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Introduction to CTF 2

Common **T**race **F**ormat

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About the speaker

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- Works at EfficiOS (company behind LTTng) in Montréal, Canada.
- Interests in tracing, file formats, protocols, embedded systems, and documentation.
- Author of barectf (tracer generator for bare-metal systems).
- Author of the CTF 2 proposal.

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2. Why the major bump?
3. Major design goals of CTF 2
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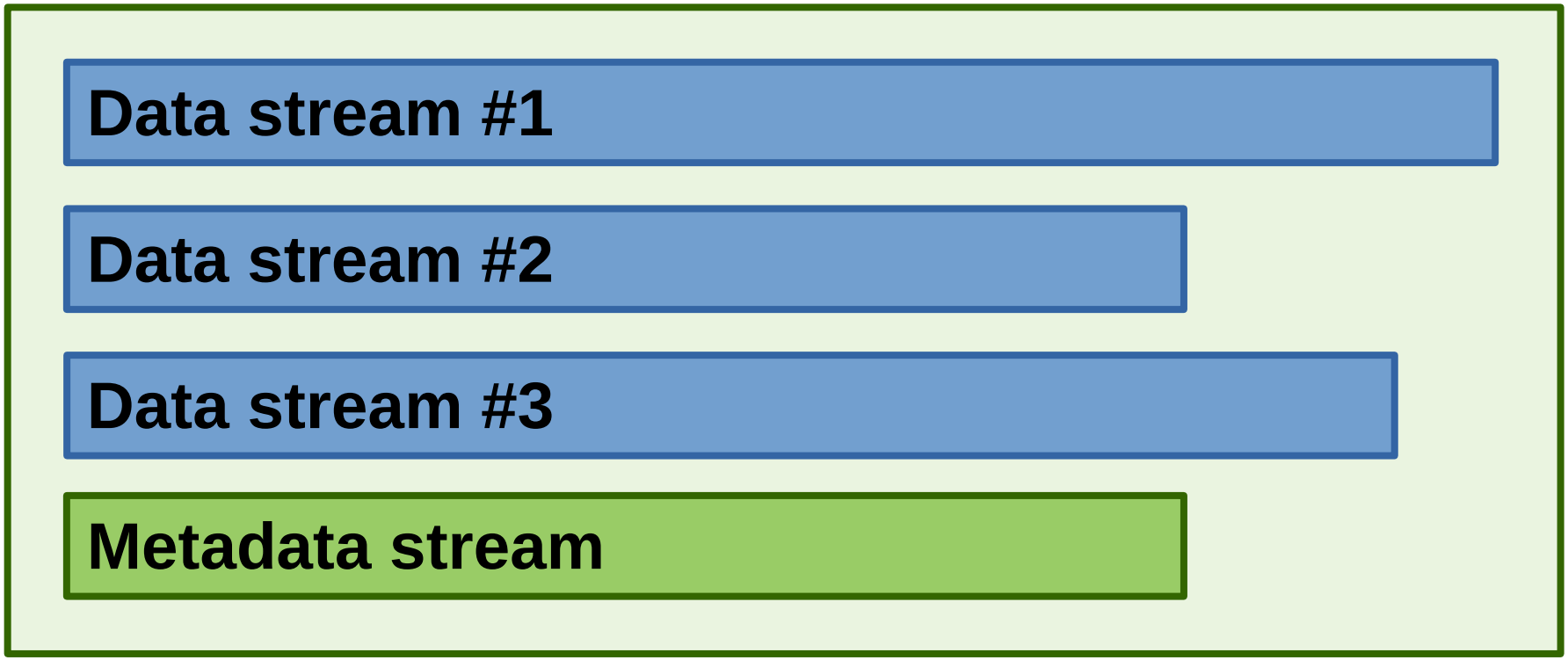
What is CTF?

CTF: **C**ommon **T**race **F**ormat



What is CTF?

