Digital Communication as the First Course in Undergraduate Telecommunication Engineering Technology Program

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DIGITAL COMMUNICATION AS THE FIRST COURSE IN UNDERGRADUATE TELECOMMUNICATION ENGINEERING TECHNOLOGY PROGRAM

Abstract- The telecommunication and networking industry has undergone transformation from analog to digital but the classroom education has lagged behind. Computers have come in front of all communication interfaces and the analog modulation and demodulation in amplitude, frequency and phase now have only conceptual values. There is a need for the first course that not only teaches basic concepts of telecommunication but also the digital communication principles and practices. The proposed course combines the fundamental concepts of frequency spectrum of signals and noise, multiplication of signals, filtering, oscillators and the voltage control of their frequency, phase locked loop, frequency synthesis and conversion, antenna analysis and design with the concepts of bandwidth of digital signals, analog to digital conversion, multiplexing of digital signals, coding, digital modulation, and multiple-access communication techniques. In this course, emphasis is put on design and simulation of digital transmitter and receiver engines, introducing the techniques of over-the-Internet communication, and Internet of Things (IoT) to effect long distance monitoring and task execution. A small project is also assigned to students select their own interesting topics to build. While searching for topics related to digital communications area, the students get an opportunity to find information about new technologies. The project encourages them to learn more in real word technologies. The proposed course has been put to test in the classroom. The paper presents the detailed syllabus comprising of week-wise lecture topics, laboratory exercises, student project topics, student satisfaction survey, student's feedback at the end of the class and instructor's self-assessment.

I. INTRODUCTION

The field of telecommunication has been part of the engineering/technology curriculum ever since the engineering education started. In this age, the society is asking for more and more means of communication and networking. The field of communication is ever expanding. The telecommunication and networking industry has undergone transformation from analog to digital but the classroom education has lagged behind. Computers have become obsequious in communication systems. The analog modulation and demodulation techniques now have only conceptual value. There is a need for reorienting teaching not only the basic concepts of telecommunication but also the digital communication principles and practices. This paper proposes a course that combines the fundamental concepts such as the frequency spectrum of signals and noise, multiplication of signals, filtering, oscillators and the voltage control of their frequency, phase locked loop, frequency synthesis and conversion, antenna analysis and design with the concepts of bandwidth of digital signals, analog to digital conversion, multiplexing of digital signals, coding, digital modulation, and multiple-access communication techniques.

The proposed course emphasizes on design and simulation of digital transmitter and receiver engines, which is shown in Figure 1. This approach is very different than the two papers in reference section[1][2][5][6]. The course brings on the modern digital techniques of packet communication, the over-the-Internet communication and Internet of Things (IoT). The course culminates with a term project wherein the students select their own topics to build which exposes them to component availability and new techniques beyond the curriculum.

II. WHERE IN THE CURRICULUM AND WHY

As per the Tec/Abet guidelines, the undergraduate technology programs, approximately 2/3rd of courses are program related technical courses. A typical curriculum of Electrical or Electronic and Computer Engineering Technology has following tracks:

a) Circuits
b) Digital design
c) Programming
d) Sensing, Acquisition and Signal Processing
e) Energy
f) Electronics
g) Communication
h) Control
i) Embedded System

Each track has the room for 2 or 3 of the 3 credit courses. Let us also look at the typical offering of courses in the telecommunication track:

a) Analog communication
b) Digital communication
c) Wireless communication
d) Fiber optic communication
e) Laser communication
f) Microwave and Millimeter wave communication
g) Antenna systems
h) Transmission Lines

Generally, one or two courses focus on delivering fundamentals, knowledge of basic components and technologies and cover one of the advanced communication technologies in the third course. The first two core courses in the communication track have been the Analog and the Digital Communication. These courses cover the legacy concepts and technology of analog modulation. Computers now appear in most communication interfaces. Along with the concepts of analog modulation in amplitude, frequency and phase, the instructors should consider teaching the digital communication technology in the first course in the communication sequence. We may skip or limit teaching of the analog technology. Bring in the concepts and techniques of coding, digital modulation and transmission. We suggest the following communication track in the undergraduate program:

Course 1: Digital communication
Course 2: Wireless communication
Course 3: Advanced Communication

Next section of this paper presents the details of the first course in digital communication with above objectives in the mind.

