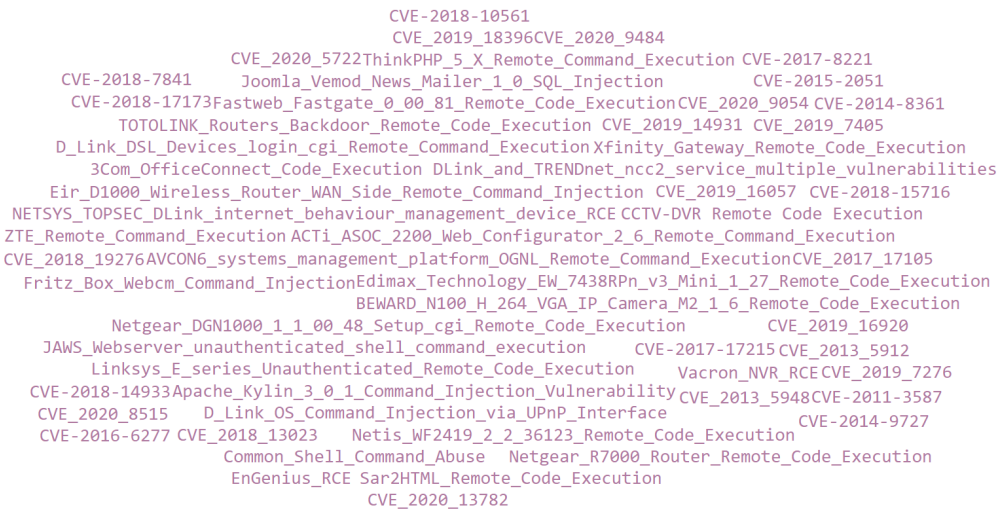


Figure 3-17 Exploit payloads of fetch

3.3.3.2 Mozi

Mozi, as a new botnet trojan first appearing at the end of 2019, grew rapidly in the first two quarters of 2020.

It has been years since the inception of IoT botnets. Today, their controllers are no longer contented with the traditional TCP-based model, but turn their eyes to other network models of high anonymity. As an example of IoT botnets' extension to peer-to-peer (P2P), Mozi uses the distributed hash table (DHT) for network construction, creating a Mozi-DHT botnet within the DHT network. Since its first appearance in 2019, Mozi has been continuously expanding its scale. Our ongoing monitoring finds that the daily number of nodes that Mozi tried to recruit has exceeded 10,000 on average since the first quarter of 2020, accounting for over 1% of the entire DHT network. This indicates that Mozi has evolved into a botnet of the medium size, capable of launching nasty attacks against worldwide targets.

From the code composition, Mozi, obviously, is not a product of independent development. Its persistence module and attack module reuse parts of the code of Gafgyt trojans and variants, delivering such functions as renaming instances, monitoring watchdogs, and adding iptables rules, and supporting launch of common DDoS attacks, including UDP, TCP, and HTTP flood attacks.

For propagation, Mozi also uses common methods. It leverages vulnerabilities and weak Telnet password cracking to attack random or specified IP addresses. Its common exploit payloads are effective for compromise of IoT devices of certain models from Netgear, Realtek, D-Link, Huawei, GPON, Vacron, and Zyxel.

The following figure shows the process of a Mozi node from joining the DHT network to executing the attacker's instruction.

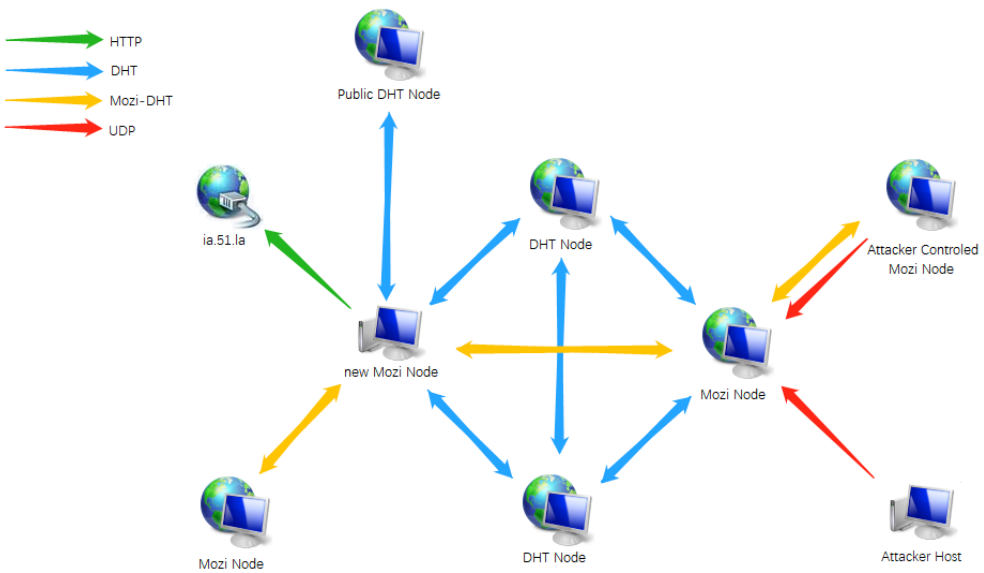


Figure 3-18 Mozi-DHT network communication model

We find that the Mozi botnet is mostly active in East Asia, Europe, and North America. It also has some nodes distributed in Australia and Brazil. China hosts 25.3% of Mozi nodes, becoming the largest source of the Mozi botnet. The USA and South Korea come in second and third, with 10.3% and 7.9% of nodes respectively. In Europe, Mozi nodes are mostly found in Russia, Germany, France, and Poland.

Based on the P2P model, Mozi will be more difficult to detect and address than traditional botnets. As Mozi employs a propagation mode common to IoT botnets, someday it will probably scale up to the same size as notorious botnets like Mirai and Gafgyt.

3.4 Malicious Traffic

3.4.1 Web Threats

3.4.1.1 Web Attack Trend

Of all web attacks detected in 2020, 90% used regular attack methods, including HTTP access control, server information disclosure, resource leech, cookie poisoning, and SQL injection. HTTP access control events were ranked first in number, calling for special attention.

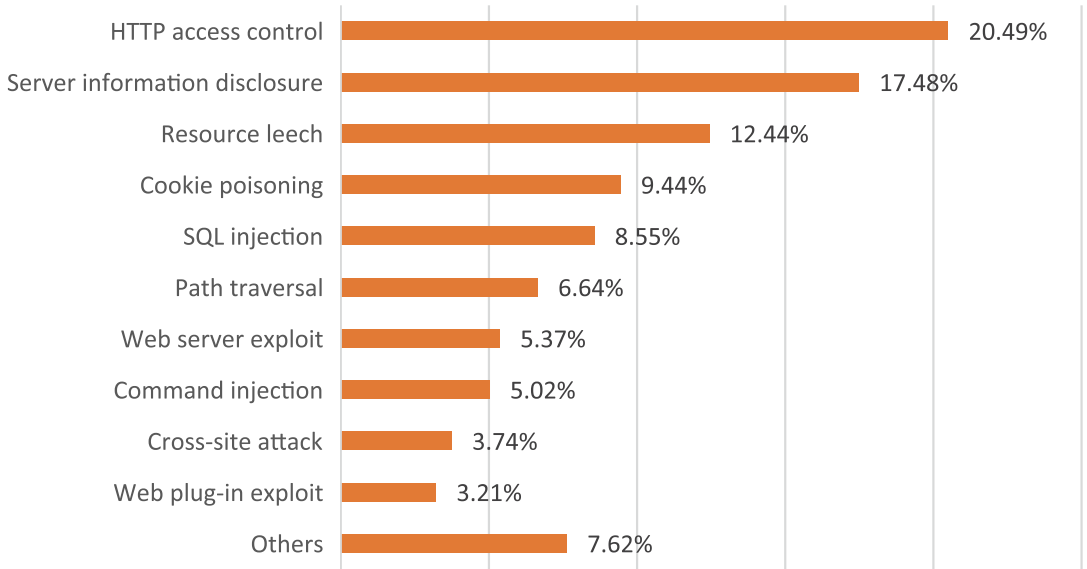


Figure 3-19 Percentages of web attack types in 2020

A breakdown of web attacks finds that web server/middleware exploits accounted for 66% of all web attacks, much higher than web framework exploits (34%). Unlike web frameworks, large servers/middleware systems boast huge user bases, with a great number of deployments, therefore becoming a magnet to hackers, who keep eyes on any vulnerabilities disclosed.

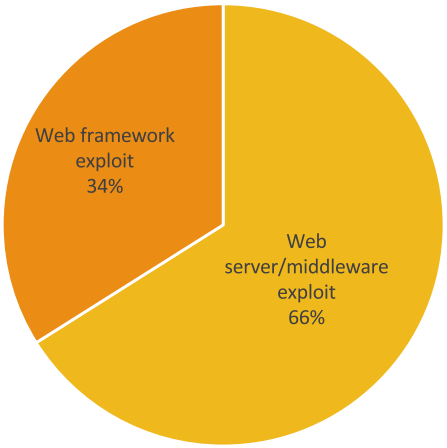


Figure 3-20 Distribution of web attacks by type in 2020

As for exploits against web servers/middleware, most targeted Apache Tomcat, Microsoft IIS, Nginx, and Lighttpd, all of which are mainstream products receiving over 75% of attacks. As for how to implement attacks, hackers still vote for conventional means. They may exploit vulnerabilities to obtain information from servers, such as source code, host information, and website configuration files. They may exploit servers' flaws in parsing URLs and file names to upload malicious web shell files to servers for execution via the file upload API. They may even exploit servers' weaknesses to directly run executables outside of the web directory.

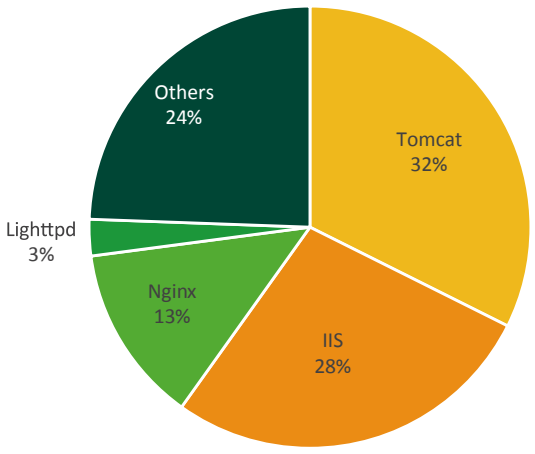


Figure 3-21 Distribution of targeted web servers/middleware

Among attacks targeting web servers/middleware in 2020, most exploited "antique" vulnerabilities, which have existed for so long that many mature methods and automatic tools are available on the Internet. Once discovering servers of a legacy version, hackers can quickly exploit such vulnerabilities for malicious purposes.

The following table lists top 5 CVE vulnerabilities exploited against web servers/middleware in 2020.

Table 3-2 Top 5 CVE vulnerabilities exploited against web servers/middleware

Vulnerability ID	Vulnerability Description	Product
CVE-2008-5519	If a malicious client submits a malicious request with an empty Content-Length header to the mod_jk module of the Apache Tomcat server, or submits the same request repeatedly in a short time, the attacker can view responses to other user requests.	Apache Tomcat
CVE-2000-0884	IIS 4.0 and 5.0 are prone to a vulnerability in Unicode decoding, allowing users to execute arbitrary commands.	Microsoft IIS
CVE-1999-0253	IIS is prone to a vulnerability in ASP file name extension parsing, allowing direct display of file contents by adding special characters in an extension.	Microsoft IIS
CVE-2000-0886	Microsoft IIS 4.0 and 5.0, when handling the CGI application (.exe, .pl, .php, and so on), do not perform a proper security check of CGI file names requested by users. This may cause IIS to mistakenly open or run a file if a special character is contained in the file name.	Microsoft IIS
CVE-2020-1899	The script handling code in IIS contains a stack overflow vulnerability in handling of repeated parameter requests. By sending a crafted URI request to the ASP page of the website carried by IIS, a remote attacker could exploit this vulnerability to crash the service.	Microsoft IIS

Compared with 2019, web framework exploits targeting Apache Struts2 soared in 2020, as shown in the following figure. Being historically vulnerable, this framework was ranked first in terms of exploits for four consecutive years.

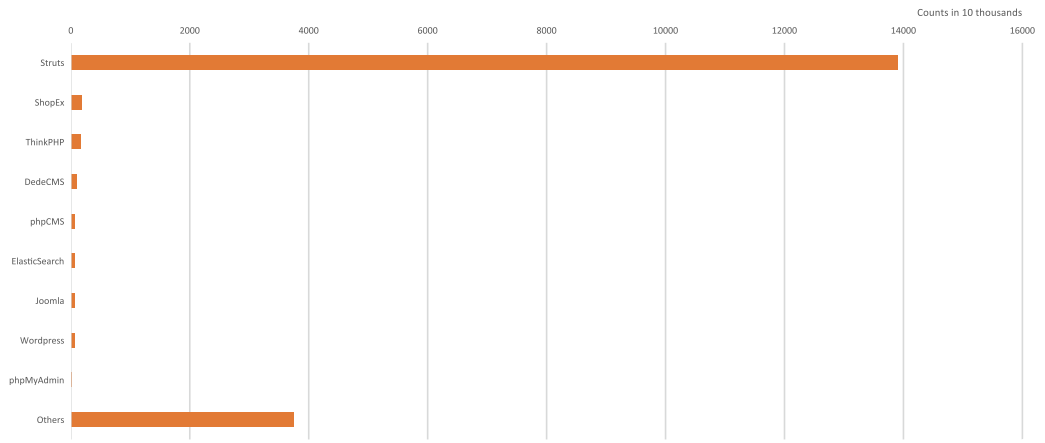


Figure 3-22 Web frameworks mostly targeted in 2020

3.4.1.2 Web Exploits

In 2020, a number of unauthorized remote code execution vulnerabilities were disclosed, including some in widely used web servers and frameworks, such as WebLogic, Tomcat, and Dubbo. Hackers are especially interested in such vulnerabilities and usually develop related exploits immediately after they are disclosed. By using these tools to automatically scan for and exploit vulnerabilities, hackers can identify vulnerable hosts on the Internet, thus putting all related vulnerable websites at risk of compromise. Administrators should be duly attentive to website vulnerabilities and act promptly to update and remediate the affected systems after receiving related alerts.

