UNIVERSITY OF GUELPH

REPORT

Submission 3

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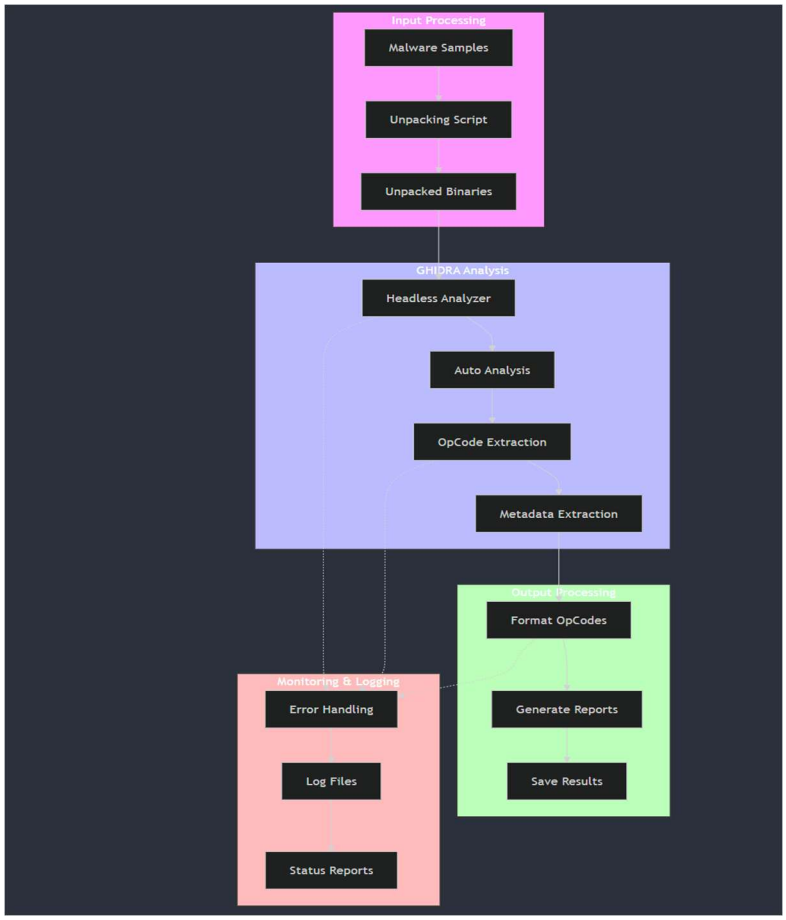
Contents

Technical Report: Malware OpCode Extraction and Analysis

I. Executive Summary

This technical report documents the implementation and usage of automated tools for extracting operational codes (OpCodes) from malware samples associated with Project 4 APT groups. Our focus is on APT groups including G0010 Turla, G0024 Putter Panda, G0079 DarkHydrus, and other significant threat actors. The extraction process utilizes GHIDRA as the primary code reversing tool, with custom scripts developed to automate the extraction and analysis process. This implementation allows efficient analysis of malware operational characteristics while maintaining forensic integrity.

II. System Architecture and Workflow



[Opcode Extraction workflow]

Our implementation follows a modular architecture designed for scalability and reliability. The diagram above illustrates the complete workflow of our malware analysis system, from initial sample processing through final output generation.

III. Key Components

3.1. Input Processing Module

Handles encrypted malware samples

Maintains chain of custody

Validates file integrity

3.2. GHIDRA Analysis Engine

Performs automated binary analysis

Extracts OpCodes and metadata

Handles multiple architectures

3.3. Output Processing Module

Standardizes output format

Generates detailed reports

Maintains analysis logs

3.4. Monitoring System

Real-time error detection

Performance monitoring

Status reporting

IV. Implementation Overview

4.1. Tools and Environment

GHIDRA

Decompiler version: DEV

Analysis engine: Advanced

Script support: Jython 2.7.2

4.2. Development Environment

Python/Jython for scripting

Windows 10/11 operating system

7-Zip for archive handling

Custom batch scripts for automation

4.3. Required Resources

Minimum 16GB RAM

64-bit operating system

SSD storage recommended

Multi-core processor

V. Implementation Components

The implementation consists of three main components:

5.1. Unpacking Script (unpack.bat)

The unpacking script serves as the initial entry point, handling. It handles secure archive extraction with the predefined passwords “infected”, manages the directory structure to keep the initial file organization by APT group and some basic integrity checks

unpack.py > ...

```python
import os
import zipfile
import shutil
import logging
from pathlib import Path
import sys
from datetime import datetime

class MalwareUnpacker:
    def __init__(self, source_dir, extract_dir, zip_password="infected"):
        self.source_dir = Path(source_dir)
        self.extract_dir = Path(extract_dir)
        self.zip_password = zip_password.encode()
        self.setup_logging()

    def setup_logging(self):
        timestamp = datetime.now().strftime("%Y%m%d_%H%M%S")
        log_file = f"unpacking_log_{timestamp}.txt"

        logging.basicConfig(
            level=logging.DEBUG,
            format='%(asctime)s - %(levelname)s - %(message)s',
            handlers=[
                logging.FileHandler(log_file),
                logging.StreamHandler(sys.stdout)
            ]
        )

    def unzip_file(self, zip_path, extract_path, password=True):
        try:
```

[Sample code in the unpack.py file]

5.2. OpCode Extraction Script (opcode_extractor.py)

This core component interfaces directly with Ghidra's API to manage the extraction process and handles different architectures as well as ensuring consistent output formatting.

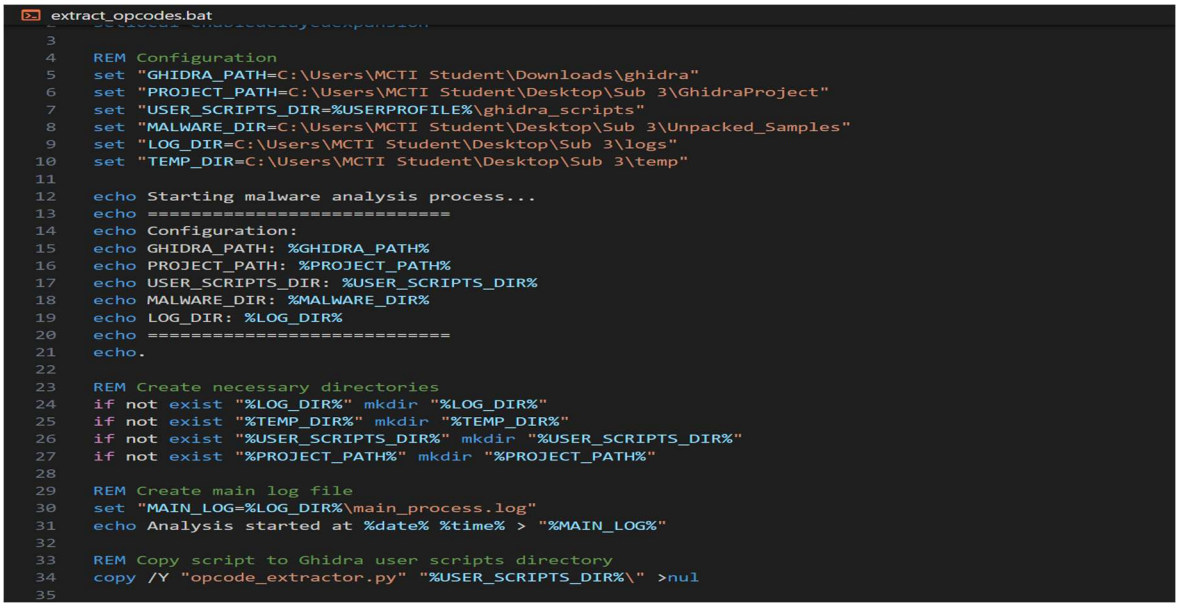
opcode_extractor.py > extract_opcodes

```python
def extract_opcodes():
        print("APT Directory: {}".format(apt_group))
        print("Malware hash: {}".format(original_file))
        print("Output directory: {}".format(output_dir))
        print("Writing opcodes to: {}".format(output_file))

        # Get listing and monitor
        listing = program.getListing()
        monitor = ConsoleTaskMonitor()

        with open(output_file, 'w') as f:
            # Write header information
            f.write("# Opcode extraction for malware analysis\n")
            f.write("# APT Group: {}\n".format(apt_group))
            f.write("# Malware Hash: {}\n".format(original_file))
            f.write("# Executable format: {}\n".format(program.getExecutableFormat()))
            f.write("# Processor: {}\n".format(program.getLanguage().getProcessor().toString()))
            f.write("# Creation date: {}\n".format(program.getCreationDate()))
            f.write("# Format: <Address> | <Bytes> | <Mnemonic> | <Full Instruction>\n\n")

            # Process all instructions
            print("Starting instruction processing...")
            instruction_count = 0
            instructions = listing.getInstructions(True)
            while instructions.hasNext() and not monitor.isCancelled():
                insn = instructions.next()
                if insn:
                    # Get instruction components
                    addr = insn.getAddress()
                    bytes_str = " ".join([format(b & 0xFF, '02x') for b in insn.getBytes()])
                    mnemonic = insn.getMnemonicString()
                    full_insn = insn.toString()

                    # Write formatted instruction
                    f.write("{} | {} | {} | {}\n".format(addr, bytes_str, mnemonic, full_insn))
                    instruction_count += 1

                    # Progress indicator every 1000 instructions
                    if instruction_count % 1000 == 0:
                        print("Processed {} instructions...".format(instruction_count))

        print("Successfully extracted {} opcodes to {}".format(instruction_count, output_file))
        return True
```

