MII course 2017 

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Content

- **Part 1.) DICOM standard and overview**
- **Part 2.) DICOM practical tutorial**
  - DCMTK 💪
  - Python 💪

Part 1.

DICOM standard and overview

DICOM

Digital Image Communications in Medicine

DICOM IS .....

- Documented set of **rules**
- Standardized **Application Protocol/Methodology**

DICOM Can/Dose Provide:

- Facilitates connectivity between devices that claim to support DICOM features.
  - Will guarantee network connection
  - Will guarantee storage of image

DICOM Cannot/Dose Not Provide:

- DICOM dose not guarantee functionality.
  - Will **not** guarantee workstation will display image correctly
  - Will **not** guarantee workstation can perform analysis

The DICOM consists of the following parts:

- PS3.1: Introduction and Overview (this document)
- PS3.2: Conformance
- PS3.3: Information Object Definitions
- PS3.4: Service Class Specifications
- PS3.5: Data Structures and Encoding
- PS3.6: Data Dictionary
- PS3.7: Message Exchange

- PS3.8: Network Communication Support for Message Exchange
- PS3.9: Retired
- PS3.10: Media Storage and File Format for Media Interchange
- PS3.11: Media Storage Application Profiles
- PS3.12: Formats and Physical Media
- PS3.13: Retired-
- PS3.14: Grayscale Standard Display Function
- PS3.15: Security and System Management Profiles

- PS3.16: Content Mapping Resource
- PS3.17: Explanatory Information
- PS3.18: Web Services
- PS3.19: Application Hosting
- PS3.20: Imaging Reports using HL7 Clinical Document Architecture

http://dicom.nema.org/

over 3000 pages 😟

American College of Radiology (ACR)

National Electrical Manufacturers Association (NEMA)

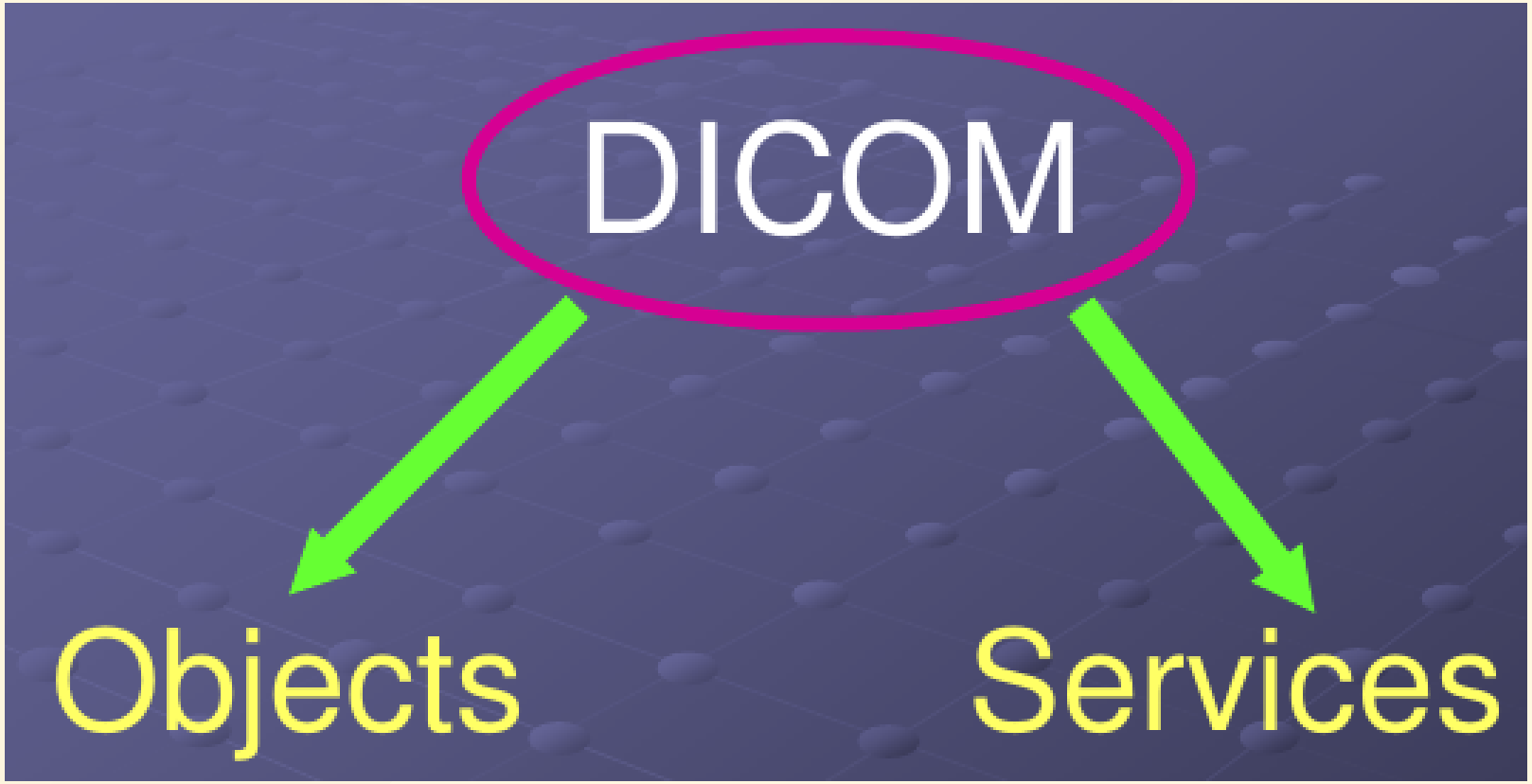
Historical Overview of DICOM

- 1983: ACR and NEMA form joint committee to find or develop an interface between imaging equipment.
- 1985: ACR-NEMA (ACR-NEMA Version 1.0) distributed at RSNA
- 1993: DICOM addresses **image information management, image transfer and print management over networks**
- Future: DICOM reaches well beyond Radiology;Cardiology, Radiotherapy and Pathology....

