

# TinyML Fundamentals

Part I



# ARTIFICIAL INTELLIGENCE

+data, +hardware, +algorithm, +network

## ARTIFICIAL INTELLIGENCE

Any technique which enables computer to mimic human behavior



## MACHINE LEARNING

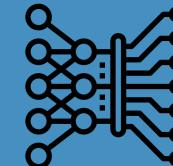
AI techniques that give computers the ability to learn without being explicitly programmed to do so



TinyML

## DEEP LEARNING

A subset of ML which make the computation of multi-layer neural network feasible



Embedded Systems

1950 - 1980

1980 - 2010

2010 - 202X

# What is TinyML?

Tiny Machine Learning (TinyML) is a **fast-growing field of machine learning** technologies and applications including **algorithms, hardware and software** capable of performing **on-device sensor data analytics** (vision, audio, IMU, biomedical, etc.) at **extremely low power**, typically in the mW range and below, and hence enabling a variety of **always-on-use-cases** and targeting **battery-operated devices**.

# Why our business need AI?

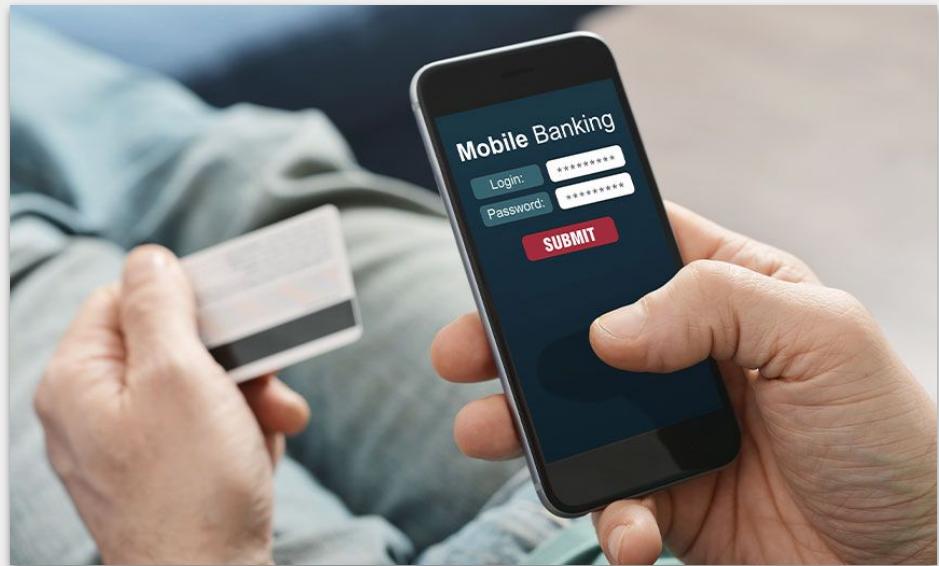




Give me another example?

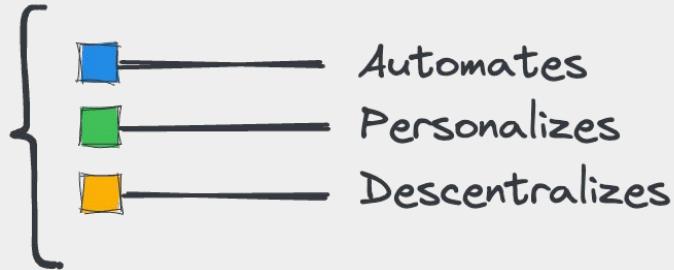


Telemedicine



Online Banking

Artificial  
Intelligence



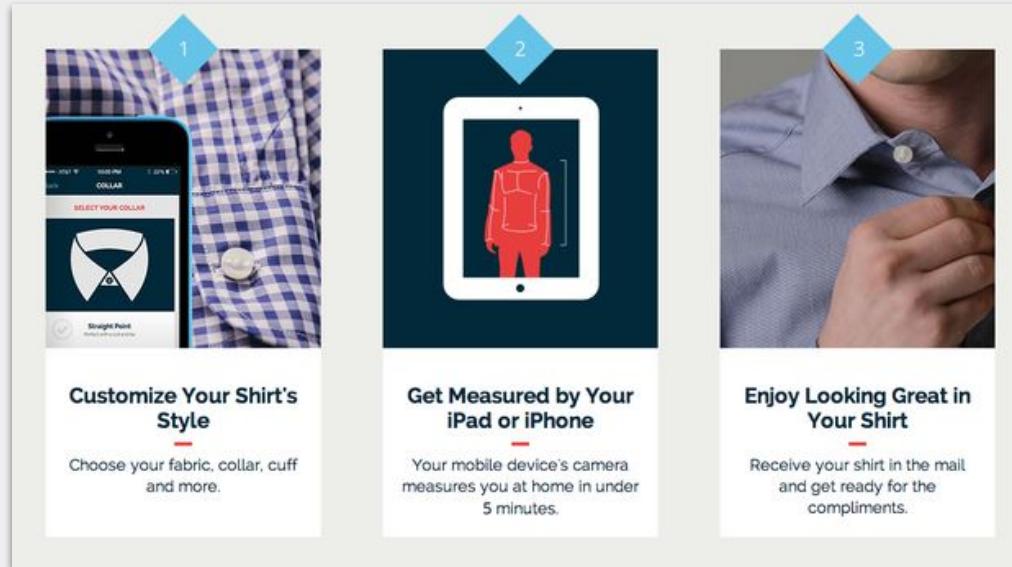
>> We gain a new range  
of biz models



# New biz model: personalized fashion

Artificial  
Intelligence

- {  It automates the body scanning process
-  It personalizes the clothes
-  It decentralizes the measurement process



The diagram illustrates a three-step process for personalized fashion:

- 1. Customize Your Shirt's Style**: An iPhone screen shows a white shirt with a collar, with the text "SELECT YOUR COLLAR" and "Straight Point". A blue diamond points to the top left of the phone screen.
- 2. Get Measured by Your iPad or iPhone**: An iPhone screen shows a red 3D human body model. A blue diamond points to the top left of the phone screen.
- 3. Enjoy Looking Great in Your Shirt**: A close-up photo of a person's neck wearing a blue shirt, with a blue diamond pointing to the top left of the image.

