RDMA programming design and case studies – for better performance distributed applications

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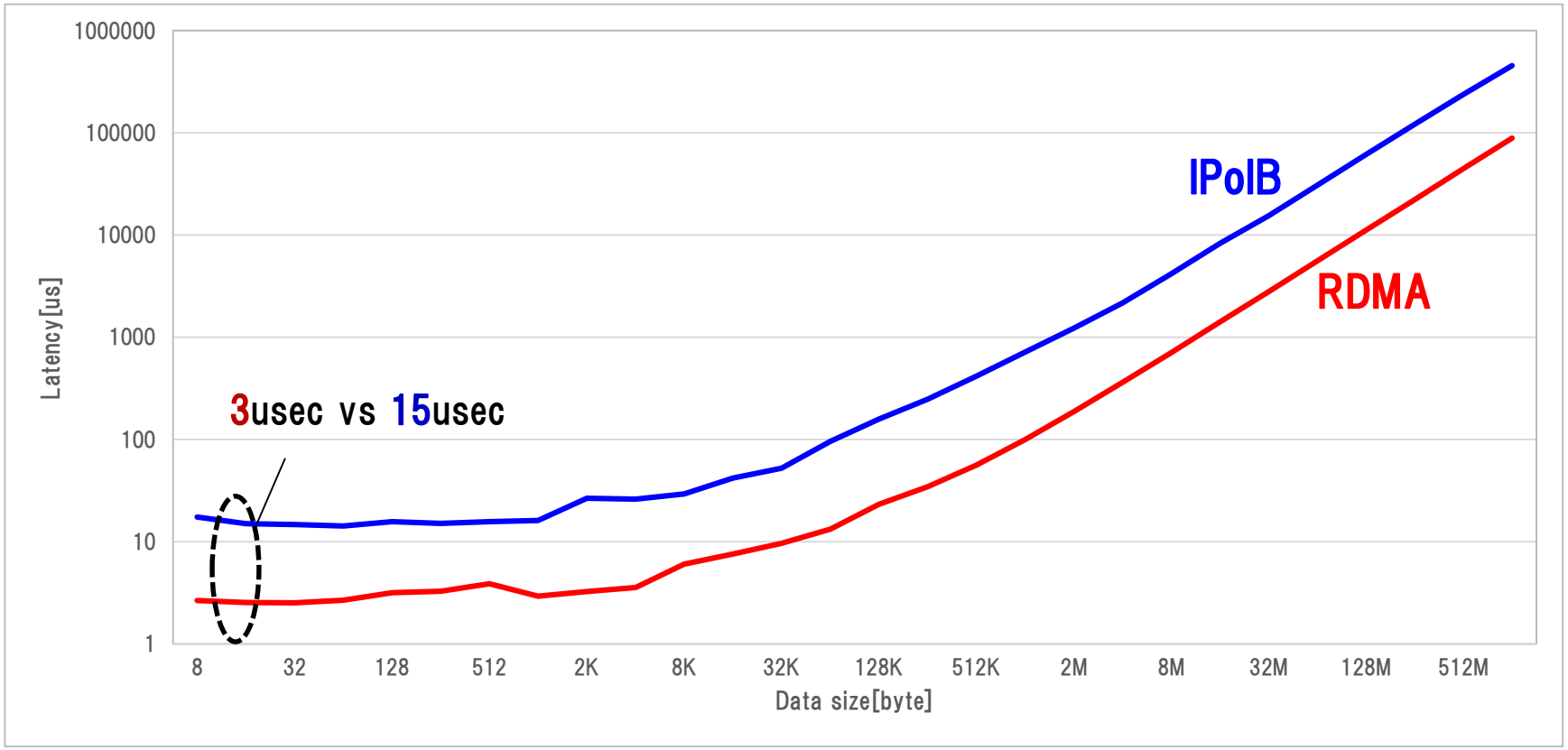
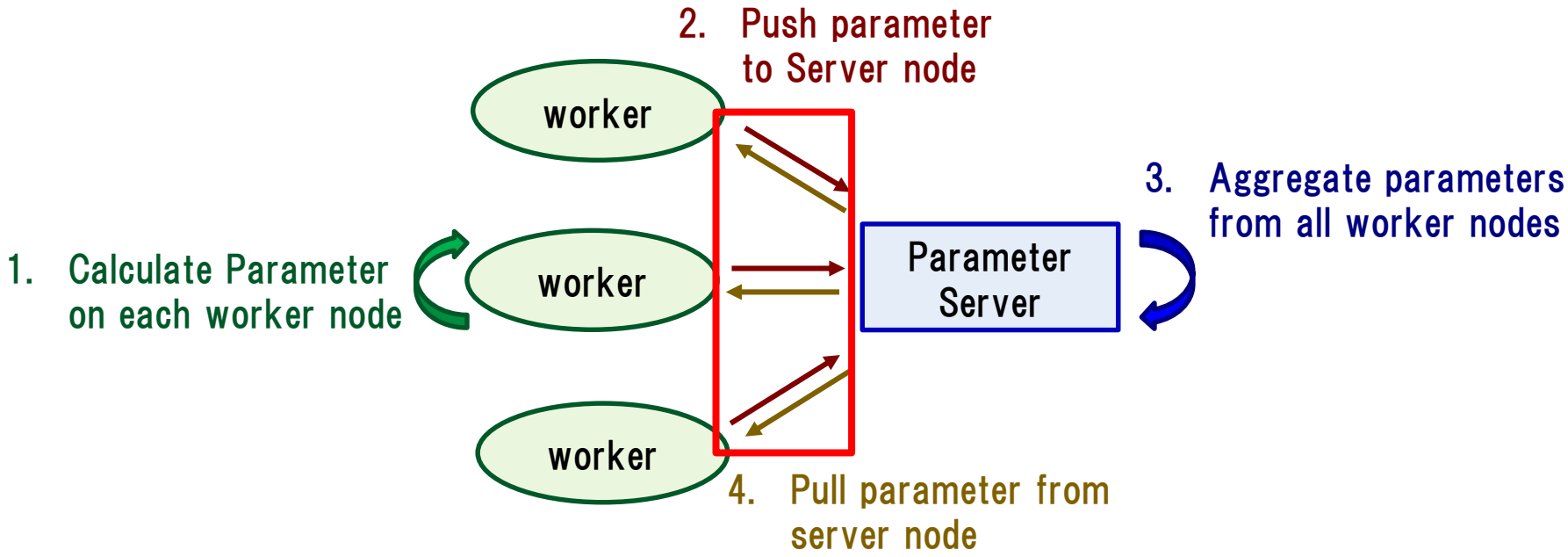
RDMA features, potential

