

Leafony

Open-Innovation IoT/CPS Platform

- Pioneering Future of IoT/CPS for Everyone, by Everyone-



Trillion-node



Takayasu Sakurai
The University of Tokyo
Professor emeritus

<https://www.trillion-node.org/>
tsakurai@iis.u-tokyo.ac.jp



A part of this document is based on results obtained from a project commissioned by the New Energy and Industrial Technology Development Organization (NEDO).



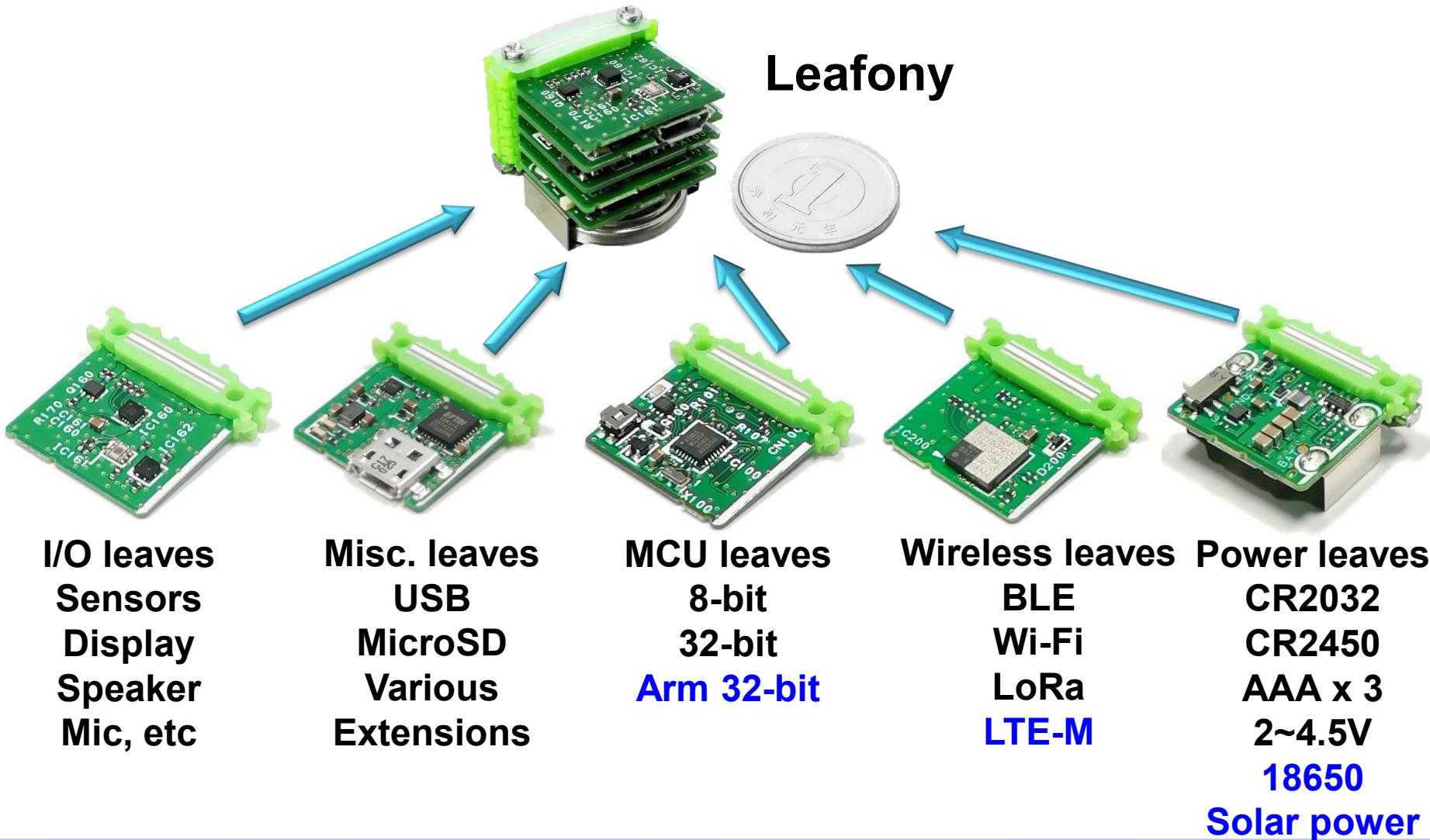
Outline

- **Background**
- **What is Leafony?**
- **Distribution**
- **Usage scenes**
- **Recent advances**



Leafony

Leafony platform: Mix & match functional module called leaf





Outline

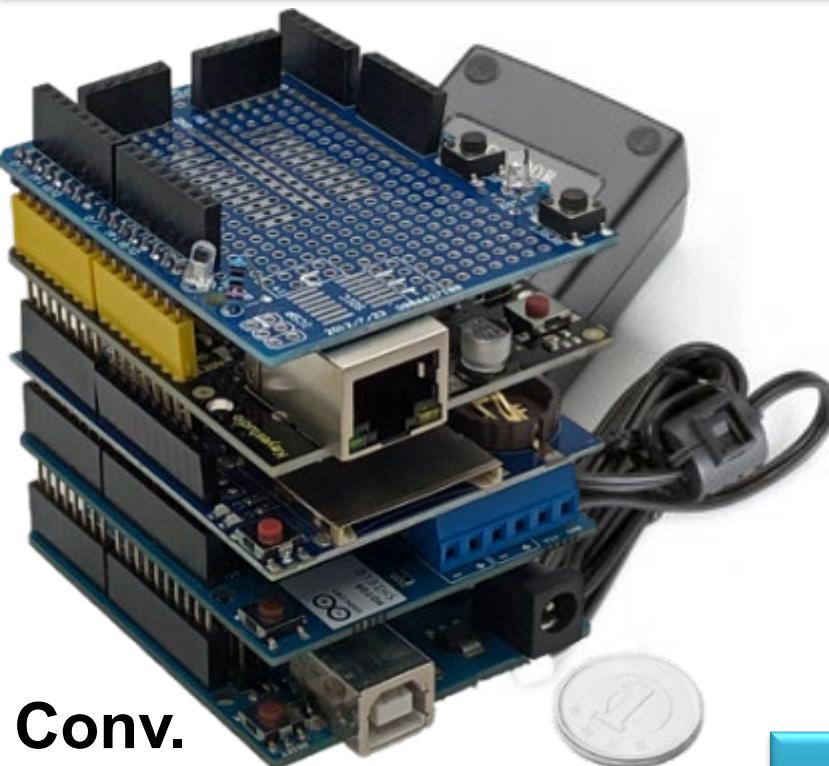
- **Background**
- **What is Leafony?**
- **Distribution**
- **Usage scenes**
- **Recent advances**



Leafony



Leafony is open-innovation platform for IoT



Conv.

Ex. ~500cc, ~300g, ~200mW

No standby



- Ultra-small
- Low-power (batt. operation)
- Open-source HW/SW
- Expandable



Leafony

Ex. ~10cc, ~20g,
~20mW (active)
~50µW (standby)

- Small foot print, no electric outlet, new sensors
→ Suitable for edge-nodes

What is Leafony?

