# Data Communication and Computer Network
# BLM3051


Dr. Öğr. Üyesi Furkan ÇAKMAK

# Lecture Information Form - Weekly Subjects

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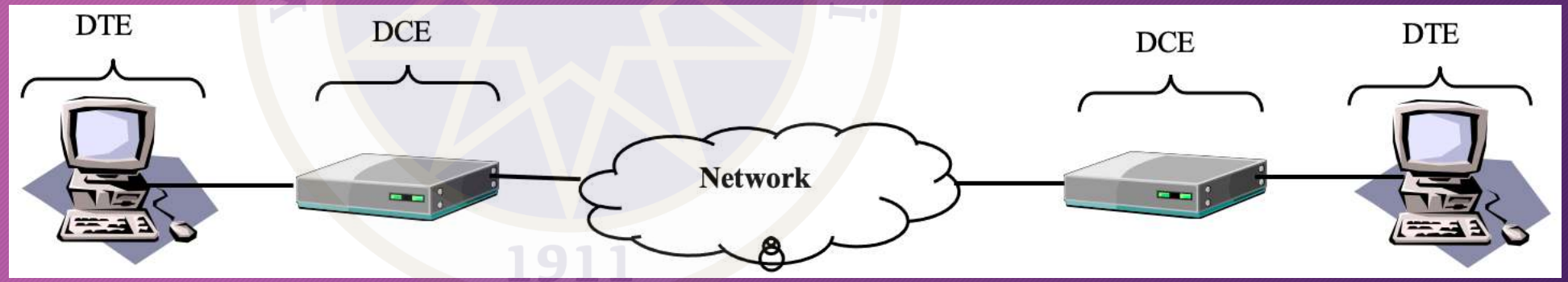
| Hafta | Tarih | Konular |
|---|---|---|
| 1 | 20.02.2024 | Introduction to Data Communication Standards Used on Data Communication, Architectural models |
| 2 | 27.02.2024 | OSI Reference Model , Layers and Their Functions, Signaling and Signal Encoding |
| 3 | 05.03.2024 | Parallel and Serial Transmission, Communication Media and Their Technical Specs., Multiplexing (TDM, FDM) |
| 4 | 12.03.2024 | Error Detection and Error Correction Techniques, Data Link Control Techniques, Flow Control |
| 5 | 19.03.2024 | Asynchronous and Synchronous Data Link Protocols (BSC, HDLC) |
| 6 | 26.03.2024 | LAN Technologies Continued, IEEE 802.4, 802.5, 802.11 |
| 7 | 02.04.2024 | Connectionless and Connection Oriented Services, Switching |
| 8 | 09.04.2024 | Tatil - Ramazan Bayramı Arifesi |
| 9 | 16.04.2024 | 1. Ara Sınav |
| 10 | 23.04.2024 | Tatil - 23 Nisan Ulusal Egemenlik ve Çocuk Bayramı |
| 11 | 30.04.2024 | Static and Dynamic Routing, Congestion in the Network Layer, Its Causes and Solutions |
| 12 | 07.05.2024 | IP (Internetworking Protocol), ICMP, BOOTP, DHCP |
| 13 | 14.05.2024 | 2. Ara Sınav |
| 14 | 21.05.2024 | UDP (User Datagram Protocol), TCP (Transmisson Control Protocol) |

# DTE-DCE Interfaces



- DCE (Data Circuit-Terminating Equipment)
  - Modem
- DTE (Data Terminal Equipment)
  - Computer
  - Printer
  - Fax
  - etc.



# DTE-DCE Interfaces – Con't

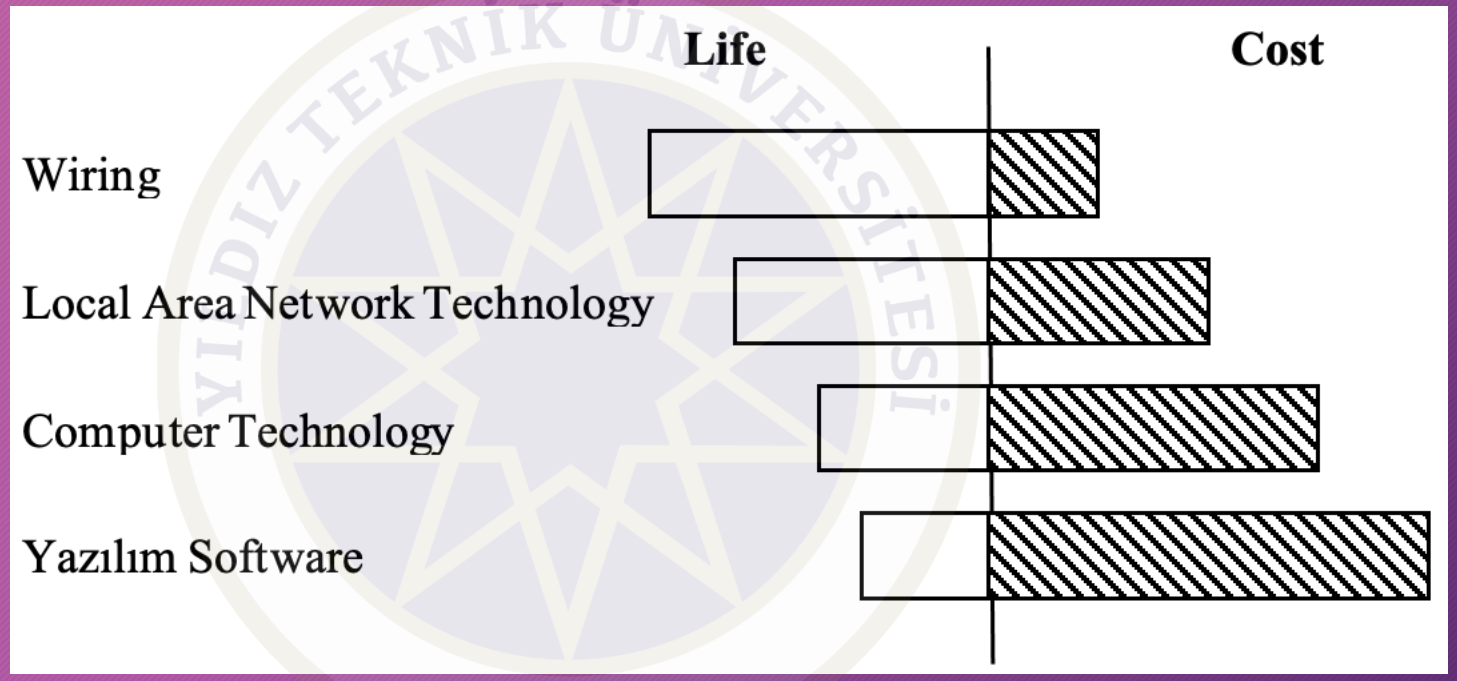


- Standards between DTE and DCE
  - EIA
    - EIA-232
    - EIA-442
    - EIA-449
  - ITU-T
    - V.24
    - V.32
    - V.32bis
    - V.34
    - X.2
    - X.24