- Remote Direct Memory Access(RDMA) is **low latency** and **low cpu overhead**, but **hard to implement**
- In simple micro-benchmark, RDMA's latency is about one fifth of IPoIB's latency (IPoIB : IP over Infiniband)



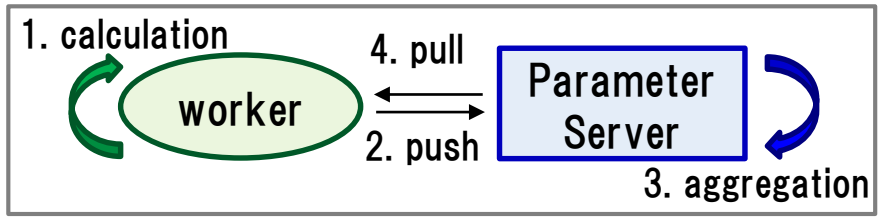
About case studies

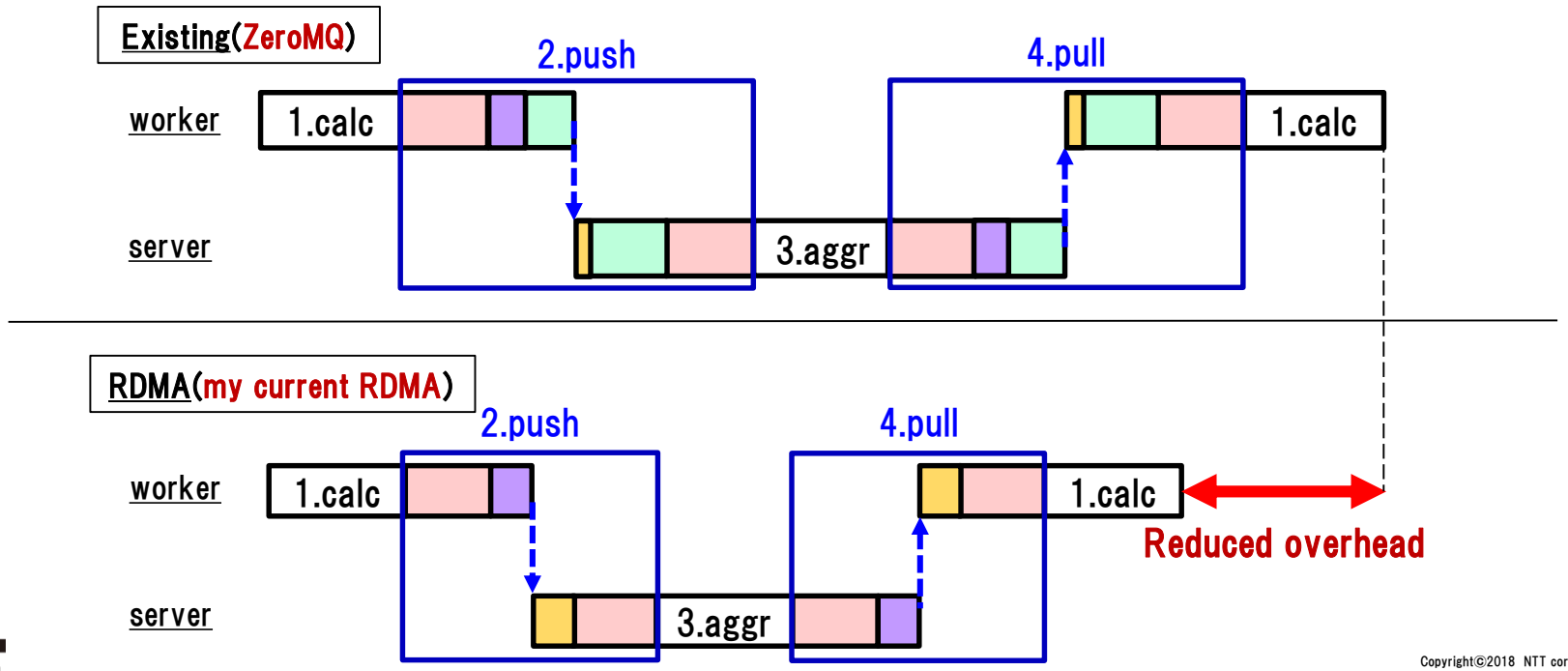
- To make use of RDMA potential, I tried to apply RDMA to MXNet, a distributed deep learning framework
  - MXNet adopts *Parameter Server mechanism* for distributed learning
- RDMA was seemed to be effective for this model
  - There are two times of communication between worker and server for each batch



Data flow comparison – existing implementation and RDMA

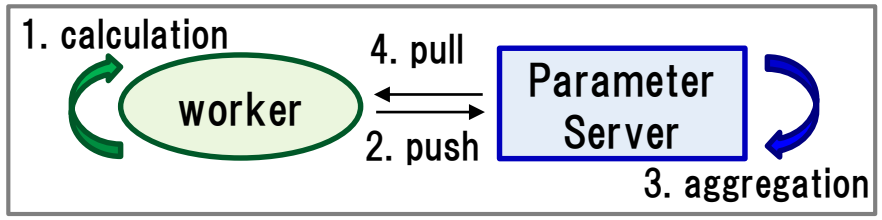
- By applying RDMA, I can reduce **2 memcpies per communication**, **total 4 copies per push and pull**

