Development of real-time data publish and subscribe system based on Fast RTPS for image data transmission
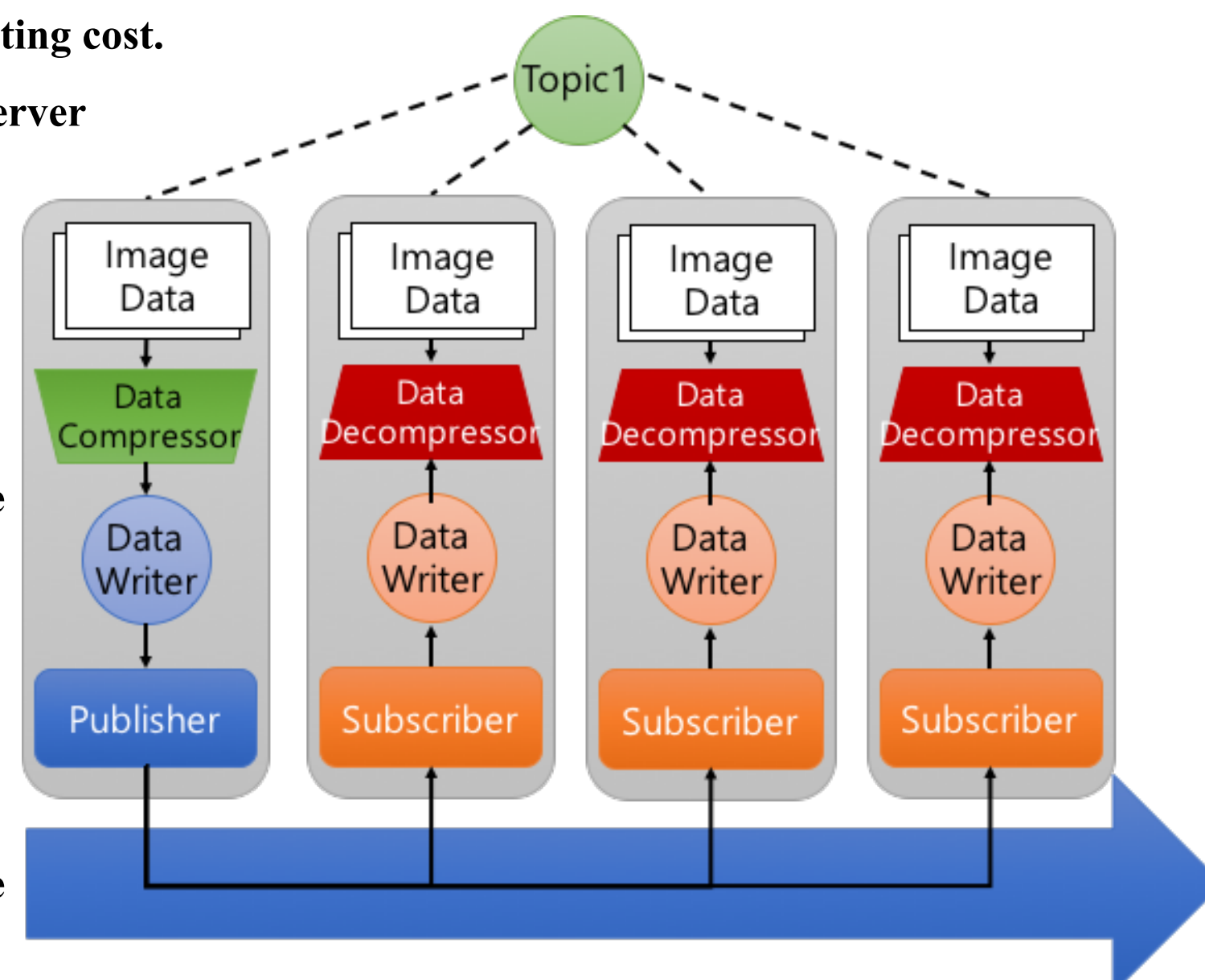
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In fusion experiment, real-time network is essential to control plasma real-time network used to transfer the diagnostic data from diagnostic device and command data from PCS(Plasma Control System). Among the data, transmitting image data from diagnostic system to another system in real-time is difficult than other types of data. Because, an image has larger data size than another type of data. To transmit the images, it need to have high throughput and best-effort property. And To transmit the data in real-time manner, the network needs to has low-latency. RTPS(Real Time Publish Subscribe) is reliable and has Quality of Service properties to enable best effort protocol. In this paper, eProsima Fast RTPS was used to implement RTPS based real-time network. Fast RTPS has low latency, high throughput and enable to best-effort and reliable publish and subscribe communication for real-time application via standard Ethernet network. This paper evaluates Fast RTPS about suitability to real-time image data transmission system. To evaluate performance of Fast RTPS base system, Publisher system publishes image data and multi subscriber system subscribe image data .

