The Dynamic Compact Control Language Version 3

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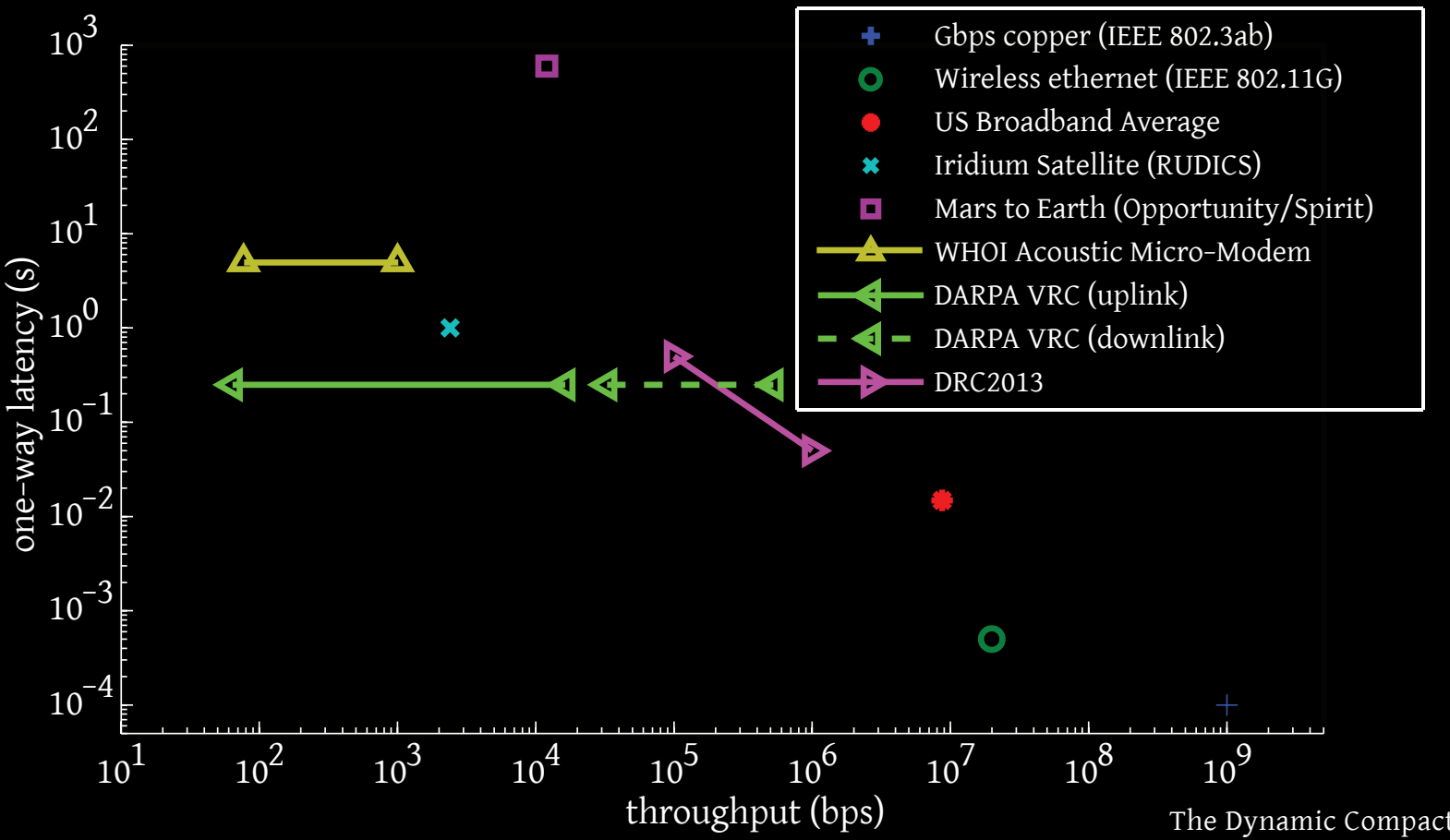
Problem

Robotic platforms are becoming increasingly widely deployed - growing need for data transfer.

Marine links tend to have (extremely) low throughput.



Solutions

Three broad (complementary) approaches to improving marine robotic performance in “poor” link scenarios:

- Improve the throughput and latency of the underlying physical link *(advances in signal processing).*
- Improve the autonomous capabilities of the individual robots *(advances in perception, autonomous control, machine learning).*
- Improve the information value of the data transmitted *(advances in source encoding).* <-- Our focus in this talk

What do *we* want?

- Vehicle position / attitude
  - latitude, longitude, depth, altitude
  - Euler angles: pitch, roll, yaw
- Vehicle health
  - battery remaining
  - sensors' status
- Sensor output
  - scalar data (pressure, temperature, turbidity)
  - imagery (sea floor, sidescan sonar)
  - processed data (beam/time record from sonar)
- Commands
- Shared state (handshaking, mission updates)

All data are not created equal

Clue from physics:

- You will not run into a `double` on the street.
- Sensors measure quantities with dimensions (mass, temperature, salinity, pressure), not *numbers*.
- These quantities are governed by rules, which are often understood, at least probabilistically:
  - Prior measurements in the region (for sensor data)
  - Motion prediction / tracking (for navigation data)
  - Conops requirements (for command messages)

All data are not created equal

Clue from object-oriented programming:

- Group collection of primitive types into sensible unit (object)
  - e.g. CTDMessage, DeployCommand, NodeReport, SonarSettings

Clue from design:

- Perfection is achieved, not when there is nothing more to add, but rather when there is nothing more to take away
  -- Antoine de Saint-Exupéry, *Terre des Hommes* (1939)

DCCL Overiew

The Dynamic Compact Control Language v3 contains:

- an interface description language (IDL) with static (compile-time) units of measure support
- a flexible data marshalling (source encoding/decoding) C++ library (which allows user extension).

