Regression Test Selection for TizenRT

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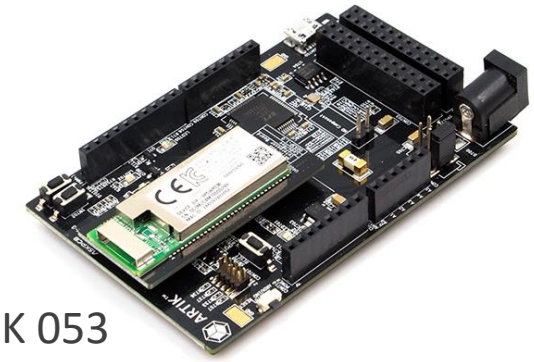
Regression Testing

- Widely practiced in industry
- Checks that changes made to the project do not break the existing functionality
- Google, Facebook, Samsung, and many others uses Regression Testing extensively, since they have thousands of engineers making changes to the same project

Regression Testing for TizenRT

- TizenRT is an open-source lightweight RTOS-based platform implemented in C to support low-end Internet of Things (IoT) devices
- TizenRT includes a collection of test suites (**I**ntegration and **U**nit) that checks different functionalities
- A Samsung IoT platform is required to execute all tests



ARTIK 053

Test Suite	Time [s]	#Test
Arastorage I-Tests	2.02	54
Arastorage U-Tests	1.01	46
Drivers Tests	3.02	26
Filesystem Tests	23.21	76
System I/O U-Tests	4.04	90
Network Tests	2.02	180
Kernel Tests	136.26	405
Total	**171.58**	**877**

Results for ARTIK 053

Regression Test Selection (RTS)

- Optimizes Regression Testing by analyzing the change
- Executes only tests that are affected by the change (and newly added tests)
- Is considered safe if it does not miss any test affected by changes

Using Existing RTS for TizenRT is Challenging

- Available RTS tools target managed languages, e.g. Java and C#
- Additional constraints for TizenRT:
  - GNU Arm Embedded Toolchain does not support compiler plugins
  - Limited memory, processing and storage space in IoT device used to execute tests
  - Transfer between device and host

Our Solution: Selfection

- Targets projects written in C
- Analyzes Arm ELF binaries using readelf and objdump tools provided by GNU Arm Toolchain
- Analyzes code statically and thus does not require extra space and memory
- Works in three phases:
  - *Analysis Phase* Select tests those are affected by the change
  - *Execution Phase* Execute the selected tests
  - *Collection Phase* Collect dependencies for all tests

Testing in TizenRT

.../le_tc/kernel/kernel_tc_main.c

```
int tc_kernel_main(int argc, char*argv[])
{  ...
   mqueue_main();
   ...
}
```

Code A

.../le_tc/kernel/tc_mqueue.c

```
int mqueue_main(void)
{  ...
   tc_mqueue_mq_notify();
   tc_mqueue_mq_timedsend_timedreceive();
   ...

   return 0;
}
```

Code B

.../le_tc/kernel/tc_mqueue.c

```
static void tc_mqueue_mq_timedsend_timedreceive(void)
{
    int ret_chk = OK;

    timedsend_check = timedreceive_check = 0;
    ret_chk = timedsend_test();
    TC_ASSERT_EQ("timedsend_test", ret_chk, OK);

    ret_chk = timedreceive_test();
    TC_ASSERT_EQ("timedreceive_test", ret_chk, OK);

    mq_unlink("t_mqueue");
    TC_SUCCESS_RESULT();
}
```

