Network Management for Picture Archiving and Communication Systems (PACS)

Edwood Yiu

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School of Engineering Science
Simon Fraser University

Road map

- Purpose
- PACS overview
- Hospital workflow
- Network protocols used in hospital environment
- Problems frequently seen in hospital
- Simple Network Management Protocol (SNMP) overview
- Software design
- Software functions
- Conclusions

Project scope

- Investigate the possibility of applying SNMP to information systems in hospital
- Develop software to monitor PACS using SNMP
- Demonstrate the use of SNMP for managing hospital network

Key accomplishments

- Defined the managed objects used by SNMP to manage PACS

- Implemented a library for exchanging SNMP messages between PACS and Windows SNMP service

- Modified PACS to support tracking of its status

- Modified PACS to reload configuration upon changes

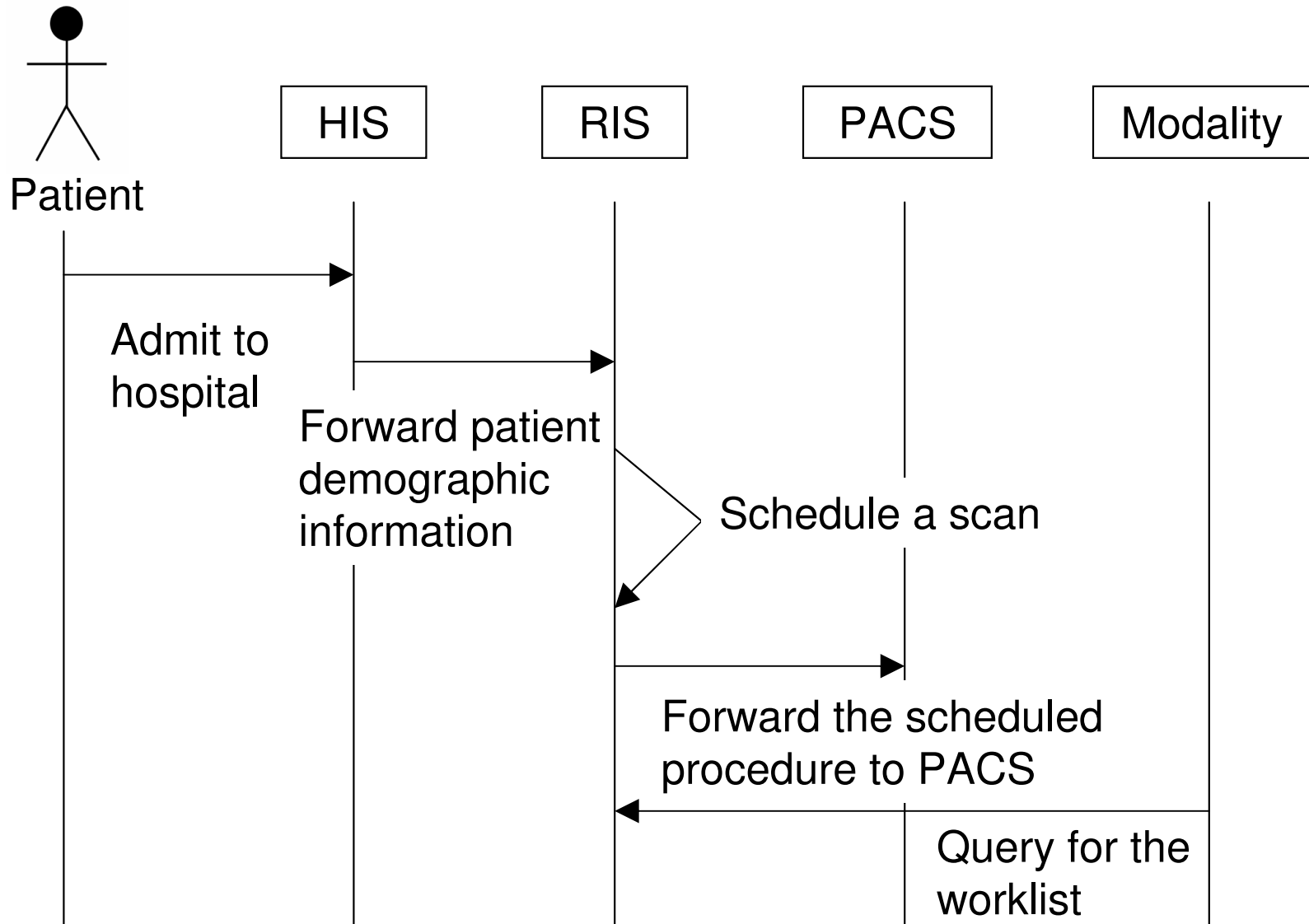- Documented the software architecture of SNMP-enabled PACS

