Communication with Double Buffering

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Fugaku QCD Coding workshop

RIKEN R-CCS RIKEN
Center for
Computational Science

Outline

1. Introduction
2. Algorithm with Double Buffering
3. Benchmark (A64FX 1 node)
4. Conclusions

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Acknowledgments

this talk is based on discussion with the codesign team for LQCD

Introduction

Performance Bottle Neck on Lattice QCD

- the most time consuming: mult of D in the solver
- memory bandwidth
- communication bandwidth

  - neighboring communication in D: need to wait for boundary data comes
  - overlapping communication and computation: as computation becomes faster, it becomes more difficult to hide communication

double buffering algorithm may reduce the comm. overhead
(implementation: RDMA through the uTofu interface)

Algorithm with Double Buffering

Neighboring Communication

process 1 (send)

send buffer

```
// 1st iter.
start receiving
pack the boundary data
start sending
computation: bulk
wait for the boundary data comes
computation: boundary
wait for sending is done
// 2nd iter.
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process 2 (recv.)

recv. buffer

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recv. buffer

R

send buf. P : Packed P : Sending

recv. buf. R : Receiving, R : Receiving done, U : being Used

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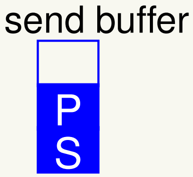

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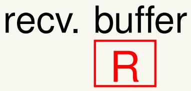

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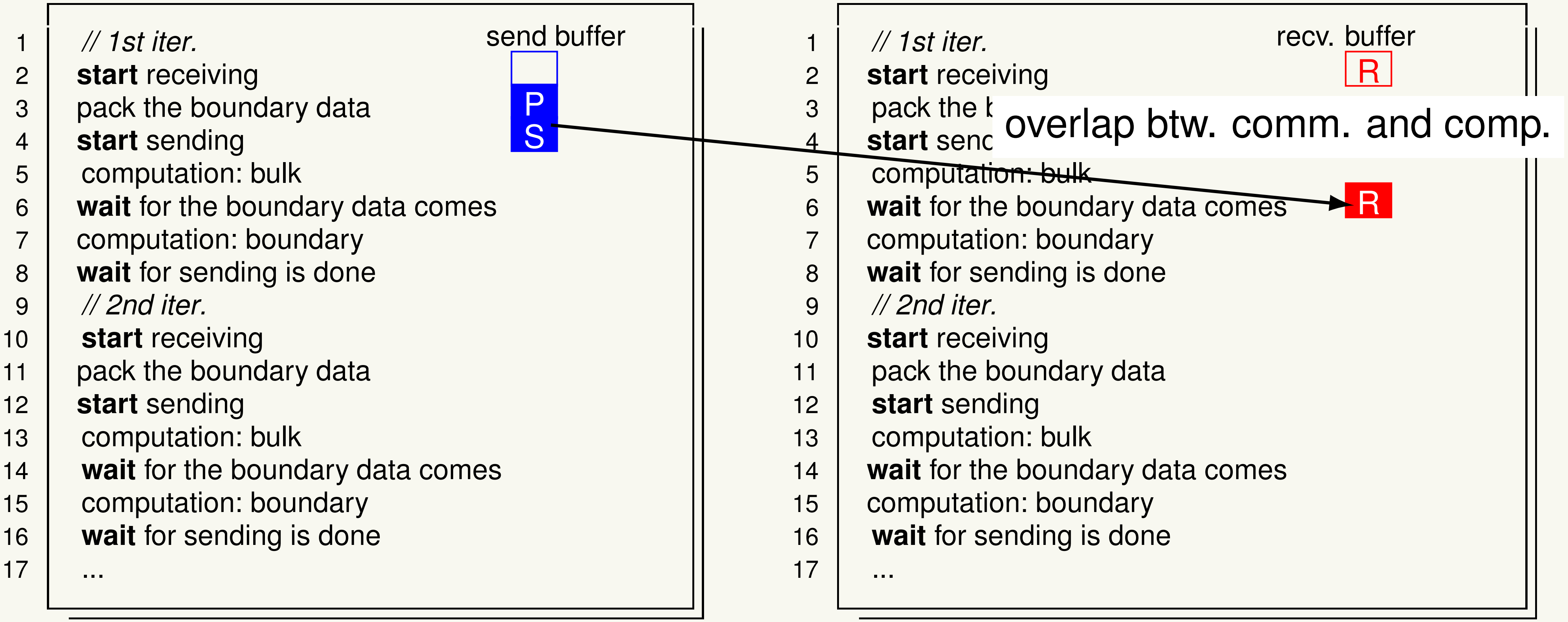
Neighboring Communication



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overlap btw. comm. and comp.

send buf. **P** : Packed **P** : Sending

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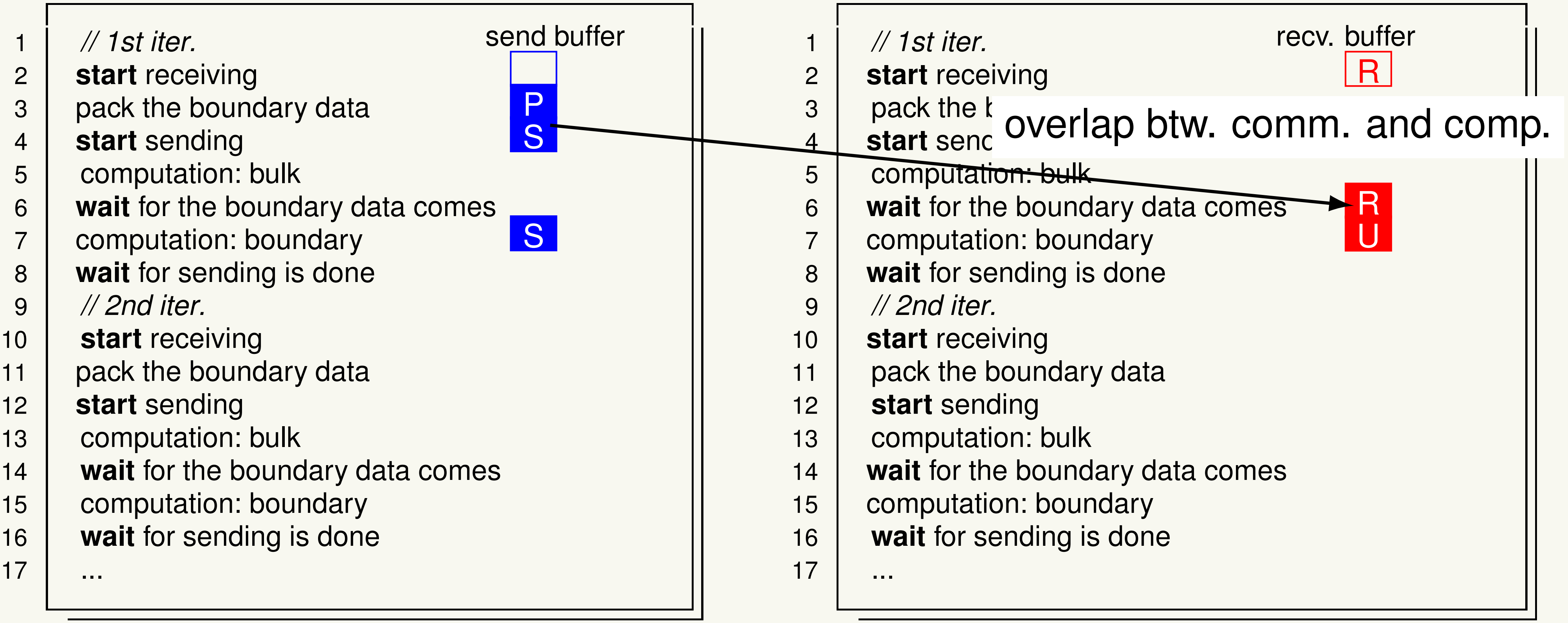
Neighboring Communication



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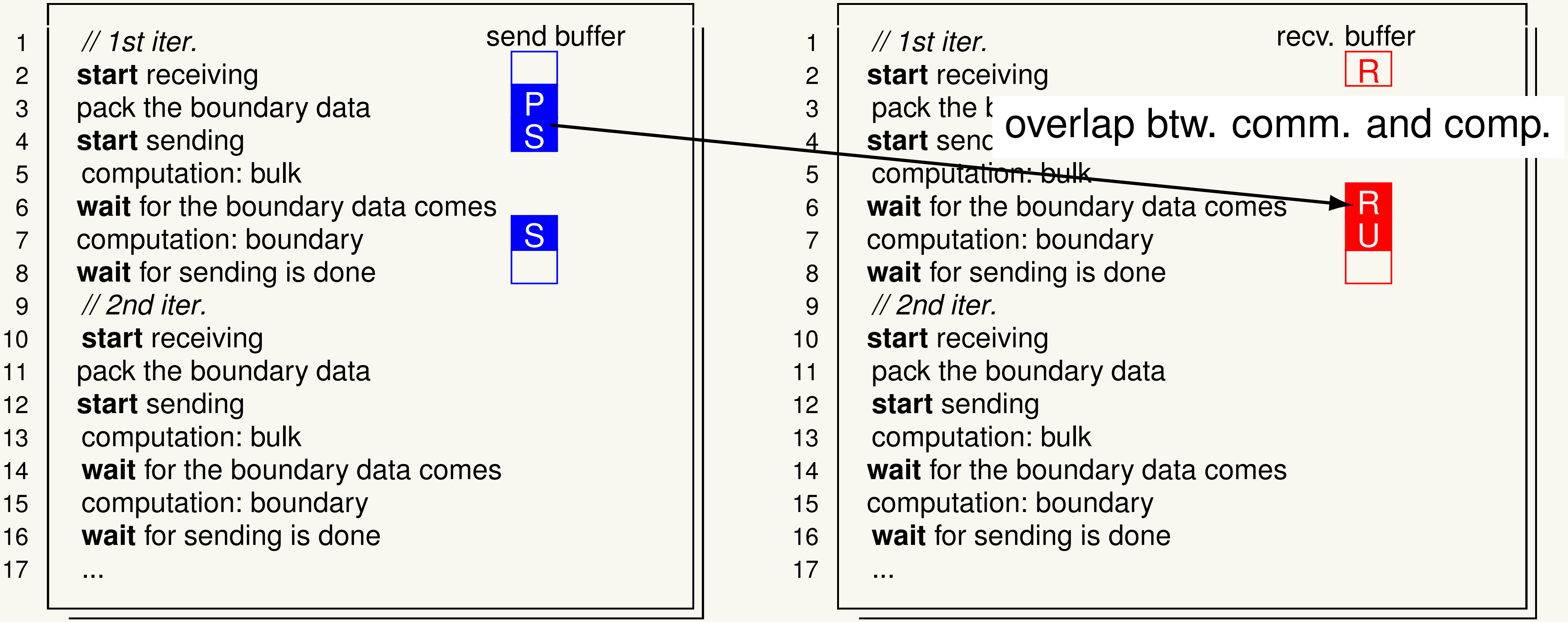
