Smart Healthcare – Demystified

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Outline

- Healthcare → Smart Healthcare
- Smart Healthcare - Characteristics
- Smart Healthcare - Components and Technologies
- Smart Healthcare - Challenges and Solutions
- Smart Healthcare - Selected Examples
Healthcare to Smart Healthcare
Human Body

From an engineering perspective, the human body can be defined as a combination of multi-disciplinary subsystems (electro-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
**Electronic Health (eHealth)**

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

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

Connected Health (cHealth)

Source: https://www.slideshare.net/tibisay_hernandez/connected-health-venfinal
Smart Healthcare (sHealth)

IoMT

Smart Hospital

Emergency Response

Smart Home

Smart Infrastructure

Smart Gadgets

Fitness Trackers

Headband with Embedded Neurosensors

Embedded Skin Patches

Sethi 2017: JECE 2017

Quality and sustainable healthcare with limited resources.

Wearable Medical Devices (WMDs)

Fitness Trackers

Headband with Embedded Neurosensors

Insulin Pump

Embedded Skin Patches

Medical grade smart watch to detect seizure

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

Source: https://www.webmd.com
**Implantable Medical Devices (IMDs)**

**Pill Camera**

- Image Sensors
- Processor
- Battery
- LED
- Antenna
- RF Transmitter
- Electromagnet
- Data Recorder

**Brain Pacemaker**


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

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 (CPS)

Smart Healthcare - 4-Layer Architecture

Smart Healthcare - Characteristics
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 predict smart health-care market value to reach US$348.5 billion by 2025.

IoMT - Impacts

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

Improved inter-device connection and synchronization

Real-time tracking and intervention

Development of evidence-based guidelines which can helpful to incorporate the local intelligence in future machine.

Data driven health prediction

Healthcare Cyber-Physical Systems (CPS)

Smart Healthcare – 7Ps

Smart Healthcare - Tasks

Daily Healthcare

(ii) Daily Diagnosis
- Wearable Medical Sensor (WMS)-based diagnosis

(i) Daily Prevention
- Fitness checkup
- Activity tracking
- Emotion analysis
- Disease risk prediction

(v) Daily Treatment
- Out-patient therapy
- Ambient healthcare
- Disease status monitoring
- Precision medicine

Clinical Boundary

(iii) Clinical Diagnosis
- Physician variance reduction
- Personalized diagnosis

(iv) Clinical Treatment
- Treatment plan selection
- Treatment method evaluation
- In-patient monitoring
- Precision medicine

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

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

Source: http://internetofthingsagenda.techtarget.com/definition/IoMT-Internet-of-Medical-Things
Types of Sensors

Brain related applications

Imaging applications

Heart related applications

Skin related applications

Blood related applications

Ingestible sensors

Motion Detection
### Smart Healthcare Communication

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

Smart Healthcare - Framework

Systems & Analytics
- Health cloud server
- Edge server
- Implantable Wearable Medical Devices (IWMDs)

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

Machine Learning Engine


Smart Healthcare -- Prof./Dr. Saraju P. Mohanty
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.

Electronic Medical Record (EMR)
Machine Learning (ML)

Supervised ML

- Data instance: features + label
- Data instance sets: training, testing
- Inference: Mathematical Model

Enhancement Techniques

- Ensemble method: base vs. meta
- Feature filtering: redundant vs. informative

Brain Computer Interface (BCI)

“Currently, people interact with their devices by thumb-typing on their phones. A high-bandwidth interface to the brain would help achieve a symbiosis between human and machine intelligence and could make humans more useful in an AI-driven world.”

-- Neuralink - neurotechnology company - Elon Musk.

Virtual Reality in Healthcare

In Surgery

For Therapy

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

Source: http://medicalfuturist.com/5-ways-medical-vr-is-changing-healthcare/
Crowdsourcing for Smart Cities

Smart Healthcare Data Gathering (Diet Dataset, Healthcare Dataset)

Urban Data Gathering (Bike Data, Energy Usage Data)

City Service Monitoring (Park Maintenance, Waste Disposal)

Last-Mile Logistics (Package Pickup Delivery)

Crowdsourcing for Smart Cities
Smart Healthcare – Challenges and Solutions
Smart Healthcare Architecture – Requirements

- Low power
- Higher efficiency
- Small form factor
- Inter operability
- Continuous connectivity
- High speed
- Security
- Privacy
Smart Healthcare – Data Quality

- Validity
- Integrity
- Reliability
- Objectivity
- Generalizability
- Utility
- Completeness
- Relevance

Smart Healthcare - Security Challenges

Selected Smart Healthcare Security/Privacy Challenges

- Data Eavesdropping
- Data Confidentiality
- Data Privacy
- Location Privacy
- Identity Threats
- Access Control
- Unique Identification
- Data Integrity

