PST SENSORS

sensing unlimited

IoT – the Internet Of T…emperature

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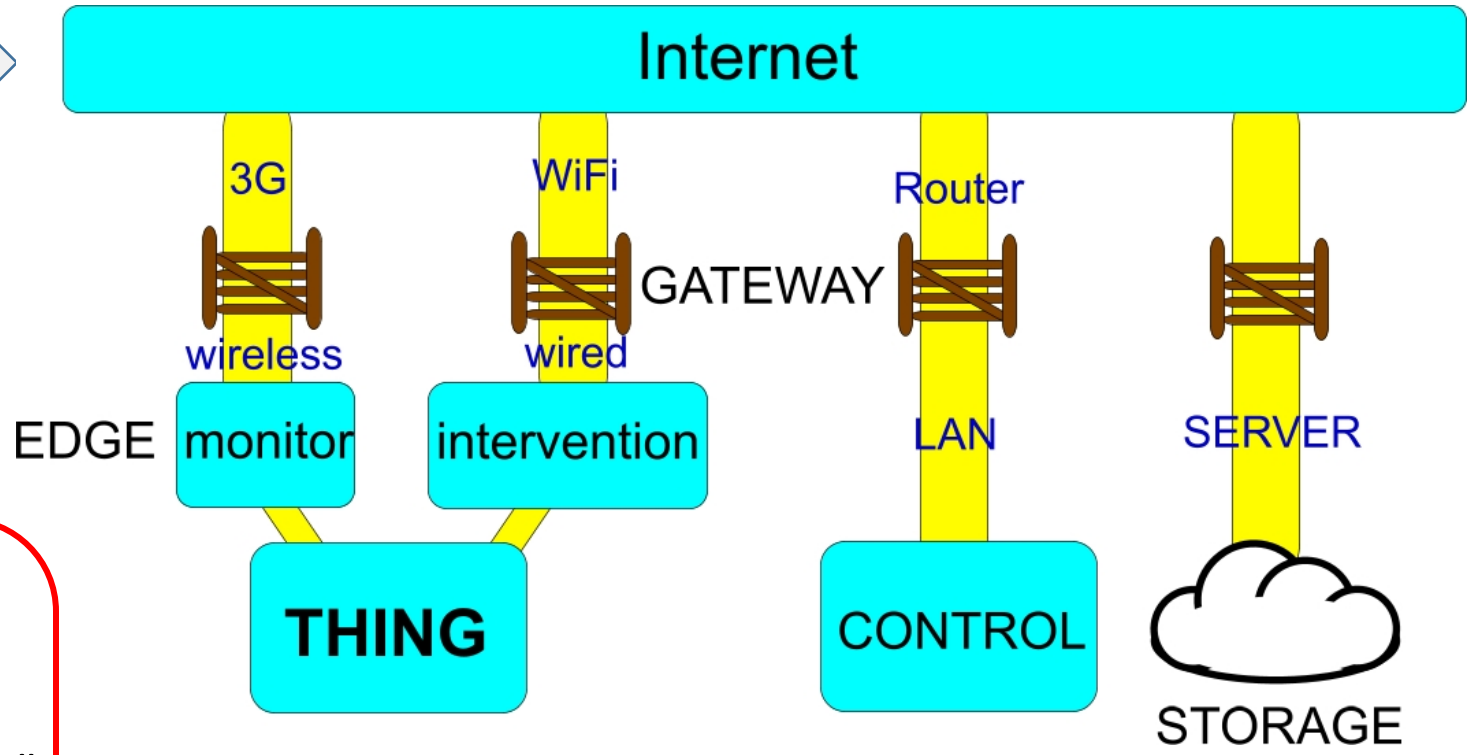
IoThings:
a non-local control and feedback loop



Internet:
global communications backbone providing connectivity:

- from a "**THING**" to "*somewhere else*"
- and back to
- the "**THING**"