3.4.2 DDoS Threats

3.4.2.1 DDoS Attack Counts and Peak Sizes

(1) Attack Counts and Traffic

As of December 2020, we had detected 152,500 DDoS attacks, which generated 386,500 TB of traffic in total, a year-on-year decrease by 16.16% and 19.67% respectively. For details about DDoS attack trends in 2020, refer to NSFOCUS's 2020 DDoS Attack Landscape.

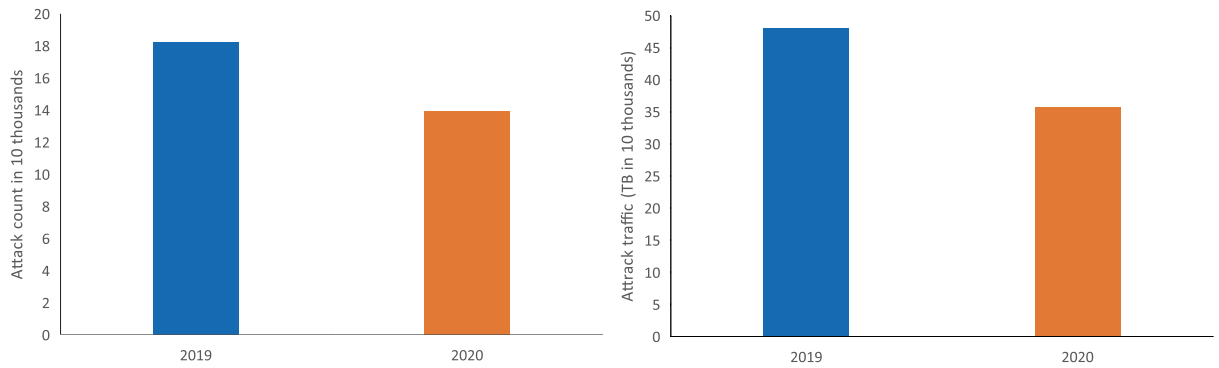


Figure 3-23 Comparison of DDoS attack counts and traffic in 2019 and 2020

(2) Attack Peak Sizes

Of all DDoS attacks, 18.16% peaked at 5–10 Gbps, making up the largest proportion. In 2019, attacks peaking at 1–5 Gbps dominated. In 2020, attacks peaking at 5–50 Gbps were distributed evenly,

together accounting for 53.07%, but the proportion of small attacks peaking below 5 Gbps dropped. According to experts, this is mainly due to the rollout of 5G networks, which increase the available bandwidth for devices as well as for DDoS attacks implemented through IoT botnets. As a result, the overall DDoS attack capability in 5G environments has improved greatly, posing a severe challenge to DDoS attack mitigation and protection.

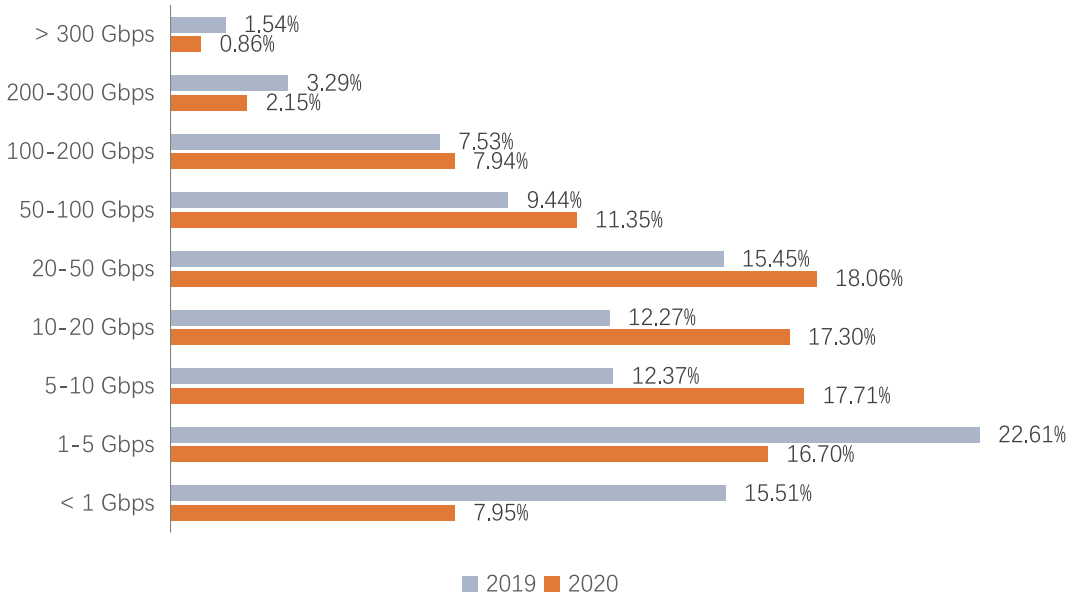


Figure 3-24 Distribution of DDoS attacks by peak size

3.4.2.2 DDoS Attack Types

(1) Proportions of Different Attack Types

In 2020, most frequently seen attacks were UDP (User Datagram Protocol) floods, SYN floods, and NTP (Network Time Protocol) reflection floods, which together accounted for 56% of all DDoS attacks. UDP flood and SYN flood attacks still stood out among all types of DDoS attacks. A noteworthy phenomenon is that ACK flood attacks dropped significantly year on year from 14.9% to 2% in terms of the attack count, losing the third place to NTP reflection flood attacks.

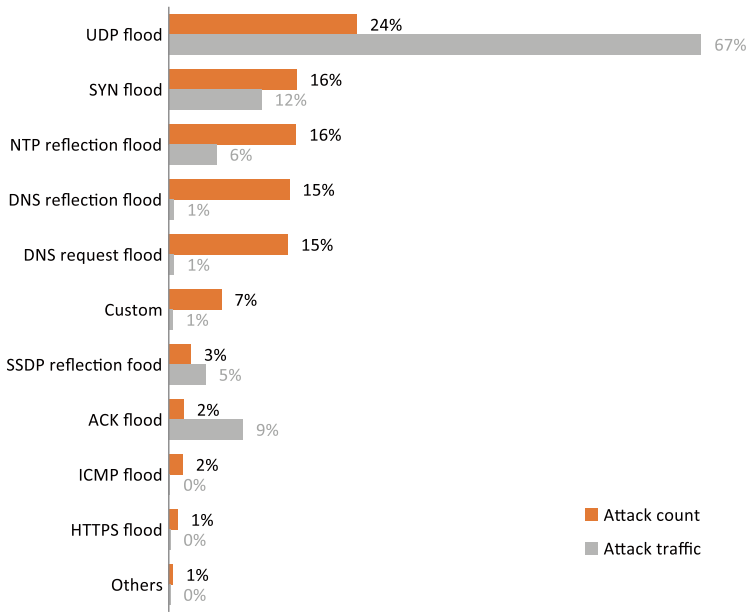


Figure 3-25 Proportions of different attack types by count and traffic

(2) Multi-Vector Attack

Compared with 2019, 2020 saw more multi-vector DDoS attacks. In actual attacks, hackers tend to employ multiple vectors simultaneously and exploit flaws in protocols and systems to achieve the best effect.

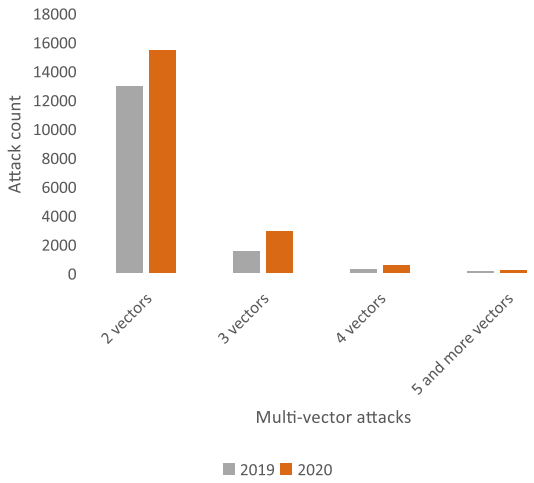


Figure 3-26 Distribution of multi-vector attacks

(3) Reflection Attacks

In 2020, reflection attacks made up 34% of all DDoS attacks. Compared with 2019, the number of reflection attacks increased significantly in 2020, and so did their proportion. In this year, NTP reflection, DNS (Domain Name System) reflection, and SSDP (Simple Service Discovery Protocol) reflection attacks stood out among all reflection attacks. To be more specific, NTP reflection attacks made up the largest proportion in both the number (80%) and traffic volume (53%).

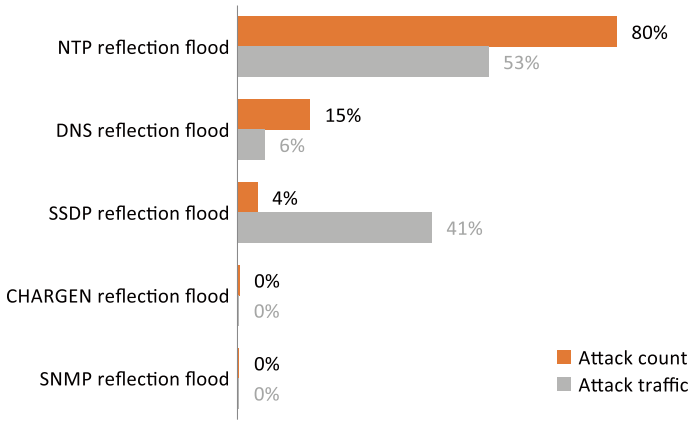


Figure 3-27 Proportions of various reflection attacks by count and traffic volume

3.4.2.3 DDoS Attack Time Profiling

(1) Attack Distribution by Duration

In 2020, the average duration of DDoS attacks was registered at 42 minutes, a 21% decrease from 2019. We noticed that the longest DDoS attack in 2020 lasted around 13 days, far shorter than the longest attacks detected in previous years.

In 2020, DDoS attacks lasting less than 30 minutes accounted for 80%, 5 percentage points higher than the previous year (75%). The high proportion of short attacks signals that attackers are attaching more and more importance to the attack cost and efficiency and are more inclined to overwhelm the target service with floods of traffic in a short time, getting users offline and causing high latency and jitters.

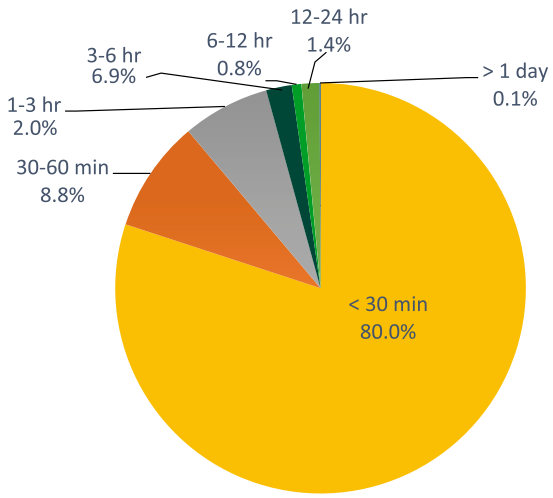


Figure 3-28 Proportions of attacks by duration

(2) Temporal Distribution of Attack Activities Within One Day

In one day from 0:00 to 24:00, busy hours (10:00–22:00) of services were the peak period of DDoS attacks, when 73.4% of attacks were spotted. The coincidence of busy hours of online service access with the peak period of DDoS attacks indicates that attackers intended to maximize their attack effect and impact.

