

ROS2共享内存零拷贝功能验证实验

1. 实验目的

本实验旨在验证ROS2中共享内存和零拷贝数据传输机制的性能优势，通过对比传统网络传输方式与共享内存传输方式在图像传输中的表现，展示共享内存存在降低延迟和减少CPU资源消耗方面的作用。通过本实验，用户可以掌握ROS2共享内存配置方法和性能优化技巧。

2. 实验要求

- 软件要求：Windows 10及以上版本；RflySim工具链^[1]。
- 硬件要求：笔记本/台式电脑1台^[2]。

3. 实验地址

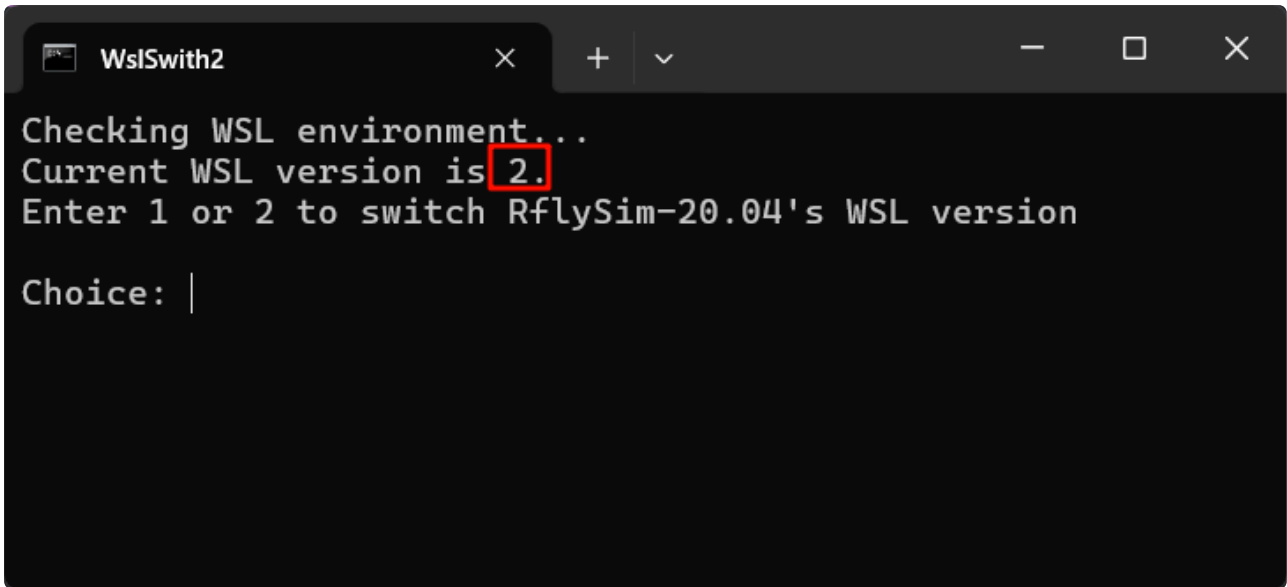
例程目录：[\[安装目录\]\RflySimAPIs\1.RflySimIntro\2.AdvExps\e12.ROS2SharedMem](#)

- [Build_src.sh](#)：编译脚本，用于编译程序代码
- [WinWSL.bat](#)：Windows与WSL切换脚本，用于打开Ubuntu环境
- [run.sh](#)：运行脚本，用于启动ROS2程序
- [fastdds_shm_zerocopy.xml](#)：FastDDS共享内存零拷贝配置文件，用于配置共享内存传输参数

4. 实验内容或步骤

4.1 步骤1：环境确认

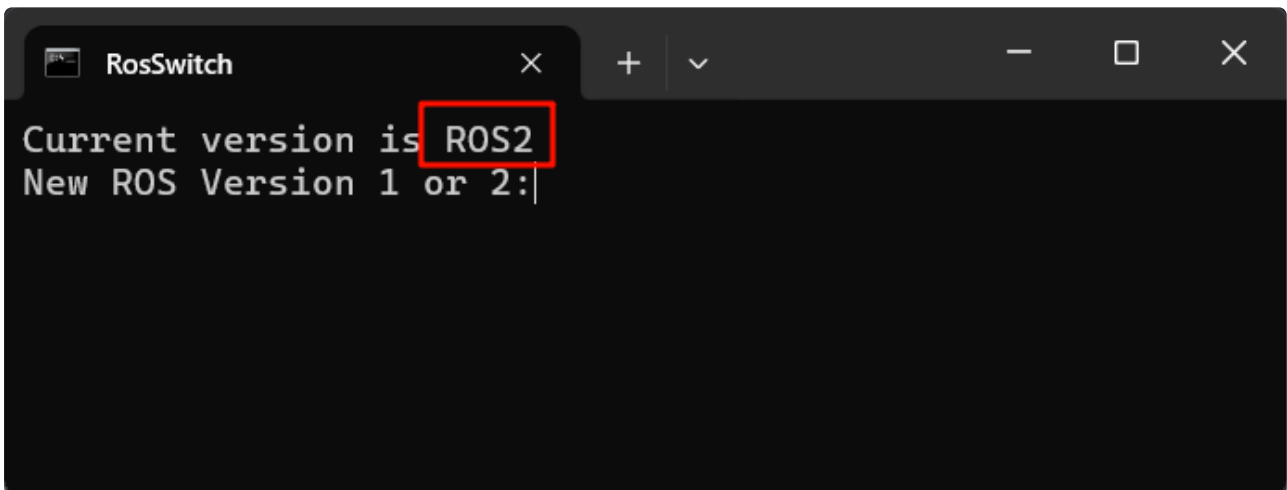
双击"[|Desktop\RflyTools\WslSwith2.Ink](#)"链接，在弹出的对话框中，确认当前WSL系统处于WSL 2状态，若不是可在对话框中输入"2"来进行切换。



```
WslSwitch2
Checking WSL environment...
Current WSL version is 2.
Enter 1 or 2 to switch RflySim-20.04's WSL version

Choice: |
```

