ALERTON

IP T1L

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T1L NETWORK SPECIFICATION GUIDE

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SECTION 1: ABOUT THIS GUIDE

This manual intends to provide reference work for Alerton products that connect to a IP T1L network. Readers are expected to be reasonably conversant with the traditional Alerton products, although references to other documentation are given where appropriate.

This manual describes how Alerton devices use the T1L network to communicate between devices over Ethernet IP. It has been written to provide a basic understanding of IP T1L Networking and how the IP T1L-supported controller/devices use these technologies. It also explains how the Alerton IP T1L-supported devices can be applied in conjunction with standard networking.

1.1 SCOPE

This design guide proposes practices, technologies, and products that help architects and engineers design a IP T1L network. It also describes the design considerations and present practices of IP T1L network. In addition, this guide describes the basics of IP T1L Ethernet and explains the technical concepts that make it possible with some examples of applications and benefits.

SECTION 2: T1L

2.1 WHAT IS IP T1L?

IP T1L is a non-proprietary networking standard that enables IP communication between devices over long distances. No special cabling or wiring is required. The standard does not define a cable specification – it only defines characteristics for the cables used. All it need is T1L Media Adapter.

The IP T1L is a “single-pair Ethernet” (SPE) standard, meaning it only needs a single pair of twisted wires rather than the two or four pairs common to many other Ethernet standards.

On November 7, 2019, the Institute of Electrical and Electronics Engineers (IEEE) approved IP T1L as a new open standard, IEEE802.3CG, T1L. This standard allows for cables up to 1 kilometer long and can transfer data at a speed of 10 Mbps (10 million bits per second).

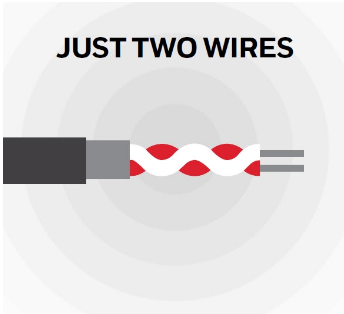


Figure 2.1: Two Wires

The IEEE developed the IP T1L with a focus on building automation, process automation, and the industrial Internet of Things (IoT). This considers the specific environments of these applications and their networking requirements, such as longer cabling distances.

IP T1L is designed to support various software and systems, offering flexibility for industrial IoT across numerous industries.

2.2 WHY IP T1L?

Companies and organizations worldwide depend on networking technology to transmit increasing amounts of data, leading to a surge in demand for cloud storage, processing speed, and low-latency apps.

Yet a potentially rich transmission source may already be installed in your building, ready to support strategic building operations. This includes optimizing occupant comfort, managing energy consumption, and progressing toward sustainability goals.

In today's fast-paced world, there is a growing need for increased data and faster networks across various systems, including a building's operational technologies. As a result, many building owners and users are keen on enhancing their building's network performance and security to align with the standards-based approach of an Internet protocol (IP) network. The promising news is that it is possible to achieve improved networking using the existing infrastructure and even the old cabling within a building by leveraging a single twisted pair of wires.

IP T1L is a solution to upgrade the building's operational technologies.

T1L Long Distance Ethernet networking technology enables rapid, dependable data transfer over long distances.

IP T1L can potentially transmits data between devices up to a kilometer apart. This provides a cost-effective option that outperforms many other IP-cabling technologies in distance. In contrast, fiber-optic cable can cover longer distances but involves prohibitive costs.

Because IP T1L is simply a different physical network layer of Ethernet connectivity, it’s a practical alternative to other physical network layers such as BACnet™ MS/TP or LonWorks®.

2.3 HOW IP T1L SIMPLIFIES FIELD NETWORKS

Field networking involves the final 500 meters within a building, connecting the backbone network to the edge. CAT5/6 TCP/IP Ethernet has traditionally been the dominant choice for backbone networks. However, with field networking, buildings now have multiple competing options for networks, protocols, and wiring. Each option varies in communication efficiency, cybersecurity, and cost. IP T1L can strike the optimal balance for a building’s field network with its flexibility, long-distance, and other capabilities.

2.4 ADVANTAGES

The potential to make use of a building's current wiring. This allows for faster upgrading of building technologies, providing more options for system optimization than a complete rip-and-replace for installing a CAT5/6 Ethernet network. For new IP network installations, T1L can enable lower network installed cost due to potentially lower cable cost and easier node termination.

By re-purposing your existing building network cables, T1L offers a cost effective way to upgrade legacy controls systems to the latest IP technology that require higher network speeds for cyber security and data throughput.

In a building management system (BMS), IP T1L provides significant advantages over traditional networking technologies. It offers higher bandwidth, long-distance connectivity, and improved network resilience.

2.5 WHY ALERTON SUPPORTS IP T1L DEVELOPMENT

Alerton is introducing IP T1L Ethernet in its building technologies to support versatile, cost-effective, and resilient IP-capable networking.

Different systems or applications can adopt the technology in various ways. For example, some systems use IP T1L in I/O Modules to enable remote IP I/O. In contrast, other systems utilize the technology as the new fieldbus network for unitary controllers.

Thanks to Ethernet connectivity, the physical benefits of a traditional BMS network are now available with 100 times the bandwidth.

The IP T1L Ethernet offers a cost-effective solution to enhance capabilities while simplifying system architecture. It is a new physical layer, like 10BASE-T (CAT5/6), but it can utilize existing twisted-pair cables.

IP T1L is simply a different physical Ethernet, therefore it still supports TCP/IP protocols, therefore supporting the latest IT applications and security standards, including certificate management for encryption – providing secure transmission all the way to the building's edge.

SECTION 3: FEATURE AND BENEFITS

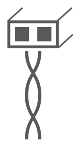
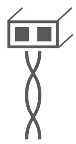
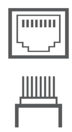
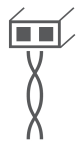
- Simplifies the adoption, installation, and maintenance of IP networks.
- Non-proprietary.
- Standards-based, with support for standard IT protocols and Reusable wiring—This enables buildings to implement standard IT protocols and applications on the networks used by operational technologies (OT).
- It enables the IP addressability of sensors and nodes, helping to cost-effectively drive secure, high-bandwidth connectivity across entire buildings.
- Compared to traditional BMS field wiring, T1L offers 10 Mbps transmission speed, distances of up to 1000 m between devices (enviornment and cable characteristics may affect actual distance) and significant benefits over traditional networking technology, including higher bandwidth, long-distance connectivity, and better network resilience.
- Functions as an Ethernet physical layer – IP T1L just uses different cables and connectors.
- Single twisted-pair fieldbus cable (no CAT5/6 cables needed).
- Solution for I/O and comms module bus.
- Full duplex, point-to-point.
- Seamless connectivity between industrial Ethernet and IP T1L.

SECTION 4: BENCHMARK WITH OTHER TECHNOLOGIES

Among established building technologies, many are based on open network protocols. These rules enable connected devices to intercommunicate despite differences in design, manufacturer, and internal processes.

Refer to below table for network technologies strengths and tradeoffs.

