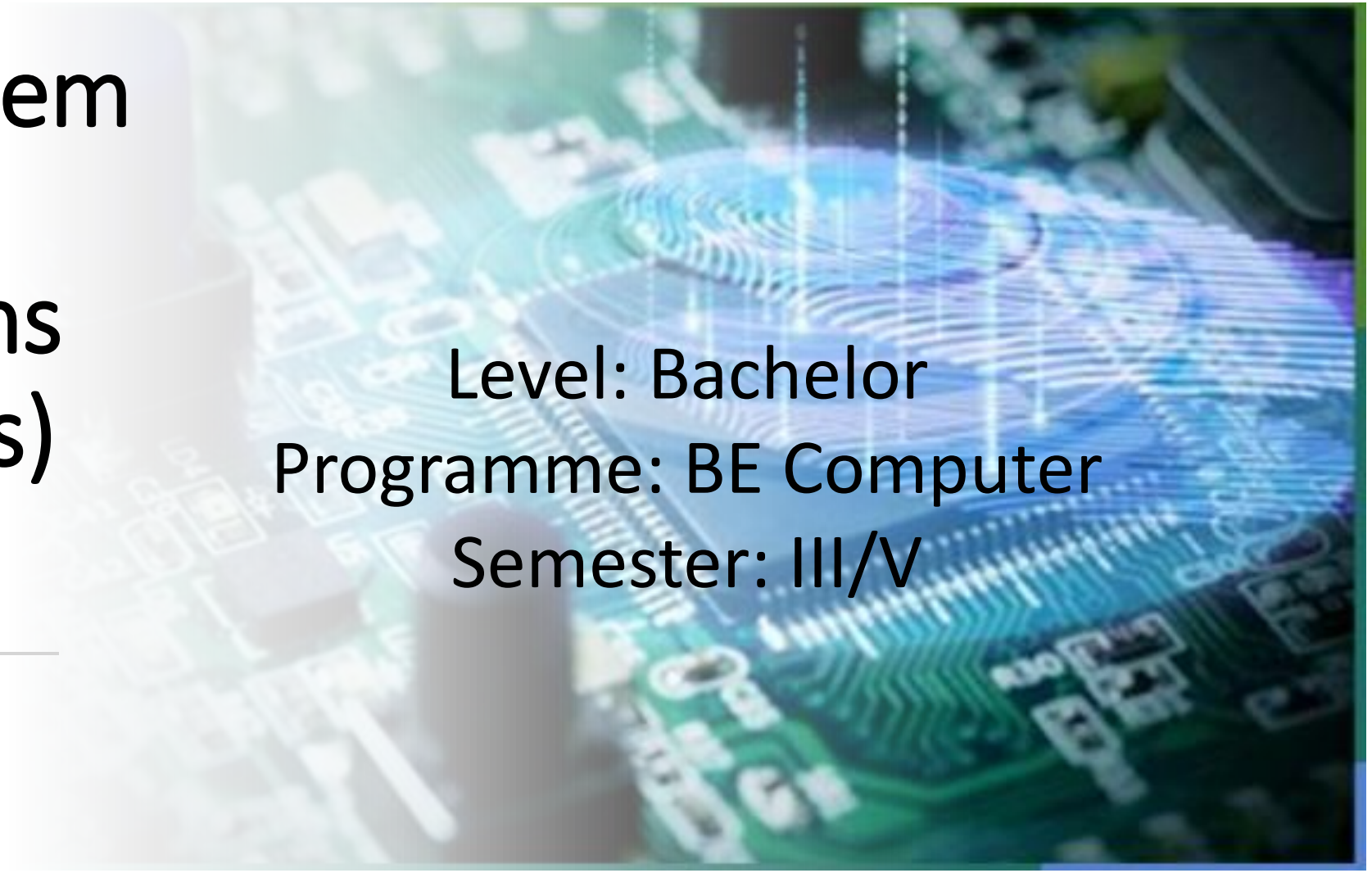
Embedded System Chapter 5. Communications Protocals (3 hrs)



Level: Bachelor
Programme: BE Computer
Semester: III/V

Ishwor Koirala, Ph.D.

