



White Paper

10 GigE: High-speed for your machine vision task.

Application benefits and requirements on system architecture

Within GigE Vision® compliant interface, 10 GigE cameras are easy to integrate and with 1.1 GB/s bandwidth, they're ideal for high-resolution, high-throughput applications. This allows the cameras to meet the ever-increasing application requirements of present-day image processing. The White Paper explains the 10 GigE Vision® standards benefits and gives recommendations for system architecture.

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1 Introduction

Image processing systems have become an integral part in machine control or quality assurance. At the same time, they must confront ever more demanding requirements – primarily driven by new sensor features and host systems with high processing power. Where previously VGA resolutions (640 × 480 px) were good enough, present-day applications call at least for HD resolutions (1920 × 1080 px). Even sensors with up to 50 megapixels have become standard. The demand for higher resolution goes together with the need for increased machine speed in 100 % final inspections. This requires the camera to deliver higher frame rates. Both high resolution and high speed have a direct effect on the bandwidth between camera and host system. In such applications, the performance of the entire image processing system is limited by the capacity of GigE Vision®. 10 GigE with 1.1 GB/s bandwidth is the ideal solution to keep up with increasing requirements and to maintain access to the knowledge and experience made with the established and widely used GigE interface.

2 10 GigE Vision®

10 GigE Vision® standard allows for use of high-resolution sensors and very high frame rates in mainstream industrial image processing. By increasing the bandwidth by the factor of 10 to 1.1 GB/s, the established and common GigE Vision® standard remains a support for the next generation of applications.

2.1 Cables

Standards copper cables (Cat 6, Cat 6a and Cat 7) used in 10 Gigabit connections support up to 100 m length. Cat 6 cables can be used for up to 55 m length, more calls for Cat 6a or Cat 7 cables. Fiber-optic cables enable considerably longer distances and ensure reliable data transmission even in interference-critical environments thanks to their immunity against electrical and electromagnetic fields. 10 Gigabit Ethernet supports Power-over-Ethernet (PoE+) and cuts down on costs for camera connection. In parallel, it reduces possible system errors thanks to the reduced number of cables used in the camera connection.

2.2 Alternative interface standards

Standards like Camera Link® or CoaXPress used to be the conventional approach in applications with very high demands on bandwidth. However, the need for frame grabbers and pre-assembled cables turns them into complex and cost-intensive solutions in terms of purchasing and system integration. This is the reason they are not recommended in mainstream applications. Latest developments such as «computing-at-the-edge» operating on small ARM®-based boards can only be covered insufficiently due to the necessary use of frame grabbers.

