

HiPE High Performance Erlang

A brief overview of the compiler

Open Source Erlang (Erlang/OTP)

- Part of Ericsson's Open Telecom Platform (OTP).
- Implemented and commercially supported by Ericsson, but the source code is free and available on-line (www.erlang.org).
- Till recently (Oct. 2001), Erlang/OTP was exclusively a byte-code interpreted system based on a virtual machine:
 - JAM (stack-based) - not supported anymore;
 - BEAM (register-based) - current VM.

HiPE: High Performance Erlang Compiler

- HiPE is a native code compiler on top of BEAM, written in Erlang.
- HiPE is fully and tightly integrated within Open Source Erlang/OTP (starting with Release 8B)
- Is a complete implementation of Erlang
- Back-ends for:
 - SPARC V8+
 - x86-based machines running Linux or Solaris
 - AMD-64 (currently under development).

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HiPE Compiler: Design Goals

A "just-in-time" native code compiler for Erlang

- Allows *flexible, user-controlled* compilation of Erlang programs to native machine code
- *Fine-grained*: Compilation unit is a single function.

Desiderata:

- Reasonable compilation times
- Acceptable sizes of object code

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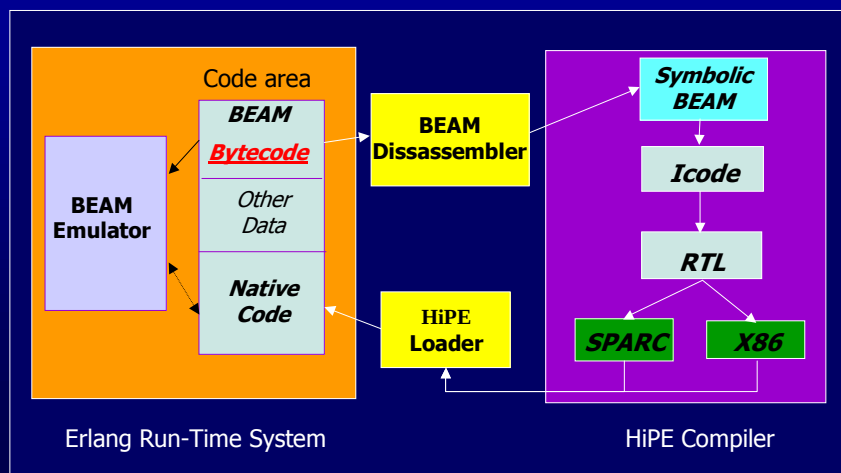
Alternatives to Emulation

- Compile to another "similar" language with a more mature implementation (e.g., Scheme).
- Compile to a sufficiently low-level and fast language such as C.
- Use C++ as a portable assembly language.
- Use a retargetable code generator as ML-RISC.
- Compile to the gcc back-end.
- Compile directly to native code.

One can roughly expect a decrease in portability and increase in performance and implementation effort for choices lower in the list.

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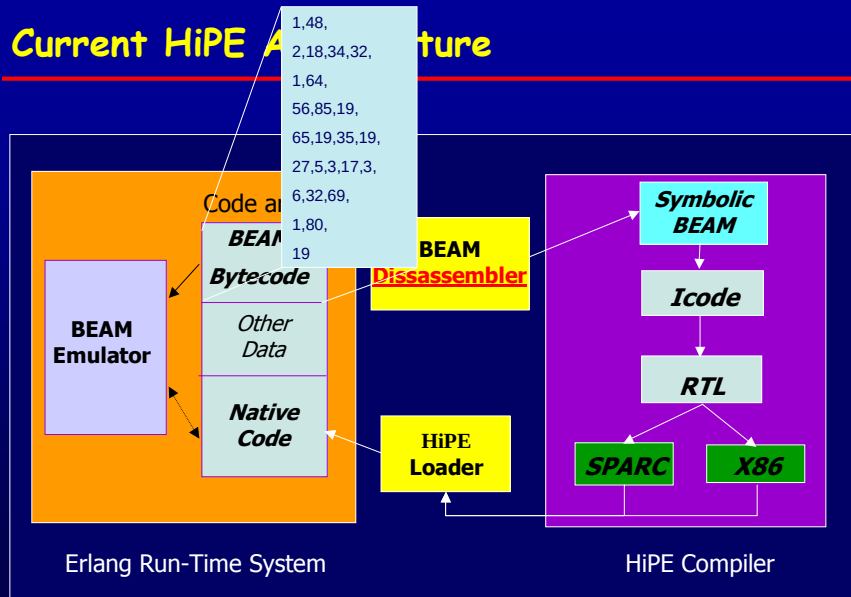
Current HiPE Architecture