DICOM Terminology

- Information Object Definition (IOD)
- DICOM Services / Service Class (SC)
- Service Class User (SCU)
- Service Class Provider (SCP)
- Service Object Pair (SOP)
- DICOM Message Service Element (DIMSE)
- Association Control Service Element (ACSE)
- Application Entity Title (AET)

- Unique Identifier (UID)
- Protocol Data Unit (PDU)
- Value Representation (VR)
- Transfer Syntax
- Abstract Syntax
- Presentation Context


DICOM
Objects
Services

DICOM Objects

- e.g. patients, images, reports
  - called information object (Information Entity) because their function is to carry information
  - the definition of what constitutes an information object in DICOM is called an Information Object Definition (IOD)
    - a list of Attributes
    - Related Attributes are grouped into Modules (mandatory, optional, conditional)

CT Image IOD Modules

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Clinical Trial Subject	C.7.1.3	U
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
	Clinical Trial Study	C.7.2.3	U
Series	General Series	C.7.3.1	M
	Clinical Trial Series	C.7.3.2	U
Frame of Reference	Frame of Reference	C.7.4.1	M
Equipment	General Equipment	C.7.5.1	M
Image	General Image	C.7.6.1	M
	Image Plane	C.7.6.2	M
	Image Pixel	C.7.6.3	M
	Contrast/bolus	C.7.6.4	C - Required if contrast media was used in this image
	CT Image	C.8.2.1	M
	Overlay Plane	C.9.2	U
	VOI LUT	C.11.2	U
	SOP Common	C.12.1	M

Patient Module Attributes

Attribute Name	Tag	Attribute Description
Patient's Name	(0010,0010)	Patient's full name
Patient ID	(0010,0020)	Primary hospital identification number or code for the patient.
Issuer of Patient ID	(0010,0021)	Identifier of the Assigning Authority (system, organization, agency, or department) that issued the Patient ID. Note: Issuer of Patient ID (0010,0021) is equivalent to HL7 v2 PID-3 component 4.
Other Patient IDs	(0010,1000)	Other identification numbers or codes used to identify the patient.
Other Patient Names	(0010,1001)	Other names used to identify the patient.
Patient's Birth Name	(0010,1005)	Patient's birth name.
Patient's Mother's Birth Name	(0010,1060)	Birth name of patient's mother.
Medical Record Locator	(0010,1090)	An identifier used to find the patient's existing medical record (e.g. film jacket).

Normalized IOD

- object comprises of only one real world entity
  - e.g. patient, study, result

Composite IOD

object comprises of more than one entity

e.g. CT image

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Clinical Trial Subject	C.7.1.3	U
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
	Clinical Trial Study	C.7.2.3	U
Series	General Series	C.7.3.1	M
	Clinical Trial Series	C.7.3.2	U
Frame of Reference	Frame of Reference	C.7.4.1	M
Equipment	General Equipment	C.7.5.1	M
Image	General Image	C.7.6.1	M
	Image Plane	C.7.6.2	M
	Image Pixel	C.7.6.3	M
	Contrast/bolus	C.7.6.4	C - Required if contrast media was used in this image
	CT Image	C.8.2.1	M
	Overlay Plane	C.9.2	U
	VOI LUT	C.11.2	U
	SOP Common	C.12.1	M

The need for Composite IOD

- e.g. in storage and retrieval
  - If the objects were broken up into smaller ones, assembling the smaller objects for use would mean searching the storage device for all of them. Such a task would be **more time-consuming** than recovering the complex object in a single retrieval.

DICOM SERVICES

Dicom Service are ACTIONS that applied to Information Objects

Verification
Storage
Query/Retrieve
Procedure Step
Print Management
Media Storage
Storage Commitment
Basic Worklist Management

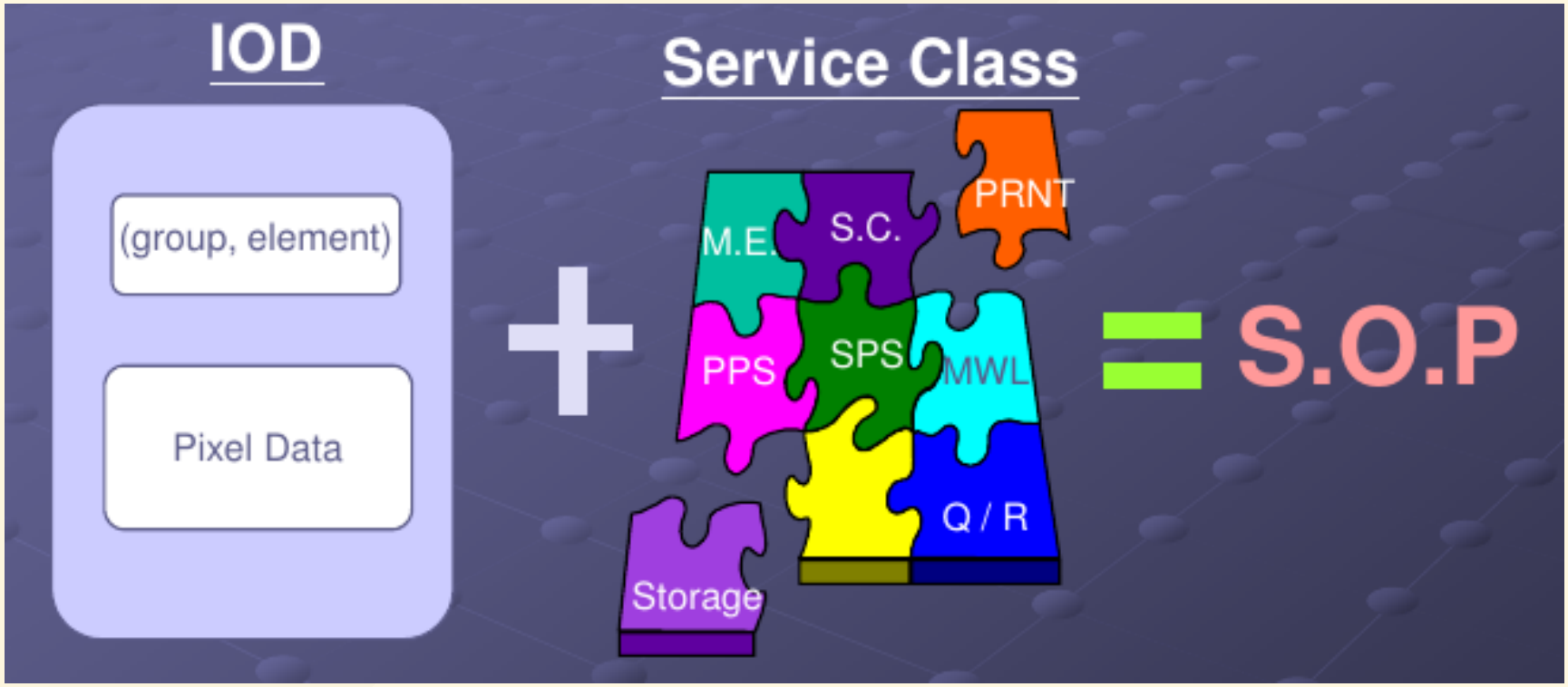
For example:

