APPLICATION FORM FOR PROPOSAL UNDER THE NATIONAL CENTER FOR IoTs GRANTS

1	**Executive Summary** Internet of Things (IoT) in the area of smart health care and medical science has played a major role in the advancement of the facilities and methods used for patients aid. With the IoT, a patient's data could be remotely sent to the health care centers and after its evaluation, a patient could get the treatment or reports without having to physically visit the health care site. In this project, development of an IoT based MEMS sensor has been proposed to detect the low concentration biomarkers from the exhaled breath. This data will be sent to the doctors using the IoT modules, which will be analyzed and based on the doctor's decision, a treatment regime could be advised. The patients data will be saved on the servers, which could be securely accessed by the health care professionals. In this regard, both desktop (Windows based) and mobile (Android based) applications will be developed. Patients with lung and kidney diseases are susceptible to conditions such as Renal Failure, Asthma, Cystic Fibrosis (CF) and Chronic Obstructive Pulmonary Diseases (COPD). Laboratory-based tests to detect these diseases are time-consuming, costly, invasive, and requires the patients to get tested onsite of the health care centers. With the advancement in the medical field, Breath Analysis (BA) has emerged as an alternative, to conventional tests, to detect lung and kidney diseases. Moreover, BAs could also monitor the effectiveness of a treatment regime. The operating principle of the breath monitoring device is that it is sensitive to a specific biomarker and detects it at the pertinent physiological concentrations with excellent precision and accuracy. However, no ideal technique is currently available to reliably measure the biomarkers in clinical setups. Therefore, these shortcomings trigger the need for the development of a simple, low-cost, hand-held and accurate BA device that could detect (in real time) the biomarkers exhaled in the breath. Thus, this research is aimed at the mathematical modeling of a novel Micro-Electro-Mechanical System (MEMS) resonator that could detect biomarkers, in real time and vapor form, in the exhaled breath. Thus, to detect the said biomarkers, the modeling and optimization of the proposed MEMS resonator will be based on the functionalized, active, sensitive and selective receptor polymers. The proposed MEMS resonator will function on the principle that its resonant frequency will change as a consequence of the absorption/adsorption of the target molecules onto

	the functionalized receptors. Based on the operating principle, the hypothesis is put forward that modeling, optimization and validation (using FEM simulations, fabrication and measurement) of the proposed MEMS resonator will lead to the early and timely detection of inflammatory diseases of the lungs and kidneys.

1.1	**Project Title** (Project must be commercially oriented) **AN IOT BASED MEMS SENSOR FOR THE DETECTION OF BIOMARKERS IN EXHALED BREATH**
1.2	**Planned Duration:** _____**36**_____ months

1.3	**Project Proposal (A detailed technical proposal with following sections):** **1. INTRODUCTION** The world has recently seen a tremendous improvement in the field of the health sector. Conventional methods for disease diagnosis and treatments have been swiftly improved using better electronics and modern information and communication technologies. Hospitals, nowadays, are moving towards smart health solutions for fast, reliable and efficient data handling and analysis. Internet of things (IoT) has emerged as a technology that could collect, manage and decide on patient's data. The evolvement of computers and information systems has given a rise to the design and development of electronic devices that are used in the medical sciences. Among many methods and techniques related to the biomedical and health informatics, breath analysis is a technique that has attracted a lot of attention. This is mainly due to the reason that breath analysis is a non-invasive method for the diagnosis of several diseases. This method of breath analysis is to look for the biomolecules in the breath, which indicates the several inflammatory ailments of lungs. In the same manner, the detection of ammonia is linked to problematic lungs, kidneys and bacterial infections of the mouth. The current standard diagnostic methods for lung and kidney diseases are complex and based on laboratory tests. For diagnosis, kidney patients must undergo a variety of invasive and tedious procedures. These include undergoing blood assessments of blood urine nitrogen (BUN) and creatinine. Moreover, before and after the dialysis treatment, the time-consuming computation of urine reduction ratio (URR) is required to determine the endpoint of dialysis. It is performed by extracting 3-5 ml of blood to asses the BUN that is used for the computation of the URR. Similarly, the collection of exhaled breath condensates (EBC) are required to detect the concentrations of the hydrogen peroxide in the exhaled breath. Although these measurements are useful, they are time and labour-intensive and lacks standardization. Moreover, the human skill also plays an important part in the reliability of these offline measurements. It is required to develop a sensitive and specific gas (from breath), it must detect the said parameters at physiologically relevant concentrations, with good precision and

accuracy, in the ppb range. Additional requirements include that an ideal breath analysis device should not be sensitive to interferences, should be portable and easy to use, give results in real-time and should be affordable.

