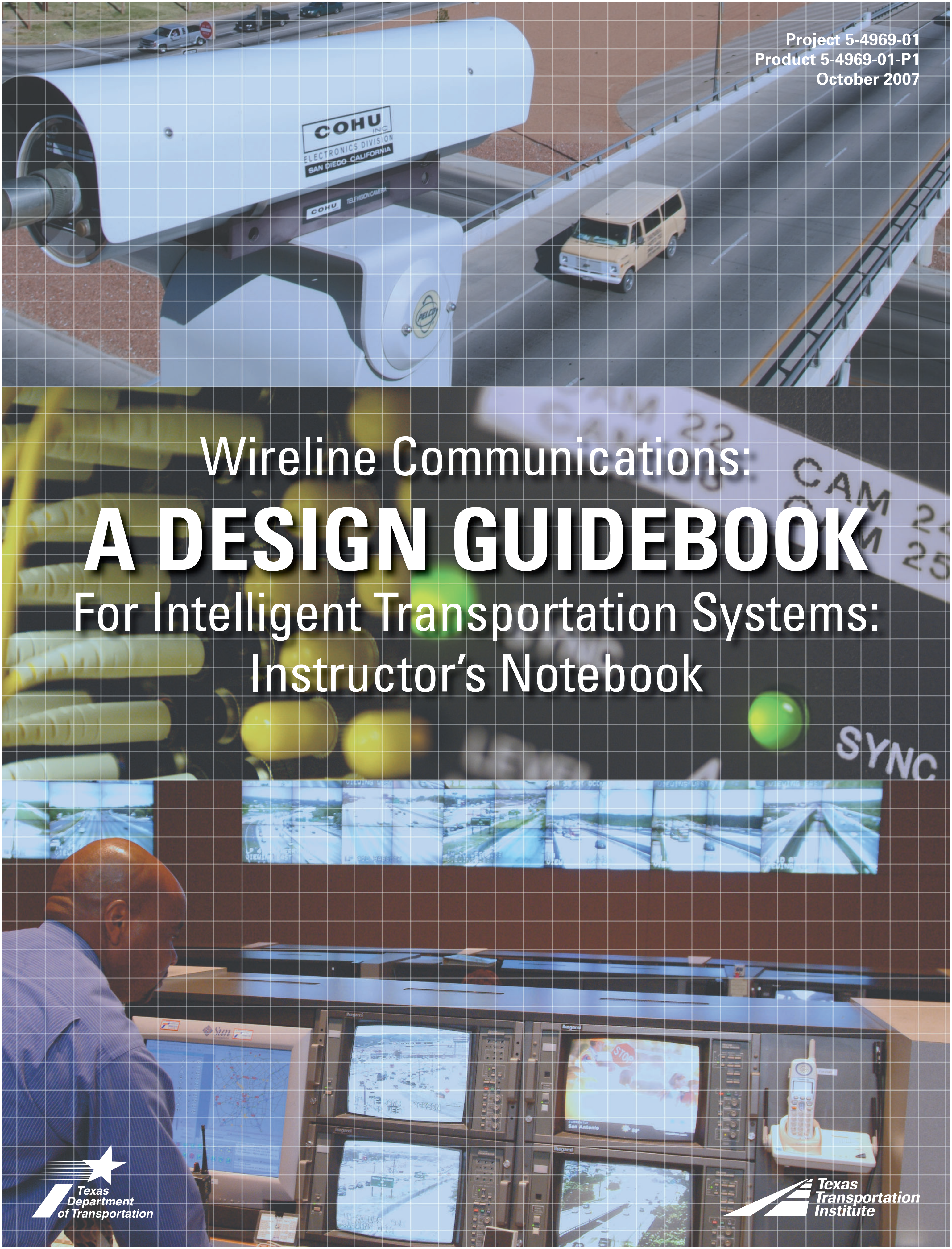
Project 5-4969-01
Product 5-4969-01-P1
October 2007



# Wireline Communications:
# A DESIGN GUIDEBOOK
## For Intelligent Transportation Systems:
## Instructor's Notebook

Texas
Department
of Transportation

Texas
Transportation
Institute

# Wireline Communications: **A DESIGN GUIDEBOOK** For ITS:

## Instructor's Notebook

Project 5-4969-01
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October 2007

Texas Department of Transportation

# WIRELINE COMMUNICATIONS: A DESIGN GUIDEBOOK FOR INTELLIGENT TRANSPORTATION SYSTEMS: INSTRUCTOR'S NOTEBOOK

**Product Number 5-4969-01-P1**

**Performed in cooperation with the**
**Texas Department of Transportation**
**and the**
**Federal Highway Administration**

**Research conducted by**
**Texas Transportation Institute**
**The Texas A&M University System**
**College Station, Texas 77843-3135**

**Authors**

**Robert E. Brydia**
**Byron E. Brackin**
**Jeremy D. Johnson**
**Gary B. Thomas**
**Kevin N. Balke**

**June 2007**
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# DISCLAIMER

The contents of this notebook reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration (FHWA) or the Texas Department of Transportation (TxDOT). This material does not constitute a standard, specification, or regulation. The researcher in charge was Robert E. Brydia.

# ACKNOWLEDGMENTS

This project was conducted in cooperation with TxDOT and FHWA.

The authors gratefully acknowledge the contributions of numerous persons who made the successful completion of this project possible

**Director, Office of Primary Responsibility**

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**Implementation Director**

- Steve Barnett, Traffic Operations Division, TxDOT

**Implementation Advisors**

- Cynthia Flores, P.E., Traffic Operations Division, TxDOT
- Theresa Sykes, Human Resources Division, TxDOT

**Research Engineer**

- Wade Odell, P.E., Research and Technology Implementation Office, TxDOT

**Contract Manager**

- Sandra Karderka, Research and Technology Implementation Office, TxDOT

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## INTRODUCTION

TxDOT engineers are responsible for the design, evaluation, and implementation of Intelligent Transportation System (ITS) solutions across the entire state. These installations occur with vast differences in requirements, expectations, and constraints. Many deployments require some type of communication system to complete the installation.

The goal of the course material is two-fold:

(1) to establish a fundamental level of understanding of wireline communication concepts and technologies, and

(2) to convey and explain a comprehensive process for assessing communication needs for ITS deployments.

## TYPICAL AUDIENCE

The typical audience of this guidebook (and corresponding workshop) is made up of employees of the Texas Department of Transportation (TxDOT) who have some level of overview or responsibility for ITS, but with little or no background in the area of communications. This guidebook provides an overview of communication concepts and their application to wireline ITS technologies. It is not intended to provide comprehensive training in all aspects of communications. The level of information contained in the guidebook should be applicable to employees across the state.

## COURSE MATERIALS

The complete set of workshop materials includes the following:

- Participant's Notebook,
- PowerPoint® Slides, and
- Instructor's Notebook.

These items all work in combination to provide TxDOT with a complete set of material that can be used to teach the course in the future.

## PARTICIPANT'S NOTEBOOK

The participant's notebook contains a significant amount of fundamental knowledge pertaining to communications. The notebook also contains the design methodologies and detailed explanations of each section. The notebook concludes with case studies demonstrating the use of the design methodologies and a glossary of terms used throughout the material. The eight chapters of the participant's notebook are:

- Chapter 1 – Introduction
- Chapter 2 – The Basics of Wireline Communications
- Chapter 3 – Understanding Telecommunications Technology
- Chapter 4 – Technology Choices
- Chapter 5 – System Design / Evaluation
- Chapter 6 – Design / Evaluation Methodologies
- Chapter 7 – Case Studies
- Chapter 8 - Glossary

It is anticipated that the participant's notebook will be a handy shelf reference for many aspects of designing communication systems and understanding communication fundamentals. For that reason, the document was written to have complete information in every major section, even if it is repeated from previous or similar sections.

## POWERPOINT SLIDES

The PowerPoint slides are the heart of the teaching materials prepared for this course. Some of the chapters from the guidebook were combined into teaching modules for course presentation. The listing below shows how the chapters equate to slide modules.

- Module 1 – Chapter 1
- Module 2 – Chapter 2
- Module 3 – Chapter 3
- Module 4 – Chapter 4
- Module 5 – Chapters 5 and 6
- Module 6 – Chapter 7

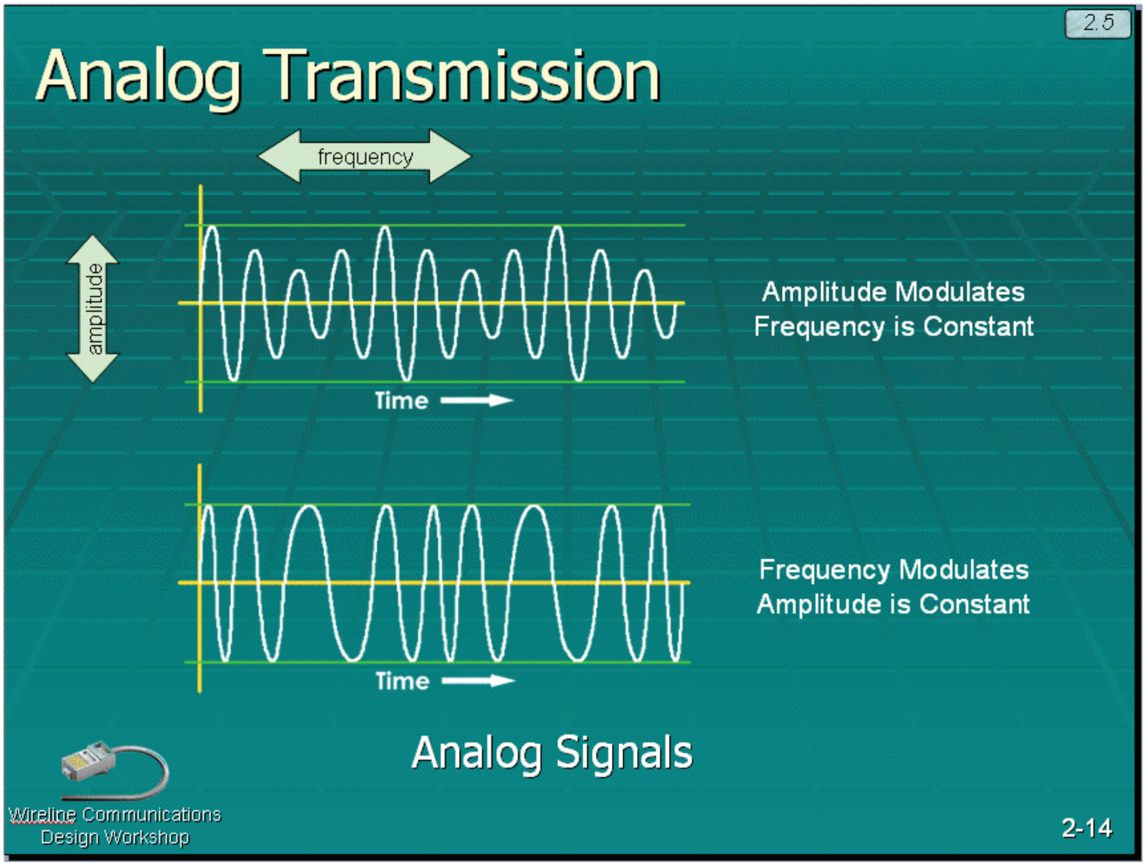
A set of learning objectives was created for each module that identifies the tasks that each participant should be able to accomplish at the end of the module. Table 1 identifies the module learning objectives.

**Table 1. Module Learning Objectives.**

| Module | | Learning Objectives |
|---|---|---|
| 1. | Introduction | N/A |
| 2. | Basics of Wireline Communication | 1. Understand the basic concepts of communications.<br>2. Recognize and be able to discuss the various media types and typical connectors.<br>3. Understand the typical "units" associated with sending and receiving communications. |
| 3. | Understanding Telecommunication Protocols and Topologies | 1. Describe the basic traits of a protocol and the performance of some of the more commonly used protocols.<br>2. Recognize and understand the differences between the types of network topologies.<br>3. Understand special communication topics including spanning tree protocol, tunneling, video encoding, security, and hardened equipment. |
| 4. | Technology Choices | 1. Summarize the different types of communication technologies.<br>2. Differentiate the costs and uses of each technology.<br>3. Identify supported protocols for each technology. |
| 5. | System Design/Evaluation Methodologies | 1. Understand the components of the evaluation methodology for assessing communications alternatives.<br>2. Use the methodology to arrive at a solution set.<br>3. Evaluate the pros, cons, and constraints of the solution set. |
| 6. | Flow Charts, Case Studies, and Class Exercise | 1. Apply the methodology to case studies.<br>2. Apply the methodology to real-world applications. |

Each module is composed of individual PowerPoint slides. Each slide was designed to convey a discrete unit of information and build upon the previous slide. In many cases, slides have been created that are interactive, to help elicit class interaction with the instructor.

A typical PowerPoint slide is shown in Figure 1. Each slide is branded with the name of the workshop and a page number to help the instructor keep track of the progress of the class materials.



2.5

Analog Transmission

Amplitude Modulates
Frequency is Constant

Frequency Modulates
Amplitude is Constant

Analog Signals

Wireline Communications
Design Workshop

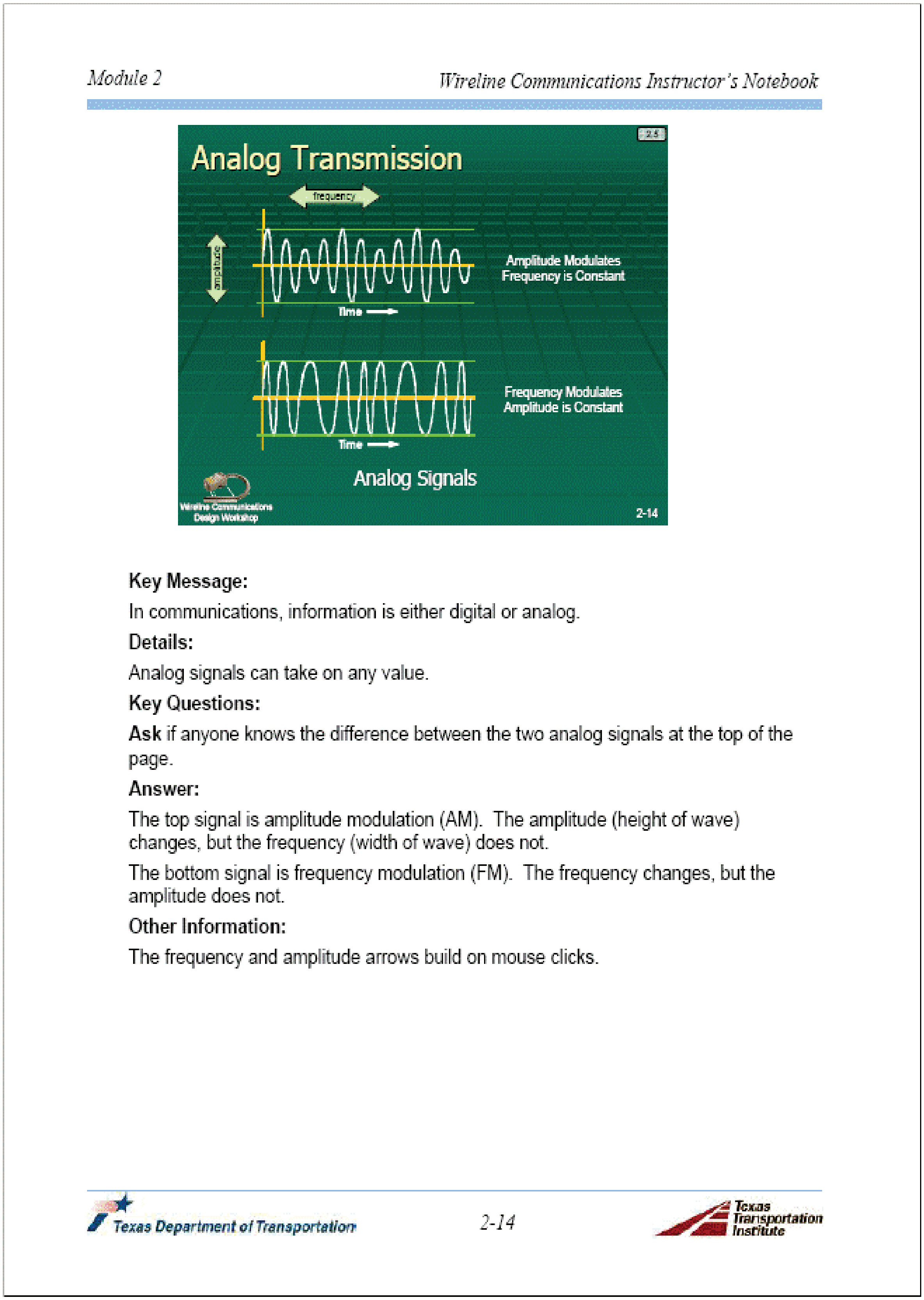
2-14

**Figure 1. Typical PowerPoint Slide Used for Workshop Instruction.**

## INSTRUCTOR'S NOTEBOOK

The instructor's notebook for this workshop was designed to be an easy reference guide for the workshop instructor. The front matter of the instructor's notebook details the objectives of the learning modules and the typical workshop agenda. The primary use of the instructor's notebook, however, is to convey pertinent information related to each slide used during the course.

This information is relayed through the use of instructor's notes entered on slide pages. Each note has a standard format which includes the Key Message, Detailed Information, Key Questions, and Other Information. Figure 2 shows a typical page from the instructor's notebook.



*Module 2* *Wireline Communications Instructor's Notebook*

Analog Transmission

Amplitude Modulates
Frequency is Constant

Frequency Modulates
Amplitude is Constant

Analog Signals

2-14

**Key Message:**

In communications, information is either digital or analog.

**Details:**

Analog signals can take on any value.

**Key Questions:**

**Ask** if anyone knows the difference between the two analog signals at the top of the page.

**Answer:**

The top signal is amplitude modulation (AM). The amplitude (height of wave) changes, but the frequency (width of wave) does not.

The bottom signal is frequency modulation (FM). The frequency changes, but the amplitude does not.

**Other Information:**

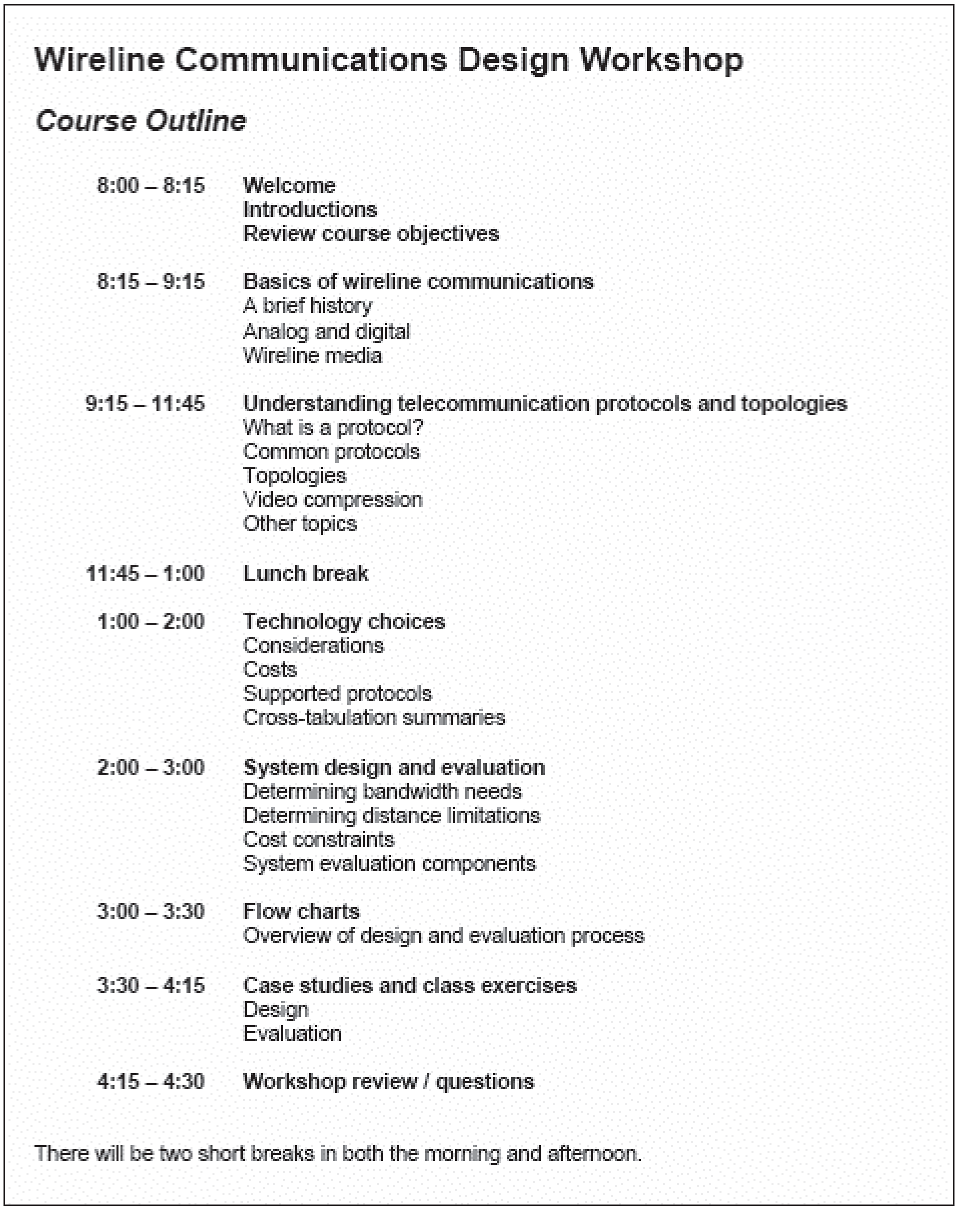
The frequency and amplitude arrows build on mouse clicks.

Texas Department of Transportation 2-14 Texas Transportation Institute

**Figure 2. Typical Instructor's Note Page.**

## ADDITIONAL WORKSHOP INFORMATION

The workshop was designed to be taught in approximately eight hours. Not every topic can be discussed in detail. It is important to remember that the guidebook was also written to be a shelf reference. Figure 3 shows the course outline and agenda along with suggested timeframes. The instructor should note the break times as these will decrease the amount of time available to teach course material.



**Wireline Communications Design Workshop**

***Course Outline***

| | |
|---|---|
| 8:00 – 8:15 | **Welcome**<br>**Introductions**<br>**Review course objectives** |
| 8:15 – 9:15 | **Basics of wireline communications**<br>A brief history<br>Analog and digital<br>Wireline media |
| 9:15 – 11:45 | **Understanding telecommunication protocols and topologies**<br>What is a protocol?<br>Common protocols<br>Topologies<br>Video compression<br>Other topics |
| 11:45 – 1:00 | **Lunch break** |
| 1:00 – 2:00 | **Technology choices**<br>Considerations<br>Costs<br>Supported protocols<br>Cross-tabulation summaries |
| 2:00 – 3:00 | **System design and evaluation**<br>Determining bandwidth needs<br>Determining distance limitations<br>Cost constraints<br>System evaluation components |
| 3:00 – 3:30 | **Flow charts**<br>Overview of design and evaluation process |
| 3:30 – 4:15 | **Case studies and class exercises**<br>Design<br>Evaluation |
| 4:15 – 4:30 | **Workshop review / questions** |

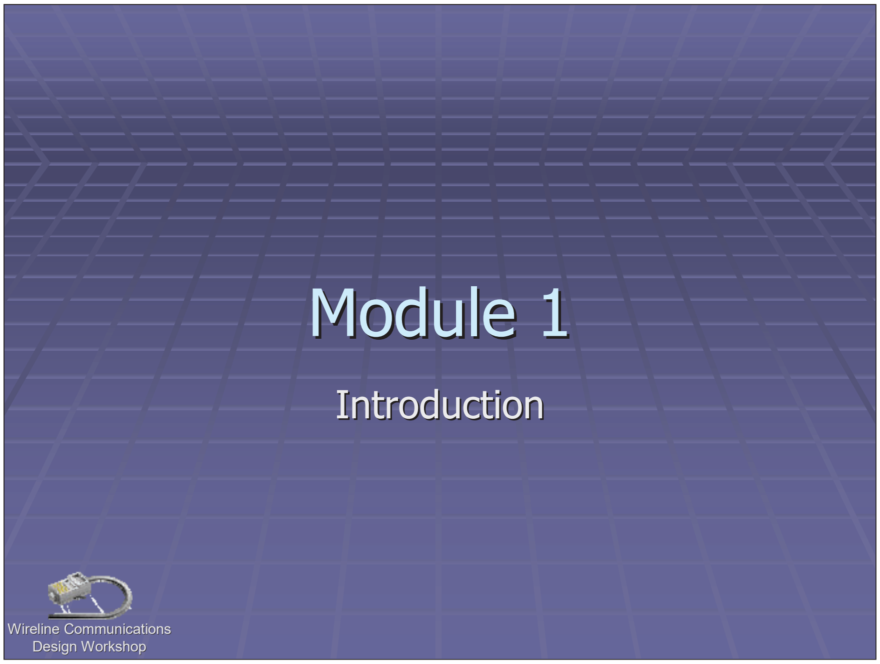
There will be two short breaks in both the morning and afternoon.

**Figure 3. Wireline Communications Design Workshop—Course Outline and Agenda.**

## EQUIPMENT REQUIREMENTS

Course presentations will be delivered primarily through computerized slides projected by a liquid crystal display (LCD) projector, or equivalent, plus flipcharts and wall charts. The following equipment is needed for presenting the course materials:

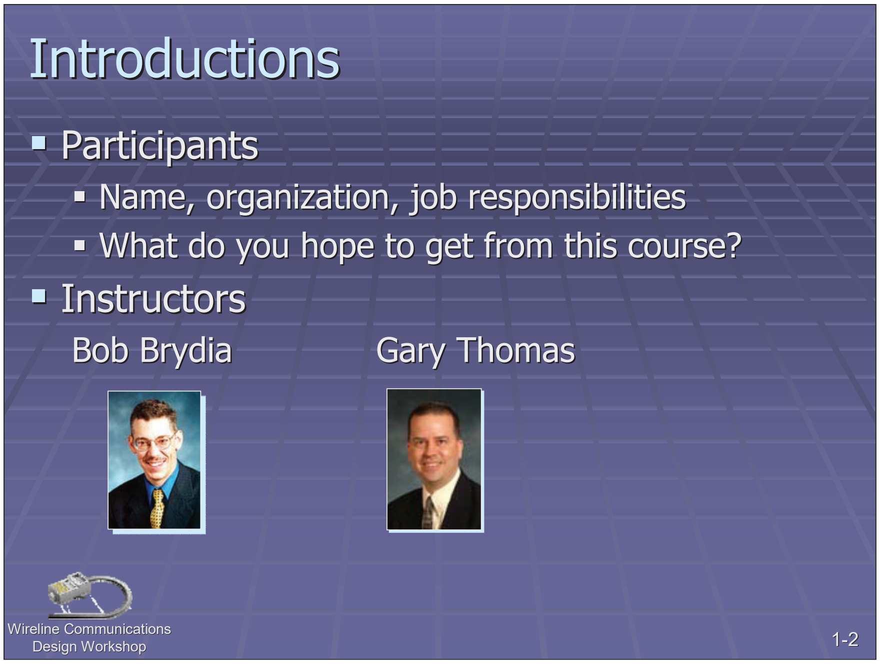
- computer (LCD) projector with minimum 1024x768 resolution;
- large projection screen (7 ft width minimum);
- a pointing device (electronic or mechanical);
- computer with at least: 300MHz CPU, 128MB of RAM (256 if Windows XP is used), 100MB hard-disk space available and external mouse; and
- MS PowerPoint 2000 or later.



# Module 1

## Introduction

Wireline Communications
Design Workshop



## Introductions

- Participants
  - Name, organization, job responsibilities
  - What do you hope to get from this course?
- Instructors

Bob Brydia Gary Thomas

**Key Message:**

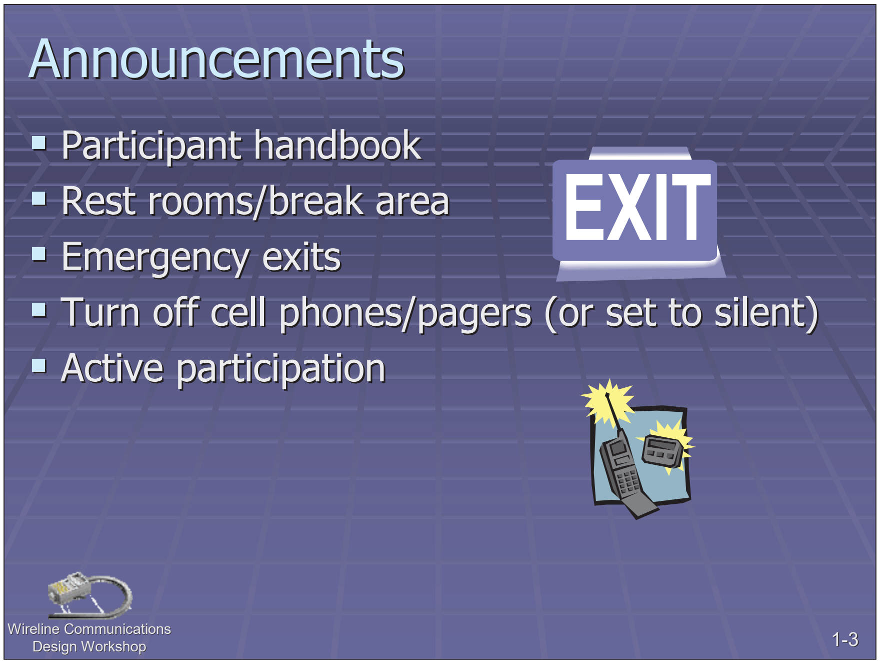
None.

**Details:**

Have all participants introduce themselves and list one thing they hope to get from this course. **Write this down on a flip chart.**

**Other Information**

None.



## Announcements

- Participant handbook
- Rest rooms/break area
- Emergency exits
- Turn off cell phones/pagers (or set to silent)
- Active participation

Wireline Communications
Design Workshop

**Key Message:**

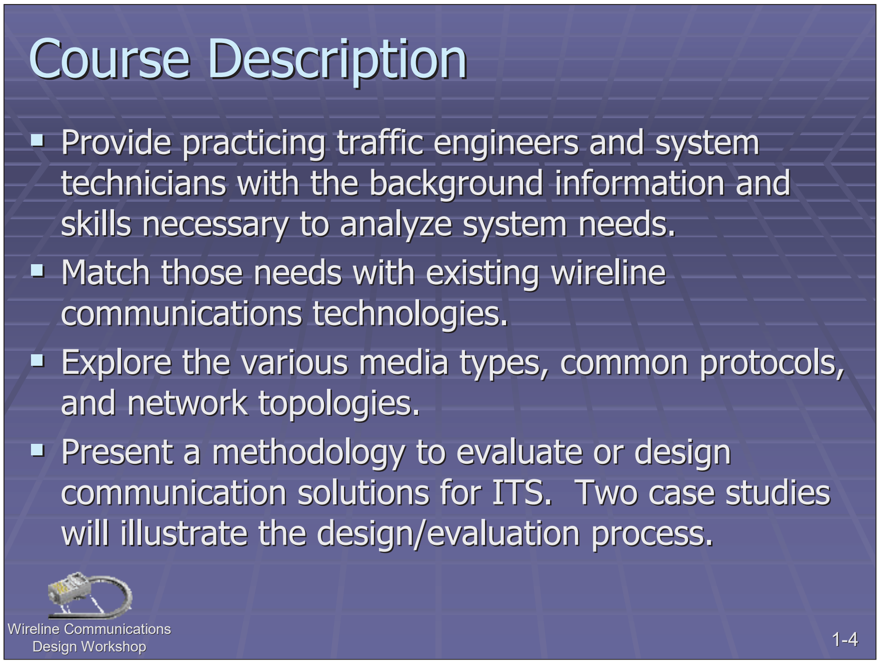
None.

**Details:**

Go over the housekeeping items. Encourage active participation.

**Other Information**

None.



## Course Description

- Provide practicing traffic engineers and system technicians with the background information and skills necessary to analyze system needs.
- Match those needs with existing wireline communications technologies.
- Explore the various media types, common protocols, and network topologies.
- Present a methodology to evaluate or design communication solutions for ITS. Two case studies will illustrate the design/evaluation process.

**Key Message:**

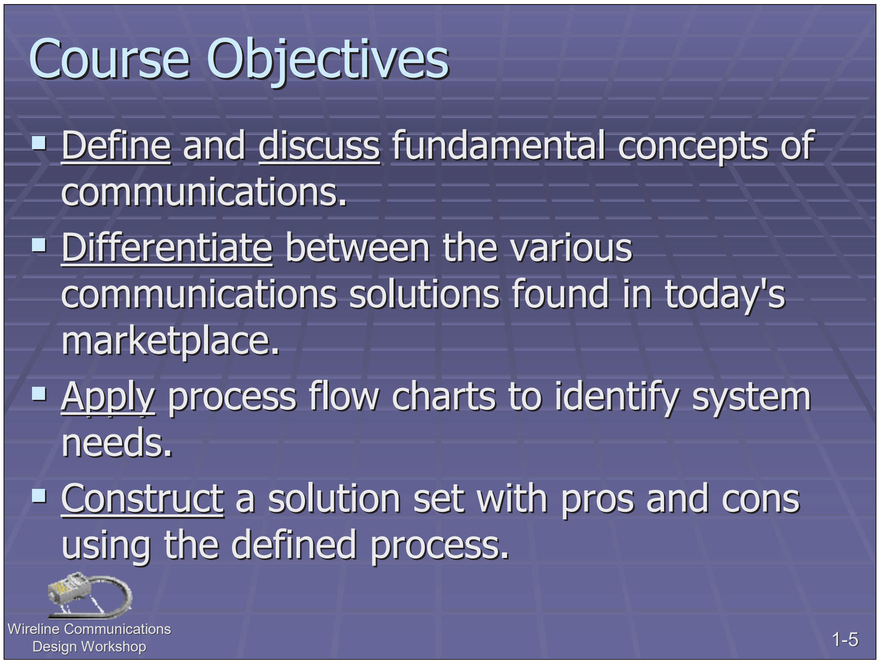
None.

**Details:**

Go over the course description.

**Other Information**

None.



## Course Objectives

- Define and discuss fundamental concepts of communications.
- Differentiate between the various communications solutions found in today's marketplace.
- Apply process flow charts to identify system needs.
- Construct a solution set with pros and cons using the defined process.

Wireline Communications
Design Workshop

1-5

**Key Message:**

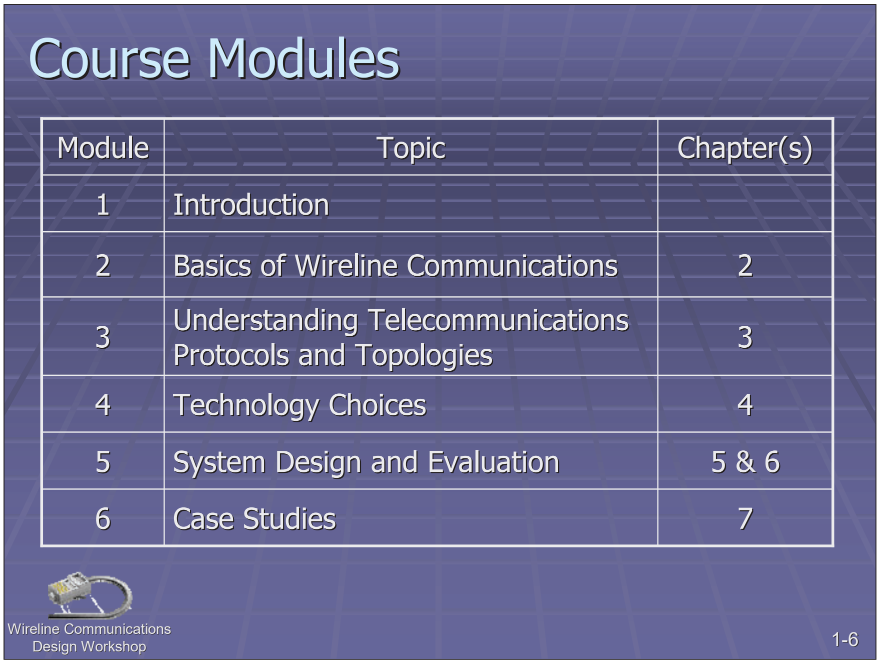
None.

**Details:**

Go over the course objectives. You may want to compare these to the items on the flip chart.

**Other Information**

None.



## Course Modules

| Module | Topic | Chapter(s) |
|---|---|---|
| 1 | Introduction | |
| 2 | Basics of Wireline Communications | 2 |
| 3 | Understanding Telecommunications Protocols and Topologies | 3 |
| 4 | Technology Choices | 4 |
| 5 | System Design and Evaluation | 5 & 6 |
| 6 | Case Studies | 7 |

Wireline Communications
Design Workshop

**Key Message:**

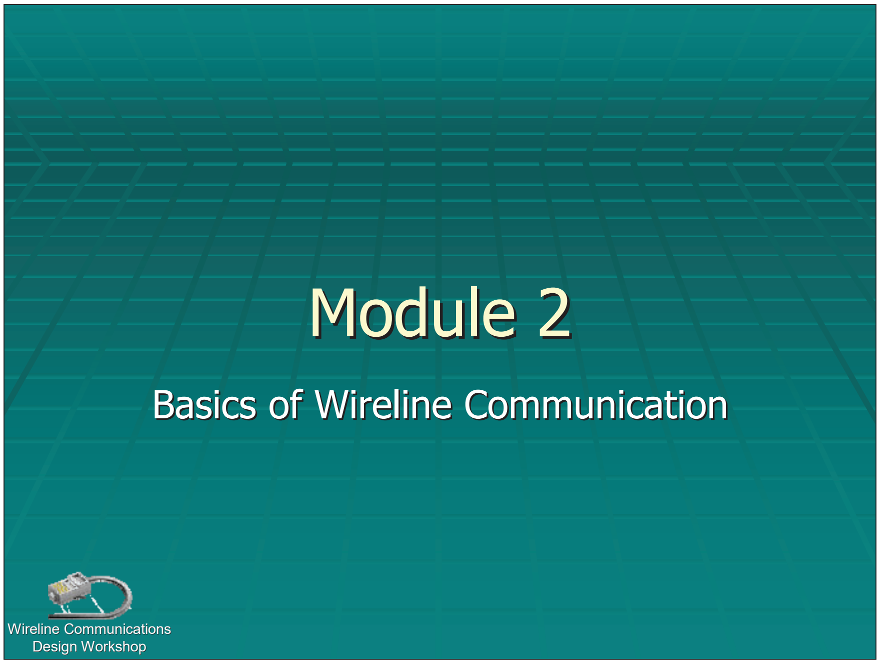
None.

**Details:**

Go over the course modules.

**Other Information**

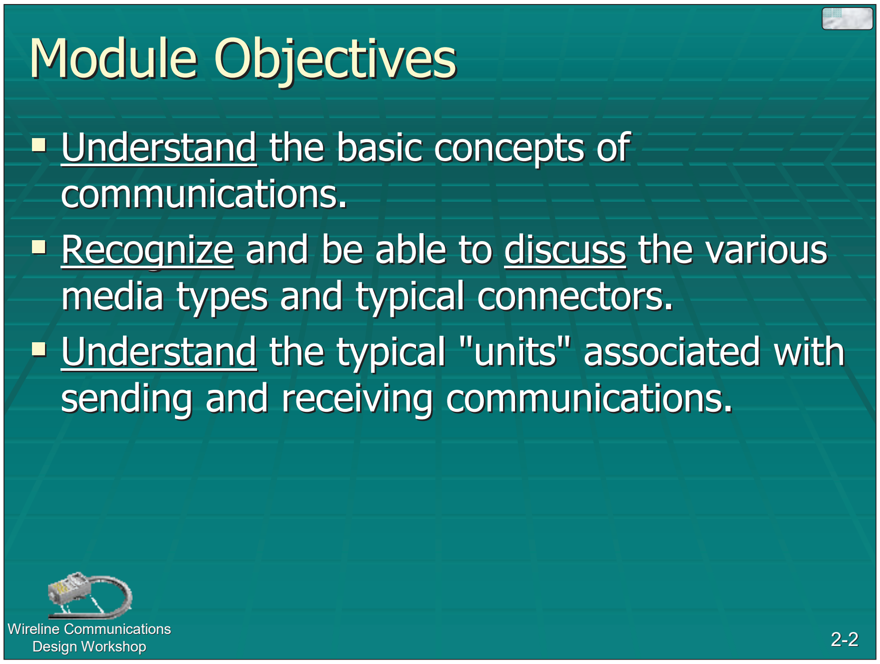
None.



# Module 2

## Basics of Wireline Communication

Wireline Communications
Design Workshop



## Module Objectives

- Understand the basic concepts of communications.
- Recognize and be able to discuss the various media types and typical connectors.
- Understand the typical "units" associated with sending and receiving communications.

**Key Message:**

None.

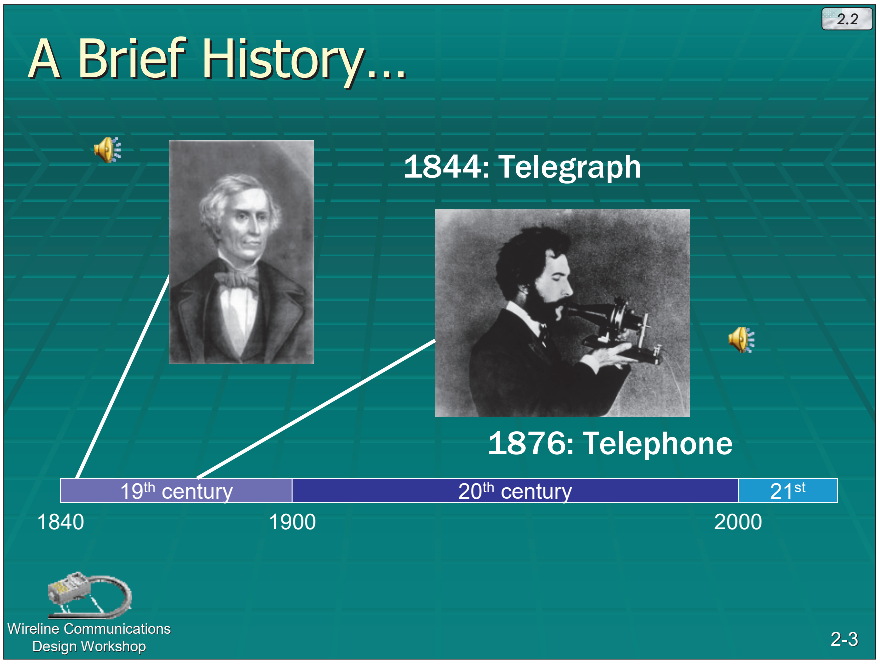
**Details:**

Go over the module objectives.

**Key Questions:**

**Other Information:**

None.



2.2

## A Brief History…

1844: Telegraph

1876: Telephone

| 19th century | 20th century | 21st |
|---|---|---|

1840 1900 2000

Wireline Communications
Design Workshop

2-3

**Key Message:**

"Modern" communication began in the mid 19th century.

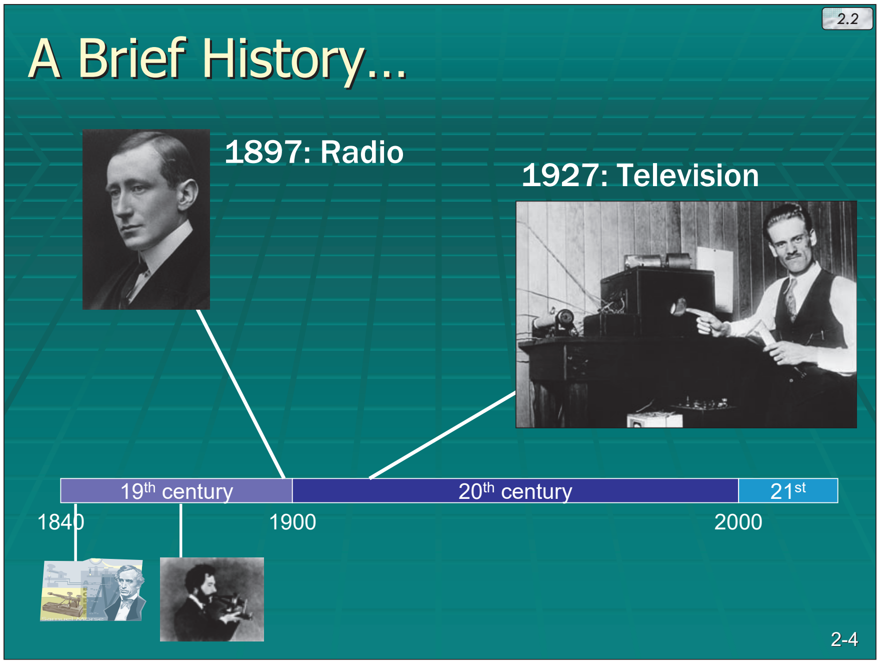
**Details:**

In 1844, Samuel Morse developed the telegraph. The first "data" transmission method.

In 1876, Alexander Graham Bell developed the telephone. The first "voice" transmission method.

**Key Questions:**

**Other Information:**



A Brief History…

1897: Radio

1927: Television

19th century

20th century

21st

1840

1900

2000

**Key Message:**

Radio communication demonstrated in 1897. The first "wireless" transmission method.

Video communication got its start in 1927. The first "video" transmission method.

**Details:**

In England, in March 1897, Marconi had transmitted Morse code signals over a distance of about 6 km (4 miles) and two months later, a distance of 14 km (8.7 miles).

The key to the television picture tube came to him at 14, when he was still a farm boy, and he had a working device at 21. Yet he died in obscurity.

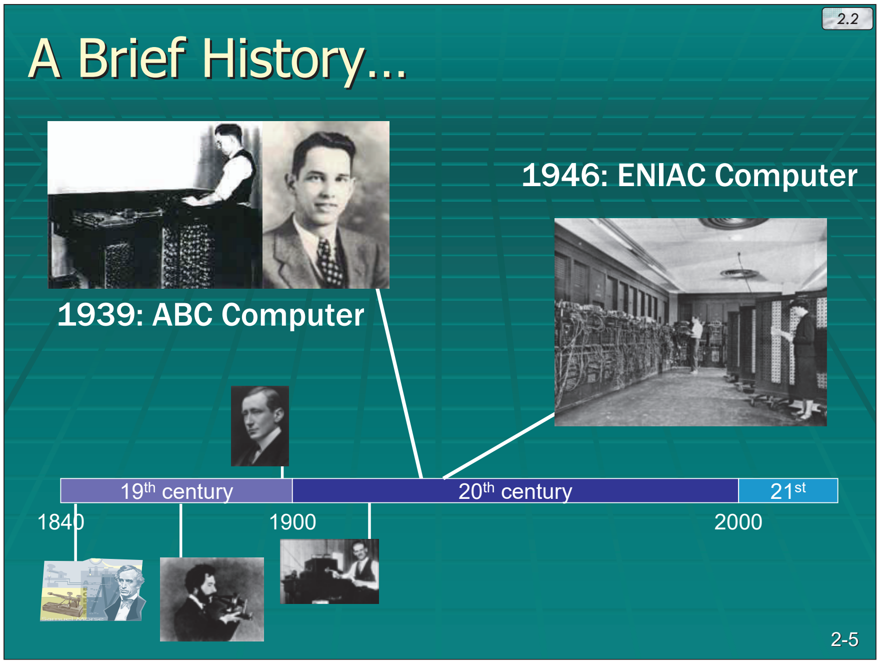
**Key Questions:**

Ask who the person is in the first picture credited with "inventing" the radio? Most should answer: (Guglielmo) Marconi

Ask who the person is in the second picture typically credited with inventing the electromechanical television? Few will likely know the answer.

Answer: Philo T. Farnsworth

**Other Information:**



2.2

## A Brief History…

1946: ENIAC Computer

1939: ABC Computer

2-5

**Key Message:**

Computers made their first appearance in the late 30's and early 40's.

**Details:**

In 1939, Professor John Atanasoff (Iowa State College) and his graduate assistant Clarence Berry developed the first computer called the ABC (for Atanasoff-Berry-Computer). It was the first electronic digital computing device. The machine, conceived in 1937, was capable of solving up to 29 simultaneous linear equations and was successfully tested, though its input/output mechanism was still unreliable in 1942 when its inventors left Iowa State College for World War II assignments.

ENIAC, short for Electronic Numerical Integrator and Computer, was developed at the University of Pennsylvania. It was the first large-scale, electronic, digital computer capable of being reprogrammed to solve a full range of computing problems. ENIAC was designed and built to calculate artillery firing tables for the U.S. Army's Ballistics Research Laboratory. The first problems run on the ENIAC however, were related to the design of the hydrogen bomb.

Other factoids:

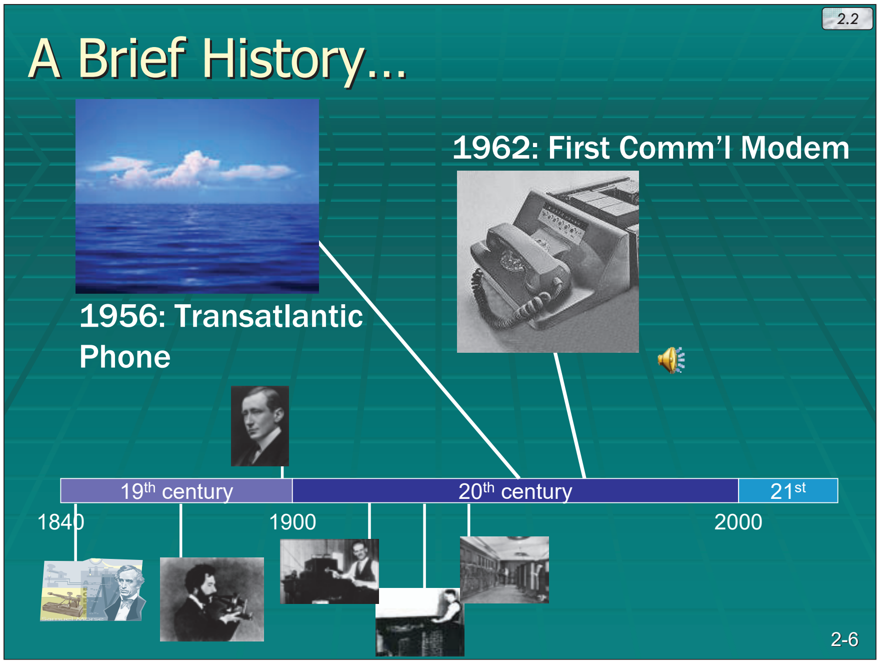
1936: Floating point calculator, "21" computer

1939: HP was founded (same year as the ABC computer)

1944: Mark I computer, used electromagnetic relays, very slow 3-5 seconds per operation

**Key Questions:**

**Other Information:**



2.2

## A Brief History…

1962: First Comm'l Modem

1956: Transatlantic Phone

**Key Message:**

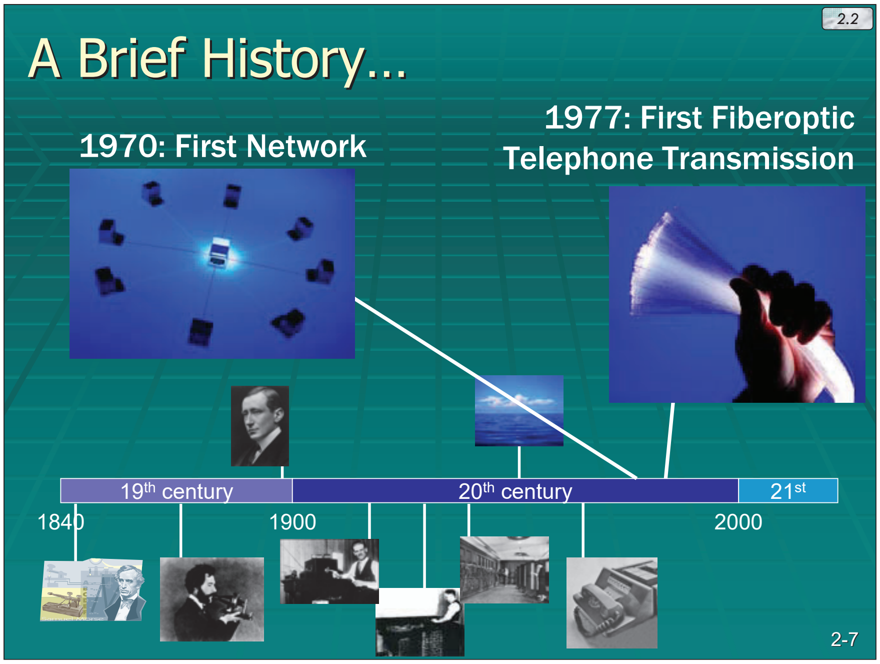
**Details:**

Trans-Atlantic telephone service via telephone cable was initiated in 1956. Previously, calls had been transmitted across the ocean via radio waves. The initial telephone cable could carry 36 simultaneous calls.

The famous AT&T 103A modem was also introduced in 1962. It provided full-duplex service at up to 300 baud over normal phone lines.

**Key Questions:**

**Other Information:**



2.2

## A Brief History…

1970: First Network

1977: First Fiberoptic Telephone Transmission

2-7

**Key Message:**

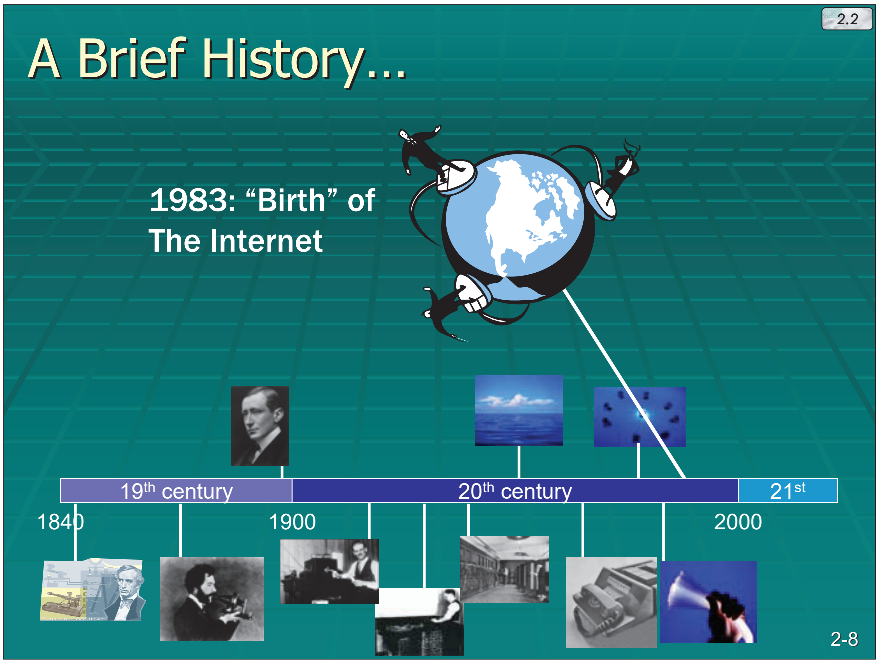
**Details:**

In 1969 the University of California at Los Angeles, SRI (in Stanford), University of California at Santa Barbara, and the University of Utah were connected as the beginning of the ARPANet (Advanced Research Projects Agency Network) using 50 kbit/s circuits.

On 22 April, 1977, General Telephone and Electronics sent the first live telephone traffic through fiber optics, at 6 Mbit/s, in Long Beach, California. In 1983, AT&T laid the first fiber optic cable on the national long distance network. The first trans-atlantic telephone cable to use optical fiber went into operation in 1988.

**Key Questions:**

**Other Information:**



2.2

A Brief History…

1983: “Birth” of
The Internet

19th century

20th century

21st

1840

1900

2000

2-8

**Key Message:**

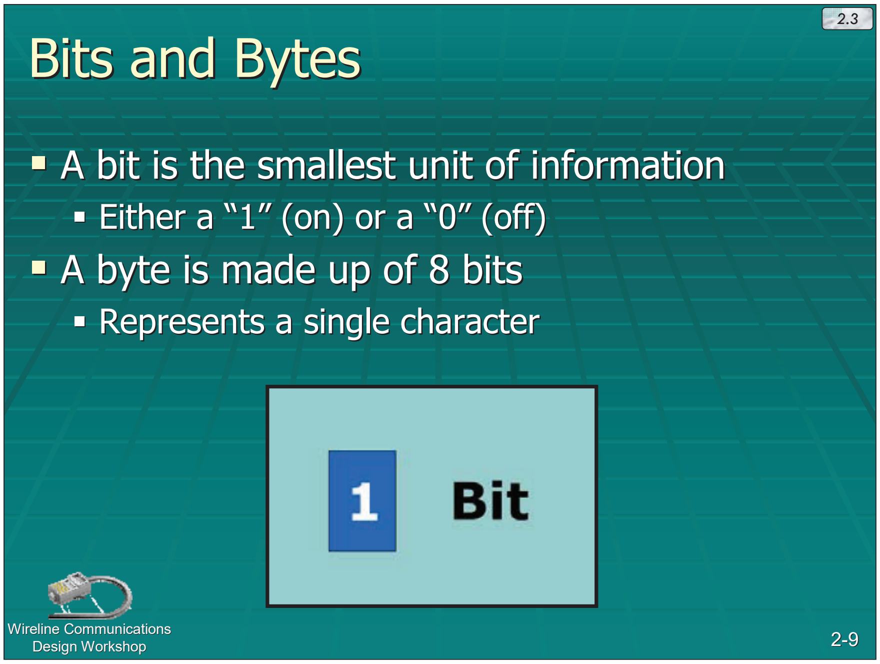
**Details:**

The first TCP/IP wide area network was operational by 1 January 1983, when the United States' National Science Foundation (NSF) constructed a university network backbone that would later become the NSFNet. (This date is held by some to be technically that of the birth of the Internet.) It was then followed by the opening of the network to commercial interests in 1985.

HTML invented in 1991. Work began circa 1989 as a method of linking related text in research papers.

**Key Questions:**

**Other Information:**



2.3

## Bits and Bytes

- A bit is the smallest unit of information
  - Either a “1” (on) or a “0” (off)
- A byte is made up of 8 bits
  - Represents a single character

Wireline Communications
Design Workshop

2-9

**Key Message:**

Bits and bytes are the building blocks of all electronic digital data.

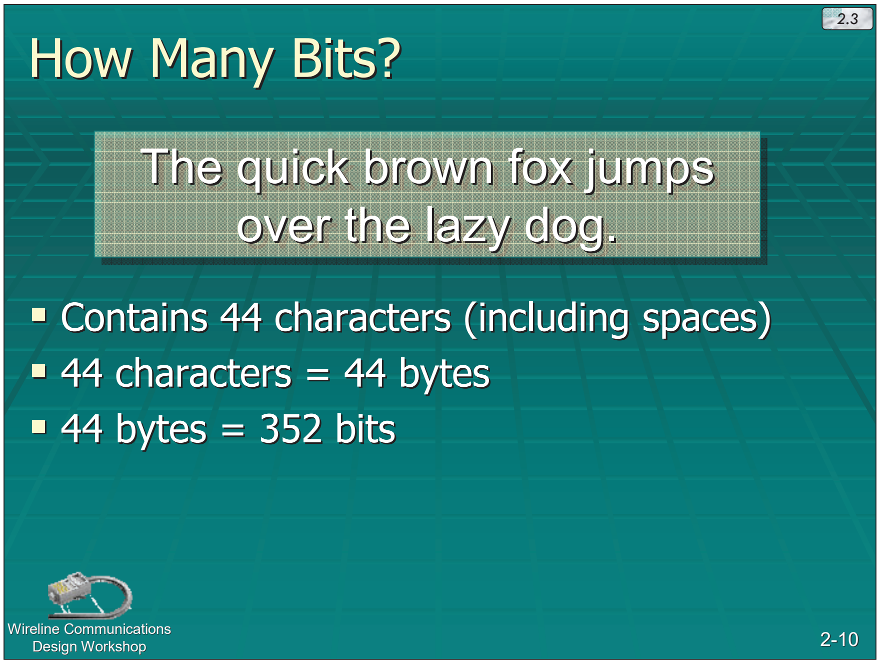
**Details:**

A **bit** is a single piece of information. A bit is either a “0” or a “1.” When you combine 8 bits together, it makes a **byte**. A byte typically represents a single character such as the letter “G” or the number “5” or perhaps a symbol “$.”

**Key Questions:**

**Other Information:**

The bit/byte graphic is an embedded flash file. It should play automatically.



2.3

## How Many Bits?

The quick brown fox jumps over the lazy dog.

- Contains 44 characters (including spaces)
- 44 characters = 44 bytes
- 44 bytes = 352 bits

Wireline Communications
Design Workshop

**Key Message:**

Bits and bytes are the building blocks of all electronic digital data.

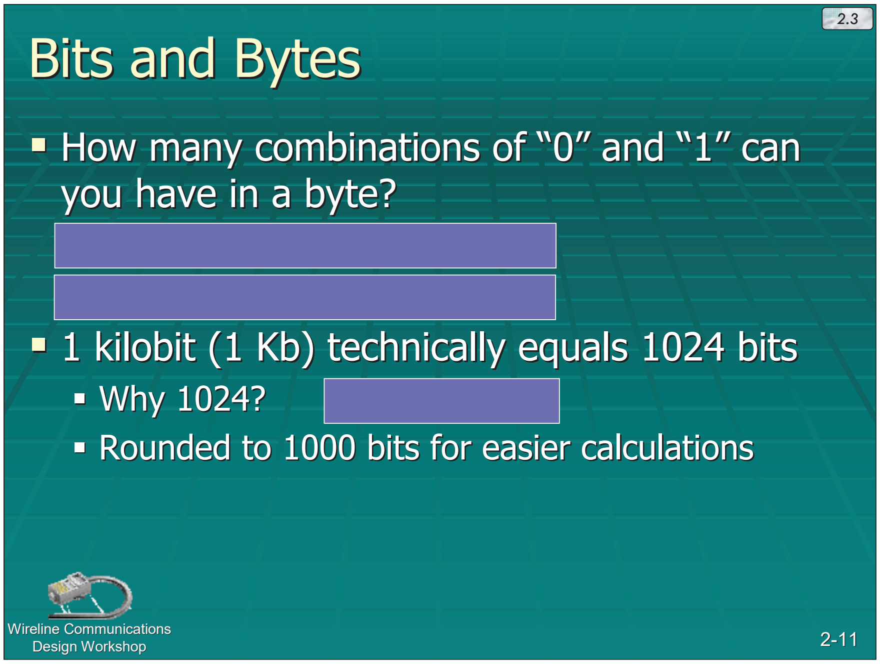
**Details:**

You can see that even a short document could therefore contain tens of thousands or even millions of bits. Other types of media, such as pictures and video streams, would contain an even greater amount of information.

**Key Questions:**

**Other Information:**

Factoid: A sentence that uses each letter of the alphabet at least once is called a "pangram."



2.3

## Bits and Bytes

- How many combinations of "0" and "1" can you have in a byte?
- 1 kilobit (1 Kb) technically equals 1024 bits
  - Why 1024?
  - Rounded to 1000 bits for easier calculations

Wireline Communications Design Workshop

2-11

**Key Message:**

Bits and bytes are the building blocks of all electronic data.

**Details:**

The final answer to the question is "256." If someone answers that right away, ask them how they determined that number.

