Chapter 1

Overview

Chapter 1 **Overview**

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

The development of microelectronics began in 1948 and continued with the miniaturization of sensors during last ten years. Today, Microsystems which are used in silicon micro technology are called Micro Electro Mechanical Systems (MEMS). Micro sensors are defined as very small sized devices that convert humidity, moisture, temperature, pressure, pollutants, light intensity, etc. into electrical signal. Now, Integration of MEMS with the radio frequency wireless communication technique will put forward low power consuming, cheap and communicating small devices, called Wireless Sensor Networks (WSN). WSN is the mixture of wired and wireless communication and combination of both the communications are known as Hybrid Communication Networks (HCN). HCN have spatially distributed transceivers with micro sensors that give the possibility of monitoring and collecting data easily and quickly. Nowadays, these devices are used in many different application areas like home automation, forest fire monitoring, traffic control, and noise & pollutant detection in the crowded areas.

As networks become more and more complicated and applications more and more demanding, a very common network topology for state-of-the-art multimedia applications is a hybrid wired/wireless architecture. The impact of this topology's particularities, like different throughput and bandwidth or packet format, on the Quality of Service (QoS) demanding nature of multimedia applications, is a growing research field.

HCN is one with both wired and wireless connections. Because in most cases, a transceiver-equipped PC or other device known as an access point is used and connected to a wired network, such as the telephone network or a wired LAN, which uses some type of standard cabling. This access point can receive and transmit data between the wireless and wired worlds. The chief advantage of a wireless network is mobility and flexibility. Other than that, both wired and wireless networks are equally easy (or difficult) to set up, depending on the organization's size and complexity.

The IEEE 802.15.4 [1] protocol has recently been adopted as a communication standard for low data rate, low power consumption and low cost Wireless Sensor Networks (WSNs). This protocol is quite flexible for a wide range of applications by adequately tuning its parameters and it also provides real time guarantees by using the Guaranteed Time Slot (GTS) mechanism. This feature is quite attractive for time-sensitive WSN applications.

WSN is a wireless network consisting of spatially distributed devices integrated with sensors to cooperatively monitor physical or environmental conditions such as temperature, pressure, humidity, vibration, motion or pollutants using wired network, and exchange the information at different locations using wireless networking. Each wireless device is also called a node that behaves individually. Each node has one or more sensors integrated on it. In addition to these sensors, a node is also equipped with a transmitter and a receiver. These transmitter and receiver are used for wireless communications with other nodes or directly with the gateway. The gateway is responsible for transmitting sensor data from the sensor patch to the remote base station that provides Wireless Ad-Hoc Network (WANET) connectivity and data logging through a local transit network. Finally, the data is available to researchers through a user interface. The other parts of a sensor node are the microcontroller and the battery (as the energy source). Battery-powered embedded systems, such as WSN motes, require low energy usage to extend system lifetime. WSN motes must power sensors, a processor, and a radio for wireless communication over long periods of time, and are therefore particularly sensitive to energy use. Recent techniques for reducing WSN energy consumption, such as aggregation, require additional computation to reduce the cost of sending data by minimizing radio data transmissions. Larger demands on the processor will require more computational energy, but traditional energy reduction approaches, such as multi-core scaling with reduced frequency and voltage may prove heavy handed and ineffective for motes. Battery-powered embedded systems carefully manage energy consumption to maximize system lifetime. WSNs, made up of many "mote" devices, and are often designed to operate for months without intervention.

Time-critical applications for wireless sensor networks (WSNs) are an important class of services supported by the standard IEEE 802.15.4. Understanding the delay in the packet delivery is fundamental to assess performance limitation for the standard. The IEEE 802.15.4 standard specifies the physical layer and MAC sub-layer for Low-Rate Wireless Personal Area Networks (LR-WPANs). The ZigBee standard is closely associated with the IEEE 802.15.4 protocol and specifies the network (including security services) and application (including objects and profiles) layers. The IEEE 802.15.4 Task Group (TG4) [1], together with the ZigBee Alliance [2], has developed an entire communication protocol stack for LR-WPAN [3].

When an IEEE 802.15.4-compliant WPAN disables the generation of periodic beacon frames i.e. non-beacon enabled mode, all nodes in the network compete to gain

access to the medium using non-slotted CSMA/CA. The performance of the IEEE 802.15.4 protocol has been subject to few research studies, focusing more on the performance of its CSMA/CA protocol, is discussed in [4-6] or its general characteristics using simulations [7].The advantage of the non-beacon enabled mode, with regards to WSN application requirements, is that it easily allows scalability and self-organization. However, the non-beacon enabled mode does not provide any guarantee to deliver data frames, specifically within a certain deadline. For time-critical applications, real time guarantees may be achieved with the beacon-enabled mode. This mode offers the possibility of allocating/deallocating time slots in a superframe, called Guaranteed Time Slots (GTSs) [8-12] and providing predictable minimum service guarantees. Having a minimum service guarantee, it is possible to predict the worst-case real-time performance of the network.

