Data Communication and Computer Network

BLM3051

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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)

Data Link Control

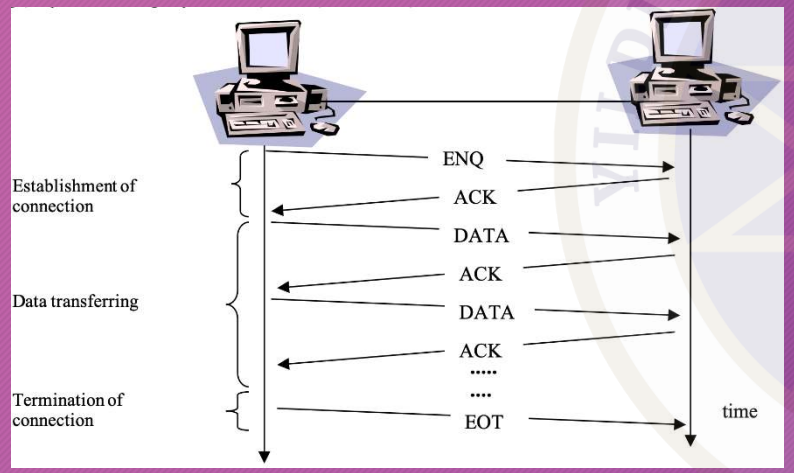
- Basic tasks of the data link layer:
  - Framming and determining of start and end points to ensure synchronization
  - Flow control
  - Error control / Retransmission
  - Addressing
  - Line dicipline / Link management

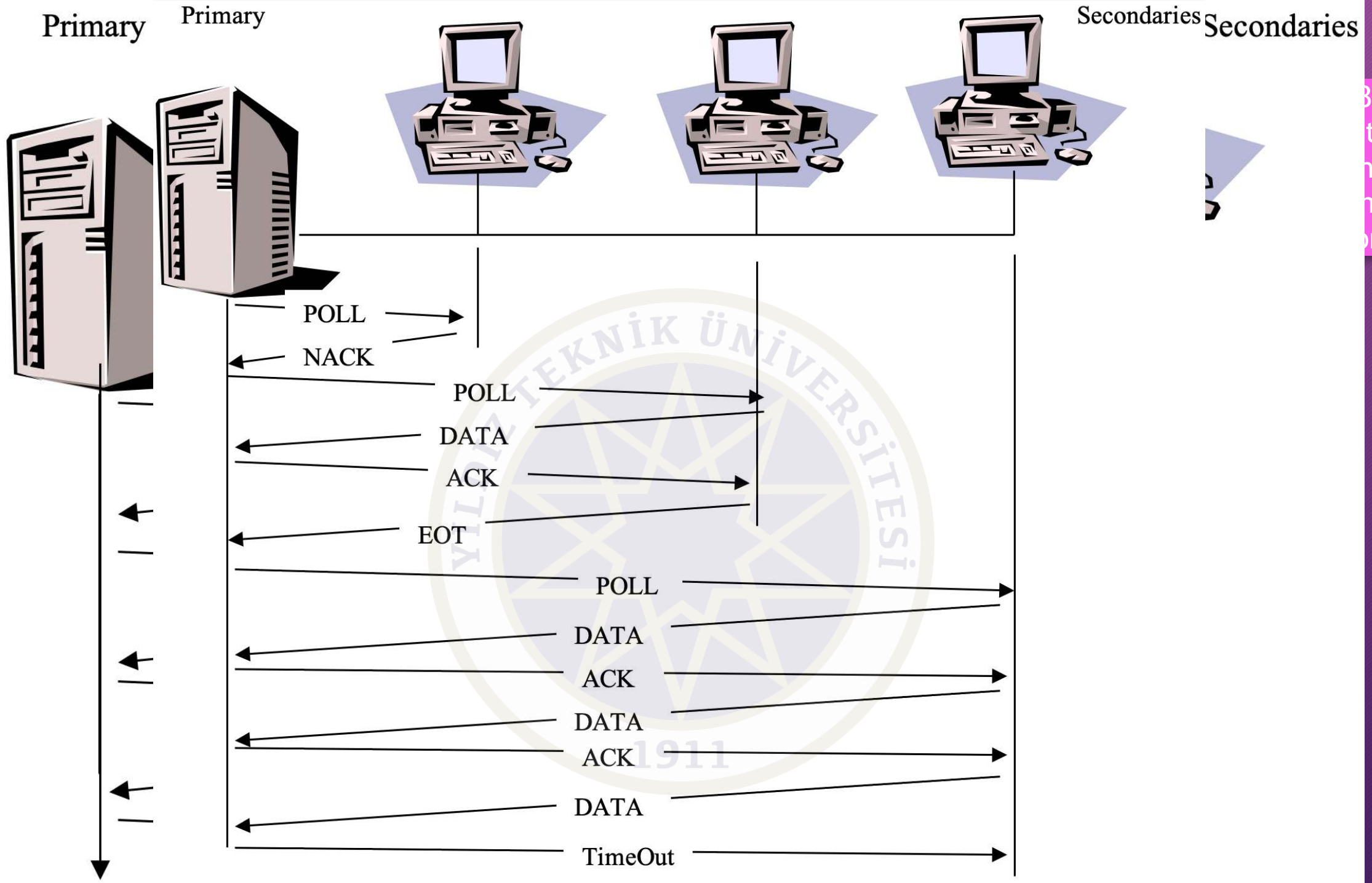
Line Dicipline / Link Management

- Enq/Ack (Enquiry/Acknowledgement)
- Poll/Select Connection Management

Enq/Ack (Enquiry/Acknowledgement)

- Point to point (in WANs)
- Units are expected to have equal properties




Primary
Primary
Secondaries
Secondaries
POLL
NACK
POLL
DATA
ACK
EOT
POLL
DATA
ACK
DATA
ACK
DATA
TimeOut

Flow Control

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- Overwhelm
- Buffer
- There are two basic techniques:
  - Stop & Wait
  - Sliding Window

Stop & Wait

- ACK is required for every transfer.
- Pros:
  - Packages consist of smaller pieces
  - Effective use of buffers
  - Medium is busy for a shorter time
  - Error probability decreases
  - Error control processing times are shortened.
  - Wait time may be shorter for other devices in LANs.

Stop & Wait – Line Utilization (U) Rate

- t_{frame}: Transmission time of a single frame
- t_{prop}: The time it takes from the sender to the receiver
- t_{ack}: The time it takes for all bits of the ACK to exit the receiver
- $T_F = t_{frame} + t_{prop} + t_{ack} + t_{prop}$
- $T_F = t_{frame} + 2t_{prop}$
- $U = \frac{t_{frame}}{t_{frame}+2t_{prop}}$
- $a = \frac{t_{prop}}{t_{frame}} \Longrightarrow U = \frac{1}{1+2a}$
- $t_{prop} = \frac{distance}{velocity} = \frac{d}{v}$ and $t_{frame} = \frac{frameSize}{dataRate} = \frac{L}{R}$

Stop & Wait – Line Utilization (U) Rate – Con't

- Example:
  - Data communication is made between two points at a distance of 1000 km (d = 1000 km = 10^6 m) at a speed of 155.52 Mbps (R=155.52 10^6 bit/sec).
  - The transmission speed of the line is 200.000.000 m/sec (V=2 10^8 m/sec).
  - Frame size is 424 bits (L = 424 bit).
  - What is the Line Utilization (U) in Stop & Wait Flow Control mode?

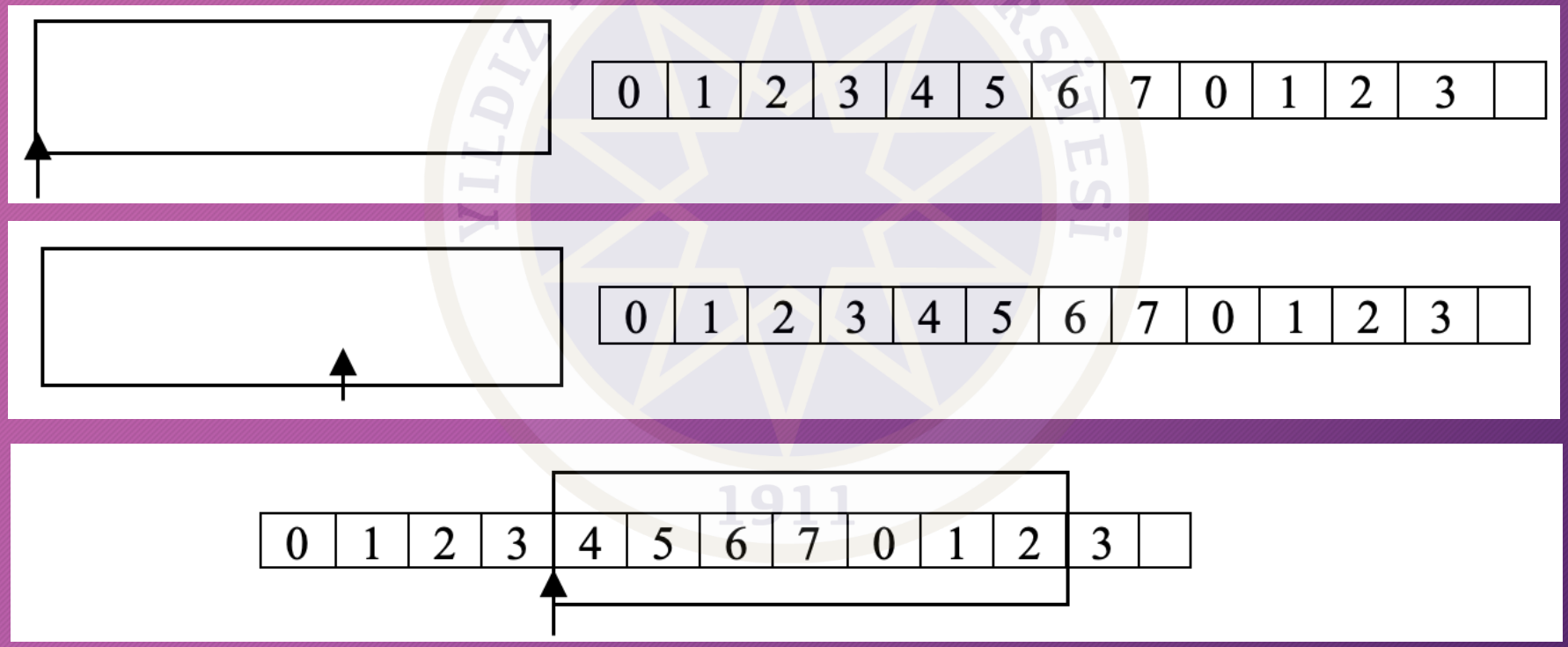
- Answer
  - $a = \frac{t_{prop}}{t_{frame}} \Rightarrow U = \frac{1}{1+2a}$
  - $t_{prop} = \frac{distance}{velocity} = \frac{d}{v}$ and $t_{frame} = \frac{frameSize}{dataRate} = \frac{L}{R}$
  - $\frac{\frac{10^6}{155{,}52x10^6}}{\frac{424}{2x10^8}} \approx 3030$
  - $\frac{1}{1+2x3030} \approx 1{,}65x10^{-4}$

