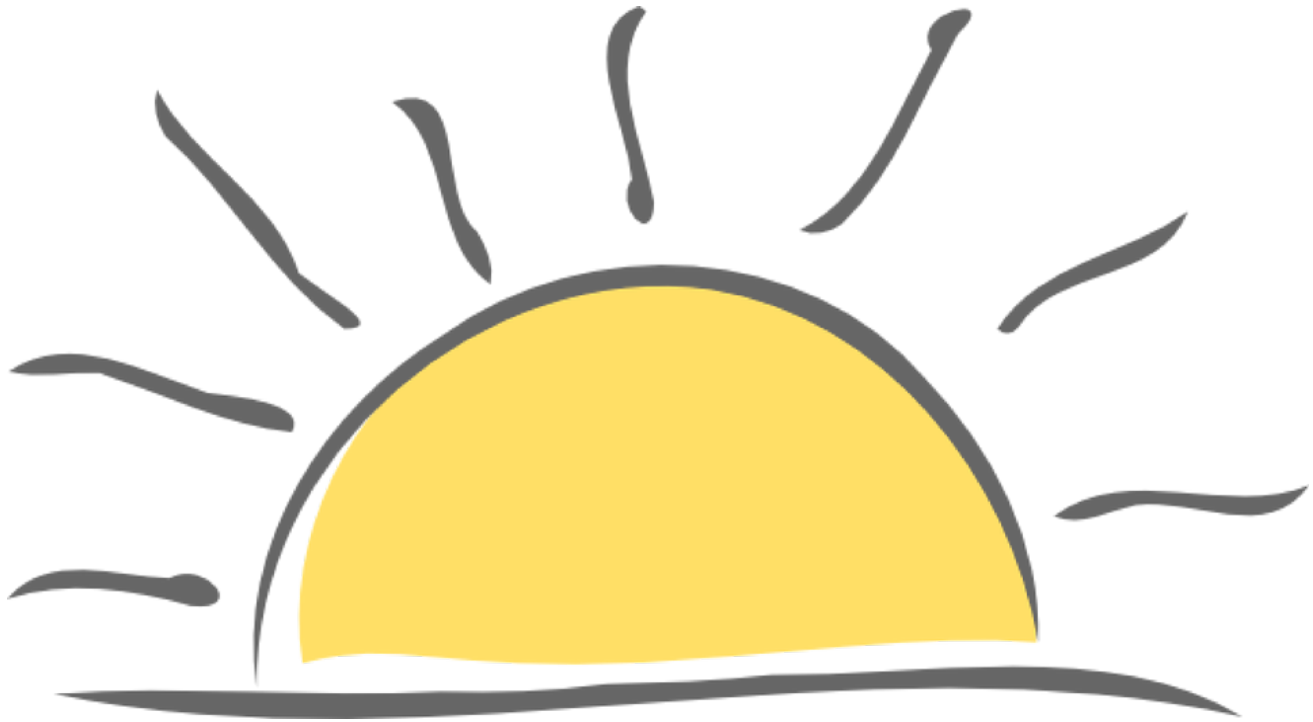
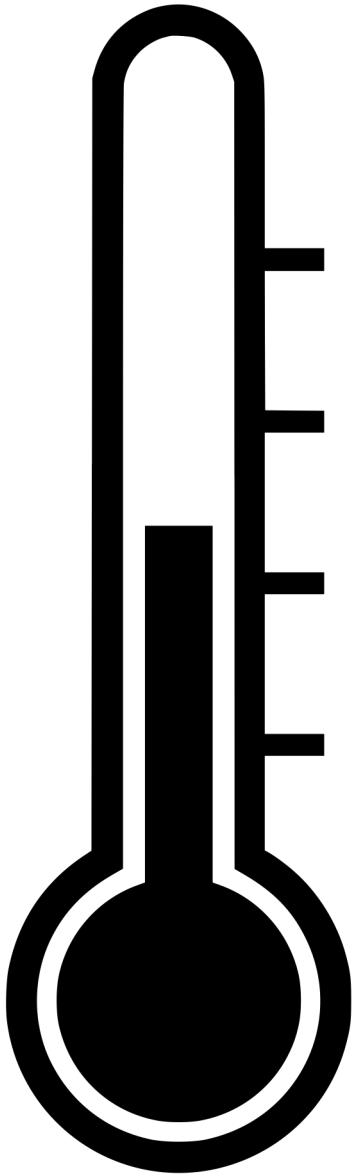
