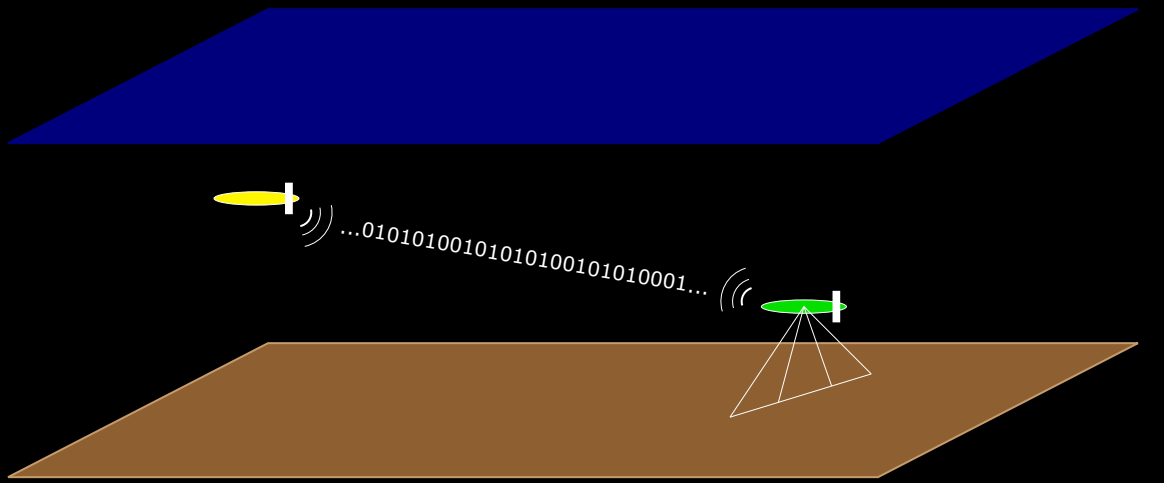
The Dynamic Compact Control Language:
A Compact Marshalling Scheme for Acoustic Communications



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Problem

Given:

1. Acoustic communications are highly rate-limited.
2. Marine robots are increasingly used in clusters.
3. Research at sea demands robust & reconfigurable software.

How can we design a data marshalling scheme that satisfies these constraints?

Prior Art

Marine specific:

- Compact Control Language (R. Stokey, WHOI)
- Ad-hoc

General purpose:

- ASN.1
- Protocol Buffers (Google)
- Text encoding (e.g. Huffman / LZW)

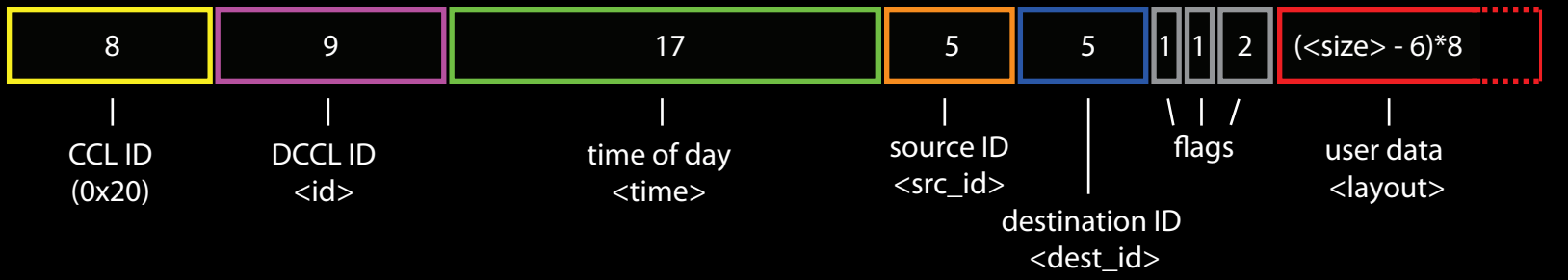
What is DCCL?

1. A structure language for fixed size small messages:
   - O(10-100) bytes
   - suitable for acoustic modems
     (e.g. WHOI Micro-Modem)

What is DCCL?

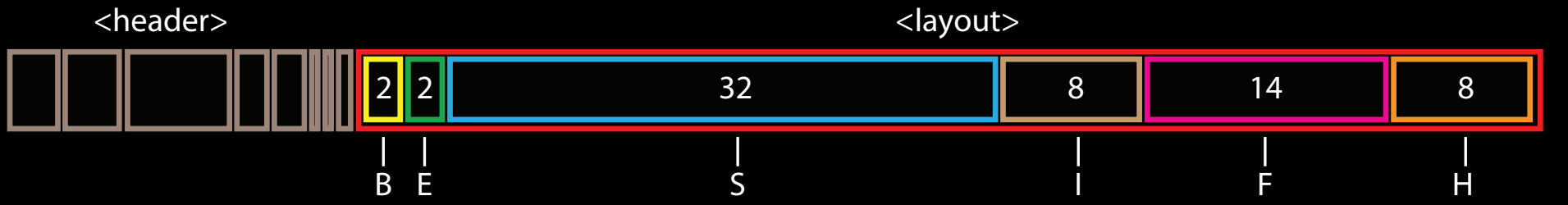
1. A structure language for fixed size small messages.
2. A set of predefined encoding & decoding algorithms (*libdccl*):
    - flexible: runtime translation of XML to C++ objects
    - efficient: bounded numbers & unaligned packing
    - simple: encoding based on unsigned integers
    - customizable: user-supplied pre-encode / post-decode callbacks
    - secure: provides (optional) AES encryption

