scademy
secure coding academy

C and C++ secure coding (ARM)

CL-CPA | Onsite / Virtual classroom | 3 days

Variant: ARM

Audience: C and C++ developers, software architects and testers
Preparedness: General C/C++ development
Exercises: Hands-on

To put it bluntly, writing C/C++ code can be a minefield for reasons ranging from memory management or dealing with legacy code to sharp deadlines and code maintainability. Yet, beyond all that, what if we told you that attackers were trying to break into your code right now? How likely would they be to succeed?

This course will change the way you look at your C/C++ code. We'll teach you the common weaknesses and their consequences that can allow hackers to attack your system, and – more importantly – best practices you can apply to protect yourself. We give you a holistic view on C/C++ programming mistakes and their countermeasures from the machine code level to virtual functions and OS memory management. We present the entire course through live practical exercises to keep it engaging and fun.

Writing secure code will give you a distinct edge over your competitors. It is your choice to be ahead of the pack – take a step and be a game-changer in the fight against cybercrime.

Outline:

- IT security and secure coding
- ARM machine code, memory layout and stack operations
- Buffer overflow
- Practical cryptography
- XML security
- Common coding errors and vulnerabilities
- Denial of service
- Principles of security and secure coding
- Knowledge sources

Participants attending this course will:

Understand basic concepts of security, IT security and secure coding

Realize the severe consequences of unsecure buffer handling

Understand the architectural protection techniques and their weaknesses

Have a practical understanding of cryptography

Learn about XML security

Learn about typical coding mistakes and how to avoid them

Be informed about recent vulnerabilities in various platforms, frameworks and libraries

Learn about denial of service attacks and protections

Get sources and further readings on secure coding practices

Related courses:

- CL-CMI - C and C++ security master course (x86) (Onsite / Virtual classroom, 5 days)
- CL-CMA - C and C++ security master course (ARM) (Onsite / Virtual classroom, 5 days)
- CL-JSM - Java and Web application security master course (Onsite / Virtual classroom, 5 days)
- CL-CTS - Security testing native code (Onsite / Virtual classroom, 3 days)

Detailed table of contents

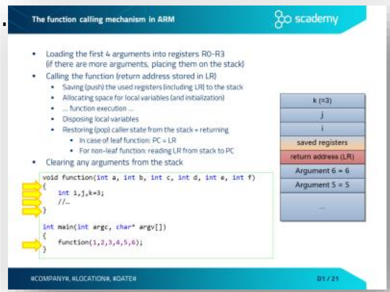
Day 1

IT security and secure coding

- Nature of security
- What is risk?
- IT security vs. secure coding
- From vulnerabilities to botnets and cybercrime
  - Nature of security flaws
  - From an infected computer to targeted attacks
- Classification of security flaws
  - Landwehr’s taxonomy
  - The Seven Pernicious Kingdoms

ARM machine code, memory layout and stack operations

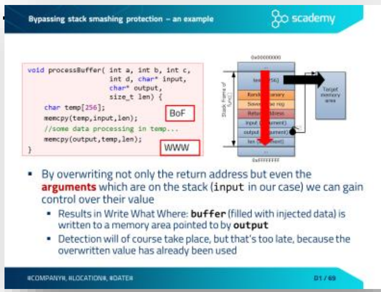
- ARM Processors – main registers
- ARM Processors – most important instructions
- ARM Processors – flags and condition fields
- ARM Processors – control instructions
- ARM Processors – stack handling instructions
- Understanding complex ARM instructions
- The function calling mechanism in ARM
- The local variables and the stack frame
- Function calls – prologue and epilogue of a function (ARM)
- Stack frame of nested calls
- Stack frame of recursive functions



Buffer overflow

- Stack overflow
  - Buffer overflow on the stack
  - Overwriting the return address
  - Exercises – introduction
  - Exercise BOFIntro
  - Exercise BOFShellcode

- Protection against stack overflow
  - Specific protection methods
  - Protection methods at different layers
  - The protection matrix of software security
  - Stack overflow – Prevention (during development)
  - The protection matrix of software security
  - Stack overflow – Detection (during execution)
  - Fortify compiler option (FORTIFY_SOURCE)
  - Exercise BOFShellcode – Using the Fortify compiler option
- Stack smashing protection
  - Stack smashing protection variants
  - Stack smashing protection in GCC
  - Exercise BOFShellcode – Stack smashing protection
  - Effects of stack smashing protection – prologue
  - Effects of stack smashing protection – epilogue
  - Bypassing stack smashing protection – an example
  - Overwriting arguments – Mitigation
  - The protection matrix of software security