Leafony

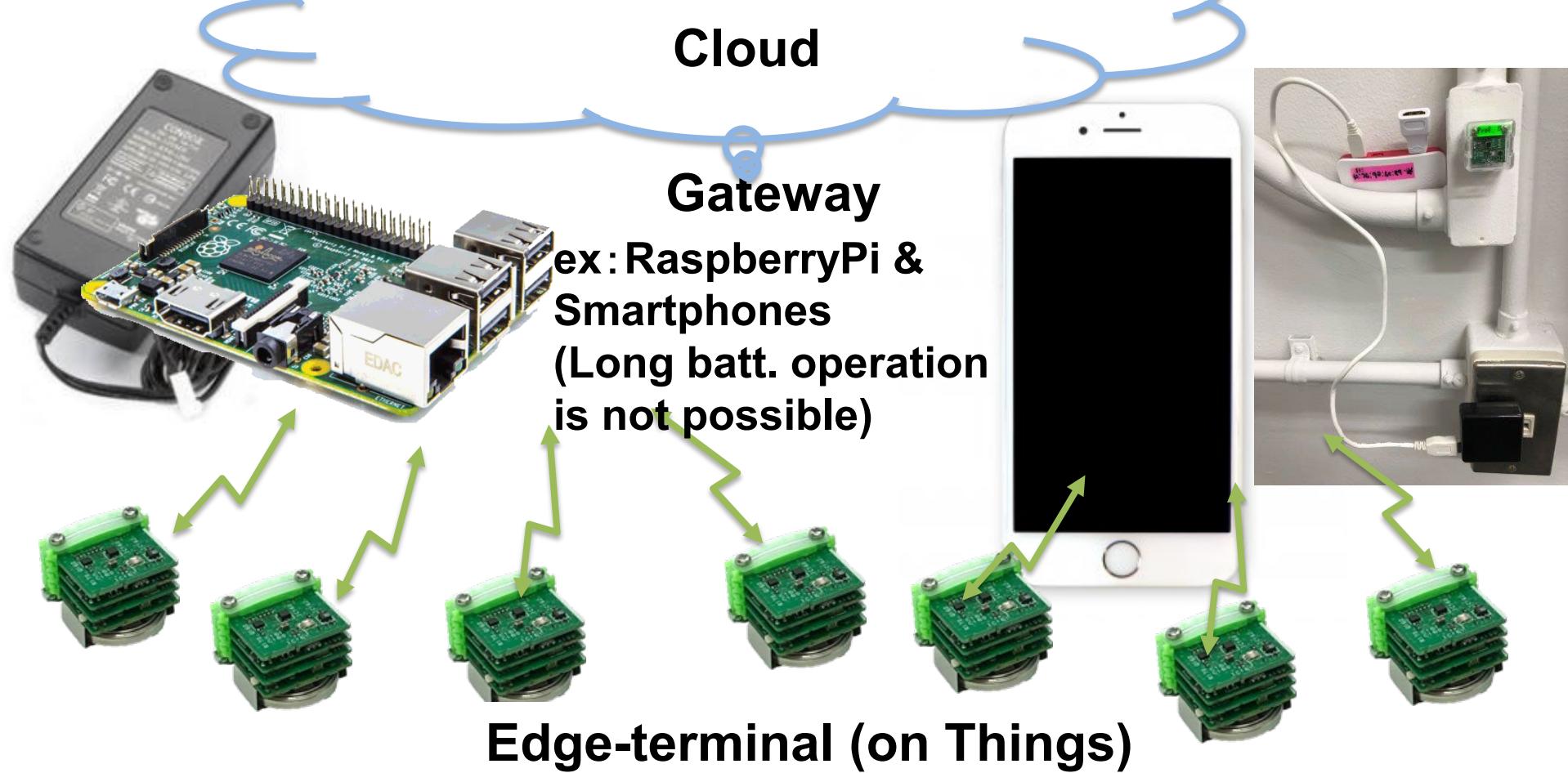
IoT Open Innovation Platform

Connecting technology to applications



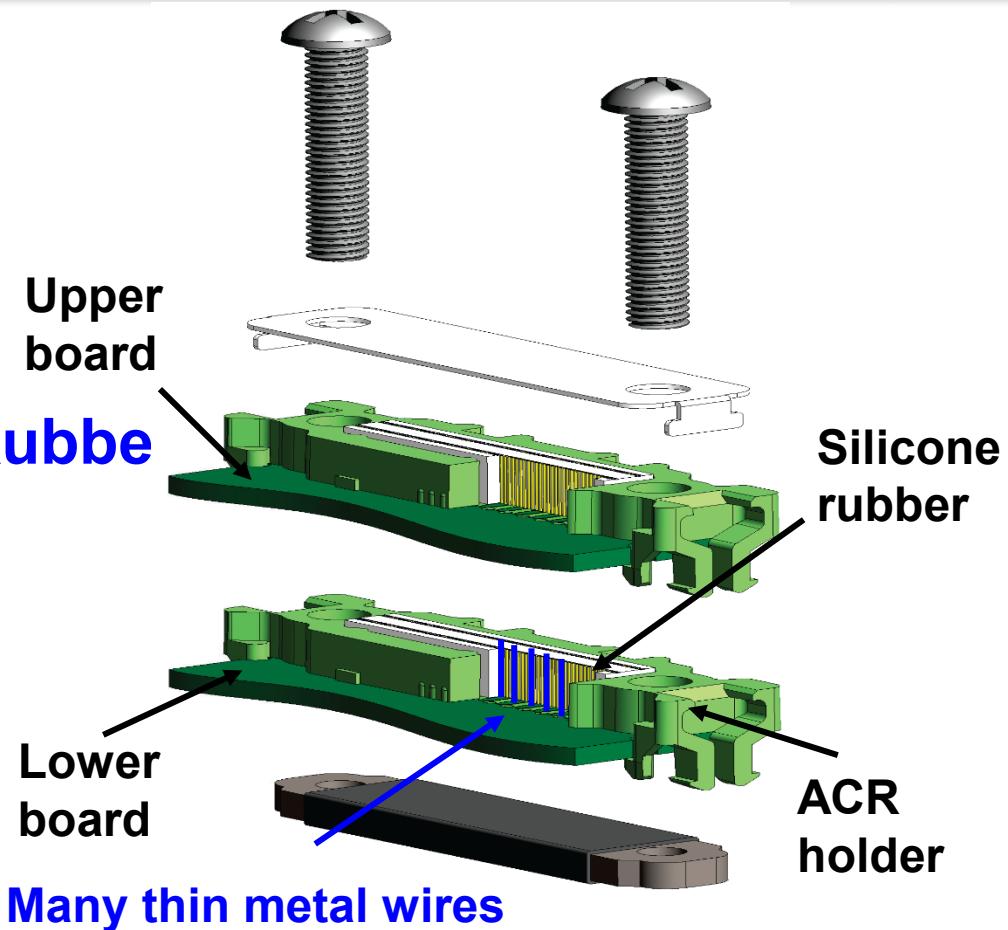
Compact, Low-power
Easy to add original leaf

Leafony creates new IoT scenes collaborating with existing platforms



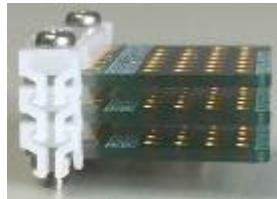
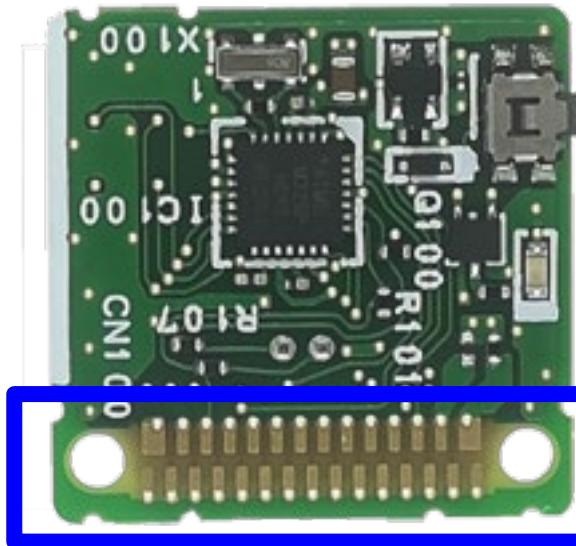
Small size, light, low power, new sensor ← best for edge node

Patented connector w/o soldering



- No need for soldering to attach
- Easy to assemble like a block toy
- No male and female connector → low profile

Connector is the key to compact system



Space between leaves
can be extended by “spacer” leaf.