Code C

Arm ELF Binary Example

- Example, dissambled Arm ELF Binary

```
04110e0c <tc_wqueue_work_queue_cancel>:
 4110e0c:       e92d41ff        push    {r0, r1, r2, r3, r4, r5, r6, r7, r8, lr}
 4110e10:       e59f021c        ldr     r0, [pc, #540]
 4110e14:       ebff127f        bl      40d5818 <tc_skip_function>
                        ...
 4110e28:       e1a06000        mov     r6, r0
 4110e2c:       e3a00020        mov     r0, #32
 4110e30:       ebff0727        bl      40d2ad4 <malloc>
                        ...
 4110ffc:       ebfef111        bl      40cd448 <work_queue>
                        ...
 4111028:       e3a00001        mov     r0, #1
 411102c:       eb031a99        bl      41d7a98 <sleep>
                        ...
 411106c:       041f8499        .word   0x041f8499
```

Selfection Analysis Phase

- Find the tests to run
- Get executable code of the functions from the binary
- Checksum the code in a smart way by using symbol names instead of symbol addresses
- Compute transitive closure of affected functions using the dependency graph obtained in Collection Phase and check if any test is in this set, and find newly added tests
- Example: The change with SHA aa7f5149 on the left side is from TizenRT, a new test is added to kernel test suite

```
-apps/examples/testcase/le_tc/kernel/kernel_tc_main.c
+apps/examples/testcase/le_tc/kernel/kernel_tc_main.c
int tc_kernel_main(int argc, char *argv[]) {
    ...
+   wqueue_main();
    ...
}

+apps/examples/testcase/le_tc/kernel/tc_wqueue.c
+int wqueue_main(void)
+{
+   ...
+   tc_wqueue_work_queue_cancel();
+   ...
+   return 0;
+}
```

Selfection Execution Phase

- Testing framework of TizenRT does not support test filtering
- We added support for test filtering to TizenRT by including functions and macros statically
- Selfection sends the selected tests to device before execution started using serial console, and only those tests will not be skipped

.../tash_main.c

```
#ifdef SELFECTION
...
while(strcmp(line_buff,">>start")!=0){ ... }
...
for(;;){ ...
 if(strcmp(line_buff,"stop<<")!=0){ tc_skip_function_set(line_buff); ... } else { ... }
};
#endif
```

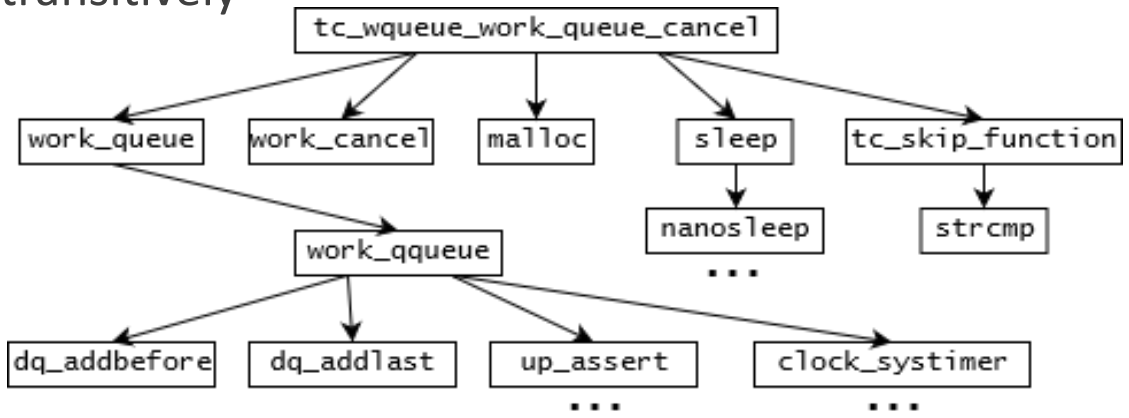
.../le_tc/kernel/tc_wqueue.c

```
static void __attribute__((noclone))
__attribute__((noinline))
tc_wqueue_work_queue_cancel(void) {

if(tc_skip_function(__func__))return;
   ...
}
```