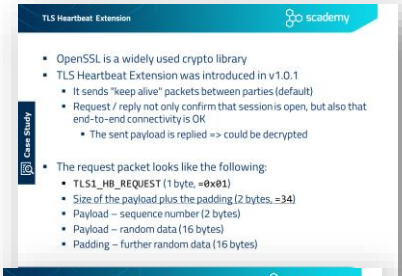
- Address Space Layout Randomization (ASLR)
  - Randomization with ASLR
  - Practical weaknesses and limitations to ASLR
  - Circumventing ASLR: NOP sledding
- Non executable memory areas – the NX bit
  - Access control on memory segments
  - The Never eXecute (NX) bit
  - Exercise BOFShellcode – Enforcing NX memory segments

Day 2

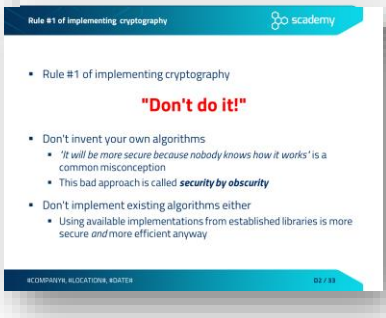
Buffer overflow

- Return oriented programming (ROP)
  - Circumventing memory execution protection
  - Return-to-libc attack in ARM
  - ROP gadget - Register fill with constants
  - ROP gadget – Memory write
  - Combining the ROP gadgets
  - Real ROP attack scenarios

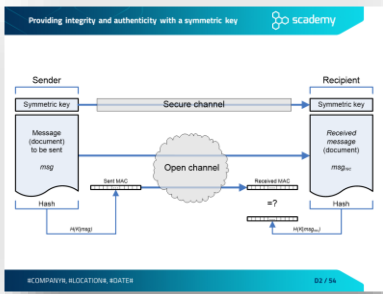
- ROP mitigation
  - Mitigation techniques of ROP attack
- Heap overflow
  - Memory allocation managed by a doubly-linked list
  - Buffer overflow on the heap
  - Steps of freeing and joining memory blocks
  - Freeing allocated memory blocks
  - Case study – Heartbleed
    - TLS Heartbeat Extension...
    - Heartbleed – information leakage in OpenSSL
    - Heartbleed – fix in v1.0.1g
  - Protection against heap overflow



Practical cryptography



- Rule #1 of implementing cryptography..
- Cryptosystems
  - Elements of a cryptosystem
- Symmetric-key cryptography
  - Providing confidentiality with symmetric cryptography
  - Symmetric encryption algorithms
  - Modes of operation
  - Symmetric encryption with OpenSSL: encryption
  - Symmetric encryption with OpenSSL: decryption
- Other cryptographic algorithms
  - Hash or message digest
  - Hash algorithms
  - SHAttered
  - Hashing with OpenSSL
  - Message Authentication Code (MAC)
  - Providing integrity and authenticity with a symmetric key................
  - Random number generation
    - Random numbers and cryptography
    - Cryptographically-strong PRNGs
    - Weak PRNGs in C and C++
    - Stronger PRNGs in C
    - Generating random numbers with OpenSSL
    - Hardware-based TRNGs



- Asymmetric (public-key) cryptography
  - Providing confidentiality with public-key encryption
  - Rule of thumb – possession of private key
  - The RSA algorithm
    - Introduction to RSA algorithm
    - Encrypting with RSA
    - Combining symmetric and asymmetric algorithms
    - Digital signing with RSA
    - Asymmetric encryption with OpenSSL
    - Digital signatures with OpenSSL
- Public Key Infrastructure (PKI)
  - Man-in-the-Middle (MitM) attack
  - Digital certificates against MitM attack
  - Certificate Authorities in Public Key Infrastructure
  - X.509 digital certificate

XML security

- XML injection
  - Injection principles
  - Exercise – XML injection
  - Protection through sanitization and XML validation
  - XML parsing in C++
- Abusing XML Entity
  - XML Entity introduction
  - Exercise – XML bomb
  - XML bomb
  - XML external entity attack (XXE) – resource inclusion
  - Exercise – XXE attack
  - Preventing entity-related attacks
  - Case study – XXE in Google Toolbar