Physical and electrical
definition only for this area

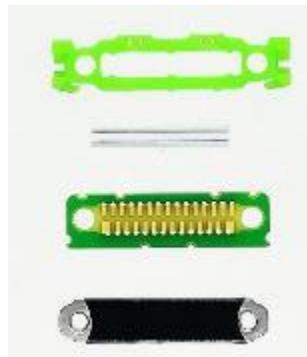
Arbitrary size

Arbitrary # of layers

Design rule is conservative

Everyone can design

Everyone can manufacture



Holder

ACR

Spacer

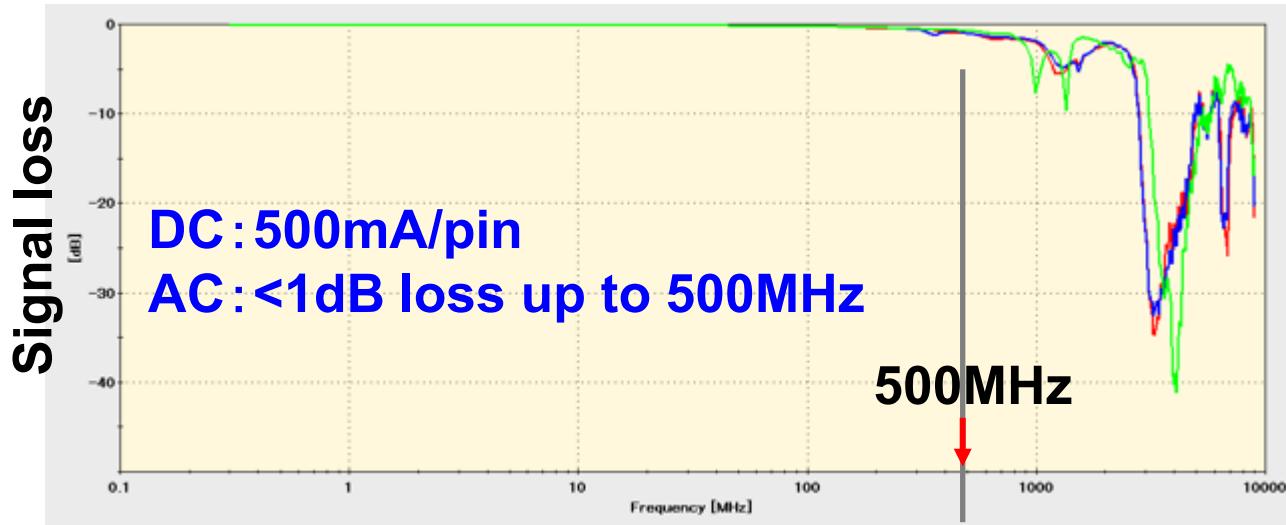
Nut plate



Connector performance

Signal transmission property of connector

4th Leaf

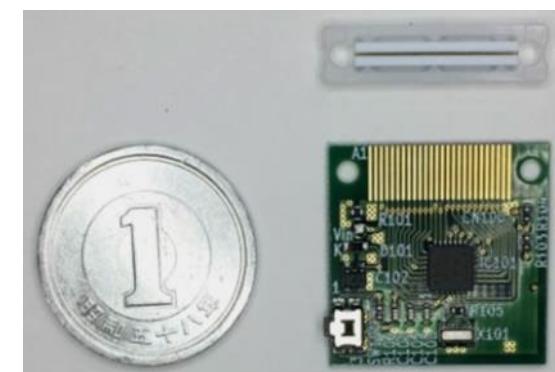
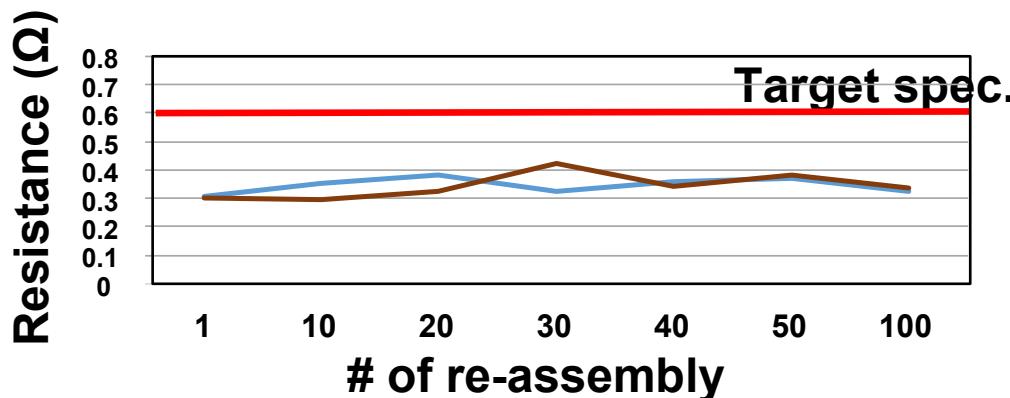


1st Leaf

From 1st to 4th Leaf



Change in resistance on re-assembly



Leaf connection example



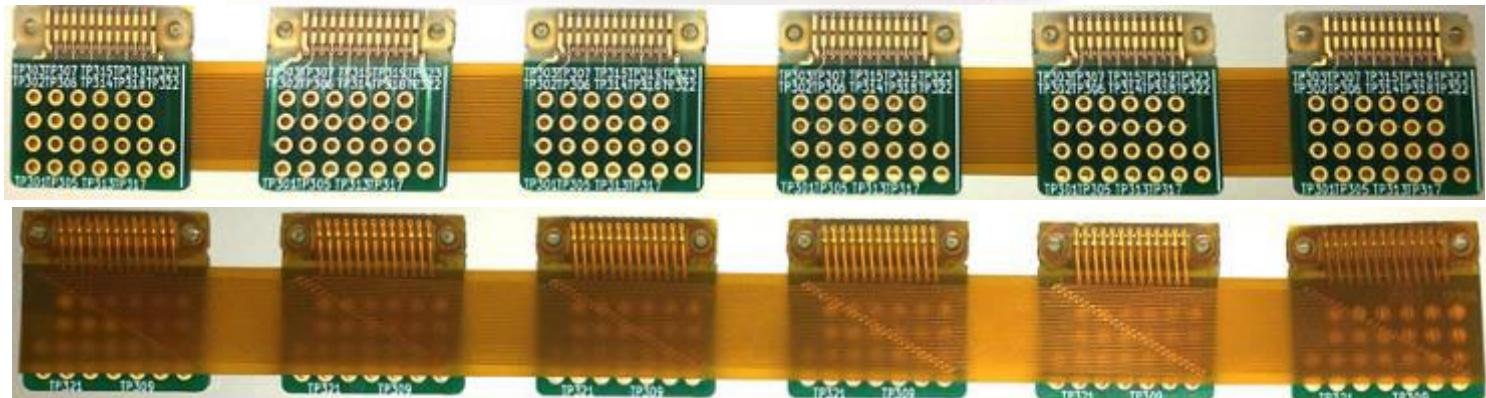
Stacking assembly



Planar type (through flexible PCB)



Try leaf block
on wrist, belt,
necktie, bag, etc



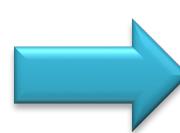
Even thinner assembly by thermocompression bonding

Technology in Leafony: Low-power



Conventional

- Compact & easy to assemble
- Battery operable
- Open-source HW/SW
- Quick to make original leaf

