Data Communication and Computer Network
BLM3051

Dr. Öğr. Üyesi Furkan ÇAKMAK

Lecture Information Form - Weekly Subjects

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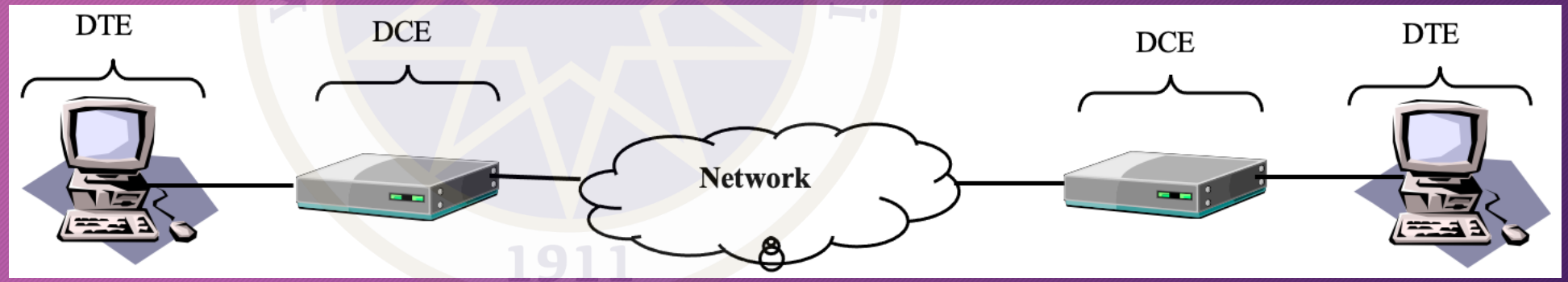
Hafta	Tarih	Konular
1	20.02.2024	Introduction to Data Communication Standards Used on Data Communication, Architectural models
2	27.02.2024	OSI Reference Model , Layers and Their Functions, Signaling and Signal Encoding
3	05.03.2024	Parallel and Serial Transmission, Communication Media and Their Technical 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.

