

# **e-CRM & MULTIMEDIA APPLICATION PROCESSOR**

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in  
**Computer Science and Engg**



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## CERTIFICATE

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I hereby certify that the work which is being presented in the thesis entitled, “**e-CRM and Multimedia Application Processor**”, in partial fulfillment of the requirements for the award of degree of Master of Engineering in Computer Science and Engineering submitted in Computer Science and Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of Dr(Mrs.)RaviKiran (Associate Professor), Dr (Mrs) Seema Bawa (Head, CSE dept) and Mr.Aman Kumar,(Project Manager, ST Microelectronics) refers other researcher’s works which are duly listed in the reference section.

The matter presented in this thesis has not been submitted for the award of any other degree of this or any other university.

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This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.

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Successful accomplishment of any task is possible only with the cooperation of people at various levels. It is difficult to express thanks in words but a little and sincere effort is made here.

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SHINY SACHDEVA

## ABSTRACT

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The purpose of this thesis is to gain a better understanding of CRM presenting case studies of different companies which have followed CRM approach to retain better understanding of their customers and finally to present an overview of different features of a semiconductor company. CRM which is a combination of business process and technology, seeks to understand a company's customer from multifaceted perspective. Who are they? What do they do and what do they like? all of the questions are answered by CRM i.e customer relationship management, which has nowadays become critical for the survival of companies in the age of never satisfied customer. Customer satisfaction is always the most important factor in any business. To keep and develop a long-term relationship with customers, a vendor should not only provide a valuable product but also thoughtful service. Through customer relationship management (CRM), we can provide the right products and services at the right time with the right deliver channel to the right customers. A case study of a dot com company has been done which describes what are their CRM objectives, how they manage relationship with the customers and how they evaluate the implementation of CRM. e-CRM facilitates the organizations to provide one to one services and also maintain the transaction security of the customers.

e-CRM is a combination of IT sector but also the key strategy to electronic commerce. e-CRM is a combination of software, hardware, application and management commitment. Aim of e-CRM system is to improve customer service, develop a relationship and retain valuable customers. e-CRM is a concern for many organizations. The purpose of this thesis is to gain a better understanding of the benefits e-CRM to customers and organization in semiconductor industry.

The convergence of computing, multimedia and mobile communications is well underway. Already the familiar voice phone is being transformed into a personal device with a wide range of multimedia capabilities. Soon mobile users will be able to benefit from a broad spectrum of multimedia features and services, to include capturing, sending and receiving images, videos and music. To deliver such data-

heavy, processing-intensive services, portable handheld systems must be optimized for high performance but low power, space and cost.

In response to this need, the **Multimedia application processor** platform from STMicroelectronics is a culmination of breakthroughs in video coding efficiency, inventive algorithms and chip implementation schemes. It will enable smart phones, wireless PDAs, internet appliances and car entertainment systems to play back media content, record pictures and video clips, and perform bidirectional audio-visual communication with other systems in real time.

The STn8815 focuses on the essential features to meet the future needs of mobile products and services: a high-performance multimedia capability coupled with low power consumption, and based on an open platform strategy.

The new multimedia functionality of mobile products brings with it an increase in power consumption that is outpacing advances in battery technology. It should save on power by avoiding the need for high clock speeds wherever possible, but extremely low power consumption results from a systematic effort at all design levels to reduce power requirements.

The application processor should feature low power smart accelerators, which should handle all audio and video functions. These free the main CPU for control and program flow tasks, or allow the CPU to enter power-saving modes to prolong battery life. The smart accelerators operate independently and concurrently to ensure the lowest absolute system power and deterministic high-performance. (.JPG file extension, pronounced Jay Peg) is the right format for those photo images which must be very small files, for example, for web sites or for email. JPG is often used on digital camera memory cards, but RAW or TIFF format may be offered too, to avoid it. The JPG file is wonderfully small, often compressed to perhaps only 1/10 of the size of the original data, which is a good thing when modems are involved. However, this fantastic compression efficiency comes with a high price. JPG uses lossy compression (lossy meaning "with losses to quality"). Lossy means that some image quality is lost when the JPG data is compressed and saved, and this quality can never be recovered.

There are times and places this compromise is an advantage. Web pages and email files need to be very small, to be fast through the modem, and some uses may not need maximum quality. In some cases, we are willing to compromise quality for size, sacrificing for the better good. And this is the purpose of JPG. There is no magic answer providing both high compression and high quality. We don't get something for nothing, and the small size has a cost in quality. Still, mild quality losses may sometimes be acceptable for less critical purposes.

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## Chapter 1 Introduction

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### 1.1 Concept of CRM

CRM (customer relationship management) is an information industry term for methodologies, software, and usually Internet capabilities that help an enterprise manage customer relationships in an organized way. For example, an enterprise might build a database about its customers that described relationships in sufficient detail so that management, salespeople, people providing service, and perhaps the customer directly could access information, match customer needs with product plans and offerings, remind customers of service requirements, know what other products a customer had purchased, and so forth [8].

CRM consists of helping an enterprise to enable its marketing departments to identify and target their best customers, manage marketing campaigns with clear goals and objectives, and generate quality leads for the sales team. It assists the organization to improve telesales, accounts, and sales management by optimizing information shared by multiple employees, and streamlining existing processes (for example, taking orders using mobile devices).

It also allows the formation of individualized relationships with customers, with the aim of improving customer satisfaction and maximizing profits; identifying the most profitable customers and providing them the highest level of service. It also provides employees with the information and processes necessary to know their customers, understand their needs, and effectively build relationships between the company, its customer base, and distribution partners.

### 1.1.1 Need of CRM

CRM is the need of the hour as it helps in:

- Improving the process to communicate with the right customers
- Providing the right offer for each customer
- Providing the right offer through the right channel for each customer
- Providing the right offer at the right time for each customer

By doing this, organizations can receive the following benefits [9]:

- i.* Increased customer retention and loyalty: Ability to retain loyal and profitable customers to increase the organization's profitability.
- ii.* Higher customer profitability: Increasing individual customer margins while offering the right product at the right time.
- iii.* Creating value for the customer: Acquiring the right customers based on knowledge or learned characteristics, which drive growth and increased margins.
- iv.* Increased revenue: Focus the sales force on increasing organizational revenues through better information and better incentives to drive top line growth.
- v.* Improve global forecasts and pipeline management: Improve information access, forecasting and pipeline management to improve organization's ability to close deals.
- vi.* Improve win probability: Improve the focus of organizational sales efforts with better information to close deals.
- vii.* Reduce cost of sales: New technologies can lower the cost of deploying sales automation solutions and at the same time improve the effectiveness of organizational sales efforts.
- viii.* Increase sales representative productivity: Reduce the steps involved in tracking and quoting customer data with integration of sales capabilities across the organization.
- ix.* Promote sales representative retention: Empower organizational sales force to proactively track and monitor their performance and compensation levels to better motivate them to achieve goals and be successful within their positions and for the organization.

### 1.1.2 Three phases of CRM

**ACQUIRING:** A company acquires new customers by promoting their product and service leadership. Companies demonstrate how they redefine the industry's performance boundaries with respect to convenience and innovation. The value proposition to the customer is the offer of a superior product backed by excellent service.

**ENHANCING:** Company enhances the relationship by encouraging excellence in cross selling and up selling there by deepening and broadening the relationship. The value proposition to the customer is an offer of greater convenience at low cost.

**RETAINING:** Retention focuses on service adaptability delivering not what the market wants, but what customers wants. The value proposition to the customer is an offer of a proactive relationship that works in his or her best interest. Nowadays leading companies focus on retention much more than on attracting new customers. The reasoning behind this strategy is simple- if you want to make money, hold on to your good customers

### 1.1.3 CRM objectives

CRM objectives can be divided into four categories as described below [10]:

A. Customer knowledge:

- i.* Collecting appropriate customer information
- ii.* Analyzing customer data
- iii.* Acquiring new customers
- iv.* Improving skills of employees
- v.* Improving CRM techniques
- vi.* Secure service

B. Customer interaction:

- i.* Appropriate response to customer's request

- ii.* Integration of business processes
- iii.* Improving channels management
- iv.* Maximizing the effectiveness and efficiency of organization operations
- v.* Customizing products and services

C. Customer value:

- i.* Improving customer retention
- ii.* Increase in Profits
- iii.* Improving customer service and support
- iv.* Building an attractive virtual community

D. Customer satisfaction:

- i.* Improving service quality
- ii.* Establishing relationships with customers

#### **1.1.4 Concept of e-CRM**

e-CRM is combination of software, hardware, application and management commitment. e-CRM can be of different types like Operational, Analytical. Operational e-CRM focuses on customer's touch points, to have contacts with customers through telephones or letters or e-mails. Thus customer touch points are web based e-mails, telephone, direct sales, fax etc. Analytical CRM is a collection of data and is viewed as a continuous process. It requires technology to process customers' data to identify and understand customers' demographic pattern of purchasing etc in order to create new business opportunities by giving importance to customers [11].

Relying on the objectives of the organizations e-CRM is about arranging in a line business process with strategies of customers provided back up of software. e-CRM is about people, process and technology and these are key paramount to success. Traditional definition of e-CRM is to include attitude for entire business. Like identifying and defining the prime goal to everyone in the organization and creating a sustainable competitive advantage. These studies explore how e-CRM enhances the

traditional definition of marketing concepts, enabling the organizations to meet their internal marketing objectives.

The aim of e-CRM systems is to improve customer service, develop a relationship and retain valuable customers. Furthermore added advantage would be that it enhances delineation in customer's value. It means to motivate valuable customers to remain loyal with the enhanced features of e-CRM, where e makes the huge difference.

## **1.2 Why e-CRM?**

The Internet presents e-Business with revenue opportunities and customer service challenges. The Web opens the world to the smallest enterprises, leveling the competitive playing field but also raising customer expectations. With time and geographic boundaries eliminated, customers expect superior, consistent, 24x7 service. Diminished customer loyalty is a natural by-product of today's Web-enabled economy, which means companies, can no longer afford to operate segregated islands of customer data across the enterprise. Indeed, it is a competitive requirement that successful e-Business raises customer service to a strategic level. Business men must deploy consistent and synchronized electronic customer relationship management (e-CRM) systems that support all customer communication channels (phone, e-mail, Web) through linkages with all front- and back-office applications and business functions across the entire enterprise. Today e-Business that refuses to heed the message that the e-Customer is more powerful and elusive than ever will be out of business tomorrow.

The Internet has not only changed the way people shop, communicate, and live, but it has also changed the way companies do business. Since the Web removes geographic and time-zone barriers, the smallest online merchant becomes a global enterprise and must be able to compete effectively with larger, more established corporations. The Internet has even altered perennial notions about customers. Customers still reign supreme, perhaps even more than before, given their new electronic powers but companies that venture into e-Commerce soon discover a new adage as well: "The customer is just a click away". The Web's popularity and ease of use enables

customers to demand, and obtain, 24x7 service and support. If they don't get just that, with a simple click of the mouse they're off to someone else's site to compare offerings. In fact, as consumers increasingly use the Web to shop and to conduct other business, they expect consistent, superior service at every point of contact. "Online consumers are demanding," say's market researchers. "Web buyers expect deep product information, real-time order confirmation and status, and around-the-clock customer service." Customers simply expect e-Businesses to provide more functionality—order tracking, streamlined order processing, and self-help capabilities—no matter how they interact with a company. And they expect that service now, in Internet time. The service must also be consistently excellent across the enterprise.

### **1.2.1 CRM becomes e-CRM**

Customer relationship management (CRM) has gone through a metamorphosis over time. A growing number of vendors of CRM software can incorporate a broad range of functionality, from low-end contact management to comprehensive suites that govern an organization's front-office marketing, sales, and customer support operations. As customers increasingly contact companies via e-mail and the Web, the companies have responded by extending their eCRM software offerings to incorporate more customer management capabilities. Organizations can provide their customers with uniform service and support quickly and easily, no matter what the customer contact method. That means complete and relevant information can be made available, in real time, across the enterprise. Essentially, e-CRM software today involves all front-end, back-office, and third-party processes that "touch" customers—from the contact center that handles customer orders, to the customer's bank for credit card authorization, to the inventory system to check for product availability, and the warehouse for fulfillment and delivery. The benefits of integrated e-CRM systems are well documented. The better and more comprehensive the data that companies can compile about their customers through automated customer management processes, the more effectively their global sales and customer support forces can collaborate and share data in real time, manage that data throughout an enterprise, and access it at any time. By tightly integrating CRM systems with the

Web and back-end ERP packages, organizations can reduce operational costs, increase sales, and enhance customer service. No longer are the front-office add-ons to ERP applications essential, but e-CRM solutions that integrate an e-Business and entire customer service infrastructure have become strategic necessities. Experts point out that the companies implement ERP solutions to cut costs and automate internal business processes. They deploy e-CRM systems to reduce costs and increase sales.

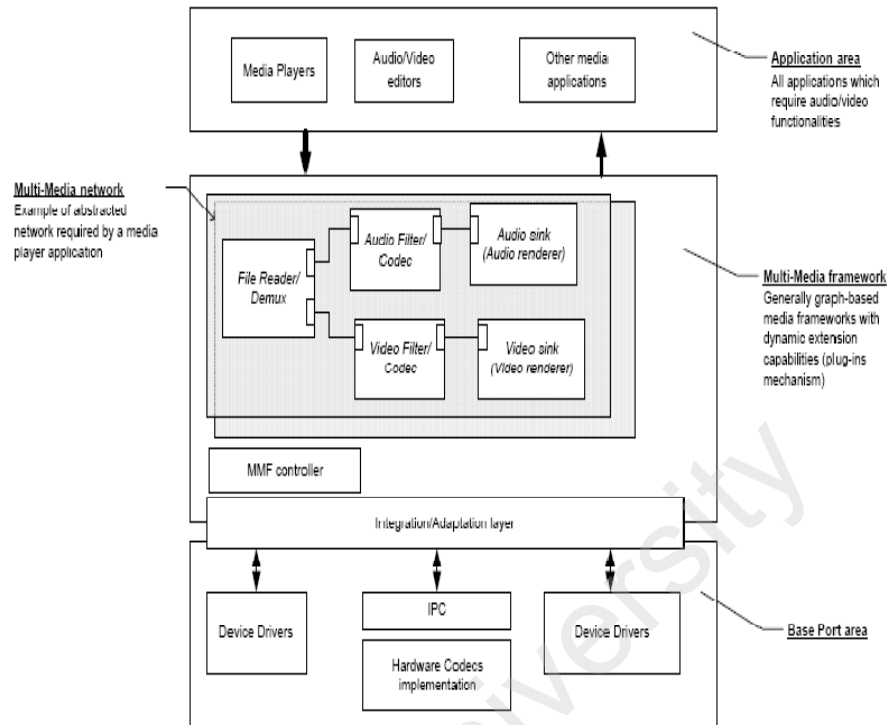
### **1.2.2 e-CRM – Competitive Necessity**

Customer service is critical for e-Business in today's Internet world. Businessmen not able to support their customers via all customer touch points may even find themselves subject to federal sanctions for failure to provide on-time delivery of products ordered online. Disgruntled online shoppers are already taking their frustrations out in class-action lawsuits. Yet sanctions may not be an e-Business's worst nightmare. Losing existing and potential customers' business to online competitors could represent even greater problems in terms of lost revenues and become an even more tangible threat. E-Business face a host of hurdles in synchronizing their customer support solutions to the Web and other customer delivery channels. However, providing excellent, consistent customer service across multiple customer touch points in an e-Business world is no longer a luxury—it is a competitive necessity.

## **1.3 Multimedia application framework**

### **1.3.1 Multimedia framework definition**

A multimedia framework [19] is a software structure (usually a set of software libraries) that handles media on a computer and through a network. A good multimedia framework must offer an intuitive API and a modular architecture to easily add support for new codec or container formats. It is meant to be used by applications such as media players and audio or video editors. Figure 1-1 depicts a high-level architecture view to indicate how a multimedia framework is integrated in a rich OS.



**Figure 1.1- Multimedia Framework [19]**

A multimedia application is abstracted from the underlying hardware via the proposed multimedia framework. Sink/source pads or other filter/codec components abstract I/O devices and transforms through the adaptation layer and derived drivers. The different frameworks search to reach the following characteristics:

- defines an architectural framework for multimedia applications (Audio/Video & Imaging)
- abstracts multimedia content handling (file type, streaming,)
- hides device complexities
- provides easy interface to audio/video playback/recording and control
- provides building blocks and advanced features for application like games, media players
- enables development of new media extensions as plug-ins
- allows dynamic, automatic media type detection

In some systems, a user-level media framework already exists. Figure 1.2 provides a brief list of the different native framework available for different operating systems.

OS	Multi-Media Framework
Linux	FFmpeg, GStreamer, Helix DNA, Media Application Server (MAS), Network-Integrated Multimedia Middleware (NMM), SDL,...
Microsoft Windows	Audio Compression Manager (ACM), DirectShow, DirectX Media Objects (DMOs), Media Foundation (Windows Vista only), Quicktime, Video for Windows (VfW) (also sometimes referred to as Video Compression Manager (VCM), Windows Media,...
Apple Mac OS	QuickTime
Symbian OS	MMF

**Figure 1. 2 – MMF and OS [19]**

ST-based solutions are designed to target the mobile phones and mobile consumer devices. The SW offering covers in priority the following OS MM frameworks:

- MMF (Symbian OS)
- DirectShow (Windows Mobile)
- GStreamer (embedded Linux)

The variability and the level of maturity of these diverse native frameworks mean that there is different level of abstraction, flexibility and design constraints. A client (user/media application) can have a constrained or a fully opened environment to build a multimedia solution. Consequently, the SW designer/integrator can have more or less facility to integrate a new feature and to take accounts in the same time an advanced distributed multimedia HW and SW architectures.

In particular, each framework provides different integration scheme to abstract the underlying hardware/system. OpenMAX Integration Layer initiative tries to resolve this last issue. It serves as a low-level interface for audio, video and imaging components used in embedded and/or mobile devices.

### **1.3.2 Application processor multimedia resources**

Application processor -based solutions are designed to target the mobile phones and mobile consumer devices. The Application processor SoC family is based on a multicore approach with dedicated and programmable HW blocks (Smart Media Accelerator). It provides an efficient and consistent HW/SW partitioning to achieve high performances for the complex multimedia use-cases and to minimize the global power consumption. The main goal is to maximize the ratio “computing performance” on “energy”. A general purpose CPU (host CPU) provides the required functionalities to support a rich OS like Symbian, Linux or Windows Mobile. The accelerators (SxA) supply a HW or/and SW support to speed up processing of some specialized media functions.

All HW resources are accessible and fully controlled by the host CPU .The IO peripherals can be also mapped in the main controller space but only a limited number of interrupt and local DMA request lines are routed to/from the main cores. DMA system is only programmable by the host CPU but each SxA subsystem controls the dedicated system DMA request lines.

### **1.3.3 Application Processor Memory Model**

The memory model for Multimedia Application Processor has the following properties:

- Not Cache Coherency – Non-Uniform Memory Access
- Non-uniform virtual memory space & non global memory protection
- Unified sub-system architecture

### **1.3.4 Application Processor Multimedia Framework Architecture**

This section describes the top level architecture of the proposal Application Processor Multimedia Framework. The main purpose is to provide a flexible way to use efficiently the multimedia resources (SxAs and related HW resources) and to export a logical view of the Processor’s multimedia functionalities for the multimedia clients

This architecture provides a low-level multimedia framework to:

- hide the complexity/specificity of the underlying hardware.
- exploit the multiprocessing environment in a transparent way.
- take advantage of platform specific features.
- provide a minimum level of abstraction for multimedia application servers above it.

## 1.4 Introduction to ST application processor

**ST Application Processor** family of **multimedia application processor** chips enable portable terminals to play music, take pictures, record video and host two-way visual communications in real time. They are aimed a 2.5G/3G mobile phones, personal digital assistants and other portable wireless products with multimedia capability. In addition they are suitable for automotive multimedia applications [18].

**ST Application Processor** is designed specifically with mobile devices in mind, offering **ultra low power consumption, unsurpassed audio and video quality** at given bit rates, simplified software development and scalability for diverse and future multimedia applications.

### 1.4.1 Brief Overview

ST application processor architecture is based on the distributed processing of audio, video and imaging, advanced security features, pervasive low-power techniques for increased autonomy, and optimized memory architecture for the best cost/performance ratio. The ST application processor combines an ARM9 core up to 393 MHz with level-two cache to audio, video, imaging and graphics accelerators, allowing both low-power multimedia performance and powerful general-purpose software processing and OS support.