Text descriptions below each step:

- Customize Your Shirt's Style**: Choose your fabric, collar, cuff and more.
- Get Measured by Your iPad or iPhone**: Your mobile device's camera measures you at home in under 5 minutes.
- Enjoy Looking Great in Your Shirt**: Receive your shirt in the mail and get ready for the compliments.





# New biz model: delivery of shopping experience

Artificial  
Intelligence

- {  It automates the delivery process
-  It personalizes the shopping experience
-  It decentralizes the supermarket itself



Introducing

# PERSO

by L'ORÉAL



# New biz model: DIY personalized make up

Artificial  
Intelligence

- {  It automates the scanning process
-  It personalizes the make up
-  It decentralizes the production





beleza  
tech

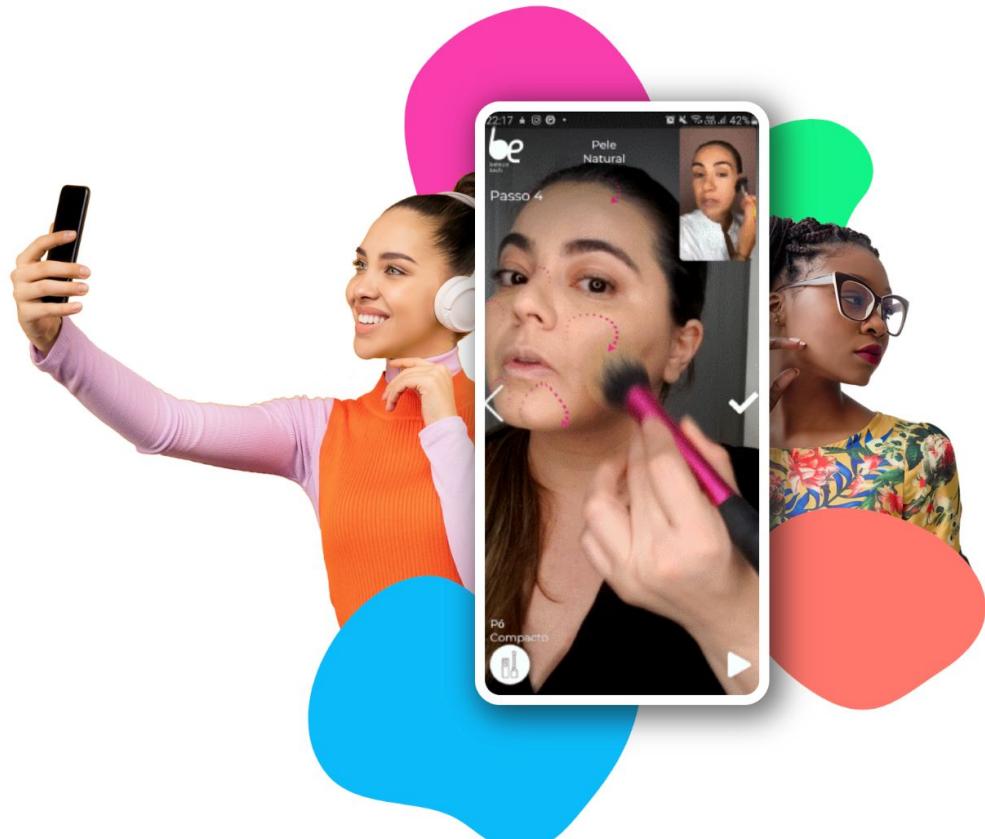
app sobre nós blog contato privacidade

15

# maquiagem sem blá blá blá

Vá além do tutorial e filtro de maquiagem! Vem pra be aprender rotinas de beleza, skincare e maquiagem no seu celular, de forma personalizada e passo a passo!

quero ser uma das 1as a usar





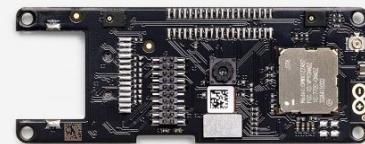
Artificial  
Intelligence

- 
- {
- It automates ...
  - It personalizes ...
  - It decentralizes ...

New biz model: ...



Portenta H7



Arduino Portenta Vision Shield - Lora

# Preservation of wildlife



# Wildlife Monitoring

## Risk Monitoring

Know when an animal is moving into a high-risk area and send real-time notifications to park rangers.

## Conflict Monitoring

Sense and alert when a specie is heading into an area where farmers live.

## Activity Monitoring

Classify the general behavior of the animal, such as when it is drinking, eating, sleeping, etc.

