Using Fiber Media Converters with Copper Networks

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The 21st century has seen a huge increase in using Ethernet for industrial automation applications such as remote monitoring. However, the advantages and versatility obtained from using Ethernet for industrial automation applications are offset by a number of drawbacks, one of which is signal interference. As a general rule, shop floor and substation environments are not nearly as friendly as what you would find in an air conditioned office, and for this reason, engineers are now using Fiber Ethernet to extend transmission distance and protect data from the effects of EMI (electromagnetic interference), or even Gigabit Ethernet[1] to provide increased bandwidth. In addition, advanced redundancy solutions, such as STP/RSTP and Moxa's own Turbo Ring[2] protocol, provide the redundancy needed when implementing Ethernet with automation applications.

In this paper we cover the following topics:

- **Overview**
- **Using Media Converters as Part of a Network**
- **Going Beyond Media Conversion—LFP and FEF**
- **Important Reminder: Use Media Converters in Pairs**
- **What to Expect from Redundancy**
- **Conclusion**

[1] See Moxa's "Redundant Gigabit Backbone Adds Speed and Reliability to Industrial Networks" white paper for more information about Gigabit networks.

[2] See Moxa's "Redundant Ring Technology for Industrial Ethernet Applications" white paper to learn more about Moxa's advanced redundant ring technology.

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Overview

In this paper, we concentrate on using Ethernet-to-fiber media converters with copper Ethernet switches. Compared to purchasing new switches with built-in fiber ports, the media converter solution is considerably more economical. In addition, since many automation networks still use large numbers of 10Base5 or 10BaseT devices that operate at a slower transmission speed and rely on RJ45 or even BNC connectors, Ethernet-to-fiber media converters may be the only viable solution available.

Using Media Converters as Part of a Network

Because of the large number of different switch and converter products available on the market today, it is quite likely that your network uses switches from different vendors, or perhaps different models of switch from the same vendor. In fact, if your network is already using one switch with a built-in fiber port and you wish to connect the fiber port to a copper-only switch, you could do this by inserting an Ethernet-to-fiber media converter between the two devices (see Fig. 1).

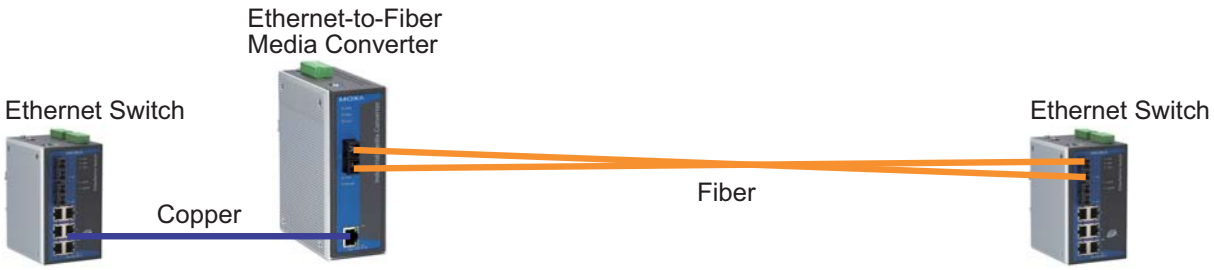


Fig. 1: Using an Ethernet-to-Fiber Media Converter to Connect a Copper Switch with a Fiber-enabled Switch

Going Beyond Media Conversion—LFP and FEF

You might think that the sole purpose of an Ethernet-to-fiber media converter is to convert between copper and fiber (the name kind of gives it away, doesn't it?). In fact, there's a little more to it than that. It's certainly true that the main role of a media converter is to pass data between two devices that are

not capable of communicating directly, and in this regard a good media converter must do its best to remain invisible to the network. In effect, the media converter must be able to "simulate a cable." Sounds simple enough, but when media converters are used in pairs the "cable" actually consists of two copper cables and two fiber cable (see Fig. 2 below). This increased complexity has motivated the introduction of the "Link Fault Pass-through" and "Far End Fault" functions.

