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Qualys Security Advisory

pwnkit: Local Privilege Escalation in polkit's pkexec (CVE-2021-4034)

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## Summary

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We discovered a Local Privilege Escalation (from any user to root) in polkit's pkexec, a SUID-root program that is installed by default on every major Linux distribution:

"Polkit (formerly PolicyKit) is a component for controlling system-wide privileges in Unix-like operating systems. It provides an organized way for non-privileged processes to communicate with privileged ones. [...] It is also possible to use polkit to execute commands with elevated privileges using the command pkexec followed by the command intended to be executed (with root permission)." (Wikipedia)

This vulnerability is an attacker's dream come true:

- pkexec is installed by default on all major Linux distributions (we exploited Ubuntu, Debian, Fedora, CentOS, and other distributions are probably also exploitable);
- pkexec is vulnerable since its creation, in May 2009 (commit c8c3d83, "Add a pkexec(1) command");
- any unprivileged local user can exploit this vulnerability to obtain full root privileges;
- although this vulnerability is technically a memory corruption, it is exploitable instantly, reliably, in an architecture-independent way;
- and it is exploitable even if the polkit daemon itself is not running.

We will not publish our exploit immediately; however, please note that this vulnerability is trivially exploitable, and other researchers might publish their exploits shortly after the patches are available. If no patches are available for your operating system, you can remove the SUID-bit from pkexec as a temporary mitigation; for example:

```
# chmod 0755 /usr/bin/pkexec
```

This vulnerability is one of our most beautiful discoveries; to honor its memory, we recommend listening to DJ Pone's "Falken's Maze" (double pun intended) while reading this advisory. Thank you very much!

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## Analysis

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pkexec is a sudo-like, SUID-root program, described as follows by its man page:

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NAME

pkexec - Execute a command as another user

SYNOPSIS

pkexec [--version] [--disable-internal-agent] [--help]

pkexec [--user username] PROGRAM [ARGUMENTS...]

DESCRIPTION

pkexec allows an authorized user to execute PROGRAM as another user. If PROGRAM is not specified, the default shell will be run. If username is not specified, then the program will be executed as the administrative super user, root.

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The beginning of pkexec's main() function processes the command-line arguments (lines 534-568), and searches for the program to be executed (if its path is not absolute) in the directories of the PATH environment variable (lines 610-640):

-----

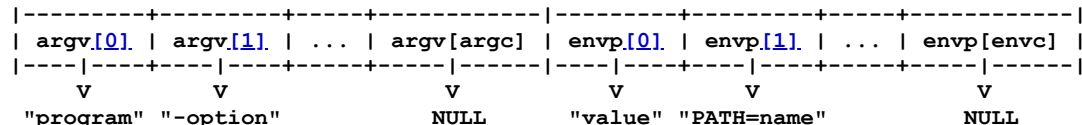
```
435 main (int argc, char *argv[])
436 {
...
534 for (n = 1; n < (quint) argc; n++)
535     {
...
568     }
...
610 path = g_strdup (argv[n]);
...
629 if (path[0] != '/')
630     {
...
632     s = g_find_program_in_path (path);
...
639     argv[n] = path = s;
640     }
```

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Unfortunately, if the number of command-line arguments argc is 0 (if the argument list argv that we pass to execve() is empty, i.e. {NULL}), then argv[0] is NULL (the argument list's terminator) and:

- at line 534, the integer n is permanently set to 1;
- at line 610, the pointer path is read out-of-bounds from argv[1];
- at line 639, the pointer s is written out-of-bounds to argv[1].

But what exactly is read from and written to this out-of-bounds argv[1]? To answer this question, we must digress briefly. When we execve() a new program, the kernel copies our argument and environment strings and pointers (argv and envp) to the end of the new program's stack; for example:



Clearly (because the argv and envp pointers are contiguous in memory), if argc is 0, then the out-of-bounds argv[1] is actually envp[0], the pointer to our first environment variable, "value". Consequently:

- at line 610, the path of the program to be executed is read out-of-bounds from argv[1] (i.e. envp[0]), and points to "value";
- at line 632, this path "value" is passed to g\_find\_program\_in\_path() (because "value" does not start with a slash, at line 629);



```
385 {
...
406     log_message (LOG_CRIT, TRUE,
407                 "The value for the SHELL variable was not found the /etc/shells file");
408     g_printerr ("\n"
409                "This incident has been reported.\n");
-----
```

g\_printerr() normally prints UTF-8 error messages, but it can print messages in another charset if the environment variable CHARSET is not UTF-8 (note: CHARSET is not security sensitive, it is not an "unsecure" environment variable). To convert messages from UTF-8 to another charset, g\_printerr() calls the glibc's function iconv\_open().

To convert messages from one charset to another, iconv\_open() executes small shared libraries; normally, these triplets ("from" charset, "to" charset, and library name) are read from a default configuration file, /usr/lib/gconv/gconv-modules. Alternatively, the environment variable GCONV\_PATH can force iconv\_open() to read another configuration file; naturally, GCONV\_PATH is one of the "unsecure" environment variables (because it leads to the execution of arbitrary libraries), and is therefore removed by ld.so from the environment of SUID programs.

Unfortunately, CVE-2021-4034 allows us to re-introduce GCONV\_PATH into pkexec's environment, and to execute our own shared library, as root.

Important: this exploitation technique leaves traces in the logs (either "The value for the SHELL variable was not found the /etc/shells file" or "The value for environment variable [...] contains suspicious content"). However, please note that this vulnerability is also exploitable without leaving any traces in the logs, but this is left as an exercise for the interested reader.

For further discussions about pkexec, GLib, and GCONV\_PATH, please refer to the following posts by Tavis Ormandy, Jakub Wilk, and Yuki Koike:

- <https://www.openwall.com/lists/oss-security/2014/07/14/1>
- <https://www.openwall.com/lists/oss-security/2017/06/23/8>
- <https://hugh0ge.github.io/2019/11/04/Getting-Arbitrary-Code-Execution-from-fopen-s-2nd-Argument/>

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Acknowledgments  
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We thank polkit's authors, Red Hat Product Security, and the members of distros@openwall for their invaluable help with the disclosure of this vulnerability. We also thank Birdy Nam Nam for their inspiring work.

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Timeline  
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- 2021-11-18: Advisory sent to secalert@redhat.
  - 2022-01-11: Advisory and patch sent to distros@openwall.
  - 2022-01-25: Coordinated Release Date (5:00 PM UTC).
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