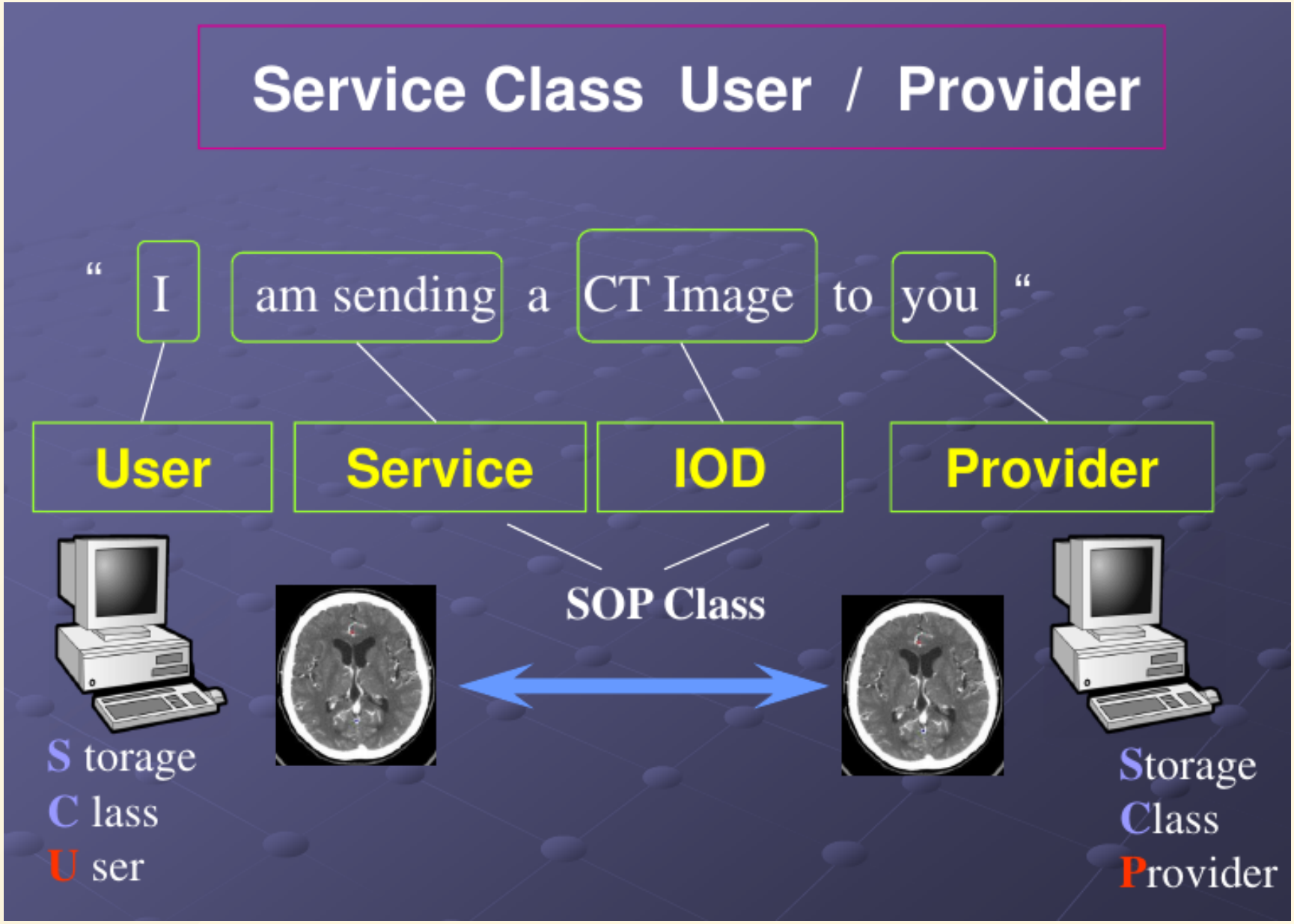
- **Object**: canned food
  Required service: ordinary shipping

- **Object**: fresh meat
  Required service: refrigerated air freight service

This combination of object and service is called service-object pair (SOP)🔥

Service Object Pair




Service Class User / Provider
" I am sending a CT Image to you "
User
Service
IOD
Provider
SOP Class
Storage Class User
Storage Class Provider

Scenario 1

- MR scanner may say:
  - I am an MR Image Storage SCU
- Workstation may say:
  - I am an MR Image Storage SCP

👍 **MR images may be transferred!** 👍

Scenario 2

- Angiography machine may say:
  - I am an XA Image Storage SCU
- Workstation may say:
  - I am not an XA Image Storage SCP though I do support other kinds of images like CT an MR

👎 **This pair cannot transfer XA images** 👎

Verification Service Class

- Very basic diagnostic function, required by DICOM on all products.
- Allows any system to send a test message to another system to verify the network connection.

Storage Service Class

- Sends and receives image data anywhere on the network.
- Storage SCU implies that the ability is available to send DICOM images from the equipment.
- Storage SCP implies that the ability is available to receive DICOM images at the equipment.

Most common service class for scanners and workstations.

Query/Retrieve Service Class

- Allows for the remote access and retrieval of data without interrupting the operator of the remote device.
- Query/Retrieve SCU implies that the ability is available to view and pull the DICOM images from another DICOM node on the network (if the other node is a Q/R SCP).

- Query/Retrieve SCP implies that the ability is available to respond to a Q/R request coming from another DICOM node on the network (if the other node is a Q/R SCU).

Both devices must have this capability for this function to work. 🎯

Modality Performed Procedure Step Service Class

- Sends DICOM conformant information about start and finish of performed procedure steps to a DICOM MPPS SCP (PACS, RIS etc.).
- Once a procedure is COMPLETED, it is considered inactive, and can be filtered out of a modality worklist .
- Also carries other information such as radiation dose (to enable the RIS to store information on patient exposure) and billing & material management codes.