Instructor

Outline

Introduction

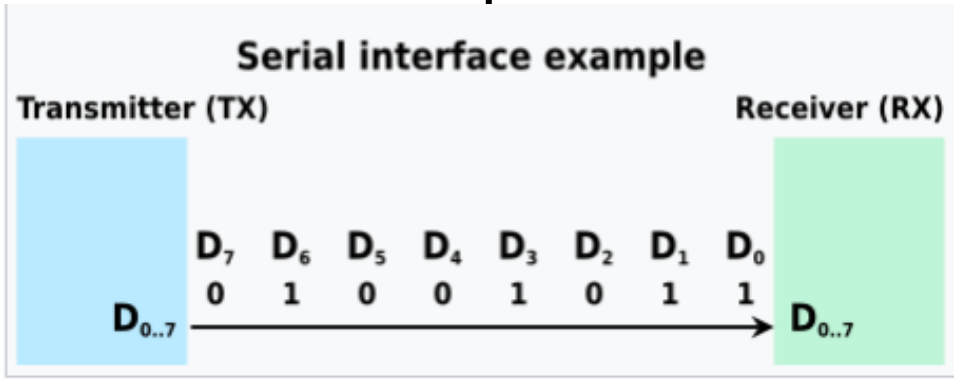
Books

Course Contents

1. Introduction to Embedded system (3 hrs)
2. Programming for Embedded systems (5 hrs)
3. Real-time operating systems (RTOS) (5 hrs)
4. Embedded System Design using VHDL (5 hrs)
5. **Communications Protocals (3 hrs)**
6. Pheripherals and Interfacing (4 hrs)
7. Internet of Things (IoT)and Embedded system (3hrs)

Serial Communication

- In telecommunication and data transmission, **serial communication** is the process of sending data one bit at a time, sequentially, over a communicatio channel or computer bus.
- This is in contrast to parallel communication, where several bits are sent as a whole, on a link with several parallel channels.
- Serial communication is used for all long-haul communication and most computer networks, where the cost of cable and synchronization difficulties make parallel communication impractical.



Serial Communication

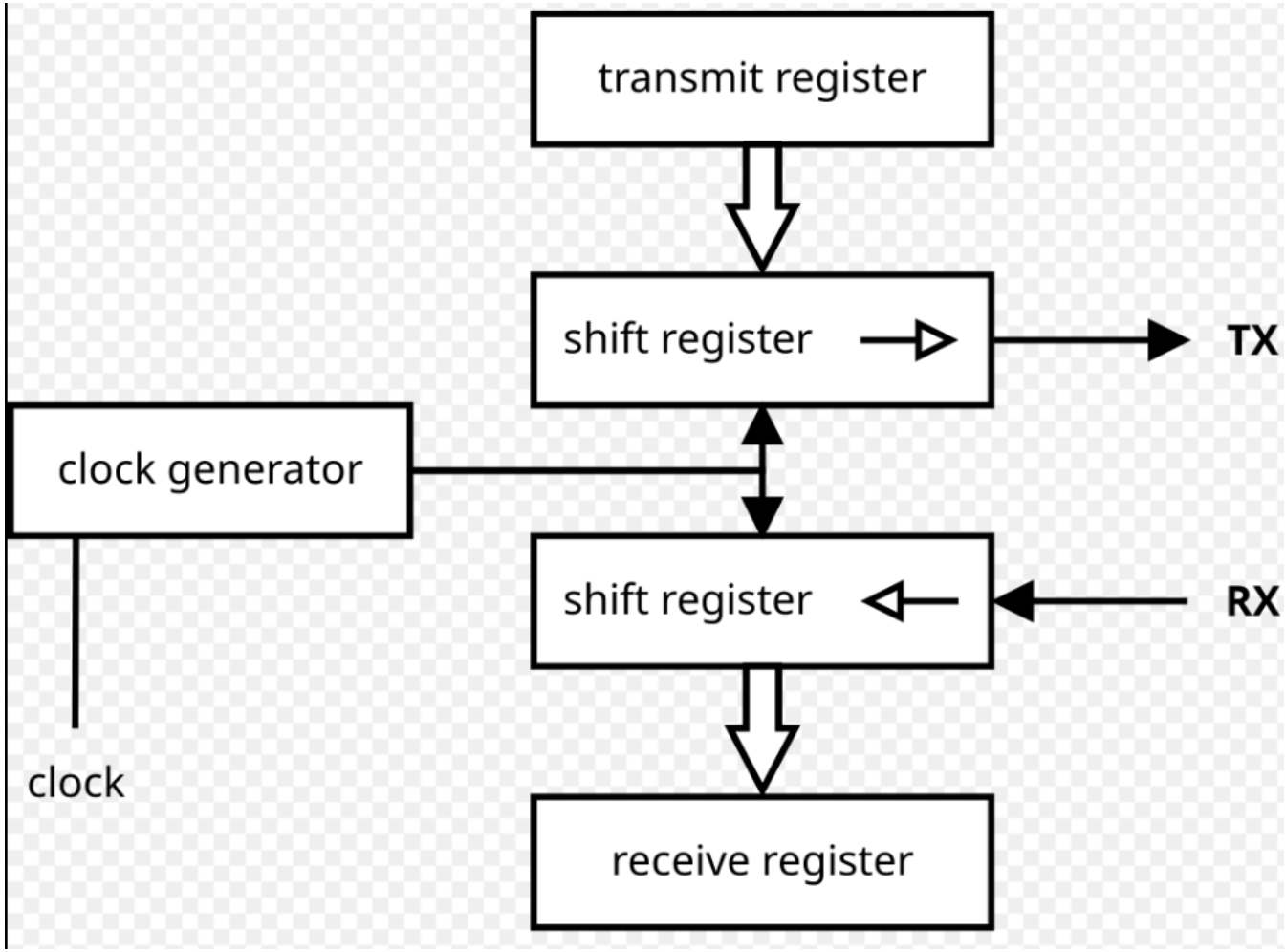
- Serial computer buses have become more common even at shorter distances, as improved signal integrity and transmission speeds in newer serial technologies have begun to outweigh the parallel bus's advantage of simplicity (no need for serializer and deserializer, or SerDes) and to outstrip its disadvantages (clock skew, interconnect density). The migration from PCI to PCI Express (PCIe) is an example