双击“\Desktop\RflyTools\RosSwitch.lnk”链接，在弹出的对话框中，确认当前的ROS版本为ROS2。若不是可在对话框中输入“2”来进行切换。



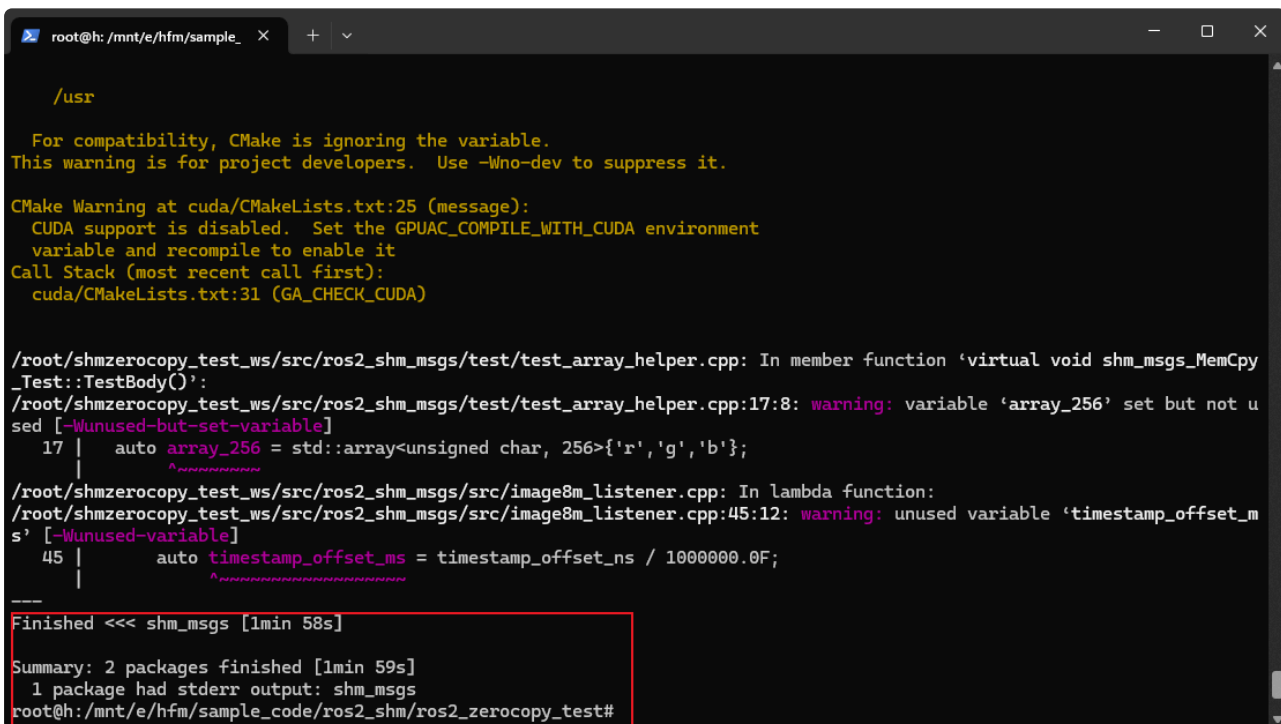
```
RosSwitch
Current version is ROS2
New ROS Version 1 or 2:|
```

4.2 步骤2：编译程序

双击 [WinWSL.bat](#)，打开Ubuntu环境，输入 `./Build_src.sh` 编译程序。

```
root@h:/mnt/e/hfm/sample_code/ros2_shm/ros2_zerocopy_test# ./Build_src.sh
Archive: ./src.zip
  creating: /root/shmzerocopy_test_ws/src/
  creating: /root/shmzerocopy_test_ws/src/image_noshmzero/
 inflating: /root/shmzerocopy_test_ws/src/image_noshmzero/CMakeLists.txt
  creating: /root/shmzerocopy_test_ws/src/image_noshmzero/include/
  creating: /root/shmzerocopy_test_ws/src/image_noshmzero/include/image_shm_demo/
  creating: /root/shmzerocopy_test_ws/src/image_noshmzero/msg/
 inflating: /root/shmzerocopy_test_ws/src/image_noshmzero/msg/ImageShm.idl
 inflating: /root/shmzerocopy_test_ws/src/image_noshmzero/msg/ImageShm.msg
 inflating: /root/shmzerocopy_test_ws/src/image_noshmzero/package.xml
  creating: /root/shmzerocopy_test_ws/src/image_noshmzero/src/
 inflating: /root/shmzerocopy_test_ws/src/image_noshmzero/src/image_publisher_node.cpp
 inflating: /root/shmzerocopy_test_ws/src/image_noshmzero/src/image_subscriber_node.cpp
  creating: /root/shmzerocopy_test_ws/src/ros2_shm_msgs/
  creating: /root/shmzerocopy_test_ws/src/ros2_shm_msgs/.git/
  creating: /root/shmzerocopy_test_ws/src/ros2_shm_msgs/.git/branches/
 inflating: /root/shmzerocopy_test_ws/src/ros2_shm_msgs/.git/config
 inflating: /root/shmzerocopy_test_ws/src/ros2_shm_msgs/.git/description
 extracting: /root/shmzerocopy_test_ws/src/ros2_shm_msgs/.git/HEAD
  creating: /root/shmzerocopy_test_ws/src/ros2_shm_msgs/.git/hooks/
 inflating: /root/shmzerocopy_test_ws/src/ros2_shm_msgs/.git/hooks/applypatch-msg.sample
 inflating: /root/shmzerocopy_test_ws/src/ros2_shm_msgs/.git/hooks/commit-msg.sample
 inflating: /root/shmzerocopy_test_ws/src/ros2_shm_msgs/.git/hooks/fsmonitor-watchman.sample
 inflating: /root/shmzerocopy_test_ws/src/ros2_shm_msgs/.git/hooks/post-update.sample
 inflating: /root/shmzerocopy_test_ws/src/ros2_shm_msgs/.git/hooks/pre-applypatch.sample
 inflating: /root/shmzerocopy_test_ws/src/ros2_shm_msgs/.git/hooks/pre-commit.sample
 inflating: /root/shmzerocopy_test_ws/src/ros2_shm_msgs/.git/hooks/pre-merge-commit.sample
```

