Pretty-printing kernel data structures

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Why?

- data as the correctness identifier
- tools need to be good with variables
- printf vs. debugger

DDB

- kernel debugger
- FreeBSD, OpenBSD, NetBSD, OS X
- single stepping kernel, breakpoints
- included in GENERIC kernel
- old & lacking some important stuff

The Problem

Enable the kernel debugger DDB to pretty-print data structures that are used in the currently loaded kernel.

Example

```
struct city {
  unsigned int population;
  char* name;
  float record_high_jan;
}
```

Example

```
>prettyprint 0x1234 ‘struct city’

0x1234 = struct city {
  unsigned int population = 30
  char* name = “Khartoum”
  float record_high_jan = 39.7
}
```

Status Quo

- `examine` command
- can specify content type (string, float, …)
- very important at the low level

Example

```
>examine/x 0x1124
kdb_sysctl_enter+0x89: 0xcafebabe
```

Better status quo

- show command
- supports few structures: buffer, domain, file, lock

Still not good enough

- still linear approach (code vs. struct)
- what happens when we add a type?
- what happens when we add a member?
- more generic approach!

Need for type information

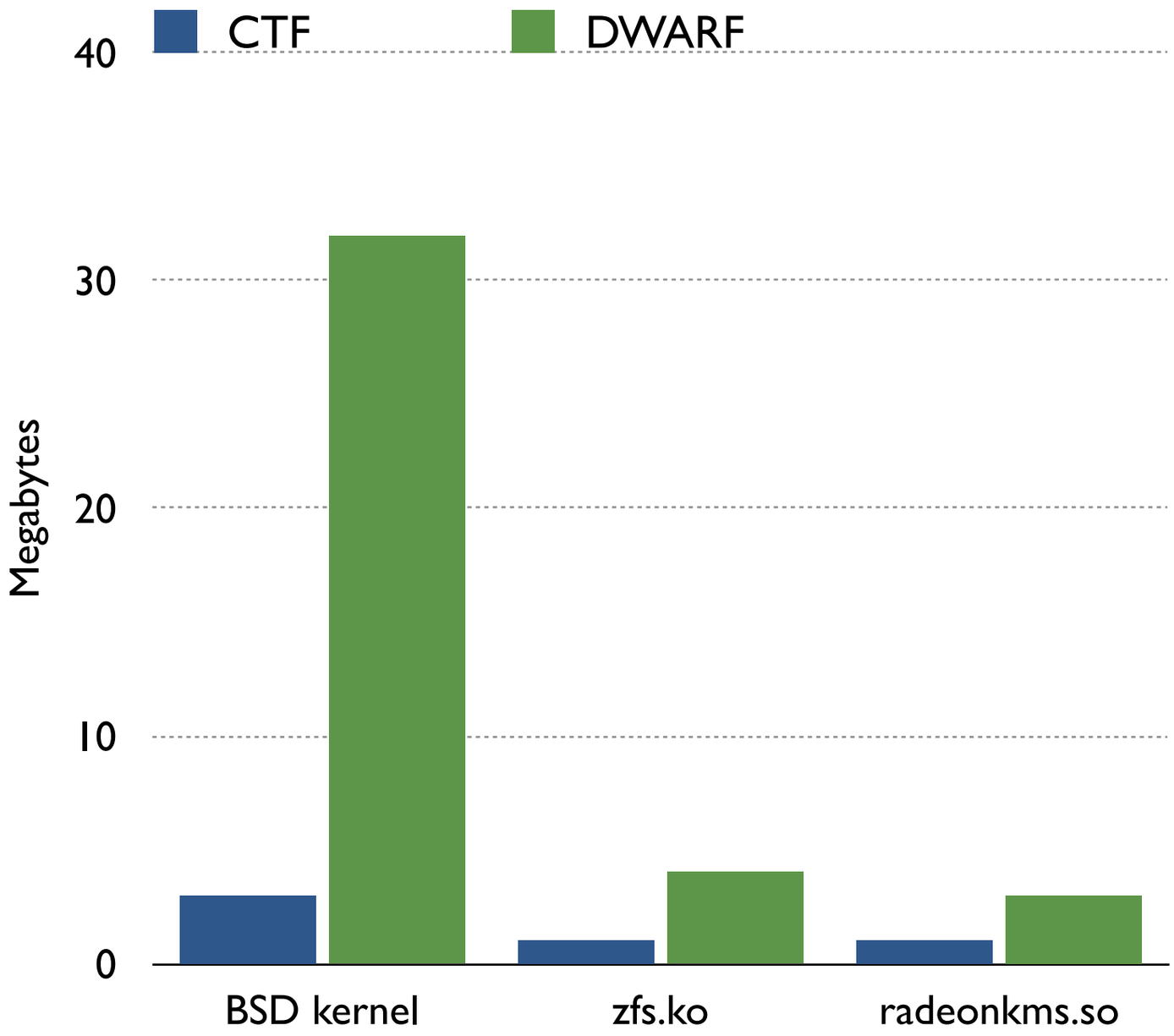
- format that describes data types
- DWARF (too big though)
- other options?
- we already have CTF

