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<td>GEV</td>
<td>GigE Vision</td>
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<td>NIC</td>
<td>Network Interface Card</td>
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<td>PCI</td>
<td>Peripheral Component Interconnect</td>
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<td>PCI-E</td>
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<td>SDK</td>
<td>Software Development Kit</td>
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<td>UDP</td>
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1. Overview

The FRAMOS Industrial Depth Camera D400e Series - Tuning System For Best Performance application note provides tips and recommendations on setting system and camera settings to achieve best performance from FRAMOS D400e camera series.
2. System Settings

2.1 General Recommendations

There are number of system related parameters and conditions that could negatively affect the system performance and consequently limit the maximum achievable performance of the FRAMOS Industrial Depth camera D400e series used in such system. Perhaps the most important factor to consider is selection and configuration of the Network Interface Card (NIC). It is recommended to use a Gigabit Ethernet NIC with PCI-E interface supporting Jumbo Frames feature.

**Information:** For best performance FRAMOS recommends Intel® PCI-E network interface cards.

2.2 Network Related Settings

The following network related settings should be adjusted to achieve optimal performance with FRAMOS Industrial RealSense D400e camera series:

- **Jumbo Frames** - Using Jumbo Frames reduces the packet overhead and workload on the target PC. This is achieved by transmitting smaller number of large packets instead of large number of small packets.
- **Receive Buffers** - The Receive Buffers feature of the NIC represents a reserved memory in the system memory, which is used to buffer incoming data. It is recommended to increase buffer size for the incoming packets (Receive Buffers) to the maximum supported value in order to decrease probability of packet loss in conditions of high system load.

The availability of the features and their limits can differ between NICs vendors and operating systems. The descriptions of driver settings in following chapters are based on Intel® NICs. The settings are shown for Microsoft Windows and Linux operating systems.

2.2.1 Network Interface Optimization for Windows Operating System

Driver settings are configured through the driver properties dialog. On the Microsoft Windows operating systems this can be accessed the following way:

- Open Control Panel -> Network Connections window (can be invoked directly by executing command "ncpa.cpl" from Windows Run application or from command prompt).
- Right-click the target network interface card and choose Properties.
- Press the Configure button bellow the name of the physical network interface, as shown in Figure 1.
The settings of the driver can be accessed by choosing the Advanced Tab of the pop-up window.

2.2.1.1 Jumbo Frames/Packets - Network Interface Cards

The Jumbo Frames (or Jumbo Packet) feature is disabled by default on most NICs, so it needs to be manually enabled within the device driver property window as shown on Figure 3. To enable Jumbo Frames, set the property to its maximum value.
Figure 3 – NIC - Enabling Jumbo Packet on Windows

**Information:** In network configurations where camera is not connected directly to NIC but via other network components (i.e., gigabit switches), it is required to enable Jumbo Frames on all the components used in the network path.

### 2.2.1.2 Receive Buffers - Network Interface Cards

Receive Buffers property can be accessed via driver property window as shown on Figure 4. It is recommended to raise the value of the Receive Buffers property to its maximum value.
2.2.2 Network Interface Optimization for Linux Operating System

2.2.2.1 Jumbo Frames - Network Interface Cards

On the Linux operating system Jumbo Frames can be enabled temporarily or it can be done at boot time by modifying appropriate configuration files.

Enabling Jumbo Frames temporarily can be done using "ip" tool:

```
sudo ip link set <ethx> mtu <size>
```

where `<ethx>` represents the name of network interface that connects PC to FRAMOS D400e camera series, and `<size>` the desired frame/packet size in bytes (i.e., 9000). Alternative approach could be using the "ifconfig" command:

```
sudo ifconfig <ethx> mtu <size>
```

This setting will last until the system is rebooted.

**Information:** "Ip" tool may not be available on all platforms. Refer to the documentation of used Linux distribution for more details.

**Information:** Refer to documentation of used Linux distribution for information on how to enable Jumbo Frames permanently.

2.2.2.2 Receive Buffers - Network Interface Cards

To increase Receive Buffers size on the Linux operating system "ethtool" provided by many Linux distributions can be used to configure the property, as per the following command:

```
sudo ethtool -G <ethx> rx <size>
```

where `<ethx>` represents the name of network interface that is being configured, and `<size>` the desired number of Receive Buffers (i.e., 2048). If "ethtool" tool is not provided by used distribution, please refer to distribution documentation for alternatives.
2.3 Application Environment Considerations

For best performance it is recommended to run applications using FRAMOS Industrial Depth camera D400e series on a dedicated system with freshly installed operating system. Having lots of concurrent processes and background services might have negative effect on software application performance. Additionally, it was observed that some applications have negative impact on network subsystem performance and overall system latency resulting in excessive packet loss and unstable streaming performance. Therefore, it is recommended to work on a freshly installed system to reduce the possibility of unwanted performance degradation.