编译完成如下图:



```
root@h:/mnt/e/hfm/sample_ x + v
/usr
For compatibility, CMake is ignoring the variable.
This warning is for project developers. Use -Wno-dev to suppress it.

CMake Warning at cuda/CMakeLists.txt:25 (message):
  CUDA support is disabled. Set the GPUAC_COMPILE_WITH_CUDA environment
  variable and recompile to enable it
Call Stack (most recent call first):
  cuda/CMakeLists.txt:31 (GA_CHECK_CUDA)

/root/shmzerocopy_test_ws/src/ros2_shm_msgs/test/test_array_helper.cpp: In member function 'virtual void shm_msgs_MemCpy_Test::TestBody()':
/root/shmzerocopy_test_ws/src/ros2_shm_msgs/test/test_array_helper.cpp:17:8: warning: variable 'array_256' set but not used [-Wunused-but-set-variable]
   17 |     auto array_256 = std::array<unsigned char, 256>{'r', 'g', 'b'};
      |         ^~~~~~
/root/shmzerocopy_test_ws/src/ros2_shm_msgs/src/image8m_listener.cpp: In lambda function:
/root/shmzerocopy_test_ws/src/ros2_shm_msgs/src/image8m_listener.cpp:45:12: warning: unused variable 'timestamp_offset_ms' [-Wunused-variable]
   45 |     auto timestamp_offset_ms = timestamp_offset_ns / 1000000.0F;
      |         ^~~~~~

-----
Finished <<< shm_msgs [1min 58s]

Summary: 2 packages finished [1min 59s]
 1 package had stderr output: shm_msgs
root@h:/mnt/e/hfm/sample_code/ros2_shm/ros2_zerocopy_test#
```

4.3 步骤3: 运行程序(未开启共享内存)

双击 WinWSL.bat, 打开Ubuntu环境, 输入 `./run.sh` 编译程序。

```

top
top - 13:36:47 up 2 min, 1 user, load average: 0.17, 0.06, 0.02
Tasks: 48 total, 1 running, 47 sleeping, 0 stopped, 0 zombie
%Cpu(s): 0.5 us, 0.1 sy, 0.0 ni, 99.2 id, 0.0 wa, 0.0 hi, 0.0 si, 0.0 st
MiB Mem : 15851.2 total, 14461.6 free, 747.0 used, 642.5 buff/cache
MiB Swap: 4096.0 total, 4096.0 free, 0.0 used, 14810.6 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR   S  %CPU  %MEM     TIME+ COMMAND
  934 root        20   0  830244  152356 50400  S   5.7   0.9   0:03.71 image_publisher
  911 root        20   0  861352  141048 109320  S   3.7   0.9   0:02.00 image8m_listene
  949 root        20   0  806000  121668 44320  S   3.7   0.7   0:02.05 image_subscribe
  164 avahi       20   0   9168   5120   3520  S   1.7   0.0   0:02.28 avahi-daemon
  890 root        20   0  843912  67520 50400  S   1.0   0.4   0:00.67 image8m_talker
  869 root        20   0  12512   8640  6240  S   0.7   0.1   0:00.25 xterm
  881 root        20   0  13128   9280  6240  S   0.7   0.1   0:00.16 xterm
  904 root        20   0  12468   8640  6240  S   0.3   0.1   0:00.16 xterm
  928 root        20   0  12204   8320  6240  S   0.3   0.1   0:00.11 xterm
   1 root        20   0  165996  10684  8124  S   0.0   0.1   0:00.27 systemd
   2 root        20   0   3072   1760  1760  S   0.0   0.0   0:00.00 init-systemd(Rf
   9 root        20   0   3088   1980  1920  S   0.0   0.0   0:00.00 init
  60 root       19  -1  31496  10880 10080  S   0.0   0.1   0:00.05 systemd-journal
  95 root        20   0  23876   6400  4640  S   0.0   0.0   0:00.08 systemd-udev
 105 systemd+   20   0  26332  13076  8640  S   0.0   0.1   0:00.03 systemd-resolve
 108 systemd+   20   0  89388   7200  6400  S   0.0   0.0   0:00.02 systemd-timesyn
 167 root        20   0   4308   2560  2400  S   0.0   0.0   0:00.00 cron

```

```

setup.bash; ros2 run image_noshmzero image_publisher_...
[INFO] [1758605805.534778917] [image_publisher]: Publishing
[INFO] [1758605805.635191089] [image_publisher]: Publishing
[INFO] [1758605805.734898934] [image_publisher]: Publishing
[INFO] [1758605805.837784603] [image_publisher]: Publishing
[INFO] [1758605805.939016646] [image_publisher]: Publishing
[INFO] [1758605806.039281193] [image_publisher]: Publishing
[INFO] [1758605806.144651849] [image_publisher]: Publishing
[INFO] [1758605806.244474011] [image_publisher]: Publishing
[INFO] [1758605806.345105277] [image_publisher]: Publishing
[INFO] [1758605806.447046446] [image_publisher]: Publishing
[INFO] [1758605806.547686514] [image_publisher]: Publishing
[INFO] [1758605806.648875729] [image_publisher]: Publishing
[INFO] [1758605806.746924120] [image_publisher]: Publishing
[INFO] [1758605806.849682519] [image_publisher]: Publishing
[INFO] [1758605806.950067280] [image_publisher]: Publishing
[INFO] [1758605807.052238456] [image_publisher]: Publishing
[INFO] [1758605807.150899198] [image_publisher]: Publishing
[INFO] [1758605807.252575718] [image_publisher]: Publishing
[INFO] [1758605807.353162033] [image_publisher]: Publishing
[INFO] [1758605807.452773261] [image_publisher]: Publishing
[INFO] [1758605807.550788115] [image_publisher]: Publishing
[INFO] [1758605807.652329952] [image_publisher]: Publishing
[INFO] [1758605807.751419371] [image_publisher]: Publishing

