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C and C++ security master course (ARM)

CL-CMA | Onsite / Virtual classroom | 5 days

Variant: ARM

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

As a developer, your duty is to write bulletproof code. However…

What if we told you that despite all of your efforts, the code you have been writing your entire career is full of weaknesses you never knew existed? What if, as you are reading this, hackers were trying to break into your code? How likely would they be to succeed?

This advanced course will change the way you look at code. A hands-on training during which we will teach you all of the attackers' tricks and how to mitigate them, leaving you with no other feeling than the desire to know more.

It is your choice to be ahead of the pack, and be seen as a game changer in the fight against cybercrime.

Outline:

- IT security and secure coding
- ARM machine code, memory layout and stack operations
- Buffer overflow
- Common coding errors and vulnerabilities
- Requirements of secure communication
- Practical cryptography
- XML security
- Security protocols
- Security in the software development lifecycle
- Security testing
- Security testing techniques and tools
- Deployment environment
- Principles of security and secure coding
- Knowledge sources

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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
Learn about typical coding mistakes and how to avoid them
Be informed about recent vulnerabilities in various platforms, frameworks and libraries
Understand the requirements of secure communication
Have a practical understanding of cryptography
Learn about XML security
Understand essential security protocols
Understand some recent attacks against cryptosystems
Understand security considerations in the SDLC
Understand security testing approaches and methodologies
Get practical knowledge in using security testing techniques and tools
Learn how to set up and operate the deployment environment securely
Get sources and further readings on secure coding practices

Related courses:

- CL-CPI - C and C++ secure coding (x86) (Onsite / Virtual classroom, 3 days)
- CL-CPA - C and C++ secure coding (ARM) (Onsite / Virtual classroom, 3 days)
- CL-CCI - Comprehensive C and C++ secure coding (x86) (Onsite / Virtual classroom, 4 days)
- CL-CCA - Comprehensive C and C++ secure coding (ARM) (Onsite / Virtual classroom, 4 days)
- CL-CTS - Security testing native code (Onsite / Virtual classroom, 3 days)

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Detailed table of contents

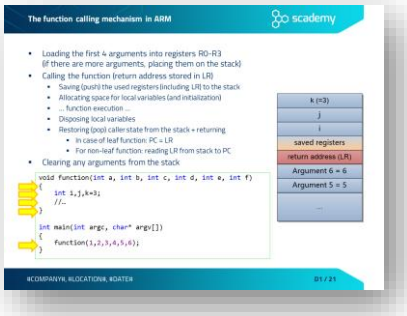
Day 1

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

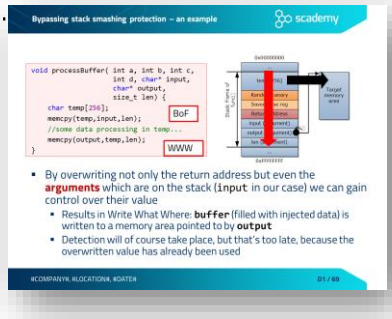
- ARM Processors – main registers
- ARM Processors – most important instructions
- ARM Processors – flags and condition fields
- ARM Processors – control instructions
- ARM Processors – stack handling instructions
- Understanding complex ARM instructions
- The function calling mechanism in ARM .....
- 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

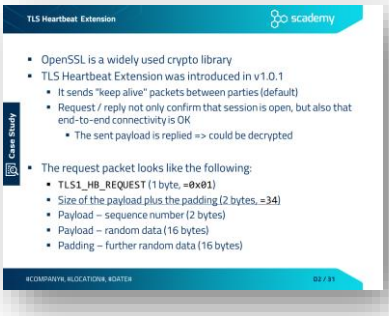


Day 2

Buffer overflow

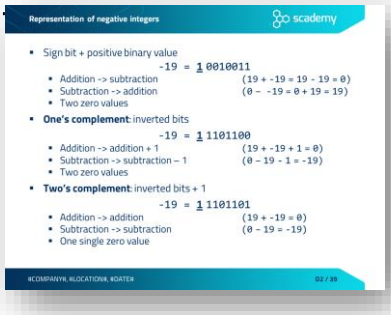
- Return oriented programming (ROP)
  - Circumventing memory execution protection
  - Return-to-libc attack in ARM
  - Exercise Return-to-libc
  - ROP gadget - Register fill with constants
  - ROP gadget – Memory write
  - Combining the ROP gadgets
  - Real ROP attack scenarios