Neighboring Communication

process 1 (send)

process 2 (recv.)



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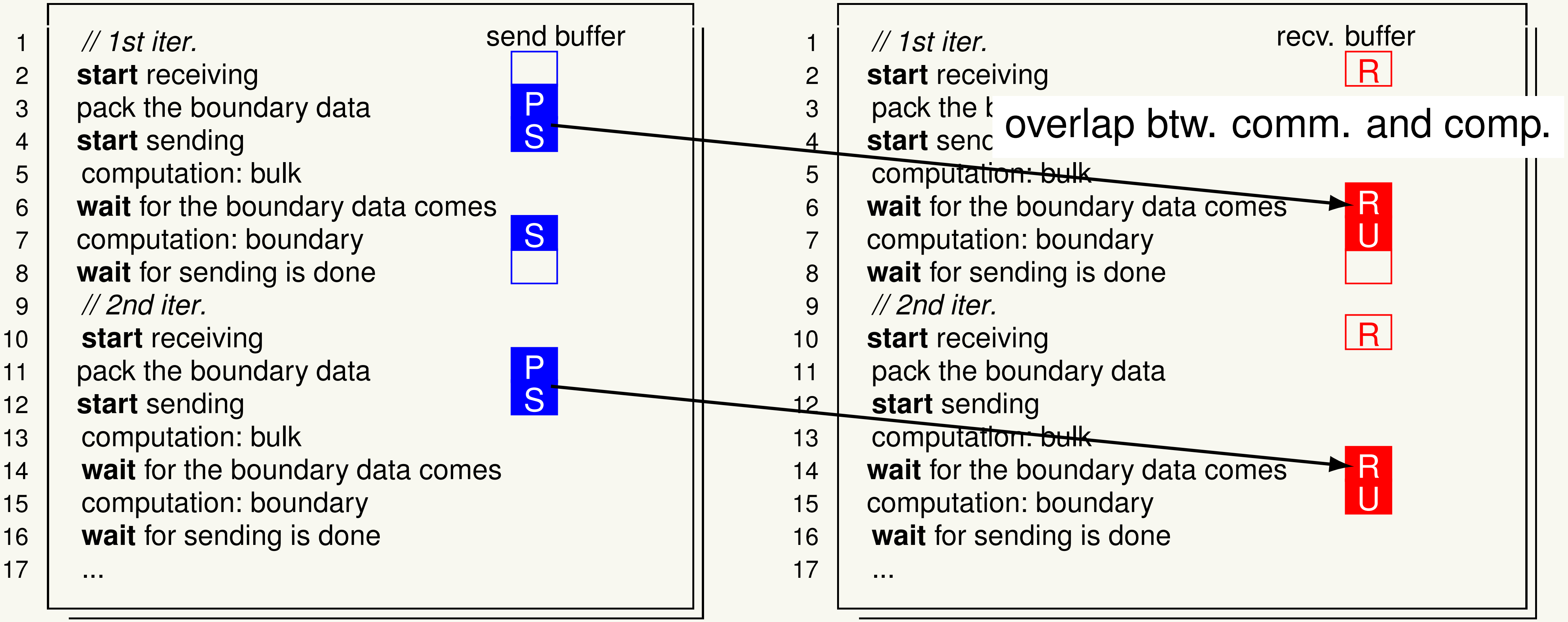

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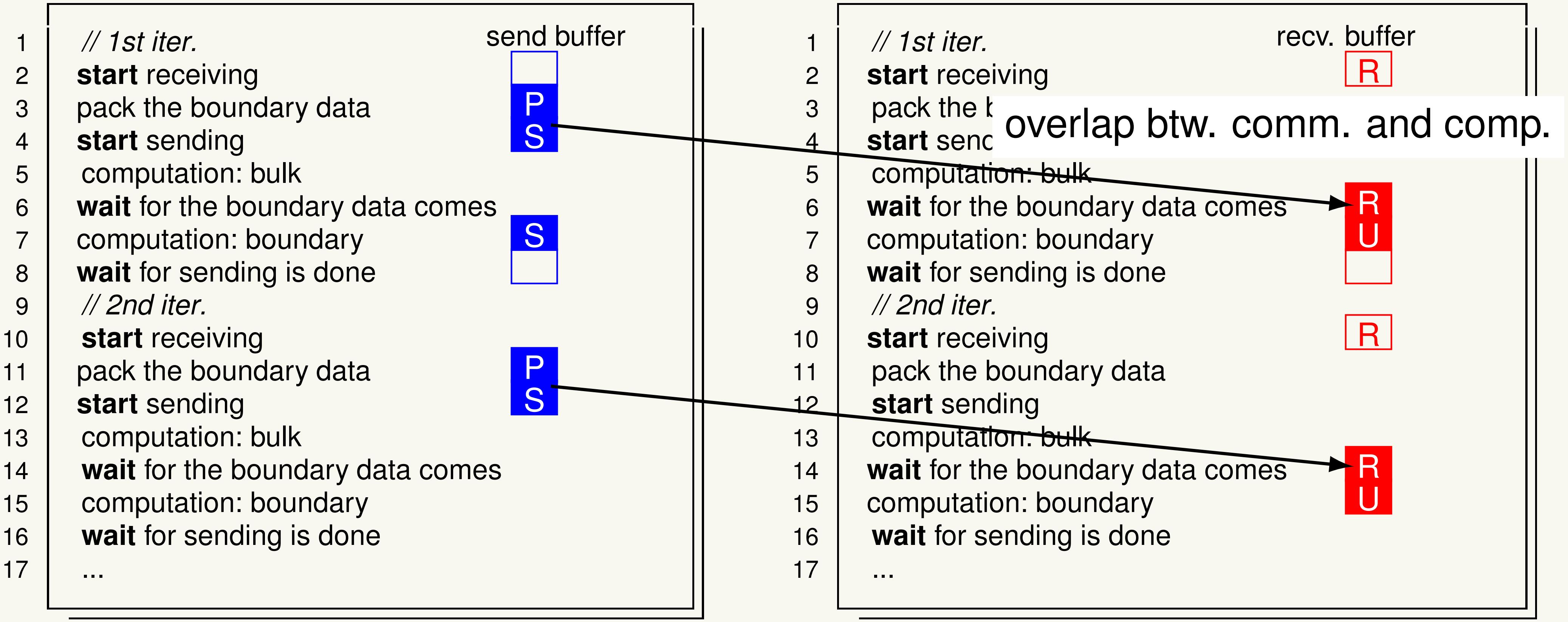

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overlap btw. comm. and comp.

send buf. P : Packed P : Sending

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Neighboring Communication, cont'd

If the receiving process delays....

send buffer

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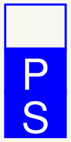

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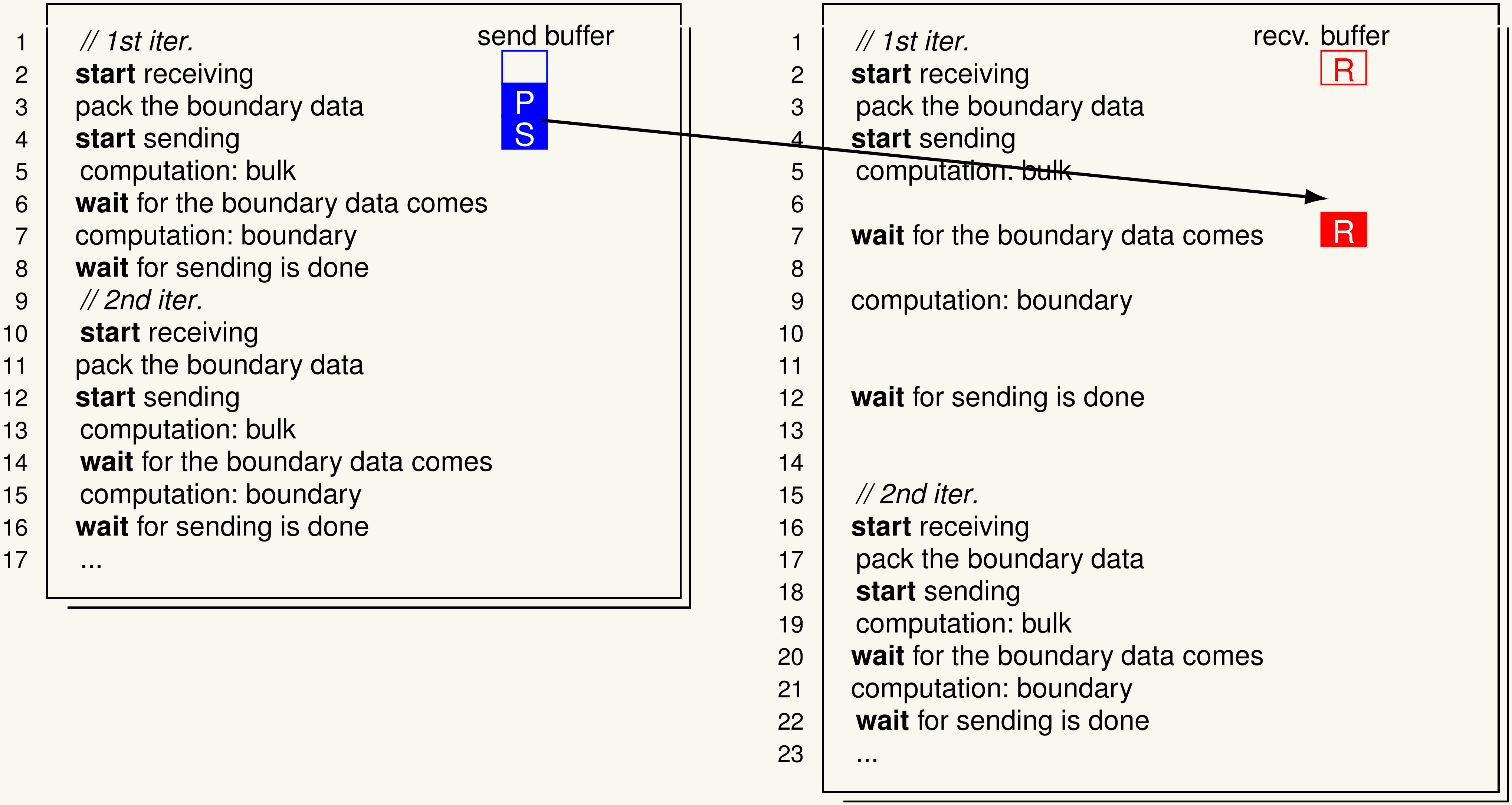

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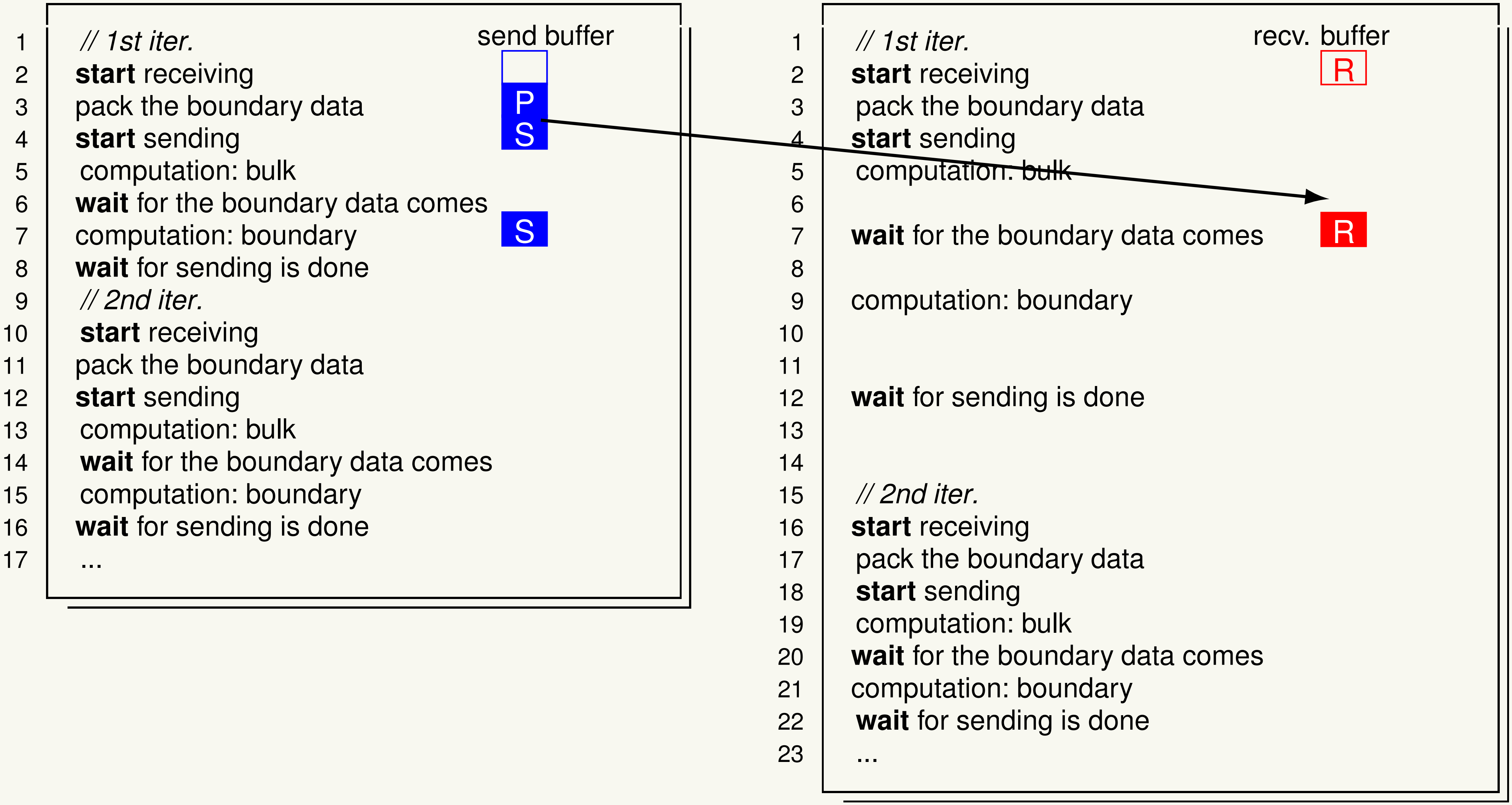

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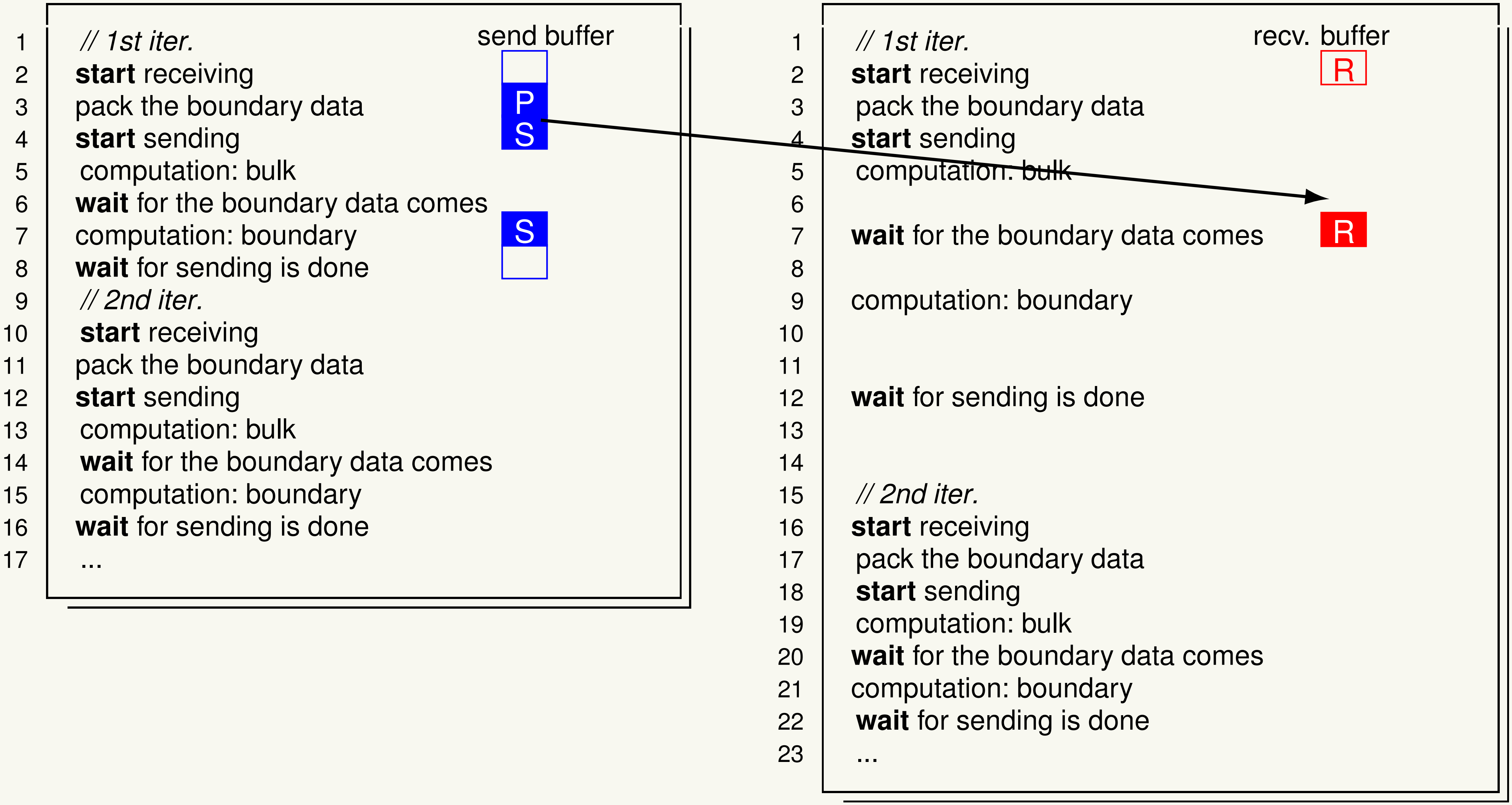

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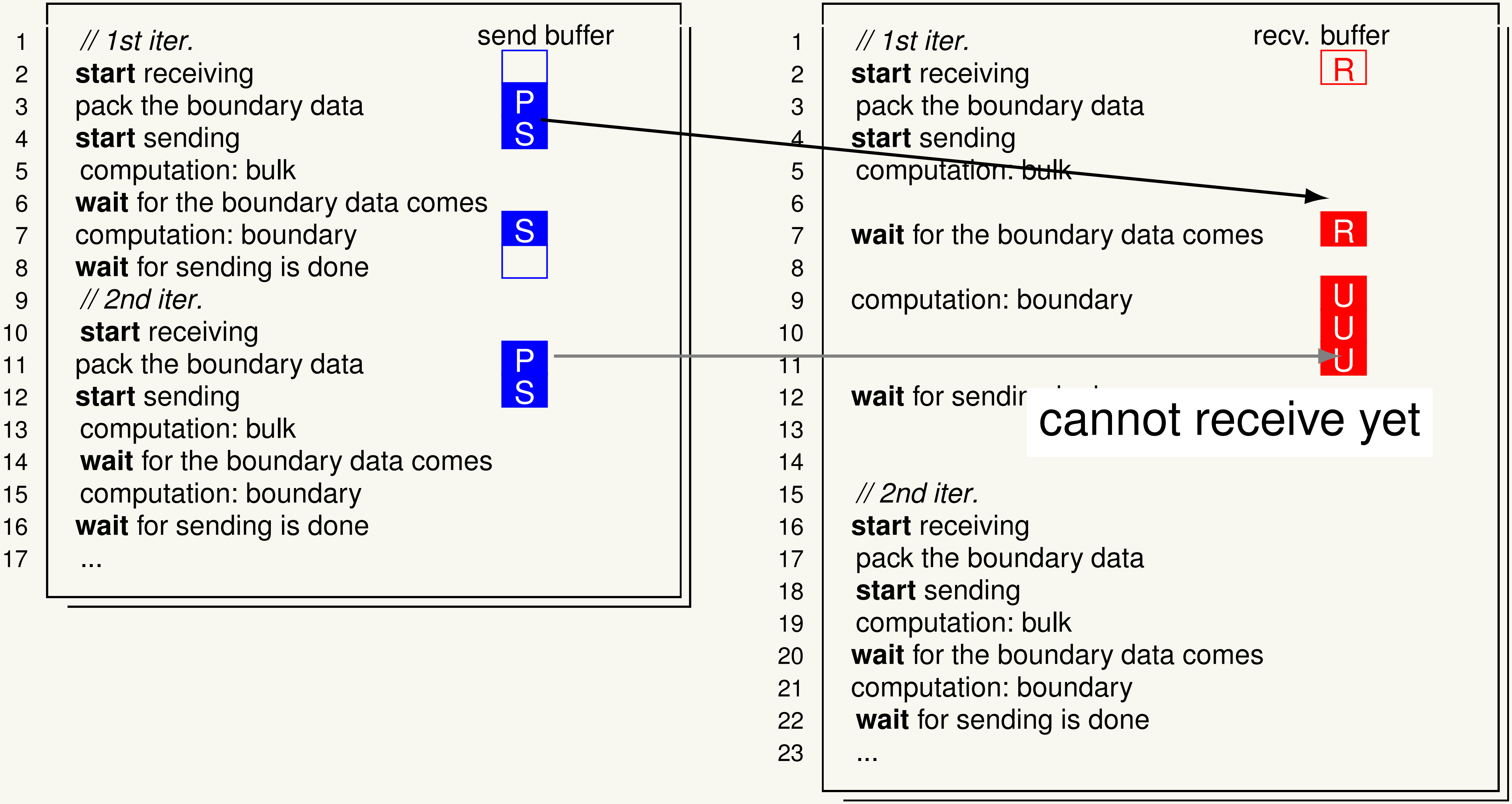

