Welcome to

8. Program Building Blocks

KEA Kompetence VF1 Software Security

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Slides are available as PDF, kramse@Codeberg

8-program-building-blocks.tex in the repo security-courses

Goals for today

Todays goals:

- Talk about the Design Patterns concept
- Present some of the ones often found in programs
- Patterns can also be found in other areas, like Patterns in Network Architecture

Photo by Thomas Galler on Unsplash

Plan for today

Subjects

- Common constructs
- Recurring code patterns
- Example programs with flaws: OpenSSH, OpenSSL, Windows MS-RPC DCOM, Linux teardrop

Exercises

- Static analysis with PMD
- Git hook example
- JuiceShop SQL login
- Use a XML library in Python

Reading Summary

Design Patterns

- *Design Patterns: Elements of Reusable Object-Oriented Software* (1994), Erich Gamma, Richard Helm, Ralph Johnson, and John Vlissides
- The book describes 23 classic software design patterns
- https://en.wikipedia.org/wiki/Design_Patterns
- Ideas of patterns precede this book, but became a more popular subject

Common constructs

- Programs exhibit the same patterns, some examples:
- Solve problems in the same domains
- Need to store lists of strings / characters etc.
- Data structures becomes useful in other programs
- Sorting routines needed in many programs

Auditing code patterns

Various pitfalls, and areas

- **Variable Relationship**
- Examples presented are C buffers
- A variable-pointer to the buffer and the variable with the length
- Their relationship can easily get invalidated, leading to vulnerabilities
- Question: would object oriented programming help?

Relevant examples

- Apache was the worlds most popular web server!
- `mod_dav` implements a very complex protocol, file server features using http!
- Bind and the resolver libraries were the de facto, and still is, for DNS resolving in most of the open source software world!
- Sendmail was the most popular mail server for many years, but replaced mostly by Qmail, Postfix and Exim. Sendmail was used on both open source and commercial Unix operating systems like SunOS, AIX, HP-UX etc.
- OpenSSH mentioned next is also the most popular SSH protocol implementation, found in almost all Linux distributions and a wide range of network devices and other internet conected things
- OpenSSL is of course the most popular open source crypto library ... famous for the heartbleed bug and other hits

Structure and Object Mismanagement

- Structures in C can help group related data elements
- Both auditors and attackers can benefit ...
- Object oriented programs and languages encapsulate this
- Responsibility is on the object implementation, good!
- We saw structures last time

Uninitialized Variables

```
Packet *p = SCMalloc(SIZE_OF_PACKET);
if (unlikely(p == NULL)) {
     return 0;
}
ThreadVars tv;
DecodeThreadVars dtv;

memset(&dtv, 0, sizeof(DecodeThreadVars));
memset(&tv,  0, sizeof(ThreadVars));
memset(p, 0, SIZE_OF_PACKET);
```

- Always make sure variables have well defined values.
- Defensive program above use memset to clear contents of buffers
- Example from Suricata allocating memory, checking it got the memory, clearing contents

Manipulating Lists - and other data structures

- Storing data in a list is nice, can add and remove elements
- Single linked list, start from head and go through list ... slow
- Double linked list can go back again from element
- More work updating, moving more pointers ... complex, may introduce errors
- Example data structure double linked list
  https://algorithms.tutorialhorizon.com/doubly-linked-list-complete-implementation/
- Multiple problems can arise, also using the wrong structure for something can result in vulnerabilities

Dont write your data structure libraries yourself

Linux Teardrop

```
#! /usr/bin/env python3
if attack == '0':
  print "Using attack 0"
  size=36    offset=3   load1="\x00"*size
  i=IP()   i.dst=target   i.flags="MF"   i.proto=17

  size=4     offset=18  load2="\x00"*size
  j=IP()   j.dst=target   j.flags=0   j.proto=17   j.frag=offset
  send(i/load1)
  send(j/load2)
```