2. THEMATIC AREA FROM SECTION 1.7

SMART HEALTH

3. SYSTEM LEVEL DIAGRAM

The system level diagram of the proposed product is shown in figure 1. The breath sensor is linked to the IoT gateway. The gateway establishes the key functionalities such as data processing, local web server, and cloud connections. The data will be received by the MEMS sensor after which it will be forwarded to an IoT cloud for further data storage, processing and visualization. This data will be available to Doctor (respondent) and the patient (client).

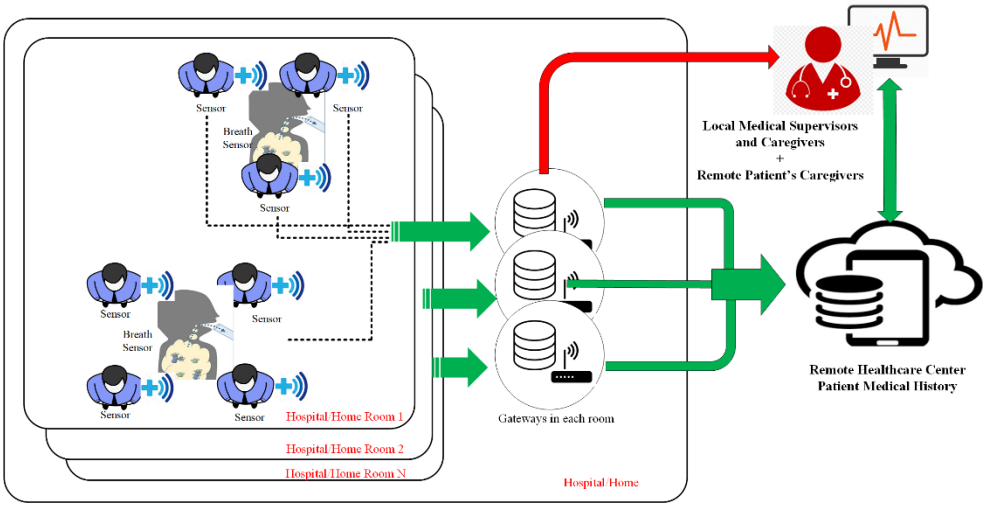

Figure 1. System Level Diagram of the IoT Based MEMS Sensor for the Detection of Biomarkers in Exhaled Breath

4. HW AND SW DESIGN

A. HARDWARE DESIGN

i. Design of the safe node

Each secure node will have a power management unit, one MCU, a LoRa module. The secure node will be supplied with a rechargeable battery, and the voltage regulator

(MCP1810) shall control the battery voltage with a constant voltage of (3.3 V). The MCU will be a Simblee with the built-in BLE function.

The RFM95 LoRa module from HoperRF Electronics will be used in this project. The selected module is a low-power (0.2 μA in sleep mode) and Long-Range (LoRa) transceiver. The LoRa is responsible for the transmission of the long-range data from the MEMS sensor to the remote gateway. The BLE receives the data from the Health Node that is attached to the breath analysis sensor.

ii. Design of Health Node

The Health Node consists of a power management unit, an MCU with BLE (Simblee), and two physiological sensors. A low-power buck-boost converter (RT6150) will be used, for the rest of the circuit, to control the battery voltage at 3.3 V. Breath analysis sensor will be connected to the MCU. Moreover, BLE network (WBAN) will transmit the health parameters to the Safe Node.

iii. Edge Gateway

The hardware architecture of the gateway will comprise One Raspberry Pi Model 3, Wireless modules, Power supply unit.