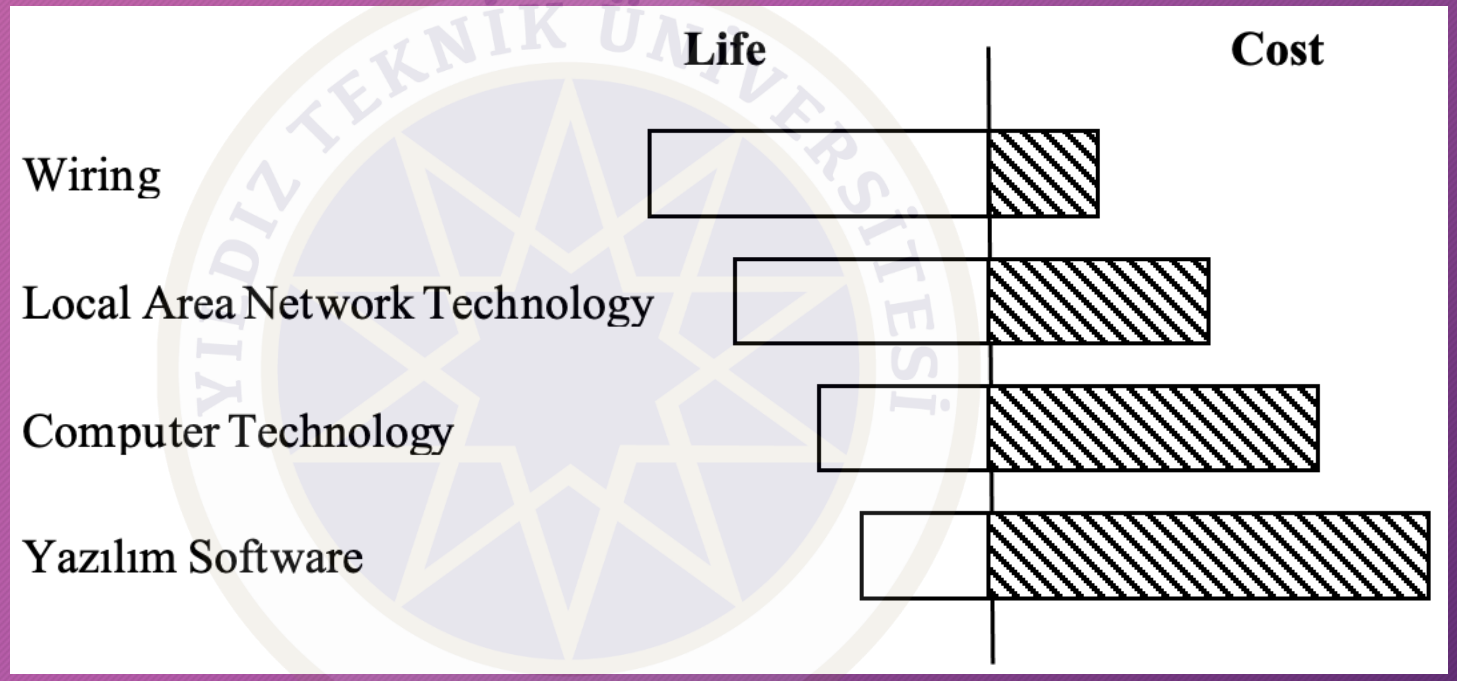


DTE-DCE Interfaces – Con't

- 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

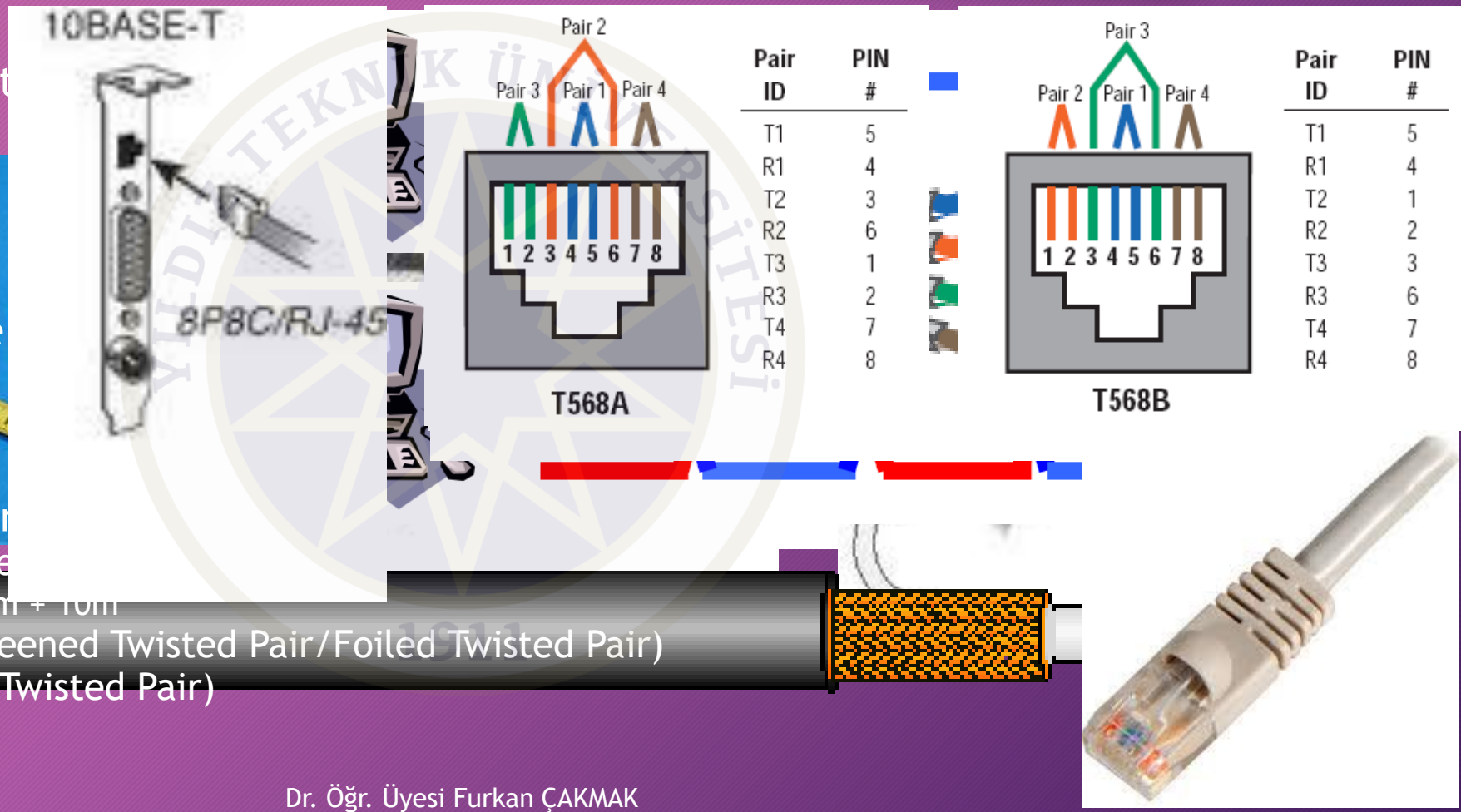
Transmission Medium

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



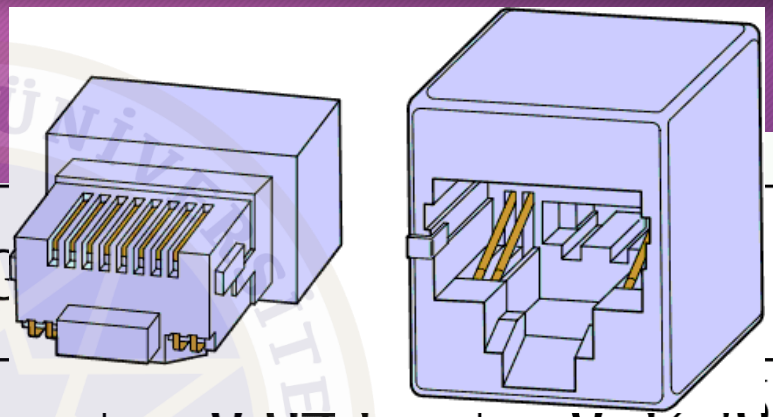
Guided Media

- 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