# Transmission Medium



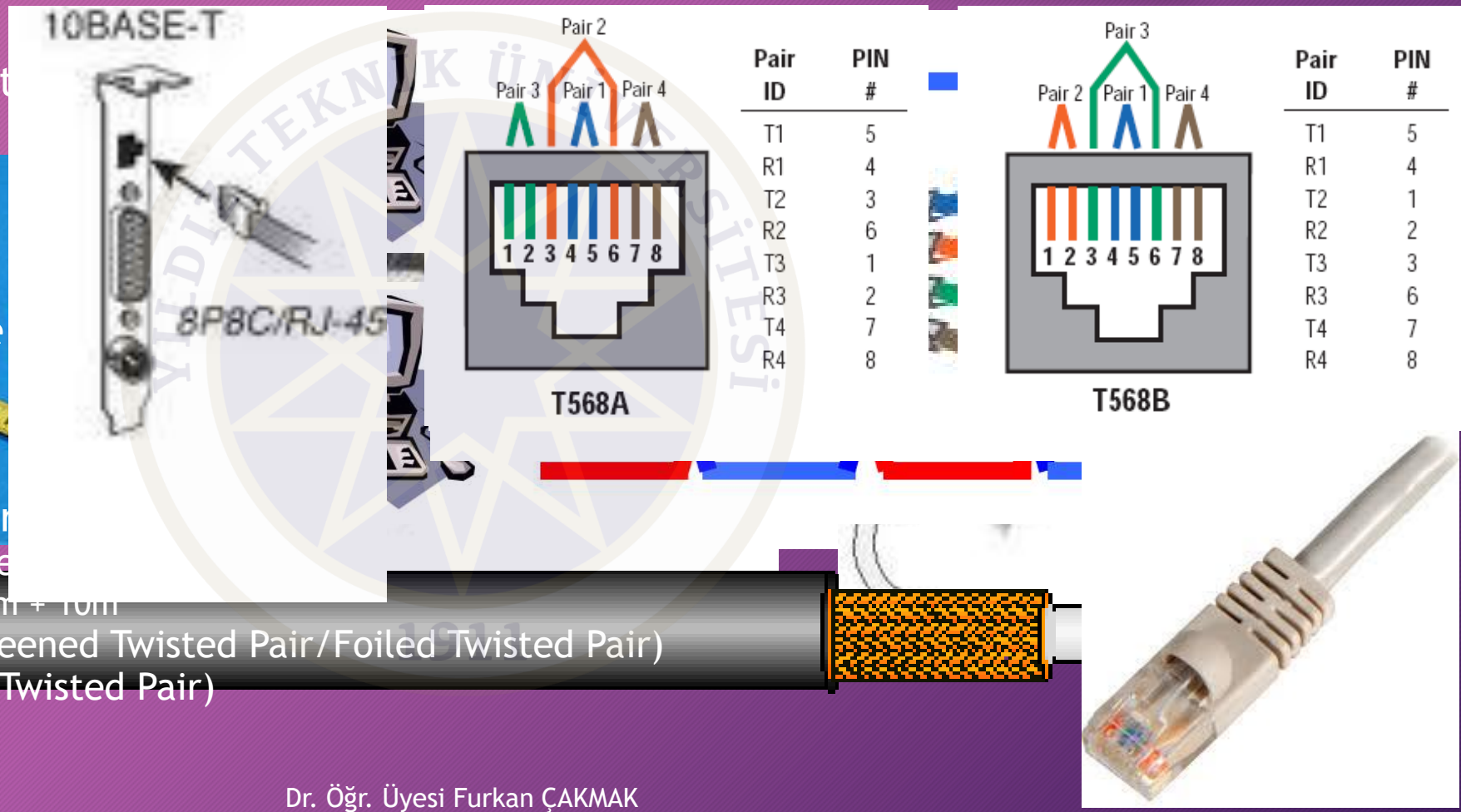
- Wire
- Light
- Radio Wave
- Guided and Unguided media



# Guided Media



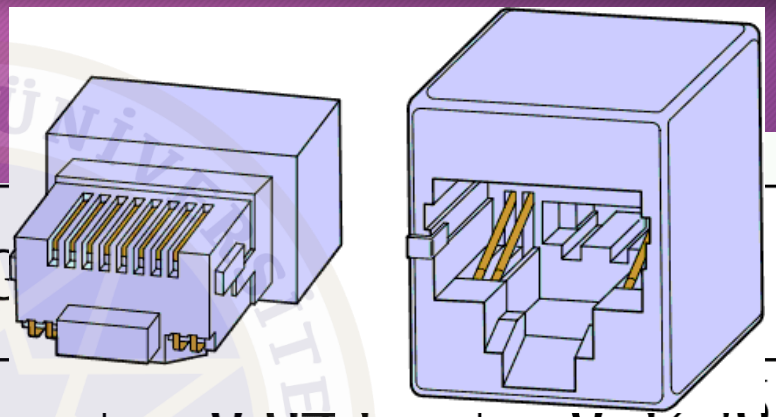
- Coaxial Cable
  - AUI (Attachement
  - Ethernet
  - Thick: 10mm
  - Thin: 5mm
- Twisted pair
  - DGM (Data Grade
  - CATs
  - 2-12 twist/step
  - Different Colors
  - There are 3 differ
    - UTP (Unshielde
      - 100m = 90m + 10m
    - ScTP/FTP (Screened Twisted Pair/Foiled Twisted Pair)
    - STP (Shielded Twisted Pair)



# Guided Media – Con't



- UTP cables category criterias:
  - Signal Frequency
  - Wire lenght
  - Correct connections
  - Attenuation
  - NEXT (Near-End Crosstalk)
  - PSNEXT (Power Sum NEXT)
  - FEXT (Far-End Crosstalk)
  - ELFEXT (Equal Level FEXT)
  - PSELFEXT (Power Sum ELFEXT)
- CAT 5e
  - gigabit Ethernet
  - 4 pieces of 2
  - Propagation delay
    - Skew
      - Fastest - Slowest



# Classification of UTP Cables

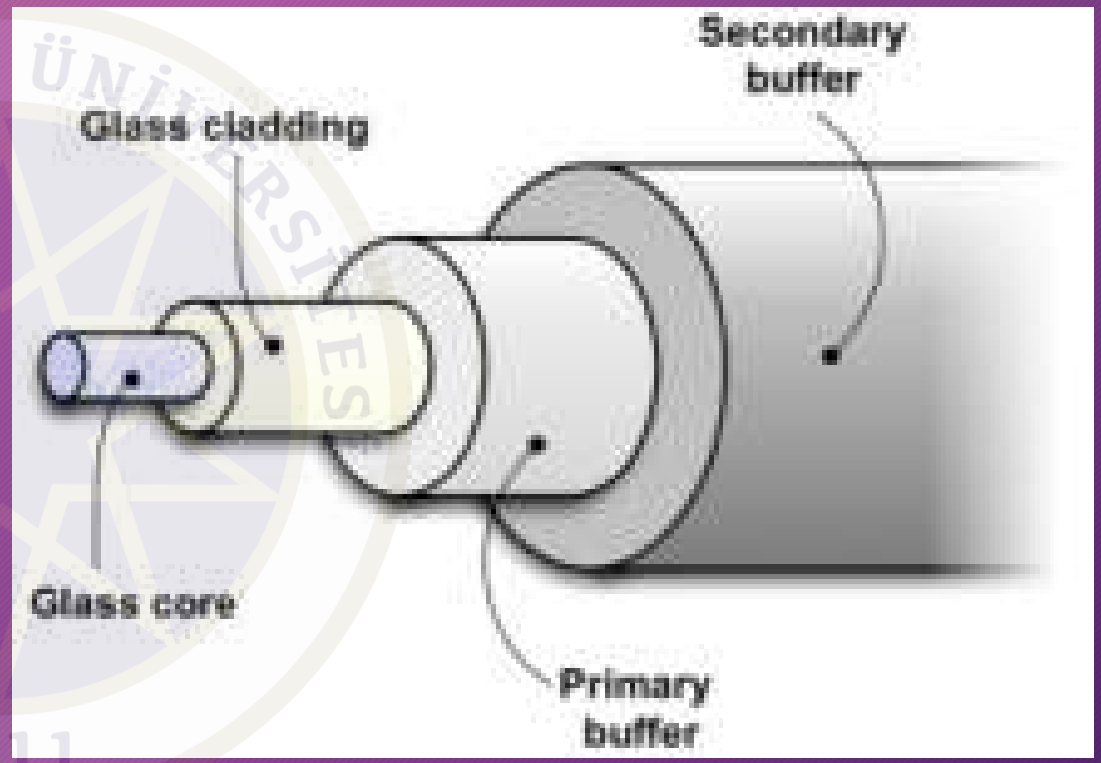


| Type | Usage Purpose | Freq. (MHz) | Connector Type[74] | Usage Area |
|---|---|---|---|---|
| **Cat-1** | Voice | 1 | 6P2C / RJ-11 | Voice / Phone |
| **Cat-2** | Voice - Data | 4 | 8P8C / RJ–45 | Voice / 4Mbps TokenRing / Terminal |
| **Cat-3** | Voice - Data | 16 | 8P8C / RJ–45 | Voice / 10Base-T / 25Mbps ATM |
| **Cat-4** | Data | 20 | 8P8C / RJ–45 | 10Base-T / TokenRing |
| **Cat-5** | Data | 100 | 8P8C / RJ–45 | 10Base-T / 100Base-T / ATM / CDDI |
| **Cat-5e** | Data | > 100 | 8P8C / RJ–45 | 100Base-T / 1000Base-T |
| **Cat-6** | Data | 250 | 8P8C / RJ–45 | 1000Base-T / 10GBase-T@55m |
| **Cat-6a[75]** | Data | > 500 | 8P8C / RJ–45 | 10GBase-T |
| **Cat-7** | Data | 600 | 8P8C / GG–45[76] | 10GBase-T |
| **Cat-7a** | Data | 1000 | 8P8C / GG–45 | 40Gbps@50m / 100Gbps@15m |
| **Cat-8** | Data | > 1.200 | Double Connectivity | > 40 Gbps@30-50m |

