Introduction to Parallel Programming for Multicore/Manycore Clusters

Part VI: Report

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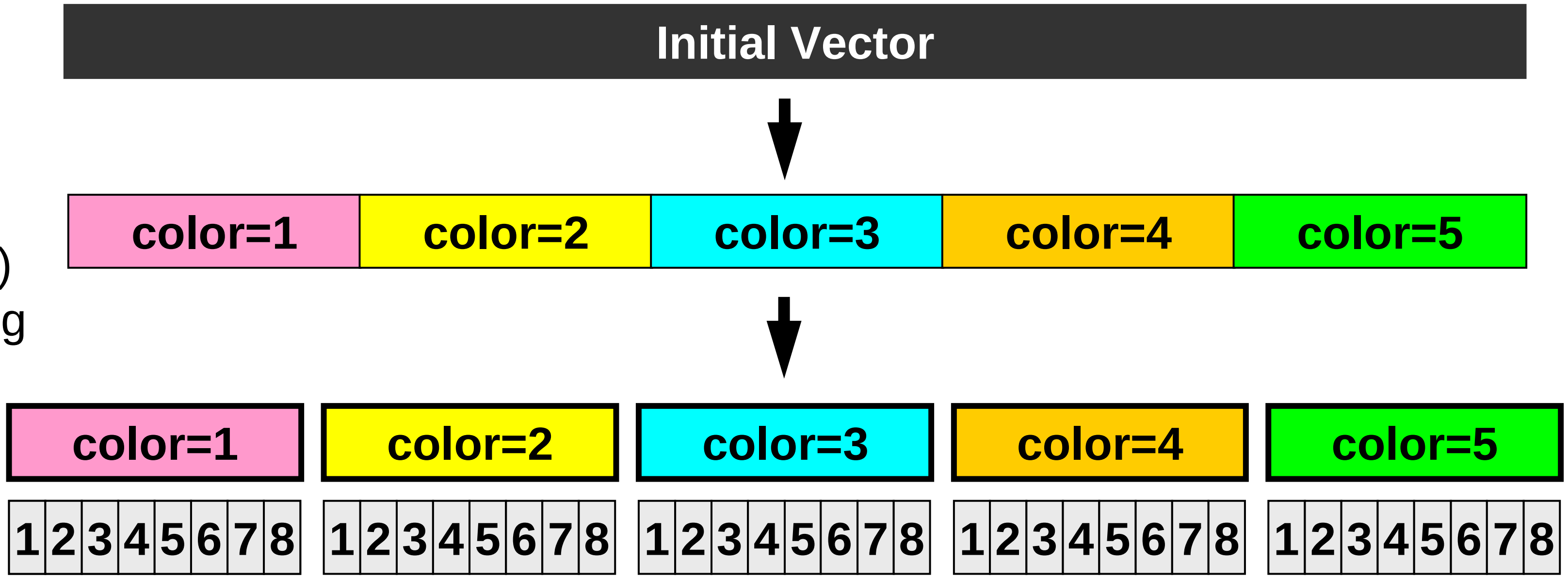
SMPindex: for preconditioning

```
for(ic=0; ic<NCOLORtot; ic++) {
#pragma omp parallel for ...
    for(ip=0; ip<PEsmpTOT; ip++) {
        ip1 = ic * PEsmpTOT + ip;
        for(i=SMPindex[ip1]; i<SMPindex[ip1+1]; i++) {
            (...)
        }
    }
}
```

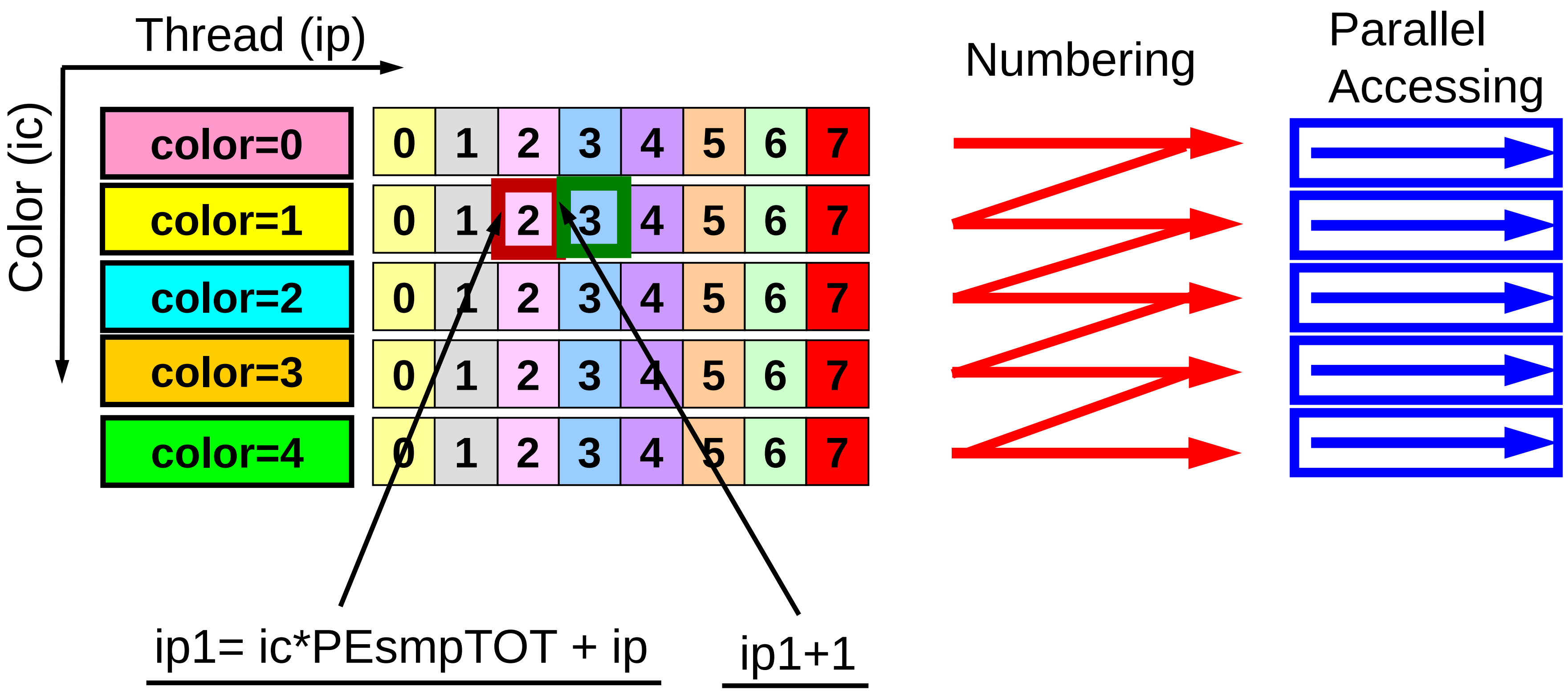
Coloring
(5 colors)
+Ordering



- 5-colors, 8-threads
- Meshes in same color are independent: parallel processing
- Reordering in ascending order according to color ID

SMPindex

```
#pragma omp parallel private (ic,ip,ip1,i,WVAL,j)
for(ic=0; ic<NCOLORtot; ic++) {
#pragma omp for
    for(ip=0; ip<PEsmpTOT; ip++) {
        ip1 = ic * PEsmpTOT + ip;
        for(i=SMPindex[ip1]; i<SMPindex[ip1+1]; i++) {…
```



SMPindex

```
COLORindex[ic  ]= 100
COLORindex[ic+1]= 200
PEsmpTOT        =   8

nn1= 200-100   = 100
num= 100 / 8   =  12 (12.5)
nr = 100 - 12*8=   4

SMPindex[ip1  ]= 100
SMPindex[ip1+1]= 113 (13 elements in the 1st thread)
SMPindex[ip1+2]= 126 (13 elements in the 2nd thread)
SMPindex[ip1+3]= 139 (13 elements in the 3rd thread)
SMPindex[ip1+4]= 152 (13 elements in the 4th thread)
SMPindex[ip1+5]= 164 (12 elements in the 5th thread)
SMPindex[ip1+6]= 176 (12 elements in the 6th thread)
SMPindex[ip1+7]= 188 (12 elements in the 7th thread)
SMPindex[ip1+8]= 200 (12 elements in the 8th thread)
```

