WHITE PAPER

# Extending Ethernet over 2-wire Copper Networks


**Eleanor Huang**
*Product Manager*

**Mark Wu**
*Technical Writer*

## Executive Summary

*To improve the efficiency of industrial automation systems, many operators are considering the possibility of IP upgrades to provide centralized control/management and remote monitoring. When migrating to a converged IP-based network, acquiring an Ethernet communication framework will be necessary to provide higher bandwidths and longer transmission distances, which can require the installation of new cables. However, installation of new cables can incur substantial costs in planning, labor, and system downtime. Under hard-to-wire circumstances, or when budgets are limited, existing legacy copper-wire networks can be a cost-effective alternative to quickly deploy an Ethernet extension.*

*Legacy 2-wire copper networks are everywhere in industrial environments, such as RS-485 twisted-pair cables and voice-grade copper wires. DSL Ethernet extenders can leverage existing copper wires to extend point-to-point industrial Ethernet networks beyond the 100-meter distance limitation and offer high data-rate transmission. In this article, we will discuss factors that can significantly improve network communication and the methods to ensure a stable, reliable, and efficient DSL Ethernet extender deployment.*

## Overview

IP convergence has been a recent trend in industrial automation systems as operators seek to centralize network management to increase system efficiency. Whether it's the integration of local video surveillance for traffic monitoring at remote traffic management centers (TMC), or the collection of environmental data from dispersed monitoring stations of oil/gas pipelines, distance and bandwidth requirements are always a concern for system engineers when converging network segments. Traditionally, network convergence that requires long-distance transmission (over 100 meters) is deployed via fiber-optic links. However, fiber-optic cables are not always available, especially in remote locations of industrial application sites, and installation can require substantial costs and a considerable amount of time.

As stated in a 2004 entry[1] of the U.S. Department of Transportation (DOT), existing copper-wire networks were used to provide transmission of real-time traffic video when compared to the high costs of deploying a new fiber-optic infrastructure. In response to the demand of such industrial application requirements, many manufacturers now offer Ethernet extension solutions based on DSL technology, which uses two-wire copper cables, such as voice-grade copper wires and RS-485 twisted-pair cables, to deliver long-distance and high-speed data services as a fiber-optic alternative.

Released on April 15, 2013





**How to contact Moxa**
Tel: 1-714-528-6777
Fax: 1-714-528-6778

MOXA Reliable Networks Sincere Service

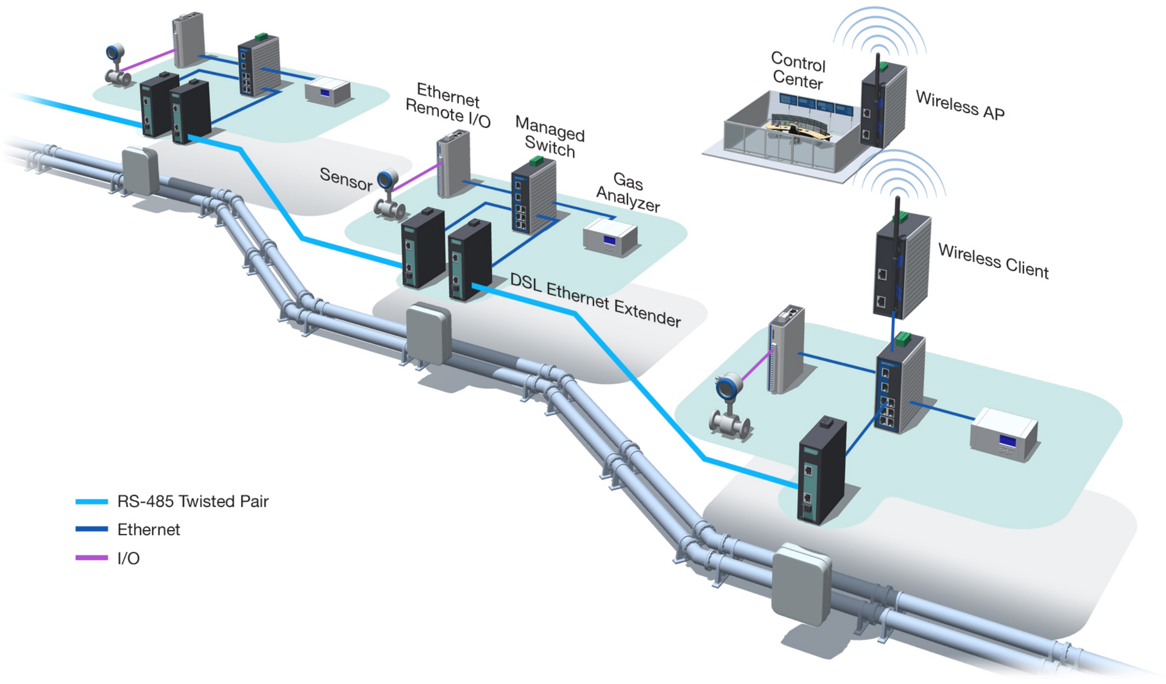
The significant advantage of using DSL Ethernet extenders for industrial automation is the fact that it is relatively inexpensive to deploy and the required physical medium, copper wire, is practically everywhere, allowing industrial operators to quickly extend a point-to-point connection between two geographically separated LANs.

