

# 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

**t2**

<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>

演習

#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

#PE2

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

t2

#PE1

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

#PE0

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

t2

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

#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    2
#NODE
  ○    ○
#IMPORTindex
  ○    ○
#IMPORTitems
  ○...
#EXPORTindex
  ○    ○
#EXPORTitems
  ○...

```

t2

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

#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
  ○   ○
#IMPORTindex
  ○   ○
#IMPORTitems
  ○...
#EXPORTindex
  ○   ○
#EXPORTitems
  ○...

```

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

#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
  ○   ○
#IMPORTindex
  ○   ○
#IMPORTitems
  ○...
#EXPORTindex
  ○   ○
#EXPORTitems
  ○...

```

t2

#PE2

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

#PE1

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

#PE0

<b>11</b> <u>11</u>	<b>12</b> <u>12</u>	<b>13</b> <u>13</u>		
<b>6</b> <u>6</u>	<b>7</b> <u>7</u>	<b>8</b> <u>8</u>	<b>9</b> <u>9</u>	<b>10</b> <u>10</u>
<b>1</b> <u>1</u>	<b>2</b> <u>2</u>	<b>3</b> <u>3</u>	<b>4</b> <u>4</u>	<b>5</b> <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=lecture8-o
#PJM -L node=1
#PJM -mpi proc=3
#PJM -L elapse=00:15:00
#PJM -g gt18
#PJM -j
#PJM -e err
#PJM -o test.lst

mpiexec ./a.out
```

# Where do Ext Pts come from ?: PE#0

#PE2

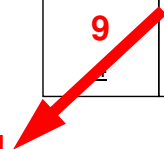
<b>7</b> <u>21</u>	<b>8</b> <u>22</u>	<b>9</b> <u>23</u>	<b>15</b> <u>24</u>
<b>4</b> <u>16</u>	<b>5</b> <u>17</u>	<b>6</b> <u>18</u>	<b>14</b> <u>19</u>
<b>1</b> <u>11</u>	<b>2</b> <u>12</u>	<b>3</b> <u>13</u>	<b>13</b> <u>14</u>
<b>10</b> <u>6</u>	<b>11</b> <u>7</u>	<b>12</b> <u>8</u>	

#PE1

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

#PE0

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



# PE#0: 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 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

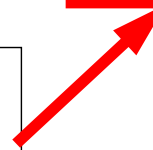
<b>7</b> <u>21</u>	<b>8</b> <u>22</u>	<b>9</b> <u>23</u>	<b>15</b> <u>24</u>
<b>4</b> <u>16</u>	<b>5</b> <u>17</u>	<b>6</b> <u>18</u>	<b>14</b> <u>19</u>
<b>1</b> <u>11</u>	<b>2</b> <u>12</u>	<b>3</b> <u>13</u>	<b>13</b> <u>14</u>
<b>10</b> <u>6</u>	<b>11</b> <u>7</u>	<b>12</b> <u>8</u>	

#PE1

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

#PE0

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

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

#PE1

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

#PE0

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

# 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

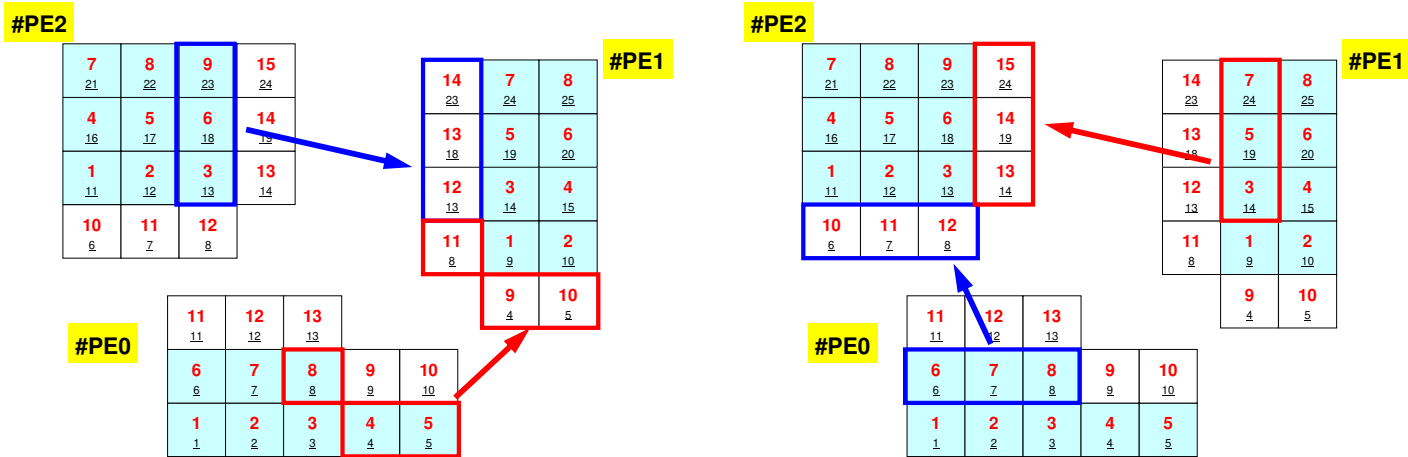
```

#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

