Evaluating GPP Predictors for Software Based Waveform Performance

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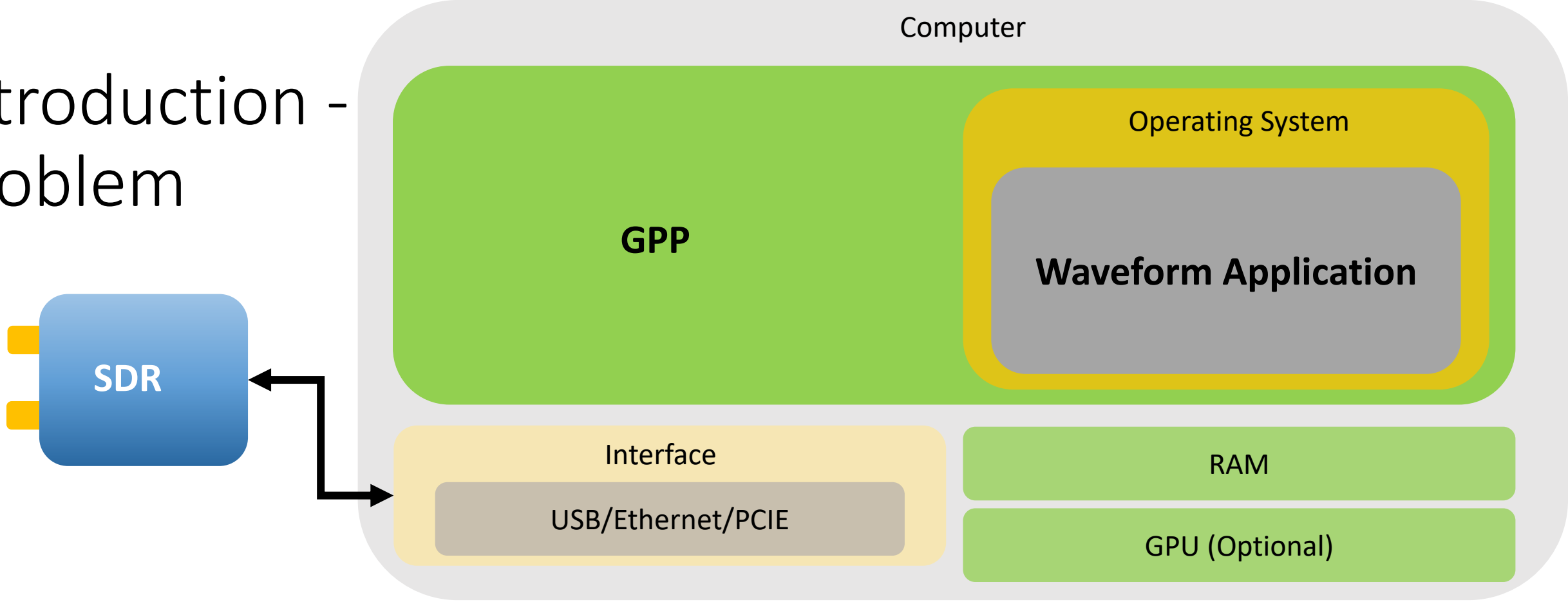
Introduction - Problem