Table 4.1: Different Network Characteristic

Characteristic	Traditional BMS Networks		IP Networks	
	LonWorks® FFT-10	BACnet™MS/TP	CAT5/6 Ethernet	IP T1L Ethernet
Cabling Connectors				
Total Wire Length	500 m	1200 m	100 m*	up to 1000m*
Typical Speed	78 Kb/s	32 Kb/s	10 Mb/s, 100 Mb/s, 1 Gb/s	10 Mb/s
Supports BACnet™ Secure Connect	No	No	Yes	Yes
Supports IT Standard Protocols	No	No	Yes	Yes
Supports Encryption	No	No	Yes	Yes
Proprietary	Yes	No	No	No

* Distance between node and switch or between devices in daisy-chain. Distance vary based on the cable, refer to the "Section 6: Cabling and Specification" on page 12.

T1L enables high-capacity, cost-effective wired networking.

Although traditional BMS networks have worked successfully in most traditional use cases, they lack the bandwidth and cyber security to support new and emerging industrial communication applications effectively.

4.1 TRADITIONAL BMS NETWORKS

LonWorks®, BACnet™ MS/TP, and other proprietary BMS networks have been successful in buildings for several reasons: they can cover long distances, are relatively easy to install, and have simple connectors that streamline the installation, configuration, and maintenance processes.

4.1.1. LON

LON®, is short for “local operating network” and is also known as LonWorks®. It is a protocol used for networking devices in building automation systems. LonWorks® is proprietary, so you might need to purchase chipsets from a specific manufacturer or pay a license fee.

The main advantage of LonWorks® is enabling devices from different manufacturers to communicate with each other, providing an open solution for device integration.

4.1.2. BACNET™

BACnet™ is a communication protocol developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). It specifies how wired devices communicate but does not define the physical network layer or system engineering.

Like LonWorks®, BACnet™ facilitates communication between devices made by different manufacturers.

4.1.3. MS/TP

MS/TP stands for "master-slave token passing." This is a protocol used in BACnet™ for exchanging information between building devices. It is a form of MS/TP networking, whereas CAT5/6 is a form of Ethernet networking.

BACnet™ MS/TP is a protocol that provides low cost but also low bandwidth, whereas CAT5/6 Ethernet offer higher bandwidth but at a higher cost.

4.1.4. CAT5/6 ETHERNET

CAT5/6 Ethernet, or Category 5 and Category 6 Ethernet, each uses a network cable made of four twisted pairs of copper wire terminated by an RJ45 connector. It is the cabling most often used in home and business IT networks, transmitting data at high speeds ranging from 10 Mbps to 10 Gbps.

4.1.5. IP T1L ETHERNET

IP T1L Ethernet is a newer open standard that utilizes a single twisted pair of wires, potentially the same wiring and connectors used in traditional BMS networks (such as MS/TP or LonWorks®). It can operate with cables up to 1000 meters long and transmit data at high speeds of up to 10 Mbps.

4.2 IP NETWORKS

Depending on the project, building, and budget, CAT5/6 Ethernet can be used in the field. CAT5/6 resolves many shortcomings of traditional networks. However, CAT5/6 networks also have their drawbacks.

For example, to ensure resilience in a CAT5/6 network, it is recommended that the distance between devices be kept at just 50 meters. Additionally, unless the installation is set up to use pre-made or precisely measured cables, costs can add up rapidly due to factors such as cabling installation, connection points, and distance.

By comparison, the 10BASE-T1L standard can use the same simple connectors as traditional networks. It defines a maximum distance of 1000 meters. **However, to improve network resilience, the recommended distance between IP T1L devices is 300 meters.**

Why do these shorter distances increase network resilience?

The strategy involves positioning devices close enough so that if two switch off unexpectedly, the rest of the network can remain stable and functional, allowing the other devices on the network to continue communicating.

IP T1L Ethernet has a recommended distance six times longer than CAT5/6 Ethernet. It can provide similar IP capabilities and security using less expensive and easier-to-install and maintain cabling. This is especially true when it reuses cable already installed in the building.