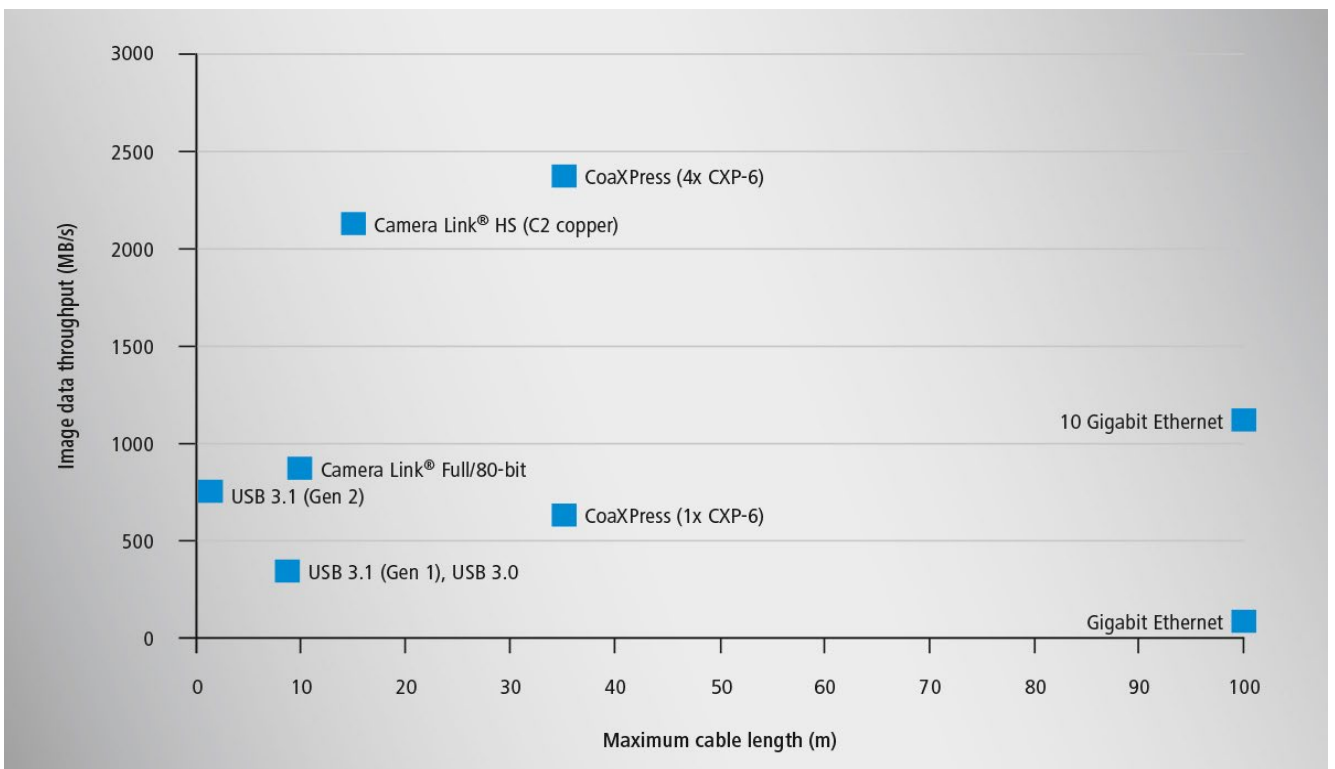


Fig. 1: Overview on different interfaces with image data throughput versus maximum cable length

2.3 Compatibility and reliability

10 Gigabit Ethernet having been established in large data centers for many years means mature technology. Many providers offer high-quality and tested network components such as switches and adapter cards. Such common products can be directly implemented in the environment of industrial image processing, without the typical drawbacks of early adopters. 10 GigE was already described in GigE Vision® 2.0 standard in 2011. The changes of version 1 can be neglected, so that cameras compliant to GigE Vision® 1.0 standard operate on 10 Gigabit Ethernet without problems. There is no need to change the application software for camera integration, since it is completely independent from the physical Ethernet interface. Image processing applications must ensure very reliable and stable operation. Every individual image must be received by the host in 24/7 operation in order to perform the required inspection task. To ensure this, 10 GigE uses the Packet Resend feature known from the GigE Vision® standard, which means optional repeated sending of lost packets (Forward Error Correction).

2.4 Speed and latency

The main benefit of using 10 GigE is certainly higher transmission speed. 1.1 GB/s interface is 10 times faster than GigE Vision® and by 35 % faster than Camera Link® Full. In addition to high bandwidth, the latency, i.e. the delay between request from host and arrival of response, has been significantly improved. While latencies between 50 µs and 125 µs used to be standard in GigE systems, 10 GigE provides latencies ranging from 5 µs to 50 µs.

2.5 IEE1588 PTP

Precise time synchronization is essential in multi-camera systems and of ever-increasing importance in view of spreading Industry 4.0 and the Internet of Things (IoT). For this reason, the Precision Time Protocol (IEE1588 PTP) is an integral part of Ethernet standard and thus also 10 GigE Vision®. PTP synchronizes various system components within few hundred nanoseconds and minimizes jitter.

2.6 Multicast

Being a network standard, GigE provides some features which are of particular interest at high frame rates. Using Multicast, the Ethernet client can send data packets to several receivers. This is an easy way to assign processing power to several host systems (i.e. one system to detect image features and another for image archiving or monitoring).

