


Networking & Communication in Signal Systems

Course 351

PARTICIPANT GUIDE

SIGNALS TRAINING CONSORTIUM

Networking and Communication in Signal Systems

Participant Guide

Signals Maintenance Training Consortium

COURSE 351

Disclaimer: This course is intended to educate employees of transit agencies that have agreed to voluntarily participate in the Signals Maintenance Consortium. It is intended only as informal guide on the matters addressed, and should not be relied upon as legal advice. Anyone using this document or information provided in the associated training program should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of care in any given circumstances. The Signals Consortium, it's participating agencies and labor unions, as well as the Transportation Learning Center, make no guaranty or warranty as to the accuracy or completeness of any information provided herein. The Signals Consortium, its participating agencies and labor unions, as well as the Transportation Learning Center, disclaims liability for any injury or other damages of any nature whatsoever, directly or indirectly, resulting from the use of or reliance on this document or the associated training program.

NOTE: All images contained within this document were contributed by Signals Training Consortium members unless otherwise noted.

TABLE OF CONTENTS **PAGE**

How to Use the Participant Guide

Purpose of the Course

The purpose of the *Networking and Communication in Signal Systems* course is to provide the participant with an introduction to networking and communication for signal maintainers. This introduction will include basic terminology; regulations and oversight specific to networking and communication; common components; common types of software; inspection, maintenance, and testing; and troubleshooting and repair.

Approach of the Book

This course begins with an outline, a statement of purpose and objectives, and a list of key terms. The *outline* will discuss the main topics to be addressed in the course. A list of *key terms* identifies important terminology that will be introduced in this course. *Learning objectives* define the basic skills, knowledge, and abilities course participants should be able to demonstrate to show that they have learned the material presented in the course. A list of *key terms* identifies important terminology that is introduced in this course. *Review exercises* conclude this course to assist the participants in reviewing key information.

Glossary of Terms

Term	Definition
Address Resolution Protocol (ARP) Application Layer	Protocol within the physical layer of the TCP/IP Model.
Analog signal	Signals transmit information usually through electrical signals and information is translated through electrical pulses of varying amplitude and displayed in a wave-type pattern.
Antenna-radio	Sometimes used in rail and signal network and communication systems, and in particular, in positive train control (PTC) and Communication Based Train Control (CBTC) systems. Collect and convert electromagnetic waves to electronic signals. Transmission lines then guide these signals to the receiver front end.
Application Layer	OSI Model Layer 7 – allows for the request of network services through applications; contains a variety of protocols commonly required; provides the file transfer function as different file systems have different file naming conventions, different ways of representing text lines, etc.; and, handles the incompatibilities between different systems. TCP/IP Model Layer - presents applications with data exchange that is standardized.
ARCnet (Attached Resources Computer Network)	Protocol - a widely-installed LAN technology that uses a token-bus scheme for managing line sharing among the workstations and other devices connected on the LAN.
ARPANET	A WAN in use before the internet.
Asynchronous transmission	Information sent byte by byte, is cheaper and more commonly used.
Bandwidth	A range of frequencies within a given band used for transmitting a signal, or the capacity for data transfer, or transmission, of information in an electronic communication system.
Bandwidth measurement	Analog signal: the bandwidth is the difference between the highest and lowest frequencies that can be sent over an analog link. Digital signal: measured in the number of bps that can be sent over a link, and the wider the bandwidth, the more diverse kinds of information can be sent.
Base radio	Provide a base role in the PTC and provide radio frequency (RF) connectivity between the locomotive and the back office applications.
Baselines	Numeric values used to reference and identify intended proper operation of networks and related equipment, often developed at installation and/or provided in OEM material.
Baud rate	The number of bits that travel down the channel in a given interval; given in signal changes per second.
Bit	Short for binary digit and is the smallest unit of data in a computer with a single binary value of either 0 or 1.

Module 1

INTRODUCTION TO NETWORKING AND COMMUNICATION IN SIGNAL SYSTEMS

Outline

Outcome and Objectives:

The participant will understand and be able to explain the history of communication in signaling, current communication and networking practices, and basic networking and communication concepts.

Following the completion of this module, the participant should be able to complete the exercises with an accuracy of 70% or greater:

- Define network and communication
- Explain types of communication in rail and transit systems
- Explain types of networks in rail and transit systems
- Explain control center communication with rail operation.
- Describe network and communication safety and security

Key Terms

- Business network
- Communication
- Encryption
- Firewall
- Quality of Service (QoS)
- Network
- Network enclave
- Router
- Supervisory Control And Data Acquisition (SCADA)
- Virtual Private Network (VPN)
- Vital network
- Virtual LAN

1-1 OVERVIEW

Signal networking and communication plays a major role in any rail & transit signaling system. A **network** consists of two or more entities or objects sharing resources and information. As we build on this in a signaling system, we further define a network as a group of computers and other devices connected in some way so as to be able to exchange data.

