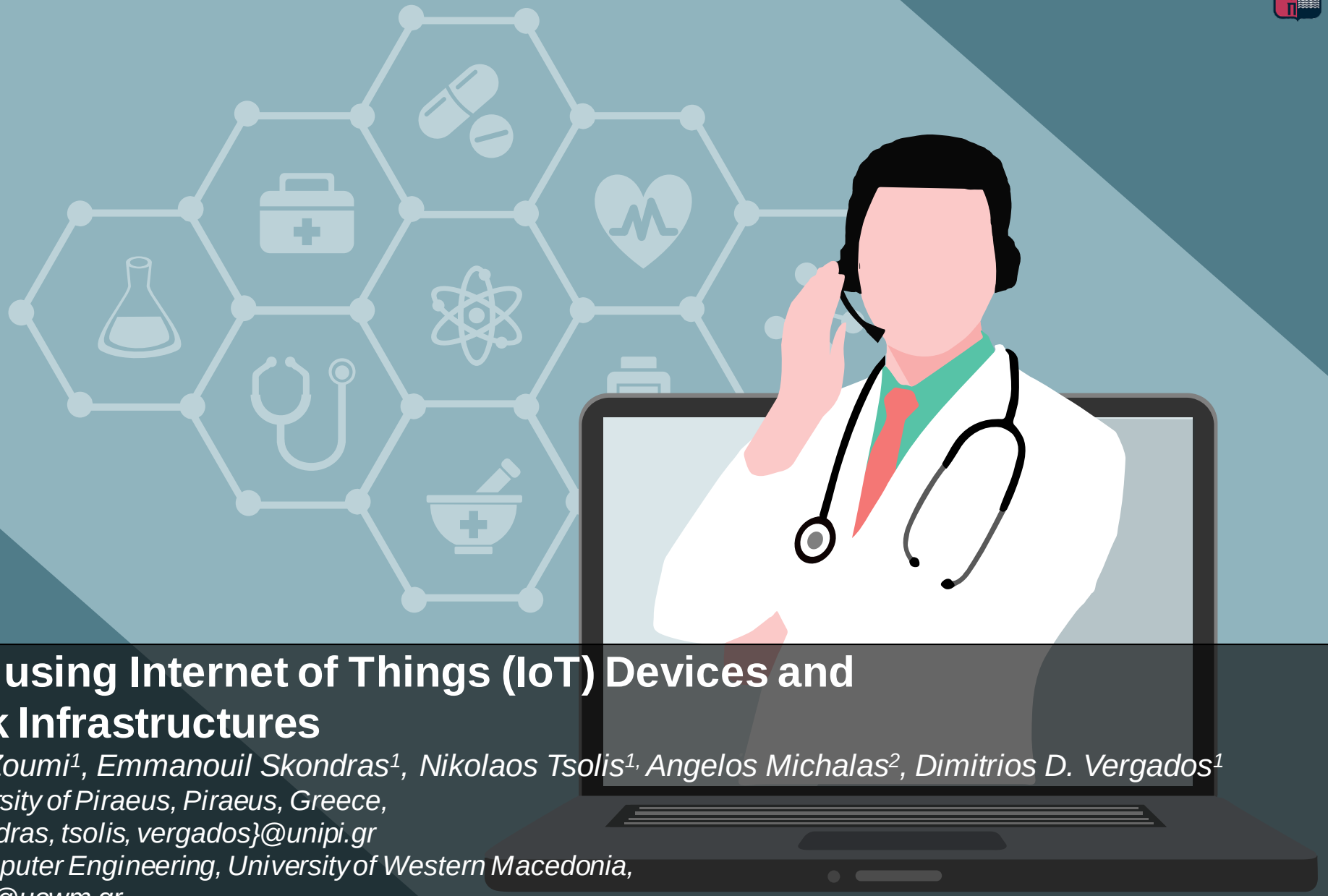

Monitoring Diabetes using Internet of Things (IoT) Devices and 5G Wireless Network Infrastructures

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Outline

- Introduction
- 5G Networks
- Smart Healthcare
- History of Diabetes Management
- Disadvantages of classic models for monitoring diabetes
- 5G-Smart Diabetes
- 5G-Smart Diabetes Layers
- Measuring Diabetes
- The Proposed Model for Diabetes Monitoring

Introduction

- Modern society is defined by the evolution of technology, 5G networks, big data analysis, Cloud Computing and Internet of Things.
- Development of innovative healthcare systems based on a human-centered model.
- Diabetes is a common metabolic disease.
  - Diabetes affects 8.5% of the population or 422 million people worldwide.
- In general, it needs constant monitoring when it occurs.
  - Existing technology can offer personalized suggestions for prevention, diagnosis and treatment.
- Goal: The 5G Smart Diabetes as a sustainable, affordable, smart and personal diagnosis and treatment of diabetes.

