Running Valgrind on multiple processors: a prototype

Philippe Waroquiers
FOSDEM 2015 valgrind devroom

Valgrind and threads

- Valgrind runs properly multi-threaded applications
- But (mostly) runs them using a single CORE
- Valgrind needs a lot of CPU :
  - Depending on the tool,
    single-threaded applications
    are slowed down
    by a factor 4x to 100x or more

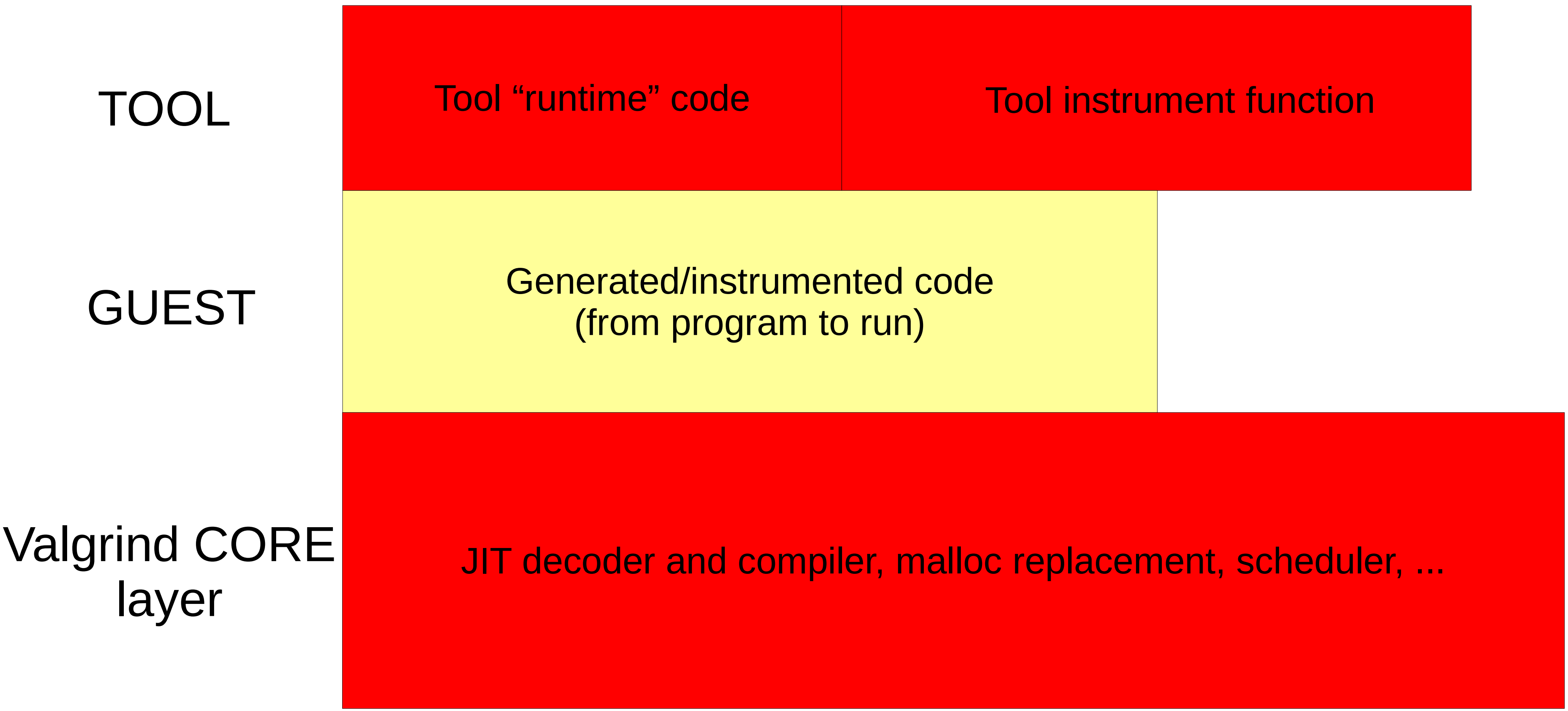
Valgrind and CPU consumption

- Significant development effort was and is spent to make Valgrind faster e.g.
  - Improvement of the JIT generated code
  - Self-modifying code detection
  - Translation chaining
  - Tool specific performance improvement
  - …

Improving Valgrind speed

- Improving 'sequential' speed is good for all applications
  - However, often, the last years, the gains are small typically around 5 .. 10%
- Multi-threaded CPU bounded applications would benefit a lot from parallelising Valgrind
  - But how hard is that ?

