



# Digital Imaging and Communications in Medicine (DICOM) - PS3.0-2015c

National Resource Centre for EHR Standards(NRCeS)

C-DAC, Pune

# What is DICOM?



- The standard for Digital Imaging and Communications in Medicine.
- Developed by the National Electrical Manufacturers Association (NEMA) in conjunction with the American College of Radiology (ACR).
- To handle developing network and image standards, a new standard DICOM, was proposed in 1981.
- Covers most image formats for all of medicine.
- Specification for messaging and communication between imaging machines.

# Why DICOM Standard?



- Single file format accommodating textual and imaging information.
- DICOM enables digital communication between diagnostic and therapeutic equipment and systems from various manufacturers.
- For physicians, anywhere access to images and reports
- For patients, it provides cost-effectiveness in health care.

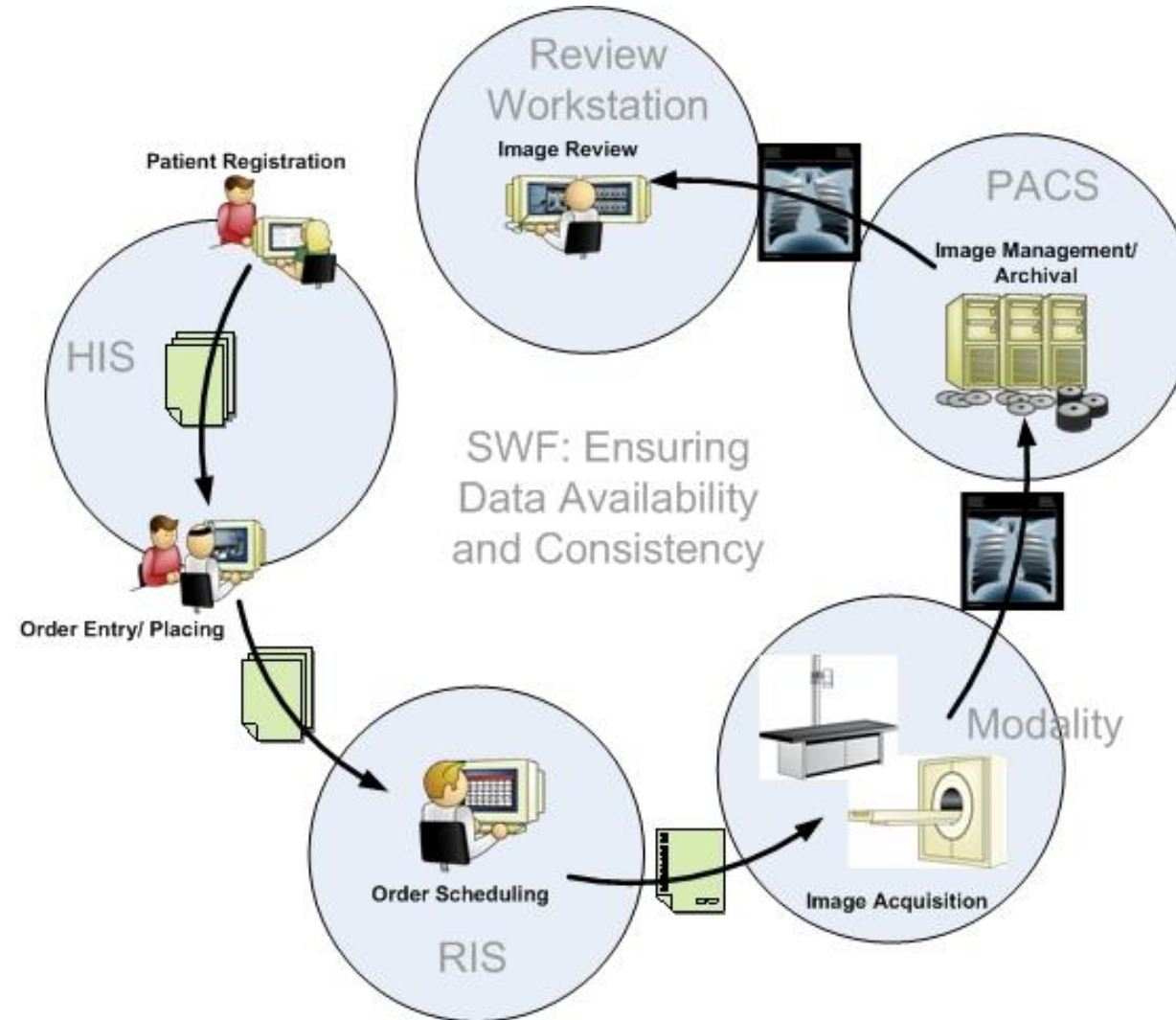
- Its goal in developing a standard was
  - To enable users to retrieve images and associated information from digital imaging equipment in a standard format using **point-to-point** connection.
  - To hide differences same across multiple image equipment manufacturers.

- DICOM not only defines the imaging file format but also the different services which makes the clinical workflow complete.
- The communication in DICOM is build on top of TCP/IP layer.

- The ability of two or more systems or components to exchange information and to use the information that has been exchanged.
- All modern medical imaging systems, Equipment like X-Rays, Ultrasounds, CT (Computed Tomography), and MRI (Magnetic Resonance Imaging) support DICOM and use it extensively.

- The ability of modern imaging equipment to seamlessly collaborate and integrate together in a multi-vendor environment is the most notable achievement of DICOM that led to a great advancement in medical imaging.
- DICOM image exchange technology, they can more accurately transmit, print and store images and files.