Role of PACS in hospital

- Many innovations and breakthroughs in the past few decades
- Diagnostic imaging equipment also known as modality
- Show the interior view of human body on film
- Film is expensive
- PACS replaces the use of film in hospital by displaying the images on computer monitor
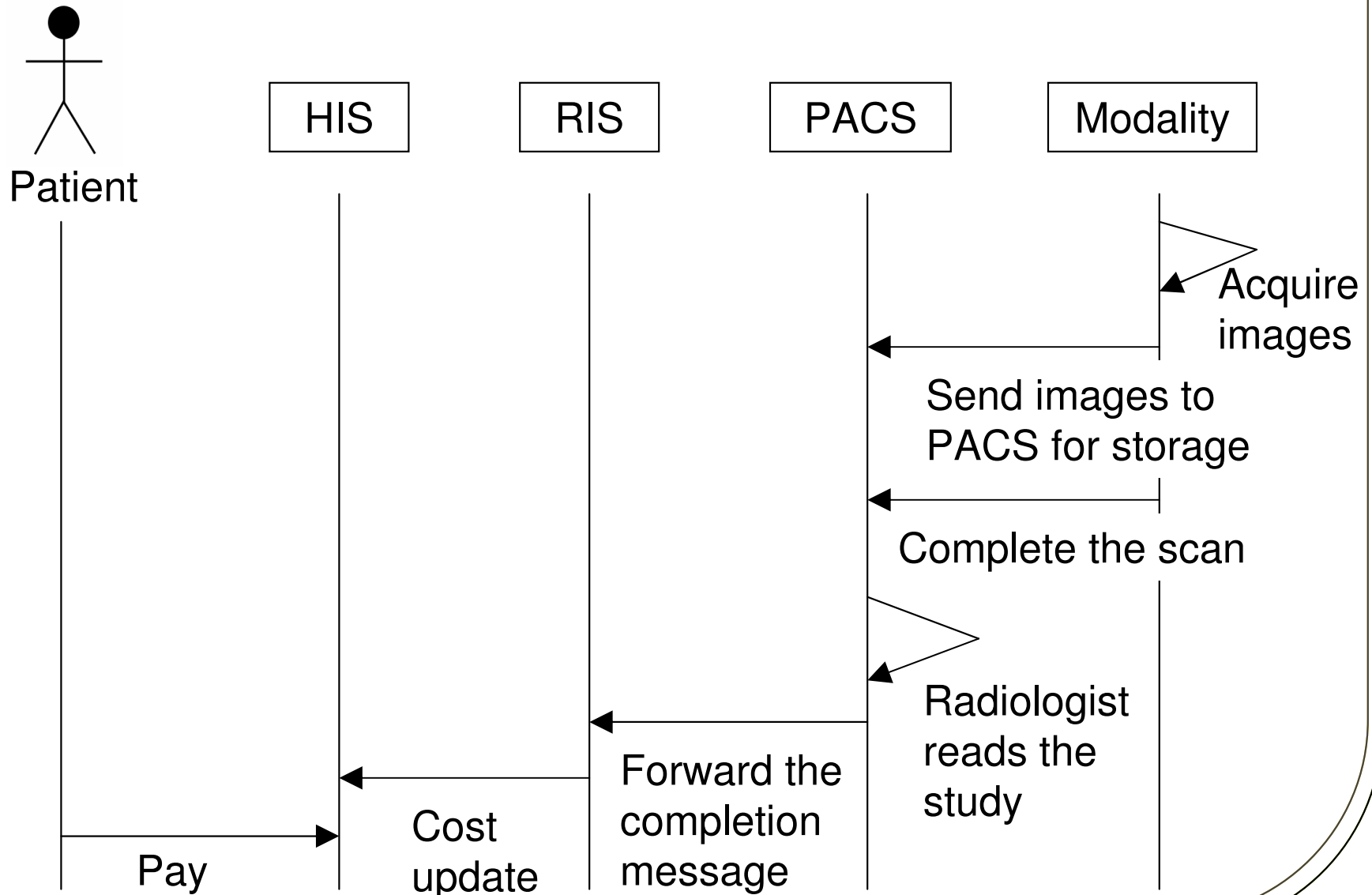- PACS manages diagnostics images

Information systems in hospital

- Hospital information system: HIS
- Radiology information system: RIS
- Picture archiving and communication system: PACS
- Modality:
  - ultrasound: US
  - magnetic resonance imaging: MRI
  - computed tomography: CT

Hospital workflow

Patient

HIS   RIS   PACS   Modality

Admit to hospital

Forward patient demographic information

Schedule a scan

Forward the scheduled procedure to PACS

Query for the worklist

Hospital workflow

Benefits of using PACS

- Film storage is eliminated
- Diagnostic images will never be lost
- Physicians can diagnose patients faster
- Use computer-aided detection software to reduce the misread cases
- 3D reconstruction images

Problems encountered with PACS

- More network issues
- Radiologists and technologists do not know how to operate computers
- PACS archiving problems
- PACS configuration issues
- PACS administrators are hired at hospitals to solve these problems
- No commercial tools was developed to help PACS administrators
- Total cost of PACS ownership is high

Network protocols and initiatives

- Network protocols
  - Health Level Seven: HL7
    - Used to manage patient demographic information
  - Digital Imaging and Communication in Medicine: DICOM
    - Used to manage diagnostic images
- Initiatives
  - Integrating the Healthcare Enterprise: IHE
    - Used to clarify the use of HL7 and DICOM in hospital workflow