A HiPE-enabled Erlang/OTP system

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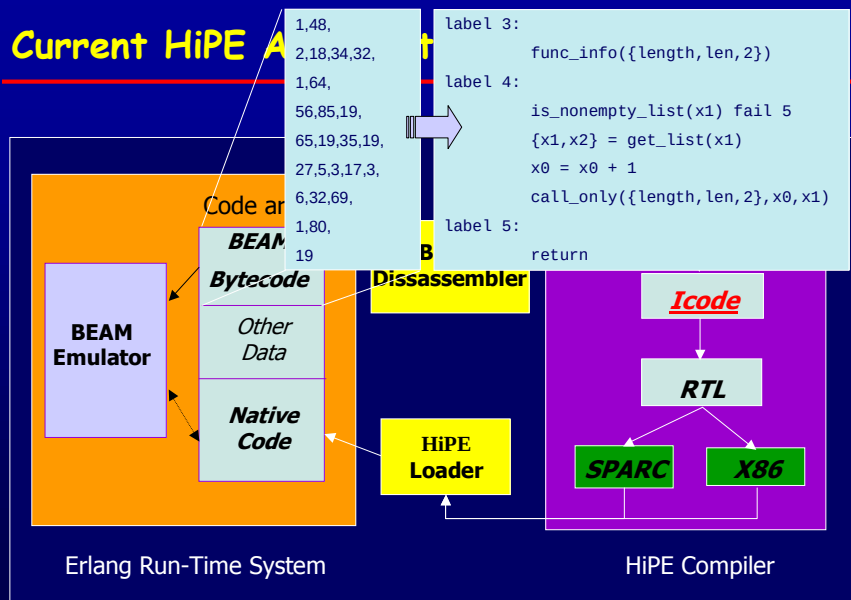
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Current HiPE Architecture



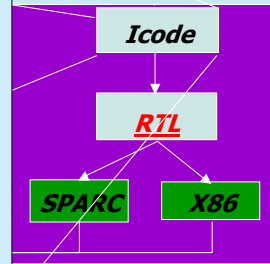
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Current HiPE Architecture

```
length:len(v0, v5) ->
%% Info:['Not a closure','Leaf function']
1:
    redtest() (primop)
    if is_cons(v5) then 3 (0.50) else 10
3:
    v5 := unsafe_tl(v5) (primop)
    v8 := 1
    v0 := '+'(v0, v8) (primop)
    goto 1
10:
    return(v0)
```

```
label 3:
    func_info({length, len, 2})
label 4:
    is_nonempty_list(x1) fail 5
    {x1,x2} = get_list(x1)
    x0 = x0 + 1
    call_only({length, len, 2}, x0, x1)
return
```



Erlang Run Time System

HiPE Compiler

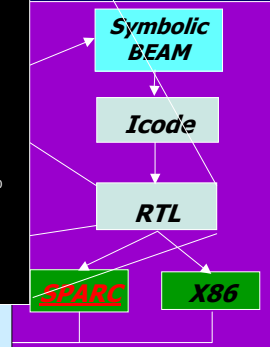
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Current

```
length:
%% Info
1:
    red
    if
3:
    v5
    v8
    v0
    got
10:
    return(v0)
```

```
{length, len, 2}(v40, v41) ->
.DataSegment
.DL0: [{length, len, 2}]
.CodeSegment
L2: v45 <- v41
    v46 <- v40
    goto L3
L3: %i5 <- %i5 sub 1 if lt then L5 (0.01) else L6
L5: <- suspend_0() [c] then L6
L6: r47 <- v45 'and' 2 if eq then L7 (0.50) else L8
L7: v48 <- [v45+3]
    v49 <- 31
    r51 <- v46 'and' 31
    r52 <- r51 'and' 15
    if (r52 eq 15) then L12 (0.99) else L11
L12:v50 <- v46 add 16 if overflow then L11 (0.01) else L10
L11:v50 <- '+'(v46, v49) [c] then L10
L10:v45 <- v48
    v46 <- v50
    goto L3
L8: return(v46)
```



Erlang Run Time System

HiPE Compiler

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```

section ".text"
.align 4
.global length_len_2
.section ".data"
length_len_2_d1_0: .word 0 ! .term [{length,len,2}]
.section ".code"
length_len_2:
length_len_2_22:
    add %i3, 16, %i3
    stw %o7, [%i3+-16]
    mov %o2, %g3
    mov %o1, %i5
length_len_2_3:
    subcc %i5, 1, %i5
    bge %icc, .length_len_2_6
    nop
length_len_2_5:
    stw %g3, [%i3+-4]
    call suspend_0 ! () <=>[c]<[4] Live: [0,1]>
    stw %i5, [%i3+-8]
    ldw [%i3+-4], %g3
    ldw [%i3+-8], %i5
length_len_2_6:
    andcc %g3, 2, %g4
    be,pn %icc, .length_len_2_7
    nop

```

