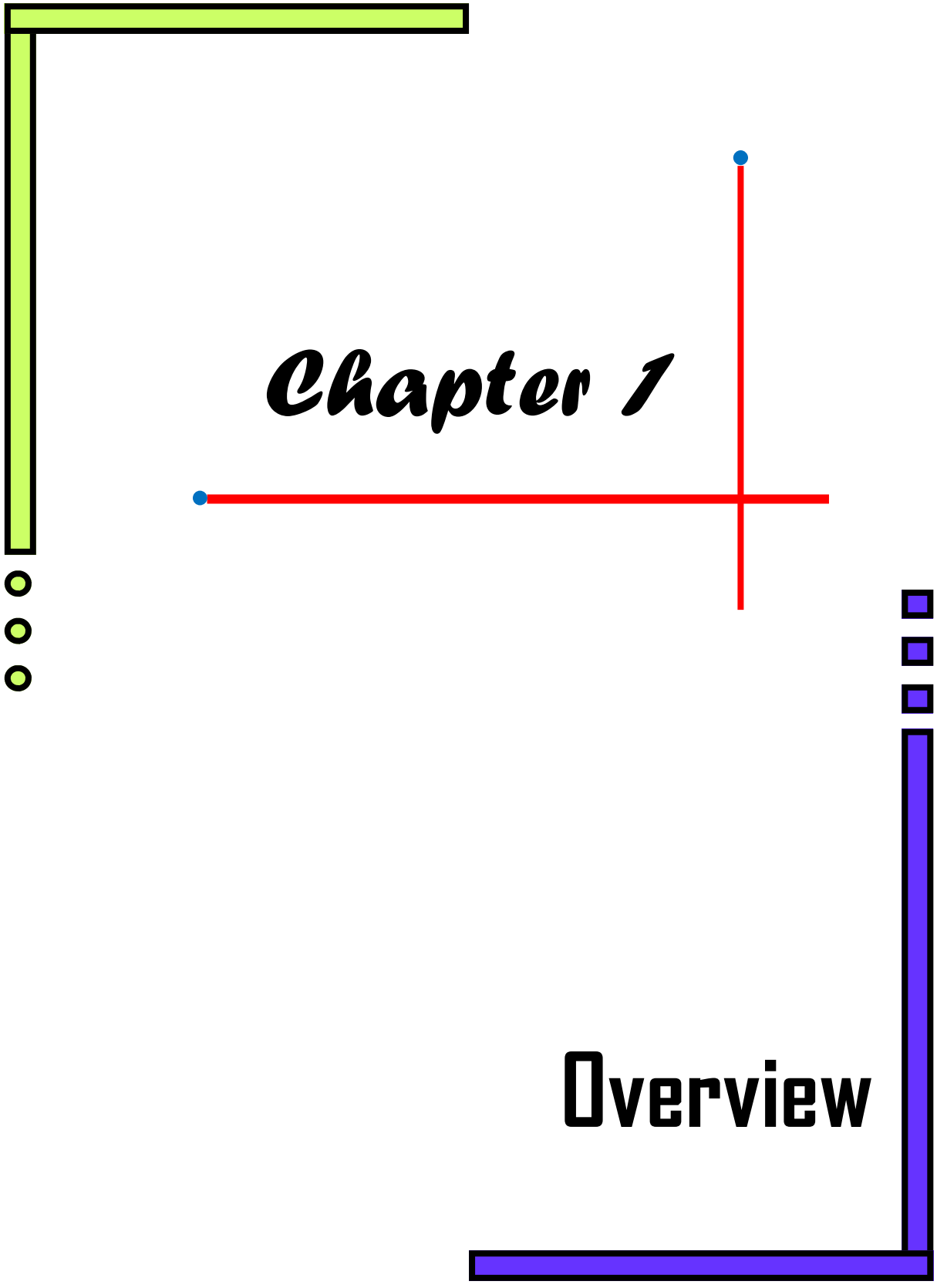
Chapter 1
Overview

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This chapter gives brief introduction of the work considered for thesis. Here brief overview of the contents of chapters described.