1. Introduction

- KSTAR uses image data to analyze plasma status and protect device.
  - Interlock system can use thermal imaging camera to monitor tokamak wall temperature status and to protect device.
  - TV Image Diagnostic system uses image data to analyze the status of plasma.
- In KSTAR, raw Image data is required to transmit remote server in real time.
  - Image data acquired from image DAQ system. And then transmitted to processing server. Because Processing image data take much computing cost.
  - Image data are transferred to remote archiving server to save image data.
- Transfer the image data in real time is difficult.
  - Most of Image data size is larger then other type of data.
  - One image source required to transfer to multiple destination.
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2. Real Time Publish Subscribe Protocol(RTPS)

- RTPS is a publish/subscribe protocol for Data Distribution Service(DDS) implementations.
  - DDS is a network communication middleware Object Management Group(OMG) standard .
- RTPS facilitate scalable, real-time ,reliable and high-performance system.
- RTPS has best effort and reliable QoS reliability mode.
- RTPS implements publisher/subscriber pattern to simplifies complex network programming.
  - RTPS uses the pattern to provide sending/receiving function for events and data among nodes.
  - Each node which share topic can share data by using publish/subscribe pattern.
- RTPS automatically discover the address of nodes which has same topic.
  - Each nodes does not require setting address in advance.
- KSTAR implement real-time image transmission based on DDS middleware.
  - Image Server acquires image from camera and publish data with specific topic.
  - Multi Image Clients subscribe this data.
  - Each node publish/subscribe image data over 1GbE UDP multicast with best effort QoS reliability mode .
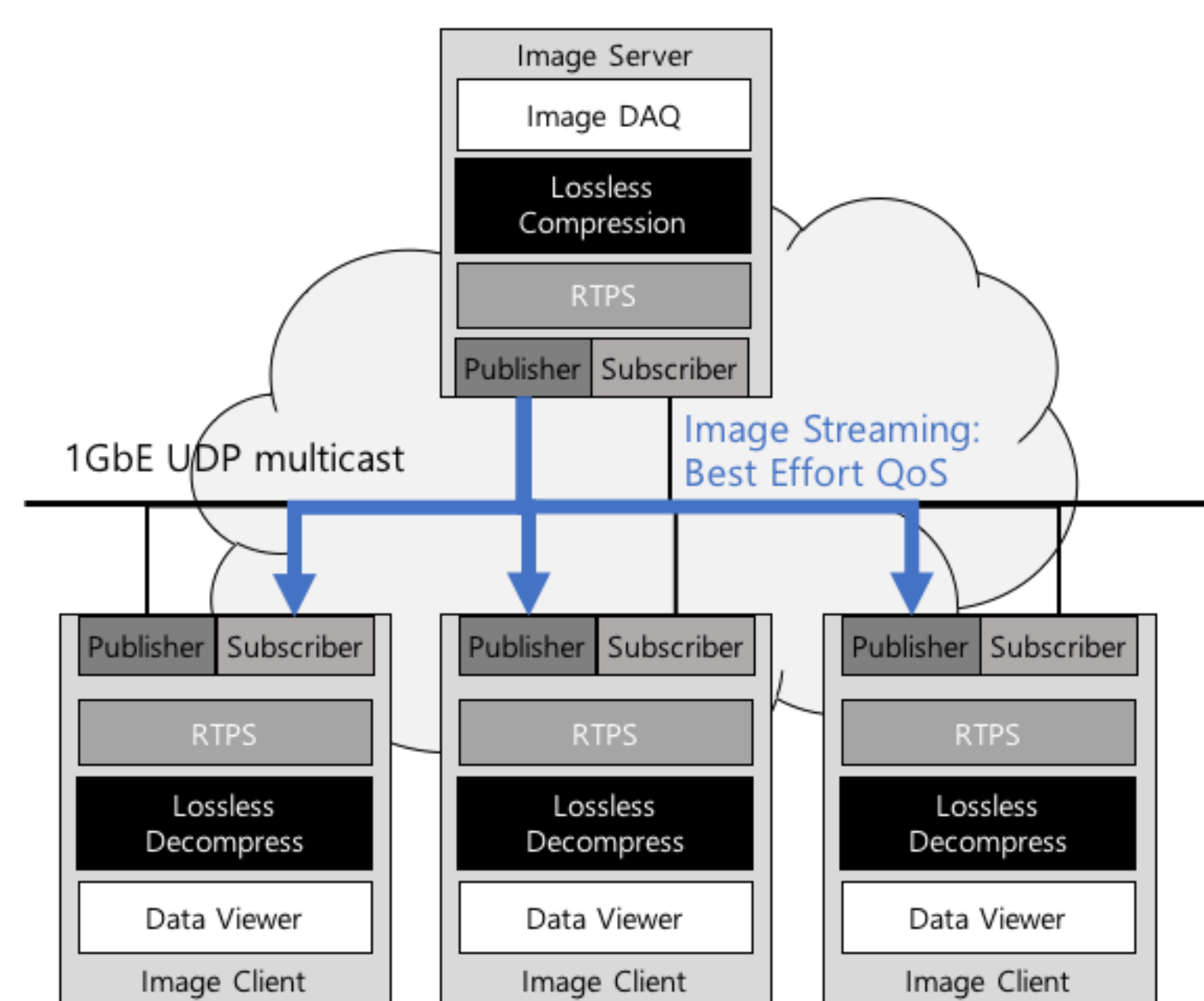 - To implement RTPS based system, we uses eprosima Fast RTPS framework.

