Diagnosing Problems in a PACS Network Using Software Emulators

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Objectives

- Identify “finger pointing” issues that arise in PACS networks
- Introduce DICOM Emulators and basic operations
- Use DICOM emulators to troubleshoot problems between systems in PACS networks
- Demonstrate DICOM Emulator troubleshooting techniques and logging
- Make troubleshooting techniques so easy you have no excuse not to implement them

What we are going to cover

- What you need to implement basic troubleshooting using emulators
  - Client/Server relationship
  - DICOM SCU/SCP
  - Port #’s and DICOM listening ports
  - AE Titles
  - DICOM PDU’s

What we are not going to cover

- DICOM Information Objects (IO's)
- DICOM SOP Classes (Service Object Pairs)
- DICOM Transfer Syntaxes
- Enhanced DICOM Services:
  - Storage Commitment
  - MPPS (Modality Performed Procedure Step)

Important Concepts

- Client/Server relationship
  - What is a client?
  - What is a server?
  - Who initiates any network communication?

- Port #'s and DICOM listening ports
  - http://www.iana.org/assignments/service-names-port-numbers/service-names-port-numbers.xhtml

Important Concepts

- DICOM SCU/SCP
  - Service Class User
  - Service Class Provider
  - Who initiates any DICOM communication?

- AE Titles
  - Application Entity – Name for DICOM application
    - 16 Character max
    - Case sensitive
    - No spaces
    - Unique within LAN

Principles of Transferring Medical Images:

Networking – The practice of linking computers together for the purpose of sharing data

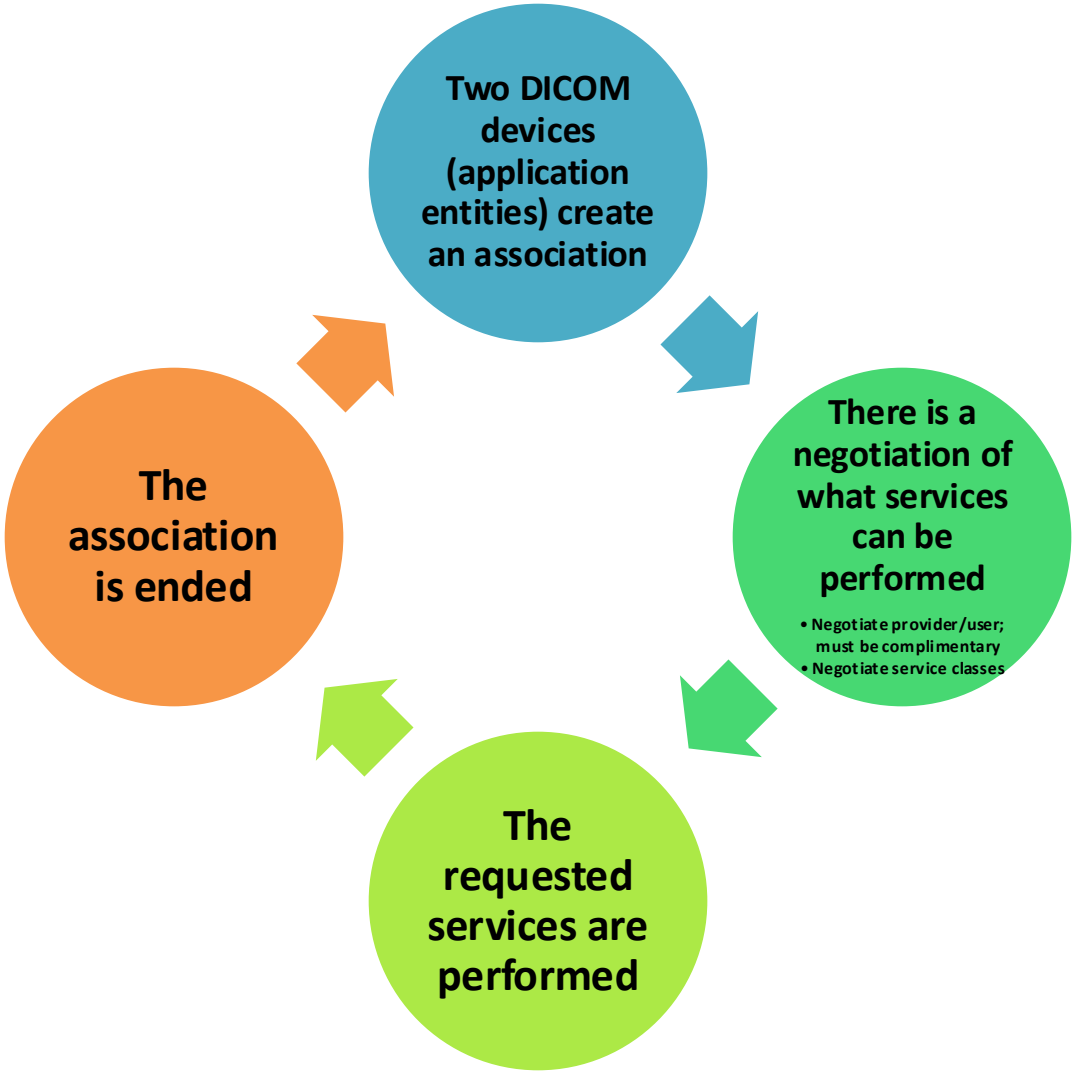
- TCP/IP – Refers to network communication
  - Transmission Control Protocol (TCP) is a Transport layer protocol
  - Internet Protocol (IP) is a Network layer protocol
- TCP transport is used to deliver data across IP networks

DICOM – Digital Imaging & Communications in Medicine

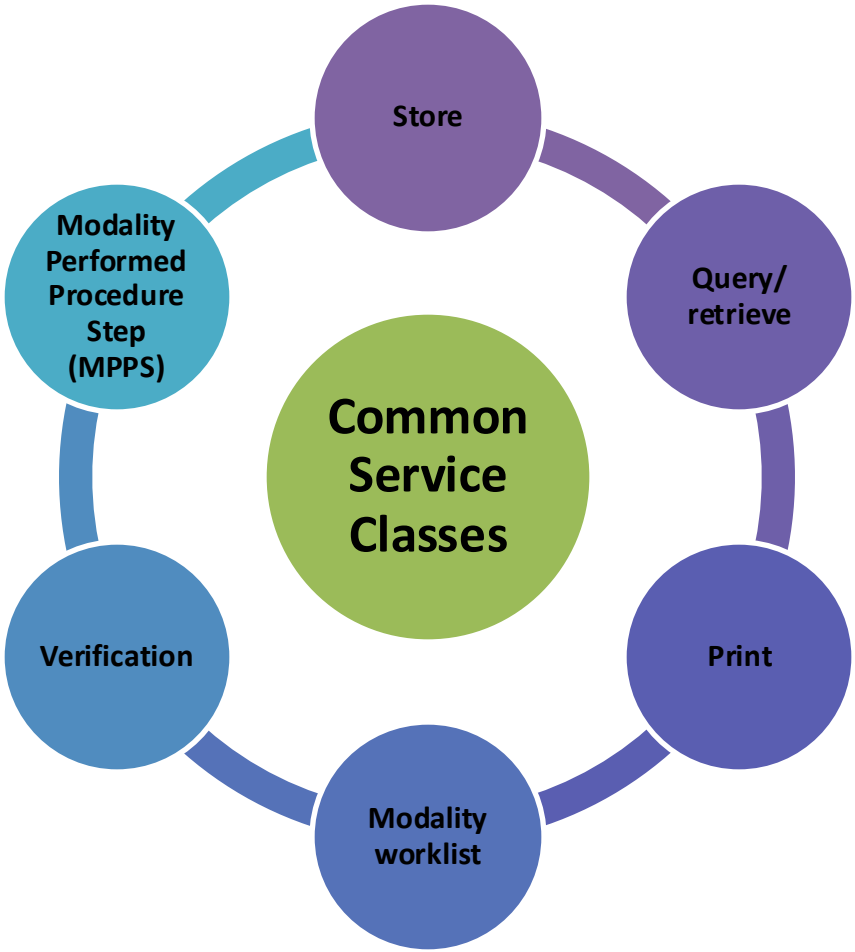
- Standard used to transfer medical images
- Includes a file format definition (.DCM) & a communications protocol (TCP/IP)

PACS/Digital Imaging Components

How does it work?



