TOTAL SYSTEM AWARENESS IN TCG

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KVM FORUM 2019

INTRODUCTION

WHO/WHERE

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ARM, TCG, Testing, KVM

WHAT

> QEMU TCG plugins provide a way for users to run experiments taking advantage of the total system control emulation can have over a guest.

HISTORY OF PLUGINS

EARLY INTENTIONS

> “ *There will be no plugin system in the near future. Such systems are mainly useful for closed source project, which QEMU is not. Moreover, as in ffmpeg, I don't want to bother about binary compatibility and API stability at this stage of the project.*

Fabrice Bellard, qemu-devel, 2004

WIN4LIN

> *..what we do is enable loading a dynamic shared object as a 'plugin'… We do not use any additional header files or anything like that in our closed source bits, since that would of course violate the GPL…. so that we could 'replace' the initialization of certain built-in peripherals in QEMU with our own proprietary versions that live in the plugin.*

Sponsorship for QEMU developers, qemu-devel, 2005

PCI PLUGINS

> “ *files will be dlopened by qemu at run time, and will register themselves as hardware to the appropriate hardware controller (ie a PCI device hardware plugin registers itself with the PCI bus).*

Interest in hardware plugin functionality, qemu-devel, 2005

PYQEMU

> “ *project to create new ARM machine emulations using the Python programming language.*

{ANN} PyQemu 1.0 (and machine plugin patches), qemu-devel, 2007

PYQEMU

> *project to create new ARM machine emulations using the Python programming language.*

> *Sorry to ruin your GSoC project, but the plugin system was discussed last year, please see..*

{ANN} PyQemu 1.0 (and machine plugin patches), qemu-devel, 2007

LESSONS FROM HISTORY

- Wary of license evasion
- Worries about API Stability
- Solved!

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(at least for upstream)

OUT OF TREE

Banyan Tree, Queensland, Jason Bennée 2003

3 USERS

> “
>
> *The problem is there currently are at least 3 users of Qemu:*
>
> *1. People who want fast simulation*
>
> *2. People who are doing virtualization*
>
> *3. People trying to do instrumentation/research*
>
> *…three groups have conflicting interests…adding instrumentation infrastructure will either slow down the common case, or … introduce lots of #ifdefs*

Instruction counting instrumentation for ARM + patch, qemu-devel, 2009

NEVER UP-STREAMED

- TEMU (~ QEMU 0.9.1)
- DECAF (~ QEMU 1.0)
- PEMU (~ QEMU 1.5)
- QTRACE (~ QEMU 1.7.1)

1ST QEMU USERS FORUM

- Cycle Accurate Simulation
- Program Instrumentation
- Cache/Pipeline Modelling

Trip Report, 1st QEMU Users Forum, qemu-devel, 2011

ATOS-TOOLS QEMU-PLUGINS

- Actively developed
- Can simulate HW in userspace
- Can wrap DineroIV
- Generates TCG ops in plugins

stable-3.1 @ github.com/atos-tool/qemu

CONCLUSIONS

- Plenty of demand
- Write-once forks
- Never to be up-streamed

THE PATH TO UPSTREAM

The Bolton Strid, Yorkshire, Alex Bennée, 2018

TCG TRACING -> INSTRUMENTATION

- trace_<eventname>_tcg
- Common Translator Loop
- Final instrumentation series never merged

USING LOGGING

```
qemu-aarch64 -d cpu,nochain -D sha1.trace \
  ./tests/tcg/aarch64-linux-user/sha1
```

```
 PC=00000000004002b4 X00=0000000000000000 X01=0000000000000000
X02=0000000000000000 X03=0000000000000000 X04=0000000000000000
X05=0000000000000000 X06=0000000000000000 X07=0000000000000000
X08=0000000000000000 X09=0000000000000000 X10=0000000000000000
X11=0000000000000000 X12=0000000000000000 X13=0000000000000000
X14=0000000000000000 X15=0000000000000000 X16=0000000000000000
X17=0000000000000000 X18=0000000000000000 X19=0000000000000000
X20=0000000000000000 X21=0000000000000000 X22=0000000000000000
X23=0000000000000000 X24=0000000000000000 X25=0000000000000000
X26=0000000000000000 X27=0000000000000000 X28=0000000000000000
```