In a signaling system, **communication** refers to the reception and transmission of data between two or more locations which may include any: train and wayside equipment or the central instrument location (CIL) and train control center. Communication in signal networking systems can provide controls, error messaging, indications, monitoring features and many other attributes that a rail agency may request. Computers and microprocessor-based devices are key components of signal networking and communication systems. The illustration below in Figure 1 shows the basic signal communication that exists between the train to the wayside or central communication location to the central train control. The wayside location communicates to other wayside locations and then back again to the train for safe and effective train operation.

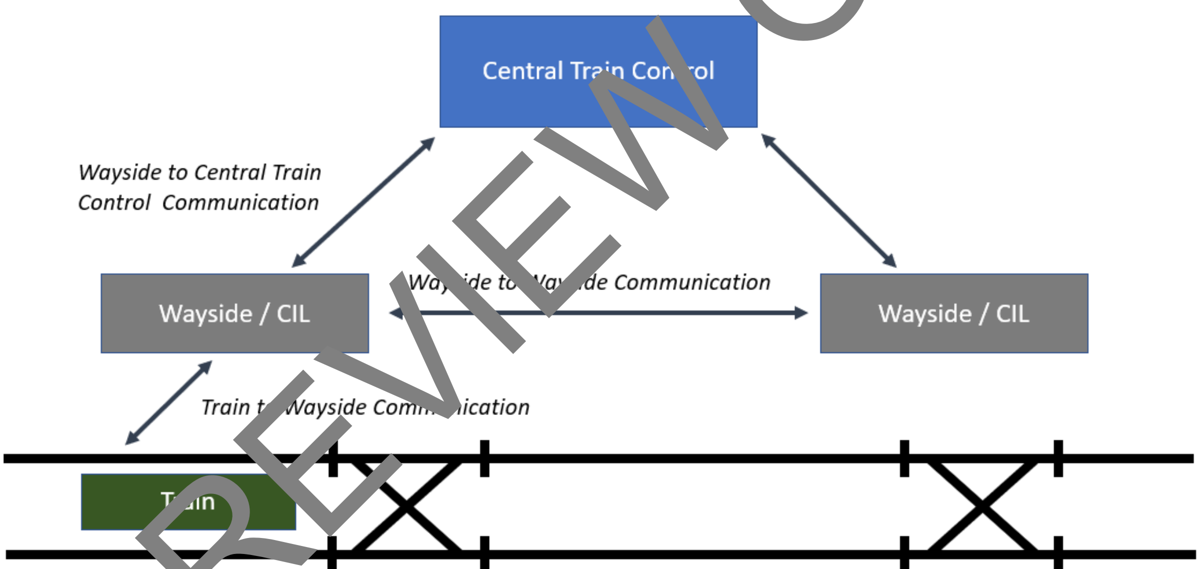

Figure 1 Train Communication

As train control systems have advanced, many track circuit systems are being enhanced with modernized communication-based systems. The computer-based communication systems are comprised of a series of networks allowing for the communication between computer systems and other computing devices connected together for the purpose of sharing information and data. This sharing of information and data allows for the safety in movement of trains throughout the rail system. As these train control communication systems have impact on the signal system, signal maintainers must have knowledge of the systems for certain job tasks.

Communication in Rail Systems

Communications take place across rail and transit agencies in many ways. As described above, communication takes place between trains, wayside locations and central train control for the purpose of safe movement of trains throughout the rail and transit system. Communication also takes place between the customers and organization in areas such as ticket vending machines, video surveillance, and schedule displays; within the agency between employees such as between maintainers and control center operators; and across the organization from rail vehicles to wayside equipment to CILs to control center operations.

Communication equipment for these purposes often includes, but is not limited to:

- Signage
- Phones (wired)
- Video
- Cellular and backup (used as backup if fiber is cut)
- Data radio
- WiFi
- Microprocessor
- GPS, satellite systems, transponders

The illustration below shows some of the areas of communication taking place in a typical rail or transit agency.