5G Networks

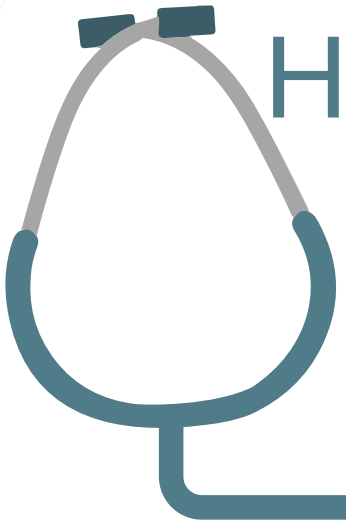
- A crucial factor on which all "smart" applications will be based.

- Selected for:
  1. Main communication infrastructure:
     - Providing high quality and continuous monitoring of the patient's condition without restrictions.
  2. 5G goals:
     - Cost-effectiveness:
       - Reduces the cost of out-of-hospital treatment.
     - Comfort:
       - Measurement with smart devices.
     - Personalization:
       - Provides personalized diabetes prevention and treatment with machine learning techniques and big data analysis.
     - Sustainability:
       - Continuous data collection and analysis with smart devices.
     - Intelligence:
       - Early symptom recognition and treatment.

Smart Healthcare

Model	Cost	Convenience	Network	Personalization	Sustainability	Flexibility	Application
Diabetes 1.0	High	Low	-	Low	Low	Low	Hospitalization, manual treatments
Diabetes 2.0	Medium	Medium	Social Networks	High	Low	Low	Sensors, drug analysis and rehabilitation
5G-Smart Diabetes	Low	High	5G Networks, Social Networks, Cloud and Big Data Networks	High	High	High	Patient-driven data, data analysis intelligence

History of Diabetes Management



2013

2014

Classical Health

Fixed Model of Medical Care [solanas2014].

2015

2016

Diabetes 1.0

Real-time glucose measurement through medical centers [lee2016].

2017

Diabetes 2.0

Automation of traditional glucose measurement methods [marie2017].

2018

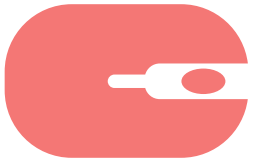
5G Smart Diabetes

Use of wearables, machine learning and big data analysis [chen2018].

2019

Our Proposal

2020



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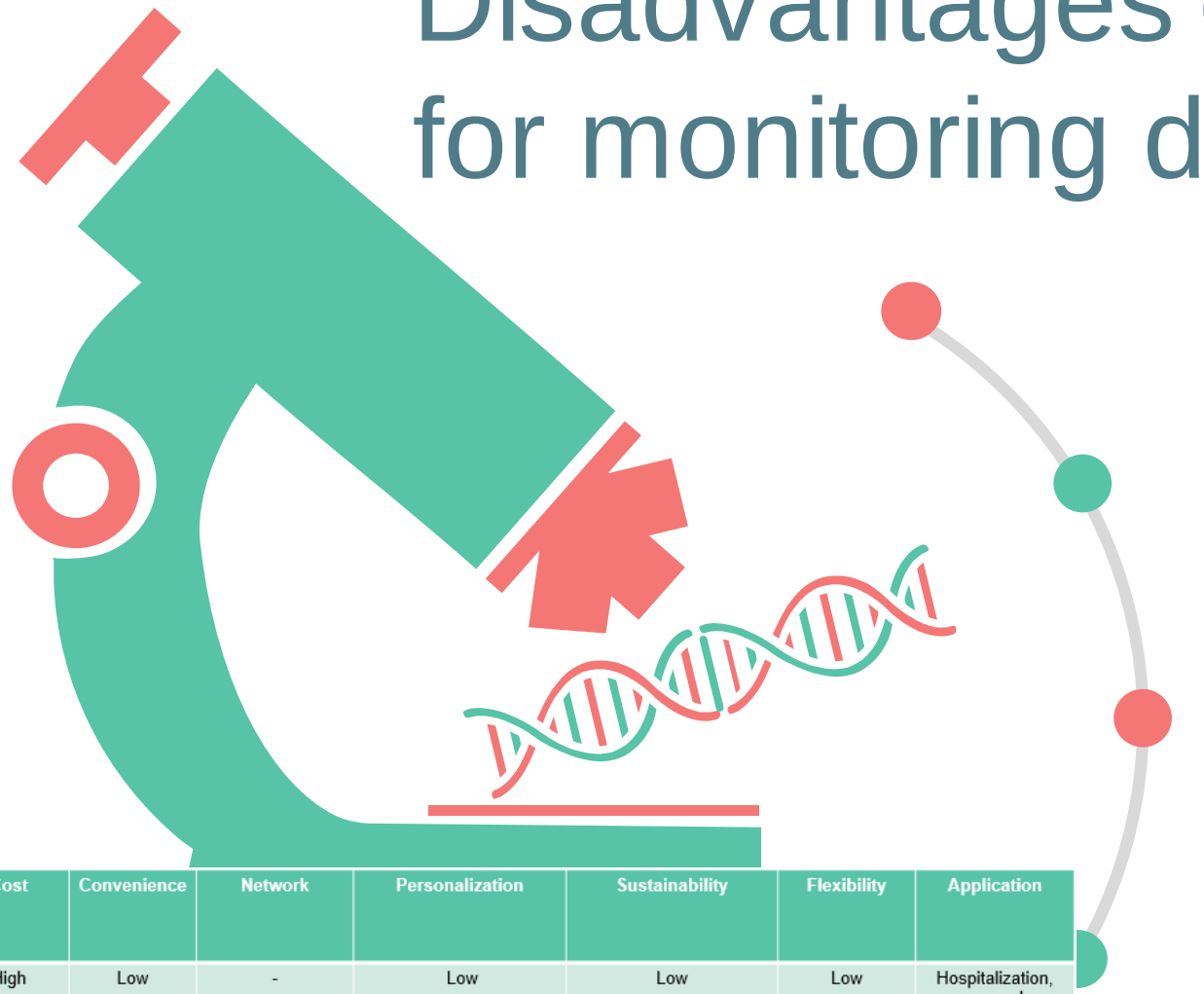
Disadvantages of classic models for monitoring diabetes