Print Management Service Class

- Digital print to hardcopy device over the network.
- Basic Print SCU implies that the ability is available to send DICOM print formatted images to a printer or laser camera.
- Basic Print SCP implies that the ability is available to receive DICOM print formatted images and print them.

This functionality will allow true sharing of laser cameras (similar to two PC sharing a laser printer across a network).

Media Storage Service Class

- Standardizes the **physical media** and the **logical format** in which the images are stored on the archive media.

Storage Commitment Service Class

- Enables a scanner acting as an SCU to request an external device acting as an SCP to make the commitment for the safekeeping of information (i.e. the information will be kept for a specific period of time and can be retrieved).
- The Storage Service Class is used in conjunction to the Storage Commitment Service Class to transfer the images to the storage device.

Basic Worklist Management Service Class

- Allows a scanner (SCU) to obtain **patient and requested procedure information** for scheduled examinations from an Information Management System (e.g. PACS Broker)
- Query from scanner to broker is performed through **C-FIND operation**

DICOM Message Service Elements (DIMSE)

- to generate appropriate commands and data sets to complete the required services
- DIMSE-C and DIMSE-N

DIMSE-N

- **DIMSE-N** for normalized information objects
  -N-EVENT-REPORT (notification of a change in MPPS SOP Instance e.g. change of procedure status from “IN PROGRESS” to “COMPLETED”)
    - N-GET (get MPPS SOP Instance)
    - N-SET (set procedure status)
    - N-ACTION (update procedure status)
    - N-CREATE (create MPPS SOP Instance)
    - N-DELETE (delete procedure)

DIMSE-C

- **DIMSE-C** for composite information objects
  C-STORE (store)
  - C-GET (get)
  - C-FIND (query)
  - C-MOVE (retrieve)
  - C-ECHO (verification - for DICOM ping which will issue a C-ECHO command and display the result)

C-FIND

- C-FIND query involves passing a dataset from SCU to SCP, the **dataset** contain two type of attribute:
  - Attributes which need to be matched, they usually have **filled** values
  - Attributes which need to be returned to the SCU, they are sent as **blank** fields.
- The SCP responds by sending a number of matching **datasets**

C-FIND attribute matching

- C-FIND have following types of matching:
  - Single Value Matching
  - List of UID Matching (e.g. \ )
  - Universal Matching (blank value)
  - Wild Card Matching (e.g. *)
  - Range Matching (e.g. date 1 - date2)

Example dataset of C-FIND query

Example 1

```
# query patient names and IDs
(0008,0052) CS [PATIENT]      # QueryRetrieveLevel
(0010,0010) PN [*]             # PatientName
(0010,0020) LO []              # PatientID
```

Example 2

```
# query patient names and IDs
(0008,0052) CS [STUDY]      # QueryRetrieveLevel
(0008,0030) DA []             # StudyDate
(0008,0050) SH []             # AccessionNumber
```

C-MOVE and C-GET

- Both C-MOVE and C-GET can be used to retrieve DICOM objects from C-STORE SCP, but C-MOVE is more commonly used.
- The main difference are
  - For C-GET, the requested composite instances are sent over the **same association** of request.
  - For C-MOVE, the requested composite instances are sent over the **separtate association** of request.

Application Entity Title

During negotiation, the two Implementations present themselves to each other

- This presentation is done using **Application Entity Title (AE Title)**
- This AE Title (max 16 characters) that must be unique on a given network. It is used to identify an application on the network.

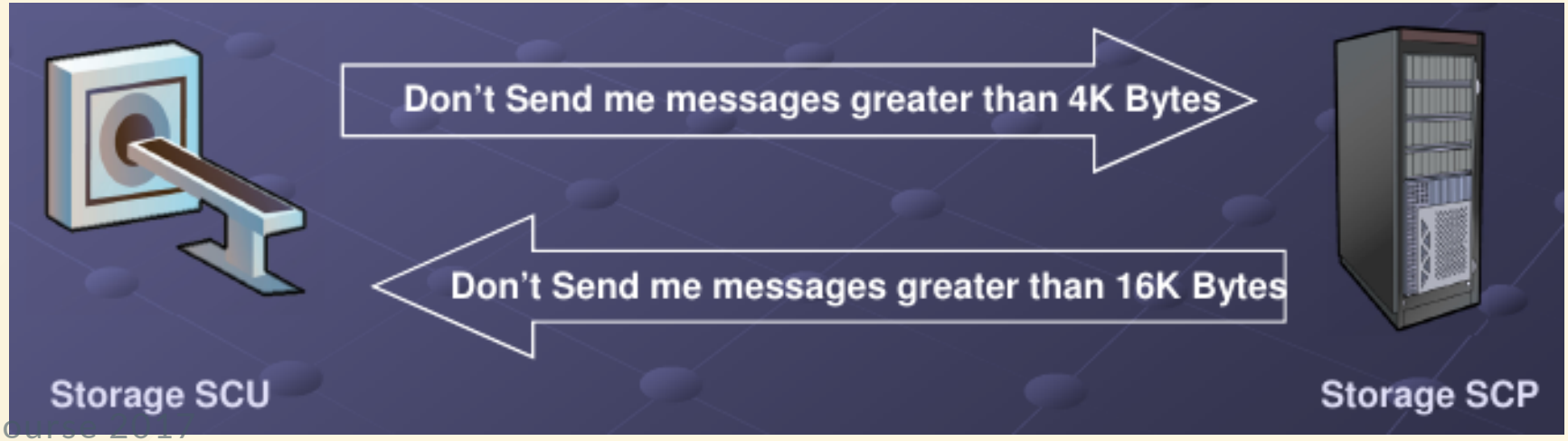
Unique Identifier (UID)

A UID is a string including numbers and “.” that **MUST be UNIQUE** around the world.