The ST application processor smart imaging accelerator (SIA) delivers impressive multimedia quality without sacrificing battery life. It operates as a real-time, programmable image reconstruction engine at up to 80-Mpixel/s. This capability enables camera-phone systems, based on 5-Mpixel sensors, to execute noise reduction, auto-focus and exposure control, and other fundamental algorithms, therefore eliminating the need for an external imaging co-processor, and reducing the system BOM (bill-of-materials). The SIA, coupled with the smart video accelerator (SVA), which is capable of 30-Mpixel/s JPEG-image encoding, allows impressive multi-shot camera performance, as well as low-power video encoding.

The ST application processor integrates two SMIA (standard mobile imaging architecture), CCP2 (compact camera port 2) camera interfaces, and supports 10-bit raw Bayer RGB data formats. The Nomadik platform gives customers the ease to differentiate products, an openness to industry standards (such as OMA and MIPI), and STMicroelectronics' expertise in open OS complex platform integration. Nomadik is reinforced by a full system offering with multiple connectivity, camera, energy management, TV out, and companion devices [19].

ST application processor -based development kits (NDK-15, NHK-15) offer a complete, flexible design environment, including a rich set of peripherals such as cameras, audio codecs, wired and wireless connectivity, LCD displays, among others. A complete set of development tools is available from ST or tools partners (ARM Ltd, Lauterbach) to support a full range of application development, from firmware customization up to OS-level applications.

## Chapter 2 : Literature review

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Review of literature is very important as it helps in placing the study in proper perspective, learn from the mistakes of the predecessors and avoid the duplication of work.

For Review of Literature the following pattern is used:

2.1 Review of Studies done on CRM

2.2 A case study I of CRM

2.3 A case study II of CRM

The analysis of the case helps in understanding the importance of CRM and sets the stage for the implementation of CRM strategies by developing a multimedia tool to assist the mobile companies to be market leaders in Implementing CRM strategies.

### 2.1 Review of Studies done on CRM

According to Yen, Young and Cheng-Yuan Ku (2002) Customer relationship management (CRM) is a fast growing category of application software. CRM is gaining interest because of its focus on the customer and thus its potential for increasing revenue. It enhances the ability of a firm to compete and to retain key customers. Furthermore, given the rapid growth of e-business applications and the increasing need to sell to and support customers through the web, CRM provides a focal point for all customer-facing activities. This review of CRM product capabilities and key CRM vendors identifies three distinct categories of CRM vendors and finds that they are attempting to offer a rich or full set of CRM features and are rapidly integrating web access into their products. The study proposes a model to aid in the selection of CRM products and the evaluation of CRM vendors.

The study by Kapanen (2004) highlights that organizations are realizing that customer-centric operations are no longer an optional differentiator, but are essential

to sustainable, profitable growth. Customer relationship management, or CRM, is a framework for developing both the business processes and the supporting infrastructure to improve service delivery. CRM solutions focus on automating and improving business processes in front-office areas such as marketing, sales, customer service and support. CRM software and hardware is only part of the solution, as the people, processes, management and reward systems must be included to successfully implement a CRM solution. CRM aims to improve organizational effectiveness by establishing the following: a single, dynamic, clear understanding of the customer, from the company's perspective, across different departments of an organization; a single, dynamic, clear understanding of the company, from the customer's perspective, regardless of communication channel utilized (personal meeting, telephone, internet); and improved communication, coordination and efficiency across marketing, sales, service and support departments, within an organization. The intended results are improving customer satisfaction, loyalty, and retention. These results lead to improved profitability from both increased revenues and reduced costs. This paper focuses upon CRM improving service delivery, and not enterprise resource planning (ERP). ERP applications have helped companies to automate and optimize business processes in areas such as finance, manufacturing, inventory management and human resources. ERP is different, but supportive, of CRM.

Michaelides, Kehoe and Tickle (2007) introduced a methodology for developing an e-CRM system that assists an aerospace manufacturing company to overcome the challenges of an e-CRM deployment. The underlying principles of CRM are well established – those manufacturers that can effectively attract and retain the customers will see significant benefits on their profitability. Kalakota and Robinson (2001) stated that on average, companies lose half of their customer base every five years and that the cost of obtaining a new customer is five to ten times more than maintaining an existing one. Therefore, it is of strategic importance for a company to track customers' needs, behaviors, and lifestyles and use this information to create a specific value-proposition. The emergence of e-business and the global internet 'new economy', present opportunities and challenges for manufacturers to build strong customer relationships. The research study presented here demonstrates that adopting a structured methodology when implementing an e-CRM solution enhances the benefits of such a system. More explicitly, the companies involved achieved a customer

transaction transparency, thus reducing instances of unresolved client transactions, eliminating duplication of effort and providing ease of access to clients and suppliers alike. The research methodology adopted was case study-based.

Although communication has been investigated within relationship-oriented contexts, studies concerning communication within Customer Relationship Management (CRM) are scarce, especially when customer relationships are managed with the aid of the mobile medium. The purpose of this study is to increase general understanding of communication within the mobile context, in which the communicating parties are connected through the mobile medium. The authors present a model of the communication process within the mobile context based on a case study. The main results of the study indicate that the communication process within the mobile context differs significantly from the process through traditional channels. ( Sinisalo, Jaakko and Karjaluoto , Heikki, 2007)

Greve, Robert A et al (2005) study the impact of routing strategies and prioritization of incoming e-mail messages on CRM objectives of an organization. Customer contact centre's represent a growing industry in which Customer Relationship Management (CRM) applications have been developed and used successfully. Customer call centers, a multi-billion dollar industry, are evolving into customer contact centers, which now include channels of communication other than the telephone. E-mail, a popular alternative to the telephone for all types of communication, is becoming a common medium for customer contact. CRM applications currently exist that allow us to implement and monitor e-mail management strategies. For example, incoming e-mail can be automatically routed to specific customer service agents according to predefined routing rules. The routing mechanisms available in the software tools are heuristic, and not based upon any scientific analysis of the performance of different routing policy alternatives. The objective of this paper is to create a model representative of and consistent with e-mail response centers in industry. The process modeled was corroborated by a domain expert. A comprehensive simulation study is conducted to analyze different routing policies and prioritization options. The results of the simulation study indicate that specific routing strategies and the use of specific priority schemes by the e-mail agent can result in a significant improvement in the response centre's performance, as

indicated by average response times and average resolution times of different categories of e-mail messages. Although call centre operations have been studied extensively, this study shows that performance of contact centers needs further investigation because of the greater flexibility that exists in the assignment and scheduling of e-mail processing tasks.

All these studies highlight the importance of CRM in the digitalized world we are living in today and the importance of CRM for organizations to acquire enhance and retain the customers

## **2.2 Case study 1- CDUNIVERSE.COM**

### **Company presentation**

Established in 1996, CD Universe is a leading Internet retailer specializing in the sale of domestic and imported music CDs and Imports, movies and video games to customers all over the world. It offers everyday low prices and a selection of product that is unmatched. CD Universe has been honored for their exemplary customer service and satisfaction year after year receiving awards such as the Bizrate Circle of Excellence in addition to top customer ratings on Yahoo Shopping, Shopping.com, Shopzilla.com and many more [9].

### **2.2.1 CRM objectives of CDUNIVERSE.COM**

CDUNIVERSE.COM has three main objectives for their customer relationships; however, they are not broken down into any specific detailed CRM objectives. CRM is an important part of the organizations marketing and communication “thinking”. The objectives are ease of use, speed, and low price. When it comes to ease of use, the respondents view technology to be very important. It is important to have the right capacity to be able to deal with a lot of customers at the same time. This is something that will become even more important in the future when most music will be downloaded from the Web site instead of being delivered to the customers by mail. The Web site should be fast to download and navigate as well as simple when it

comes to the buying process and Web site environment. Low price is also important to attract and acquire new customers and the customers should always be aware of that CDUNIVERSE.COM offers very low prices compared to many of their competitors.

The three objectives mentioned above are the ones that are officially stated. However, the other issues are of importance when it comes to the organizations' customer relationships. To build and maintain relationships is very important to make the customers loyal to CDUNIVERSE.COM. It is obvious that it is good to keep the customers and prevent them from leaving CDUNIVERSE.COM and instead purchase the products from one of their competitors. It is also more cost effective to retain the existing customers instead of having to find new ones all the time.

To improve the organizations knowledge about their customers is also important. By improving this knowledge CDUNIVERSE.COM can offer their customers products that are more in line with the customers needs. This also makes the marketing efforts more effective since the organizations will know what the customer wants and is searching for. By knowing what the customers want and will request also improve the organizations own logistics. This makes the stocks smaller and the stock holding becomes more effective. CDUNIVERSE.COM has stated that the products should be delivered to the customers within one week.

Since the potential target market for CDUNIVERSE.COM products are very large, segmentation becomes important. Therefore, it is important to segment the customer into groups and learn how each group of customers want to interact with CDUNIVERSE.COM when it comes to issues such as channel management and product preferences. The issue of secure payment is not of very high priority to CDUNIVERSE.COM. The reason for this is that only ten percent of their customers pay with a credit card and the remaining ones pay by cash on delivery. However, the issue of privacy is somewhat important. Therefore, CDUNIVERSE.COM will keep the collected customer information secret and not exaggerate the flow of information to the customers [9].

### **2.2.2 Management of customer relationships by CDUNIVERSE.COM**

CRM is important as with this the organization tries to break down the information flow from their customers to make it as cost effective as possible. Since CDUNIVERSE.COM is quite a small organization, the top management is involved every time CDUNIVERSE.COM is implementing new CRM objectives. Sometimes the customer service or other employees affected by the implemented CRM are also involved. However, even though the decisions come from top management CDUNIVERSE.COM tries to have a keen ear of their employees' opinions according to the new implementation. The employees that come into contact with the new-implemented CRM are also educated even though CDUNIVERSE.COM aims to keep it as simple as possible.

CDUNIVERSE.COM always has a long-term view for their implementation of CRM, both externally and internally to get the best possible return on investment. CDUNIVERSE.COM says it is hard to keep it alive, due to the fact that in the beginning it is of importance but as time goes by, it has a tendency to become less important. CDUNIVERSE.COM views CRM as a natural business connection by having both back office and front office integrated when they implement CRM. This is done so that the implemented CRM would be as cost effective as possible. CDUNIVERSE.COM aims to keep full control of the interaction with their customers since they are an organization that conducts business at distance and need to react fast to their customers' demands, therefore CDUNIVERSE.COM conducts all CRM by themselves within the organization.

CDUNIVERSE.COM conducts new campaigns by their media department. The media department chooses the customers that should be targeted and also decide which media forum they are going to utilize for promoting the new offers. CDUNIVERSE.COM sends the mail catalogue to their customers every month, except to those that have made the choice not to receive a catalog. The fact that CDUNIVERSE.COM sends their news e-mail to their customers is the Strategy used by CDUNIVERSE.COM to make their existing customers buy more. At the moment CDUNIVERSE.COM doesn't give its customers offers according to what they have purchased before, but this is something that CDUNIVERSE.COM plans to do.

Though it hasn't yet found the software that can combine those offers in a satisfying way. CDUNIVERSE.COM only sells the same products wherever the customers buy it but it doesn't have any up-selling.

To be able to understand why CDUNIVERSE.COM customers sometimes abandon CDUNIVERSE.COM for one of their competitors is something that could be investigated more even though it is of importance that CDUNIVERSE.COM tries to keep their customer by selling products at low price as well as always having the products in stock. CDUNIVERSE.COM only sells low-margin products they cannot do too much and have too many offers if they are going to keep the business being cost effective. However, CDUNIVERSE.COM controls its customers' behavior by investigating how the customers purchase and how the customers navigate on CDUNIVERSE.COM Web site. All this are done so that CDUNIVERSE.COM are able to predict what the customers would like to purchase but much is done with the help of experience of the industry rather than by using the latest techniques.

The customers in CDUNIVERSE.COM are divided into different purchase intervals on the basis of their profitability to the organization. This information is collected from statistics that CDUNIVERSE.COM gets from the customers like past purchase history. Those customers that end up into a specific interval are given special offers by CDUNIVERSE.COM in order to induce them to purchase more products and to get either a better discount or a cheaper delivery agreement. However, CDUNIVERSE.COM does not deny anyone to buy from them, even though the customer might not be as profitable for CDUNIVERSE.COM. CDUNIVERSE.COM has investigated the possibility of introducing a loyalty program for their customers. However, CDUNIVERSE.COM cannot implement it with current margins on the products they sell. CDUNIVERSE.COM does not want to divide their customers for this purpose and this is the reason why CDUNIVERSE.COM does not give its customers any offers on the basis of loyalty programs. Wherever the customers may chose to buy them, CDUNIVERSE.COM tries to compete by offering low prices and short delivery time [9].

Now the personalization features at CDUNIVERSE.COM are under construction. Today the customer can receive tailor made news e-mail. CDUNIVERSE.COM views

Web chat, Web callback, and telephone as communication channels to interact with their customers. Today CDUNIVERSE.COM views e-mails that are sent to approximately 130 000 customer each week and their mail-catalogues that are sent to approximate 250 000 customers every month as the two important communication channels. However, CDUNIVERSE.COM chose to utilize the communication channels that customers demand, so if the customer wants to interact through Web chat or Web callback this is something that CDUNIVERSE.COM will do in order to please the organization's customers. If a customer has sent an e-mail and then later on calls the customer services, this e-mail will be visible for the customer service employee, so that the customer need not repeat the same question or questions again. This is the reason why CDUNIVERSE.COM views telephone as an important communication channel that they need to have, even though it is not cost efficient.

Event marketing is also considered very important for CDUNIVERSE.COM. The events that CDUNIVERSE.COM are associated with are for festivals like Rock Festival. These events must have a natural connection to CDUNIVERSE.COM line of business. When these events are approaching, tickets, VIP packets, and backstage pass are raffled out on the Web site to customers that CDUNIVERSE.COM believe are interested in such specific events. The information CDUNIVERSE.COM utilizes for this selection comes from the customers past purchases.

Since the potential target market for CDUNIVERSE.COM products is very large, segmentation becomes important. Therefore, it is important to segment the customers into groups and learn how each consumer group wants to interact with CDUNIVERSE.COM, especially when it comes to issues channel management and product preferences. The issue of secure payment is not given high priority at CDUNIVERSE.COM. The reason for this is that only ten percent of their customers pay with a credit card and the remaining pay by cash on delivery. Therefore, CDUNIVERSE.COM keeps on collecting the customer information secretly and doesn't exaggerate the flow of information to the customers.

## 2.3 Case Study II: ST Microelectronics

### A Brief Overview of STMicroelectronics

STMicroelectronics is a global independent semiconductor company and is a leader in developing and delivering semiconductor solutions across the spectrum of microelectronics applications. An unrivaled combination of silicon and system expertise, manufacturing strength, Intellectual Property (IP) portfolio and strategic partners positions the Company at the forefront of System-on-Chip (SoC) technology and its products play a key role in enabling today's convergence trends. According to preliminary rankings for 2002 from market analysts, ST was placed among the top five semiconductor manufacturers worldwide for the second year running. Gartner Dataquest ranked ST as the fourth largest semiconductor company in the world and IC Insights and Supply ranked the Company fourth and third, respectively.

According to the most recent data from independent sources, ST is also the world's leading supplier of analog ICs and MPEG-2 decoder ICs, and is ranked number two for non-volatile memories overall and at number four for Flash memory. In application segments ST is number one for ICs for set-top boxes and hard disk drives; at number two for smart cards and DVDs; at number three for automotive ICs; and finally, at number four for telecom ICs. The Company's products are manufactured and designed using a broad range of fabrication processes and proprietary design methods. To complement this depth and diversity of process and design technology, the Company also possesses a broad intellectual property portfolio that it has used to enter into cross-licensing agreements with many other leading semiconductor manufacturers.

ST has developed a worldwide network of strategic alliances, including product development with key customers, technology development with customers and other semiconductor manufacturers, and equipment and CAD development alliances with major suppliers. By augmenting its rich portfolio of proprietary technologies and core competencies with complementary expertise from a variety of carefully chosen strategic partners, ST has developed an unsurpassed capability to offer leading edge solutions to customers in all segments of the electronics industry [20].

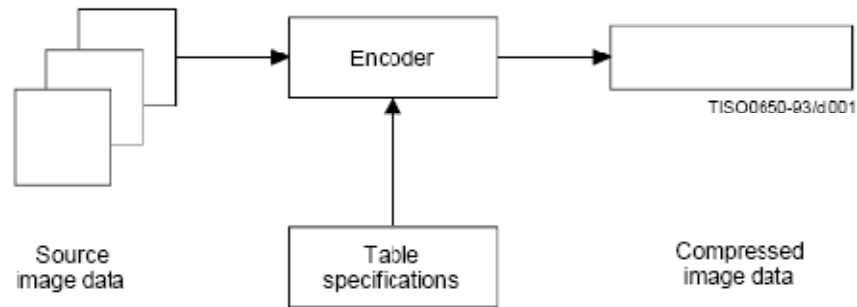
The Company currently offers over 3,000 main types of products to more than 1,500 customers, including Alcatel, Bosch, DaimlerChrysler, Ford, Hewlett-Packard, IBM, Motorola, Nokia, Nortel Networks, Philips, Seagate Technology, Siemens, Sony, Thomson and Western Digital. In 2002, approximately 69% of ST's revenue derived from differentiated products, A combination of dedicated, semi-custom and programmable products designed to suit a specific customer or a specific application and therefore having high system content. This result reflects ST's exceptionally early recognition of the importance of system-on-chip technology, which is the key for addressing the fast growing market for convergence products, and the success of the strategies it developed to ensure its leading position in this key emerging field.

The ST group was formed in June 1987 as a result of the merger between SGS Microelettronica of Italy and Thomson Semiconductors of France. In May 1998, the company changed its name from SGS-THOMSON Microelectronics to STMicroelectronics [20].

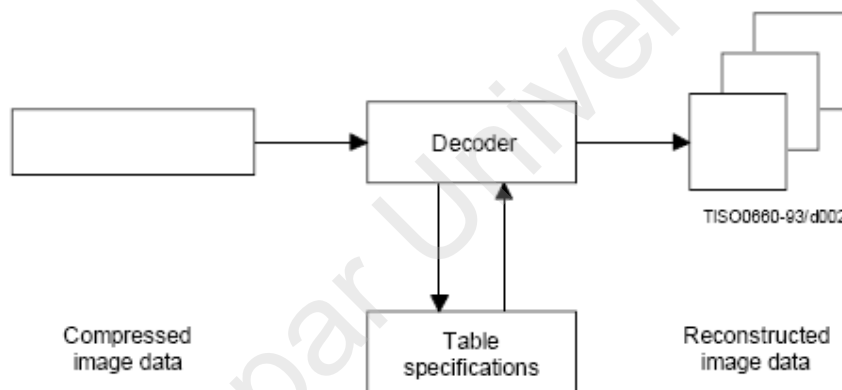
### 2.3.1 Jpeg encoding and decoding

There are three elements mainly used in JPEG encoding and decoding:

- a) An *encoder* is an embodiment of an *encoding process*. As shown in Figure 2.2, an encoder takes as input *digital source image data* and *table specifications*, and by means of a specified set of *procedures* generates as output *compressed image data*.
- b) A *decoder* is an embodiment of a *decoding process*. As shown in Figure 2.2, a decoder takes as input *compressed image data* and *table specifications*, and by means of a specified set of *procedures* generates as output *digital reconstructed image data*.
- c) The interchange format, shown in Figure 2.3, is a compressed image data representation which includes all table specifications used in the encoding process. The interchange format is for exchange between *application environments*.

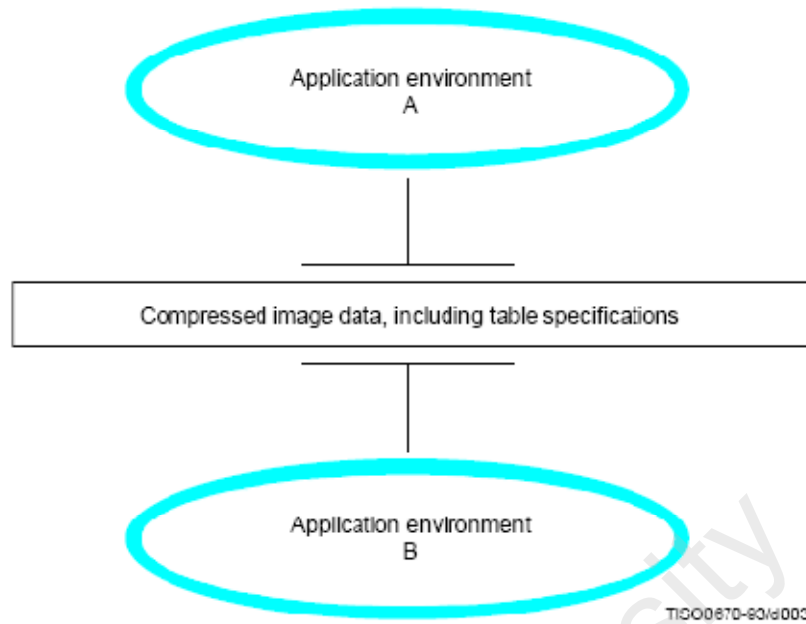


**Figure 2.1. Encoder [3]**



**Figure 2.2: Decoder [3]**

Figures 2.2 and 2.2 illustrate the general case for which the *continuous-tone* source and reconstructed image data consist of multiple *components*. (A *colour* image consists of multiple components; a *grayscale* image consists only of a single component.) A significant portion of this Specification is concerned with how to handle multiple-component images in a flexible, application-independent way.