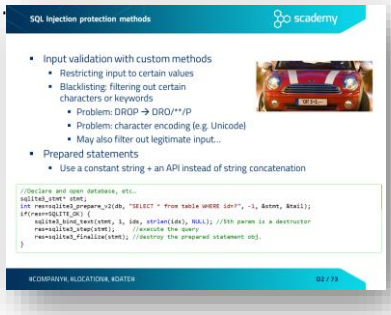
- ROP mitigation
  - Mitigation techniques of ROP attack
- Heap overflow
  - Memory allocation managed by a doubly-linked list
  - Buffer overflow on the heap
  - Steps of freeing and joining memory blocks
  - Freeing allocated memory blocks
  - Case study – Heartbleed
    - TLS Heartbeat Extension
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



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
  - Injection
    - Injection principles
    - SQL Injection exercise
    - Typical SQL Injection attack methods
    - Blind and time-based SQL injection
    - SQL Injection protection methods
    - Command injection
    - Command injection exercise – starting Netcat
  - 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

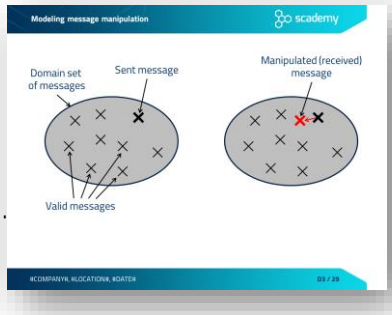
- Time and state problems
  - Time and state related problems
  - Serialization errors
  - Exercise TOCTTOU
  - Best practices against TOCTTOU
  - Problems with temp files
  - Requirements for creating temp files
  - Requirements explained
  - Creating temp files on POSIX systems
  - Creating temp files portably
  - Deleting temp files

Day 3

Requirements of secure communication

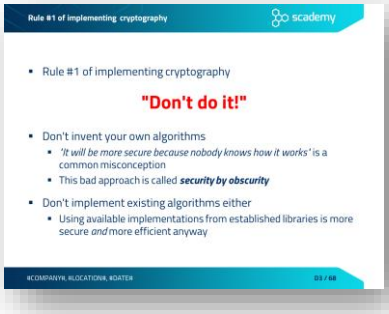
- Security levels
- Secure acknowledgment
  - Malicious message absorption
    - Feasibility of secure acknowledgment
    - The solution: Clearing Centers
  - Inadvertent message loss

- Integrity
  - Error detection - Inadvertent message distortion (noise)
    - Modeling message distortion
    - Error detection and correction codes
  - Authenticity - Malicious message manipulation
    - Modeling message manipulation
    - Practical integrity protection (detection)
  - Non-repudiation

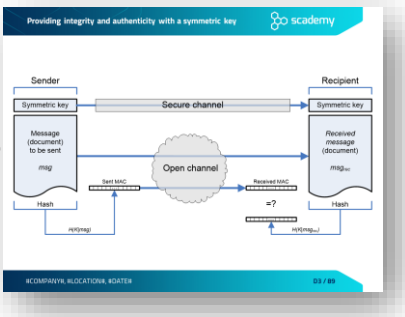


- Summary
  - Detecting integrity violation
- Confidentiality
  - Model of encrypted communication
  - Encryption methods in practice
  - Strength of encryption algorithms
- Remote identification
  - Requirements of remote identification
- Anonymity and traffic analysis
  - Model of anonymous communication
  - Traffic analysis
  - Theoretically strong protection against traffic analysis
  - Practical protection against traffic analysis
- Summary
  - Relationship between the requirements

