Security of Computer Systems

Project Report

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Version: 1.0

Versions

Version	Date	Description of changes
1.0	04.04.2025	Creation of the document

1. Project – control and final term

1.1 Description

The PAdES Signature Application is a comprehensive tool that enables users to create and verify PDF Advanced Electronic Signatures with strong cryptographic security. It implements a complete workflow for generating RSA key pairs, securely storing the private key on USB storage devices protected by PIN-based AES encryption, and signing PDF documents in compliance with industry standards. The application features an intuitive graphical user interface with clear visual indicators for system status, allowing users to easily manage the entire signature process from key generation to signature verification.

1.2 Results

- **Key Management**
    - Implemented 4096-bit RSA key generation
    - Private keys are encrypted with AES using PIN-based security
    - Keys are properly stored (private on USB, public locally)

- **Document Operations**
    - PDF signing with proper document hashing
    - Signature verification functionality
    - Clear visual feedback during operations

- **User Interface**
    - Three-panel design (keygen, sign, verify)
    - Real-time USB detection and status display
    - Secure PIN entry with visual keypad

- **Application Architecture**
    - Multi-threaded design for responsive UI
    - Modular code structure with clear separation of concerns
    - Comprehensive error handling

- **Documentation**
    - Complete Doxygen documentation
    - Automated documentation generation via GitHub Actions
    - Code properly documented with standard tags

1.3 Code description

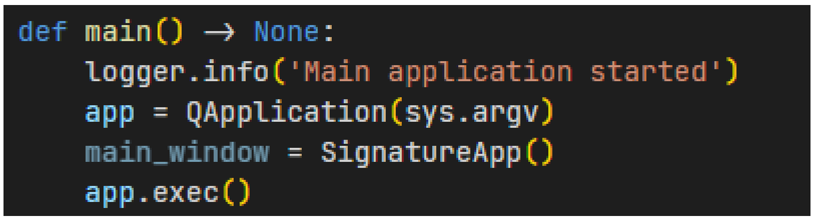
Architecture Overview

The PAdES Signature Application follows a modular architecture with clear separation of concerns. The codebase is organized into three primary components:

- **GUI Layer**: Contains the user interface implementation using PyQt6
- **Utility Layer**: Implements core cryptographic and file operations
- **Logger**: Handles application-wide logging

Key Components

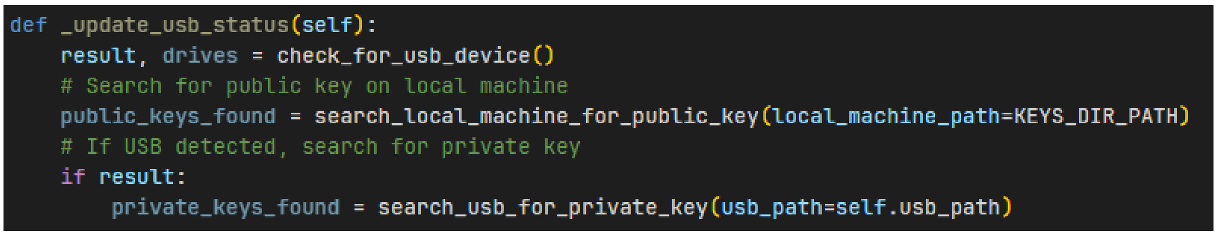
- **Main Application (**main.py**) -** The entry point of the application initializes the logger and launches the main window:



```python
def main() -> None:
    logger.info('Main application started')
    app = QApplication(sys.argv)
    main_window = SignatureApp()
    app.exec()
```

