NSCOM01

Unreliable Data Delivery

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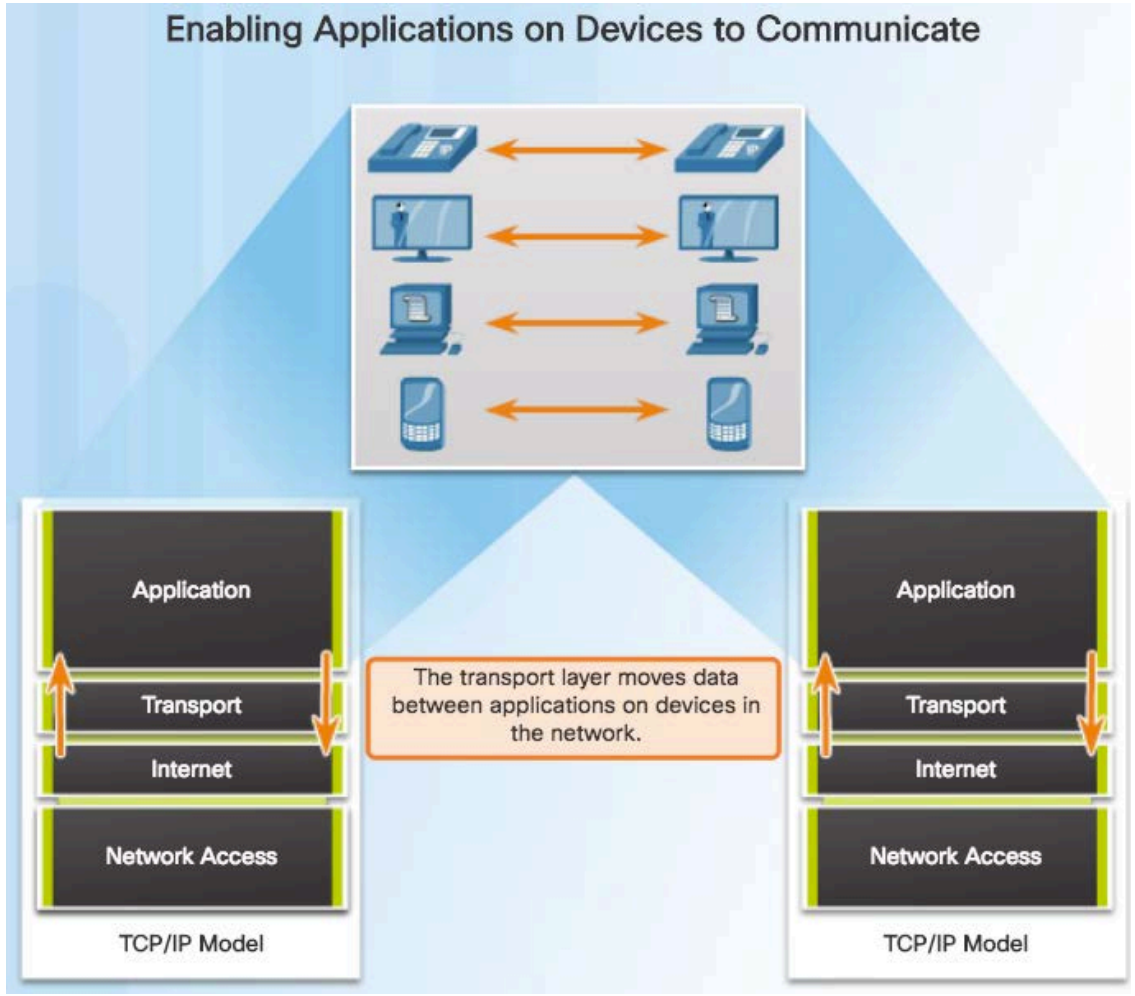
SPIRAL REVIEW: TRANSPORT LAYER

- **Responsible for establishing a temporary communication session between two applications and delivering data between them.**
- **Link between the application layer and the lower layers that are responsible for network transmission.**



