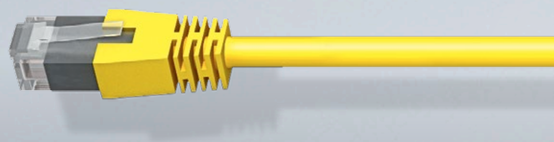

Efficiency and reliability – two sides of the same coin

In our everyday perception, high-performance systems can be seen as particularly sensitive, while more robust systems are thought to be lacking in performance. In fact, efficient motors are just as robust as high-consumption ones, and powerful digital cameras are even more robust than many mechanical devices. Ethernet in particular is a good example of how technological progress goes hand in hand with high robustness. The thought that high efficiency leads to a destabilization of a system when an error occurs is not applicable in many ways. How this relates to the higher-level protocol layers in industrial communicaton is explained in the following.

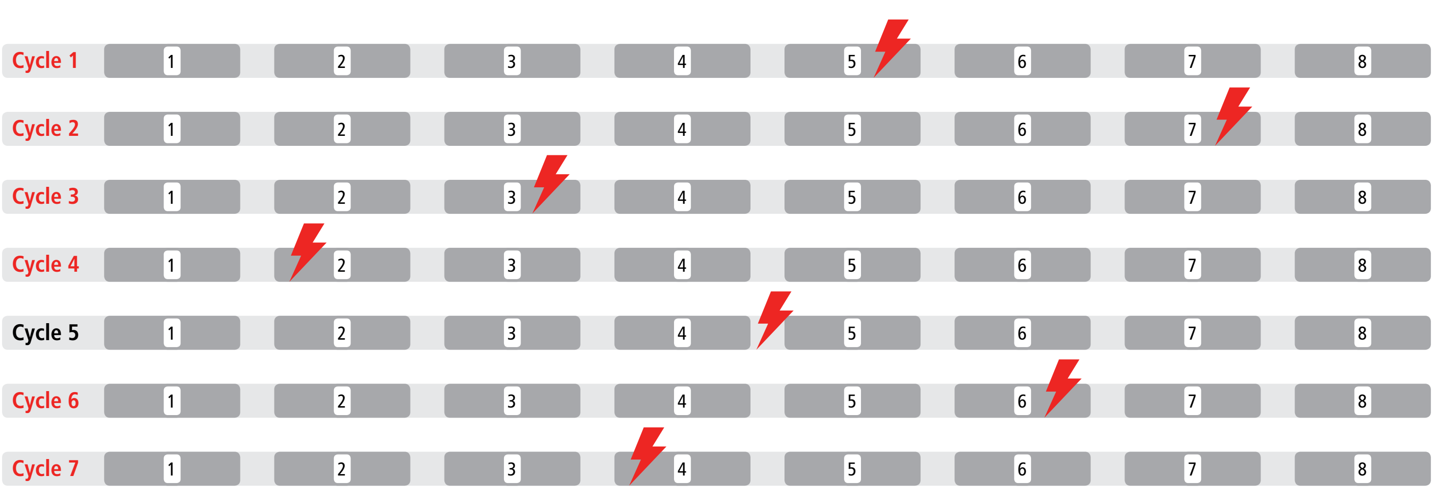

Figure 1: A random cycle error impacts the individual frame in six out of seven cases.

Industrial communication encompasses various effects that influence error situations in different ways. Determining what happens, when it occurs, where it happens, and for which reason are the key questions that must be answered quickly (which is not always easy) when an error occurs. On the other hand, one has to keep an eye on data consistency when dealing with error cases.

In many applications, Ethernet has become very popular. The robustness of the physical data transmission with 100 Mbit/s (Fast Ethernet) has proven itself extremely successful in the industrial field. Therefore, the efficiency of the protocol layers above the physical level, with regards to their reliability, must be discussed.

Single frame for each I/O operation means huge overhead and high frame error rate

One approach for evaluation is the investigation of the protocol overhead. Using an individual Ethernet frame for every network participant results in significant overhead, since even at minimum frame size, a total of 84 bytes (Fig. 1) must be sent, whereas the typical fieldbus payload is smaller than 8 bytes (e.g., CAN between 1 and 8). This leads to an overhead of more than 90 percent.