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
    - 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

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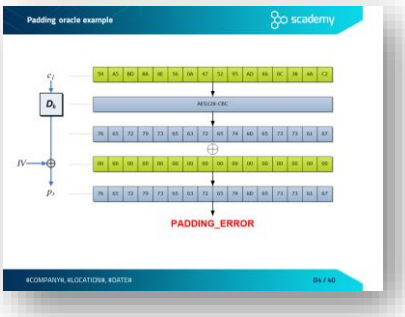
Day 4

Security protocols

- Secure network protocols
- Specific vs. general solutions
- IPSEC protocol family
  - IPSEC standards
  - Security Association (SA)
  - Message formats
  - AH packet structure
  - ESP packet structure
  - Protected channels
  - More complex set-ups
  - Traffic control
  - SA structure
  - Key management
- The TLS protocol
  - SSL and TLS
  - Usage options
  - Security services of TLS
  - SSL/TLS handshake
- Protocol-level vulnerabilities
  - BEAST
  - FREAK
  - FREAK – attack against SSL/TLS
  - Logjam attack
- Padding oracle attacks
  - Adaptive chosen-ciphertext attacks
  - Padding oracle attack
  - CBC decryption
  - Padding oracle example.....
  - Lucky Thirteen
  - POODLE



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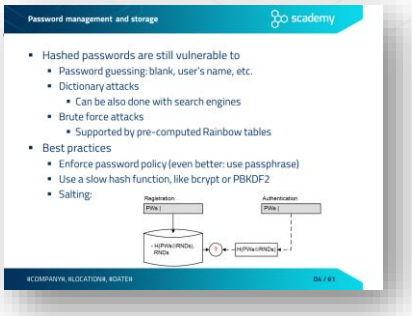
Common coding errors and vulnerabilities

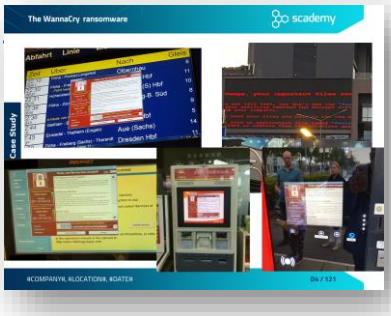
- Improper use of security features
  - Typical problems related to the use of security features
  - Password management
    - Exercise – Weakness of hashed passwords
    - Password management and storage .....



    - Brute forcing
    - 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
  - Insufficient anti-automation
    - Captcha
    - Captcha weaknesses
- 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
  - Case study – "#iamroot" authentication bypass in macOS
    - Authentication process in macOS (High Sierra)
    - Incorrect error handling in opendirectoryd
    - The #iamroot vulnerability (CVE-2017-13872)
    - Information leakage through error reporting

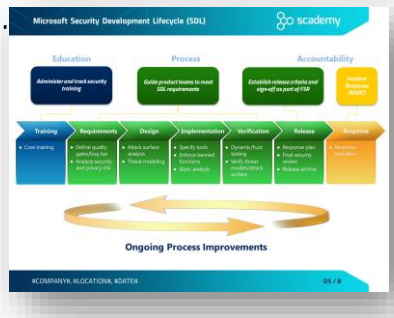
- Code quality problems
  - Dangers arising from poor code quality
  - Poor code quality – spot the bug!
  - Unreleased resources
  - Type mismatch – Spot the bug!
  - Exercise TypeMismatch
  - Memory allocation problems
    - Smart pointers
    - Zero length allocation
    - Double free
    - Mixing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



Day 5

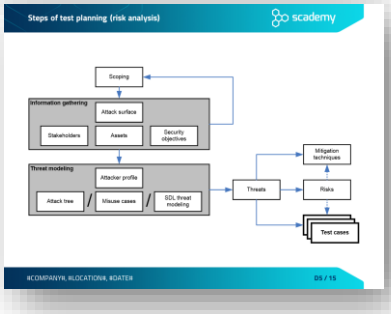
Security in the software development lifecycle