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computation: boundary


wait for sendir


// 2nd iter.
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Neighboring Communication, cont’d

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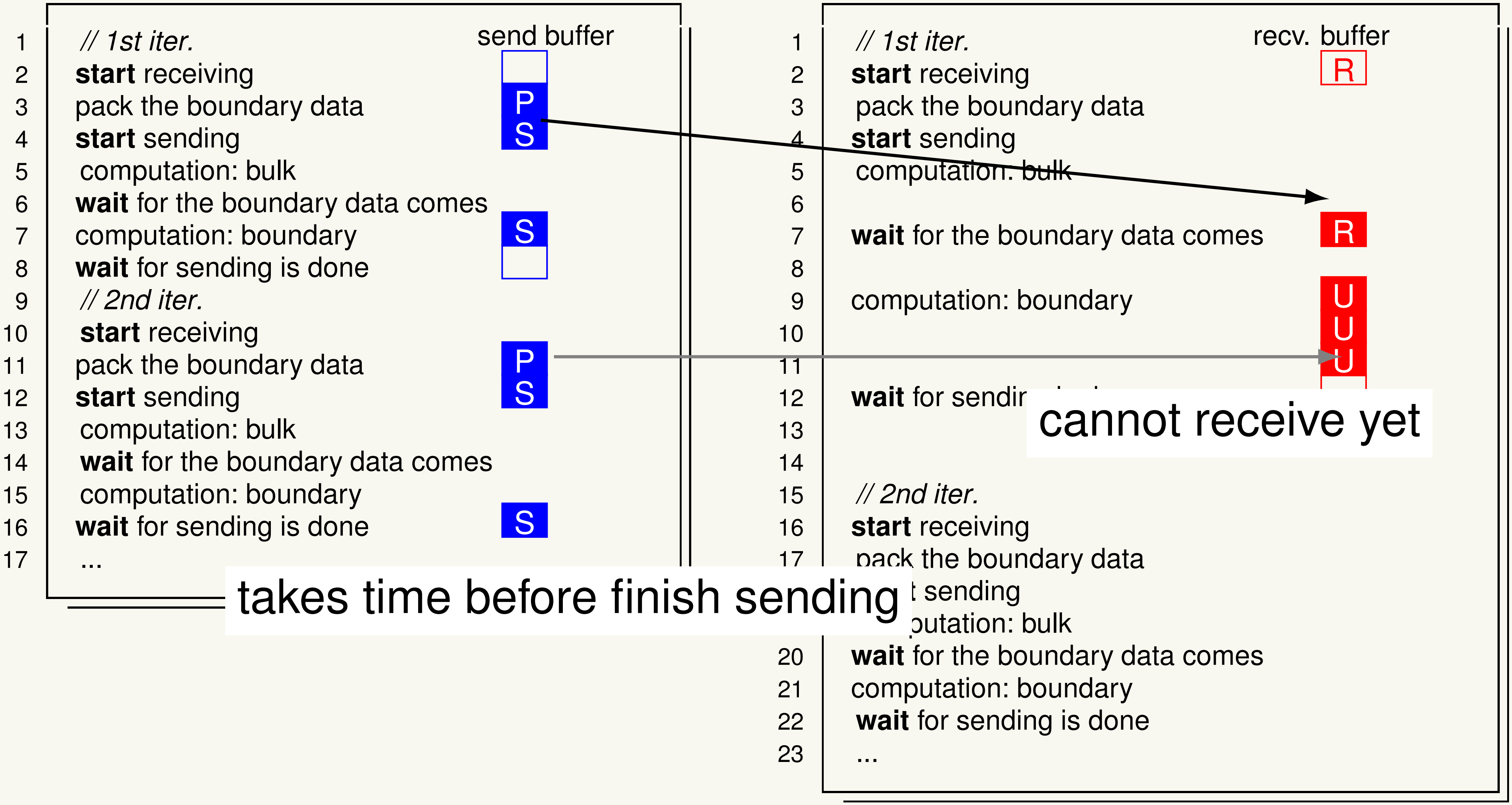

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// 2nd iter.
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 wait for sending is done
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```

cannot receive yet

takes time before finish sending

Neighboring Communication, cont'd

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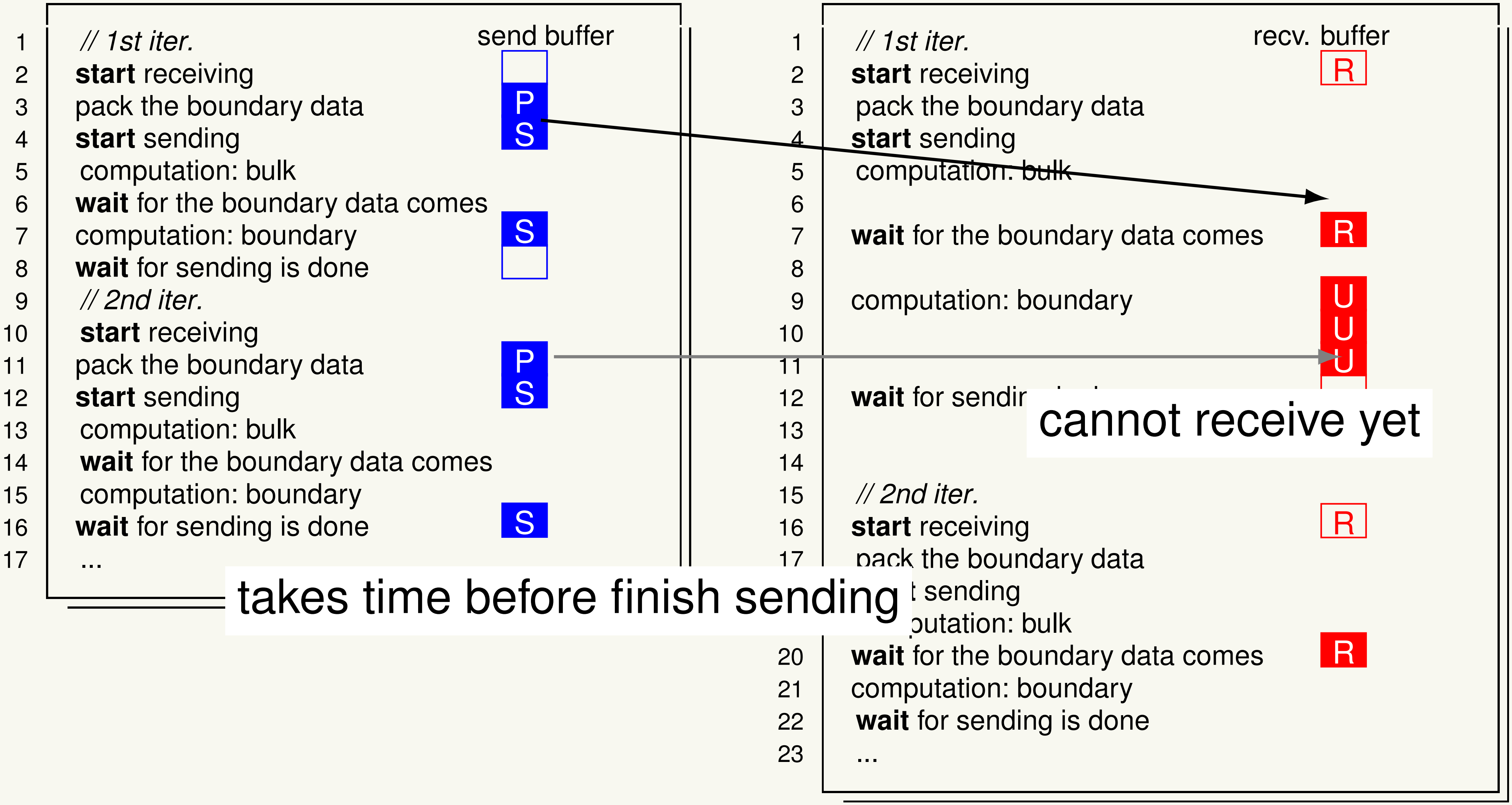

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Neighboring Communication, cont’d

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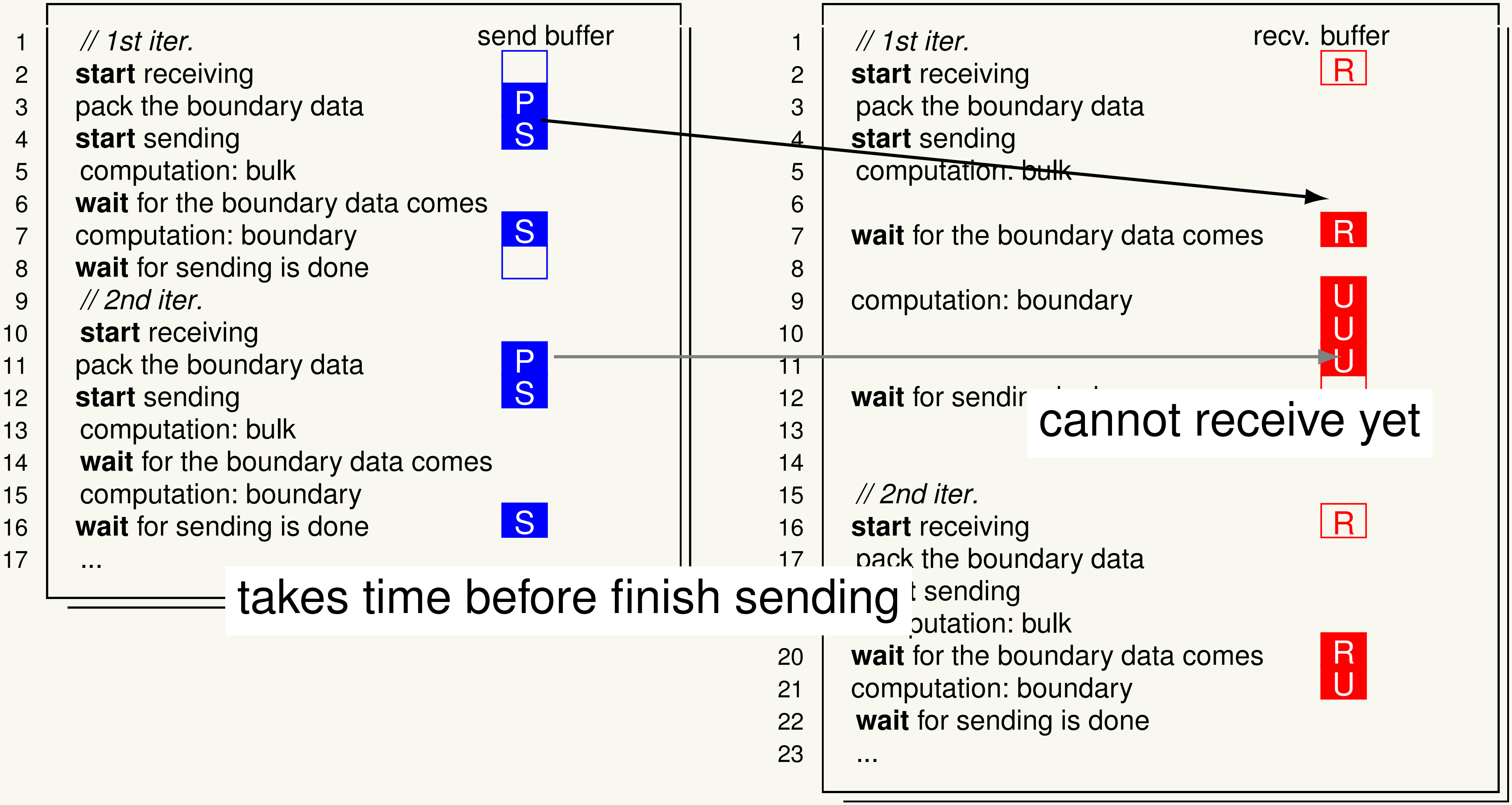

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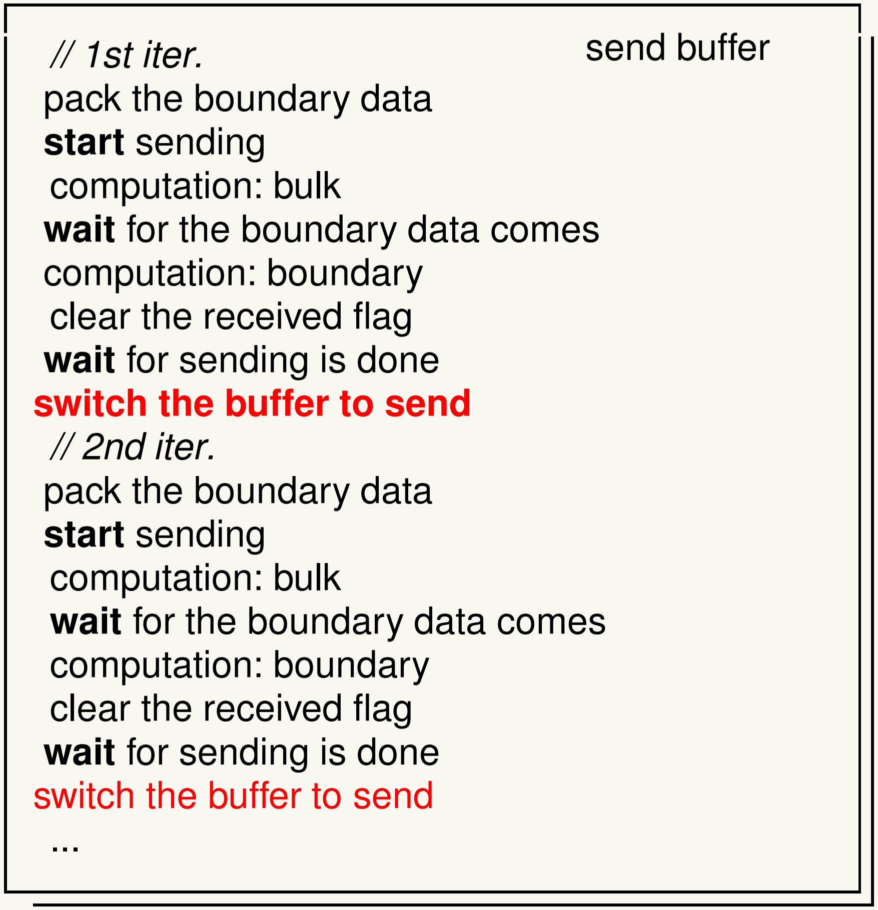
Neighboring Communication: Double Buffering (RDMA)