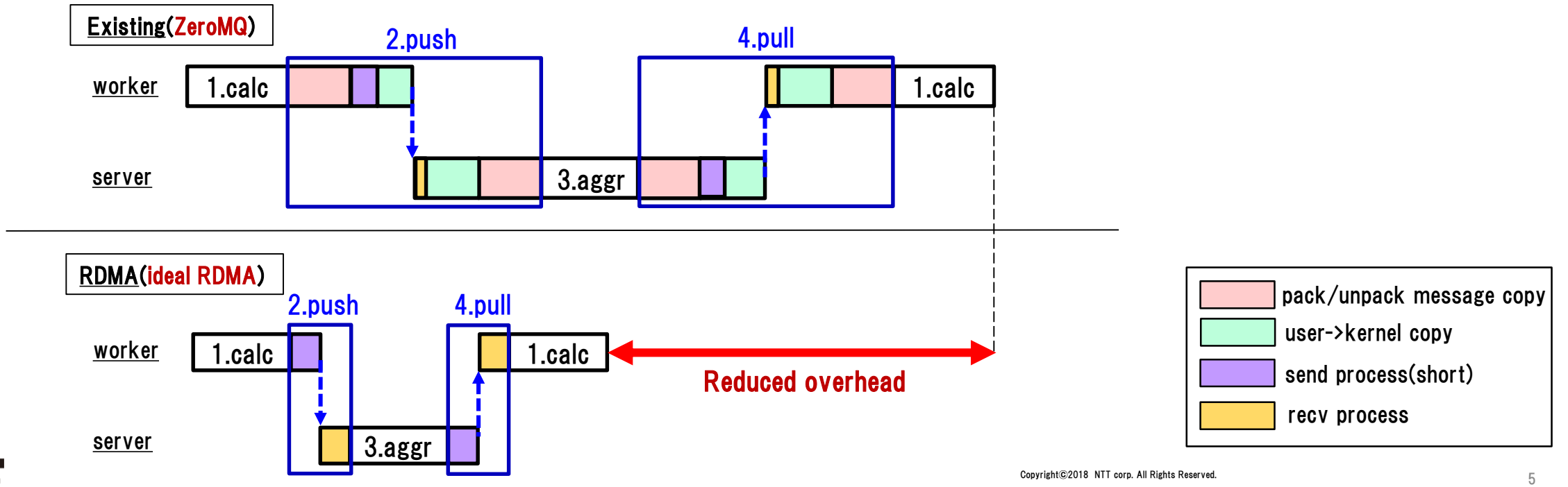




Data flow comparison – existing implementation and ideal RDMA

- By applying RDMA ideally, **all 4 memcpy per communication will be reduced, but this is out of scope in this work due to very high implementation cost**





