META: Memory Exploration Tool for Android Devices

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Introduction and Motivation

- More than 2 billion mobile devices are being used today.[1]
- With every passing year, new Android OS versions are being released and the diversity of applications supported is growing.
- With the rapid increase in usage of mobile devices, focus is needed on architecture of handheld devices to keep the mobile computing ecosystem evolving and in pace with people's expectations.
- DRAM being the primary contributor to SoC energy consumption[2], increase it memory requirements will significantly increase power budget of SoC.

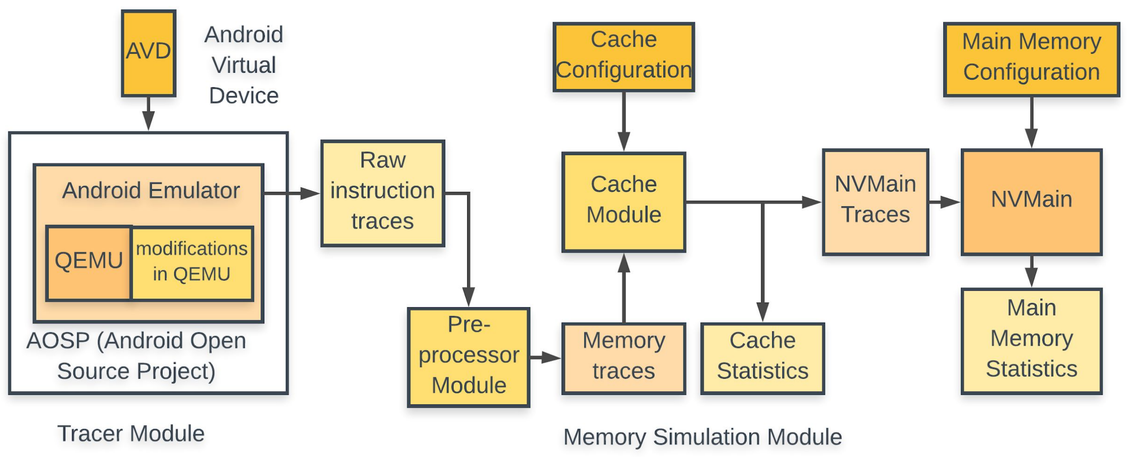
Background

- Today, only 1 percent of all architecture research papers published each year in the top computer architecture conferences focus on mobile computing.[1]
- We believe that this dearth of research is due to unavailability of tools supporting latest operating system platforms for the architectural studies of mobiles.
- The tools currently present - GemDroid[3], MofySim[4] support only the older Android OS version (KitKat 4.4)
- Older versions of OS => older versions of apps which are not representative of the future apps.
- Simulators which allow user interaction are required as mobile apps involve significant amount of user interaction.

Contributions of META

META aims to catalyse research in field of mobile computer architecture by acting as a simulation tool which:

- Is compatible with all Android OS versions - current and upcoming
- Allows accounting of effects of user interactions with devices during simulation
- Can perform comprehensive analysis of memory subsystem.



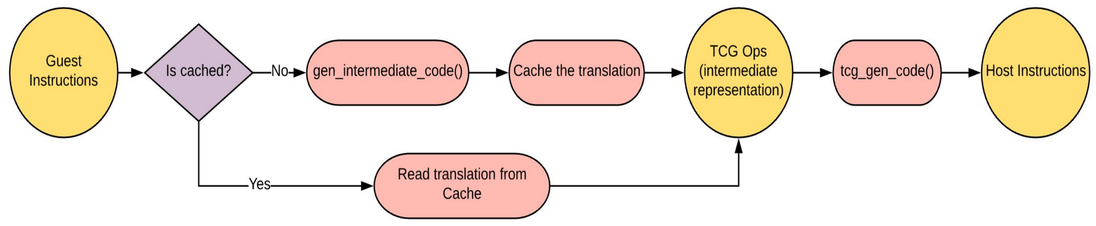
Tool Diagram

META Tool Design

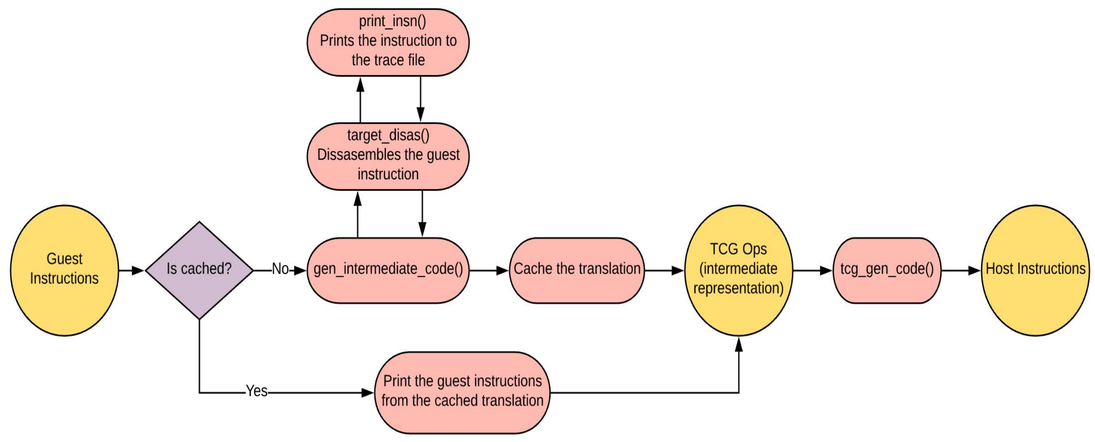
- META is built on top of the Android Emulator, shipped with the Android Open Source Project (AOSP)[6].
- Android emulator uses Android Virtual Device(AVD) to specify hardware profile, system image, storage areas etc. of the device being simulated.
- For future compatibility, newer AVDs will have to be provided, which are typically shipped with AOSP, making the integration of future Android versions much smoother.
- META has a modular design which enables outputs of multiple stages to be used independent of each other.
- The tool mainly consists of two modules:
  - Tracer Module
  - Memory Simulation Module.