UART

- A **universal asynchronous receiver-transmitter** (**UART**) is a peripheral device for asynchronous serial communication in which the data format and transmission speeds are configurable.
- It sends data bits one by one, from the least significant to the most significant, framed by start and stop bits so that precise timing is handled by the communication channel.
- The electric signaling levels are handled by a driver circuit external to the UART. Common signal levels are RS-232, RS-485, and raw TTL for short debugging links.
- Early teletypewriters used current loops.
- A UART is usually an individual (or part of an) integrated circuit (IC) used for serial communications over a computer or peripheral device serial port.

Block Diagram of UART

- One or more UART peripherals are commonly integrated
  in microcontroller chips.
- Specialised UARTs are used for automobiles, smart cards and SIMs.

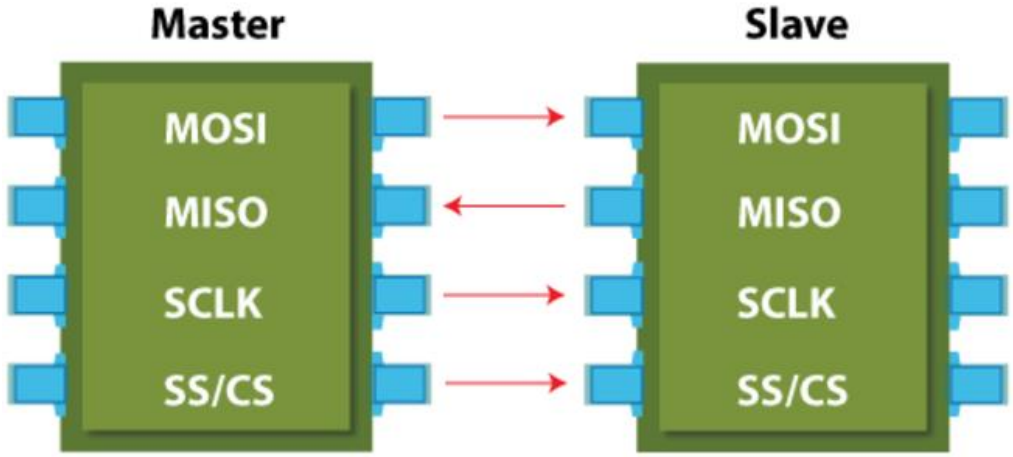


SPI

- **SPI (Serial Peripheral Interface)** is a **synchronous serial communication protocol** used by microcontrollers to connect with peripheral devices such as sensors, flash memory, and analog-to-digital converters.
- It allows for high-speed data transfer and is commonly used in digital communication applications and embedded systems.
- In this protocol, devices are communicated in the master-slave relationship. The master device controls the slave device, and the slave device takes the instruction from the master device.

SPI

SPI protocol uses the four wires for the communication as shown in the figure.



- **MOSI:** MOSI stands for Master Output Slave Input. It is used to send data from the master to the slave.

- **MISO:** MISO stands for Master Input Slave Output. It is used to send data from the slave to the master.
- **SCK or SCLK (Serial Clock):** It is used to the clock signal.
- **SS/CS (Slave Select / Chip Select):** It is used by the master to send data by selecting a slave.