**Figure 2.3: Interchange Format for Compressed Image data [3]**

These figures are also meant to show that the same tables specified for an encoder to use to compress a particular image must be provided to a decoder to reconstruct that image.

The interchange format shown in Figure 2.3, in which table specifications are included within compressed image data. An image compressed with a specified encoding process within one application environment, A, is passed to a different environment, B, by means of the interchange format. The interchange format does not specify a complete coded image representation.

### 2.3.2 Lossy and lossless compression

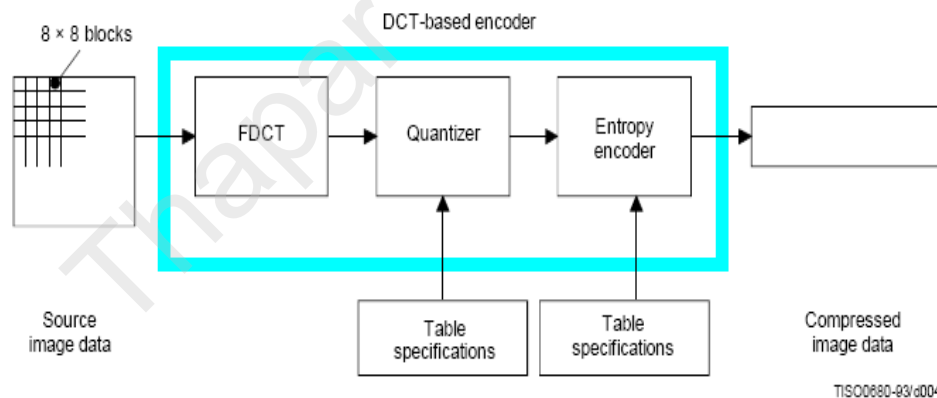
There are two classes of encoding and decoding processes, lossy and lossless processes. Those based on the discrete cosine transform (DCT) are lossy, thereby allowing substantial compression to be achieved while producing a reconstructed image with high visual fidelity to the encoder's source image. The simplest DCT-based coding process is referred to as the baseline sequential process. It provides a capability, which is sufficient for many applications. There are additional DCT-based processes, which extend the baseline sequential process to a broader range of

applications. In any decoder using extended DCT-based decoding processes, the baseline decoding process is required to be present in order to provide a default decoding capability. The second class of coding processes is not based upon the DCT and is provided to meet the needs of applications requiring lossless compression. These lossless encoding and decoding processes are used independently of any of the DCT-based processes.

The amount of compression provided by any of the various processes is dependent on the characteristics of the particular image being compressed, as well as on the picture quality desired by the application and the desired speed of compression and decompression.

### 2.3.3 DCT-based coding

Figure 2.4 shows the main procedures for all encoding processes based on the DCT. It illustrates the special case of a single component image.



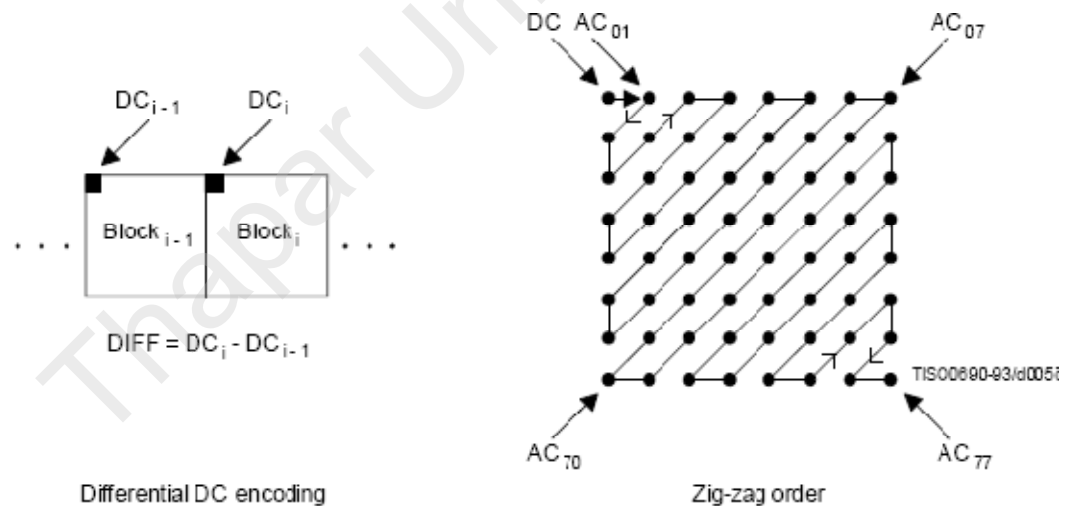
**Figure 2.4: DCT based encoder [3]**

In the encoding process the input component's *samples* are grouped into  $8 \times 8$  *blocks*, and each block is transformed by the *forward DCT* (FDCT) into a set of 64 values referred to as *DCT coefficients*. One of these values is referred to as the *DC coefficient* and the other 63 as the *AC coefficients*. Each of the 64 coefficients is then *quantized* using one of 64 corresponding values from a *quantization table*. Applications may

specify values which customize picture quality for their particular image characteristics, display devices, and viewing conditions.

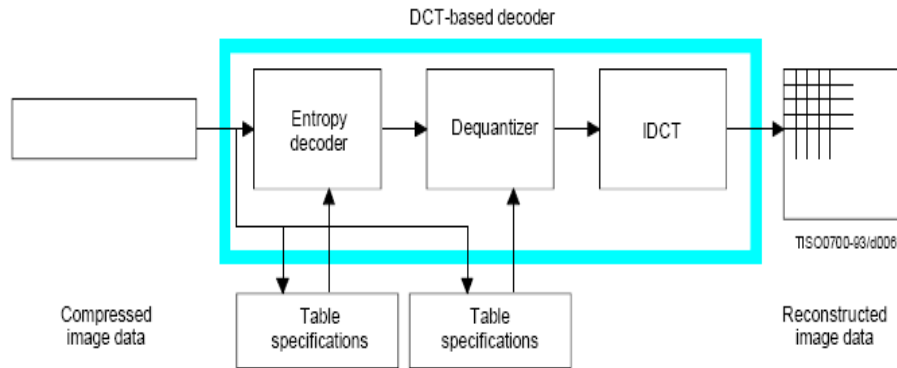
After quantization, the DC coefficient and the 63 AC coefficients are prepared for *entropy encoding*, as shown in Figure 2.5. The previous quantized DC coefficient is used to predict the current quantized DC coefficient, and the difference is encoded. The 63 quantized AC coefficients undergo no such differential encoding, but are converted into a one dimensional *zig-zag sequence*, as shown in Figure 2.5.

The quantized coefficients are then passed to an entropy encoding procedure which compresses the data further. One of two entropy coding procedures can be used. If *Huffman encoding* is used, *Huffman table* specifications must be provided to the encoder. If *arithmetic encoding* is used, arithmetic coding *conditioning table* specifications may be provided; otherwise the default conditioning table specifications shall be used.



**Figure 2.5: Preparation of quantized coefficients for entropy encoding [3]**

Figure 2.6 shows the main procedures for all DCT-based decoding processes. Each step shown performs essentially the inverse of its corresponding main procedure within the encoder. The entropy decoder decodes the zig-zag sequence of quantized DCT coefficients. After *de-quantization* the DCT coefficients are transformed to an 8 × 8 block of samples by the *inverse DCT* (IDCT).

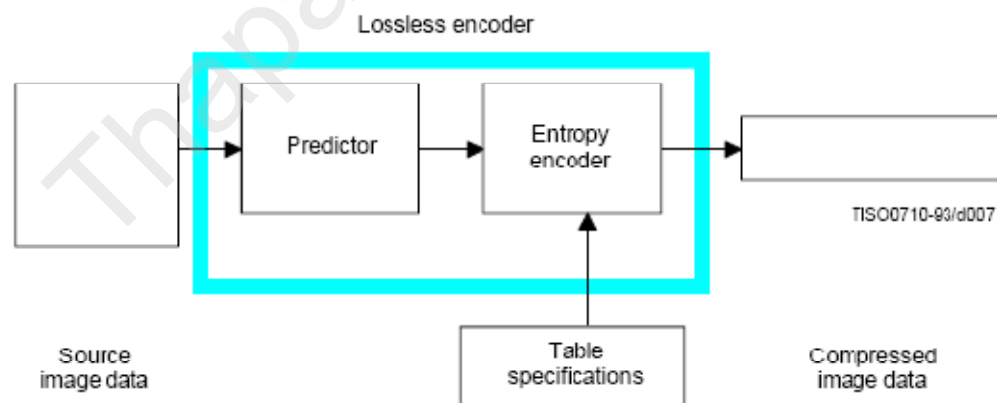


**Figure 2.6: DCT based decoder [3]**

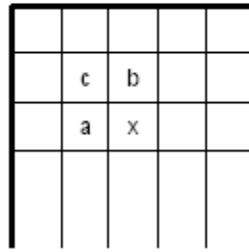
### 2.3.4 Lossless coding

Figure 2.7 shows the main procedures for the lossless encoding processes. A *predictor* combines the reconstructed values of up to three neighborhood samples at positions a, b, and c to form a prediction of the sample at position x as shown in

Figure 2.8. This prediction is then subtracted from the actual value of the sample at position x, and the difference is losslessly entropy-coded by either Huffman or arithmetic coding.



**Figure 2.7: Lossless encoder [3]**



**Figure 2.8: 3 -sample prediction neighborhood [3]**

This encoding process may also be used in a slightly modified way, whereby the *precision* of the input samples is reduced by one or more bits prior to the lossless coding. This achieves higher compression than the lossless process (but lower compression than the DCT-based processes for equivalent visual fidelity), and limits the reconstructed image's worst-case sample error to the amount of input precision reduction.

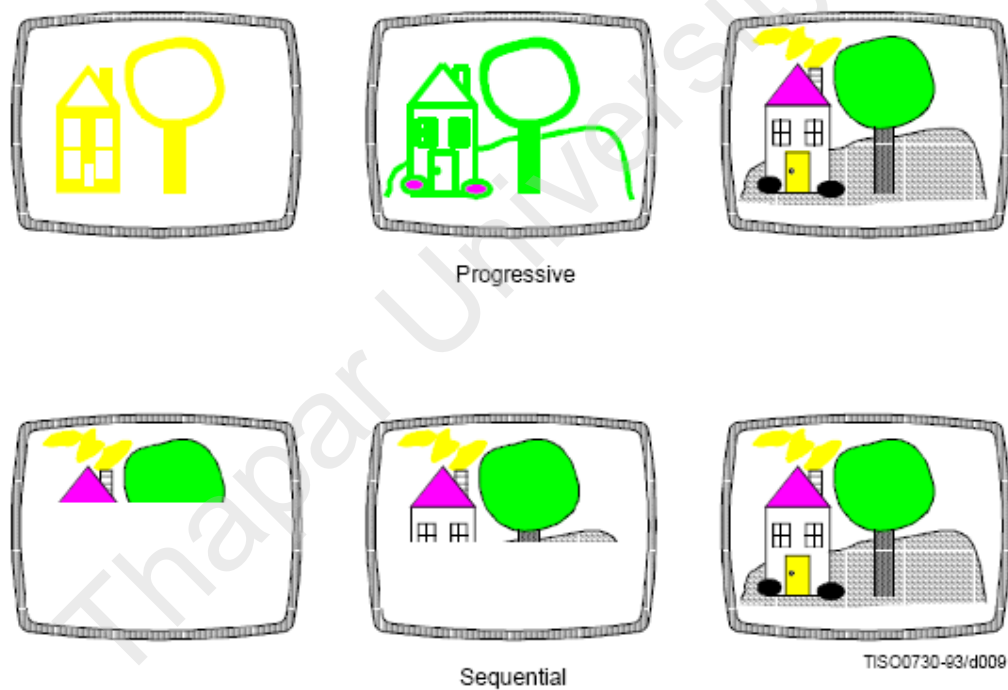
### 2.3.5 Modes of operation

There are four distinct *modes of operation* under which the various coding processes are defined:

- **Sequential DCT-based**
- **Progressive DCT-based**
- **Lossless,**
- **Hierarchical.**

For the **sequential DCT-based mode**,  $8 \times 8$  sample blocks are typically input block by block from left to right, and block row by block-row from top to bottom. After a block has been transformed by the forward DCT, quantized and prepared for entropy encoding, all 64 of its quantized DCT coefficients can be immediately entropy encoded and output as part of the compressed image data, thereby minimizing coefficient storage requirements.

For the **progressive DCT-based mode**,  $8 \times 8$  blocks are also typically encoded in the same order, but in multiple *scans* through the image. This is accomplished by adding an image-sized coefficient memory buffer between the quantizer and the entropy encoder. As each block is transformed by the forward DCT and quantized, its coefficients are stored in the buffer. The DCT coefficients in the buffer are then partially encoded in each of multiple scans. The typical sequence of image presentation at the output of the decoder for sequential versus progressive modes of operation is shown in Figure 2.9.

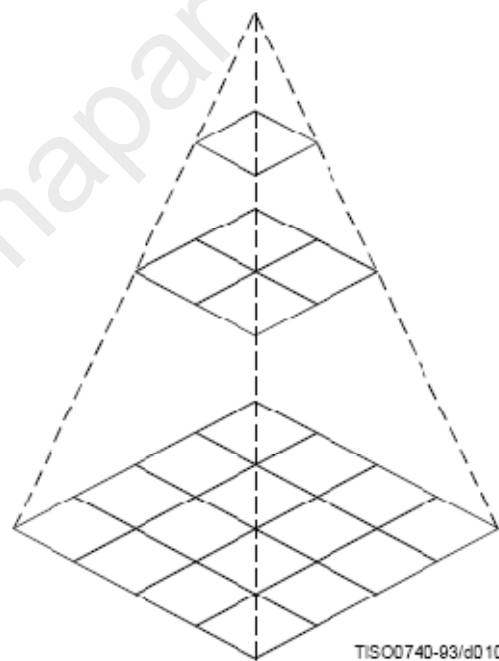


**Figure 2.9: Progressive versus Sequential Presentation [3]**

There are two procedures by which the quantized coefficients in the buffer may be partially encoded within a scan. First, only a specified *band* of coefficients from the zigzag sequence need be encoded. This procedure is called **spectral selection**, because each band typically contains coefficients, which occupy a lower or higher part of the *frequency* spectrum for that  $8 \times 8$  block. Secondly, the coefficients within the current band need not be encoded to their full (quantized) accuracy within each

scan. Upon a coefficient's first encoding; a specified number of most significant bits is encoded first. In subsequent scans, the less significant bits are then encoded. This procedure is called **successive approximation**. Either procedure may be used separately, or they may be mixed in flexible combinations.

In the **hierarchical mode**, an image is encoded as a sequence of *frames*. These frames provide reference-reconstructed components which are usually needed for prediction in subsequent frames. Except for the first frame for a given component, differential frames encode the difference between source components and reference reconstructed components. The coding of the differences may be done using only DCT-based processes, only lossless processes, or DCT-based processes with a final lossless process for each component. *Down sampling* and *up sampling filters* may be used to provide a pyramid of spatial resolutions as shown in Figure 2.10. Alternatively, the hierarchical mode can be used to improve the quality of the reconstructed components at a given spatial resolution. Hierarchical mode offers a progressive presentation similar to the progressive DCT-based mode but is useful in environments, which have multi-resolution requirements. Hierarchical mode also offers the capability of progressive coding to a final lossless stage.



**Figure 2.10: Hierarchical multi-resolution encoding [3]**

### 2.3.6 Entropy coding alternatives

Two alternative entropy-coding procedures are specified: Huffman coding and arithmetic coding. Huffman coding procedures use Huffman tables; Arithmetic coding procedures use arithmetic coding conditioning tables, which may also be determined by a table specification. No default values for Huffman tables are specified, so that applications may choose tables appropriate for their own environments. Default tables are defined for the arithmetic coding conditioning. The baseline sequential process uses Huffman coding, while the extended DCT-based and lossless processes may use either Huffman or arithmetic coding.

### 2.3.7 Sample precision

For DCT-based processes, two alternative sample precisions are specified: either 8 bits or 12 bits per sample. Applications, which use samples with other precisions, can use either 8-bit or 12-bit precision by shifting their source image samples appropriately. The baseline process uses only 8-bit precision. DCT-based implementations, which handle 12-bit source image samples, are likely to need greater computational resources than those which handle only 8-bit source images. Consequently in this Specification separate normative requirements are defined for 8-bit and 12-bit DCT-based processes.

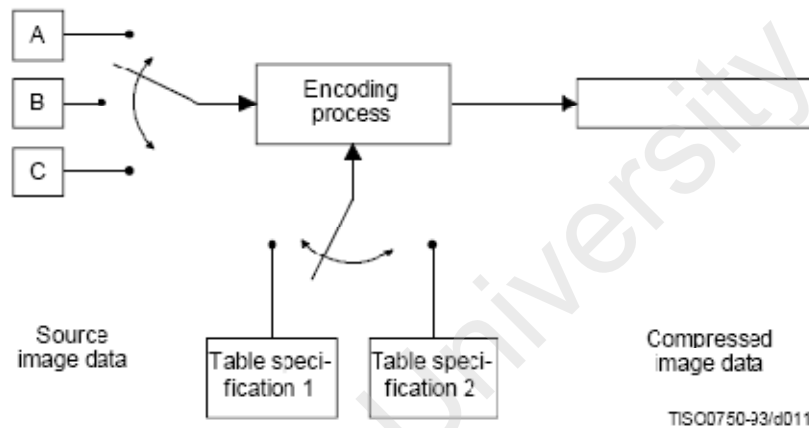
For lossless processes the sample precision is specified to be from 2 to 16 bits.

### 2.3.8 Multiple-component control

The procedures which control the order in which the image data from multiple components are processed to create the compressed data, and which ensure that the proper set of table data is applied to the proper *data units* in the image. (A data unit is a sample for lossless processes and an  $8 \times 8$  block of samples for DCT-based processes.)

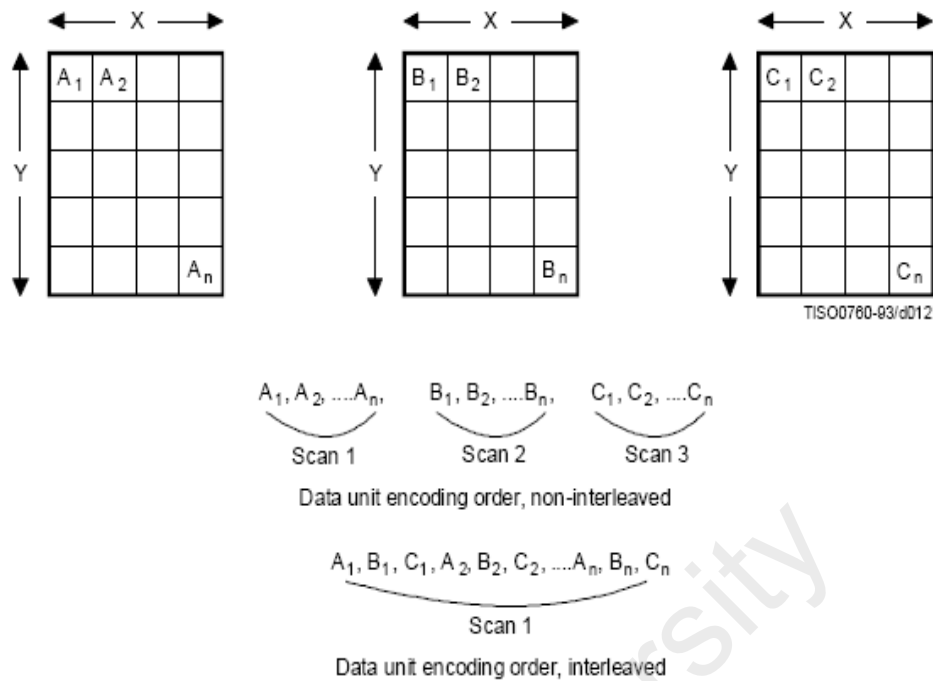
### 2.3.9 Interleaving multiple components

Figure 2.11 shows an example of how an encoding process selects between multiple source image components as well as multiple sets of table data, when performing its encoding procedures. The source image in this example consists of the three components A, B and C, and there are two sets of table specifications. (This simplified view does not distinguish between the quantization tables and entropy coding tables.)