- IP fragments, packets are split when crossing a link with lower MTU
- If fragments created by an attacker are overlapping it creates a problem
- Scapy example code by Sam Bowne, full code can be found at: https://samsclass.info/123/proj10/teardrop.htm
- what is a Maximum Transmission Unit (MTU)
  See https://en.wikipedia.org/wiki/Maximum_transmission_unit for a description, related/similar attack setting source=destination https://en.wikipedia.org/wiki/LAND

Other problems

- Hashing algorithms
- There have been multiple problems with hashing algorithms
- Denial of Service and arbitrary code can be the result
- Example vulns from popular programming languages, others have similar!
  https://www.cvedetails.com/vulnerability-list/vendor_id-74/product_id-128/cvssscoremin-7/cvssscoremax-7.99/PHP-P
  html search for hash
  https://github.com/bk2204/php-hash-dos specific example in PHP 7.0.0 rc3-3
  https://www.ruby-lang.org/en/security/ Ruby has some
- also when programmers selected wrong, or weak, hashing algorithms for passwords

Control Flow

- If constructs, make sure to exercise each path
- Case/switch constructs, make sure to catch a default
- Loops being subverted to create buffer overflow, terminating conditions
- Forgetting a `break` in a case
- Picture selected due to the Apple "goto fail- certificate validation https://dwheeler.com/essays/apple-goto-fail.html

Apple Goto Fail CVE-2014-1266

```
if ((err = SSLHashSHA1.update(&hashCtx, &clientRandom)) != 0)
    goto fail;
if ((err = SSLHashSHA1.update(&hashCtx, &serverRandom)) != 0)
    goto fail;
if ((err = SSLHashSHA1.update(&hashCtx, &signedParams)) != 0)
    goto fail;
    goto fail;  /* MISTAKE THIS LINE SHOULD NOT BE HERE */
if ((err = SSLHashSHA1.final(&hashCtx, &hashOut)) != 0)
    goto fail;
```

- Always going to goto fail, second goto is always active
- Leading to later checks not performed
- Example code from*Anatomy of a "goto fail" – Apple's SSL bug explained*

https://nakedsecurity.sophos.com/2014/02/24/anatomy-of-a-goto-fail-apples-ssl-bug-explained-plus-an-unofficial-patch/

Loop running over buffer

- MS-RPC DCOM buffer overflow
- Ended up in the Blaster worm infecting : https://en.wikipedia.org/wiki/Blaster_(computer_worm)
- notice the timeline, even if patches ARE available people didn't patch
- This is why we have *patch tuesdays*
- Blaster was not as fast as SQL Slammer, which infected the internet in just minutes
- Other example from book, NTPD, which is also a common and thought to be safe service to run
- And `mod_php` nonterminating buffer vulnerability
- Plus a few off-by-one errors in `mod_rewrite` and OpenBSD ftpd
- ...

Side effects, corner cases and 32-bit vs 64-bit

- Functions can change variables in global scope while doing something
- Allocating memory can go wrong, check return values
- Asking for 0 bytes of memory is technically legal but may cause problems
- Doing 64-bit check with if and then being truncated to 32-bit when doing actual memory allocation function, result in unintended behaviour
- Double free is also mentioned, freeing an already free location may exploit heap management routines
  Check malloc and free very carefully

Who do you trust?

- Example programs shown with flaws in this chapter: OpenSSH, OpenSSL, Windows MS-RPC DCOM, Linux teardrop
- Who do you trust?
- Can we trust any software?
- What about Suricata? - CVE list

  https://www.cvedetails.com/vulnerability-list/vendor_id-13364/product_id-27771/Openinfosecfoundation-Suricata.html
- Spoiler: Bypass vulnerabilities, getting data past the IDS, Denial of Service crashing the IDS

Example applications from Microsoft

How to get ahead? - use existing good examples!

Microsoft has released sample applications.