SPI

Advantages of SPI

- The main advantage of the SPI is to transfer the data without any interruption.
- It is simple hardware.
- It provides full-duplex communication.
- There is no need for a unique address of the slave in this protocol.
- This protocol does not require precise oscillation of slave devices because it uses the master's clock.
- In this, software implementation is very simple.
- It provides high transfer speed.
- Signals are unidirectional.
- It has separate lines of MISO and MOSI, so the data can be sent and received at the same time.

SPI

Disadvantages of SPI

- Usually, it supports only one master.
- It does not check the error like the UART.
- It uses more pins than the other protocol.
- It can be used only from a short distance.
- It does not give any acknowledgment that the data is received or not.

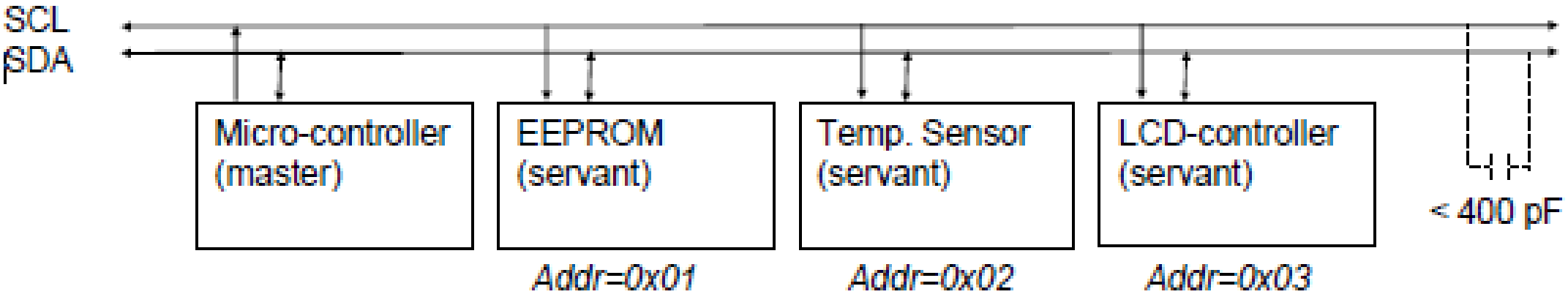
Applications of SPI

- Memory: SD Card, MMC, EEPROM, and Flash.
- Sensors: Temperature and Pressure.
- Control Devices: ADC, DAC, digital POTS, and Audio Codec.
- Others: Camera Lens Mount, Touchscreen, LCD, RTC, video game controller, etc.

Inter Integrated Circuit (I2C)

- I2C is a serial protocol for two wire interface to connect low speed devices like microcontroller, EEPROMs, A/D and D/A converters, I/O interface and other similar peripherals in embedded systems.
- Philips Semiconductor developed the Intel-IC or I2C bus in early 1980's.
- Its original purpose was to provide an easy way to connect a CPU to peripheral chips in a TV-set.
- Based on original specification I2C has 7-bit address space, that allows a total of 128 devices to communicate over a shared bus and data transfer rate of up to 100kbits/s.
- With increased data transfer rate requirements, the I2C specification has been recently enhanced to include fast-mode, 3.4Mbits/s, with 10-bit addressing.

I2C

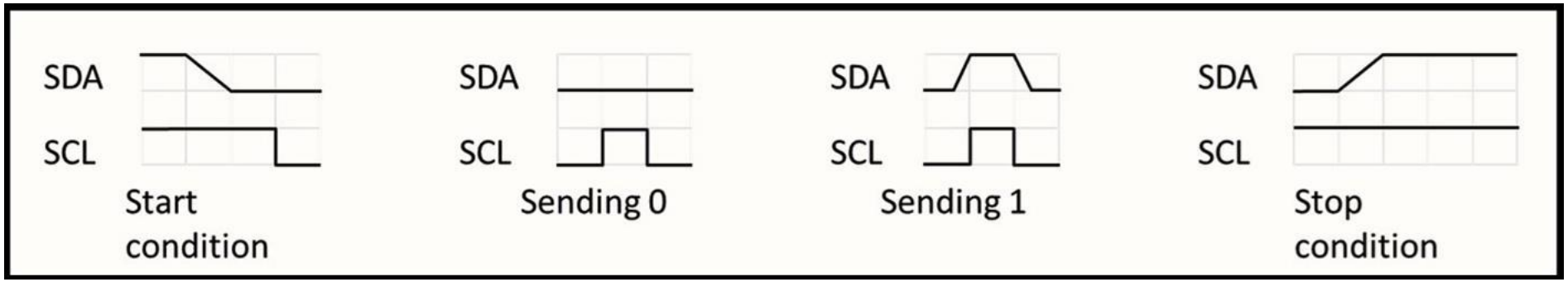

SCL
SDA
Micro-controller
(master)
EEPROM
(servant)
Temp. Sensor
(servant)
LCD-controller
(servant)
< 400 pF
Addr=0x01
Addr=0x02
Addr=0x03

