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IoT & Fog Computing

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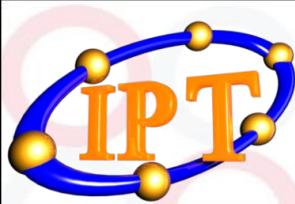
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About me



Trayan Iliev

- CEO of IPT – Intellectual Products & Technologies
- Oracle® certified programmer 15+ Y
- End-to-end reactive fullstack apps with Java, ES6/7, TypeScript, Angular, React and Vue.js
- 12+ years IT trainer
- Voxxed Days, jPrime, jProfessionals, BGOUG, BGJUG, DEV.BG speaker
- Organizer RoboLearn hackathons and IoT enthusiast (<http://robolearn.org>)
- Lecturer @ Sofia University – courses: Internet of Things (with SAP), Multiagent Systems and Social Robotics



Since 2003: IT Education Evolved

- ❖ Spring 5, Webflux, Java SE/Web/EE 7/8/9
- ❖ Reactive Robotics & IoT with Reactor / RxJava / Akka
- ❖ Node.js + Express + React + Redux + GraphQL
- ❖ Angular + TypeScript + Redux (ngrx)
- ❖ SOA & REST HATEOAS
- ❖ DDD & Reactive Microservices

Fog Computing – between IoT Devices and The Cloud

- ❖ Edge, Fog, Mist & Cloud Computing
- ❖ Fog domains and fog federation, wireless sensor networks, multi-layer IoT architecture
- ❖ Fog computing standards and specifications
- ❖ Practical use-case scenarios & advantages of fog
- ❖ Fog analytics and intelligence on the edge
- ❖ Technologies for distributed asynchronous event processing and analytics in real time
- ❖ Lambda architecture – Spark, Storm, Kafka, Apex, Beam, Spring Reactor & WebFlux
- ❖ Eclipse IoT platform

We Live in Exponential Time!

“The future is widely misunderstood. Our forebears expected it to be pretty much like their present, which had been pretty much like their past.”

*–Ray Kurzweil, *The Singularity Is Near**

We Live in Exponential Time

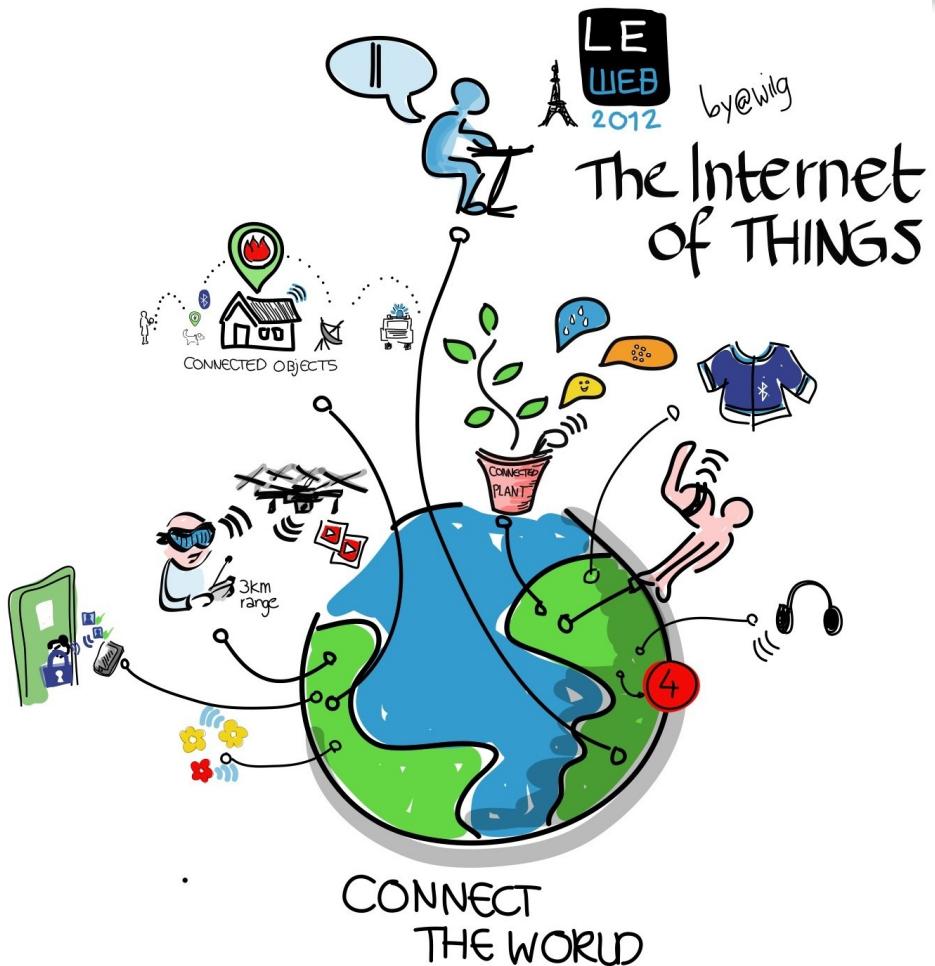
- ❖ “intuitive linear” view of technological progress vs. the “historical exponential” view.
- ❖ The Law of Accelerating Returns: Evolution applies **positive feedback** in that the more capable methods resulting from one stage of evolutionary progress are used to create the next stage. As a result, the rate of progress of an evolutionary process **increases exponentially** over time.
- ❖ A correlate of the above observation is that the “**returns**” of an evolutionary process (e.g., the speed, cost-effectiveness, or overall “power” of a process) **increase exponentially** over time.

IoT, IoE, WoT – What It Means?

The **Internet-of-Things (IoT)** is a self-configuring and adaptive network which connects real-world things to the Internet enabling them to communicate with other connected objects leading to the realization of a new range of ubiquitous services.

*R. Minerva et al. - Towards a definition of IoT
Technical report, IEEE, 2015*

Example: Internet of Things (IoT)



Radar, GPS, lidar for navigation and obstacle avoidance (2007 DARPA Urban Challenge)

CC BY 2.0, Source:
<https://www.flickr.com/photos/wilgengebroed/8249565455/>



Интернет на нещата (IoT, IoE)

Today computers—and, therefore, the Internet—are almost wholly dependent on human beings for information. Nearly all of the roughly 50 petabytes (a petabyte is 1,024 terabytes) of data available on the Internet were first **captured and created by human beings**—by typing, pressing a record button, taking a digital picture, or scanning a bar code. ... The problem is, people have limited time, attention and accuracy—all of which means they are not very good at capturing data about **things in the real world**. ... We're physical, and so is our environment ... If we had computers that knew everything there was to know about things ... we would be able to track and count everything, and **greatly reduce waste, loss and cost**. We would know when things needed replacing, repairing or recalling, and whether they were fresh or past their best. **The Internet of Things has the potential to change the world, just as the Internet did. Maybe even more so.**

— Kevin Ashton, 'That 'Internet of Things' Thing', RFID Journal,
July 22, 2009



Интернет на нещата (IoT, IoE)

Интернет на нещата има потенциала да промени света, така както го направи Интернет. Дори повече.

— Kevin Ashton, 'That 'Internet of Things' Thing', RFID Journal, 2009

- ❖ 50 петабайта данни се **създават и въвеждат от хора**
- ❖ Хората имат ограничено време, внимание и точност
- ❖ Данни за **нещата от реалния свят в реално време**
- ❖ Проследяване и управление на всичко, **намаляване на проблемите, загубите и цената**
- ❖ Ще знаем кога нещата се нуждаят от **замяна, ремонт или извеждане от експлоатация**



Интернет на нещата в цифри

- According to Gartner, there will be nearly **26 billion** devices on the Internet of Things by 2020.
[Gartner, 2013-12-12,
<http://www.gartner.com/newsroom/id/2636073>]
- According to ABI Research, more than **30 billion** devices will be wirelessly connected to the Internet of Things by 2020 (Internet of Everything)
[ABI Research, <https://www.abiresearch.com/press/more-than-30-billion-devices-will-wirelessly-conne>]
- It's expected to be a **19 Trillion USD** market
[John Chambers, Cisco CEO,
<http://www.bloomberg.com/news/2014-01-08/cisco-ceo-pegs-internet-of-things-as-19-trillion-market.html>]

Internet of Things – перспективи

“Of the executives surveyed, 82% say their organisations grew their IoT investment in the past three years, up from 62% who said the same in 2017. One in five businesses (20%) grew that investment by 50% or more. For 10% of manufacturers, it more than doubled. This investment is delivering returns, respondents say: most agree either “somewhat” (38%) or “strongly” (19%) that their use of IoT has delivered “more than its expected return on investment”.

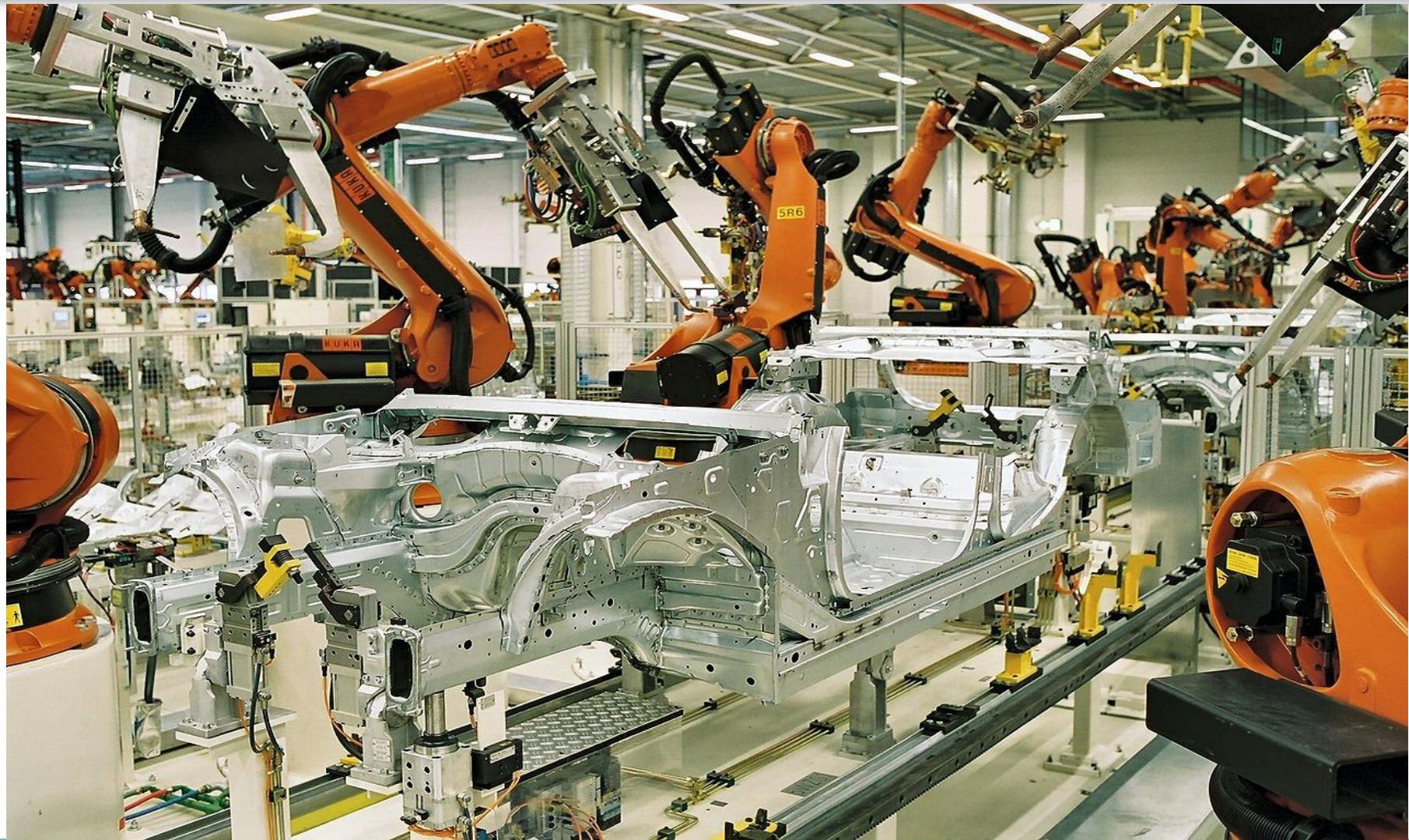
[The Economist Intelligence Unit Limited 2020:
<https://learn.arm.com/economist-iot-report-typ.html>]

Internet of Things & AI

“Artificial intelligence (AI) is viewed as vital to realising the value of IoT data. Just over a quarter of survey respondents (26%) say that IoT data are pivotal to their current or planned use of AI, with 56% identifying IoT as “one of many important sources” for AI initiatives. Furthermore, 64% agree that “the value of IoT data to my organisation has increased as we have developed our AI capabilities”. Many interviewees view IoT and AI as two components of an advanced analytics capability. Reportedly, algorithms trained on data sources including IoT provide the greatest value and competitive differentiation.”

[The Economist Intelligence Unit Limited 2020:
<https://learn.arm.com/economist-iot-report-typ.html>]

В промышленности ...



Industrial IoT – перспективи

“The IIoT market is expected to grow from USD 77.3 billion in 2020 to USD 110.6 billion by 2025, at a CAGR of 7.4% during the forecast period. The growth of the IIoT industry is driven by factors such as technological advancements in semiconductor and electronic devices, increased use of cloud computing platforms, standardization of IPv6, and support from governments of different countries for R&D activities related to IIoT.”

Maarkets and Markets,2019 - Industrial IoT (IIoT) Market:
<https://www.marketsandmarkets.com/Market-Reports/industrial-internet-of-things-market-129733727.html>

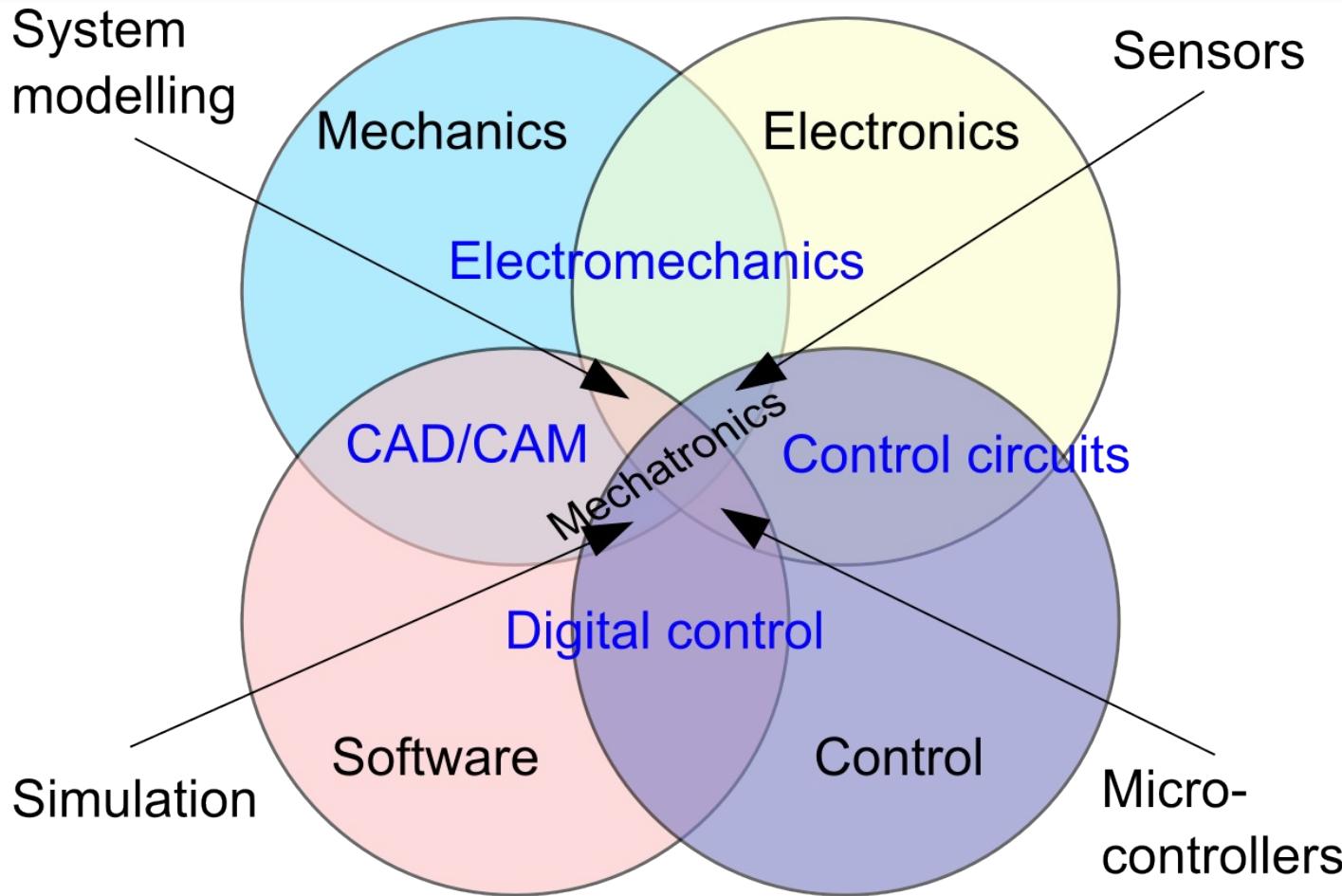
Internet of Things (IoT) – архитектурни изисквания

