ECLIPSE PAX

A NEW PROGRAMMING LANGUAGE FOR THE EMBEDDED IOT

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Eclipse PAX
Shock detector example

- We want to detect a shock (i.e. device being dropped) and send a BLE notification
  - Reset on button press
  - Use LEDs to show device is running


```
setup smartphone : BLE {
    deviceName = "ShockDetector";

    var shockDetected = bool_characteristic(UUID=0xCAFE);
}

setup hmi : LED {
    var deviceRunning = light_up(color=Red);
}


every 100 milliseconds {
    if(accelerometer.magnitude > 5000) {
        smartphone.shockDetected = true;
    }
}

every button_one.pressed {
    smartphone.shockDetected = false;
}
```

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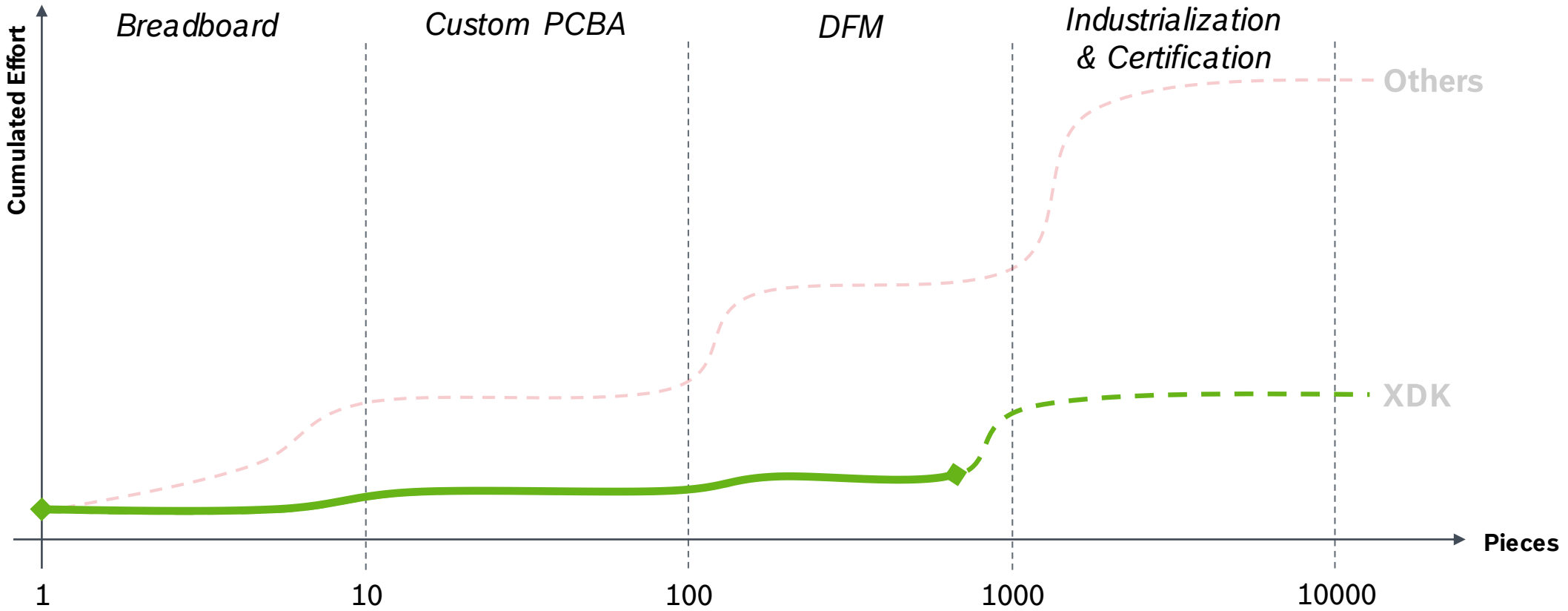
Scaling over quantity demands flexibility and control



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We need a way to program that

Lowers barriers

- Familiar and easy to learn
- "Feels" good
  → user centred design
- Convenience matters
  → high abstraction
- Doesn't annoy power users
  → high ceiling
- Enable IoT development for new user groups