Tracer Module

- To enable the tracing functionality in Android Emulator, we modified the source code of translation path of QEMU.



Original Translation Path



Modified Translation Path

Memory Simulation Module

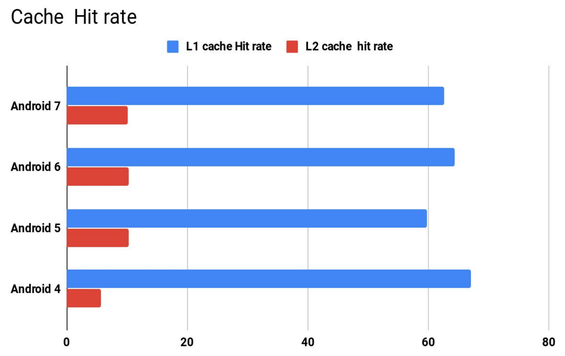
- Memory traces are generated from the raw instruction traces using a preprocessing module.
- The cache module simulates the behaviour of a N-level cache using the memory traces. It provides:
  - Cache statistics like hit rate, total requests etc.
  - Trace file containing memory traces for the main memory.
- The newly generated traces are fed to NVMain which return main memory statistics like bank power, refresh power, number of activates, precharges etc at a bank level.

```
[
{
    "level" : 1,
    "size"  : 32768,
    "associativity" : 8,
    "sets" : 64,
    "read_time" : 1,
    "write_time" : 2
},
{
    "level" : 2,
    "size"  : 262144,
    "associativity" : 4,
    "sets" : 1024,
    "read_time" : 10,
    "write_time" : 15
}
]
```

Cache configuration

```
channel0.rank0.bank1.bankEnergy 165824mA*t
channel0.rank0.bank1.activeEnergy 81459mA*t
channel0.rank0.bank1.burstEnergy 35145mA*t
channel0.rank0.bank1.refreshEnergy 49220mA*t
channel0.rank0.bank1.bankPower 0.00409577W
channel0.rank0.bank1.activePower 0.002012W
channel0.rank0.bank1.burstPower 0.000868064W
channel0.rank0.bank1.refreshPower 0.00121571W
channel0.rank0.bank1.bandwidth 3239.79MB/s
channel0.rank0.bank1.dataCycles 2308
channel0.rank0.bank1.powerCycles 60730
channel0.rank0.bank1.utilization 0.0380043
channel0.rank0.bank1.reads 367
channel0.rank0.bank1.writes 210
channel0.rank0.bank1.activates 431
channel0.rank0.bank1.precharges 430
channel0.rank0.bank1.refreshes 23
channel0.rank0.bank1.activeCycles 51643
channel0.rank0.bank1.standbyCycles 9087
channel0.rank0.bank1.fastExitActiveCycles 0
channel0.rank0.bank1.fastExitPrechargeCycles 0
channel0.rank0.bank1.slowExitPrechargeCycles 0
channel0.rank0.bank1.actWaits 0
channel0.rank0.bank1.actWaitTotal 0
channel0.rank0.bank1.actWaitAverage -nan
channel0.rank0.bank1.averageEndurance 0
channel0.rank0.bank1.worstCaseEndurance 18446744073709551615
```

Output from NVMain



Potential Usecases

- Trace Generation
  - The traces can also be used to analyze instruction distribution profile.
- Cache Hierarchy Modeling
  - A custom N-level cache hierarchy can be modelled. Size, associativity and number of sets can be specified in the configuration file.
- DRAM, Non-volatile and Hybrid Memory Simulation
  - This can be done by altering the configuration files of NVMain. Configuration files of PCM, STTRAM, RRAM and hybrid memory are shipped along with NVMain.

Future Plan

The tool has reached the final stages of development. After completing the development stage we plan to perform extensive testing of the tool to uncover all the corner cases. We intend to open source the tool once the testing stage is completed.

We also aim to create a benchmark of applications and simulate them using META to showcase the analysis that can be performed using META.

References

1. V. J. Reddi, H. Yoon, and A. Knies, "Two billion devices and counting," IEEE Micro, vol. 38, no. 1, pp. 6–21, January/February 2018.
2. A. Carroll and G. Heiser, "The Systems Hacker's Guide to the Galaxy Energy Usage in a Modern Smartphone," in APSYS, 2013.
3. C. Nachiappan et al., "Gemdroid: A framework to evaluate mobile platforms," in Proceedings of SIGMETRICS, 2014
4. M. Ju, H. Kim, and S. Kim, "MofySim: A mobile full-system simulation framework for energy consumption and performance analysis," in ISPASS, 2016
5. Matt Poremba, Yuan Xie, "NVMain: An Architectural-Level Main Memory Simulator for Emerging Non-volatile Memories" in 2012 IEEE Computer Society Annual Symposium on VLSI
6. Android Open Source Project : https://source.android.com/
7. Qemu : https://www.qemu.org/