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# CTF and BTF debug formats in the GNU Toolchain: status update and what's next

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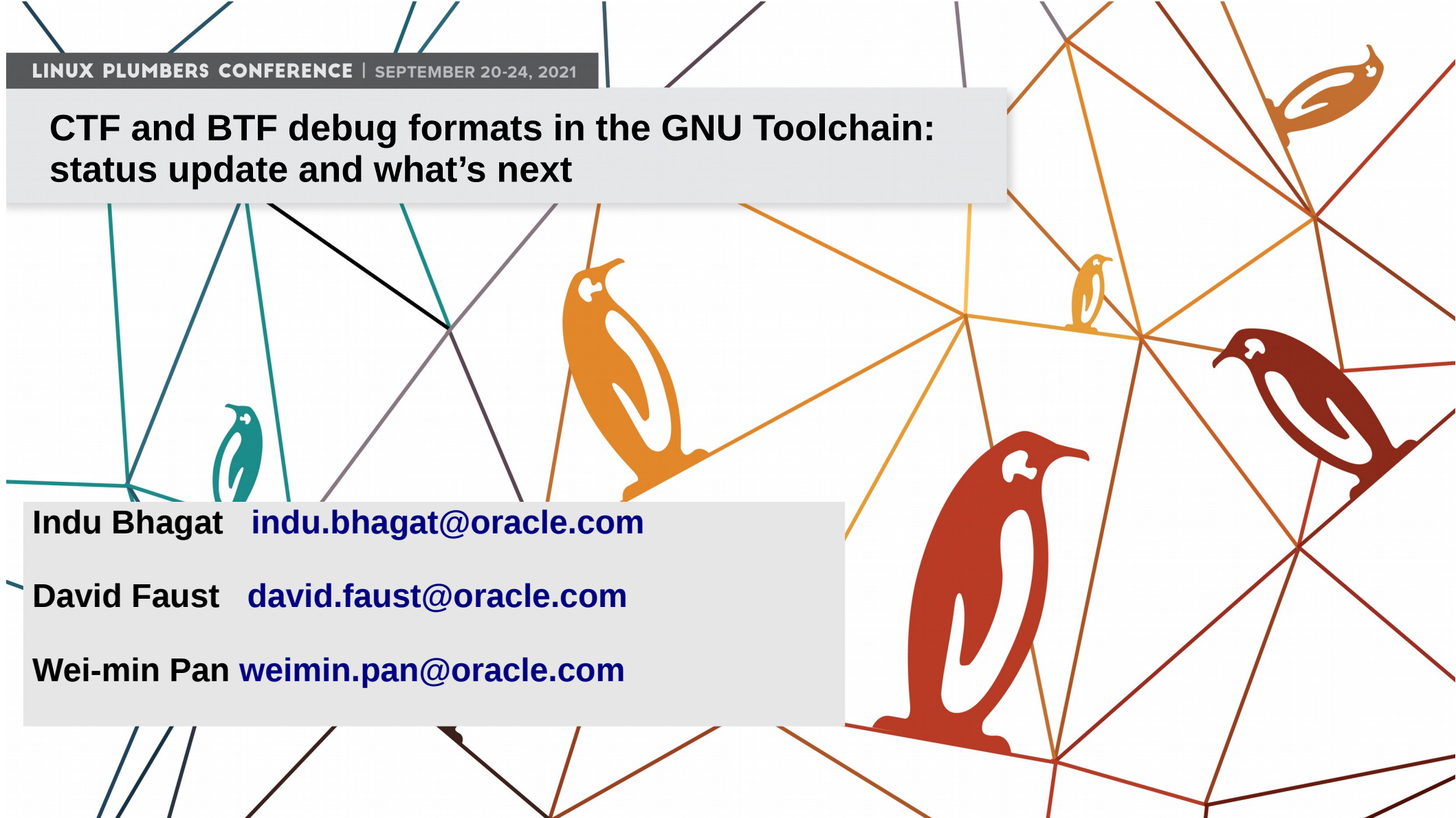


# Agenda

- Introduction: CTF/BTF debug formats
- Updates since GNU Tools track 2020
- CTF/BTF debug info generation in GCC
- What's next

