Co-located RFID Systems Unite!

IEEE RFID 2019

Jeffrey Dungen

reelyActive

This **(8:30am!!!)** Workshop will focus on the potential for, and strategies around, combining physically co-located RFID systems for real-world applications.

Let's wake up to...

a Polarising Example

...to which we can all relate.

RFID Systems Co-located in a Retail Store

The ***IEEE engineer*** in me says that we can “advance such technology for the benefit of humanity.”

The ***[insert title here]*** in me has serious reservations about who will benefit from the highly exploitable potential of such technology.

Now that we're all awake...

a bit of History

...should add some context.

Back to the past...

The Internet of Things

A presentation by **Kevin Ashton** to

P&G

We need to empower computers with their own means of **gathering information**, so they can see, hear and smell the world for themselves, in all its random glory. **RFID** and sensor technology enable computers to observe, identify and understand the world—***without the limitations of human-entered data.***

— Kevin Ashton

That 'Internet of Things' Thing
RFID Journal, 2009

Back to the Future...

RAIN RFID

20 years of blue. (thanks to you)

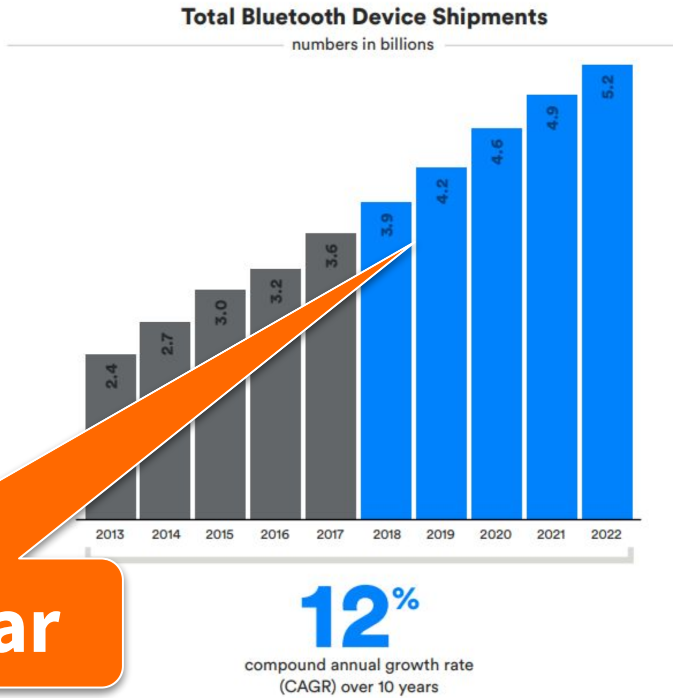
FOR IMMEDIATE RELEASE

Over 15 Billion RAIN RFID Tag Chips Sold in 2018

RAIN Technology Growing Fast Across Many Markets

Pittsburgh, PA – 27 February 2019

The RAIN RFID Alliance announced today that 15.4 billion RAIN RFID tag chips were sold in 2018. This is 23% growth over 2017, an[d] the RAIN RFID market is on track to over 20 billion tag chips sold annually for 2[...] and beyond. Tag chip forecast discussions began after the RAIN RF[ID All]iance was founded in 2014, and the industry has been expecting to achieve an[...]es of over 20 billion tag chips by 2020.



15 Billion / Year

4 Billion / Year

Today, just about everything is in place for computers to gather information about **people**, **products** and **places** *interacting* in the physical world in which we live.

—without the need for human-entered data.

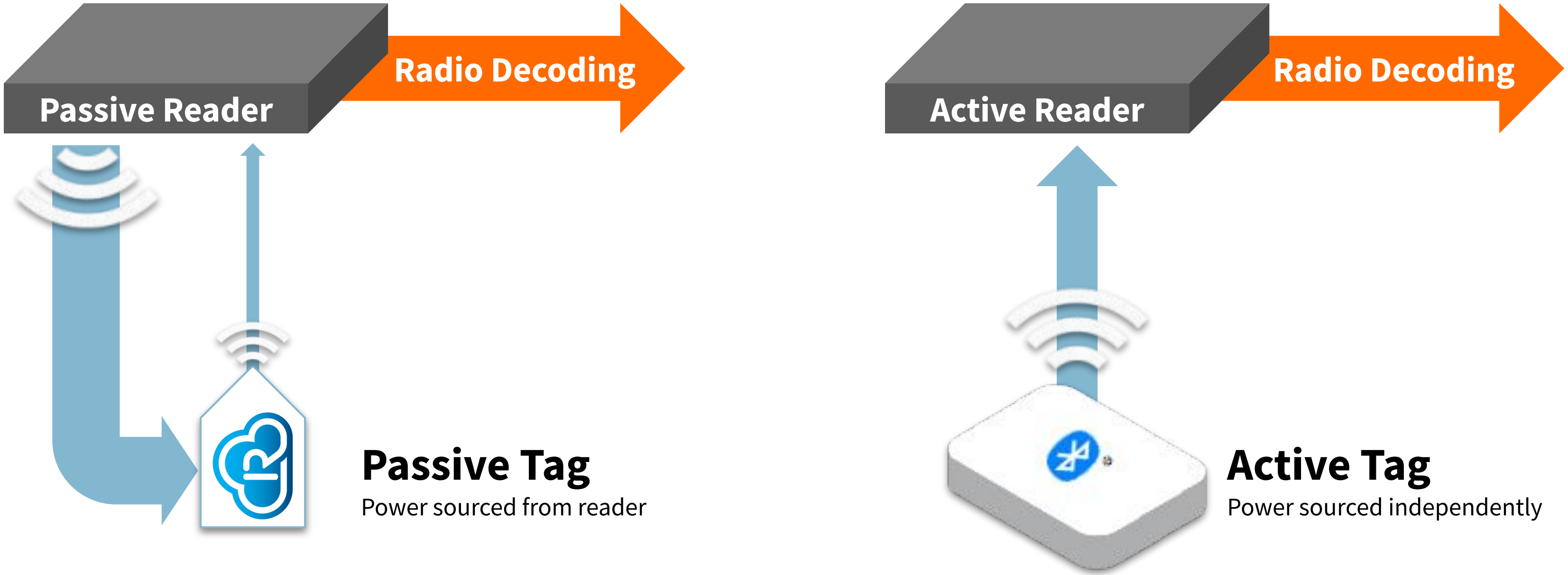
The engineer in us wonders...

How do we do it?

So let's get to it!

What **commonalities** of passive and active RFID systems can we use to our advantage?

Different processes, but **common properties**, for each **radio decoding**



Passive Tag
Power sourced from reader

Active Tag
Power sourced independently

Each **radio decoding** includes:

- ➔ unique **transmitter** (tag) identifier
- ➔ unique **receiver** (reader) identifier
- ➔ **RSSI** (signal strength)
- ➔ **timestamp**

Real-time “table of occupants”

Transmitter ID	Receiver ID	RSSI	Time
11:22:33:44:55:66	aa:bb:cc:dd:ee:ff	-81dBm	12:34:56
99:88:77:66:55:44	aa:bb:cc:dd:ee:ff	-72dBm	12:34:55
21203d2a916e8...	00-1b-c5-09-4...	-96dBm	12:34:56
5490:8256:4169...	00-1b-c5-09-4...	-64dBm	12:34:57
...	...	...	...

Index

Computers understand what/where/when?

Transmitter ID	Receiver ID	RSSI	Time
11:22:33:44:55:66	aa:bb:cc:dd:ee:ff	-81dBm	12:34:56
99:88:77:66:55:44	aa:bb:cc:dd:ee:ff	-72dBm	12:34:55
21203d2a916e8...	00-1b-c5-09-4...	-96dBm	12:34:56
5490:8256:4169...	00-1b-c5-09-4...	-64dBm	12:34:57
...	...	...	...

