CHAPTER 1

INTRODUCTION

1.1 MOTIVATION

Media streaming, video conferencing and interactive online games are some of the applications that are expected to attract an increasing number of users in the future. Supporting these applications will be a major challenge for next generation wireless networks. Existing wireless, mobile multimedia systems are specifically tailored to individual wireless network technologies and do not address the heterogeneity that is expected in next generation networks.

Mobile users expect high quality and transparent service independent of the network access technology. At the same time, network operators need to efficiently allocate the wireless resources to increase network capacity and provide services to as many users as possible at the best possible quality level (Khan et al 2006).

1.2 REQUIREMENTS OF MULTIMEDIA SERVICES

The major challenge in multimedia services over wireless networks is satisfying the Quality of Service (QoS) requirements with efficient resource utilization. Multimedia data transmissions experience a number of constraints that result in low QoS being offered to the end user. These constraints are mainly due to the nature of multimedia applications, which are characterized by three main properties: the demand for high data transmission rates
(bandwidth-consuming applications), the sensitivity to packet delays (latency and jitter) and the tolerance to packet losses (packet-loss tolerant applications), when compared to other kind of applications (Bouras et al 2008). Heterogeneous multimedia applications in future Internet protocol-based wireless networks require a more complex QoS model and more sophisticated management of scarce radio resources. QoS can be classified according to its implementation in the networks, based on a hierarchy of four different levels: bit level, packet level, call level and application level (Jiang et al 2005). Transmission accuracy, transmission rate (i.e., throughput), timeliness (i.e. delay and jitter), fairness and user perceived quality are the main considerations in this classification.

- **Bit-level QoS** – Each user has to be ensured with a certain degree of accuracy in the received application and hence a maximum permissible Bit Error Rate (BER) is set. Any transmission with BER greater than the maximum permissible limit is not acceptable for applications which have stringent QoS requirements. Data applications are more sensitive to bit errors than video applications.

- **Packet-level QoS** – For delay sensitive applications like Voice over Internet Protocol and video conferencing, each packet should be transmitted within a delay bound. On the other hand, data applications like internet downloads can tolerate delay to a certain degree. Throughput is a better QoS criterion for data applications. Packet Loss Rate (PLR) is also one of the important QoS parameter. Certain application like real time video transmission can accept certain degree of PLR because of the error concealment techniques however data applications cannot accept this.
• **Call-level QoS** – In a wireless system, there are chances that a new call will be blocked or a handoff call will be dropped if there are limited resources in the network. From the user’s point of view, handoff call dropping is more unacceptable than new call blocking because the user might be in the middle of some important transaction during handoff. It is necessary to devise an effective call admission control to ensure that there is less probability of dropping a handoff call rather than new call blocking.

• **Application-level QoS** – User perceived QoS parameters like Peak Signal to Noise Ratio (PSNR) for video application and the end to end throughput for data application provided by the responsive Transmission Control Protocol, more suitably represent the service quality seen by the end user, than bit and packet level QoS.

The required quality of service support has become thus essential for the operation of today’s multimedia wireless networks. However, this introduces a major challenge due to the variable nature of wireless links and the diverse QoS requirements of different applications including voice, video and data. In the current paradigm of the layered protocol stack, each layer of the communication network stack works independently to provide a solution to these challenges. The benefits of dynamic adaptation to system and channel conditions have been accepted, but the true potential of optimised adaptation is lost if the layers operate in an individual fashion, ignoring possible interdependencies between them. Cross Layer Design (CLD) provides mechanisms in which these interdependencies are exploited to achieve challenging objectives by providing QoS guarantee for multimedia traffic over wireless links (Quazi et al 2009). The pros and cons of the traditional
layered approach are discussed below before introducing the advantages and issues related to the CLD.

1.3 CONVENTIONAL LAYERED APPROACH

The conventional approach to network design is to identify the functions to be performed, group them into layered stack and design each of them in isolation. The layered approach has been widely used in the past, but it is no longer adequate to meet the challenges of next generation mobile systems. Mobile multimedia communication is especially challenging due to the time varying transmission characteristics of the wireless channel and the dynamic QoS requirements of the application like variable bit rate, prioritized delivery of important media units and variable tolerance versus bit or packet errors. Since the layers are independent in the conventional approach, the design procedure is simple. Setting the control modes and tuning the parameters of the protocols during design process based on worst case scenarios lead to poor performance and inefficient utilization of resources (Shakkottai et al 2003, Khan et al 2006). The advantages of traditional ISO/OSI layering approach are listed below.