Existing copper wire infrastructures can be used to establish high-speed Ethernet networks and can extend transmission distances to exceed those previously attained with traditional DSL connections. Variations of DSL technology, such as G.SHDSL (symmetric high-speed digital subscriber line) for long-distance communication and VDSL2 (very-high-bit-rate digital subscriber line 2) for high-bandwidth applications, have since emerged to meet specific transmission distance and data rate requirements of various industrial applications. For example, VDSL2 extenders can provide enough bandwidth for 5 video streams with 1280 x 720 HD video resolution (H.264 @ 30 fps) across a distance of one kilometer.

## DSL Ethernet Extender Applications

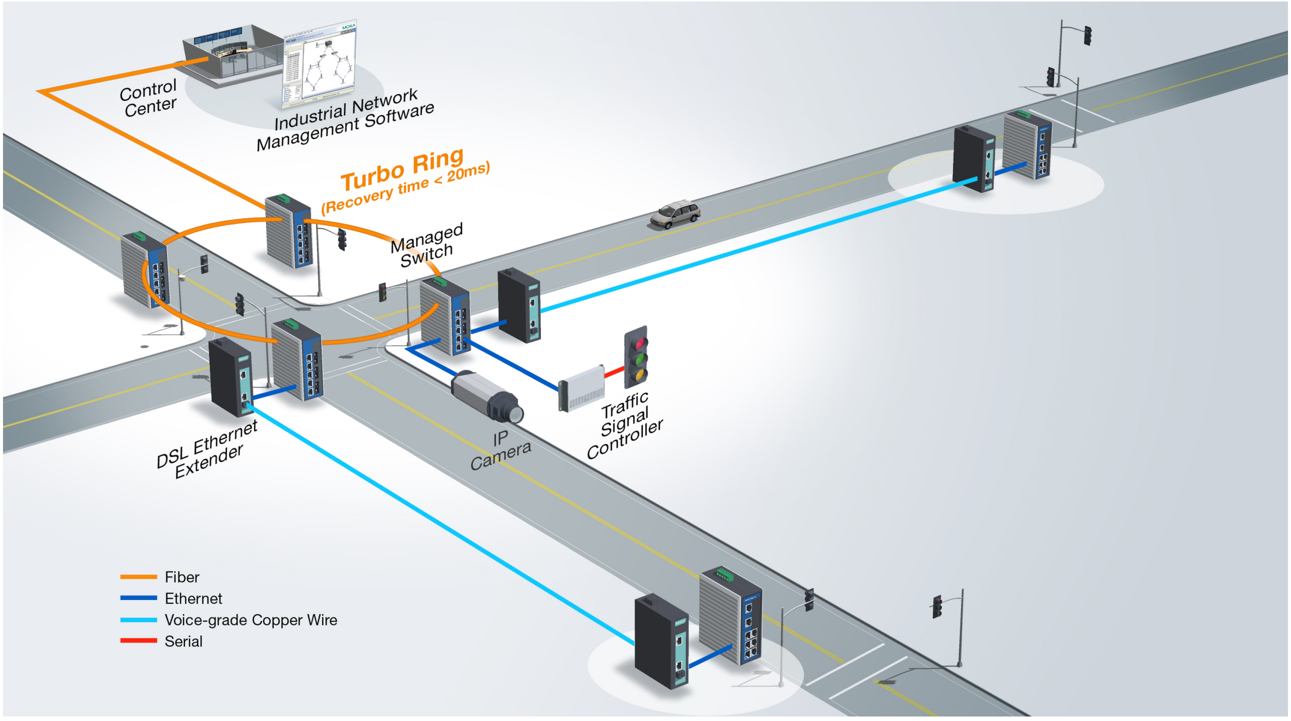
**G.SHDSL for long distance transmission over RS-485 twisted-pair wires**