What?

Where?

When?

What if multiple readers simultaneously decode the same tag? How does this affect **“where”**?

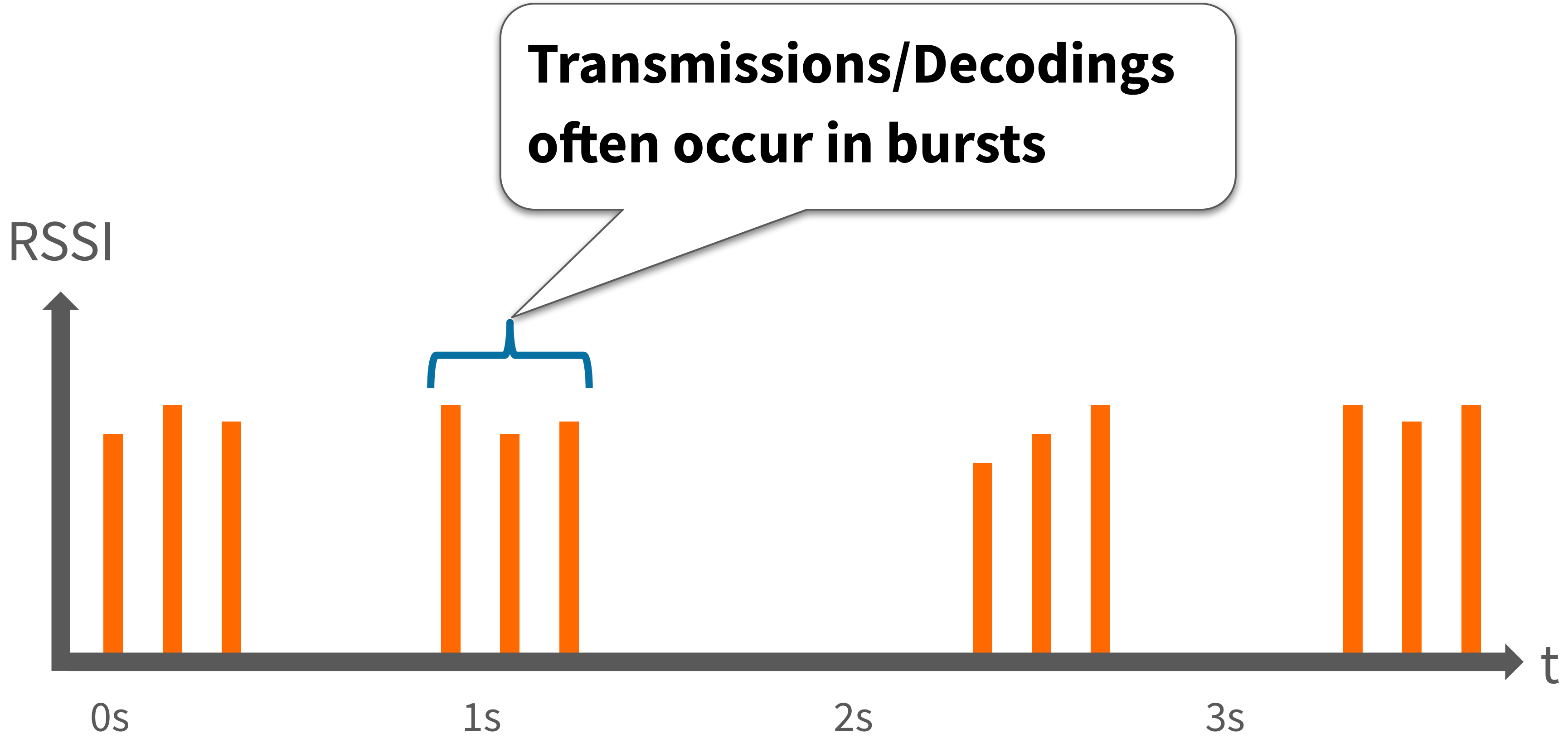
“RSSI Signature”

Receiver ID	RSSI
bb:bb:bb:bb:bb:bb	-72dBm
cc:cc:cc:cc:cc:cc	-83dBm
aa:aa:aa:aa:aa:aa	-91dBm
...	...

Order by decreasing RSSI, assuming strongest is closest

Some tags might be decoded more frequently than required?

How does this affect **"when"**?


Transmissions/Decodings often occur in bursts
RSSI
t
0s
1s
2s
3s

"RSSI Signature" with number of decodings

Receiver ID	RSSI	Decs.
bb:bb:bb:bb:bb:bb	-72dBm	7
cc:cc:cc:cc:cc:cc	-83dBm	7
aa:aa:aa:aa:aa:aa	-91dBm	5
...	...	...

RSSI becomes AVERAGE of all decodings in given time period

Some tags might include a **payload**?

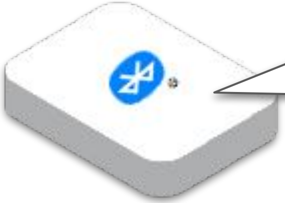
How does this affect **“what”**?

Could this introduce **“how”**?

BLE offers 31 bytes of usable payload*†

iBeacon:
- ➔ 128-bit UUID
- ➔ 16-bit Major
- ➔ 16-bit Minor

Vendor-proprietary:
- ➔ 3-axis acceleration
- ➔ Temp/Humidity
- ➔ Identifiers...



Eddystone:
- ➔ Short URL
- ➔ 128-bit identifier
- ➔ Battery/Temp/...

Many, many, many payloads can be observed, *some* observing open standards, but typically not.

** Bluetooth 5.0 adds provisions for even larger payloads*

† Refer to Jeff's 2017 IEEE RFID tutorial "BLE as Active RFID"

Plenty of payloads with RAIN!

SIMPLE ISO TAG WITH 128 BITS UII

MB-01 PC Bits					MB-01 UII
UII len	UserMem	XI	Standard	AFI	UII as specified by the AFI
01000	0	0	1 (ISO)	8 bits	128 bits as per UII len

SIMPLE GS1 TAG WITH 96 BITS EPC

MB-01 PC Bits					MB-01 UII
EPC len	UserMem	XI	Standard	RFU	EPC as specified by GS1
00110	0	0	0 (GS1)	0x00	96 bits as per EPC len

GS1 OR ISO TAG WITH ISO/IEC 15961 & 15962 DEFINED USER MEMORY DATA

MB-01 PC Bits					MB-01 UII	MB-11 User Memory	
UII/EPC len	UserMem	XI	Standard ISO|GS1	AFI/ RFU	UII/ EPC	DSFID	Data fields according to ISO/IEC 15961 & 15962
00110	1	0	1 or 0	0x00	*96 bits*	8 bits	*≥ 0 bits*

ISO TAG WITH ISO/IEC 20248 DEFINED USER MEMORY DATA

MB-01 PC Bits					MB-01 UII			MB-11 User Memory
UII Len	UserMem	XI	Standard	AFI	DAID	CID	Optional company assigned fields	signature, timestamp Optional company assigned fields
00110	1	0	1 (ISO)	0x92	32, 40 or 48 bits	16 bits	48 bits	≥ 256 bits

GS1 TAG WITH ISO/IEC 20248 DEFINED USER MEMORY DATA

MB-01 PC Bits					MB-01 UII	MB-11 User Memory			
EPC len	UserMem	XI	Standard	RFU	EPC	DSFID	DAID	CID	Signature, timestamp & optional company assigned fields
00110	1	0	1 (GS1)	0x00	*96 bits*	0x11	*32 or 40 bits*	*16 bits*	*≥ 0 bits*

ISO TAG WITH A SIMPLE SENSOR

MB-01 PC Bits					MB-01 UII	MB-01 Simple Sensor Data	XPC
UII len	UserMem	XI	Standard	AFI	UII as specified by the AFI	As specified by ISO	Simple sensor bit set

Source: What is RAIN RFID? p. 42

And if we put it all together?