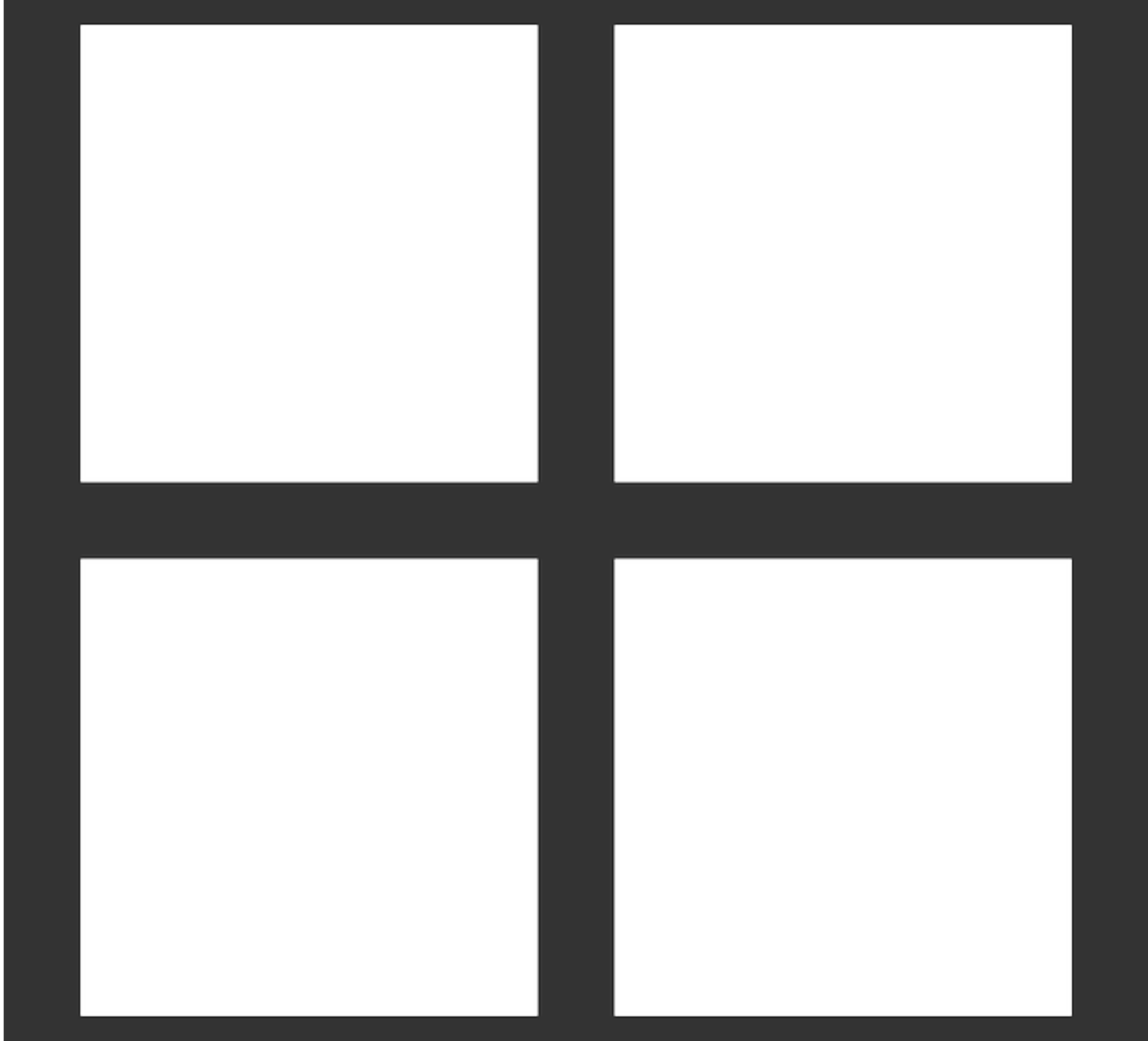
2019



