IoT Technologies for Embedded Computing: A Survey

Presented by: Sachin Bharadwaj, Vinay Sawant

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INTRODUCTION

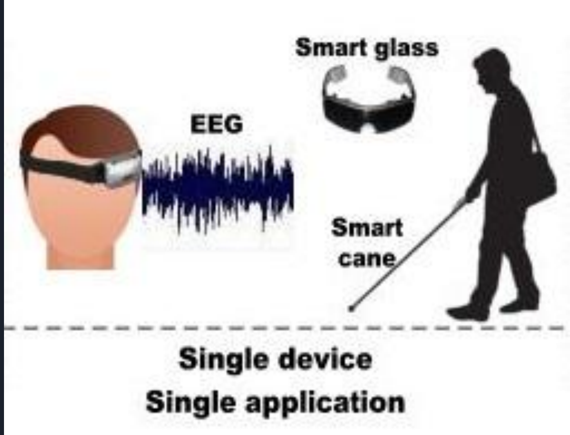
- IOT : A multidisciplinary pattern where objects/devices are networked and connected to Internet.
- Emergence of Internet-of-Things brings a whole new class of applications and higher efficiency for existing services.
- Connectivity (wired or wireless) is what distinguishes embedded IoT systems from conventional embedded systems.
- The Internet connectivity, lets devices and smart objects (also known as machines) communicate and interact with (i) other machines and devices, or (ii) humans.
- Many research efforts on IoT from the perspective of networking, object identification, security and privacy have been presented.
- However, it has gained less attention from the perspective of embedded computing.

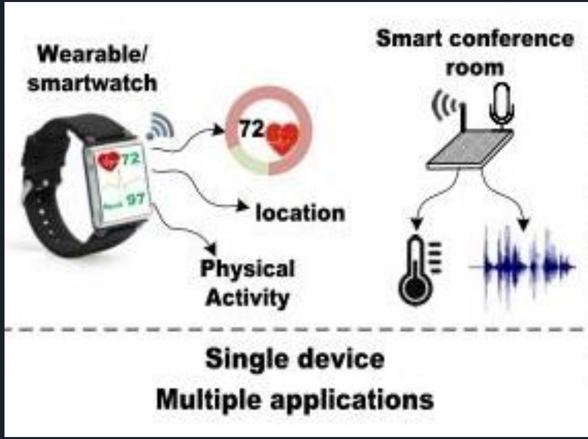
The IoT embedded designer faces some questions

Q. Which wireless communication technology 1) covers the required range, 2) provides the required data rate, 3) is still (ultra) low-power and meets energy constraints?

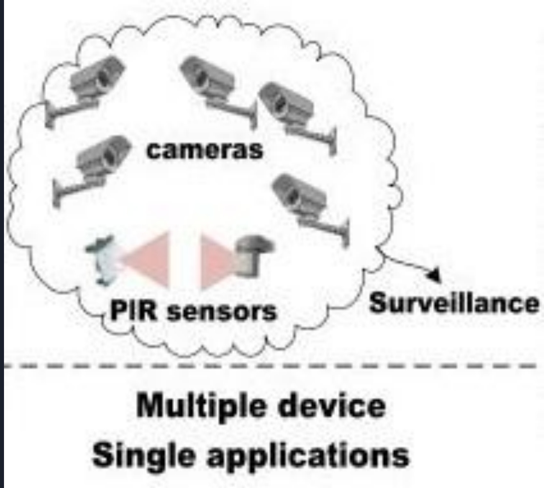
Q. What trade-offs to make between 1) Quality of Service(QoS) and energy consumption, 2) on-board processing and computation offloading, etc.? How to handle the uncertainty and unpredictability of IoT systems (mainly caused by communication)?