Networks in Rail Systems

Various types of networks to support various communications exist across rail and transit systems. Networks in rail and transit systems generally include:

- SCADA
- Vital
- Business

Supervisory Control Data Acquisition, or **SCADA**, systems use a combination of hardware and software along with radio and/or direct-wired connections to create highly distributed systems for rail and transit agencies to control assets, or equipment, often scattered over a large geographical region where centralized data acquisition and control are critical to system operation. A control center performs, that is part of the SCADA system, centralizes monitoring and control for field sites over long-distance communications networks, including monitoring alarms and processing status data. Information sent to SCADA central control from remote areas of the rail or transit system can generate automated or operator-driven supervisory commands that can then be pushed to field devices. Field devices control local operations such as collecting data from sensor systems and monitoring for alarm conditions.

Like SCADA, **vital networks** are also comprised of a combination of hardware and software along with radio and/or direct-wired connections used for vital operations within the rail or transit agency.

Again, comprised of a combination of hardware and software along with radio and/or direct-wired connections, **business networks** provide the means for communication for organization business purposes such as organization email, public media communication, etc.

A signal maintainer should have knowledge of the network systems that are part of their rail or transit agency.

Classroom Activity 1.1

With guidance from your instructor, list the networks that exist in your rail or transit agency.

Module 2

NETWORKING AND COMMUNICATION BASICS

Outline

2-1 Overview
2-2 Communication and Data Transmission
2-3 Network Basics
2-4 Summary

Outcome and Objectives

The participant will understand and be able to explain the essentials for communication including data transmission and networking concepts.

Following the completion of this module, the participant should be able to complete the exercises with an accuracy of 70% or greater:

- Describe essentials for communication
- Explain data transmission
- Explain key network concepts

Key Terms

- Analog signal
- ARCnet (attached Resources Computer Network)
- Asynchronous transmission
- Bandwidth
- Bandwidth measurement
- Baud rate
- Bit
- Bit error rate (BER)
- Bits per second (Bps)
- Broadcast links
- Bytes
- Bus typology
- Category
- Channel
- Client/server networks
- Data
- Data movement
- Data rate
- Desktop area network (DAN)
- Digital signal
- Domain Name System (DNS)
- Error rate
- Ethernet
- FDDI (Fiber Distributed Data Interference)
- Full-duplex Transmission
- Full mesh typology
- Gateway computer
- Gbps
- Guided medium
- Half-duplex transmission
- Hertz
- Hyper Text Transfer Protocol (HTTP)
- Internet protocol (IP) address
- Kbps
- Latency
- Link capacity
- Local area network (LAN)
- Mbps
- MAC (Media Access Control)
- Medium
- Mesh typology
- Metropolitan area network (MAN)
- Multichannel
- Multiplexing
- Network protocol
- Network typology
- Non-broadcast Multi-access (NBMA) links
- Nodes
- Noise
- Open Transport Technology (OTN)
- Partial mesh typology
- Peer-to-peer networks
- Point-to-Point links
- Radio wave
- Ring typology
- Routes
- Semantics
- Serial Line Internet Protocol (SLIP) / Point to Point Protocol (PPP)
- Server
- Signal speed
- Simple Network Management Protocol (SNMP)
- Simplex transmission
- Single channel
- SONET (Synchronous Optical Networking)
- Star typology
- Synchronous transmission
- Syntac
- Telecommunication
- Telnet
- Timing
- Token ring
- Transmission control protocol / Internet Protocol (TCP/IP)
- Transmission medium
- Tree typology
- Trunking
- Typology
- Unguided medium
- Wide area network (WAN)

2-1 OVERVIEW

In order to understand networks and communication systems in rail and transit agencies, fundamental knowledge and key concepts must be identified and described. Module 2 explains these key concepts necessary for foundational knowledge related to networks and communication.

2-2 COMMUNICATION AND DATA TRANSMISSION

Before examining key network concepts, it is important to first describe basic concepts related to communication and data transmission including:

- Communication Essentials
- Data Transmission
- Digital Communication and Hierarchy

Communication Essentials

Communication is activity associated with distributing or exchanging information often for a purpose. Humans have communicated with one another since the earliest primitive humans inhabited the earth. In those pre-historic times, human communication involved cave pictures drawn on walls of the caves, some of which can still be viewed today. Earliest written records using a consistent system of symbols date as far back as ancient Mesopotamia, 3500 B.C.

Telecommunications involves the technology of communication over distances which permits information to be created or obtained in any location and shared to any other location within some distance, as determined by the **medium**, or technology used for communication, with little delay. Early telecommunication involved smoke signals and drum rhythms used to pass messages. As time progressed, animals became mediums for helping to transport messages. In wars, battlefield music was used to send messages to troops. In 1835, the electric telegraphy was invented by Joseph Henry and Edward Davey successfully demonstrated an electromagnetic rely with an electrical signal amplified and transmitted across long distances. Not long after, Samual Morse developed the Morse code, a system that correlated numbers, letters and characters to signal-induced indentations. In 1876, Alexander Graham Bell was granted a patent for improving technology for telegraphy and electromagnetic telephones. Modern telecommunication involves not only these early inventions, such as land-line telephone systems, but also utilizes computers and other newer mediums for developing and distributing information over short and long distances.