Network protocols in hospital network

PACS workstation

HIS

PACS

MRI

RIS

US

HL7
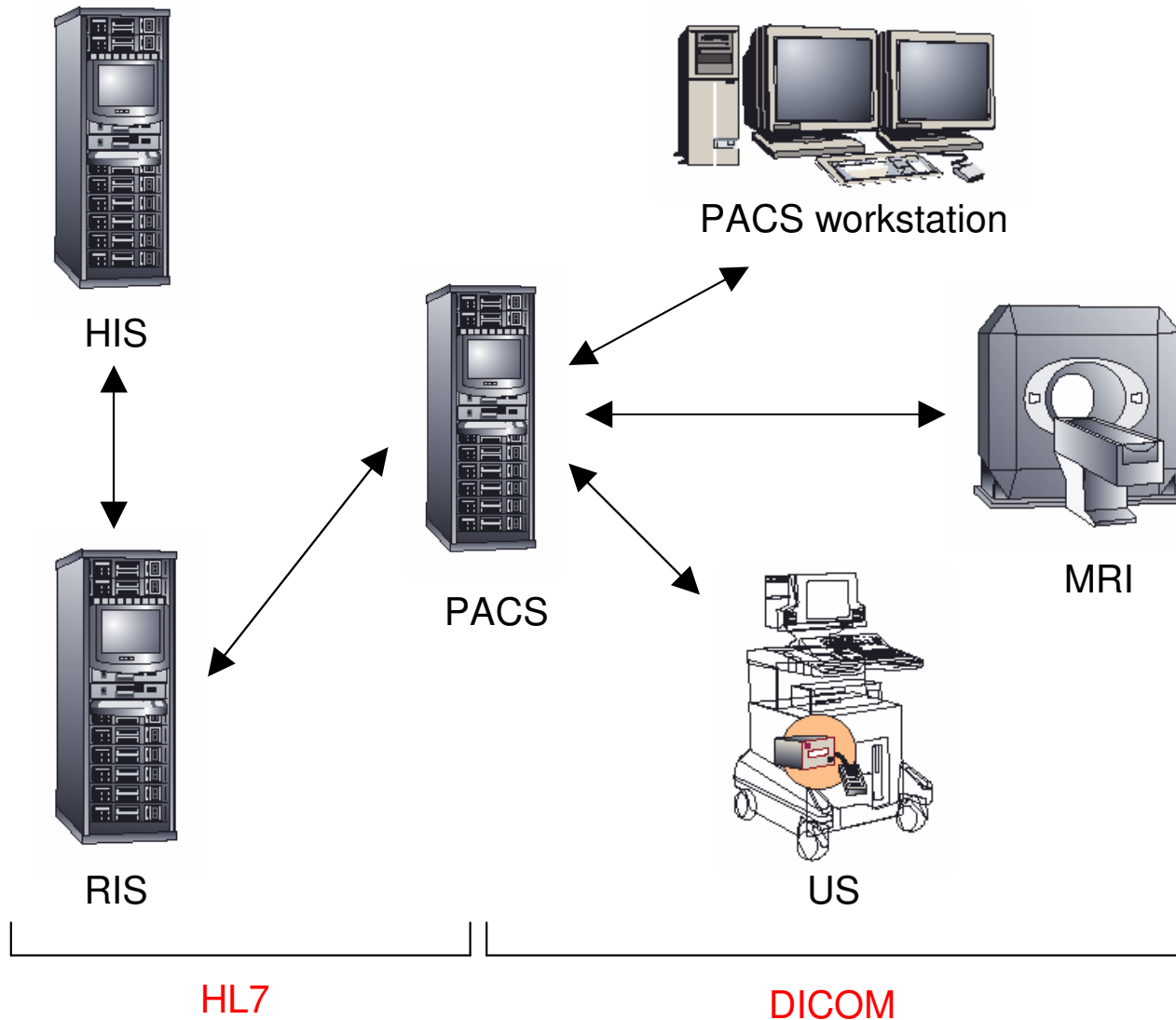
DICOM

Acronym:
HIS – Hospital information
system
MRI – Magnetic resonance
imaging
PACS – Picture archiving and
communication system
RIS – Radiology information
system
US – Ultrasound

DICOM

- Diagnostic image storage format
- Communication layer for exchanging messages
- Syntax and semantics of commands

DICOM file storage format

- DICOM header and pixel data
- DICOM header contains information:
  - patient demographic
  - study
  - series
  - image
- Pixel data contains images:
  - single-frame
  - multiple-frame

DICOM communication

- Use TCP/IP network
- DICOM connection consists of three stages
  - Association establishment
    - negotiate the types of DICOM file or query for this transaction
  - Data transfer
    - sending images for storage: C-STORE
    - query: C-FIND
    - retrieve: C-MOVE
  - Association release
    - graceful release
    - abort