```
 // 1st iter.
pack the boundary data
start sending
 computation: bulk
wait for the boundary data comes
computation: boundary
 clear the received flag
wait for sending is done
switch the buffer to send
 // 2nd iter.
pack the boundary data
start sending
 computation: bulk
 wait for the boundary data comes
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```

Neighboring Communication: Double Buffering (RDMA)

send buffer

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  ...
```

recv. buffers

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 wait for sending is done


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Neighboring Communication: Double Buffering (RDMA)

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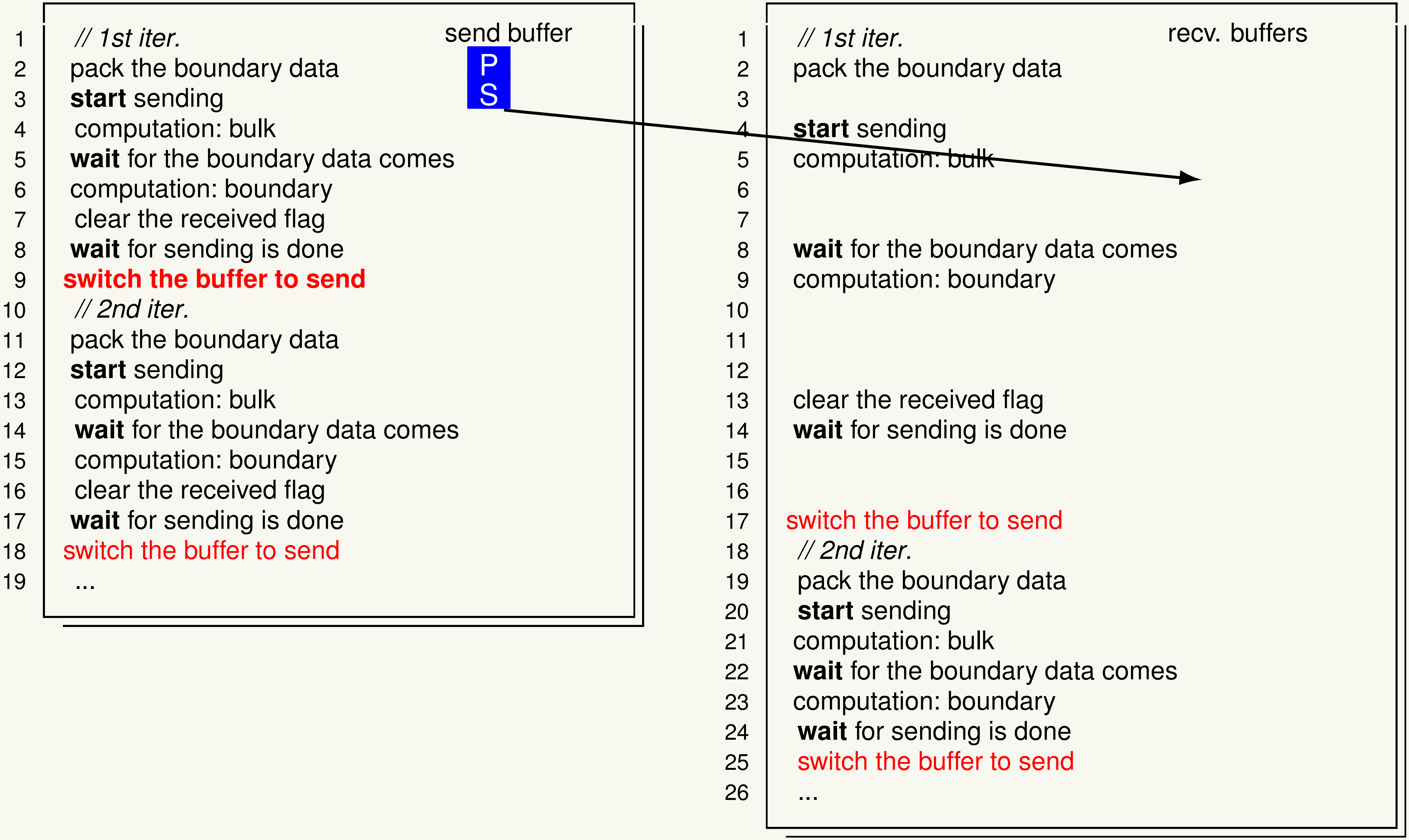

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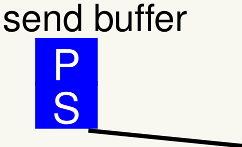

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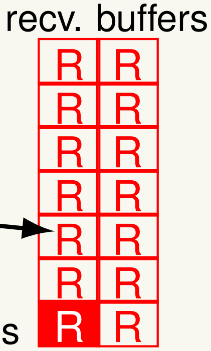
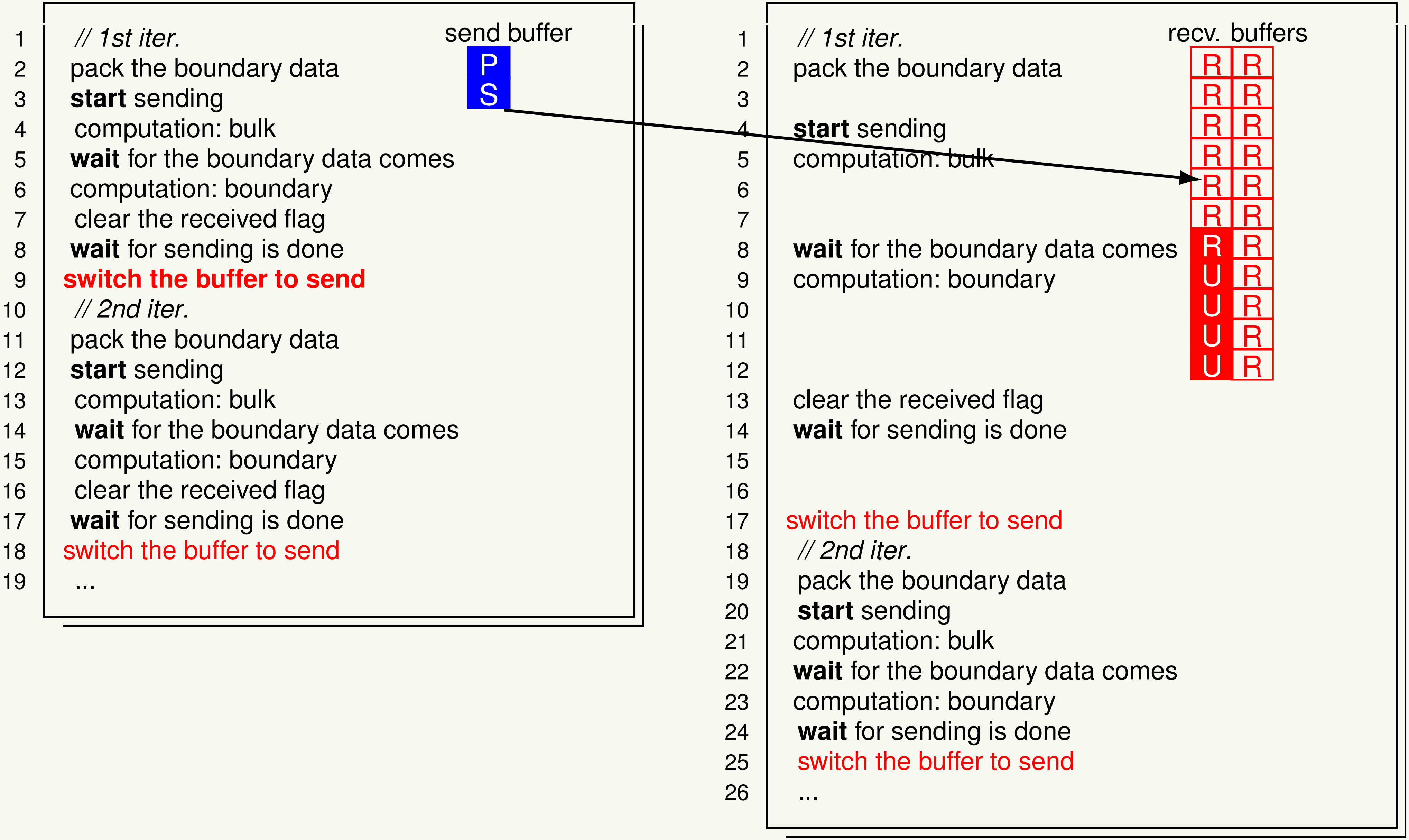


Neighboring Communication: Double Buffering (RDMA)



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// 1st iter.
pack the boundary data
start sending
 computation: bulk
wait for the boundary data comes
computation: boundary
 clear the received flag
wait for sending is done
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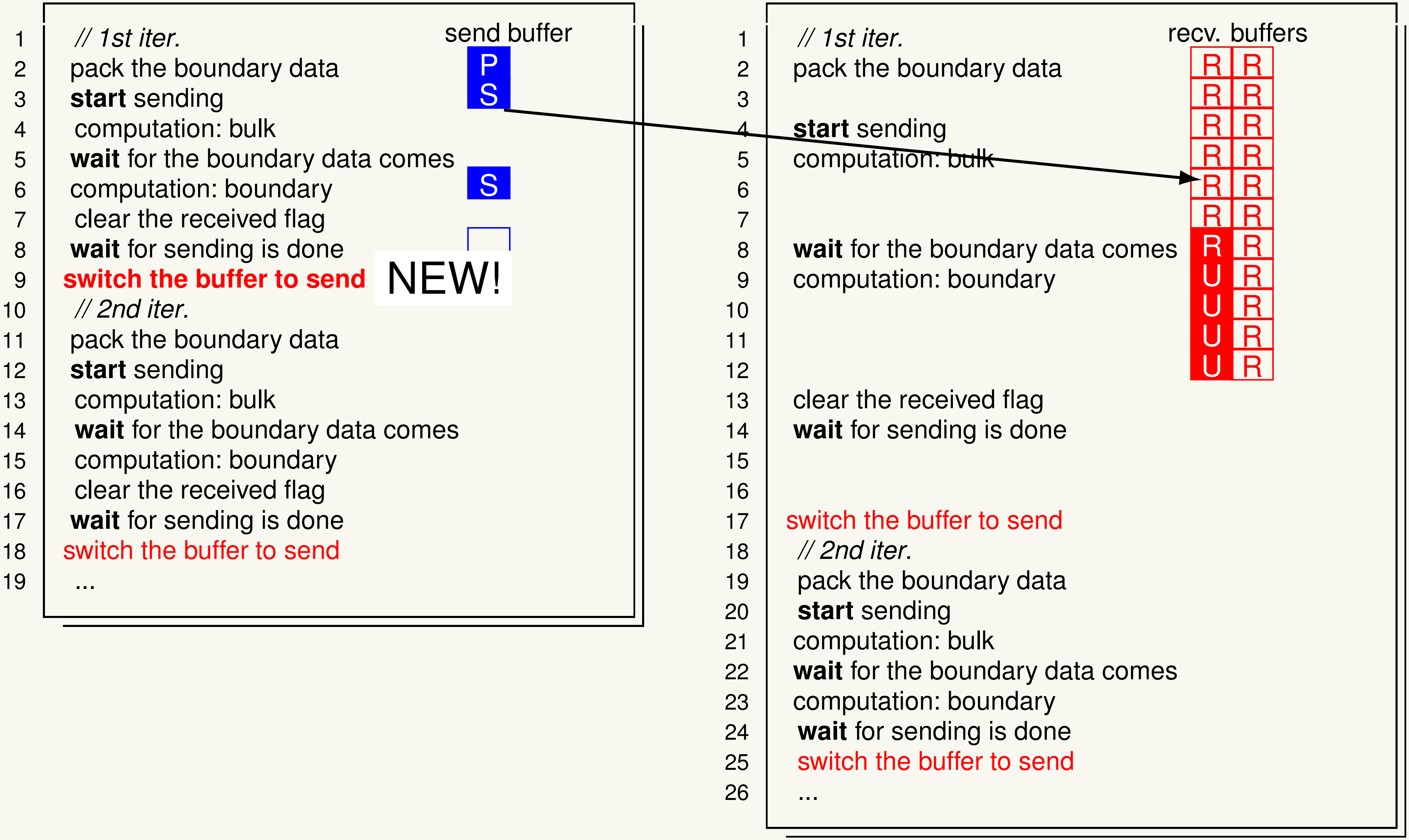

