N Institute for the Wireless
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Internet of Medical Things

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Outline – Internet of Medical Things

- Internet of Medical Things Outline

  - Introduction

  - Emergent Technologies

  - Applications

  - Security Requirements

  - Challenges

  - Future Applications

  - Conclusions

Introduction – Internet of Medical Things

- Definition: a network of interconnected medical devices, hardware, and software used for healthcare applications.
    - Motivation: Improve the conventional healthcare infrastructure and equipment to provide a more cost-effective system and improve the quality of life for patients
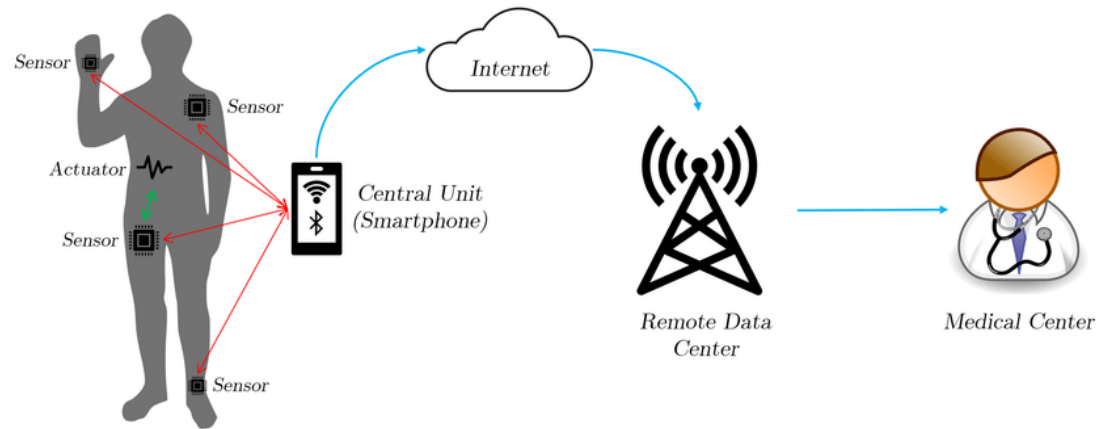

Internet of Medical Things

IoMT Challenges

- Regulations & red tape

- The human body is a lossy medium

- Humans are highly dynamic

- Cells are "fragile"

- Energy consumption
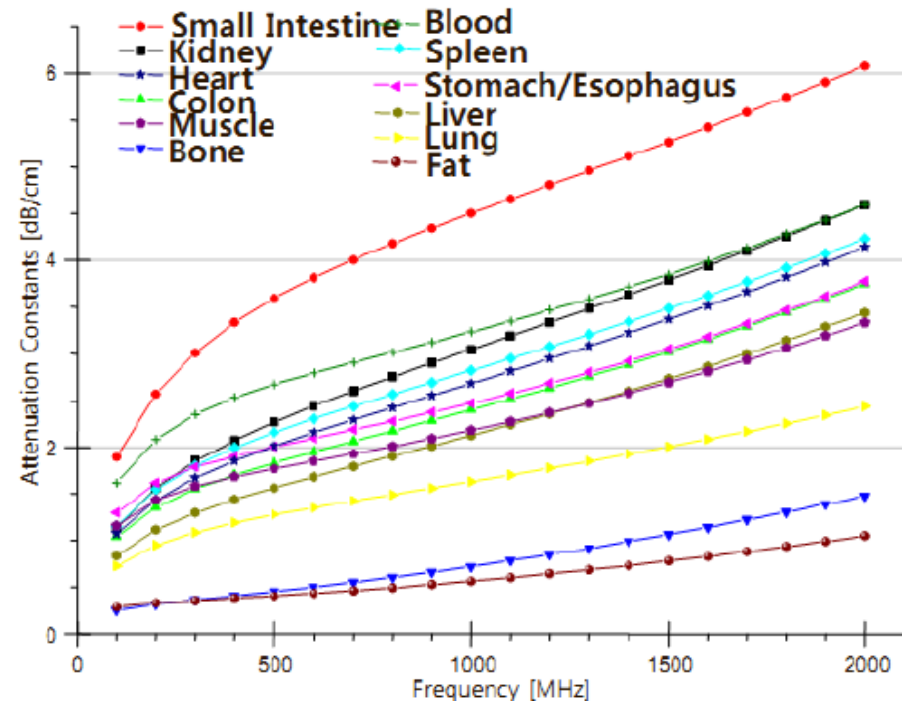
IoMT Innovations

- Wireless Body Area Networks (WBAN)