Storing images at remote server: C-STORE command
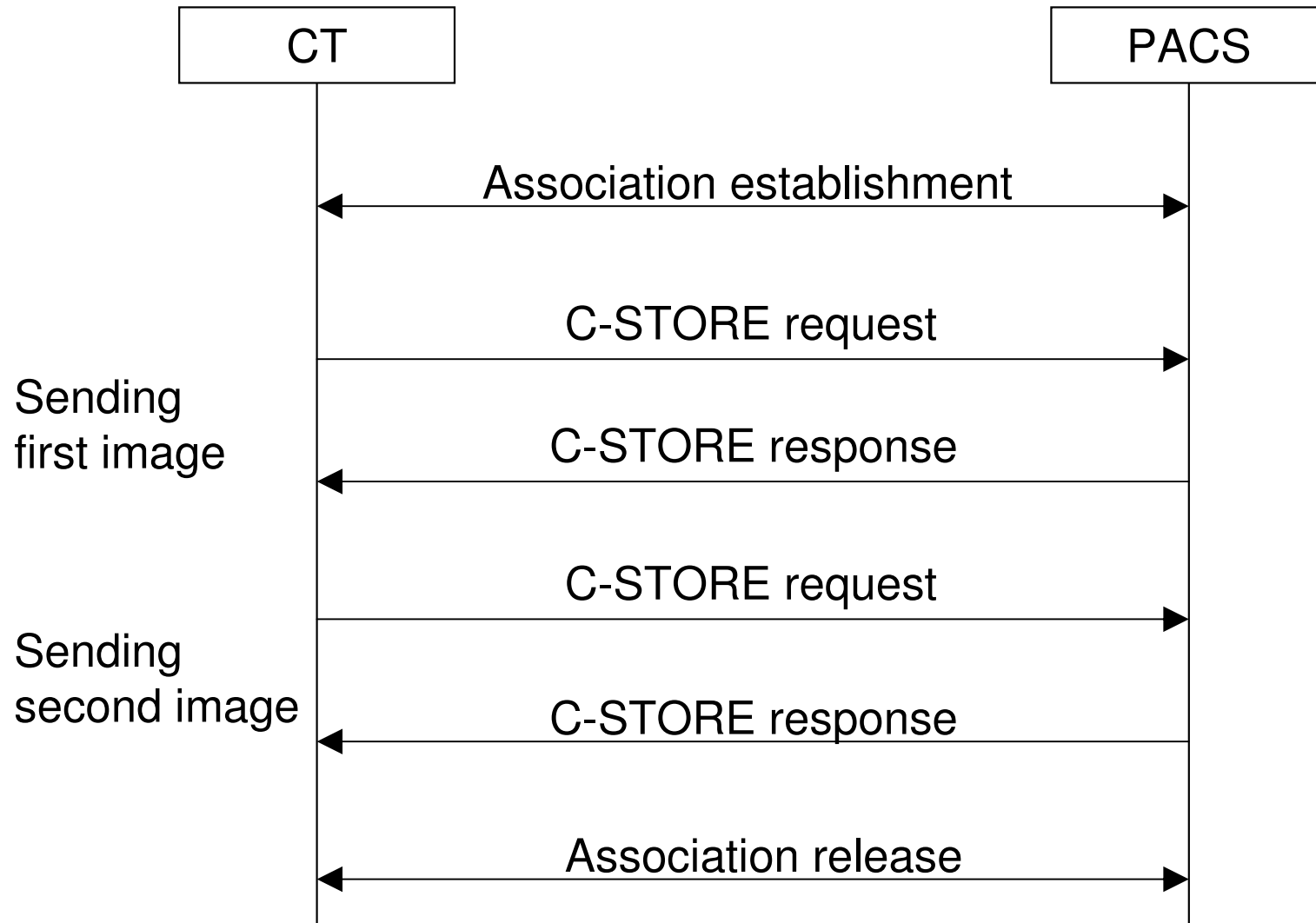
Querying remote server for study information: C-FIND command

Review workstation		PACS

Association establishment

C-FIND request

First match — C-FIND response

Second match — C-FIND response

Third match — C-FIND response

Association release
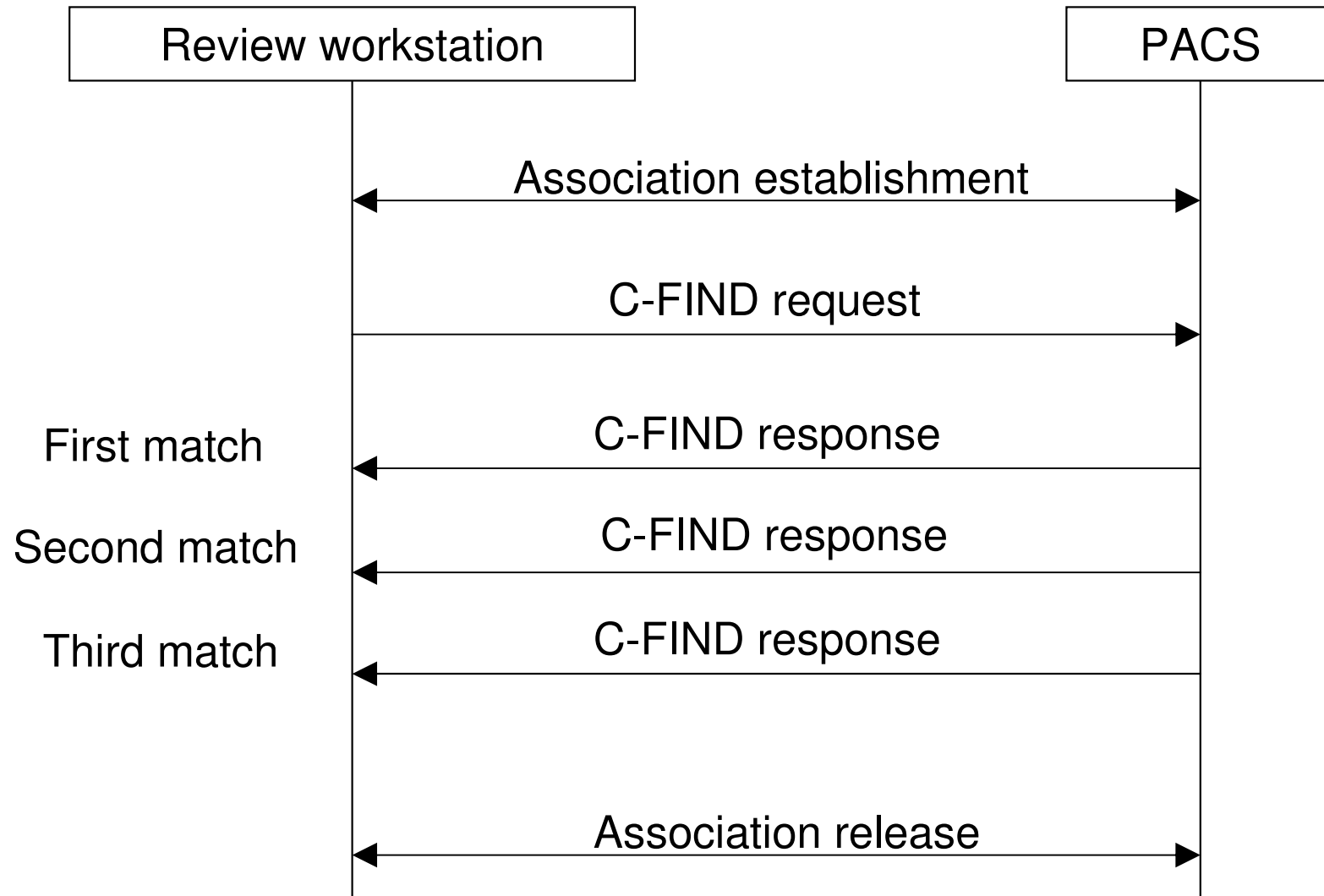
Retrieving images from remote server: C-MOVE command