> Secure Development Documentation Learn how to develop and deploy secure applications on Azure with our sample apps, best practices, and guidance.
> Get started Develop a secure web application on Azure

Source: https://docs.microsoft.com/en-us/azure/security/develop/

Yes, this describes how to run Alpine Linux on their Azure Cloud.

Resources

Microsoft Security Development Lifecycle (SDL) – The SDL is a software development process from Microsoft that helps developers build more secure software. It helps you address security compliance requirements while reducing development costs.

Open Web Application Security Project (OWASP) – OWASP is an online community that produces freely available articles, methodologies, documentation, tools, and technologies in the field of web application security.

Pushing Left, Like a Boss – A series of online articles that outlines different types of application security activities that developers should complete to create more secure code.

Microsoft identity platform – The Microsoft identity platform is an evolution of the Azure AD identity service and developer platform. It's a full-featured platform that consists of an authentication service, open-source libraries, application registration and configuration, full developer documentation, code samples, and other developer content. The Microsoft identity platform supports industry-standard protocols like OAuth 2.0 and OpenID Connect.

Security best practices for Azure solutions – A collection of security best practices to use when you design, deploy, and manage cloud solutions by using Azure. This paper is intended to be a resource for IT pros. This might include designers, architects, developers, and testers who build and deploy secure Azure solutions.

Security and Compliance Blueprints on Azure – Azure Security and Compliance Blueprints are resources that can help you build and launch cloud-powered applications that comply with stringent regulations and standards.

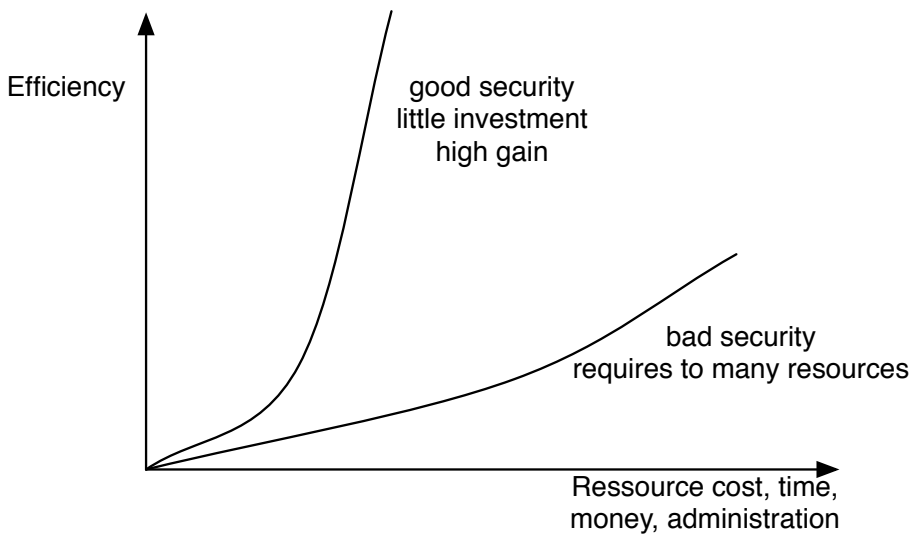
Next steps

In the following articles, we recommend security controls and activities that can help you design, develop, and deploy secure applications.

* Design secure applications * Develop secure applications * Deploy secure applications