SPIRAL REVIEW: TRANSPORT LAYER

❑ Tracking the Conversation

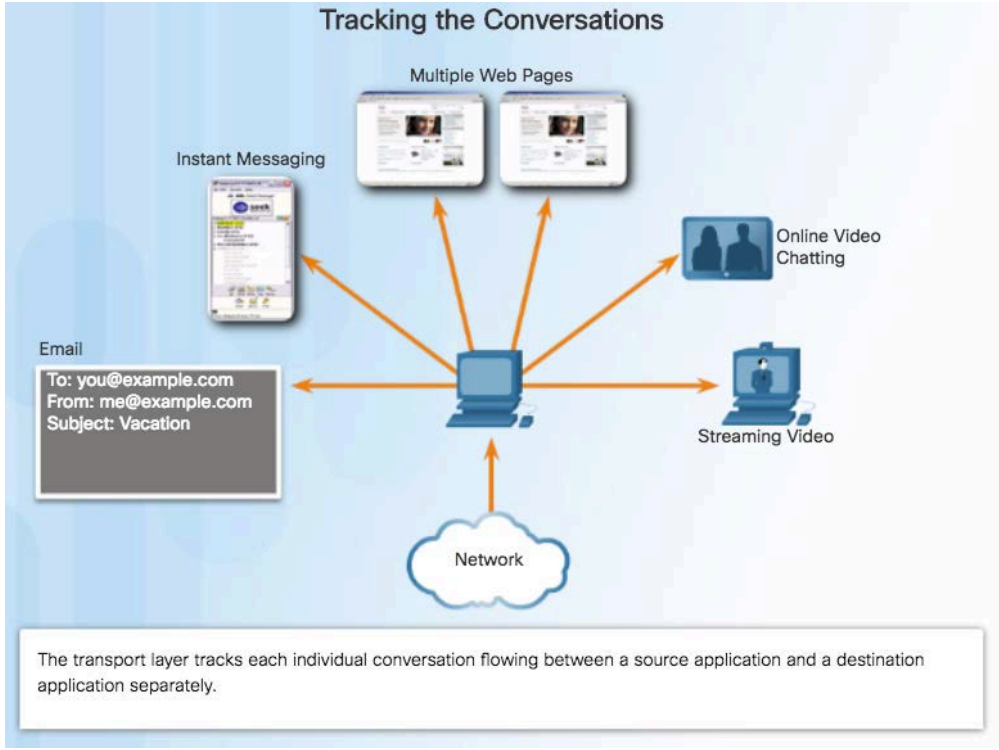
- Tracks each individual conversation flowing between a source and a destination application.

❑ Segmentation

- Divides the data into segments that are easier to manage and transport. Header used for reassembly is used for tracking.

