

Distributed Local Data Structure for Parallel Computation

- Distributed local data structure for domain-to-domain communications has been introduced, which is appropriate for such applications with sparse coefficient matrices (e.g. FDM, FEM, FVM etc.).
 - SPMD
 - Local Numbering: Internal pts to External pts
 - Generalized communication table
- Everything is easy, if proper data structure is defined:
 - Values at boundary pts are copied into sending buffers
 - Send/Recv
 - Values at external pts are updated through receiving buffers



Initial Mesh

<u>21</u>	<u>22</u>	<u>23</u>	<u>24</u>	<u>25</u>
<u>16</u>	<u>17</u>	<u>18</u>	<u>19</u>	<u>20</u>
<u>11</u>	<u>12</u>	<u>13</u>	<u>14</u>	<u>15</u>
<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>
<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>

#PE2

<u>21</u>	<u>22</u>	<u>23</u>	<u>24</u>
<u>16</u>	<u>17</u>	<u>18</u>	<u>19</u>
<u>11</u>	<u>12</u>	<u>13</u>	<u>14</u>
<u>6</u>	<u>7</u>	<u>8</u>	

#PE1

<u>23</u>	<u>24</u>	<u>25</u>
<u>18</u>	<u>19</u>	<u>20</u>
<u>13</u>	<u>14</u>	<u>15</u>
<u>8</u>	<u>9</u>	<u>10</u>
	<u>4</u>	<u>5</u>

#PE0

<u>11</u>	<u>12</u>	<u>13</u>		
<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>
<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>

Three Domains

t2

#PE2

7 <u>21</u>	8 <u>22</u>	9 <u>23</u>	15 <u>24</u>
4 <u>16</u>	5 <u>17</u>	6 <u>18</u>	14 <u>19</u>
1 <u>11</u>	2 <u>12</u>	3 <u>13</u>	13 <u>14</u>
10 <u>6</u>	11 <u>7</u>	12 <u>8</u>	

#PE1

14 <u>23</u>	7 <u>24</u>	8 <u>25</u>
13 <u>18</u>	5 <u>19</u>	6 <u>20</u>
12 <u>13</u>	3 <u>14</u>	4 <u>15</u>
11 <u>8</u>	1 <u>9</u>	2 <u>10</u>
	9 <u>4</u>	10 <u>5</u>

#PE0

11 <u>11</u>	12 <u>12</u>	13 <u>13</u>		
6 <u>6</u>	7 <u>7</u>	8 <u>8</u>	9 <u>9</u>	10 <u>10</u>
1 <u>1</u>	2 <u>2</u>	3 <u>3</u>	4 <u>4</u>	5 <u>5</u>

PE#0: sqm.0: fill O's

#PE2

<u>7</u> 21	<u>8</u> 22	<u>9</u> 23	<u>15</u> 24
<u>4</u> 16	<u>5</u> 17	<u>6</u> 18	<u>14</u> 19
<u>1</u> 11	<u>2</u> 12	<u>3</u> 13	<u>13</u> 14
<u>10</u> 6	<u>11</u> 7	<u>12</u> 8	

#PE1

<u>14</u> 23	<u>7</u> 24	<u>8</u> 25
<u>13</u> 18	<u>5</u> 19	<u>6</u> 20
<u>12</u> 13	<u>3</u> 14	<u>4</u> 15
<u>11</u> 8	<u>1</u> 9	<u>2</u> 10
	<u>9</u> 4	<u>10</u> 5

#PE0

<u>11</u> 11	<u>12</u> 12	<u>13</u> 13		
<u>6</u> 6	<u>7</u> 7	<u>8</u> 8	<u>9</u> 9	<u>10</u> 10
<u>1</u> 1	<u>2</u> 2	<u>3</u> 3	<u>4</u> 4	<u>5</u> 5

```
#NEIBPEtot
2
#NEIBPE
1      2
#NODE
  O      O
#IMPORTindex
  O      O
#IMPORTitems
  O...
#EXPORTindex
  O      O
#EXPORTitems
  O...
```