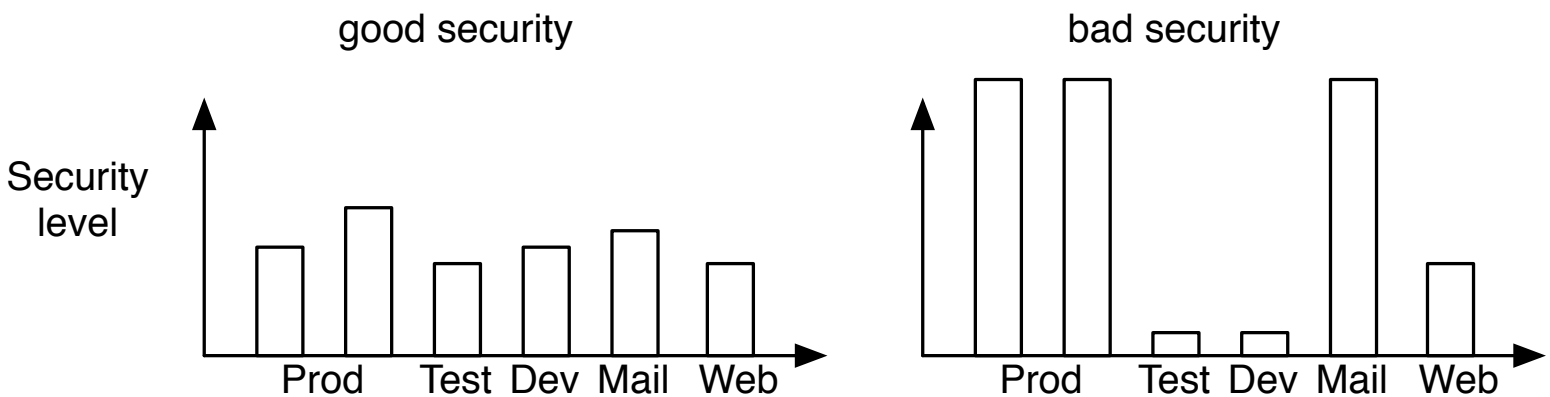
Source: https://docs.microsoft.com/en-us/azure/security/develop/secure-dev-overview

Good security



You always have limited resources for protection - use them as best as possible

Balanced security



Better to have the same level of security

If you have bad security in some part - guess where attackers will end up

Hackers are not required to take the hardest path into the network

Realize there is no such thing as 100% security

Jumping through networks and systems

Hackers break into systems they can reach

and hackers break into systems they can reach from hacked systems ☺

In real life networks, a remote root exploit from the internet to the main database is rare

but jumping through others can possibly break the whole network

There are a lot of hackers which have presented how they hacked companies, example

https://arstechnica.com/security/2016/04/how-hacking-team-got-hacked-phineas-phisher/

Example hacks we have done during testing

My own examples include pentest assignments where we:

- Two servers under test, Solaris
  had NFS world export, we could mount, found a backup of the other system, extracted /etc/passwd from backip, user logins with empty password, Solaris Telnet allows login, your password is empty - enter one
- Another test had SRX firewall as a core component. Due to misconfiguration we could access with SNMP, and thereby found the complete network structure revealed, how many network segments, subnets, netmask, ARP, interface counters - which lead to access files with password pictures, it was a bank
- Countless times we have found either a password file for a database, and used the same passwords for the operating system, or vice versa
- Countless times we have found either a password file in test systems, and people have used the same password in production, or vice versa

First advice use the modern operating systems

Newer versions of Microsoft Windows, Mac OS X and Linux

- Buffer overflow protection
- Stack protection, non-executable stack
- Heap protection, non-executable heap
- *Randomization of parameters* stack gap m.v.