The Raspberry Pi will be powered by the Raspbian system that is an open-source Linux operating system. Several different languages including Java, Node.js, Python, C and C++ are supported. It requires meager power (2.5 A and 5 V power supply will be used). Since the power requirements are low, they could be easily fulfilled using a portable power bank. Another advantage of the mobile power bank will be that the gateway could be easily relocated without having to be permanently attached to the main power supply. The wireless data from the Safe Nodes will be received using the LoRa module that connected to the Raspberry Pi.

B. SOFTWARE DESIGN

The wearable network will be based on LoRa network. In this way, LoRa will ensure the communication between each safe node. In order to transmit the data from one point to another, LoRa network will be based on a star network topology. The security

will be improved because if the data is not addressed and encrypted, it can be received and seen by all the LoRa nodes in the same region with the same specifications. The security and privacy of the network will be reinforced using data encryption that will be embedded before each packet transmission. 1) Mode of Operation: There will be three operation modes for the safe node, which are Idle mode, transmit mode and low power mode. Each Safe Node will be able to transmit two types of RF packet: class 1 packet and class 2 packet. Class 1 packet data will be transmitted when no biomarkers are detected. This message will be sent to the IoT gateway. Class 2 packet will be transmitted when the targeted biomarkers are detected. This packet will also be transmitted to the IoT gateway. The RF data will be differentiated soon after it is received. This procedure will be carried out using an RF data differentiation function that will check whether the RF data is a warning message with detected biomarkers from the breath analysis device. If it is harmful data, it will notify the user via a smartphone application. Otherwise, the software algorithm will ignore the message and go back to Idle mode. Furthermore, class 1 packet will be generated and transmitted to the IoT gateway if the desired biomarkers are not detected.

5. UI / UX DESIGN OF MOBILE APPLICATION

An IoT based MEMS sensor for the detection of Biomarkers in the exhaled breath is a product that will have an android mobile application and a desktop application for efficient use. The GUI application has a database for storing the data received from the MEMS device and serves as a source of communication between the client and the doctor (server). We will use the Firebase database to store the data on the cloud, which may be served to the doctor for a detailed examination of the client and may also be used for analytical purposes (research). The Firebase Real-time Database has many key features. It is a cloud-hosted, cross-platform and synchronized in real-time to every client connected. Firebase apps remain responsive even when offline. Firebase provides not only cloud storage but also user authentication, in-app messaging, cloud messaging, google analytics, crash report analytics etc. which will be used by the GUI application to provide the best services to its clients.

The GUI application will have two parts:

- **Doctor (respondent) application:**

The data received from MEMS device will be uploaded to the cloud through IoT client to the Firebase Database. We will use an android mobile application and a Desktop application to fetch the data from the cloud server and display it to the doctor. The doctor may then send back a reply as a prescription or advice to the client based on the data received. The doctor may also be able to read the feedback received from the clients to improve the quality of response.

- **Client application:**

The client will instantly receive the reply sent from the doctor and follow up the prescription/ advice. The client may be able to consult back the doctor by using our instant messaging. If the client has any queries regarding the application or the response from the doctor, he may use our feedback form to submit any questions which will be responded shortly.

Key features:

- Reliability
- Easy user interface
- In-app messaging
- Conflicts between the doctor and the client to be assured by our secure Database
- Instant replies saving time
- Feedback queries

6. DEVELOPMENT METHODOLOGY

The research methods and materials that will be used for the proposed research are given below:

Part 1: <u>Selection of Polymers sensitive/selective to intended Biomarkers</u>:

This research will be based on the sensitive and selective detection of the biomarkers. To accomplish such a task, it would be prudent to use materials that are

selective/sensitive to specific biomarkers. Therefore, the study of active materials will be required to detect the ailments related to the lungs and kidneys. The targeted biomarkers will selectively interact with these active materials to evaluate a specific infection. These materials will be studied through the collection of literature. Specifically, research on polymers that are sensitive to the hydrogen peroxide and ammonia will be studied in this phase. After the selection of the appropriate polymer(s), various parameters such as thickness, surface area, etc. will be optimized to enhance their absorption/adsorption volume for the desired biomarkers, which therefore will improve its selectivity and sensitivity. The optimization of the polymers will be followed by a process in which the surface of the MEMS resonators will be functionalized. In this way, the MEMS resonator, by interacting with the deficient concentrations of the target molecules in the exhaled breath, can detect them.