PE#1: sqm.1: fill O's

#PE2

<u>7</u> 21	<u>8</u> 22	<u>9</u> 23	<u>15</u> 24
<u>4</u> 16	<u>5</u> 17	<u>6</u> 18	<u>14</u> 19
<u>1</u> 11	<u>2</u> 12	<u>3</u> 13	<u>13</u> 14
<u>10</u> 6	<u>11</u> 7	<u>12</u> 8	

#PE1

<u>14</u> 23	<u>7</u> 24	<u>8</u> 25
<u>13</u> 18	<u>5</u> 19	<u>6</u> 20
<u>12</u> 13	<u>3</u> 14	<u>4</u> 15
<u>11</u> 8	<u>1</u> 9	<u>2</u> 10
	<u>9</u> 4	<u>10</u> 5

#PE0

<u>11</u> 11	<u>12</u> 12	<u>13</u> 13		
<u>6</u> 6	<u>7</u> 7	<u>8</u> 8	<u>9</u> 9	<u>10</u> 10
<u>1</u> 1	<u>2</u> 2	<u>3</u> 3	<u>4</u> 4	<u>5</u> 5

```
#NEIBPEtot
2
#NEIBPE
0      2
#NODE
  O      O
#IMPORTindex
  O      O
#IMPORTitems
  O...
#EXPORTindex
  O      O
#EXPORTitems
  O...
```

PE#2: sqm.2: fill O's

#PE2

<u>7</u> 21	<u>8</u> 22	<u>9</u> 23	<u>15</u> 24
<u>4</u> 16	<u>5</u> 17	<u>6</u> 18	<u>14</u> 19
<u>1</u> 11	<u>2</u> 12	<u>3</u> 13	<u>13</u> 14
<u>10</u> 6	<u>11</u> 7	<u>12</u> 8	

#PE1

<u>14</u> 23	<u>7</u> 24	<u>8</u> 25
<u>13</u> 18	<u>5</u> 19	<u>6</u> 20
<u>12</u> 13	<u>3</u> 14	<u>4</u> 15
<u>11</u> 8	<u>1</u> 9	<u>2</u> 10
	<u>9</u> 4	<u>10</u> 5

#PE0

<u>11</u> 11	<u>12</u> 12	<u>13</u> 13		
<u>6</u> 6	<u>7</u> 7	<u>8</u> 8	<u>9</u> 9	<u>10</u> 10
<u>1</u> 1	<u>2</u> 2	<u>3</u> 3	<u>4</u> 4	<u>5</u> 5

```
#NEIBPEtot
2
#NEIBPE
1      0
#NODE
  O      O
#IMPORTindex
  O      O
#IMPORTitems
  O...
#EXPORTindex
  O      O
#EXPORTitems
  O...
```

#PE2

7 <u>21</u>	8 <u>22</u>	9 <u>23</u>	15 <u>24</u>
4 <u>16</u>	5 <u>17</u>	6 <u>18</u>	14 <u>19</u>
1 <u>11</u>	2 <u>12</u>	3 <u>13</u>	13 <u>14</u>
10 <u>6</u>	11 <u>7</u>	12 <u>8</u>	

t2

#PE1

14 <u>23</u>	7 <u>24</u>	8 <u>25</u>
13 <u>18</u>	5 <u>19</u>	6 <u>20</u>
12 <u>13</u>	3 <u>14</u>	4 <u>15</u>
11 <u>8</u>	1 <u>9</u>	2 <u>10</u>
	9 <u>4</u>	10 <u>5</u>

#PE0

11 <u>11</u>	12 <u>12</u>	13 <u>13</u>		
6 <u>6</u>	7 <u>7</u>	8 <u>8</u>	9 <u>9</u>	10 <u>10</u>
1 <u>1</u>	2 <u>2</u>	3 <u>3</u>	4 <u>4</u>	5 <u>5</u>