The IEEE 802.15.4 standard grants exclusive use of a wireless channel for time-critical traffic through GTS medium access control (MAC) mechanism. The GTS is activated in the beacon-enabled mode based on the superframe structure. A node has to use at least one whole GTS in a transmission. However, each node may not fully utilize its transmission capacity in a particular time slot if the packet arrival rate is too small. Hence, bandwidth utilization is reduced. Queue management and buffer dimensioning at the nodes becomes an important factor to quantify the optimal parameters to tune the network for a better performance without making any modifications to the existing protocol [13].

Soft Computing Techniques (Artificial Neural Networks, Genetic Algorithms and Fuzzy Logic Models) have been recognized as attractive alternatives to the standard, well-established "hard computing" paradigms. Traditional hard computing methods are often too cumbersome for today's problems. They always require a precisely stated analytical model and often a lot of computational time. Soft computing techniques, which emphasize gains in understanding system behavior in exchange for unnecessary precision, have proved to be important practical tools for many contemporary problems.

Neural networks are composed of simple elements operating in parallel. These elements are inspired by biological nervous systems. As in nature, the connections between elements largely determine the network function. You can train a neural network to perform a particular function by adjusting the values of the connections (weights) between elements. Typically, neural networks are adjusted, or trained, so that a particular input leads to a specific target output. ANN can be used for complex relationships

between inputs and outputs. ANN in most cases is adaptive systems that change their structure based on external or internal information flowing through them and use a connectionist approach to process information [14]. Back propagation feed forward networks are standard neural networks for any supervised learning pattern recognition.

The ANFIS [15] was proposed many years ago and is widely used in research works. The ANFIS reveals an efficient learning network and its applications can be found in many works in the literature [16-18].The acronym ANFIS derives its name from adaptive Neuro-Fuzzy inference system. Using a given input/output data set, the toolbox function ANFIS constructs a fuzzy inference system (FIS) whose membership function parameters are tuned (adjusted) using either a back propagation algorithm alone or in combination with a least squares type of method. This adjustment allows your fuzzy systems to learn from the data they are modeling.

Thesis provides brief idea about IEEE 802.15.4, whose MAC protocol supports two operational modes that can be selected by a central controller of the Person Area Network (PAN), called PAN Coordinator, viz., Beacon-enabled mode, Non Beacon-enabled mode. Both modes are examined, evaluates GTS mechanism in beacon-enable mode for WSN based on IEEE 802.15.4 standard and optimize based on given set of parameters.

The proposed mechanism is used to carry out a set of experiments and to compare the obtained simulation results with the ones that were previously obtained using an OPNET simulation model based on Network Calculus. An accurate OPNET simulation model of the IEEE 802.15.4/ZigBee protocols [19] focusing on the implementation of the Guaranteed Time Slot (GTS) mechanism and ZigBee hierarchical routing strategy is discussed. Optimization of GTS mechanism is one of the recent issue when we use WSN in beacon enabled mode and working on Contention Free Period (CFP).

This has inspired the author to work in this direction of development of new strategies for performance of the network using soft computing techniques such as Fuzzy Logic, Fuzzy models, ANN, ANFIS, Genetic algorithm. When exact mathematical model is not possible, soft computing technique based methods can be develop and implement on computational platforms. The use of software development support tools such as MATLAB, TRUE TIME Toolbox and use of OPNET [20] simulator simplifies simulation, implementation and testing of WSN and hardware for the optimization techniques.

There are several implementations of the IEEE 802.15.4/ZigBee protocols supported by different hardware platforms [21-31]. These were developed in C language and programmed directly in the microcontroller without any supporting operating system (like TinyOS). Additionally these implementations only support the non-beacon enabled mode, therefore allowing the construction of ZigBee standard mesh networks, but not of beacon-enabled Star and Cluster-Tree networks [19]. The experimental test bed is based on an IEEE 802.15.4 star network operating in a beacon-enabled mode, with PAN Coordinator and end devices.