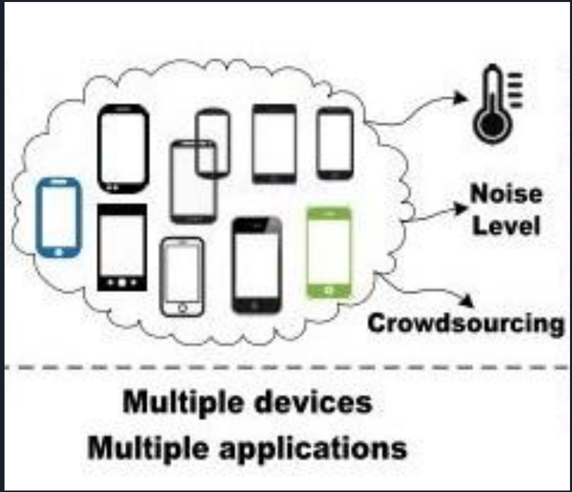
Devices vs Applications



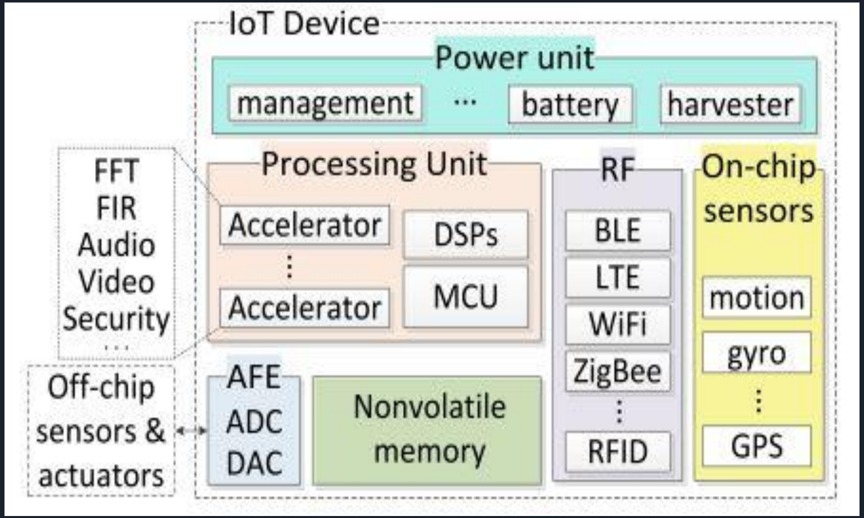


Devices vs Applications (contd)





General Architecture of an IoT Embedded Device

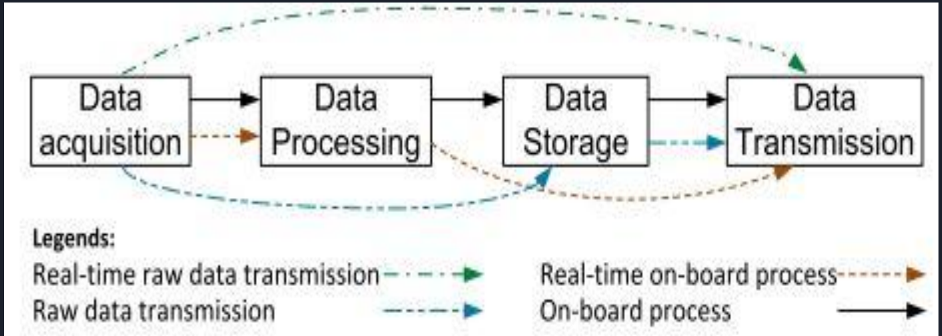


Components and units :

