

# 1 Large array benchmark

The size of data that must be analyzed keeps increasing year after year and the prize for DRAM are not getting cheaper. NVDIMM offer a lot of storage at a cheaper prize. This opens the opportunity to save money by offloading some of the data to the NVDIMM where the data will be analyzed the same way as the data on the DRAM. The downside to this strategy is that NVDIMM is slower than DRAM so the question is how much data can be offloaded to NVDIMM. If the user offload too much data to NVDIMM then the threads working on analyzing the data on DRAM will be idle while waiting for NVDIMM threads to complete.

The goal is to find a formula that can easily calculate how much data can be offloaded to the NVDIMM from DRAM. The time taken to perform calculation on NVDIMM must be equal to the amount of time it takes to run calculation on the remaining data on DRAM.

In order to use the formula one must measure the NVDIMM and DRAM speed using a benchmark made in a previous chapter where speed was measured when data was transferred from DRAM-DRAM and NVDIMM-NVDIMM simultaneously with different amount threads allocated to the different processes. By using using the speed from the benchmark in the formula below along with the size of the data that will be used in the calculation the user can easily calculate how much data can be transferred to NVDIMM without losing time. The formula only decide how much data can be allocated to NVDIMM with a certain amount of threads. This means that the user must probably use the formula several times where the number of NVDIMM threads varies from one to five in order to find the best combination of threads and data allocated to the NVDIMM process.

Formula

$$\frac{Total\_data - nvdim\_data}{dram\_speed} = \frac{nvdim\_data}{nvdim\_speed}$$
$$nvdim\_data = \frac{nvdim\_speed * Total\_data}{nvdim\_speed + dram\_speed}$$

Calculation

This program have an two dimensional array filled with data. The program start at element (1,1) of the array where it sum ups all of its eight neighbors and then takes the average. The result is stored in the same position in another two dimensional array. The program does this for

every element between (1,1) and (m-2,n-2). The programs repeats this process ten times and after each time the programs will swap both the DRAM arrays and NVDIMM array. The time is measured at the beginning of the process and at the end, this time is called `total_time` in the code. Each thread will also measure the time they takes to complete their own tasks, in the code this is called `individual_time`.

## 1.1 First version

There are two groups of threads that works in parallel in this program. The first group of threads works on the part of the data that is stored on DRAM and the other works on the data stored on NVDIMM. One thread in each group works on data that borders with the other group. In the DRAM group that is the thread with the highest `thread_id`. Each of the elements in the last row of data will have three neighbours that exist on the NVDIMM side. This means that the thread must access the NVDIMM in order to get the data. The NVDIMM thread with the lowest `thread_id` also have elements in the first row of data that have three neighbours that exist in DRAM that must be accessed by the thread directly.

Listing 1: First version

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```

1  while(k<K_length){
2      #pragma omp barrier
3      #pragma omp single
4      {
5          total_time[k] = mysecond();
6      }
7      //#pragma omp barrier
8      if( thread_id < dram_threads ){
9
10         //for the thread bordering on nvdimmm thread.
11         if( thread_id==(dram_threads-1) ){
12             individual_time[k][thread_id] = mysecond();
13             for( i=slice_start; i<slice_end-1; i++){
14                 for( j=1; j<nMinusOne; j++){
15                     temp = A[i-1][j-1] + A[i-1][j] + A[i-1][j+1]+
16                         A[i][j-1]      +      A[i][j+1]+
17                         A[i+1][j-1] + A[i+1][j] + A[i+1][j+1];
18                     B[i][j] = temp*inverseEigth;
19                 }
20             }

```

```

21
22     i = slice_end-1;
23     for( j=1; j<nMinusOne; j++){
24         temp = A[i-1][j-1] + A[i-1][j] + A[i-1][j+1]+
25               A[i][j-1]      +      A[i][j+1]+
26               D_RO(C)[i*n+j] + D_RO(C)[i*n+j] +
27               D_RO(C)[i*n+j];
28         B[i][j] = temp*inverseEigth;
29     }
30     individual_time[k][thread_id] = mysecond() -
31         individual_time[k][thread_id];
32 }else{
33     individual_time[k][thread_id] = mysecond();
34     for( i=slice_start; i<slice_end; i++){
35         for( j=1; j<nMinusOne; j++){
36             temp = A[i-1][j-1] + A[i-1][j] + A[i-1][j+1]+
37                   A[i][j-1]      +      A[i][j+1]+
38                   A[i+1][j-1] + A[i+1][j] + A[i+1][j+1];
39             B[i][j] = temp*inverseEigth;
40         }
41     }
42     individual_time[k][thread_id] = mysecond() -
43         individual_time[k][thread_id];
44 }
45 }
46 }else{
47     if( thread_id==dram_threads ){
48         individual_time[k][thread_id] = mysecond();
49         i=0;
50         for( j=1; j<nMinusOne; j++){
51             temp =
52                 A[dram_part-1][j-1]+A[dram_part-1][j]+A[dram_part-1][j+1]+
53                 D_RO(C)[i*n+(j-1)]      +
54                 D_RO(C)[i*n+(j+1)]+
55                 D_RO(C)[(i+1)*n+(j-1)] + D_RO(C)[(i+1)*n+j]
56                 + D_RO(C)[(i+1)*n+(j+1)];
57             D_RW(D)[i*n+j] = temp*inverseEigth;
58         }
59         for( i=slice_start+1; i<slice_end-1; i++){
60             for( j=1; j<nMinusOne; j++){
61                 temp = D_RO(C)[(i-1)*n+(j-1)] +
62                       D_RO(C)[(i-1)*n+j] + D_RO(C)[(i-1)*n+(j+1)]+
63                       D_RO(C)[i*n+(j-1)]      +
64                       D_RO(C)[i*n+(j+1)]+

```