- Simplification: Breaking the complex task of end to end networking into disjoint parts simplifies design.

- Modularity: Protocols are easier to optimize, manage and maintain and provides more insight into the layer operation.

- Abstract functionality: Lower layers can be changed without affecting the upper layers.

- Reuse: Upper layers can reuse the functionality provided by the lower layers.
The following is the list of disadvantages of the conventional layered approach:

- **Suboptimal**: Layering introduces inefficiency and redundancy, in other words same functions may be performed at multiple layers.

- **Information hiding**: Information about operation at one layer cannot be used by higher or lower layers.

- **Performance**: Layering can lead to poor performance especially for applications with hard QoS constraint.

The above aspects lead to suboptimal performance of the network. Instead, if a network observes the behavior of the application and of the lower layers up to the physical channel and if it can dynamically adapt to the changes, and then it is possible to maintain optimal allocation of resources and optimized QoS performance. However this requires timely exchange of parameters across layers and periodic reconfiguration of modes and parameters of the protocol layers during network operation. This approach is termed as the CROSS LAYER DESIGN.

### 1.4 CROSS LAYER DESIGN

Cross layer design is a new paradigm in network architecture design that takes into account the dependencies and interactions among layers and supports optimization across layer boundaries. A common misconception about CLD is that it carries out design of networks without layers. CLD should not be viewed as an alternative to the layered approach, but rather as a complement. Layering and cross layer optimization are tools that should be used together to design highly adaptive wireless networks (Khan et al 2006).
The CLD can be implemented in two approaches namely bottom-up and top-down. These approaches differ by the layer with which it is going to optimize the other layers (Mihaela Van Der Schaar and Sai Shanker 2005, Khan et al 2006).

1.4.1 Bottom-Up Approach

Bottom-up approach optimizes the Application layer based on the parameters provided by transport, network, data link and Physical (PHY) layers. The set of layer parameters used to optimize depends on the type of application and design complexity issues.

The bottom-up approach typically exploits information about the current channel situation to adapt the transmission policy of the application layer.

1.4.2 Top-Down Approach

Top-down approach optimizes the physical, data link or network layers to the application requirements. The top-down approach typically passes priority labels to the lower layers, which perform, for instance, class-based queuing and priority-based transmission.

Recent research shows that efficient designs adopt a combination of top-down and bottom-up approaches. As explained earlier, the set of layers used for cross layer optimization depends on the type of application, time complexity and cost. In some cases, there is a necessity to trade-off between the parameters.
1.5 CROSS LAYER ARCHITECTURE

1.5.1 Architecture

A typical Cross Layer Architecture (CLA) considered here in order to have a better understanding, is composed of layers in the network stack and a Cross Layer Optimizer (CLO), as visualized in Figure 1.1. The CLO jointly optimizes multiple network layers, making predictions on their states and selecting optimal values for their parameters.

![Figure 1.1 A Generic Cross Layer Architecture](Image)

1.5.2 Implementation Steps

The CLO concept presented above consists of following three steps of implementation (Khan et al 2006).

- **Layer Abstraction**: This computes an abstraction of layer specific parameters. The number of parameters used by the CLO is significantly reduced by the abstraction process.
- **Optimization**: This finds the values of layer parameters that optimize a specific objective function. Some of the typical objective functions are, to enhance the expected video reconstruction quality for multiple users, to reduce the end to end delay of the perceived video, to reduce the packet loss rate and to increase the throughput and so on.

- **Layer Reconfiguration**: This distributes the optimal values of the abstracted parameters to the corresponding layers. It is the responsibility of the individual layers to translate the selected abstracted parameters back into layer specific parameters and actual modes of operation.