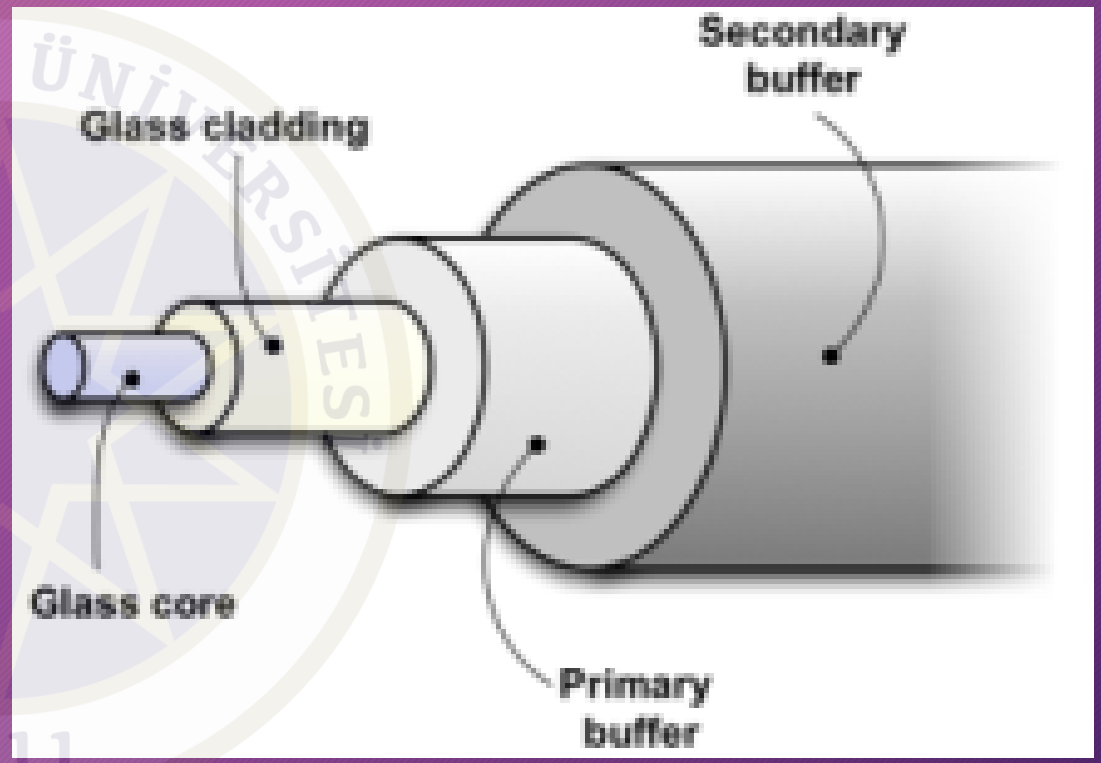


Classification of UTP Cables

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

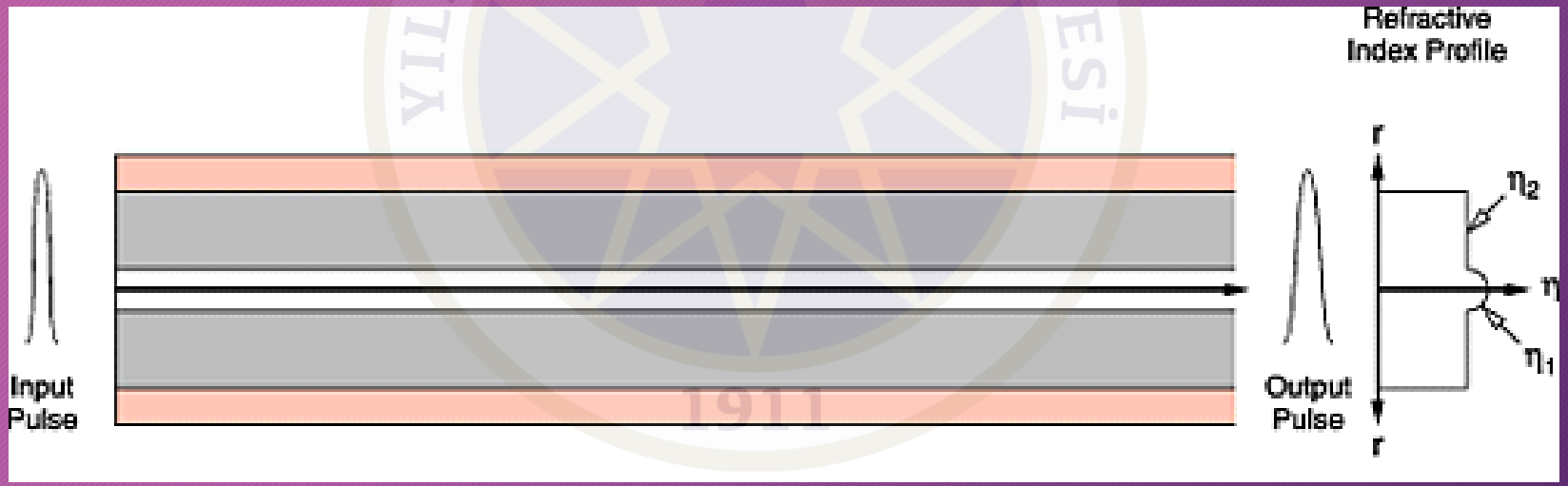
Guided Media – Fiber Optic Cabels

- ~~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)



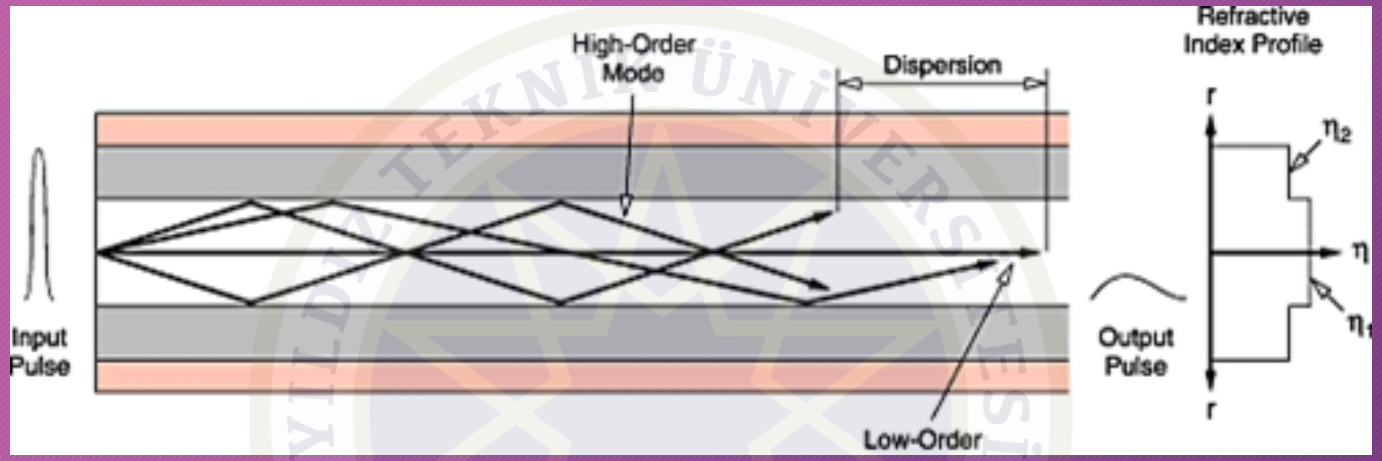
Guided Media – Fiber Optic Cabels – Con't

