
Smart Healthcare – An Overview

Faculty Development Program

Sponsored by TEQIP-III, Govt. of India

Govt. College of Engineering and Technology, Bhubaneswar

19 Sep - 23 Sep 2020

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Outline

- Healthcare to Smart Healthcare
- Smart Healthcare - Characteristics
- Smart Healthcare - Components
- Smart Healthcare - Examples
- Smart Healthcare - Challenges
- Conclusions and Future Directions

Healthcare to Smart Healthcare

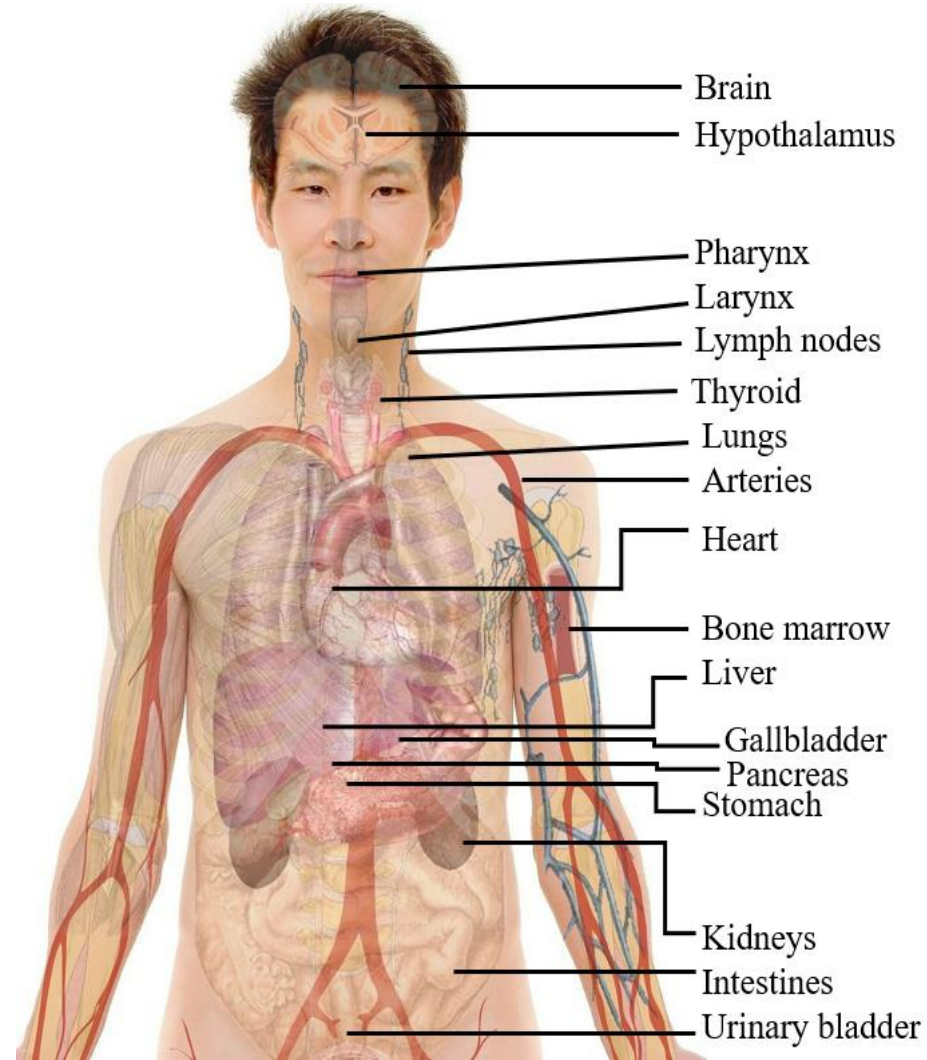
Human Body and Health

Human Body

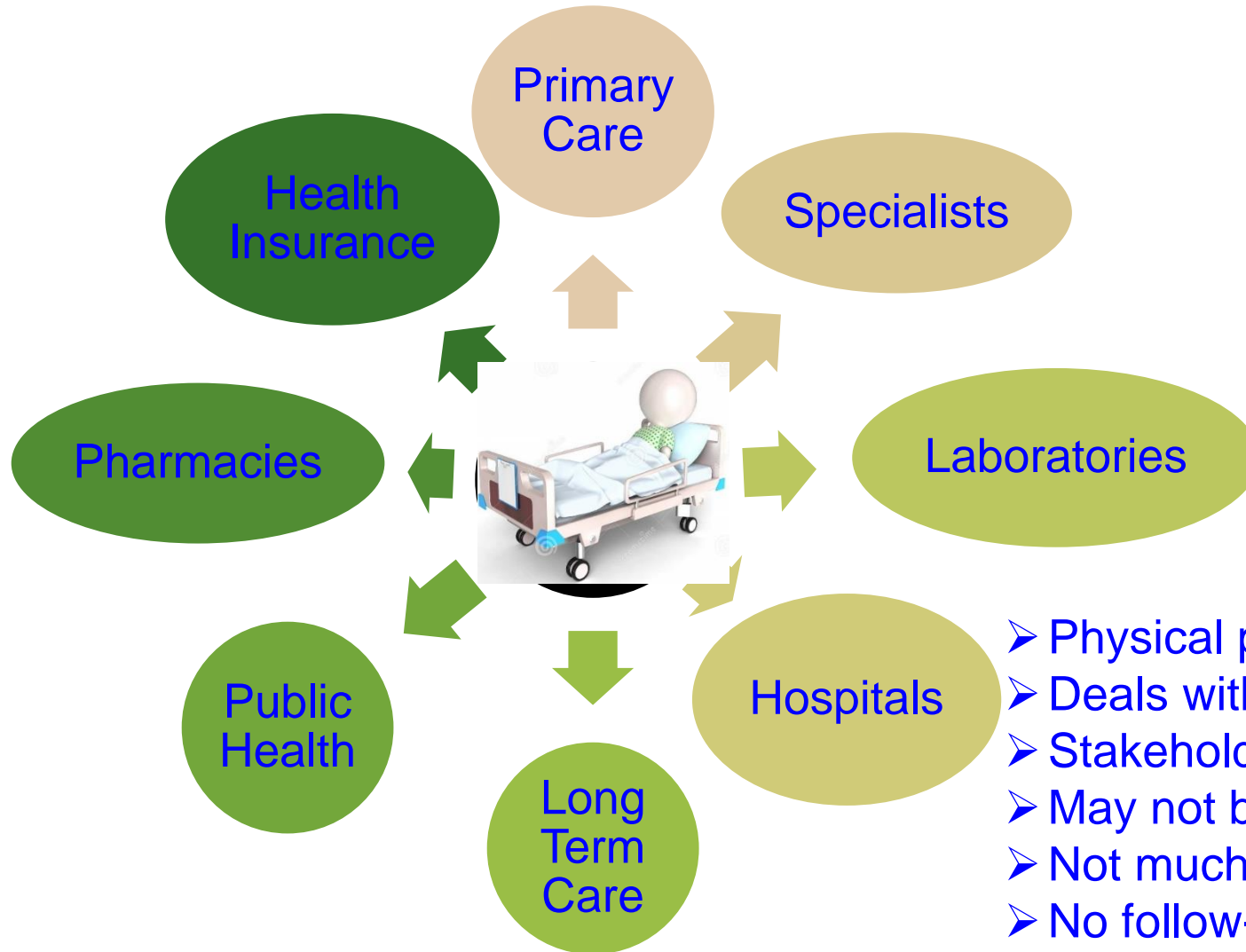
- From an engineering perspective, the human body can be defined as a combination of multi-disciplinary subsystems (electrical, mechanical, chemical ...).

Health

- Human health is a state of complete physical, mental and social well-being.



Traditional Healthcare



- Physical presence needed
- Deals with many stakeholders
- Stakeholders may not interact
- May not be personalized
- Not much active feedback
- No follow-up from physicians

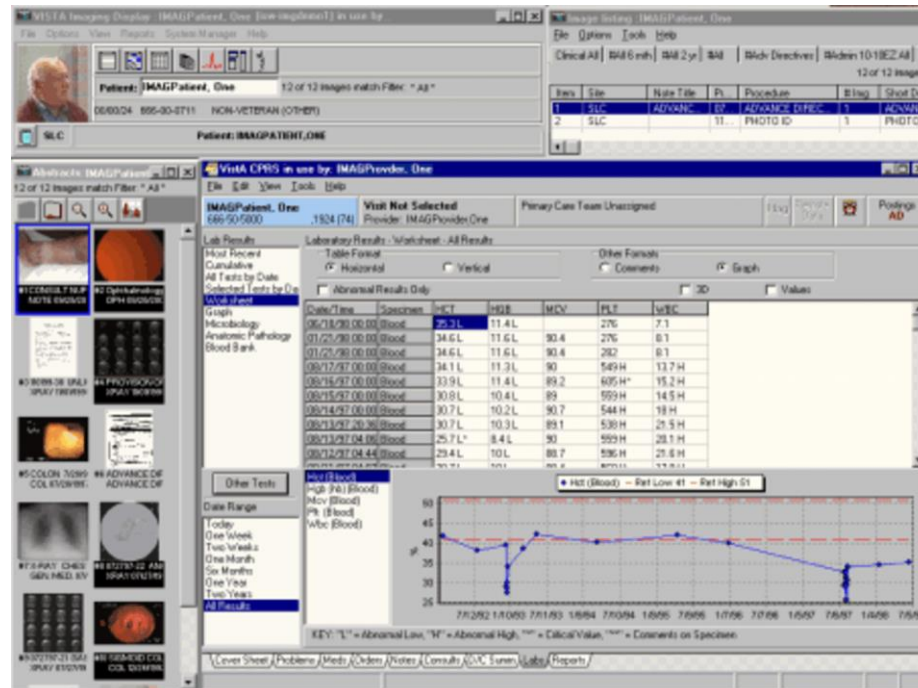
Telemedicine



Telemedicine is the use of telecommunication and information technology to provide clinical health care from a distance.

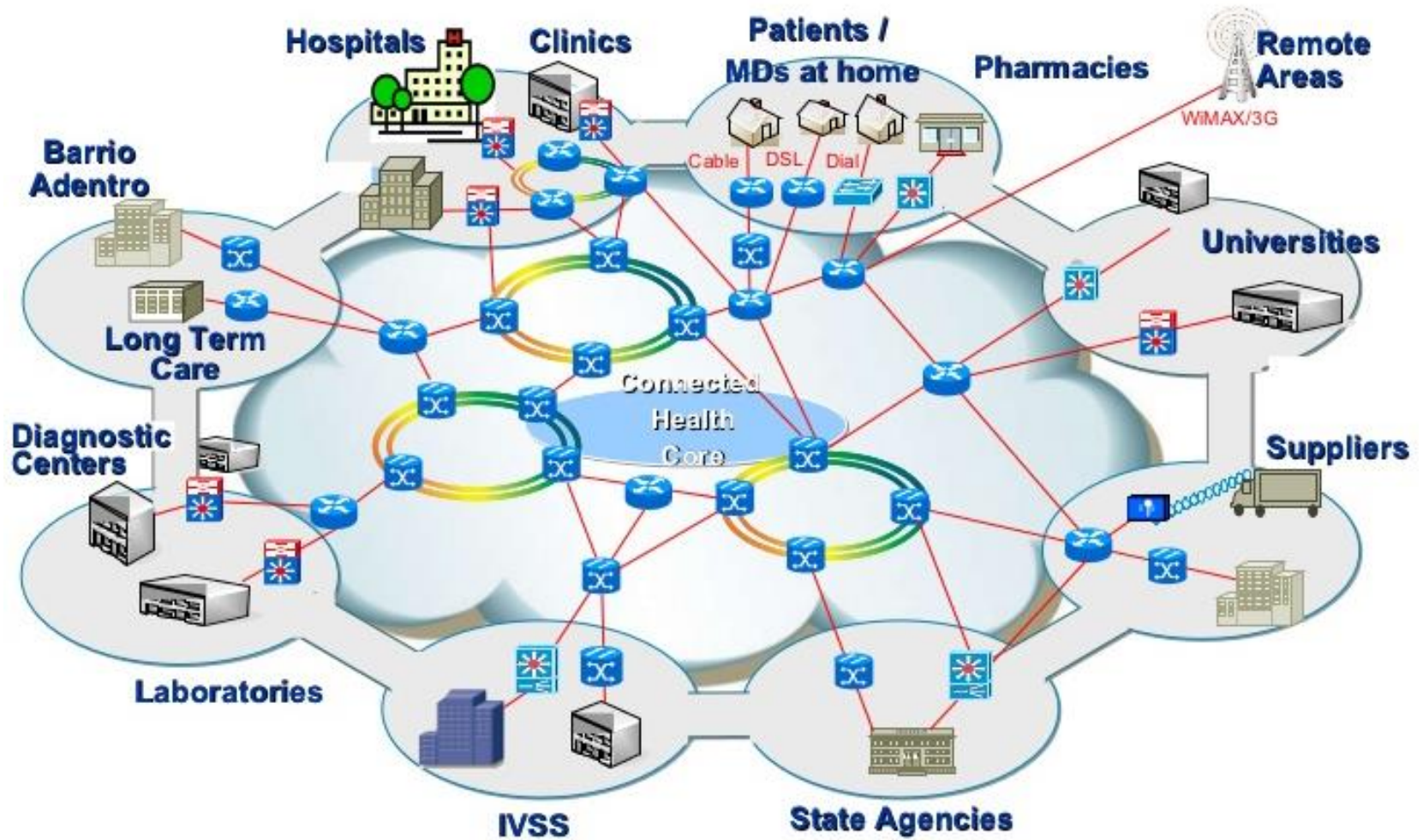
Electronic Health (eHealth)

- eHealth: The use of information and communication technologies (ICT) to improve healthcare services.



Source: W. O. Nijeweme-d'Hollosy, L. van Velsen, M. Huygens and H. Hermens, "Requirements for and Barriers towards Interoperable eHealth Technology in Primary Care," *IEEE Internet Computing*, vol. 19, no. 4, pp. 10-19, July-Aug. 2015.

Connected Health (cHealth)



Source: https://www.slideshare.net/tibisay_hernandez/connected-health-venfinal

Mobile Health (mHealth)

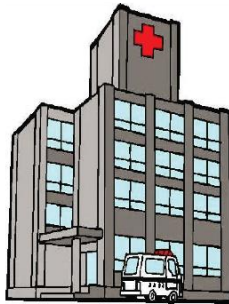
- mHealth: Healthcare supported by *mobile devices* that uses mobile telecommunications and multimedia technologies for the delivery of healthcare services and health information.



Source: H. Zhu, C. K. Wu, C. H. KOO, Y. T. Tsang, Y.Liu, H. R. Chi, and K. F. Tsang, "Smart Healthcare in the Era of Internet-of-Things", *IEEE Consumer Electronics Magazine*, vol. 8, no. 5, pp. 26-30, Sep 2019.

Smart Healthcare (sHealth)

Smart Hospital



Emergency Response



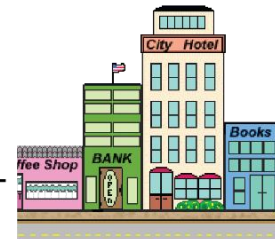
Smart Home



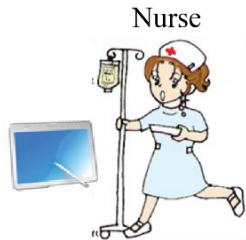
Fitness Trackers



Smart Infrastructure



Headband with Embedded Neurosensors



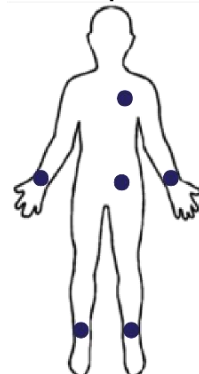
Nurse



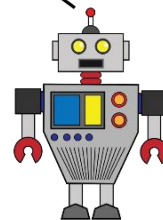
Doctor



Technician



On-body Sensors



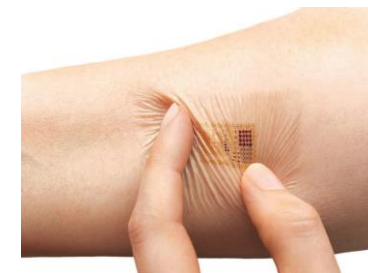
Robots

Smart Gadgets



Quality and sustainable healthcare with limited resources.

Source: P. Sundaravadivel, E. Kougianos, S. P. Mohanty, and M. Ganapathiraju, "Everything You Wanted to Know about Smart Health Care", *IEEE Consumer Electronics Magazine (MCE)*, Vol. 7, Issue 1, January 2018, pp. 18-28.



Embedded Skin Patches

Sethi 2017: JECE 2017

Smart Healthcare - Characteristics

Wearable Medical Devices (WMDs)



Fitness Trackers



Headband with Embedded Neurosensors

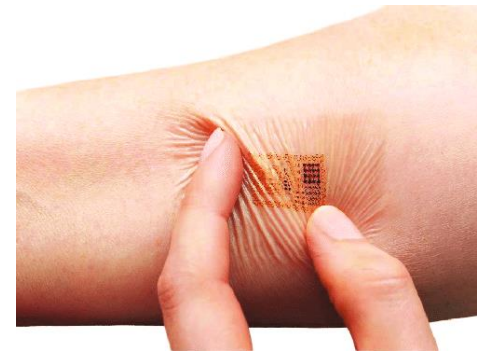


Source: <https://www.empatica.com/embrace2/>
Medical grade smart watch to detect seizure



Insulin Pump

Source: <https://www.webmd.com>

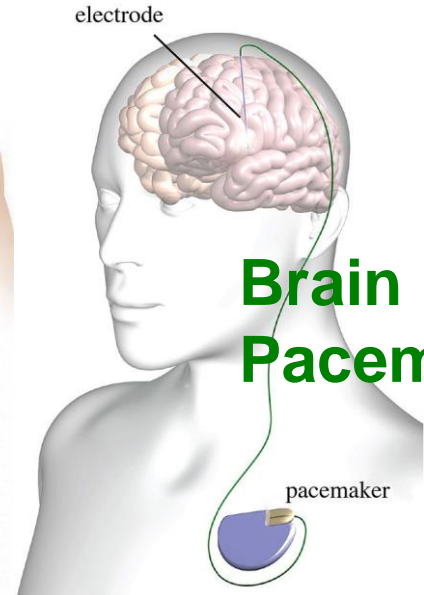
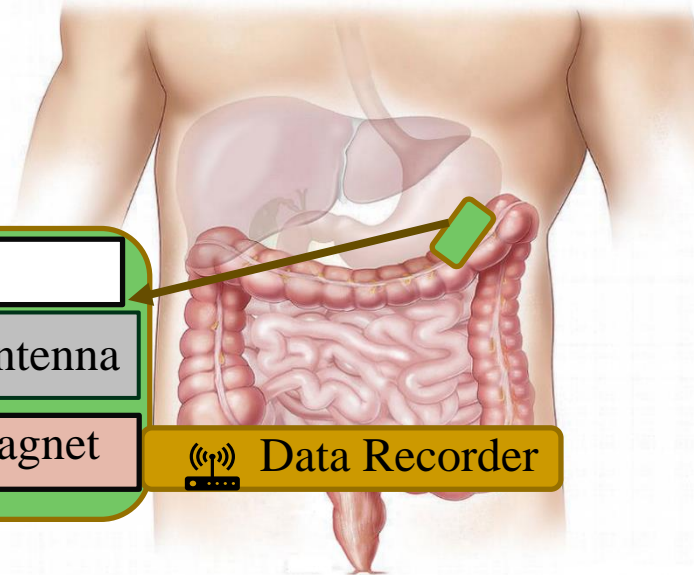


Embedded Skin Patches

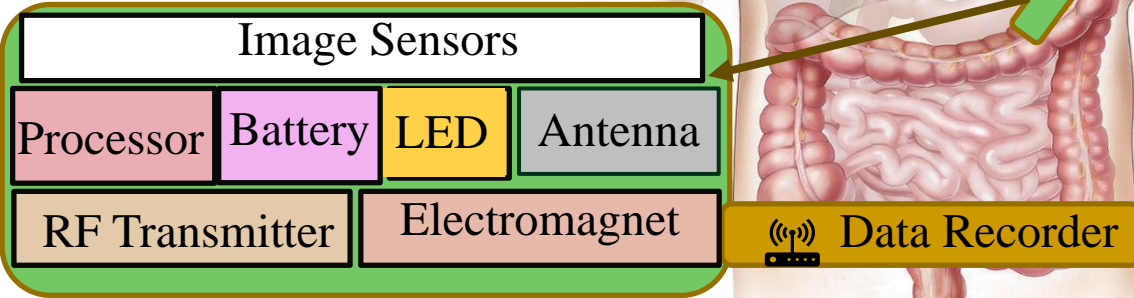
Implantable Medical Devices (IMDs)



Pill Camera



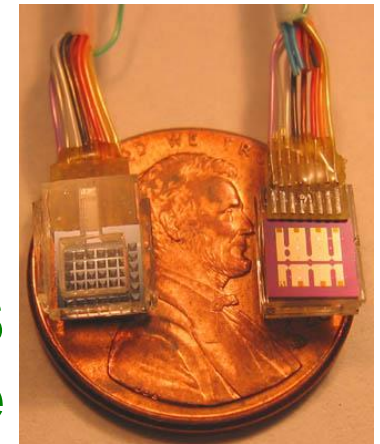
Brain Pacemaker



Source: P. Sundaravadivel, E. Kougianos, S. P. Mohanty, and M. Ganapathiraju, "Everything You Wanted to Know about Smart Health Care", IEEE Consumer Electronics Magazine (MCE), Volume 7, Issue 1, January 2018, pp. 18-28.

**Collectively:
Implantable and Wearable
Medical Devices (IWMDs)**

**Implantable MEMS
Device**



Source: <http://web.mit.edu/cprl/www/research.shtml>

Smart Healthcare



Healthy Living

- Fitness Tracking
- Disease Prevention
- Food monitoring

Home Care

- Mobile health
- Telemedicine
- Self-management
- Assisted Living

Acute Care

- Hospital
- Specialty clinic
- Nursing Home
- Community Hospital

Internet of Medical Things (IoMT)

Frost and Sullivan predicts smart healthcare market value to reach US\$348.5 billion by 2025.

Source: P. Sundaravadivel, E. Kougianos, S. P. Mohanty, and M. Ganapathiraju, "Everything You Wanted to Know about Smart Health Care", *IEEE Consumer Electronics Magazine (MCE)*, Vol. 7, Issue 1, January 2018, pp. 18-28.



What is Smart Healthcare?

Smart Healthcare ←
Conventional Healthcare
+ Body sensors
+ Smart Technologies
+ Information & Communication Technology (ICT)
+ AI/ML

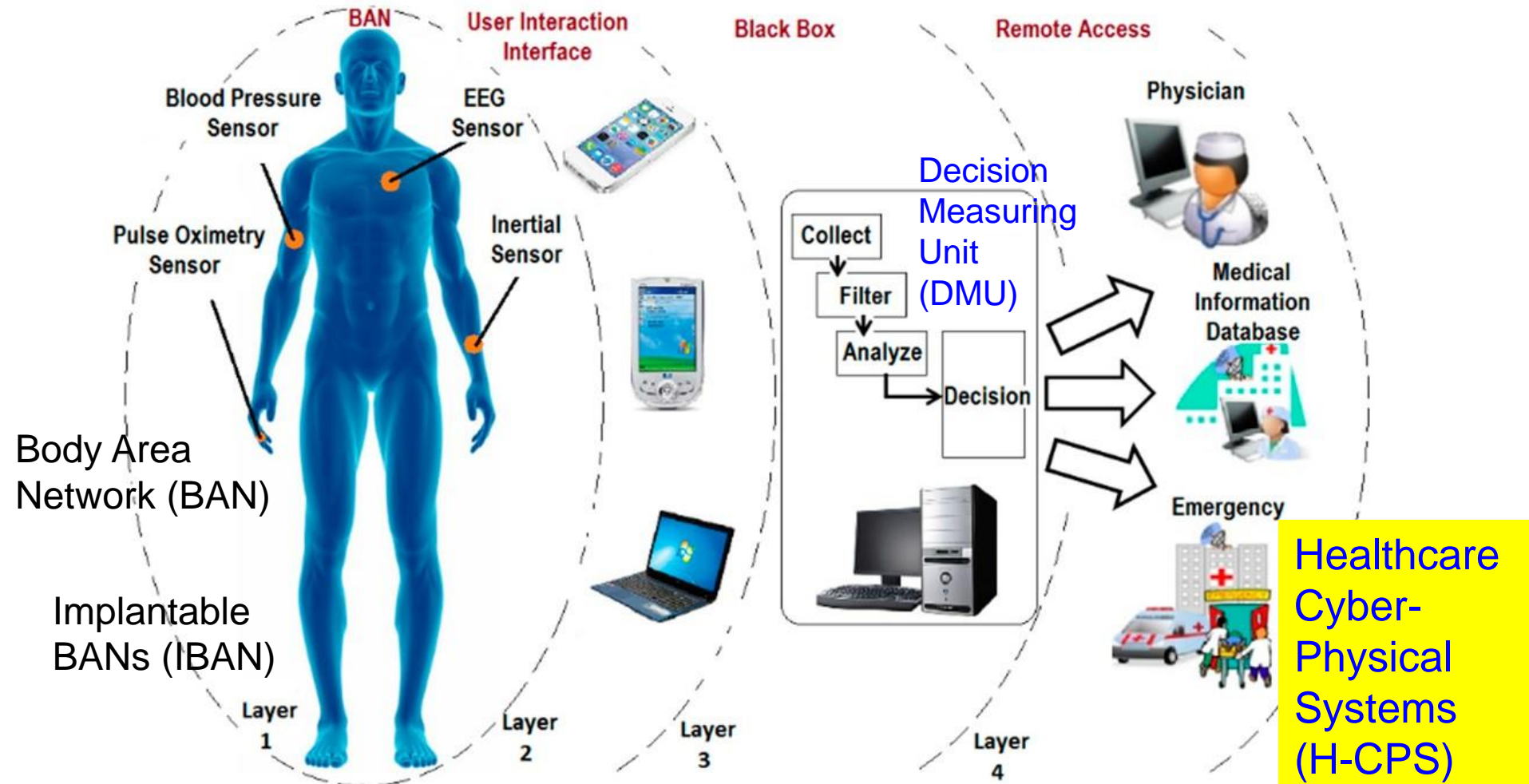
Internet of Medical Things (IoMT)

Internet of Health Things (IoHT)

Healthcare Cyber-Physical Systems (H-CPS)

Source: P. Sundaravadivel, E. Kougianos, S. P. Mohanty, and M. Ganapathiraju, "Everything You Wanted to Know about Smart Health Care", *IEEE Consumer Electronics Magazine (MCE)*, Volume 7, Issue 1, January 2018, pp. 18-28.

Smart Healthcare - 4-Layer Architecture



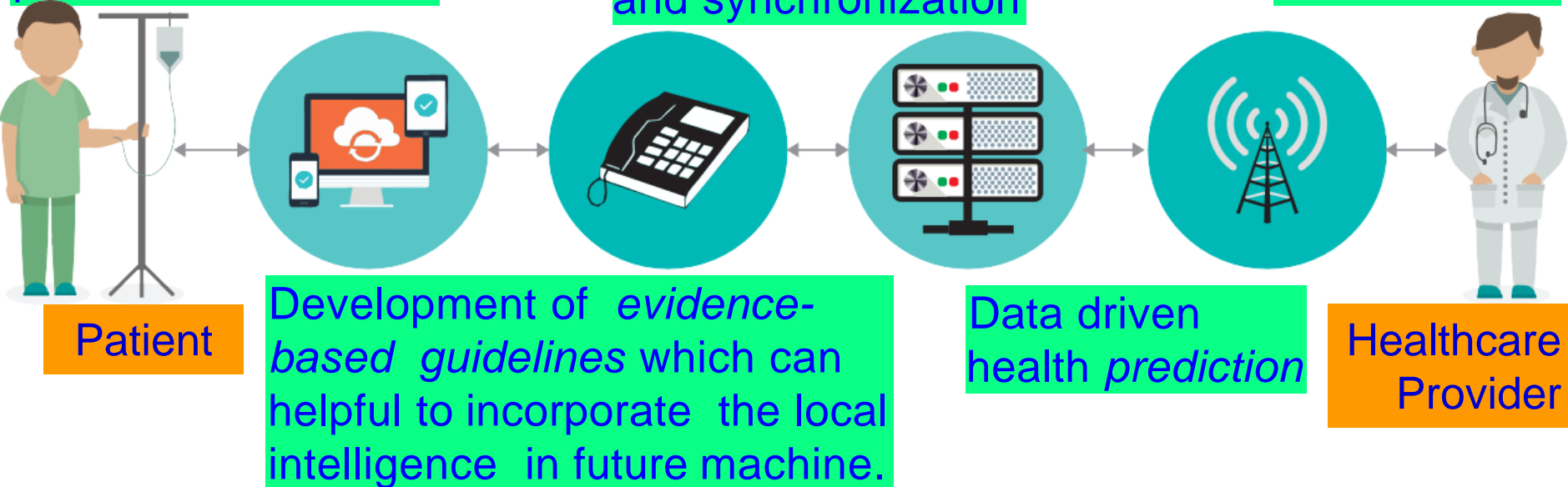
Source: M. Ghamari, B. Janko, R.S. Sherratt, W. Harwin, R. Piechockic, and C. Soltanpur, "A Survey on Wireless Body Area Networks for eHealthcare Systems in Residential Environments", *Sensors*, 2016. 16(6): p. 831.

IoMT based H-CPS

Patient-specific care with context and enabled through past health records.

Improved inter-device connection and synchronization

Real-time tracking and intervention



Healthcare Cyber-Physical Systems (H-CPS)

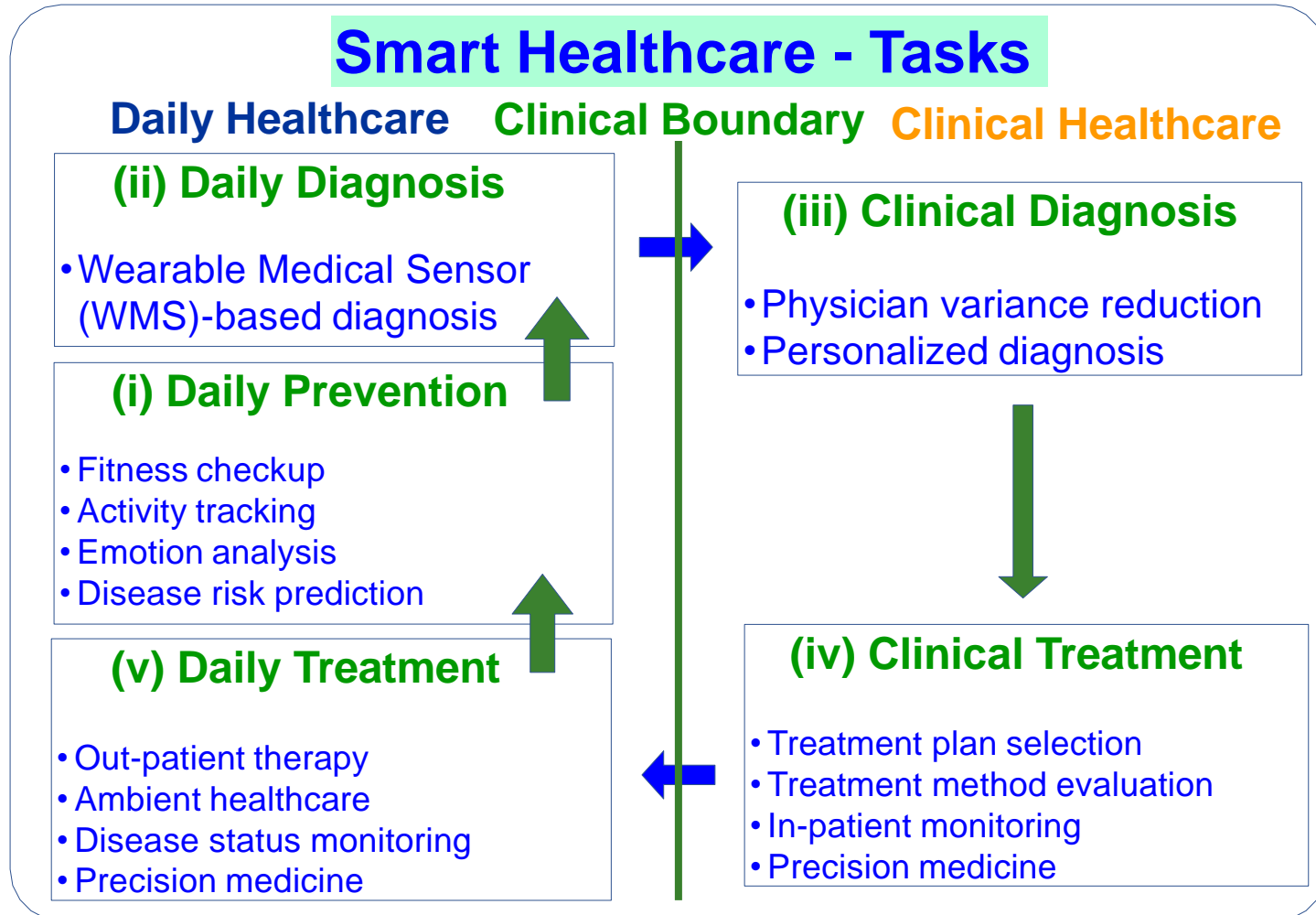
Source: Y. Shelke and A. Sharma, "Internet of Medical Things", 2016, Aranca, <https://www.aranca.com/knowledge-library/special-reports/ip-research/the-internet-of-medical-things-iomt>, Last Visited 10/18/2017.

Smart Healthcare – 7Ps



Source: H. Zhu, C. K. Wu, C. H. KOO, Y. T. Tsang, Y.Liu, H. R. Chi, and K. F. Tsang, "Smart Healthcare in the Era of Internet-of-Things", *IEEE Consumer Electronics Magazine*, vol. 8, no. 5, pp. 26-30, Sep 2019.