SECTION 5: SYSTEM OVERVIEW

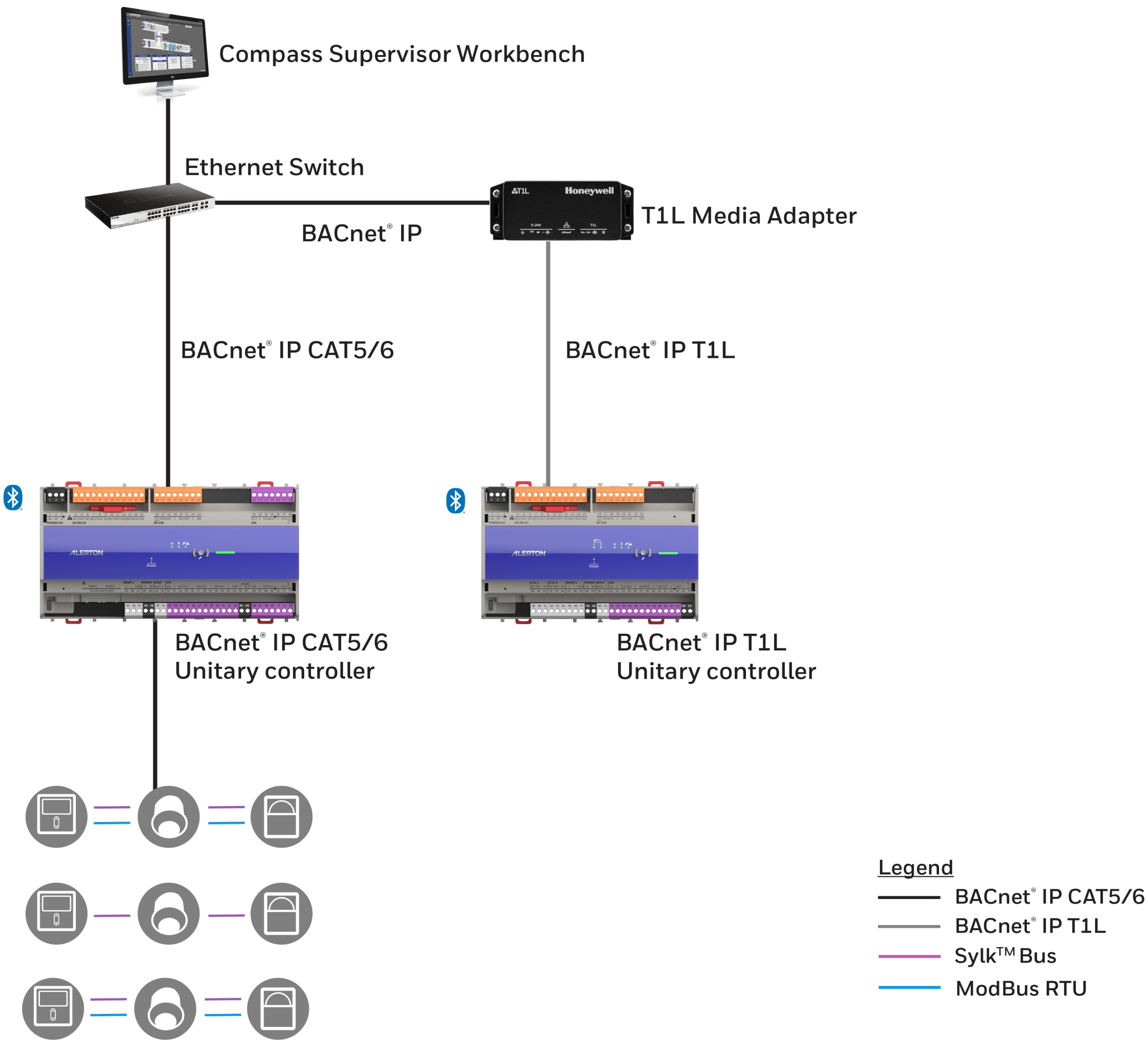


Figure 5.1: System Overview

SECTION 6: CABLING AND SPECIFICATION

In the IEEE Std 802.3cg™-2019, IEC 61156-13:2023 describes cables intended to be used for transmission of 10 Mbit/s over a single twisted pair and distances of up to 1 km. The transmission characteristics of these cables are specified up to a frequency of 20 MHz.

The cables below have been tested by Alerton and our supplier, and the maximum distance may vary based on the number of devices connected and the environment. Refer to the Scenarios"Section 8: Network Connections" on page 18.

Ensure the quality of cable connection is good. It is important that all connections are tight, twisted pair cables are not untwisted for more than required to terminate, the bend radius of the cable is respected.

Table 6.1: Cable Specifications

Cable	Typical Uses	Cable Characteristics	Max Distance (between working nodes)
74040NH – Belden #	T1L- Long distance harsh environments	2 cores solid 18AWG,SF/UTP Shielded and foil, unshielded twisted pair.	1000 m
8471 – Belden #	LON	2 cores stranded/tinned 16AWG, unshielded cable.	560 m
9841 – Belden # TP/1/1/24/200/HF-600V	MSTP (Serial)	2 cores stranded/tinned 24AWG, Foil shield & drain wire, twisted pair.	400 m
8723NH – Belden # ~ TP/2/2/22/200/HF-600V	Trend 4 wire LAN	4 cores, 2 pairs, stranded/tinned, 22AWG, Foil shield & drain wire, twisted pairs.	200 m
8761NH – Belden # TP/1/1/22/200/HF-600V	Trend 2 wire LAN	2 cores stranded/tinned, 22 AWG, Foil shield & drain wire, twisted pairs.	320 m
5501UE 0081000 – Belden/BAV	Security, speaker, PA, & telephone systems	3 cores stranded bare copper, 22 AWG, no shield or twist.	600 m
82836 – Helukabel *	Profibus - Industrial Ethernet	2 cores solid, 18AWG Foil + braded screen twisted pair.	800 m
3076F – Belden *	Harsh environment digital and serial two-way communication	2 cores solid 18AWG, Shielded and foil, unshielded twisted pairs.	428 m
Helukabel J-Y(ST)Y LG *	Telecommunications & Fire Alam Cable (Fire Warning Cable)	Multicore solid bare copper, 20AWG (0.8mm), foil wrapped.	320 m
CAT5/6	Standard wired IT network cable	8 core, 4 pairs, solid bare copper, 23AWG, twisted pairs.	720 m
0043280ALR - Windy City Wire	BACNet, Alerton Ascent & BACTALK MS/TP Plenum, VLX-EXP Comm Bus, IBEX Alerton LAN Plenum	22 AWG 2 Conductor Tinned Copper, Shielded Plenum Lo-Cap	600 m
042002 – Windy City wire 24-1P OAS STR CMP LC Org Jkt/ 24AWG	BACnet/RS232/485/T1L	1 Pair, 24 AWG Tinned Copper Shielded RS-232, RS-422, RS-485 Low Capacitance Communication, Instrumentation and Special Application Plenum Cable	300 m

NOTE

Depending on the cable type and assuming the distance between functional nodes does not exceed the maximum stated above, the maximum number of offline IP T1L devices on the bus varies between 2 and 10 for daisy-chaining to remain functional.
* Testing source - Analog Devices standard IP T1L cable testing.
# Testing source - Analog Devices standard IP T1L cable testing.
~ Do not combine pairs as this impacts performance.

SECTION 7: STANDARDS AND SPECIFICATIONS

7.1 NETWORK PROTOCOLS

A protocol is a set of rules that two or more devices must follow to communicate with each other. It includes everything from the meaning of data to the voltage levels on connection wires. A network protocol defines how a network will handle the following problems and tasks:

- Communication line errors
- Flow control.
- Access by multiple devices
- Failure detection
- Data translation
- Interpretation of messages

Networks adhere to specific protocols to facilitate the transmission and reception of data across the network medium.

The Open Systems Interconnection (OSI) reference model, or ISO IS 7498, offers comprehensive guidelines for network protocols. This model organizes the functions that protocols must execute into seven hierarchical layers. Each layer exclusively interfaces with its adjoining layers and operates independently from the other layers. Refer to the below figure for IP T1L Network layers.

