The Mirai Botnet

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IoT Devices

- Nonstandard computing devices that connect wirelessly to a network and have the ability to transmit data
- Usually some form of user interaction
  - Through application
  - Gestures
  - Speech
Security?
What can you do with default passwords?
Cyberattack Knocks Out Access to Websites

Popular sites such as Twitter, Netflix and PayPal were unreachable for part of the day.

Mirai botnet adds three new attacks to target IoT devices

Mirai botnet hacker ordered to pay $8.6 million in damages

21 Oct 16

Hacked Cameras, DVRs Powered Today’s Massive Internet Outage

21

KrebsOnSecurity Hit With Record DDoS

How to not break the Internet

October 25, 2016

Did the Mirai Botnet Really Take Liberia Offline?

Perhaps the most striking point about last week’s huge DDoS attack, which took down more than 80 big websites and online services, is that the criminals behind the attack accomplished it not by particularly sophisticated or cutting-edge means, but by creating a veritable army of consumer connected devices — what we call the Internet of Things (IoT). In this post we explain the critical
Mirai Botnet: What is it?
The Original

- Worm-like family of malware that infected IoT devices
- Corralled them into a DDoS botnet
- Port scanning and brute force dictionary attack
  - Used a dictionary of 62 username/password pairs

```bash
// Set up passwords
add_auth_entry("'x90|x40|v40|x56'", "'x8|x41|x12|x17|x31|x33'", 10);  // root xc3511
add_auth_entry("'x90|x40|v40|x56'", "'x54|x48|x58|x51|x54'", 9);  // root vixxx
add_auth_entry("'x90|x40|v40|x56'", "'x43|x46|x4f|x48|x4c'", 8);  // root admin
add_auth_entry("'x90|x40|v40|x56'", "'x43|x46|x4f|x48|x4c'", 7);  // admin admin
add_auth_entry("'x90|x40|v40|x56'", "'x41|x1a|x1a|x1a|x1a'", 6);  // root admin
add_auth_entry("'x90|x40|v40|x56'", "'x54|x46|x4f|x48|x52|x41'", 5);  // root xmhdipc
add_auth_entry("'x90|x40|v40|x56'", "'x46|x47|x44|x31|x57|x45|x56'", 5);  // root default
add_auth_entry("'x90|x40|v40|x56'", "'x48|x57|x43|x4d|x56|x47|x41|x4d'", 5);  // root juventech
add_auth_entry("'x90|x40|v40|x56'", "'x3|x10|x11|x16|x3|x4'", 5);  // root 123456
add_auth_entry("'x90|x40|v40|x56'", "'x17|x16|x12|x18|x3'", 5);  // root 54321
add_auth_entry("'x51|x57|x52|x52|x40|x50|x56'", "'x51|x57|x52|x52|x40|x50|x56'", 5);  // support support
add_auth_entry("'x90|x40|v40|x56'", "'x43|x46|x4f|x48|x4c'", 4);  // root (none)
add_auth_entry("'x52|x43|x51|x55|x40|x50|x60'", "'x52|x43|x51|x55|x40|x50|x60'", 4);  // root (none)
add_auth_entry("'x90|x40|v40|x56'", "'x90|x40|v40|x56'", 4);  // root root
add_auth_entry("'x90|x40|v40|x56'", "'x13|x18|x11|x16|x7'", 4);  // root 12345
add_auth_entry("'x57|x51|x47|x50'", "'x57|x51|x47|x50'", 3);  // user user
add_auth_entry("'x43|x46|x4f|x48|x4c'", "'x43|x46|x4f|x48|x4c'", 3);  // admin (none)
add_auth_entry("'x90|x40|v40|x56'", "'x90|x40|v40|x56'", 3);  // root pass
add_auth_entry("'x43|x46|x4f|x48|x4c'", "'x43|x46|x4f|x48|x4c'", 3);  // admin admin1234
add_auth_entry("'x90|x40|v40|x56'", "'x13|x13|x13|x13'", 3);  // root 1111
add_auth_entry("'x90|x40|v40|x56'", "'x13|x13|x13|x13'", 3);  // admin secdeadin
add_auth_entry("'x43|x46|x4f|x48|x4c'", "'x51|x4f|x43|x46|x4f|x48|x4c'", 3);  // admin 1111
add_auth_entry("'x43|x46|x4f|x48|x4c'", "'x13|x13|x13|x13'", 2);  // root 666666
add_auth_entry("'x90|x40|v40|x56'", "'x90|x40|v40|x56'", 2);  // root password
add_auth_entry("'x90|x40|v40|x56'", "'x13|x18|x11|x6'", 2);  // root 1234
add_auth_entry("'x90|x40|v40|x56'", "'x49|x4f|x54|x13|x28|x11'", 1);  // root kv123
...```
Mirai Botnet: What did it do?
Figure 1: *Mirai Timeline*—Major attacks (red), exploits (yellow), and events (black) related to the Mirai botnet.
Krebs on Security (Blog):
- 623 Gbps DDoS attack (largest publicly disclosed)

Dyn (DNS Provider):
- Disrupted name resolution for clients including Amazon, Github, Netflix, Paypal, Reddit.
- 21 short lived (25s) attacks then two sustained 1 and 5 hour long

Lonestar (Telecom Operator):
- 341 attacks - most targeted victim by attack account
- claims that Mirai substantially deteriorated Liberia’s overall Internet connectivity

Figure 1: Mirai Timeline — Major attacks (red), exploits (yellow), and events (black) related to the Mirai botnet.
Unconventional DDoS

(From Arbor Networks global DDoS report) DDoS attacks usually:

- 65% volumetric, 18% TCP state, 18% application attacks

Mirai:

- 33% volumetric, 32% TCP state, 34% application attacks

Limited reflection/amplification attacks

- 2.8% reflection attacks, mostly just SYN along with a few ACK and GRE IP attacks.
Mirai Botnet: How did it do this?
Understanding the Mirai Botnet

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Research Setup

Network Telescope (Distributed Monitoring Infrastructure)
- Monitored all requests to a network telescope from July 18, 2016 - February 28, 2017