Smart Healthcare - Tasks



Source: Hongxu Yin, Ayten Ozge Akmandor, Arsalan Mosenia and Niraj K. Jha (2018), "Smart Healthcare", *Foundations and Trends® in Electronic Design Automation*: Vol. 12: No. 4, pp 401-466. <http://dx.doi.org/10.1561/10000000054>

IoMT Advantages & Limitations

Advantages

Patients/Users

- Real-time interventions in emergency
- Cost reduction
- Reduced morbidity and financial burden due to less follow up visits

Healthcare Service Providers

- Optimal utilization of resources
- Reduced response time in emergency

Manufacturers

- Standardization/compatibility and uniformity of data available
- Capability to sense and communicate health related information to remote location

Limitations

Technical Challenges

- ❖ Security of IoT data - hacking and unauthorized use of IoT
- ❖ Lack of standards and communication protocols
- ❖ Errors in patient data handling
- ❖ Data integration
- ❖ Need for medical expertise
- ❖ Managing device diversity and interoperability
- ❖ Scale, data volume and performance

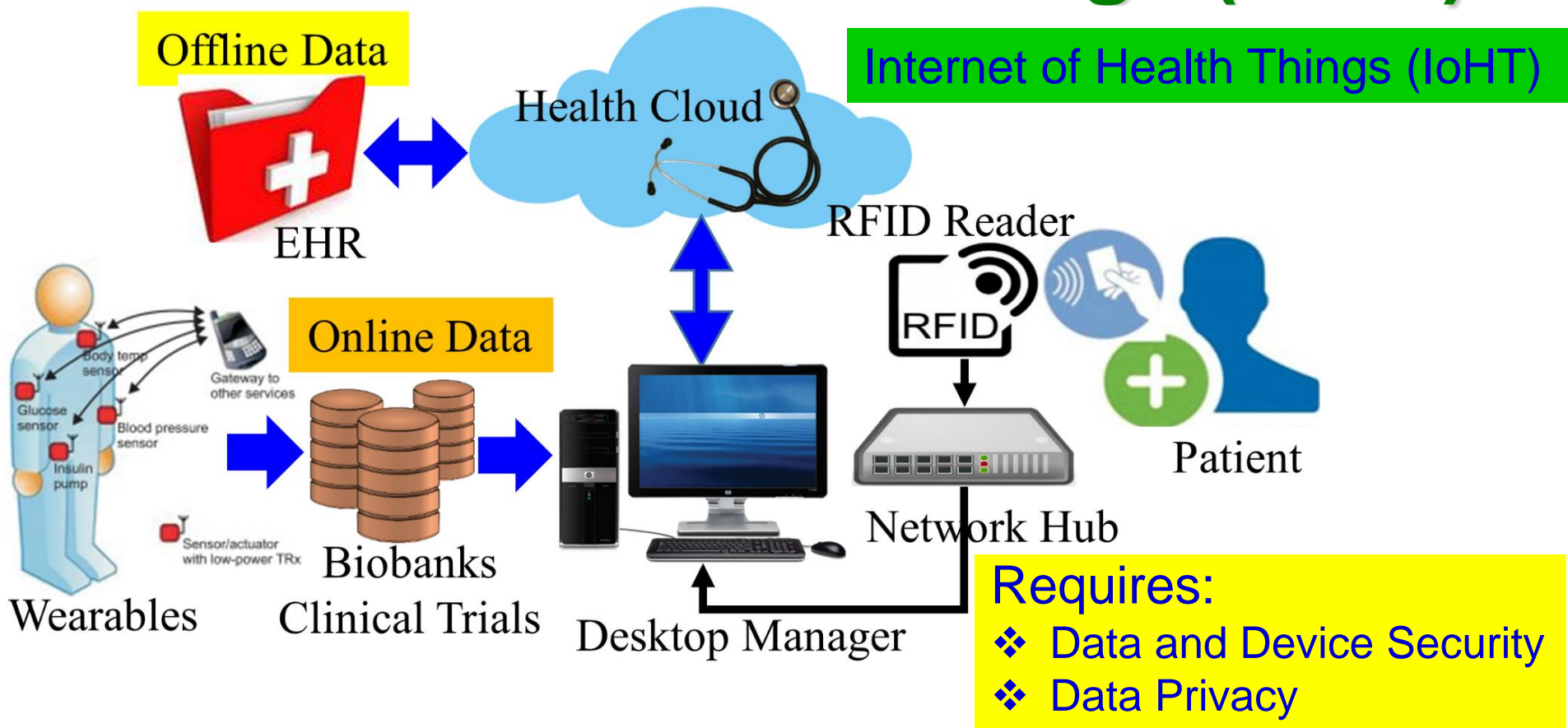
Market Challenges

- ❖ Physician compliance
- ❖ Data overload on healthcare facility
- ❖ Mobile hesitation
- ❖ Security policy compliance

Source: Y. Shelke and A. Sharma, "Internet of Medical Things", 2016, Aranca, <https://www.aranca.com/knowledge-library/special-reports/ip-research/the-internet-of-medical-things-iomt>, Last Visited 10/18/2017.

Smart Healthcare - Components

Internet of Medical Things (IoMT)

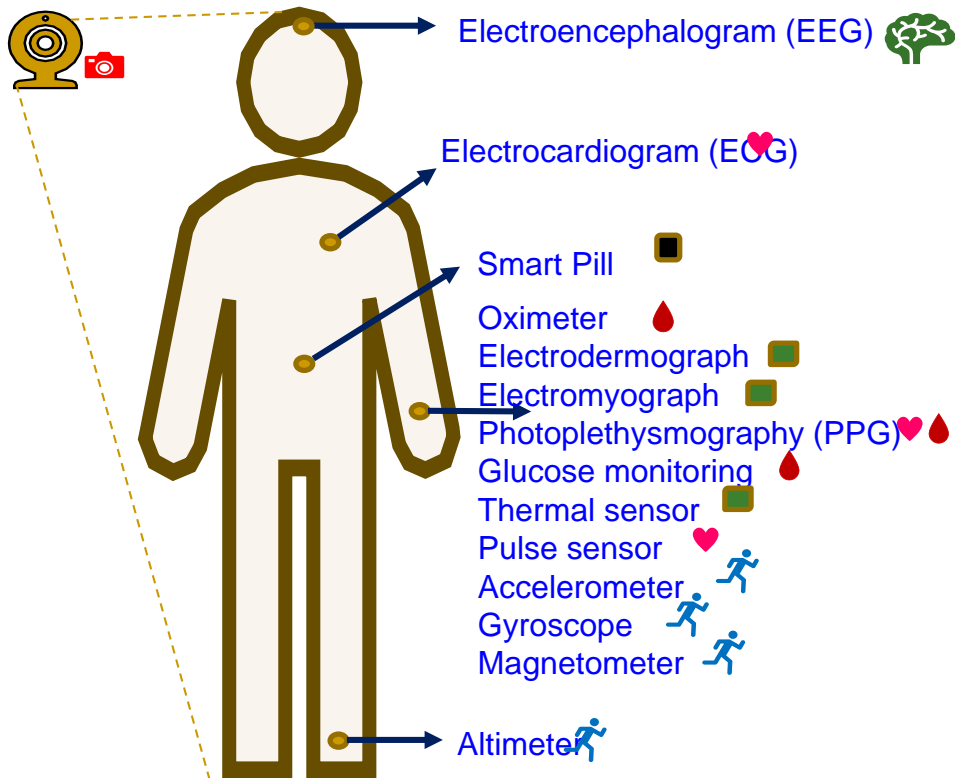


IoMT is a collection of medical sensors, devices, healthcare database, and applications that connected through Internet.

Source: <http://www.icemiller.com/ice-on-fire-insights/publications/the-internet-of-health-things-privacy-and-security/>

Source: <http://internetofthingsagenda.techtarget.com/definition/IoMT-Internet-of-Medical-Things>

Smart Healthcare Sensors



Types of Sensors	
	Brain related applications
	Imaging applications
	Heart related applications
	Skin related applications
	Blood related applications
	Ingestible sensors
	Motion Detection

Smart Healthcare Communication

Technology	Frequency Band	Data Rate	Range	Transmission Power
Bluetooth 4.0 (LE)	2.4 GHz	50–200 Kbps	30 m	~10 mW
Zigbee	868 MHz/ 915 MHz/ 2.4 GHz	20–250 Kbps	30 m	30 mW
ANT	2400-2485 MHz	1 Mbps	Up to 10 m	0.01–1 mW
IEEE 802.15.6	2,360-2,400/ 2,400-2,483.5 MHz UWB: 3–10 GHz HBC: 16/27 MHz	NB: 57.5–485.7 Kbps UWB: 0.5–10 Mbps	1.2 m	0.1 μ W
Medical Implant Communications Service (MICS)	402-405 MHz	Up to 500 Kbps	2 m	25 μ W

Source: V. Custodio, F.J. Herrera, G. López, and J. I. Moreno, “A Review on Architectures and Communications Technologies for Wearable Health-Monitoring Systems”, *Sensors*, 2012. 12(10): p. 13907-13946.

Electronics Health Record (EHR)

Electronic Health Record (EHR) is the systematized collection of health information of individuals stored in a digital format.

Created by various health providers such as hospitals and clinics.

Handy patients enterprise edition

File Edit View Help

David (8 month and 10 day)
John (2 years and 3 month)

Mother: Teacher
Father: Financial advisor
Parents: Married

Last: Anderson P
First: David Boy
Birth: 5 January 2009
Age: 8 month and 10 days Patient nb: 3

Appointments

Forms: Meeting (Doctor), Full status (Doctor), Assistant, Billing, Reports, Statistics

Sheets: Neurologic, Vascular, Cardiac, Respiratory, Abdomen, Exams, Radiology, Summary, Patient documents, Letter

Meetings: 2 month checkup (5 Mar 09, 2m.0d), 1 month checkup (5 Feb 09, 1m.0d), Respiration problem (22 Jan 09, 17d), 10 days checkup (13 Jan 09, 8d), Control for return at home (9 Jan 09, 4d), Birth (5 Jan 09, 0d)

Diagnosis: General, My Diagnosis, Social

New documents: Abdomen palpat (15 Sep 2009), Cardiac auscul (15 Sep 2009)

To Do: Send checkup

Notes: Father ask many questions, add 10 minutes to consultation

Current doctor: Dr Herman

Menu 1 Menu 2 Menu 3 Search

Digestive

Thursday, 22 Jan 2009

Digestive inspection: Normal

Digestive auscultation: Normal abdomen noises

Digestive palpation: Little pain on the right lower area

Liver: No hepatomegaly.

Rectal

Documents manager

Page 1/1
Draw
Mark
Color
Pen
8

Previous page Next page

Electronic Medical Record (EMR)

Smart Healthcare - Framework

Smart Healthcare - System and Data Analytics : To Perform Tasks

Systems & Analytics

- Health cloud server
- Edge server
- Implantable Wearable Medical Devices (IWMDs)
- Machine Learning Engine



Data

- Physiological data
- Environmental data
- Genetic data
- Historical records
- Demographics

Systems & Analytics

- Clinical Decision Support Systems (CDSSs)
- Electronic Health Records (EHRs)

Machine Learning Engine



Data

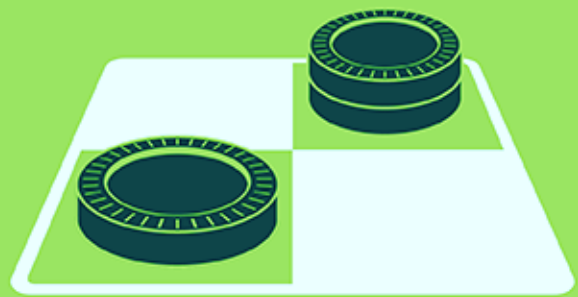
- Physician observations
- Laboratory test results
- Genetic data
- Historical records
- Demographics

Source: Hongxu Yin, Ayten Ozge Akmandor, Arsalan Mosenia and Niraj K. Jha (2018), "Smart Healthcare", *Foundations and Trends® in Electronic Design Automation*, Vol. 12: No. 4, pp 401-466. <http://dx.doi.org/10.1561/10000000054>

AI, Machine Learning, and Deep Learning

ARTIFICIAL INTELLIGENCE

Early artificial intelligence stirs excitement.



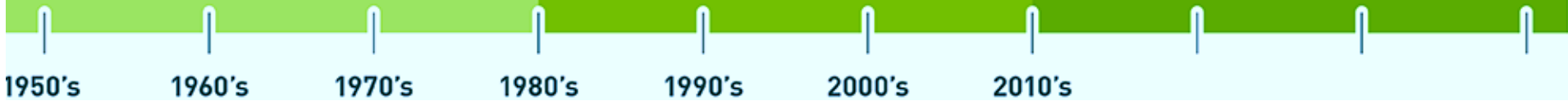
MACHINE LEARNING

Machine learning begins to flourish.



DEEP LEARNING

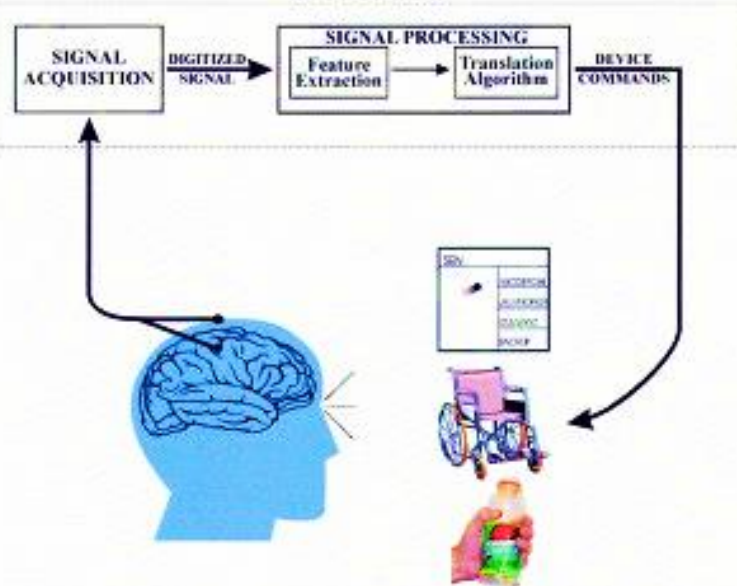
Deep learning breakthroughs drive AI boom.



Source: <https://blogs.nvidia.com/blog/2016/07/29/whats-difference-artificial-intelligence-machine-learning-deep-learning-ai/>

Brain Computer Interface (BCI)

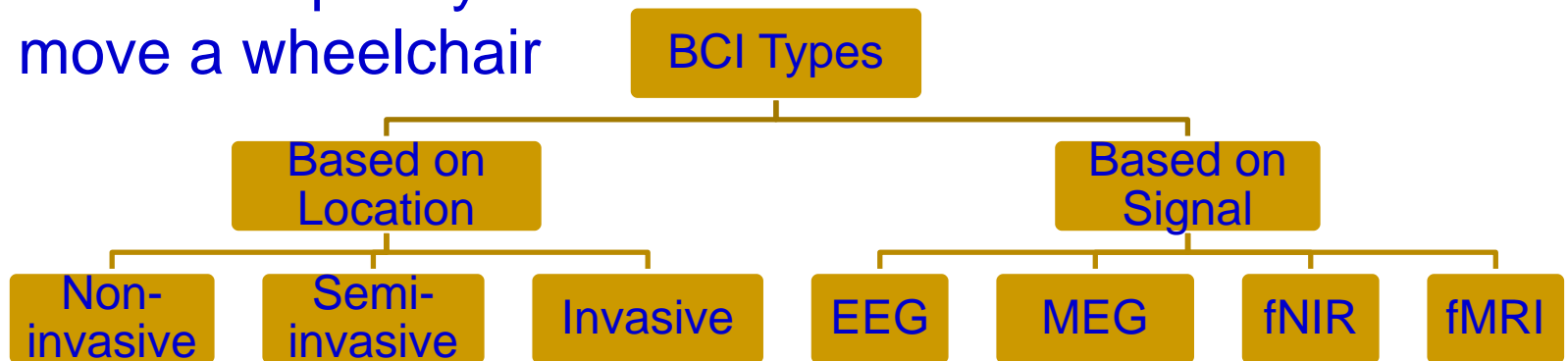
BCI SYSTEM



Source: <http://brainpedia.org/brain-computer-interface-allows-paralysis-als-patients-type-much-faster/>

BCI Allows paralysis patients to Type

Source: <http://brainpedia.org/what-is-brain-computer-interface-bci/>
 BCI Allows paralysis patients move a wheelchair



Virtual Reality in Healthcare



Source: <https://touchstoneresearch.com/tag/applied-vr/>

In Surgery

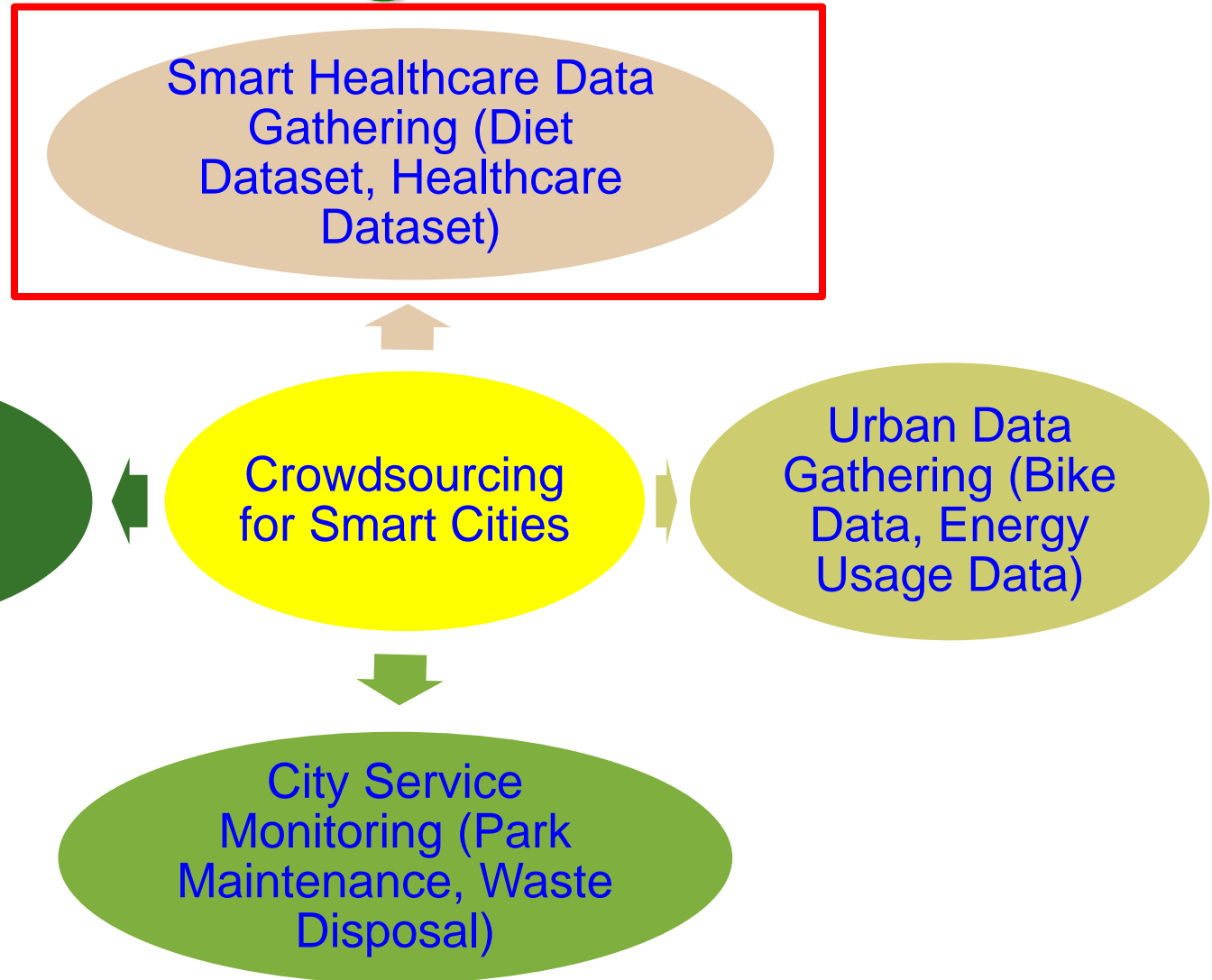


Source: <http://medicalfuturist.com/5-ways-medical-vr-is-changing-healthcare/>

For Therapy

- Help women get through labor pain
- Help post traumatic stress disorder (PTSD)

Crowdsourcing for Smart Cities



Smart Healthcare – Specific Examples

Stress is a Global Issue

- In major global economies - 6 in 10 workers experiencing increased workplace stress.
- In USA: 75% of adults reported experiencing moderate to high levels of stress. 1 out of 75 people may experience panic disorder.
- In Australia: 91% of adults feel stress in at least one important area of their lives.
- In UK: An estimated 442,000 individuals, who worked in 2007/08 believed that they were experiencing work-related stress
- Depression is among the leading causes of disability worldwide. 25% of those with depression world-wide have access to effective treatments → 75% don't have.

Source: <http://www.gostress.com/stress-facts/>

Why Stress Needs to be Resolved?

When there is an encounter with sudden **stress**, your brain floods your **body** with chemicals and hormones such as **adrenaline and cortisol**.

- Lack of Energy
- Type 2 Diabetes
- Osteoporosis
- Mental cloudiness (brain fog) and memory problems
- A weakened immune system, leading to more vulnerable to infections



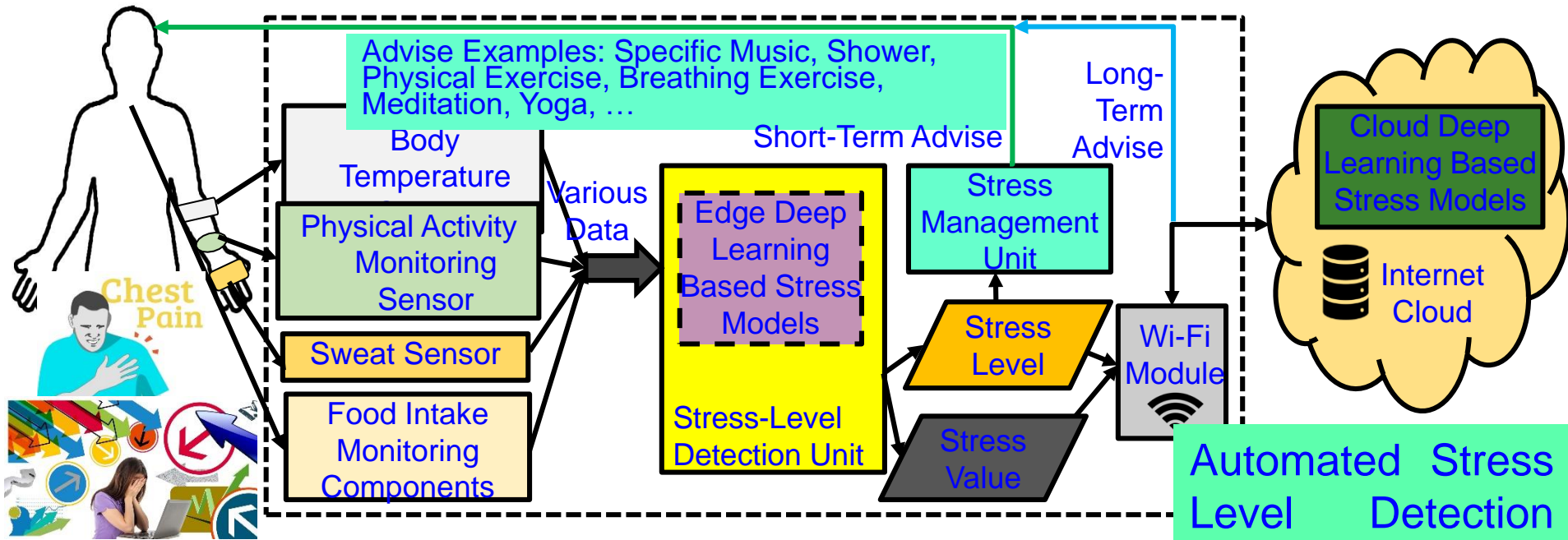
Distress



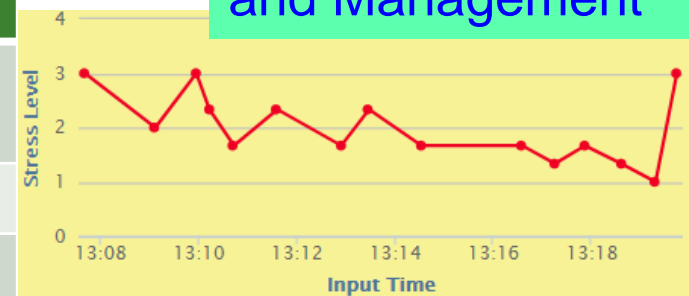
Eustress

Stress is the **body's reaction** to any change that requires an adjustment or response.

Smart Healthcare - Stress Monitoring & Control



Sensor	Low Stress	Normal Stress	High Stress
Accelerometer (steps/min)	0-75	75-100	101-200
Humidity (RH%)	27-65	66-91	91-120
Temperature °F	98-100	90-97	80-90



Automated Stress Level Detection and Management

Source: L. Rachakonda, S. P. Mohanty, E. Kougianos, and P. Sundaravadivel, "Stress-Lysis: A DNN-Integrated Edge Device for Stress Level Detection in the IoMT", *IEEE Transactions on Consumer Electronics (TCE)*, Vol 65, No 4, Nov 2019, pp. 474--483.

Consumer Electronics Devices – Can Provide Data for Stress Detection

Brand	Device	Signals	RTI	Ambulant
Empatica	E4 wristband	PPG, GSR, HR, ACC, ST	Yes	Yes
Garmin	Vivosmart	HR, HRV, ACC	Yes	Yes
Zephyr	BioHarness 3.0	HR, HRV, GSR, ACC, ST	Yes	Yes
iMotions	Shimmer 3+ GSR	GSR, PPG	Yes	No
BIOPAC	Mobita Wearable	ECG, EEG, EGG, EMG, and EOG	Yes	No

GSR = Galvanic Skin Response, HR = Heart Rate, ACC = Acceleration, ST = Skin Temperature, HRV = Heart Rate Variability, PPG = Photoplethysmograph, RTI = Real Time Implementation

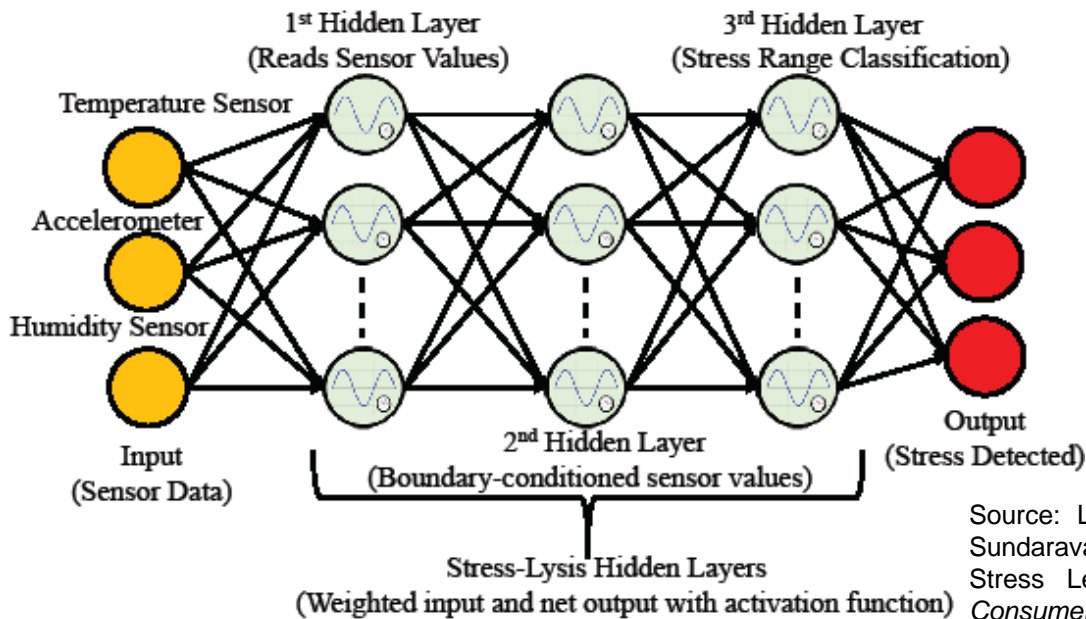
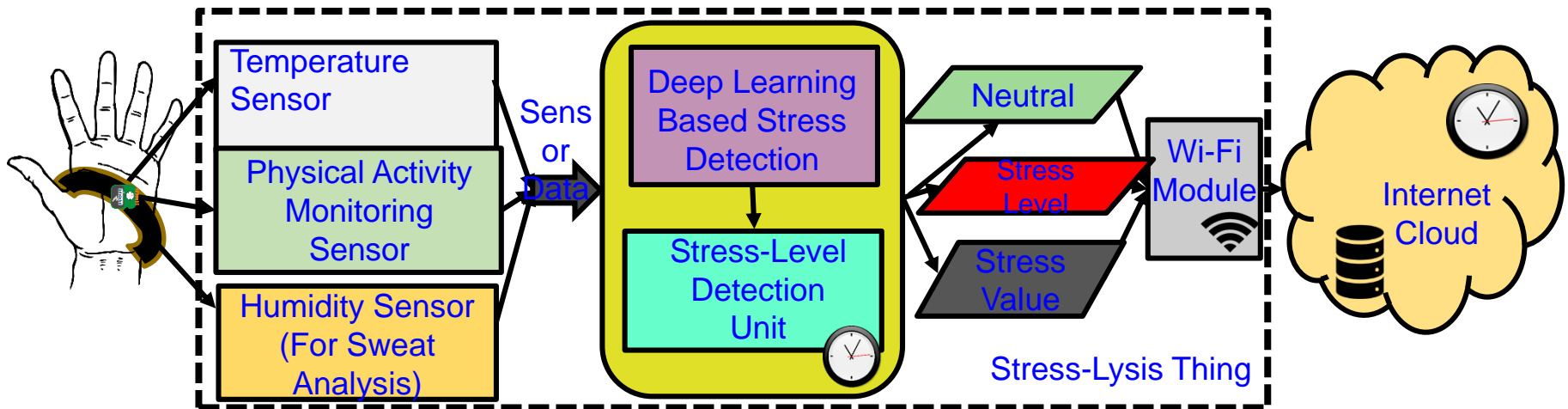
Source: R. K. Nath, H. Thapliyal, A. Caban-Holt, and S. P. Mohanty, "Machine Learning Based Solutions for Real-Time Stress Monitoring", *IEEE Consumer Electronics Magazine (MCE)*, Vol. 9, XX, No. YY, ZZ 2020, DOI: 10.1109/MCE.2020.2993427.

Stress-Lysis: Research Question

- How to have an accurate and rapid Stress Level Detection system that acquires and models sensor data, and detects stress level at the user end (at *IoT-Edge*) and stores the data at the cloud end (at *IoT-Cloud*)?

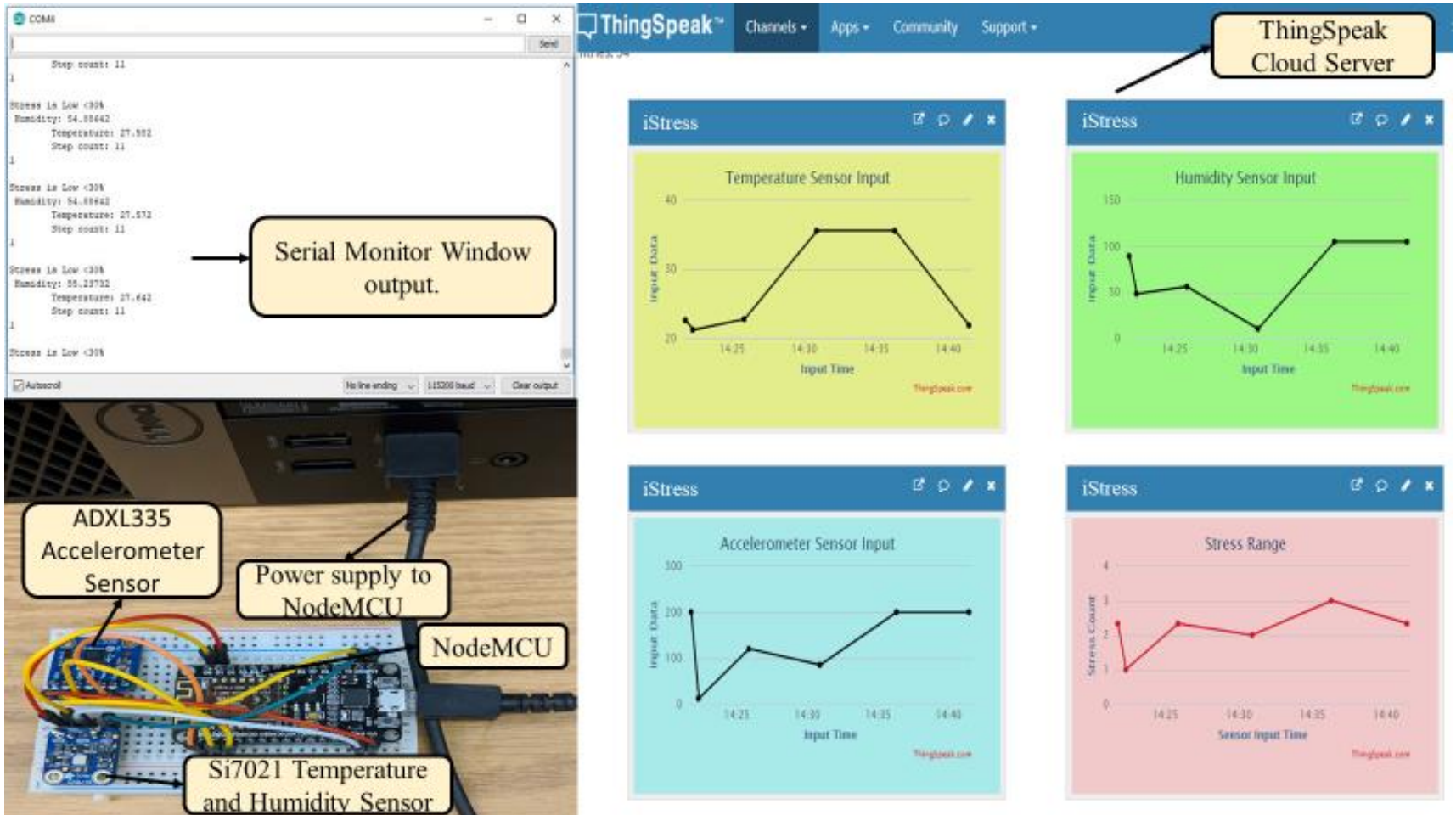
Source: L. Rachakonda, S. P. Mohanty, E. Kougianos, and P. Sundaravadivel, "Stress-Lysis: A DNN-Integrated Edge Device for Stress Level Detection in the IoMT", *IEEE Transactions on Consumer Electronics (TCE)*, Vol 65, No 4, Nov 2019, pp. 474--483.