Compact C Type Format

(CTF)

- DTrace/mdb origin
- storing types - integers, floats, structs, …
- can represent everything
- very compact

So, how compact?



The Solution

CTF, duh

Old library

- made at Sun/Joyent
- CDDL license
- unstable private API
- does not contain full implementation

New library

- made by me!
- 2-clause BSD
- FreeBSD support
- github.com/lovasko/libctf

Implementation

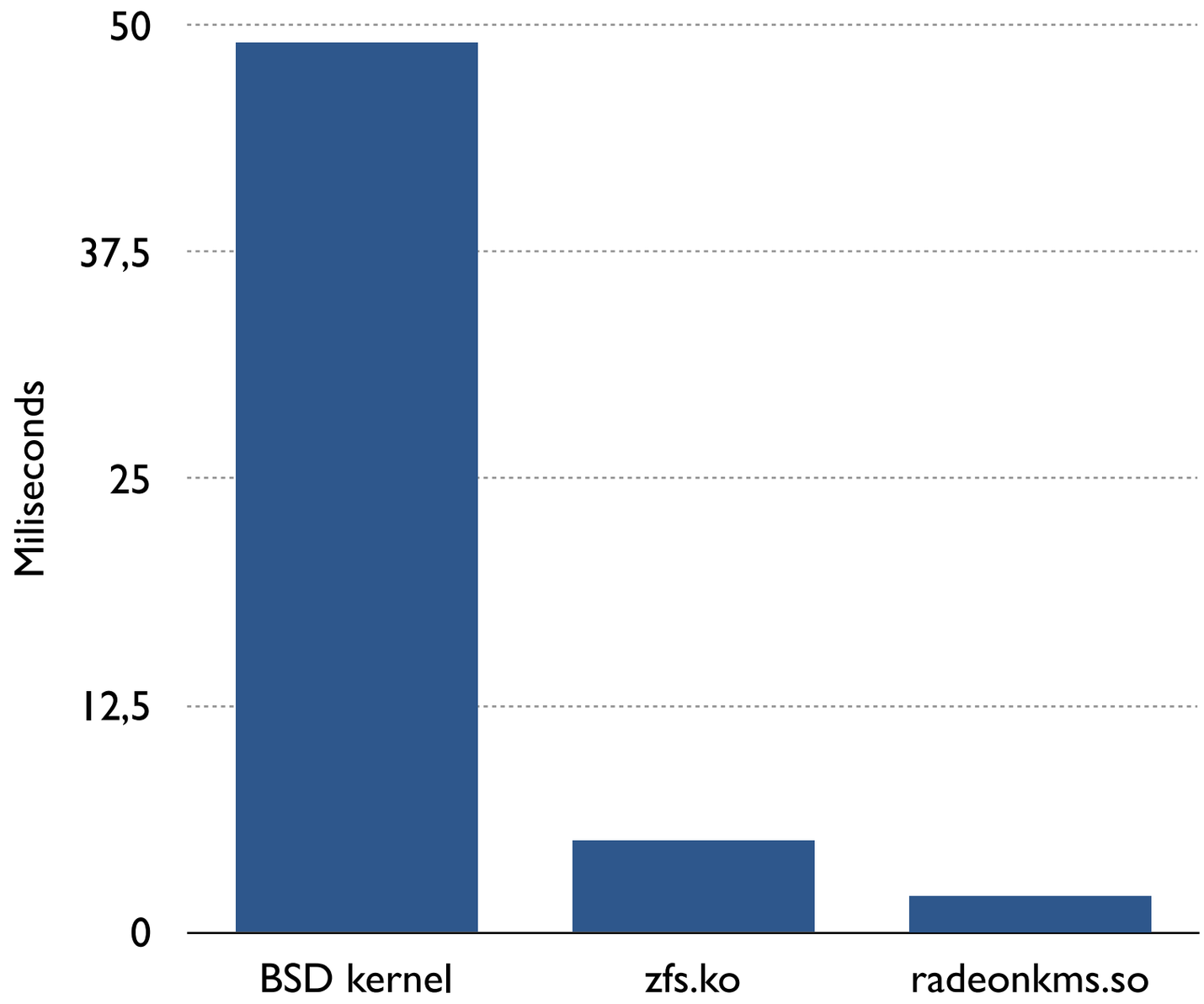
- C99 (almost)
- using `queue(3)`
- using `stdint(7)`
- unit tests