ABUSE TRACE POINTS

> *Trace points already exist as a series of interesting places in QEMU exposing information that can be used for analysis. By re-using them we avoid potential duplication of concerns. Adding new hook points becomes a simple case of adding a new trace point.*

Trace updates and plugin RFC, qemu-devel, 2018

PROBLEMS

- Very wide API
- Helper per-operation

PAVEL'S SERIES

- Iteration of ISP RAS plugins tree
- *_needs filter
- directly calls helpers

Instrumentation, Introspection and Debugging with QEMU, KVM Forum 2017

RFC v2 QEMU binary Instrumentation Prototype, qemu-devel, 2018

EMILIO'S SERIES

- Direct helpers & inline ops
- Instruction granularity
- Required 2 pass translation
- Time control/lockstep vCPUS
- Guest hooks

RFC Plugin Support, qemu-devel, 2018

WHAT HAVE WE LEARNT

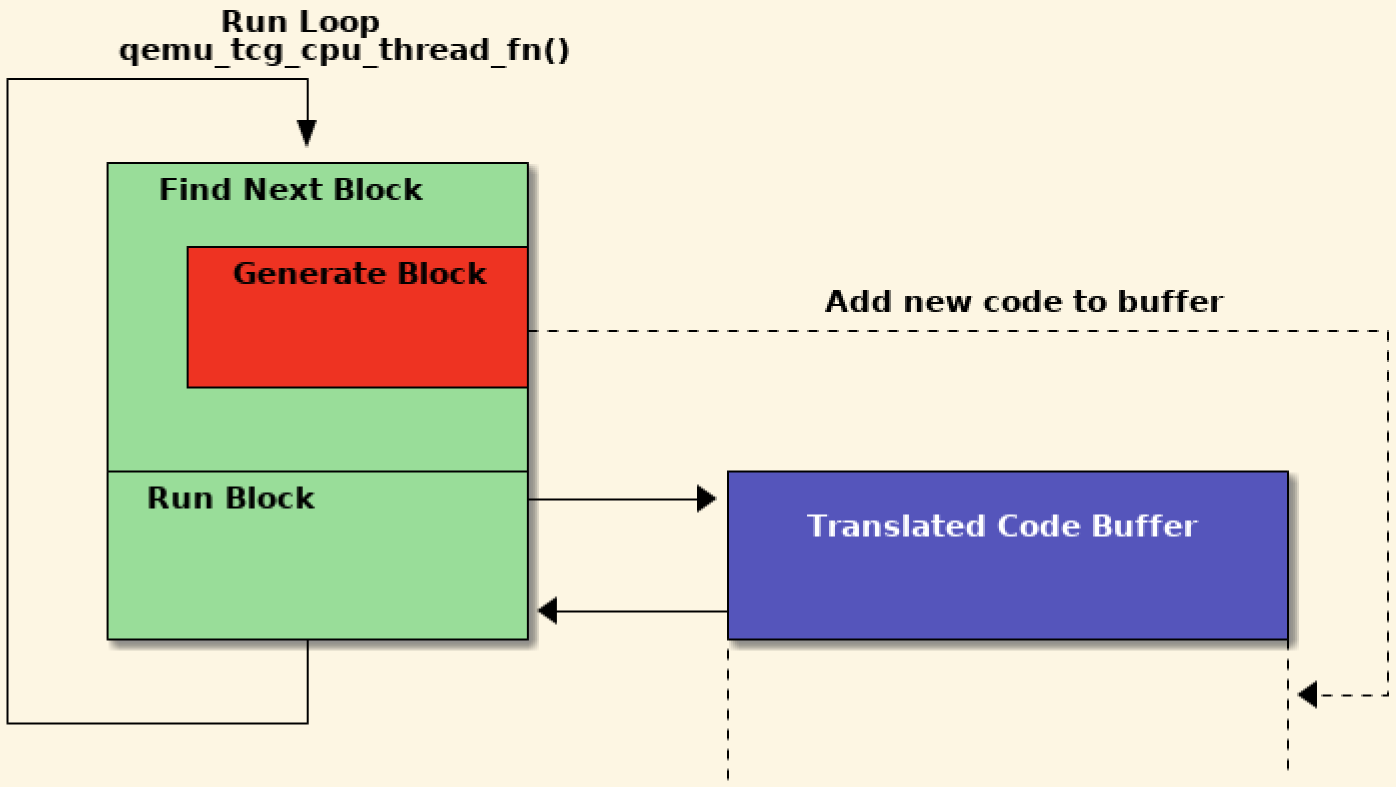
- APIs are hard
- Don't leak internals

TCG PLUGINS

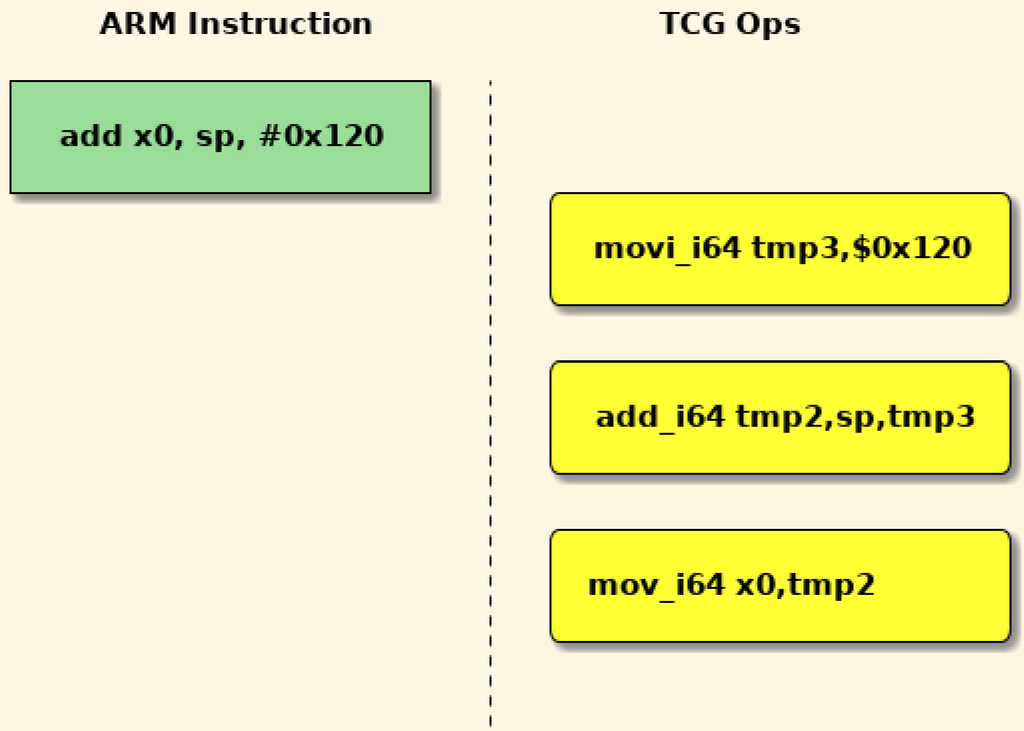
DESIGN PRINCIPLES

- Low impact
- Simple non-leaky API
- No state modification
- Minimal viable plugin

VCPU RUN LOOP (TCG)