Stress-Lysis: From Physiological Signals



Source: L. Rachakonda, S. P. Mohanty, E. Kougianos, and P. Sundaravadivel, "Stress-Lysis: A DNN-Integrated Edge Device for Stress Level Detection in the IoMT", *IEEE Transactions on Consumer Electronics (TCE)*, Vol 65, No 4, Nov 2019, pp. 474--483.

Stress-Lysis: Experiments



Source: L. Rachakonda, S. P. Mohanty, E. Kougianos, and P. Sundaravadivel, "Stress-Lysis: A DNN-Integrated Edge Device for Stress Level Detection in the IoMT", *IEEE Transactions on Consumer Electronics (TCE)*, Vol 65, No 4, Nov 2019, pp. 474--483.

Smart-Pillow: Research Question

- How to have a non-invasive, optimized, IoT enabled system which detects the stress level variations based on the sleeping parameters, analyses the data at the user end (at *IoT-Edge*) and stores the data at the cloud end (at *IoT-Cloud*)?

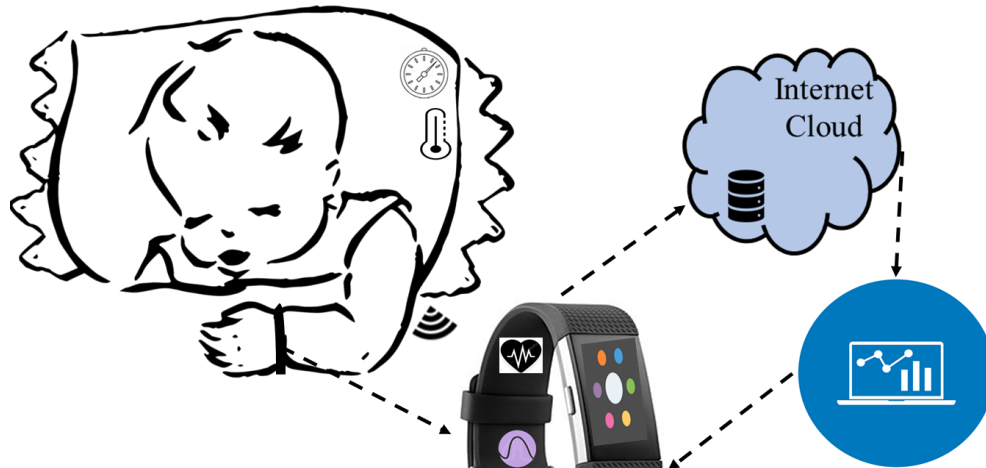
Source: Mohanty iSES 2018: "Smart-Pillow: An IoT based Device for Stress Detection Considering Sleeping Habits", in *Proc. of 4th IEEE International Symposium on Smart Electronic Systems (iSES) 2018*.

Consumer Electronics Sleep Trackers

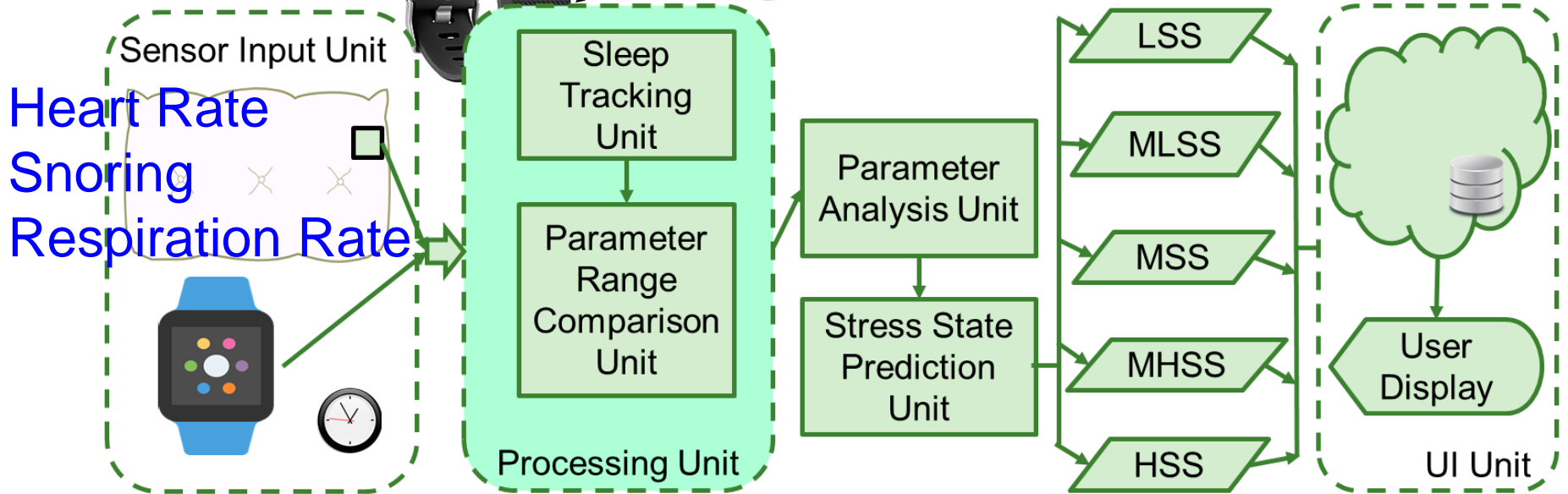
Consumer Products	Approach	Features	Drawbacks
Fitbit [34]	Wearable	Heart rate monitor, sleep stages monitor. Has techniques to improve the sleep score.	Relationship between stress and sleep is not discussed.
SleepScore Max [36]	Non-wearable	Invisible radio wave sleep tracking	Does not manage stress with sleep.
Nokia Sleep [38]	Non-wearable	Uses Ballistocardiography sensor	Does not explain the relationship with stress with sleep.
Xiaomi Mi Band 3 [31]	Wearable	Pulse Monitor	No information on importance of quality sleep.
Eversleep [32]	wearable	Snoring and breathing interruptions	No explanation on the relationship between stress and sleep.
Beddit [35]	Non-wearable	Monitors snoring	Doesn't consider other possible features.
Eight [37]	Non-Wearable	Humidity, temperature, heartbeat, breathing rate	No data on how it is important to have a good sleep.
Dreem [33]	Wearable	Simulates slow brain waves	It doesn't consider other features; Does not manage stress with sleep.
Muse [26]	Wearable	Simulates brain waves	No understanding of the importance of quality sleep.

Source: L. Rachakonda, A. K. Bapatla, S. P. Mohanty, and E. Kougianos, "SaYoPillow: A Blockchain-Enabled, Privacy-Assured Framework for Stress Detection, Prediction and Control Considering Sleeping Habits in the IoMT", *arXiv Computer Science*, arXiv:2007.07377, July 2020, 38-pages.

Smart Healthcare – Smart-Pillow



Automatically monitors stress levels during the day and relates to sleeping behaviors at night.



Source: Mohanty iSES 2018: "Smart-Pillow: An IoT based Device for Stress Detection Considering Sleeping Habits", in *Proc. of 4th IEEE International Symposium on Smart Electronic Systems (iSES) 2018*.

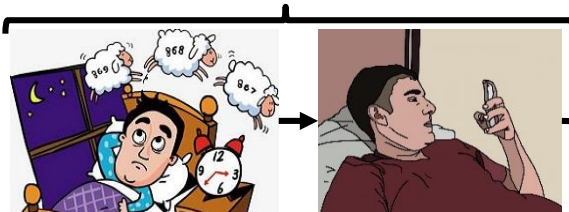
Smart-Yoga Pillow (SaYoPillow) – Sleeping Pattern

Person On Pillow:

Physiological Sensor Data Monitoring Starts



Period 1: Lying on bed but not Sleeping



Period 3: Drift from Wakefulness to Sleep

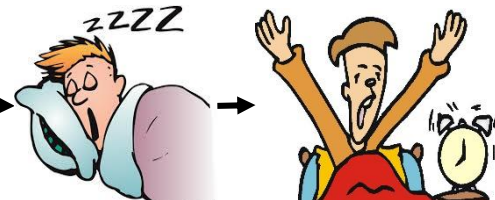


Period 2: Trying to Sleep

Physiological Sensor Data Monitoring Ends



Period 5: Awake Person



Period 4: Deep Sleep

Transitions of a person drifting into non-rapid eye movement (NREM) followed by rapid eye movement (REM) to Awake State.



Source: L. Rachakonda, A. K. Bapatla, S. P. Mohanty, and E. Kougianos, "SaYoPillow: A Blockchain-Enabled, Privacy-Assured Framework for Stress Detection, Prediction and Control Considering Sleeping Habits in the IoMT", *arXiv Computer Science*, arXiv:2007.07377, July 2020, 38-pages.

Parameter Ranges

Snoring Range (dB)	Respiration Rate (bpm)	Heart Rate (bpm)	Stress State
50-60	17-19	54-57	LSS
60-70	19-21	57-60	MLSS
70-80	21-22	60-64	MSS
80-89	23-25	65-70	MHSS
90+	25+	70+	HSS

Smart-Pillow - simple fuzzy logic-based design finds classify stress to 5 levels

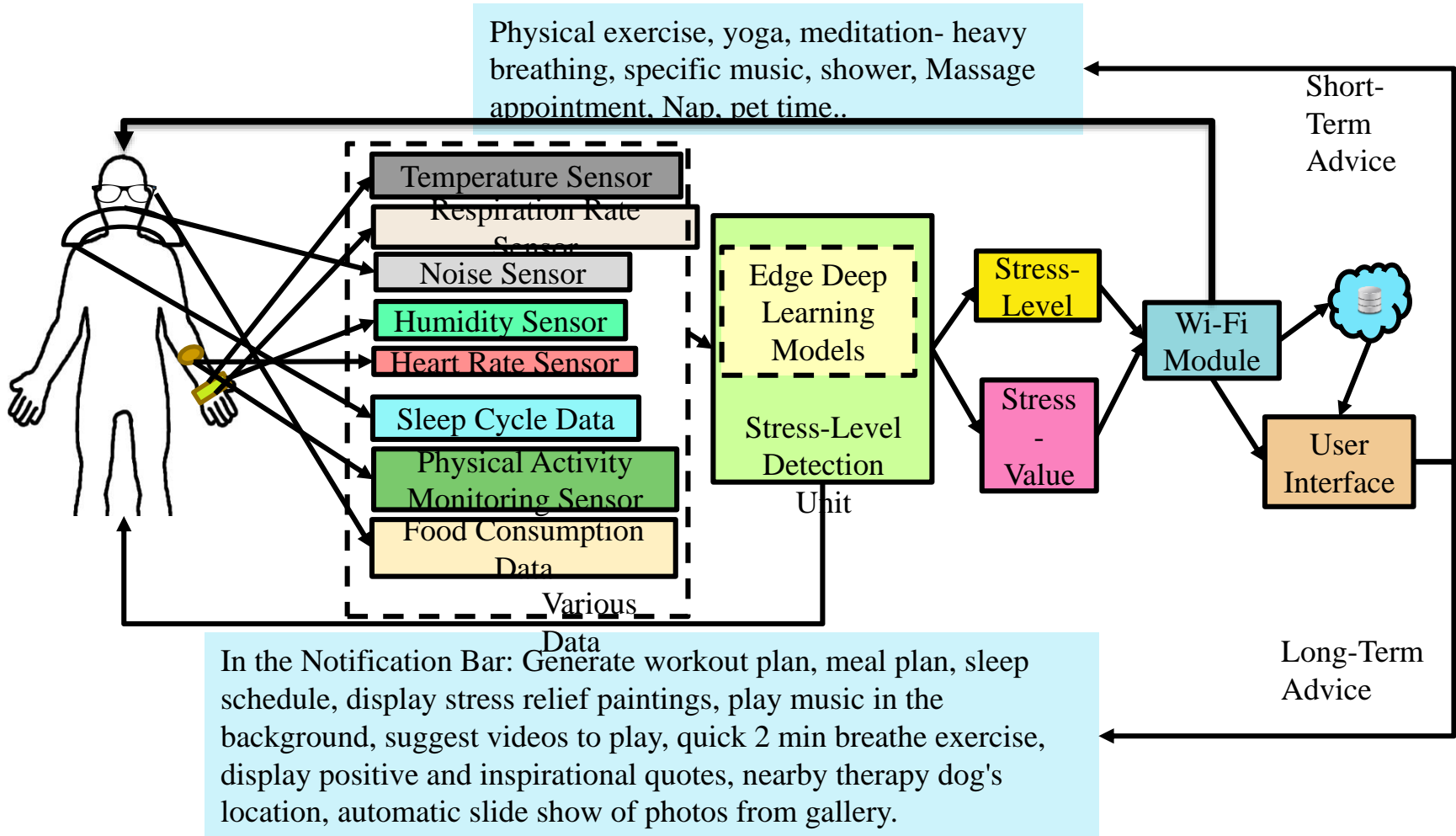
SaYoPillow – Uses deep learning for 96% accuracy with blockchain based security features

iFeliz: Research Question

- How to have an accurate and rapid **Stress Control** system at the user end (at ***IoT-Edge***) and stores the data at the cloud end (at ***IoT-Cloud***)?

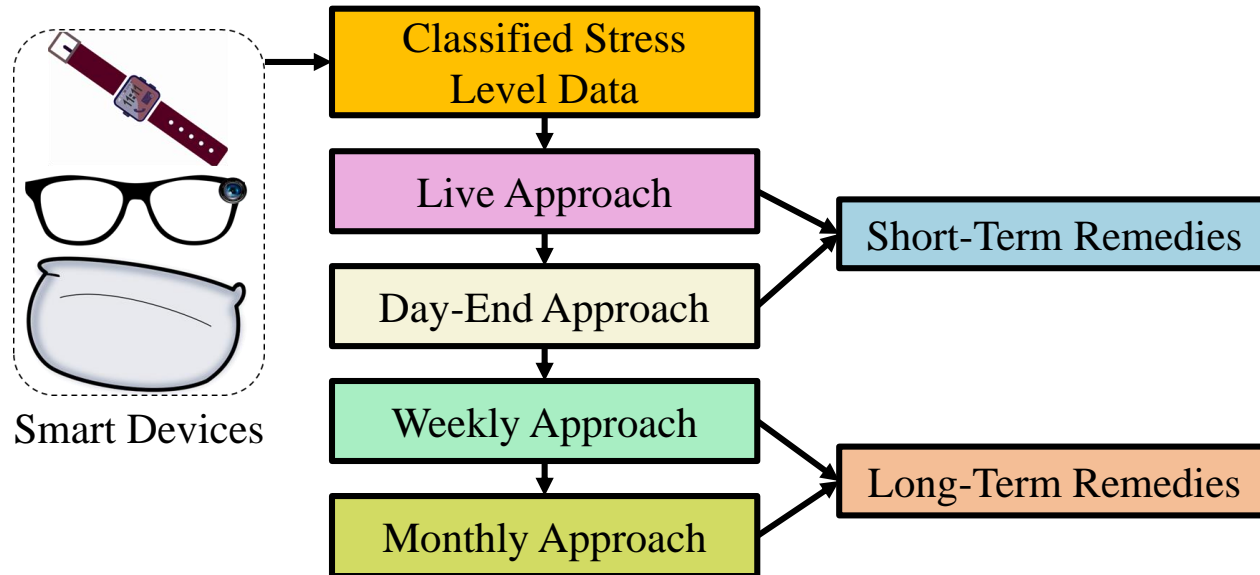
Source: L. Rachakonda, S. P. Mohanty, and E. Kougianos, "iFeliz: An Approach to Control Stress in the Midst of the Global Pandemic and Beyond for Smart Cities using the IoMT", in *Proc. of IEEE Smart Cities Conference*, 2020, pp. Accepted on 24 Aug 2020.

iFeliz: Proposed System



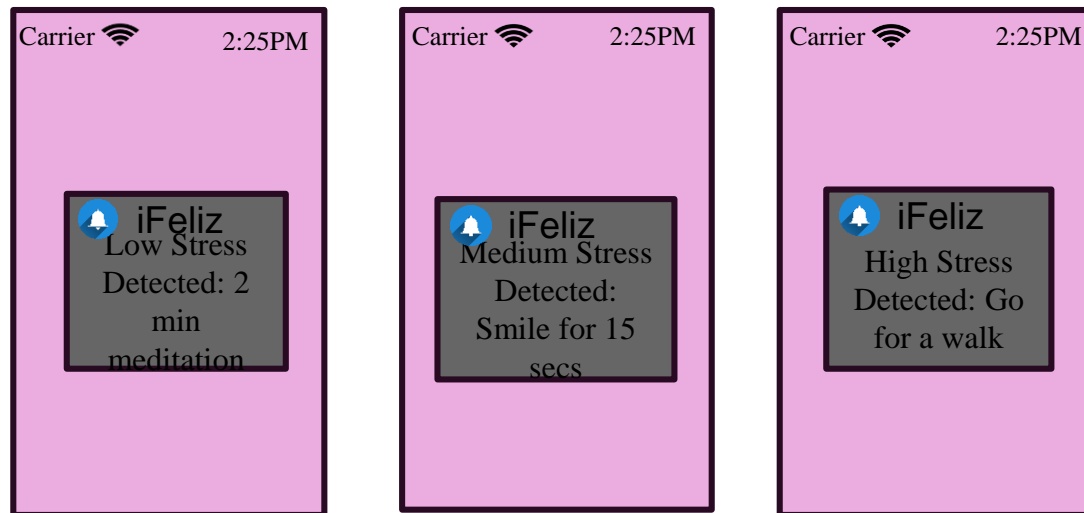
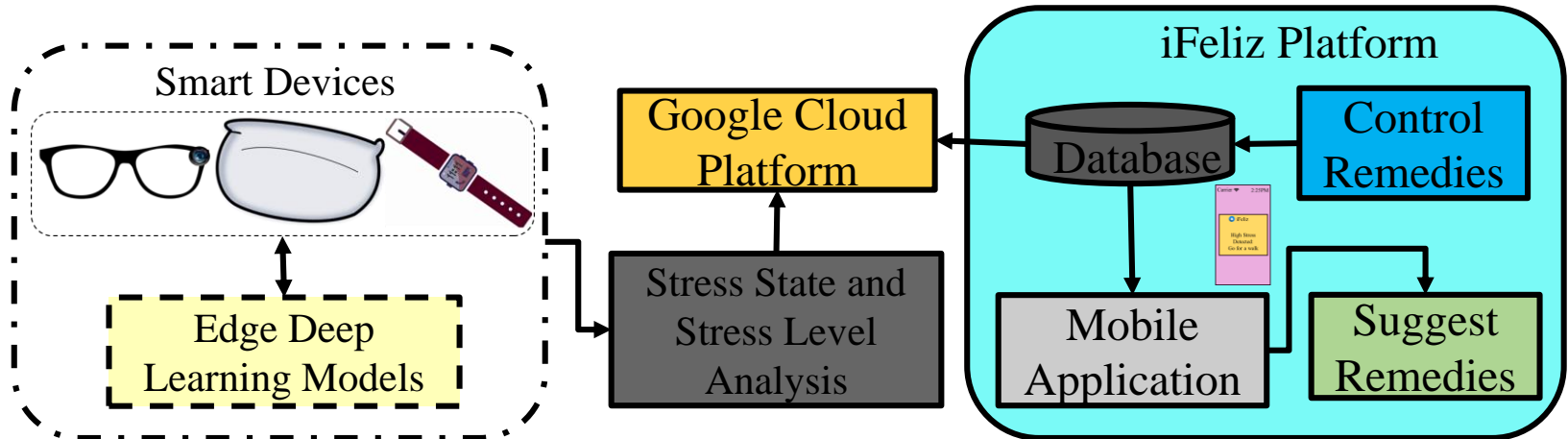
Source: L. Rachakonda, S. P. Mohanty, and E. Kougianos, "iFeliz: An Approach to Control Stress in the Midst of the Global Pandemic and Beyond for Smart Cities using the IoMT", in *Proc. of IEEE Smart Cities Conference*, 2020, pp. Accepted on 24 Aug 2020.

iFeliz: Stress Control Approaches



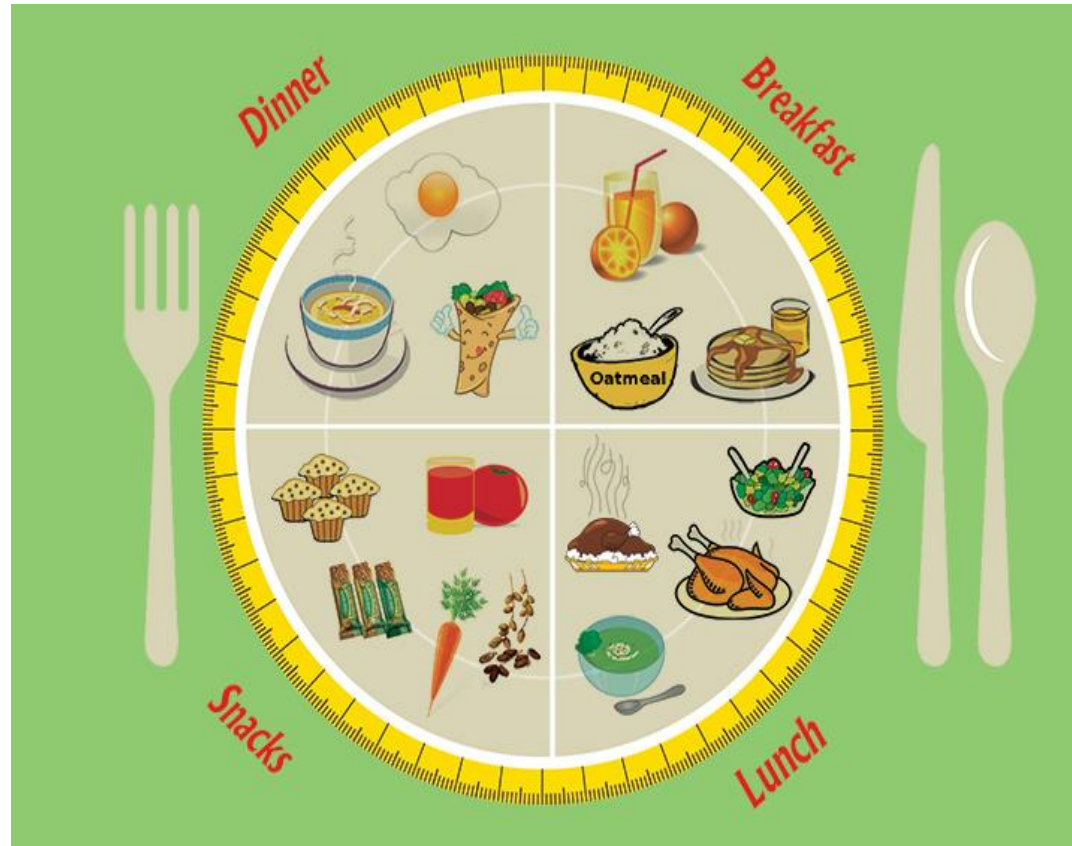
Source: L. Rachakonda, S. P. Mohanty, and E. Kougianos, "iFeliz: An Approach to Control Stress in the Midst of the Global Pandemic and Beyond for Smart Cities using the IoMT", in *Proc. of IEEE Smart Cities Conference*, 2020, pp. Accepted on 24 Aug 2020.

iFeliz: Prototyping



Source: L. Rachakonda, S. P. Mohanty, and E. Kougianos, "iFeliz: An Approach to Control Stress in the Midst of the Global Pandemic and Beyond for Smart Cities using the IoMT", in *Proc. of IEEE Smart Cities Conference*, 2020, pp. Accepted on 24 Aug 2020.

Automatic Food Intake Monitoring and Diet Management is Important



Imbalance Diet is a Global Issue

- Imbalanced diet can be either more or fewer of certain nutrients than the body needs.
- In 2017, 11 million deaths and 255 million disability-adjusted life-years (DALYs) were attributable to dietary risk factors.
- Eating wrong type of food is potential cause of a dietary imbalance:

- Psychiatric disorders
- Coronary heart disease
- High blood pressure

- Obesity
- Tooth decay
- Diabetes

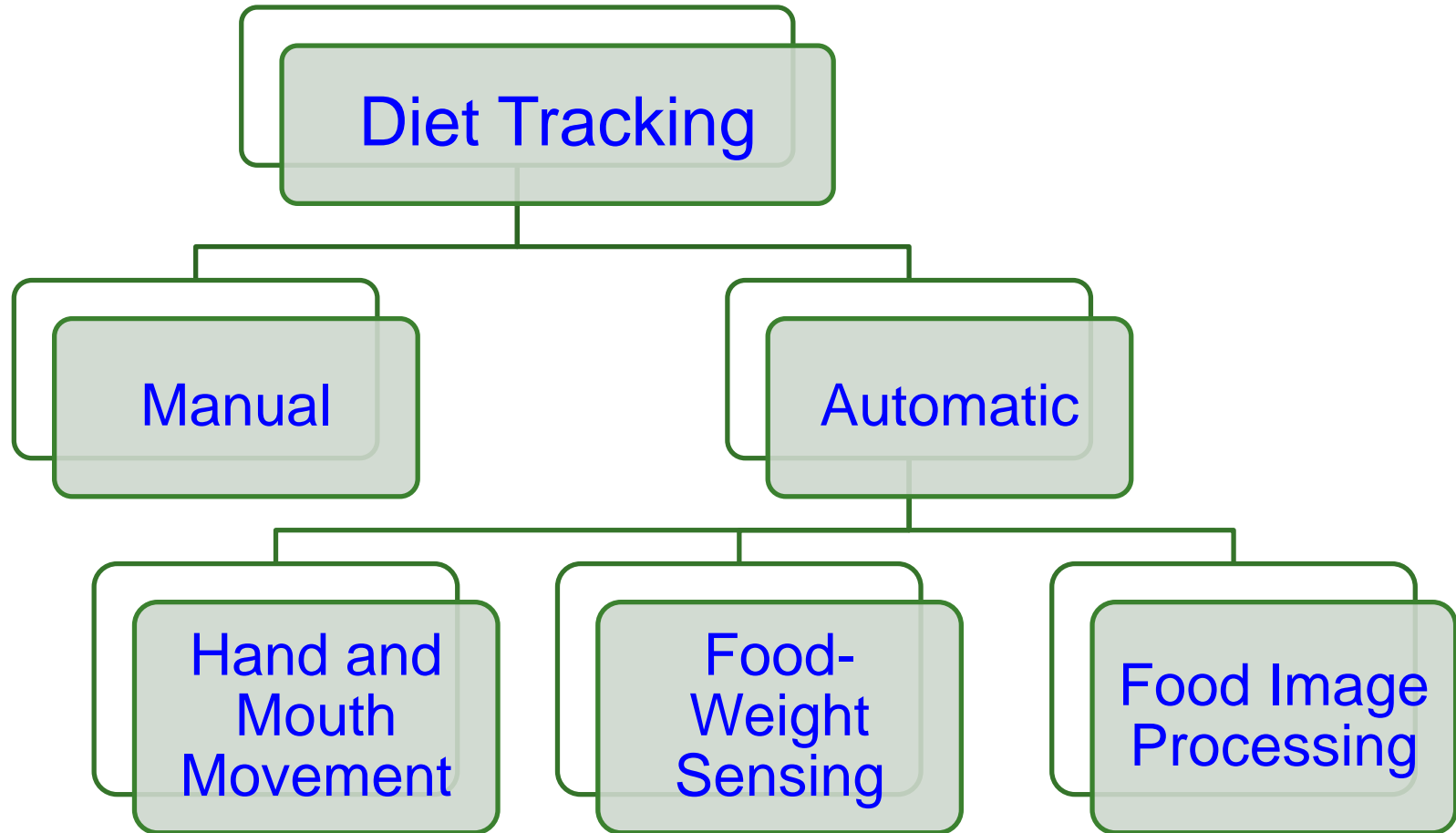
Source: <https://obesity-diet.nutritionalconference.com/events-list/imbalanced-diet-effects-and-causes>
[https://www.thelancet.com/article/S0140-6736\(19\)30041-8/fulltext](https://www.thelancet.com/article/S0140-6736(19)30041-8/fulltext)

Food Tracking Apps

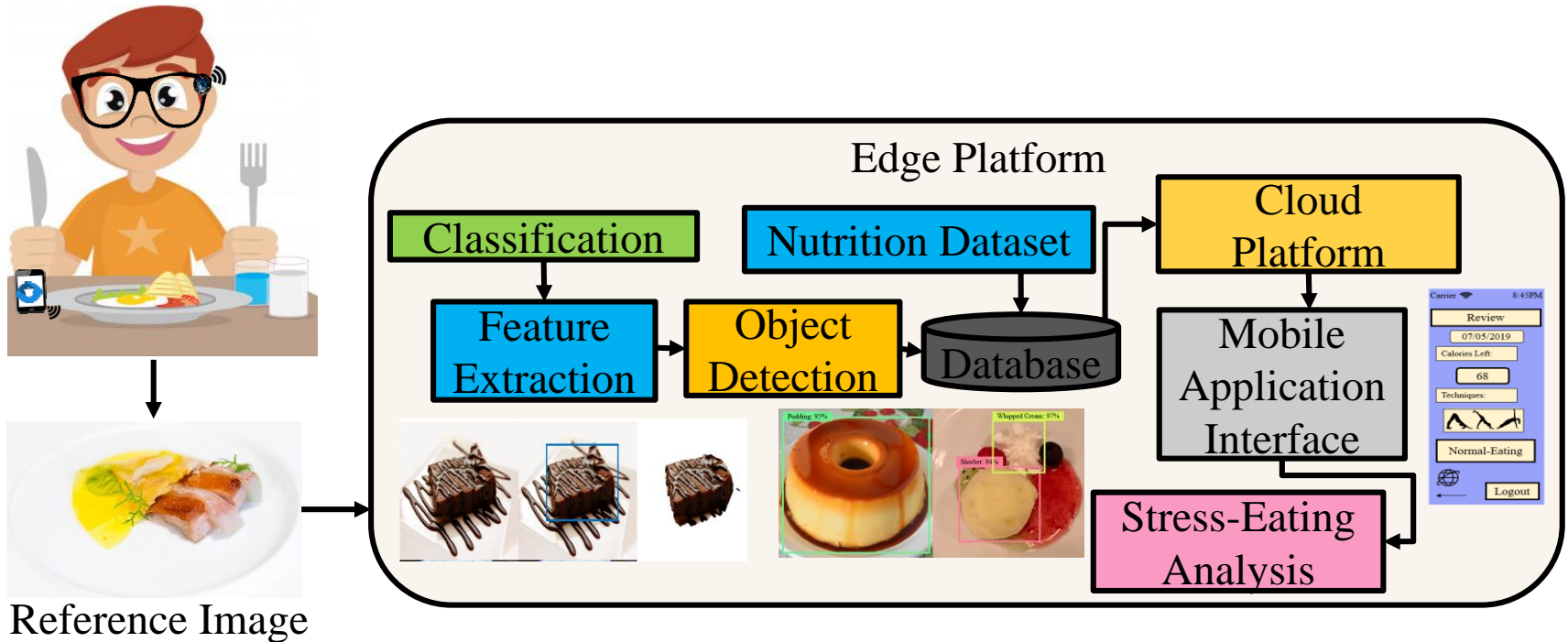
Table 1. Overview of popular food tracking approaches and their capabilities.

App Name	Downloa ds	Reviews	Rating	Input Method				Manu al	Scan ning	Spee ch	Datab ase searc h	Calori es	Nutriti on
				Imag e	Food-Label in Image	Manu al	Crow d Sour ced						
					Auto	Manu al	Crow d Sour ced						
MyFitnessPal	50 M	2 M	4.6					X	X			X	
FatSecret	10 M	268 k	4.5					X	X			X	X
My Diet Coach	10 M	144 k	4.4					X				X	
Lose it	10 M	77 k	4.4	X				X	X			X	
MyPlate	1 M	31 k	4.6					X	X			X	X
mynetdiary	1 M	31 k	4.5					X				X	X
Macros	500 k	3 k	4.5					X	X			X	
Cron-o-meter	100 k	1 k	4.2					X					
Eating Habit	100 k	549	4	X		X						X	
21 day Fix	100 k	470	3.7					X				X	
Bite Snap	50 k	2k	4.7	X								X	X
MealLogger	50 k	225	3.5	X				X				X	X
EatRight	10 k	220	4.5					X				X	
Keto Meal Plan	10 k	19	2.6								X		
YouAte	10 k			X									
KudoLife	1 k	11	3.4								X	X	X
Calorific	19		3.2								X		
Ate				X				?				?	?
Foodlog				X	X			X				X	

Diet Tracking Approaches



Smart Healthcare – iLog



iLog- Fully Automated Detection System with 98% accuracy.

Source: L. Rachakonda, S. P. Mohanty, and E. Kougianos, "iLog: An Intelligent Device for Automatic Food Intake Monitoring and Stress Detection in the IoMT", *IEEE Transactions on Consumer Electronics (TCE)*, Vol. 66, No. 2, May 2020, pp. 115--124.