I2C

- It is a true multi-controller bus including collision detection and arbitration to prevent data corruption if two or more controllers simultaneously initiate data transfer.
- In figure, there are four devices attached to the bus. One of these devices, the microcontroller, is a master. The other three devices are servants.
- Each servant devices is assigned a unique address.
- Only master can initiate a data transfer on an I2C bus.
- The protocol does not limit the number of master devices on an I2C bus.
- Both master and servant devices can be senders or receivers of data.
- The two bus lines are, a serial data line (SDA) and a serial clock line (SCL).
- Length of the wires is not limited as long as the total bus capacitance is less than 400pF.

I2C

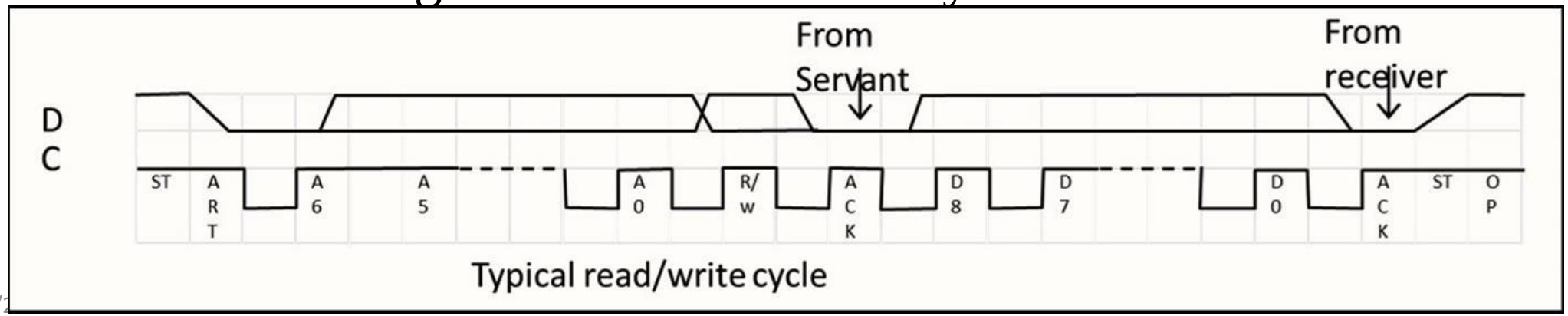
- All data transfer on an I2C bus are initiated by a start condition, which is a high to low transition of SDA line while the SCL line is held high.
- All data transfer on an I2C bus are terminated by a stop condition, which is a low to high transition of SDA line while the SCL signal is held high.
- Actual data transferred in between the start and stop conditions.
- Ones and zeros are sent as in figure.
- Here, the bit value is placed on the SDA line by the master device while the SCL line is low and maintained stable until after a clock pulse on SCL.



I2C

A typical I2C write cycle works as follows:

- The master device initiates the transfer by a start condition.
- Then the address of the device that the byte is being written to is sent starting with the most significant down to the least significant bit.
- If performing a write, right after sending the address of the receiving device, the master sends a zero.
- The receiver device in return acknowledges the transmission by holding the SDA line low during the first ACK clock cycle.



Typical read/write cycle

I2C

- Following the acknowledgment the master device transmits a byte of data starting from the most significant down to the least significant bit.
- The receiving device, in this case the servant, acknowledges the reception of data by holding the SDA line low during the second ACK cycle.
- In performing a read operation, the master initiates the transfer by a start condition, sends the address of the device that is being read, sends a one (logic high on SDA line) requesting a read and waits to receive acknowledgment.
- Then, the sender sends a byte of data.
- The receiver, master device in this case, acknowledges the reception of data and terminates the transfer by generating a stop condition.

Wireless Communication

Bluetooth:

- Bluetooth is a wireless technology standard for exchange over short distances from fixed and mobile devices.
- It operates at frequencies between 2402 and 2480 MHz which is the globally unlicensed industrial, scientific and medical (ISM) 2.4GHz short-range frequency band.
- Since Bluetooth uses a radio based link, it does not require line of sight for communication.
- Bluetooth 4.0 may provide the transfer rate of up to 25Mbps.
- Bluetooth is a packet based protocol with a master-slave structure and one master may communicates up to maximum of seven devices.