Fig2. Configuration of RTPS based real time image transmission system

3. Lossless Real Time Image Compression

- Compressing image data is essential for real-time image transmission
  - Image data size is too large to transfer image through network.
- Our system use real time compression method to compress image data
  - Real time compression method compress and decompress data in real time.
  - Lossless encoding codec guarantee mathematical lossless. However while converting image format(such as RGB to YUV 4:4:4 conversion), image data loss may occurs by data type conversion.

- Zstadard(Zstd)
  - KSTAR uses Zstd library to compress/decompress each image.
  - Zstd is faster and provide higher compression rate than other compression methods(such as zlib, brotli).

5. Image data transmission process

- Image publisher node acquire image from camera.
- Real time compression method train image to make dictionary for real time compression at first time.(This process is performed only once at the beginning.)
- Compress image data with the dictionary(compression with dictionary is faster than standard compression method).
- Compressed data are published with the topic
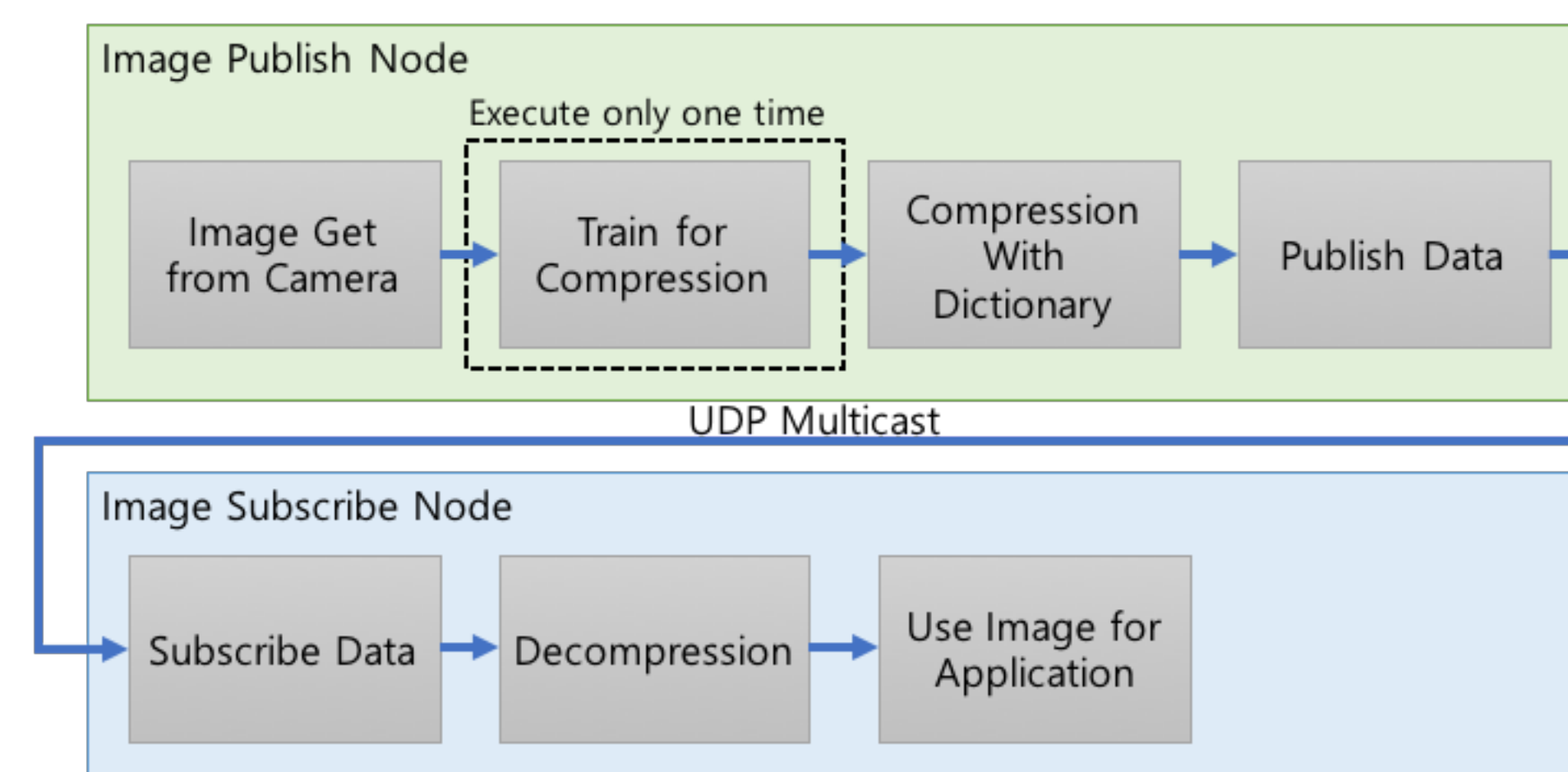- Subscriber node subscribe image data .and decompress the data.