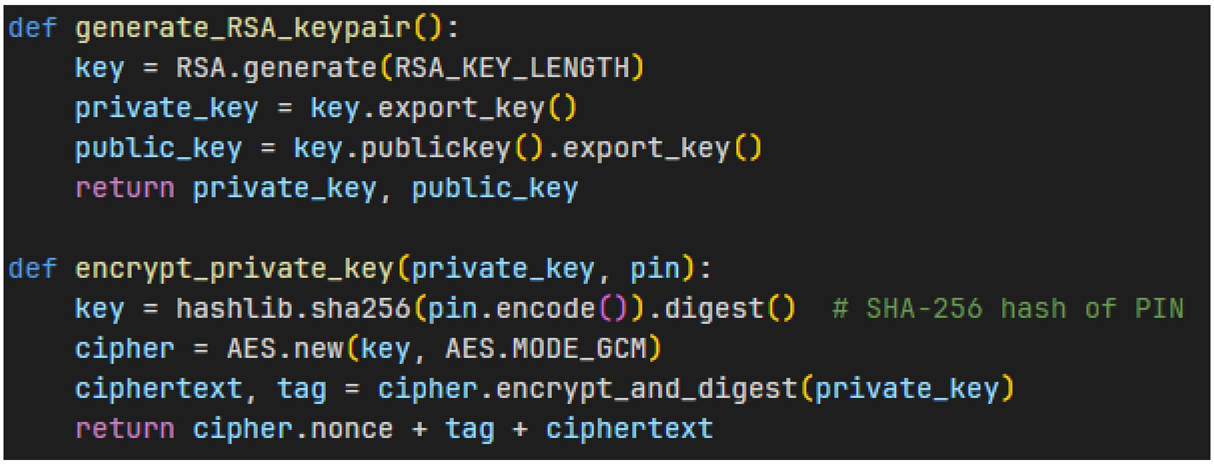
- **Signature Application (**SignatureApp.py**) -** The main application window manages three key pages:
  - Key Generation Page
  - Document Signing Page
  - Signature Verification Page

  It also handles USB detection, key discovery, and page navigation:



```python
def _update_usb_status(self):
    result, drives = check_for_usb_device()
    # Search for public key on local machine
    public_keys_found = search_local_machine_for_public_key(local_machine_path=KEYS_DIR_PATH)
    # If USB detected, search for private key
    if result:
        private_keys_found = search_usb_for_private_key(usb_path=self.usb_path)
```

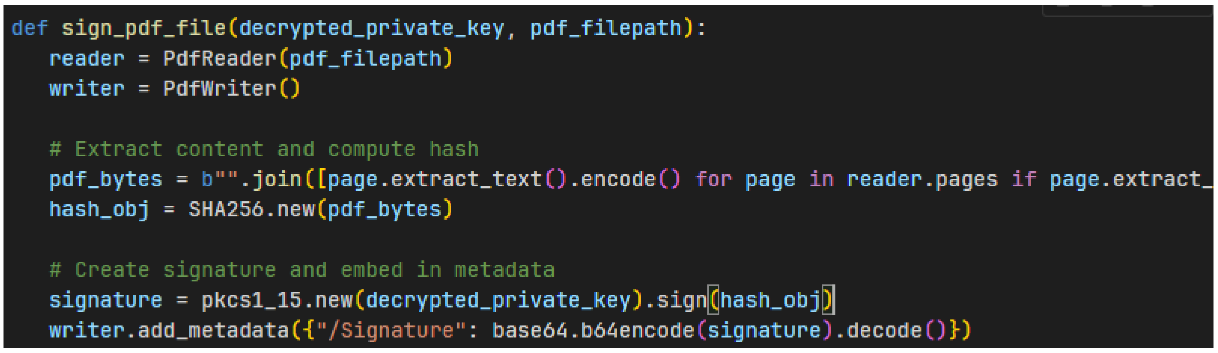
- **Cryptographic Operations (keygen.py, pdf_sign.py) -** The core security operations are implemented in specialized modules:



```
def generate_RSA_keypair():
    key = RSA.generate(RSA_KEY_LENGTH)
    private_key = key.export_key()
    public_key = key.publickey().export_key()
    return private_key, public_key

def encrypt_private_key(private_key, pin):
    key = hashlib.sha256(pin.encode()).digest()  # SHA-256 hash of PIN
    cipher = AES.new(key, AES.MODE_GCM)
    ciphertext, tag = cipher.encrypt_and_digest(private_key)
    return cipher.nonce + tag + ciphertext
```