```

56         D_RO(C) [(i+1)*n+(j+1)] +
           D_RO(C) [(i+1)*n+j] +
           D_RO(C) [(i+1)*n+(j+1)];
57         D_RW(D) [i*n+j] = temp*inverseEigth;
58     }
59 }
60     individual_time[k][thread_id] = mysecond() -
        individual_time[k][thread_id];
61 }else{
62     individual_time[k][thread_id] = mysecond();
63     for( i=slice_start; i<slice_end; i++){
64         for( j=1; j<nMinusOne; j++){
65             temp = D_RO(C) [(i-1)*n+(j-1)] +
                   D_RO(C) [(i-1)*n+j] + D_RO(C) [(i-1)*n+(j+1)] +
66                   D_RO(C) [i*n+(j-1)] +
                   D_RO(C) [i*n+(j+1)] +
67                   D_RO(C) [(i+1)*n+(j-1)] +
                   D_RO(C) [(i+1)*n+j] +
                   D_RO(C) [(i+1)*n+(j+1)];
68             D_RW(D) [i*n+j] = temp*inverseEigth;
69         }
70     }
71     individual_time[k][thread_id] = mysecond() -
        individual_time[k][thread_id];
72 }
73 }
74 #pragma omp barrier
75 #pragma omp single
76 {
77     tempArray = B;
78     B=A;
79     A=tempArray;
80     total_time[k] = mysecond() - total_time[k];
81     temp_nvdim = C;
82     C = D;
83     D = temp_nvdim;
84     k++;
85 }
86 #pragma omp barrier
87 }//End of while

```

---

m	2,000			
n	500,000			
total M	8,000			
speed				
Nvm-th	dram	nvm	nvm par	rows
1	64,447	3,248	383.84	48
2	61,872	6,500	760.55	95
3	58,423	9,979	1167.10	146
4	55,367	13,416	1560.39	195
5	51,955	16,933	1966.44	246
6	48,656	20,438	2366.40	296

Table 1: First version, distribution

		<u>nvdimm</u>	dram	<u>nvdimm</u>	dram	dram	dram	<u>nvdimm</u>	<u>nvdimm</u>	<u>nvdimm</u>	total	total	total		
m	n	length	threads	threads	average	min	max	average	min	max	average	min	max		
2000	500000	48	15	1	0.3885	0.3645	0.4543	0.3533	0.3519	0.3597	0.4340	0.3967	0.4543		
0.3912	0.3925	0.3939	0.3952	0.3897	0.3878	0.3896	0.3927	0.3930	0.3936	0.3913	0.3928	0.3930	0.3929	0.3934	0.3525
0.4034	0.3877	0.3892	0.3905	0.3843	0.3832	0.3865	0.3895	0.3922	0.3933	0.3887	0.3891	0.3906	0.3924	0.4057	0.3524
0.4130	0.3893	0.3907	0.3922	0.3865	0.3844	0.3863	0.3895	0.3899	0.3905	0.3877	0.3898	0.3900	0.3898	0.3896	0.3546
0.3895	0.3902	0.3914	0.3928	0.3868	0.3857	0.3890	0.3918	0.3944	0.3954	0.3910	0.3914	0.3966	0.3947	0.3951	0.3525
0.3779	0.3791	0.3805	0.3863	0.3761	0.3742	0.3763	0.3793	0.3796	0.3850	0.3774	0.3794	0.4028	0.4475	0.4543	0.3524
0.3672	0.3693	0.3707	0.3720	0.3659	0.3645	0.3681	0.3712	0.3740	0.3752	0.3974	0.4315	0.4428	0.4240	0.4046	0.3597
0.3678	0.3694	0.3705	0.3768	0.3658	0.3701	0.3661	0.3695	0.4070	0.4477	0.4397	0.4198	0.3837	0.3698	0.3699	0.3519
0.3673	0.3746	0.3760	0.3728	0.3660	0.3646	0.4088	0.4433	0.4333	0.4163	0.3801	0.3708	0.3729	0.3749	0.3751	0.3522
0.3673	0.3688	0.3704	0.3720	0.4135	0.4508	0.4356	0.4121	0.3784	0.3755	0.3668	0.3692	0.3695	0.3695	0.3696	0.3521
0.3672	0.3772	0.4225	0.4514	0.4256	0.4023	0.3682	0.3720	0.3752	0.3763	0.3710	0.3774	0.3790	0.3755	0.3755	0.3522
		1	2	3	4	5	6	7	8	9	10				
Total Time		0.3952	0.4057	0.4130	0.3967	0.4543	0.4428	0.4477	0.4433	0.4508	0.4514				
		<u>nvdimm</u>	dram	<u>nvdimm</u>	dram	dram	dram	<u>nvdimm</u>	<u>nvdimm</u>	<u>nvdimm</u>	total	total	total		
m	n	length	threads	threads	average	min	max	average	min	max	average	min	max		
2000	500000	95	14	2	0.3894	0.3657	0.4669	0.3491	0.3424	0.3587	0.4439	0.4163	0.4669		
0.3918	0.3917	0.3917	0.3902	0.3911	0.3916	0.3918	0.3867	0.3907	0.3897	0.3921	0.3928	0.3906	0.4184	0.3520	0.3429
0.3868	0.3910	0.3909	0.3895	0.3878	0.3876	0.3881	0.3871	0.3905	0.3890	0.3891	0.3893	0.3911	0.4163	0.3534	0.3430
0.3855	0.3903	0.3902	0.3887	0.3895	0.3901	0.3902	0.3855	0.3893	0.3883	0.3907	0.3915	0.4205	0.4016	0.3585	0.3430
0.3697	0.3737	0.3737	0.3723	0.3706	0.3705	0.3711	0.3695	0.3735	0.3722	0.3941	0.4305	0.4536	0.4355	0.3518	0.3428
0.3699	0.3743	0.3743	0.3729	0.3737	0.3744	0.3743	0.3694	0.3966	0.4263	0.4489	0.4329	0.3867	0.3720	0.3579	0.3487
0.3657	0.3705	0.3703	0.3686	0.3668	0.3667	0.4032	0.4447	0.4458	0.4266	0.3871	0.3728	0.3707	0.3743	0.3515	0.3424
0.3726	0.3772	0.3769	0.3712	0.4089	0.4394	0.4318	0.4115	0.3865	0.3757	0.3733	0.3743	0.3767	0.3700	0.3516	0.3425
0.3920	0.3685	0.4053	0.4493	0.4410	0.4157	0.3810	0.3690	0.3679	0.3663	0.3661	0.3714	0.3687	0.3725	0.3587	0.3424
0.4344	0.4545	0.4447	0.4036	0.3795	0.3718	0.3760	0.3666	0.3706	0.3695	0.3720	0.3729	0.3705	0.3692	0.3516	0.3494
0.4669	0.4094	0.3828	0.3814	0.3797	0.3794	0.3800	0.3786	0.3824	0.3812	0.3810	0.3815	0.3830	0.3868	0.3519	0.3427
		1	2	3	4	5	6	7	8	9	10				
Total Time		0.4184	0.4163	0.4205	0.4536	0.4489	0.4458	0.4394	0.4493	0.4545	0.4669				

Table 2: First version part 1

		<u>nvdimm</u>	<u>dram</u>	<u>nvdimm</u>	<u>dram</u>	<u>dram</u>	<u>dram</u>	<u>nvdimm</u>	<u>nvdimm</u>	<u>nvdimm</u>	<u>total</u>	<u>total</u>	<u>total</u>		
m	n	length	threads	threads	average	min	max	average	min	max	average	min	max		
2000	500000	146	13	3	0.3888	0.3699	0.4589	0.3577	0.3502	0.3700	0.4221	0.3953	0.4590		
0.3889	0.3857	0.4451	0.3845	0.3876	0.3901	0.3878	0.3848	0.3806	0.3821	0.3798	0.3807	0.3828	0.3616	0.3580	0.3502
0.3880	0.4019	0.3909	0.3890	0.3893	0.3923	0.3921	0.3939	0.3865	0.3877	0.3853	0.3865	0.3883	0.3616	0.3671	0.3505
0.4303	0.4589	0.4298	0.3747	0.3780	0.3805	0.3781	0.3750	0.3709	0.3723	0.3699	0.3709	0.3731	0.3700	0.3579	0.3584
0.3971	0.4157	0.3864	0.3848	0.3852	0.3880	0.3882	0.3899	0.3822	0.3834	0.3803	0.3819	0.3839	0.3613	0.3585	0.3505
0.3889	0.3915	0.3915	0.3899	0.3926	0.3953	0.3931	0.3903	0.3862	0.3877	0.3849	0.3863	0.3883	0.3615	0.3581	0.3504
0.4231	0.3859	0.3917	0.3841	0.3846	0.3873	0.3875	0.3894	0.3815	0.3828	0.3801	0.3811	0.3832	0.3616	0.3592	0.3505
0.4006	0.3868	0.3873	0.3853	0.3886	0.3947	0.3888	0.3860	0.3817	0.3830	0.3803	0.3818	0.4215	0.3615	0.3581	0.3502
0.3789	0.3857	0.3822	0.3800	0.3806	0.3835	0.3837	0.3854	0.3817	0.3784	0.3754	0.4199	0.4330	0.3630	0.3580	0.3503
0.3795	0.3820	0.3824	0.3802	0.3837	0.3865	0.3880	0.3853	0.3761	0.3778	0.4067	0.4231	0.3976	0.3614	0.3583	0.3502
0.3774	0.3800	0.3804	0.3782	0.3791	0.3859	0.3822	0.3839	0.3752	0.4043	0.4265	0.4062	0.3768	0.3614	0.3579	0.3503
		1	2	3	4	5	6	7	8	9	10				
Total Time		0.4451	0.4019	0.4590	0.4158	0.3953	0.4231	0.4215	0.4330	0.4232	0.4265				
		<u>nvdimm</u>	<u>dram</u>	<u>nvdimm</u>	<u>dram</u>	<u>dram</u>	<u>dram</u>	<u>nvdimm</u>	<u>nvdimm</u>	<u>nvdimm</u>	<u>total</u>	<u>total</u>	<u>total</u>		
m	n	length	threads	threads	average	min	max	average	min	max	average	min	max		
2000	500000	195	12	4	0.3940	0.3676	0.4916	0.3568	0.3494	0.3673	0.4344	0.3984	0.4916		
0.3872	0.3868	0.3872	0.3893	0.3872	0.3894	0.4412	0.3909	0.3868	0.3812	0.3883	0.3935	0.3610	0.3568	0.3570	0.3497
0.3875	0.3875	0.3879	0.3894	0.3882	0.4464	0.3956	0.3937	0.3925	0.3849	0.3864	0.3992	0.3608	0.3570	0.3571	0.3502
0.3740	0.3735	0.3868	0.4345	0.4916	0.4548	0.3763	0.3776	0.3739	0.3680	0.3750	0.3804	0.3673	0.3641	0.3645	0.3496
0.3703	0.4364	0.4566	0.4436	0.3955	0.3708	0.3742	0.3725	0.3813	0.3676	0.3752	0.3783	0.3604	0.3565	0.3567	0.3498
0.4774	0.4403	0.4076	0.3818	0.3740	0.3764	0.3756	0.3781	0.3739	0.3679	0.3753	0.3806	0.3599	0.3566	0.3567	0.3494
0.3949	0.3917	0.3927	0.3938	0.3904	0.3926	0.3951	0.3938	0.3972	0.3894	0.3911	0.3993	0.3608	0.3569	0.3572	0.3497
0.3928	0.3923	0.3929	0.3969	0.3925	0.3947	0.3936	0.3960	0.3925	0.3864	0.3936	0.3984	0.3606	0.3570	0.3635	0.3498
0.4121	0.3897	0.3904	0.3917	0.3881	0.3904	0.3928	0.3915	0.3948	0.3876	0.3889	0.3967	0.3609	0.3569	0.3572	0.3497
0.3939	0.3924	0.3931	0.3949	0.3928	0.3948	0.3940	0.3964	0.3923	0.3867	0.3939	0.3986	0.3606	0.3569	0.3569	0.3500
0.3903	0.3900	0.3906	0.3918	0.3884	0.3907	0.3934	0.3917	0.3951	0.3877	0.3893	0.4295	0.3607	0.3571	0.3572	0.3499
		1	2	3	4	5	6	7	8	9	10				
Total Time		0.4413	0.4464	0.4916	0.4566	0.4774	0.3993	0.3984	0.4122	0.3986	0.4295				

Table 3: First version part 2

		<u>nvdimm</u>	<u>dram</u>	<u>nvdimm</u>	<u>dram</u>	<u>dram</u>	<u>dram</u>	<u>nvdimm</u>	<u>nvdimm</u>	<u>nvdimm</u>	<u>total</u>	<u>total</u>	<u>total</u>		
m	n	length	threads	threads	average	min	max	average	min	max	average	min	max		
2000	500000	249	11	5	0.3958	0.3780	0.4837	0.3640	0.3566	0.3763	0.4353	0.3978	0.4838		
0.3933	0.4028	0.4028	0.3949	0.3975	0.3980	0.3908	0.3948	0.3971	0.3903	0.3906	0.3687	0.3642	0.3640	0.3641	0.3568
0.4526	0.4837	0.3859	0.3833	0.3843	0.3831	0.3780	0.3817	0.3909	0.3802	0.3863	0.3683	0.3640	0.3639	0.3639	0.3570
0.3931	0.4026	0.3975	0.3950	0.3974	0.3982	0.3908	0.3949	0.3972	0.3902	0.3905	0.3686	0.3642	0.3640	0.3642	0.3568
0.3937	0.3973	0.3978	0.3957	0.3967	0.3957	0.3906	0.3943	0.3975	0.3932	0.3921	0.3687	0.3644	0.3641	0.3641	0.3569
0.4338	0.3926	0.3934	0.3906	0.3931	0.3939	0.3865	0.3907	0.3928	0.3860	0.3859	0.3763	0.3641	0.3663	0.3639	0.3571
0.4147	0.3912	0.3924	0.3900	0.3942	0.3895	0.3845	0.3883	0.3919	0.3868	0.4391	0.3684	0.3643	0.3641	0.3640	0.3567
0.3882	0.3907	0.3918	0.3888	0.3915	0.3958	0.3842	0.3888	0.3911	0.4121	0.4316	0.3686	0.3642	0.3641	0.3640	0.3570
0.3840	0.3878	0.3888	0.3902	0.3872	0.3859	0.3809	0.3845	0.3967	0.4386	0.4173	0.3698	0.3642	0.3640	0.3639	0.3567
0.3851	0.3922	0.3896	0.3869	0.3892	0.3936	0.3823	0.3867	0.4401	0.4237	0.3822	0.3684	0.3640	0.3639	0.3639	0.3569
0.3825	0.3866	0.3874	0.3848	0.3859	0.3847	0.3796	0.4454	0.4502	0.3817	0.3814	0.3737	0.3642	0.3694	0.3640	0.3566
		1	2	3	4	5	6	7	8	9	10				
Total Time		0.4029	0.4838	0.4027	0.3978	0.4339	0.4391	0.4316	0.4387	0.4401	0.4502				
		<u>nvdimm</u>	<u>dram</u>	<u>nvdimm</u>	<u>dram</u>	<u>dram</u>	<u>dram</u>	<u>nvdimm</u>	<u>nvdimm</u>	<u>nvdimm</u>	<u>total</u>	<u>total</u>	<u>total</u>		
m	n	length	threads	threads	average	min	max	average	min	max	average	min	max		
2000	500000	296	10	6	0.4046	0.3759	0.4938	0.3636	0.3559	0.3718	0.4588	0.4176	0.4938		
0.3955	0.3975	0.3966	0.3952	0.3950	0.3925	0.3888	0.3954	0.4560	0.4029	0.3663	0.3643	0.3636	0.3636	0.3637	0.3563
0.3972	0.4042	0.3982	0.4010	0.3952	0.3976	0.3936	0.4387	0.4020	0.4072	0.3664	0.3645	0.3639	0.3638	0.3637	0.3564
0.3902	0.3880	0.3866	0.3853	0.3851	0.3823	0.4310	0.4938	0.4322	0.3932	0.3663	0.3640	0.3635	0.3635	0.3635	0.3560
0.4035	0.4008	0.3987	0.4020	0.4015	0.3982	0.4024	0.4176	0.4029	0.4031	0.3666	0.3657	0.3651	0.3662	0.3645	0.3571
0.3899	0.3861	0.3849	0.3879	0.4284	0.4597	0.4791	0.3838	0.3861	0.3908	0.3663	0.3645	0.3635	0.3635	0.3634	0.3560
0.3851	0.3865	0.4013	0.4532	0.4722	0.4464	0.3759	0.3840	0.3846	0.3848	0.3718	0.3638	0.3635	0.3634	0.3634	0.3559
0.3903	0.3925	0.4086	0.4614	0.3996	0.3872	0.3836	0.3900	0.3921	0.3974	0.3689	0.3650	0.3633	0.3637	0.3660	0.3560
0.3911	0.4367	0.4468	0.3947	0.3888	0.3962	0.3874	0.3949	0.3998	0.3959	0.3665	0.3641	0.3637	0.3637	0.3705	0.3562
0.4742	0.4694	0.4422	0.3812	0.3807	0.3786	0.3812	0.3814	0.3835	0.3886	0.3662	0.3642	0.3634	0.3634	0.3635	0.3628
0.4453	0.4128	0.3897	0.3926	0.3865	0.3894	0.3852	0.3928	0.3935	0.4432	0.3660	0.3640	0.3636	0.3636	0.3636	0.3609
		1	2	3	4	5	6	7	8	9	10				
Total Time		0.4560	0.4387	0.4938	0.4176	0.4792	0.4723	0.4614	0.4468	0.4742	0.4453				

Table 4: First version part 3

		<u>dram</u>	<u>dram</u>	<u>dram</u>	<u>dram</u>	<u>total</u>	<u>total</u>	<u>total</u>							
m	n	threads	average	min	max	average	min	max							
2000	500000	16	0.3936	0.3809	0.4436	0.4255	0.4005	0.4436							
0.3978	0.3983	0.3987	0.3967	0.3966	0.3943	0.3956	0.3961	0.3946	0.3989	0.3980	0.3934	0.3957	0.3999	0.4001	0.3949
0.3969	0.3979	0.3983	0.3964	0.3961	0.3947	0.4004	0.3960	0.3944	0.3968	0.3965	0.3935	0.3955	0.3997	0.3993	0.3932
0.4262	0.3933	0.3936	0.3915	0.3913	0.3890	0.3906	0.3909	0.3893	0.3938	0.3929	0.3881	0.3905	0.3949	0.3950	0.3897
0.3943	0.3986	0.3959	0.3940	0.3935	0.3919	0.3941	0.3935	0.3919	0.3946	0.3938	0.3905	0.3930	0.3973	0.3963	0.4255
0.3976	0.3992	0.3961	0.3939	0.3937	0.3913	0.3929	0.3935	0.3915	0.3967	0.3953	0.3907	0.3927	0.3971	0.3990	0.4093
0.3873	0.3875	0.3884	0.3857	0.3858	0.3842	0.3864	0.3858	0.3837	0.3869	0.3900	0.3830	0.3853	0.4007	0.4436	0.4211
0.3868	0.3876	0.3883	0.3860	0.3895	0.3831	0.3847	0.3848	0.3879	0.3884	0.3869	0.3822	0.4012	0.4353	0.4240	0.3842
0.3846	0.3859	0.3864	0.3846	0.3840	0.3824	0.3883	0.3839	0.3819	0.3850	0.3845	0.4074	0.4318	0.4244	0.3876	0.3809
0.3869	0.3877	0.3880	0.3858	0.3856	0.3830	0.3839	0.3845	0.3826	0.3887	0.4105	0.4239	0.4100	0.3893	0.3935	0.3887
0.3849	0.3905	0.3870	0.3851	0.3849	0.3832	0.3856	0.3843	0.3829	0.4121	0.4335	0.4059	0.3882	0.3889	0.3881	0.3825
Total time		0.4001	0.4005	0.4262	0.4255	0.4093	0.4436	0.4353	0.4318	0.4240	0.4335				

Table 5: First version, dram only



## 1.2 Second version

Same as the first version there are two groups of threads that works in parallel in this program. The first group of threads works on the part of the data that is stored on DRAM and the other works on the data stored on NVDIMM. In this version the two threads that has a row of elements with neighbours in the other type of memory will not directly access this data. Instead the two arrays will have their own ghost array on their memory that they will access instead of fetching data from the other side.

Listing 2: Second version

---

