Set-versioned package dependencies

addressing the problem of shared library updates

Vladimir D. Seleznev

August 2019

LVEE
Linux Vacation / Eastern Europe

The problem of shared library updates

Risk of incompatibility between shared libraries and their clients

- Update of a shared library
- Update of a shared library client
- Addition of a new shared library client

When does it happen in package repositories?

- Update of a shared library

When does it happen in installed OS?

- OS update from a buggy package repository
- Selective shared library update
- Selective shared library client update
- Installation of a new shared library client

What kind of ABI incompatibilities are problematic [3/18]

ELF level

- Non-versioned symbol removed
- Versioned symbol removed but the version remains
- Non-versioned symbol added
- Versioned symbol added into already existing version
- Symbol version changed
- Soname changed

Dwarf level

- Function signature changed in incompatible way
- Type of variable changed in incompatible way

Other

- Function semantics changed

Why these ABI incompatibilities arise

Shared libraries are very easy to produce

- gcc: `-fpic/-fPIC` to compile, `-shared` to link
- autotools: add `AC_PROG_LIBTOOL` to `configure.ac`, replace `lib_LIBRARIES = libhello.a` with `lib_LTLIBRARIES = libhello.la` and `libhello_a_SOURCES` with `libhello_la_SOURCES` in `Makefile.am`

ABI stability is hard to maintain

- Maintaining ABI requires intelligent design and technical skills
- High entry threshold: part 3 "Maintaining APIs and ABIs" of "How To Write Shared Libraries" takes 8 pages (37K) of technical text

ABI incompatibilities are easy to miss [5/18]

```
$ git show 8f6be98bf7b9e9015ad035f34b8414e82c7b68ca
...
@@ -287,7 +287,7 @@
   --prefix=%_prefix --openssldir=%_sysconfdir/pki/tls $sslflags \
   --system-ciphers-file=%_sysconfdir/crypto-policies/back-ends/openssl.config \
   zlib sctp enable-camellia enable-seed enable-tlsext enable-rfc3779 \
- enable-cms enable-md2 \
+ enable-cms enable-md2 enable-ssl2 \
   no-mdc2 no-rc5 no-ec2m no-gost no-srp \
   --with-krb5-flavor=MIT --enginesdir=%_libdir/openssl/engines \
   --with-krb5-dir=/usr shared  $sslarch %?!nofips:fips
@@ -502,6 +502,10 @@ rm -rf $RPM_BUILD_ROOT/%_libdir/fipscanister.*
 %postun libs -p /sbin/ldconfig

 %changelog
+* Wed Mar  2 2016 Tomáš Mráz <tmraz@redhat.com> 1.0.2g-2
+- reenable SSL2 in the build to avoid ABI break (it does not
+  make the openssl vulnerable to DROWN attack)
+
 * Tue Mar  1 2016 Tomáš Mráz <tmraz@redhat.com> 1.0.2g-1
 - minor upstream release 1.0.2g fixing security issues
```

What could be done about it

Classroom

- Educate students how to write shared libraries

Package repository

- Detect and fix incompatible ABI changes early
- Ensure that all libraries being used are linked with
- Check that nothing is indirectly linked with two library versions

Installed OS

Check at package installation time that

- every required shared library is provided
- every required shared library version interface is provided
- **every ELF symbol required from a shared library is provided by that shared library**

ELF symbol package dependencies

Naïve approach 1

- Put into package Requires all undefined symbols
- Put into package Provides all symbols suitable for resolving undefined symbols

Pros

- Similar to the behaviour of dynamic linker

Cons

- The size of Provides and Requires is prohibitively big
- Resolving of these dependencies is prohibitively slow

Naïve approach 2

- Put into package Requires all undefined symbols for each shared library being linked, e.g.
  `libdw Requires: libz.so.1 = [gzclose,gzdopen,gzread,gzerror,gzdirect], ...`
- Put into package Provides all symbols suitable for resolving undefined symbols

Pros

- Similar to the behaviour of dynamic linker
- Resolving of these dependencies is faster than in Naïve approach 1

Cons

- The size of Provides and Requires is still prohibitively big
- Resolving of these dependencies is still very slow

ELF symbol package dependencies

Probabilistic approach

- Put into package Requires **hash values** of all undefined symbols for each shared library being linked instead of strings themselves
- Put into package Provides **hash values** of all symbols suitable for resolving undefined symbols instead of strings themselves

Pros, compared to Naïve approach 2

- The size of Provides and Requires does not depend on symbol length and can be made much smaller
- Resolving of these dependencies can be made much faster

Cons, compared to Naïve approach 2

- False positives
- Error diagnostics does not contain symbol names

Size required to pack arbitrary number of strings

For the given false positive rate P:

- Theoretical minimum:
  $-log_2 P$ bits per string,
  for $P = 2^{-10}$ it is **10** bits per string
- Bloom filter minimum:
  $-log_2 P / log 2 \approx -1.44 log_2 P$ bits per string,
  for $P = 2^{-10}$ it is $\approx$ **14.43** bits per string
- Set-versions minimum:
  $log_2 \binom{N/P}{N} / N = -log_2 P + log_2 N - log_2 N!/N \approx$
  $-log_2 P + 1/log 2 \approx -log_2 P + 1.44$ bits per string,
  for $P = 2^{-10}$ it is $\approx$ **11.44** bits per string

Complexity of *Requires* $\subset$ *Provides* test

$\mathcal{O}(|Requires| + |Provides|)$

Hash function

- Based on Jenkins's one-at-a-time 32-bit hash
- Bitness selected automatically on the number N of strings: $ceil(log_2 N - log_2 P)$
- For the false positive rate $P = 2^{-10} \approx 0.1\%$ the bitness is $ceil(log_2 N) + 10$

Compression

- Hash values are sorted and delta-encoded,
- then compressed using Golomb-Rice coding
- and encoded using Base62 encoding

Decompression

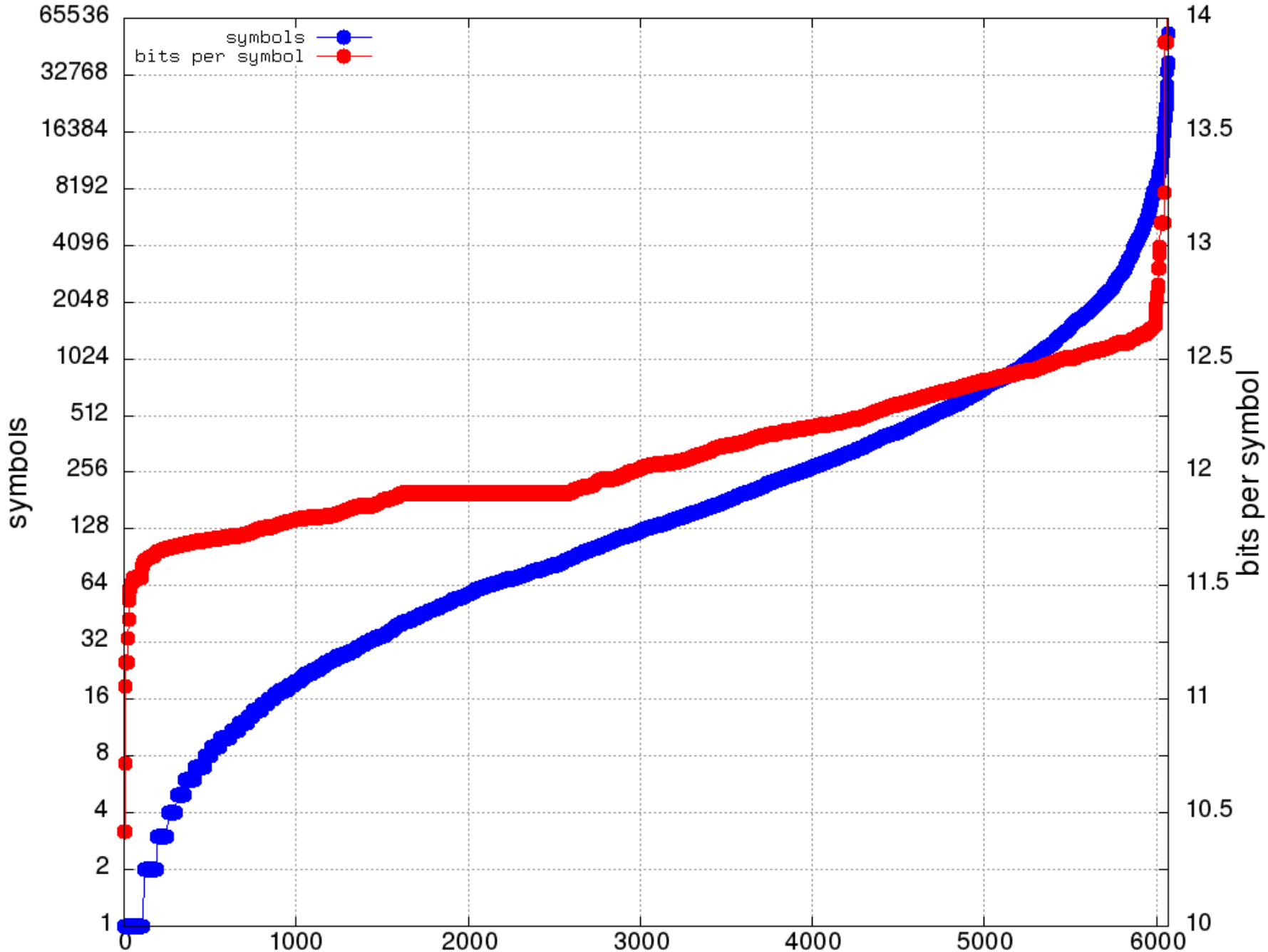
- Set is decoded using Base62 decoding
- and decompressed using Golomb-Rice coding