For oil & gas applications, existing copper infrastructures, such as the RS-485 networks found within oil & gas refineries, can be used to easily connect remotely separated analyzer devices to enable IP-based centralized control.



### VDSL2 for high-bandwidth transmission over voice-grade copper wires

For ITS (intelligent transportation system) applications, existing embedded copper loops can be used to connect traffic signals and video cameras with traffic management centers (TMC) for centralized control and monitoring. DSL Ethernet extenders can provide highly cost-effective connectivity for various ITS applications.




## Major Challenges and Concerns of DSL Deployment

Previously used mainly for residential triple-play services (voice/data/video), DSL technology is relatively new to industrial automation sectors but can potentially reduce significant deployment costs for industrial operators. Conventional point-to-point Ethernet connectivity using DSL Ethernet extender pairs can be quite a challenge, especially for engineers who are unfamiliar with DSL technology.

### Transmission Distance and Data Rates

A general inverse relationship exists between transmission distance and data rate; when the transmission distance increases, the transmission rate will decrease. Two major types of DSL communication, G.SHDSL and VDSL2, are available for point-to-point data transmission across twisted-pair copper wire and their approximate limitations are shown below in **Figure 1**.

**Figure 1**

| Application | Standard | Performance Reference | |
|---|---|---|---|
| Mid-range and High Data Rate | VDSL2 | 200 m | 100 Mbps/100 Mbps |
| | | 1 km | 38 Mbps/4 Mbps |
| | | 3 km | 2.5 Mbps/350 kbps |
| Long-range and Low Data Rate | G.SHDSL | 2 km | 5696 kbps |
| | | 8 km | 192 kbps |

**Signal-to-Noise Ratio (SNR)**

SNR compares the strength of intended signals to the level of background noise that is present on the transmission medium and is derived by dividing the signal value with the noise value. However, this comparison is often expressed as the SNR margin, which is the logarithmic value measured in decibels (dB), that indicates the difference between the actual SNR value and the minimum SNR value required (typically 6 dB) to sustain a connection at a certain speed. When the SNR margin falls below the 6 dB threshold, the connection is dropped. Therefore, a higher SNR or SNR margin will result in a stable connection that is more reliable and less likely to be affected by noise.

- **Below 6dB** – unstable connection with frequent drops
- **6dB - 10dB** – average connection but very vulnerable to noise
- **11dB - 20dB** – good connection
- **20dB - 28dB** – excellent connection but speed is not maximized
- **Above 28dB** – superb connection with leeway to increase speed

When the data rate is not manually configured, DSL Ethernet extender pairs will generally conduct a handshake (training) to determine the highest data rate possible with acceptable SNR margins, which is usually between 6dB and 10dB. A faster connection speed will typically mean a lower SNR, and vice versa. This should be taken into consideration when manually configuring data rates on DSL Ethernet extenders.

**Line Quality & Condition**

Wires with a larger cross-section (AWG) will generally provide a greater transmission distance, but the physical condition of the medium can also affect transmission quality and distance. Especially in outdoor applications, where exposure to environmental contaminants can corrode wire joins and deteriorate wire sheaths/jackets over time, line attenuation and noise can gradually impede signal transmission and eventually prevent the transmission of usable data.

Many factors will determine the overall quality of the point-to-point DSL Ethernet connection. When DSL Ethernet extenders attempt to negotiate (sync) communication speed, attenuation and noise level data will be collected to determine the optimal data rate. However, relying solely on device training based on this initial handshake will not ensure a reliable DSL connection because line conditions can deteriorate quickly and interference can severely impact communication, especially for industrial applications that are often deployed in outdoor environments.

