Network Programming (Sockets)

Redes e Serviços

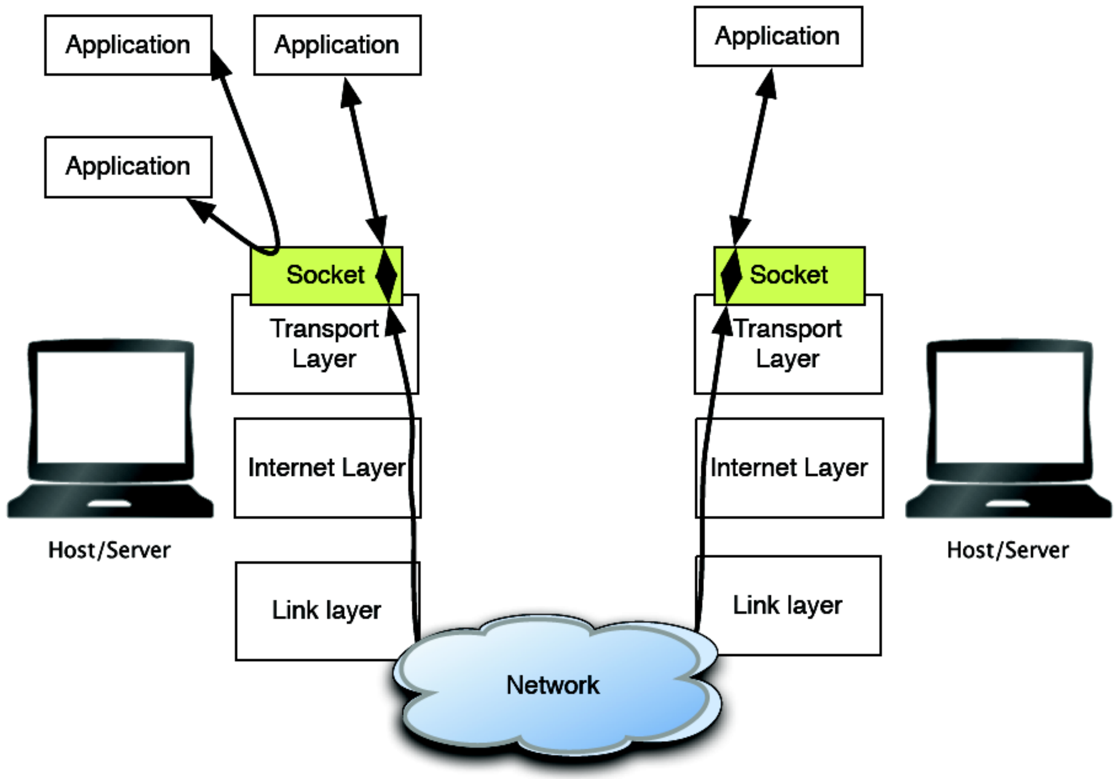
Licenciatura em Engenharia Informática
DETI-UA

universidade de aveiro

deti.ua.pt

Sockets (1)

- Inter-process communication mechanism
  - Either local or remote processes
- Provide an abstraction for processes to exchanging information
  - Follows a client/server paradigm.



Sockets (2)