"Basket of remotes" problem – we'll have hundreds of applications to interface with hundreds of devices that **don't share protocols for speaking with one another**

[Jean-Louis Gassée, Apple initial alumni team, and BeOS co-founder,
<http://www.mondaynote.com/2014/01/12/internet-of-things-the-basket-of-remotes-problem/>]

- IoT устройствата трябва да бъдат лесно достъпни за своите потребители и техните агенти
- IoT архитектурите трябва да бъдат конкурентни разпределени, устойчиви на грешки, високо-производителни, еластични и децентрализирани, **динамично** разширяеми и еволюиращи

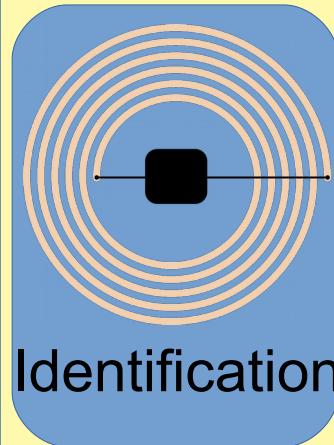
Engineering, Science & Art



Source: <https://commons.wikimedia.org/w/index.php?curid=551256>, CC BY-SA 3.0

Key Elements of IoT

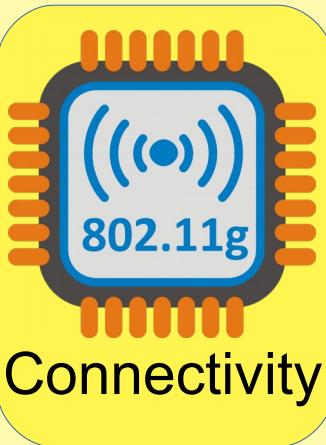
Internet of Things (IoT)



Identification



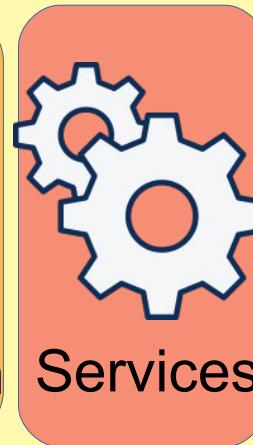
Sensors



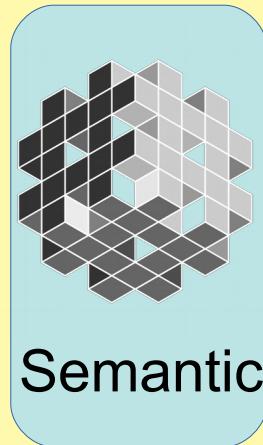
Connectivity



Computation

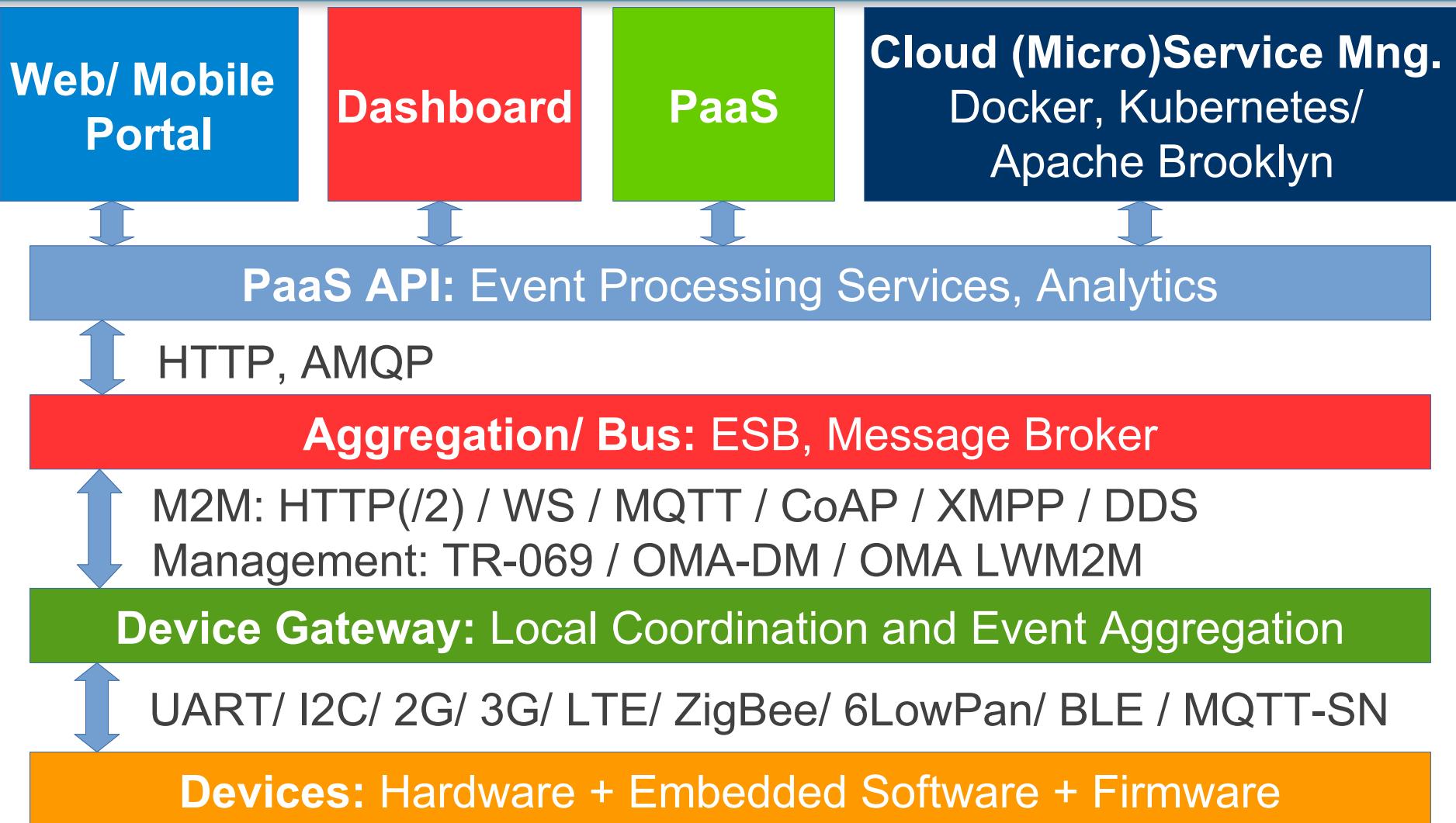


Services



Semantic

IoT Services Architecture



Cloud Computing - Definition

Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three service models, and four deployment models.

National Institute of Standards and Technology

Essential Characteristics of Cloud

- ❖ On-demand self-service
- ❖ Broad network access
- ❖ Resource pooling
- ❖ Rapid elasticity
- ❖ Measured service

Cloud Service Models

- ❖ Software as a Service (SaaS)
- ❖ Platform as a Service (PaaS)
- ❖ Infrastructure as a Service (IaaS)

Cloud Deployment Models

- ❖ Private cloud
- ❖ Community cloud
- ❖ Public cloud
- ❖ Hybrid cloud

Edge Computing (Mesh Computing)

“... places applications, data and processing at the logical extremes of a network rather than centralizing them. Placing data and data-intensive applications at the Edge reduces the volume and distance that data must be moved.”

IoT Guide

http://internetofthingsguide.com/d/edge_computing.htm

Fog Computing: Definition

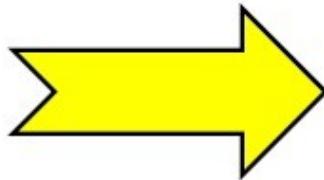
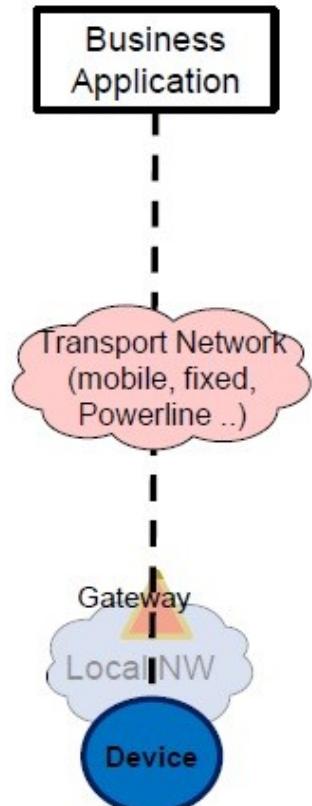
A horizontal, system-level architecture that distributes computing, storage, control and networking functions closer to the users along a cloud-to-thing continuum.

OpenFog™ Consortium

Vertical vs. Horizontal IoT

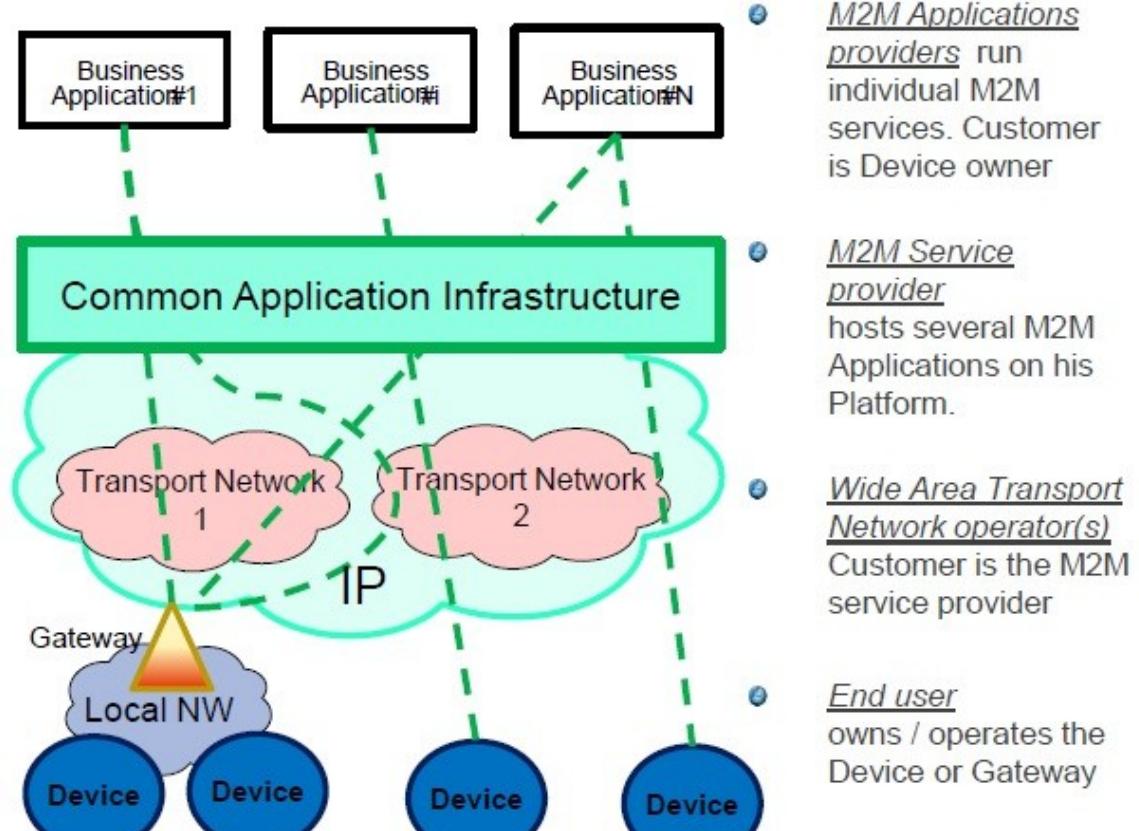
Pipe (vertical):

1 Application, 1 NW,
1 (or few) type of Device



Horizontal (based on common Layer)

Applications share common infrastructure, environments
and network elements



Fog vs. Edge Computing - Diff

Fog computing	Edge computing
Works with the Cloud	Defined separately without Cloud
Multi-layered architecture, N-tier deployments, multiple IoT verticals	Limited number of local layers, not aware of IoT verticals
Independent of the devices and aware of the entire fog domain	Device and few local services aware, no domain awareness
Addresses networking, storage, control, processing acceleration	Addresses computation only, little interoperability
Analytics: collection, analysis, ML, anomalies, optim., multiple devices	Analytics scoped to a single device – printer, camera, machine, etc.
End-to-end (E2E) security – data protection, session, hardware level	Custom security, partial point solution, VPN, Firewall
Virtualization, containerization, App/ Soft PLC hosting, RT control, modularity, High Availability (HA)	No virtualization, Hard PLC/ Soft PLC stack integrated on device hardware, not modular, not HA

Cloud, Fog and Mist Computing

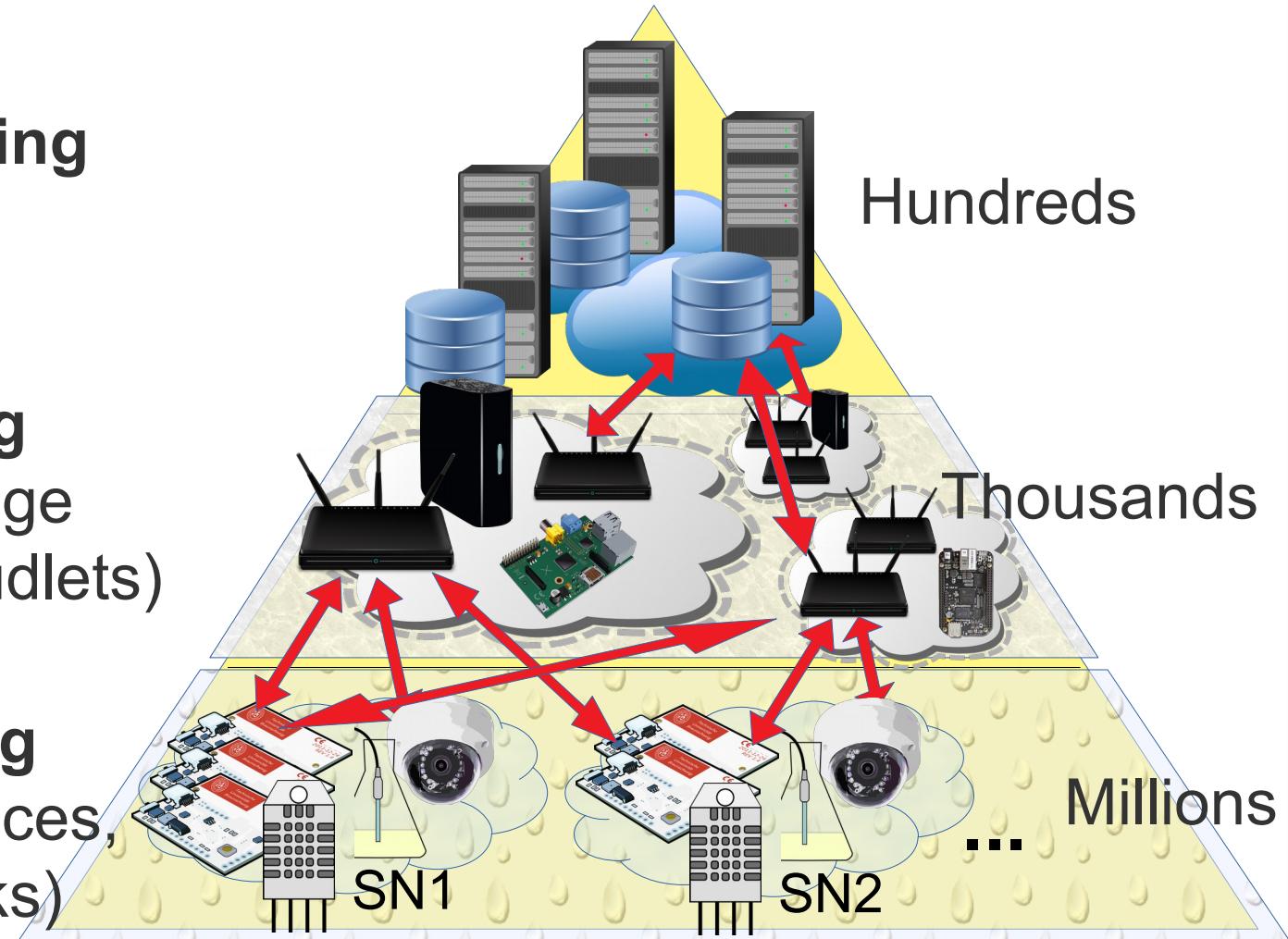
Cloud Computing
(Data-centers)



Fog Computing
(Fog Nodes, Edge
Gateways, Cloudlets)



Mist Computing
(Smart IoT Devices,
Sensor Networks)



Mist Computing - Definition

Mist computing is a lightweight and rudimentary form of computing power that **resides directly within the network fabric** at the edge of the network, the fog layer closest to the smart end-devices, **using microcomputers and microcontrollers** to feed into fog computing nodes and potentially onward towards the cloud computing services.