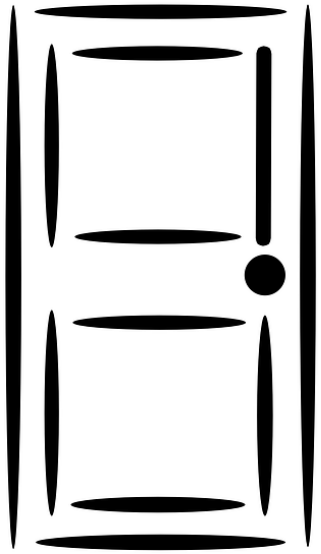
32°



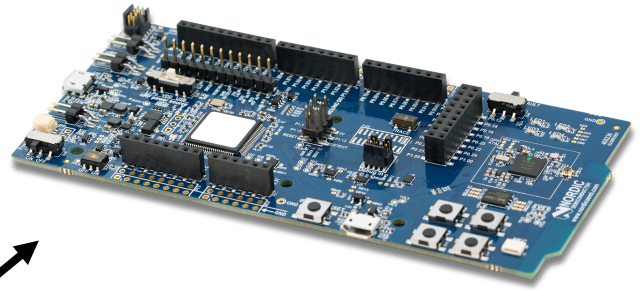
Open?



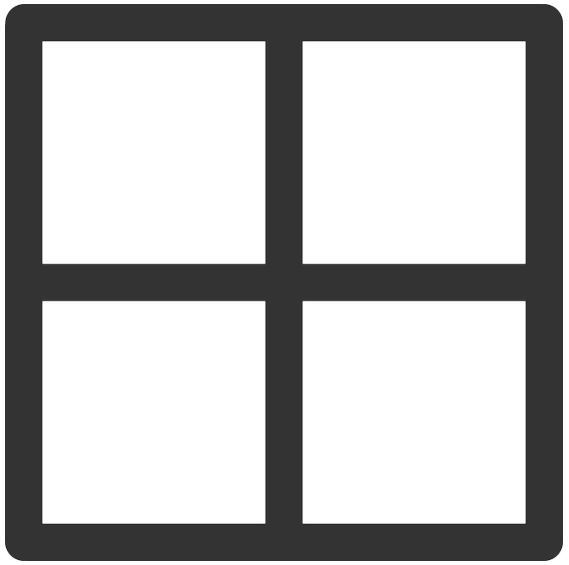
In



Halexa



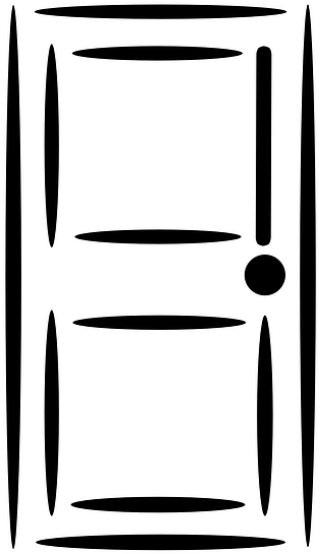
Open



> 30°

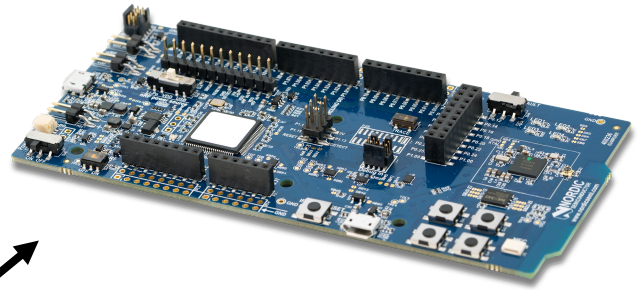
(64 MHz, 256 KB RAM, BLE)