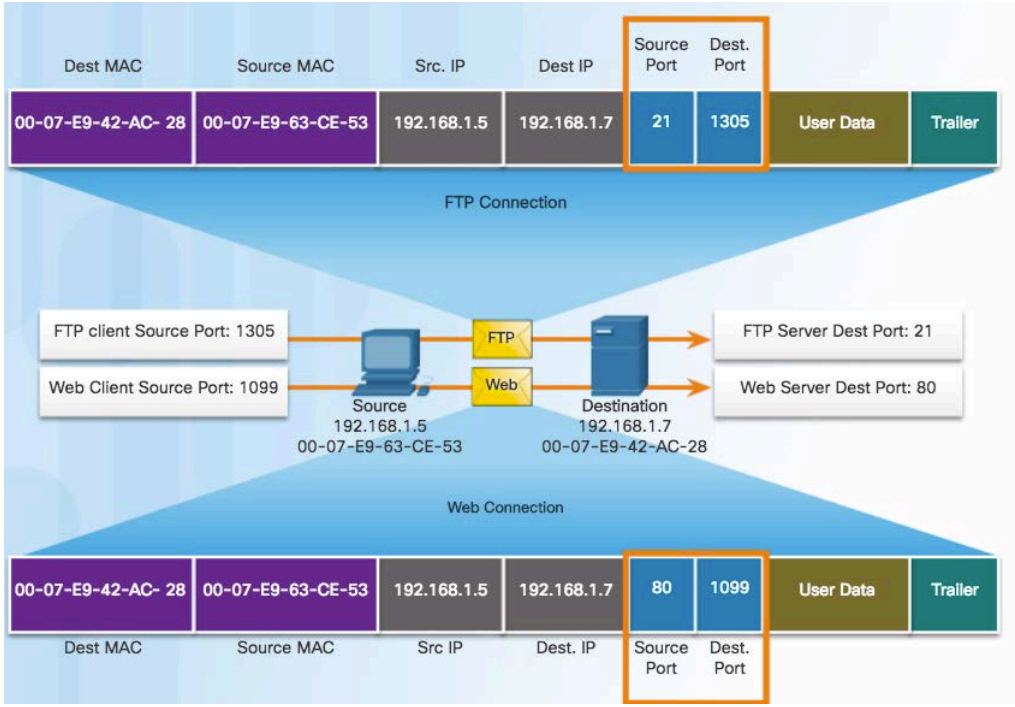
❑ Identifying the Application

- Ensures that even with multiple applications running on a device, all applications receive the correct data via port numbers.



SPIRAL REVIEW: TRANSPORT LAYER

- **The transport layer of the TCP/IP protocol suite uses ports to differentiate data transfers occurring simultaneously on the same host**
  - Well-known Ports (0 to 1023) - reserved for services and applications.
  - Registered Ports (1024 to 49151) - assigned by IANA to a requesting entity to use with specific processes or applications.
  - Dynamic Ports (49152 to 65535) - assigned dynamically by the client's OS and used to identify the client application during communication.



CONNECTIONLESS SERVICES

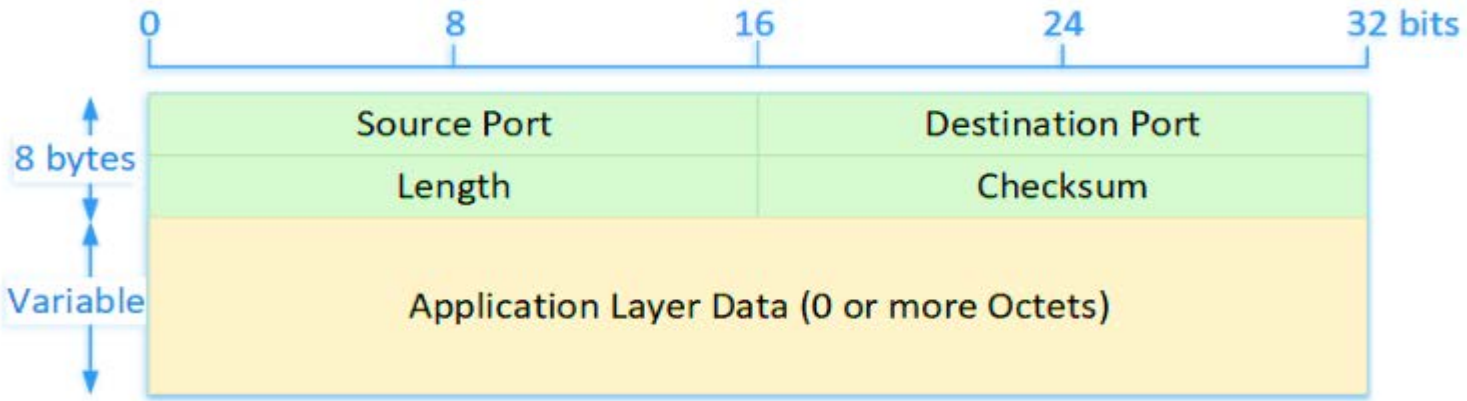
- **Commonly used with applications where occasional data loss is tolerable in exchange for reduced protocol overhead:**

1. Inward Data Collection – periodic sampling of data sources such as sensors or automatic self-test reports from network equipment
2. Outward Data Dissemination – message broadcasting to nodes or distribution of data to a network
3. Request – Response – query-based applications that use a transaction service provided by a single server where a single request-response is typical
4. Real-time applications – applications with a degree of redundancy or real-time requirement e.g. voice, telemetry