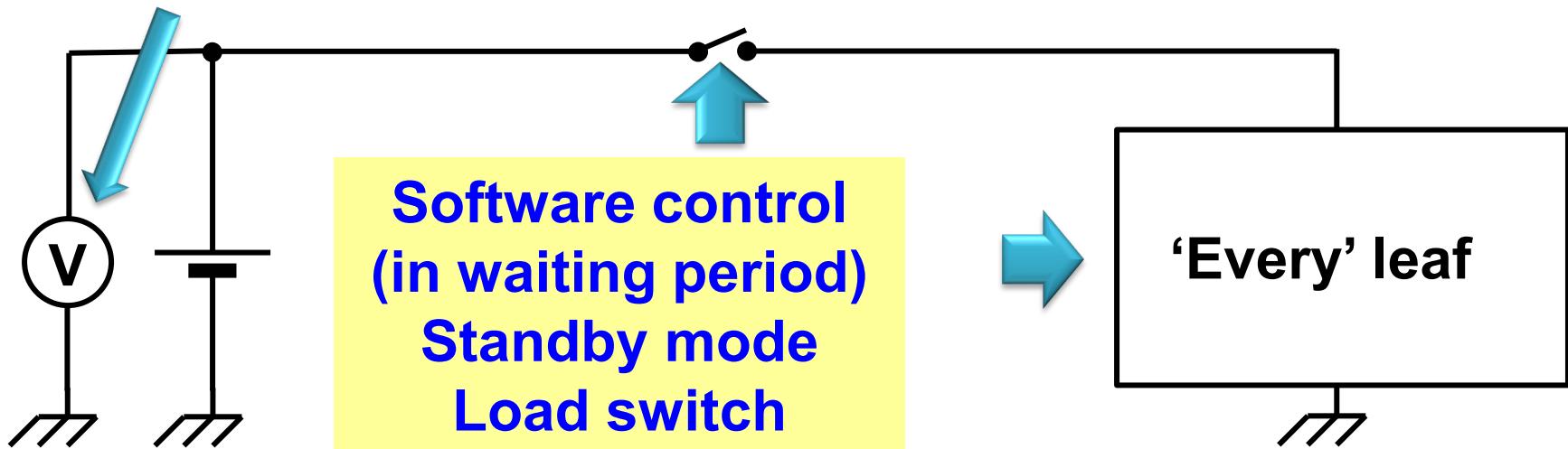


Leafony

Achieving low power by unique architecture

- Standby mode or load switch is implemented in ‘every’ leaf.
Cut out current when system is not active.
- Quick sleep & wakeup operation by H/W + S/W.

Battery voltage monitor



Estimated battery life

Comm. type		BLE beacon	Wi-Fi	LTE-M
MCU		STM32	ESP32	STM32
Sensor		4-sensors*	4-sensors	4-sensors
Active time		1s	10s	14s
Batt. type		CR2032	18650	18650
Interval	10-sec	12	2	2
	1-min	54	8	5
	10-min	186	67	40
	1-hr	241 days	354 days	209 days
	2.4-hr	250	721	420
	1-day	256	2174	1202

*) 4-sensors: temp., humidity, luminance, acceleration

Unit is in days.

Further improvements may occur as S/W is improved.



Technology in Leafony: Open-source



Conventional

- Compact & easy to assemble
- Battery operable
- Open-source HW/SW
- Quick to make original leaf

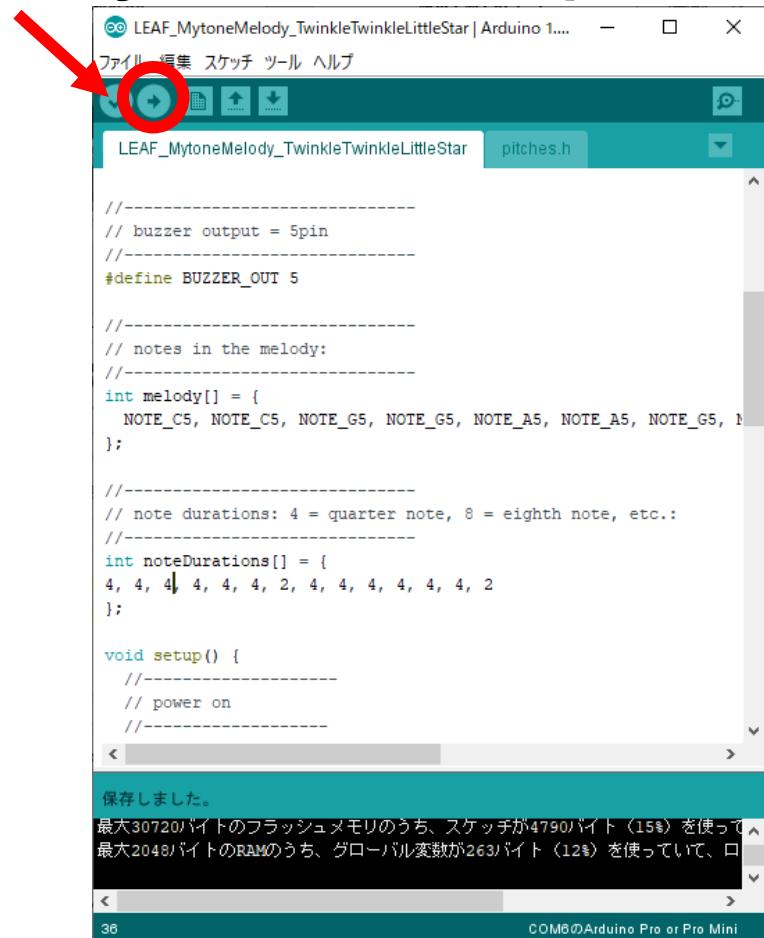


Leafony

Software development is easy

Just push this button.
Compilation, writing to flash
memory, etc are transparent.

- **Arduino compatible:**
**Download tens of thousands
of software for free.**
**(Musicians and artists are
using by themselves.)**
- **Other software development
environments can be used.**
**ex. platformIO, mbed, vendor
specific IDE**



```
LEAF_MytoneMelody_TwinkleTwinkleLittleStar | Arduino 1.8.10
LEAF_MytoneMelody_TwinkleTwinkleLittleStar pitches.h

// -----
// buzzer output = 5pin
// -----
#define BUZZER_OUT 5

// -----
// notes in the melody:
// -----
int melody[] = {
    NOTE_C5, NOTE_C5, NOTE_G5, NOTE_G5, NOTE_A5, NOTE_A5, NOTE_G5, NOTE_A5
};

// -----
// note durations: 4 = quarter note, 8 = eighth note, etc.:
// -----
int noteDurations[] = {
    4, 4, 4, 4, 4, 2, 4, 4, 4, 4, 4, 4, 4, 2
};

void setup() {
    // -----
    // power on
    // -----
}

保存しました。
最大30720バイトのフラッシュメモリのうち、スケッチが4790バイト（15%）を使って
最大2048バイトのRAMのうち、グローバル変数が263バイト（12%）を使っていて、口
```

What is ‘open’ for Leafony

- **Specification, schematic, artwork, software***, application are open. Free of charge including commercial use.

Details of licensing terms, visit

<https://docs.leafony.com/docs/license/>



Leafony

Leafony is a registered trademark.

Only Leafony Systems puts
‘Leafony’ brand on a leaf.



Leafony bus

A blue arrow points from the text below to the highlighted area on the PCB image. The text states:
Artwork for 20mm x 5.5mm bus area is copyrighted and distributed with **CC-BY license**. When it is used, just specify that it is Leafony-bus compatible. Other artwork is not copyrighted.

*MIT license



Outline

- **Background**
- **What is Leafony?**
- **Distribution**
- **Usage scenes**
- **Recent advances**



Leafony

Group of leaves/kits

Basic Kit

Extension Kit

ESP32 Wi-Fi Kit

Communication

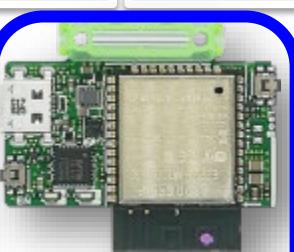


Bluetooth



LoRa

Processor



ESP32
Wi-Fi



AVR
MCU



STM32
MCU



CR2032



2~4.5V



CR2450

Misc.