- 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

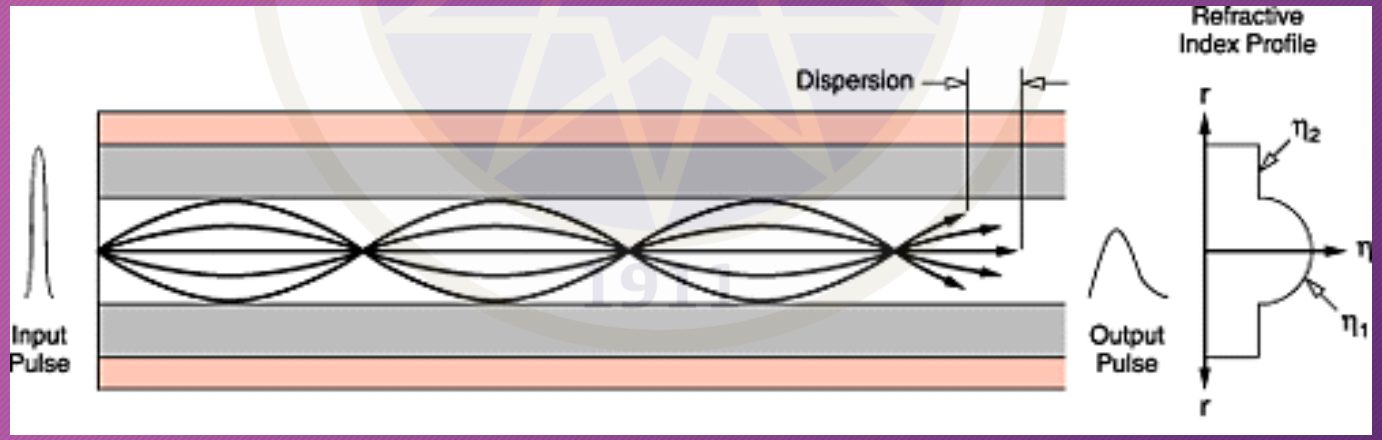


Guided Media – Fiber Optic Cabels – Con't

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

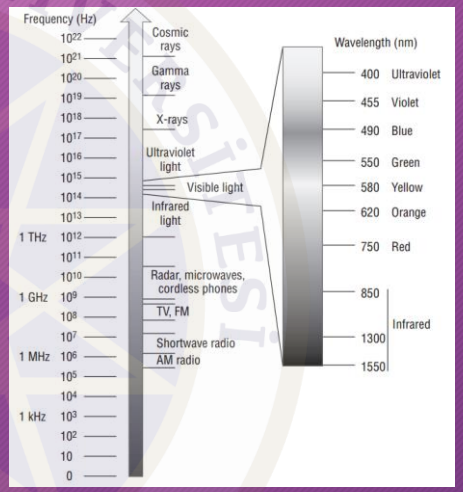
- Broad Bandwidth
- Immunity to Electromagnetic Interference
- Attenuation
- Insulation
- Space Saving
- Security
  - Eavesdrop

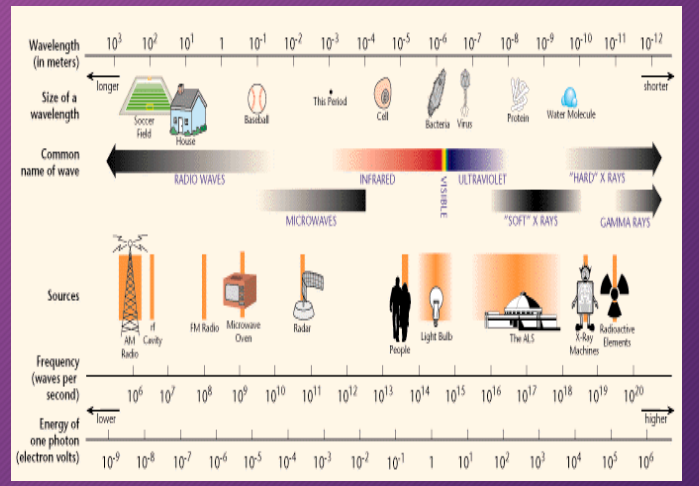
Things to Consider When using Fiber Optic Cables

- 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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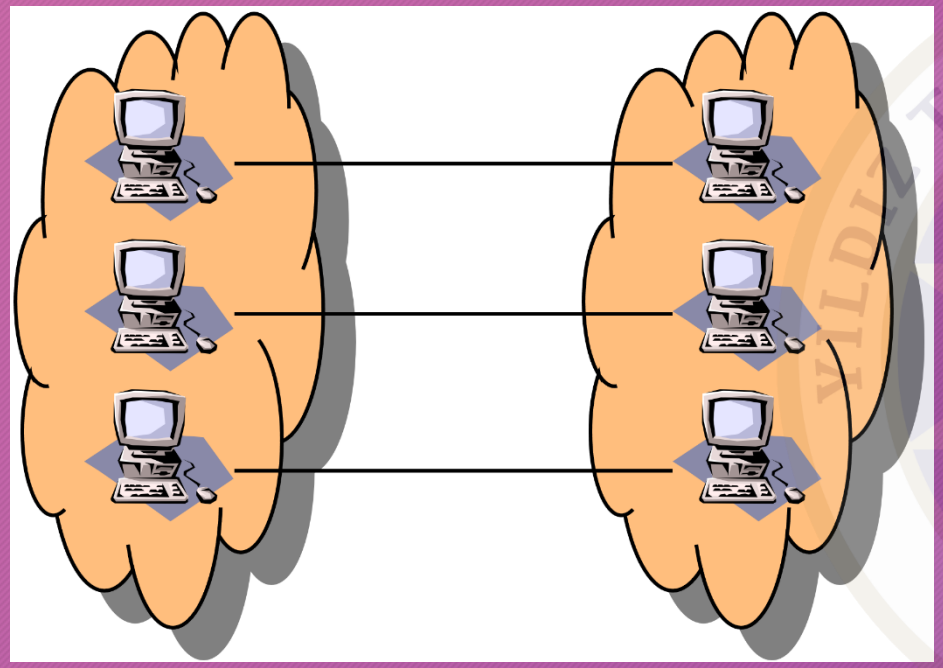