```

```

fastdds_shm_zerocopy.xml RMW_FASTRTPS_USE_QOS_FR...
[INFO] [1758605805.588141835] [shm_image8m_talker]: Publishing
[INFO] [1758605805.688825749] [shm_image8m_talker]: Publishing
[INFO] [1758605805.789784833] [shm_image8m_talker]: Publishing
[INFO] [1758605805.890777668] [shm_image8m_talker]: Publishing
[INFO] [1758605805.992014672] [shm_image8m_talker]: Publishing
[INFO] [1758605806.093391002] [shm_image8m_talker]: Publishing
[INFO] [1758605806.194680882] [shm_image8m_talker]: Publishing
[INFO] [1758605806.295769922] [shm_image8m_talker]: Publishing
[INFO] [1758605806.396981935] [shm_image8m_talker]: Publishing
[INFO] [1758605806.498313516] [shm_image8m_talker]: Publishing
[INFO] [1758605806.599403425] [shm_image8m_talker]: Publishing
[INFO] [1758605806.700636586] [shm_image8m_talker]: Publishing
[INFO] [1758605806.801498036] [shm_image8m_talker]: Publishing
[INFO] [1758605806.902048081] [shm_image8m_talker]: Publishing
[INFO] [1758605807.002579927] [shm_image8m_talker]: Publishing
[INFO] [1758605807.103208192] [shm_image8m_talker]: Publishing
[INFO] [1758605807.203535646] [shm_image8m_talker]: Publishing
[INFO] [1758605807.303914633] [shm_image8m_talker]: Publishing
[INFO] [1758605807.404310974] [shm_image8m_talker]: Publishing
[INFO] [1758605807.504726882] [shm_image8m_talker]: Publishing
[INFO] [1758605807.605210997] [shm_image8m_talker]: Publishing
[INFO] [1758605807.705412301] [shm_image8m_talker]: Publishing
[INFO] [1758605807.805800198] [shm_image8m_talker]: Publishing

```

```

setup.bash; ros2 run image_noshmzero image_subscriber_...
[INFO] [1758605805.544920341] [image_subscriber]: End-to-end delay: 13.35 ms
[INFO] [1758605805.637124341] [image_subscriber]: End-to-end delay: 4.43 ms
[INFO] [1758605805.745612390] [image_subscriber]: End-to-end delay: 12.62 ms
[INFO] [1758605805.839255333] [image_subscriber]: End-to-end delay: 4.50 ms
[INFO] [1758605805.940429262] [image_subscriber]: End-to-end delay: 4.42 ms
[INFO] [1758605806.049758288] [image_subscriber]: End-to-end delay: 13.03 ms
[INFO] [1758605806.146524483] [image_subscriber]: End-to-end delay: 7.30 ms
[INFO] [1758605806.251827561] [image_subscriber]: End-to-end delay: 12.93 ms
[INFO] [1758605806.346664556] [image_subscriber]: End-to-end delay: 5.53 ms
[INFO] [1758605806.448620693] [image_subscriber]: End-to-end delay: 6.20 ms
[INFO] [1758605806.549310543] [image_subscriber]: End-to-end delay: 6.13 ms
[INFO] [1758605806.659176653] [image_subscriber]: End-to-end delay: 14.53 ms
[INFO] [1758605806.748426597] [image_subscriber]: End-to-end delay: 3.38 ms
[INFO] [1758605806.859763546] [image_subscriber]: End-to-end delay: 13.57 ms
[INFO] [1758605806.960323590] [image_subscriber]: End-to-end delay: 13.46 ms
[INFO] [1758605807.054050890] [image_subscriber]: End-to-end delay: 6.63 ms
[INFO] [1758605807.152264711] [image_subscriber]: End-to-end delay: 4.51 ms
[INFO] [1758605807.254285598] [image_subscriber]: End-to-end delay: 6.01 ms
[INFO] [1758605807.362723936] [image_subscriber]: End-to-end delay: 14.05 ms
[INFO] [1758605807.462981334] [image_subscriber]: End-to-end delay: 13.81 ms
[INFO] [1758605807.561395374] [image_subscriber]: End-to-end delay: 12.78 ms
[INFO] [1758605807.663404507] [image_subscriber]: End-to-end delay: 13.52 ms
[INFO] [1758605807.762350524] [image_subscriber]: End-to-end delay: 12.74 ms