A standardised radio decoding

Transmitter ID	RSSI Signature	Payloads	Time
11:22:33:44:55:66	[{ bb:bb:bb:bb:bb:bb, -72dBm, 7 }, ...	[02ab1234..., 9143ce2f...]	12:34:56
What?	Where?	How?	When?

An iPhone	In or near Aisle 7	AirPlay, AirDrop	Now
Clothing item	In or near Aisle 7	SKU: 123456	Now

At reelyActive, we created an open standard called **raddec** as an open source library.

github.com/reelyactive/raddec

raddec

```
{
  transmitterId: "aabbccddeeff",
  transmitterIdType: 2,
  rssiSignature: [{
      receiverId: "001bc50940810000",
      receiverIdType: 1,
      rssi: -69,
      numberOfDecodings: 3
  }],
  packets: [ /* As hex strings */ ],
  timestamp: 1343392496789
}
```

Open-standard JSON

Encode

Decode

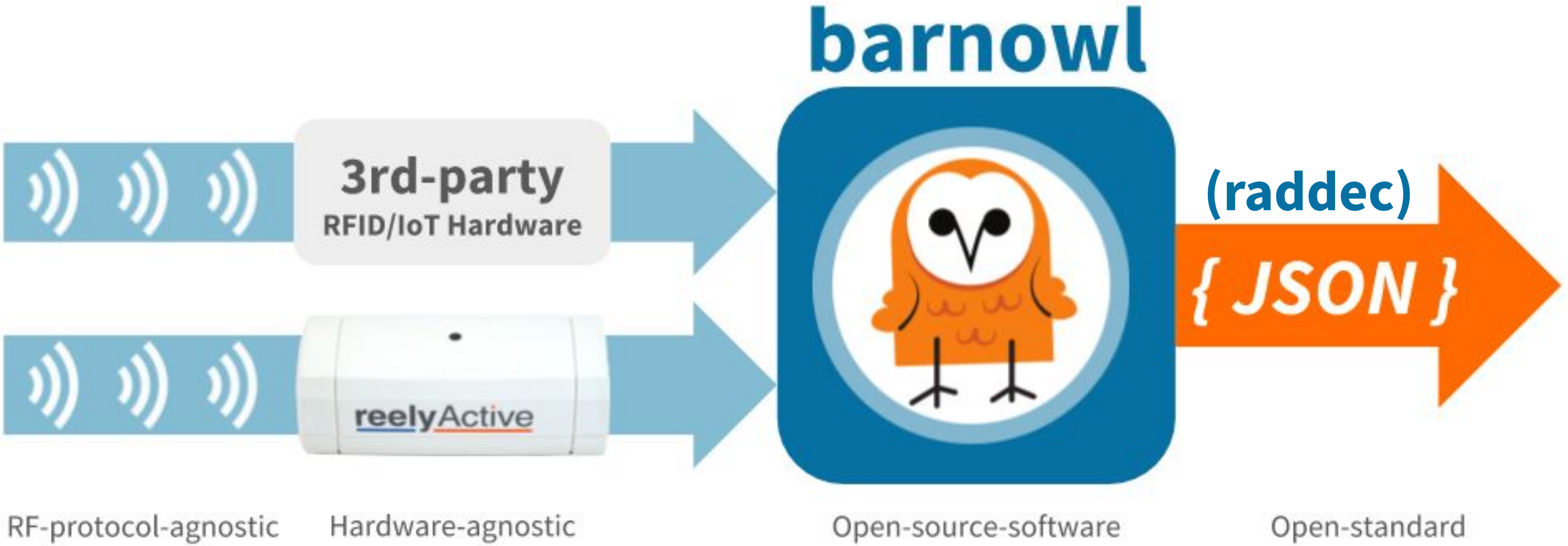
10001e02aabbccddeeff013a0301001bc50940810000f00138c86ebc95c4

Compact binary representation *(ex: 30 bytes)*

Radio decodings manipulated as friendly JSON or compact binary

At reelyActive, we created
open source software
called **barnowl** as middleware.

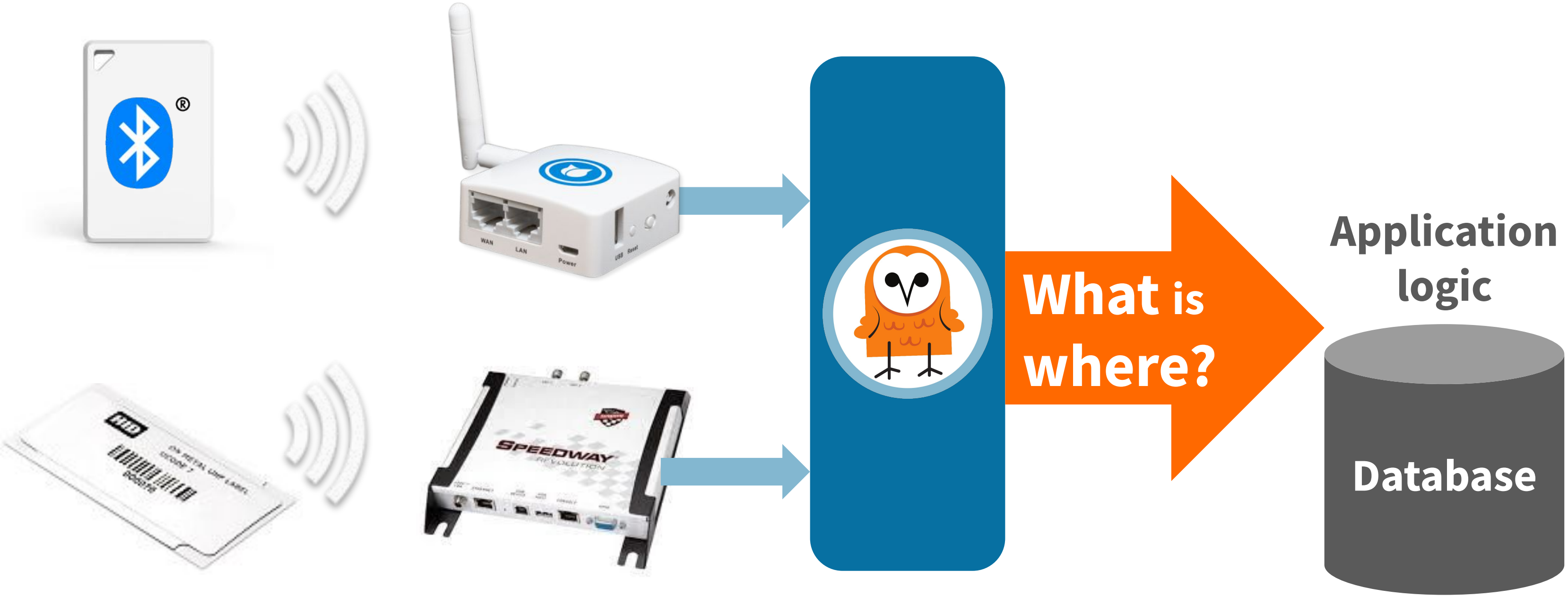
`github.com/reelyactive/barnowl`



RF packets decoded as a real-time JSON event stream

What's a real-world application of **barnowl** and the **raddec** library?