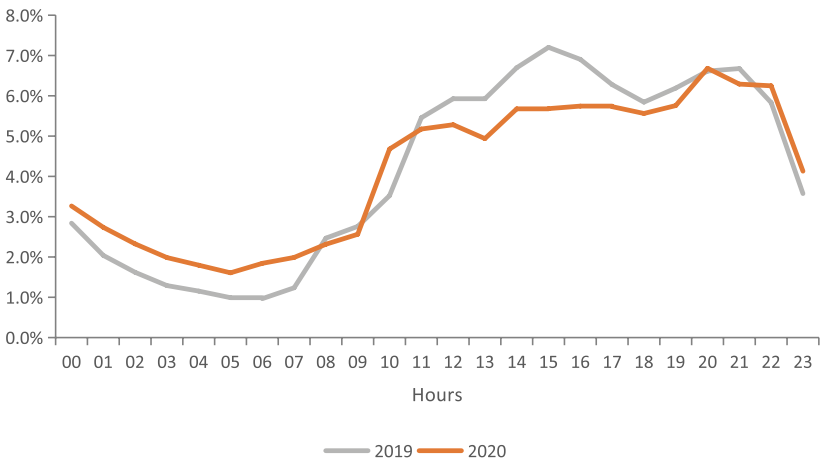
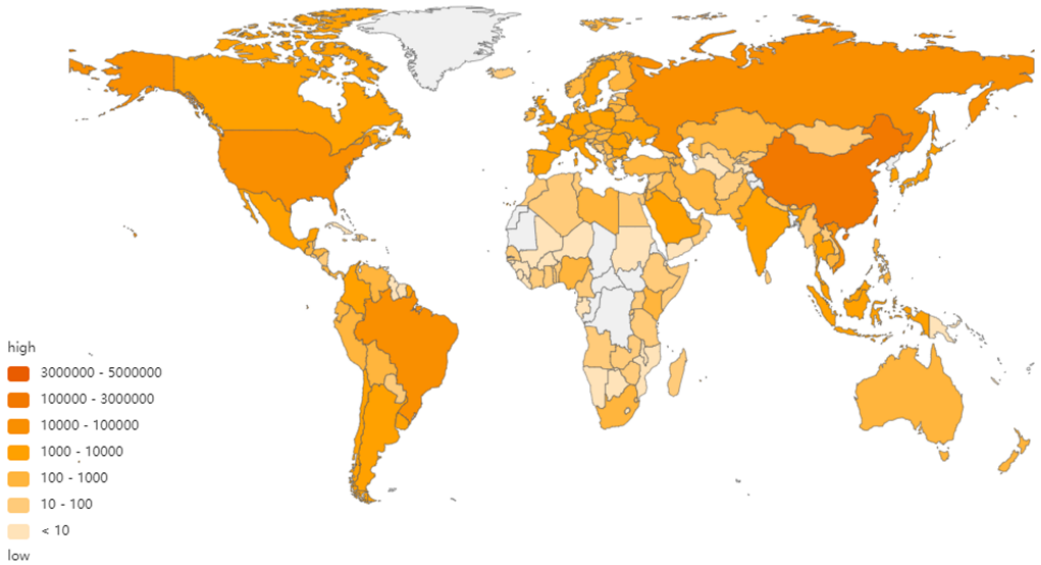


Figure 3-29 Temporal distribution of DDoS attacks within one day in 2019 and 2020

3.4.2.4 Geographical Distribution of DDoS Attacks

(1) Controlled DDoS Attack Sources

According to statistics, China was still home to the largest number of controlled DDoS attack sources (59.7%) in 2020, followed by the USA (7.8%) and Russia (3.4%).



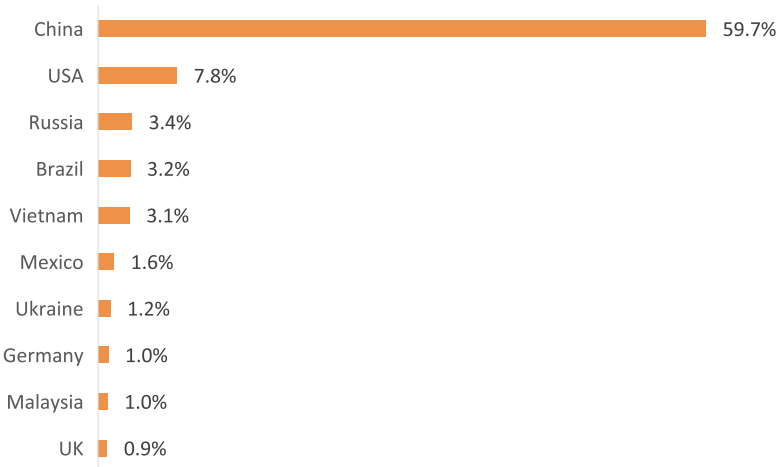


Figure 3-30 Global distribution of attack source IP addresses

(2) DDoS Attack Targets

In 2020, China was the most severely attacked country, seeing 70.7% of DDoS attacks, followed by the USA (12.7%).

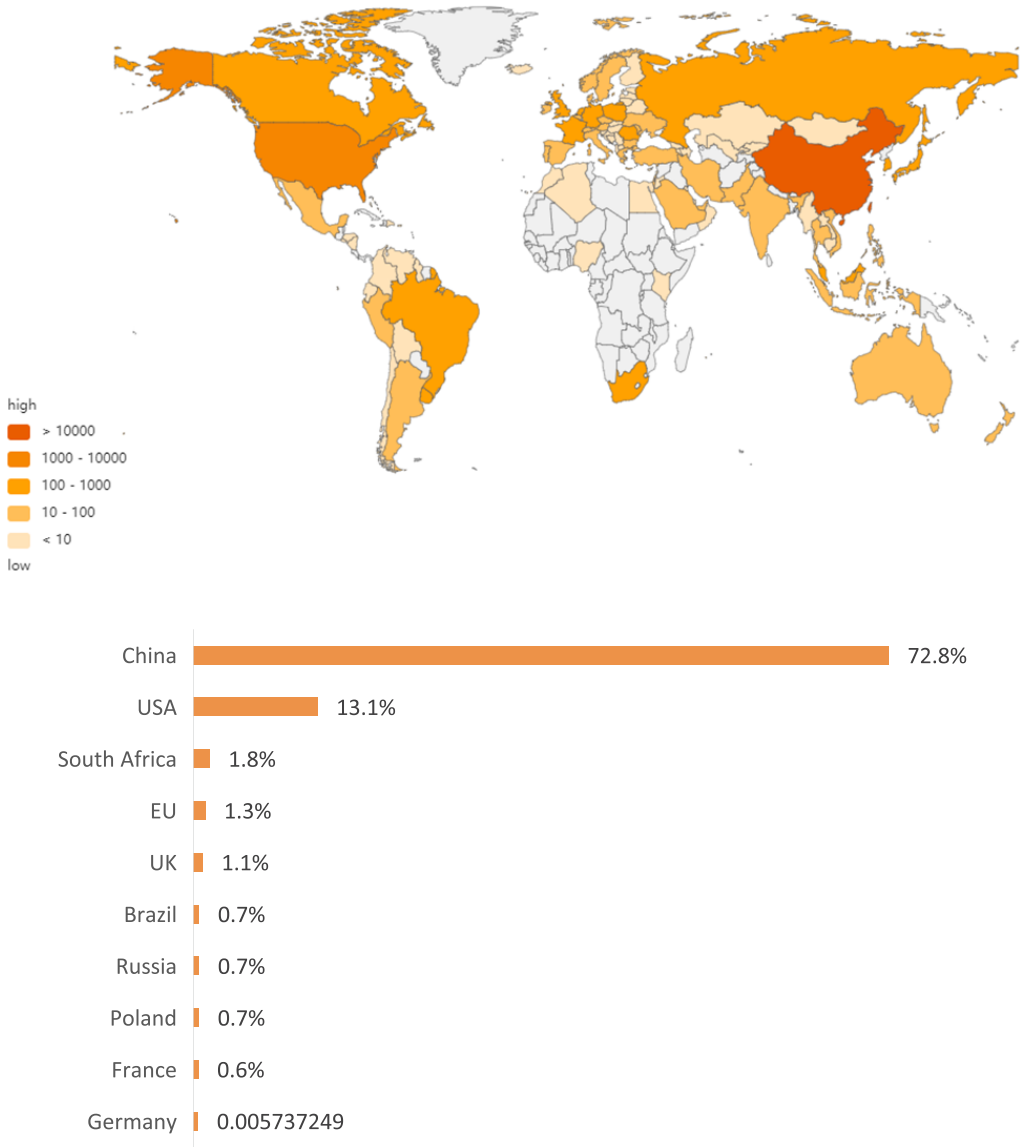


Figure 3-31 Global distribution of targeted IP addresses

3.4.3 Cryptojacking

3.4.3.1 Internal Cryptojacking

We counted the number of cryptojacking events and hosts within enterprises in 2020 based on data of various alerts collected by NSFOCUS.

The cryptomining market pattern has undergone some changes since Bitcoin halved in May 2020 for the third time. A Bitcoin halving event means that the reward for mining Bitcoin transactions is cut in half. Overall, cryptojacking within enterprises trended down in 2020, with both the number of events and the number of hosts declining, indicating that enterprises pay more and more attention to internal cryptojacking and take corresponding protective measures.

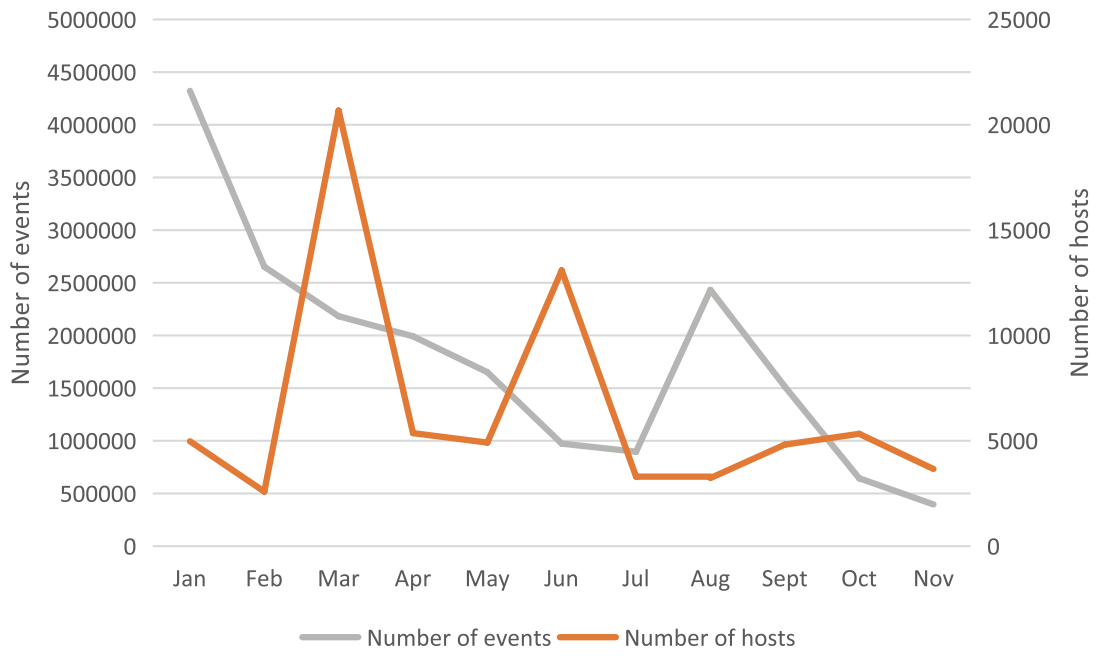


Figure 3-32 Trend of cryptojacking activities within enterprises in 2020

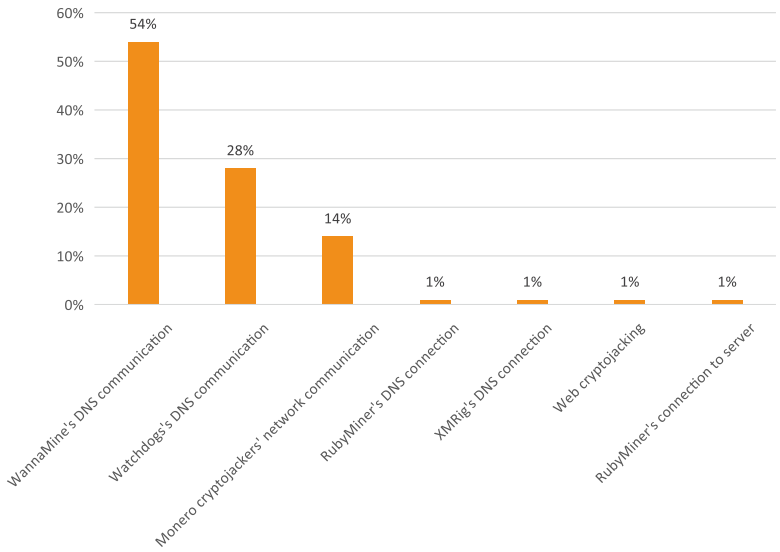


Figure 3-33 Distribution of cryptomining behaviors

As shown in the preceding figure, 54% of cryptojacking activities were conducted by the WannaMine worm for communication with DNS servers. WannaMine evolved to WannaMine 4.0 in 2019, having some new antivirus evasion techniques and being able to rapidly spread laterally within the local area network (LAN). For this reason, this new variant merits our attention.

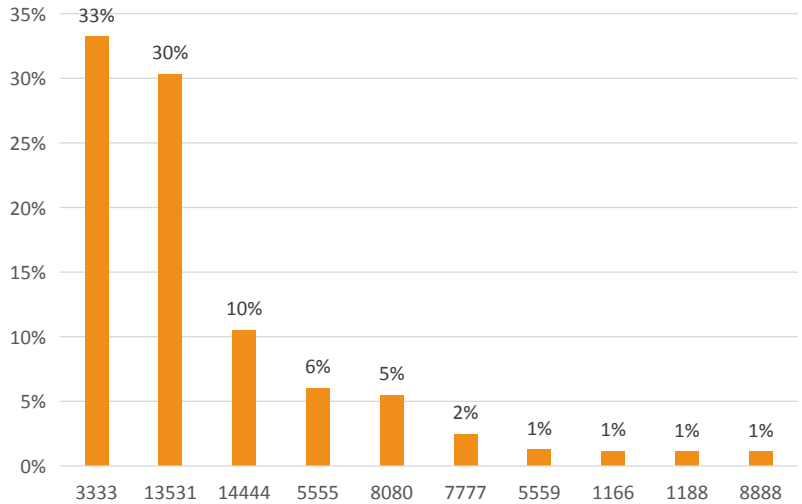


Figure 3-34 Common ports used in cryptojacking activities

Besides ports 53, 80, and 443, attackers tend to use less common ports to connect to the mining pool. As shown in the preceding figure, port 3333 is the most favored port of cryptojackers, followed by ports 13531 and 14444. As specific ports and mining pool addresses are signatures of cryptojacking activities, enterprises can prevent this kind of activities by blocking these ports.

3.4.3.2 Cryptojacking Botnets

According to statistics about monthly active bots, we can learn how active a cryptojacking botnet was in 2020. As shown in the following figure, this botnet became increasingly active in 2020, especially in October when 17,684 bots were spotted.

