Internet of Things
Patterns Language and Usage

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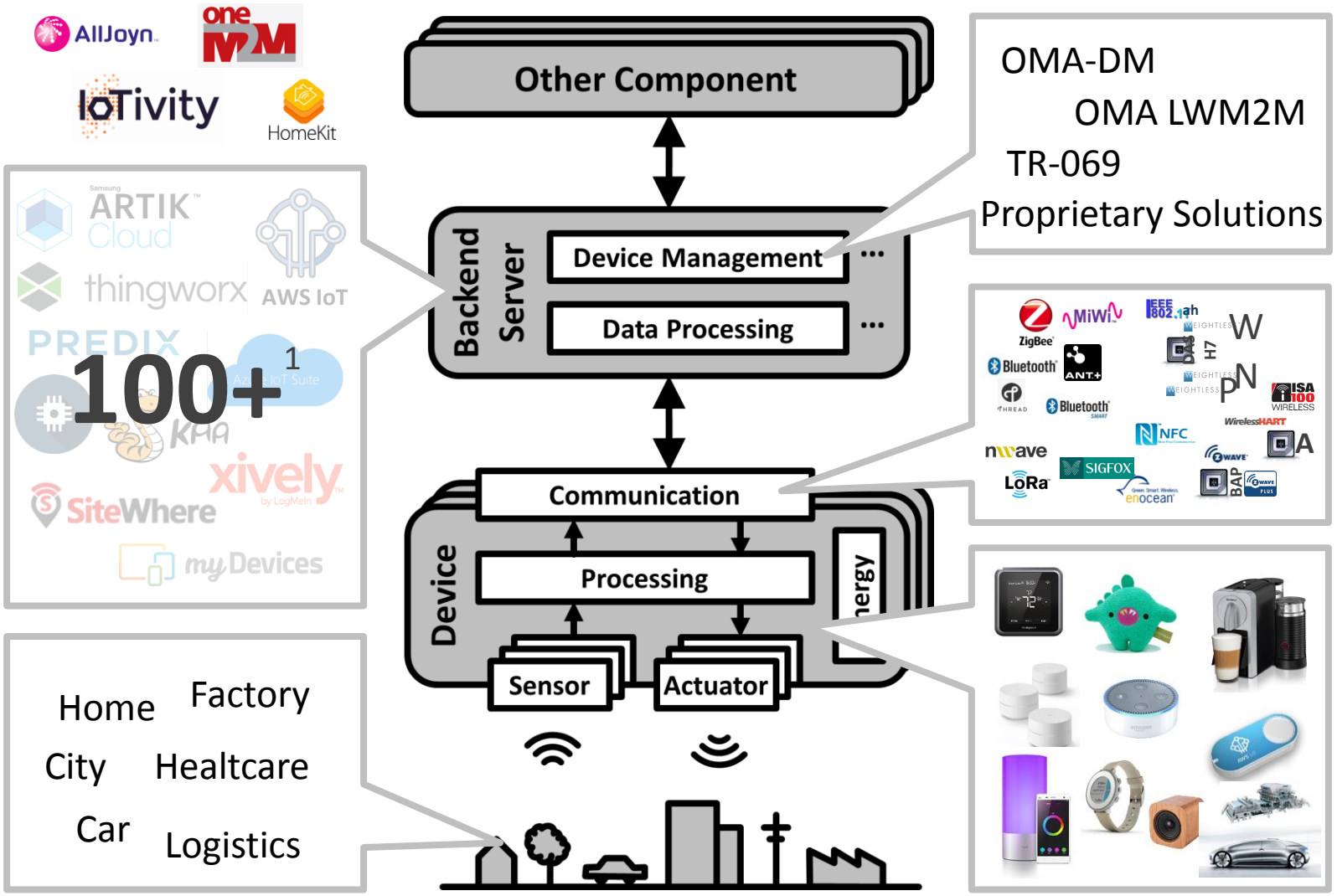
Agenda

- Introduction
- Design Patterns
- IoT Patterns Overview
- Using IoT Patterns
- Summary

Introduction



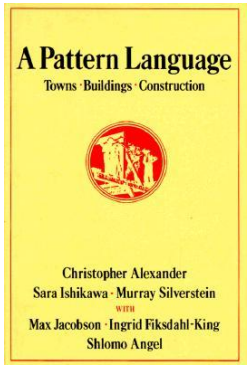
[1] http://www.postscapes.com/internet-of-things-platforms/

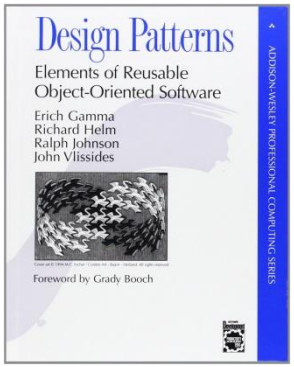
Design Patterns - Overview

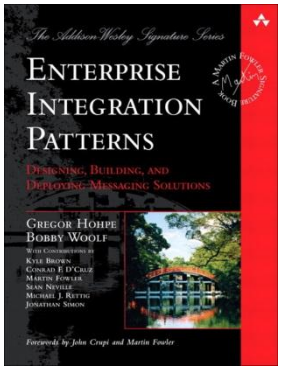
"[A] pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice."

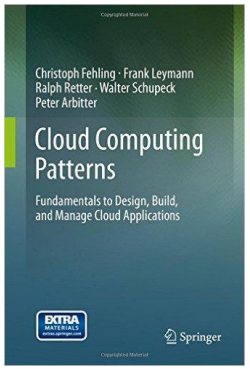
Alexander, C., Ishikawa, S., and Silverstein, M. 1977. *A Pattern Language: Towns, Buildings, Construction*

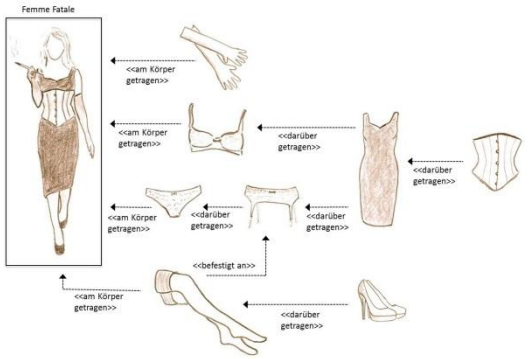
- Started by Christopher Alexander
- Today applied in many domains, including computing











Design Patterns - Format

Name

Aliases: ——, ——, ——

Context: —— —— — —— ——

—— — — —— — — —— —

Problem: —— ——— — —

— —— — ——— —— —

Forces:

- —— ——— —
- — ——

Solution: ——— — —— —— ——

—— ——— — —— — —— —

Result: —— — —— ——— ——

— —— — —— — —— ——

Variants: —— —— ——

Related Patterns:

- — —— ——
- ——— —

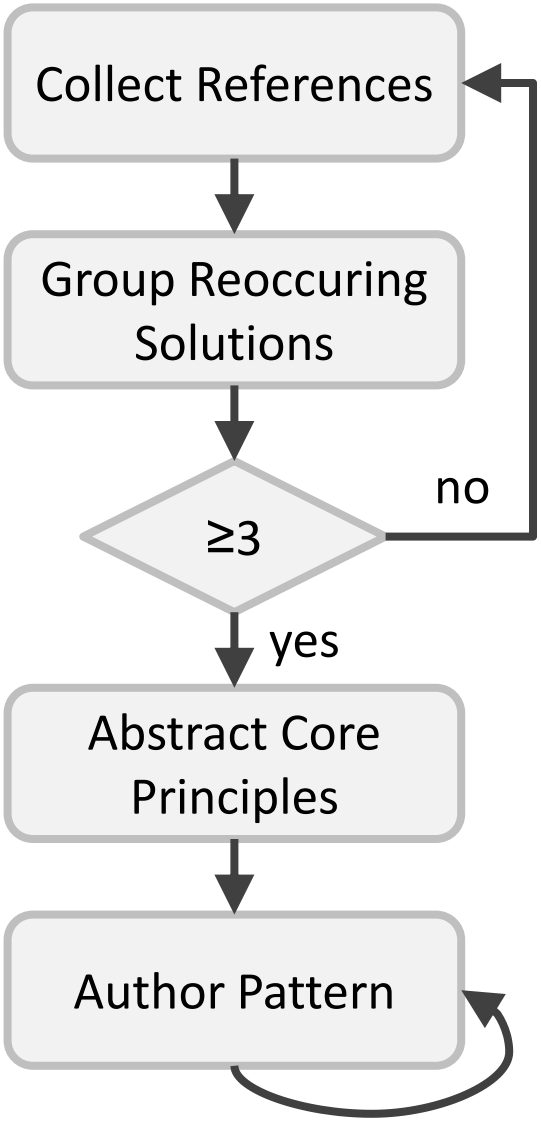
Known Uses: —— — —— —— —

—— — ——— — —— — ——

Known Uses

- Concrete examples of the pattern
- Real world descriptions on which the pattern is based

Design Patterns – Identification Process



Author Pattern

- Bring into pattern format
- Formulate fitting problem
- Context vs. Forces
- Relations to other patterns
- …

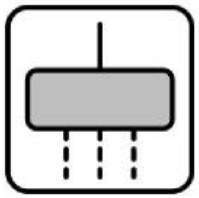
Design Patterns – Example

In this section, we present five IoT Patterns that were identified following the procedure described in Section 2. The format follows the definition presented in Section 3.

5.1 Device Gateway

Aliases: Gateway, Field Gateway, Intermediate Gateway, Physical Hub, Protocol Converter

Context: A number of devices have to be connected to a network. These might include *Constrained Devices* or *Semi-Constrained Devices* that are limited in their processing power and do not support the communication methods of the network. Or these might also include *Unconstrained Devices* from legacy systems that cannot connect to the network due to outdated technology. A backend server reachable over this network is intended to process data from these devices.



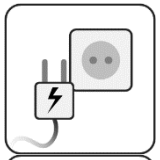
Problem: You want to connect many different devices to an already existing network, but some of them might not support the networks communication technology or protocol.

Forces:

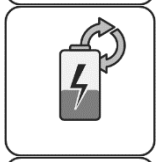
- **Connectivity:** Devices have to be connected to a network because you want to access their data and functionality regularly. Doing this manually is not an option.
- **Upgradability:** Changing or building up a network so that it supports the communication technology required by the device is often not possible. You might not control the network, or

IoT Patterns Overview

Energy Supply

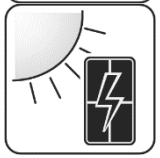


Mains-Powered Device



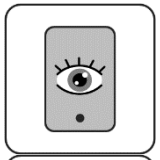
Period Energy-Limited Device

Lifetime Energy-Limited Device

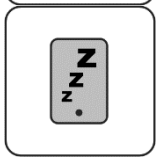


Energy-Harvesting Device

Operation Mode

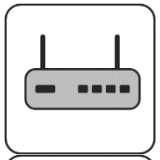


Always-On Device

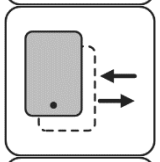


Normally-Sleeping Device

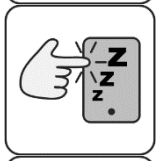
Communication



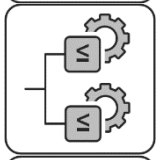
Device Gateway



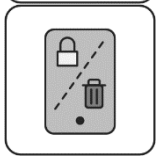
Device Shadow



Device Wakeup Trigger



Rules Engine



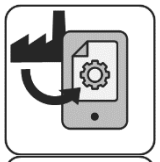
Remote Lock and Wipe

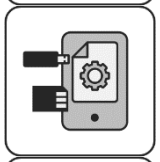
L. Reinfurt et al.,
"Internet of Things Patterns for Devices",
In Ninth international Conferences on Pervasive Patterns and Applications (PATTERNS) 2017, 117–126.