Part 2: <u>Analytical Modeling of the MEMS sensor</u>:

This research will be based on the study of various fields. It includes mechanics, electronics, vibration, waves, and mathematics relevant to all these fields. After the MEMS resonator functionalization with polymer that is sensitive/selective to a specific biomarker molecule, the next step will be to analyze the change in its resonance frequency. This change is due to the absorption/adsorption of a biomarker on the surface of the MEMS resonator platform. Such a change in the resonance frequency, therefore, indicates the detection of the targeted biomarker. The analytical modeling part encompasses equations that could calculate and optimize the dimensions of the tuned resonator. Moreover, the deposition of the polymer, to functionalize the MEMS resonator, will be calculated and studied parametrically. This parametric study on the thickness, length, and volume of active polymers will help to choose optimized values that in turn produce the best parameters to achieve high mass sensitivity. Once mass sensitivity is achieved, it will be possible to detect extremely low concentrations (in parts per billion) of the desired biomarkers.

Part 3: Validation of the MEMS sensor (Simulations & Experiments):

The parameters calculated and optimized, of the MEMS resonator and the sensitive polymer, will be validated using the Finite Element Method (FEM) simulations. The FEM simulations will be performed to validate the changes in the resonance frequency due to the added mass. This added mass will be calculated relative to the mass absorption/adsorption on the active polymer. The comparison between the two results obtained from the analytical modeling and the FEM simulations will indicate that the device is functional and works according to the requirements. The fabrication of the MEMS sensor will be performed using a three-layer polysilicon surface micromachining process. The MEMS sensor will be manufactured using a three-layer polysilicon surface micromachining process. As far as we know, this facility is currently not available in Pakistan. Therefore, the fabrication of the proposed MEMS sensor will be obtained from a cost-effective and reliable fabrication facility abroad.

Part 4. Integration of IoT with MEMS sensor:

After the development of the MEMS sensor, it will be linked to the IoT gateway. The development of the IoT will establish key functionalities such as data processing, local web server, and cloud connections. The data will be received by the MEMS sensor after which it will be forwarded to an IoT cloud for further data storage, processing and visualization.

7. BETA SITE / CUSTOMER FOR DEPLOYMENT

The developed product first will be tested on a group of people identified with kidney or lung diseases at a small vicinity developed at Dawood University. These people will be provided with the product for a stipulated period. These users will be provided with user guidance for right use of the product. The test will not only describe the technical issues faced by these users but also indicate what features to add and what to avoid. The bugs and any issue faced by the users and the feedback collected from them can be used to improve the accuracy of the product.

8. EXPECTED OUTCOME

- MEMS biomarker Architecture
- Exhibit MEMS biomarker functioning
- Identification of the depth of disease instantly at remote areas
- This product will play an important role in the development of the existing healthcare system by introducing MEMS biosensors that detect and measure the lungs and kidney diseases remotely using IoT.
- This project will enable patients to directly use this sensor as a self-care diagnostic without interventions of testing laboratories. Therefore, it can reduce the time taken by test to diagnosis and eliminate the need for samples required for testing.
- It will be applied as a low-cost solution at an individual and also on a population to improve public health care.

9. FINAL PRODUCT

The finished product will be a standalone breath analysis device that will be connected to the IoT gateway. The developed product will be easy to use, cost-effective, connected, non-invasive, convenient and will provide real-time status of lungs and kidneys.

10. TARGET MARKET SEGMENT

The finished product is aimed at improving the methods that are currently in use for the diagnosis of lungs and kidney diseases. This product has the potential to cater to the needs of the masses; this includes both patients with lung and kidney ailments and health care providers.

1.4

How the project will help in knowledge economy & develop made in Pakistan brand?