Problems in Reordering

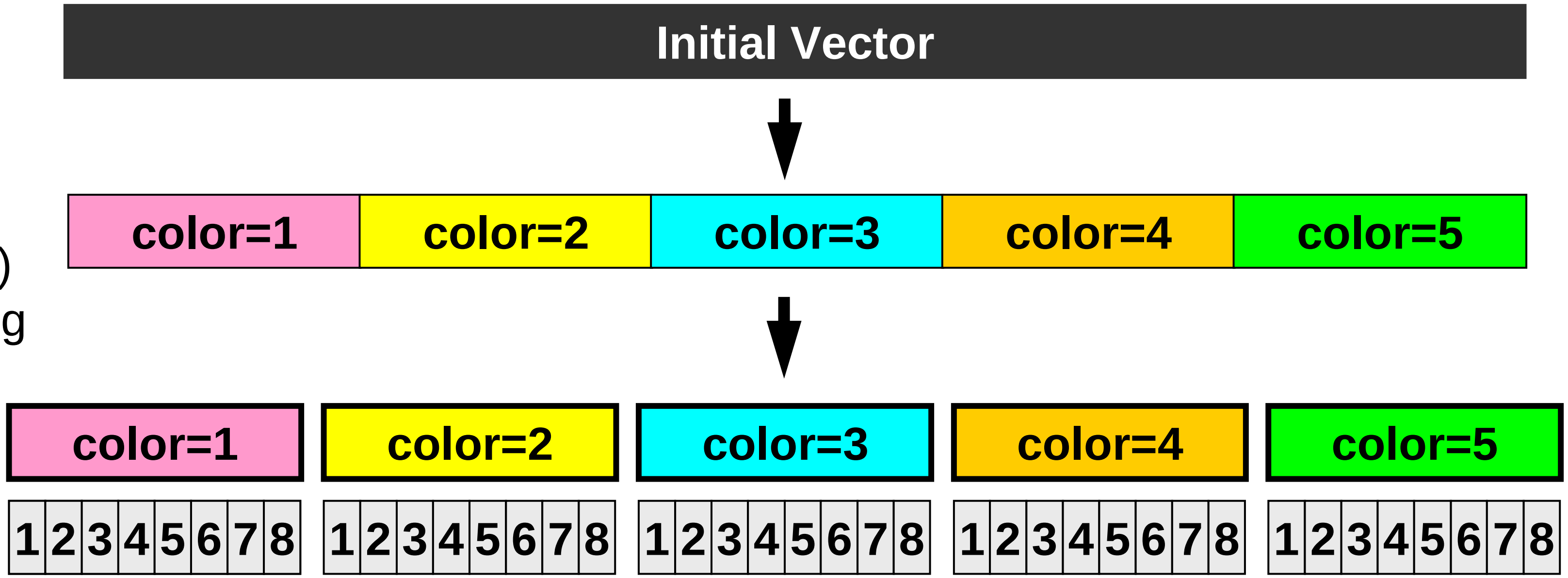
- Coloring
  - MC
  - RCM
  - CM-RCM
- Renumbering is according to color/level ID
- On each thread, numbering is not continuous
  - reduced performance

SMPindex:

for preconditioning

```
for(ic=0; ic<NCOLORtot; ic++) {
#pragma omp parallel for ...
    for(ip=0; ip<PEsmpTOT; ip++) {
        ip1 = ic * PEsmpTOT + ip;
        for(i=SMPindex[ip1]; i<SMPindex[ip1+1]; i++) {
            (...)
        }
    }
}
```

Coloring
(5 colors)
+Ordering



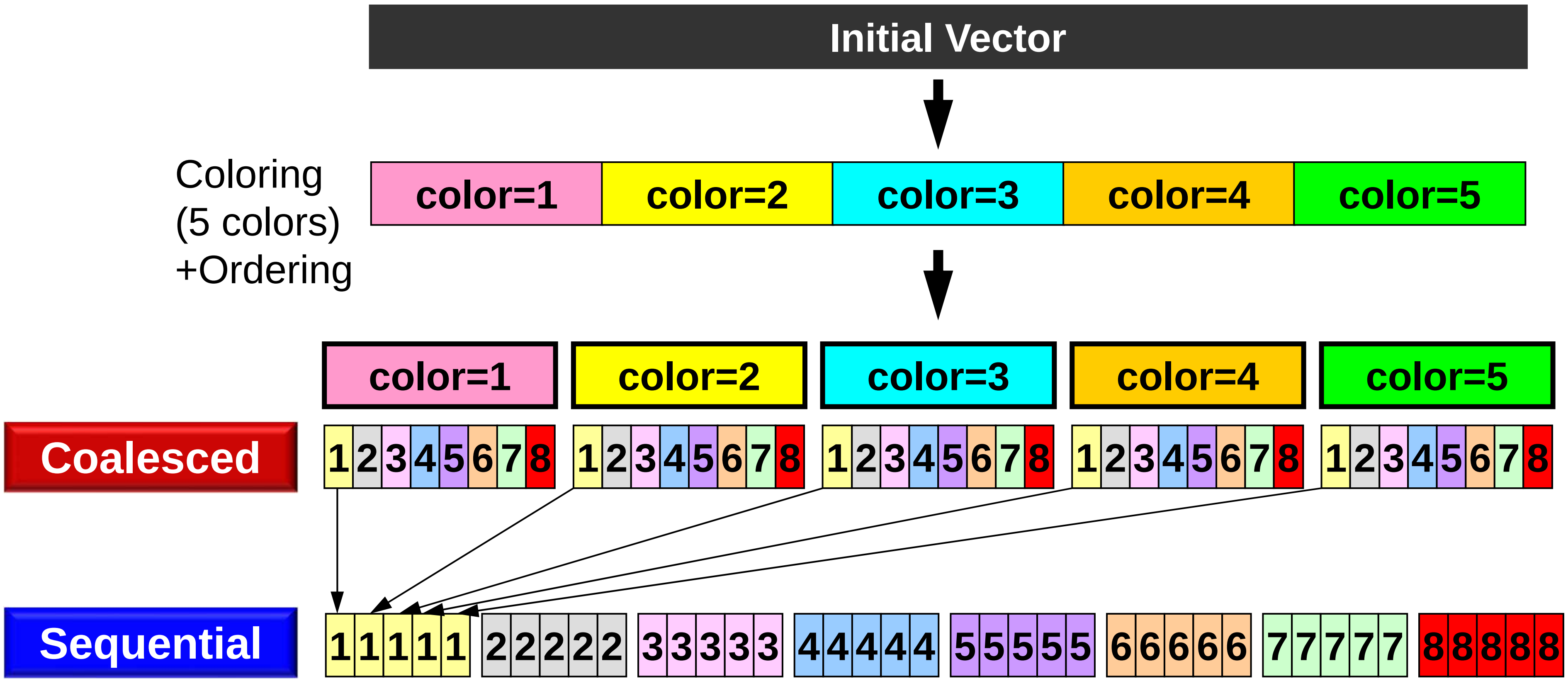
- 5-colors, 8-threads
- Meshes in same color are independent: parallel processing
- Reordering in ascending order according to color ID

Sequential Reordering

- Reordering for continuous memory access on each thread (core)
  - Performance is expected to be better.
    - Continuous address of arrays, such as coefficient matrices
    - Locality (2-page later)

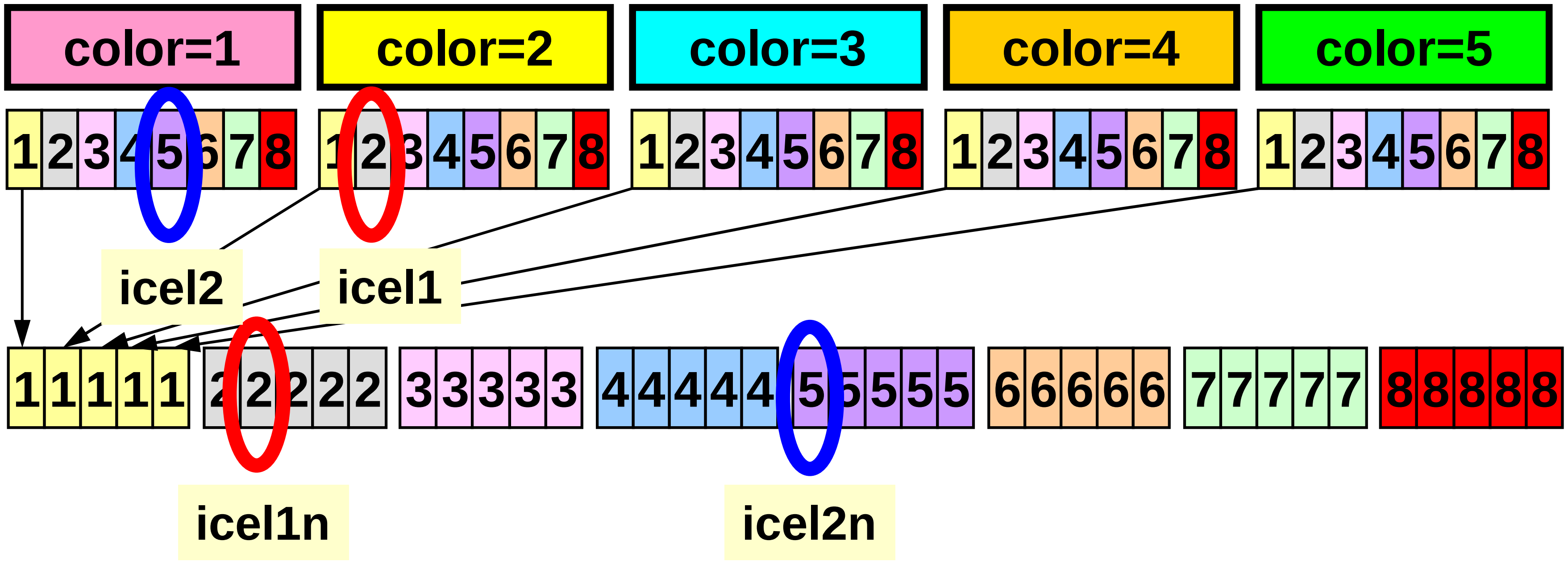
Sequential Reordering

Further reordering for continuous memory access on each thread, 5-color, 8-threads