One of the most promising and discussed technologies in the last decade is the wireless technology which allows users to utilize devices that enable the access to information at any time any place. These needs make wireless networks the best solution for interconnecting devices and people. The 1990s have seen a rapid growth of research interests in wireless ad hoc networking. The networks are dynamic in nature and infrastructure less, demands new set of networking strategies to be implemented to provide efficient end-to-end communication [1]. Ad-hoc networks employ the traditional TCP/IP structure to provide end-to-end communication between nodes. However, due to their mobility and the limited resource in wireless networks, each layer in the TCP/IP model requires redefinition or modifications to function efficiently [2, 3].

A Wireless Ad-hoc Network (WANET) is a collection of nodes where the nodes will self configure and self organize themselves forming a wireless medium without any requirement of stationary infrastructure like base station. In WANETs each node will not only act as a host but also acts as a router. Due to mobility of nodes, the topology of the network is dynamic that is, it changes most of the time. Some examples where the possible use of Ad-hoc networks are in military, in emergency situation like hurricanes, earth quakes, conferences etc. WANET nodes are dynamically and arbitrarily located in a manner such that the interconnections between nodes are capable of changing on a continual basis. A routing protocol is used to discover routes between nodes and to facilitate communication within the network [4, 5]. The aim of such an ad hoc network routing protocol is correct and efficient route establishment between a pair of nodes and messages may be able to be delivered in a timely manner [6]. Route construction should be done with a minimum of power usage and bandwidth consumption. An intelligent routing strategy is required to efficiently use the limited resources while at the same time being adaptable to the changing network conditions such as: network size, traffic density and network partitioning [7, 8, 9]. In parallel with this, the routing protocol may need to provide different levels of Quality of Service (QoS) to different types of applications and users.

Routing is used to detecting and maintaining the optimal route to send data packets between a source and destination via intermediate node(S) in a network [10].This has led to development of many different routing protocols for Wireless Ad-Hoc Networks (WANETs), and each author of each proposed protocol argues that the strategy proposed provides an improvement over a number of different strategies. So, it is quite difficult to determine which protocols may perform best under a number of different network scenarios, such as increasing node density and traffic [11, 12]. Most wireless terminals can be expected to have limited energy storage, power awareness is very important [13, 14]. The objective is not

only the reduction in transmission power consumption, but also the management of routing protocol parameters which affect to the performance of the WANET.

Thesis examines routing protocols for ad hoc networks and evaluates these protocols based on a given set of parameters. It provides an overview of different protocols with their characteristics, and then provides a comparison and discussion of their respective merits and drawbacks while WANET exhibit much promise. Here the OLSR and FSR are considered for the proactive type of protocol and AODV, DSR are for the reactive type of protocol, and ZRP as the hybrid type of protocol is considered for the comparison and to decide which one is better. The challenges are due to their lack of backbone infrastructure, the need for decentralized control, dynamic topology, and wireless channel characteristics. To achieve continuous updates of nodes topology of the network, each node in the WANET maintains the routing tables by exchanging information packets [15].

Due to nodes' mobility, the efficiency of a dynamic ad hoc routing protocol depends highly on updating speed of network topology changes. To achieve continuous updated routing tables, the nodes periodically broadcast short Hello messages to their neighbors [16]. Although benefits of these messages have been proven, many studies show some drawbacks for these messages.

AODV is the reactive routing protocol which uses the static value for its route lifetime parameter called Active Route Timeout (ART) which indicates the time that the route can stay active in the routing table [17, 18]. Route lifetime may be more accurately determined dynamically via measurement, instead of static value. AODV also uses static value for hello message interval. The default value of hello messages is defined as 1 Sec [19]. Adaptive values for ART and hello message interval depending on the situation of the transmitter and intermediate nodes. Instead of taking fixed value of the Hello Interval to the routing protocol, if we make it adaptive then it can improve the performance of the routing protocol. Each node can get to know its neighborhood by using local broadcasts, so-called HELLO messages. Neighbors Nodes are all the nodes that can communicate directly with other node. Although AODV is a reactive protocol it uses these periodic HELLO messages to inform the neighbors that the link is still alive. The HELLO messages will never be forwarded because they are broadcasted with Time To Live (TTL) = 1. When a node receives a HELLO message it refreshes the corresponding lifetime of the neighbor information in the routing table [20]. AODV uses destination sequence number for each route entry. The destination sequence number is created by the destination to be included along with any route information it sends to requesting nodes. Using destination sequence numbers ensures loop freedom. If the multiple routes exist between the nodes of the network, a requesting node is required to select the one with the greatest sequence number [19].