Procedures

- Number of Internal/External Points
- Where do External Pts come from ?
 - **IMPORTindex, IMPORTitems**
 - Sequence of **NEIBPE**
- Then check destinations of Boundary Pts.
 - **EXPORTindex, EXPORTitems**
 - Sequence of **NEIBPE**

Answer

/work/gt00/z30088/pFEM/answer/t2

go3. sh

```
#!/bin/sh
#PJM -N "test"
#PJM -L rscgrp=lecture9
#PJM -L node=1
#PJM --mpi proc=3
#PJM -L elapse=00:15:00
#PJM -g gt39
#PJM -j
#PJM -e err
#PJM -o test.lst

mpiexec.hydra -n ${PJM_MPI_PROC} ./a.out
```

Where do Ext Pts come from ? : PE#0

#PE2

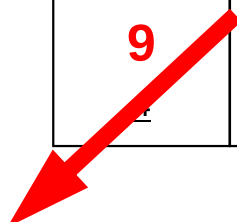
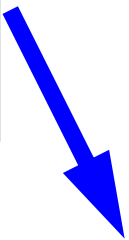
7 <u>21</u>	8 <u>22</u>	9 <u>23</u>	15 <u>24</u>
4 <u>16</u>	5 <u>17</u>	6 <u>18</u>	14 <u>19</u>
1 <u>11</u>	2 <u>12</u>	3 <u>13</u>	13 <u>14</u>
10 <u>6</u>	11 <u>7</u>	12 <u>8</u>	

#PE1

14 <u>23</u>	7 <u>24</u>	8 <u>25</u>
13 <u>18</u>	5 <u>19</u>	6 <u>20</u>
12 <u>13</u>	3 <u>14</u>	4 <u>15</u>
11 <u>8</u>	1 <u>9</u>	2 <u>10</u>
	9 <u>4</u>	10 <u>5</u>

#PE0

11 <u>11</u>	12 <u>12</u>	13 <u>13</u>		
6 <u>6</u>	7 <u>7</u>	8 <u>8</u>	9 <u>9</u>	10 <u>10</u>
1 <u>1</u>	2 <u>2</u>	3 <u>3</u>	4 <u>4</u>	5 <u>5</u>



PE#0: Distributed Local Data

#PE2

<u>7</u> 21	<u>8</u> 22	<u>9</u> 23	<u>15</u> 24
<u>4</u> 16	<u>5</u> 17	<u>6</u> 18	<u>14</u> 19
<u>1</u> 11	<u>2</u> 12	<u>3</u> 13	<u>13</u> 14
<u>10</u> 6	<u>11</u> 7	<u>12</u> 8	

#PE1

<u>14</u> 23	<u>7</u> 24	<u>8</u> 25
<u>13</u> 18	<u>5</u> 19	<u>6</u> 20
<u>12</u> 13	<u>3</u> 14	<u>4</u> 15
<u>11</u> 8	<u>1</u> 9	<u>2</u> 10
	<u>9</u> 4	<u>10</u> 5

#PE0

<u>11</u> 11	<u>12</u> 12	<u>13</u> 13		
<u>6</u> 6	<u>7</u> 7	<u>8</u> 8	<u>9</u> 9	<u>10</u> 10
<u>1</u> 1	<u>2</u> 2	<u>3</u> 3	<u>4</u> 4	<u>5</u> 5

```
#NEIBPEtot
2
#NEIBPE
1 2
#NODE
13 8
#IMPORTindex
2 5
#IMPORTitems
9
10
11
12
13
#EXPORTindex
3 6
#EXPORTitems
4
5
8
6
7
8
```