USER DATAGRAM PROTOCOL

- **The User Datagram Protocol (UDP) is a connectionless transport protocol used in TCP/IP networks**
- **Considered as a 'bare-bones' protocol that provides only the essential capabilities needed to transport a data segment between applications**
- **Features:**
  1. Unreliable – datagrams are not acknowledged
  2. No congestion control mechanism- datagrams sent as quickly as possible
  3. Stateless – Server does not keep track of status and session information of a client. Each request-response exchange with a client is treated as an independent transaction
  4. Unordered delivery – datagrams do not contain any sequencing information

UDP HEADER



- Source Port (Optional): indicates the port of the sending process and is assumed to be the port where a reply is to be sent. Set to 0 if unused
- Destination Port: port number of receiving process
- Length: length in octets of the UDP segment datagram including header and the data
- Checksum (Optional): Used for error detection, calculated based on packet header, transport header and payload bits. Set to all 0's if not used

UDP-BASED APPLICATION PROTOCOLS

- **Several well-known application protocols use UDP as transport protocol to support their operations:**
  - System Logging Protocol (syslog) – Message logging protocol used to convey event notification messages from network applications or devices
  - Network Time Protocol (NTP) - Used to synchronize the time of a computer client or server to another server or reference time source
  - Domain Name System (DNS)
  - Dynamic Host Configuration Protocol (DHCP)
  - Trivial File Transfer Protocol (TFTP) - a lightweight file transfer mechanism used for transferring short configuration files to routers and other devices, typically over a short dedicated link or within a LAN environment
  - Simple Network Management Protocol (SNMP) - Protocol for collecting and modifying information about managed devices on IP networks

CONSIDERATION WHEN USING UDP

- **When using a best-effort transport protocol like UDP, an application may need to implement mechanisms to address the following issues:**
  - Connection Establishment and Termination
  - Data Error Detection and Recovery
  - Ordered Delivery
  - Retransmission Strategy
  - Duplicate Detection
  - Crash Recovery
  - Congestion Control

CONSIDERATION WHEN USING UDP

❑ Connection Establishment and Termination

- Applications using unreliable transport protocols may require mechanisms to signal the start and end of data transfer:
  - Transferring a stream of data that is segmented into multiple datagrams
- To create some semblance of a connection, the following may be done:
  - Application level commands that initiate a transaction with a host
  - Application commands that signify the end of a transaction
- Consequently, the following are possible using UDP because no connection is needed:
  - Using a broadcast to simultaneously transmit to clients instead of sending multiple copies of the same segment
  - Have a single socket accepting traffic from multiple sources

CONSIDERATION WHEN USING UDP

❑ Ordered Delivery

- Maximum segment lifetime (MSL) of UDP is 2 minutes. Application needs to be able to handle any segment that arrives within this time interval
- Segments may be complete but arrive out of order
- If application needs to reconstruct a data stream from several datagrams:
  - Needs to incorporate numbers for sequencing
  - Needs the capability to reassemble the original data stream from its individual datagrams