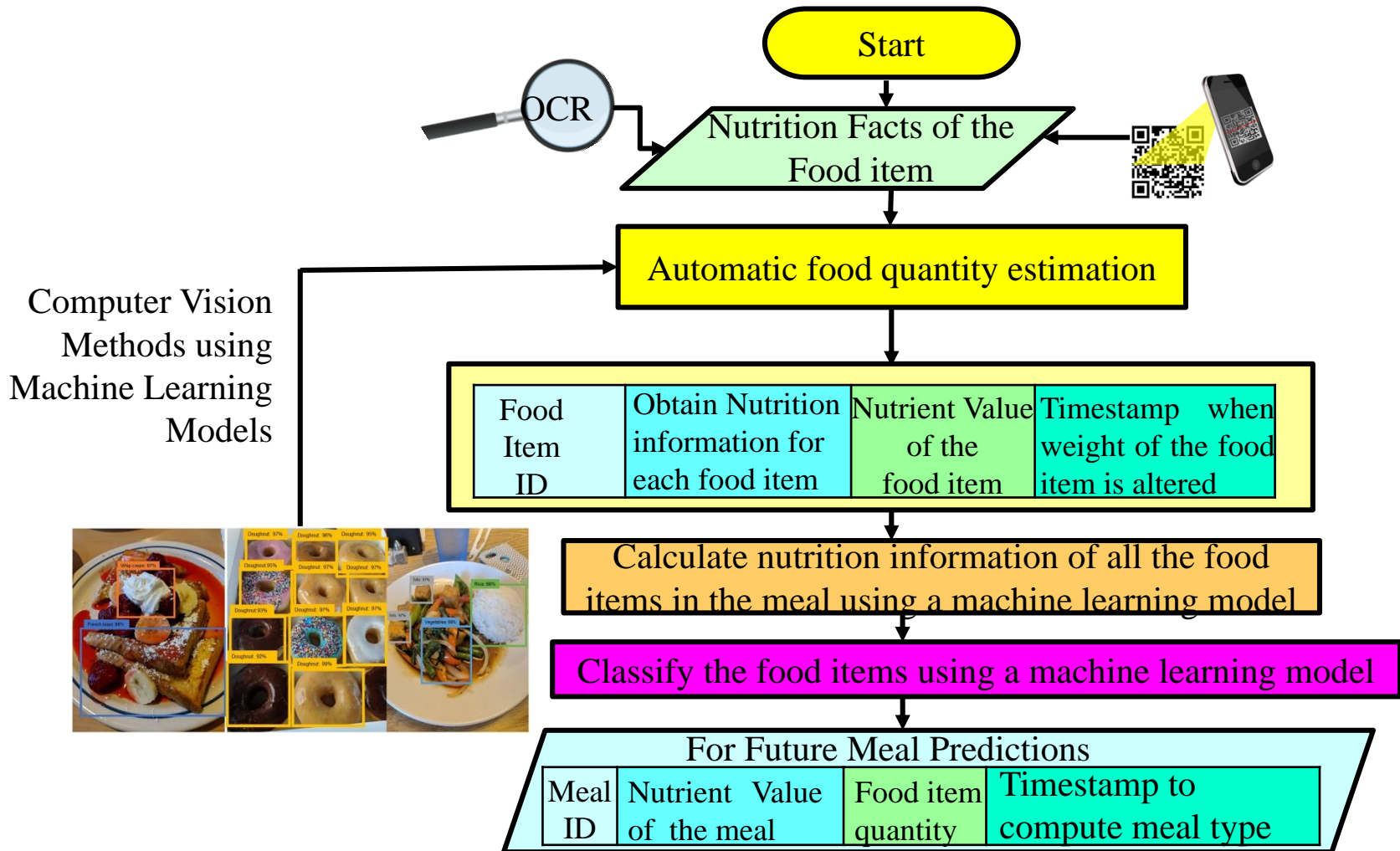
Smart Healthcare – iLog



The data collected is sent to the Firebase Database in which the calorie count is generated by using a dataset with calories and sugars count of individual items from data.gov.

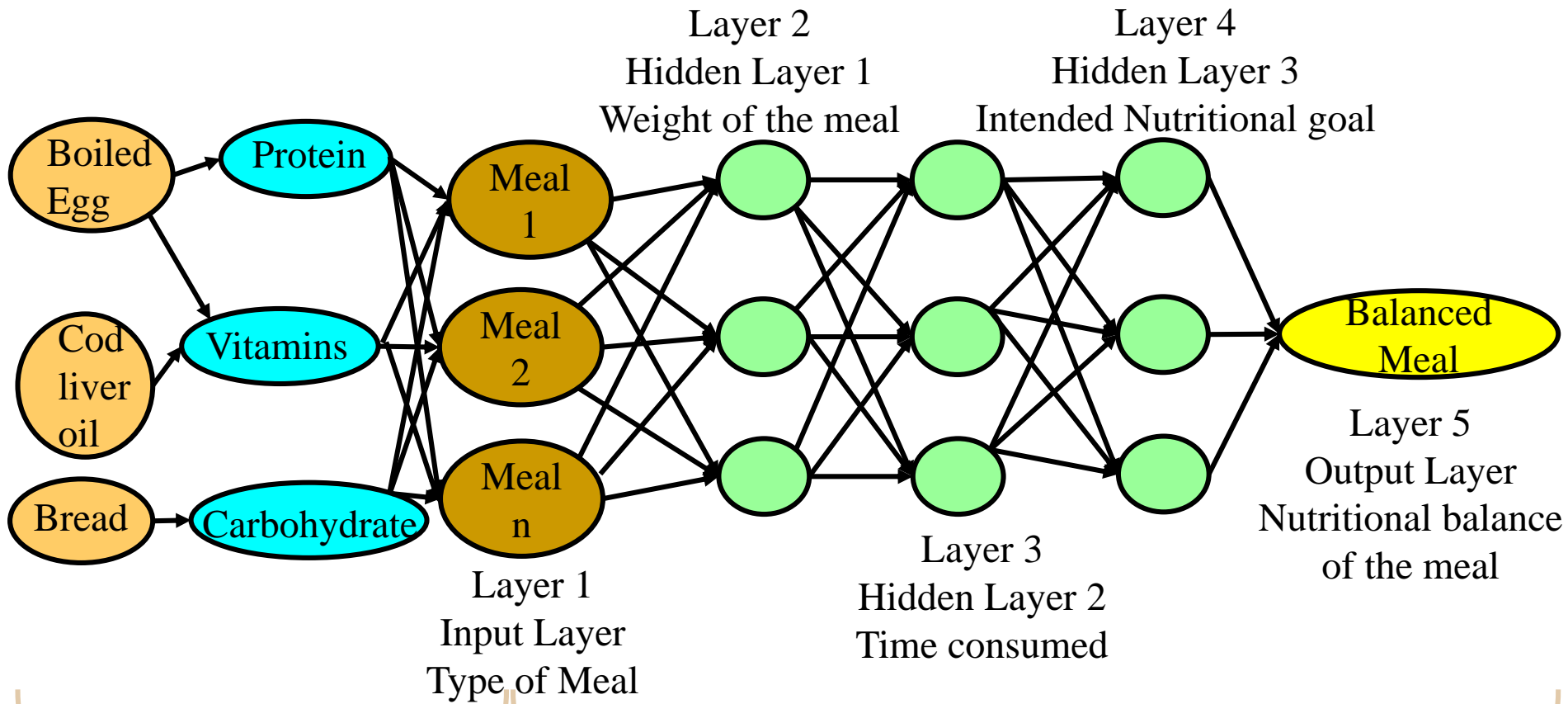
Source: L. Rachakonda, S. P. Mohanty, and E. Kougianos, "iLog: An Intelligent Device for Automatic Food Intake Monitoring and Stress Detection in the IoMT", *IEEE Transactions on Consumer Electronics (TCE)*, Vol. 66, No. 2, May 2020, pp. 115--124.

Smart Healthcare – Diet Prediction



Source: P. Sundaravadivel, K. Kesavan, L. Kesavan, **S. P. Mohanty**, and E. Kougianos, "Smart-Log: A Deep-Learning based Automated Nutrition Monitoring System in the IoT", *IEEE Transactions on Consumer Electronics*, Vol 64, Issue 3, Aug 2018, pp. 390-398.

Smart Healthcare – Diet Prediction



Bayesian Network for classifying food items

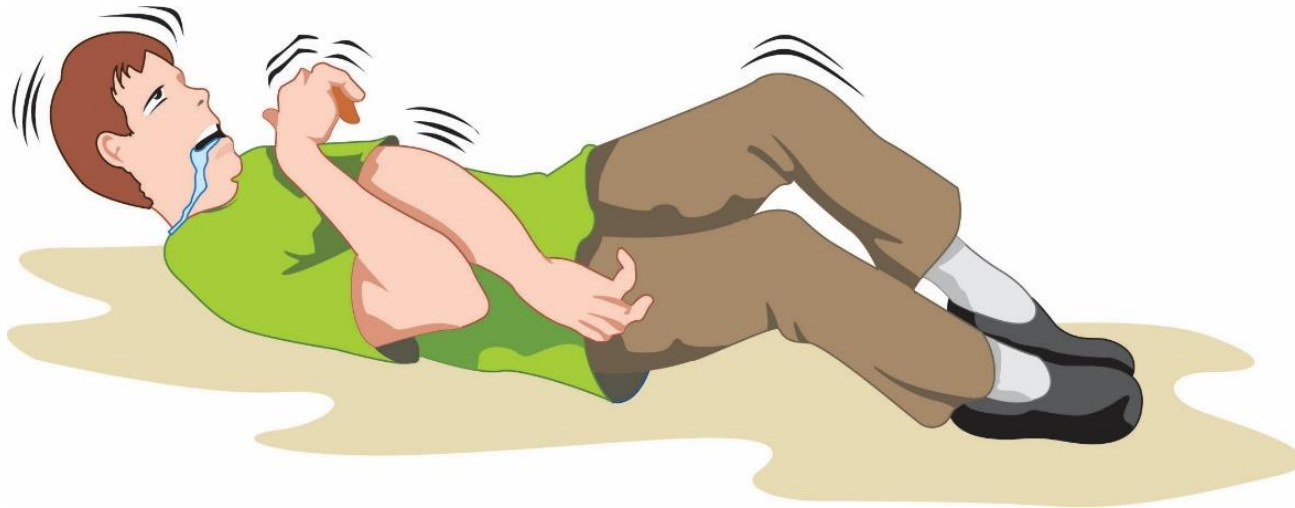
Neural Network for computing Nutritional balance

Prediction (Automated) accuracy of Smart-Log - 98.6%

Source: P. Sundaravadivel, K. Kesavan, L. Kesavan, S. P. Mohanty, and E. Kougianos, "Smart-Log: A Deep-Learning based Automated Nutrition Monitoring System in the IoT", *IEEE Transactions on Consumer Electronics (TCE)*, Volume 64, Issue 3, August 2018, pp. 390--398.

Epileptic Seizure

- A seizure is an abnormal activity in the nervous system which causes its sufferers to lose consciousness and control.

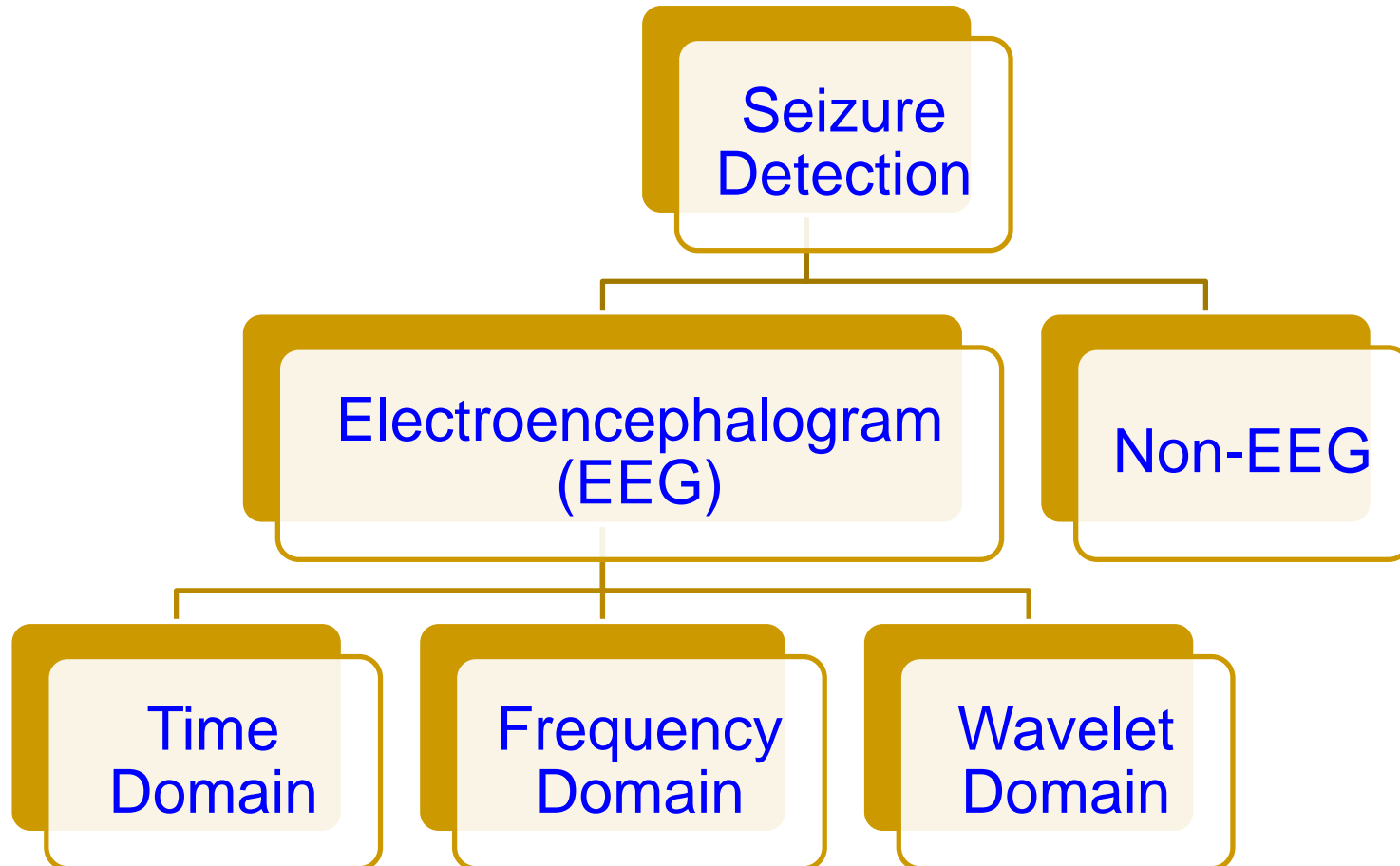


Epileptic Seizure Has Global Impact

- Up to 1% of the world's population suffers from epilepsy.
- Epilepsy is the fourth most common neurological disease after migraine, stroke, and Alzheimer's.
- Individuals can suffer a seizure at any time with potentially disastrous outcomes including a fatal complication called “Sudden Unexpected Death in Epilepsy” (SUDEP).

Source: <https://www.epilepsy.com/learn/about-epilepsy-basics/epilepsy-statistics>

Seizure Detection Methods



Consumer Electronics for Seizure Detection



Source: <https://spectrum.ieee.org/the-human-os/biomedical/diagnostics/this-seizuredetecting-smartwatch-could-save-your-life>

- Embrace2: Smart-band which uses machine learning to detect convulsive Seizures and notifies caregivers.

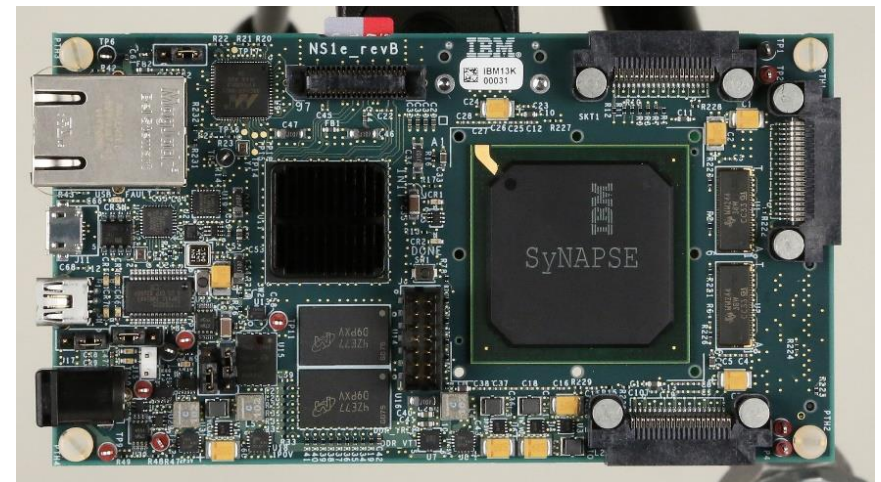


Source: <https://www.empatica.com/embrace2/>

- Medical grade smart watch: It detects generalized clonic-tonic Seizures and notifies physicians.

IBM's Implantable Seizure Detector

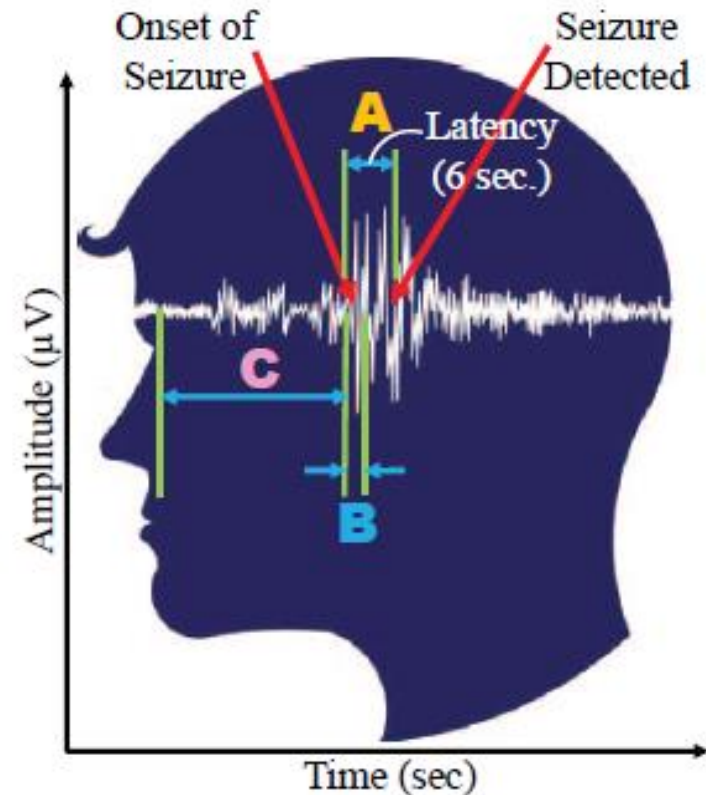
- The TrueNorth chip is postage stamp-sized and consumes over 1,000 times less power than a conventional processor of similar size.



Source: http://uberveillance.squarespace.com/?category=health_care

Drawbacks of Existing Works?

- High seizure detection latency.
- Not suitable for real time IoMT deployment.
- Intervention mechanism after detection is lacking.

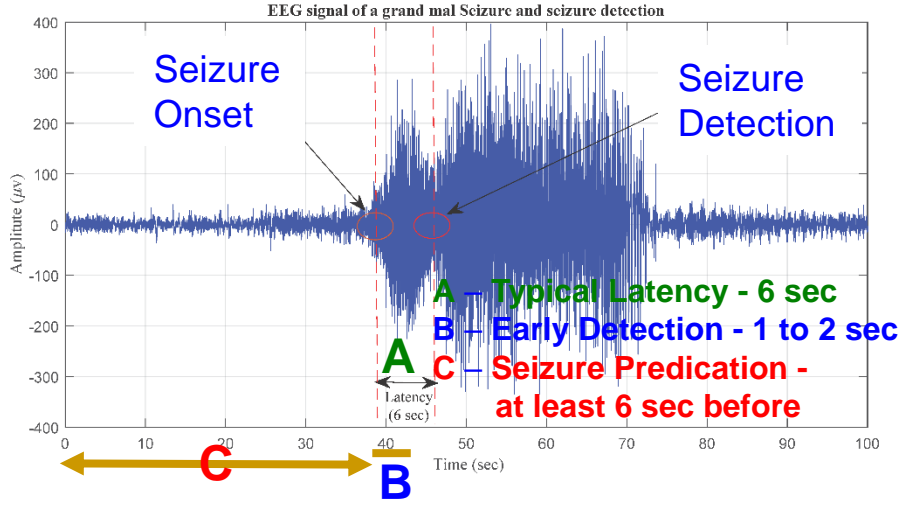
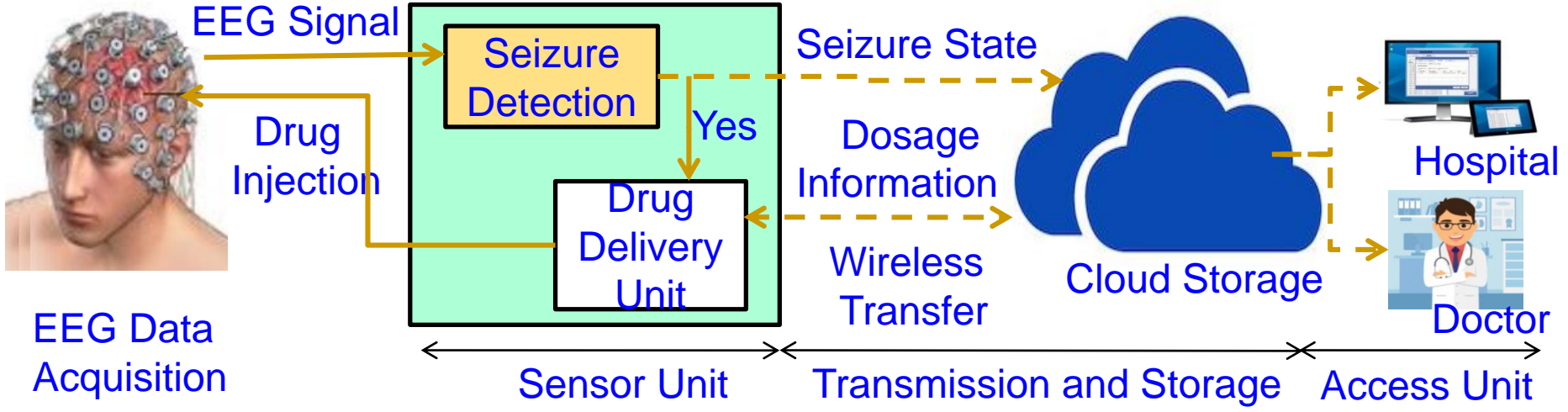


A-Typical Latency (4 to 6s)

B-Early Detection (1 to 2s)

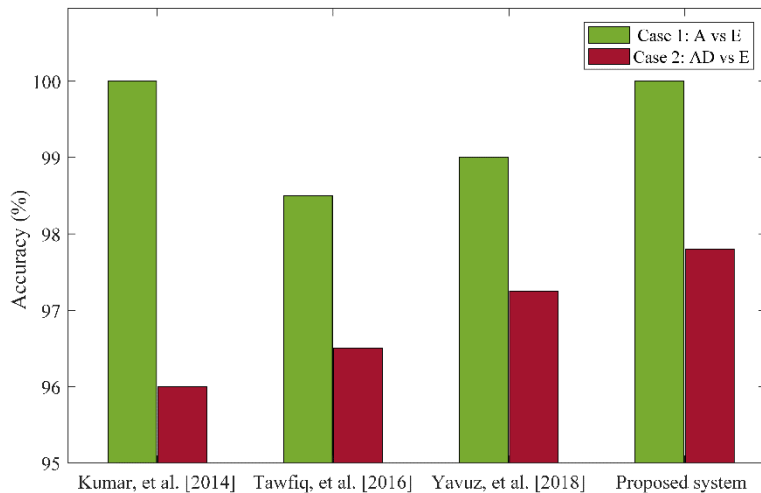
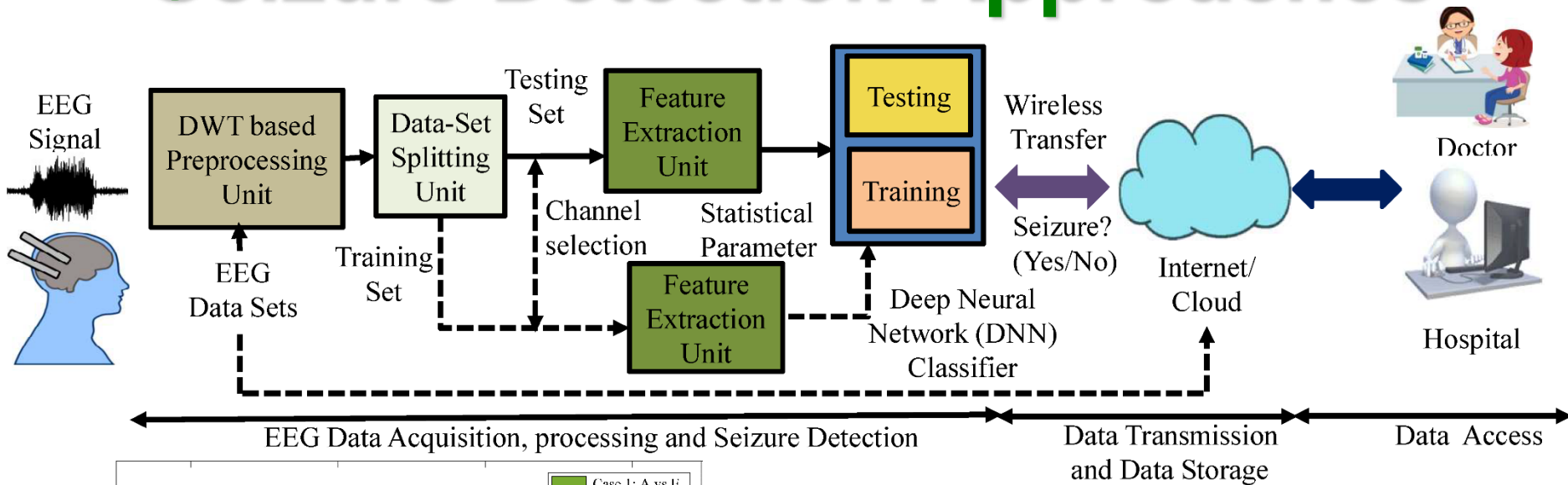
C-Prediction (≥ 6 s prior)

Smart Healthcare - Seizure Detection & Control



Source: M. A. Sayeed, S. P. Mohanty, E. Kougianos, and H. Zaveri, "eSeiz: An Edge-Device for Accurate Seizure Detection for Smart Healthcare", *IEEE Transactions on Consumer Electronics (TCE)*, Volume 65, Issue 3, August 2019, pp. 379--387.

Seizure Detection Approaches

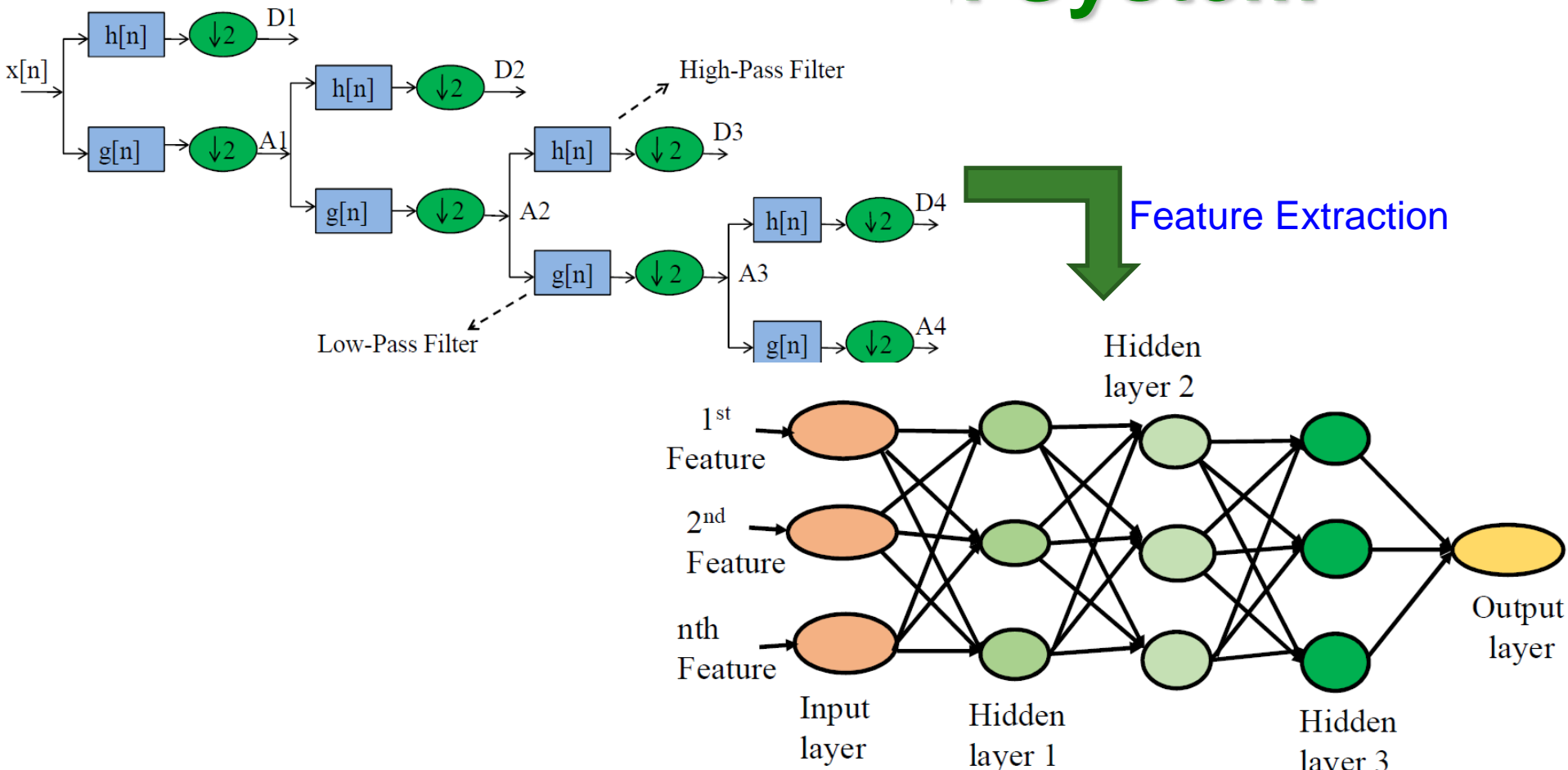


Cloud Vs Edge Computing

Cloud Vs Edge	Latency	Accuracy
Cloud-IoT based Detection	2.5 sec	98.65%
Edge-IoT based Detection	1.4 sec	98.65%

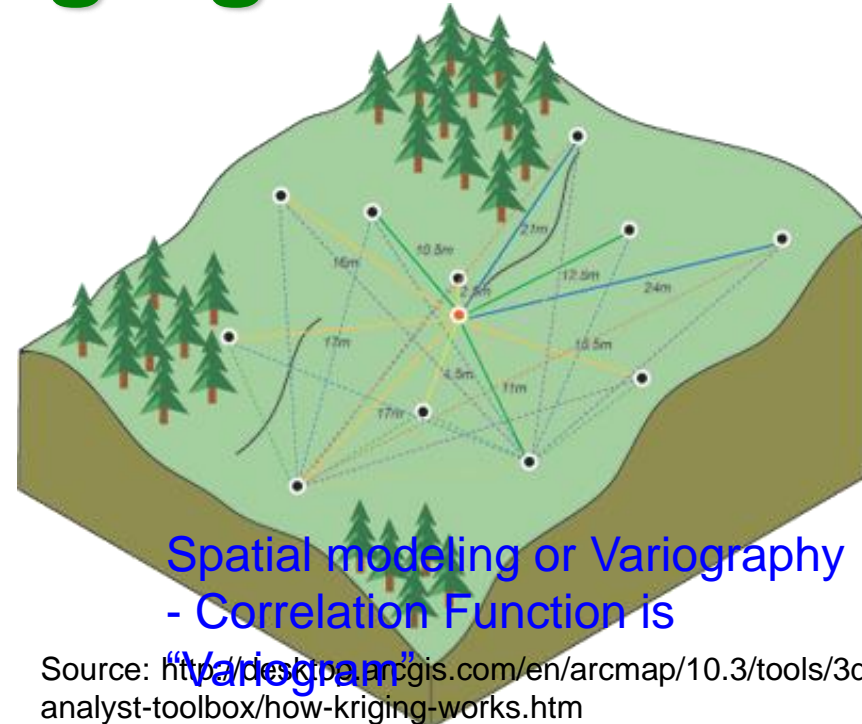
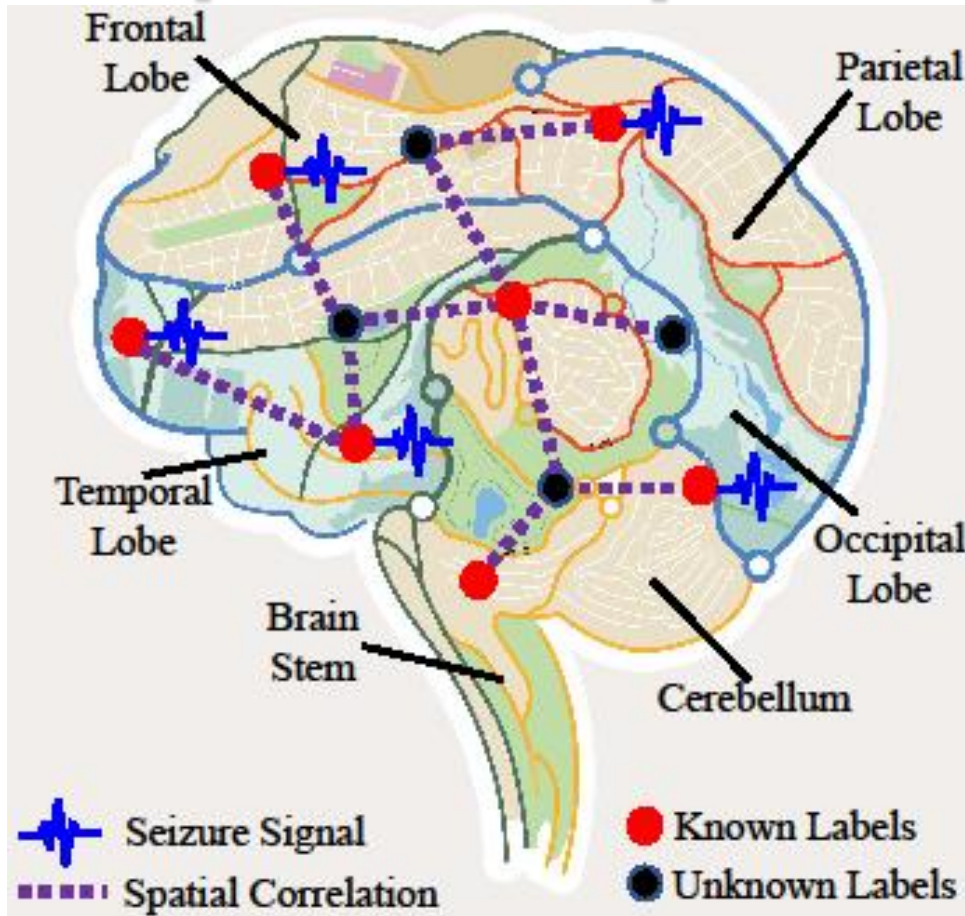
Source: M. A. Sayeed, S. P. Mohanty, E. Kougianos, and H. Zaveri, "Neuro-Detect: A Machine Learning Based Fast and Accurate Seizure Detection System in the IoMT", *IEEE Transactions on Consumer Electronics (TCE)*, Vol 65, No 3, Aug 2019, pp. 359--368.