Inconsistent numbering may occur

- Coalesced
  - **`icel1 > icel2`**, therefore, **`icel2= itemL[k]`**, where **`indexL[icel1]`**≦**`k`**<**`indexL[icel1+1]`**
- Sequential
  - **`icel1n < icel2n`**, but still **`icel2n= itemL[k]`**, where **`indexL[icel1n]`**≦**`k`**<**`indexL[icel1n+2]`**



Sequential Reordering

CM-RCM(2), 4-threads

Continuous Data Access on a Thread: Utilization of Cache, Prefetching

45	10	39	5	35	2	33	1
17	46	11	40	6	36	3	34
53	18	47	12	41	7	37	4
24	54	19	48	13	42	8	38
59	25	55	20	49	14	43	9
29	60	26	56	21	50	15	44
63	30	61	27	57	22	51	16
32	64	31	62	28	58	23	52

CM-RCM(2)

29	18	15	5	11	2	9	1
33	30	19	16	6	12	3	10
45	34	31	20	25	7	13	4
40	46	35	32	21	26	8	14
59	49	47	36	41	22	27	17
53	60	50	48	37	42	23	28
63	54	61	51	57	38	43	24
56	64	55	62	52	58	39	44

Sequential Reordering, 4-threads

Sequential Reordering

CM-RCM(2), 4-threads

1st-Color

#0 thread, #1, #2, #3

45	10	39	5	35	2	33	1
17	46	11	40	6	36	3	34
53	18	47	12	41	7	37	4
24	54	19	48	13	42	8	38
59	25	55	20	49	14	43	9
29	60	26	56	21	50	15	44
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CM-RCM(2)

29	18	15	5	11	2	9	1
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40	46	35	32	21	26	8	14
59	49	47	36	41	22	27	17
53	60	50	48	37	42	23	28
63	54	61	51	57	38	43	24
56	64	55	62	52	58	39	44

Sequential Reordering, 4-threads

Sequential Reordering

CM-RCM(2), 4-threads

2^{nd}-Color

#0 thread, #1, #2, #3

45	10	39	5	35	2	33	1
17	46	11	40	6	36	3	34
53	18	47	12	41	7	37	4
24	54	19	48	13	42	8	38
59	25	55	20	49	14	43	9
29	60	26	56	21	50	15	44
63	30	61	27	57	22	51	16
32	64	31	62	28	58	23	52

CM-RCM(2)

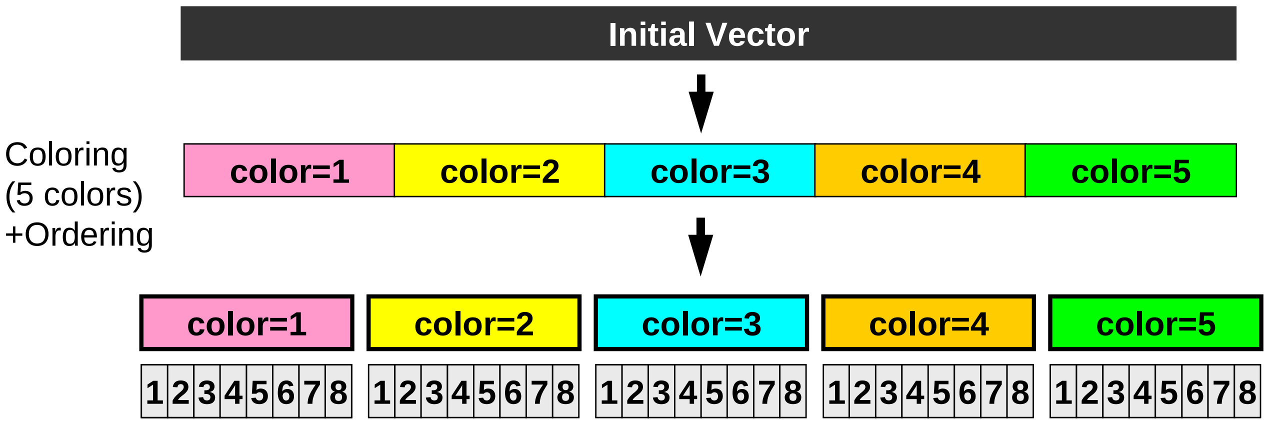
→

29	18	15	5	11	2	9	1
33	30	19	16	6	12	3	10
45	34	31	20	25	7	13	4
40	46	35	32	21	26	8	14
59	49	47	36	41	22	27	17
53	60	50	48	37	42	23	28
63	54	61	51	57	38	43	24
56	64	55	62	52	58	39	44

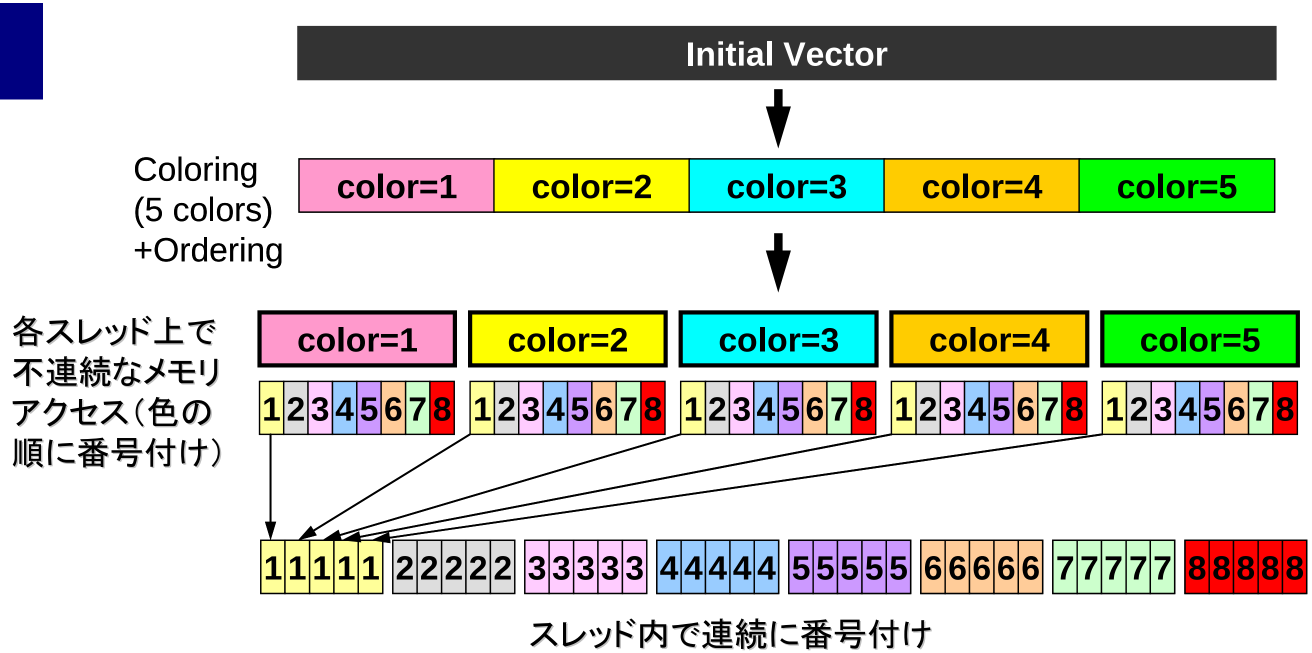
Sequential Reordering, 4-threads

Sequential Reordering

Coalesced
Good for GPU



Sequential



Additional Code

- Location
  - **`<$O-L3>: /work/gt51/t51YYY/multicoe/L3`**
  - **`<$O-L3>/reorder0`**, **`<$O-L3>/run`**
- Compile & Run
  - Source Code
    - `cd <$O-L3>/reorder0`
    - `make`
    - `<$O-L3>/run/L3-rsol0` execution file
  - Control Data
    - `<$O-L3>/run/INPUT.DAT`
  - Shell Script
    - `<$O-L3>/run/gor.sh`

gor.sh

```
#!/bin/sh
#PJM -N "test"
#PJM -L rscgrp=lecture1
#PJM -L node=1
#PJM --omp thread=24     (= PEsmpTOT)
#PJM -L elapse=00:15:00
#PJM -g gt51
#PJM -j
#PJM -e err
#PJM -o test1.lst

export KMP_AFFINITY=granularity=fine,compact
./L3-rsol0
```