The usual setup of a machine shows a linear topology for the communication system, whereas the Fast Ethernet infrastructure requires active coupling of the interfaces. The coupling is carried out by a Bridged LAN, or Switched Ethernet, whereas the switches are often an integrated part of the network nodes, as with I/O devices or drives. Since all frames are processed in each node, one can alternatively collect the complete user data information in one common frame and, similar to EtherCAT, process while the frame runs through the system. This method of protocol processing can be referred to as a shared frame solution (Fig. 2). The result is an overhead of less than 50 percent, even if the number of connected network nodes is small. If the total payload of the system is more than 400 bytes, this influences the overhead in the shared frame solution by less than 10 percent.

Even if the physical layer (PhL) of Ethernet is robust in general, strong electromagnetic interfering signals can lead to communication errors. When comparing the effects of such interference in the traditional, individual frame approach to those in the shared frame principle, the latter shows a far smaller error probability within the network cycle.

Figure 2: A random cycle error influences the frame in the shared-frame principle, occurring in one out of every seven cases.

EtherCAT Technology Group

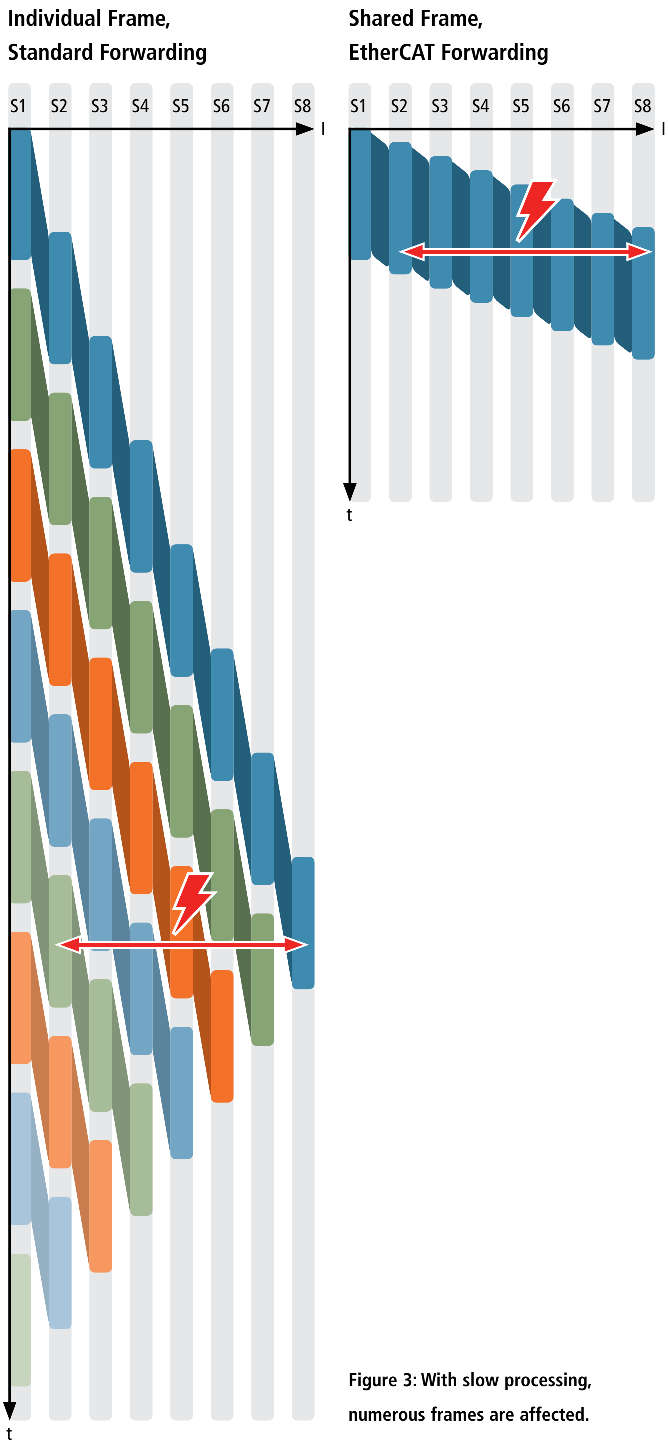

Figure 3: With slow processing, numerous frames are affected.

Normally, most networked applications can overcome one single error without any harm, but if there are two errors following directly, it is already a critical situation. Thus, the relation between communication errors per cycle corresponds with the critical situations. Related to the quite realistic example noted at the beginning of the article, this means a much higher number of corrupted frames are created with the individual frame approach than compared with the shared frame solution because the latter uses only one sixth of the transmission time. As a result, the disturbance influences the common frame only in one out of every six cases.