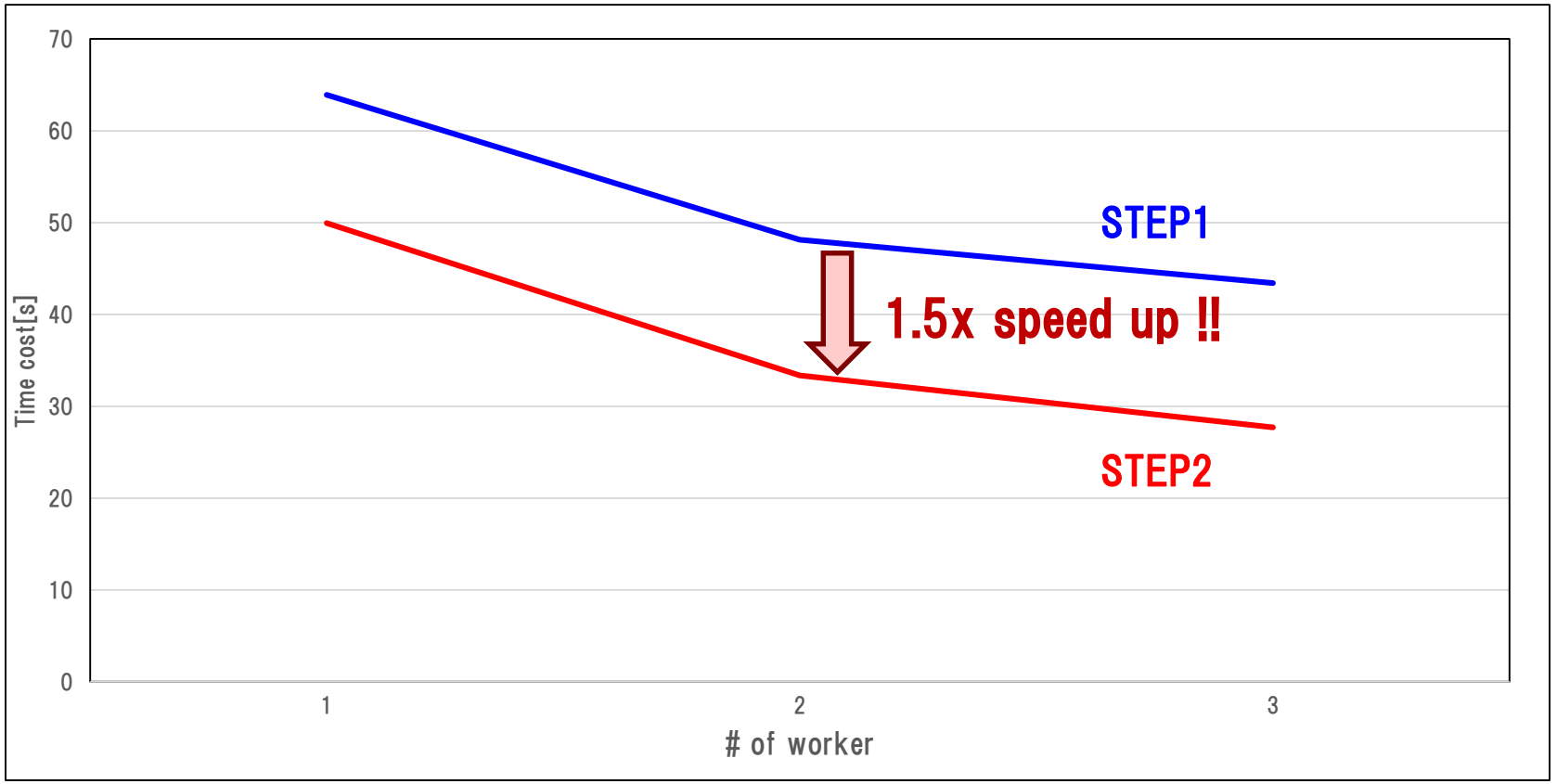
- **Optimal RDMA options**
  - RDMA operations(Operations : WRITE(put), READ(get), etc…)
  - Way to detect communication completions(Polling or MSI-X interrupt)
- **Importing Kernel layer mechanisms**
  - ring buffer for asynchronous communication (≒ socket buffer)
  - Separating detect completion thread

Types	Techniques	STEP0	STEP1	STEP2
RDMA mechanisms	RDMA operations	RDMA WRITE	RDMA WRITE	RDMA WRITE
	Detecting completion	interrupt	interrupt	polling
Kernel layer mechanisms	Ring buffer	×	○	○
	Separating detect completion thread	-	-	○

By implementing ring buffer,
the performance increased over 10x !!

Result(Step1 vs Step2)