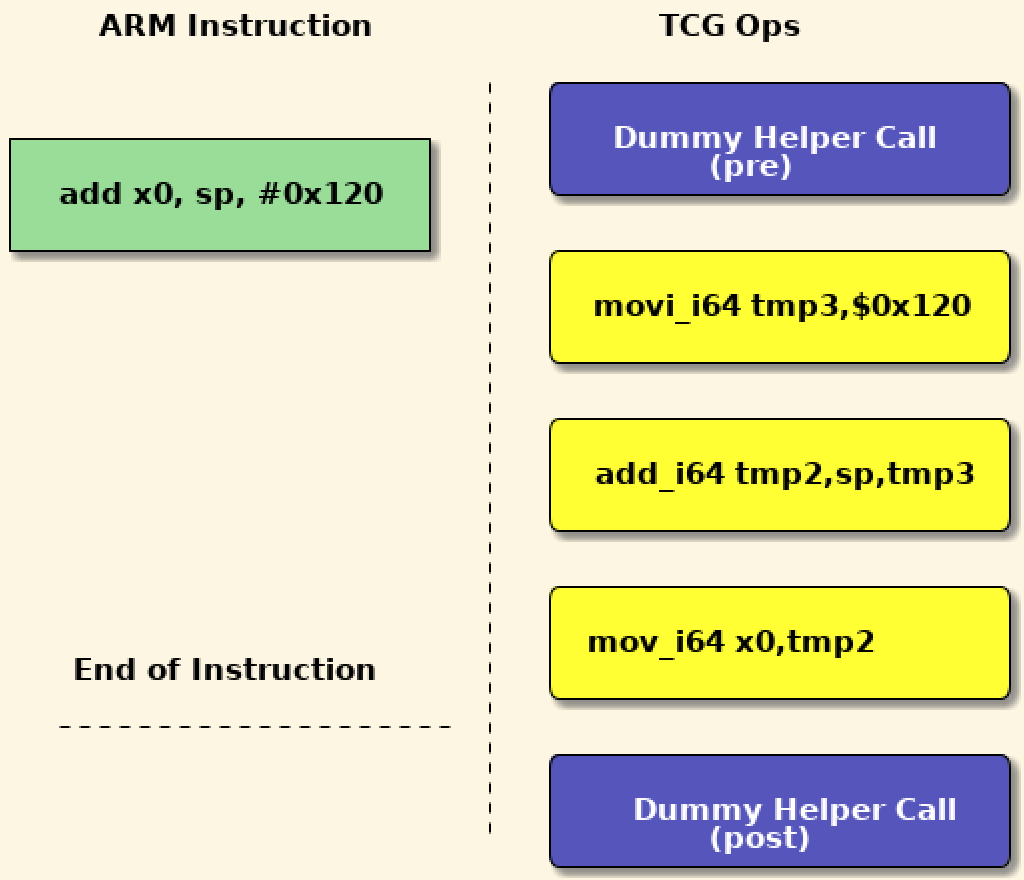
TCG OPS



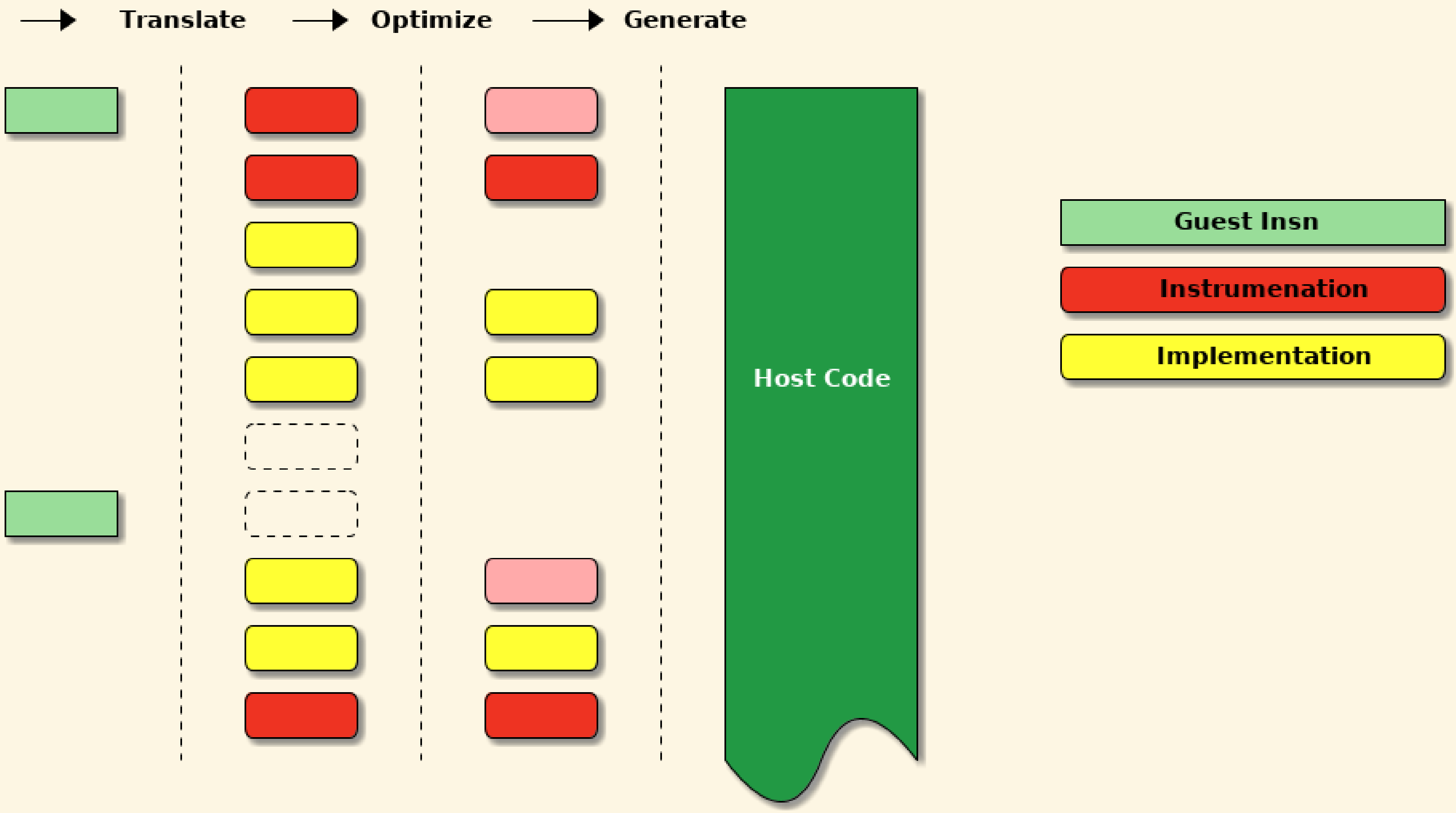
```
add x0, sp, #0x120
```

```
movi_i64 tmp3,$0x120
add_i64 tmp2,sp,tmp3
mov_i64 x0,tmp2
```

INSERTING DUMMY OPS



FINAL SETUP


Translate
Optimize
Generate
Host Code
Guest Insn
Instrumenation
Implementation

TCG PLUGIN API

RULES

- Threading aware
- Opaque Handles
  - valid during callback only
- Do own housekeeping

SETUP

```c
int qemu_plugin_install(qemu_plugin_id_t id, const qemu_info_t *info,
                        int argc, char **argv)
{
    if (argc) {
        /* process args */
    }

    /* setup plugin bits... */

    /* register initial callbacks */
    qemu_plugin_register_vcpu_tb_trans_cb(id, vcpu_tb_trans);
    qemu_plugin_register_atexit_cb(id, plugin_exit, NULL);
    return 0;
}
```

BLOCK LEVEL ACTIONS

```
static void vcpu_tb_trans(qemu_plugin_id_t id, struct qemu_plugin_tb *tb)
{
    /*  query details */
    uint64_t pc = qemu_plugin_tb_vaddr(tb);
    unsigned long insns = qemu_plugin_tb_n_insns(tb);