National Institute of Standards and Technology

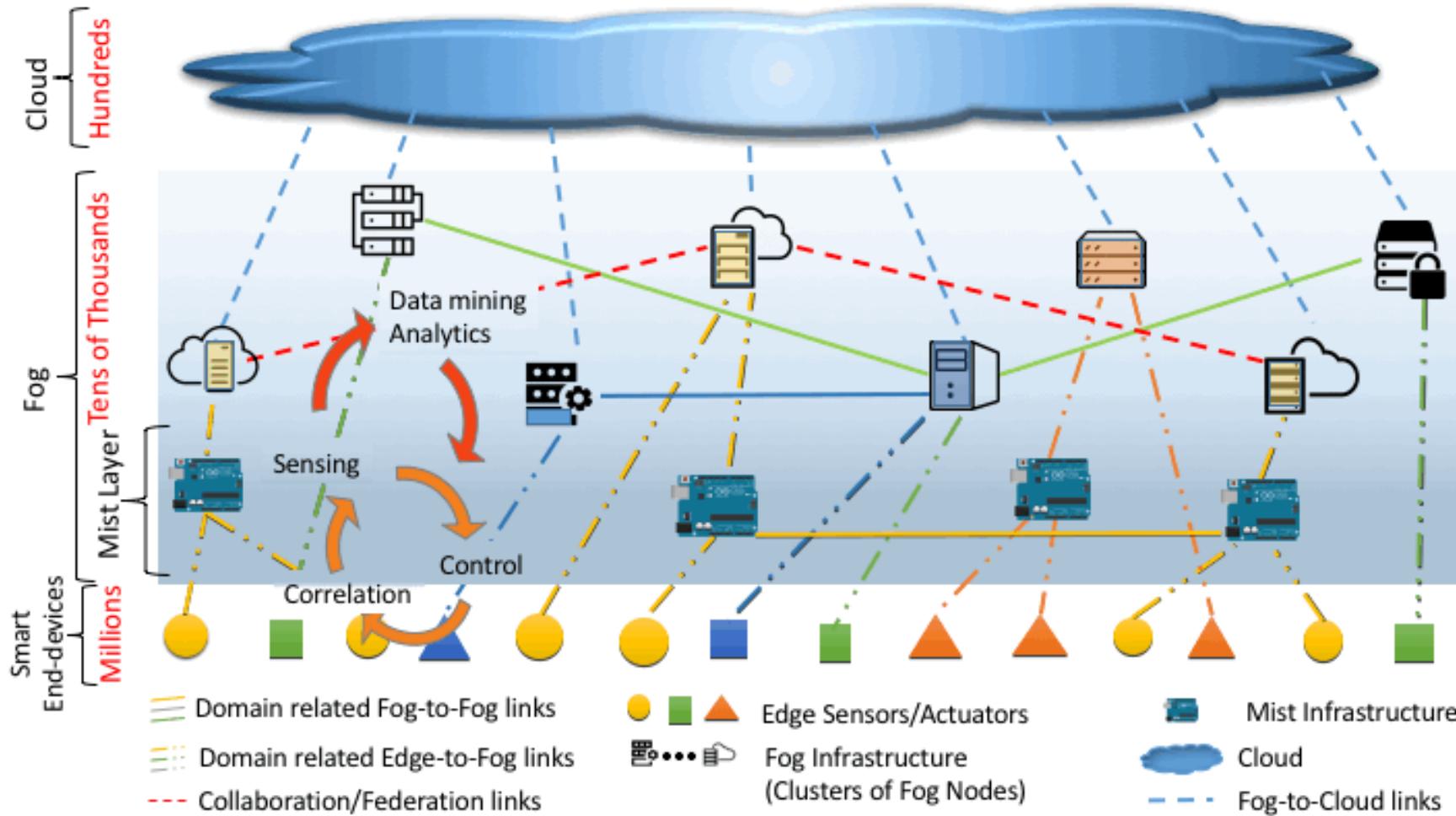
Why Fogging?

- ❖ **Exponential Data in Realtime** – data generated by IoT devices is growing exponentially – especially high bandwidth devices and apps like: LIDARs, 3D cameras, US arrays, gaming, streaming, augmented reality, etc.
- ❖ **If all data should go to the cloud** for analysis and speech/ image/ 3D scene recognition → a recipe for network congestion, high-latency, and self-made DoS.
- ❖ Many metrics like **performance, efficiency, scalability, latency, security, bandwidth, reliability, privacy** could be greatly improved if the processing, analysis, and partially decision making are **done locally** – close to the source of data.

Fog Nodes, Domains & Federation

- ❖ **Fog Node** – The physical and logical network element that implements fog computing services. It is somewhat analogous to a server in cloud computing.
- ❖ **Fog Domain** – seamlessly extends cloud computing to the edge for secure control and management of domain specific hardware, software, and standard compute, storage and network functions.
- ❖ **Fog Federation** – secure control and management of ***multiple fog domain instances***, including edge devices, computes, networking, storage & services in a distributed and consistent manner, providing horizontal expansion of functionality over disperse geolocations.

Fog Computing – a Cloud-Based Ecosystem for Smart End-Devices



Virtual Network Functions

Open Baton

Compute
Virtualization

Storage
Virtualization

Network
Virtualization

OpenStack + Kubernetes

KVM

LXD

Ceph

OpenDaylight

ONOS

OpenContrail

OVN

Compute

Storage

Network

Data Plane

FD.io

DPDK

OVS

ODP

Infrastructure

Pharos Community Labs

OPNFV Bare Metal Lab

Upstream
Project
Collaboration

Integration

Alignment

Installers

Composition

Testing

Functional

System

Performance

New Features

NFV
Features

Continuous Integration / Continuous Deployment

Documentation

Security

IoT Networking & Identification

- ❖ Time-Sensitive Networking (TSN) – IEEE 802.1
- ❖ ISO/IEC 20248 Automatic Identification and Data Capture Techniques – QR Code, RFID, NFC – secure identification of Things.
- ❖ GS1's EPC Tag Data Standard (TDS) and EPCglobal Architecture Framework (EPC Network) – allows storing and querying of data related to objects identified with Electronic Product Code numbers.
- ❖ IPv6 – allows identification of network interfaces and IP package routing, not permanent

Fog Standards and Specifications

- ❖ National Institute of Standards and Technology (NIST)
Definition of Fog Computing – Special Publication Draft 800-191
- ❖ OpenFog Consortium – *OpenFog Reference Architecture for Fog Computing* – medium to high level description of system architectures for fog nodes and networks, including of multiple viewpoints (Functional, Deployment), views (Software, System, Node), and Perspectives (cross-cutting concerns). Based on:
- ❖ ISO/IEC/IEEE 42010:2011 – *Systems and software engineering — Architecture description*

NIST Definition of Fog Computing

Fog computing is a horizontal, physical or virtual resource paradigm that resides between smart end-devices and traditional cloud or data centers. This paradigm supports vertically-isolated, latency-sensitive applications by providing ubiquitous, scalable, layered, federated, and distributed computing, storage, and network connectivity.

National Institute of Standards and Technology

Fog Computing Characteristics - I

- ❖ Contextual **location awareness**, and **low latency**
- ❖ **Geographical distribution** & distributed deployment
- ❖ **Large-scale sensor networks** – environment monitoring, Smart Grid → distributed computing and storage
- ❖ **Very large number of nodes** – geo-distributed
- ❖ **Support for mobility** – mobile devices: smartphones, etc.
- ❖ **Real-time interactions** – streaming, lambda architecture
- ❖ **Predominance of wireless IoT access**: analytics, compute
- ❖ **Heterogeneity** – deployed in wide variety of environments

Fog Computing Characteristics - II

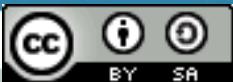
- ❖ **Interoperability and federation** - seamless support of certain services (e.g. real-time streaming) requires the cooperation of different providers.
- ❖ **Support for real-time analytics and interplay with the Cloud** -while Fog nodes provide localization, therefore enabling low latency and context awareness, the Cloud provides global centralization. Many applications require both Fog localization and Cloud globalization, particularly for analytics and Big Data.
- ❖ **Fog is particularly well suited to real-time streaming analytics** as opposed to historical, Big Data batch analytics that is normally carried out in a data center.

Fog as a Service (FaaS)

- ❖ Pay-as-you-go model
- ❖ Includes:
 - Software as a Service (SaaS)
 - Platform as a Service (PaaS)
 - Infrastructure as a Service (IaaS)

OpenFog Consortium

- ❖ Founded in November 2015 by ARM, Cisco, Dell, Intel, Microsoft and Princeton University
- ❖ Open participation from across industry, academia and non-profit organizations that have an interest in the emerging IoT landscape
- ❖ Defines open architectural framework enabling IoT industry convergence and game-changing innovation through fog computing
- ❖ Efforts complementary to other initiatives like: Industrial Internet Consortium (IIC), ETSI-MEC (Mobile Edge Computing), OPC-UA, Open Connectivity Foundation (OCF), OpenNFV, etc.



Example Use Cases

- ❖ **Traffic Control and Smart Cars** – Vehicle-to-X – including: Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Manufacturer (V2M), multiple public and private fog and cloud networks.
- ❖ **Security Cameras and Surveillance** – in smart cities / homes, retail stores, factories, public transportation, airports – terabytes per day by single camera → local processing, anomaly detection, and decision making.
- ❖ **Smart cities**- parking, shopping, healthcare, infrastructure
- ❖ **Smart Buildings** – HVAC, lighting, doors, parking, security, elevators, support for smartphones, tablets, etc.

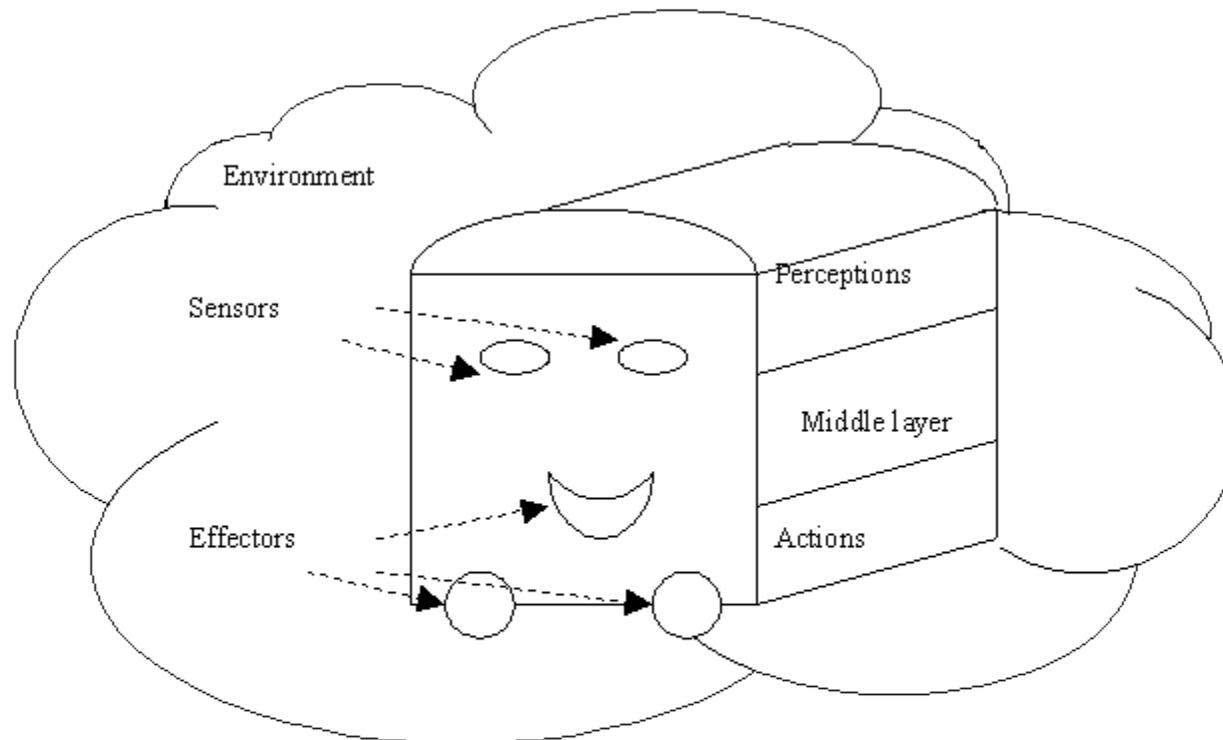
Core Principles

- ❖ Scalable
- ❖ Agile and open
- ❖ Secure
- ❖ Autonomous
- ❖ Flexible & programmable
- ❖ Highly available
- ❖ Reliable
- ❖ Remotely serviceable
- ❖ Hierarchically structured based on business needs

Fog Analytics

- ❖ Descriptive Analytics
- ❖ Reactive (Diagnostic) Analytics
- ❖ Predictive Analytics
- ❖ Prescriptive Analytics

Intelligent Agents - Looks Similar?





Documentation

FAQ

Download

Mailing List

Code

Commercial Support

Build powerful concurrent & distributed applications more easily.

Akka is a toolkit and runtime for building highly concurrent, distributed, and resilient message-driven applications on the JVM.

Simple Concurrency & Distribution

Asynchronous and Distributed by design. High-level abstractions like Actors, Futures and STM.

Resilient by Design

Write systems that self-heal. Remote and/or local supervisor hierarchies.



High Performance

50 million msg/sec on a single machine. Small memory footprint; ~2.5 million actors per GB of heap.

Elastic & Decentralized

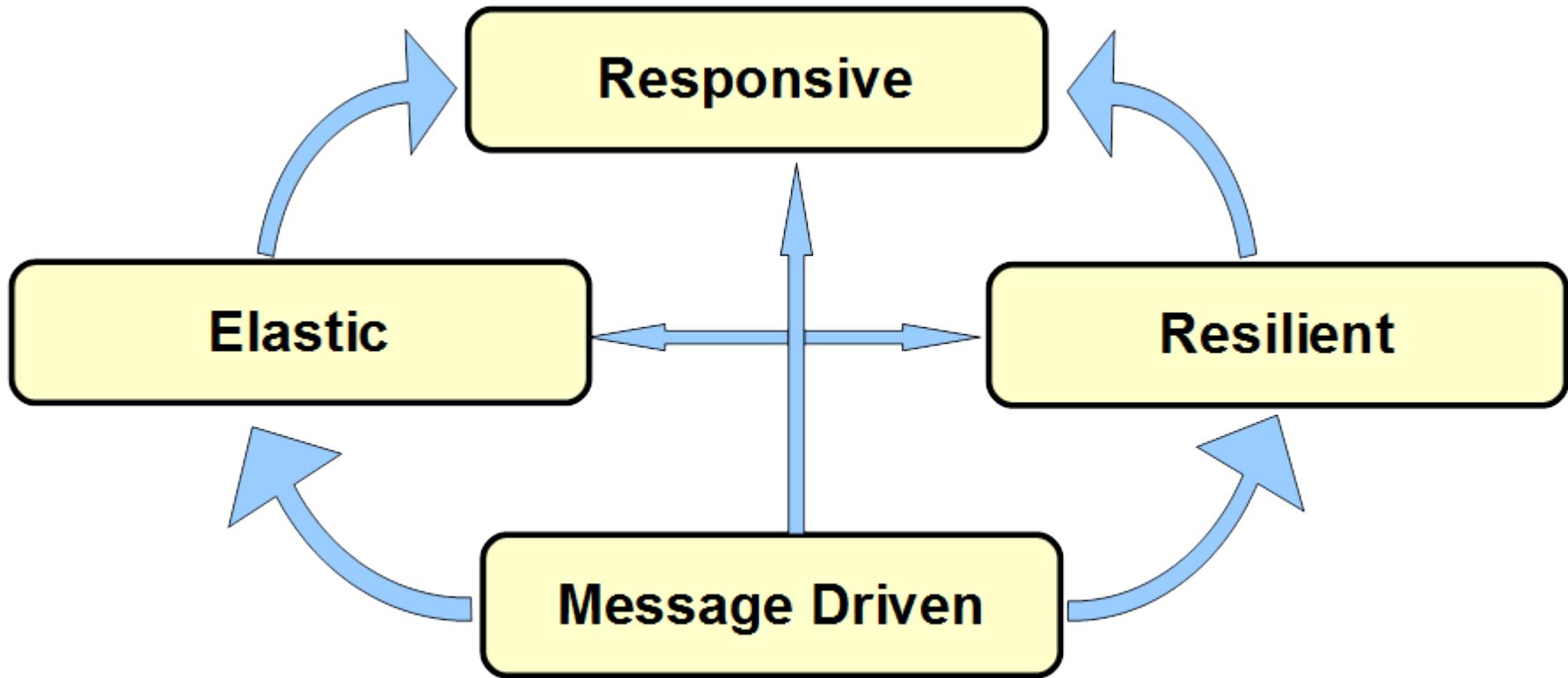
Adaptive load balancing, routing, partitioning and configuration-driven remoting.