The repetition rate of these steps depends on the rate at which the application requirements and transmission capabilities of the physical medium vary. Identifying the layer specific parameters to be optimized to meet the QoS requirement is an important task and it depends on the application. A layer description with a large set of parameters is accurate but usually results in high cost in terms of data processing and communication overhead. Therefore, abstractions have to be used to reduce the number of parameters. Also, abstracted parameters hide the actual technology and therefore allow for an approach to design the cross layer optimizer in a more general way and to use the same optimizer in different systems.

### 1.5.3 Concern and Precautions to consider in CLD

Though there are advantages associated with cross layer design, some precautions and concern need to be considered when a cross layer design architecture is proposed. Kawadia and Kumar (2005), and Melodia et al (2005) list them as given below:
A cross layer design approach may loosen the decoupling between design and development process, which may impair both the design and the implementation and slow down the innovation.

Design improvements and innovations may become difficult in a cross layer design, since it will be hard to assess how a new modification will interact with the already existing solutions.

In cross layer design, the effect of any single design choice may affect the whole system, leading to many negative consequences such as instability. This is a non trivial problem to solve, since it is well known from control theory that stability is a big issue. Moreover, the fact that some interactions are not easily foreseen makes cross layer design choices even more complicated.

Hence, great care should be taken to prevent design choices from negatively affecting the overall system performance.

1.6 LITERATURE SURVEY

The past decade has seen a lot of research in the area of cross layer design for wireless networks. Shakkottai et al (2003) have considered the cross layer information exchange between the physical and network layer in the TCP protocol where the inclusion of explicit congestion notification bit differentiates the packet loss due to congestion and wireless channel condition and optimize the throughput performance. Further they suggest a cross layer communication between the physical layer and Medium Access Control (MAC) layer for Wireless Local Area Network (WLAN) in the multiuser context where the channel state information aids the channel state dependent scheduling mechanism resulting in improved throughput compared to the channel state independent simple round robin scheduling mechanism. Srivastava and Motani (2005) present a survey of the literature in the area
of cross layer design and optimization. They define cross layer design and discuss the basic types of cross layer design with examples drawn from the literature, and categorize the initial proposals on how cross layer interactions may be implemented. Some open challenges and new opportunities for cross layer design are highlighted. The authors Xia et al (2005) have proposed an algorithm that exploits the multi user diversity manifested by the instantaneous channel conditions of multiple users and assigns the bandwidth and time while maintaining fairness among the users. The “Weighted Fair Scheduling based on Adaptive Rate Control” is a framework, wherein the PHY layer knowledge is shared with the MAC and logical link control layers in order to provide efficient resource allocation. In order to cope up with random behaviour of the channel and maintain fairness among the users dynamic weight values are assigned. The MAC layer contains the rate controller and logical link layers contain the packet scheduler. The algorithm is applied for the downlink that is the communication from the AP to the wireless terminal.

A similar cross layer communication between PHY and MAC layers is also applied by Verikoukis et al (2006). This literature proposes two novel cross layer mechanisms namely Cross Layer 1 and Cross Layer 2 to be included in a WLAN system where a near-optimum distributed MAC protocol is used. The performance of these mechanisms in terms of throughput and packet delay are analysed and a significant improvement in system efficiency is realized. Though there exist trade-off between performance enhancement and fairness among the schemes, they gain the advantage through smart scheduling that takes the channel state measurement and the waiting time of the packet into account. This scheme enables the communication and optimization between MAC and PHY layers. Prommak and Deeka (2007) deal with the problem of optimal access point placement and frequency channel assignment for WLAN with the help of cross layer design procedure in order to achieve the desired signal quality as well as system throughput in a
specific service area. This cross layer approach, accounts for the physical layer and the data link layer functionalities in the design of WLANs.

Long et al (2008) have proposed a framework for joint rate control and power control and classified the methods as the “layering as optimization decomposition” approach. The authors claim that this three layer joint optimization can maintain modularity among the layers. Here interference in the communication link is taken into account. Hence the link capacity is a function of power level of transmission. So the rate control at the transport layer is done in association with cross layer information from the physical layer and link layer. This joint optimization problem is converted from a nonconvex, non-separable nonlinear programming to convex programming problem using the geometric programming with variable substitute. Though this is computationally complex, it promises improved end to end throughput and energy efficiency compared to the work of its kind (Lin and Shroff 2004, 2005). Lin and Wong (2009) have proposed cross layer design schemes for a WLAN network with Multiple Input Multiple Output physical layer which combines the PHY and MAC layers. The joint cross layer design problem of power control and scheduling with the objective of minimizing the total transmit power, subject to the end to end QoS guarantee in terms of their bandwidth and bit error rate guarantee in multihop wireless network is discussed by Kozat et al (2004).