Selfection Collection Phase

- Selfection statically analyzes binaries to build function call graph
- Example: On the right side, function call instructions are shown as bold
- `tc_wqueue_work_queue_cancel` depends on `tc_skip_function`, `malloc`, `work_queue` and `sleep` functions, and any function they depend on transitively




```
04110e0c <tc_wqueue_work_queue_cancel>:
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 4110e10:       e59f021c        ldr     r0, [pc, #540]
 4110e14:       ebff127f        bl      40d5818
<tc_skip_function>
                               ...
 4110e28:       e1a06000        mov     r6, r0
 4110e2c:       e3a00020        mov     r0, #32
 4110e30:       ebff0727        bl      40d2ad4 <malloc>
                               ...
 4110ffc:       ebfef111        bl      40cd448 <work_queue>
                               ...
 4111028:       e3a00001        mov     r0, #1
 411102c:       eb031a99        bl      41d7a98 <sleep>
                               ...
 411106c:       041f8499        .word   0x041f8499
```
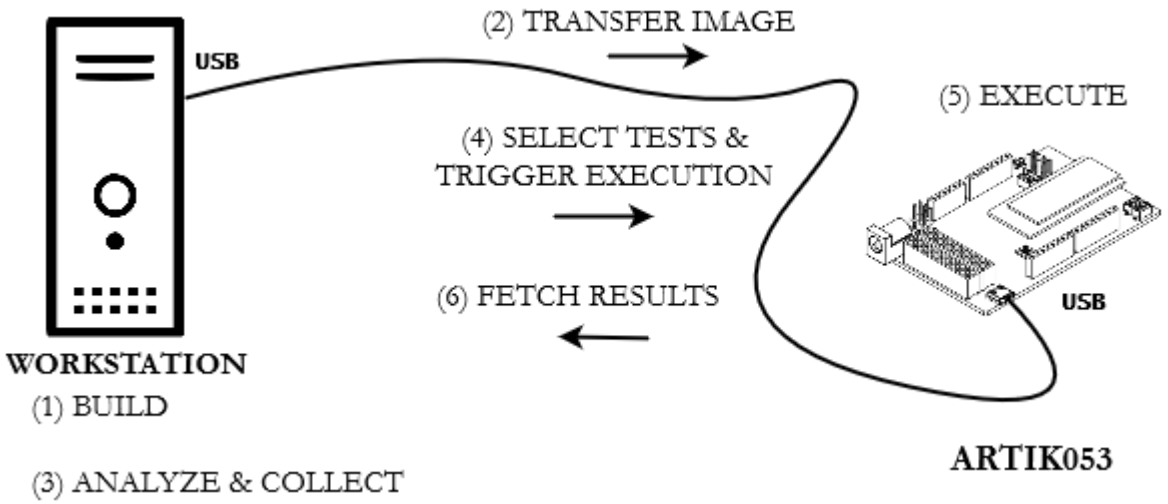

Evaluation

- We asked three Research Questions (RQs):
- RQ1: How many tests does Selfection skip on average across a large number of revisions?
- RQ2: What is the reduction, on average, in end-to-end test execution time across a large number of revisions?
- RQ3: How does time for Analysis, Execution, and Collection phases compare to other build steps?