# CTF/BTF Debug Formats

- Two distinct debug formats to convey type information
  - Compact C Type Format (CTF) describes C types (mid 2000s)
    - Solaris Kernel → Linux
    - Current version = V3
  - BPF Type Format (BTF) is inspired by Solaris CTF. With a focus on BPF programs/kernel (first LLVM/kernel patches circa 2018)
    - Current version = V1
- Remarkable similarities owing to a common ancestor
  - But they are binary incompatible, distinct formats

# CTF/BTF Debug Formats

Distinct formats with independent evolution history and use-cases

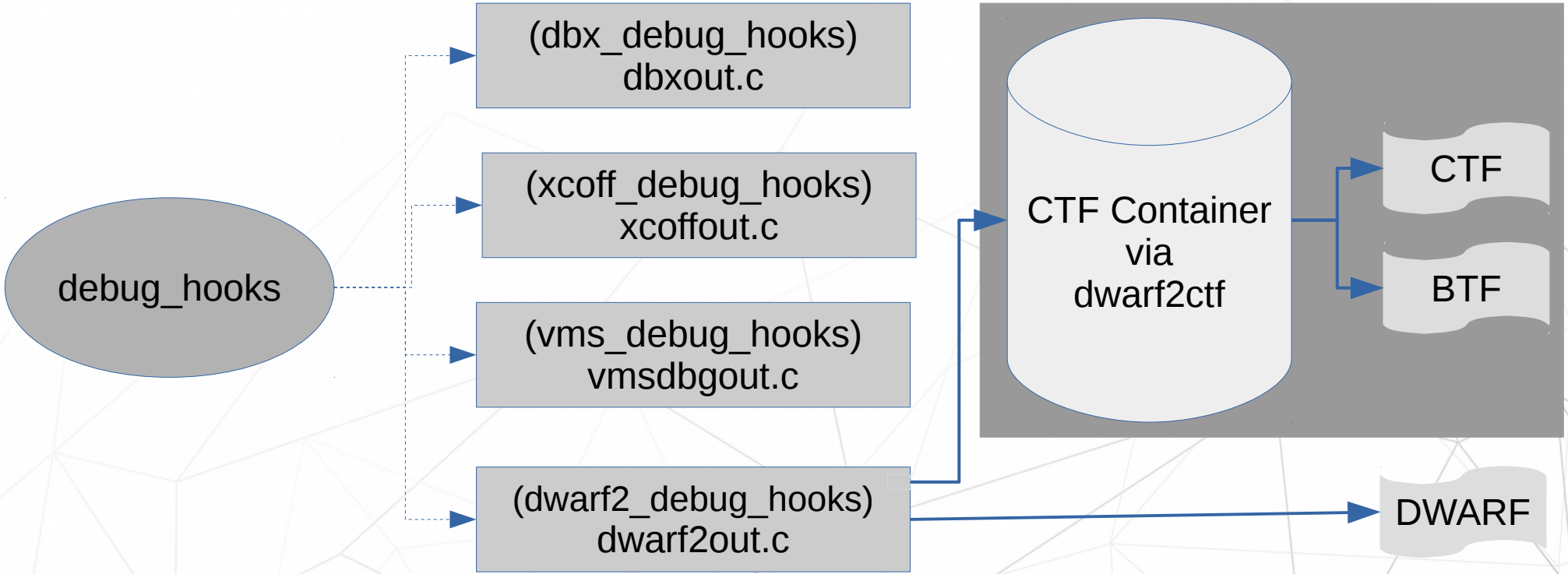
| | | |
|---|---|---|
| Most recent additions | CTF_K_SLICES for representing bitfields | BTF_KIND_FLOAT for fp types<br>BTF_KIND_TAG for attributes |
| Support for multiple CUs | CTF has representation of parent-child dictionaries (archives) | BTF does not have such a representation |
| library support | libctf (binutils >=2.36) for ld, gdb | [No linker support]<br>libbpf (kernel) does BPF program loading, performs relocations, ... |
| Miscellaneous | No src location information | BTF/CO-RE (.BTF.ext), src location information, relocations, ... |