## Communication Monitoring

Listen for vocal communication between animals via the onboard microphone

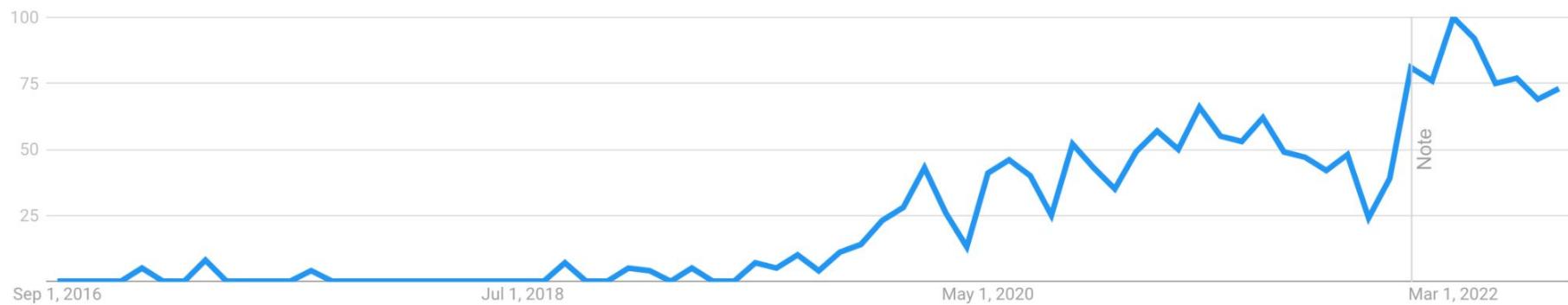
What do they  
have in  
common?



Google Trends



# tinyML





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P Warden, D Situnayake - 2019 - tinymlbook.com

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## Tinyml-enabled frugal smart objects: Challenges and opportunities

R Sanchez-Iborra, AF Skarmeta - IEEE Circuits and Systems ..., 2020 - ieeexplore.ieee.org

... In this work, a comprehensive review of the novel **TinyML** ... survey of the available **TinyML** frameworks for integrating ML ... To this end, several **TinyML** frameworks are evaluated and ...  
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## Benchmarking TinyML systems: Challenges and direction

CR Banbury, VJ Reddi, M Lam, W Fu, A Fazeli, ... - arXiv preprint arXiv ..., 2020 - arxiv.org

... -power machine learning (**TinyML**) hardware promises to unlock ... **TinyML** and discuss the challenges and direction towards developing a fair and useful hardware benchmark for **TinyML** ...  
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[PDF] [arxiv.org](#)

## [HTML] Tinyml meets iot: A comprehensive survey

L Dutta, S Bharali - Internet of Things, 2021 - Elsevier

... In this article, we introduce the definition of **TinyML** and provide background information on ... in **TinyML**-IoT scenario. Furthermore, it touches on the recent progress in **TinyML** research in ...  
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[HTML] [sciencedirect.com](#)

## [HTML] A review on TinyML: State-of-the-art and prospects

PP Ray - Journal of King Saud University-Computer and ..., 2021 - Elsevier

... improvement of **TinyML** systems. Fourthly, we present state-of-the-art about frameworks for **TinyML**. ... To present state-of-the-art frameworks for **TinyML** wherein we discuss about **TinyML** ...  
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Mohammed Zubair M. Shamim

IEEE Sensors Letters

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► Abstract  

Single Year  Range

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From

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**TinyOps: ImageNet Scale Deep Learning on Microcontrollers**



Gulcinen Ozturk, Jonathan Hess, Partha Maji, Simeon Warner, Geoff V. Mather

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1 TiWS-iForest: Isolation forest in weakly supervised and tiny ML scenarios Barbariol, T., Susto, G.A. Information Sciences, 2022 610, pp. 126–143 0

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2 Stride segmentation of inertial sensor data using statistical methods for different walking activities Jain, R., Semwal, V.B., Kaushik, P. Robotica, 40(8), pp. 2567–2580 1

