A wireless multi-hop network is composed of a large number of wireless nodes deployed randomly in a two or three dimensional space. In such networks communication between nodes are typically achieved through multi-hop paths. Each node is usually battery powered, which makes such networks highly energy constrained. It is desirable that the nodes transmit with minimum possible power, so that the lifetime of the network is prolonged. In addition, transmission with lower power decreases the possibility of collision in the network. On the other hand, choosing lower transmission power level for nodes may result in a disconnected network. One example of such networks is wireless sensor networks, where lifetime of the network is strongly dependent on the optimal usage of power. Wireless mesh networking has evolved as a gifted technology for unlimited wireless access with wide bandwidth. In a communication network, wireless mesh network plays a vital role in transmission and are structured in a mesh topology. The coordination of mesh routers and mesh clients forms the wireless mesh networks which are routed through the gateways. To successfully implement this coordination, in this research, collision control techniques are embedded into the network layer so that the conventional requirement of maintaining a high power level at nodes to avoid collision is eliminated.

The different algorithms were studied through extensive simulations and hardware implementation to assess their effectiveness and existing limitations. This study identified multiple objective requirements of a wireless network as minimizing power consumption and also maintaining desired network topology properties. In this context, a distributed
space time and space frequency codes based algorithm is presented with an objective of achieving cooperative diversity specifically in wireless network. The topology control algorithm assists in regulating the node power, without connectivity tradeoff and also the scheme is applicable for networks with mobile nodes.

To ensure fault tolerance and security along with topology control, adaptive algorithms are used in modulation identification and the scope of various approaches differs in their signature characteristics. In the decision theoretic approach, probabilistic and hypothesis testing arguments are used. (Similar to the classification in recognition problem). This approach is difficult to implement and requires high computational complexity. The pattern recognition approach has two fold applications (feature extraction and recognition) and overcomes the limitations such as model mismatch and is robust.

The Feature extraction extracts the prominent characteristics of the signal and recognition indicates the membership of modulation type. The Feature extraction module extracts the training sequence (which helps to identify the type of modulation used) from the transmitted sequence. Clustering aims at discovering groups and identifying the corresponding nodes. Clustering techniques for wireless communication proposed in the literature can be generally classified based on the overall network architectural and operation model. The objective of the node grouping process includes the desired count and properties of the generated clusters.

A Software Defined Radio (SDR) is a radio that includes a transmitter in which the operating parameters of the transmitter, including the frequency range, modulation type or maximum radiated or conducted output power can be altered by making a change in software without making any hardware changes. Gateway Name Utility (GNU) radio is free software toolkit for learning, building, and deploying software defined radio systems. GNU Radio provides a library of signal processing blocks and the glue to tie it all together. The cognitive radio ad hoc networks increase the coverage area of the network through self-configuration, multi-hop connections and improve the accuracy of
measuring spectrum utilization. It is possible to access spectrum in a flexible and dynamic way, depending on local traffic loads and spectrum utilization. Techniques that assist in moving digital signal processing as close as possible to the antenna are presented by integrating rigid hardware with flexible software based solutions.

1.1. OBJECTIVES OF RESEARCH

(i) To provide a generic framework for grouping similar nodes in a network.
(ii) To provide an appropriate abstraction of specific detection mechanisms, and there from model the unique properties of modulation techniques. Based on the framework, different modulation schemes can coexist.
(iii) To ensure that corresponding nodes can collude at will.
(iv) To identify the largest number of corresponding nodes with minimal false positives in the grouping process. Grouping of various nodes into clusters has been vital to support some design objectives like scalability, energy saving, etc.
(v) To explore the theoretical aspects of power control for throughput maximization.