Hardware-agnostic asset tracking



Tags from Vendor A

Readers from Vendor B

Open source software

Application developer

Tracking air movers with BLE beacons

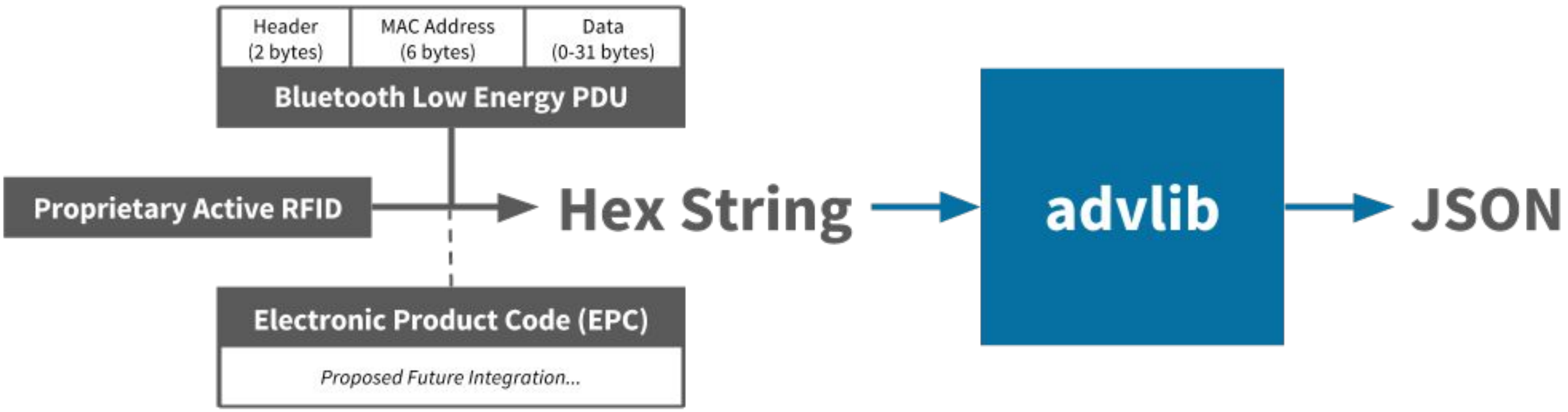
Client-Product-Interaction observation

Collaboration with:
ESG UQÀM
Photo: Samad Rostampour

What about the **payloads** and the sensor data and identifiers they contain?

At reelyActive, we created an open source library called **advlib**, also published at IEEE IoT 2015.

`github.com/reelyactive/advlib`



Header
(2 bytes)
MAC Address
(6 bytes)
Data
(0-31 bytes)
Bluetooth Low Energy PDU
Proprietary Active RFID
Hex String
advlib
JSON
Electronic Product Code (EPC)
Proposed Future Integration...

Transmitter ID	RSSI Signature	Payloads	Time
11:22:33:44:55:66	[{ bb:bb:bb:bb:bb:bb, -72dBm, 7 }, ...	[02ab1234..., 9143ce2f...]	12:34:56

advlib

```
acceleration: [ 1.0, 0.0, 0.0 ],
batteryPercent: 100,
companyName: "Apple, Inc.",
companyIdentifierCode: "004c",
complete16BitUUIDs: "feed"
temperature: 22.859375,
txPower: "0dBm",
url: "https://www.ieee.org/"
```

1. **Who should be responsible** for integrating ***open standards*** into libraries such as advlib?
2. **What are the consequences** of integrating ***closed standards*** into libraries such as advlib?

Aren't payload properties like sensor data ***dynamic*** whereas payload properties like identifiers are ***static***?

Static & Dynamic payload properties

Static

```
acceleration: [ 1.0, 0.0, 0.0 ],
batteryPercent: 100,
companyName: "Apple, Inc.",
companyIdentifierCode: "004c",
complete16BitUUIDs: "feed"
temperature: 22.859375,
txPower: "0dBm",
url: "https://www.ieee.org/"*
```

Dynamic

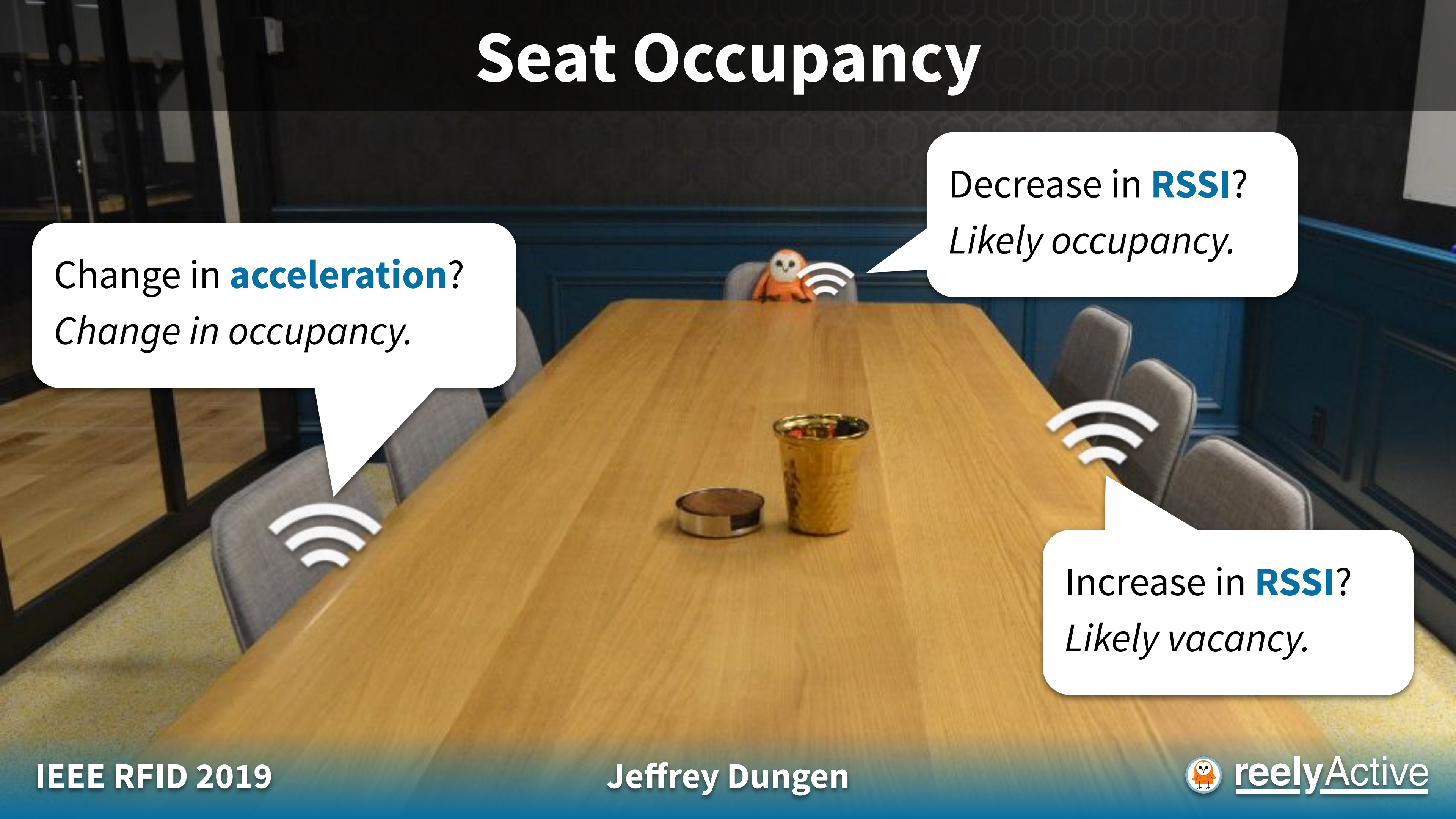
** URL is a powerful concept that we'll return to later…*

What's a real-world application with ***dynamic sensor data*** from **barnowl**, **raddec** and **advlib**?

Workplace Environmental Monitoring

What are the **temperature**, **humidity** and **ambient light** levels whenever a workplace incident occurs?