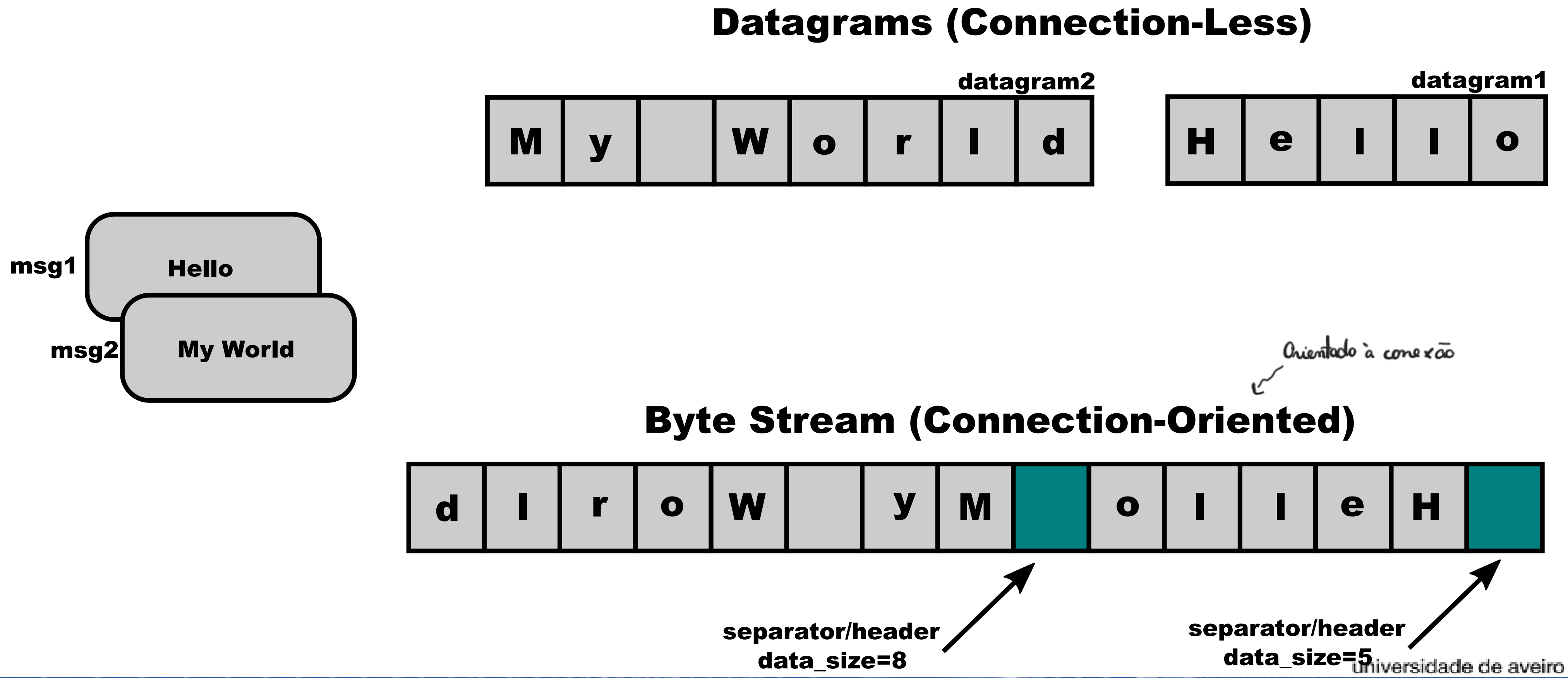
- A Socket is identified by
  - Family: AF_INET (IPv4), AF_INET6 (IPv6) and many other less common.
    - Defines the address structure.
    - Defines also the communications layer (e.g. IP version).
  - Type: Determines what transport protocol is used.
    - UDP – Connectionless (SOCK_DGRAM).
    - TCP – Connection oriented (SOCK_STREAM).
    - RAW – Direct access to a layer of the stack (SOCK_RAW).
      - Allows to send and receive crafted packets.
      - e.g. the ping command (ICMP packets).
  - Address: local address (IP or path)
    - Also remote address if connection oriented
  - Port: Local port 0-65535
    - Also remote port if connection oriented
- Restriction
  - 1 socket per Address, per Port, per Protocol, per Family, per Host

Sockets (3)

- AF_INET/AF_INET6 families
  - Allows communication between processes on any IP/IPv6 enabled machine.
  - Endpoints can be on local or remote machines
    - 127.0.0.1 or ::1 for the localhost
- A Socket must be “Bound” to a local IP/PORT
  - Sockets can be bound to a specific address or to any address
    - e.g. 192.168.0.1 (only listens in this address)
    - e.g. 0.0.0.0 (listens in all active addresses and broadcast)
  - bind() method can be used to associate a Socket to a local IP/Port.