Extensible

Use Akka Extensions to adapt Akka to fit your needs.

Reactive Manifesto

[<http://www.reactivemanifesto.org>]



Scalable, Massively Concurrent

- ❖ **Message Driven** – asynchronous message-passing allows to establish a boundary between components that ensures loose coupling, isolation, location transparency, and provides the means to delegate errors as messages [Reactive Manifesto].
- ❖ The main idea is to separate concurrent producer and consumer workers by using **message queues**.
- ❖ **Message queues** can be **unbounded or bounded** (limited max number of messages)
- ❖ **Unbounded** message queues can present memory allocation problem in case the producers outrun the consumers for a long period → **OutOfMemoryError**

Data / Event / Message Streams

“Conceptually, a stream is a (potentially never-ending) flow of data records, and a transformation is an operation that takes one or more streams as input, and produces one or more output streams as a result.”

Apache Flink: Dataflow Programming Model

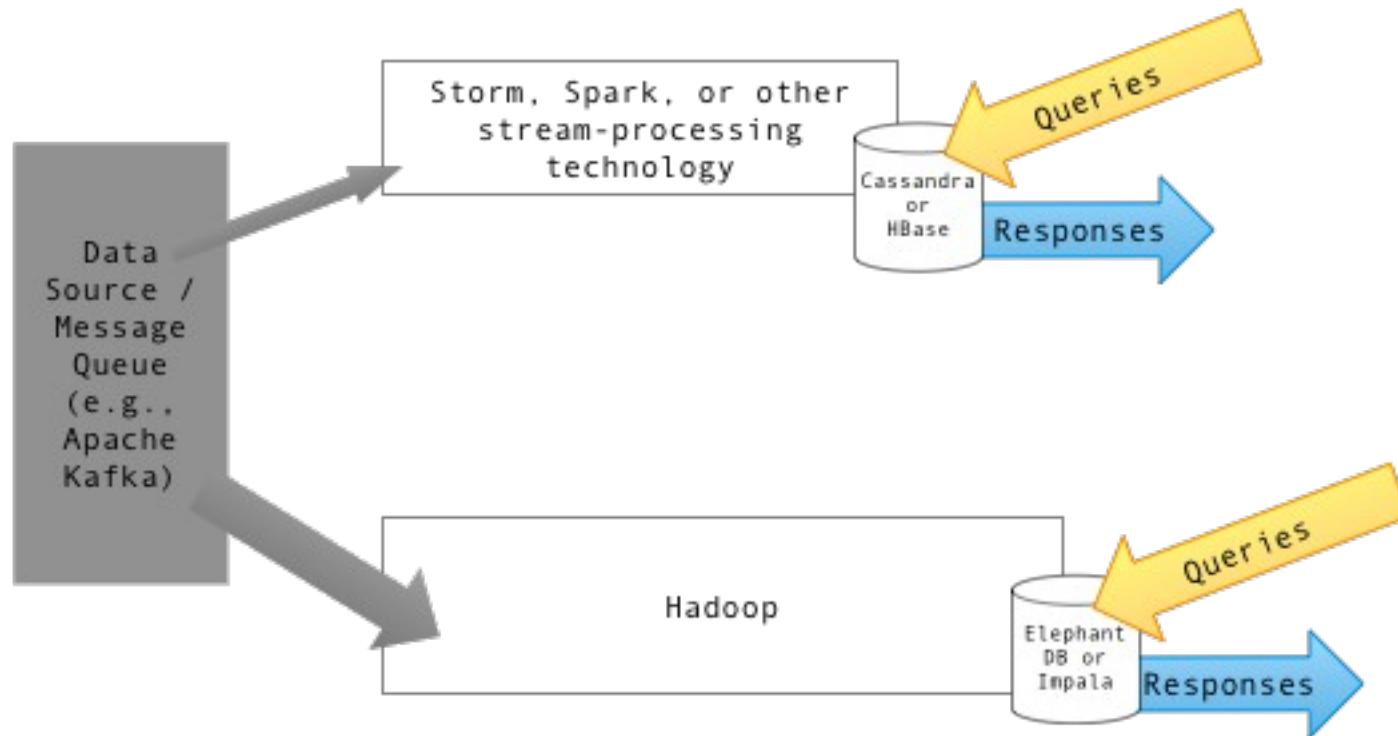
Data Stream Programming

The idea of abstracting logic from execution is hardly new -- it was the dream of SOA. And the recent emergence of microservices and containers shows that the dream still lives on.

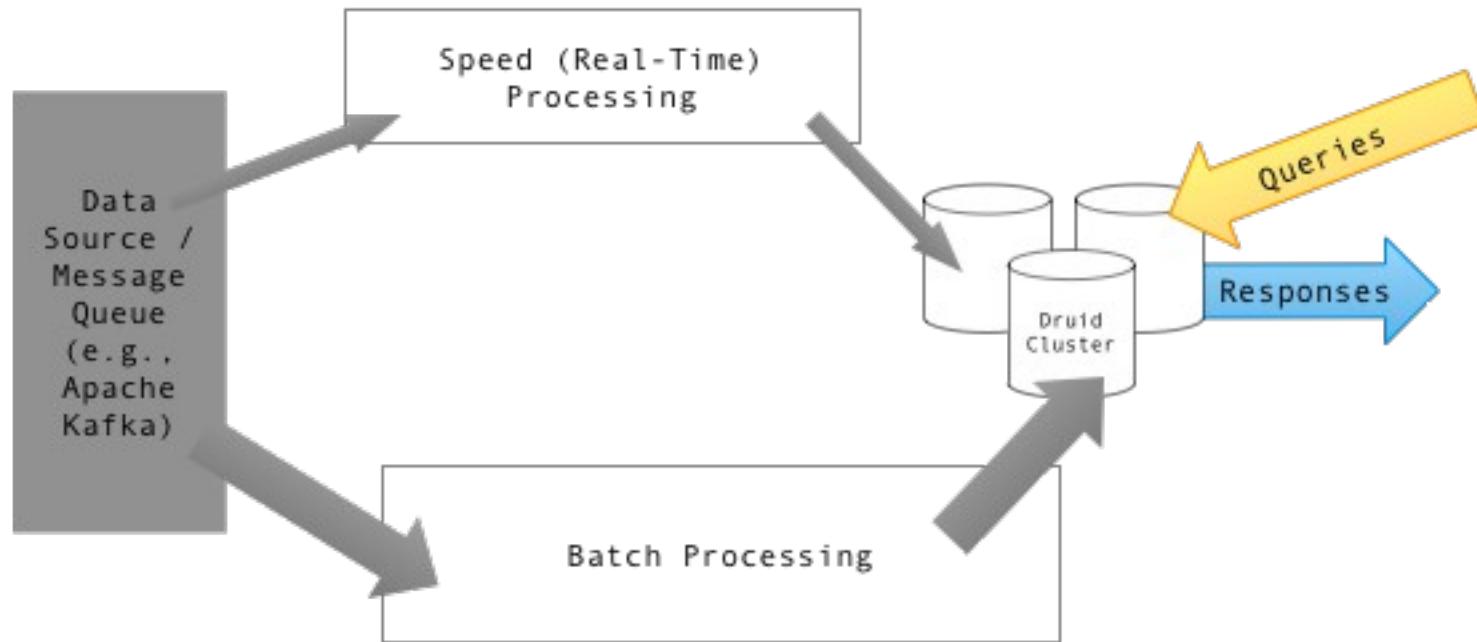
For developers, the question is whether they want to learn yet one more layer of abstraction to their coding. On one hand, there's the elusive promise of a common API to streaming engines that in theory should let you mix and match, or swap in and swap out.

*Tony Baer (Ovum) @ ZDNet - Apache Beam and Spark:
New coopetition for squashing the Lambda Architecture?*

Lambda Architecture - I



Lambda Architecture - II



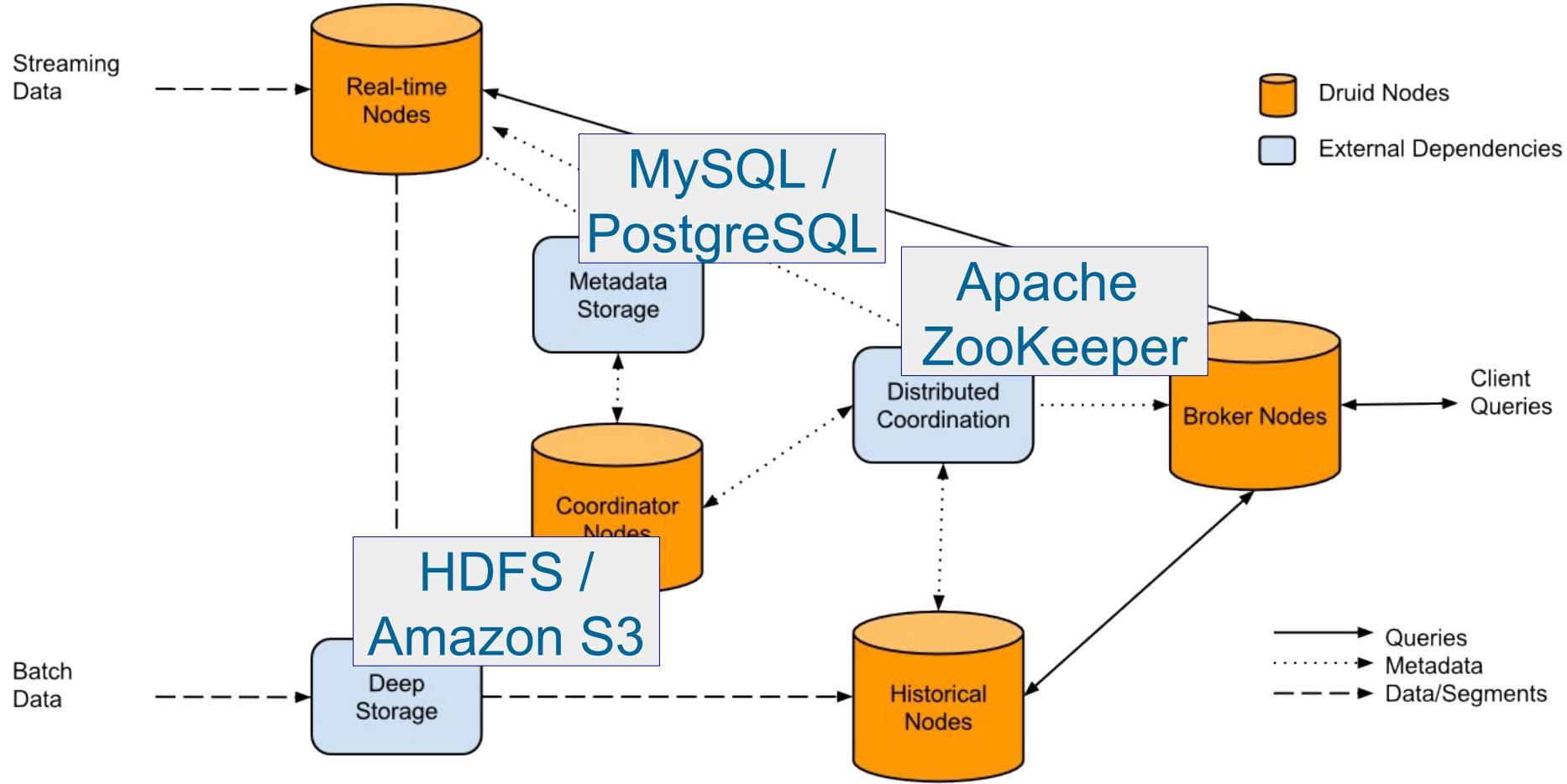
<https://commons.wikimedia.org/w/index.php?curid=34963987>, By Textractor - Own work, CC BY-SA 4



Lambda Architecture - III

- ❖ Data-processing architecture designed to handle massive quantities of data by using both *batch-* and *stream-processing* methods
- ❖ Balances *latency, throughput, fault-tolerance, big data, real-time analytics*, mitigates the latencies of map-reduce
- ❖ Data model with an append-only, *immutable data* source that serves as a system of record
- ❖ Ingesting and processing *timestamped events* that are appended to existing events. State is determined from the *natural time-based ordering* of the data.

Druid Distributed Data Store (Java)



<https://commons.wikimedia.org/w/index.php?curid=33899448> By Fangjin Yang - sent to me personally, GFDL



Lambda Architecture: Projects - I

- ❖ Apache Spark is an open-source cluster-computing framework. Spark Streaming, Spark Mllib
- ❖ Apache Storm is a distributed stream processing – streams DAG
- ❖ Apache Apex™ unified stream and batch processing engine.

