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Hitchhiker's Tour of the BEAM

What IS the BEAM?

- A virtual machine to run Erlang
- Interfaces to the "outside" world
  - Ports and NIFs
- A bunch of built-in "useful" functions
  - BIFs

Properties of the Erlang system

- Lightweight, massive concurrency
- Asynchronous comunication
- Process isolation
- Error handling
- Continuous evolution of the system
- Soft real-time

Properties of the Erlang language

- Immutable data
- Pattern matching
- Functional language

So to run Erlang the BEAM needs to support all this.

AT LEAST

We will look at

- Schedulers
- Processes
- Memory management
- Message passing
- Multi-core
- ...

Schedulers

- Semi-autonomous BEAM VM
- One per VM thread
  - By default one VM thread per core
- Run as separately as possible
  - Reduce nasties like locks/synchronisation
- Contains its own run-queue
  - Run-queue contains things to be done
- Settable with erl "+S" emulator flags

Schedulers: balancing

- Once every period (40k reductions) a new master scheduler is chosen
  - Basically first to reach that count
- Master balances/optimises workloads on schedulers
- Suspends unneeded schedulers
- Schedules changes on other schedulers run-queues
- Behaviour settable with erl "+s" emulator flags

Schedulers: scheduling processes

- A process can be state
  - running
  - runnable
  - waiting (for a message)
  - exiting
  - garbage_collecting
  - suspended

Schedulers: scheduling processes

- Each scheduler has its own run-queue
- Waiting for messages is a **non-busy wait**
- Waiting processes become runnable when a message arrives
  - Put on the run-queue
- Running processes do not block a scheduler
  - Suspended waiting for a message
  - Re-scheduled after 2000 reductions

Memory

Many separate memory areas/types

- Process heaps
- ETS tables
- Atom table
- Large binary space
- Code space
- Timers
- ...

Memory: Atom table

- All atoms are interned in a global atom table
  - FAST equality comparison
    - NEVER need to use integers as tags for speed
- Atoms are NEVER deleted
  - Create with caution
  - Avoid programs which rampantly creates atoms in an uncontrolled fashion
- Fixed size table
  - System crashes when full

Memory: large binary space

- Large binaries (> 64 bytes) stored in separate area
- Fast message passing as only pointer sent
  - Can save a lot of memory as well
- Can be long delay before being reclaimed by GC
  - All processes which have “seen” the binary must first do a GC
  - Can grow and crash system

Memory: ETS tables

- Separate from process heaps
- Not implicitly garbage collected
- But memory reclaimed when table/element deleted
- All access by elements being copied to/from process heaps
  - `match/select` allows more complex selection without copying
- Can store LARGE amounts of data

Memory: Process heaps

- Each process has a separate heap
- All process data local to process
- Can set minimum process heap size
  - Per process and for whole system

- Sending messages means copying data

- This NOT required by Erlang which just specifies process isolation

Isn't all this data copying terribly inefficient?

Well, yes. Sort of. Maybe.

BUT ...

Process heaps: Garbage collection

Having separate process heaps has some important benefits

- Allows us to collect each process separately
  - Processes small so GC pauses not noticeable
- Garbage collection becomes more efficient
- Garbage collector becomes simpler
- Needs no synchronisation
  - This is a BIG WIN™
  - And it gets bigger the more cores you have!

Process heaps: Garbage collection

- Copying collector
- Generational collector
  - 2 spaces, new and old
  - New data is kept in new space for a number of collections before being passed to the old heap
  - Not much data unnecessarily ends up in old heap
  - Eventually old heap must be collected as well

Process heaps: Tuning

- Minimum process heap size (`min_heap_size`)
  - Process starts bigger, never gets smaller
  - Be selective or pay the price in memory
- Full sweep in garbage collector (`fullsweep_after`)
  - Black magic, just test and see
  - Forces collections more often, reclaim memory faster
    - Uses less memory, reclaims large binaries faster
    - Less efficient collection

Async thread pool

- File i/o can be problematic
  - It takes time
  - It blocks the scheduler while waiting
- Async threads moves i/o operations out of the scheduler thread
  - Scheduler thread now no longer waits for file i/o
- From R16 there are 10 threads by default
- Settable with the erl "+A" emulator flags

Async thread pool

- File i/o will automatically use them if created
- Inet driver never uses them
  - Not really necessary as it is possible to do cross-platform non-blocking i/o.
- Linked-in port drivers can use them if they exist

How to crash the BEAM

- Fill the atom table
- Overflow binary space
- Uncontrolled process heap growth
  - Infinite recursion
  - VERY long message queues
  - A lot of data
- Errors in NIFs and linked-in port drivers!
  - These can **really** get you

Thank you!