Is there a correlation?

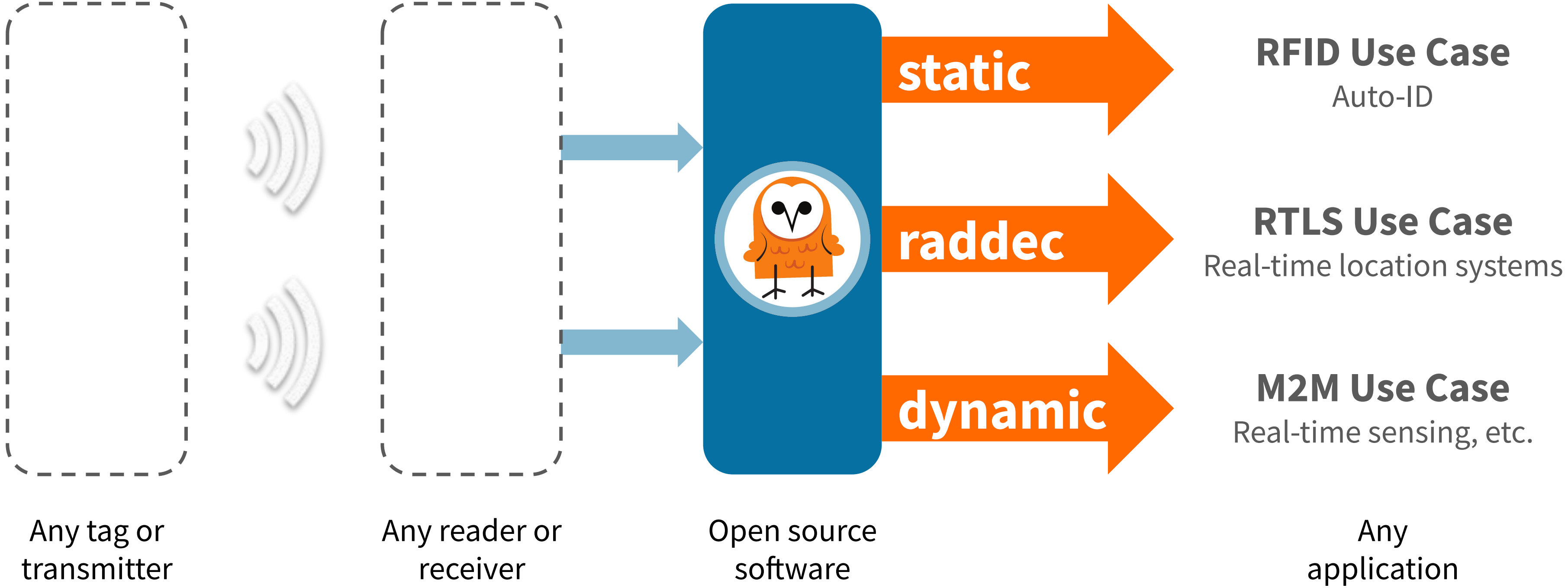

Seat Occupancy
Change in acceleration? Change in occupancy.
Decrease in RSSI? Likely occupancy.
Increase in RSSI? Likely vacancy.
IEEE RFID 2019
Jeffrey Dungen
reelyActive

Putting it all together...

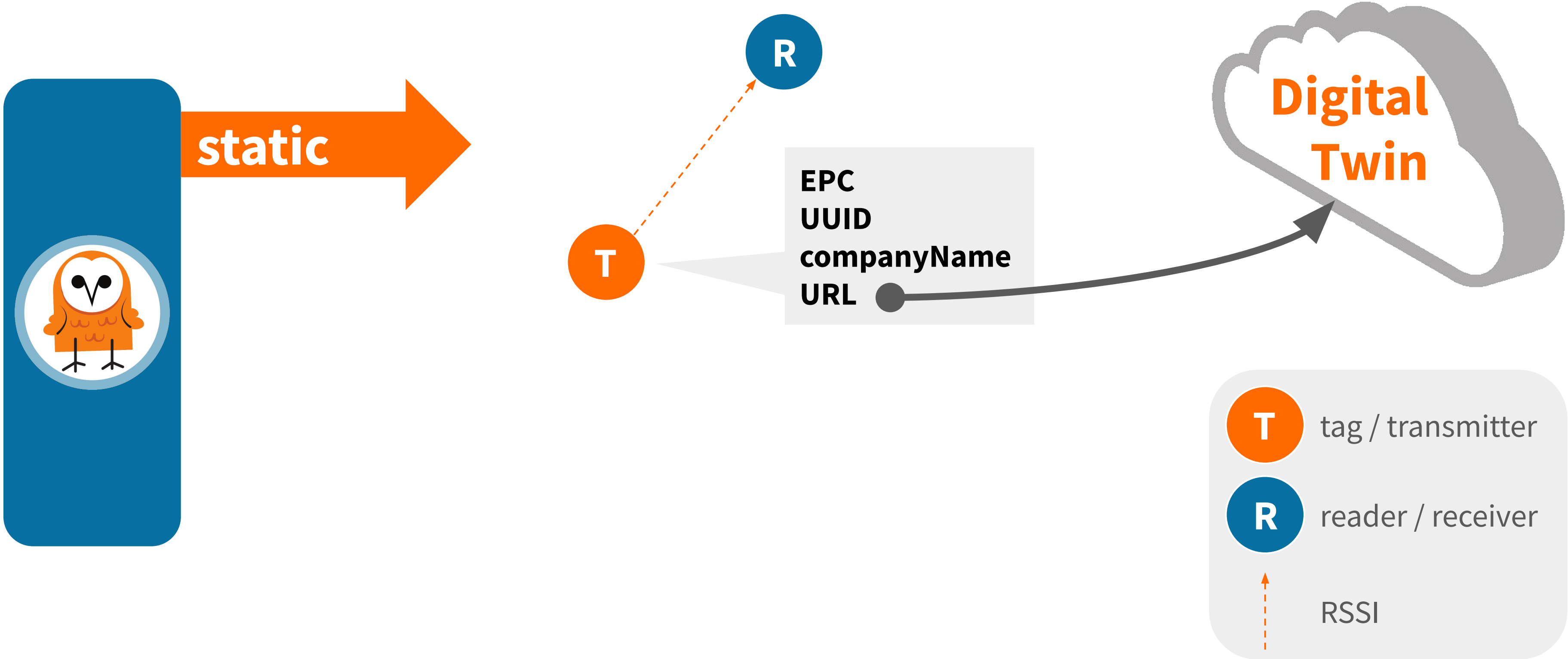
What did we create?

And is it IoT?