```
1 while(k<K_length){
2     #pragma omp barrier
3     #pragma omp single
4     {
5         total_time[k] = mysecond();
6     }
7     if( thread_id < dram_threads ){
8         individual_time[k][thread_id] = mysecond();
9         for( i=slice_start; i<slice_end; i++){
10             for( j=1; j<nMinusOne; j++){
11                 temp = A[i-1][j-1] + A[i-1][j] + A[i-1][j+1]+
12                     A[i][j-1] + A[i][j+1]+
13                     A[i+1][j-1] + A[i+1][j] + A[i+1][j+1];
14                 B[i][j] = temp*inverseEigth;
15             }
16         }
17         individual_time[k][thread_id] = mysecond() -
18             individual_time[k][thread_id];
19     }else{
20         individual_time[k][thread_id] = mysecond();
21         for( i=slice_start; i<slice_end; i++){
22             for( j=1; j<nMinusOne; j++){
23                 temp = D_RO(C)[(i-1)*n+(j-1)] +
24                     D_RO(C)[(i-1)*n+j] + D_RO(C)[(i-1)*n+(j+1)]+
25                     D_RO(C)[i*n+(j-1)] +
26                     D_RO(C)[i*n+(j+1)]+
27                     D_RO(C)[(i+1)*n+(j-1)] + D_RO(C)[(i+1)*n+j]
28                     + D_RO(C)[(i+1)*n+(j+1)];
29                 D_RW(D)[i*n+j] = temp*inverseEigth;
30             }
31         }
32     }
```