DICOM Services



DICOM Services

Store SCU
Print SCU
MWL SCU

- DICOM Store
- DICOM Print
- DICOM Query/Retrieve
- DICOM Modality Worklist

Print SCP

Store SCU
Store SCP
Print SCU
Q/R SCU

Store SCP
Store SCU
Q/R SCP

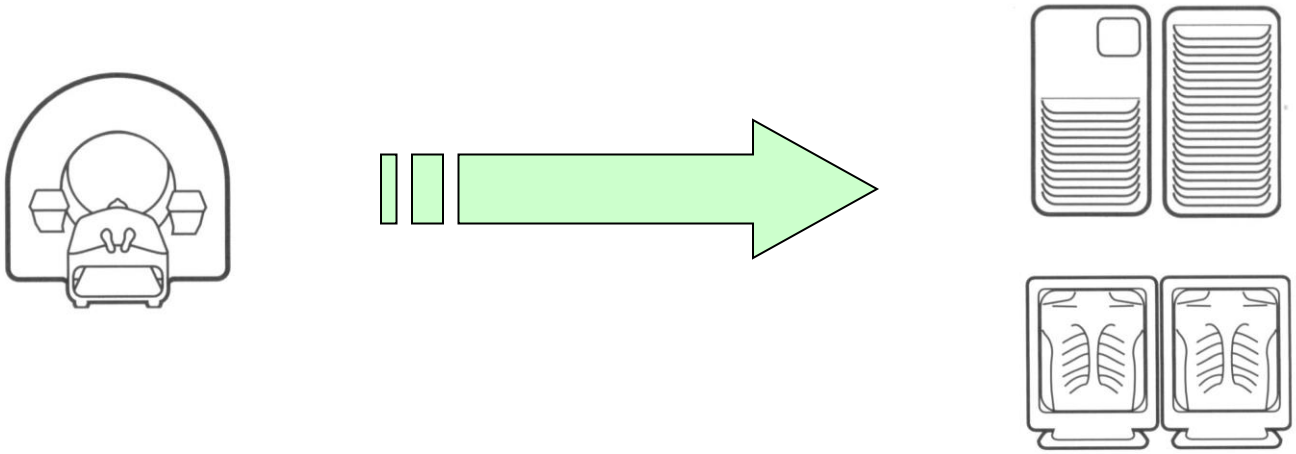
MWL SCP

What is needed for DICOM communications?

- Application entity (AE) title
  - Name 16 characters & case sensitive
- IP Address
  - Address
- SNM
  - Sub Net Mask
- Port Number
  - Listening port #

What DICOM Service Classes Do You Need?

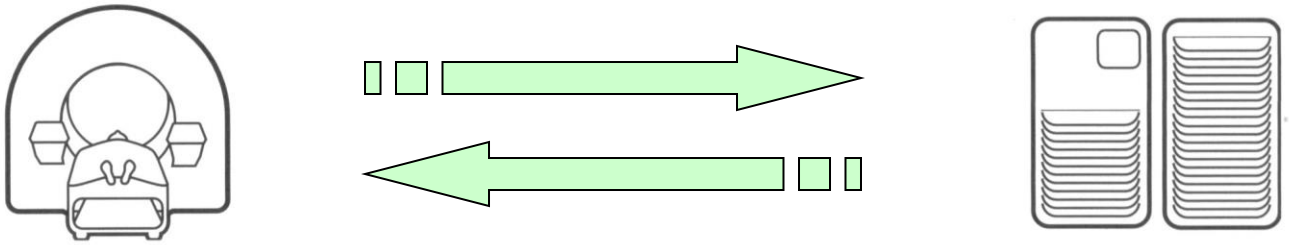
- DICOM Store



•Modality (SCU) Store to viewstation (SCP) or PACS (SCP)

Query Retrieve

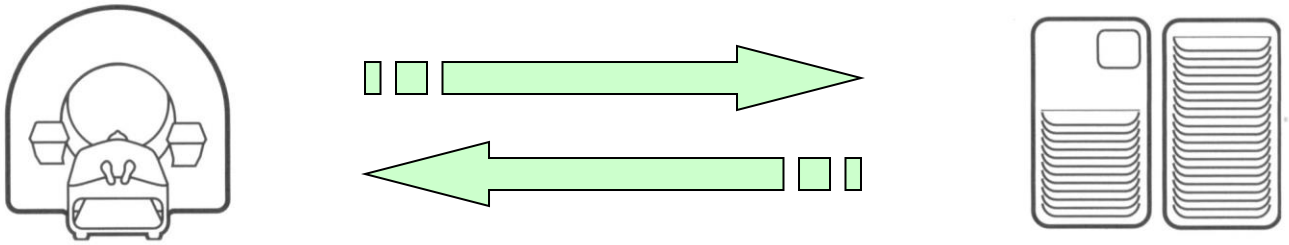
- DICOM Query/Retrieve



•Modality (SCU) Queries PACS (SCP)

Modality Worklist (MWL)

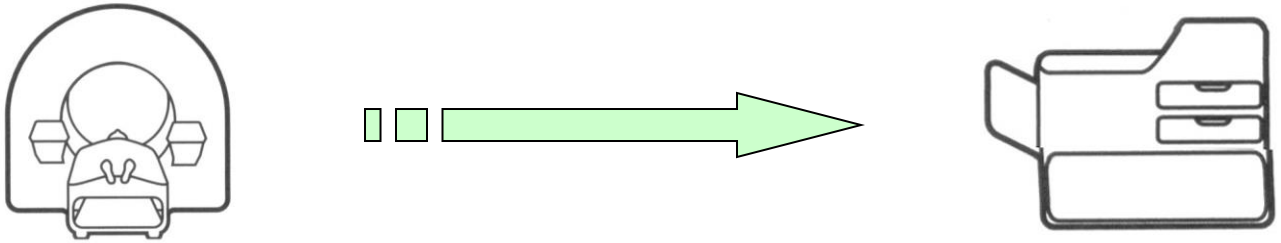
- DICOM MWL



•Modality (SCU) Queries RIS/MWL (SCP) for scheduling data

Print

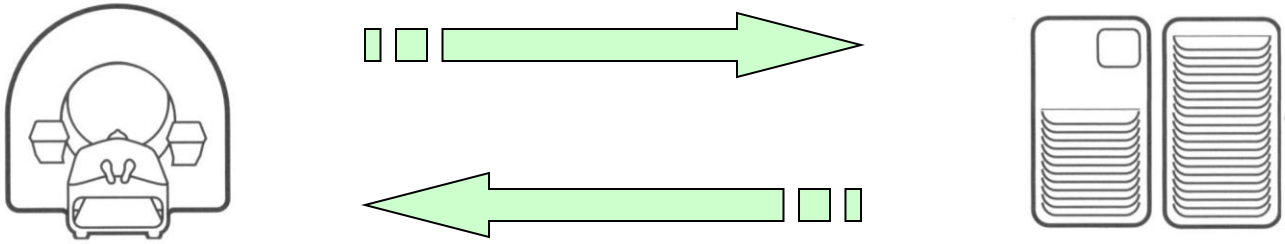
- DICOM Print



•Modality (SCU) Prints to Printer (SCP)

Verification

- Modality Verification – DICOM Verify



•Modality Verify (SCP&SCU) existence and readiness of destination (SCP)

•"DICOM Ping"