Byte Stream vs. Datagrams

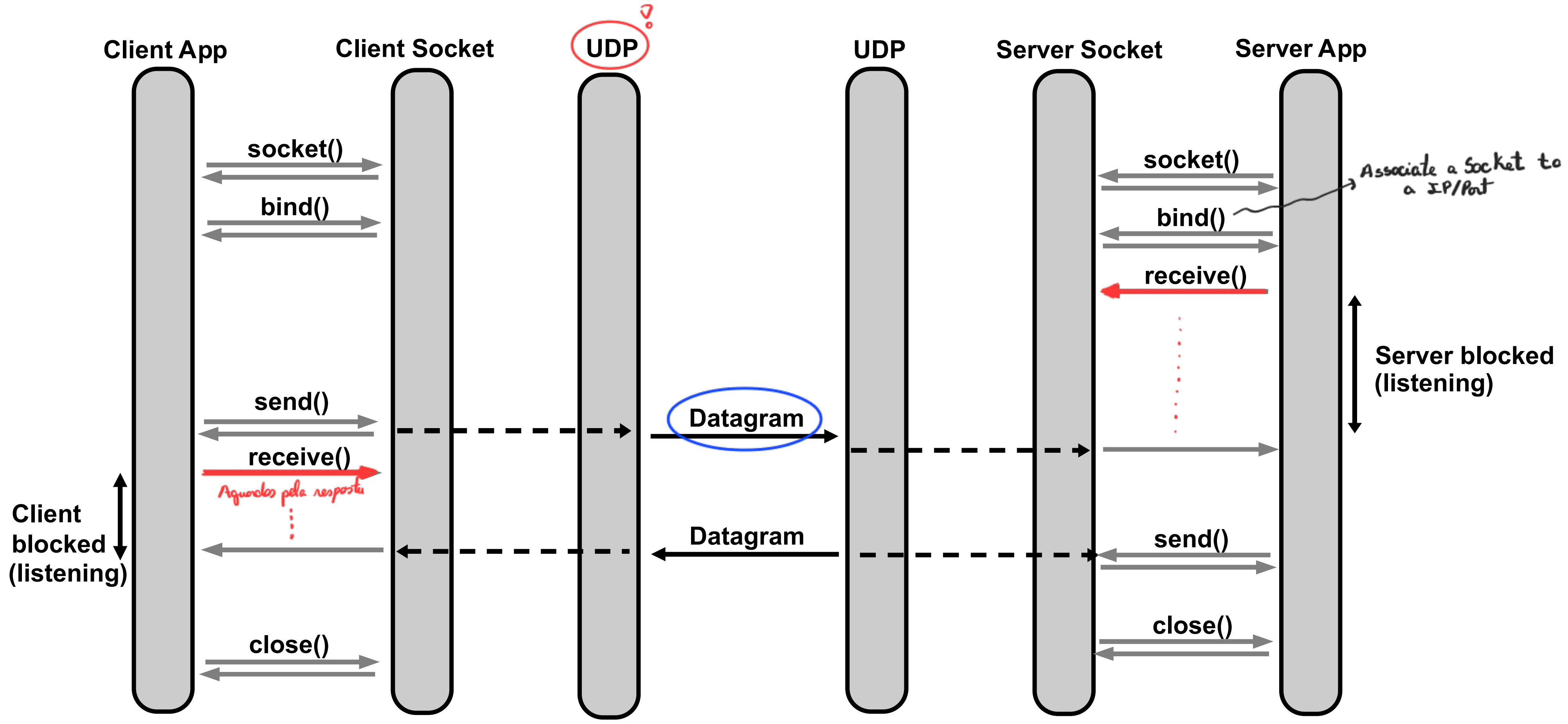
- TCP needs application-level message separators (headers).
  - Must contain size information of each “independent” data chunk in the bytestream.


Datagrams (Connection-Less)
datagram2
M y W o r l d
datagram1
H e l l o
msg1
Hello
msg2
My World
Orientado à conexão
Byte Stream (Connection-Oriented)
d l r o W y M o l l e H
separator/header data_size=8
separator/header data_size=5