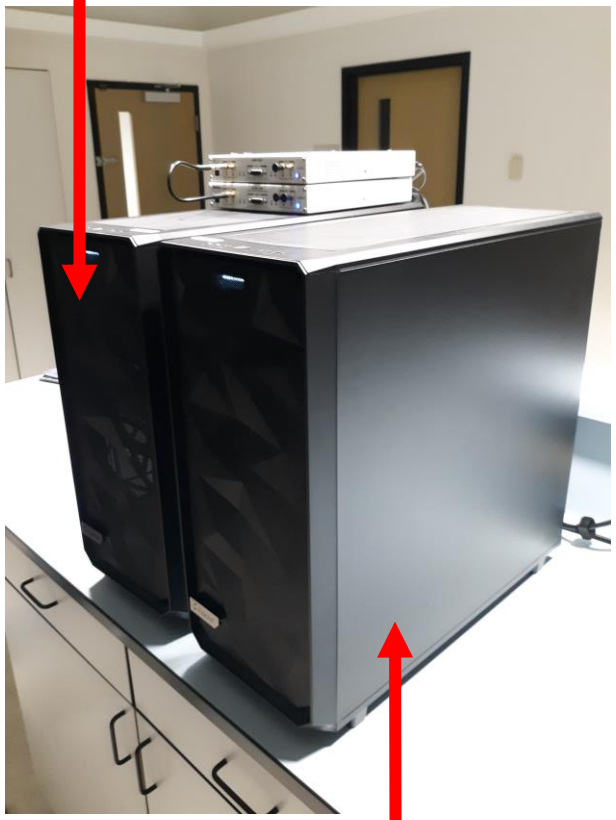


- Waveform max sample/symbol/data rates tied to CPU performance
- How do you select/compare CPUs based on their properties?
- Higher end CPUs – Moore's law
- Lower end CPUs – performance critical

Introduction - Method

Test	System	Result Metric
ANDRO LDPC	Intel i9-13900K	Throughput (Bits/sec)
	AMD Ryzen 9 7900X	
AFF3CT LDPC	Intel i9-13900K	Throughput (Bits/sec)
	AMD Ryzen 9 7900X	
XDSOPL LDPC	Intel i9-13900K	Throughput (Bits/sec)
	AMD Ryzen 9 7900X	
ANDRO DVB-S2	Intel i9-13900K	Max Symbol Rate (Syms/sec)
	AMD Ryzen 9 7900X	
AFF3CT DVB-S2	Intel i9-13900K	Max Symbol Rate (Syms/sec)
	AMD Ryzen 9 7900X	
gr-dvbs2rx DVB-S2	Intel i9-13900K	Max Symbol Rate (Syms/sec)
	AMD Ryzen 9 7900X	

Desktop A: Ryzen



Desktop B: i9

Introduction - Method

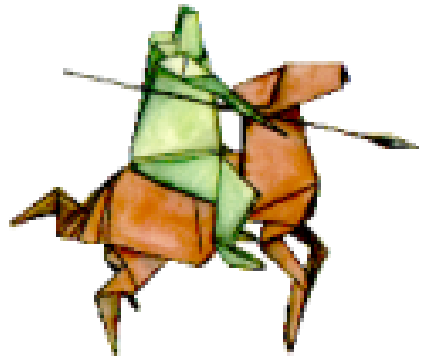
Intel VTune Profiler

- “Hotspots” (Top Functions Used)
- Memory Consumption
- Microarchitecture exploration
- Memory Access
- Intel GPPs only

GNU gprof

- Top functions used
- Requires specific compilation flag
- AMD & Intel

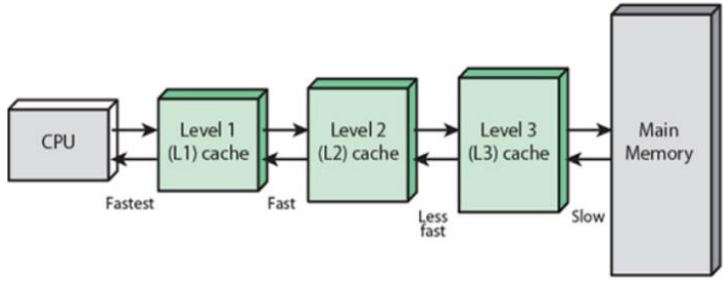
Cachegrind



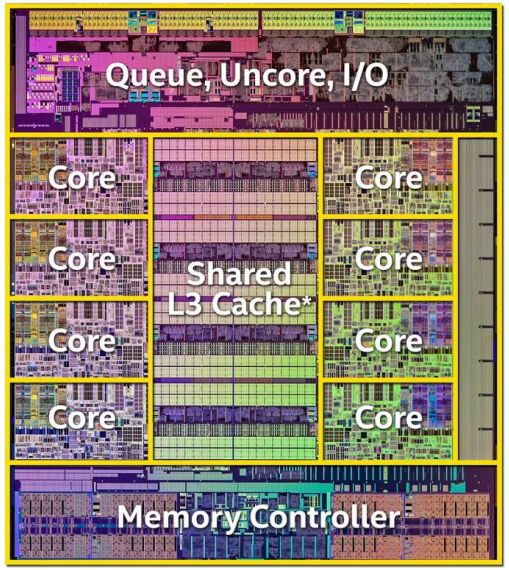
- Part of Valgrind suite
- Runs in simulation - slow
- Cache analysis