1.6.1 Cross Layer Design for Multimedia Applications

There is an increasing demand for the media streaming and online gaming applications in today’s world and this places significant challenges in the design and upgrading of wireless communication technologies. A lot of research has been carried out by researchers to exploit CLD for accommodating the challenges and improving end user perceived quality of the multimedia applications.
The authors in (Li and Mihaela Van Der Schaar 2004) propose a cross layer based adaptive MAC retry limit algorithm for real time video transmission. Here the impact of the retry limit on the interface queue in terms of buffer overflow rate and packet loss rate is analysed and a adaptation algorithm called Real Time Retry limit Adaptation (RTRA) algorithm is developed. The effectiveness of this algorithm is tested against the fixed retry limit case and the authors show that the algorithm reduces the packet loss rate and improves the PSNR. But in fact the improvement is very marginal. Always the number of retransmission has a direct effect on the delay incurred by the packets. The delay time is a crucial parameter like PSNR in video transmissions. The authors have not analysed the impact of RTRA on the delay performance.

The authors Yoo et al (2004) focus on joint optimization of capacity and flow assignment for live video transmission while minimizing the congestion and end to end delay using cross layer communication between the MAC and Network layer. Su et al (2006) authors discuss the application of cross layer design technique in the multi user environment for different networks like cellular network, WLAN and next generation Orthogonal Frequency Division Multiple Access networks, for different forms of video delivery. Authors discuss the need for joint optimization of physical layer parameters and application layer parameters like modulation rate, power control and Forward Error Correction (FEC) decoding rate respectively. Authors also point out the fact that the optimization is to be done not only vertically (i.e across the layers) but also horizontally (i.e across the users) as the problem considered here is for a multi user environment. So they declare that the optimization problem is a complex nonlinear and/or nonconvex problem. Hence the authors try to give a solution close to the optimum by reducing the search space boundary with the help of updated information about the resources available at a central entity using the cross layer
communication. Thus cross layer design methodology helps to solve the trade off between efficiency and fairness in multiuser environment for video communication in different networks.

In (Fallah et al 2008), the cross layer optimization is applied between the MAC and PHY layers based on the application layer requirement. This Intelligent Link Adaptation scheme (ILA) does the link adaptation for the efficient transmission of scalable video in a multi rate WLAN. ILA scheme demonstrates that the improvement in video quality in terms of average PSNR is better compared to the conventional CLD, as the cross layer communication is further established between Application, MAC and PHY rather than between PHY and MAC as in CLD. In conventional CLD, the enhancement layer is simply dropped in case of bad channel condition, where as, in ILA, depending on the channel condition the link rate and coding scheme are adjusted for different enhancement layer, thus the extended feature of H.264/AVC (i.e scalable video coding) is exploited for improved performance. Here centralized cross layer optimization is done in the sense, the optimizer receives information from the upper layer and from the lower layer and jointly determines the link layer rate and adjusts the physical layer parameters to satisfy the application requirements. In this work, the received video quality is considered only in terms of average PSNR. The end to end delay which is also a critical parameter in case of real time video transmission is not considered.

Authors in (Atici and Sunay 2009) describe the cross layer optimization problem attempted in their work as a multi objective optimization problem because it aims to perform the optimization with respect to the physical layer modulation rate and application layer parameters like Group Of Pictures (GOP), Quantization Parameter (QP) and FEC aiming to balance the two conflicting QoS parameters like maximizing PSNR and
minimizing outage probability. The authors have applied the technique to the cellular network scenario. A cross layer design technique that utilizes the communication between application, transport (scheduling) and physical layer (network state information) is discussed in (Zhou et al 2009). This aims to maximize the multi user video streaming performance by jointly optimizing the source and channel coding based on the available bit rate and round trip delay time. This scheme is efficient for the application that uses the scalable video coding. Wu et al (2009) have proposed a cross layer design (CLD) which employs an adaptive link estimator for the reliable video transmissions in ad hoc networks. This link-quality estimation scheme predicts the link characteristics for the next time interval using Kalman filter, and provides accurate link quality information for routing decisions.