If no one offers an explanation, ask them how many options are there in each position? **Answer: 2.**

Then ask how many positions? **Answer: 8.**

Uncover the first answer at this point.

Ask how to calculate the number of combinations? **Answer: 2 to the 8th power.**

Uncover the second answer.

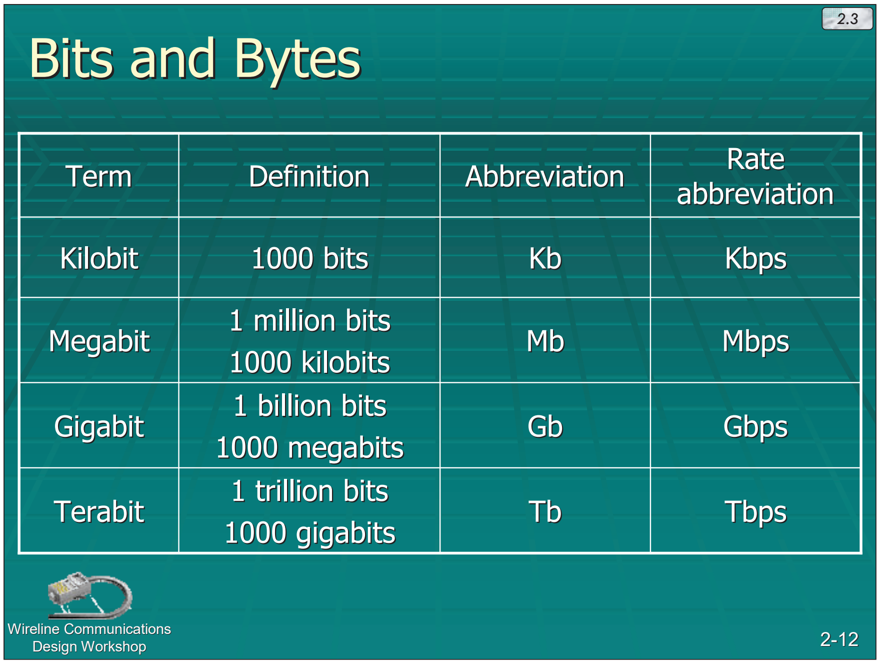
Why does 1 kilobit actually equal 1024 bits (instead of 1000 bits)?

**Answer: 2 to the 10th power.**

**Key Questions:**

**Other Information:**

None.



## Bits and Bytes

| Term | Definition | Abbreviation | Rate abbreviation |
|---|---|---|---|
| Kilobit | 1000 bits | Kb | Kbps |
| Megabit | 1 million bits<br>1000 kilobits | Mb | Mbps |
| Gigabit | 1 billion bits<br>1000 megabits | Gb | Gbps |
| Terabit | 1 trillion bits<br>1000 gigabits | Tb | Tbps |

Wireline Communications
Design Workshop

**Key Message:**

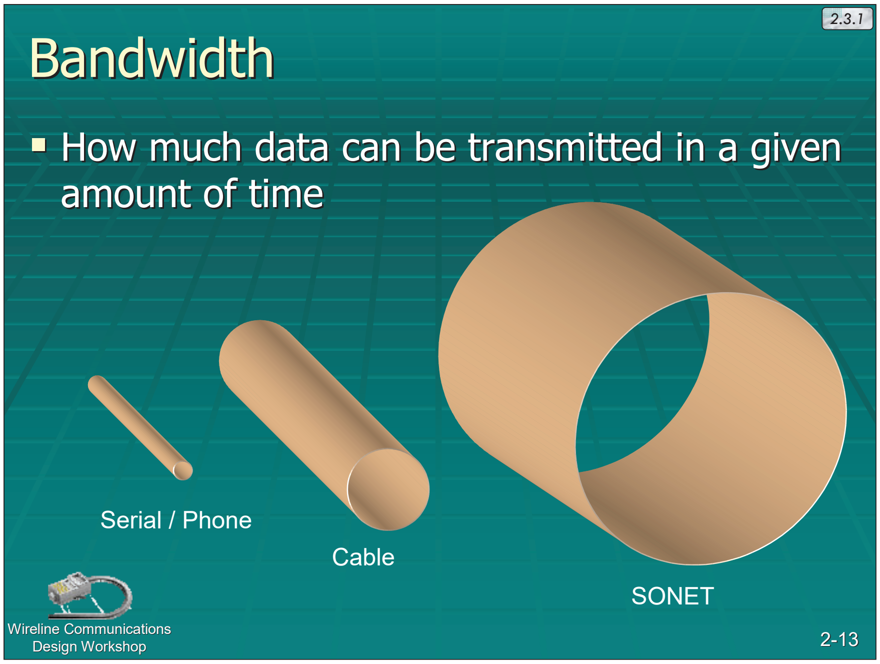
Description of the various magnitudes of bits.

**Details:**

**Key Questions:**

**Other Information:**

What's next? Peta (10^15 or 2^50) and Exa (10^18 or 2^60).



2.3.1

## Bandwidth

- How much data can be transmitted in a given amount of time

Wireline Communications Design Workshop

2-13

**Key Message:**

Bandwidth describes how much data can be transmitted by a particular medium in a given amount of time.

**Details:**

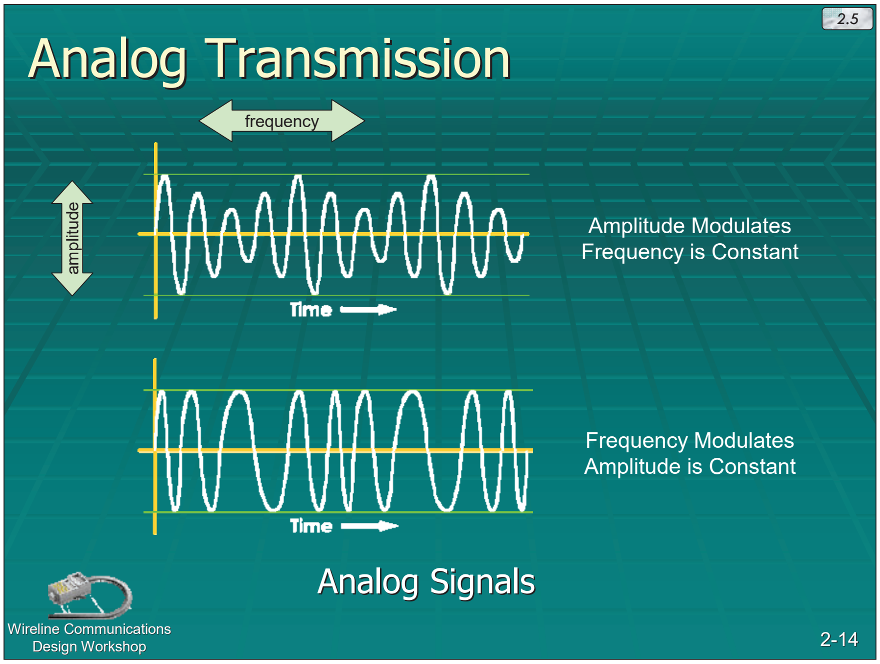
The larger the number of bits that any given technology can transfer in the same amount of time, the larger its bandwidth. In essence, bandwidth is a "virtual" measure of the size of the pipe.

Bandwidth is often expressed in terms of its ultimate capacity but is rarely achievable. Inefficiencies in the system tend to grow and create a practical limit to how much bandwidth can actually be achieved on any given technology.

**Key Questions:**

**Other Information:**

None.



## Analog Transmission

Amplitude Modulates
Frequency is Constant

Frequency Modulates
Amplitude is Constant

Analog Signals

Wireline Communications
Design Workshop

2-14

**Key Message:**

In communications, information is either digital or analog.

**Details:**

Analog signals can take on any value.

**Key Questions:**

**Ask** if anyone knows the difference between the two analog signals at the top of the page.

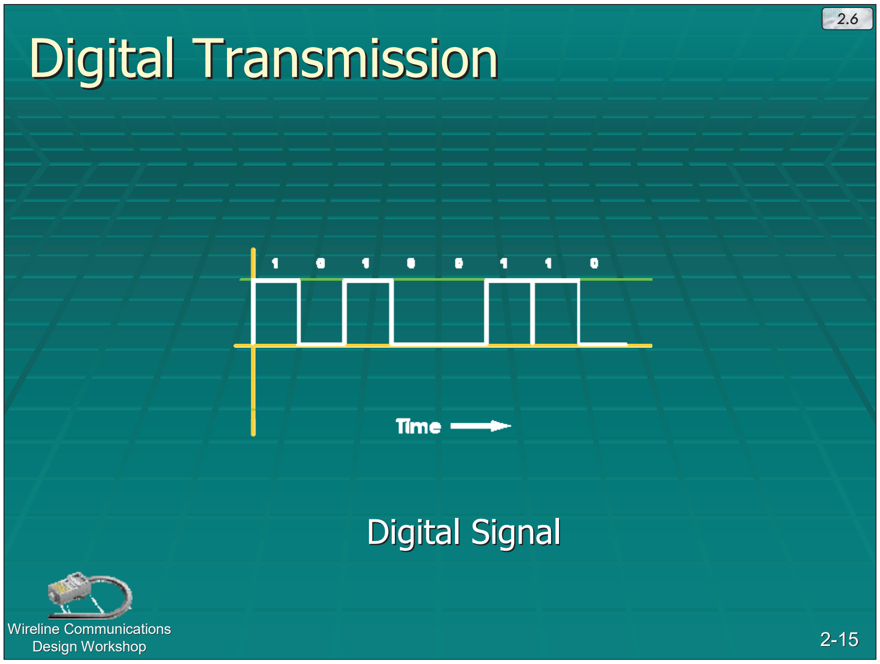
**Answer:**

The top signal is amplitude modulation (AM). The amplitude (height of wave) changes, but the frequency (width of wave) does not.

The bottom signal is frequency modulation (FM). The frequency changes, but the amplitude does not.

**Other Information:**

The frequency and amplitude arrows build on mouse clicks.



2.6

## Digital Transmission

Digital Signal

Wireline Communications
Design Workshop

2-15

**Key Message:**

In communications, information is either digital or analog.

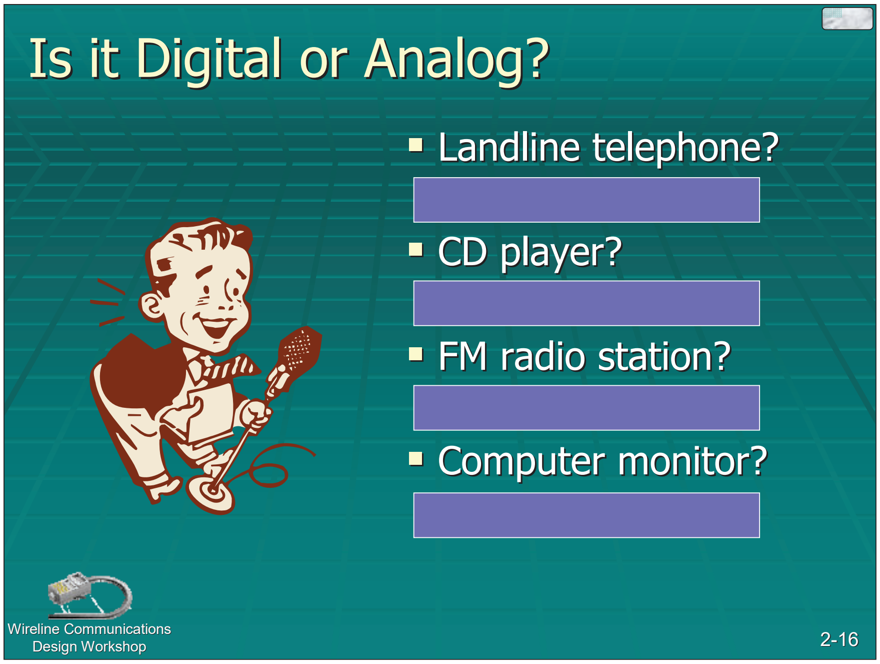
**Details:**

Digital signals are either on or off (1 or 0). There is no in-between state. It is also referred to as "binary" communications.

**Key Questions:**

**Other Information:**

None.



## Is it Digital or Analog?

- Landline telephone?
- CD player?
- FM radio station?
- Computer monitor?

Wireline Communications
Design Workshop

**Key Message:**

A quick quiz to see if participants understand the difference between digital and analog.

**Details:**

Landline telephone: analog

CD player: digital

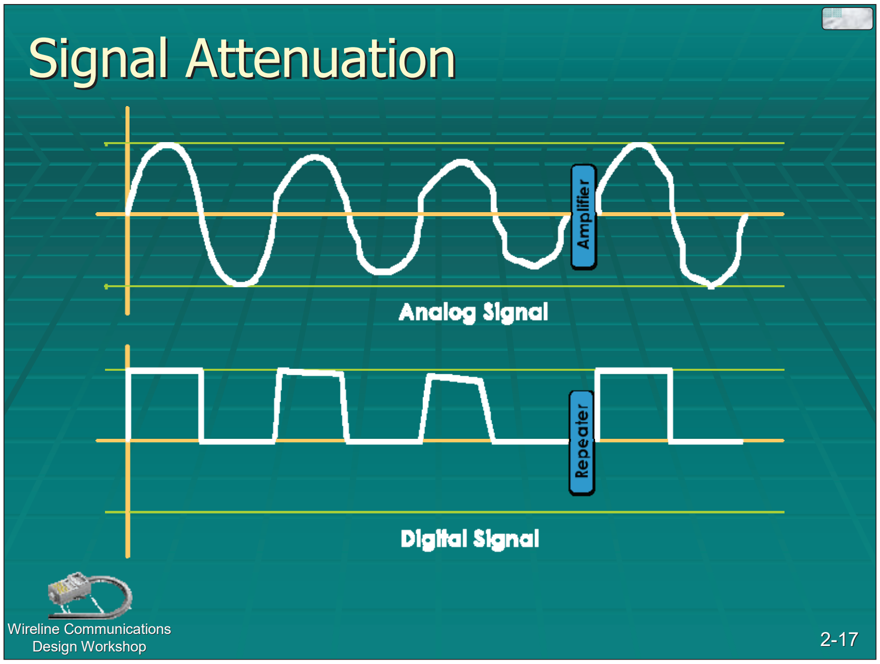
FM radio station: analog

Computer monitor: digital or analog

**Key Questions:**

**Other Information:**

None.



## Signal Attenuation

Wireline Communications
Design Workshop

2-17

**Key Message:**

All signals degrade (or attenuate) regardless of medium or type.

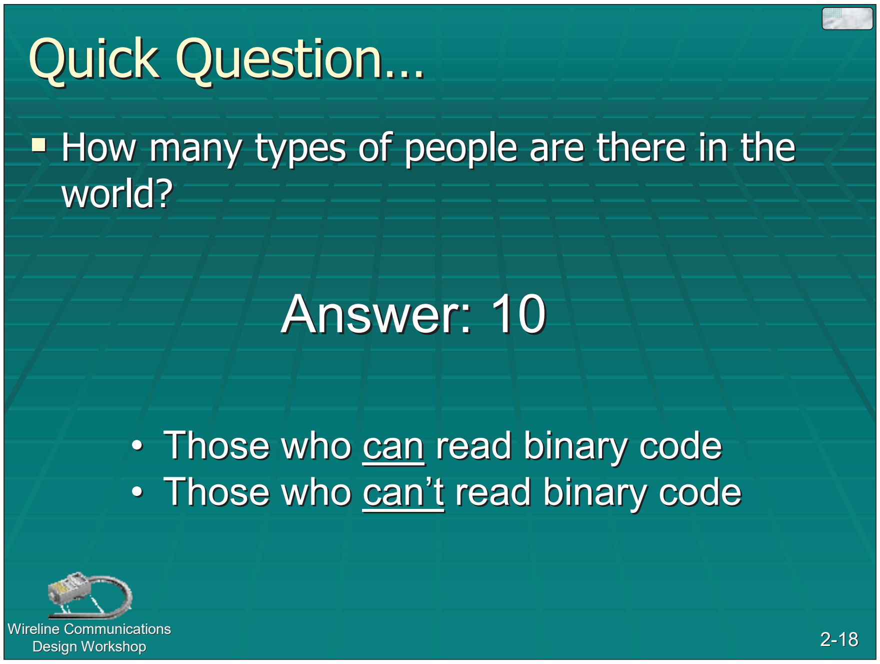
**Details:**

It doesn't matter if it's digital or analog, copper or fiber.  All signals degrade over distance.  They both experience a loss of amplitude and an increase in "noise." Analog signals need to be boosted (or amplified) and digital signals are regenerated. When an analog signal gets amplified, all of the noise gets amplified too.  Therefore, there is a limit to how many times an analog signal can be amplified before it is unusable.  Digital signals can be regenerated many times over, but equipment to do so is expensive so not necessarily practical over long distances.

**Key Questions:**

**Other Information:**

None.



## Quick Question…

- How many types of people are there in the world?

Answer: 10

- Those who can read binary code
- Those who can't read binary code

Wireline Communications Design Workshop

**Key Message:**

Just a fun little riddle for the class.

**Details:**

**Key Questions:**

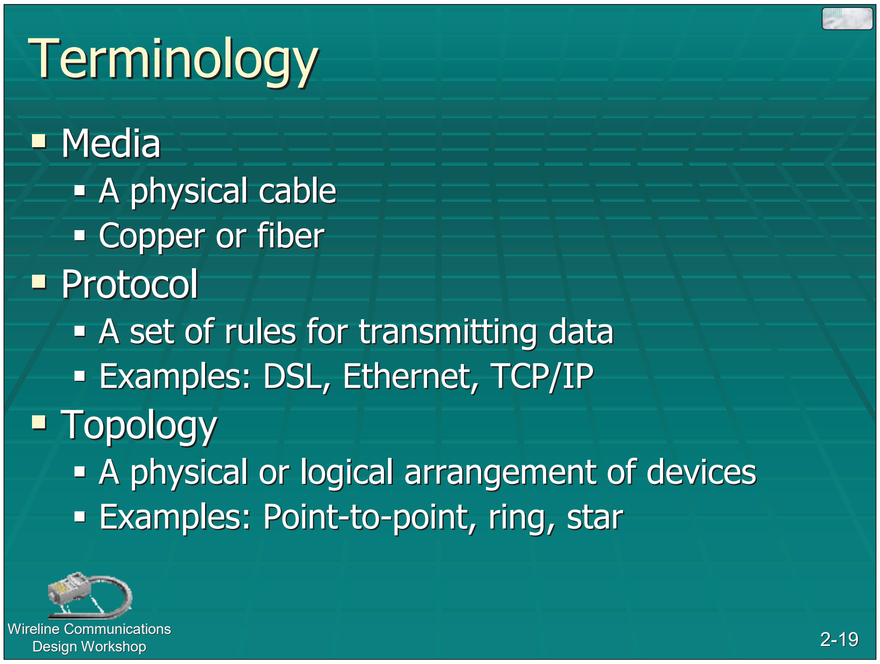
Ask: How many types of people there are in the world?

Click to reveal answer and say: "The answer is this many." Don't say "ten" or "two" or the joke won't work as well.

Then say: "Let's list all of them" Click twice to reveal/build the list of 2.

**Other Information:**

None.



### Terminology

- Media
  - A physical cable
  - Copper or fiber
- Protocol
  - A set of rules for transmitting data
  - Examples: DSL, Ethernet, TCP/IP
- Topology
  - A physical or logical arrangement of devices
  - Examples: Point-to-point, ring, star

Wireline Communications
Design Workshop

2-19

**Key Message:**

Clearly define the three terms: media, protocol, and topology.

**Details:**

In the case of wireline communications, **media** (singular is medium) refers to a physical cable either copper or fiber.

A **protocol** is simply a set of rules for data transmission (includes error checking, compression, format, etc.).

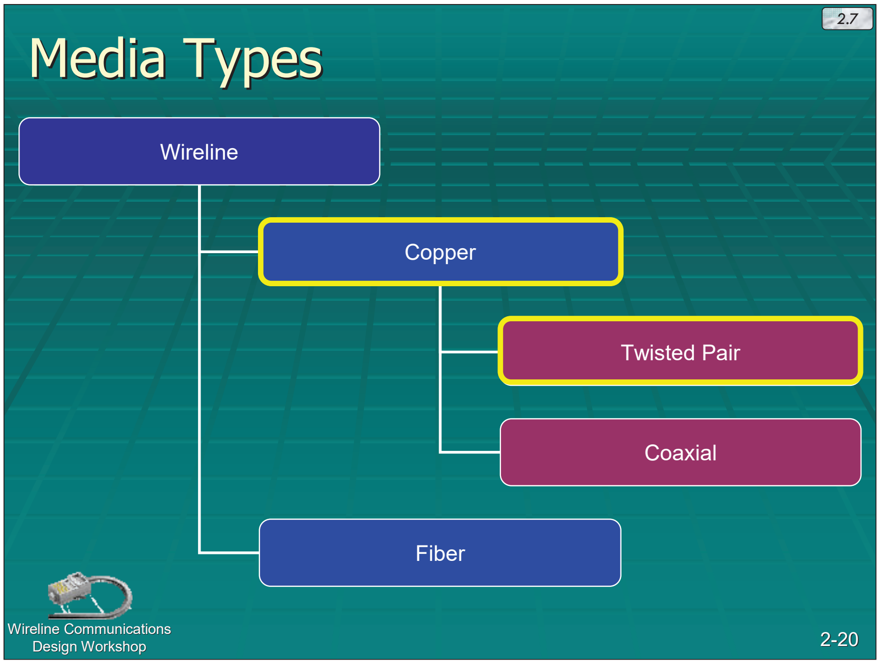
**Topology** describes how the devices are physically or logically arranged.

This module will discuss media in more detail.

**Key Questions:**

**Other Information:**

None.



2.7

# Media Types

Wireline

Copper

Twisted Pair

Coaxial

Fiber

Wireline Communications
Design Workshop

2-20

**Key Message:**

This is a transition slide.  It is intended to show the various media types.

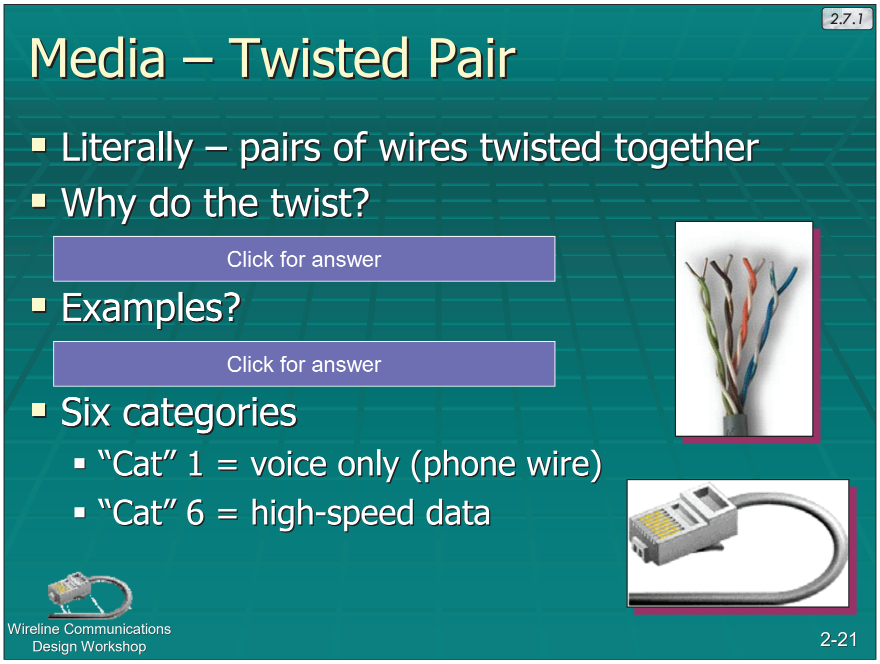
**Details:**

The next slide will discuss twisted pair.

**Key Questions:**

**Other Information:**

None.



2.7.1

# Media – Twisted Pair

- Literally – pairs of wires twisted together
- Why do the twist?

Click for answer

- Examples?

Click for answer

- Six categories
  - "Cat" 1 = voice only (phone wire)
  - "Cat" 6 = high-speed data

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Design Workshop

**Key Message:**

Twisted pair wires are a popular type of copper media.

**Details:**

Why are the wires twisted (as shown in the graphic)?

**Answer: By twisting, electrical "noise" is cancelled out.**

What are some examples?

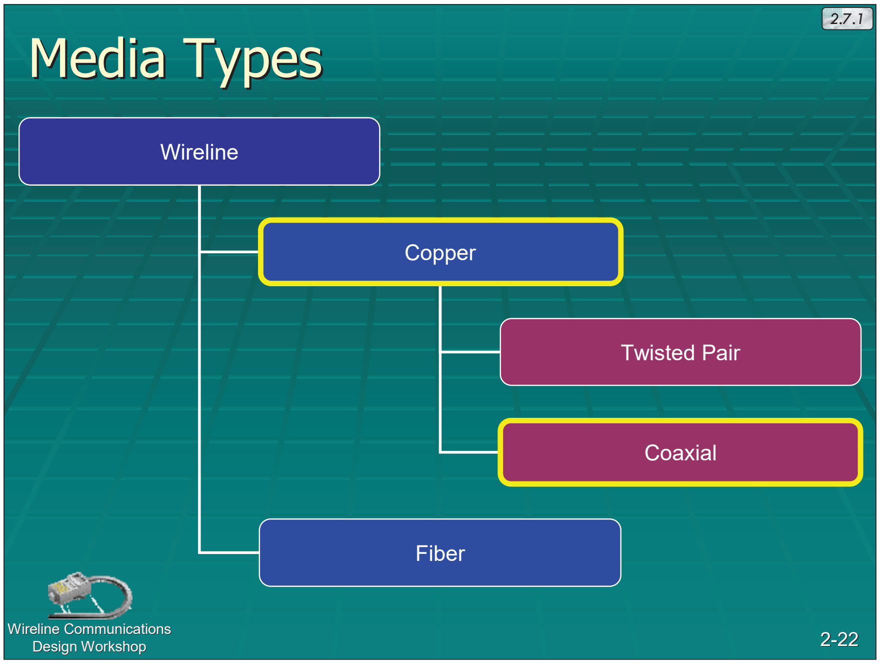
**Answer: Phone lines, computer cables.**

Twisted pair comes in 6 categories. Cat-1 through Cat-6. Cat-1 through Cat-4 are rarely used in communication designs anymore. Cat-5 and Cat-6 are for high bandwidth solutions like "gigabit ethernet."

**Key Questions:**

**Other Information:**

Instructor should pass around the physical examples of twisted pair media.



Media Types

Wireline

Copper

Twisted Pair

Coaxial

Fiber

**Key Message:**

This is a transition slide. It is intended to show the various media types.

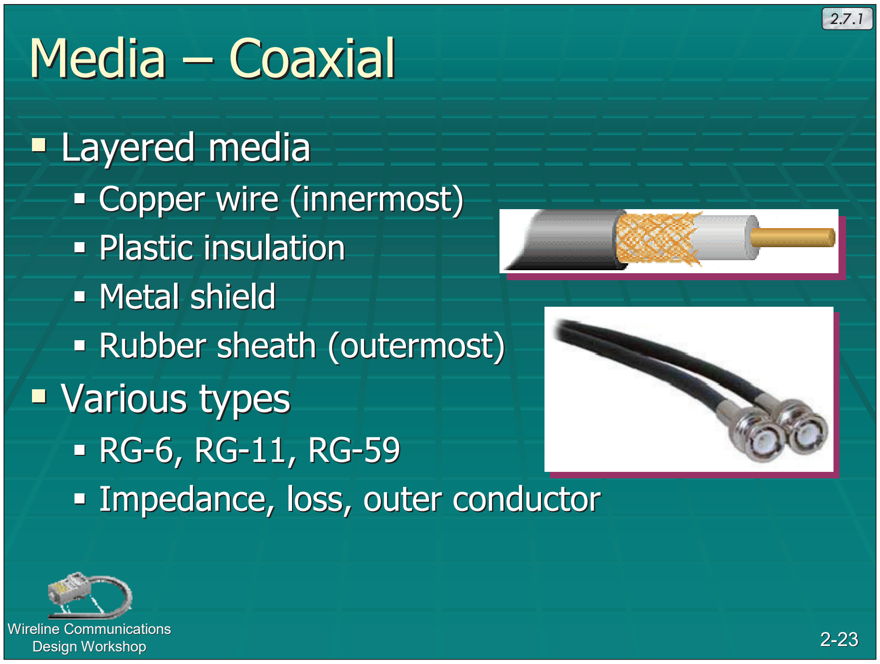
**Details:**

The next slide will discuss coaxial cable.

**Key Questions:**

**Other Information:**

None.



2.7.1

## Media – Coaxial

- Layered media
  - Copper wire (innermost)
  - Plastic insulation
  - Metal shield
  - Rubber sheath (outermost)
- Various types
  - RG-6, RG-11, RG-59
  - Impedance, loss, outer conductor

**Key Message:**

Coaxial cable is another popular type of copper media.

**Details:**

Coaxial cable is a layered media with a single copper wire at the center of the assembly. The metal shield is a ground and helps shield the copper wire from outside sources.

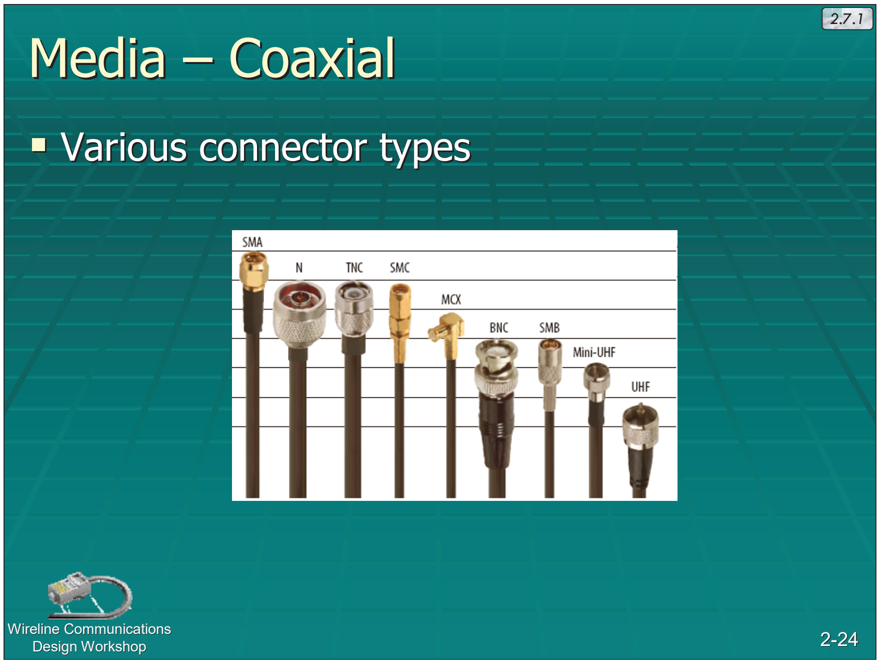
**Key Questions:**

**Other Information:**

Instructor should pass around the physical examples of coaxial cables and connectors.

RG stands for radio grade.

RJ (not shown) stands for recommended jack.



2.7.1

## Media – Coaxial

- Various connector types

Wireline Communications
Design Workshop

2-24

**Key Message:**

Coaxial cable uses a variety of different connectors.

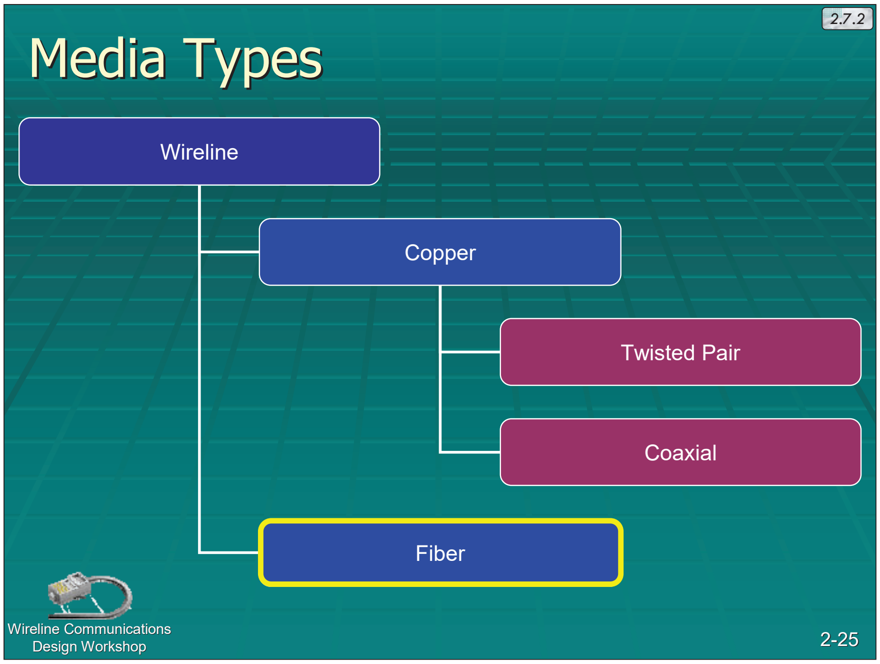
**Details:**

None.

**Key Questions:**

**Other Information:**

Instructor should pass around the physical examples of coaxial cables and connectors.



2.7.2

## Media Types

Wireline

Copper

Twisted Pair

Coaxial

Fiber

Wireline Communications
Design Workshop

**Key Message:**

This is a transition slide. It is intended to show the various media types.

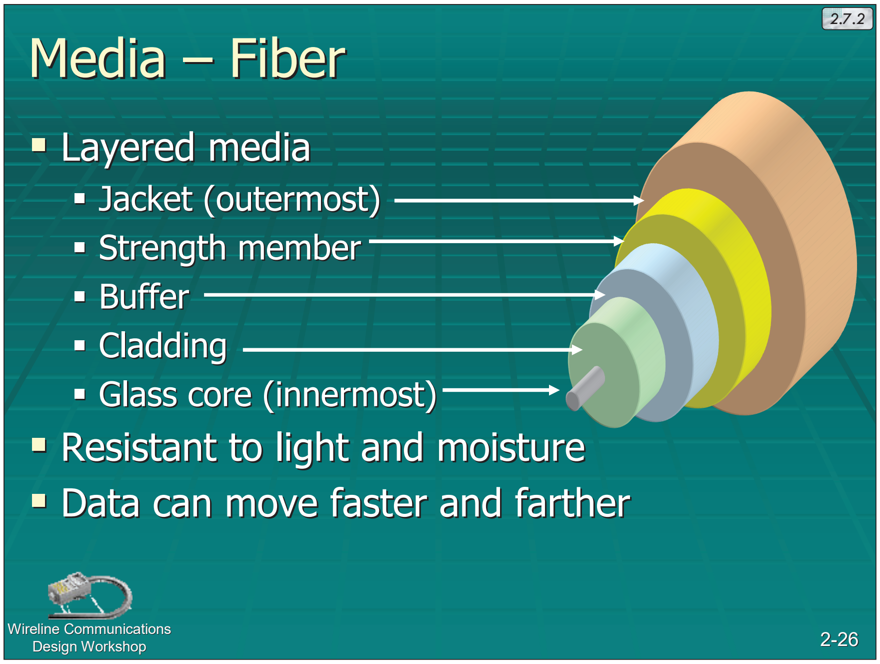
**Details:**

The next slide will discuss fiber optic media.

**Key Questions:**

**Other Information:**

None.



2.7.2

## Media – Fiber

- Layered media
  - Jacket (outermost)
  - Strength member
  - Buffer
  - Cladding
  - Glass core (innermost)
- Resistant to light and moisture
- Data can move faster and farther

Wireline Communications
Design Workshop

2-26

**Key Message:**

Fiber is becoming increasingly popular to use due to ever decreasing costs.

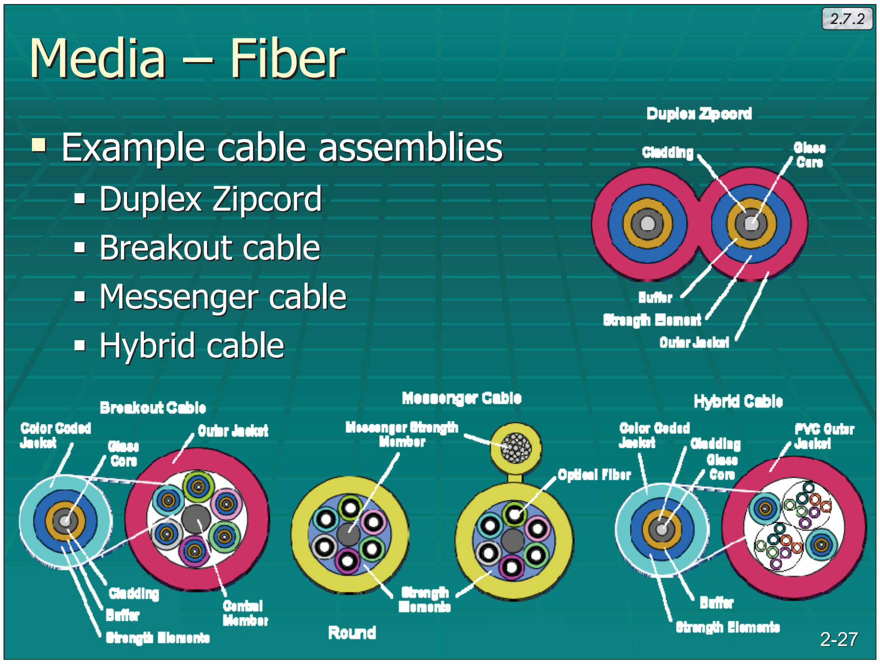
**Details:**

Fiber optic cable (or fiber) is also a layered media. The innermost core is not a copper wire, but glass fiber. Because data are transmitted using light instead of electrical impulses, they are not as susceptible to outside electrical interference.

**Key Questions:**

**Other Information:**

Instructor should pass around the physical examples of fiber optic media. Note that when you look at the fiber cable from the side, you are seeing the cladding, not the actual glass core.



## Media – Fiber

- Example cable assemblies
  - Duplex Zipcord
  - Breakout cable
  - Messenger cable
  - Hybrid cable

**Key Message:**

There are numerous types of cable assemblies. Some of them are shown here.

**Details:**

There are many types of fiber optic cable assemblies available for purchase. The choice of cabling depends on the task requirements. Other considerations include the need for fire retardant plenum cable for use in air spaces or riser cable to run vertically between floors in buildings. Cable assemblies also come in different modes, size bundles (number of fibers) and lengths.

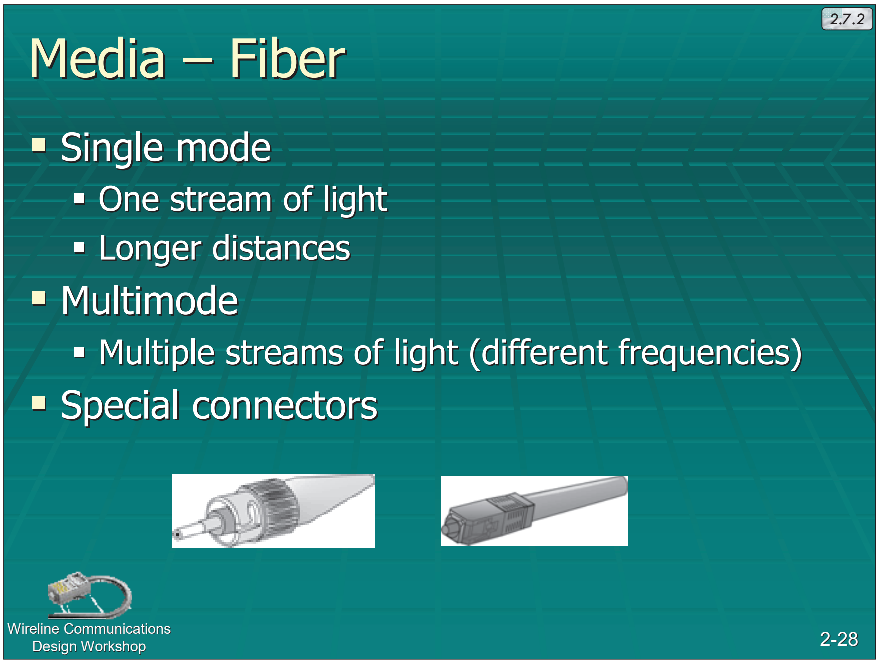
More examples are in the guidebook.

**Key Questions:**

Question: What might be a good example of the need for a hybrid cable?

Answer: Deep sea transmissions lines (e.g. trans-atlantic). Why? Power will be needed to supply signal regenerators along the way.

**Other Information:**



2.7.2

## Media – Fiber

- Single mode
  - One stream of light
  - Longer distances
- Multimode
  - Multiple streams of light (different frequencies)
- Special connectors

**Key Message:**

Fiber can run in two different mode types: single and multimode.

**Details:**

**Key Questions:**

**Other Information:**

Instructor should pass around the physical examples of fiber optic connectors.

2.8

## What's Next?

- Video on mobile devices
- Nanotechnology
- Increased standardization
- Globalization

Wireline Communications
Design Workshop

2-29

**Key Message:**

Technology is rapidly changing and there are always newer things on the horizon that will affect ITS projects.

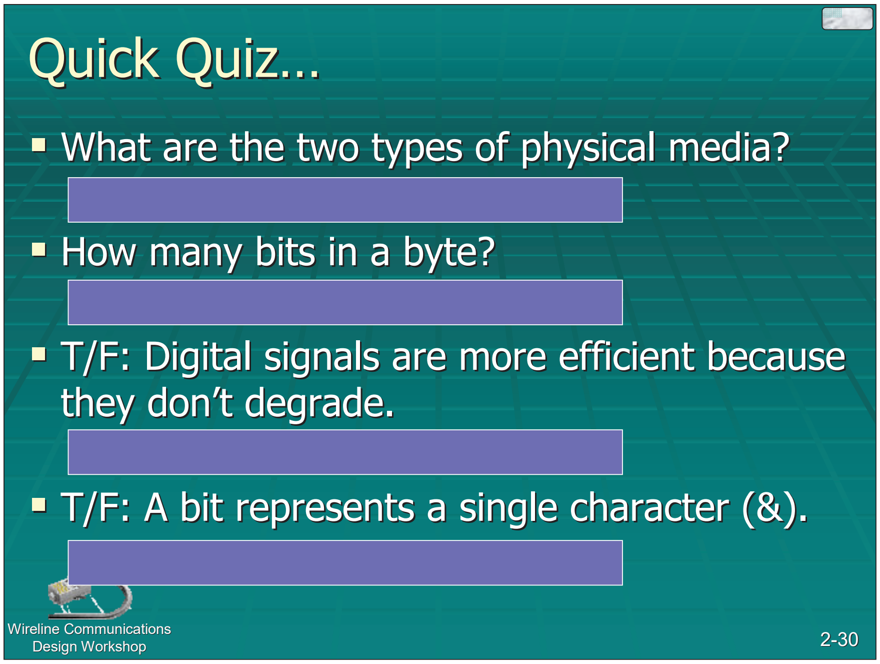
**Details:**

**Key Questions:**

**ASK:** How can standards (or standardization) help us in designing ITS projects?

**ANSWERS:** Reduced capital costs, interchangability, interoperability, simpler maintenance, etc.

**Other Information:**



# Quick Quiz…

- What are the two types of physical media?
- How many bits in a byte?
- T/F: Digital signals are more efficient because they don't degrade.
- T/F: A bit represents a single character (&).

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Design Workshop

Quiz Q&A:

**What are the two types of physical media?**

Copper and fiber

**How many bits in a byte?**

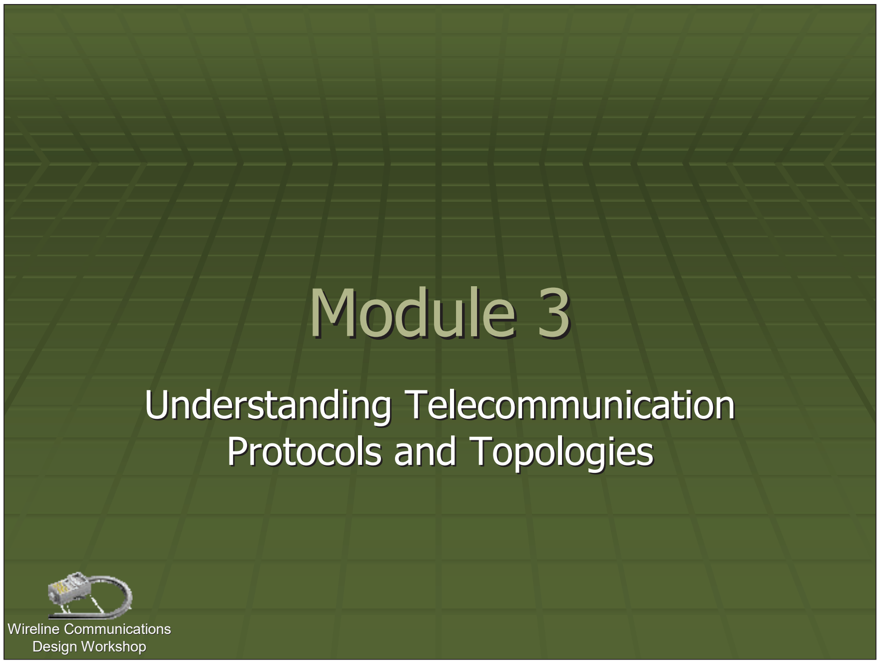
Eight

**T/F: Digital signals are more efficient because they don't degrade.**

False, all signals degrade

**T/F: A bit represents a single character (&).**

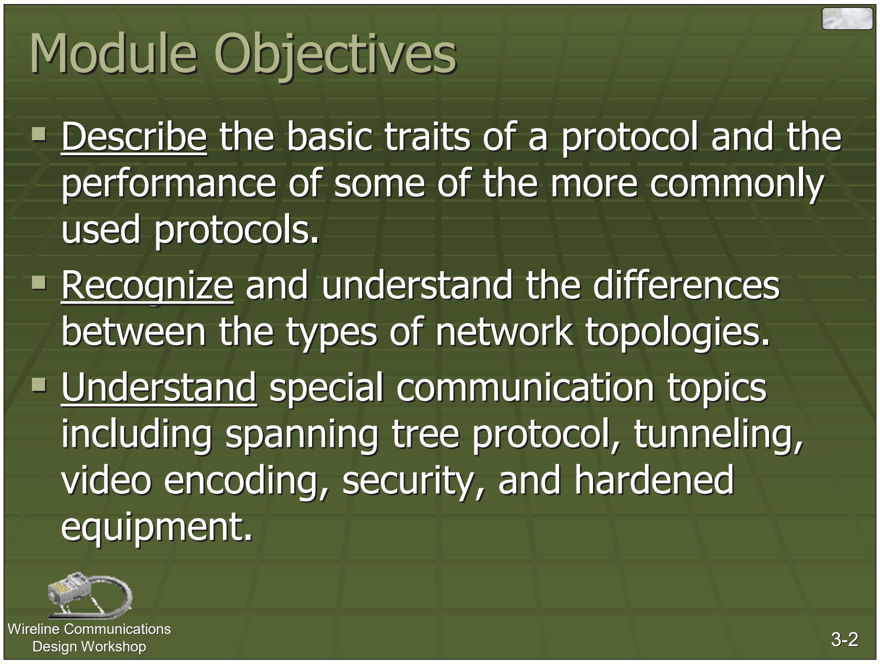
False, a byte is a single character



# Module 3

## Understanding Telecommunication Protocols and Topologies

Wireline Communications
Design Workshop



## Module Objectives

- Describe the basic traits of a protocol and the performance of some of the more commonly used protocols.
- Recognize and understand the differences between the types of network topologies.
- Understand special communication topics including spanning tree protocol, tunneling, video encoding, security, and hardened equipment.

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**Key Message:**

None.

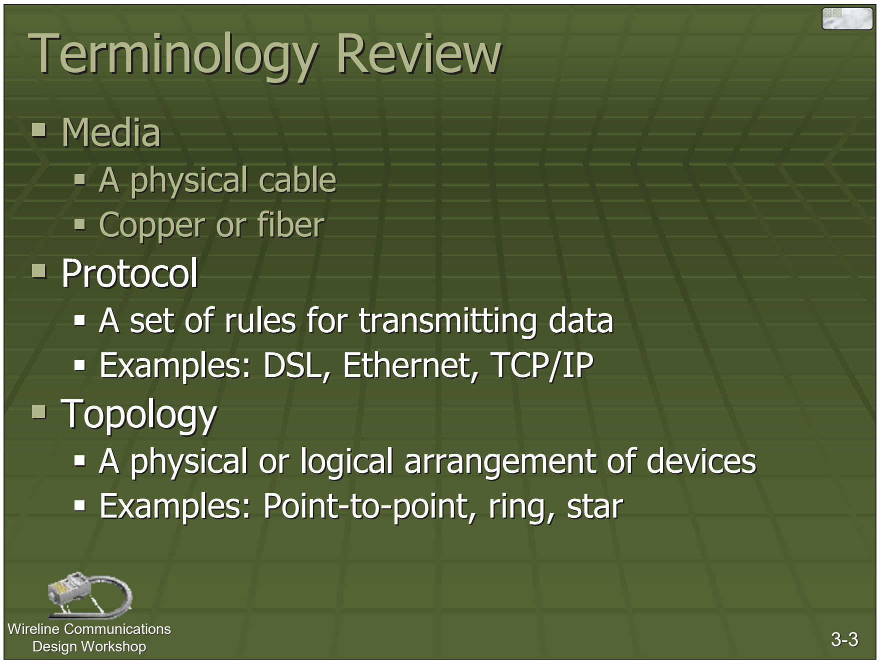
**Details:**

Go over the module objectives.

**Key Questions:**

**Other Information:**

None.



## Terminology Review

- Media
  - A physical cable
  - Copper or fiber
- Protocol
  - A set of rules for transmitting data
  - Examples: DSL, Ethernet, TCP/IP
- Topology
  - A physical or logical arrangement of devices
  - Examples: Point-to-point, ring, star

Wireline Communications
Design Workshop

**Key Message:**

This slide is a repeat of one in the previous module. Media has already been discussed. This module will discuss protocols and topologies.

**Details:**

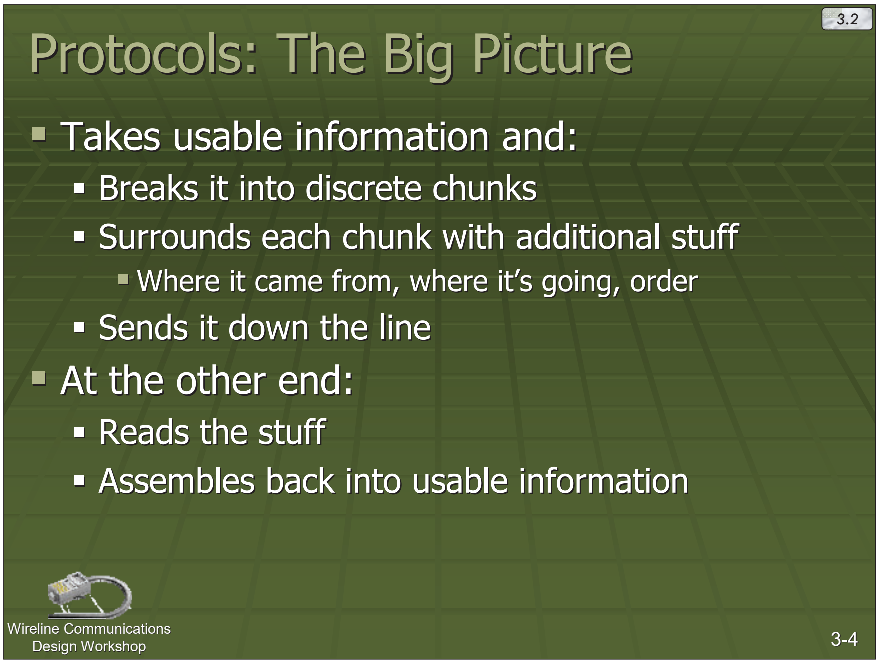
A **protocol** is simply a set of rules for data transmission (includes error checking, compression, format, etc.).

**Topology** describes how the devices are physically or logically arranged.

**Key Questions:**

**Other Information:**

None.



3.2

## Protocols: The Big Picture

- Takes usable information and:
    - Breaks it into discrete chunks
    - Surrounds each chunk with additional stuff
        - Where it came from, where it's going, order
    - Sends it down the line
- At the other end:
    - Reads the stuff
    - Assembles back into usable information

Wireline Communications
Design Workshop

3-4

**Key Message:**

A protocol is really nothing more than a set of rules for handling and exchanging information.

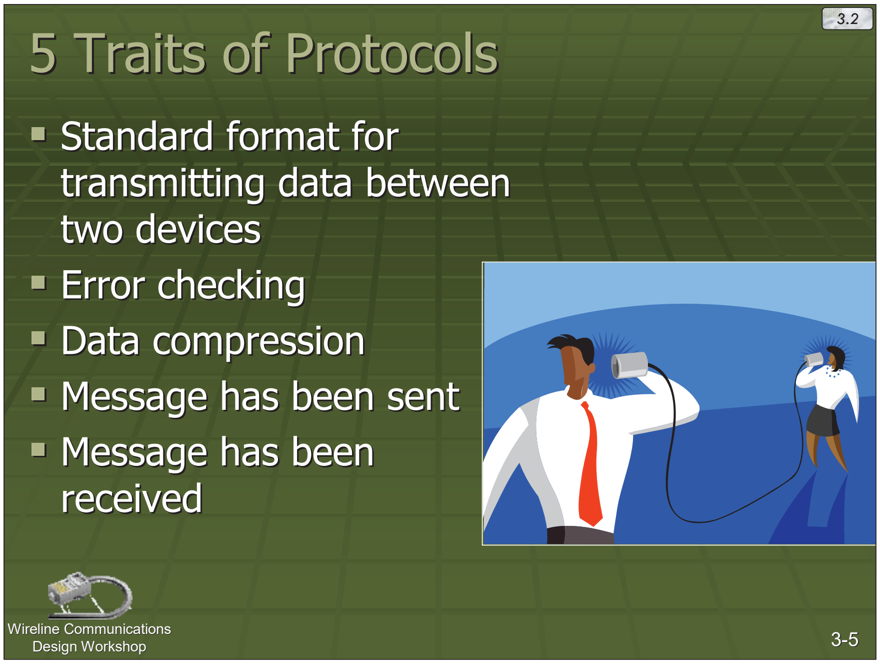
**Details:**

Describe protocols in a very "untechnical" way: You take information and break it into **chunks**. You surround the **chunks** with **stuff** and send it down the pathway. At the other end you look at the **stuff** and reassemble the **chunks** into usable information.

**Key Questions:**

**Other Information:**

Analogy: Ordering a PC from Dell (or other on-line vendor). You will order several parts (CPU, monitor, printer, 2$^{nd}$ monitor, etc). They will not all arrive in one box. Nor will the separate boxes necessarily arrive on the same day. But the boxes should be labeled with your address, Dell's address, and an indication of how many boxes to expect (1 of 5, 2 of 5, etc.).



3.2

5 Traits of Protocols

- Standard format for transmitting data between two devices
- Error checking
- Data compression
- Message has been sent
- Message has been received

Wireline Communications Design Workshop

3-5

**Key Message:**

A protocol is really nothing more than a set of rules for handling and exchanging information.

**Details:**

A protocol is a standardized method of taking any type of information and breaking it up into discrete units that can be sent along the media.

All protocols have the following common traits:

Specification of a standard format for transmitting data between two devices,

Specification of the type of error checking to be used,

Specification of any data compression utilized,

Specification of how the sending device will indicate that it has finished sending a message, and

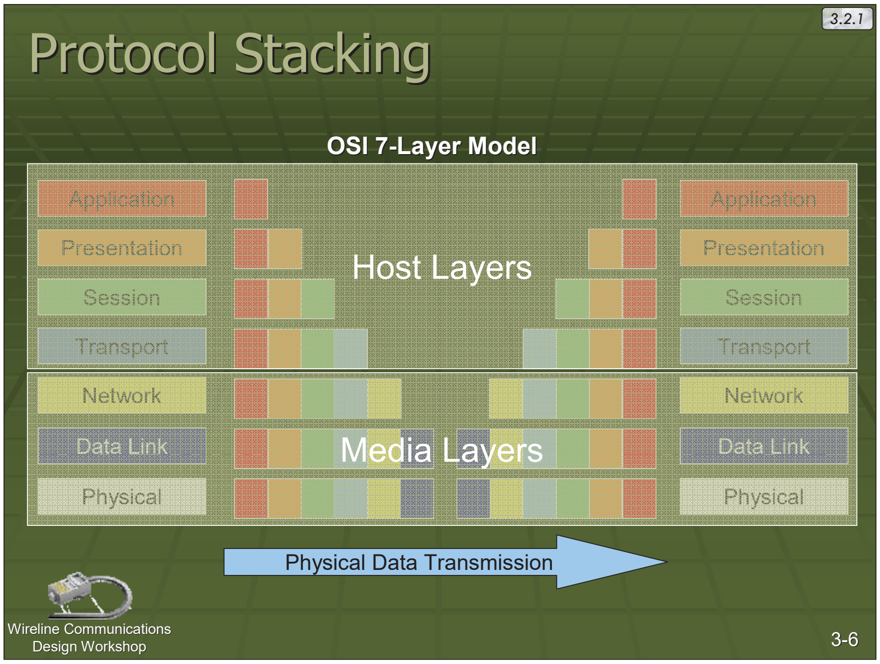
Specification of how the receiving device will indicate that it has received a message.

**Key Questions:**

**Other Information:**

Telephone analogy

Consider a standard telephone conversation between two people. You first initiate a call by picking up the phone and listening for a dial tone. If present, you then dial a set of numbers to reach a destination phone. The person at the other end hears the phone ring, picks up the phone and says “Hello.” At that point you begin your conversation, by identifying who is calling and what you are calling about.



3.2.1

## Protocol Stacking

**OSI 7-Layer Model**

| | | |
|---|---|---|
| Application | | Application |
| Presentation | Host Layers | Presentation |
| Session | | Session |
| Transport | | Transport |
| Network | | Network |
| Data Link | Media Layers | Data Link |
| Physical | | Physical |

Physical Data Transmission

Wireline Communications
Design Workshop

3-6

**Key Message:**

When multiple protocols are involved in the transmission of information, they are said to be 'stacked.' Each layer adds additional features and capabilities not provided by the underlying protocols. Stacking is essential to providing interoperability.

**Details:**

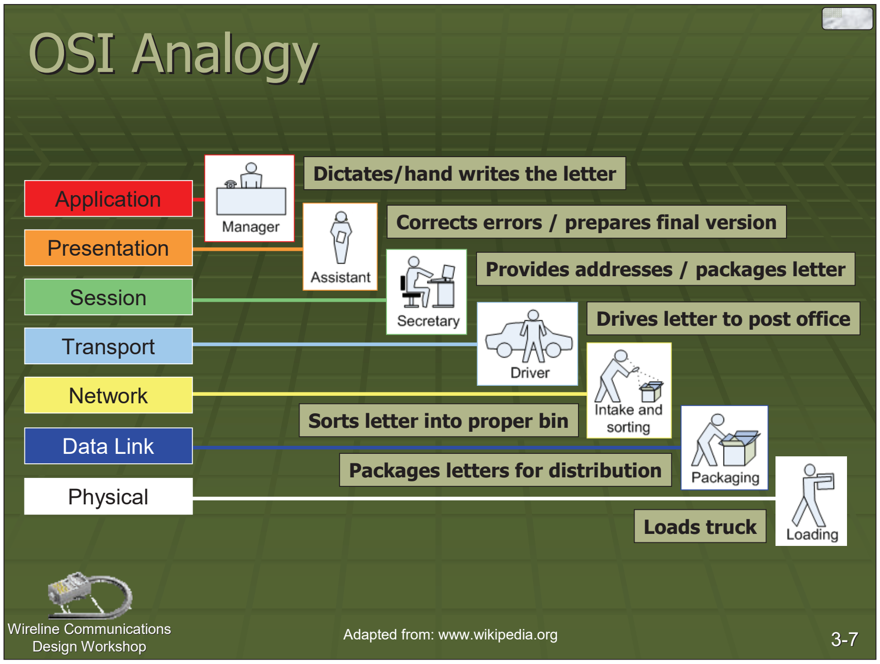
This slide illustrates the 7 layers of the model and how data from each level are assembled and passed down to the point where they are transmitted across the 'wire' where the process is then reversed. At each level, the information from the layer above it is encapsulated or surrounded with additional information. As an example, information originating from Layer 7 is encapsulated in Layer 6, which is encapsulated in Layer 5 and so on, until it reaches Layer 1. At Layer 1, the information is sent out over the wire (either copper or fiber in our case) to another device. At the other device, the information is received and moves back up the seven layers with each layer now stripping away the extra information. At the top of the stack, it arrives at Layer 7 and is passed back to the application that can use it.

The process of starting at the application layer and moving down is encapsulation.

The reverse process is stripping.

**Key Questions:**

**Other Information:**



## OSI Analogy

| | | |
|---|---|---|
| Application | Manager | Dictates/hand writes the letter |
| Presentation | Assistant | Corrects errors / prepares final version |
| Session | Secretary | Provides addresses / packages letter |
| Transport | Driver | Drives letter to post office |
| Network | Intake and sorting | Sorts letter into proper bin |
| Data Link | Packaging | Packages letters for distribution |
| Physical | Loading | Loads truck |

Wireline Communications Design Workshop

Adapted from: www.wikipedia.org

3-7

**Key Message:**

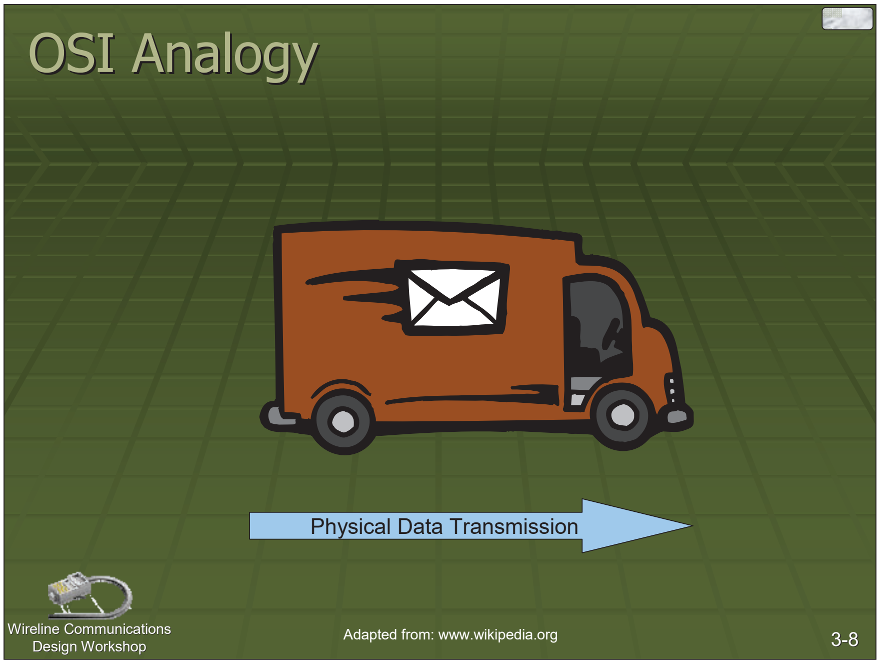
The next 3 slides will give an analogy to the OSI model. The analogy is a company manager sending a written communication to another company manager in perhaps another city. Keep in mind this is a very loose analogy. But is intended to show how protocols are "stacked."

