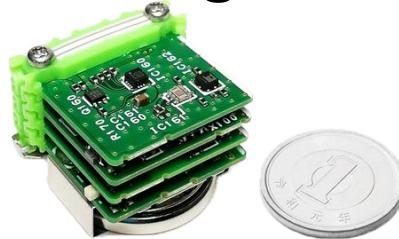


Leafony

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).



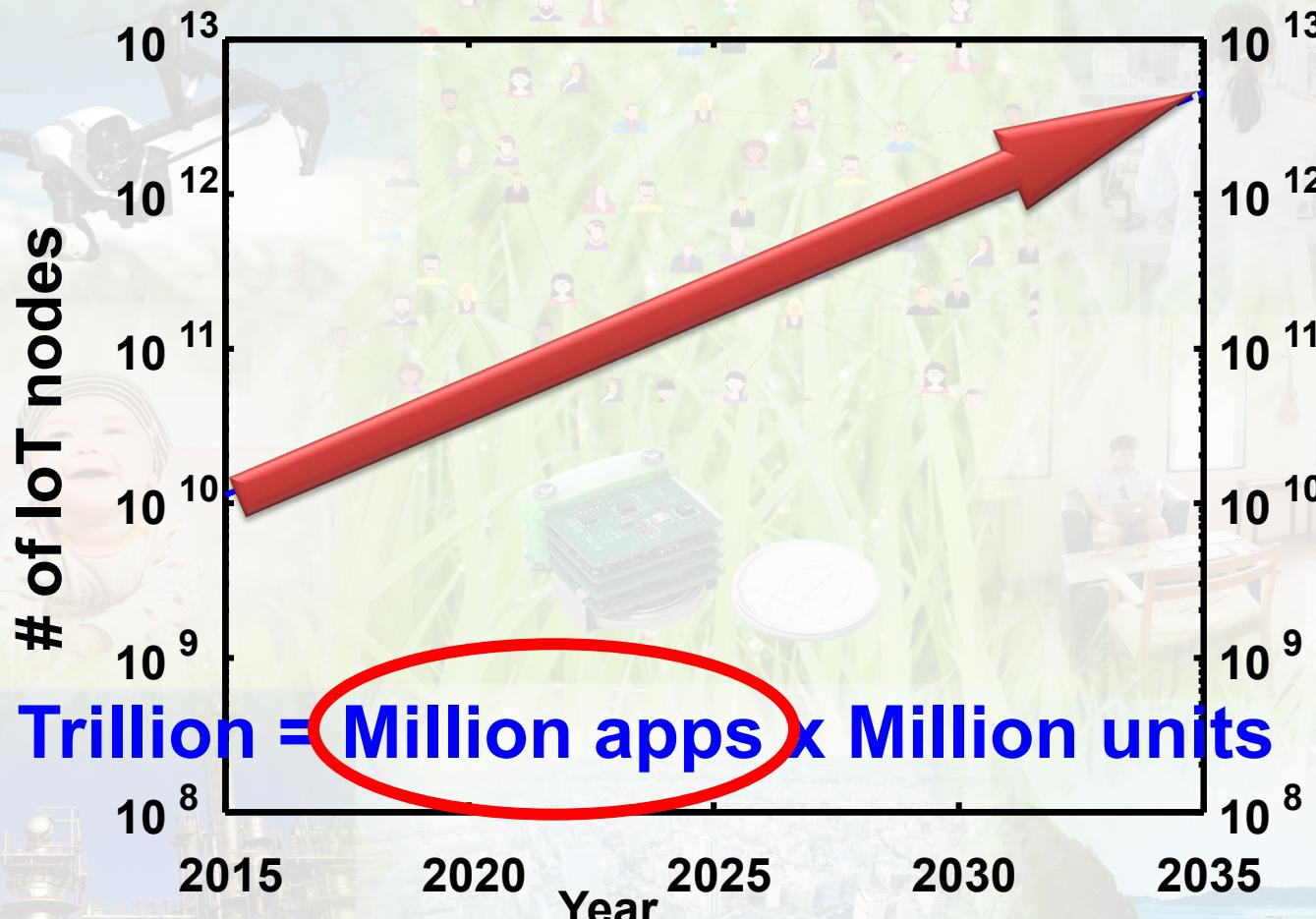
Outline

- **Background**
- **What is Leafony?**
- **Distribution**
- **Usage scenes**
- **Future**



Leafony

IoT: apps and services are important



- Estimated # of edge nodes in 2030s is more than a trillion.
- Related economy effect is more than \$14T in 2030s.

Issues in making IoT system for apps

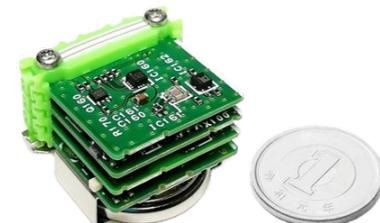
- Structural health-care, smart city, smart fab., wearable,...
High variety and small quantity → **Improving dev. efficiency**
- No power line, small size and light-weight open up new apps. → **Compact & low-power**
- Value chain is not established → **Mechanism to connect needs & seeds**





Outline

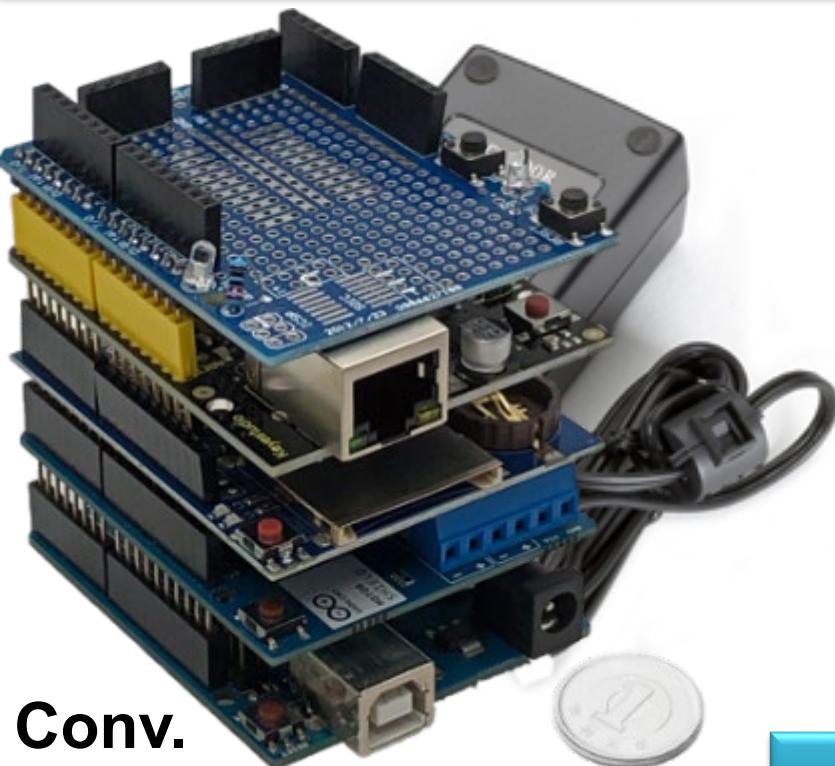
- **Background**
- **What is Leafony?**
- **Distribution**
- **Usage scenes**
- **Future**



Leafony



Leafony is open-innovation platform for IoT



Conv.

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

No standby



Leafony

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

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

- Mix and match required functions by selecting leaves.
- Leafony = Leaf + Symphony accelerates development.

What is Leafony?