from  — to

TINY



GRAN

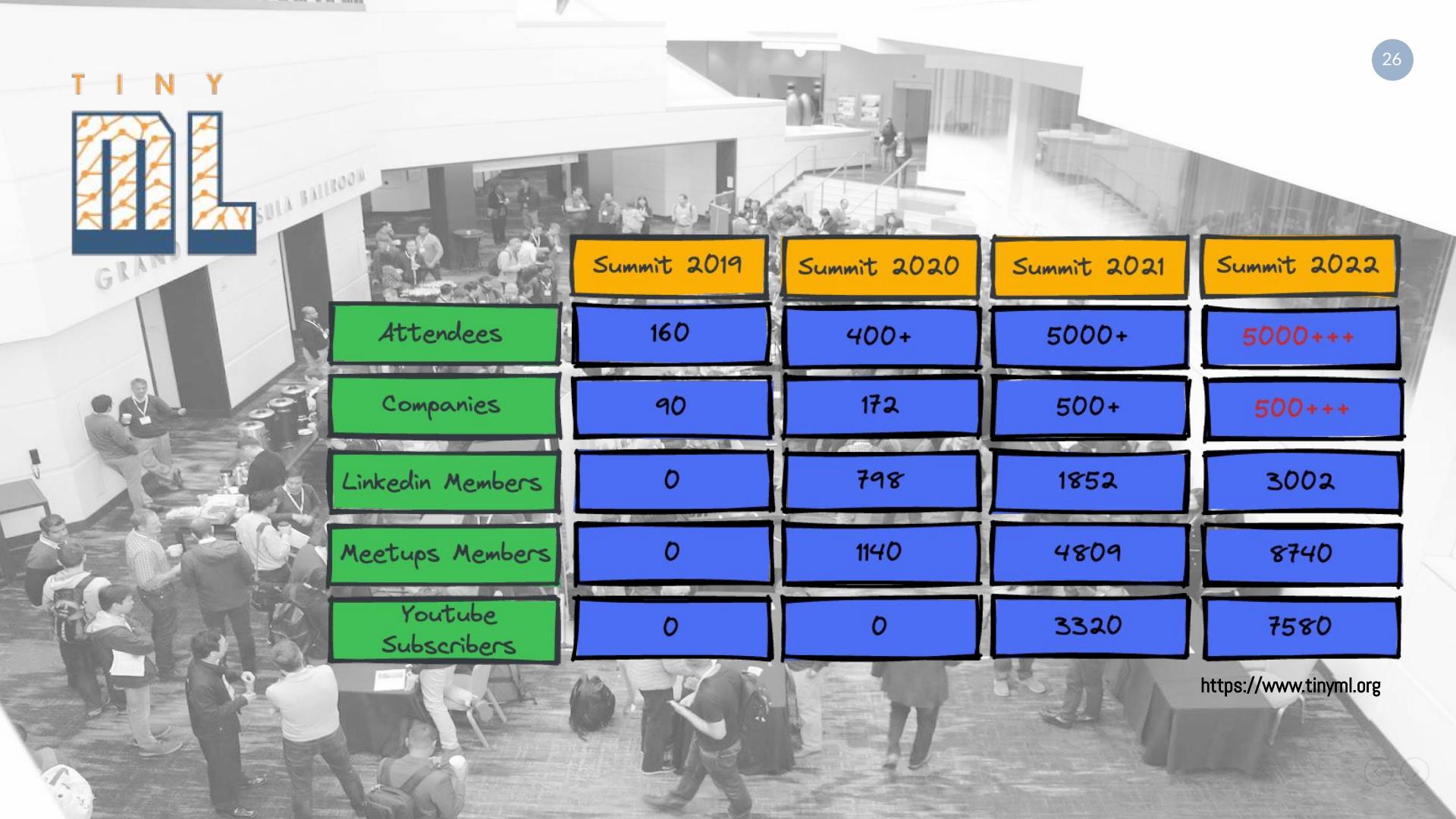
CLOUD

DATA

ML

AI

ML



Summit 2019

Summit 2020

Summit 2021

Summit 2022

Attendees

160

400+

5000+

5000+++

Companies

90

172

500+

500+++

Linkedin Members

0

798

1852

3002

Meetups Members

0

1140

4809

8740

Youtube  
Subscribers

0

0

3320

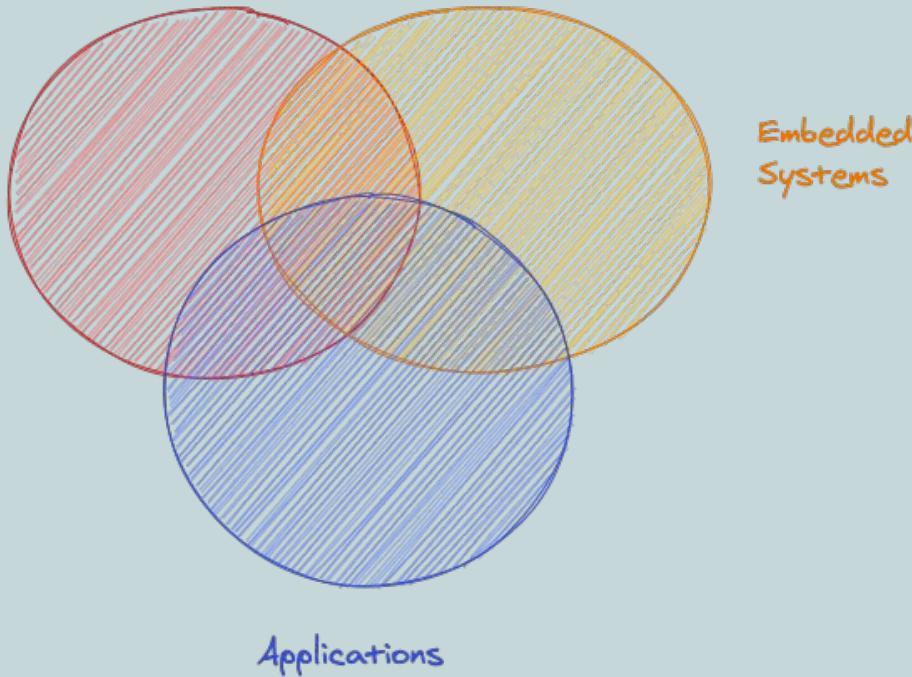
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<https://www.tinyml.org>