Open source (LGPL 2) implementation

(http://libdccl.org).

(Prior releases part of Goby project / DCCL3 is stand-alone)

Interface Description Language (IDL)

```
message CommandMessage
{

 required int32 destination = 1

 optional string description = 2

 enum SonarPower { NOMINAL = 10; LOW = 5; OFF = 0; }
 optional SonarPower sonar_power = 10;
 required double speed = 11


 repeated int32 waypoint_depth = 12


}
```

Base Protobuf message example

DCCL acts as an "invisible" extension to Google Protocol Buffers (Protobuf).

- Code unaware of DCCL can still use the same messages (e.g. internal vehicle data)
- Extensions provide additional information (e.g. numeric bounding).

Protobuf is widely used and provides syntax checking and multi-language support (C++, Python, Java, C, ...)

IDL: Field bounds

```
import "dccl/protobuf/option_extensions.proto";

message CommandMessage
{
 option (dccl.msg) = { id:  125  max_bytes:  32  codec_version: 3 }

 required int32 destination = 1
                [(dccl.field)  = { max: 31 min: 0 in_head: true }];
 optional string description = 2
                [(dccl.field).omit = true];
 enum SonarPower { NOMINAL = 10; LOW = 5; OFF = 0; }
 optional SonarPower sonar_power = 10;
 required double speed = 11
                [(dccl.field) = { units { base_dimensions: "LT^-1" }
                                  max: 2.0  min: -0.5 precision: 1 }];
 repeated int32 waypoint_depth = 12
                [(dccl.field) = { units { base_dimensions: "L" }
                                  max: 40  min: 0 max_repeat: 4 }];
}
```

DCCL message example

Numerics are bounded by

- *max*: largest value
- *min*: smallest value
- *precision*: *decimal* digits of precision preserved.

Message level information

- id: identifies message (CommandMessage == 125)
- max_bytes: enforced upper bound for MTU targetting

IDL: Static units of measure

For scientific data, unit safety is as important as type safety.

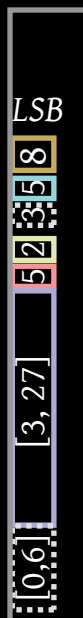
Each numeric field is given a unit system (e.g. SI) and specified dimension (e.g. length, power, speed) or a unit outside a consistent system (e.g. nautical mile).

BASE DIMENSIONS IN DCCL

Physical dimension	Symbol character
length	L
time	T
mass	M
plane angle	A
solid angle	S
current	I
temperature	K
amount	N
luminous intensity	J
information	B
dimensionless	-

Optionally, DCCL produces "unit safe" accessors and mutators for fields with units using the Boost Units library.

Default encoders (sizes)

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}
```

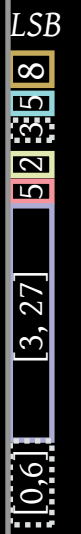
Header Fields:

- 8 bits header (dccl.id)
- 5 bits: destination [0, (2^5-1)]
- (3 bits padding to byte)

Body Fields (can be encrypted):

- 2 bits: sonar_power
- 5 bits: speed
- [3, 27] bits: waypoint_salinity vector (size varies on # of elements)
- ([0, 6] bits padding to byte)

Default encoders (example)

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}
```

Message definition

Example instantiation (x) and encoded values (x_{enc})

x_{enc} (bin)	x_{enc} (dec)	x
11111010	250	id: 125 (CommandMessage)
00011	3	destination: 3
000	(padding)	
10	2	sonar_power: LOW (i = 1)
10001	17	speed: 1.2
100	4 [10 15 10 12]	waypoint_depth: [10, 15, 10, 12]
[001010		
001111		
001010		
001100]		
000000	(padding)	

hex: fa 03 46 2a 8f c2 00
bin: 11111010 00000011 01000110 00101010 10001111 11000010 00000000

Compression performance

	DCCL Performance				
Message	Example Instantiation	GPB Size (bytes)	Python `struct` Size (bytes)	DCCL Size (bytes)	DCCL Compression
CommandMessage	destination: 3, sonar_power: LOW, speed: 1.2, waypoint_depth: [10, 15, 10, 12]	21	15	7	53-67%
AUVStatus	timestamp: 1427316658, source: 1, destination: 2, x: 2326, y: 1100, speed: 1.1, heading: 152.4, depth: 2150, altitude: 100, pitch: 0.01, roll: -0.02, mission_state: SEARCH, depth_mode: DEPTH_BOTTOM_FOLLOWING	90	48	19	60-79%
CTDMessage	temperature: 10, depth: 50, salinity: 32, sound_speed: 1485	29	18	7	61-76%

"GPB" is the default Protobuf encoding

Python *struct* is a formalized version of commonly used ad-hoc encoders (N-byte signed or unsigned integers byte-packed)

DCCL provides compression of 53-79% over these other approaches.

Application Examples

MOOS-IvP / Goby

- Numerous vehicle types (WaveGlider, Bluefin, OceanServer, CMRE OEX)
- Acoustic modems (primarily WHOI Micro-Modem), Iridium RUDICS/ Short-Burst Data
- Sonar data, oceanographic sensors data, command messages, multi-vehicle behavior synch.

TOPICS

- Bluefin vehicles with Iridium Short-Burst Data and/or acoustic modems.
- Command messages / vehicle navigation & status

DARPA Robotics Challenge (humanoid disaster relief robots)