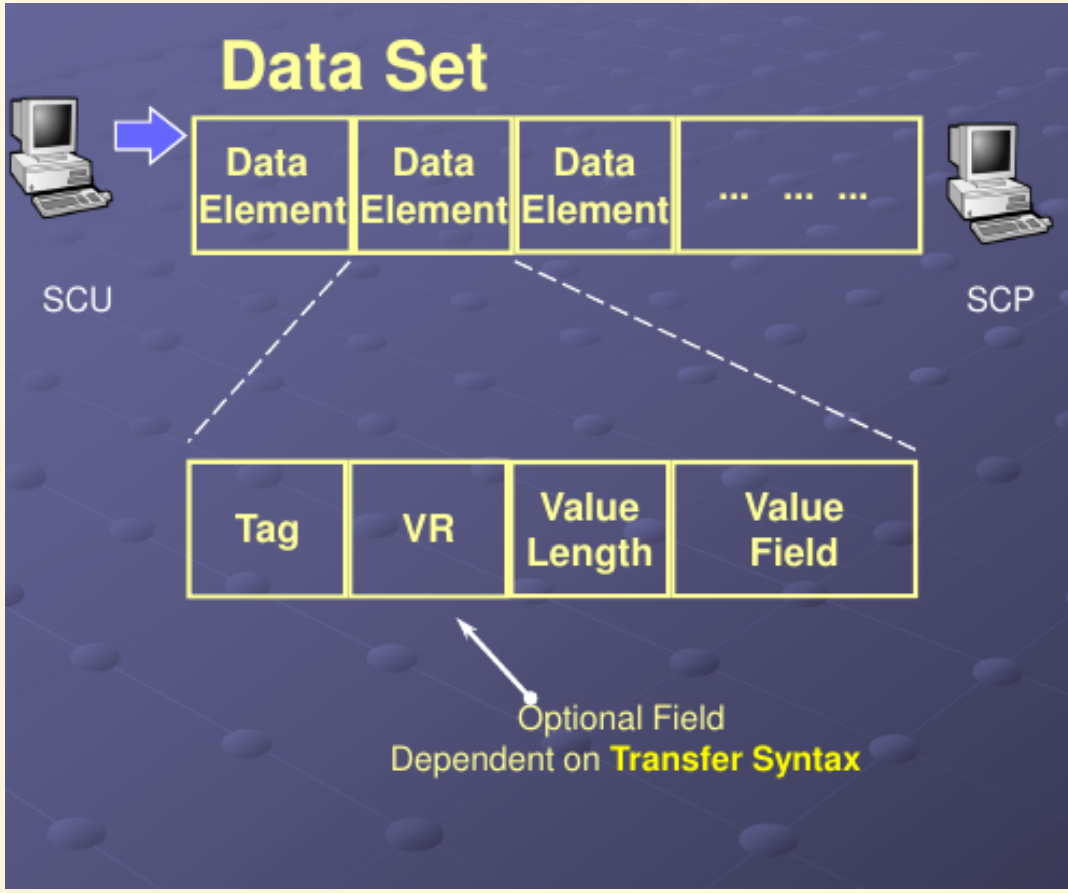
- e.g. 1.2.840.12345.19980924
- no leading zero’s in UID allowed!! UIDs are an internal DICOM mechanism to uniquely identify SOP Classes, Studies, Equipment's, Series, Images, etc.....

Protocol Data Unit (PDU)

- Structure data sets
- Describes data as it moves in the network
- Synonymous with packet
- The Maximum length PDU is the maximum size of messages the SCU is able to handle



DICOM Data Structure



Attributes are assigned a unique Tag (group + element)

tag=(0010, 0010)

groups deals with patient information for example

element is patient name for example

Attribute encoding is defined by Value Representation (VR).

Data Element Types

- TYPE 1
  Required Data Elements
  Value Field shall not be zero length
- TYPE 1C
  Type 1C elements have the same requirements as Type 1 elements under certain specified conditions
- Type 2
  Required Data Elements
  Value Field may be zero length

- Type 2C
  Type 2C elements have the same requirements as Type 2 elements under certain specified conditions
- Type 3
  Optional Data Elements

Example DICOM Tag's

Group / Element	Type	Attribute Name	Attribute Desc.
0008 , 0060	1	Modality	Orig. Modality
0020 , 2810	1	Rows	# of rows in image
0010 , 0010	2	Patient Name	Pat. Full Name
0010 , 0030	2	Patient Birthdate	Pat. Date of Birth
0010 , 1030	3	Patient Weight	Wt. of Patient kg
0010 , 2180	3	Patient Occupation	Occ. of Patient

Value Representation (VR)

- It describes the type and the format of the information sent in a DICOM Message. For instance, the Patient Date of Birth (0010, 0030) is a 8 characters string following the format : **YYYYMMDD**
- It is in the Value Field of the Data Element.

Value Representation (VR)

- Each VR is enumerated by a 2 character code.
- The codes are: AE (Application Entity), AS (AgeString), AT (Attribute Tag), CS (Code String), DA (Date), DS (Decimal String), DT (Date Time), FL (Floating Point Single), FD (Floating Point Double), IS (Integer String), LO (Long String), LT (Long Text), OB (Other Byte), OW (Other Word), PN (Patient Name), SH (Short String), SQ (Sequence of Items), SS (Signed Short),TM (Time), UI (Unique Identifier), UL (Unsigned Long), US (Unsigned Short)

Value Representation (VR)

- **Explicit VR** means that the VR is to be included in each Data Element in the Data Set.
- **Implicit VR** means that the VR is not to be included in each Data Element in the Data Set. The VR of each Data Element must be looked up in the Data Dictionary.

Grayscale Softcopy Presentation State (GSPS)

- the output grayscale space in P-Values
- grayscale contrast transformations including modality and VOI LUT
- mask subtraction for multi-frame images
- selection of the area of the image to display and whether to rotate or flip it
- image and display relative annotations, including graphics, text and overlays

Transfer Syntax

- the encoding methodology used to send data over the network
- such as Data Element Structure, Byte Ordering, and Image Compression