```

28     individual_time[k][thread_id] = mysecond() -
        individual_time[k][thread_id];
29 }
30 total_time[k] = mysecond() - total_time[k];
31 #pragma omp barrier
32 #pragma omp single
33 {
34     tempArray = B;
35     B=A;
36     A=tempArray;
37     total_time[k] = mysecond() - total_time[k];
38     temp_nvdim = C;
39     C = D;
40     D = temp_nvdim;
41     k++;
42 }
43 #pragma omp barrier
44 } //End of while

```

---

m	2,000			
n	500,000			
total M	8,000			
speed				
Nvm-th	dram	nvm	nvm par	rows
1	64,447	3,248	383.84	48
2	61,872	6,500	760.55	95
3	58,423	9,979	1167.10	146
4	55,367	13,416	1560.39	195
5	51,955	16,933	1966.44	246
6	48,656	20,438	2366.40	296

Table 6: First version, distribution

m	n	<u>nvdimm</u> length	<u>dram</u> threads	<u>nvdimm</u> threads	<u>dram</u> average	<u>dram</u> min	<u>dram</u> max	<u>nvdimm</u> average	<u>nvdimm</u> min	<u>nvdimm</u> max	<u>total</u> average	<u>total</u> min	<u>total</u> max		
2000	500000	48	15	1	0.3912	0.3664	0.4737	0.3752	0.3746	0.3777	0.4105	0.3795	0.4513		
0.3898	0.3949	0.3940	0.3943	0.3967	0.3970	0.3972	0.3900	0.3955	0.3957	0.3942	0.3918	0.3925	0.3928	0.3924	0.3762
0.4004	0.3938	0.3926	0.3925	0.3938	0.3924	0.3932	0.3874	0.3916	0.3950	0.3935	0.3947	0.3955	0.3959	0.3958	0.3777
0.4274	0.3900	0.3893	0.3893	0.3918	0.3918	0.3922	0.3846	0.3907	0.3907	0.3893	0.3865	0.3877	0.3879	0.3876	0.3751
0.3881	0.3943	0.3975	0.3931	0.3944	0.3934	0.3939	0.3885	0.3924	0.3956	0.3943	0.3955	0.3962	0.3965	0.3974	0.3753
0.3822	0.3879	0.3826	0.3826	0.3852	0.3896	0.3858	0.3778	0.3882	0.3840	0.3826	0.3796	0.3825	0.4412	0.4703	0.3749
0.3676	0.3775	0.3720	0.3718	0.3727	0.3768	0.3725	0.3664	0.3758	0.3744	0.3876	0.4354	0.4737	0.4256	0.4041	0.3747
0.3667	0.3726	0.3716	0.3768	0.3791	0.3747	0.3753	0.3669	0.3966	0.4519	0.4643	0.4176	0.3806	0.3755	0.3693	0.3747
0.3683	0.3799	0.3736	0.3732	0.3749	0.3789	0.4014	0.4407	0.4521	0.4170	0.3759	0.3766	0.3772	0.3777	0.3771	0.3747
0.3688	0.3739	0.3732	0.3732	0.4077	0.4609	0.4603	0.4089	0.3745	0.3789	0.3731	0.3704	0.3715	0.3720	0.3713	0.3746
0.3683	0.3744	0.4100	0.4600	0.4436	0.4035	0.3737	0.3679	0.3721	0.3759	0.3741	0.3757	0.3765	0.3822	0.3764	0.3747
		1	2	3	4	5	6	7	8	9	10				
Total Time		0.3786	0.3843	0.3808	0.3795	0.4310	0.4008	0.4231	0.4159	0.4513	0.4277				
m	n	<u>nvdimm</u> length	<u>dram</u> threads	<u>nvdimm</u> threads	<u>dram</u> average	<u>dram</u> min	<u>dram</u> max	<u>nvdimm</u> average	<u>nvdimm</u> min	<u>nvdimm</u> max	<u>total</u> average	<u>total</u> min	<u>total</u> max		
2000	500000	95	14	2	0.3915	0.3656	0.4667	0.3724	0.3664	0.3812	0.3921	0.3760	0.4177		
0.3912	0.3885	0.3874	0.3871	0.4204	0.3922	0.3921	0.3915	0.3885	0.3912	0.3932	0.3924	0.3918	0.3925	0.3759	0.3667
0.3859	0.3900	0.3889	0.4066	0.4126	0.3897	0.3915	0.3900	0.3904	0.3891	0.3909	0.3899	0.3941	0.3900	0.3775	0.3670
0.3744	0.3988	0.4403	0.4660	0.3823	0.3818	0.3863	0.3812	0.3778	0.3808	0.3876	0.3864	0.3816	0.3824	0.3747	0.3667
0.4342	0.4650	0.4326	0.3793	0.3747	0.3739	0.3759	0.3746	0.3747	0.3730	0.3751	0.3739	0.3738	0.3742	0.3745	0.3735
0.4264	0.3902	0.3850	0.3837	0.3904	0.3905	0.3903	0.3900	0.3863	0.3897	0.3918	0.3907	0.3903	0.3910	0.3747	0.3668
0.3898	0.3934	0.3923	0.3903	0.3938	0.3932	0.3951	0.3937	0.3938	0.3926	0.3944	0.3935	0.3931	0.4074	0.3748	0.3743
0.3802	0.3787	0.3773	0.3754	0.3820	0.3820	0.3864	0.3813	0.3786	0.3809	0.3879	0.4026	0.4373	0.4667	0.3747	0.3669
0.3716	0.3740	0.3728	0.3706	0.3748	0.3786	0.3759	0.3792	0.3750	0.3935	0.4215	0.4566	0.4304	0.3871	0.3745	0.3737
0.3656	0.3692	0.3680	0.3661	0.3729	0.3726	0.3774	0.3979	0.4285	0.4576	0.4393	0.3856	0.3773	0.3731	0.3812	0.3664
0.3704	0.3742	0.3775	0.3705	0.3747	0.3970	0.4297	0.4426	0.4307	0.3913	0.3795	0.3741	0.3735	0.3739	0.3746	0.3665
		1	2	3	4	5	6	7	8	9	10				
Total Time		0.3833	0.3895	0.4177	0.3791	0.3786	0.3930	0.4071	0.3893	0.3987	0.3760				

Table 7: First version part 1

		<u>nvdimm</u>	<u>dram</u>	<u>nvdimm</u>	<u>dram</u>	<u>dram</u>	<u>dram</u>	<u>nvdimm</u>	<u>nvdimm</u>	<u>nvdimm</u>	<u>total</u>	<u>total</u>	<u>total</u>		
m	n	length	threads	threads	average	min	max	average	min	max	average	min	max		
2000	500000	146	13	3	0.3905	0.3612	0.4555	0.3802	0.3737	0.3893	0.4088	0.3805	0.4319		
0.3891	0.3870	0.3869	0.3859	0.3906	0.3882	0.3887	0.3887	0.4345	0.3871	0.3861	0.3854	0.3801	0.3837	0.3821	0.3741
0.3857	0.3881	0.3886	0.3871	0.3921	0.3905	0.3915	0.4144	0.3964	0.3939	0.3928	0.3911	0.3832	0.3848	0.3823	0.3742
0.3770	0.3793	0.3793	0.3784	0.3870	0.3908	0.4339	0.4423	0.4091	0.3834	0.3785	0.3780	0.3733	0.3820	0.3823	0.3740
0.3642	0.3669	0.3671	0.3656	0.4193	0.4446	0.4477	0.4163	0.3753	0.3730	0.3718	0.3699	0.3612	0.3819	0.3819	0.3739
0.3692	0.3710	0.4167	0.4468	0.4423	0.4154	0.3781	0.3730	0.3704	0.3713	0.3703	0.3698	0.3646	0.3817	0.3817	0.3877
0.4038	0.4555	0.4417	0.4106	0.3781	0.3703	0.3719	0.3719	0.3728	0.3788	0.3731	0.3712	0.3676	0.3819	0.3817	0.3737
0.3868	0.4170	0.3890	0.3881	0.3925	0.3903	0.3907	0.3908	0.3880	0.3889	0.3883	0.3878	0.3831	0.3823	0.3822	0.3741
0.3876	0.3908	0.3904	0.3888	0.3943	0.3925	0.3935	0.3935	0.3946	0.3958	0.3948	0.3932	0.3852	0.3822	0.3821	0.3741
0.4279	0.3837	0.3838	0.3828	0.3872	0.3849	0.3898	0.3899	0.3827	0.3838	0.3830	0.3823	0.4202	0.3893	0.3821	0.3742
0.4017	0.3710	0.3713	0.3695	0.3758	0.3785	0.3751	0.3747	0.3759	0.3818	0.4072	0.4449	0.4469	0.3818	0.3817	0.3738
		1	2	3	4	5	6	7	8	9	10				
Total Time		0.3806	0.3825	0.4099	0.4319	0.4242	0.4293	0.3805	0.3811	0.4084	0.4316				
		<u>nvdimm</u>	<u>dram</u>	<u>nvdimm</u>	<u>dram</u>	<u>dram</u>	<u>dram</u>	<u>nvdimm</u>	<u>nvdimm</u>	<u>nvdimm</u>	<u>total</u>	<u>total</u>	<u>total</u>		
m	n	length	threads	threads	average	min	max	average	min	max	average	min	max		
2000	500000	195	12	4	0.3935	0.3649	0.4712	0.3810	0.3733	0.3886	0.4195	0.3831	0.4450		
0.3931	0.3950	0.3945	0.3977	0.3977	0.3975	0.3952	0.3927	0.3868	0.3861	0.3895	0.3949	0.3828	0.3816	0.3817	0.3739
0.3832	0.3858	0.3850	0.3876	0.3875	0.3852	0.3894	0.3922	0.3777	0.3777	0.4209	0.4407	0.3842	0.3873	0.3816	0.3798
0.3752	0.3775	0.3768	0.3842	0.3802	0.3799	0.3778	0.3748	0.4025	0.4481	0.4622	0.4075	0.3814	0.3814	0.3817	0.3734
0.3687	0.3719	0.3709	0.3779	0.3735	0.3709	0.4157	0.4712	0.4554	0.4164	0.3714	0.3725	0.3813	0.3812	0.3814	0.3792
0.3736	0.3753	0.3746	0.3825	0.4165	0.4539	0.4561	0.4085	0.3706	0.3653	0.3748	0.3753	0.3816	0.3814	0.3814	0.3792
0.3688	0.3714	0.4143	0.4642	0.4575	0.4245	0.3751	0.3739	0.3689	0.3681	0.3660	0.3722	0.3813	0.3876	0.3813	0.3733
0.3990	0.4542	0.4523	0.4161	0.3864	0.3772	0.3747	0.3718	0.3654	0.3649	0.3685	0.3787	0.3879	0.3813	0.3879	0.3734