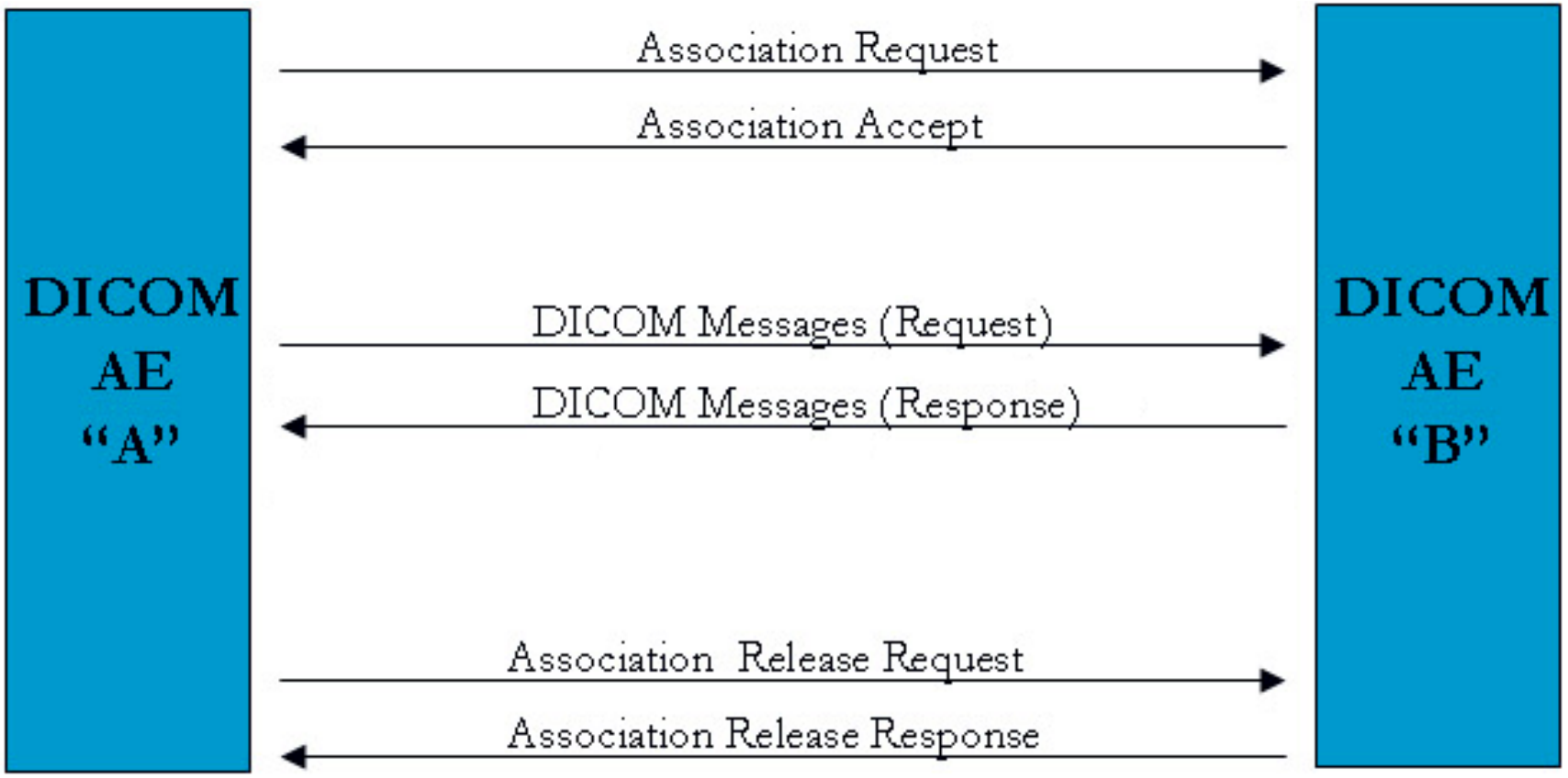
•SCP's are required to support Verification SCP

•How do you send a DICOM ECHO?

DICOM PDU's

- PDU's:
  - PDU1 - Associate-RQ
  - PDU2 - Associate-AC
  - PDU3 - Associate-RJ
  - PDU4 - Data
  - PDU5 - Release-RQ
  - PDU6 - Release-RP
  - PDU7 - Abort
- Review JDICOM example

DICOM PDU's



- Review DICOM Dump examples

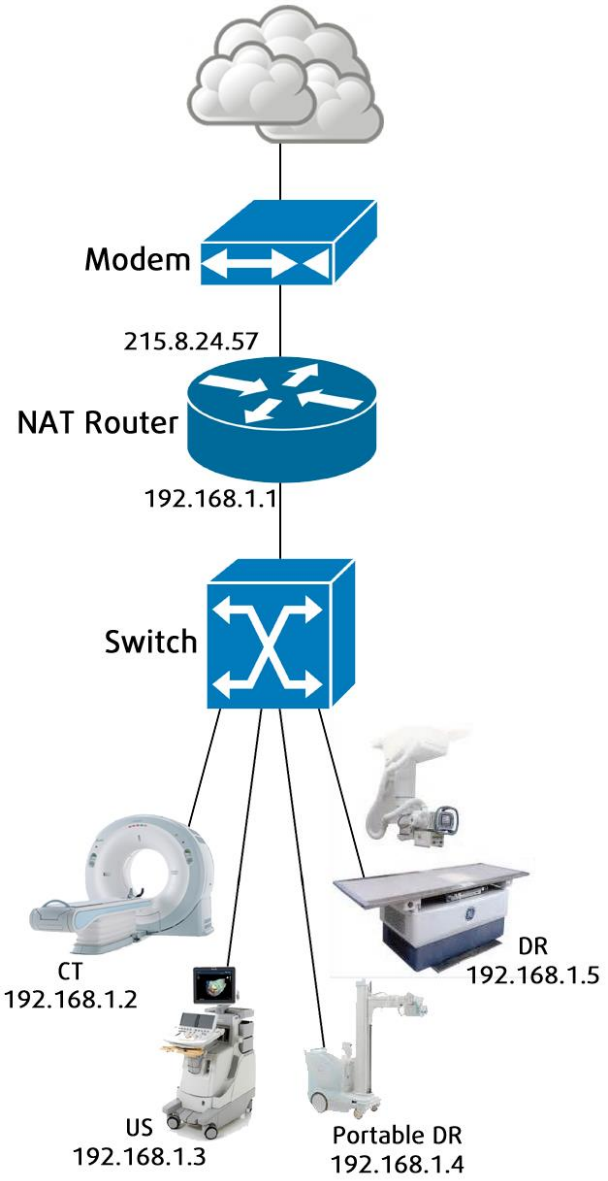
DICOM Header

0008,0005,Specific Character Set: ISO.IR 100
0008,0008,Image Type: ORIGINAL\PRIMARY
0008,0016,SOP Class UID: 1.2.840.10008.5.1.4.1.1.1.2.1.
0008,0018,SOP Instance UID: 1.2.840.1136817.754.3212254898.9
0008,0020,Study Date: 20021016
0008,0021,Series Date: 20021016
0008,0022,Acquisition Date: 20021016
0008,0023,Image Date: 20021016
0008,0030,Study Time: 170140
0008,0031,Series Time: 170144
0008,0032,Acquisition Time: 170744
0008,0033,Image Time: 170744
0008,0050,Accession Number: 48275
0008,0060,Modality: MG
0008,0068,?: FOR PROCESSING
0008,0070,Manufacturer: LORAD
0008,0080,Institution Name: RSTI Training Center
0008,0081,City Name: 30745 Solon Rd. Solon, OH
0008,0090,Referring Physician's Name: Todd Boyland
0008,1010,Station Name: selenia
0008,1030,Study Description: Standard Screening
0008,103E,Series Description: 1128472652
0008,1060,Name Phys(s) Read Study:
0008,1070,Operator's Name: Andrea
0008,1080,Admitting Diagnosis Description: Screening
0008,1090,Manufacturer's Model Name: Mammo-Clinical
0008,2111,?: 93.Breast.2.25456.2.0.1.0.46.151.151.151.59.41.341.143

0018,0060,KVP [Peak Output, KV]: 28
0018,1000,Device Serial Number: H1KRHR830f12f3
0018,1004,?: Array Temp 22.22C
0018,1020,Software Version: MAMMODROC.1.1.0.3
0018,1030,Protocol Name: 1128472652
0018,1110,Distance Source to Detector [mm]: 650
0018,1111,Distance Source to Patient [mm]: 610
0018,1147,?: RECTANGLE
0018,1150,Exposure Time [ms]: 540028982
0018,1151,X-ray Tube Current [mA]: 100
0018,1152,Acquisition Device Processing Description:
0018,1164,?: .070\.070
0018,1166,?: HTC.IN
0018,1170,Generator Power:
0018,1190,Focal Spot[s]: 540225072
0018,11A0,?: 808333881
0018,11A2,?: 0.0000000
0018,1200,Date of Last Calibration: 021124
0018,1201,Time of Last Calibration: 143000
0018,1260,Plate Type: aSe
0018,1400,Acquisition Device Processing Description:
0018,1401,Acquisition Device Processing Code:
0018,1402,Cassette Orientation: PORTRAIT
0018,1403,Cassette Size: 24CMx29CM
0018,1508,?: MAMMOGRAPHIC
0018,1510,Positioner Primary Angle: 8240
0018,5101,View Position: CC
0019,1028,?: 24x29
0028,0030,Pixel Spacing: .070\.070