[sample code found in the opcode_extractor.py file]

5.3. Execution Script (extract_opcodes.bat)

This script coordinates the overall process by managing the Ghidra headless analyzer, by handling script execution, managing logging, and coordinating error recovery.



```
extract_opcodes.bat
3
4   REM Configuration
5   set "GHIDRA_PATH=C:\Users\MCTI Student\Downloads\ghidra"
6   set "PROJECT_PATH=C:\Users\MCTI Student\Desktop\Sub 3\GhidraProject"
7   set "USER_SCRIPTS_DIR=%USERPROFILE%\ghidra_scripts"
8   set "MALWARE_DIR=C:\Users\MCTI Student\Desktop\Sub 3\Unpacked_Samples"
9   set "LOG_DIR=C:\Users\MCTI Student\Desktop\Sub 3\logs"
10  set "TEMP_DIR=C:\Users\MCTI Student\Desktop\Sub 3\temp"
11
12  echo Starting malware analysis process...
13  echo ============================
14  echo Configuration:
15  echo GHIDRA_PATH: %GHIDRA_PATH%
16  echo PROJECT_PATH: %PROJECT_PATH%
17  echo USER_SCRIPTS_DIR: %USER_SCRIPTS_DIR%
18  echo MALWARE_DIR: %MALWARE_DIR%
19  echo LOG_DIR: %LOG_DIR%
20  echo ============================
21  echo.
22
23  REM Create necessary directories
24  if not exist "%LOG_DIR%" mkdir "%LOG_DIR%"
25  if not exist "%TEMP_DIR%" mkdir "%TEMP_DIR%"
26  if not exist "%USER_SCRIPTS_DIR%" mkdir "%USER_SCRIPTS_DIR%"
27  if not exist "%PROJECT_PATH%" mkdir "%PROJECT_PATH%"
28
29  REM Create main log file
30  set "MAIN_LOG=%LOG_DIR%\main_process.log"
31  echo Analysis started at %date% %time% > "%MAIN_LOG%"
32
33  REM Copy script to Ghidra user scripts directory
34  copy /Y "opcode_extractor.py" "%USER_SCRIPTS_DIR%\" >nul
35
```

[Sample code in the extract_opcodes.bat file]