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Diabetes 1.0

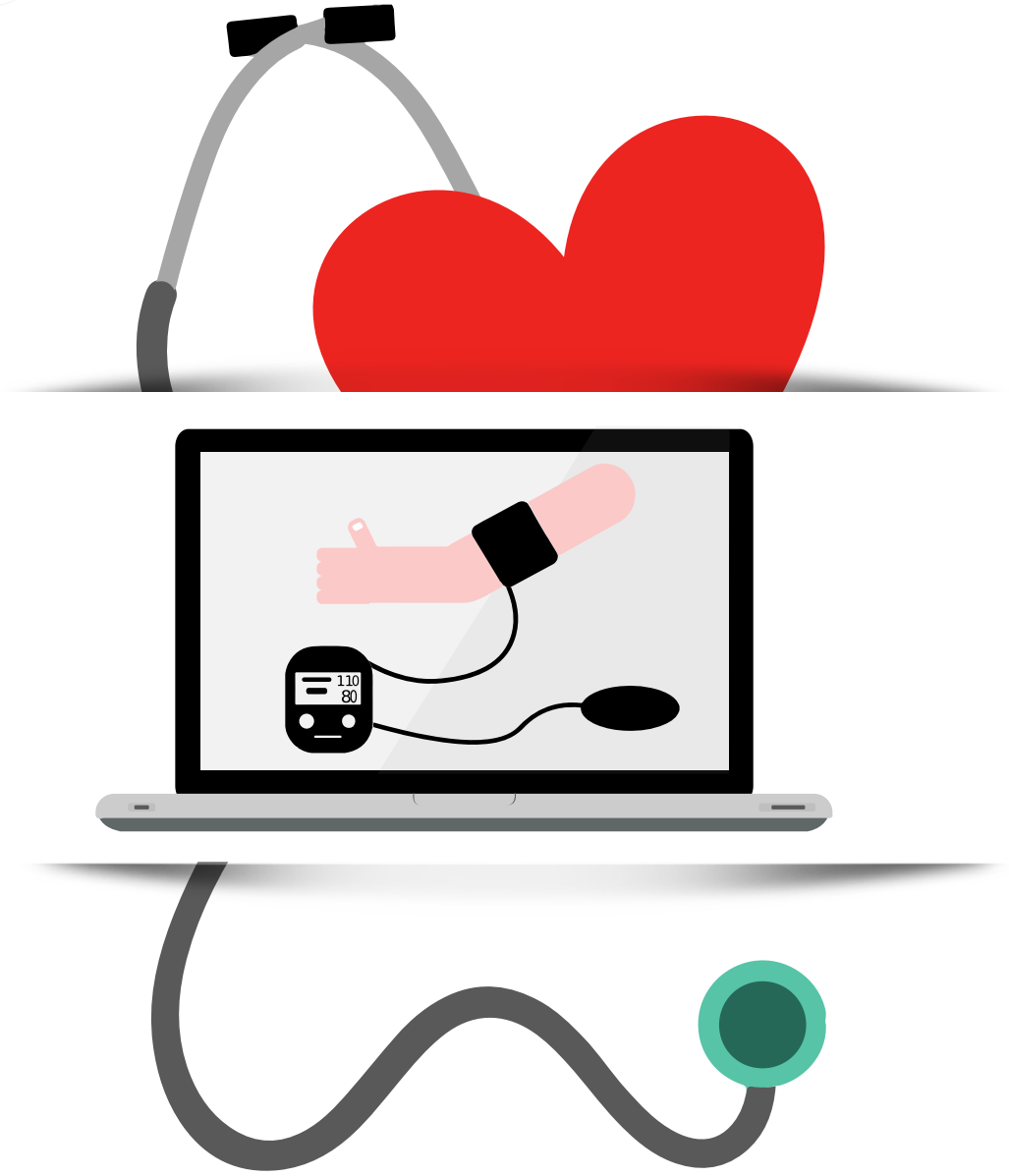
Provision of treatment in medical centers, consumption of limited medical resources.