Evaluation of performance of WANET and to calculate the best path for routing the packets to its destination using Routing protocols several metrics can be considered. These metrics are a standard

measurement that could be number of hops, which is used by the routing algorithm to determine the optimal path for the packet to its destination. To evaluate the performance of the WANET using the specific routing protocol here we have considered mainly four types of performance of metrics viz. Average End to End Delay, Average Packet Delivery Ratio, Jitter, Average throughput and number of Received packets by the destination node.

Soft computing differs from conventional (hard) computing in that, unlike hard computing, it is tolerant of imprecision, uncertainty, partial truth, and approximation. In effect, the role model for soft computing is the human mind. The guiding principle of soft computing is: Exploit the tolerance for imprecision, uncertainty, partial truth, and approximation to achieve tractability, robustness and low solution cost.

Recently, many researchers adaptively optimize the ad hoc routing protocols functions and parameters using the Fuzzy Reasoning Algorithm (FRA). The routing protocol parameters can be determined more accurately and dynamically by FRA, instead of static values. The application of FRA to Ad-Hoc network problems allows us to specify these parameters using "if...then..." type of linguistic rules.

Fuzzy Inference System (FIS) is used to configure the protocols parameters instead of using static values. The dynamical configuration can adapt to the changes of the network topology and improve the protocol performance. Using static parameters for the protocols in ad hoc environments that suffer from frequent change of network topology and different traffic intensity may degrade the routing protocols performance. [20] Wang et al. used a FRA to dynamically configure five routing parameters of Ad hoc On-demand Distance Vector (AODV) routing protocol. They used mathematical models to represent nodes moving mode and their traffic mode. These models were used to categorize the network environments to nine categories. The fuzzy reasoning was used to estimate the nodes membership degree in these environments. Depending on the node membership degree, the values of the protocol parameters are increased or decreased. FIS , Artificial Neural Network(ANN), Adaptive Neuro Fuzzy Inference System (ANFIS) is used to determine the adaptive value of the Hello Interval for the AODV routing protocol using hybrid simulation in MATLAB and Qualnet simulator to evaluate and optimize the performance of the routing protocol and WANET. The comparison among the different optimization method is discussed in thesis. [20] Has discussed, adaptively optimization of the frequent needs of those messages using a FIS is described. Extensive performance analysis via simulation proves the effectiveness of the proposed method to improve the accuracy of neighborhood information and, hence, overall network performance.

Artificial neural networks (ANN) [21] are among the newest signal-processing technologies for optimization of performances. The Artificial Neural Network is built with a systematic step-by-step

procedure to optimize a performance criterion or to follow some implicit internal constraint, which is commonly referred to as the learning rule. The input/output training data are fundamental in neural network technology, because they convey the necessary information to "discover" the optimal operating point. The nonlinear nature of the neural network Processing Elements (PEs) provides the system with lots of flexibility to achieve practically any desired input/output map. An Artificial Neural Network is an adaptive, most often nonlinear system that learns to perform a function (an input/output map) from data. Adaptive means that the system parameters are changed during operation, normally called the training phase. After the training phase the ANN parameters are fixed and the system is deployed to solve the problem at hand (the testing phase).

ANFIS [22] uses a hybrid learning algorithm to identify the membership function parameters of single-output, Sugeno type FIS. A combination of least-squares and back-propagation gradient descent methods are used for training FIS membership function parameters to model a given set of input/output data. This is the major training routine for Sugeno-type FIS. Genetic Algorithms (GAs) [23] are robust, numerical search methods that mimic the process of natural selection. Although not guaranteed to absolutely find the true global optima in a defined search space, GAs are renowned for finding relatively suitable solutions within acceptable time frames and for applicability to many problem domains. During the last decade, GAs has been applied in a variety of areas, with varying degrees of success within each. A significant contribution has been made within control systems engineering. GA exhibit considerable robustness in problem domains that are not conducive to formal, rigorous, classical analysis. Tuning of weights of feed forward ANN using Genetic Algorithms (GAs) techniques is described in [24]. The GAs are used for selecting bias and the weights for the each layer and nodes of the neural controller, as well as training the network to minimize the error between the actual output and the output after the training of using GA. Enhanced synergy of GAs with Fuzzy Inference System(FIS) and Artificial Neural Networks (ANN) and proper fitness functions to form hybrid AI systems, will harness fully the strengths of each technique, thus providing GAs a niche role in future intelligent systems design.