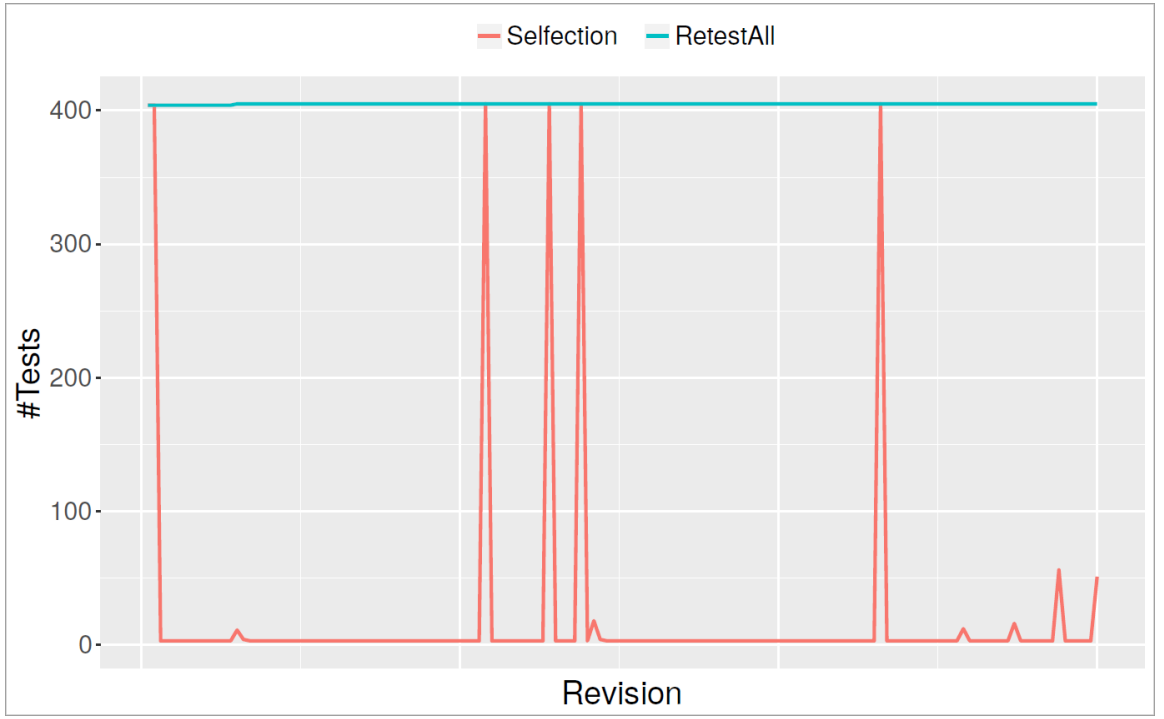
Experiment Setup

- 150 revisions used in the experiment is annotated to support test selection in an automated manner
- ARTIK 053 IoT device by Samsung is used to execute all tests
- QEMU emulator is also used, however only kernel test can be executed without hardware
- For each revision repeat:
  - Checkout the revision
  - Execute all tests (RetestAll) and collect the number of executed tests and time to execute them
  - Apply three phases of Selfection, and collect the number of selected tests and time to execute them



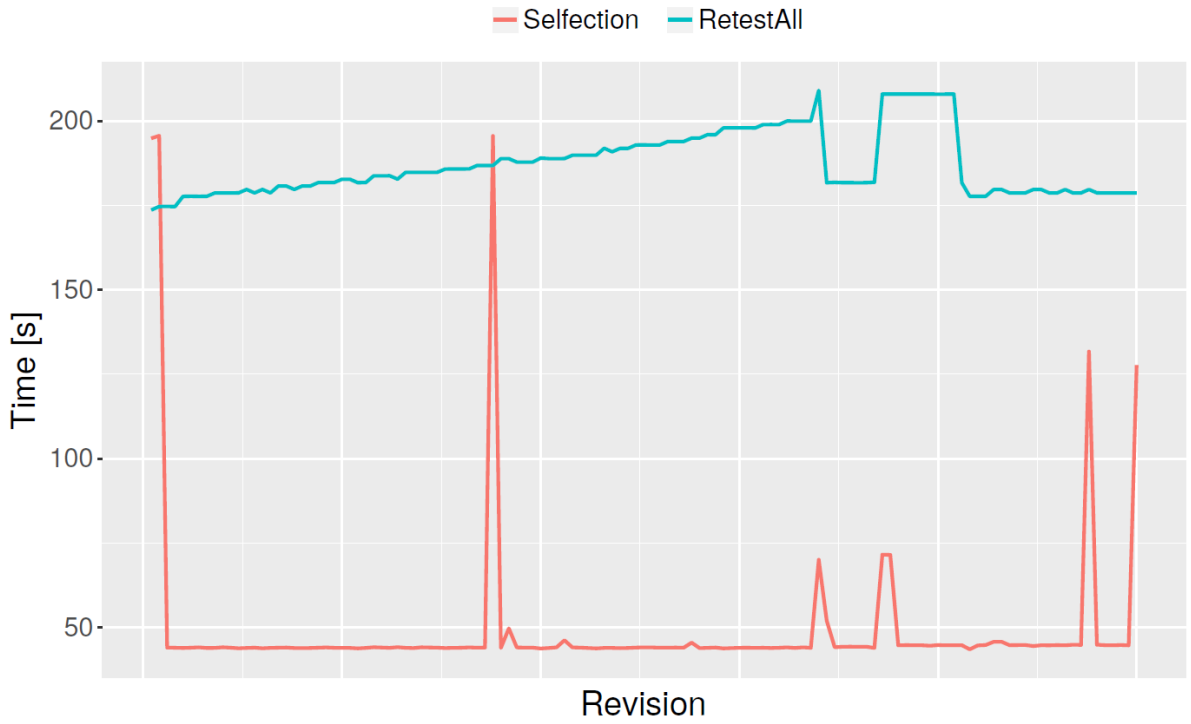
RQ1: How many tests does Selfection skip on average across a large number of revisions?