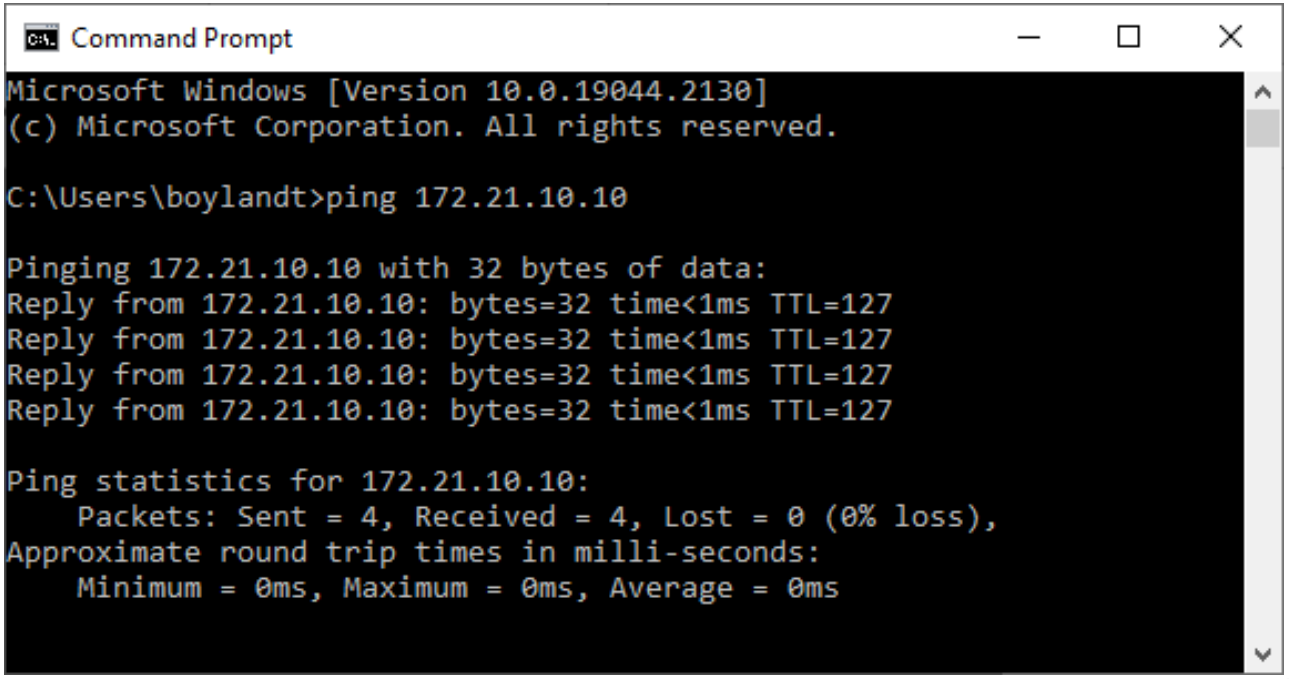
Connectivity Testing

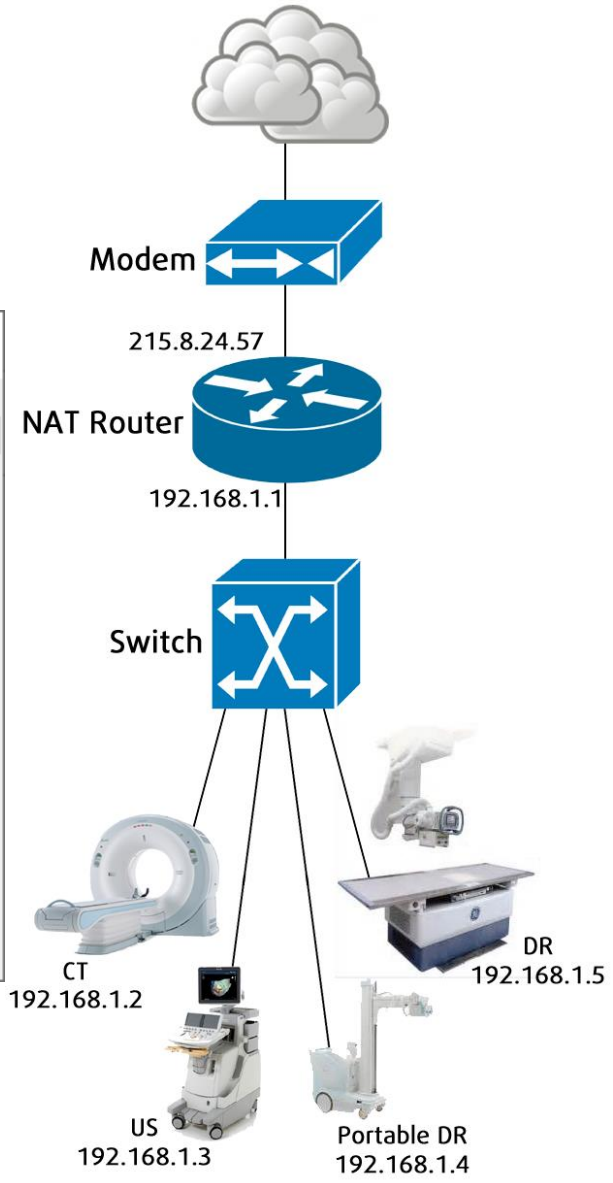
- TCP/IP ping
  - Used to test and verify hardware communication between two devices.
  - TCP/IP command, which means it is part of the TCP/IP protocol stack, and not built into the OS (Operating System).
    - This makes ping OS independent and will function on Windows, UNIX, Linux, Solaris, etc...
  - Beware: firewalls



Connectivity Testing

- TCP/IP ping





Connectivity Testing

- TCP/IP netstat
  - Command line tool that displays network connections, routing tables, and many more network statistics.
    - -a displays all active connections
    - -n displays all TCP connections

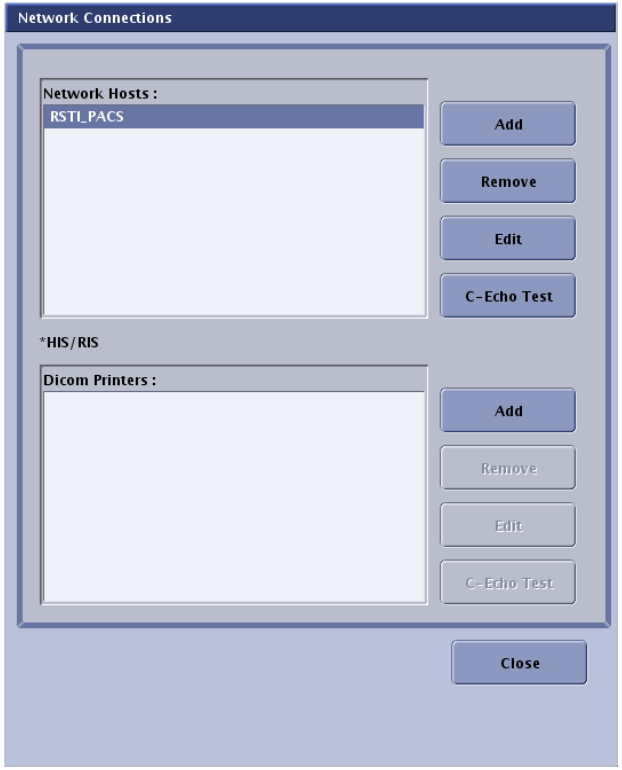
```
C:\Documents and Settings\Todd Boyland>netstat -a

Active Connections

  Proto  Local Address          Foreign Address        State
  TCP    TB:104                 TB:0                   LISTENING
  TCP    TB:epmap               TB:0                   LISTENING
  TCP    TB:microsoft-ds        TB:0                   LISTENING
  TCP    TB:104                 10.0.0.10:1099         ESTABLISHED
  TCP    TB:netbios-ssn         TB:0                   LISTENING
  TCP    TB:1099                10.0.0.10:104          ESTABLISHED
  TCP    TB:1030                TB:0                   LISTENING
  TCP    TB:1038                TB:0                   LISTENING
  TCP    TB:1069                localhost:1070         ESTABLISHED
  TCP    TB:1070                localhost:1069         ESTABLISHED
  TCP    TB:1072                localhost:1073         ESTABLISHED
  TCP    TB:1073                localhost:1072         ESTABLISHED
  TCP    TB:5152                TB:0                   LISTENING
```