Field Programmable Gate Array (FPGAs) [25] are a family of programmable device based on an array of configurable logic blocks (CLBs), which gives a great flexibility in prototyping, designing and development of complex hardware real time systems. Each block is programmed to perform a logic function that can be interconnected, so that the complete logic functions are implemented. The main advantage of FPGA is the flexibility that they afford. ”Field Programmable” means that the FPGA’s function is defined by a user’s program rather than by the manufacturer of the device. The Very high speed integrated circuit Hardware Description Language (VHDL) [26] is heavily used for FPGA programming. VHDL simplifies the development of ANNs on FPGA [27], since it is possible to model and simulate a digital system from a high level of abstraction with important facilities for modular design.

VHDL project discusses hardware implementation of ANN architecture for AODV routing protocol in WANET on LUT110T ML505 Virtex-5 FPGA kit.

The routing is considered one of the most challenging and interesting research areas in WANET. A routing protocol must be capable of handling very large number of nodes with limited bandwidth and power availability. Also they should respond quickly to the hosts that broken or newly formed in various locations. Many protocols have been proposed to solve these problems in the ad-hoc networks. In this mainly discussion of the performance comparison of three classes of wireless multi-hop routing protocols; viz. proactive, reactive protocols and hybrid is considered. The results of the experimental study carried out for the most common traditional routing protocols and their extensions. It is found that AODV is more desirable protocol in MANETs, especially in the case of high mobility and the high traffic load [28, 29, 30]. From comparative simulation study of routing protocol it can be concluded that it is good for WANETs [15].

This has inspired the author to work in this direction of development of new strategies for performance optimization of the network using soft computing techniques such as Fuzzy logic, Fuzzy models, ANN, Neuro-Fuzzy and genetic algorithm. When it is not possible to have an exact mathematical model, an alternative Fuzzy, ANN and GA based methods developed and implemented on computational platforms. The research work aims at developing new algorithms for making the adaptive value of the default parameters in the routing protocol. The use of software development support tools such as MATLAB, SIMULINK, TRUETIME Toolbox, and use of simulators viz. NETWORK SIMULATOR NS-2 and Qualnet 5 [31, 32, 33] simplifies simulation, implementation and testing of WANET and hardware for the optimization techniques.

The primary focus of this thesis is routing and power control protocols in WANETs. The type and classification with the characteristic is studied. Specially, Reactive routing protocol AODV is studied, the comparison of it with other protocols, performance evaluation and optimization of AODV in WANET is done by applying soft computing techniques viz. FIS, ANN, ANFIS and GA.

The features and discussion of research carried out in the thesis includes:

- An extensive study in WANET in the area of routing protocols and their comparisons among the different types of protocols.
- Simulation study and comparative performance analysis of wired and wireless network on software tools viz. Network Simulator NS-2, OMNET++, OPNET, QUALNET, MATLAB/ TRUETIME Toolbox.
- Design and simulation of reactive routing protocol for all types network topologies using Network Simulator NS-2 software.

- Effect of variation in the mobility and the node density of the network [34] for a wireless network configuration having nodes varying from 10 to 50 with random traffic between the nodes using Qualnet.
- Simulation and comparative performance analysis of routing protocol viz. Proactive, Reactive, Hybrid protocols [30, 34].
- Survey of research trends in application of soft computing techniques for parameter value selection.
- Development of the FIS for adaptive decision on selection of parameters values of the standard routing protocol for optimization of performance of WANET [35, 36].
- Design, Development and Implementation of ANN and ANFIS to determine the Hello Interval parameter for optimization of the routing protocol and performance of WANET [37, 38, 39].
- ANN architecture implementation on LUT110T ML505Virtex-5 FPGA Kit using VHDL programming language in Xilinx software [40].
- Development of Genetic Algorithm (GA) for training of ANN to optimize the parameters of WANET [41].

The thesis is organized in the form of ten chapters. Brief description of the contents of the other chapters of the thesis is as follows.