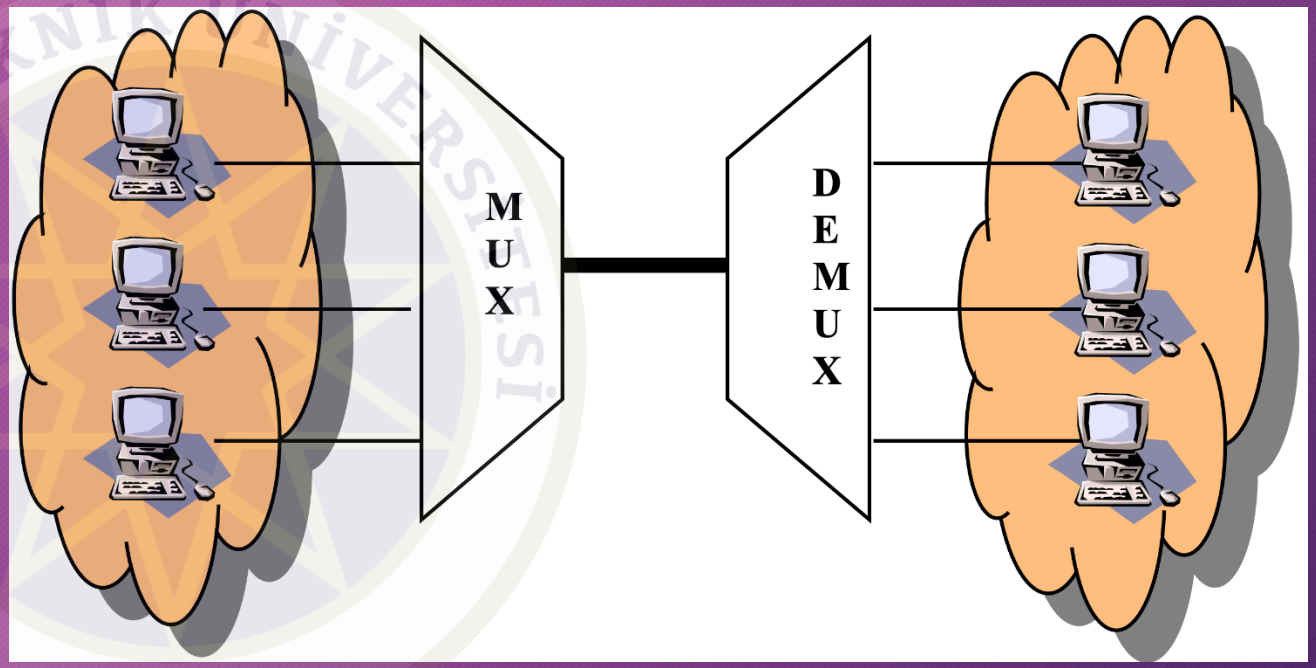

Multiplexing Technics

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

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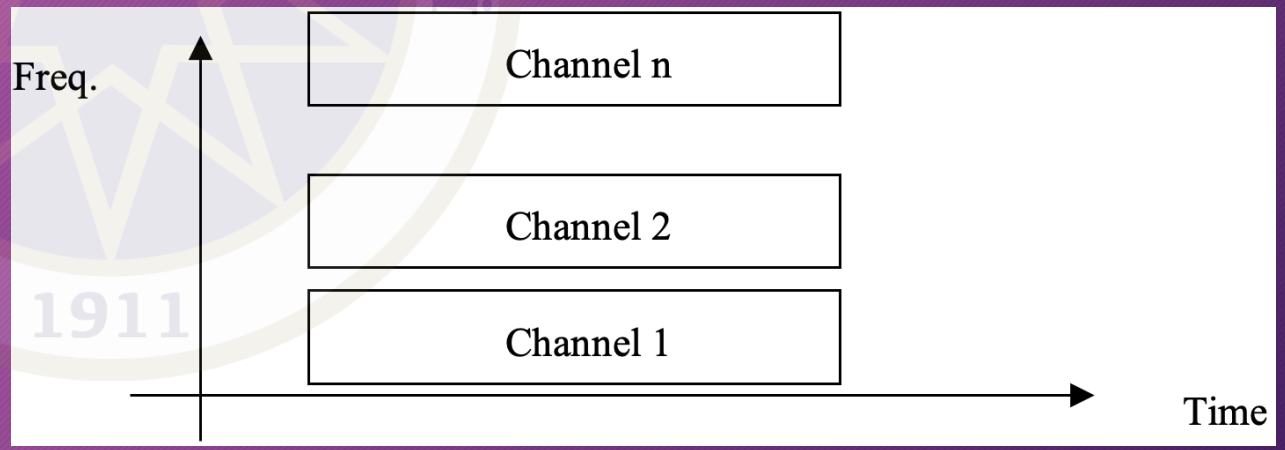
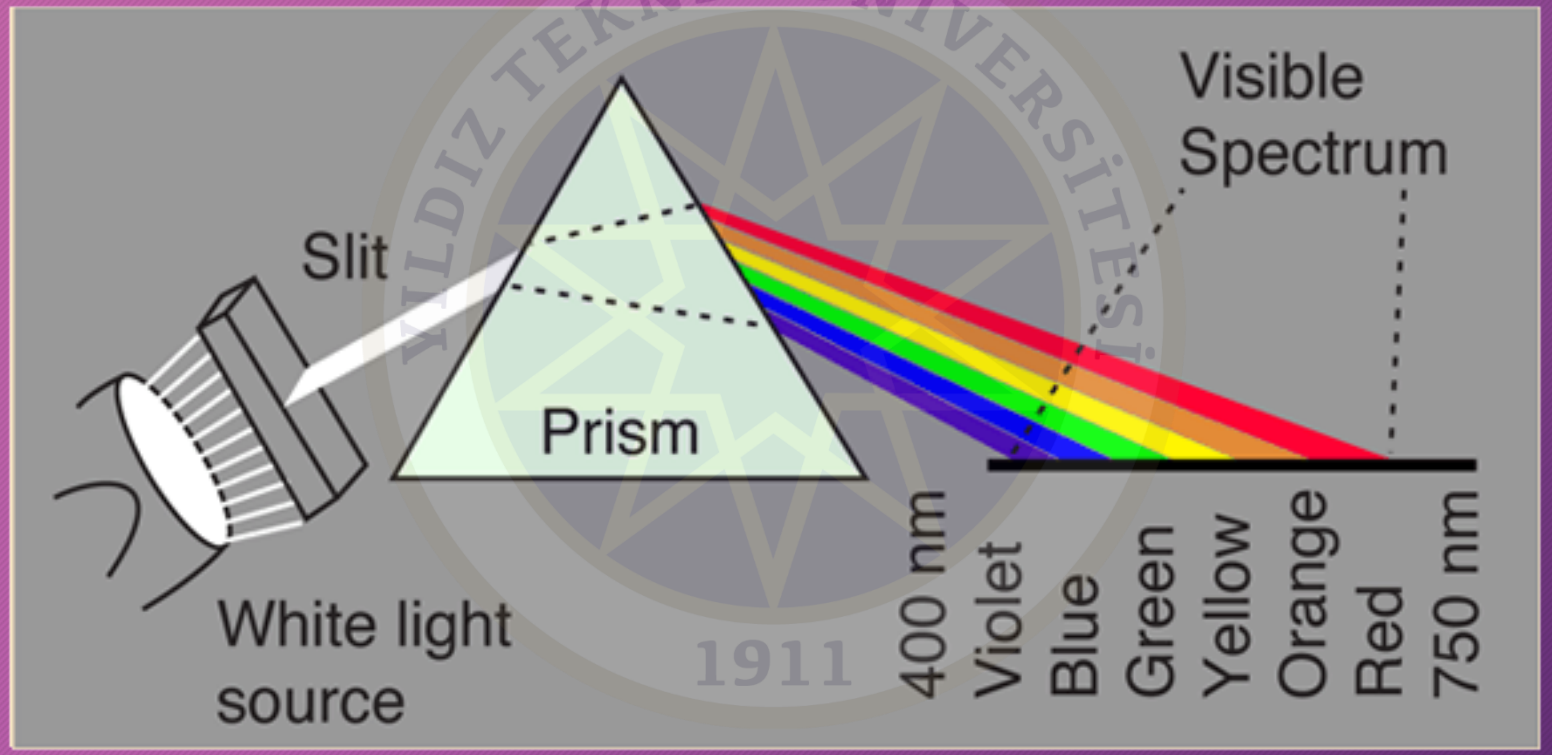
FDM (Frequency Division Multiplexing)