In addition, anti-virus software, firewalls, third-party filter drivers and network traffic monitoring software can affect the performance of the system as they monitor the incoming packets at different network stack layers. It is recommended to disable or uninstall such software if performance degradation is observed.
3. Camera Settings

3.1 Inter Packet Delay

The **Inter Packet Delay** (GevSCPD GenICam feature) is the delay introduced by the camera between sending two consecutive packets on the stream channel. This delay reduces the effective network load (on NIC or switch) and creates timeslots for processing packets from other devices on the network. The **Inter Packet Delay** is very useful when multiple cameras are streaming to one PC on the same Network Interface Card (NIC).

![Figure 5](image)

**Figure 5** – Packet flow when inter packet delay is not used

If **Inter Packet Delay** feature is not used, excessive packet collisions may occur which can result in data loss, like illustrated in Figure 5. Packets from two cameras are sent to PC over the same network connection. Without any **Inter Packet Delay** set, collision between packets from different cameras may occur in case both cameras stream packets at the same time. **Figure 6** illustrates a well configured **Inter Packet Delay** to prevent collisions.

![Figure 6](image)

**Figure 6** – Packet flow with properly configured inter packet delay

Assuming that the **Packet Size** (GevSCPSPacketSize GenICam feature) is 1500 bytes, effective Ethernet packet size including inter-frame gap, preamble, header and CRC on the wire is 1538 bytes. It takes 8ns to transfer one byte over Gigabit Ethernet network, so time required to transfer one packet of 1538 bytes is 12,3μs. In other words, camera is able to send maximum of 81274 packets via the Ethernet interface every second. In case two cameras are streaming to one NIC,
the Inter Packet Delay should be a bit larger than the time required to transfer one packet, in order to ensure that packets from second camera will fit in the vacant time slot.

Increasing Inter Packet Delay extends frame transfer time which means higher latency but can also result in lower framerate. For example, if one camera is producing 30000 packets per second (50 frames per second, 600 packets per frame), total packet transfer time (packet + inter packet delay) must not exceed 33.3us to preserve frame rate.

In the more complex system, including multiple cameras with multiple streams, determining Inter Packet Delay is not so intuitive anymore. It is advised to iteratively increase Inter Packet Delay until stable stream is achieved. On the other side, Inter Packet Delay must not be set too high due the increased latency and possible lower framerate. With the empirical approach, Inter Packet Delay should be determined quickly.

3.1.1 Example for Adjusting Inter Packet Delay

One camera is configured with following stream profile: 1280x720, @30FPS for both Stereo Module and RGB Camera. Wireshark is used for network protocol analysis. Results may variate with different NICs and its configurations.

Case 1:
Stereo Module Inter Packet Delay: 0.
Stereo Module Packet Size: 7996.
RGB Camera Inter Packet Delay: 0.
RGB Camera Packet Size: 7996.

As consequence of inadequate Inter Packet Delay there are no streams as shown below.
In addition, there is an excessive number of Packet Resend requests issued from PC to camera as shown on Figure 8. Packet Resend is the mechanism used to recover the missing packets in case of packet loss.

Figure 7 – Inter Packet Delay set to 0 - no frames received

Figure 8 – Wireshark log for Packet Resend requests, Case 1
Case 2:
Stereo Module Inter Packet Delay: 25.
Stereo Module Packet Size: 7996.
RGB Camera Inter Packet Delay: 25.
RGB Camera Packet Size: 7996.

With increased Inter Packet Delay value for both Stereo and RGB modules, streams are active, but framerate drop is noticeable due the insufficient Inter Packet Delay value.

Figure 9 – Inter Packet Delay too small - frames received, frame rate drops

For Case 2, there are a smaller number of Packet Resend requests comparing to the Case 1, as shown on Figure 10.
Case 3:
Stereo Module Inter Packet Delay: 65.
Stereo Module Packet Size: 7996.
RGB Camera Inter Packet Delay: 65.
RGB Camera Packet Size: 7996.

With further increased Inter Packet Delay value for both Stereo and RGB modules, streams are stable at 30FPS.
Chapter 3: Camera Settings

Analyzing the network traffic with Wireshark for Case 3 shows that the number of Packet Resend requests dropped to minimum as shown on Figure 12.

Figure 11 – Inter Packet Delay optimal - frames received, frame rate stable

Figure 12 – Wireshark log for Packet Resend requests, Case 3
Information: Regardless of the Inter Packet Delay value set, Packet Resend requests can be observed occasionally as a reaction to packet loss, which is typically a result of high system or network load.

