

Performance Analysis and Loop Optimization

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Winning with High-K 45nm Technology
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Agenda

- Dominant issues in loop analysis
- Using LBRs
- Example

What matters when optimizing a loop?

1. The Trip Count
2. The Trip Count
3. **The TRIP COUNT!**
4. Variations in the tripcount
5. And some other things

**BUT..what you do about them depends on
THE TRIP COUNT**

**And of course there are virtually no tools to assist you in
determining this..other than printf**

(you can use PIN..)

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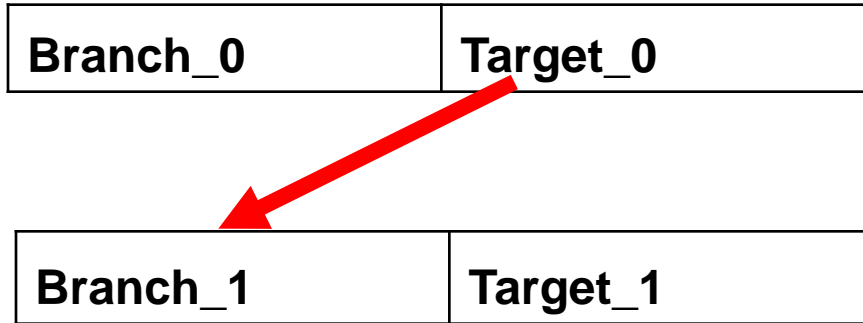
Basic loop tripcount ranges (for short loops)

- The tripcount dictates optimization options, as it defines the time available to amortize the cost of the proposed solution
- Short loops $\text{tripcount} < 7$?
 - Unroll the loop completely/vectorize
- Medium loops $7 < \text{tripcount} < 15-20$?
 - Most difficult case..too short to do much of anything, only option is vectorize
- Medium_long $20 < \text{tripcount} < 50$
 - Almost long enough for real options
- Long loops $50-100 < \text{tripcount}$
 - Lots of options
- Of course all loops have their own issues

Basic Branch Analysis

- **Vastly improved precise branch monitoring capabilities**
 - **16 deep Last Branch Record (LBR)**
 - Records Taken Branches and their targets
 - LBR can be filtered by branch type and privilege level
- **Precise br retired by branch type**
 - **Calls, conditional and all calls**
 - **Coupled with LBR capture yields**
 - Call counts
 - Basic Block execution counts
 - “HW call graph”

Processing LBRs



- **All instructions between Target_0 and Branch_1 are retired 1 time**
- **All Basic Blocks between Target_0 and Branch_1 are executed 1 time**
 - **All Branch Instructions between Target_0 and Branch_1 are not taken**