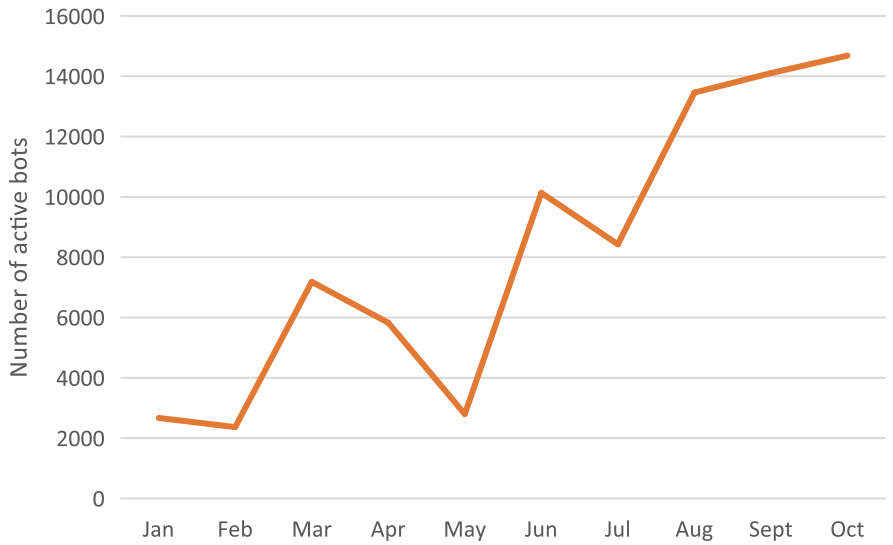


Figure 3-35 Activity of a cryptojacking botnet in 2020

We conducted a geographical analysis of cryptojacking bots before identifying top 10 countries with the most bots. As shown in the following figure, China was ranked first, with 16,394 cryptojacking bots that accounted for 38% of the world's total.

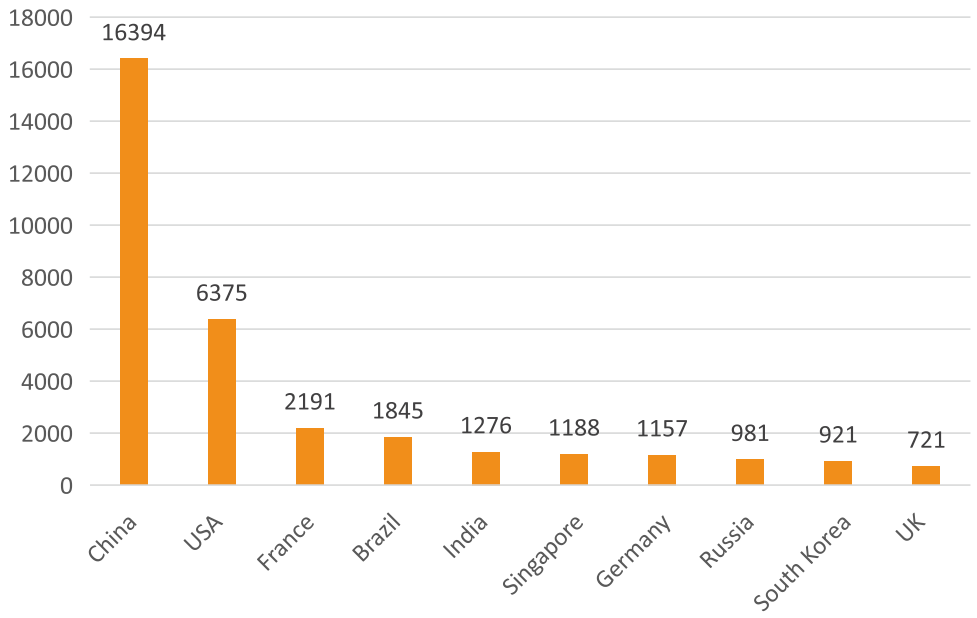


Figure 3-36 Top 10 countries with the most cryptojacking bots

4

Biggest Trends in 2020

4.1 Advanced Persistent Threats

For years, NSFOCUS has been continuing to track and analyze advanced persistent threats (APTs), including attack activities and their tactical and technical features as well as attacker groups behind these activities.

4.1.1 Activity Tracking

4.1.1.1 Impact of APT Groups

Through ongoing monitoring, NSFOCUS discovered 21 APT groups in 2020 suspected to engage in APT activities. The following figure shows top 10 active APT groups in terms of the number of compromised hosts.

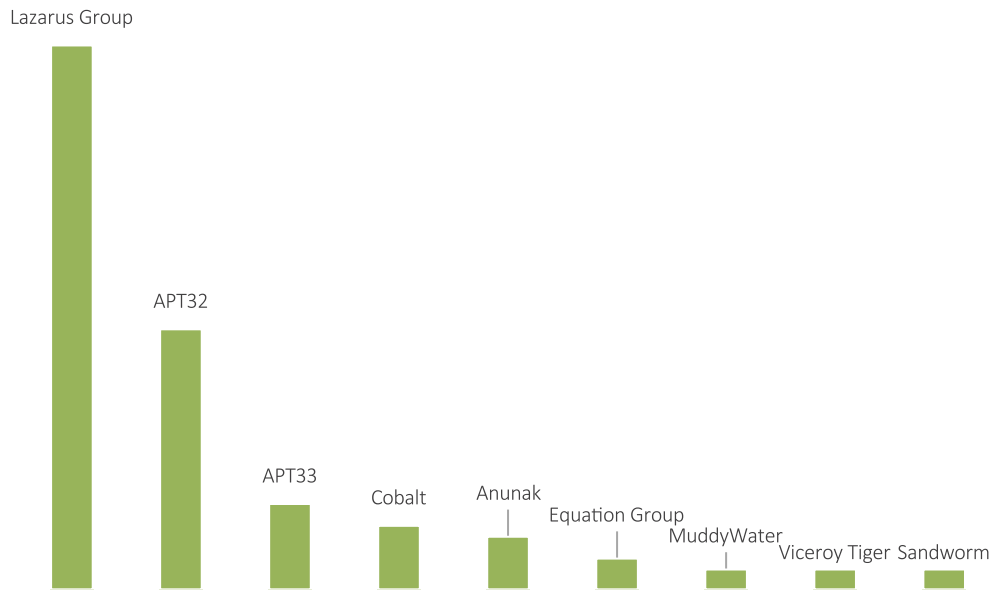


Figure 4-1 Top 10 active APT groups in 2020 in terms of the number of compromised hosts

4.1.1.2 Activity Duration

According to related data on hand, most APT groups in 2020 were active for only a short period, as shown in the following figure.

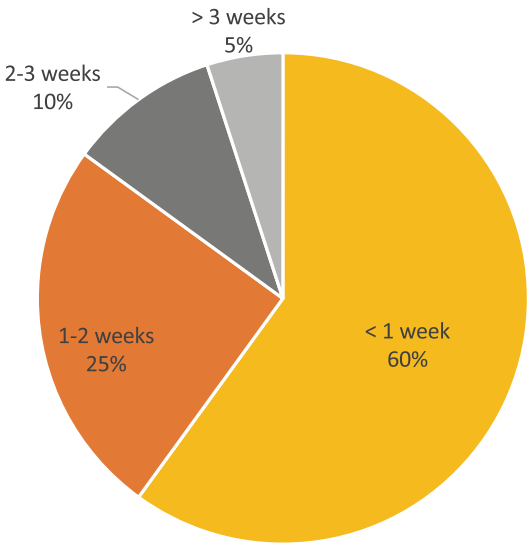


Figure 4-2 Distribution of APT activities by duration

4.1.1.3 Targeted Sectors

From the perspective of targeted sectors, websites and hosts of government and education sectors were the major targets of APT attacks, as shown in the following figure.

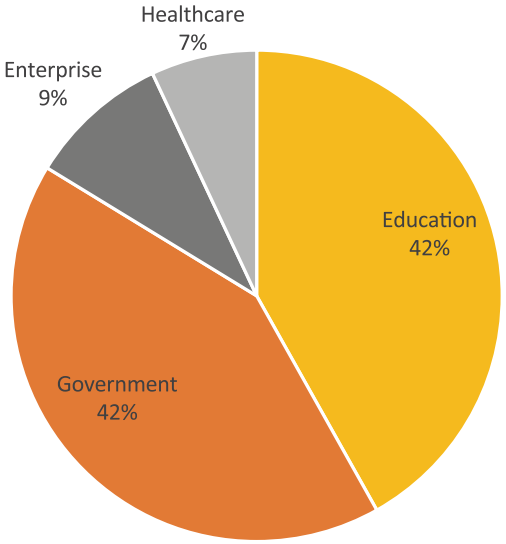


Figure 4-3 Major targeted sectors of APT attacks

4.1.1.4 Technical Methods

As for attack methods, APT groups mainly used watering holes and web exploits, as shown in the following figure.

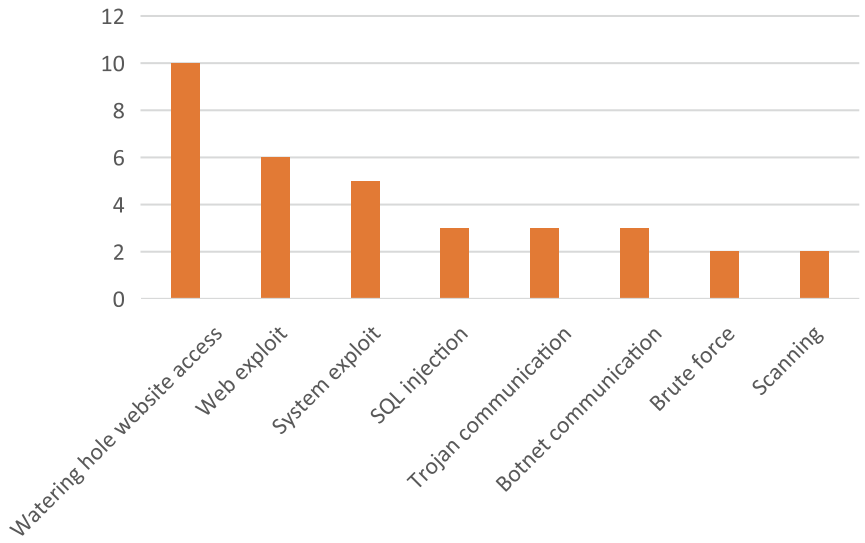


Figure 4-4 Major attack methods of APT groups

4.1.2 Intelligence About APT Groups

From February 17 to November 13, 2020, we collected 98 threat intelligence analysis reports regarding 60 APT groups. The following figure ranks major APT groups in terms of the number of exposures.

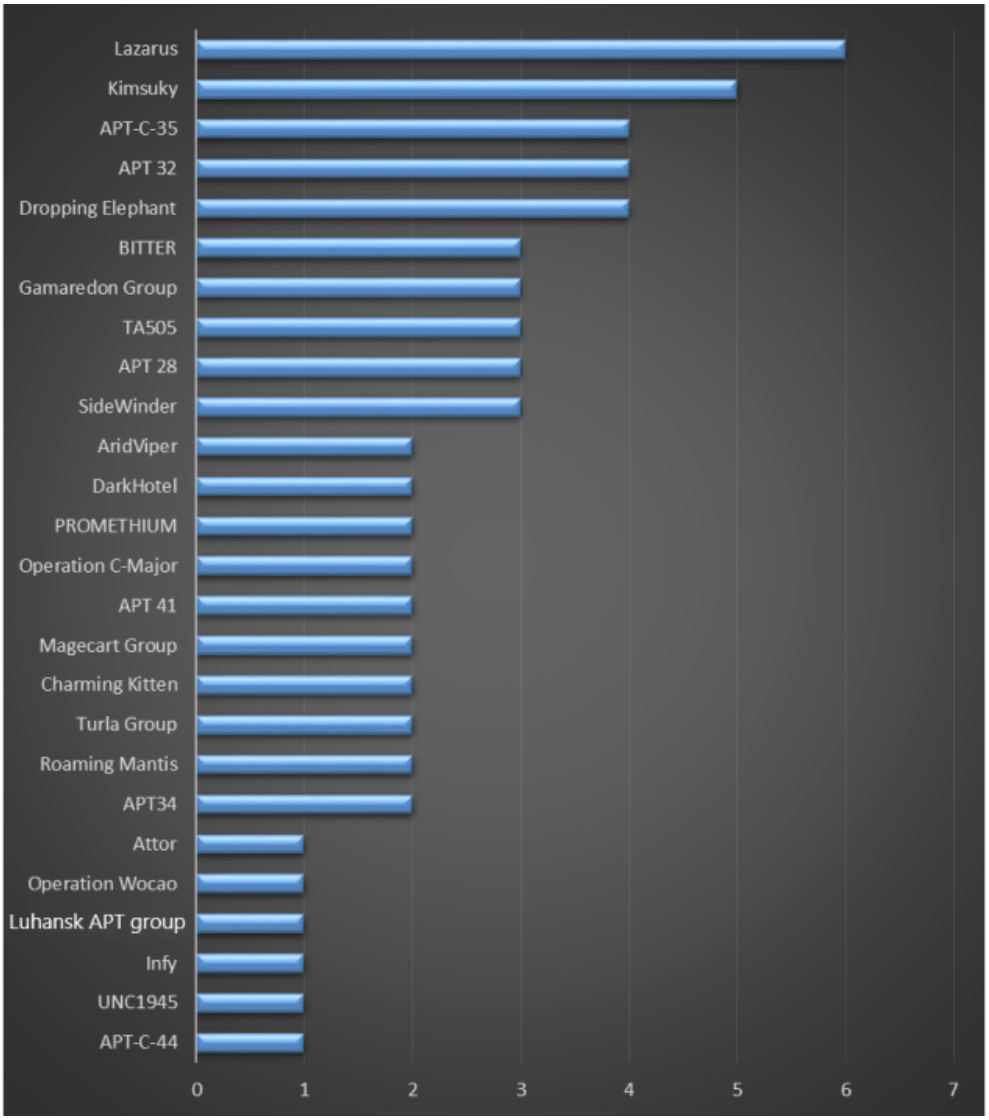


Figure 4-5 Ranking of APT groups by the number of exposures

Of all these groups listed in the preceding figure, Lazarus and Kimsuky, the two North Korean APT groups, took top 2 spots with 6 and 5 times of exposure respectively. Other APT groups making it into top 5 are APT-C-35, APT32, and Dropping Elephant, all located in Southeast Asia.