# Updates since GNU Tools track 2020

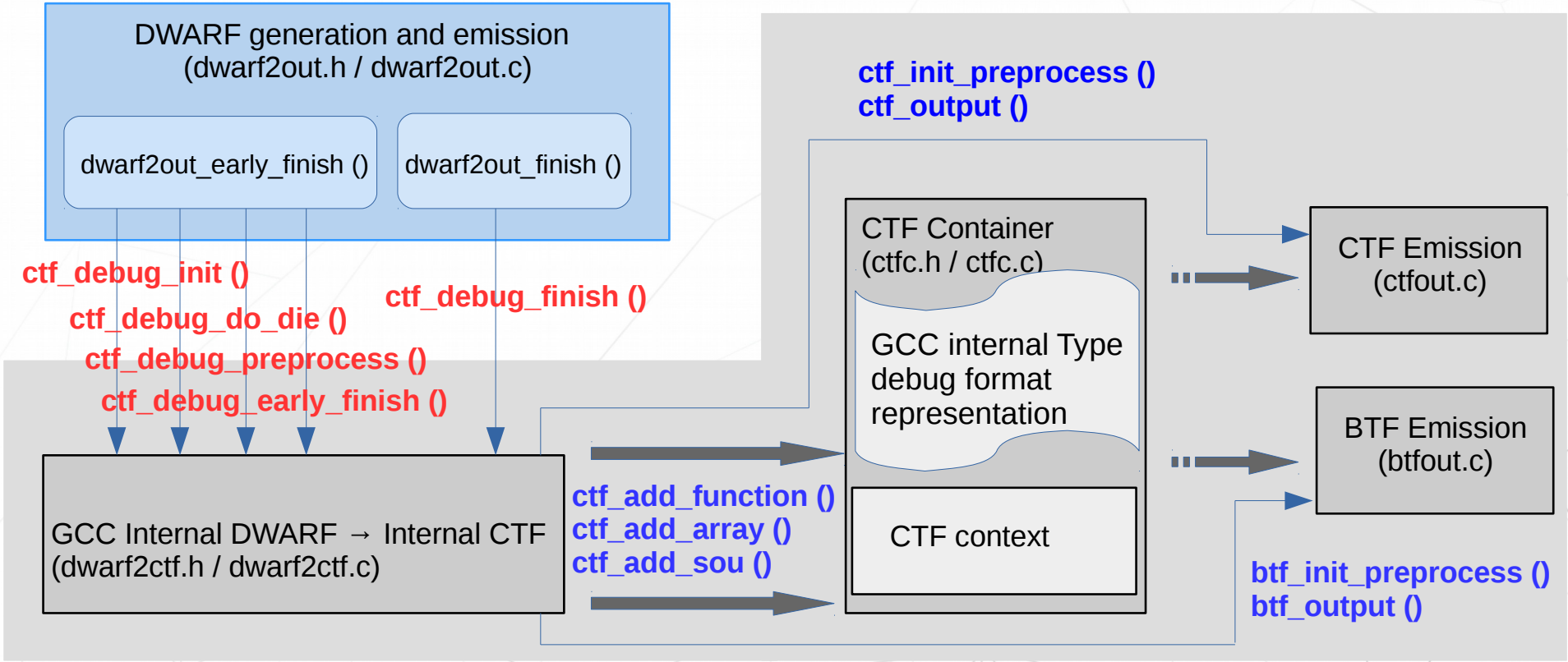
- CTF and BTF debug formats are now fully supported
  - GCC: -gctf, -gbtf generates the .ctf/.BTF section
  - Binutils ld, objdump: --ctf=.ctf
    - CTF Type de-duplication contributed in 2020.
  - GDB: Support for CTF Archives
- CTF Spec and mailing lists @ ctfstd.org
- Is it ready for uptake?
  - Yes! Please try it out and report issues on bugzilla or mailing lists

# Implementation Notes

# Implementation in GCC



# CTF/BTF debug info generation in GCC



# BTF support in GCC

- BTF generation for any target via -gbtf
  - No debug levels are necessary
- For BTF generation and emission, the CTF container is:
  - Post-processed after initialization
    - BTF encodes bitfields differently
    - Unrepresented types are removed
  - Pre-processed before emission
    - Add BTF_KIND_FUNC and BTF_KIND_DATASEC records
- For BPF backend, -gbtf generates BTF/CO-RE

# CTF Support in GDB

- Implements a CTF reader, using libctf, to read and set CTF data
  - Skips reading CTF data if DWARF debugging info exists
- Enables GDB commands such as ptype, print, and whatis to support CTF types
- Supports single compilation unit and CTF Archives
- Next task:
  - Support for CTF V4 (backtraces and other CTF format changes)