- $\sum(p2p\ BW) < total\ BW$
- 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



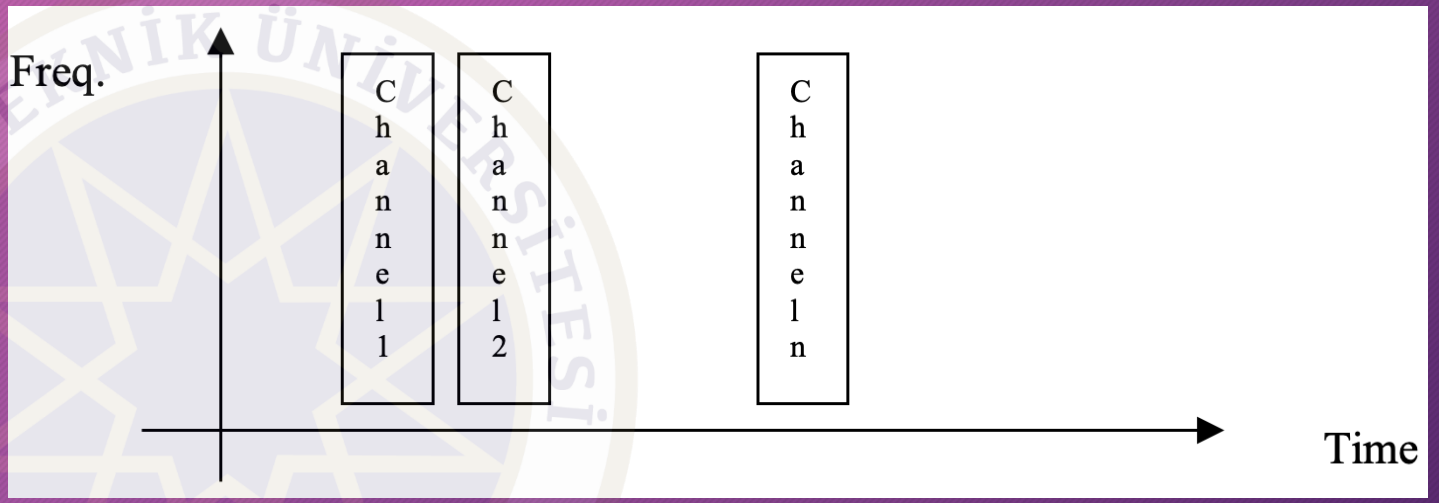
WDM (Wavelength Division Multiplexing)

- Like FDM in FO

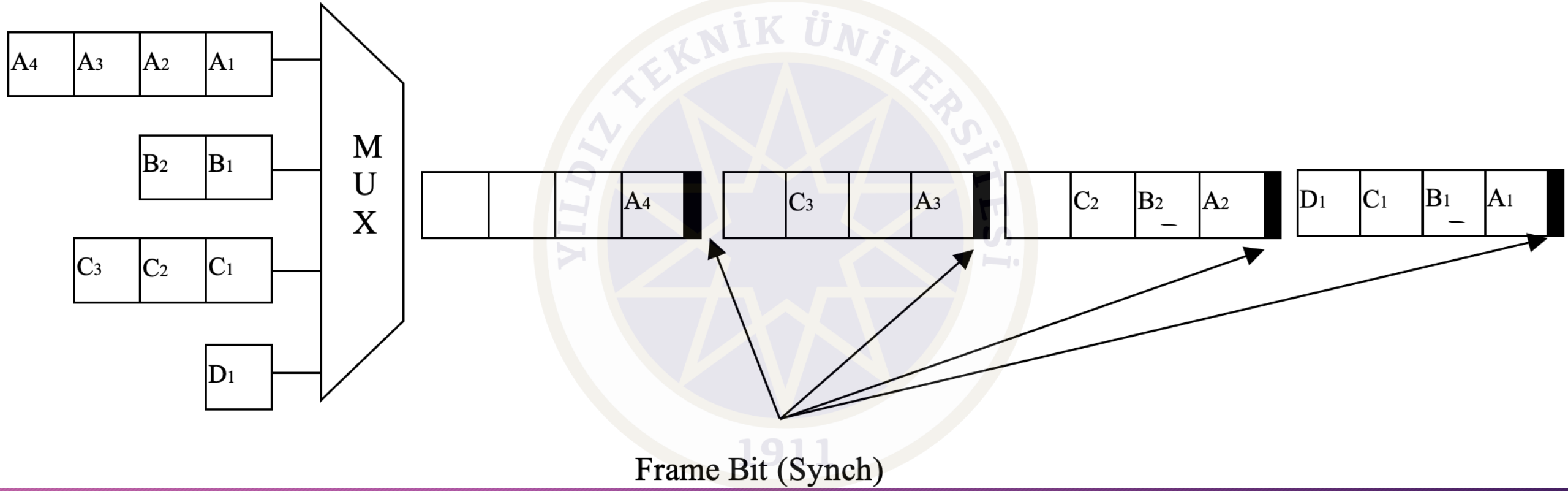


TDM (Time Division Multiplexing)