III. COURSE DESCRIPTION

Below is the course syllabus of ECET 30300 in the undergraduate ECET program in the college of Technology of Purdue University Northwest. This course is run once in a year and is a required core course.

Title: Fundamentals of Communication
Credits: class 2, lab 3, total 3 credits, 5 contact hours

Textbook: 1) Digital Communications, Andy Bateman, Prentice-Hall, ISBN: 0-201-34301-0
2) Analog & Digital Communication Lab: MATLAB/SIMULINK +Arduino Uno +Circuits - Jai P Agrawal, www.createspace.com, ISBN-13: 978-1511651271

Prerequisites: Analog Electronics, Basic C Programming skills

Course Goals/Objectives:

By the end of this course, the student should be able to understand and work with the digital communication systems and as such will be ready to pursue a course in higher-level communication courses. The course emphasizes on computer-based methods to solve problems.

Instruction Outcomes:

1. Learn the spectrum of signals and noise. (ABET criteria 2 (a) and (b))
2. Learn the theory and operation of communication components. (ABET criteria 2 (a) and (b))
3. Learn the principles of modulation and demodulation. (ABET criteria 2 (a) and (b))
4. Learn the principles of coding, multi-user access techniques. (ABET criteria 2 (a) and (b))
5. Learn to use MATLAB/SIMULINK and utilize it for system modeling. (ABET criteria 2(c))
6. Introduction to the Internet of Things Technology

3.1 Topics

1 Elements of digital communication system, Decibels
2 Time domain and frequency spectrum of standard signals, data and noise
3 Filter, Mixer, Voltage Controlled Oscillator, Phase Lock Loop
4 Principles of modulation/demodulation, heterodyning, up and down conversion
5 Baseband Data Transmission, carrier, clock and data recovery
6 Data Impairment: Inter Symbol Interference, Raised Cosine filtering
7 Source Coding: Analog to Digital, Digital to Analog, Signaling, Cyclic Redundant Coding, Forward Error Correction, Scrambling, Interleaving, packetization
8 Digital Modulation Techniques: ASK, FSK, PSK and QAM
9 Multi-level Digital Modulation: M-ASK, M-FSK, M-PSK, and M-QAM,
10 Introduction to Antenna
11 Introduction to fiber optic communication

The lecture portion concentrates on the teaching concepts and components and prerequisite technologies of modern communication. The lab portion focuses on providing the experience of digital communication technology.

The above syllabus assumes that in non-communication track, students may not pursue further courses in the communication sequence. Therefore, the syllabus includes the topics like the brief introduction to fiber optic communication, a topic which they may not encounter in any further course. On the same logic, we should have included a brief introduction to wireless communication, but that would have increased the content beyond the tenure of a semester-long course. If the communication track in the program includes the second and third courses, then the topics of antenna and fiber-optic communication may be removed from the proposed first course.

3.2 WHAT IT DOES NOT INCLUDE

Since the course is designed for the undergraduate program, it does not include the following topics:

a) Antenna arrays
b) Radio Frequency Electronic circuits
c) Multi-user access techniques

IV. SIMULATION AND LABORATORY EXERCISES

The laboratory exercises include introductory exercises such as the Maximum Power transfer, frequency spectrum of signals and data, filtering and phase lock loop operation. After introductory exercises, the course bring up the digital communication exercises which are aimed to eventually build and simulate a digital communication system as shown below in Figure 1.