**Details:**

Build the slide with mouse clicks. Each layer is represented by a different step in the process.

**Key Questions:**

**Other Information:**



OSI Analogy

Physical Data Transmission

Wireline Communications Design Workshop

Adapted from: www.wikipedia.org

3-8

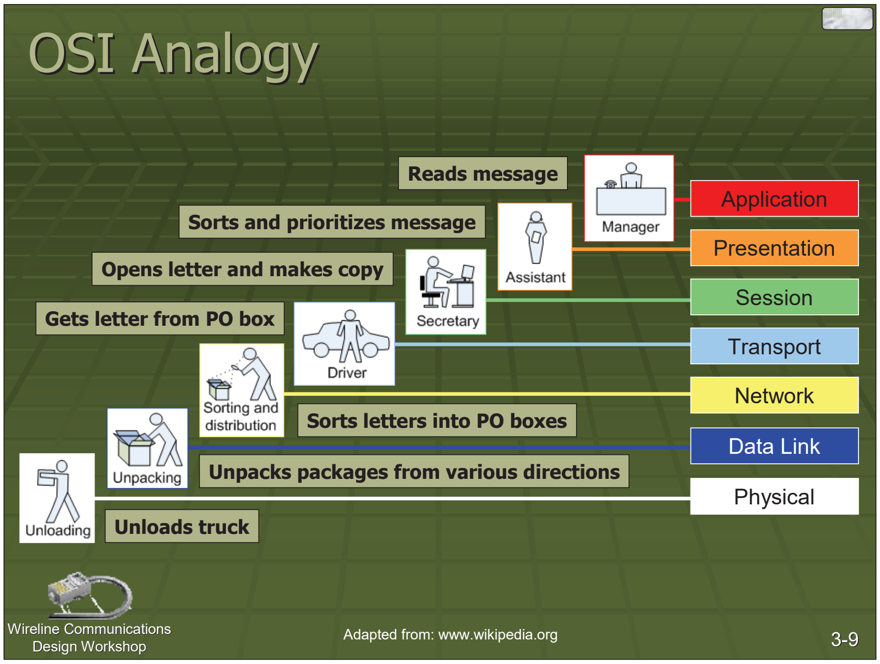
**Key Message:**

Continuation of the OSI analogy.

**Details:**

**Key Questions:**

**Other Information:**



## OSI Analogy

Reads message — Manager — Application

Sorts and prioritizes message — Assistant — Presentation

Opens letter and makes copy — Secretary — Session

Gets letter from PO box — Driver — Transport

Sorting and distribution — Sorts letters into PO boxes — Network

Unpacking — Unpacks packages from various directions — Data Link

Unloading — Unloads truck — Physical

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Design Workshop

Adapted from: www.wikipedia.org

3-9

**Key Message:**

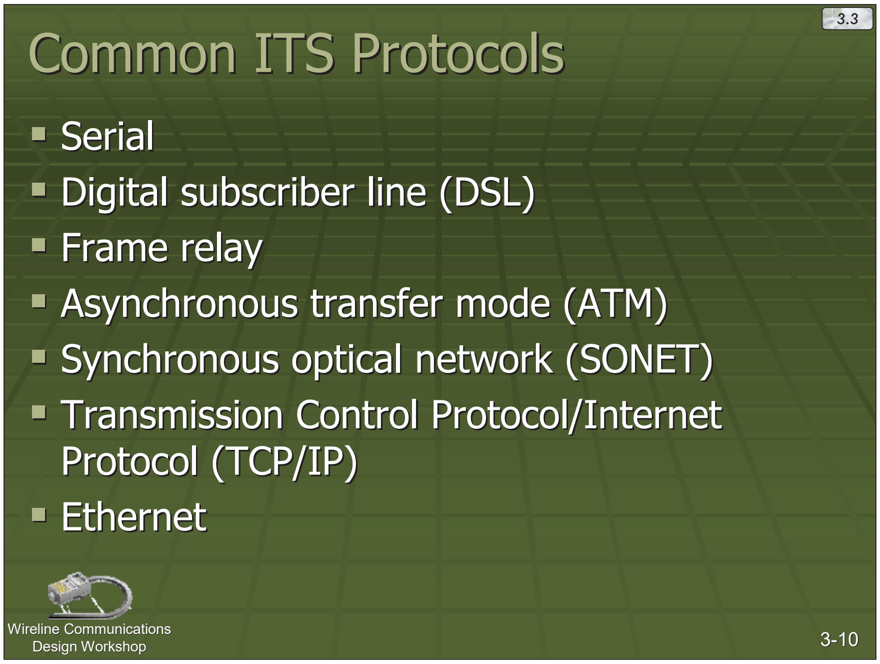
Continuation of the OSI analogy.

**Details:**

Build the slide with mouse clicks. Each layer is represented by a different step in the process.

**Key Questions:**

**Other Information:**



3.3

## Common ITS Protocols

- Serial
- Digital subscriber line (DSL)
- Frame relay
- Asynchronous transfer mode (ATM)
- Synchronous optical network (SONET)
- Transmission Control Protocol/Internet Protocol (TCP/IP)
- Ethernet

Wireline Communications
Design Workshop

3-10

**Key Message:**

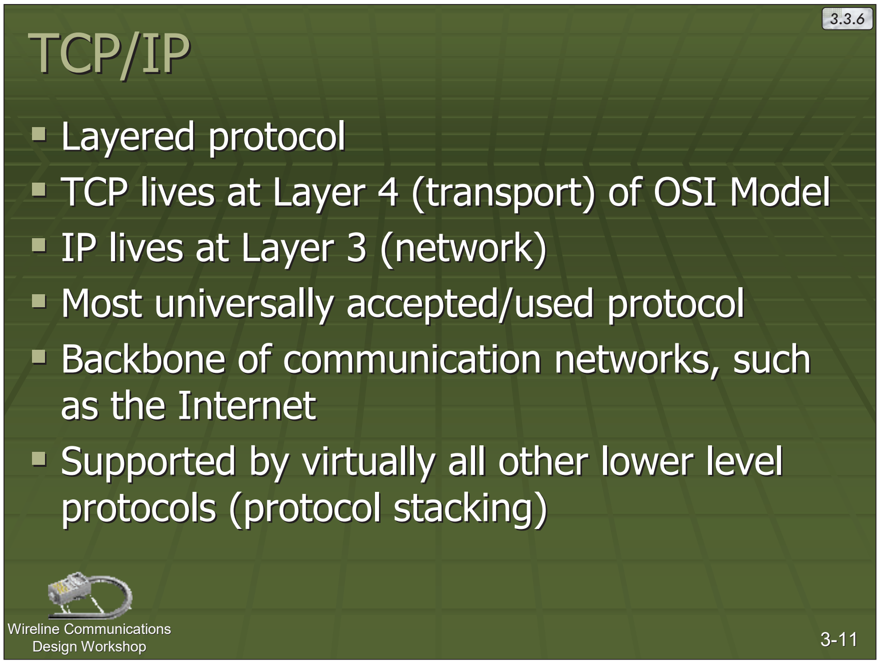
Certain protocols are commonly used in the ITS field.

**Details:**

Do not spend much time on this slide. Each of these protocols will be gone over in the next module as it relates to their technology. TCP/IP, however, will be discussed a little more in the next slides because it is not associated with any particular technology (like DSL, for example).

**Key Questions:**

**Other Information:**



3.3.6

## TCP/IP

- Layered protocol
- TCP lives at Layer 4 (transport) of OSI Model
- IP lives at Layer 3 (network)
- Most universally accepted/used protocol
- Backbone of communication networks, such as the Internet
- Supported by virtually all other lower level protocols (protocol stacking)

Wireline Communications Design Workshop

3-11

**Key Message:**

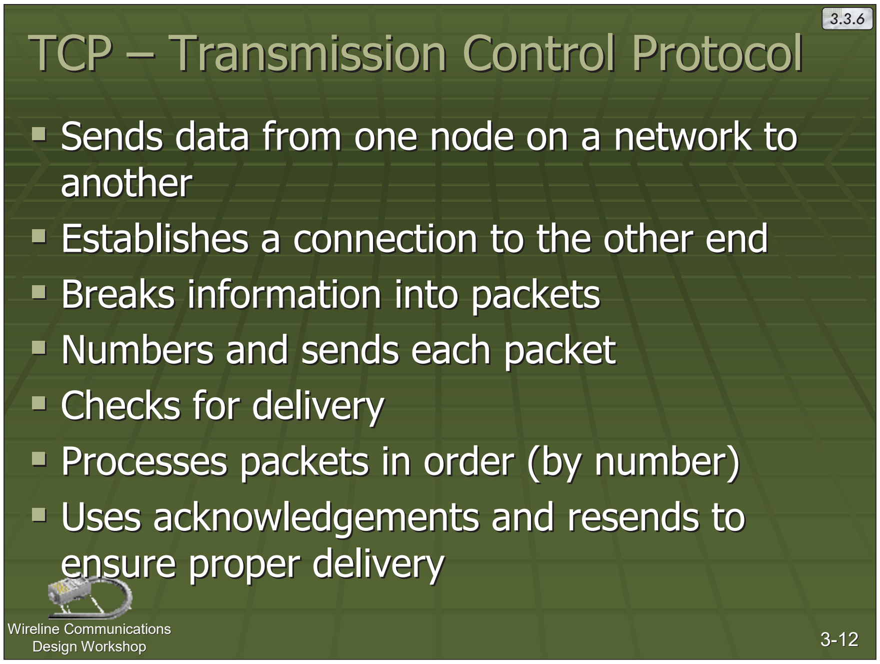
TCP/IP is a layered protocol that is the most universally accepted of all protocols.

**Details:**

The TCP/IP protocol is widely used in not only the transportation industry, but for all industries. It is such a widely accepted (and mature) protocol, that there is very little reason to develop a different protocol just for our ITS uses.

**Key Questions:**

**Other Information:**



3.3.6

## TCP – Transmission Control Protocol

- Sends data from one node on a network to another
- Establishes a connection to the other end
- Breaks information into packets
- Numbers and sends each packet
- Checks for delivery
- Processes packets in order (by number)
- Uses acknowledgements and resends to ensure proper delivery

Wireline Communications
Design Workshop

3-12

**Key Message:**

TCP is one of the two layers of TCP/IP.

**Details:**

TCP is used for the reliable transmission of data from one node on a network to another. Typically, a TCP packet contains:

A source TCP port number

A destination TCP port number

A sequence number (for data that have to be broken up into multiple packets)

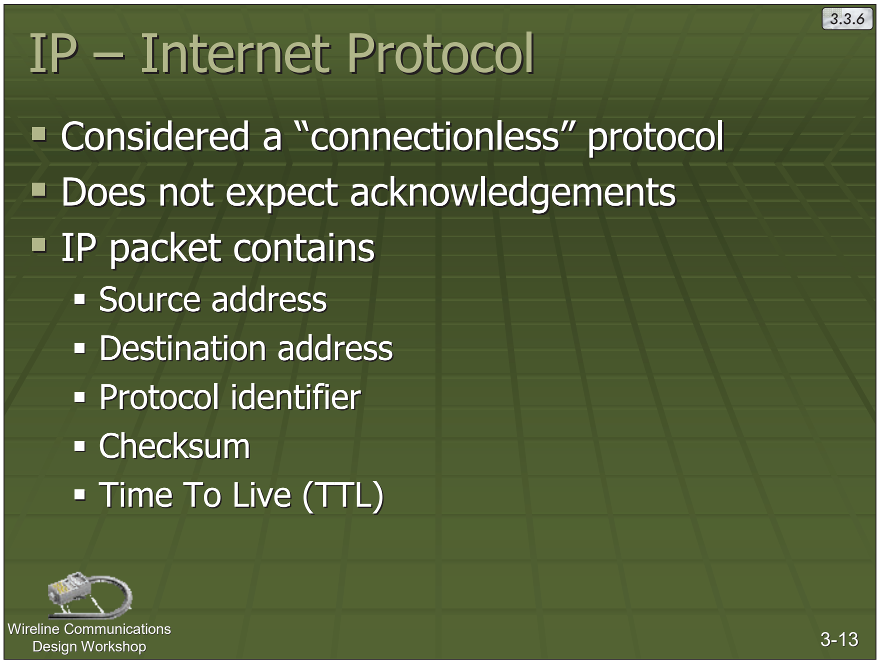
A checksum

An acknowledgement

**Key Questions:**

**Other Information:**

UDP = User Datagram Protocol. This can also be used on the transport layer.



3.3.6

## IP – Internet Protocol

- Considered a "connectionless" protocol
- Does not expect acknowledgements
- IP packet contains
  - Source address
  - Destination address
  - Protocol identifier
  - Checksum
  - Time To Live (TTL)

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Design Workshop

3-13

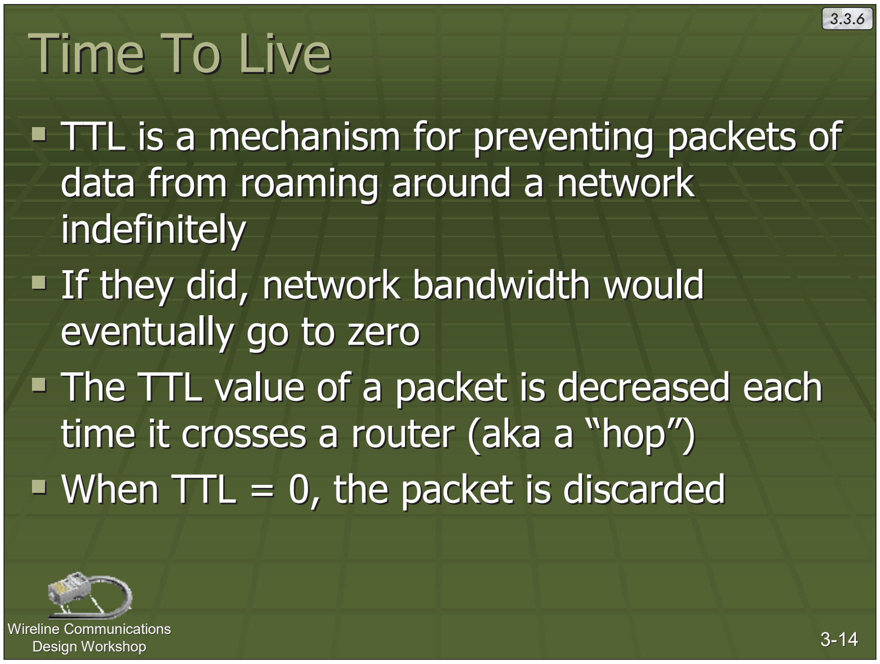
**Key Message:**

IP is the other layer of TCP/IP.

**Details:**

**Key Questions:**

**Other Information:**



3.3.6

## Time To Live

- TTL is a mechanism for preventing packets of data from roaming around a network indefinitely
- If they did, network bandwidth would eventually go to zero
- The TTL value of a packet is decreased each time it crosses a router (aka a "hop")
- When TTL = 0, the packet is discarded

Wireline Communications
Design Workshop

**Key Message:**

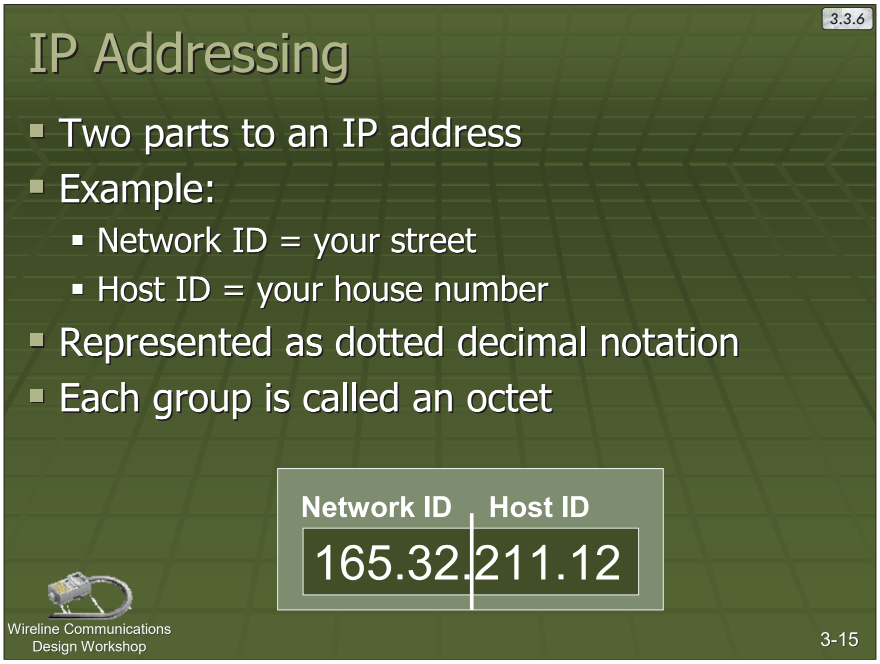
TTL is a key mechanism for keeping bandwidth available.

**Details:**

Packets of data are "expired" when they reach their destination. However, damaged or incomplete packets won't be taken out of circulation and will keep attempting delivery. Networks decrement the TTL value on a packet until zero then throw it away, which prevents them from clogging networks. TTL is also an important concept important in multicast to prevent network storms.

**Key Questions:**

**Other Information:**



3.3.6

## IP Addressing

- Two parts to an IP address
- Example:
  - Network ID = your street
  - Host ID = your house number
- Represented as dotted decimal notation
- Each group is called an octet

**Network ID** **Host ID**

165.32.211.12

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Design Workshop

**Key Message:**

Explanation of IP addressing.

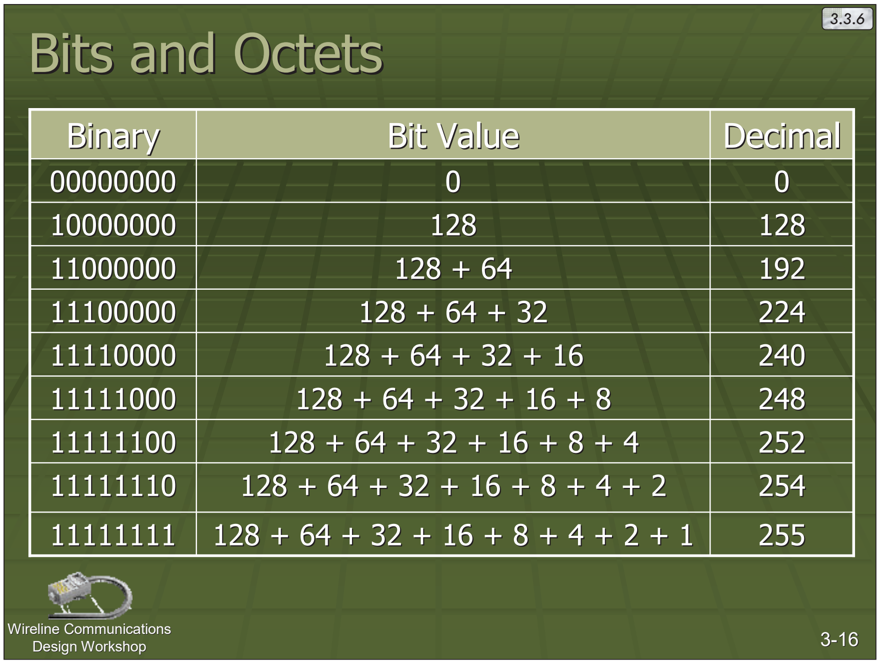
**Details:**

Post office analogy:  The Internet is your neighborhood.  The Network ID routes the packet (letter) to your street (Main).  The Host ID routes it to the particular location on the network (street address) (17 Main Street).

A number of different ways to represent IP addressing….all will be done in octets (each octet is  8 bits, 8.4 = 32 bit addressing).

**Key Questions:**

**Other Information:**



3.3.6

## Bits and Octets

| Binary | Bit Value | Decimal |
|---|---|---|
| 00000000 | 0 | 0 |
| 10000000 | 128 | 128 |
| 11000000 | 128 + 64 | 192 |
| 11100000 | 128 + 64 + 32 | 224 |
| 11110000 | 128 + 64 + 32 + 16 | 240 |
| 11111000 | 128 + 64 + 32 + 16 + 8 | 248 |
| 11111100 | 128 + 64 + 32 + 16 + 8 + 4 | 252 |
| 11111110 | 128 + 64 + 32 + 16 + 8 + 4 + 2 | 254 |
| 11111111 | 128 + 64 + 32 + 16 + 8 + 4 + 2 + 1 | 255 |

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3-16

**Key Message:**

Explanation of how binary gets translated to octets and decimal values.

**Details:**

Chart shows the "break points"

225 for example would then be 11100001 (224 + 1)

226 would be 11100010 (224 + 2)

From RIGHT to LEFT, each places adds in the following values

1
2
4
8
16
32
64
128

So for another example, 67 is going to be 01000011

Easy way to convert:

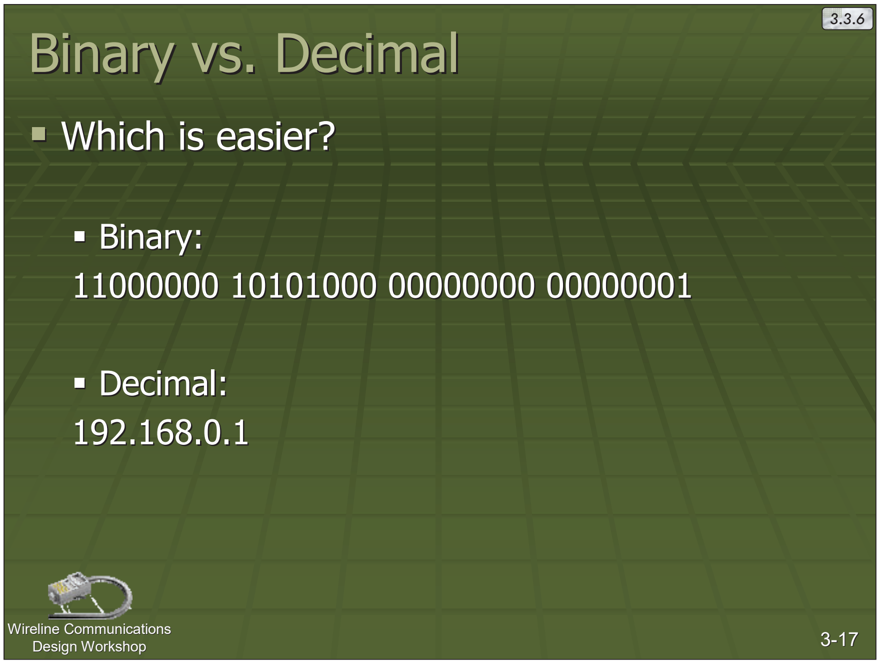
Start from the LEFT! Add up the values (128, 64, etc.) until you would go over your target on the next step. All of those are 1's. Then, flip to the right side and start adding in those values (1, 2, etc.) until you hit the combination you need. All of those are 1's as well. All other values are 0.

**Key Questions:**

Ask what 67 would be: 67 is going to be 01000011

Ask what 127 would be: 127 is going to be 01111111

**Other Information:**



3.3.6

## Binary vs. Decimal

- Which is easier?
  - Binary:
  11000000 10101000 00000000 00000001
  - Decimal:
  192.168.0.1

Wireline Communications Design Workshop

3-17

**Key Message:**

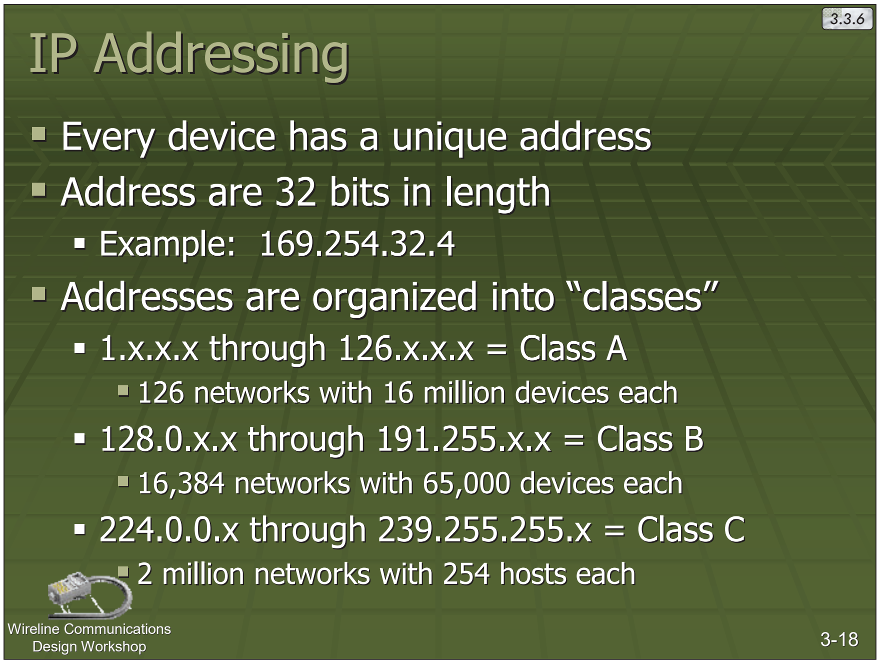
Take a look at binary vs. decimal expressions of IP addressing.

**Details:**

Which is easier to read / work with / understand?

**Key Questions:**

**Other Information:**



3.3.6

## IP Addressing

- Every device has a unique address
- Address are 32 bits in length
  - Example:  169.254.32.4
- Addresses are organized into "classes"
  - 1.x.x.x through 126.x.x.x = Class A
    - 126 networks with 16 million devices each
  - 128.0.x.x through 191.255.x.x = Class B
    - 16,384 networks with 65,000 devices each
  - 224.0.0.x through 239.255.255.x = Class C
    - 2 million networks with 254 hosts each

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**Key Message:**

IP addressing is done in an orderly fashion.

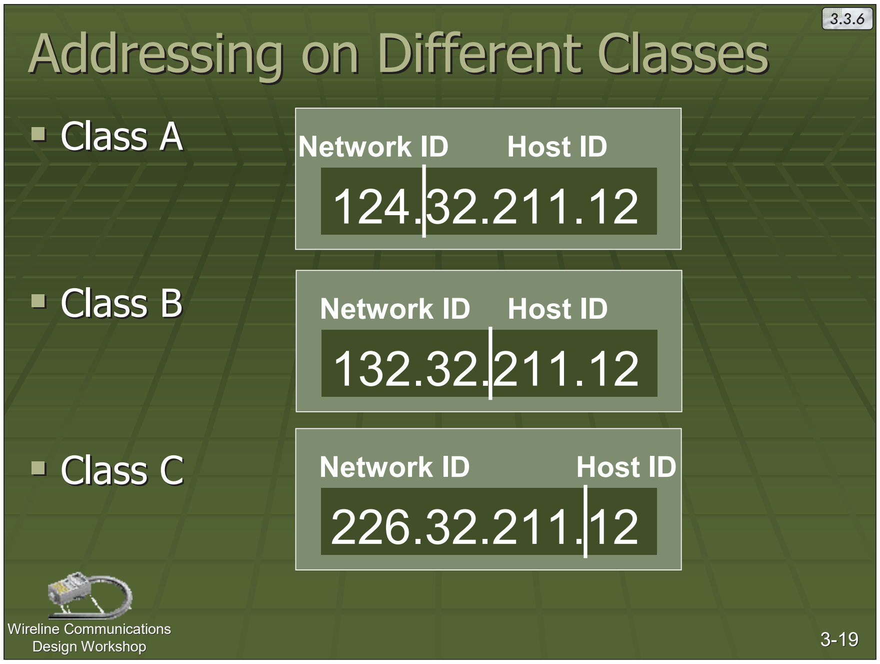
**Details:**

IP addresses are managed by Internet Corporation for Assigned Names and Numbers (ICANN).  The Internet Assigned Numbers Authority (IANA) is a part of ICANN.

IP addresses are divided into several classes.  An example of a Class A network might be a large telecommunications company like AT&T.  An example of a Class B network might be a major university.  An example of a Class C network might be a small to medium size company.

**Key Questions:**

**Other Information:**



3.3.6

## Addressing on Different Classes

- Class A

Network ID Host ID
124.|32.211.12

- Class B

Network ID Host ID
132.32.|211.12

- Class C

Network ID Host ID
226.32.211.|12

Wireline Communications
Design Workshop

3-19

**Key Message:**

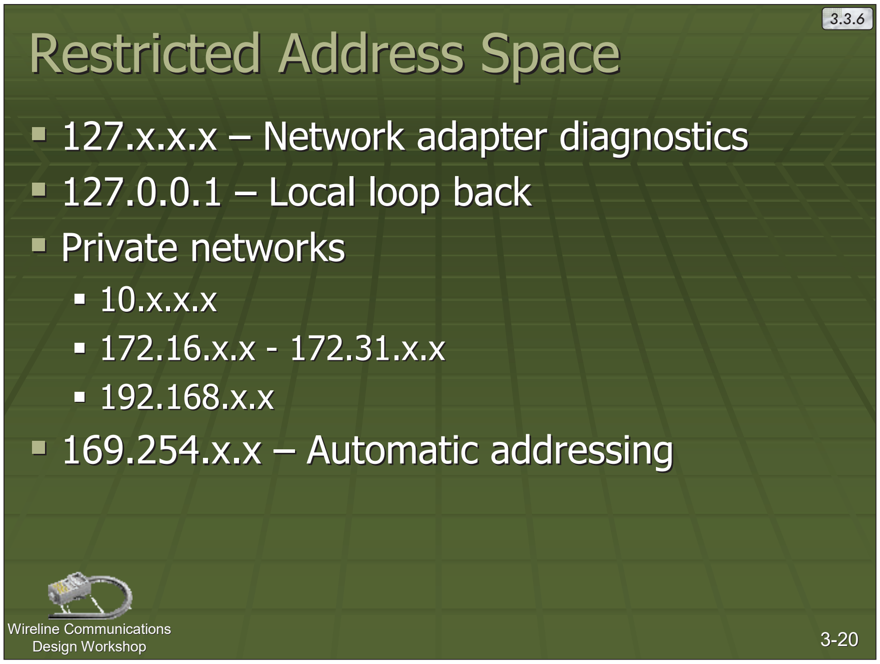
Examples of addressing on different classes of networks.

**Details:**

The network and host id portions of the IP address change, depending on the class of the network you are on.

**Key Questions:**

**Other Information:**



3.3.6

## Restricted Address Space

- 127.x.x.x – Network adapter diagnostics
- 127.0.0.1 – Local loop back
- Private networks
  - 10.x.x.x
  - 172.16.x.x - 172.31.x.x
  - 192.168.x.x
- 169.254.x.x – Automatic addressing

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3-20

**Key Message:**

Some address space is restricted for special purposes.

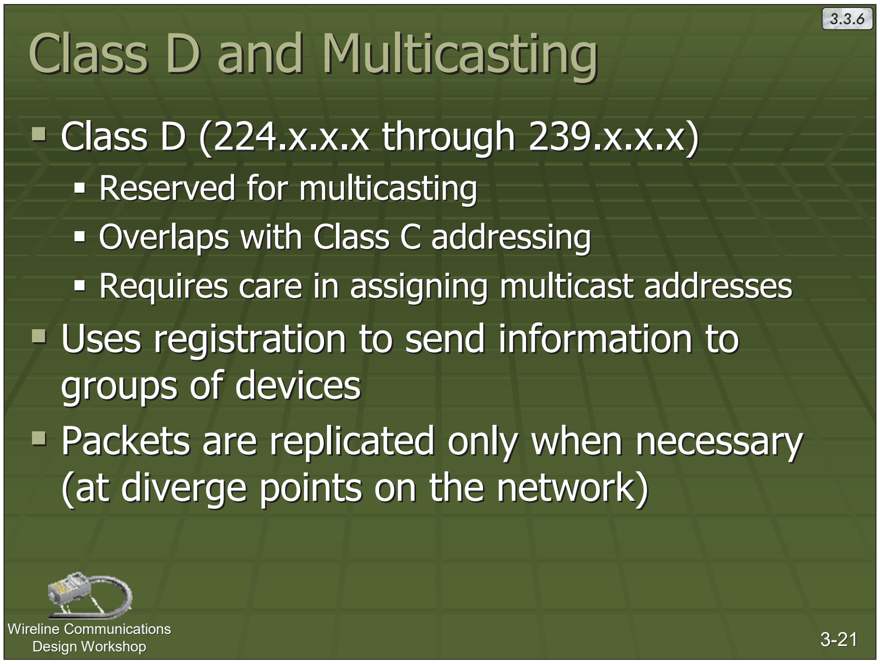
**Details:**

The ranges listed and their purposes describe restricted ranges that should note be used for general purposes.

**Key Questions:**

Can these ranges be used by companies wishing to preserve public address space. YES! (see NAT explanation).

**Other Information:**



3.3.6

### Class D and Multicasting

- Class D (224.x.x.x through 239.x.x.x)
  - Reserved for multicasting
  - Overlaps with Class C addressing
  - Requires care in assigning multicast addresses
- Uses registration to send information to groups of devices
- Packets are replicated only when necessary (at diverge points on the network)

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3-21

**Key Message:**

Multicasting is a special application requiring special addressing.

**Details:**

Multicast is not a connection-oriented mechanism and doesn't use TCP. It uses IP or UDP.

Devices must register to send and receive information.

Registration handled by a multicast manager.

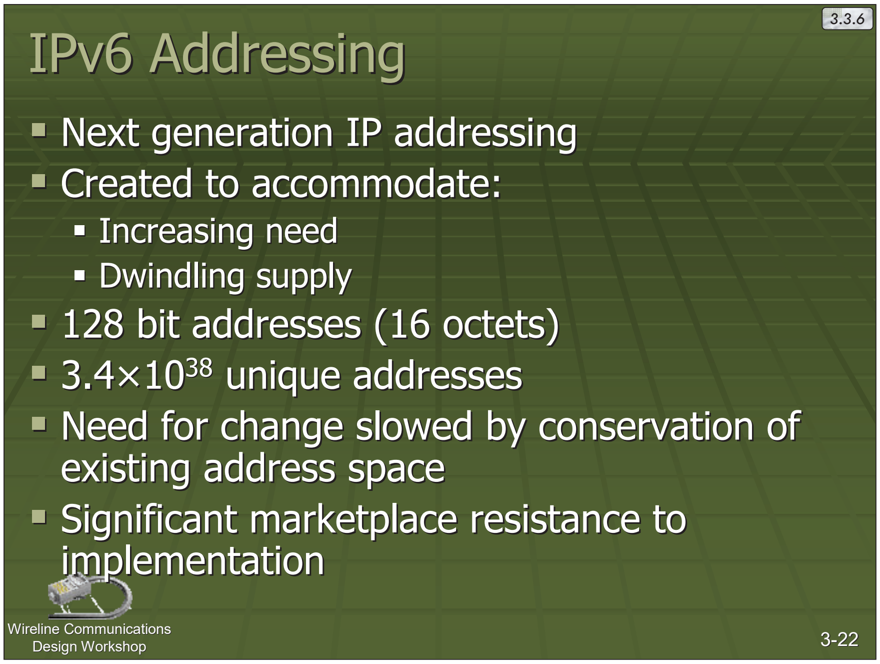
Significant care must be taken in assigning multicast addresses as they overlap with Class C addressing and differ by the subnet mask.

There are special protocols used to manage multicast traffic, such as IGMP (Internet Group Multicast Protocol).

In current implementations, video is often sent multicast.

**Key Questions:**

**Other Information:**



3.3.6

## IPv6 Addressing

- Next generation IP addressing
- Created to accommodate:
  - Increasing need
  - Dwindling supply
- 128 bit addresses (16 octets)
- $3.4 \times 10^{38}$ unique addresses
- Need for change slowed by conservation of existing address space
- Significant marketplace resistance to implementation

Wireline Communications
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3-22

**Key Message:**

Current generation of IP addressing is IPv4. IPv6 is a significant expansion of the address space.

**Details:**

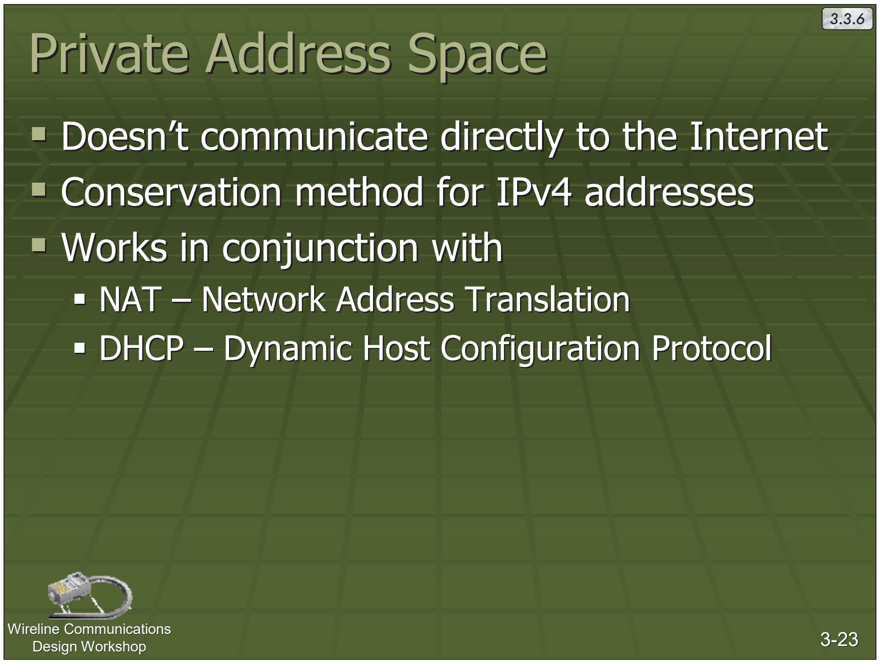
$5 \times 10^{28}$ addresses for *each* of the roughly 6.5 billion people on the planet today.

Because of the cost of changing ove to IPv6, there is significant marketplace resistance to doing so.

Federal government has specified the use of IPv6 for all federal agencies by 2008.

**Key Questions:**

**Other Information:**



3.3.6

## Private Address Space

- Doesn't communicate directly to the Internet
- Conservation method for IPv4 addresses
- Works in conjunction with
  - NAT – Network Address Translation
  - DHCP – Dynamic Host Configuration Protocol

Wireline Communications
Design Workshop

**Key Message:**

IP addressing is done in an orderly fashion.  IP addresses are managed by Internet Assigned Numbers Authority (IANA).

**Details:**

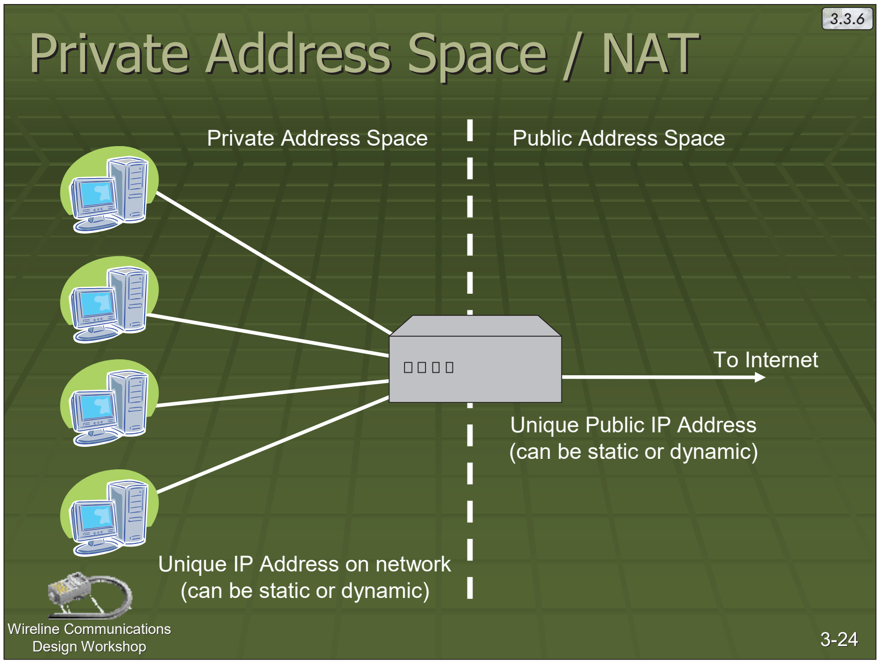
Some IP addresses are reserved for certain functions.

Other IP addresses are reserved for devices that don't communicate out to the Internet.  Example: your home wireless router.  It communicates with a cable or DSL modem that is dynamically assigned an IP address by your ISP to communicate with the Internet.

The use of dynamically assigned IP addresses and private addresses has dramatically delayed the need for more IP addresses.  However, as more and more devices become "wired" to the Internet (think: refrigerators, security systems, televisions/home entertainment, heating/cooling systems), the need for more IP addresses will likely need to be addressed.  IPv6 will increase the number of IP addresses.

**Key Questions:**

**Other Information:**



3.3.6

## Private Address Space / NAT

Private Address Space

Public Address Space

To Internet

Unique Public IP Address
(can be static or dynamic)

Unique IP Address on network
(can be static or dynamic)

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Design Workshop

3-24

**Key Message:**

Private addressing has delayed the need to implement IPv6.

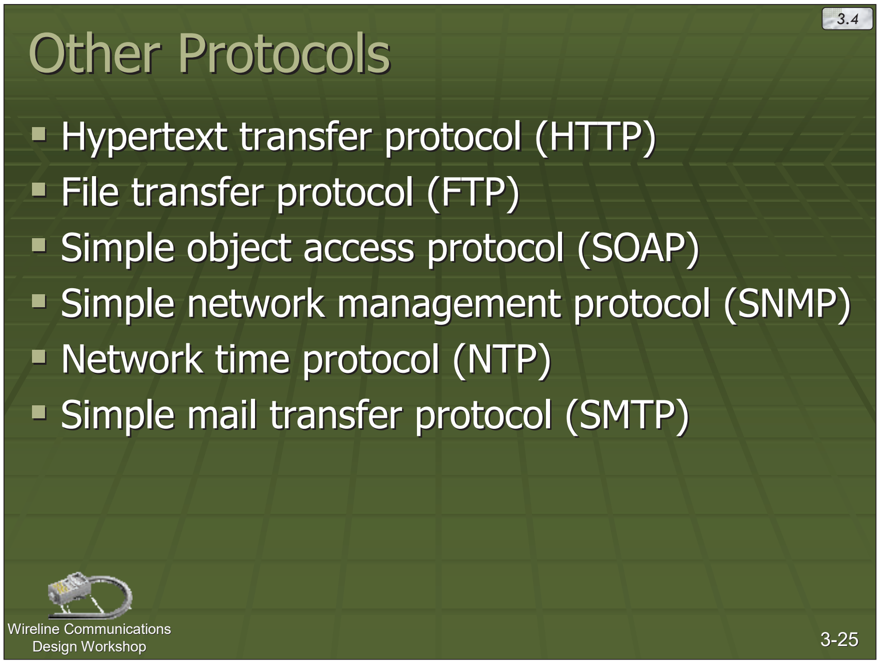
**Details:**

Graphic shows a very basic set-up of a network of computers hooked to a router that is connected to the internet. The router is assigned a unique public IP address so that it can communicate with the Internet. This IP address may be static (if a company has been assigned a block of IP addresses) or dynamic (like a home user).

Each computer is connected to the router with a unique network IP address. This address can be static or dynamic. The address can also be a public IP address that is unique to the Internet.

**Key Questions:**

**Other Information:**



3.4

## Other Protocols

- Hypertext transfer protocol (HTTP)
- File transfer protocol (FTP)
- Simple object access protocol (SOAP)
- Simple network management protocol (SNMP)
- Network time protocol (NTP)
- Simple mail transfer protocol (SMTP)

**Key Message:**

Other protocols that are commonly used in communications. These are higher level protocols that are not addressed in this workshop.

**Details:**

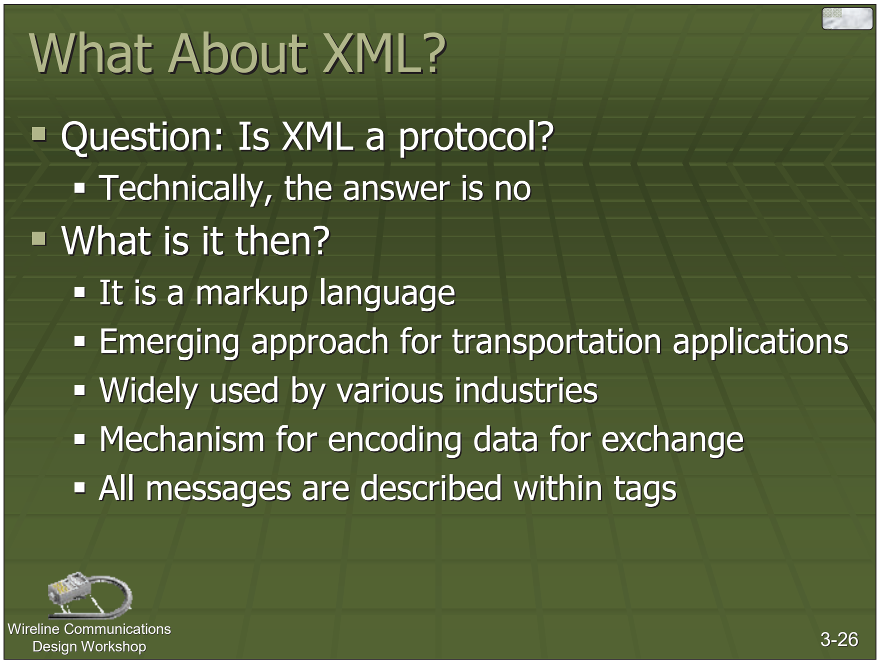
These protocols apply to the overall topic of NTCIP.

**Key Questions:**

**ASK:** How many are familiar with NTCIP?

**ASK** for any experiences they may want to share.

**Other Information:**



## What About XML?

- Question: Is XML a protocol?
  - Technically, the answer is no
- What is it then?
  - It is a markup language
  - Emerging approach for transportation applications
  - Widely used by various industries
  - Mechanism for encoding data for exchange
  - All messages are described within tags

**Key Message:**

XML is often discussed like it is a protocol, but it isn't truly a protocol.

**Details:**

XML is a way of describing data, much like HTML is a way of formatting data.

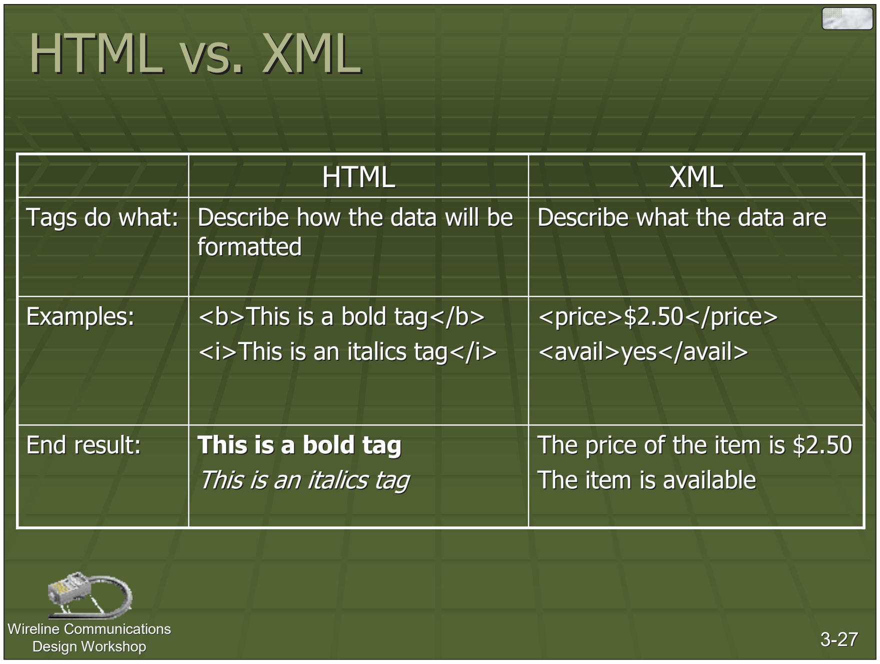
**Key Questions:**

What is metadata?

Answer: Data about data.

**Other Information:**

A schema defines your XML data.



### HTML vs. XML

| | HTML | XML |
|---|---|---|
| Tags do what: | Describe how the data will be formatted | Describe what the data are |
| Examples: | <b>This is a bold tag</b><br><i>This is an italics tag</i> | <price>$2.50</price><br><avail>yes</avail> |
| End result: | **This is a bold tag**<br>*This is an italics tag* | The price of the item is $2.50<br>The item is available |

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Design Workshop

**Key Message:**

XML is a markup language that is analogous to HTML.

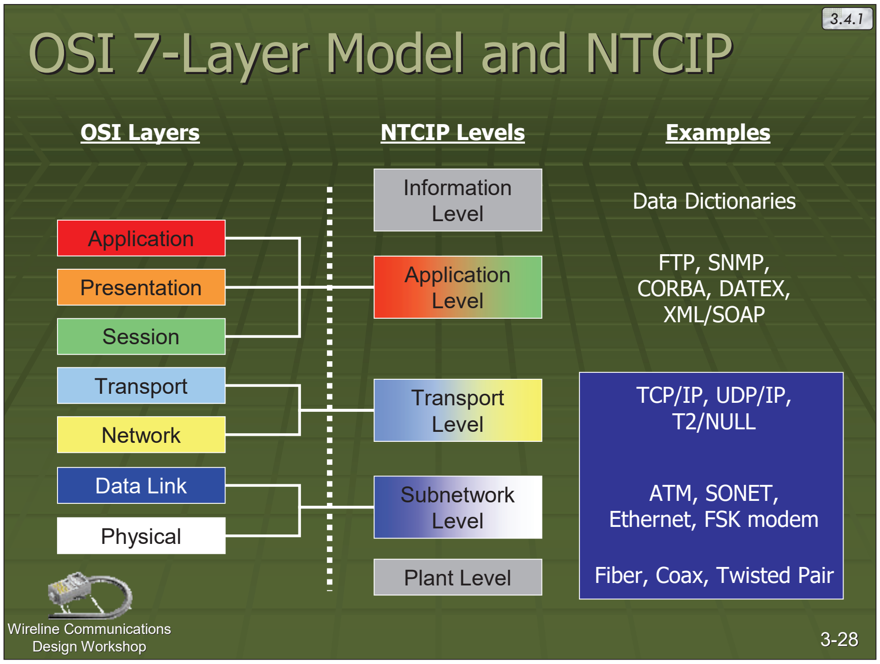
**Details:**

HTML uses tags to describe how data is formatted. "Bold" tags make text appear bold in a web browser.

XML uses tags to describe the data. "Price" tags indicate that the data element is a price.

**Key Questions:**

**Other Information:**



3.4.1

## OSI 7-Layer Model and NTCIP

**OSI Layers**

Application

Presentation

Session

Transport

Network

Data Link

Physical

**NTCIP Levels**

Information Level

Application Level

Transport Level

Subnetwork Level

Plant Level

**Examples**

Data Dictionaries

FTP, SNMP, CORBA, DATEX, XML/SOAP

TCP/IP, UDP/IP, T2/NULL

ATM, SONET, Ethernet, FSK modem

Fiber, Coax, Twisted Pair

Wireline Communications Design Workshop

3-28

**Key Message:**

NTCIP is based on the OSI 7-Layer model.

**Details:**

For simplicity, NTCIP groups some of the OSI layers.

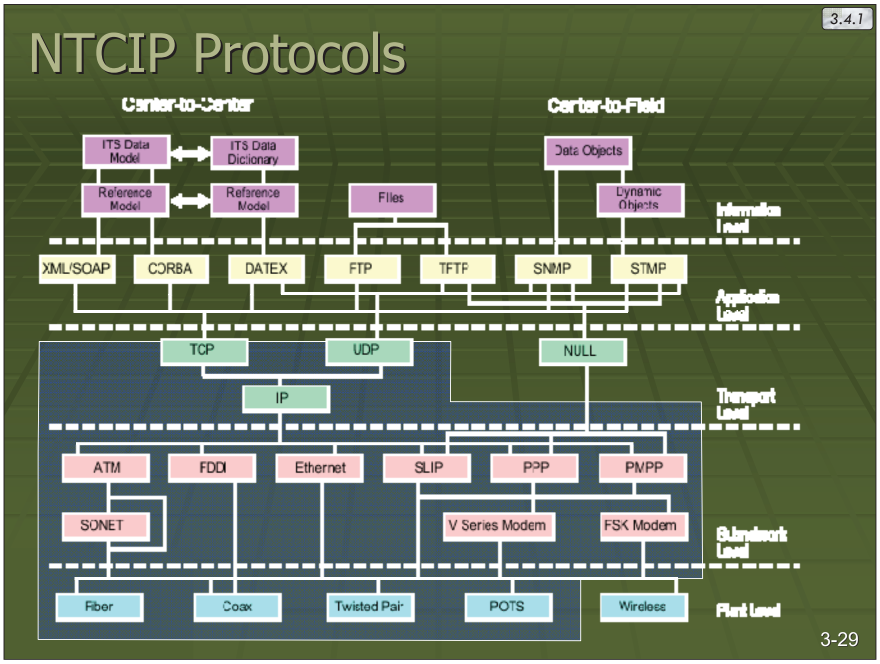
NTCIP also adds two additional levels: information and plant.

Use mouse clicks to build this slide.

Last blue box indicates the focus of this course.

**Key Questions:**

**Other Information:**



NTCIP Protocols

**Key Message:**

There are numerous protocols used within the context of NTCIP.

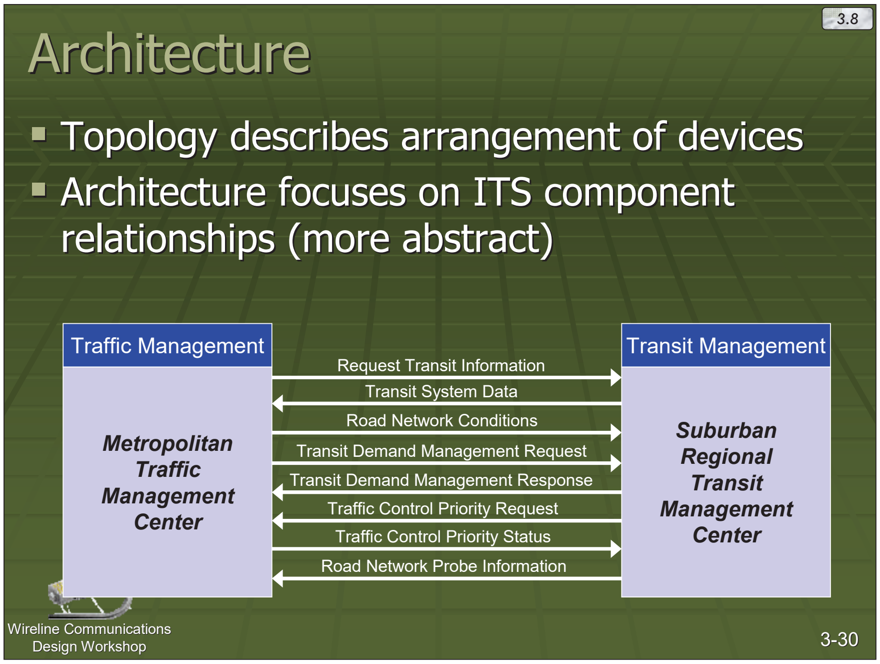
**Details:**

This illustrates the various protocols used at the different levels defined by NTCIP.

Mouse click will again highlight the focus of this course.

**Key Questions:**

**Other Information:**



3.8

## Architecture

- Topology describes arrangement of devices
- Architecture focuses on ITS component relationships (more abstract)

**Traffic Management**

***Metropolitan Traffic Management Center***

Request Transit Information
Transit System Data
Road Network Conditions
Transit Demand Management Request
Transit Demand Management Response
Traffic Control Priority Request
Traffic Control Priority Status
Road Network Probe Information

**Transit Management**

***Suburban Regional Transit Management Center***

Wireline Communications Design Workshop

**Key Message:**

Topology is different from architecture.

**Details:**

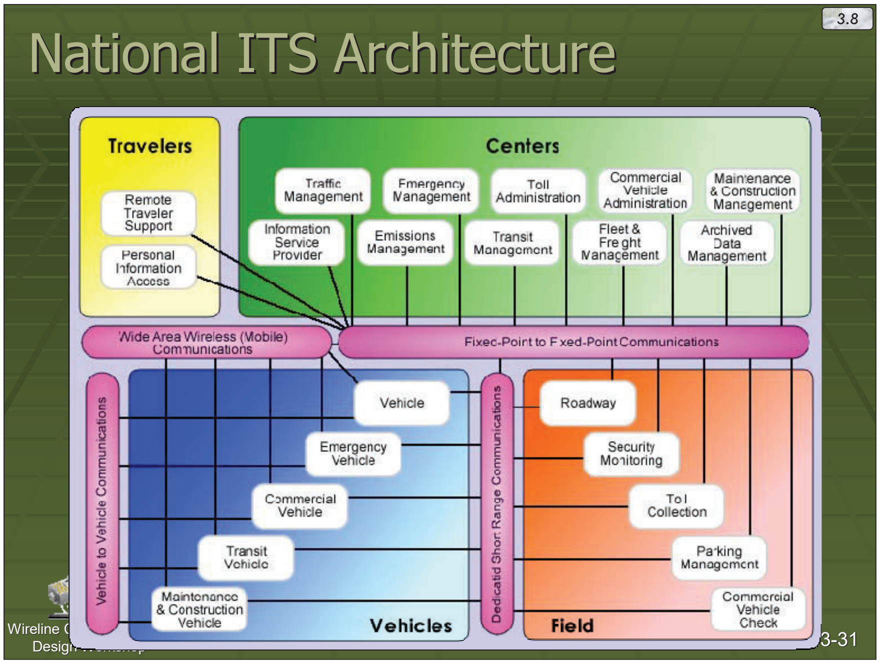
An architecture functionally defines what the pieces of the system are and the information that is exchanged between them.

While you can have a physical architecture that describes wires and connections, the typical architecture really describes “functions” and when information is transmitted from one place to another within a communications system.

The key to architectures is that they remain effective over time. It defines "what must be done," not "how it will be done."

**Key Questions:**

**Other Information:**



3.8

National ITS Architecture

3-31

**Key Message:**

The National ITS Architecture provides a framework for planning, defining, and integrating Intelligent Transportation Systems.

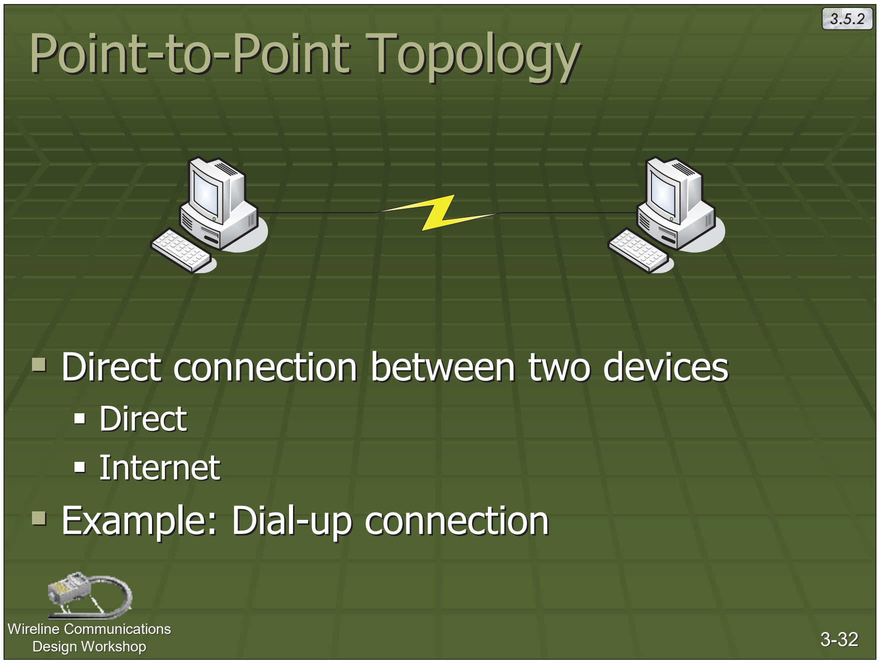
**Details:**

Architectures can be much more specific and focused than the national level.

Many states have statewide or regional architectures that use the same concepts, but cover a smaller geographic area.

**Key Questions:**

**Other Information:**



3.5.2

## Point-to-Point Topology

- Direct connection between two devices
  - Direct
  - Internet
- Example: Dial-up connection

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Design Workshop

3-32

**Key Message:**

This and the next 4 slides will illustrate the different topologies that may be used to connect devices. This slide discusses point-to-point topology.

**Details:**

Recall that topology refers to the arrangement of computers or devices inside a network.

Topologies can be either physical or logical.

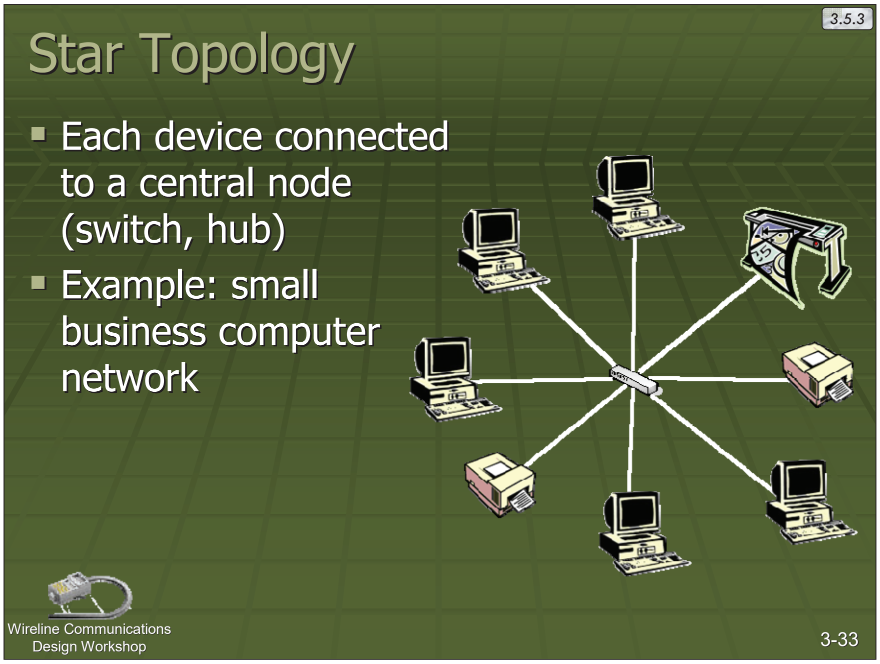
A physical topology would look at the actual location and connections at various devices.

A logical topology is the way that data pass through a network from device to device without concern for how they are physically connected or where they are located.

Point-to-point topology is perhaps the simplest form.

**Key Questions:**

**Other Information:**



3.5.3

## Star Topology

- Each device connected to a central node (switch, hub)
- Example: small business computer network

Wireline Communications Design Workshop

**Key Message:**

This slide discusses star topology.