- Overcome the high attenuation
  - Use ultra-wideband (UWB) communication
  - Use ultra-sonic waves instead

IoMT Innovations

- Five main modes that humans are in
    - Lying down
    - Standing
    - Sitting
    - Walking
    - Running

- How can we leverage the classification system to make more efficient transmission algorithms?

IoMT Innovations

- Emerging Protocols for IoMT

  - Humans while in motion are periodic
  - Transmit and receive where the RSSI is at its peak
  - Predict human motion for maximized efficiency

  - BANMAC (Body Area Network MAC)
    - Built on IEEE 802.15.4
    - Flexible scheduling and *no* random channel access
    - Very low packet loss
  - HACMAC
    - Link quality-aware protocol to adapt mechanisms based on the link quality
  - DeepBAN uses a temporal convolution network (TCN) based deep learning approach to lower response time and increase efficiency by 15%

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IoMT Innovations

- Implantable Internet of Medical Things (IIoMT)

  - How to charge the device?

  - How to send/receive signals?

- Investigate usage of ultrasonic frequencies for communication as well as for wireless charging
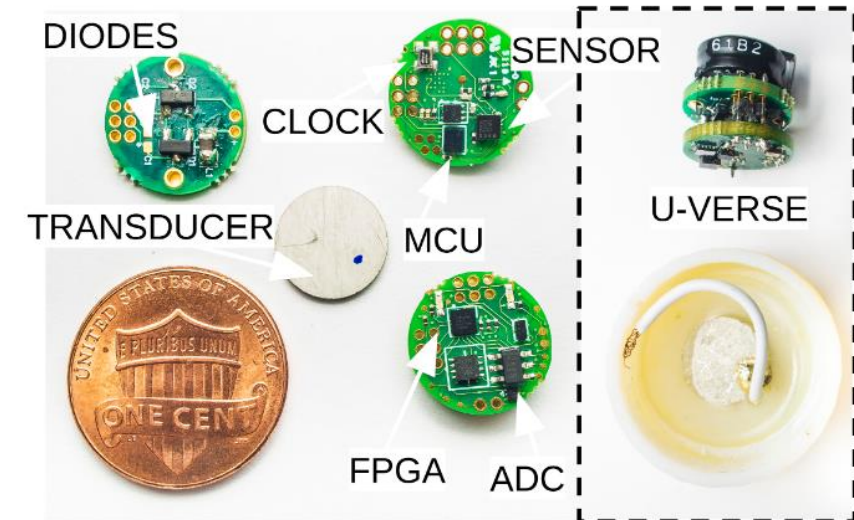
U-Verse Implantable IoMT Device [1]