Health Insurance Portability and Accountability Act (HIPPA)

HIPPA Privacy Violation by Types:
- Data Physically Stolen: 55%
- Data Compromised by Hackers: 6%
- Improper Disposal of Data: 5%
- Data Lost and Not Accounted For: 12%
- Other: 2%
- Data Disclosed Without Authorization from Patient: 20%
IoMT Security Issue is Real & Scary

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

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

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

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IoMT Security – Selected Attacks

Impersonation Attacks

Eavesdropping Attacks

Physical Attack

Network Attack

Security Threats for IoMT

Software Attack

Encryption Attack

Reverse Engineering Attacks

Radio Attacks

Smart Healthcare

IoMT Security Measures is Hard - Energy Constrained

- Implantable Medical Devices (IMDs) have integrated battery to provide energy to all their functions → Limited Battery Life depending on functions
- Higher battery/energy usage → Lower IMD lifetime
- Battery/IMD replacement → Needs surgical risky procedures

Our Secure by Design Approach for Robust Security in Healthcare CPS

Threat Model

IoMT devices on the patient

Vulnerable to Attacks

IoMT devices on the patient

Communication between Edge Server and IoMT Device

Successful Attack

Malicious code by Attacker Impersonating Server

Physical Unclonable Function (PUF) based Solution

Communication between Edge Server and IoMT Device

No Malicious Code

PUF Authentication

Malicious code by Attacker Impersonating Server

Our Secure by Design Approach for Robust Security in Healthcare CPS

IoMT Security – Our Proposed PMsec

Enrollment Phase

PUF Security Full Proof:
- Only server PUF Challenges are stored, not Responses
- Impossible to generate Responses without PUF

Device Registration Procedure

IoMT Security – Our Proposed PMsec

Authentication Phase

Device Authentication Procedure

Secure Database

PUF in Server

IoMT Device

Challenge 1 → Response 1 → Challenge

Challenge 2 → Response 2 → Challenge

Device in Question

Response

Hash

Output

Original String

Compare

Device is Authentic

Device is not Authentic

C1

C1 → R1’

R1’ → C’

R’ → C2’

C’ → R’

X’ = H(R2’)

Compare

X = X’

IoMT Security – Our PMsec in Action

--- Enrollment Phase ---
Generating the Keys
Sending the keys to the Client
Receiving the Keys from the client
Saving the database

Output from Server during Enrollment

Output from Server during Authentication

Output from IoMT Device

--- Authentication Phase ---
Input to the PUF at server: 01001101
Generating the PUF key
Sending the PUF key to the client
PUF Key from client is: 1011100001011100101111000101110010110100110110010100101000011
SHA256 of PUF key is: 580cdc9339c940c60889c4d8a3b1a3c1876750e88701c6d4f5223f6d23e76
Authentication Successful

IoMT Security – Our Proposed PMsec

Average Power Overhead – ~ 200 μW

<table>
<thead>
<tr>
<th>Proposed Approach Characteristics</th>
<th>Value (in a FPGA / Raspberry Pi Platform)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to Generate the Key at Server</td>
<td>800 ms</td>
</tr>
<tr>
<td>Time to Generate the Key at IoMT Device</td>
<td>800 ms</td>
</tr>
<tr>
<td>Time to Authenticate the Device</td>
<td>1.2 sec - 1.5 sec</td>
</tr>
</tbody>
</table>

Blockchain for Smart Healthcare?

Blockchain Challenges
- Fake Block Generation
- High Energy Consumption
- Lack of Scalability
- High Latency
- Lack of Privacy

➢ Energy for mining of 1 bitcoin → 2 years consumption of a US household.
➢ Energy consumption for each bitcoin transaction → 80,000X of energy consumption of a credit card processing.

Blockchain Challenges - Energy

The requested “Transaction” is broadcasted to a Peer-to-Peer (P2P) network consisting of Computing Machines (i.e. “Nodes”).

A “Transaction” is requested by a Computing Machine (i.e. “Node”).

Peer-to-Peer (P2P) network of “Nodes”

The “Verified Transaction” is combined with other verified transactions to create a new “Block” of data for the Blockchain.

The “Verified Transaction” (e.g. Cryptocurrency, Contracts, Records).

Verified Transactions

A “Validated Block” is added to the existing Blockchain in a permanent and unalterable way.

A “Block”

New Block

Oldest Block

Blockchain (i.e. Ledger)

The Transaction is complete.

Transaction Validation

(The Network of Nodes validates the transaction as well as status of the user who requested transaction using a Validation Algorithm, e.g. Public Key Cryptography).