USB



RTC &
microSD



Four
sensors



Speaker
IR sensor



LED
Mic

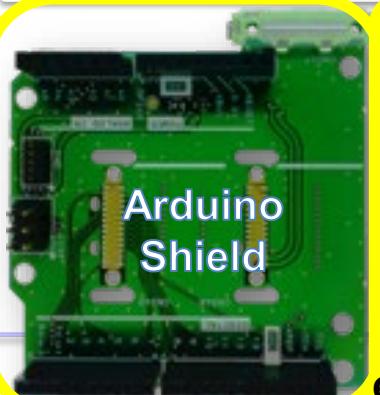


Display



AA

Extender



Arduino
Shield



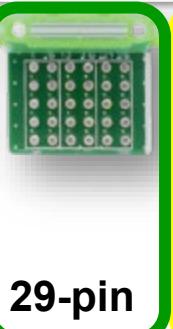
Lateral
extender



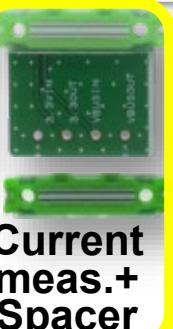
Vertical
extender



29-pin
header



29-pin



Current
meas.+
Spacer



Grove
& 5V



Conn.
x 10



Nut
plate
x 10

BLE, Wi-Fi, LoRa, LTE-M

© 2023 Trillion-Node Engine Project

頒布キット 3種類

Basic Kit 2

Coin battery operation, BLE basic kit



Leafony

ESP32 Wi-Fi Kit 2

ESP32(32bit CPU), Wi-Fi powerful kit
(AAA battery operation)



Extension Kit

Extension leaves kit





Outline

- **Background**
- **What is Leafony?**
- **Distribution**
- **Usage scenes**
- **Recent advances**



Leafony

Usage scenes

Companies

Proof of Concept (PoC)

Promotion tool

Demonstration of products

Reference design

Education / University

IoT education

Research & experiment



Users' voice from educational field

- 当方は、Wi-Fi と BLE の電波を計測する混雑度センサを開発し、九州大学伊都キャンパス内のバス停と食堂、さらに、昭和バスの車両に搭載しています。これまで Raspberry Pi に、LTE モジュールを追加する形であったため、サイズおよび電源確保の観点で問題がありました。今回、LTE-M と ESP32 が搭載された Leafony によって、体積で 1/10 程度になるとともに、バッテリ駆動も可能となり、どこでも手軽に混雑度センサを設置できるようになります。〈九州大学 教授 荒川 豊 先生〉



- 当校 AI システム科では Edge AI を含めた IoT をテーマとした授業も展開しており、これまで他の製品を利用して授業を進めて参りました。今回参加したナノコン応用コンテストで初めて Leafony に触れましたが、基本性能の高さ、機能拡張の豊富さ / 容易さ、開発環境の完備、ドキュメント / 利用事例の豊富さなどにより、学生さんのアイデアをとてもスムーズに形にすることができたと思います。〈日本電子専門学校 AI システム科 安中 悟 先生〉



- 当研究室では、地盤の上に構造物を建て、その上で安心して人々が生活するために、それを支える地盤の特性(強度・変形)を調べる研究を行っています。これまで傾斜の経過を簡易的にモニタリングする技術がありませんでしたが、Leafony の活用により、地盤がどのように傾斜していくかを 0.2 度の高精度で観測できるセンサを開発することができ、研究室の成果に繋がりました。〈東海大学 教授 杉山 太宏 先生〉

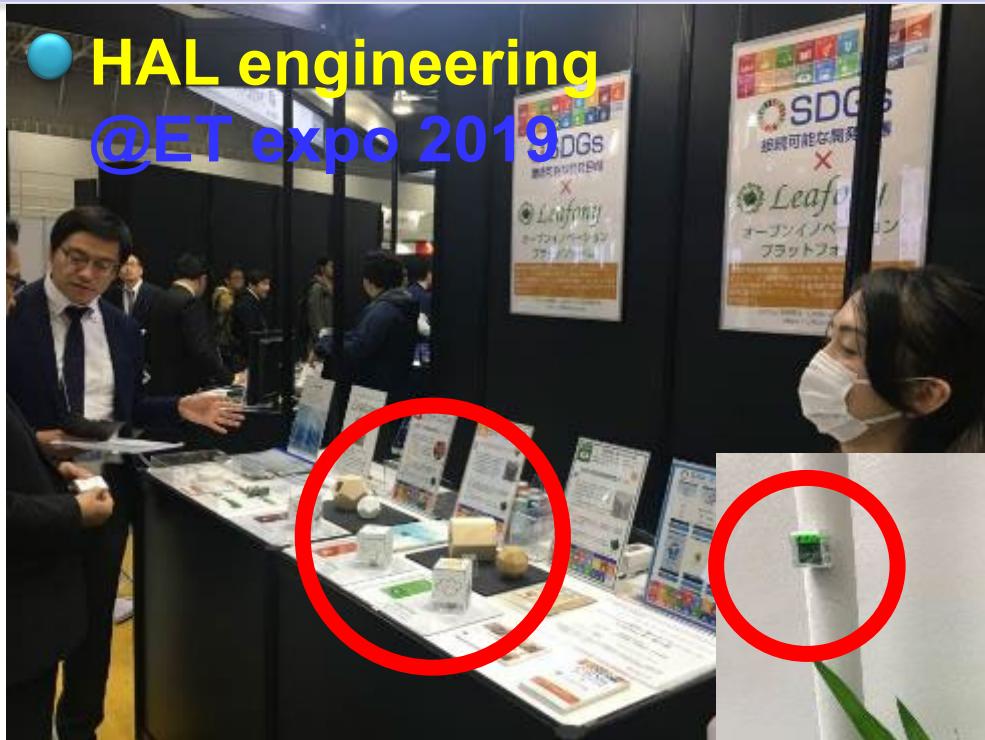


- 当研究室では、IoT サービスとしてヘルスケア機能を持つ RFID タグやスマートフォンと連携可能なセンサー モジュールなどの開発を進めてきましたが、デバイスの大きさや既存マイコンの消費電力の高さが課題でした。2015 年頃から消費電力が低い ARM 系マイコンへの実装環境を変更しましたが技術的ハンドルの高さも実感していました。Leafony は小型・低消費マイコン等を簡単に利用できる環境を準備されており、サービスを短期間で実現できる点は大きなメリットを感じています。〈愛知工業大学 准教授 内藤 克浩 先生〉



Systems integrator deploys Leafony

- HAL engineering
@ET expo 2019



- ELECOM
@ET expo 2019



- IoT-EX
@COMMA house

https://www.youtube.com/watch?v=pL0QEK2C_U

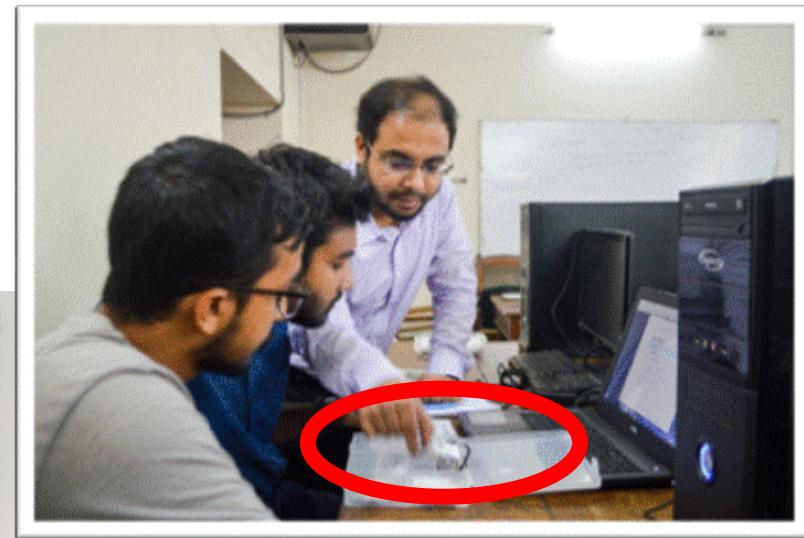


International collaboration with Dhaka Univ.