Our Neuro-Detect : A ML Based Seizure Detection System



Source: M. A. Sayeed, S. P. Mohanty, E. Kougianos, and H. Zaveri , "Neuro-Detect: A Machine Learning Based Fast and Accurate Seizure Detection System in the IoMT", *IEEE Transactions on Consumer Electronics (TCE)*, Vol 65, Issue 3, Aug 2019, pp. 359-368.

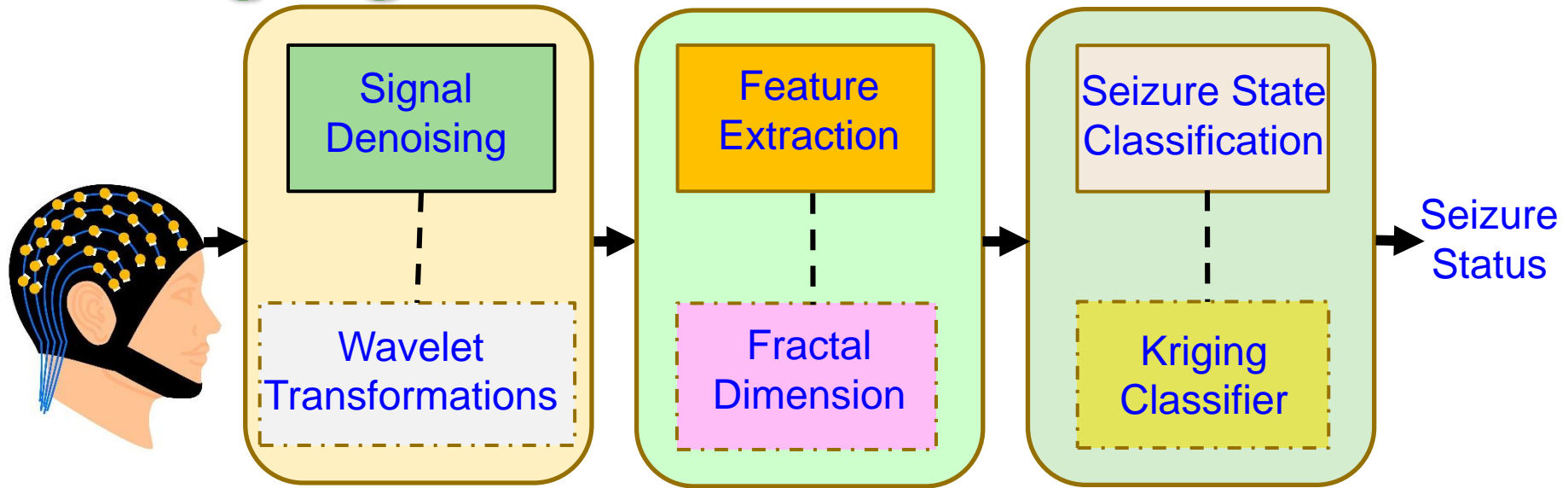
Smart Healthcare – Brain as a Spatial Map → Kriging Methods



Spatial autocorrelation principle
- things that are closer are more alike than things farther

Source: I. L. Olokodana, S. P. Mohanty, and E. Koungianos, "Ordinary-Kriging Based Real-Time Seizure Detection in an Edge Computing Paradigm", in *Proceedings of the 38th IEEE International Conference on Consumer Electronics (ICCE)*, 2020, Accepted.

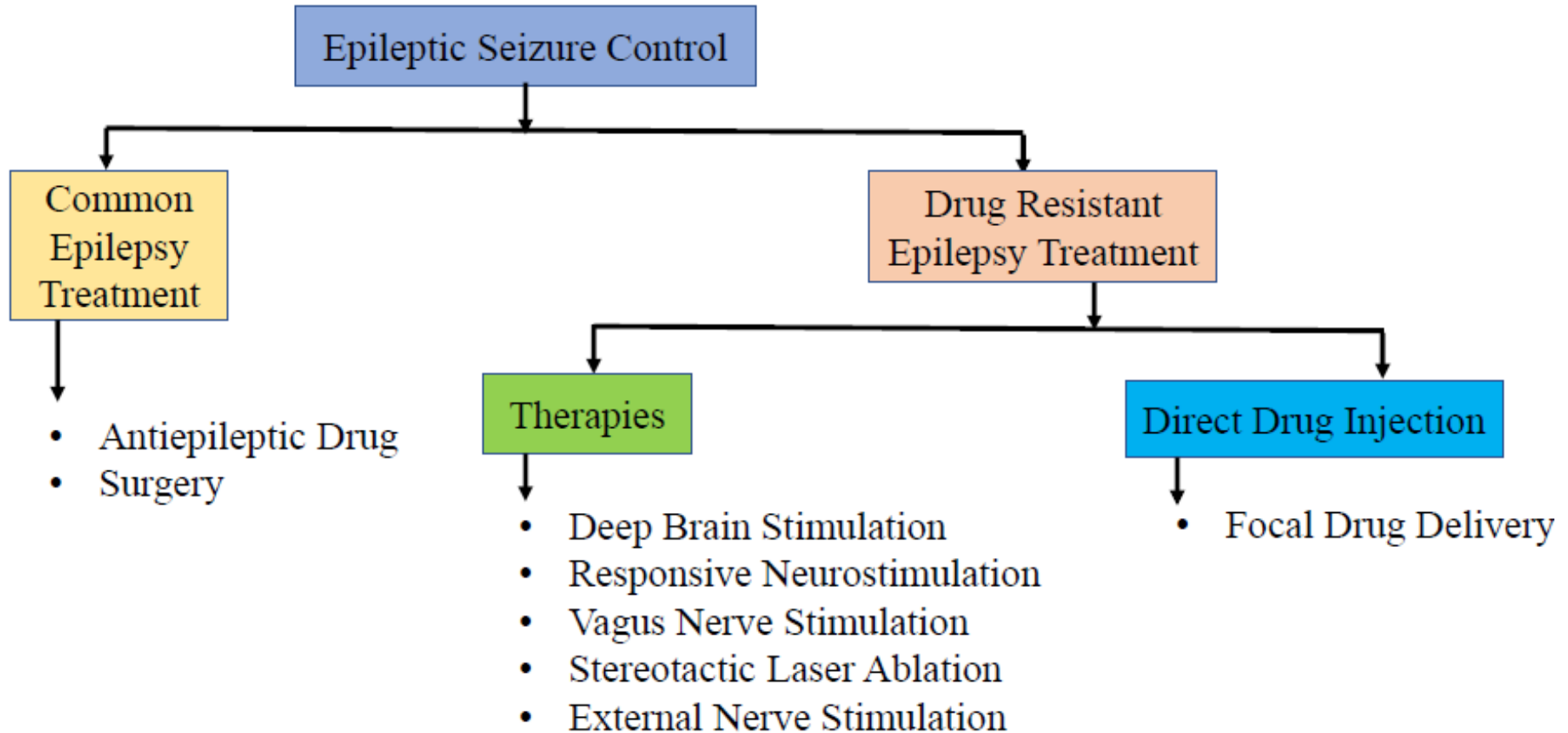
Kriging based Seizure Detection



Works	Extracted Features	Classification Algorithm	Sensitivity	Latency
Zandi, et al. 2012 [23]	Regularity, energy & combined seizure indices	Cumulative Sum thresholding	91.00%	9 sec.
Altaf,etal. 2015 [24]	Digital hysteresis	Support Vector Machine	95.70%	1 sec
Vidyaratne, et al. 2017 [25]	Fractal dimension, spatial/ temporal features	Relevance Vector Machine (RVM)	96.00%	1.89 sec
Our Proposed	Petrosian fractal dimension	Kriging Classifier	100.0%	0.85 s

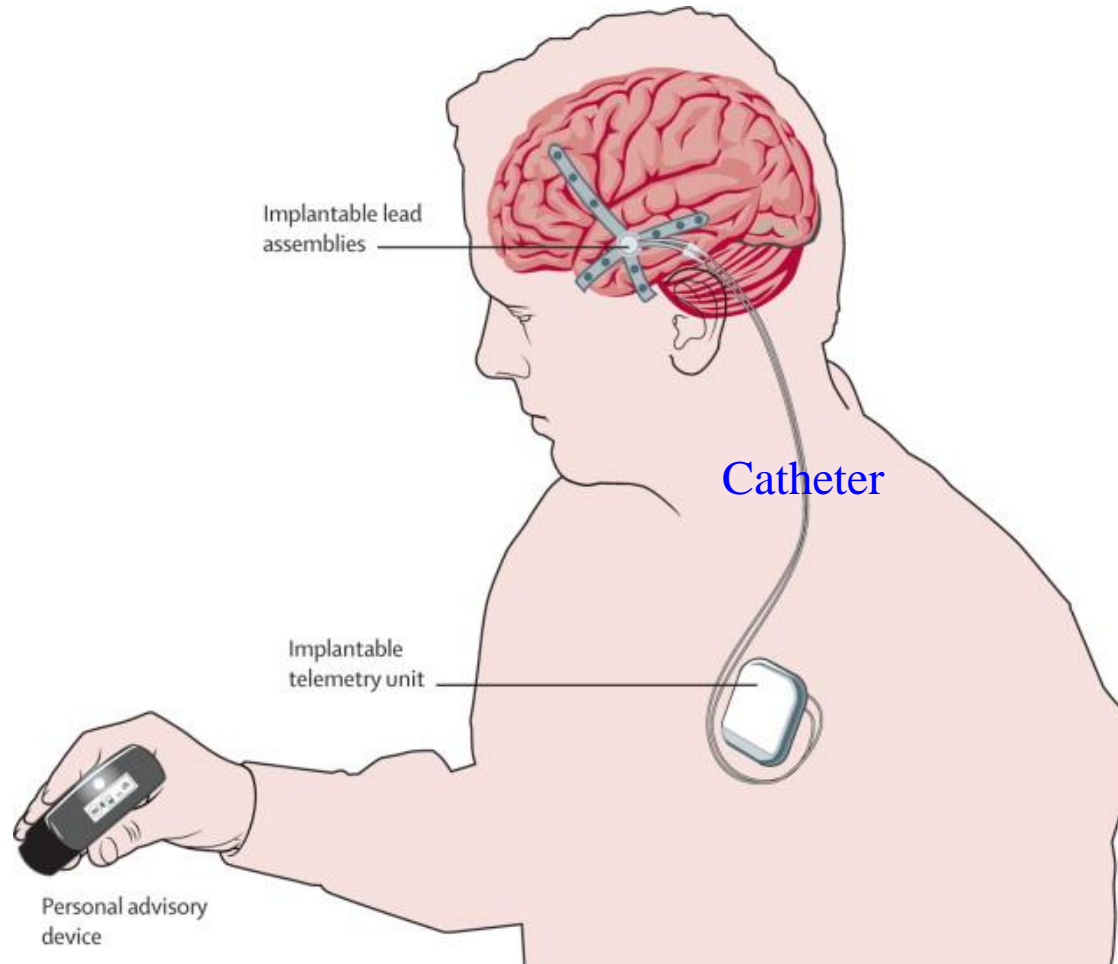
Source: I. L. Olokodana, S. P. Mohanty, and E. Kougianos, "Ordinary-Kriging Based Real-Time Seizure Detection in an Edge Computing Paradigm", in *Proceedings of the 38th IEEE International Conference on Consumer Electronics (ICCE)*, 2020, Accepted.

Seizure Control Methods



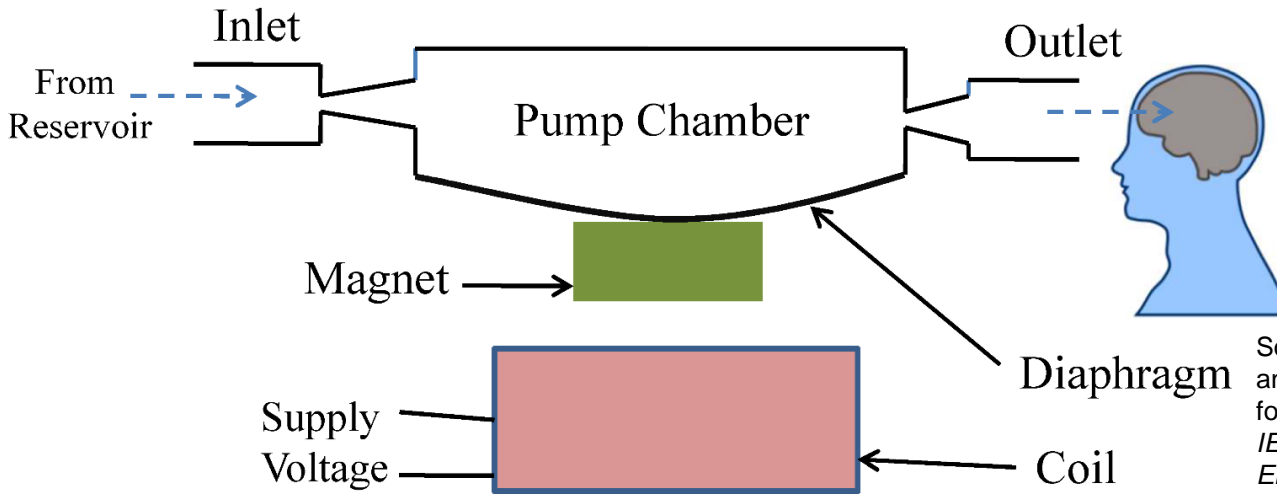
Source: M. A. Sayeed, S. P. Mohanty, E. Kougianos, and H. Zaveri, "iDDS: An Edge-Device in IoMT for Automatic Seizure Control using On-Time Drug Delivery", in *Proceedings of the 38th IEEE International Conference on Consumer Electronics (ICCE)*, 2020.

Implantable for Seizure Detection and Control



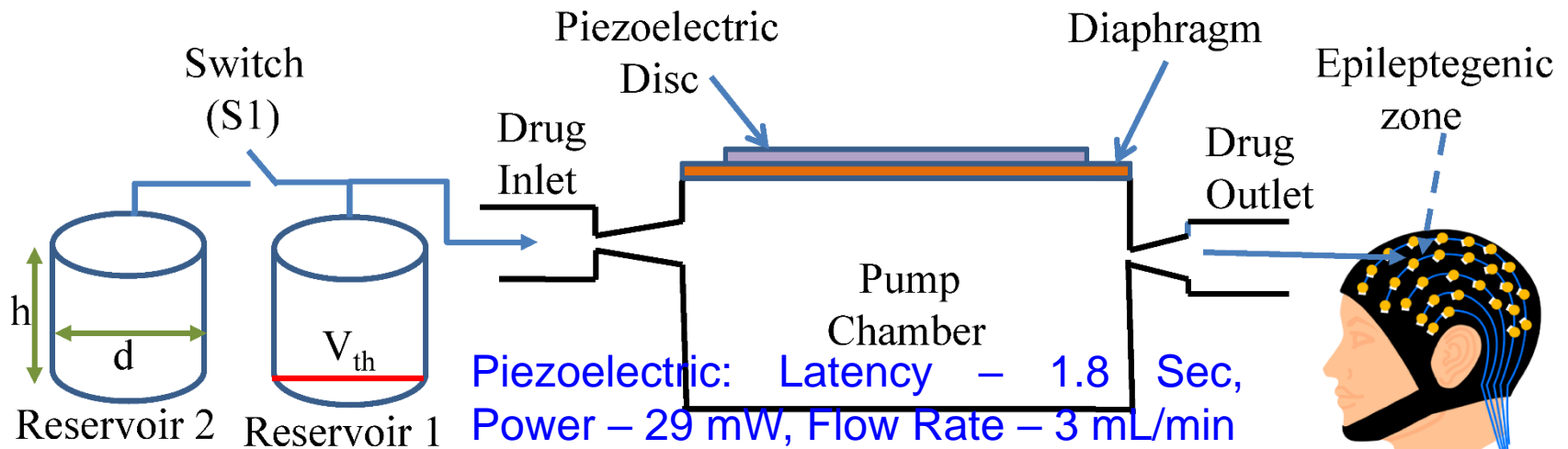
Source: <https://www.kurzweilai.net/brain-implant-gives-early-warning-of-epileptic-seizure>

Seizure Control Methods



Electromagnetic: Latency – 1.8 Sec, Power – 12.81 mW, Flow Rate – 0.34 mL/min

Source: M. A. Sayeed, S. P. Mohanty, E. Kougianos, and H. Zaveri, "An IoT-based Drug Delivery System for Refractory Epilepsy", in *Proceedings of the 37th IEEE International Conference on Consumer Electronics (ICCE)*, 2019.



Piezoelectric: Latency – 1.8 Sec, Power – 29 mW, Flow Rate – 3 mL/min





Source: M. A. Sayeed, S. P. Mohanty, E. Kougianos, and H. Zaveri, "iDDS: An Edge-Device in IoMT for Automatic Seizure Control using On-Time Drug Delivery", in *Proceedings of the 38th IEEE International Conference on Consumer Electronics (ICCE)*, 2020.

Elderly Fall Automatic Detection is Needed to Improve Quality of Life

- Elderly Fall: Approximately a third of elderly people 65 years or older fall each year.
- Fall Caused: Over 800,000 hospital admissions, 2.8 million injuries and 27,000 deaths have occurred in the last few years.

Source: L. Rachakonda, A. Sharma, S. P. Mohanty, and E. Kougianos, "Good-Eye: A Combined Computer-Vision and Physiological-Sensor based Device for Full-Proof Prediction and Detection of Fall of Adults", in *Proceedings of the 2nd IFIP International Internet of Things (IoT) Conference (IFIP-IoT)*, 2019, pp. 273--288.

Consumer Electronics for Fall Detection

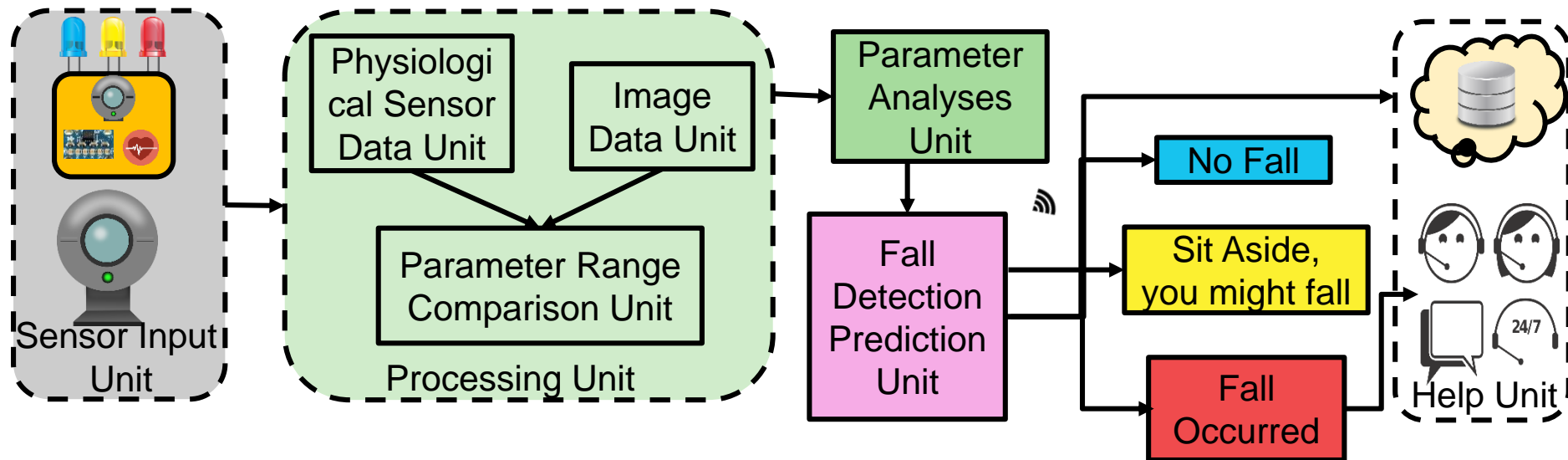
Wearables	Drawbacks
	<p>Apple watch: uses only accelerometers, doesn't work on low thresholds like double carpet, bathroom, hardwood floors. The user must manually select the option SOS and as a reason it fails if the person is unconscious. Users may remain on the floor with no help for large hours.</p>
	<p>Philips Lifeline: Uses only accelerometers and barometric sensors for pressure changes. After the fall, the system waits for 30 sec and directly connects to help.</p>
	<p>Lively Mobile by greatcall and Sense4Care Angel4: Monitors fluctuations using only accelerometers.</p>
	<p>Bay Alarm Medical and Medical Guardian: Use only accelerometers. Have huge base stations limiting the usage and location access.</p>

Good-Eye: Research Question

- How to have a non-invasive, optimized, IoT enabled system which detects and predicts the falls in elderly based on the physiological and vision signal data, analyses the data at the user end (at IoT-Edge) and stores the data at the cloud end (at IoT-Cloud)?

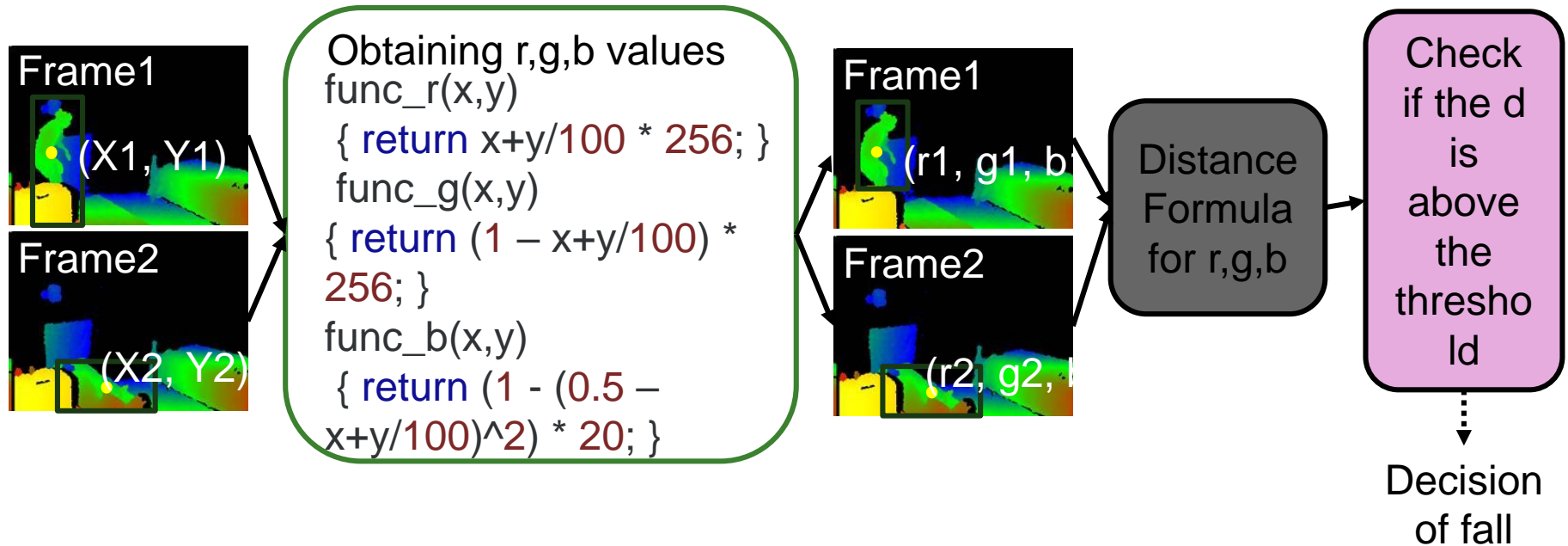
Source: L. Rachakonda, A. Sharma, S. P. Mohanty, and E. Kougianos, "Good-Eye: A Combined Computer-Vision and Physiological-Sensor based Device for Full-Proof Prediction and Detection of Fall of Adults", in *Proceedings of the 2nd IFIP International Internet of Things (IoT) Conference (IFIP-IoT)*, 2019, pp. 273--288.

Good-Eye: Our Multimodal Sensor System for Elderly Fall Prediction and Detection



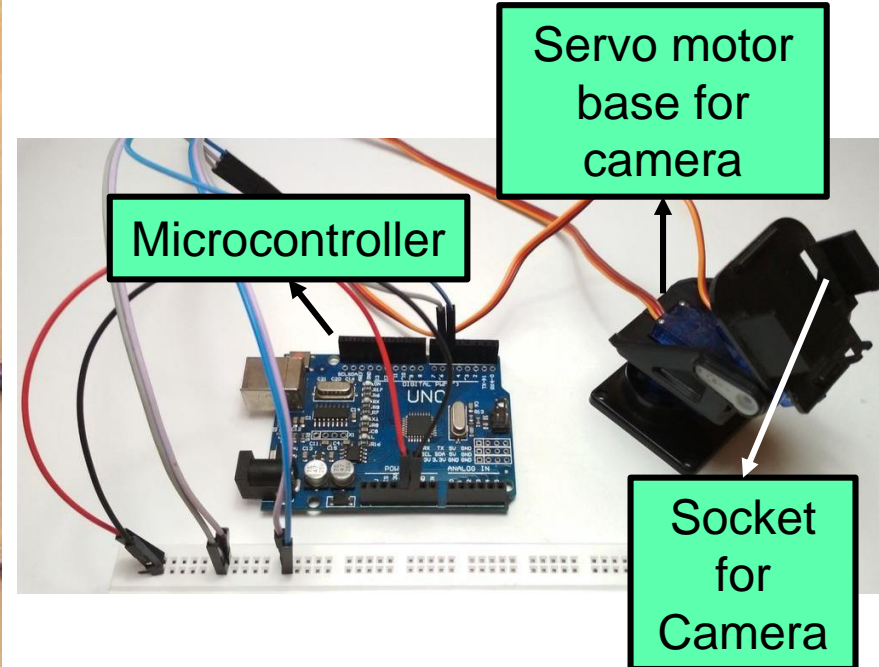
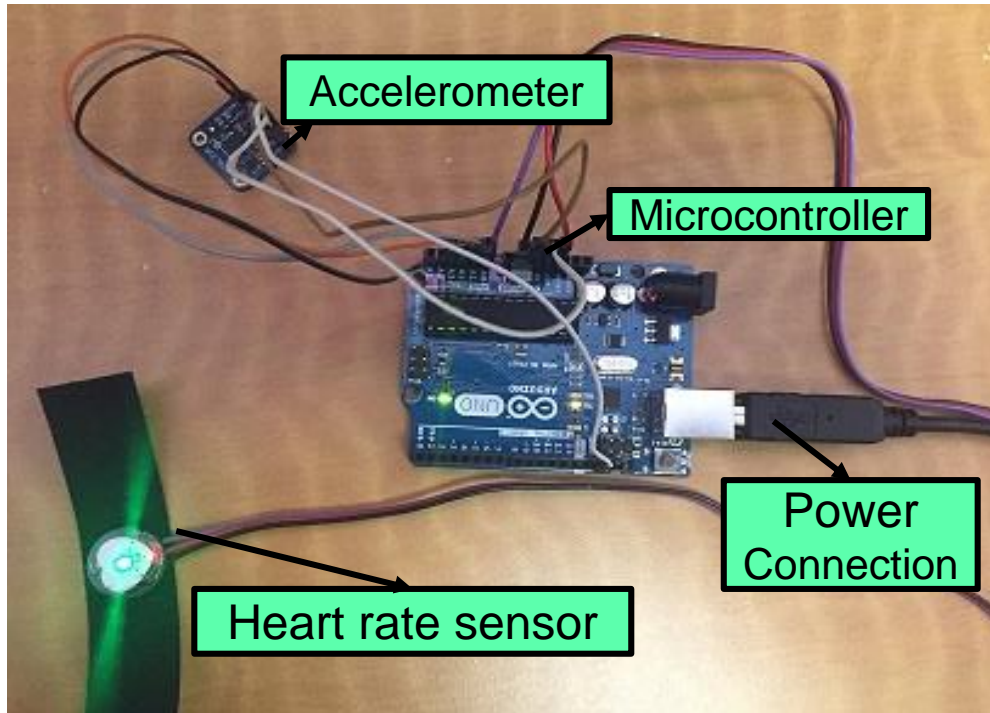
Source: L. Rachakonda, A. Sharma, S. P. Mohanty, and E. Kougianos, "Good-Eye: A Combined Computer-Vision and Physiological-Sensor based Device for Full-Proof Prediction and Detection of Fall of Adults", in *Proceedings of the 2nd IFIP International Internet of Things (IoT) Conference (IFIP-IoT)*, 2019, pp. 273--288.

Good-Eye: Elderly Fall Detection



Source: L. Rachakonda, A. Sharma, S. P. Mohanty, and E. Kougianos, "Good-Eye: A Combined Computer-Vision and Physiological-Sensor based Device for Full-Proof Prediction and Detection of Fall of Adults", in *Proceedings of the 2nd IFIP International Internet of Things (IoT) Conference (IFIP-IoT)*, 2019, pp. 273--288.

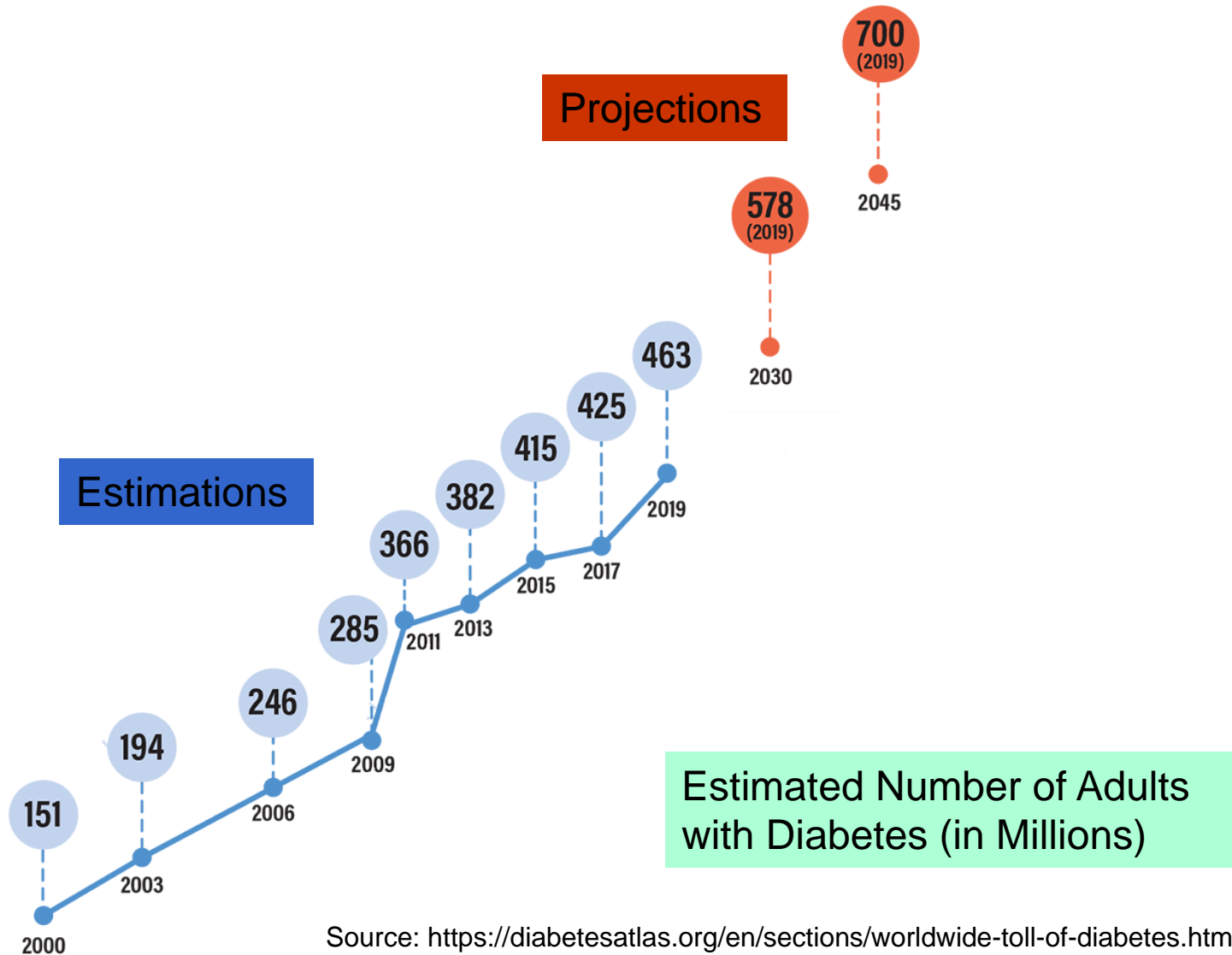
Good-Eye: Prototyping



Good-Eye: Fall detection and prediction Accuracy - 95%.

Source: L. Rachakonda, A. Sharma, S. P. Mohanty, and E. Kougianos, "Good-Eye: A Combined Computer-Vision and Physiological-Sensor based Device for Full-Proof Prediction and Detection of Fall of Adults", in *Proceedings of the 2nd IFIP International Internet of Things (IoT) Conference (IFIP-IoT)*, 2019, pp. 273--288.