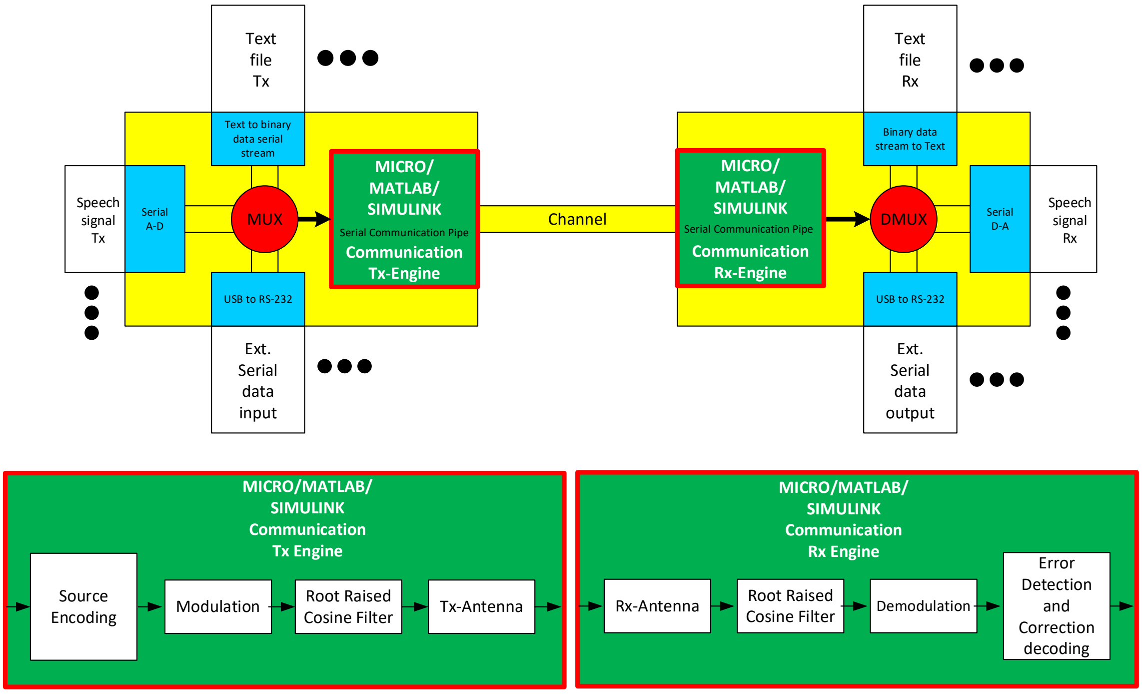

Fig. 1 Digital Communication Engine[4]

A suggested sequence of laboratory exercises is given below:

1 MATLAB Tutorial
2 SIMULINK Primer and Arduino Uno Basics
3 Matching for Maximum Power Transfer
4 Frequency Spectrum- Data Stream
5 Phase Locked Loop
6 ASCII Character Communication
7 ASCII Text Communication
8 Time-Division Duplex Channel
9 Analog Voltage to Binary Data
10 Digitized Analog Signal Communication
11 Digital Voice Communication
12 Binary Phase Shift Keying (BPSK) on AWGN Channel
13 USB Serial Data Communication
15 A Simple Internet of Things (IoT)
16 Time-Division-Multiplexing
17 Packet Communication
18 QPSK Communication

The labs and simulation exercises are a mix of hardware and MATLAB/SIMULINK based simulations. The exercises involving hardware and circuits are used for simple techniques. Complex systems use simulation route because they require huge instrumentation and huge efforts in trouble shooting of circuit building. The labs provide the conceptual experience of growing technologies of packet communication and Internet of Things.

It is left to the discretion of the instructor to reduce the number of labs to 11-12 by combining some simple labs or assigning some labs as home assignments. We present a few interesting laboratory exercises to demonstrate the breadth and depth of the laboratory experience.

4.1 Example 1- USB SERIAL DATA COMMUNICATION[4]

Objective of this lab exercise is to get a byte instruction from Arduino Uno serially via USB, which is transmitted on a channel, received on the receiver and sent serially to Arduino Uno and execute the instruction. The system diagram is given in Fig. 2. Transmitter and the receiver are implemented in MATLAB. The AWGN channel is modeled in SIMULINK. The two Arduinos are interfaced using MATLAB serial interfaces. Code for all blocks are presented in Appendix 1.