Wireless Communication

Bluetooth: (contd…)

- Low power consumption and short range based communication is the typical feature of Bluetooth.
- For class 3 radio, range is up to 1m with max permitted power of about 1mW.
- For class 2 radio, range is up to 10m and max permitted power of about 2.5mW.
- For class 1 radio, range is up to 100m and 100mW of transmission power.

ZigBee

- **Zigbee** is an IEEE 802.15.4-based specification for a suite of high-level communication protocols used to create personal area networks with small, low-power digital radios, such as for home automation, medical device data collection, and other low-power low-bandwidth needs, designed for small scale projects which need wireless connection.
- Hence, Zigbee is a low-power, low-data-rate, and close proximity (i.e., personal area) wireless ad hoc network.
- Zigbee is a low-power wireless mesh network standard targeted at battery-powered devices in wireless control and monitoring applications.
- Zigbee delivers low-latency communication.
- Zigbee chips are typically integrated with radios and with microcontrollers.

ZigBee

- Zigbee operates in the industrial, scientific and medical (ISM) radio bands. With the 2.4 GHz band being primarily used for lighting and home automation devices in most jurisdictions worldwide.
- While devices for commercial utility metering and medical device data collection often use *sub-GHz* frequencies, (902-928 MHz in North America, Australia, and Israel, 868-870 MHz in Europe, 779-787 MHz in China, even those regions and countries still using the 2.4 GHz for most globally sold Zigbee devices meant for home use.
- With data rates varying from around 20 kbit/s for sub-GHz bands to around 250 kbit/s for channels on the 2.4 GHz band range).
- Its low power consumption limits transmission distances to 10–100 meters (33–328 ft) line-of-sight, depending on power output and environmental characteristics.

Wi-fi

- **Wi-Fi** is a family of wireless network protocols based on the IEEE 802.11 family of standards, which are commonly used for local area networking of devices and Internet access, allowing nearby digital devices to exchange data by radio waves.
- These are the most widely used computer networks, used globally in home and small office networks to link devices and to provide Internet access with wireless routers and wireless access points in public places such as coffee shops, hotels, libraries, and airports.
- Wi-Fi uses multiple parts of the IEEE 802 protocol family and is designed to work seamlessly with its wired sibling, Ethernet.
- Compatible devices can network through wireless access points with each other as well as with wired devices and the Internet.

Wi-fi

- Different versions of Wi-Fi are specified by various IEEE 802.11 protocol standards, with different radio technologies determining radio bands, maximum ranges, and speeds that may be achieved.
- Wi-Fi most commonly uses the 2.4 gigahertz (120 mm) UHF and 5 gigahertz (60 mm) SHF radio bands, with the 6 gigahertz SHF band used in newer generations of the standard; these bands are subdivided into multiple channels.
- Channels can be shared between networks, but, within range, only one transmitter can transmit on a channel at a time.
- Wi-Fi's radio bands work best for line-of-sight use.
- The range of an access point is about 20 m (66 ft) indoors, while some access points claim up to a 150 m (490 ft) range outdoors.

LoRa

- LoRa is a wireless modulation technique derived from **Chirp Spread Spectrum (CSS)** technology.
- It encodes information on radio waves using chirp pulses - similar to the way dolphins and bats communicate!
- LoRa modulated transmission is robust against disturbances and can be received across great distances.
- Don’t be alarmed about the complex terms; **LoRa modulation** and **Chirp Spread Spectrum technology** are simple to understand in practice.
- In case you are curious, in this video, **Richard Wenner** explains how **Chirp Spread Spectrum technology** works:
- LoRa is ideal for applications that transmit small chunks of data with low bit rates..