In

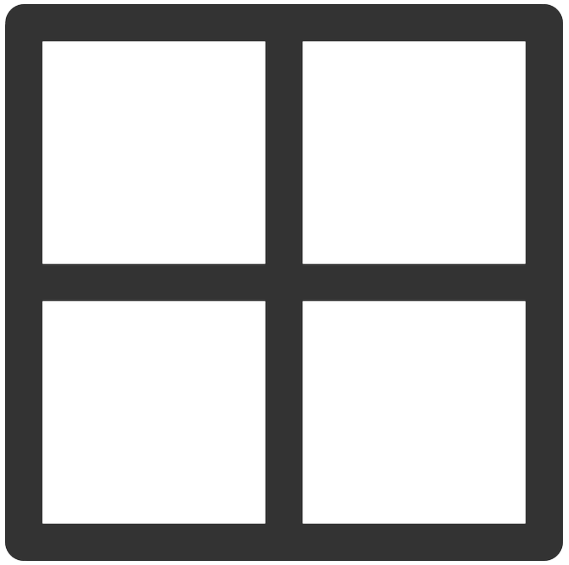


≤ 30°

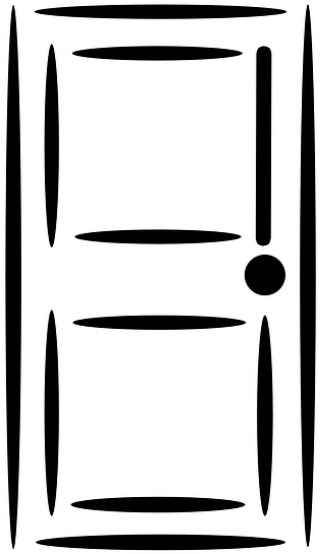
Halexa



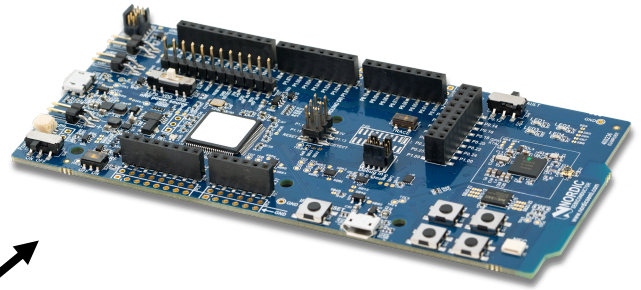
Close



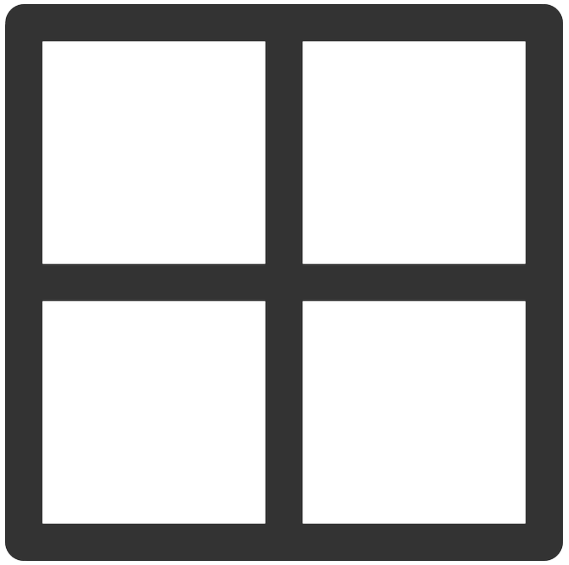
Out



Halexa

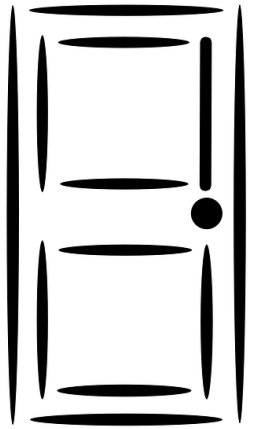


Close



Challenge: Modeling Inputs

Changes need not be *periodic* or *synchronized* with other inputs



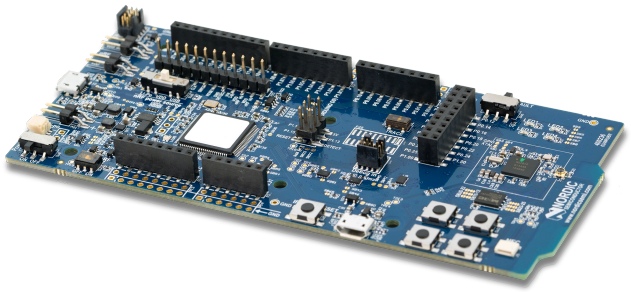
In, __ , __ , __ , Out , __ , In ,...