L. Reinfurt et al., "Internet of Things Patterns," in *Proceedings of the 21st European Conference on Pattern Languages of Programs (EuroPLoP)*: ACM, 2016

IoT Patterns Overview continued

Bootstrapping

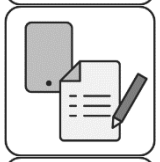

Factory Bootstrap


On-Site Bootstrap

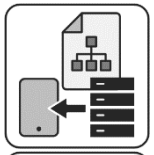

Remote Bootstrap

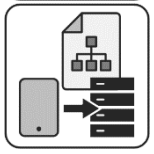
Registration

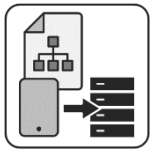

Manual User-Driven Registration


Automatic Client-Driven Regsitration


Automatic Server-Driven Regsitration

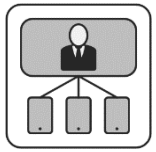

Server-Driven Model


Pre-Defined Device-Driven Model


Self-Defined Device Driven Model


Device Registry

Management & Communication


Remote Device Management


Delta Update


Visible Light Communication

IoT Patterns Overview continued

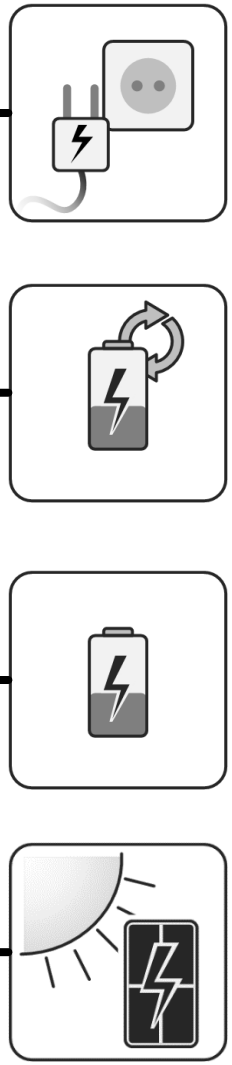
Communication **Processing** **Management**

Sensing **Security**

Using IoT Patterns – Motivating Example

Using IoT Patterns – Energy Source

Which energy source ?



~~Mains-Powered Device~~

Devices are in remote places

Period Energy-Limited Device

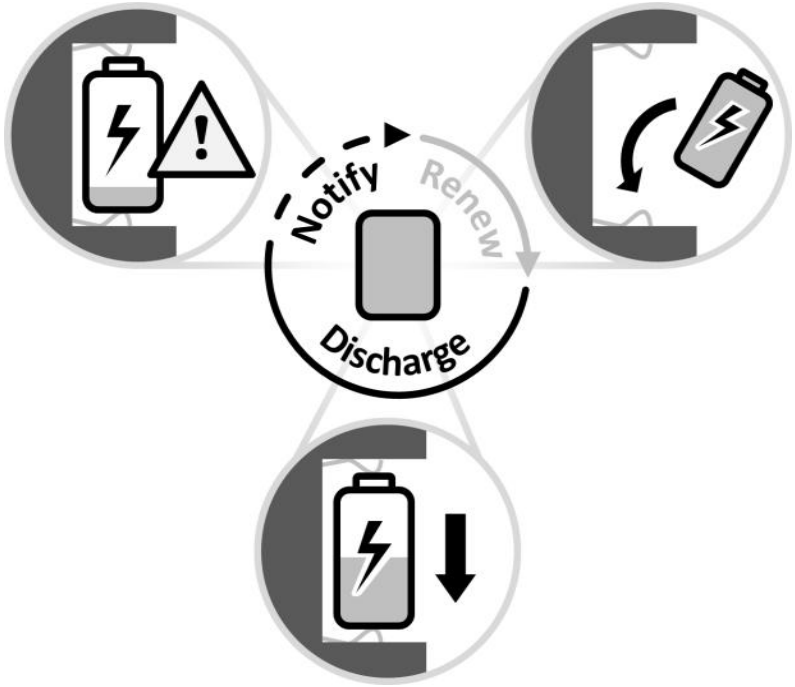
~~Lifetime Energy-Limited Device~~

Devices need more energy

~~Energy Harvesting Device~~

Not enough ambient energy

Using IoT Patterns – Period Energy Limited Device



Solution: Use a replaceable or rechargeable source of energy to power the device. Implement a notification mechanism that informs you when the power source is nearly empty. Replace or recharge the power source when needed.

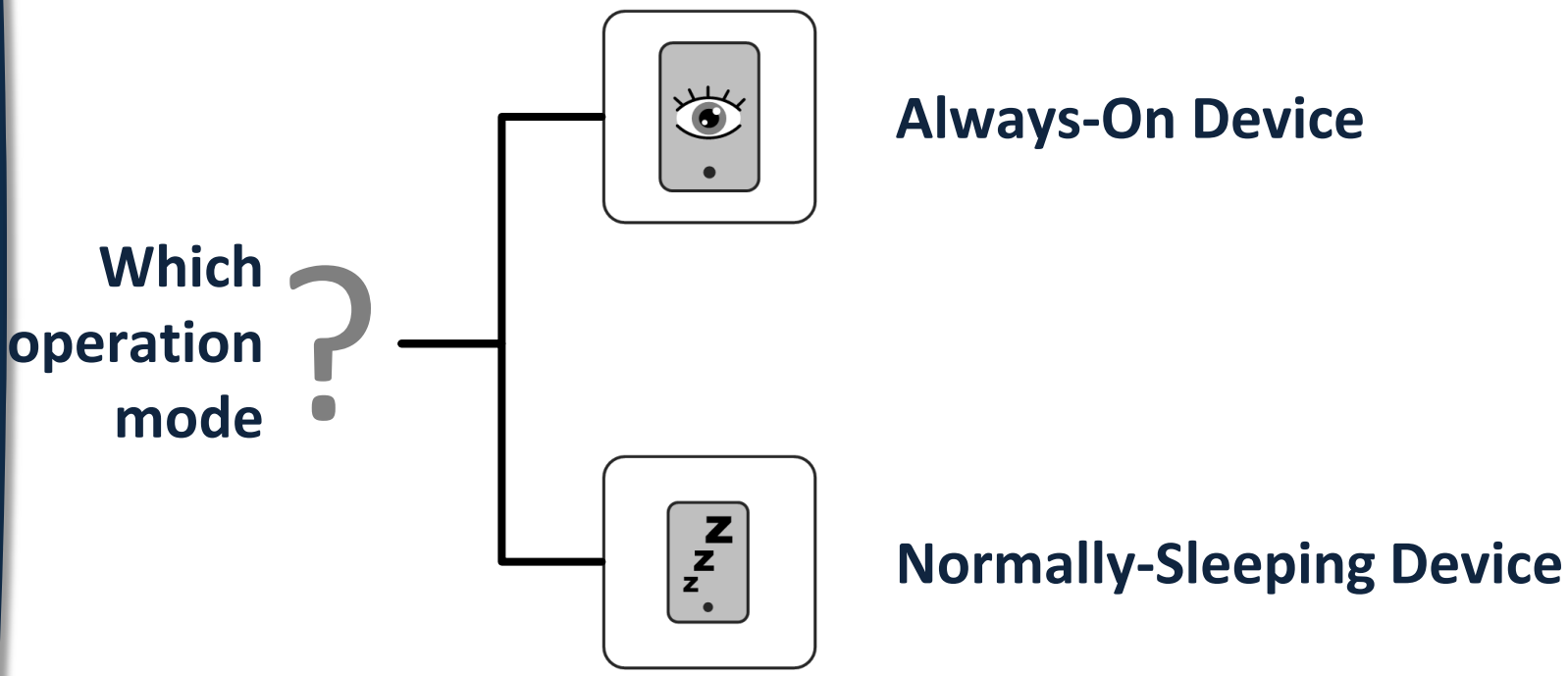
Flic Wireless Smart Button

Logitech POP Home Switch

Nest Learning Thermostat

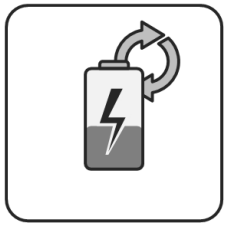
Roost Smart Battery

Using IoT Patterns – Device Operation Modes



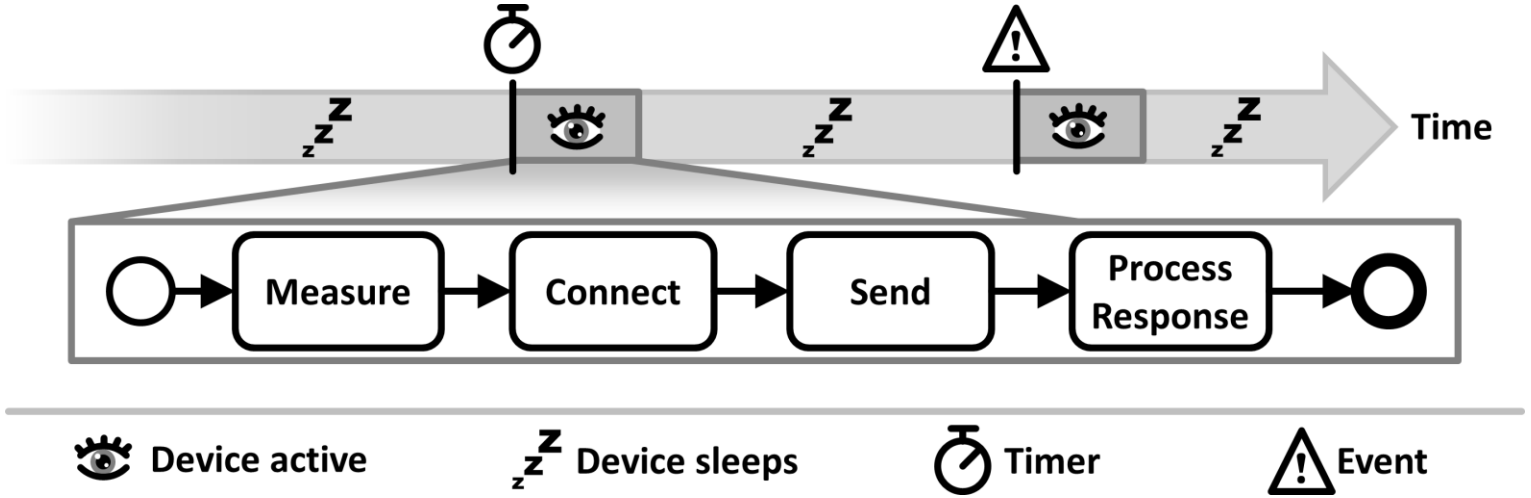
Using IoT Patterns – Drawbacks

Period Energy-Limited Device



- **Costs:** You need to replace or recharge the power source in regular intervals which increases maintenance costs. Also being an ENERGY-HARVESTING DEVICE or a NORMALLY-SLEEPING DEVICE increases the interval length.

Using IoT Patterns – Normally-Sleeping Device



Solution: Program the device to disable its main components when they are not needed. Leave a small circuit powered which reactivates the components after a predefined amount of time has passed or when an event occurs.