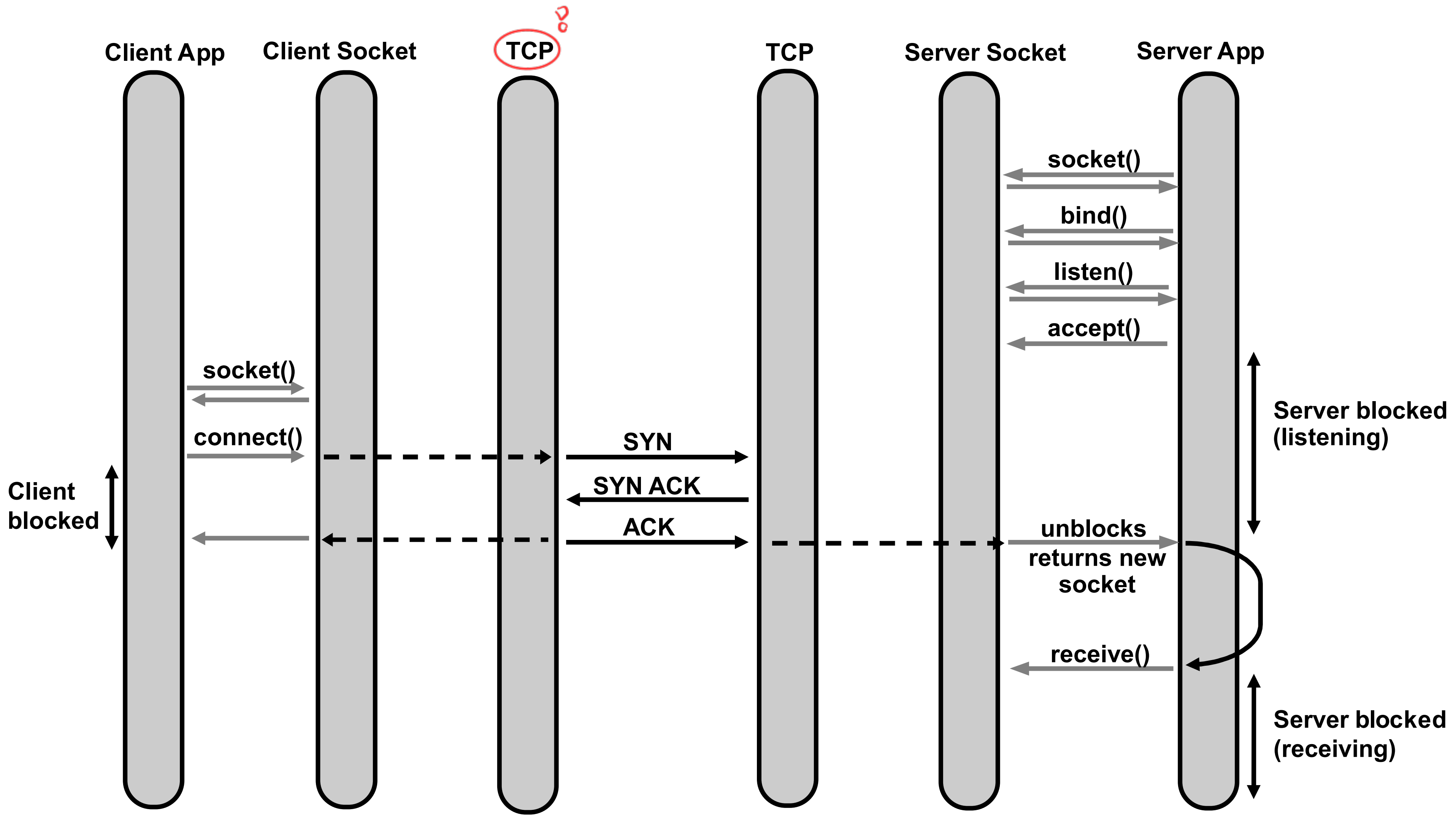
Socket IO / Blocking

- Socket Operations are Blocking
  - They block until:
    - Packet is fully sent,
    - Client is accepted,
    - Packet is received,
    - Etc…
  - Can be set to non-blocking.
    - Program flow must take that in consideration.