30°, 31°, 32°, 33°, 31°, 28°, 26°,...

Input values may change over time

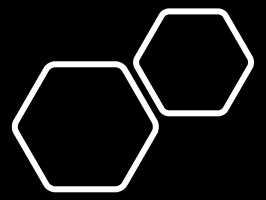
Challenge: SDK is low-level

C



- *manual* memory management
- *difficult* to protect sensitive data
- `Segmentation fault (core dumped)`

How should you program Halexa?



Towards Secure IoT Programming in Haskell

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ALEJANDRO RUSSO

KOEN CLAESSEN

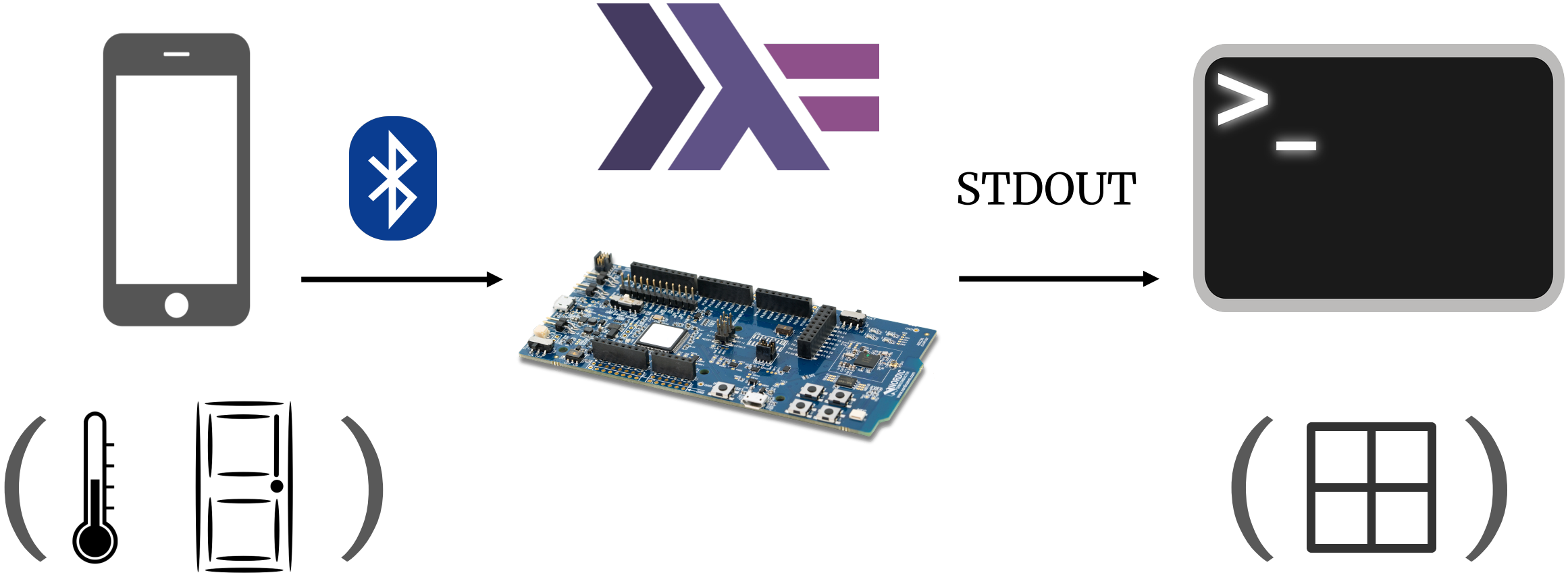
OCTOPI

CHALMERS
UNIVERSITY OF TECHNOLOGY

Main Idea

Program Halexa and similar “reactive” IoT applications using a Haskell eDSL that generates C

Demo Setup



What is Haski?