3.1.2 Example for Three Cameras Streaming to One NIC

Three cameras are streaming packets of size 1500 bytes to one NIC simultaneously. Inter Packet Delay should be set such that packets from all three cameras are serialized to the PC’s Network Interface Card. Setting inter packet delay to 25us (12,3us + 12,3us ~= 25us) on each camera will ensure that packets from other two cameras will fit in the gap between two consecutive packets.

![Packet flow example with three cameras and properly configured inter packet delay](image)

3.2 Setting Inter Packet Delay

Option “RS2_OPTION_INTER_PACKET_DELAY” is used for setting camera Inter Packet Delay. Example of configuring Inter Packet Delay through Intel RealSense Viewer is shown on Figure 14.

In relation with Jumbo Frames/Packets, FRAMOS D400e camera series Packet Size can be adjusted using RealSense Viewer as well.
To set **Inter Packet Delay** in code, call "set_option" function with option name and requested value as shown below.

```c
// To set an option to a different value, call set_option with a new value
sensor.set_option(RS2_OPTION_INTER_PACKET_DELAY, inter_packet_delay);
```

Configuring **Packet Size** can be done in the same way using the following code.

```c
// To set an option to a different value, call set_option with a new value
sensor.set_option(RS2_OPTION_PACKET_SIZE, packet_size);
```

### 3.3 Tuning Inter Packet Delay with Packet Statistic Feature

Tuning the Inter Packet Delay is an adjusting process aiming to reduce the amount of Packet Resend requests while preserving the configured frame rate.

As mentioned in the Chapter “Example for adjusting Inter Packet Delay” Wireshark logging can be used to measure the amount of the packet resend requests.

Another approach is to use the Packet Statistic feature. By enabling the RealSense logging (DEBUG severity), packet statistic is logged every 10 seconds in the RealSense log file or terminal.
To enable logging in code, use the code snippet as shown below.

```cpp
//C++
int main(int argc, char * argv[]) try
{
    rs2::log_to_file(RS2_LOG_SEVERITY_DEBUG, "//path/to/file.txt");
    ...
}
```

```python
rs.log_to_file(rs.log_severity.debug, file_path='//path/to/file.txt'):
```

Example of a logged packet statistic is given below (screenshot from the log file).

```
27/09 15:00:24,728 DEBUG [20300] (cs-sensor.cpp:2112) GEV filter driver api packet statistics:
PacketResendsAmount: 103
LostPackets: 168
LostImages: 2
IgnoredPackets: 30
IncompleteImages: 6
AllPackets: 652193
LeaderPackets: 5614
PayloadPackets: 639786
TrailerPackets: 6210
FrameTimeExceeded: 0
ResendTimeExceeded: 0
ResendRetriesExceeded: 2
```

Tune the Inter Packet Delay while monitoring the PacketResendsAmount. This can be done during the stream.

---

**Information:** Packet Statistic feature is available from the D400e software package v2.2.0 (or higher).

---

### 3.4 GigE Vision Drivers

D400e software package comes with two different GigE Vision (GEV) drivers:

- FRAMOS GigE Vision filter driver – high-performance network filter driver
- GigE Vision socket driver – a driver that uses system socket API

The GigE Vision socket driver is part of the CameraSuite library while the FRAMOS GigE Vision filter driver is standalone installation package. During the installation of a Camera Suite library, user will be prompted to install the FRAMOS GigE Vision filter driver as shown in Figure 15 and Figure 16.
Information: Only one driver can be used on a system. FRAMOS recommends the usage of a filter driver which is designed to ensure optimal performance.

Information: Tuning of system settings should be applied regardless of which version of the driver is used.

Information: Socket driver is available from the D400e software package v2.4.0 (or higher).
3.4.1 Checking the Driver Used

The filter driver has precedence over the socket driver. The CameraSuite library will check if the filter driver is present on the system and will try to load it. If the filter driver is not installed or fails to load, socket driver will be used. This information is available through a RealSense log mechanism. The RealSense log mechanism will indicate this information on start of an image stream. An example of a log from RealSense Viewer is depicted in Figure 17.

![RealSense Viewer using socket driver](image-url)
Chapter 4: Revision History

### 4. Revision History

<table>
<thead>
<tr>
<th>Date</th>
<th>Version</th>
<th>Changes</th>
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<tr>
<td>2020-06-30</td>
<td>1.0.0</td>
<td>Initial release</td>
</tr>
<tr>
<td>2021-07-15</td>
<td>1.1.0</td>
<td>Added chapter “Tuning Inter Packet Delay with Packet Statistic Feature”</td>
</tr>
<tr>
<td>2021-10-15</td>
<td>1.2.0</td>
<td>Updated chapter “Tuning Inter Packet Delay with Packet Statistic Feature”; added Chapter “GigE Vision Drivers”</td>
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**Table 1 – Revision History**

NOTE: This document replaces and supersedes the application note “FRAMOS Industrial Depth Camera D435e - Tuning System for Best Performance” v1.0.0.