CTF 1 metadata stream

```
// ...
event.header := struct {
  uint64 timestamp;
  uint16 id;
};
// ...
event {
  name = new_msg;
  id = 23;
  fields := struct {
    uint32 msg_id;
    string msg;
  } align(32);
};
// ...
```

CTF data stream

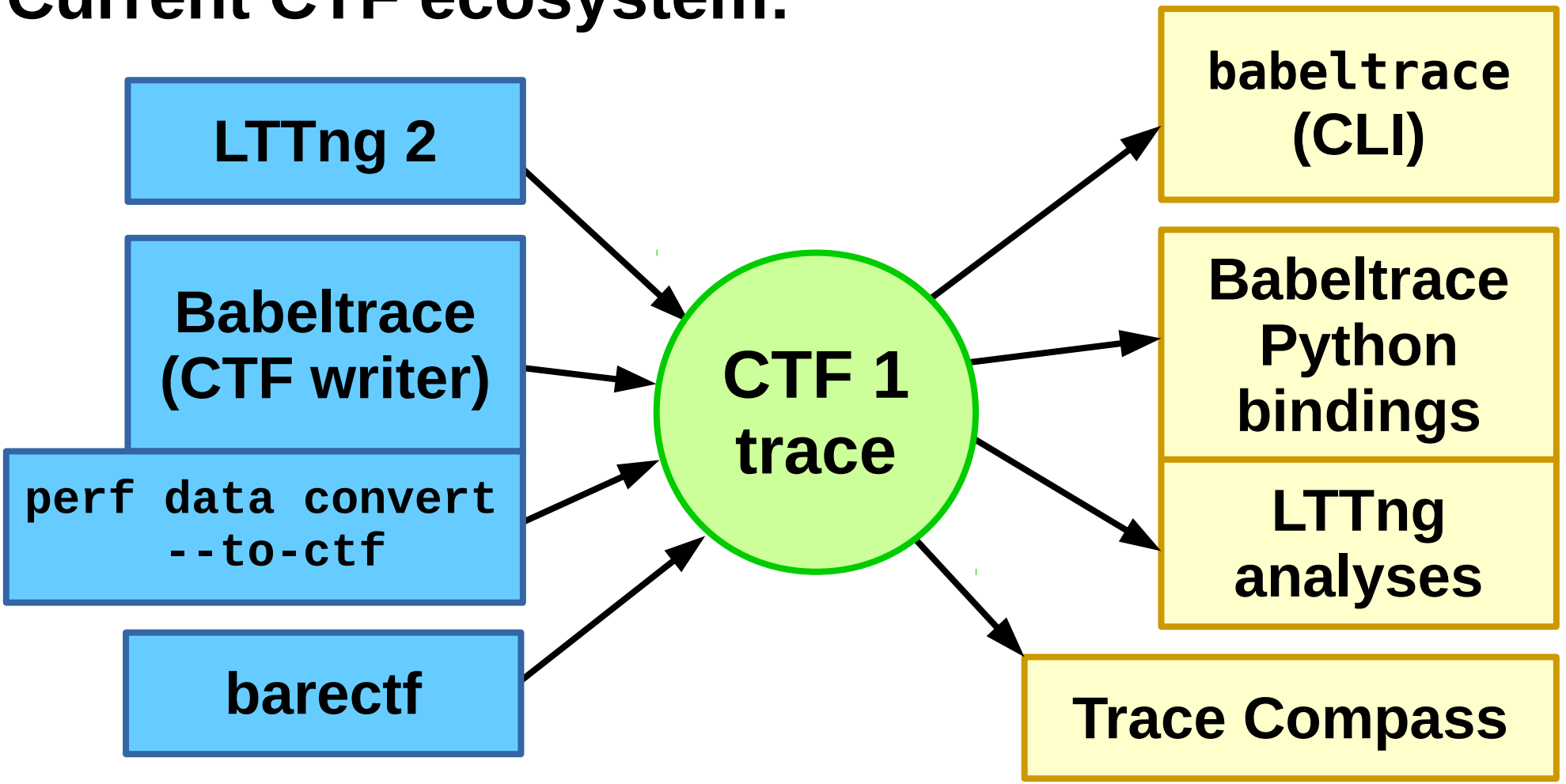
```
...7d ee 9c b8 8b 99 d1
89 dd ed 84 c3 02 00 00
17 00 00 00 2d ff 00 00
48 65 6c 6c 6f 2c 20 57
6f 72 6c 64 21 00 2d ff
40 52 d9 8d ff 90 ff...
```

Encoded event record:

- *Name*: “new_msg”
- *timestamp*: **15h47:11.2839912**
- *msg_id*: **65325** (**0xff2d**)
- *msg*: “**Hello, World!**”

What is CTF?

