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10GigE Technology Guide

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Abstract

The demand for cameras offering high resolution and high speed has continued to increase at a rapid pace. This has resulted in data transmission loads far exceeding the capacity of standard Gigabit Ethernet environments. While several dedicated high capacity options have emerged, many vision system designers and users want to maintain the networking flexibility, long cable lengths, and other Ethernet features to which they have grown accustomed, while still supporting the much higher bandwidth requirements of these high-speed, high-resolution cameras. 10GigE has been designed to do just that. This document provides the answer to some of the key questions vision system designers and users have about 10GigE's ability to support their high performance system requirements.

1 Do I need a whole new network to run a 10GigE camera? Can I mix a 10GigE camera with some standard GigE cameras or equipment on the same network?

A 10GigE camera is 10 times faster than a standard 1 GigE camera. This means that the network must have the capacity to handle and transmit 10 times higher data. For running a 10GigE camera to its full potential, a network supporting 10 Gb/s is required. However, in case an existing network is to be used, it must be well understood that the maximum transmission bandwidth in Ethernet networks is limited by the slowest network component such as router, network switch, cables, network adapter or the camera). Auto-negotiation (defined in IEEE 802.3 standard) allows a 10GigE camera to run in a 1 GigE network (1000BASE-T). This backwards compatibility is a big advantage for 10GigE cameras working on Ethernet over twisted copper pair cables (10GBASE-T). It allows two connected devices (in this case the 10GigE camera and the 1 GigE network adapter to choose common transmission parameters such as speed). 10GigE has been described in the GigE Vision 2.0 standard. Cameras and other machine vision devices that are compliant to GigE Vision 1.0 standard can work on a 10GigE network. 10GBASE-T cameras can not only run on 1 Gb/s network but also on 2.5 and 5 Gb/s networks which are based on the 2.5GBASE-T and 5GBASE-T standards better known as NBASE-T.

2 What cable lengths are achievable with 10GigE and which Ethernet cable standards are relevant?

Standard twisted pair copper cables of Cat6, Cat6e, Cat6A and Cat7 support 10GigE connections. Cat6 and Cat6e can support a cable length up to 55m whereas Cat6A and Cat7 can support cable lengths up to 100m. The main difference between the cable standards is the transmission frequency and the cable architecture. Cat7 supports a much higher transmission frequency than the Cat6 standard.

3 What pixel formats can a 10GigE Vision camera support? Can it handle the same range of pixel formats and bit depths available with a traditional Camera Link, USB or 1GigE camera?

A 10GigE Vision camera can support all the pixel formats that GigE Vision supports. These formats are defined in the GenICam Pixel Format Naming Convention (PFNC). The pixel formats include supporting monochrome, color RGB and 4-channel RGB + alpha video streams (defined as RGB8a). The GigE Vision standard can handle the same range of pixel formats and bit depths as a traditional Camera Link and USB camera. In addition, GigE Vision standard also supports multi-video streaming which allows the streaming of two and more parallel video streams using the same interface. The challenge for multi-video streaming is currently on the software side regarding how to accept and arrange two or more parallel streams in the right order. Many software suppliers are today working to support multi-video streaming which will become an important image acquisition function in the near future.

4 What is the future of 10GigE Vision?

10GigE Ethernet has been a basic data transmission standard for data centers and IT infrastructure for several years. Since the advent of 10GigE in 2010, the Ethernet standard has continuously evolved. The key growth catalysts have been the ever-increasing requirement for high speed and high data transmission capacities (amount of data transferred per second). The evolution of Ethernet has also been due to the key drivers within the IT business such as Google, Cisco, Intel, IBM and many others. Today 40 GigE Ethernet is the state of art in data centers moving onto 100 Gb/s and beyond to several Tbit/s. With established standards from the IT industry, machine vision has been fast catching up on its high speed, high data rate requirements. Today, not only are

several 10Gb/s cameras on the market but there have also been dual 10Gb/s and 25Gb/s cameras introduced. The key drivers for increasing the number of GigE Vision compatible products on the market are achieving compatibility with standard IT architecture, frame-grabberless camera operation, continuous improvement on latency, reduced complexity of cable handling and system costs.

5 Is a 10GigE network reliable?

About 90% of the data servers today use a 10GigE network. It is used for data transmission for critical tasks such as virtualization, video streaming, communication, data storage and also as connectivity to backup and backbone data architectures. It is a widely accepted standard which has been adopted by the machine vision industry. The reliability of a 10GigE network, or for that matter a GigE network in general, is questioned due to issues such as loosing packets or dropping frames while the camera is in operation. This happens typically due to some hardware caches/buffers on a network switch or network cards becoming temporarily overfilled due to the sudden burst of incoming network packets. In order to achieve a reliable network to run the 10GigE camera, the settings on the CPU, memory bandwidth, PCIe slot configuration and the network card must be optimized and well synchronized.