**Details:**

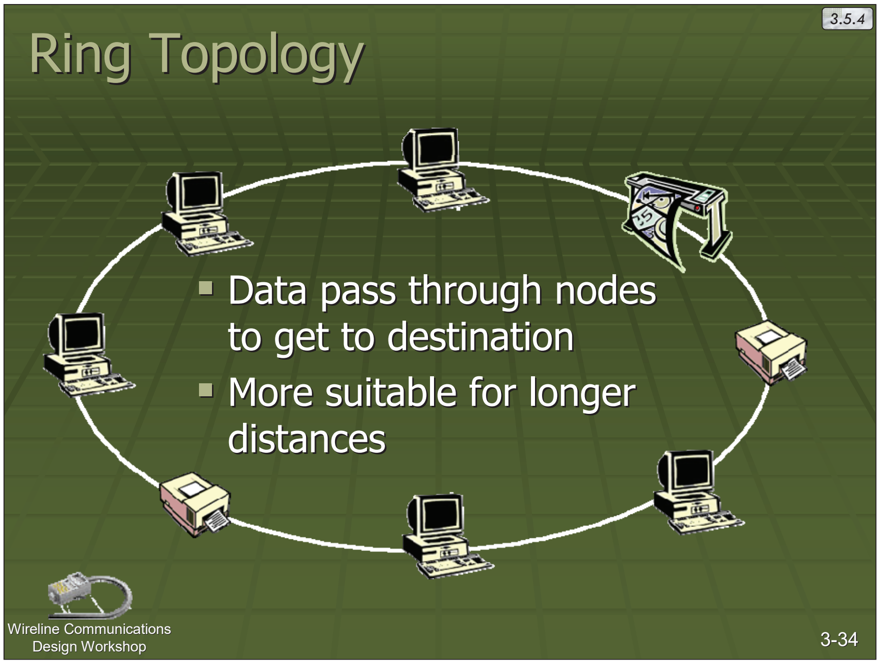
In a star topology every node in the network is connected to a central device, such as a server or switch. The central device acts as a managing station, controlling the links between the different nodes in the network.

Benefits: failure of any node will not affect other devices, easy to add devices.

Drawback: failure of the hub can disrupt the entire network.

**Key Questions:**

**Other Information:**



3.5.4

## Ring Topology

- Data pass through nodes to get to destination
- More suitable for longer distances

Wireline Communications Design Workshop

3-34

**Key Message:**

This slide discusses ring topology.

**Details:**

Every device is connected within a loop system. Data are sent into the ring and they pass from one node to the next, along one direction of the ring, until they reach their desired destination. Each node acts as a repeater and forwards any messages intended for other nodes in the network on to the next node.

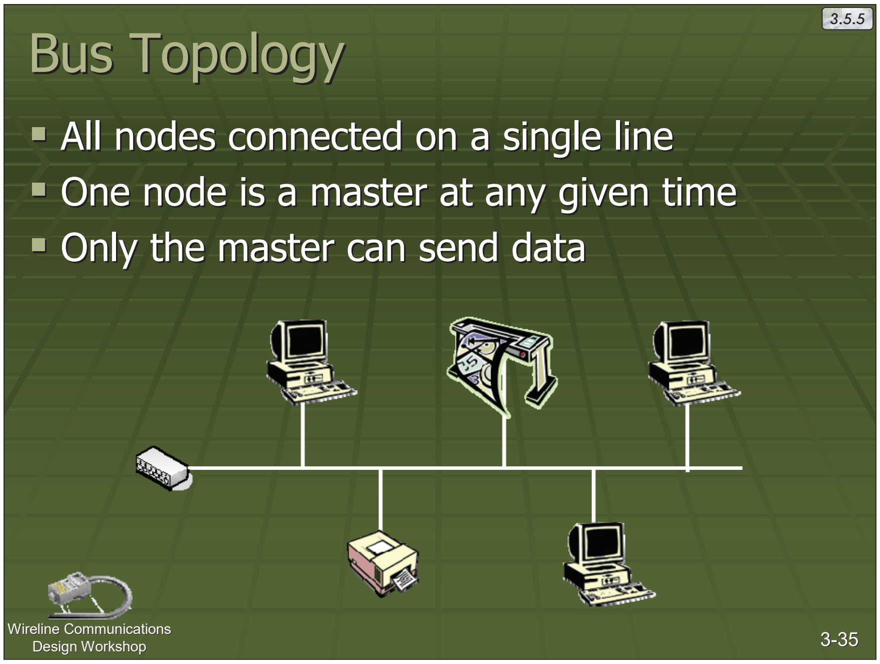
Benefits: can span longer distances because each node is a repeater.

Drawback: more nodes can slow down network traffic.

Newer ring networks are more logical than physical.

**Key Questions:**

**Other Information:**



3.5.5

## Bus Topology

- All nodes connected on a single line
- One node is a master at any given time
- Only the master can send data

Wireline Communications
Design Workshop

**Key Message:**

This slide discusses bus topology.

**Details:**

All nodes are connected on a single line. One node is considered a master and can send data. All others listen.

To help manage this exchange of data, rules help resolve situations when multiple machines try to send simultaneously.

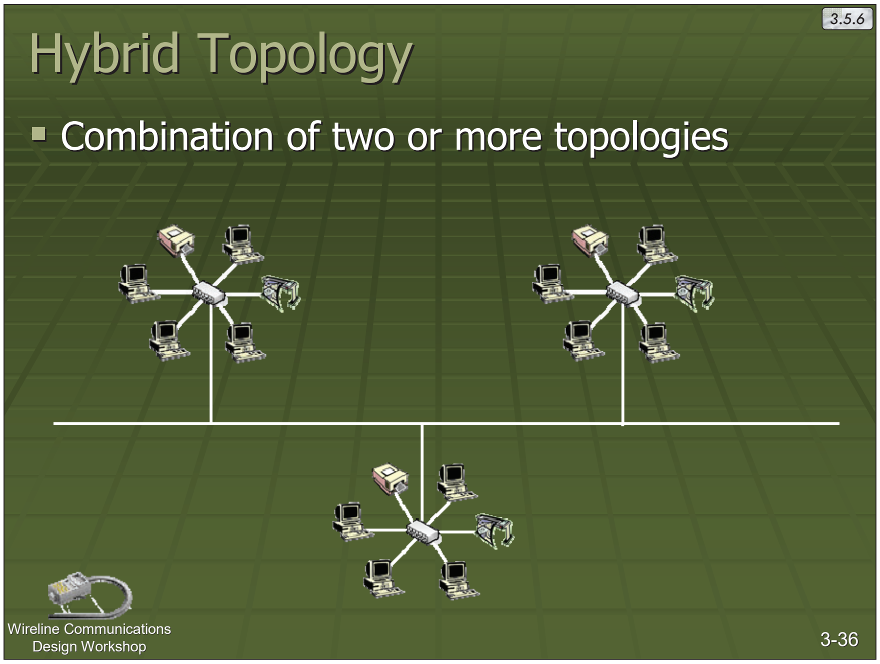
Ethernet (for example) uses decentralized control: Each node is allowed to send whenever it has data to send. When two packets collide along the network the sending nodes simply wait a random amount of time and attempt to send again.

Benefits:

Drawback:

**Key Questions:**

**Other Information:**



3.5.6

## Hybrid Topology

- Combination of two or more topologies

Wireline Communications
Design Workshop

**Key Message:**

This slide discusses hybrid topology.

**Details:**

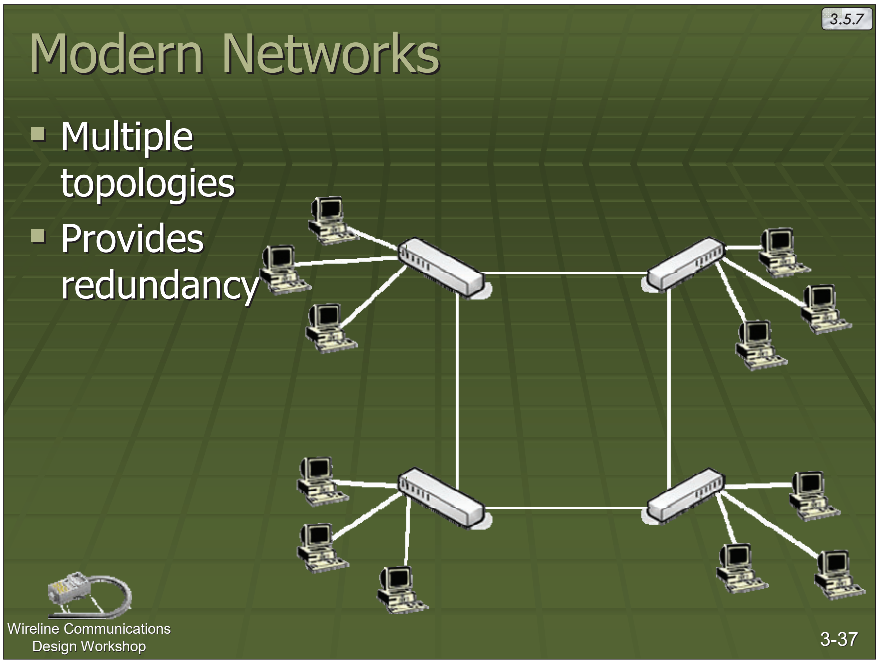
As the name implies, it combines more than one topology into a single network. This illustration shows 3 star topologies connected to a bus topology. The bus connection would likely be a very high speed connection (e.g. ATM, SONET) and the star topologies would likely be a slower connection (e.g. Ethernet, cable)

Benefits:

Drawback:

**Key Questions:**

**Other Information:**



3.5.7

## Modern Networks

- Multiple topologies
- Provides redundancy

Wireline Communications Design Workshop

3-37

**Key Message:**

Modern networks are comprised of various topologies.

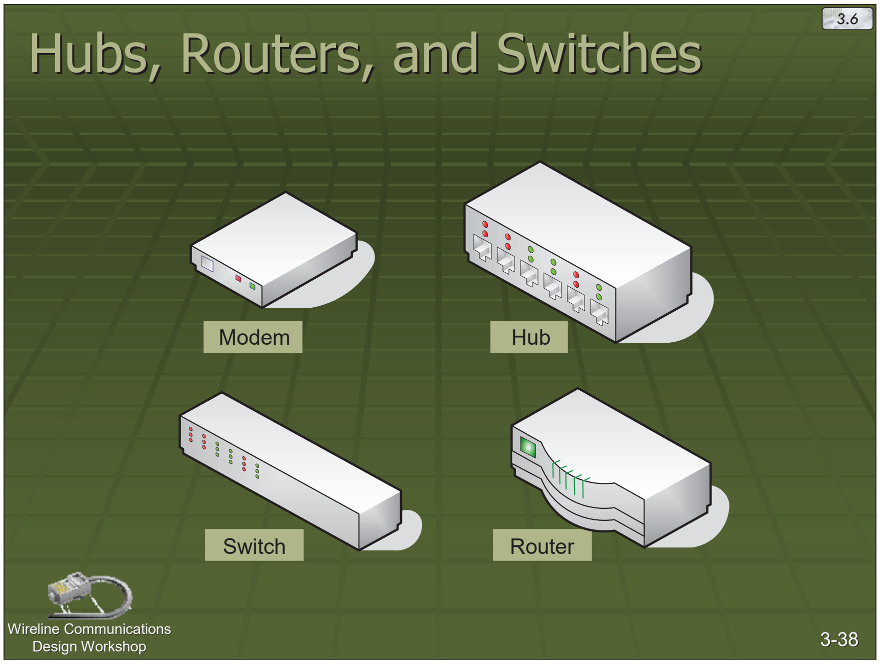
**Details:**

Devices are connected together to provide multiple paths to devices.

This provides for redundancy in case of failures along one part of the network.

**Key Questions:**

**Other Information:**



3.6

Hubs, Routers, and Switches

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3-38

**Key Message:**

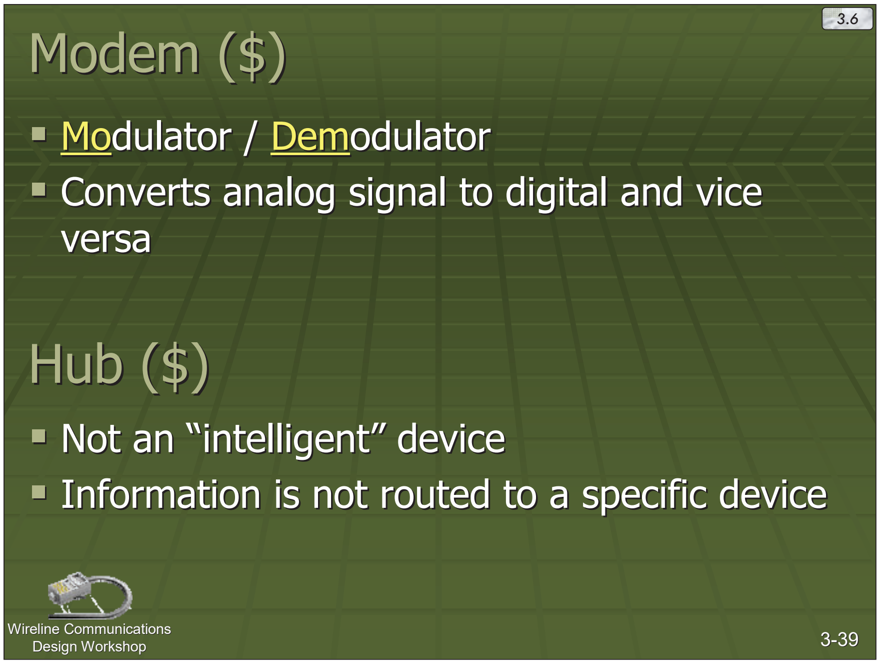
There are several different types of equipment that can be used to transmit data through networks.

**Details:**

Oftentimes these terms are used interchangeably. But that is incorrect. Each device has a slightly different way of operating. These will be discussed in detail on the next two slides.

**Key Questions:**

**Other Information:**



3.6

## Modem ($)

- Modulator / Demodulator
- Converts analog signal to digital and vice versa

## Hub ($)

- Not an "intelligent" device
- Information is not routed to a specific device

Wireline Communications Design Workshop

**Key Message:**

This slide discusses modems and hubs.

**Details:**

Modem:

A modem is a device which transmits and receives information over a communications line.

A modem is a converter.

It converters signals from digital to analog and analog to digital so they can be passed between the device and the communications wire.

Hub:

Simple piece of network equipment that connects various devices into a network.

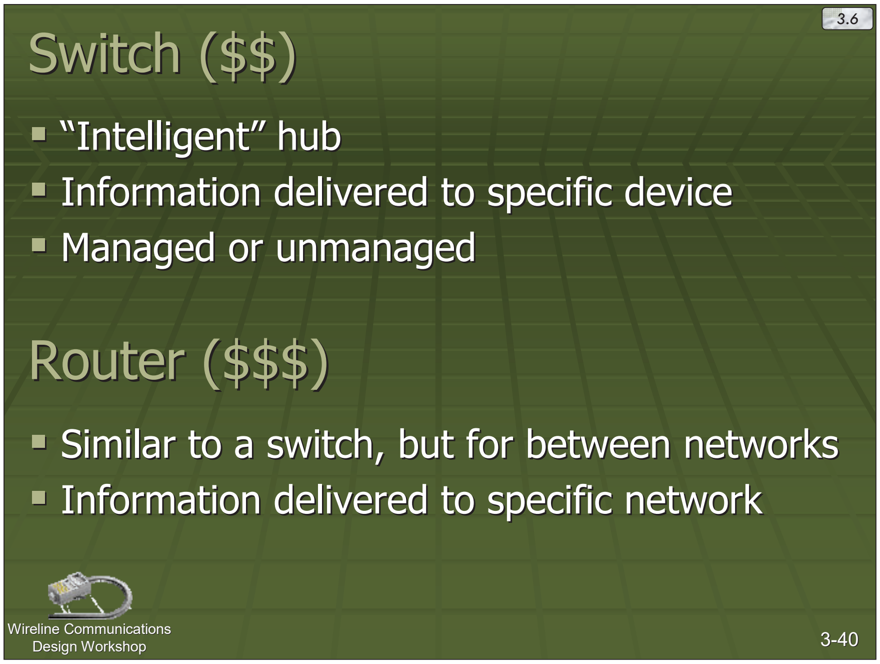
These connections are established at points on the hub called ports. A port is simply a two-way street for information. Information can flow into the hub from the device, or it can flow into the device from the hub.

Hubs are independent of the specific protocols in use.

Typically, hubs are not intelligent devices. The most common form of operation for a hub is that all information is distributed to all ports. There is no effort to identify which port should get which particular piece of information. The hub acts like a megaphone, announcing everything to anyone that is connected.

**Key Questions:**

**Other Information:**



3.6

## Switch ($$)

- "Intelligent" hub
- Information delivered to specific device
- Managed or unmanaged

## Router ($$$)

- Similar to a switch, but for between networks
- Information delivered to specific network

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Design Workshop

3-40

**Key Message:**

This slide discusses switches and routers.

**Details:**

Switch:

An intelligent hub.

A switch is like a courier service, dispatching couriers constantly to specific destinations.

Can increase the speed of a network, but costs more.

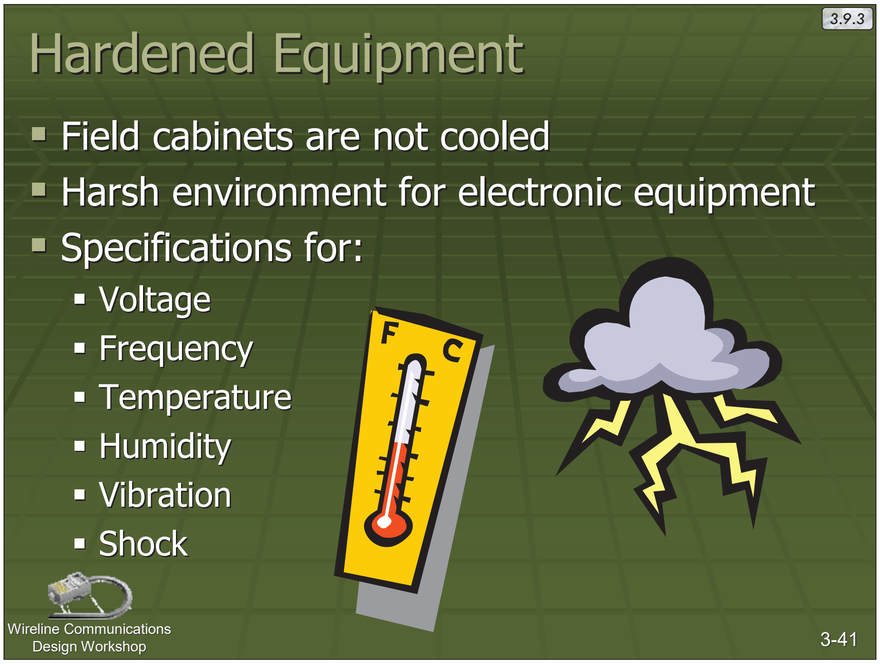
Router:

Much like a switch in that data are transmitted to specific devices. If a switch is like a courier service, a router is like a company that owns multiple courier services and must decide which service to use to send the package.

**Key Questions:**

**Other Information:**

Someone may bring up that routers are very cheap. You can buy one at Best Buy for under $100. True. But ask if they are willing to put that router in one of their controller cabinets. Why not? Because it is not field hardened. Leads into discussion on next slide.



3.9.3

## Hardened Equipment

- Field cabinets are not cooled
- Harsh environment for electronic equipment
- Specifications for:
  - Voltage
  - Frequency
  - Temperature
  - Humidity
  - Vibration
  - Shock

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Design Workshop

**Key Message:**

A great deal of equipment utilized in ITS solutions resides in outdoor cabinets, where it is typically exposed to extreme conditions of both temperature and humidity.

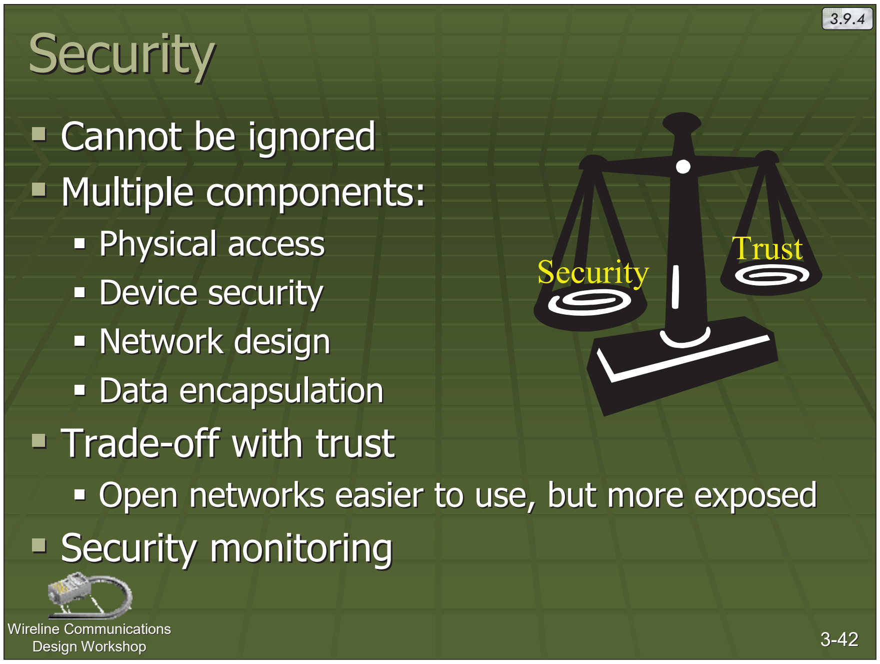
**Details:**

Before purchasing any communications equipment for outdoor use, check the manufacturer's specifications to ensure that it can survive in a harsh environment. One rule of thumb is that if a piece of equipment was not designed and manufactured for harsh environments, it will eventually fail. Another rule of thumb is that generally equipment manufacturers will not honor warranties if the equipment was used in conditions that exceeded their specifications.

**Key Questions:**

**Other Information:**

Specifications do not currently exist for networking or communications equipment that must reside in the same environment. But many manufacturers now produce, test, and support equipment for use in these harsh environments.



## Security

- Cannot be ignored
- Multiple components:
  - Physical access
  - Device security
  - Network design
  - Data encapsulation
- Trade-off with trust
  - Open networks easier to use, but more exposed
- Security monitoring

**Key Message:**

Security can be achieved through a multifaceted approach.

**Details:**

Ask people if they remember some of the major viruses that have come out, like ILOVEYOU or CODE RED, or Michelangelo.

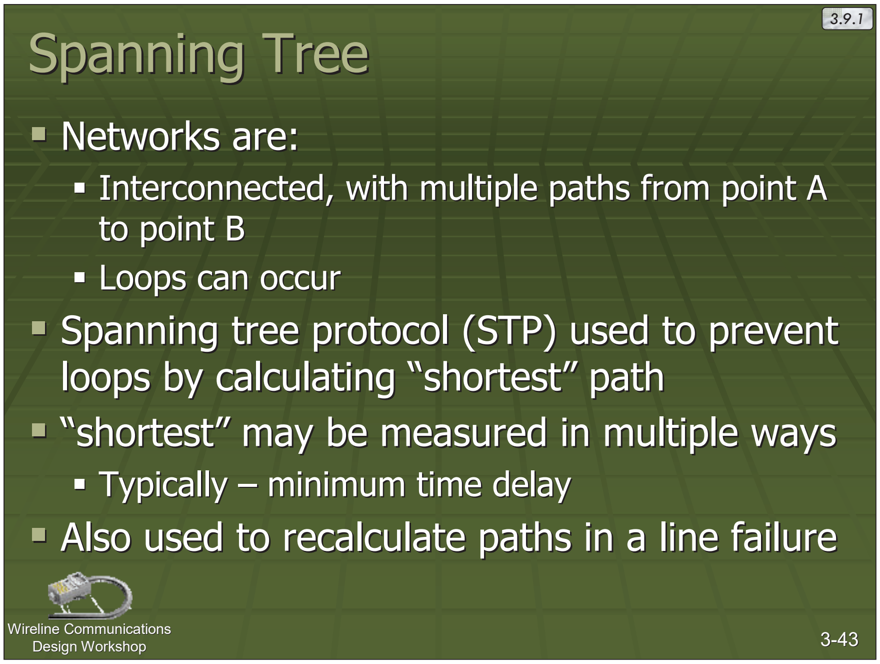
Systems today are not as prone to those viruses because they are less open. Microsoft security initiatives, increased virus checking, etc. Ask how many can no longer send an EXE file through email? (And if that's caused them a problem…Security vs. Trust).

With ITS devices, security is a BIG deal…they're out in the middle of (potentially), nowhere, sending information, etc. While compromising one device may not bring down a system, taking an entire system of network traffic controllers off-line could seriously impact the public.

24x7 security monitoring is an established component of all major networks and should be given considerable thought in the design of any communications system.

**Key Questions:**

**Other Information:**



3.9.1

## Spanning Tree

- Networks are:
  - Interconnected, with multiple paths from point A to point B
  - Loops can occur
- Spanning tree protocol (STP) used to prevent loops by calculating "shortest" path
- "shortest" may be measured in multiple ways
  - Typically – minimum time delay
- Also used to recalculate paths in a line failure

Wireline Communications Design Workshop

**Key Message:**

Spanning Tree Protocol (STP) is a link management protocol.

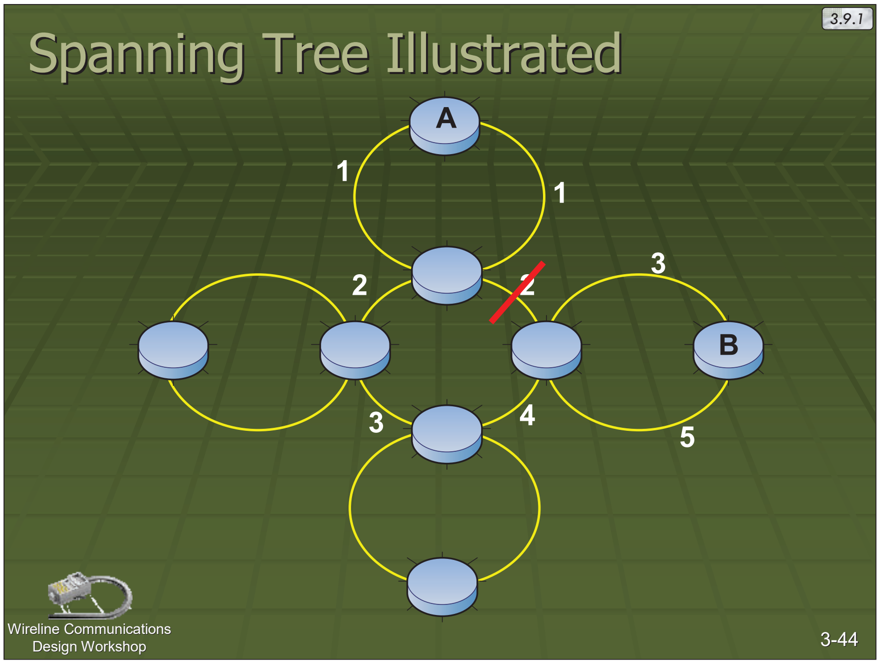
**Details:**

In any network, there may be multiple possible paths for connections between multiple stations. This essentially causes loops in the physical media connecting stations. When loops are present, data in the network can become stuck by continually traversing the loops. This greatly increases the amount of traffic on the network and slows down performance.

STP was designed to help alleviate this problem. STP creates a view of the entire network, keeping track of all paths between stations. If multiple paths occur, STP activates one path and puts the rest in a standby, or blocked state, removing all possible loops.

**Key Questions:**

**Other Information:**



3.9.1

Spanning Tree Illustrated

Wireline Communications Design Workshop

3-44

**Key Message:**

This slide illustrates the concept of spanning tree.

**Details:**

**ASK** for the quickest way between point A and B.

Most will respond with the path sequence of 1-2-3 (comes in with mouse click).

Now, a fiber break is represented by the red line (comes in with mouse click).

**ASK:** What is shortest route now?

Next mouse click removes old route.

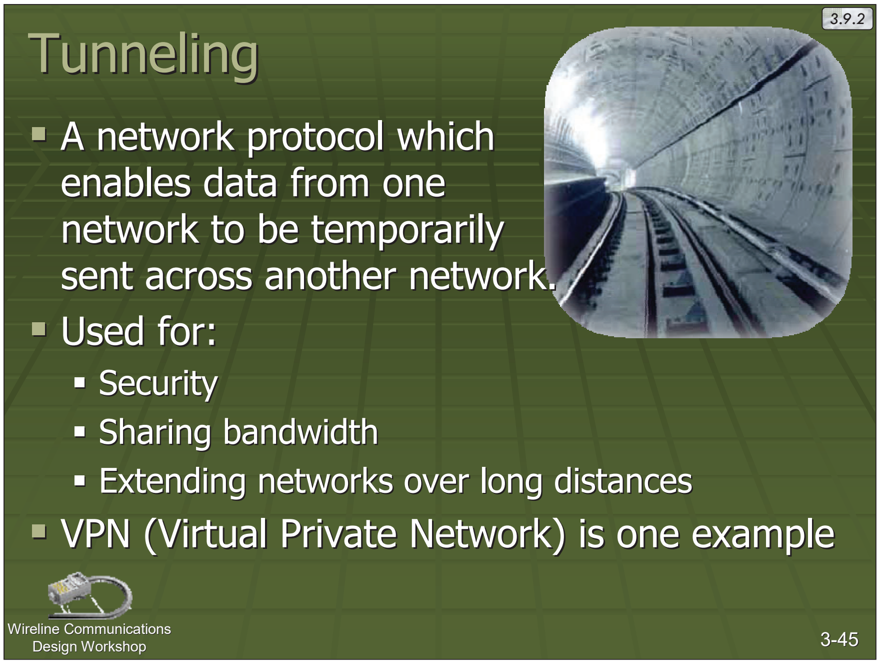
Next click brings in new routing of 1-2-3-4-5.

Note that 1 and 5 could go on either side of the loop. They're simply drawn as they are for illustration. You could say that the STP will (in real-time) examine traffic and make those kinds of jumps (from one side of the loop to the other) depending on the priority of the traffic and the level of delay being experienced.

STP used to take approx 30 seconds to recalculate a new path. Path routing now is done in milliseconds.

**Key Questions:**

**Other Information:**



3.9.2

## Tunneling

- A network protocol which enables data from one network to be temporarily sent across another network.
- Used for:
  - Security
  - Sharing bandwidth
  - Extending networks over long distances
- VPN (Virtual Private Network) is one example

**Key Message:**

Tunneling is a technology that enables a network to temporarily send data using a separate, second network.

**Details:**

May want to remind audience that tunneling is accomplished via encapsulation, which was the whole concept of the 7 layers OSI model back in slide 3-6.

There are MANY tunneling protocols.  Trunking is a related terminology in which separate VIRTUAL networks are tunneled (trunked) across one physical pipe that serves all of them…i.e., creates a backbone.

**Key Questions:**

**Other Information:**

3.10

## Video

- Critical component of many transportation systems
- Used to:
  - Monitor traffic conditions
  - Verify incidents
  - Provide security at priority locations

**Key Message:**

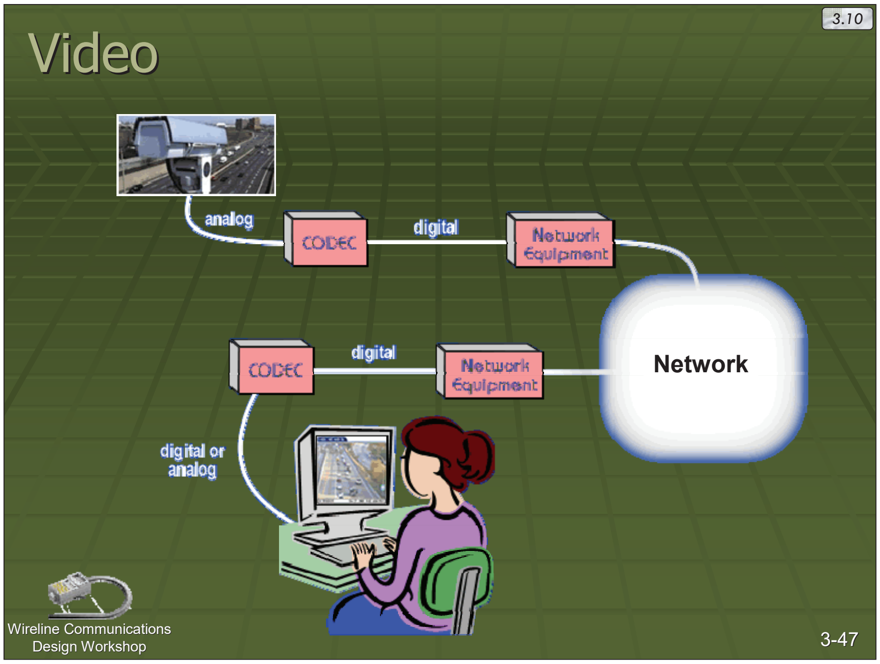
Video is a critical component of many transportation systems.

**Details:**

Typically, video is produced at a location, such as a spot along a highway or an intersection, and then transported to a remote location for viewing. This is the basic principle behind all of the traffic management centers in operation today. Among other purposes, video can be useful for monitoring critical areas of roadways, monitoring operations at intersections, verifying incidents, and for security considerations.

**Key Questions:**

**Other Information:**



3.10

Video

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Design Workshop

3-47

**Key Message:**

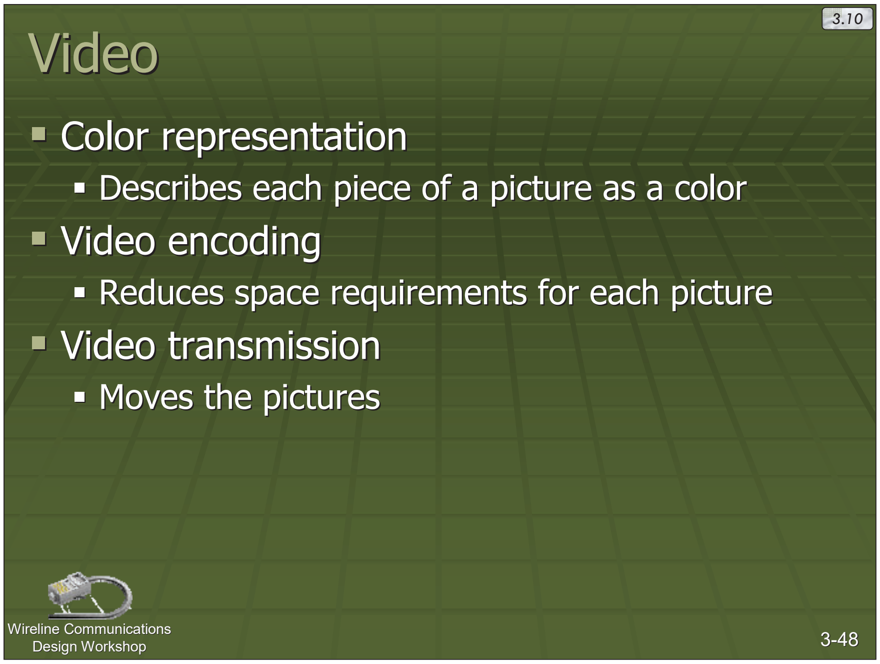
In order to move video from one location to another, the information must be transmitted from one location to another.

**Details:**

This illustration shows the path in a very rudimentary fashion. A camera transmits an analog signal to a codec. The codec transforms it to a digital signal. The digital signal goes into some network equipment for transmission to the TMC. The process is reversed at the other end.

**Key Questions:**

**Other Information:**



3.10

## Video

- Color representation
  - Describes each piece of a picture as a color
- Video encoding
  - Reduces space requirements for each picture
- Video transmission
  - Moves the pictures

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Design Workshop

3-48

**Key Message:**

There are three primary steps in transmitting video.

**Details:**

The three steps are:

•Color representation – the process of representing each individual piece of a picture (video) with color information.

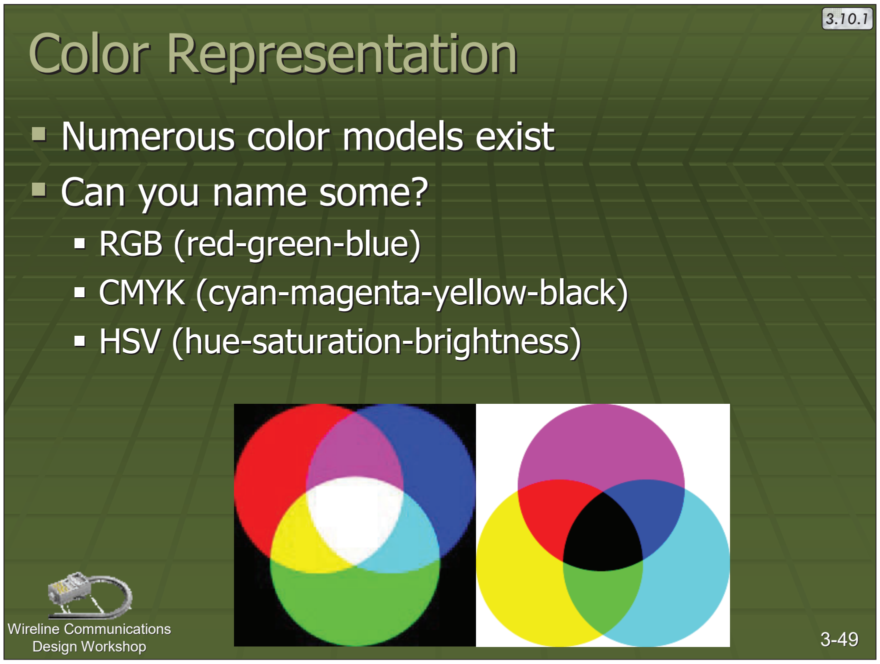
•Video encoding – the process of reducing the amount of space necessary for transmitting video information.

•Video transmission – the process of moving video information from one location to another.

These will be discussed in detail in the next slides.

**Key Questions:**

**Other Information:**



3.10.1

## Color Representation

- Numerous color models exist
- Can you name some?
  - RGB (red-green-blue)
  - CMYK (cyan-magenta-yellow-black)
  - HSV (hue-saturation-brightness)

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**Key Message:**

Video must be represented by some type of color model.

**Details:**

The science behind how to represent video is fairly complicated and there are multiple techniques that have been developed. All methods use some combination of color and brightness information to achieve a unique representation of a particular portion of a video image, typically called an element.

**Key Questions:**

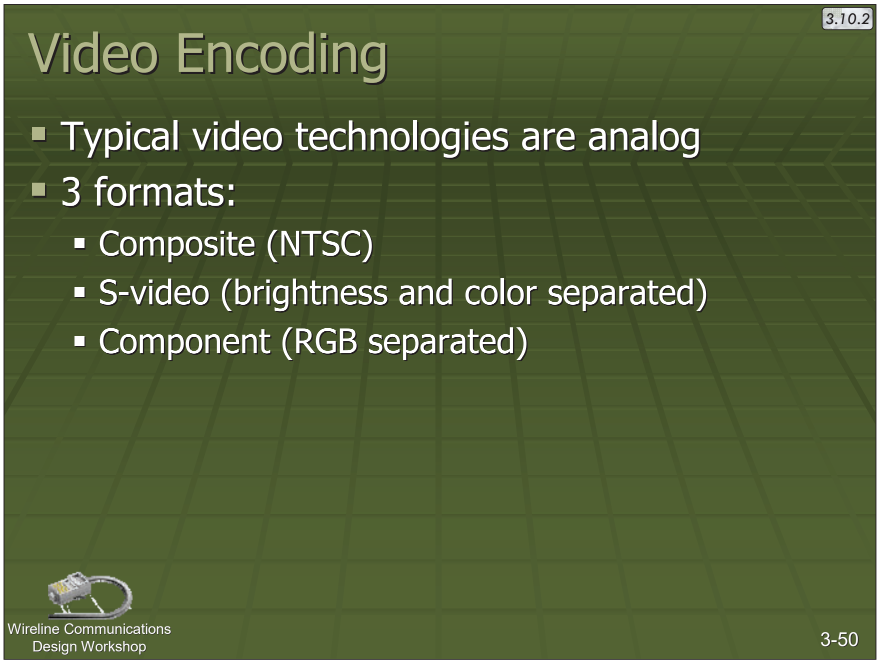
**ASK:** Can you name some color models?

If you get no response, you can prod them by asking what type of color model your inkjet printer might use. The answer to that is CMYK.

**Other Information:**

RGB uses the intensity of each color on a scale of 0 to 1. For example full intensity red is represented as 1.0, 0, 0, where the 1.0 represents the intensity of red, the first 0 represents the intensity of green, and the second 0 represents the intensity of blue. Full intensity of all three colors, or 1.0, 1.0, 1.0 is white. Zero intensity of all three colors, or 0, 0, 0 is black.

In computer applications, programmers have found it convenient to store the intensity of each color as one byte of information. Recall that one byte has 256 discrete values (28), ranging from 0 to 255. In computer applications, white would then be represented as 255, 255, 255, while black would be 0, 0, 0. This method lends itself very well to a digital environment.



3.10.2

## Video Encoding

- Typical video technologies are analog
- 3 formats:
  - Composite (NTSC)
  - S-video (brightness and color separated)
  - Component (RGB separated)

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**Key Message:**

There are three primary types of analog signals.

**Details:**

Analog video can be provided in one of three forms, including:

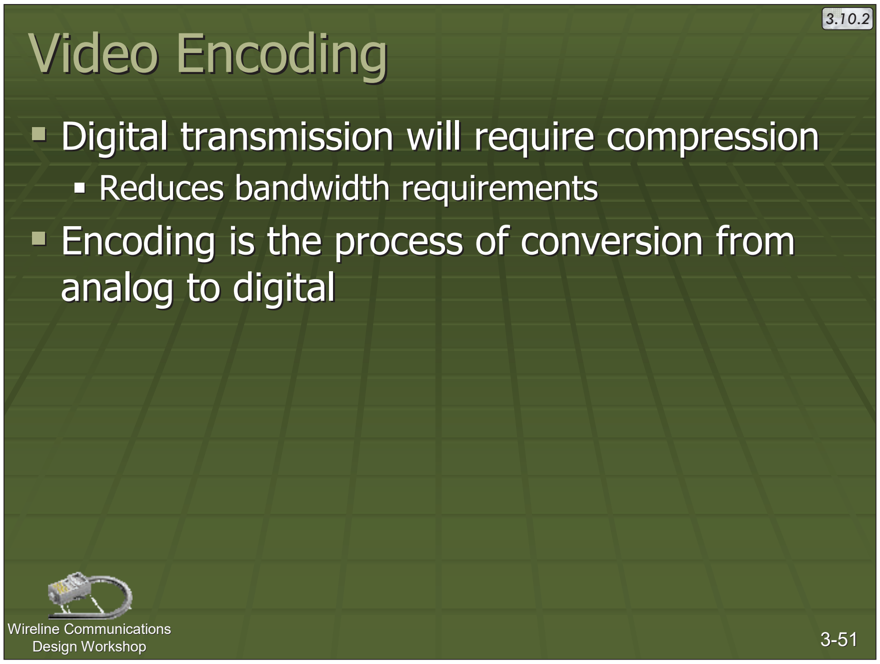
•Composite – also known as National Television Systems Committee (NTSC).

•S-video – a signal type which carries the brightness and color components of the signal on separate wires.

•Component – the use of two or more separate signals, such as Red, Green, and Blue to provide color information.

**Key Questions:**

**Other Information:**



3.10.2

## Video Encoding

- Digital transmission will require compression
  - Reduces bandwidth requirements
- Encoding is the process of conversion from analog to digital

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3-51

**Key Message:**

Video encoding is the process of taking a video signal and altering it in some manner.

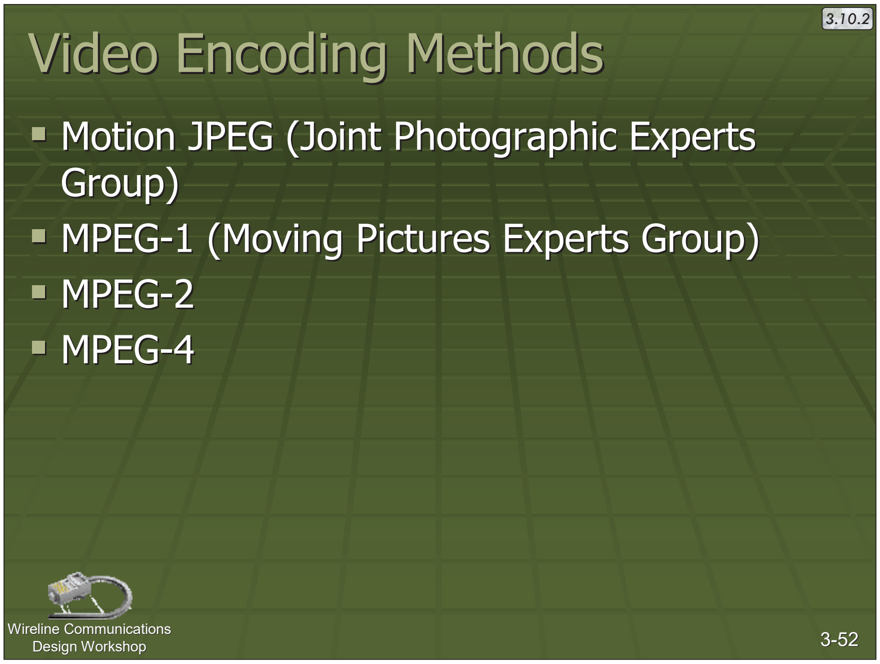
**Details:**

Video can be transmitted between the field and traffic management center using either analog or digital formats. An analog video typically looks the best, but each video stream takes an enormous amount of information and therefore bandwidth. Analog transmission of video is often done on dedicated fiber connections, one per camera, because of the bandwidth requirements.

By comparison, digital transmissions can take much less bandwidth because of the encoding (also known as compression) techniques utilized to reduce the amount of information that is necessary to recreate the picture.

**Key Questions:**

**Other Information:**



3.10.2

## Video Encoding Methods

- Motion JPEG (Joint Photographic Experts Group)
- MPEG-1 (Moving Pictures Experts Group)
- MPEG-2
- MPEG-4

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**Key Message:**

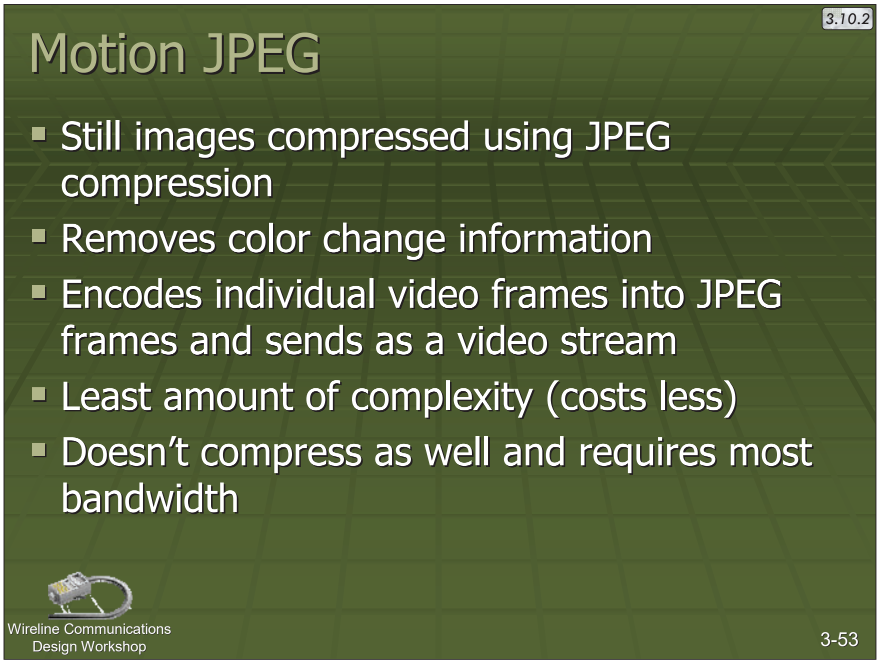
There are several different video encoding methods.

**Details:**

This is a transition slide.  Each of them will be discussed on separate slides.

**Key Questions:**

**Other Information:**



3.10.2

## Motion JPEG

- Still images compressed using JPEG compression
- Removes color change information
- Encodes individual video frames into JPEG frames and sends as a video stream
- Least amount of complexity (costs less)
- Doesn't compress as well and requires most bandwidth

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3-53

**Key Message:**

Motion JPEG is one of the simplest methods, but requires the most bandwidth.

**Details:**

Still images are compressed into smaller sizes using the JPEG compression method. This method removes color change information from a still picture that the human eye normally cannot see. This trimming of non-useful information allows the still picture to be stored using fewer bytes than the original image. Motion JPEG takes advantage of these compression savings by encoding individual video frames into JPEG frames and then sending the sequence of JPEG frames as a video stream.

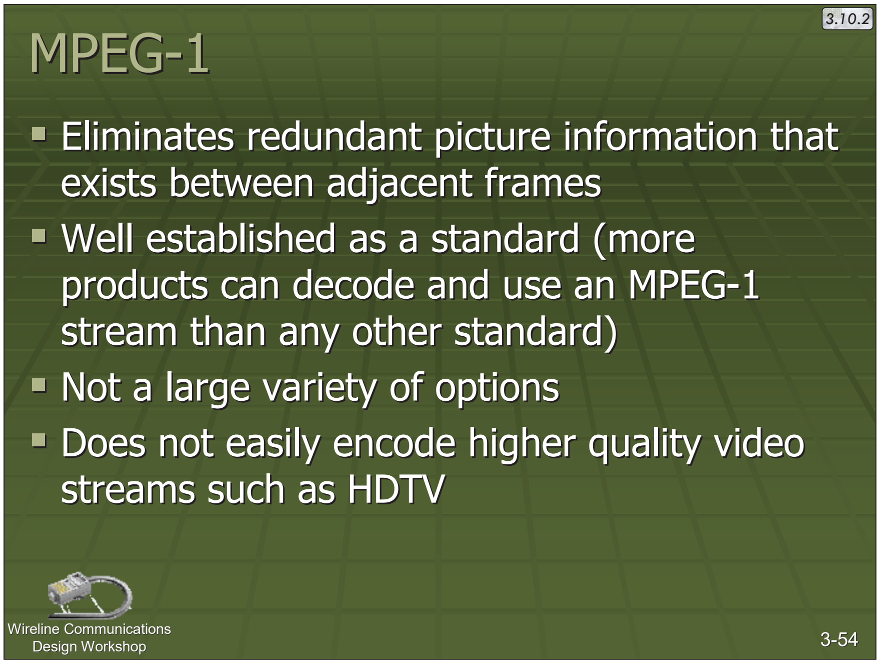
The advantage of Motion JPEG is that it requires the least amount of equipment complexity to encode and decode. Therefore, Motion JPEG equipment tends to cost less than other types of video encoding equipment.

The disadvantage of Motion JPEG is that it does not compress video as well as the other MPEG routines and it requires the most bandwidth to transmit a video stream.

**Key Questions:**

**Other Information:**

Analogy: Animated flip book or "old-style" movie and cartoon animation (non-CGI).



3.10.2

## MPEG-1

- Eliminates redundant picture information that exists between adjacent frames
- Well established as a standard (more products can decode and use an MPEG-1 stream than any other standard)
- Not a large variety of options
- Does not easily encode higher quality video streams such as HDTV

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**Key Message:**

MPEG-1 introduces techniques that eliminate redundant picture information that exists between adjacent frames in a video sequence.

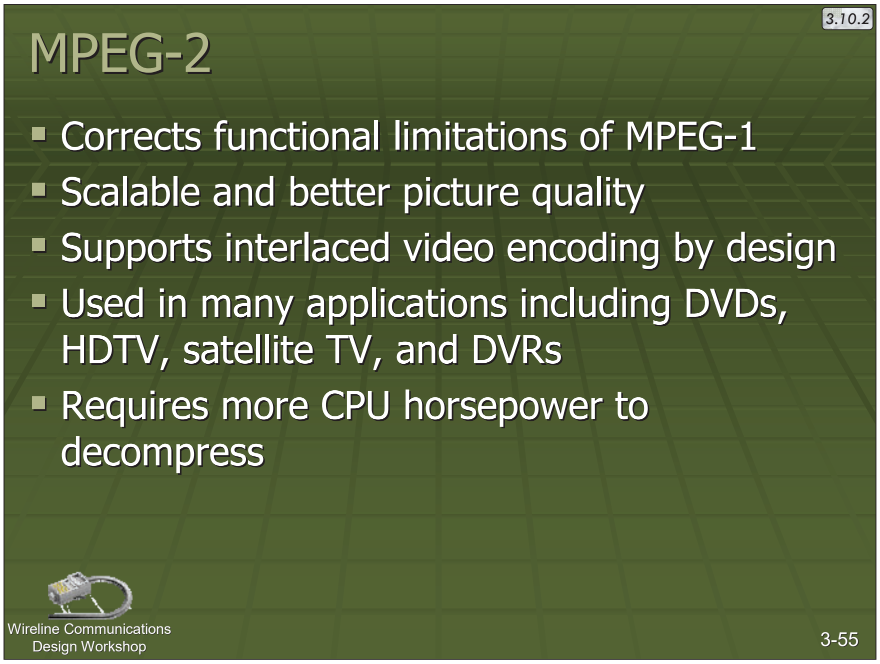
**Details:**

The advantage of MPEG-1 is that it is well established as a standard. More products can decode and use an MPEG-1 stream than any other standard mentioned here.

The disadvantage is that MPEG-1 does not have a large variety of options compared to other MPEG standards. Additionally, because MPEG-1 is designed to compress progressive-scan video, interlaced television signals are difficult to compress using MPEG-1. It does not easily encode higher quality video streams such as high-definition television (HDTV).

**Key Questions:**

**Other Information:**



3.10.2

## MPEG-2

- Corrects functional limitations of MPEG-1
- Scalable and better picture quality
- Supports interlaced video encoding by design
- Used in many applications including DVDs, HDTV, satellite TV, and DVRs
- Requires more CPU horsepower to decompress

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3-55

**Key Message:**

MPEG-2 inherited the benefits of Motion JPEG and MPEG-1, but went further to correct the functional limitations of MPEG-1.

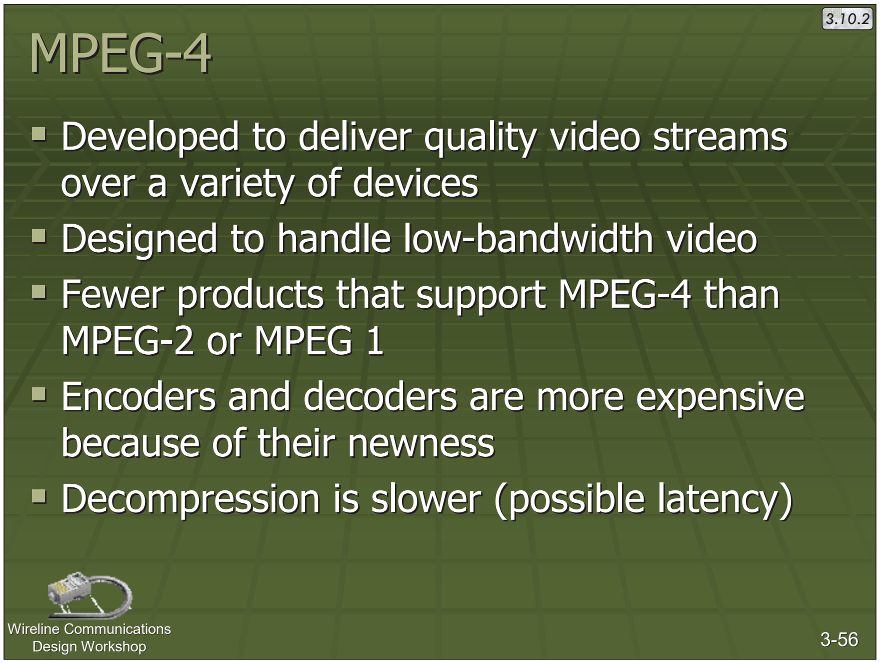
**Details:**

The advantage of MPEG-2 is that it is scalable and allows better picture quality than MPEG-1. It supports interlaced video encoding by design. It is used in many applications including digital video disks (DVDs), HDTV, satellite television distribution, and personal video recorders such as TiVo®.

The disadvantage of MPEG-2 video streams is that they require more central processing unit (CPU) horsepower to decompress than MPEG-1. When encoding video at lower resolutions, the MPEG-2 standard has little advantage over MPEG-1.

**Key Questions:**

**Other Information:**



3.10.2

## MPEG-4

- Developed to deliver quality video streams over a variety of devices
- Designed to handle low-bandwidth video
- Fewer products that support MPEG-4 than MPEG-2 or MPEG 1
- Encoders and decoders are more expensive because of their newness
- Decompression is slower (possible latency)

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3-56

**Key Message:**

MPEG-4 is the newest standard, and commercial products that use it are just now populating the market.

**Details:**

MPEG-4 is designed to deliver close to MPEG-2 quality video at lower data rates yet use smaller file sizes. Where previous MPEG development was aimed at television and HDTV encoding, MPEG-4 was developed in response to industry demands to deliver quality video streams over a variety of devices ranging from bandwidth-limited cell phones to broadband video providers.

The main advantage of MPEG-4 is that it was designed to handle low-bandwidth video. If a network suffers from bandwidth limitation, more parallel MPEG-4 streams can be placed on that network than other MPEG methods.

The current disadvantage of MPEG-4 is that there are fewer products that support MPEG-4 than MPEG-2 or MPEG-1. Additionally, MPEG-4 encoders and decoders are more expensive because of their relative newness in the market. These disadvantages will likely disappear over time. Another disadvantage that is inherent in the standard is that MPEG-4 video stream decompression is slower because of the techniques in the standard. This could lead to latency in the video stream compared to the other MPEG methods.

**Key Questions:**

**Other Information:**

3.10.2

## Codecs

- Equipment that COmpresses and DECompresses video signals
- Beware of interoperability

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Design Workshop

3-57

**Key Message:**

The equipment used to encode or compress video is called a codec.

**Details:**

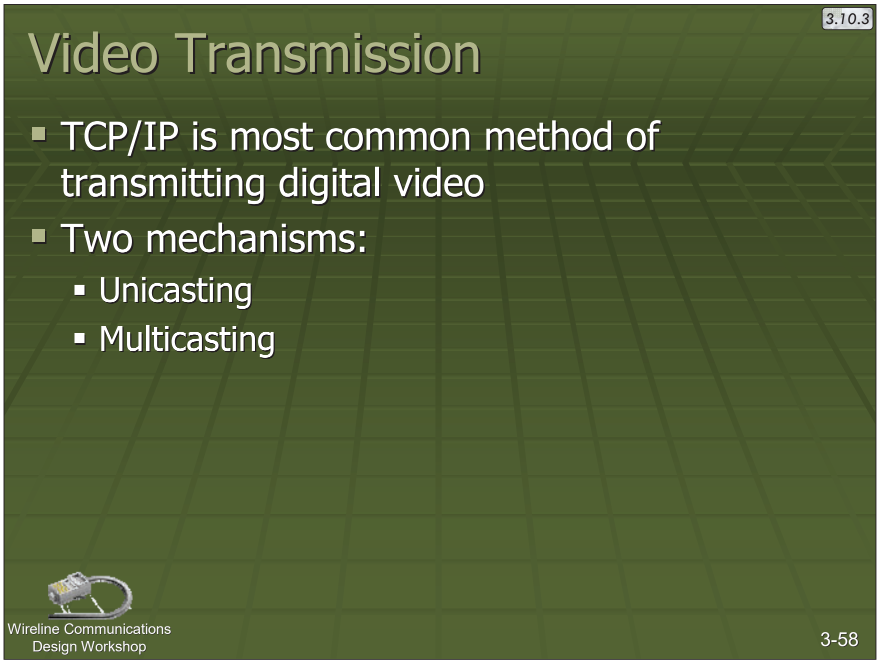
Codec stands for Compression/Decompression.

Codecs are typically purchased as either an encoder or a decoder. An encoder will reside in the field, taking the video information from the camera and compressing it using a standard such as in Table 3-1 and delivering it to the transmission mechanism. A decoder will reside at the traffic management center, receive the transmitted information, and assemble it back into a video image for display.

It is important to note that the use of encoding standards and codec equipment is typically not a situation where there is complete interoperability between vendors. A codec from Vendor A will typically not interoperate with a codec from Vendor B, even though they may both be utilizing the same encoding standard, such as MPEG-4. While the level of interoperability is improving, it is by no means common and readers are urged to consider purchasing decisions carefully to ensure the maximum possible level of video interoperability. This is an especially important consideration if video is to be shared among multiple agencies. As of the writing of this guidebook, it is a critical design decision that the agencies employ the same brand or vendor of video codecs for maximum interoperability and video sharing.

**Key Questions:**

**Other Information:**



3.10.3

## Video Transmission

- TCP/IP is most common method of transmitting digital video
- Two mechanisms:
  - Unicasting
  - Multicasting

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3-58

**Key Message:**

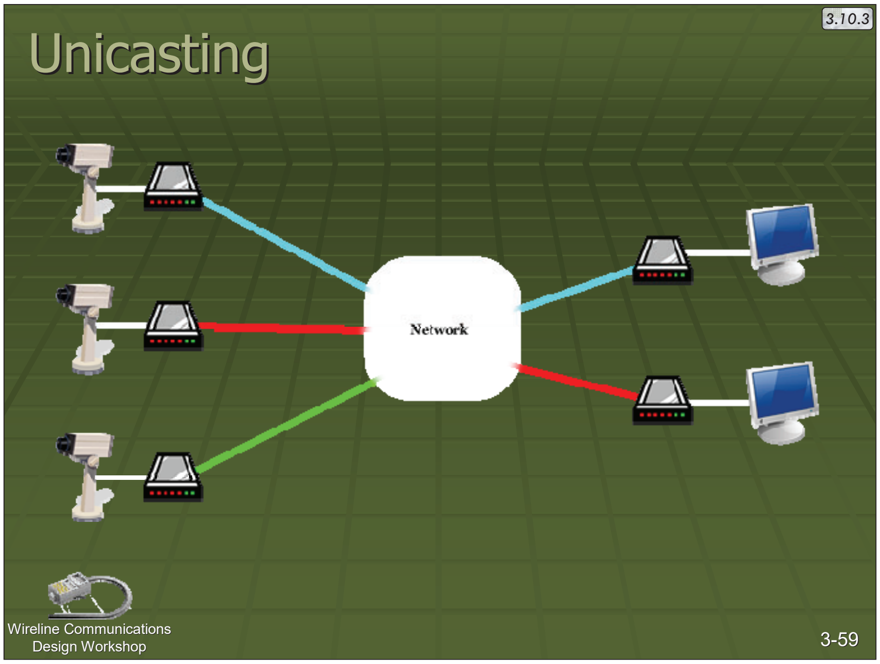
There are two basic mechanisms for transmitting video: unicasting and multicasting.

**Details:**

Primarily a transition slide.

**Key Questions:**

**Other Information:**



3.10.3

## Unicasting

Network

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3-59

**Key Message:**

The principal aspect of unicasting video transmission is that it represents a one to one scenario.