Essentials for modern telecommunication include the following:

- Message – the content, or **data**, of the communication process
- Transmitter – an electronic device to produce or send data through a signal
- Medium – the channel or system of communication by which the message is transferred from the transmitter to the intended destination
- Language – the method of communication using words, programs or algorithms so the message is understood as it transmitted and received
- Security level – a determination who can access the communication by means of technology

transmission. With analog signals, information is translated through electrical pulses of varying amplitude, and displayed in a wave-type pattern as shown in Figure 2. A digital signal transmits information in binary format of either 0 or 1 where each bit is representative of two distinct amplitudes and displayed in a square-type pattern.

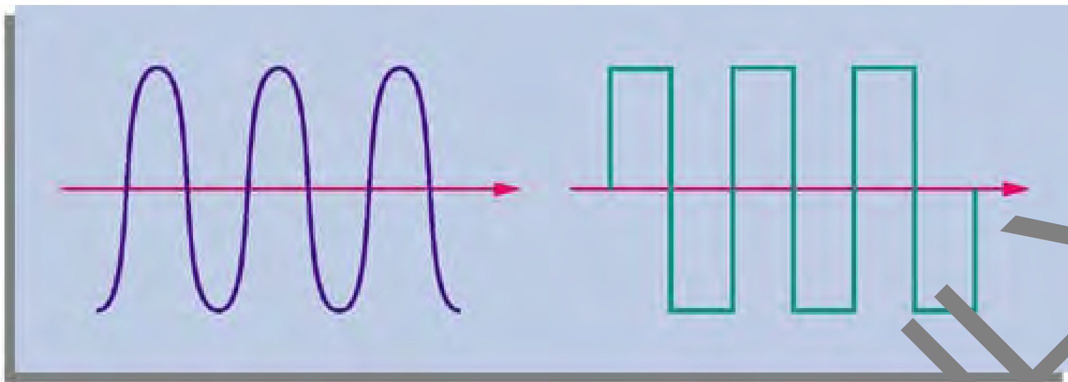

Figure 2 Analog and Digital Signal Waves - courtesy of SEPTA

For more information on analog and digital signals, including a comparison chart, see Diffen's web page: "Analog vs. Digital" @ **https://www.diffen.com/difference/Analog_vs_Digital**

Signal Speed. Signal speed is the speed at which the signal is transmitted, or how fast the data travels from one place to another. In digital systems, speed is measured in **bits per second (bps)** and **baud rate**. Bps refers to the number of bits, 0's or 1's, that travel down the channel per second, whereas the baud rate refers to the number of bits that travel down the channel in a given interval. The baud rate number is given in signal changes per second, not necessarily bits per second.

Link Capacity. As earlier described, the capacity of a communication link is measured in bandwidth. For both analog and digital signal, bandwidth indicates how much information can flow over a channel, and the wider the bandwidth, the more information can flow over the channel.

However, **bandwidth measurement** differs between analog and digital signals. With an analog signal, the bandwidth is the difference between the highest and lowest frequencies that can be sent over an analog link, such as a phone line, and measurement is given in hertz (Hz).

Digital bandwidth is measured in the number of bps that can be sent over a link, and the wider the bandwidth, the more diverse kinds of information can be sent. For example, more simple voice transmission requires a smaller bandwidth while moving videos require a wider bandwidth. Digital data rate measurements in bits include:

- **Kbps** (Kilobits per seconds) – 125 chars/sec
- **Mbps** (Megabits per seconds) – 1,250 chars/sec
- **Gbps** (Gigabits per seconds) – 12,500 chars/sec

Module 3

NETWORKING MODELS

Outline

3-1 Overview
3-2 The OSI Model
3-3 The TCP/IP Model
3-4 Summary

Outcome and Objectives

The participant will understand and be able to explain and compare the two fundamental and widely used networking models.

Following the completion of this module, the participant should be able to complete the exercises with an accuracy of 70% or greater:

- Explain OSI Model
- Explain the TCP/IP Model
- Compare the OSI and TCP/IP Models

Key Terms

- Address Resolution Protocol (ARP)Application Layer
- ARPANET
- Defense Advanced Research Projects Agency (DARPA)
- Data Link Layer
- International Standards Association (ISO)
- Lower Layers
- Network Layer
- Network segments
- Open Systems Interconnection (OSI)
- Physical Layer
- Presentation Layer
- Session Layer
- System Application Architecture (SSA)
- Systems Network Architecture (SNA)
- Transport Layer
- Upper Layers

3-1 OVERVIEW

Two main models for networking include the OSI and the TCP/IP. Module 3 explains each of these models, the layers within each model, and the provides a brief comparison of the two and their respective layers.