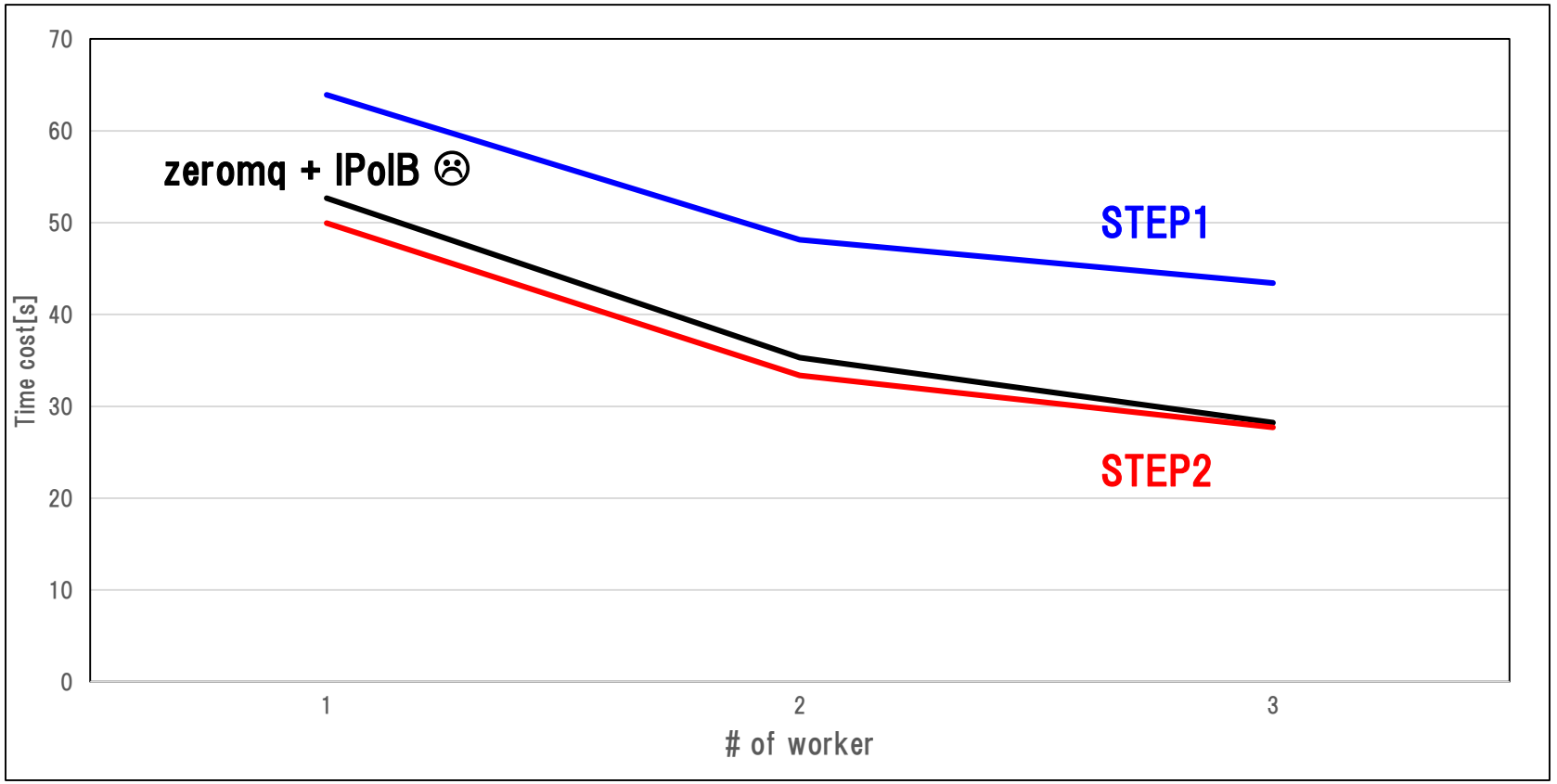
- Environment : 4machines(1server – 3worker), one Tesla V100 GPU for each machine, cifar10
- **Step2 implementation is 1.5x faster than Step1 implementation!☺**



Result(But…)

- **Existing implementation(zeromq) is fast!! ☹**
  - Step2 implementation is faster than it, but a bit…

(There are still other tuning, so RDMA can be faster ! !)



Conclusion

- **RDMA is efficient for reducing latency, cpu overhead, but there are many techniques to achieve high performance**
  - Selecting optimal options, flags, and redesign functions!
  - Porting a part of kernel layer tunings into user programs

- **As a matter of course, it is need to choose appropriate applications for RDMA**
  - CPU centric, network bottleneck, etc…
  - In this workload and environment, network load may be not adequate for confirming RDMA effect with lightweight change(Tesla V100 is very fast! & cifar10 is lightweight…)