- Building Security In Maturity Model (BSIMM)
- Software Assurance Maturity Model (SAMM)
- Microsoft Security Development Lifecycle (SDL)

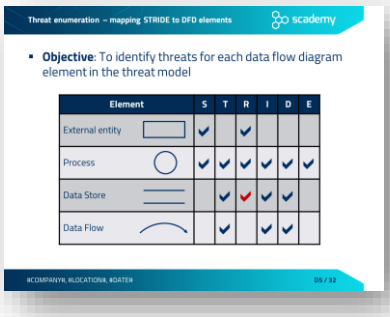


Security testing

- Functional testing vs. security testing
- Security vulnerabilities
- Prioritization – risk analysis
- Security assessments in various SDLC phases
- Security testing methodology
  - Steps of test planning (risk analysis)
  - Scoping and information gathering
    - Stakeholders
    - Assets
    - Security objectives for testing



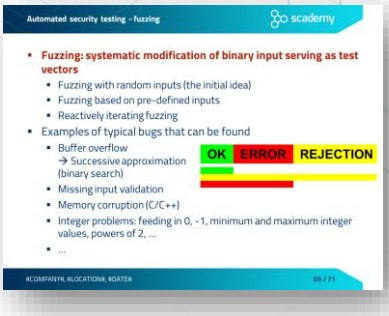
- Threat modeling
  - Attacker profiles
  - Threat modeling
  - Threat modeling based on attack trees
  - Threat modeling based on misuse/abuse cases
  - Misuse/abuse cases – a simple example
  - SDL threat modeling
  - The STRIDE threat categories
  - Diagramming – elements of a DFD
  - Data flow diagram – example
  - Threat enumeration – mapping STRIDE to DFD elements.....
  - Risk analysis – classification of threats
  - The DREAD risk assessment model
- Testing steps
  - Deriving test cases
  - Accomplishing the tests
  - Processing test results
  - Mitigation concepts
  - Standard mitigation techniques of MS SDL
  - Review phase



Security testing techniques and tools

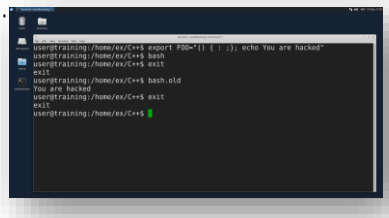
- General testing approaches
- Design review
  - Assessment of security requirements
  - Identifying security-critical aspects – hotspots
- Source code review
  - Code review for software security
  - Taint analysis
  - Heuristic-based
  - Static code analysis
    - Exercise – Static code analysis using FlawFinder
- Testing the implementation
  - Manual vs. automated security testing
  - Penetration testing
  - Stress tests
  - Binary and memory analysis
    - Exercise – Binary analysis with strings
  - Instrumentation libraries and frameworks
    - Exercise – Using Valgrind
  - Fuzzing

- Automated security testing - fuzzing
- Challenges of fuzzing
- Exercise – Fuzzing with AFL (American Fuzzy Lop)



Deployment environment

- Assessing the environment
  - Searching for online devices with SHODAN
  - Exercise – using SHODAN
  - Finding weaknesses with search engines
  - Exercise – Finding weaknesses with search engines
  - Password audit
  - Exercise – using John the Ripper
  - Testing random number generators
  - Exercise – Testing random number generators
- Configuration management
- Hardening
  - Network-level hardening
  - Hardening the deployment – server administration
  - Hardening the deployment – access control
- Patch and vulnerability management
  - Patch management
  - Vulnerability repositories
  - Vulnerability attributes
  - Software identification through CPE and SWID
  - Common Vulnerability Scoring System – CVSS
  - Vulnerability management software
  - Case study - Shellshock
    - Shellshock – basics of using functions in bash
    - Shellshock – vulnerability in bash
    - Exercise - Shellshock
    - Shellshock fix and counterattacks
    - Exercise – Command override with environment variables



Principles of security and secure coding

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

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Knowledge sources

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