Sliding Window

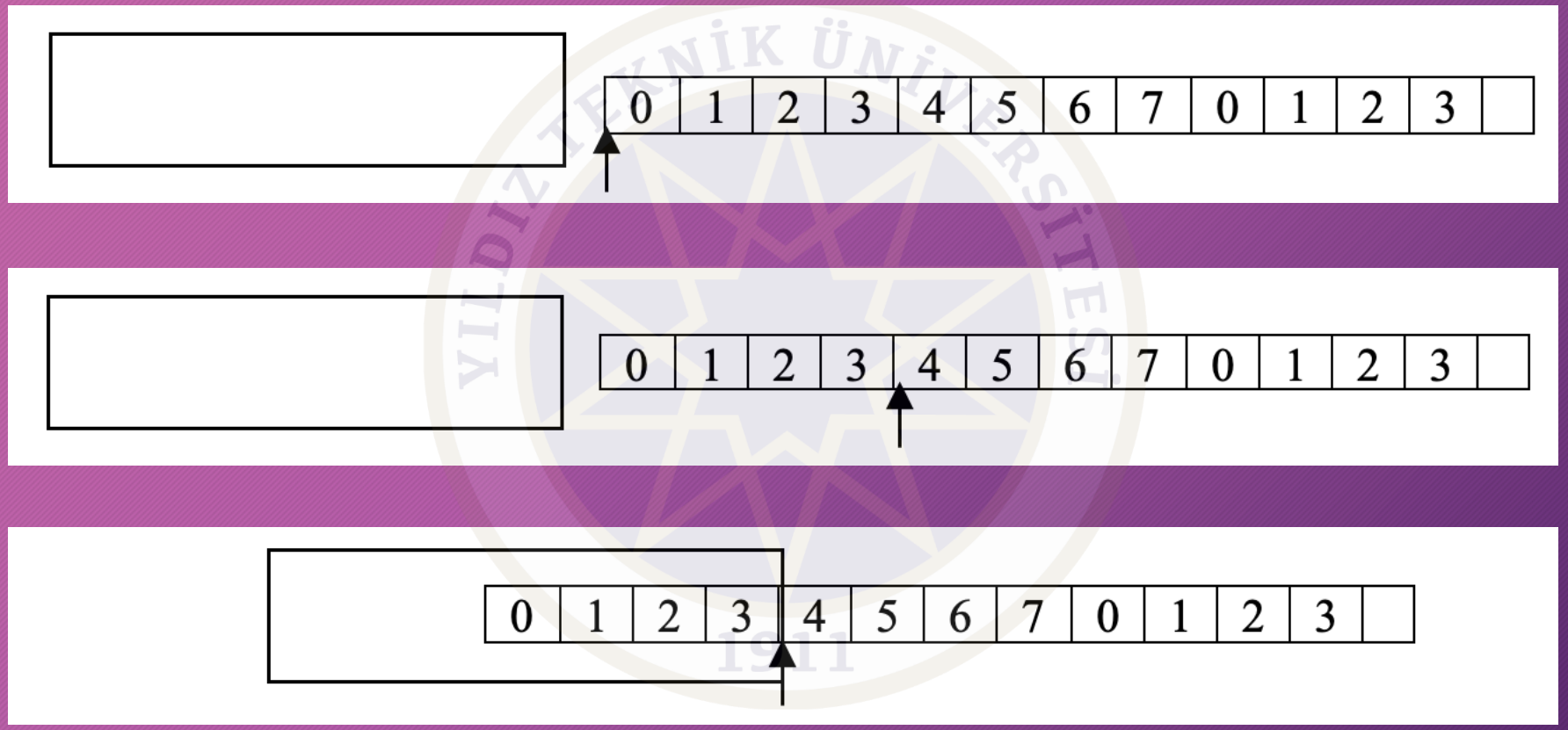
- U rate is low in Stop & Wait
- The sender sends a certain amount of data to the receiver without ACK data.
- Frames are transmitted in convoys.
- The receiver can send ACK data for several frames.
- Frame number is necessary
  - n-bit ⇒ 2^n frame
- Piggy backing

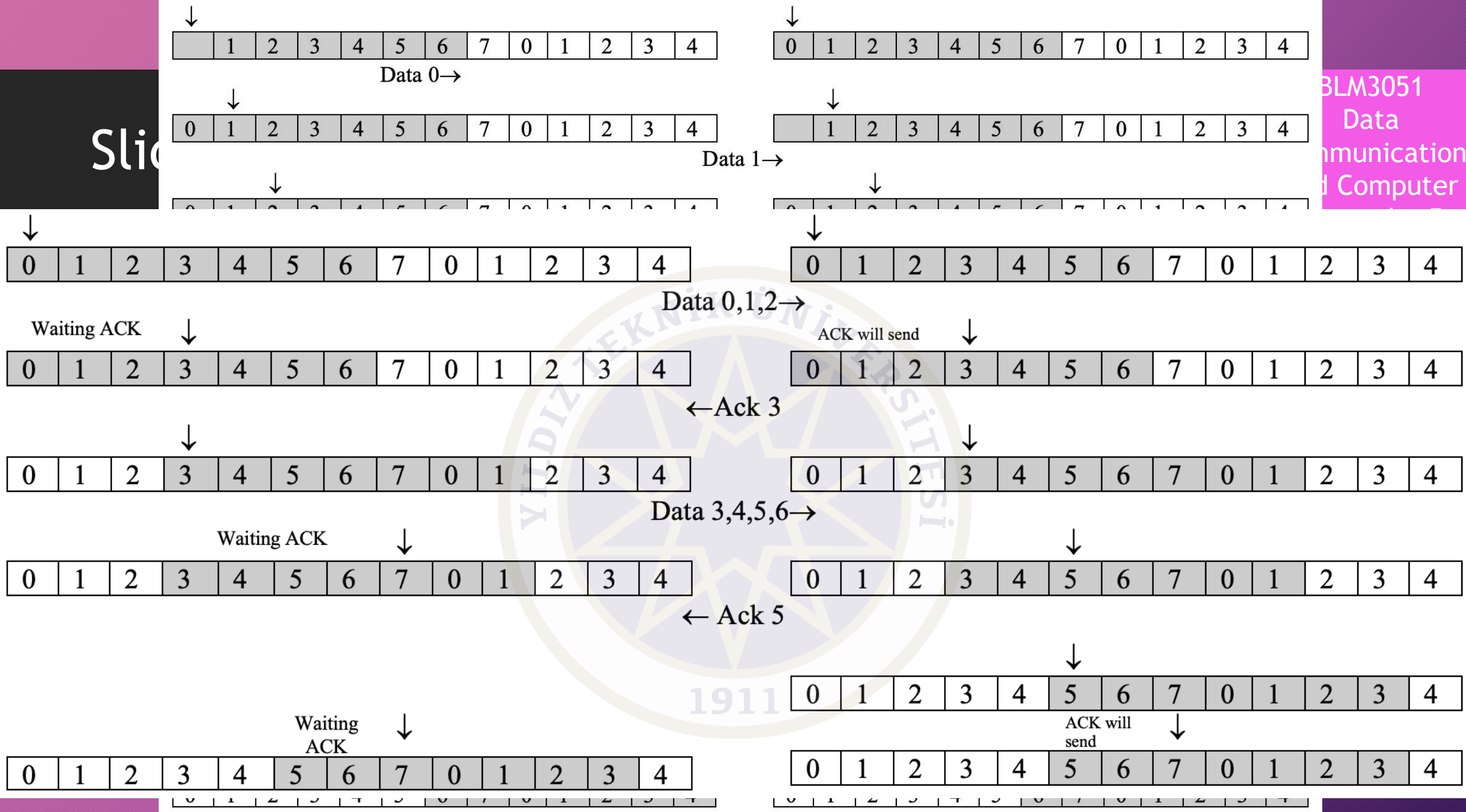
Sliding Window – Sender Side

- Window size: 2^n-1
  - Example: If frame sequence number bit length is n=3, windows size is 2^n-1 = 7

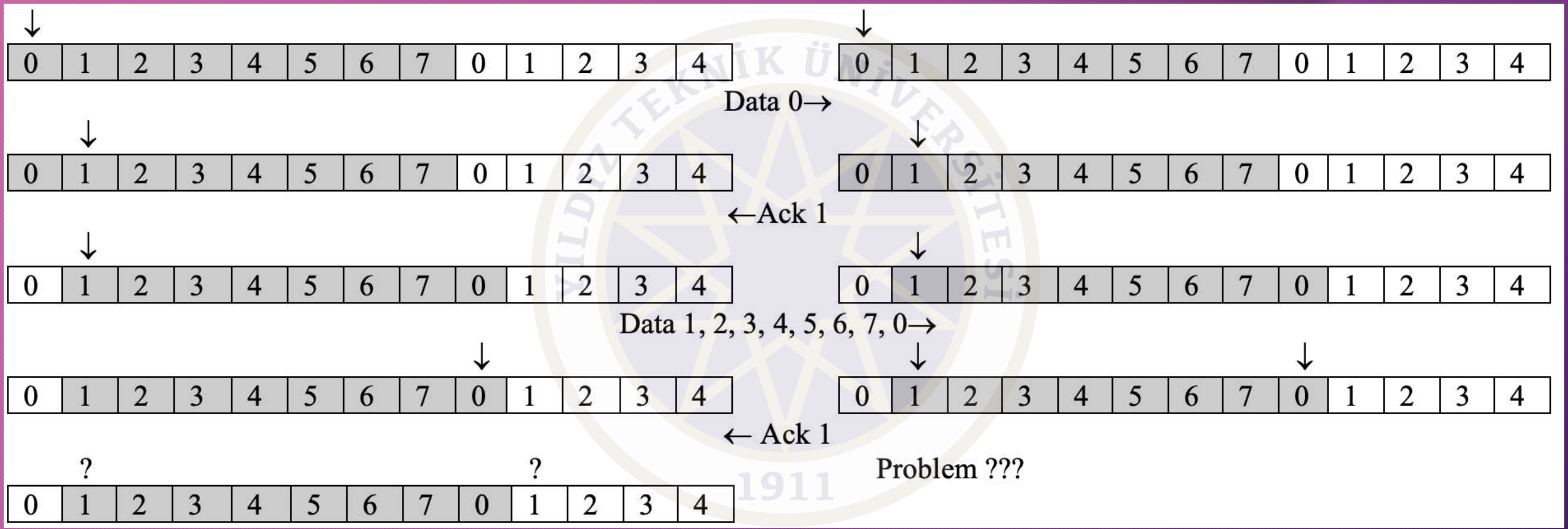


Sliding Window – Receiver Side




0 1 2 3 4 5 6 7 0 1 2 3 4
Data 0→
Data 1→
Data 0,1,2→
Waiting ACK
ACK will send
←Ack 3
Data 3,4,5,6→
Waiting ACK
← Ack 5
ACK will send
Waiting ACK