Leafony

IoT Open Innovation Platform

Connecting technology to applications

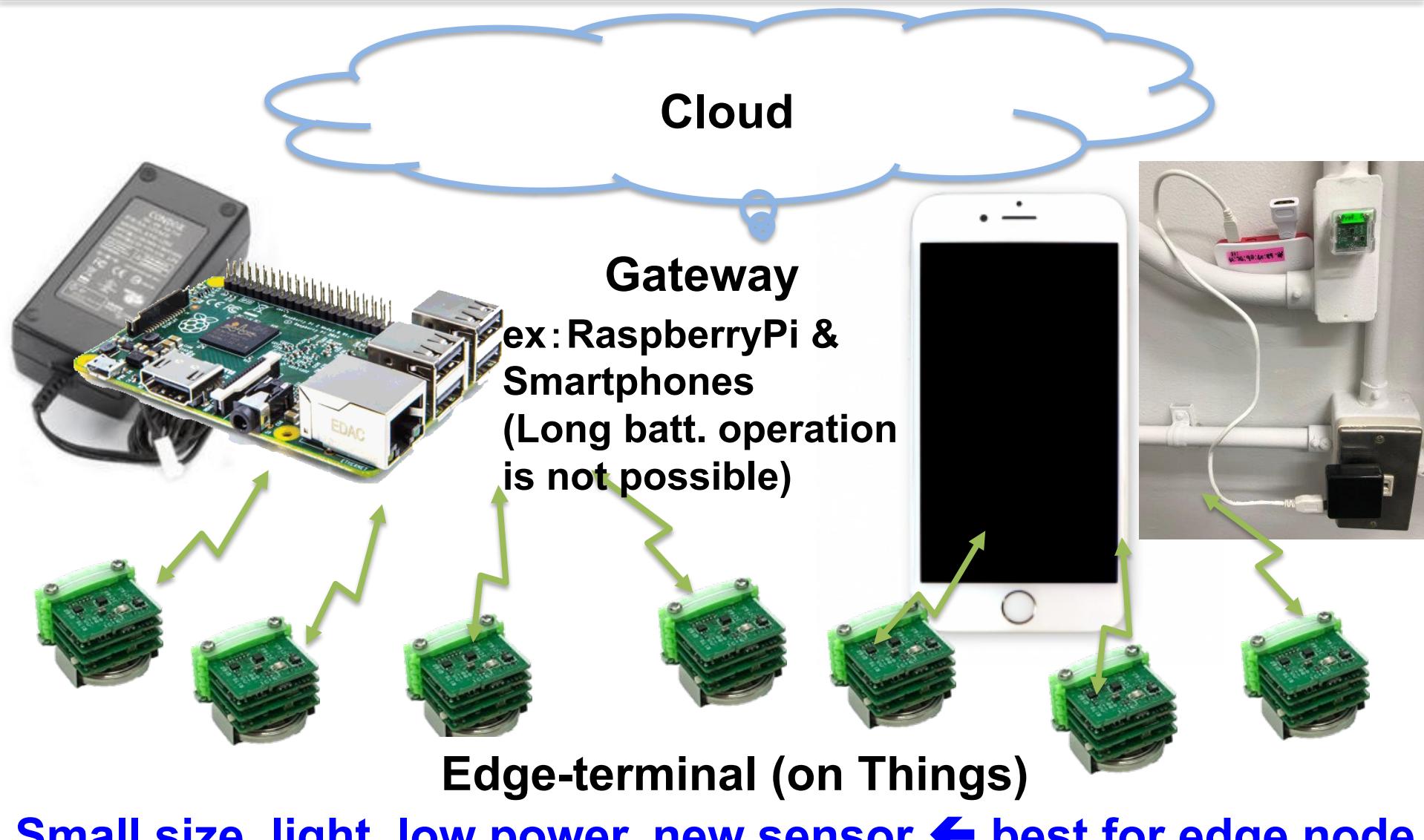


Compact, Low-power
Easy to add original leaf



trillion-node

Best fit for ‘edge’ node



Technology in Leafony: Small footprint



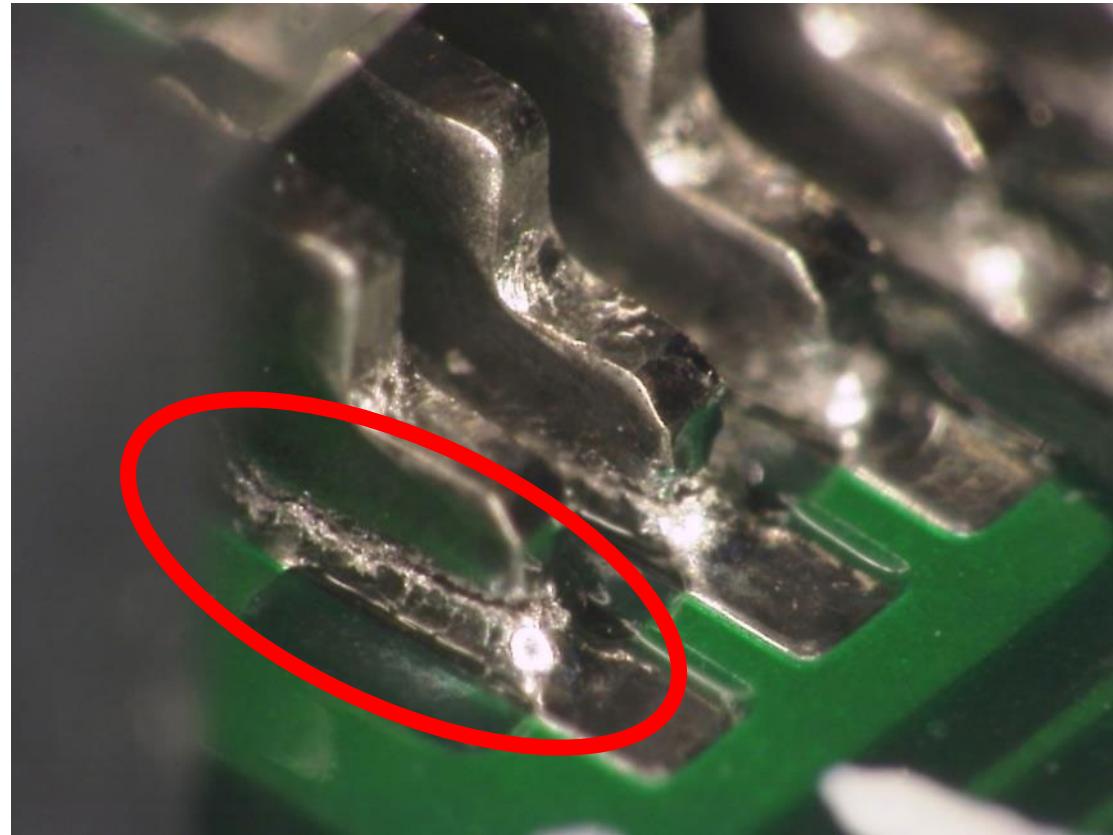
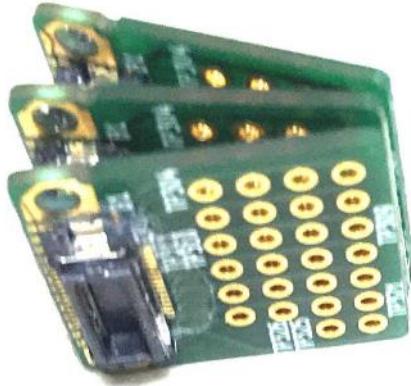
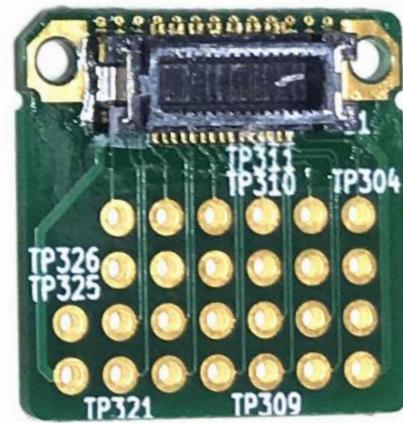
Conventional

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



Leafony

If we use standard small connector...