0.4287	0.4312	0.3856	0.3865	0.3865	0.3837	0.3883	0.3874	0.3769	0.3764	0.3797	0.3855	0.3818	0.3816	0.3818	0.3736
0.3933	0.3949	0.3942	0.3975	0.3974	0.3971	0.3951	0.3925	0.3864	0.3862	0.3895	0.3948	0.3818	0.3817	0.3819	0.3738
0.4034	0.3891	0.3930	0.3908	0.3952	0.3882	0.3928	0.3914	0.3812	0.3811	0.3843	0.4331	0.3817	0.3816	0.3886	0.3737
		1	2	3	4	5	6	7	8	9	10				
Total Time		0.3812	0.4136	0.4370	0.4450	0.4343	0.4315	0.4234	0.4198	0.3831	0.3875				

Table 8: First version part 2

		<u>nvdim</u>	<u>dram</u>	<u>nvdim</u>	<u>dram</u>	<u>dram</u>	<u>dram</u>	<u>nvdim</u>	<u>nvdim</u>	<u>nvdim</u>	<u>total</u>	<u>total</u>	<u>total</u>		
m	n	length	threads	threads	average	min	max	average	min	max	average	min	max		
2000	500000	249	11	5	0.3970	0.3809	0.4542	0.3881	0.3813	0.3950	0.4074	0.3864	0.4319		
0.4362	0.4061	0.3946	0.3900	0.3927	0.3948	0.3943	0.3912	0.3968	0.3988	0.3929	0.3905	0.3897	0.3894	0.3895	0.3816
0.3948	0.3992	0.3976	0.3934	0.3943	0.3985	0.3980	0.3928	0.3957	0.3975	0.4004	0.3920	0.3896	0.3895	0.3894	0.3816
0.3951	0.3993	0.3977	0.3931	0.3959	0.3981	0.3976	0.3943	0.3999	0.4019	0.3960	0.3895	0.3897	0.3893	0.3894	0.3816
0.4186	0.4012	0.3981	0.3898	0.3906	0.3952	0.3946	0.3892	0.3921	0.3942	0.3971	0.3895	0.3896	0.3894	0.3894	0.3817
0.4542	0.3888	0.3874	0.3822	0.3848	0.3912	0.3870	0.3833	0.3896	0.3916	0.4358	0.3895	0.3894	0.3891	0.3892	0.3813
0.3867	0.3912	0.3897	0.3851	0.3866	0.3907	0.3940	0.3844	0.3879	0.4200	0.4443	0.3893	0.3893	0.3892	0.3892	0.3815
0.3868	0.3911	0.3901	0.3850	0.3875	0.3902	0.3894	0.3860	0.3987	0.4424	0.4184	0.3893	0.3894	0.3893	0.3893	0.3813
0.3827	0.3916	0.3859	0.3809	0.3824	0.3870	0.3864	0.4064	0.4510	0.4353	0.3885	0.3893	0.3894	0.3945	0.3893	0.3837
0.3814	0.3861	0.3845	0.3839	0.3818	0.3848	0.4062	0.4530	0.4451	0.3885	0.3825	0.3894	0.3893	0.3892	0.3892	0.3814
0.3853	0.3902	0.3887	0.3837	0.3850	0.3897	0.4432	0.4232	0.3868	0.3888	0.3914	0.3950	0.3895	0.3892	0.3891	0.3814
		1	2	3	4	5	6	7	8	9	10				
Total Time		0.3924	0.3881	0.3864	0.3892	0.4319	0.4106	0.4044	0.4166	0.4249	0.4139				
		<u>nvdim</u>	<u>dram</u>	<u>nvdim</u>	<u>dram</u>	<u>dram</u>	<u>dram</u>	<u>nvdim</u>	<u>nvdim</u>	<u>nvdim</u>	<u>total</u>	<u>total</u>	<u>total</u>		
m	n	length	threads	threads	average	min	max	average	min	max	average	min	max		
2000	500000	296	10	6	0.4015	0.3822	0.4758	0.3882	0.3811	0.3918	0.4100	0.3906	0.4451		
0.4560	0.4074	0.4008	0.3978	0.4002	0.3994	0.3924	0.3929	0.3939	0.3942	0.3904	0.3894	0.3892	0.3893	0.3894	0.3814
0.4021	0.4124	0.4026	0.4001	0.4008	0.3999	0.3958	0.3957	0.3967	0.3970	0.3918	0.3896	0.3893	0.3892	0.3894	0.3815
0.4036	0.4052	0.4037	0.4008	0.4032	0.4026	0.3956	0.3958	0.3967	0.3971	0.3894	0.3897	0.3894	0.3893	0.3894	0.3815
0.4190	0.4024	0.4008	0.3982	0.4030	0.4032	0.3939	0.3940	0.3950	0.3956	0.3894	0.3895	0.3893	0.3893	0.3894	0.3815
0.4687	0.3973	0.3923	0.3893	0.3919	0.3912	0.3838	0.3841	0.3850	0.4330	0.3892	0.3893	0.3892	0.3892	0.3892	0.3861
0.3930	0.3950	0.3933	0.3907	0.3913	0.3908	0.3857	0.3864	0.4278	0.4611	0.3891	0.3892	0.3891	0.3890	0.3892	0.3864
0.3924	0.3943	0.3966	0.3893	0.3920	0.3915	0.3832	0.4220	0.4591	0.4082	0.3890	0.3893	0.3890	0.3891	0.3891	0.3811
0.3933	0.3958	0.3940	0.3911	0.3916	0.3914	0.4021	0.4487	0.4150	0.3877	0.3891	0.3892	0.3891	0.3891	0.3892	0.3865
0.3951	0.4009	0.3957	0.3922	0.3949	0.3943	0.4441	0.4265	0.3872	0.3885	0.3891	0.3893	0.3892	0.3893	0.3891	0.3813
0.3888	0.3948	0.3895	0.3866	0.3980	0.4758	0.4524	0.3822	0.3832	0.3837	0.3890	0.3893	0.3890	0.3890	0.3891	0.3811
		1	2	3	4	5	6	7	8	9	10				
Total Time		0.3955	0.3906	0.3928	0.3914	0.4258	0.4210	0.4058	0.4049	0.4124	0.4451				

Table 9: First version part 3

### 1.3 From previous weeks

		dram	dram	dram	dram	total	total	total							
m	n	threads	average	min	max	average	min	max							
2000	500000	16	0.3957	0.3727	0.4556	0.3583	0.3727	0.4556							
0.3980	0.4009	0.4019	0.4002	0.4008	0.3996	0.3996	0.3985	0.4017	0.4021	0.4001	0.4004	0.3998	0.4007	0.4016	0.4011
0.3960	0.3989	0.4044	0.3982	0.4168	0.3974	0.3977	0.3967	0.3996	0.3998	0.3981	0.3981	0.3976	0.3987	0.3995	0.3990
0.3767	0.3798	0.4116	0.4453	0.4556	0.4198	0.3775	0.3837	0.3803	0.3806	0.3845	0.3794	0.3782	0.3846	0.3860	0.3796
0.4200	0.4542	0.4555	0.4154	0.3878	0.3796	0.3740	0.3727	0.3759	0.3768	0.3806	0.3745	0.3738	0.3811	0.3755	0.3756
0.4421	0.4166	0.3869	0.3878	0.3856	0.3838	0.3844	0.3831	0.3862	0.3870	0.3849	0.3853	0.3846	0.3856	0.3861	0.4287
0.3941	0.3960	0.4019	0.3955	0.3969	0.3991	0.3952	0.3947	0.3973	0.3978	0.3961	0.3962	0.3957	0.3967	0.4188	0.4104
0.3819	0.3893	0.3863	0.3882	0.3887	0.3828	0.3828	0.3819	0.3853	0.3858	0.3839	0.3844	0.3960	0.4323	0.4407	0.4164
0.3832	0.3855	0.3878	0.3900	0.3861	0.3897	0.3841	0.3838	0.3873	0.3878	0.3901	0.4097	0.4364	0.4274	0.3977	0.3861
0.3915	0.3885	0.3906	0.3883	0.3893	0.3877	0.3876	0.3868	0.3902	0.3906	0.4187	0.4331	0.4146	0.3888	0.3900	0.3892
0.3942	0.3974	0.3991	0.3971	0.3980	0.3959	0.3964	0.3956	0.3985	0.4031	0.3973	0.4151	0.3966	0.3978	0.3985	0.3978
0.3980	0.4009	0.4020	0.4002	0.4008	0.3996	0.3996	0.3985	0.4017	0.4021	0.4001	0.4004	0.3998	0.4007	0.4016	0.4011
0.3960	0.3989	0.4044	0.3982	0.4168	0.3974	0.3977	0.3967	0.3996	0.3998	0.3981	0.3981	0.3976	0.3987	0.3995	0.3990
0.3767	0.3798	0.4116	0.4453	0.4556	0.4198	0.3775	0.3837	0.3803	0.3806	0.3845	0.3794	0.3782	0.3846	0.3860	0.3796
0.4200	0.4542	0.4555	0.4154	0.3878	0.3796	0.3740	0.3727	0.3759	0.3768	0.3806	0.3745	0.3738	0.3811	0.3755	0.3756
0.4421	0.4166	0.3869	0.3878	0.3856	0.3838	0.3844	0.3831	0.3862	0.3870	0.3849	0.3853	0.3846	0.3856	0.3861	0.4287
0.3941	0.3960	0.4019	0.3955	0.3969	0.3991	0.3952	0.3947	0.3973	0.3978	0.3961	0.3962	0.3957	0.3967	0.4188	0.4104
0.3819	0.3893	0.3863	0.3882	0.3887	0.3828	0.3828	0.3819	0.3853	0.3858	0.3839	0.3844	0.3960	0.4323	0.4407	0.4164
0.3832	0.3855	0.3878	0.3900	0.3861	0.3897	0.3841	0.3838	0.3873	0.3878	0.3901	0.4097	0.4364	0.4274	0.3977	0.3861
0.3915	0.3885	0.3906	0.3883	0.3893	0.3877	0.3876	0.3868	0.3902	0.3906	0.4187	0.4331	0.4146	0.3888	0.3900	0.3892
0.3942	0.3974	0.3991	0.3971	0.3980	0.3959	0.3964	0.3956	0.3985	0.4031	0.3973	0.4151	0.3966	0.3978	0.3985	0.3978

Table 10: First version, dram only



m:1000	n:1000000	<u>nvdim</u>	<u>size:48</u>													
		<u>nvdim</u>	<u>dram</u>	<u>nvdim</u>	<u>dram</u>	<u>dram</u>	<u>dram</u>	<u>nvdim</u>	<u>nvdim</u>	<u>nvdim</u>	<u>total</u>	<u>total</u>	<u>total</u>			
m	n	length	threads	threads	average	min	max	average	min	max	average	min	max			
1000	1000000	296	10	6	0.4122	0.3445	0.4545	0.9137	0.7143	0.7568	0.9138	0.7143	0.7568			
0.3078	0.3090	0.2965	0.3148	0.3173	0.3173	0.3156	0.3147	0.3150	0.3357	2.4630	2.6225	2.6307	2.6286	2.6321	2.6078	