## Making DSL Deployments More Manageable

After initial installation or routine maintenance, system engineers will generally perform a test to verify connectivity. When communication is unable to be established between the DSL Ethernet extenders, determining the root cause can be quite an inconvenience, considering the fact that DSL Ethernet extenders will only work in pairs and the distance between the extenders can span several kilometers. Without another engineer present at the opposite end of the DSL connection to verify device configurations and make corresponding adjustments, one engineer will likely need to travel between the extenders repeatedly when communication issues arise on the DSL segment.

Different applications will have many requirements and encounter unpredictable environments with variable line conditions; identifying the precise relationships between these variable factors in every possible scenario would be nearly impossible. Instead, let's take a look at a few common problematic scenarios in which operators and engineers can encounter connectivity issues during deployment, and how new innovations for DSL Ethernet extenders have evolved to help overcome these challenges.

**Auto-Pairing (CO/CPE Configuration)**
Communication failure can be caused by improper settings (usually DIP switches) on the DSL Ethernet extender pair. Similar to traditional DSL service from the phone company, DSL Ethernet extender pairs will need to have one Ethernet extender designated as the CO (central office) device and the other Ethernet extender designated as the CPE (customer premise equipment) device. Unless the Ethernet extenders are capable of auto-pairing, CO/CPE settings should first be checked when communication between the Ethernet extender pair cannot be established.

**Indicators for Onsite Diagnostics**
Pertinent connection/device status information, such as SNR margin and data rate, should be readily displayed on the device panel to enable onsite maintenance and troubleshooting without the need for special DSL diagnostic tools. When connections are unstable, SNR margins and data rates are two of the most useful parameters to determine the root cause of the problem. For example, if the connection is unstable and the SNR margin indicator is showing a low level, data transmission will likely need to be set to a lower rate. If data rates need to remain relatively high, then the transmission distance will need to be reduced and/or the copper wires will need to be checked for excessive noise or physical damage.

**Tools for Remote Management**
For efficient DSL Ethernet extender management, a diagnostic utility or a virtual panel should be available to provide remote access to real-time device information, such as port, power, speed, and SNR statuses. Some managed DSL Ethernet extenders are SNMP-enabled, which allows the devices to be visible on network management software (NMS) to allow total network monitoring. Operators should have tools to perform preliminary diagnostics, adjust configurations, and conduct routine maintenance checks from the control room. Maintenance personnel will only need to be dispatched to onsite locations only when hardware needs to be repaired or replaced.

**LFP/LFF (Link Fault Pass-through/Forwarding)**
Many applications will require LFP/LFF to ensure that link failures are detected as soon as possible to minimize system downtime. LFP/LFF forwards a link failure status to adjacent ports to disabled the link to other network nodes, allowing operators to quickly diagnose the problem and recover the connection.

Traditional means of extending Ethernet connectivity beyond the 100-meter distance limitation includes wireless, fiber-optic cable, and coaxial cable. When budgets are limited or hard-to-wire conditions exist, DSL Ethernet extenders can now provide an alternative solution for long-distance (up to 10 km) transmission and high bandwidth (up to 100 Mbps) requirements to provide reliable and low-cost connectivity across existing copper wires when configured and maintained properly.

Factors that can individually impact DSL communication – such as transmission distance, SNR, data rate, configuration, wire quality, and environmental conditions – can sometimes be difficult to detect immediately. In addition, the relationships between these factors are closely intertwined and a slight change in one factor can mean significant changes to other factors.

DSL Ethernet extender installation and maintenance can be quite a challenge for engineers without much DSL configuration experience. A combination of software utilities for remote diagnostics, and tools for onsite configuration, can enable operators to maintain optimized communication between extender pairs to make DSL Ethernet extensions more manageable.

For more information on how DSL Ethernet extenders can be quickly deployed for efficient point-to-point Ethernet extension, please visit: www.moxa.com/product/DSL_Extender.htm

********************************************************************************

## Credits/sources

1. Research and Innovative Technology Administration - U.S. DOT, <http://www.benefitcost.its.dot.gov/ITS/benecost.nsf/0/D7365B9BB0E7A7C9852570300069C742?OpenDocument&Query=Home> Website last accessed April 15, 2013.