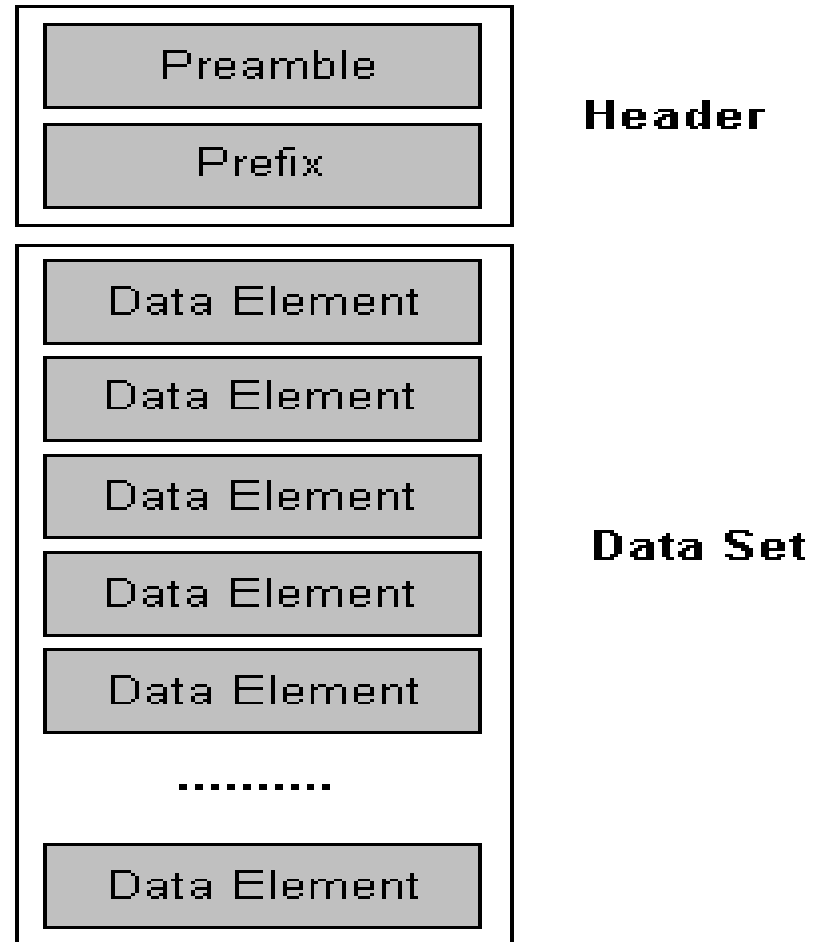
# DICOM in Healthcare Workflow





- The DICOM header includes
- Preamble
- DICM prefix
- Pinch of DICOM file attributes (Data elements)

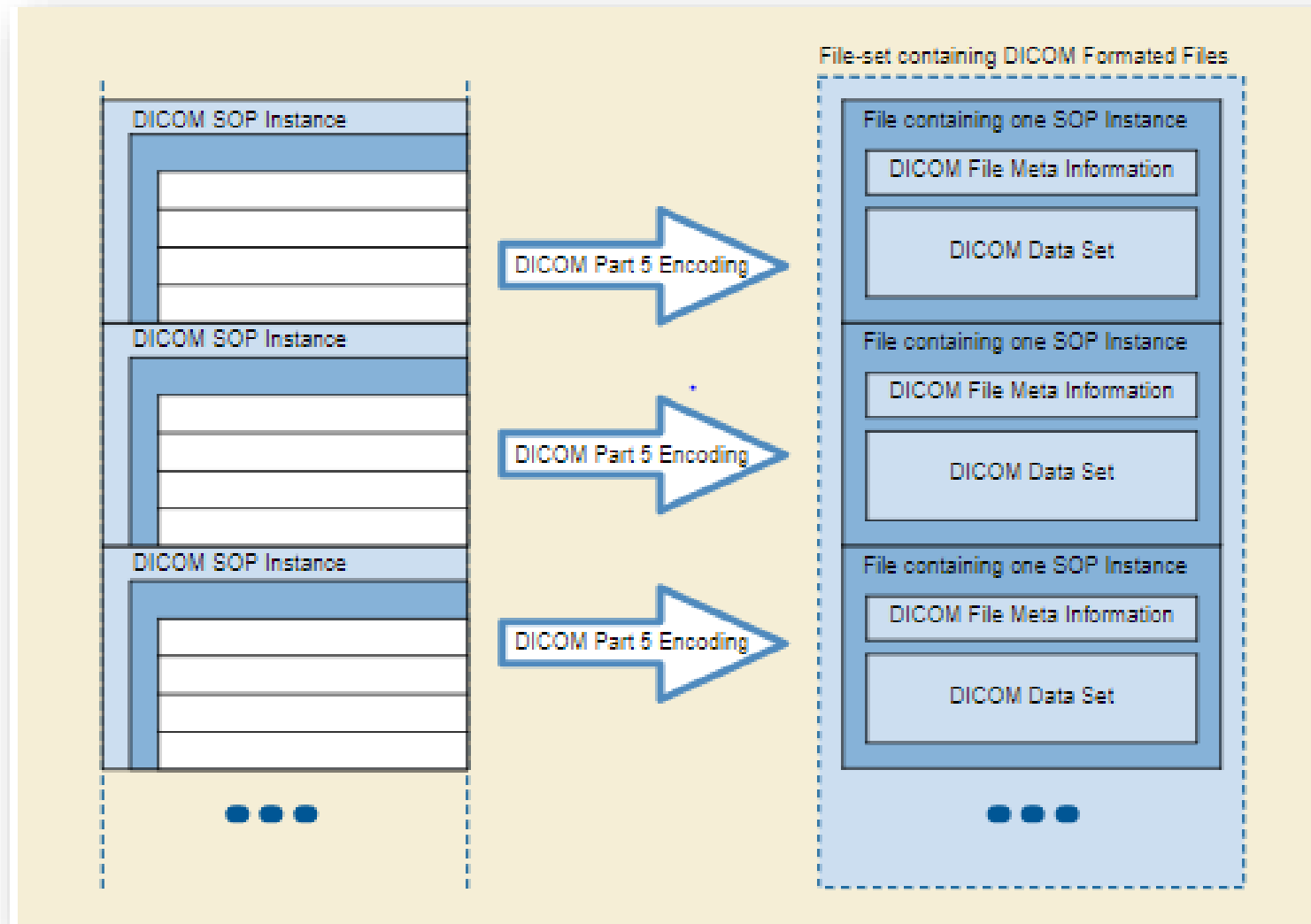
# DICOM File Structure



- The preamble is a string of 128 bytes, which opens any DICOM file.
- Available for Application Profile or implementation specified use. If not used by an Application Profile or a specific implementation all bytes shall be set to 00H.
- The use of a preamble is common in many imaging and data formats (consider TIFF images, for example), and DICOM adapted the same style.
- However, the DICOM standard does not define any particular preamble structure or content.
- It is intended to facilitate access to the images and other data in the DICOM file by providing compatibility with a number of commonly used computer image file formats.