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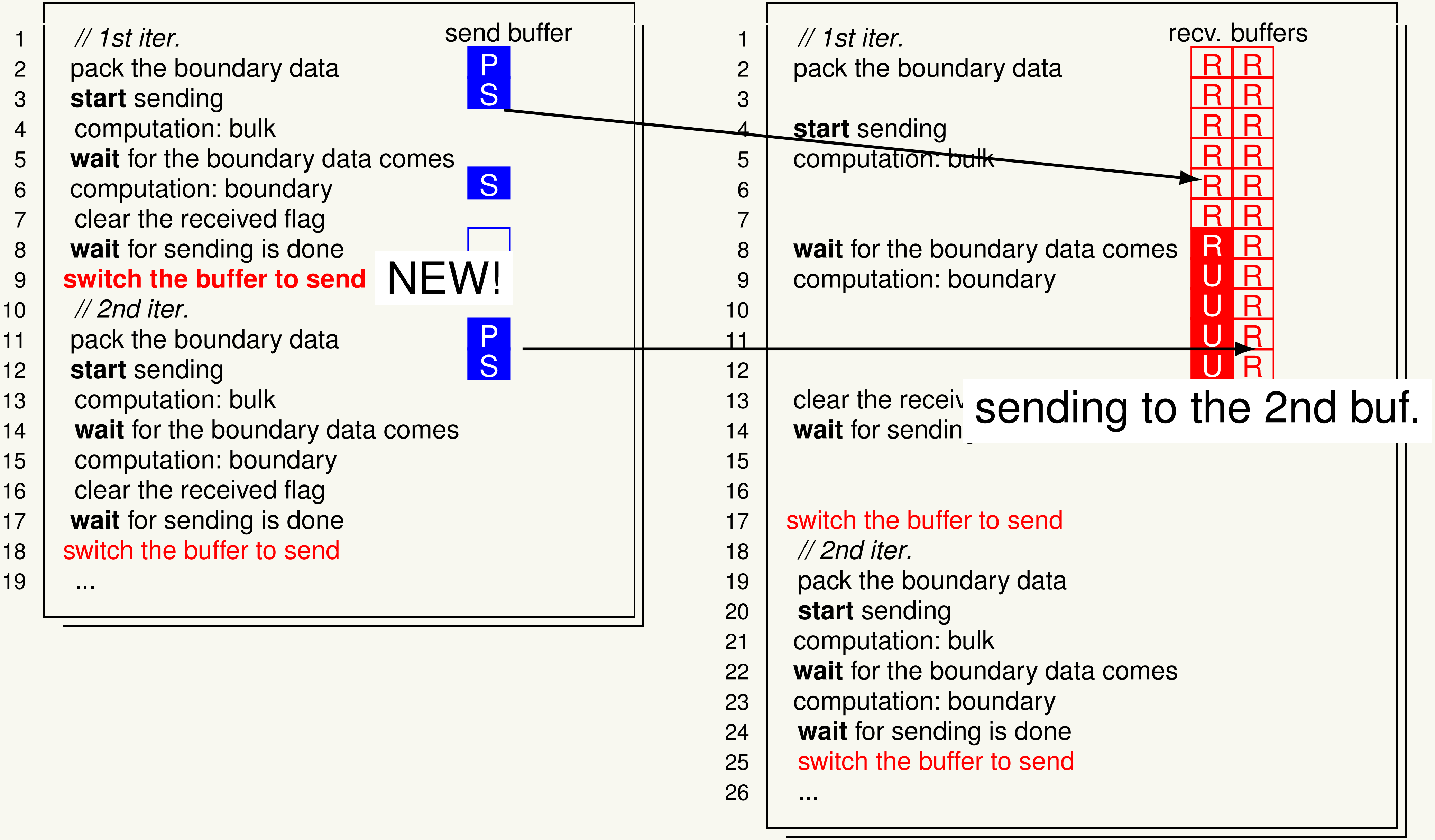

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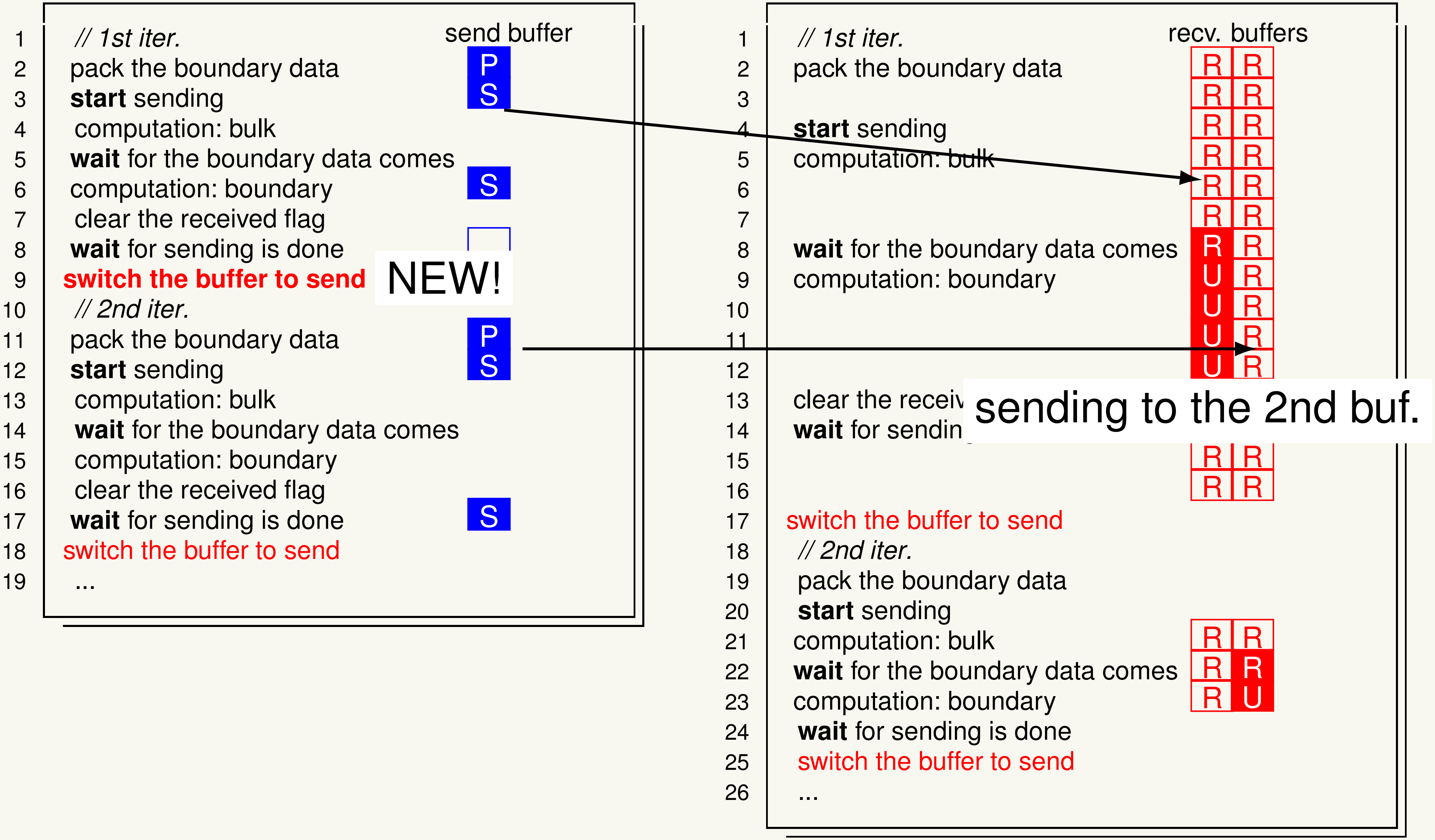

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NEW!

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sending to the 2nd buf.

Remote Direct Memory Access (RDMA)

we use “put” in sending

it directly writes to the memory on the remote process

- send: put (directly memory on the remote process)

  boundary data + watchdog flag

- Wait (recv.): check the flag is updated

  after the boundary computation, the flag is reset

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NOTE 2: one can alternatively use MPI (persistent) communication to implement double buffering.

Benchmark

Test detail: Jacobi method for 2-dim system

base: `http://theo.phys.sci.hiroshima-u.ac.jp/~ishikawa/APL9WG/stencil_double_buffering_mpi-1.0.tar.gz`

target system: $Mx = b$ with

$$(Mx)(i,j) =$$
$$\underbrace{(4+m^2)x(i,j)}_{\equiv Dx}\underbrace{-x(i+1,j) - x(i-1,j) - x(i,j+1) - x(i,j-1)}_{\equiv Hx}$$

$$\xrightarrow{\text{cont. limit}} (m^2 - \partial^2)x$$

Jacobi method

$$x^{(k)} \to x^{(k+1)} = D^{-1}(b - Hx^{(k)})$$

Only the hopping H contains the communication

- fixed number of iterations: 10
- local lattice size: 60×60
- communication buffer: needed size + dummy (+ flag)

$$s = \frac{\text{needed} + \text{dummy}}{\text{needed}}, 1 \le s \le 8192$$