INPUT.DAT

```
128 128 128                        NX/NY/NZ
1.00e-00 1.00e-00 1.00e-00         DX/DY/DZ
1.0e-08                            EPSICC
24                                 PEsmpTOT
-10                                NCOLORtot
0                                  NFLAG
0                                  METHOD
```

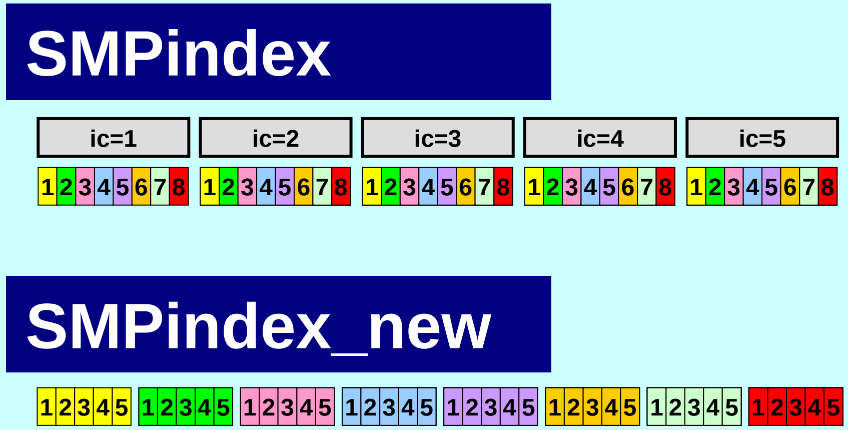
- **PEsmpTOT**
  - Thread Number **(--omp thread=XX)**
- **NCOLORtot**
  - Reordering Method + Initial Number of Colors/Levels
  - ≧2: MC, =0: CM, =-1: RCM, -2≧: CMRCM
- **NFLAG**
  - =0: without first-touch, =1: with first-touch
- **METHOD**
  - Loop structure for Mat-Vec
  - =0: conventional way, =1: similar to forward/backward substitution

Sequential Reordering (1/4) Main

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <errno.h>

#include "struct.h"
#include "pcg.h"
(…)

int main(){
        double *WK;
        int ISET, ITR, IER;
        int icel, ic0, i;
        double Stime, Etime;

        if(INPUT()) goto error;
        if(POINTER_INIT()) goto error;
        if(BOUNDARY_CELL()) goto error;
        if(CELL_METRICS()) goto error;
        if(POI_GEN()) goto error;

        ISET = 0;
        if(METHOD == 0 ){
                if(solve_ICCG_mc(ICELTOT, NL, NU, indexLnew, itemLnew,
                        indexUnew, itemUnew, D, BFORCE, PHI, ALnew, AUnew,
                        NCOLORtot, PEsmpTOT, SMPindex_new, EPSICCG,
                        &ITR, &IER)) goto error;
        }else if (METHOD == 1){
                if(solve_ICCG_mc_ft(ICELTOT, NL, NU, indexLnew, itemLnew,
                        indexUnew, itemUnew, D, BFORCE, PHI, ALnew, AUnew,
                        NCOLORtot, PEsmpTOT, SMPindex_new, EPSICCG,
                        &ITR, &IER)) goto error;
        }

        for(ic0=0; ic0<ICELTOT; ic0++){
                icel = NEWtoOLDnew[ic0];
                WK[icel-1] = PHI[ic0];
        }
        for(icel=0; icel<ICELTOT; icel++){
                PHI[icel] = WK[icel];
        }

        if(OUTUCD()) goto error;
        return 0;

error:
        return -1;
}
```

Sequential Reordering (2/4) poi_gen-1

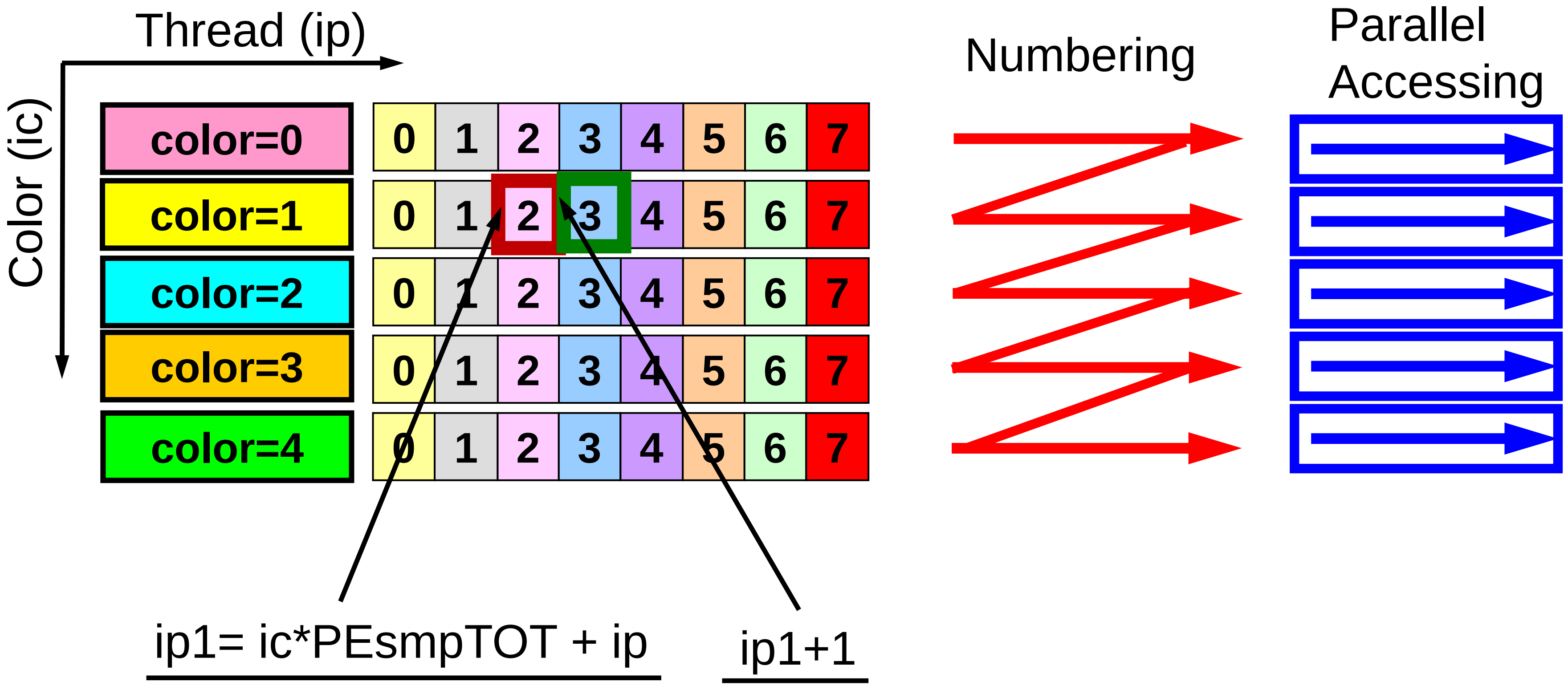
```
SMPindex = (int *) allocate_vector(sizeof(int), NCOLORtot * PEsmpTOT + 1);
memset(SMPindex, 0, sizeof(int)*(NCOLORtot*PEsmpTOT+1));

for(ic=1; ic<=NCOLORtot; ic++) {
    nn1 = COLORindex[ic] - COLORindex[ic-1];
    num = nn1 / PEsmpTOT;
    nr  = nn1 - PEsmpTOT * num;
    for(ip=1; ip<=PEsmpTOT; ip++) {
        if(ip <= nr) {
           SMPindex[(ic-1)*PEsmpTOT+ip] = num + 1;
        } else {
           SMPindex[(ic-1)*PEsmpTOT+ip] = num;
        }
    }
}
```