CONSIDERATION WHEN USING UDP

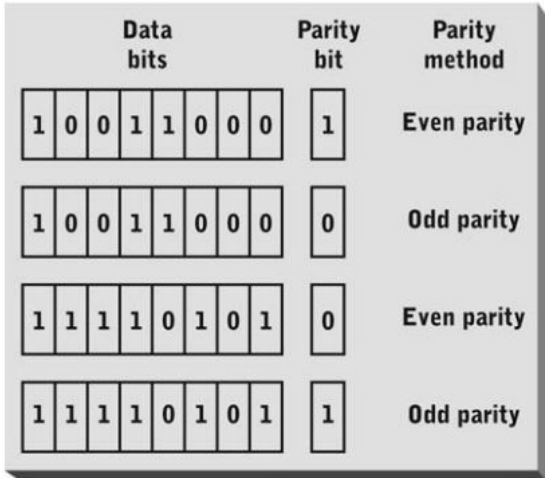
❑ Data Error Detection and Correction

- As with any data transmission, UDP segments may be damaged in transit due to issues such as noise on transmission lines or physical layer damage
- UDP header checksum uses a weak error detection algorithm
- Application using UDP that require data integrity such as those transmitting high value data or those that support critical systems may implement additional error checking mechanisms to handle data corruption.
- Type of error checking used is dependent on the probability of errors on the connection and the importance of data accuracy of the application
- Checksums can be used if only error detection is needed
  - Sender computes checksum based on data then transmits checksum together with data
  - Receiver computes checksum based on received data
  - Receiver compares computer checksum and received checksum and accepts data only if checksums are equal

CONSIDERATION WHEN USING UDP

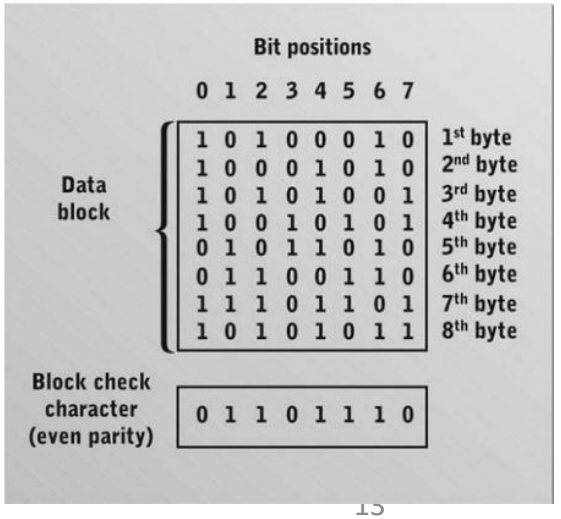
❑ Data Error Detection and Correction

- Parity Checking a.k.a. vertical redundancy checking
  - Count number of 1's in the data.
  - Even parity; - set parity bit to '0' of count of 1 bits is even, '1' if odd
  - Odd parity: set parity bit to '0' of count of 1 bits is odd, '1' if even.



- Block Checking a.k.a. Longitudinal redundancy checking
  - Sending device counts the number of 1-valued bits at each bit position in a block, then combines parity bits for each position into a block check character (BCC) and adds it to the end of the block
  - Vulnerable to the same types of errors as parity checking

- Cyclic Redundancy Check (CRC)
  - Most widely used error-detection method.
  - Produces a BCC for a group of characters or bytes but uses more than 8 bits and a different mathematical algorithm



CONSIDERATION WHEN USING UDP

❑ Data Error Detection and Correction

- Forward Error Correction (FEC) Codes may be used if errors need to be corrected
  - Receiver may correct errors on its own provided that errors are limited to a few bits only
  - Avoids the additional cost of having to request for a retransmission
  - Requires additional redundant bits to be sent
  - Triple module redundancy code example
    - ‘**0**’ sent as ‘**000**’ and ‘**1**’ sent as ‘**111**’
    - A value ‘**0101**’ is sent as ‘**000111000111**’
    - A received value ‘**000101000111**’ is detected as an error and automatically corrected to ‘**000111000111**’

CONSIDERATION WHEN USING UDP

❑ Retransmission Strategy

- Retransmission of data may be needed when:
  - Segment arrives at the destination but is damaged in transit
  - Segment does not arrive at the destination
- An application that needs confirmation of successful transmission of data may implement the following:
  - Acknowledgments for received segments
  - Retransmission timer to limit waiting time for a segment to be acknowledged before retransmission
  - Application-level commands that signify a request for a missing or damaged segment

CONSIDERATION WHEN USING UDP

❑ Duplicate Detection

- Duplicate transmissions can happen under the following scenarios:
  - The acknowledgment for a segment is lost in transit prompting the sender to retransmit a copy
  - A transmitted segment is delayed hence the intended recipient does not acknowledge before the sender's timer expires and retransmits a copy
- An application that needs the ability to handle and differentiate potential duplicate segments must implement the following:
  - The receiver must assume that the acknowledgment was lost and acknowledge the duplicate
  - The segment sender must be able to handle multiple acknowledgments for the same segment
  - If implementing a sequence or identifying number for each segment, ensure that the range of values is large enough to not cycle within the expected lifetime of a segment
  - Use application commands that are repeatable without side effects