Scales to production

- Afford a lot of control → go really low level
- Based on proven infrastructure
  (LLVM on bare metal, e.g. Rust + Zinc or Taylor Swift are still years out)
- Enable trust in software → allow inspection in a world people know

Scales to low-power HW

- Very low runtime impact
- No garbage collection
- Preference for static memory allocation

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What about existing languages

LUA

+ LUA is widely adopted
+ Integration of C codebase is straight forward
+ Common choice for embedding

- Incurs performance penalty
- We would move away from production code

Python

+ Python is widely adopted
+ MicroPython offers a small Open Source Python 3 implementation

- Incurs a runtime performance penalty
- We would move away from production code
- Written for STM32M4F only

mRuby

+ Ruby is widely adopted
+ mRuby is a project by Matz to bring Ruby to the embedded world
+ Initial effort to compile was low

- Incurs a runtime performance penalty
- We would move away from production code
- The mRuby binary is ~ 1mb → very large for embedded

Javascript

+ Javascript is widely adopted
+ Seems to be perceived as an attractive language
+ 300kB large embedded JS implementation available (Duktape)

- Consumes a lot of RAM → severely limits practicability
- Integration is unclear (load programs from SD card, how?)
- We would move away from production code

Widespread adoption but
expensive at runtime and far removed the system

Eclipse PAX

What about existing languages and platforms

Rust

+ Code can be compiled and executed on the XDK
+ Interaction with existing C codebase is fairly straight forward
+ Little runtime performance penalty as Rust is a system-level language

Far away from being production ready on bare metal

- Rust on bare-metal MCU's is not production ready yet
- Compilation process is anything but straight forward
- Rust is not too widely adopted yet

C++

+ Code can be compiled and executed on the XDK
+ Interaction with existing C codebase is fairly straight forward
+ Widespread adoption

Incredibly high "accidental complexity"

- Incurs a runtime higher* performance penalty (dynamic dispatch)
- Runtime memory allocation makes behaviour harder to predict
- Very powerful language features introduce a lot of complexity

Arduino

+ Very widespread adoption
+ Offers an easy API and plenty of learning resources
+ API has been ported to other non-official HW before

Based on C++ / removed from other industry-grade platforms

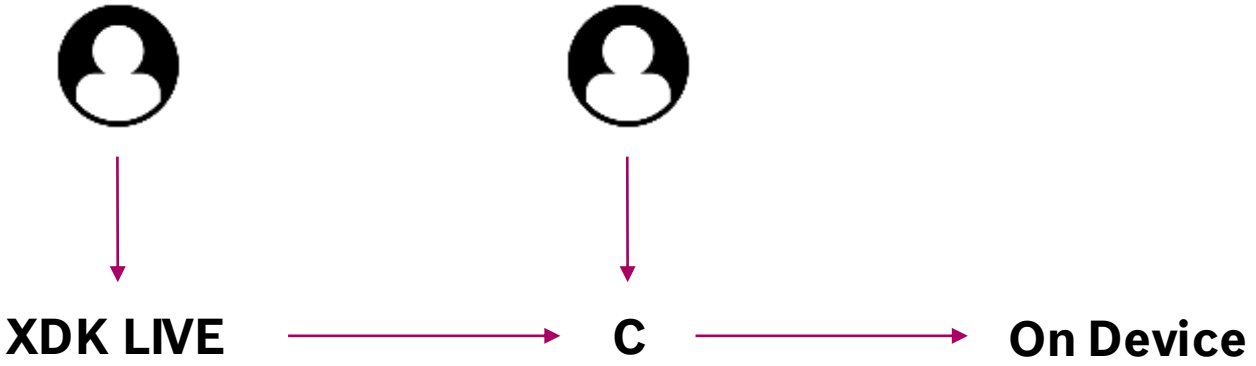
- Build process is very hard to control
- IDE does (intentionally) little to support beginners
- Wiring is based on C++
- Low ceiling

mbed OS

+ Backed by ARM and chip manufacturers
+ Offers convenient API in an online IDE
+ Designed for portability

