Dryverl: a Flexible Erlang/C Binding Compiler

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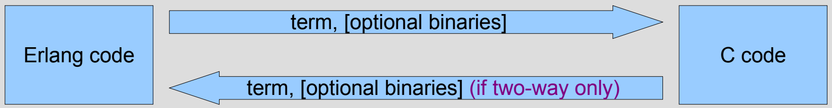
The problem: Erlang/C bindings

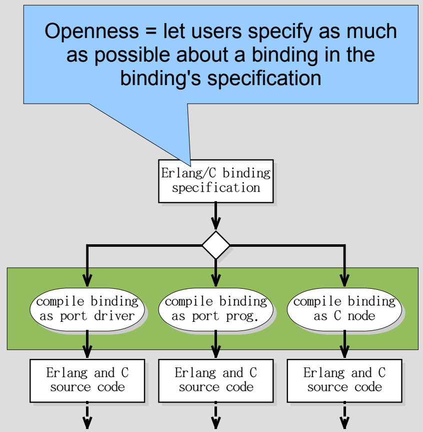
- How to integrate any Erlang and C code?
  - Dryverl generates all the Erlang and C code that implements a binding
- Purpose: offer maximum openness
  - Programmers control much of the implementation of a binding
- While also meeting those requirements:
  - Transparency / available mechanism
    - Hide ≠ and tricky implementation details
    - Cope with little openness / flexibility
  - Efficiency of generated code

What is an Erlang to C binding?

- No standard terminology for cross-language integration (?)
  - 1 binding = 1 Erlang function implemented in C
  - Information transmitted to/from C code:
    - 1 Erlang term
    - + 1 optional list of binaries (the port driver mechanism allows to pass binaries by reference)
  - Interactions can be two-way (interrogations) or one-way (announcements)
- 3 available mechanisms: driver, port, node



Openness = expressiveness of the specification language



- Purpose of Dryverl
  - Generates all the code given a binding specification
  - Generate code for any available mechanism
  - Openness: offers maximum control over a binding's implementation

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Why is openness important?

- Integration of legacy Erlang APIs and C code and Adaptation of idioms and type systems
  - Most existing compilers are not flexible enough and require wrappers
  - More verbose, more difficult to maintain
  - Using Dryverl: no need for wrappers
- Improved performance
  - Terms must be encoded/decoded in Erlang/C bindings
    - Fine control of encoding helps
    - E.g.: atoms encoded as integers
  - Static global optimizations: easier iff a spec contains everything, and in a structured format

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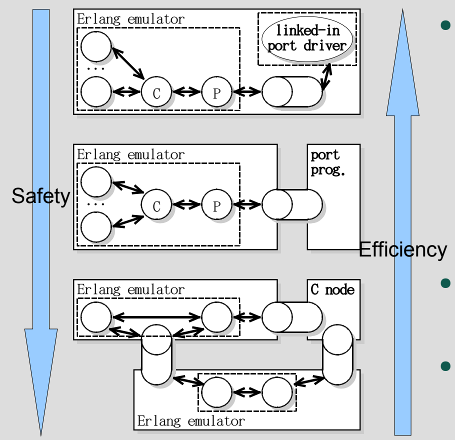
Transparency / 3 mechanisms (1/2)



- Strong similarities
  - Erlang terms must be encoded/decoded
  - Same level of abstraction
  - Similar openness / level of control
- But ≠ efficiency / safety trade-offs
- Transparency: hide differences in details