Key Takeaways

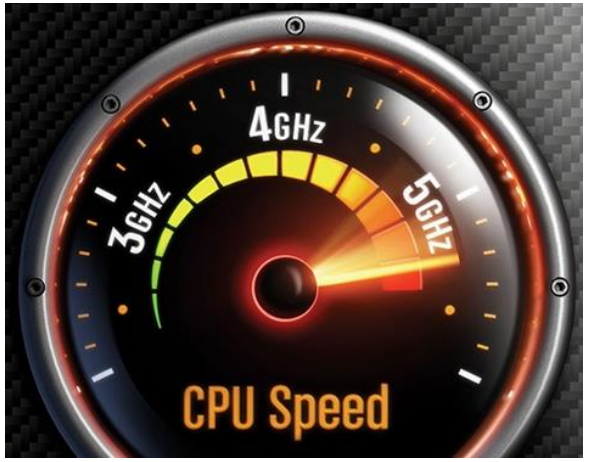
- Find cache/memory an important factor besides just CPU frequency
- More CPU cores not necessarily better
- Overclocking ability is an important consideration



https://www.hierarchystructure.com/4-level-page-caching-cpu-k.html



https://techgage.com/article/core-i7-5960x-extreme-edition-review-intels-overdue-desktop-8-core-is-here/



https://free-techtips.blogspot.com/2016/04/what-is-overclocking-why-do-we-need.html