    /* register execution callback */
    if (do_inline) {
        qemu_plugin_register_vcpu_tb_exec_inline(tb, QEMU_PLUGIN_INLINE_ADD
                                                 &count, insns);
    } else {
        qemu_plugin_register_vcpu_tb_exec_cb(tb, vcpu_tb_exec,
                                             QEMU_PLUGIN_CB_NO_REGS,
                                             (void *)insns);
    }
}
```

BLOCK HELPERS

qemu_plugin_tb_vaddr

qemu_plugin_tb_n_insns

INSTRUCTIONS LEVEL ACTIONS

```
static void vcpu_tb_trans(qemu_plugin_id_t id, struct qemu_plugin_tb *tb)
{
    size_t i, n = qemu_plugin_tb_n_insns(tb);
    for (i = 0; i < n; i++) {
        struct qemu_plugin_insn *insn = qemu_plugin_tb_get_insn(tb, i);

        if (do_inline) {
            qemu_plugin_register_vcpu_insn_exec_inline(
                insn, QEMU_PLUGIN_INLINE_ADD_U64, &insn_count, 1);
        } else {
            qemu_plugin_register_vcpu_insn_exec_cb(
                insn, vcpu_insn_exec_before, QEMU_PLUGIN_CB_NO_REGS, NULL);
        }
    }
}
```