Current CTF ecosystem:



Why the major bump?

Major limitations of CTF 1 (current version):

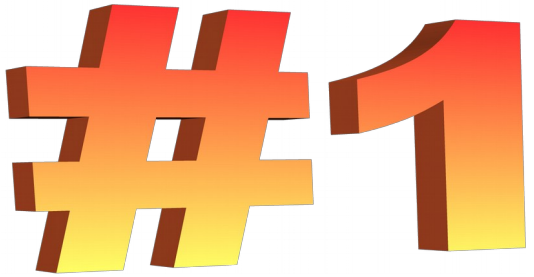
- Metadata stream is written in a custom language (TSDL) which is complicated to parse correctly without bugs.
- TSDL is strict: it has no extension points for custom user metadata and future enhancements.
- TSDL has no specified support for event record namespacing and versioning.
- CTF 1 has no support for variable-length integer and union fields, both of which can be very useful.

Why the major bump?

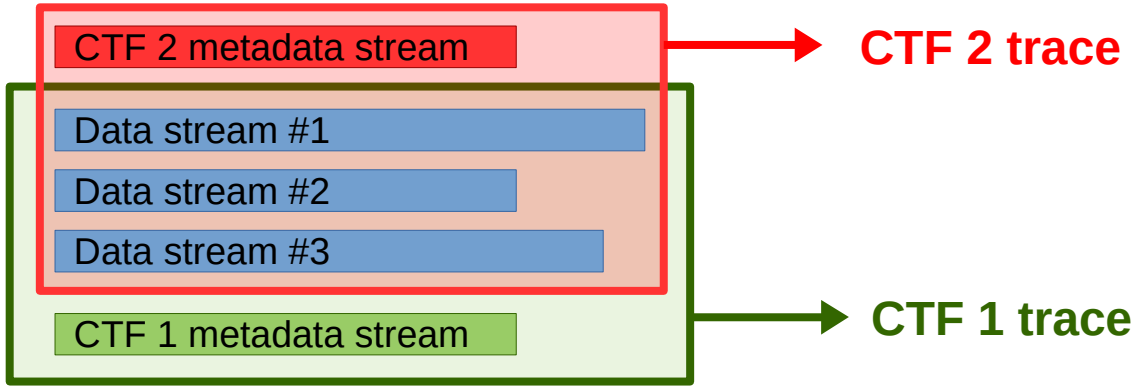
CTF 1 ≠ CTF 2

- Metadata stream is *not* backward compatible. Its language is different.
- Data streams *are* backward compatible.
- A CTF 1-only consumer cannot decode a CTF 2 trace.
- A CTF 2-only consumer cannot decode a CTF 1 trace.

Major design goals of CTF 2



CTF 2 data streams *must* be compatible with CTF 1 data streams.



Major design goals of CTF 2

The CTF 2 streams *must* be **as efficient as possible** to produce by a tracer.

Major design goals of CTF 2

CTF 2's model should be as close as possible to CTF 1's model.

Major design goals of CTF 2

A CTF 2 trace should be **as easy as possible to consume**.

Major design goals of CTF 2

A CTF 2 trace sh **to consume**.

Parse *this*:

```
struct {
  typealias integer {size = 33;} :=
    some_int;
  enum : integer {
    size = 17;
    align = 0b100;
    byte_order = be; // big endian
    base = x;          /* "hex" */
    signed = true;
  } {
    INIT = 0x23d,
    "/* best */ state" = -50 ... 21,
  } state[17]
          [stream.packet.context.a.b.c];
  variant var <previous.selection> {
    some_int CHOICE0;
    struct {string z;}
      align(32) SOME_ENTRY[2];
  };
} align(64);
```

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Major design goals of CTF 2

A CTF 2 metadata stream *must* be **extensible** by producers and by future minor revisions of the specification (forward compatibility).