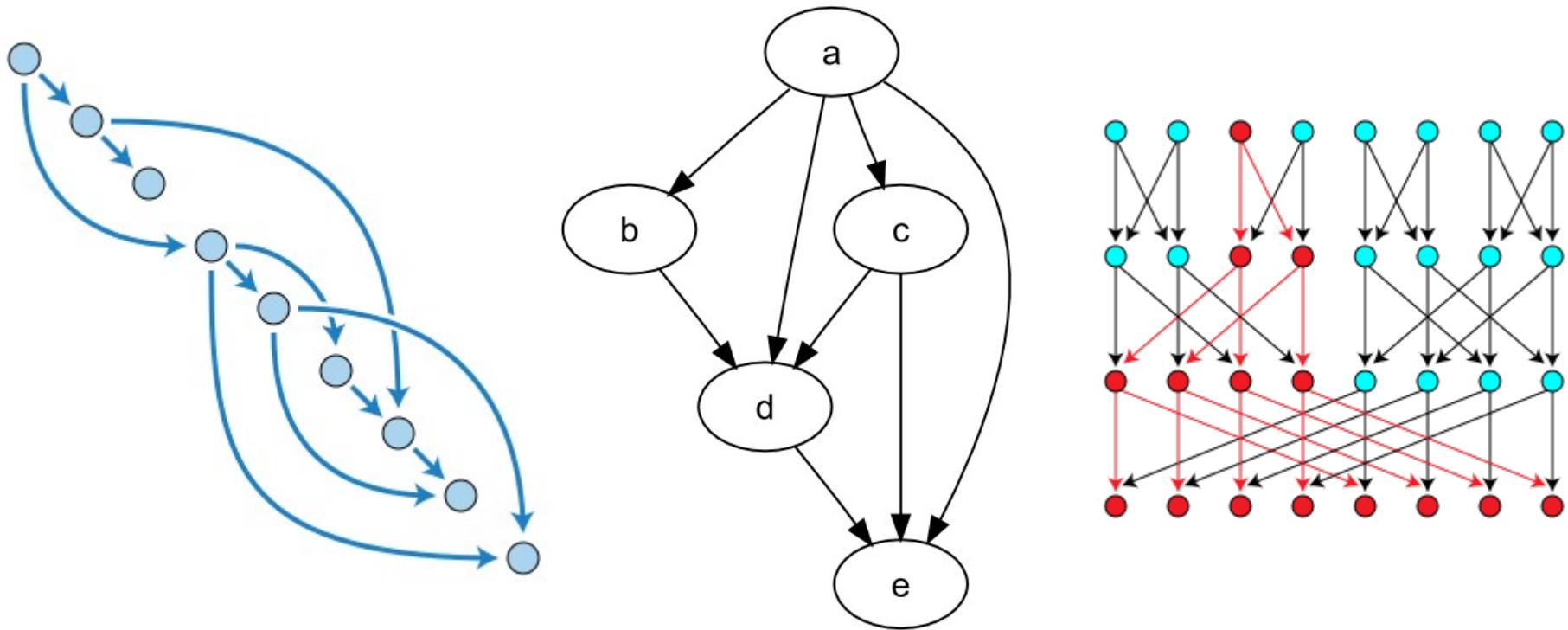


Lambda Architecture: Projects - II

- ❖ Apache Flink - open source stream processing framework – Java, Scala
- ❖ Apache Kafka - open-source stream processing (Kafka Streams), real-time, low-latency, high-throughput, massively scalable pub/sub
- ❖ Apache Beam – unified batch and streaming, portable, extensible

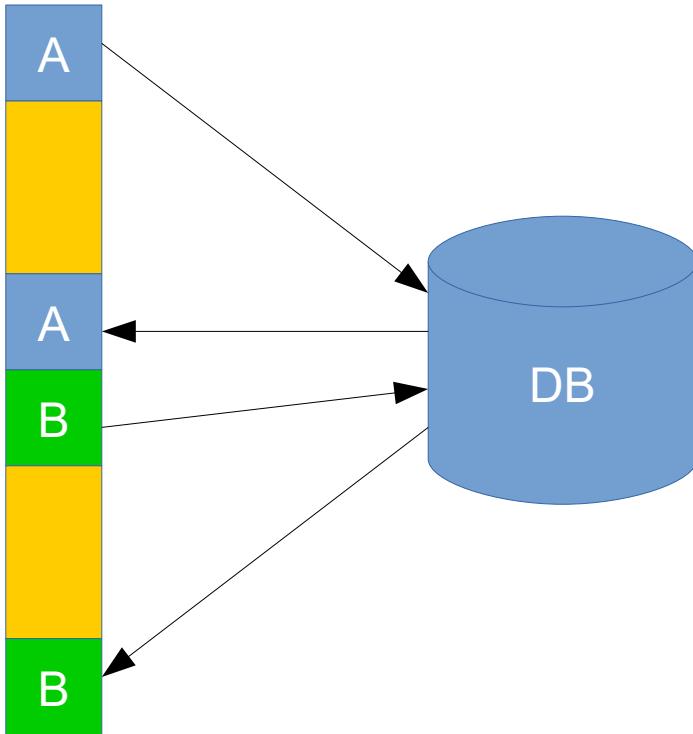


Direct Acyclic Graphs - DAG

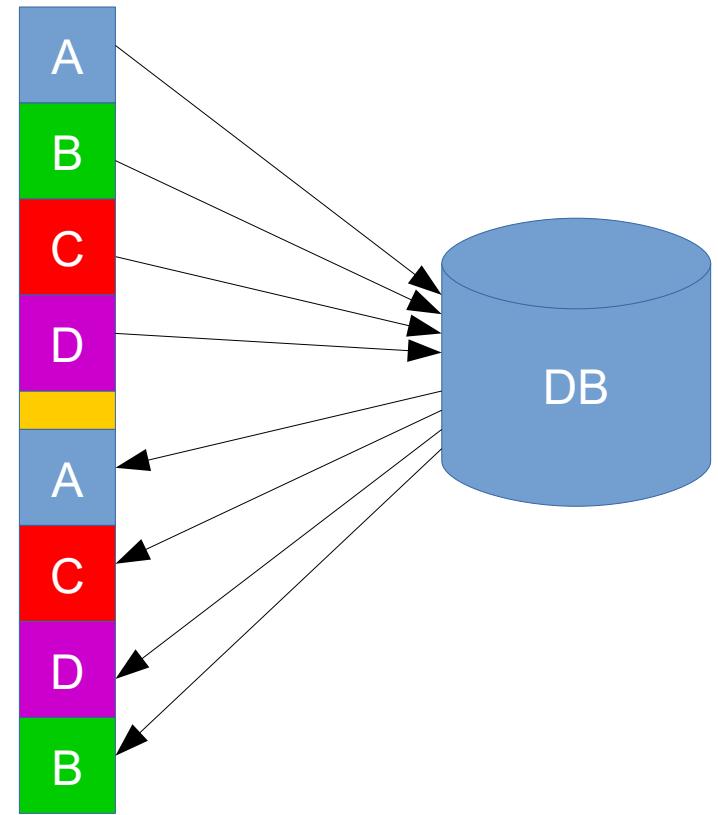


Synchronous vs. Asynchronous IO

Synchronous



Asynchronous



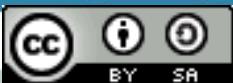
Reactive Programming

- ❖ Microsoft® opens source polyglot project **ReactiveX** (**Reactive Extensions**) [<http://reactivex.io>]:

Rx = Observables + LINQ + Schedulers :)

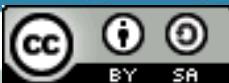
Java: RxJava, JavaScript: RxJS, C#: Rx.NET, Scala: RxScala, Clojure: RxClojure, C++: RxCpp, Ruby: Rx.rb, Python: RxPY, Groovy: RxGroovy, JRuby: RxJRuby, Kotlin: RxKotlin ...

- ❖ **Reactive Streams Specification**
[<http://www.reactive-streams.org/>] used by:
 - ❖ (Spring) Project Reactor [<http://projectreactor.io/>]
 - ❖ Actor Model – Akka (Java, Scala) [<http://akka.io/>]



Reactive Streams Spec.

- ❖ Reactive Streams – provides standard for asynchronous stream processing with non-blocking back pressure.
- ❖ Minimal set of interfaces, methods and protocols for asynchronous data streams
- ❖ April 30, 2015: has been released version 1.0.0 of Reactive Streams for the JVM (Java API, Specification, TCK and implementation examples)
- ❖ Java 9: `java.util.concurrent.Flow`



Reactive Streams Spec.

- ❖ **Publisher** – provider of potentially unbounded number of sequenced elements, according to Subscriber(s) demand.

`Publisher.subscribe(Subscriber) => onSubscribe onNext*`
`(onError | onComplete)?`

- ❖ **Subscriber** – calls `Subscription.request(long)` to receive notifications
- ❖ **Subscription** – one-to-one `Subscriber ↔ Publisher`, request data and cancel demand (allow cleanup).
- ❖ **Processor** = `Subscriber + Publisher`

FRP = Async Data Streams

- ❖ FRP is asynchronous data-flow programming using the building blocks of functional programming (e.g. map, reduce, filter) and explicitly modeling time
- ❖ Used for GUIs, robotics, and music. Example (RxJava):

`Observable.from(`

```
    new String[]{"Reactive", "Extensions", "Java"})
    .take(2).map(s -> s + " : on " + new Date())
    .subscribe(s -> System.out.println(s));
```

Result:

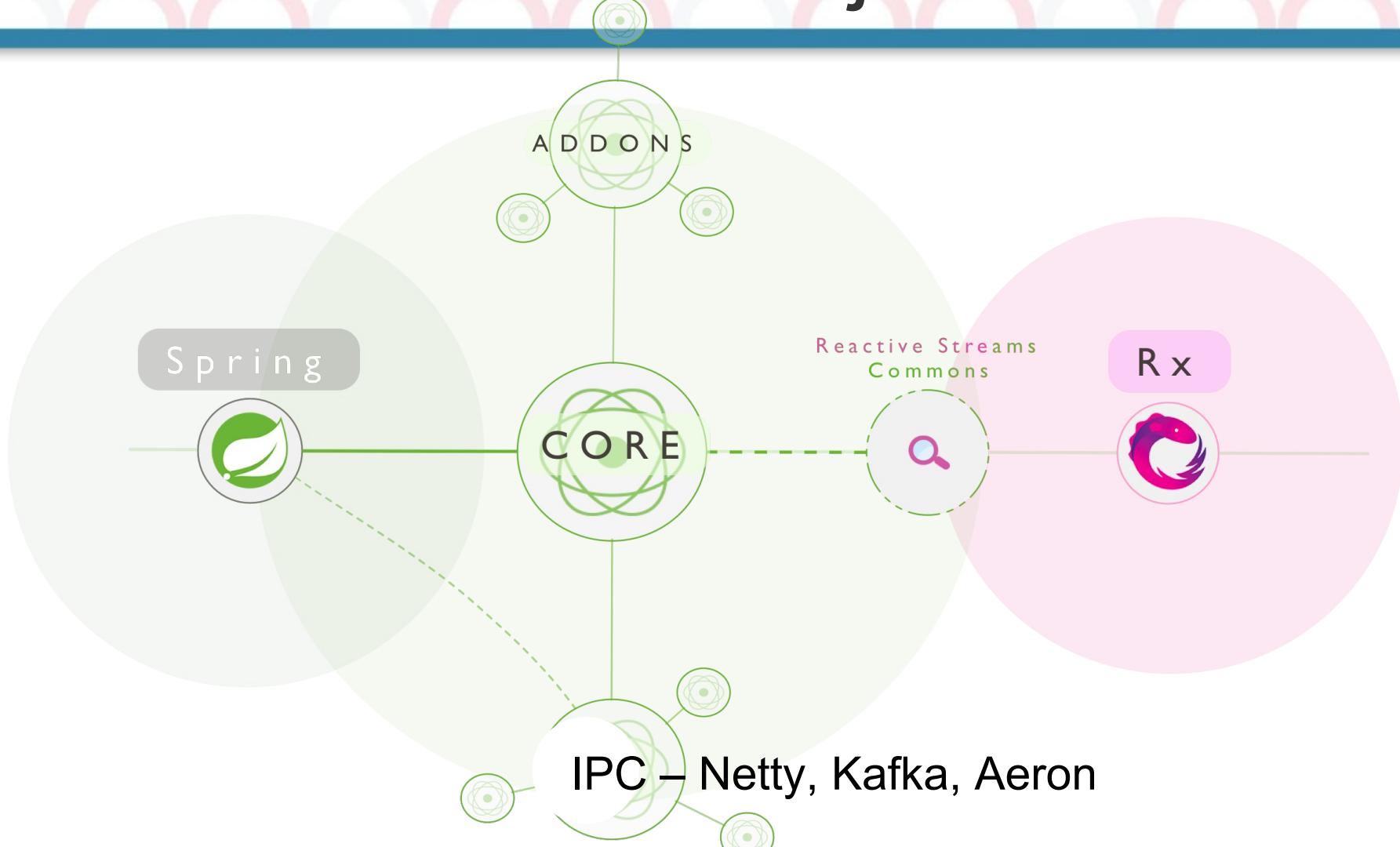
Reactive : on Wed Jun 17 21:54:02 GMT+02:00 2015

Extensions : on Wed Jun 17 21:54:02 GMT+02:00 2015

Project Reactor

- ❖ Reactor project allows building **high-performance (low latency high throughput)** non-blocking asynchronous applications on JVM.
- ❖ Reactor is designed to be extraordinarily fast and can sustain throughput rates on order of **10's of millions of operations per second**.
- ❖ Reactor has powerful API for declaring **data transformations** and **functional composition**.
- ❖ Makes use of the concept of **Mechanical Sympathy** built on top of **Disruptor / RingBuffer**.

Reactor Projects



<https://github.com/reactor/reactor>, Apache Software License 2.0



Reactor Flux

This is the timeline of the Flux. Time flows from left to right.

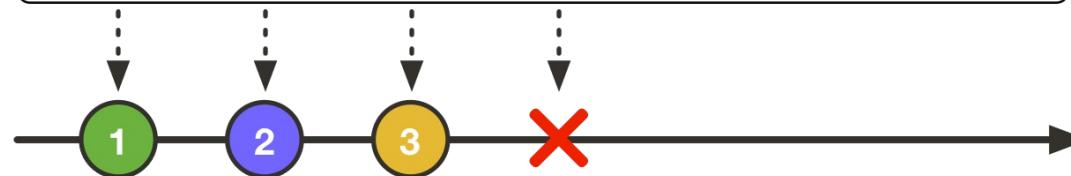
These are items emitted by the Flux.

This vertical line indicates that the Flux has completed successfully.



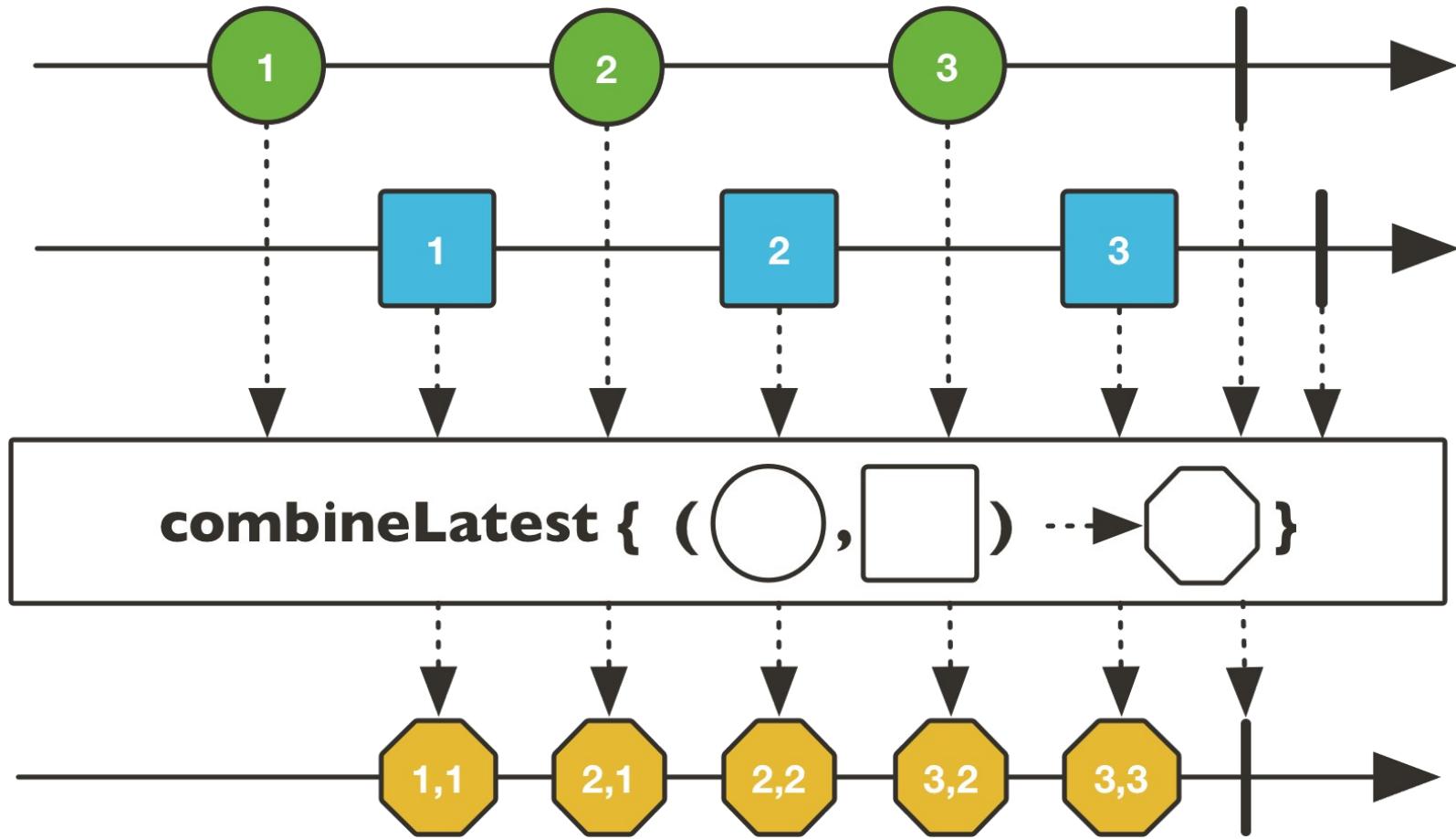
This Flux is the result of the transformation.

These dotted lines and this box indicate that a transformation is being applied to the Flux. The text inside the box shows the nature of the transformation.