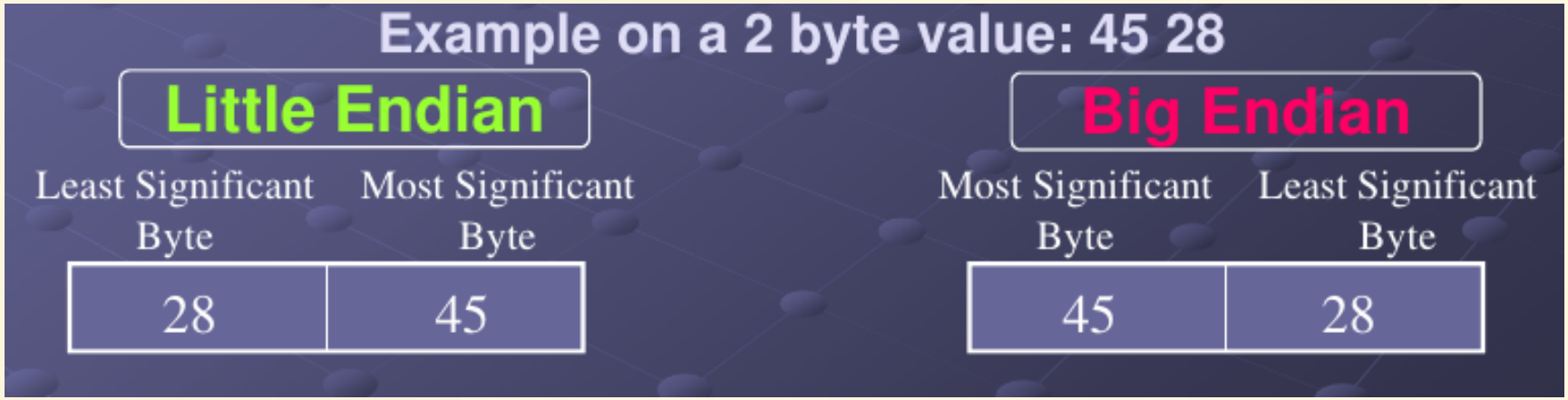
Transfer Syntax

DICOM defines several transfer syntaxes :

- Implicit VR Little Endian (Default DICOM Network Transfer Syntax)
- Explicit VR Little Endian (Default for DICOM Media Storage)
- Explicit VR Big Endian
- JPEG Lossless
- Others.....

Transfer Syntax

Little Endian versus Big Endian byte ordering
DICOM defines two different byte orderings that affect binary values sent on more than 1 byte



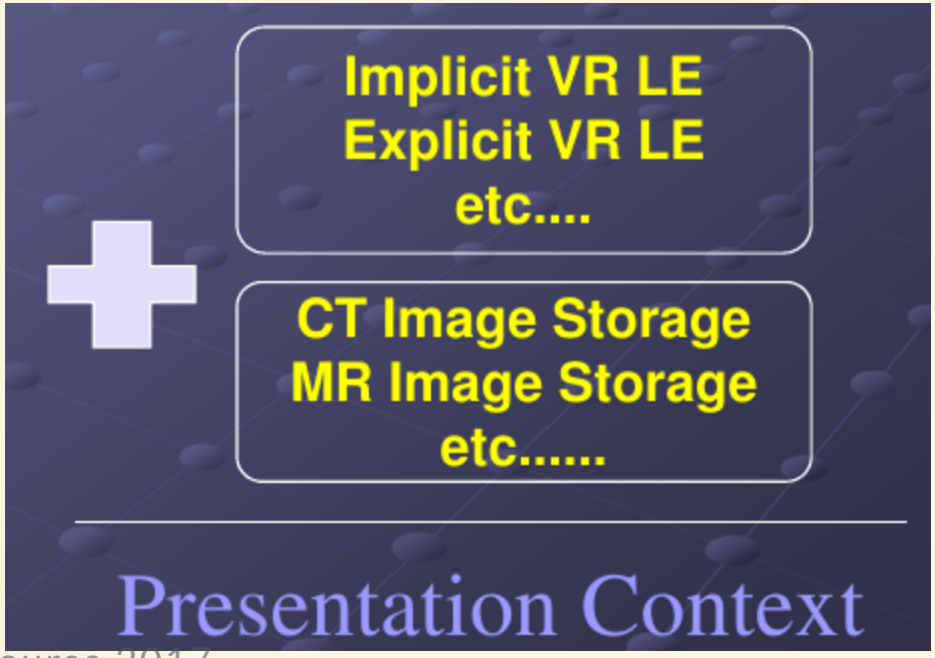
Transfer Syntax

- In the default case of Little Endian encoding, Big Endian Machines interpreting Data Sets shall do **'byte swapping'** before interpreting or operating on certain Data Elements.

Presentation Context

A Presentation Context is the association of:

- One or Several SOP Class
- One or several Transfer Syntax(es)



DICOM Upper Layer Services

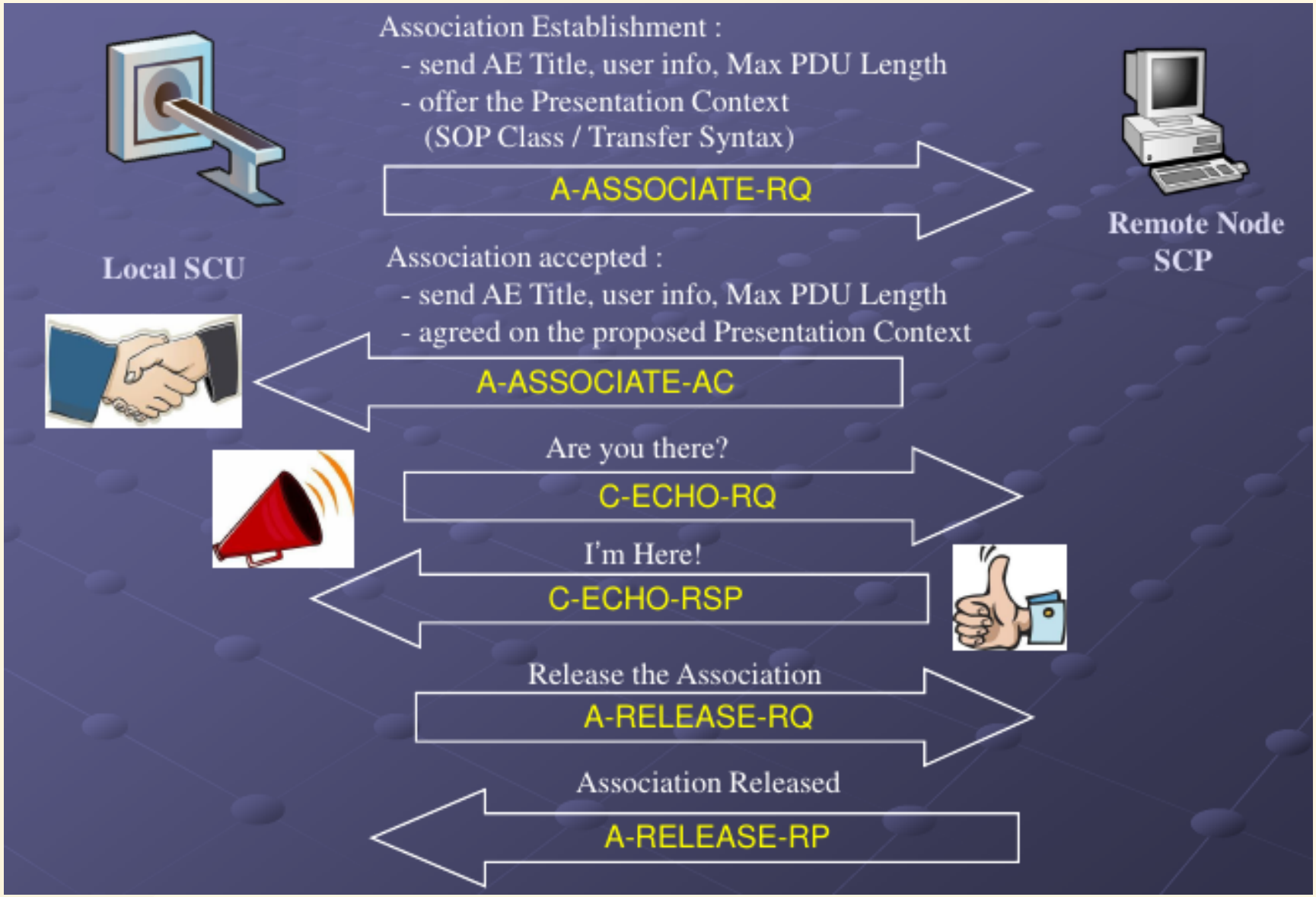
- allows Application Entities to
  - establish associations
  - transfer data
  - terminate associations
- a subset of OSI Presentation Service (OSI layer 6) and OSI Association Control Service Element (ACSE – OSI layer 7 protocol) (other protocols in the OSI Application Layer include HTTP, SMTP, FTP etc.)