- **PDF Operations (**pdf_sign.py**) -** The PDF signing and verification uses PyPDF2 to handle the PDF files, with custom signature embedding and extraction:

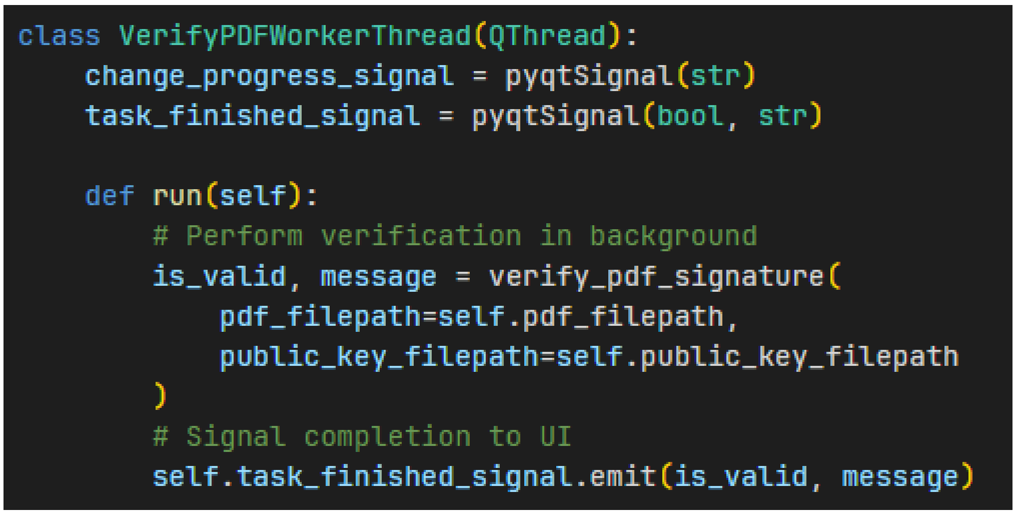


```
def sign_pdf_file(decrypted_private_key, pdf_filepath):
   reader = PdfReader(pdf_filepath)
   writer = PdfWriter()

   # Extract content and compute hash
   pdf_bytes = b"".join([page.extract_text().encode() for page in reader.pages if page.extract_
   hash_obj = SHA256.new(pdf_bytes)

   # Create signature and embed in metadata
   signature = pkcs1_15.new(decrypted_private_key).sign(hash_obj)
   writer.add_metadata({"/Signature": base64.b64encode(signature).decode()})
```

- **Worker Threads (**RSAWorkerThread.py, PDFWorkerThread.py, VerifyPDFWorkerThread.py**) -** Long-running operations are executed in background threads to keep the UI responsive:



```
class VerifyPDFWorkerThread(QThread):
    change_progress_signal = pyqtSignal(str)
    task_finished_signal = pyqtSignal(bool, str)

    def run(self):
        # Perform verification in background
        is_valid, message = verify_pdf_signature(
            pdf_filepath=self.pdf_filepath,
            public_key_filepath=self.public_key_filepath
        )
        # Signal completion to UI
        self.task_finished_signal.emit(is_valid, message)
```

1.4 Summary

The PAdES Signature Application successfully implements all required functionality for creating and verifying PDF Advanced Electronic Signatures. The application features robust key management with 4096-bit RSA key pairs, PIN-protected private keys on USB devices, and local public key storage. Document operations include PDF signing and verification with proper security measures. The implementation uses a user-friendly interface with clear status indicators and multi-threaded architecture for responsive operation. The application is fully documented with Doxygen comments and includes GitHub Actions for automatic documentation generation.

2. Literature

[1] Doxygen docs, https://www.doxygen.nl/manual/index.html

[2] Wikipedia Digital Signature, https://en.wikipedia.org/wiki/Digital_signature

[3] Python docs, https://docs.python.org/3/

[4] GitHub Actions docs, https://docs.github.com/en/actions