CONSIDERATION WHEN USING UDP

❑ Crash Recovery

- When the system upon which an application is running fails, any ongoing data transfer is halted, and the other side of the communication may not realize the failure that occurred.
- An application where a single stream of data may require multiple segments to be transferred with confirmation of receipt needs to handle receiver crashes so as not to enter an indefinite waiting state
- Handling methods:
  - Implementation of maximum retransmission attempts in case the receiving side does not recover
  - Implementation of application-level commands to restart or resume the transfer in case the receiving side recovers immediately

CONSIDERATION WHEN USING UDP

❑ Congestion Control

- UDP does not have any flow control mechanisms; hence an application may potentially transmit segments at a rate that consumes all available bandwidth
- Applications that use UDP should incorporate mechanisms that control their transmission rate to avoid causing congestion
- Typical approaches:
  - Low Data Volume applications (e.g. transaction-based apps)
  - Limit send rate to 1 packet per round trip time
  - Bulk Data applications (e.g. streaming apps)
  - Monitor packet loss and/or round trip time on the network and adjust such that the UDP packet flow using a windowing technique to increase or decrease flow
  - Maintain send rate but dynamically resize segment based on congestion

SOCKETS

- A socket is a structure in memory that represents the endpoint for communication
- A pair of sockets belonging to each communicating process are connected together, to create communication channels between the processes.
- Each socket is associated with the address of the process, which includes both its IP address (identifying the host computer) and the port number
- Socket primitives are essentially commands (or functions) that control the operation of a network socket

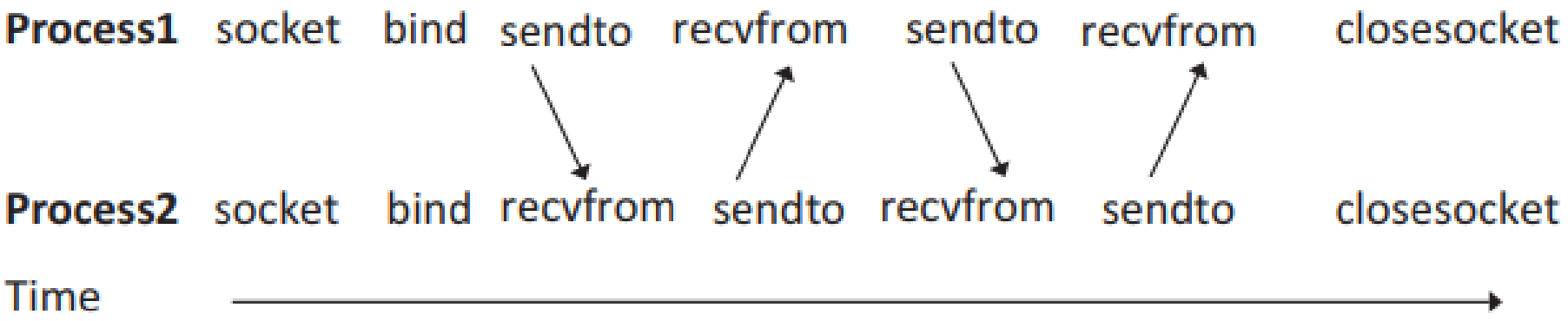
BINDING

- **Binding is the term referring to the association between a process and a port and is performed by the host OS**
- **Binding a process to a port requires that the port is not already in use by another process**
- **When a message arrives:**
  - The OS filters messages based on their destination IP address
  - The destination port number in the segment header is used to know which process to pass a particular arriving message to.
  - If there is no existing binding for the destination port, then the message is discarded

UDP SOCKETS

❑ UDP Sockets support the following primitives:

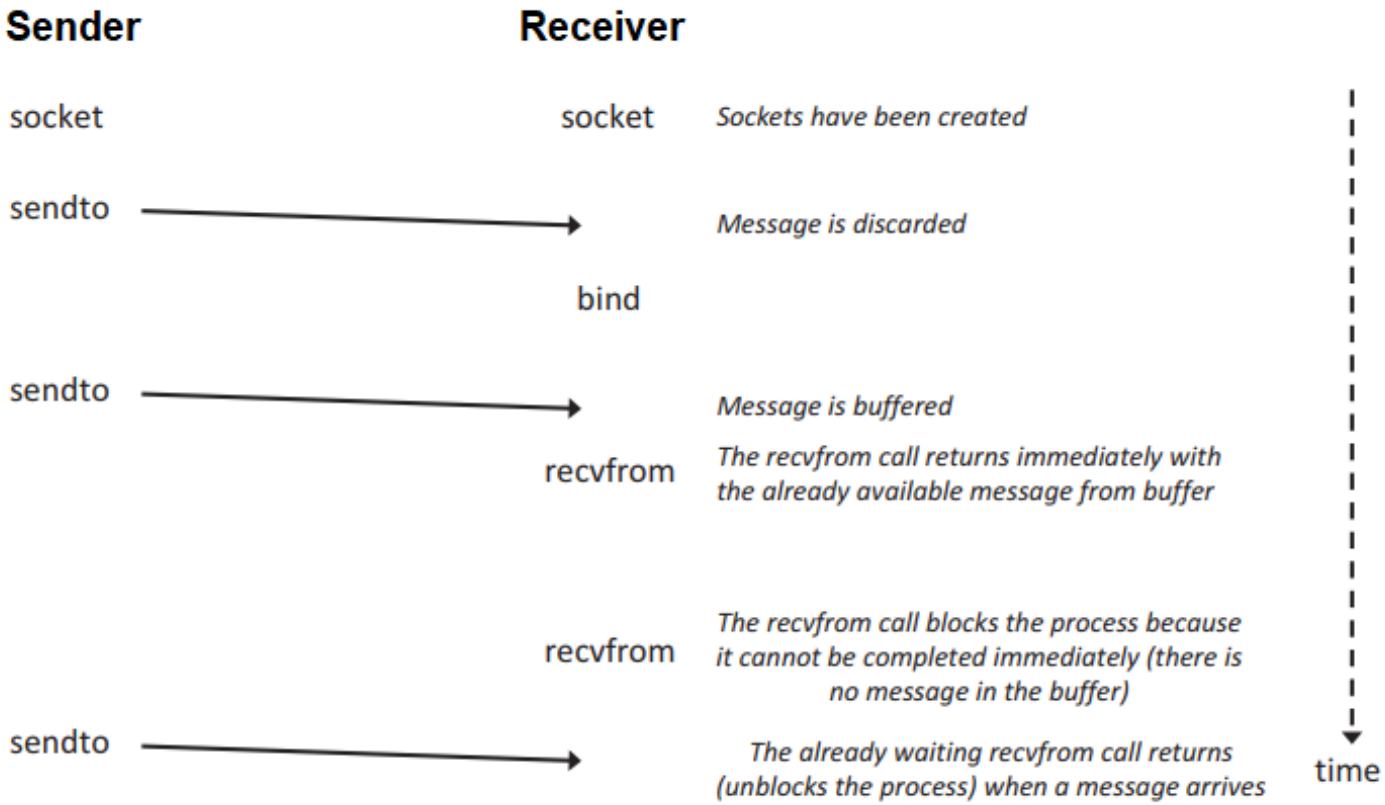
- Socket primitive is used to create a socket which may be set to blocking or non-blocking IO mode
- Bind primitive is used to map a process to a port
- Sendto primitive is used to send data to another process.
- Recvfrom primitive is used to retrieve data from the receive buffer.
- Closesocket primitive is used to close the socket.