Diabetes 1.0

Lack of comfort, personalized care and waste of time.

Diabetes 1.0

Difficulty in dealing with or preventing critical situations.



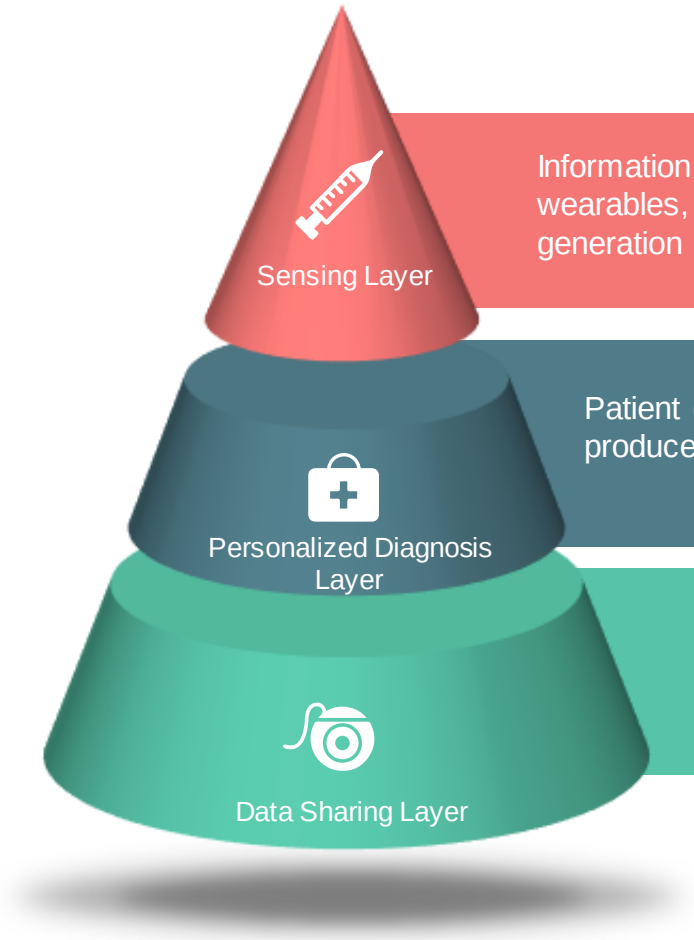
5G-Smart Diabetes

- In addition to glucose, diet, psychological status and exercise are recorded.
- Exploitation of infrastructures such as Cloud, IoT, 5G, wearables, smart clothing, medical devices.
- Storage and retrieval of information from the healthcare data cloud.
- Complete personalized content for the patient.

Next Generation Technologies for Smart Healthcare

It offers a multi-level flexible architecture combining data sharing technologies between users and the cloud to provide personalized services that meet the needs of each user.

5G-Smart Diabetes Layers



Information such as blood glucose, temperature, heart rate, food intake and exercise is collected through wearables, smart clothing or smart phones. All data is stored in the healthcare big data cloud via 5th generation networks.

Patient data is processed, analyzed and integrated into machine learning techniques (as training data) to produce a personalized model that predicts and treats diabetes.

This level includes social space and data space. The social space includes a single space for the exchange of knowledge and socialization between people related to diabetes (patients, doctors). Data space is related to the storage of generated information in the cloud.