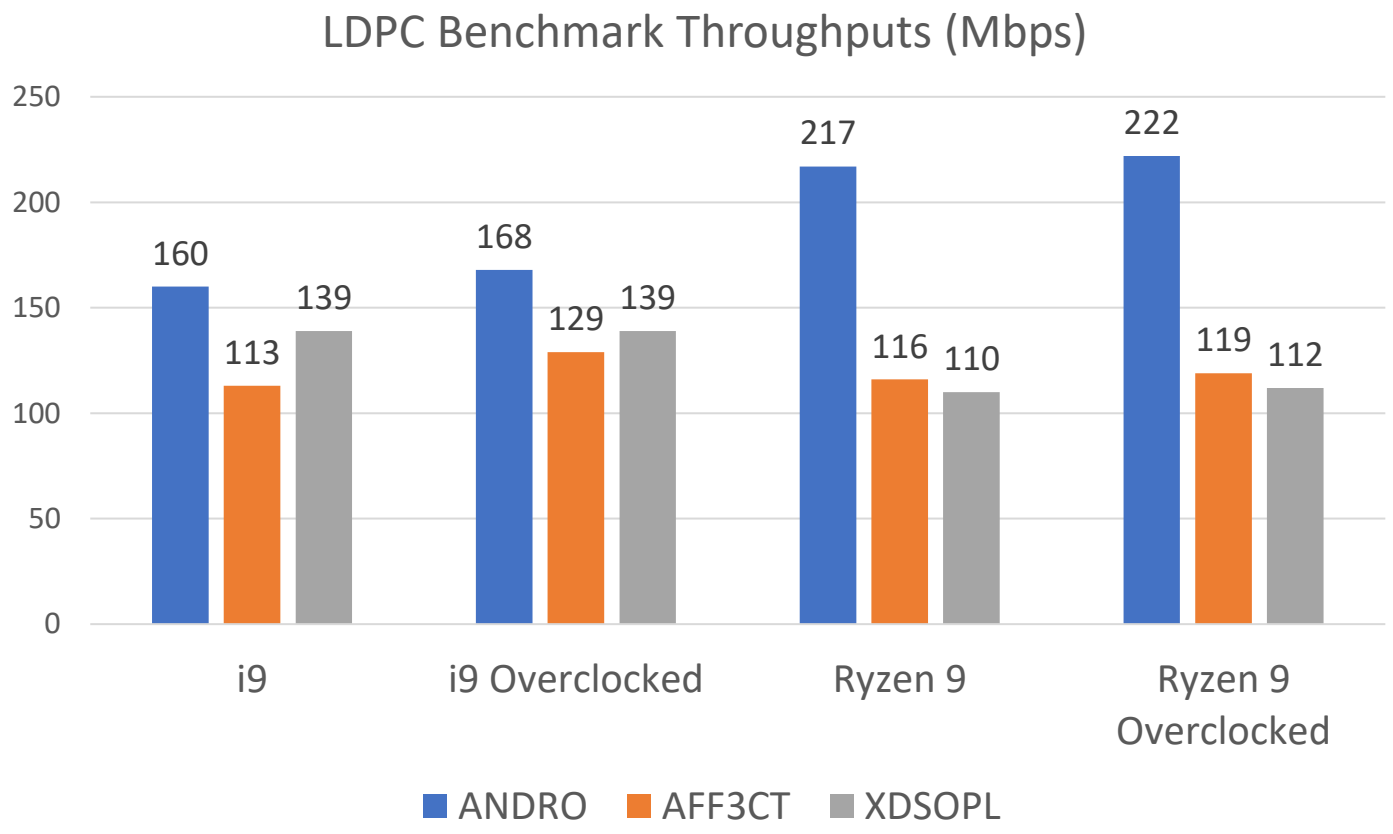
GPPs

	Intel Core i9-13900K	AMD Ryzen 9 7900X
Price	$569.97 - BUY	$409 - BUY
Socket Type	FCLGA1700	AM5
CPU Class	Desktop	Desktop
Clockspeed	3.0 GHz	4.7 GHz
Turbo Speed	Up to 5.8 GHz	Up to 5.6 GHz
# of Physical Cores	24 (Threads: 32)	12 (Threads: 24)
Cache	L1: 1,536KB, L2: 16.0MB, L3: 36MB	L1: 768KB, L2: 12.0MB, L3: 64MB
TDP	125W	170W
Yearly Running Cost	$22.81	$31.03
Other	Intel UHD Graphics 770	AMD Radeon Graphics
First Seen on Chart	Q3 2022	Q3 2022
# of Samples	3707	1503
CPU Value	105.0	128.1
Single Thread Rating	4677	4325
(% diff. to max in group)	*(0.0%)*	*(-7.5%)*
CPU Mark	**59859**	**52383**
(% diff. to max in group)	*(0.0%)*	*(-12.5%)*

https://www.cpubenchmark.net/compare/5022vs5027/Intel-i9-13900K-vs-AMD-Ryzen-9-7900X

LDPC Benchmarks

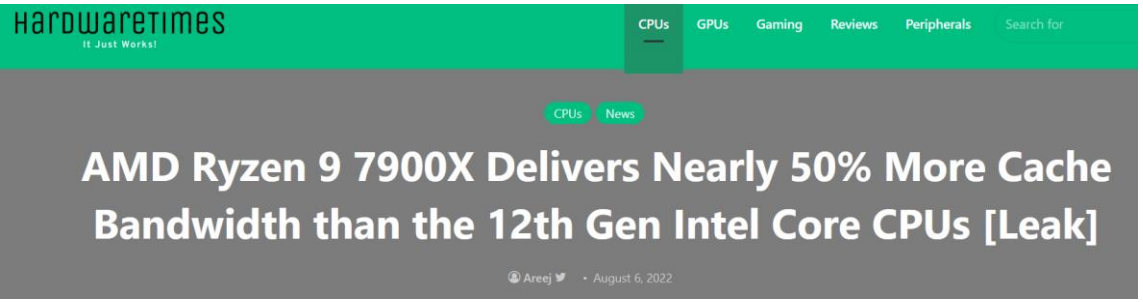
- Rate ½, Normal frame length (64800)
- Separate benchmark programs included with each implementation
- AFF3CT
  - 4 threads (default = # cores)
  - 16 threads max Tput was 101 Mbps
- 10 iterations, early termination disabled
- AFF3CT/XDSOPL syntax in appendix