DICOM Upper Layer Services

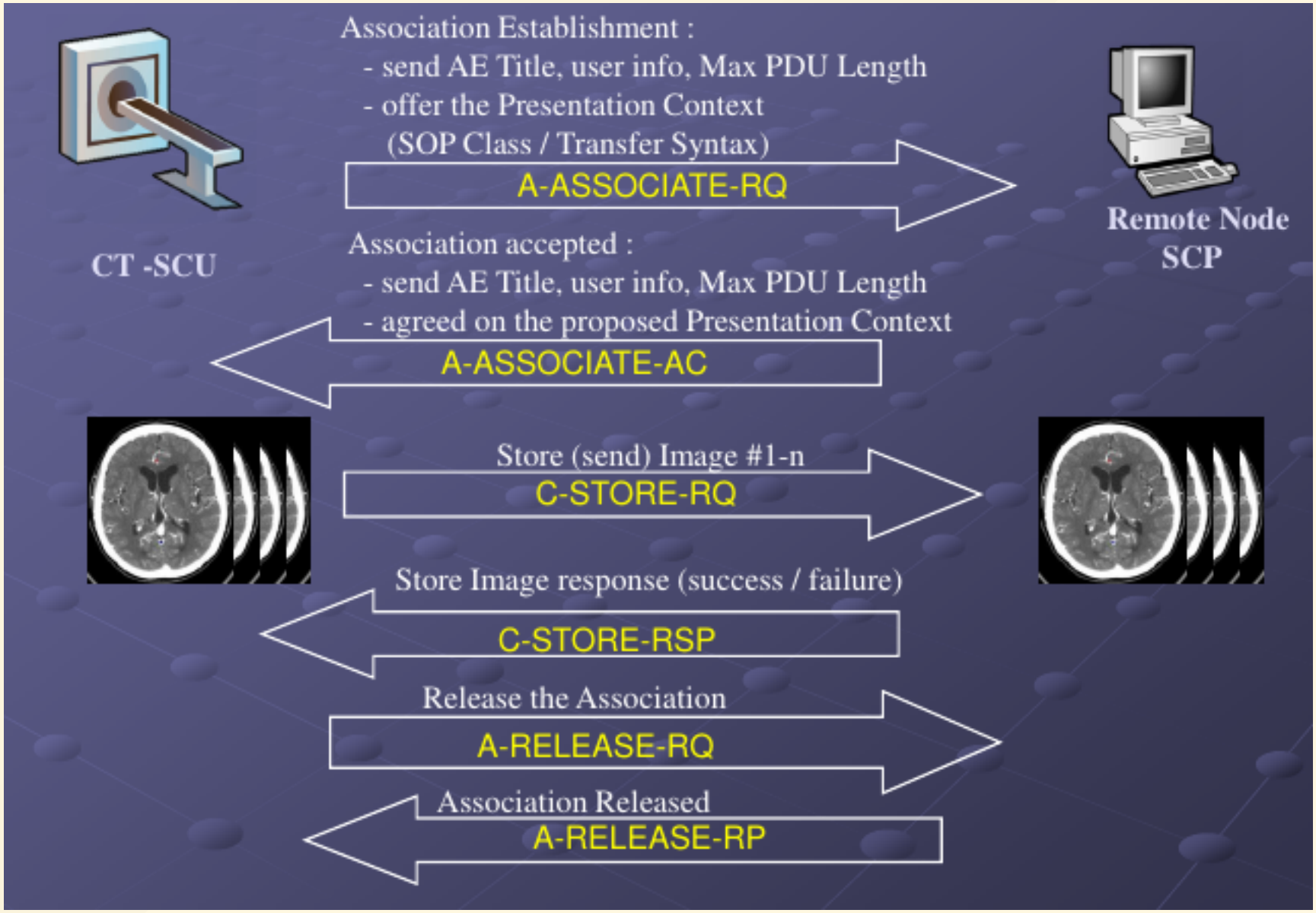
- **A-ASSOCIATE** Service
  - A-ASSOCIATE-RQ PDU (request association)
  - A-ASSOCIATE-AC PDU (accept association)
  - A-ASSOCIATE-RJ PDU (reject association)
- **A-RELEASE** Service
  - A-RELEASE-RQ PDU (request to release the association)
  - A-RELEASE-RP PDU (respond to the request)

- **A-ABORT** Service
  - A-ABORT PDU (abort the association)
- **P-DATA** Service
  - P-DATA-TF PDU (transfer data such as image data)

Service Class "Verification"