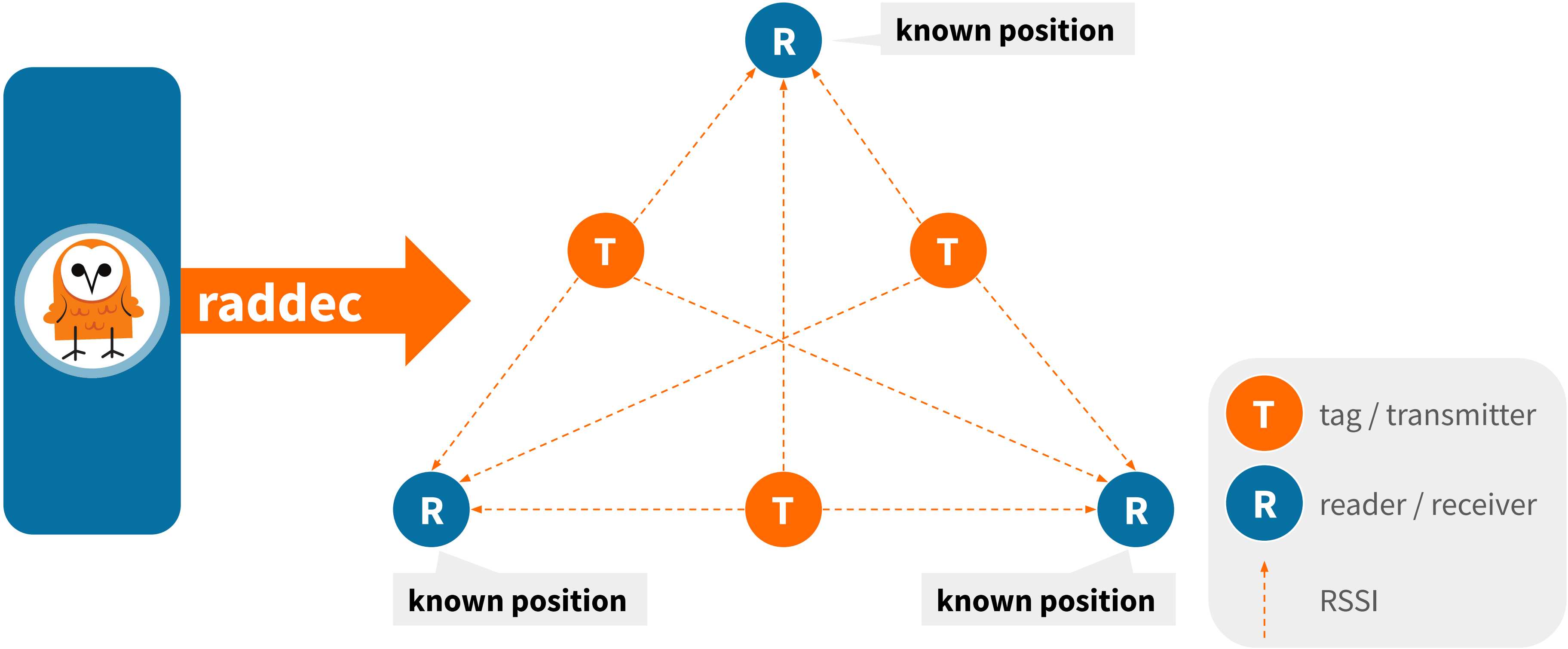
Hardware-agnostic application interface



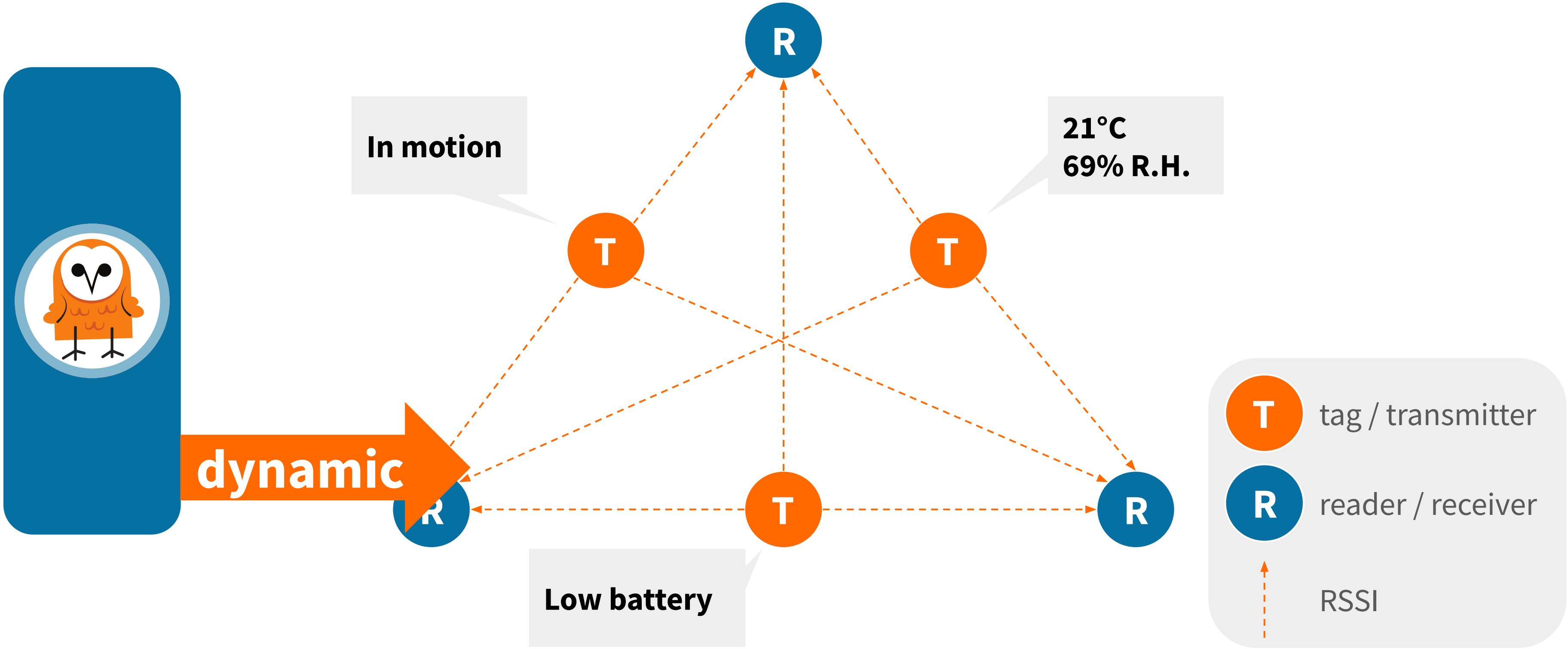
RFID: who/what is present?



RTLS: where are the occupants?



M2M: how are the occupants?



This combination of who/what is where/how is what we call **hyperlocal context**, and it can be encoded using *web standards*.


{
"@context": {
"schema": "http://schema.org/"
},
"@graph": [, , ,]
}
{
"@id": "112233445566:2",
"@type": "schema:Product",
"url": "https://..product/",
"name": "Dynabook",
"sameAs": ["https://../"],
"rtl:nearest": [{ }]
}
{
"@id": "001bc50940810000:1",
"@type": "schema:Place",
"url": "https://..place/",
"name": "Agora",
"geo": { ... "lat": _ , "lon": _ }
}

Tens of billions of devices can be identified, located and understood ***by computers***, without the need for human-entered data, in real-time and in any physical space.

Imagine real-time physical-world search...

Where is the nearest available...

conference room *(3 options)*
salesperson *(7 options)*
electrical outlet with USB *(4 options)*
...more places
...more people
...more things

But what if co-located RFID readers exist in parallel **silos**?

(Which is often the case)

Each RFID system has its own independent hyperlocal context.


My hyperlocal context is available at:
hlc.vendor-a.com
My hyperlocal context is available at:
vendor-b.com/hlc
Discovery
Passive Reader
Active Reader


Exchange
Discovery
Passive Reader
Active Reader

Towards collective hyperlocal contextual awareness among heterogeneous RFID systems

Jeffrey Dungen, Juan Pinazo Neto
reelyActive
Montréal, Québec, Canada
Email: jeff@reelyactive.com, juan@reelyactive.com

***Abstract*—Until recently, cases of independently operated radio frequency identification (RFID) deployments occupying a common space could be considered rare. However, the recent emergence of the RAIN Alliance and Bluetooth Low Energy (BLE) is resulting in the proliferation of fixed and mobile infrastructure for the radio-identification of both things and people through standardised passive and active RFID technologies, respectively. Consequently, today, there are everyday situations where independently operated RFID systems are likely to co-exist, both ephemerally and indefinitely. In this paper, we present a mechanism for mutual discovery and the subsequent exchange of structured data among such colocated, and often heterogeneous, systems. The resulting machine-readable real-time representation of the real-world on a human scale is what we call hyperlocal context, an open, standards-based language for the Internet of Things. We argue that hyperlocal context and the presented mechanisms foster efficient crowd-sensing which combines the complementary characteristics of both active and UHF passive RFID systems. The underlying framework has been successfully implemented in open source software with BLE supported and UHF passive RFID integration in progress. Collaboration among the scientific and industrial communities to advance standards for collective context will only become more critical as the proliferation of RFID infrastructure accelerates.**

I. Introduction

The Internet of Things (IoT) may be defined as the understanding, by computers, of the real world in real time, without the need for human-entered data. Said differently, the IoT is about computers understanding both the spatio-temporal and semantic relationships among physical *things*, as life unfolds. The aforementioned definition was offered by Kevin Ashton, ten years after he coined the phrase in 1999, while working at the MIT Auto-ID lab [1]. At that time, passive radio-frequency identification (RFID) promised to be a key enabling technology for the IoT.