This project aims to play an essential role in the development of the present healthcare system in Pakistan by introducing MEMS biosensors that can detect and measure the lungs and kidney diseases. Our project provides low-cost, painless, portable, and practical MEMS-based solution that detects lungs and kidney infections from exhaled breath of the patient. This project will add a value-addition product in the medical industry of Pakistan. The project is itself unique in the field of disease diagnosis based on MEMS and rare work has been done on the non-invasive method of detection of kidney and lung diseases. The project can be patented as the applications MEMS devices are increasing in many fields such as automotive industry, biomedical applications.

1.5

Organizations Involved in the Project

Industrial/Commercial Partner Organization:	
Organization Name	xFlow Research Pvt. Ltd
Address	Software Technology Park, Service Rd N, I-9/3, Islamabad, Islamabad Capital Territory.
Academic Organization:	
Organization Name	Dawood University of Engineering & Technology, Karachi.
Address	New M. A. Jinnah Rd, Jamshed Quarters Muslimabad, Karachi, Karachi City, Sindh 74800.

1.6

Industrial/Commercial Partner Organization

Website: www.xflowresearch.com	
Number of Current Employees:	82
Annual Revenue:	Rs. 85 million
Professional Affiliation/Certification: (PSEB/PASHA/CMMI/ISO/Other): PASHA, PSEB	

Portfolio including Core Projects:

1. Open Stack Cloud OS

2. Software defined networks

3. Network function virtualization

4. Security products

5. IoT in smart metering for homes

(you may want to attach a separate document of the company portfolio)

Experience in the area of IoTs or related technologies:

We are also involved with research work around IoT communication protocols, and have published a book titled "Survey of IoT Communication Protocols". It discusses the most popular communication protocols used in IoT; along with their applications, their uses and pitfalls, and so on.

http://xflowresearch.com/wp-content/uploads/2016/02/Survey-of-IoT-Communication-Protocols.pdf

1.7

Thematic Area In IoTs (select target area)

Smart Manufacturing (Industry 4.0)	☐
Smart Agriculture	☐
Smart Health	√
Cyber Security for IoTs	☐
Smart Energy	☐
Smart City (Including Smart Home)	☐
Social and Legal Justice	☐
Others	☐
Others' Details and Importance for Pakistan and Knowledge Economy:	

1.8

Business Plan

Market Size (Both National and International)

According to the Global Burden of Disease (GBD) study, over 750 million people in world are affected by kidney disease, causing 2.4 million deaths annually. Pakistan ranked 8th in the world in kidney diseases and around 17 million persons are suffering from kidney disease.

Potential Users and its Size

Patients who are infected by kidney disease can directly use this proposed MEMs-based sensor and various healthcare laboratories, non-governmental organizations (NGOs) as well as governmental organizations can adopt this project as a non-invasive diagnostic method for detection of diseases related to kidneys.

User for Beta Testing and Deployment if any

The patients affected by kidney diseases and the concerned physicians will be involved for beta testing of the product. Based on the reviews/feedback the product will be made more user friendly. The process of refining the product is eternal and the reviews/feedback from the end users is of utmost importance. We plan to launch it with local hospitals such as Jinnah Hospital.

Revenue Model with the Industrial Partner

70% for university and 30% for industrial partner.

Business Model

We plan to test our beta version at local hospitals and then release the product for the Pakistan market. Future markets include Middle east and Asia.

1.9

Proposed Budget: PKR 1,28,75,000/-

Ser	Head	Amount
1	MEMS fabrication, and characterization	30,00,000/-
2	IoT infrastructure	30,00,000/-
3	-Principal Investigator (@ Rs.120,000/- per year) -Co PI investigator Industry @ Rs. 120,000 -Co-Principal Investigator(@ Rs.100,000/- per year)	3×340,000=10,20,000/-
4	-Professional/Technical Personnel *(Research Associate) Rs.25000/- per month	6×25,000×36=54,00,000/-
5	**Travel within country:** -For projects involving field work -Participation in conferences within country to present the project results	300,000/-
6	-Advertisement for Research Associate	10,000/-
7	Stationary	60,000/-
8	Literature	20,000/-
9	Contingencies, Postage etc.	35,000/-
10	Report Writing and Publications	30,000/-
	Total	1,28,75,000/-