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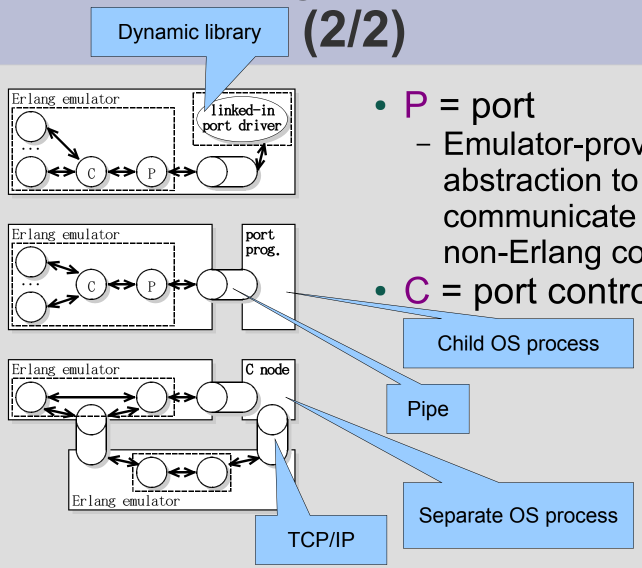
Transparency / 3 mechanisms (2/2)



- P = port
  - Emulator-provided abstraction to communicate with non-Erlang code
- C = port controller

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How is Dryverl open?

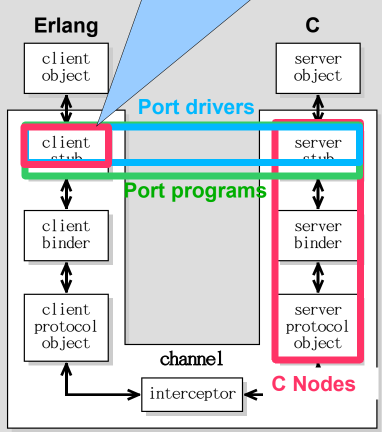
- How to achieve openness?
  - = expressiveness of the specification language
  - Mix of declarative and programmatic approach
    - Declarative where appropriate
      - Signatures of functions
    - Mostly fragments of Erlang and C code + macros
      - Encoding/decoding of terms
      - Dictionaries (“value maps” that map C data and integers)
      - More concise than using wrappers
  - Existing spec languages are declarative only
    - Simpler for simple cases
    - But more difficult for difficult cases
- Openness is limited by transparency
  - Dryverl opens only what can be opened using all three mechanisms

What can be open? (1/2)

- Erlang/C bindings are distributed bindings
  - Term must be encoded/decoded
  - ...
  - Similar to bindings in CORBA, Java RMI, etc.
- Model: ISO RM-ODP engineering viewpoint
  - General model of distributed bindings / channels

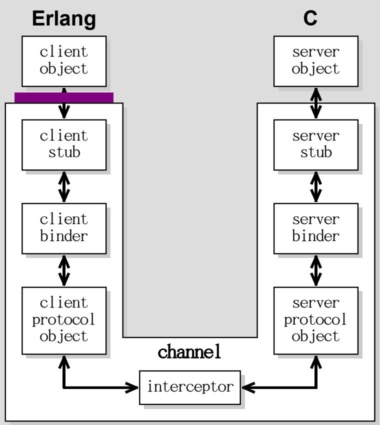
What can be open? (2/2)

“Artificial” client stub process will be added in the case of nodes, to get the same level of openness



- Erlang/C bindings are distributed bindings / channels
- Port drivers are the openness limiting factor
- Only stubs are open in all 3
- Open except for the term encoding / decoding part

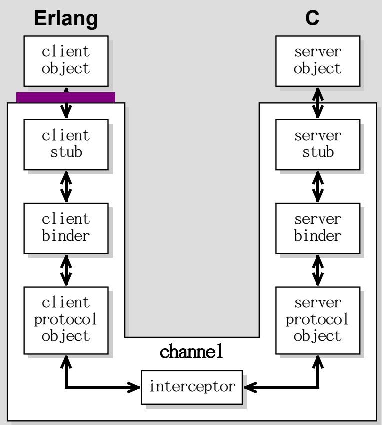
Binding specification: signature (1/2)



- Signature of the Erlang function
  - Arity
  - Two- or one-way
- Documentation
  - In OTP's edoc format
  - Type and name of arguments
  - Type of returned term