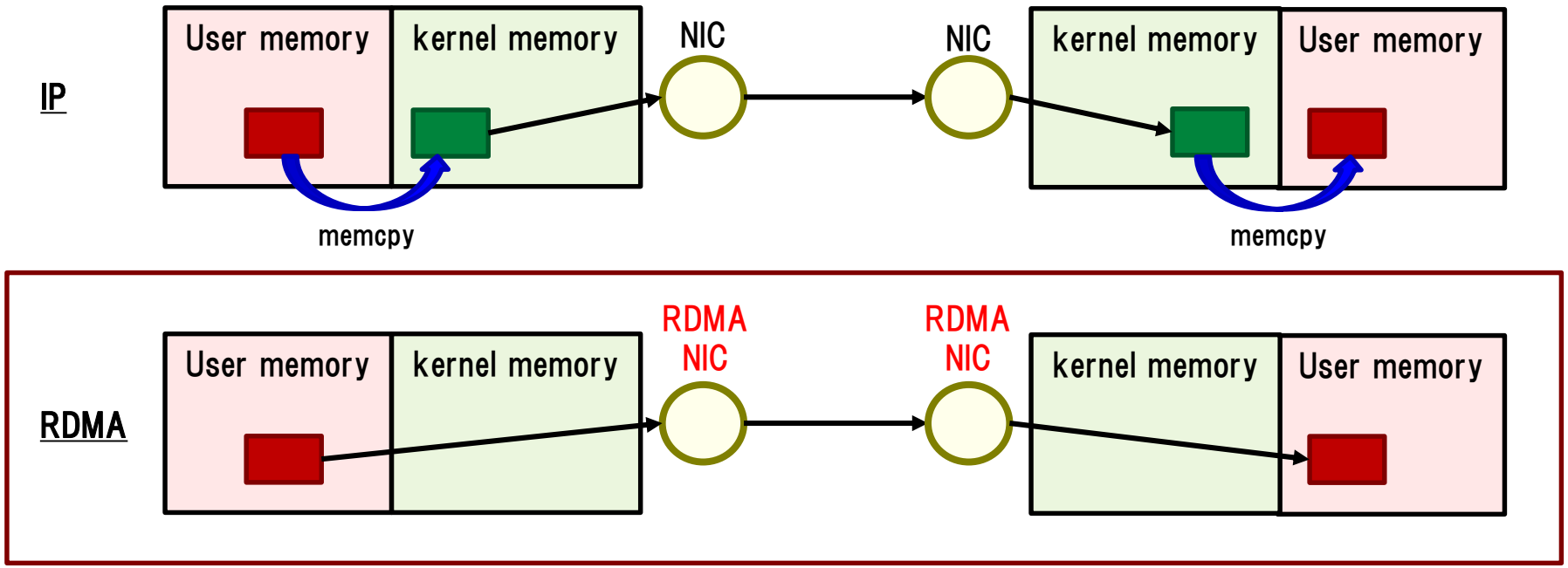
- **My Conclusion**
  - To enjoy RDMA effect easily, libraries providing RDMA design patterns are needed
  - ***"true zero-copy RDMA implementation"*** is needed for higher performance

Innovative R&D by NTT

Appendix

The Features of RDMA

- RDMA can reduce overhead and accelerate applications by these two features
  - **zero-copy**
    - NIC can read/write data to user memory directly
  - **cpu-bypass**
    - When using one-sided RDMA, client can send data without involving server's cpu



Experimental environment

- Environment

OS	Ubuntu16.04
CPU	Intel® Xeon® CPU E5-2697 v3 @ 2.60GHz
# of core, node	2 numa nodes and 14core 28thread for each numa node
Memory	256GB
Network	Mellanox ConnectX-5, 100Gbps cable
GPU	Tesla V100