Where do Ext Pts come from?: PE#1

#PE2

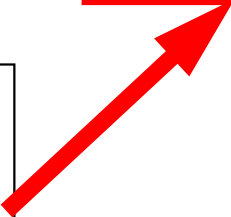
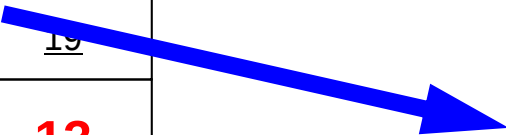
7 <u>21</u>	8 <u>22</u>	9 <u>23</u>	15 <u>24</u>
4 <u>16</u>	5 <u>17</u>	6 <u>18</u>	14 <u>19</u>
1 <u>11</u>	2 <u>12</u>	3 <u>13</u>	13 <u>14</u>
10 <u>6</u>	11 <u>7</u>	12 <u>8</u>	

#PE1

14 <u>23</u>	7 <u>24</u>	8 <u>25</u>
13 <u>18</u>	5 <u>19</u>	6 <u>20</u>
12 <u>13</u>	3 <u>14</u>	4 <u>15</u>
11 <u>8</u>	1 <u>9</u>	2 <u>10</u>
	9 <u>4</u>	10 <u>5</u>

#PE0

11 <u>11</u>	12 <u>12</u>	13 <u>13</u>		
6 <u>6</u>	7 <u>7</u>	8 <u>8</u>	9 <u>9</u>	10 <u>10</u>
1 <u>1</u>	2 <u>2</u>	3 <u>3</u>	4 <u>4</u>	5 <u>5</u>



PE#1: Distributed Local Data

#PE2

7 21	8 22	9 23	15 24
4 16	5 17	6 18	14 19
1 11	2 12	3 13	13 14
10 6	11 7	12 8	

#PE1

14 23	7 24	8 25
13 18	5 19	6 20
12 13	3 14	4 15
11 8	1 9	2 10
	9 4	10 5

#PE0

11 11	12 12	13 13		
6 6	7 7	8 8	9 9	10 10
1 1	2 2	3 3	4 4	5 5

```
#NEIBPEtot
2
#NEIBPE
0 2
#NODE
14 8
#IMPORTindex
3 6
#IMPORTitems
9
10
11
12
13
14
#EXPORTindex
2 5
#EXPORTitems
1
2
3
5
7
```

Where do Ext Pts come from ? : PE#2

#PE2

7 <u>21</u>	8 <u>22</u>	9 <u>23</u>	15 <u>24</u>
4 <u>16</u>	5 <u>17</u>	6 <u>18</u>	14 <u>19</u>
1 <u>11</u>	2 <u>12</u>	3 <u>13</u>	13 <u>14</u>
10 <u>6</u>	11 <u>7</u>	12 <u>8</u>	

#PE1

14 <u>23</u>	7 <u>24</u>	8 <u>25</u>
13 <u>18</u>	5 <u>19</u>	6 <u>20</u>
12 <u>13</u>	3 <u>14</u>	4 <u>15</u>
11 <u>8</u>	1 <u>9</u>	2 <u>10</u>
	9 <u>4</u>	10 <u>5</u>

#PE0

11 <u>11</u>	12 <u>12</u>	13 <u>13</u>		
6 <u>6</u>	7 <u>7</u>	8 <u>8</u>	9 <u>9</u>	10 <u>10</u>
1 <u>1</u>	2 <u>2</u>	3 <u>3</u>	4 <u>4</u>	5 <u>5</u>



PE#2: Distributed Local Data

#PE2

<u>7</u> 21	<u>8</u> 22	<u>9</u> 23	<u>15</u> 24
<u>4</u> 16	<u>5</u> 17	<u>6</u> 18	<u>14</u> 19
<u>1</u> 11	<u>2</u> 12	<u>3</u> 13	<u>13</u> 14
<u>10</u> 6	<u>11</u> 7	<u>12</u> 8	