- Monadic eDSL that models input and output as streams

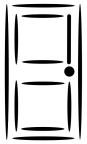
```
prg :: Stream Input -> Haski (Stream Output)
```

- Generates C code

```
Output prg_step(Input inp, prg_mem *self)
```

Programming in Haski, an Overview

```
halexa :: Stream Status
       -> Stream Int
       -> Haski (Stream WindowOp)
```



```
type Status   = Maybe Action
data Action   = In    | Out
data WindowOp = Open  | Close
```

Programming in Haski, an Overview

```
halexa :: Stream Status -> Stream Int -> Haski (Stream WindowOp)

halexa = node "halexa" $ \stat temp -> mdo
  isHot     <- letDef $ temp `gtE` 30
  recentAct <- stat `match` (maybe pastAct val)
  pastAct   <- Out `fby` recentAct
  dec       <- recentAct `match` \case
    In  -> ifte isHot (val Open) (val Close)
    Out -> val Close
  return dec
```

Mutually recursive definitions

```
{-# LANGUAGE RecursiveDo #-}

halexa                                    -> mdo
  ...
  recentAct <- stat `match` (maybe pastAct val)
  pastAct   <- Out `fby` recentAct
  ...

instance MonadFix Haski where
  mfix f = …
```

Pattern Matching

```
match :: … => Stream a -> (a -> Stream b)
      -> Haski (Stream b)
```

```
halexa
  ...
  dec <- recentAct `match` \case
    In  -> ifte isHot (val Open) (val Close)
    Out -> val Close
  ...
```

```
\x -> case x of
```

```
switch (recentAct) {
   case In:     dec = …
   case Out:   dec = …
}
```

Pattern Matching using “The Trick”

Require type ‘a’ to be *finitely enumerable*

```
match :: (HaskiType a, FinEnum a)
      => Stream a -> (a -> Stream b)
      -> Haski (Stream b)
```

Generate code for the branches by enumerating all values of ‘a’!
(a.k.a. “The Trick”)

Functions (or “nodes”)

```
halexa :: Stream Status -> Stream Int -> Haski (Stream WindowOp)
halexa = node "halexa" $ \stat temp -> mdo
```

```
node :: … => String -> (a -> b) -> (a -> b)
```

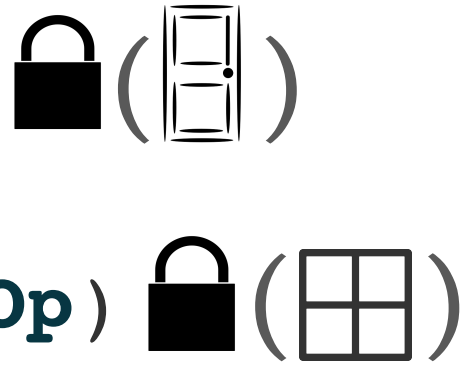
```
int hal_step(int stat, int temp, hal_mem *self){
    …
}

struct hal_mem { int prevAct; };
```

Your whereabouts must be private!

Haski supports an information-flow control extension

```
sec_halexa :: LStream Status
    -> Stream Int
    -> Haski (LStream WindowOp)
```



IFC Labeling primitives

```
label (High :: Label) (stat :: Stream Status)
      :: LStream Status

unlabel (secretStat :: LStream Status)
      :: Haski (Stream Status)

… (see paper)
```

Secure Halexa

```
sec_halexa :: LStream Status -> Stream Int
              -> Haski (LStream WindowOp)
sec_halexa = node "halexa" $ \secretStat temp -> mdo
    ...
    stat <- unlabel secretStat
    dec <- ...
    secretDec <- label High dec
    return secretDec
```