For the fifteen years following, widespread adoption of RFID technologies surely lagged behind the ambitions of the early proponents of the IoT. Nonetheless, in 2014, two significant milestones were reached. First, a group of key stakeholder companies formed the RAIN RFID Alliance [2] [illegible] of billions of [illegible] frequency (UHF) passive RFID tags and readers. And, second, Bluetooth Low Energy (BLE) attained sufficient traction to become, arguably

While RFID technologies are catalysts of the notion of a *physical* web, in a separate sphere, but over roughly the same timeline, the *semantic* web had lived a similar story. In 2014, coincidentally, JSON-LD, a popular enabling standard, became a W3C recommendation [4]. Today, combined with Schema.org, it is championed by industry giants such as Google as the preferred means for representing *things*, including, incidentally, the growing number of people, products and places identified and tracked using RFID technology.

Each of the three aforementioned technologies has achieved independent success. UHF passive RFID is notably used for real-time inventory, leveraging dedicated reader infrastructure. BLE has instead adopted a mobile-centric approach due to its widespread adoption in smartphones, which today represent no fewer than 3.2 billion smart edge devices, a number expected to double by 2021 [5]. And JSON-LD is commonly used by online search engines. In this paper we will argue that the three could, and should, complement one another in the context of IoT, to further the understanding of the real world in real time.

First we present the common characteristics of RFID-based real-time location systems (RTLS) which support the endeavour. We then present the concept of structured, linked data to associate semantic meaning to RFID/RTLS data. Next we combine identity, location and structured data to introduce the concept of hyperlocal context, and present a standards-based mechanism for spontaneous, collective crowd-sensing among independent RFID platforms. Finally, we conclude with practical, real-world applications under exploration and provide recommendations for ongoing development.

II. Real-Time Location

RFID technology, both active and passive, enables the unique identification of devices at a distance by readers. When a reader (which we will instead refer to as *receivers* throughout this paper) receives the radio packet from the identified device, the collected information comprises of:

- the identifier (and any additional payload) of the device
- the identifier of the receiver itself
- the time of reception
- the received signal strength indication (RSSI)

More at:
www.reelyactive.com/science/

Open source software via:
reelyactive.github.io

Now we ask ourselves...

How should we do it?

...knowing one can only delay the inevitable.

WHOSE DATA IS IT ANYWAY?

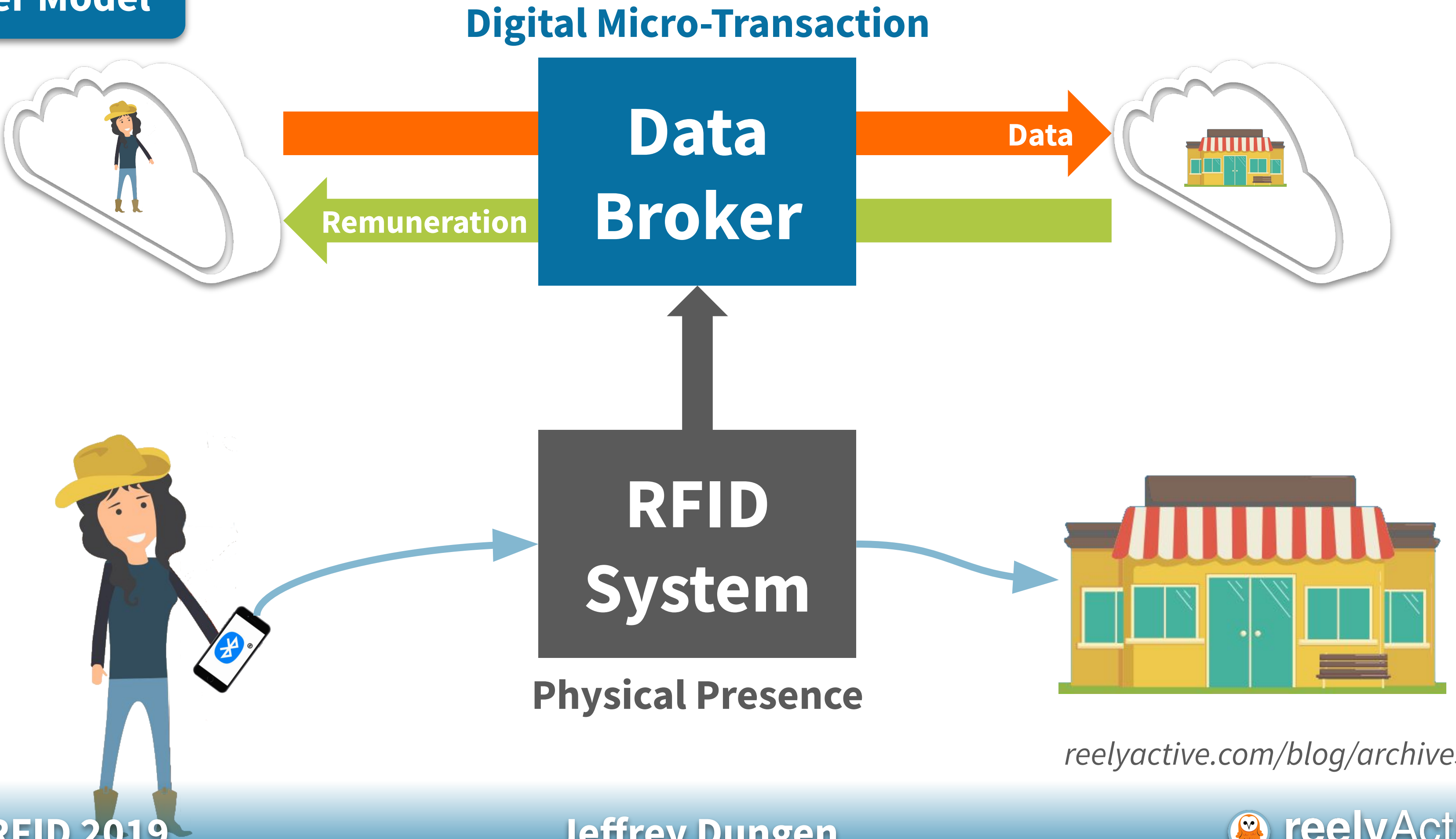
Data is the pollution problem of the information age, and protecting privacy is the environmental challenge. Almost all computers produce information. It stays around, festering. How we deal with it—how we contain it and how we dispose of it—is central to the health of our information economy. Just as we look back today at the early decades of the industrial age and wonder how our ancestors could have ignored pollution in their rush to build an industrial world, our grandchildren will look back at us during these early decades of the information age and judge us on how we addressed the challenge of data collection and misuse.

We should try to make them proud.