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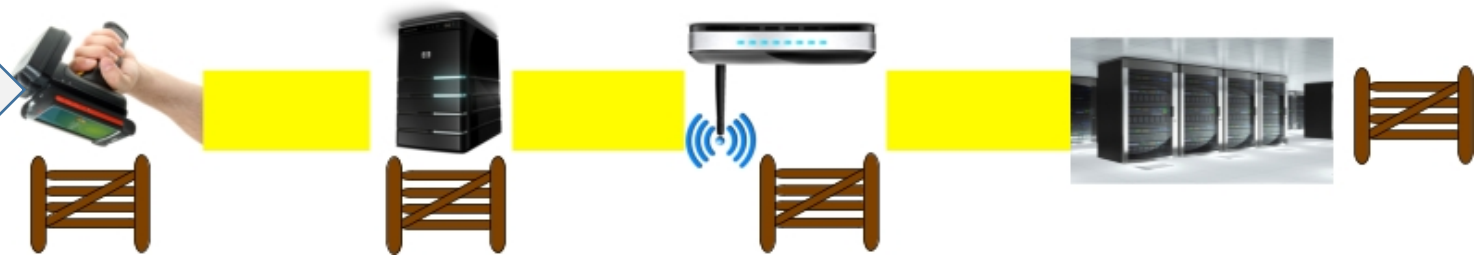
gateways connect to the internet by information exchange



- WLAN router
- 3G, 4G, 5G modem
- satellite
- laptop or mobile phone
- RFID reader

IoT features:

- multiple gateways
- internet its own internal gateways
- **communication is transparent above first few gateway levels**

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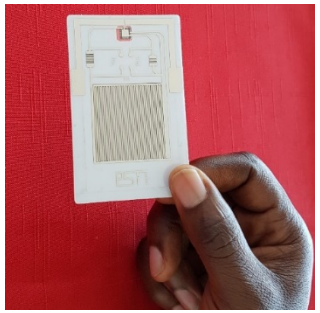
edge devices connect to the THING



edge device may be:

- part of the **Thing**
- an add-on, or
- a separate unit.

edge device = sensor and/or an actuator + direct connection to a gateway

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THINGS: assets, equipment and even living things

the IoT provides the opportunities for:

- assets being maintained more effectively
- equipment doing something in an optimal fashion

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the internet of temperature

temperature is the **key indicator** and **environmental factor** for:

- human and animal health
- food safety
- safe and productive environment
- process efficiency and safety
- product stability and lifetime
- manufacturing reliability

as the most often measured physical quantity temperature is needed anywhere and everywhere

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the most often measured quantity: temperature

PST's contribution: PRINTED SENSORS

temperature sensors

humidity sensors

NEW

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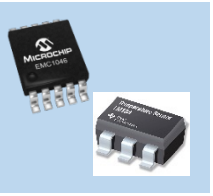
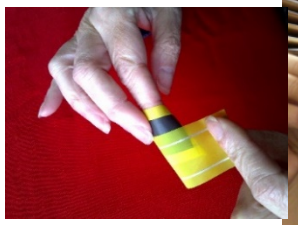
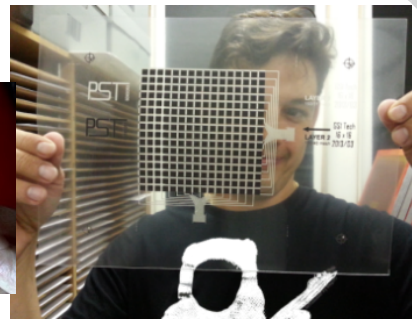
why printed temperature sensors?

traditional sensing



- rigid
- bulky
- slow
- high power
- self-heating





- ultra thin
- flexible and conformable
- ultra fast
- ultra low power
- no self-heating
- very wide temperature range

state of the art sensing

PST's temperature sensing solutions allow you to offer products and services fulfilling requirements beyond the conventional

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printed sensors:
unique
form factor

customized size

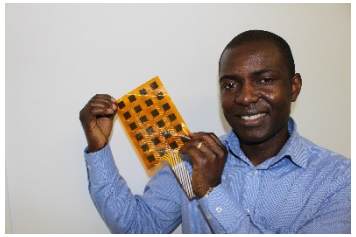
- **from the diameter of bead thermistors**

- **to the size of an airplane wing**

customized shape

- **from rectangular to irregular**

- **to temperature sensor arrays**



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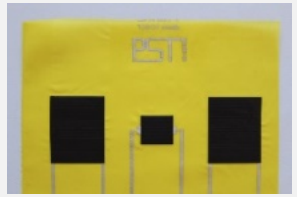
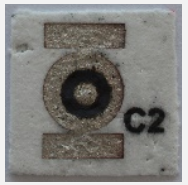
PST's temperature sensors: wide temperature range