**Details:**

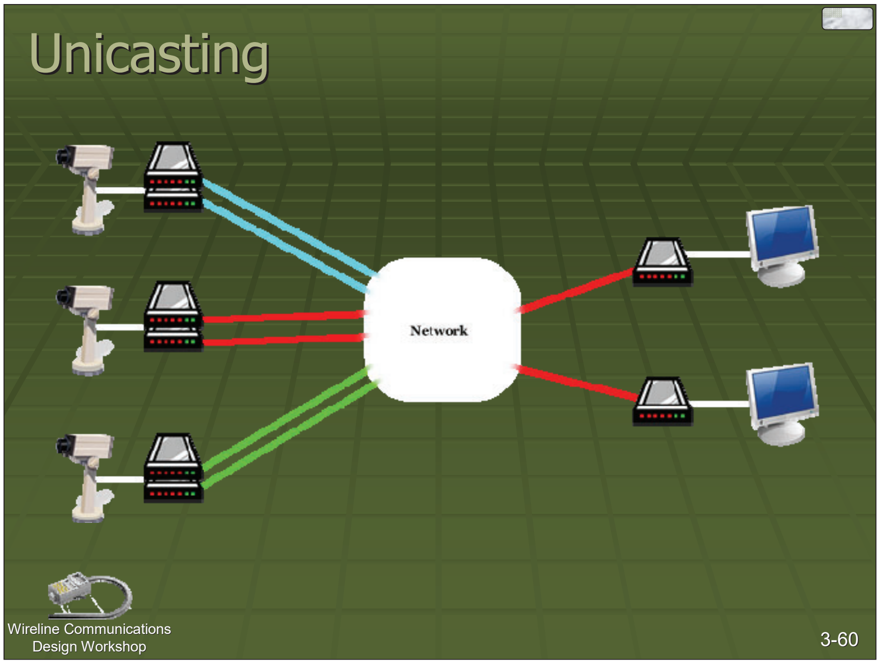
In this arrangement, an encoder in the field can send a video stream to only one other location, a decoder, located somewhere else. Another name for this arrangement is point-to-point. While a system can have more encoders in the field than decoders in the management center, each encoder can only send to one decoder at a time. This distinction is critical when designing a video system that needs to be shared between multiple locations or agencies. Using a unicast video scenario, Agency A can not simultaneously receive the same video as Agency B.

**Key Questions:**

**ASK:** What if I wanted to receive the same video at multiple locations?

**ANSWER:** Unicasting can be used with multiple codecs, or multicasting. Illustrated in the next 2 slides.

**Other Information:**



Unicasting

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3-60

**Key Message:**

Unicasting can be used to transmit images to multiple locations.

**Details:**

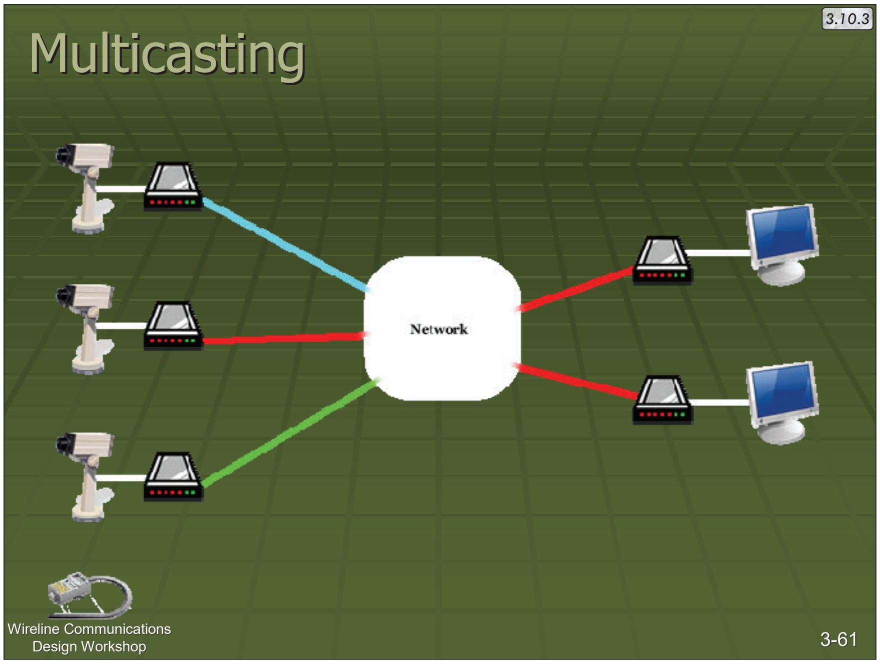
A work-around for the limitation of this point-to-point setup is the use of multiple encoders at the same location. Typically, video from a camera source would be split and then fed into multiple encoders at the field site. Each encoder would then have a one-to-one connection with a decoder at a different agency. If five agencies wished to receive the video simultaneously, 5 encoders would be needed in the field.

The tremendous disadvantage to this system is the cost. While encoders continue to drop in price, having multiple encoders at each location can be a substantial cost component for a system implementation. A second disadvantage to this system is the increased bandwidth that is necessary to field sites. In the scenario above, 5x the bandwidth would be required, which can also have a substantial impact on the cost of any system implementation.

One technique used to get around bandwidth limitations is putting a single encoder at each field location, bringing all video back to a central location, then retransmitting the video from that central location. This relocates the heavy bandwidth need to the office location, where it is typically more feasible to provide it. The disadvantage to this setup is that the delivery of video to other agencies is then delayed as multiple encoding and decoding operations must take place. Depending on the level of codec equipment and the encoding format in use, this delay could be several seconds.

**Key Questions:**

**Other Information:**



3.10.3

Multicasting

Wireline Communications Design Workshop

**Key Message:**

Multicasting represents a one-to-many relationship.

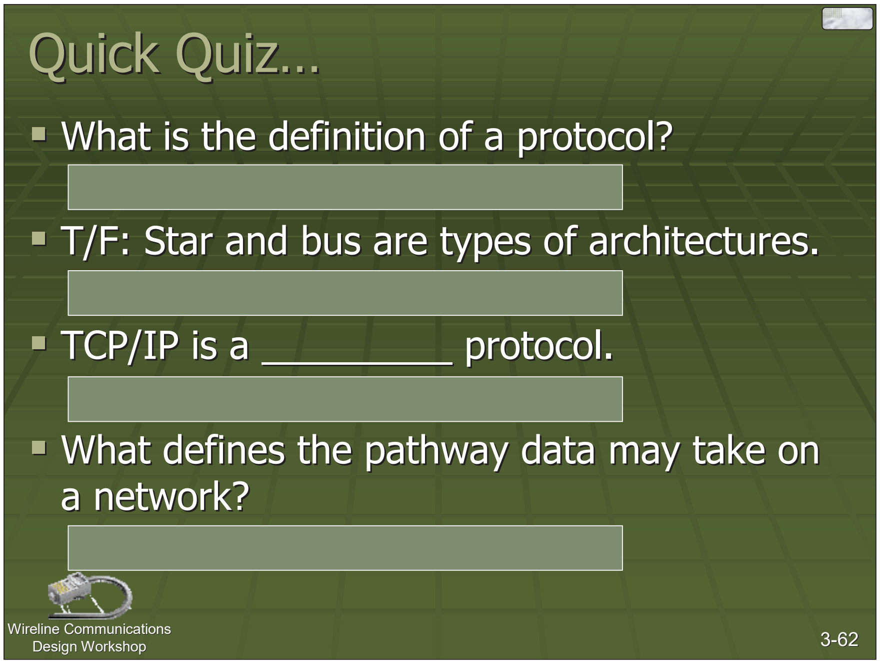
**Details:**

Multicast is advantageous from the standpoint that a single encoder source can be received by multiple decoders simultaneously. This makes an ideal video transmission system for a multi-agency operation.

The disadvantage to multicast is that the design of the transmission network is more difficult and requires some additional expertise that may not be common. Also, vendor support of multicast operations, while increasing, is not yet universal. Significant cost savings can be realized from the perspective of equipment purchases, but agencies must be willing to make an investment in the design and operation of the network to provide the level of operations required for multicast video systems.

**Key Questions:**

**Other Information:**



## Quick Quiz…

- What is the definition of a protocol?
- T/F: Star and bus are types of architectures.
- TCP/IP is a _________ protocol.
- What defines the pathway data may take on a network?

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3-62

Quiz Q&A:

**What is the definition of a protocol?**

A set of rules

**T/F: Star and bus are types of architectures.**

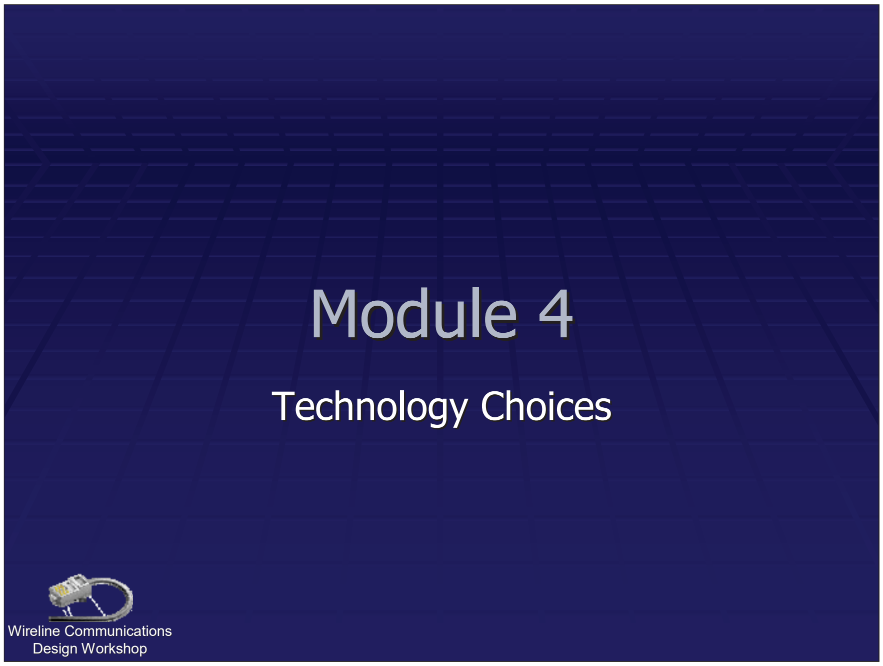
False: They are topologies

**TCP/IP is a _________ protocol.**

Layered

**What defines the pathway data may take on a network?**

Spanning tree



# Module 4

## Technology Choices

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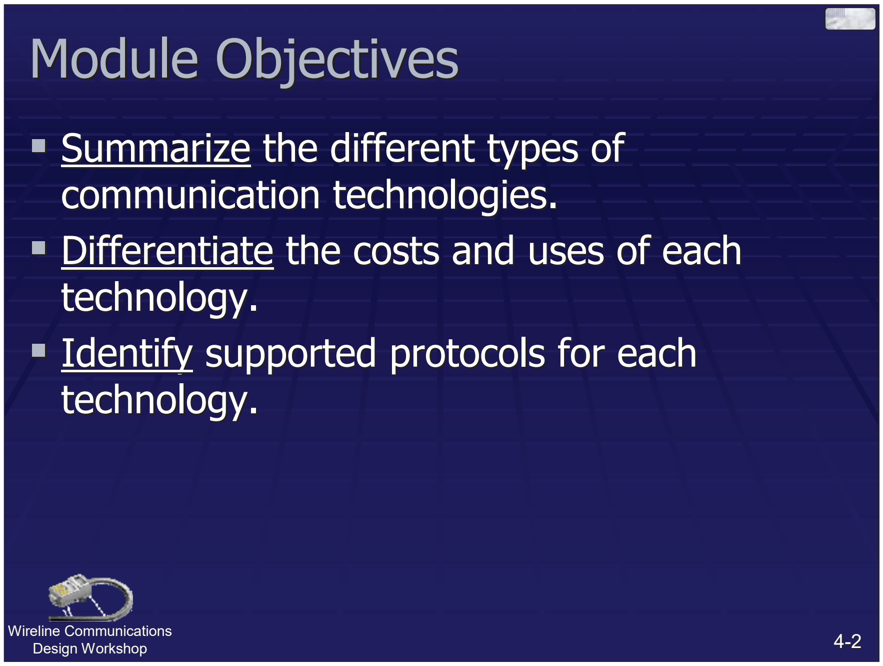

## Module Objectives

- Summarize the different types of communication technologies.
- Differentiate the costs and uses of each technology.
- Identify supported protocols for each technology.

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4-2

**Key Message:**

None.

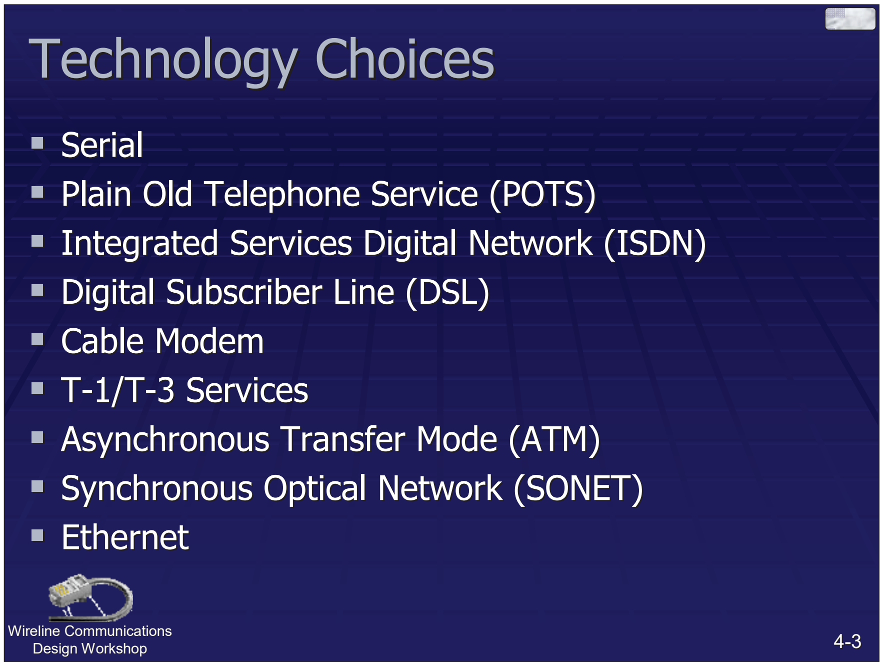
**Details:**

Go over the module objectives.

**Key Questions:**

**Other Information:**

None.



## Technology Choices

- Serial
- Plain Old Telephone Service (POTS)
- Integrated Services Digital Network (ISDN)
- Digital Subscriber Line (DSL)
- Cable Modem
- T-1/T-3 Services
- Asynchronous Transfer Mode (ATM)
- Synchronous Optical Network (SONET)
- Ethernet

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4-3

**Key Message:**

There are numerous technology choices available.

**Details:**

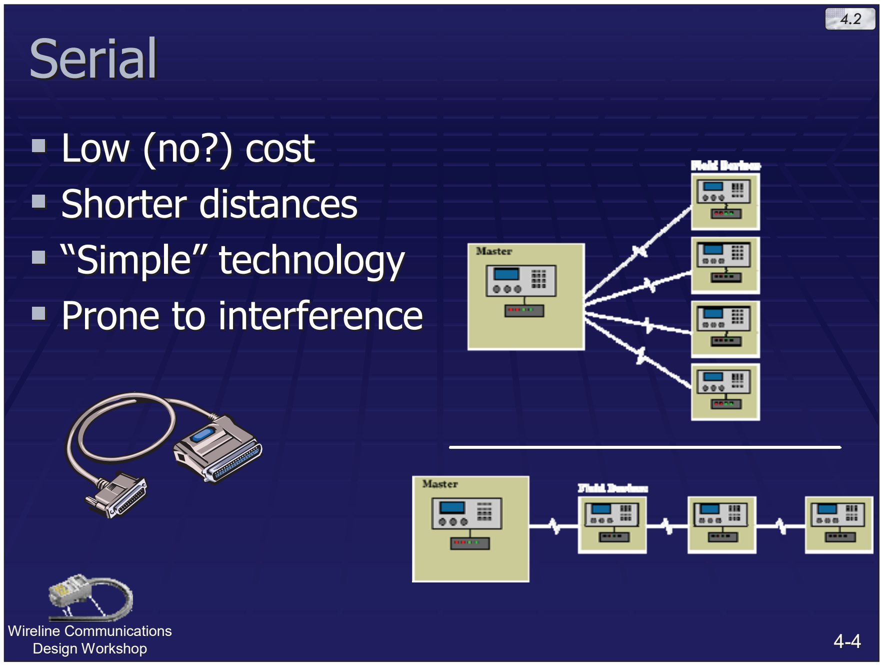
Do not spend much time on this slide. Each technology will be discussed on the next 15 slides.

**Key Questions:**

Perhaps ask what experience the participants have with any of these technologies.

**Other Information:**

None.



4.2

## Serial

- Low (no?) cost
- Shorter distances
- "Simple" technology
- Prone to interference

Wireline Communications
Design Workshop

4-4

**Key Message:**

Serial communications is one of the most basic technologies. It is also the slowest.

**Details:**

Low-speed data connection.

Developed in the 1960s.

RS-232 was original protocol and suited for short distances (up to 100 ft).

RS-422 was developed to go longer distances (up to 4000 ft) – good for low-speed ITS apps such as PTZ camera control.

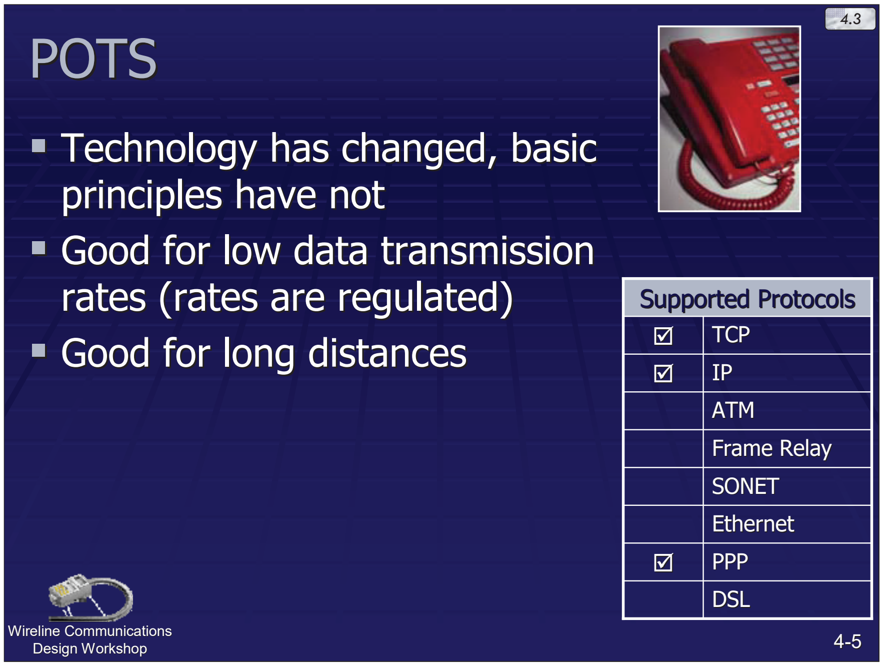
RS-485 was developed to allow multi-drop capabilities.

No operating costs.

**Key Questions:**

**Other Information:**

Early "closed loop" traffic control systems used this type of technology.



4.3

## POTS

- Technology has changed, basic principles have not
- Good for low data transmission rates (rates are regulated)
- Good for long distances

| Supported Protocols | |
|---|---|
| ☑ | TCP |
| ☑ | IP |
| | ATM |
| | Frame Relay |
| | SONET |
| | Ethernet |
| ☑ | PPP |
| | DSL |

Wireline Communications
Design Workshop

4-5

**Key Message:**

Plain Old Telephone Service is another low-speed technology that is widely available and reliable.

**Details:**

Can carry both analog and digital signals.

Mechanics of phone system have changed little since Bell's invention.

Operating environment has changed radically.

Requires modems where the phone line interfaces with the device (to convert analog to digital).

Good for non-video ITS applications.

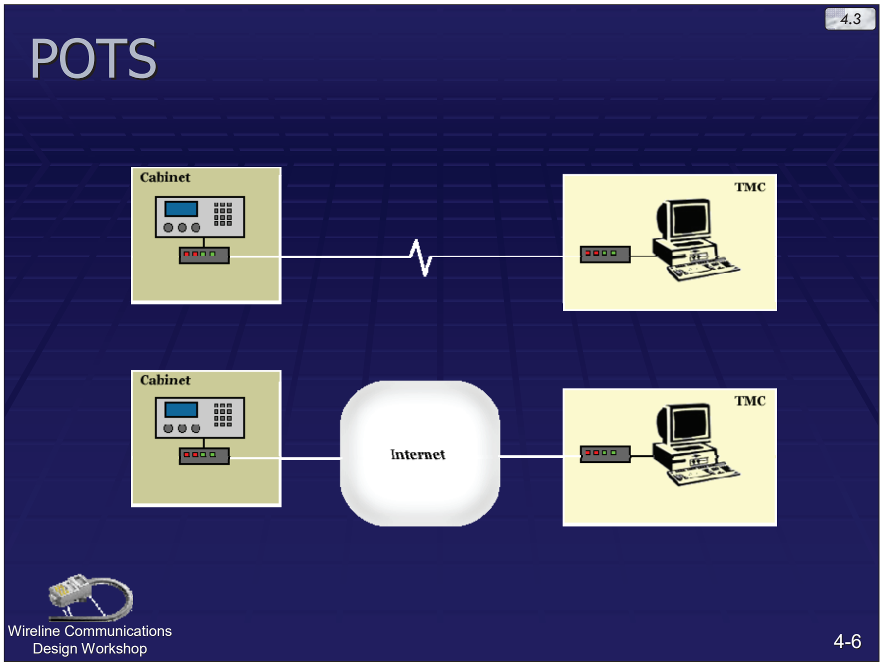
15-30 second connection times.

No distance limitiations.

**Key Questions:**

**Other Information:**

None.



4.3

POTS

Wireline Communications
Design Workshop

4-6

**Key Message:**

Devices can be connected in one of two ways using POTS.

**Details:**

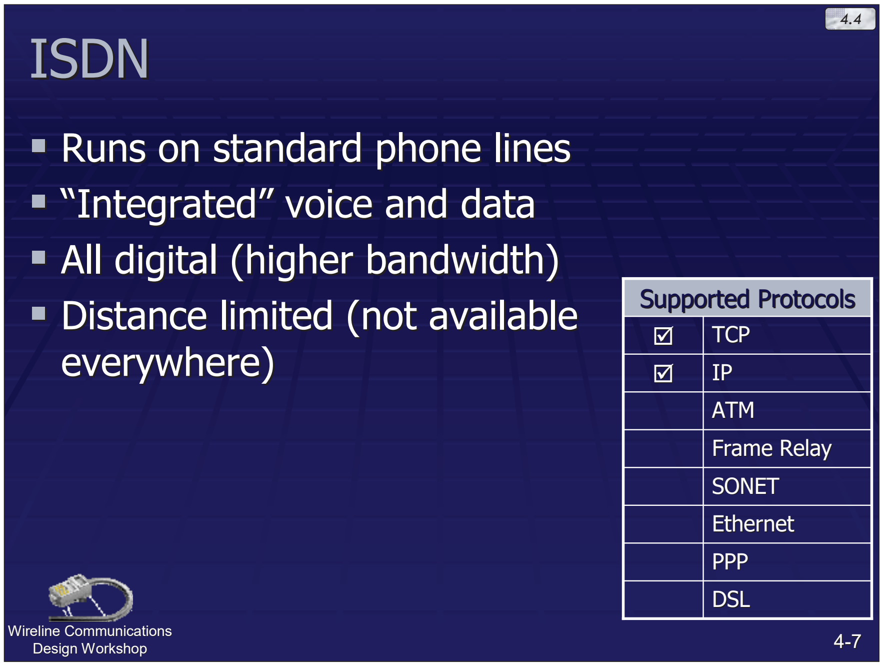
Devices can be connected directly to each other: connection can be always on, minimal security issues, lowest cost.

Devices can communicate through the Internet (using an ISP): connection speeds do not have to be the same on both ends, more security issues, some costs.

**Key Questions:**

**Other Information:**

None.



4.4

## ISDN

- Runs on standard phone lines
- "Integrated" voice and data
- All digital (higher bandwidth)
- Distance limited (not available everywhere)

| Supported Protocols | |
|---|---|
| ☑ | TCP |
| ☑ | IP |
| | ATM |
| | Frame Relay |
| | SONET |
| | Ethernet |
| | PPP |
| | DSL |

Wireline Communications
Design Workshop

4-7

**Key Message:**

Integrated Services Digital Network is an all-digital system that runs on standard phone lines.

**Details:**

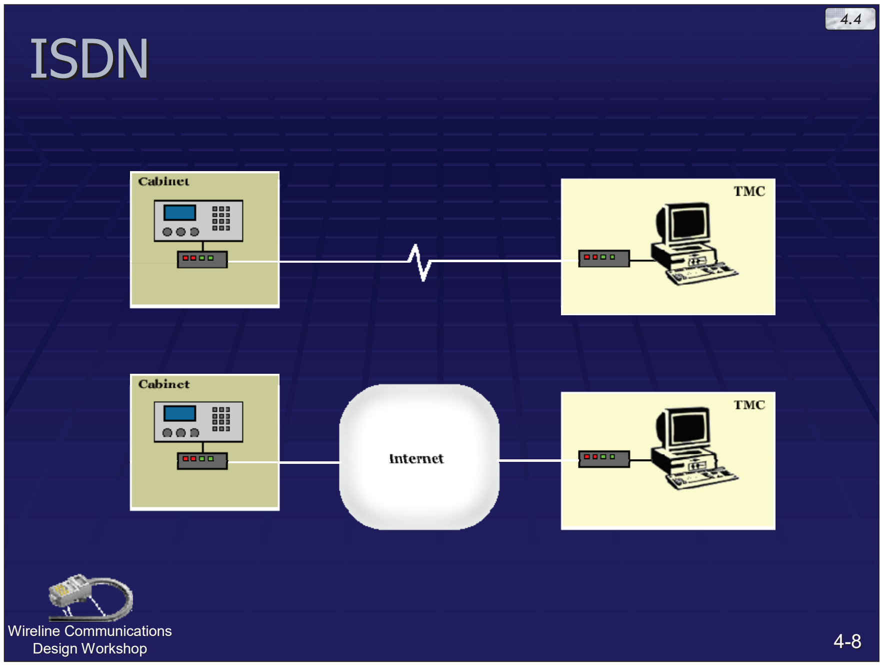
Physical cabling is the same as for POTS, but the infrastructure that supports it at either end and at the phone company is substantially different.

Main advantage of ISDN is that it is an all-digital system.

**Key Questions:**

**Other Information:**

None.



4.4

ISDN

Wireline Communications
Design Workshop

4-8

**Key Message:**

Devices can be connected in one of two ways using ISDN.

**Details:**

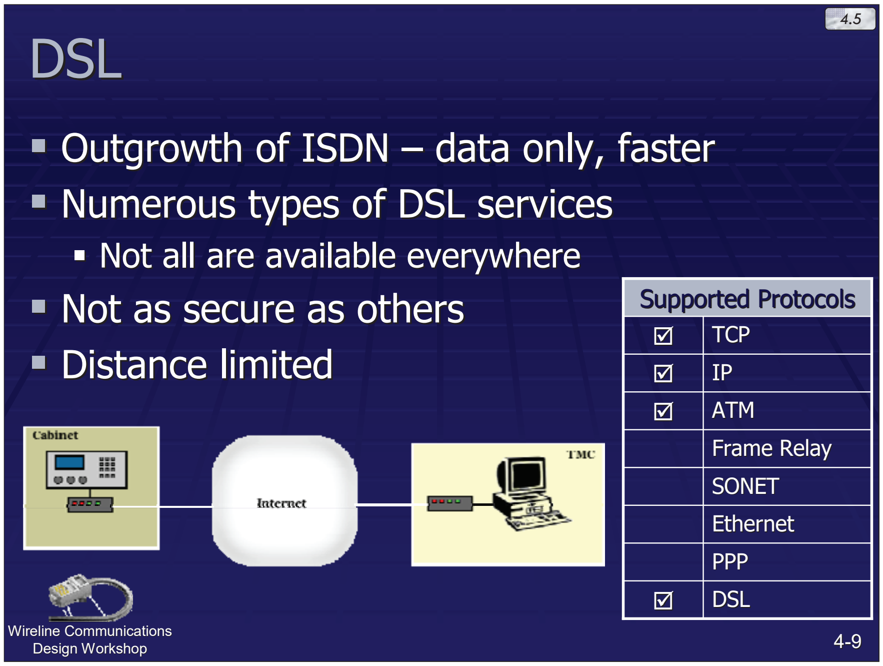
Devices can be connected directly to each other: connection can be always on, minimal security issues, higher bandwidth than POTS direct connection, lowest cost.

Devices can communicate through the Internet (using an ISP): connection speeds do not have to be the same on both ends, more security issues, some costs.

**Key Questions:**

**Other Information:**

None.



4.5

# DSL

- Outgrowth of ISDN – data only, faster
- Numerous types of DSL services
  - Not all are available everywhere
- Not as secure as others
- Distance limited

| Supported Protocols | |
|---|---|
| ☑ | TCP |
| ☑ | IP |
| ☑ | ATM |
| | Frame Relay |
| | SONET |
| | Ethernet |
| | PPP |
| ☑ | DSL |

Wireline Communications Design Workshop

4-9

**Key Message:**

DSL is a technology for bringing high-bandwidth capabilities over ordinary copper telephone lines.

**Details:**

DSL uses the same phone lines (copper twisted pair cabling).

Encoding of the data is very different than ISDN. This different encoding scheme causes less interference, allows for more efficient data transfers, and reduces the cost of equipment.

DSL is typically substantially faster than ISDN.

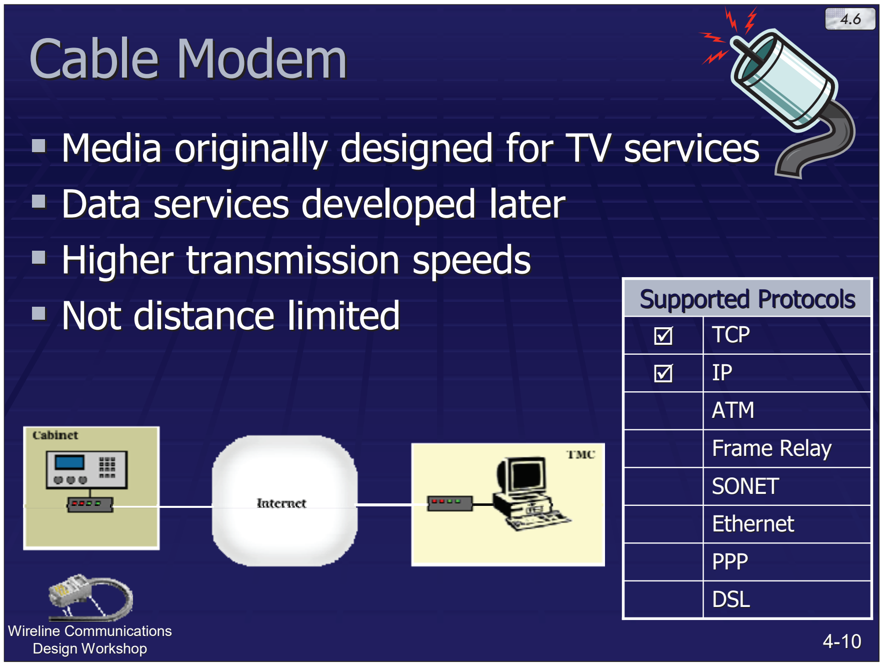
Download speeds typically faster than upload speeds.

DSL requires an Internet connection.

**Key Questions:**

**Other Information:**

None.



## Cable Modem

- Media originally designed for TV services
- Data services developed later
- Higher transmission speeds
- Not distance limited

| Supported Protocols | |
|---|---|
| ☑ | TCP |
| ☑ | IP |
| | ATM |
| | Frame Relay |
| | SONET |
| | Ethernet |
| | PPP |
| | DSL |

**Key Message:**

Cable modem is a technology for bringing high-bandwidth capabilities over coaxial cable lines.

**Details:**

Not distance limited like DSL.

Upload and download speeds can be highly variable.

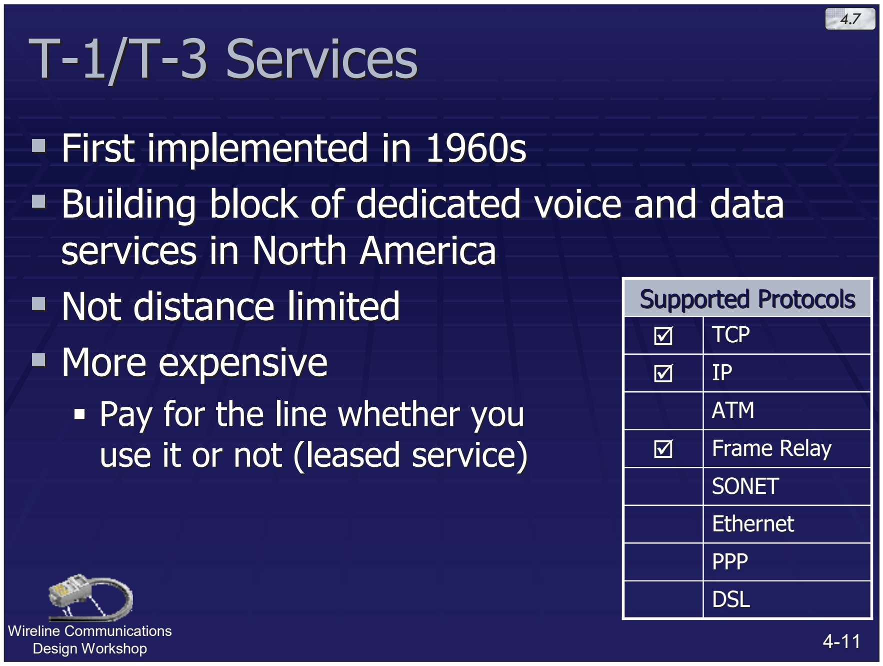
Network can slow down as more users are on it.

Not as secure.

**Key Questions:**

**Other Information:**

None.



## T-1/T-3 Services

- First implemented in 1960s
- Building block of dedicated voice and data services in North America
- Not distance limited
- More expensive
  - Pay for the line whether you use it or not (leased service)

| Supported Protocols | |
|---|---|
| ☑ | TCP |
| ☑ | IP |
| | ATM |
| ☑ | Frame Relay |
| | SONET |
| | Ethernet |
| | PPP |
| | DSL |

**Key Message:**

T-1 has become the building block of dedicated voice and data service in North America.

**Details:**

Developed in 1957 by AT&T.
The primary innovation of T-1 was to introduce "digitized" voice and to create a network fully capable of digitally representing what was, up until then, a fully analog telephone system.

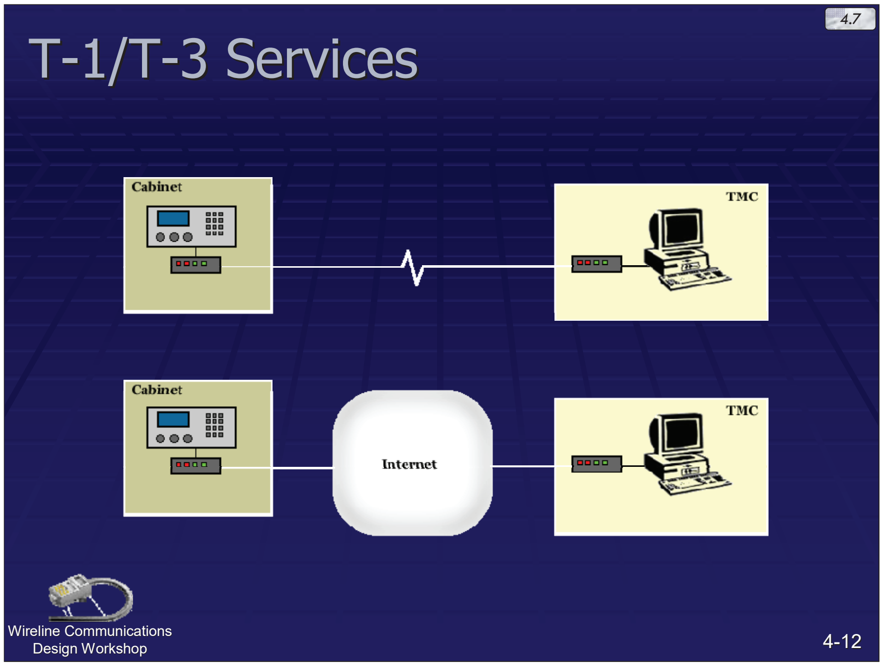
The T-3 is a higher multiple of a T-1 that has been joined (also known as bonded or multiplexed) together. A T-3 is comprised of 28 individual T-1 lines.

T-1 / T-3 can be provided over twisted pair copper wiring or fiber optic cabling.

**Key Questions:**

**Other Information:**

None.



4.7

T-1/T-3 Services

Wireline Communications Design Workshop

4-12

**Key Message:**

Devices can be connected in one of two ways using T-1/T-3.

**Details:**

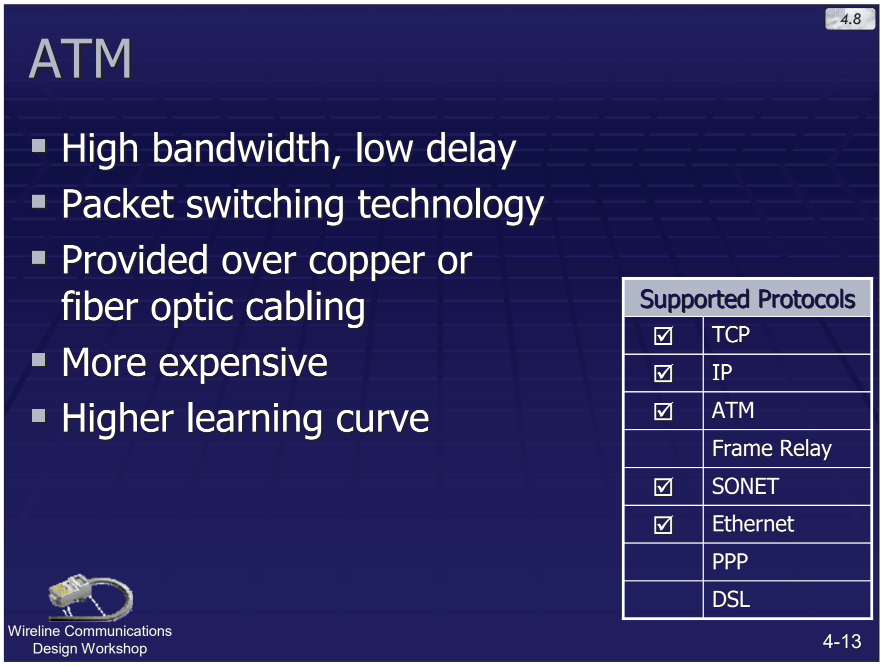
Devices can be connected directly to each other: connection can be always on, minimal security issues, lowest cost.

Devices can communicate through the Internet (using an ISP): connection speeds do not have to be the same on both ends, more security issues, some costs.

**Key Questions:**

**Other Information:**

None.



## ATM

- High bandwidth, low delay
- Packet switching technology
- Provided over copper or fiber optic cabling
- More expensive
- Higher learning curve

| Supported Protocols | |
|---|---|
| ☑ | TCP |
| ☑ | IP |
| ☑ | ATM |
| | Frame Relay |
| ☑ | SONET |
| ☑ | Ethernet |
| | PPP |
| | DSL |

Wireline Communications
Design Workshop

**Key Message:**

Asynchronous Transfer Mode is a high-bandwidth, low-delay technology that is capable of very high transmission rates.

**Details:**

Research started around 1980.

ATM is the result of a compromise to find a single common denominator that was best for all types of data.

ATM is a packet switching technology that divides upper-level data units into 53-byte cells for transmission over the physical medium.

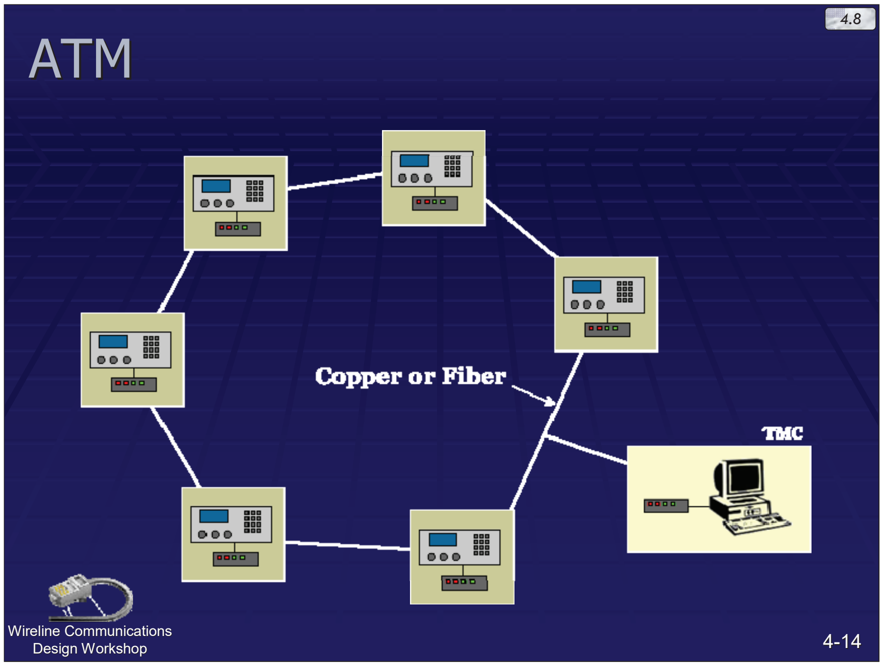
ATM is a connection-oriented technology, which means it requires a channel to be established between the sender and receiver before any messages are transmitted.

ATM can interface with SONET and Ethernet technologies.

**Key Questions:**

**Other Information:**

ATM uses Quality of Service (QoS) to prioritze traffic.



4.8

ATM

Copper or Fiber

TMC

Wireline Communications
Design Workshop

4-14

**Key Message:**

An ATM network would typically be constructed, operated, and maintained by an agency with total control over the equipment and infrastructure.

**Details:**

While the figure shows a ring topology, any of the other topologies could also be utilized.

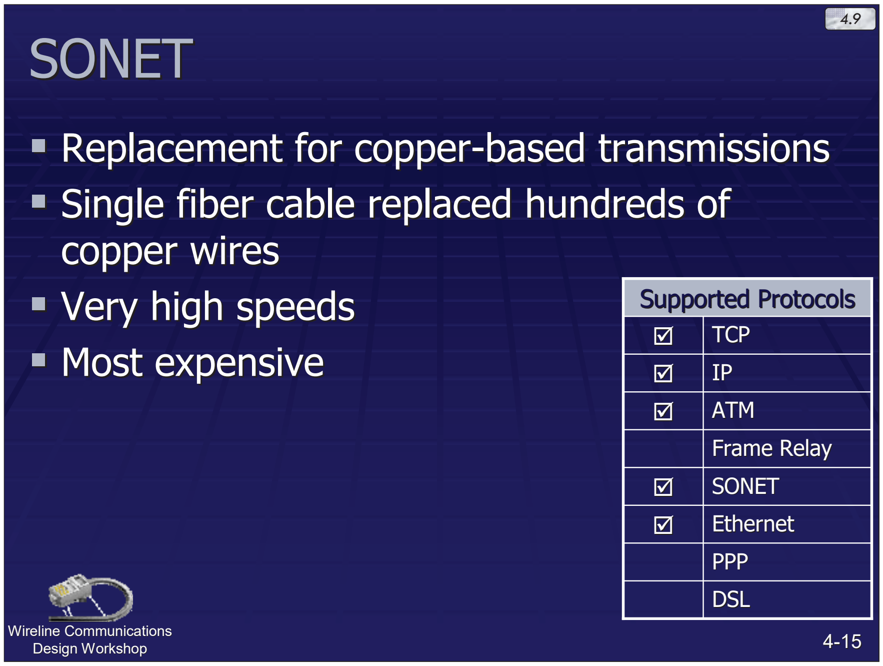
Be aware that an ATM network simply provides the means to transport information from Point A to Point B. Additional equipment, such as codecs, would still be necessary to encode video signals and place them into the network for transport.

ATM is currently thought of as more of a backbone or Wide Area Network (WAN) technology.

**Key Questions:**

**Other Information:**

None.



4.9

# SONET

- Replacement for copper-based transmissions
- Single fiber cable replaced hundreds of copper wires
- Very high speeds
- Most expensive

| Supported Protocols | |
|---|---|
| ☑ | TCP |
| ☑ | IP |
| ☑ | ATM |
| | Frame Relay |
| ☑ | SONET |
| ☑ | Ethernet |
| | PPP |
| | DSL |

Wireline Communications
Design Workshop

4-15

**Key Message:**

The driving force behind the creation of SONET (Synchronous Optical Network Transmission) was to create a standard for manufacturers to build fiber optic gear and ensure operability with other fiber optic equipment.

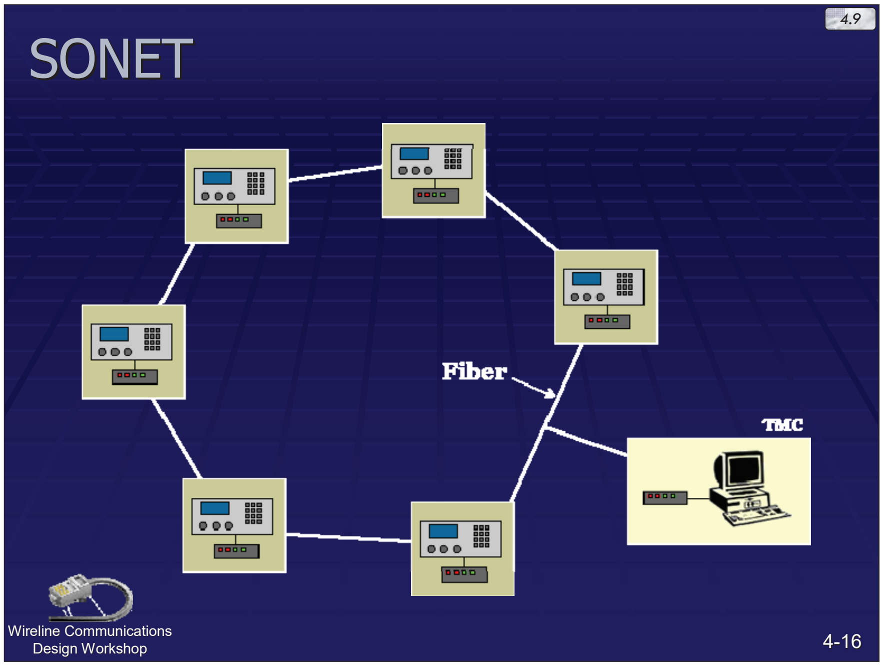
**Details:**

SONET was really born out of necessity and as a replacement for copper-based transmissions. As the communication demands grew, copper ceased to be economical to carry the vast number of calls being made nationwide. Copper also had practical limitations, since it is prone to electrical spikes from storms and other interference.

**Key Questions:**

**Other Information:**

None.



4.9

## SONET

Wireline Communications
Design Workshop

**Key Message:**

A SONET network would typically be constructed, operated, and maintained by an agency with total control over the equipment and infrastructure.

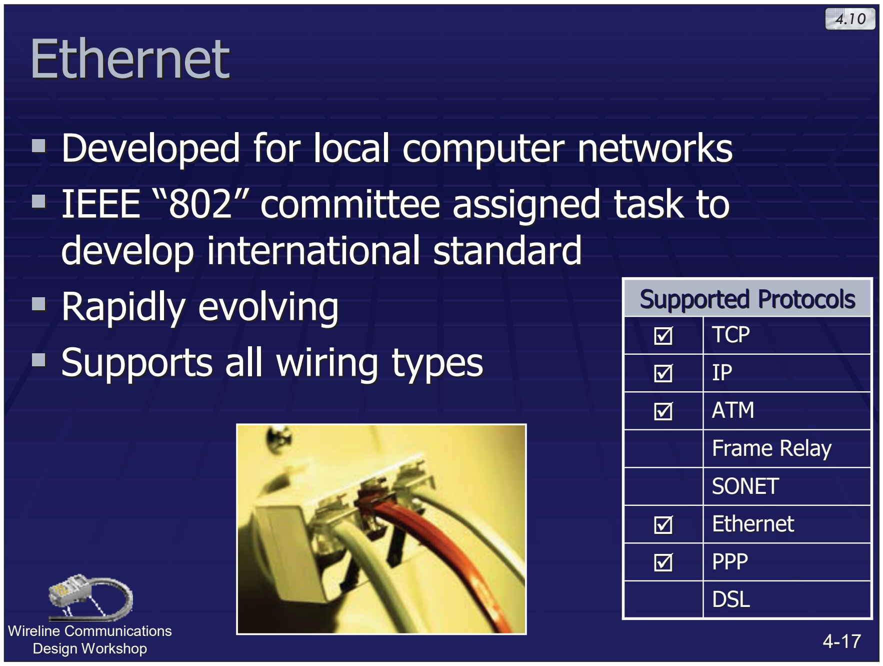
**Details:**

The figure illustrates a ring topology. Be aware that a SONET network simply provides the means to transport information from Point A to Point B. Additional equipment, such as codecs, would still be necessary to encode video signals and place them into the network for transport. The same situation holds true for data communications such as connecting to traffic controllers, dynamic message signs, or other field devices.

**Key Questions:**

**Other Information:**

None.



4.10

## Ethernet

- Developed for local computer networks
- IEEE "802" committee assigned task to develop international standard
- Rapidly evolving
- Supports all wiring types

| Supported Protocols | |
|---|---|
| ☑ | TCP |
| ☑ | IP |
| ☑ | ATM |
| | Frame Relay |
| | SONET |
| ☑ | Ethernet |
| ☑ | PPP |
| | DSL |

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4-17

**Key Message:**

Ethernet was invented as a project to connect computer, printers, and workstations within a small area.

**Details:**

The first Ethernet network was designed and built in 1973 by Bob Metcalfe, who was with the Xerox Corporation. The term 'Ethernet' was a registered trademark of Xerox Corporation.

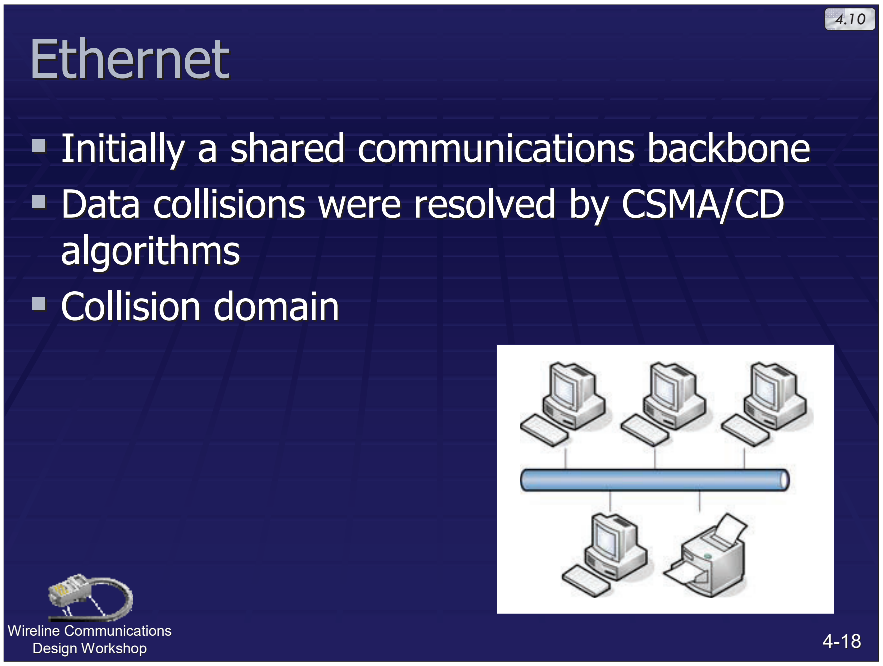
Ethernet has evolved more rapidly than perhaps any other technology. From simple beginnings with low speeds just 30 years ago, Ethernet now boasts speeds of 10 Gbps and features such as Quality of Service (QoS).

It is important to recognize that the line speed of Ethernet can never truly be realized, as it is a technology based on random transmission of data. However, because of increases in the efficiency of how Ethernet works, Ethernet provides more bandwidth at a lower cost than any other technology.

**Key Questions:**

**Other Information:**

None.



## Ethernet

- Initially a shared communications backbone
- Data collisions were resolved by CSMA/CD algorithms
- Collision domain

**Key Message:**

The design of Ethernet networks has changed considerably since the inception of the protocol.

**Details:**

In the first implementations, the Ethernet "wire" or media was truly a shared communications backbone amongst multiple nodes.

Because multiple devices were on the same media, the CSMA/CD algorithm was used to detect collisions between packets of information and to provide rules for retransmitting the information to ensure that all packets got through the "wire."

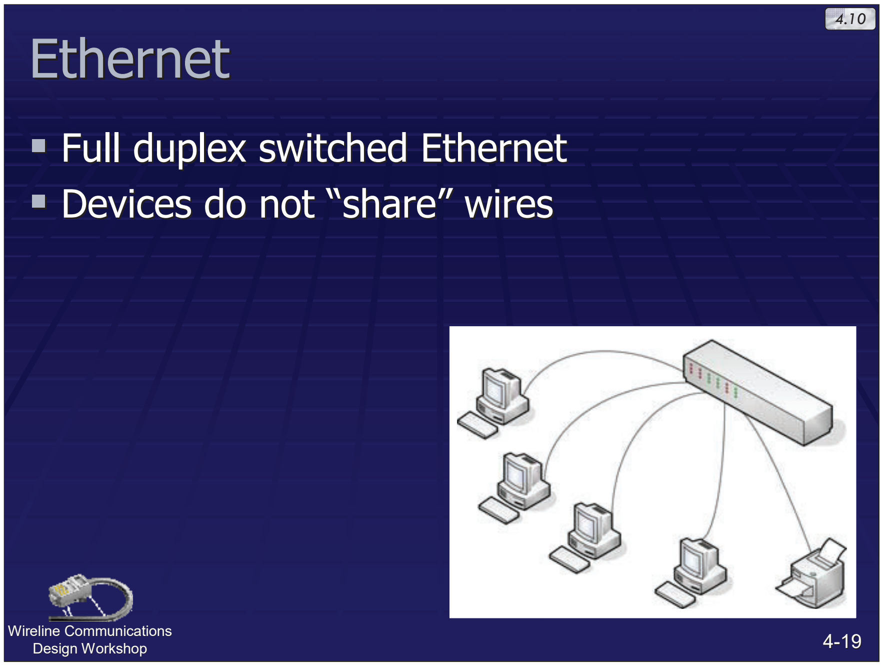
Each "wire" was called a network segment. Network segments were typically joined by hubs or switches. The number and layout of the devices on the "wire" determined what was called a collision domain. A collision domain was the extent of the network devices which would conflict with one another when trying to send and receive information. If the collision domain was too large, the number of collisions would greatly increase and performance would suffer. Special design considerations were employed to reduce the extent of the collision domain, usually by reducing the number of devices on any particular network segment.

Over time, as Ethernet advanced in capabilities, equipment, and design the design situation this illustration became outdated. Virtually all Ethernet implementations that are being put in place today are known as full-duplex switched Ethernet.

**Key Questions:**

**Other Information:**

None.



# Ethernet

- Full duplex switched Ethernet
- Devices do not "share" wires

**Key Message:**

The design of Ethernet networks has changed considerably since the inception of the protocol.

**Details:**

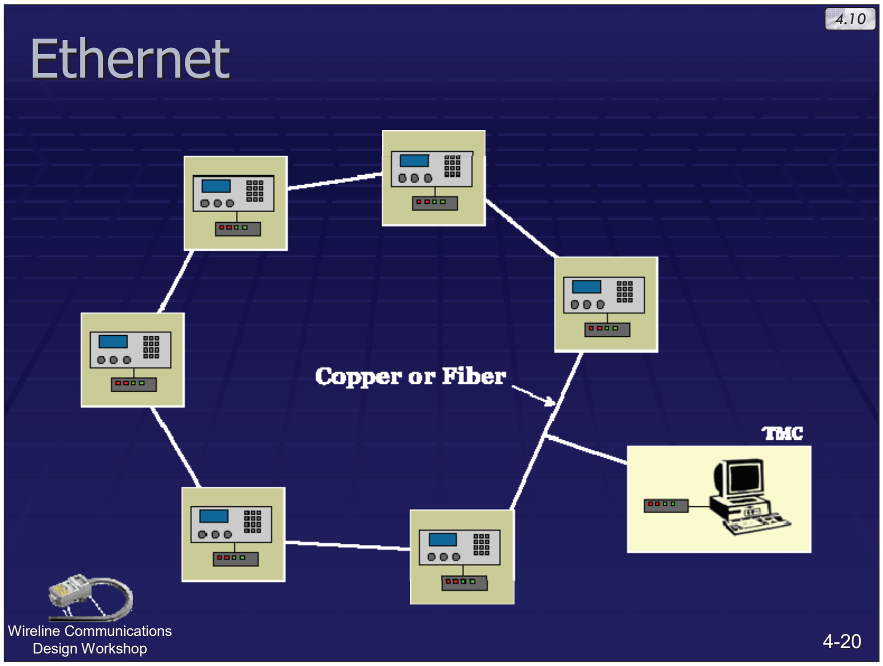
Because each device has its own "wire" back to the switch, there is no longer any conflict with other devices, since there is no more sharing of that particular wire. The switch essentially segregates each device from the other devices, only permitting packet flow if they are trying to communicate to each other. These improvements in both hardware and design have helped to greatly advance the performance of Ethernet.

Although the full duplex switched Ethernet in use today is leaps and bounds more advanced in design and application, the design of an Ethernet network can still be a challenge. Typical networks today have multiple switches, each communicating back to a central location, be it another switch or router. Available bandwidth is a significant consideration in this design. Even though individual devices may not exceed the available bandwidth from an individual port on a switch, the cumulative bandwidth may be an issue. Other concerns include items such as the packet forwarding performance of the network switching and routing equipment—basically, can they keep up with the end devices generating the packets. Standards for items such as transmission distance should still be observed, to reduce problems and keep performance at optimal values.

**Key Questions:**

**Other Information:**

None.



4.10

Ethernet

Wireline Communications Design Workshop

4-20

**Key Message:**

An Ethernet network would typically be constructed, operated, and maintained by an agency with total control over the equipment and infrastructure.

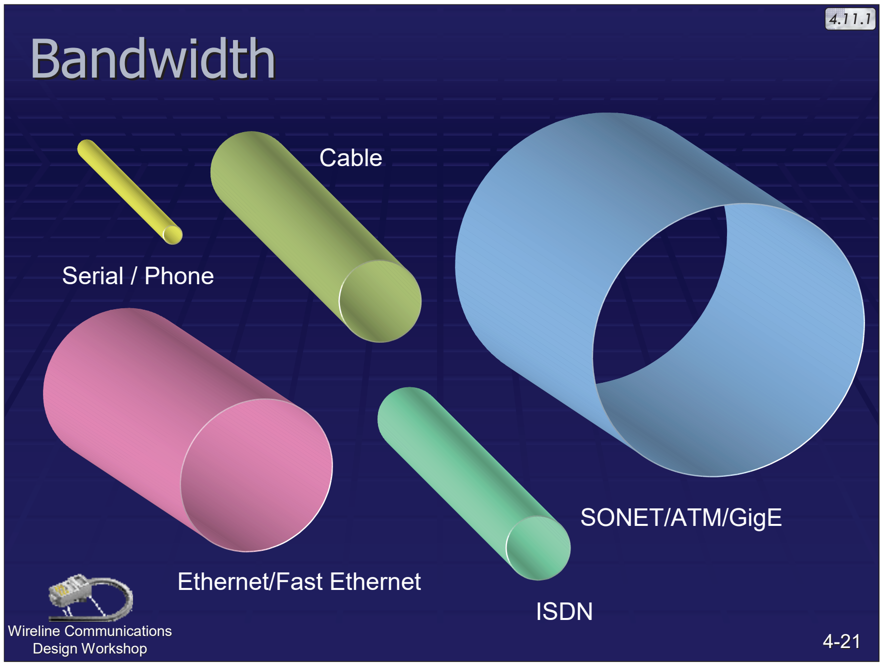
**Details:**

The figure illustrates a ring topology. Be aware that an Ethernet network simply provides the means to transport information from Point A to Point B. Additional equipment, such as codecs, would still be necessary to encode video signals and place them into the network for transport. The same situation holds true for data communications such as connecting to traffic controllers, dynamic message signs, or other field devices.

**Key Questions:**

**Other Information:**

None.



4.11.1

## Bandwidth

Cable

Serial / Phone

SONET/ATM/GigE

Ethernet/Fast Ethernet

ISDN

Wireline Communications
Design Workshop

4-21

**Key Message:**

Bandwidth is a parameter that will most likely reduce the available options quickly.

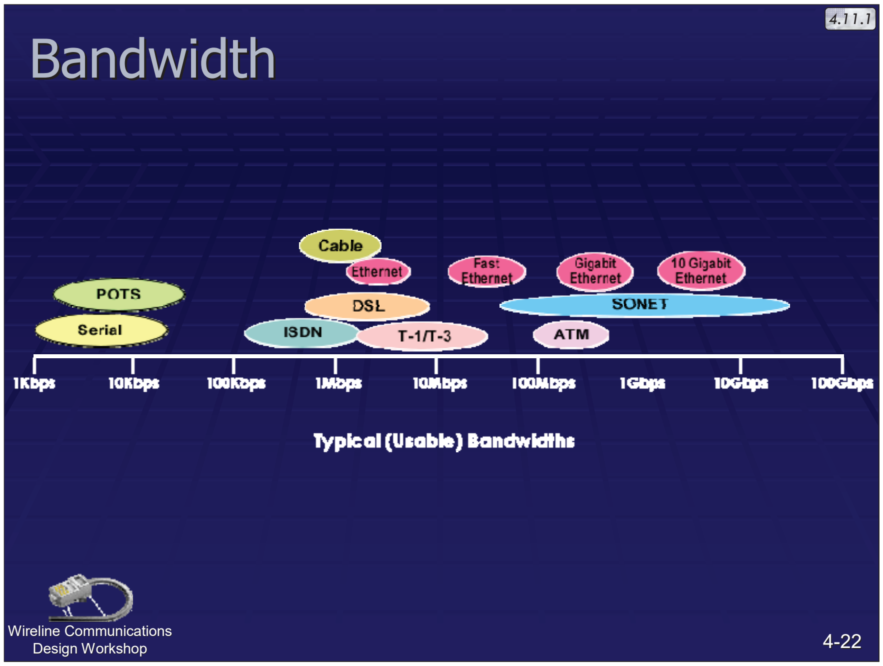
**Details:**

Do not spend much time on this slide.

**Key Questions:**

**Other Information:**

None.



4.11.1

## Bandwidth

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4-22

**Key Message:**

Bandwidths vary greatly between technologies.

**Details:**

This figure illustrates the ranges of bandwidths for the various technologies.