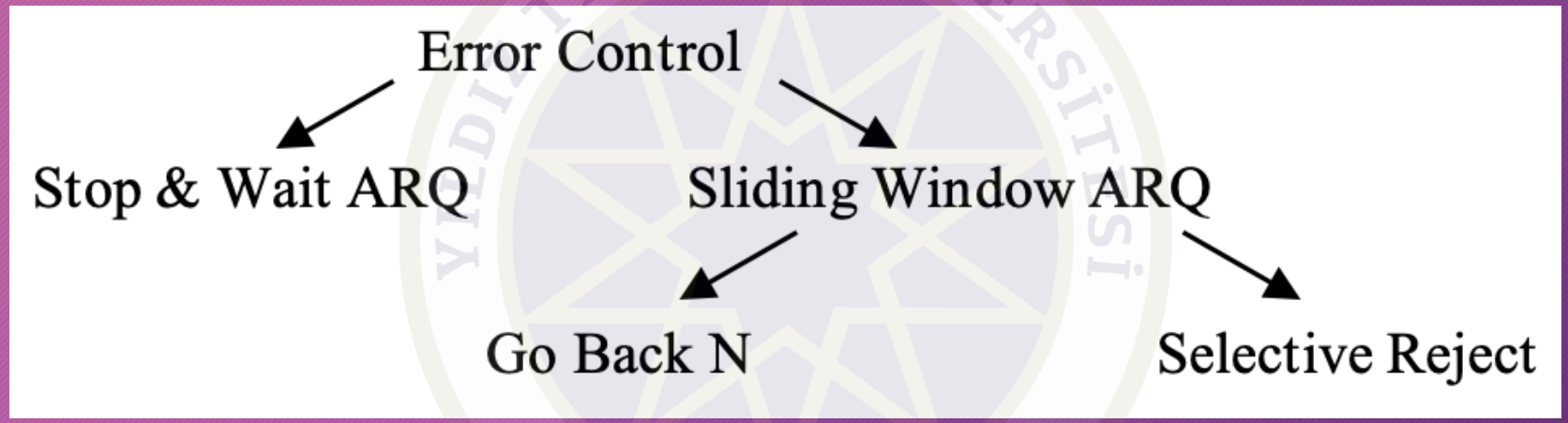
Sliding Window – Window Size 2^n-1



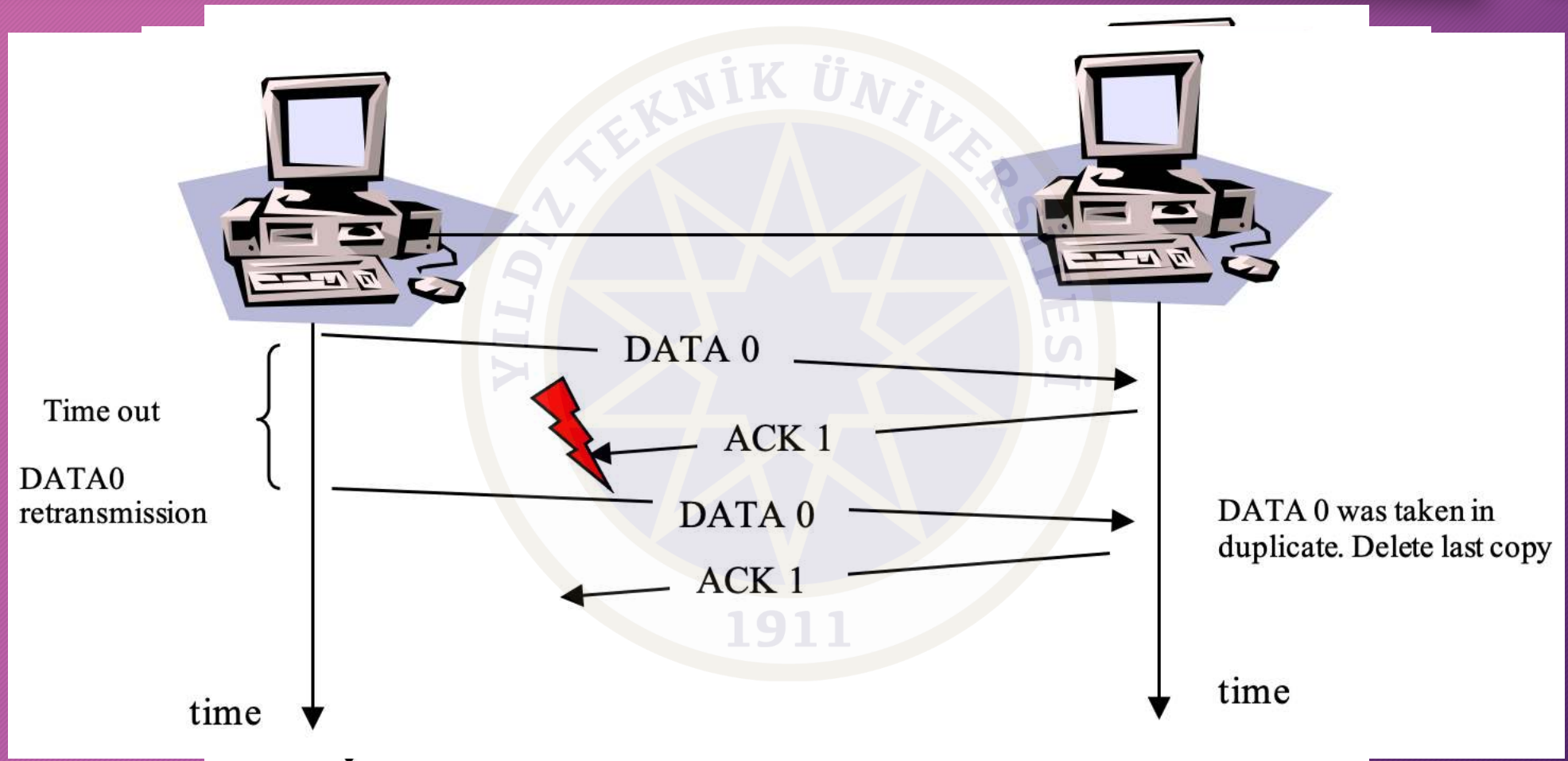
Sliding Window - Line Utilization (U) Rate

- In Stop & Wait $a = \frac{t_{prop}}{t_{frame}}$
- In Sliding Windows $t_{frame} = 1 \Longrightarrow a = t_{prop}$
- If w (window size) ≥ (2a +1)
  - U = %100
- If w < (2a+1)
  - $U = \frac{w}{2a+1}$
- $U = \begin{cases} 1 & w \geq 2a+1 \\ \frac{w}{2a+1} & w < 2a+1 \end{cases}$

Error Control, Automatic Repeat reQuest (ARQ)