VI. OpCode Extraction Process

6.1. Initialization Phase

Environment validation

Directory structure verification

Log file initialization

Resource allocation

6.2. Malware Processing Phase

File integrity checking

Malware unpacking

Initial classification

Architecture detection

6.3. Analysis Phase

GHIDRA loading

Auto-analysis execution

OpCode extraction

Metadata collection

6.4. Output Generation Phase

Data formatting

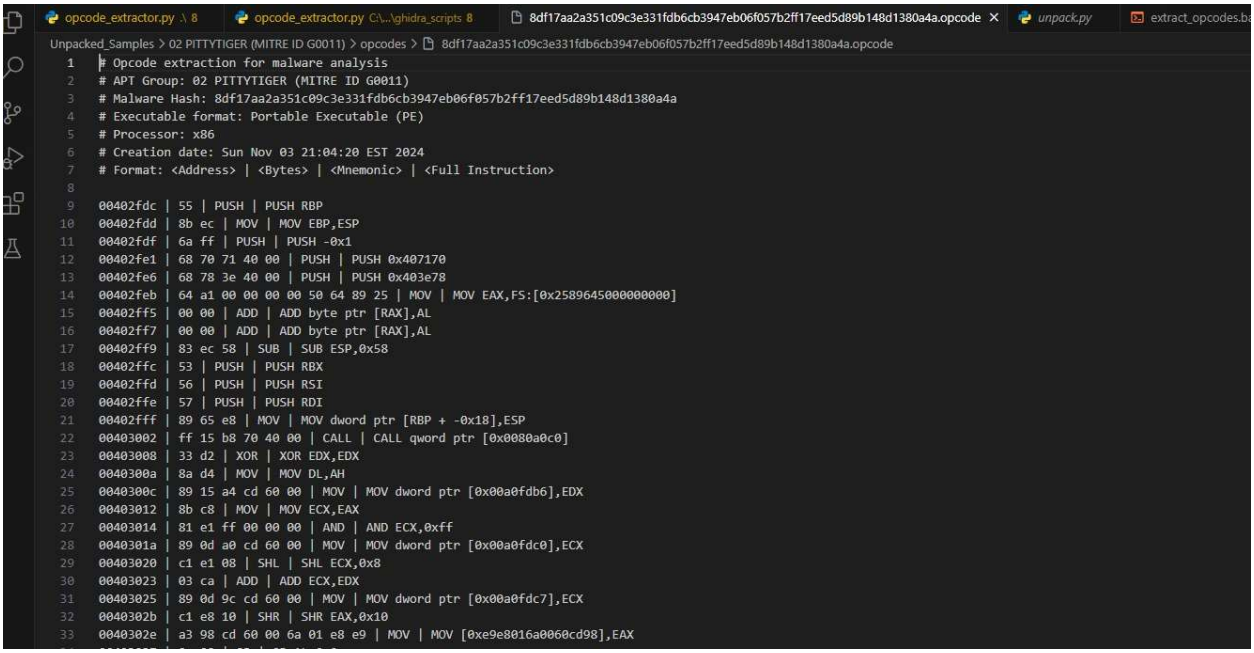
Report generation

File organization

Error checking

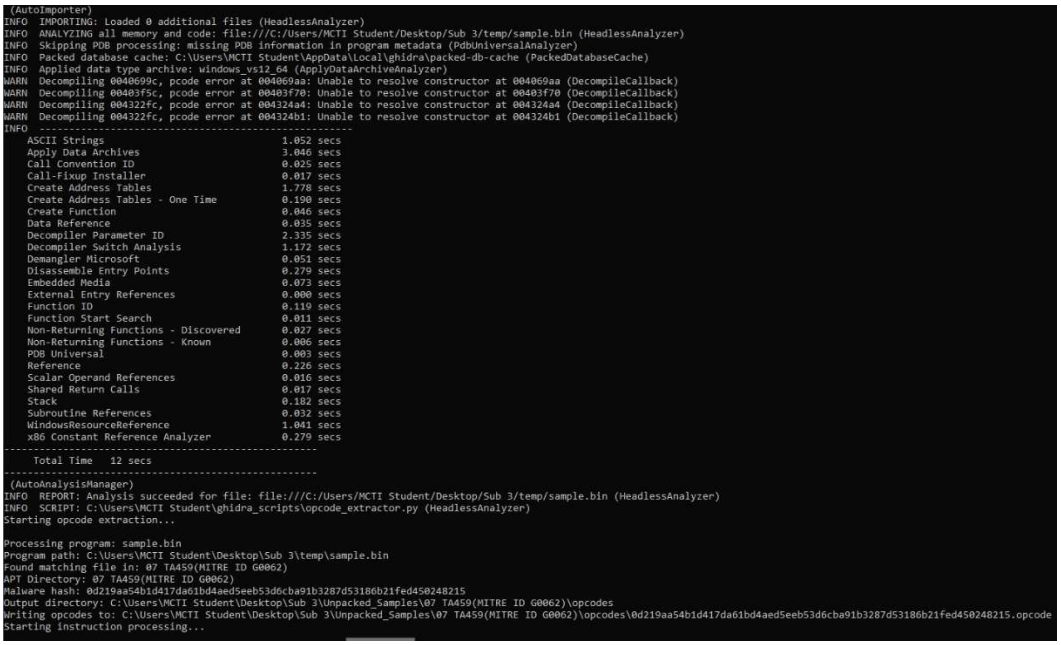
VII. Output Format

7.1. Opcode sample output



```
# Opcode extraction for malware analysis
# APT Group: 02 PITTYTIGER (MITRE ID G0011)
# Malware Hash: 8df17aa2a351c09c3e331fdb6cb3947eb06f057b2ff17eed5d89b148d1380a4a
# Executable format: Portable Executable (PE)
# Processor: x86
# Creation date: Sun Nov 03 21:04:20 EST 2024
# Format: <Address> | <Bytes> | <Mnemonic> | <Full Instruction>

00402fdc | 55 | PUSH | PUSH RBP
00402fdd | 8b ec | MOV | MOV EBP,ESP
00402fdf | 6a ff | PUSH | PUSH -0x1