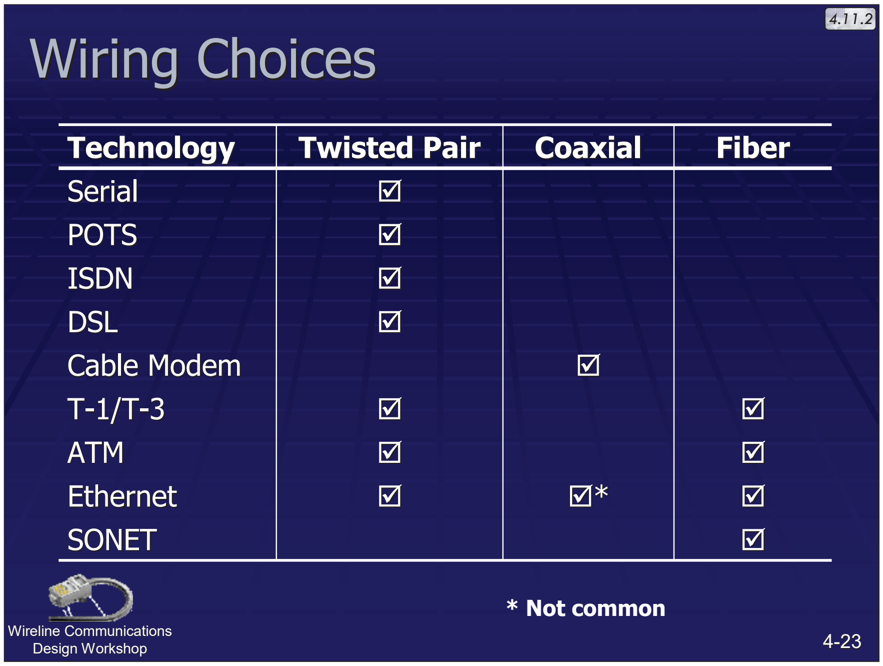
Note the scale is logarithmic.

This concept and graphic will be used in the evaluation methodology.

**Key Questions:**

**Other Information:**

None.



## Wiring Choices

| Technology | Twisted Pair | Coaxial | Fiber |
|---|---|---|---|
| Serial | ☑ | | |
| POTS | ☑ | | |
| ISDN | ☑ | | |
| DSL | ☑ | | |
| Cable Modem | | ☑ | |
| T-1/T-3 | ☑ | | ☑ |
| ATM | ☑ | | ☑ |
| Ethernet | ☑ | ☑* | ☑ |
| SONET | | | ☑ |

*** Not common**

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**Key Message:**

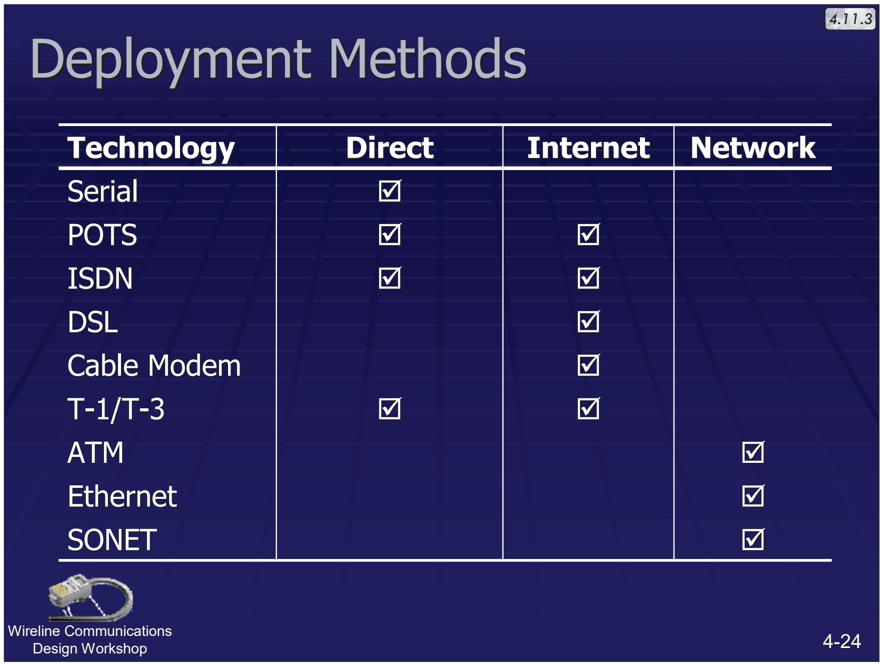
There are limited wiring choices available to implement the current technology choices.

**Details:**

**Key Questions:**

**Other Information:**

None.



## Deployment Methods

| Technology | Direct | Internet | Network |
|---|---|---|---|
| Serial | ☑ | | |
| POTS | ☑ | ☑ | |
| ISDN | ☑ | ☑ | |
| DSL | | ☑ | |
| Cable Modem | | ☑ | |
| T-1/T-3 | ☑ | ☑ | |
| ATM | | | ☑ |
| Ethernet | | | ☑ |
| SONET | | | ☑ |

**Key Message:**

This slide reviews the deployment methods for the various technologies.

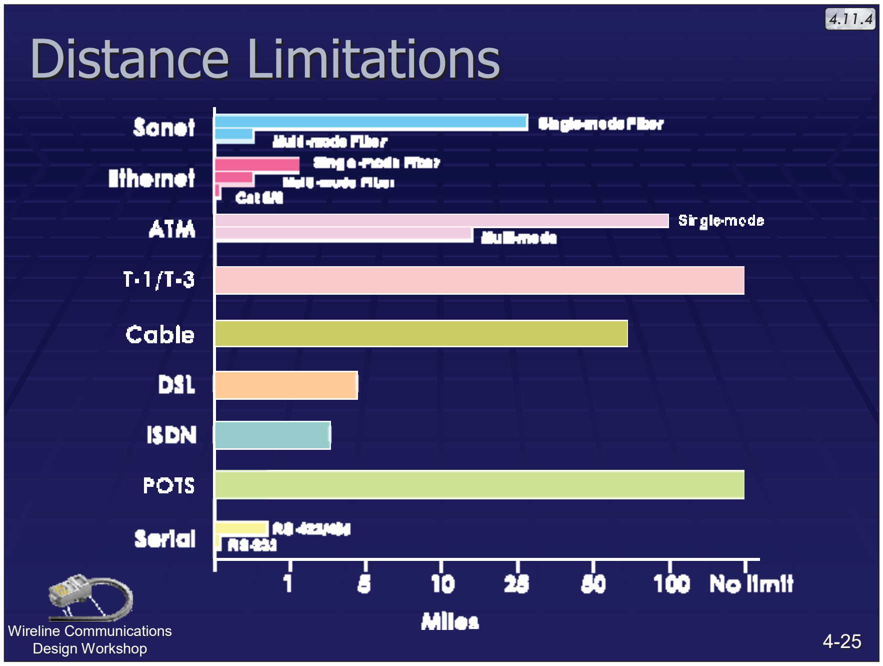
**Details:**

These details were covered in the technology slides.  Do not spend much time here.

**Key Questions:**

**Other Information:**

None.



4.11.4

## Distance Limitations

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Design Workshop

4-25

**Key Message:**

Many of the technology choices have some sort of distance limitation associated.

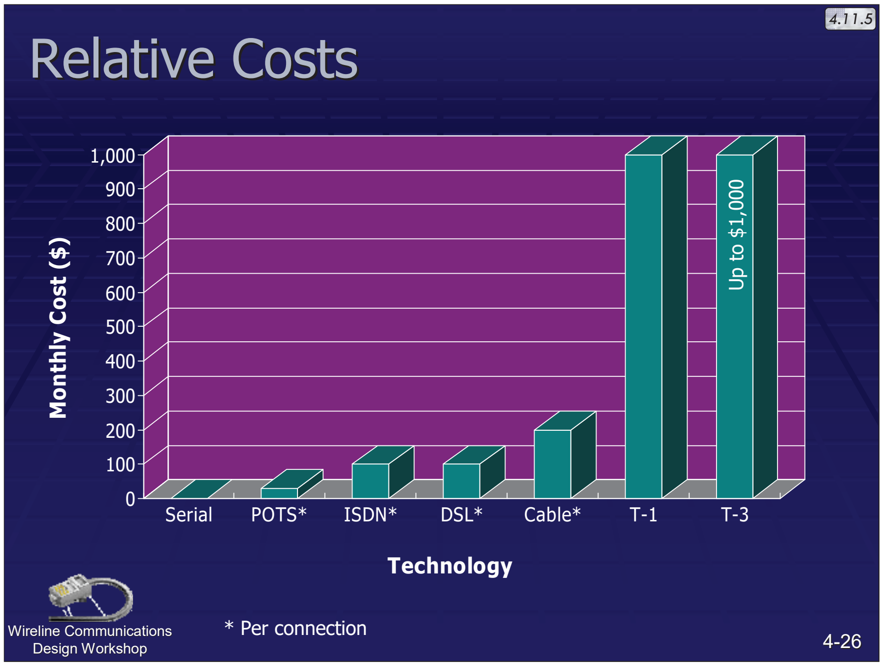
**Details:**

This figure is only an approximation of the distance limitations. The table in the guidebook gives more specific information. Just use this slide to illustrate the magnitude of the differences. Note the scale is not linear.

**Key Questions:**

**Other Information:**

None.



4.11.5

## Relative Costs

Wireline Communications Design Workshop

* Per connection

**Key Message:**

The costs of the various technology choices vary greatly.

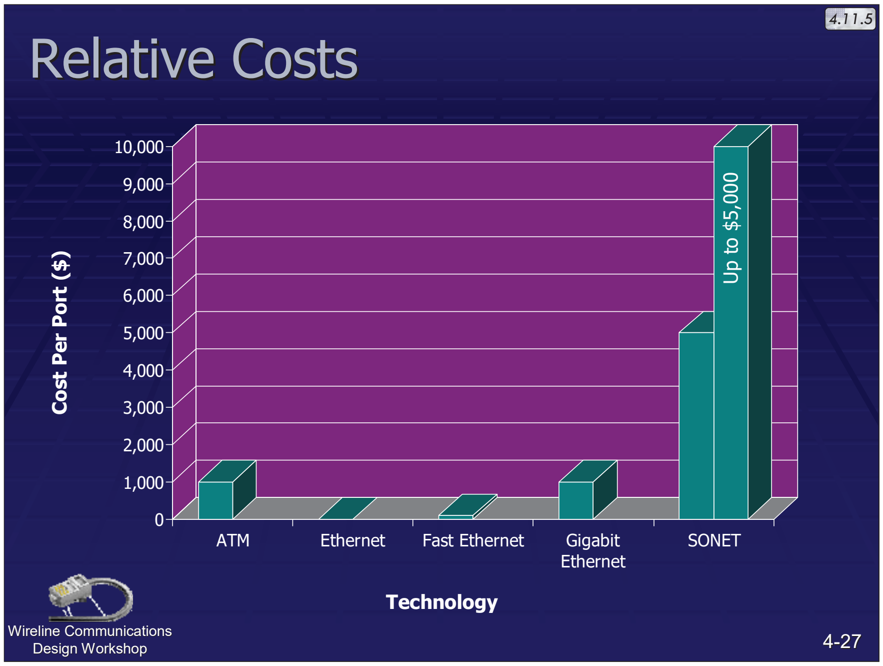
**Details:**

The figure illustrates the costs of the technologies that would typically have a monthly cost associated with them.

**Key Questions:**

**Other Information:**

None.



4.11.5

Relative Costs

Wireline Communications Design Workshop

4-27

**Key Message:**

The costs of the various technology choices vary greatly.

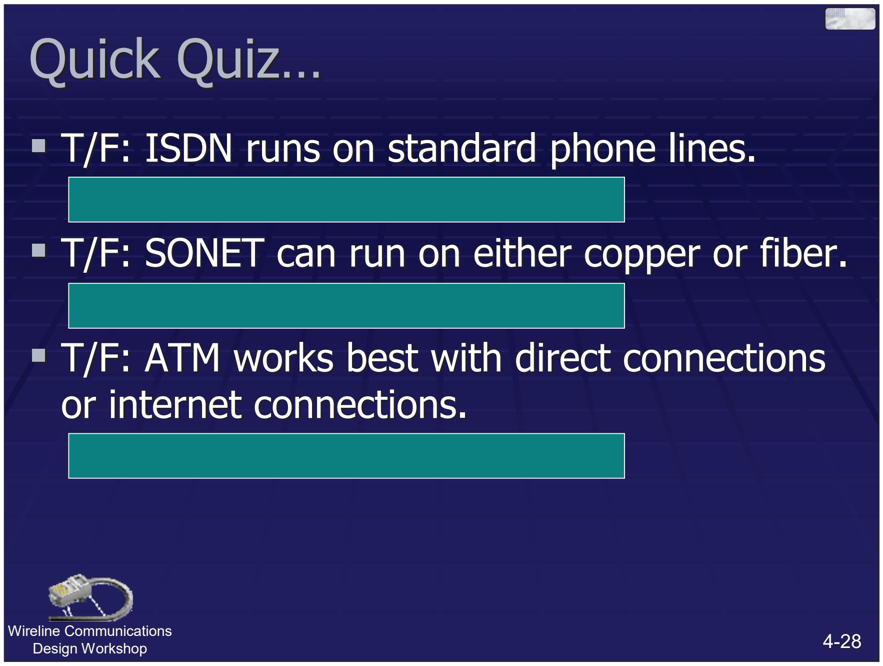
**Details:**

The figure illustrates the costs of the technologies that would typically have a per connection cost associated with them.

**Key Questions:**

**Other Information:**

GigE costs are dropping and are closer to $300/port.



## Quick Quiz…

- T/F: ISDN runs on standard phone lines.
- T/F: SONET can run on either copper or fiber.
- T/F: ATM works best with direct connections or internet connections.

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Quiz Q&A:

**T/F: ISDN runs on standard phone lines.**

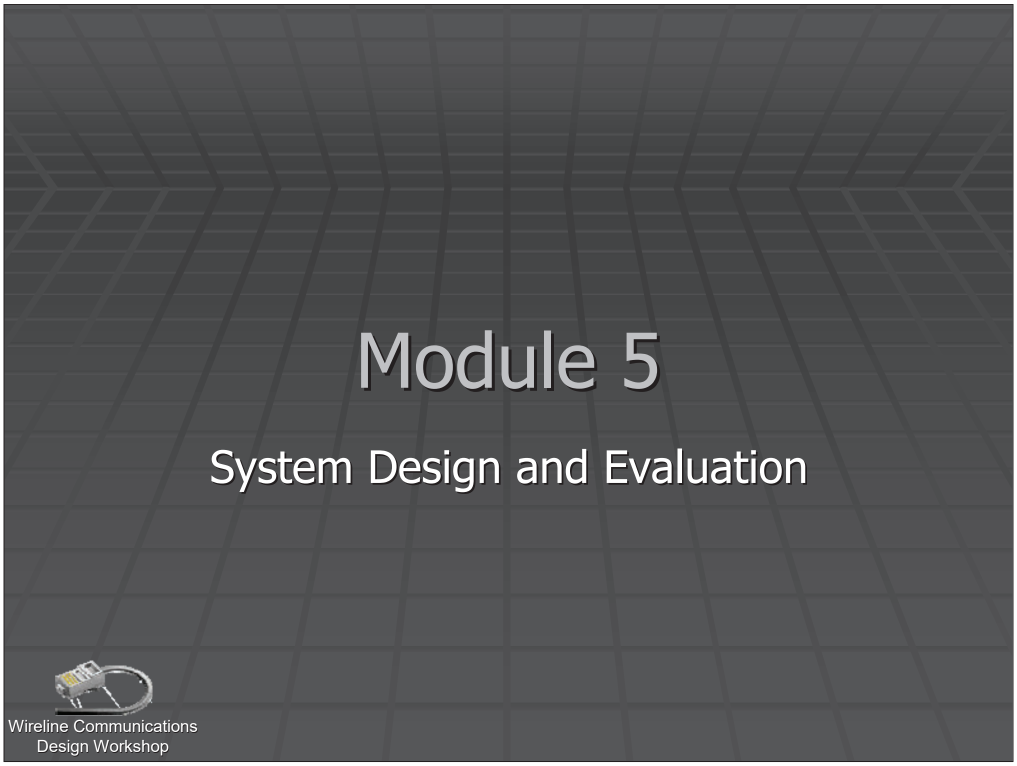
True

**T/F: SONET can run on either copper or fiber.**

False, fiber only.

**T/F: ATM works best with direct connections or internet connections.**

False, network connection only.



# Module 5

## System Design and Evaluation

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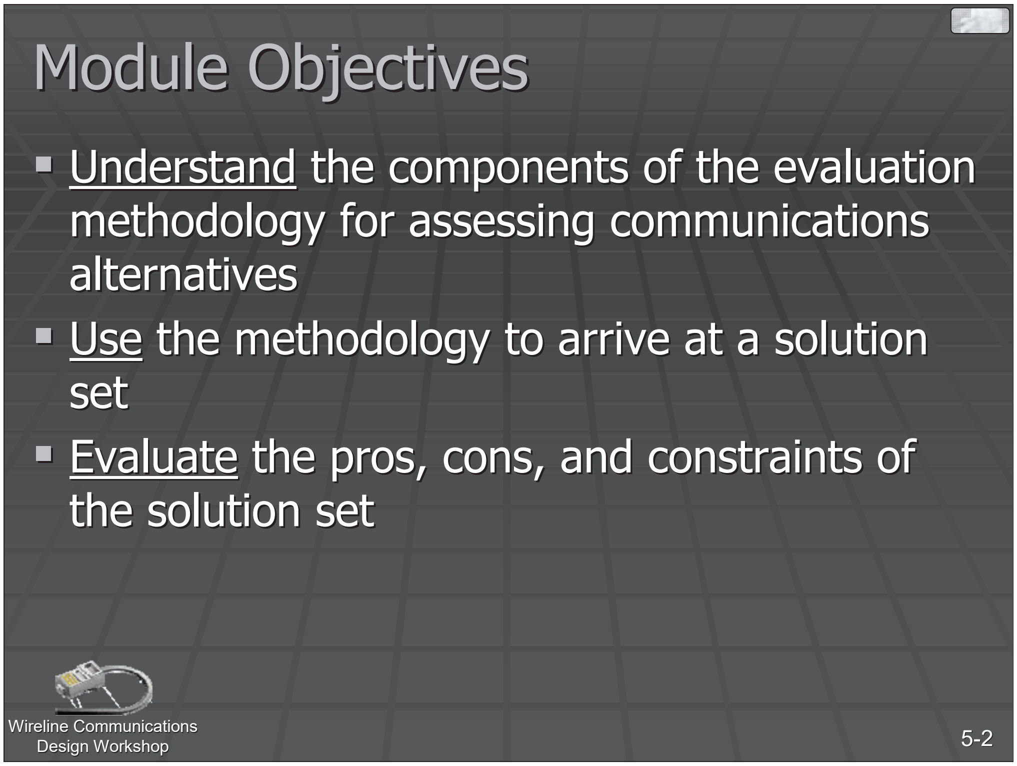


## Module Objectives

- Understand the components of the evaluation methodology for assessing communications alternatives
- Use the methodology to arrive at a solution set
- Evaluate the pros, cons, and constraints of the solution set

Wireline Communications Design Workshop

**Key Message:**

None.

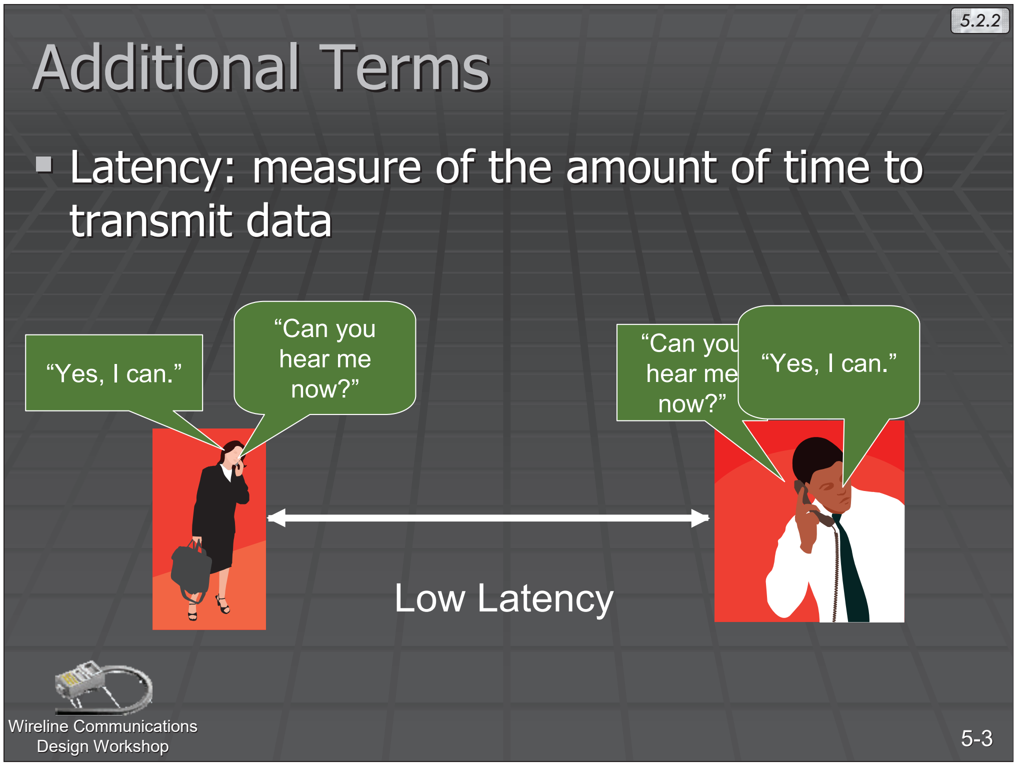
**Details:**

Go over the module objectives.

**Key Questions:**

**Other Information:**

None.



5.2.2

## Additional Terms

- Latency: measure of the amount of time to transmit data

Wireline Communications Design Workshop

5-3

**Key Message:**

Latency is a measure of the amount of time it takes a piece of information to get from one designated point to another. Every device and communications solution has latency.

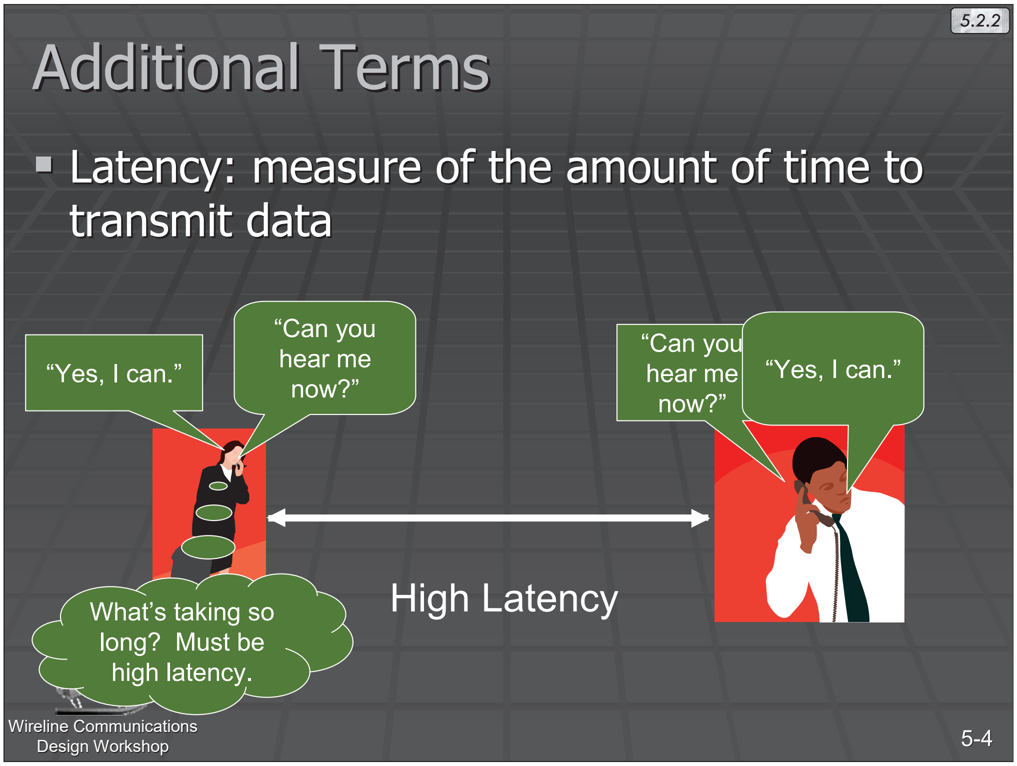
**Details:**

This slide illustrates low latency (i.e. no/little delay).

**Key Questions:**

**Other Information:**

This slides builds with mouse clicks.



5.2.2

## Additional Terms

- Latency: measure of the amount of time to transmit data

Wireline Communications Design Workshop

5-4

**Key Message:**

Latency is a measure of the amount of time it takes a piece of information to get from one designated point to another. Every device and communications solution has latency.

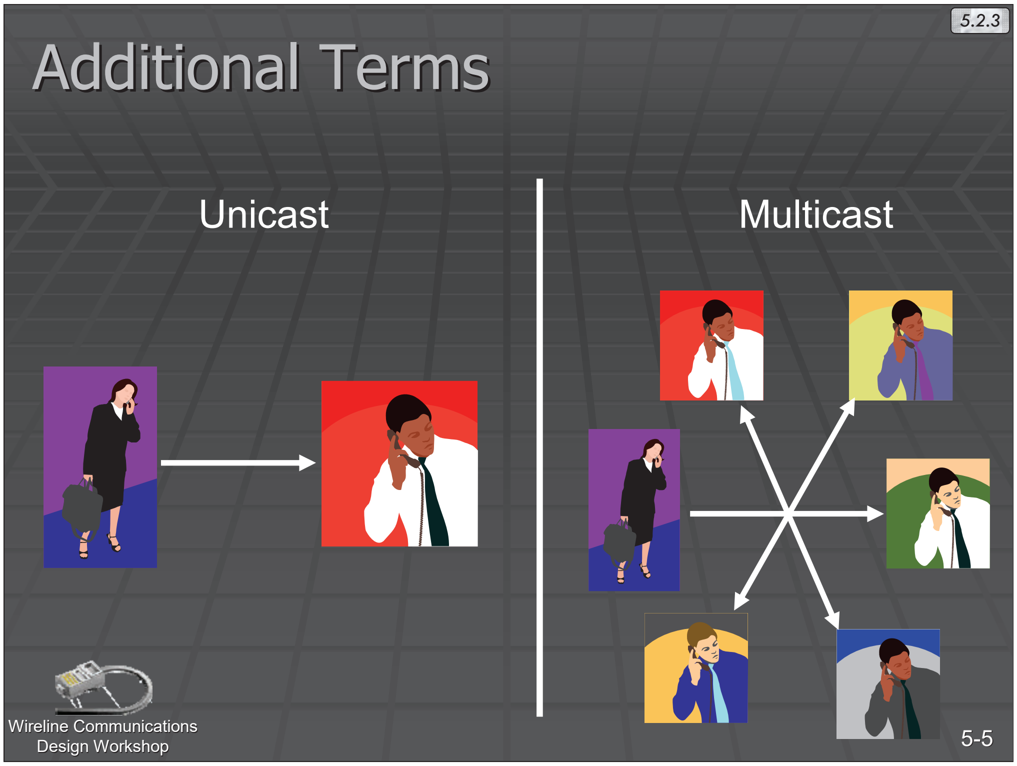
**Details:**

This slide illustrates high latency (i.e. significant delay).

**Key Questions:**

**Other Information:**

This slides builds with mouse clicks.



5.2.3

Additional Terms

**Key Message:**

Communication systems can be built to be either 'unicast' or 'multicast.'

**Details:**

Multicast communications can be easier (since the same conversation does not have to be repeated individually).

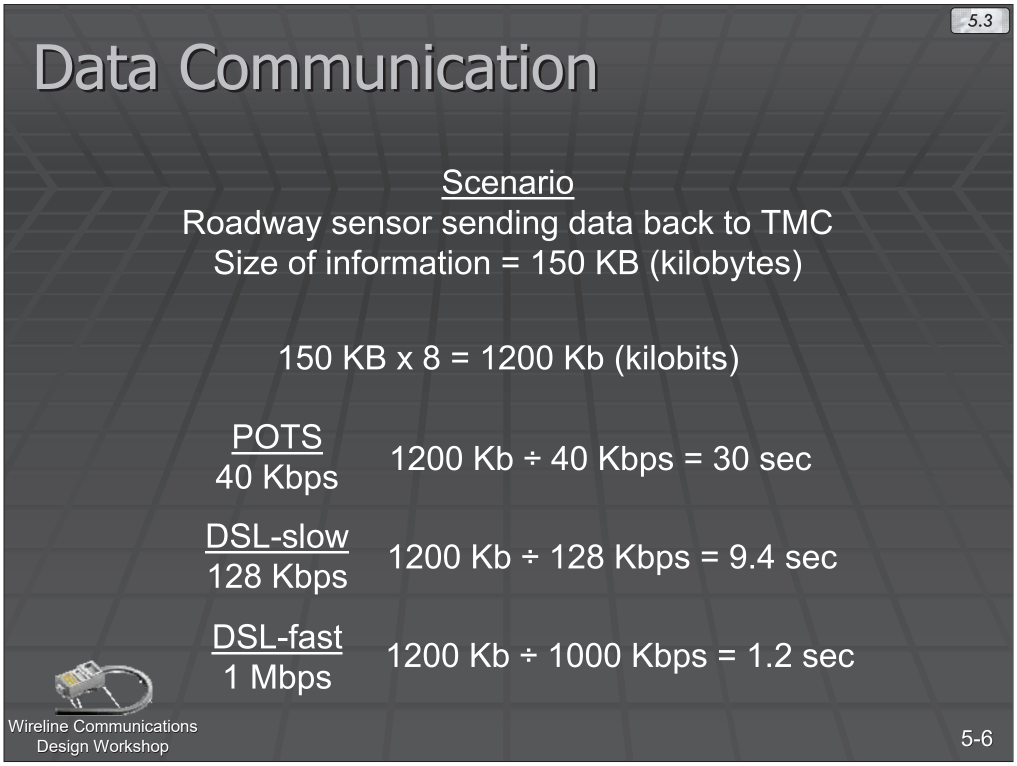
However, many conversations do not need to be multicast.

Multicast networks are more difficult to set up and maintain, and may require more significant expertise to achieve stable operations.

**Key Questions:**

**Other Information:**

None.



5.3

## Data Communication

Scenario
Roadway sensor sending data back to TMC
Size of information = 150 KB (kilobytes)

150 KB x 8 = 1200 Kb (kilobits)

POTS
40 Kbps
1200 Kb ÷ 40 Kbps = 30 sec

DSL-slow
128 Kbps
1200 Kb ÷ 128 Kbps = 9.4 sec

DSL-fast
1 Mbps
1200 Kb ÷ 1000 Kbps = 1.2 sec

Wireline Communications
Design Workshop

5-6

**Key Message:**

Data communications do not typically require extensive bandwidth.

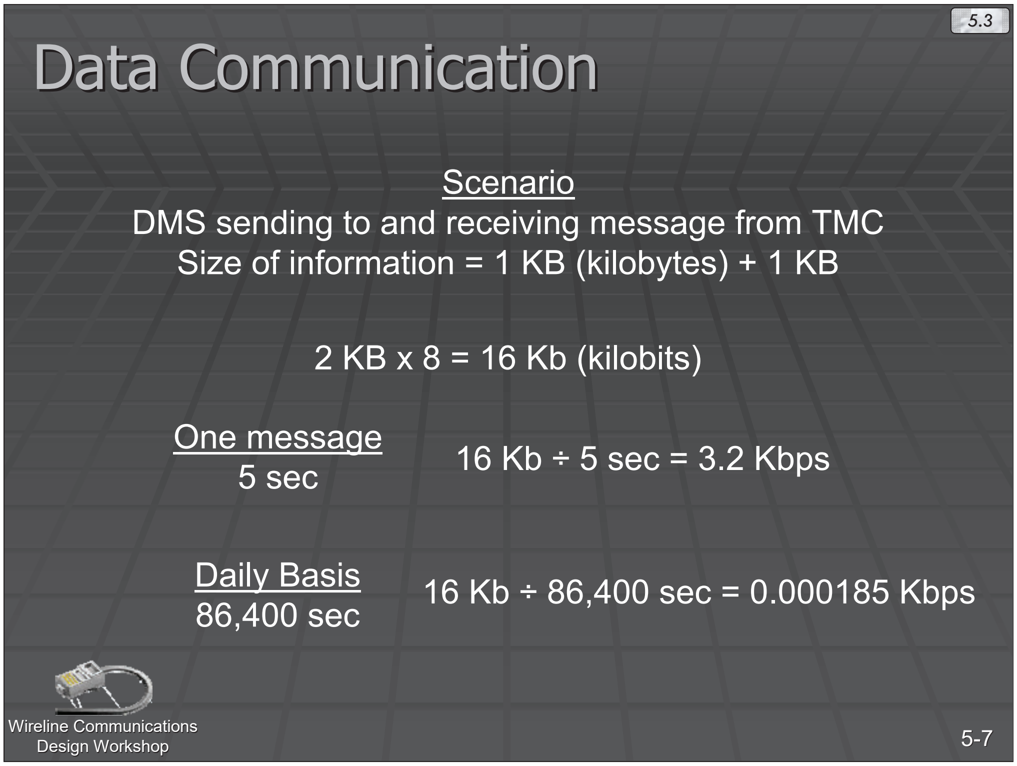
**Details:**

**Key Questions:**

The instructor may want the class to make the calculations prior to revealing. Depends on how much time is left.

**Other Information:**

Slide builds with mouse clicks.



5.3

## Data Communication

Scenario

DMS sending to and receiving message from TMC

Size of information = 1 KB (kilobytes) + 1 KB

2 KB x 8 = 16 Kb (kilobits)

| | |
|---|---|
| One message<br>5 sec | 16 Kb ÷ 5 sec = 3.2 Kbps |
| Daily Basis<br>86,400 sec | 16 Kb ÷ 86,400 sec = 0.000185 Kbps |

Wireline Communications
Design Workshop

**Key Message:**

Data communications do not typically require extensive bandwidth.

**Details:**

One method of calculating the proper bandwidth requirement is to take the total bandwidth used during DMS transmissions and convert it to an equivalent usage per second, the typical timeframe used for bandwidth. (top answer)

An alternative approach would be to simply break down every device's communication on a per second basis across a single day. (bottom answer)

The design methodology presented in the following sections assumes that all data communications are constant (all devices are constantly transmitting information at their maximum rate).

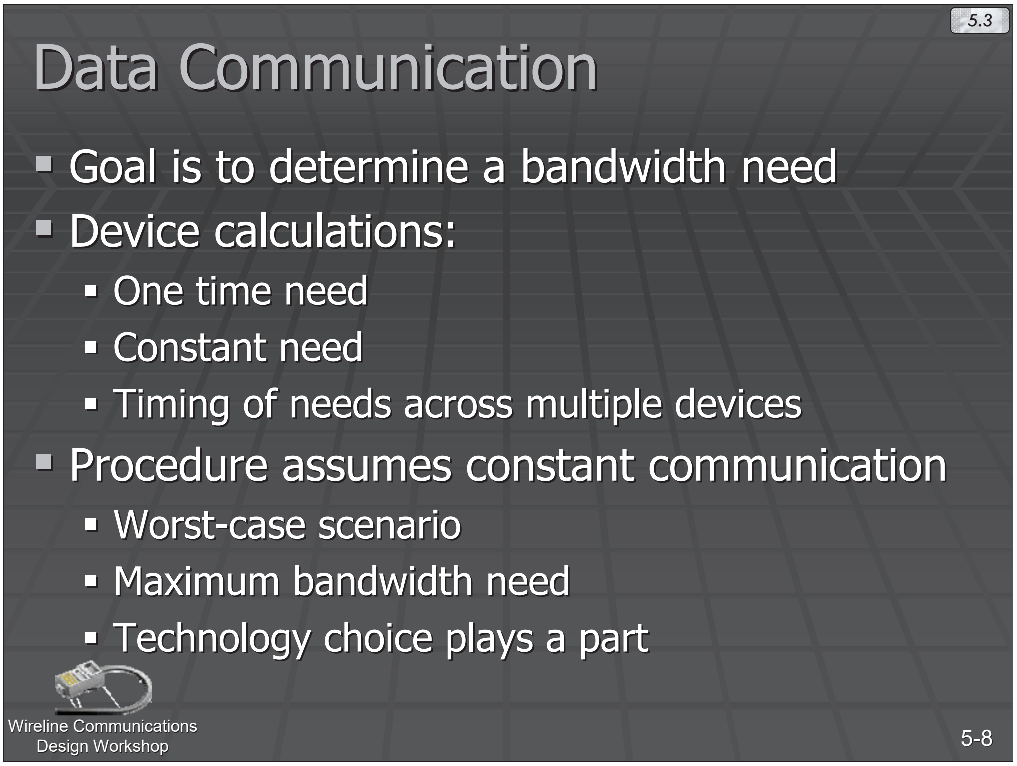
This errs on the side of designing for an increased bandwidth need, it removes much of the tedious work and inaccuracies of trying to pinpoint when and how often a device communicates.

**Key Questions:**

The instructor may want the class to make the calculations prior to revealing. Depends on how much time is left.

**Other Information:**

Slide builds with mouse clicks.



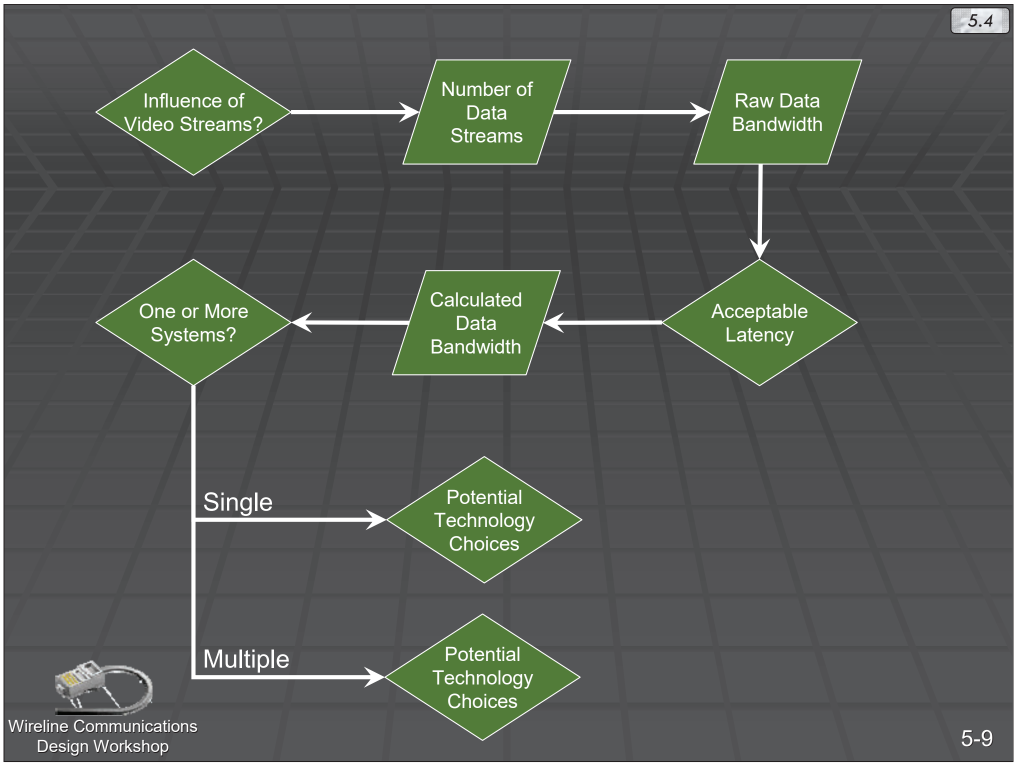
5.3

## Data Communication

- Goal is to determine a bandwidth need
- Device calculations:
  - One time need
  - Constant need
  - Timing of needs across multiple devices
- Procedure assumes constant communication
  - Worst-case scenario
  - Maximum bandwidth need
  - Technology choice plays a part

Wireline Communications
Design Workshop

5-8



Influence of Video Streams?

Number of Data Streams

Raw Data Bandwidth

Acceptable Latency

Calculated Data Bandwidth

One or More Systems?

Single

Potential Technology Choices

Multiple

Potential Technology Choices

**Key Message:**

There are 7 steps to designing a data communication system.

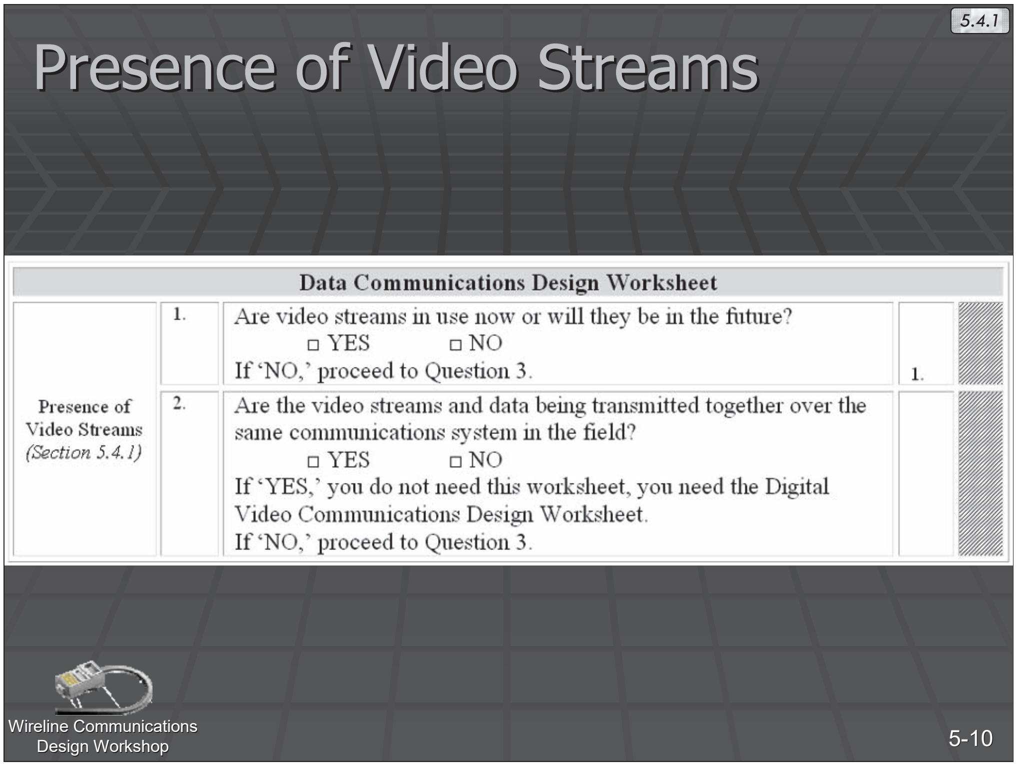
**Details:**

This flowchart is the process for data communication systems.

**Key Questions:**

**Other Information:**

None.



5.4.1

## Presence of Video Streams

**Data Communications Design Worksheet**

| | | | | |
|---|---|---|---|---|
| Presence of Video Streams *(Section 5.4.1)* | 1. | Are video streams in use now or will they be in the future?<br>☐ YES ☐ NO<br>If 'NO,' proceed to Question 3. | 1. | ▨ |
| | 2. | Are the video streams and data being transmitted together over the same communications system in the field?<br>☐ YES ☐ NO<br>If 'YES,' you do not need this worksheet, you need the Digital Video Communications Design Worksheet.<br>If 'NO,' proceed to Question 3. | | ▨ |

Wireline Communications Design Workshop

5-10

**Key Message:**

The presence of video has a significant impact on the design.

**Details:**

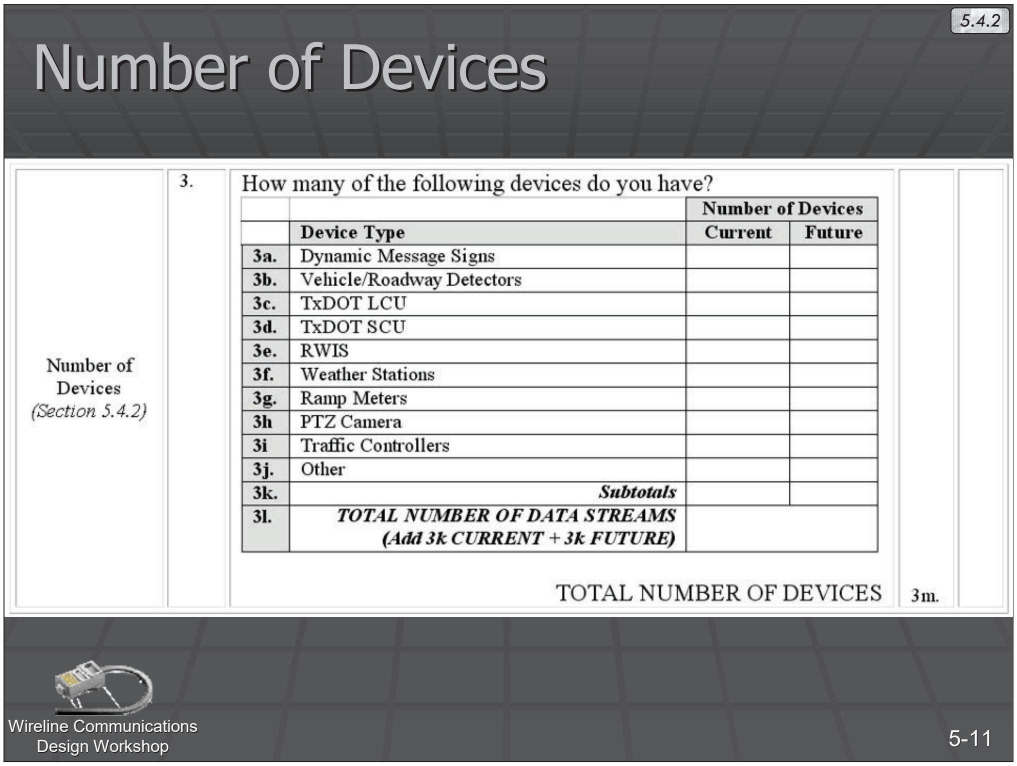
The first two questions in the data methodology inquire about the presence of video streams. Video takes a considerably greater amount of bandwidth than data communications. If video will be present and will be sharing the same communication system, the appropriate methodology to use is the video design methodology presented in section 5.6 of the guidebook.

If video will be present and the data will be on a separate communications system, the designer will have to perform both a data analysis and a video analysis. Using current communications design philosophy, this would be a relatively rare design situation.

**Key Questions:**

**Other Information:**

None.



5.4.2

## Number of Devices

Number of Devices *(Section 5.4.2)*

3\. How many of the following devices do you have?

| | | Number of Devices | |
|---|---|---|---|
| | **Device Type** | **Current** | **Future** |
| **3a.** | Dynamic Message Signs | | |
| **3b.** | Vehicle/Roadway Detectors | | |
| **3c.** | TxDOT LCU | | |
| **3d.** | TxDOT SCU | | |
| **3e.** | RWIS | | |
| **3f.** | Weather Stations | | |
| **3g.** | Ramp Meters | | |
| **3h** | PTZ Camera | | |
| **3i** | Traffic Controllers | | |
| **3j.** | Other | | |
| **3k.** | ***Subtotals*** | | |
| **3l.** | ***TOTAL NUMBER OF DATA STREAMS (Add 3k CURRENT + 3k FUTURE)*** | | |

TOTAL NUMBER OF DEVICES 3m.

Wireline Communications Design Workshop

5-11

**Key Message:**

The number of devices (current and future) needs to be identified.

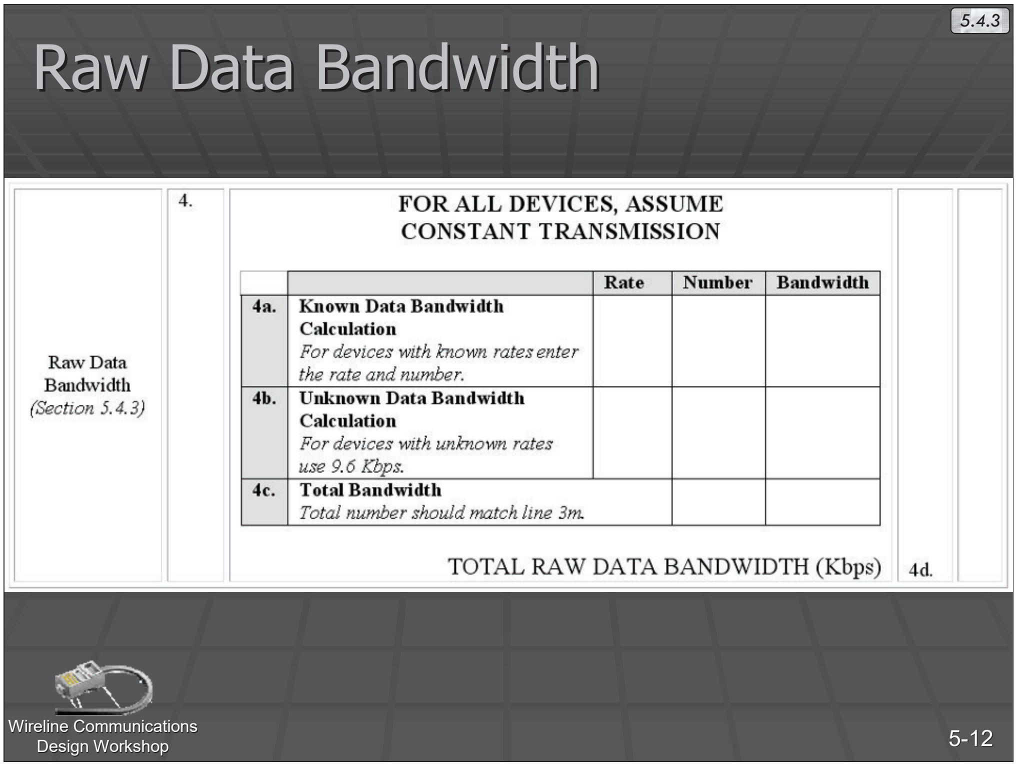
**Details:**

The breakdown by type of device is provided simply to help the designer identify different data sources. Other than the bandwidth in use, there is no inherent difference in the data stream from one type of device to another.

**Key Questions:**

**Other Information:**

None.



5.4.3

# Raw Data Bandwidth

Raw Data Bandwidth
*(Section 5.4.3)*

4.

FOR ALL DEVICES, ASSUME
CONSTANT TRANSMISSION

| | | Rate | Number | Bandwidth |
|---|---|---|---|---|
| 4a. | **Known Data Bandwidth Calculation**<br>*For devices with known rates enter the rate and number.* | | | |
| 4b. | **Unknown Data Bandwidth Calculation**<br>*For devices with unknown rates use 9.6 Kbps.* | | | |
| 4c. | **Total Bandwidth**<br>*Total number should match line 3m.* | | | |

TOTAL RAW DATA BANDWIDTH (Kbps) 4d.

Wireline Communications
Design Workshop

**Key Message:**

Identify the bandwidth that will be used by each device.

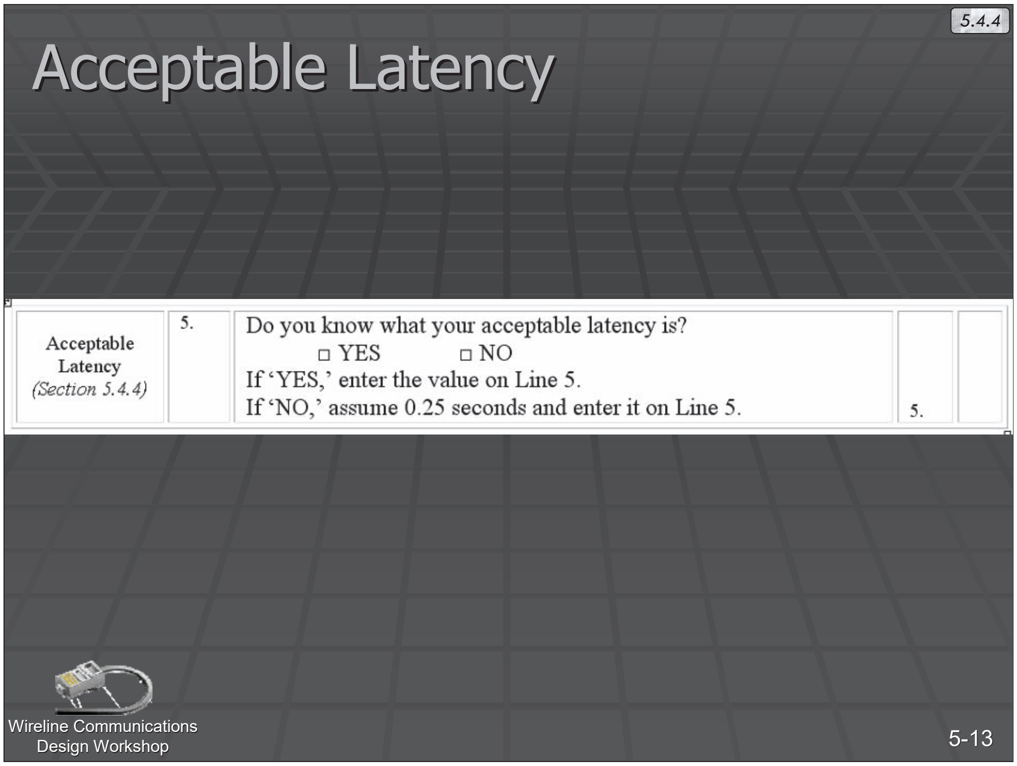
**Details:**

If average bandwidth numbers are not known, the procedure suggests the use of 9.6 Kbps for use. This is in accordance with accepted design principles.

**Key Questions:**

**Other Information:**

None.



5.4.4

## Acceptable Latency

| | | | | |
|---|---|---|---|---|
| Acceptable<br>Latency<br>*(Section 5.4.4)* | 5. | Do you know what your acceptable latency is?<br>☐ YES ☐ NO<br>If 'YES,' enter the value on Line 5.<br>If 'NO,' assume 0.25 seconds and enter it on Line 5. | 5. | |

Wireline Communications
Design Workshop

**Key Message:**

Latency is a fairly important consideration in the design or evaluation of communication systems.

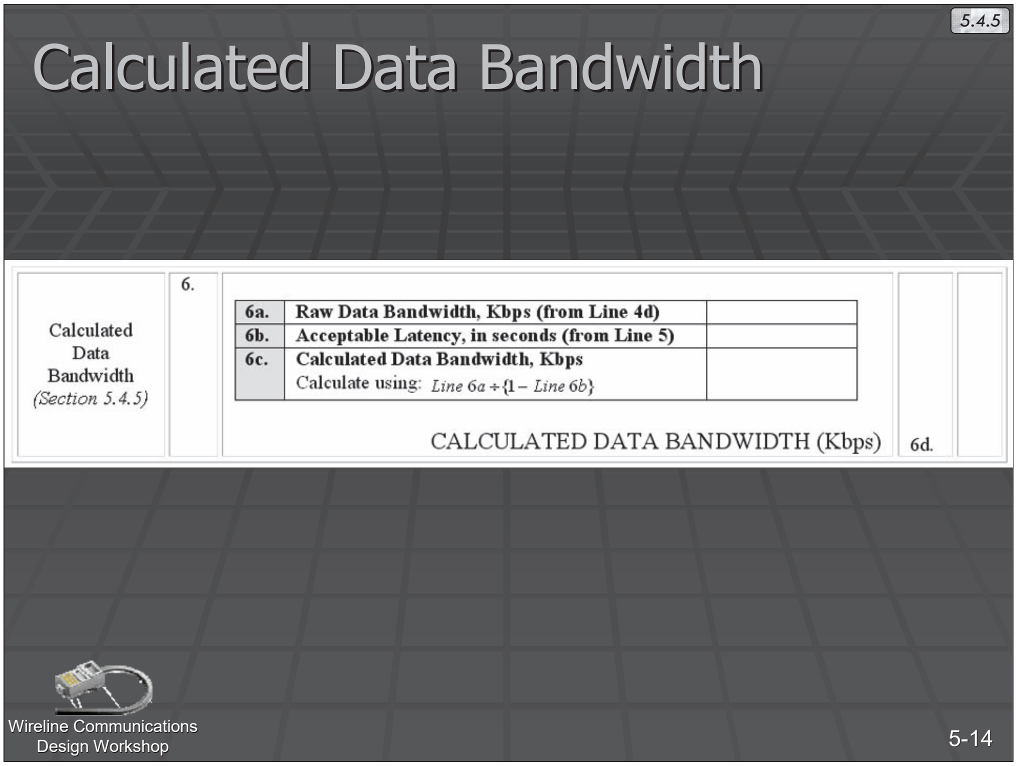
**Details:**

The procedure suggests that if a value is not known, a value of 250 milliseconds should be assumed. This is a reasonable expectation based upon standard practices and design procedures.

**Key Questions:**

**Other Information:**

None.



5.4.5

## Calculated Data Bandwidth

| | | |
|---|---|---|
| **6a.** | **Raw Data Bandwidth, Kbps (from Line 4d)** | |
| **6b.** | **Acceptable Latency, in seconds (from Line 5)** | |
| **6c.** | **Calculated Data Bandwidth, Kbps**<br>Calculate using: $Line\ 6a \div \{1 - Line\ 6b\}$ | |

| | | | | |
|---|---|---|---|---|
| Calculated Data Bandwidth *(Section 5.4.5)* | 6. | CALCULATED DATA BANDWIDTH (Kbps) | 6d. | |

Wireline Communications Design Workshop

**Key Message:**

Calculate the data bandwidth.

**Details:**

Delays through the communications equipment and system will always occur.

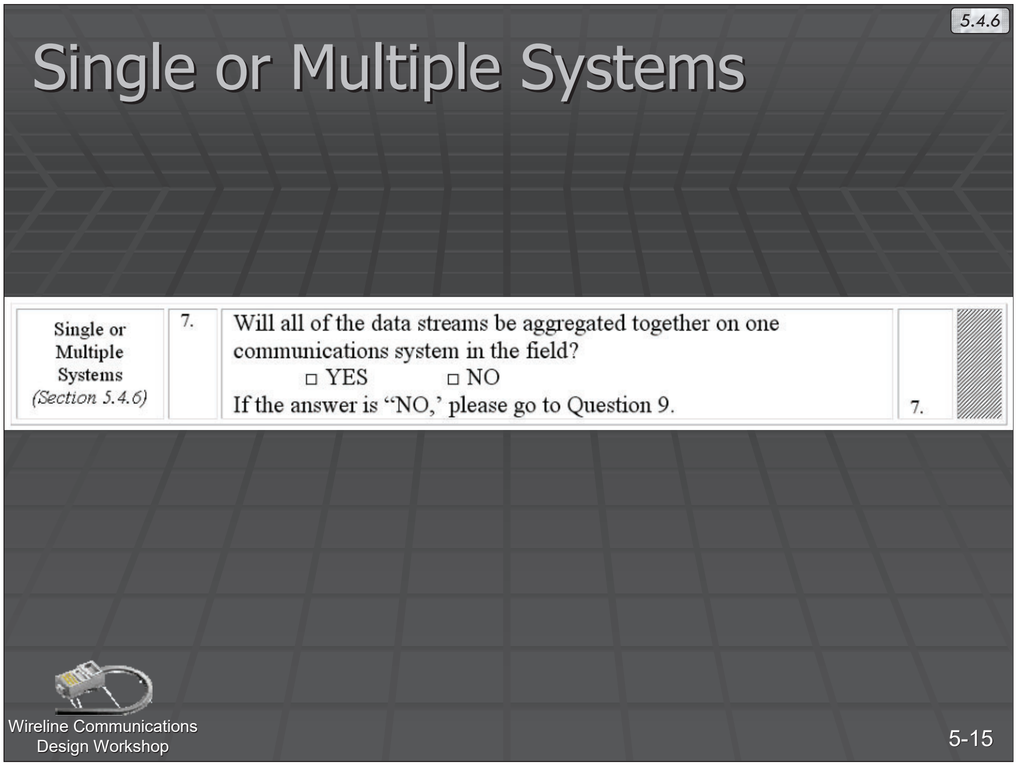
Delays will be more problematic at lower bandwidths.

The use of latency to inflate the bandwidth to a higher number essentially acts like a factor of safety, ensuring that the design situation is not exceeded and that overall system delays have a negligible impact on the operations of the communications system.

**Key Questions:**

**Other Information:**

None.



5.4.6

## Single or Multiple Systems

| | | | | |
|---|---|---|---|---|
| Single or Multiple Systems<br>*(Section 5.4.6)* | 7. | Will all of the data streams be aggregated together on one communications system in the field?<br>☐ YES ☐ NO<br>If the answer is "NO,' please go to Question 9. | 7. | ▨ |

Wireline Communications Design Workshop

5-15

**Key Message:**

The decision of single or multiple systems will dramatically change the design.

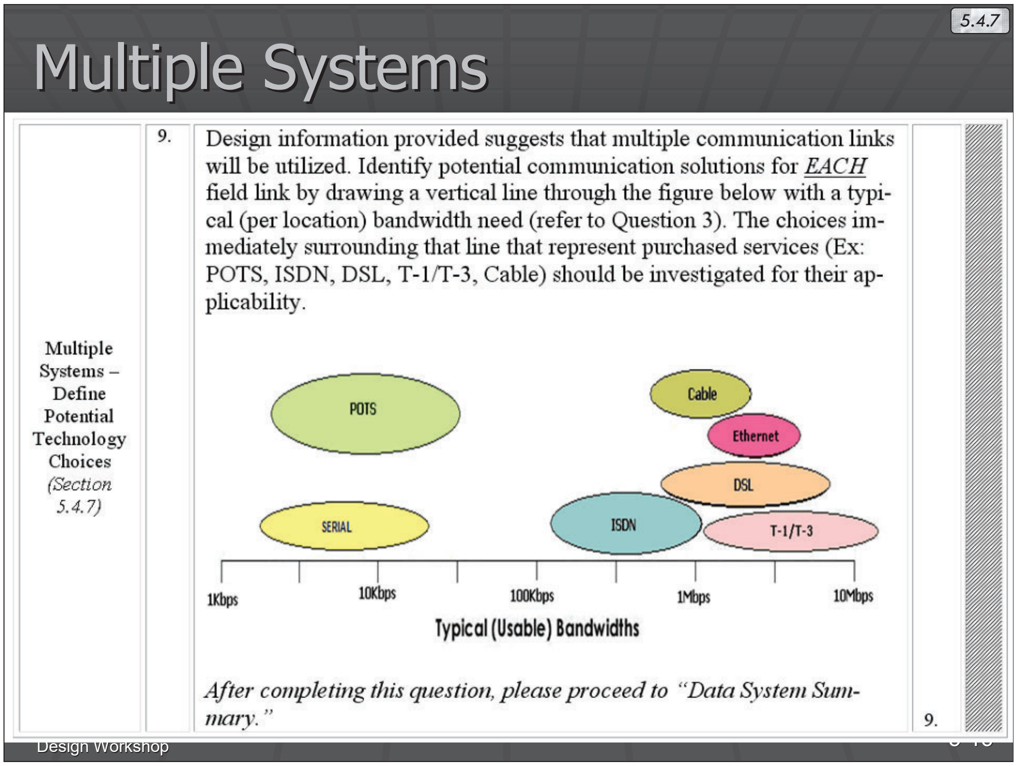
**Details:**

Rather than designing for a single comprehensive solution, an answer of 'NO' indicates you are designing for more of a stand-alone solution for each individual device or cluster of devices. This reduces the aggregate bandwidth necessary and orients the possible solutions towards multiple communication systems with smaller bandwidths.

**Key Questions:**

**Other Information:**

None.