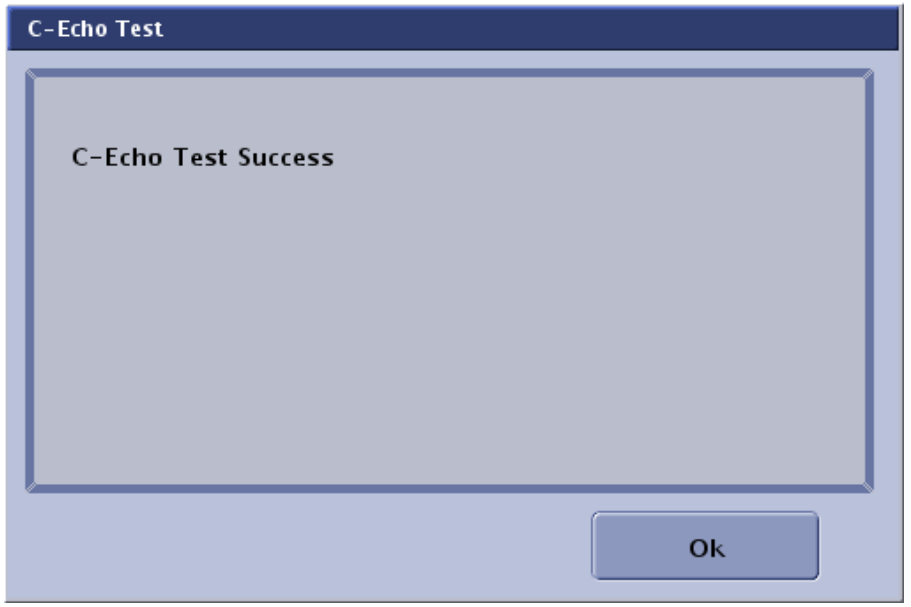
Connectivity Testing

- DICOM ECHO
- Understanding:
  - What does a failed ping tell you?
  - What does a successful ping, but failed DICOM ECHO tell you?
  - What does a successful DICOM ECHO tell you?
  - Troubleshooting starts by isolating hardware vs content

Connectivity Testing

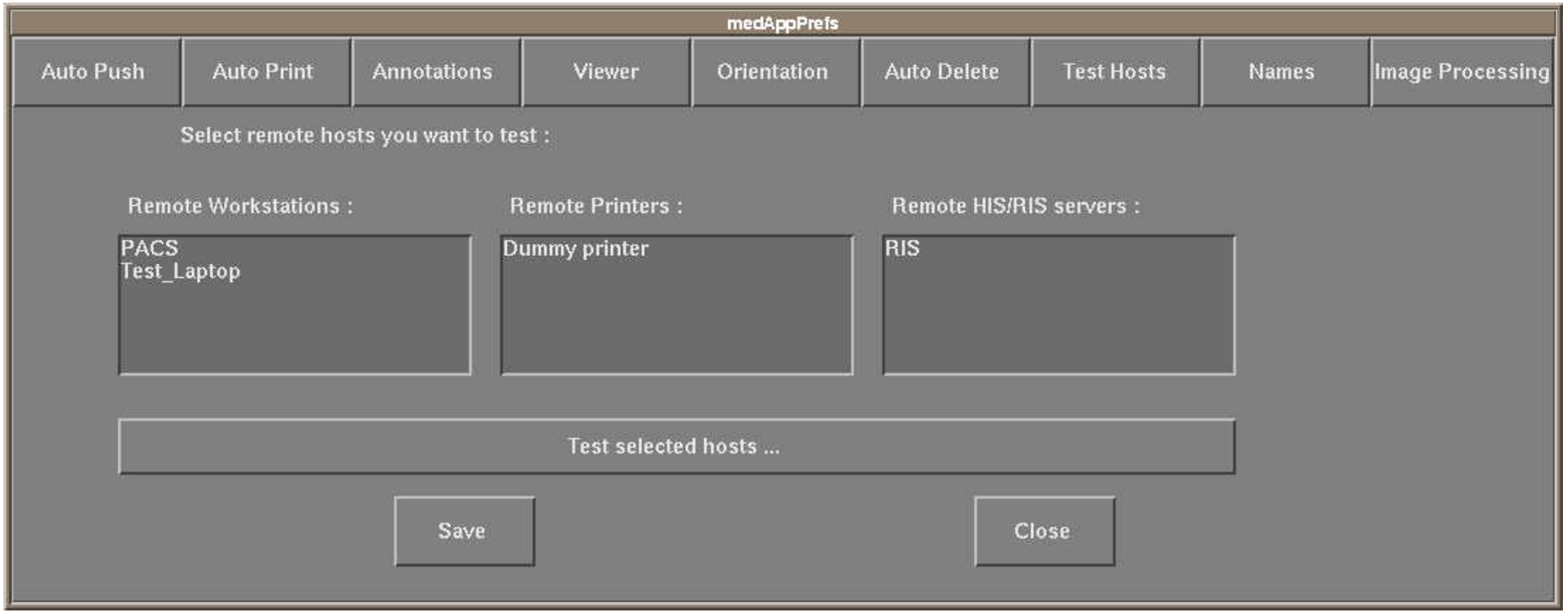
- DICOM ECHO
  - May not be available, results may not be intuitive
  - Examples: GE DR





