Chapter 1

Introduction

1.1 Mobile Ad hoc Networks

Ad hoc network [Per 02] is a collection of wireless nodes that can communicate among each other without the help of fixed infrastructure. Usually the transmission range of a node is limited and hence a node can communicate directly with those nodes which are in its radio range. However, a node communicates with distant nodes, not in its radio range, by the method of relaying with the help of intermediate nodes. So, a node in an ad hoc network is capable of acting as a host as well as a router. A Mobile Ad hoc Network (MANET) may be characterized as a multi-hop infrastructure-less wireless network where the participating nodes may be mobile. An ad hoc network can be deployed quickly without elaborate planning and deployment of costly infrastructure. Because of quick deployment, low cost of implementation and infrastructure-less feature, ad-hoc networks are fast becoming popular.

MANET has wide range applications. Some of the systems, which exploit the characteristics of MANET, include Wireless Local Area Networks (WLAN) and Personal Area Networks (PAN) such as bluetooth and UWB. A few emerging applications of MANET are for disaster management, traffic regulation and in battlefields. Recent research on sensor networks is also based on several characteristics of MANET.

Now, looking at the recent history of development of data networks, it is not difficult to appreciate that one important reason for wide scale deployment of DTE-s (Data Terminal Equipment) and various network elements has been the systematic and layered approach to their design. Layered architecture has worked well for wire-line networks. A wireless channel however, is an unguided medium and transmission by one node may act as interference to other transmission. Further, many a times, a wireless channel is a time varying one due to multipath, user mobility and interference. A mobile ad hoc network uses wireless links, mobile nodes and decentralized control. So, it is argued that layered architecture may not perform equally well for MANET. A cross layer design approach exploiting the interdependence among protocol layers may achieve performance improvement in MANET. Thus research is also focused on cross layer design architecture for MANET. Several cross layer design approaches have been proposed recently by [Set

‘05], [Sri ‘05]. As for example, the application layer can adopt the transmission rate based on network throughput and a routing layer can avoid a link experiencing deep fade However characterizing the information to be exchanged between layers is a difficult task.

The grand success of mobile telephony offering good quality speech services and moderate rate data services naturally leads to the next step of high speed mobile communications. So, in recent times there is growing demand for high speed services such as multimedia. It is worthwhile to investigate appropriate issues in the physical layer, MAC and routing layers to examine feasibility of high data rate services over wireless networks. Physical layer design based on Orthogonal Frequency Division Multiplexing (OFDM) technique is being advocated for supporting broadband services using wireless channel. OFDM is known to be very bandwidth efficient and also robust to multipath fading. However OFDM is highly sensitive to synchronization error [Pol ‘95].

1.2 Importance of Synchronization

Sub-carriers in OFDM system occupy a narrow bandwidth and they overlap. A small offset of carrier frequency and timing offset at the receiver may lead to loss of orthogonality between sub-carriers and result in severe performance degradation of the OFDM system [Pol ‘95], [Pol ‘95a],[Spe ‘99]. Maintaining orthogonality of the sub-carriers is one of the essential requirements of an OFDM system. However, dispersive channel, oscillator instability and Doppler spread results in loss of orthogonality [Spe ‘99]. So, synchronization is one of the important tasks to be performed at the receiver. Several schemes have been proposed for effective time and frequency synchronization in an OFDM receiver. Effectiveness of a synchronization scheme is considerably dependent on the wireless channel and applications. A data unaided synchronization scheme is more suitable for online communication but computationally complex. Cyclic based system utilizes the redundant information in cyclic prefix portion. Pilot aided synchronization schemes are adopted in WLAN standards for low computational complexity. We have also worked on synchronization schemes for WLAN systems.

1.3 Research Objective

Detail analysis of synchronization for OFDM based systems and cross layer interaction on higher layers of MANET are the focus of our study. The objectives of our research are as follows.

(i) To study the performance of MANET for different number of sources and varying mobility scenario.

(ii) Understand the effects of timing and carrier frequency synchronization errors on OFDM based WLAN systems and to try to develop new timing and carrier frequency synchronization schemes for OFDM receivers.

(iii) To investigate the effects of synchronization schemes on higher layers of MANET for different channel conditions.

The following steps have been pursued to achieve the above objectives:

i. Specific literature survey on MANET, cross layer interaction and synchronization of OFDM receivers for supporting high speed data services in MANET.
ii. Performance evaluation of MANET for different number of sources (i.e. 5-25) and different mobility scenario, and study of the factors responsible for packet loss and routing load.
iii. Implementation of prominent timing synchronization schemes for OFDM based WLAN. A new timing metric has been suggested in the process.
iv. Implementation of promising frequency synchronization schemes for OFDM based WLAN. A new residual frequency offset scheme has been suggested in the process.
v. The new frequency offset estimation scheme has been applied to investigate its performance for MB-OFDM based UWB systems.
vi. Study of cross layer interaction of PHY with MAC and routing layers.

1.4 Approach to Work

The work is based on analysis and simulation. We have studied the variation in packet delivery and routing load of mobile ad hoc network for different mobility and load conditions. Results have also been compared with other reported work wherever appropriate.

Effects of timing and synchronization error in OFDM system are analytically studied. An expression for a new timing metric is proposed for preamble based WLAN using OFDM. Two coarse frequency offset estimations have been implemented to gain insight. Residual frequency offset has been found to result in considerable packet error rate. So, detail investigation on residual frequency offset correction has been done.

Analytical expression for the variance of residual frequency offset estimation error of a new scheme for OFDM based WLAN system and its Cramer Rao Lower Bound (CRLB) have been found. Simulation is performed to compare the variance of frequency offset estimation error with CRLB.

Effect of synchronization scheme for OFDM based WLAN system in term of BER is used to study the cross layer interaction of the PHY layer on the higher layers in a MANET in AWGN and fading channel using network simulation. Subsequently a cross layer design approach is proposed at MAC and routing layer based on the PHY cross layer information using network simulation.

1.5 Thesis Organization

The work and results have been reported in six chapters. The first chapter gives a cursory introduction to MANET, cross layer design approach and use of OFDM in wireless networks including the objective and methodology of the work.

The review Chapter (Chapter 2) presents a detail review on MANET, cross layer design approaches for nodes and network elements, and synchronization schemes for OFDM receivers. The third Chapter (Chapter 3) contains detail results of our simulation on packet loss, routing load and other parameters for a typical MANET configuration. Performance of AODV and DSR routing protocols have been investigated and compared in this Chapter as well.

Frequency and timing offset estimation for OFDM receiver in a WLAN environment have been the focus of the Chapter 4. Attention has been paid to the issue of residual frequency offset estimation as this parameter has a significant role in degrading both symbol and packet error rate in an OFDM receiver. An improved scheme for residual frequency offset has also been presented in this chapter. Extensive results based on simulation have been presented for OFDM receivers incorporating schemes for residual frequency offset estimation as well as timing estimation. An improved timing estimating procedure using two windows for IEEE 802.11a have been found to perform very well.

These studies on performance of OFDM receivers have helped us to bring out the dependence of two key parameters of MAC and routing layers on the physical layer models. Chapter 5 substantiates this through simulation results later in this chapter. Two case examples for adapting operating parameters at MAC and routing layers have also been provided.

Summary of our observation and findings are represented in the concluding chapter i.e. Chapter 6.