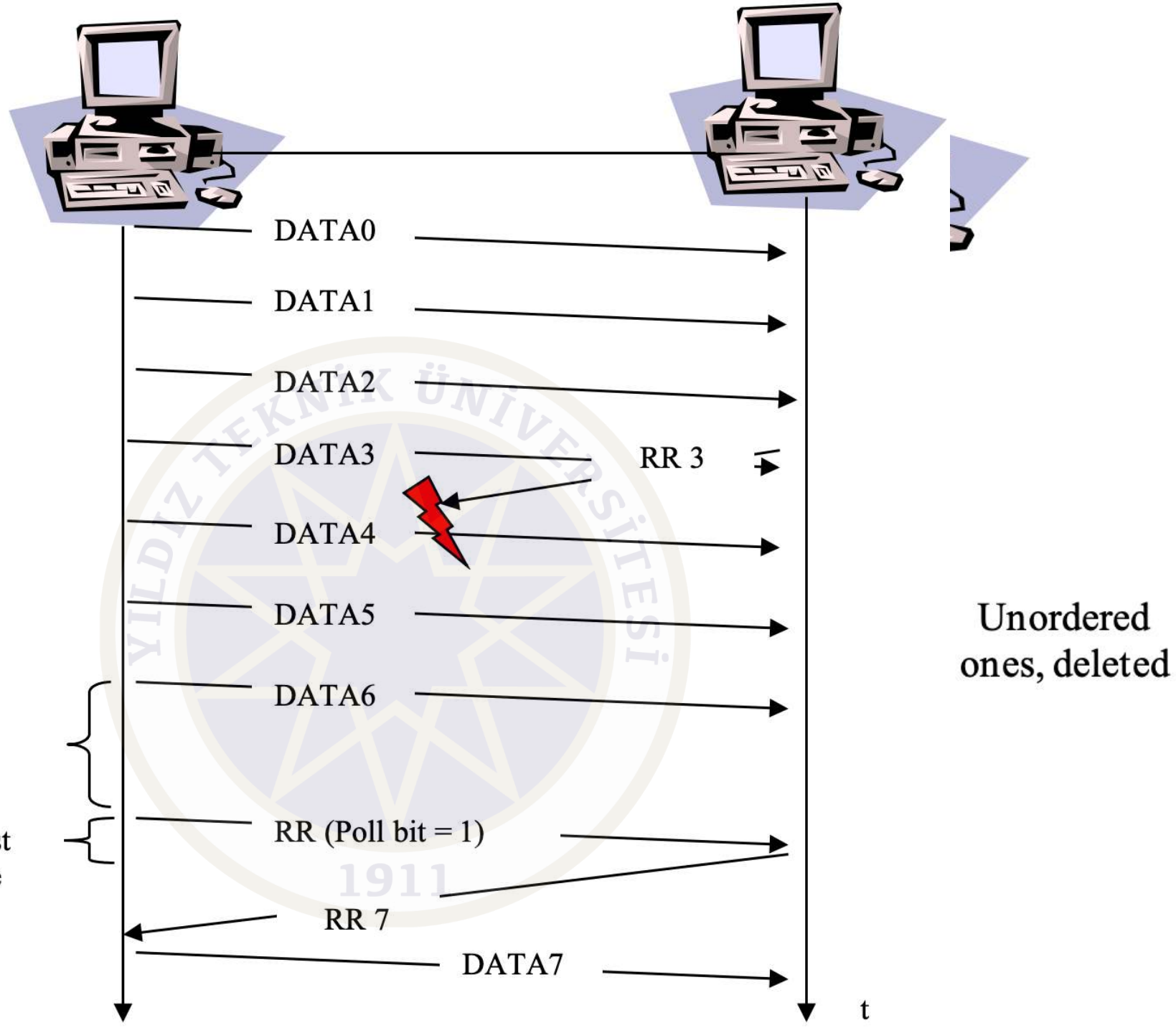


Stop & Wait ARQ



Sliding Window ARQ

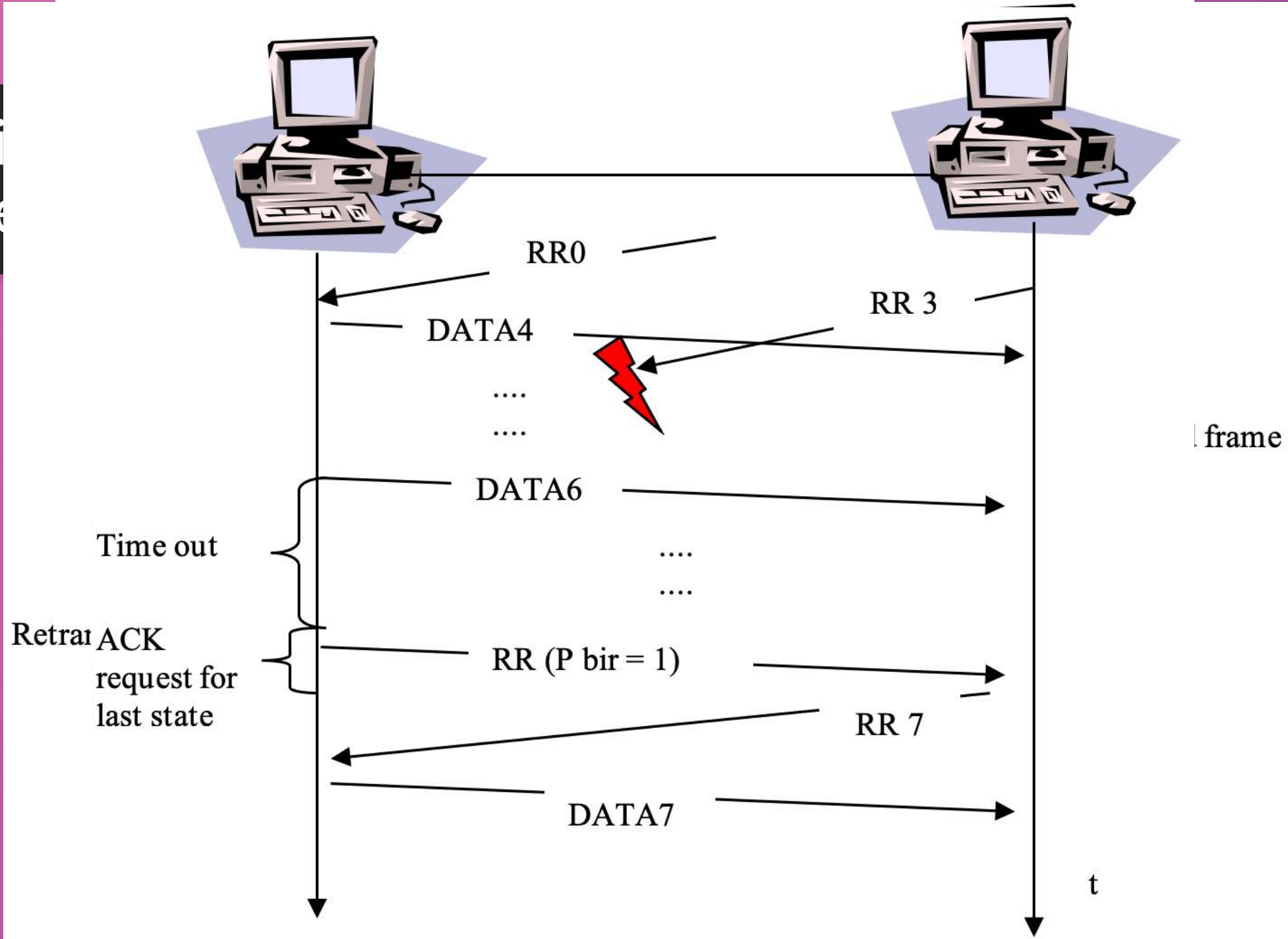
- **There are some differences** caused by the sliding window technique when the frames inside the window are sent **without a receipt**.
  - The sender continues to **store the frames in the buffer until** it receives **ACK** for the frames.
  - In the **ACK / NACK information** coming from the **receiver**, there will be **a number field** showing **which** numbered frame **it is for**.
  - Receive Ready
    - RR 3 and RR 6 means: I have **received 3, 4, 5** numbered frames, **waiting for frame 6**.
  - **Each faulty frame is immediately reported by the receiver** to the sender.
    - REJ - Reject
    - SREJ – Selective Reject
  - **The send**er also **has a timer** in the sliding window approach.
    - Lost data frame
    - Lost acknowledge frame


DATA0
DATA1
DATA2
DATA3
RR 3
DATA4
DATA5
Unordered
ones, deleted
DATA6
Time out
Retransmitted
ones
ACK request
for last state
RR (Poll bit = 1)
RR 7
DATA7
t
t

Sliding Window - Selective Reject / Selective Repeat ARQ

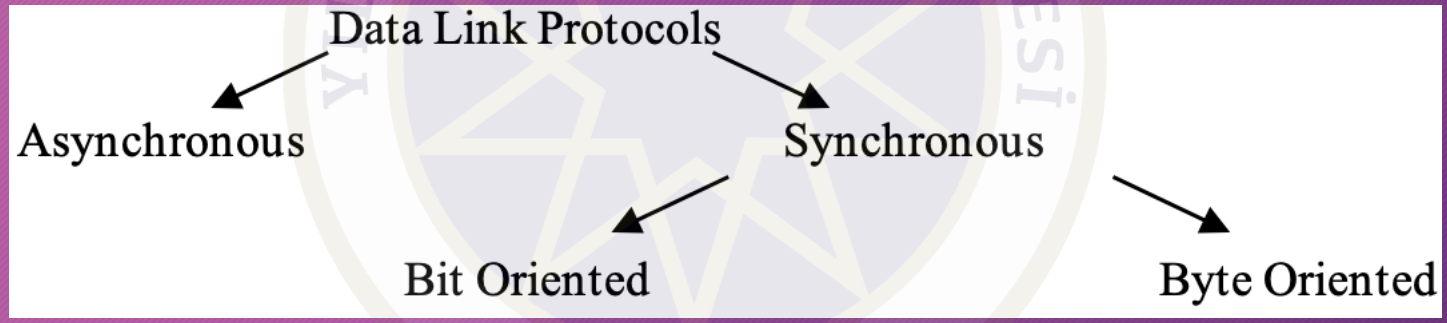
- In this technique, the receiver will receive the frames unordered.
  - Search and Sort Algorithms are necessary.
  - Processing complexity increases
    - In Go Back n: $w = (2^n-1)$
    - In Selective Reject: $w \leq (2^n+1)/2$
  - SREJ
  - The receiver accepts frames without error after faulty frame.
  - Frames will come in different order due to faulty frames.
    - Duplicated ones

Slidi
Repe


RR0
RR 3
DATA4
....
....
frame
DATA6
Time out
....
....
Retrai
ACK
request for
last state
RR (P bir = 1)
RR 7
DATA7
t

Data Link Protocols

- Protocol is a set of rules used to perform the necessary operations during data flow.
  - Synchronous
  - Asynchronous



Data Link Controls (DTC)

- Components
  - Software
  - Hardware (UART/USART)
- Tasks
  - Synchronous Transmission
    - Physical Level: Common timing signal
    - Logical Level: Special bit or bit-arrays
  - Flow Control
  - Error Control
  - Transmission Rules
    - Which one is sender/receiver?
    - Whether frames are for data or control purposes

Asynchronous Protocols

- Used for connections made with a modem
- Logical Sync.
  - Start bit
  - End bit
- There may be gaps of variable sizes between data blocks.
- Cons: Additional data
- Cons: Slow transmission
- Most Common Examples:
  - X-Modem
  - Y-Modem
  - Z-Modem
  - Kermit

Synchronous Protocols

- Instead of start and end bits, FLAGS is used
  - Synchronization premise (SYN) bit-arrays
  - Synchronization successor (EOT) bit-arrays
- 2 types:
  - Physical Level Synchronization
    - Common Clock Signal
  - Logical Level Synchronization (in Data Link Layer)
    - FLAGs
- Thanks to the fast transmission
  - Used in LAN, MAN and WAN technologies
- The protocol perceives the data sent as a consecutive byte sequence.
  - According to the coding system used (ASCII or EBCDIC)

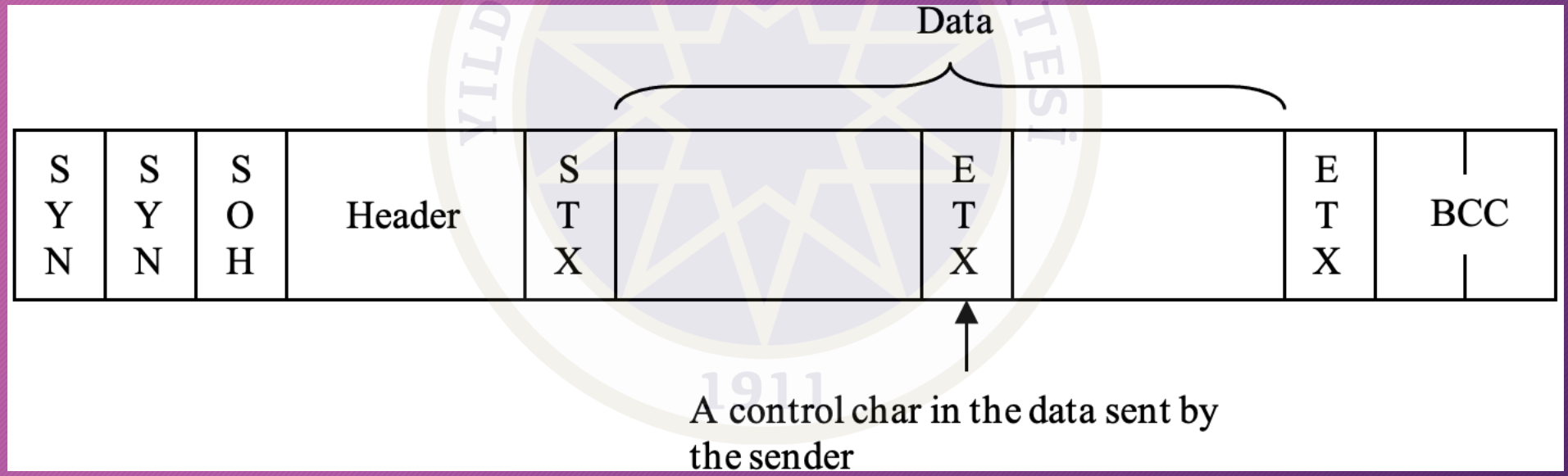
Synchronous Protocols - Byte Oriented

- *Character Oriented
- ASCII or EBCDIC coding
- 2 types of frames
  - Control frames
  - Data frames

Control Chars	Explanation
SYN	Synchronous idle (makes the channel active)
PAD	Frame PAD (used for completion)
DLE	Data Link Escape (Escape char for control chars)
ENQ	Enquiry (Request)
SOH	Start of Heading
STX	Start of Text
ITB	End of Intermediate Block
ETB	End of Transmission Block
ETX	End of Text
EOT	End of Transmission
BCC	Block Check Count (LRC -> 1 byte, CRC -> 2 bytes)
ACK0	Acknowledge Even Numbered Blocks
ACK1	Acknowledge Odd Numbered Blocks
WACK	Wait Before Transmitting
TTD	Temporary Text Delay (While filling buffer in sender side)
RVI	Reverse Interrupt (Request for urgent response)
NUL	(Filling spaces)

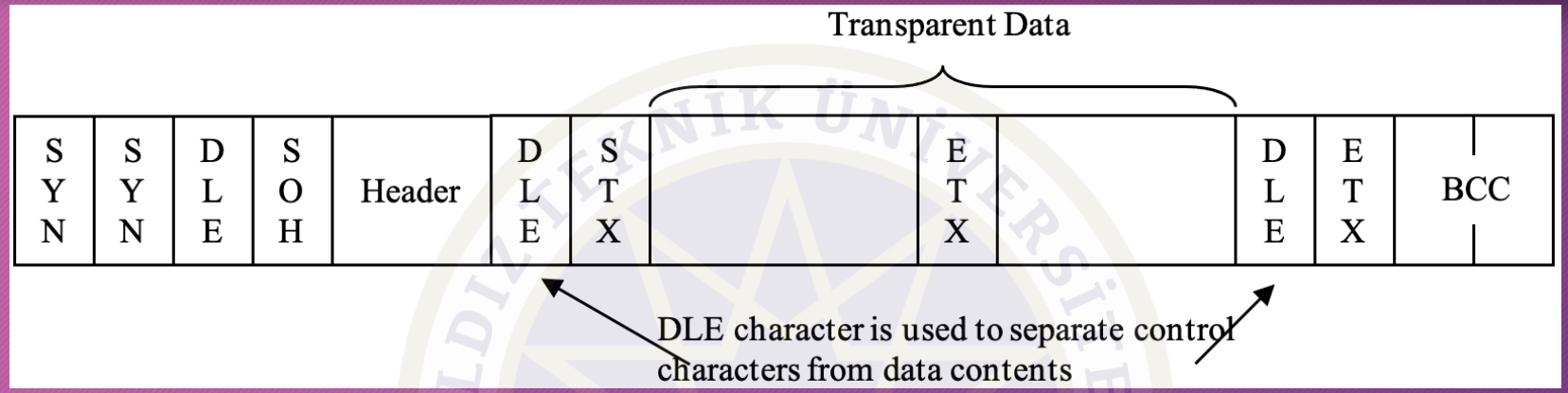
Synchronous Protocols - Byte Oriented - Data Frames