0.4292	0.3480	0.2647	0.2862	0.3140	0.4524	0.4440	0.4467	0.4473	0.4545	0.6976	0.7568	0.7558	0.7556	0.7562	0.7427	
0.3301	0.3310	0.3202	0.3402	0.3397	0.3406	0.3370	0.3380	0.3381	0.3445	0.6661	0.7234	0.7196	0.7233	0.7192	0.7076	
0.3165	0.3172	0.3275	0.4126	0.4360	0.3275	0.3235	0.3247	0.3249	0.3311	0.6576	0.7152	0.7162	0.7164	0.7204	0.7038	
0.4152	0.4485	0.4224	0.3657	0.3132	0.3192	0.3103	0.3113	0.3115	0.3174	0.6613	0.7180	0.7155	0.7159	0.7160	0.7050	
0.3587	0.3255	0.3145	0.3352	0.3348	0.3357	0.3320	0.3329	0.3331	0.3855	0.6565	0.7139	0.7114	0.7119	0.7144	0.6988	
0.3159	0.3166	0.3056	0.3262	0.3256	0.3262	0.3224	0.3545	0.4240	0.4040	0.6634	0.7230	0.7179	0.7175	0.7185	0.7098	
0.3163	0.3169	0.3062	0.3264	0.3257	0.3270	0.3953	0.4165	0.3479	0.3305	0.6561	0.7117	0.7143	0.7141	0.7124	0.7011	
0.3146	0.3153	0.3044	0.3364	0.3870	0.4390	0.3747	0.3222	0.3250	0.3286	0.6592	0.7148	0.7169	0.7169	0.7154	0.7019	
0.3120	0.3239	0.3759	0.4376	0.3846	0.3344	0.3197	0.3204	0.3209	0.3270	0.6585	0.7147	0.7129	0.7131	0.7182	0.7028	
		<u>nvdim</u>	<u>dram</u>	<u>nvdim</u>	<u>dram</u>	<u>dram</u>	<u>dram</u>	<u>nvdim</u>	<u>nvdim</u>	<u>nvdim</u>	<u>total</u>	<u>total</u>	<u>total</u>			
m	n	length	threads	threads	average	min	max	average	min	max	average	min	max			
1000	1000000	246	11	5	0.4045	0.3475	0.4516	0.8973	0.7128	0.7561	0.8973	0.7128	0.7561			
0.3190	0.3236	0.3247	0.3218	0.3171	0.3235	0.3191	0.3139	0.3149	0.3148	0.3351	2.3276	2.4411	2.4358	2.4330	2.4191	
0.4494	0.4509	0.4516	0.3960	0.2946	0.3014	0.2966	0.2911	0.2919	0.3382	0.4341	0.6935	0.7507	0.7508	0.7527	0.7389	
0.3420	0.3433	0.3475	0.3438	0.3393	0.3452	0.3413	0.3363	0.3373	0.3369	0.3421	0.6751	0.7314	0.7325	0.7332	0.7210	
0.3335	0.3349	0.3394	0.3355	0.3304	0.3368	0.3329	0.3269	0.3671	0.3858	0.3329	0.6550	0.7122	0.7092	0.7162	0.6999	
0.3223	0.3238	0.3286	0.3243	0.3188	0.3443	0.3794	0.4109	0.3938	0.3297	0.3306	0.6576	0.7105	0.7102	0.7128	0.6981	
0.3183	0.3198	0.3245	0.3524	0.4056	0.4203	0.3745	0.3351	0.3129	0.3123	0.3180	0.6584	0.7103	0.7116	0.7150	0.7035	
0.3249	0.3553	0.4027	0.4080	0.3487	0.3284	0.3288	0.3187	0.3199	0.3195	0.3251	0.6584	0.7166	0.7114	0.7113	0.6982	
0.4309	0.4103	0.3677	0.3209	0.3164	0.3226	0.3182	0.3130	0.3142	0.3137	0.3617	0.6597	0.7561	0.7141	0.7161	0.7026	
0.3276	0.3267	0.3273	0.3234	0.3176	0.3247	0.3202	0.3278	0.3757	0.4246	0.4096	0.6602	0.7141	0.7123	0.7086	0.6972	
0.3174	0.3190	0.3239	0.3196	0.3186	0.3579	0.3982	0.4300	0.3807	0.3300	0.3160	0.6578	0.7113	0.7149	0.7129	0.6977	
		<u>nvdim</u>	<u>dram</u>	<u>nvdim</u>	<u>dram</u>	<u>dram</u>	<u>dram</u>	<u>nvdim</u>	<u>nvdim</u>	<u>nvdim</u>	<u>total</u>	<u>total</u>	<u>total</u>			
m	n	length	threads	threads	average	min	max	average	min	max	average	min	max			
1000	1000000	195	12	4	0.4194	0.3610	0.4609	0.8003	0.6938	0.7376	0.8003	0.6938	0.7376			
0.3339	0.3425	0.3327	0.3383	0.3440	0.3444	0.3423	0.3390	0.3386	0.3393	0.3393	0.3510	1.5855	1.6687	1.6728	1.6619	
0.4408	0.4505	0.3848	0.3175	0.3247	0.3249	0.3223	0.3189	0.3182	0.3190	0.4399	0.4609	0.6780	0.7376	0.7374	0.7247	
0.3505	0.3593	0.3498	0.3551	0.3607	0.3610	0.3587	0.3556	0.3554	0.3559	0.3560	0.3582	0.6424	0.6976	0.6991	0.6834	
0.3319	0.3408	0.3305	0.3361	0.3426	0.3429	0.3403	0.3855	0.4219	0.4545	0.3533	0.3399	0.6414	0.7010	0.7011	0.6891	
0.3199	0.3287	0.3183	0.3239	0.3864	0.4370	0.4536	0.4050	0.3639	0.3253	0.3250	0.3280	0.6411	0.7030	0.7038	0.6879	
0.3340	0.3909	0.4350	0.4574	0.4080	0.3506	0.3294	0.3259	0.3255	0.3263	0.3262	0.3284	0.6421	0.7035	0.7026	0.6897	
0.4529	0.4074	0.3426	0.3353	0.3416	0.3419	0.3395	0.3362	0.3357	0.3364	0.3362	0.3890	0.6393	0.6938	0.6938	0.6814	
0.3506	0.3591	0.3494	0.3549	0.3607	0.3610	0.3586	0.3556	0.3552	0.3558	0.3557	0.3581	0.6421	0.6952	0.6962	0.6845	
0.3416	0.3503	0.3400	0.3462	0.3521	0.3524	0.3498	0.3468	0.3463	0.3470	0.3989	0.4004	0.6394	0.6946	0.6980	0.6814	
0.3326	0.3416	0.3311	0.3369	0.3434	0.3437	0.3413	0.3433	0.3897	0.4417	0.3980	0.3499	0.6483	0.6974	0.6950	0.6823	

Table 11: First version, more detailed 1

		<u>nvdim</u>	dram	<u>nvdim</u>	dram	dram	dram	<u>nvdim</u>	<u>nvdim</u>	<u>nvdim</u>	total	total	total		
m	n	length	threads	threads	average	min	max	average	min	max	average	min	max		
1000	1000000	146	13	3	0.4255	0.4131	0.4619	0.7816	0.6928	0.7811	0.7816	0.6928	0.7811		
0.3501	0.3519	0.3500	0.3504	0.3500	0.3506	0.3512	0.3487	0.3498	0.3488	0.3497	0.3478	0.3600	1.3751	1.4686	1.4489
0.3158	0.3696	0.4255	0.4501	0.4500	0.4503	0.4236	0.3141	0.3149	0.3142	0.3151	0.3137	0.3251	0.7087	0.7811	0.7682
0.4619	0.4170	0.3588	0.3396	0.3412	0.3400	0.3407	0.3380	0.3390	0.3378	0.3387	0.3372	0.3793	0.6535	0.7060	0.6919
0.3443	0.3465	0.3444	0.3448	0.3447	0.3452	0.3458	0.3430	0.3466	0.3430	0.3867	0.4325	0.4108	0.6426	0.6948	0.6811
0.3460	0.3502	0.3457	0.3463	0.3461	0.3465	0.3472	0.3444	0.3792	0.4135	0.4033	0.3580	0.3486	0.6430	0.6945	0.6855
0.3462	0.3483	0.3463	0.3467	0.3463	0.3470	0.3477	0.3983	0.4137	0.3779	0.3454	0.3441	0.3492	0.6434	0.6928	0.6871
0.3438	0.3482	0.3439	0.3441	0.3507	0.4008	0.4463	0.3891	0.3435	0.3422	0.3433	0.3417	0.3468	0.6430	0.6947	0.6854
0.3471	0.3490	0.3471	0.3829	0.4342	0.3900	0.3484	0.3456	0.3467	0.3455	0.3463	0.3450	0.3501	0.6420	0.6931	0.6864
0.3474	0.3675	0.4131	0.4088	0.3547	0.3479	0.3486	0.3462	0.3471	0.3460	0.3469	0.3453	0.3505	0.6427	0.6955	0.6845
0.4163	0.4296	0.3793	0.3465	0.3470	0.3436	0.3443	0.3415	0.3427	0.3418	0.3422	0.3410	0.3575	0.6423	0.6950	0.6825
m	n	<u>nvdim</u>	dram	<u>nvdim</u>	dram	dram	dram	<u>nvdim</u>	<u>nvdim</u>	<u>nvdim</u>	total	total	total		
		length	threads	threads	average	min	max	average	min	max	average	min	max		
1000	1000000	95	14	2	0.4314	0.3890	0.4787	0.7298	0.6581	0.7028	0.7298	0.6581	0.7028		
0.3621	0.3699	0.3672	0.3706	0.3715	0.3663	0.3618	0.3581	0.3588	0.3578	0.3587	0.3593	0.3708	0.3880	1.2456	1.3069
0.4731	0.4787	0.4398	0.3529	0.3537	0.3480	0.3431	0.3395	0.3401	0.3391	0.3398	0.3405	0.3529	0.3651	0.6633	0.7028
0.3696	0.3774	0.3747	0.3778	0.3788	0.3740	0.3693	0.3659	0.3666	0.3656	0.3664	0.3668	0.3782	0.3890	0.6427	0.6620
0.3611	0.3690	0.3678	0.3696	0.3704	0.3676	0.3606	0.3573	0.3581	0.3570	0.3578	0.3584	0.4079	0.4649	0.6263	0.6631
0.3503	0.3591	0.3561	0.3596	0.3608	0.3602	0.3496	0.3458	0.3467	0.3454	0.3970	0.4437	0.4180	0.3853	0.6250	0.6626
0.3539	0.3639	0.3608	0.3644	0.3654	0.3594	0.3532	0.3618	0.3974	0.4310	0.4022	0.3613	0.3645	0.3766	0.6269	0.6606
0.3485	0.3585	0.3553	0.3592	0.3602	0.3758	0.4030	0.4197	0.4023	0.3800	0.3443	0.3446	0.3594	0.3713	0.6258	0.6581
0.3471	0.3609	0.3531	0.3872	0.4349	0.4314	0.3936	0.3632	0.3435	0.3422	0.3432	0.3438	0.3567	0.3683	0.6273	0.6616
0.3509	0.3995	0.4423	0.4271	0.3839	0.3551	0.3501	0.3497	0.3471	0.3463	0.3471	0.3505	0.3598	0.3713	0.6277	0.6601