DCCL Structure: Header




```
<?xml version="1.0" encoding="UTF-8"?>
<message_set>
  <message>
    <name>Example</name>
    <size>32</size>
    <id>1</id>
    <header>
      <src_id>
        <name>Src</name>
      </src_id>
      <dest_id>
        <name>Dest</name>
      </dest_id>
      <time>
        <name>Time</name>
      </time>
    </header>
    <layout>
      ...
    </layout>
  </message>
</message_set>
```

DCCL Structure: Layout




```
<?xml version="1.0" encoding="UTF-8"?>
<message_set>
  <message>
    <name>Example</name>
    <size>32</size>
    <id>1</id>
    <header>
      ...
    </header>
    <layout>
      <bool>
        <name>B</name>
      </bool>
      <enum>
        <name>E</name>
        <value>cat</value>
        <value>dog</value>
        <value>mouse</value>
      </enum>
      <string>
        <name>S</name>
        <max_length>4</max_length>
      </string>
      <int>
        <name>I</name>
        <max>100</max>
        <min>-50</min>
      </int>
      <float>
        <name>F</name>
        <max>100</max>
        <min>-50</min>
        <precision>2</precision>
      </float>
      <hex>
        <name>H</name>
        <num_bytes>1</num_bytes>
      </hex>
    </layout>
  </message>
</message_set>
```

libdccl Encoder: Algorithms

All types have “not given” or “invalid” == 0

- <bool>: true is 2; false is 1
- <float>:

    subtract <min>
    multiply by $10^{\text{<precision>}}$
    round to nearest integer
    size defined by <max>, <min>, & <precision>

  example:

    precision = 1, min = 2, max = 3
    encode 2.5 as (2.5-2)*10 = 5
    need field size: ceil($\log_2((3-2)*10)$) = 4

libdccl Encoder: Algorithms

- <int>: same as <float> with precision = 0
- <hex>: send as is.
- <string>: ASCII octets; no '\0' needed.
- <enum>: map values to integers 1,2,N.

Header fields: fixed size (always).

Time sent as seconds since start of day.

Integrating DCCL with Robots

Publish / subscribe software architectures are popular in marine robotics; we use MOOS.

DCCL provides additional features for these architectures:

1. Source variables: architecture variable to extract data from for a given message field.
2. Triggers: publish event or time based trigger to create message.
3. Publish variables: architecture variables to publish data upon message receipt. Supports printf-type syntax.

Experiments: Messages

Message Name	Category	Size (bytes)	Hypothetical CCL Size (bytes)	Description
ACTIVE_CONTACTS	Data	32	41	Active acoustic contact report message.
ACTIVE_TRACKS	Data	32	41	Active acoustic tracking message.
LAMSS_DEPLOY	Command	31	40	Underwater vehicle command message.
LAMSS_STATUS	Data / Collaboration	26	35	Vehicle Status message (position, speed, Euler angles, autonomy state)
LAMSS_CONTACT	Data	29	34	Passive acoustic contact report message.
SURFACE_DEPLOY	Command	13	23	Command message for surface vehicles.
ACOUSTIC_MOOSPOKE	Command	32	31	Underwater debugging / safety message.
SOURCE_ACTIVATION	Collaboration	9	8	Vehicle to buoy source command message.
WINCH_CONTROL	Collaboration	7	6	Underwater vehicle to surface vehicle command message.
BTRCODEC	Data	256	255	Beam-Time Record Data from a towed passive acoustic array.
CTDCODEC	Data	256	496	Salinity, temperature, depth data from a CTD instrument (delta-encoded).