```

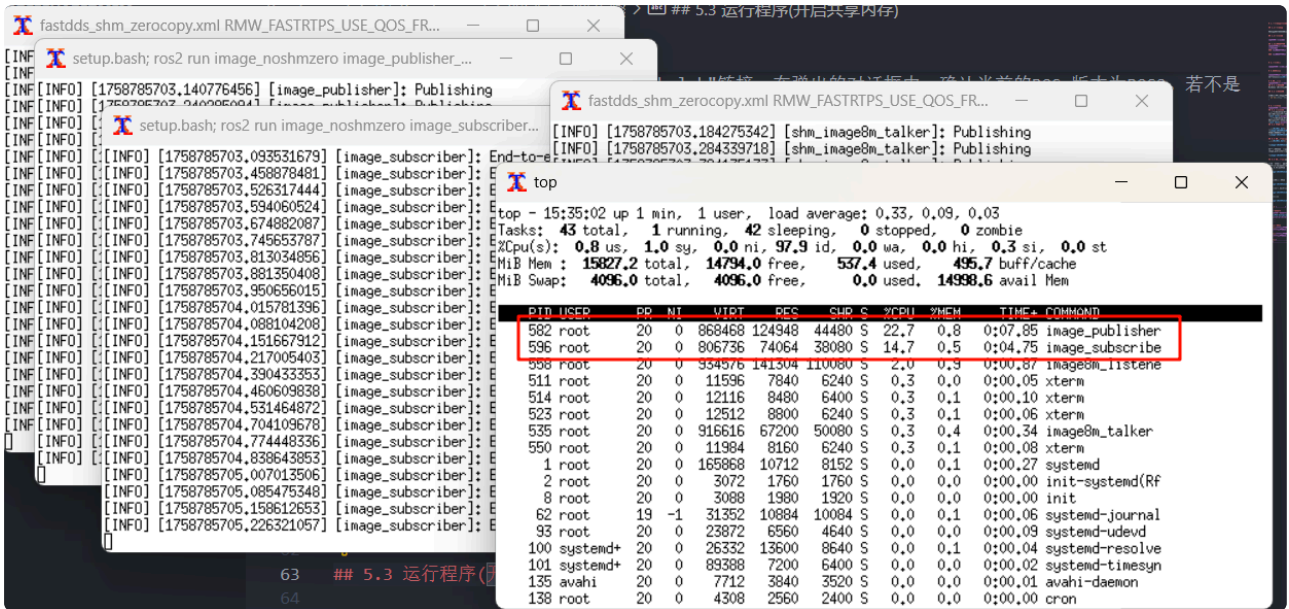
```

[INFO] [1758605806.702797794] [shm_image8m_listener]: End-to-end delay: 2.17 ms
[INFO] [1758605806.805138064] [shm_image8m_listener]: Received...
[INFO] [1758605806.805323814] [shm_image8m_listener]: End-to-end delay: 3.84 ms
[INFO] [1758605806.904156910] [shm_image8m_listener]: Received...
[INFO] [1758605806.904242041] [shm_image8m_listener]: End-to-end delay: 2.20 ms
[INFO] [1758605807.005894715] [shm_image8m_listener]: Received...
[INFO] [1758605807.006025070] [shm_image8m_listener]: End-to-end delay: 3.45 ms
[INFO] [1758605807.106915964] [shm_image8m_listener]: Received...
[INFO] [1758605807.107135939] [shm_image8m_listener]: End-to-end delay: 3.94 ms
[INFO] [1758605807.207512361] [shm_image8m_listener]: Received...
[INFO] [1758605807.207735806] [shm_image8m_listener]: End-to-end delay: 4.27 ms
[INFO] [1758605807.307813284] [shm_image8m_listener]: Received...
[INFO] [1758605807.307809751] [shm_image8m_listener]: End-to-end delay: 3.90 ms
[INFO] [1758605807.408097443] [shm_image8m_listener]: Received...
[INFO] [1758605807.408346893] [shm_image8m_listener]: End-to-end delay: 4.04 ms
[INFO] [1758605807.507960908] [shm_image8m_listener]: Received...
[INFO] [1758605807.508048655] [shm_image8m_listener]: End-to-end delay: 3.33 ms
[INFO] [1758605807.609482430] [shm_image8m_listener]: Received...
[INFO] [1758605807.609673217] [shm_image8m_listener]: End-to-end delay: 4.47 ms
[INFO] [1758605807.707593535] [shm_image8m_listener]: Received...
[INFO] [1758605807.707684741] [shm_image8m_listener]: End-to-end delay: 2.28 ms
[INFO] [1758605807.808246357] [shm_image8m_listener]: Received...
[INFO] [1758605807.808357732] [shm_image8m_listener]: End-to-end delay: 2.56 ms

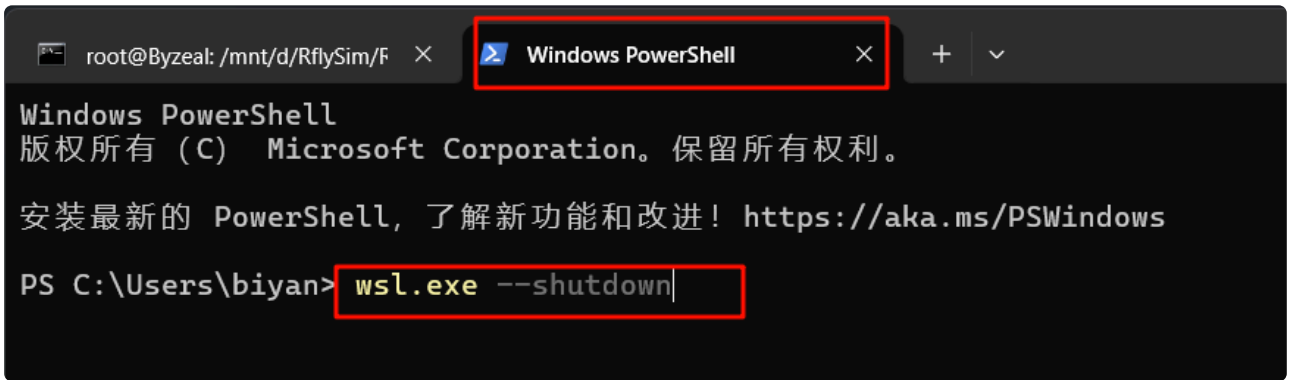
```

下图为默认不开启共享内存加零拷贝普通传输情况，一张图片传输延迟大约在12ms左右，资源占用情况：

- 1 image_publisher(cpu: 22.7%, mem: 0.8%)
- 2
- 3 image_subscriber(cpu: 14.7%, mem: 0.5%)
- 4



新开一个CMD窗口，输入 `wsl.exe --shutdown` 关闭WSL系统。



4.4 步骤4：运行程序(开启共享内存)

修改 `~/.bashrc` 文件，开启共享内存，重新运行 `WinWSL.bat`，依次输入：

```
1 | echo "export ROS_LOCALHOST_ONLY=0" >> ~/.bashrc
2 | source ~/.bashrc
```

