Project: Implementation Of Communication Protocols on FPGA

Component: Project Definition and Scope

Introduction

Communication protocols are very important in today's world because many devices need to communicate with each other, and protocols make this possible. Communication protocols are simply sets of rules and standards that define how devices exchange data across a network. They ensure that information is sent, received, and interpreted correctly by all participants. For instance, PCs typically use UART (Universal Asynchronous Receiver-Transmitter), while embedded systems like microcontrollers often rely on SPI (Serial Peripheral Interface) or I²C (Inter-Integrated Circuit).

My project is the implementation of communication protocols on FPGA. In this project, I have implemented real-time communication between different devices using multiple communication protocols. The protocols I used are UART and SPI, both of which are serial communication protocols. The working of the project is as follows: data is sent from one terminal to a USB-UART adaptor connected to port COM3. This adaptor transfers the data to the FPGA Cyclone II EP2C5T144 board through the UART protocol. UART is a point-to-point, 2-wire asynchronous communication protocol. From the FPGA, the data is then sent to the Arduino through the SPI protocol, where the FPGA acts as the Master device and the Arduino as the Slave device. SPI is a 4-wire synchronous protocol.

The Arduino is connected to another port, and in its terminal, the hexadecimal and decimal values of the received data can be seen. The Arduino increments the received data by 1 and sends it back to the FPGA, which then returns it to the adaptor in the same way. Finally, in the terminal (COM3) where the adaptor is connected, the incremented value is displayed. This forms a complete communication loop, demonstrating how data travels across different devices and how different protocols work together.

Additionally, the project integrates simulation using ModelSim and proposes a web-based dashboard for real-time visualization of communication waveforms.

Problem Statement

In digital systems, one of the main problems is how different devices share data with each other. Every device works in its own way, and without a proper method, the data sent by one device may not be received or understood by another. Communication protocols solve this problem by providing a common set of rules for data transfer. They make sure that the information is sent, received, and interpreted correctly. In my project, I have implemented UART and SPI protocols on FPGA to show how data can travel between devices like PC,

FPGA, and Arduino in real time. This solves the problem of reliable communication between devices using different standards.

Objectives

1. To study and understand the working of serial communication protocols, mainly UART and SPI, and their role in reliable data transfer.

2. To implement UART protocol on FPGA for establishing point-to-point communication between PC (through USB-UART adaptor) and FPGA.

3. To implement SPI protocol on FPGA for communication between FPGA (as Master) and Arduino (as Slave).

4. To create a complete communication loop where data is sent from PC, transferred through FPGA, received by Arduino, incremented, and sent back to PC, proving correct working of both protocols.

5. To verify the implementation by displaying the received and transmitted data in both hexadecimal and decimal formats on the terminal.

6. To simulate the design using ModelSim and validate the waveform results to ensure correctness of the protocol operation.

7. To explore the use of a web-based dashboard for real-time visualization of communication flow and waveform outputs.

Relevance to ICT Domain

Communication is one of the most important parts of ICT because all systems depend on reliable data transfer. Without proper communication protocols, devices like PCs, microcontrollers, and FPGAs cannot exchange information correctly. My project is directly connected to this domain because it focuses on implementing two widely used serial communication protocols, UART and SPI, on FPGA. This is relevant to ICT as protocols are the backbone of digital systems, embedded applications, IoT devices, and computer networks. By working on FPGA, the project also shows how hardware-level implementation of protocols is important for high-speed and real-time applications. It demonstrates how devices can be connected together and made to communicate properly using existing ICT standards. The project also relates to areas like digital logic design, embedded systems, and VLSI design, which are core fields in the ICT domain.

Feasibility Analysis

a) Technical Feasibility

- Tools: **Quartus Prime (FPGA design)**, **ModelSim (simulation)**, **Arduino IDE**, and **web technologies** for the dashboard.
- Hardware: **Cyclone II FPGA board**, **Arduino Uno**, **USB-UART adapter**.
- Justification: FPGA offers high speed, parallelism, and reliability for protocol implementation.

b) Economic Feasibility

- FPGA board and Arduino Uno: available/low-cost.
- Software: Quartus and ModelSim (student/free editions).
- Estimated budget < ₹5000, making it affordable within academic constraints.

c) Ethical Considerations

- The project does not involve personal or sensitive data, so privacy risks are low. Ethical focus is on ensuring reliable design without data loss. Plagiarism is avoided by independent implementation and proper citations. In future, features like encryption or error checking can improve security. If extended to IoT applications, data privacy and secure communication mechanisms must be ensure.

Market/User Needs Analysis

Reliable communication between devices is a key requirement in ICT, embedded systems, and IoT. Since PCs, FPGAs, and microcontrollers often use different protocols, there is a need for solutions that enable smooth data transfer across them.

Studies show that UART and SPI are still widely used in embedded systems because of their simplicity and low cost [1]. Protocol bridging is also highlighted as essential in heterogeneous IoT systems [2]. Industry reports note that lightweight serial protocols remain popular in low-power devices [3]. FPGA-based implementations provide faster and more reliable real-time communication compared to software-only designs [4], and are also useful for teaching and prototyping in academia [5].

This shows the project is relevant for both students (for learning practical protocol design) and industries (for testing device-to-device communication).

References (sample):

[1] IEEE Xplore – Serial Communication in Embedded Systems
[2] ACM Digital Library – Protocol Bridging in IoT
[3] Texas Instruments – Serial Communication Protocols for Low-Power Devices

[4] IEEE Xplore – FPGA-based UART and SPI Implementations
[5] IEEE/ACM – FPGA and Microcontrollers in Education

Novelty

This project is not fully novel since UART and SPI have already been implemented separately in many works. The difference here is that both protocols are combined on the same FPGA to act as a bridge between PC and Arduino. At the hardware level, this adds a small novelty, as it demonstrates real-time interoperability between two widely used protocols. The main focus is on studying and understanding communication protocols through hardware implementation, simulation (ModelSim), and visualization