—Bruce Schneier

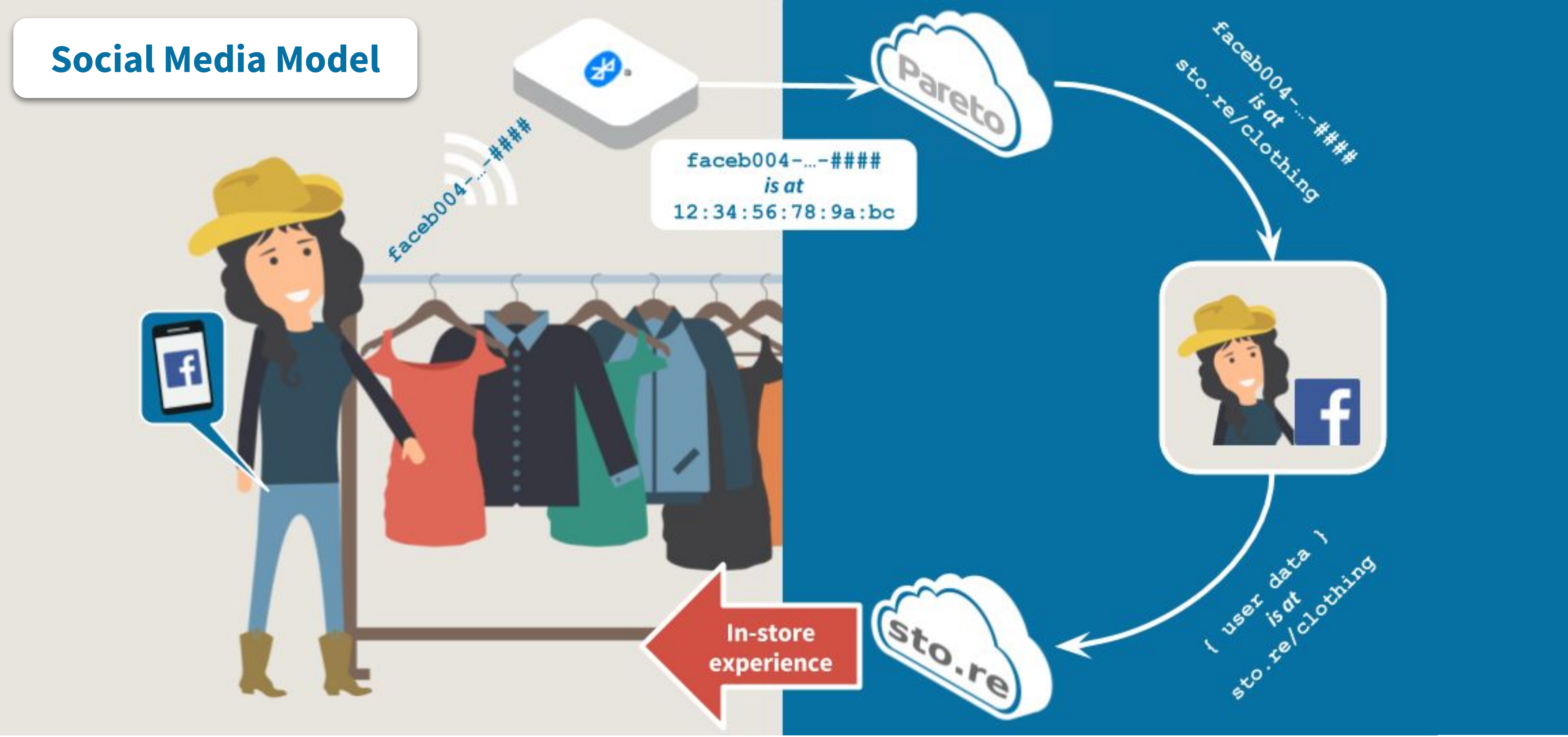
Data and Goliath: The Hidden Battles to Collect your Data and Control your World

Broker Model



reelyactive.com/blog/archives/579

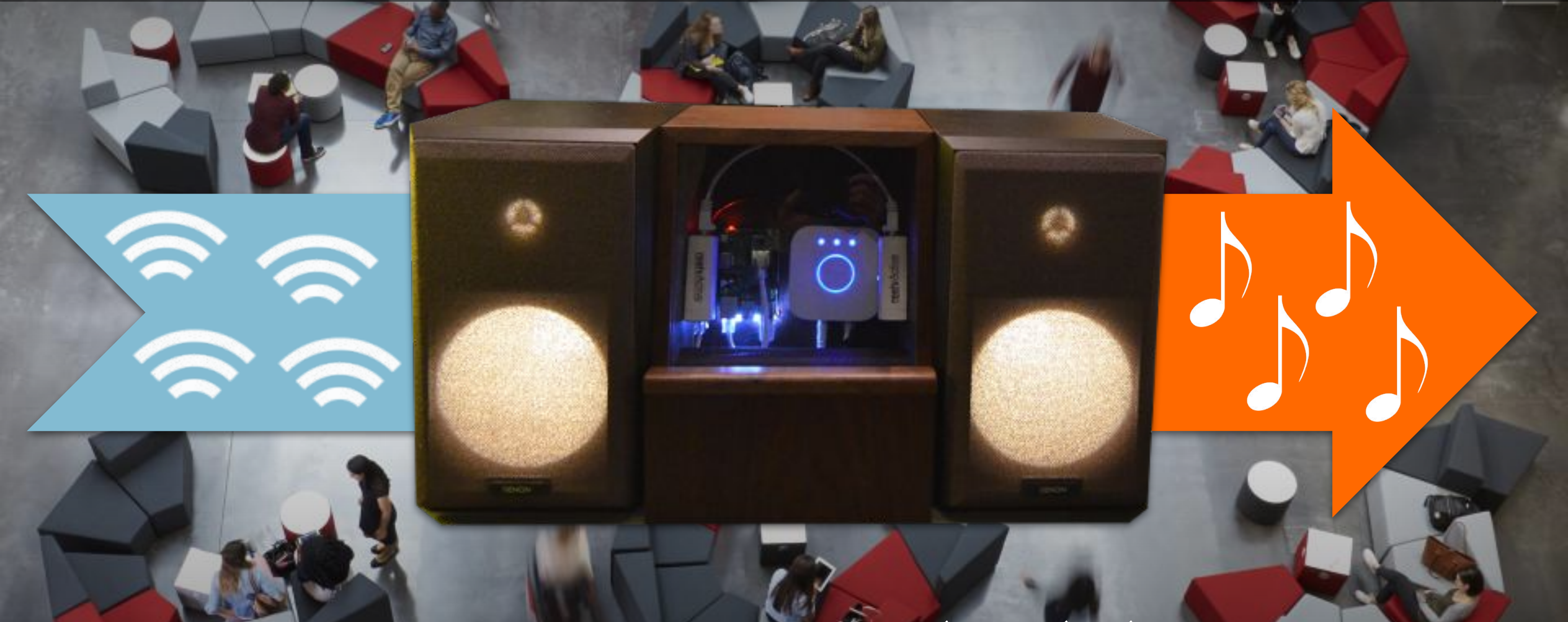
Social Media Model



reelyactive.com/blog/archives/1329

How to increase public consciousness and promote informed adoption?

Art installations accessible to all...



Présences Périphériques: www.reelyactive.com/art/

...visceral experiences of RFID prevalence

GeneraBLE open source software:

github.com/reelyactive/generable

In summary:

- ➔ ~20 Billion radio-identifiable devices shipping annually!
- ➔ Computers can observe occupants of physical spaces
- ➔ Web-standard representation of hyperlocal context
- ➔ Potential for exchange among co-located RFID systems
- ➔ Data ownership and responsibility?
- ➔ How do we foster widespread informed debate?

Co-located RFID Systems Unite!

For questions contact:

Jeffrey Dungen, co-founder & CEO

jeff@reelyactive.com | @reelyActive