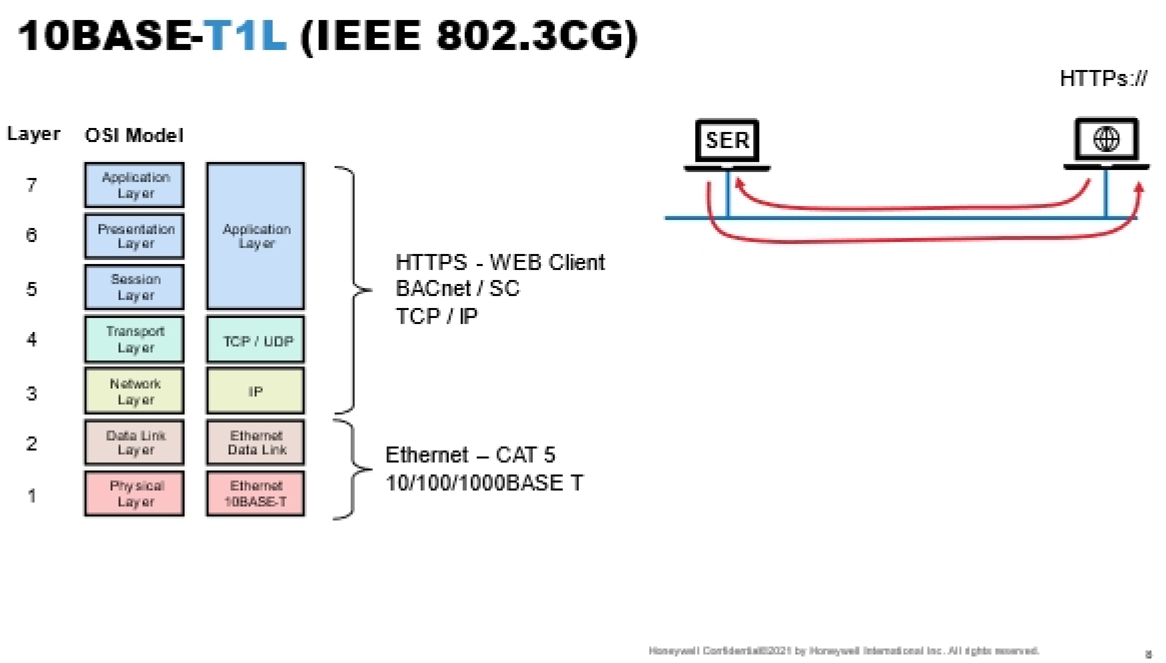


Table 7.1: Details of OSI reference model layers

Layer number	Layer Name	Function
Layer 7	Application	The level seen by users; the user interface
Layer 6	Presentation	The system executes control functions as the user requests and undergoes data restructuring from various standard formats. Additionally, it includes the conversion of code and data.
Layer 5	Session	This interface manages the system-to-system connection and enables control over log-in and log-off processes. It also serves as the platform for establishing and terminating connections.
Layer 4	Transport	The system ensures dependable data transfer between end devices; the protocol establishes network connections for each transmission.
Layer 3	Network	Outbound communications are segmented into packets, and inbound packets are reassembled into messages, facilitating interconnections between networked equipment at higher protocol layers.
Layer 2	Data link	Outgoing messages are organized into frames for transmission and then acknowledged; error detection and correction are performed.
Layer 1	Physical	Parameters such as signal voltage swing, bit duration, and electrical connections are established at this layer.

The network's layers from layer 7 to layer 3 remain mostly the same as standard IT protocols, but layer 2 and layer 1 will change because of the T1L device.

The beauty of T1L (10BASET1L) is it simply defines a new network standard for the physical layer, one which is suitable for building and process automation. Its characteristics of cable, connectors and electrical signals are more suited to our needs than those of CAT5/6 (10Base10/100/1000).

A simple 2 core cable can be used with screw or push fit terminals, rather than a multi core (4 core) cable with an RJ45 plug/socket arrangement. Distances are increased from 100m to up to 1km.

However, as it is just a change to the lowest layer in the networking model, with the interfaces between the layers still respected, then standard applications using a TCP/IP or UDP/IP network can still operate on the solution.

When the T1L supported device is connected to the system, as shown in the figure below, parameters such as signal voltage swing, bit duration, and electrical connections will be established based on the 10BASE-T1L communication.

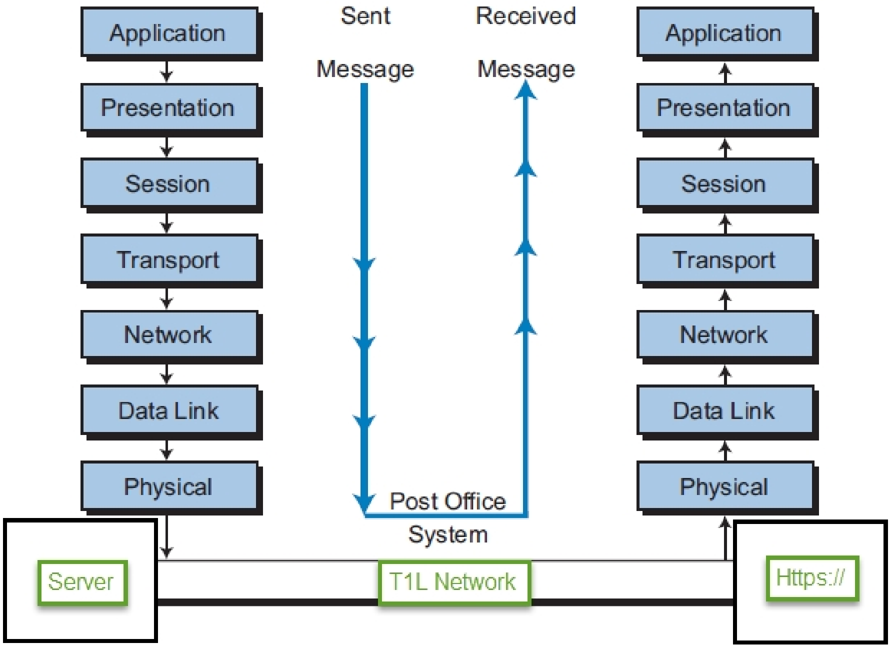


Figure 7.1: Network Layer

7.2 IEEE STANDARDS

The IEEE 802.3 standard, developed by the Institute of Electrical and Electronics Engineers (IEEE) in partnership with the International Organization for Standardization (ISO), covers the specifications for local area networks (LANs) with transmission speeds ranging from 1 to 20 megabits per second. The ISO has accepted this standard as its own (ISO 8802) and governs the specifications for layers 1 and 2A of the OSI model..