```
SMPindex_new = (int *) allocate_vector(sizeof(int), NCOLORtot * PEsmpTOT + 1);
memset(SMPindex_new, 0, sizeof(int)*(NCOLORtot*PEsmpTOT+1));

for(ic=1; ic<=NCOLORtot; ic++) {
    for(ip=1; ip<=PEsmpTOT; ip++) {
        j1 =(ic-1)*PEsmpTOT + ip;
        j0 =j1-1;
        SMPindex_new[(ip-1)*NCOLORtot+ic] = SMPindex[j1];
        SMPindex[j1] = SMPindex[j0] + SMPindex[j1];
    }
}

for(ip=1; ip<=PEsmpTOT; ip++) {
    for(ic=1; ic<=NCOLORtot; ic++) {
        j1 = (ip-1) * NCOLORtot + ic;
        j0 = j1 - 1;
        SMPindex_new[j1] += SMPindex_new[j0];
    }
}
```

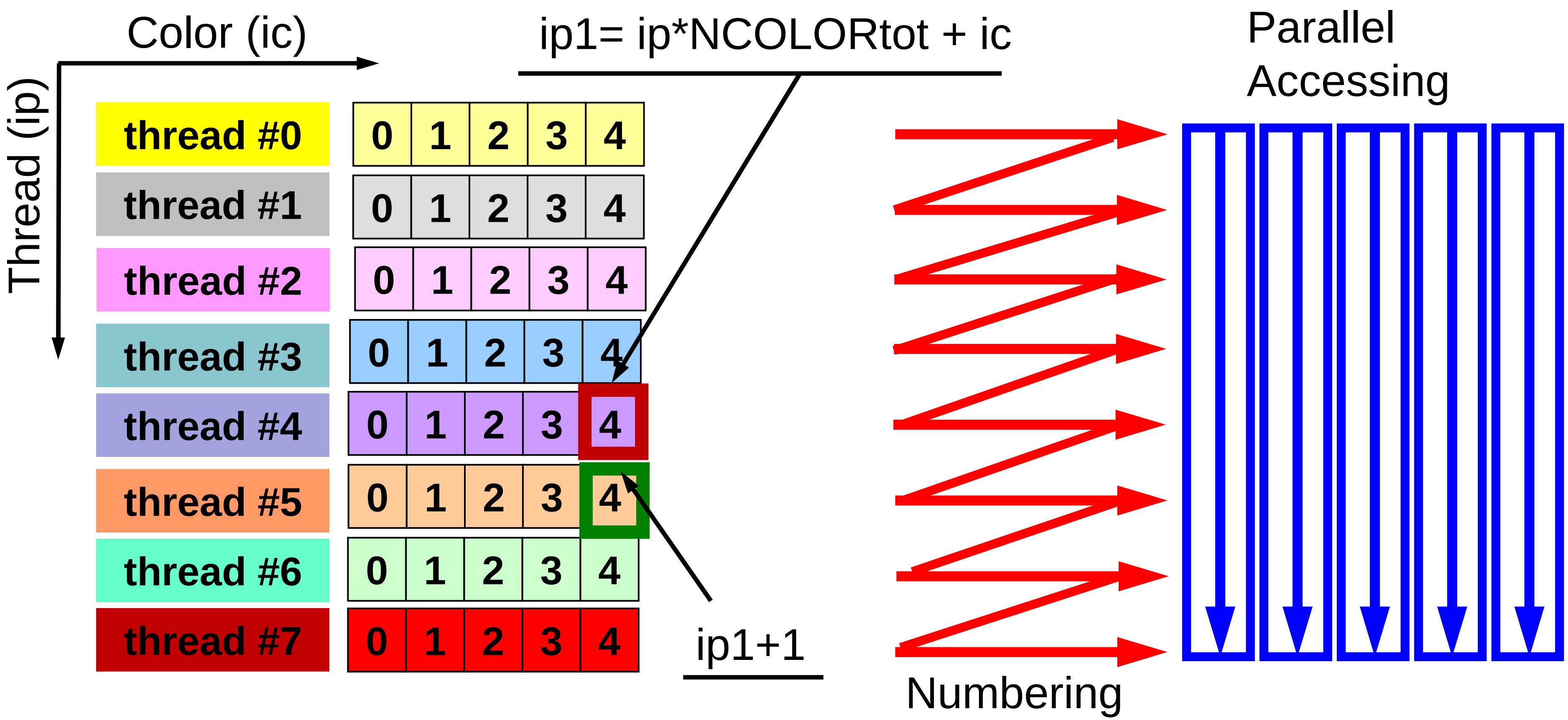
Coalesced

```
#pragma omp parallel private (ic,ip,ip1,i,WVAL,j)
for(ic=0; ic<NCOLORtot; ic++) {
#pragma omp for
    for(ip=0; ip<PEsmpTOT; ip++) {
        ip1 = ic * PEsmpTOT + ip;
        for(i=SMPindex[ip1]; i<SMPindex[ip1+1]; i++) {…
```



Sequential

```
#pragma omp parallel private (ic,ip,ip1,i,WVAL,j)
for(ic=0; ic<NCOLORtot; ic++) {
#pragma omp for
   for(ip=0; ip<PEsmpTOT; ip++) {
       ip1 = ip * NCOLORtot + ic;
       for(i=SMPindex_new[ip1]; i<SMPindex_new[ip1+1]; i++) {…
```



Sequential Reordering (3/4) poi_gen-2

```
for(ip=0; ip<PEsmpTOT; ip++){
    for(ic=0; ic<NCOLORtot; ic++){
        icNS = SMPindex_new[ip*NCOLORtot + ic];
        ic01 = SMPindex[ic*PEsmpTOT + ip];
        ic02 = SMPindex[ic*PEsmpTOT + ip+1];
        icou = 0;
        for(k=ic01; k<ic02; k++){
            icel=NEWtoOLD[k];
            icou = icou +1;
            icelN=icNS+icou;
            OLDtoNEWnew[icel-1] = icelN;
            NEWtoOLDnew[icelN-1]= icel;
        }
    }
}
```

OLDtoNEWnew: Original -> Sequential
NEWtoOLDnew: Sequential -> Original
-Original: Initial icel
-Sequential icelN

```
for(ip=1; ip<=PEsmpTOT; ip++) {
    id1 = ip    *NCOLORtot;
    id2 = (ip-1)*NCOLORtot;

    for(icel=SMPindex_new[id2]+1; icel<=SMPindex_new[id1]; icel++) {
        ic0  = NEWtoOLDnew[icel-1];
        ik0  = OLDtoNEW[ic0-1];

        INLnew[icel-1] =INL[ik0-1];
        INUnew[icel-1] =INU[ik0-1];
    }
}
```

Sequential **Coalesced**

```
for(i=1; i<=ICELTOT; i++){
    indexL[i]=indexL[i-1]+INLnew[i-1];
    indexU[i]=indexU[i-1]+INUnew[i-1];
}
```

-Original: Initial ic0
-Coalesced ik0
-Sequential icel

Sequential Reordering (4/4) poi_gen-3

```
#pragma omp parallel for private (icel,id1, id2 …)
for(ip=1; ip<=PEsmpTOT; ip++) {
    id1= ip    *NCOLORtot; id2= (ip-1)*NCOLORtot;
    for(icel=SMPindex_new[id2]+1; icel<=SMPindex_new[id1]; icel++) {
        ic0  = NEWtoOLDnew[icel-1];
        ik0  = OLDtoNEW[ic0-1];
        icN10 = NEIBcell[ic0-1][0];
(…)
        icN50 = NEIBcell[ic0-1][4];
        icN60 = NEIBcell[ic0-1][5];
        isL=indexL[ik0-1]; ieL=indexL[ik0  ];
        isU=indexU[ik0-1]; ieU=indexU[ik0  ];

        if(icN50 != 0) {
           icN5 = OLDtoNEW[icN50-1];
           coef = RDZ * ZAREA;
           D[icel-1] -= coef;
           if(icN5 < ik0) {
              for(j=isL; j<ieL; j++) {
                  if(itemL[j] == icN5) {
                     j_new=indexLnew[icel-1]+j-isL;
                     ALnew[j_new]     = coef;
                     itemLnew[j_new] = OLDtoNEWnew[icN50-1];
                     break;
                  }
              }
           } else {
              for(j=isU; j<ieU; j++) {
                  if(itemU[j] == icN5) {
                     j_new=indexUnew[icel-1]+j-isU;
                     AUnew[j_new] = coef;
                     itemUnew[j_new] = OLDtoNEWnew[icN50-1];
                     break;
                  }
              }
           }
    }
```

icel: Sequential
ic0: Original
ik0: Coalesced

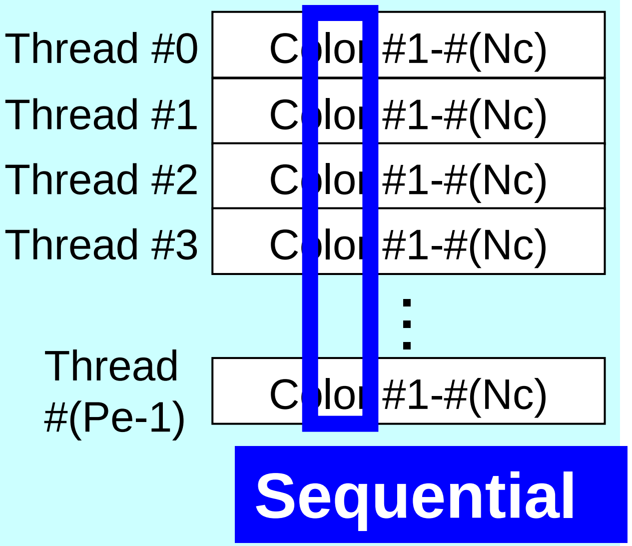
icN50: Original
icN5 : Coalesced

icN5>ik0: Upper (AU)
icN5<ik0: Lower (AL)

Forward Substitution