LoRa

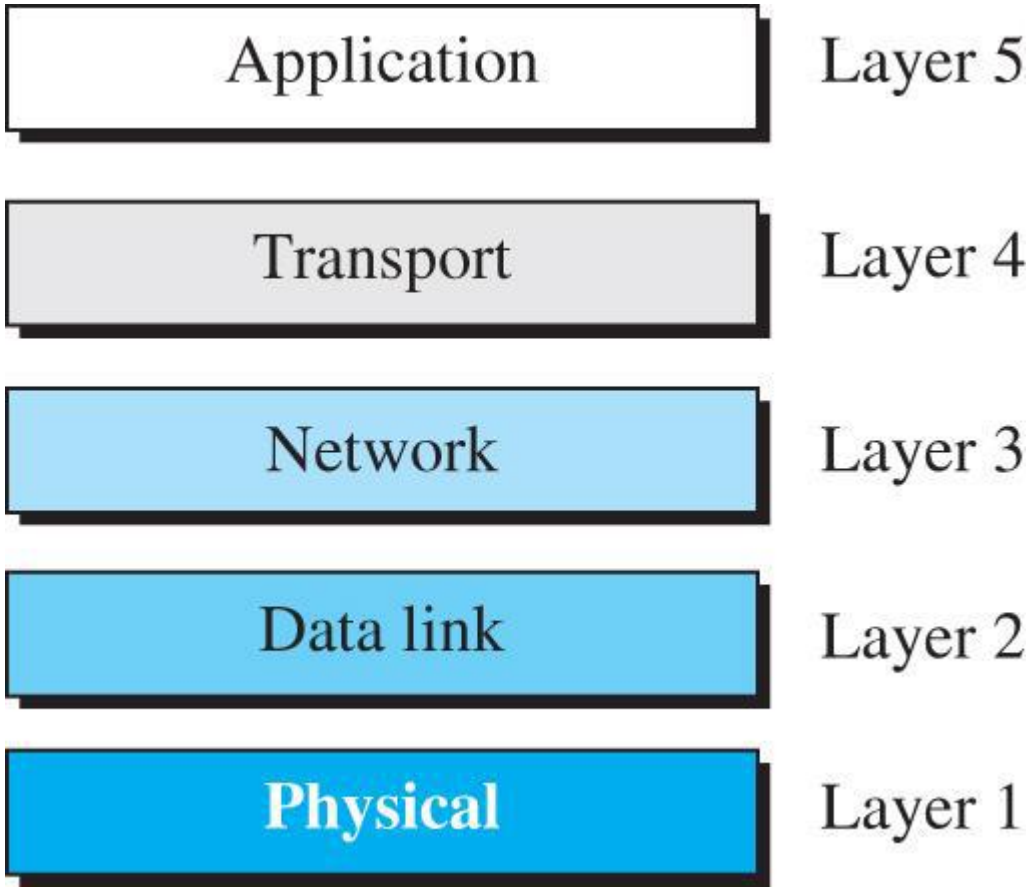
- Data can be transmitted at a longer range compared to technologies like WiFi, Bluetooth or ZigBee
- These features make LoRa well suited for sensors and actuators that operate in low power mode.
- LoRa can be operated on the license free **sub-gigahertz** bands, for example, 915 MHz, 868 MHz, and 433 MHz.
- It also can be operated on **2.4 GHz** to achieve higher data rates compared to sub-gigahertz bands, at the cost of range.
- These frequencies fall into ISM bands that are reserved internationally for industrial, scientific, and medical purposes.