Fig3. Image data transmission process

6. Experiment and Result

- Loop back test with varying image resolution
  - Node1 acquire image from camera and publish data with the topic that has publish time information and image data.
  - When node2 subscribe the data, node2 publish with different topic that has received image data and publish time information.
  - Latency is the time difference between publish time and returned topic subscribe time .
  - The test conducted 500 times.
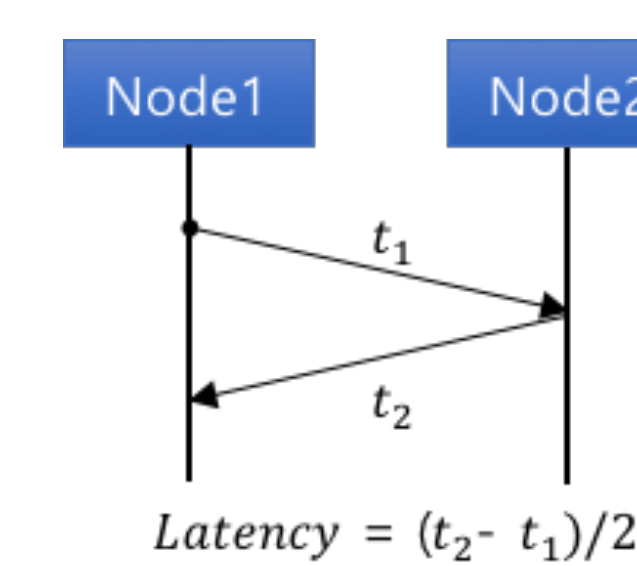 - Each test result store into file system.

	Test H/W configuration	
	Node1	**Node2**
CPU	Intel Core i7 (2.7GHz,4core)	Intel Core i3 (3.3GHz,2core)
Memory	16GB	8GB
Storage	1TB SSD	256GB SSD

