Design and Basic Functional Verification of Re-usable IP of L2CAP Layer of Bluetooth v4.1

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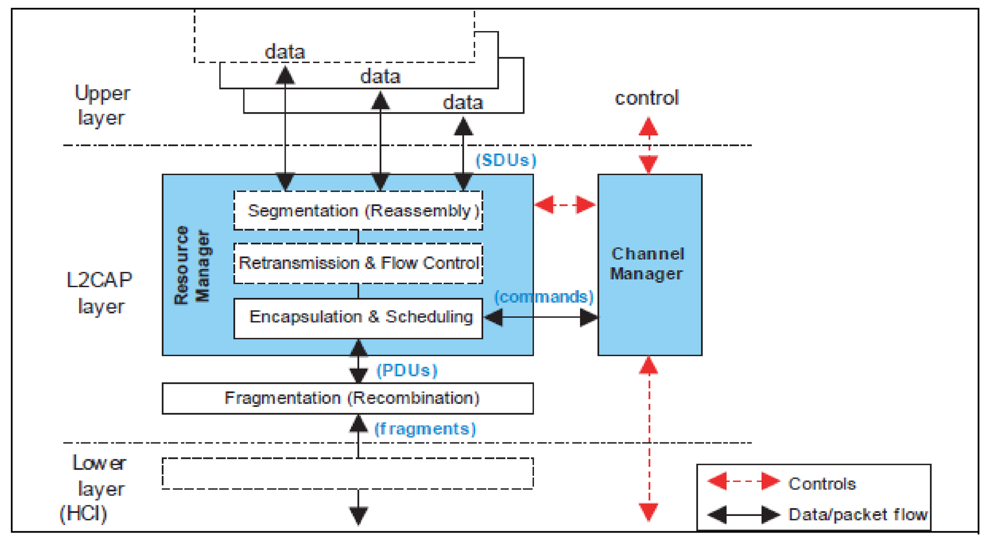
Introduction

This project presents an IP (Intellectual Property) Design approach of L2CAP layer from the protocol stack of Bluetooth v4.1 using Verilog as Hardware Description Language for implementation and functional verification purpose. The inspiration behind choosing implementation of L2CAP layer in Digital domain lies in the fact that Bluetooth being an active element of today's communication world and consequently dominating the Internet of Things network by large proportion.L2CAP is a layer protocol inside the Bluetooth 4.1v. The main purpose of the main use of the L2CAP layer is to perform the Logical Link Control and along with that provide the Adaption. Hence due to this the name of the layer is kept as L2CAP. In addition to above things, L2CAP also provides features like connection less and connection oriented data services to the entities sitting on the top of the L2CAP layer by means of protocol multiplexing capability and segmentation followed by reassembly operation. These entities are nothing but the top layer entities inside the Bluetooth protocol stack. Also, L2CAP allows the higher level entities to send or receive upper layer data packets i.e. Service Data Units which belongs to L2CAP. These packets are known as SDU. One of the main features of L2CAP is per-channel flow control and re-transmission. Now in order to communicate within two devices, L2CAP uses logical channels, named as L2CAP channels. These channels are multiplexed with specific selection logic.