6% of tests are selected in ARTIK 053

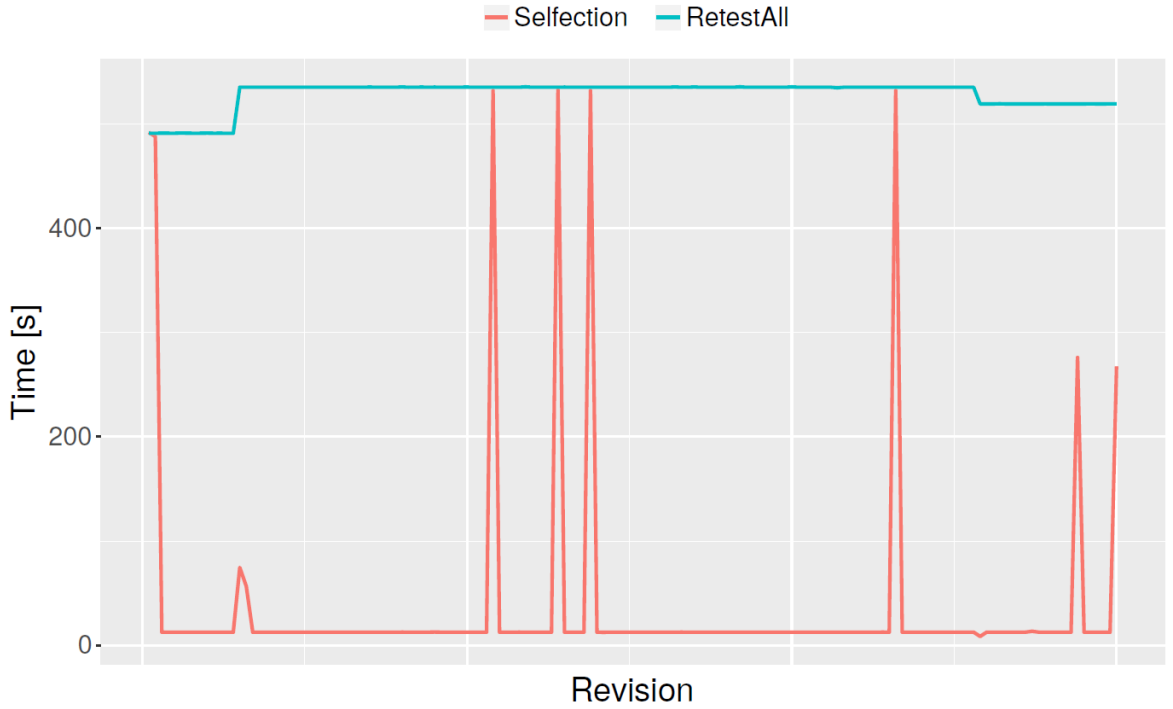


5% of tests are selected in QEMU

RQ2: What is the reduction, on average, in end-to-end test execution time across a large number of revisions?