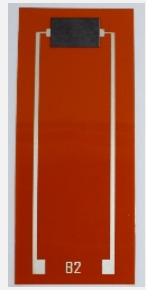
wide temperature range

- **from our environment**
  e.g. printed
  on PET, fabric or any
  other material

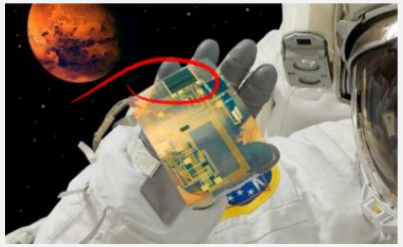


- **to a hazardous environment**
  up to **800° C**
  printed on polyimide
  or even higher
  temperature substrates





- **to no environment at all**
  down to **-267°C**



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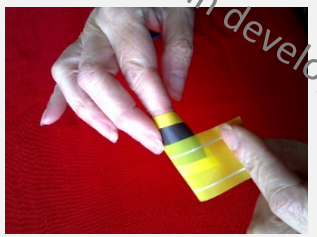
printed sensors:
conformable and flexible

conformable and flexible

- **from flat to curved and conformable**

- **to fully flexible**



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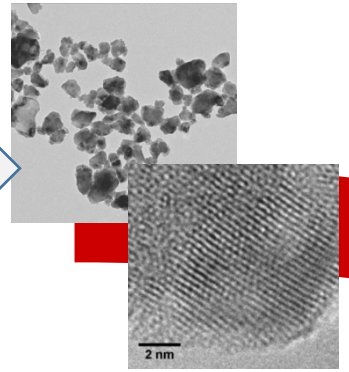
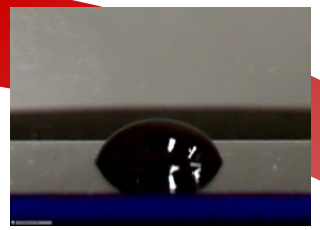
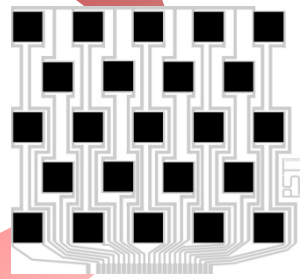
technology base: nano-structured silicon



ink formulation

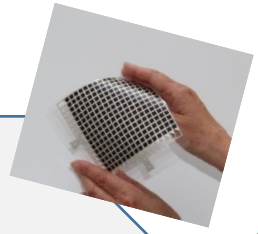


device design

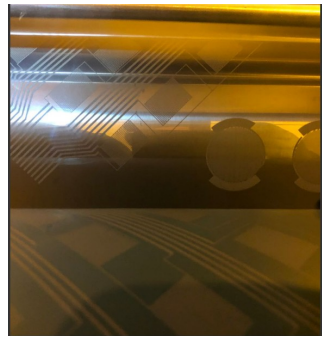


printing on any substrate

unique temperature sensors



now also R2R production of temperature sensors



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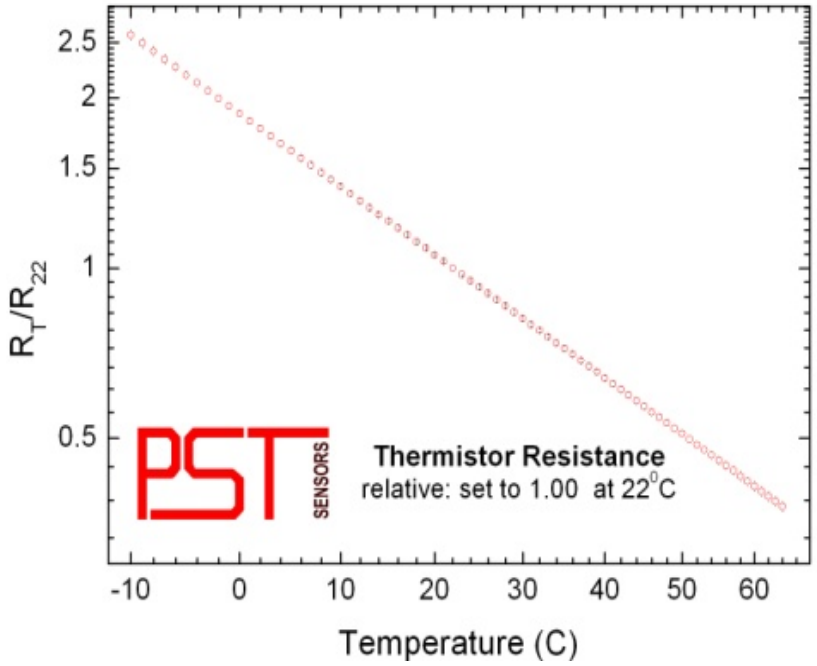
PST's printed temperature sensors are thermistors