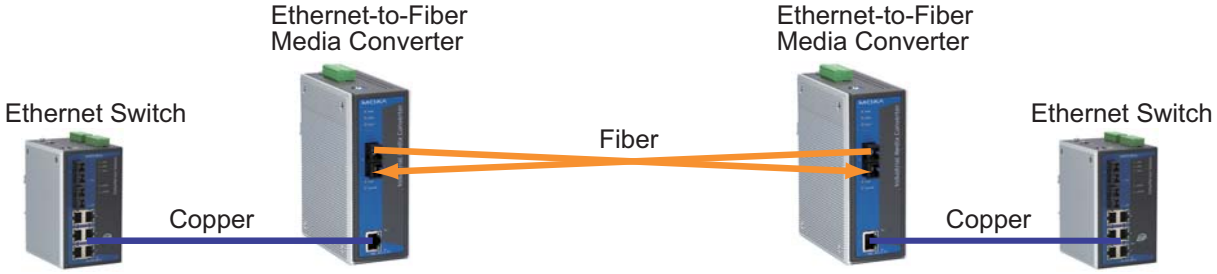
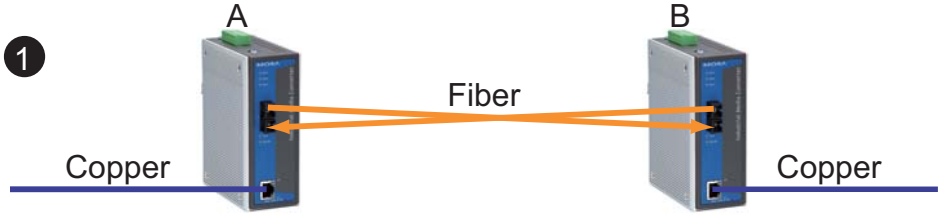


Fig. 2: Using Ethernet-to-Fiber Media Converters in Pairs

Link Fault Pass-through (LFP)—Consider what happens if the copper cable connecting the switch on the left with the media converter gets unplugged unexpectedly (see Fig. 2). In this case, the switch on the right will have no idea what has happened, and even though the connection has been disconnected the network will continue on its merry way assuming that the connection is still viable. This is where Link Fault Pass-through comes in. The detailed operation of LFP is illustrated in Fig. 3 below.

Image 1: Normal operation of the two media converters.
Image 2: Copper cable to converter A gets disconnected.
Image 3: Converter A disables the connection to converter B.
Image 4: Converter B disables its copper connection.
Image 5: Converter B disables the connection to converter A.