- Based on C++
- Integration with other platforms is hard

Eclipse PAX
Transpiles to C



Eclipse PAX

Base Language

- Imperative
  with future aspirations for functional elements
- Event driven
- Exceptions
  try/catch instead of return
- Extension methods
  provide OO feeling
- String interpolation
  built into the language

Type System

- Statically typed
  with generics and optional types
- Type inference
- Generic Types
- Static Heapless Memory Management
  through Data Structure Size Inference

Model-Driven

- Declarative Setup
  of platform-defined system resources
- Direct Access to System Resources
  such as sensors, connectivity and GPIO
- Generic Extensible Platform Support
  not specific to XDK
- Built-in Library Mgmt

Transpiler

- Transpiles to C code
- Traceability between XDK LIVE and C code
  (thanks to Xtext > 2.12)
- Variable names, function names and comments are carried over

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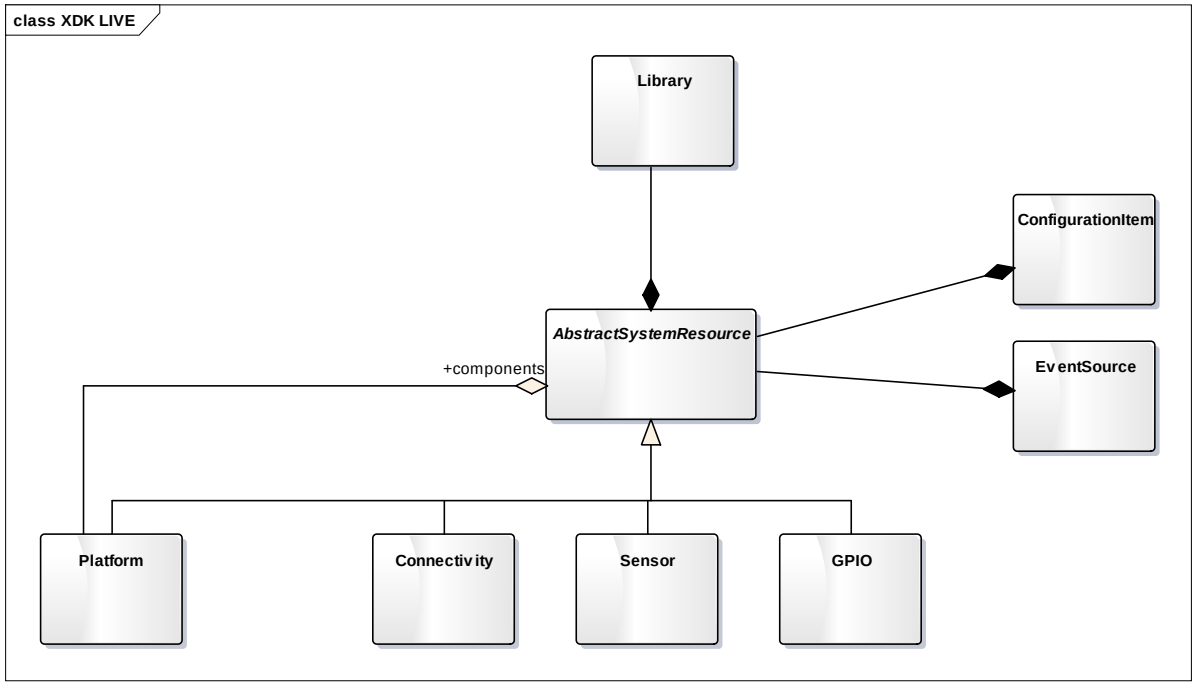
Eclipse PAX
Declarative Setup

- We need to configure the system we run on
  - Sensors, Connectivity and GPIO
- All of those define “configuration items”
  - Accelerometer Range
  - Bluetooth Advertising Interval
  - SPI clock speed
- All of those can offer events
  - Accelerometer Activity
  - Bluetooth Connection Incoming
  - SPI Slave Message Received