```
#pragma omp parallel private (ic,ip,ip1,i,WVAL,j)
for(ic=0; ic<NCOLORtot; ic++) {
#pragma omp for
    for(ip=0; ip<PEsmpTOT; ip++) {
        ip1 = ic * PEsmpTOT + ip;
        for(i=SMPindex[ip1]; i<SMPindex[ip1+1]; i++) {
            WVAL = W[Z][i];
            for(j=indexL[i]; j<indexL[i+1]; j++) {
                WVAL -= AL[j] * W[Z][itemL[j]-1];
            }
            W[Z][i] = WVAL * W[DD][i];
        }
    }
}
```


```
#pragma omp parallel private (ic,ip,ip1,i,WVAL,j)
for(ic=0; ic<NCOLORtot; ic++) {
#pragma omp for
   for(ip=0; ip<PEsmpTOT; ip++) {
       ip1 = ip * NCOLORtot + ic;
       for(i=SMPindex_new[ip1]; i<SMPindex_new[ip1+1]; i++) {
           WVAL = W[Z][i];
           for(j=indexLnew[i]; j<indexLnew[i+1]; j++) {
               WVAL -= ALnew[j] * W[Z][itemLnew[j]-1];
           }
           W[Z][i] = WVAL * W[DD][i];
       }
   }
}
```



Mat-Vec

```
#pragma omp parallel for private(ip,i)
for(ip=0; ip<PEsmpTOT; ip++) {
    for(i=SMPindexG[ip]; i<SMPindexG[ip+1]; i++) {
        VAL = D[i] * W[P][i];
        for(j=indexL[i]; j<indexL[i+1]; j++) {
            VAL += AL[j] * W[P][itemL[j]-1];
        }
        for(j=indexU[i]; j<indexU[i+1]; j++) {
            VAL += AU[j] * W[P][itemU[j]-1];
        }
        W[Q][i] = VAL;
    }
}
```

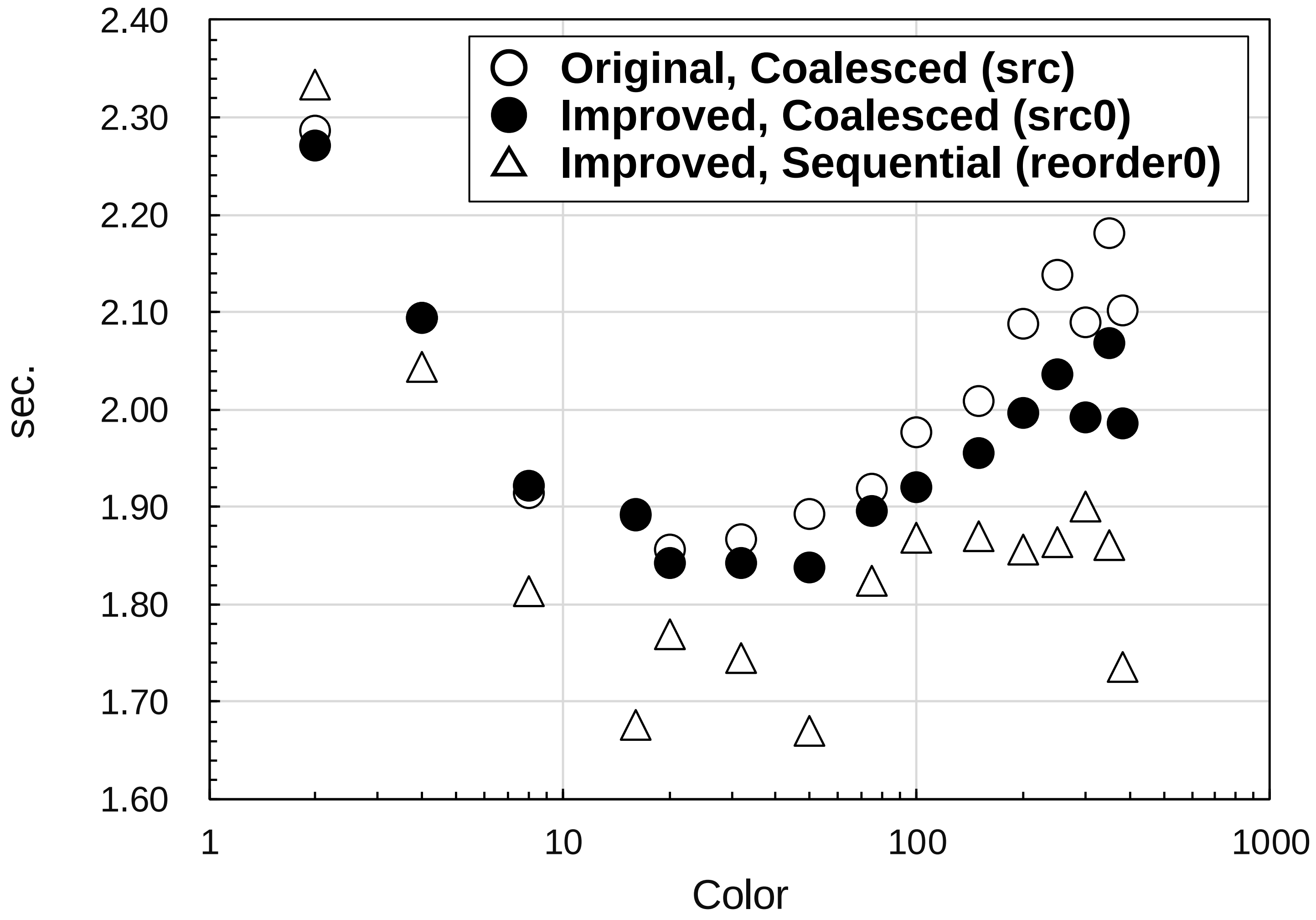
METHOD=0