1. Power unit
2. Processing unit
3. RF communication modules
4. On-chip sensors
5. Storage unit
6. AFE

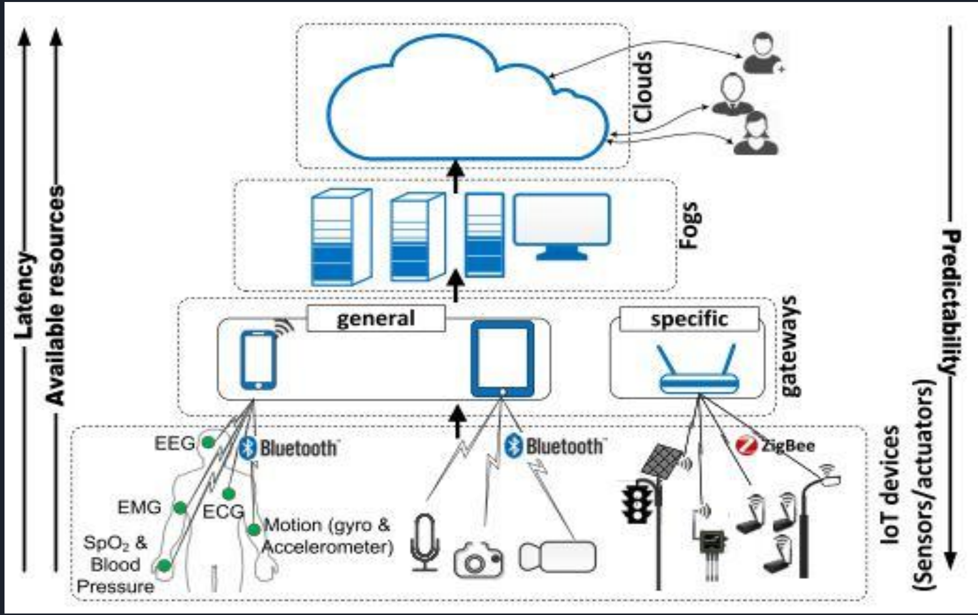
Operation Stages of IOT applications

1) Data Acquisition
2) Data Processing
3) Data Storage
4) Data Transmission



Processing and computing layers

1. Device Centric
2. Gateway Centric
3. Fog Centric
4. Cloud Centric
5. Hybrid Approach



Approximate vs Exact computing :

Approximate computing is a computation which gives inaccurate results.

It relaxes the requirement of exact equivalence between the specification and implementation to gain more energy efficiency.

Use cases: an approximate multi-bit adder, error-resilient algorithms like image, sound and video processing, data mining.

Approximate vs Exact computing : (cntd.)

Q. Why not exact computing everywhere??

- exact solutions comes at a high energy cost.
- unnecessary accuracy is wasteful.

But, the final output or QoS should be in a certain range even though the tolerable error can be accepted at hardware and software parts.