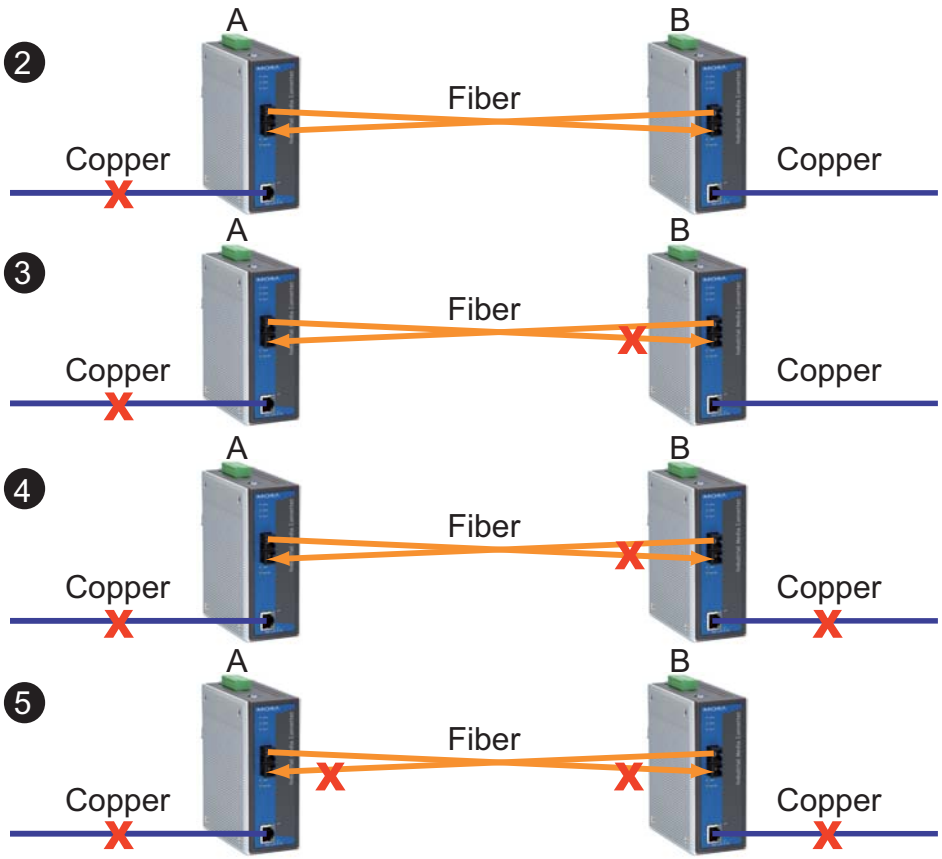


Fig. 3: Link Fault Pass-through in Action

Far End Fault (FEF 802.3u)—Consider what would happen if the fiber cable connecting the media converter on the left to the media converter on the right gets disconnected unexpectedly. In this case, the switch on the left will not be able to transmit data to the switch on the right. However, if the other fiber cable is still viable, the switch on the right *will* continue transmitting to the switch on the left, which could lead to transmission faults across the network. This is where Far End Fault comes in. The detailed operation of FEF is illustrated in Fig. 4 below.

Image 1: Normal operation of the two media converters.

Image 2: Fiber cable from converter A to converter B gets disconnected.

Image 3: Converter B disables its copper connection.

Image 4: Converter B disables its fiber connection to converter A.

Image 5: Converter A disables its copper connection.