```



# Where do Boundary Pts go to ?: PE#0



# PE#0: Distributed Local Data

#PE2

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

#PE1

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

#PE0

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

#PE0: 4-5-8 ⇒ #PE1: 9-10-11 (4-5-8)#PE0: 6-7-8 ⇒ #PE2: 10-11-12 (6-7-8)

```
#NEIBPEtot
2
#NEIBPE
1 2
#NODE
13 8
#IMPORTindex
2 5
#IMPORTitems
9
10
11
12
13
14
#EXPORTindex
3 6
#EXPORTitems
4
5
8
6
7
8
```

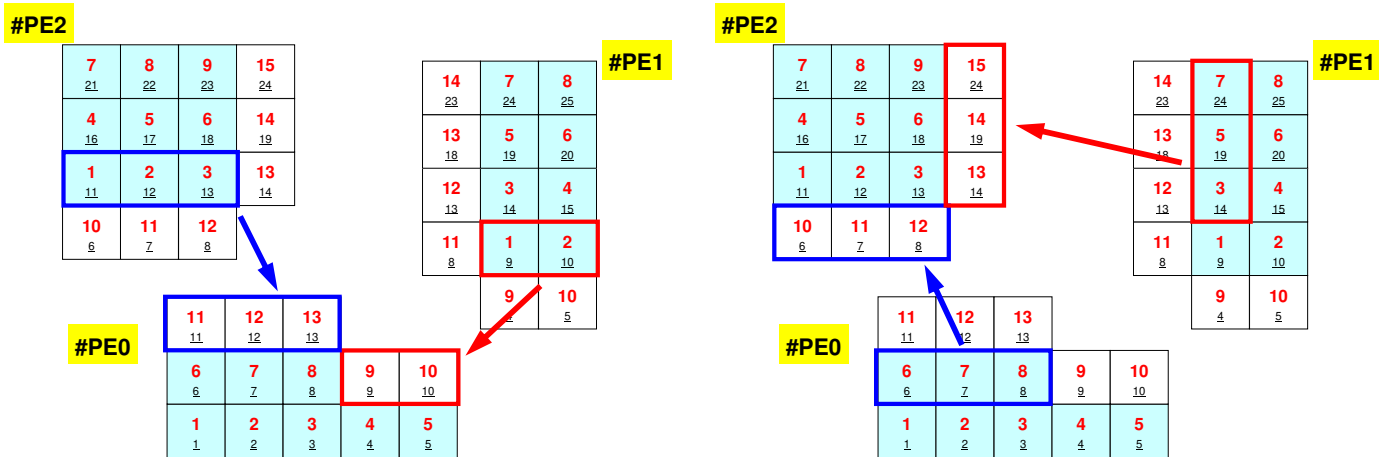
PE#1

```
#NEIBPE
0 2
#IMPORTindex
3 6
#IMPORTitems
9
10
11
12
13
14
```

PE#2

```
#NEIBPE
1 0
#IMPORTindex
3 6
#IMPORTitems
13
14
15
10
11
12
```

# 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

#PE1: 1-2 ⇒ #PE0: 9-10 (9-10)  
 #PE1: 3-5-7 ⇒ #PE2: 13-14-15 (14-19-24)

```
#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
```