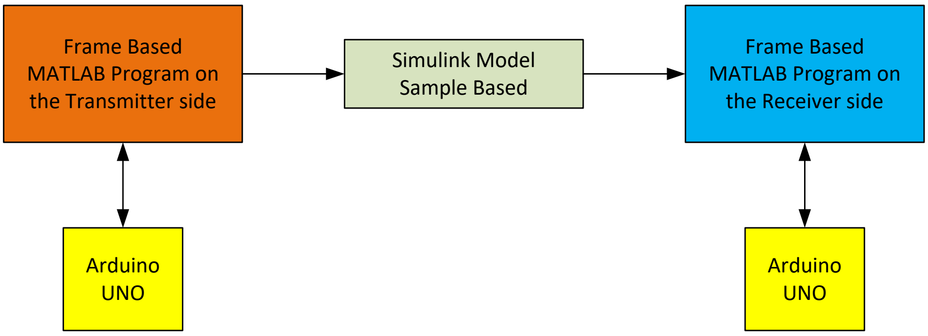

Fig. 2 Serial data communication

4.2 Example 2- A SIMPLE INTERNET of THINGS (IoT)[4]

Objective of this lab exercise is to design a simple Internet of Things system using MATLAB and Microcontroller Arduino Uno to perform a simple task remotely as shown in Fig. 3. In the simple IoT system, the Thing is an LED, connected to an embedded system made of Arduino UNO. The system communicates with a remote communication system over Internet. In this exercise, we will assume that an instruction byte **byte_act (=8)** has been uploaded on the transmitter, recovered on the receiver on the other end of the Internet connection and passes on to Arduino UNO via MATLAB workspace. The MATLAB workstation on the receiver establishes an USB Serial link with Arduino Uno. MATLAB sends a **(=3)** to the Thing to alert it for the arrival of the instruction byte. The alert is indicated by turning on a LED at pin 9. The MATLAB workspace on the receiver then sends the instruction byte **byte_act** on the serial link which makes the Thing (LED on pin 8) to blink 3 times and return a string ‘job completed.’ back to the MATLAB transmitter. The serial port is automatically recognized as port COM20.

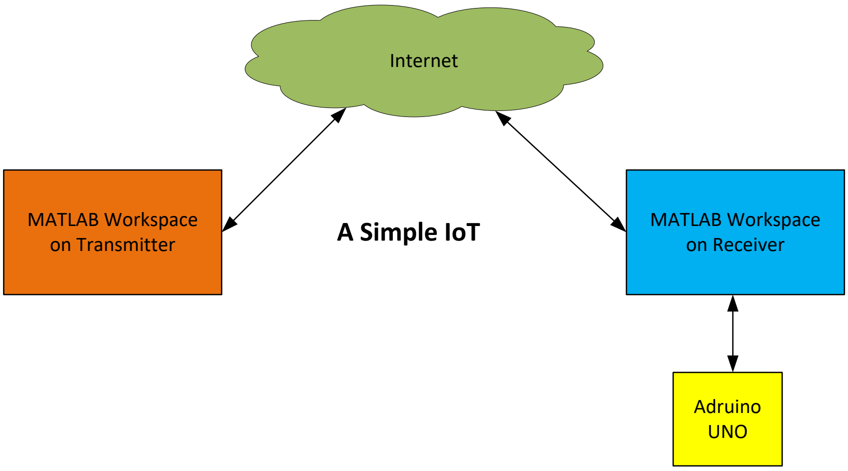

Fig. 3 A simple Internet of Thing

4.3 Example 3- PACKET COMMUNICATION[4]

Most of the data communication is through packet communication. Packet communication is asynchronous and can utilize multiple paths from the source to destination with numerous integrity preserving techniques. Objective of the lab in packet communication is to learn to break a data stream in to packets and pack a data packet in to standard frames for transmission over the channel. On the receiver the packets are de-framed to recover the original data packet. The original data stream is reconstructed from the data packets. The whole process is implemented in MATLAB/SIMULINK as shown in the Fig. 4.