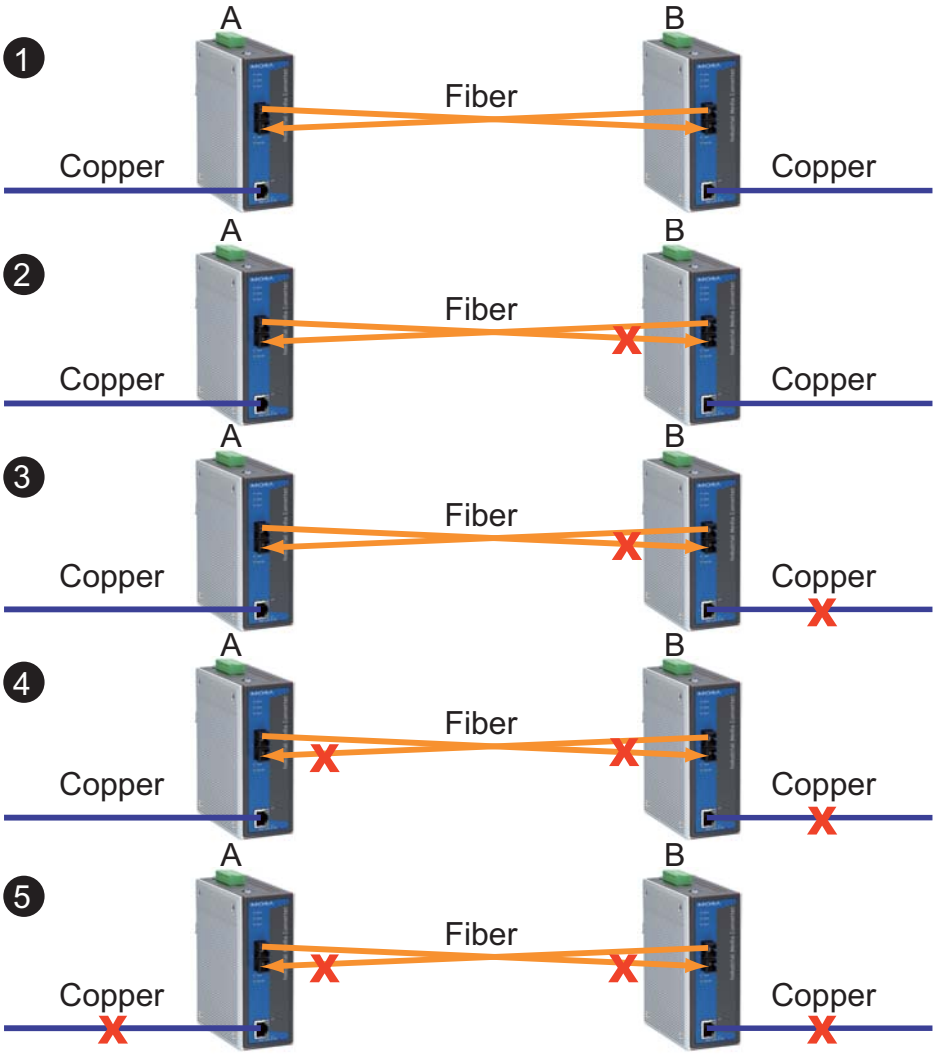


Fig. 4: Far-End Fault in Action

Important Reminder: Use Media Converters in Pairs

In the above illustrations we showed media converters being used in pairs. In fact, most vendors illustrate LFP and FEF with two media converters used in pairs, as they well should, but nevertheless many engineers disregard this point and use only one Ethernet-to-fiber converter. The problem with using only one media converter is that if the media converter's "Far End Fault" and "Link Fault Pass Through" functions are activated, the functions will not work properly. Not only should the media

converters should be used in pairs, but in addition, you should also choose the same brand and same model. This is because different vendors could use proprietary protocols to run “Far End Fault” and the “Link Fault Pass Through.” In fact, the same vendor could use different converter ICs in different models, which will result in the different models being incompatible.

Let’s take a closer look at what happens if we use LFP with a single Ethernet-to-fiber media converter (see Fig. 5 below). In fact, it’s easy to understand why using LFP in this situation will cause problems. To begin with, keep in mind that LFP is a function that resides in the media converter. If the copper connection between the switch on the left and the media converter fails, the media converter will send a message to the switch on the right notifying it that the link has failed. The problem with this scenario is that the switch will not understand the LFP message, and hence the message will be discarded. Because of this, the switch on the right will continue transmitting data to the media converter with the expectation that the data will be passed on to the switch on the left. The fact that this does not happen can cause the network to fail.

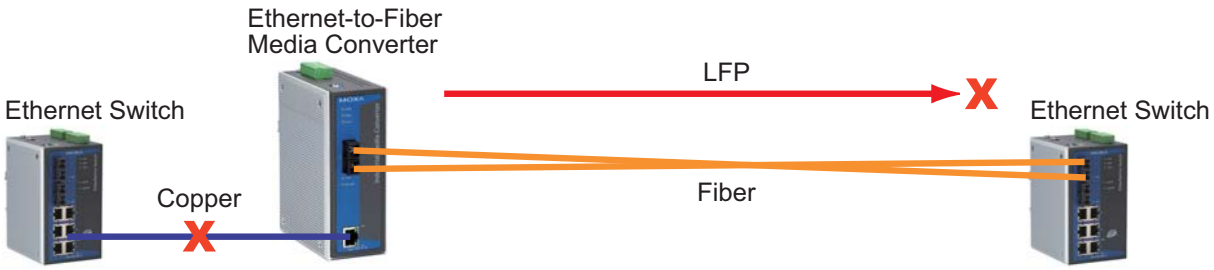


Fig. 5: Link Fault Pass-through with only one Media Converter

What to Expect from Redundancy

Redundancy is an important aspect of any network, but is particularly important for industrial networks. Many Ethernet switches support both the STP/RSTP protocols and some form of proprietary redundant ring protocol, such as Moxa’s own Turbo Ring™.

STP/RSTP (802.1d/w) serve two purposes. When a complex

network is first activated, the STP/RSTP protocols will analyze the network and then remove any redundant links. Once the network is up and running, if an active link is disconnected accidentally, the STP/RSTP protocols will react by activating one of the inactive links. The switches on the network monitor the state of the links in the network by exchanging BPDUs (Bridge Protocol Data Units) with other once every 2 seconds or so.

Turbo Ring™ is a proprietary protocol developed by Moxa specifically for ring-type industrial networks. Since ring networks only have one redundant link, and a ring topology is considerably less complex than tree-type topologies, Turbo Ring™ can react extremely quickly (less than 20 ms in most cases) to activate the redundant link if one of the active links fails. The Turbo Ring™ protocol also makes use of BPDUs to monitor the state of the links making up the redundant ring.

Case Study—We recently worked on a project that originally planned to adopt a ring topology using a copper Ethernet network. However, one section of the ring needed to use fiber since the transmission distance was greater than 100 meters, which surpasses the distance limit for copper Ethernet. Instead of incorporating switches with built-in fiber ports, the design engineers for the project decided to use Ethernet-to-fiber media converters (see Fig. 6).

