LLVM Libc: Status, Challenges and Future Plans

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Agenda

1. What is LLVM libc
2. Current Status
    a. Functions
    b. Loader
    c. Infrastructure
3. Challenges
4. Future Plans

LLVM libc

- ➔ A greenfield libc developed with certain goals
  - ◆ Sanitizer friendly
  - ◆ Implemented in C/C++ source code without assembly
  - ◆ Moduler

  Full list of features and goals is available here:
  http://llvm.org/docs/Proposals/LLVMLibC.html

Status: Code Metrics

➔ Development was kicked off a year ago

- Over 10,000 lines of code from 200+ commits by 17 different contributors
- Over a 100 libc functions implemented
- Made a start to build a fully functional static-pie ELF loader
- Build, unittest, CI and other infrastructure setup

Status: Functions

Functions from math.h

- **Basic floating point operations**
  - `fabs[f|l]`, `fdim[f|l]`, `fmax[f|l]`, `fmin[f|l]`
- **Nearest integer functions**
  - `ceil[f|l]`, `floor[f|l]`, `trunc[f|l]`, `round[f|l]`
- **Floating point manipulation functions**
  - `copysign[f|l]`, `frexp[f|l]`, `logb[f|l]`, `modf[f|l]`
- **Exponential functions**
  - Single precision floating point versions of the exponential functions `expf` and `exp2f`
- **Trigonometric functions**
  - Single precision floating point versions of trigonometric functions `sinf`, `cosf` and `sincosf`
- **Quotient and Remainder functions**
  - `remquo[f|l], remainder[f|l]`
- **Power functions**
  - `sqrt[f|l], hypotf`

Credits: The exponential and trigonometric functions are adaptations of Arm’s contribution from their AOR project:

Status: Functions

Functions from string.h

- **Memory Functions:** `bzero, memcpy, memset`
  - Optimized for the statistically significant subset of inputs

Function	% of calls with size ≤ 128	% of calls with size ≤ 1024
memcpy	96%	99%
memset	91%	99.9%

- **Null terminated string functions**: `memchr, memrchr, strcat, strchr, strcmp, strcpy, strcspn, strlen, strnlen, strpbrk, strrchr, strspn, strstr, strtok, strtok_r`

Status: Functions

- **Functions from threads.h**
    - `call_once`, `mtx_init`, `mtx_lock`, `thrd_create`, `thrd_join` (all for Linux)
    - Port them to non-linux platforms very soon.

- **Functions from signal.h**

  `raise`, `sigaction`, `sigaddset`, `sigdelset`, `sigemptyset`, `sigfillset`, `signal`, `sigprocmask` (all for Linux)

- **Functions from ctype.h**

  All ctype.h functions for the default locale

Status: Functions

Miscellaneous Functions

Linux implementations of

- `abort`
- `assert`
- `errno`
- `_Exit`
- `fwrite`
- POSIX functions `mmap` and `munmap`

Status: Loader

Loader

- A start has been made to build a static-pie ELF loader.
- Just enough has been built to be able to test thread functions.
- Near term goal is to build a full static-pie ELF loader.

Status: Infrastructure

Build Infrastructure

- Libc specific CMake rules have been implemented
- The rules are one of the core components which make the libc implementation modular.
- Libc targets added via libc specific CMake rules have Python like fully qualified names.
  - `libc.src.math.sinf`

Status: Infrastructure

Collection of Utils

- Unit test framework
- Standalone library of C++ utilities
- Template library of floating point operations
- MPFR as reference for math function testing
  - MPFR is a C library for multi-precision floating point operations: http://mpfr.org