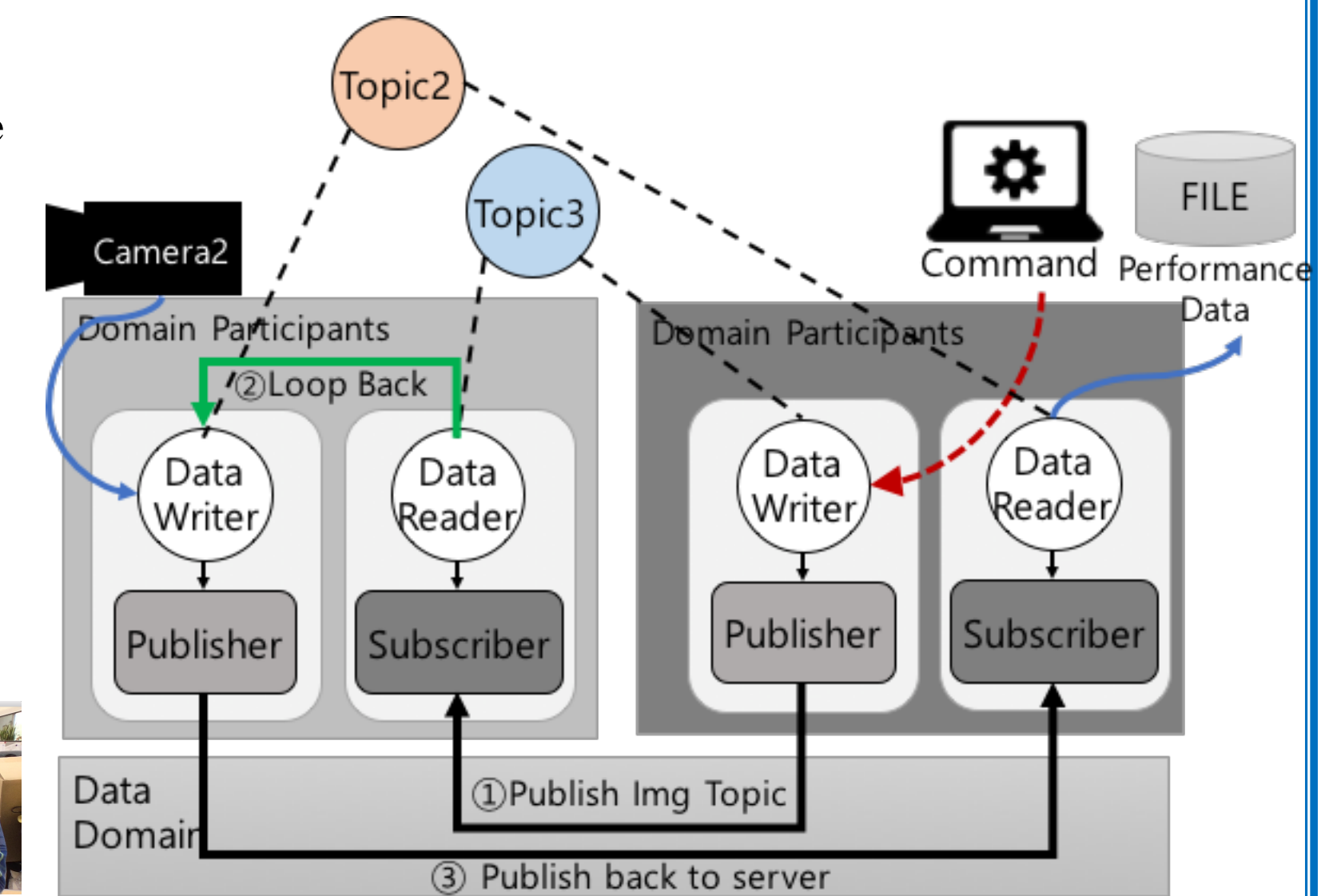$$Latency = (t_2 - t_1)/2$$

Fig4. Loopback test

Fig5. (right) test image, (left)Performance test configuration

- Network latency
  - Network Latency decreases as image resolution increases
  - Max fps is 30, because of camera maximum fps is 30
  - As image resolution increases fps decreases.
  - Network latency is relatively smaller than other process.
- Compression take time however this process reduce image data size to minimum 80%.
- By compressing the data, we can reduce the transmission time.
- As the image size is increase, we can get more benefit from compression.

- Compression/ Decompression
  - As image resolution increases, compression rate is increases. Larger image can get larger compression ration than smaller image.
  - Decompress process take smaller time than compression process

640x360 gray image	
Name	Time(msec)
compression train	9978.331000
Image acquire	47.821472
Compression	19.491242
network latency	6.184039
decomp exe	4.972109

Fig6. 640x360 process time

Conclusions

- The real-time Image transmission system has been developed transfer image data to destination nodes inreal time.
- A real-time Image transmission system was developed by using Fast RTPS and Compression library(Zstd).
- Publisher nodes send data to multi subscriber nodes without additional computational cost. Because RTPS can configured to run over UDP multicast.
- The system do lossless compression to acquired image from camera to reduce size of data and network latency(minimum compressed data size is 80% of original size, network latency is 6msec per 640x360 monocular image, compression take 20msec per image,) .
- the publisher node run at *3fps (1280x720 gray image), 15fps* (640x360 gray image), 27fps(320x180 gray image).