Header includes address

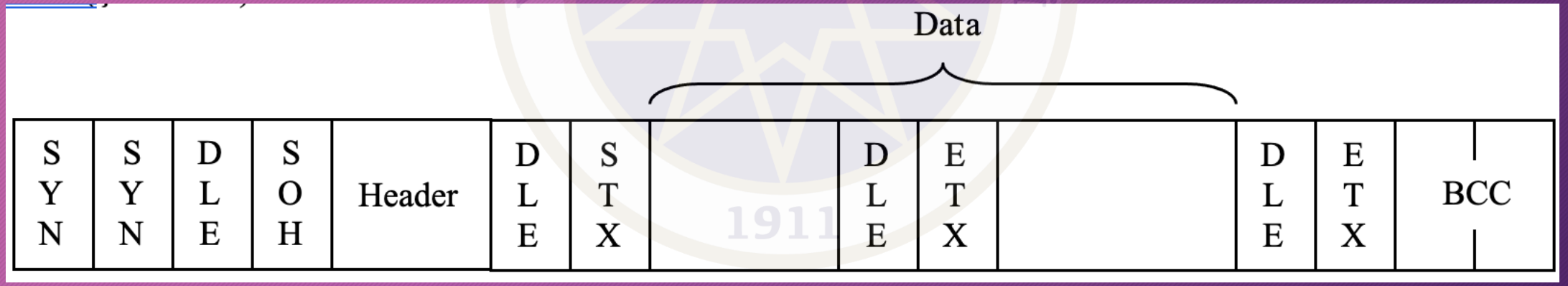


Data Transparency ? (in voice and image data)

Synchronous Protocols - Byte Oriented - Data Frames

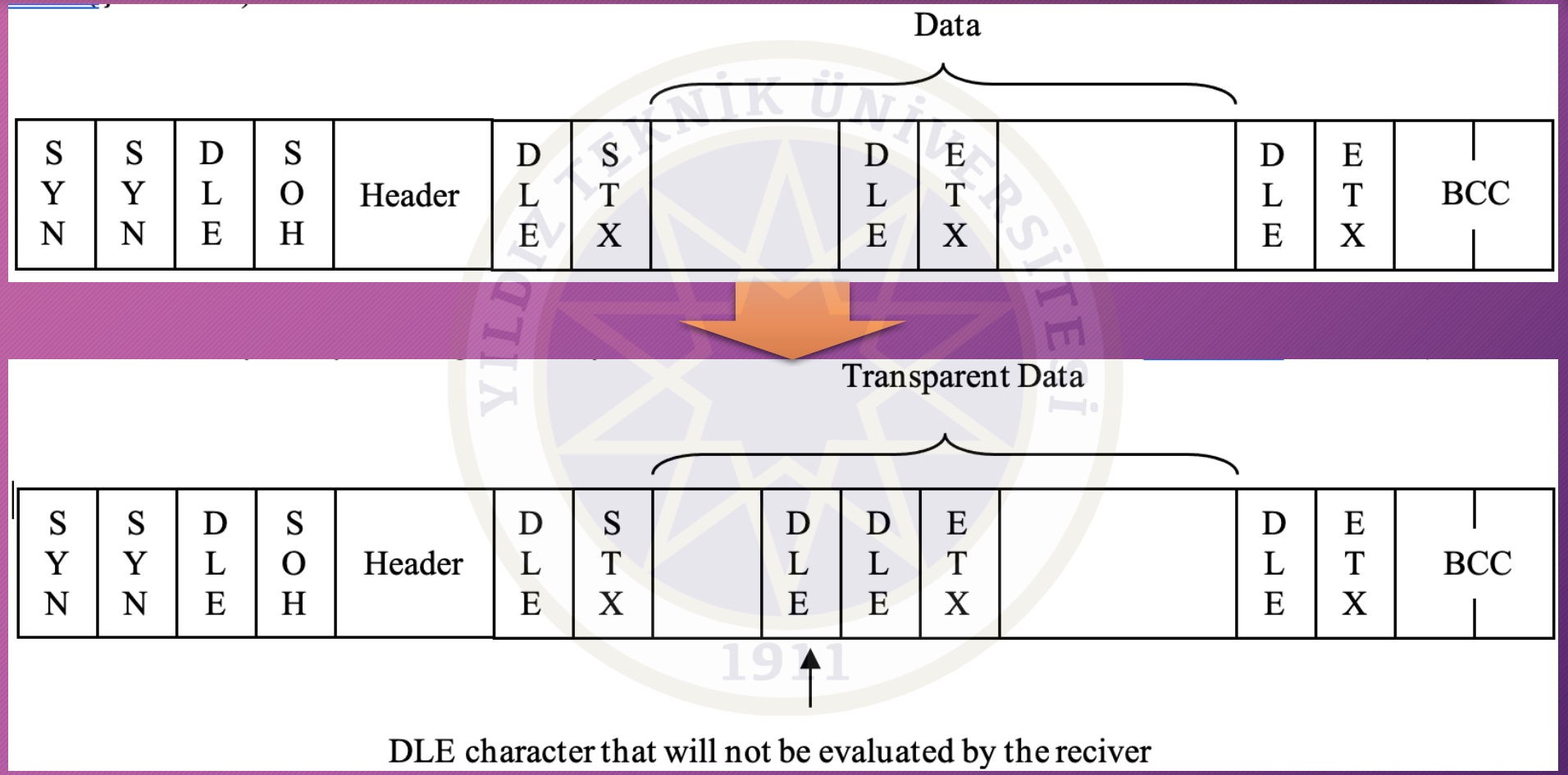


DLE before STX, ETX, ETB, ITB, SOH control chars

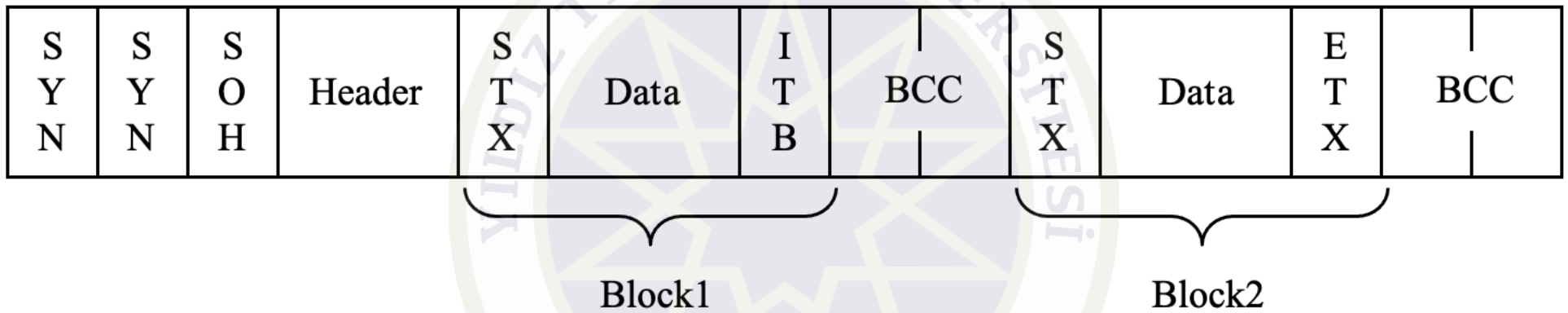


If data includes DLE char?

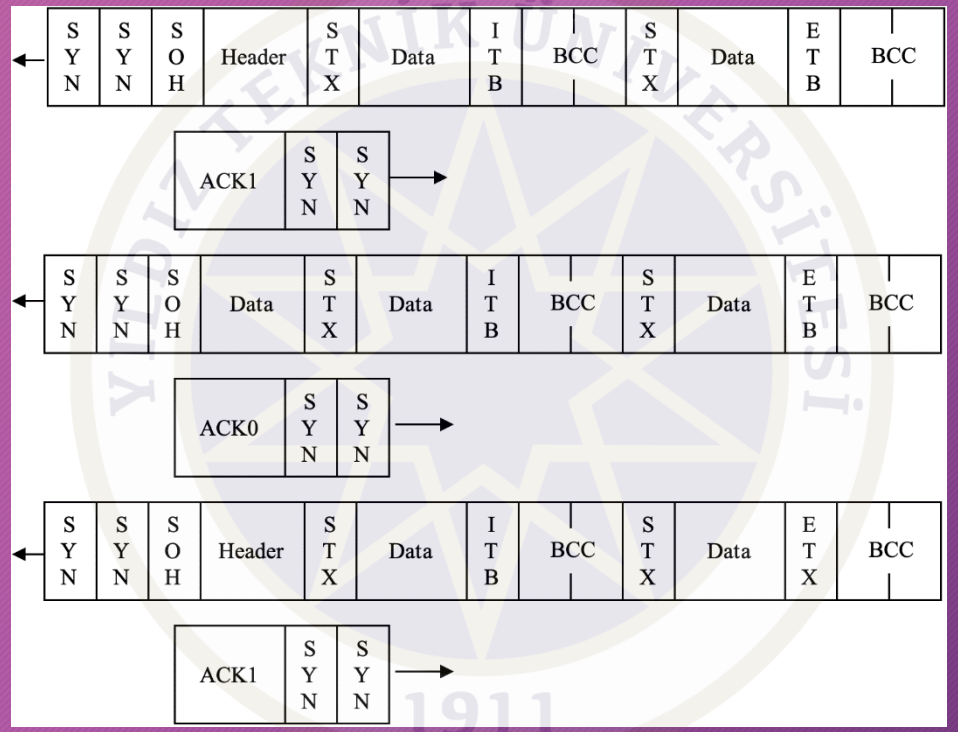
Synchronous Protocols - Byte Oriented - Data Frames



Synchronous Protocols - Byte Oriented - Multi Block Frames



Synchronous Protocols - Byte Oriented - Multi-Frame



Synchronous Protocols - Byte Oriented - Control Frames

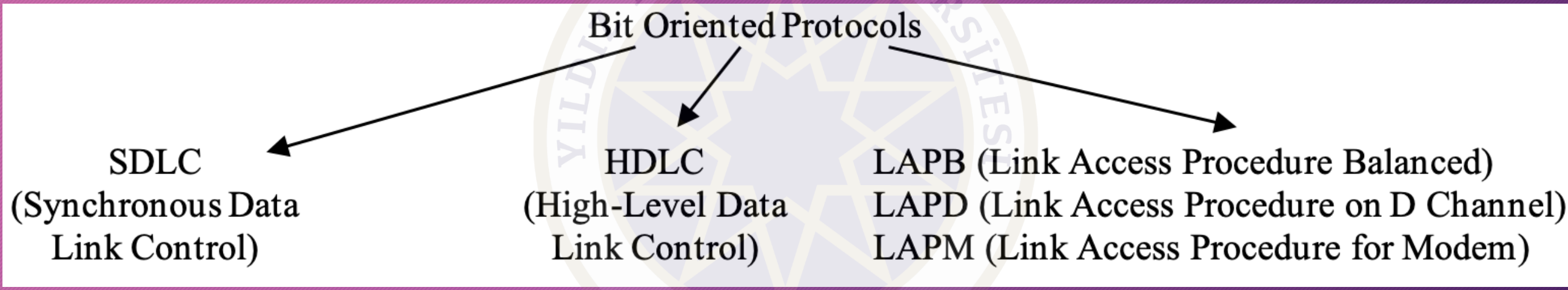
Synchronous Protocols - Byte Oriented - *BSC (Binary Synchronous Communication)*