# TinyML Fundamentals



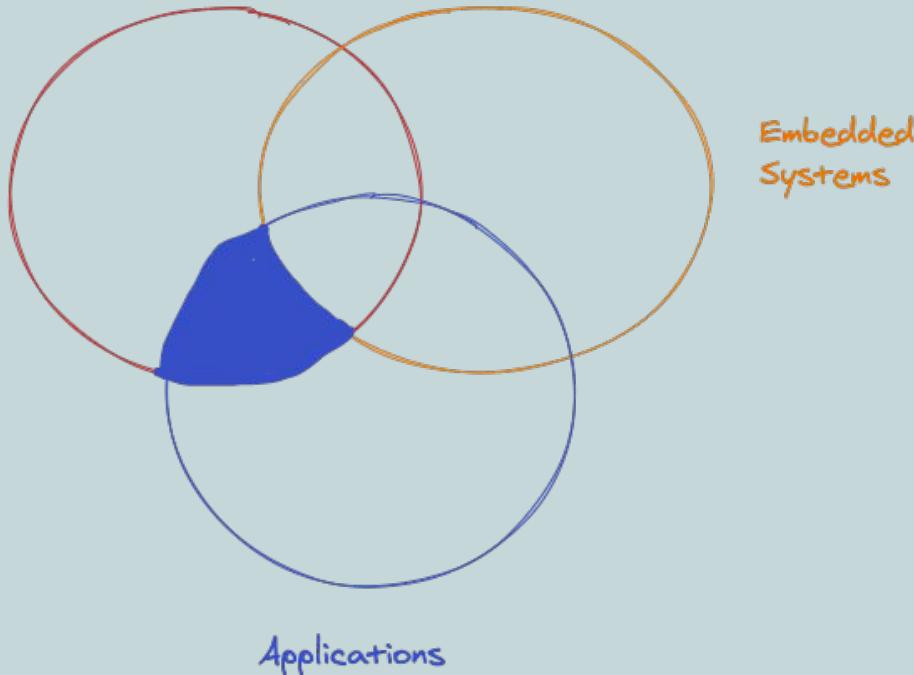
Machine  
Learning



# Interactions

In addition, we will bring these diverse topics together to reveal the interesting learning at the various **intersections**.