Methodology

Specific Structure

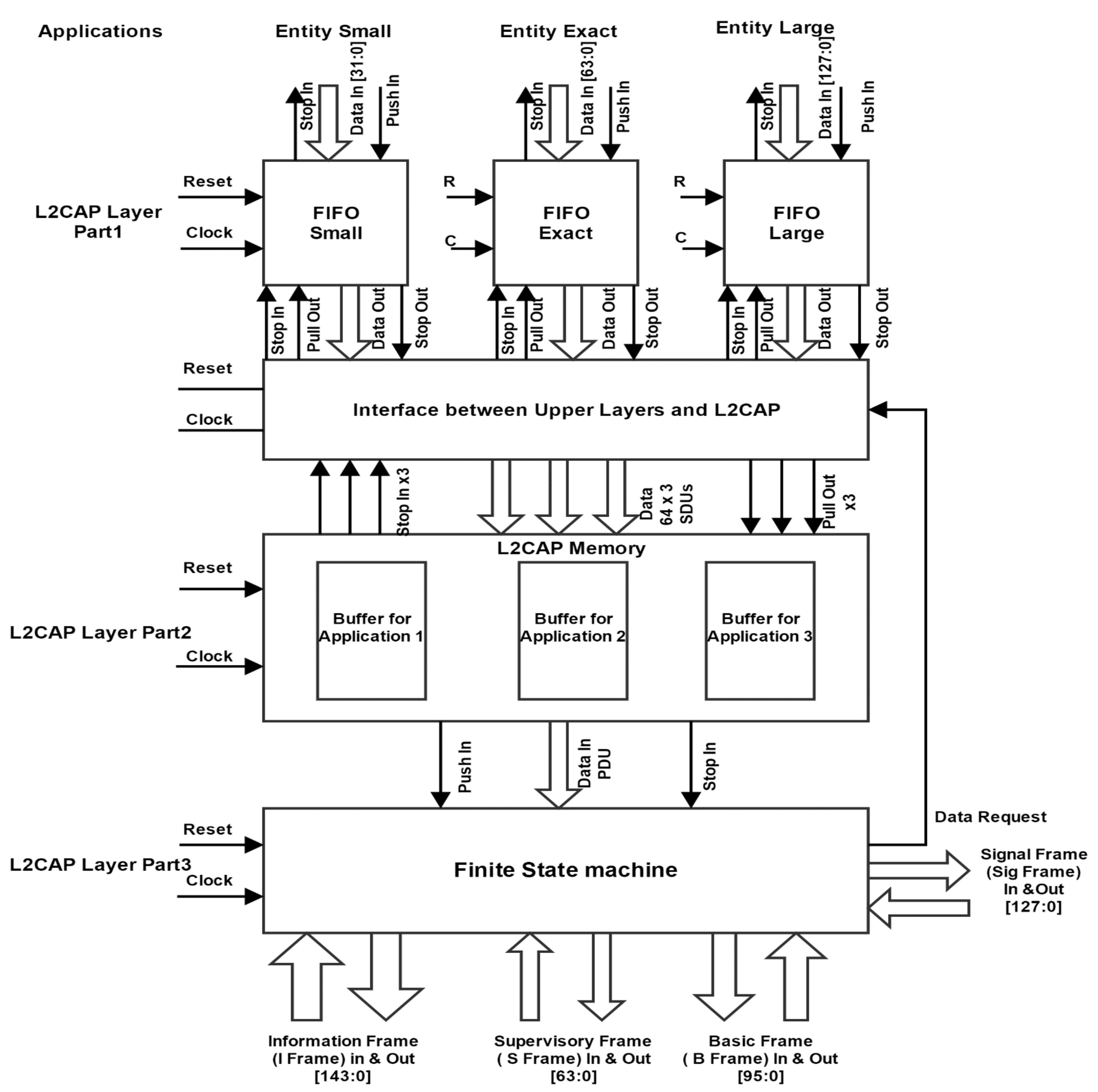
The Logical Link Control and Adaptation Protocol is part of ' Bluetooth HOST'. It lies between the application and the control section of the entire stack. The SIG states a structural model.
The following diagram shows how the L2CAP is fitted inside the protocol stack of Bluetooth 4.1 :-



Methodology

Implemented Architecture

As the project is focused on simulation at Hardware Level, the parameters of design had a need to be specified precisely. Various elements were assumed as a huge part of design can be design specific. As per the specification the following architecture was constructed in Verilog.