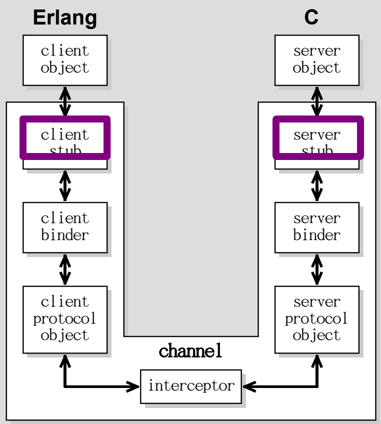
Binding specification: signature (2/2)

declarative specification




```
<def-erlang-input
  function-
  name=”print_hello”>
   <def-erlang-arg
  name=”Message” type-
  doc=”string()”/>
</def-erlang-input>
...
<def-erlang-output>
   <def-erlang-return
  type-
  doc=”{ok,int()}”/>
</def-erlang-output>
```

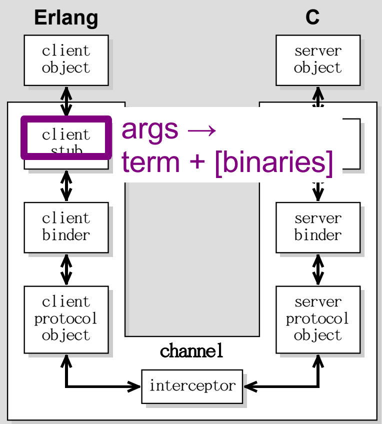
Binding specification: data transformation



- Four data transformation parts in Erlang and C stubs
  - Arguments into 1 term + [binaries]
    - E.g. atoms become integer constants
  - 1 term + [binaries] into C variables
  - And vice-versa

Binding specification: input data transformation (1/2)

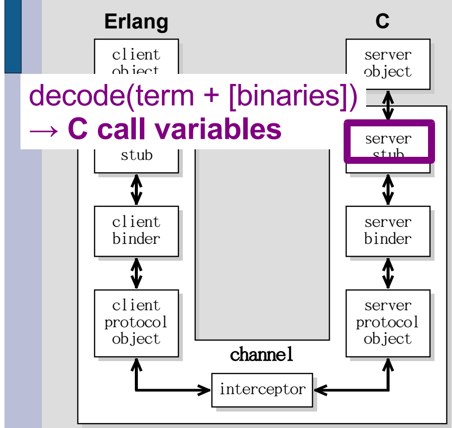
programmatic specification




```
<encode-input>
  <encode-input-main-
  term>
    string:strip(
      <erlang-arg
      name="Message"/>)
  </encode-input-main-
  term>
</encode-input>
```

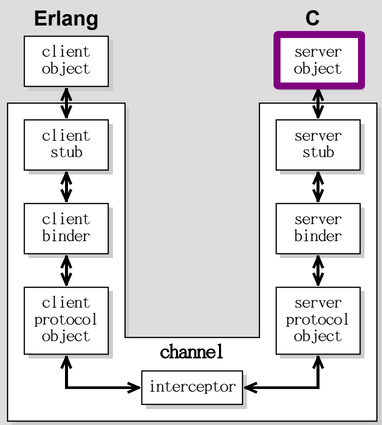

Binding specification: input data transformation (2/2)

programmatic specification




```
<decode-input>
  <assign-c-call-
  variables>
    /*...*/
    <decode-input-
    string-into>
      <c-call-variable
      name="msg"/>
    </decode-input-
    string-into>
  </assign-c-call-
  variables>
</decode-input>
```

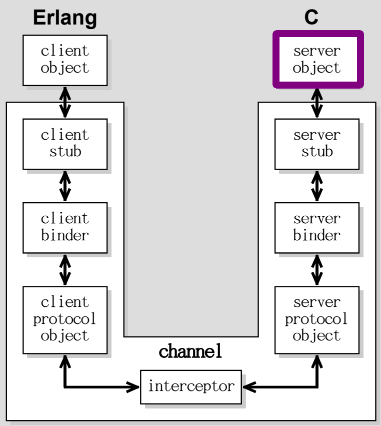

Binding specification: C implementation (1/2)