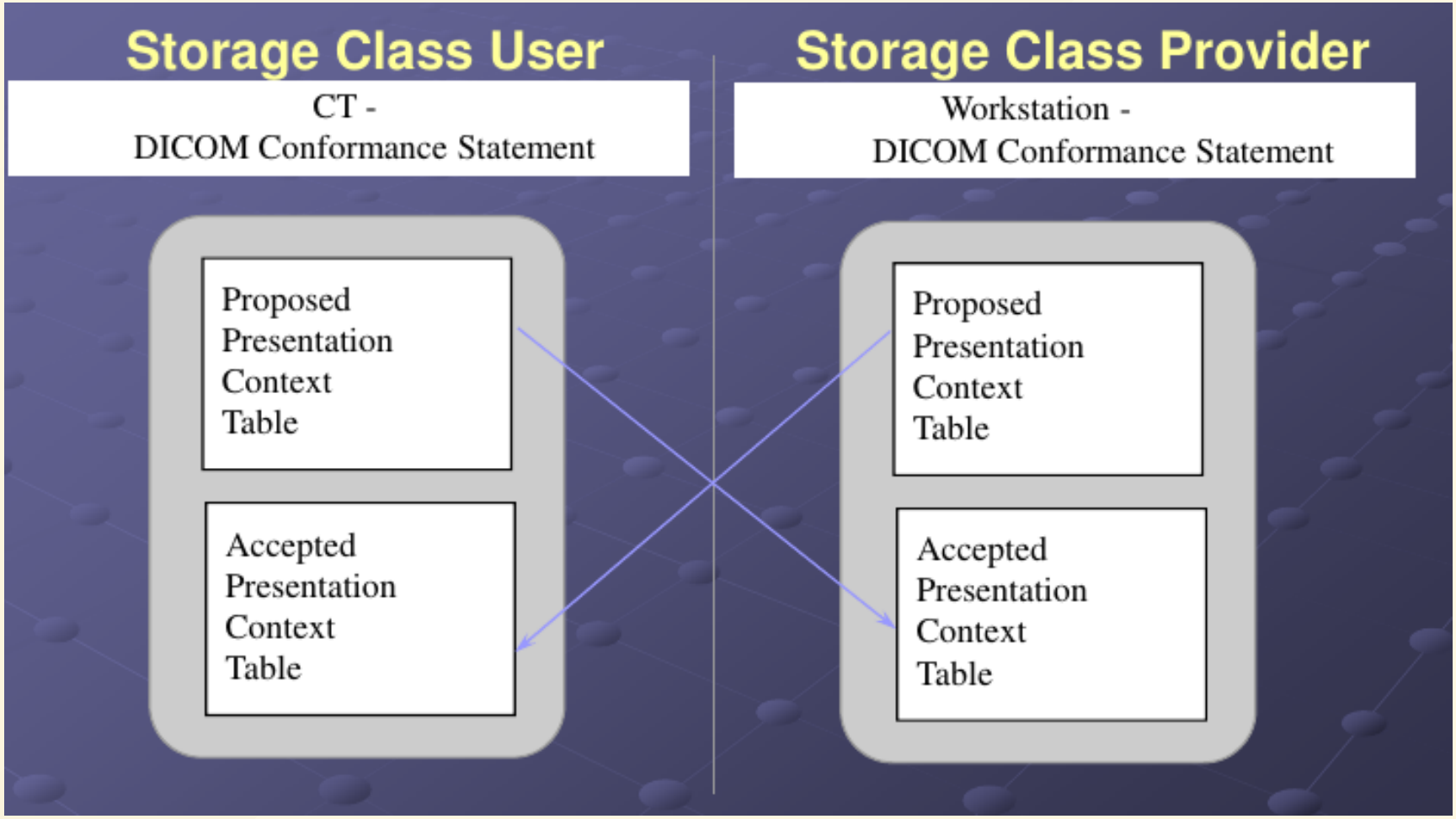
Service Class "Storage"



Information Contained in a DICOM Conformance Statement

- Product Name and Version
- Application Data Flow Diagram
- Proposed Presentation Context
- Accepted Presentation Context
- Configurable Parameters

Match Proposed with Accepted



Proposed / Accepted Presentation Context Table Example

SOP Class Name	UID	Transfer Syntax	Role
CR Image Storage CT Image Storage	1.2.840.10008.5.1.4.1.1.1 1.2.840.10008.5.1.4.1.1.2	Implicit Little Endian Implicit Little Endian	SCP SCP
Study Root Q/R Move	1.2.840.10008.5.1.4.1.2.2.2	Implicit Little Endian	SCU
Study Root Q/R Find	1.2.840.10008.5.1.4.1.2.2.1	Implicit Little Endian	SCU
Verification	1.2.840.10008.1.1	Implicit Little Endian	SCP

DICOM Web Services

- WADO (Web Access to DICOM Persistent Objects)
- Simplify access to DICOM information with web access
- Through WADO, web client can request DICOM persistent objects, such as images or medical imaging reports, from a remote repository.

DICOM Web Services

- **WADO-URI**
  - formerly WADO
  - URI based using HTTP GET
  - Example:
- **http://www.dicomserver.co.uk/wado/WADO.asp?requestType=WADO&studyUID=1.2.276.0.7230010.3.1.4.4102548718.9920.1502697243.819&seriesUID=1.2.276.0.7230010.3.1.4.4102548718.9920.1502697243.820&objectUID=1.2.276.0.7230010.3.1.4.4102548718.9920.1502697243.818&contentType=image/jpeg&rows=512&columns=512**

- **WADO-RS**
  - DIMSE-C counterpart **C-GET**
  - RESTful Services (RS) using HTTP GET
  - Example: http://dicomserver.co.uk:81/wado/studies/1.2.826.0.1.3680043.9.7189.280149246809144.150632457063200000/metadata

- **QIDO-RS**
  - DIMSE-C counterpart **C-FIND**
  - RESTful Services (RS) using HTTP GET
  - Example: http://dicomserver.co.uk:81/qido/studies?StudyDate=20170901-20170930
- **STOW-RS**
  - DIMSE-C counterpart **C-STORE**
  - RESTful Services (RS) using HTTP POST

Part 2.

DICOM practical tutorial

Tools to be used

- DCMTK (DICOM toolkit)
  - C-FIND
- Python
  - C-FIND
  - QIDO-RS
  - WADO-RS