UDP SOCKETS

❑ Blocking

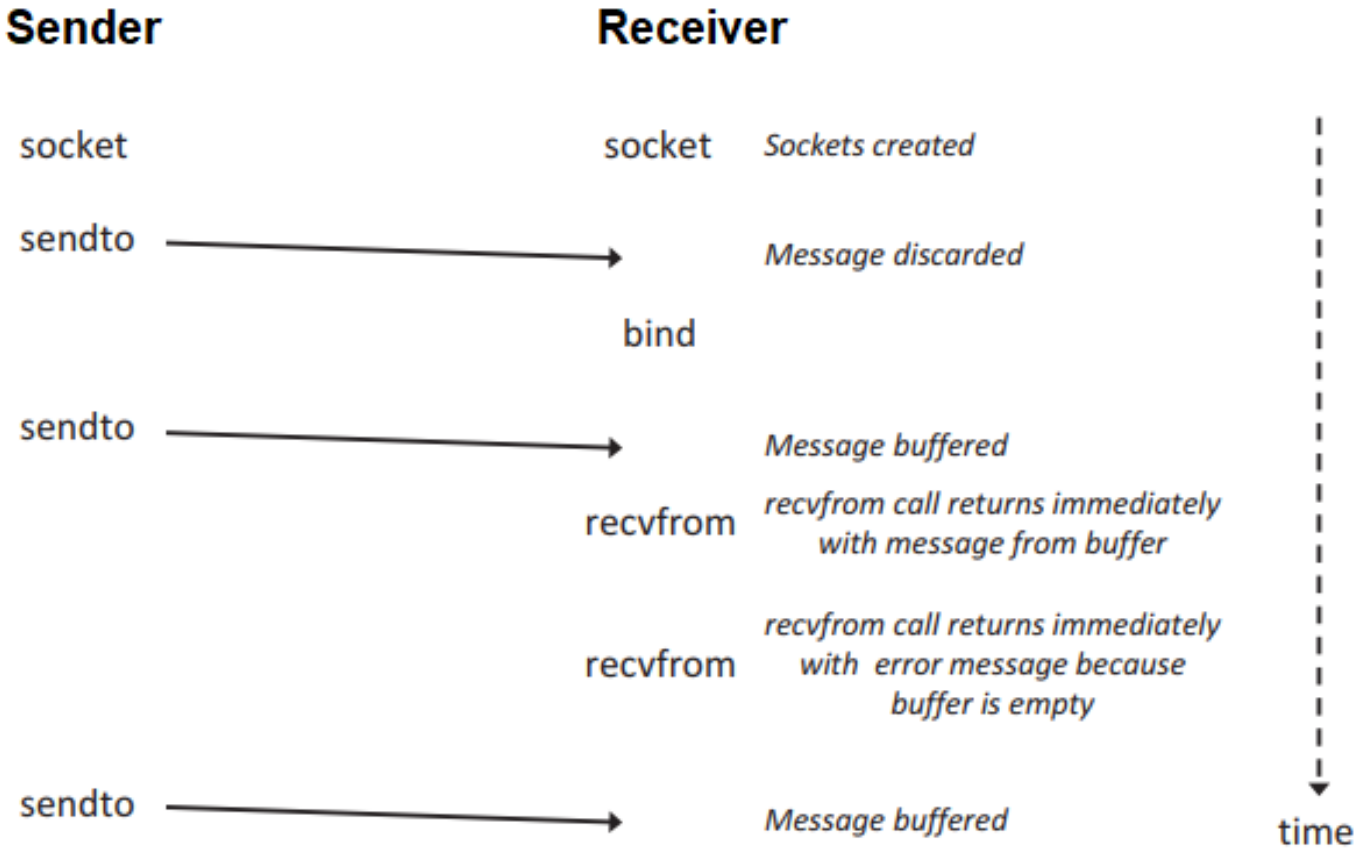
- Process has to wait for data to arrive(blocking state) when it attempts to receive and cannot do other activities while in this state



UDP SOCKETS

❑ Non-Blocking

- Process gets an error when it attempts to receive non-existing data and can choose to carry on with other activities then retry receiving later
- Working with non-blocking sockets usually entails the use of a timer to schedule periodic calls to the recvfrom primitive to check for new messages



RFC READINGS

- **UDP - RFC 768**

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