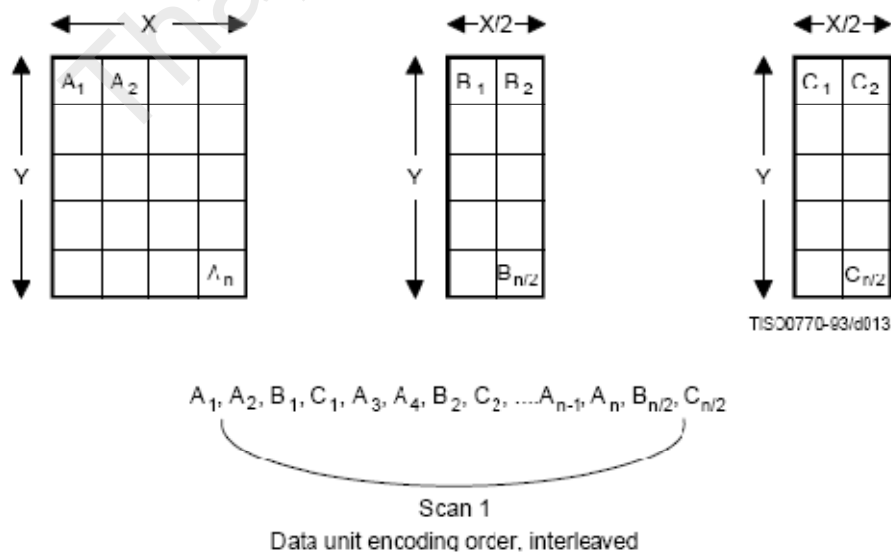
**Figure 2.11: Component interleave and table switching control [3]**

In sequential mode, encoding is *non-interleaved* if the encoder compresses all image data units in component A before beginning component B, and then in turn all of B before C. Encoding is *interleaved* if the encoder compresses a data unit from A, a data unit from B, a data unit from C, then back to A, etc. These alternatives are illustrated in Figure 2.12, which shows a case in which all three image components have identical dimensions:  $X$  columns by  $Y$  lines, for a total of  $n$  data units each.



**Figure 2.12: Interleaved versus non-interleaved encoding [3]**

These control procedures are also able to handle cases in which the source image components have different dimensions. Figure 2.13 shows a case in which two of the components, B and C, have half the number of horizontal samples relative to component A. In this case, two data units from A are interleaved with one each from B and C. Cases in which components of an image have more complex relationships, such as different horizontal and vertical dimensions, can be handled as well.



**Figure 2.13: Interleaved order for components with different dimensions [3]**

### 2.3.10 Minimum coded unit

Related to the concepts of multiple-component interleave is the *minimum coded unit* (MCU). If the compressed image data is non-interleaved, the MCU is defined to be one data unit. For example, in Figure 2.22 the MCU for the non interleaved case is a single data unit. If the compressed data is interleaved, the MCU contains one or more data units from each component. For the interleaved case in Figure 2.22, the (first) MCU consists of the three interleaved data units A1, B1, C1. In the example of Figure 2.23, the (first) MCU consists of the four data units A1, A2 , B1, C1.

### 2.3.11 Image, frame, and scan

Compressed image data consists of only one image. An image contains only one frame in the cases of sequential and progressive coding processes; an image contains multiple frames for the hierarchical mode.

A frame contains one or more scans. For sequential processes, a scan contains a complete encoding of one or more image components. In Figures 2.22 and 2.23, the frame consists of three scans when non-interleaved, and one scan if all three components are interleaved together. The frame could also consist of two scans: one with a non-interleaved component, the other with two components interleaved.

For progressive processes, a scan contains a partial encoding of all data units from one or more image components. Components shall not be interleaved in progressive mode, except for the DC coefficients in the first scan for each component of a progressive frame.

## Comparison of coding processes

Baseline process (required for all DCT-based decoders)
<ul style="list-style-type: none"> <li>• DCT-based process</li> <li>• Source image: 8-bit samples within each component</li> <li>• Sequential</li> <li>• Huffman coding: 2 AC and 2 DC tables</li> <li>• Decoders shall process scans with 1, 2, 3, and 4 components</li> <li>• Interleaved and non-interleaved scans</li> </ul>
Extended DCT-based processes
<ul style="list-style-type: none"> <li>• DCT-based process</li> <li>• Source image: 8-bit or 12-bit samples</li> <li>• Sequential or progressive</li> <li>• Huffman or arithmetic coding: 4 AC and 4 DC tables</li> <li>• Decoders shall process scans with 1, 2, 3, and 4 components</li> <li>• Interleaved and non-interleaved scans</li> </ul>
Lossless processes
<ul style="list-style-type: none"> <li>• Predictive process (not DCT-based)</li> <li>• Source image: P-bit samples (<math>2 \leq P \leq 16</math>)</li> <li>• Sequential</li> <li>• Huffman or arithmetic coding: 4 DC tables</li> <li>• Decoders shall process scans with 1, 2, 3, and 4 components</li> <li>• Interleaved and non-interleaved scans</li> </ul>
Hierarchical processes
<ul style="list-style-type: none"> <li>• Multiple frames (non-differential and differential)</li> <li>• Uses extended DCT-based or lossless processes</li> <li>• Decoders shall process scans with 1, 2, 3, and 4 components</li> <li>• Interleaved and non-interleaved scans</li> </ul>

**Figure 2.14: Comparison of coding processes**

## 2.4 Jpeg encoding process

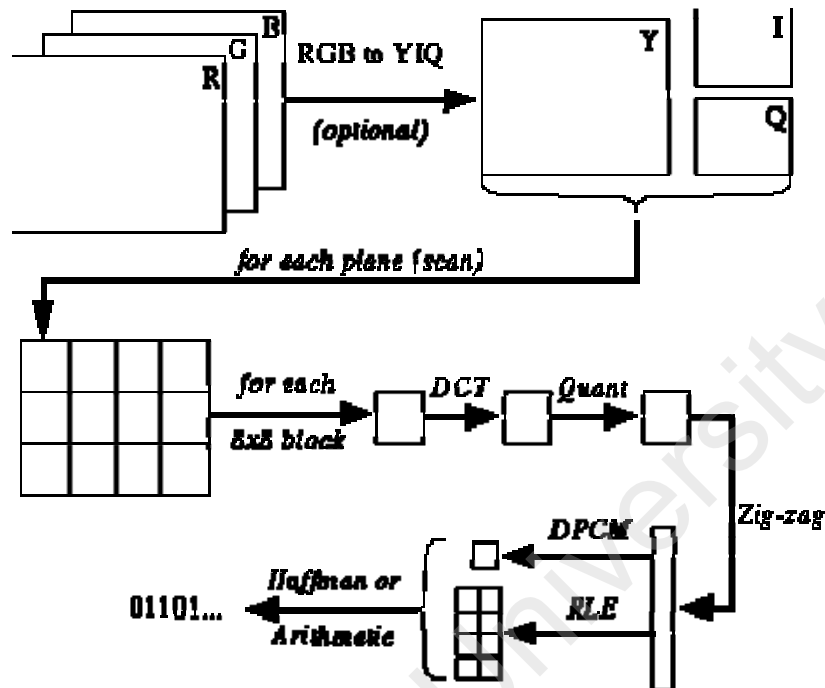
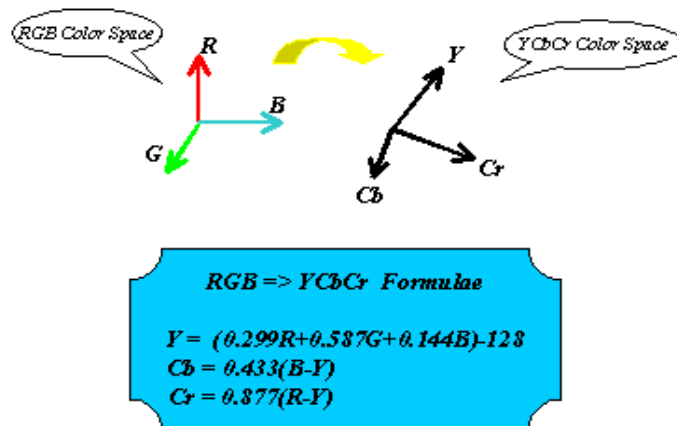


Figure 2.15: Coding of an image:

- RGB to YUV color-space conversion
- Chrominance Sub-sampling.
- Removal of spatial redundancy:
  - Partitioning into 8x8-pixel blocks.
  - 2-D DCT of each block.
  - Quantization of each DCT coefficient.
- Zigzag scanning.
- Entropy Coding.

### 2.4.1: RGB to YUV conversion



**Figure 2.16: RGB to YUV conversion [2]**

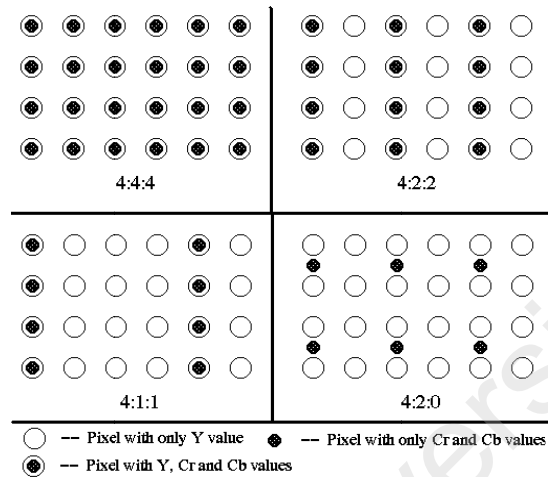
All three RGB components need to be of equal bandwidth to generate any color within the RGB color cube. The result of this is a frame buffer that has the same pixel depth and display resolution for each RGB component.

- To modify the intensity or color of a given pixel, the three RGB values must be read from the frame buffer, the intensity or color calculated, the desired modifications performed, and the new RGB values calculated and written back to the frame buffer.
- If the system had access to an image stored directly in the intensity and color format, some processing steps would be faster.
- The human eye distinguishes difference in brightness more readily than difference in pure color value so the chrominance bandwidth may be reduced relative to the luminance without significantly affecting the picture.
- RGB: 720 pixel X 480 lines X 30 frames/s X 24 bits = 237 Mbps
- 4:2:0 YUV: 720 pixel X 480 lines X 30 frames/s X 12 bits = 118 Mbps

### 2.4.2. Chrominance Sub-Sampling

Chroma sub sampling is the practice of encoding images by implementing more resolution for luminance information than for color information .

Because the human visual system is less sensitive to the position and motion of color than luminance, bandwidth can be optimized by storing more luminance detail than color detail.



**Figure 2.17: Chrominance Sub sampling [2]**

### 2.4.3 Spatial Redundancy

Elements that are duplicated within a structure, such as pixels in a still image and bit patterns in a file

- Picture property that horizontally and vertically adjacent pixels have a very high probability of being of the same intensity (luminance) and/or color (chrominance).
- To some extent, the value of a pixel is predictable given the values of neighboring pixels.

### 2.4.4 Temporal Redundancy

Pixels in two video frames that have the same values in the same location

- Picture property that similarly located pixels of sequential pictures have a very high probability of being of the same luminance and/or chrominance.

### 2.4.5 Block Splitting

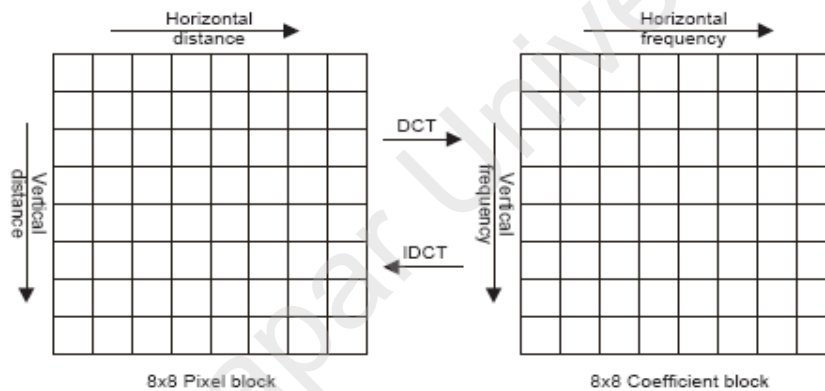
After sub\_sampling, each channel must be split into  $8 \times 8$  blocks (of pixels).

Next, each component (Y, Cb, Cr) of each  $8 \times 8$  block is converted to a frequency-domain representation, using a normalized, two-dimensional type-II discrete\_cosine transform (DCT).

### 2.4.6 Discrete Cosine Transform

The DCT is a lossless, reversible, mathematical process which converts spatial amplitude data i.e. pixel values into spatial frequency data: indicates the rate at which pixel intensities change. DCT is used to remove spatial redundancy in the image.

Calculation is done on  $8 \times 8$  luma or chroma block.



**Figure 2.18: Discrete Cosine Transform [2]**

#### Properties of DCT

In  $8 \times 8$  DCT co-efficient matrix, upper left (first coefficient) is the DC term, the rest are AC (Any DCT coefficient for which the frequency in one or both dimensions is non zero).

- DCT itself doesn't achieve any compression.
- It converts the source pixels into a form in which redundancy can be identified.
- It separates out the higher frequency coefficients in right-bottom corner while low frequency components are in left-upper region.
- Human Visual System is less sensitive to high frequency AC terms.
- The bit rate reduction is achieved by quantizing the high frequency component.

- It is the nature of video that a DCT-based transformation often results in very small values for many higher spatial frequency coefficients.

**Example:**

As an example, one such 8×8 8-bit sub image might be:

52	55	61	66	70	61	64	73
63	59	55	90	109	85	69	72
62	59	68	113	144	104	66	73
63	58	71	122	154	106	70	69
67	61	68	104	126	88	68	70
79	65	60	70	77	68	58	75
85	71	64	59	55	61	65	83
87	79	69	68	65	76	78	94

Before computing the DCT of the sub image, its grey values are shifted from a positive range to one centered around zero. For an 8-bit image each pixel has 256 possible values: [0,255]. To center around zero it is necessary to subtract by half the number of possible values, or 128.

$$\frac{2^{bit}}{2} = \frac{2^8}{2} = 2^7 = 128$$

The next step is to take the two-dimensional DCT, which is given by:

$$\begin{array}{c}
 u \\
 \rightarrow \\
 \begin{bmatrix}
 -415 & -30 & -61 & 27 & 56 & -20 & -2 & 0 \\
 4 & -22 & -61 & 10 & 13 & -7 & -9 & 5 \\
 -47 & 7 & 77 & -25 & -29 & 10 & 5 & -6 \\
 -49 & 12 & 34 & -15 & -10 & 6 & 2 & 2 \\
 12 & -7 & -13 & -4 & -2 & 2 & -3 & 3 \\
 -8 & 3 & 2 & -6 & -2 & 1 & 4 & 2 \\
 -1 & 0 & 0 & -2 & -1 & -3 & 4 & -1 \\
 0 & 0 & -1 & -4 & -1 & 0 & 1 & 2
 \end{bmatrix} \\
 \downarrow \\
 v
 \end{array}$$

The large value of the top-left corner. This is the DC coefficient. The remaining 63 coefficients are called the AC coefficients

### 2.4.7 Quantization

A common quantization matrix is:

$$\begin{bmatrix} 16 & 11 & 10 & 16 & 24 & 40 & 51 & 61 \\ 12 & 12 & 14 & 19 & 26 & 58 & 60 & 55 \\ 14 & 13 & 16 & 24 & 40 & 57 & 69 & 56 \\ 14 & 17 & 22 & 29 & 51 & 87 & 80 & 62 \\ 18 & 22 & 37 & 56 & 68 & 109 & 103 & 77 \\ 24 & 35 & 55 & 64 & 81 & 104 & 113 & 92 \\ 49 & 64 & 78 & 87 & 103 & 121 & 120 & 101 \\ 72 & 92 & 95 & 98 & 112 & 100 & 103 & 99 \end{bmatrix}$$

The quantized DCT coefficients are computed with

$$B_{j,k} = \text{round}\left(\frac{A_{j,k}}{Q_{j,k}}\right) \text{ for } j = 0, 1, 2, \dots, N_1 - 1; k = 0, 1, 2, \dots, N_2 - 1$$

where  $A$  is the un-quantized DCT coefficients;  $Q$  is the quantization matrix above; and  $B$  is the quantized DCT coefficients .

For example, using  $-415$  (the DC coefficient) and rounding to the nearest integer

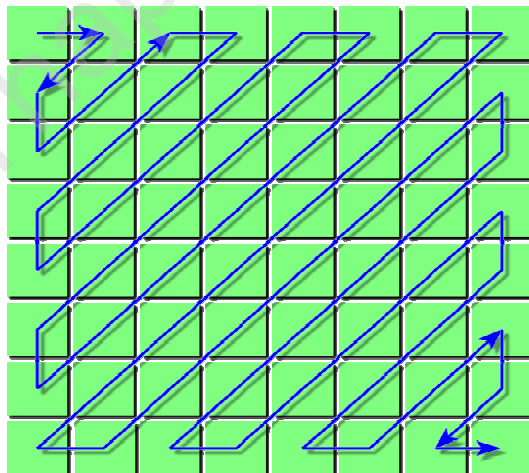
$$\text{round}\left(\frac{-415}{16}\right) = \text{round}(-25.9375) = -26$$

$$\begin{bmatrix} -26 & -3 & -6 & 2 & 2 & -1 & 0 & 0 \\ 0 & -2 & -4 & 1 & 1 & 0 & 0 & 0 \\ -3 & 1 & 5 & -1 & -1 & 0 & 0 & 0 \\ -4 & 1 & 2 & -1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

### 2.4.8 Zigzag scanning

What is it?

A specific sequential ordering of the DCT coefficients from the lowest spatial frequency to the highest. Why is it used? After DCT and quantization most AC values will be zero. Processing the 64 coefficients in the 8X8 blocks using a zigzag pattern maximizes runs of zero values for more efficient compression.



**Figure 2.19: Zigzag Scanning [2]**

**Zigzag formation of quantized values**

-26							
-3	0						
-3	-2	-6					
2	-4	1	-4				
1	1	5	1	2			
-1	1	-1	2	0	0		
0	0	0	-1	-1	0	0	
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	
0	0	0	0	0	0		
0	0	0	0	0			
0	0	0	0				
0	0	0					
0	0						
0							
0							

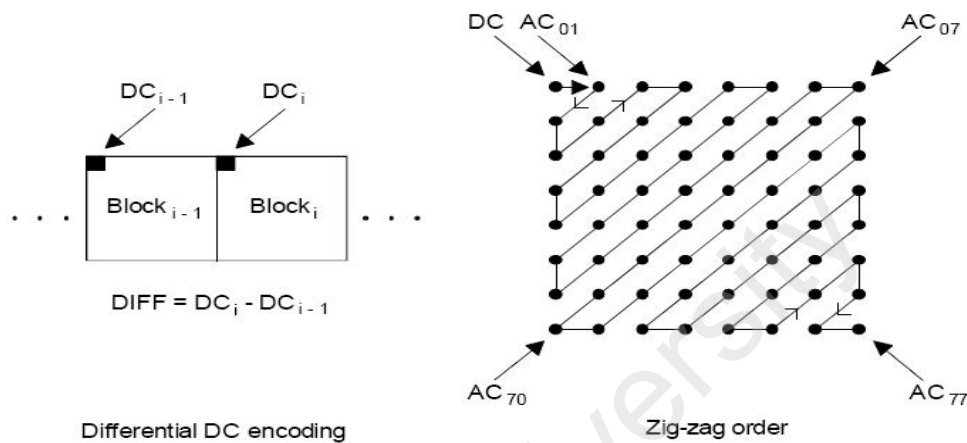
**2.4.9 Entropy coding**

To reduce the amount of data lossless processes can be used. These methods make use exclusively of the redundancy of the data. Processes with this principle are called entropy encoding. There are several of this kind. Entropy encoding is used regardless of the media's specific characteristics. The data stream to be compressed is considered to be a simple digital sequence, and the semantic of the data is ignored. Entropy encoding is an example of lossless encoding as the decompression process regenerates the data completely. The raw data and the decompressed data are identical, no information is lost.

- **Huffman**
- **Runlength**
- **Arithmetic**

For DC coefficients DPCM method is used.

- Because DC coefficient varies slowly from one block to the next.
- Only the difference in value of DC coefficient is encoded so number of bits required reduces.



**Figure 2.20: Differential DC encoding [2]**

## HUFFMAN ENCODING

Huffman encoding is an example of entropy encoding. It is based on statistical methods. Given the character that must be encoded, together with the probability of their occurrences, the Huffman encoding algorithm determines the optimal code using the minimum number of bits.