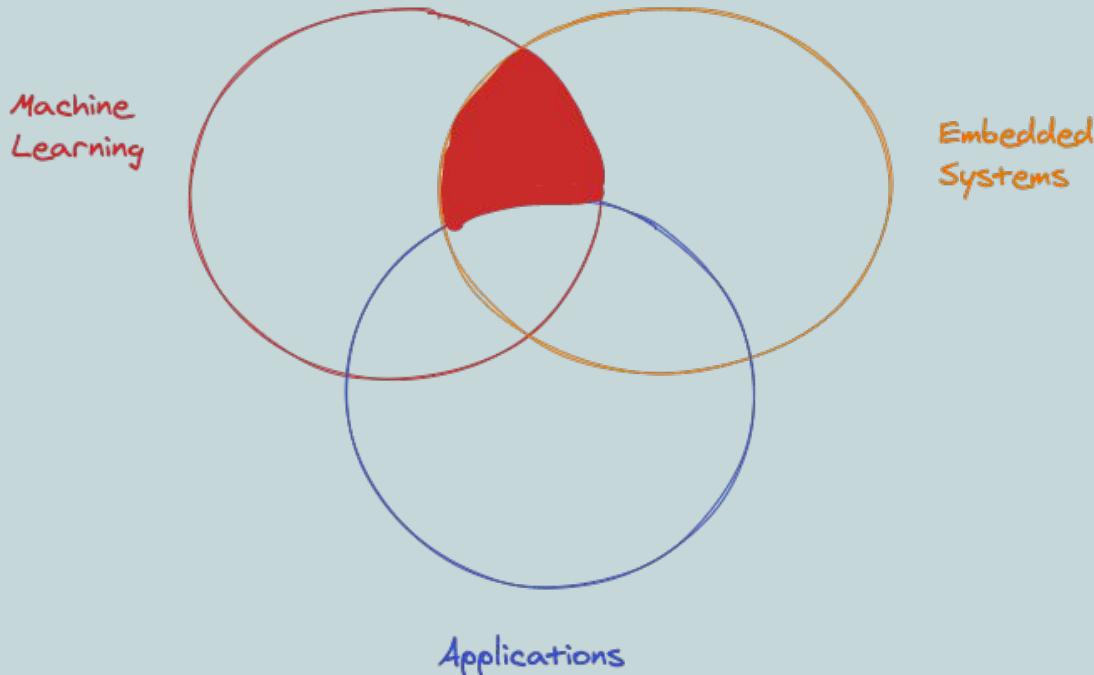
Machine Learning



# Interactions

**How** machine learning  
can enable and  
interesting **TinyML**  
applications?

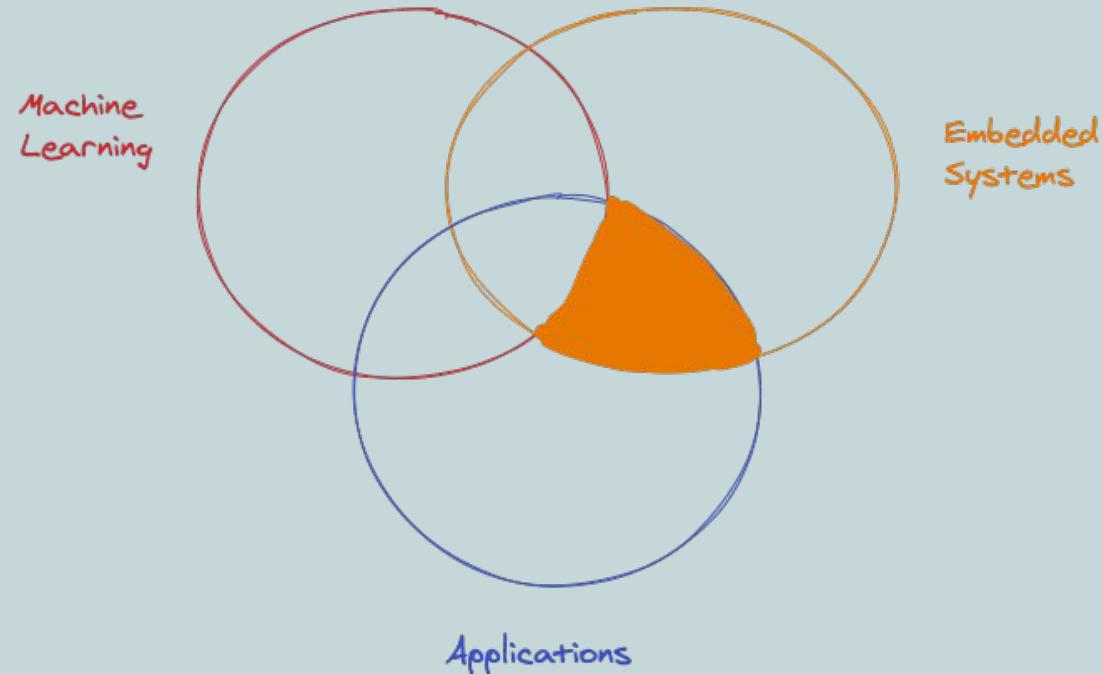




# Interactions

**What** are the challenges with enabling ML on **Tiny**, resource-constrained embedded devices?

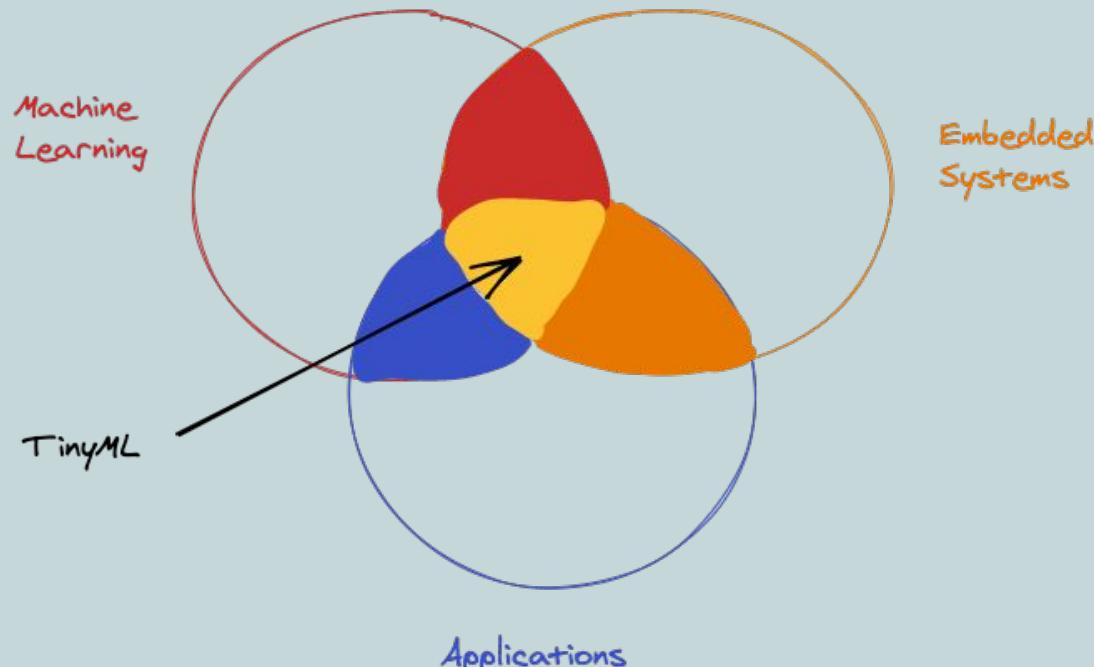




# Interactions

What type of **new use cases** can we possibly enable on embedded system what we could not otherwise do before?