- negative temperature coefficient (NTC) thermistors,
- universal (perfect Arrhenius) characteristic for its electrical resistance in the environmental temperature range
- one point calibration is sufficient
- they are also varistors



universal temperature characteristic relative to the resistance at 22°C (R_T/R_{22} = 1.00 at 22°C)

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technical data

- operating temperature: -267°C to 800°C
- resistance value at 25°C: 10 kΩ - 100 MΩ
- tolerance on R_{25}-value: ±10%
- beta-value: 2300 K
- tolerance on beta-value: ±5%
- typical precision: ± 0.1 °C
- temperature sensitivity: 2.5 %
- operating voltage: 1 mV to 200 V
- power consumption: nW to µW
- measurement speed: 100Hz
- substrate: everything that can be printed on
- minimum size : minimum: 1 x 1 mm^2
- maximum size: limited by printing equipment
- sensor thickness: > 20 µm
- device thickness: depending on substrate

enables energy harvesting solutions

new frontiers in temperature sensing

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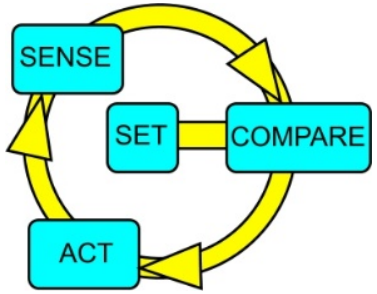
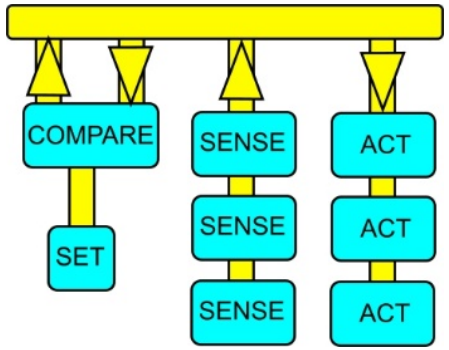
traditional control loop:



compares single **sequential data** and performs a single action
(sensors, actuator and digital/anolog algorithm in one unit (e.g PID controller))

the Internet of Things:



compares **correlated sets of data** and performs multiple actions

the new way of monitoring, intervention, and control

IoT and printed sensor electronics:

pushes the boundaries for monitoring, intervention and control

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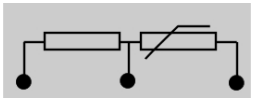
SENSOR INTEGRATION

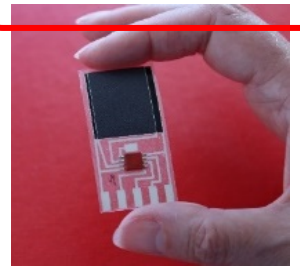
active-T Sensors



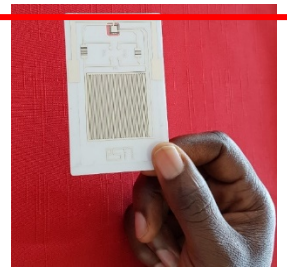
- fully printed analog circuit
- series bridge
- the output voltage tracks the temperature

Chip on Sensor Hybrid CoSH

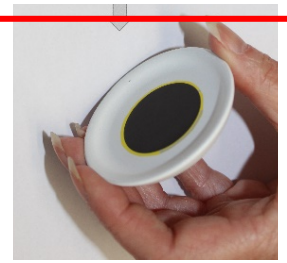
- hybrid electronics
- digital serial temperature sensor
- temperature without measuring resistance or voltage



Kushushu:
IoT edge device - temperature
passive RAIN RFID Gen 2 sensor tag



The Pod:
IoT BLE edge device
temperature, humidity, activity



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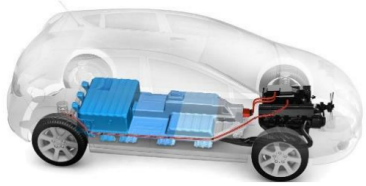
APPLICATIONS - ELECTRIC VEHICLES