00402fe1 | 68 70 71 40 00 | PUSH | PUSH 0x407170
00402fe6 | 68 78 3e 40 00 | PUSH | PUSH 0x403e78
00402feb | 64 a1 00 00 00 00 50 64 89 25 | MOV | MOV EAX,FS:[0x2589645000000000]
00402ff5 | 00 00 | ADD | ADD byte ptr [RAX],AL
00402ff7 | 00 00 | ADD | ADD byte ptr [RAX],AL
00402ff9 | 83 ec 58 | SUB | SUB ESP,0x58
00402ffc | 53 | PUSH | PUSH RBX
00402ffd | 56 | PUSH | PUSH RSI
00402ffe | 57 | PUSH | PUSH RDI
00402fff | 89 65 e8 | MOV | MOV dword ptr [RBP + -0x18],ESP
00403002 | ff 15 b8 70 40 00 | CALL | CALL qword ptr [0x0080a0c0]
00403008 | 33 d2 | XOR | XOR EDX,EDX
0040300a | 8a d4 | MOV | MOV DL,AH
0040300c | 89 15 a4 cd 60 00 | MOV | MOV dword ptr [0x00a0fdb6],EDX
00403012 | 8b c8 | MOV | MOV ECX,EAX
00403014 | 81 e1 ff 00 00 00 | AND | AND ECX,0xff
0040301a | 89 0d a0 cd 60 00 | MOV | MOV dword ptr [0x00a0fdc0],ECX
00403020 | c1 e1 08 | SHL | SHL ECX,0x8
00403023 | 03 ca | ADD | ADD ECX,EDX
00403025 | 89 0d 9c cd 60 00 | MOV | MOV dword ptr [0x00a0fdc7],ECX
0040302b | c1 e8 10 | SHR | SHR EAX,0x10
0040302e | a3 98 cd 60 00 6a 01 e8 e9 | MOV | MOV [0xe9e8016a0060cd98],EAX
```