Z-Wave Sleepy Devices

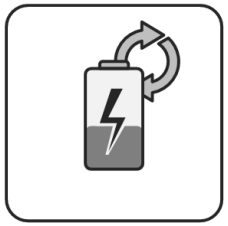
Libelium Waspmote

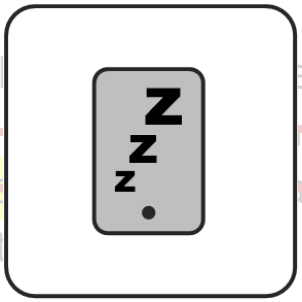
Amazon Dash Button

PawTrax

Using IoT Patterns – Drawbacks

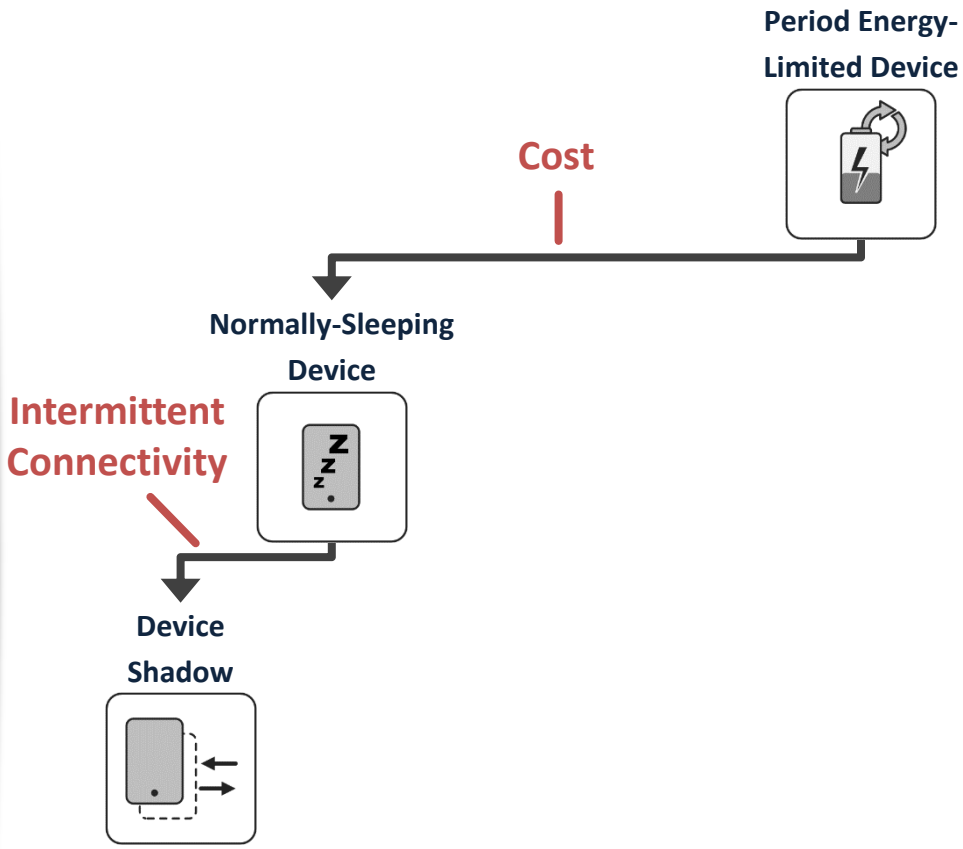
Period Energy-Limited Device



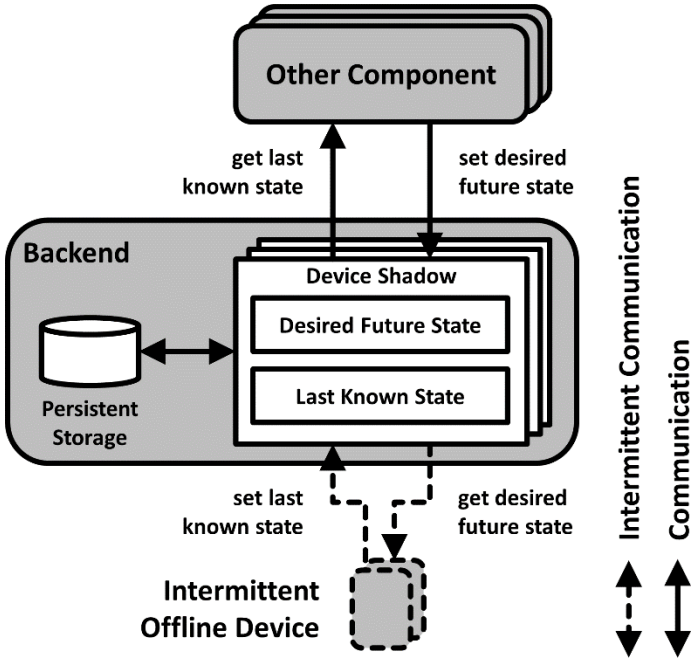


- **Costs:** You need to repl… the power source in regular intervals which … tenance costs. Also being an ENERGY-HARVE… NORMALLY-SLEEPING DEVICE increases the int…

Using IoT Patterns – Next Step



Using IoT Patterns – Device Shadow



L. Reinfurt et al., "Internet of Things Patterns," in *Proceedings of the 21st European Conference on Pattern Languages of Programs (EuroPLoP)*: ACM, 2016

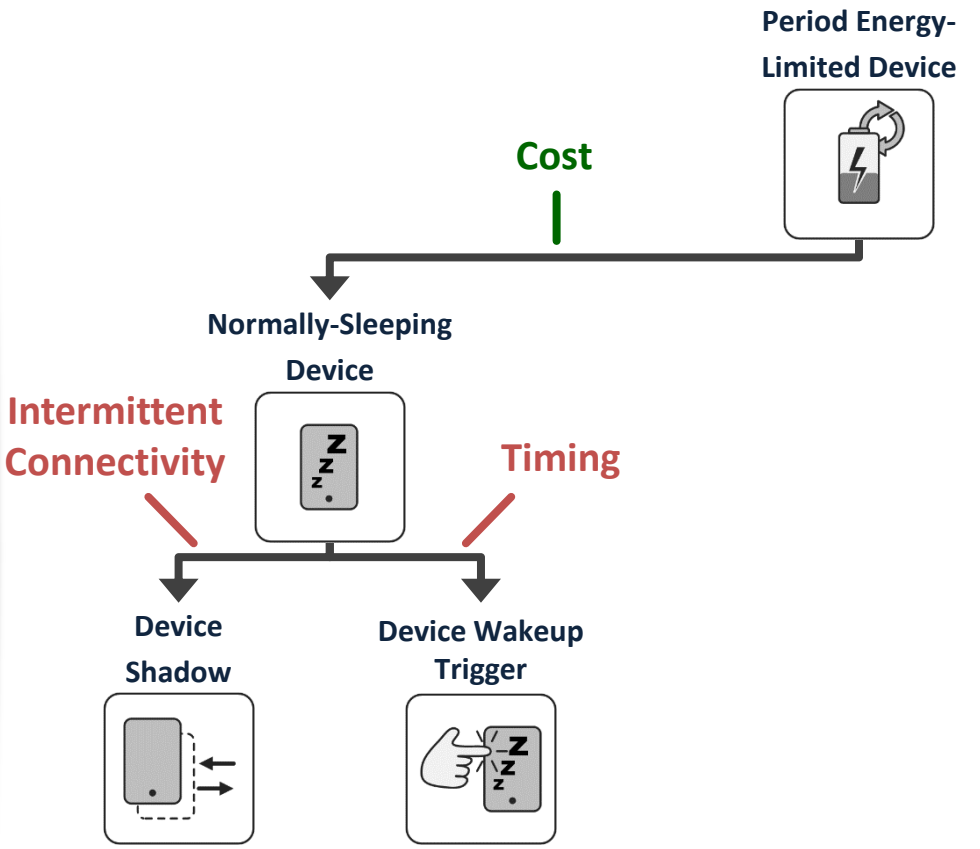
Solution: Store a persistent virtual representation of each device on some backend server. Include the latest received state from the device, as well as commands not yet sent to the device. Do all communication from and to the device through this virtual version. Synchronize the virtual representation with the actual device state when the device is online.

AWS IoT

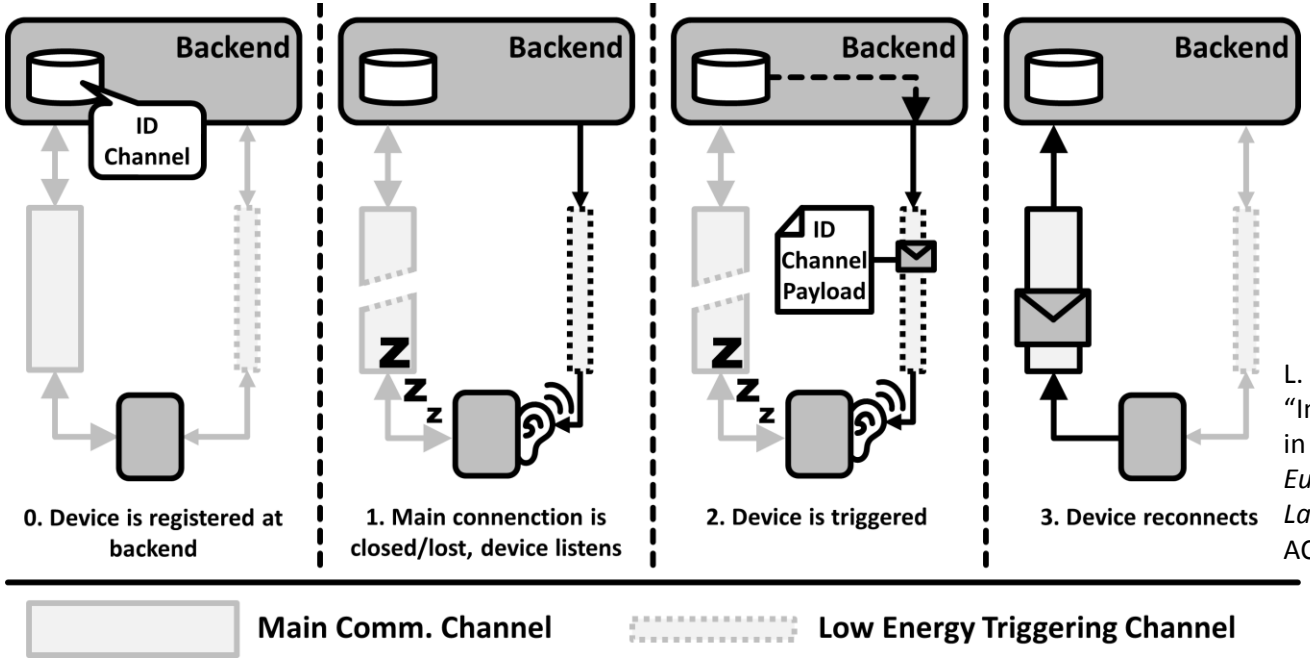
Azure IoT

Kii IoT

Using IoT Patterns – Next Step



Using IoT Patterns – Device Wakeup Trigger



L. Reinfurt et al., "Internet of Things Patterns," in *Proceedings of the 21st European Conference on Pattern Languages of Programs (EuroPLoP)*: ACM, 2016