Generality independent from language

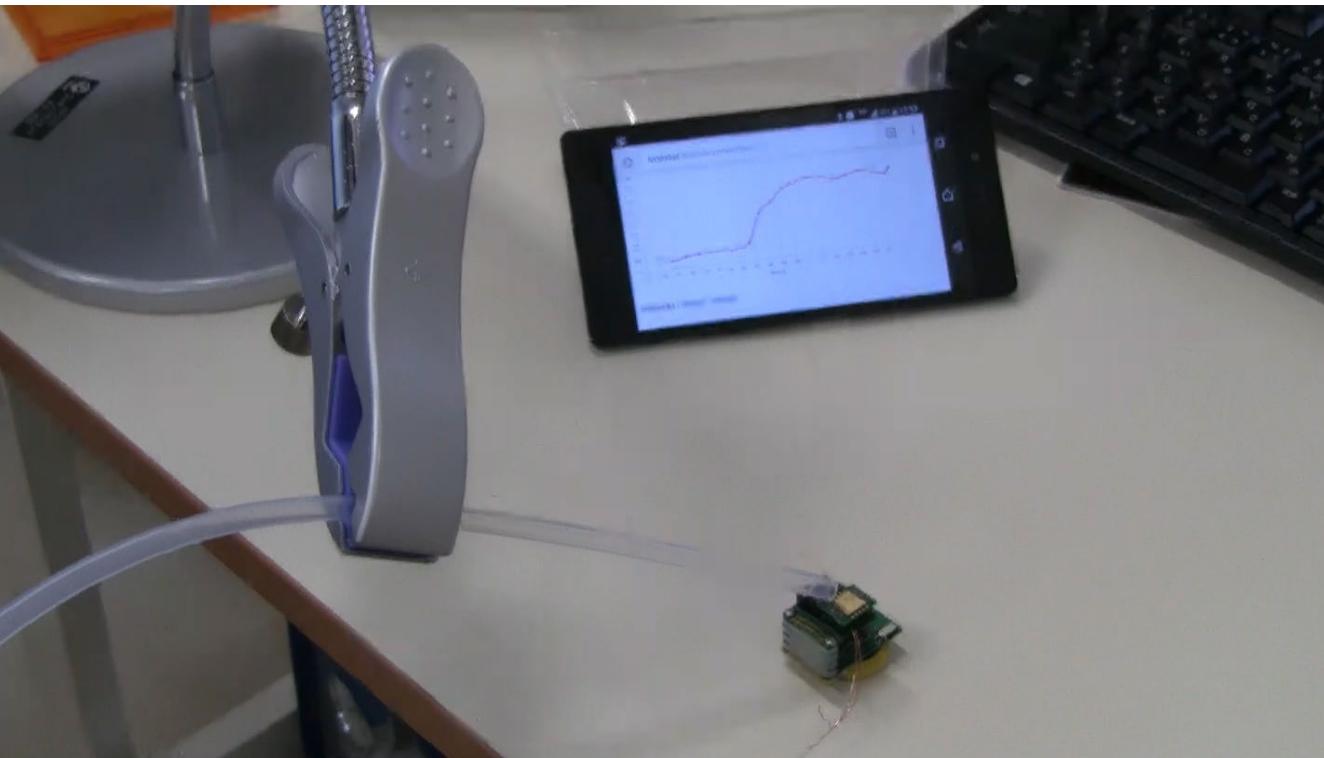


Wearable by Leafony
→ IEEE paper



Breath sensor demo based using Leafony

- Breath contains H_2 only when food reaches intestine.
 H_2 sensor gets portable enabling to sense breath.
- Received **demonstration award at VLSI Symposia** using Leafony platform.



Drone R&D using LoRa leaves



Leaf examples from other organizations

Nexty



32-bit
MCU1



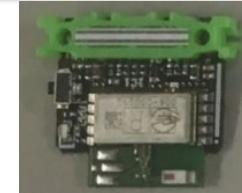
32-bit
MCU2



Low-power
Accelerometer
Sensor



Sensor



BLE

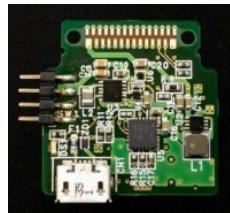


USB

Ricoh



Solar battery
Power supply



Power
Supply

Keio1



NO_x
Sensor

Keio2



CO₂
Sensor

U.Tokyo



H₂ Sensor
Demo prize in conf.

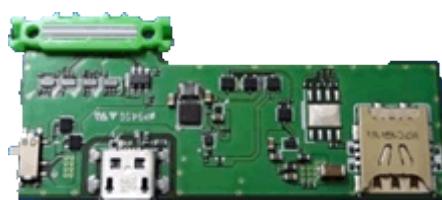
FPGA

Toshiba



Fingerprint
Sensor

KDDI



Cellular LTE-M

Sony



Bridge between
Platforms

Trillion-node study group

- Companies and organizations related to infrastructure, plant, system, carrier, trading, electric, semiconductor, component, jisso, etc.



Twice a year
Next event: Feb.



<https://www.trillion-node.org/>



- Early access to Leafony R&D
- Leafony IoT use-case exchange
- Connecting app side and tech side

Trillion-node study group (twice a year)

- Companies and organizations related to infrastructure, plant, system, carrier, trading, electric, semiconductor, component, jisso, etc.



Next is Sept. 8 '23

参加費75,000円



<https://www.trillion-node.org/>



- Early access to Leafony advances
- Introducing Leafony IoT use-cases
- Lending leaves not in market (LTE-M, LoRa...)
- Connecting app side and tech side

Organizations supporting Leafony

1	IoT-EX株式会社	29	金沢大学振動発電開発グループ
2	KDDI株式会社	30	慶應義塾大学SFC研究所ソーシャルファブリケーション・ラボ
3	LEAFONY SYSTEMS 株式会社	31	慶應大学SFC
4	Mouser Japan GK	32	計画工学研究所
5	Quest7	33	埼玉大学
6	STマイクロエレクトロニクス株式会社	34	三菱ケミカルエンジニアリング株式会社
7	エイミー株式会社	35	新光電気工業株式会社
8	システムニコル株式会社	36	新日本無線株式会社
9	セイコーホールディングス株式会社	37	青葉電子株式会社
10	ソニーセミコンダクタソリューションズ株式会社	38	川崎重工業株式会社
11	ディー・クルー・テクノロジーズ株式会社	39	大和無線電機株式会社
12	パナソニック株式会社	40	地方独立行政法人東京都立産業技術研究センター
13	日清紡マイクロデバイス株式会社	41	中部電力パワーグリッド株式会社
14	リンテック株式会社	42	長野県工業技術総合センター
15	夏目光学 株式会社	43	東京エレクトロンデバイス株式会社
16	株式会社AOKI	44	東京大学 工学系研究科
17	株式会社FUJI	45	東京大学協創プラットフォーム開発株式会社
18	株式会社SUSUBOX	46	東芝インフラシステムズ株式会社
19	株式会社アド・ソー	47	東芝テック株式会社
20	株式会社エイチアイ	48	東芝デバイス＆ストレージ株式会社
21	株式会社ジェイエスピー	49	東芝デベロップメントエンジニアリング株式会社
22	株式会社チップワンストップ	50	東電設計株式会社
23	株式会社ネクスティ エレクトロニクス	51	日昭無線株式会社
24	株式会社リサシステム	52	日本ガイシ株式会社
25	株式会社図研	53	日本航空電子工業株式会社
26	株式会社創成電子	54	富士通クライアントコンピューティング株式会社
27	株式会社椿本チェイン	55	明光電子株式会社
28	株式会社東和テック	56	有限会社ケイ・ピー・ディ