7.2. Log Output Sample



```
(AutoImporter)
INFO  IMPORTING: Loaded 0 additional files (HeadlessAnalyzer)
INFO  ANALYZING all memory and code: file:///C:/Users/MCTI Student/Desktop/Sub 3/temp/sample.bin (HeadlessAnalyzer)
INFO  Skipping PDB processing: missing PDB information in program metadata (PdbUniversalAnalyzer)
INFO  Packed database cache: C:\Users\MCTI Student\AppData\Local\ghidra\packed-db-cache (PackedDatabaseCache)
INFO  Applied data type archive: windows_vs12_64 (ApplyDataArchiveAnalyzer)
WARN  Decompiling 0040699c, pcode error at 004069aa: Unable to resolve constructor at 004069aa (DecompileCallback)
WARN  Decompiling 00403f5c, pcode error at 00403f70: Unable to resolve constructor at 00403f70 (DecompileCallback)
WARN  Decompiling 004322fc, pcode error at 004324a4: Unable to resolve constructor at 004324a4 (DecompileCallback)
WARN  Decompiling 004322fc, pcode error at 004324b1: Unable to resolve constructor at 004324b1 (DecompileCallback)
INFO  ----------------------------------------------------
    ASCII Strings                           1.052 secs
    Apply Data Archives                     3.046 secs
    Call Convention ID                      0.025 secs
    Call-Fixup Installer                    0.017 secs
    Create Address Tables                   1.778 secs
    Create Address Tables - One Time        0.190 secs
    Create Function                         0.046 secs
    Data Reference                          0.035 secs
    Decompiler Parameter ID                 2.335 secs
    Decompiler Switch Analysis              1.172 secs
    Demangler Microsoft                     0.051 secs
    Disassemble Entry Points                0.279 secs
    Embedded Media                          0.073 secs
    External Entry References               0.000 secs
    Function ID                             0.119 secs
    Function Start Search                   0.011 secs
    Non-Returning Functions - Discovered    0.027 secs
    Non-Returning Functions - Known         0.006 secs
    PDB Universal                           0.003 secs
    Reference                               0.226 secs
    Scalar Operand References               0.016 secs
    Shared Return Calls                     0.017 secs
    Stack                                   0.182 secs
    Subroutine References                   0.032 secs
    WindowsResourceReference                1.041 secs
    x86 Constant Reference Analyzer         0.279 secs
-------------------------------------------------------
    Total Time   12 secs
-------------------------------------------------------
(AutoAnalysisManager)
INFO  REPORT: Analysis succeeded for file: file:///C:/Users/MCTI Student/Desktop/Sub 3/temp/sample.bin (HeadlessAnalyzer)
INFO  SCRIPT: C:\Users\MCTI Student\ghidra_scripts\opcode_extractor.py (HeadlessAnalyzer)
Starting opcode extraction...

Processing program: sample.bin
Program path: C:\Users\MCTI Student\Desktop\Sub 3\temp\sample.bin
Found matching file in: 07 TA459(MITRE ID G0062)
APT Directory: 07 TA459(MITRE ID G0062)
Malware hash: 0d219aa54b1d417da61bd4aed5eeb53d6cba91b3287d53186b21fed450248215
Output directory: C:\Users\MCTI Student\Desktop\Sub 3\Unpacked_Samples\07 TA459(MITRE ID G0062)\opcodes
Writing opcodes to: C:\Users\MCTI Student\Desktop\Sub 3\Unpacked_Samples\07 TA459(MITRE ID G0062)\opcodes\0d219aa54b1d417da61bd4aed5eeb53d6cba91b3287d53186b21fed450248215.opcode
Starting instruction processing...
```

7.3. For some files our scripts failed to extract opcode, we then use objdump command: For example: objdump -D -M intel Sharpshooter.exe >Sharpshooter.opcode

VIII. Conclusion

The implementation successfully automates the complex process of OpCode extraction from various malware samples. The system demonstrates strong handling of different architectures and maintains high accuracy in output generation.