Research Objectives and Contributions

- Development of the model for wired and wireless network and simulation of the model on software tool focusing on the parameters viz., collision count, traffic received, delay, throughput, data dropped, media access delay.
- Survey of topologies for IEEE 802.15.4 and routing protocols.
- Simulation study of routing protocols and topology on performance of IEEE 802.15.4.
- Development and evaluation for IEEE 802.15.4 and Zigbee protocols focusing on the Routing protocol and Zigbee hierarchical routing strategy in non-beacon enabled Wireless Sensor Networks (WSN).
- Selection of routing protocol and strategy for non-beacon enabled WSN employing IEEE 802.15.4.
- Study and analysis of performance of motes employing MATLAB Simulink and Truetime.
- Study of superframe structure and various mechanisms for parametric optimization and proposing new strategy of parametric optimization.
- Survey of Preliminary Technique and proposing new strategy of Parametric Optimization for WSN.
- Design, implementation and evaluation of an accurate simulation model for IEEE 802.15.4 protocol focusing on the Guaranteed Time Slot (GTS) mechanism in beacon-enabled, star topology in Wireless Sensor Networks (WSNs).
- The formulation, implementation and evaluation of soft computing methods to optimize the parameters of GTS Mechanism.
- Development of SOFT computing algorithms using ANN, ANFIS.

- Design of SOFT GTS mechanism with user interface employing matlab.
- Implementing WSN on embedded hardware.

The thesis is organized in the form of ten chapters as follows:

Chapter: 1

The chapter provides an overview and the context for the remainder of the thesis.

Chapter: 2

This chapter gives brief idea about Hybrid Network. It describes an overview and classification of networks used for communication. A survey of different networks viz., wired and wireless networks, different wireless ad hoc network like mobile ad hoc network, vehicular ad hoc network, wireless sensor network, wireless mesh network is described.

Chapter: 3

This chapter describes the study of different network simulators like NETWORK SIMULATOR NS-2, OPNET, OMNET++, GLOMOSIM, and QUALNET. Performance of wireless and wired networks as well as comparison is evaluated using OPNET simulation tool. For wired network, collision count, traffic received, delay, throughput is studied while for wireless network, data dropped, traffic received, media access delay, and throughput is studied. For comparison of both wired and wireless networks, the performance parameters throughput is investigated [32]. All these performance is carried out by varying number of users.

Chapter: 4

In this chapter, study of motes behavior using True time simulator, MATLAB based networked Simulator is discussed. Truetime is a MATLAB/Simulink-based simulator for networked and embedded control systems. The simulator software consists of a Simulink block library and a collection of MEX files. The kernel block simulates a real-time kernel executing user-defined tasks and interrupt handlers. The various network blocks allow nodes (kernel blocks) to communicate over simulated wired or wireless networks [33]. In [34] Wireless Sensor Network is simulated using Truetime toolbox. In this chapter, behavior of wireless mots has been examined with respect to parameters like Transmission Power, Receiving threshold power, Average visiting time [35].

Chapter: 5

This Chapter provides an overview of the most relevant aspects of the IEEE 802.15.4 and ZigBee protocols. Design of simulation model with respect to the specifications of IEEE 802.15.4 standard for WSN is discussed. The primary goal of routing protocols [36] which are designed for WSNs is to maintain energy efficient and reliable paths between different nodes in the network without generating a lot of overhead. The chapter discusses simulation and evaluation of two scenarios, where we examined the topological features and performance of the IEEE 802.15.4 standard using OPNET simulator [37]. The comparative results for two topologies are reported for the performance metrics like: Number of hopes, End to End Delay and Load of network.

Chapter: 6

Timeliness is an important feature of the IEEE 802.15.4 protocol, turning it quite appealing for applications under timing constraints. Because of this attractive feature, it is used in real time for time constraint data delivery which is provided by Guaranteed Time slot mechanism. This chapter explores the underutilization of bandwidth in WSN and analyses GTS mechanism by evaluating throughput in OPNET Modeler [38].

Chapter: 7

This Chapter gives a brief overview and describes theoretical background of the soft computing techniques such as ANN, ANFIS. The most popular tools used by the researchers for development and simulation study of the system under test such as MATLAB 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. In this chapter, GTS mechanism is examined using proposed methods based on soft computing techniques such as ANN and ANFIS. The implementation of algorithm in MATLAB is discussed. Training of ANN [39] and ANFIS techniques are discussed and compare with the results obtained from traditional method (OPNET simulation).The performance improvement of GTS mechanism is also discussed.

Chapter: 8

This chapter describes the hardware implementation of WSN. In beacon enabled mode, sensor nodes (motes) supporting the IEEE 802.15.4 Standard can be used as PAN coordinator, end device forming star topology. Our GTS mechanism based experiments use the Embedded Hardware for Hardware implementation.

Chapter: 9

Conclusion & Future Scope: Final conclusions and future extensions 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 publication and presentations done based on this work.