In April 2020, Lazarus used COVID-19 as a lure to deliver phishing emails and had malicious macro-

embedded documents obtained from remote servers executed by means of template injection, thus bypassing antivirus detection. In the following month, researchers found that the TinkaOTP application looked like the Dacls trojan developed by the Lazarus group, indicating the group's extension of targeted platforms from Windows and Linux to MacOS. In September and November, the Lazarus group's Crat trojan was found to rapidly evolve from V1 to V2, adding new functions such as malware download, obfuscation of strings, API names, and C&C links, and identification of security check processes, network adapters, and detection tools to evade security checks.

Kimsuky is trying to enhance antivirus evasion techniques. In an October campaign against the forthcoming 2020 American presidential election, Kimsuky attempted to bypass antivirus detection by embedding VBS scripts into HWP documents. In November, the backdoor component dropped in an attack that leveraged the WSF script component installed itself as a Windows Defender update.

After analyzing changes in tactics, techniques, and procedures (TTPs) employed by the 60 APT groups, we have the following findings:

1. APT groups showed an inclination to launch campaigns by leveraging trending events, especially the COVID-19 pandemic.

   Most such attacks used COVID-19 information as the decoy. Typical examples of such groups in 2020 include Dropping Elephant (India), APT32 (Vietnam), Operation C-Major (Pakistan), TA505, Sidewinder (India), Lazarus Group (North Korea), and Wizard Spider (Russia).

2. Command and control (C&C) communication means and channels are difficult to detect. Such groups include Death Stalker, APT-C-35, APT41, and Turla Group.

   - Death Stalker leverages a variety of public services, such as Google+, Imgur, Reddit, ShockChan, Tumblr, Twitter, YouTube, and WordPress, as the storage media and inserts strings in posts, comments, and user profiles before reassembling these strings into C&C addresses.
   - APT-C-35 abuses Google Firestarter messages for delivery of their payloads. Even if hardcoded C&C servers are shut down, the group can proceed with C&C communication by

this means.

- APT41 uses iodine to establish DNS tunnels.
- Turla Group uses HTTP/HTTPS status codes for C&C communication.

3. Lateral movement and data exfiltration methods are varying, as is true, for example, of UNC1945, APT34, and Gamaredon Group.
   - UNC1945 attempts to move laterally by loading and executing virtual machines.
   - APT34 leverages DNS over HTTPS (DoH) for lateral movement and data exfiltration.
   - Gamaredon Group injects malicious macros or remote templates into documents already present on the compromised system for lateral movement.
4. Attacks are extended to or even mainly target mobile devices. Groups acting like this include Lazarus, APT-C-44, Arid Viper, Confucius, PhantomLance, Roaming Mantis, and APT-C-35.
   - The DacIs trojan of the Lazarus group has evolved to target MacOS.
   - Arid Viper disguises as chat software to trick victims into downloading it. It may also forge Android app markets and official websites for delivery of malicious applications.
   - PhantomLance available on Google Play does not contain any malicious payload initially until the release of subsequent updates.
5. Attack detection evasion techniques keep iterating and evolving, as is the case with Lazarus, SideWinder, SWEED, PROMETHIUM, Hellsing, Roaming Mantis, Dropping Elephant, APT-C-35, APT-C-36, APT37, and The Gorgon Group.
   - The Gorgon Group saves malicious samples on Pastebin, a code hosting platform, to evade detection.
   - Roaming Mantis looks for the strings "Emulator" and "x86" and checks for the device ID, phone number, and International Mobile Station Equipment Identity (IMEI) to evade sandbox detection.

- SWEED's Guloader has the capabilities of sandbox escape, code obfuscation, anti-debugging, C&C/URL encryption, and payload encryption.
- Lazarus's CratV2 trojan detects security software by querying process names and network adapter names.
- Hellsing uses legitimate application signatures, such as wsc_proxy.exe (Avast remediation service), qcconsol.exe, and mcvsshld.exe (McAfee component), and legitimate Microsoft and Google utilities to evade detection.

6. Groups pursuing economic benefits are undergoing industrial transformation. Examples of such groups are TA2101, TA505, FIN6, and Evilnum. To be specific, FIN6 and Evilnum both have purchased some toolkits from the malware as a service (MaaS) provider Golden Chickens.

4.2 IoT Security

Smart devices are becoming an integral part of our daily lives. While bringing convenience to us, they are posing a severe threat to the IoT considering the large number of hidden security issues. Based on NTI's asset intelligence, we ranked most exposed IoT assets in 2020, as shown in the following figure. Globally, over 19 million routers were exposed, far exceeding the number of other exposed IoT devices. Video surveillance devices came in second, standing at 15.6 million.

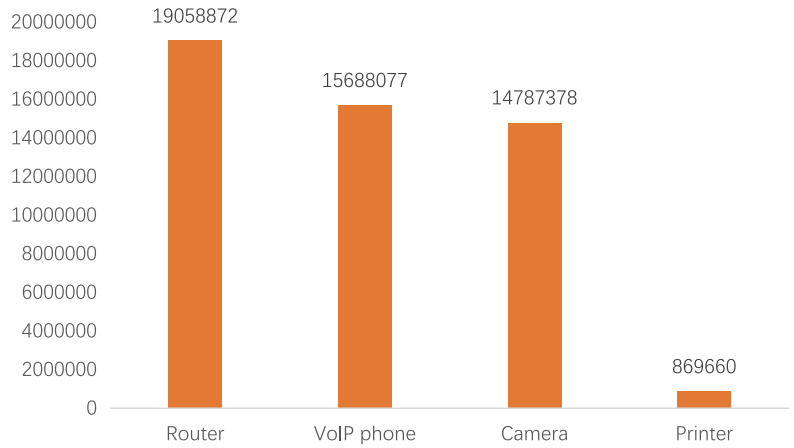


Figure 4-6 Global distribution of exposed IoT assets

The following figure shows the geographical distribution of exposed IoT assets in top countries. Of all these countries, Germany was ranked first with 8,250,000, followed by the USA with 3,430,000 and China with 3,190,000.

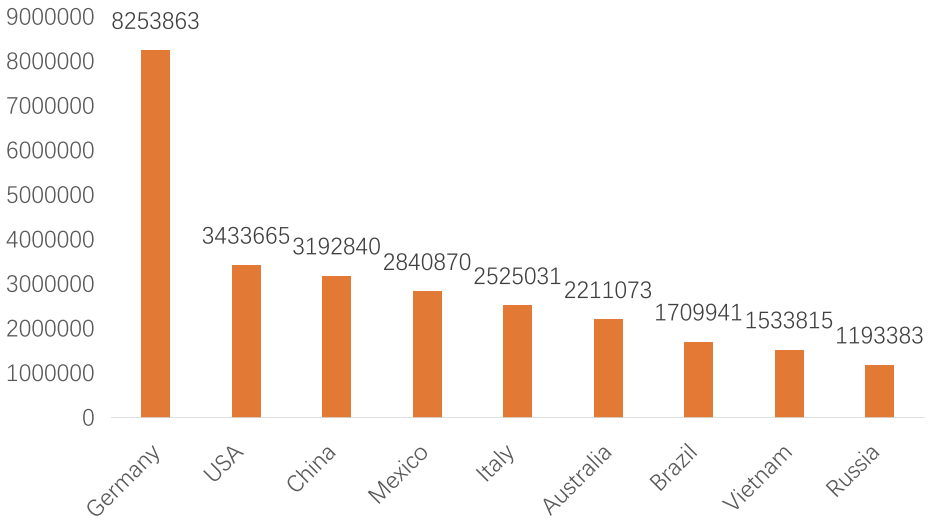


Figure 4-7 Geographical distribution of exposed IoT assets

4.2.1 Exploits

NSFOCUS uses its own threat hunting system[1] to detect and analyze IoT exploits. In 2020, the system observed over 100 exploits targeting the IoT[2], mostly (70%) remote command execution exploited by up to 110,000 attackers. Interestingly, privilege escalation vulnerabilities were on a par with information disclosure vulnerabilities in the percentage, but attracted twice as many attackers as the latter.

1 NSFOCUS Threat Hunting System's (THS) sensor nodes are distributed across the world, covering over 20 countries and common services, IoT services, and industrial control services. Built on a hybrid awareness architecture featuring full-port simulation and intelligent interactions, this system captures a large quantity of threat intelligence from the Internet every day, enabling users to detect threats in real time.

2 Here, only vulnerabilities in IoT assets are discussed, without considering vulnerabilities in non-IoT assets exploited by IoT botnets.

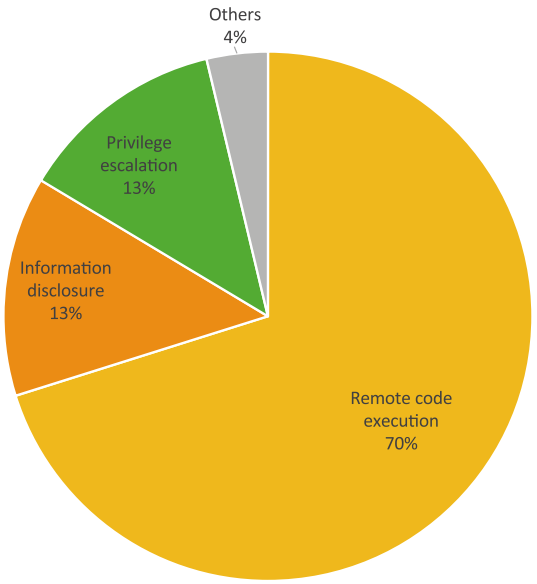


Figure 4-8 Distribution of IoT vulnerabilities by type

The following figure shows device types that exploits of these IoT vulnerabilities mainly targeted. Obviously, routers and cameras were often targeted, together accounting for 90%. Besides, network storage devices and VoIP phones began to attract attention from attackers.

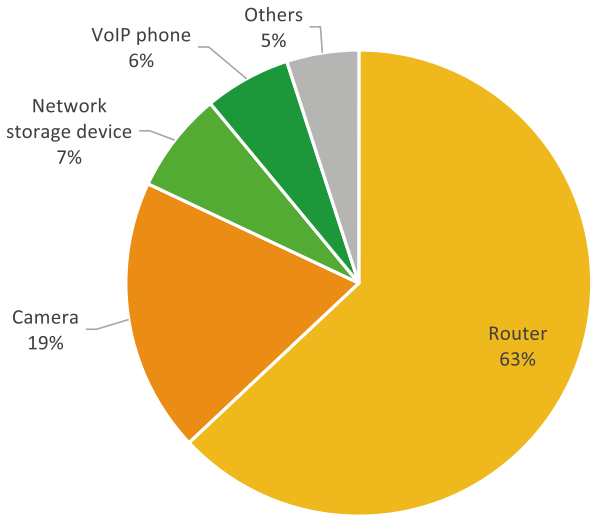


Figure 4-9 Distribution of IoT devices targeted by IoT exploits

4.2.2 Reflection Attacks

According to NTI's survey data and THS's threat data, more and more protocols exploitable for UDP reflection attacks come into view, including the Constrained Application Protocol (CoAP), Ubiquiti, WS-Discovery, OpenVPN, DHDiscover, and Advanced Disconnection Detection Protocol (ADDP). Different from well-known DNS, SSDP, NTP, and Memcached reflection attacks, these attacks target the IoT, posing challenges to DDoS protection. As shown in the following figure, WS-Discovery, OpenVPN, and CoAP were each found on over 700,000 devices. Following them was DHDiscover, found on over 300,000 devices.

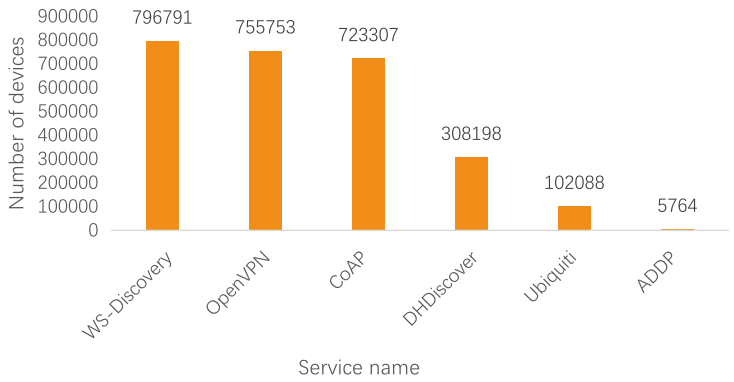


Figure 4-10 Global exposure of IoT services

4.3 Industrial Internet Security

The industrial Internet is an emerging industry of large scale, having various players on the long chain. Security is crucial to the sound development of the industrial Internet. The following sections analyze industrial Internet security respectively from the exposure of industrial control system (ICS) assets, ICS vulnerabilities and attacks, and major ICS security incidents in 2020.

4.3.1 Exposure of ICS Assets

To minimize the chance of ICS devices being hit by cyberattacks, ICSs should run in a physically isolated environment. However, this is rarely implemented in actual production environments. The following figures show the distribution of global ICS assets detected by NTI based on common protocols.