Review workstation		PACS

Association establishment

C-MOVE request

Association establishment

C-STORE request

C-STORE response

Repeat for more images

C-MOVE response

Final C-MOVE response

Association release

Association release
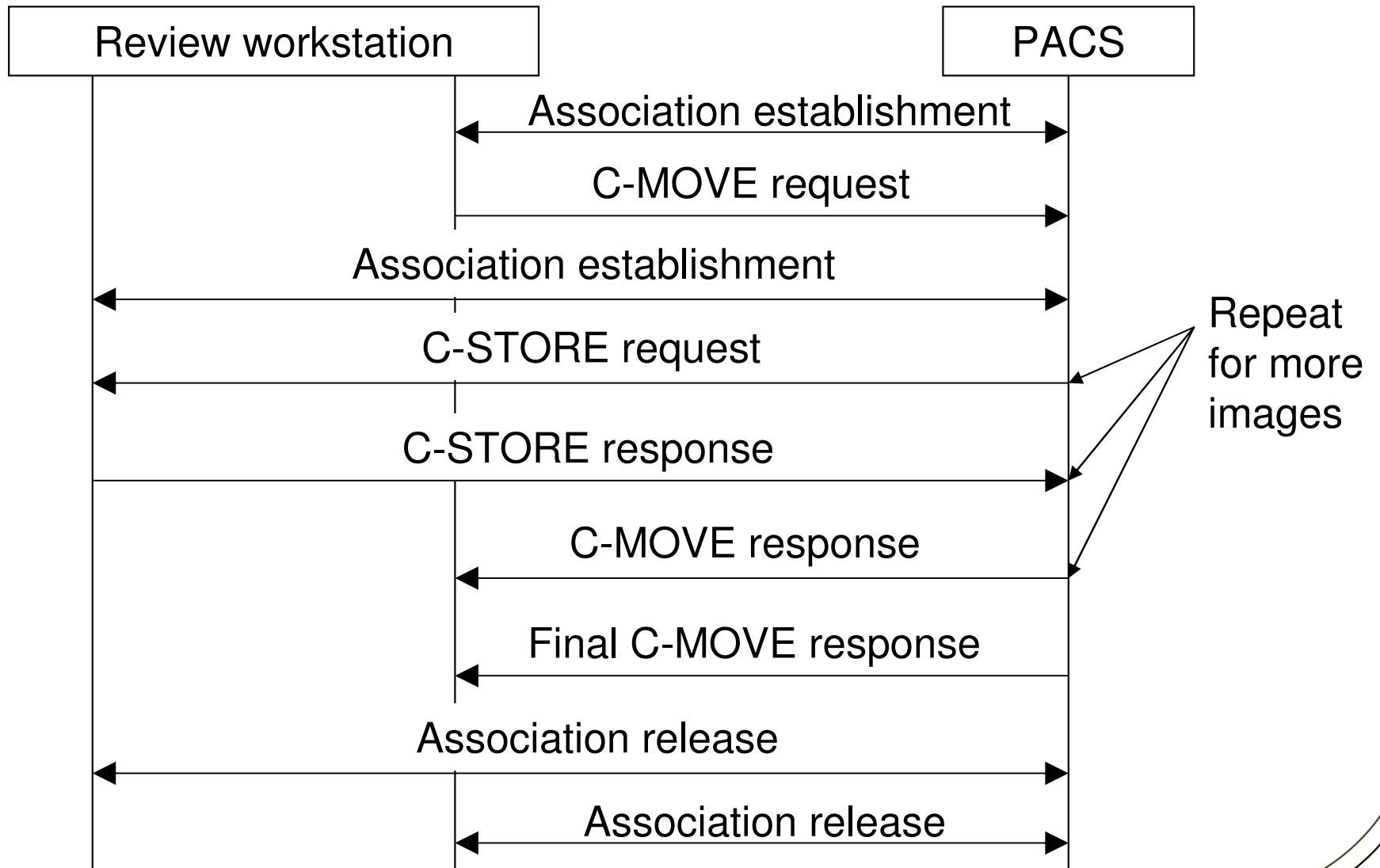
SNMP overview

- Network management protocol
- Simplicity nature
- Lightweight: performance impact is minimized
- Portable: independent of operating system and programming language
- Extensible: management information can be extended to support new devices
- Standardized: actively maintained by Internet activities board