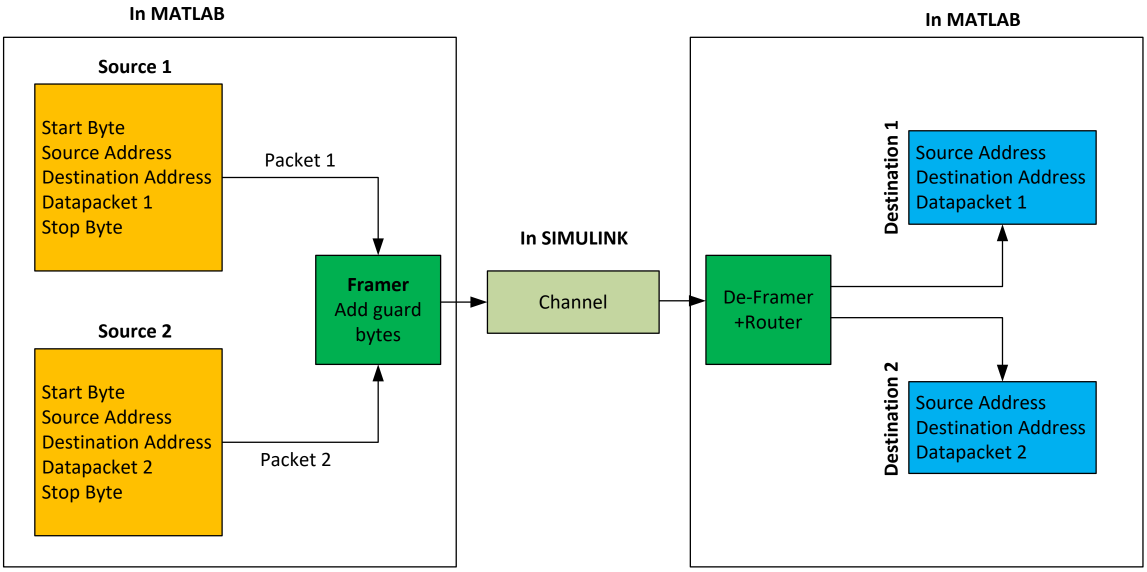

Fig. 4 Packet Communication

4.4 Example 4- BINARY PHASE SHIFT KEYING (BPSK) [4]

Modulation of a high frequency sinusoidal carrier by the data stream or packetized frame is the essential process in digital communication. In this lab, the students learn to modulate a 10 MHz sinusoidal carrier by a 5 Kbps data. The modulation scheme employed is Binary Phase Shift Keying. The data is sent over a ‘100 km long AWGN channel’ in the presence of white Gaussian noise. The whole process is implemented in MATLAB/SIMULINK as shown in the Fig. 5.

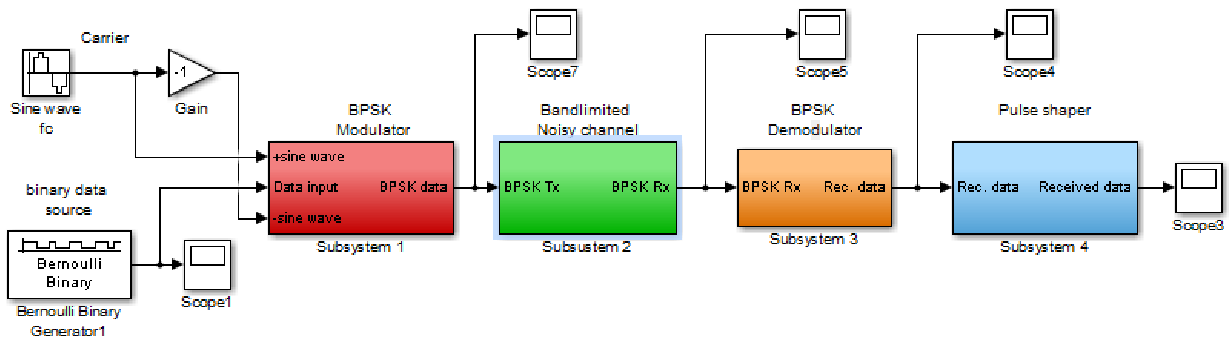

Fig. 5 BPSK Communication

V. DESIGN PROJECT

The class instruction ends with a 2-3 week long term project. It is a team/individual project, of no more than two students per team. The project topic is picked by the students, in one of the following options:

1. Hardware project involving digital communication Transmitter plus receiver in free band.
2. Simulation project involving digital communication technique, not covered in the class.
3. A suggested project on Digital Phone system is as shown below:

Laboratory MATLAB/ SIMULINK Project to simulate a Digital Phone (DFON) system.

1. Record voice
2. Convert to digital format
3. Modulate using QPSK
4. Transmit over AWGN channel
5. Receive, demodulate and recover voice

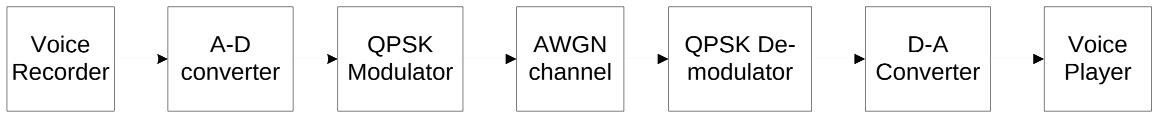

Fig. 6 Project Digital Phone

While the students search for all possible topics related to digital communications area, they can get an opportunity to find out more information about new technologies.