3-2 THE OSI MODEL

The **Open Systems Interconnection (OSI)** protocols and model was one of the first network models. The OSI contained a seven-layer protocol called the **Systems Network Architecture (SNA)**. The SNA was a proprietary of IBM architecture and was a set of implementing products for their network computing with an enterprise. The SNA became part of IBM's **System Application Architecture (SSA)** and is currently part of IBM's Open Blueprint. At the time, IBM was a domineering computer company, and the OSI was to be produced like an IBM-reference model. The OSI became the world standard at that time, and was not controlled by any one organization, but instead by a neutral organization, the **International Standards Association (ISO)**.

The OSI is a reference model that defines, or breaks the various aspects of a computer network, into seven layers of functions that take place at each end of communication with each layer adding its own set of special related functions. While the OSI is not a networking standard, the model does specify what aspects of a network's operation can be handled by various network standards. The seven layers include:

- Layer 7 – Application
- Layer 6 – Presentation
- Layer 5 – Session
- Layer 4 – Transport
- Layer 3 – Network
- Layer 2 – Data Link
- Layer 1 – Physical

Layers 1 – 3 are also known as the **lower layers** as they are related to the mechanics of how information is transferred between computers through a network. On the other hand, layers 4 – 7 are also known as the **upper layers** as they deal with the relation of application software and application programming interfaces through the network.

Layer 7, the **Application Layer**, allows for the request of network services through applications; contains a variety of protocols commonly required; provides the file transfer function as different file systems have different file naming conventions, different ways of representing text lines, etc.; and, handles the incompatibilities between different systems. The Application Layer includes protocols such as FTP (File Transfer Protocol), HTTP, Electronic Mail Protocols,