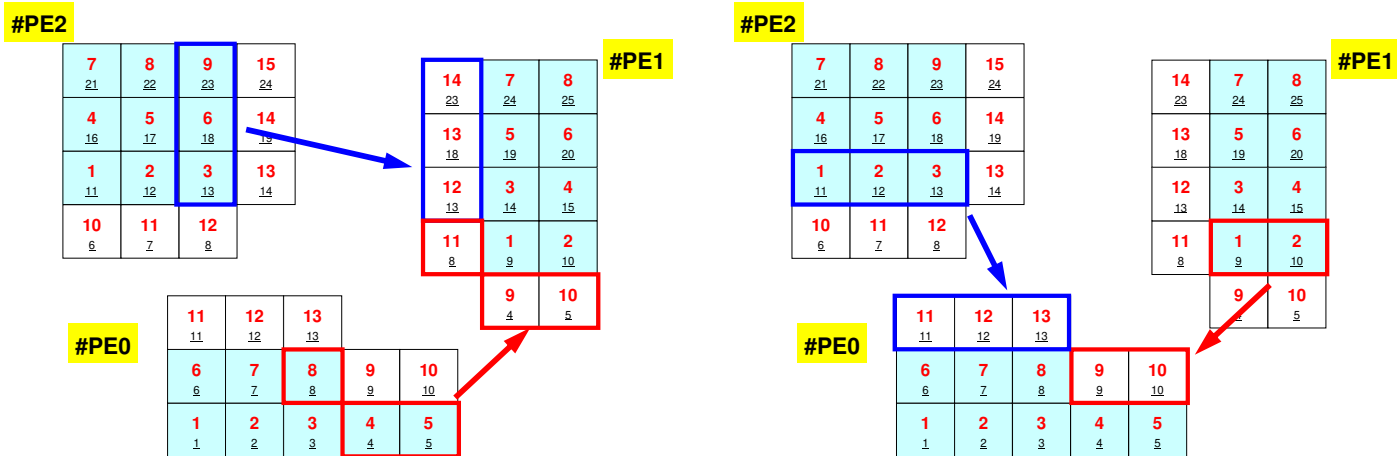
PE#0

```
#NEIBPE
1 2
#IMPORTindex
2 5
#IMPORTitems
9
10
11
12
13
```

PE#2

```
#NEIBPE
1 0
#IMPORTindex
3 6
#IMPORTitems
13
14
15
10
11
12
```

# 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

#PE2: 3-6-9 ⇒ #PE1: 12-13-14 (13-18-23)

#PE2: 1-2-3 ⇒ #PE0: 11-12-13 (11-12-13)

```
#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
```

PE#1

```
#NEIBPE
0 2
#IMPORTindex
3 6
#IMPORTitems
9
10
11
12
13
14
```

PE#0

```
#NEIBPE
1 2
#IMPORTindex
2 5
#IMPORTitems
9
10
11
12
13
```

t2

#PE2

	<b>7</b>	<b>8</b>	<b>9</b>	<b>15</b>
RECVbuf	2	1	14	13
RECVbuf	2	1	19	14
RECVbuf	2	1	24	15
RECVbuf	2	0	6	10
RECVbuf	2	0	7	11
RECVbuf	2	0	8	12
	<u>11</u>	<u>12</u>	<u>13</u>	<u>14</u>
	<b>10</b>	<b>11</b>	<b>12</b>	
	<u>6</u>	<u>7</u>	<u>8</u>	

#PE1

<b>14</b>	<b>7</b>	<b>8</b>		
<u>23</u>			RECVbuf	1
			RECVbuf	0
			RECVbuf	4
			RECVbuf	9
<b>13</b>			RECVbuf	1
<u>18</u>			RECVbuf	0
			RECVbuf	5
			RECVbuf	10
			RECVbuf	1
			RECVbuf	0
			RECVbuf	8
			RECVbuf	11
<b>12</b>			RECVbuf	1
<u>13</u>			RECVbuf	2
			RECVbuf	13
			RECVbuf	12
			RECVbuf	1
			RECVbuf	2
			RECVbuf	18
			RECVbuf	13
			RECVbuf	2
			RECVbuf	23
			RECVbuf	14
<b>11</b>	<b>1</b>	<b>2</b>		
<u>8</u>	<u>9</u>	<u>10</u>		
	<b>9</b>	<b>10</b>		
	<u>4</u>	<u>5</u>		

#PE0

	<b>11</b>	<b>12</b>	<b>13</b>		
	<u>11</u>	<u>12</u>	<u>13</u>		
	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>
	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>
RECVbuf	0	1	9	9	
RECVbuf	0	1	10	10	
RECVbuf	0	2	11	11	
RECVbuf	0	2	12	12	
RECVbuf	0	2	13	13	
			<b>4</b>	<b>5</b>	
			<u>4</u>	<u>5</u>	