# Guided Media – Fiber Optic Cabels



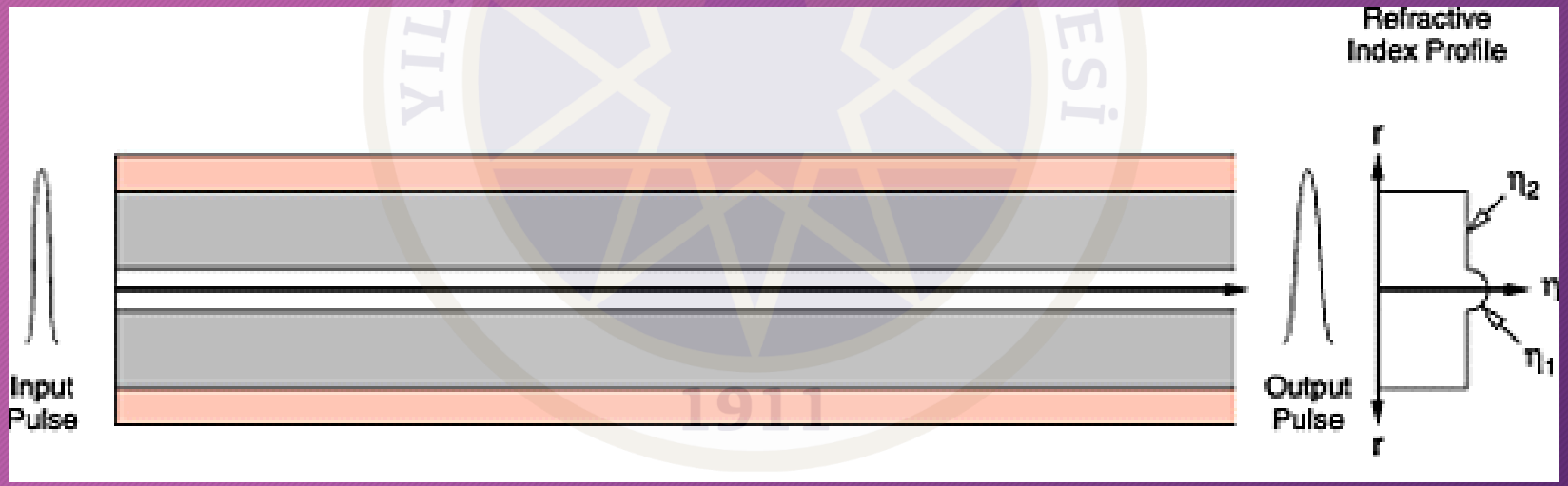
- ~~Coaxial Cables~~
- ~~Twisted Pair Cables~~
- Fiber Optic Cables
  - 300.000 km/sec
  - >= 100 Gbps (reached 500 Gpbs)
  - Core
  - Cladding
  - Primary buffer
  - Secondary buffer
  - Armor
  - Plastic Shield
- SMF (Single Mode Fiber)
- MMF (Multi Mode Fiber)



# Guided Media – Fiber Optic Cabels – Con't



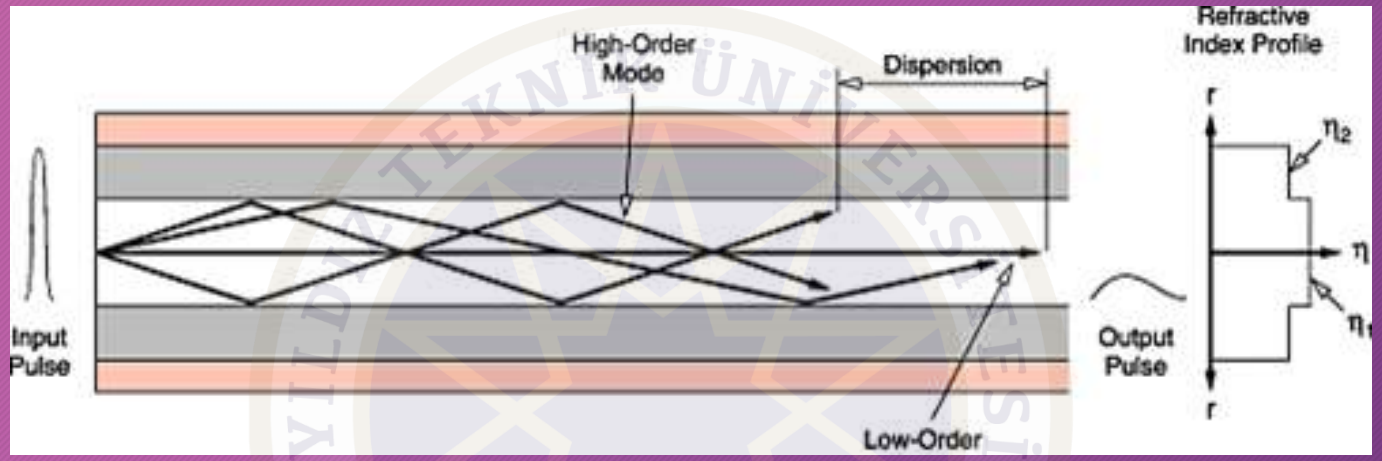
- Single Mode Fiber (SMF)
  - **Core:** 9 µm
  - Light wavelength: 1.3 – 1.5 µm
  - 1.3 µm ≈ 9 µm → Transmission is carried out as a single, unbreakable beam



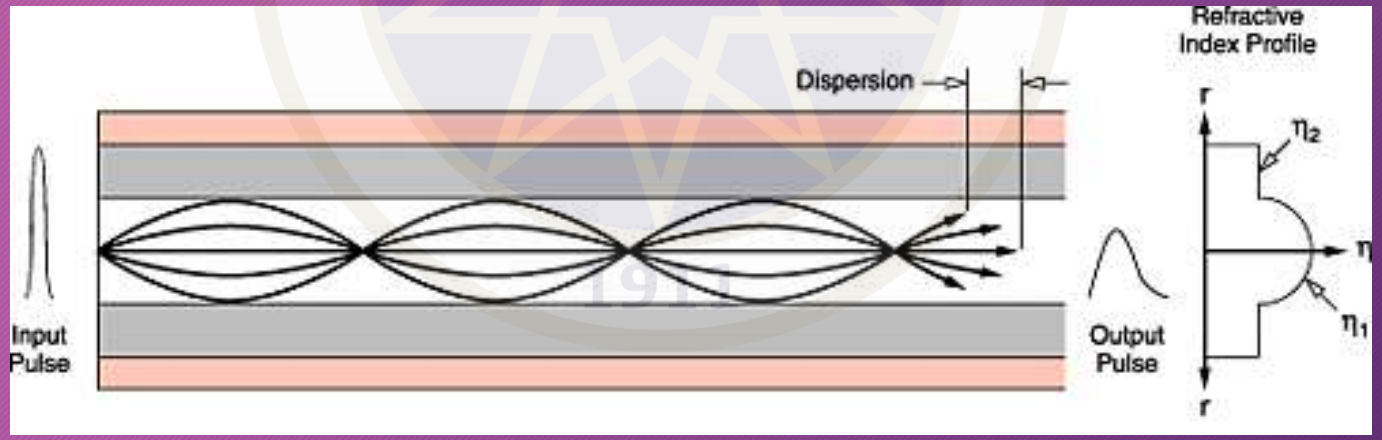
# Guided Media – Fiber Optic Cabels – Con't



Step Index




Grade Index



# Guided Media – Fiber Optic Cabels – Con’t

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# Guided Media – Fiber Optic Cabels – Con't



- Light sources used in fiber optic media:
  - LED (Light Emitting Diode)
    - Nonfocusable
  - ILD (Injection Laser Diode)
    - Focusable
  - Receiver side: fotodiod (Photosensitive cell)
    - It is a circuit element that can generate electrical signals depending on the strength of the light falling on it.