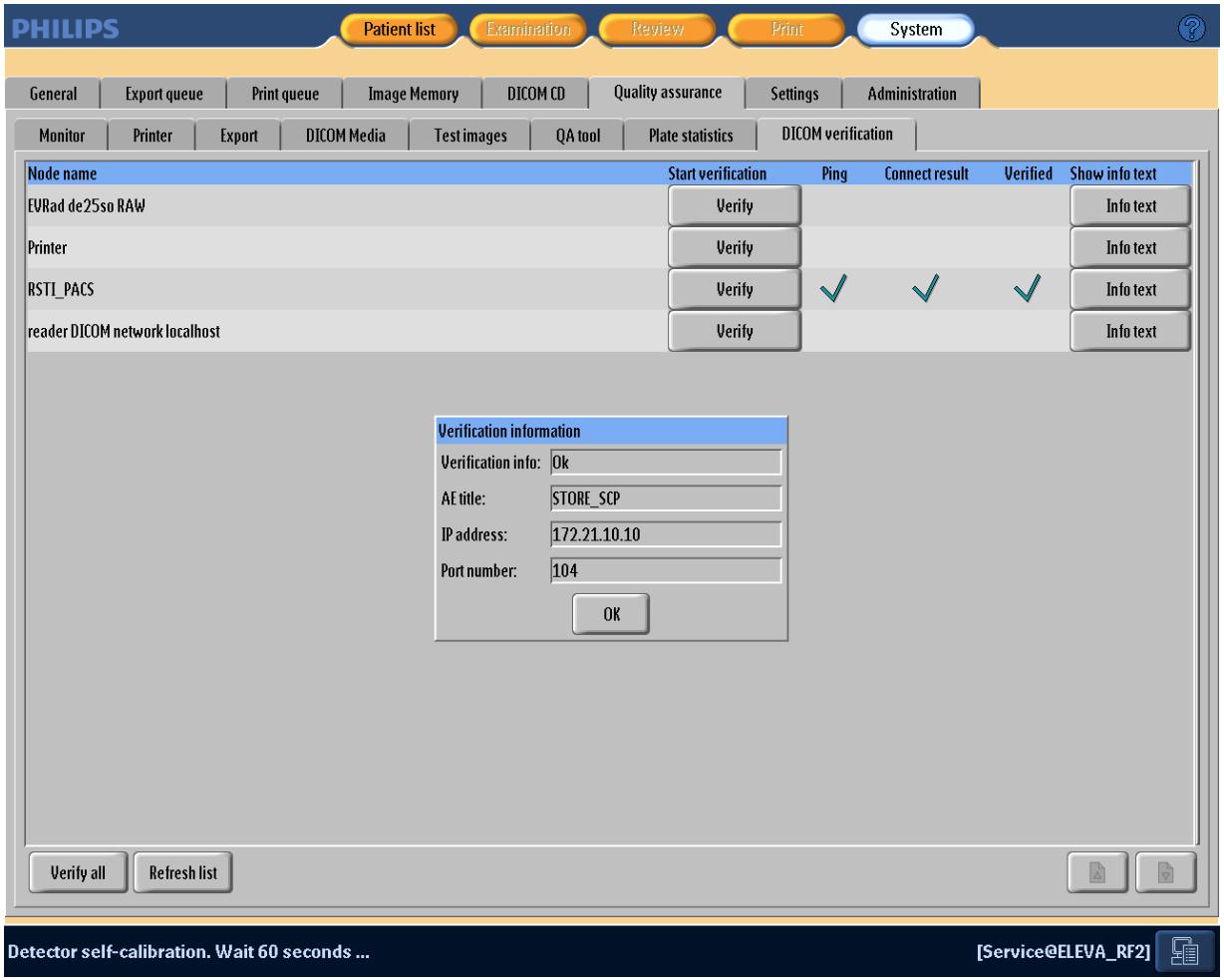
Connectivity Testing

- DICOM ECHO examples: GE MG



Connectivity Testing

- DICOM ECHO examples: Philips DR

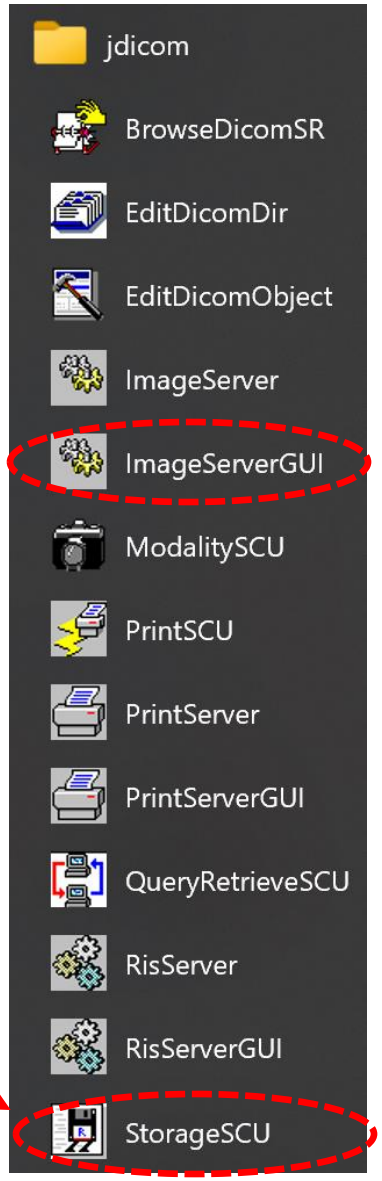


Advanced Troubleshooting Tools: DICOM Emulation

- DICOM Emulators:
  - JDICOM (<=Win XP)
    - All tools built within 1 application
    - No longer supported, but works great for basic troubleshooting
  - DVTk (>=Win7)
    - Separate application for each tool
      - Send image
      - Receive image
      - Request worklist
      - Provide worklist
      - Etc…
    - Currently updates being released

JDICOM - Installation

- JDICOM is a Java-based DICOM emulator used for validating and diagnosing communication problems in medical environments.
- Run single JDICOM installer
- Each SCU/SCP is a standalone application
  - Most useful
- No longer supported/updated
  - Still extremely useful
  - Easy install & ease of use makes this my go-to

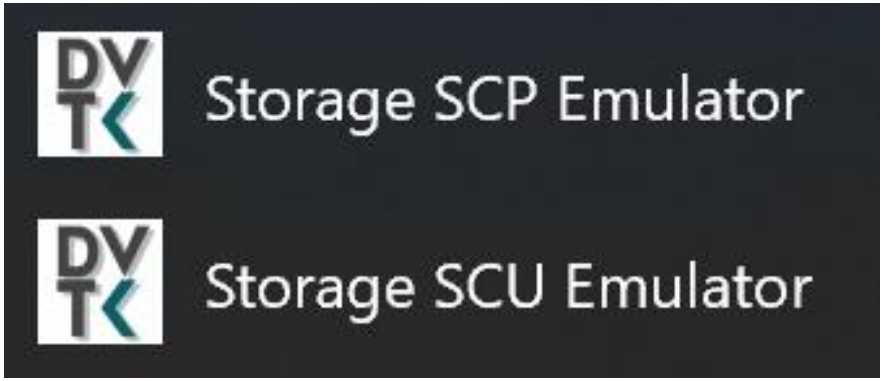


DICOM Emulation - DVTk

- DVTk is an open-source project for testing, validating and diagnosing communication protocols and scenarios in medical environments. It supports DICOM, HL7 and IHE integration profiles.
- Each SCU/SCP is a standalone application:
  - Storage SCU Emulator
  - Storage SCP Emulator
  - Query/Retrieve SCP Emulator
  - RIS Emulator
- Definition Files
  - Contain validation rules that enable DICOM Messages and DICOM Files to be validated against the DICOM standard. These DICOM Definition Files are used by all DVTk based applications.
  - Required to ensure SCU/SCP applications are up to date w/ changes to the DICOM standard

DVTk - Installation

- Install desired DVTk application on service laptop based on troubleshooting scenario:
  - Storage SCU Emulator
  - Storage SCP Emulator
  - Query/Retrieve SCP Emulator
  - RIS Emulator
- Install DVTk Definitions
- Note:
  - AV may recognize as threat



Before You Begin

(With any emulator/sniffer troubleshooting)

- Determine & record connectivity parameters for all systems involved!
  - For all systems:
    - IP Address (always required)
    - Subnet Mask (may be required)
    - Default Gateway (may be required)
    - AE Title (always required)
    - Listening Port (always required, If system is SCP)
- Eliminate the obvious:
  - Has this ever worked?
  - What has changed recently?
    - Product upgrades/patches/reconfiguration/vendor visit?
  - Ping
    - A > B
    - B > A
    - A > C (default gateway)
    - B > C (default gateway)

Problem Scenario: Modality cannot send image to PACS

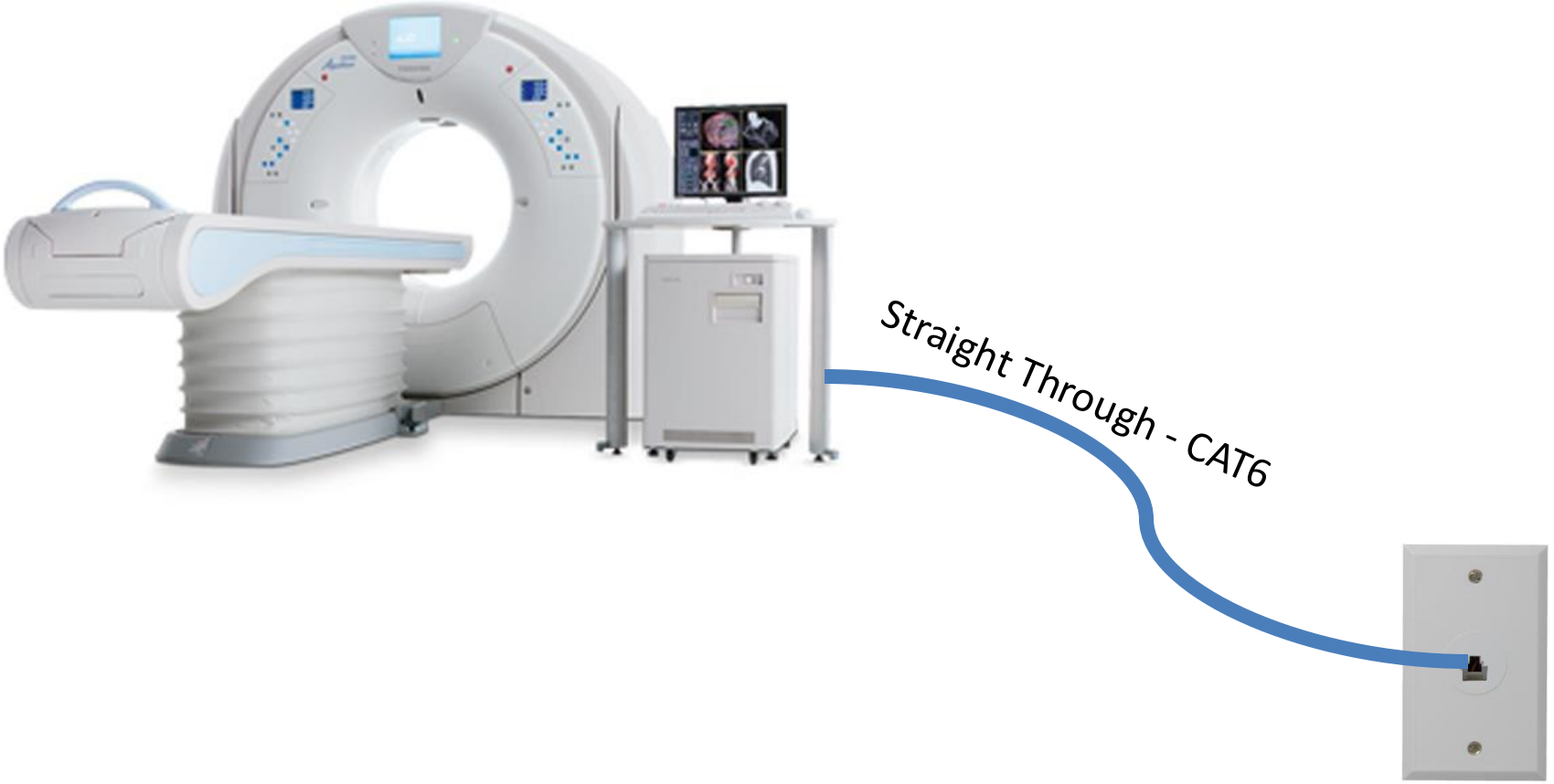
- Modality OEM: “Our unit is working fine”
- PACS Admin: “PACS is working fine”, “We haven’t changed anything lately”

Scenario 1, Emulate SCU

- What settings do I use on my laptop?
  - Can I make up any settings?
    - IP
    - SNM
    - AE Title
    - Port #

  - Can I getting static IP settings from IT to verify there is no conflict?
  - What would be the best solution?
  - Why is this the best solution?
  - How do I accomplish this if those settings are already in use by other systems?