### Example:

A (0.12), E (0.42), I (0.09), O (0.30), U (0.07)

1. Consider each of the letters as a symbol with its respective probability.
2. Find the two symbols with the smallest probability and combine them into a new symbol with both letters by adding the probabilities.
3. Repeat step 2 until there is only one symbol left with a probability of 1.

4. To see the code, redraw all the symbols in the form of a tree, where each symbol contains either a single letter or splits up into two smaller symbols. Label all the left branches of the tree with a 0 and all the right branches with a 1. The code for each of the letters is the sequence of 0's and 1's that lead to it on the tree, starting from the symbol with a probability of 1.

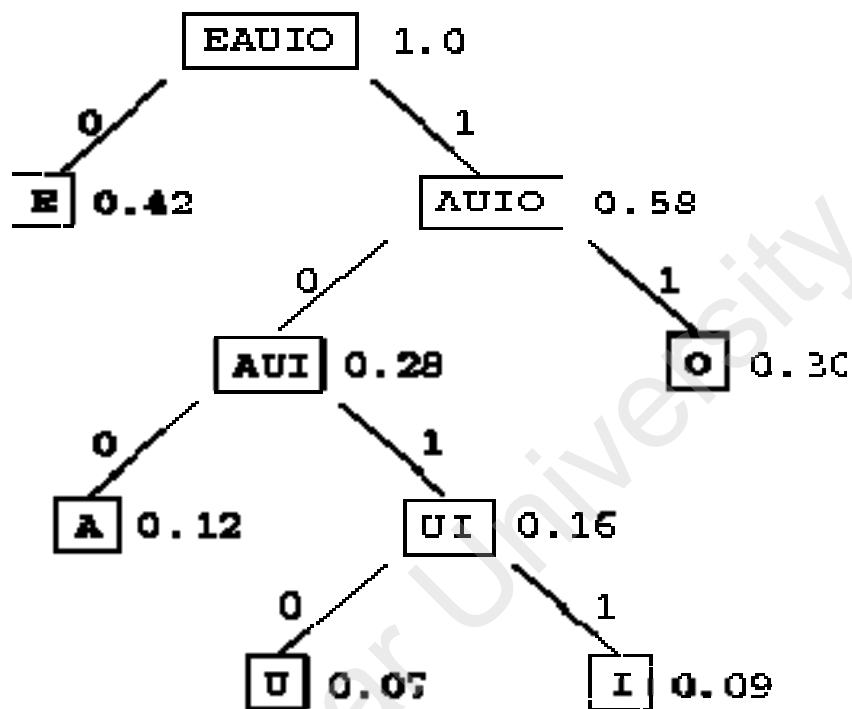


Figure 2.21: Huffman Tree

Thus the codes for each letter are:

A - 100

E - 0

I - 1011

O - 11

U - 1010

## RUN LENGTH ENCODING

For AC coefficients Run Length Encoding (RLE) is used. Run length coding is an example of entropy encoding. If a byte occurs at least four consecutive times the

number of occurrences is counted . The compressed data contains this byte followed by a special flag, called M-byte , and the number of its occurrences. The exclamation mark “!” can be defined as this M-byte. A single occurrence of this exclamation mark is interpreted as M-byte during the decompression; two consecutive exclamation marks are interpreted as an exclamation mark occurring within the data .

**Example:**

ABCCCCCCCCDEFGGG

Compressed data: AB C!8DEFGGG

**VARIABLE LENGTH ENCODING (VLC)**

Variable length encoding is a process that identifies common patterns (or words) in the Run Length Coded data and uses fewer bits to code frequently occurring values and more words to code less frequently occurring values. Makes the code string shorter than the original data . The most frequent one get the shortest code. Variable length coding is lossless. VLC coding uses tables to map patterns to codes. These tables, combined with the mapped codes, generally take much less data than the original data patterns.

**VLC : Example**

Assume: **After DCT, Q, ZZ**

12, 6, 6, 0, 4, 3, 0, 0, 0...0 (512 bits)

Then

**After RLE:**

(0,12) (0,6) (0,6) (1,4) (0,3) EOB

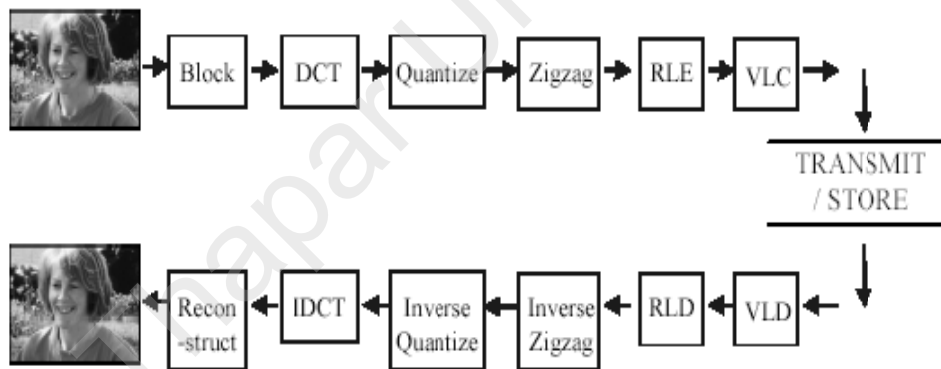
And

**After VLC:**

0000 0000 1101 00, 0010 0001 0, 0010 0001 0, 0000 0011 000, 0010 10, 10 (51 bits)

**VLC table**

Length of runs zeros	Non-zero of zero coeff.	VLC code Word
0	12	0000 0000 1101 00
0	6	0010 0001 0
1	4	0000 0011 000
0	3	0010 10
EOB		10



**Figure 2.22: Summary of Coding and decoding process**

## 2.5 Jpeg decoding process

Decoding to display the image consists of doing all the above in reverse. Taking the DCT coefficient matrix (after adding the difference of the DC coefficient back in) and taking the entry-for-entry product with the quantization matrix from above results in a matrix which closely resembles the original DCT coefficient matrix for the top-left portion. Taking the inverse DCT (type-III DCT results in an image with values (still shifted down by 128) and adding 128 to each entry gives the uncompressed sub image and can be compared to the original sub image by taking the difference (original – uncompressed) results in error values with an average absolute error of about 5 values per pixels.

## Chapter 3: Problem statement

---

JPEG file format is supported by a wide variety of applications on a variety of platforms and is the most common file format used. JPEG images are constructed from RGB data. Compression allows more images to be saved in the same amount of disk space while preserving the color profile and caption information. Note, however, that JPEG compression results in loss of image information that cannot afterwards be restored. EXIF is an extension of the JPEG format that allows thumbnail data and information about the image to be included in a JPEG file.

As explained in the literature review, the encoding process results in a compressed Jpeg file. Now, whenever a Jpeg image is selected for viewing, the image data needs to be loaded, before the image data is loaded, the markers must be read. Most markers will have additional information following them. When this is the case, the marker and its associated information is referred to as a "**header.**" After the basic process of encoding (compression), the compressed image consists of an ordered collection of parameters, markers, and entropy-coded data segments. Parameters and markers in turn are often organized into marker segments. Because all of these constituent parts are represented with byte-aligned codes, each compressed data format consists of an ordered sequence of 8-bit bytes. For each byte, a most significant bit (MSB) and a least significant bit (LSB) are defined.

Therefore to view the compressed Jpeg image, it is necessary to read the header information from the compressed image, and hence there is a need to devise some mechanism to read the header of compressed Jpeg files.

The basic Objective of this thesis work is:

- To design a tool, which can read the header of compressed Jpeg files, which further helps, in loading the image data needed for viewing the Jpeg files and which passes the quantized DCT coefficients to the decoder during the decoding of an image.

## CHAPTER 4 :Design and implementation of JPEG Parser

Jpeg Parser is a tool, which is used to read the header of Jpeg files .Header of Jpeg files contains different information about the image in terms of different markers and parameters. Jpeg header is explained in detail in this chapter.

### 4.1 Jpeg header

This document specifies the interchange format syntax, which applies to all coding processes for sequential DCT-based, progressive DCT-based, and lossless modes of operation. Whenever a Jpeg image is selected for viewing, the image data needs to be loaded ,before the image data is loaded, the markers must be read. Most markers will have additional information following them. When this is the case, the marker and its associated information is referred to as a "header."

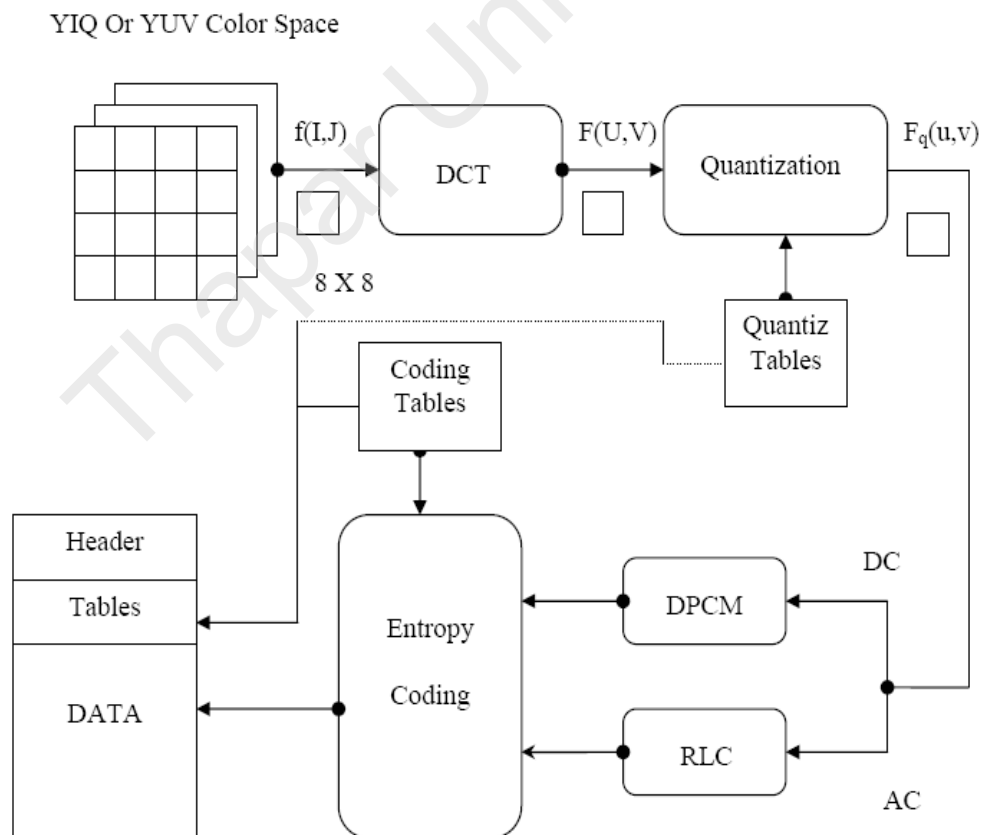


Figure 4.1: Basic Process of Encoding.

After the basic process of encoding (compression), the compressed image consists of an ordered collection of parameters, markers, and entropy-coded data segments. Parameters and markers in turn are often organized into **marker segments**. Because all of these constituent parts are represented with byte-aligned codes, each compressed data format consists of an ordered sequence of 8-bit bytes. For each byte, a most significant bit (MSB) and a least significant bit (LSB) are defined.

### TERMS USED

- i.* **Parameters:-** Parameters are integers, with values specific to the encoding process, source image characteristics, and other features selectable by the application. Parameters are assigned either 4-bit, 1-byte, or 2-byte codes. Parameters encode critical information without which the decoding process cannot properly reconstruct the image. For eg: length is a parameter and its value can be 00 10(2 bytes in hex).
- ii.* **Markers:-** Markers serve to identify the various structural parts of the compressed data formats.. All markers are assigned two-byte codes: an X'FF'byte followed by a byte, which is not equal to 0 or X'FF'. Because of this special code-assignment structure, markers make it possible for a decoder to parse the compressed data and locate its various parts without having to decode other segments of image data. For eg: X'FFD8' is a marker for Start of Image.

**NOTE:-** All markers shall be assigned two-byte codes: a X'FF' byte followed by a second byte which is not equal to 0 or X'FF'.The following table shows different markers .An asterisk (\*) indicates a marker which stands alone,that is, which is not the start of a marker segment.

- iii.* **Marker segments: -** A marker segment consists of a marker followed by a sequence of related parameters. The first parameter in a marker segment is the two-byte length parameter. This length parameter encodes the number of bytes in the marker segment, including the length parameter and excluding the two-

byte marker. E.g.:- X'FFDB specifies the marker segment which defines one or more quantization tables, the parameters DQT,LQ etc following the X'FFDB marker are all related to the quantization table.

**NOTE:** -The marker segments identified by the SOF (Start Of Frame markers) and SOS (Start of scan) marker codes are referred to as headers: the frame header and the scan header respectively.

- iv.* **Entropy-coded data segments:** - An entropy-coded data segment contains the output of an entropy-coding procedure. It consists of an integer number of bytes, whether the entropy-coding procedure used is Huffman or arithmetic. The three markers shown in Figure 4.2 are defined as follows:

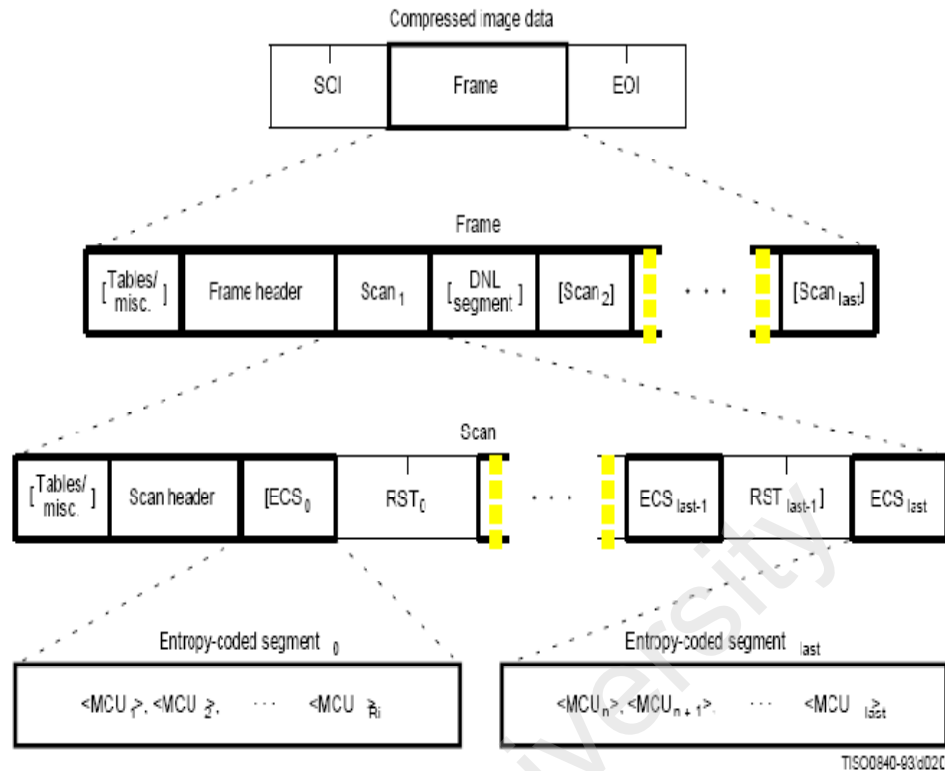
**SOI: Start of image marker** – Marks the start of a compressed image represented in the interchange format or abbreviated format.

**EOI: End of image marker** – Marks the end of a compressed image represented in the interchange format or abbreviated format.

**RSTm: Restart marker** – A conditional marker, which is placed between entropy-coded, segments only if restart is enabled. There are 8 unique restart markers ( $m = 0 - 7$ ) which repeat in sequence from 0 to 7, starting with zero for each scan, to provide a modulo 8 restart interval count.

Code Assignment	Symbol	Description
Start Of Frame markers, non-differential, Huffman coding		
X'FFC0' X'FFC1' X'FFC2' X'FFC3'	SOF <sub>0</sub> SOF <sub>1</sub> SOF <sub>2</sub> SOF <sub>3</sub>	Baseline DCT Extended sequential DCT Progressive DCT Lossless (sequential)
Start Of Frame markers, differential, Huffman coding		
X'FFC5' X'FFC6' X'FFC7'	SOF <sub>5</sub> SOF <sub>6</sub> SOF <sub>7</sub>	Differential sequential DCT Differential progressive DCT Differential lossless (sequential)
Start Of Frame markers, non-differential, arithmetic coding		
X'FFC8' X'FFC9' X'FFCA' X'FFCB'	JPG SOF <sub>9</sub> SOF <sub>10</sub> SOF <sub>11</sub>	Reserved for JPEG extensions Extended sequential DCT Progressive DCT Lossless (sequential)
Start Of Frame markers, differential, arithmetic coding		
X'FFCD' X'FFCE' X'FFCF'	SOF <sub>13</sub> SOF <sub>14</sub> SOF <sub>15</sub>	Differential sequential DCT Differential progressive DCT Differential lossless (sequential)
Huffman table specification		
X'FFC4'	DHT	Define Huffman table(s)
Arithmetic coding conditioning specification		
X'FFCC'	DAC	Define arithmetic coding conditioning(s)
Restart interval termination		
X'FFD0' through X'FFD7'	RST <sub>m</sub> *	Restart with modulo 8 count "m"
Other markers		
X'FFD8' X'FFD9' X'FFDA' X'FFDB' X'FFDC' X'FFDD' X'FFDE' X'FFDF' X'FFE0' through X'FFE7' X'FFF0' through X'FFF7' X'FFFE'	SOI* EOI* SOS DQT DNL DRI DHP EXP APP <sub>n</sub> JPG <sub>n</sub> COM	Start of image End of image Start of scan Define quantization table(s) Define number of lines Define restart interval Define hierarchical progression Expand reference component(s) Reserved for application segments Reserved for JPEG extensions Comment
Reserved markers		
X'FF01' X'FF02' through X'FFBF'	TEM* RES	For temporary private use in arithmetic coding Reserved

Figure 4.2: Marker Code Assignments [4]



**Figure4.3: Syntax for Sequential DCT based, Progressive DCT based and Lossless modes of operation [4]**

The **top level** of Figure 4.3 specifies that the non-hierarchical interchange format shall begin with an SOI marker, shall contain one frame, and shall end with an EOI marker.

The **second level** of Figure 4.3 specifies that a frame shall begin with a frame header and shall contain one or more scans. A frame header may be preceded by one or more table-specification or miscellaneous marker segments .

**NOTE:** A **scan** is a single pass through the data for one or more of the components in an image.

**Scan header:** A marker segment that contains a start-of-scan marker and associated scan parameters that are coded at the beginning of a scan.

For sequential DCT-based and lossless processes each scan shall contain from one to four image components. If two to four components are contained within a scan, they shall be interleaved within the scan. For progressive DCT-based processes each image component is only partially contained within any one scan. Only the first scan(s) for the components (which contain only DC coefficient data) may be interleaved.