Outline

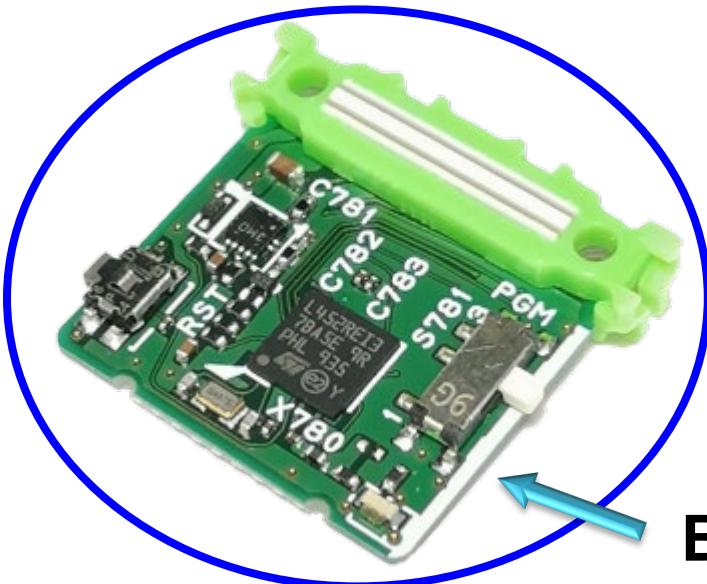
- **Background**
- **What is Leafony?**
- **Distribution**
- **Usage scenes**
- **Recent advances**



Leafony

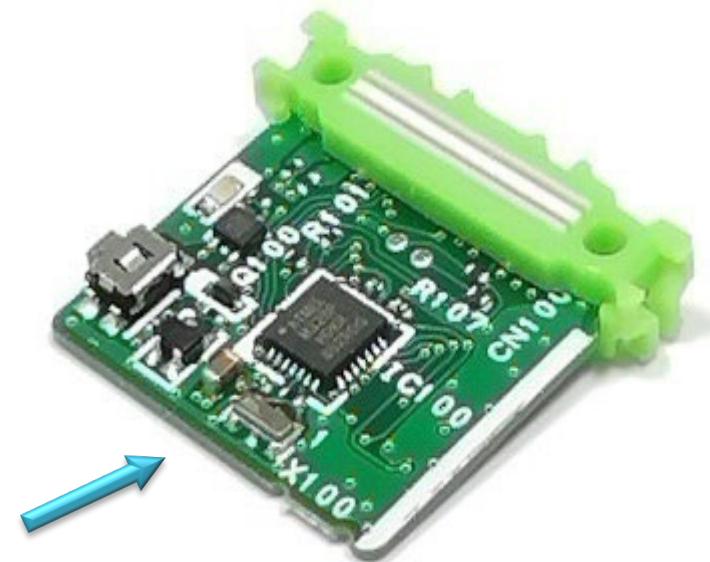
ARM 32-bit MCU leaf

- STmicro 32-bit MCU (STM32L452RE) frequently used by IoT systems and Arduino IDE compatible
- 32-bit STM32, Active: 8.5mA@80MHz, st'by: 0.5µA
8-bit AVR Active: 5.2mA@8MHz, st'by: 4.7µA



32-bit STM32 MCU leaf
High

Both in
Basic Kit 2



8-bit AVR MCU leaf
Max. compatibility w/ Arduino

Edge-AI demo: face detection by STM32 leaf



Ultra-small LTE-M leaf by KDDI

Lending to members of
Trillion-node RG

Area: ~1/8
Power: ~1/2

Conv.: 48 x 108 mm²

Sleep: 0.09mA

Active: 300mA

New: 23 x 30 mm²

Sleep: 0.048mA

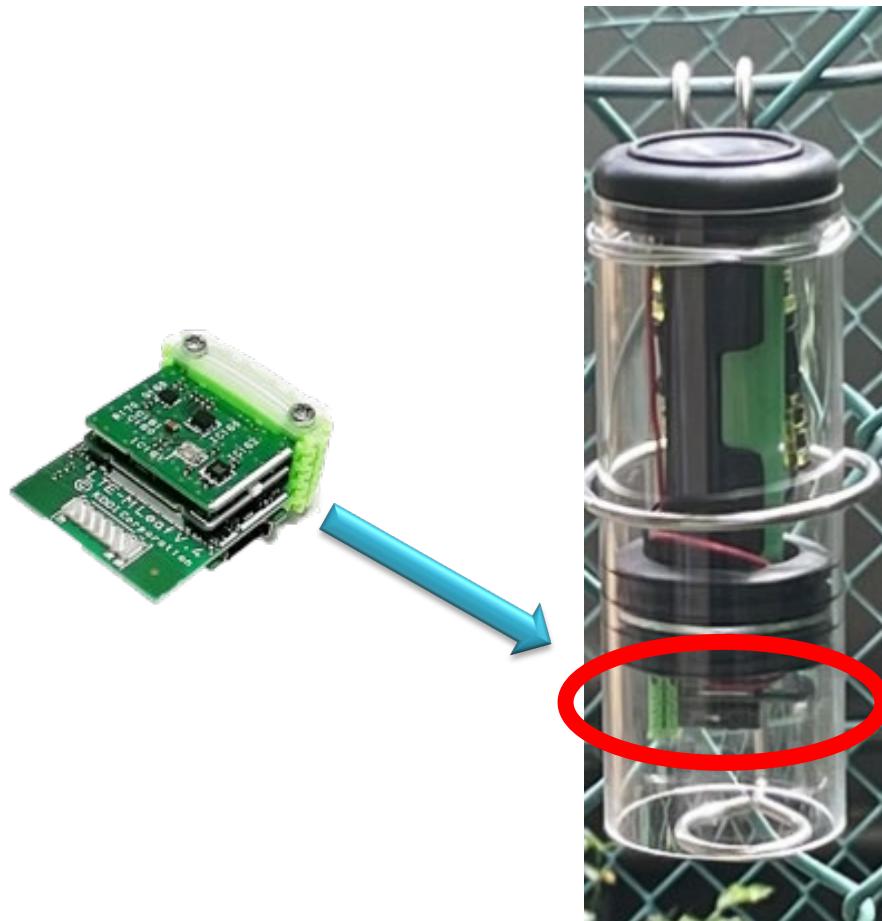
Active: 170mA

Setup example

© 2023 Trillion-Node Engine Project

36

18650 battery + LTE-M leaf



フィールドに設置

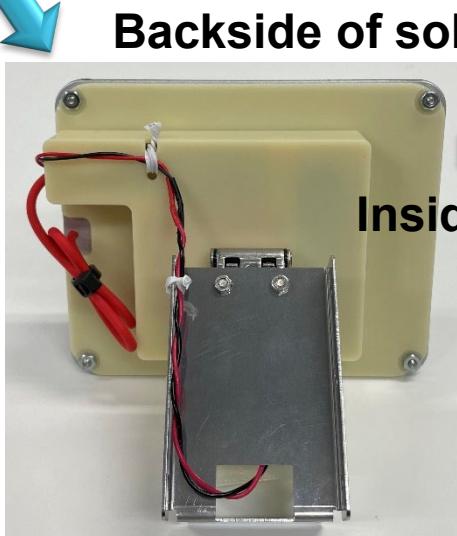
© 2023 Trillion-Node Engine Project

Palm sized solar + LTE-M IoT

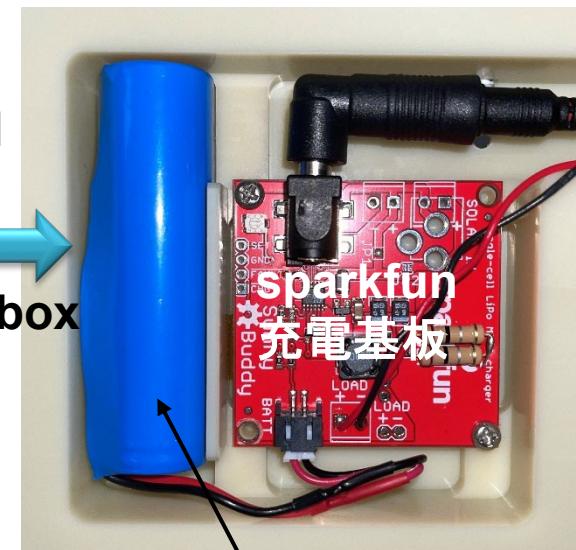
- Data is uploaded to cloud through LTE-M
- 2 days to charge battery to the full.
40-days battery life time is measured
with data collection with 10-min intervals.