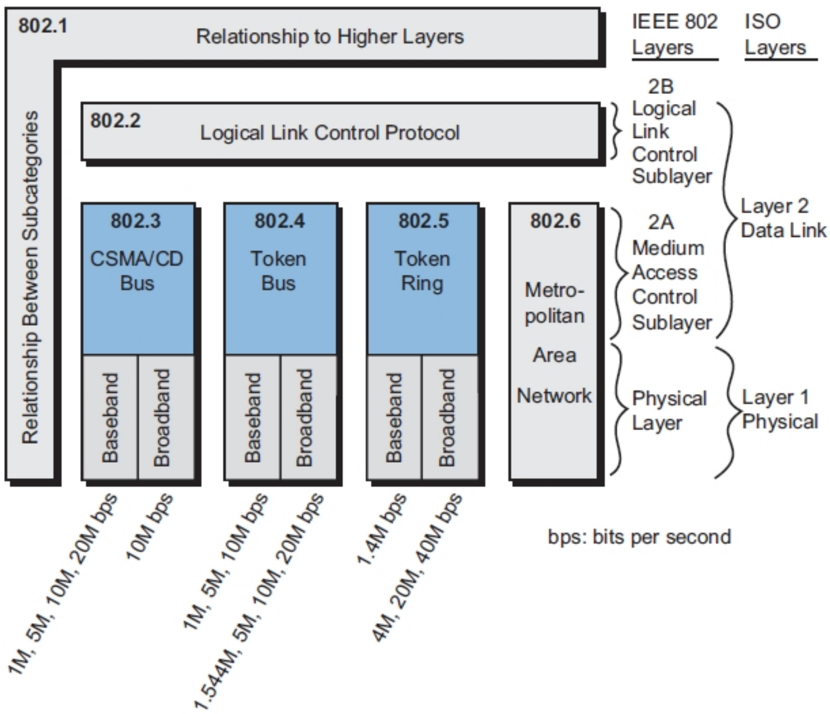


Figure 7.2: IEEE 802 Standard

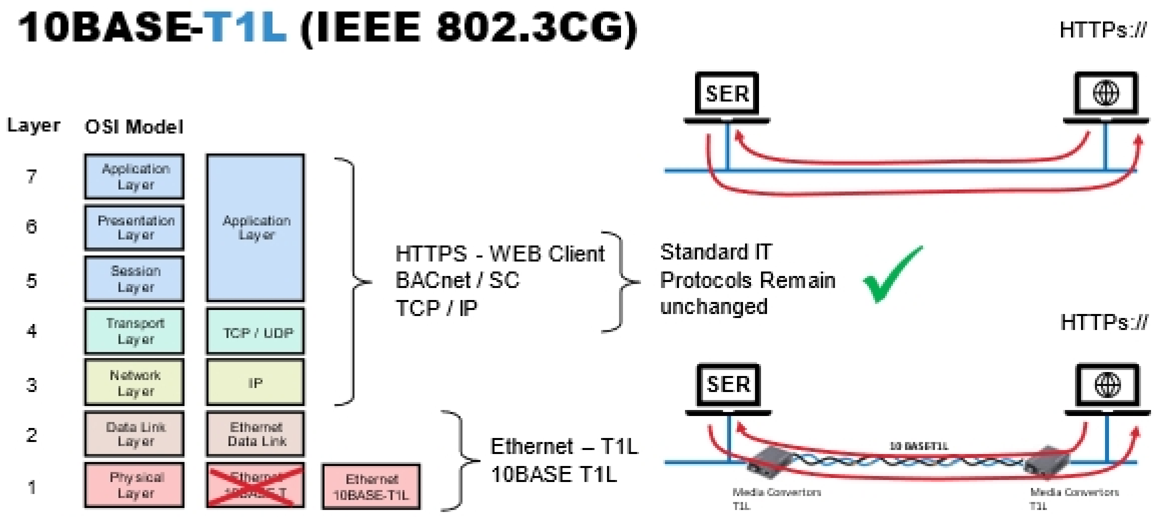


Figure 7.3: 10BASE-T1L Network Layer

SECTION 8: NETWORK CONNECTIONS

8.1 DETAILS

Assume that you have devices connected through Ethernet connection and now user want to utilize the benefits of the T1L networking. User must replace the existing controllers with the T1L supported controllers and connect the Ethernet.

8.2 SYSTEM OVERVIEW

Unitary and VAV Controllers

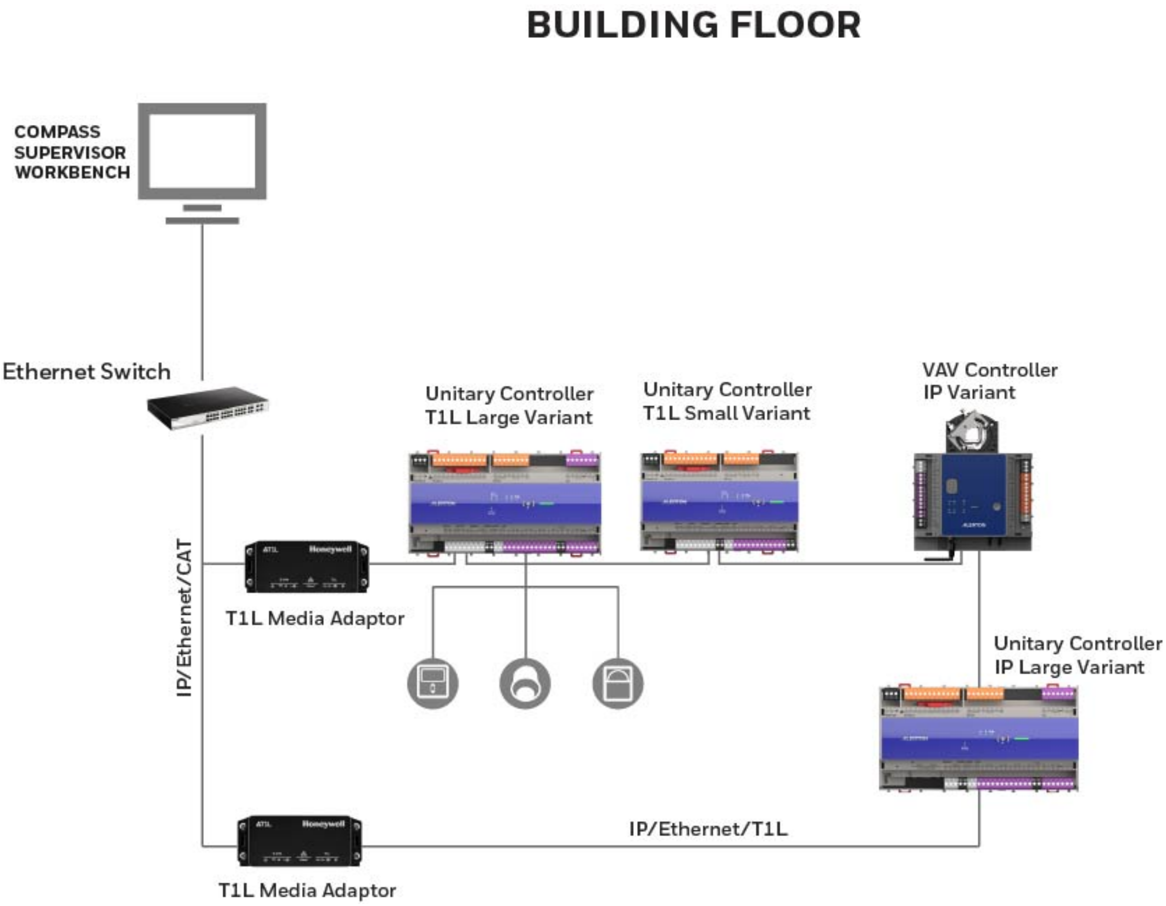


Figure 8.1: Unitary Controller System Overview

8.3 INSTALL AND REUSE OF EXISTING NETWORK

This sections explained the various scenarios of installing the T1L unitary controller and reusing the existing cabling.

> **NOTE:** The devices are subjected to vary from project to project.

Rules to follow:

01. Distance between the each (working nodes) device should not exceed the max distance of the cable support.
02. Design the network accounting for the fail-safe limitations which are dependent on the type of cable.
03. Design the network accounting for the fail-safe limitations which are dependent on the distance between functional nodes.
04. Media adapter is Layer 1 device and does not count as a BACnet device

8.3.1. SCENARIO

Cable specification may change based on the installation requirement and site. For specifications refer to the "Section 6: Cabling and Specification" on page 12.

> **EXAMPLE**
>
> 74040NM cable is used here. Based on the cable specification the distance will change.

- **Cable:** 74040NM - Belden
- **Cable Characteristics:** 2 cores solid 18AWG,SF/UTP Shielded and foil, unshielded twisted pair.
- **Maximum distance between each device:** 1000 m
- **Devices:** T1L supported controllers

8.3.1.2. Multiple device in a network communication

Background:
A company utilizes an Ethernet-based building automation network to manage various machines and processes on the same floor. This network consists of multiple controllers connected in a daisy-chain configuration, with each controller overseeing a specific section of the manufacturing process. The T1L cables used in this setup can support a maximum distance of 1000 meters between each device.