Model Development

1. Acquisition of Dataset
Acquisition of hospital public data on diabetes. Specifically EMR (Electronic Medical Data).

2. Dataset editing
Separation of structured and non-structured data for exporting features. Connective Neural Networks (due to images) are used for the unstructured.

3. Model extraction
Use of features and big data analysis for an early public diabetes diagnosis model.

4. Acquisition of personalized data
As long as the user generates data stored in the healthcare cloud, they are used as a test to for the functionality of the application. The model is retrained in the new personalized data.

5. Use of model
The user through smart clothing, smart devices, phones or wearables continuously generates data stored in the Cloud for utilization.

6. Model optimization
Users are constantly generating personalized data, The model is being re-trained in it and producing more and more detailed results.

5G-Smart Diabetes

- Collection of personal data through glucose measuring device, wearable devices.
- Build an application that communicates with patient sensors and the Cloud and provides the user interface.
- Construction of a cloud platform for storing medical data.
- Public data collection and cleaning for model training.
- Performance control using learning mechanisms such as decision trees, neural networks and support vector machines.

Measuring Diabetes

Measuring Diabetes

CGM – Continuous Glucose Monitoring (modern way)

- During the last years a new method has introduced.
- The patient “installs” a sensor on the body and wear it for about 15 days continuously.
- After this period the sensor must be replaced for two reasons, first for health safety reasons and second because the battery of the sensor might get depleted.
- The sensor measures the glucose levels.
- The sensor communicates wirelessly with a mobile device or a smartphone using an application.
- The application receives the measurements from the sensor and notifies the patient if the glycose measurement is out of range.

Measuring Diabetes

Internet Of Things

- Internet of Things (IoT) is mainly a network of interconnected devices that communicate one another by sending and receiving data.
- IoT devices can embed various sensors.
- Indicatively, the CGM sensor for the continuous glucose measurement is an IoT device that measures glucose and through a communication network, send the measured values to a smart device or smartphone.
- The communication protocol could be any available in the market of the IoT.
  - 3G/4G/5G wireless communications, Bluetooth, NFC, Wi-Fi, ZigBee.
- But for the patient's comfort (not to carry many devices with him), an optimal solution is the Bluetooth, since all the smartphones support this kind of communication.
- Bluetooth protocol can cover the range that is needed for the connection of the body sensor and the smartphone which will be near the patient.

Measuring Diabetes

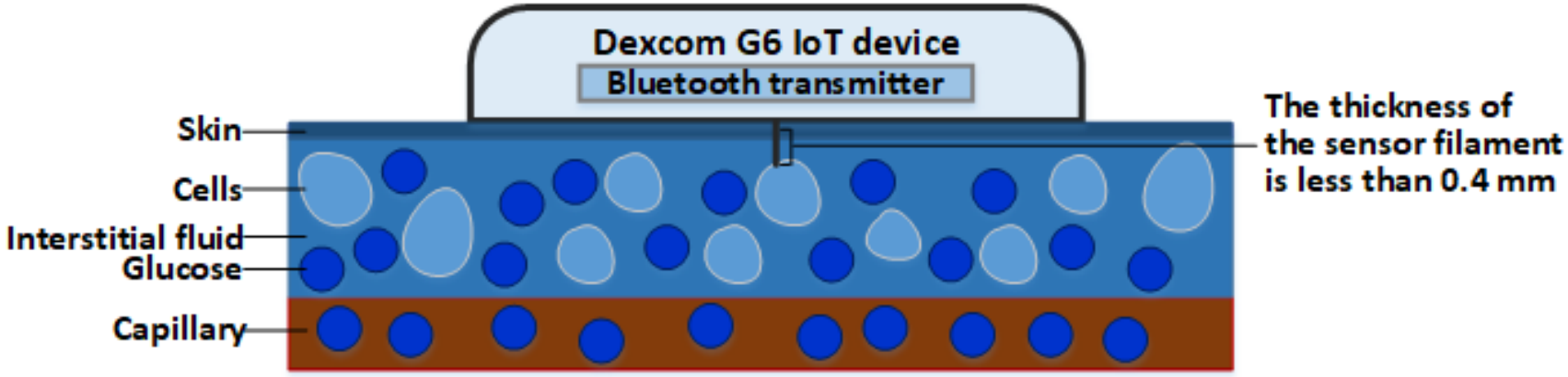
For the moment, two companies have CE certification for the medical use of their CGM based systems and these results can be used for medical evaluation.

- The models are the Abbott Freestyle Libre and the Dexcom G6.
- The first one uses Near Field Communication (NFC) with a few centimetres distance to achieve communication, and the patient must be conscious to get the measurement.
- The second system uses Bluetooth communication which gives approximately 10 meters distance for communication and there is no need for the patient to be conscious to get a measurement.