INSTRUCTION HELPERS

qemu_plugin_insn_data	readable buffer
qemu_plugin_insn_size	size
qemu_plugin_insn_vaddr	virtual address
qemu_plugin_insn_haddr	hardware address
qemu_plugin_insn_disas	allocated string

INSTRUMENTING MEMORY ACCESSES

```
static void vcpu_tb_trans(qemu_plugin_id_t id, struct qemu_plugin_tb *tb)
{
    size_t i, n = qemu_plugin_tb_n_insns(tb);
    for (i = 0; i < n; i++) {
        struct qemu_plugin_insn *insn = qemu_plugin_tb_get_insn(tb, i);
        qemu_plugin_register_vcpu_mem_cb(insn, vcpu_haddr,
                                         QEMU_PLUGIN_CB_NO_REGS,
                                         rw, NULL);
    }
}
```

MEMORY CALLBACK

```
static void vcpu_haddr(unsigned int cpu_index, qemu_plugin_meminfo_t meminf
                       uint64_t vaddr, void *udata)
{
    ...
}
```

MEMORY INFO HELPERS

qemu_plugin_mem_size_shift

qemu_plugin_mem_is_sign_extended

qemu_plugin_mem_is_big_endian

qemu_plugin_mem_is_store

HW ADDRESS HELPERS

```
struct qemu_plugin_hwaddr *hwaddr = qemu_plugin_get_hwaddr(meminfo, vaddr);
```

qemu_plugin_hwaddr_is_io	IO?
qemu_plugin_hwaddr_device_offset	offset (including RAM)

OTHER APIS AND HELPERS

qemu_plugin_outs	-d plugin output
plugin_reset/uninstall	un-register callbacks
syscall/syscall_ret	user syscall tracking
vcpu_[init/idle/exit]	vcpu state

EXAMPLE PLUGINS

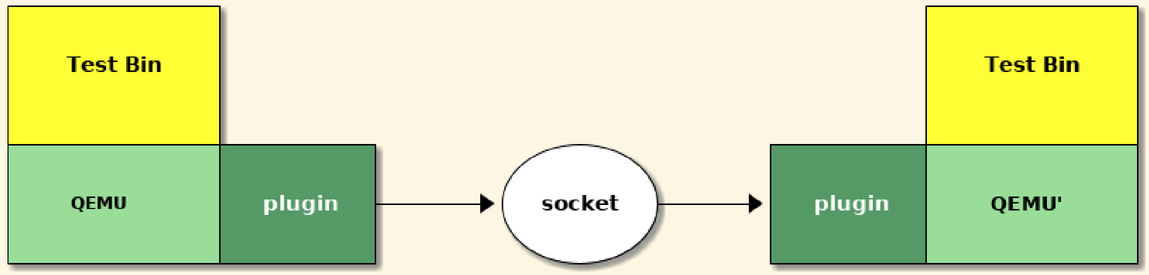
empty	measure overhead
bb	count translations
insn	count instructions
mem	count mem transactions
hotblocks	profile execution
hotpages	profile memory patterns
howvec	profile instruction patterns

FUTURE WORK

MORE SYSTEM STATE

- System memory
- Registers
- Integrate with gdbstub?
- Device State?

DEVELOPER TOOLS



TIME

- Currently based on Host
  - emulation overhead visible
  - use icount
  - but icount not MTTCG
- Expose to plugins
  - read only, or
  - allow plugins to drive timers?

SUMMARY

- A long journey
- Common non-invasive interface
- Efficient in the null case
- Can be extended
  - in and out-of-tree

QUESTIONS?

EXTRA SLIDES

SUMMARY

- Translation Phase
  - Guest Insn -> TCGops
  - Optimise TCG Ops
  - TCGOps -> Host Instructions
- Execution Phase