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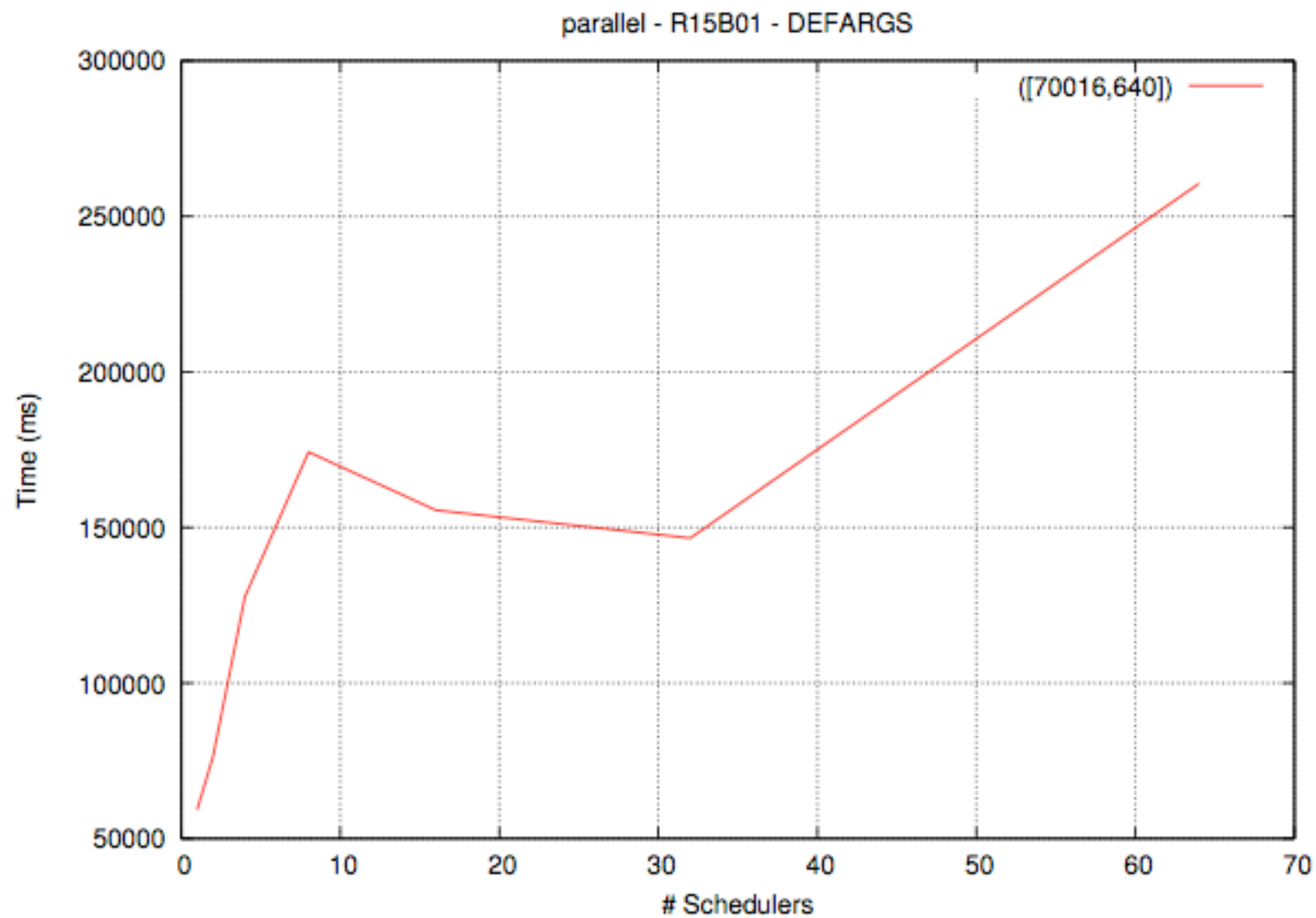
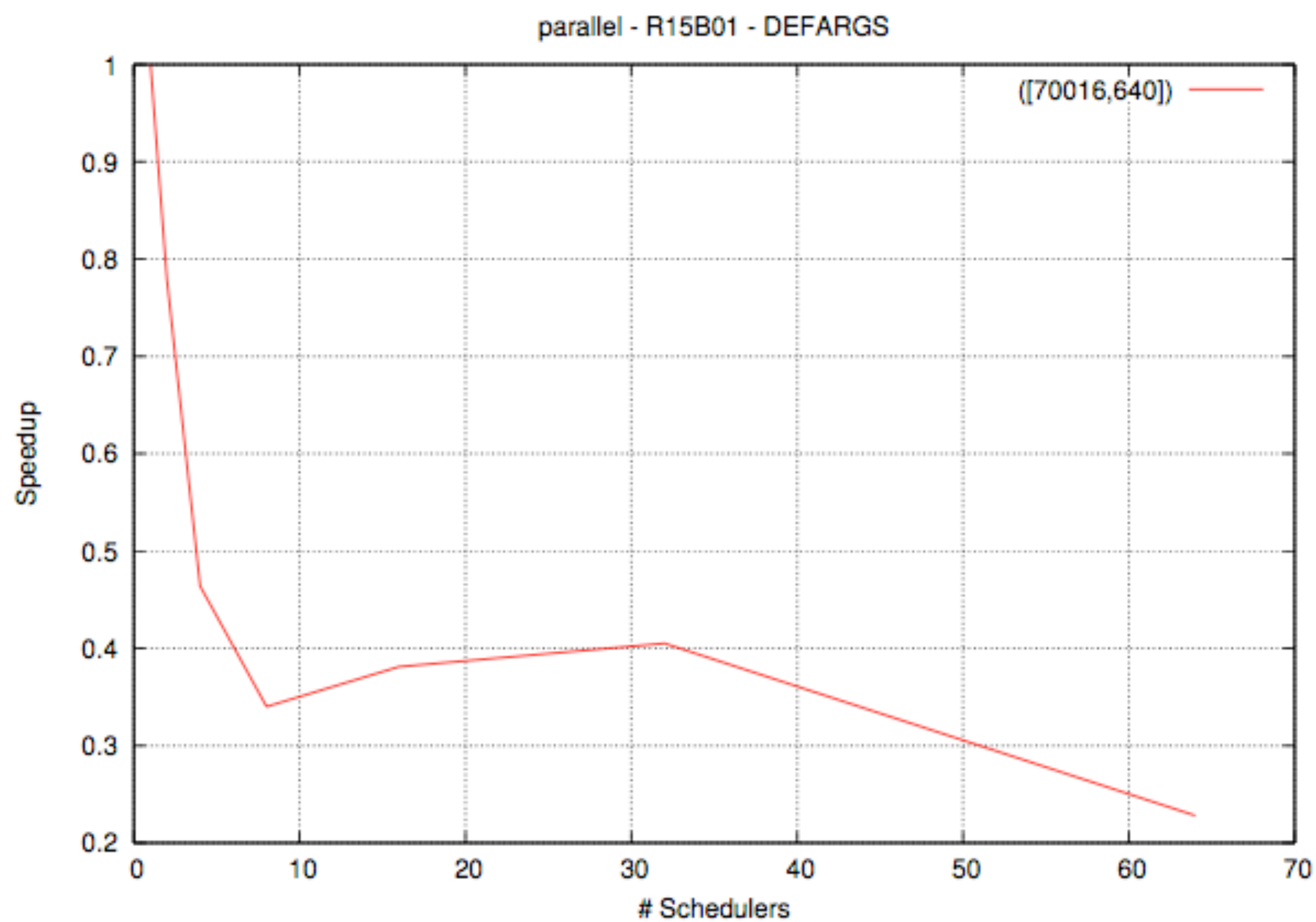
Lock example



Lock example



Lock example

- Spawns processes which creates timestamps checks if there in order and sends the result to its parent

- Uses `erlang:now/0`
  - `Guaranteed continuously increasing values`
  - `Which needs synchronisation`