Health Monitoring IoT System for Vehicle

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Outline

- **Introduction**
  - Motivations
  - Target Applications
  - Application Scenario
- **Evolution**
- **System Architecture**
- **Technology**
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  - Tx & Rx
  - DVFS
  - AIoT System
- **Industry Analysis**
- **Conclusion**
- **References**
- **Team Member task partition**

Motivation

- **The lack of awareness of vehicle maintenance**
  - Higher risk of nasty accident
  - Spending more time and money to repair
- **The small vibration or signal for the early stage vehicles' failure is hard to notice**
- **Important information for car insurance company**

Target Applications

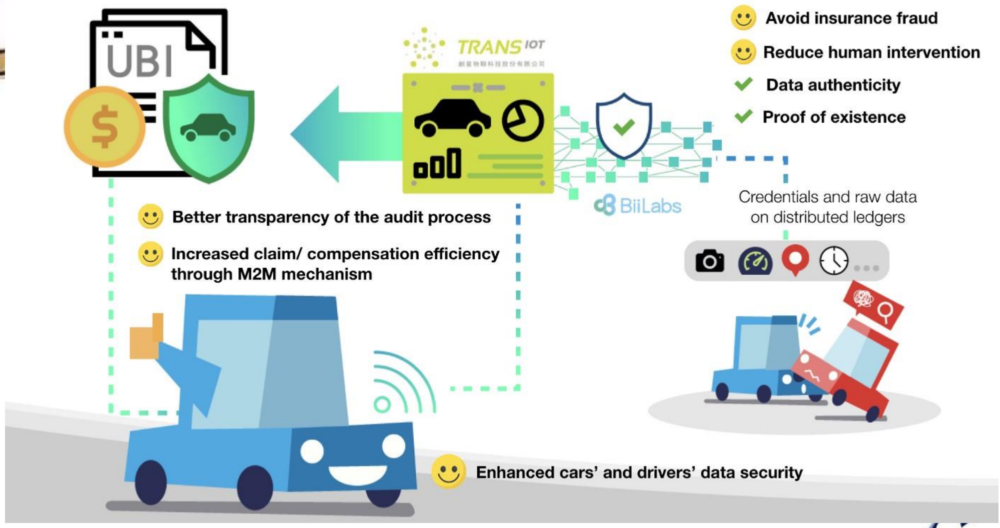
- **Detects early-stage failures:**
  - Reduce the risk of breakdown
  - Improve machine performance
  - Extend machine use life

- **Scoring machine health and your driving habbits**

- **Predicts failures:**
  - Predicting machine failure from sensors detection and users' driving style

Application Scenario

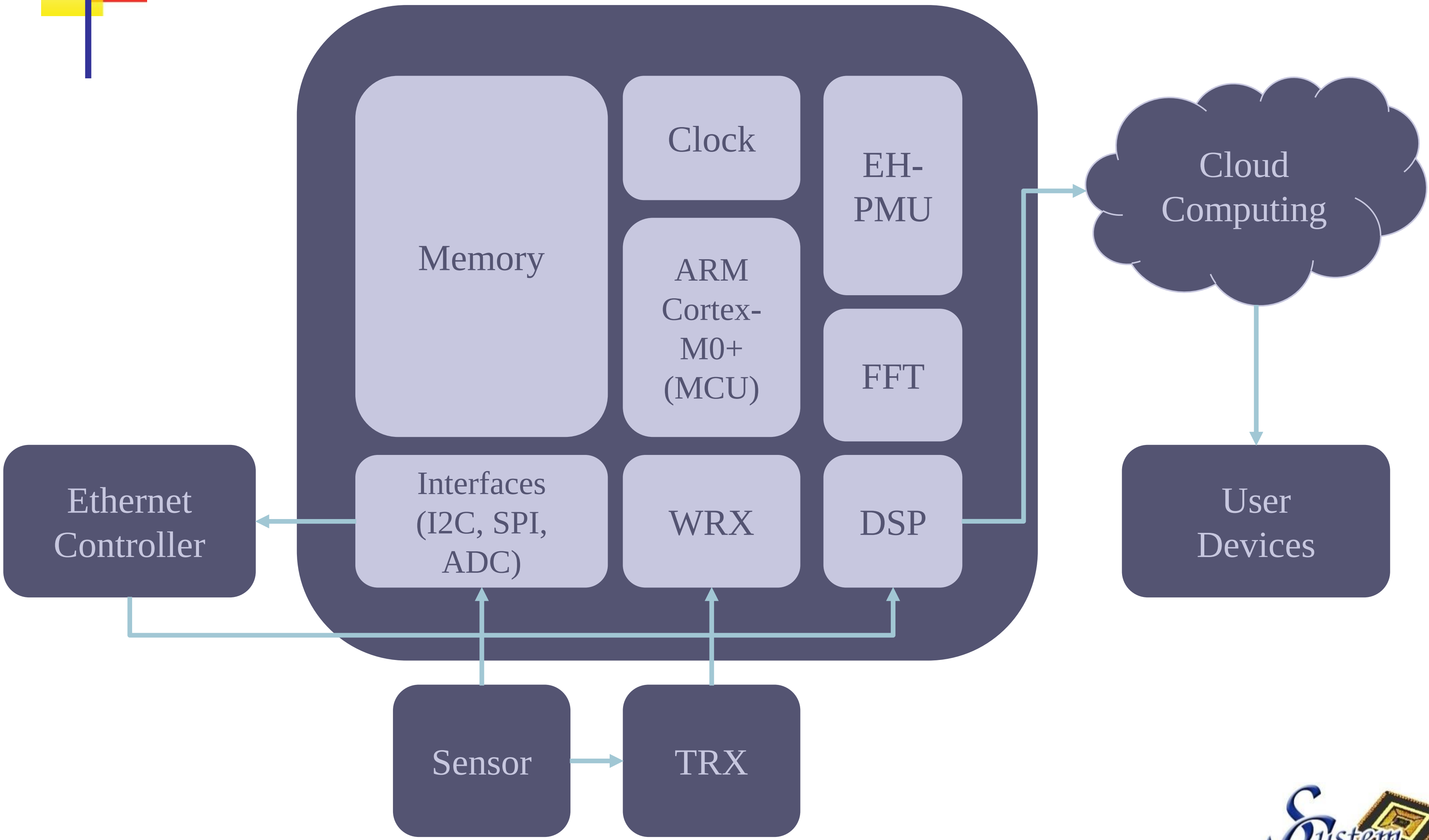
- Vehicle failure alert system
- Usage Based Insurance