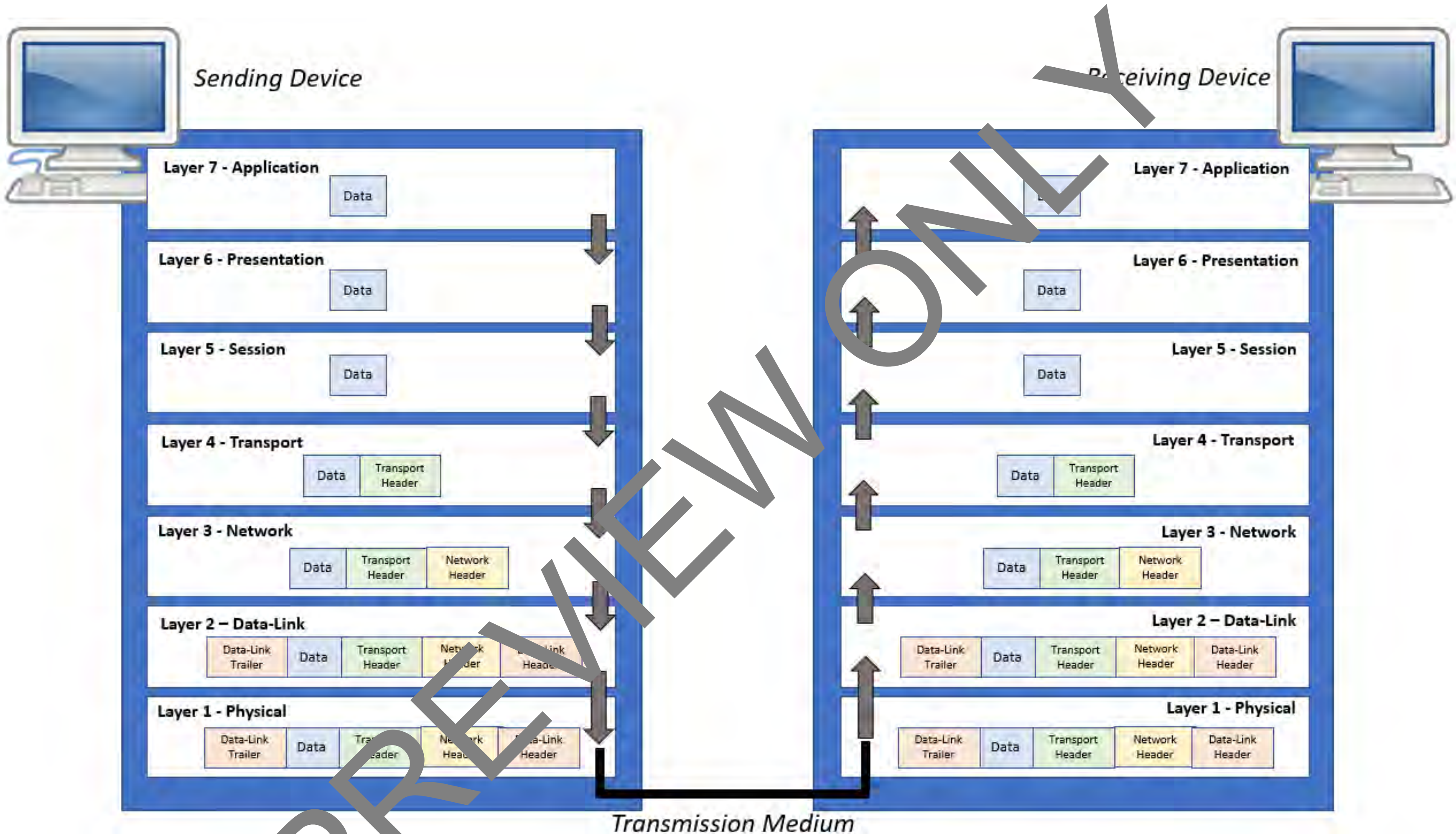

Figure 18 Data Flow – GSandoval, Nhuber 2019

Module 4

HARDWARE & SOFTWARE FOR NETWORKING AND COMMUNICATION

Outline

4-1 Overview
4-2 Computers and Workstations
4-3 Network Devices
4-4 Network Mapping
4-5 Networking and Communication Software
4-6 Summary

Outcome and Objectives:

The participant will understand and be able to explain the hardware and software used for networking and communication in signal systems and most frequently encountered by signal maintainers.

Following the completion of this module, the participant should be able to complete the exercises with an accuracy of 70% or greater:

- Describe common hardware components for rail and transit signal networking systems.
- Explain the importance of network maps.
- Describe common software for networking in rail and transit signal systems

Key Terms

- Antenna-radio
- Bandwidth
- Base radio
- Bridge
- Cable
- Coaxial cable
- Conductor
- D-series connector
- Datalink control (DLC) address
- Desktop personal computer (PC)
- Direct
- Directionality
- Director element
- Driven element
- Electromagnetic interference (EMI)
- Fiber Distributed Data Interface (FDDI)
- Fiber optic cable
- Gain
- Gateway node
- Gauge
- Graphical User Interface (GUI)
- Host node
- Hub
- Jacket/sheath
- Isotropic antenna
- LC connector
- Locomotive radio
- Locomotive radio
- Media access control (MAC) address
- Media converter
- Modal dispersion
- Modem
- MT RJ connector
- Multilayer switch
- Multimode fiber
- Network devices
- Network Interface Card (NIC)
- Network map
- Network operating system (NOS)
- Omnidirectional antenna
- Plastic optic fiber (POF)
- Polarization
- Radio wave
- Repeater
- Reflector element
- Ribbon cable
- RJ45 connector
- Safety and security software
- Serial cable
- Server
- Server language
- SFP connector
- Shielded twisted pair (STP) cable
- Shielding
- Signaling software
- Single mode fiber
- SC connector
- ST connector
- Switch
- Terminal emulation software
- Transceiver
- Troubleshooting and diagnostic software
- Twisted pair cable
- Unshielded twisted pair (UTP) cable
- Uninterrupted power supply (UPS)
- USB cable
- USB connector
- Wayside radio
- Wireless LAN
- Workstation
- XFP connector
- Yagi directional antenna

Ethernet Standards and Cables

As earlier explained in Module 2, the medium the makes up the pathway by which ethernet devices communicate are comprised of networking wires and cables. Historically, the ethernet was provided by coaxial copper cable, but more recently, twisted pair cable and fiber optic cable are also being used.

Table 5 is a summary table of Ethernet standards as they relate to transmission speed, signal type, cable type and maximum cable segment length.