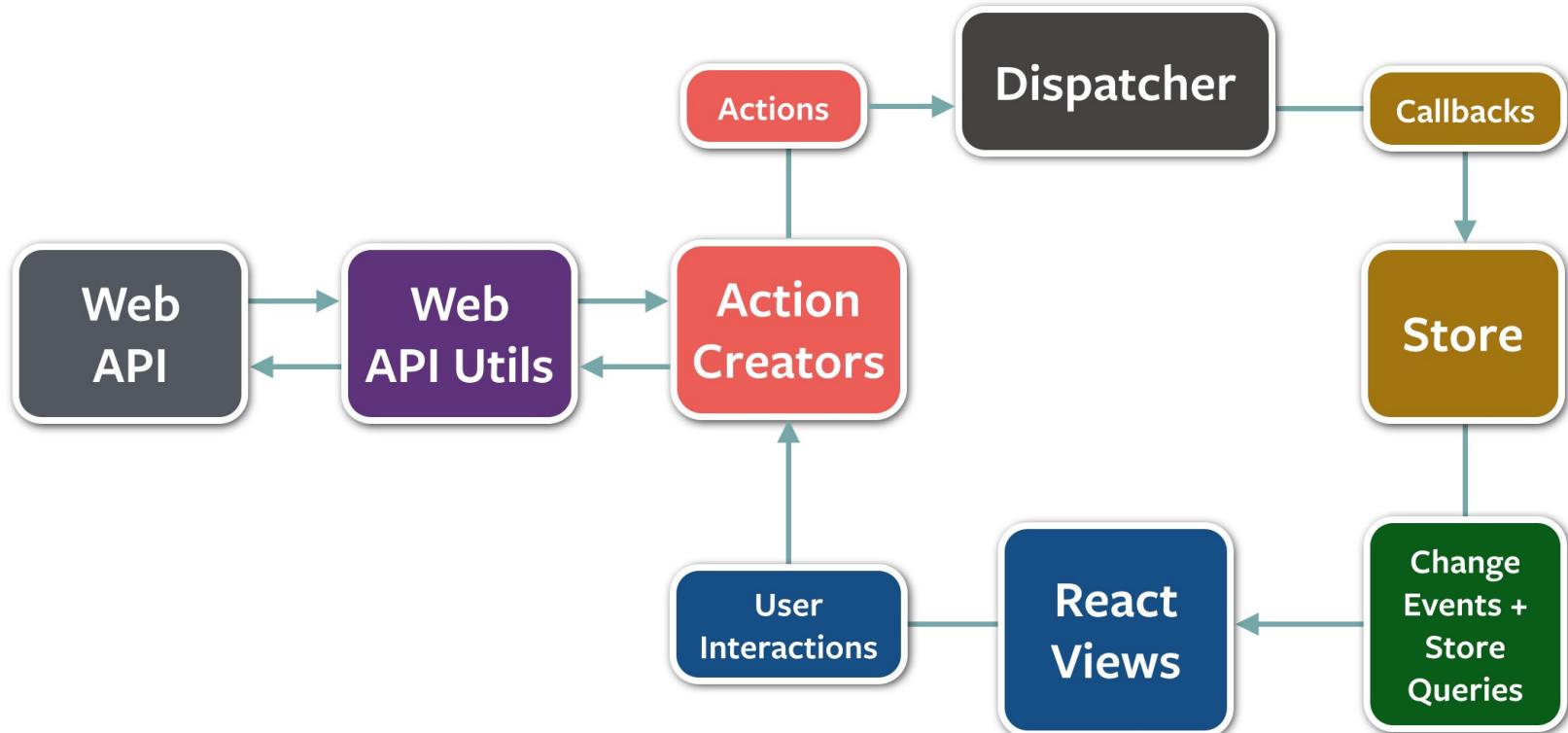


If for some reason the Flux terminates abnormally, with an error, the vertical line is replaced by an X.

Example: Flux.combineLatest()

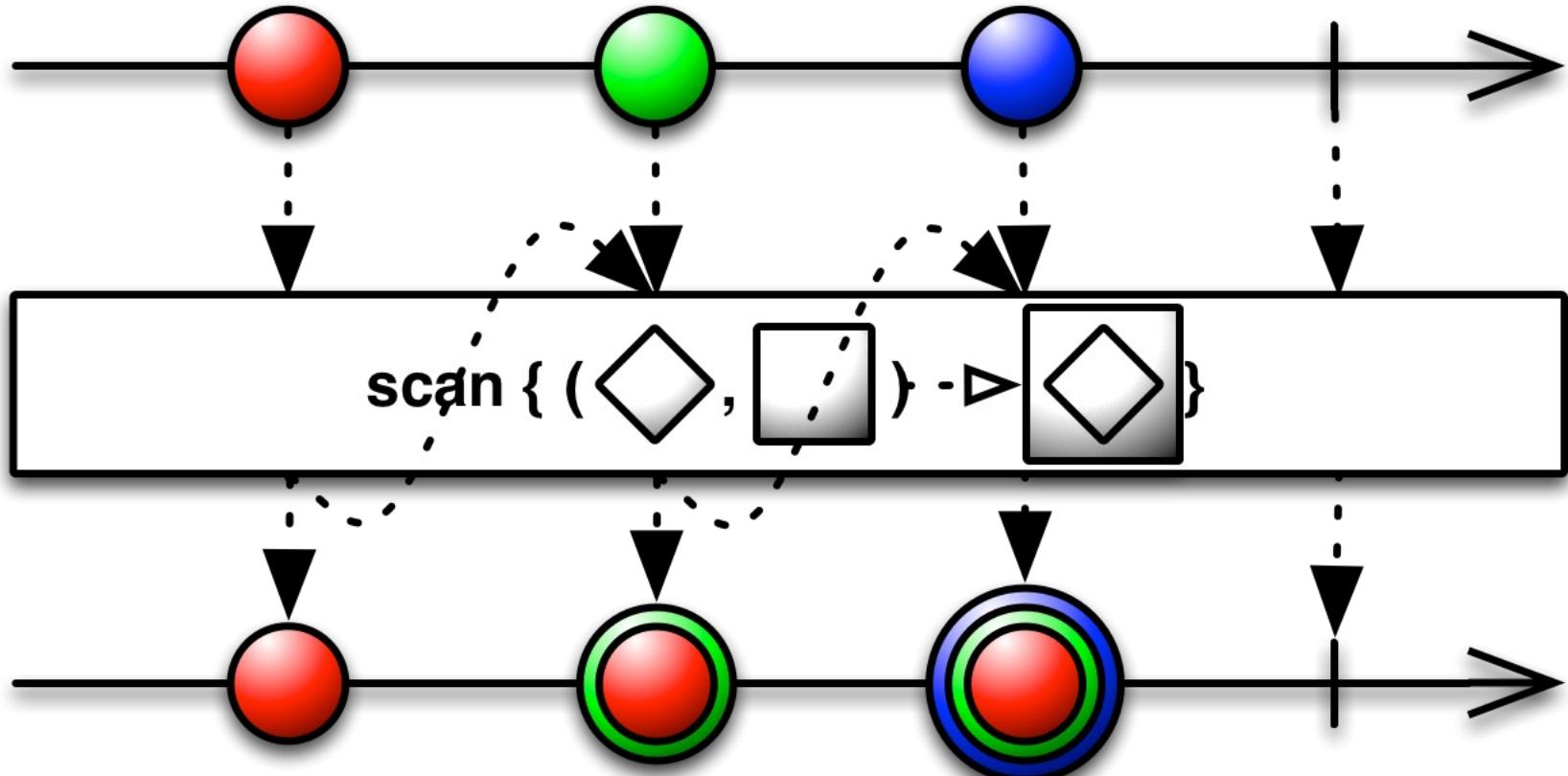


Flux & Redux Design Patterns



Source: Flux in GitHub, <https://github.com/facebook/flux>, License: BSD 3-clause "New" License

Redux == Rx Scan Operator



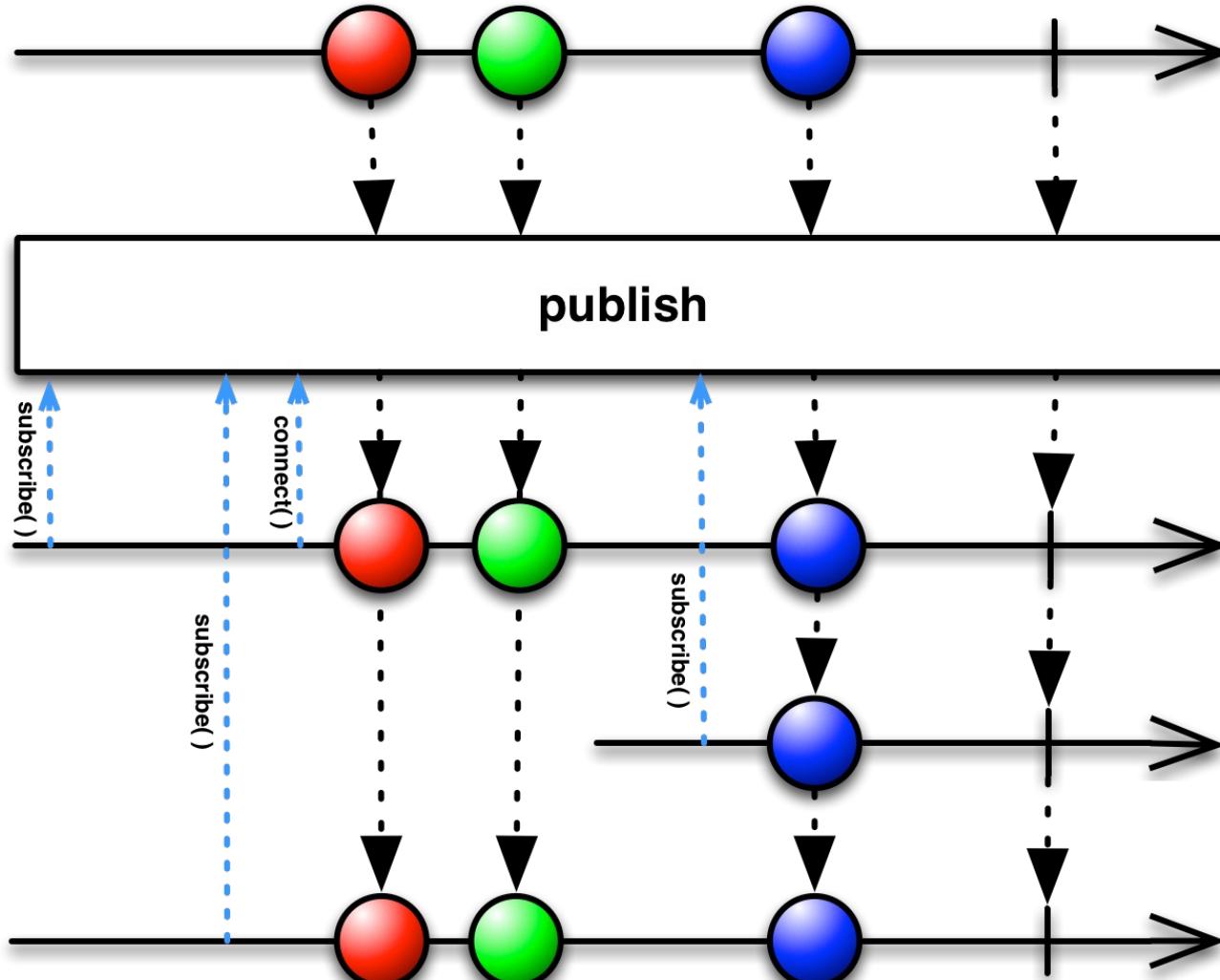
Source: RxJava 2 API documentation, <http://reactivex.io/RxJava/2.x/javadoc/>

Hot and Cold Event Streams

- ❖ **PULL-based (Cold Event Streams)** – Cold streams (e.g. RxJava Observable / Flowable or Reactor Flow / Mono) are streams that run their sequence when and if they are subscribed to. They present the sequence from the start to each subscriber.
- ❖ **PUSH-based (Hot Event Streams)** – emit values independent of individual subscriptions. They have their own timeline and events occur whether someone is listening or not. When subscription is made observer receives current events as they happen.

Example: mouse events

Converting Cold to Hot Stream



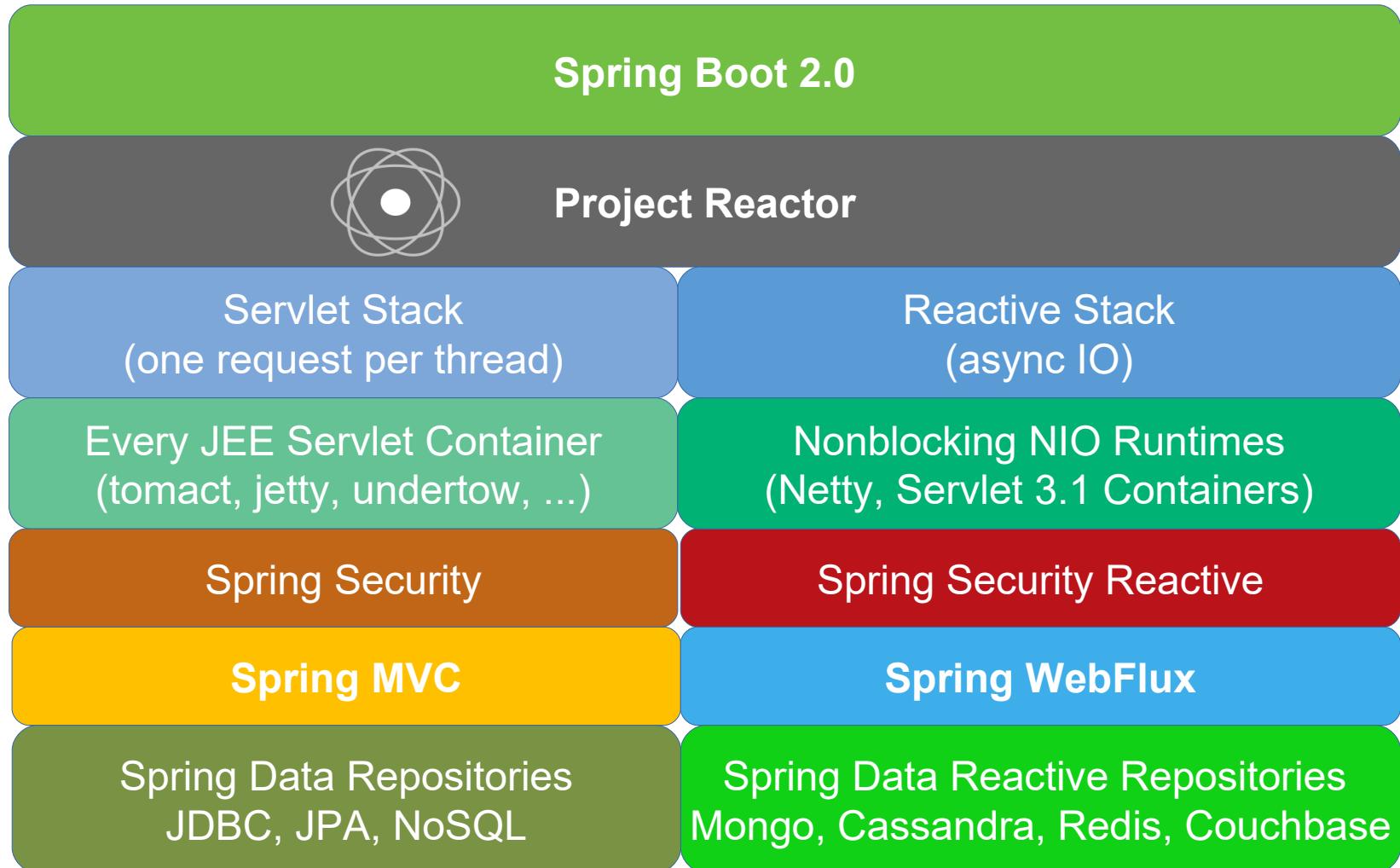
Hot Stream Example - Reactor

```
EmitterProcessor<String> emitter =  
    EmitterProcessor.create();  
FluxSink<String> sink = emitter.sink();  
emitter.publishOn(Schedulers.single())  
    .map(String::toUpperCase)  
    .filter(s -> s.startsWith("HELLO"))  
    .delayElements(Duration.of(1000, MILLIS))  
    .subscribe(System.out::println);  
sink.next("Hello World!"); // emit - non blocking  
sink.next("Goodbye World!");  
sink.next("Hello Trayan!");  
Thread.sleep(3000);
```

Top New Features in Spring 5

- ❖ Reactive Programming Model
- ❖ Spring Web Flux
- ❖ Reactive DB repositories & integrations + hot event streaming: MongoDB, CouchDB, Redis, Cassandra, Kafka
- ❖ JDK 8+ and Java EE 7+ baseline
- ❖ Testing improvements – WebTestClient (based on reactive WebFlux WebClient)
- ❖ Kotlin functional DSL