Major design goals of CTF 2

CTF 2's specification should focus on how to encode and decode **data streams**.

~~integer base~~

~~event name~~

~~event's log level~~

~~trace's environment~~

Major design goals of CTF 2

CTF 2's specification *must not* specify how to **transport** or **store** a trace.

```
trace dir/
  metadata
  stream0
  stream1
```

What's new in CTF 2?

DiaMon workgroup publishes CTF 2 documents

Look at those pixels!

What's new in CTF 2?

Terminology update

Event	*Event record class*
Stream	*Stream class*
Clock	*Clock class*
Declaration	*Field type*
Event's fields	*Event's payload*
...	...

What's new in CTF 2?

Metadata stream is written in JSON

```
event {
   id = 23;
   name = "my_event";
   loglevel = 4;
   fields := struct {
      my_int intField;
      string stringField;
   } align(64);
};
```

```
{
  "fragment": "event-record-class",
  "user-attrs": {
    "diamon.org/ctf/ns/basic": {
      "name": "my_event",
      "log-level": 4
    }
  },
  "id": 23,
  "payload-field-type": {
    "field-type": "struct",
    "alignment": 64,
    "fields": [
      {
        "name": "intField",
        "field-type": "my_int"
      },
      {
        "name": "stringField",
        "field-type": {
          "field-type": "string"
        }
      }
    ]
  }
}
```

What's new in CTF 2?

Metadata stream is written in JSON

- Structure field names are strings ➡ any name is allowed.
- Fields with special semantics to decode data streams can also have any name (e.g. *`magic`*, *`stream_id`*, *`id`*, *`events_discarded`*).
  - They are *tagged* as special fields instead of strictly relying on the name.

What's new in CTF 2?

Metadata objects can contain namespaced user attributes

```
{
  "fragment": "event-record-class",
  "user-attrs": {
    "diamon.org/ctf/ns/basic": {
      "name": "my_event",
      "log-level": 4
    }
  },
  "id": 23,
  "payload-field-type": {
    "field-type": "struct",
    "alignment": 64,
    "fields": [
      {
        "name": "intField",
        "field-type": "my_int"
      },
      {
        "name": "stringField",
        "field-type": {
          "field-type": "string"
        }
      }
    ]
  }
}
```

```
{
  "field-type": "int",
  "size": 32,
  "alignment": 32,
  "byte-order": "le",
  "user-attrs": {
    "std": {
      "base": 16
    }
  }
}
```

```
{
  "field-type": "string",
  "user-attrs": {
    "my custom namespace": {
      "this is a special string": true,
      "style": {
        "fg": "#15cd49",
        "bg": "#c0c0c0"
      }
    },
    "other namespace": {
      "hide when": "Hello, World!"
    }
  }
}
```

What's new in CTF 2?

New field type:
bit array

- Parent field type of all **fixed-size field types**
  - Integer, boolean, floating point number, enumeration
- Contains the **size** and **byte order** properties
- *Not* an integer field type: has no sign property

What's new in CTF 2?

New field type:
bit array

CTF 2 metadata stream

```
// ...
{
  "field-type": "bitarray",
  "alignment": 16,
  "size": 24,
  "byte-order": "le"
}
// ...
```

CTF data stream

```
...7d ee 9c b8 8b 99 d1
89 dd ed 84 c3 02 00 00
17 00 00 00 2d ff 00...
```

Encoded field's value:

- **11000011 10000100 11101101**
- **0xc384ed**

What's new in CTF 2?

New field type:
null

- Special field type which represents a 0-bit data field
- Still has an alignment property
- Cleaner than empty structure in some situations
  - E.g., as a variant field type's choice

What's new in CTF 2?

New field type:
null

CTF 2 metadata stream

```
// ...
{
  "field-type": "null",
  "alignment": 16
}
// ...
```

CTF data stream

```
...7d ee 9c b8 8b 99 d1
89 dd|ed 84 c3 02 00 00
17 00 00 00 2d ff 00...
```

Encoded field's value:

- **null** (only possible value)

What's new in CTF 2?

New field type:
boolean

- Inherit the properties of a bit array field type
  - Alignment, byte order, size in bits
- Specific meaning:
  - All the bits are 0 ➡ ***false***
  - Anything else ➡ ***true***

What's new in CTF 2?