```
#pragma omp parallel for private (ip1,i,VAL,j)
for(ip=0; ip<PEsmpTOT; ip++) {
    for(i=SMPindex_new[ip*NCOLORtot]; i<SMPindex_new[(ip+1)*NCOLORtot];i++){
        VAL = D[newi] * W[P][i];
        for(j=indexLnew[i]; j<indexLnew[i+1]; j++) {
            VAL += ALnew[j] * W[P][itemLnew[j]-1];
        }
        for(j=indexUnew[i]; j<indexUnew[i+1]; j++) {
            VAL += AUnew[j] * W[P][itemUnew[j]-1];
        }
        W[Q][i] = VAL;
    }
}
```

METHOD=1

Comp. Time for ICCG, CM-RCM

Generally “sequential (reorder0)” is stable and faster than “coalesced (src, src0)”. Effects should be more significant in cases with more colors, but … (24 threads)



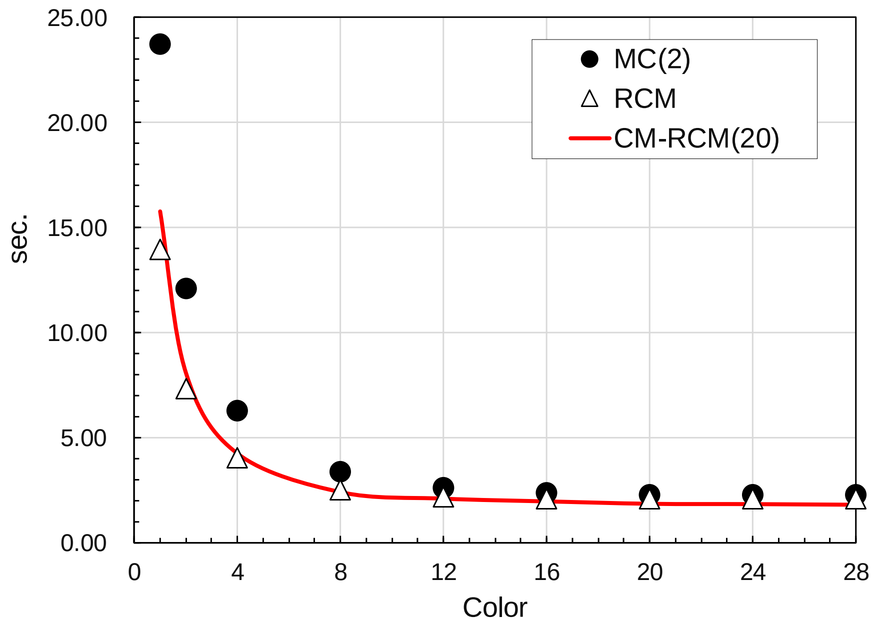
Results on OBCX：128^3

24 cores, **<u>src</u>**: MC（2-colors）：424 iter's, 2.287 sec.

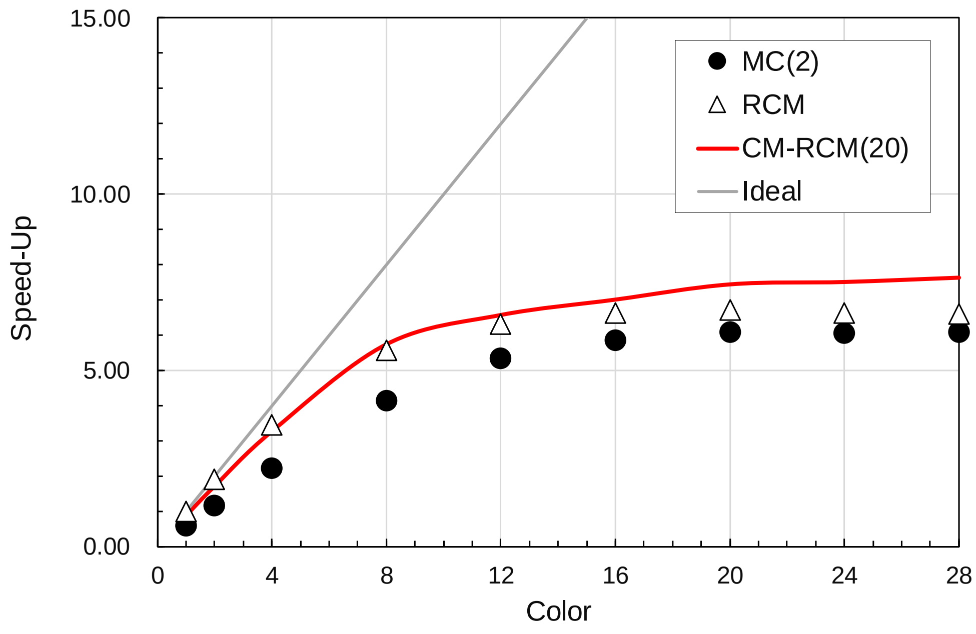
RCM（382-levels）：287 iter's, 2.117 sec.

CM-RCM（Nc=20）：318 iter's, 1.830 sec.

Computation Time



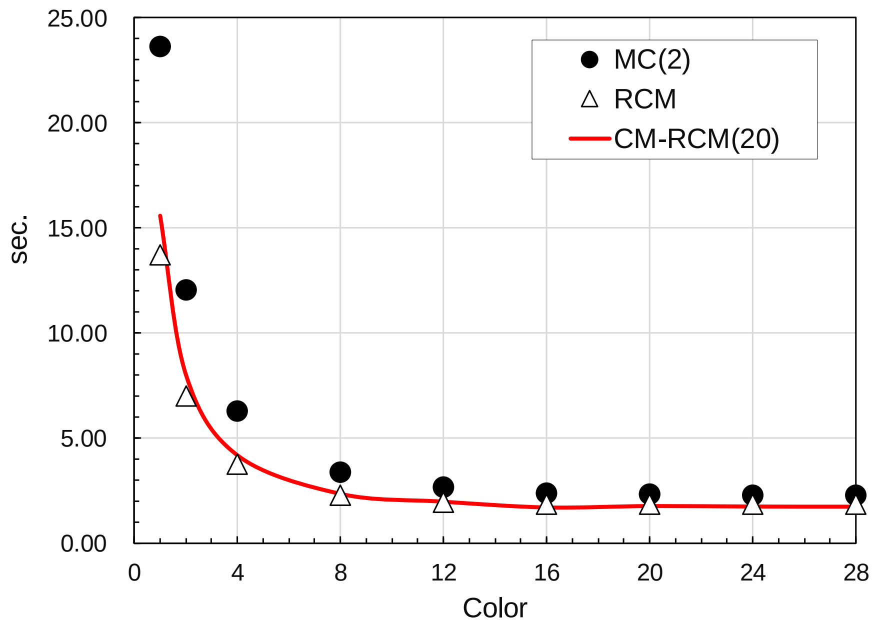
Speed-Up based on RCM (src) with 1 thread



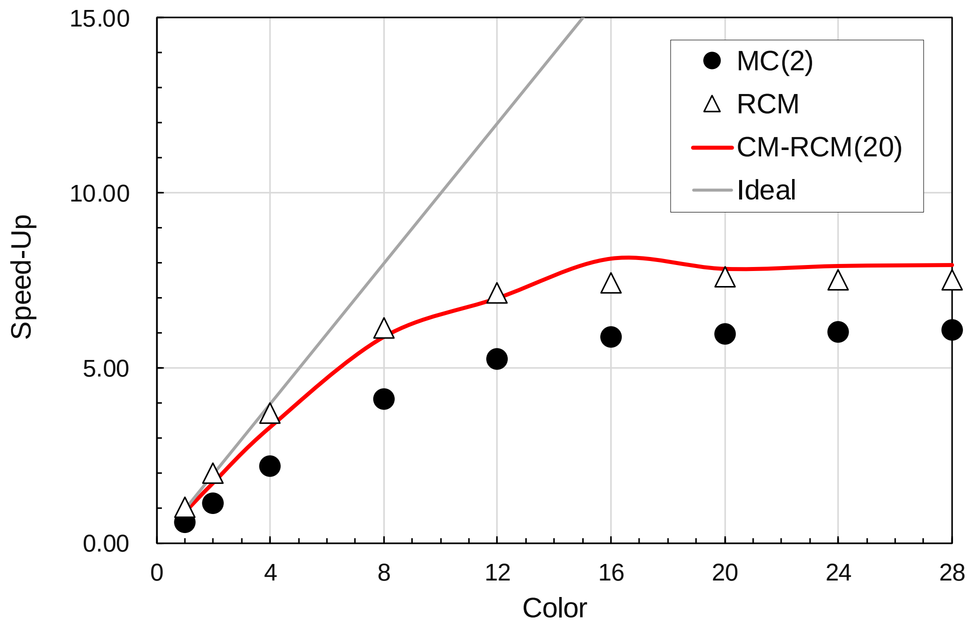
Results on OBCX: 128^3

24 cores, **reorder0**: MC(2-colors): 424 iter's, 2.287 sec.
RCM(382-levels): 287 iter's, 1.857 sec.
CM-RCM(Nc=20): 318 iter's, 1.754 sec.

Computation Time

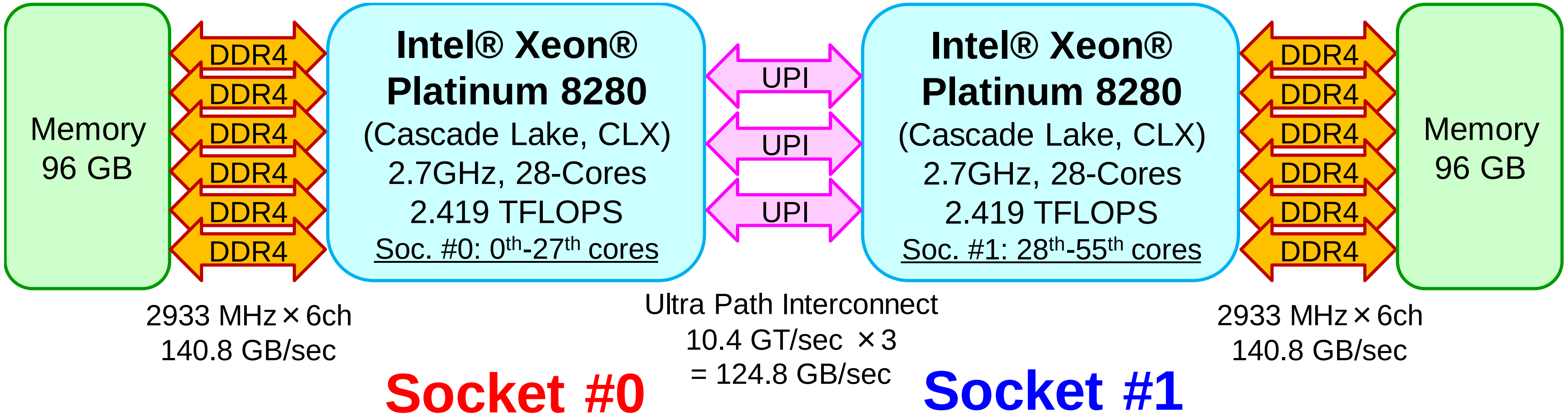


Speed-Up based on RCM (src) with 1 thread



OBCX

1-node: 2-CPU's/sockets



- Each Node of OBCX
  - 2 Sockets (CPU's) of Intel Cascade Lake
  - Each socket has 28 cores
- Each core of a socket can access to the memory on the other socket : NUMA (Non-Uniform Memory Access)
- Utilization of the local memory is more efficient
- So far, only a single socket has been used
  - Let's utilize both sockets

First Touch Data Placement

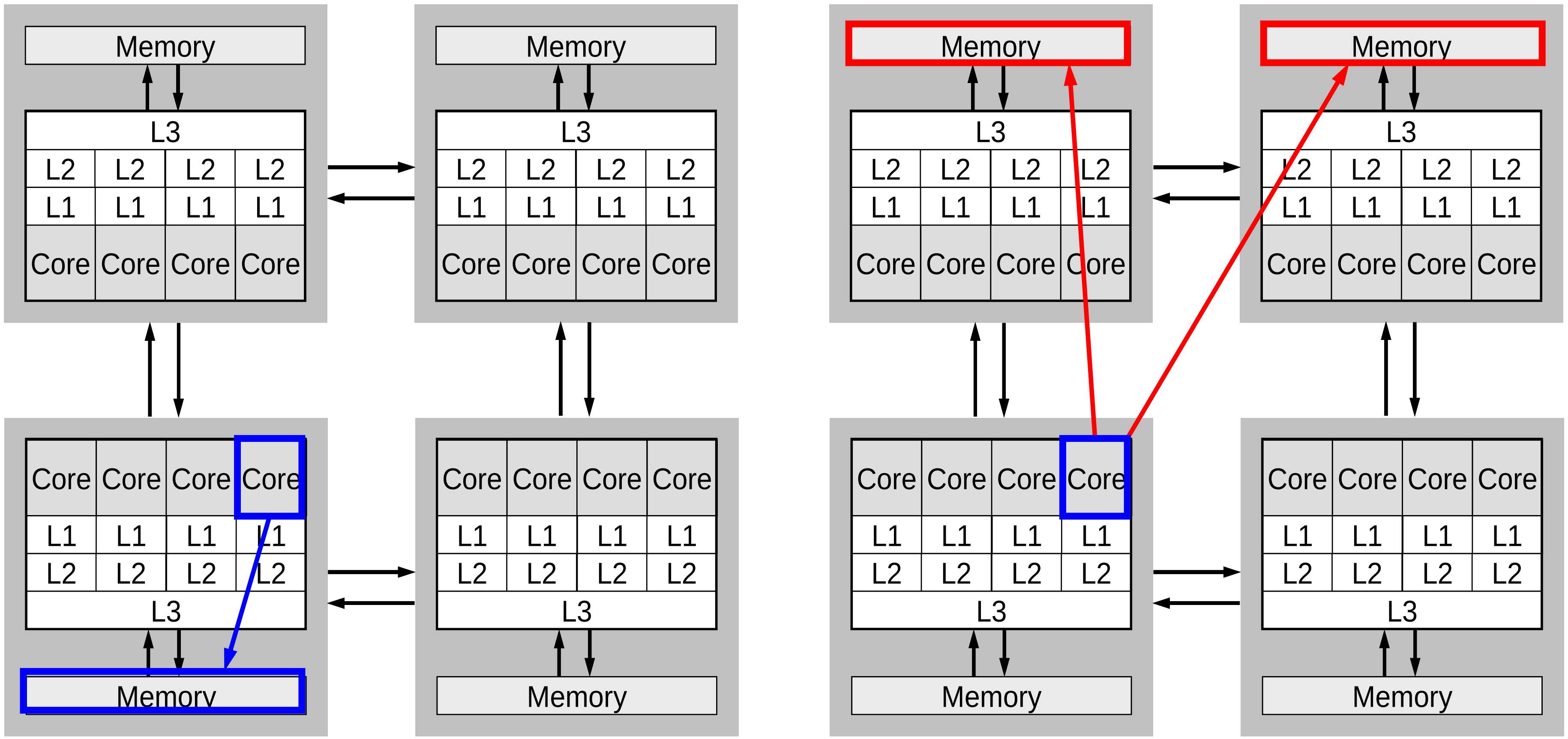
“Patterns for Parallel Programming” Mattson, T.G. et al.

- To reduce memory traffic in the system, it is important to keep the data close to the PEs that will work with the data (e.g. NUMA control).
- On NUMA computers, this corresponds to making sure the pages of memory are allocated and “owned” by the PEs that will be working with the data contained in the page.
    - ✓ **Page/Memory Page/Virtual Page**: A fixed-length continuous block of virtual memory, smallest unit of data for memory management in a virtual memory OS
- The most common NUMA page-placement algorithm is the “first touch” algorithm, in which the PE first referencing a region of memory will have the page holding that memory assigned to it.
- A very common technique in OpenMP program for optimization is to initialize data in parallel using the same loop schedule as will be used later in the computations.

Summary: First Touch Data Placement

- On NUMA architecture (Non-Uniform Memory Access), “pages of memory” are not allocated when variables and arrays are declared/allocated in the program.
- “Pages” are allocated at the local memory of the “socket” for the “core/thread” that first touches the variables and/or arrays.
- If the pages are not on the local memory of the socket for each thread, performance of the program is very bad.
- A very common technique in OpenMP program for optimization is to initialize data in parallel using the same loop schedule as will be used later in the computations.
- You have to consider this if you use two sockets of the OBCX system for a single OpenMP program
  - Not needed for a single socket case

Local/Remote Memory



Local Memory **Remote Memory**

Control Data: INPUT.DAT