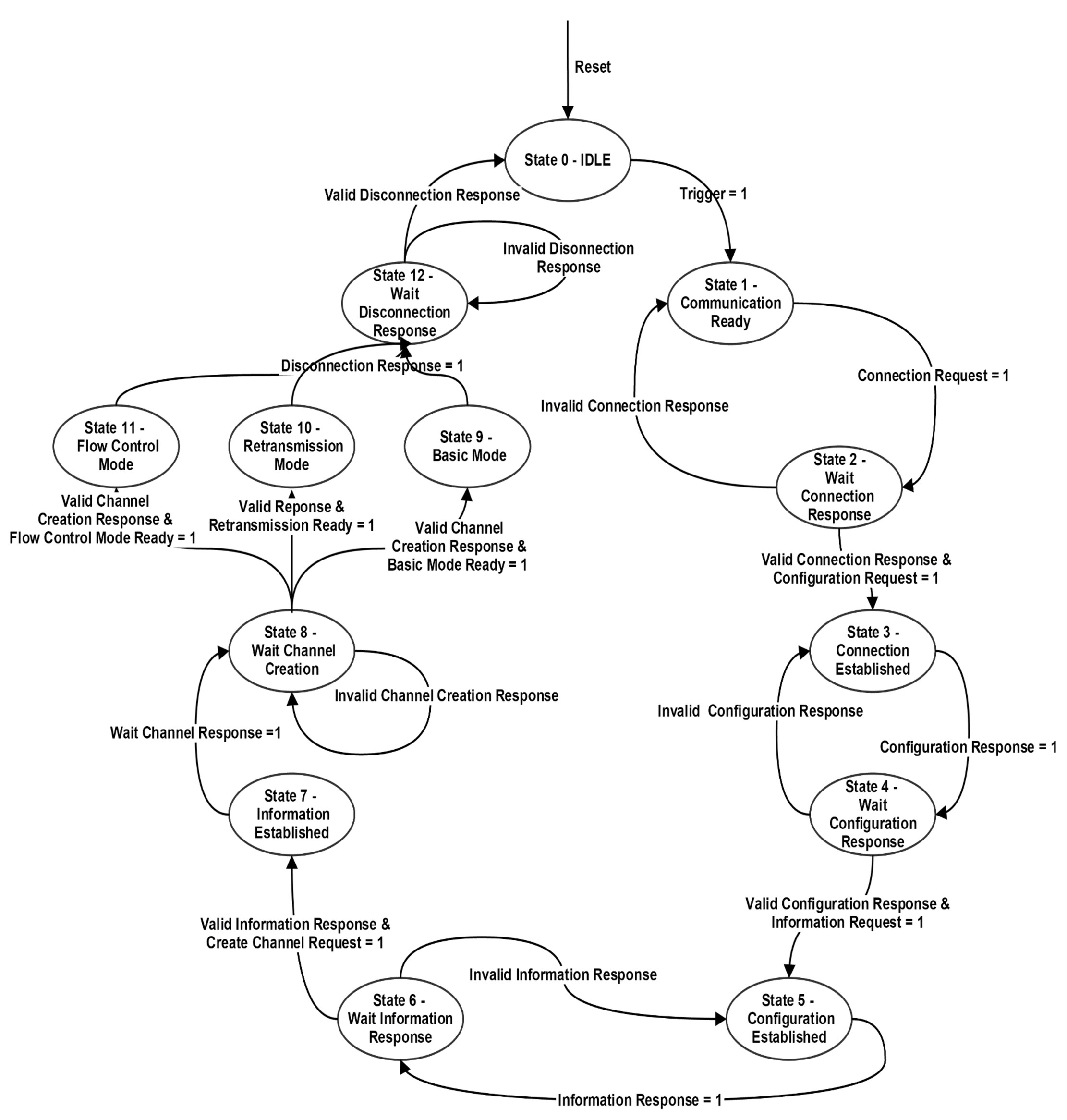


The architecture can be sub-divided into four parts:

- Applications :- The actual entities which intend to use Bluetooth protocol for communication which include transaction of data, broadcast of messages or just signaling. Practically there are multiple such applications which have different requirements. 3 such applications were assumed.
- L2CAP Part 1 : - The layers which communicate with the applications. its. This section performs the task of segmentation of data packets. The data packets are called as SDUs with maximum size allowed is 64 bits.
- L2CAP Part 2 :- The L2CAP memory, of material being deposited. This memory is used for the condition when multiple applications are talking in parallel. As we had three applications, the memory of L2CAP layer is capable of storing data from these applications.
- L2CAP Part 3 :- This FSM is designed to control the data flow, different modes and the signaling of between the L2CAP layers. In simple term this machine exchanges the signal packets to establish communication and negotiate the type of services with the remote devices.

Finite State Machine

L2CAP Finite State Machine



The state machine consists 13 states. The machine stands at 'Idle' at 'reset' or after end of transaction.
It performs several negotiations in the initial stages and also decides the mode of data transaction.
It has three modes of transactions namely Basic Mode, Flow Control Mode & Retransmission Mode.
After every communication whether failed or successful, the machine makes sure that the engaged channels freed and counters are reset.

Results

The Simulation Results for Basic Mode

present state is 0 - Idle State
present state is 1 - Communication Ready State
present state is 2 - Wait Connection Response State
present state is 1 - Communication Ready State
present state is 2 - Wait Connection Response State
present state is 3 - Connection Established State
present state is 4 - Wait Configuration Response State
present state is 3 - Connection Established State
present state is 4 - Wait Configuration Response State
present state is 5 - Configuration Established State
present state is 6 - Wait Information Response State
present state is 5 - Configuration Established State
present state is 6 - Wait Information Response State
present state is 7 - Information Established State
present state is 8 - Wait Channel Creation Resp State
present state is 9 - Basic Mode State
present state is 9 - Basic Mode State
present state is 9 - Basic Mode State
present state is 9 - Basic Mode State
present state is 9 - Basic Mode State
present state is 12 - Wait Disconnection Response State
present state is 12 - Wait Disconnection Response State
present state is 0 - Idle State

Summary

The project was successfully implemented as per the specifications. It meets all the basic signaling requirements and also performs the data transmission as stated. The project is open for integration and future modification. Using the flag interfaces from the top module it can be integrated in any other application based on network simulation. The number of CIDs and entities were kept small. The CIDS can be increased to a larger extent only the logic 'Communication Ready state where CID is allotted will require modification. The design can be given additional LE (Lower Energy Mode), this will just require addition of an extra state in the L2CAP FSM.

Key References

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