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



Synchronous TDM

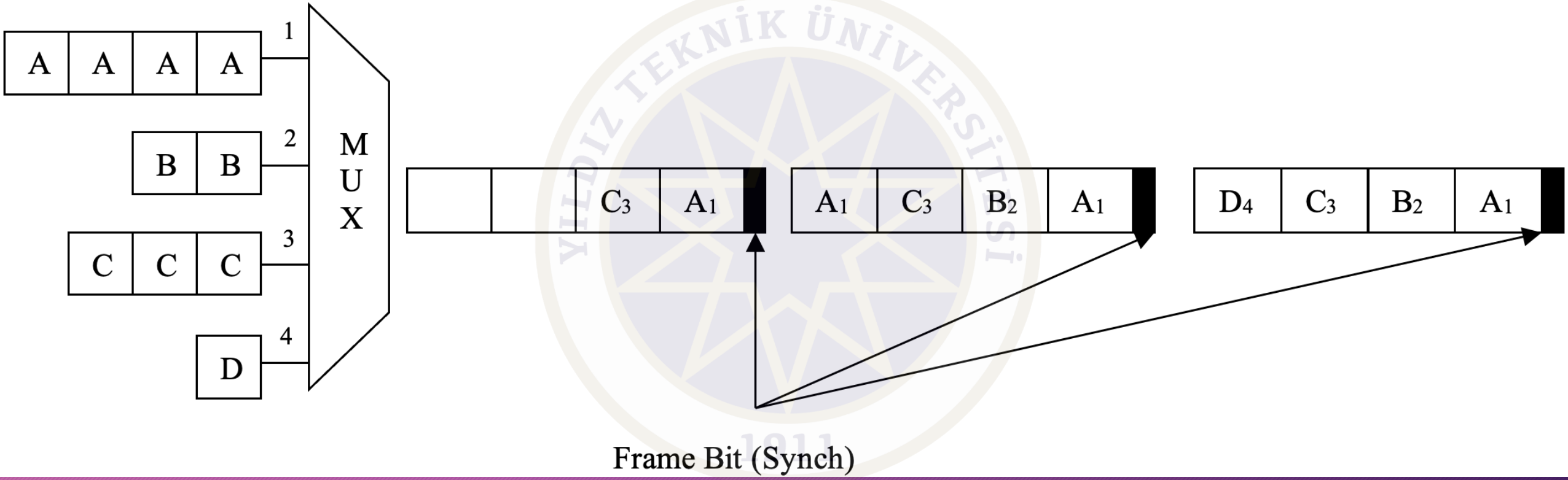


Synchronous TDM – Con't

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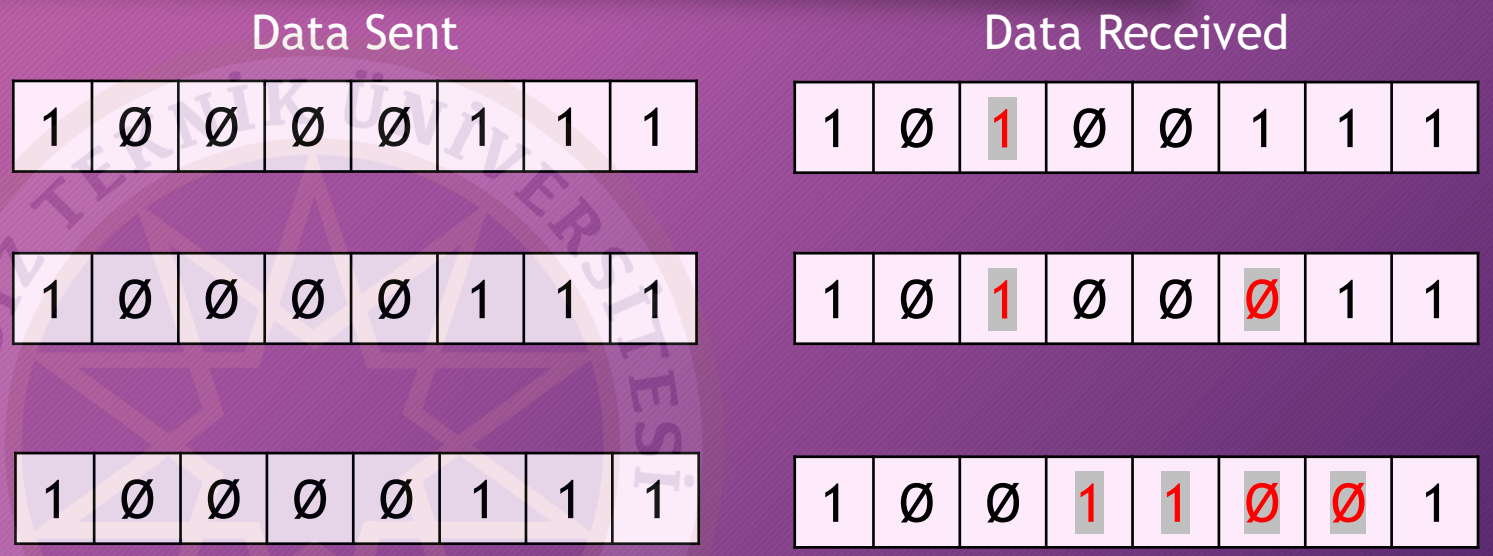
- Data Link Layer (in OSI model)
- Error reasons
  - Attenuation
  - Delay Distortion
    - Video + Voice
    - Problem in time sensitive conditions
  - Noise in the communication environment
    - Thermal noise
      - Random electron motion
    - Intermodulation noise
    - CrossTalk
    - Impulse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