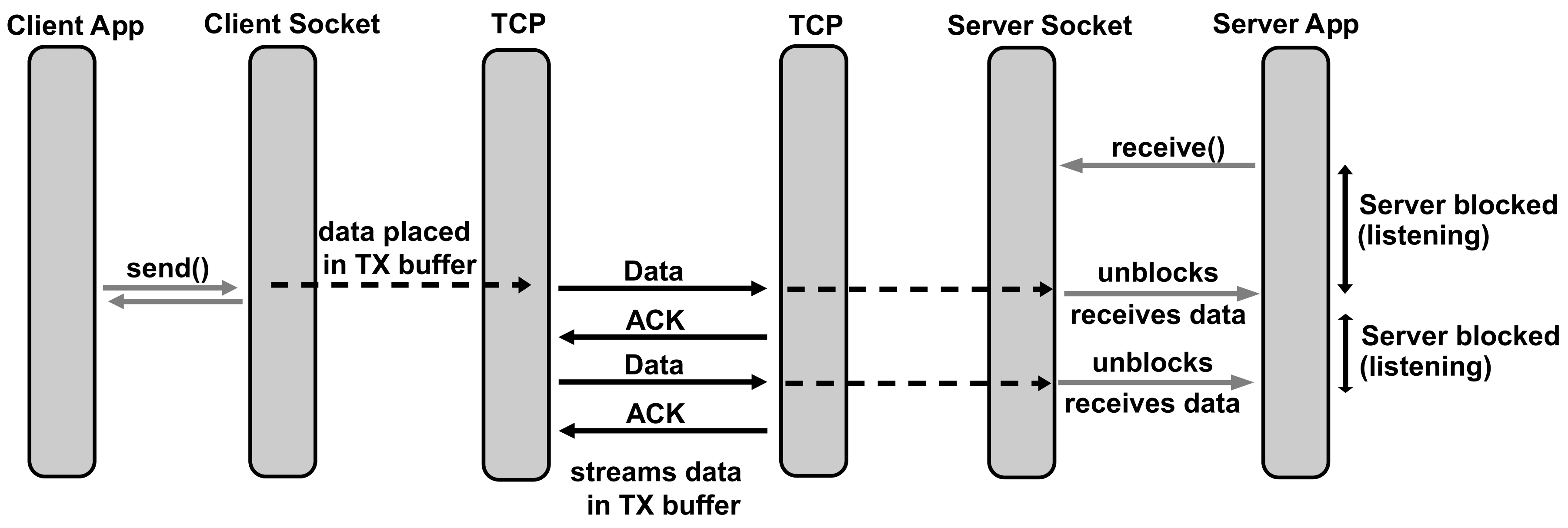
Connection-Less



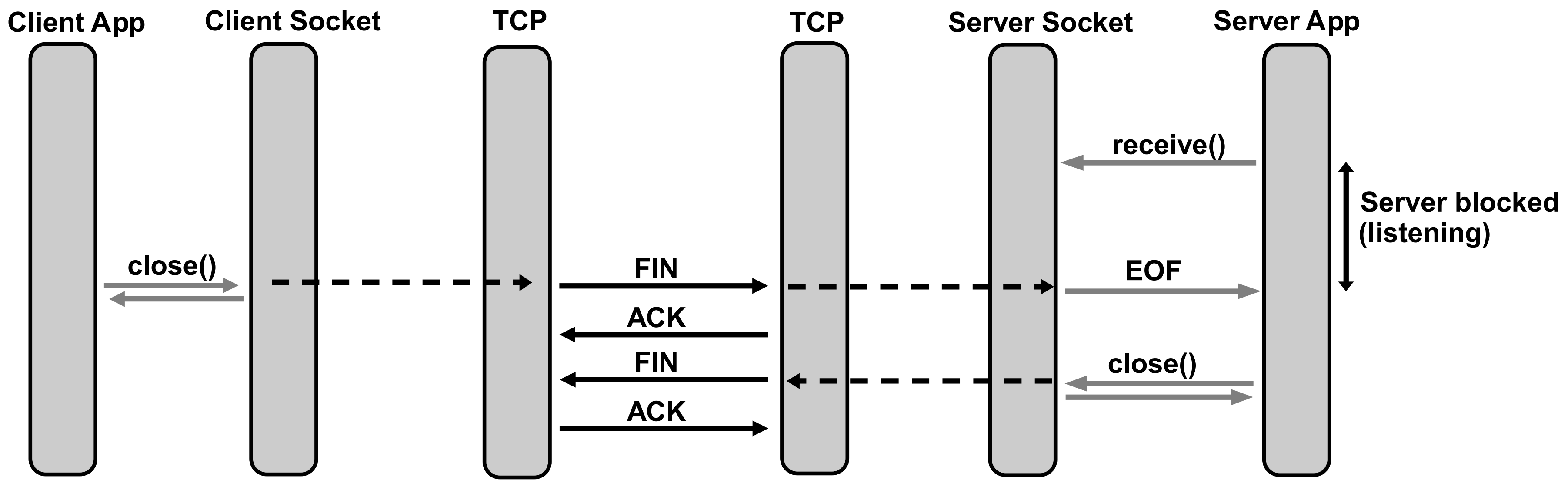
Connection-Oriented (1)



Connection-Oriented (2)