Valgrind layers



Valgrind layers typical control flow

1. CORE decodes guest code : instructions to IR
2. CORE calls TOOL instrument : IR to IR. Instrumented code typically contains many calls to TOOL runtime code or CORE code.
3. CORE translates instrumented code to executable code : IR to instructions
4. Instructions stored in the translation table
5. Valgrind scheduler calls the translation

(Most of) Valgrind code is non-reentrant/non thread-safe

- Translation is non thread-safe: VEX lib, tool instrument function, CORE translation framework, ...
- “Run time” is non thread-safe:
  - CORE scheduler, CORE malloc/free, CORE aspacemgr, CORE statistics, …
  - TOOL runtime code, e.g. memcheck malloc/free, memcheck VA bits data structures, …
- So, why is Valgrind able to run properly multi-threaded applications ?

Valgrind “big lock” model

- Valgrind has a big lock
  - The big lock protects all Valgrind data structures/all Valgrind global variables/all tool data structures/...
  - Big lock implemented via a 'pipe based lock' (default) or via futex ('ticket lock'), cfr **--fair-sched**
- To execute JIT-ted guest or tool or core code, a thread first must acquire the big lock
- A thread releases the lock
  - After it has executed 100K basic blocks

or

  - Before entering in a blocking syscall

To parallelise Valgrind

- We must
  - Remove the big lock

  or
  - At least decrease the use of the big lock

Parallelising Valgrind possible techniques

- Read/write locks
- (fine grained) mutex locks
- Atomic instructions
- Thread local storage instead of global variables
- Lock-less algorithms/data structures
- ….

- A prototype has used some of the above to parallelise some (small) parts of Valgrind

What to parallelise (first) ?

- A typical tool/application spends most of CPU in the generated JIT code, in the TOOL and CORE “runtime” code
- The time spent in TOOL instrument function is normally not a major part
- => First idea: ensure that the threads are running guest JIT-ted code in parallel

Running JIT-ted code in parallel Basic idea

- Replace 'mutex Big lock' by 'read/write Big lock'
- A thread acquires the RW Big lock
  - In read mode to run guest JIT-ted code
  - In write mode to do anything else
- First implementation of basic idea:
  - Objective: ensure 'none' tool runs in parallel
  - How : RW lock implemented on top of 'pipe based locks'

Running JIT-ted code in parallel First implementation expected results

- Of **course**, first implementation will be efficient
  - As the pipe based lock is efficient enough for current Valgrind, the rw lock will be efficient enough for parallel use
- Of **course**, first implementation will be correct
  - As “none” tool means no Valgrind data structure are accessed when running JIT-ted guest code
- Of **course**, all above
  - was shown <u>**WRONG**</u> !!!

Running JIT-ted code in parallel First implementation problems

- Lack of efficiency when translating new code:
  - When new code to be translated, sequential valgrind just keeps the lock
  - Parallel Valgrind needs to (re-)acquire the lock in Write mode => a lot more (expensive) 'lock/unlock'
- Lack of correctness
  - What looks like a 'read-only' action (execute already translated code) is in fact doing many updates e.g.
    - statistical counters
    - fast cache associating guest code with JIT code
    - Translation chaining
    - ...

Running JIT-ted code in parallel
Fixing first implementation

- Better way to find non thread safe code
  - Valgrind and helgrind were improved to allow to run an 'inner parallel valgrind' under an outer helgrind
  - Improvements are now in Valgrind release :
    it is now easy/ier to run Valgrind under Valgrind
  - Helgrind was used to find race conditions in prototype parallel Valgrind
- Efficiency :
  - RW lock based on (slow) pipe based mutexes replaced by RW lock code copied/modified from glibc

Read the patch...

Prototype code accessible in SVN MTV branch
see also doc/internals/mtV.txt

Multi-threaded Valgrind : challenges Valgrind core

- Make (more of) core parallel/thread-safe
  - Prototype is far to be complete/correct
- Probably/maybe we need an option
  to have sequential run of parallel tools
  (e.g. to avoid memcheck false + or -)
  or avoid running non parallel tools in parallel
- Implement atomic ops for other arch
- What about Darwin and fast mutex ?

Multi-threaded Valgrind : challenges Making Valgrind tools parallel

- At least memcheck (the most used tool)
- Keep cpu and/or memory efficiency is difficult (apart of trivial tools such as **--tool=none**)
- No tool was made parallel (except **none**)
  - Parallel memcheck somewhat discussed/tried
  - Draft proposal of new VA-bits approach made by Julian Seward

Multi-threaded Valgrind : challenges Memcheck VA-bits data structure

- Is currently highly optimised, CPU and memory
- No solution found that at the same time
  - Is efficient in CPU and memory
  - and has no false + and/or false -
- Maybe make 'VA-bits read' inline fast, 'VA-bits write' use mutex ? (or an option to activate write mutex)
- Maybe we need tuning options such as
  --va-bits=sequential | parallel-cpu
  | parallel-memory | …

Multi-threaded Valgrind : challenges

- Probably many challenges not known yet …
  - Because not exercised by the prototype 'testing'
  - Many core modules not looked at
    e.g. Valgrind malloc, error mgr, stack unwind, ...
- Do all the above without slowing down the sequential case
  - Many optimisations to be redone/reworked !

Questions?