# Advantages of Fiber Optic Cables over Copper Cables



- Broad Bandwidth
- Immunity to Electromagnetic Interference
- Attenuation
- Insulation
- Space Saving
- Security
  - Eavesdrop

# Things to Consider When using Fiber Optic Cables

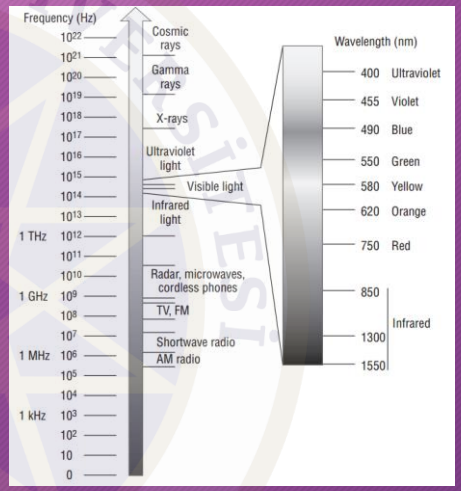


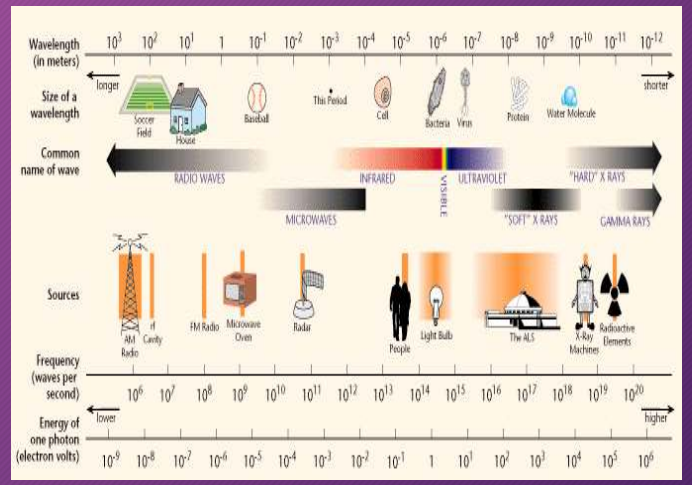
- The core parts of the fibers used at both ends must overlap exactly.
  - Attention should be paid to dirt, oil, dust and scratches.
  - Dirt, dust, etc. should be cleaned with air gun or alcohol.
  - Scratches should be polished and rounded.
- Fiber cables are fragile like glass and must be kept gently bent.
- When not in use, fiber cables should be stored with special headers to protect them from dust and scratches.
- The laser beam at the end of the fiber optic cable is dangerous to the eyes.

# Unguided Media



- Technologies that aim to use the atmosphere:
  - RF (Radio Frequency)
  - Microwave
  - IR (Infra Red)
- Ionosphere
  - Ground propagation < 2 MHz
  - Sky propagation 2-30 MHz
  - Line of sight propagation > 30 MHz



# Unguided Media - Radio Frequency



- 3 kHz – 1 GHz
- Television ve Radio
- Omnidirectonal
- Antennas do not need to be aligned
- RF can go through the Wall.
- Obtain approval from authorities to use RF.
- Non-approval RF types:
  - Bluetooth, IEEE 802.11, etc.

# Unguided Media - Microwaves



- 1-300 GHz
- Satellite - Ground Station
- Parabolic and horn antennas
  - Unidirectional
  - LOS – Line Of Sight
- Microwaves can not go through the Wall
- It can be harmful to the living creature between the transceiver, depending on the signal strength used.

# Unguided Media - Infra Red



- 300GHz-400THz
- Point-to-point
  - Device's remotes
- Infra Red can not go through the Wall
- Tapping-eavesdropping
- Jamming Immune
- 75 kbps in max. 8m distance
  - Top: 4 Mbps

# Comparison of Transmission Medium



| Ortam / Özellik | UTP | STP | Coax | FO | RF | IR | Mikro Dalga | Uydu | Hücresel |
|---|---|---|---|---|---|---|---|---|---|
| **Fiyat ($/m)** | Düşük | Orta | Orta | Yüksek | Orta | Düşük (Yüksek) | Yüksek | Yüksek | Yüksek |
| **Hız** | 1 Mbps-1 Gbps | 1 Mbps-150 Mbps | 1 Mbps-1 Gbps | 10 Mbps-10 Gbps | 1 Mbps-10 Mbps | 4 Mbps (Gbps) | 1 Mbps-10 Gbps | 1 Mbps-10 Gbps | 9.6 kbps-19.2 kbps |
| **Sinyal Zayıflaması** | Yüksek | Yüksek | Orta | Düşük | Düşük-Orta | Düşük-Orta | Değişken | Değişken | Düşük |
| **EMI** | Yüksek | Orta | Orta | Düşük | Yüksek | Yüksek | Yüksek | Yüksek | Orta |
| **Güvenlik** | Düşük | Düşük | Düşük | Yüksek | Düşük | Orta-Yüksek | Orta | Orta | Düşük |
| **Düğüm Ekleme** | Kolay | Kolay | Kolay | Zor | Kolay | Kolay | Kolay | Kolay | Kolay |
| **Mesafe** | Kısa | Kısa | Orta | Uzun | Orta-Uzun | Kısa-Uzun | Uzun | Uzun | Uzun |

# Multiplexing

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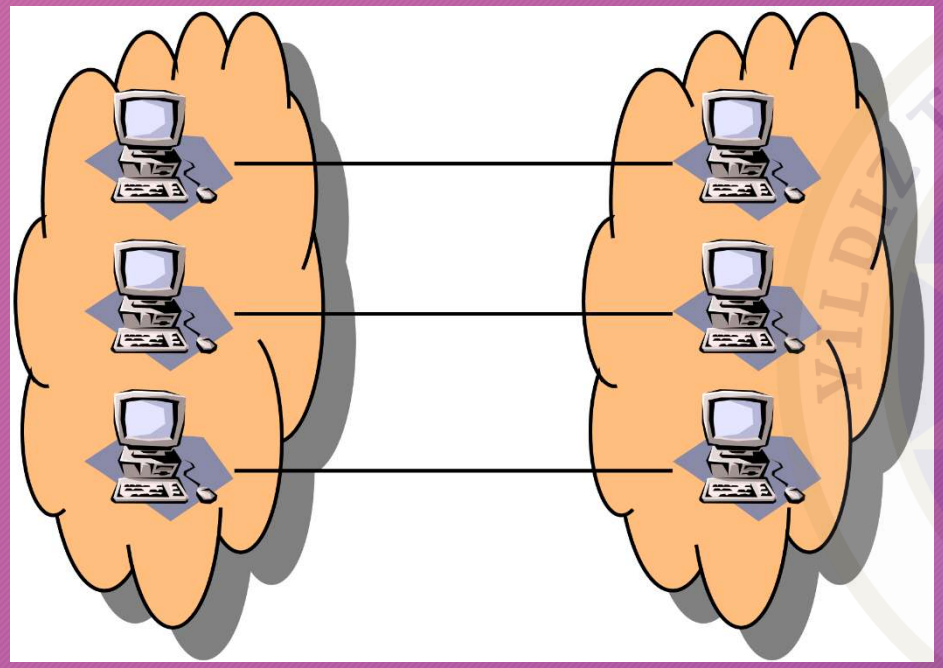