- The DICM prefix (indicating the DICOM file format) follows the 128-byte preamble verbatim. It simply consists of the four uppercase letters (D I C M) written into bytes 129–132
- Neither the preamble nor the DICM prefix use DICOM VR encoding rules. They are simply stored in the first  $128 + 4 = 132$  bytes.
- If you are writing a program to identify DICOM files, make it skip the first 128 bytes, and then verify the DICM prefix.

# File-set and File Format



## DICOM Message

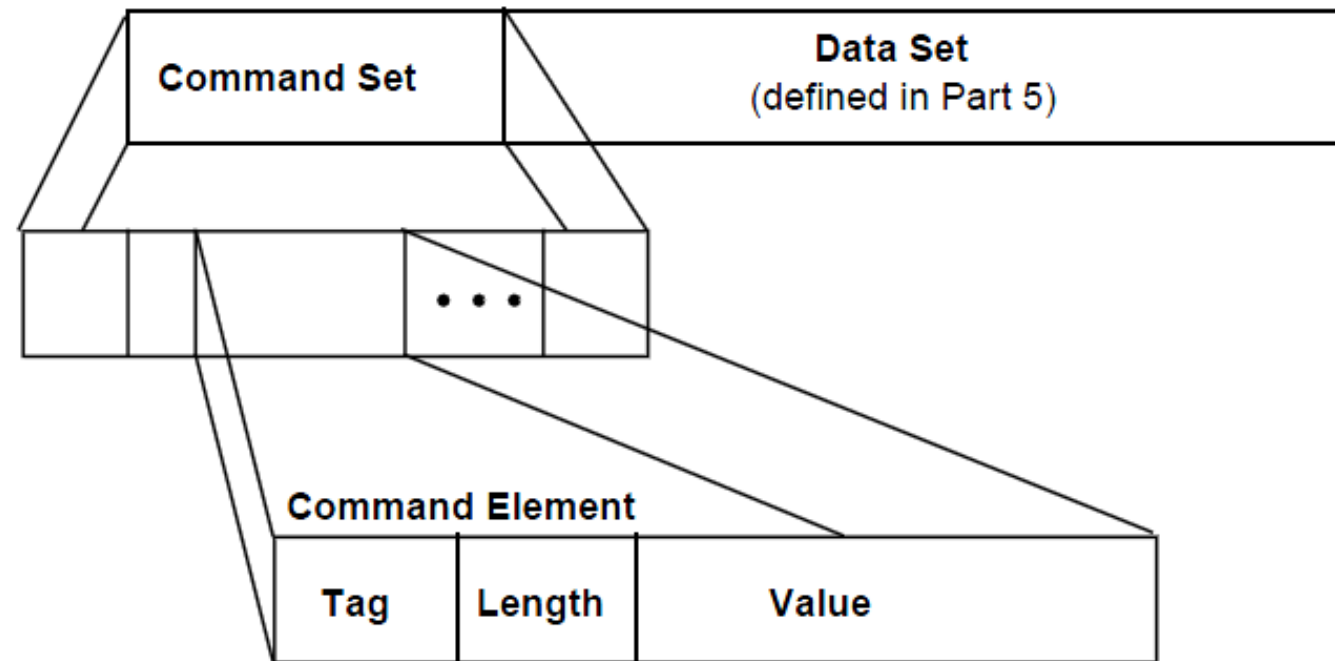


Figure 6.3-1  
DICOM MESSAGE STRUCTURE

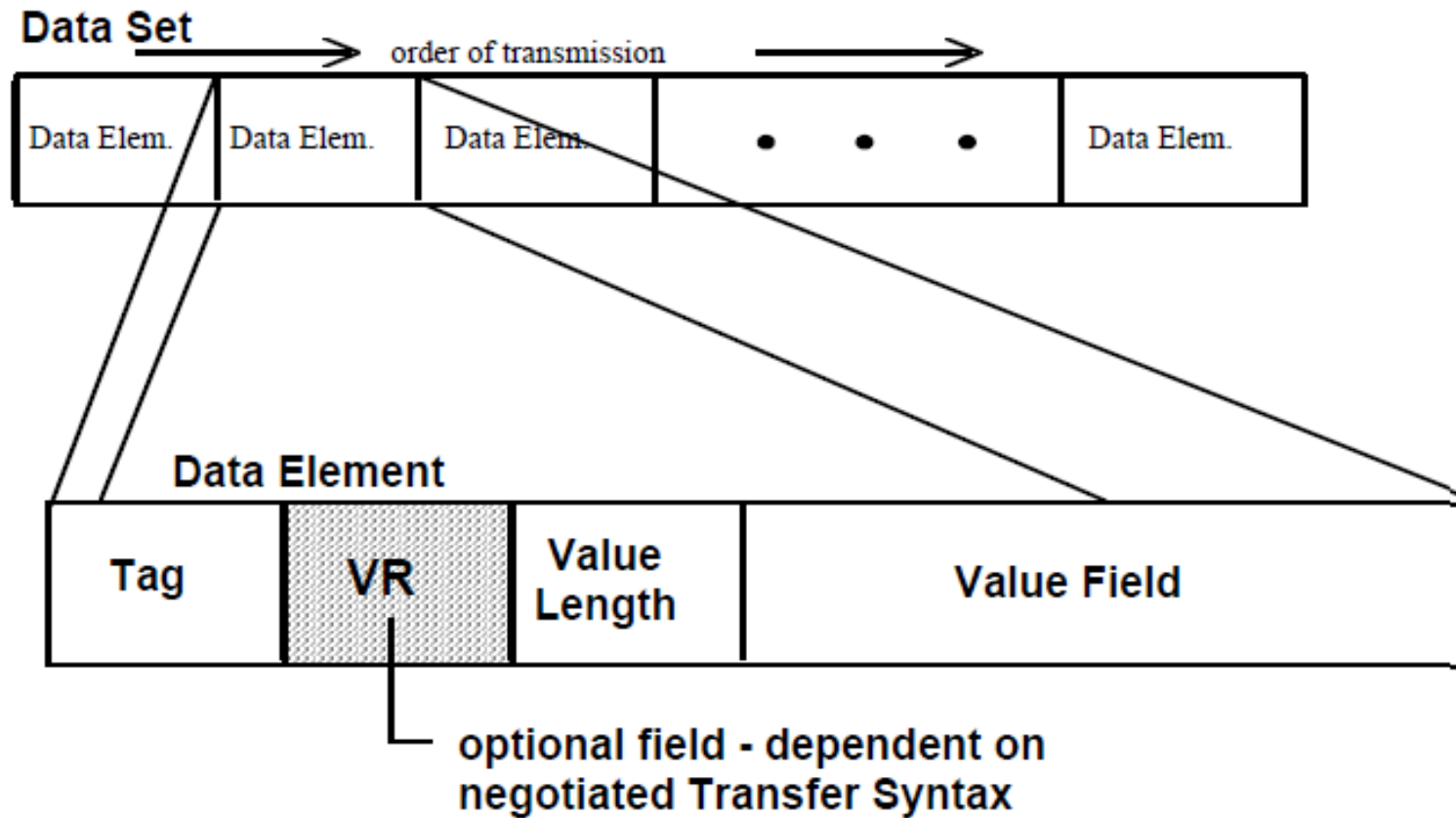
- The Command Elements in a Command Set shall be ordered by increasing Command Element Tag number.
- A Command Element Tag uniquely identifies a Command Element and shall occur at most once in a Command Set.
- The encoding of the Command Set shall be Little Endian Byte Ordering.
- Private Command Elements can not be defined.