IoMT Applications

- Various Applications exist for IoMT can be split into two categories
  - Body-Centric: Physical devices attached to patients for monitoring of vital information
    - Heart Rate Monitoring
    - Sleep Monitoring
    - Glucose monitoring
  - Object-Centric: IoT devices used to enhance functionality of medical equipment
    - Electronic Health Record
    - Medical Device Tracking
    - Smart Ambulances
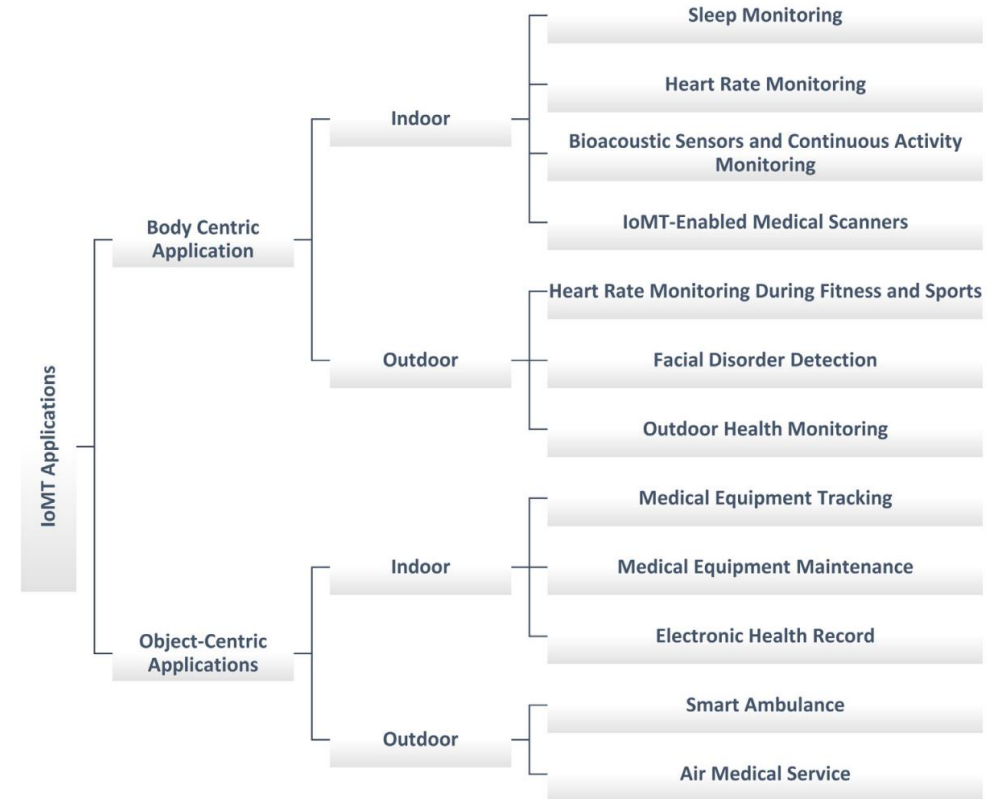
Overview of IoMT Applications [2]

IoMT Applications – Smart Hospitals

- Definition: Hospital that implements IoT-technologies to optimize:
    - its management systems
    - medical equipment
    - infrastructure
- Goal: Administer a more effective healthcare service to those in need of medical assistance
    - Improving Quality of Life for patients
    - Reducing hospital occupancy via remote monitoring
    - Allowing for telehealth appointments with doctors

IoMT Applications – Smart Hospitals

- Methods:
  - Electronic Health Records
    - Appointment registrations and access to medical records for patient via smartphone or computer
    - Wi-Fi based smart tablets for doctors and nurses to access patient information
  - RFID tagged medical equipment
    - quickly locate valuable equipment in hospital
    - Also used for inventory check to avoid overstocking equipment
  - Remote Monitoring
    - Vital information collected from different sensors and transmitted to cloud server for doctors/nurses to observe health data remotely or respond during emergencies

Smart tablet with access to medical database

RFID tags on equipment, test samples, patient ID

IoMT Applications – Telehealth

- Definition: Allowing patients of any age to keep track of their own vital health data and own well-being
- Motivation: To provide remote solutions to increase healthcare accessibility outside the hospital setting
  - Benefits those who are incapable of getting themselves to hospital
    - Handicapped or elderly patients
- Ambient Assisted Living [3]
 - Monitored patient's heart rate, location in home, temperature, humidity, and CO2 levels