Evolution

SHM	Structural Health Monitoring	1960
VHM	Vehicle Health Monitoring	1970
IVHM	Integrated Vehicle Health Management	1980
ISHM	Integrated System Health Monitoring	1990
PHM	Prognostics and Health Management	2000
ISHM	Integrated System Health Management	2020 +
IHMM	Intelligent Health and Mission Management	

System Architecture



Technology

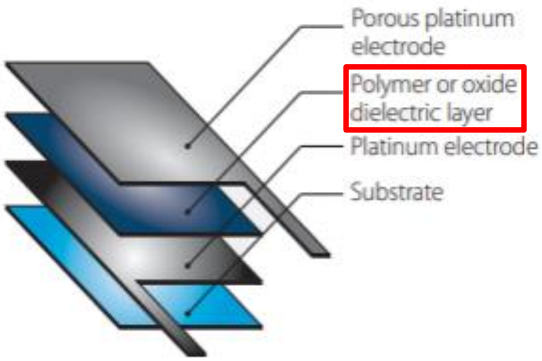
- **Sensors:**
  - Acceleration
  - Temperature
  - Humdity
- **Tx & Rx:**
  - IEEE 802.11ba
  - Wake-up Radio receiver
- **Power management**
  - Microcontroller
  - DVFS
  - Energy Harvesting
- **Storage Device:**
  - Cloud Storage
- **Network**
  - LTE / Wi-Fi backhaul

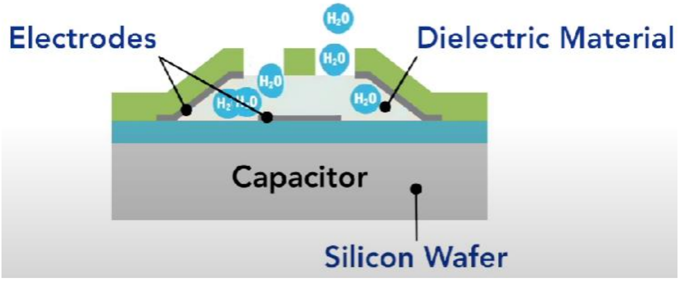
Sensors

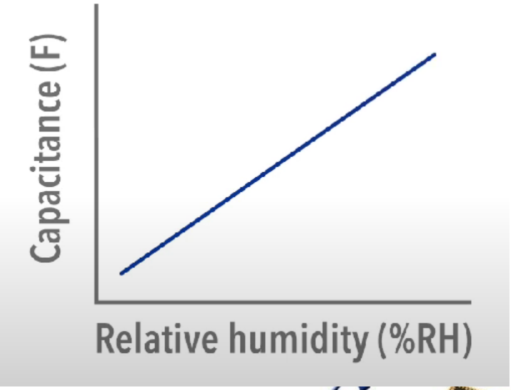
- Relative Humidity Sensor
- Accelerometer
- Magnetometer
- Thermistor

Relative Humidity Sensor

- **Capacitive humidity sensor**
  - Dielectric layer absorbing moisture from air
  - Wide range detection from 0% to 100%
  - Low power, Linear output, High stability
  - Temperature dependence (combined with temp sensor)

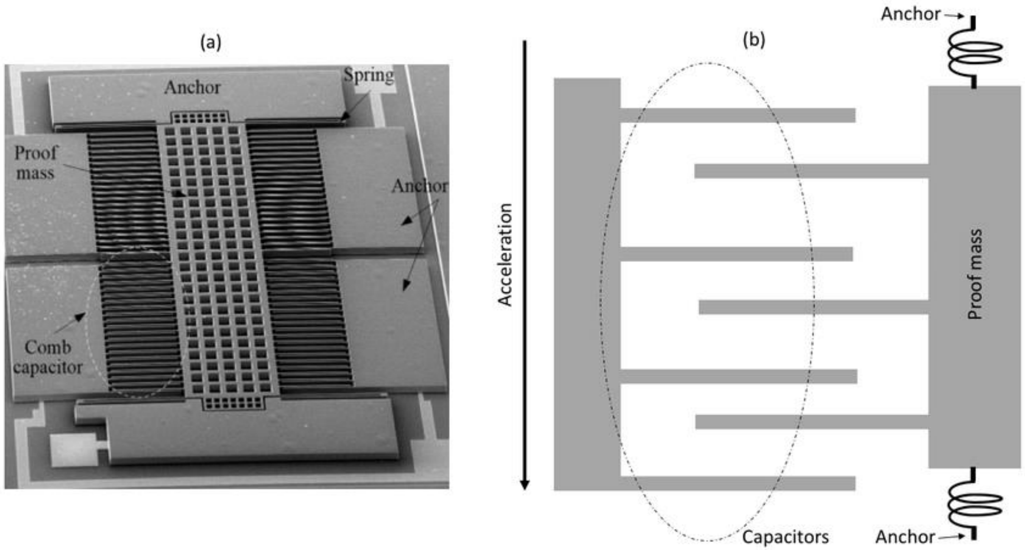


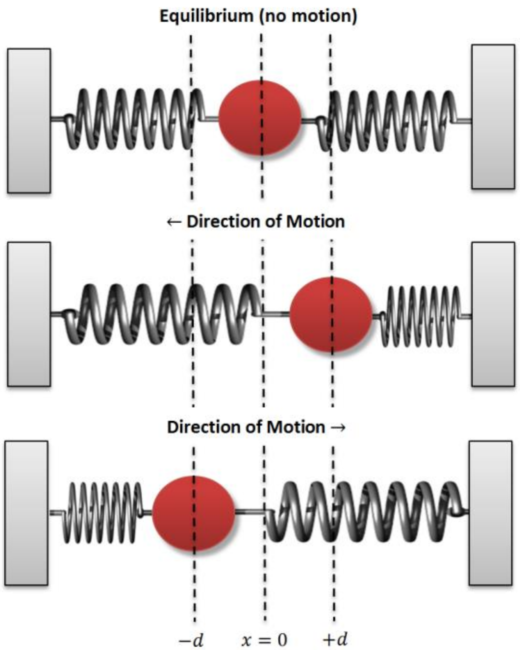




Accelerometer

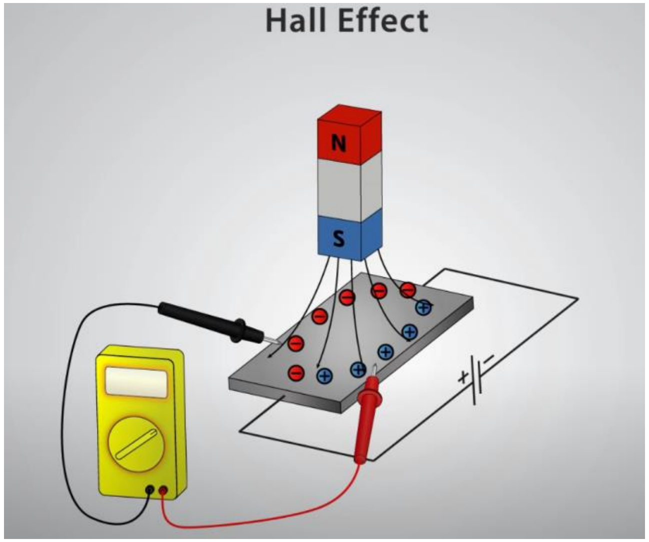
- **Capacitive Accelerometer**
  - Movement changes capacitance between mass & comb fingers
  - Proof of mass + Comb capacitor + Spring