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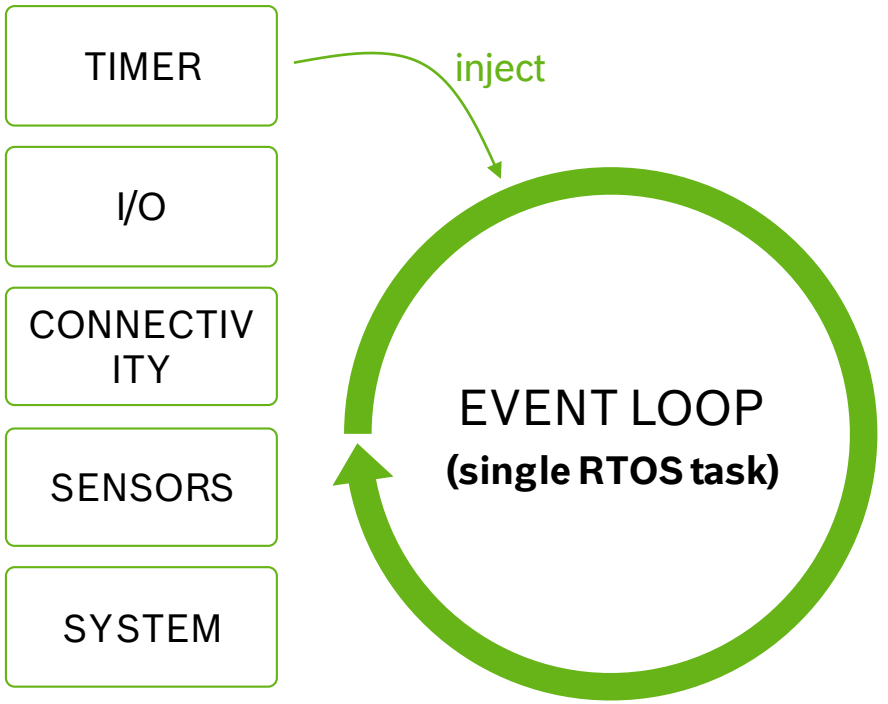
Event Driven

```
every system.startup {
    // system just started
}

every 100 milliseconds {
    // TODO: do something every 100ms
}

every accelerometer.activity {
    // our device was just moved
}
```



ECLIPSE PAX

Is a new programming language for the embedded IoT

Enables high-level features transpiled to C

Is not limited to the XDK

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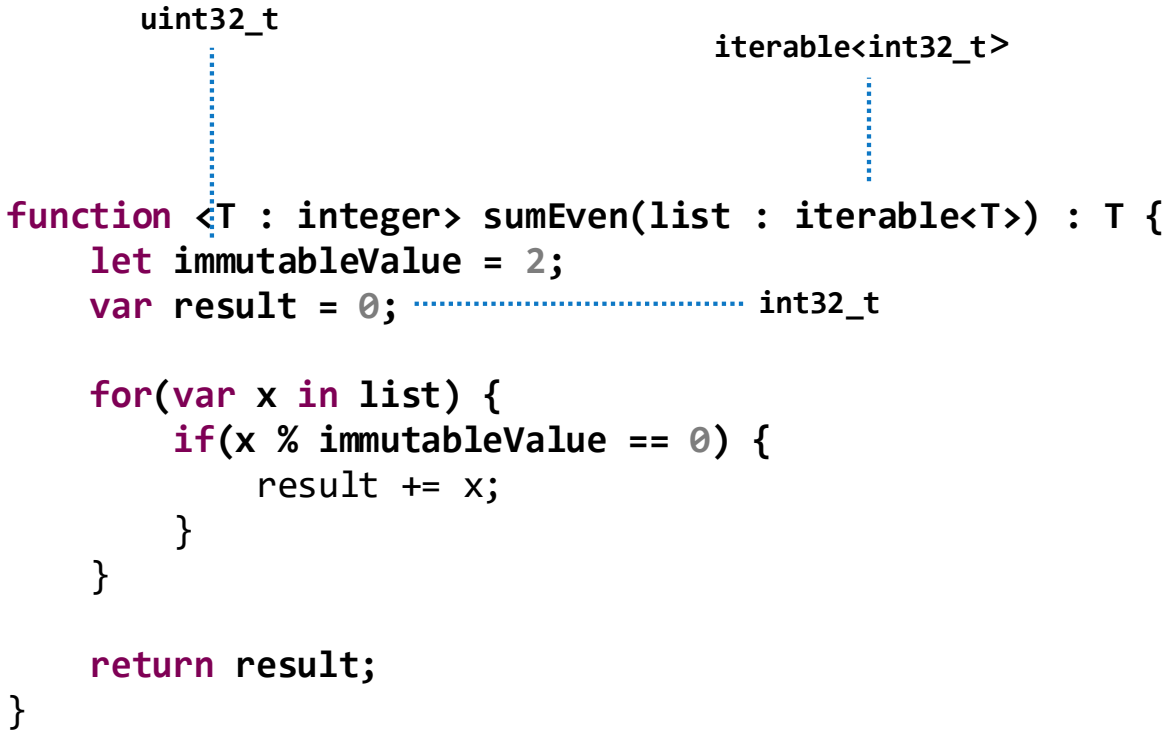
Eclipse PAX
Imperative and Statically Typed