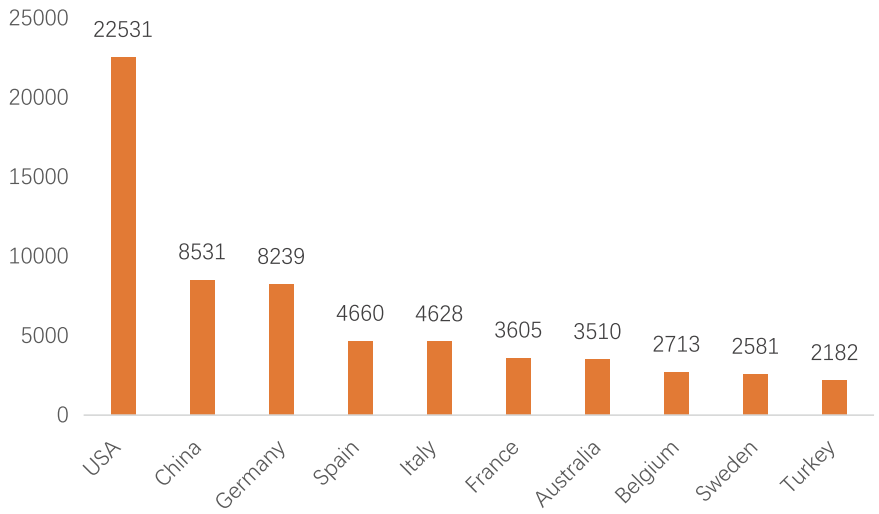


Figure 4-11 Top 10 countries by the number of ICS devices using Modbus

As shown in the preceding figure, the USA is home to the most ICS assets using Modbus, followed by China and Germany, both with over 5000 assets. Evidently, the number of ICS devices exposed is in direct proportion to the industrial automation level of a country.

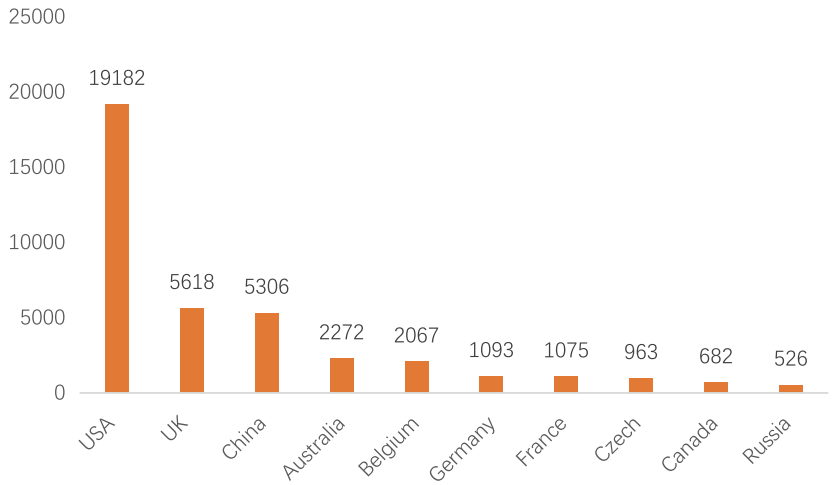


Figure 4-12 Top 10 countries by the number of ICS devices using the S7 protocol

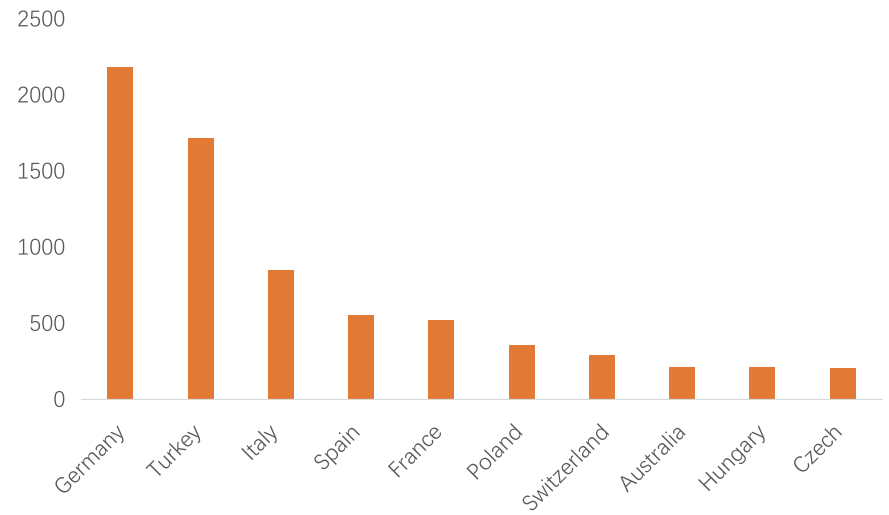


Figure 4-13 Top 10 countries by the number of ICS devices using CODESYS

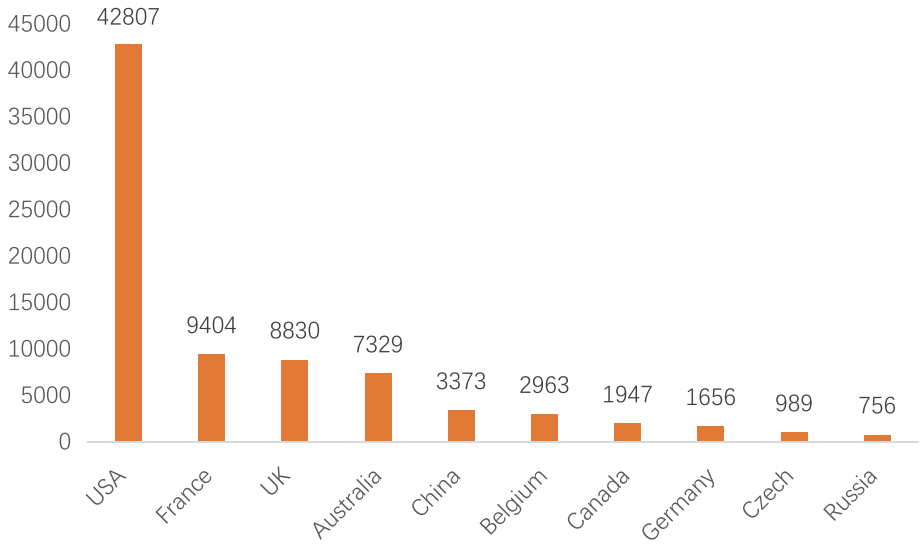


Figure 4-14 Top 10 countries by the number of ICS devices using ENIP

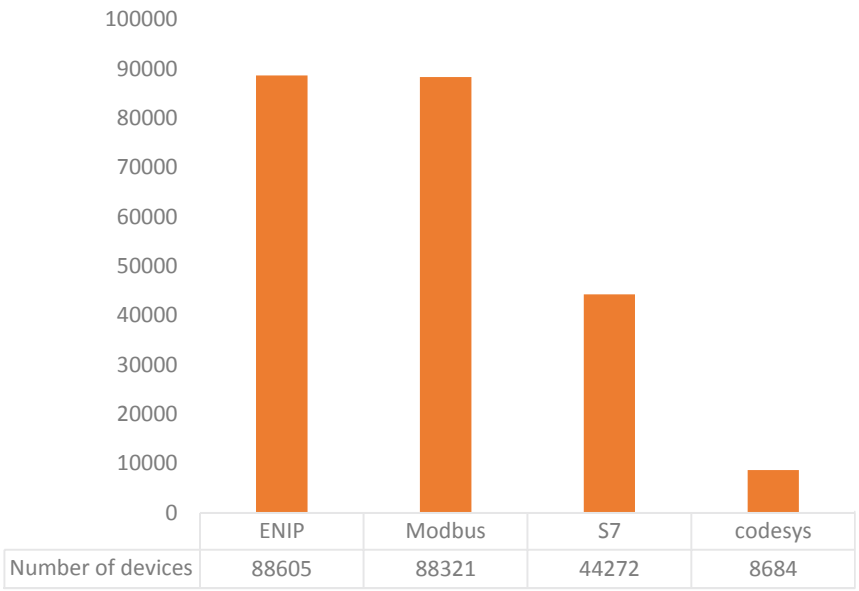


Figure 4-15 Ranking of common protocols used by ICS assets

Of these common ICS protocols, ENIP was ranked first because of being used by the largest number of exposed ICS assets, and Modbus came in second.

For attackers, all these ICS devices exposed on the Internet have the potential to become stepping stones for their penetration into industrial control networks. Some vulnerable ICS devices, if unpatched in time, are very likely to be targeted by attackers once that vulnerability is disclosed.

4.3.2 ICS Vulnerabilities and Attacks

According to information available on the Internet, more ICS security events happened in 2020 than in 2019. The public concern about ICS events was at a level a bit lower than the annual average at the beginning of the year, and then steadily rose over time until the end of the year, a trend coinciding with those in previous years. Among all ICS events in 2020, the proportion of events other than exploits and attacks increased, including but not limited to policy interpretation, expert analysis, and general introduction to ICSs. This, to some extent, reflects people's increasing concern about ICSs and interest in knowing more about this field.

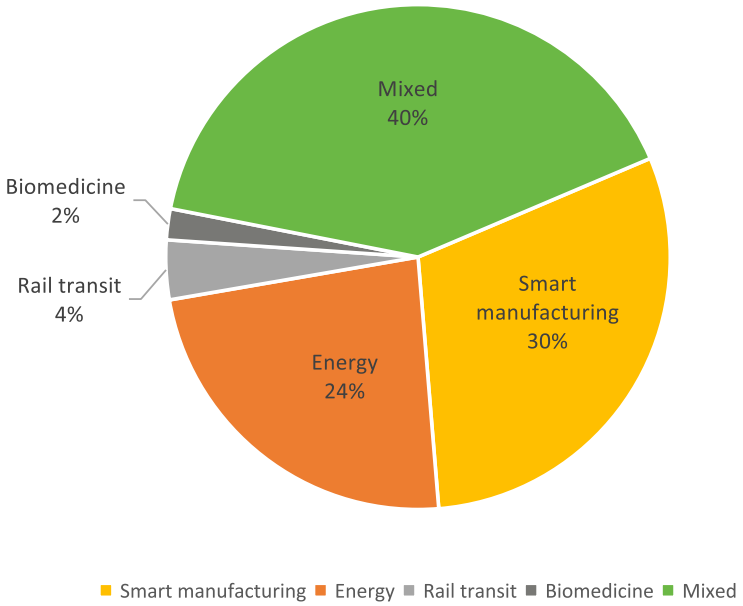


Figure 4-16 Industries involved in ICS events

A marked phenomenon in 2020 is that, ICS events, especially security-related events, mostly involved the mixed industry. Besides, the proportion of attacks targeting smart manufacturing was on the rise, making the industry the biggest target of ICS attacks.

4.3.3 Major Events

In 2020, the major threat to ICS environments and operations was from ransomware. Owing to the nature of ICSs, perpetrators are not particular about vulnerabilities when conducting ransomware attacks. It is enough to cause the system to crash, which will impose a great impact on the overall operations of ICSs. Victims are often taken unawares, not knowing what to do when hit by a ransomware attack. This makes ransomware attacks an especially serious threat. In February 2020, NTI observed that the US Cybersecurity and Infrastructure Security Agency (CISA) released a report, saying that an unidentified natural gas operator had its gas compression facility shut down for two days because of a ransomware attack. Two months later, EDP, a Portuguese energy company, suffered a ransomware attack and was demanded to pay 1580 BTC (approximately USD 10,900,000 or EUR 9,900,000) as ransom.

With the accelerated development of the IoT, more and more ICS assets are exposed on the Internet, making it easier for attackers to compromise the targeted systems for subsequent attacks. According to rough statistics, nearly 60% of ICS attacks start with compromise of assets exposed on the Internet, followed by attackers penetrating the targeted network before moving laterally within the intranet and directly targeting ICS devices by obtaining routing configurations. Data from NTI shows that, in April 2020, supervisory control and data acquisition (SCADA) systems of waste water treatment, pump stations, and sewage treatment facilities in Israel were repeatedly hacked. These attacks were successfully implemented because of programmable logic controllers (PLCs) exposed on the Internet. After compromising these PLCs, hackers took direct control of water facilities and caused a devastating impact.

At the same time, hackers began to turn their eyes to supply chain attacks so as to escalate the impact and efficiency of attacks. Once an upstream component comes with a hidden hazard, a large number of downstream products using this component are all potentially vulnerable. A typical example of this is Ripple20 disclosed in 2020. Ripple20 is a collective name of vulnerabilities found in the Treck TCP/IP protocol stack. These vulnerabilities are common in embedded devices from different vendors, including HP, Schneider Electric, Intel, Rockwell Automation, Caterpillar, and Baxter. Successful exploitation of these vulnerabilities may allow remote code execution or disclosure of sensitive information. Medical, aviation, transportation, home appliance, enterprise, energy (oil/gas), telecom, and retail sectors are affected by Ripple20. By leveraging the trust formed between vendors and ICS operators, hackers can directly break into the targeted system through an external network via social engineering like phishing. Some APT groups are especially interested in this type of attacks. After compromising a system, they usually lie low, collecting information stealthily, and will jump at the chance of attack when the occasion arises to achieve their malignant purposes.

Besides malicious attacks and demands for ransom, attackers may conduct espionage, such as intellectual property theft. When conducting these activities, hackers are often economically motivated. But sometimes, they may be sponsored by governments, stealing design drawings or core algorithms for political purposes.

4.4 5G Security

5G networks employ new technologies, such as network functions virtualization (NFV), network slicing, edge computing, and network exposure function, which will definitely bring new security threats and risks, posing challenges to security protection and operations[1].