1.10

Project Schedule and Milestones (There must be 3-4 measurable milestones for review and disbursement of funds)

Ser	Activity	Milestone	Duration
1	To plan initial layout and design of MEMS sensor	Completion of Design and Layout of MEMS Sensor.	One Year
2	To validate the initial design of sensor through mathematical modelling and FEA simulations	Completion of Mathematical Modelling of the Sensor and Validation through FEA Simulations	06 Months
3	To work on fabrication and characterisation of the sensor	Completion of Fabrication, Measurements and Testing	06 Months
4	To integrate IoT with the fabricated sensor	Completion of the IoT integration with the sensor and initial test	06 Months
5	To start beta testing	Completion of beta testing with all the bugs removed	06 Months

1.11

Patents In The Relevant Area (from industrial partner or PI, Co-PIs) if any

Patents (Awarded)
1.
2.
Patents (Filed)
1.
2.

1.12

Publications in the Area Of IoTs Or Related Fields (from PI OR Co-PIs) if any

1.13

Project Team:

Title / Position (please change titles as required)	***Number***
PI from Academia	Dr. Arsalan Ansari
Co-PI from Industry Co-PI from Academia	Fazal Rehman Khan Dr. Ramesh Kumar
Planned positions (names are not required) for execution of the project, and their distribution from the industry and academia	
Quality Assurance Head (will be provided by PMU)	

1.14

Additional Information Regarding Previous Funding Sources

Has this project or the activities proposed previously been submitted for funding, or has already received funding?	Yes ☐ No ☑
If yes, Please provide details here.	

The following are important points.

1. This project will be closely monitored by the project management unit (PMU)
2. A Quality Assurance (QA) Head will be directly hired by the PMU office and will lead the QA and shall closely work with the team.
3. The project should use Agile Methodology on scrum model. The tool for project management shall be provided by PMU to get visibility in the development.

2	**Contact Details**		
2.1	Applicant	Applicant's Academic organization / institution	Dawood University of Engineering & Technology, Karachi.
	☑ Mr. ☐ Ms.	Applicant (name)	Dr. Arsalan Ansari
		Functional Title	Assistant Professor/Chairperson
		Section / Department	Department of Electronic Engineering
		Address	Department of Electronic Engineering, DUET, Karachi.
		Phone	03435813424
		Fax	
		E-Mail	dr.arsalanansari@duet.edu.pk
		Website address (if available)	

2.2	Project Industrial / Commercial Partner Organization's Representative	Name of the organization / institution	xFlow Research Inc.
	☑ Mr. ☐ Ms.	Representative name	Fazal Rehman Khan
		Functional Title	Vice President
		Section / Department	Engineering
		Address	Software Technology Park, Service Rd N, I-9/3 I 9/3 I-9, Islamabad, Islamabad Capital Territory.
		Phone	+92-312-513-5260
		Fax	
		E-Mail	fazal.rehman@xflowresearch.com
		Website address (if available)	http://xflowresearch.com/
2.4	Applicant Certification		
	I certify that the information provided in this application, including all enclosures, is accurate and relevant.		
	☑ Mr. ☐ Ms.	Name and title	Dr. Arsalan Ansari
	Date and signature	1/11/19	

Dawood University of Engg & Technology Karachi
CHAIRMAN
Department of Electronic Engg
New M.A Jinnah Road

2.5 CEO/Head Of Industrial Partner Organization Certification

I certify that the information regarding the industrial partner organization provided in this application, including all enclosures, is accurate and relevant and we are willing to participate in this project.

☑ Mr. ☐ Ms.	Name and title	~~Ashok Malani~~ FAZAL REHMAN KHAN
Date and signature Stamp		Fazal Khan NOV 1, 2019

2.6 Vice-Chancellor/Rector/ Head Of The Academic Organization Certification

I certify that the information regarding the academic organization provided in this application, including all enclosures, is accurate and relevant and we are willing to participate in this project.

☑ Mr. ☐ Ms.	Name and title	Dr. Faizullah Abbasi
Sign and Date, Stamp Vice Chancellor Dawood University of Engineering and Technology, Karachi-74800		1/11/2019