A low complexity sub optimal cross layer communication based solution is proposed by Li et al (2011) for the packet scheduling and resource allocation problem in the multi user environment. The CLO assumed to be in base station, gets the video content information from the application layer, the queue status from the MAC layer and channel state information from the PHY layer. Based on these information, the optimizer decides the number of subcarriers to be allocated for the individual users and packet scheduling so that the distortion is minimized in the received video. Hence this is a combination of top down and bottom up cross layer optimization scheme. This optimization is really a low complex three step algorithm which maintains the fairness among the users.

Shi et al (2011), present a simple cross layer design that enables the communication from application layer to MAC layer for video transmission over 802.11e WLAN network. The quality layers in scalable video are mapped to the different access categories adaptively based on their
significance in the received video quality and thereby ensure improved QoS in the user perceived video quality. But this work does not consider the channel quality and hence the number of retransmissions and the network load, which may reduce the performance in a real time scenario. Recently authors in (Azhaguramyaa et al 2012) propose an enhanced QoS provisioning approach for Worldwide Interoperability for Microwave access (WiMAX) network using the cross layer communication between application and physical layers. Here the channel condition is measured in terms of the channel byte loss. Depending on the probability of byte loss the size of redundant information is added in a piggy back manner in association with the Adaptive Modulation and Coding (AMC) in PHY layer. This is a simple example for the bottom up cross layer approach. This scheme is suggested for video transmission in WiMAX network and the performance is analysed in terms of PSNR.

1.6.2 Cognitive Networks and Cross Layer Design

With regard to the bandwidth requirement for real-time video streaming, the common belief is that the spectrum is scarce. Contrary to this, regulatory bodies in various countries, including the Federal Communications Commission in the United States, and Ofcom in the United Kingdom, have found that most of the radio frequency spectrum is actually used inefficiently. This finding has stimulated a flurry of exciting activities in engineering, economics and regulatory communities in searching for better spectrum management policies and techniques (Zhao et al 2007). The main idea for better spectrum utilization is to allow licensed spectrum assigned to the primary users if underutilized, to be exploited by the unlicensed or secondary users opportunistically. This calls for cognitive capability by the unlicensed users. Software defined radios and cognitive capabilities provide a solution to
this problem. The terms *software-defined radio* and *cognitive radio* were introduced by Mitola 1992 and in 1998, respectively. Software defined radio is generally a multiband radio that supports multiple air interfaces and protocols and is reconfigurable through software run on digital signal processor or general-purpose microprocessors (Mitola 2000). Cognitive Radio (CR), built on a software radio platform, is a context-aware intelligent radio, potentially capable of autonomous reconfiguration by learning from and adapting to the communication environment (Mitola 1998). Cognitive radio represents a broader paradigm where many aspects of communication systems can be improved via cognition. Dynamic spectrum access in CR is an important aspect with three basic components, namely spectrum identification, spectrum exploitation and spectrum regulation. Spectrum identification involves sensing the licensed primary user frequencies/channels for busy or idle condition, spectrum exploitation involves efficient usage of idle frequencies/channels and spectrum regulation involves spectrum usage by secondary users maximizing their performance without degrading the performance of primary networks. The trade-off between the secondary users’ desire for performance and the primary users’ need for protection dictates effective interaction across opportunity identification, opportunity exploitation and regulatory policy. The optimal design of Opportunistic Spectrum Access (OSA) thus calls for a cross layer approach that integrates signal processing and networking with regulatory policy making (Akildiz et al 2006, Zhao et al 2007).