Diabetes is a Global Crisis



Blood Glucose Monitoring – Invasive Vs Noninvasive

Invasive Approach (Capillary Glucose Measurement)

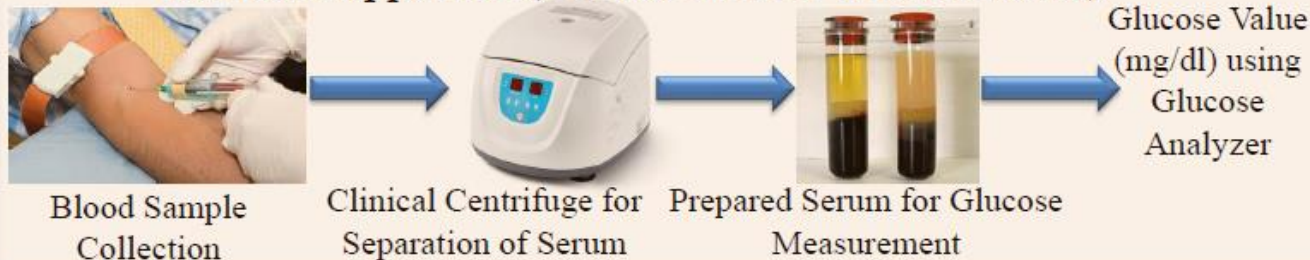


Traditional – Finger Pricking



Invasive Approach – Processing Blood/Serum

Invasive Approach (Serum Glucose Measurement)

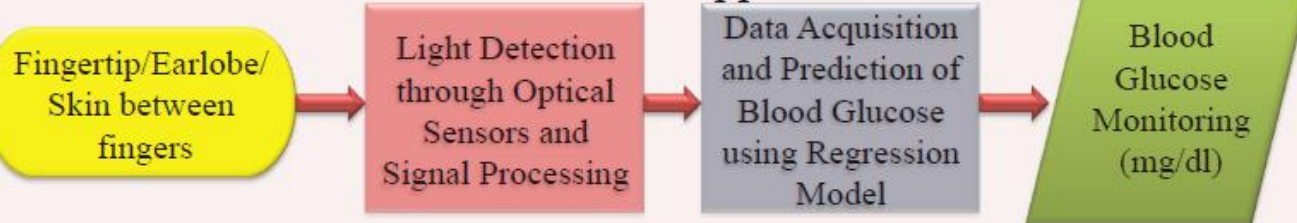


Noninvasive – Wearable

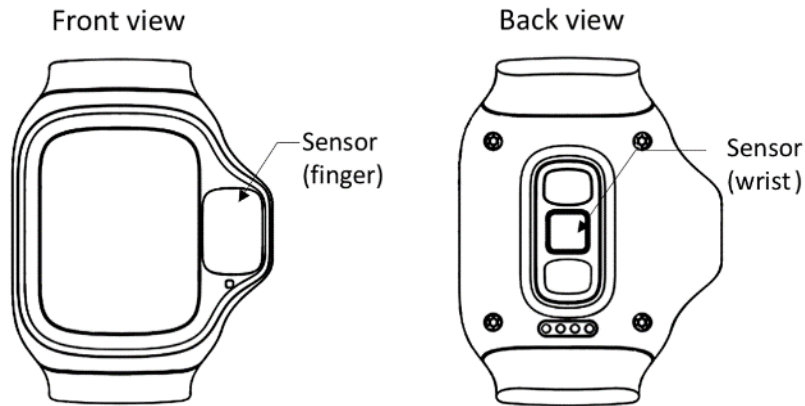


Noninvasive Approach – Processing Light

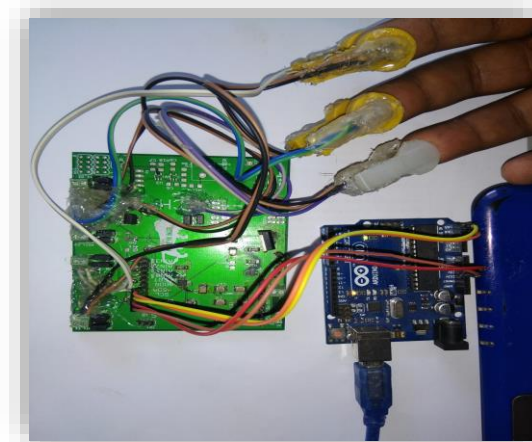
Non Invasive Approach



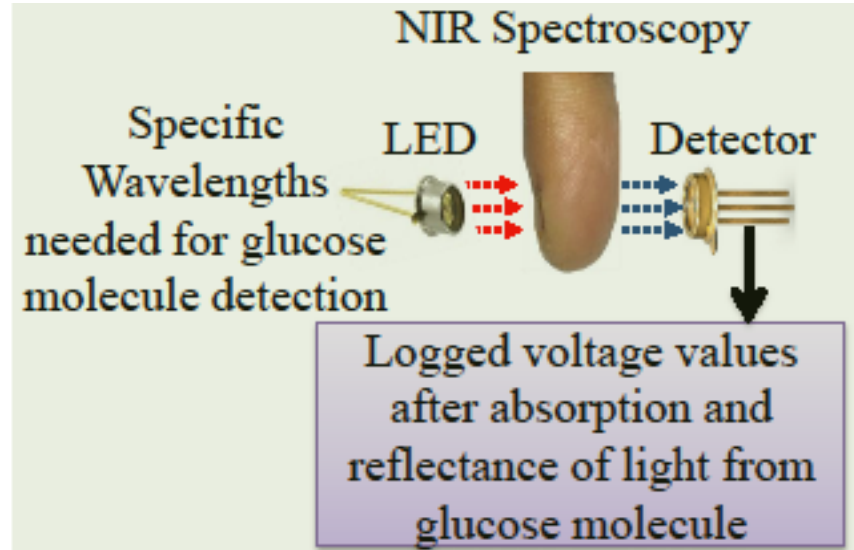
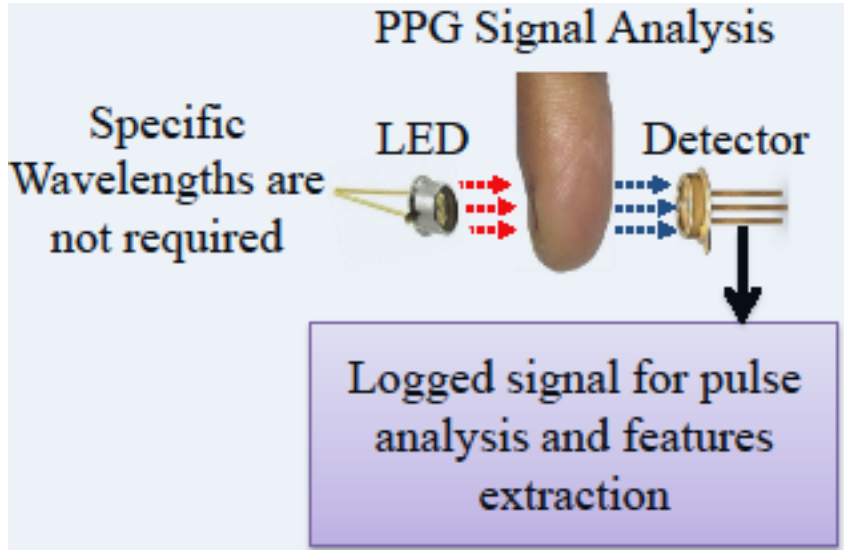
Noninvasive Glucose-Level Monitoring



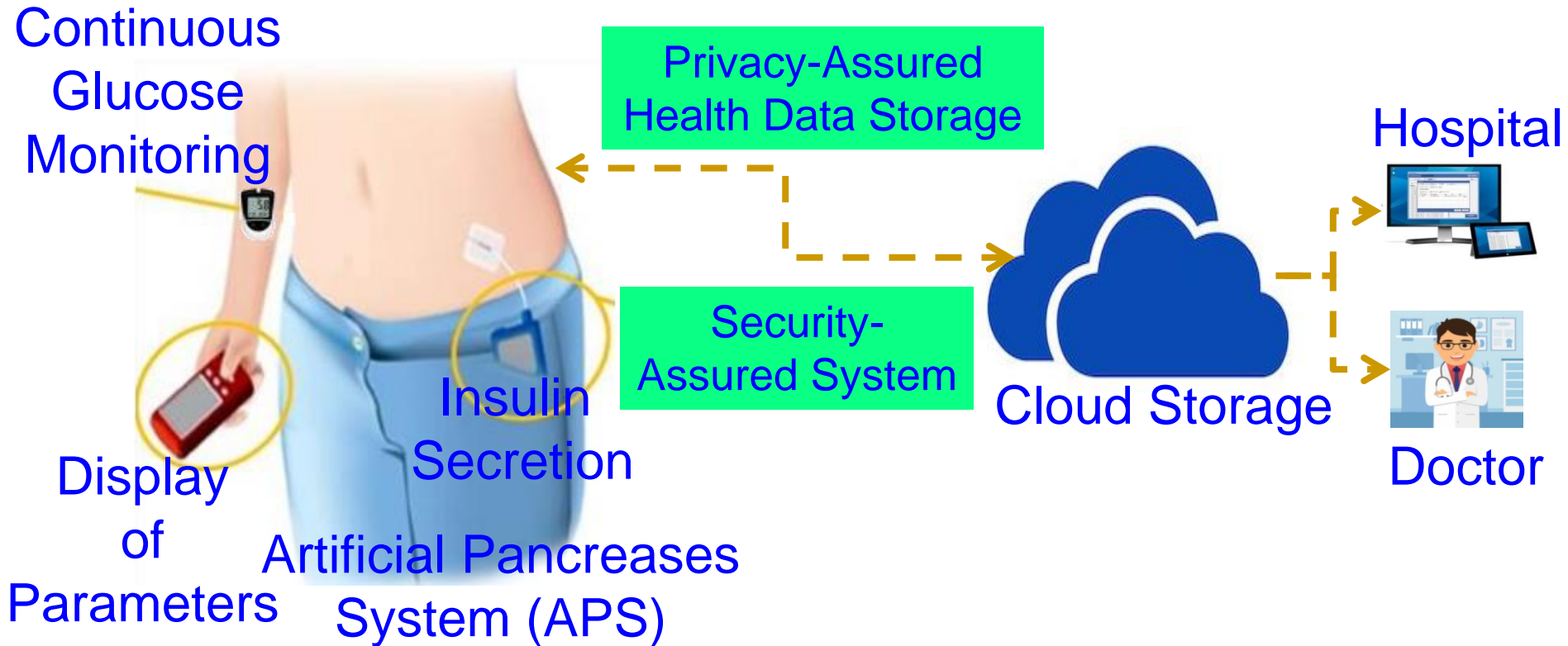
Photoplethysmogram (PPG)



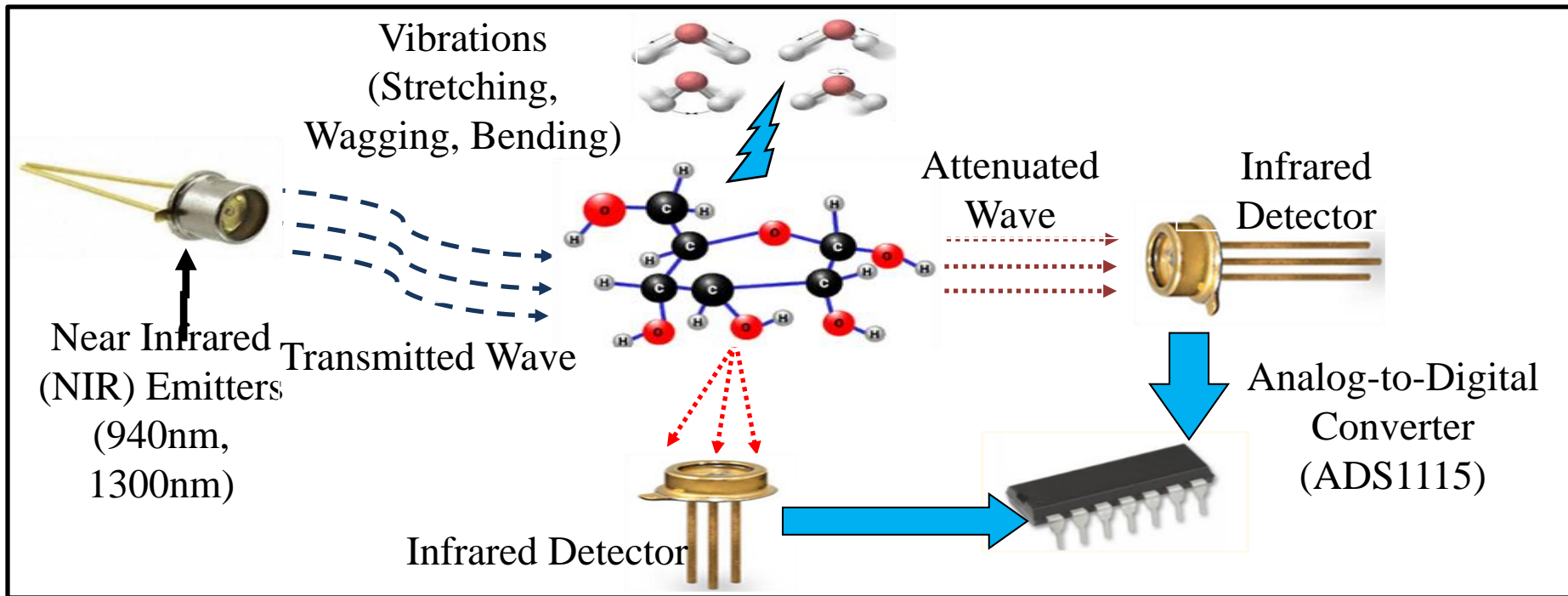
Near Infrared (NIR)



Our Vision – iGLU (Intelligent Noninvasive Monitoring and Control)



iGLU 1.0: Capillary Glucose

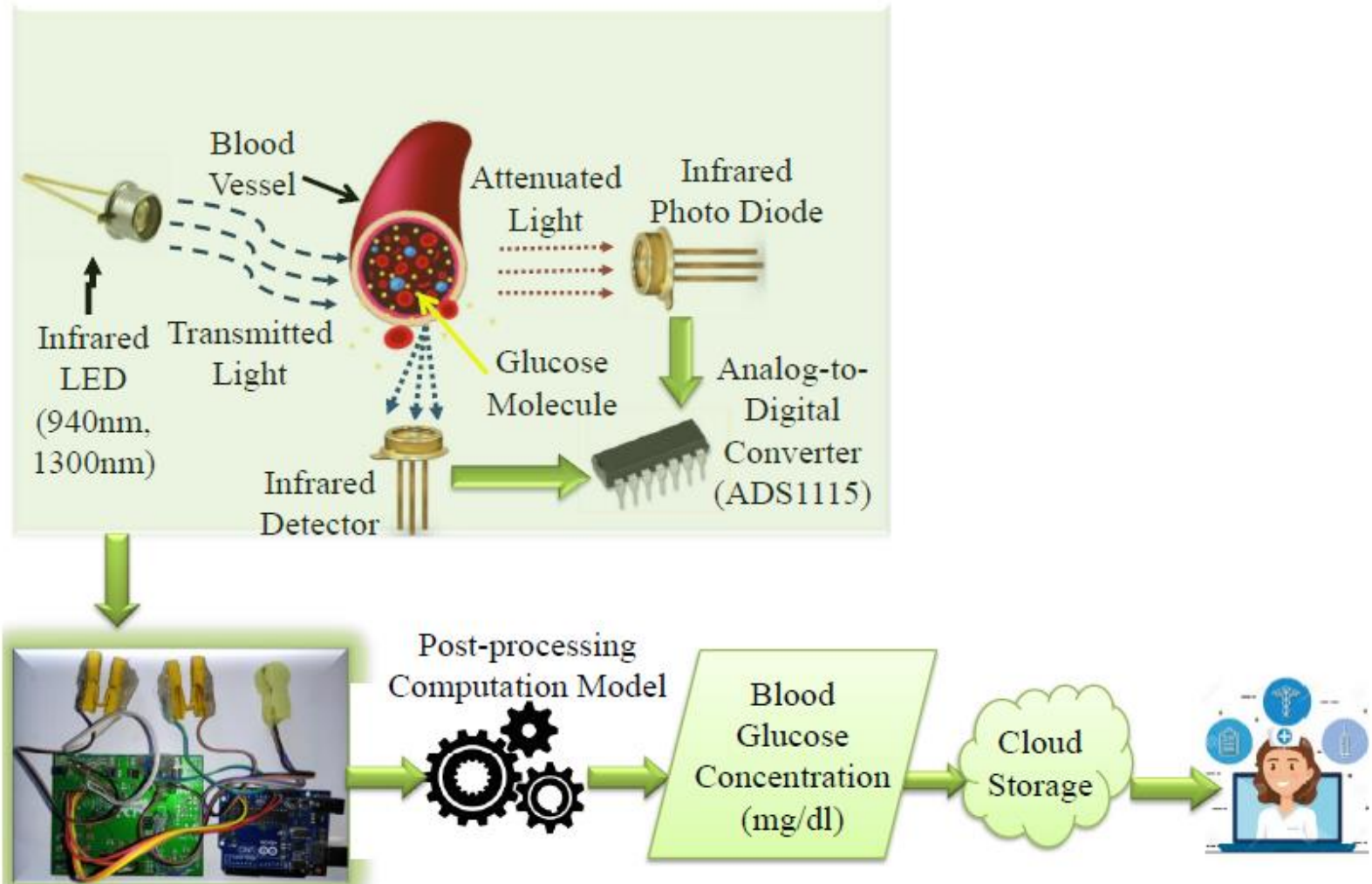


Clinically tested in an hospital.

Cost - US\$ 20
Accuracy - 100%

Source: P. Jain, A. M. Joshi, and S. P. Mohanty, "iGLU: An Intelligent Device for Accurate Non-Invasive Blood Glucose-Level Monitoring in Smart Healthcare", *IEEE Consumer Electronics Magazine (MCE)*, Vol. 9, No. 1, January 2020, pp. 35-42.

iGLU 2.0: Serum Glucose

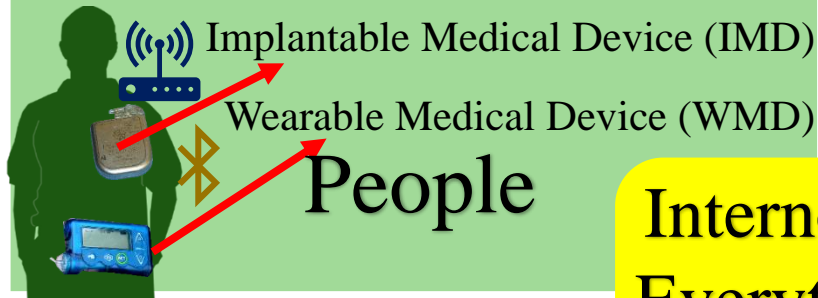


Source: P. Jain, A. M. Joshi, N. Agrawal, and S. P. Mohanty, "iGLU 2.0: A New Non-invasive, Accurate Serum Glucometer for Smart Healthcare", *arXiv Electrical Engineering and Systems Science*, arXiv:2001.09182, January 2020, 19-pages.

Smart Healthcare – Some Challenges

Users are Integral Part: For Them and By Them

Connecting people to the Internet
for more valuable communications



People

Data

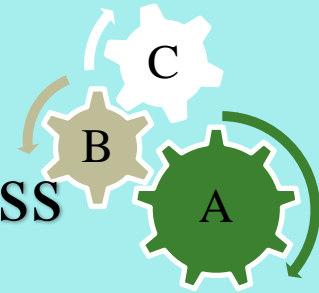
Collecting data and leverage it
for decision making



Crowdsourcing

Deliver right information to right
place, person or machine at the
right time

Process



Things

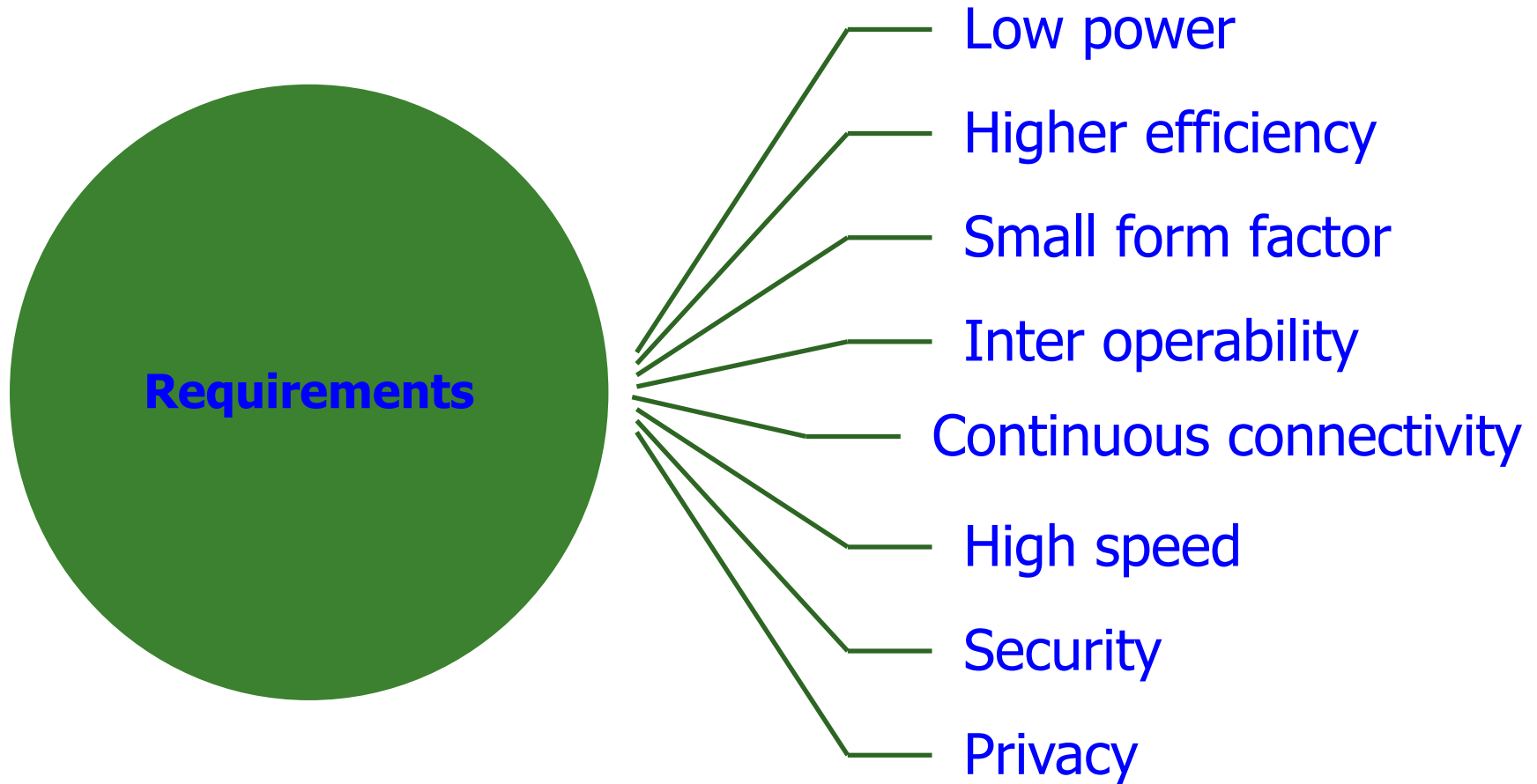
Devices connected to each
other and the internet
(Internet of Things (IoT)).

Perform decision making
whenever necessary.



Source: S. P. Mohanty, V. P. Yanambaka, E. Kougianos, and D. Puthal, "PUFchain: Hardware-Assisted Blockchain for Sustainable Simultaneous Device and Data Security in Internet of Everything (IoE)", *IEEE Consumer Electronics Magazine (MCE)*, Vol. 9, No. 2, March 2020, pp. 8--16.

Smart Healthcare Architecture – Requirements



Smart Healthcare – Data Quality



Source: H. Zhu, C. K. Wu, C. H. KOO, Y. T. Tsang, Y.Liu, H. R. Chi, and K. F. Tsang, "Smart Healthcare in the Era of Internet-of-Things", *IEEE Consumer Electronics Magazine*, vol. 8, no. 5, pp. 26-30, Sep 2019.

Machine Learning Challenges



High Energy Requirements

High Computational Resource Requirements

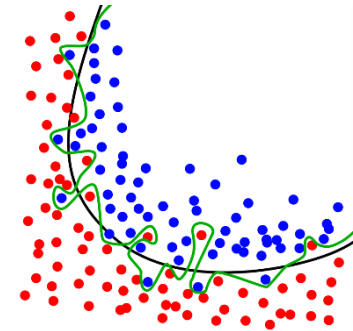
Large Amount of Data Requirements

Machine Learning Issues

Underfitting/Overfitting Issue

Class Imbalance Issue

Fake Data Issue

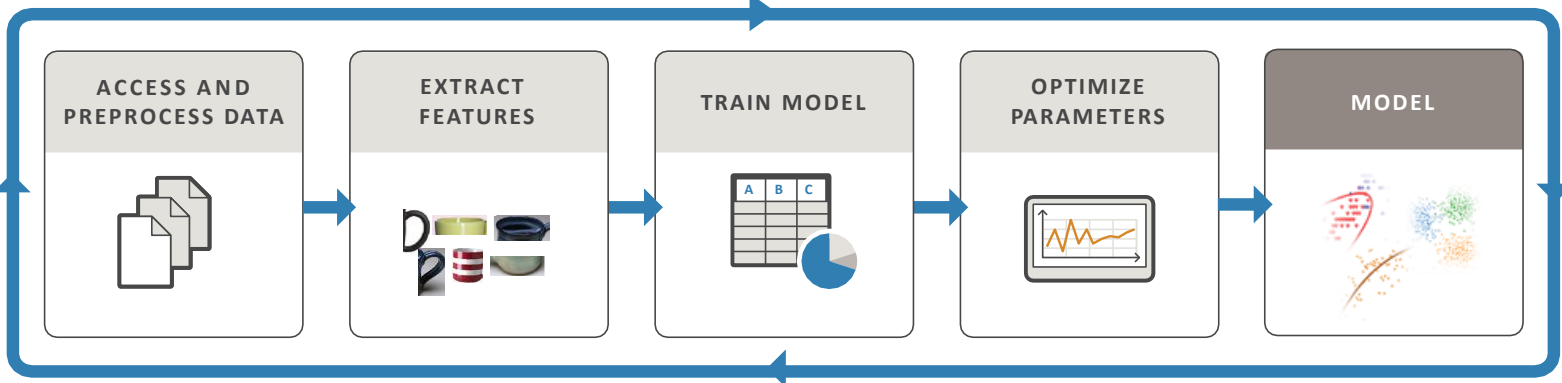


Source: Mohanty ISCT Keynote 2019

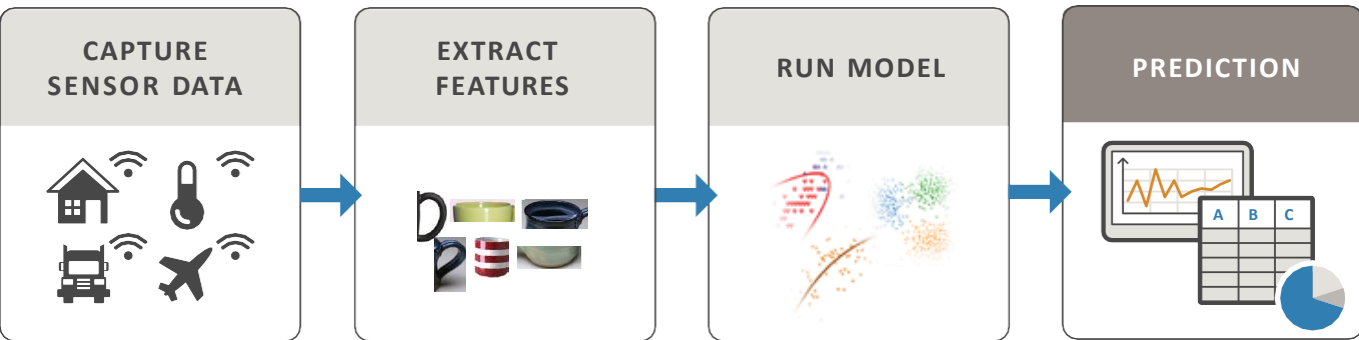
Deep Neural Network (DNN) - Resource and Energy Costs

TRAIN: Iterate until you achieve satisfactory performance.

Needs Significant:
➤ Resource
➤ Energy



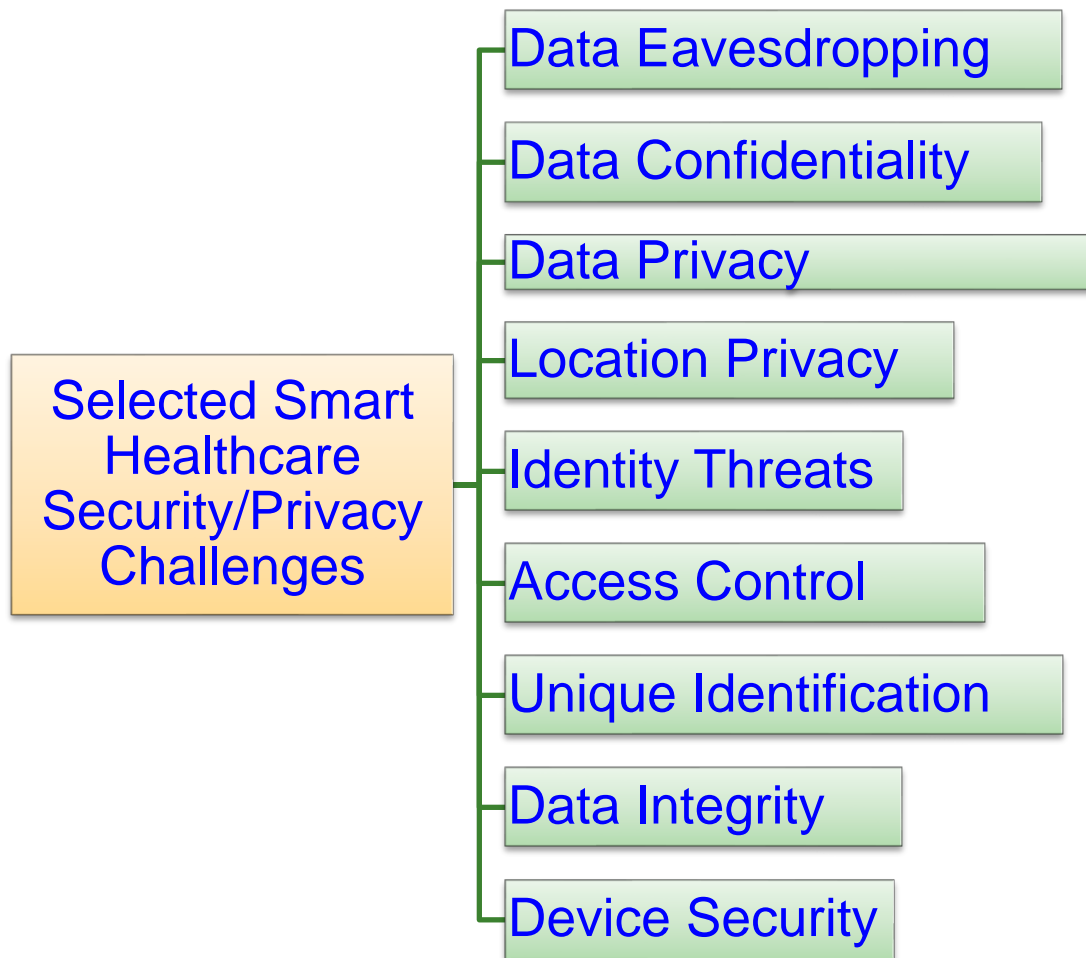
PREDICT: Integrate trained models into applications.



Needs:
➤ Resource
➤ Energy

Source: <https://www.mathworks.com/campaigns/offers/mastering-machine-learning-with-matlab.html>

Smart Healthcare - Security Challenges

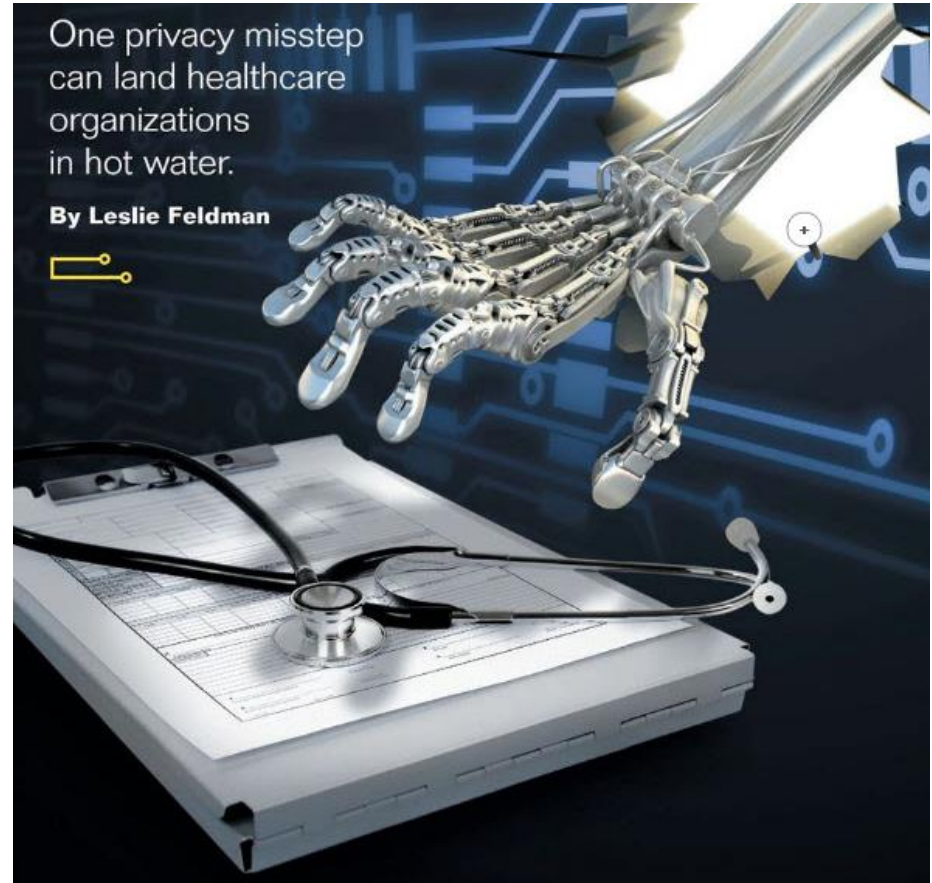


Source: P. Sundaravadivel, E. Kougianos, S. P. Mohanty, and M. Ganapathiraju, "Everything You Wanted to Know about Smart Health Care", *IEEE Consumer Electronics Magazine (CEM)*, Volume 7, Issue 1, January 2018, pp. 18-28.