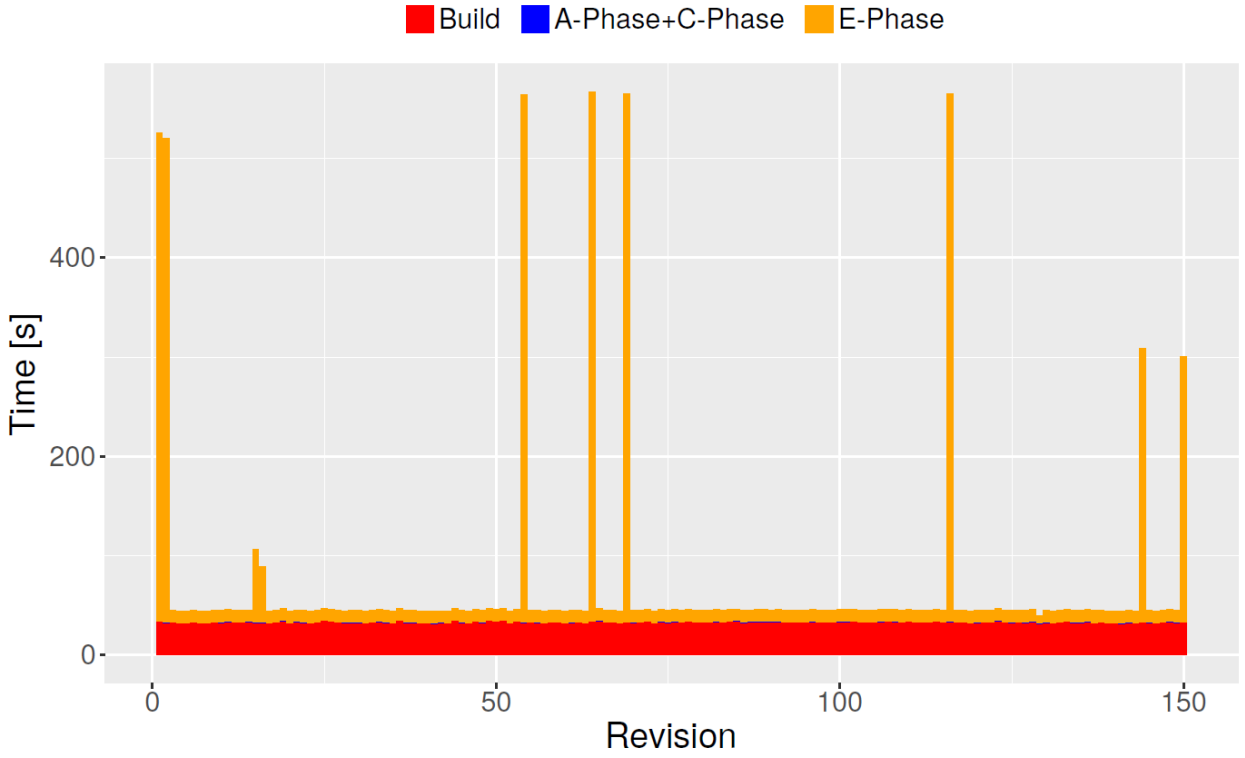
Execution time reduced to 27% of RetestAll in ARTIK 053



Execution time reduced to 7% of RetestAll in QEMU

RQ3: How does time for Analysis, Execution, and Collection phases compare to other build steps?

ARTIK 053



QEMU

Conclusion

- S*elf*ection
  - RTS tool for projects in C that compiles to Arm ELF binary
  - Statically analyzes binaries to collect call-graph dependencies and find affected tests
- Substantial savings in testing time and number of executed tests
- Only the execution phase is specific to TizenRT

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