- Arbitrary C code
  - Typically, calls functions of a legacy C library
  - Processes values of the C call variables
  - Modifies the C call variables

Binding specification: C implementation (2/2)

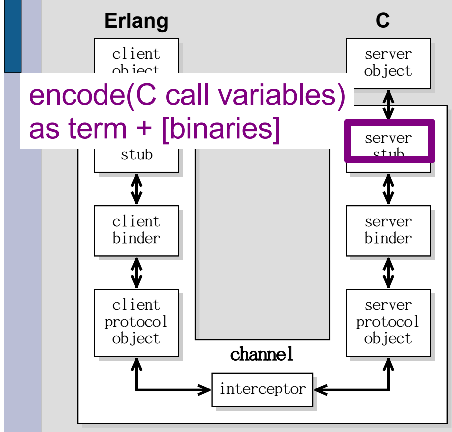
programmatic specification




```
<execute-body>
  <process-c-call-
  variables>
    int i;
    i = printf(“hello,
      %s\r\n”,
      <c-call-variable
      name=”msg”/>);
    <c-call-variable
    name=”prt”/> = i;
  </process-c-call-
  variables>
</execute-body>
```


Binding specification: output data transformation (1/2)

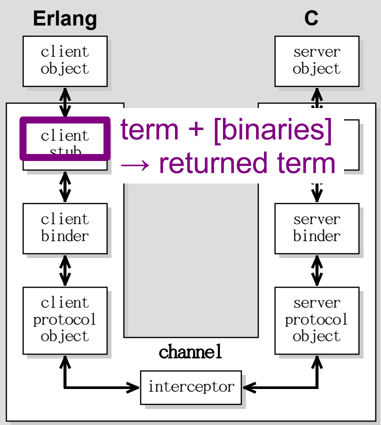
programmatic specification




```
<encode-output>
  <encode-output-...>
    <encode-output-
    ulong>
      <c-call-variable
      name="prt"/>
    </encode-output-
    ulong>
  </encode-output...>
</encode-output>
```


Binding specification: output data transformation (2/2)

programmatic specification




```
<decode-output>
  <create-output-
  term>
    Prt = <erl-output-
      main-term/>,
    {ok, Prt}
  </create-output-
  term>
</encode-input>
```


Dryverl's binding specification language

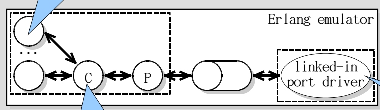
- The specification language allows specifying
  - The Erlang function signature
  - Data transformation Erlang and C code
    - Including code usually in wrappers
  - The executed C code
  - Full control is given on those parts
- The specification language is an XML dialect
  - Specified and documented in an XML Schema
- Dryverl is a set of XSLT 1.0 stylesheets

Bindings as port drivers (1/2)

- Only port drivers are currently supported as a target
- This was the top priority because:
  - Best performance
    - Only mechanism which allows passing binaries by reference
  - Least open: this was the limiting factor for the openness of Dryverl
  - Most difficult to deal with
    - Was designed for I/O drivers and fits well that purpose
    - But not adapted to integrate arbitrary C code

Bindings as port drivers (2/2)

hello.erl
Helper functions module: have the signatures specified in the bindings specs



hello_gen_server.erl
Port controller as a gen_server: implements the Erlang terms transformation code

hello_drv.c + hello_drv.h
Port driver (dynamic library): maps the Erlang terms to C variables, and implements the main C code

- Generated code
  - Helper functions
  - Port controller as gen_server
  - Port driver

Related works (1/2)

- Erlang/C binding generators
  - EDTK 1.1
    - The ancestor of Dryverl: many similarities
    - Dryverl is more open and powerful
    - Complete critical analysis on the Dryverl website
  - IG (Interface Generator)
    - Supports C-to-Erlang bindings
    - Little openness: no way to specify function signatures...
- Cross-language bindings for other languages
  - JNI, Python/C, GreenCard, etc.
  - Bindings between similar languages
  - Allow direct interactions without requiring encoding/decoding
  - Too different from the Erlang/C case