Chapter: 2 A Surveys of different networks viz. wired and wireless networks, infrastructure and infrastructure less networks, different wireless ad hoc networks like mobile ad hoc network, vehicular ad hoc network, wireless sensor network, wireless mesh network: This chapter describes the study of different network simulators like NETWORK SIMULATOR NS-2, OPNET, OMNET++, GLOMOSIM, QUALNET, MATLAB/TRUETIME [42] to simulate wired and wireless topologies. NS-2 Simulator is used to study and simulation o behaviour of wired and wireless network, transmission and reception of the packets between the nodes and the performance of the network using different performance metrics as end to end delay, packet delivery ratio.

Chapter: 3 Routing protocols are the responsible for the proper end to end delivery of packets between the nodes with the proper source and destination nodes. Different routing protocols can be classified according to the keeping way of updating information in the network as proactive, reactive and hybrid routing protocol. This chapter describes the characteristic and behavior of the all the three types of the protocol and also the simulation of these protocol using the Qualnet simulator. The FSR and OLSR protocols considered for the

proactive type of protocols, AODV and DSR are considered for Reactive type and ZRP is for Hybrid type of protocol is considered in this chapter. We have considered the performance metrics like end to end delay, packet delivery ratio, average throughput, and average jitter to evaluate the performance of routing protocols and to determine best routing protocol among all the routing protocol [30].

Chapter: 4 Chapter gives a brief overview and describes theoretical background of the computing techniques such as FIS, ANN, ANFIS and GA. The most popular tools used by the researchers for development and simulation study of the system under test such as MATLAB, SIMULINK and associated tool boxes for software development and testing are also described. Toolboxes available for deploying soft computing techniques in MATLAB and used in our research work for the design and testing of proposed techniques are described in detail. Procedural steps to be followed in each trait are discussed in detail.

Chapter: 5 Chapter has described the detail performance evaluation of the reactive routing protocol using the TRUETIME toolbox of MATLAB/SIMULINK [43, 44]. The performance evaluation of the routing protocol was done using the performance metrics Signal Reach , Average End To End Delay, Average Packet Delivery Ratio with respect to change in the transmission power of each nodes. Performance improvement of the network was done using the adaptive value of the default parameters instead of the static values. The adaptive value of the parameters could be determined by the soft computing techniques such as FIS and ANFIS [45]. Finally the performance of the network and the routing protocol used is done with these methods also.

Chapter: 6 In this chapter FIS based optimization of reactive routing protocol AODV have been described. AODV uses the Hello messages to update the topology information and routing protocol in the wireless network. The frequency of the number of Hello messages affects the performance of the routing protocol. Instead of using static value of 1 sec standard for the hello interval which is the fixed interval between the hello messages, here it is determined by the FIS. The performance comparison of the Reactive routing protocol AODV has been evaluated in terms of changing the hello interval decided by FIS with the AODV protocol uses the standard static value of the hello interval of 1Sec and 1.5 Sec. [36].

Chapter: 7 Artificial Neural Network (ANN) [37] applications for performance of the routing protocol and throughput of the WANET improvement has been discussed in this chapter. The procedure for ANN based decision regarding parameters of routing protocols such as hello interval parameter has been proposed. The implementation of algorithm in MATAB is

discussed. Procedure for Interfacing MATLAB and Qualnet 5 simulator has been developed. Communication between MATLAB & Qualnet5 has been developed for the performance evaluation through simulation. Training of ANN using the genetic algorithm and comparative study of Feed Forward and GA trained ANN has been discussed in this chapter. The performance improvement of the routing protocol and throughput of the WANET is discussed.

Chapter: 8 The Very high speed integrated circuit Hardware Description Language (VHDL) [26] is used for programming of ANN architecture. VHDL simplifies the development of complex system of ANNs, as it is possible to model and simulate a digital system from a high level of abstraction with important facilities for modular design. Technique and script for firmware hybrid implementation of the ANN using VHDL is discussed in this chapter. Use of LUT 110T ML505Pvirtex-5 FPGA kit [46, 47] for Hardware implementation of ANN is discussed. Application of ANFIS to optimize the hello interval in AODV routing protocol for wireless ad hoc network and its comparison with ANN is discussed.

Chapter: 9 Conclusions and Future Scopes**:** Final conclusions and future extension of the work and future scope in this field are elaborated in this chapter.

Chapter: 10 Thesis ends with Bibliography which includes the list of references used in each chapter and list of publications and presentations done based on this work.