LDPC Analysis – ANDRO/XDSOPL

Metric	i9	Ryzen 9
LL cache size	37748736 B	67108864 B
LL cache type	18-way associative	direct-mapped

ANDRO LDPC Cachegrind Last-Level (LL) output



https://tinyurl.com/3fhejcnc

Metric	ANDRO	XDSOPL
Top AVX Intrinsic	_mm256_store_si256	_mm256_max_epi8
Back-End Bound	63.3%	28.7%
Memory Bound	33.3%	23.3%
L3 Bound	6.3%	0.6%

Selected Vtune Profiler Results Comparison

LDPC Analysis – AFF3CT

```
Flat profile:

Each sample counts as 0.01 seconds.
  %   cumulative   self              self     total
 time   seconds   seconds    calls   s/call   s/call  name
  6.03      0.07     0.07        7     0.01     0.05  void aff3ct::module::Decoder_LDPC_BP_hori
zontal_layered_ONMS_inter<int, float>::_decode_single_ite<0>(std::vector<mipp::Reg<float>, mipp
::allocator<mipp::Reg<float> > >&, std::vector<mipp::Reg<float>, mipp::allocator<mipp::Reg<floa
t> > >&)
  4.31      0.12     0.05 199067496     0.00     0.00  unsigned char const& std::forward<unsign
ed char const&>(std::remove_reference<unsigned char const&>::type&)
  4.31      0.17     0.05        1     0.05     0.05  __static_initialization_and_destruction_0
(int, int)
  3.88      0.22     0.05 99533748     0.00     0.00  std::enable_if<std::__and_<std::__and_<st
d::__not_<std::allocator_traits<mipp::allocator<unsigned char> >::__construct_helper<unsigned c
har, unsigned char const&>::type>, std::is_constructible<unsigned char, unsigned char const&> >
 >::value, void>::type std::allocator_traits<mipp::allocator<unsigned char> >::_S_construct<uns
igned char, unsigned char const&>(mipp::allocator<unsigned char>&, unsigned char*, unsigned cha
r const&)
  3.88      0.26     0.05       41     0.00     0.00  mipp::allocator<unsigned char>::deallocat
e(unsigned char*, unsigned long)
```