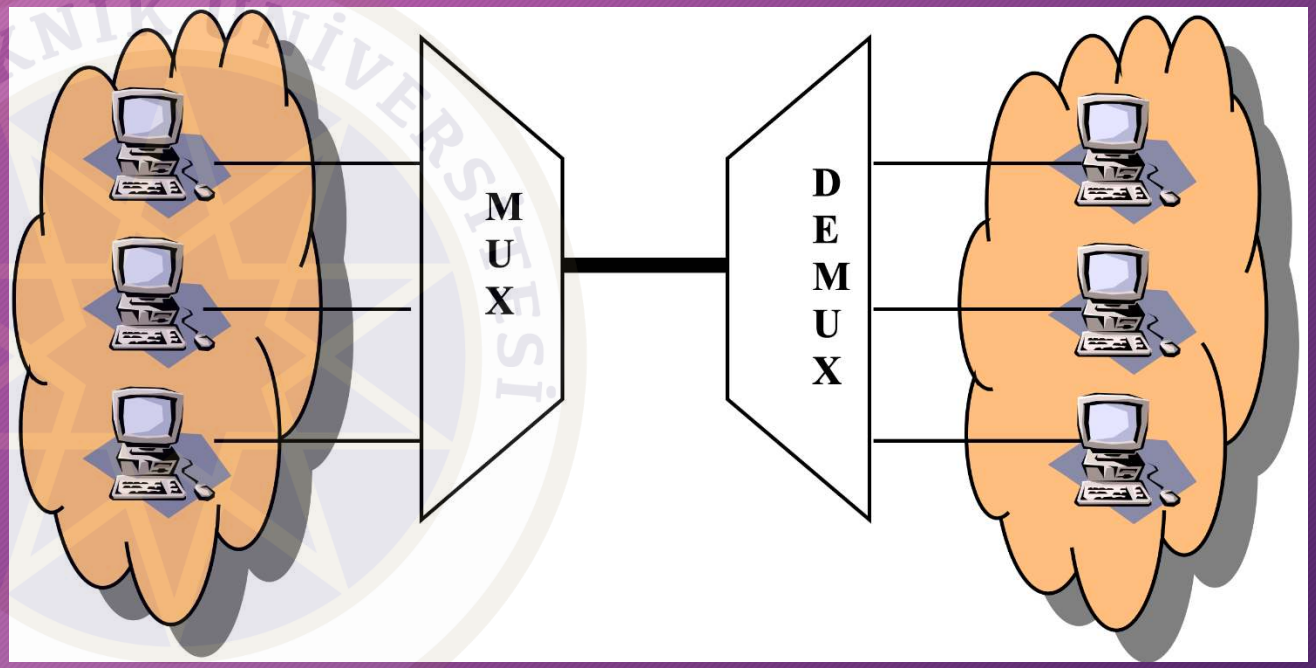

# Multiplexing Technics

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- *FDM (Frequency Division Multiplexing)*
- *WDM (Wavelength Division Multiplexing)*
- *TDM (Time Division Multiplexing)*

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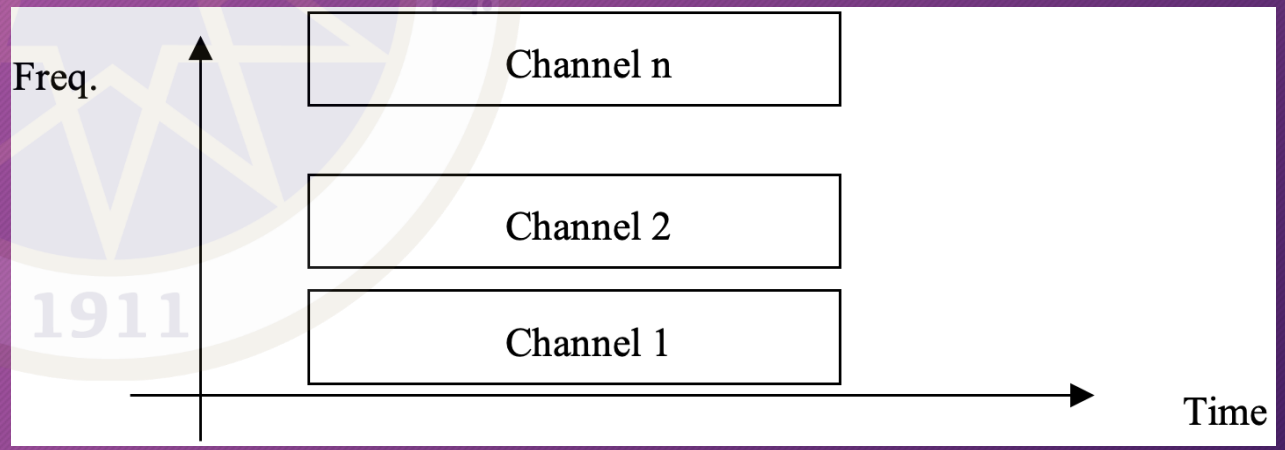
# FDM (Frequency Division Multiplexing)



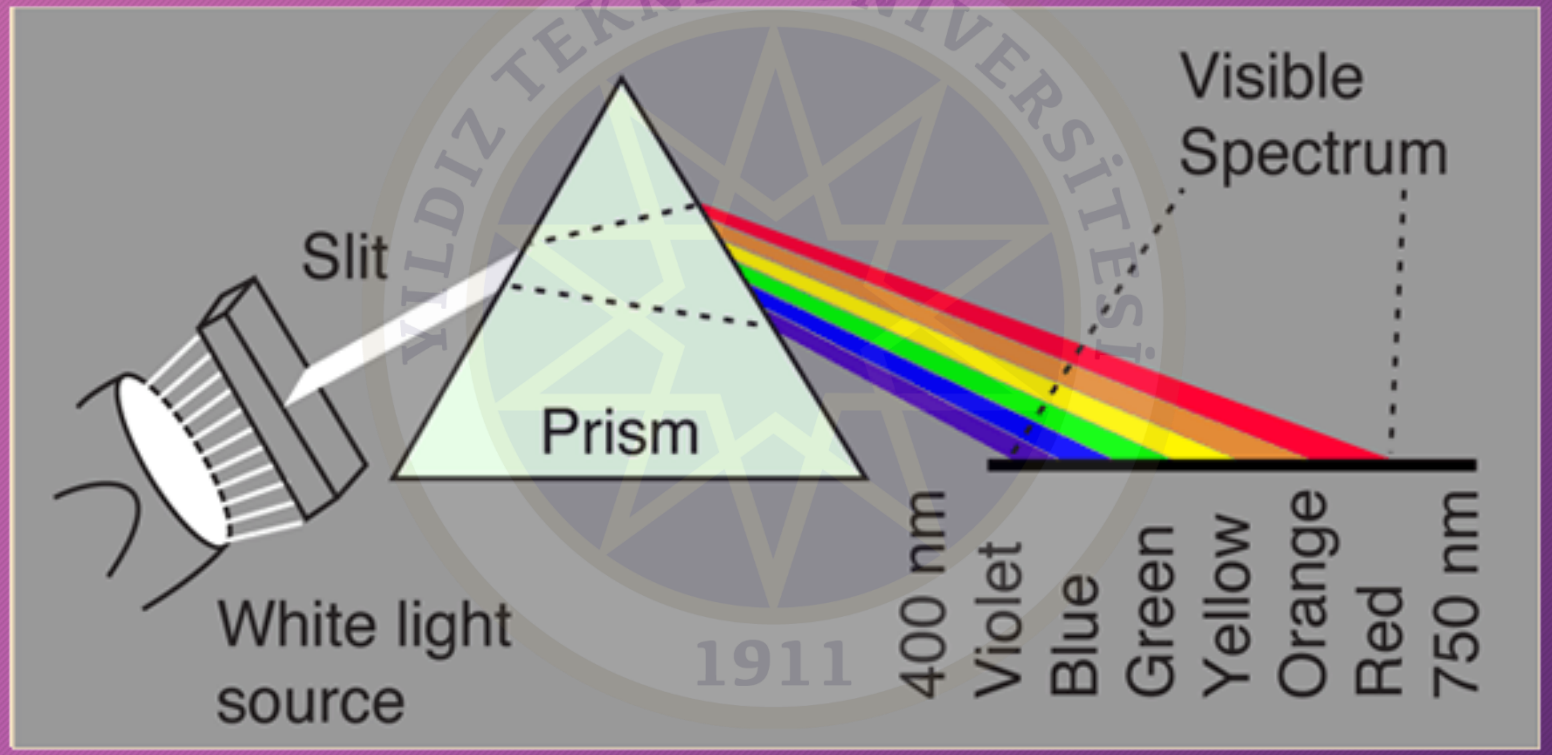
- $\sum(p2p\ BW) < total\ BW$
- Each signal has a different carriage signal
  - The signal to be sent is the sum of the carrier signals
  - Voice: 300-3300Hz BW
  - Guarded Band
- Television and radio broadcasts