Status: Infrastructure

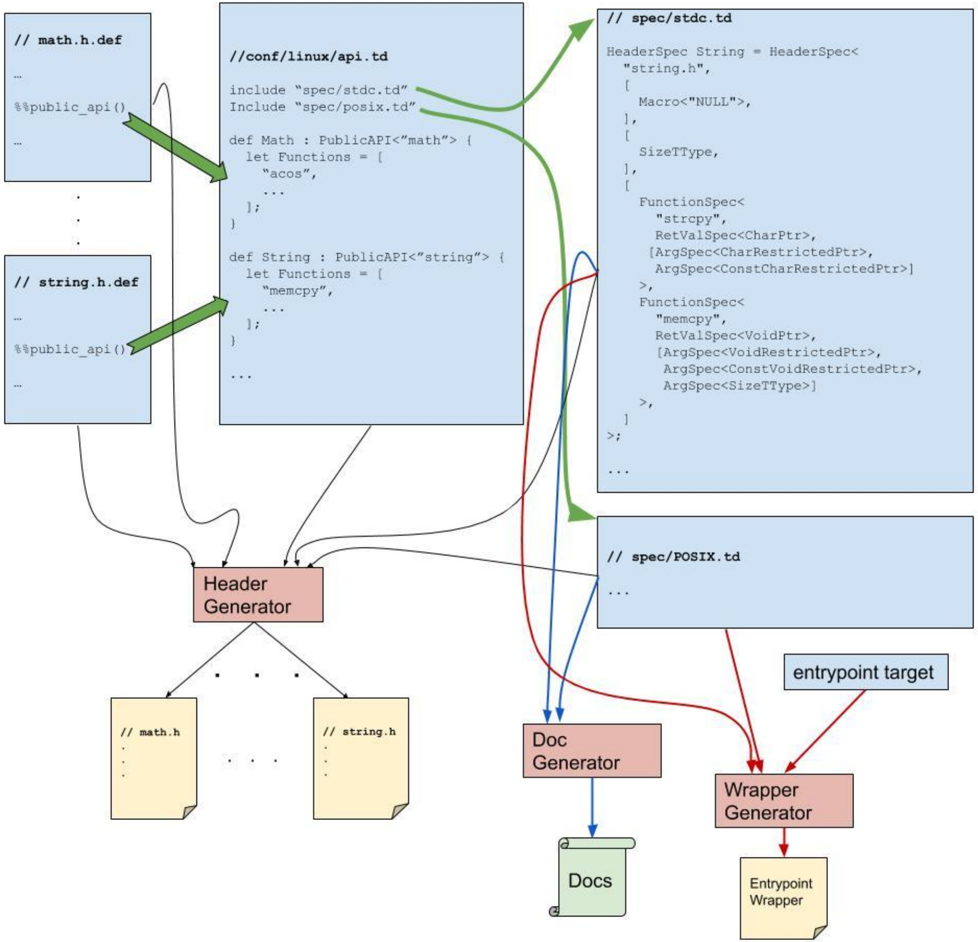
Header generation framework

- Standards are encapsulated in table gen files
- Each platform defines an API file
- The header generation tool reads the API file and generates the header files containing only the API listed in the API file
- Provides the pick the choose ability for header files

Note: A platform is a combination of the target OS + target machine architecture.

Status: Infrastructure

Header Generation Scheme



```
// math.h.def

…

%%public_api()

…
```

```
// string.h.def

…

%%public_api()

…
```

```
//conf/linux/api.td

include “spec/stdc.td”
Include “spec/posix.td”

def Math : PublicAPI<”math”> {
  let Functions = [
    “acos”,
    ...
  ];
}

def String : PublicAPI<”string”> {
  let Functions = [
    “memcpy”,
    ...
  ];
}

...
```

```
// spec/stdc.td

HeaderSpec String = HeaderSpec<
  "string.h",
  [
    Macro<"NULL">,
  ],
  [
    SizeTType,
  ],
  [
    FunctionSpec<
      "strcpy",
      RetValSpec<CharPtr>,
     [ArgSpec<CharRestrictedPtr>,
      ArgSpec<ConstCharRestrictedPtr>]
    >,
    FunctionSpec<
      "memcpy",
      RetValSpec<VoidPtr>,
      [ArgSpec<VoidRestrictedPtr>,
       ArgSpec<ConstVoidRestrictedPtr>,
       ArgSpec<SizeTType>]
    >,
  ]
>;

...
```

```
// spec/POSIX.td

...
```

Status: Infrastructure

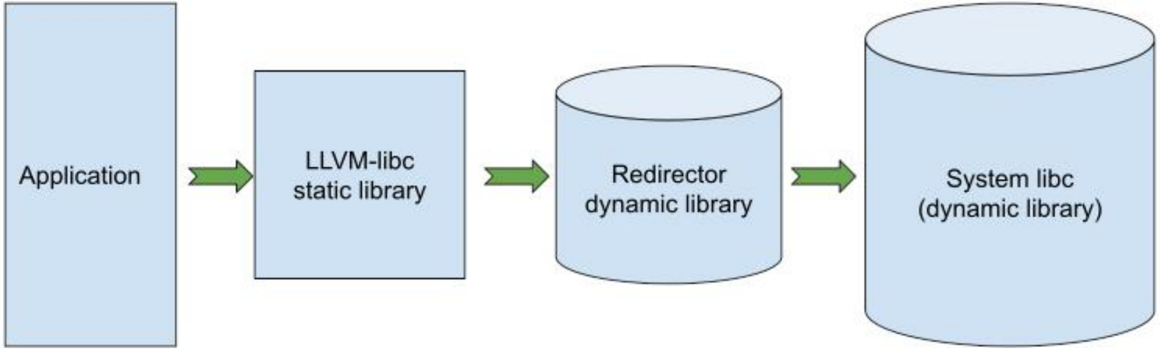
Clang-tidy checks

- Clang-tidy checks specific to LLVM libc have been implemented
- Protect against including undesired system headers
- Protect against polluting global namespace
- They run as part of the build and hence alert developers about deviant code at development time.
- They run on the public CI builders.

Status: Infrastructure

Redirectors

- A concept built for enabling the *mix-with-other-libcs* feature
- Redirectors are essentially wrapper functions in LLVM libc which intentionally call into the system libc
- Useful when an implementation of a particular function is not available yet in LLVM libc.



Challenges

- **Ability to mix with other libcs**
  - Challenge: Avoid header file mixup
  - Challenge: Avoid symbol mixup
  - Challenge: Namespace pollution

  Solution: libc specific clang-tidy checks

- **Ability to pick only parts of LLVM libc**
  - Challenge: Avoid pulling in parts not required

  Solution: Header generation + build system + redirectors

Future Plans

In the next one year

1. Complete the math library; that is, have an implementation for all functions coming from `math.h`.
2. Likewise, complete the null-terminated strings library.
3. Implement the API from stdio.h and stdlib.h at least for Linux.
4. Setup public CI builders for non-x86/non-linux platforms.
5. Implement full static-pie ELF loaders on linux.
6. Finish the standard threads library (threads.h).
7. Setup infrastructure to compare the results and performance of the math functions with similar functions from other popular libcs.
8. Run LLVM libc fuzz tests on OSS fuzz:
   https://github.com/google/oss-fuzz

Thank You