## What is Data Set ?

- A Data Set represents an instance of a real world Information Object.
- A Data Set is constructed of Data Elements.
- Data element is an atomic unit of data that has precise meaning or precise semantics.



# Data Set and Data Element Structure



- **Data Element Tag** – Unique identifier (**4 bytes**)

It is composed of Group Number and Element Number

For example, in (0010,0020) tag the Group Number is 0010 and the Element Number is 0020.

- **VR** – Value representation describes the type of data (2 byte)
- **Value Length** – Either a 16 or 32-bit containing the Length of the Value Field .It does not include the length of the Data Element Tag, Value Representation, and Value Length Fields.
- **Value Field** – Even number of bytes containing the value.
- **Data Element Types** –
  - Explicit Data Element
  - Implicit Data Element

# Structure of Explicit Data Element



Tag		VR	Value Length	Value
Group Number (16-bit unsigned integer)	Element Number (16-bit unsigned integer)	VR (2 byte character string)	(16-bit unsigned integer)	Even number of bytes containing the Data Element Value(s) encoded according to the VR and negotiated Transfer Syntax.
2 bytes	2 bytes	2 bytes	2 bytes	'Value Length' bytes

# Structure of Implicit Data Element



**Data element with implicit VR**

Tag		Value Length	Value
Group Number (16-bit unsigned integer)	Element Number (16-bit unsigned integer)	32-bit unsigned integer	Even number of bytes containing the Data Elements Value encoded according to the VR specified in PS 3.6 and the negotiated Transfer Syntax. Delimited with Sequence Delimitation Item if of Undefined Length.
2 bytes	2 bytes	4 bytes	'Value Length' bytes or Undefined Length

# How DICOM Data Set is created ?



- From data elements is the only way to do it .
- But with around 2000 data elements in the DICOM Data Dictionary how can it be possible?
- How DICOM Data Set is created?

Some MR Related Data Elements +

Some CT Related Data Elements +

X-Ray Image = DICOM Data Set

?

NO

# Building blocks of DICOM Data Set



- Data Elements are the smallest building block in the DICOM World.
- In order to avoid such mixing of Data Elements , some larger building blocks should be define to process DICOM Image.
- These Building blocks are Modules, Information Entities and IODs.
- These all are hierarchical .
- Modules form IEs, and these IEs is used to build IODs.

- All real-world data – patients, studies, medical devices, and so on – are viewed by DICOM as objects .
- These objects and attributes are standardized according to DICOM Information Object Definitions (IODs).
- The Patient Identification Module is always mandatory for any DICOM modality; we cannot have a digital image without knowing who it belongs to.
- DICOM classifies IODs as
  - Normalized IODs
  - Composite IODs

- Normalized IOD represents a single, real-world entity just as our Patient IOD represents a patient.
- The DICOM Study IOD, for example, is Normalized and contains only inherent study properties such as study date and time.
- When an instance of a Normalized IOD is communicated, the context for that instance is not exchanged .