Information Privacy



Source: <http://ciphercloud.com/three-ways-pursue-cloud-data-privacy-medical-records/>



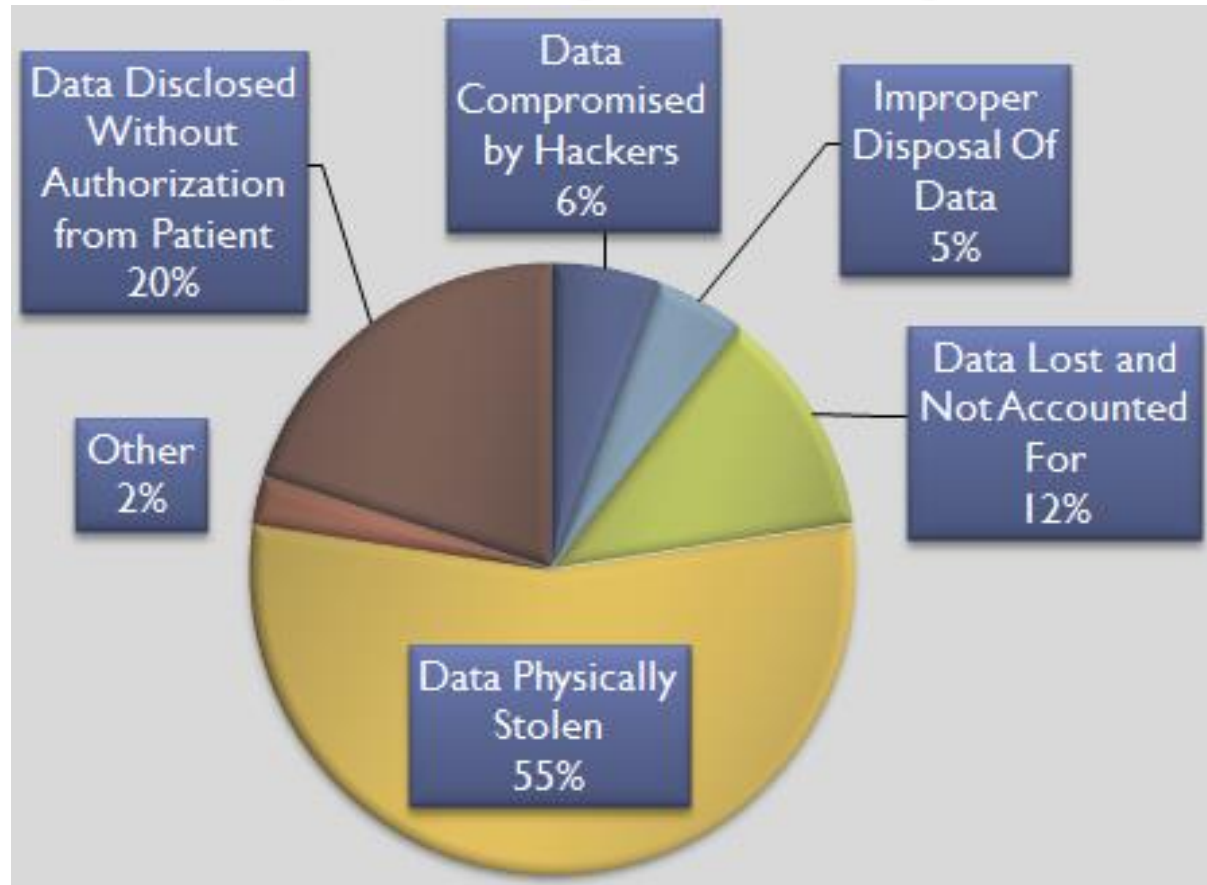
One privacy misstep can land healthcare organizations in hot water.

By Leslie Feldman



Source: <http://blog.veriphys.com/2012/06/electronic-medical-records-security-and.html>

Health Insurance Portability and Accountability Act (HIPAA)



HIPPA Privacy Violation by Types

IoMT Device Security Issue is Scary

- Insulin pumps are vulnerable to hacking, FDA warns amid recall:

<https://www.washingtonpost.com/health/2019/06/28/insulin-pumps-are-vulnerable-hacking-fda-warns-amid-recall/>

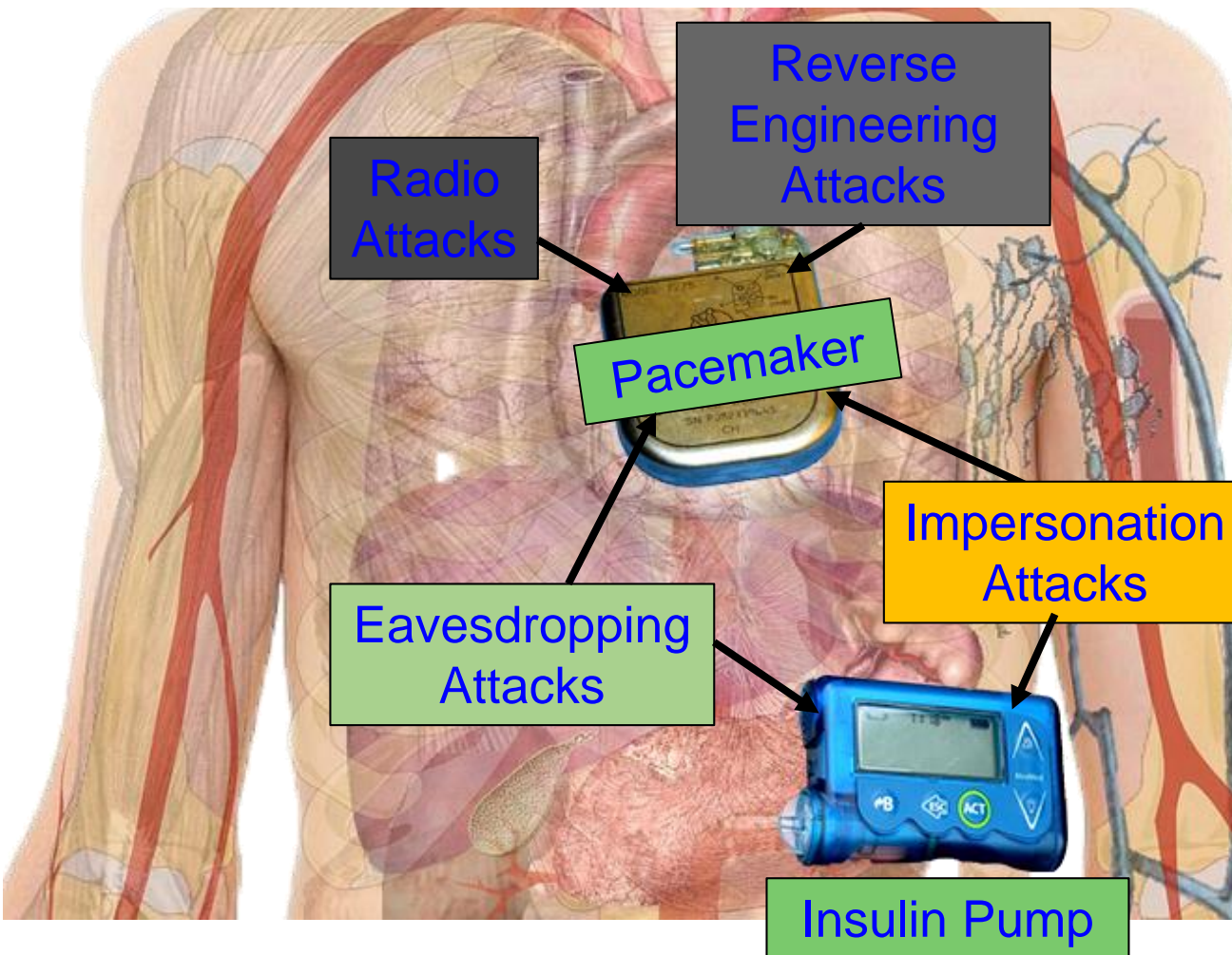
- Software vulnerabilities in some medical devices could leave them susceptible to hackers, FDA warns:

<https://www.cnn.com/2019/10/02/health/fda-medical-devices-hackers-trnd/index.html>

- FDA Issues Recall For Medtronic mHealth Devices Over Hacking Concerns:

<https://mhealthintelligence.com/news/fda-issues-recall-for-medtronic-mhealth-devices-over-hacking-concerns>

IoMT Security Measures is Hard



Collectively (WMD+IMD):
Implantable and
Wearable Medical
Devices (IWMDs)

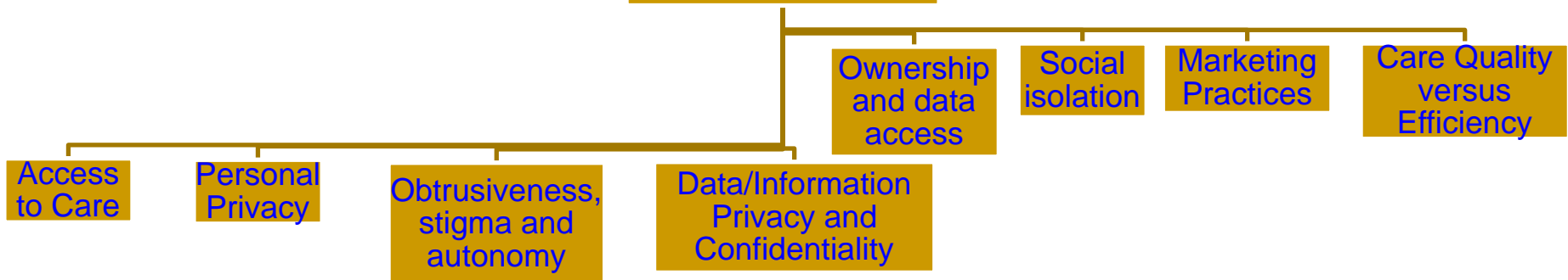
Implantable and
Wearable Medical
Devices (IWMDs) --
Battery Characteristics:
→ Longer life
→ Safer
→ Smaller size
→ Smaller weight

Smart Healthcare - Ethics



Source: <https://online.alvernia.edu/articles/ethical-issues-in-healthcare/>

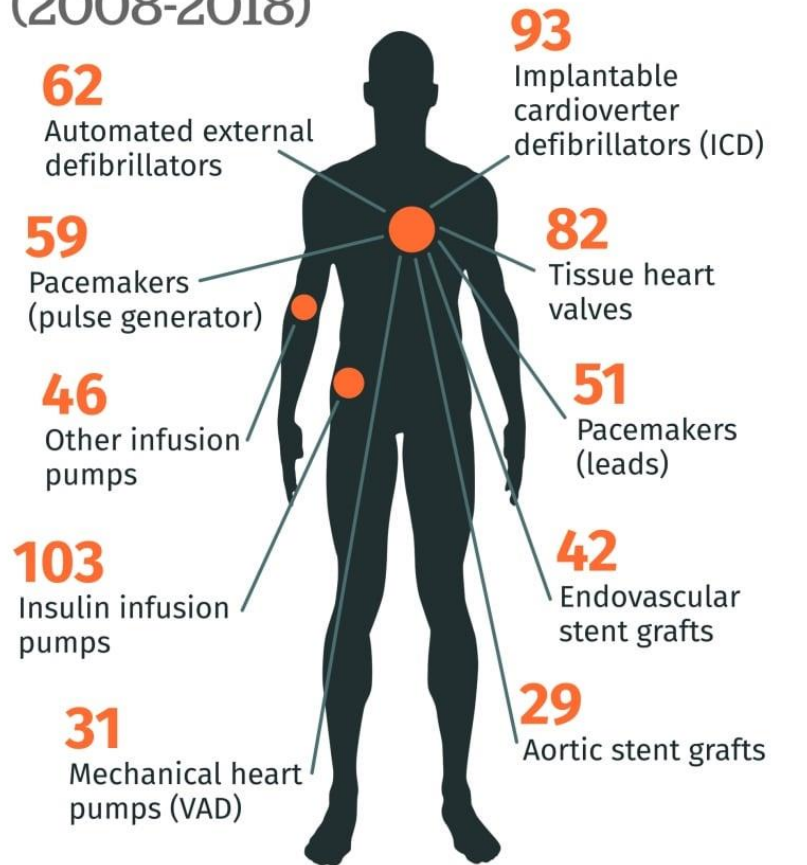
Ethical Issues Include



Source: B. Mittelstadt, "Ethics of the health-related internet of things: a narrative review", *Ethics Inf Technol* **19**, 157–175 (2017), DOI: <https://doi.org/10.1007/s10676-017-9426-4>.

Smart Healthcare - Safety

10 devices tied to the most reports involving death (2008-2018)



CBC NEWS

Source: Health Canada & ICIJ

Source <https://planet-report.com/canadian-advocates-call-for-all-medical-implants-to-be-registered-cbc-news/>

CENTRAL ILLUSTRATION: Cardiac-Implantable Electronic Devices: Technical and Safety Considerations

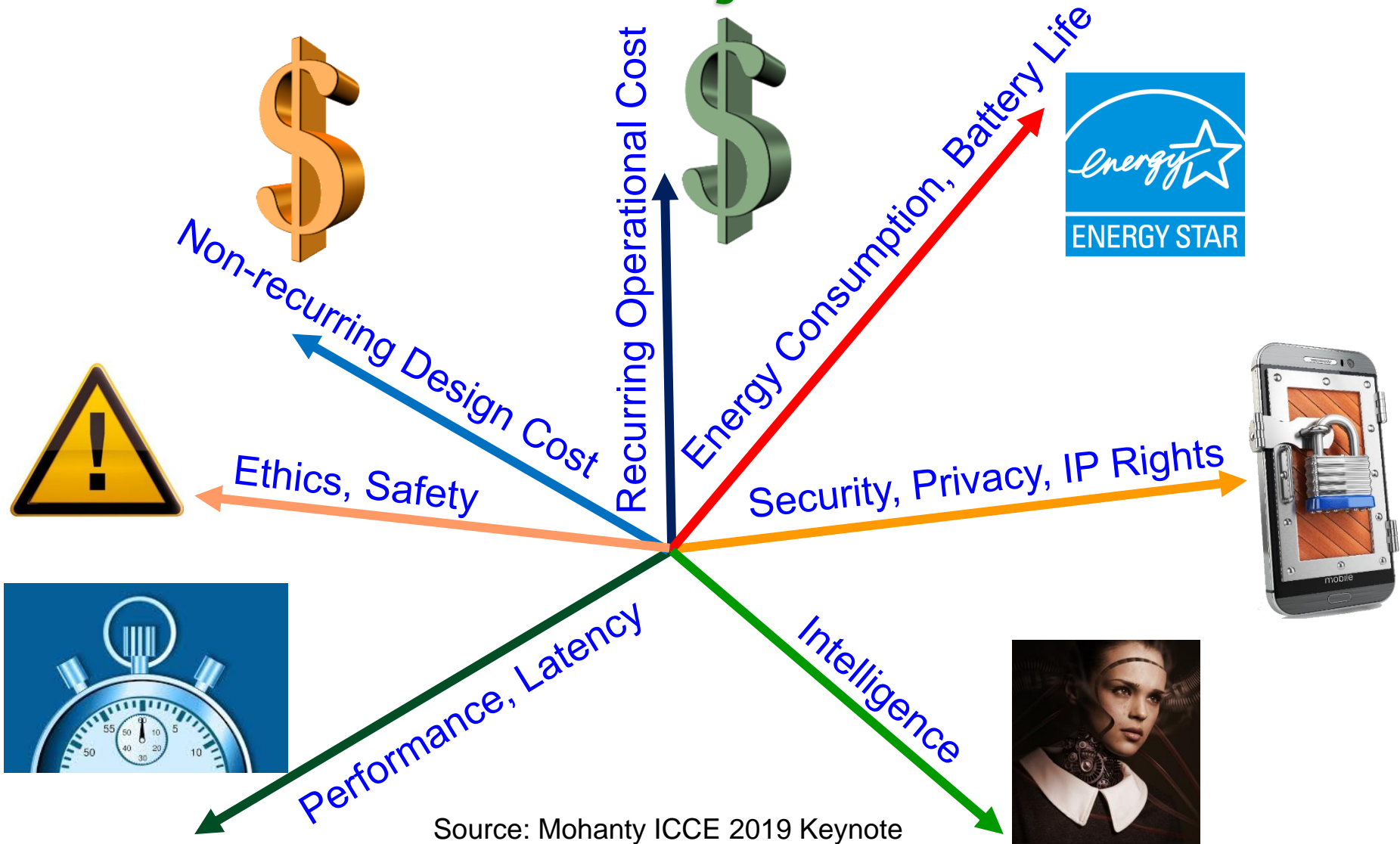
FACTORS INFLUENCING SAFETY	SMALL POTENTIAL RISKS
MR magnet: <ul style="list-style-type: none"> Magnet strength Radiofrequency power Magnet position 	Heating effects: Tissue injury (Mainly theoretical) Strategy to minimize risk: Lead designed to limit current induction
Cardiac implantable device: <ul style="list-style-type: none"> Ferromagnetic material Presence of reed switch Device programming 	Mechanical effects: Device movement (Mainly theoretical) Strategy to minimize risk: Limitation of ferromagnetic materials
Leads: <ul style="list-style-type: none"> Ferromagnetic material Lead stability 	Electromagnetic effects: <ul style="list-style-type: none"> Altered sensing/capture Inhibited therapies Inappropriate therapies (No significant adverse patient outcomes) Strategy to minimize risk: Lead designed to limit current induction, replacement of reed switch with Hall sensor, temporary device reprogramming
Patient: <ul style="list-style-type: none"> Patient position Patient size 	
Indication to scan: If the benefits outweigh the very small potential risks, MRI is acceptable	

Miller, J.D. et al. J Am Coll Cardiol. 2016;68(14):1590-8.

Source: J. D. Miller, S. Nazarian, H. R. Halperin, "Implantable Electronic Cardiac Devices and Compatibility With Magnetic Resonance Imaging", J Am Coll Cardiol. 2016 Oct, 68 (14), pp. 1590-1598.

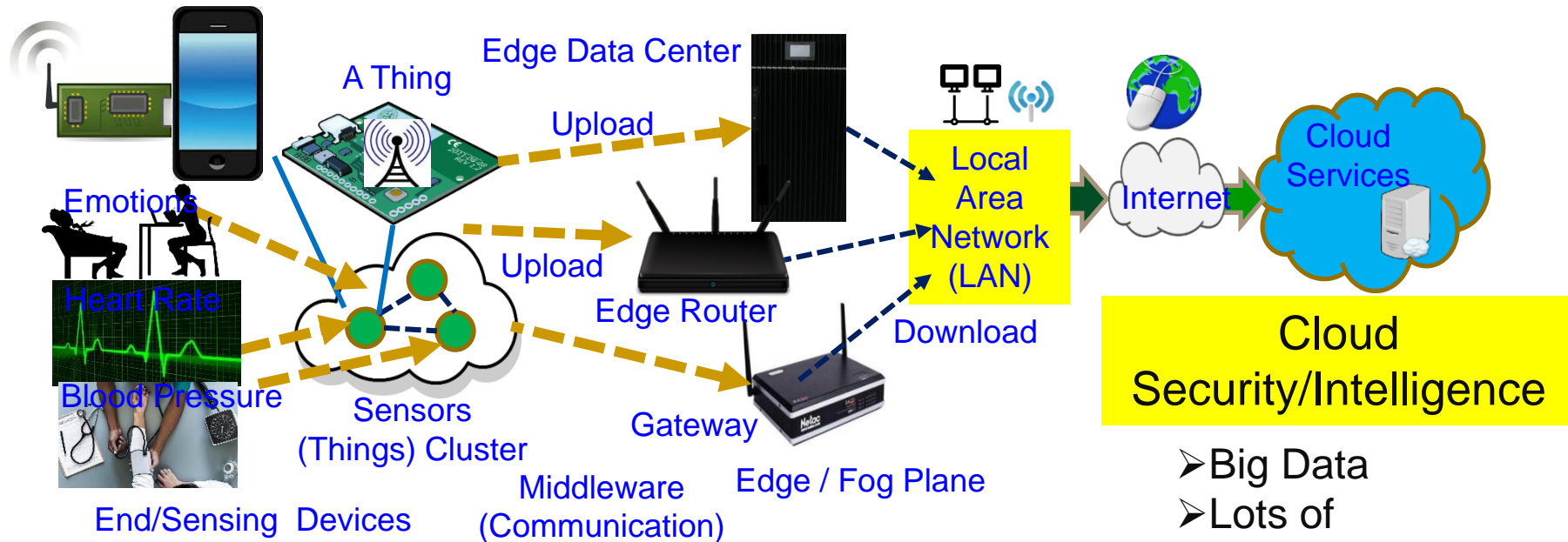
Smart Healthcare – Some Solutions

H-CPS - Multi-Objective Tradeoffs



Source: Mohanty ICCE 2019 Keynote

Smart Healthcare – Edge Vs Cloud



End Security/Intelligence

- Minimal Data
- Minimal Computational Resource
- Least Accurate Data Analytics
- Very Rapid Response

Edge Security/Intelligence

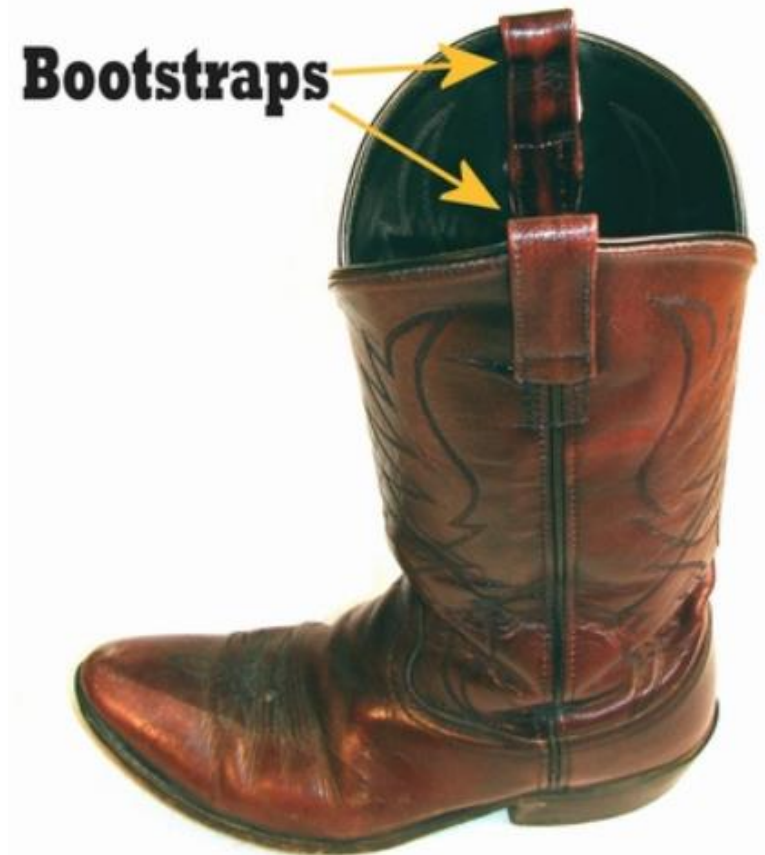
- Less Data
- Less Computational Resource
- Less Accurate Data Analytics
- Rapid Response

Cloud Security/Intelligence

- Big Data
- Lots of Computational Resource
- Accurate Data Analytics
- Latency in Network
- Energy overhead in Communications

Hierarchical ML to Reduce Training Time - Bootstrapping

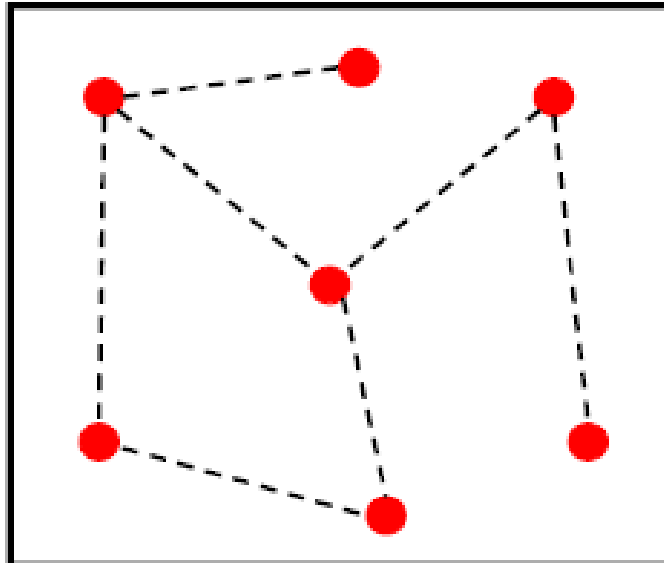
- A Bootstrap helps in pulling on a boot.
- It means solving a problem without external resources



Source: <http://www.lemen.com/dictionary-b.html#bootstrap>

Bootstrapped Kriging

Initial Sample Field

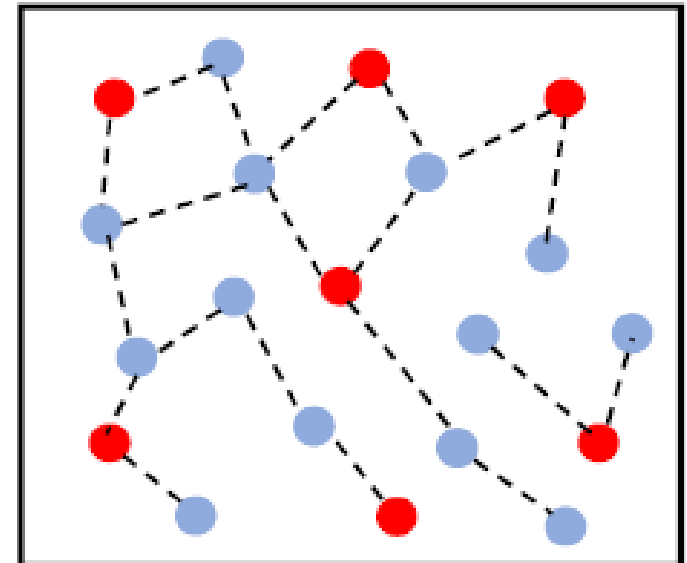


Sample Size = 7



Bootstrapping
by Kriging

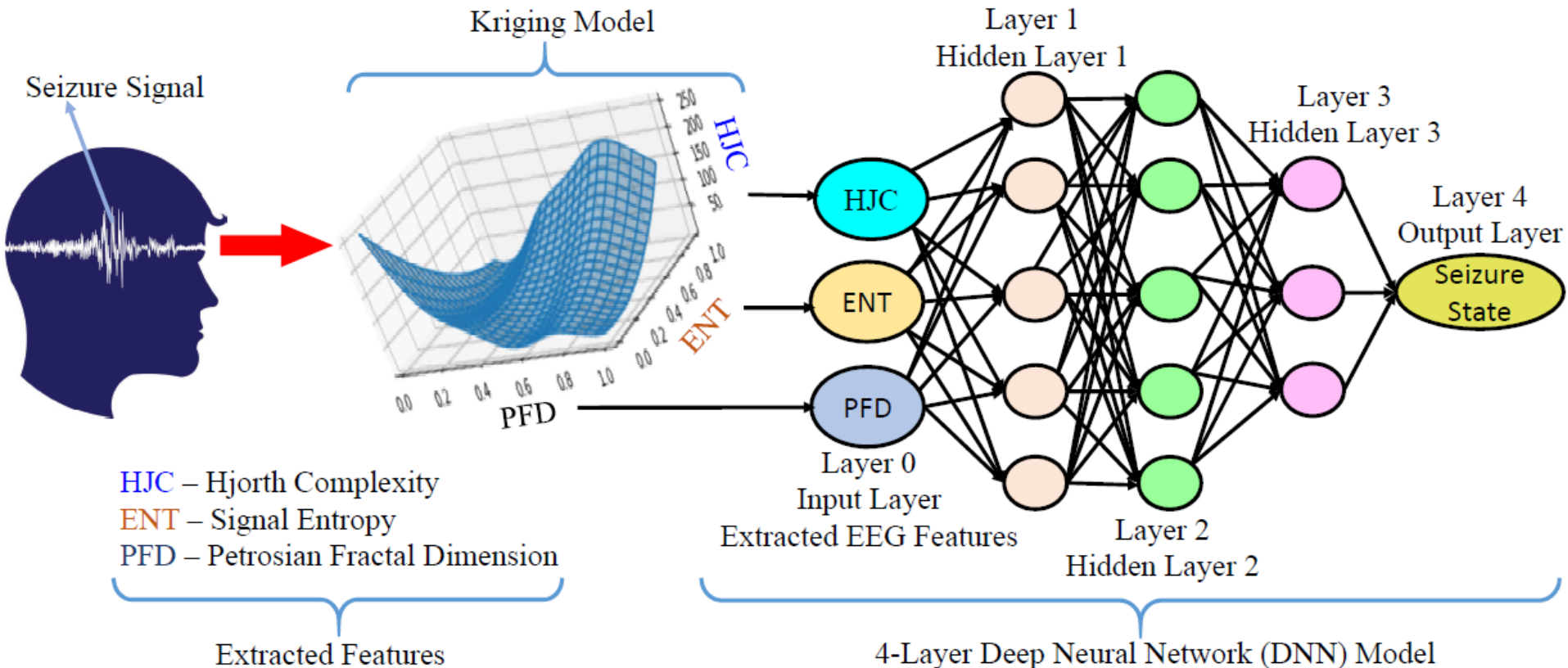
New Sample Field



Bootstrap Size = 20
13

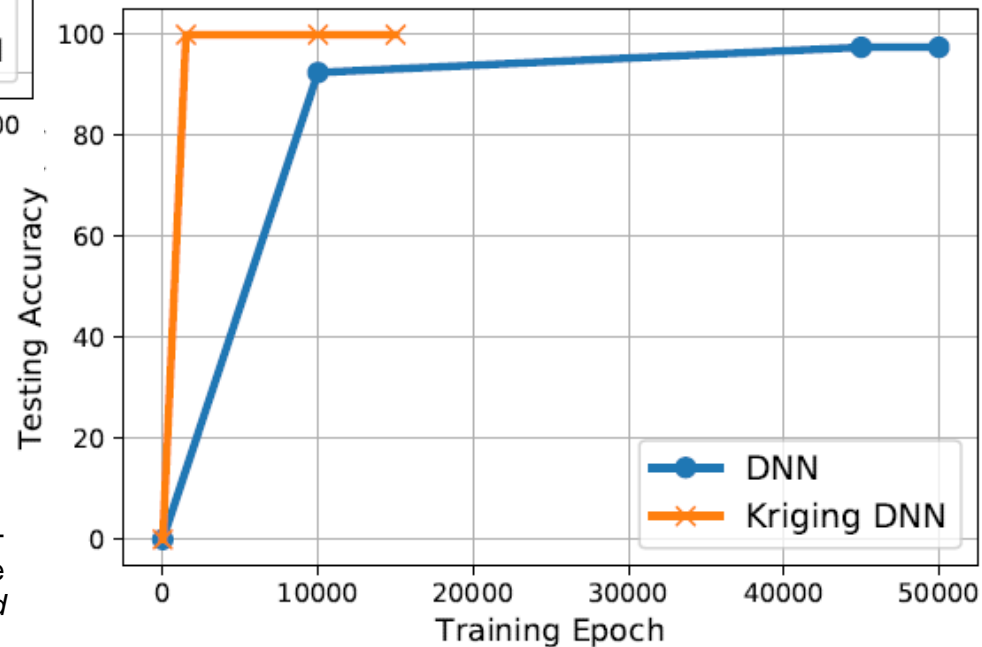
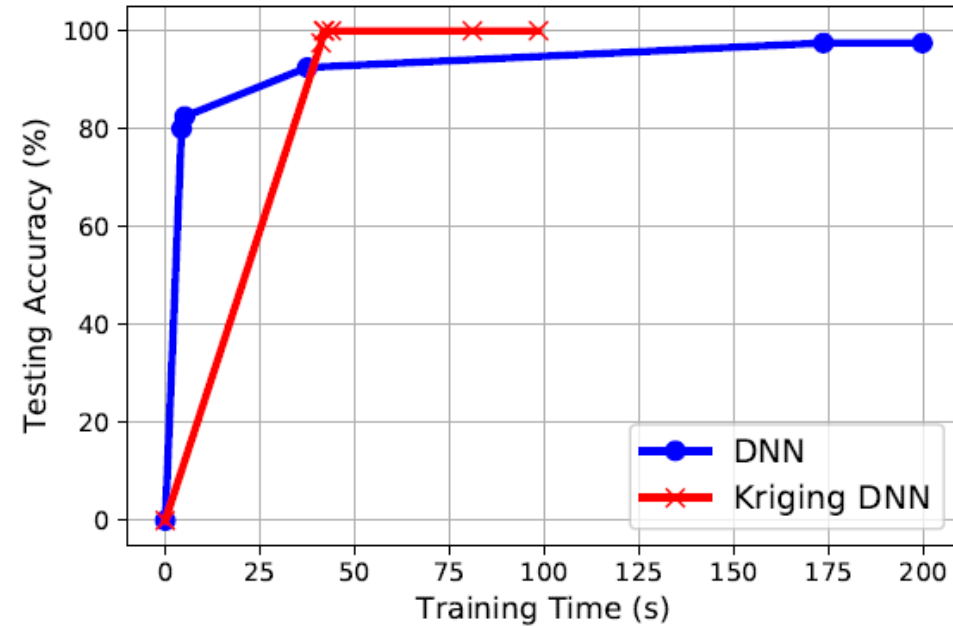
Source: I. L. Olokodana, S. P. Mohanty, and E. Kougianos, "Kriging-Bootstrapped DNN Hierarchical Model for Real-Time Seizure Detection from EEG Signals", in *Proceedings of the 6th IEEE World Forum on Internet of Things (WF-IoT)*, 2020