- Composed of 4.7 million IP addresses operated by Merit Network
- Uniquely fingerprinted Mirai probes based on how Mirai does stateless scanning
- Observed 116.2 billion Mirai probes from 55.4 million IP addresses

Active Scanning
- Used Censys, a public search engine backed by data collected from ongoing Internet-wide scans
  - Actively scans IPv4 space and aggregates application layer data about hosts
- Focused analysis on scans of HTTPS, FTP, SSH, TELNET, and CWMP to identify devices by model
Research Setup

**Telnet Honeypots**

- **Collected binaries** installed on honeypots pretending to be vulnerable IoT devices
  - Logged all incoming traffic and downloaded binaries being installed via wget or tftp
- 141 Mirai binaries collected from this method, and 1028 in total from all sources
- Extracted logins and passwords, IP blacklists, and Command and Control (C2) domains

**Active and Passive DNS**

- Mapped IP addresses in attack commands to victim names
- Created graph reflecting shared infrastructure used by Mirai variants
Research Setup

**Attack Commands**
- Simulated Mirai-infected device listened for commands from C2 servers
- Akamai observed 64K attack commands issued by 484 unique C2 servers (by IP address)

**DDoS Attack Traces**
- Compared network traces and statistics from Akamai, Google Shield and Dyn to those found scanning their passive network telescope
- Were able to attribute the Krebs, Dyn and Lonestar attacks to Mirai
Botnet Size

- Initial 2-hour bootstrapping scan
- Botnet emerges with 834 scanning devices
- 11K hosts infected within 10 minutes
- 65K devices within 20 hours
- 75 minute doubling time
- Initial steady state of 200-300K devices
Mirai Adaptation/Variants

- Updated from IP-based to domain-based
- Deletion of executing binary and obfuscation of process ID
- More username/password pairs
- Closing of infection ports TCP/23 and TCP/2323
- Aggressive killing of competitive malware
- Attacks on CPE WAN Management Protocol (CWMP)
  - scans for TCP/7547 and TCP/5555
  - an HTTP-based protocol that enables auto-configuration and remote management of home routers
### Device Bandwidth

- Half of the Mirai bots that scanned the network telescope sent fewer than 10,000 scan packets.
- Majority scanned at a rate below 250 bytes per second.
- In contrast, SQL Slammer scanned at 1.5 MBps (about 6000 times faster), and the Witty worm scanned even faster at 3 MBps.
- Devices with limited computational capacity and/or located in regions with low bandwidth?
Device Composition

- Analyzed credentials hardcoded into binaries
  - Observed 371 unique passwords
- Identified 84 devices and/or vendors associated with these passwords
- Security Cameras, DVRs, and consumer routers made up majority
  - Also printers and tv receivers
  - Manufacturers responsible were Dahua, Huawei, ZTE, Cisco, ZyXEL, and MikroTik.
Global Distribution

- Disproportionate number of devices concentrated in South America and Southeast Asia at the time of Krebs attack

- CWMP exploit were concentrated in Europe, but prompt patching returned Mirai back to its original concentration in South America and Southeast Asia

<table>
<thead>
<tr>
<th>Country</th>
<th>Mirai Infections</th>
<th>Mirai Prevalence</th>
<th>Telnet Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>49,340</td>
<td>15.0%</td>
<td>7.9%</td>
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<tr>
<td>Colombia</td>
<td>45,796</td>
<td>14.0%</td>
<td>1.7%</td>
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<td>Vietnam</td>
<td>40,927</td>
<td>12.5%</td>
<td>1.8%</td>
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<td>China</td>
<td>21,364</td>
<td>6.5%</td>
<td>22.5%</td>
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<tr>
<td>S. Korea</td>
<td>19,817</td>
<td>6.0%</td>
<td>7.9%</td>
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<td>Russia</td>
<td>15,405</td>
<td>4.7%</td>
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<td>Turkey</td>
<td>13,780</td>
<td>4.2%</td>
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<tr>
<td>India</td>
<td>13,357</td>
<td>4.1%</td>
<td>2.9%</td>
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<tr>
<td>Taiwan</td>
<td>11,432</td>
<td>3.5%</td>
<td>2.4%</td>
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<td>Argentina</td>
<td>7,164</td>
<td>2.2%</td>
<td>0.2%</td>
</tr>
</tbody>
</table>
Mirai Botnet: How do we fix this?
Author Suggestions

- Basic security practices like NOT using default passwords and limiting remote access
- Automatic Updates
- Out-of-band notifications
- Device Attribution
- Mechanisms for End-of-life of devices
Takeaways and Discussion

Do we need to enforce these policies in a way similar to GDPR?

This botnet was not the biggest in device size or in power of devices - why was it so impactful?

Weakest link - adversaries will continue to abuse the most fragile hosts.

How much overhead would security add to these devices?
Questions?