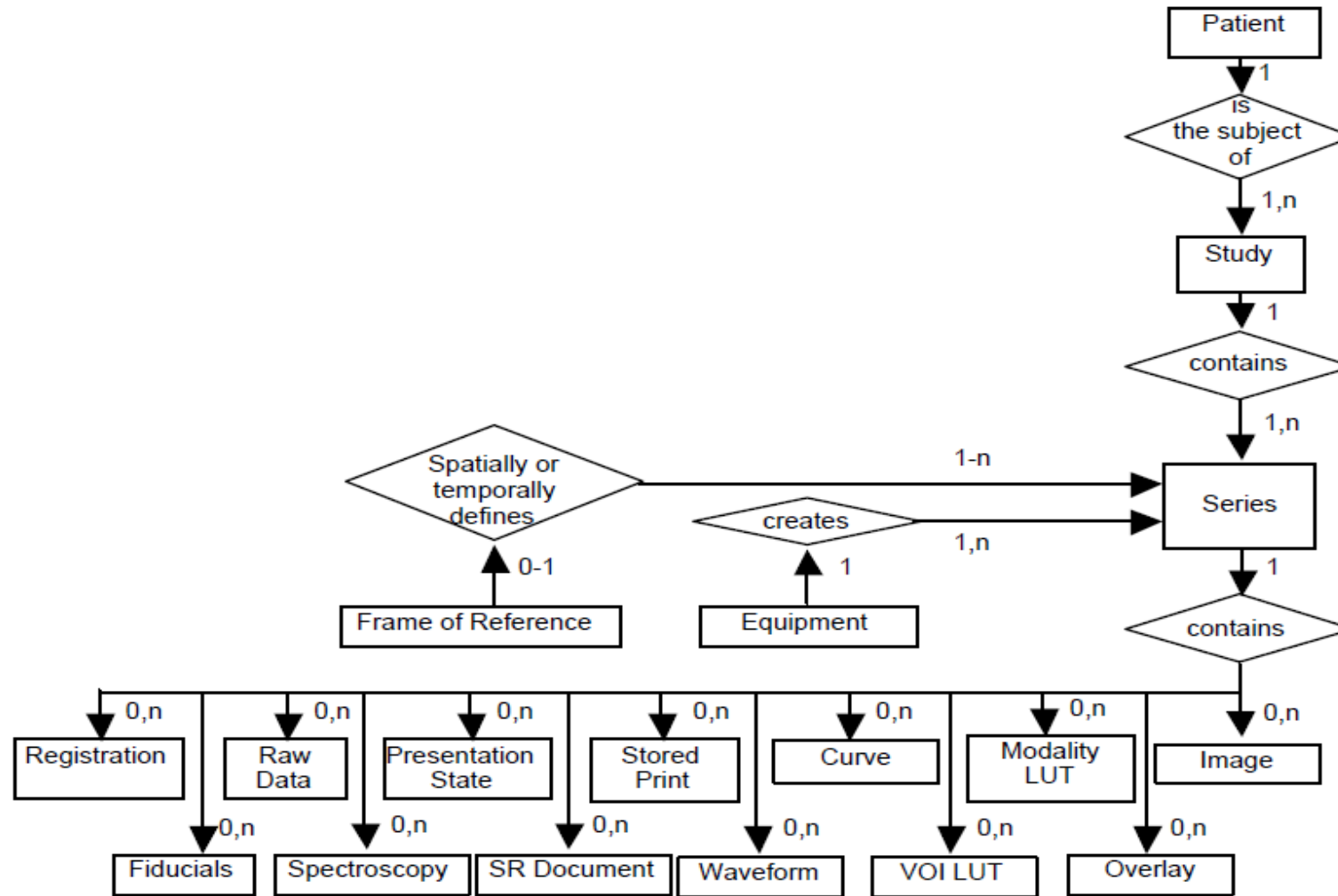
- Composite IODs are combination of several real-world entities or their constituent parts.

**For Example :**

Consider a CT image IOD, for example: in DICOM this IOD will contain some of the patient attributes (name, ID, and so on to identify the patient this image belongs to) along with attributes of the CT scanner, patient study, and more.

- These related Real-World Objects provide a complete context for the exchanged information. When an instance of a Composite IOD is communicated, this entire context is exchanged between Application Entities. Relationships between Composite IOD Instances shall be conveyed in this contextual information.

# Composite Instance Information model



# DICOM Message Service Element



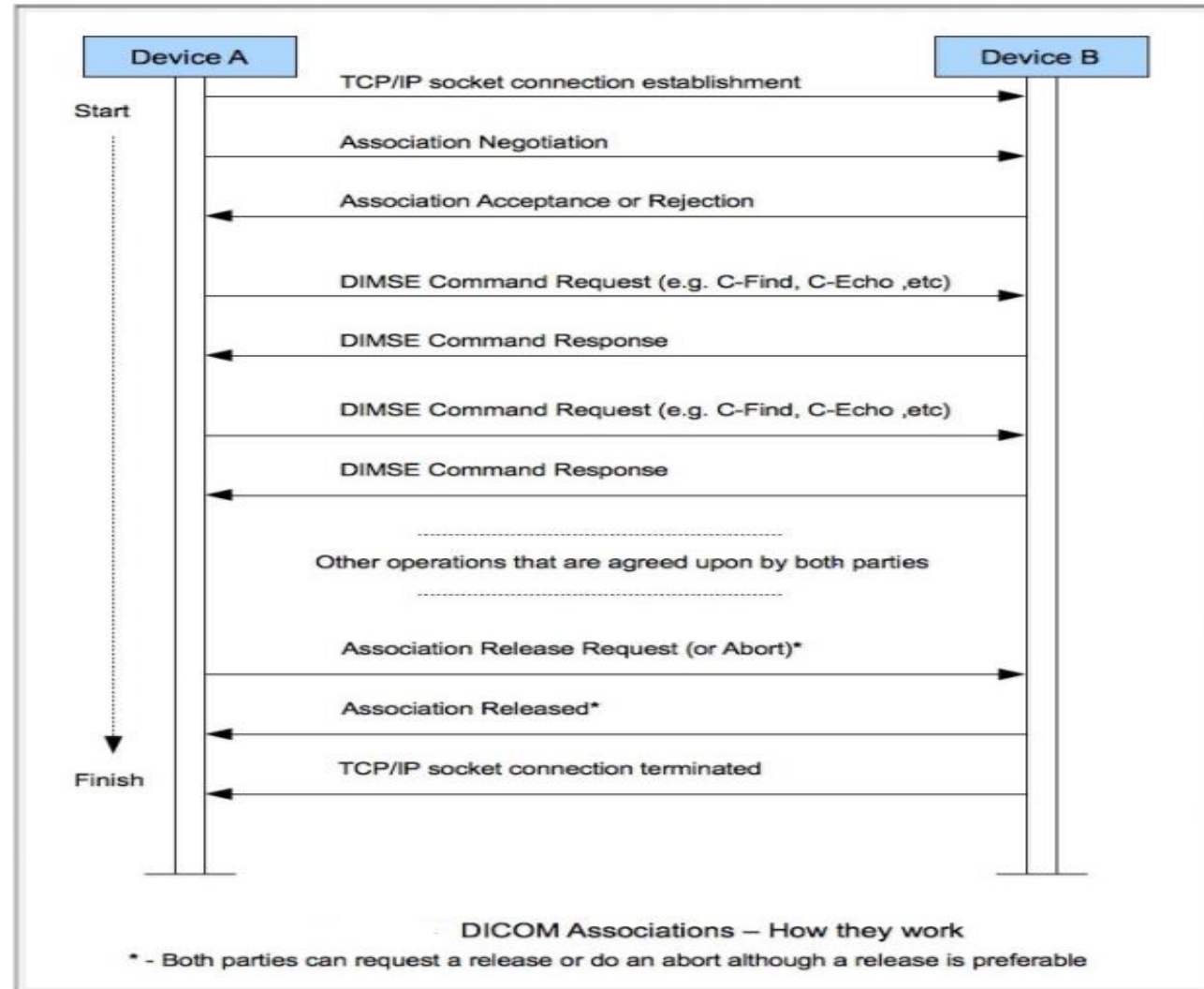
- DICOM AEs send service messages to each other, requesting or providing service information. This is why all service commands are known in DICOM as DIMSE(DICOM Message Service Element).
- DIMSE protocol sets the rules for DICOM service exchange, the backbone of DICOM networking.
- DIMSE service usually has request and response message components.