Related works (2/2)

- Open Distributed Processing frameworks
  - Standards: Java RMI, CORBA...
  - Open: xKernel, ObjectWeb Jonathan, FlexiNet...
  - Similarity
    - Stub compilers
    - Very similar architecture (cf. ISO RM-ODP)
  - Openness is much more limited in Erlang
    - No control of binders and protocol objects
    - Implemented in the “black-box” emulator
    - When control is offered (cf. inet_ssl...), impossible to control every binding separetely

Conclusion

- Dryverl generates the complete implementation of Erlang/C bindings
  - Openness: offers full control over transformation of data, and the signatures of Erlang functions
  - Can target transparently any mechanism
  - Efficiency: automatic choice of best alternatives to perform a binding call
  - Drawback: XML is verbose, but Dryverl is a backend for higher-level languages
- Perspectives
  - Support port programs and C nodes
  - C-to-Erlang bindings

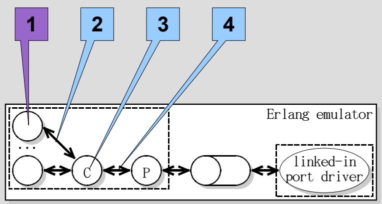
The Dryverl project

- Dryverl is Free Software (BSD license)
- It can be downloaded from:

http://dryverl.objectweb.org/

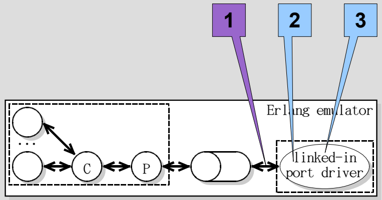
Bonus slides (^_^)

Bindings as port drivers



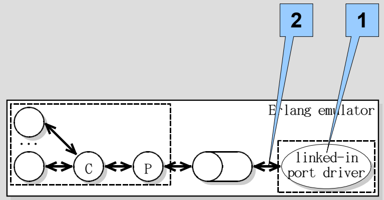
- Invocation (1/2)
  1. Helper function call
     - `print_hello()`
  2. gen_server "call"
     - Or "cast", if one-way binding
  3. Transforms args into 1 term + [binaries]
  4. Calls `port_call`
     - Or encodes term & calls `port_command` if [binaries] ≠ []

Bindings as port drivers



- Invocation (2/2)
  1. The emulator calls outputv() or call()
     - Whether we called port_command() or port_call()
  2. Decodes the Erlang term + [binaries] into C variables
  3. Main C code: processes and modifies those C variables

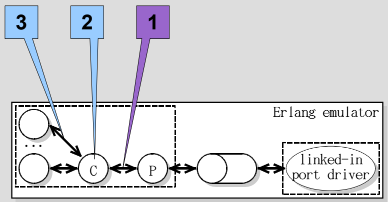
Bindings as port drivers



For two-way bindings only

- Termination (1/2)
  1. Encodes C variables into 1 Erlang term + [binaries]
  2. Calls `driver_output_term`
     - Or returns the term in the `port_call` call, if [binaries] = []
     - If [binaries] ≠ [] and `port_call` was called, returns `noreply`

Bindings as port drivers



For two-way bindings only

- Termination (2/2)
  1. Receives 1 term + [binaries] as a message
     1. Or the `port_call` call returns a term
  2. Transforms the term + [binaries] into one term to return
  3. Unblocks the gen_server "call"
     - `gen_server:reply()`

Bindings as port drivers

- Asynchronous operations
  - Multiple client calls can be executed simultaneously
  - gen_server "casts" for one-way bindings
- Problems with current implementation
  - Uses emulator's `driver_async` function to start a concurrent task for every call
  - Calls `driver_output_term` in tasks: not allowed, although worked in my small-scale tests
- Perspectives
  - Start multiple ports, and avoid `driver_async`
  - One gen_server will dispatch to port controllers
  - Transparent to clients