5.4.7

## Multiple Systems

Multiple Systems – Define Potential Technology Choices *(Section 5.4.7)*

9. Design information provided suggests that multiple communication links will be utilized. Identify potential communication solutions for *EACH* field link by drawing a vertical line through the figure below with a typical (per location) bandwidth need (refer to Question 3). The choices immediately surrounding that line that represent purchased services (Ex: POTS, ISDN, DSL, T-1/T-3, Cable) should be investigated for their applicability.

*After completing this question, please proceed to "Data System Summary."*

9.

Design Workshop

**Key Message:**

Determine the technologies available for each device or group of devices on the same communications link.

**Details:**

Draw a vertical line through the graphic for the bandwidth needed at each location.

If one location has a single device, the necessary bandwidth would be the rate for that device.

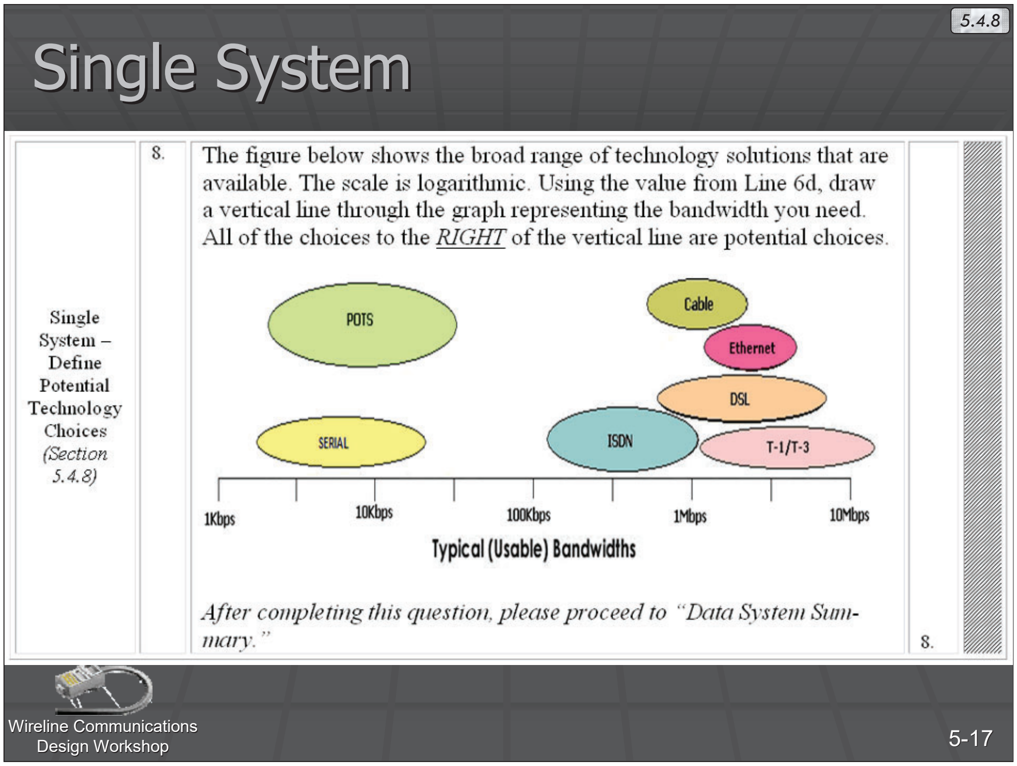
If there will be multiple devices tied to a single communications link at one location, enter the figure in question 9 with the aggregate bandwidth of that location.

If you have to recalculate bandwidths at a particular location, do not forget to include the adjustment for latency to provide a factor of safety for that communications link.

**Key Questions:**

**Other Information:**

None.



5.4.8

## Single System

| | | | |
|---|---|---|---|
| Single System – Define Potential Technology Choices *(Section 5.4.8)* | 8. | The figure below shows the broad range of technology solutions that are available. The scale is logarithmic. Using the value from Line 6d, draw a vertical line through the graph representing the bandwidth you need. All of the choices to the *RIGHT* of the vertical line are potential choices.<br>*After completing this question, please proceed to "Data System Summary."* | 8. |

Wireline Communications Design Workshop

5-17

**Key Message:**

Determine the technologies available for the system.

**Details:**

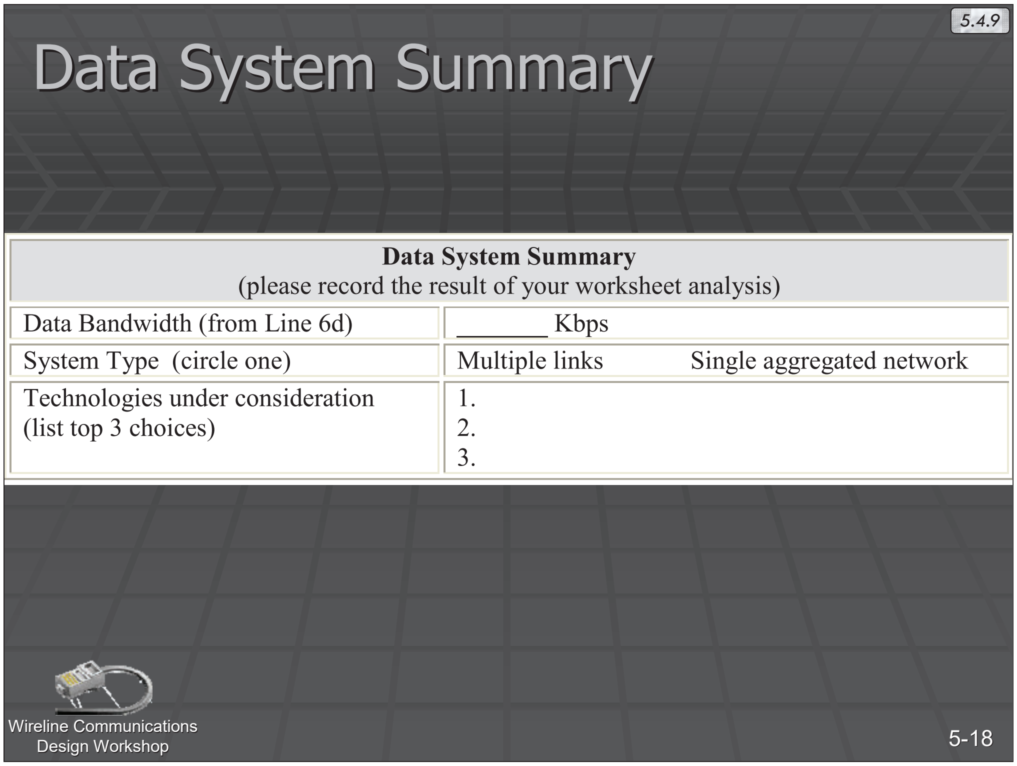
Draw a vertical line through the graphic for the calculated bandwidth from Question 6d.

Anything to the right of that vertical line will be a potential technology choice. Since the vertical line through the diagram represents the *minimum* bandwidth necessary for the data, solutions to the right represent technologies that can supply the necessary bandwidth or more.

**Key Questions:**

**Other Information:**

None.



5.4.9

## Data System Summary

**Data System Summary**
(please record the result of your worksheet analysis)

| | |
|---|---|
| Data Bandwidth (from Line 6d) | _______ Kbps |
| System Type (circle one) | Multiple links<br>Single aggregated network |
| Technologies under consideration (list top 3 choices) | 1.<br>2.<br>3. |

**Key Message:**

None.

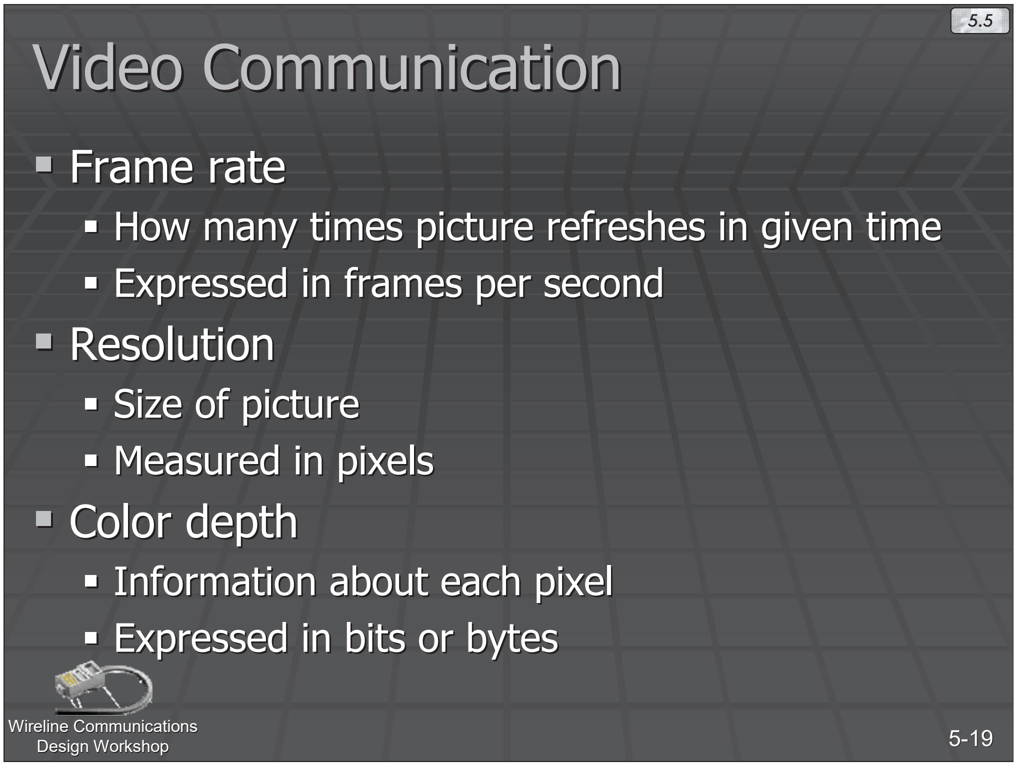
**Details:**

This is just a summary table for a data-only system.

**Key Questions:**

**Other Information:**

None.



5.5

## Video Communication

- Frame rate
  - How many times picture refreshes in given time
  - Expressed in frames per second
- Resolution
  - Size of picture
  - Measured in pixels
- Color depth
  - Information about each pixel
  - Expressed in bits or bytes

Wireline Communications
Design Workshop

**Key Message:**

Video has 3 main factors that need to be understood.

**Details:**

Frame rate is how many times the picture refreshes in a certain amount of time. The typical measure is frames per second (fps). The standard is 30 fps, relating back to the beginning of the television era. Many video solutions in use today have frame rates as high as 60 fps. The higher the frame rate, the more bandwidth is required.

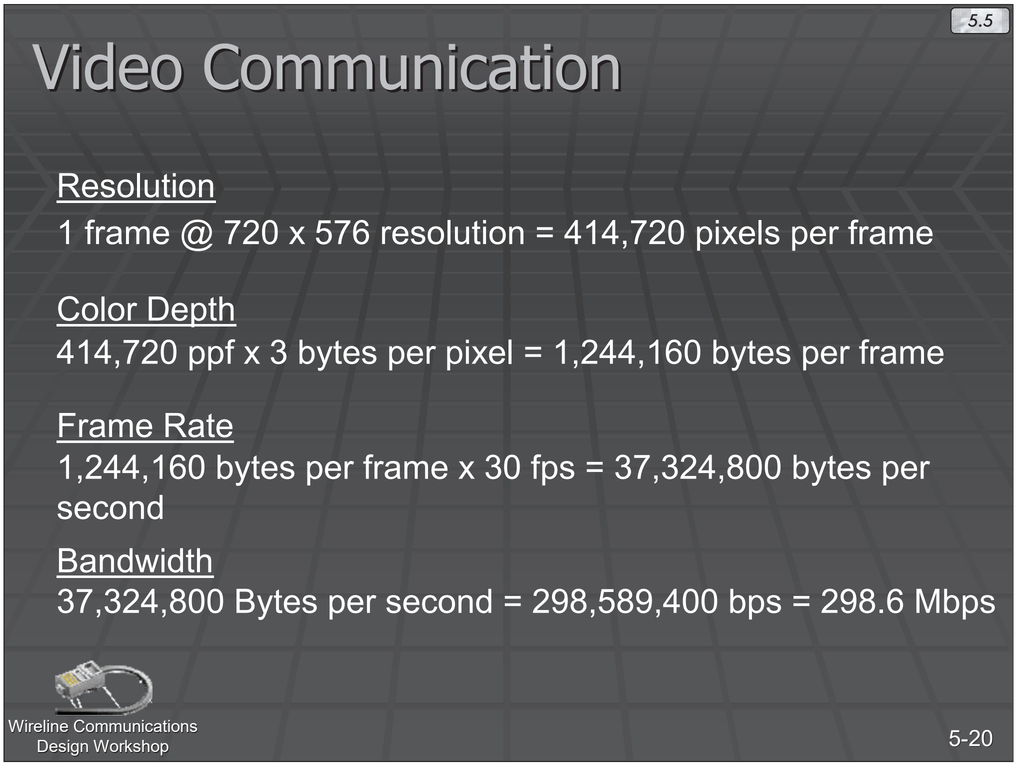
Resolution is the size of the picture, typically measured in pixels. A pixel is an abbreviation for the term Picture Element. One pixel is one point or individual dot of light. Resolution is specified by telling the number of pixels horizontally and then the number of pixels vertically.

Color depth refers to how much information is necessary to convey about each individual pixel. Computers often use 24-bit color. Since we know that 8 bits equals 1 byte, it takes 3 bytes to convey information about each pixel.

**Key Questions:**

**Other Information:**

None.



## Video Communication

Resolution

1 frame @ 720 x 576 resolution = 414,720 pixels per frame

Color Depth

414,720 ppf x 3 bytes per pixel = 1,244,160 bytes per frame

Frame Rate

1,244,160 bytes per frame x 30 fps = 37,324,800 bytes per second

Bandwidth

37,324,800 Bytes per second = 298,589,400 bps = 298.6 Mbps

**Key Message:**

The total bandwidth of a video stream can then be calculated as the product of the resolution, frame rate, and color depth.

**Details:**

Go over the module objectives.

**Key Questions:**

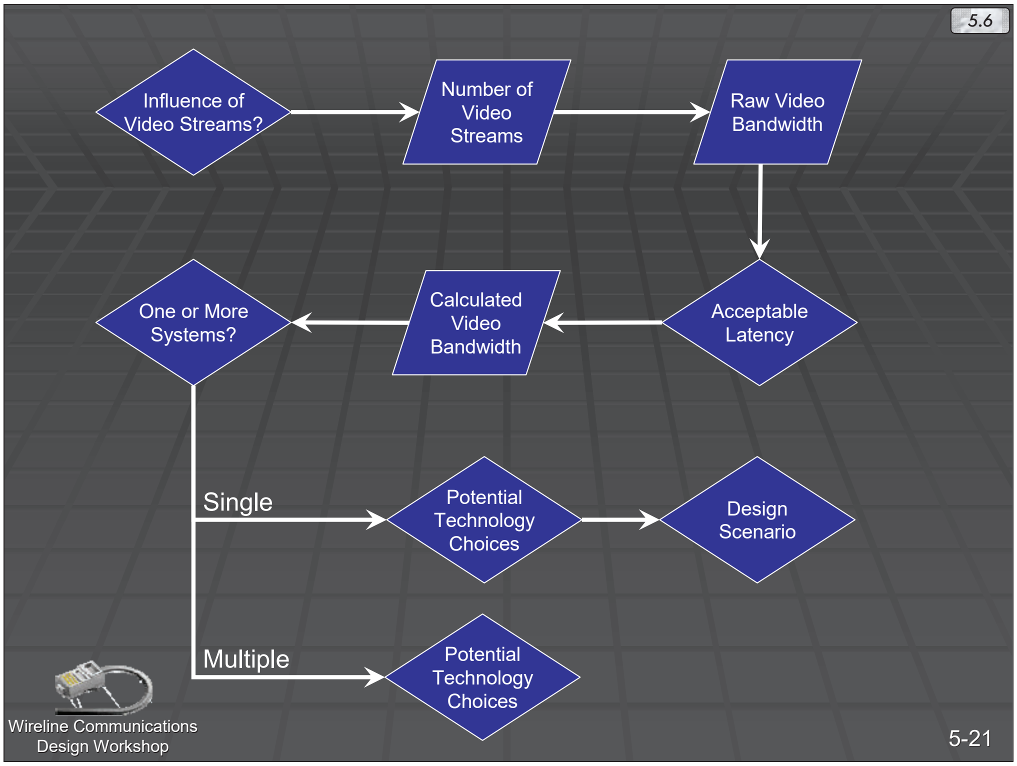
Ask the participants what options are available to reduce this number?

Possible answers: lower resolution, lower frame rate, *compress video.*

Discuss pros and cons of each.

**Other Information:**

None.


5.6

Influence of Video Streams?

Number of Video Streams

Raw Video Bandwidth

Acceptable Latency

Calculated Video Bandwidth

One or More Systems?

Single

Potential Technology Choices

Design Scenario

Multiple

Potential Technology Choices

Wireline Communications Design Workshop

5-21

**Key Message:**

There are 8 steps to designing a video communication system.

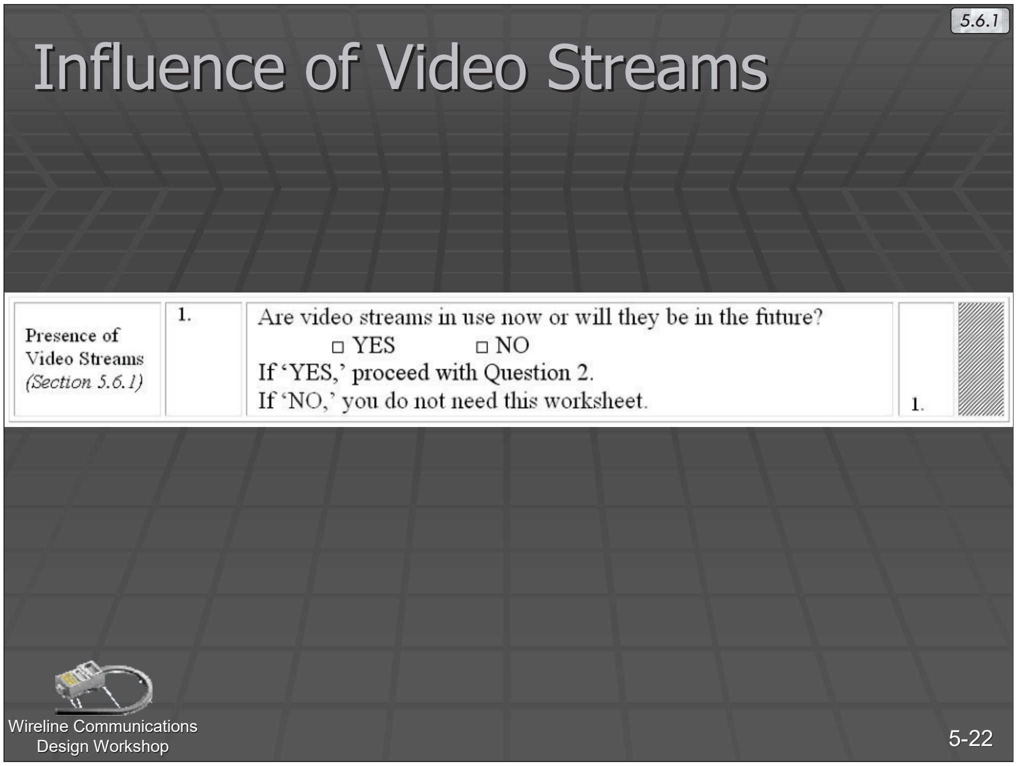
**Details:**

This flowchart is the process for video communication systems.

**Key Questions:**

**Other Information:**

None.



5.6.1

## Influence of Video Streams

| | | | | |
|---|---|---|---|---|
| Presence of Video Streams *(Section 5.6.1)* | 1. | Are video streams in use now or will they be in the future?<br>☐ YES ☐ NO<br>If 'YES,' proceed with Question 2.<br>If 'NO,' you do not need this worksheet. | 1. | ▨ |

Wireline Communications
Design Workshop

**Key Message:**

The presence of video has a significant impact on the design.

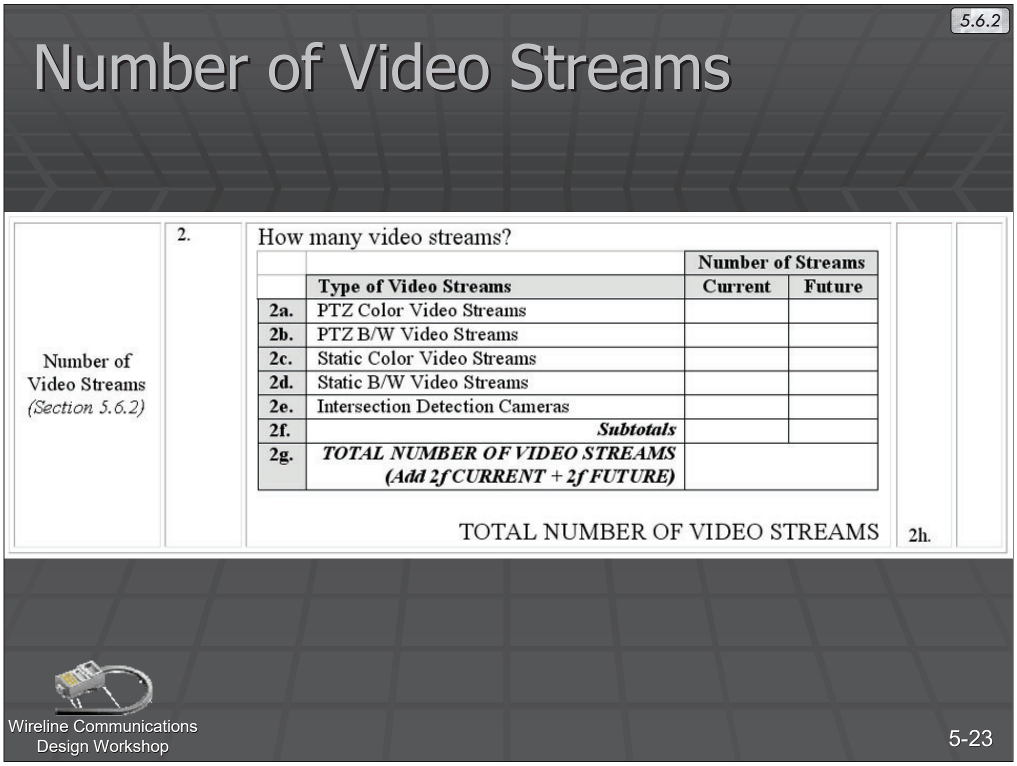
**Details:**

If video is not going to be used, this is not the correct worksheet.

**Key Questions:**

**Other Information:**

None.



5.6.2

## Number of Video Streams

Number of Video Streams *(Section 5.6.2)*

2\. How many video streams?

| | | Number of Streams | |
|---|---|---|---|
| | **Type of Video Streams** | **Current** | **Future** |
| **2a.** | PTZ Color Video Streams | | |
| **2b.** | PTZ B/W Video Streams | | |
| **2c.** | Static Color Video Streams | | |
| **2d.** | Static B/W Video Streams | | |
| **2e.** | Intersection Detection Cameras | | |
| **2f.** | ***Subtotals*** | | |
| **2g.** | ***TOTAL NUMBER OF VIDEO STREAMS (Add 2f CURRENT + 2f FUTURE)*** | | |

TOTAL NUMBER OF VIDEO STREAMS 2h.

Wireline Communications Design Workshop

**Key Message:**

The number of devices (current and future) needs to be identified.

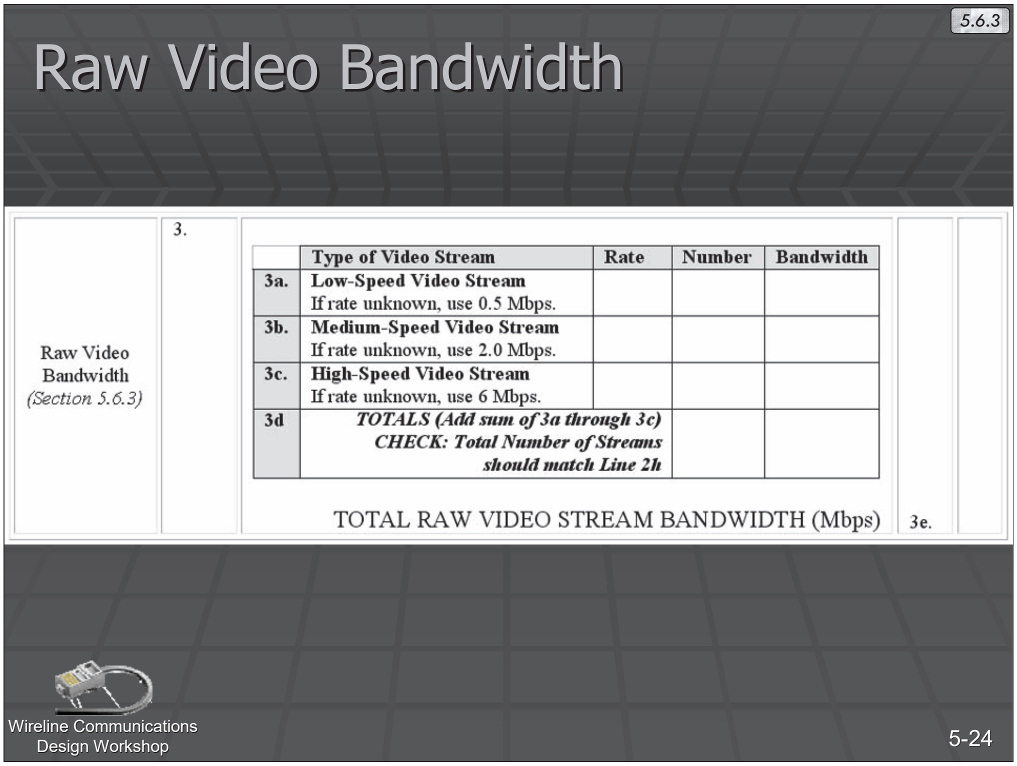
**Details:**

The breakdown by type of device is provided simply to help the designer identify different video sources. Other than the bandwidth in use, there is no inherent difference in the data stream from one type of device to another.

**Key Questions:**

**Other Information:**

None.



5.6.3

## Raw Video Bandwidth

Raw Video Bandwidth *(Section 5.6.3)*

3.

| | Type of Video Stream | Rate | Number | Bandwidth |
|---|---|---|---|---|
| **3a.** | **Low-Speed Video Stream**<br>If rate unknown, use 0.5 Mbps. | | | |
| **3b.** | **Medium-Speed Video Stream**<br>If rate unknown, use 2.0 Mbps. | | | |
| **3c.** | **High-Speed Video Stream**<br>If rate unknown, use 6 Mbps. | | | |
| **3d** | ***TOTALS (Add sum of 3a through 3c)***<br>***CHECK: Total Number of Streams should match Line 2h*** | | | |

TOTAL RAW VIDEO STREAM BANDWIDTH (Mbps) 3e.

Wireline Communications Design Workshop

5-24

**Key Message:**

Identify the bandwidth that will be used by each device.

**Details:**

If average bandwidth numbers are not known, the procedure suggests some for use.

A low-bandwidth video stream is suggested for 0.5 Mbps.

A medium stream at 2.0 Mbps.

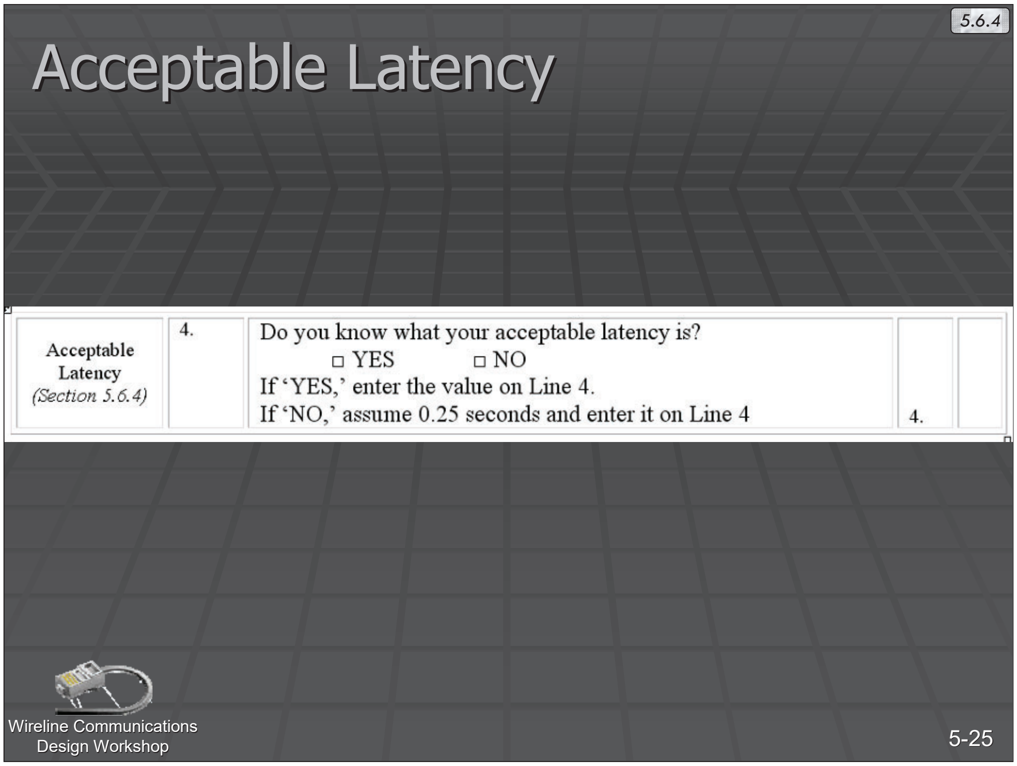
A high-bandwidth stream at 6.0 Mbps.

The higher numbers reflect less compression and therefore a higher quality picture at the receiving end.

**Key Questions:**

**Other Information:**

None.



5.6.4

## Acceptable Latency

| | | | | |
|---|---|---|---|---|
| Acceptable Latency<br>*(Section 5.6.4)* | 4. | Do you know what your acceptable latency is?<br>☐ YES ☐ NO<br>If 'YES,' enter the value on Line 4.<br>If 'NO,' assume 0.25 seconds and enter it on Line 4 | 4. | |

Wireline Communications Design Workshop

**Key Message:**

Latency is a fairly important consideration in the design or evaluation of communication systems.

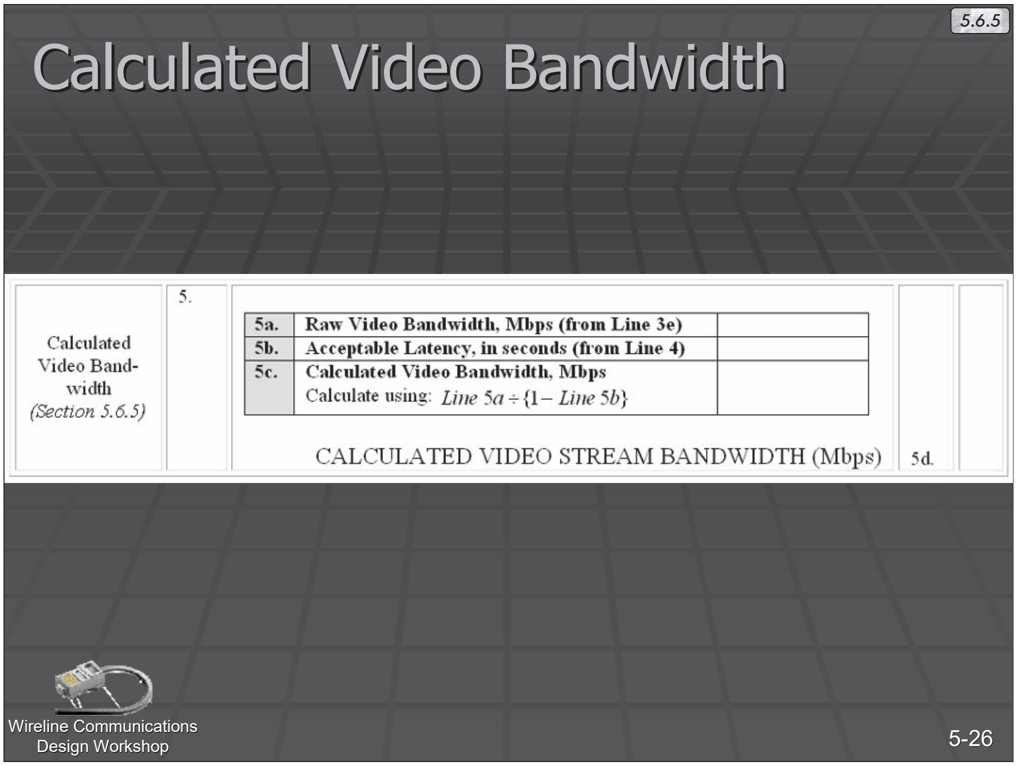
**Details:**

The procedure suggests that if a value is not known, a value of 250 milliseconds should be assumed. This is a reasonable expectation based upon standard practices and design procedures.

**Key Questions:**

**Other Information:**

None.



5.6.5

# Calculated Video Bandwidth

Calculated Video Bandwidth (Section 5.6.5)

5.

| | | |
|---|---|---|
| 5a. | **Raw Video Bandwidth, Mbps (from Line 3e)** | |
| 5b. | **Acceptable Latency, in seconds (from Line 4)** | |
| 5c. | **Calculated Video Bandwidth, Mbps**<br>Calculate using: $\mathit{Line}\ 5a \div \{1 - \mathit{Line}\ 5b\}$ | |

CALCULATED VIDEO STREAM BANDWIDTH (Mbps) 5d.

Wireline Communications Design Workshop

**Key Message:**

Calculate the video bandwidth.

**Details:**

Delays through the communications equipment and system will always occur.

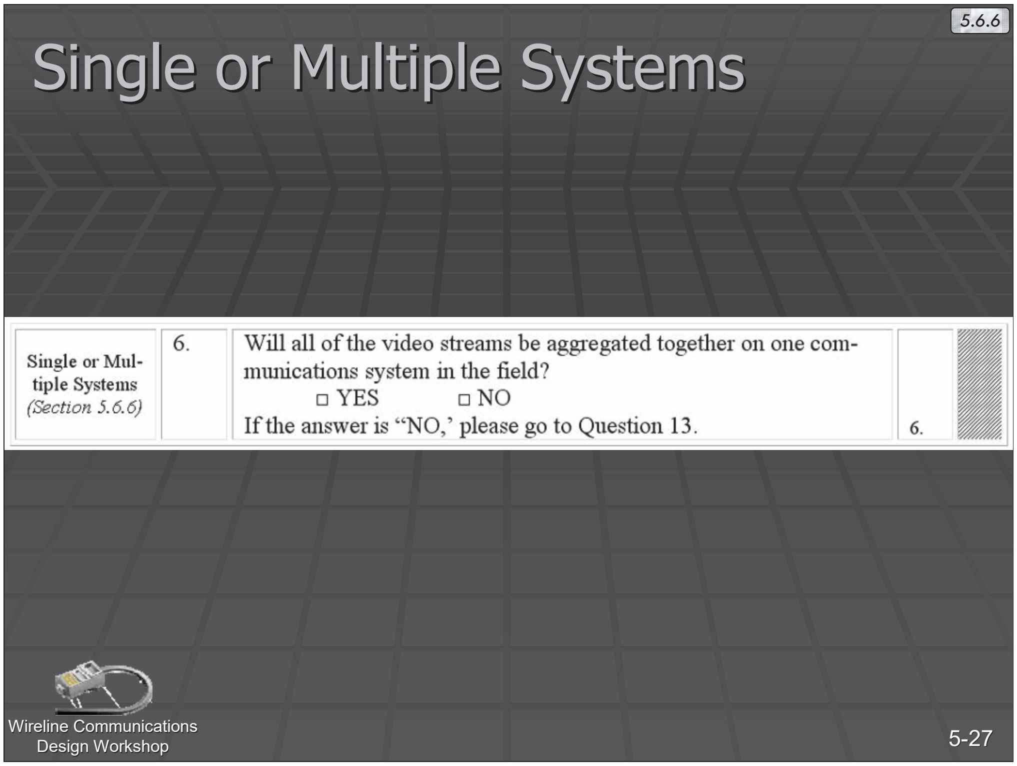
Delays will be more problematic at lower bandwidths.

The use of latency to inflate the bandwidth to a higher number essentially acts like a factor of safety, ensuring that the design situation is not exceeded and that overall system delays have a negligible impact on the operations of the communications system.

**Key Questions:**

**Other Information:**

None.



5.6.6

## Single or Multiple Systems

| | | | | |
|---|---|---|---|---|
| Single or Multiple Systems<br>*(Section 5.6.6)* | 6. | Will all of the video streams be aggregated together on one communications system in the field?<br>☐ YES ☐ NO<br>If the answer is “NO,’ please go to Question 13. | 6. | ▨ |

Wireline Communications
Design Workshop

**Key Message:**

The decision of single or multiple systems will dramatically change the design.

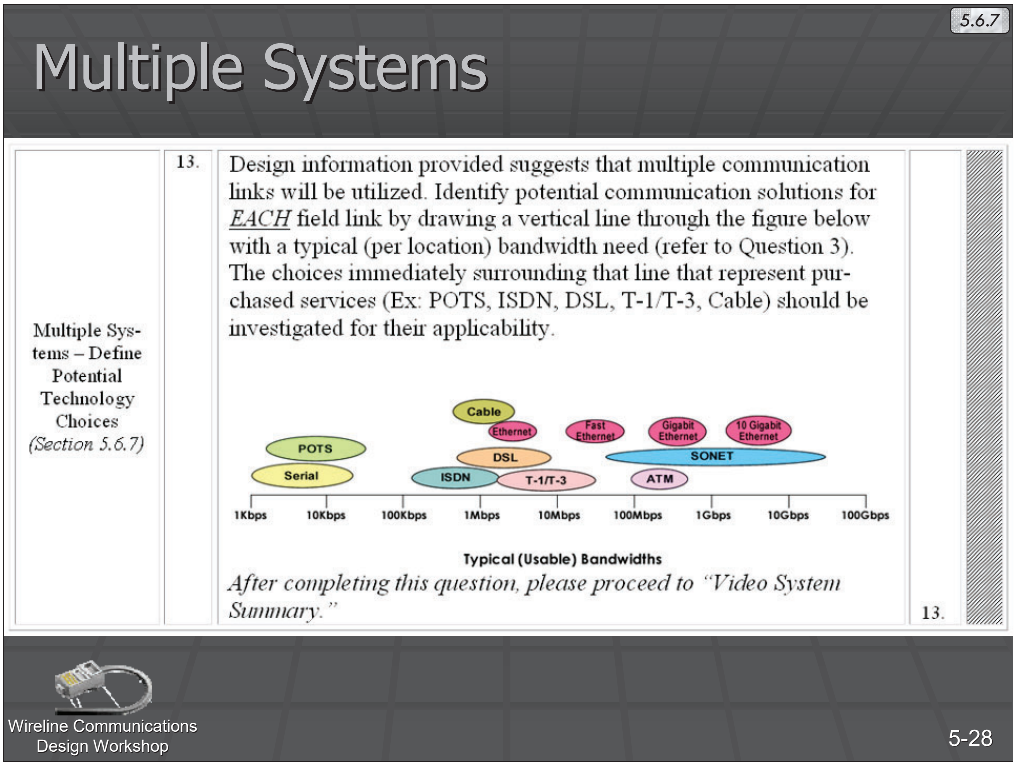
**Details:**

Rather than designing for a single comprehensive solution, you are designing for more of a stand-alone solution for each individual camera or cluster of video streams. This reduces the aggregate bandwidth necessary and orients the possible solutions towards multiple communication systems with smaller bandwidths.

**Key Questions:**

**Other Information:**

None.



5.6.7

## Multiple Systems

Multiple Systems – Define Potential Technology Choices *(Section 5.6.7)*

13. Design information provided suggests that multiple communication links will be utilized. Identify potential communication solutions for *EACH* field link by drawing a vertical line through the figure below with a typical (per location) bandwidth need (refer to Question 3). The choices immediately surrounding that line that represent purchased services (Ex: POTS, ISDN, DSL, T-1/T-3, Cable) should be investigated for their applicability.

Typical (Usable) Bandwidths

*After completing this question, please proceed to "Video System Summary."*

13.

Wireline Communications Design Workshop

5-28

**Key Message:**

Determine the technologies available for each device or group of devices on the same communications link.

**Details:**

Draw a vertical line through the graphic for the bandwidth needed at each location.

If one location has a single device, the necessary bandwidth would be the rate for that device.

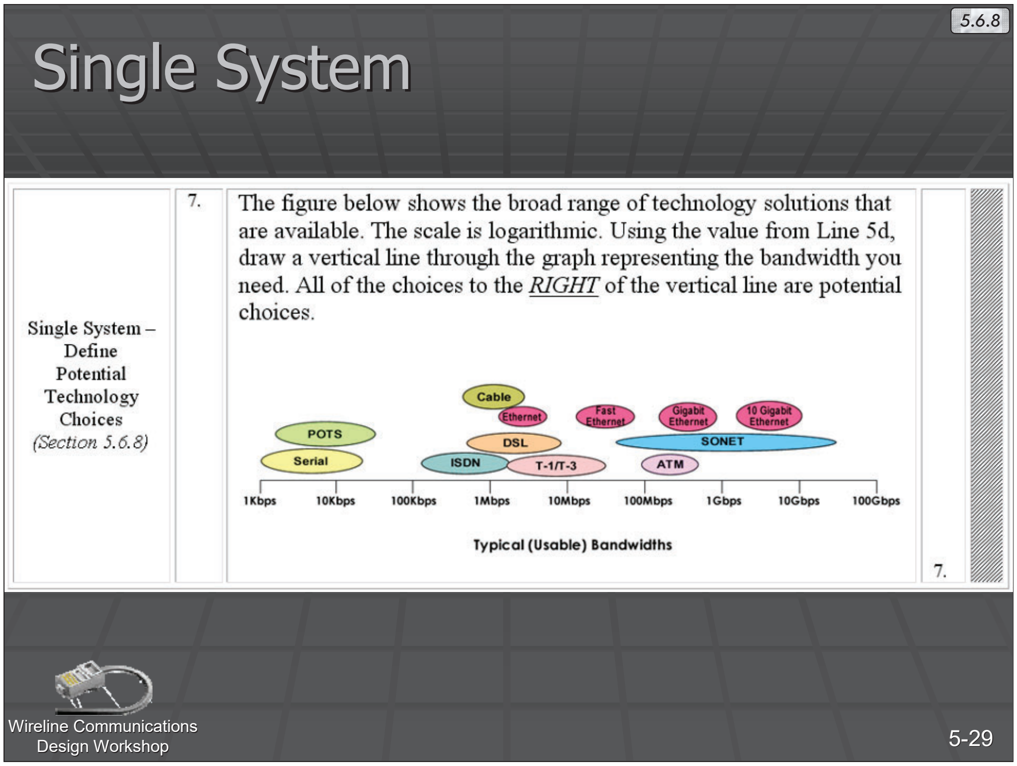
If there will be multiple devices tied to a single communications link at one location, enter the figure in question 9 with the aggregate bandwidth of that location.

If you have to recalculate bandwidths at a particular location, do not forget to include the adjustment for latency to provide a factor of safety for that communications link.

**Key Questions:**

**Other Information:**

None.



5.6.8

## Single System

| | | | |
|---|---|---|---|
| Single System – Define Potential Technology Choices *(Section 5.6.8)* | 7. | The figure below shows the broad range of technology solutions that are available. The scale is logarithmic. Using the value from Line 5d, draw a vertical line through the graph representing the bandwidth you need. All of the choices to the *RIGHT* of the vertical line are potential choices. | 7. |

Wireline Communications Design Workshop

5-29

**Key Message:**

Determine the technologies available for the system.

**Details:**

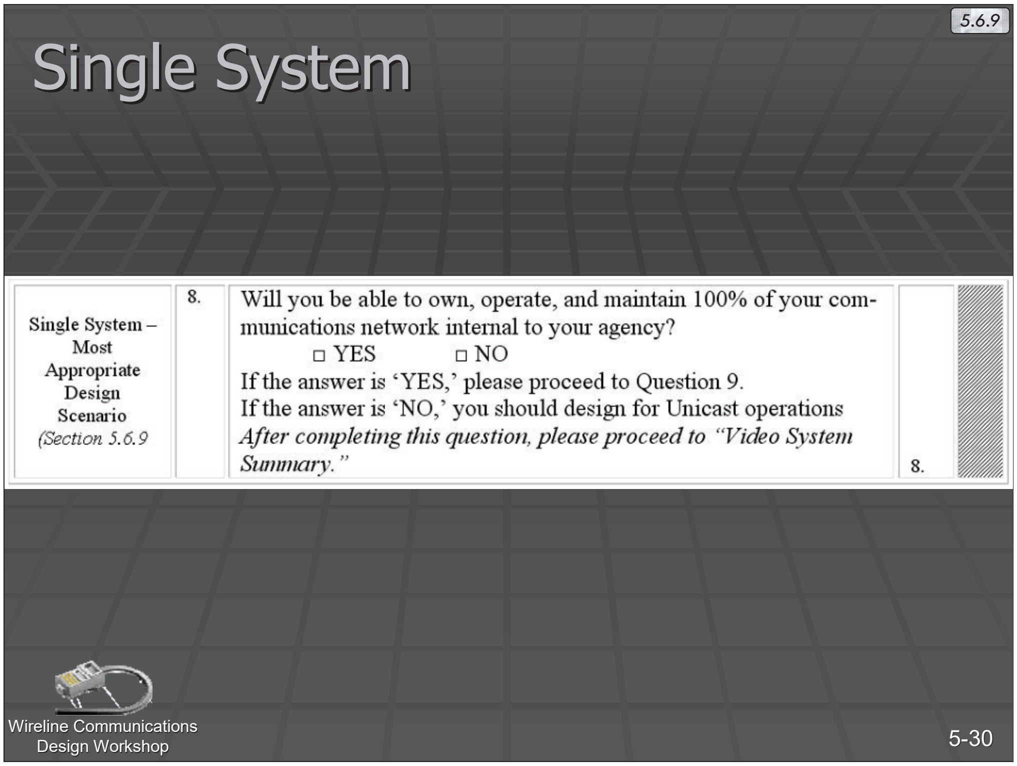
Draw a vertical line through the graphic for the calculated bandwidth from Question 5d.

Anything to the right of that vertical line will be a potential technology choice. Since the vertical line through the diagram represents the *minimum* bandwidth necessary for the video streams, solutions to the right represent technologies that can supply the necessary bandwidth or more.

**Key Questions:**

**Other Information:**

None.



5.6.9

# Single System

| | | | |
|---|---|---|---|
| Single System – Most Appropriate Design Scenario (Section 5.6.9 | 8. | Will you be able to own, operate, and maintain 100% of your communications network internal to your agency?<br>☐ YES ☐ NO<br>If the answer is ‘YES,’ please proceed to Question 9.<br>If the answer is ‘NO,’ you should design for Unicast operations<br>*After completing this question, please proceed to “Video System Summary.”* | 8. |

Wireline Communications Design Workshop

**Key Message:**

If an agency does not own and operate 100% of the system, including the media and all of the equipment, multicast is not the preferred design scenario.

**Details:**

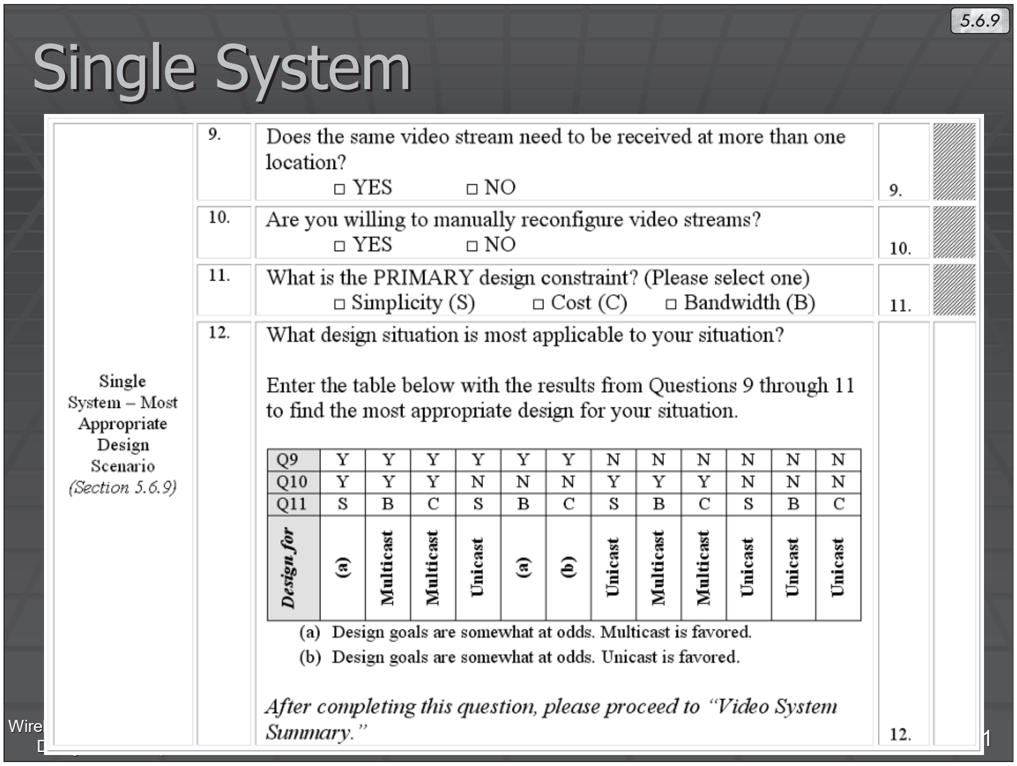
If the answer to Question 8 is ‘NO’ - that an agency does not own, operate, and maintain 100% of the communications network - the appropriate design scenario is Unicast operations.

If the answer to Question 8 is ‘YES’ - that an agency does own, operate, and maintain 100% of the communications network - the appropriate design scenario is still open for consideration and the designer should proceed to Questions 9-12.

**Key Questions:**

**Other Information:**

None.



5.6.9

## Single System

Single System – Most Appropriate Design Scenario *(Section 5.6.9)*

9. Does the same video stream need to be received at more than one location?
☐ YES ☐ NO
9.

10. Are you willing to manually reconfigure video streams?
☐ YES ☐ NO
10.

11. What is the PRIMARY design constraint? (Please select one)
☐ Simplicity (S) ☐ Cost (C) ☐ Bandwidth (B)
11.

12. What design situation is most applicable to your situation?

Enter the table below with the results from Questions 9 through 11 to find the most appropriate design for your situation.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Q9 | Y | Y | Y | Y | Y | Y | N | N | N | N | N | N |
| Q10 | Y | Y | Y | N | N | N | Y | Y | Y | N | N | N |
| Q11 | S | B | C | S | B | C | S | B | C | S | B | C |
| ***Design for*** | **(a)** | **Multicast** | **Multicast** | **Unicast** | **(a)** | **(b)** | **Unicast** | **Multicast** | **Multicast** | **Unicast** | **Unicast** | **Unicast** |

(a) Design goals are somewhat at odds. Multicast is favored.
(b) Design goals are somewhat at odds. Unicast is favored.

*After completing this question, please proceed to "Video System Summary."*

12.

**Key Message:**

Determine whether unicast or multicast is appropriate.

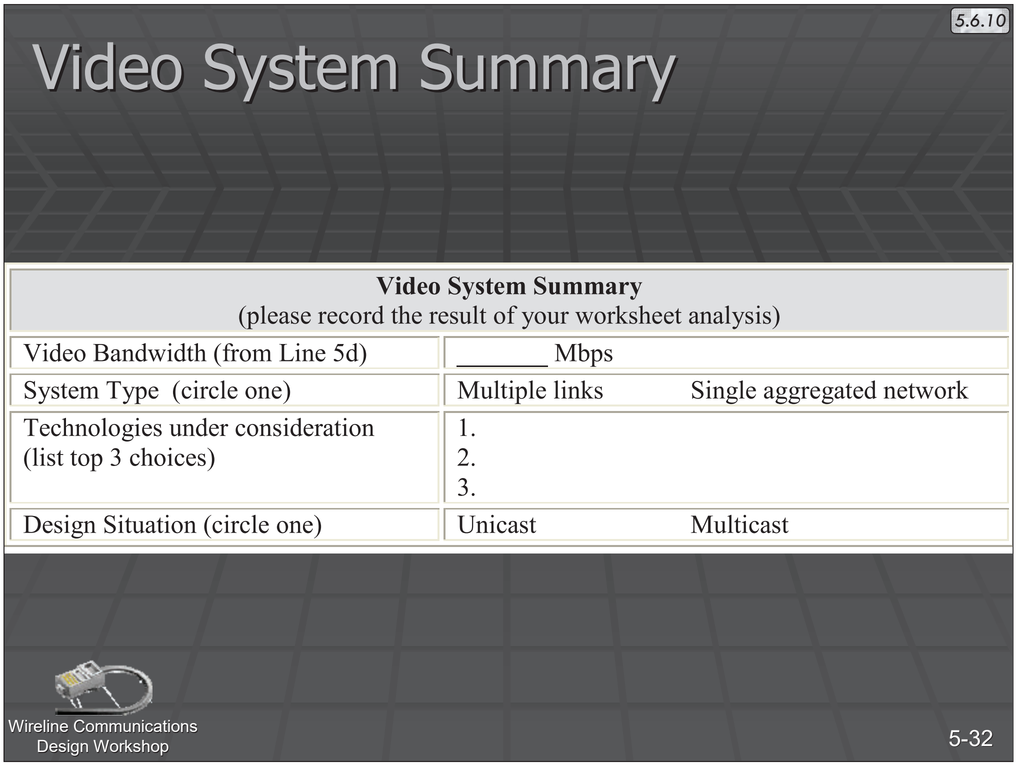
**Details:**

Question 10 seeks to determine if your agency or operators are equipped to change parameters on the various types of hardware found in the system. Many deployments typically have more cameras in the field than they have the capability to view at any given time. While many system software solutions can easily change video streams operating in a unicast scenario, the state-of-the-practice is not as advanced in the multicast scenario. Enterprise level solutions that change all of the parameters necessary for switching multicast streams are in their infancy. If employees are not familiar with changing equipment parameters and are not comfortable operating in that environment, multicast would not be the preferred design option.

**Key Questions:**

**Other Information:**

None.



5.6.10

# Video System Summary

**Video System Summary**
(please record the result of your worksheet analysis)

| | | |
|---|---|---|
| Video Bandwidth (from Line 5d) | _______ Mbps | |
| System Type (circle one) | Multiple links | Single aggregated network |
| Technologies under consideration (list top 3 choices) | 1.<br>2.<br>3. | |
| Design Situation (circle one) | Unicast | Multicast |

Wireline Communications
Design Workshop

**Key Message:**

None.

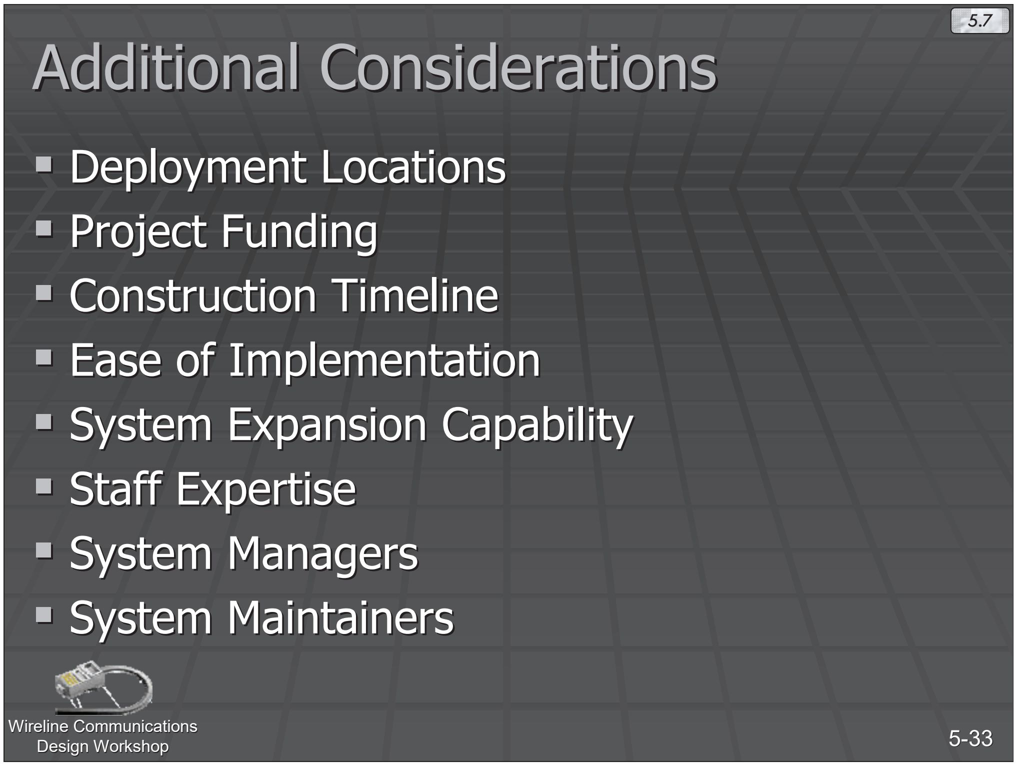
**Details:**

This is just a summary table for a video system.

**Key Questions:**

**Other Information:**

None.



## Additional Considerations

- Deployment Locations
- Project Funding
- Construction Timeline
- Ease of Implementation
- System Expansion Capability
- Staff Expertise
- System Managers
- System Maintainers

Wireline Communications
Design Workshop

**Key Message:**

While the methodology used for data and video communication solutions in this guidebook covers numerous technologies and implementations, they can not cover every design situation.

**Details:**

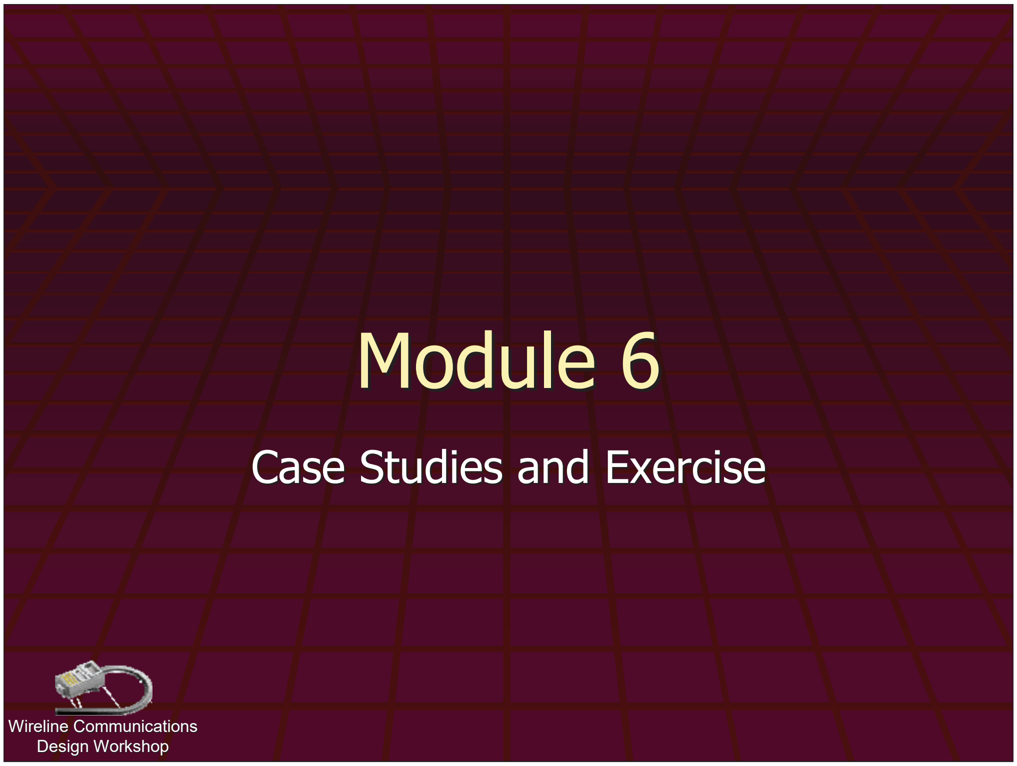
The prudent designer should take items such as those identified in Table 5-19 into consideration before a final design decision is made.

More details on each of these is provided in the guidebook.  Do not spend much time on this slide.

**Key Questions:**

**Other Information:**

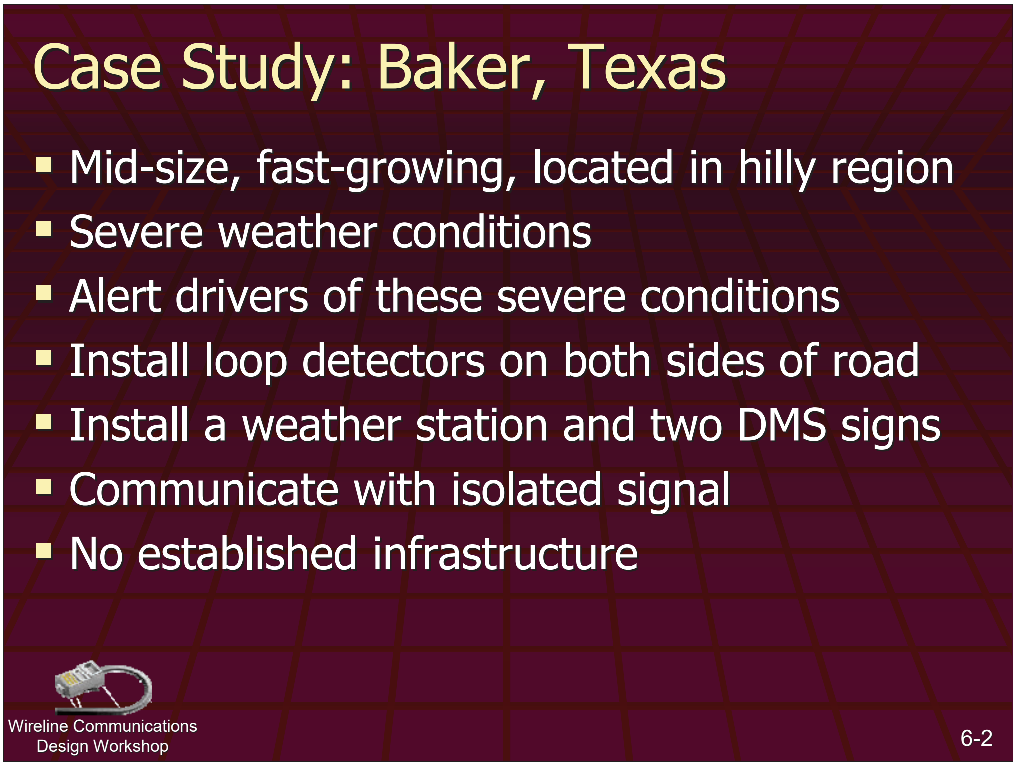
None.