SNMP v1

- Object identifier (OID) is introduced to manage vast amount of data
- OID is numerical string where digits are hierarchically organized
  - 1.3.6.1.4.1.9.9.48.1.1.1.6.1
- When requesting for specific data from a device, the corresponding OID is included in the request
- Four commands:
  - GET, GET-NEXT, SET, and TRAP
- SNMP manager and SNMP agent

Software architecture

```
PACS monitor
GUI
         ↕
PACS SNMP
manager                          PACS
         ↕                        ↕
Microsoft                 PACS SNMP
SNMP library              extension agent library
         ↕                        ↕
Microsoft                 Microsoft
SNMP service              SNMP service
         ↕                        ↕
Microsoft                 Microsoft
TCP/IP stack  ←→          TCP/IP stack
```

PACS monitor system   PACS system
(SNMP manager)   (SNMP agent)

my work

Edlic's work

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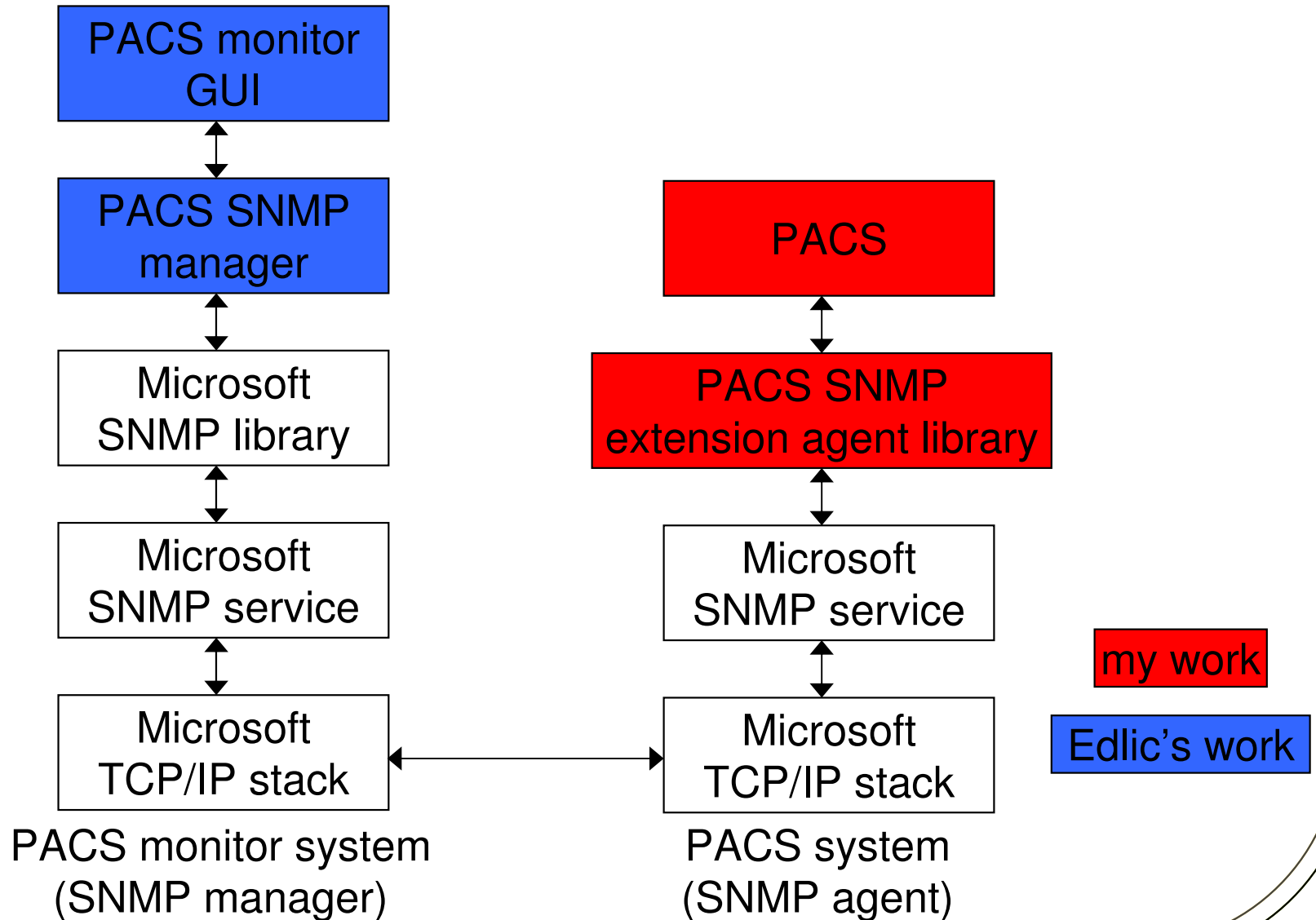
Implementation overview