- IBM
- Used until the late 1960s
- General Specs:
  - Suitable for point-to-point or multi-point connections
  - Half duplex
  - Use STOP & WAIT for Flow Control and ARQ
  - Code Dependent

Synchronous Protocols - Bit Oriented

- Used more actively than byte oriented protocols
  - Fit more information into a shorter frame size
  - Less faced with data transparency problem
- All bit oriented protocols reference HDLC (High Level Data Link Control)
  - ISO
- General Specs:
  - Suitable for point-to-point or multi-point connection.
  - Support Half duplex and Duplex
  - Use Sliding Windows for Flow Control and ARQ
  - Code Independent

Synchronous Protocols - Bit Oriented



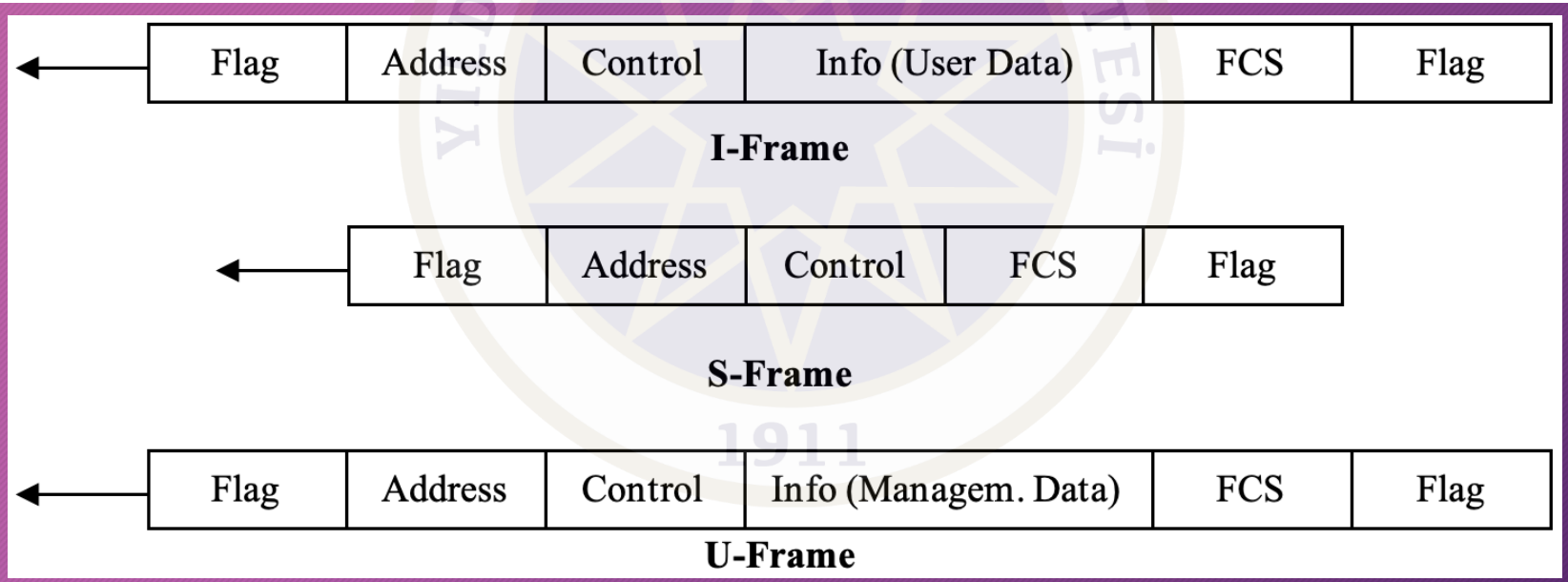
Synchronous Protocols - Bit Oriented - HDLC (High Level Data Link Control)

- Concepts used in HDLC
  - Station types
    - Primary
    - Secondary
    - Combined
  - Configuration
    - Unbalanced
    - Balanced (not defined in HDLC)
  - Modes of communication
    - NRM (Normal Response Mode): Unbalanced. The usual primary/secondary relationship
    - ARM (Asynch. Response Mode): Unbalanced. Secondary station transmit data without primary station's permission if line is available.
    - ABM (Asynch. Balanced Mode): Balanced

Modes of Communication	NRM	ARM	ABM
Station Types	Primary/Secondary	Primary/Secondary	Combined
Transmission Starter	Primary	Primary/Secondary	Any of them

Synchronous Protocols - Bit Oriented - HDLC Frame Structure

I-Frame	Information	It is used to carry user data and related control information.
S-Frame	Supervisory	It is the type of frame used at the data link layer to perform functions such as error and flow control.
U-Frame	Unnumbered	It is a special purpose management frame used to provide system management.



Synchronous Protocols - Bit Oriented - HDLC Frame Structure - FLAG Field

- Consist of 8-bits
  - 01111110
- Determinin start and end point of frames
- Ensure synchronicity
- Critical point for data transparency
  - Bit stuffing
    - Sender add a 0-bit between 1's (like escape char)

Synchronous Protocols - Bit Oriented - HDLC Frame Structure - FLAG Field - Bit Stuffing

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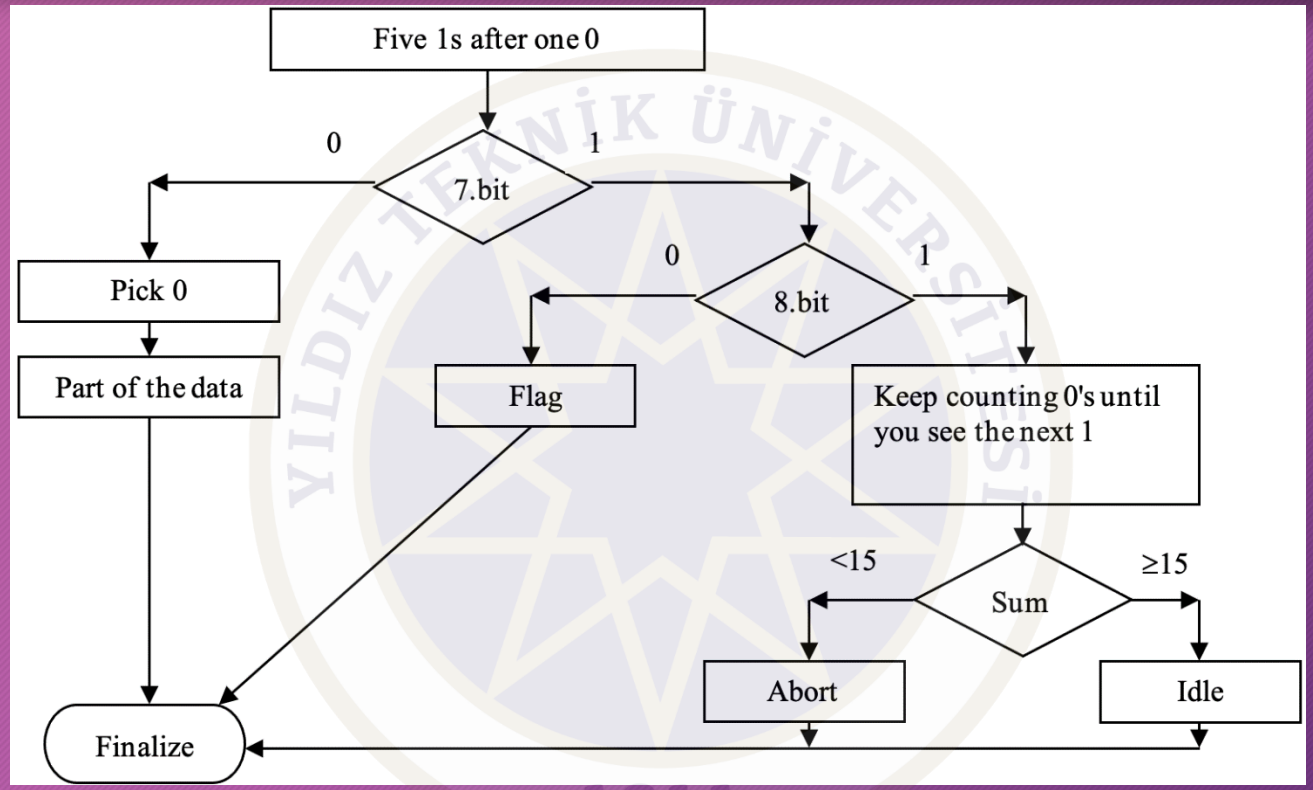
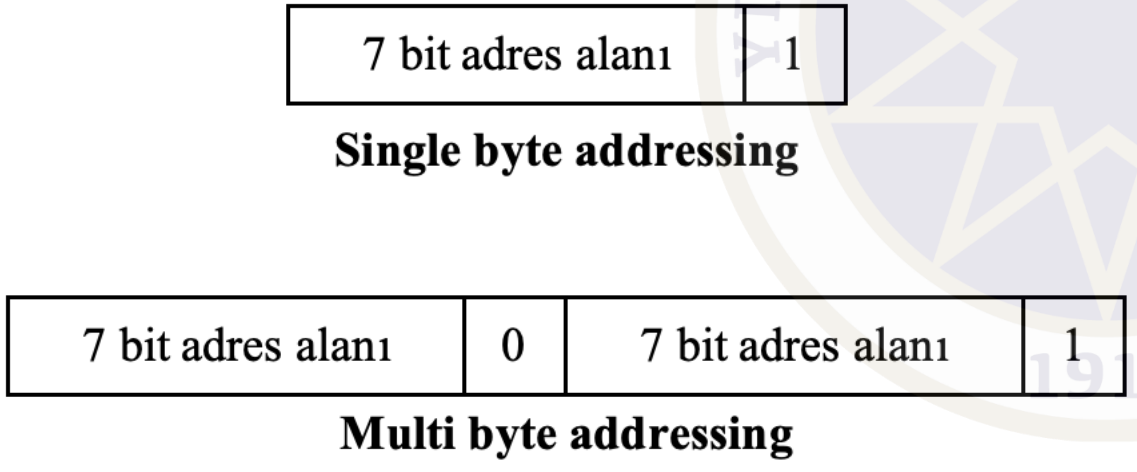


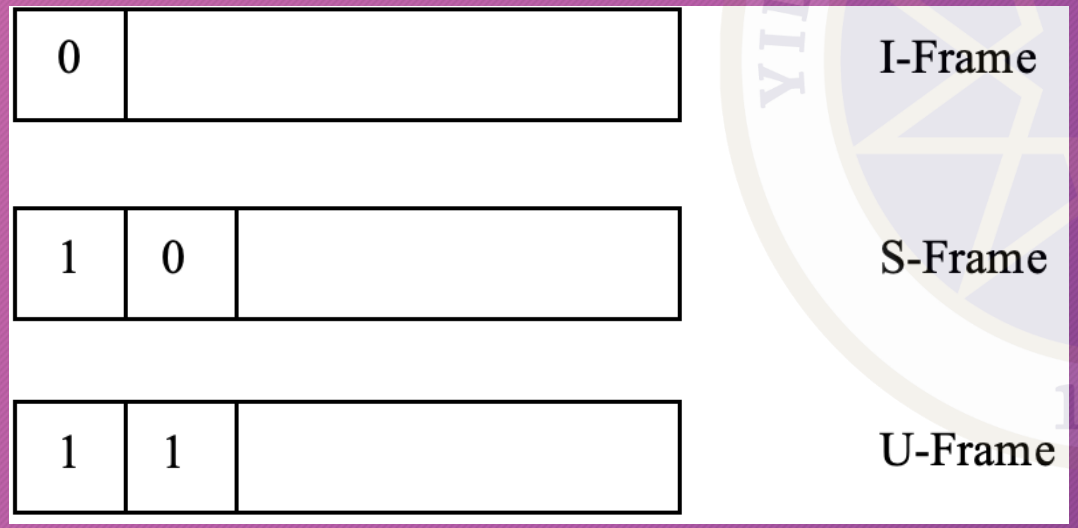
Synchronous Protocols - Bit Oriented - HDLC Frame Structure - ADDRESS Field

- Contains the address of the secondaries.
- Address data is in Network Layer (Third Layer)
  - Used to determine whether;
    - Is it command? or Is it answer?