New field type:
boolean

CTF 2 metadata stream

```
// ...
{
  "field-type": "bool",
  "alignment": 16,
  "size": 24,
  "byte-order": "be"
}
// ...
```

CTF data stream

```
...7d ee 9c b8 8b 99 d1
89 dd ed 84 c3 02 00 00
17 00 00 00 2d ff 00...
```

Encoded field's value:

- As bit array: **0xc384ed**
- As boolean: **true**

What's new in CTF 2?

New field type:
boolean

CTF 2 metadata stream

```
// ...
{
  "field-type": "bool",
  "alignment": 16,
  "size": 24,
  "byte-order": "be"
}
// ...
```

CTF data stream

```
...7d ee 9c b8 8b 99 d1
89 dd 00 00 00 02 00 00
17 00 00 00 2d ff 00...
```

Encoded field's value:

- As bit array: **0x000000**
- As boolean: **false**

What's new in CTF 2?

New field type: *variable-length bit array*

- Represents **little-endian base 128** (LEB128) data fields (used by DWARF and Google's protocol buffers)
- Smallest bit array data field can be encoded on a single byte; larger bit arrays use as many bytes as needed
- Saves data stream space in situations where a data field is usually small, but can sometimes be large
- Parent field type of the variable-length *integer* field type

What's new in CTF 2?

CTF 2 metadata stream

```
// ...
{
  "field-type": "varbitarray"
}
// ...
```

CTF data stream

```
...7d ee 9c b8 8b 99 d1
89 e5 8e 26 02 00 00 ab
17 00 00 00 2d ff 00...
```

New field type:
variable-length bit array

```
0xe5      0x8e      0x26
11100101 10001110 00100110
00100110 10001110 11100101
 0100110  0001110  1100101
```

Encoded field's value:

- **0x98765**
- **0100110 0001110 1100101**

What's new in CTF 2?

New field type: *union*

- Represents data fields which can be decoded as different field types
- Chosen mechanism to **add field types** in future minor revisions of the CTF 2 specification: old consumers can always read/skip a data field
- Example: union of sequence of bytes (in CTF 2 spec.) *and* UTF-16 string (not in CTF 2 spec.)

What's new in CTF 2?

CTF 2 metadata stream

```
// ...
{
  "field-type": "union",
  "alignment": 16,
  "fields": [
    {"name": "as uint32",
     "field-type": "uint32"},
    {"name": "as string",
     "field-type": {
       "field-type": "string"
     }}
  ]
}
// ...
```

New field type:
union

CTF data stream

```
...7d ee 9c b8 8b 99 d1
89 e5 43 54 46 00 ed ab
17 00 00 00 2d ff 00...
```

Encoded field's value:

- **4609091** ("as uint32")
- "**CTF**" ("as string")

Potential future extensions

- UTF-16 and UTF-32 string fields
- Fixed-point number fields
- Frequency scaling support
- Standard format string user attribute (most probably inspired by Python's `format()` string method)

Planned adoption

- **Babeltrace (consumer and producer)**: v2.1
- **LTTng**: ~v2.10/v2.11 if the discussion is active enough.
  - *Condition*: Babeltrace v2.1 *must* be released.
  - *Idea*: Implement a temporary hybrid mode where you can choose to generate either a CTF 1 or a CTF 2 trace. No interest so far.
- **barectf**: As soon as Babeltrace v2.1 is released.
- **Trace Compass**: Synchronized with LTTng producing CTF 2 traces.

CTF 2 resources

- **Proposal**:
  - https://lists.linuxfoundation.org/pipermail/diamon-discuss/2016-October/000099.html
  - **HTML version**:
    - http://diamon.org/ctf/files/CTF2-PROP-1.0.html
- **Other documents**:
  - http://diamon.org/ctf/files/CTF2-BASICATTRS-1.0.html
  - http://diamon.org/ctf/files/CTF2-DOCID-1.0.html
  - http://diamon.org/ctf/files/CTF2-FS-1.0.html
  - http://diamon.org/ctf/files/CTF2-PMETA-1.0.html

Questions?