- PACS SNMP extension agent library
  - define the managed objects used by SNMP to manage the C-STORE operation
  - implement a library for exchanging SNMP messages between PACS and Windows SNMP service
- PACS modification
  - support tracking of its status
  - reload configuration upon changes

Development work

- C programming language
- Added around 5800 lines of code
- Added two threads in PACS for tracking its status and for reloading with new configuration changes
- Created the PACS SNMP extension agent library to extract PACS status and to return the managed data to the PACS monitor system
- Created shared memory region for the communication between PACS and PACS SNMP extension agent library
- Thread-safe implementation

Software component diagram

Windows operating system

Microsoft
SNMP service
process space

PACS SNMP
extension agent
library

PACS process
space

Shared
memory
region
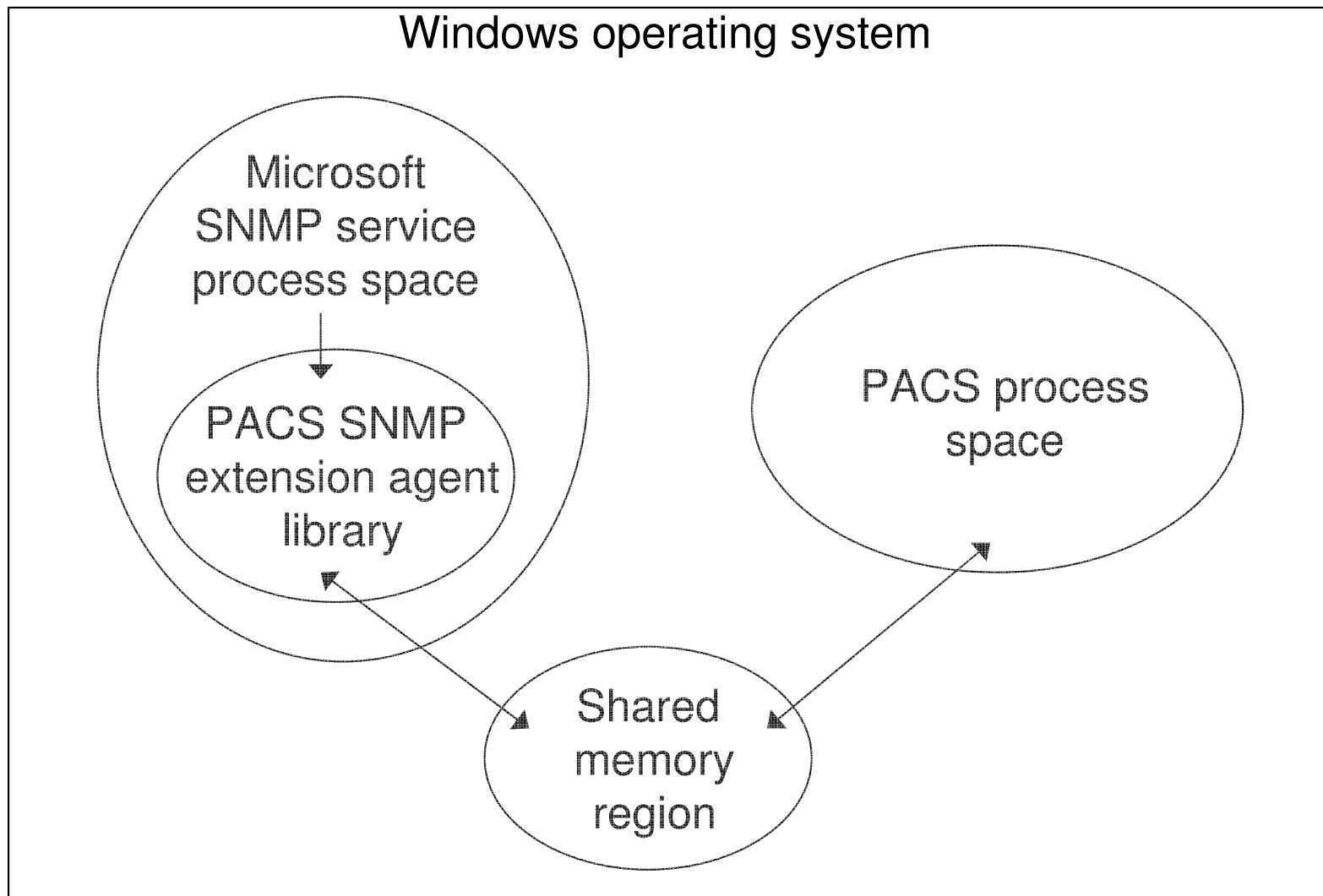
Software design for PACS SNMP extension agent library

- Four public functions were implemented as required by Microsoft SNMP service
  - SnmpExtensionInit(): inform Microsoft SNMP service the OIDs that PACS support, and allocate resources used in this library
  - SnmpExtensionClose(): de-allocate resources used in this library
  - SnmpExtensionTrap(): for Microsoft SNMP service to find out the error occurred in PACS
  - SnmpExtensionQuery(): for Microsoft SNMP service to exchange GET, GET-NEXT, and SET requests and responses with PACS