#PE1

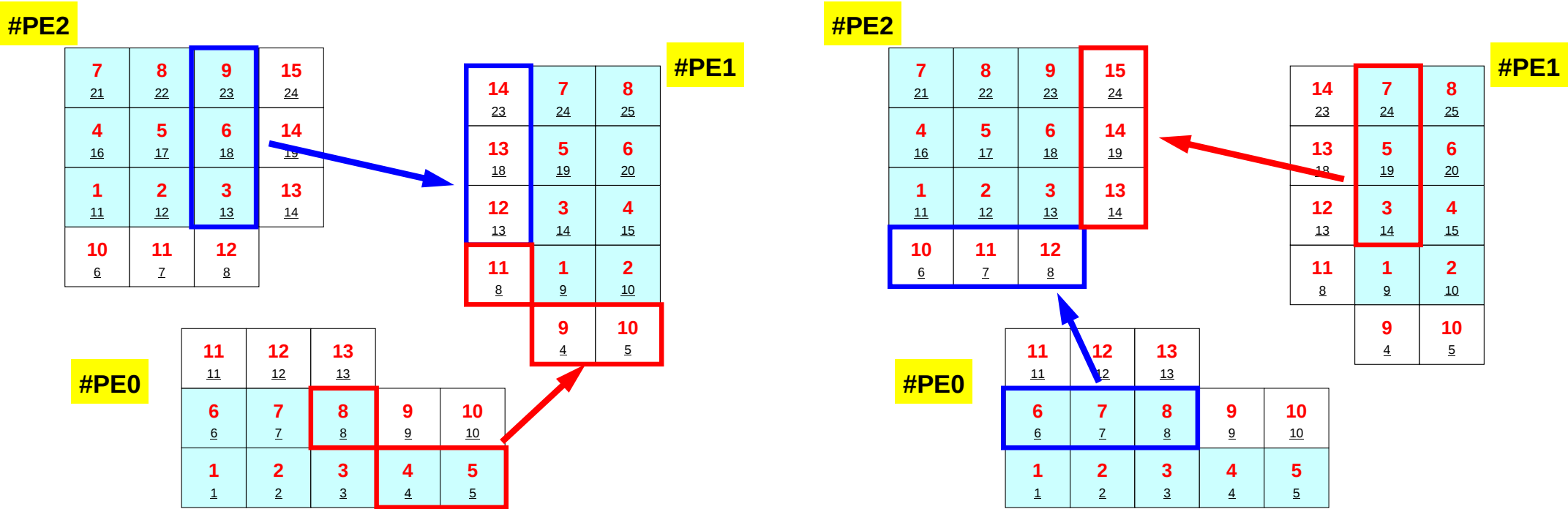
<u>14</u> 23	<u>7</u> 24	<u>8</u> 25
<u>13</u> 18	<u>5</u> 19	<u>6</u> 20
<u>12</u> 13	<u>3</u> 14	<u>4</u> 15
<u>11</u> 8	<u>1</u> 9	<u>2</u> 10
	<u>9</u> 4	<u>10</u> 5

#PE0

<u>11</u> 11	<u>12</u> 12	<u>13</u> 13		
<u>6</u> 6	<u>7</u> 7	<u>8</u> 8	<u>9</u> 9	<u>10</u> 10
<u>1</u> 1	<u>2</u> 2	<u>3</u> 3	<u>4</u> 4	<u>5</u> 5

```
#NEIBPEtot
2
#NEIBPE
1 0
#NODE
15 9
#IMPORTindex
3 6
#IMPORTitems
13
14
15
10
11
12
#EXPORTindex
3 6
#EXPORTitems
3
6
9
1
2
3
```

Where do Boundary Pts go to ? : PE#0



PE#0: Distributed Local Data

#PE2

7 <u>21</u>	8 <u>22</u>	9 <u>23</u>	15 <u>24</u>
4 <u>16</u>	5 <u>17</u>	6 <u>18</u>	14 <u>19</u>
1 <u>11</u>	2 <u>12</u>	3 <u>13</u>	13 <u>14</u>
10 <u>6</u>	11 <u>7</u>	12 <u>8</u>	