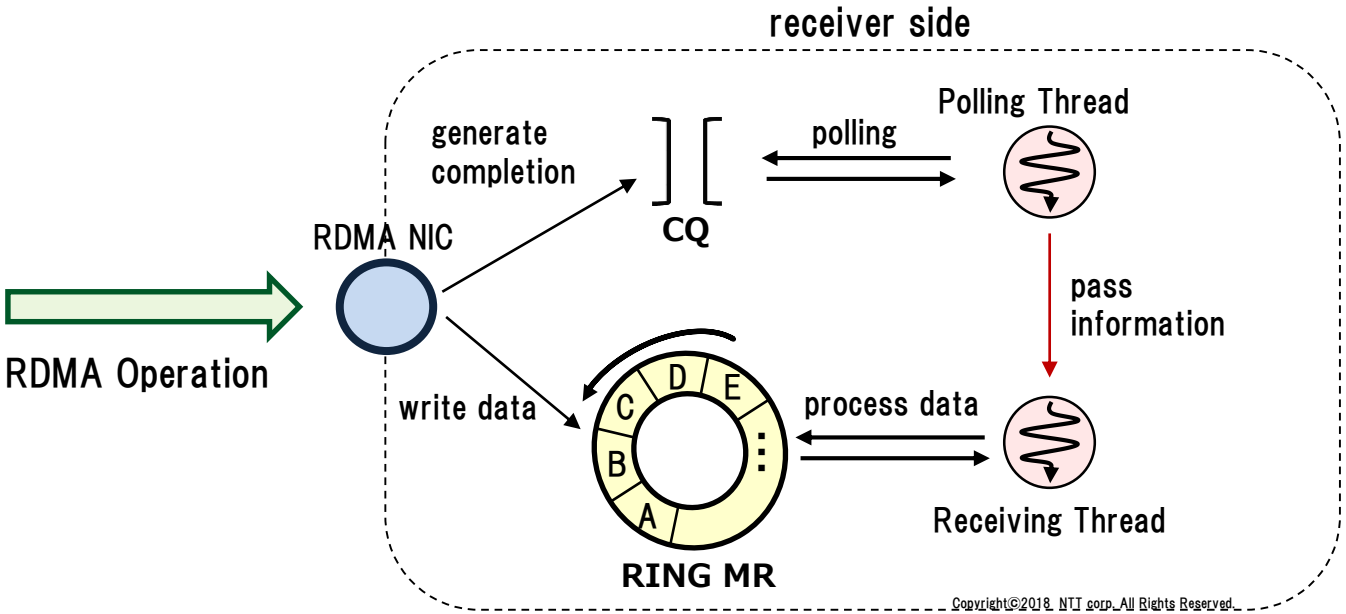
- Using 1 server nodes and 1-3 worker nodes
- GPU and HCA are on the same numa node(e.g. node1) on all machines, and using numactl to avoid “remote access”
- Using Cifar-10 and ResNet50 to training

RDMA Programming Resources

- **Memory Region(MR)**
  - RDMA NIC can only read data on MR / write data to MR
- **Completion Queue(CQ)**
  - Communication's success/failure information(*completion*) are pushed into CQ, and program can get it by pop from CQ by two ways
    - ***Polling*** or ***completion channel(MSI-X interrupt)***
- **Queue Pair(QP)**
  - similar to socket
  - By posting request to QP, RDMA NIC execute data transfer referring to it.
- **RDMA Operations**
  - SEND, RDMA WRITE, RDMA READ, ATOMIC
    - SEND needs for receiver side to post receive request to QP(two-sided RDMA)
    - Others don't need for receiver side to any operation (one-sided RDMA, cpu-bypass)
  - Service Types
    - RC, UC, UD, RD
    - RC can detect packet loss and re-send, but slower than other UC and UD

- **Ring Memory Region**
  - By using ring MR, sender can issue RDMA independent of receiver status
  - It's similar to IP's socket buffer in kernel space

- **Create additional thread for getting completion from CQ**
  - Getting completion in send function in application is inefficient because IP's send function returns when send data pass to kernel
  - Using polling to get work completion because CPU resource waste can be avoided by pinning thread to core



Other implementation techniques

- **Inline send**
  - Can send short packet with low latency than normal send
  - Short : depend on RNIC's kind. Mellanox ConnectX-5 is about 512 Bytes

- **Immediate data**
  - Can send 32bit data besides send data

- **Serialize at Completion Queue**
  - By sharing CQ with many QPs, can process completion serially
  - It can reduce performance, but it make implementation easier

- **Parallelize at Completion Queue**
  - Implementation becomes complicated, but performance will increase
  - Opposite to "Serialize at Completion Queue"