Hopping (Mult of H)

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5. calculate: boundary area
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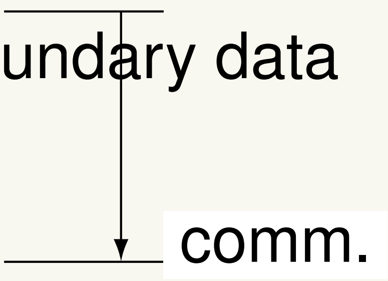

comm.

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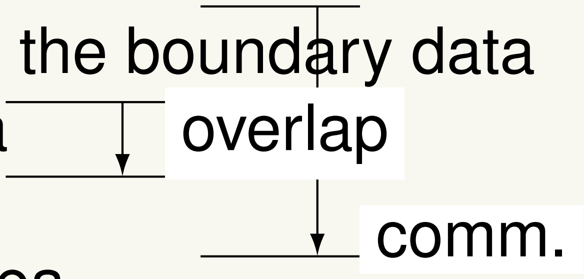

overlap

comm.

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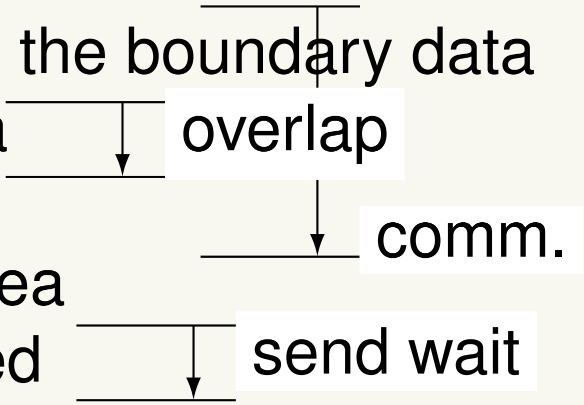

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overlap

comm.

send wait

non-overlap = comm. $-$ overlap
= start sending/receiving + wait for receiving

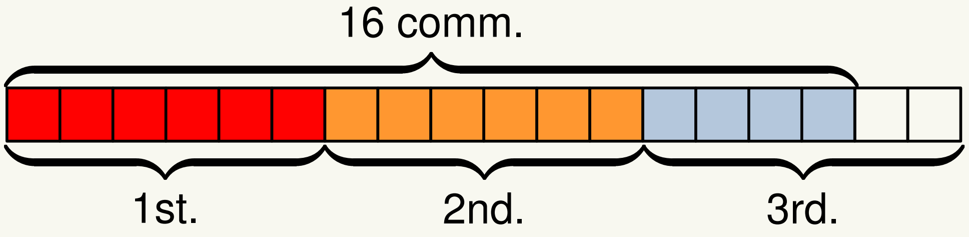
Estimated Bandwidth and uTofu Interface

uTofu

- Low level interface to use Tofu Interconnect
- It allows to specify Tofu Network Interface (TNI) to use
  tuning with the optimal TNI assignment for QCD
- 6 TNI/node, 6.8GB/s for each TNI

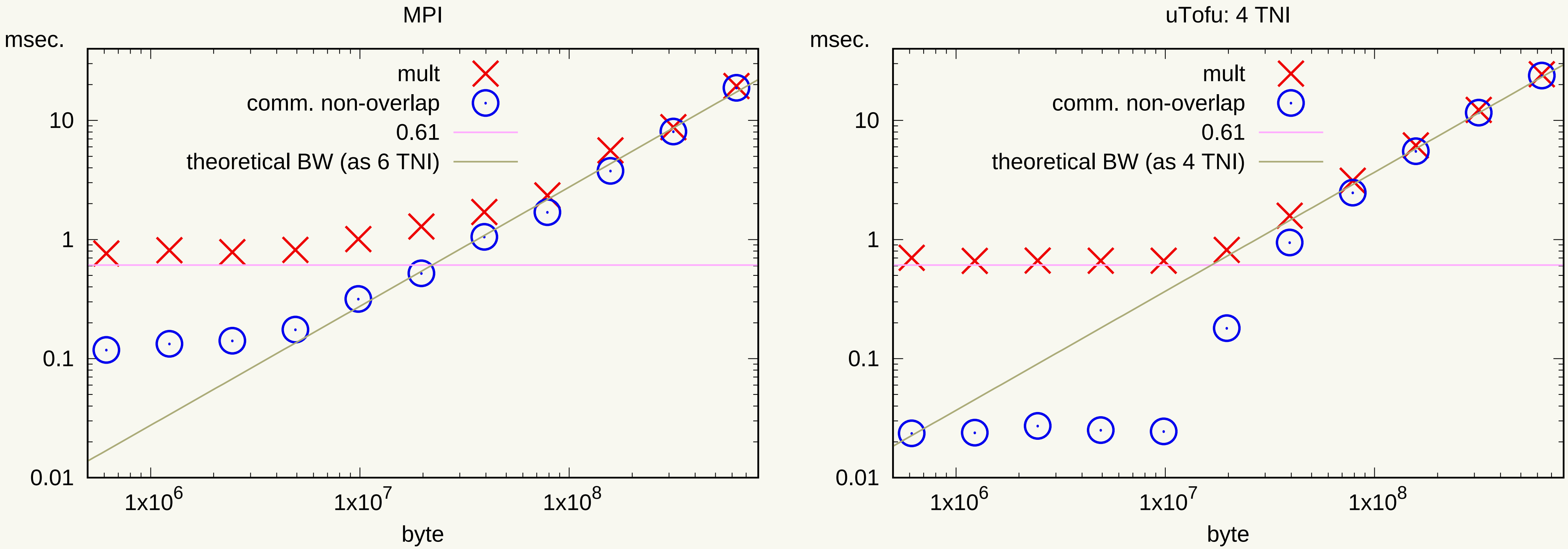
Bandwidth estimate

- 1 node with 4 MPI proc.
  $\Rightarrow$(4 directions) × (4 ranks) = 16 comm.
  (each comm. has the same size)
- Using 4 TNI: each TNI is used 4 times
  $6.8 \times 4 = 27.2$ GB/s
- Using 6 TNI: each TNI is used 2 or 3 times
  $6.8 \times 6 \times \frac{16}{18} = 36.3$ GB/s



Performance: mult of H on A64fx 1 node

NOTE: result on the evaluation environment, it does not guarantee the performance on the actual Fugaku



- comm. overlap $\simeq$ 0.61 msec. (replaced with a line in the plots)