Software design for PACS to support SNMP

```
                    ┌─────────────────────┐
                    │   Program starts    │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
          ┌─────────│  Create in-memory   │─────────┐
          │         │ managed object storage│        │
          │         └─────────────────────┘         │
          ▼                    ▼                     ▼
┌──────────────────┐ ┌──────────────────┐ ┌──────────────────┐
│ Create a thread to│ │ Notify PACS SNMP │ │ Create a thread to│
│ maintain the managed│ extension agent library│ monitor any     │
│ object instances  │ │ when an error occurs│ │ configuration change│
└──────────────────┘ └──────────────────┘ └──────────────────┘
          │                    │                     │
          ▼                    ▼                     ▼
┌──────────────────┐                    ┌──────────────────┐
│ Update managed   │                    │  Reload with new │
│ objects as images arrive│              │  configuration   │
│      PACS        │                    └──────────────────┘
└──────────────────┘                              │
          │                                        │
          ▼                                        ▼
        ┌──────────────────────────────────────┐
        │      Signal PACS to terminate        │
        └──────────────────────────────────────┘
                          │
                          ▼
```

GET, GET-NEXT   TRAP   SET

26
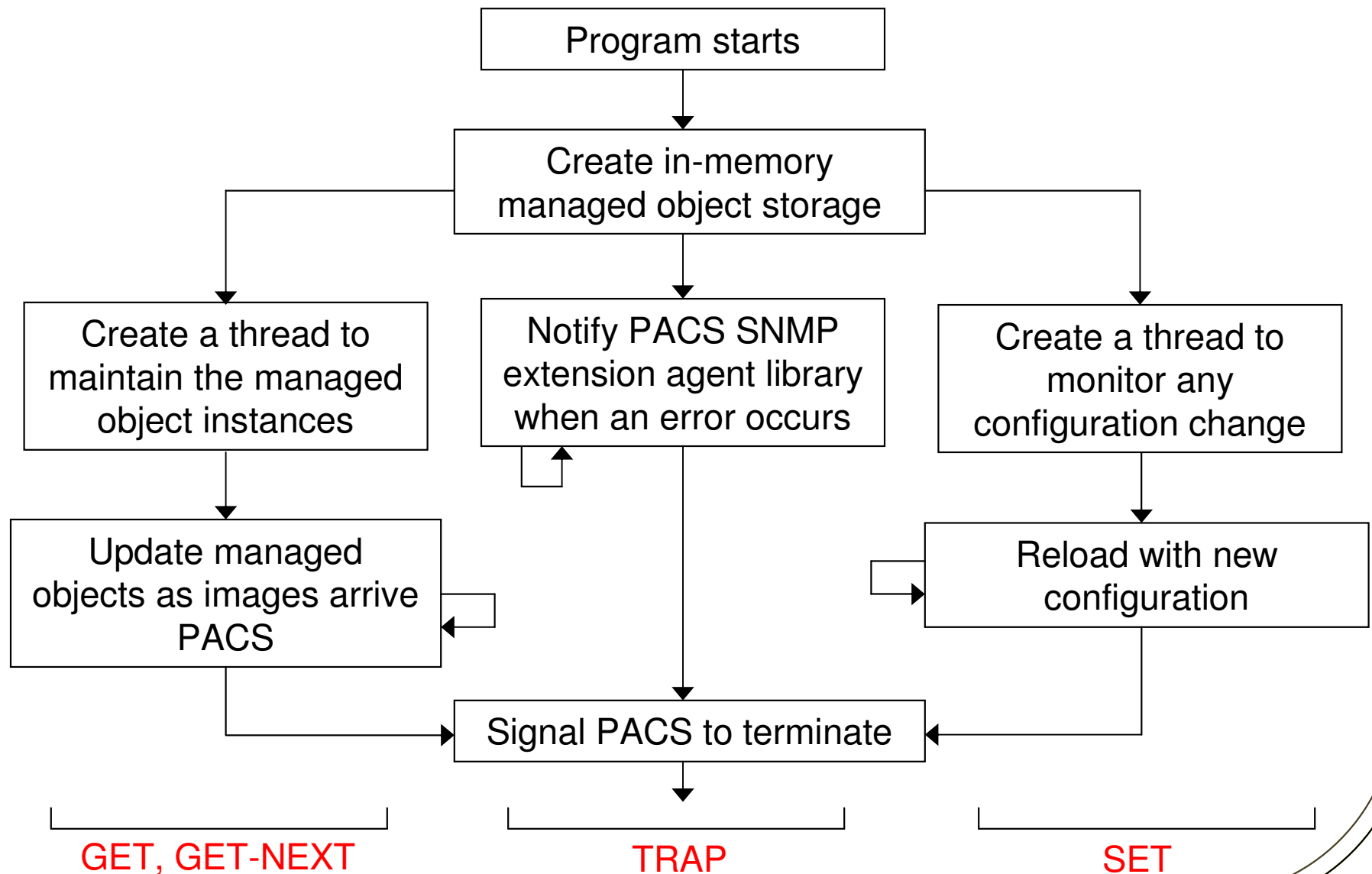
Software functions

- Retrieve PACS status: GET and GET-NEXT
  - Host name of modality sending images to PACS
  - Number of studies received in the past hour
  - Average time spent on receiving a study in the past hour
- Configure PACS: SET
- Monitor errors found in the PACS operations: TRAP

Conclusions

- Future of healthcare industry
- PACS management tool is required
- My development work
  - defined the managed objects used by SNMP to manage PACS C-STORE operation
  - modified PACS to support SNMP managed objects
  - implemented the PACS SNMP extension agent library for the communication between Windows operating system and PACS

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Acknowledgements

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Any Questions?