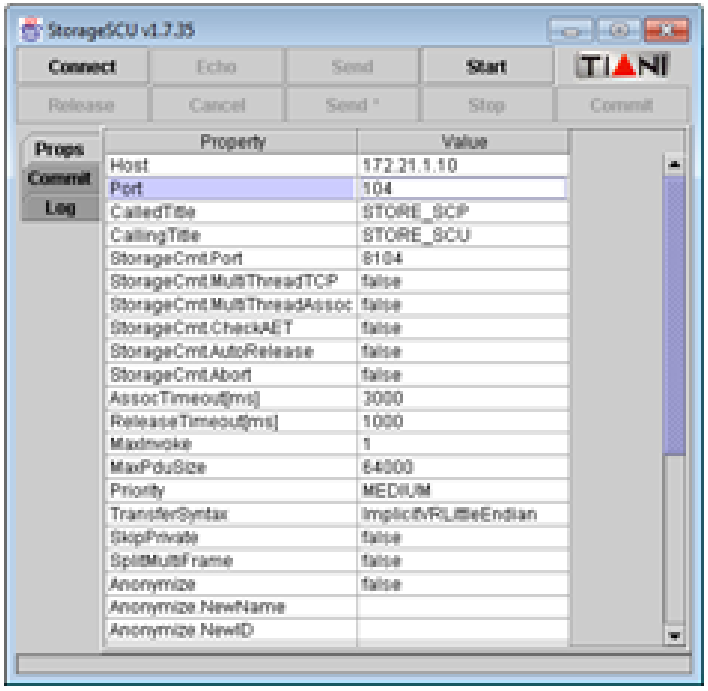
Scenario 1, Emulate SCU



Scenario 1, Emulate SCU

JDICOM Scenario 1 (Emulate SCU): DICOM ECHO

1. Set static IP in OS
2. Run JDicom program “StorageSCU”
3. In the “Props” tab, fill in:
   - Host = IP Address of SCP (of the PACS/destination)
   - Port = DICOM port # (of the PACS/destination)
   - Called Title = AE Title (of the PACS/destination)
   - Calling Title = AE Title of Your Laptop (Modality/Store SCU)
   - Set Verbose to:
     - 1 for no PDU logging
     - 2 for DIMSE logging in PDU’s
     - 3 for detailed DIMSE logging in PDU’s
4. Click: Connect



JDICOM Scenario 1 (Emulate SCU): DICOM ECHO & STORE

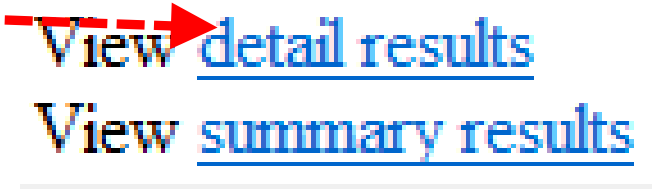
5. Click Log Tab
   - Log should now read (Where STORE_SCP is the AE Title of the PACS/destination):
     - jdicom: #2:STORE_SCP << A-ASSOCIATE-RQ PDU
     - jdicom: #2:STORE_SCP >> A-ASSOCIATE-AC PDU
6. Click: Echo (or Send, to transfer an image)
   - Log should now read:
     - jdicom: #2:STORE_SCP << C-ECHO-RQ Verification SOP Class
     - jdicom: #2:STORE_SCP >> C-ECHO-RSP , status #0000H[Success]
7. Click: Release
   - Log should now read:
     - jdicom: #2:STORE_SCP << A-RELEASE-RQ PDU
     - jdicom: #2:STORE_SCP >> A-RELEASE-RP PDU
     - jdicom: #2:STORE_SCP closing socket

DVTk Scenario 1 (Emulate SCU): DICOM ECHO

- Set static IP in OS
- Open “Storage SCU Emulator”
  - Configure/Verify SCP settings
  - Configure/Verify SCU settings
  - Ping SCP
  - Perform DICOM Echo
  - Review Logging (tab)
  - Select: Display Validation Result
  - Select: Detail Results
  - Verify:
    - A_ASSOCIATE_RQ
    - A_ASSOCIATE_AC
    - C_ECHO_RQ
    - C_ECHO_RSP
      - 0000,0900 = Status Code, Value of 0000 = SUCCESS
    - A_RELEASE_RQ
    - A_RELEASE_RP

DVTk Scenario 1 (Emulate SCU): DICOM STORE

- Open “Storage SCU Emulator”
  - Configure/Verify SCP settings
  - Configure/Verify SCU settings
  - Ping SCP
  - File > Export DICOM Data > Select DICOM Files
  - Review Logging (tab)
  - Select: Display Validation Result
  - Select: Detail Results
  - Verify:
    - A_ASSOCIATE_RQ
    - A_ASSOCIATE_AC
    - C_STORE_RQ
    - C_STORE_RSP
      - 0000,0900 = Status Code, Value of 0000 = SUCCESS
    - A_RELEASE_RQ
    - A_RELEASE_RP



Scenario 1 (Emulate SCU): DICOM ECHO

- What do these results tell us?
  - A_ASSOCIATE_RQ
  - A_ASSOCIATE_AC
  - C_ECHO_RQ
  - C_ECHO_RSP
    - 0000,0900 = Status Code, Value of 0000 = SUCCESS
  - A_RELEASE_RQ
  - A_RELEASE_RP

- Why don't you see a (0000,0900) tag in the C_ECHO_RQ?

Scenario 1 (Emulate SCU): DICOM STORE

- What do these results tell us?
  - A_ASSOCIATE_RQ
  - A_ASSOCIATE_AC
  - C_STORE_RQ
  - C_STORE_RSP
    - 0000,0900 = Status Code, Value of 0000 = SUCCESS
  - A_RELEASE_RQ
  - A_RELEASE_RP

Scenario 1 (Emulate SCU): DICOM ECHO

- What would it mean if the DICOM ECHO was successful, but the DICOM STORE failed?
  - A_ASSOCIATE_RQ
  - A_ASSOCIATE_AC
  - C_ECHO_RQ
  - C_ECHO_RSP
    - 0000,0900 = Status Code, Value of 0000 = SUCCESS
  - A_RELEASE_RQ
  - A_RELEASE_RP