关闭终端。再重新运行 `WinWSL.bat`，打开Ubuntu环境，输入 `./run.sh` 编译程序。

```

top
top - 13:36:47 up 2 min, 1 user, load average: 0.17, 0.06, 0.02
Tasks: 48 total, 1 running, 47 sleeping, 0 stopped, 0 zombie
%Cpu(s): 0.5 us, 0.1 sy, 0.0 ni, 99.2 id, 0.0 wa, 0.0 hi, 0.0 si, 0.0 st
MiB Mem : 15851.2 total, 14461.6 free, 747.0 used, 642.5 buff/cache
MiB Swap: 4096.0 total, 4096.0 free, 0.0 used, 14810.6 avail Mem

  PID USER   PR  NI  TSTIMESTAMP           VIRT     RES     SHR  S  %CPU  %MEM     TIME+ COMMAND
  934 root    20   0   830244 152356 50400  S   5.7   0.9   0:03.71 image_publisher
  911 root    20   0   861352 141048 109320  S   3.7   0.9   0:02.00 image8m_listene
  949 root    20   0   806000 121668 44320  S   3.7   0.7   0:02.05 image_subscribe
  164 avahi   20   0   9168   5120   3520  S   1.7   0.0   0:02.28 avahi-daemon
  890 root    20   0   843912 67520 50400  S   1.0   0.4   0:00.67 image8m_talker
  869 root    20   0   12512   8640  6240  S   0.7   0.1   0:00.25 xterm
  881 root    20   0   13128   9280  6240  S   0.7   0.1   0:00.16 xterm
  904 root    20   0   12468   8640  6240  S   0.3   0.1   0:00.16 xterm
  928 root    20   0   12204   8320  6240  S   0.3   0.1   0:00.11 xterm
  1 root    20   0   165996 10684  8124  S   0.0   0.1   0:00.27 systemd
  2 root    20   0   3072   1760  1760  S   0.0   0.0   0:00.00 init-systemd(Rf
  9 root    20   0   3088   1980  1920  S   0.0   0.0   0:00.00 init
  60 root    19  -1   31496 10880 10080  S   0.0   0.1   0:00.05 systemd-journal
  95 root    20   0   23876   6400  4640  S   0.0   0.0   0:00.08 systemd-udev
  105 systemd+ 20   0   26332 13076  8640  S   0.0   0.1   0:00.03 systemd-resolve
  108 systemd+ 20   0   89388   7200  6400  S   0.0   0.0   0:00.02 systemd-timesyn
  167 root    20   0   4308   2560  2400  S   0.0   0.0   0:00.00 cron

```

```

setup.bash; ros2 run image_noshmzero image_publisher_...
[INFO] [1758605805.534778917] [image_publisher]: Publishing
[INFO] [1758605805.635191089] [image_publisher]: Publishing
[INFO] [1758605805.734898934] [image_publisher]: Publishing
[INFO] [1758605805.837784603] [image_publisher]: Publishing
[INFO] [1758605805.939016646] [image_publisher]: Publishing
[INFO] [1758605806.039281193] [image_publisher]: Publishing
[INFO] [1758605806.144651849] [image_publisher]: Publishing
[INFO] [1758605806.244474011] [image_publisher]: Publishing
[INFO] [1758605806.345105277] [image_publisher]: Publishing
[INFO] [1758605806.447046446] [image_publisher]: Publishing
[INFO] [1758605806.547686514] [image_publisher]: Publishing
[INFO] [1758605806.648875729] [image_publisher]: Publishing
[INFO] [1758605806.746924120] [image_publisher]: Publishing
[INFO] [1758605806.849682519] [image_publisher]: Publishing
[INFO] [1758605806.950067280] [image_publisher]: Publishing
[INFO] [1758605807.052238456] [image_publisher]: Publishing
[INFO] [1758605807.150899198] [image_publisher]: Publishing
[INFO] [1758605807.252575718] [image_publisher]: Publishing
[INFO] [1758605807.353162033] [image_publisher]: Publishing
[INFO] [1758605807.452773261] [image_publisher]: Publishing
[INFO] [1758605807.550788115] [image_publisher]: Publishing
[INFO] [1758605807.652329952] [image_publisher]: Publishing
[INFO] [1758605807.751419371] [image_publisher]: Publishing

```

```

setup.bash; ros2 run image_noshmzero image_subscriber_...
[INFO] [1758605805.544920341] [image_subscriber]: End-to-end delay: 13.35 ms
[INFO] [1758605805.637124341] [image_subscriber]: End-to-end delay: 4.43 ms
[INFO] [1758605805.745612390] [image_subscriber]: End-to-end delay: 12.62 ms
[INFO] [1758605805.839255333] [image_subscriber]: End-to-end delay: 4.50 ms
[INFO] [1758605805.940429262] [image_subscriber]: End-to-end delay: 4.42 ms
[INFO] [1758605806.049758288] [image_subscriber]: End-to-end delay: 13.03 ms
[INFO] [1758605806.146524483] [image_subscriber]: End-to-end delay: 7.30 ms
[INFO] [1758605806.251827561] [image_subscriber]: End-to-end delay: 12.93 ms
[INFO] [1758605806.346664556] [image_subscriber]: End-to-end delay: 5.53 ms
[INFO] [1758605806.448620693] [image_subscriber]: End-to-end delay: 6.20 ms
[INFO] [1758605806.549310543] [image_subscriber]: End-to-end delay: 6.13 ms
[INFO] [1758605806.659176653] [image_subscriber]: End-to-end delay: 14.53 ms
[INFO] [1758605806.748426597] [image_subscriber]: End-to-end delay: 3.38 ms
[INFO] [1758605806.859763546] [image_subscriber]: End-to-end delay: 13.57 ms
[INFO] [1758605806.960323590] [image_subscriber]: End-to-end delay: 13.46 ms
[INFO] [1758605807.054050890] [image_subscriber]: End-to-end delay: 6.63 ms
[INFO] [1758605807.152264711] [image_subscriber]: End-to-end delay: 4.51 ms
[INFO] [1758605807.254285598] [image_subscriber]: End-to-end delay: 6.01 ms
[INFO] [1758605807.362723936] [image_subscriber]: End-to-end delay: 14.05 ms
[INFO] [1758605807.462981334] [image_subscriber]: End-to-end delay: 13.81 ms
[INFO] [1758605807.561395374] [image_subscriber]: End-to-end delay: 12.78 ms
[INFO] [1758605807.663404507] [image_subscriber]: End-to-end delay: 13.52 ms
[INFO] [1758605807.762350524] [image_subscriber]: End-to-end delay: 12.74 ms