Compile time IFC, *but not using types*

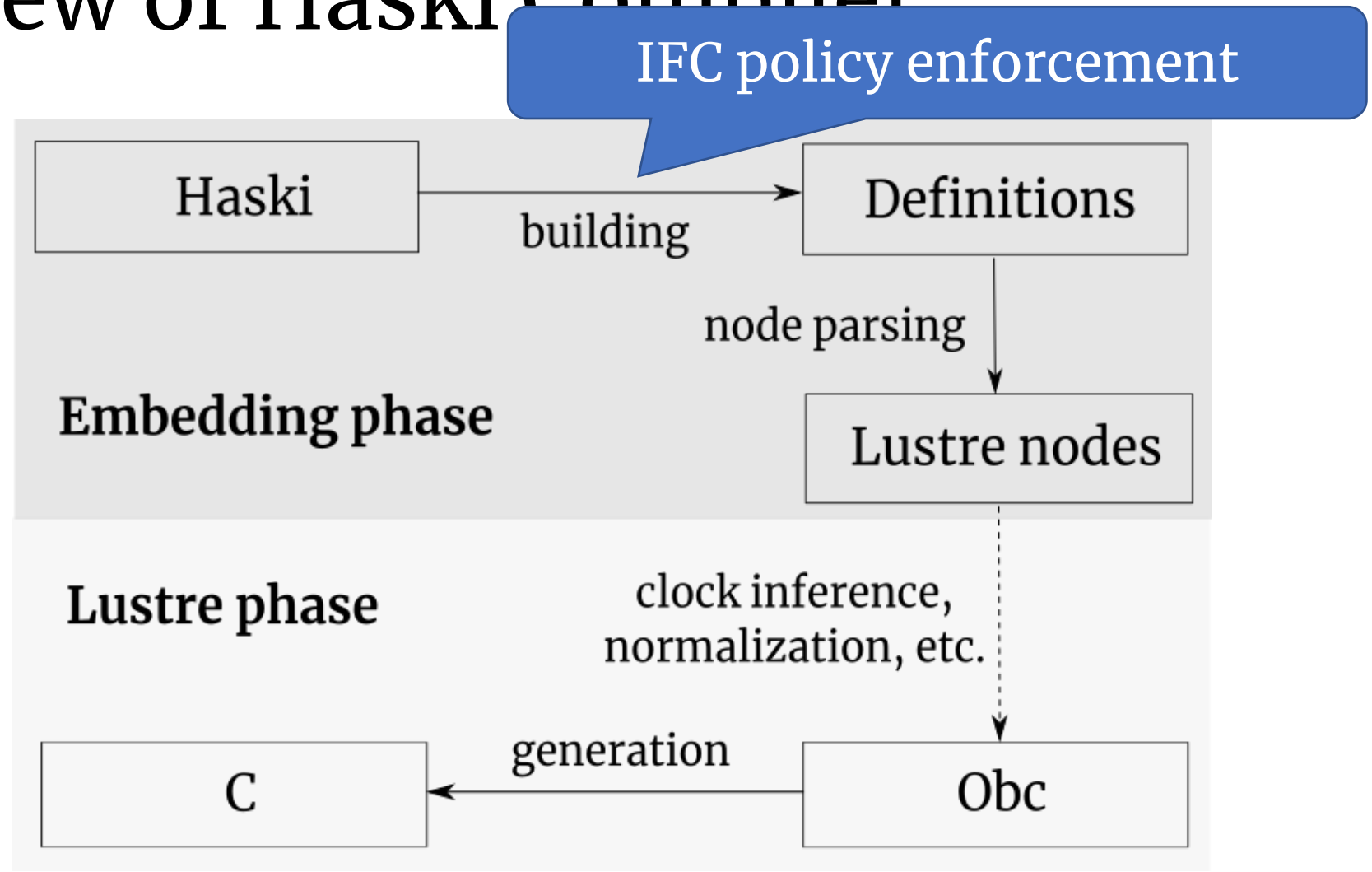
> Labels are *static values*, not types

i.e., `High :: Label`, not `High :: *`

> IFC primitives are “computed away” at compile time

i.e., `sec_halexa ≈ halexa`, if there’s no violation

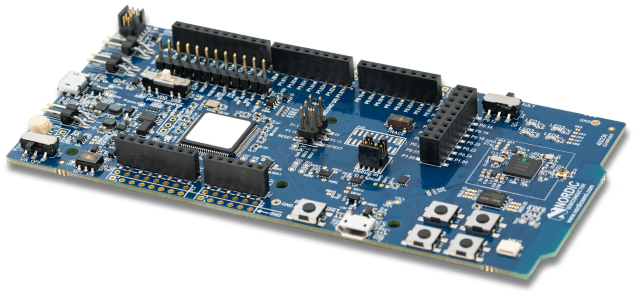
Overview of Haski Compiler



Halexa in Action

`Halexa`

Zephyr™



Haski + runtime for Zephyr

RTOS with a callback-based C API

nRF52840-DK Nordic Semiconductor

Stream functions and Callbacks