Table 5 Ethernet Standards Table

Ethernet Standard	Transmission Speed	Signal Type	Cable Type	Maximum Segment Length
10Base5	10 Mbps	Baseband	Coaxial	500 meters
10Base2	10 Mbps	Baseband	Coaxial	185 meters
1Base5	10Mbps	Baseband	Unshielded Twisted Pair	250 meters
10BaseT	10 Mbps	Baseband	Unshielded Twisted Pair	100 meters
10Broad36	10 Mbps	Broadband	Coaxial	3600 meters
100BaseTX	100 Mbps	Baseband	2-Pair Category 5 or Higher Unshielded Twisted Pair	100 meters
100BaseT4	100 Mbps	Baseband	4-Pair Category 3 or Higher Unshielded Twisted Pair	100 meters
100BaseFX	100 Mbps	Baseband	Fiber Optic	1000 meters
1000BaseSX	1000 Mbps	Baseband	Fiber Optic	100 meters
1000BaseLX	1000 Mbps	Baseband	Fiber Optic	100 meters
1000BaseCX	1000 Mbps	Baseband	Specialized Balanced Copper	25 meters
1000BaseT	1000 Mbps	Baseband	Category 5E or Higher Unshielded Twisted Pair	100 meters

Figure 41 Switch - courtesy of MD MTA

Figure 42 RS900 Switch used in Denver RTD - courtesy of Denver RTD

As described in Module 3, a segment is any portion of a network, and these portions are separated by a switch, bridge or a router from another part of a network.

Three common switches and network devices used in signal networks include the RS400, as shown in Figure 42, RS900, RS1500, and RS2100 that are used depending on their application. The RS400 is a serial device server with an integrated and fully managed Ethernet switch used for interfacing with microprocessors and controllers. The RS900 switch interfaces fiberoptic to copper RJ45 cables for signaling communications. The RS2100 manage terminal to terminal communication, FCM/ACM/DCM communication to the network device and handles indication and control to and from SCADA.

Figure 43 shows a network switch with indicating lights showing normal operation.

Module 5

INSPECTION, MAINTENANCE AND TESTING OF NEWORKS IN SIGNAL SYSTEMS

Outline

5-1 Overview
5-2 Safety and Security
5-3 Tools for Inspection and Maintenance
5-4 Equipment Inspection and Maintenance
5-5 Other Tasks
5-6 Summary

Outcome and Objectives

The participant will understand and be able to explain procedures, safety requirements and tools needed for the inspection, maintenance and testing of transit and rail signal network and communication systems.

Following the completion of this module, the participant should be able to complete the exercises with an accuracy of 70% or greater:

- Explain safety and security concerns for maintenance of networking systems
- Identify and describe tools used for the maintenance of networking systems
- Identify and explain proprietary concerns
- Identify network and communication-related housekeeping tasks
- Explain how to verify the communication system is operating as designed
- Explain hardware maintenance
- Explain software maintenance
- Explain agency procedures for addressing problems
- Explain the importance of documentation procedures

Key Terms

- Baselines
- Cable Sweep Test
- Configuration manager
- Continuity checker
- Data download
- Data rate settings
- Dielectric mat
- Distance to Fault (DTF)
- Electrostatic discharge (ESD)
- Fiber optic power meter
- FM200 fire suppression system
- Halon fire suppression system
- Ionizer
- Loaded Return Loss (RL)
- OEM bulletin
- Onsite storage
- Plates
- Power-on Self-Test (POST)
- Power switch control
- Proprietary
- Shortened Insertion Loss (IL)
- Software maintenance
- System Return Loss (RL)
- Verifying communication

5-1 OVERVIEW

Ensuring proper operation of signal networking and communication systems is mandatory and accomplished through effective maintenance & testing. Most often, the signal maintainer will be responsible for routine inspection and maintenance of signal-related network and communication systems, particularly network and communication related equipment located at the CIL or wayside. In some instances, and depending on agency job roles, employees from other departments may be responsible for certain tasks and/or may be consulted as needed for networking and communication inspection and maintenance in the field. Along with knowing and following all safety and security guidelines, a signal maintainer should know the network and communication inspection and maintenance tasks they are responsible for in their agency, have awareness of tasks handled by other departments in their agency, and know when to consult other departments for support as needed.

Module 5 explains common inspection and maintenance tasks for signal-related network and communication systems, safety and security considerations, the tools required, as well as other related tasks generally handled by other agency departments.

Warning: Safety Precautions!

Each agency defines roles and tasks for the inspection and maintenance of signal -elated network and communication systems. A signal maintainer should know their assigned tasks, have awareness of tasks handled by other departments, and understand when they should consult other departments for any additional required support.

5-2 SAFETY AND SECURITY

Maintenance, inspection and testing of the networking and communication systems can create potentially dangerous situations to the employees charged with completing these tasks. Strict adherence to sound safety practices and constant awareness are the requirements for avoiding accidents and fatalities. **The signal maintainer must have complete knowledge of all safety rules, policies, and guidelines of the rail system when inspecting and maintaining electrically connected networking and communication equipment used for signal systems. Roadway Worker Safety training along with any previous course work should be followed. Compliance with federal, state and local requirements is mandatory.**

To prevent injuries, the signal maintainer must complete training & testing, follow supervisor and mentor lead, follow agency rules and procedures, maintain careful and accurate records, and use reference material when required.