There are lots of works carried out in cross layer design for cognitive networks. The cross layer design challenges in spectrum management and spectrum handoff and challenges in higher layers are discussed by Akildiz et al (2006). Unlike the primary wireless networks, in cognitive network the spectrum sensing and spectrum management in the presence of sensing errors are challenging tasks. From the literature it is,
found that there are numerous research work done in spectrum sensing. Energy detection based spectrum sensing is the most commonly used method of spectrum detection as it simple and less complex. More over energy detection based sensing does not require the knowledge of primary activity (Akildiz et al 2006, Ganesan and Li 2005, McHenry et al 2007). Authors in literature (Shiang and Mihaela Van Der Schaar 2008) suggest a dynamic channel selection scheme based on the priority packet scheduling for multiuser CR networks and they do not concentrate on channel sensing.

A survey of challenges in spectrum sensing and the trade-offs involved are given in Ghasemi and Souza, (2008). There are numerous sensing algorithms proposed in the literature. Su and Zhang (2008) have proposed two sensing algorithms namely Negotiation based Sensing Policy (NSP) and Random Sensing Policy (RSP) which make use of cooperation among the secondary users in a distributed network. Specifically in NSP, secondary users sense the channels that are not sensed by other users by negotiating with each other and performance is optimized. In RSP, a kind of AND logic is used in making a decision about the primary channel activity which is a more conservative approach. In Jia et al (2008), HC-MAC (Hardware Constrained cognitive MAC) protocol that represents the sensing process as an optimal stopping problem in order to determine how long a cognitive radio should observe the wireless bands to optimize its expected throughput is discussed. Here channel bonding and aggregation techniques set the limit for the finite horizon problem. Fan and Jiang (2009), have proposed channel sensing order with optimal stopping rule which makes use of primary free probability.

In (Kushwaha et al 2008), authors propose a technique for distributed multimedia transmission over the secondary user network, which makes use of opportunistic spectrum access with the help of cognitive radios and use
digital fountain codes to distribute the multimedia content over unused spectrum and also to compensate for the loss incurred due to primary user interference. The authors make use of spectrum pooling technique to select a set of sub channels to establish a communication link for the secondary users’ multimedia transmission. The spectrum pooling concept along with the digital fountain coding technique help to reduce the interference and loss experienced by the secondary user due to the need for vacating the sub channel when primary user occupies the band. As the primary user traffic is modelled as Poisson process, when the arrival rate increases, the spectral efficiency and the performance is reduced. This reduction could have been overcome by the cross layer communication technique which enables the channel Signal to Noise Ratio (SNR) to be available for a particular sub channel. Based on this channel state information, spectrum pooling can be done effectively and higher modulation rates can be employed at the PHY layer to improve the performance. In literature (Yang 2008), the authors propose a proactive spectrum access approach where secondary users utilize past histories to make predictions on future spectrum availability, and intelligently schedule channel usage in advance. Two channel selection and switching techniques are proposed to minimize disruptions to primary users and maintain reliable communication at secondary users.

1.6.3 Cross Layer Design for Multimedia Applications in Cognitive Networks

In recent times, researchers have started to apply the cross layer design to support multimedia applications in cognitive networks. A Real time Distributed Multi Agent Learning algorithm is proposed by Qin and Cui (2009) for the video transmission in a multi hop cognitive network. This uses the cross layer communication among PHY, MAC, Network and Application
layers to achieve lower packet loss rate with decrease in time overheads in terms of the cost of information exchange.

Authors in (Hu et al 2010) propose a cross layer optimization approach for video multicast in a CR network. This work focuses on the fairness among the multiple users in infrastructure based CR networks with base stations having multiple transceivers that sense multiple channels simultaneously, while objective is to optimize the overall received video quality as well as achieving proportional fairness among multicast users, by keeping the interference to primary users below a prescribed threshold. Authors Aripin et al (2011) propose a cross layer design involving Application, MAC and PHY layer communications for the improved video transmission while minimizing the packet loss over a cognitive Ultra Wide Band network. Here the authors have considered the frame priority, queue status and SNR and sensing time as the parameters to be abstracted and hence chosen the source coding rate, packet scheduling and adaptive data rate as the parameters to be optimized at the Application layer, MAC layer and PHY layer respectively.