Smartphone Appointments with Doctors/Clinicians
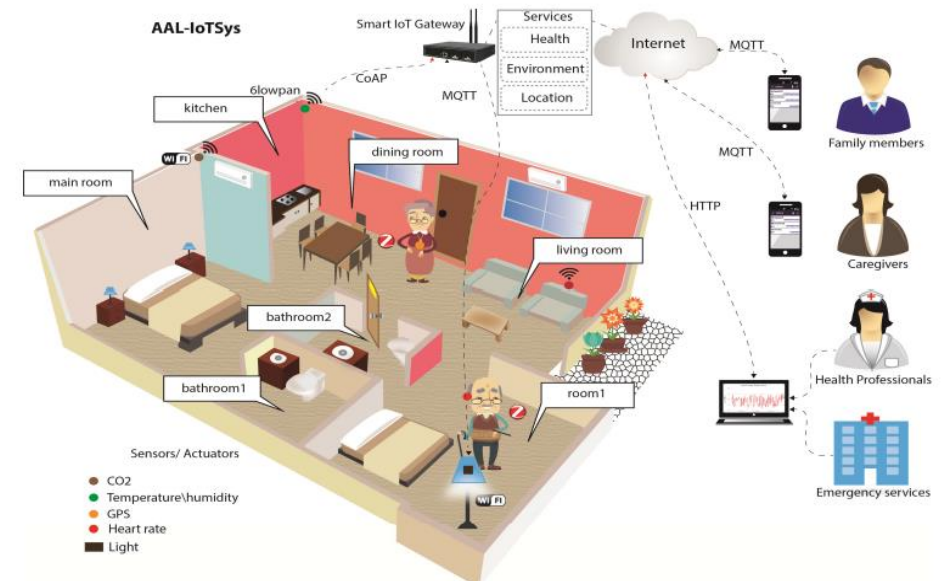
Ambient Assisted Living System with IoT Gateway [3]

IoMT Applications – Remote Monitoring

- Main Areas utilized in Remote Monitoring:
  - **Heart Rate Monitoring**
    - Wireless body sensors and ECG wearables such as smart watches/bands
    - Stress levels can indicate hidden diseases like arrythmia
  - **Diabetic Monitoring**
    - Blood glucose sensors that measure patient's blood sugar, transmit data via Bluetooth to smartphone
  - **Prescription Drug Monitoring**
    - Prescriptions can be manually submitted into smartphone application tied to cloud server for doctors to verify patient's intake
    - Help combat adverse drug reactions and compliance
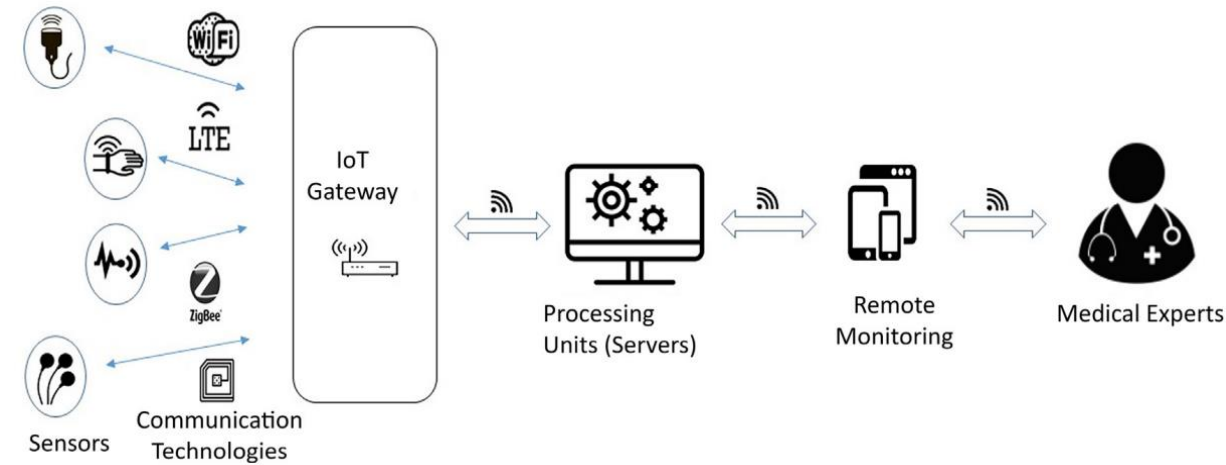
Architecture of Remote Monitoring Systems [1]
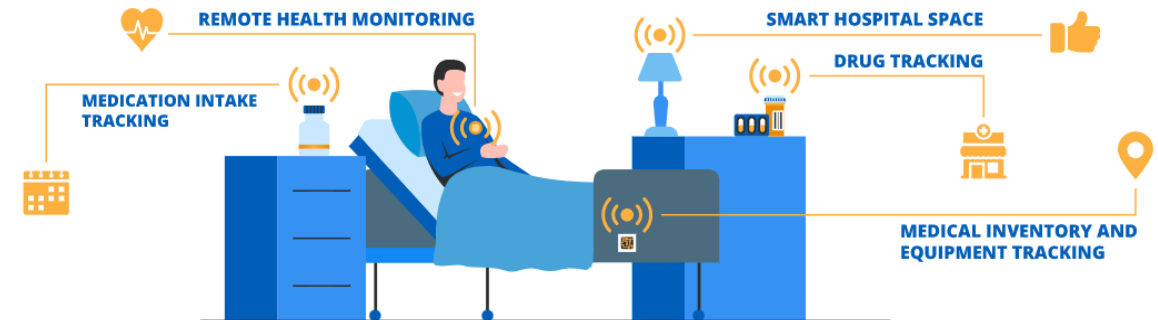
Security / Requirements of IoMT Devices