Signal maintainers should be aware of fiber cable power, light and scrap concerns taking the necessary precautions when working with fiber optic cabling including:

- Keep all food and beverages out of the work area as ingesting fiber particles can cause internal hemorrhaging.
- Follow all stripping and splicing fiber precautions.
- Always wear protective eyewear with side shields.
- Never look directly into fiber cable until it is confirmed the fiber is dark and the light source has been removed.
    - Use a fiber optic power meter to make certain the fiber is dark.
    - When using an optical tracer or continuity checker, observe the fiber from an angel holding the fiber at least 6 inches away from eyes to determine if the fiber is dark or if the light is visible.
- Do not touch eyes until hands have thoroughly washed. If wearing contact lenses, lenses should not be handled until hands have been thoroughly washed.
- Treat fiber optic splinters the same as glass splinters.
- Do not touch your eyes while until hands have been washed.
- Work should be completed in well-ventilated areas.
- All combustible materials should be kept away from curing ovens and fusion splicers.
- Keep track of all fiber and cable scraps.
- Work on dark plastic mats and work surfaces when possible to assist in identifying scraps more easily.
- Dispose of fiber and cable scraps immediately into a labeled container.
- Ensure no flammable gasses are present when using fusion splicers.
- Follow all MSDS for cleaners and other chemicals used.
- Wear disposable aprons to minimize fiber particles on clothing.
- Thoroughly clean work areas when work is completed.
- Contamination on the end of the fiber can cause loss of signal. Ensure the end of the fiber is clean.

For more information on fiber optic safety, see The Fiber Optic Association's web page: "Guide to fiber Optic and Premises Cabling" @ **https://www.thefoa.org/tech/ref/safety/safe.html**

Figure 69 Example Safety Glasses for Eye Protection

Figure 70 Example Safety Glasses for Eye Protection

Module 6

TROUBLESHOOTING AND REPAIR OF NETWORKS IN SIGNAL SYSTEMS

Outline

6-1 Overview and Safety
6-2 General Networking and Communication Troubleshooting Process
6-3 Tools
6-4 Networking and Communication Problems, Troubleshooting and Repair
6-5 Network and Communication Troubleshooting Software
6-6 The Ping Process
6-7 Troubleshooting Scenarios
6-8 Summary

Outcome and Objectives

The participant will understand and be able to explain the tools and procedures used for troubleshooting and repairing networking and communication systems.

Following the completion of this module, the participant should be able to complete the exercises with an accuracy of 70% or greater:

- Describe tools for network troubleshooting and repair
- Describe troubleshooting and repair practices for network problems
- Explain the process of pinging
- Explain the purpose of troubleshooting and diagnostic software
- Examine possible network and communication problems a signal maintainer may encounter

Key Terms

- Ethernet cable tester
- Fiber cable tester
- Fiber microscope
- Fiber optic tool kit
- Fiber splicer
- Fox and hound
- Net Bios
- Net Disco
- Optical time domain reflector (OTDR)
- Ping process
- Portable oscilloscope
- Redundant ports
- Received Signal Strength Indication (RSSI)
- Solar Winds
- Time
- Time to Live (TTL)

6-1 OVERVIEW AND SAFETY

A signal maintainer's role in troubleshooting and repair of network and communication systems may vary by agency and / or level of signal maintainer experience.

This module focuses on general troubleshooting procedures as they apply to networking and communication, specific tools generally used in the process, problems and related procedures typically addressed by signal maintainers, issues typically handled by other departments, as well as an introduction to commonly used software for networking and communication troubleshooting purposes.

As always, general troubleshooting procedures and any agency specific procedures and guidelines should always be followed. All earlier mentioned safety guidelines as well as any other agency specific safety guidelines should always be followed.

Warning: Safety Precautions:

- Always follow all safety guidelines as outlined and described in earlier courseware.
- Always follow OEM recommended safety procedures for the troubleshooting and repair of transit network and communication systems.
- Always follow your agency safety procedures and policies for the troubleshooting and repair of transit network and communication systems

Figure 83 Fox and Hound Tool - courtesy of MD MTA

Figure 84 Fox and Hound Tool - courtesy of MD MTA

Figure 85 Fox and Hound Tool - courtesy of MD MTA

Figure 86 Fox and Hound Tool in Use - courtesy of MD MTA