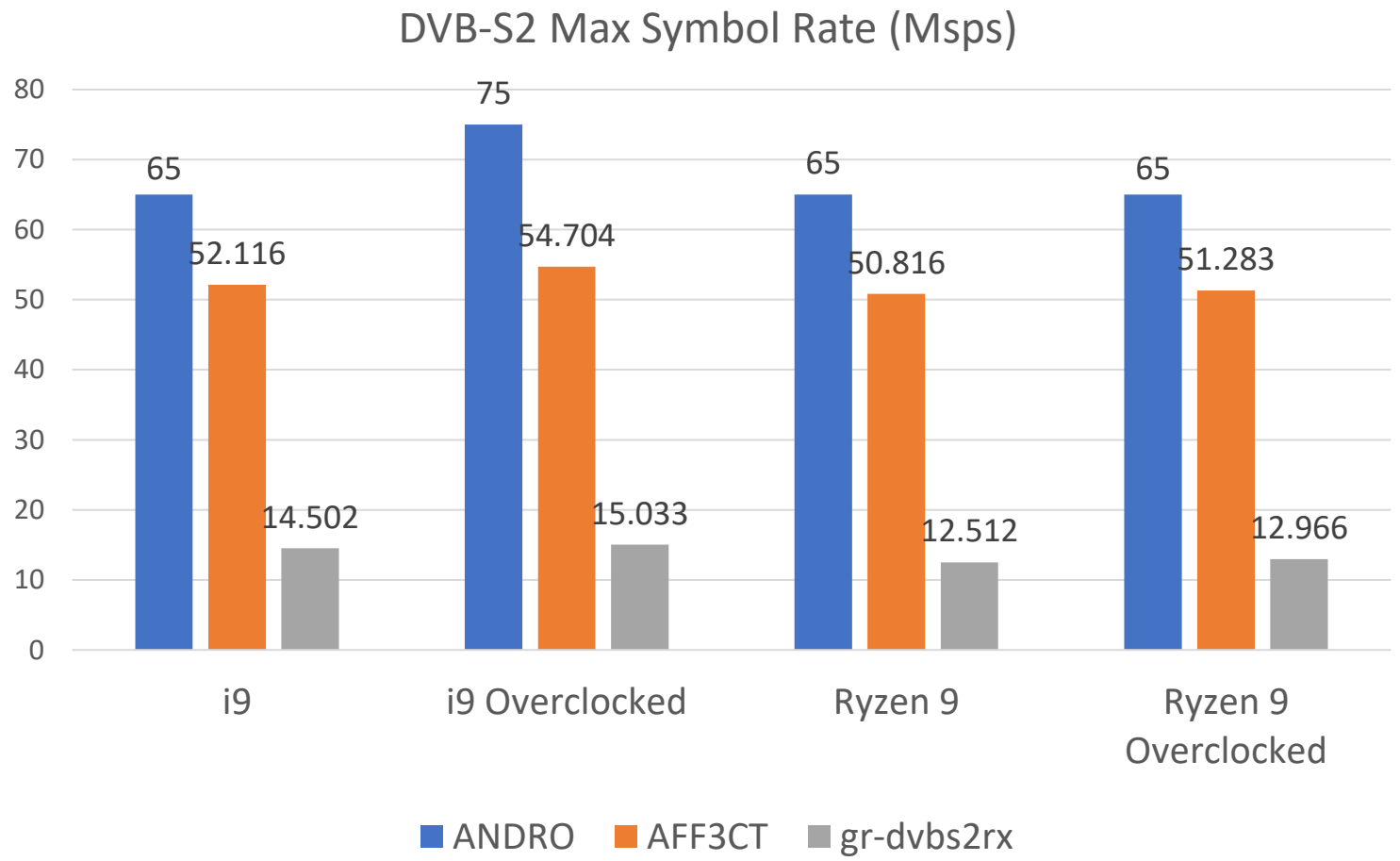
AFF3CT gprof results

Metric	I9 Base	I9 Ovr.	Ryzen 9 Base	Ryzen 9 Ovr.
CPU Speed	5.5 GHz	5.9 GHz	5.73 GHz	5.82 GHz

GPP Overclocking Results

DVB-S2 Benchmarks

- ANDRO/gr-dvbs2rx QPSK, rate ½, normal frame length
- AFF3CT QPSK, rate 3/5, short frames
- AFF3CT/gr-dvbs2rx: simulation
- ANDRO ran w/ 2 X300s, SMA cabled
- AFF3CT/gr-dvbs2rx syntax in appendix