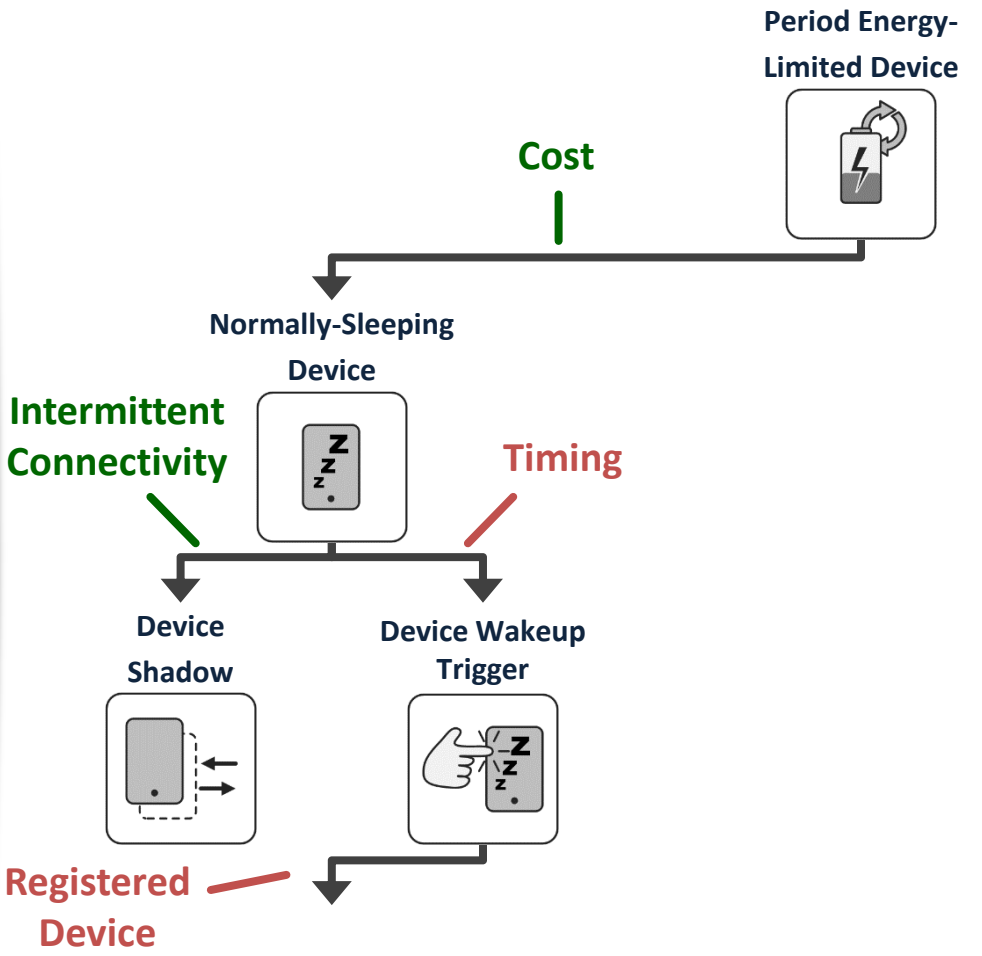
Solution: Implement a mechanism that allows the server to send a trigger message to the device via a low energy communication channel. Have the device listening for these triggering messages and immediately establish communication with the server when it receives such a message.

3GPP A GLOBAL INITIATIVE

oma Open Mobile Alliance For a Connected World

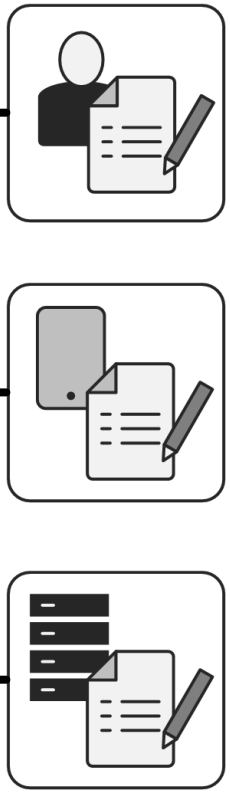
OMA LWM2M

Using IoT Patterns – Next Step



Using IoT Patterns – Registration

How to register a device ?



Manual User-Driven Registration

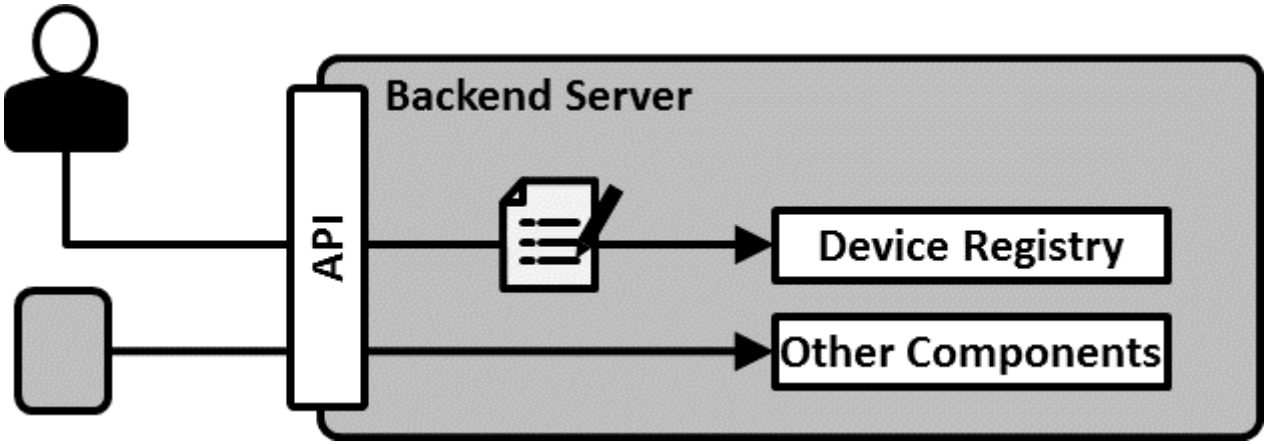
~~**Automatic Client-Driven Registration**~~

Devices too expensive

~~**Automatic Server-Driven Registration**~~

Infrastructure too expensive

Using IoT Patterns – Manual User-Driven Registration



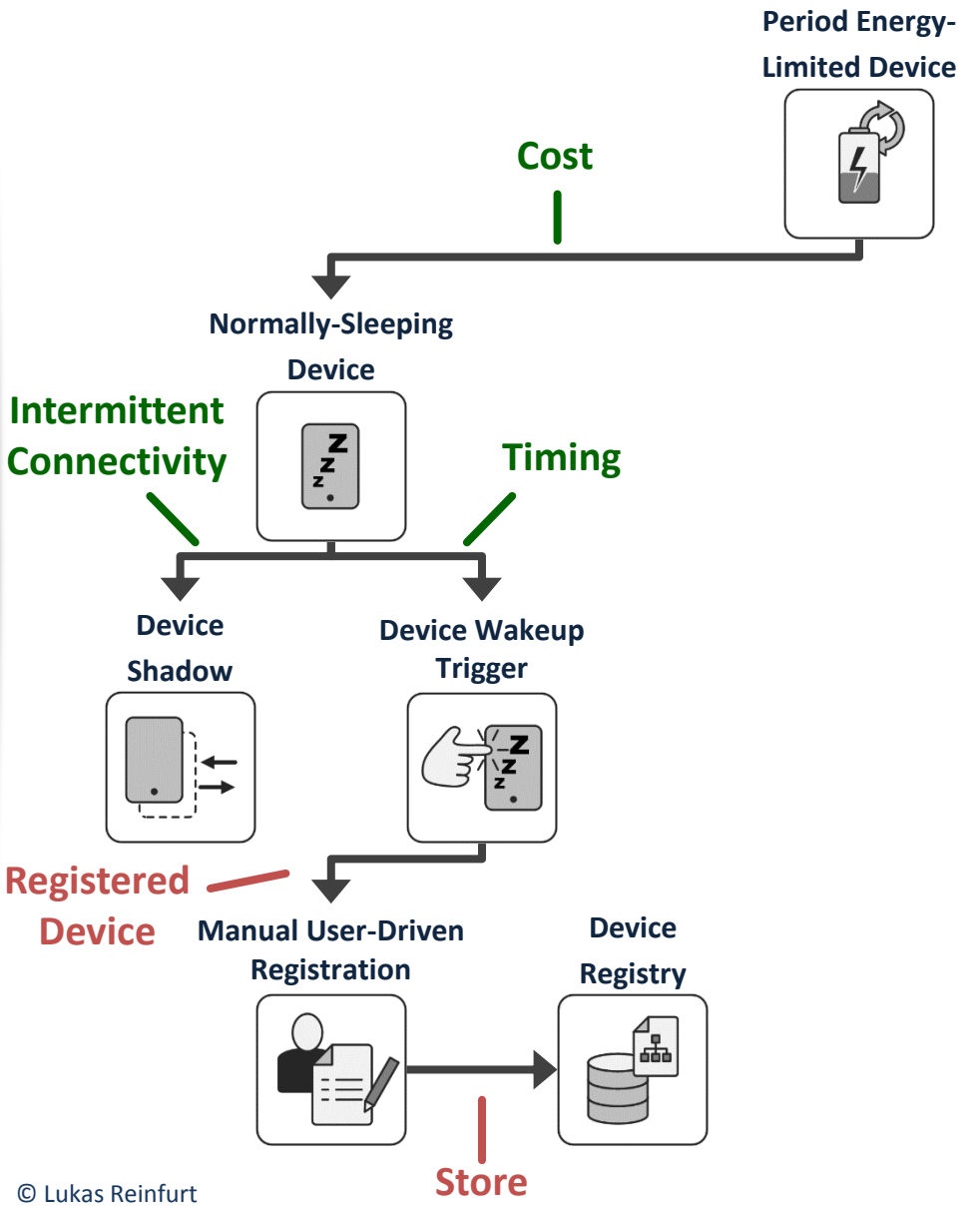
Solution: Allow authorized users to manually register devices on the backend server. Provide them an API or GUI where they can enter the device details for first registration. Allow them to change these details later on if needed.