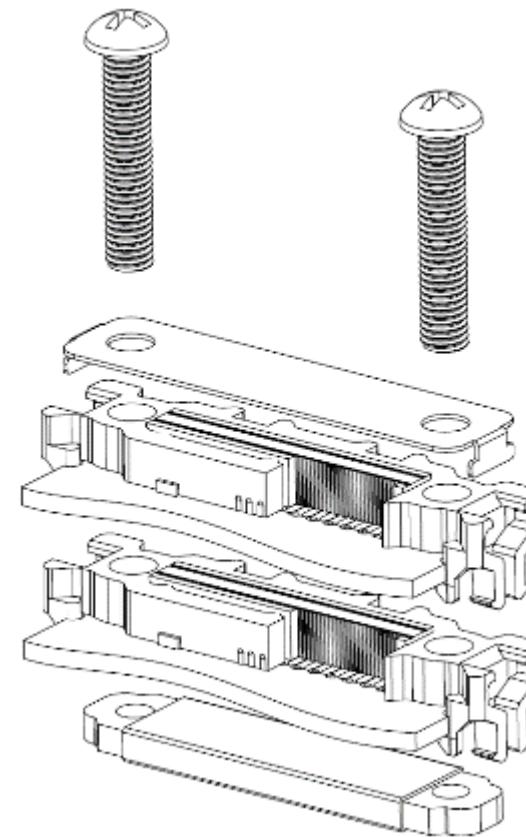


- Unstable
 - Higher spacing
 - Need special conn.
before making board
- Connector + screw → solder crack
- New connector with
Anisotropic Conductive Rubber

Original connector does not need soldering

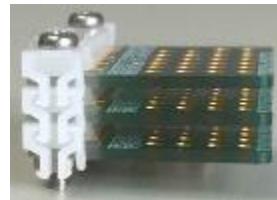
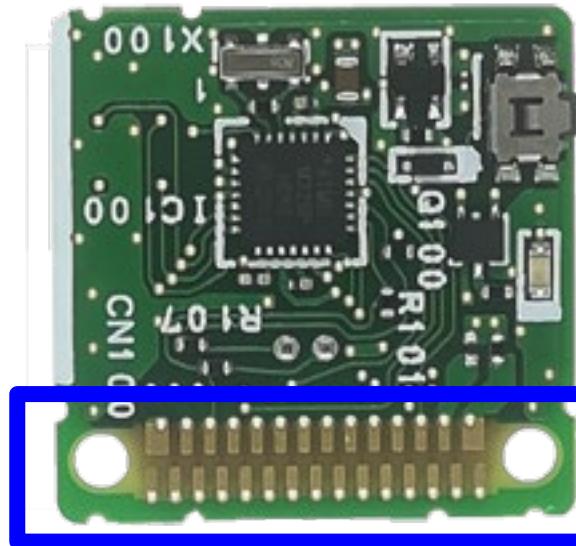


Anisotropic Conductive Rubber



- No need to prepare special micro-connector before board assembly → QTAT in leaf making
- Easy to assemble like a block toy

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

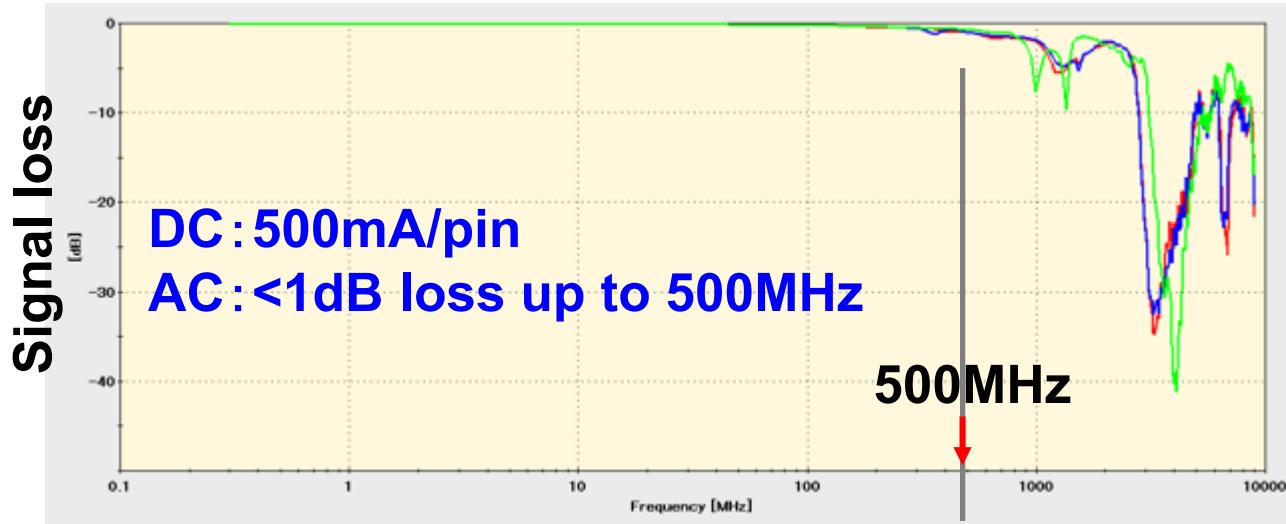
Nut plate



Connector performance

Signal transmission property of connector

4th Leaf



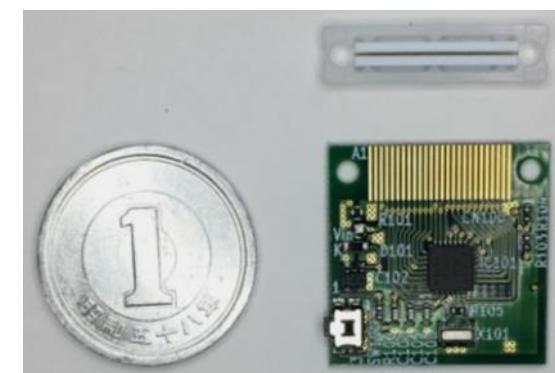
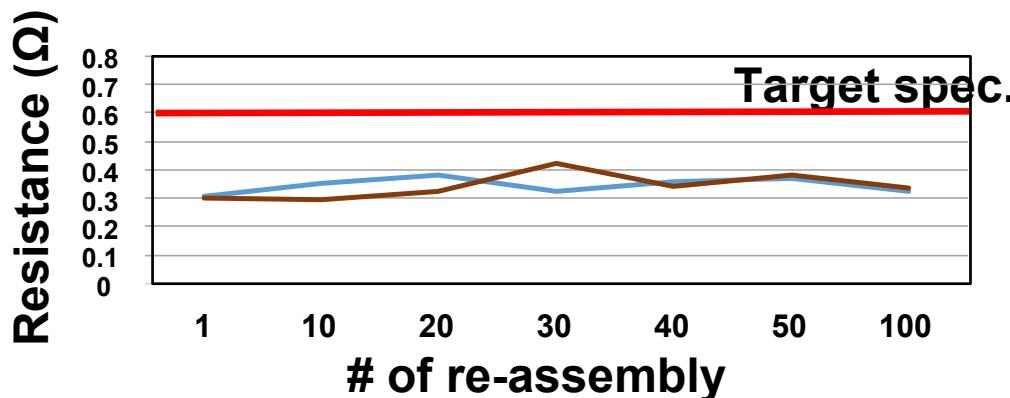
1st Leaf