# What's Next

# Next Steps

- Continue to support CTF/BTF in GNU Toolchain
- Towards CTF V4
  - Inviting community discussion and participation on the public mailing list at ctfstd.org

# Future CTF Work (GCC)

- Testing of interaction between debug flags which affect the generation of DWARF DIEs and -gctf / -gbtf
  - **[debug_info_level] -gLEVEL** OR **-gtoggle**
  - */ CTF/BTF generation feeds off DWARF dies. For optimal CTF/BTF, switch debug info level to 2. If off or at level 1, set it to level 2, but if already at level 3, don't lower it. */

| | | |
|---|---|---|
| -g0 -gctf -gtoggle | 0 → 2 → 0 | emits no DWARF, emits no CTF |
| -gctf -g0 -gtoggle | 2 → 0 → 2 | emits DWARF, emits CTF |

  - Need to differentiate between **user-specified** debug info level (output/emission) vs **internal** GCC debug info level (debug info generation)

# Future CTF work (GCC)

- Modularize / Refactor dwarf2out.c / dwarf2out.h
  - Usage: DWARF die creation, add and get attribute APIs
  - Functionality: Split off a dwarf2cfi.h
- Prepare for CTF V4
  - Make the CTF Container (CTFC) version aware
  - Command line options -gctf-version=<NUMBER> to chose CTF version

# CTF version 4 – Backtraces Requirements

- Generate Backtraces with the following requirements:
  - Exact at each instruction boundary
  - With original value of the arguments at the point of function call
  - Keep it simple and compact. No complex expression encoding, no location lists, no stack machine

# CTF version 4 – Backtraces
## Callsite information

- Each ABI defines the parameter passing rules
  - #1: Assign storage class to the argument
    - High-level language type → machine type
  - #2: Assign reg/stack location to each argument, given its machine type
- Proposal
  - Debug format specifies #1
  - Backtrace client does #2

# CTF version 4 – Backtraces

- The natural location of the argument is not encoded explicitly in the format. It is inferred from position and class of the argument and the ABI (by the client)
  - **[AMD64]** INTEGER / SSE / SSEUP / X87 / X87UP / … / MEMORY
  - **[AARCH64]** INTEGER / SIMD / FP / SCALABLE VECTOR / SCALABLE PREDICATE/ MEMORY

# CTF version 4 – Backtraces

## Few examples

| Examples for argument passing | Representation [AMD64] |
|---|---|
| // all integers<br>**func1** (int a, int b, int c, int d, int e, int f); | a in RDI, b in RSI, c in RDX, d in RCX, e in R8, f in R9<br>Storage class = **I I I I I I**<br>implicit loc info = **[ REG REG REG REG REG REG ]** |
| // small aggregates<br>typdef struct structparm {<br>int a, b; double d; } structparm;<br>**func2** (int a, structparm s); | a in RDI, s.a and s.b in RSI, s.d in XMM0<br>Storage class = **I 2 { I NO_CLASS FP }**<br>Implicit loc info = **[ REG 2 { REG - REG } ]** |
| // large aggregates<br>typedef struct { float lg1[10]; }<br>structlarge;<br>**func7** (__int128 a, structlarge b); | // large is defined as any composite struct with more than 8 eightbytes in size.<br>a in RDI+RSI, b on stack<br>Storage class = **2 {I I} 10 { MEM }**<br>Implicit loc info = **[ 2 { REG REG } 10 { MEM } ]** |

# CTF version 4 – Backtraces [Phase 1]

- **[Phase 1]** Get the original value of the argument from its natural location if it has not been clobbered
- Two sections with relevant information
  - .ctf section will contain the Callsite and Callsite parameter records
  - A new section (.ctf_frame) will contain the unwinding info
    - [Callsite Index] Given a PC, get ref to the CTF callsite record
    - [CFA Index] Given a PC, get the CFA

# CTF version 4 – Backtraces [Phase 1]

- ...cont'd
- Each object file contains a .ctf and .ctf_frame section which the linker will merge/de-dup if necessary
- The client needs an ABI specific method of deciphering the exact register/stack location of the argument given its storage class

# Thanks!

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