# WDM (Wavelength Division Multiplexing)



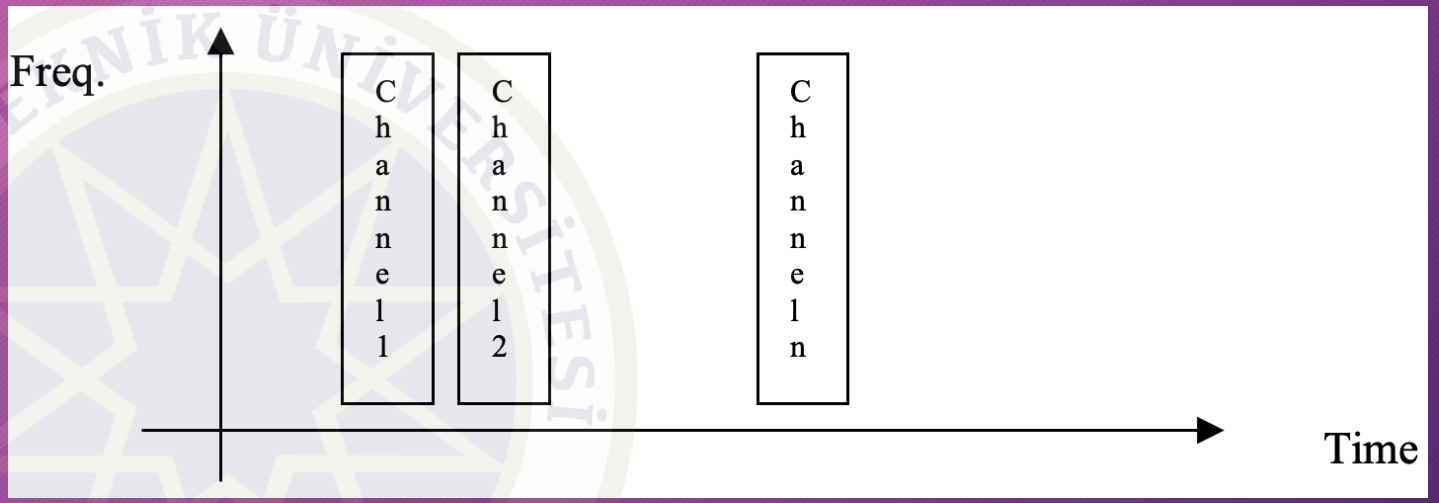
- Like FDM in FO



# TDM (Time Division Multiplexing)

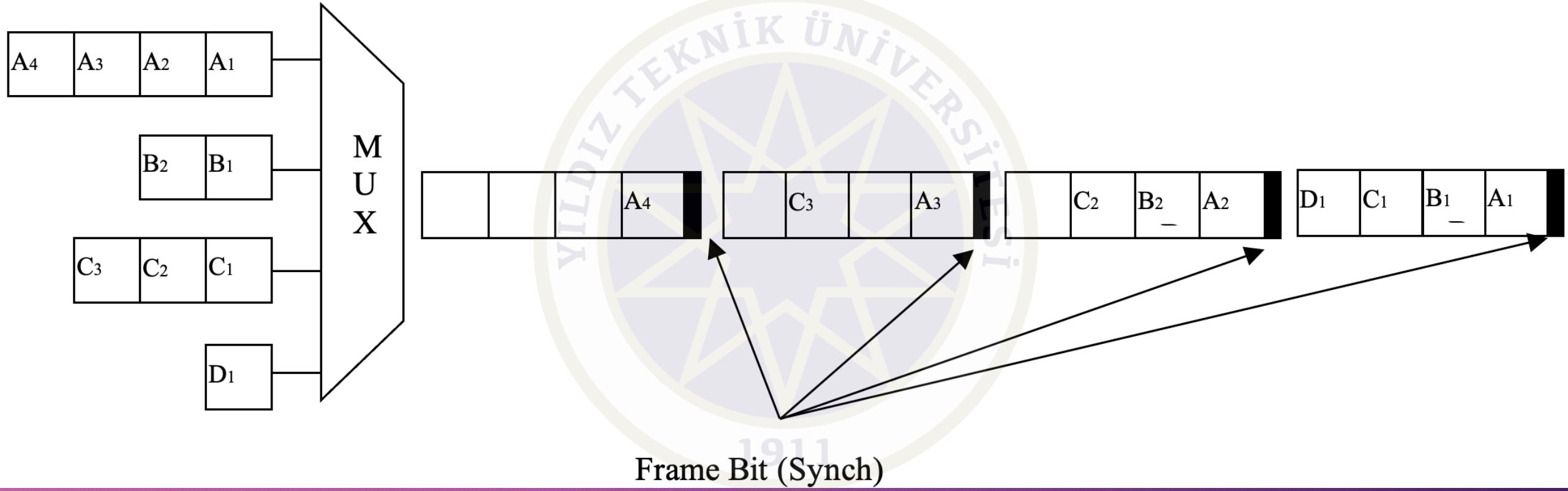


- $\max(p2p\ BW) < BW$
- 2 Types
  - Synchronous TDM
    - Data
    - Digitized Voice
  - Asynchronous TDM



# Synchronous TDM





# Synchronous TDM – Con't

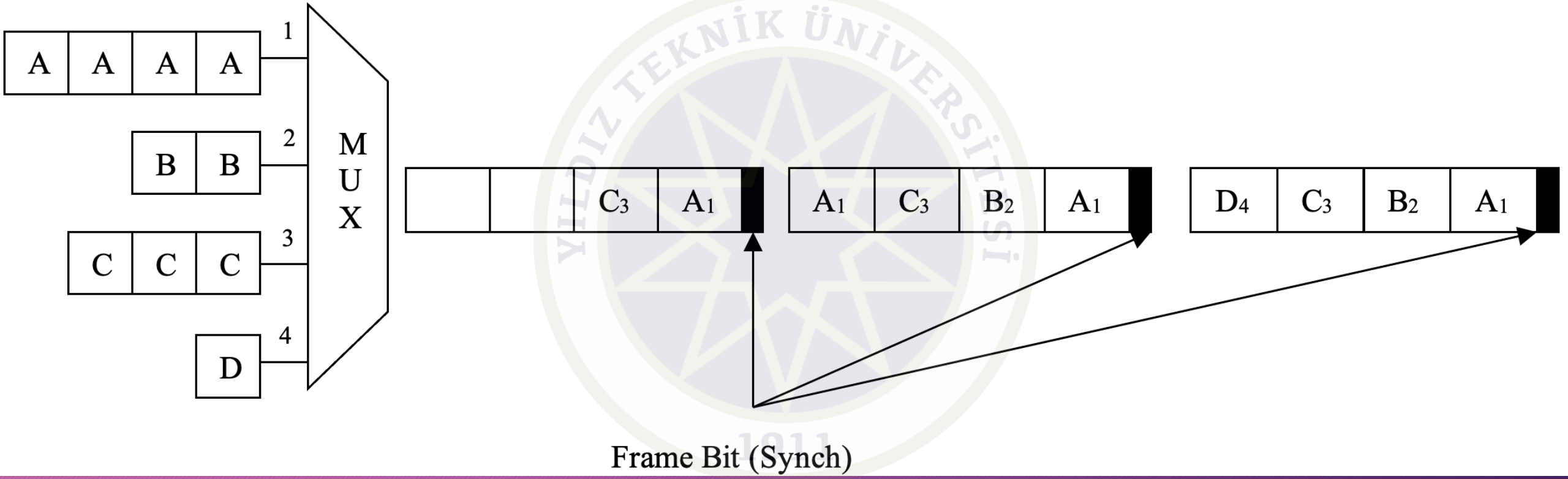


- Example
  - In Sync. TDM where 4 units are connected, each unit produces 250 characters / sec output.
  - 1 bit is used for each frame to ensure synchronization.
  - Each frame contains a character from each unit.
  - Accordingly, calculate the obtained data communication speed as bps.