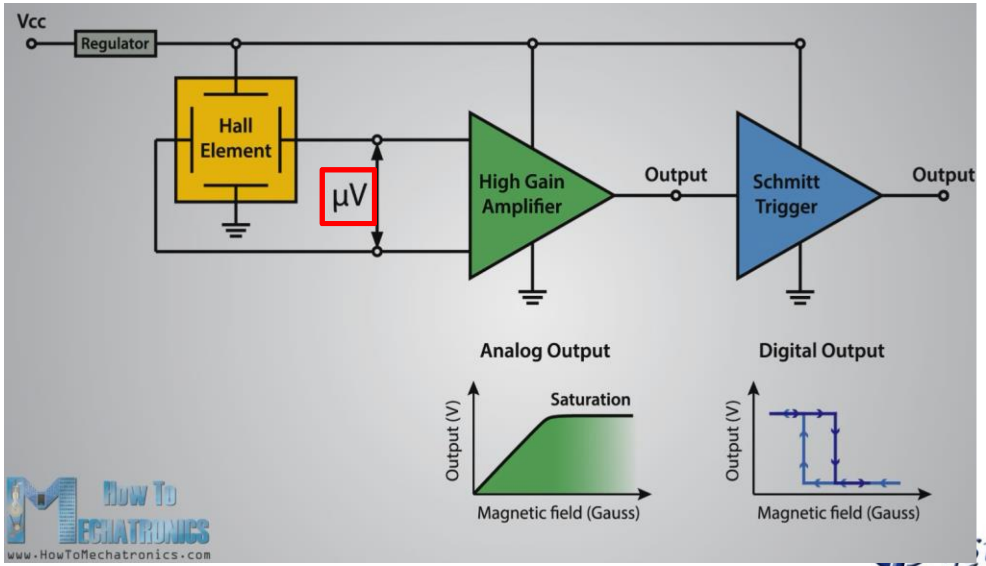




Magnetometer

- **Hall Effect Magnetometer**
  - Drift voltage caused by Lorentz force when a magnetic field is present
  - Amplifier is needed due to small drift voltage
  - Schmitt trigger to resist noise & bounce



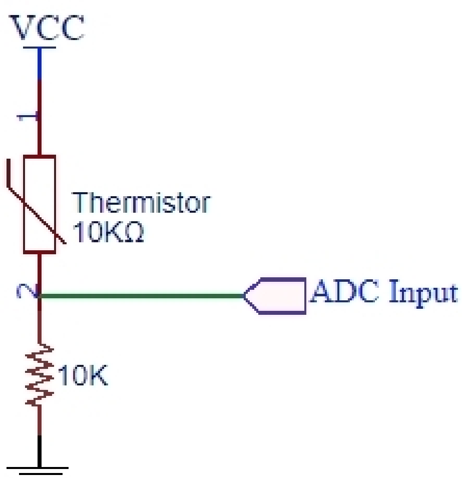


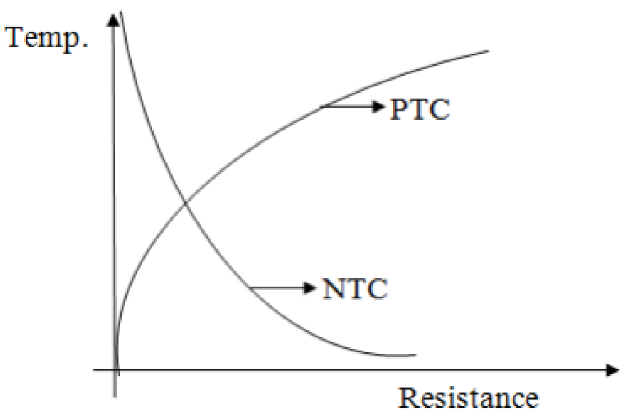
Thermistor

- 2 basic types:

1. **Positive Temperature Coefficient (PTC)**
2. **Negative Temperature Coefficient (NTC)**

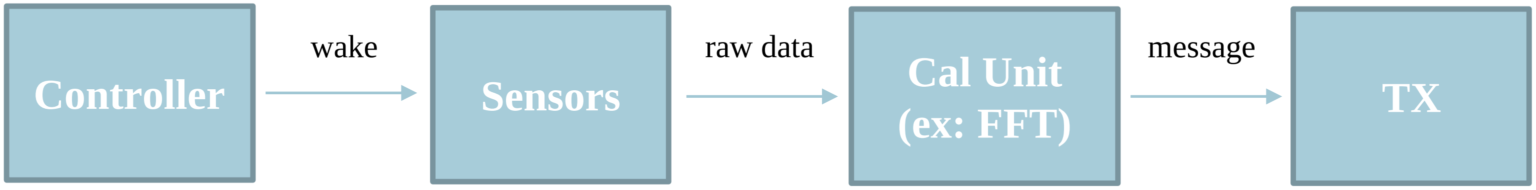
- Temperature range: −100 °C and 300 °C
- Monitoring temperature by ADC