The Proposed Model for Diabetes Monitoring

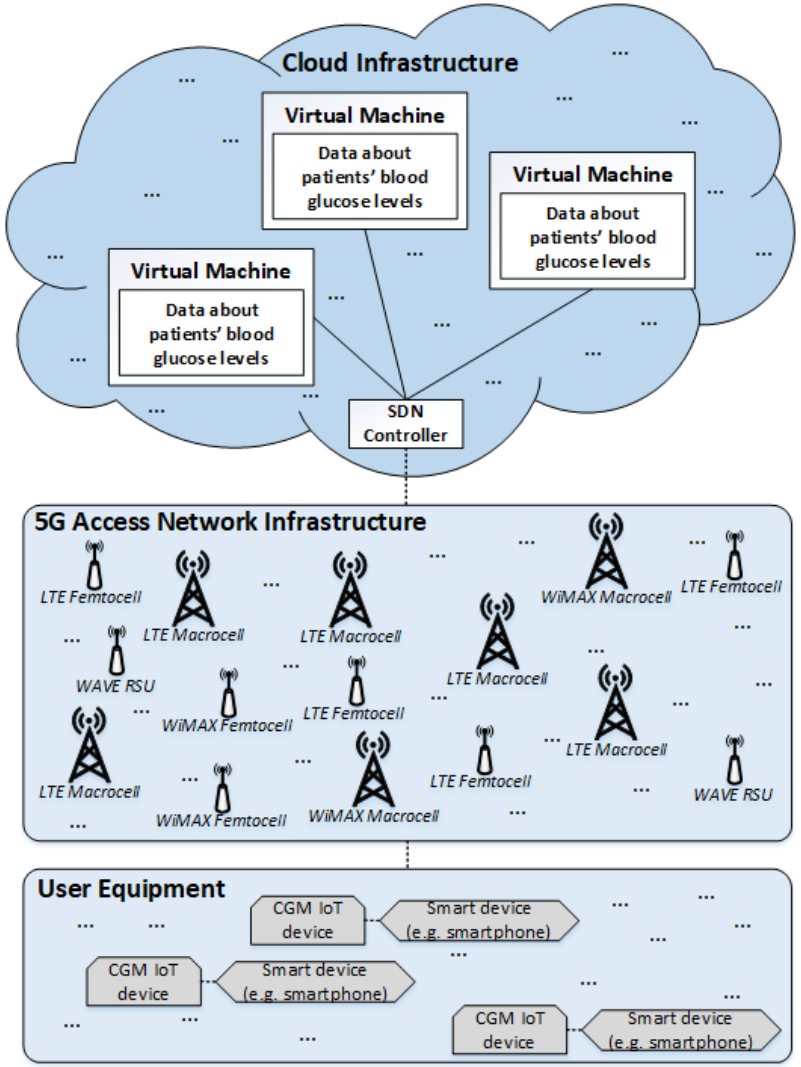
The design of the Dexcom G6 IoT device

- The CGM device is equipped with:
  - A filament for performing the glucose measurements.
    - It is less than 0.4mm thick, as well as
  - A Bluetooth transmitter.
    - It is used for sending the measured values to nearby smart devices.
      - such as smartphones, tablets or vehicular On-Board Units (OBUs).