The number of erroneous bits has no impact on processing quality

In motion control applications, complex algorithms are used to interpolate the target value and the actual values in case of a single communication error. The individual frame approach leads to unforeseeable results, especially when several axes are coupled. Thus, the much higher rate of erroneous cycles in this approach results in a series of cascaded and, therefore, critical situations. Additionally, the low efficiency of this solution (around 10 percent) increases the rate of erroneous cycles and makes reliable control of the application much more difficult.

Control of speed and position also relates to motion. Regarding the position, the control of a value is much more critical than speed when dealing with small, incremental changes. The pre-planning of interactions can help to ensure readiness in cases of error. In addition, the programming motto “keep values as long as nothing changes” helps to reduce the effects of errors in general, as well as to avoid bundled errors.

The mentioned circumstances show that there is no direct dependence between the number of errors in one cycle and the resulting control error. Single errors can even be more critical than bundled errors.

The individual frame approach cannot prevent several errors

Another problem of a solution with single frames for each node centers on the isolation of errors. Generally, Ethernet avoids the transmission of disturbances, since each connection is controlled by a special transceiver. In today’s Ethernet, the PhL is not a bus but rather a collection of peer-to-peer connections. This can cause errors, for instance, because power supply disturbances can impact several nodes at a time. A comparable source for errors would be a poor connection to the protective conductor when the direct shield method

Dr. Karl Weber,
Senior Technology Expert

is used. EtherCAT documentation does not recommend this, but it is mandatory in some consortiums especially because multi-protocol devices must follow that approach and may not use alternative methods. Since grounding in cabinets is sometimes worse than expected, disturbances on the shield can appear where different parts of the cabling are joined. In such a case, the diagnosis is very difficult – which is the reason why this kind of disturbance transmission should be avoided if possible. If you use common frames, such as with EtherCAT, this type of disturbance transmission only affects the same frame several times.

In case of short individual frames with the typical switch forwarding method, which is defined by the IEEE standard and is normally at least 10 times slower than the time EtherCAT need for forwarding, several frames are transmitted on different network participants during the same time period. During that process, a huge time delay leads to several different affected frames in the case of a disturbance transmission. As a result, data from different cycles or communication types can be affected. For this reason, the disturbance transmission is a very critical factor that almost always entails some kind of domino effect. By choosing EtherCAT, the forwarding times become so short that even a disturbance at the beginning of a frame cannot affect the end of a previous frame in the network.

When several single frames are affected, the resulting error type is hard to define. Some input data is new, some is old. Ultimately, the conclusion that there are only single errors with that method is not true. Rather, it requires especially sophisticated and complex error handling strategies. Additionally, most switches/bridges only transmit when they have received a frame correctly (store and forward), which leads to different frames at each interface and the disturbance transmission to influence a high number of frames.

Feedback can help to accelerate error handling

For efficiency reasons, approaches with individual frames generally do not deliver prompt feedback. Direct feedback on updates to the output data would require forwarding from control to connected device and back. This duplication of the forwarding time would present a limiting factor for the cycle time. Thus, the reaction to the loss of individual output frames is limited to the single components – without direct notification of the control unit. In this situation, the control cannot initiate any measures. The earliest time that such an error can be reported is one incoming cycle later. Until the error time-out is triggered, the system normally needs three cycles.

EtherCAT provides immediate feedback

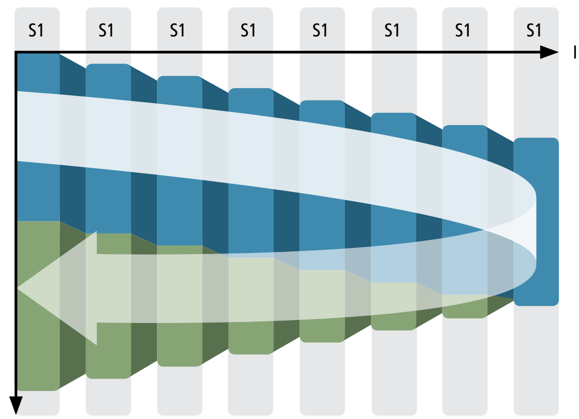

Abb. 4: Direktes Feedback mit EtherCAT

More information:
www.ethercat.org