Note: these still have errors and bugs, but are better than older versions

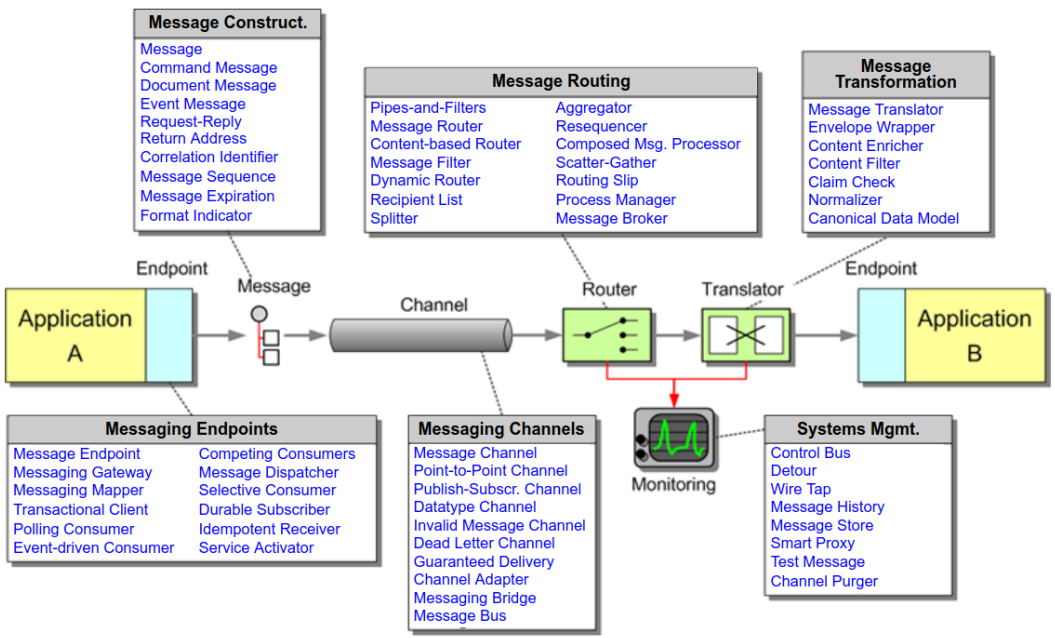
OpenBSD has shown the way in many cases
http://www.openbsd.org/papers/

Always try to make life worse and more costly for attackers

EIP Patterns

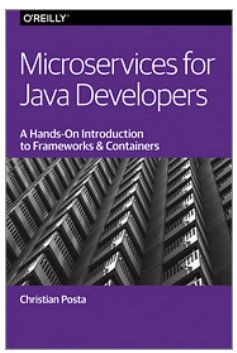
Messaging Patterns

We have documented 65 messaging patterns, organized as follows:



Following slides are mostly inspiration, and not specifically curriculum

Microservices for Java chapter 1



Microservices for Java Developers , Christian Posta, 2016 O'Reilly
https://www.oreilly.com/programming/free/files/microservices-for-java-developers.pdf

We will use the introduction, which is recommended.

Whats in the book

> This book is for Java developers and architects interested in developing microservices. We start the book with the high-level understanding and fundamental prerequisites that should be in place to be successful with a microservice architecture.

Introducing some Java frameworks

- The Spring ecosystem, Dropwizard and WildFly Swarm, we'll use JBoss Forge CLI
- Finally, when we build and deploy our microservices as Docker containers running inside of Kubernetes
- They use VirtualBox with Docker and Kubernetes, YMMV
- With source on Github, not updated in years though!
  https://github.com/redhat-developer/microservices-by-example-source

Source:

Microservices for Java Developers , Christian Posta, 2016 O'Reilly

Open source is also leading the charge in the technology space

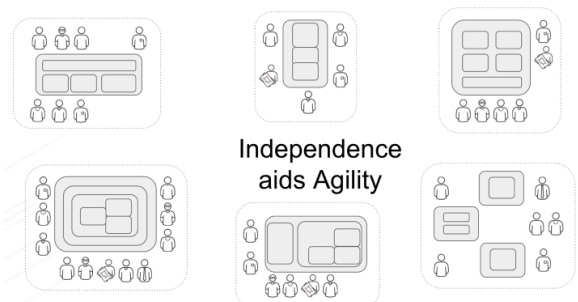
> Open source is also leading the charge in the technology space. Following the commoditization curves, open source is a place developers can go to challenge proprietary vendors by building and innovating on software that was once only available (without source no less) with high license costs. This drives communities to build things like operating systems (Linux), programming languages (Go), message queues (Apache ActiveMQ), and web servers (httpd). Even companies that originally rejected open source are starting to come around by open sourcing their technologies and contributing to existing communities. As open source and open ecosystems have become the norm, we're starting to see a lot of the innovation in software technology coming directly from open source communities (e.g., Apache Spark, Docker, and Kubernetes).