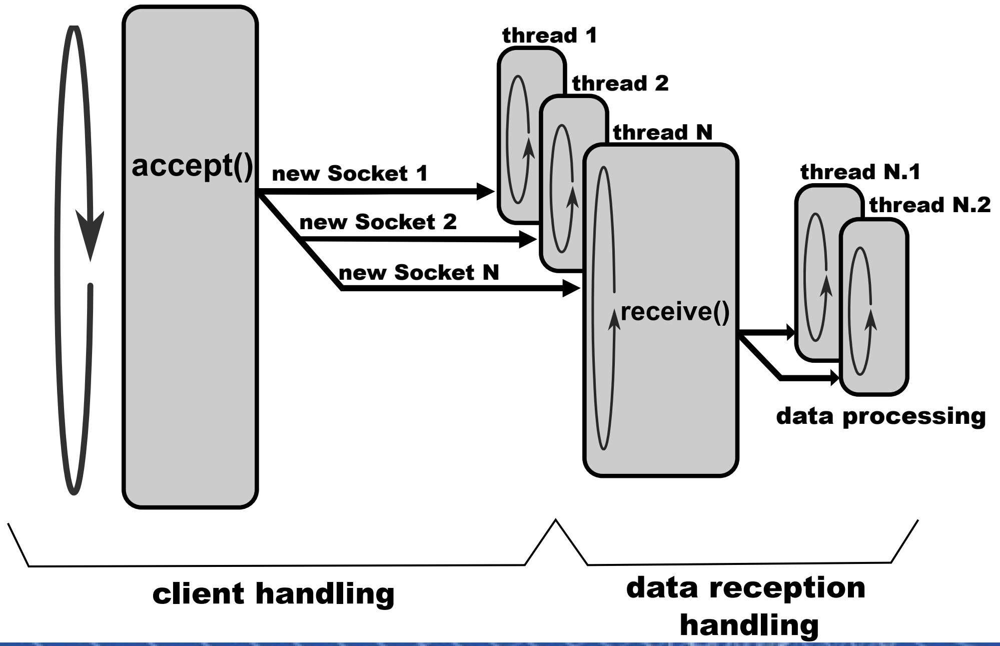


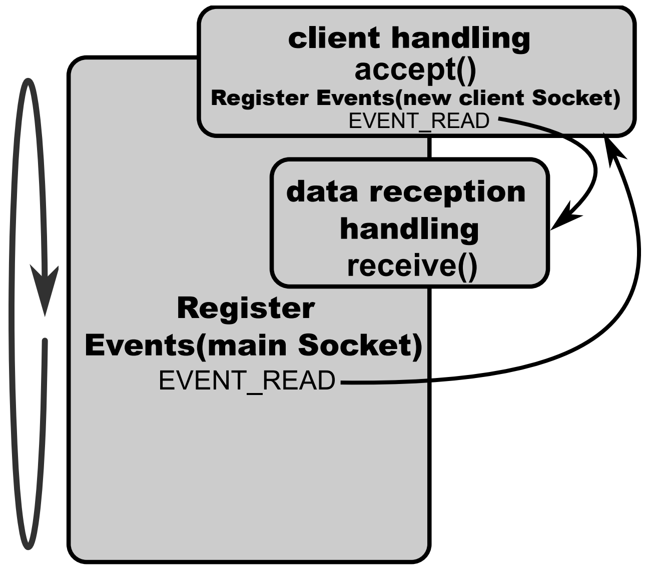
Connection-Oriented (3)



Non-Blocking IO

- Solutions for Socket Operations Blocking
  - Threads → processamento paralelo
    - Multiple parallel process can be used to process simultaneous connections.
    - Most solutions used (and still use) IO operations with multiple threads.
  - Selector → já não é eficiente!
    - Socket is set to non-blocking.
    - Actions are performed upon the detection of predefined socket events (e.g., EVENT_READ – data available to read).





Socket Timeouts

- A socket can be in one of three modes:
  - Blocking,
    - Default state.
  - Non-blocking,
  - or Timeout. → quando criamos definimos
- In blocking mode, operations block until complete or the system returns an error (such as connection timed out).
- In non-blocking mode, operations fail if they cannot be completed immediately.
  - Selects can be used to know when and whether a socket is available for reading or writing.
- In timeout mode, operations fail if they cannot be completed within the timeout specified for the socket (they raise a timeout exception)or if the system returns an error.