Proposed Kriging-Bootstrapped DNN Model



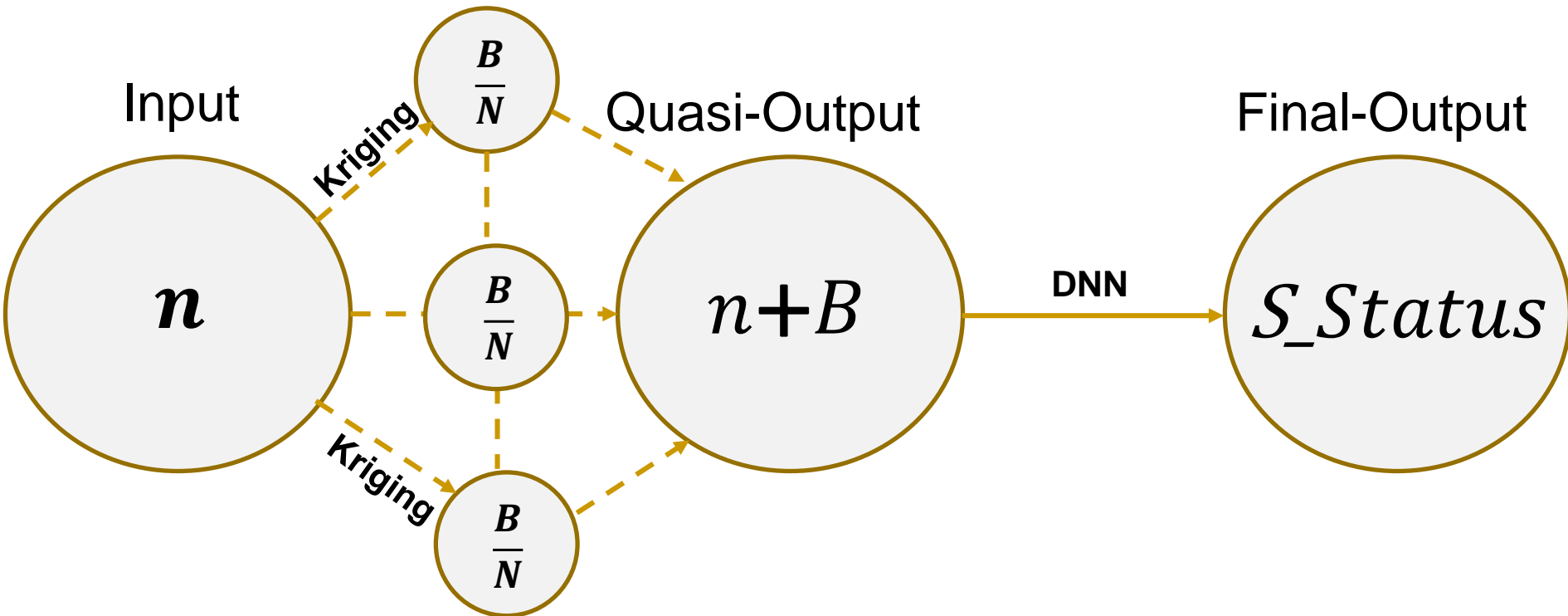
Source: I. L. Olokodana, S. P. Mohanty, and E. Kougianos, "Kriging-Bootstrapped DNN Hierarchical Model for Real-Time Seizure Detection from EEG Signals", in *Proceedings of the 6th IEEE World Forum on Internet of Things (WF-IoT)*, 2020

Experimental Results



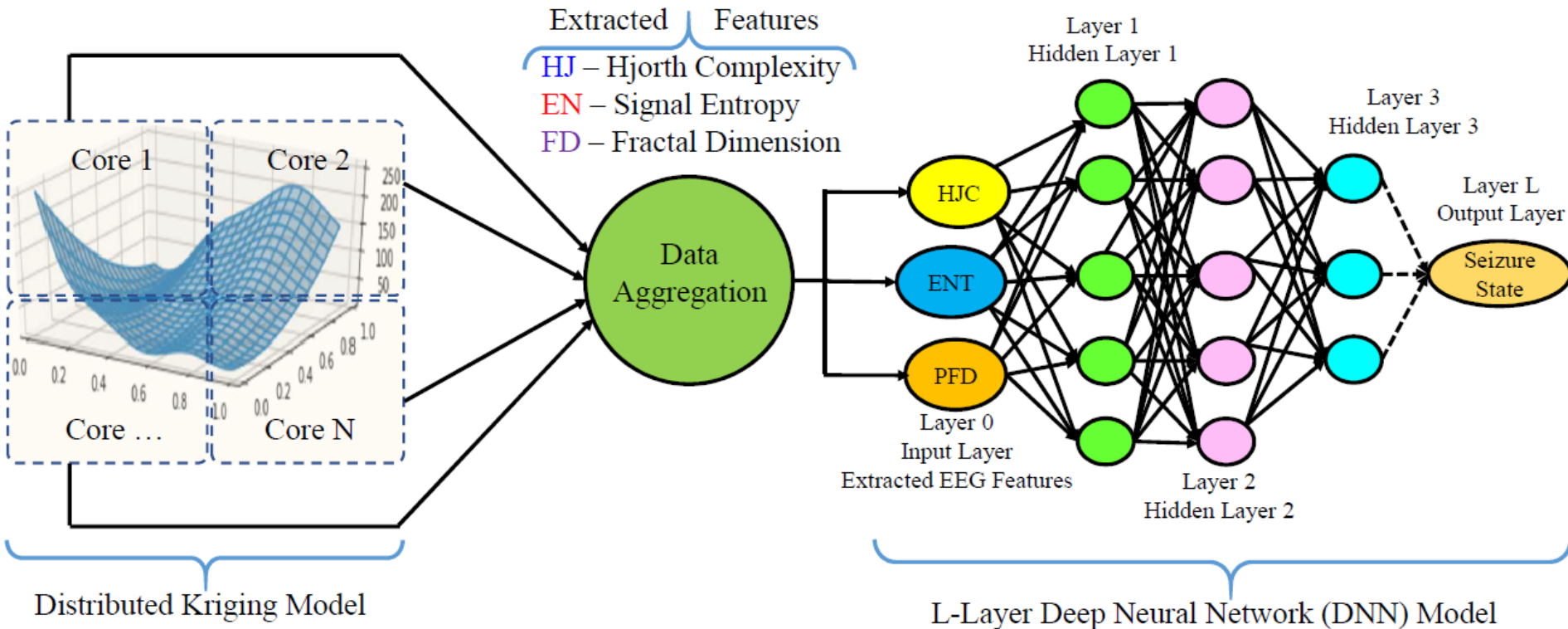
Source: I. L. Olokodana, S. P. Mohanty, and E. Kougianos, "Kriging-Bootstrapped DNN Hierarchical Model for Real-Time Seizure Detection from EEG Signals", in *Proceedings of the 6th IEEE World Forum on Internet of Things (WF-IoT)*, 2020

Model Training or Learning Process



Source: I. L. Olokodana, S. P. Mohanty, and E. Kougianos, "Distributed Kriging-Bootstrapped DNN Model for Fast, Accurate Seizure Detection from EEG Signals", *Proceedings of the 19th IEEE Computer Society Annual Symposium on VLSI (ISVLSI)*, 2020.

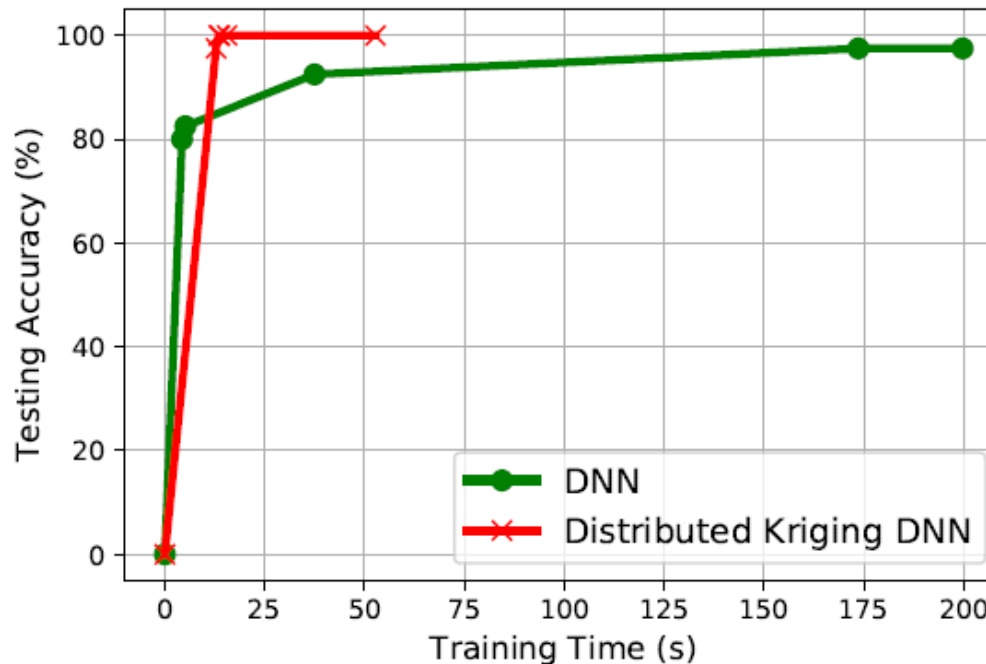
Our Distributed Kriging-Bootstrapped DNN Model



Source: I. L. Olokodana, S. P. Mohanty, and E. Kougianos, "Distributed Kriging-Bootstrapped DNN Model for Fast, Accurate Seizure Detection from EEG Signals", *Proceedings of the 19th IEEE Computer Society Annual Symposium on VLSI (ISVLSI)*, 2020.

Experimental Results: Dataset A

Models	DNN	Ordinary Kriging	Kriging DNN	Distributed Kriging DNN
Tr. Data Size	10000	2000	10000	10000
Tr. Epochs	45000	NA	1500	1500
Learning Rate	0.00001	NA	0.001	0.001
Training Acc.	99.99%	100.00%	99.92%	99.92%
Testing Acc.	97.50%	99.78%	100.00%	100.00%
Training Time	173.57s	72.24s	43.83s	15.56s

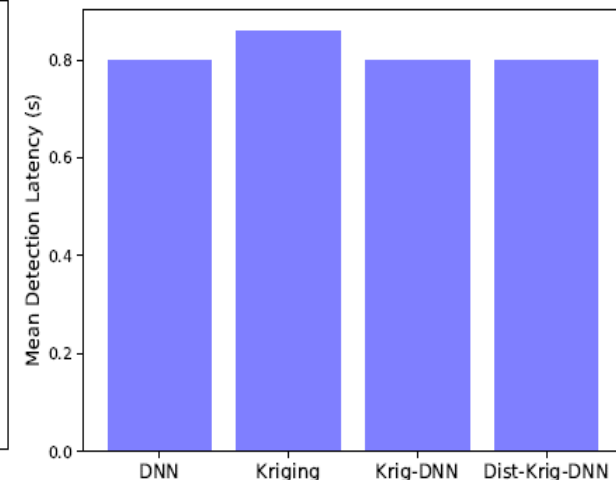
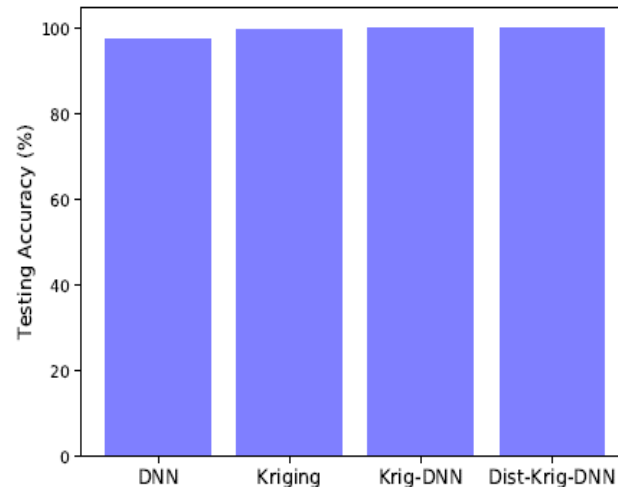
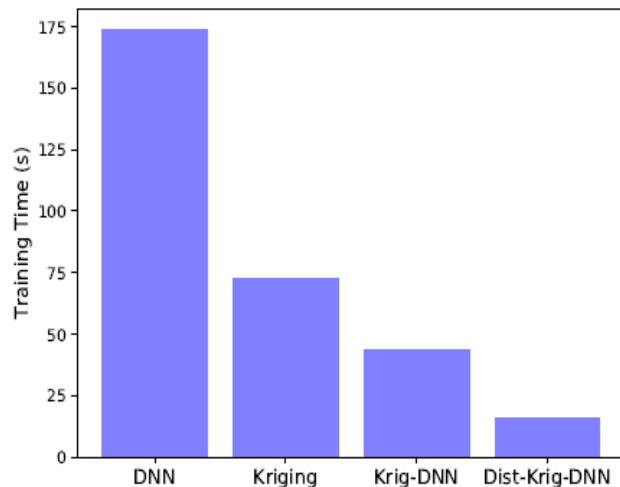


■ Training Time reduced by 91%

Source: I. L. Olokodana, S. P. Mohanty, and E. Kougianos, "Distributed Kriging-Bootstrapped DNN Model for Fast, Accurate Seizure Detection from EEG Signals", *Proceedings of the 19th IEEE Computer Society Annual Symposium on VLSI (ISVLSI)*, 2020.

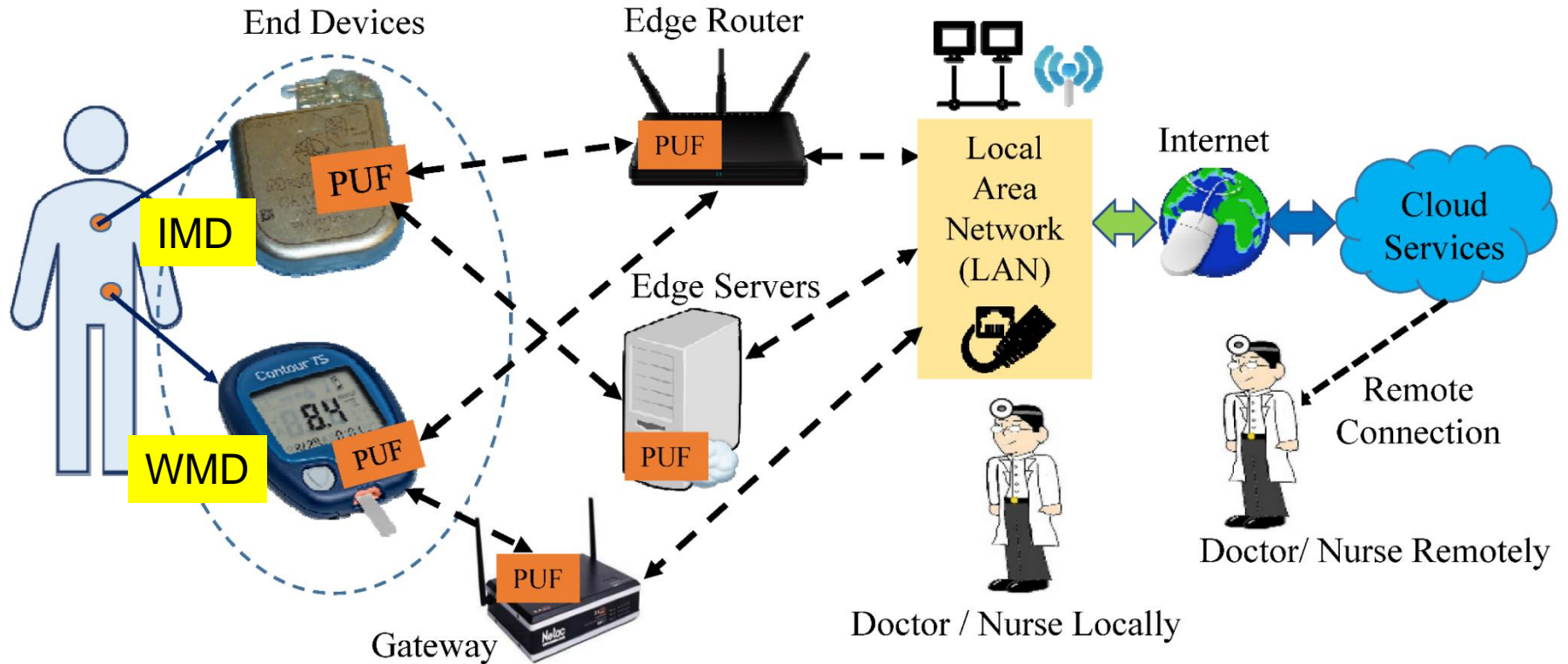
Experimental Results: Dataset A

Models	Detection Latency
DNN	0.80s
Ordinary Kriging	0.86s
Krig-DNN	0.80s
Dist-Krig-DNN	0.80s



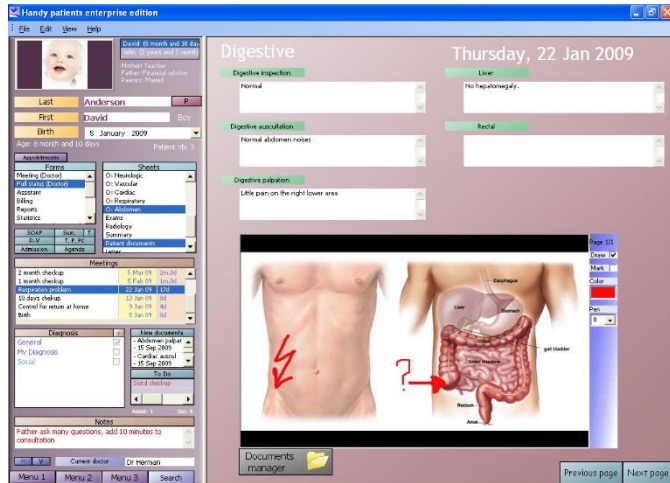
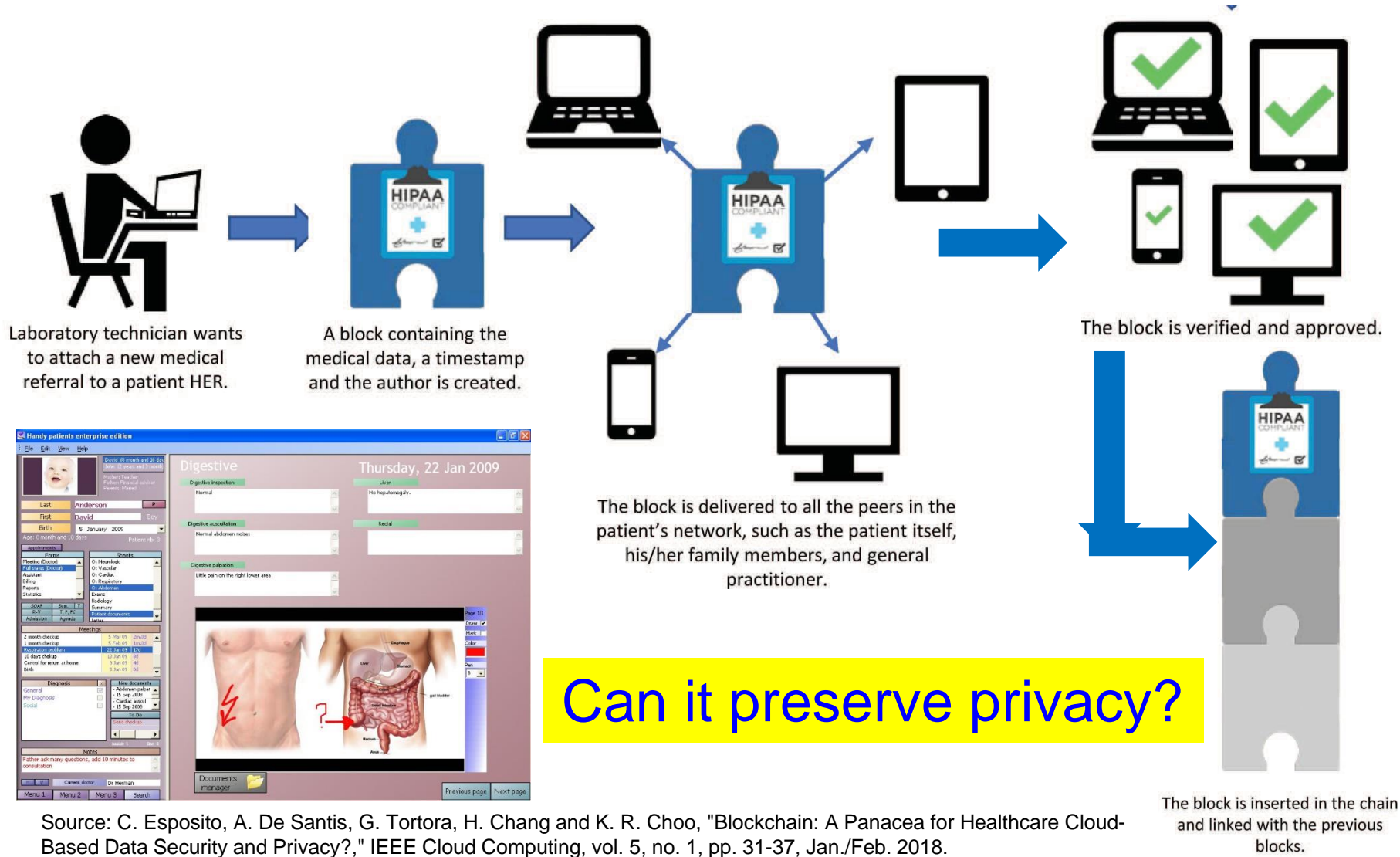
Source: I. L. Olokodana, S. P. Mohanty, and E. Kougiyanos, "Distributed Kriging-Bootstrapped DNN Model for Fast, Accurate Seizure Detection from EEG Signals", *Proceedings of the 19th IEEE Computer Society Annual Symposium on VLSI (ISVLSI)*, 2020.

Our Secure by Design Approach for Robust Security in Healthcare CPS



Source: V. P. Yanambaka, S. P. Mohanty, E. Kougianos, and D. Puthal, "PMsec: Physical Unclonable Function-Based Robust and Lightweight Authentication in the Internet of Medical Things", *IEEE Transactions on Consumer Electronics (TCE)*, Volume 65, Issue 3, August 2019, pp. 388--397.







Blockchain in Smart Healthcare



Can it preserve privacy?

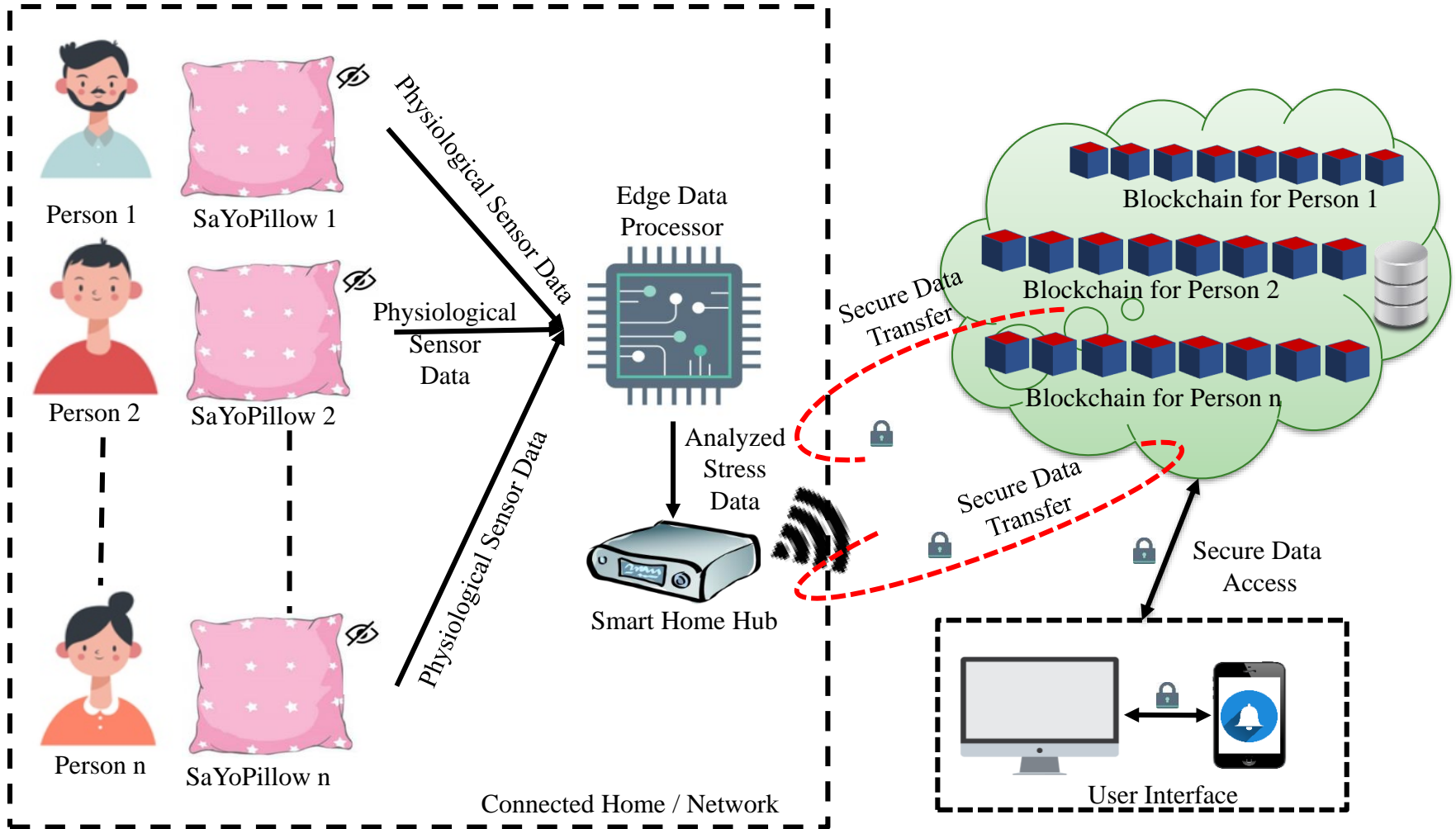
Source: C. Esposito, A. De Santis, G. Tortora, H. Chang and K. R. Choo, "Blockchain: A Panacea for Healthcare Cloud-Based Data Security and Privacy?," IEEE Cloud Computing, vol. 5, no. 1, pp. 31-37, Jan./Feb. 2018.

Traditional Versus Blockchain EHR

Health Information Exchange (HIE) Pain Points	Blockchain Opportunities
 <p>Establishing a Trust Network depends on the HIE as an intermediary to establish point-to-point sharing and “book-keeping” of what data was exchanged.</p>	<p>Disintermediation of Trust likely would not require an HIE operator because all participants would have access to the distributed ledger to maintain a secure exchange without complex brokered trust.</p>
 <p>Cost Per Transaction, given low transaction volumes, reduces the business case for central systems or new edge networks for participating groups.</p>	<p>Reduced Transaction Costs due to disintermediation, as well as near-real time processing, would make the system more efficient.</p>
 <p>Master Patient Index (MPI) challenges arise from the need to synchronize multiple patient identifiers between systems while securing patient privacy.</p>	<p>Distributed framework for patient digital identities, which uses private and public identifiers secured through cryptography, creates a singular, more secure method of protecting patient identity.</p>
 <p>Varying Data Standards reduce interoperability because records are not compatible between systems.</p>	<p>Shared data enables near real-time updates across the network to all parties.</p>
 <p>Limited Access to Population Health Data, as HIE is one of the few sources of integrated records.</p>	<p>Distributed, secure access to patient longitudinal health data across the distributed ledger.</p>
 <p>Inconsistent Rules and Permissions inhibit the right health organization from accessing the right patient data at the right time.</p>	<p>Smart Contracts create a consistent, rule-based method for accessing patient data that can be permissioned to selected health organizations.</p>

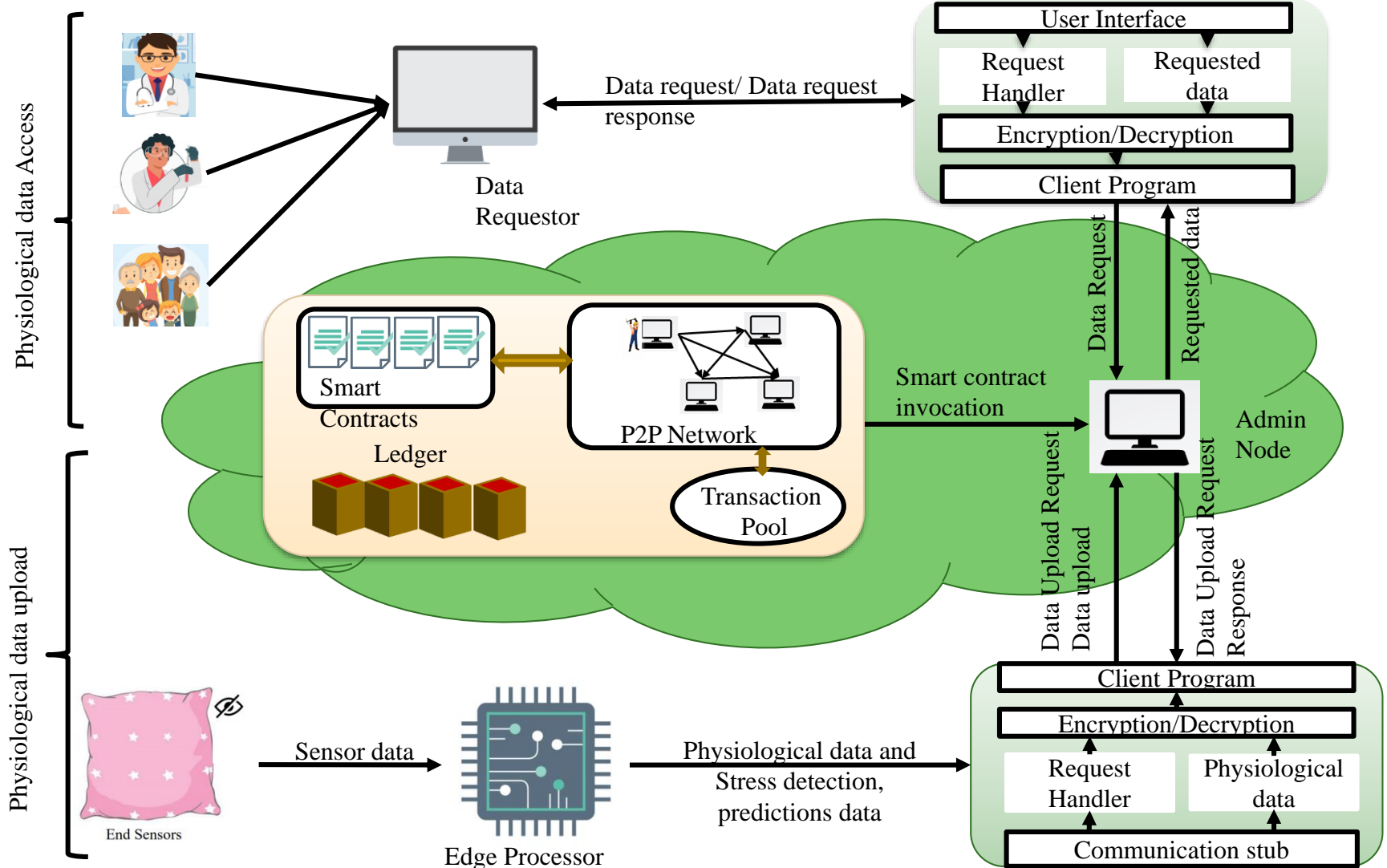
Source: Exploring the Use of Blockchain for EHRs, Healthcare Big Data, <https://healthitanalytics.com/features/exploring-the-use-of-blockchain-for-ehrs-healthcare-big-data>

Smart-Yoga Pillow (SaYoPillow) - Idea



Source: L. Rachakonda, A. K. Bapatla, S. P. Mohanty, and E. Kougianos, "SaYoPillow: A Blockchain-Enabled, Privacy-Assured Framework for Stress Detection, Prediction and Control Considering Sleeping Habits in the IoMT", *arXiv Computer Science*, arXiv:2007.07377, July 2020, 38-pages.

SaYoPillow: Blockchain Details



Source: L. Rachakonda, A. K. Bapatla, S. P. Mohanty, and E. Kougianos, "SaYoPillow: A Blockchain-Enabled, Privacy-Assured Framework for Stress Detection, Prediction and Control Considering Sleeping Habits in the IoMT", *arXiv Computer Science*, arXiv:2007.07377, July 2020, 38-pages.

SaYoPillow: Prototyping

Transaction View information about an Ethereum transaction

0x8629d9ee638a181b1454771666bc579ba8189bdb2f78665b739214184587d3b9

0x0adfcca4b2a1132f82488546aca086d7e24ea324 → 0x212c30420fce0f7ed1192b6e01de238f295f8505 0 ETH

15297 Confirmations 0 ETH

Summary

Block Hash: 0x44214514875cdcb9d8e27ed1290716ce7a1d52bd0c1575771a8ec4298c9aed0b

Received Time: Jul 2, 2020 8:49:19 AM

Included In Block: 23663

Gas Used: 241,526 m/s

Gas Price: 0.000000010 ETH

Transaction Confirmations: 15297

Number of transactions made by the sender prior to this one: 53

Transaction price: 0.000241526 ETH

Data: 0x8e9cf29c00

SaYoPillow Dashboard Logged in as: 0x9537cb86f5a03c8cb52c44b49757861eca0004b

Hours Slept: 2	Snoring Range: 75	Respiration Rate: 22	Heart Rate: 51
Blood Oxygen Level: 91	Eye Movement: 61	Limb Movement: 15	Hours Slept: 95

Detected Stress Level: **Medium Low**

Follow below suggestions to relieve stress
 Play lullaby's or peaceful music to regulate sleep.

Average Values (Last 24 hours)

🛏️	Average Hours Slept	2
👁️	Average Snoring Range	64
🌬️	Average Respiration Rate	21
📈	Average Heart Rate	54
💧	Average Blood Oxygen Level	92
👁️	Average Eye Movement	72
🚶	Average Limb Movement	13
🌡️	Average Temperature	96

Source: L. Rachakonda, A. K. Bapatla, S. P. Mohanty, and E. Kougianos, "SaYoPillow: A Blockchain-Enabled, Privacy-Assured Framework for Stress Detection, Prediction and Control Considering Sleeping Habits in the IoMT", *arXiv Computer Science*, arXiv:2007.07377, July 2020, 38-pages.



Conclusions and Future Research



Conclusions

- Healthcare has been evolving to Healthcare-Cyber-Physical-System (H-CPS) i.e. smart healthcare.
- Internet of Medical Things (IoMT) plays a key role smart healthcare.
- Smart healthcare can reduce cost of healthcare and give more personalized experience to the individual.
- IoMT provides advantages but also has limitations in terms of security, and privacy.
- Smart Healthcare can be effective during stay-at-home scenario during pandemic.

Future Research

- Machine learning (ML) models for smart healthcare needs research.
- Internet-of-Everything (IoE) with Human as active part as crowdsourcing need research.
- IoE will need robust data, device, and H-CPS security need more research.
- Security of IWMDs needs to have extremely minimal energy overhead to be useful and hence needs research.
- Integration of blockchain for smart healthcare need research due to energy and computational overheads associated with it.