Kii IoT

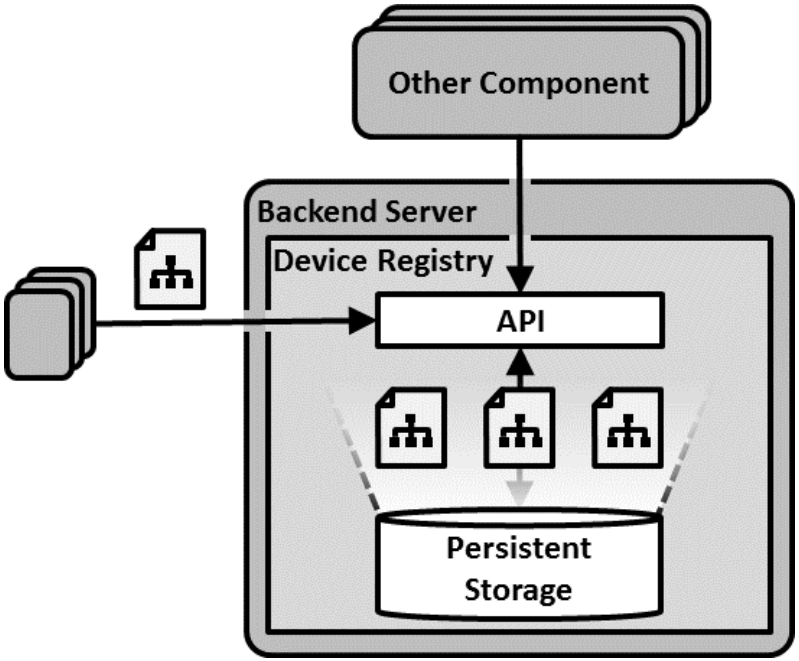
IBM IoT Platform

SiteWhere™
The Open Platform for the Internet of Things ™

Using IoT Patterns – Next Step



Using IoT Patterns – Device Registry



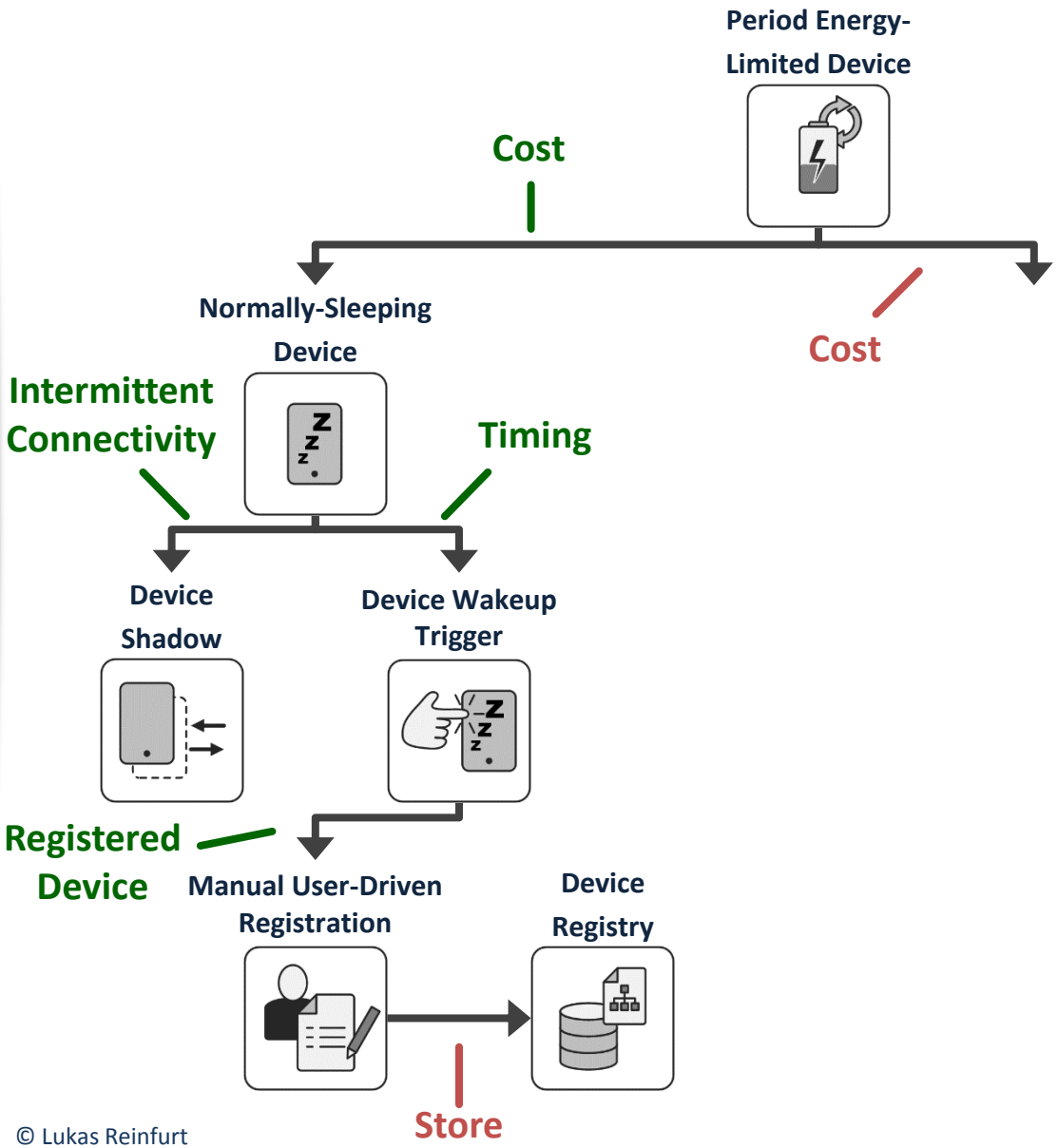
Solution: Add all registered devices to a Device Registry. For the duration where their registration is valid, permanently store their device model. Make the device models accessible and queryable for other components through a standard interface.

AWS IoT

Azure IoT

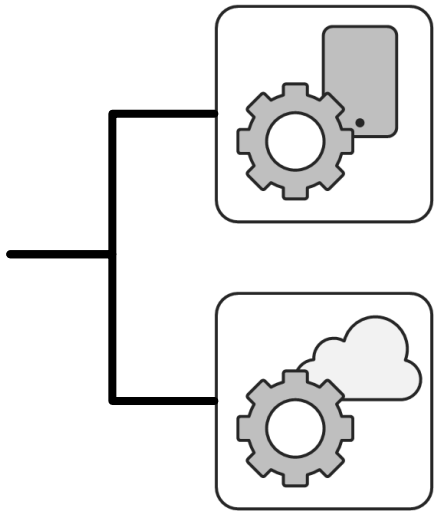
ORACLE
INTERNET OF THINGS
CLOUD SERVICE

Using IoT Patterns – Next Step



Using IoT Patterns – Processing

Where to process the data ?

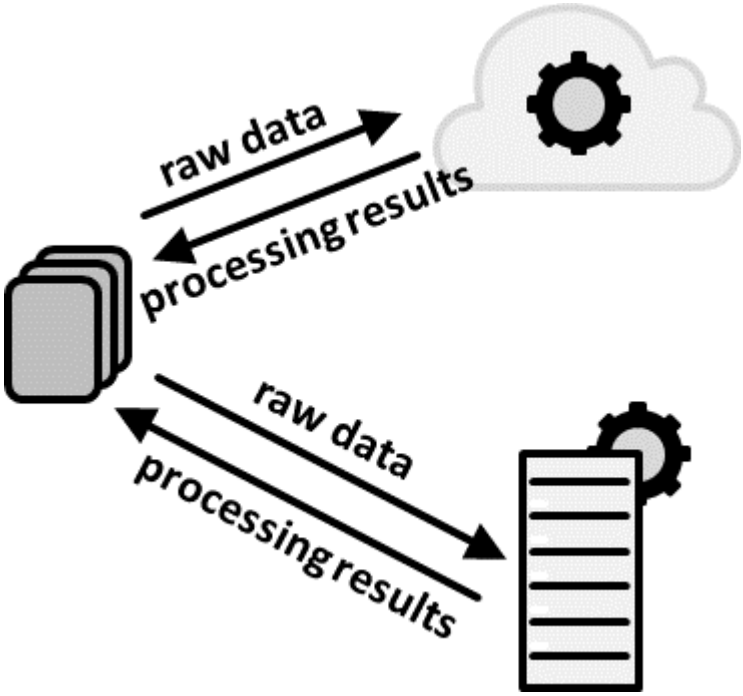


~~Local Processing~~

Devices not powerful enough

Remote Processing

Using IoT Patterns – Remote Processing



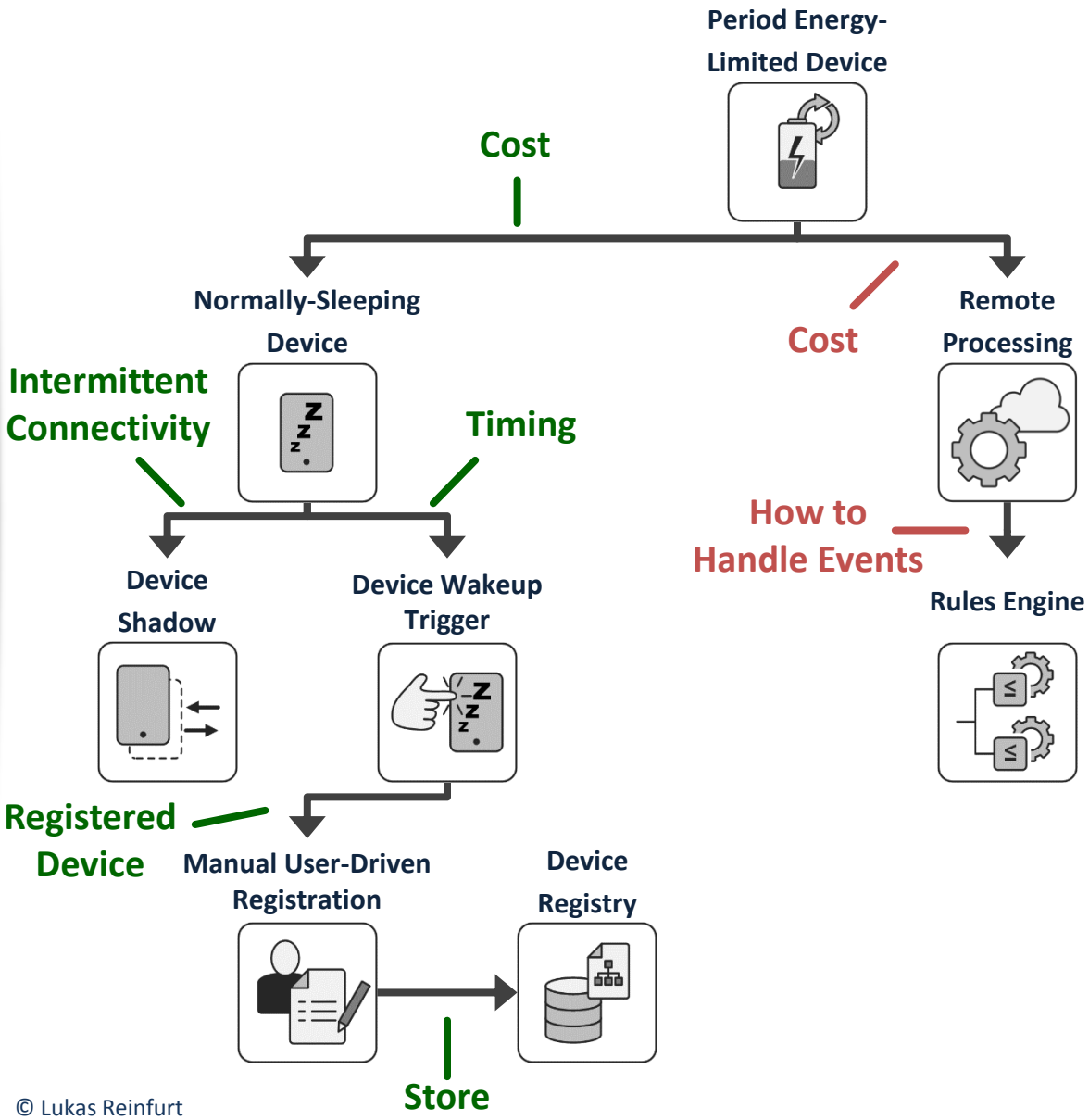
Solution: Send the raw data collected or generated by devices to a remote processing component in a cloud or data center. Process the raw data on the remote component to get the result you require. Send the result of the remote processing back to the device where the raw data originated.