- both show good scaling for large communication data size
- uTofu interface has a smaller overhead
- TNI for uTofu — 0:$+x$, 1:$-x$, 2:$+y$, 3:$-y$

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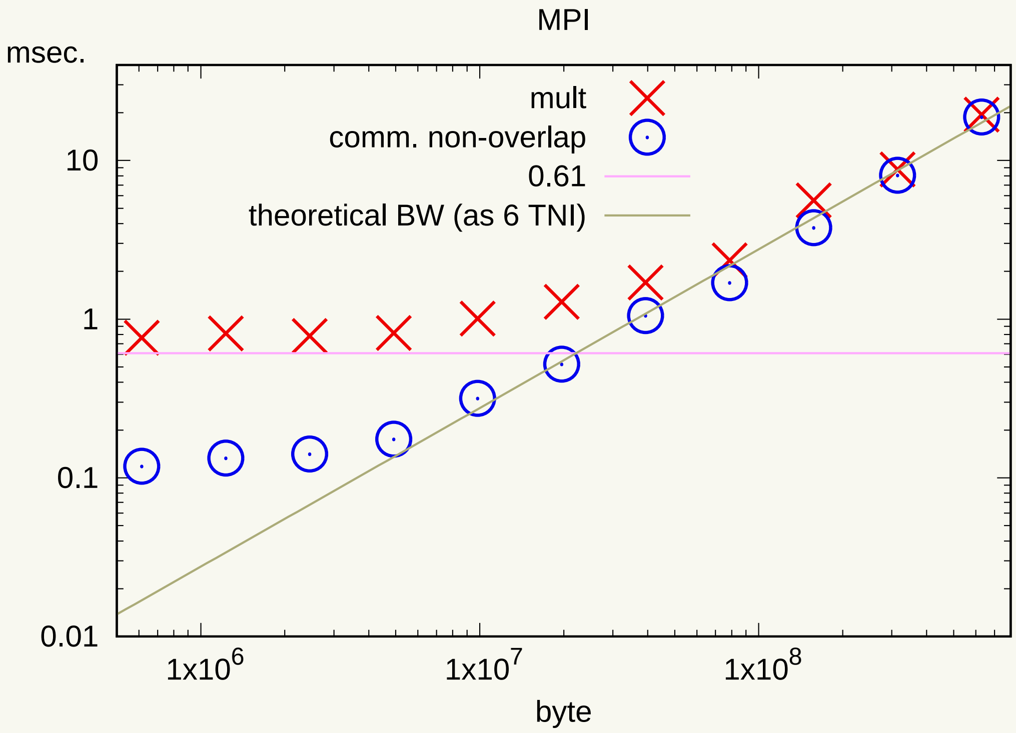

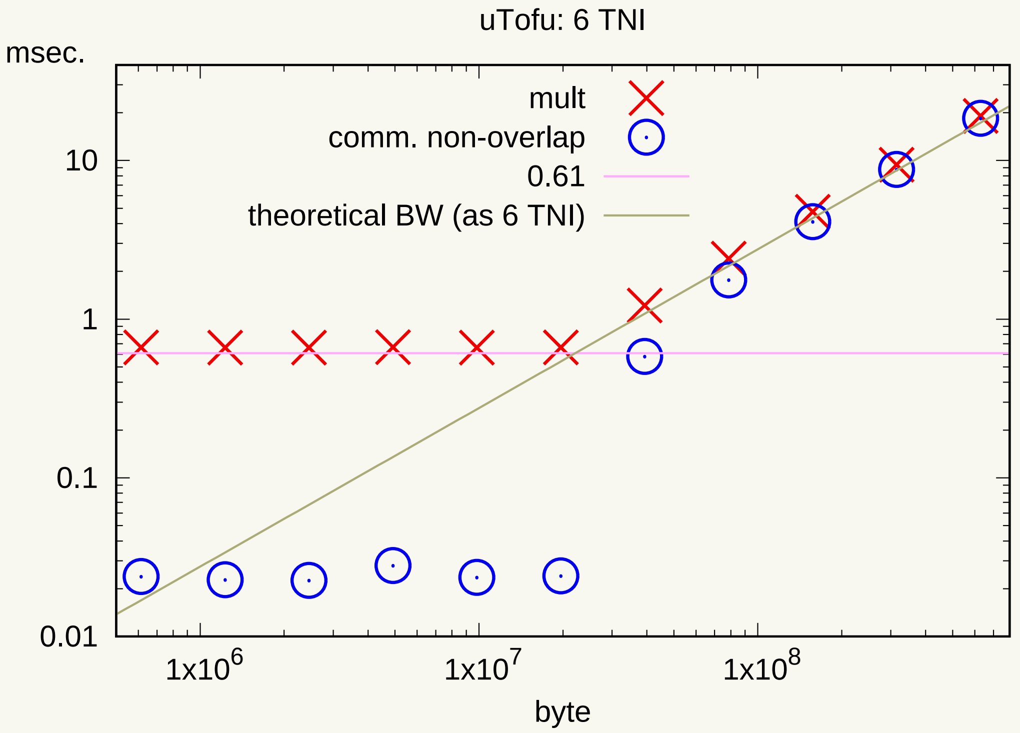

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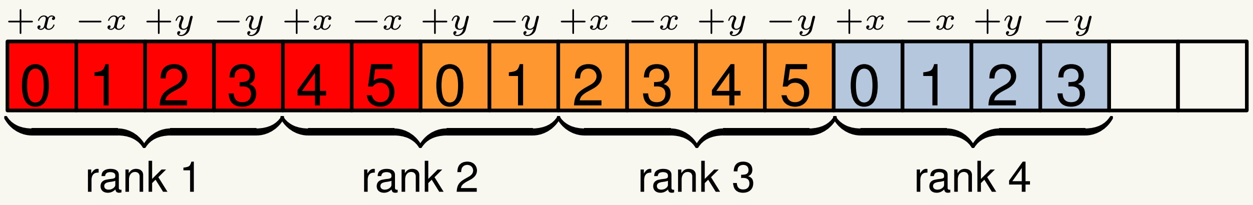
$+x$ $-x$ $+y$ $-y$ $+x$ $-x$ $+y$ $-y$ $+x$ $-x$ $+y$ $-y$ $+x$ $-x$ $+y$ $-y$
0 1 2 3 4 5 0 1 2 3 4 5 0 1 2 3
rank 1
rank 2
rank 3
rank 4

Performance: mult of H on A64fx 1 node, cont'd

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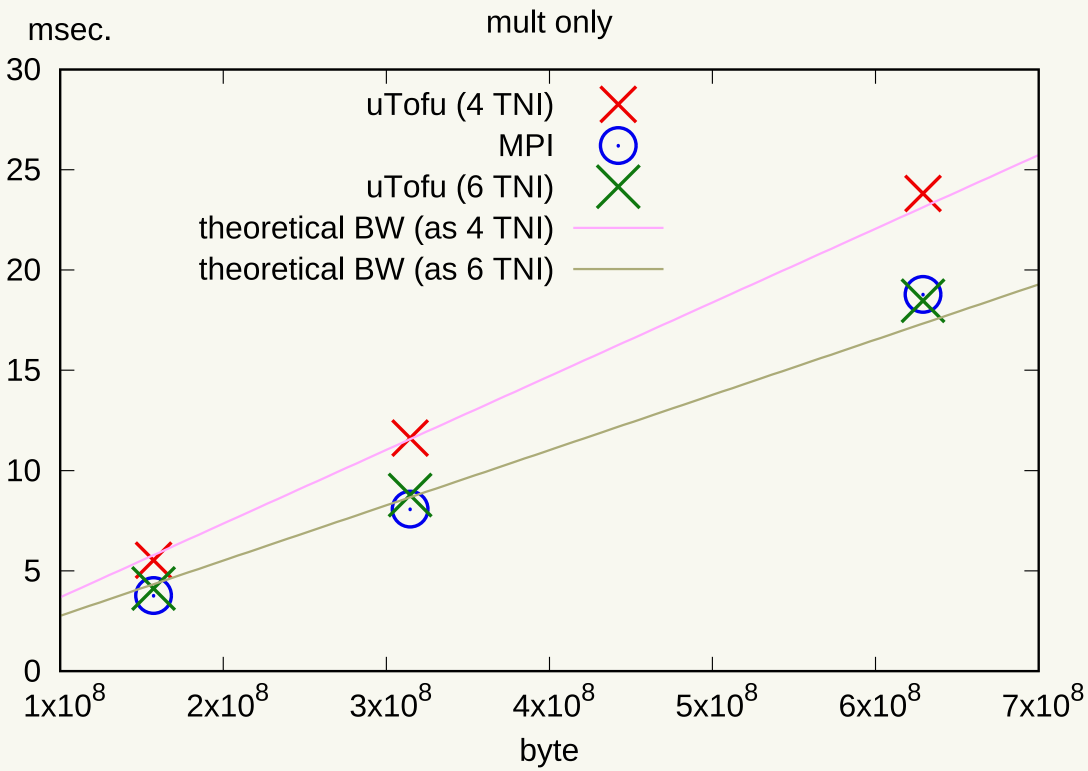

large comm. size
$\Rightarrow$time for mult
$\simeq$ time for comm.

saturation of the network bandwidth

- MPI: 32.4 GB/s
- uTofu (4 TNI): 25.8 GB/s — cf. $6.8 \times 4 = 27.2$ GB/s
- uTofu (6 TNI): 33.0 GB/s — cf. $6.8 \times 16/18 = 36.3$ GB/s

Conclusions

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to accelerate neighboring communication, we have implemented double buffering algorithm

test with a simple 2-dim system

- using uTofu interface seems promising

Future: to do (or on going) for Fugaku

- implement double buffering+uTofu to QCD code

  qws: Nakamura-san's talk
- multi nodes, proper TNI settings,...
- official predicted performance for LQCD (vs. K-computer): x25+

  "+" will be how much????