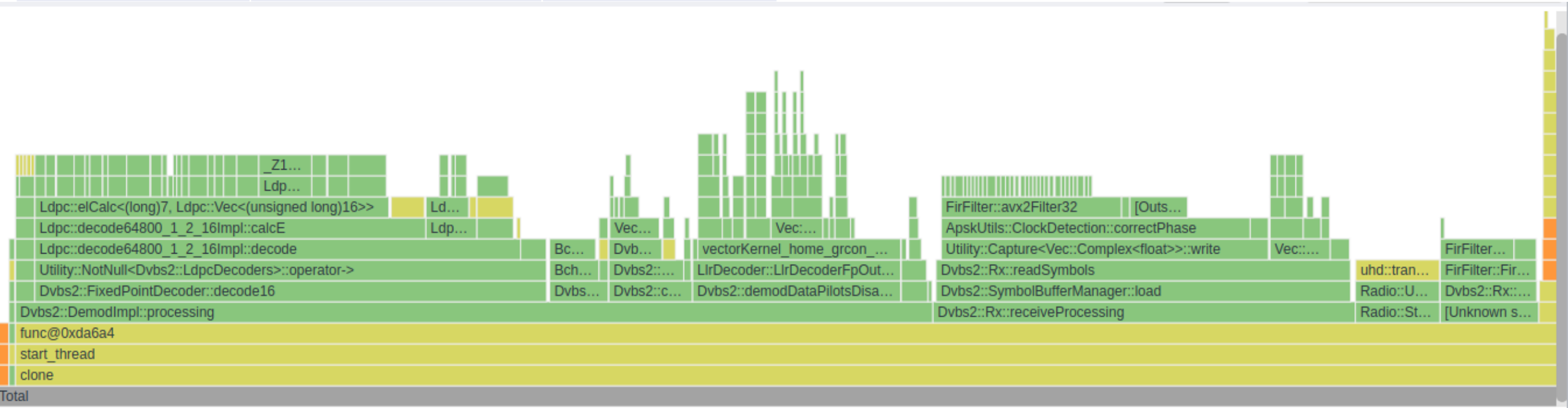


DVB-S2 Analysis - ANDRO

Metric	ANDRO LDPC	ANDRO DVB-S2
Top Hotspot	_mm256_store_si256	correctPhase
Band-End Bound	63.3%	52.2%
Memory Bound	33.3%	25.8%
L3 Bound	6.3%	6.9%
L3 Latency	35.7%	12.6%
DRAM Bound	11.3%	8.8%

ANDRO Benchmarks VTune Results Comparison

ANDRO DVB-S2 VTune flame graph



DVB-S2 Analysis – AFF3CT/gr-dvbs2rx

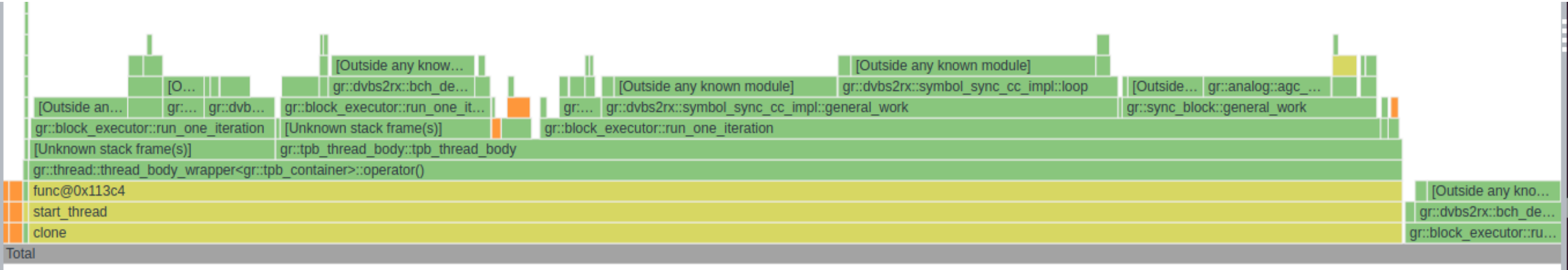
```
Flat profile:

Each sample counts as 0.01 seconds.
  %   cumulative   self              self     total
 time   seconds   seconds    calls   s/call   s/call  name
  9.04      1.85     1.85 473242796     0.00     0.00  std::complex<float> std::operator*<floa
t>(std::complex<float> const&, float const&)
  8.53      3.59     1.74     3314     0.00     0.00  aff3ct::module::Filter_FIR_ccr<float>::_
filter(float const*, float*, int)
  7.50      5.12     1.53 473243566     0.00     0.00  std::complex<float>::__rep() const
  5.63      6.27     1.15 467233576     0.00     0.00  std::complex<float>& std::complex<float
>::operator+=<float>(std::complex<float> const&)
  3.92      7.07     0.80 316454399     0.00     0.00  mipp::Reg<float> mipp::fmadd<float>(mip
p::Reg<float>, mipp::Reg<float>, mipp::Reg<float>)
  3.72      7.83     0.76 2919610385     0.00     0.00  mipp::Reg<float>::~Reg()
  2.74      8.39     0.56  5887296     0.00     0.00  aff3ct::module::Filter_FIR_ccr<float>::s
tep(std::complex<float> const*, std::complex<float>*)
  2.55      8.91     0.52       73     0.01     0.02  aff3ct::module::Encoder_BCH_inter<int>::
__encode(int const*, int*)
```