From 1st to 4th Leaf



Red: at center
Blue: at center
(after re-assembly)
Green: at edge
of connector

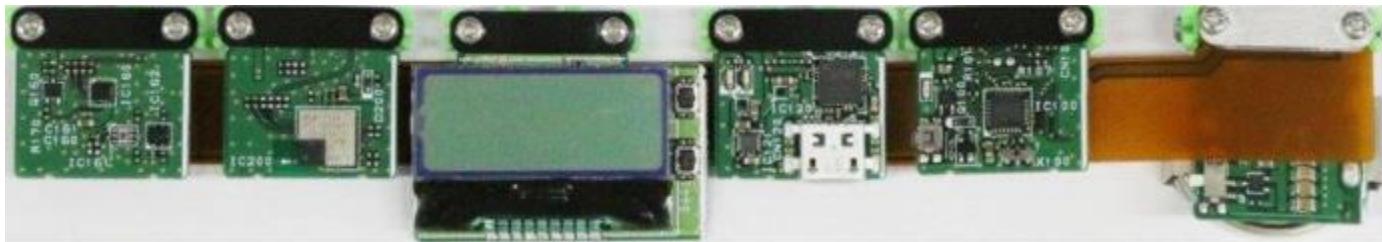
Change in resistance on re-assembly



Leaf connection example



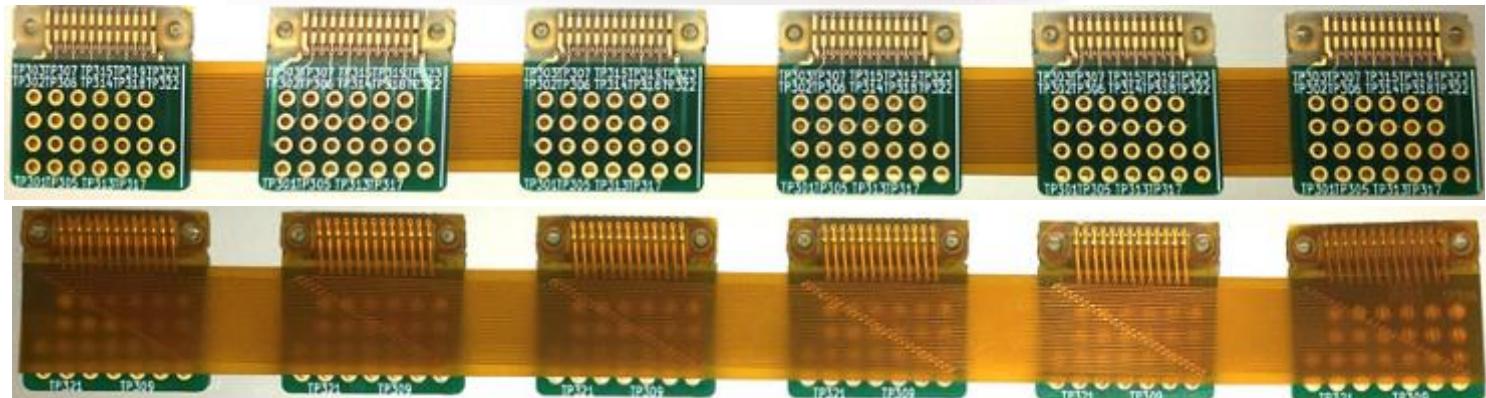
Stacking assembly



Planar type (through flexible PCB)



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



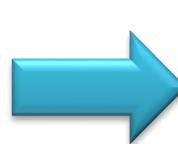
Even thinner assembly by thermocompression bonding

Technology in Leafony: Low-power



Conventional

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

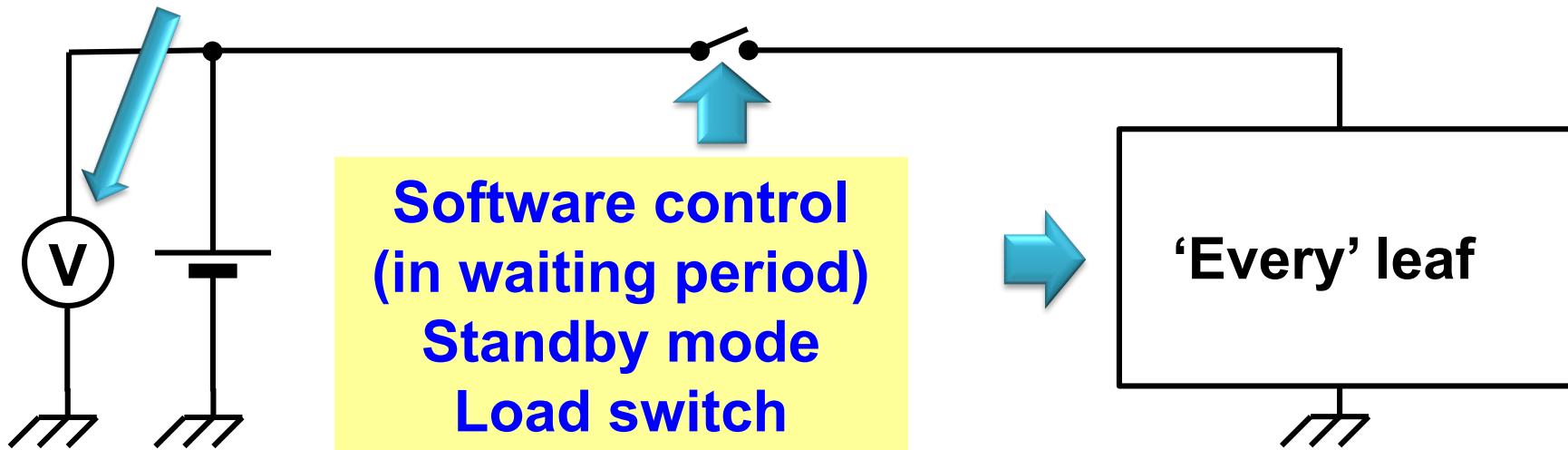


Leafony

Low power by architecture

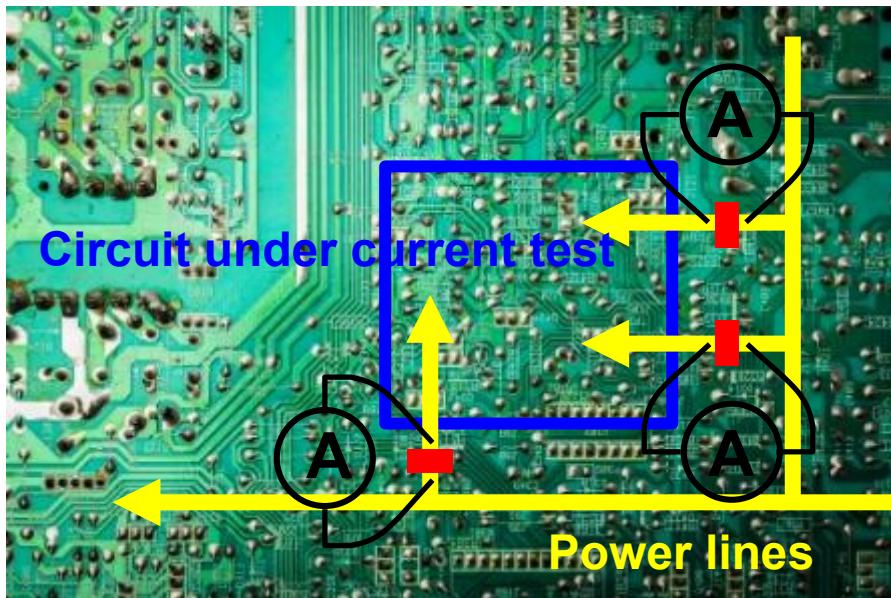
- Standby mode or load switch is implemented in every leaf.
Cut out current when system is in standby.
- Battery voltage monitor is added for every battery leaf.