Our PoAh-Chain: The IoT Friendly Private Blockchain for Authentication


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Blockchain Consensus Types

**Blockchain Consensus Algorithm**

**Validation Based**
- Proof of Work (PoW)
- Proof of Stack (PoS)
- Proof of Activity (PoA)
- Proof of Relevance (PoR)
- Proof of Elapsed Time

**Voting Based**
- Ripple
- Proof of Vote
- Proof of Trust

**Authentication Based**
- Proof of Authentication (PoAh)
- Proof of PUF-Enabled Authentication (PoP) (Current Paper)
Our Proof-of-Authentication (PoAh)

Proof of Authentication (PoAh)

- Create Block
- Solve Puzzle
- Broadcast the Proof-of-Work (PoW)
- Process Starts Again

Proof-of-Work (PoW)

Eliminates cryptographic “puzzle” solving to validate blocks.

Nodes form Block of Transactions

Uses a cryptographic authentication mechanism.

Transmit to Trusted Nodes

Add the Device-ID

Trusted Nodes Network

Device Authenticated?

Yes

No

B_i-2

B_i-1

B_i

B_i

B_i-2

B_i-1

B_i
Our PoAh-Chain: Proposed New Block Structure

Conventional Block Structure

- Block in Conventional Blockchain (B_i)
  - Hash of Previous Block
  - Number only used once (Nonce)
  - Transactions Tx1, Tx2, …, TxN

- Hash of the following:
  - Hash of B_{i-2}
  - Nonce of B_{i-1}
  - Transactions of B_{i-1}

PoAh Block Structure

- Block in PoAh (B_i)
  - Hash of Previous Block
  - Unique Block Token (UBT)
  - Transactions Tx1, Tx2, …, TxN

- Hash of the following:
  - Hash of B_{i-2}
  - PoAh of B_{i-1}
  - Device ID
  - Transactions of B_{i-1}
**Our PoAh is 200X Faster than PoW**

Eliminates cryptographic “puzzle” solving to validate blocks.

<table>
<thead>
<tr>
<th></th>
<th>Proof-of-Work (PoW)</th>
<th>Proof-of-Stake (PoS)</th>
<th>Proof-of-Activity (PoA)</th>
<th>Proof-of-Authentication (PoAh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy consumption</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Computation requirements</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Latency</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Search space</td>
<td>High</td>
<td>Low</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

PoW - 10 min in cloud | PoAh - 3 sec in Raspberry Pi | PoAh - 200X faster than PoW

Machine Learning Challenges

- High Energy Requirements
- High Computational Resource Requirements
- Large Amount of Data Requirements
- 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

DNN considers many training parameters, such as the size, the learning rate, and initial weights.

High computational resource and time: For sweeping through the parameter space for optimal parameters.

DNN needs: Multicore processors and batch processing.

DNN training happens mostly in cloud not at edge or fog.

Source: Mohanty iSES 2018 Keynote
CE/IoT System - Multi-Objective Tradeoffs

Non-recurring Design Cost

Recurring Operational Cost

Energy Consumption, Battery Life

Security, Privacy, IP Rights

Performance, Latency

Intelligence

Safety

Source: Mohanty ICCE 2019 Keynote

Smart Electronic Systems Laboratory (SESLS)
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

Source: Our IFIP IoT 2019 Talk (Good-Eye: A Combined Computer-Vision and Physiological-Sensor based Edge Device for Full-Proof Prediction and Detection of Fall of Adults)
Smart Healthcare – Specific Examples
Food Intake Monitoring and Diet Management is Important
Smart Healthcare – Diet Monitoring

Automated Food intake Monitoring and Diet Prediction System

- Smart plate
- Data acquisition using mobile
- ML based Future Meal Prediction

Smart-Log

- User takes a picture of the Nutrition Facts using Smart Phone
- Use Optical Character Recognition (OCR) to convert images to text
- Nutrition facts obtained through OCR
- User scans the barcode of the product
- Using Open Application Program Interface (API)’s and Database approach, the nutrition facts are acquired from Central database
- Nutrient facts obtained through API’s
- Weight and Time information obtained through Sensing Board
- Calculate Nutrient Value of the meal
- Save the Nutrient value, Weight, Time of each meal for future predictions

USDA National Nutrient Database used for nutrient values of 8791 items. 8172 user instances were considered

<table>
<thead>
<tr>
<th>Research Works</th>
<th>Food Recognition Method</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>This Work</td>
<td>Mapping nutrition facts to a database</td>
<td>98.4</td>
</tr>
</tbody>
</table>

Smart-Log Diet Monitoring and Prediction: DNN Model

Captures Food Images

Automatic Food Image Analysis

IoT Cloud

Automatically monitors food intake to determine if the eating is stress-eating or normal-eating.