Spring 5 Main Building Blocks

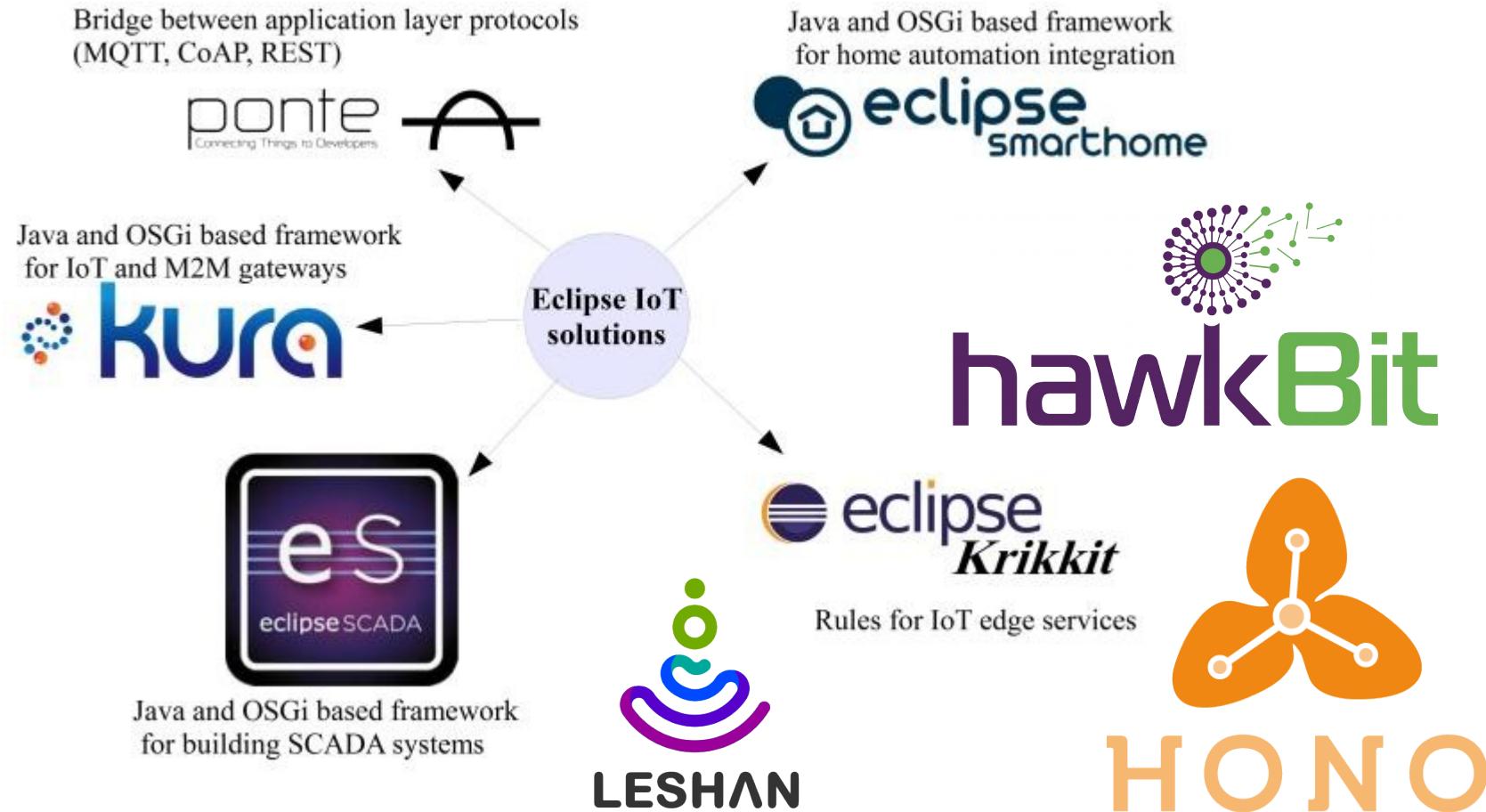


WebFlux: Best Explained in Code

Lets see REST service **Spring 5 WebFlux** demos. Available @GitHub:

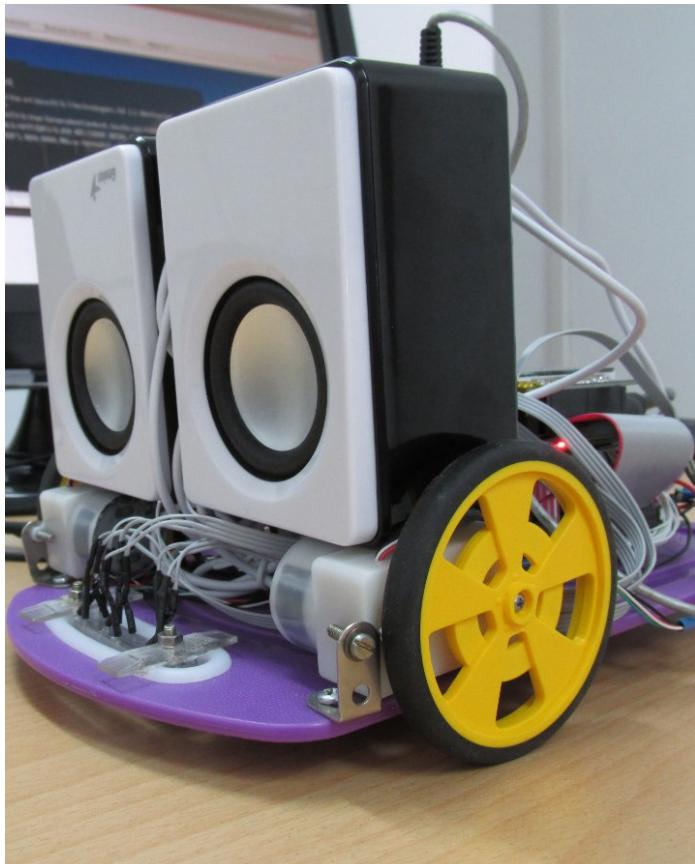
<https://github.com/iproduct/spring-5-webflux>

Eclipse IoT Platform



Based on: https://www.researchgate.net/publication/279177017_Internet_of_Things_A_Survey_on_Enabling_Technologies_Proocols_and_Applications, By Ala Al-Fuqaha et al. - Internet of Things: A Survey on Enabling Technologies, Protocols and Applications

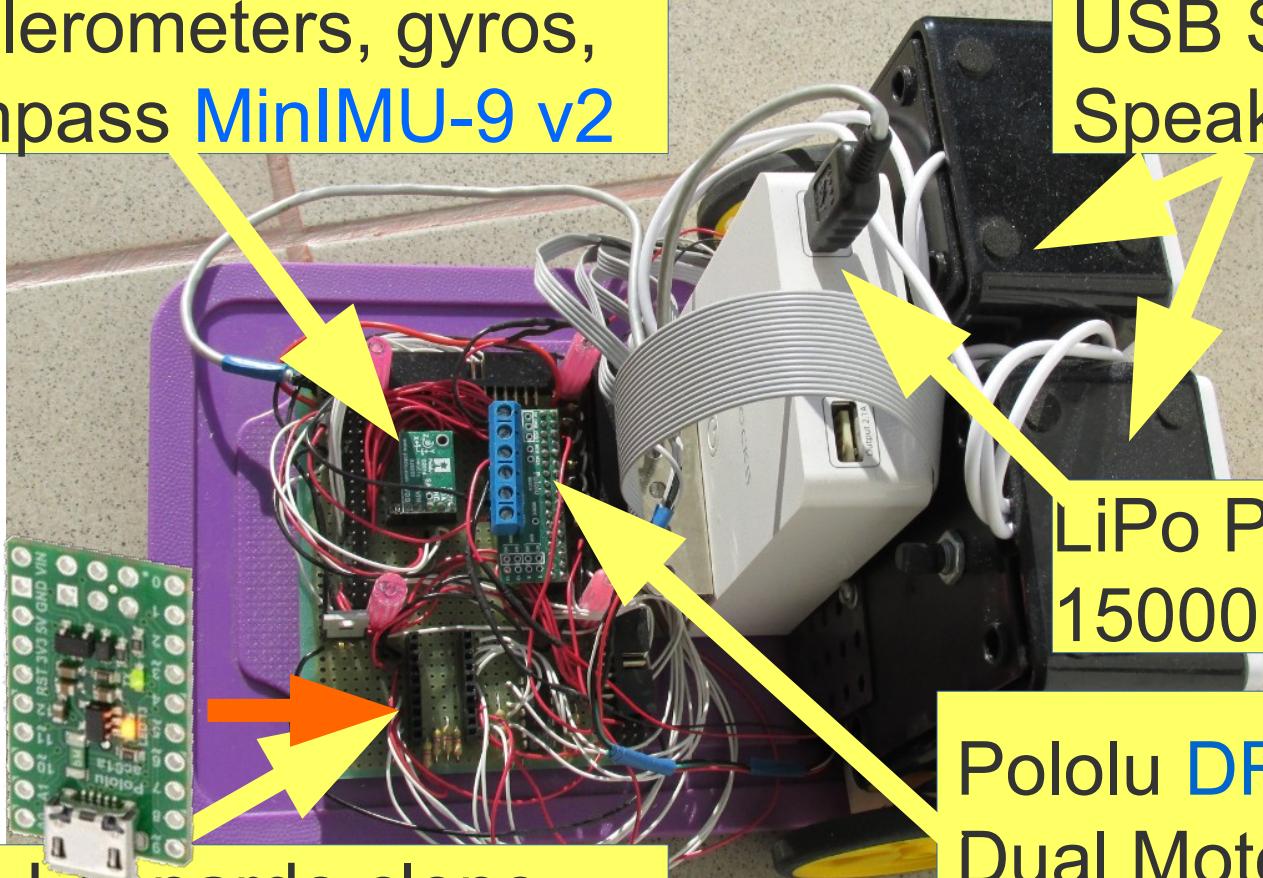
IPTPI: RPi2 + Arduunio Robot



- ❖ Raspberry Pi 2 (quad-core ARMv7 @ 900MHz) + Arduino Leonardo clone **A-Star 32U4 Micro**
- ❖ *Optical encoders* (custom), IR optical array, 3D accelerometers, gyros, and compass **MinIMU-9 v2**
- ❖ **IPTPI** is programmed in Java using **Pi4J**, **Reactor**, **RxJava**, **Akka**
- ❖ More information about IPTPI:
<http://robolearn.org/iptpi-robot/>

IPTPI: RPi2 + Arduinio Robot

3D accelerometers, gyros,
and compass [MinIMU-9 v2](#)



Arduino Leonardo clone
[A-Star 32U4 Micro](#)

USB Stereo
Speakers - 5V

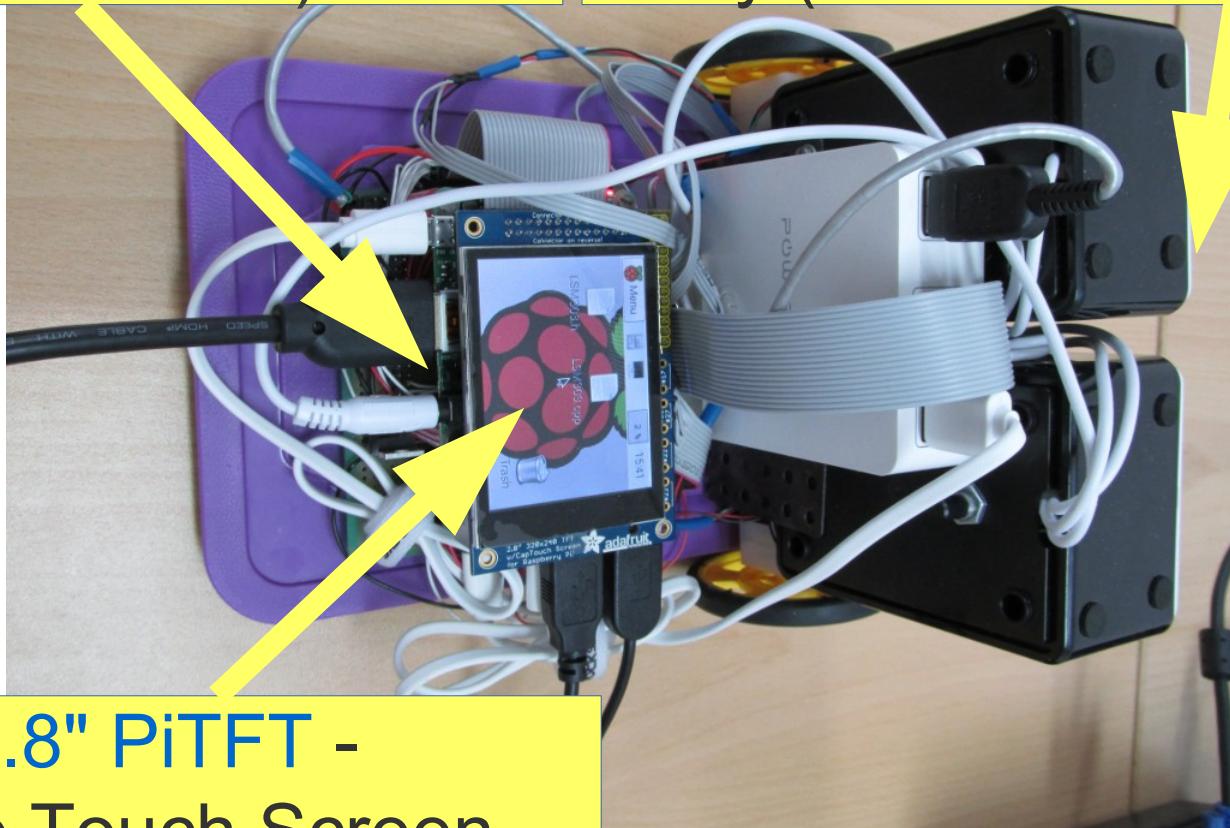
LiPo Powebank
15000 mAh

Pololu [DRV8835](#)
Dual Motor Driver
for Raspberry Pi

IPTPI: RPi2 + Arduunio Robot

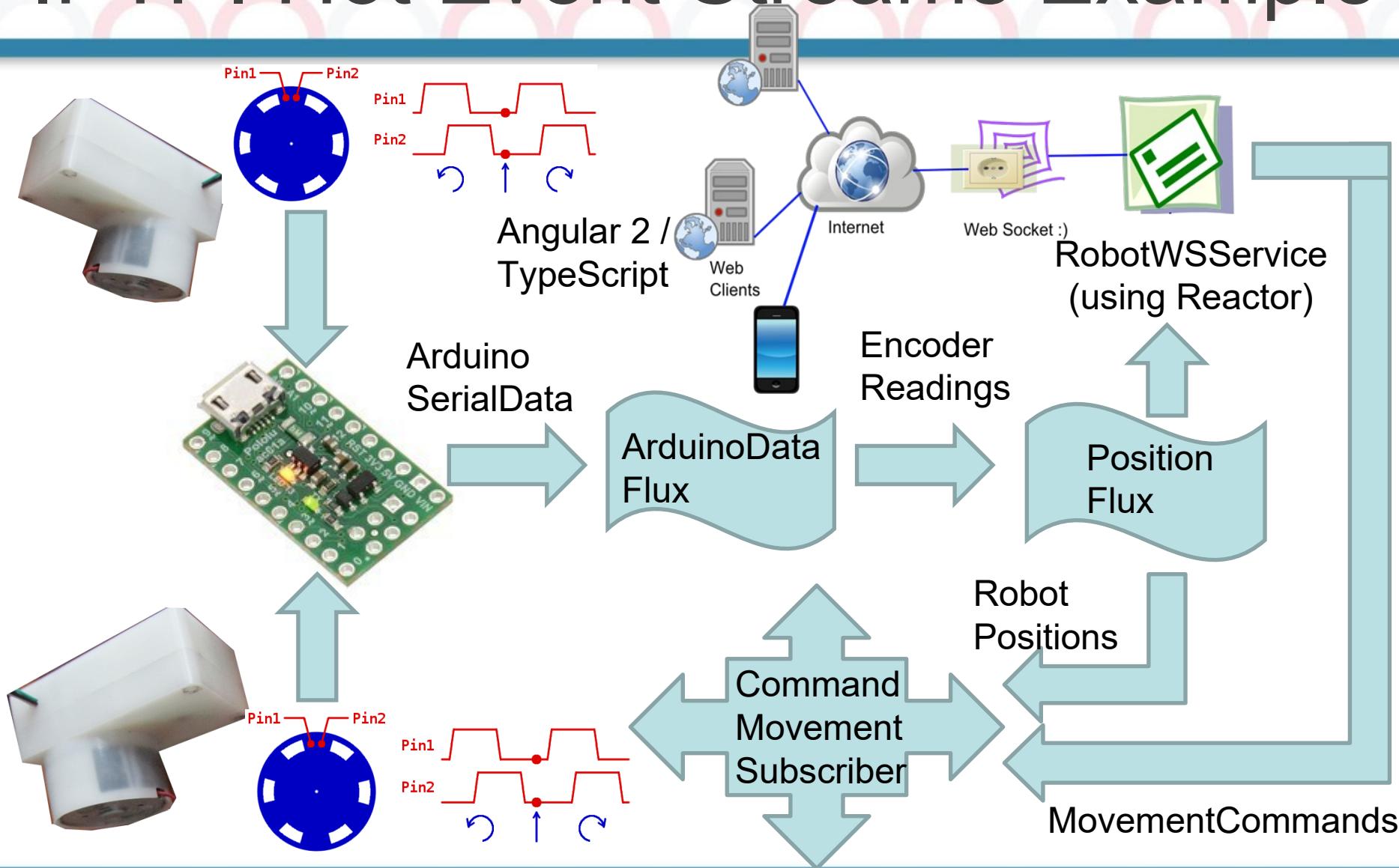
Raspberry Pi 2 (quad-core
ARMv7 @ 900MHz)