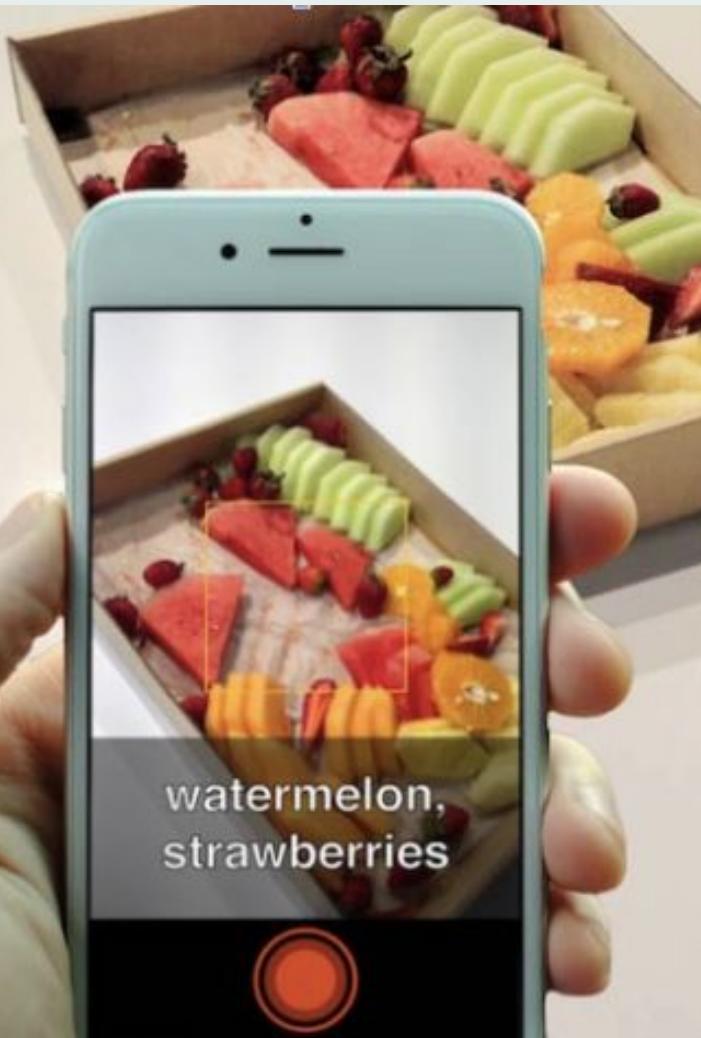


# At the end of the day

Given your understanding of things at these various intersections, you will have a deep understanding for **how to apply TinyML**

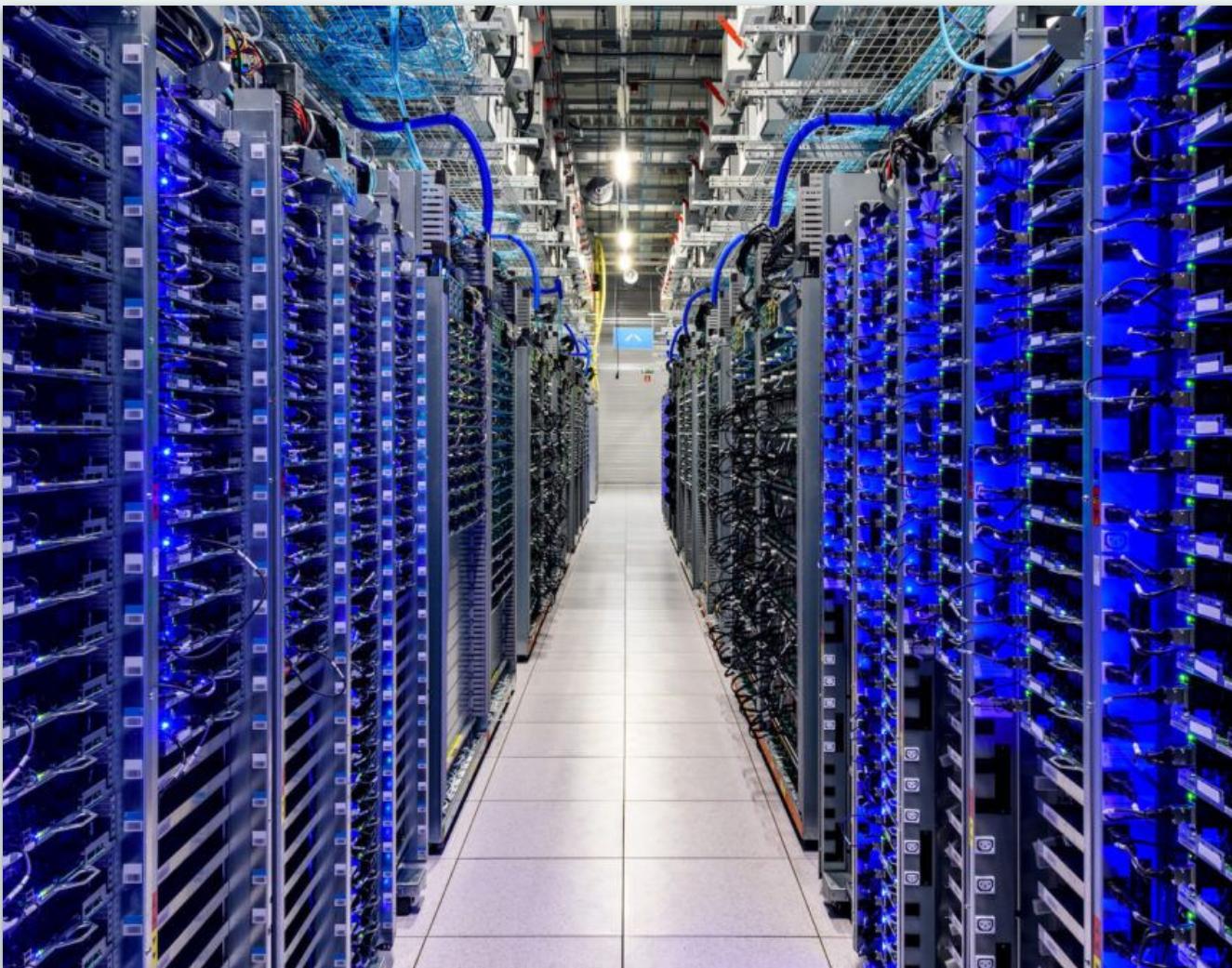


Why the future of  
machine learning is  
**tiny** and **bright**?