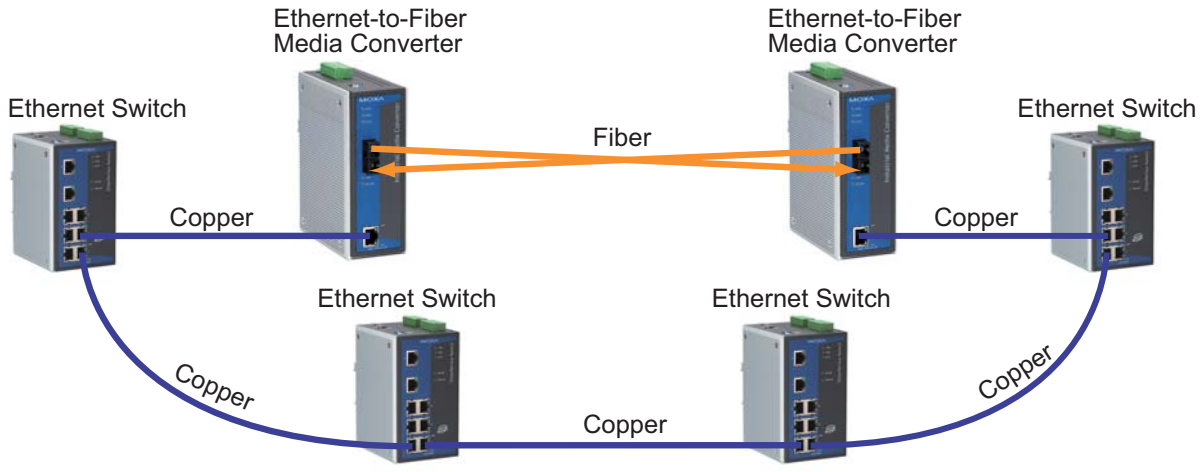


Fig. 6: Ethernet-to-Fiber Media Converters as Part of a Redundant Ring

When it came time to configure the network, the design engineers set up the Turbo Ring™ protocol. As far as the media converters were concerned, they had to choose between one of two operating modes: "Store-and-Forward" and "Pass-through." They decided to go with Store-and-Forward mode since it mimics the normal operation of a switch by doing a CRC check on incoming packets.

What do you think happened next? Once the BPDUs started flying around the ring they noticed that the fiber link was completely inactive. What the engineers didn't realize is that the Ethernet-to-fiber converters do not recognize BPDUs, and consequently the converters treated the BPDUs as illegal packets and refused to pass them on.

The solution to this problem is to configure the converters for Pass-Though mode, since in this case the fiber link works as a tunnel to provide transparent communication.

Recovery Speed—When using Ethernet-to-fiber media converters as part of copper Ethernet network that uses either STP/RSTP or Turbo Ring™, you should take into consideration the effect that the media converters will have on the recovery speed. We consider each case separately:

- Recovery Speed for STP/RSTP: As mentioned earlier in this paper, the recovery speed for STP/RSTP tends to be fairly slow, and although including media converters as part of the network will slow things down a bit, you shouldn't see a noticeable difference in the recovery speed.
- Recovery Speed for Redundant Rings: Redundant ring protocols tend to respond much more quickly than STP/RSTP. Moxa's own Turbo Ring™ for example has a recovery time of under 20 ms. However, once you include Ethernet-to-fiber media converters in the ring you should expect a noticeable slow down in the recovery time.

Conclusion

Media converters try to remain as invisible as possible by "simulating a cable," but since some properties of media converters may not be completely compatible with Ethernet switches or routers (such as LFP or FEF) you should consider several factors before deciding to use media converters as part of a network. We suggest that you seek expert advice from your vendor, who will assist you with evaluating your needs and then help you determine the best solution for your application.

Keep the following important factors in mind:

1. If you intend to enable the "Link Fault Pass-through" function, be sure to use Ethernet-to-fiber media converters as a pair. In addition, remember to select the same brand and model for the two sides of the connection.
2. Test the functions you intend to use before actually implementing the functions on a working network.
3. If you intend to use Ethernet-to-fiber media converters in conjunction with Turbo Ring™, test the recovery function before implementation.
4. Be sure to seek expert advice from your system vendor.