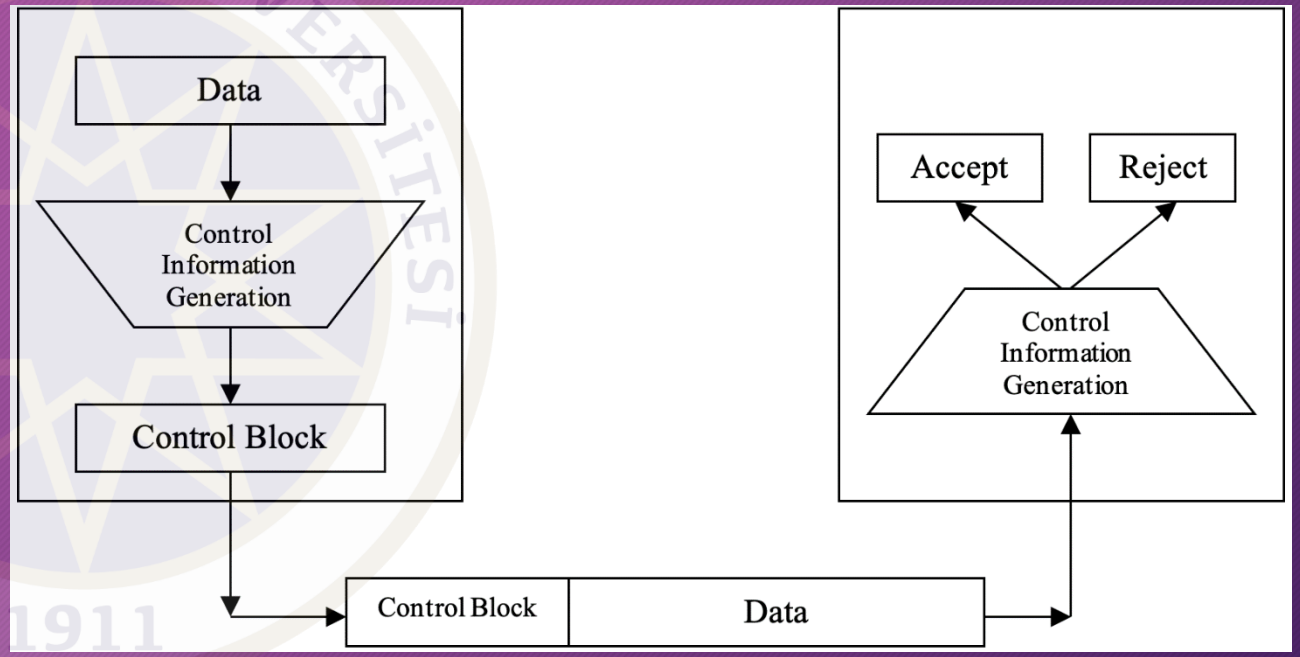
Error Types

- 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

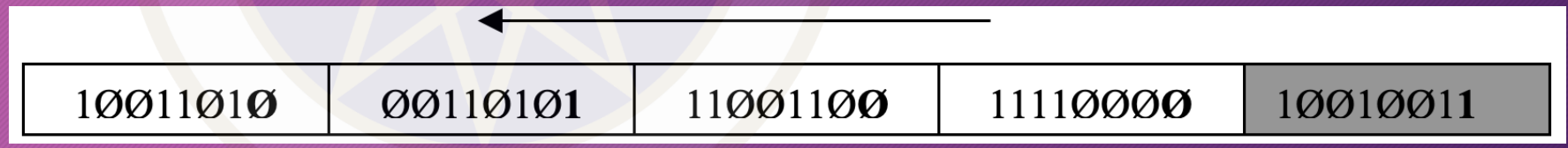
Data Received 3

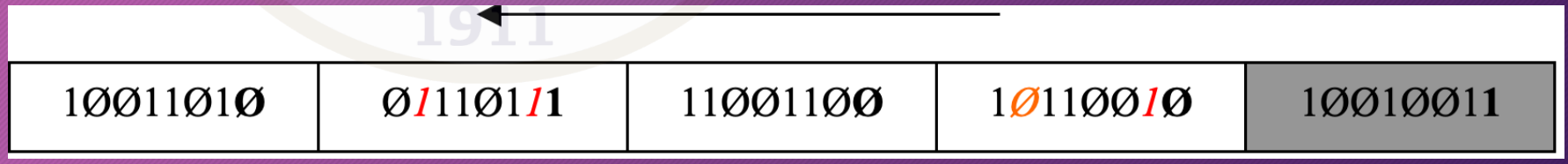
1	Ø	1	1	Ø	1	Ø	Ø

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





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 $x^{32}+x^{26}+x^{23}+x^{22}+x^{16}+x^{12}+x^{11}+x^{10}+x^8+x^7+x^5+x^4+x^2+x+1$

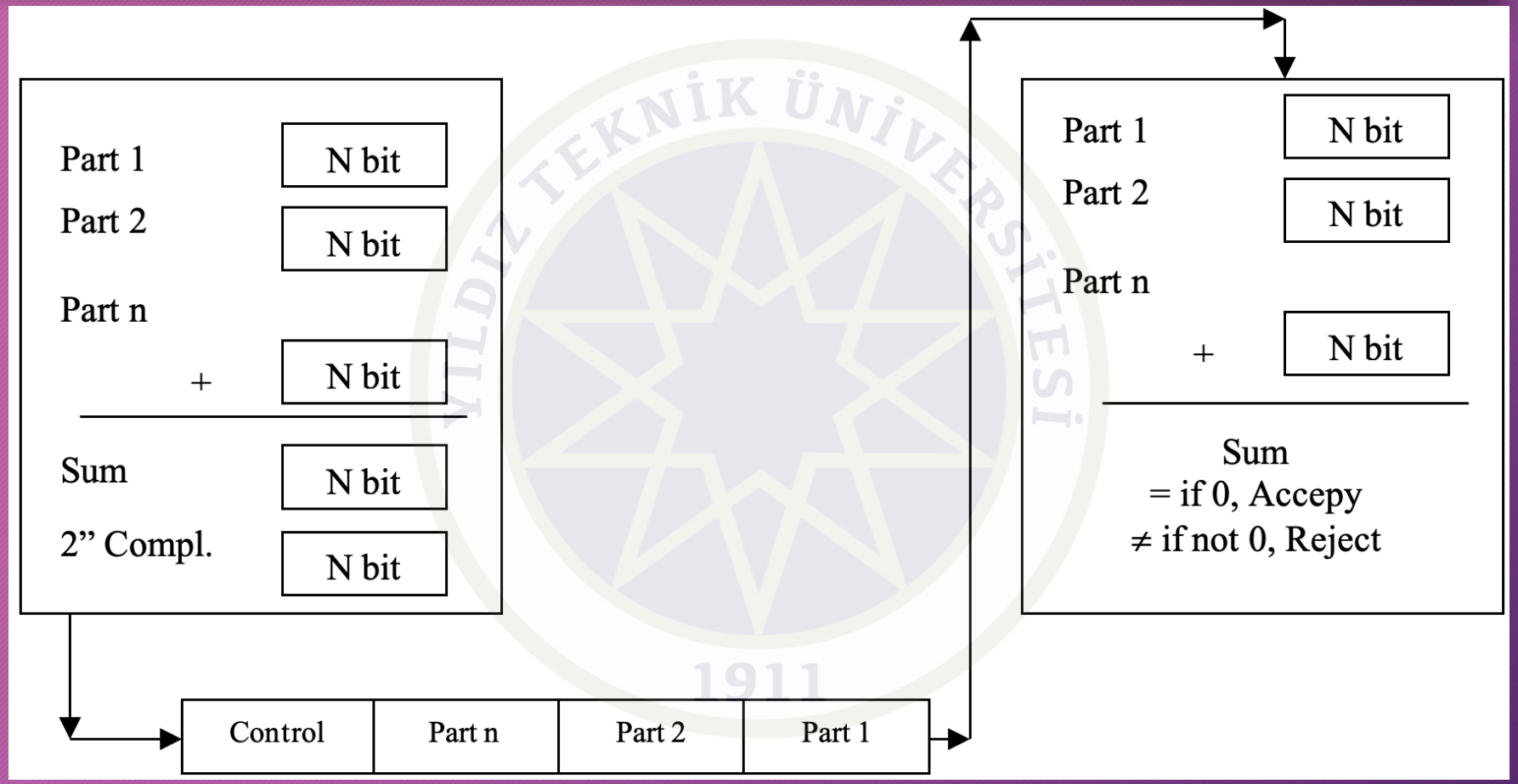
CRC (Cyclic Redundency Check) - Con’t

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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