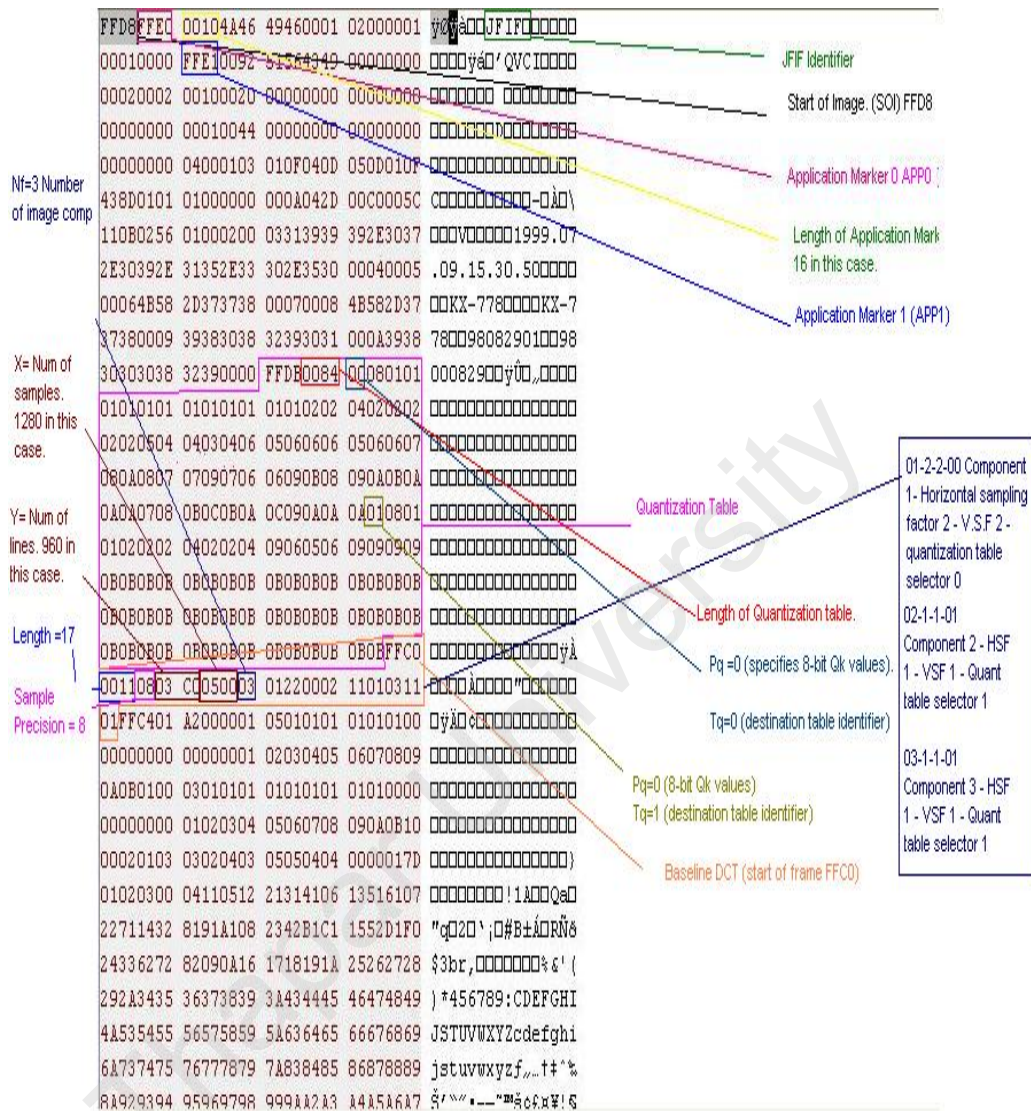
The **third level** of Figure 4.3 specifies that a scan shall begin with a scan header and shall contain one or more entropy coded data segments. Each scan header may be preceded by one or more table-specification or miscellaneous marker segments. If restart is not enabled, there shall be only one entropy-coded segment (the one labeled “last”), and no restart markers shall be present. If restart is enabled, the number of entropy-coded segments is defined by the size of the image and the defined restart interval. In this case, a restart marker shall follow each entropy-coded segment except the last one.

The **fourth level** of Figure 4.3 specifies that each entropy-coded segment is comprised of a sequence of entropy coded MCUs. If restart is enabled and the restart interval is defined to be  $R_i$ , each entropy-coded segment except the last one shall contain  $R_i$  MCUs. The last one shall contain whatever number of MCUs completes the scan.

**NOTE:**

**MCU:-** The smallest group of data units that is coded.

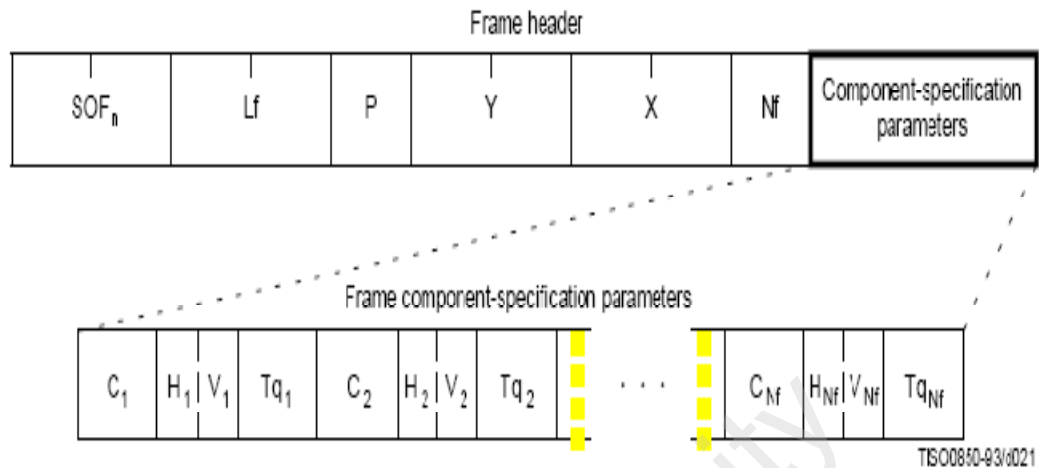
**EXAMPLE:**



**Figure 4.4 : Compressed Jpeg image showing**

- i) Application Marker**
- ii) Quantization table marker**
- iii) Frame header**

## 4.2 Frame header



**Figure 4.5: Frame Header syntax [4]**

**Frame:** A group of one or more scans (all using the same DCT-based or lossless process) through the data of one or more of the components in an image.

**Frame header:** A marker segment that contains a start-of-frame marker and associated frame parameters that are coded at the beginning of a frame. This header is present at the start of the frame, and specifies the source image characteristics, the components in the frame, and the sampling factors for each component, and specifies the destinations from which the quantized tables to be used with each component are retrieved. The markers and parameters shown in Figure 4.5 are defined below:

**SOF<sub>n</sub>:** Start of frame marker – Marks the beginning of the frame parameters. The subscript  $n$  identifies whether the encoding process is baseline sequential, extended sequential, progressive, or lossless, as well as which entropy encoding procedure is used.

**SOF0:** Baseline DCT

**SOF1:** Extended sequential DCT, Huffman coding

**SOF2:** Progressive DCT, Huffman coding

**SOF3:** Lossless (sequential), Huffman coding

**SOF9:** Extended sequential DCT, arithmetic coding

**SOF10:** Progressive DCT, arithmetic coding

**SOF11:** Lossless (sequential), arithmetic coding

**Lf:** Frame header length – Specifies the length of the frame

**P:** Sample precision – Specifies the precision in bits for the samples of the components in the frame.

**Y:** Number of lines – Specifies the maximum number of lines in the source image. This shall be equal to the number of lines in the component with the maximum number of vertical samples. Value 0 indicates that the number of lines shall be defined by the DNL marker and parameters at the end of the first scan.

**X:** Number of samples per line – Specifies the maximum number of samples per line in the source image. This shall be equal to the number of samples per line in the component with the maximum number of horizontal samples.

**Nf:** Number of image components in frame – Specifies the number of source image components in the frame.

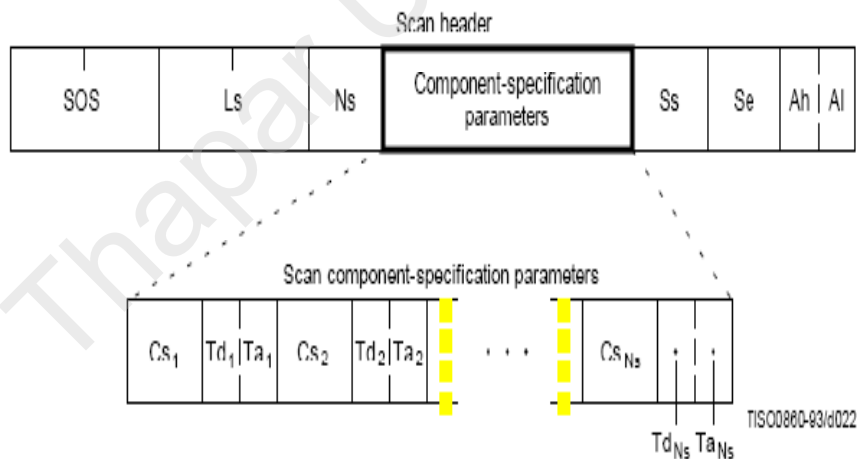
**Ci:** Component identifier – Assigns a unique label to the  $i$ th component in the sequence of frame component specification parameters. These values shall be used in the scan headers to identify the components in the scan.

**Hi:** Horizontal sampling factor – Specifies the relationship between the component horizontal dimension and maximum image dimension  $X$  also specifies the number of horizontal data units of component  $C_i$  in each MCU, when more than one component is encoded in a scan.

**Vi:** Vertical sampling factor – Specifies the relationship between the component vertical dimension and maximum image dimension  $Y$  also specifies the number of vertical data units of component  $C_i$  in each MCU, when more than one component is encoded in a scan.

**Tqi:** Quantization table destination selector – Specifies one of four possible quantization table destinations from which the quantization table to use for dequantization of DCT coefficients of component  $C_i$  is retrieved. If the decoding process uses the dequantization procedure, this table shall have been installed in this destination by the time the decoder is ready to decode the scan(s) containing component  $C_i$ . The destination shall not be respecified, or its contents changed, until all scans containing  $C_i$  have been completed.

### 4.3 Scan header



**Figure 4.6: Scan Header Syntax [4]**

Scan Header is a marker segment that contains a start-of-scan marker and associated scan parameters that are coded at the beginning of a scan.

Figure 4.6 specifies the scan header which shall be present at the start of a scan. This header specifies which component(s) are contained in the scan, specifies the destinations from which the entropy tables to be used with each component are retrieved, and (for the progressive DCT) which part of the DCT quantized coefficient data is contained in the scan. For lossless processes the scan parameters specify the predictor and the point transform.

**SOS:** Start of scan marker – Marks the beginning of the scan parameters.

**Ls:** Scan header length – Specifies the length of the scan header

**Ns:** Number of image components in scan – Specifies the number of source image components in the scan. The value of Ns shall be equal to the number of sets of scan component specification parameters (C<sub>sj</sub>, T<sub>dj</sub>, and T<sub>aj</sub>) present in the scan header.

**C<sub>sj</sub>:** Scan component selector – Selects which of the N<sub>f</sub> image components specified in the frame parameters shall be the *j*th component in the scan.

**T<sub>dj</sub>:** DC entropy coding table destination selector – Specifies one of four possible DC entropy coding table destinations from which the entropy table needed for decoding of the DC coefficients of component C<sub>sj</sub> is retrieved. The DC entropy table shall have been installed in this destination by the time the decoder is ready to decode the current scan. This parameter specifies the entropy coding table destination for the lossless processes.

**T<sub>aj</sub>:** AC entropy coding table destination selector – Specifies one of four possible AC entropy coding table destinations from which the entropy table needed for decoding of the AC coefficients of component C<sub>sj</sub> is retrieved. The AC entropy table selected shall have been installed in this destination by the time the decoder is ready to decode the current scan. This parameter is zero for the lossless processes.

**Ss:** Start of spectral or predictor selection – In the DCT modes of operation, this parameter specifies the first DCT coefficient in each block in zig-zag order which shall be coded in the scan. This parameter shall be set to zero for the sequential DCT processes. In the lossless mode of operations this parameter is used to select the predictor.

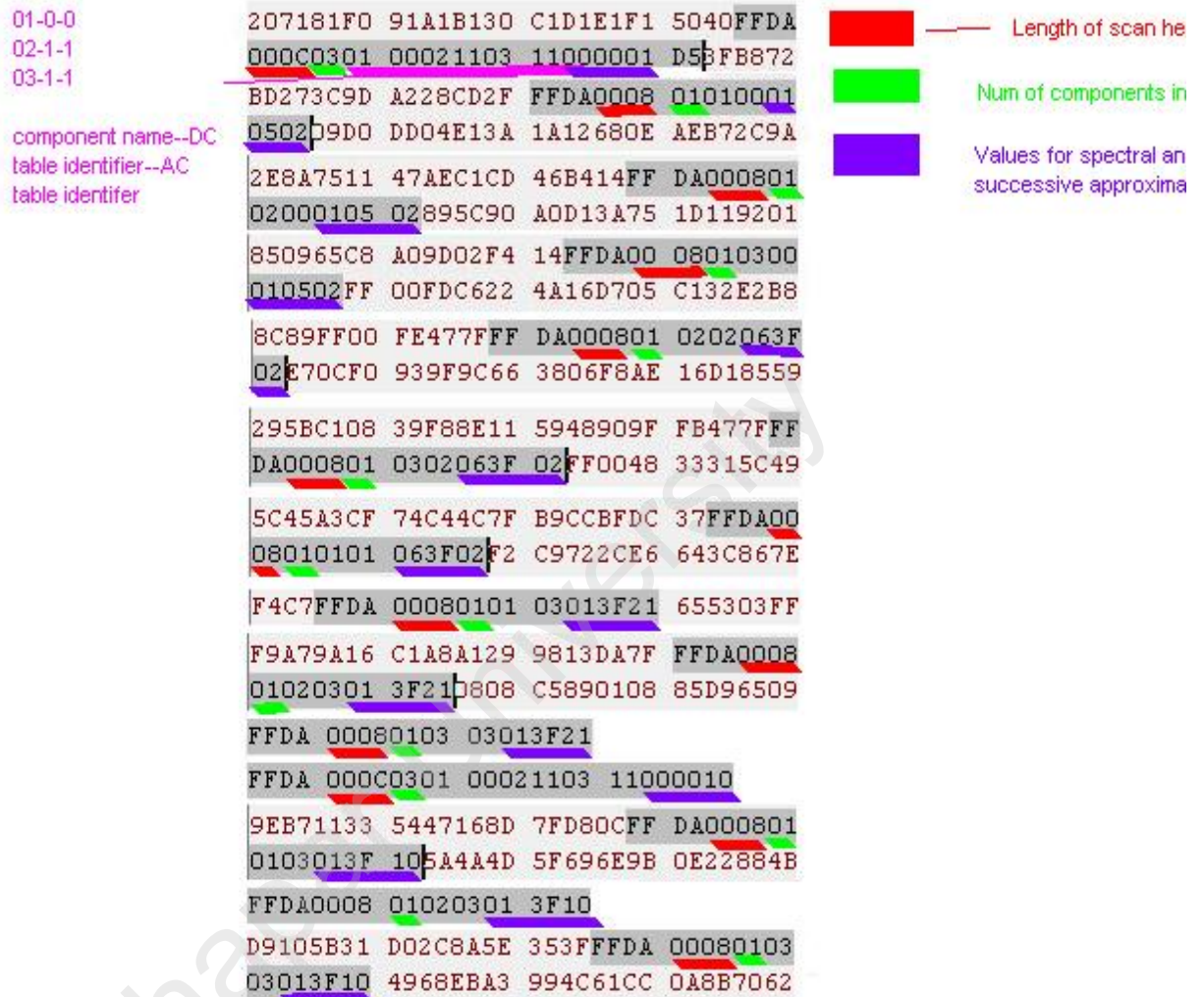
**Se:** End of spectral selection – Specifies the last DCT coefficient in each block in zig-zag order which shall be coded in the scan. This parameter shall be set to 63 for the sequential DCT processes. In the lossless mode of operations this parameter has no meaning. It shall be set to zero.

**Ah:** Successive approximation bit position high – This parameter specifies the point transform used in the preceding scan (i.e. successive approximation bit position low in the preceding scan) for the band of coefficients specified by Ss and Se. This parameter shall be set to zero for the first scan of each band of coefficients. In the lossless mode of operations this parameter has no meaning. It shall be set to zero.

**Al:** Successive approximation bit position low or point transform – In the DCT modes of operation this parameter specifies the point transform, i.e. bit position low, used before coding the band of coefficients specified by Ss and Se. This parameter shall be set to zero for the sequential DCT processes. In the lossless mode of operations, this parameter specifies the point transform.

**NOTE:** -The entropy coding table destination selectors, Tdj and Taj, specify either Huffman tables (in frames using Huffman coding) or arithmetic coding tables (in frames using arithmetic coding).

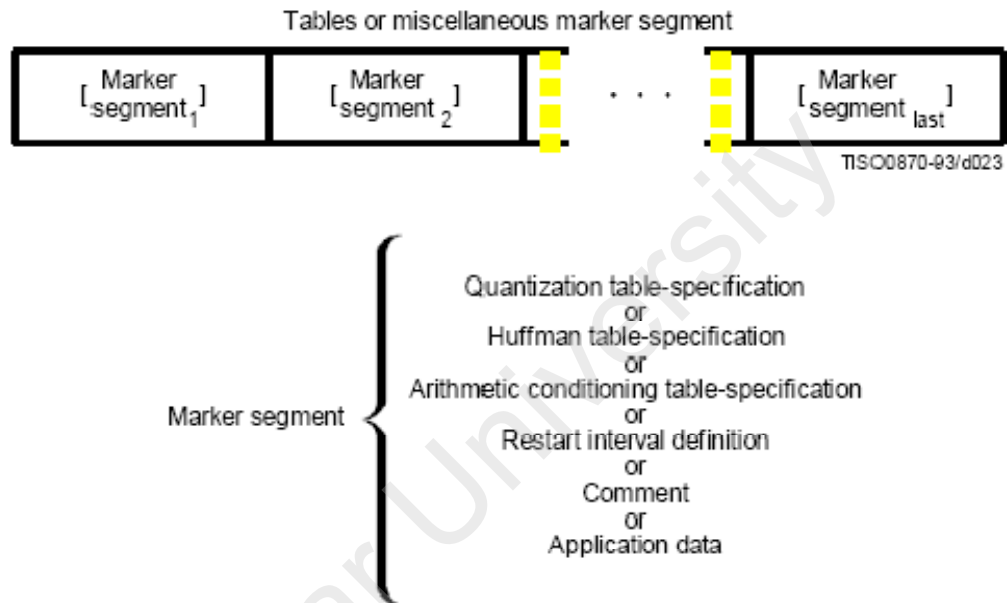
**EXAMPLE**



**Figure4.7: Jpeg Image with multiple scans.**

#### 4.4 Table specifications and miscellaneous marker segments

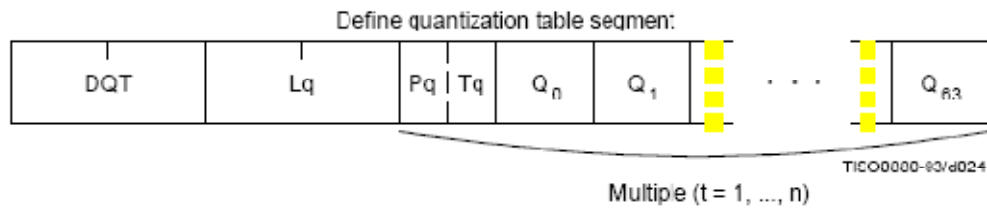
The following figure specifies that, at the places indicated in Figure 4.8, any of the table-specification segments or miscellaneous marker segments may be present in any order and with no limit on the number of segments.



**Figure 4.8: Table specification and miscellaneous marker segment [4]**

**NOTE:** -If any table specification for a particular destination occurs in the compressed image data, it shall replace any previous table specified for this destination, and shall be used whenever this destination is specified in the remaining scans in the frame or subsequent images represented in the abbreviated format for compressed image data. If a table specification for a given destination occurs more than once in the compressed image data, each specification shall replace the previous specification. The quantization table specification shall not be altered between progressive DCT scans of a given component.

## 4.5 Quantization table specification syntax



**Figure 4.9: Quantization table syntax [4]**

The marker and parameters shown in Figure 4.9 defined below:

**DQT:** Define quantization table marker – Marks the beginning of quantization table-specification parameters.

**Lq:** Quantization table definition length – Specifies the length of all quantization table parameters .

**Pq:** Quantization table element precision – Specifies the precision of the Q<sub>k</sub> values. Value 0 indicates 8-bit Q<sub>k</sub> values; value 1 indicates 16-bit Q<sub>k</sub> values. P<sub>q</sub> shall be zero for 8 bit sample precision P

**Tq:** Quantization table destination identifier – Specifies one of four possible destinations at the decoder into which the quantization table shall be installed.

**Q<sub>k</sub>:** Quantization table element – Specifies the *k*th element out of 64 elements, where *k* is the index in the zigzag ordering of the DCT coefficients. The quantization elements shall be specified in zig-zag scan order.

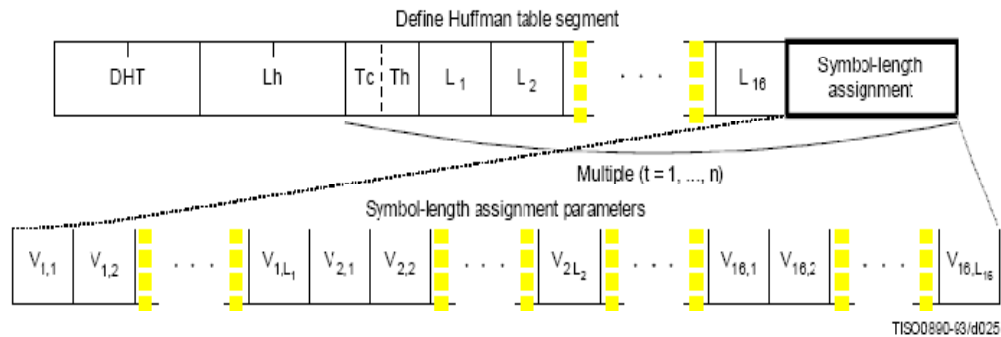
**NOTE:-** Once a quantization table has been defined for a particular destination, it replaces the previous tables stored in that destination and shall be used, when referenced, in the remaining scans of the current image and in subsequent images represented in the abbreviated format for compressed image data. If a table has never been defined for a particular destination, then when this destination is specified in a frame header, the results are unpredictable.