4.4.1 SDN Controller

A software-defined networking (SDN) controller, as the brain of the transport network and core network for scheduling, contains many security vulnerabilities. After compromising an SDN controller, an attacker can send instructions to all network facilities, thus easily paralyzing the whole network. Therefore, it is essential to design a secure and reliable SDN controller for mobile communication networks[2].

Table 4-1 SDN's security risks and countermeasures

Asset	Risk	Countermeasure
Application plane	(1) Impersonation. For example, an attacker may impersonate an SDN controller to obtain sensitive data of applications. (2) Applications are not securely isolated from each other. Disclosure of information from one application may lead to the same attack on other applications. (3) Applications themselves are vulnerable.	Authenticate the SDN controller and applications and harden applications.
Control plane	(1) The SDN controller is vulnerable to application-plane and forwarding-plane attacks, such as DDoS caused by large quantities of access requests or data exchanges between applications and forwarding devices and malicious applications' bypass of security policies by leveraging flow table conflicts. (2) As a centralized control point, the SDN controller is prone to penetration attacks.	Authenticate the SDN controller and forwarding devices, mitigate DDoS attacks by using rate limiting and other mechanisms, prioritize flow table entries to prevent policy conflicts, encrypt sensitive data, and harden the controller software and the server that hosts the controller.
Forwarding plane	(1) Controller impersonation attacks for, for example, disclosure of sensitive data or unauthorized access. (2) Flow table attacks such as injection of malicious/bogus flow rules and flow table overflows.	Authenticate the controller, set an appropriate flow table expiry time, and mitigate DDoS attacks by using rate limiting and other mechanisms.
Southbound and northbound interfaces	Data in transit may be intercepted, tampered with, or replayed.	Encrypt data in transit and protect the confidentiality and integrity of hash-based message authentication codes (HMACs) and timestamps to prevent replay attacks.

1 *Exploration into and Practice of 5G Network Security in the Context of New Infrastructure Construction, 2020 West Lake Cybersecurity Conference.*

2 *Whitepaper of 5G Security Requirements and Architecture for Smart Cities, IMT-2020 (5G) Promotion Group, May 2020.*

4.4.2 NFV Technology

The NFV technology is key to dynamic and flexible deployment of elements of core networks. However, the NFV platform itself is vulnerable and has insecure interfaces, and virtual security functions (such as elements of 5G core networks) that it carries are at the risks of remote debugging and data theft and tampering. Therefore, NFV security should be considered from various aspects, as listed in the following table.

Table 4-2 NFV's security risks and countermeasures

Asset	Risk	Countermeasure
Networking	The infrastructure consists of the cloud management network, storage network, service network, and out-of-band management network. Failure to isolate management, control, and storage traffic or failure to set security zones may lead to one threat in one network affecting other networks.	Physically isolate management, control, and storage traffic by, for example, deploying different leaf switches for different networks and connecting an out-of-band management switch to the out-of-band management port. Set security zones and use virtual local area networks (VLANs) to separate security zones of different security levels.
NFVI	Security risks regarding Network Functions Virtualization Infrastructure (NFVI) are similar to those facing cloud computing infrastructure, including virtualization software vulnerabilities, host and virtual machine (VM) system vulnerabilities, VM escape, inter-VM attacks or information theft, and container security issues.	Harden virtualization software and host and VM operating systems (OSs). Isolate and protect VMs to prevent inter-VM attacks.
VNF	(1) Virtualized network functions (VNFs) themselves are vulnerable. (2) VNFs share underlying resources. If one VNF is attacked, the impact may extend to other VNFs.	Harden VNF network elements (NEs). Isolate NEs and protect their interactions and properly enforce authentication. Encrypt critical data of VNFs in transit and storage and protect users' privacy. Manage VNFs throughout their lifecycles.
MANO	(1) The management and orchestration (MANO) system itself contains exploitable vulnerabilities. (2) Internal interfaces of MANO or interfaces between MANO and other systems may be illegally invoked, and exchanged data may be intercepted, tampered with, or replayed. (3) Virtualization and elastic scaling add to the complexity of NFV account and password management.	Harden MANO entities by adopting mutual authentication for communication between MANO entities and communication between a MANO entity and external entities and by protecting the confidentiality and integrity of data in transit.

4.4.3 Multi-access Edge Computing

Multi-access edge computing (MEC) provides services at the edge of the network, specifically access equipment rooms close to base stations, edge equipment rooms at the aggregation points of a metropolitan area network (MAN), and edge equipment rooms at core nodes of a MAN. A number of edge nodes form an edge cloud. Edge clouds at access equipment rooms are usually small, prone to physical attacks. Nevertheless, they are closest to user devices and can guarantee ultra-low latency.

Edge clouds at edge equipment rooms are larger, with higher latency, but are more reliable and secure.

While facilitating the implementation of 5G technology, MEC gives rise to new security requirements, as listed in the following table.

Table 4-3 MEC's security risks and countermeasures

Asset	Risk	Countermeasure
Physical environment and network architecture	Close to the network edge, MEC nodes are in relatively insecure physical environments, vulnerable to unauthorized access, sensitive data disclosure, DDoS, and physical attack threats. Besides, a single MEC node is limited in security capabilities, so it is often necessary to leverage multiple MEC nodes in collaboration.	Emphasize physical security, set up zones/domains (management, core network, basic service, third-party applications), and add various virtual security capabilities (access control, intrusion detection, anomalous traffic analysis, anti-APT, ⋯). As distributed edge nodes have limited capabilities, it is advisable to deploy detection devices at multiple MEC nodes to implement collaborative protection. Where MEC nodes are deployed on premises, isolation measures should be adopted to prevent these nodes from launching attacks on the core network.
UPF	The user plane function (UPF), when hit by a physical contact attack, may have its diversion policies tampered with, leading to a data transmission error. An attacker may further attack the core network by first taking down the UPF. A malicious application may also initiate a DDoS attack against the UPF.	Enhance the UPF security. Sensitive data of the UPF, such as diversion policies, should be encrypted for storage. Use mechanisms like role-based access control (RBAC) for access control. Enforce rate limiting for data sent by mobile edge (ME) applications.
NFV system	This system faces risks from the NFVI, service communication system, and management system, and is vulnerable to virtualization-related security issues.	Incorporate countermeasures for the NFVI, service communication system, and management system.
MEC platform	The MEC platform itself is vulnerable, the MEC platform software or image is tampered with, sensitive data stored on the MEC platform is disclosed, or the MEC platform is accessed by unauthorized ME applications, leading to a DoS attack or data disclosure.	Harden the MEC platform and software, protect the integrity of MEC software and image, encrypt sensitive data and protect the integrity of such data, authenticate ME applications, and grant access only to authorized applications.
MEC orchestration management system	Similar to MANO, this system consists of the MEC platform manager, MEC application orchestrator, and virtual infrastructure manager.	Similar to countermeasures for MANO.
ME App	ME applications' vulnerabilities are exploited, ME applications or images are tampered with, sensitive data is disclosed, unauthorized users access applications, and internal applications of MEC are diverse, with complicated privileges that are difficult to manage.	Harden ME applications, protect the integrity of these applications or images, encrypt sensitive data for storage and protect the integrity of such data, authenticate users who intend to access ME applications, and properly isolate and manage internal applications.

4.4.4 Network Slicing Technology

The International Telecommunication Union (ITU) divides 5G businesses into three types: Enhanced Mobile Broadband (eMBB), Ultra Reliable Low Latency Communications (URLLC), and Massive Machine

Type Communications (mMTC). Each type has its own service quality requirements. For instance, URLLC business requires low latency and high bandwidth, while mMTC needs to support massive connections but is insensitive to network latency.

In order to set up different networks for different businesses, 5G has introduced the concept of network slicing. The following table lists security requirements regarding this technology.

Table 4-4 Network slicing's risks and countermeasures

Asset	Risk	Countermeasure
Terminal access	(1) Supplementary information about slice selection, if exposed during transmission, will result in devices accessing a specific splice being traced, hence exposure of device user information. (2) In the process of terminal access, unauthorized user equipment (UE) may access a specific or wrong slice, thus leaking information.	(1) Privacy protection for slice selection information: After a security context is established, take measures to protect the confidentiality of slice selection information. (2) Security of UE's access to slices: Use the UE access authentication mechanism to ensure that only authorized UE can access the network.
Slice	(1) Risks from slices' share of NEs: For example, if the control plane of different slices uses the same security context, the confidentiality and integrity of control-plane data may be compromised. Another example might be a malicious user launching a DDoS attack on a shared NE, disrupting the running of other slices. (2) Mutual impact of slices: VNFs in one slice may impact those in other slices because of virtualization vulnerabilities, extending network attack, unauthorized usage, and unauthorized connection risks across slices. The fault of a slice or improper use of resources in a slice may affect the normal running of other slices. (3) Mutual access between slices: NEs in a specific slice may be accessed by shared or external NEs in an unauthorized manner.	(1) Security of the shared network functions (NFs): Adopt the authentication mechanism to enable mutual trust between internal NFs and external shared NFs. Perform frequency monitoring or deploy firewalls for access and mobility management functions (AMFs) or network repository functions (NRFs) to prevent malicious users from consuming resources of shared NFs. Set different policies for communication between UE and different slices. Set different shared NFs for slices of different security levels. (2) Security between internal NFs and external devices: Deploy a virtual or physical firewall between internal NFs and external devices to protect the security of both. (3) Isolation of NFs in different slices: Adopt such measures as network segmentation, resource isolation, and service-based architecture (SBA) access control to ensure NFs in one slice are isolated from those in other slices.
Slice management	(1) Attackers may compromise slicing templates by using malware, thus threatening the security of all network slicing instances generated based on these templates. (2) Attackers may attack slices during configuration or execution via the configuration interface. (3) If slice removal is improperly handled, attackers may obtain confidential data during such removal.	(1) For proper slice management, set appropriate protection mechanisms, including mutual authentication and authorization, integration and confidentiality protection for communication between the slice management system and network slices, and protection against replay attacks. (2) For slice lifecycle management, an inspection and check mechanism should be in place for slicing templates and configurations to avoid access control failures and data transmission and storage risks arising from incorrect templates and misconfigurations. After a slice is deactivated or terminated, data should be cleared according to data isolation requirements. (3) Detect legitimate users' anomalous behavior and contain such behavior by restricting their access or forcing them offline.

4.4.5 Network Exposure Function

5G provides some network function (mobility, session, quality of service (QoS), billing, ⋯) interfaces for third-party applications, enabling them to independently implement some basic network functions. Besides, 5G provides MANO for third-party service providers to independently implement network orchestration, such as network deployment, updates, and capacity expansion, for the ultimate purpose of dynamic network customization. This is what we call network exposure function (NEF) of 5G networks. Risks and security requirements of NEF are listed in the following table.

Table 4-5 NEC's risks and countermeasures

Asset	Risk	Countermeasure
Privacy information	NEF releases users' personal information, network data, and service data from network operators' internal platforms, incurring risks of data leaks.	Enhance protection of 5G network data as well as threat monitoring and disposal, for example, encryption of data in transit and at rest, protection of data integrity, and protection against replay attacks.
NEF interface	The NEF interface uses common Internet protocols and may introduce existing security risks in the current Internet to 5G networks.	Enhance protection of the NEF interface to prevent attackers from compromising an operator's network through an open interface, for example, privilege management for access to APIs.

4.5 AI Security

Artificial intelligence (AI) is a core driver to the new round of industrial transformation, accelerating the upgrade of digital economies and industries worth trillion of yuan. This raises new requirements for the stability and security of network infrastructure. On the one hand, attacks in network infrastructure, such as DDoS and exploits, could cause network problems, which, in turn, will result in data exchange failures between the AI cloud service platform and the developer and user, thus exposing data on the cloud side and device side to more complicated security challenges than in traditional information systems. On the other hand, algorithm infrastructure represented by AI-enabled, open-source frameworks/platforms and pretrained model libraries is prone to backdoors and code vulnerabilities because of developers' sabotage or poor code implementations.

4.5.1 Training Data

With the accelerated convergence of different systems and services, sharing data across organizations, industries, and regions is becoming a pressing need. AI is currently at the stage of learning driven by massive data. AI training datasets formed by collecting data shared by other parties are at the risks of data unbalance, data poisoning, and data leaks. NSFOCUS observed that multiple AI-related data security events happened in 2020, especially data leaks, which brought uncontrollable risks to sensitive personal data and other critical data. The following table lists top 5 AI-related data leaks in 2020.

Table 4-6 Top 5 AI-related data leaks in 2020

Time	Event	Description
April 2020	The World Health Organization (WHO) suffered five times more cyberattacks during the pandemic than the same period in the previous year.	The WHO claimed that the number of cyberattacks that it suffered during the pandemic rose sharply and about 450 WHO organizations and thousands of WHO employees had their email accounts and passwords leaked.
October 2020	A Greek telecom tycoon was hacked, resulting in a leak of massive personal information of users.	Cosmote, the largest telecom company in Greece, encountered a critical data breach, which resulted in a leak of massive user information, potentially having a major impact on "national security issues". It is reported that this data breach was caused by a cyberattack launched by foreign hackers, who stole phone data and other information from September 1 to 5, 2020. According to Cosmote, the stolen files did not include phone (chat) or short message contents, user names or addresses, credit card numbers, or bank accounts, and users did not need to take any action. At the time of writing, the investigation was ongoing, without any signs showing that the stolen information had been disclosed or exploited in any other ways.
June 2020	Over 200 judicial and law enforcement agencies in the USA had 296 GB of data leaked.	The activist group Distributed Denial of Secrets (DDoSecrets) claimed that they stole 296 GB of data from US law enforcement agencies (an event known as BlueLeaks), involving reports, security bulletins, and law enforcement guides of over 200 police departments and fusion centers. Some of the files stolen supposedly contain sensitive and personal information, such as names, bank account numbers, and phone numbers.
April 2020	The AI-assisted COVID-19 detection technology of a Chinese medical company was hacked.	According to a media report, a hacker was selling the source code and experimental data of a technology from Huiying Medical. This technology, with the assistance of AI, can detect the COVID-19 virus. A hacker with the screen name of "THE0TIME" was suspected to be the threat actor. The hacker, in his or her post, claimed that he or she had obtained the source code of the COVID-19 detection technology and the experimental data of COVID-19, and asked for a price of 4 BTC. The data on sale included 1.5 MB of user data, 1 GB of technology-related content and source code for detection technology, and 150 MB of lab research on the novel coronavirus.
May 2020	The Swiss railway vehicle maker Stadler was hit by a cyberattack.	Stadler, a Swiss railway vehicle maker, disclosed that it was hit by a cyberattack, where the attacker managed to penetrate into its IT network and used malware to infect some computers, possibly obtaining some data.