Synchronous Protocols - Bit Oriented - HDLC Frame Structure - CONTROL Field

- 1 or 2 byte length
  - If w=7 in sliding window technique, length is 1
  - If w=127 in sliding window technique, length is 2
    - In applications with high line delays such as WAN



Synchronous Protocols - Bit Oriented - HDLC Frame Structure - I-Frame

- If w=7;
  - Each I-Frame contains 2 three-bit fields for flow an error control.
    - N(S): Sequence number of the sending window
      - Like ACK
    - N(R): Sequence number of the receiving window
      - If last frame is error-free, N(R) contains next frame's number
      - If last frame has errors, N(R) contains number of faulty frame
- If w=127
  - Each I-Frame contains 2 seven-bit fields for flow an error control.

0	N(S)	P/F	N(R)

Synchronous Protocols - Bit Oriented - HDLC Frame Structure - S-Frame

- S-Frame means that neither sides has data to send to the other.

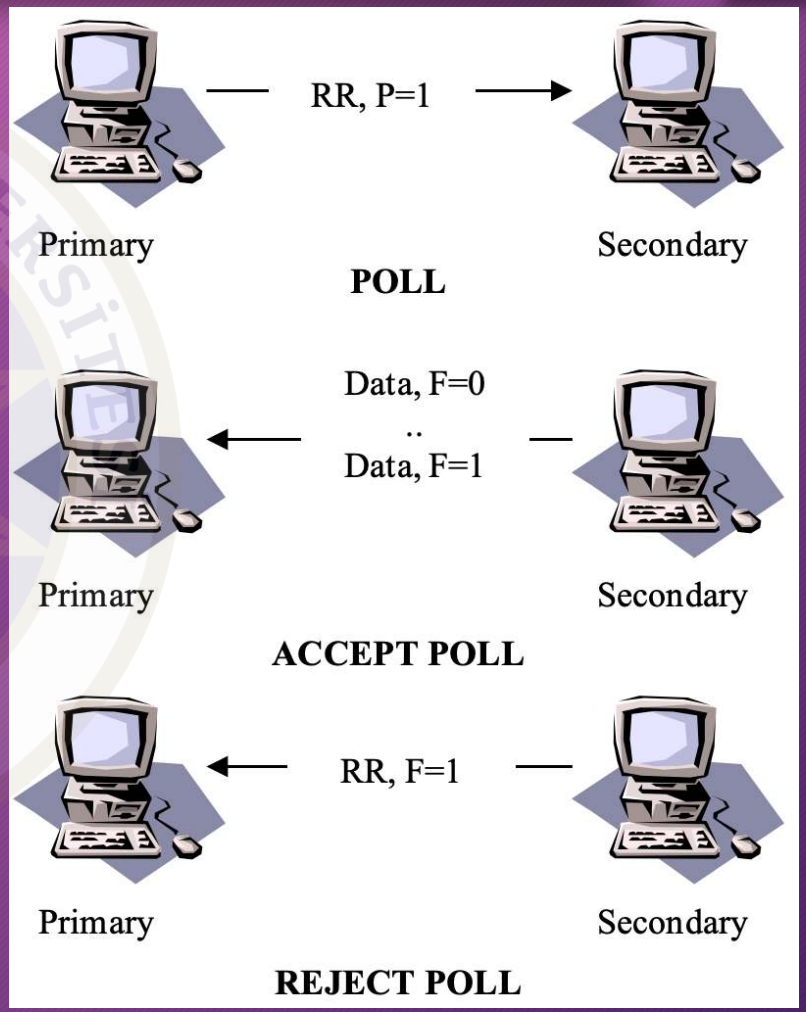
1	0	Code	P/F	N(R)

Code	Abbreviation	Explanation
00	RR	Receive Ready
01	REJ	Reject – (go back n)
10	RNR	Receive Not Ready
11	SREJ	Selective Reject - (selective reject)

Synchronous Protocols - Bit Oriented - HDLC Frame Structure - S-Frame - RR

- It has four basic uses:
  - ACK
  - POLL
    - P=1
  - REJECT POLL
    - F=1
  - ACCEPT SELECT
    - F=1

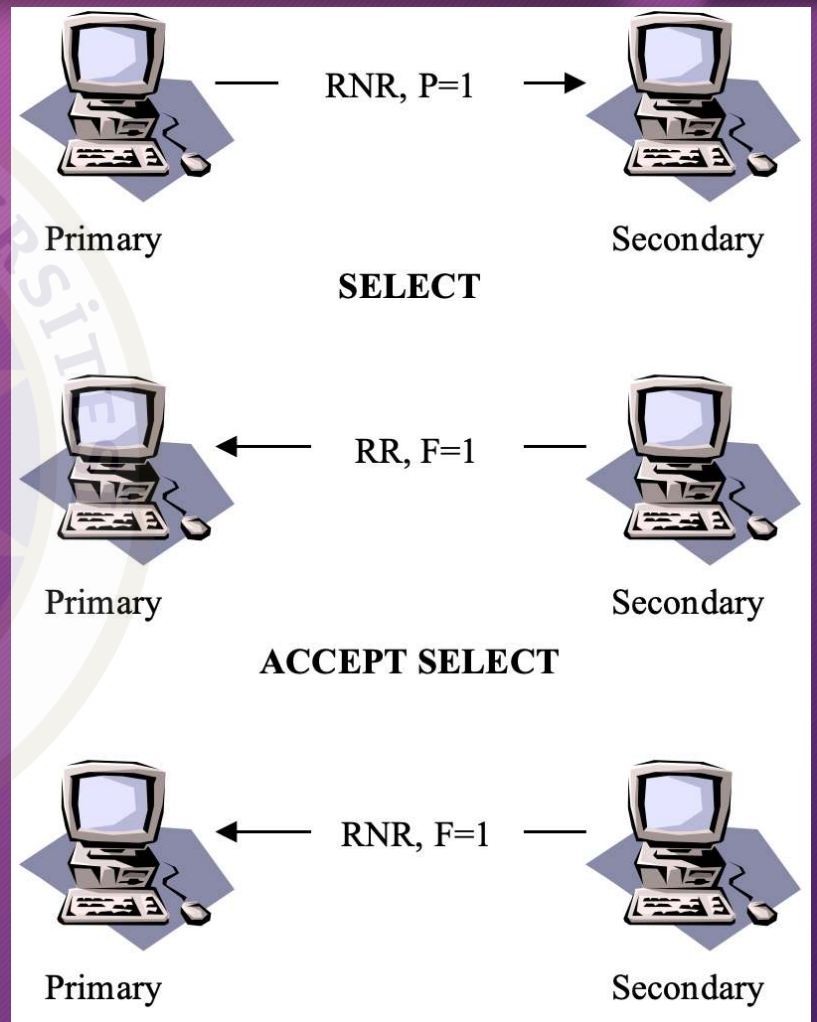
1	0	Code	P/F	N(R)



Synchronous Protocols - Bit Oriented - HDLC Frame Structure - S-Frame - RNR

- It has three basic uses:
  - ACK
  - SELECT
    - P=1
    - If primary sends RR and P=1, it means POLL.
  - REJECT SELECT
    - F=1

1	0	Code	P/F	N(R)



Synchronous Protocols - Bit Oriented - HDLC Frame Structure - S-Frame - REJ, SREJ

- Used to return negative feedback from the receiver
  - REJ: Go Back N ARQ
    - It is used to inform the sender that the frame whose number is written in the N (R) field and the frames that come after it did not reach the receiver or that it received incorrectly, and to ensure that it is sent again.
  - SREJ: Selective Reject ARQ
    - It is used in the N (R) field to inform the sender that the data frame whose number is written on it did not reach the receiver or that it was received incorrectly and to send it again.

Synchronous Protocols - Bit Oriented - HDLC Frame Structure - U-Frame

- Used to provide session control
- The data area is used to carry information required for system management functions
- 1st code field consist of 2 bits
- 2nd code field consist of 3 bits
- 2^5 = 32 different state
- These states (commands and answers) can be collected in 5 different categories:
  - Mode setting
  - Unnumbered exchange
  - Disconnection
  - Initialization
  - Miscellaneous

Synchronous Protocols – Bit Oriented – HDLC Frame Structure – U-Frame – Mode Setting

- How will the transmission be?
  - 00-001 (SNRM-Set Normal Response Mode) -> w=7
  - 11-000 (SARM-Set Async. Response Mode) -> w=7
  - 11-100 (SABM-Set Async. Balanced Mode) -> w=7
  - 11-011 (SNRM Extended) -> w=127
  - 11-010 (SARM Extended) -> w=127
  - 11-110 (SABM Extended) -> w=127

Synchronous Protocols – Bit Oriented – HDLC Frame Structure – U-Frame – Unnumbered Exchange

- Data connection information exchange
  - 00-100 (UP-Unnumbered Poll): POLL request
  - 00-000 (UI-Unnumbered Info): exchange of date/time information to be used for sync.
    - UI would be a command or answer.
      - If it is used for command, it transports list of parameters to be used for transmission.
      - If it is used for answer, it carries information that determines the capability of the receiver.
  - 00-110 (UA-Unnumbered Ack): Sent in response to the UP command

Synchronous Protocols – Bit Oriented – HDLC Frame Structure – U-Frame – Disconnection

- There are 3 types of disconnection command.
  - 00-010 (DISC): Sent by the first side to terminate the connection to the other.
  - 00-010 (RD): It is used to notify the request to terminate the connection from the second station to the first.
  - 11-000 (DM): When the address is sent from the specified station to the station wishing to establish the connection, it is sent as negative feedback information to the mode setting command.