```

length_len_2_8:
    mov %i5, %o0
    ldw [%i3+-16], %o7
    jmpl %o7+8, %g0 ! (%o0)
    sub %i3, 16, %i3
length_len_2_7:
    and %i5, 31, %o4
    and %o4, 15, %o5
    subcc %o5, 15, %g0
    be %icc, .length_len_2_12
    ldw [%g3+3], %g5
length_len_2_11:
    mov %i5, %o1
    mov 31, %o2
    call '+' ! (%o1, %o2) <=>[c]<[4] Live: [2]>
    stw %g5, [%i3+-12]
    ldw [%i3+-12], %g5
length_len_2_19:
    mov %o0, %i0
length_len_2_10:
    mov %g5, %g3
    ba .length_len_2_3
    mov %i0, %i5
length_len_2_12:
    addcc %i5, 16, %i0
    bvc %icc, .length_len_2_10
    nop
    ba .length_len_2_11
    nop

```

Erlang Run-Time System

HiPE Compiler

A HiPE-enabled Erlang/OTP system

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Intermediate Representations

Icode

- Idealized Erlang assembly language;
- Stack is implicit; unlimited number of temporaries which survive function calls;
- Most of memory management is now explicit
- Process scheduling is implicit.

RTL (Register Transfer Language)

- Generic 3-address target-independent language;
- Tagging is made explicit: RTL has both tagged and untagged registers;
- Data accesses and initializations are turned into loads and stores.

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HiPE: Technical Details

- HiPE exists as a new component (currently about 90,000 lines of Erlang code and 15,000 lines of C and assembly code) added to an otherwise mostly unchanged Open-Source Erlang/OTP system.
- HiPE provides its user with a set of profiling tools to identify the hot-code parts of the applications.

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HiPE: Runtime System Issues

- Both virtual machine code and native code can happily co-exist in the runtime system
 - To simplify the garbage collector, we use separate stacks for native and interpreted execution
- HiPE optimizes calls to functions which execute in the same mode (no overhead)
- Preserves tail-calls (required feature of Erlang)

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The HiPE Linker

- When a function **f** is compiled to native code
 - The bytecode for **f** is patched so that future calls to **f** are redirected to its native code
 - If **f** contains calls to a function **g** that is not (yet) compiled to native code, a native code-stub for the callee (**g**) is created to redirect the call to the emulator.
- When a module is reloaded or recompiled, all calls from native code to that module are patched to call the new module
(in accordance to the hot-code loading semantics)

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Optimizations performed by the HiPE Compiler

- Copy & sparse conditional constant propagation, constant folding (partly make up for the absence of types).
- Dead & unreachable code removal.
- Merging of heap-overflow checks through backward propagation.

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HiPE Compiler: SPARC back-end

- Parameter-passing in registers (up to 16)
- Register allocation based on choice between a Briggs-style graph coloring, iterated coalescing, or a linear scan algorithm [PADL'02].
- Cache-conscious code linearization.
- Garbage collection:
 - Based on *two-generational copying*
 - Aided by *stack descriptors* (live-variable maps)
 - Performs *generational stack collection*.

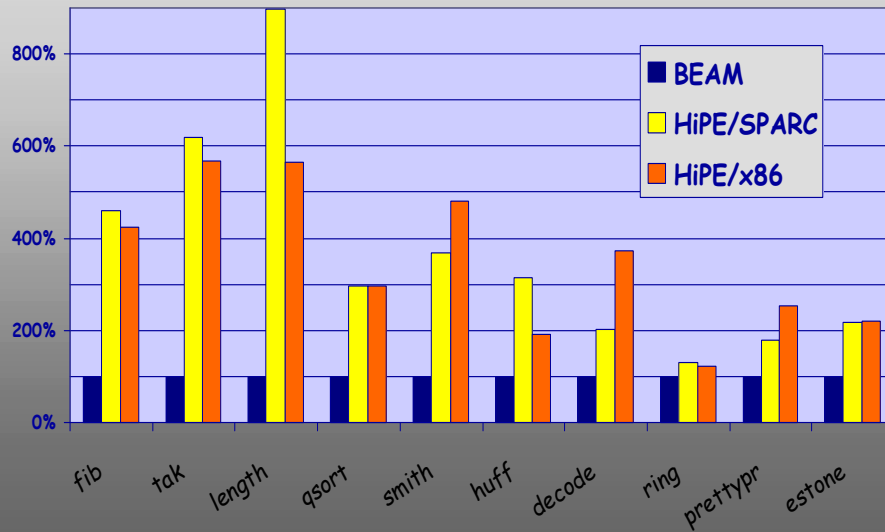
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HiPE Compiler: x86 back-end

- Use the native stack of the machine
 - Use `%esp` as the current process' stack pointer
- Pay attention to register usage
 - Preferred register allocator:
graph coloring with iterated coalescing
- Stack-frame minimization
 - Spill-slot coalescing
- Pay attention to branch prediction
 - Use `call` and `ret` instructions consistently.

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Performance of HiPE on SPARC & x86 (Feb 2002)



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Space Performance (very rough)

HiPE generates native code that is roughly about 2.5 to 3 times bigger than BEAM bytecode

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