Battery voltage monitor



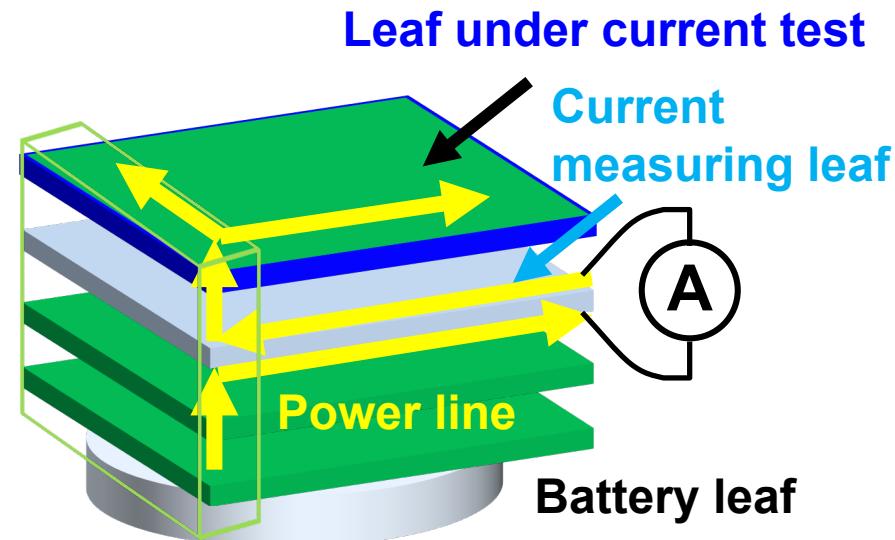
Current debugging

Conv.: current test is not easy.



■ Cutting point of power line

Leafony



- Current test is easy just by inserting **current measuring leaf**.
- Quicken development of battery-based system

Example of current debugging

● Sensor + Bluetooth system

Before fix

After fix

Low-power implementation by HW and SW

Leaf	Active [mA]	Standby [mA]
AVR(μP)	3.6	0.112
BLE	3.3	0.009
Sensor	0.1	0.002
USB	10	10
Total	17	10.1
Batt. life	~3 days	

Leaf	Active [mA]	Standby [mA]
AVR(μP)	3.6	0.005
BLE	3.3	0.009
Sensor	0.1	0.002
USB	0.001	0.001
Total	7	0.017
	~1 year	

● Assuming CR2540(610-mAHR) battery and 30s activation every 1 hour.



Technology in Leafony: Open-source



Conventional



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

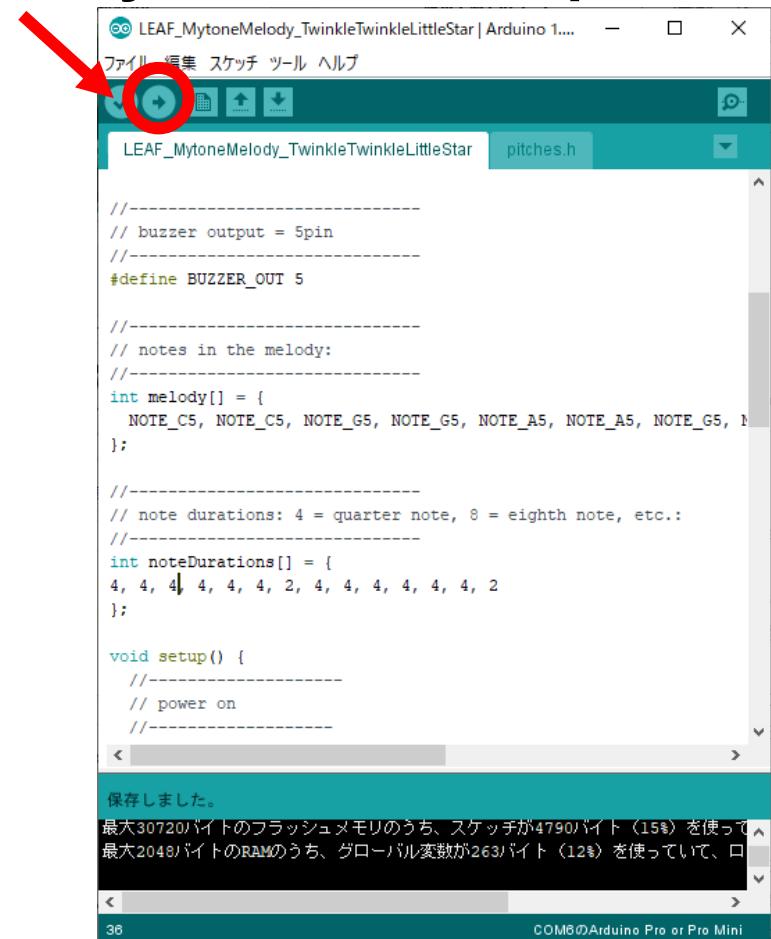


Leafony

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**

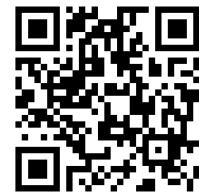


What is ‘open’ for Leafony

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

Details of licensing terms, visit

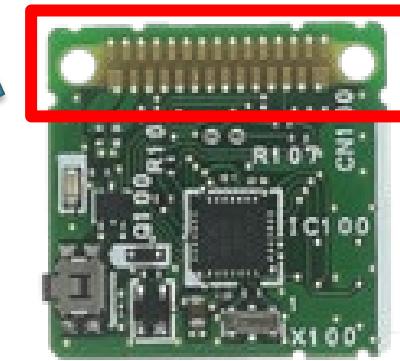
<https://docs.leafony.com/docs/license/>



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.
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**
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Leafony

Group of leaves/kits

Basic Kit

Extension Kit

ESP32 Wi-Fi Kit

Communication



BLE



LoRa



ESP32
Wi-Fi



AVR
MCU



CR2032



CR2450



2~4.5V



AA bat.

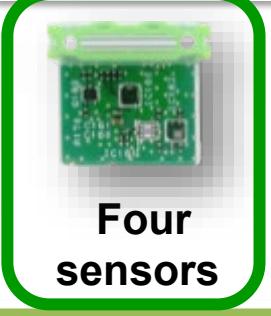
Misc.