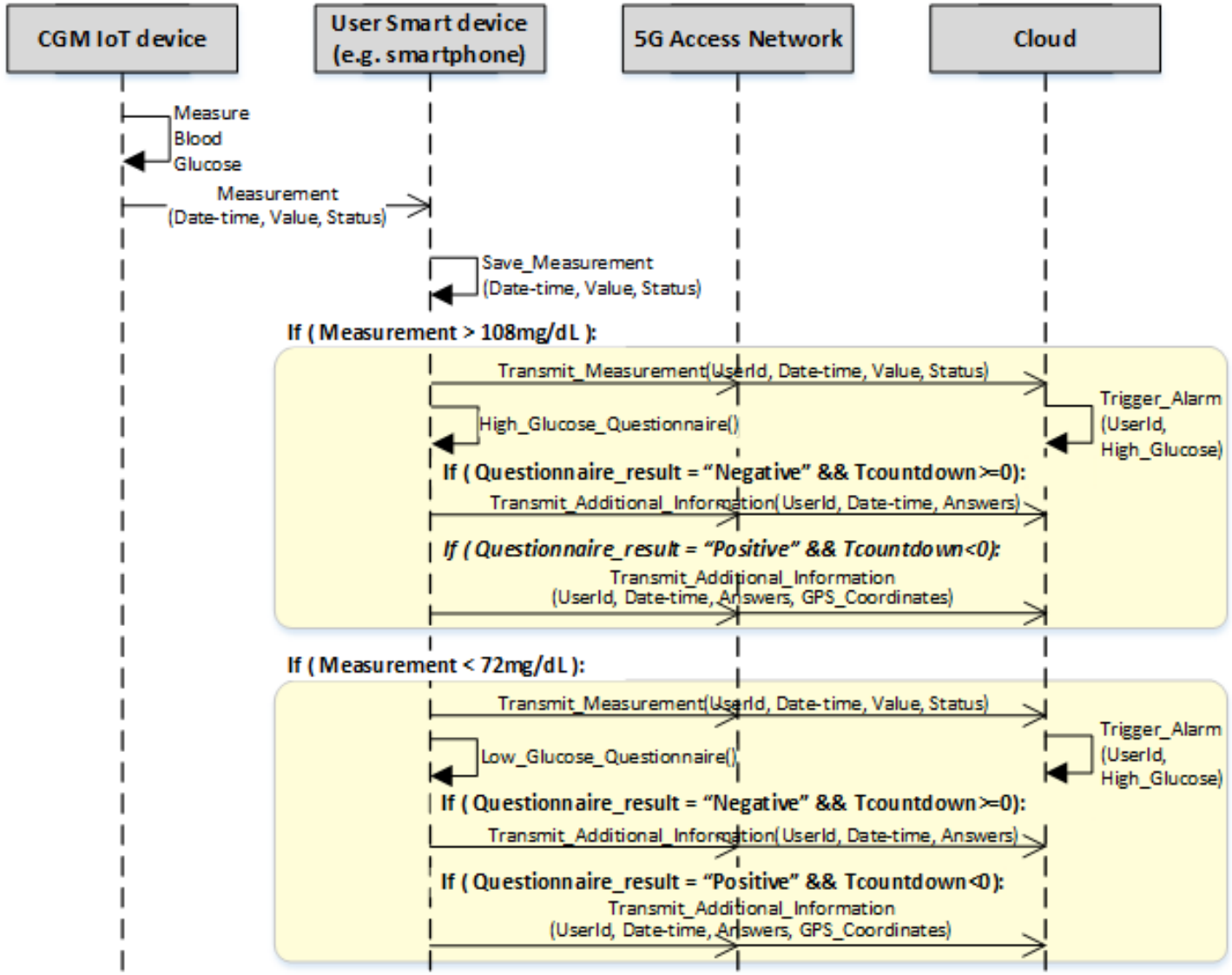


The proposed system architecture

- A mobile application is deployed to patient's smart device is also used.
- Both the CGM device and the mobile application are interconnected using Bluetooth.
- The architecture includes:
  - Cloud Infrastructure.
    - Virtual Machines store data about patient's blood glucose levels.
  - 5G Access Network Infrastructure.
    - LTE Macrocells & Femtocells.
    - WiMAX Macrocells & Femtocells.
    - WAVE RSUs.
  - User Equipment.
    - CGM IoT devices.
    - User Smart devices (e.g. smartphones or tablets).