Accuract of detecting food - 97%

Stress-Log: Implementation

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.

Stress-Log: GUI

Username: neustress
Password: ********
Gender: Female

Meal Entry
Name of Food: Cereal No of servings: 2
Name of Food: Boiled Egg No of servings: 1
Time Consumed: 8:00 AM

Mood Entry
Mood Before Eating:
Happy Normal Sad
Mood After Eating:
Happy Normal Sad

Normal Eating
Food Input
Calories Consumed: 1744 Calories Left: 256
Mood Input
Current Mood: Normal Remedies

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Stress is a Major Health Issue

Stress is the relationship between a person and a situation, which adversely impacts the happiness and health of the sufferer or physiological reactions.

Stress can be divided into two parts: stressor and reaction.

Stressor is the activity or effect that triggers a change in the physiological parameter values of the human body.

Reaction is the deviation of these parameter values from their normal levels.
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

Stress-Lysis: From Physiological Signals

Stress-Lysis: Experiments

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

Smart Healthcare - Seizure Detection & Control

Seizure Detection

Sensor Unit

Transmission and Storage

Access Unit

Drug Delivery Unit

Yes

Seizure State

Dosage Information

Wireless Transfer

Cloud Storage

Hospital

Doctor

EEG Data Acquisition

EEG Signal

Drug Injection

Drug Detection

Seizure Onset

Seizure Detection

Typical Latency - 6 sec

Early Detection - 1 to 2 sec

Seizure Prediction - at least 6 sec before

### Seizure Detection Approaches

**Cloud Vs Edge Computing**

<table>
<thead>
<tr>
<th></th>
<th>Latency</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cloud-IoT based Detection</strong></td>
<td>2.5 sec</td>
<td>98.65%</td>
</tr>
<tr>
<td><strong>Edge-IoT based Detection</strong></td>
<td>1.4 sec</td>
<td>98.65%</td>
</tr>
</tbody>
</table>


**Smart Healthcare -- Prof./Dr. Saraju P. Mohanty**
Seizure Control Methods

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

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


Spatial modeling or Variography
- Correlation Function is "Variogram"

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


Kriging based Seizure Detection

Signal Denoising
Wavelet Transformations

Feature Extraction
Fractal Dimension

Seizure State Classification
Kriging Classifier

Seizure Status

<table>
<thead>
<tr>
<th>Works</th>
<th>Extracted Features</th>
<th>Classification Algorithm</th>
<th>Sensitivity</th>
<th>Latency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zandi, et al. 2012 [23]</td>
<td>Regularity, energy &amp; combined seizure indices</td>
<td>Cumulative Sum thresholding</td>
<td>91.00%</td>
<td>9 sec</td>
</tr>
<tr>
<td>Our Proposed</td>
<td>Petrosian fractal dimension</td>
<td>Kriging Classifier</td>
<td>100.0%</td>
<td>0.85 s</td>
</tr>
</tbody>
</table>

Blood Glucose Monitoring – Invasive Vs Noninvasive

Traditional – Finger Pricking

Photoplethysmogram (PPG)

Near Infrared (NIR)

PPG Signal Analysis

Specific Wavelengths are not required

Logged signal for pulse analysis and features extraction

NIR Spectroscopy

Specific Wavelengths needed for glucose molecule detection

Logged voltage values after absorption and reflectance of light from glucose molecule
Smart Healthcare – iGLU –
Noninvasive, Accurate, Continuous Glucose Monitoring

Vibrations (Stretching, Wagging, Bending)

Near Infrared (NIR) Emitters (940nm, 1300nm)

Transmitted Wave

Infrared Detector

Attenuated Wave

Infrared Detector

Analog-to-Digital Converter (ADS1115)

Clinically tested in an hospital.

Cost - US$ 20
Accuracy - 100%


Smart Healthcare -- Prof./Dr. Saraju P. Mohanty
Internet of Every Things (IoE)

People
Connecting people to the Internet for more valuable communications
- Implantable Medical Device (IMD)
- Wearable Medical Device (WMD)

Wearing a Smart Healthcare

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

Data
Collecting data and leverage it for decision making

Crowdsourcing

Things
Devices connected to each other and the internet (Internet of Things (IoT)). Perform decision making whenever necessary

Requires:
❖ Data, Device, and System Security
❖ Data, Location, and System Privacy

Conclusions and Future Research
Conclusions

- Healthcare has been evolving to Healthcare-Cyber-Physical-System (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, privacy, etc.
Future Research

- Internet-of-Everything (IoE) with Human as active part as crowdsourcing need research.
- IoE will need robust data, device, and 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.
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