USB



RTC &
microSD



Four
sensors



Speaker
IR sensor



LED
Mic



Display



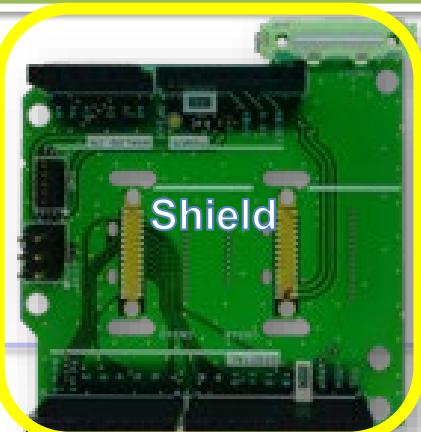
Conn.
x 10



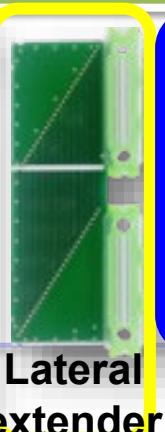
Nut
plate
x 10

I/O

Extender



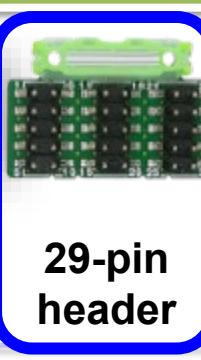
Shield



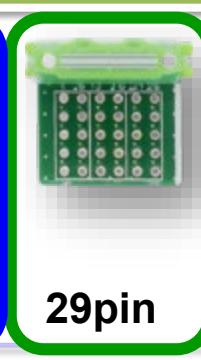
Lateral
extender



Vertical
extender



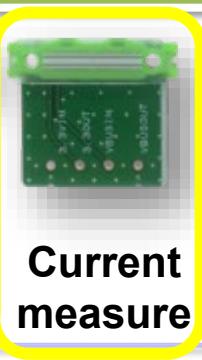
29-pin
header



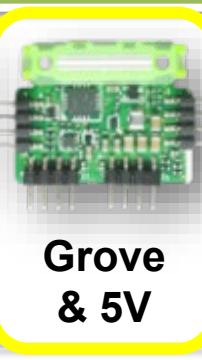
29pin



Spacer



Current
measure



Grove
& 5V

3 Distribution Kits

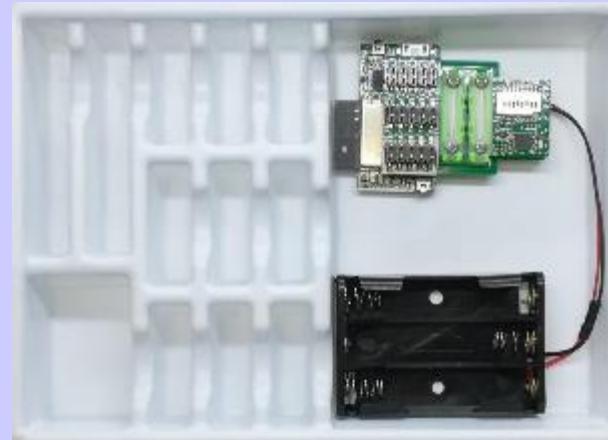
Basic Kit

Coin operation, BLE basic kit



ESP32 Wi-Fi Kit

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



- **ESP32**
32-bit MCU & Wi-Fi
- Real time clock & MicroSD
- 2V~4.5V battery
- 29-pin header Back-to-back

Extension Kit

Extension leaves kit



Leafony



Leaf examples from other organizations

Nexty



32-bit
MCU1



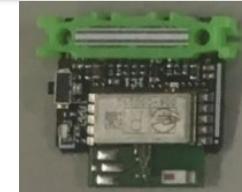
32-bit
MCU2



Low-power
Accelerometer
Sensor



Sensor



BLE

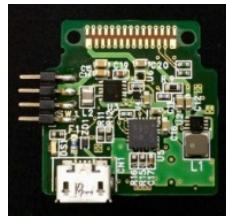


USB

Ricoh



Solar battery
Power supply



Power
Supply

Keio1



NO_x
Sensor

Keio2



CO₂
Sensor

H₂ Sensor

Demo prize in conf.



FPGA

Toshiba

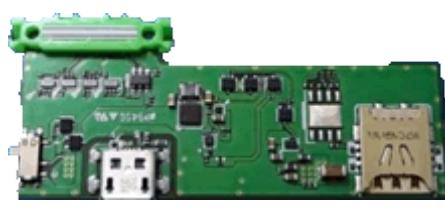


Fingerprint
Sensor



Secure
Element

KDDI



Cellular LTE-M

Sony



Bridge between
Platforms



Outline

- **Background**
- **What is Leafony?**
- **Distribution**
- **Usage scenes**
- **Future**



Leafony

Usage scenes

Companies

- Proof of Concept (PoC)**
- Reference design**
- Promotion tool**
- Demonstration of products**

Makers

- Quick prototyping**
- Demonstration experiments**

Education / University

- IoT education**
- Research & experiment**



Human resource development by Leafony

● Hackathon inside corporate



● Saitama Univ. enPiT IT education



Integrator company based on Leafony



● IoT-EX
@COMMA house

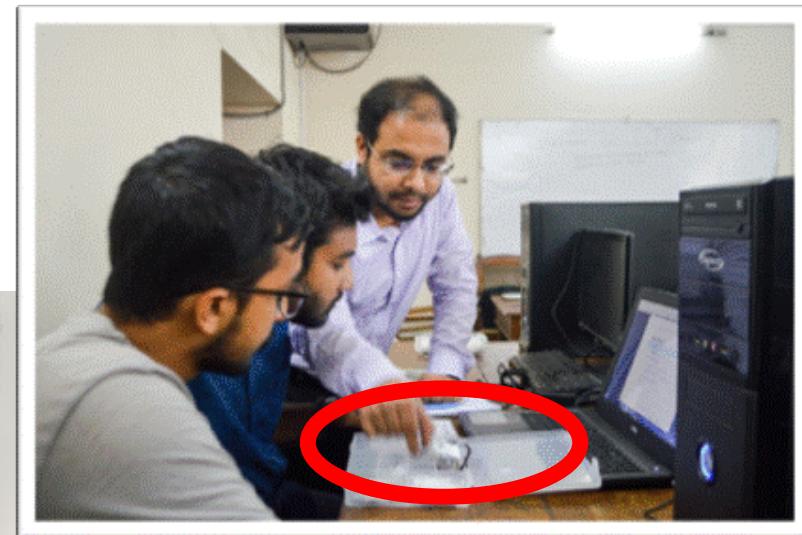
https://www.youtube.com/watch?v=pL0QEK2C_U

International collaboration with Dhaka Univ.