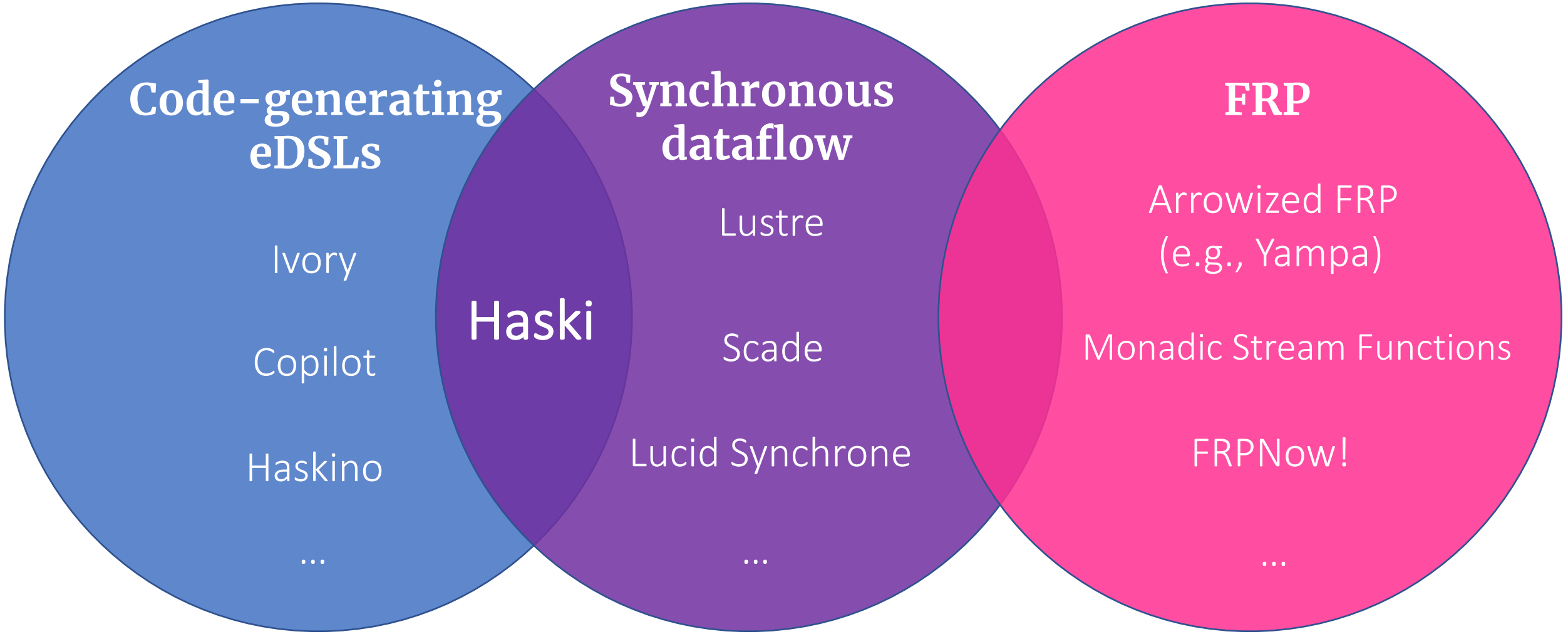
Halexa

```
int hal_step(int stat, int temp, hal_mem *self)
```

currently requires manual intervention


```
static u8_t notify_temperature(...,void* data){
    ...
    int *temperature = (int*)data;
    hal_step(*temperature, NOTHING, mem);
    ...
}
```

Landscape of reactive DSLs



In a nutshell

Haski presents a novel eDSL design, based on Lustre, for programming resource constrained IoT devices, and supports a lightweight IFC extension.

https://github.com/OctopiChalmers/haski/