```

```

fastdds_shm_zerocopy.xml RMW_FASTRTPS_USE_QOS_FR...
[INFO] [1758605805.588141835] [shm_image8m_talker]: Publishing
[INFO] [1758605805.688825749] [shm_image8m_talker]: Publishing
[INFO] [1758605805.789784833] [shm_image8m_talker]: Publishing
[INFO] [1758605805.890777668] [shm_image8m_talker]: Publishing
[INFO] [1758605805.992014672] [shm_image8m_talker]: Publishing
[INFO] [1758605806.093391002] [shm_image8m_talker]: Publishing
[INFO] [1758605806.194680882] [shm_image8m_talker]: Publishing
[INFO] [1758605806.295769922] [shm_image8m_talker]: Publishing
[INFO] [1758605806.396981935] [shm_image8m_talker]: Publishing
[INFO] [1758605806.498313516] [shm_image8m_talker]: Publishing
[INFO] [1758605806.599403425] [shm_image8m_talker]: Publishing
[INFO] [1758605806.700636586] [shm_image8m_talker]: Publishing
[INFO] [1758605806.801498036] [shm_image8m_talker]: Publishing
[INFO] [1758605806.902048081] [shm_image8m_talker]: Publishing
[INFO] [1758605807.002579927] [shm_image8m_talker]: Publishing
[INFO] [1758605807.103208192] [shm_image8m_talker]: Publishing
[INFO] [1758605807.203535646] [shm_image8m_talker]: Publishing
[INFO] [1758605807.303914633] [shm_image8m_talker]: Publishing
[INFO] [1758605807.404310974] [shm_image8m_talker]: Publishing
[INFO] [1758605807.504726882] [shm_image8m_talker]: Publishing
[INFO] [1758605807.605210997] [shm_image8m_talker]: Publishing
[INFO] [1758605807.705412501] [shm_image8m_talker]: Publishing
[INFO] [1758605807.805800198] [shm_image8m_talker]: Publishing

[INFO] [1758605806.702797794] [shm_image8m_listener]: End-to-end delay: 2.17 ms
[INFO] [1758605806.805139064] [shm_image8m_listener]: Received...
[INFO] [1758605806.805323814] [shm_image8m_listener]: End-to-end delay: 3.84 ms
[INFO] [1758605806.904156910] [shm_image8m_listener]: Received...
[INFO] [1758605806.904242041] [shm_image8m_listener]: End-to-end delay: 2.20 ms
[INFO] [1758605807.005894715] [shm_image8m_listener]: Received...
[INFO] [1758605807.006025070] [shm_image8m_listener]: End-to-end delay: 3.45 ms
[INFO] [1758605807.106915964] [shm_image8m_listener]: Received...
[INFO] [1758605807.107135939] [shm_image8m_listener]: End-to-end delay: 3.94 ms
[INFO] [1758605807.207512361] [shm_image8m_listener]: Received...
[INFO] [1758605807.207735806] [shm_image8m_listener]: End-to-end delay: 4.27 ms
[INFO] [1758605807.307813284] [shm_image8m_listener]: Received...
[INFO] [1758605807.307809751] [shm_image8m_listener]: End-to-end delay: 3.90 ms
[INFO] [1758605807.408097443] [shm_image8m_listener]: Received...
[INFO] [1758605807.408346893] [shm_image8m_listener]: End-to-end delay: 4.04 ms
[INFO] [1758605807.507960908] [shm_image8m_listener]: Received...
[INFO] [1758605807.508048655] [shm_image8m_listener]: End-to-end delay: 3.33 ms
[INFO] [1758605807.609482430] [shm_image8m_listener]: Received...
[INFO] [1758605807.609673217] [shm_image8m_listener]: End-to-end delay: 4.47 ms
[INFO] [1758605807.707593535] [shm_image8m_listener]: Received...
[INFO] [1758605807.707684741] [shm_image8m_listener]: End-to-end delay: 2.28 ms
[INFO] [1758605807.808246357] [shm_image8m_listener]: Received...
[INFO] [1758605807.808357732] [shm_image8m_listener]: End-to-end delay: 2.56 ms