Generality independent from language

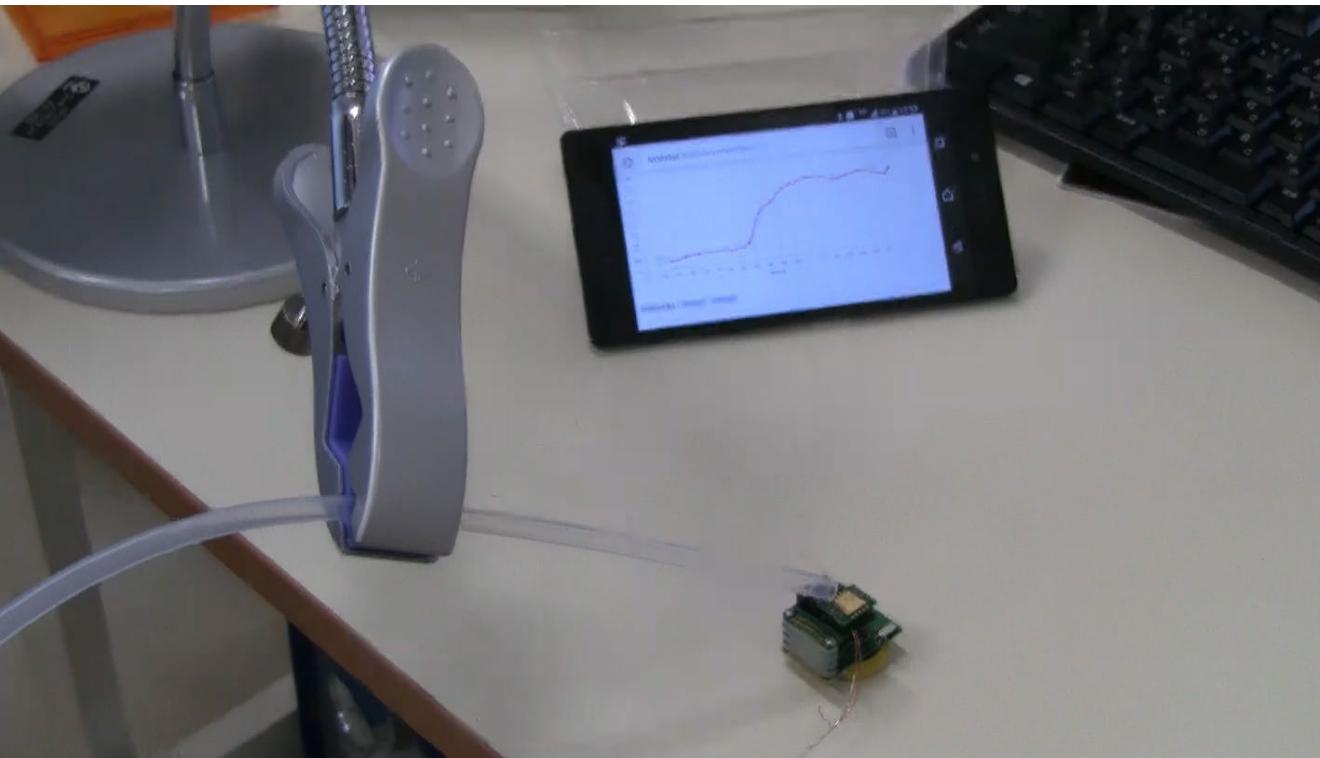


Wearable by Leafony
→ IEEE paper



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



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

Organizations supporting Leafony

1 IoT-EX株式会社	29 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
2 KDDI株式会社	30 慶應大学湘南藤沢キャンパス 岩研究室
3 LEAFONY SYSTEMS 株式会社	31 計画工学研究所
4 Mouser Japan	32 国立大学法人 埼玉大学
5 Quest7	33 三菱ケミカルエンジニアリング株式会社
6 STマイクロエレクトロニクス株式会社	34 新光電気工業株式会社
7 WES-VI	35 新日本無線株式会社
8 エイミー株式会社	36 青葉電子株式会社
9 サーキットデザイン株式会社	37 川崎重工業株式会社
10 システムニコル株式会社	38 双葉電子工業株式会社
11 セイコーホールディングス株式会社	39 太陽誘電株式会社
12 ソニーセミコンダクタソリューションズ株式会社	40 大和無線電機株式会社
13 ディー・クルー・テクノロジーズ株式会社	41 地方独立行政法人東京都立産業技術研究センター
14 リコー電子デバイス株式会社	42 中部電力パワーグリッド株式会社
15 リンテック株式会社	43 長野県工業技術総合センター
16 夏目光学株式会社	44 東京大学 工学系研究科
17 株式会社 図研	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AOKI	46 東芝インフラシステムズ株式会社
19 株式会社FUJI	47 東芝テック株式会社
20 株式会社SUSUBOX	48 東芝デバイス&ストレージ株式会社
21 株式会社チップワンストップ	49 東芝デベロップメントエンジニアリング（株）
22 株式会社デバイス＆システム・プラットフォーム開発センター	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 株式会社創成電子	53 日立製作所
26 近畿日本鉄道株式会社	54 富士通クライアントコンピューティング株式会社
27 金沢大学振動発電開発グループ	55 明光電子株式会社
28 群馬大学大学院	56 有限会社ケイ・ピー・ディ



Outline

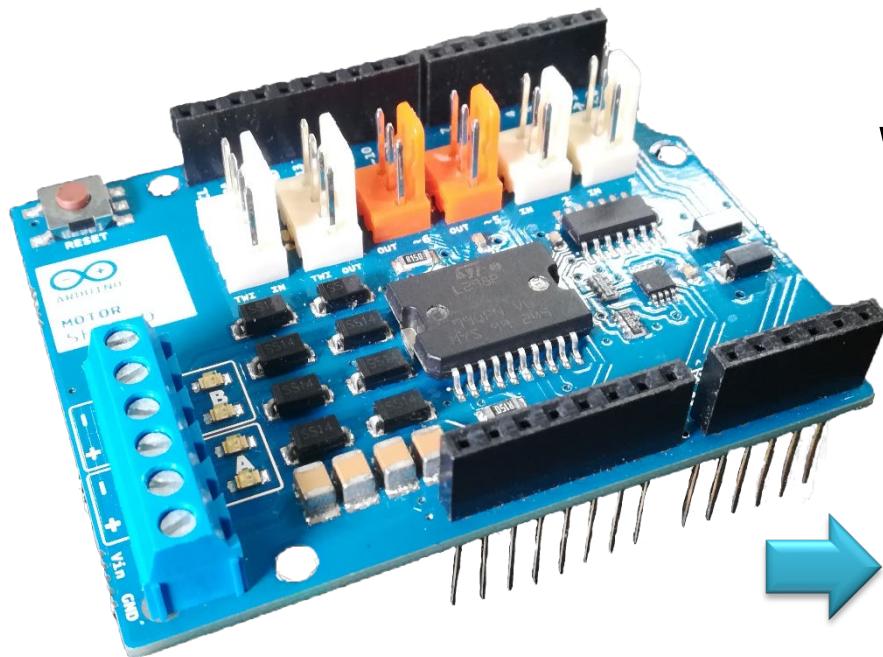
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Leafony

Motor leaf to come

- Actuator oriented leaf
- Software compatible with Arduino motor shield



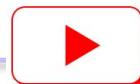
**Watering system
for office plants**



Motor leaf



モータリーフ デモ



AI-ready ARM 32-bit MCU leaf to come

- ARM 32-bit MCU is on 2cm x 2cm leaf
(STM32L4, 80MHz, 512kB flash, 160kB SRAM, **Arduino**)
- Low-power (Active: 9mA, Standby: <1µA)
Ex. AVR MCU (Active: 5.2mA@8MHz, Standby: 4.7µA)
- Delivers high performance covering **edge-AI** applications