0.4029	0.4221	0.3778	0.3667	0.3677	0.3671	0.3570	0.3535	0.3540	0.3535	0.3540	0.3545	0.3668	0.3779	0.6303	0.6601
m	n	<u>nvdim</u>	dram	<u>nvdim</u>	dram	dram	dram	<u>nvdim</u>	<u>nvdim</u>	<u>nvdim</u>	total	total	total		
		length	threads	threads	average	min	max	average	min	max	average	min	max		
1000	1000000	48	15	1	0.4496	0.4140	0.4759	0.6884	0.6252	0.6792	0.6884	0.6252	0.6792		
0.3785	0.3860	0.3854	0.3887	0.3863	0.3880	0.3793	0.3758	0.3740	0.3748	0.3755	0.3811	0.3803	0.3793	0.3827	1.1083
0.3553	0.3670	0.3637	0.3676	0.3649	0.3667	0.4085	0.4368	0.4598	0.4620	0.3785	0.3584	0.3572	0.3559	0.3527	0.6792
0.3600	0.3680	0.3695	0.4079	0.4318	0.4759	0.4100	0.3823	0.3547	0.3556	0.3564	0.3630	0.3618	0.3608	0.3582	0.6642
0.3969	0.4410	0.4579	0.4286	0.4240	0.3661	0.3564	0.3503	0.3487	0.3495	0.3500	0.3566	0.3552	0.3568	0.3522	0.6265
0.4140	0.4016	0.3820	0.3852	0.3829	0.3847	0.3755	0.3720	0.3703	0.3709	0.3717	0.3775	0.3767	0.3758	0.3731	0.6252
0.3827	0.3831	0.3813	0.3872	0.3797	0.3815	0.3716	0.3681	0.3665	0.3672	0.3679	0.3741	0.3733	0.4107	0.4442	0.6310
0.3559	0.3625	0.3619	0.3700	0.3632	0.3690	0.3540	0.3498	0.3481	0.3487	0.3907	0.4322	0.4588	0.4232	0.3849	0.6328
0.3519	0.3609	0.3644	0.3642	0.3615	0.3633	0.3519	0.3859	0.4213	0.4580	0.4261	0.3957	0.3602	0.3522	0.3487	0.6417
0.3509	0.3635	0.3582	0.3622	0.4074	0.4513	0.4617	0.4244	0.3853	0.3457	0.3464	0.3534	0.3523	0.3512	0.3484	0.6401
0.3706	0.4205	0.4451	0.4747	0.4305	0.3814	0.3527	0.3482	0.3467	0.3541	0.3548	0.3548	0.3540	0.3529	0.3500	0.6350

Table 12: First version, more detailed 2.



		<del>nvdimm</del>	<del>dram</del>	<del>nvdimm</del>	<del>dram</del>	<del>dram</del>	<del>dram</del>	<del>nvdimm</del>	<del>nvdimm</del>	<del>nvdimm</del>	<del>total</del>	<del>total</del>	<del>total</del>
m	n	<del>length</del>	<del>threads</del>	<del>threads</del>	<del>average</del>	<del>min</del>	<del>max</del>	<del>average</del>	<del>min</del>	<del>max</del>	<del>average</del>	<del>min</del>	<del>max</del>
1,000	1,000,000	100	10	6	0.4823	0.4213	0.5350	0.3320	0.2711	0.8619	0.5260	0.4213	0.8619
1,000	1,000,000	100	11	5	0.4628	0.3977	0.5020	0.4063	0.3391	0.9953	0.5226	0.4040	0.9953
1,000	1,000,000	100	12	4	0.4450	0.4045	0.4901	0.4728	0.4195	0.9261	0.4986	0.4218	0.9261
1,000	1,000,000	100	13	3	0.4452	0.3841	0.5099	0.5823	0.5246	1.0428	0.5823	0.5246	1.0428
1,000	1,000,000	100	14	2	0.4440	0.3814	0.4807	0.8134	0.7380	1.3800	0.8134	0.7381	1.3801
1,000	1,000,000	100	15	1	0.4367	0.3729	0.4590	1.2964	1.1864	2.2079	1.2964	1.1864	2.2080
		<del>nvdimm</del>	<del>dram</del>	<del>nvdimm</del>	<del>dram</del>	<del>dram</del>	<del>dram</del>	<del>nvdimm</del>	<del>nvdimm</del>	<del>nvdimm</del>	<del>total</del>	<del>total</del>	<del>total</del>
m	n	<del>length</del>	<del>threads</del>	<del>threads</del>	<del>average</del>	<del>min</del>	<del>max</del>	<del>average</del>	<del>min</del>	<del>max</del>	<del>average</del>	<del>min</del>	<del>max</del>
1,000	1,000,000	200	10	6	0.4293	0.3801	0.5221	0.6604	0.5321	1.7671	0.6604	0.5321	1.7671
1,000	1,000,000	200	11	5	0.4225	0.3513	0.4817	0.7697	0.6238	2.0151	0.7698	0.6238	2.0151
1,000	1,000,000	200	12	4	0.4146	0.3415	0.4519	0.8611	0.7571	1.7370	0.8611	0.7571	1.7370
1,000	1,000,000	200	13	3	0.3970	0.3359	0.4278	1.0750	0.9597	1.9889	1.0750	0.9597	1.9889
1,000	1,000,000	200	14	2	0.3902	0.3389	0.4095	1.5548	1.3768	2.8569	1.5548	1.3769	2.8570
1,000	1,000,000	200	15	1	0.3812	0.3273	0.3937	2.4958	2.2860	4.2250	2.4958	2.2860	4.2250
		<del>nvdimm</del>	<del>dram</del>	<del>nvdimm</del>	<del>dram</del>	<del>dram</del>	<del>dram</del>	<del>nvdimm</del>	<del>nvdimm</del>	<del>nvdimm</del>	<del>total</del>	<del>total</del>	<del>total</del>
m	n	<del>length</del>	<del>threads</del>	<del>threads</del>	<del>average</del>	<del>min</del>	<del>max</del>	<del>average</del>	<del>min</del>	<del>max</del>	<del>average</del>	<del>min</del>	<del>max</del>
1,000	1,000,000	300	10	6	0.4187	0.3337	0.4504	0.9607	0.7672	2.5984	0.9607	0.7672	2.5984
1,000	1,000,000	300	11	5	0.3860	0.3149	0.4189	1.1095	0.8941	2.9522	1.1095	0.8941	2.9522
1,000	1,000,000	300	12	4	0.3716	0.3147	0.4021	1.2554	1.0973	2.5936	1.2555	1.0973	2.5936
1,000	1,000,000	300	13	3	0.3553	0.2994	0.3754	1.5950	1.4262	2.9722	1.5950	1.4262	2.9722
1,000	1,000,000	300	14	2	0.3586	0.2939	0.4467	2.2757	2.0535	4.0482	2.2757	2.0536	4.0482
1,000	1,000,000	300	15	1	0.3440	0.2899	0.4570	3.6785	3.3726	5.9822	3.6785	3.3726	5.9823
		<del>nvdimm</del>	<del>dram</del>	<del>nvdimm</del>	<del>dram</del>	<del>dram</del>	<del>dram</del>	<del>nvdimm</del>	<del>nvdimm</del>	<del>nvdimm</del>	<del>total</del>	<del>total</del>	<del>total</del>
m	n	<del>length</del>	<del>threads</del>	<del>threads</del>	<del>average</del>	<del>min</del>	<del>max</del>	<del>average</del>	<del>min</del>	<del>max</del>	<del>average</del>	<del>min</del>	<del>max</del>
1,000	1,000,000	400	10	6	0.3859	0.3285	0.4935	1.2587	0.9947	1.0591	1.2587	0.9947	1.0591
1,000	1,000,000	400	11	5	0.3522	0.3021	0.4969	1.4667	1.1868	1.2097	1.4667	1.1868	1.2097
1,000	1,000,000	400	12	4	0.3175	0.2716	0.4268	1.6739	1.4492	1.5125	1.6739	1.4492	1.5126
1,000	1,000,000	400	13	3	0.3242	0.2898	0.4059	2.1027	1.8852	1.9380	2.1028	1.8852	1.9380
1,000	1,000,000	400	14	2	0.2966	0.2831	0.4023	3.0072	2.7257	2.8082	3.0072	2.7257	2.8083
1,000	1,000,000	400	15	1	0.2930	0.2775	0.3902	4.9659	4.5704	5.0607	4.9659	4.5704	5.0607

Table 13: First version.

		nvdi	dram	nvdi	dram	dram	dram	nvdim	nvdim	nvdim	total	total	total
m	n	leng	threa	threa	average	min	max	average	min	max	average	min	max
1,000	1,000,000	100	10	6	0.5031	0.4696	0.5522	0.3221	0.2608	0.2654	0.5421	0.4696	0.5522
1,000	1,000,000	100	11	5	0.4612	0.4093	0.4975	0.3968	0.3246	0.3328	0.5246	0.4093	0.4975
1,000	1,000,000	100	12	4	0.4513	0.4098	0.4884	0.4552	0.4048	0.4098	0.5014	0.4098	0.4884
1,000	1,000,000	100	13	3	0.4422	0.3912	0.4799	0.5642	0.5084	0.5379	0.5642	0.5084	0.5379
1,000	1,000,000	100	14	2	0.4334	0.3799	0.4681	0.8098	0.7294	0.8177	0.8098	0.7295	0.8177
1,000	1,000,000	100	15	1	0.4367	0.4298	0.4616	1.4619	1.3356	1.4728	1.4619	1.3356	1.4728
		nvdi	dram	nvdi	dram	dram	dram	nvdim	nvdim	nvdim	total	total	total
m	n	leng	threa	threa	average	min	max	average	min	max	average	min	max
1,000	1,000,000	200	10	6	0.4462	0.4150	0.5193	0.6424	0.5142	0.5365	0.6424	0.5142	0.5365
1,000	1,000,000	200	11	5	0.4145	0.3720	0.4703	0.7537	0.6025	0.6358	0.7537	0.6025	0.6358
1,000	1,000,000	200	12	4	0.4130	0.3786	0.4469	0.8285	0.7306	0.7617	0.8285	0.7306	0.7617
1,000	1,000,000	200	13	3	0.4032	0.3466	0.4310	1.0511	0.9367	1.0338	1.0511	0.9367	1.0338