1.2. BENEFITS OF THE RESEARCH WORK

(i) The diffusion of high speed digital wireless communications necessitates reliable high data rate communications in variable channel conditions. This research allow maximization of the spectral efficiency (SE) in fading channels without compromising the performance in terms of bit error probability (BEP) and bit error outage (BEO).
(ii) Different order modulations allow sending more bits per symbol (higher throughputs) with better spectral efficiencies. However, it must also be noted
that when using a modulation technique such as 64-QAM, higher signal power is essential to overcome the interference and reduce the bit error rate (BER).

(iii) The use of adaptive modulation allows a wireless system to choose the highest order modulation depending on the channel conditions.

(iv) In addition, the work allows the system to overcome fading and other interference. Both QAM and QPSK are modulation techniques used in IEEE 802.11 (Wi-Fi*), IEEE 802.16 (WiMAX*) and 3G (WCDMA/HSDPA) wireless technologies are demonstrated. The modulated signals are then demodulated at the receiver where the original digital message can be recovered.

(v) The use of adaptive tracking and noise filtering schemes allows wireless technologies to optimize metrics, yielding higher throughputs while also covering long distances.

(vi) By adjusting the transmission parameters to the momentary link quality, adaptive mechanisms aim at improving both spectral efficiency and link reliability. The term “link” refers to a physical link. However, when considering multiple powers and bit-rates, the concept of a logical link arises. For example, a physical link may support M modulation/coding schemes. This can be modeled as M logical links, each with a different bit-rate, but between the same pair of physical nodes. In this case, the logical link $x_m$ would refer to the physical link $x$ transmitting at the $m$th modulation/coding scheme. Nevertheless, in order to guarantee the Quality of Service (QoS) constraints from the upper layers, adaptive mechanisms implement a sub-optimal trade-off between link robustness and bandwidth efficiency.

(vii) Can be used to study the problem of how best to share the available radio channels among multiple access points and the associated mobile stations in single-hop radio networks.
1.3 METRICS IDENTIFIED FOR STUDY

The optimization over a set of bit-rates and a set of transmission powers (using scheduled optimization) results in a higher dimension problem compared to the optimization for single bit-rate and single transmission power. In most cases, this added flexibility, results in an increase in the computation time as well as increase in computed throughput. Alternately, various subsets of bit-rates and transmission powers in hope of increasing the computed throughput without greatly increasing the computation time can also be considered. However, as more bit-rates are considered, the increase in throughput is smaller and the increase in computation time is larger. Roughly speaking, the ‘sweet spot” is with two or three bit-rates and two transmission powers. Additional metrics include packet loss rate, frequency of out-of-order delivery, send-to-receive latency, and throughput of the UDP and TCP transport protocols.

1.4. METHODOLOGY

The proposed system for the classification of signals in cognitive radio is built based on second-order statistics, multiclass SLBC and Non SLBC classifier. In the classification phase, the unknown signal is classified as any one of the three modulation types. The second order statistical features are extracted from the unknown signal and this feature vector is processed along with the features in the database by using the SLBC and Non SLBC classifier.

The implementation of various signal processing and modulation/demodulation blocks is done using GNU radio. GNU Radio is a free and open-source software development toolkit that provides signal processing blocks to implement software radios.
It can be used with readily-available low-cost external RF hardware to create software-defined radios, or without hardware in a simulation-like environment. It is widely used in hobbyist, academic and commercial environments to support both wireless communications research and real-world radio systems. GNU Radio applications are primarily written using the Python programming language, while the supplied performance-critical signal processing path is implemented in C++ using floating-point extensions, wherever available. Thus, the developer is able to implement real-time, high-throughput radio systems in a simple-to-use, rapid-application-development environment.

GNU Radio provides a library of signal processing blocks and the glue to tie it all together. The programmer builds a radio by creating a graph where the vertices are signal processing blocks and the edges represent the data flow between them. The signal processing blocks are implemented in C++. Conceptually, blocks process infinite streams of data flowing from their input ports to their output ports. Blocks' attributes include the number of input and output ports; they have as well as the type of data that flows through each. The most frequently used types are short, float and complex. Some blocks have only output ports or input ports. These serve as data sources and sinks in the graph. There are sources that read from a file or Analog-to-Digital converter (ADC), and sinks that write to a file, Digital-to-Analog converter (DAC) or graphical display. About 100 blocks come with GNU Radio and also supports extensibility.