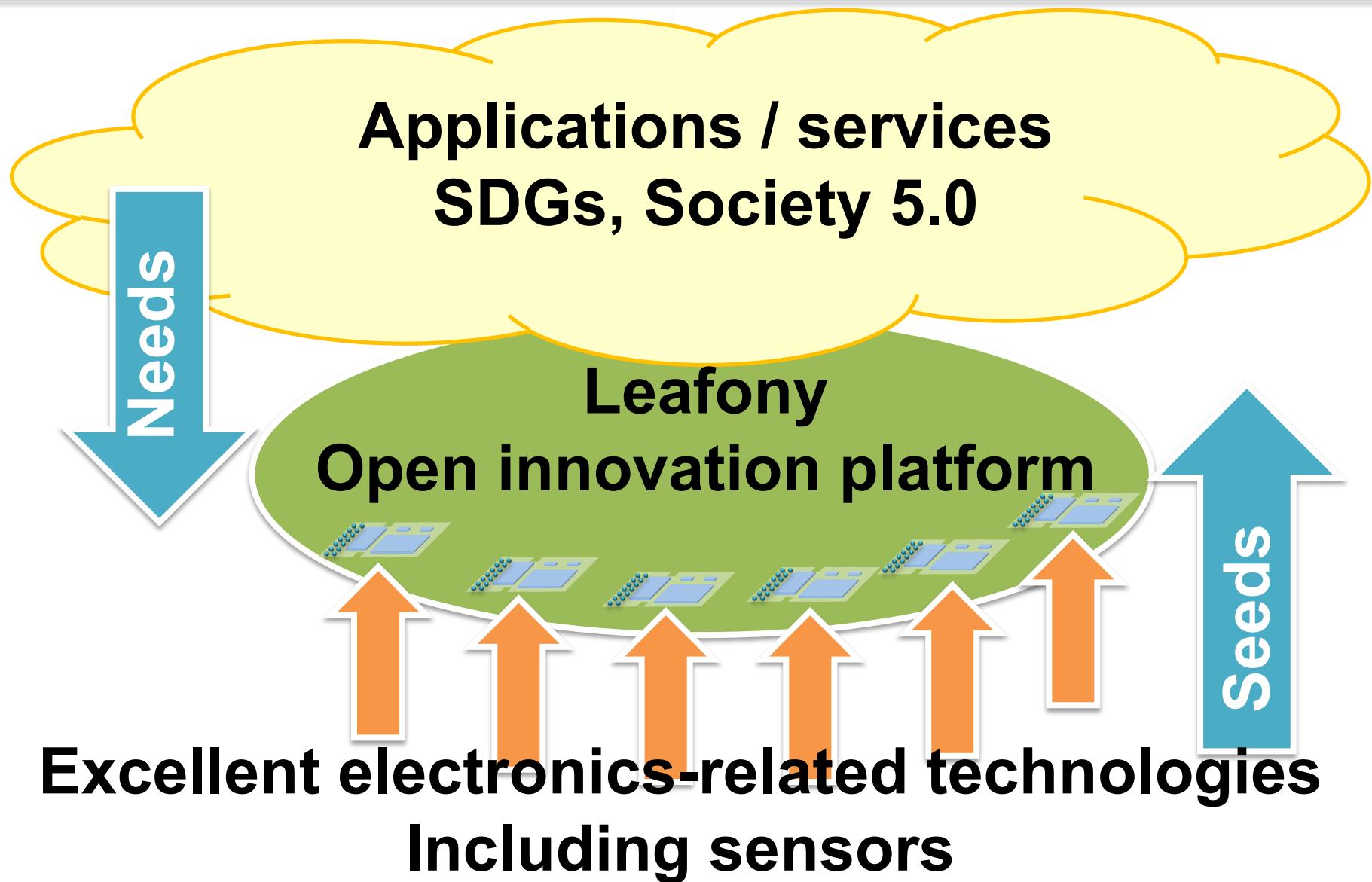
Stay tuned😊

Issues in making IoT/CPS systems

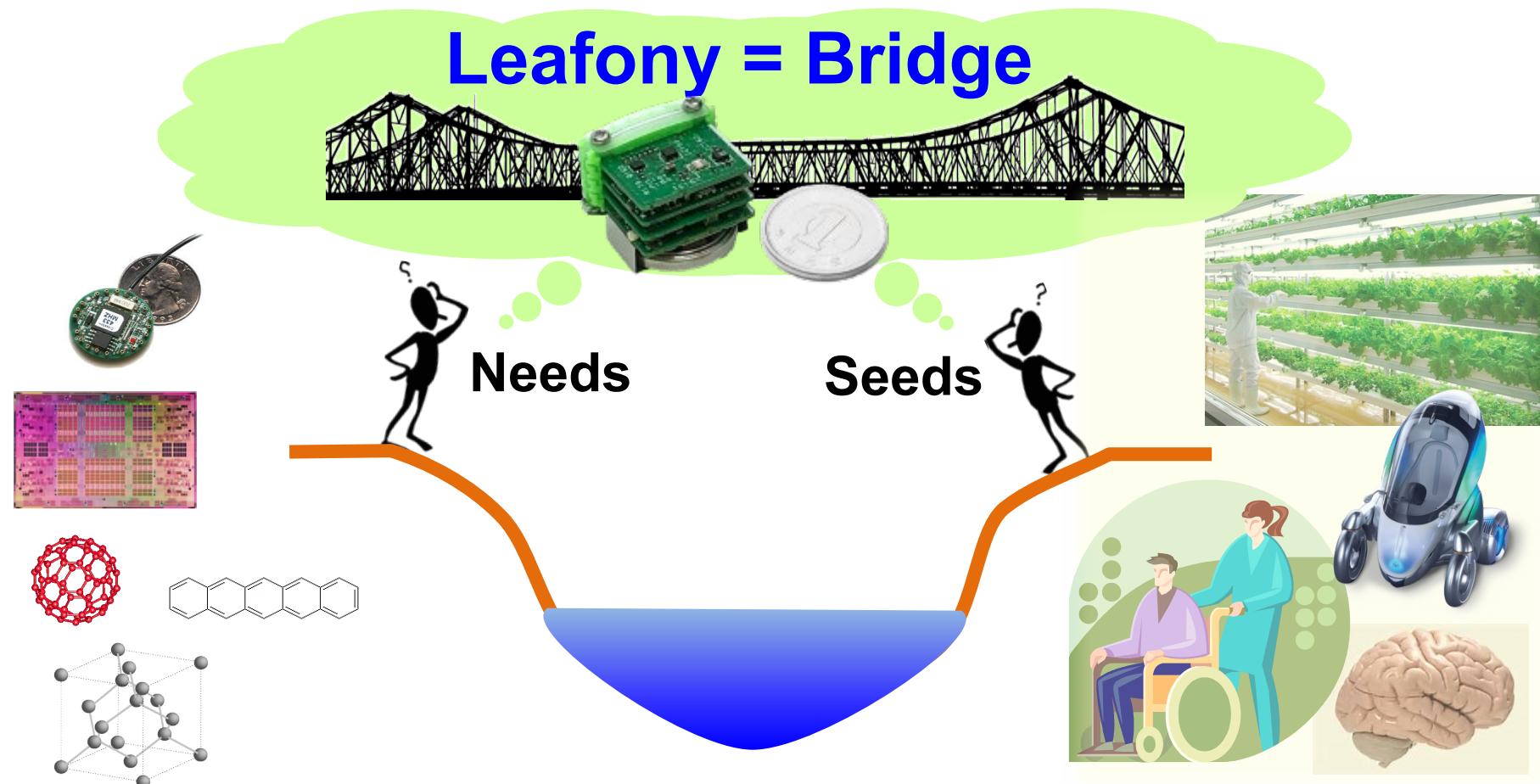
- Structural health-care, smart city, smart fab., wearable,...
High variety and small quantity → Improving dev. efficiency
- No power line, small and light-weight open up new apps. →
Compact & low-power **Leafony**
Trillion-node study group
- Value chain is not established → **Mechanism to connect needs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



Platform to show values of semicon tech.



Accelerates DX & vitalizes semicon industry



**Sensor & semiconductor
technologies**

**Applications &
services**

Leafony → BLE → PC → Cloud → PC browser

The image displays two side-by-side browser windows showing a web-based interface for monitoring four sensors. Both windows have a header bar with tabs and icons.

Left Window (4-Sensors Edge):

- Header:** 4-Sensors Edge
- URL:** tk2-258-38976.vs.sakura.ne.jp/notification
- Content:**
 - Buttons:** Disconnect, Sleep Mode
 - Text:** Device Name Leaf_A_#05308, Unique Name Leafony_AC02
 - Data:** 日時 2019/08/24 12:05:48, 溫度 [°C] 31.0, 濕度 [%RH] 124.3, 照度 [lux] 69, 傾き [deg] 30, 電圧 [V] 2.66, サイクロの日 1

Right Window (4-Sensors Client Chart):

- Header:** 4-Sensors Client Chart
- URL:** tk2-258-38976.vs.sakura.ne.jp/clientchart
- Content:**
 - Buttons:** Connect
 - Chart:** A line graph showing Temperature (度) over time, with a red area indicating the temperature range. The graph shows a sharp peak around 32°C.
 - Text:** Leafony 気温が30度を超えました。体調に気をつけてください。
 - Device Info:** Device Name Leaf_A_#05308, Unique Name Leafony_AC02

Demo