6 How does 10GigE perform in terms of speed and latency?

As the name goes, 10GigE is 10 times faster than 1GigE with usable bandwidth of 9.5 Gbps. Latency is a more complex discussion. Imaging system designers rely on latency performance data to help determine how quickly a system can process, analyze and in some applications display images. Low latency enables higher-speed quality inspection and is critical for several real-time applications. Latency in a 10GigE vision system is generated due to the network, not the camera itself. Hence in order to improve latency in a 10GigE vision system, the network must be optimized. Host computer and resource sharing (between buses, memories, CPU´s, operating system, core imaging and graphic libraries) have the great impact on latency. Processes and devices which place a high processing overhead on the CPU can drastically increase the latency.

7 Does 10GigE support the PTP protocol?

Precision Time Protocol is an integral part of the GigE Vision standard including 10GigE Vision. This is defined in the IEEE 1588 standard. With the ever-increasing use of multiple camera systems in machine vision

applications, precise synchronization of various vision and non-vision components in an application plays an important role to minimize jitter and other non-sync effects.

8 Are frame grabbers required for using 10GigE?

One of the benefits of 10GigE is eliminating the need for frame grabbers. 10GigE Vision can work well with standard network adapter cards which are easily available from many vendors. In the early days of using 10GigE in machine vision, there were discussions on whether network cards would be able to manage the CPU usage effectively and whether or not frame grabbers would prove to be a better choice. After testing several different network cards at JAI, it was found that connecting a camera with a 10GigE interface resulted in a CPU load of somewhere between 7 – 14% on an Intel Xeon E5-1620 v4 3.5Ghz with a memory of 16Gb and a Windows 7 64-bit OS. This load was observed when the cameras were running at full resolution, max. line rate. From the perspective of PC architecture, this load can be easily managed. This has also been the reason as to why the frame grabber manufacturers have hesitated to bring out boards supporting 10GigE Vision. It would be quite challenging for 10GigE frame grabbers to compete on price and performance against network cards unless for niche applications which may require on-board image processing, deep learning or complex triggering options.

9 Is using 10GigE Vision cost efficient?

Apart from the optical components in a machine vision system, there are several other parts that add to system costs. These are cables, frame grabbers and data processing. 10GigE vision requires simple Cat6 or Cat7 cabling which is not expensive. These cables are easily available at standard IT hardware stores. Frame grabbers are not a pre-requisite for using 10GigE Vision. Standard network adapter cards support 10GigE, are inexpensive and available at many vendors. The cables and network cards alone cut down the system costs to a great extent. In addition, runtime costs are low as these components are easy to replace and are low maintenance, hence supporting to reduce the inventory. There is no risk of component obsolescence due to very high usage in state-of the-art IT infrastructure. Hence long-term projects can be planned well.

10 How can I achieve cable lengths longer than 100 m but using the 10GigE vision protocol?

It is true that a 10GigE twisted pair copper cable (10GBASE-T), can support cable lengths up to 100 m regardless of using a Cat6A or a Cat7

cable. Longer cable lengths up to 10 km are supported using a 10GigE based SFP+ (small form-factor pluggable enhanced) transmission. In this case, the 10GigE protocol is used but the physical data transmission layer is an optical fiber. An SFP+ module can be inserted in the camera's SFP+ cage which can connect to PC architectures using cables and a module at the PC side. JAI supports 10GBASE-SR, 10GBASE-LR and 10GBASE-CR standards which basically support SFP+. 10GBASE-SX and 10GBASE-LX standards which are SFP standards are not supported.

11 Apart from the cable length, what are the differences between twisted pair copper and optical cables for data transmission?

Fiber optic cables are excellent mediums of data transmission in electrostatic environments. Such environments do not induce the cables with data transmission noise. Many applications involve electrostatic environments which cannot use twisted pair copper cables. Hence, fiber optic networks are an advantage for long transmission distances involving high data rates. It is important to note that fiber optic cables can be more fragile than twisted pair copper and therefore need to be handled with care. Aside from this, the main difference in 10GigE twisted pair copper and 10GigE-based SFP+ transmission, is that SFP+ transmission does not support backwards compatibility to 1 GigE and NBASE-T while twisted pair copper transmission does.

About the author

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Paritosh is a part of JAI product management team since April 2017. He studied print and media technology at Chemnitz University of Technology in Germany and specialized in multi-spectral camera systems for high speed applications. Having worked in previous positions within R&D for paper technology, camera development, application management for 3D & spectral cameras and sales he brings a broad perspective to the table.

About JAI

JAI provides innovative digital CCD/CMOS camera technology for applications in industrial machine vision, medical imaging and high-end surveillance systems, as well as complete solutions for traffic imaging/vehicle recognition in Intelligent Traffic Systems (ITS). The company has a global presence through companies in Denmark, Germany, Japan, China and USA, and via distribution partners in more than 35 countries.

JAI's vision systems help improve customer businesses in numerous ways, whether by improving quality and accuracy of products, lowering production line inspection costs, increasing production yields or creating higher efficiency in road traffic. Common to our customers around the globe is that they value the trademark characteristics of our products: proven technology, high reliability, consistent quality and superior image fidelity backed by JAI's long-term viability.

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