Operation Flow

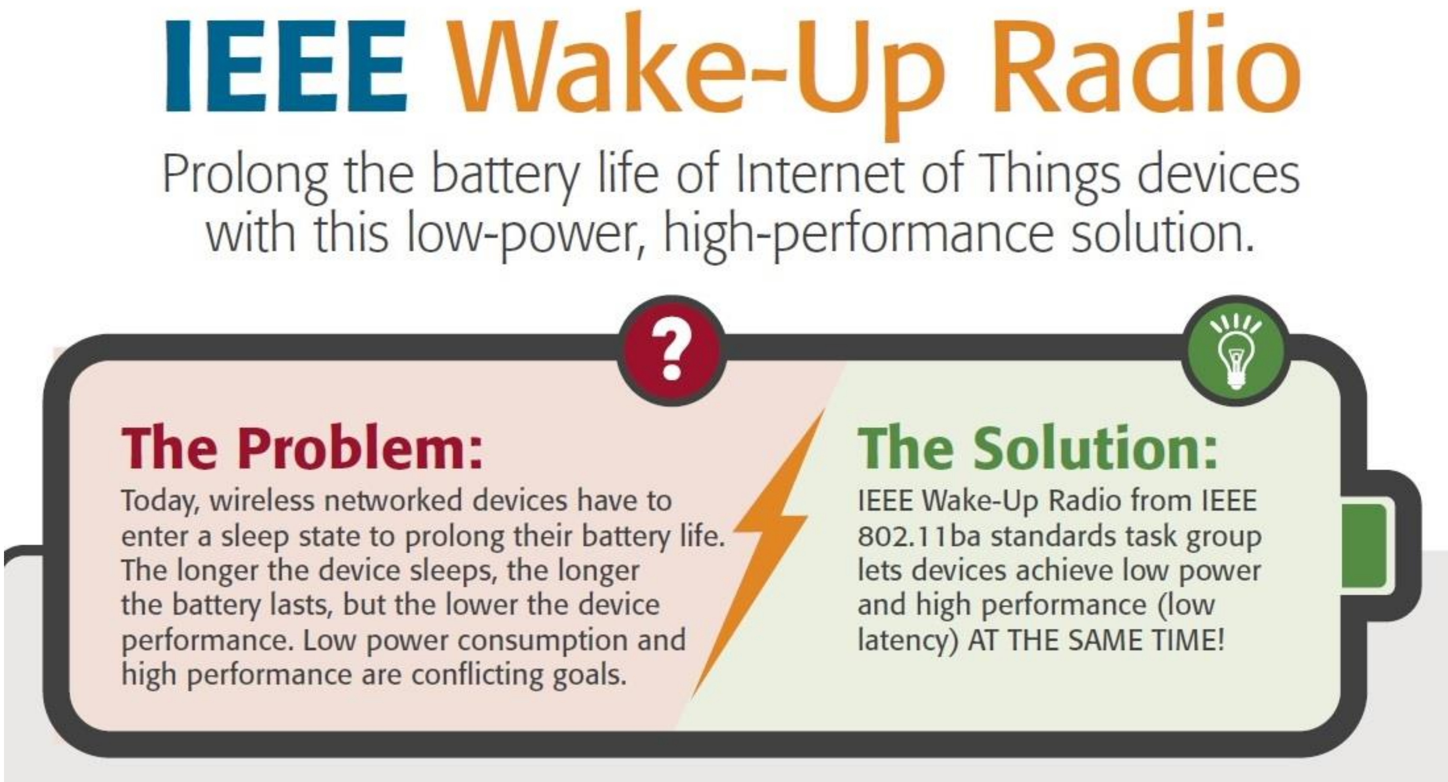
- **Target:** continuous monitoring in varying condition
- Extracting information on chip through calculation
- **Interface:** I2C, SPI, ADC



Tx & Rx

- **Wake-Up Radio**
- **IEEE 802.11ba**
- **Wake-Up Radio system architecture**
- **WuRx wake-up circuit**

Wake-Up Radio



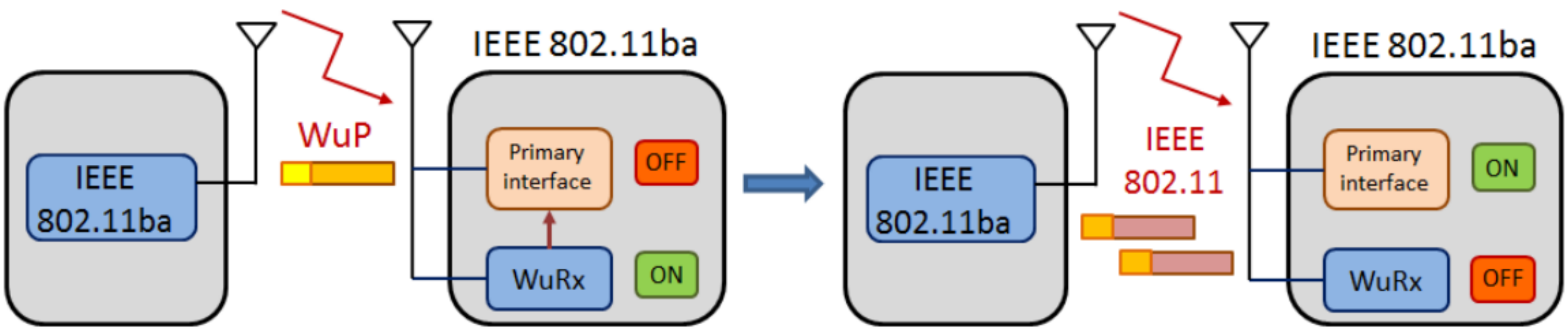
IEEE 802.11ba

July to November 2016, the scope and targets of the standard were defined. There are three key requirements:

- The Wake-Up Radio (WuR) power < 1mW.
- The WuR should coexist with legacy IEEE 802.11 devices in the same band.
- The WuR should meet the same range requirement as the primary connectivity radio.