1.5. PROBLEM STATEMENT AND PROPOSED SOLUTION

The following problems are taken up for study in this thesis and the solutions presented for the same are given along with the metrics studied.

PROBLEM 1:

Network flooding and resource sharing constraints.
PROPOSED SOLUTION:

Improved collision detection schemes to avoid broadcast storms and to protect network speed without any excess power requirements at node. Time slot communication is effectively demonstrated. Hardware implementation with ARM processor HY-LPC 1788 is demonstrated. Metrics studied include

(i) Variable inter packet transfer delay
(ii) Variable packet length
(iii) Variable file size
(iv) Throughput and
(v) Latency.

These concepts are presented in chapter 5 and chapter 6 of the thesis.

PROBLEM 2:

To make use of cooperative diversity schemes to improve network performance and to be energy aware.

PROPOSED SOLUTION:

Link state algorithms are integrated so that the active state of neighboring node is ascertained, thus the network topology is dynamic. Cross layer interaction design schemes used for effective study. Discussed in chapter 3 and chapter 6 of the thesis.

PROBLEM 3:

To use adaptive modulation and perform node grouping based on similar modulation schemes.

PROPOSED SOLUTION:

A number of popular modulation schemes are used (without any apriori information) and automatic detection in the presence of noise is demonstrated. Clustering scheme is also used to group nodes with identical modulation. Studied metrics include
(i) PLL design values
(ii) Control voltage variations
(iii) PLL lock and capture range for different frequency of input signal study etc.

Hardware implementation is done on FL2440 board with S3C2440 processor. These concepts are presented in chapter 3, chapter 4 and chapter 6 of the thesis.

PROBLEM 4:

To implement the algorithms with real time concepts for easy deployment.

PROPOSED SOLUTION:

The Wireless connectivity used is Zigbee. The cores are implemented using “GNU radio” blocks and are available as open source. This has the advantage of being

(i) scalable
(ii) Generic
(iii) Less cost.

All real-time variations are available for test purpose and logs are created in mass storage devices onboard. The details are presented in chapter 4 of the thesis.

PROBLEM 5:

Need to integrate cross layer connection among the layers.

PROPOSED SOLUTION:

In this research, the cross layer protocols are used effectively with

(i) The data in individual nodes using the MAC layer concepts
(ii) Internodes communication using the broadcast scheme with UDP layer.
(iii) Link performance analysis includes the session layer concepts.

This is presented in chapter 5 of the thesis.
1.6 ORGANIZATION OF THE THESIS

The thesis is organized as follows:

CHAPTER 2

Literature review in three major related areas is presented. It includes;

(i) Automatic modulation recognition
(ii) Phase Locked Loop based phase frequency detection
(iii) Clustering algorithms

CHAPTER 3

In this chapter, clustering and various modulation schemes are discussed. The spectra of different digital modulation signal schemes are analyzed for their power spectral variation. Structured learning based classifiers are implemented. This classification task usually involves training and testing phase. A gain boosting charge pump for PLL is designed to track the frequency drift and other non linear effects of voltage controlled oscillator.

CHAPTER 4

In this chapter, automatic modulation and detection is performed with various approaches. Frequency and phase estimation using PLL is discussed. The hardware implementation of transmitter and receiver block using the software radio cores is done in GNU radio.

CHAPTER 5

In this chapter ARM based hardware and Zigbee communication is implemented for cooperative diversity based data transfer between nodes. The cross layer protocols are implemented for effective inter node communication suited for broadcast scheme.
CHAPTER 6

Results and discussion are presented in chapter 6

CHAPTER 7

Conclusion and future scope is presented in chapter 7.