- Overview
  - Why is security so important?
    - Importance of authentication
  - Diffie-Hellman and Curve25519
  - Promises of smartphones as medical devices


Internet of Medical Things

Why is Security of IoMT Devices Important?

- HIPPA, GDPR
  - Organizational frameworks for protection and visibility of personal health data
  - Importance of data that is contained
- Importance of authentication
  - Authentication vs. Data transmission
  - Why does authentication matter so much?
  - Current industry trends

Diffie-Hellman Encryption and Curve25519

- What is the Diffie-Hellman protocol?
  - RSA encryption
- Modulus function and elliptic curves
  - Difficulty of prime number factoring
- Modern protocol variants on iOS, iPadOS, MacOS
  - Curve 25519
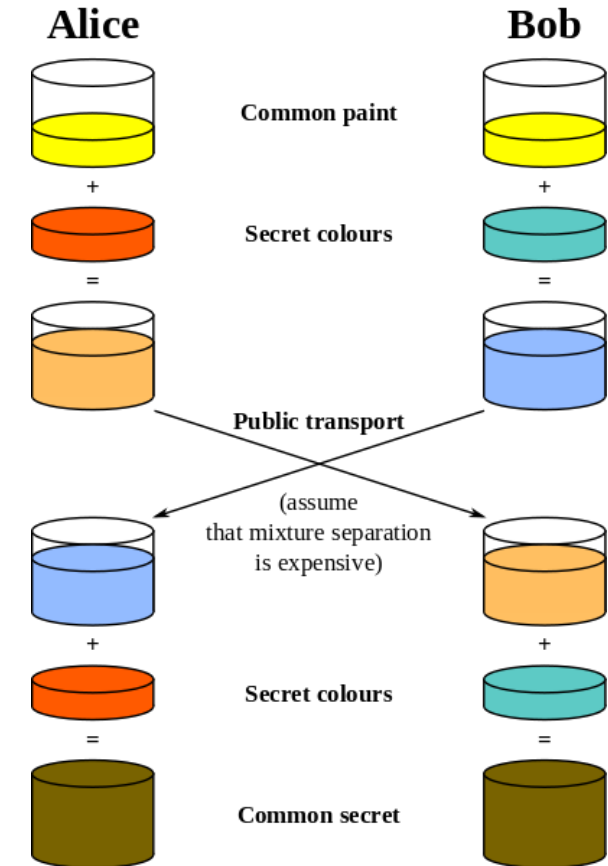
Smartphones as Medical Devices

- Smartphones are changing the way we think about medical devices
  - Bringing medical technologies to the masses
- Smartwatches improve health metric gathering
- FDA regulation and smartphone apps
- Reliability of AI in making medical decisions