# Module 6

## Case Studies and Exercise

Wireline Communications
Design Workshop



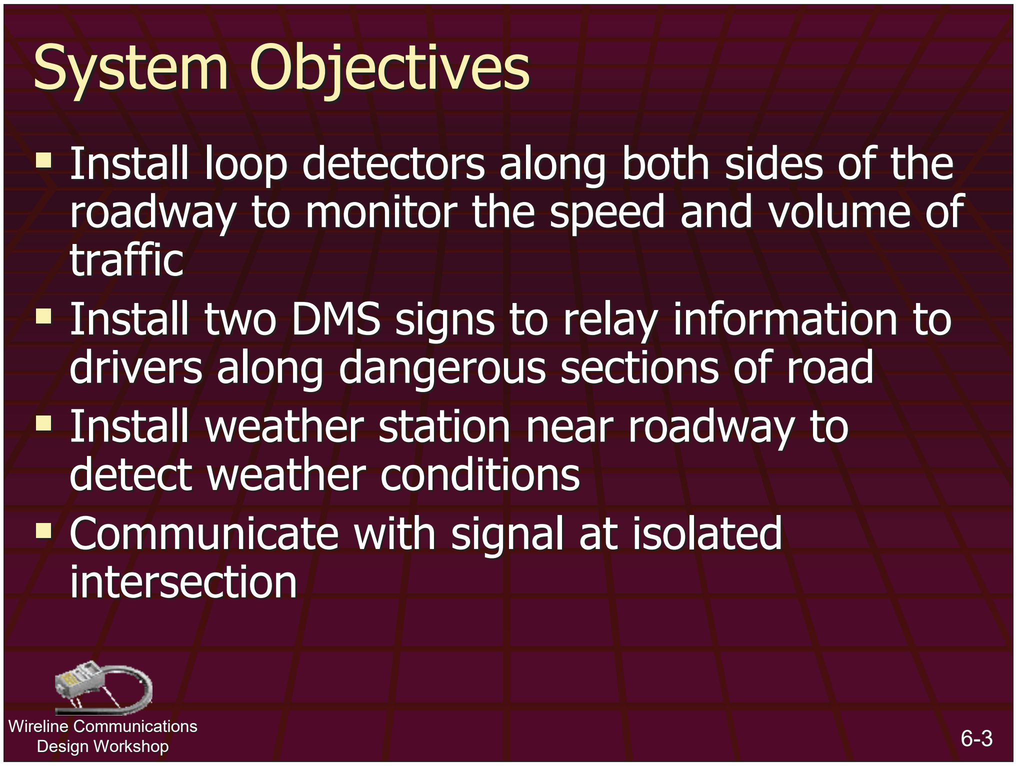
# Case Study: Baker, Texas

- Mid-size, fast-growing, located in hilly region
- Severe weather conditions
- Alert drivers of these severe conditions
- Install loop detectors on both sides of road
- Install a weather station and two DMS signs
- Communicate with isolated signal
- No established infrastructure

Wireline Communications
Design Workshop

Instructor notes are not included for the case studies and exercise.

Slides are self-explanatory.



## System Objectives

- Install loop detectors along both sides of the roadway to monitor the speed and volume of traffic
- Install two DMS signs to relay information to drivers along dangerous sections of road
- Install weather station near roadway to detect weather conditions
- Communicate with signal at isolated intersection

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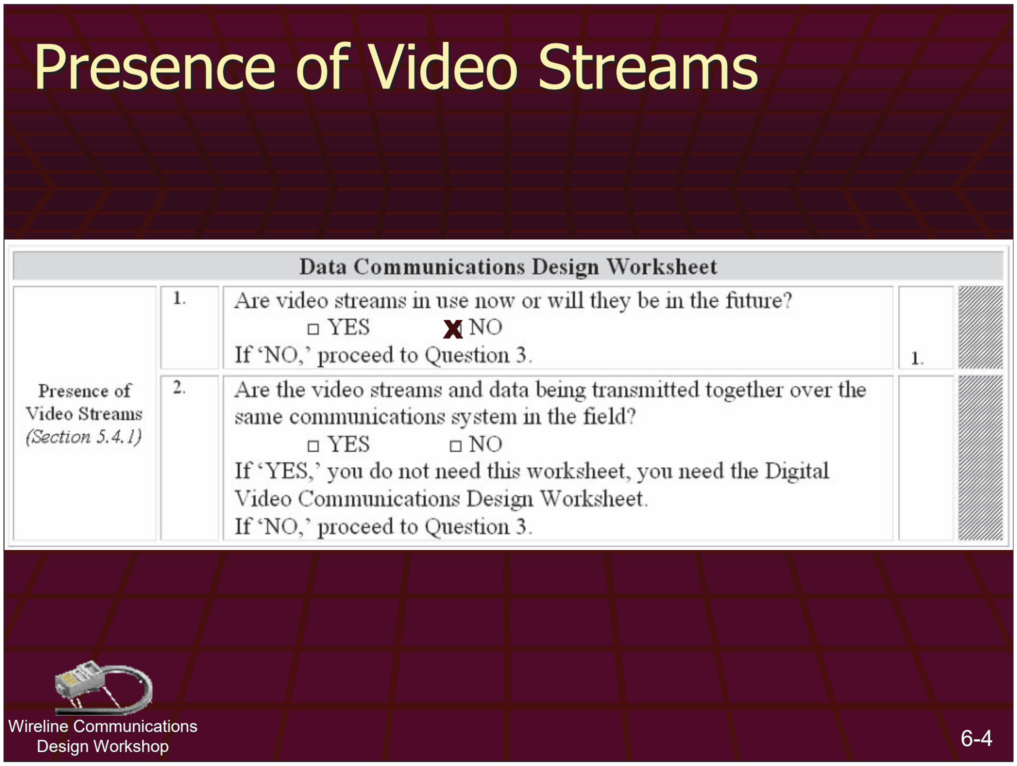
Design Workshop



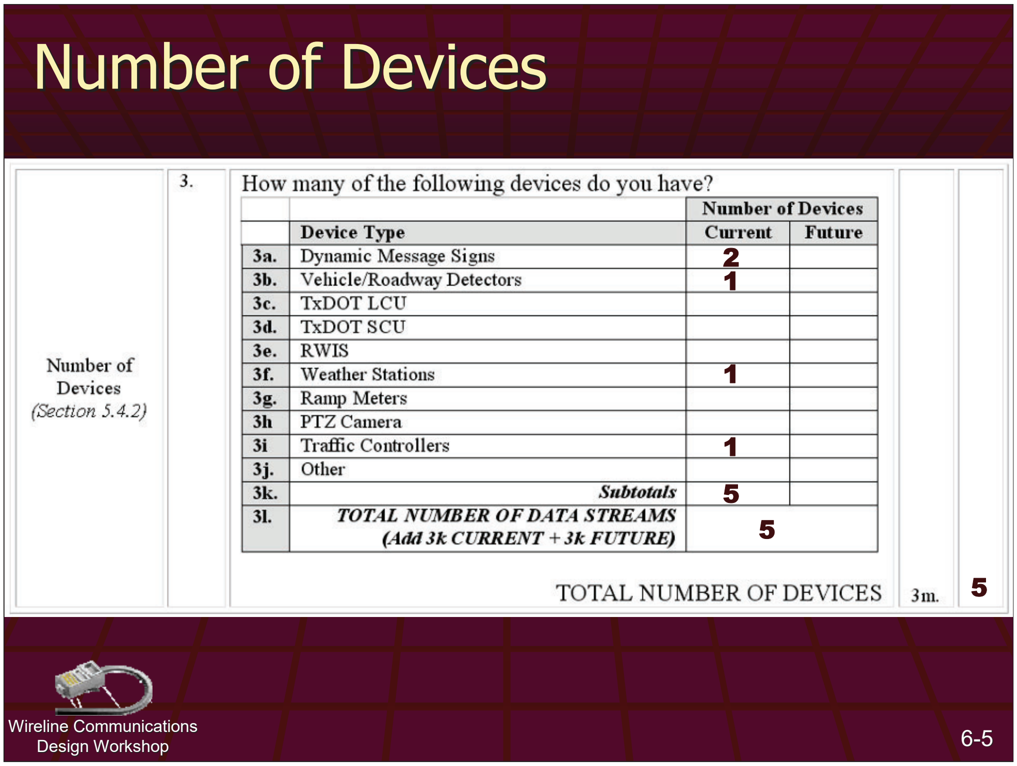
# Presence of Video Streams

**Data Communications Design Worksheet**

| | | | | |
|---|---|---|---|---|
| Presence of Video Streams<br>*(Section 5.4.1)* | 1. | Are video streams in use now or will they be in the future?<br>☐ YES ☒ NO<br>If 'NO,' proceed to Question 3. | 1. | ▨ |
| | 2. | Are the video streams and data being transmitted together over the same communications system in the field?<br>☐ YES ☐ NO<br>If 'YES,' you do not need this worksheet, you need the Digital Video Communications Design Worksheet.<br>If 'NO,' proceed to Question 3. | | ▨ |

Wireline Communications
Design Workshop

6-4



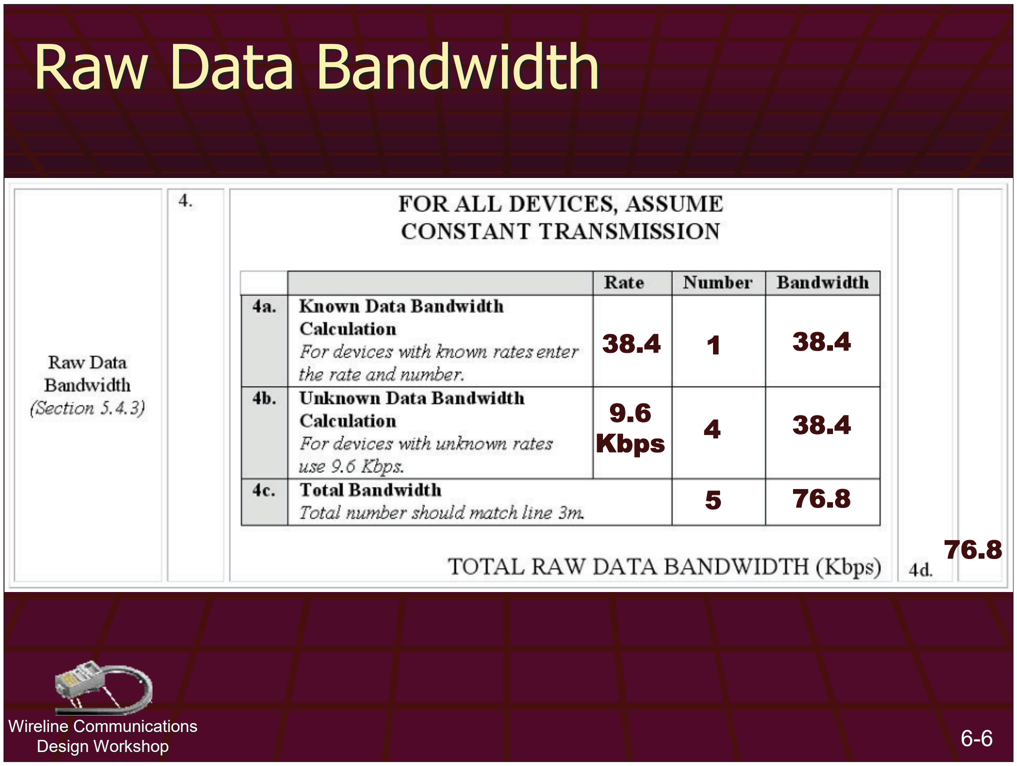
# Number of Devices

Number of Devices *(Section 5.4.2)*

3\. How many of the following devices do you have?

| | | Number of Devices | |
|---|---|---|---|
| | **Device Type** | **Current** | **Future** |
| **3a.** | Dynamic Message Signs | 2 | |
| **3b.** | Vehicle/Roadway Detectors | 1 | |
| **3c.** | TxDOT LCU | | |
| **3d.** | TxDOT SCU | | |
| **3e.** | RWIS | | |
| **3f.** | Weather Stations | 1 | |
| **3g.** | Ramp Meters | | |
| **3h** | PTZ Camera | | |
| **3i** | Traffic Controllers | 1 | |
| **3j.** | Other | | |
| **3k.** | ***Subtotals*** | 5 | |
| **3l.** | ***TOTAL NUMBER OF DATA STREAMS (Add 3k CURRENT + 3k FUTURE)*** | 5 | |

TOTAL NUMBER OF DEVICES 3m. 5



# Raw Data Bandwidth

Raw Data Bandwidth
*(Section 5.4.3)*

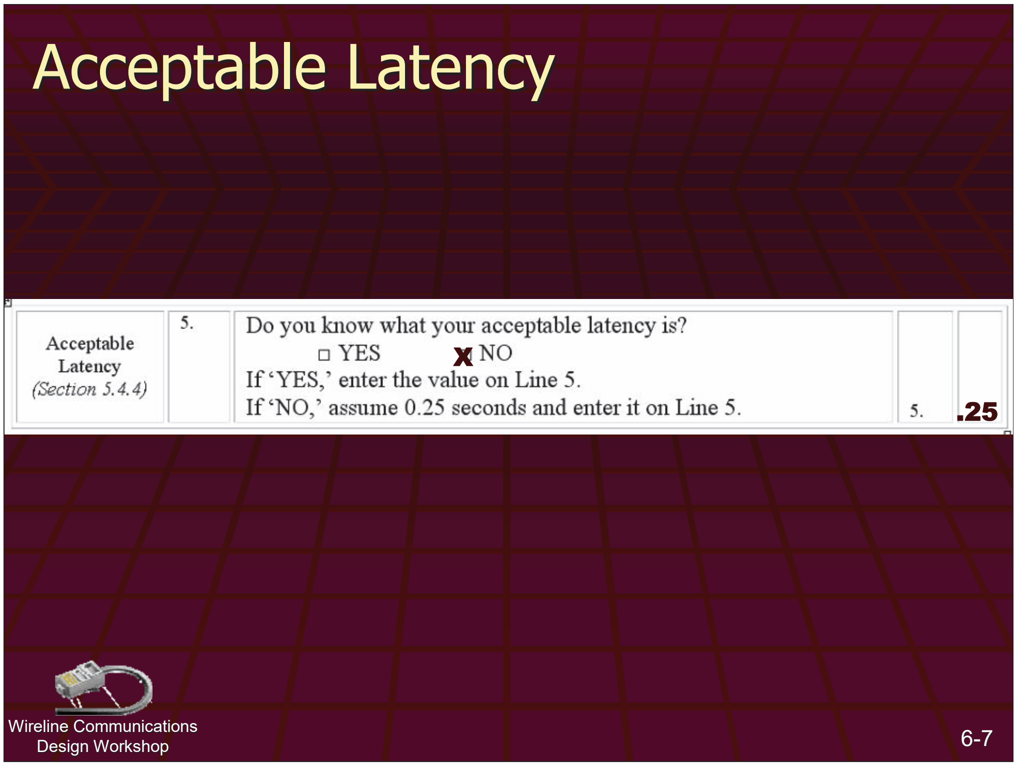
4.

FOR ALL DEVICES, ASSUME
CONSTANT TRANSMISSION

| | | Rate | Number | Bandwidth |
|---|---|---|---|---|
| **4a.** | **Known Data Bandwidth Calculation**<br>*For devices with known rates enter the rate and number.* | 38.4 | 1 | 38.4 |
| **4b.** | **Unknown Data Bandwidth Calculation**<br>*For devices with unknown rates use 9.6 Kbps.* | 9.6 Kbps | 4 | 38.4 |
| **4c.** | **Total Bandwidth**<br>*Total number should match line 3m.* | | 5 | 76.8 |

TOTAL RAW DATA BANDWIDTH (Kbps) 4d. 76.8

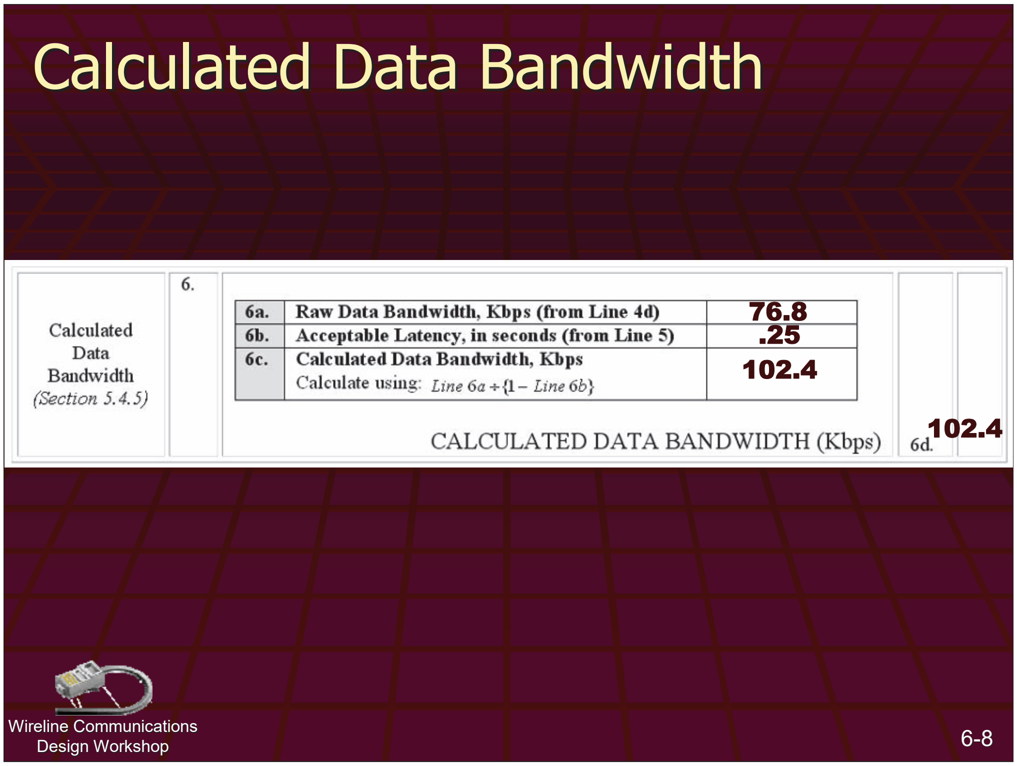
Wireline Communications
Design Workshop



# Acceptable Latency

| | | | | |
|---|---|---|---|---|
| Acceptable Latency<br>*(Section 5.4.4)* | 5. | Do you know what your acceptable latency is?<br>☐ YES ☒ NO<br>If 'YES,' enter the value on Line 5.<br>If 'NO,' assume 0.25 seconds and enter it on Line 5. | 5. | **.25** |

Wireline Communications
Design Workshop

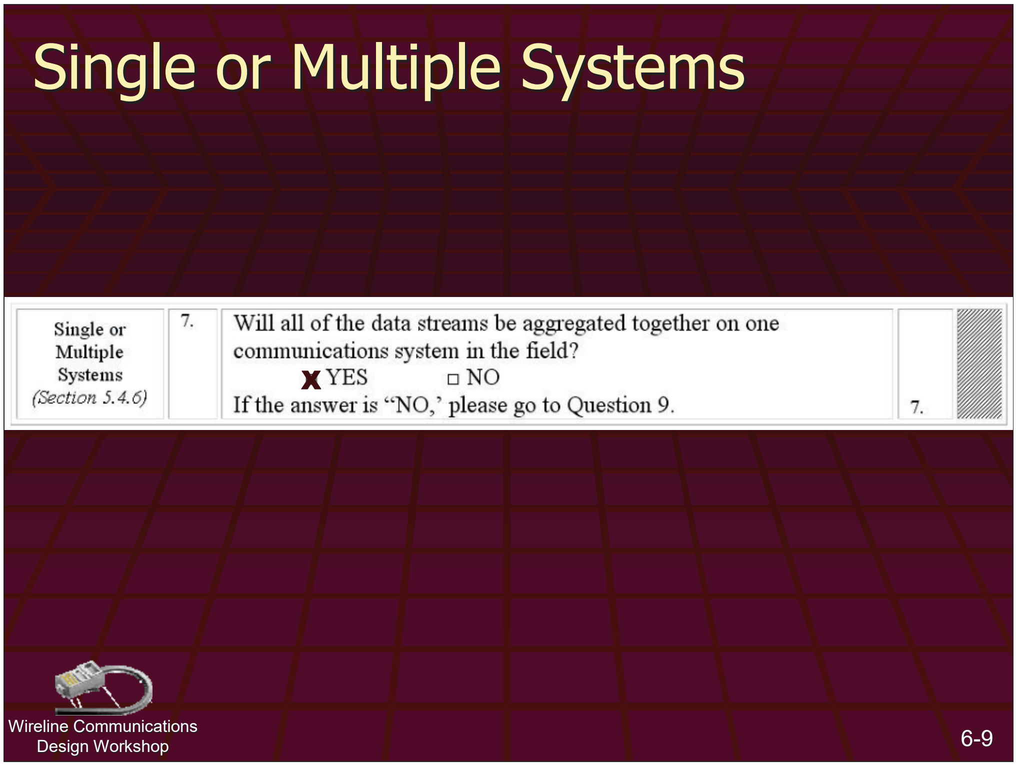


# Calculated Data Bandwidth

| | | | | |
|---|---|---|---|---|
| Calculated Data Bandwidth *(Section 5.4.5)* | 6. | see below | | |
| | | CALCULATED DATA BANDWIDTH (Kbps) | 6d. 102.4 | |

| | | |
|---|---|---|
| 6a. | **Raw Data Bandwidth, Kbps (from Line 4d)** | 76.8 |
| 6b. | **Acceptable Latency, in seconds (from Line 5)** | .25 |
| 6c. | **Calculated Data Bandwidth, Kbps**<br>Calculate using: $Line\ 6a \div \{1 - Line\ 6b\}$ | 102.4 |

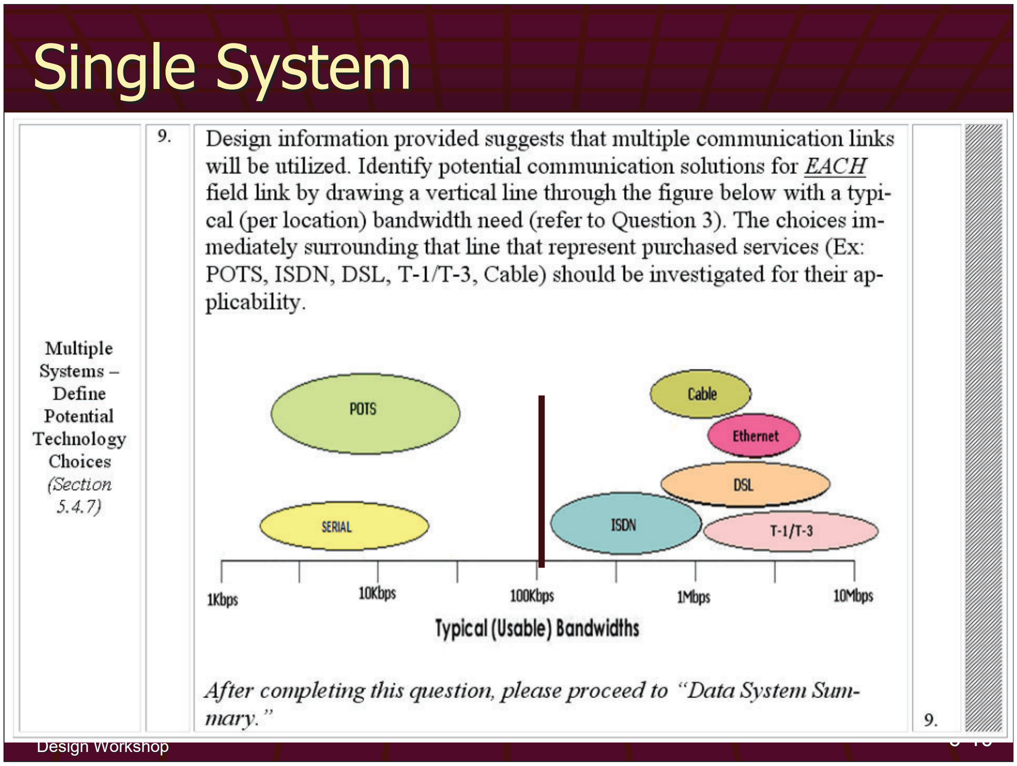
Wireline Communications
Design Workshop



## Single or Multiple Systems

| | | | | |
|---|---|---|---|---|
| Single or Multiple Systems<br>*(Section 5.4.6)* | 7. | Will all of the data streams be aggregated together on one communications system in the field?<br>☒ YES ☐ NO<br>If the answer is "NO,' please go to Question 9. | 7. | ▨ |

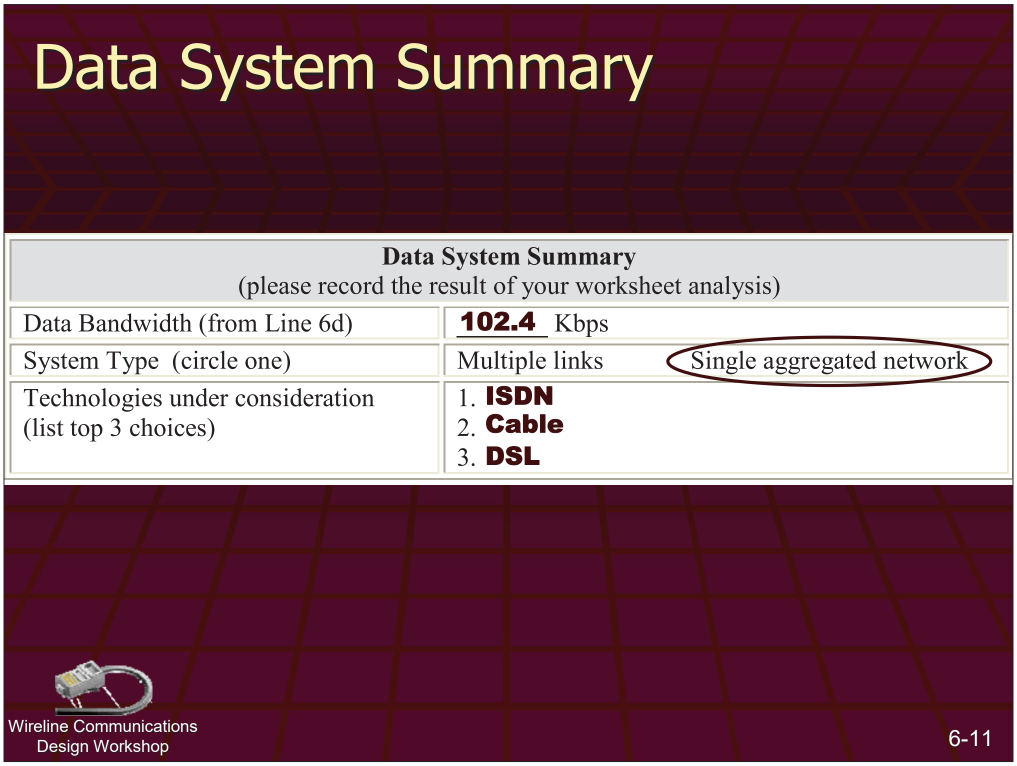
Wireline Communications
Design Workshop



# Single System

| | | | |
|---|---|---|---|
| Multiple Systems – Define Potential Technology Choices *(Section 5.4.7)* | 9. | Design information provided suggests that multiple communication links will be utilized. Identify potential communication solutions for *EACH* field link by drawing a vertical line through the figure below with a typical (per location) bandwidth need (refer to Question 3). The choices immediately surrounding that line that represent purchased services (Ex: POTS, ISDN, DSL, T-1/T-3, Cable) should be investigated for their applicability.<br>*After completing this question, please proceed to "Data System Summary."* | 9. |

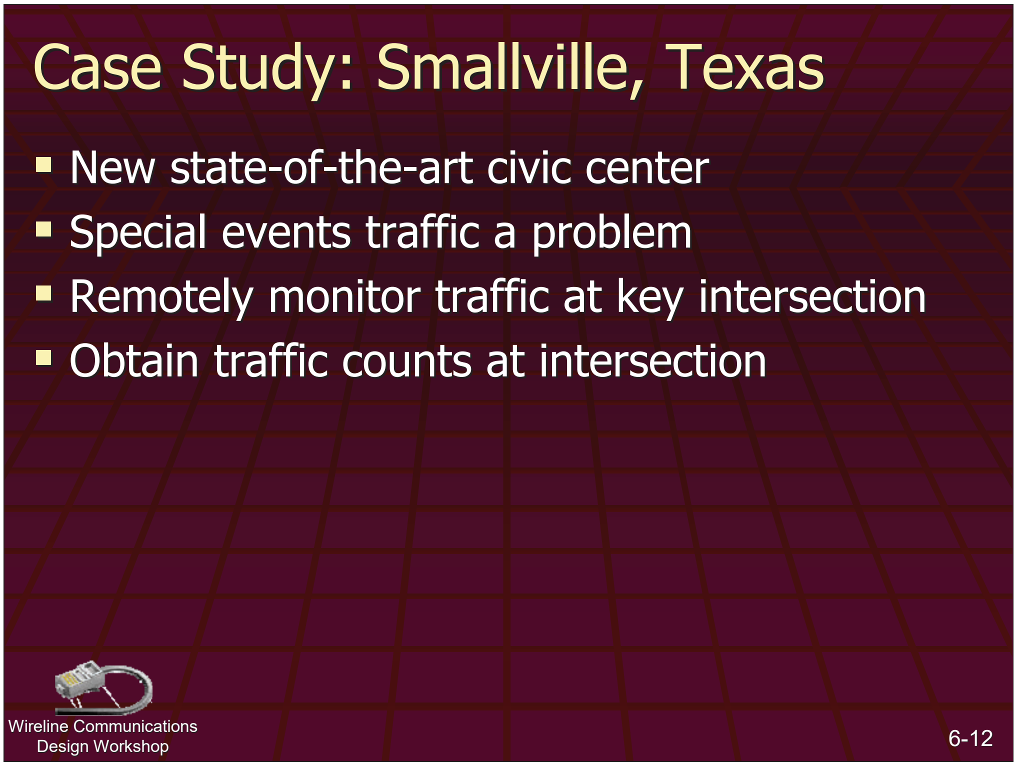
Design Workshop



# Data System Summary

| **Data System Summary**<br>(please record the result of your worksheet analysis) | |
|---|---|
| Data Bandwidth (from Line 6d) | **102.4** Kbps |
| System Type (circle one) | Multiple links [✓ Single aggregated network] |
| Technologies under consideration (list top 3 choices) | 1. **ISDN**<br>2. **Cable**<br>3. **DSL** |

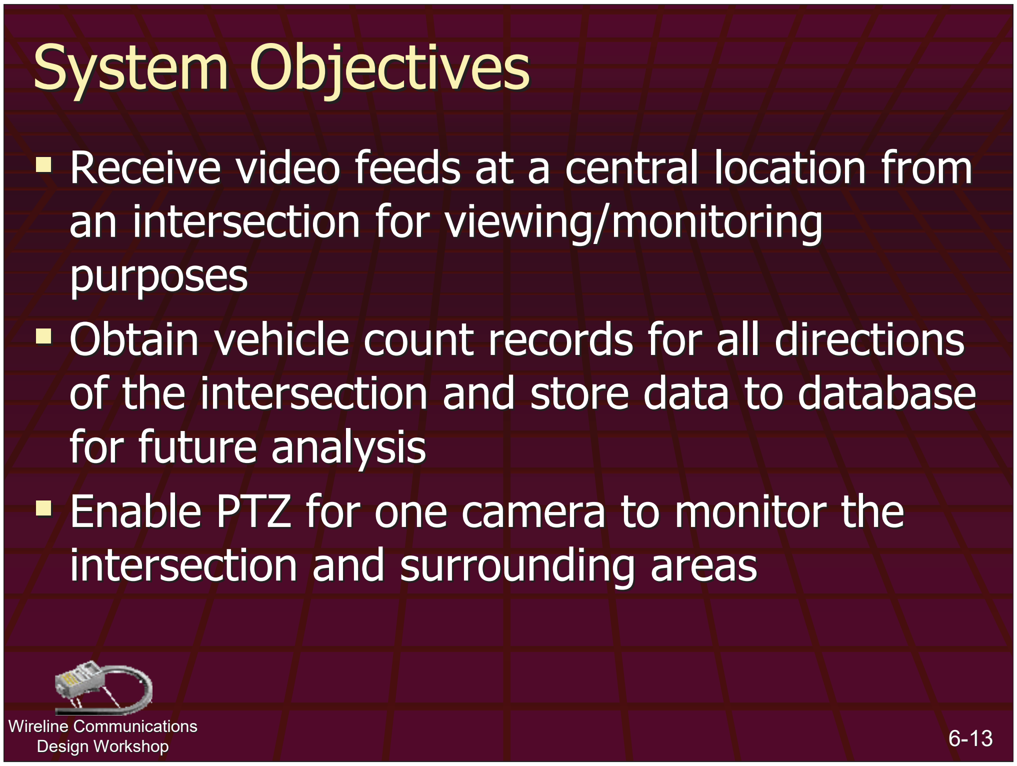
Wireline Communications
Design Workshop



## Case Study: Smallville, Texas

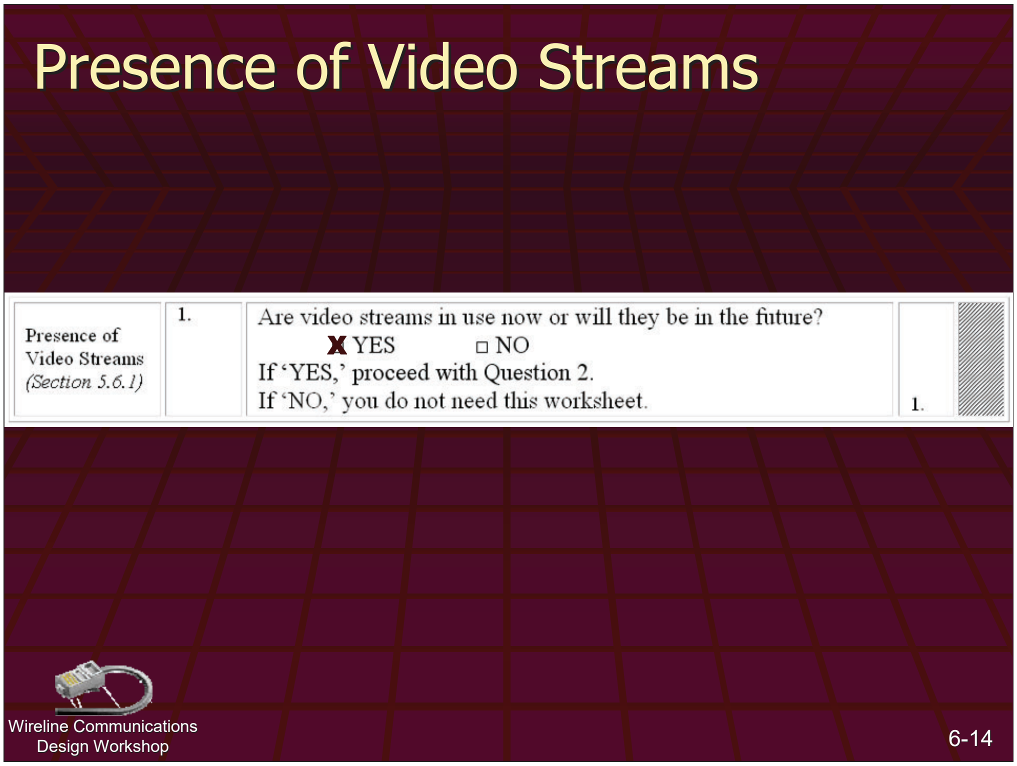
- New state-of-the-art civic center
- Special events traffic a problem
- Remotely monitor traffic at key intersection
- Obtain traffic counts at intersection

Wireline Communications
Design Workshop



## System Objectives

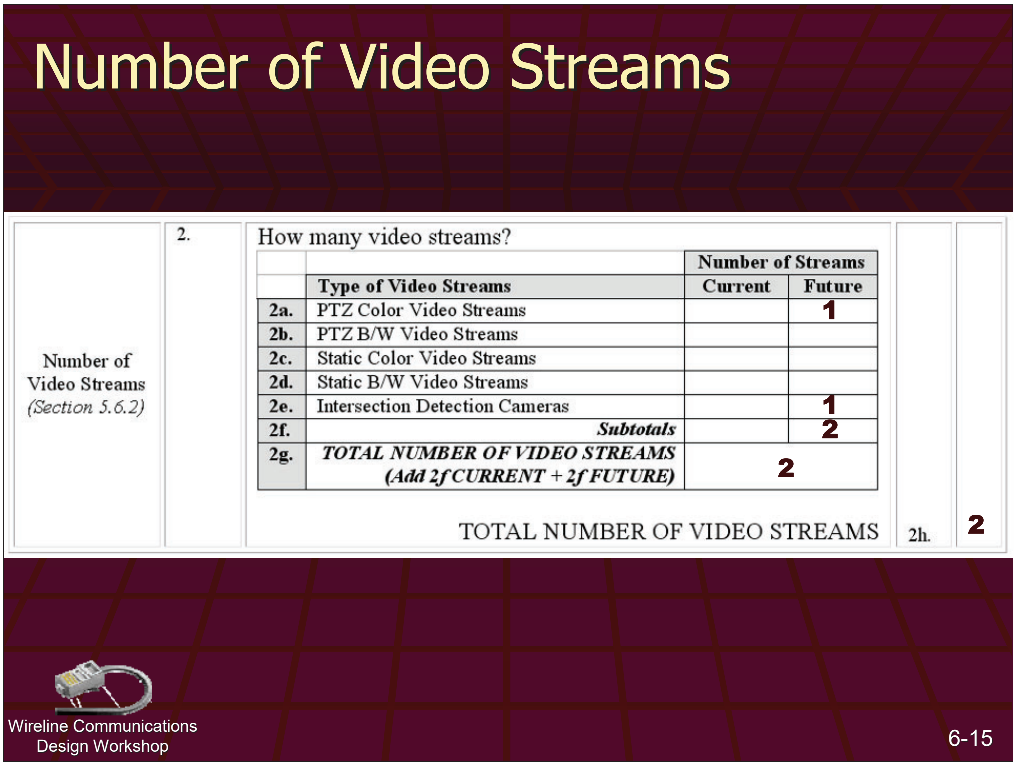
- Receive video feeds at a central location from an intersection for viewing/monitoring purposes
- Obtain vehicle count records for all directions of the intersection and store data to database for future analysis
- Enable PTZ for one camera to monitor the intersection and surrounding areas



# Presence of Video Streams

| | | | | |
|---|---|---|---|---|
| Presence of Video Streams<br>*(Section 5.6.1)* | 1. | Are video streams in use now or will they be in the future?<br>☒ YES ☐ NO<br>If 'YES,' proceed with Question 2.<br>If 'NO,' you do not need this worksheet. | 1. | ▨ |

Wireline Communications
Design Workshop



# Number of Video Streams

Number of Video Streams *(Section 5.6.2)*

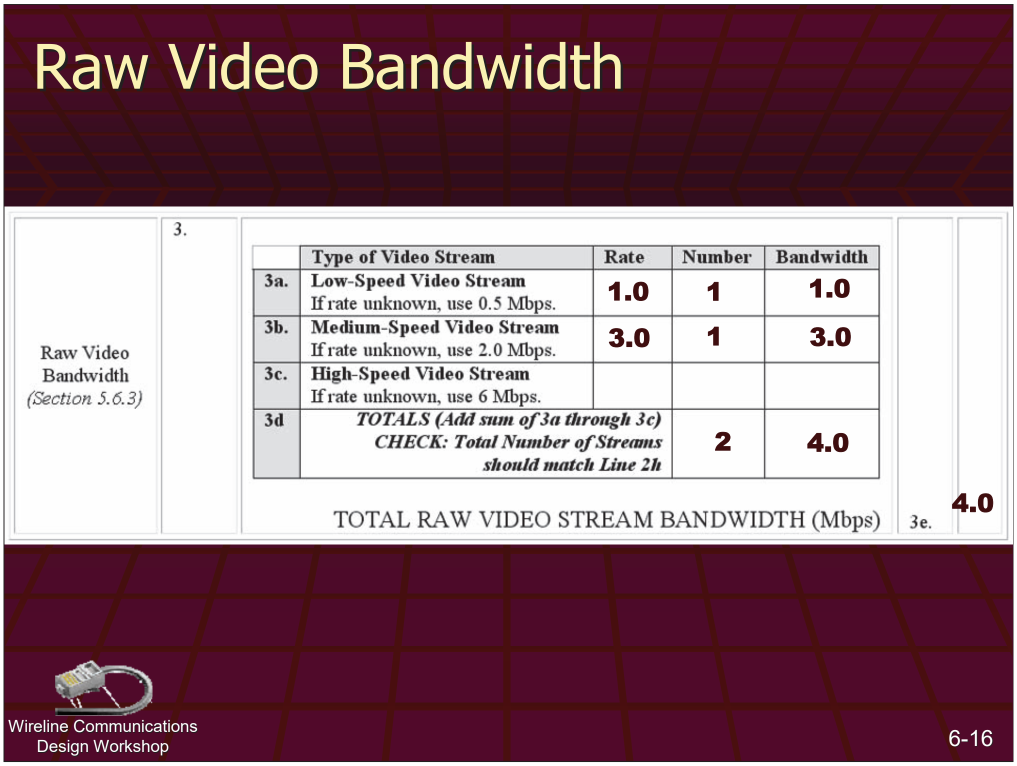
2.

How many video streams?

| | | Number of Streams | |
|---|---|---|---|
| | **Type of Video Streams** | **Current** | **Future** |
| **2a.** | PTZ Color Video Streams | | **1** |
| **2b.** | PTZ B/W Video Streams | | |
| **2c.** | Static Color Video Streams | | |
| **2d.** | Static B/W Video Streams | | |
| **2e.** | Intersection Detection Cameras | | **1** |
| **2f.** | ***Subtotals*** | | **2** |
| **2g.** | ***TOTAL NUMBER OF VIDEO STREAMS (Add 2f CURRENT + 2f FUTURE)*** | **2** | |

TOTAL NUMBER OF VIDEO STREAMS 2h. **2**

Wireline Communications Design Workshop



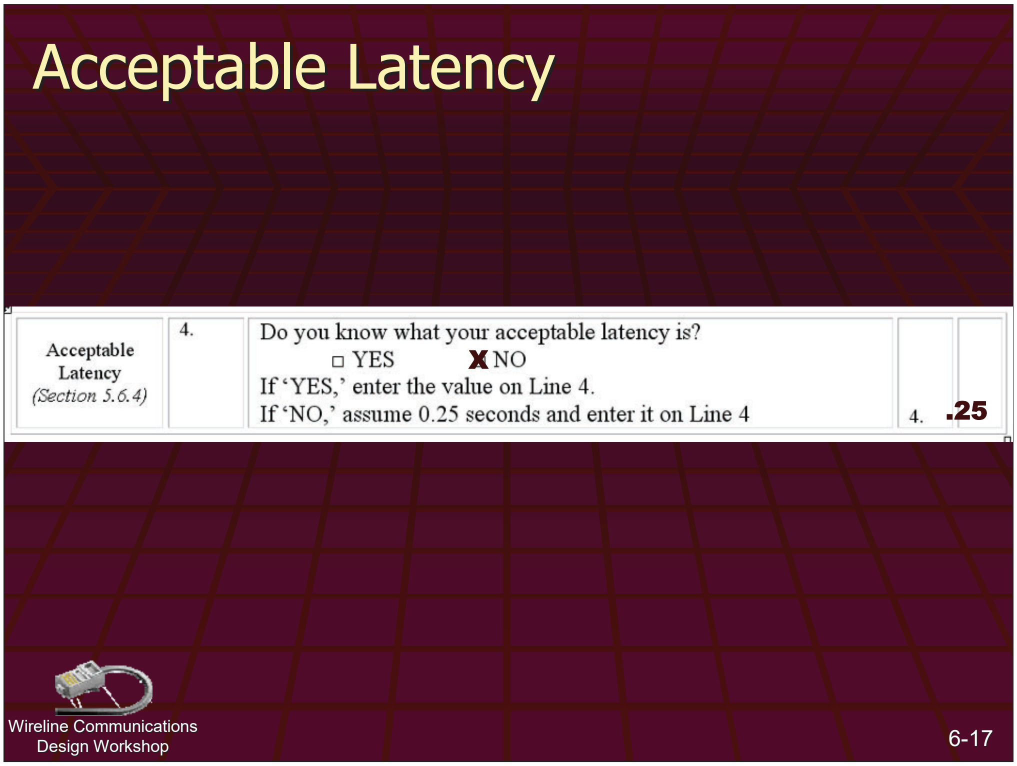
# Raw Video Bandwidth

Raw Video Bandwidth *(Section 5.6.3)*

3.

| | Type of Video Stream | Rate | Number | Bandwidth |
|---|---|---|---|---|
| 3a. | **Low-Speed Video Stream**<br>If rate unknown, use 0.5 Mbps. | **1.0** | **1** | **1.0** |
| 3b. | **Medium-Speed Video Stream**<br>If rate unknown, use 2.0 Mbps. | **3.0** | **1** | **3.0** |
| 3c. | **High-Speed Video Stream**<br>If rate unknown, use 6 Mbps. | | | |
| 3d | ***TOTALS (Add sum of 3a through 3c)***<br>***CHECK: Total Number of Streams should match Line 2h*** | | **2** | **4.0** |

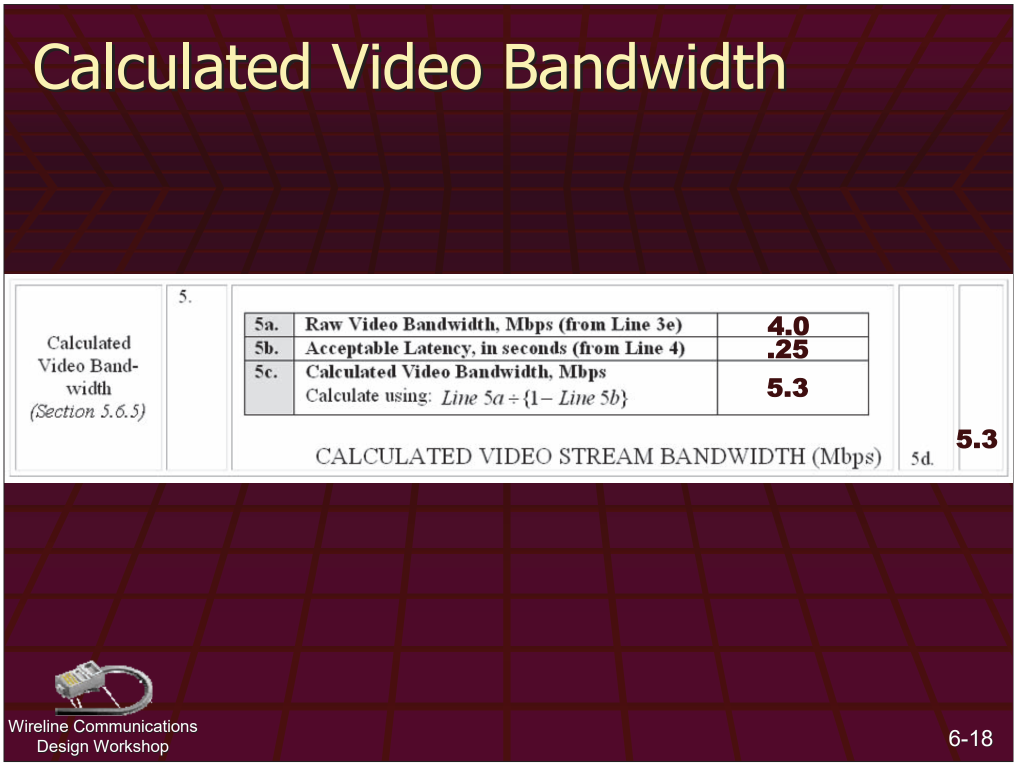
TOTAL RAW VIDEO STREAM BANDWIDTH (Mbps) 3e. **4.0**



## Acceptable Latency

| | | | | |
|---|---|---|---|---|
| Acceptable Latency<br>*(Section 5.6.4)* | 4. | Do you know what your acceptable latency is?<br>☐ YES ☒ NO<br>If 'YES,' enter the value on Line 4.<br>If 'NO,' assume 0.25 seconds and enter it on Line 4 | 4. | **.25** |

Wireline Communications Design Workshop



# Calculated Video Bandwidth

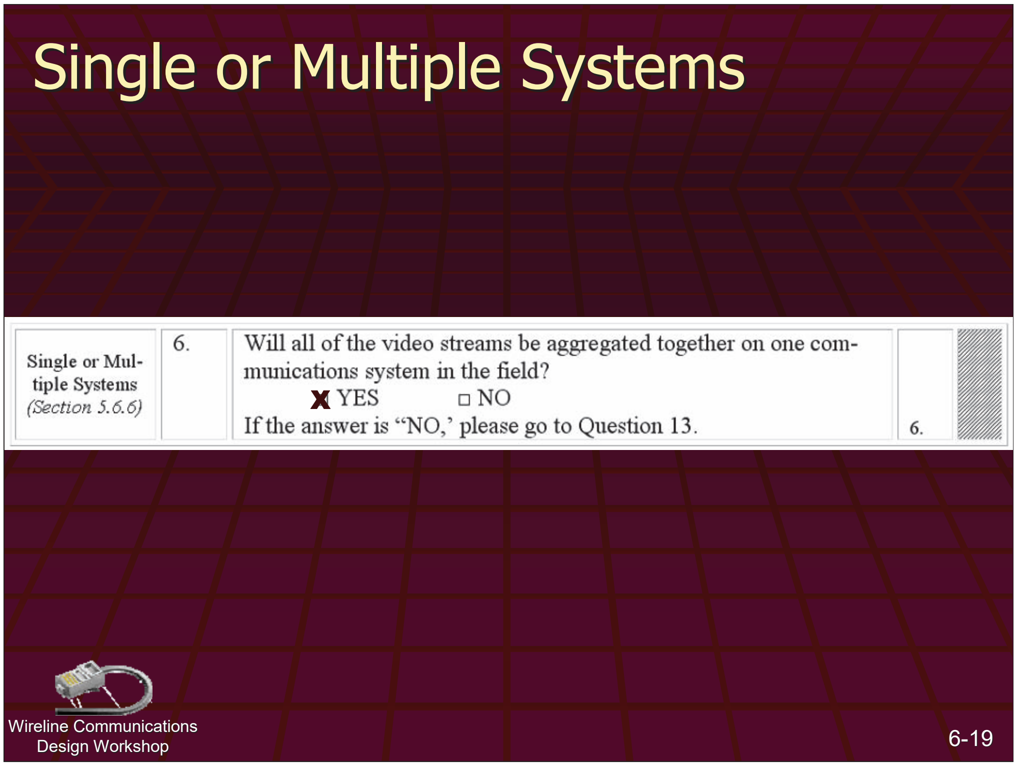
Calculated Video Band-width *(Section 5.6.5)*

5.

| | | |
|---|---|---|
| **5a.** | **Raw Video Bandwidth, Mbps (from Line 3e)** | **4.0** |
| **5b.** | **Acceptable Latency, in seconds (from Line 4)** | **.25** |
| **5c.** | **Calculated Video Bandwidth, Mbps**<br>Calculate using: $Line\ 5a \div \{1 - Line\ 5b\}$ | **5.3** |

CALCULATED VIDEO STREAM BANDWIDTH (Mbps) 5d. **5.3**

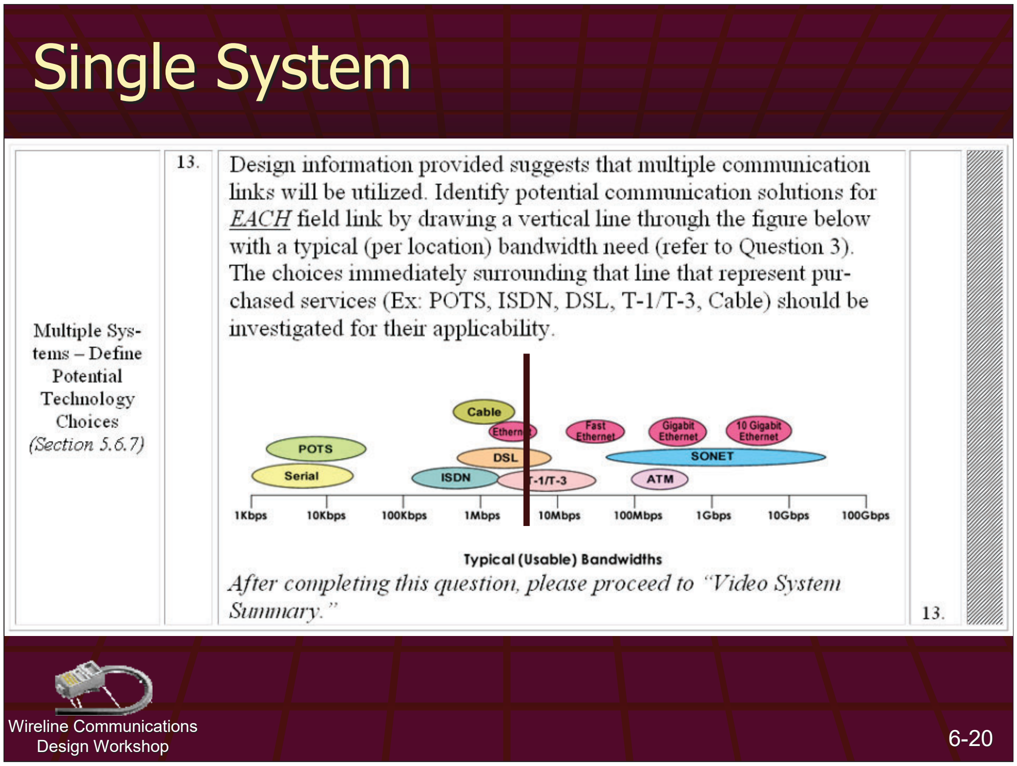
Wireline Communications
Design Workshop



# Single or Multiple Systems

| | | | | |
|---|---|---|---|---|
| Single or Multiple Systems<br>*(Section 5.6.6)* | 6. | Will all of the video streams be aggregated together on one communications system in the field?<br>☒ YES ☐ NO<br>If the answer is "NO,' please go to Question 13. | 6. | ▨ |

Wireline Communications
Design Workshop



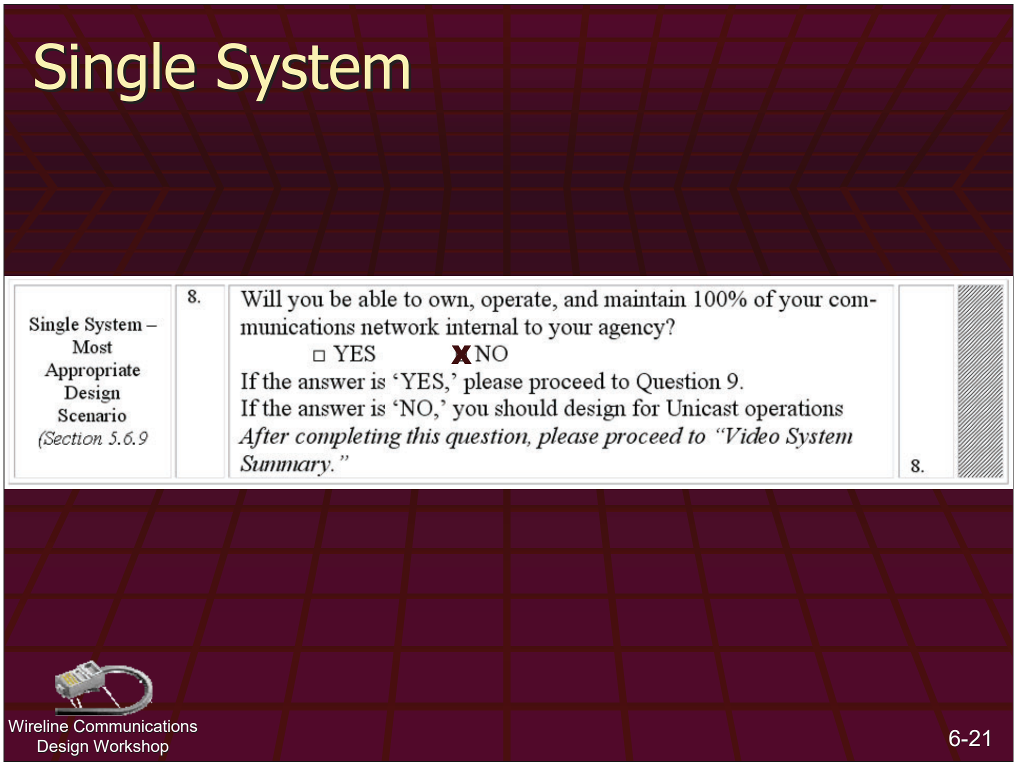
# Single System

Multiple Systems – Define Potential Technology Choices *(Section 5.6.7)*

13. Design information provided suggests that multiple communication links will be utilized. Identify potential communication solutions for *EACH* field link by drawing a vertical line through the figure below with a typical (per location) bandwidth need (refer to Question 3). The choices immediately surrounding that line that represent purchased services (Ex: POTS, ISDN, DSL, T-1/T-3, Cable) should be investigated for their applicability.

*After completing this question, please proceed to “Video System Summary.”*

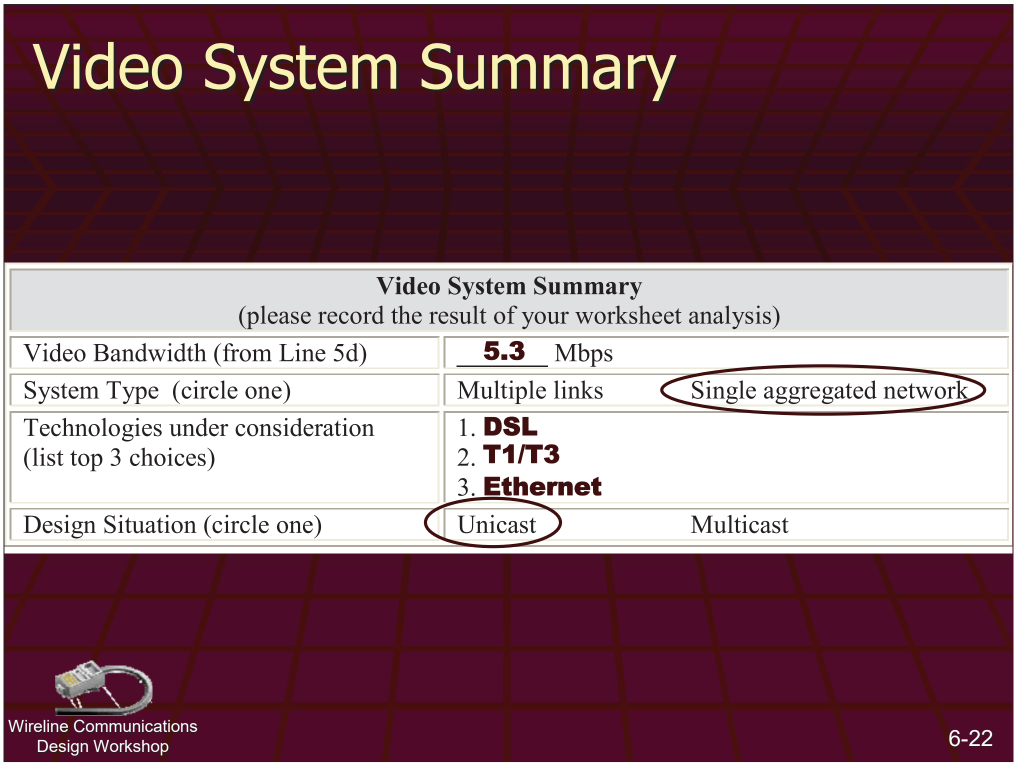
13.



# Single System

| | | | | |
|---|---|---|---|---|
| Single System – Most Appropriate Design Scenario<br>*(Section 5.6.9* | 8. | Will you be able to own, operate, and maintain 100% of your communications network internal to your agency?<br>☐ YES ☒ NO<br>If the answer is 'YES,' please proceed to Question 9.<br>If the answer is 'NO,' you should design for Unicast operations<br>*After completing this question, please proceed to "Video System Summary."* | 8. | ▨ |

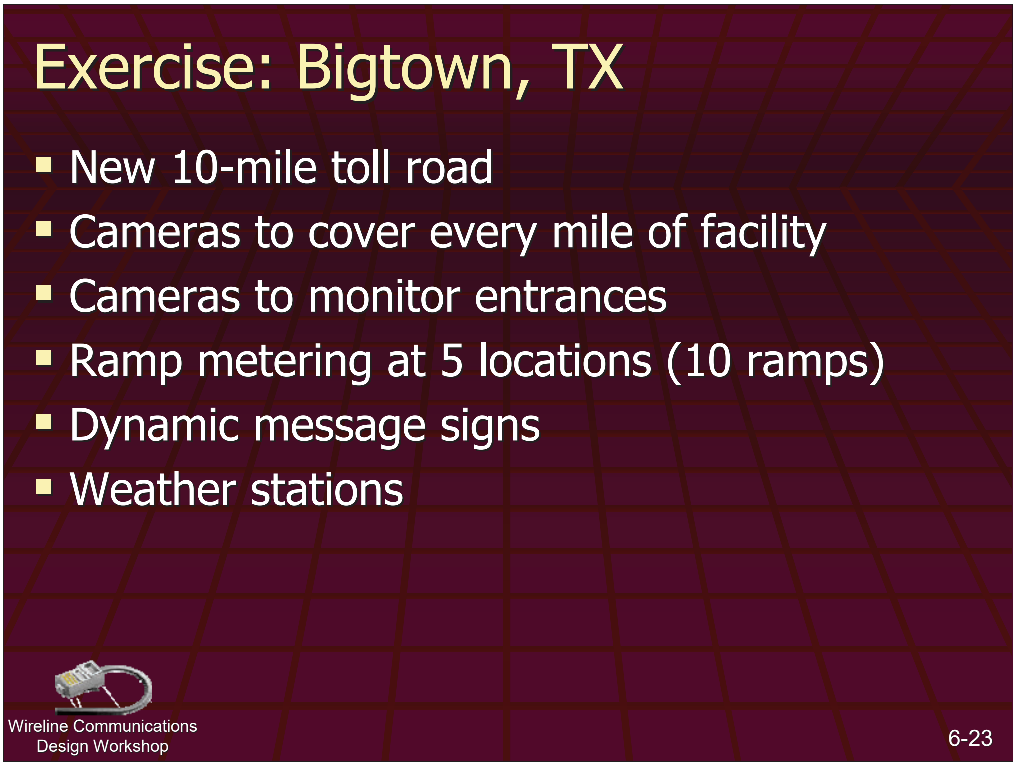
Wireline Communications Design Workshop



# Video System Summary

**Video System Summary**
(please record the result of your worksheet analysis)

| | |
|---|---|
| Video Bandwidth (from Line 5d) | **5.3** Mbps |
| System Type (circle one) | Multiple links [✓ Single aggregated network] |
| Technologies under consideration (list top 3 choices) | 1. **DSL**<br>2. **T1/T3**<br>3. **Ethernet** |
| Design Situation (circle one) | [✓ Unicast] Multicast |



# Exercise: Bigtown, TX

- New 10-mile toll road
- Cameras to cover every mile of facility
- Cameras to monitor entrances
- Ramp metering at 5 locations (10 ramps)
- Dynamic message signs
- Weather stations

# System Objectives

- Monitor traffic conditions on 10-mile stretch of toll road via video streams
- Monitor traffic occupancy at locations of toll road and implement ramp metering strategies based on occupancies
- Detect toll payment violators at toll booth sites
- Update dynamic message signs for current situations, including traffic and weather conditions