- Answer:
  - 250 frame + 250 bit (for sync.)
  - 250 frame x (4 unit x 8 bits/unit) / frame + 250 bit = 8250 bps

# Asynchronous TDM





# Error Detection and Correction Techniques

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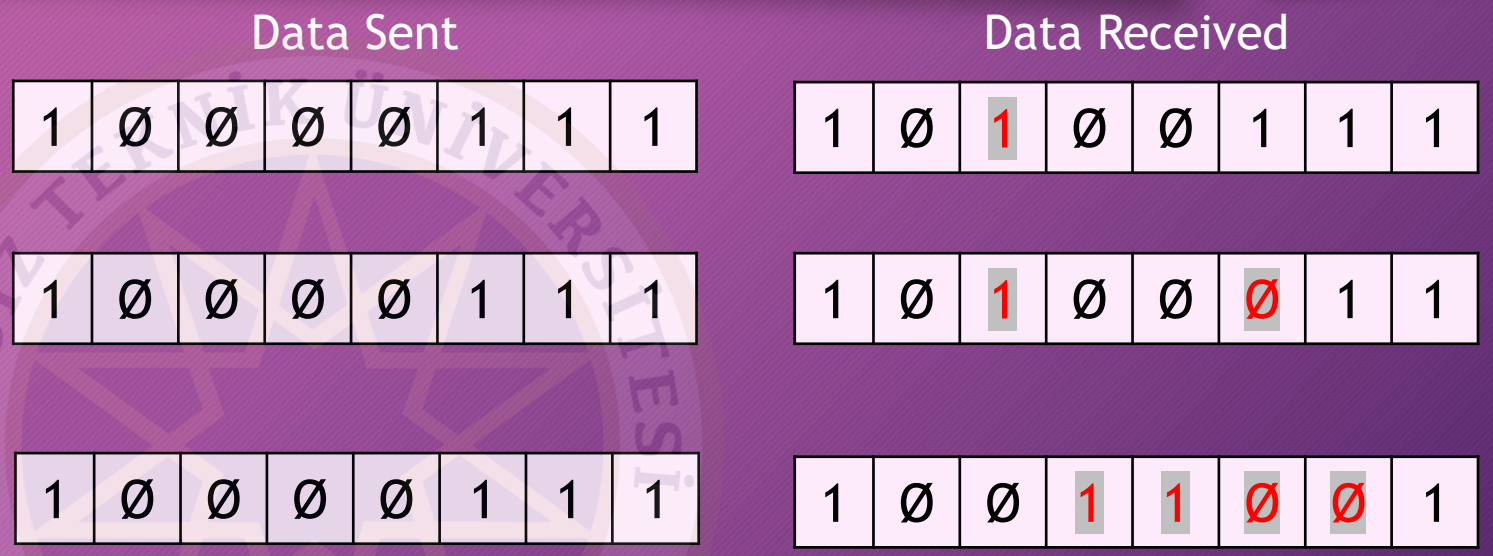
- Data Link Layer (in OSI model)
- Error reasons
  - Attenuation
  - Delay Distortion
    - Video + Voice
    - Problem in time sensitive conditions
  - Noise in the communication environment
    - Thermal noise
      - Random electron motion
    - Intermodulation noise
    - CrossTalk
    - Impulse Noise

# Error Types



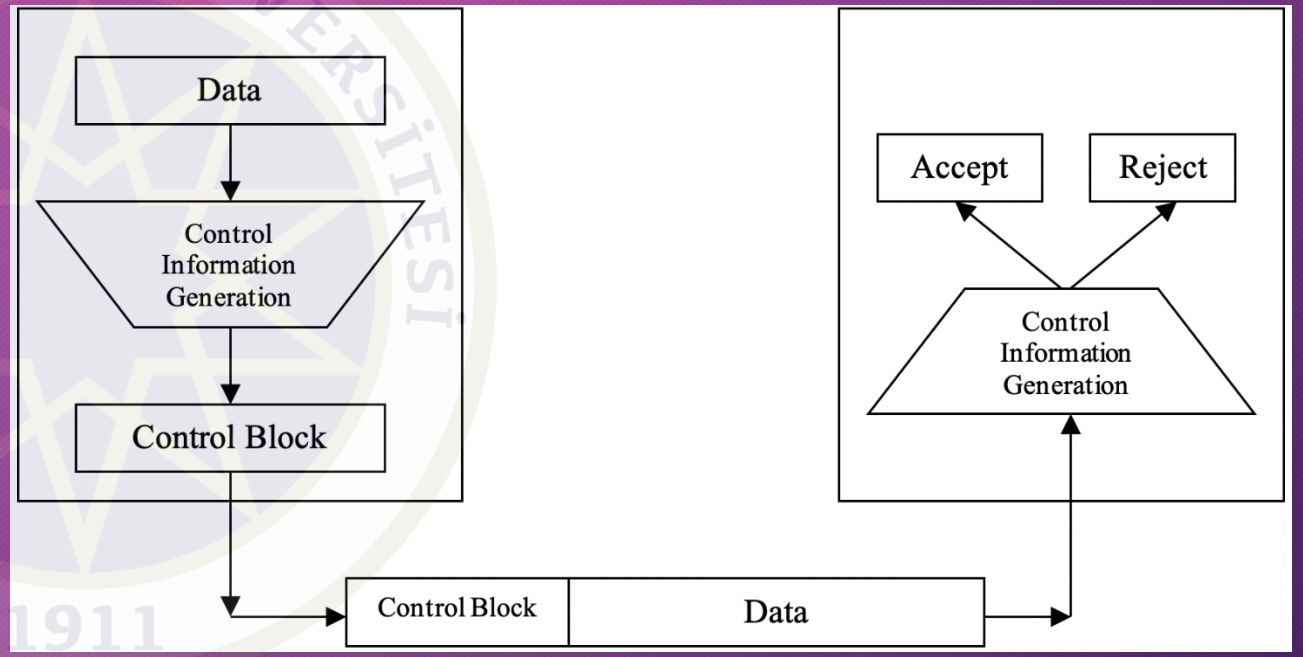
- Single bit error
- Multi bit error
- Error bursts



# Error Detection



- Both sides have original data?
- Sending data twice?
- Control block?
  - 4 different types
    - VRC (Vertical Redundency Code)
    - LRC (Longitudial Redundency Code)
    - CRC (Cyclic Redundency Check)
    - Checksum



# VRC (Vertical Redundency Code)



- Parity check
- Simple error coding technique
- The number of errors should be **odd**.
- XOR operation

Data Sent

| VRC | Data | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Ø | 1 | Ø | Ø | 1 | 1 | Ø |

Data Received 1

| VRC | Data | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Ø | 1 | Ø | Ø | 1 | 1 | Ø |

Data Received 2

| VRC | Data | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Ø | 1 | 1 | Ø | 1 | 1 | Ø |

Data Received 3

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Ø | 1 | 1 | Ø | 1 | Ø | Ø |

# LRC (Longitudial Redundency Code)



- LRC is 2D-VRC

| | Byte 1 | | Byte 2 | | Byte 3 | | Byte 4 | | LRC |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | | Ø | | 1 | | 1 | | 1 |
| | Ø | | Ø | | 1 | | 1 | | Ø |
| | Ø | | 1 | | Ø | | 1 | | Ø |
| | 1 | | 1 | | Ø | | 1 | | 1 |
| | 1 | | Ø | | 1 | | Ø | | Ø |
| | Ø | | 1 | | 1 | | Ø | | Ø |
| | 1 | | Ø | | Ø | | Ø | | 1 |
| VRC | Ø | | 1 | | Ø | | Ø | | 1 |

| | | | | |
|---|---|---|---|---|
| 1ØØ11Ø1Ø | ØØ11Ø1Ø1 | 11ØØ11ØØ | 1111ØØØØ | 1ØØ1ØØ11 |

| | | | | |
|---|---|---|---|---|
| 1ØØ11Ø1Ø | Ø*1*11Ø1*1*1 | 11ØØ11ØØ | 1*Ø*11ØØ*1*Ø | 1ØØ1ØØ11 |

# CRC (Cyclic Redundency Check)



- The data to be sent is divided into a predetermined prime polynomial.
- The remainder value is added to the data to be sent as an error control code.
- The remainder zero in receiver side means that error-free transmission.
- Common polynomials used for CRC: 13-bits, 17-bits, 33-bits
  - The number of undetectable errors is almost zero
- Commonly used polynomials in CRC technique:
  - CRC-12 $x^{12}+x^{11}+x^3+x+1$
  - CRC-16 $x^{16}+x^{15}+x^2+1$
  - CRC-ITU $x^{16}+x^{12}+x^5+1$
  - CRC-32 $x^{32}+x^{26}+x^{23}+x^{22}+x^{16}+x^{12}+x^{11}+x^{10}+x^8+x^7+x^5+x^4+x^2+x+1$

# CRC (Cyclic Redundancy Check) - Con’t



Example: Data Sent: 100100, polynom: $x^3 + x^2 + 1$, CRC = ?