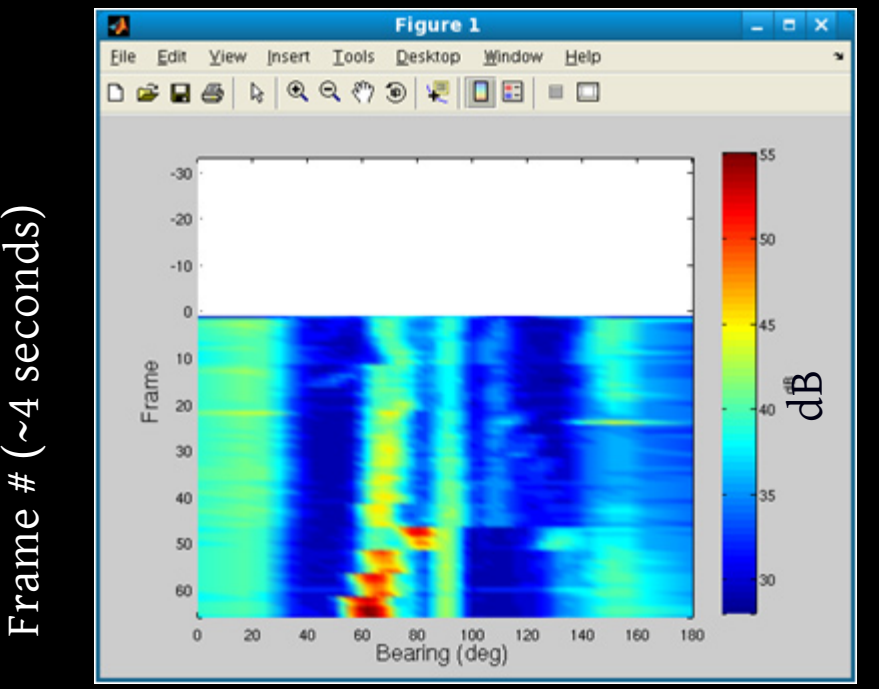
Experiments: Case Studies

- SWAMSI09: Bistatic detection of mine-like targets with two AUVs. Messages: LAMSS_DEPLOY, LAMSS_STATUS, ACTIVE_CONTACTS, ACTIVE_TRACKS

Operator Display: AUVs are green / purple track

Experiments: Case Studies

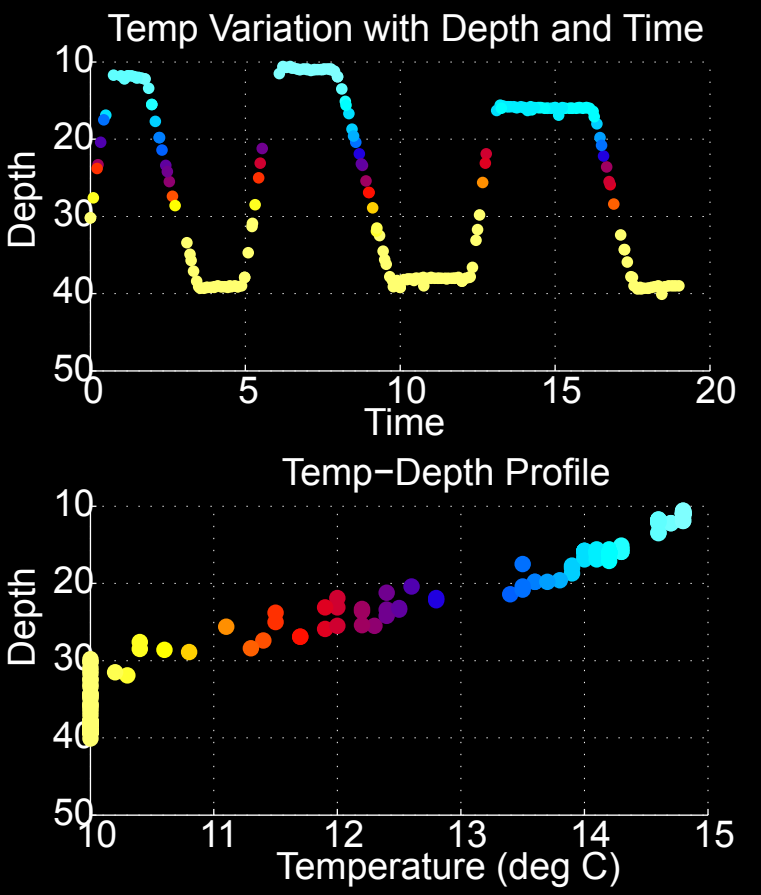
- GLINT09: Active detection of submarine-like target with surface craft (gateway), AUV, and source buoy.
  Messages: LAMSS_DEPLOY, LAMSS_STATUS, WINCH_CONTROL, SOURCE_ACTIVATION



Beam-Time Record

Experiments: Case Studies

- CHAMPLAIN09: Adaptive sampling of physical data (T, S, c) using an AUV
  - Messages: LAMSS_DEPLOY, LAMSS_STATUS, CTDCODEC



CTD Display

Summary

The Dynamic Compact Control Language provides:

- An XML based structure language for defining short messages for acoustic modems.
- Set of algorithms for compactly encoding DCCL messages.
- Tools for interacting with robotic software architectures.

DCCL code and documentation: http://gobysoft.com

Acknowledgments

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- LAMSS: A. Balasuriya, K. Cockrell, S. Petillo