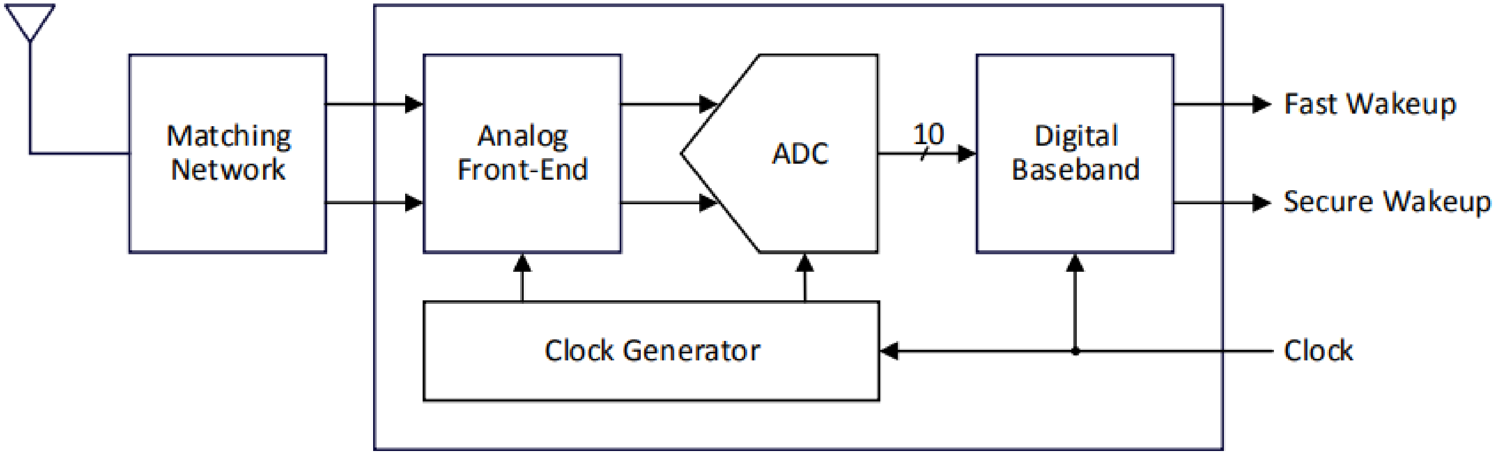
Wake-Up Radio system architecture

- The primary radio of an IEEE 802.11ba-capable low-power device is put to sleep in order to save energy
- When the sleeping device is required, a packet is sent in order to generate a call to wake up the device's primary radio



WuRx wake-up circuit

- An off-chip matching network to provide passive gain into the analog front-end
- SAR ADC and digital baseband issue fast wakeup or secure wakeup signal to MCU



Power Management

- **Microcontroller**
- **DVFS**
- **Energy Harvesting**

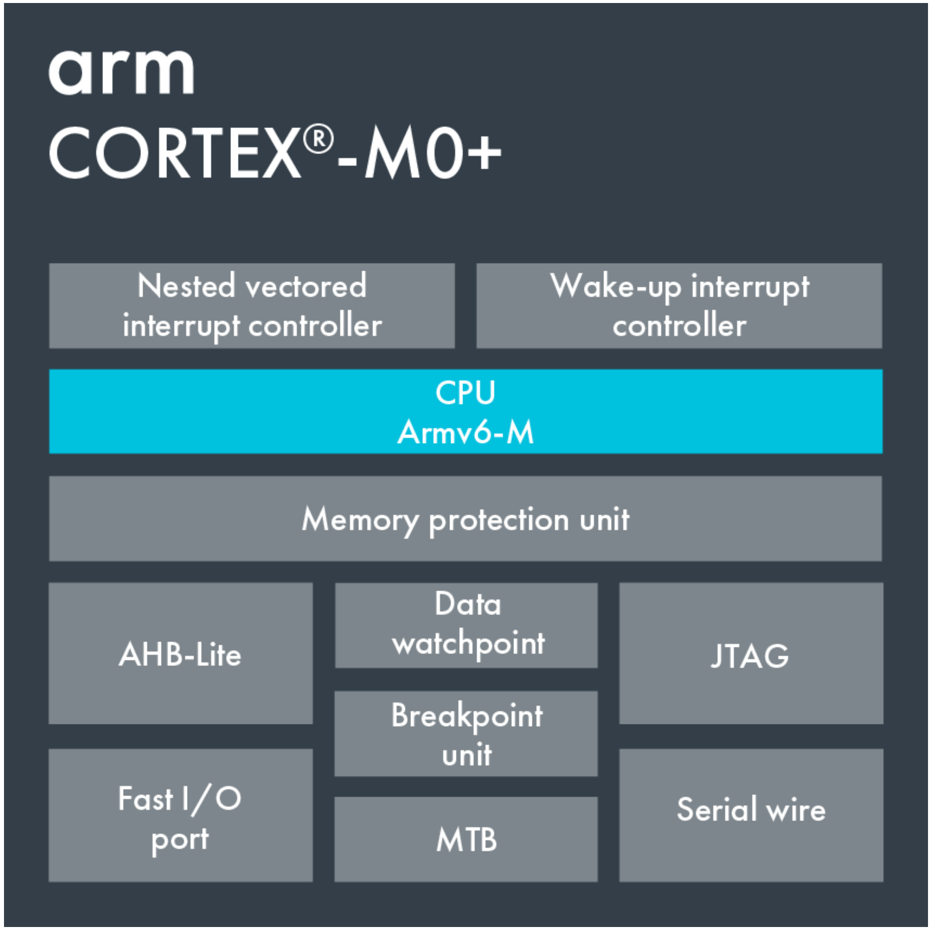
Microcontroller

Three Sleep modes

1. Normal Sleep

1. Deep Sleep
   (Wake up Interrupt Controller (WIC))

1. Deep Sleep with State Retention Power Gating (SRPG) support (WIC + SRPG)



Microcontroller

Feature of Cortex M0+ :

- Similar size and programmer's model to Cortex M0
- Low gate count same as Cortex M0
- Two-stage pipeline (more low energy consumption)
- Memory Protection

DVFS

DVFS is dynamic voltage frequency adjustment, and dynamic technology is to dynamically adjust the operating frequency and voltage of the chip

Adjustment Steps:

When power needs to be boosted

Increase the supply voltage → Increase the clock frequency

When power needs to be reduced

Reduce the clock frequency → Reduce the supply voltage

Energy Harvesting

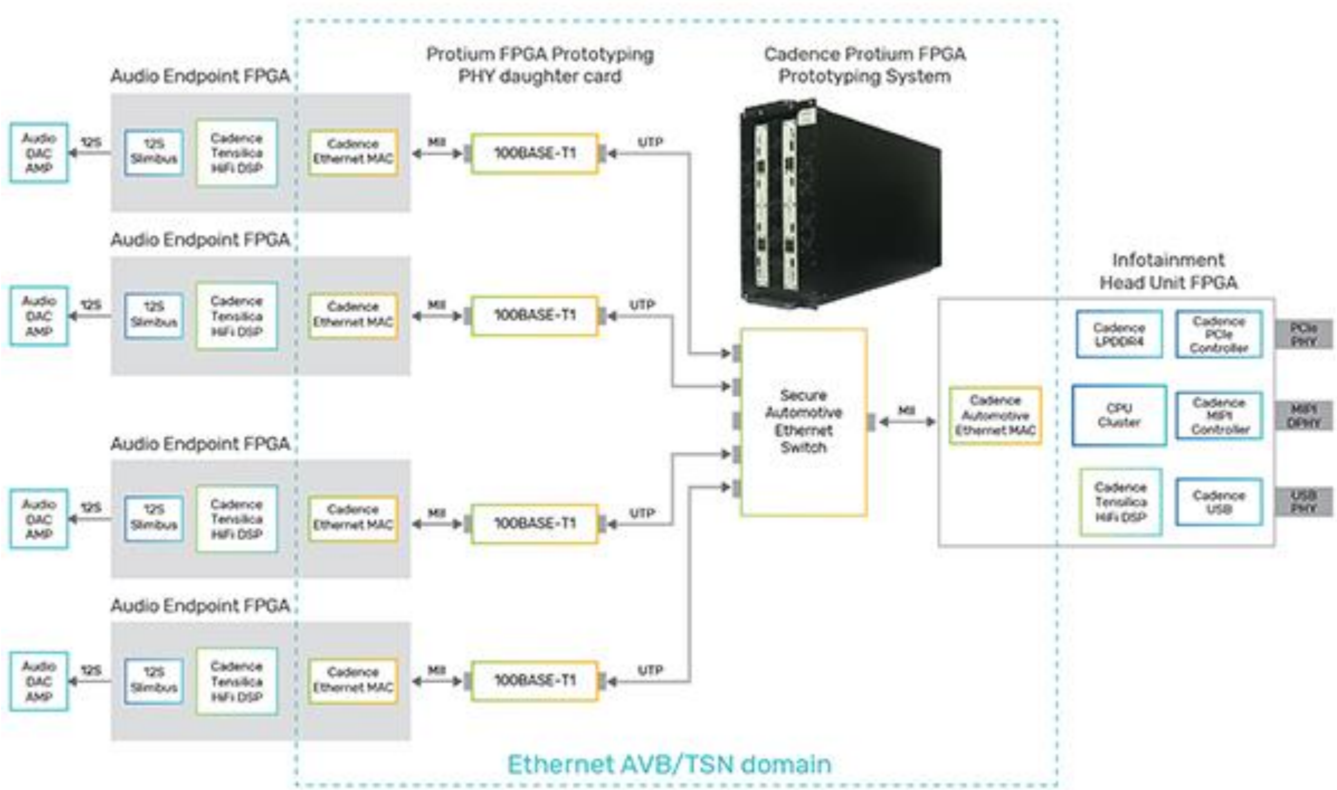
Multi-modal energy-harvesting power management unit (EH-PMU) with supercapacitor

Harvest from:

1. EM (electromagnetic) coil
2. Photovoltaic (PV) cell
3. Thermoelectricgenerator (TEG)
4. Vibration
5. RF energy

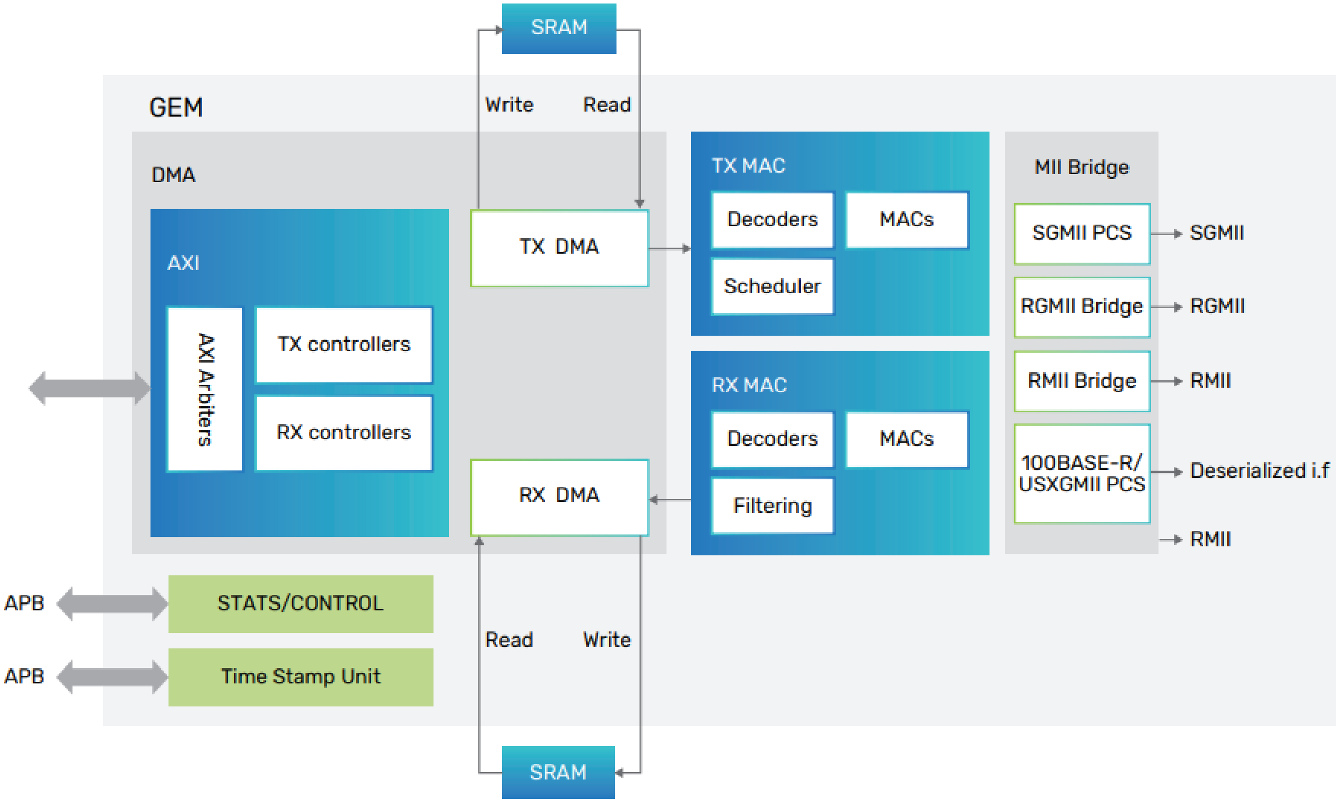
Automotive Ethernet

- **The automotive industry has adopted Ethernet for in-vehicle networking (IVN) based on open IEEE standards.**



Automotive Ethernet

- **10G/2.5G/1G Multi-Speed Ethernet Controller IP for Automotive Applications from Cadence**



Communication Protocols

Parameters	LIN	CAN	FlexRay
Architecture	Single master and up to 15 slaves	Multiple nodes (20, 32)	Multiple nodes (up to 64)
Medium access or Bus access	Polling method	CSMA-CR method	TDMA method
Topology	Bus topology	Bus topology	Bus/Star topology
Message transmission	Synchronous	Asynchronous	Synchronous/Asynchronous
Data rate or Baud rate	Max. 20kbps	Max. 1Mbps	Max. 10Mbps
Bit coding	NRZ	NRZ and bit stuffing	NRZ
Error checking mechanism	Checksum over the Protected Identifier and Data fields	CRC computation over the entire frame	Two CRC computations. 1. Header CRC: Over the header field (starting from the Sync frame indicator field) 2. Trailer CRC: Over the entire frame
Hamming Distance (HD)	HD for the checksum is 2	HD for the CRC computation is 6	HD for the header CRC is 6 and for the trailer CRC it is 6 up to 2048 bits and 4 for data up to 4096 bits.
Physical layer	Single electrical wire	Electrical dual wire	Dual wire – optical or electrical
Operating voltage	8v to 9v	3.3v	Differential voltage of +2.0v
Cabling impedance	1k ohms	120 ohms	80-110 ohms
Range	1-5 kilometers	40 meters	10 meters