Synchronous Protocols - Bit Oriented - HDLC Frame Structure - U-Frame - Initialization

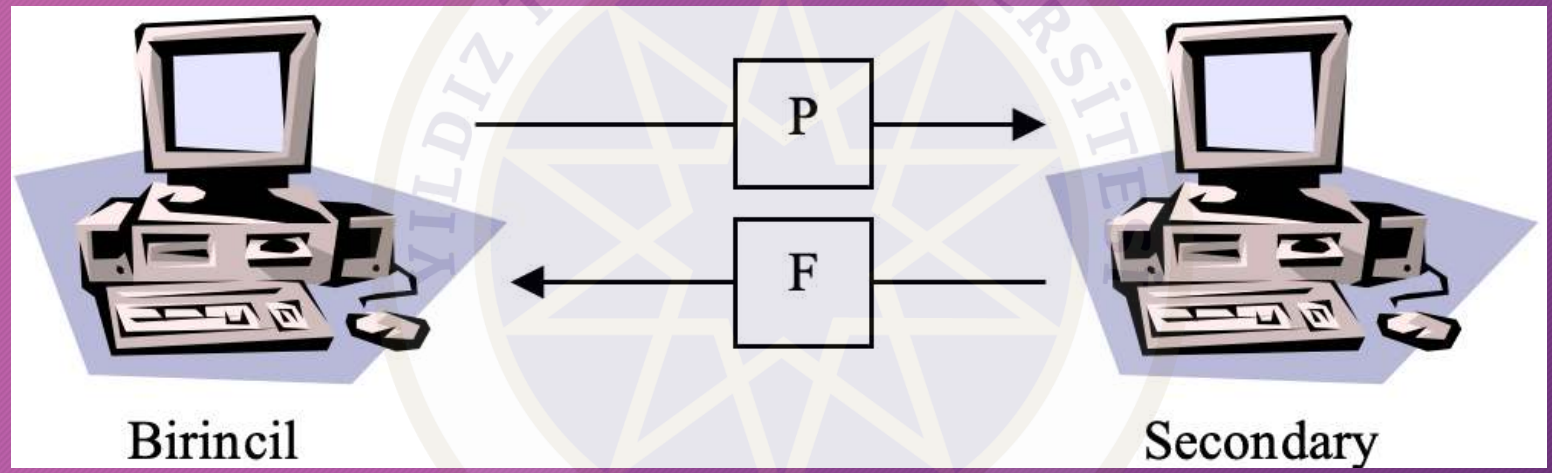
- Used for initializations for all sides.
  - 10-000 with P (SIM-Set Initialization Mode)
    - Command is sent from the first station to the second
    - UI command will be sent in response to SIM command
  - 10-000 with F (RIM-Request Initialization Mode)
    - It means that «I am waiting SIM commad»
    - It is used when the second station cannot respond to the mode setting command without receiving the SIM command from the first.

Synchronous Protocols – Bit Oriented – HDLC Frame Structure – U-Frame – Miscellaneous

- 11-001 (RESET)
  - This is usually sent in response to a received FRMR code.
  - Explains that the secondary station must do the same
- 11-101 (XID)
  - Emphasizes that a self-determining information is requested from the secondary station.
  - Like questioning what your address is
- 10-001 (FRMR)
  - Used to determine that a syntax error was encountered in the received frame.

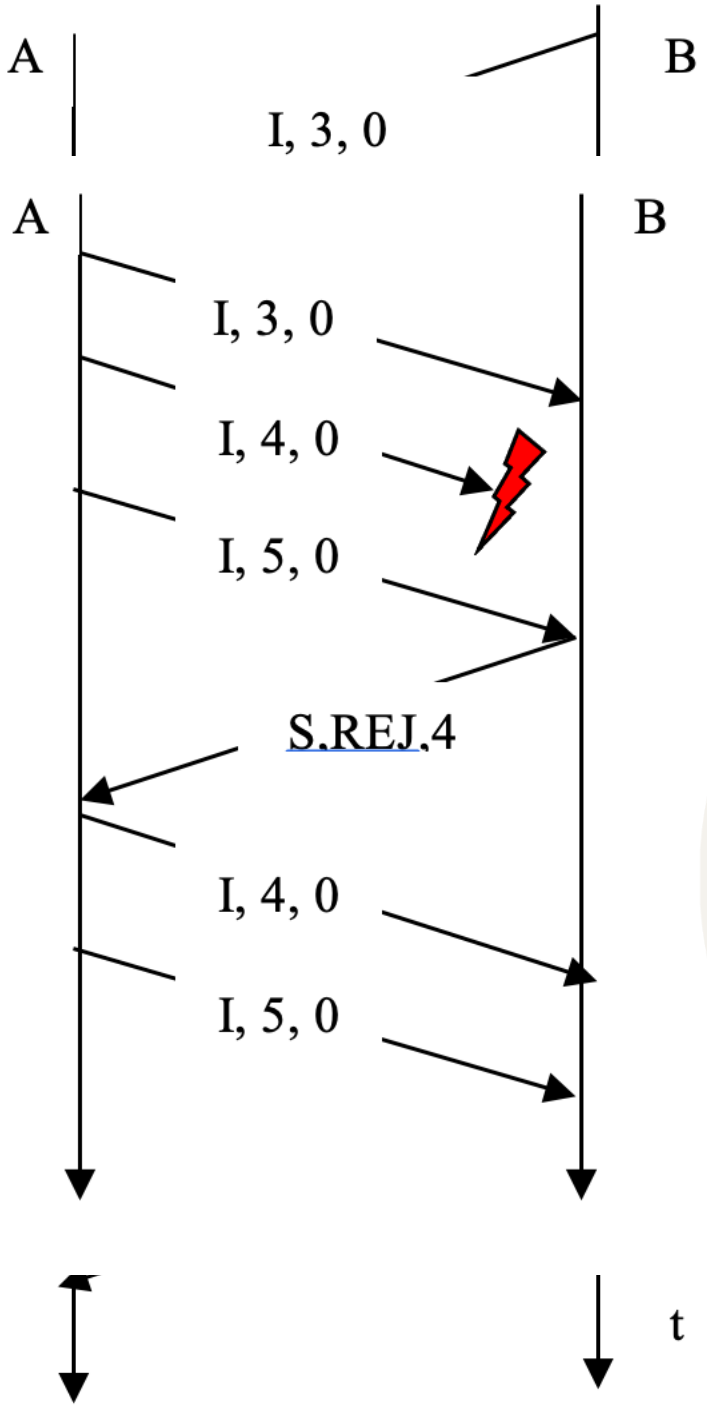
Synchronous Protocols - Bit Oriented - HDLC Frame Structure - S-Frame - P/F (Poll/ Final)

- P/F bit is always 1



Synchronous Protocols - Bit Oriented - HDLC Mechanism

- I, U and S frames
- 3-phase mechanism
  - One of the sides must install the link
    - in order to be able to exchange data sequentially
  - User data, flow and control information required for error control must be transferred between the two ends.
  - One of the sides terminates the connection



FLAG	A	I-Frame				Data	FCS	FLAG
		0	011	P/F	000			

FLAG	B	I-Frame				Data	FCS	FLAG
		0	011	P/F	000			

FLAG	B	I-Frame				Data	FCS	FLAG
		0	101	P/F	000			

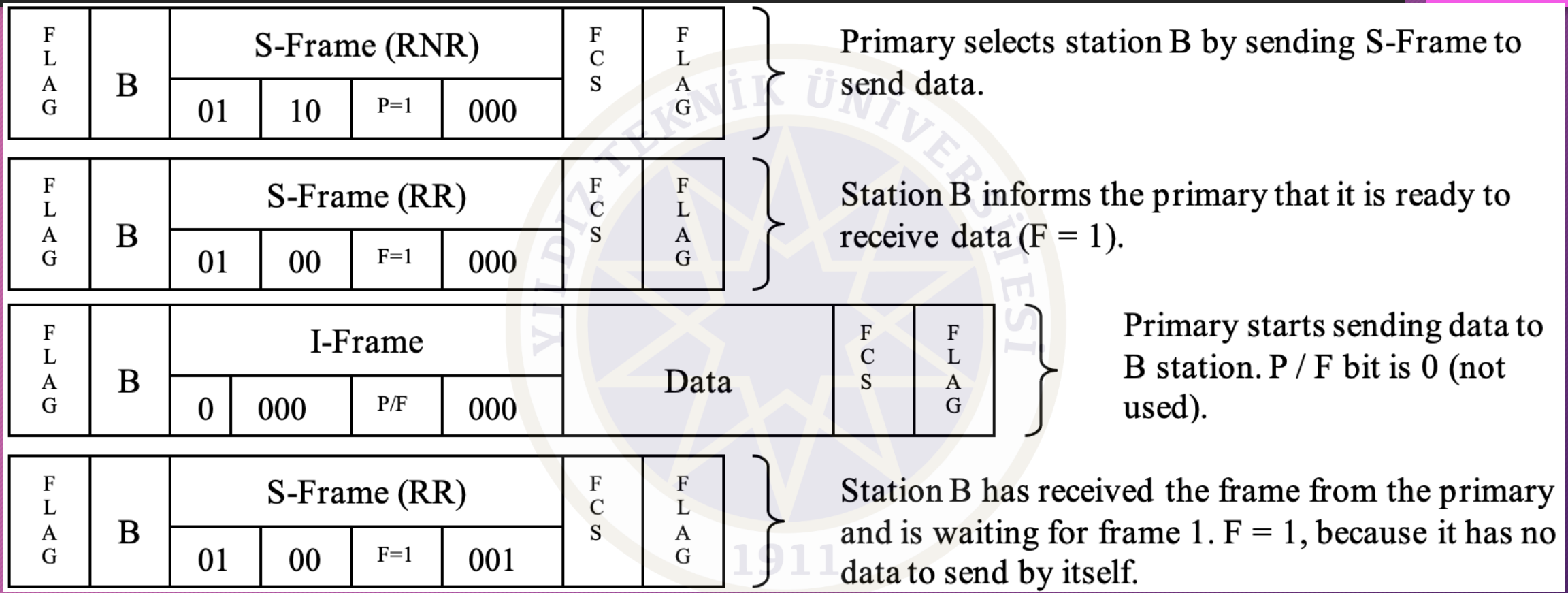
FLAG	A	S-Frame (REJ)				FCS	FLAG
		10	01	P/F	100		

FLAG	B	I-Frame				Data	FCS	FLAG
		0	100	P/F	000			

FLAG	B	I-Frame				Data	FCS	FLAG
		0	101	P/F	000			

FLAG	A	I-Frame				Data	FCS	FLAG
		0	100	P/F	000			

Synchronous Protocols - Bit Oriented - HDLC Mechanism - Multi-Point



Synchronous Protocols - Bit Oriented - HDLC Mechanism - Combined

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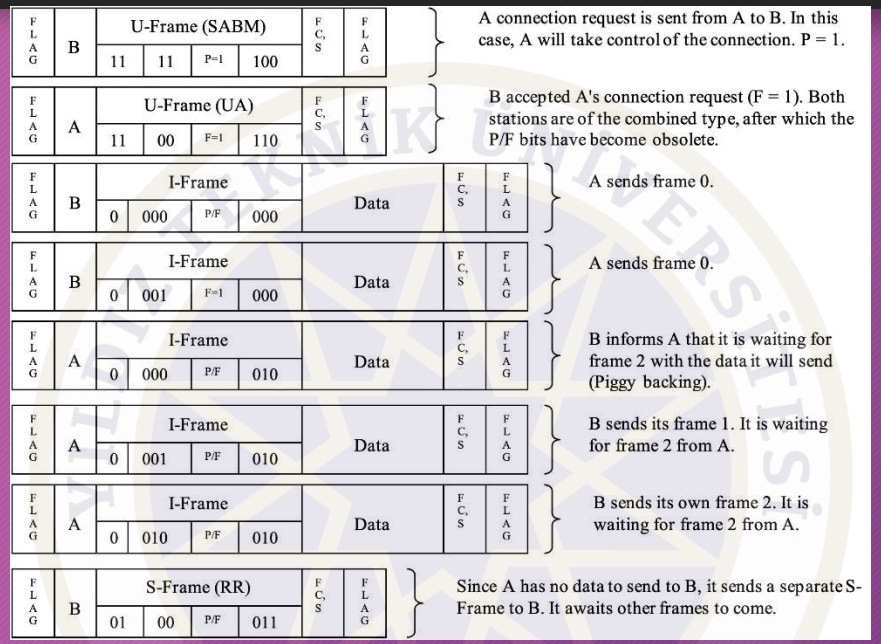

Thank you for your listening.

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