VI. STUDENT AND FACULTY FEEDBACK REGARDING THE DEVELOPED COURSE

The proposed course was offered in the Fall semester of 2016 on the two campuses of Purdue University Northwest to a combined student population of 40. This course is a required course in the undergraduate ECET program. The pre-delivery survey was answered by 36 students. The post-delivery survey was answered by 24 students on the last day of the instruction.

6.1 PRE-DELIVERY SURVEY QUESTIONS, RESULTS AND COMMENTS

	Question	Affirmative %	Negative %	No Response
1	Is this course elective or required in your program of study?	100	0	0
2	Do you think you will like to pursue a career in Communication?	40	30	30
3	Do you think this course will help you in achieving your future objective?	0	0	100
4	Do you feel your background knowledge is sufficient for the course syllabus?	30	0	70
5	Do you find the list of laboratory exercises interesting?	70	0	30
6	Does the course outline appear difficult to follow?	40	10	50
7	Did you find the textbook helpful or meet the need of the course?	50	0	50
8	Which part of the course you are excited about?	55	30	15
9	Why do you think you will benefit more by learning the digital communication than the conventional analog communication?	75	0	25

Question 4: low affirmative response from students is due to the unfamiliarity of the students with content of the course.
Question 6: 50% students saying that the course content seems difficult as they are seeing topics about which they do not have prior knowledge.
Question 8: approximately 65% students liked the laboratory exercises.
Question 9: approximately 75% students answered that Digital Communication is currently practiced.

6.2 POST-DELIVERY SURVEY QUESTIONS, RESULTS AND COMMENTS

	Question	Affirmative %	Negative %	No Response
1	Do you have interest in pursuing a career in Communication?	65	15	20
2	Do you think this course will help you in achieving your future objective?	65	15	20
3	Do you feel your background knowledge was sufficient for the course?	70	10	20
4	Did you find the laboratory exercises useful?	90	10	0
5	Was the course difficult to follow?	40	50	10
6	Did you find the textbook helpful or meet the need of the course?	50	0	50
7	Which part of the course you like the most, Lectures or Labs?	75	20	5
8	Why do you think you will benefit more by learning the digital communication than the conventional Analog Communication?	80	0	20
9	Any suggestions making the course more alive and efficient?			

Question 4: approximately 90% students liked the laboratory exercises, but 10% wanted more hardware exercises.

Question 5: in the post-delivery survey the negative response of 50% is a significant improvement over the 10% negative opinion in the pre- survey question 6. The affirmative 40% in both the pre and post delivery response can be attributed to those students who are not interested in Controls as a subject and they feel that they are forced to take the as a required course.
Question 7: approximately 75% students liked the laboratory exercises., which is a good response.
Question 8: approximately 80% students answered that the industry demands Digital Communication.

Some of the suggestions to improve the course are as the following:

1. Have some hardware experiments involving data transmission between two systems.
2. Have some hardware experiments involving Internet of Things (IoT) long distance action.
3. Plan a visit to some local communication industry.

The suggestions are all very good and will be kept in mind for future improvements.

6.3 INSTRUCTOR'S SELF EVALUATION:

It is a bit hard to cover such a breadth of topics in a 2-hour/week lecture class. Probably we should move topic of Antenna to the next course in Wireless Communication. Introduction to fiber optic communication should also be shifted to a new course on Advanced communication. It was gratifying that the students liked what they learned in the laboratory exercises. The search for a better textbook[3] must continue.

There is no data to compare the student performance vis. a vis. earlier versions of course instruction without focus on digital communication. In every course instruction, we employ a relative curve based grading, therefore, inter-course comparison of performance is not meaningful.

VII. SUMMARY

The proposed course combines the instruction in fundamental concepts and components of the communication systems with the modern practices in the digital communication. The emphasis is put on simulation of digital transmitter and receiver engines The laboratory exercises introduce the techniques of packet communication, the over-the-Internet communication, and the Internet of Things (IoT) to enable long distance monitoring and task execution. A small project is also assigned to students so they select their own interesting topics to build, present to the class and obtain the feedback. The proposed course has been put to test in the classroom. The paper presents the detailed syllabus comprising of week-wise lecture topics and laboratory exercises, and the student satisfaction survey, student's feedback at the beginning and at the end of the class.

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