# (A)

## Comparative Analysis of Onboard Communication Protocols

A rover is made up of many electronic modules and sensors that must share data continuously. This internal data exchange is handled through onboard communication protocols such as **UART**, **I²C**, **SPI**, and **CAN**.

**1. UART (Universal Asynchronous Receiver/Transmitter):**

It's one of the simplest forms of serial communication. It allows two devices to communicate directly using just two data lines Transmit (TX) and Receive (RX). It is suitable for one to one connections, for example, between a microcontroller and a GPS module or Bluetooth module. UART is easy to implement but does not support multiple devices on the same line and its speed is moderate typically up to 1 Mbps.

**2. I²C (Inter-Integrated Circuit):**

It's a two-wire communication protocol that uses a shared bus to connect multiple sensors and devices to a single controller. It supports multiple masters and slaves making it very efficient for connecting various sensors such as IMUs, temperature or pressure sensors. However, it is slower than SPI and less suitable for long-distance communication within a system due to signal noise sensitivity.

**3. SPI (Serial Peripheral Interface):**

It's a high-speed protocol designed for fast data transfer between a master device and several slaves. It typically uses four lines: MOSI, MISO, SCK, and CS and can achieve speeds higher than both UART and I²C. SPI is ideal for components that require rapid data exchange such as SD cards, high-resolution encoders or fast sensors. Its main drawback is the need for multiple chip-select pins which increases wiring complexity as the number of devices grows.

**4. CAN (Controller Area Network):**

It's a robust, multi-master communication protocol widely used in automotive and robotic systems. It allows multiple microcontrollers and devices to communicate over a single two-wire bus with excellent noise resistance and error detection. Although its data rate is not as high as SPI, its reliability and ability to connect many nodes which make it perfect for complex systems like a rover. For instance, CAN can link the main controller, motor drivers, and sensor nodes efficiently ensuring that even if one part fails, communication among other components continues.

# (B)

For a rover to be of any use, it must report to a base-station to report real-time telemetry data such as position, velocity, battery, and sensor information. It must also receive control signals from the base station in emergency or override situations. This type of long-range wireless communication requires a telemetry system that will make sacrifices in terms of range, reliability, speed, and power consumption.

Common telemetry technology includes WiFi, Bluetooth, LoRa, 4G/LTE, and Satellite communication. WiFi can accommodate high data speed but has a very limited range of around 100 meters and is therefore not suitable for use outside laboratory testing. Bluetooth's range is even shorter and is mostly used for proximity control. 4G/LTE provides wide-area coverage and high speed but relies on cellular networks and is power-intensive. Satellite communication is highly global in coverage but extremely expensive and power-hungry and is thus inappropriate for use by small rover systems.

LoRa (Long Range Radio) is the most suitable choice among these for rover telemetry. LoRa communicates over several kilometers using low-frequency radio waves with very little power consumption. Although its data rate is relatively low, it is sufficient for transmitting small packets such as sensor data, GPS location, or status messages. It also operates suitably in outdoor and remote regions where internet or cellular service is not available. LoRa is being used by many robotics and research rovers due to its high reliability along with long range.

Therefore, for this rover, LoRa has been chosen as the telemetry system because it provides an optimal trade-off of power efficiency, range, and reliability. It enables the base station to receive continuous updates from the rover and also permits the transmission of manual override commands back in an event of emergency while offering safe and reliable operation.