**EXAMPLE:**

Length of Huffman table = 418	FFC401 A2000001 05010101 01010100	00 L1	00L1	00 L1	00L1
	00000000 00000001 02030405 06070809	01 L2	03L2	02 L2	02L2
	0A0B0100 03010101 01010101 01010000	05 L3	01L3	01 L3	01L3
Tc=0 (DC table)	00000000 01020304 05060708 090A0B10	01 L4	01L4	03 L4	02L4
Th=0 Destination Identifier	00020103 03020403 05050404 0000017D	01 L5	01L5	03 L5	04L5
	01020300 04110512 21314106 13516107	01 L6	01L6	02 L6	04L6
	22711432 8191A108 2342B1C1 1552D1F0	01 L7	01L7	04 L7	03L7
	24336272 82090A16 1718191A 25262728	01 L8	01L8	03 L8	04L8
	292A3435 36373839 3A434445 46474849	01 L9	01L9	05 L9	07L9
	4A535455 56575859 5A636465 66676869	12	01L10	05 L10	05L10
	6A737475 76777879 7A838485 86878889		01L11	04 L11	04L11
	8A929394 95969798 999AA2A3 A4A5A6A7		12	04 L12	04L12
	A8A9AAB2 B3B4B5B6 B7B8B9BA C2C3C4C5			00 L13	00L13
	C6C7C8C9 CAD2D3D4 D5D6D7D8 D9DAE1E2			00 L14	01 L14
	E3E4E5E6 E7E8E9EA F1F2F3F4 F5F6F7F8			01 L15	02L15
	F9FA1100 02010204 04030407 05040400			7D L16	77L16
	01027700 01020311 04052131 06124151			162	162
	07617113 22328108 144291A1 B1C10923				
	3352F015 6272D10A 162434E1 25F11718				
	191A2627 28292A35 36373839 3A434445				
	46474849 4A535455 56575859 5A636465				
	66676869 6A737475 76777879 7A828384				
	85868788 898A9293 94959697 98999AA2				
	A3A4A5A6 A7A8A9AA B2B3B4B5 B6B7B8B9				
	BAC2C3C4 C5C6C7C8 C9CAD2D3 D4D5D6D7				
	D8D9DAE2 E3E4E5E6 E7E8E9EA F2F3F4F5				
	F6F7F8F9 FA				

**Figure 4.10: Jpeg Compressed Image showing Huffman table syntax**

## 4.6 Huffman table specification syntax



**Figure 4.11: Huffman table Specification syntax [4]**

The marker and parameters shown in Figure 4.11 are defined below:

**DHT:** Define Huffman table marker – Marks the beginning of Huffman table definition parameters.

**Lh:** Huffman table definition length – Specifies the length of all Huffman table parameters

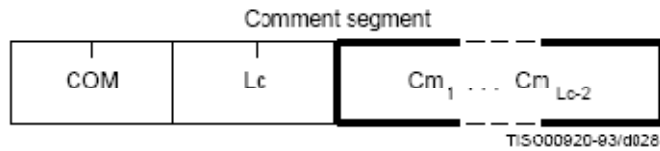
**Tc:** Table class – 0 = DC table or lossless table, 1 = AC table.

**Th:** Huffman table destination identifier – Specifies one of four possible destinations at the decoder into which the Huffman table shall be installed.

**Li:** Number of Huffman codes of length  $i$  – Specifies the number of Huffman codes for each of the 16 possible lengths allowed by this Specification.  $L_i$ 's are the elements of the list BITS.

**$V_{i,j}$ :** Value associated with each Huffman code – Specifies, for each  $i$ , the value associated with each Huffman code of length  $i$ . The meaning of each value is determined by the Huffman coding model. The  $V_{i,j}$ 's are the elements of the list HUFFVAL.

## 4.7 Comment marker syntax



**Figure 4.12: Comment Syntax [4]**

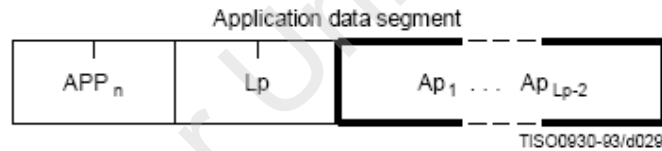
Figure 4.12 specifies the marker segment structure for a comment segment.

**COM:** Comment marker – Marks the beginning of a comment.

**Lc:** Comment segment length – Specifies the length of the comment segment

**Cmi:** Comment byte – The interpretation is left to the application.

## 4.8 Application marker syntax



**Figure 4.13: Application data syntax [4]**

The marker and parameters shown in Figure 4.13 are defined below.

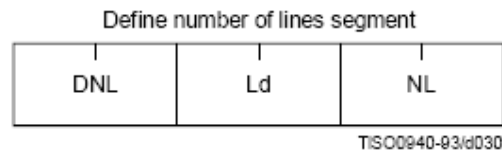
**APP<sub>n</sub>:** Application data marker – Marks the beginning of an application data segment.

**Lp:** Application data segment length – Specifies the length of the application data segment .

**Api:** Application data byte – The interpretation is left to the application.

**NOTE:-** The APPn (Application) segments are reserved for application use. Since these segments may be defined differently for different applications, they should be removed when the data are exchanged between application environments.

#### 4.9 Define number of lines syntax



**Figure 4.14: Define number of lines syntax [4]**

Figure 4.14 specifies the marker segment for defining the number of lines. The DNL (Define Number of Lines) segment provides a mechanism for defining or redefining the number of lines in the frame (the Y parameter in the frame header) at the end of the first scan. The value specified shall be consistent with the number of MCU-rows encoded in the first scan. This segment, if used, shall only occur at the end of the first scan, and only after coding of an integer number of MCU rows. This marker segment is mandatory if the number of lines (Y) specified in the frame header has the value zero.

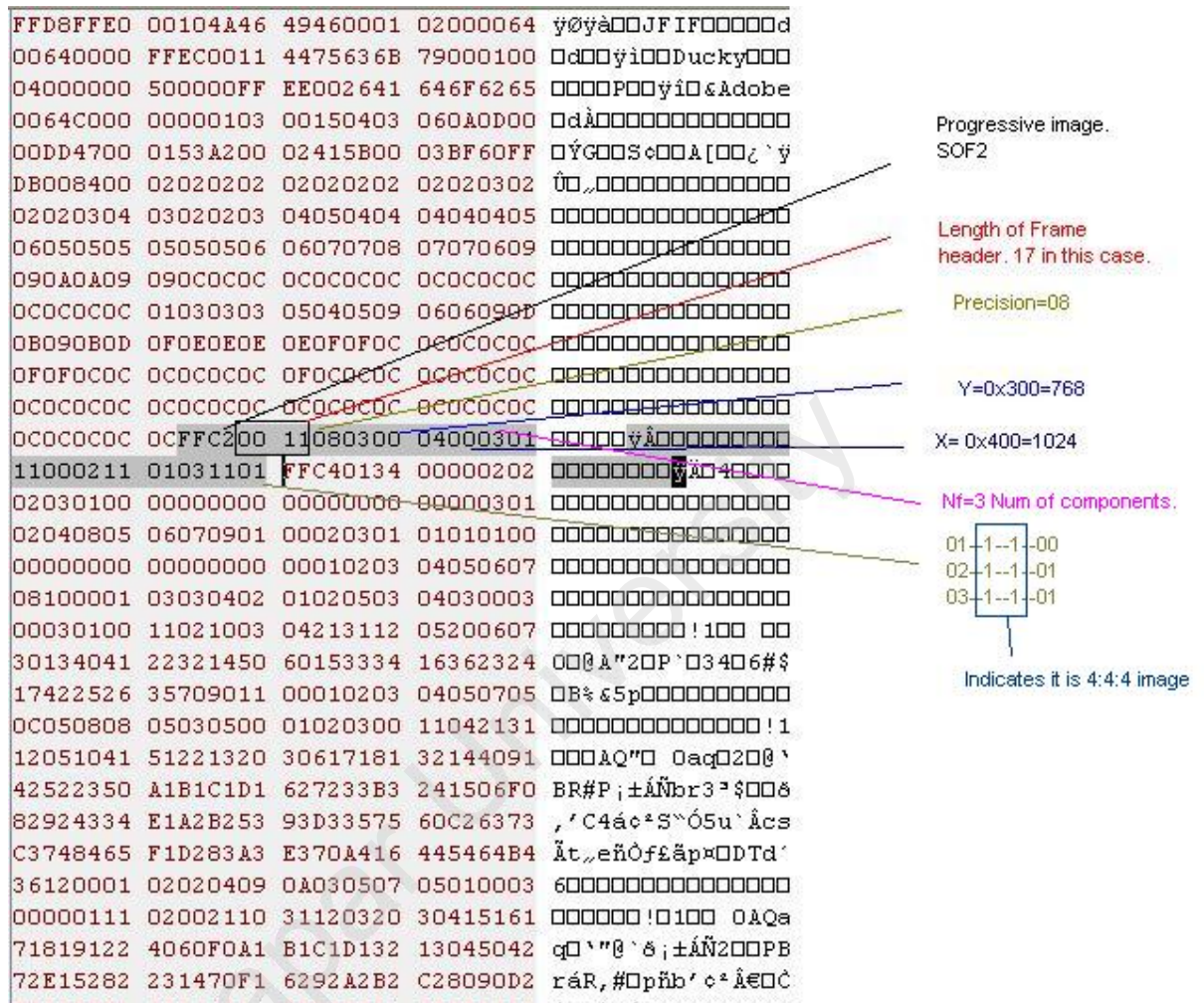
The marker and parameters shown in Figure 4.14 are defined below:

**DNL:** Define number of lines marker – Marks the beginning of the define number of lines segment.

**Ld:** Define number of lines segment length – Specifies the length of the define number of lines segment.

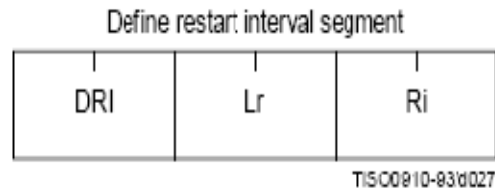
**NL:** Number of lines – Specifies the number of lines in the frame.

**EXAMPLE:**



**Figure 4.15: Jpeg Progressive Image with frame marker FFC2**

## 4.10 Restart interval definition syntax



**Figure 4.16 Restart interval definition syntax [4]**

The marker and parameters shown in Figure 4.15 are defined below.

**DRI:** Define restart interval marker – Marks the beginning of the parameters which define the restart interval.

**Lr:** Define restart interval segment length – Specifies the length of the parameters in the DRI segment shown in Figure 4.15

**Ri:** Restart interval – Specifies the number of MCU in the restart interval.

## 4.11 JFIF(JPEG File Interchange Format)

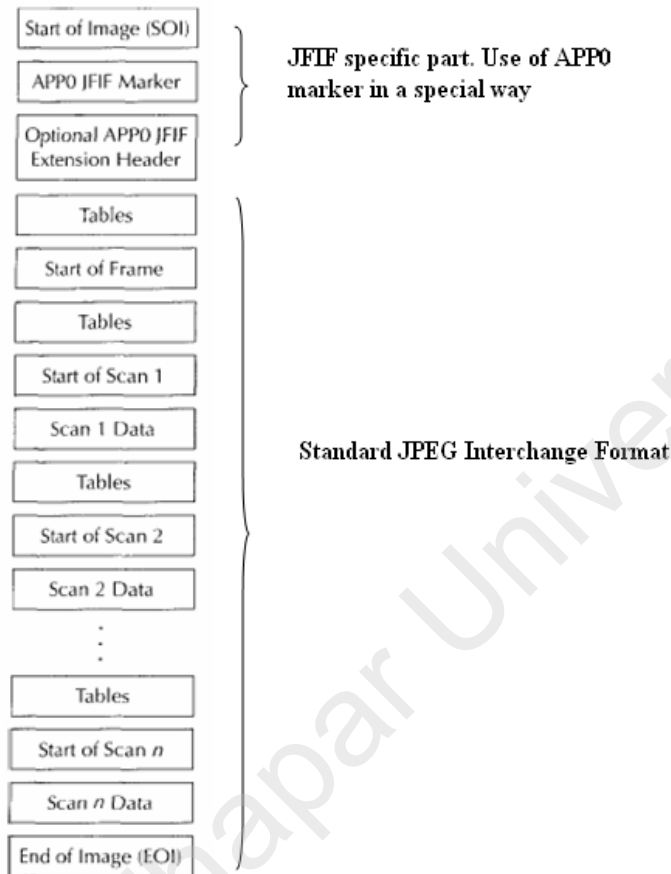
- Minimal File format for exchanging JPEG bit streams between a Wide variety of platforms and applications.
- Not much complex.
- In compliance with the JPEG interchange format defined in chapter 2 and 4.

### 4.11.1 Features of JFIF

- Uses JPEG compression (Stresses on using Baseline DCT).
- Uses JPEG interchange format compressed image representation.
- Standard color space: one or three components. For three components, YCbCr
- APP0 marker used to specify Units, X pixel density, Y pixel density, thumbnail.

- APP0 marker also used to specify JFIF extensions.
- APP0 marker also used to specify application-specific information.

#### 4.11.2 Format of JFIF file



**Figure 4.17 JFIF file format**

#### 4.11.3 JPEG File Interchange Format Specification

- JFIF file uses APP0 marker segments and constrains certain parameters in the frame header.
- JFIF file has JFIF marker header, JFIF extensions, Application specific headers followed by standard file format specified in chapter 4.

- For JFIF marker header APP0 marker should come immediately after SOI marker with “JFIF” string followed by 0.
- For JFIF extensions header APP0 marker should come immediately after JFIF marker header with “JFXX” string followed by 0.
- Application specific data or headers should follow immediately after above headers.
- If the decoder is not able to understand the application specific data it should ignore it and move further to decode.

#### 4.11.4 JFIF Marker Header Specification

X'FF', SOI

X'FF', APP0, length, identifier, version, units, Xdensity, Ydensity, Xthumbnail, Ythumbnail, (RGB)<sub>n</sub>

length	(2 bytes)	Total APP0 field byte count, including the byte count value (2 bytes), but excluding the APP0 marker itself
identifier	(5 bytes)	= X'4A', X'46', X'49', X'46', X'00' This zero terminated string (“JFIF”) uniquely identifies this APP0 marker. This string shall have zero parity (bit 7=0).
version	(2 bytes)	= X'0102' The most significant byte is used for major revisions, the least significant byte for minor revisions. Version 1.02 is the current released revision.
units	(1 byte)	Units for the X and Y densities. units = 0: no units, X and Y specify the pixel aspect ratio units = 1: X and Y are dots per inch units = 2: X and Y are dots per cm
Xdensity	(2 bytes)	Horizontal pixel density
Ydensity	(2 bytes)	Vertical pixel density
Xthumbnail	(1 byte)	Thumbnail horizontal pixel count
Ythumbnail	(1 byte)	Thumbnail vertical pixel count
(RGB) <sub>n</sub>	(3n bytes)	Packed (24-bit) RGB values for the thumbnail pixels, n = Xthumbnail * Ythumbnail

**Figure 4.18 JFIF Marker Header Specification**

## Chapter 5: Testing and results of Jpeg parser

---

This chapter describes the test framework, which was used for the design, test and implementation of the Jpeg parser.

### 5.1 A brief description of test framework:

The video test framework consists as a library of C++ objects and PERL scripts that ease the development of video tests. Video tests embed  $\mu$ C-OS kernel for making it multi-threaded.

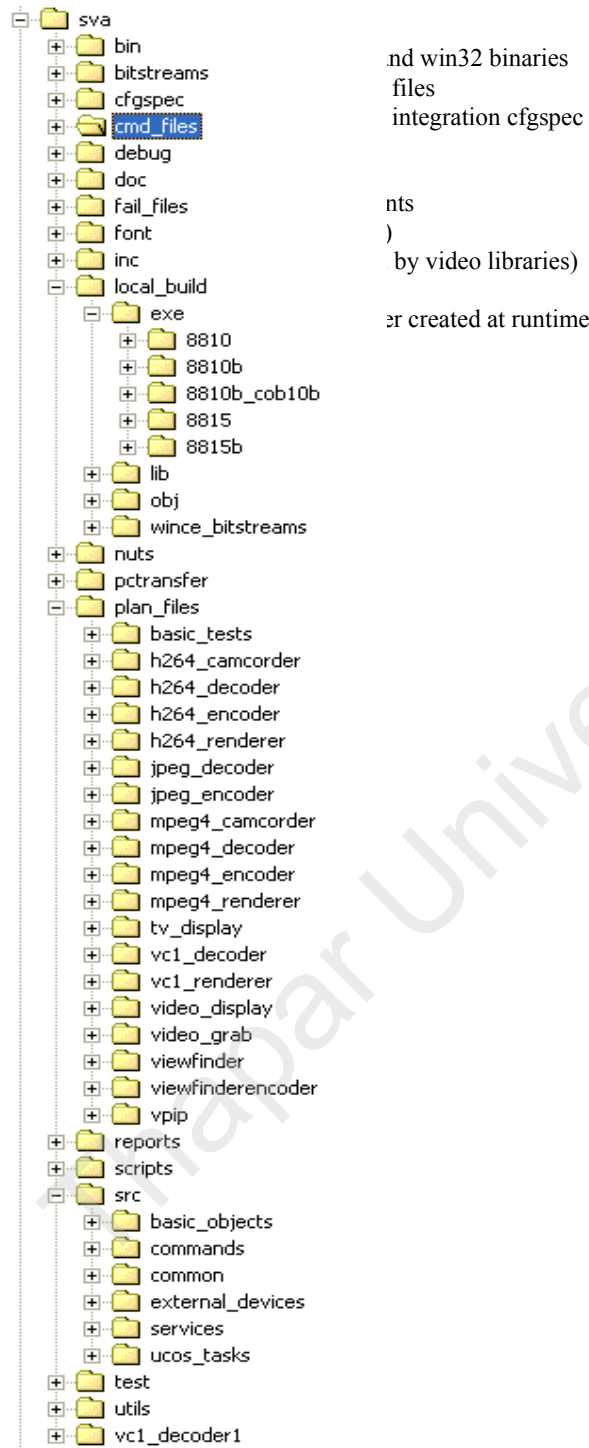
### 5.2 Path of the Test Framework:

The SVA HCL test framework is available under Clearcase MPU\_OSI vob. The test Framework is located in the following Clearcase location

`\MPU_OSI\tests\platform\st_pool\system\sva.`

The sva file tree is given below with their contents mentioned in front of them

`MPU_OSI\tests\platform\st_pool\system\sva → $ROOT_DIR`



**Figure 5.1: Path of the Test Framework**

### 5.3 Standard Architecture

This architecture enables video testing only. It is built on the HCL and service layers and is partitioned in  $\mu$ C-OS tasks. The motivations for using  $\mu$ C-OS operating system are

- The basic multi-tasking capability (despite several tasks cannot have the same priority)
- The conveniences it brings for timeout management.