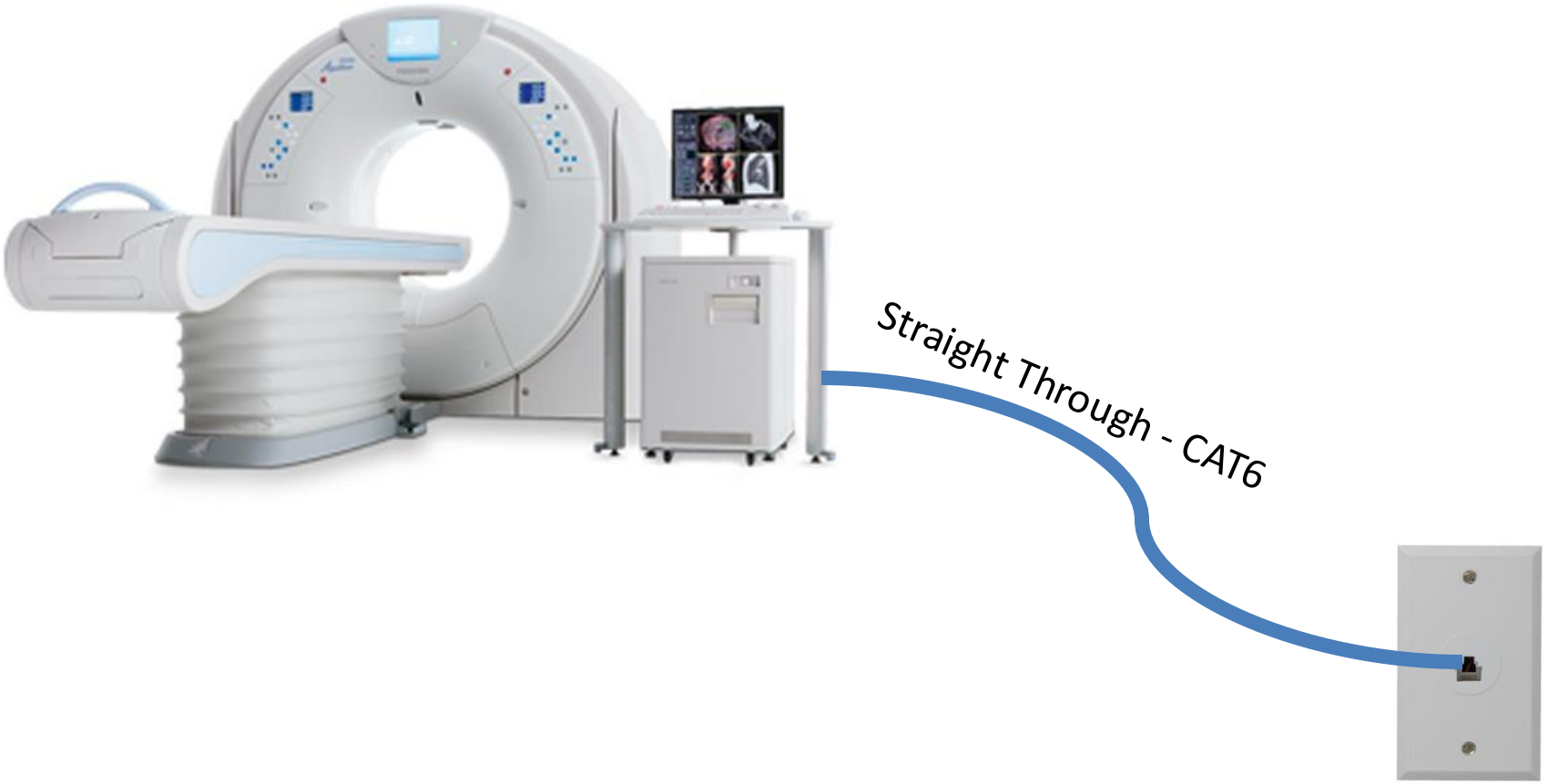
  - A_ASSOCIATE_RQ
  - A_ASSOCIATE_AC
  - C_STORE_RQ
  - C_STORE_RSP
    - 0000,0900 = Status Code, other than 0000 = Problem
  - A_RELEASE_RQ
  - A_RELEASE_RP

Scenario 2, Emulate SCP

- What settings do I use on my laptop?
  - Can I make up settings?
    - IP
    - SNM
    - AE Title
    - Port #

  - Can I get static IP settings from IT to verify there is no conflict?
  - What would be the best solution?
  - Why is this the best solution?
  - How do I accomplish this if those settings are already in use by other systems?

Scenario 2, Emulate SCP



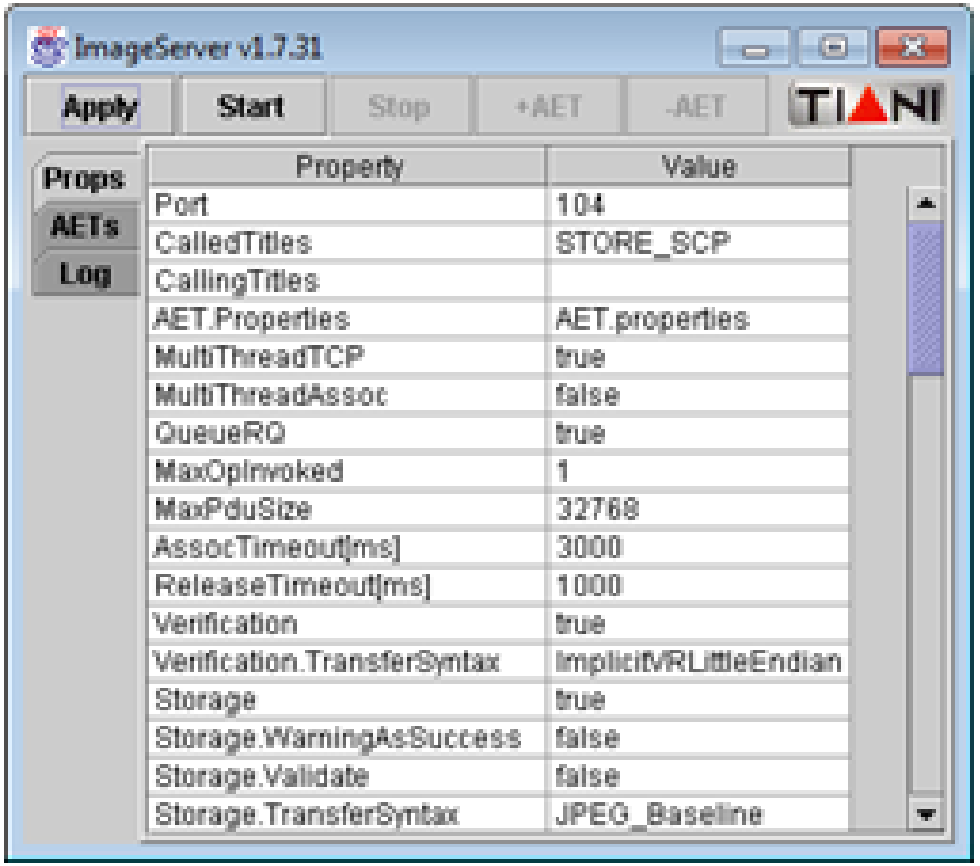
Scenario 2, Emulate SCP

JDICOM Scenario 2: Emulate SCP

1. Set static IP in OS
2. Run JDicom program “ImageServerGUI”
3. In the “Props” tab, fill in:
   - Port = DICOM port # of the SCP (your laptop)
   - Called Title = AE Title of the STORE SCP (your laptop)
   - Calling Title = AE Title of STORE SCU (the modality, leave blank for promiscuous mode)
   - Set Verbose to:
     - 1 for no PDU logging
     - 2 for DIMSE logging in PDU’s
     - 3 for detailed DIMSE logging in PDU’s
   - Fileset.Path must be set to a valid directory where you want received images to be stored. (ex. Create a directory called “images” in the JDICOM folder, the path will then read: c:/program files/jdicom/images

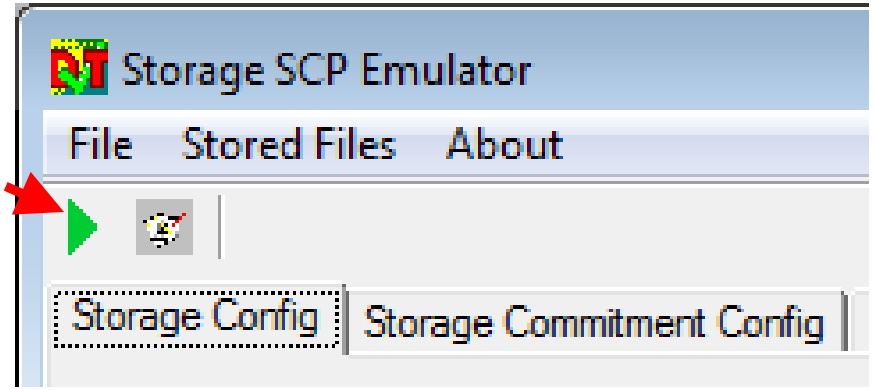
JDICOM Scenario 2: Emulate SCP

4. Check to ensure transfer syntaxes are the same as device trying to communicate with.
5. Click: Apply
6. Click: Start
7. Click Log Tab
   - Log should now read: “Waiting for invocations from clients...” near the bottom of the log



DVTk Scenario 2: Emulate SCP

- Set static IP in OS
- Open “Storage SCP Emulator”
  - Configure/Verify settings in “Storage Config” (tab)
  - Click: Run Emulator
  - From modality:
    - Perform DICOM Echo (if possible)
    - Perform DICOM STORE functions
  - Review Logging (tab)
  - Verify:
    - ASSOCIATE_RQ
    - ASSOCIATE_AC
    - STORE_RQ
    - STORE_RSP
      - 0000,0900 = Status Code, Value of 0000 = SUCCESS
    - RELEASE_RQ
    - RELEASE_RP



Emulator Overview

- Program your laptop to act as a DICOM device
- Laptop actively participates in DICOM communication
- Cut the problem in half
- Obtain record of what is actually happening
- Can send logs to PACS Admin's, Vendors, or tech support personnel
- Can utilize more advanced techniques than we have time to cover:
  - Changing SOP classes
  - Using compression
  - Changing Transfer Syntaxes
  - Multiple vs Single association settings
  - Etc…
- It is as easy as it sounds

Questions?

Thank You For Your Time

Todd Boyland, CEO, RSTI Training

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