2.7 Costs

Right from the start, 10 Gigabit Ethernet without the need for frame grabbers was intended as low-cost standard. High-performance standard network adapters with up to 4 ports are cheap

and available at many vendors. Common copper cables are not expensive either and can be easily assembled on site. Individual cable assembly at the customer's cuts down on system costs and at the same time significantly reduces inventory compared to other interfaces. Additionally, in the event of error, cables can be immediately and easily exchanged right on the spot. Another benefit in terms of cost is GenlCam™ compatibility. Widely used in the image processing industry, many individual application requirements of specific scenarios are conveniently met by configuration. In addition, many years of experience allow for reliable estimates in customer-specific software projects and minimize implementation risks.

2.8 Reverse and future compatibility

Typically, the maximum transmission bandwidth in Ethernet networks is limited by the slowest network component (e.g. network adapter, switch, router, camera). The same applies to 10 GigE Vision® for reasons of reverse compatibility. To invest in new technologies means to invest in the future. 10 Gigabit Ethernet is the next Ethernet upgrade and already existing knowledge must remain accessible to support the versions to come. 10 Gigabit Ethernet came into being in 2010, and ever since the Ethernet standard has considerably evolved. Today, 40 Gigabit Ethernet networks are already operated by data centers throughout the world, and the development of 100 Gigabit Ethernet is constantly pushed forward. Induced by Internet giants such as Google, ever increasing speed under the name Terabit Ethernet is subject of present-day discussions.

3 Host system requirements

High transmission rates and the requirement of 100 % image data transmission in 24/7 operation must be taken into account when selecting the host PC. Even short interruptions at the processing host system, for example caused by parallel or background processes, can result in packet loss which might result in the the loss of images (worst case scenario). It is of vital importance that the entire component chain is capable of processing the data stream with demanding 10 GigE data amounts. The full 10 GigE bandwidth tested on a system with i7-7820X processor revealed that about 5 % of the overall processing power are required for image reception. This processor is only one possible alternative, but it works well in terms of price-performance ratio, high clock rate and turbo frequency. The system memory must also be capable of the required bandwidth. The DDR3-1866 memory module provides the maximum data rate of 14.9 GB/s. However, since not only image transfer consumes memory capacity but also other processes and the operating system itself, the system configuration must always consider the memory bandwidth. The network card is another factor in the maximum possible system bandwidth. Here, PCIe bus is used.