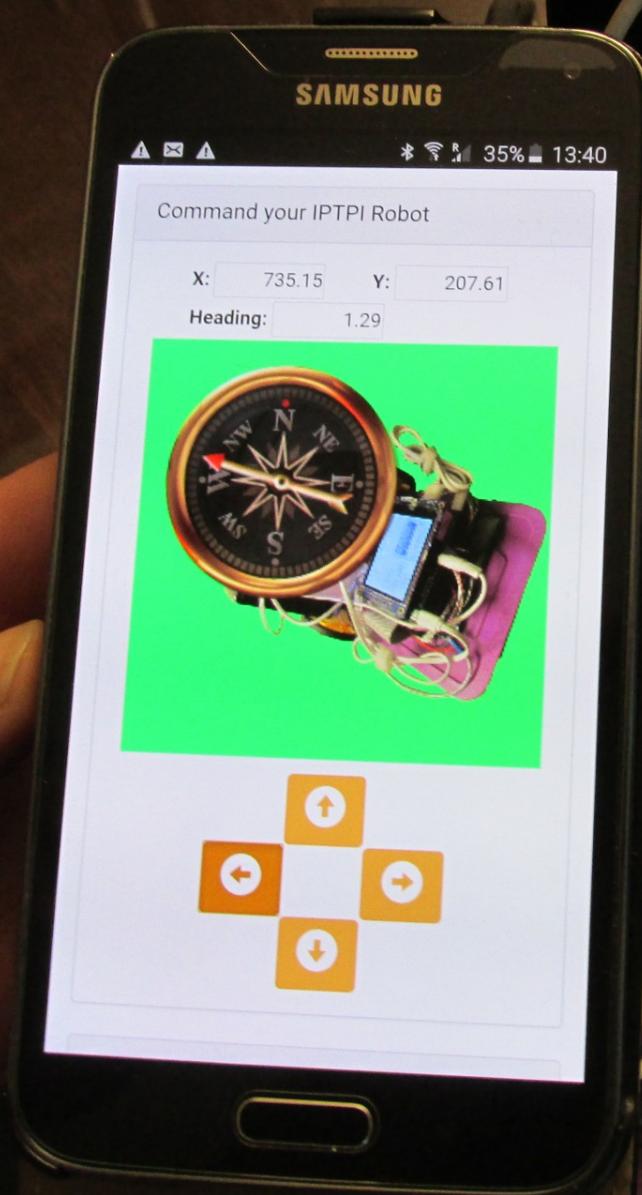
IR Optical Sensor QRD1114
Array (Line Following)



Adafruit 2.8" PiTFT -
Capacitive Touch Screen

IPTPI Hot Event Streams Example



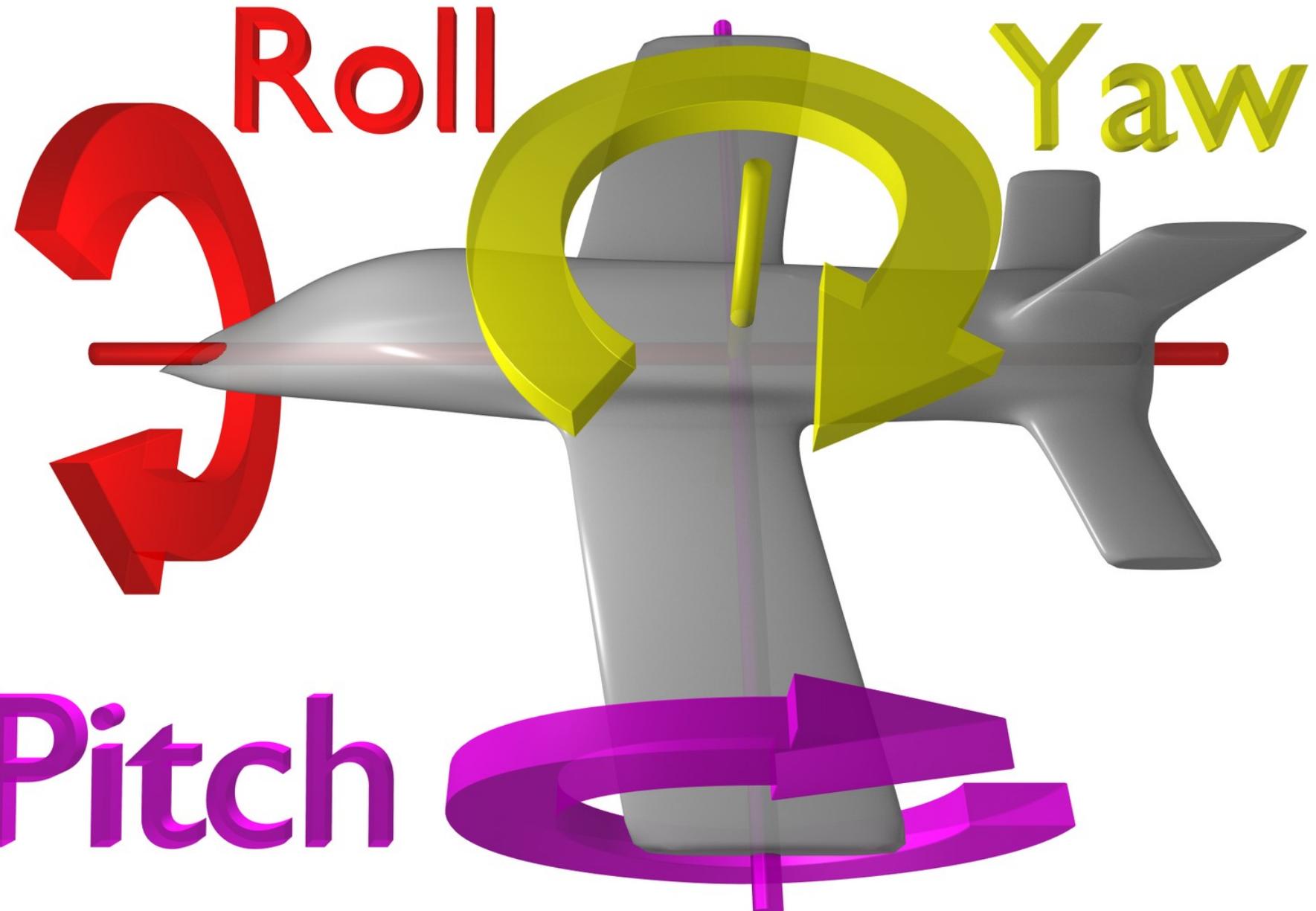




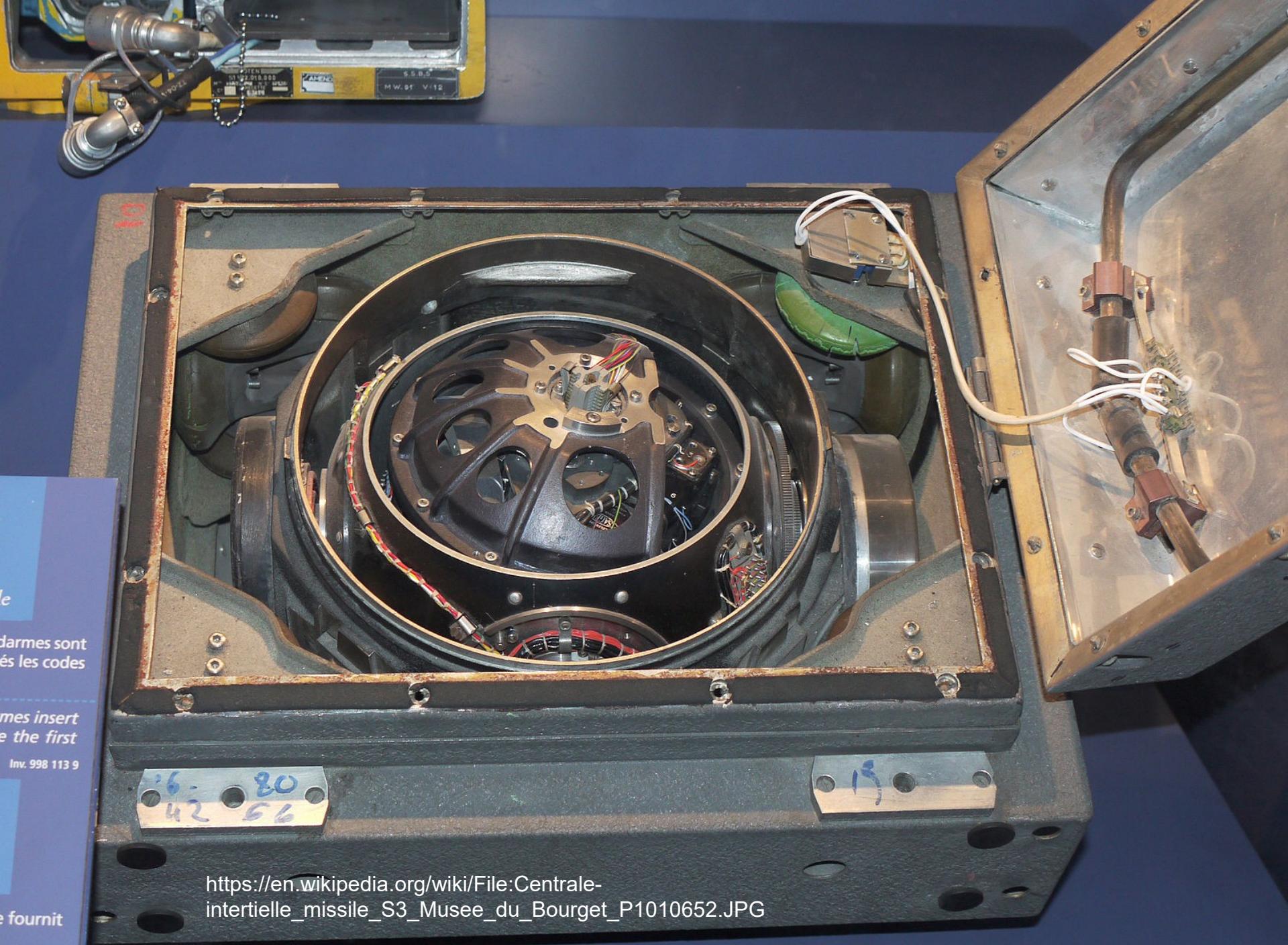
LeJaRo: Lego® Java Robot

- ❖ Modular – 3 *motors (with encoders)* – one driving each track, and third for robot clamp.
- ❖ Three sensors: *touch sensor* (obstacle avoidance), *light color sensor* (follow line), *IR sensor* (remote).
- ❖ LeJaRo is programmed in Java using **LeJOS** library.
- ❖ More information about LeJaRo:
<http://robolearn.org/lejaro/>
- ❖ Programming examples available @GitHub:
https://github.com/iproduct/course-social-robotics/tree/master/motors_demo



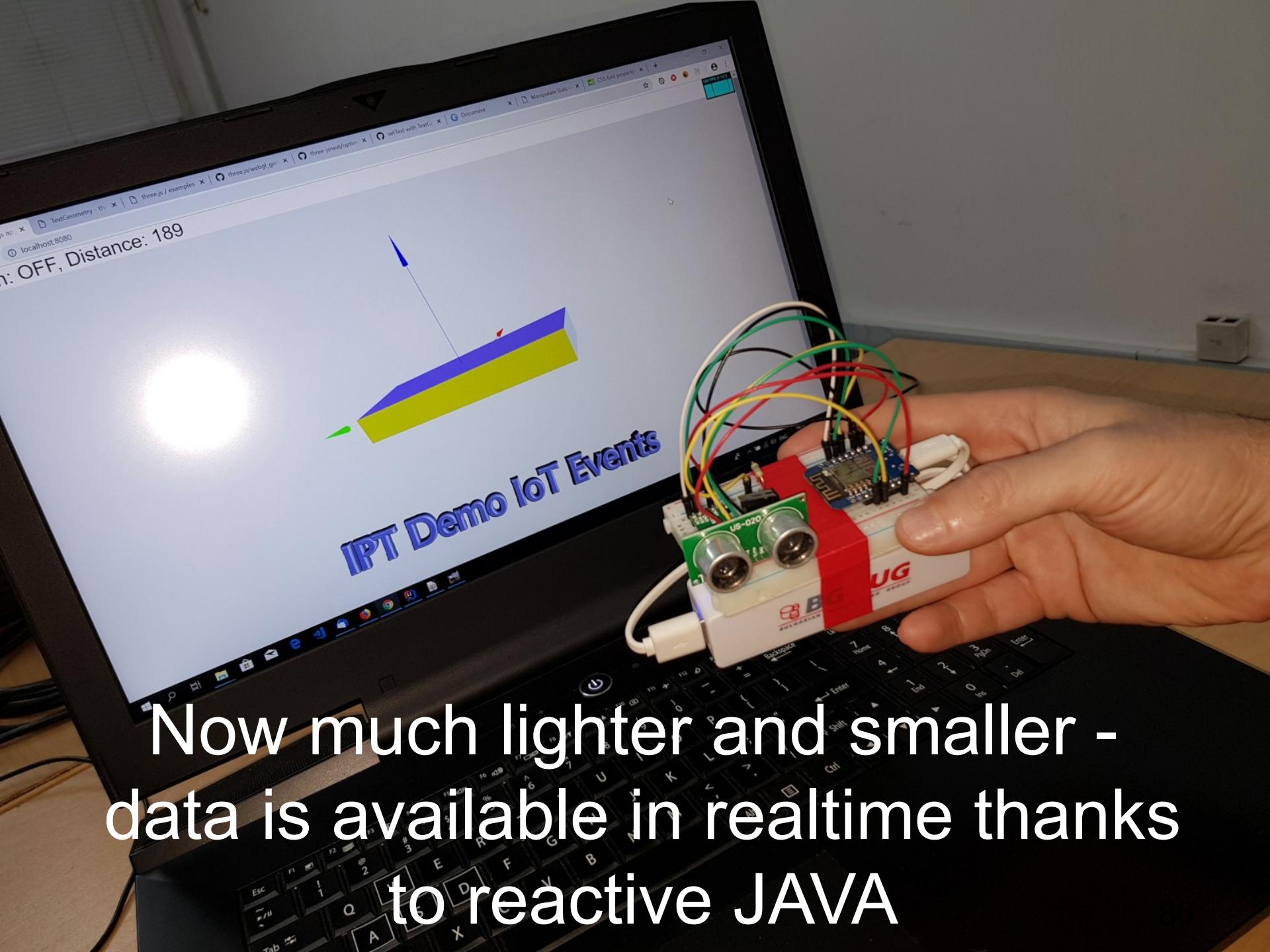


https://en.wikipedia.org/wiki/File:Flight_dynamics_with_text.png



https://en.wikipedia.org/wiki/File:Centrale-intelligente_missile_S3_Musee_du_Bourget_P1010652.JPG

Now much lighter and smaller -
data is available in realtime thanks
to reactive JAVA



Demo Code

Reactive Java Robotics and IoT with Reactor,
RxJS, Angular 2 Demos are available @
GitHub:

<https://github.com/iproduct/course-social-robotics>

Thank's for Your Attention!



Trayan Iliev

CEO of IPT – Intellectual Products
& Technologies

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