So it would all Seem Very Straight Forward

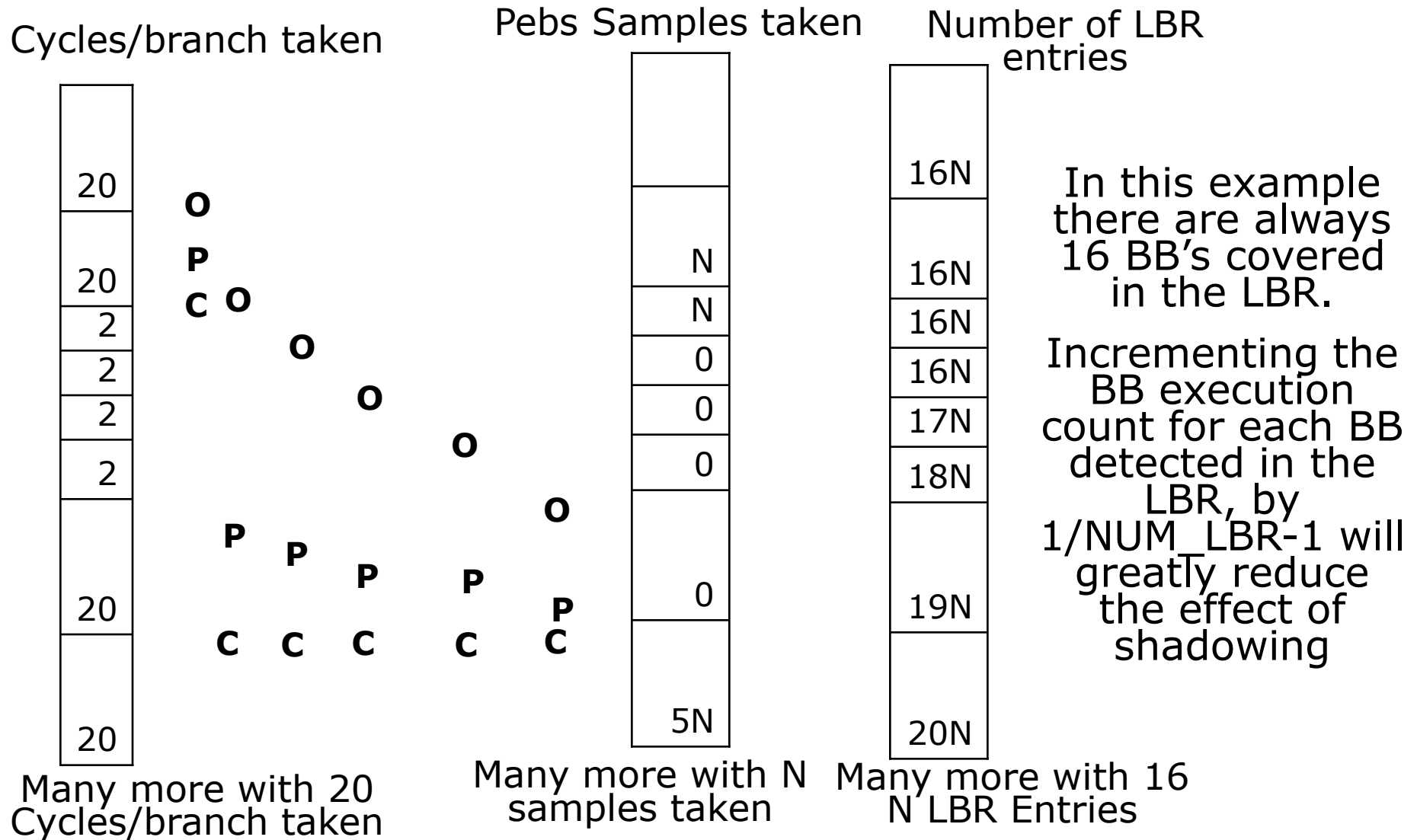
Shadowing and Precise Data Collection

- **The time between the counter overflow and the PEBS arming creates a “shadow”, during which events cannot be collected**
 - ~8 cycles?**
- **Ex: conditional branches retired**
 - **Sequence of short BBs (< 3 cycles in duration)**
 - **If branch into first overflows counter, Pebs event cannot occur until branch at end of 4th BB**
 - **Intervening branches will never be sampled**

Reducing Shadowing Impact

- Some “events” will never occur!
 - Falling into shadowed window
- Use LBR to extend range of the single sample
- Count the number of objects in LBR and increment count for all of them by $1/\text{NUM}$
 - Since you have only one sample

Minimizing Shadowing Impact on BB Execution Count



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Nested Loop with 8 Basic Blocks

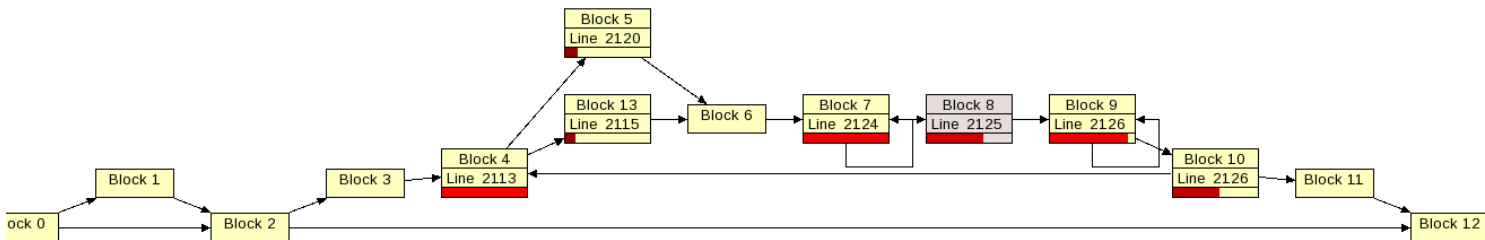
Intel(R) Performance Tuning Utility - quark_stuff4.c - Eclipse Platform

File Edit View Window Help

quark_stuff4.c

Event of Interest: BR_INST_RETIRED.ALL_BRANCHES

Source	CPU_C...	INST_R...	BR_I...	Address	Line	Assembly	CPU_C...	INST_R...	BR_I...	B...	CPU_C...
su3_projector_for_inline(&(ba...				Block 0			1			2	1
scalar_mult_add_su3_matrix(tm...				Block 1							
su3_projector_for_inline(&(ba...				Block 2							
scalar_mult_add_su3_matrix(tm...				Block 3							
}				Block 4	2...		4,689	1,936	914		4,689
}				Block 5	2...		11	6	140		11
/* Add in contribution to the for...				Block 6			384	241			384
/* Put antihermitian traceless pa...				Block 7	2...		1,909	2,757	904		1,909
/* This variant takes a list of p...				Block 8	2...		3,520	8,476	601		3,520
void add_3f_force_to_mom_pp(half...				Block 9	2...		2,025	4,228	830		2,025
half_wilson_vecto...				Block 10	2...		4,335	10,516	487		4,335
int dir, float co...	1			Block 11							
register site *s ;				Block 12							
				Block 13	2...		53	60	116		53
Total Selected:	5,603	12,814	1,918	Total Selected (158 instructions):			3,520	8,476	601		3,520



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Basic Block Execution Counts

Basic Block	Instructions	inst ret	BB exec(inst)	br ret	lbr all	lbr tkn	expected
0	4	0	0	0	0	0	
1	8	0	0	0	0	0	
2	6	0	0	0	0	0	
3	8	0	0	0	0	0	
4	3	1036	345.33	914	9267	6286	1
5	2	6	3	140	5054	3167	0.5
6	11	241	21.91	0	9270	6287	1
7	40	2757	68.92	904	28312	19394	3
8	158	8476	53.65	601	9543	6726	1
9	40	4228	105.7	830	28602	19761	3
10	183	10516	57.46	487	9633	6727	1
11	3	0	0	0	5	2	
12	2	0	0	0	5	2	
13	5	60	12	116	4251	3122	0.5
					3990	2762	
tripcount			78.793	405.1429	9427.048	6480.952	
sav			2000000	200000	13333.3	13333.3	
loop executions			157587619	81028571	1.26E+08	86412482	

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Normalization = Tripcount

- Using `br_inst_retired.near_call` is difficult as the function is only called a few thousand times, while the hottest function is called \sim 1million times
- The true tripcount is 16384
- "call count" = `loop_executions/16384`

BB_exec(inst)	br_ret	lbr_all	lbr_tkn
9618.38	4945.59	7671.73	5274.2

**True Call Count from printf ~ 5750
(done with new 11.1 based build)**

Summary

- LBRs are very useful