#PE1

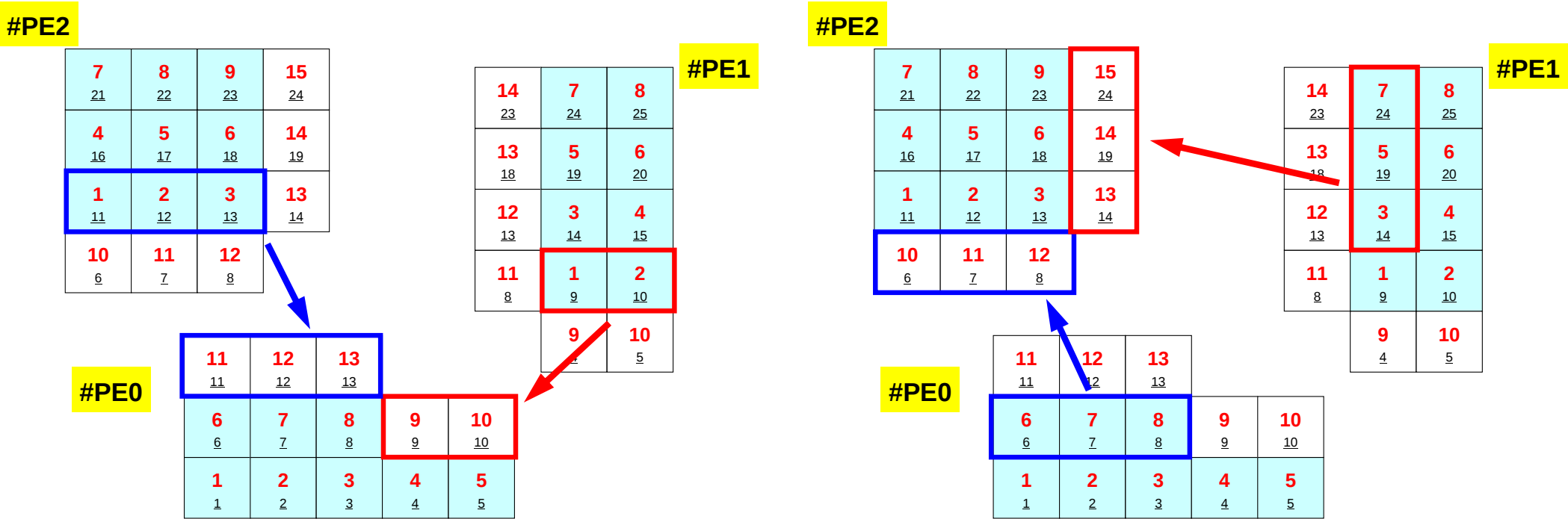
14 <u>23</u>	7 <u>24</u>	8 <u>25</u>
13 <u>18</u>	5 <u>19</u>	6 <u>20</u>
12 <u>13</u>	3 <u>14</u>	4 <u>15</u>
11 <u>8</u>	1 <u>9</u>	2 <u>10</u>
	9 <u>4</u>	10 <u>5</u>

#PE0

11 <u>11</u>	12 <u>12</u>	13 <u>13</u>		
6 <u>6</u>	7 <u>7</u>	8 <u>8</u>	9 <u>9</u>	10 <u>10</u>
1 <u>1</u>	2 <u>2</u>	3 <u>3</u>	4 <u>4</u>	5 <u>5</u>

```
#NEIBPEtot
2
#NEIBPE
1 2
#NODE
13 8
#IMPORTindex
2 5
#IMPORTitems
9
10
11
12
13
#EXPORTindex
3 6
#EXPORTitems
4
5
8
6
7
8
```