AFF3CT gprof results

- Both performed better on i9, same as LDPC results
- Find BCH decoding and symbol sync highest CPU usage for gr-dvbs2rx, matching author results (Freire 2022)

gr-dvbs2rx VTune flame graph



Summary/Conclusions

- General consumer benchmarks not necessarily indicators of your results
  - Look for single thread performance as opposed to overall score
- More threads/cores not necessarily better
  - Grayver, 2019 finds “performance scaling is limited by the amount of available cache memory rather than the number of cores”
  - Similarly, AFF3CT LDPC achieved higher throughput using 4 threads instead of default equal to number of cores
- Based on if program is more memory or CPU bound:
  - Look for cache/memory speed/performance if memory bound
  - Look for CPU speed/performance if CPU bound
- Consider overclocking ability
  - Allowed AFF3CT higher LDPC throughput on i9

Future Work

- Real-time AFF3CT/gr-dvbs2rx DVB-S2, simulated ANDRO DVB-S2
- Comparing AFF3CT LDPC number of threads vs. throughput and cache usage
- Multithreaded ANDRO LDPC
- Scheduling (round robin, FIFO), thread priorities
- Mapping threads to cores
  - hwloc disabled for AFF3CT
- Real time operating systems
- Low latency kernel
- Threading architectures
  - Have seen performance improvement moving from pipeline to thread pool/worker approach in previous waveforms

References

- Areej. Amd ryzen 9 7900x delivers nearly 50% more cache bandwidth than the 12th gen intel core cpus, August 2022. URL https://tinyurl.com/3fhejcnc. Last Accessed July 26, 2023.
- PassMark Software. Cpu benchmarks, 2023. URL https://www.cpubenchmark.net/compare/5022vs5027/Intel-i9-13900K-vs-AMD-Ryzen-9-7900X.
- Grayver, Eugene. Scaling the fast x86 dvb-s2 decoder to 1 gbps. In 2019 IEEE Aerospace Conference, pp. 1–9, 2019. doi: 10.1109/AERO.2019.8742225
- Freire, Igor. Grcon22: gr-dvbs2rx: An overview of the project state and path forward, Oct 2022. URL https://www.youtube.com/watch?v=qcqvfElQUVk. Last accessed 18 July 2023.

Appendix

- XDSOPL LDPC Syntax: testbench 10 T2 A1 QAM16 32
- AFF3CT LDPC Syntax: aff3ct -C "LDPC" -K "32400" -N "64800" --enc-type "LDPC_DVBS2" -m "6.9897" -M "7.0" --dec-simd "INTER" --mdm-type BPSK --mdm-implem FAST --src-type "RAND" --src-implem "FAST" --chn-implem "FAST" --dec-type "BP_HORIZONTAL_LAYERED" --dec-implem "NMS" --dec-norm "0.75" --dec-ite "10" --sim-threads 4 --dec-no-synd
- gr-dvbs2rx DVB-S2 syntax: ./dvbs2-tx --source file --in-file ./example.ts --in-repeat --frame-size normal --modcod QPSK1/2 --sym-rate 5000000 --samp-rate 10000000 --snr 10.5 --freq-offset 0 | ./dvbs2-rx --frame-size normal --modcod QPSK1/2 --ldpc-iterations 10 --log-all --sym-rate 5000000 --samp-rate 10000000 --out-fd 3 3> /dev/null
- AFF3CT DVB-S2 syntax: ./bin/dvbs2_tx_rx -F 8 --src-type USER_BIN --src-path ./example.ts --snk-path output_stream_fifo.ts --mod-cod QPSK-S_3/5 --dec-implem NMS --dec-ite 10 --dec-simd INTER