A user has set up an Ethernet-based network to connect 10 controllers on the same floor of a building. The network is configured in a daisy-chain topology, where each controller is connected to the next. The Twisted Pair cable used can support a maximum distance of 1,000 meters between each device. However, the total distance from controller 1 to controller 10 is 3,600 meters.

Network Configuration:

- **Controller 1 to Controller 2:** 200 meters
- **Controller 2 to Controller 3:** 200 meters
- **Controller 3 to Controller 4:** 500 meters
- **Controller 4 to Controller 5:** 500 meters
- **Controller 5 to Controller 6:** 500 meters
- **Controller 6 to Controller 7:** 500 meters

- **Controller 7 to Controller 8:** 200 meters
- **Controller 8 to Controller 9:** 500 meters
- **Controller 9 to Controller 10:** 500 meters

Normal Operation:

Each controller communicates with the central control system and other controllers to coordinate the manufacturing process during normal operation. Data flows through the network seamlessly, enabling real-time monitoring and control of the machines.

Communication Success:

01. All controllers are working and communicating.

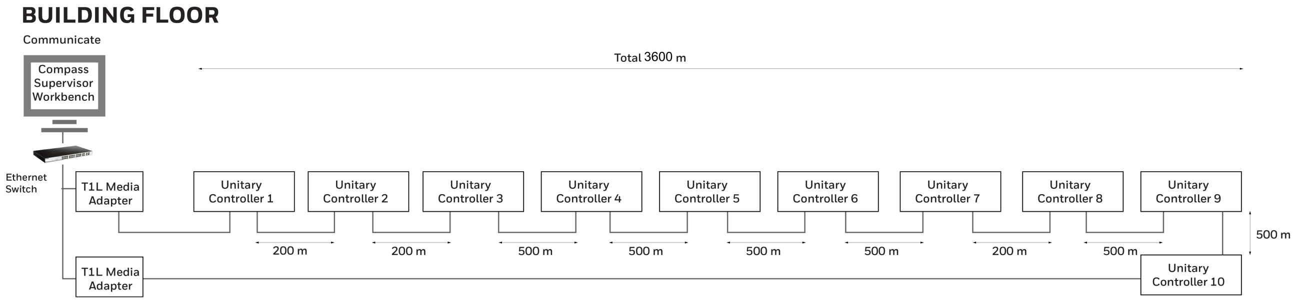


Figure 8.3: Communication Success

02. Controllers 2, 3, and 6 fail simultaneously, but the communication is success because the total distance between the failed devices are with in the maximum cable distance.

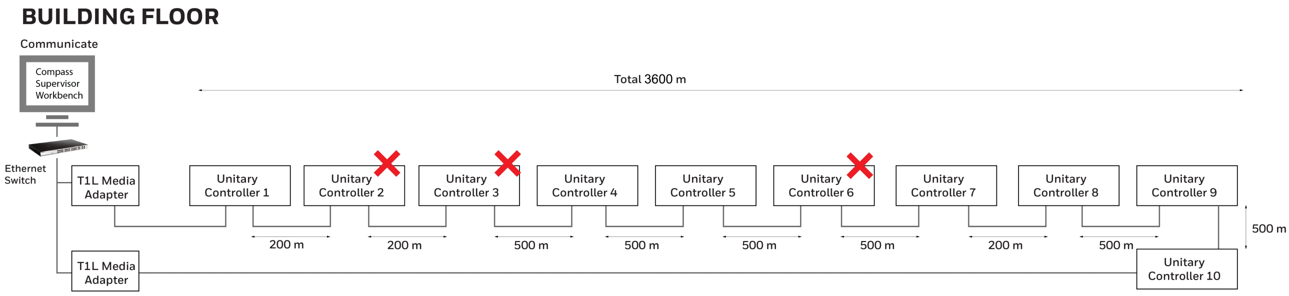


Figure 8.4: Communication Success

Communication Loss:

01. Controllers 2, 3, and 4 fail simultaneously, resulting in a total distance of 1400 meters of network disruption.

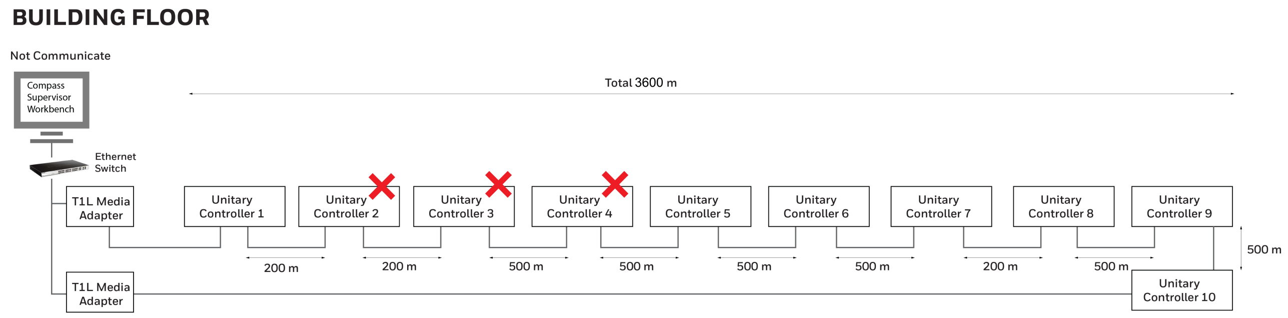


Figure 8.5: Communication Loss

02. Controllers 2, 3, 4,5, 6, 7, 8, 10 and 11 fail simultaneously. The devices distance are with in the cable maximum distance, but the maximum device limit exceeds (10 devices in a network) so the network disrupts.

- **Controller 1 to Controller 2:** 100 meters
- **Controller 2 to Controller 3:** 100 meters
- **Controller 3 to Controller 4:** 50 meters
- **Controller 4 to Controller 5:** 50 meters
- **Controller 5 to Controller 6:** 50 meters
- **Controller 6 to Controller 7:** 100 meters
- **Controller 7 to Controller 8:** 50 meters
- **Controller 8 to Controller 9:** 100 meters
- **Controller 9 to Controller 10:** 100 meters
- **Controller 10 to Controller 11:** 50 meters
- **Controller 11 to Controller 12:** 100 meters

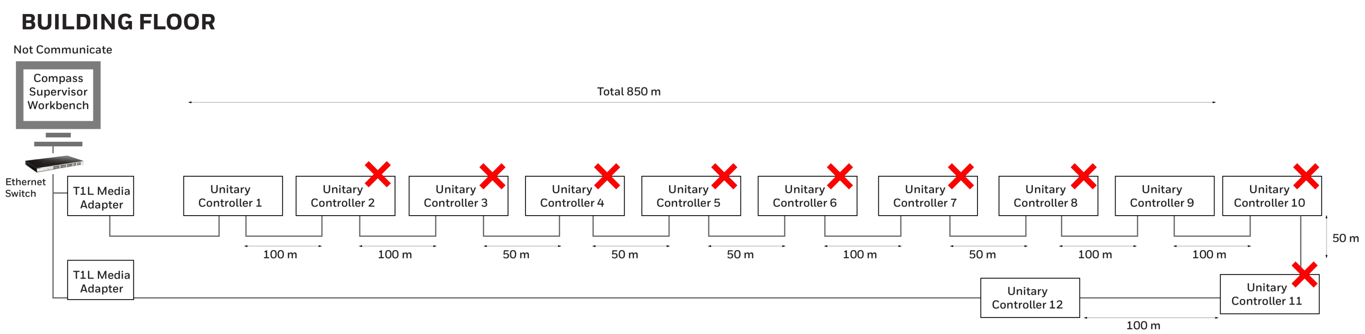


Figure 8.6: Communication Loss

8.3.1.7. Device to Device Connection

If you are connecting the controllers with in the same building floor or across the building floors with the same parameters. The network has a different distance between devices and has total 1000 m. If one device goes down than the communication will be disrupted in the network.