```

测试传输的是一张1920_1080.jpg的图片，下图部分是开启共享内存加零拷贝传输延迟情况，一张图片传输延迟大约在2~4ms左右，资源占用情况：

- 1 | image8m_talker(cpu: 5.7%, mem: 0.4%)
- 2 |
- 3 | image8m_talker(cpu: 3.7%, mem: 0.9%)

```
fastdds_shm_zerocopy.xml RMW_FASTRTPS_USE_QOS_FR...
[INFO] [1758605805.588141835] [shm_image8m_talker]: Publishing
[INFO] [1758605805.688825749] [shm_image8m_talker]: Publishing
[INFO] [1758605805.789784833] [shm_image8m_talker]: Publishing
[INFO] [1758605805.890777668] [shm_image8m_talker]: Publishing
[INFO] [1758605805.992014672] [shm_image8m_talker]: Publishing
[INFO] [1758605806.093391002] [shm_image8m_talker]: Publishing
[INFO] [1758605806.194680882] [shm_image8m_talker]: Publishing
[INFO] [1758605806.295769922] [shm_image8m_talker]: Publishing
[INFO] [1758605806.396981935] [shm_image8m_talker]: Publishing
[INFO] [1758605806.498313516] [shm_image8m_talker]: Publishing
[INFO] [1758605806.599403425] [shm_image8m_talker]: Publishing
[INFO] [1758605806.700636586] [shm_image8m_talker]: Publishing
[INFO] [1758605806.801498036] [shm_image8m_talker]: Publishing
[INFO] [1758605806.902048081] [shm_image8m_talker]: Publishing
[INFO] [1758605807.002579927] [shm_image8m_talker]: Publishing
[INFO] [1758605807.103208192] [shm_image8m_talker]: Publishing
[INFO] [1758605807.203535646] [shm_image8m_talker]: Publishing
[INFO] [1758605807.303914633] [shm_image8m_talker]: Publishing
[INFO] [1758605807.404310974] [shm_image8m_talker]: Publishing
[INFO] [1758605807.504726882] [shm_image8m_talker]: Publishing
[INFO] [1758605807.605210997] [shm_image8m_talker]: Publishing
[INFO] [1758605807.705412501] [shm_image8m_talker]: Publishing
[INFO] [1758605807.805800198] [shm_image8m_talker]: Publishing

[INFO] [1758605806.702797794] [shm_image8m_listener]: End-to-end delay: 2.17 ms
[INFO] [1758605806.805138064] [shm_image8m_listener]: Received...
[INFO] [1758605806.805323814] [shm_image8m_listener]: End-to-end delay: 3.84 ms
[INFO] [1758605806.904156910] [shm_image8m_listener]: Received...
[INFO] [1758605806.904242041] [shm_image8m_listener]: End-to-end delay: 2.20 ms
[INFO] [1758605807.005894715] [shm_image8m_listener]: Received...
[INFO] [1758605807.006025070] [shm_image8m_listener]: End-to-end delay: 3.45 ms
[INFO] [1758605807.106915964] [shm_image8m_listener]: Received...
[INFO] [1758605807.107135599] [shm_image8m_listener]: End-to-end delay: 3.94 ms
[INFO] [1758605807.207512361] [shm_image8m_listener]: Received...
[INFO] [1758605807.207795806] [shm_image8m_listener]: End-to-end delay: 4.27 ms
[INFO] [1758605807.307613284] [shm_image8m_listener]: Received...
[INFO] [1758605807.307809751] [shm_image8m_listener]: End-to-end delay: 3.90 ms
[INFO] [1758605807.408097443] [shm_image8m_listener]: Received...
[INFO] [1758605807.408346893] [shm_image8m_listener]: End-to-end delay: 4.04 ms
[INFO] [1758605807.507960908] [shm_image8m_listener]: Received...
[INFO] [1758605807.508048655] [shm_image8m_listener]: End-to-end delay: 3.33 ms
[INFO] [1758605807.609483430] [shm_image8m_listener]: Received...
[INFO] [1758605807.609673217] [shm_image8m_listener]: End-to-end delay: 4.47 ms
[INFO] [1758605807.707593535] [shm_image8m_listener]: Received...
[INFO] [1758605807.707684741] [shm_image8m_listener]: End-to-end delay: 2.28 ms
[INFO] [1758605807.808246357] [shm_image8m_listener]: Received...
[INFO] [1758605807.808357732] [shm_image8m_listener]: End-to-end delay: 2.56 ms
```

5. 关键知识点

关键知识点1：共享内存通信机制

ROS2支持通过共享内存进行进程间通信，相比传统的网络传输方式，共享内存可以避免数据在不同进程间的复制操作，从而显著降低通信延迟和CPU使用率。FastDDS作为ROS2的默认中间件，提供了共享内存传输的支持。当多个节点运行在同一台机器上时，ROS2会自动尝试使用共享内存作为传输通道，这需要通过环境变量配置启用。

关键知识点2：零拷贝数据传输

零拷贝技术是指数据在发送端和接收端之间传输时不需要进行内存拷贝操作，直接通过共享内存区域访问数据。这种方式可以显著提高大数据量传输的效率，特别是在传输图像、点云等大型数据时效果明显。在本实验中，通过启用共享内存和零拷贝机制，图像数据可以直接在发布者和订阅者之间共享，避免了传统TCP/IP协议栈中的多次数据复制。

关键知识点3：ROS2环境配置

通过设置环境变量 `ROS_LOCALHOST_ONLY=0` 可以控制ROS2的通信方式，当设置为0时允许使用共享内存传输，而默认的网络传输方式会消耗更多CPU资源并产生更高的延迟。此外，还需要确保ROS2的DDS实现（如FastDDS）正确配置以支持共享内存传输。这些配置对于优化ROS2系统性能至关重要。

6.参考资料

1. [ROS2官方文档](#)
2. [FastDDS官方文档](#)
3. [ROS2通信机制详解](#)
4. [FastDDS共享内存传输配置](#)
5. [RflySim工具链使用手册](#)

7.常见问题

Q1：运行程序时报错找不到相关节点或服务未启动

A1：请确认是否正确启动了WSL环境，并且ROS2环境配置正确。可以尝试执行 `wsl.exe --shutdown` 命令后重新启动WSL环境，并确保在执行 `./run.sh` 前已经正确设置了环境变量。

Q2: 共享内存模式下性能提升不明显或出现异常

A2: 请检查是否正确设置了环境变量`ROS_LOCALHOST_ONLY=0`, 并且确保FastDDS配置文件(`fastdds_shm_zerocopy.xml`)已正确配置并被加载。可以使用 `source ~/.bashrc` 命令重新加载环境变量。

Q3: 编译过程中出现依赖库缺失或编译错误

A3: 请确认系统已安装完整的ROS2环境和相关依赖库。可以尝试在Ubuntu环境中执行 `sudo apt update` 和 `sudo apt install ros-humble-desktop` 来安装或修复ROS2环境。

-
1. <https://rflysim.com/> ↩
 2. 推荐配置请见: <https://rflysim.com/doc/zh/HowToInstall.pdf> ↩