4.5.2 Algorithmic Model

In 2020, adversarial example attacks, backdoor attacks on algorithms, model stealing attacks, feedback weaponization, and other new types of attacks aiming to damage AI algorithm models emerged on end. Among these attacks, adversarial example attacks are the major type of threat to AI systems. For example, an attacker may use adversarial examples to poison AI/ML training data in business applications so as to cripple the decision-making and operations capabilities. In the driverless scenario, self-driving cars need to be always aware of road conditions and traffic signs. An adversarial example may cause such cars to misread their environments, resulting in traffic accidents. Therefore, AI needs to be robust enough against malicious adversarial examples.

Backdoor attacks and training data poisoning are also serious threats facing AI systems. For AI models trained offline in laboratories, such threats have a limited impact. But in actual usage scenarios, these threats may be devastating. Self-driving cars can learn other successful driving cases in real time and rapidly adapt to unexpected and dangerous road conditions. But when the model's training results deviate from the actual conditions because of a backdoor or poisoning, self-driving cars may misjudge the situation. Therefore, mission-critical AI systems must be equipped with the capabilities of promptly identifying malicious training examples and detecting intrusions.

4.5.3 AI Abuse

In August 2020, the University College London (UCL) released a report, identifying 20 ways AI could be used to facilitate crime in years to come. As AI-synthesized audio and video contents are hard to detect and defeat, DeepFake was ranked first because of its risk of abuse. The open-source project DeepFake can swap faces in images or videos and create fake images or videos that look very genuine. As great strides are made in the computing power, network transmission is accelerating. Besides, with the increasing demand for data sharing, disinformation is generated and spread at a higher speed. In this process, AI may become a handy weapon for false information, fraudulence, and other forms of crime. These problems, if left unresolved, will put AI-assisted services in jeopardy.

4.6 Data Security

When it comes to data breaches, 2020 was an eventful year, seeing great losses arising therefrom. According to NSFOCUS's observation, more and more ransomware families have established their own data leak websites on the dark web, and data and privacy leaks are growing in scale, with increasingly serious consequences.

4.6.1 Data Breaches

In 2020, data breaches continued to be a ghost haunting people and organizations around the globe. According to the 2020 Q3 Report – Data Breach QuickView from Risk Based Security (RBS), there were 2953 publicly reported breaches from January to September 2020, a 51% decrease from 2019's 6021 in the same period, but the number of records exposed reached 36.107 billion, a 332.21%[1] increase compared with the same period of the previous year (8.354 billion), hitting a new record high. Generally speaking, data breaches were still a serious problem that affected many organizations and users in 2020.

NSFOCUS collected information about massive data breaches around the world in 2020 and identified seven typical ones, as shown in the following table. A look into the scale found three breaches that leaked hundreds of millions of records, including one that involved a staggering 10 billion. From the perspective of causes, misconfiguration and hacking stood out as major contributors. For example, event 1 was caused by misconfiguration of Elasticsearch clusters[2] and event 3 by cloud misconfiguration issues[3], both of which led servers to expose unprotected or unencrypted sensitive data. Events 2, 4, and 5 were caused by hacking such as server breaches[4] and brute-force matching[5].

1 *https://pages.riskbasedsecurity.com/hubfs/Reports/2020/2020%20Q3%20Data%20Breach%20QuickView%20Report.pdf*
2 *https://www.wired.com/story/cam4-adult-cam-data-leak-7tb/*
3 *https://www.hackread.com/worlds-most-secure-online-backup-provider-exposes-records/*
4 *https://www.upguard.com/blog/biggest-data-breaches*
5 *https://www.sohu.com/a/381339588_161795*

To mitigate data breach risks, organizations should attach importance to the protection of database servers and assets by promptly loading software patches and regularly scanning systems for vulnerabilities and checking configurations. In addition, they should do a good job in the lifecycle management of sensitive data by taking such technical measures as sensitive data identification, classification, and masking as well as masking effect evaluation.

Table 4-7 World's biggest data breaches in 2020 (sorted by the scale of data leaked)

Event	Time	Scale	Event Description	Cause
1	March 2020	10.88 billion	CAM4, an adult website, had 10.88 billion records of sensitive user information and log data exposed[1].	Exposure on the Internet and misconfiguration
2	February 2020	538 million	Sina Weibo had accounts and associated mobile numbers of 538 million users leaked and sold on the dark web[2].	Hacking
3	April 2020	135 million	SOS Online Backup, a US cloud-based backup provider, had personal records of nearly 135 million customers exposed[3].	Exposure on the Internet and misconfiguration
4	February 2020	10.6 million	MGM Grand, a US hotel, had 10.6 million guest records leaked[4].	Hacking
5	May 2020	9 million	easyJet, a British airline group, had personal information and credit card details of 9 million customers leaked[5].	Hacking
6	March 2020	5.2 million	Marriott, a US hotel, detected a data breach that affected nearly 5.2 million guests[6].	Unknown
7	March 2020	4.9 million	Personal details of more than 4.9 million Georgians (almost the whole population) were disclosed and published on a hacking forum[7].	Unknown

1 *https://www.wired.com/story/cam4-adult-cam-data-leak-7tb/*

2 *https://www.sohu.com/a/381339588_161795*

3 *https://www.hackread.com/worlds-most-secure-online-backup-provider-exposes-records/*

4 *https://www.upguard.com/blog/biggest-data-breaches*

5 *https://www.upguard.com/blog/biggest-data-breaches*

6 *https://www.upguard.com/blog/biggest-data-breaches*

7 *https://www.zdnet.com/article/personal-details-for-the-entire-country-of-georgia-published-online/*

4.6.2 Regulations and Policies

By 2020, most countries had enacted data and privacy protection laws. According to data collected by the United Nations Conference on Trade and Development (UNCTAD) as of November 24, 2020[1], 128 out of 194 countries (66%) had put in place legislation to secure the protection of data and privacy, including the EU, the USA, China, Russia, India, Australia, Canada, and Japan.

The EU promulgated the General Data Protection Regulation (GDPR) on May 25, 2018. As a comprehensive framework for personal information protection, GDPR has a far-reaching effect on many countries' new legislation concerning data privacy. In 2020, data privacy legislation activities were seen everywhere: On June 5, 2020, Japan passed the amendments to the Act on the Protection of Personal Information; on July 1, South Africa's Protection of Personal Information Act came into force; Singapore amended the Personal Data Protection Act (PDPA); Pakistan introduced a new draft of the Personal Data Protection Bill; Indonesia submitted the Personal Data Protection Bill to the legislature; South Korea revised the Personal Information Protection Act.

GDPR enforcement has been in full swing since the promulgation of the regulation, turning out one after another big fine. According to statistics on the GDPR Enforcement Tracker website2, by November 27, 2020, EU member states had imposed 415 fines since 2018. The number over a two-year period from 2018 to 2019 was only 152, but climbed to 263 in 2020.

At the time of writing, GDPR Enforcement Tracker recorded a total of EUR 260 million of GDPR fines and penalties, or EUR 638,000 on average3. Most of these fines were imposed for the following reasons: (1) insufficient legal basis for data processing; (2) insufficient technical and organizational measures to ensure information security; (3) non-compliance with general data processing principles; (4) insufficient fulfilment of data subjects rights.

1 *https://unctad.org/page/data-protection-and-privacy-legislation-worldwide*

2 *https://www.enforcementtracker.com/*

3 *https://www.enforcementtracker.com/*

GDPR not only is binding on local enterprises of EU member states but also affects cross-border enterprises doing business with EU member states. To lower non-compliance risks, enterprises should, on the one hand, proactively make organization-wide efforts to promote GDPR compliance, for example, adding a user rights response page and handling process on their websites; on the other hand, take such measures as data encryption, masking, and audits to protect sensitive data from being leaked.

4.6.3 Technological Development Trend

Driven by privacy legislation, data security technologies and products have gained momentum for fast development, divided into small segments around regulatory compliance. In a report released in November 2020, Gartner predicts that, before year-end 2023, more than 80% of companies worldwide will be facing at least one privacy-focused data protection regulation and the privacy-driven spending on compliance tooling will break through to over USD 8 billion worldwide. Obviously, compliance with data protection regulations will be a promising field where security vendors have a lot to do. We predict that data technologies will march towards the following directions in the future:

1. Driven by the GDPR and California Consumer Privacy Act (CCPA), techniques of automating response to user data rights and other related technologies will grow rapidly.

   Some privacy regulations grant data subjects (users) the rights to access, modify, and delete personal data, and so require enterprises to handle and respond to users' such requests within a stipulated period of time. For example, GDPR sets the time limit to one month, while CCPA's limit is 45 days. Fast response to data subject rights requests (SRRs) is a big challenge for most enterprises. According to a survey, about two-thirds of organizations should spend more than two weeks handling a single SRR manually, and the average cost is as high as USD 1400. In a word, the traditional manual way is unfeasible for handling of highly concurrent SRRs within a reasonable time.

   Securiti.AI, a winner of the Innovation Sandbox Contest at RSA Conference 2020, engages in

R&D of automated SRR and CPM response products. BigID, another "Most Innovative Startup" named at the same event in 2018, also focuses on development of privacy compliance products. OneTrust, another well-known startup, takes privacy compliance as its major area of interest, and delivers products of the same nature as Securiti.AI. The three security startups have raised more than USD 60 million in total. This, to some extent, reflects the popularity of SRR response products, which are now in steady demand in the security market.

These products mainly employ process automation and various AI technologies. Process automation automates routine work within an enterprise, freeing the data security operations team from such trivial matters as repeated response to requests. This can not only lower the operations expenses but also reduce the non-compliance risk arising from prolonged response. When it comes to AI, natural language processing (NLP) is used to identify unstructured sensitive data, knowledge graphs are used to link all information related to a data subject, and chatbots are used to automatically handle some queries.

2. The underlying technologies of compliance products, such as sensitive data identification and data masking, are maturing.

   The EU's GDPR and the USA's CCPA both state that the data objects to be protected are personal data (or personal information) and it is enterprises' obligations to protect such data.

   For the purpose of compliance, the first step is to identify various types of sensitive data at rest and in transit, including not only personal information (names, ID card numbers, mobile numbers, ⋯) but also privacy data (medical privacy, financial privacy, network behavior privacy like cookies, ⋯). Currently, multiple methods have been developed to identify sensitive data based on: (1) regular expressions; (2) keyword library; (3) data similarity; (4) machine learning. The first two methods are relatively mature in the industry and players usually have comprehensive rule libraries or dictionaries. The last two methods are usually used in scenarios

where the first two methods are not applicable, such as when it is difficult to define rules or keywords. As for the third method, signatures are first extracted from reference data, then the same process is conducted for other data, and finally a comparison is made to determine their similarity. When a predefined threshold is exceeded, the two groups of data are deemed to be of the same type. The fourth method leverages the robust learning and prediction capabilities of machine learning to collect enough examples for classification and model training. After that, a model is deployed to automatically identify the types of new data.

After being identified, sensitive data needs to be masked to avoid legal risks arising from the secondary use and during the circulation (non-production environments, such as data analysis and testing). Data masking can be reversible or irreversible, depending on whether the data can be transformed back to the original. Reversible data masking can be understood as a process of replacing sensitive data with insensitive data based on enterprises' internal sensitive and insensitive data mapping tables. Using the same table, the replacement can be transformed back to the original data. Irreversible masking can be achieved by various means, including rounding, quantization, generalization, masking out, truncation, hashing, and perturbation. For different usage scenarios, static data masking (SDM) or dynamic data masking (DDM) can be adopted. The former is usually for non-production environments (testing, statistical analysis, ⋯) and the latter for production environments. SDM techniques are now quite mature, and DDM is also implemented in some products.

3. Balancing regulatory compliance and data uses, privacy-enhanced computation techniques and applications are emerging.

   The big data era is characterized by the frequent use and fast circulation of sensitive data. On the one hand, data should be secured; on the other hand, data should be available for convenient use. This poses a big challenge to traditional data security techniques that focus on encryption. In response to compliance requirements and the needs to use data, a series of novel data security techniques specific to business scenarios have been developed and implemented, including homomorphic encryption, secure multiparty computation (MPC), federated learning,

and differentiated privacy. These techniques can not only ensure that the original data is not leaked (invisible) but also ensure the availability of data for particular business scenarios (aggregation, set operation, and AI modeling). For this reason, they are called "availability + invisibility" techniques. Gartner refers to these techniques as privacy-enhanced computation and lists it as one of the top strategic technology trends in 2021 together with anywhere operations and AI engineering.

5

Conclusion

2020 witnessed an unprecedented impact on cybersecurity from the COVID-19 pandemic. With the construction and development of the IoT, industrial Internet, 5G networks, AI, and data security come new cybersecurity requirements. To keep pace with the booming digital economy, NSFOCUS will intensify its efforts in cybersecurity research, continuing to develop and deliver enterprise-grade cybersecurity products, solutions, and operations services around its core competitiveness.

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