Where do Boundary Pts go to ? : PE#1



PE#1: Distributed Local Data

#PE2

7 21	8 22	9 23	15 24
4 16	5 17	6 18	14 19
1 11	2 12	3 13	13 14
10 6	11 7	12 8	

#PE1

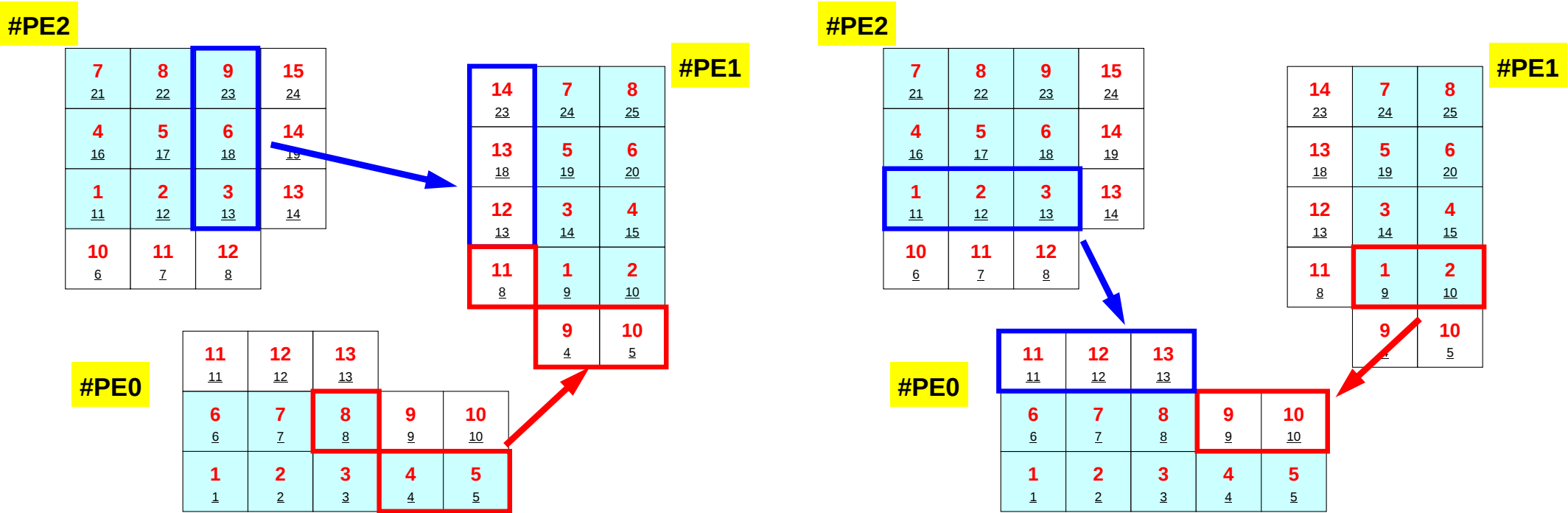
14 23	7 24	8 25
13 18	5 19	6 20
12 13	3 14	4 15
11 8	1 9	2 10
	9 4	10 5

#PE0

11 11	12 12	13 13		
6 6	7 7	8 8	9 9	10 10
1 1	2 2	3 3	4 4	5 5

```
#NEIBPEtot
2
#NEIBPE
0 2
#NODE
14 8
#IMPORTindex
3 6
#IMPORTitems
9
10
11
12
13
14
#EXPORTindex
2 5
#EXPORTitems
1
2
3
5
7
```

Where do Boundary Pts go to ? : PE#2



PE#2: Distributed Local Data

#PE2

7 21	8 22	9 23	15 24
4 16	5 17	6 18	14 19
1 11	2 12	3 13	13 14
10 6	11 7	12 8	

#PE1

14 23	7 24	8 25
13 18	5 19	6 20
12 13	3 14	4 15
11 8	1 9	2 10
	9 4	10 5

#PE0

11 11	12 12	13 13		
6 6	7 7	8 8	9 9	10 10
1 1	2 2	3 3	4 4	5 5

```
#NEIBPEtot
2
#NEIBPE
1 0
#NODE
15 9
#IMPORTindex
3 6
#IMPORTitems
13
14
15
10
11
12
#EXPORTindex
3 6
#EXPORTitems
3
6
9
1
2
3
```