Communication within the building:

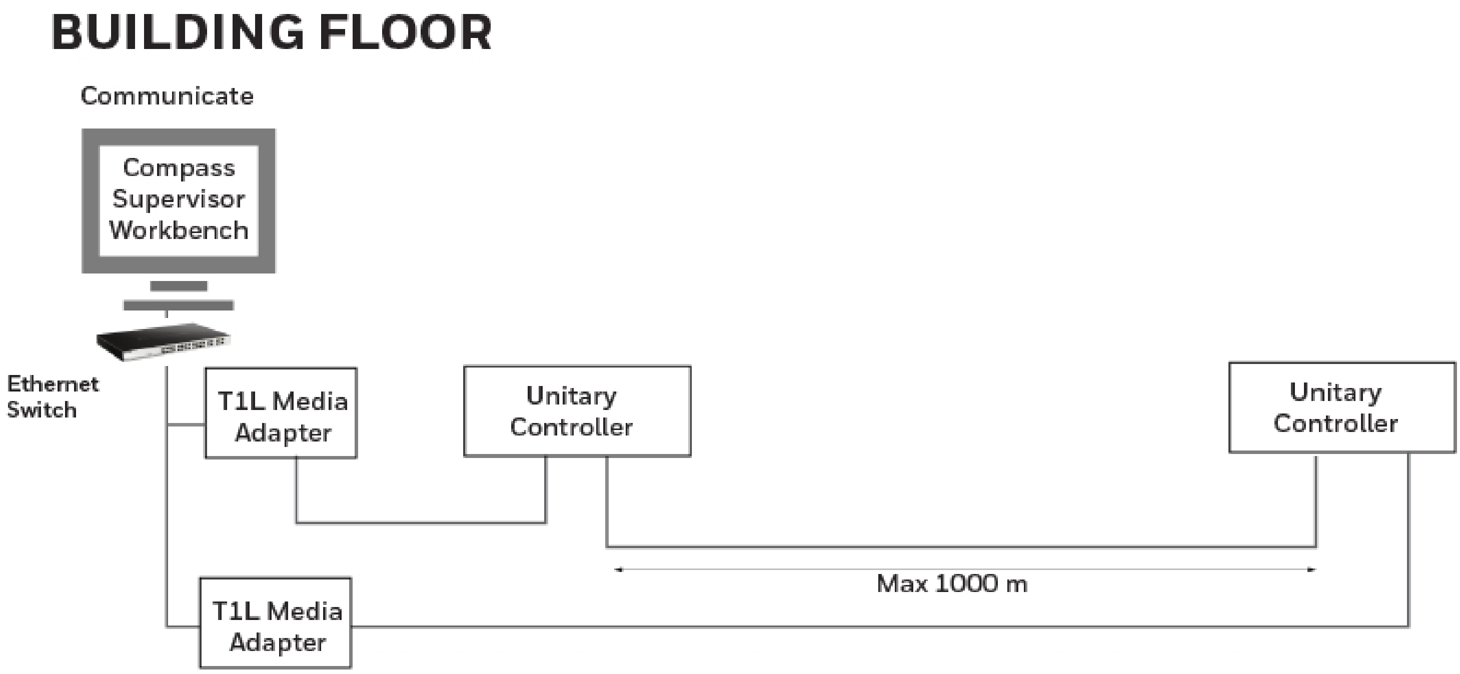


Figure 8.8: Communication Success

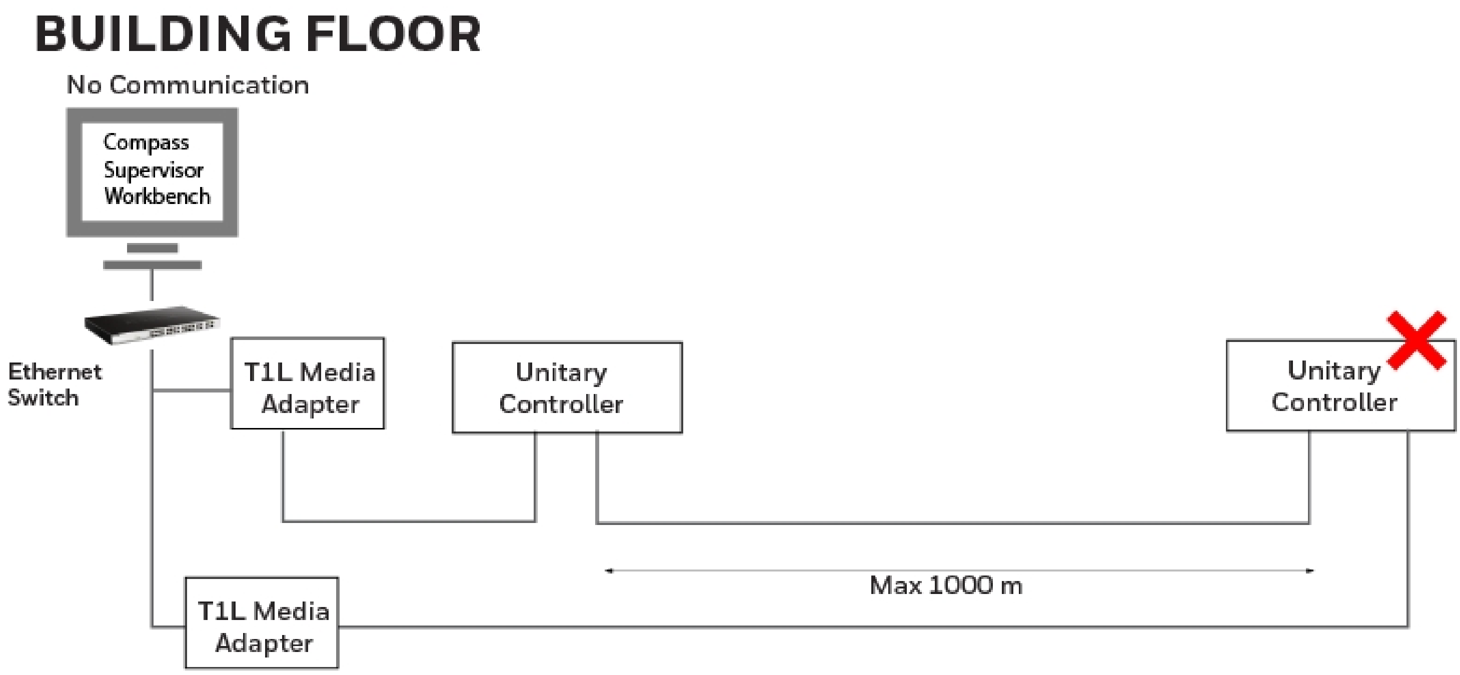


Figure 8.9: Communication Loss

Communication Across the building:

BUILDING FLOOR A TO BUILDING FLOOR B

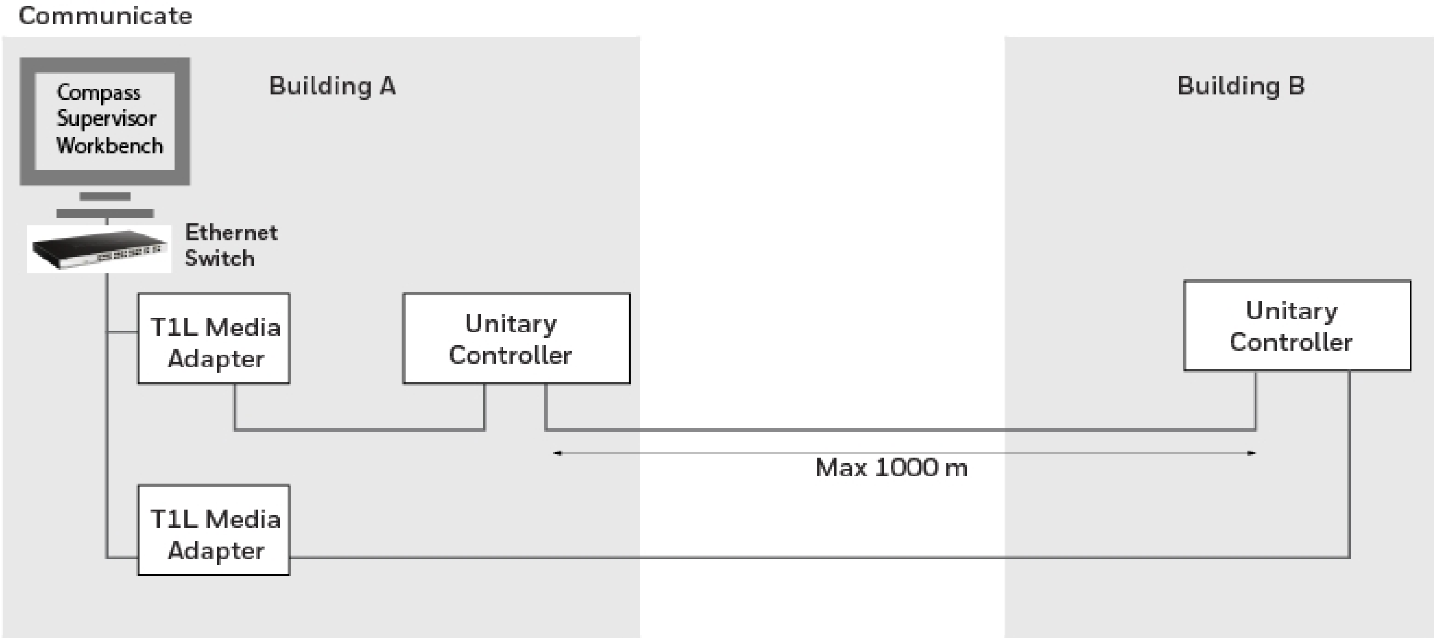


Figure 8.10: Communication Success

BUILDING FLOOR A TO BUILDING FLOOR B

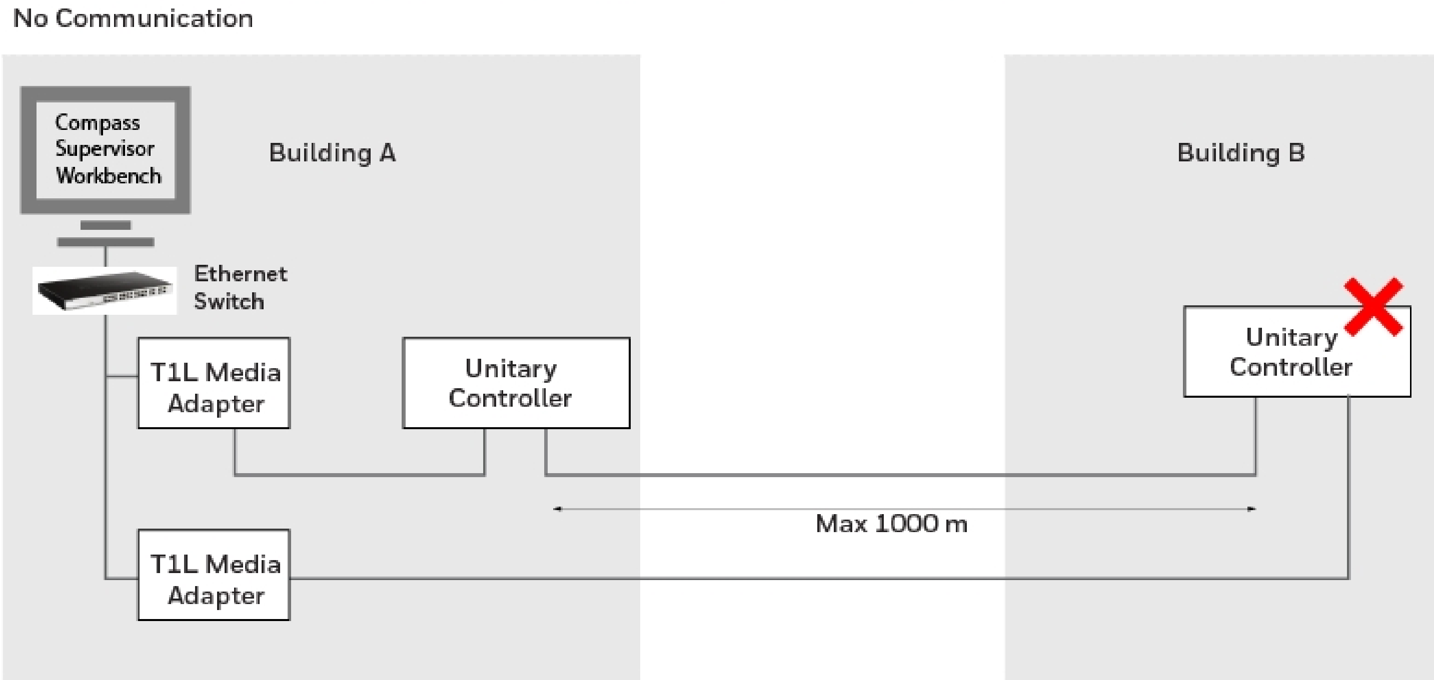


Figure 8.11: Communication Loss

SECTION 9: REFERENCE

T1L Media Adapter Datasheet - 31-00581