Average inflation

```
$ find /boot/kernel -name '*.symbols' -
exec ctfmemusage -r {} \; | awk '{s+=$1}
END{print s/NR}'
```

2.67788

Average loading time



DDB work

- DDB lives in kernel space
- libctf needs to adapt (FreeBSD only)
- I/O in the debugger is too limited
- caching the data set before

libctf in every space

- the same codebase shared between kernel and userland
- heavy use of macros

```
#ifdef _KERNEL
  #define _CTF_FREE(ptr) free(ptr, M_CTF)
#else
  #define _CTF_FREE(ptr) free(ptr)
#endif
```

Casual types

- adapt proper encoding (float as a floating point number, char as a letter, …)
- struct members in offset order with indentation
- optionally follow pointers

Recursive data types

- linked lists, binary trees, n-ary trees, queues, …
- ubiquitous
- indentation model does not work

Bad example

```
0x123 = struct two_int_list {
   int a = 11
   int b = 12
   struct two_int_list* next = {
      int a = 21
      int b = 22
      struct two_int_list* next = {
         int a = 31
         int b = 32
         struct two_int_list* next = {
            int a = 41
            int b = 42
            struct two_int_list* next = NULL
} } } }
```

Good example

```
0x123 = struct two_int_list = {
   int a = 11
   int b = 12
}
   | next
   v
{
   int a = 21
   int b = 22
}
   | next
   v
NULL
```

mdb approach

- addr::list type field

Detecting data structures

- observe various common patterns
  - names, position in the structure, types
  - `queue(3)` and `tree(3)`
  - create a view for each one (or die trying)

Possible views

(not done)

- on demand
- interactive tree discovery
- hashtable querying

Frequently asked questions

What about my BSD?

- currently only FreeBSD
- libelf and zlib dependency for libctf
- happy to help

What about my arch?

- currently only x86
- will provide ARM and MIPS port
- happy to help

Why is it not in the tree?

- needs review
- needs testing

Where can I get it?

- will be available at my FreeBSD wiki
- VirtualBox image

What more is there to do?

- finish endianness in libctf
- sizeof command
- finish port to Linux and illumos

Future projects

- CTF userland tools
- libkvm + libctf
- LLVM/Clang integration
- C++

CTF userland tools

- ctfdump
- ctfstats
- ctfcorequery
- ctfmerge
- ctfconvert
- ctfdiff
- ctfmemusage

libkvm + libctf

- utilise this for tools such as ps(1) or netstat(1)
- kernel and userland must not match
- not even architectures

LLVM/Clang integration

- generate CTF data during compilation
- merge CTF data during linking
- new library has good license

C++

- add C++ type support
- needs full circle - DTrace integration

Thanks

- George Neville-Neil
- rest of the FreeBSD Community
- Google
- Foundation and Conference Orgs

kthxbai

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