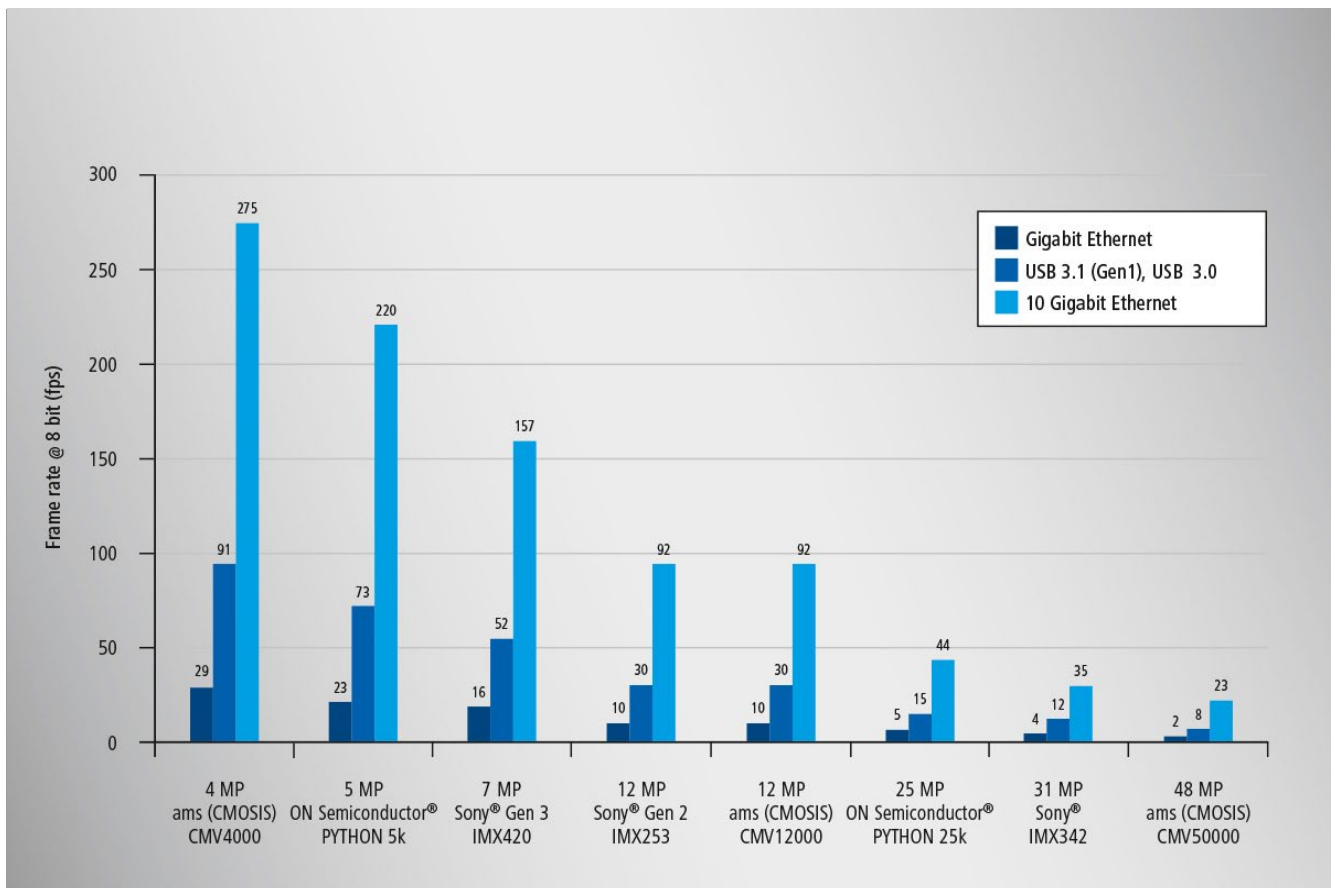


Fig. 2: Overview on frame rates of different sensors and interfaces

The different levels (PCIe gen 1, 2, 3 and 4) together with bandwidths from 1 to 16 lanes can be confusing. Therefore the slot of the installed network card should operate at least on PCIe gen 3 and should provide 4 lanes. The slot should be directly connected to the CPU without intermediate chipset. Usually, the mainboard manual describes the different PCIe slot properties. Transmission errors are often caused by processes running in the background of the operating system. Bursts by Antivirus software and indexing services have a significant effect on the performance of the overall system and must also be taken into consideration.

4 Summary

Data processing at 10 Gigabit Ethernet bandwidth is certainly challenging, but not the implementation of networked standard components. A wide choice of manufacturers, low prices and Ethernet flexibility speak for the deployment of 10 GigE cameras such as the Baumer LX or QX series in high-speed image processing. Present developments for the evolution of Terabit Ethernet prove that the Ethernet standard will meet the future required bandwidths and will ensure reverse compatibility to carry the experience and knowledge of the past into the next generations of machine vision.

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Baumer Group

The Baumer Group is one of the worldwide leading manufacturers of sensors, encoders, measuring instruments and components for automated image-processing. Baumer combines innovative technologies and customer-oriented service into intelligent solutions for factory and process automation and offers an unrivalled wide technology and product portfolio. With around 2700 employees and 38 subsidiaries in 19 countries, the family-owned group of companies is always close to the customer. Baumer provides clients in most diverse industries with vital benefits and measurable added value by worldwide consistent high quality standards and outstanding innovative potential. Learn more at www.baumer.com on the internet.