Figure B.2 – Syntax for sequential DCT-based, progressive DCT-based, and lossless modes of operation
Control and Data Structure

- Two classes of segments:
  - Entropy coded segments: data
  - Marker segments: headers, tables and other general information

- Markers start with a unique two-byte code.

A typical image data stream
Interchange/Abbreviated Data Formats

3 formats for JPEG compressed data:

• Interchange format for compressed data: includes all required tables (for the decoder)

• Abbreviated format for compressed data: may omit some or all tables (decoder must have them some other way)

• Abbreviated format for table specification: only tables are sent (no frames, entropy coded data etc.)
Image Data Ordering

• **Internal representation:**
  – Upto 255 unique components for each image
  – Each component is represented as a rectangular array of samples
  – All processing of those rectangulars are from left to right, top to bottom

• Those are merely convenience, except the rectangular array which **must** be.
Data Units

- For **lossless modes**: arrays are processed sample at a time, left-to-right, top-to-bottom
- For **DCT modes**: a block of 8x8 samples is a basic unit
- **Minimum Coded Units (MCU)**, are groups containing interleaved/non-interleaved data from different components (if more than one).
- Each block is 8x8 samples
- The preceding DC value is always the predictor for the current one (first is 0)
## Data units ordering example:

<table>
<thead>
<tr>
<th>Component block</th>
<th>MCU</th>
<th>Component block</th>
<th>MCU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Interleaved data units</td>
<td></td>
<td>Horizontally Interleaved</td>
<td></td>
</tr>
<tr>
<td>Scan 1:</td>
<td>Y1 1</td>
<td>Scan 1:</td>
<td>Y1 1</td>
</tr>
<tr>
<td></td>
<td>Y2 2</td>
<td></td>
<td>Y2 1</td>
</tr>
<tr>
<td></td>
<td>.</td>
<td></td>
<td>Cb1 1</td>
</tr>
<tr>
<td></td>
<td>Y8 8</td>
<td></td>
<td>Cr1 1</td>
</tr>
<tr>
<td>Scan 2:</td>
<td>Cb1 1</td>
<td></td>
<td>.</td>
</tr>
<tr>
<td></td>
<td>.</td>
<td></td>
<td>.</td>
</tr>
<tr>
<td></td>
<td>Cb4 4</td>
<td></td>
<td>Y7 4</td>
</tr>
<tr>
<td></td>
<td>.</td>
<td></td>
<td>Y8 4</td>
</tr>
<tr>
<td>Scan 3:</td>
<td>Cr1 1</td>
<td></td>
<td>Cb4 4</td>
</tr>
<tr>
<td></td>
<td>.</td>
<td></td>
<td>Cr4 4</td>
</tr>
<tr>
<td></td>
<td>Cr4 4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Marker Definitions

• Each marker segment begins with X’FF and a non-zero one byte ‘marker code’ to identify its function.

• An occasionally created X’FF (in the entropy coded data) is followed by a stuffed zero byte.

• All marker segments and entropy coded segments contain an integer number of bytes, so in Huffman coding one-bits used to pad data to achieve byte alignment for the next marker.
Start-of-Frame (SOF) Markers

For example: Huffman coded frames:

\[\text{SOF}_0 \quad \text{X'}\text{FFC0} \quad \text{Baseline DCT}\]
\[\text{SOF}_1 \quad \text{X'}\text{FFC1} \quad \text{Extended Sequential DCT}\]
\[\text{SOF}_2 \quad \text{X'}\text{FFC2} \quad \text{Progressive DCT}\]
\[\text{SOF}_3 \quad \text{X'}\text{FFC3} \quad \text{Lossless (Sequential)}\]

....

\[\text{SOF}_{15} \quad \text{X'}\text{FFCF} \quad \text{Differential Lossless (Arithmetic Coding)}\]
Non-SOF Markers

- **APP** X’FFE0 - X’FFEFEF Reserved for application use
- **DHT** X’FFC4 Define Huffman table
- **DQT** X’FFD4 Define Quant. table
- **SOS** X’FFDA Start of Scan

- (About 20 non-SOF markers)
Structure of Compressed Data

- Example of non-hierarchical data:
# Frame Header

- **Frame**: Basic attributes of the image

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame header length</td>
<td>16 bits</td>
</tr>
<tr>
<td>Sample precision</td>
<td>8</td>
</tr>
<tr>
<td>Number of lines</td>
<td>16</td>
</tr>
<tr>
<td>Number of samples/line</td>
<td>16</td>
</tr>
<tr>
<td>Number of components</td>
<td>8</td>
</tr>
</tbody>
</table>

**Frame component specification**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identifier</td>
<td>8</td>
</tr>
<tr>
<td>Horiz. sampling factor</td>
<td>4</td>
</tr>
<tr>
<td>Vertical sampling factor</td>
<td>4</td>
</tr>
<tr>
<td>Quantization table</td>
<td>8 (4 optional tables)</td>
</tr>
</tbody>
</table>
Scan Header

- Many scans can occur in a frame
- If scan has only one component than data is non-interleaved (MCU contains one data unit)
- If more than one component - interleaved data
- Components are always coded independently
- **Scan parameters are:** Number of components, DC and AC entropy coding table, Spectral selection and successive approximation parameters etc.
Number of Data Units in MCU

- Data Unit = Block or samples (in lossless)
- If more than one component in a scan, the total number of data units in the MCU up to 10 units.
- Any combination of components and sampling factors that gives more than 10 is forbidden.
Other Markers

- Define Huffman Table (DHT) segment
- Arithmetic Conditioning table (DAC) segment
- Quantization table (DQT) segment
- Restart interval (DRI) segment
Web sites & Reviews

- Official site of JPEG group:
  http://www.jpeg.org/
- JPEG FAQ:
  http://www.faqs.org/faqs/jpeg-faq/

Wallace, K. Gregory,
The JPEG Still Picture Compression Standard,

Furht B.
A Survey of Multimedia Compression Techniques and Standards.
Part I: JPEG Standard, Journal of Real-Time Imaging,