# Communication between DICOM Application Entity

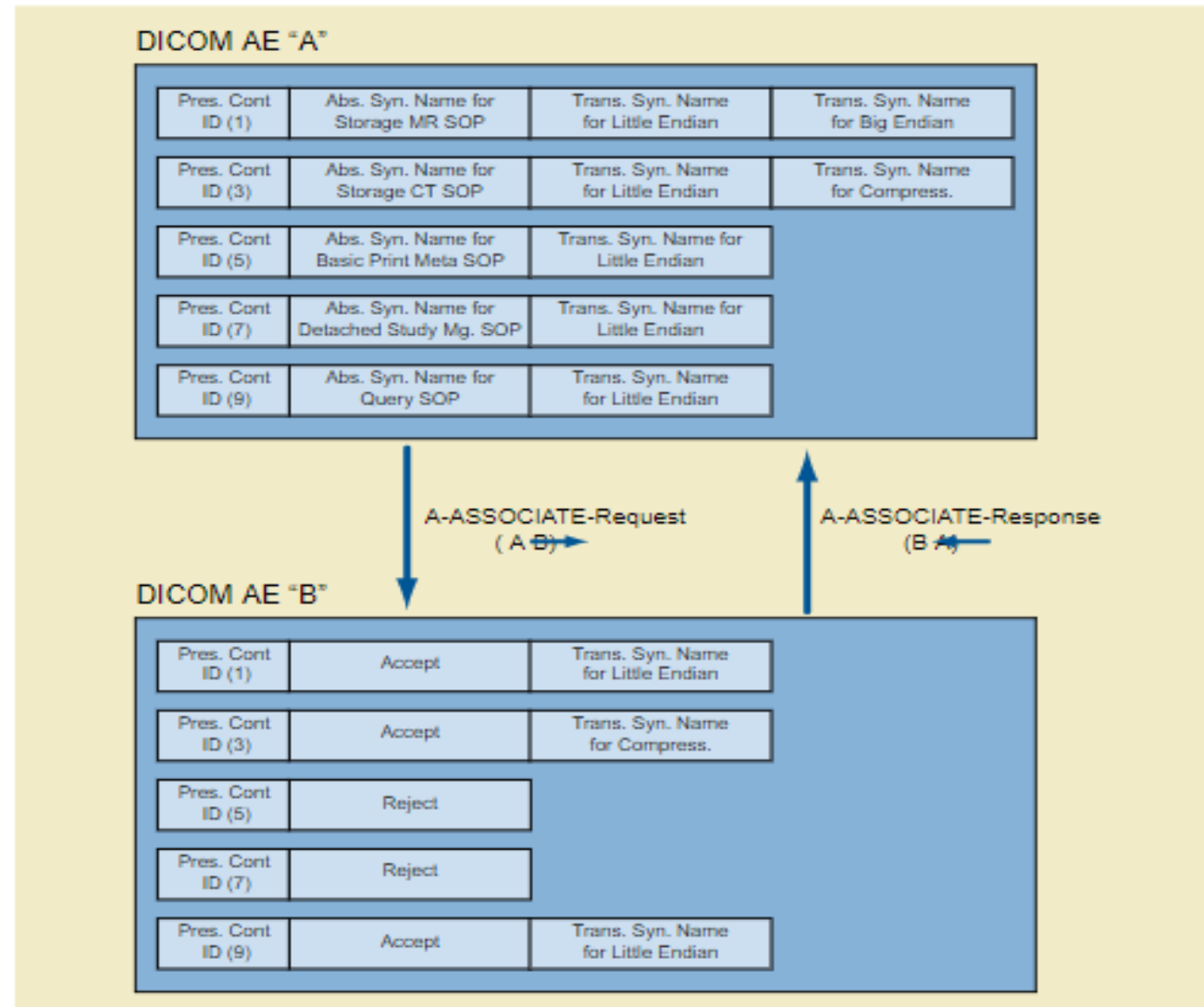


- Establishment of connection between two AE.
- Establishment of Association between two AE.
- Processing request of Service Class User by Service Class Provider.
- Release of Association.
- Connection closes.