```
128 128 128                         NX/NY/NZ
1.00e-00 1.00e-00 1.00e-00           DX/DY/DZ
1.0e-08                              EPSICC
48                                   PEsmpTOT
-50                                  NCOLORtot
0                                    NFLAG (0 or 1)
0                                    METHOD
```

- **PEsmpTOT**
  - Thread Number **(--omp thread=XX)**
- **NCOLORtot**
  - Reordering Method + Initial Number of Colors/Levels
  - ≧2: MC, =0: CM, =-1: RCM, -2≧: CMRCM
- **NFLAG**
  - =0: without first-touch, =1: with first-touch
- **METHOD**
  - Loop structure for Mat-Vec
  - =0: conventional way, =1: similar to forward/backward substitution

go2.sh: reorder0

```
#!/bin/sh
#PJM -N "test"
#PJM -L rscgrp=lecture1
#PJM -L node=1
#PJM --omp thread=48     (= PEsmpTOT)
#PJM -L elapse=00:15:00
#PJM -g gt51
#PJM -j
#PJM -e err
#PJM -o test1.lst

export KMP_AFFINITY=granularity=fine,compact
./L3-rsol0
```

Array Initialization: NFLAG=0/1 (1/2)

```
if(NFLAG == 0){
   for(i=0; i<ICELTOT; i++) {
       BFORCE[i] = 0.0;
       D[i]      = 0.0;
       PHI[i]    = 0.0;
   }
   for(i=0; i<=ICELTOT; i++) {
       indexLnew[i] = indexLnew_org[i];
       indexUnew[i] = indexUnew_org[i];
   }
   for(i=0; i<NPL; i++) {
       itemLnew[i] = 0;
       ALnew[i] = 0.0;
   }
   for(i=0; i<NPU; i++) {
       itemUnew[i] = 0;
       AUnew[i] = 0.0;
   }

   }else {
```

Pages are allocated at the local memory of the master thread

A very common technique in OpenMP program for optimization is to initialize data in parallel using the same loop schedule as will be used later in the computations.

Array Initialization: NFLAG=0/1 (2/2)

```
    }else {
          indexLnew[0]=0;
          indexUnew[0]=0;
#pragma omp parallel for private (icel, j)
     for(ip=1; ip<=PEsmpTOT; ip++){
        for(icel = SMPindex_new[(ip-1)*NCOLORtot]+1;
            icel<=SMPindex_new[ip*NCOLORtot]; icel++){
            BFORCE[icel-1] = 0.0;
            PHI[icel-1] = 0.0;
            D[icel-1] = 0.0;
            indexLnew[icel]=indexLnew_org[icel];
            indexUnew[icel]=indexUnew_org[icel];

            for(j=indexLnew_org[icel-1];j<indexLnew_org[icel];j++){
                itemLnew[j]=0;
                ALnew[j] = 0.0;
            }
            for(j=indexUnew_org[icel-1];j<indexUnew_org[icel];j++){
                itemUnew[j]=0;
                AUnew[j] = 0.0;
            }
        }
     }
  }
```

Pages are allocated at the local memory of each thread

A very common technique in OpenMP program for optimization is to initialize data in parallel using the same loop schedule as will be used later in the computations.

Results: reoder0, L3-rsol0

```
128 128 128                        NX/NY/NZ
1.00e-0 1.00e-0 1.00e0             DX/DY/DZ
1.0e-08                            OMEGA, EPSICCG
48                                 PEsmpTOT
-1                                 NCOLORtot
0                                  NFLAG
0                                  METHOD
```

Thread #	NFLAG	RCM	CM-RCM(50)
24	0	1.736	1.670
28	0	1.859	1.764
48	0	1.550	1.275
	1	1.274	0.891
56	0	1.681	1.297
	1	1.321	0.819

Programming Exercise for Report

- Implement “Sequential Reordering”
- Optimize “Two-Socket” cases with 48-56 cores by “First Touch Data Placement”
- Evaluate the performance of the code, and make comparison with that of the “Coalesced” code
- Original “Coalesced” Code
  - **`/work/gt51/t51XXYYY/multicore/L3/src0`**

- Questions in the Class on July 22

Report

- Deadline: 17:00 August 24 (Mon), 2020
- Send files via e-mail at **`nakajima(at)cc.u-tokyo.ac.jp`**
- Report : 日本語でもOK
  - Cover Page: Name and ID must be written.
  - No more than 20 pages including figures and tables (A4).
    - Strategy
    - Structure of the Program, Details of Modification
    - Validation
    - Numerical Experiments
    - Performance Analysis
    - Remarks (Important !!)
  - Source list of the entire program (not included in the 20 pages above)