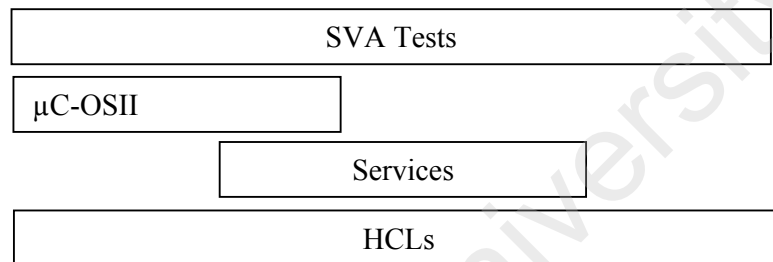
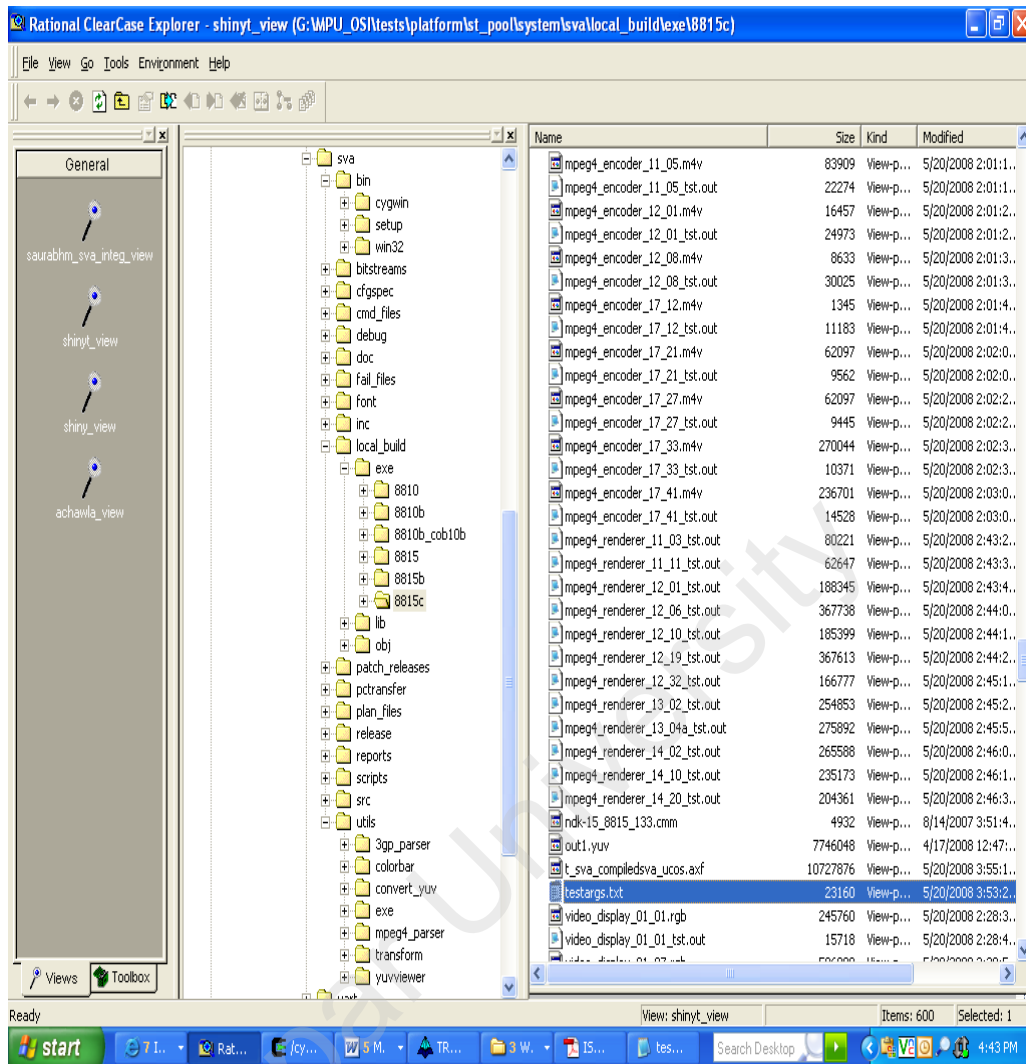


Figure 5.2: Software Layers for video testing (Standard architecture)

### 5.4 System Prerequisites:

#### 1. Rational Clearcase



In the prospect to compile and execute, the following vobs must be mounted:

**MPU\_OSI** // HCL, service, tests ...

**MPU\_TOOLS\_TEST** // CTE, avte, Nuts

**MPU\_uCOS-II** //  $\mu$ C-OSII sources

**JPEG\_DEC**

**JPEG\_ENC**

**MP4\_ARCH**

**MPEG4\_DEC**

**Bit streams** // h263, mp4 bit stream patterns

**sequences\_\*** // uncompressed patterns (YUV)

## 2. ARM Development Tool Chain

The ARM RVCT tool chain must be installed. RVCT2.2 [Build 559] is currently used. Trace32 must be installed for loading image, executing and debugging purpose

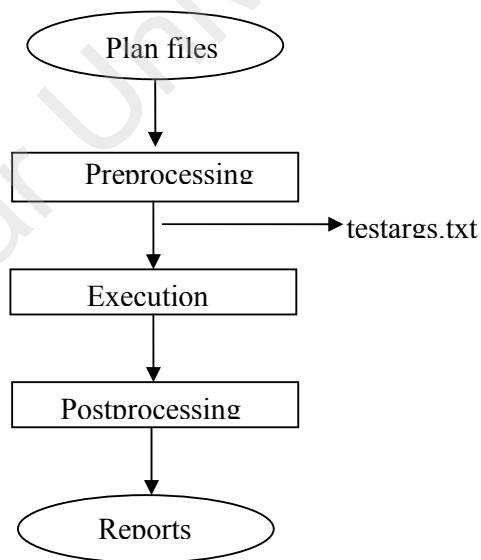
3. Perl must be installed. Perl v4.8.6 built for MSWin32-x86-multi-thread is currently used.

4. GNU make 3.81 is used to compile.

4. Cygwin usage is advised. It is required to generate prerequisites automatically with gcc -M and sed. However this feature is not mandatory. Also more make file targets are available. Cygwin package is available at the following URL: <http://www.cygwin.com/>.

5. Setups Logs, reports and documentation are generated in the \$SVA\_LOG\_DIR location. This variable MUST be defined prior invoking Perl scripts (example; c:\DATA\sva\_tests) as an environment variable

## 5.5 Flow of test framework

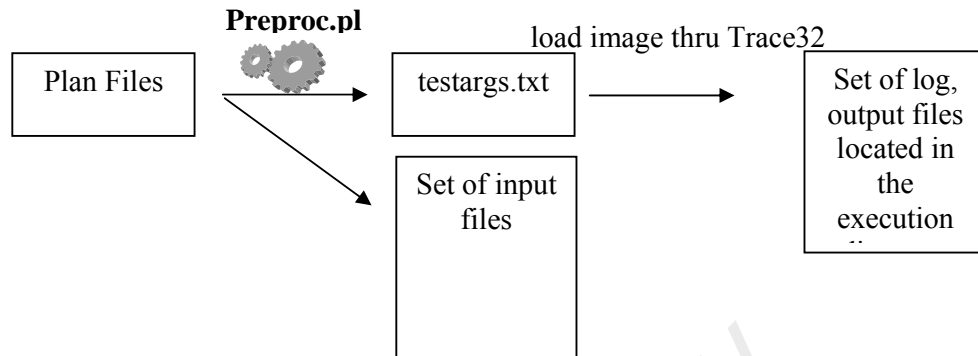


**Figure 5.3: Flow of test framework**

### 5.4.1 Preprocessing Phase

The ARM embedded software does not directly read the plan-file but another file named **testargs.txt**. The preprocessing phase takes as input one or several plan-files located in the *\$ROOT\_DIR/plan files* directory and generates this *testargs.txt* file,

located in the execution directory (i.e.  $\$ROOT\_DIR/\$PLATFORM/\$TARGET$ ). The preprocessing action is performed by a Perl script located in  $\$ROOT\_DIR/scripts$ , called *preproc.pl*.



**Figure 5.4 Preprocessing phase**

#### 5.4.2 Execution Phase

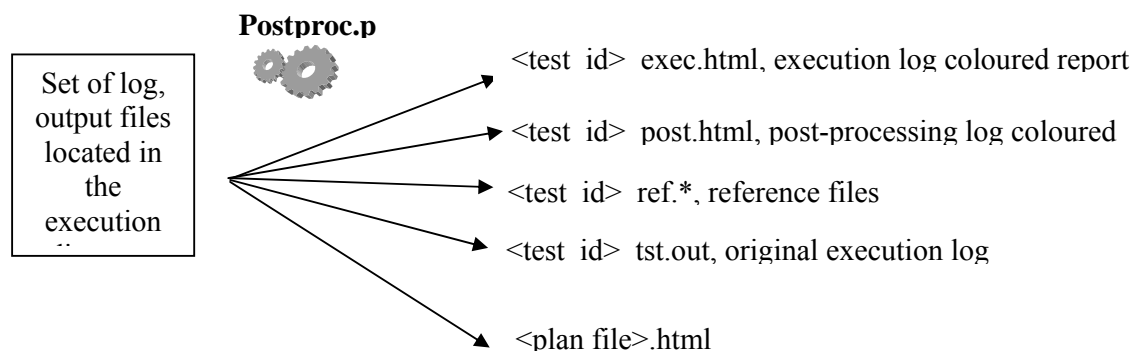
The execution on the board is launched manually thru Trace32 or by invoking the command:

```
axd <platform>/exe/<target>/t_sva_all_ucos.axf.
```

The main is aimed at executing all the tests of a the “testargs.txt” resulting from the pre-processing phase.

All outputs of the execution remain in the execution directory.

#### 5.4.3 Post processing Phase



**Figure 5.5 Post processing phase**

The post-processing phase is run by the *postproc.pl* Perl script located in *\$ROOT\_DIR/scripts*. It takes as input plan-files and performs for each line (i.e. each test function) the relevant post processing tasks.

First, it moves outputs from the execution area to the log area (whose root is *\$SVA\_LOG\_DIR*). It also analyzes the logs and generates a html report that synthesizes the results of the plan-file execution. After the post-processing phase, the execution area is voided from all plan-file execution logs and outputs.

The post processing actions can be split into 3 steps:

The execution logs analysis.

The file tree check.

The functional post-processing

### The report generation

A test is passed if the 2 following conditions are true

- No error occurred during the execution and the test completed normally
- All expected output files are found and the test performed the expected function (functional checks)

Post-processing Steps	Purpose	Output
execution log analysis	No error occurred during execution and test completed	A colorized execution log <TestId>_exec.html
file tree check and functional post-processing	All expected output files are found and the test performed the expected function	\$LOG_DIR/<TestId>_post.html

**Figure 5.6: Purpose and outputs of the post-processing steps**

Phase 1 is test independent whereas Phase 2 fully depends on the test execution being

post-processed. During the file tree checks, all the output and log files are moved from the execution directory (\$RUN\_DIR) to the log area (\$LOG\_DIR).

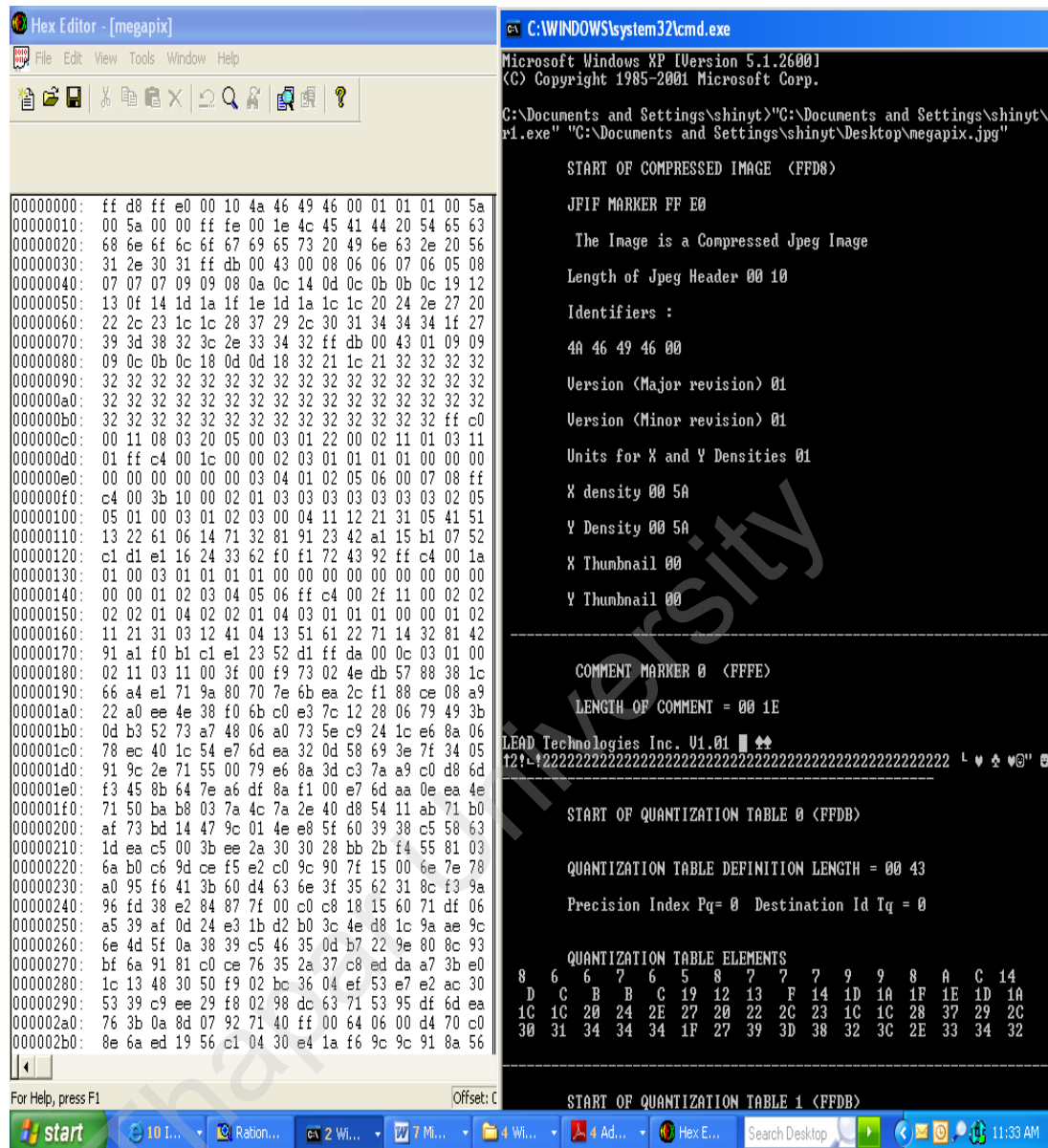
At the end of all post-processing actions, an html report is generated that synthesizes the results of all the tests listed in the plan-file. It is named <plan file>.html. And located in the \$REPORT\_DIR.

## 5.6 Parsing the Jpeg header

A jpeg image megapix is taken as an example and its parsed view is shown as results in this section



**Figure 5.7 Example of JPEG image**



**Figure 5.8: Parsed Jpeg Image**

The following image shows

- i. Start of image marker FFD8
- ii. Application marker FFE0
- iii. Comment marker FFFE
- iv. Quantization table 0 FFDB



**Figure 5.9: Parsed Jpeg Image**

The following image shows

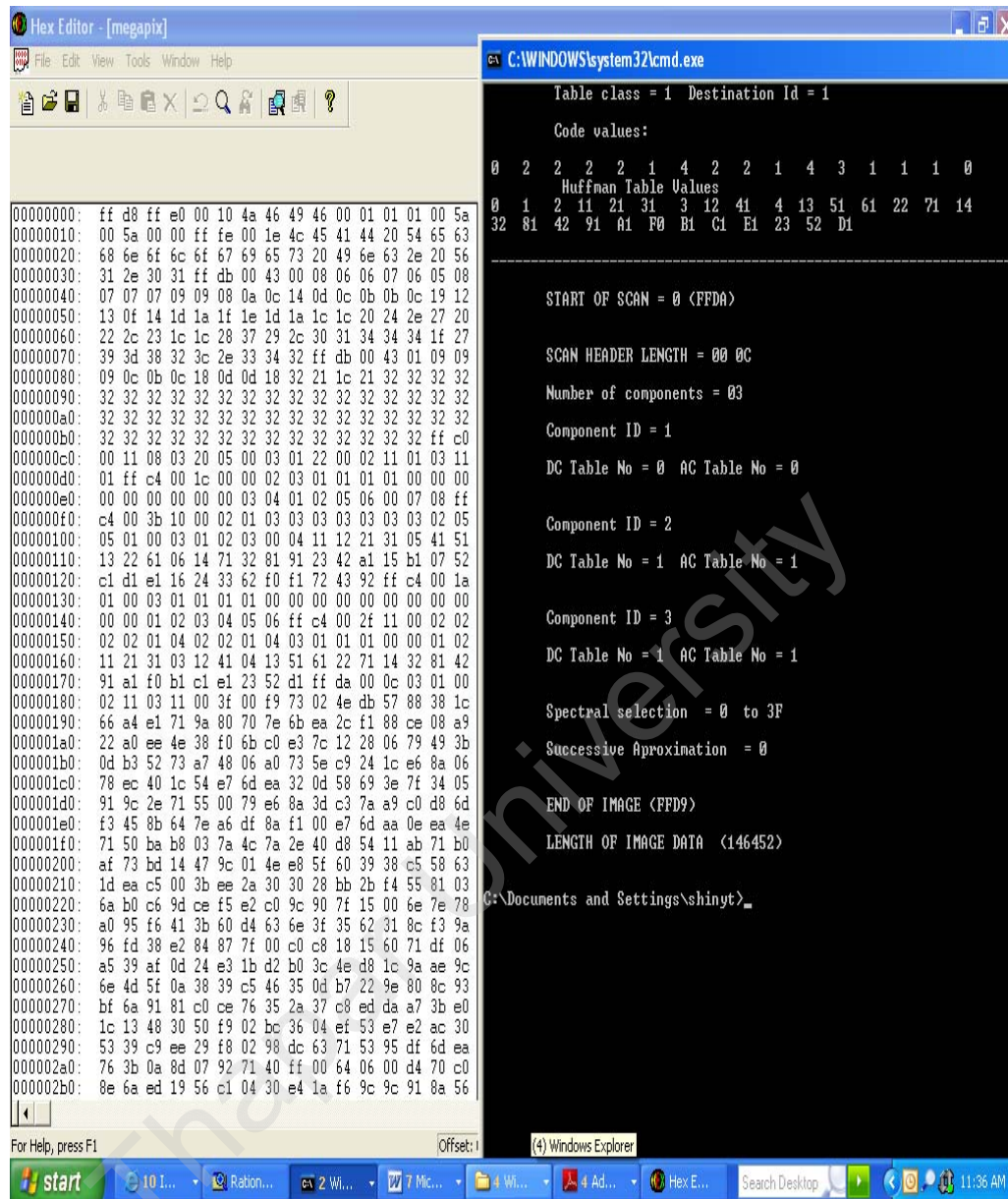
- i. Quantization table 1
- ii. Start of Frame marker FFC0 ( Baseline mode)



**Figure 5.10: Parsed Jpeg Image**

The following image shows

- i. **Huffman Table 0 FFC0**
- ii. **Huffman Table 1**
- iii. **Huffman Table 2**
- iv. **Huffman Table 3**



**Figure 5.11: Parsed Jpeg Image**

The following image shows

- i. Start of Scan marker FFDA
- ii. End Of Image marker FFD9
- iii. Length of Image data in bytes

## Chapter 6: Conclusions and Future Work

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In this thesis the main objective was to study how eCRM concept is being carried out in today's world, how eCRM has become a vital ingredient for the survival of companies nowadays. eCRM consists of helping an enterprise to enable its marketing departments to identify and target their best customers, manage marketing campaigns with clear goals and objectives, and generate quality leads for the sales team. It assists the organization to improve telesales, accounts, and sales management by optimizing information shared by multiple employees, and streamlining existing processes.

From Case study 1, i.e. of CDUNIVERSE.com we conclude that in commercial world the importance of retaining existing Customers is utterly important for the firms. The costs associated with finding new customers means that every customer could be important. Companies, increasingly under pressure to grow, are now looking to improve their CRM through a greater use of technology. CDUNIVERSE.com followed the same approach. CDUniverse a leading Internet retailer specializing in the sale of domestic and imported music CDs and Imports, movies and video games to customers all over the world offers everyday low prices and a selection of product that is unmatched. CDUniverse has been honored for their exemplary customer service and satisfaction year after year receiving awards such as the Bizrate Circle of Excellence in addition to top customer ratings on Yahoo Shopping, Shopping.com, Shopzilla.com and many more [9].

Its different features like

1. Selection and Pricing.
2. Superior Service
3. Safe & Secure make the shopping for the customers an entirely different and wonderful experience.

From Case study 2 dealing with Multimedia framework it can concluded that after the basic process of encoding (compression), the compressed image consists of an ordered collection of parameters, markers, and entropy-coded data segments. The basic Objective of this thesis work has been to design a tool which can read the header

of compressed Jpeg files which further helps in loading the image data needed for viewing the Jpeg files and which helps in decoding process by passing the quantized DCT coefficients to the decoder.

A good multimedia framework must offer an intuitive API and a modular architecture to easily add support for new codec or container formats. It is meant to be used by applications such as media players and audio or video editors. This feature leads to enhance the customer relations.

Therefore to view the compressed Jpeg image, it is necessary to read the header information from the compressed image and with the help of the tool explained in this thesis report, reading the Jpeg header has become a simpler task. The Internet has had a great impact on business and society all over the globe, enabling more and more organizations to become networked and share resources. Supply chain management, customer relationship management, selling Chain Management, Business Intelligence are the emerging areas causing transformations in the way business is conducted now. In this changing scenario organizations have to follow the examples of CDUniverse.Com and ST Application Processor to emerge as winners in CRM.

The future work of this thesis work would include

1. Building a more comprehensive e-CRM model – one that relies not only on call centers and leading-edge software to provide detailed information about customers, but also on mobile, wireless and Web-based systems. By developing a more holistic, seamless and integrated approach, organizations are improving the quality of customer sales and service as CRM becomes pervasive – moving from the desktop to the palmtop.
2. Creating tool for the investigation of compressed video data that has been encoded using the H.264/AVC, MPEG-4, MPEG-2, H.263+, H.263, and H.261 video standards.

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