# Association



# Association



# Introduction to DIMSE Services



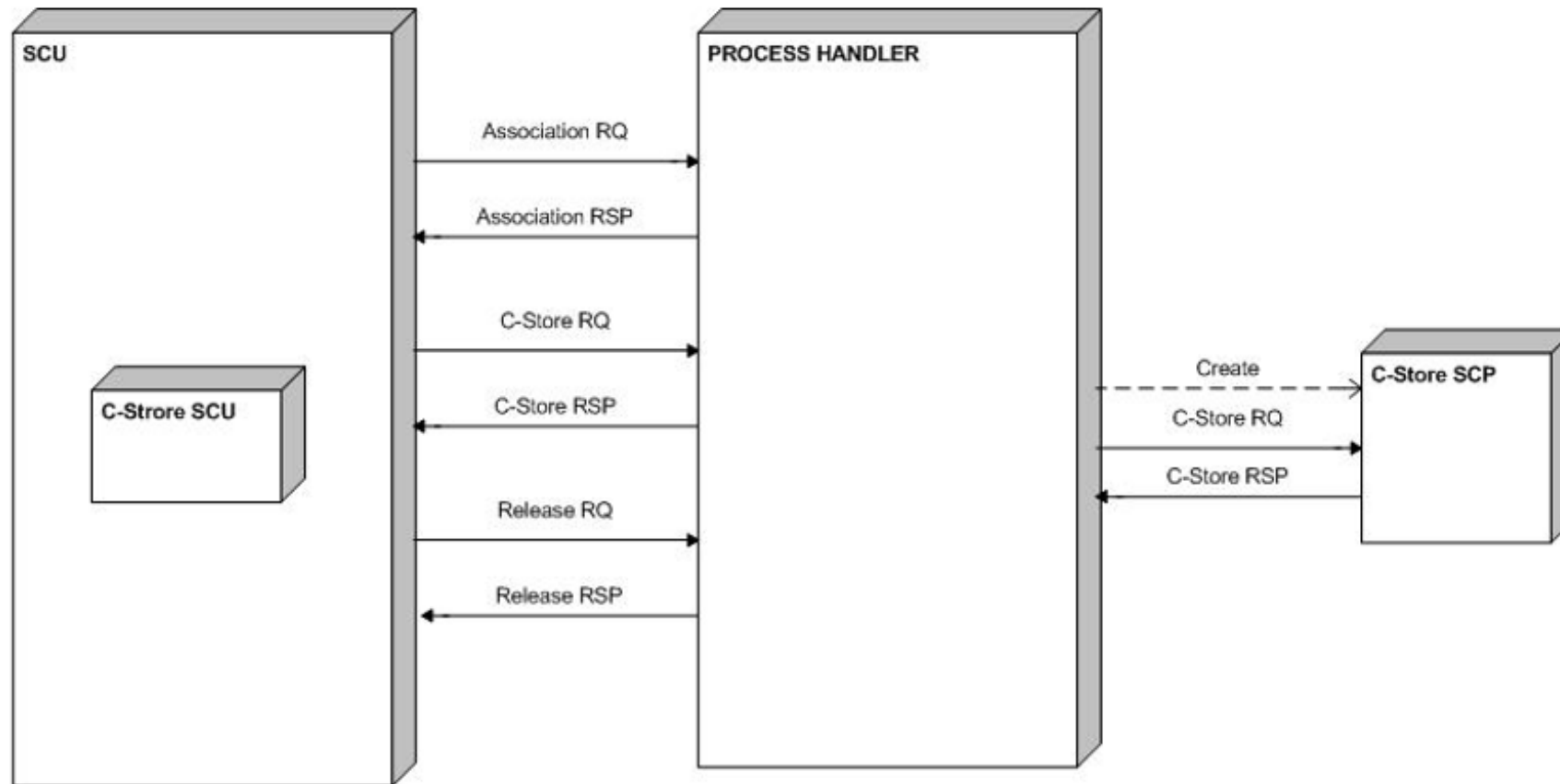
- DIMSE – DICOM Information Message Service Element.
- Two types of services to exchange them over network:
  - C-Services (Composite Information Object Definitions)
  - N-Services (Normalized Information Object Definitions)

- ▶ DICOM communication involves the exchange of SOP instances (ex: DICOM files) with use of DICOM messages.
- ▶ DICOM Message consist of
  - Command Set, Information regarding DIMSE service
  - Data Set, Information regarding Data to be transfer
- ▶ Each service has a Service Provider application and a Service Requester application.
- ▶ Any device which performs operations and invokes notification is an **SCP – Service Class Provider**.
- ▶ Any device which requests an operation is a **SCU - Service Class User**.



- C-Echo
- C-Store
- C-Get
- C-Move
- C-Find

# C-Store Usage Scenario



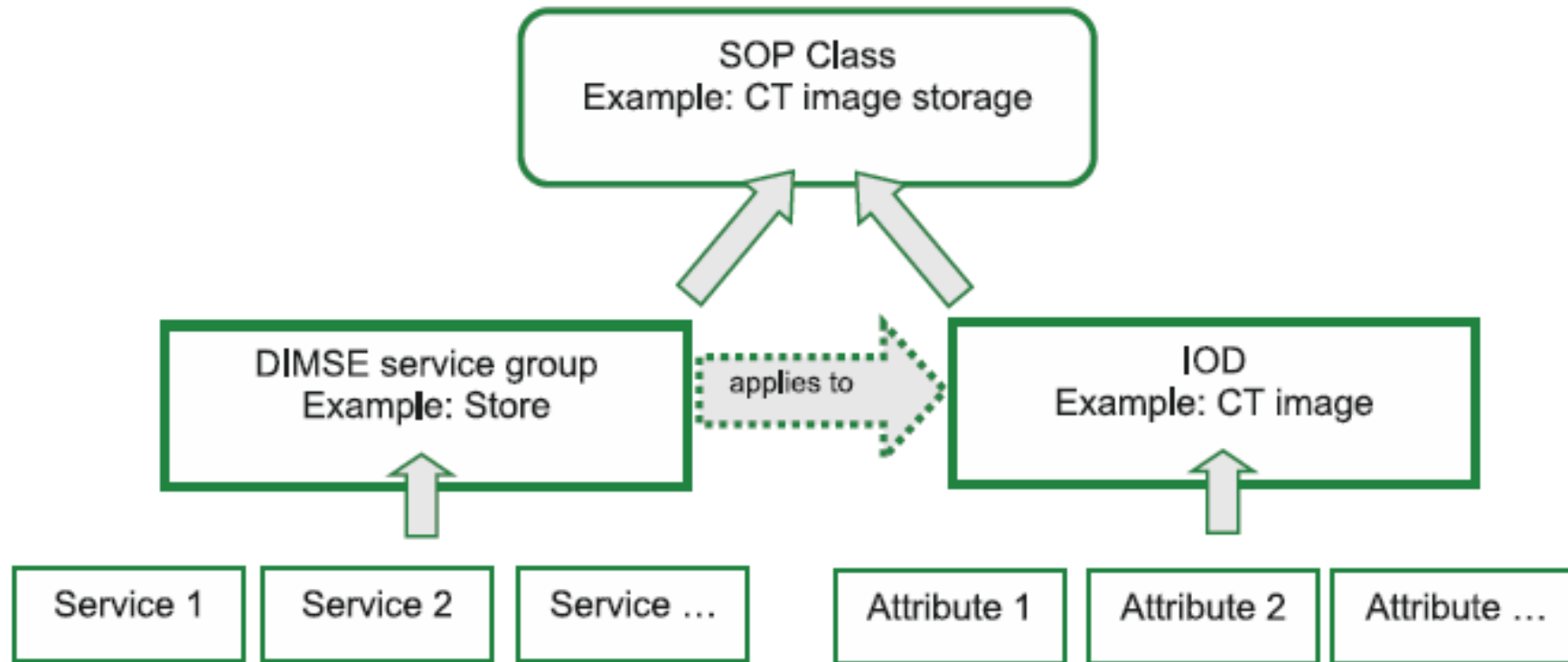
- The C-ECHO service is invoked by a DIMSE-service-user to verify end-to-end communications with a DIMSE-service-user.
- The C-STORE service is invoked by a DIMSE-service-user to request the storage of Composite SOP Instance information by a DIMSE-service-Provider.
- The C-FIND service is invoked by a DIMSE-service-user to match a series of Attribute strings against the Attributes of the set of SOP Instances managed by a DIMSE-service-user. The C-FIND service returns for each match a list of requested Attributes and their values.
- The C-GET service is invoked by a DIMSE-service-user to fetch the information for one or more information objects from a DIMSE-service-user, based upon the Attributes supplied by the invoking DIMSE-service-user.
- The C-MOVE service is invoked by a DIMSE-service-user to move the information for one or more Composite SOP Instances from a DIMSE-service-user, to a third party DIMSE-service-user, based upon the Attributes supplied by the invoking DIMSE-service-user.