Barriers/Problems of IoMT Devices

- The are many challenges that IoMT Devices face

- For example:
    - Privacy and Security
    - Standardization Protocols
    - Accuracy and Risk of failure
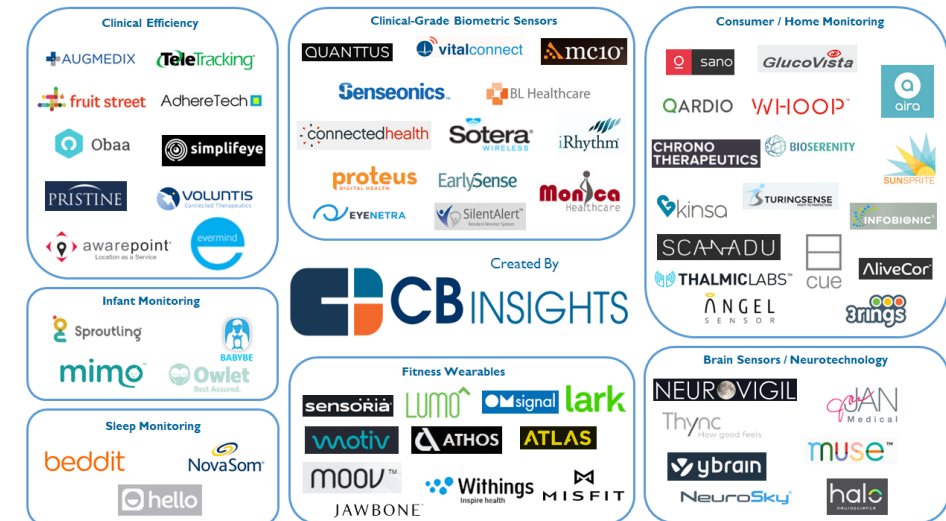   - Cost
    - Acceptability

Barriers/Problems of IoMT Devices

- Privacy and Security :
  - Is my Data safe and Secure ?
  - Cyber attacks
  - Implementation of Complex algorithms
  - National Institute of Standards and Technology

- Standardization Protocols :
  - What protocols does my system use ?
 - Interoperability
  - Smooth Integration

Is Your IoT Device Safe and Secure?
Managing Security Risks Still a Concern for Many!

The Healthcare Internet of Things (IoT) Market Map

Barriers/Problems of IoMT Devices

- Accuracy and Risk of failure :

  - How accurate is my device ?

  - What if my device fails

  - Software updates

- Cost:

  - Design and Development Cost

  - Cost of Implementation

  - Training staff
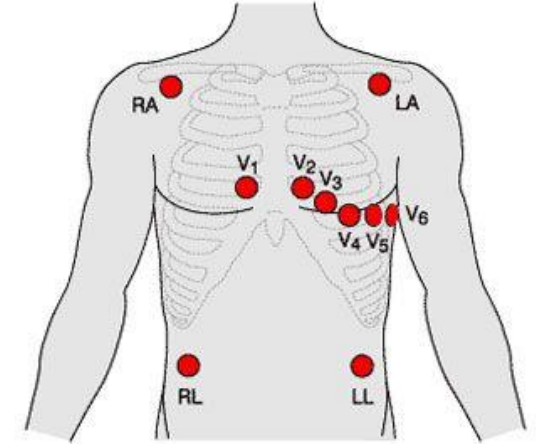
Barriers/Problems of IoMT Devices

- Acceptability:

    - Is the general public ready ?

    - True value of IoT

    - Acceptance of IoT

IoMT Future Tech & Conclusions

- **Future Tech**
  - Wearables
    - Many alternatives in the coming years focusing on miniaturization of devices for more comfortable and unobtrusive designs
  - Implantable IoMT
    - Allow for ultrasonic based wireless transmissions and charging
- **Conclusions**
  - Providing alternative options than in-person healthcare are becoming more demanding
  - Earlier prevention of diseases obtainable via remote monitoring
  - More development needed to overcome security and FDA regulation

References

[1] Guida, Raffaele & Dave, Neil & Restuccia, Francesco & Demirors, Emrecan & Melodia, Tommaso. (2019). U-Verse: a miniaturized platform for end-to-end closed-loop implantable internet of medical things systems. 311-323. 10.1145/3356250.3360026.

[2] F. Al-Turjman, M. H. Nawaz, and U. D. Ulusar, "Intelligence in the internet of medical things era: A systematic review of current and future trends," Computer Communications, vol. 150, pp. 644–660, 2020

[3] D. C. Yacchirema, C. E. Palau, and M. Esteve, "Enable IoT interoperability in ambient assisted living: Active and healthy aging scenarios," in Proc. 14th IEEE Annu. Consum. Commun. Netw. Conf. (CCNC), Las Vegas, NV, USA, 2017, pp. 53–58