- We have used Linux and multiple products from the Apache website/foundation

Source:

Microservices for Java Developers , Christian Posta, 2016 O'Reilly

Building distributed systems is hard



Microservice architecture (MSA) is an approach to building software systems that decomposes business domain models into smaller, consistent, bounded-contexts implemented by services. These services are isolated and autonomous yet communicate to provide some piece of business functionality. Microservices are typically implemented and operated by small teams with enough autonomy that each team and service can change its internal implementation details (including replacing it outright!) with minimal impact across the rest of the system.

Source:

Microservices for Java Developers , Christian Posta, 2016 O'Reilly

Teamwork

- Teams communicate through promises
- specify these promises with interfaces of their services and via wikis that document their services
- Each team would be responsible for designing the service, picking the right technology for the problem set, and deploying, managing and waking up at 2 a.m. for any issues
- Understand what the service is doing without being tangled into other concerns in a larger application
- Quickly build the service locally
- Pick the right technology for the problem (lots of writes? lots of queries? low latency? bursty?)
- Test the service
- Build/deploy/release at a cadence necessary for the business, which may be independent of other services
- Identify and horizontally scale parts of the architecture where needed
- Improve resiliency of the system as a whole

Source:

Microservices for Java Developers , Christian Posta, 2016 O'Reilly

Challenges

- Microservices may not be efficient. It can be more resource intensive.
- You may end up with what looks like duplication.
- Operational complexity is a lot higher.
- It becomes very difficult to understand the system holistically.
- It becomes significantly harder to debug problems.
- In some areas you may have to relax the notion of transaction.

Source:

Microservices for Java Developers , Christian Posta, 2016 O'Reilly

Design for Faults

> Things will fail, so we must develop our applications to be resilient and handle failure, not just prevent it. We should be able to deal with faults gracefully and not let faults propagate to total failure of the system.
>
> Building distributed systems is different from building shared- memory, single process, monolithic applications. One glaring differ- ence is that communication over a network is not the same as a local call with shared memory.

- Networks are inherently unreliable

Source:

Microservices for Java Developers , Christian Posta, 2016 O'Reilly

Design with Dependencies in Mind

> To be able to move fast and be agile from an organization or distributed-systems standpoint, we have to design systems with dependency thinking in mind; we need loose coupling in our teams, in our technology, and our governance.

Source:

Microservices for Java Developers , Christian Posta, 2016 O'Reilly

Design with Promises in Mind

> In a microservice environment with autonomous teams and serv- ices, it's very important to keep in mind the relationship between service provider and service consumer. As an autonomous service team, you cannot place obligations on other teams and services because you do not own them; they're autonomous by definition. All you can do is choose whether or not to accept their promises of functionality or behavior. As a provider of a service to others, all you can do is promise them a certain behavior.

- Promises as published by APIs and versions in those!
- References *Consumer-Driven Contracts: A Service Evolution Pattern* https://martinfowler.com/articles/consumerDrivenContracts.html

Source:

Microservices for Java Developers , Christian Posta, 2016 O'Reilly

Chapter 10: Service API and Contract Versioning with Web Services and REST Services

After a service contract is deployed, consumer programs will naturally begin forming dependencies on it. When we are subsequently forced to make changes to the contract, we need to figure out:

- Whether the changes will negatively impact existing (and potentially future) service consumers
- How changes that will and will not impact consumers should be implemented and communicated

Included in the chapter are references to:

- Versioning Web Services
- Versioning REST Services
- Fine and Coarse-Grained Constraints

Source:

Service-Oriented Architecture: Analysis and Design for Services and Microservices, Thomas Erl, 2017

Versioning and Compatibility

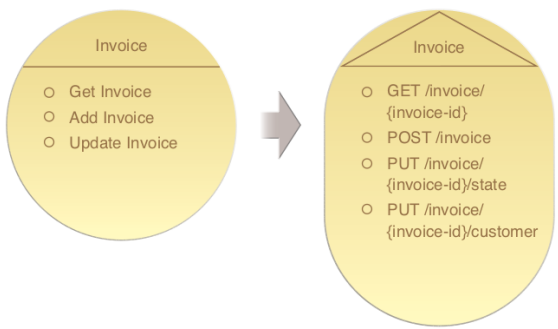
- Backwards Compatibility
  A backwards-compatible change to a REST-compliant service contract might involve adding some new resources or adding new capabilities to existing resources. In each of these cases the existing service consumers will only invoke the old methods on the old resources, which continue to work as they previously did.
- Forwards Compatibility
  When a service contract is designed in such a manner so that it can support a range of future consumer programs, it is considered to have an extent of forwards compatibility. This means that the contract can essentially accommodate how consumer programs will evolve over time.

Source:

Service-Oriented Architecture: Analysis and Design for Services and Microservices, Thomas Erl, 2017

REST Service Capability Granularity

Figure 7.19
A REST service candidate can be modeled specifically to incorporate uniform contract characteristics. The Update Invoice service capability candidate is split into two variations of the PUT /invoice/ service capability: one that updates the invoice state value, and another that updates the invoice customer value.



- REST using HTTP has the standard HTTP methods available (e.g., GET, POST, PUT, DELETE);
- See also https://en.wikipedia.org/wiki/Representational_state_transfer

Source:

Service-Oriented Architecture: Analysis and Design for Services and Microservices, Thomas Erl, 2017

Docker

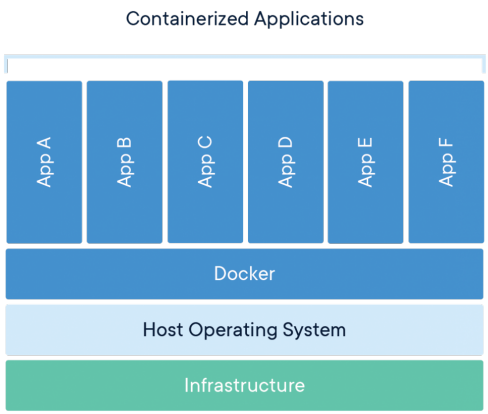
> Package Software into Standardized Units for Development, Shipment and Deployment A container is a standard unit of software that packages up code and all its dependencies so the application runs quickly and reliably from one computing environment to another. A Docker container image is a lightweight, standalone, executable package of software that includes everything needed to run an application: code, runtime, system tools, system libraries and settings.

Source:

https://www.docker.com/resources/what-container

- One of the most popular deployment methods today

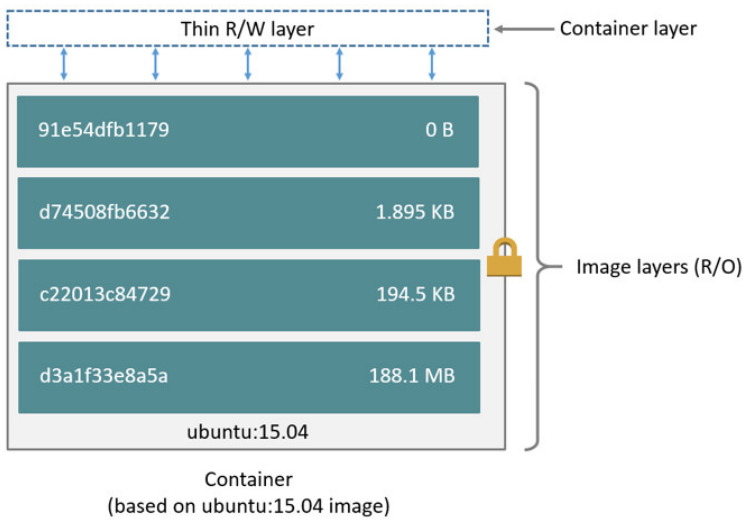
Containerized Applications



Source: https://www.docker.com/resources/what-container

- See also https://en.wikipedia.org/wiki/Linux_namespaces
  Various container software use Linux namespaces in combination with cgroups to isolate their processes, including Docker[11] and LXC.

Docker Images and layers



A Docker image is built up from a series of layers. Each layer represents an instruction in the image's Dockerfile. Each layer except the very last one is read-only.

Source: https://docs.docker.com/storage/storagedriver/

Kubernetes

> Kubernetes (K8s) is an open-source system for automating deployment, scaling, and management of containerized applications. It groups containers that make up an application into logical units for easy management and discovery. Kubernetes builds upon 15 years of experience of running production workloads at Google, combined with best-of-breed ideas and practices from the community.

Source: https://kubernetes.io/

Key points:

- Open source originally from Google
- Scalable
- Uses containers inside
- Infrastructure as code

Infrastructure as code

> **Infrastructure as code (IaC)** is the process of managing and provisioning computer data centers through machine-readable definition files, rather than physical hardware configuration or interactive configuration tools.[1] The IT infrastructure managed by this comprises both physical equipment such as bare-metal servers as well as virtual machines and associated configuration resources. The definitions may be in a version control system. It can use either scripts or declarative definitions, rather than manual processes, but the term is more often used to promote declarative approaches.

Source: https://en.wikipedia.org/wiki/Infrastructure_as_code

- Has become the norm in many places

Getting started with Kubernetes: Minikube

Not running it now, but do on your own, if you like

```
minikube start --cpus 2 --memory 2048 --disk-size 10g
```

The last parameter is important; it specifies which VM driver to use (see Minikube documentation for details). After the installation is complete, you can get the status of Minikube:

```
$ minikube status
minikubeVM: Running
localkube: Running
kubectl: Correctly Configured: pointing to minikube-vm at 192.168.64.2
```

This means the local Kubernetes cluster is up and running.

This is a nice way to try Kubernetes – can be done locally or in the cloud:
https://kubernetes.io/docs/tutorials/hello-minikube/

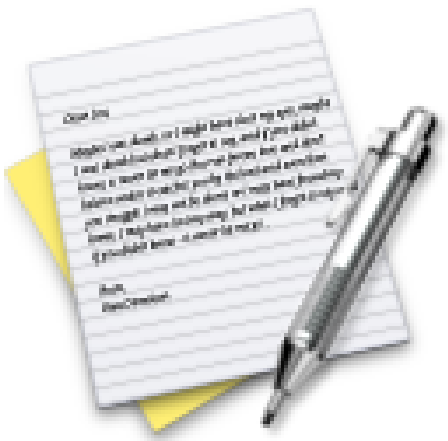
Exercise

Now lets do the exercise

⚠ Trying PMD static analysis 30 min

which is number **25** in the exercise PDF.

Exercise



Now lets do the exercise

⚠ Git hook 30 min

which is number **26** in the exercise PDF.

Exercise

Now lets do the exercise

⚠ JuiceShop Login 15 min

which is number 27 in the exercise PDF.

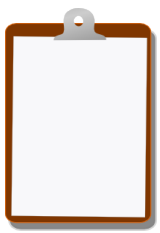
Exercise

Now lets do the exercise

ℹ Use a XML library in Python up to 45min

which is number **28** in the exercise PDF.

For Next Time



Think about the subjects from this time, write down questions

Check the plan for chapters to read in the books

Visit web sites and download papers if needed

Retry the exercises to get more confident using the tools