SAMSUNG SmartThings

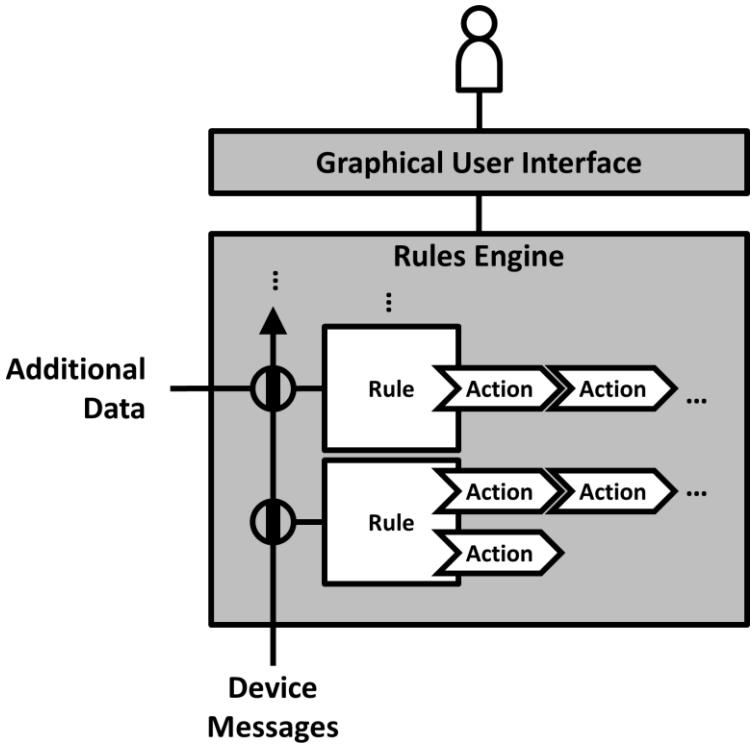
AWS IoT

Azure IoT

Using IoT Patterns – Next Step



Using IoT Patterns – Rules Engine



L. Reinfurt et al.,
"Internet of Things Patterns,"
in *Proceedings of the 21st European Conference on Pattern Languages of Programs (EuroPLoP)*:
ACM, 2016

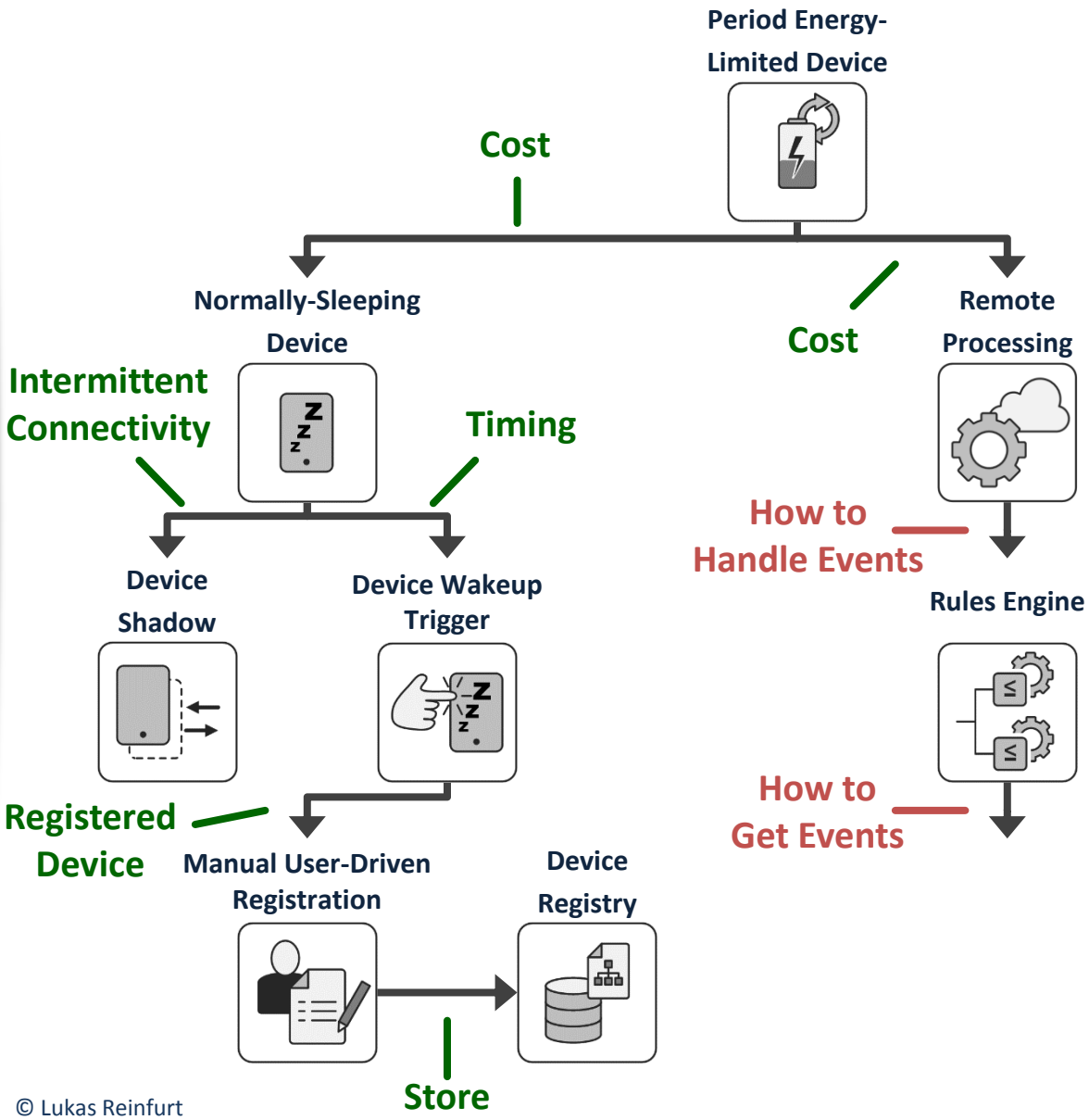
Solution: Pass all messages received from devices through a RULES ENGINE. Allow users to define rules using a graphical user interface that evaluate the content of incoming messages or metadata about the message against a set of comparators. Also allow external data sources to be included in these comparisons. Let users associate a set of actions with these rules. Apply each rule on each message and trigger the associated actions if a rule matches.

AWS IoT

stringify

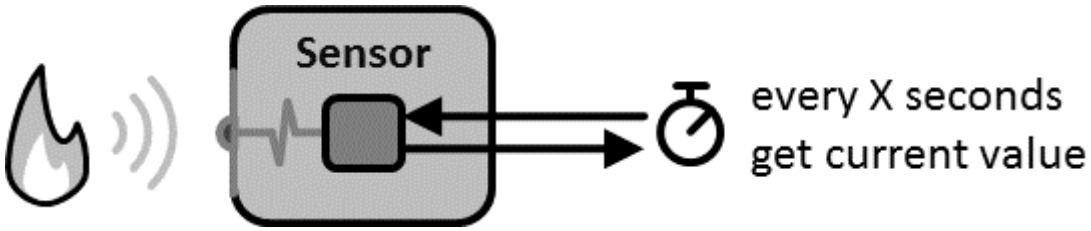
waylay.io

Using IoT Patterns – Next Step



Using IoT Patterns – Sensing

Using IoT Patterns – Survey-Based Sensing

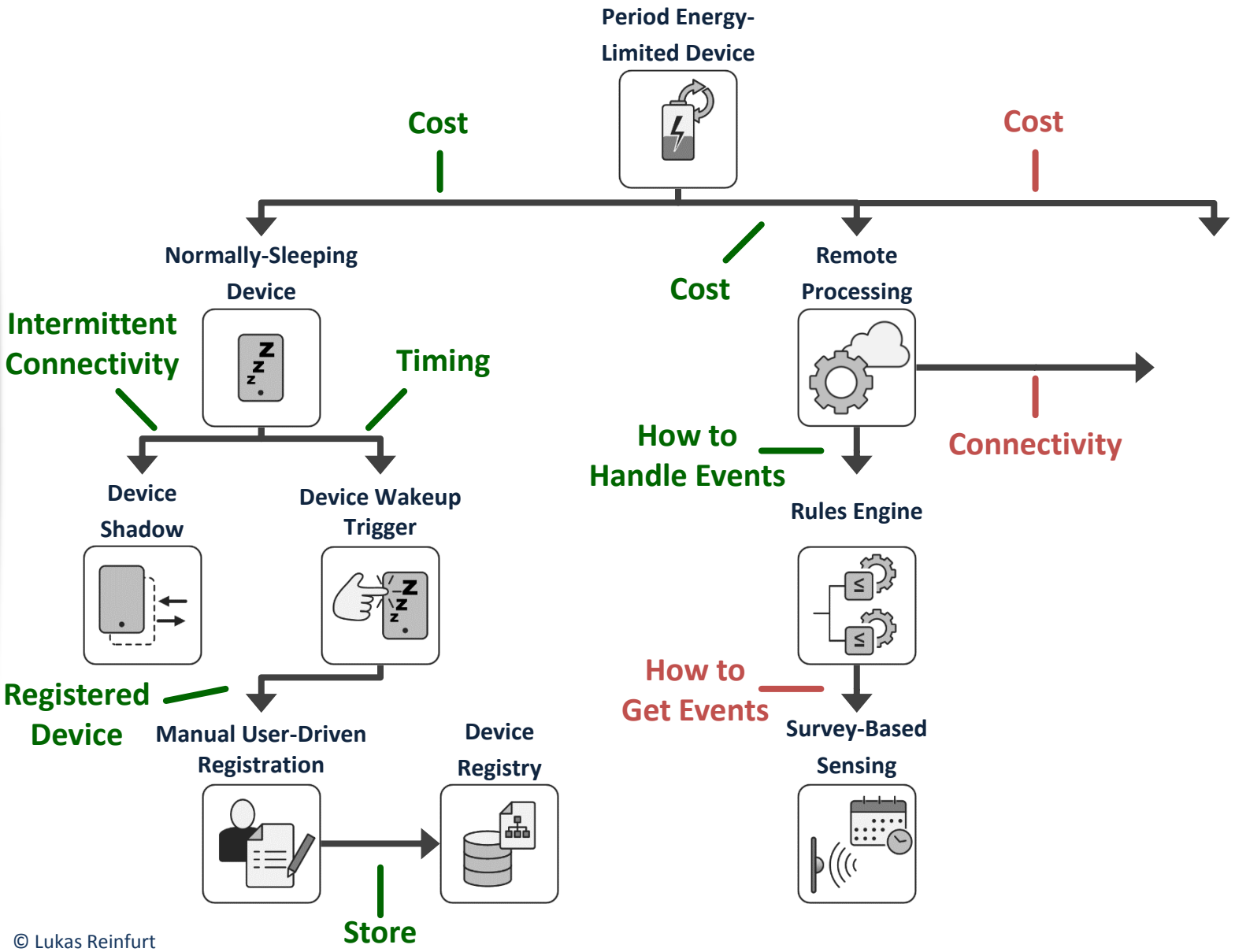


Solution: Decide on a frequency with which you need new sensor readings. Program your device to read the sensor value with this frequency.

Libelium Waspmote

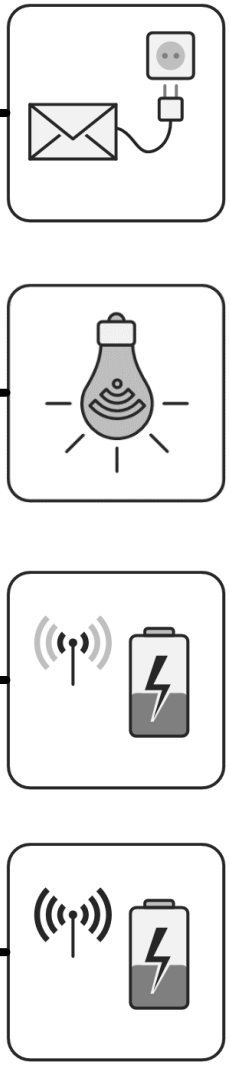
Raspberry Pi etc.

Using IoT Patterns – Next Step



Using IoT Patterns – Communication

How to communicate the data ?