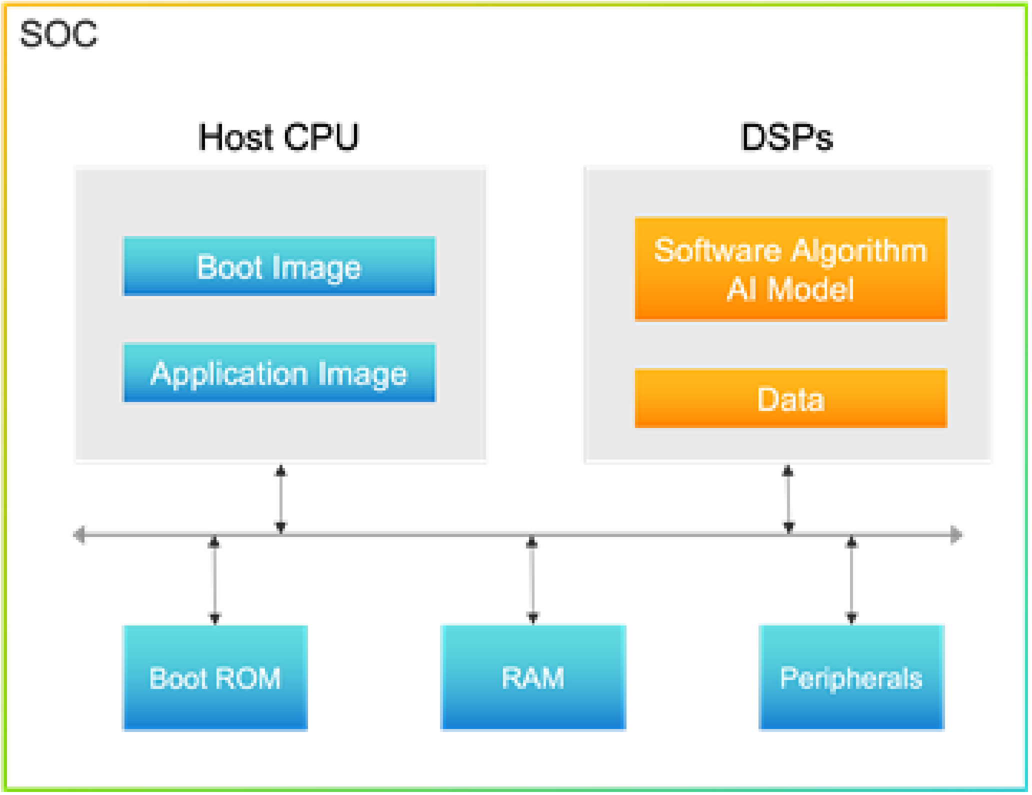
Neural Network

- Improved BP (Back-propagation) Neural Network
- The average absolute error of the traditional BP neural network algorithm is 0.5976, The average absolute error of the traditional BP neural network algorithm is 0.5976

The target output	Actual output based on the improved BP neural network					Diagnostic number	Diagnostic results
00001	0.0001	-0.0001	0.0000	-0.0001	0.9999	1	True
00010	0.0002	-0.0002	-0.0003	0.9998	0.0001	2	True
00011	-0.0002	0.0000	-0.0002	1.0000	1.0003	3	True
00100	-0.0003	-0.0005	0.9992	0.0000	0.0008	4	True
00101	0.0001	0.0001	1.0000	0.0002	0.9995	5	True
00110	0.0000	0.0000	0.9998	0.9999	0.0002	6	True
00111	0.1751	0.4825	-0.0322	0.6006	0.2937	7	False
01000	0.0000	1.0001	0.0000	0.0001	0.0003	8	True
01001	-0.0001	1.0000	0.0003	0.0000	1.0000	9	True
01010	0.0003	0.9996	-0.0003	0.9997	0.0003	10	True
01011	-0.0000	0.9999	-0.0000	1.0000	1.0001	11	True
01100	0.0000	1.0000	0.9999	-0.0000	0.0001	12	True
01101	-0.0001	0.9996	1.0001	0.0001	0.9998	13	True
01110	0.0001	0.9997	0.9990	1.0000	0.0008	14	True
01111	0.0000	0.9999	0.9999	1.0000	1.0000	15	True
10000	1.0000	0.0000	-0.0002	0.0001	0.0003	16	True

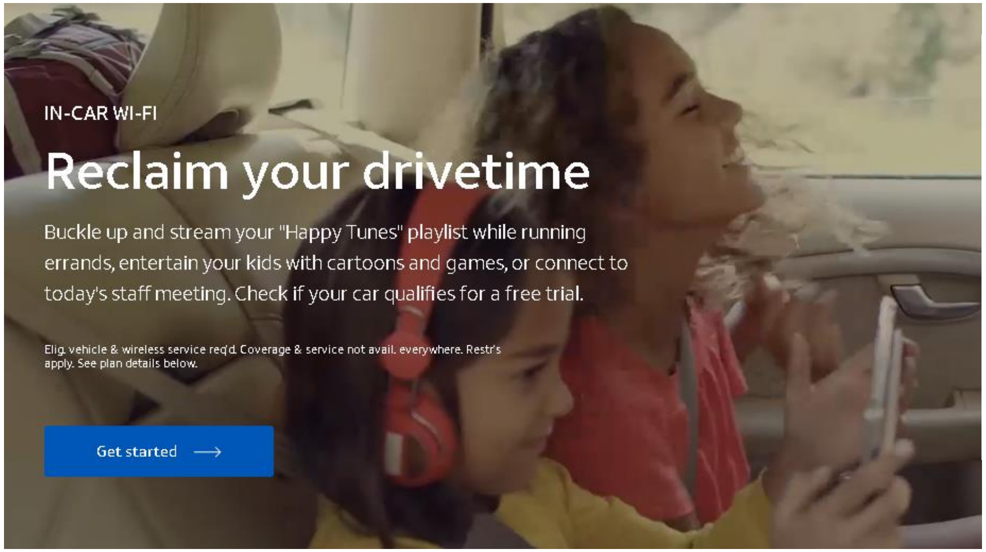
Neural Network

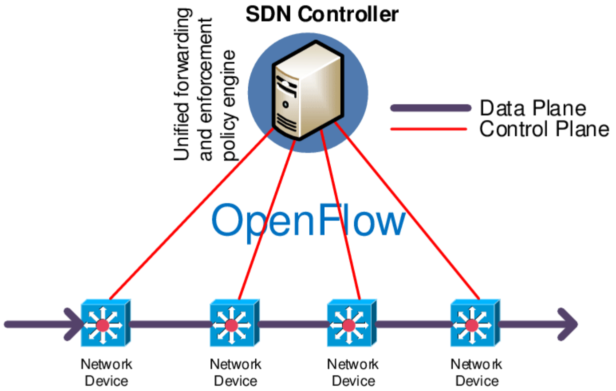
- Software IP and data that needs protection are stored as encrypted hash to ensure security