1,000	1,000,000	200	14	2	0.3898	0.3712	0.4123	1.4831	1.3442	1.3693	1.4831	1.3442	1.3694
1,000	1,000,000	200	15	1	0.3867	0.3754	0.4716	2.8308	2.5865	2.6867	2.8309	2.5866	2.6867
		nvdi	dram	nvdi	dram	dram	dram	nvdim	nvdim	nvdim	total	total	total
m	n	leng	threa	threa	average	min	max	average	min	max	average	min	max
1,000	1,000,000	300	10	6	0.3999	0.3447	0.4524	0.9276	0.7416	0.7500	0.9276	0.7416	0.7500
1,000	1,000,000	300	11	5	0.3932	0.3244	0.4249	1.0898	0.8660	0.9322	1.0898	0.8660	0.9322
1,000	1,000,000	300	12	4	0.3749	0.3143	0.4042	1.2065	1.0654	1.0783	1.2065	1.0654	1.0783
1,000	1,000,000	300	13	3	0.3481	0.3203	0.3696	1.5408	1.3923	1.4199	1.5408	1.3923	1.4199
1,000	1,000,000	300	14	2	0.3501	0.3459	0.3733	2.1808	2.0092	2.0432	2.1808	2.0092	2.0432
1,000	1,000,000	300	15	1	0.3404	0.3264	0.4569	4.1787	3.8467	3.9795	4.1788	3.8468	3.9795
		nvdi	dram	nvdi	dram	dram	dram	nvdim	nvdim	nvdim	total	total	total
m	n	leng	threa	threa	average	min	max	average	min	max	average	min	max
1,000	1,000,000	400	10	6	0.3710	0.2957	0.5086	1.2246	0.9551	1.0135	1.2246	0.9551	1.0135
1,000	1,000,000	400	11	5	0.3437	0.2816	0.4704	1.4251	1.1364	1.2231	1.4251	1.1364	1.2231
1,000	1,000,000	400	12	4	0.3336	0.2733	0.4385	1.5954	1.3988	1.4362	1.5954	1.3988	1.4363
1,000	1,000,000	400	13	3	0.3182	0.2837	0.4174	2.0210	1.8115	1.8356	2.0210	1.8115	1.8356
1,000	1,000,000	400	14	2	0.3018	0.2896	0.4058	2.9019	2.6311	2.7827	2.9019	2.6312	2.7827
1,000	1,000,000	400	15	1	0.2974	0.2847	0.4018	5.4534	5.0678	5.1469	5.4535	5.0679	5.1469

Table 14: Second version.

m	n	<u>nvdim</u> length	dram threads	<u>nvdim</u> threads	dram average	dram min	dram max	<u>nvdim</u> average	<u>nvdim</u> min	<u>nvdim</u> max
1,000	1,000,000	200	1	15	2.4969	2.3980	2.6683	0.2652	0.1845	0.5940
1,000	1,000,000	200	2	14	1.4481	1.2292	1.7017	0.2503	0.1988	0.6042
1,000	1,000,000	200	3	13	1.0203	0.8528	1.2142	0.2675	0.2131	0.6043
1,000	1,000,000	200	4	12	1.0637	0.6941	1.2707	0.4761	0.2276	0.6246
1,000	1,000,000	200	5	11	0.7014	0.5716	0.8123	0.3013	0.2567	0.6231
1,000	1,000,000	200	6	10	0.5767	0.5035	0.6715	0.3755	0.2848	0.8516
1,000	1,000,000	200	7	9	0.5649	0.4562	0.6394	0.3539	0.3151	0.6364
1,000	1,000,000	200	8	8	0.4774	0.4289	0.5666	0.4176	0.3599	0.6759
1,000	1,000,000	200	9	7	0.4865	0.4106	0.5245	0.4371	0.4061	0.7098
1,000	1,000,000	200	10	6	0.4713	0.3851	0.5153	0.5126	0.4728	0.8159
1,000	1,000,000	200	11	5	0.4563	0.3681	0.4958	0.6027	0.5551	0.9569
1,000	1,000,000	200	12	4	0.3926	0.3576	0.4642	0.7724	0.6760	1.1671
1,000	1,000,000	200	13	3	0.3822	0.3459	0.4368	0.9688	0.8599	1.5051
1,000	1,000,000	200	14	2	0.3931	0.3430	0.4605	1.5638	1.2419	2.4540
1,000	1,000,000	200	15	1	0.3820	0.3332	0.4844	2.7315	2.3613	4.0120

Table 15: First version. OLD

m	n	<u>nvdim</u> length	dram threads	<u>nvdim</u> threads	dram average	dram min	dram max	<u>nvdim</u> average	<u>nvdim</u> min	<u>nvdim</u> max
1000	1000000	400	1	15	1.9421	1.7041	2.5587	0.5400	0.3737	1.1992
1000	1000000	400	2	14	1.6456	1.3045	2.1652	0.9189	0.7172	1.4330
1000	1000000	400	3	13	0.7794	0.6837	0.9609	0.5340	0.4342	1.1997
1000	1000000	400	4	12	0.7031	0.5605	0.9786	0.7232	0.4821	1.2280
1000	1000000	400	5	11	0.5446	0.4239	0.6813	0.6175	0.5254	1.2250
1000	1000000	400	6	10	0.4830	0.3795	0.6112	0.6968	0.5731	1.2296
1000	1000000	400	7	9	0.4217	0.3497	0.5369	0.7117	0.6213	1.2246
1000	1000000	400	8	8	0.4217	0.3202	0.6186	0.9400	0.6843	1.3209
1000	1000000	400	9	7	0.3489	0.3263	0.4202	0.8846	0.7568	1.4615
1000	1000000	400	10	6	0.3534	0.2994	0.4695	1.2051	0.9452	1.6556
1000	1000000	400	11	5	0.3400	0.3112	0.4017	1.1752	1.0287	1.8976
1000	1000000	400	12	4	0.3907	0.2700	0.5614	2.4105	1.5335	2.8562
1000	1000000	400	13	3	0.2984	0.2701	0.3220	1.8764	1.6555	2.8262
1000	1000000	400	14	2	0.2894	0.2565	0.3947	2.7862	2.4556	3.9577
1000	1000000	400	15	1	0.3067	0.2609	0.3710	5.4896	4.7125	7.1350

Table 16: First version. OLD

m	n	<u>nvdimm</u> length	dram threads	<u>nvdimm</u> threads	dram average	dram min	dram max	<u>nvdimm</u> average	<u>nvdimm</u> min	<u>nvdimm</u> max
1,000	1,000,000	200	1	15	4.3506	3.0851	5.4226	12.5578	12.0879	13.9106
1,000	1,000,000	200	2	14	2.4177	1.6629	3.3427	12.5061	11.9543	13.8187
1,000	1,000,000	200	3	13	1.6175	1.1164	2.1824	12.0978	11.6232	13.2806
1,000	1,000,000	200	4	12	1.2294	0.8984	1.6496	11.8080	11.4248	12.8516
1,000	1,000,000	200	5	11	0.9603	0.5595	1.3311	11.2715	10.9282	12.2981
1,000	1,000,000	200	6	10	0.8311	0.4913	1.1458	11.2827	11.0103	11.8192
1,000	1,000,000	200	7	9	0.7681	0.4157	1.2062	11.0349	10.3212	12.9057
1,000	1,000,000	200	8	8	0.6855	0.4458	0.9048	10.7173	10.1667	12.3145
1,000	1,000,000	200	9	7	0.6231	0.3692	1.0769	10.5659	9.9144	12.4387
1,000	1,000,000	200	10	6	0.5536	0.3801	0.7129	10.2459	9.4983	12.5660
1,000	1,000,000	200	11	5	0.4918	0.3547	0.6574	9.5222	9.1636	10.7587
1,000	1,000,000	200	12	4	0.4674	0.3504	0.6201	8.6057	8.3691	9.3879
1,000	1,000,000	200	13	3	0.4439	0.3312	0.5859	7.9526	7.5966	8.5104
1,000	1,000,000	200	14	2	0.4377	0.3325	0.6917	5.6382	5.1366	6.2976
1,000	1,000,000	200	15	1	0.3979	0.3336	0.5328	2.7644	2.4067	3.7062

Table 17: Second version. OLD

m	n	<u>nvdimm</u> threads	<u>nvdimm</u> average	<u>nvdimm</u> min	<u>nvdimm</u> max
200	1,000,000	1	2.9744	2.5180	3.9372
200	1,000,000	2	4.9422	4.6678	5.4835
200	1,000,000	3	5.0508	4.8935	5.6034
200	1,000,000	4	5.5549	5.3542	6.7077
200	1,000,000	5	5.2473	4.9133	6.5496
200	1,000,000	6	5.3491	5.0966	6.7279
200	1,000,000	7	5.6929	5.4649	6.3630
200	1,000,000	8	5.8173	5.3828	6.8326
200	1,000,000	9	5.3901	5.2969	5.9944
200	1,000,000	10	5.5692	5.2874	6.2419
200	1,000,000	11	5.4967	5.2975	6.0858
200	1,000,000	12	5.8591	5.6733	7.0265
200	1,000,000	13	6.0996	5.8470	7.0950
200	1,000,000	14	5.7147	5.5264	6.6942
200	1,000,000	15	5.7758	5.5657	6.6912
200	1,000,000	16	5.8444	5.6211	6.4624

Table 18: NVDIMM only of second version. OLD

				predicted	
m	n	threads	time	time	bandwidth
1,000	1,000,000	1	1.7719	0.4233	18,898.7
1,000	1,000,000	2	1.0333	0.2800	28,571.4
1,000	1,000,000	3	1.0121	0.2744	29,158.2
1,000	1,000,000	4	0.9899	0.2736	29,235.5
1,000	1,000,000	5	0.6998	0.2011	39,789.2
1,000	1,000,000	6	0.6439	0.1792	44,646.4
1,000	1,000,000	7	0.5595	0.1565	51,121.6
1,000	1,000,000	8	0.5318	0.1486	53,839.6
1,000	1,000,000	9	0.4858	0.1357	58,964.7
1,000	1,000,000	10	0.4578	0.1263	63,321.0
1,000	1,000,000	11	0.4300	0.1198	66,792.3
1,000	1,000,000	12	0.3985	0.1139	70,227.7
1,000	1,000,000	13	0.3873	0.1083	73,838.5
1,000	1,000,000	14	0.3694	0.1041	76,823.2
1,000	1,000,000	15	0.3594	0.1004	79,680.9
1000	1000000	16	0.3394	0.0972	82,326.0
Formula for prediction					
$(m*n*8*0.000001)/\text{bandwidth}$					

Table 19: DRAM only on n50. OLD