In (Yu et al 2011) a cross layer based approach to jointly optimize multimedia intra refreshing rate, an application layer parameter, together with access strategy and spectrum sensing for multimedia transmission in a CR network with time varying wireless channels is proposed. Primary network usage and channel gain are modelled as a finite state Markov process. With Partially Observable Markov Decision process applied for channel sensing and state information, the system showed that the proposed scheme outperforms the scheme with fixed intra refreshing rate. The performance is also close to the scheme with perfect knowledge of channel sensing and state information in terms of the average distortion caused.
The authors Chen et al (2011) have proposed a cross layer design approach to jointly consider optimal relay selection, power allocation, adaptive modulation and coding, as well as intra-refreshing rate to improve multimedia transmissions over underlay CR relay networks, while guarantee that the primary link is provided with a minimum-rate for a certain percentage of time. The objective is to minimize multimedia distortion, increase spectral efficiency as well as prolong network lifetime. From the literature, it is found that research on the support of multimedia applications in cognitive network using the cross layer design has just started. Further the literature on video streaming shows that there is not much work carried out for video transmission over cognitive networks using cross layer design. In this research work, an attempt is made to improve the performance of real-time video transmission in cognitive network using cross layer design.

1.7 RESEARCH OBJECTIVES

Literature survey has been carried out to understand the concept of cross layer design and the pros and cons of this scheme compared to the layered architecture. The quantum of research works available in the literature shows its significance in wireless networks with different applications. The proliferation of multimedia applications over wireless networks and the associated challenges are also reviewed. The cross layer design approach is seen as a promising technique to meet these challenges. Hence an attempt is made in this research work to apply the cross layer design approach in different wireless networks like Wireless LAN, Wireless Ad hoc networks and Cognitive networks to improve the QoS performance parameters such as throughput, average PSNR and the end to end delay for multimedia services. Towards meeting the above mentioned QoS goals, different cross layer strategies are proposed for different types of networks as listed below:
• A cross layer frame work providing Unequal Error Protection for video frames based on the information content of the video for transmission over a Wireless LAN network is designed to optimize QoS performance in terms of average PSNR and end to end delay.

• A cross layer strategy is proposed for an Ad hoc network using the power saving Sustainable Physical Activity in Neighbourhood (SPAN) protocol, wherein cross layer signalling is added between PHY and MAC layers of the protocol for rate adaptation, to achieve improved throughput and delay performances.

• A cross layer based multichannel MAC protocol is evolved for the Cognitive radio networking scenario, wherein, the channel sensing and the channel state information from the physical layer are used to adapt the transmission rate at the MAC layer, to improve the overall network throughput. The impact of the interference and the channel sensing algorithm on the network performance are also studied.

• Finally, a multi channel cognitive MAC protocol with optimal channel sensing scheme is proposed, to exploit the PHY layer channel state information and the Application layer source coding for video transmission over cognitive networks, to demonstrate the improvement in the QoS performance of video transmission.

1.8 THESIS ORGANIZATION

The research work carried out is organized and presented in six chapters in this thesis.
Chapter 1 presents the QoS requirements of multimedia applications. It introduces the cross layer design technique which is seen as a technique to meet the challenges of multimedia transmission over wireless networks. The literature review is presented on cross layer designs evolved by researchers for different networks and their limitation, based on which the research objectives are derived.

In Chapter 2, a brief introduction to digital video and implementation of video streaming in network simulator is presented. A cross layer framework providing Unequal Error Protection for video frames based on the information content of the video for transmission over a Wireless LAN network is presented with the performance results and discussion.

Chapter 3 describes the cross layer design based Rate Adaptive SPAN protocol developed for wireless ad hoc network and highlights its superior performance over the SPAN protocol.

Chapter 4 begins with a brief introduction to cognitive radio and the significance of sensing in CR networks. The effect of interference on sensing is analysed and a multichannel MAC protocol with two sensing algorithms is presented with their performance evaluation. A neural network based time prediction method is also presented to enhance the throughput of the network.

Chapter 5 presents the scope for cross layer design based CR network to support video streaming application. A cross layer design based OCSM-CMAC protocol is proposed and described and the performance is compared with single channel CMAC and RS-CMAC.

Chapter 6 concludes the thesis by presenting the significant inferences obtained and the future scope of the works presented.