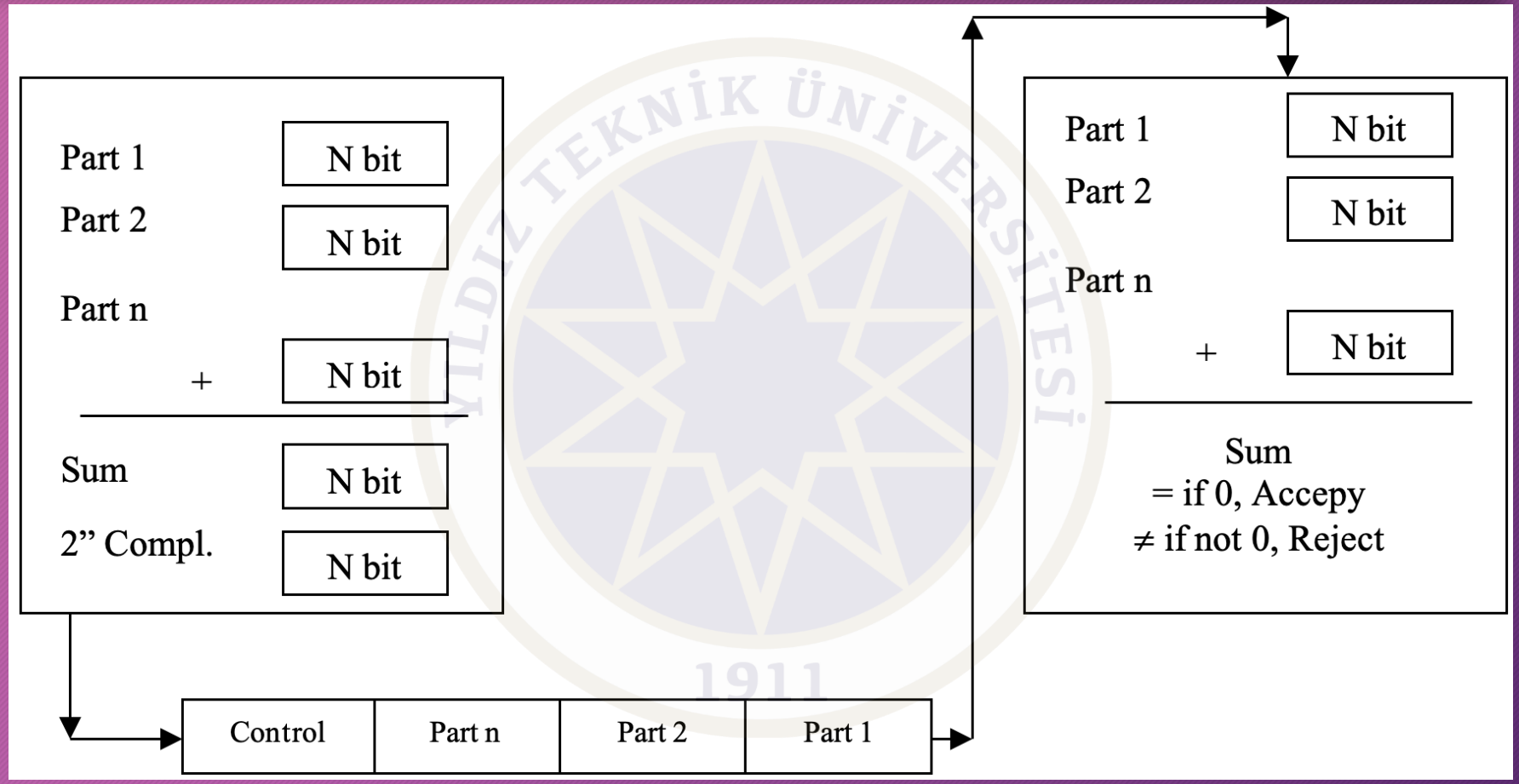
# Checksum



- The sender divides the data into N-bits parts (usually 16 bits are used).
- The parts are collected using the first complementary arithmetic.
  - In this way, a total value of only N bits is obtained.
- Calculate two's complement using summed value
  - The calculated value is added to the end of the information to be sent.
- The checksum detects all of the odd errors and most of the even numbers.
  - However, if one or more bits in a part are 0 when they are 1, but there is a 0 when 1 in another part, the error will not be understood because there will be no difference in this column sum.

# Checksum - Con't





# Error Correction



- 2 methods
  - Send data again
  - If one bit error
    - Hamming Code / Distance

# Hamming Code



- If we sent m bit data, the error occurs in 1,2,…,m bit
- Adding error-free state, the data length will be m+1
- Control block length must be $log_2(m+1) \leq r$
- $m+r$ bit must be sent error-free
- So, control block length must be $log_2(m+r+1) \leq r$
- (1, 2, 4, 8, 16. bits)

| $B_{11}$ | $B_{10}$ | $B_9$ | $B_8$ | $B_7$ | $B_6$ | $B_5$ | $B_4$ | $B_3$ | $B_2$ | $B_1$ |
|---|---|---|---|---|---|---|---|---|---|---|
| $D_7$ | $D_6$ | $D_5$ | $R_4$ | $D_4$ | $D_3$ | $D_2$ | $R_3$ | $D_1$ | $R_2$ | $R_1$ |

# Hamming Code – Con't



- $R_1=B_1 \oplus B_3 \oplus B_5 \oplus B_7 \oplus B_9 \oplus B_{11}$
- $R_2=B_2 \oplus B_3 \oplus B_6 \oplus B_7 \oplus B_{10} \oplus B_{11}$
- $R_3=B_4 \oplus B_5 \oplus B_6 \oplus B_7$
- $R_4=B_8 \oplus B_9 \oplus B_{10} \oplus B_{11}$

| $B_{11}$ | $B_{10}$ | $B_9$ | $B_8$ | $B_7$ | $B_6$ | $B_5$ | $B_4$ | $B_3$ | $B_2$ | $B_1$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | | 1 | 1 | 0 | | 1 | | |

- $R_1=B_3 \oplus B_5 \oplus B_7 \oplus B_9 \oplus B_{11}$ $= 1 \oplus 0 \oplus 1 \oplus 0 \oplus 1$ $= 1$
- $R_2=B_3 \oplus B_6 \oplus B_7 \oplus B_{10} \oplus B_{11}$ $= 1 \oplus 1 \oplus 1 \oplus 0 \oplus 1$ $= 0$
- $R_3=B_5 \oplus B_6 \oplus B_7$ $= 0 \oplus 1 \oplus 1$ $= 0$
- $R_4=B_9 \oplus B_{10} \oplus B_{11}$ $= 0 \oplus 0 \oplus 1$ $= 1$

| $B_{11}$ | $B_{10}$ | $B_9$ | $B_8$ | $B_7$ | $B_6$ | $B_5$ | $B_4$ | $B_3$ | $B_2$ | $B_1$ |
|---|---|---|---|---|---|---|---|---|---|---|
| $D_7$ | $D_6$ | $D_5$ | $R_4$ | $D_4$ | $D_3$ | $D_2$ | $R_3$ | $D_1$ | $R_2$ | $R_1$ |

| | $R_4$ | $R_3$ | $R_2$ | $R_1$ | Info |
|---|---|---|---|---|---|
| **0** | 0 | 0 | 0 | 0 | Error-free |
| **1** | 0 | 0 | 0 | 1 | 1. bit error |
| **2** | 0 | 0 | 1 | 0 | 2. bit error |
| **3** | 0 | 0 | 1 | 1 | 3. bit error |
| **4** | 0 | 1 | 0 | 0 | 4. bit error |
| **5** | 0 | 1 | 0 | 1 | 5. bit error |
| **6** | 0 | 1 | 1 | 0 | 6. bit error |
| **7** | 0 | 1 | 1 | 1 | 7. bit error |
| **8** | 1 | 0 | 0 | 0 | 8. bit error |
| **9** | 1 | 0 | 0 | 1 | 9. bit error |
| **10** | 1 | 0 | 1 | 0 | 10. bit error |
| **11** | 1 | 0 | 1 | 1 | 11. bit error |

# Thank you for your listening.

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