Machine Learning  
is here to stay



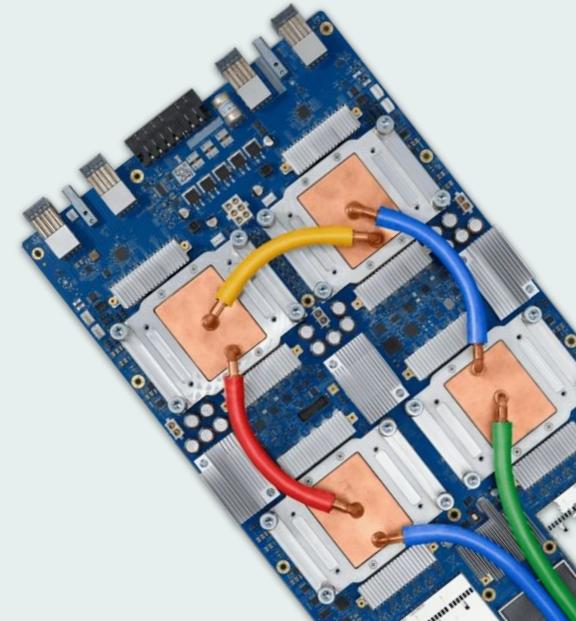


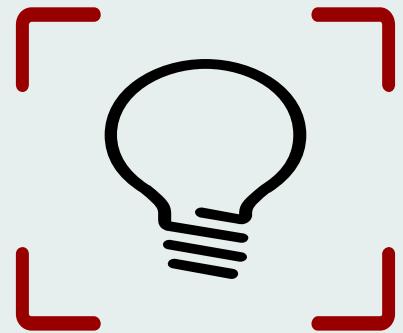
These capabilities require a remarkable of computing capabilities.

DataCenter



# Graph Processing Units (GPU) vs Tensor Processing Units (TPU)





Bigger is Not  
Always Better!!!

# Interactivity? Responsiveness?





High Power  
High Bandwidth  
High Latency

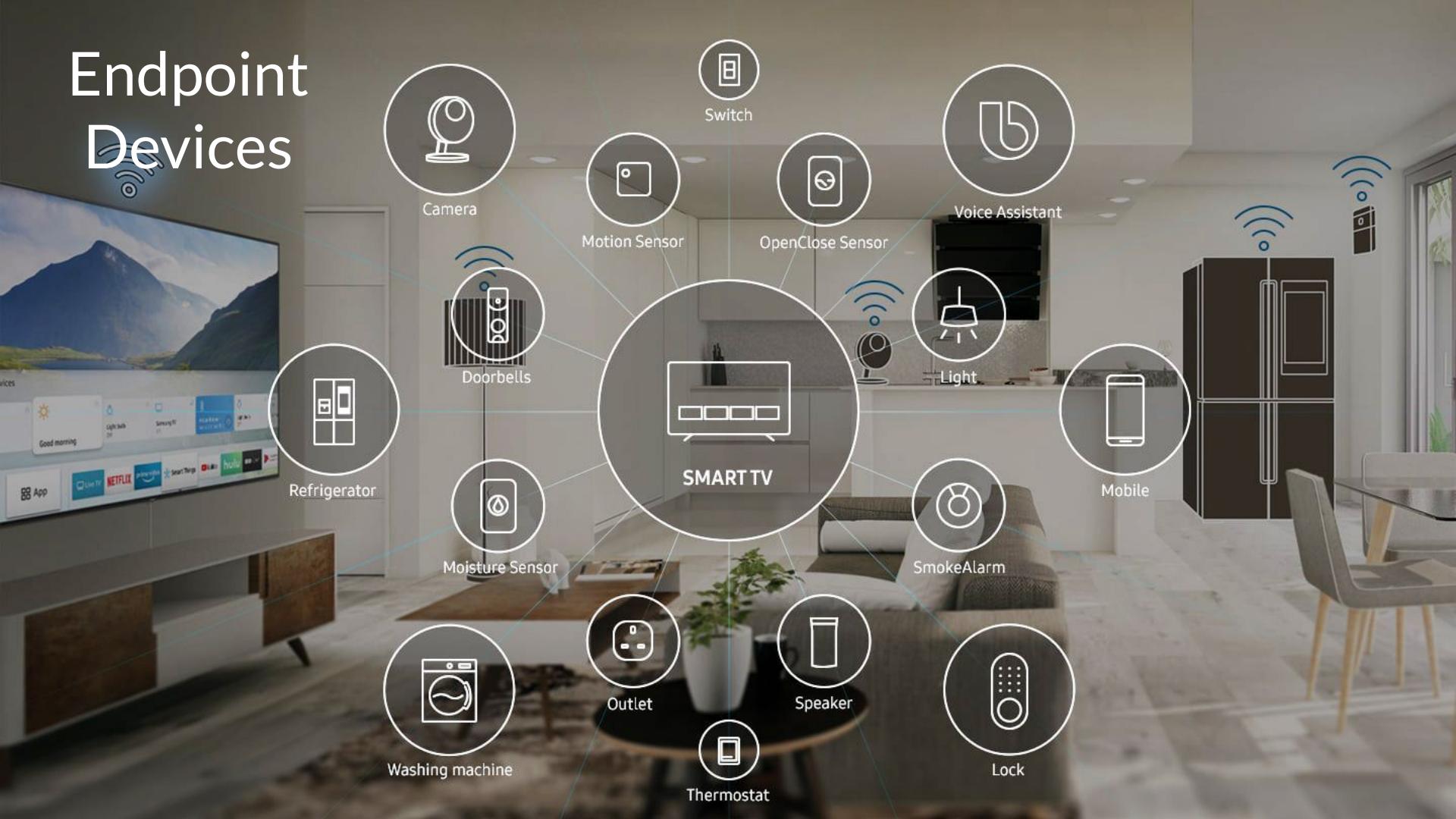


Low Power  
Low Bandwidth  
Low Latency

# Machine Learning running on phone all the time, always on?



# Endpoint Devices



## (i) A brief recap

- ML has several diverse applications in the real-world
- ML is increasingly moving from the cloud to endpoint devices
- Endpoint devices are everywhere around us