GSM/GPRS

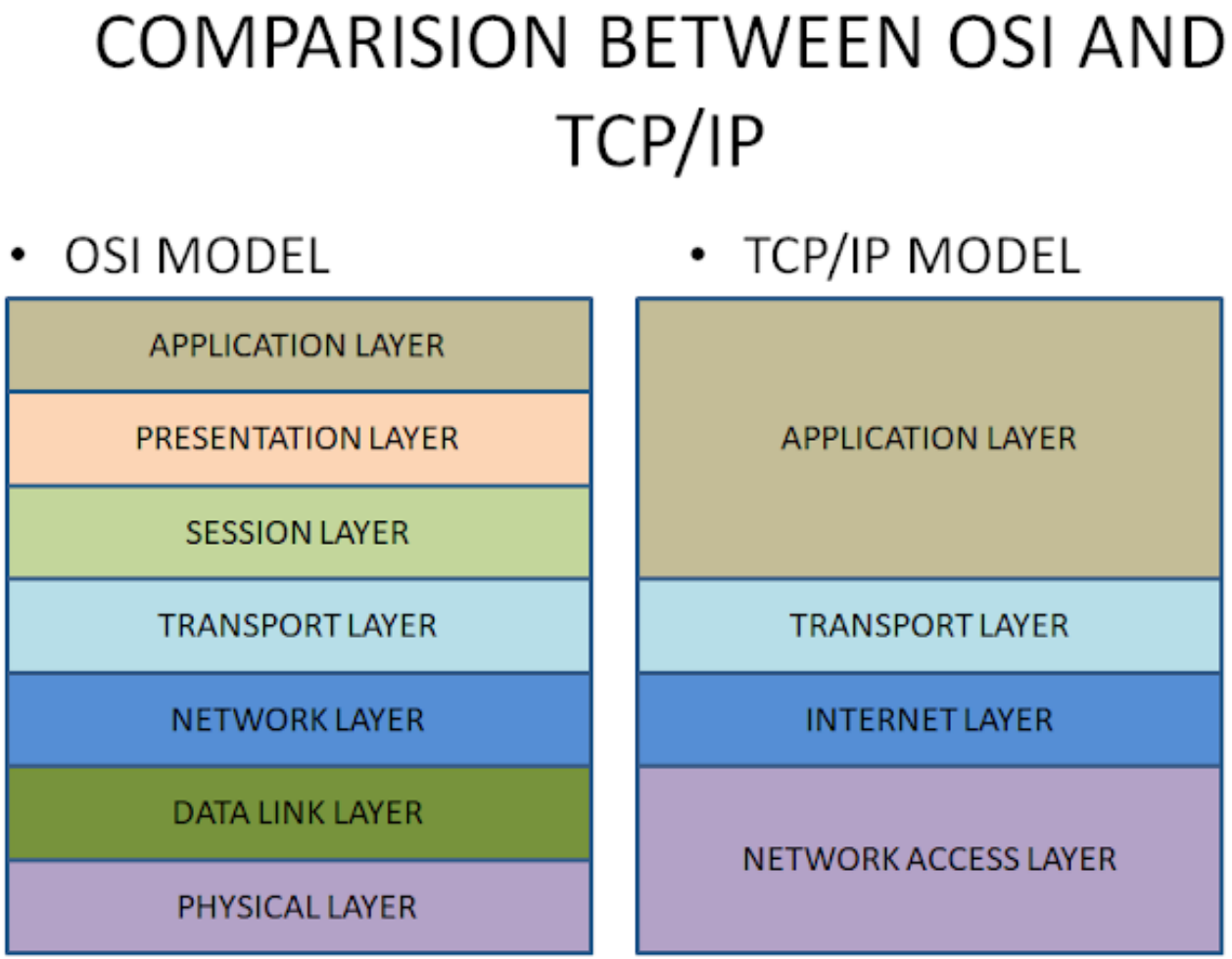
- GPRS or General Packet Radio Service is a **packet-oriented mobile data service on the 2G and 3G cellular communication system's global system for mobile communications (GSM)**.
- It was originally standardized by European Telecommunications Standards Institute (ETSI).
- GPRS is a software overlay on top of the GSM standard that made services like the internet access and e-mail possible on phones by putting in place packet-data technology.
- GPRS is slow by today's standards, with data transfer speeds of up to 115 kbps at that time, with an average of 40 to 50 kbps.
- Common applications of GPRS include internet access, intranet/corporate access, instant messaging, and multimedia messaging

Networking: TCP/IP layers

- This is the protocol suite used in the Internet today.



Comparison of TCP/IP and OSI model



Comparison of TCP/IP and OSI model

- TCP/IP combines the presentation and session layer into its application layer.
- TCP/IP combines the OSI data link and physical layers into one layer.
- TCP/IP appears simpler because it has fewer layers.
- TCP/IP transport layer using UDP does not always guarantee reliable delivery of packets as the transport layer in the OSI model does.

TCP/IP layers

1. Network Access Layer

- First layer of the four-layer TCP/IP model.
- It defines details of how data is physically sent through the network, including how bits are electrically or optically signaled by hardware devices that interface directly with a network medium, such as coaxial cable, optical fibre, or twisted pair cable.
- The protocols/standards included in Network access layer are Ethernet, Token Ring, X.25, Frame Relay

TCP/IP layers

2. Internet Layer

- The main responsibility of the internet layer is to send the packets from any network, and they arrive at the destination irrespective of the route they take.
- Protocols used in this layer: Internet Protocol (IP), Address Resolution Protocol (ARP), Internet Control Message Control (ICMP)

3. Transport Layer

The transport layer is responsible for the reliability, flow control, and correction of data which is being sent over the network. Two protocols used in the transport layer: User Datagram Protocol and Transmission Control layer

TCP/IP layers

UDP

- Best effort (unreliable) datagram service
- Connectionless: No handshaking, no connection state
- No flow control, no error control, no congestion control
- Applications: Multimedia- VoIP, video, RTP, Network Service: DNS,SNMP

TCP

- Reliable Byte stream service
- Connection oriented: Connection setup, connection state, connection release
- Higher delay than UDP
- Error control, flow control, congestion control
- Most applications use TCP: HTTP, SMTP, TELNET, FTP,..

TCP/IP layers

4. Application Layer

- This layer allows the user to interact with the application.
- When one application layer protocol wants to communicate with another application layer, it forwards its data to the transport layer.
- e.g HTTP, DNS,SMTP,SNMP, TELNET, FTP