Outbound Data Flow

- **AT&T In-Car WiFi**
  - An Internet data plan working with your vehicle's built-in Wi-Fi hotspot
  - In-car Wi-Fi turns your vehicle into a Wi-Fi hotspot with fast, reliable internet access even when you're far from home.
  - The collected components' data are sent through WiFi to the data center for predicting component failure.





Industry analysis

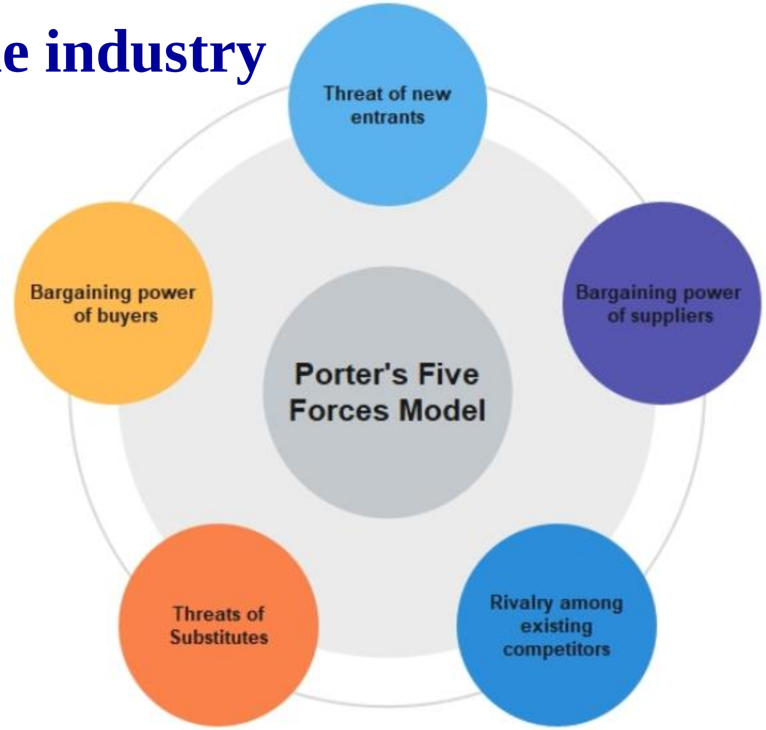
1. Competition in the industry

2. Potential of new entrants into the industry

3. Bargaining power of suppliers

4. Bargaining power of customers

5. Threat of substitute products



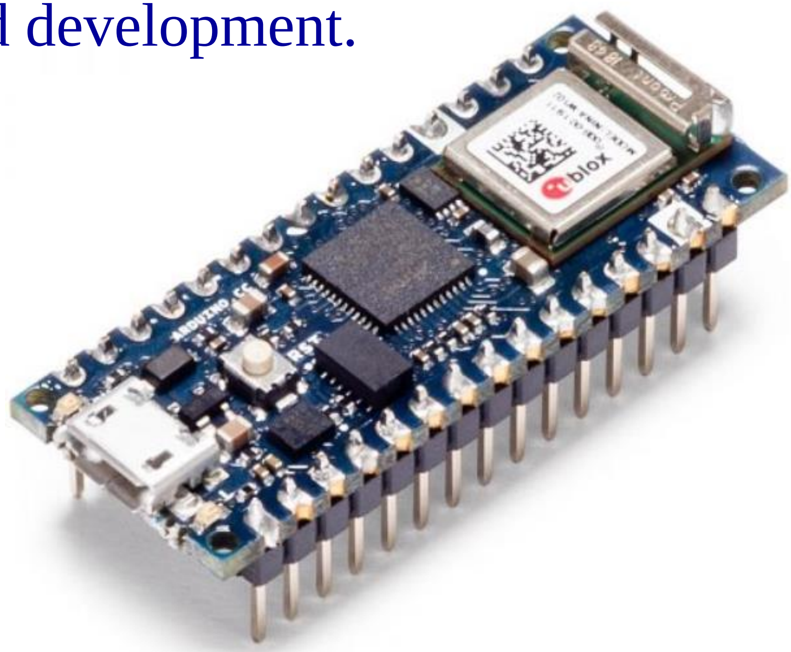
Industry analysis

1. Competition in the industry

- Medium, fewer similar products in the early stage.

2. Potential of new entrants into the industry

- High, because the will be more manufacturers investing in research and development.



Industry analysis

3. Bargaining power of suppliers

- High, it’s a important safety issue to vehicle.

4. Bargaining power of customers

- Low, because of the Novelty of product.

Industry analysis

5. Threat of substitute products

- Medium, Some functions for diagnosing the health of components are now integrated into the car chip.

Industry analysis

SWOT Outline

S — Strengths

1.It can respond to problems in the car faster than manual inspection
2.A safe driving environment is important

W — Weaknesses

1.Long product life cycle
2.Severe standard of safety issue makes a higher cost

O — Opportunities

1.The growing market size of electric vehicle
2.Attract investment cooperation from insurance companies

T — Threats

1.Diagnosing the health of components may be integrated into the car chip.

Conclusion

- **Planning the SoC that combines with multiple functions for responding to different situations during driving**
  - Vary types of sensors that can detect vehicles' health
  - WRX design for fast respond and power management
  - DVFS and energy harvesting technology focus on further low-power SoC design
  - AIoT collects and computes the data generated by the SoC for different kinds of applications

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Team Member task partition

- **Introduction** -*all*
- **System Architecture** -*all*
- **Technology**
  - Sensors -*徐詠祺*
  - Tx & Rx -*張睿紘*
  - DVFS -*張文彥*
  - AIoT System -*楊文彣*
- **Industry Analysis** -*王瑞賢*
- **Conclusion** -*all*