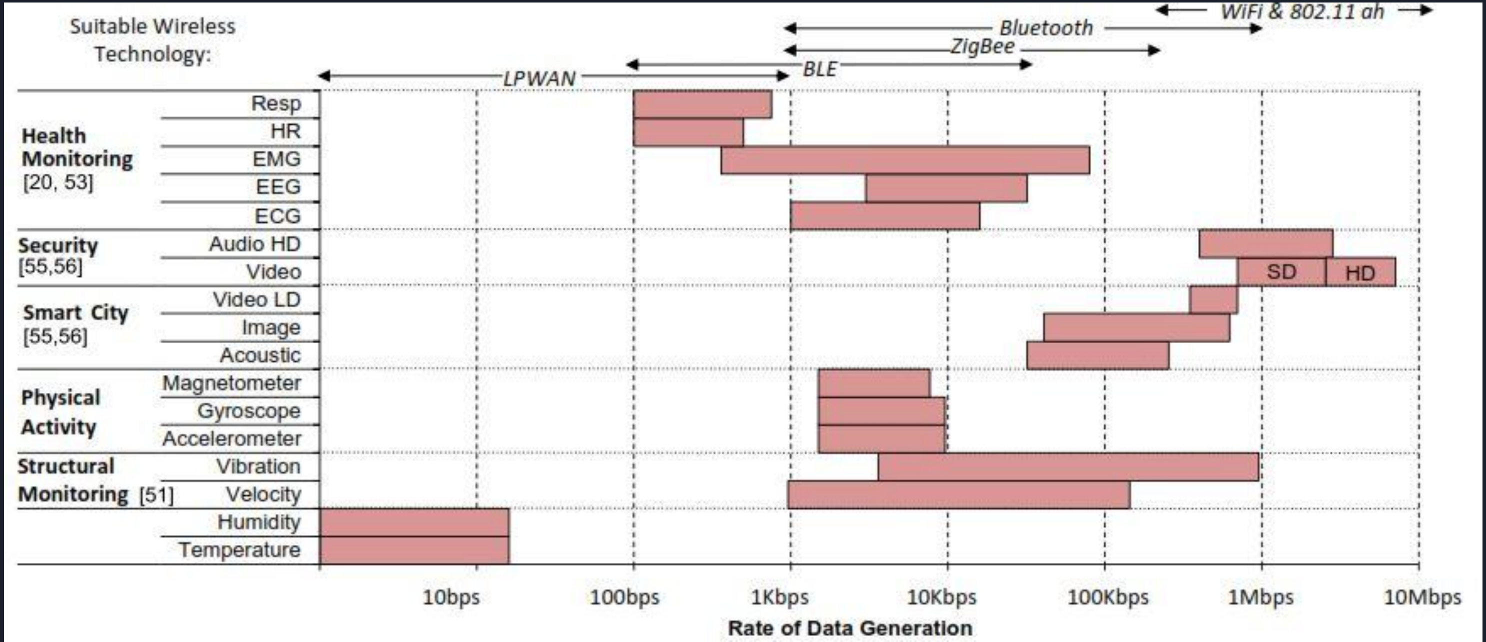
The IoT specific characteristics

1. Interaction with physical world (by means of sensors and actuators).
2. Communication ability (intra and inter devices communication).

IOT Sensors

- Ambient/Object Temperature, Humidity,
- Accelerometers and Gyroscopes,
- Magnetometer,
- Light,
- Chemical Sensors,
- Location-GPS,
- Imaging,
- Acoustic,
- Ultra Violet (UV),
- Ultrasonic,
- RF radio modules,
- Health Monitoring Sensors- Heart Rate, ECG, EMG, EEG, Blood Pressure, Respiration Rate, SpO2, Skin Conductivity.

Data rate generation by different sensors



Wireless Communication Technologies

		NFC	Bluetooth	BLE	BT v5	ZigBee	HaLow 802.11 b/g/n	LP WiFi 802.11ah	LPWAN	Cellular network 3G	Cellular network LTE
Range	indoor	<0.2 m	1–100 m	∼100 m	<300 m	<20 m	<70 m	<700 m	<10 Km	>5 Km	>5 Km
	outdoor					<1500 m	<230 m	<1000 m			
Bit rate [Mpbs]		0.424	1–3	1	2	0.25	>1	0.15–40	<0.05	0.17	75–300
Throughput [Mbps]		0.22	1.5	0.30	1.5	0.15	2-50	>0.1	<0.05	NA	
freq. [GHz]		0.014	2.4–2.5	2.4–2.5	2.4	2.4	2.4/5	0.9	sub-GHz	0.8–1.9	2.1
Network topology		p2p	scatternet	star, scatternet	NA	star, tree, mesh	star	star	star	NA	

Wireless Communication Technologies (cntd.)

		Application domains					Local Network (M2M)
		Healthcare	Smart Cities	Smart Building	Automotive	Industry	
wireless tech.	NFC	medium	high	low	very low	very high	medium
	BLE	very high	low	low	very low	low	high
	ZigBee, BT v5	medium	high	very high	low	high	high
	WiFi b/g/n	low	high	medium	medium	low	high
	HaLow	high	very high	high	high	high	very high
	LPWAN	low	very high	high	high	very high	high
	Cellular networks (3G, LTE, etc.)	low	high	high	high	medium	very low

Timing schemes of data transmission

For designing an efficient IoT system, the timing scheme of data transmission matters, especially for managing low power modes (deep sleep, standby, active).

Timing Scheme:

- Continuous
- Sporadic
- On-demand:
    - User drive
    - Event driven

Typical data processing operations in IoT applications

FFT, FIR, AES, CRC

Operation		Exe. time [μs]	# of cycles	Code Size [B]
FFT (256 p)		18	586	3850
FIR		1492	23872	1750
AES	Enc	18.25	292	3666
	Dec	22.75	364	
CRC		3.75	60	500

IoT Application Domains

- Healthcare - personal health monitoring, patient monitoring
- Assisted Living - for aged/ disabled/ spl abled people
- Smart Building and Home
- Smart City
- Smart Industry