Set-versioned package dependencies: example

```
$ rpm -q -R -p libdw-0.175-alt1.x86_64.rpm | grep set:
libbz2.so.1()(64bit) >= set:igvOXRQuy1
liblzma.so.5()(64bit) >= set:kiyIz7cr3p0
libz.so.1()(64bit) >= set:khSFaXxmvvC5PDH1
```

```
$ rpm -q --provides -p bzlib-1.0.6-alt5.x86_64.rpm \
 liblzma-5.2.4-alt1.x86_64.rpm \
 zlib-1.2.11-alt1.x86_64.rpm | grep set:
libbz2.so.1()(64bit) = set:idMZep0Zzy6jybSdPuI0CajZg3s7TjOERZ→
lcin9a3qkZsRn56ka0
liblzma.so.5()(64bit) = set:kdZ9NO3hrVYeaE0SbKiT8b9c84UbuG7B0→
XUj1MZCGedD5YiFxjIAdhzXR5o8CQ9Z6HkvBEDz41TGgGNipGBCzEVIqgOg6R→
4HNUpGJZtc8MtMMRZciN7oopDEhZ0XJRieegsaZJTneJqYA72bwK9GMURtIR4→
mmexdkksaxFHPovnvVxR4tgyEKGhm69bLwhaDjhW6Ac0
libz.so.1()(64bit) = set:kd3mbJvh56uTOsqJBEJlZghvEz1oLBSeJ8Mt→
xDeef1N9vYPZBxcnLIDXTS3wRwf8Z5d2bl56CGApsvXkI26pVRfR0YqhzwdhF→
BhPqAvWklha4wsxwNQ7Mc3PyEJUOa99NqO668JZGLecvY9B0cXVPAxOrK2r2z→
EurrbdvRRvG6HbcG1
```

Set-versioned package dependencies: statistics [13/18]



Pros

- Guarantees that every ELF symbol required from a shared library is provided by that shared library
- The check is performed in the beginning of every package install/upgrade transaction
- Performance is close to the theoretical maximum

Cons

- The check is probabilistic
- The check takes time
- Provides and Requires for large libraries look quite big
- Error diagnostics does not contain symbol names
- Base62 is not the most compact ASCII representation, Base85 would save $1/3 - 1/4 = 1/12$ of the final representation

Code complexity

- Based on math and uses relatively uncommon algorithms
- Heavily optimized for performance, it takes efforts and time to understand.
- Some people are unwilling to invest their time into complex things.
  The main rpm.org guy once shamelessly admitted that "it's too clever for my taste" and refused to **discuss** it:
  `github.com/rpm-software-management/rpm/issues/362#issuecomment-364926552`

Integration complexity

- Various projects tend to implement package version checks themselves
- All package depsolvers have to be taught to use version check routines provided by the OS

Encoding implementation enhancements

- Replace Base62 with Base85
- Optimize Golomb Parameter selection in Golomb-Rice coding

Check ELF symbol version changes

- Non-versioned undefined symbol can be resolved either to a non-versioned symbol or to a symbol with any version
- Versioned undefined symbol can be resolved either to a non-versioned symbol or to a symbol with the specified version

Check Dwarf level incompatibilities

- Use signatures instead of names
- Ignore "insignificant" differences

- 2004: A. Kiely
  Selecting the Golomb Parameter in Rice Coding
  ipnpr.jpl.nasa.gov/progress_report/42-159/159E.pdf
- 2005: Anna Pagh, Rasmus Pagh, S. Srinivasa Rao
  An Optimal Bloom Filter Replacement
  www.it-c.dk/people/pagh/papers/bloom.pdf
- 2007: Felix Putze, Peter Sanders, Johannes Singler
  Cache-, Hash- and Space-Efficient Bloom Filters
  algo2.iti.kit.edu/singler/publications/cacheefficientbloomfilters-wea2007.pdf
- 2010: Alexey Tourbin
  Комплементарное хеширование подмножеств
  ftp.altlinux.org/pub/people/at/protva-2010.pdf
- 2019: Dmitry Levin
  Set-versioned package dependencies
  https://archive.fosdem.org/2019/schedule/

Deployed in ALT:

- set-string, golomb, and base62 routines
  `git.altlinux.org/gears/r/..git?p=rpm-build.git;a=blob;f=lib/set.c`
- mkset tool
  `git.altlinux.org/gears/r/..git?p=rpm-build.git;a=blob;f=tools/mkset.c`
- suggest_bpp tool
  `git.altlinux.org/gears/r/..git?p=rpm-build.git;a=blob;f=tools/suggest_bpp.c`
- provided_symbols tool
  `git.altlinux.org/gears/r/..git?p=rpm-build.git;a=blob;f=scripts/provided_symbols`

Research by Alexey Tourbin:

- rpm set-versions work in progress
  `github.com/svpv/rpmss`