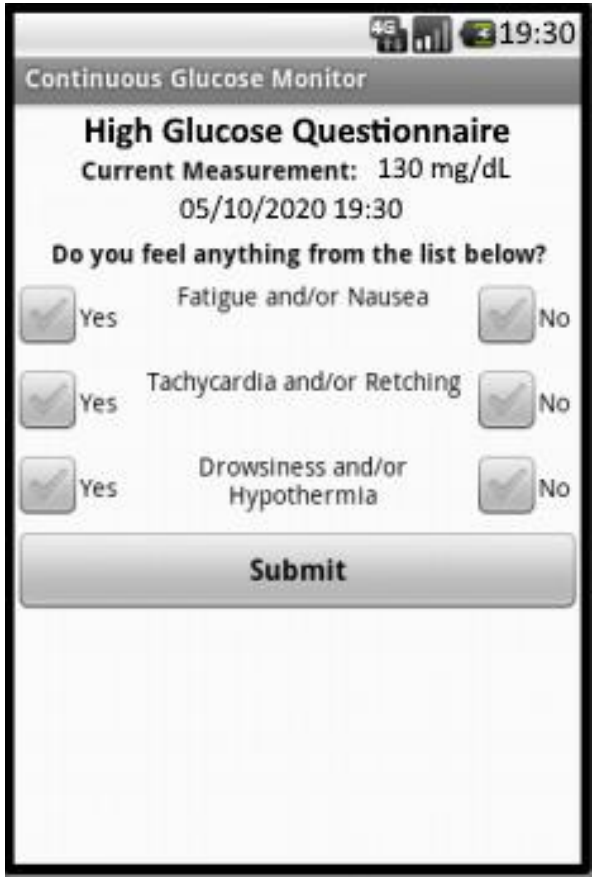


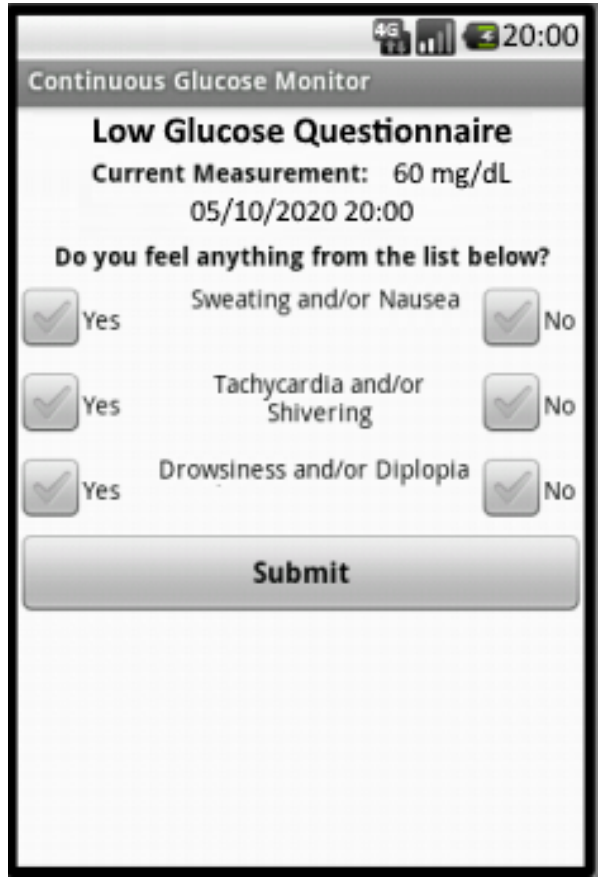
The proposed methodology



The questionnaires implemented for Android devices

- The mobile application deployed to patient's smart device is also used.
- Both the CGM device and the mobile application are interconnected using Bluetooth.
- High Glucose Questionnaire & Low Glucose Questionnaire.





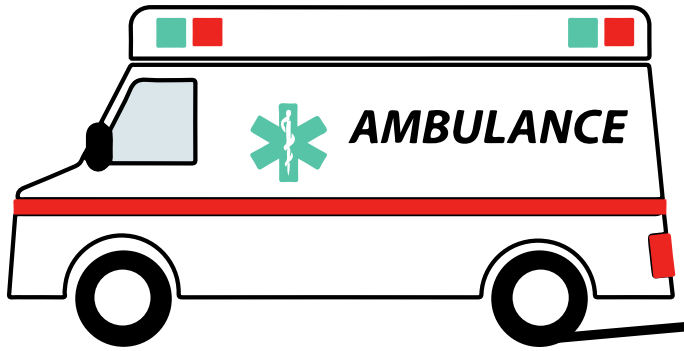
Sample data

Id	Date	Time	Measurement	Status
1	05/10/2020	14:00	65 (mg/dL)	Low Glucose
2	05/10/2020	14:30	70 (mg/dL)	Low Glucose
3	05/10/2020	15:00	80 (mg/dL)	Normal Glucose
4	05/10/2020	15:30	145 (mg/dL)	High Glucose
5	05/10/2020	16:00	140 (mg/dL)	High Glucose
6	05/10/2020	16:30	125 (mg/dL)	High Glucose
7	05/10/2020	17:00	100 (mg/dL)	Normal Glucose
8	05/10/2020	17:30	125 (mg/dL)	High Glucose
9	05/10/2020	18:00	105 (mg/dL)	Normal Glucose
10	05/10/2020	18:30	80 (mg/dL)	Normal Glucose

Data Manipulation Techniques

Conclusion

- Regarding the Proposed Methodology:
  - Whenever a new measurement is performed, the IoT device transmits the measured values to a patients' smart device (e.g. a smartphone).
  - If the patient's glucose levels are Low or High, the smart device communicates with a remote medical infrastructure and triggers an alarm.
  - In order to assure the immediate response of the remote medical staff, the proposed model is deployed upon a 5G wireless network architecture which ensures minimal communication delays.
  - Thus, the medical staff can immediately provide the required care or advice remotely each patient.



Thank you!