NEED

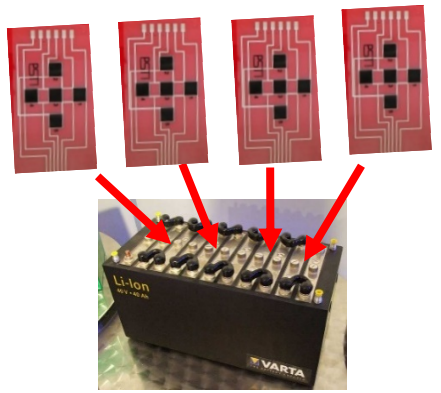
efficiency:

- faster charging
- better load management

safety: prevent thermal runaway

- detect hot-spots
- switch out defective cells

SOLUTION



- **ultrathin sensor arrays**
- temperature and pressure monitoring
- work inside and outside cell chemistry
- time dependent 3D reconstruction of temperature/pressure profiles from 2D maps

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APPLICATIONS – REMOTE AMPUTEE MONITORING

PROBLEM AND NEED

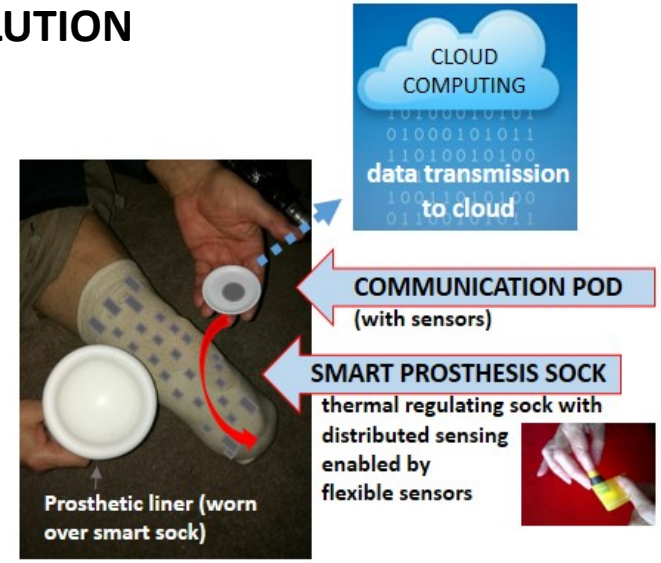
- prosthesis wear causes skin diseases in 75% of lower limb amputees

bony prominence with decubiti[3] | Infected abscess below knee[3] | allergic contact dermatitis[3]

- prevention relies on daily self- inspection
- amputees can't wear a prosthesis
- immobile amputees miss social and vocational activities

e.g. United Kingdom:
UK's 75,000 lower limb amputees cost the National Health Service £117M only for ulcer treatment

SOLUTION



- **ultrathin and flexible sensor arrays**
- unbiased, evidence based information
- temperature, humidity, pressure and activity
- anonymous and secure data format
- continuous monitoring of physiological parameter → prevalence reduced to 15%

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APPLICATIONS – CONVERSION LINE PROCESS MONITORING

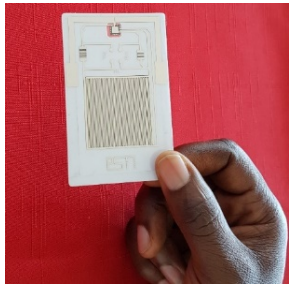
PROBLEM

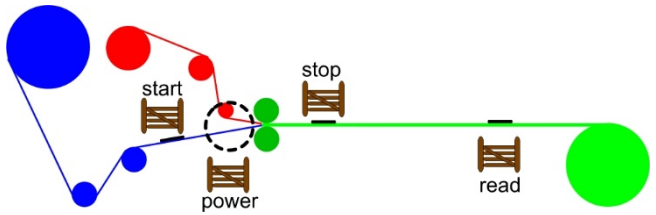
- in conversion lines producing paper products the temperature is not sufficiently known

- consequence: large amount of product is rejected

SOLUTION

- **ultrafast and ultrathin temperature sensors**
- high sampling rate allows temperature monitoring when probe travelling with the product





- edge devices with UHF RAIN Gen 2 (860 – 960 MHz)
- gateway devices: RFID readers, embedded computers
- monitoring: time temperature profile
- enabling intervention before production fails
- control provided by on-site software

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THANK YOU FOR YOUR ATTENTION

… but now we are also in the UK

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