~~Powerline Communication~~

No powerlines availabe

~~Visible Light Communication~~

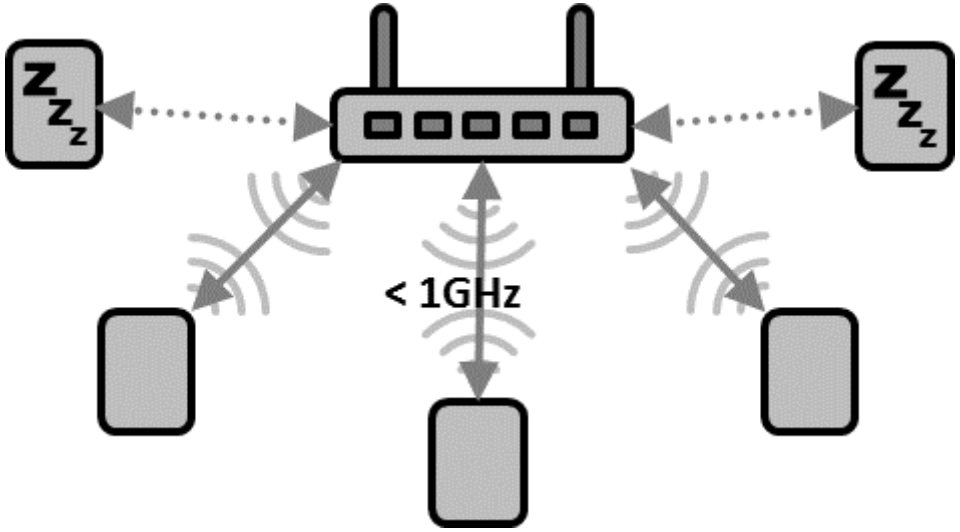
Range too short

~~Low-Power Short-Range Communication~~

Range too short

Low-Power Long-Range Communication

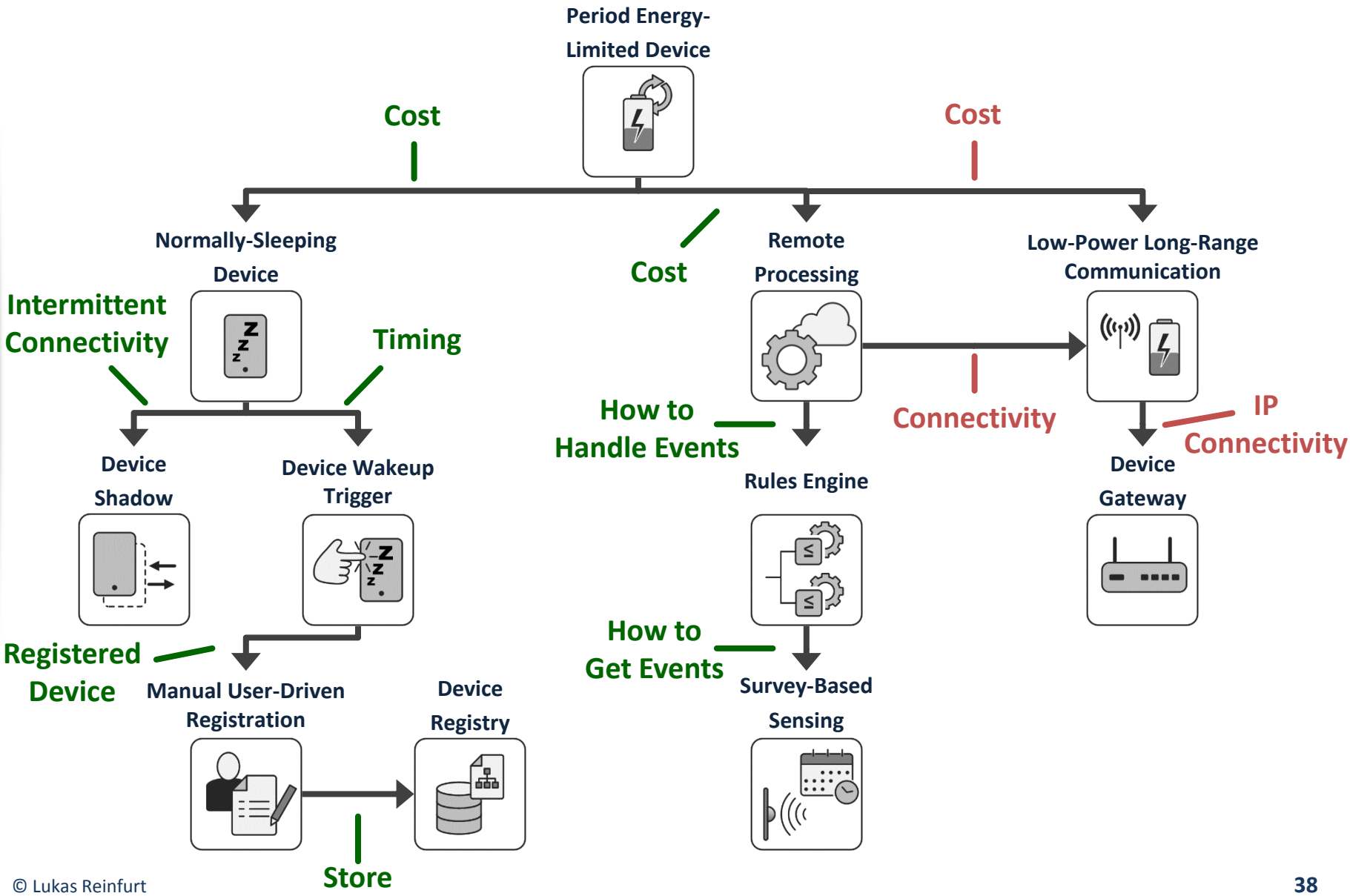
Using IoT Patterns – Low-Power Long-Range Communication



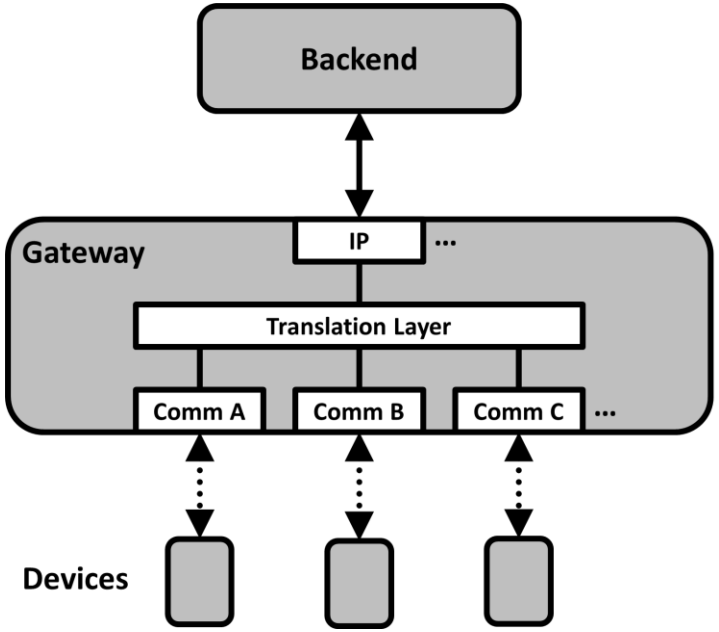
Solution: Use Sub-1GHz band to decrease the effects of obstacles and increase range. Use a slow modulation rate to put more energy into each message and increase reliability. Use a star topology to avoid having to spend energy on message retransmission. Use duty cycling to turn of the transceivers when not required and offload complexity to the base stations to safe energy.

WEIGHTLESS™ nwave LoRa™ SIGFOX

Using IoT Patterns – Next Step



Using IoT Patterns – Device Gateway



L. Reinfurt et al., "Internet of Things Patterns," in *Proceedings of the 21st European Conference on Pattern Languages of Programs (EuroPLoP)*: ACM, 2016

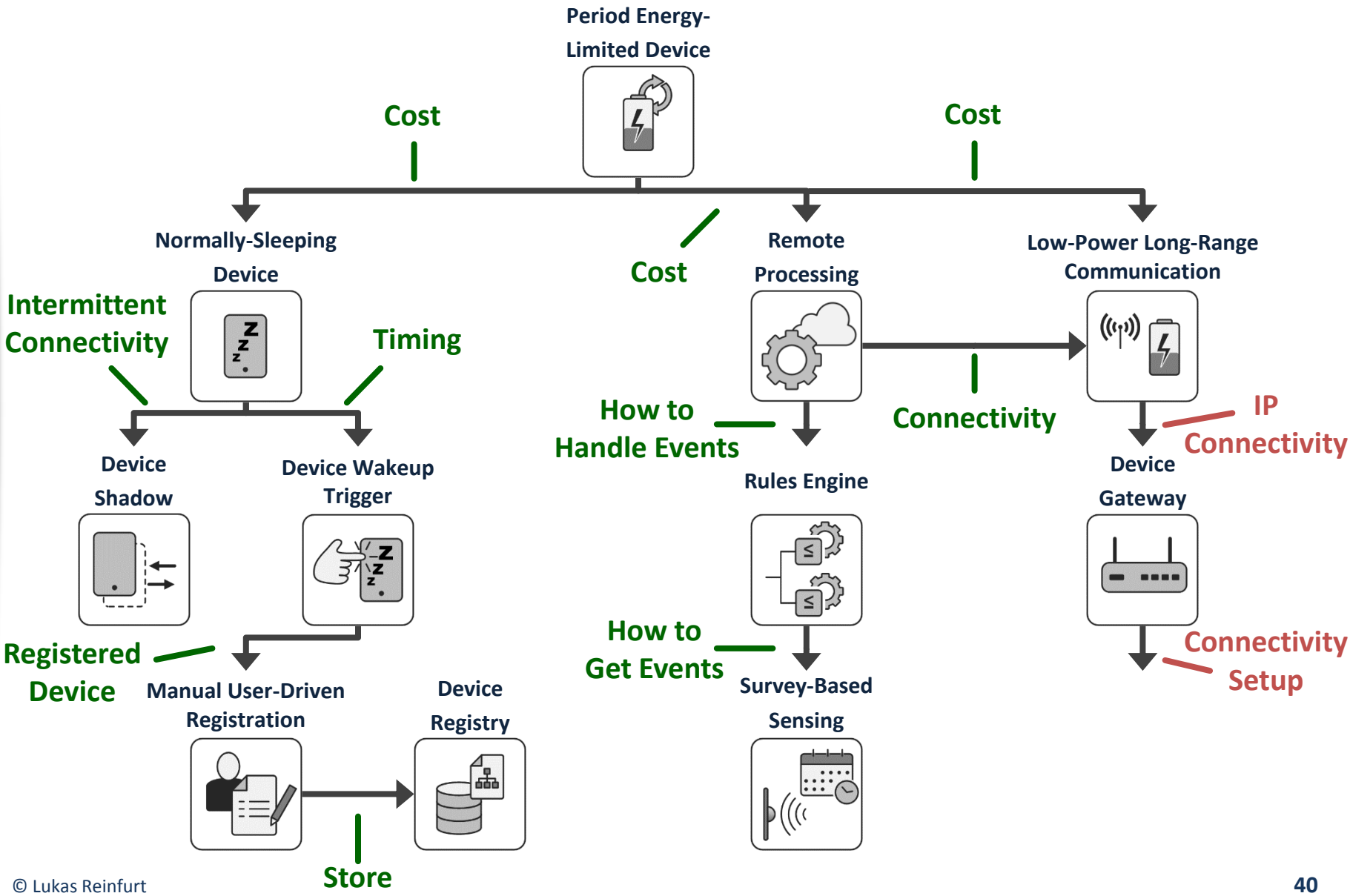
Solution: Connect devices to an intermediary DEVICE GATEWAY that translates the communication technology supported by the device to communication technology of the network and vice-versa.

wink

SAMSUNG SmartThings

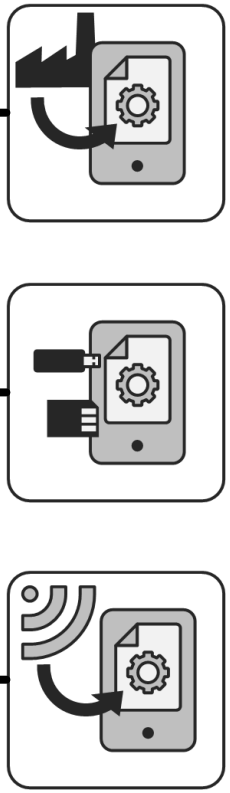
kura

Using IoT Patterns – Next Step



Using IoT Patterns – Bootstrapping

How to bootstrap communication ?