- Language design inspired to TypeScript, Swift, Rust, Scala
- Supports all classic control structures
- Immutable and mutable variables
- Static typing → all expressions have a type at compile time
  - Generics are supported for types and functions

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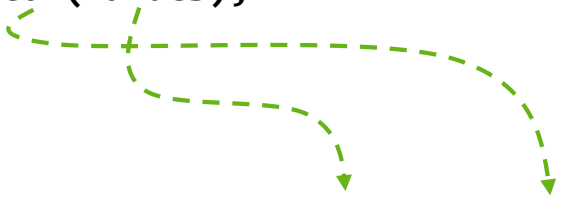
Extension Methods

```
function mean(self : iterable<float>) : float {
    var result = 0.0;
    for(var x in self) {
        result += x;
    }
    return self.sum() / self.length();
}

let values = [0.0, 1.0, 2.0, 3.0];
var meanValueA = mean(values);
```



```
var meanValueB = values.mean();
```

- First parameter can be written on left side during function invocation
- Provides an “object oriented feeling”
  - It helps that functions are polymorphic
  - Very similar to Eclipse Xtend
- Standard library is implemented this way

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Declarative Setup of Sensors

All setup starts with the **`setup`** keyword

Followed by the resource we want to configure

```
setup accelerometer {
    range = Range_8g;
    activity_threshold = 200;
}
```

Sensors offer platform-defined *configuration* items

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Declarative Setup of Connectivity

Connectivity (and GPIO) can be named

```
setup devNetwork : WLAN {
    ssid = "BCDS_DevNet";
    psk = "MySuperSecretPassword";
}
```

Setup connectivity become global variables and can be referenced

```
setup backend : LWM2M {
    transport = devNetwork;
    server = “10.0.0.1”;

    var shockDetected =
        property(url="/1/2", init=false);
}
```

Variable Configuration Items (VCI) configure things like LWM2M properties, BLE characteristics, REST APIs or GPIO pins

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Declarative Setup of GPIO

Every system resource has their own VCI

```
setup gpio {
    var externalLed = digitalOut(pin=A4, driveStrength=High);
    var battery = analogIn(pin=B2);
}

setup mySensor : I2C {
    sda = Pins.A1;
    scl = Pins.A2;

    var creg1 = register(address=0x0A, init=0x00 as uint16_t);
    var value = register(address=0xAB, init=0x00 as uint32_t);
}
```

I2C registers mapping, including data type

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Direct Access

Access sensor values as if they were variables

```
every 100 milliseconds {
    if(accelerometer.magnitude > 5000) {
        // TODO: do something
    }
}
```