Leafony
in radiation shield

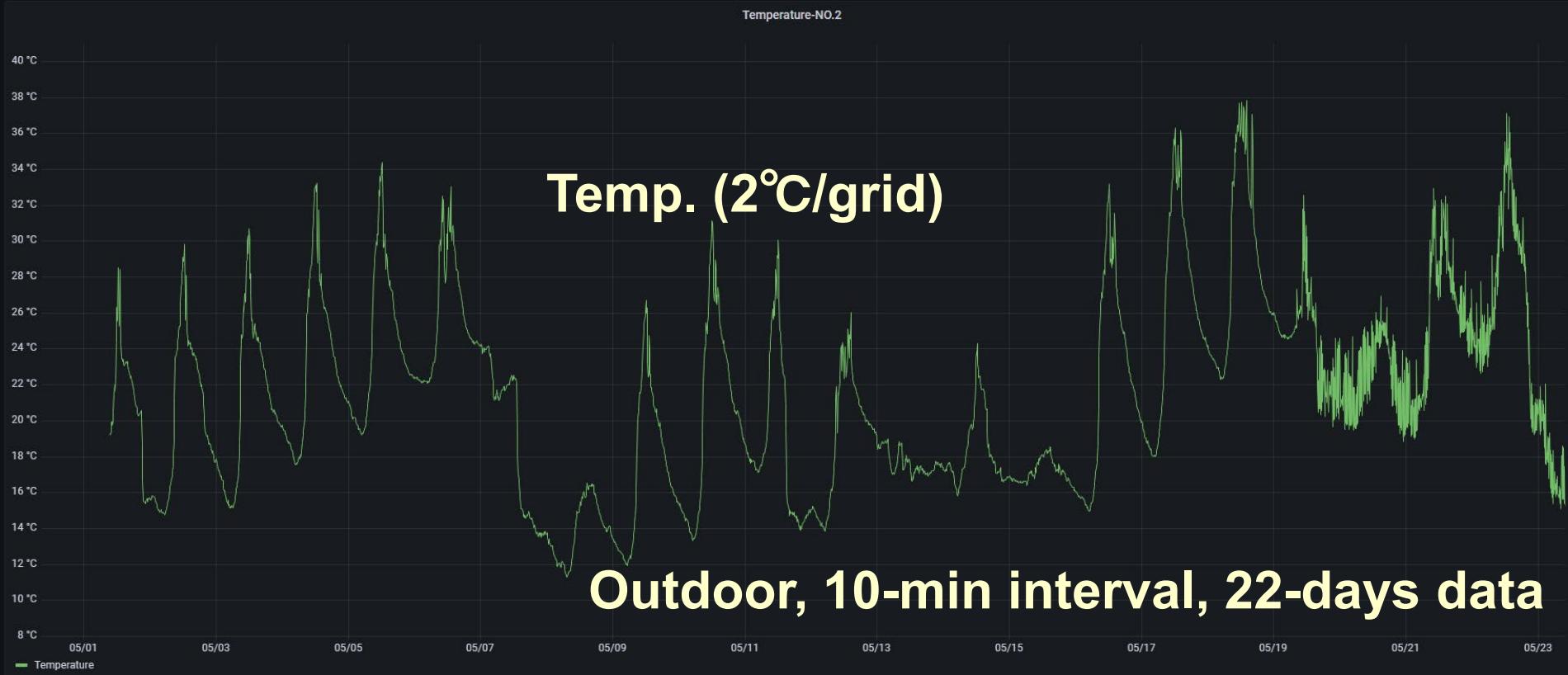


Inside the box



Made by REF Electronics
18650 battery

Solar battery + LTE-M leaf + cloud



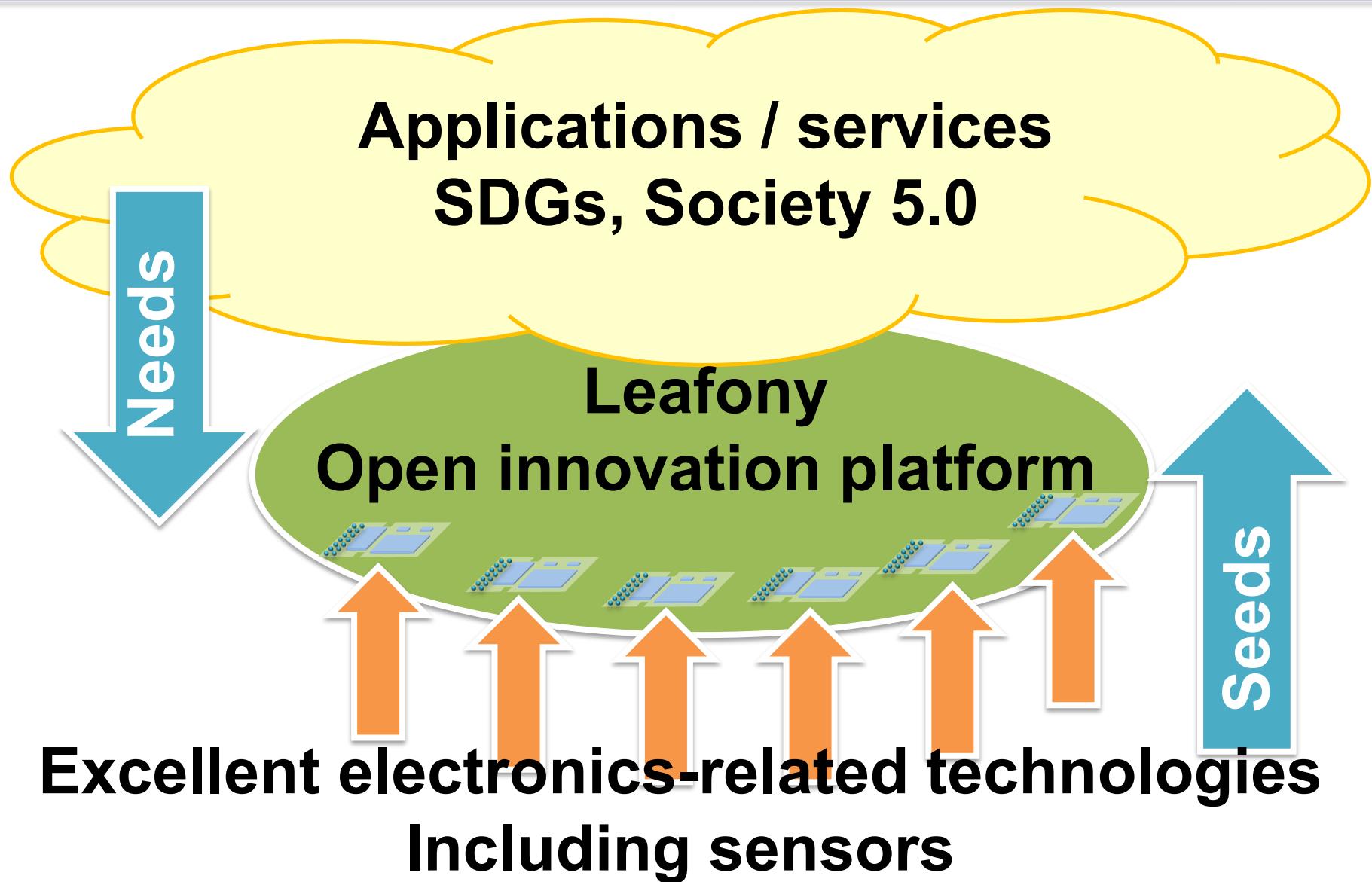
Applications are being developed for agriculture, structural healthcare, plants, monitoring, urban measurements, etc.

Issues in making IoT/CPS systems

- Structural health-care, smart city, smart fab., wearable,...
High variety and small quantity → Improving dev. efficiency
- No power line, small and light-weight open up new apps. →
Compact & low-power **Leafony**
Trillion-node study group
- Value chain is not established → Mechanism to connect
needs & seeds



Platform to show values of semicon tech.



Leafony connects technology to services and accelerates DX



Please consider joining
Trillion-node research group.