Data Format

Textual vs. Binary Structure

?

- Textual
  - Pure text (format based on CSV, TSV, newline, …), HTML, JSON, XML.
  - Larger messages and higher processing times.
    - Higher Bandwidth, CPU and Memory requirements.
    - Constrains utilization in high performance applications.
- Binary Structure
  - Defined by the protocol stack (definition of formats and methodologies).
  - Faster at all levels.
  - Little/Big Endian concerns.
    - Must depend on platform and/or be defined by the protocol stack.

```
{"msg_id":21654,
"values":[12, 45, 109]
}
```

Message data has **42 bytes**

VS.

Structure format

```
uint16 msg_id
uint8 num_values
uint8 values[]
```

Message data has **6 bytes**

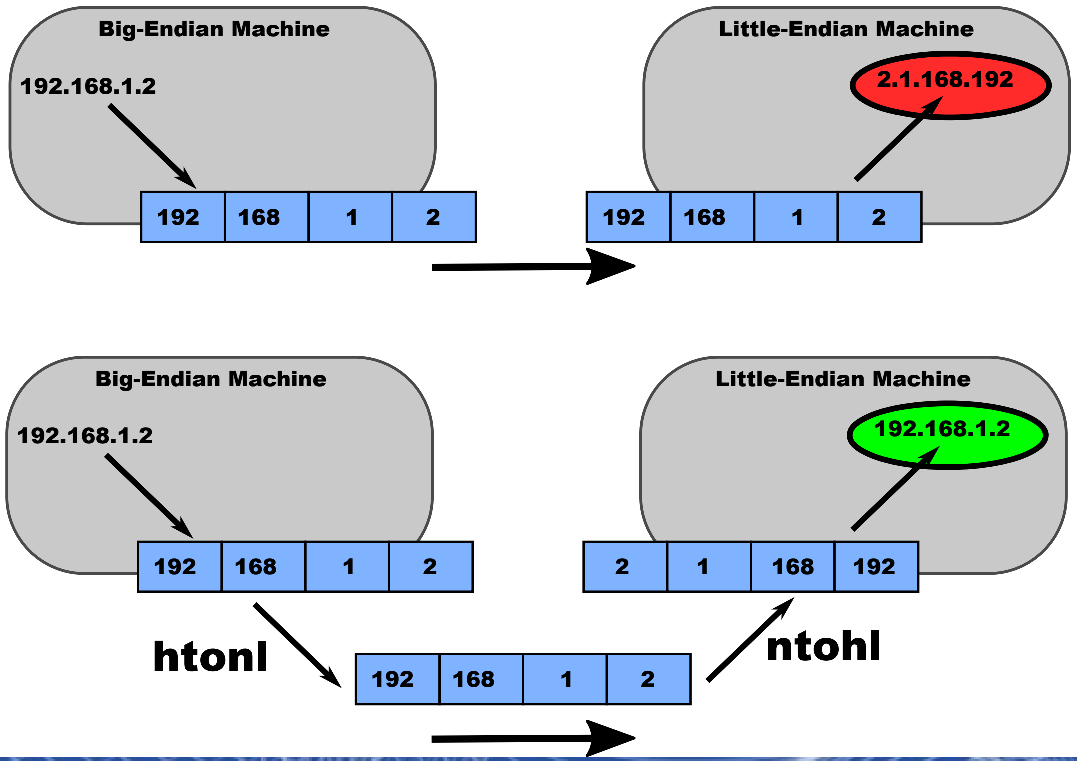
```
0x5496
0x03
0x0C 0x2D 0x6D
```

Big Endian

esquerda para a direita ou ao contrário...

Network/Host Formats

- Different computers architectures/OS use different byte orderings internally for their multibyte integer.
  - **`htonl(i), htons(i)`**
    - 32-bit or 16-bit integer from host format to network format (Big-endian).
  - **`ntohl(i), ntohs(i)`**
    - 32-bit or 16-bit integer from network format to host format.



Big-Endian Machine
192.168.1.2
192 168 1 2
Little-Endian Machine
2.1.168.192
192 168 1 2
Big-Endian Machine
192.168.1.2
192 168 1 2
htonl
192 168 1 2
ntohl
Little-Endian Machine
192.168.1.2
2 1 168 192