~~Factory Bootstrap~~

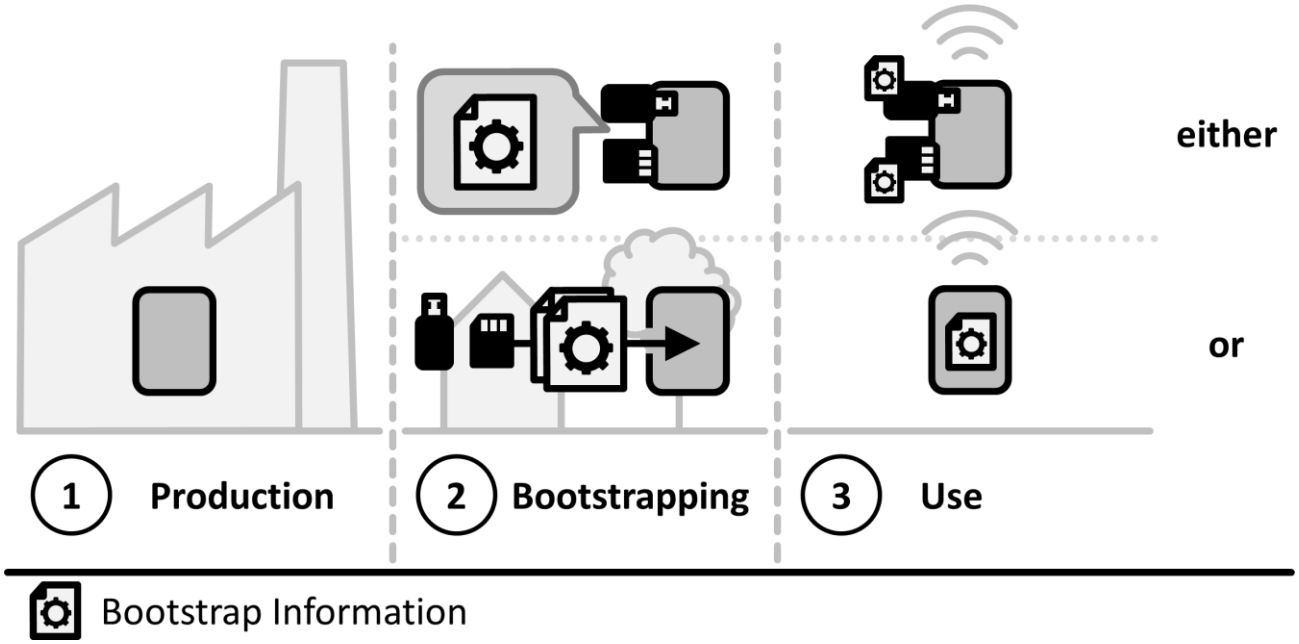
Not flexible enough

On-Site Bootstrap

~~Remote Bootstrap~~

Infrastructure too complicated

Using IoT Patterns – On-Site Bootstrap



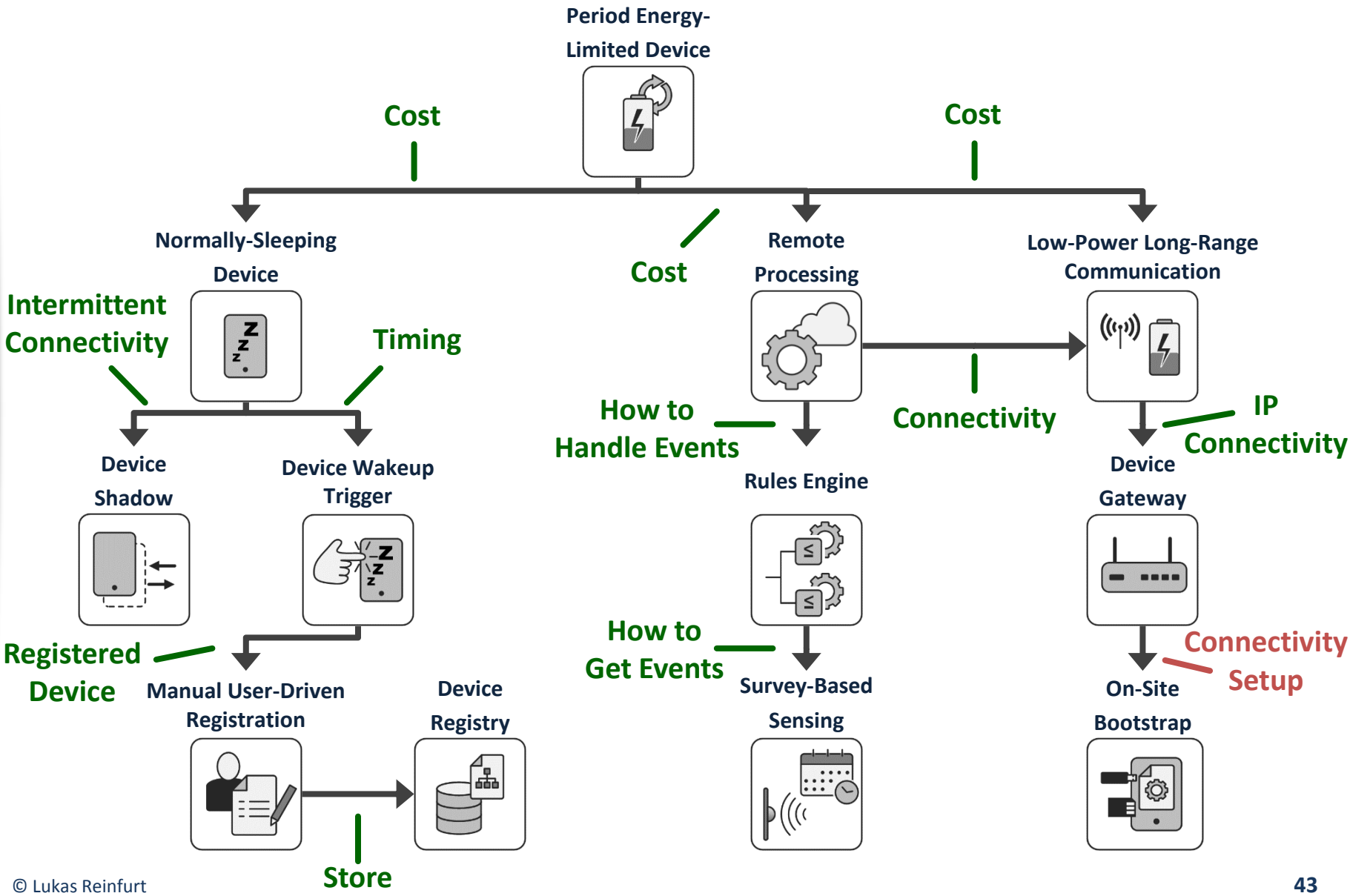
Solution: Bootstrap the device on-site from a replaceable storage medium. When the device starts, have it read and execute the instructions placed on this medium. Either leave the medium or have the device copy its content for later use.

LightweightM2M specified at oma

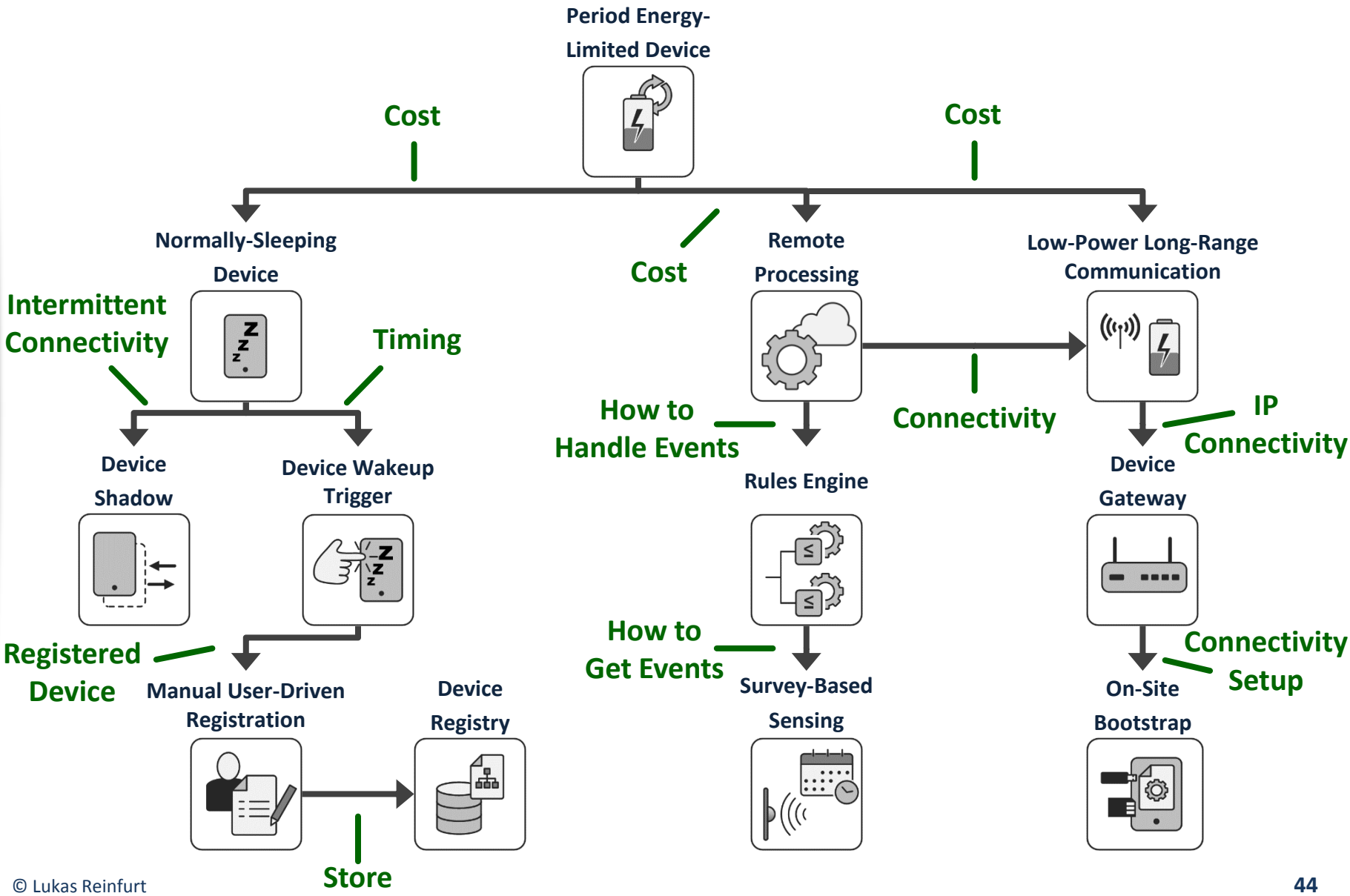
Libelium Waspmote

gemalto security to be free

Using IoT Patterns – Next Step



Using IoT Patterns – Next Step



Summary

- IoT is growing
- Number of solutions can be confusing
- Patterns abstract solutions to common problems
- IoT Patterns can help architects and developers
- Build solutions by stepping through related patterns

- More IoT Patterns
- IoT Pattern Language

Thank You!