Common coding errors and vulnerabilities

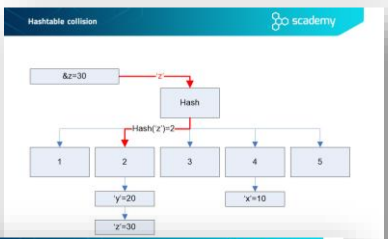
- Improper error and exception handling
  - Typical problems with error and exception handling
  - Empty catch block
  - Overly broad catch
  - Exercise ErrorHandling – spot the bug!
  - Exercise – Error handling

- Code quality problems
  - Dangers arising from poor code quality
  - Poor code quality – spot the bug!
  - Unreleased resources
  - Type mismatch – Spot the bug!
  - Exercise TypeMismatch
  - Memory allocation problems
    - Smart pointers
    - Zero length allocation
    - Double free
    - Mixing delete and delete[]
  - Use after free
    - Use after free – Instance of a class
    - Spot the bug
    - Use after free – Dangling pointers
    - Case study - WannaCry

Day 3

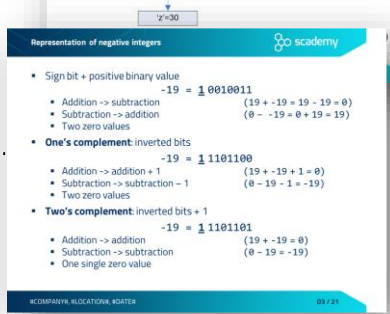
Denial of service

- DoS introduction
- Asymmetric DoS
- Regular expression DoS (ReDoS)
  - Exercise ReDoS
  - Case study – ReDos in Stack Exchange
- Hashtable collision attack
  - Using hashtables to store data
  - Hashtable collision



Common coding errors and vulnerabilities

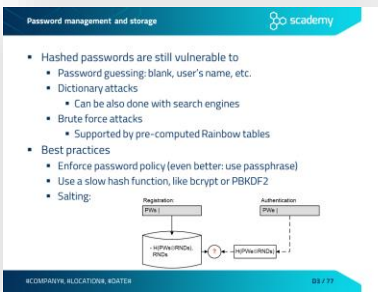
- Input validation
  - Input validation concepts
  - Integer problems
    - Representation of negative integers
    - Integer ranges
    - Integer overflow
    - Integer problems in C/C++
    - The integer promotion rule in C/C++
    - Arithmetic overflow – spot the bug!



- Exercise IntOverflow
- What is the value of abs(INT_MIN)?
- Signedness bug – spot the bug!
- Integer truncation – spot the bug!
- Integer problem – best practices
- Case study – Android Stagefright

- Printf format string bug
  - Printf format strings
  - Printf format string bug – exploitation
  - Exercise Printf
- Printf format string problem – best practices
- Some other input validation problems
  - Array indexing – spot the bug!
  - Off-by-one and other null termination errors
  - The Unicode bug
- Path traversal vulnerability
  - Path traversal – weak protections
  - Path traversal – best practices
- Log forging
  - Some other typical problems with log files

- Improper use of security features
  - Typical problems related to the use of security features
  - Password management
    - Exercise – Weakness of hashed passwords
    - Password management and storage ....
    - Special purpose hash algorithms for password storage
    - Argon2 and PBKDF2 implementations in C/C++
    - bcrypt and scrypt implementations in C/C++
    - Case study – the Ashley Madison data breach
    - Typical mistakes in password management
    - Exercise – Hard coded passwords
  - Sensitive information in memory
    - Protecting secrets in memory
    - Sensitive info in memory - minimize the attack surface
    - Your secrets vs. dynamic memory
    - Zeroisation
    - Zeroisation vs. optimization – Spot the bug!
    - Copies of sensitive data on disk
    - Core dumps
    - Disabling core dumps
    - Swapping
    - Memory locking - preventing swapping
    - Problems with page locking
    - Best practices



- Time and state problems
    - Time and state related problems
    - Serialization errors
    - Exercise TOCTTOU
    - Best practices against TOCTTOU

Principles of security and secure coding

- Matt Bishop's principles of robust programming
- The security principles of Saltzer and Schroeder

Knowledge sources

- Secure coding sources – a starter kit
- Vulnerability databases
- Recommended books – C/C++