- N-Event-Report
- N-Action
- N-Delete
- N-Create
- N-Set
- N-Get

- N-EVENT-REPORT service is invoked by a DIMSE-service-user to report an event about a SOP Instance to a DIMSE-service-user.
- N-GET service is invoked by a DIMSE-service-user to request the retrieval of information from a DIMSE-service-user.
- N-SET service is invoked by a DIMSE-service-user to request the modification of information by a DIMSE-service-user.
- N-ACTION service is invoked by a DIMSE-service-user to request a DIMSE-service-user to perform an action.
- N-CREATE service is invoked by a DIMSE-service-user to request a DIMSE-service-user to create an instance of a information object.
- N-DELETE service is invoked by a DIMSE-service-user to request a DIMSE-service-user to delete an instance of a information object.

- First, we have IODs to define DICOM data.
- Next we have DICOM services commands.
- A Service-Object Pair (SOP) Class is defined by the union of an IOD and a DIMSE Service Group DICOM services and IOD objects and call them SOPs.
- The SOP Class definition contains the rules and semantics that may restrict the use of the services in the DIMSE Service.
- Normalized SOP Classes are defined as the union of a Normalized IOD and a set of DIMSE-N Services
- Composite SOP Classes are defined as the union of a Composite IOD and a set of DIMSE-C Services.

# Service-Object Pairs (contd...)



**Fig. 36** SOP Class structure: DIMSE services applied to IOD instances

- **Media Storage Service Class**
  - The Media Storage Service Class defines an application level class of service that facilitates the simple transfer of images and associated information between DICOM AEs by means of Storage Media
- **Storage Commitment Service Class**
  - Storage Commitment Service Class defines an application level class of service that facilitates this commitment to storage.
- **Basic Worklist Management Service**
  - The Basic Worklist Management Service Class defines an application-level class of service that facilitates the access to worklists.
- **Structured Reporting Storage SOP Classes**
  - DICOM SR is the standardization of structured data and clinical observations in the imaging environment.
- **DICOM Directory Information(DICOMDIR)**
  - Provide a directory that facilitates access to the information stored in the files of a File-set based on key medical information.



- **Application Event Logging Service Class**
  - The Application Event Logging Service Class defines an application-level class-of-service that facilitates the network transfer of Event Log Records to be logged or recorded in a central location.
- **Relevant Patient Information Query Service Class**
  - The Relevant Patient Information Query Service Class defines an application-level class-of-service that facilitates the access to relevant patient information
- **Instance Availability Notification Service Class**
  - The Instance Availability Notification Service Class defines an application-level class-of-service that allows one DICOM AE to notify another DICOM AE of the presence and availability of SOP instances that may be retrieved.
- **Media Creation Management Service Class**
  - The Media Creation Management Service Class defines a mechanism by which it can instruct a device to create Interchange Media containing a set of Composite SOP Instances that have already been transferred to the media creation device using the Storage Service Class.
- **Color Palette Storage Service Class**
  - The Color Palette Storage Service Class defines an application-level class-of-service that allows one DICOM AE to send a Color Palette SOP Instance to another DICOM AE.

- **Print Management Service Class**

- The Print Management Service Class defines an application level class of service that facilitates the printing of images and image related data.

- **Hanging Protocol Storage and Query Retrieval Service class**

- A hanging protocol is the series of actions performed to arrange images for optimal softcopy viewing

- **Substance Administration Query Service Class**

- The Substance Administration Query Service Class defines an application-level class-of-service that facilitates obtaining detailed information about substances or devices used in imaging, image-guided treatment, and related procedures.

- **Instance and Frame Level Retrieve SOP Class**

- The retrieve capability of this service allows a DICOM AE to retrieve Composite Instances or selected frames from a remote DICOM AE over a single Association or request the remote DICOM AE to initiate a transfer of Composite Object Instances or selected frames from image objects to another DICOM AE.

- **The Unified Procedure Step Service Class**
  - It provides for management of simple worklists, including creating new worklist items, querying the worklist, and communicating progress and results.
- **RT Machine Verification Service Class**
  - The RT Machine Verification Service Classes define an application-level class-of-service that facilitates the independent verification of geometric and dosimetric settings on a radiation delivery system prior to delivery of a radiation treatment.
- **Display System Management Service class**
  - It is an abstraction of the soft-copy display system and is the basic Information Entity to monitor the status of a Display System.

- SDK for DICOM provide implementation for DICOM standard. It provides to build and customized applications.
- It is a toolkit that provides API for medical devices to comply with DICOM standard.
- It is platform independent and provides easy communication and information interchange with other DICOM compliant device.

# References



- [http:// dicom.nema.org /](http://dicom.nema.org/)
- DICOM Standard PS3.0-2015 specifications:  
<http://dicom.nema.org/medical/Dicom/2015c/output/pdf/>

# Thank You

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