

# IoT in Healthcare: Using the PI System for Continuous Patient Monitoring

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UNIVERSIDAD  
DE GRANADA



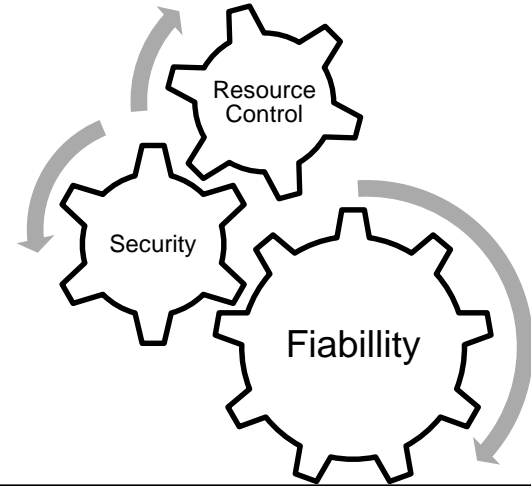
# Agenda

- About Granada University & Research Group
- Motivation
- The evolution from eHealth to uHealth. Monitoring
- Healthcare System
- PI system infrastructure
- Study case: COPD.
- Conclusion and Future works

# Granada University, Concurrent Systems Research Group

- The University of Granada was officially founded in 1531 by Carlos I of Spain.
- It is the fourth university in Spain by number of students, member of the Coimbra Group and Campus of International Excellence.
- The University of Granada is among the top ten in Spain.
- Globally, it is one of the top fifty universities in computer engineering and one of the top hundred in mathematics.

## Concurrent Systems Research Group



Hardware

Industrial System

Communications

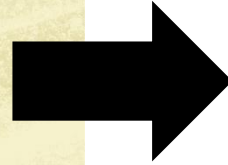
Middleware  
Frameworks

Software,  
semantics and  
reasoning, final  
applications.

# Motivation

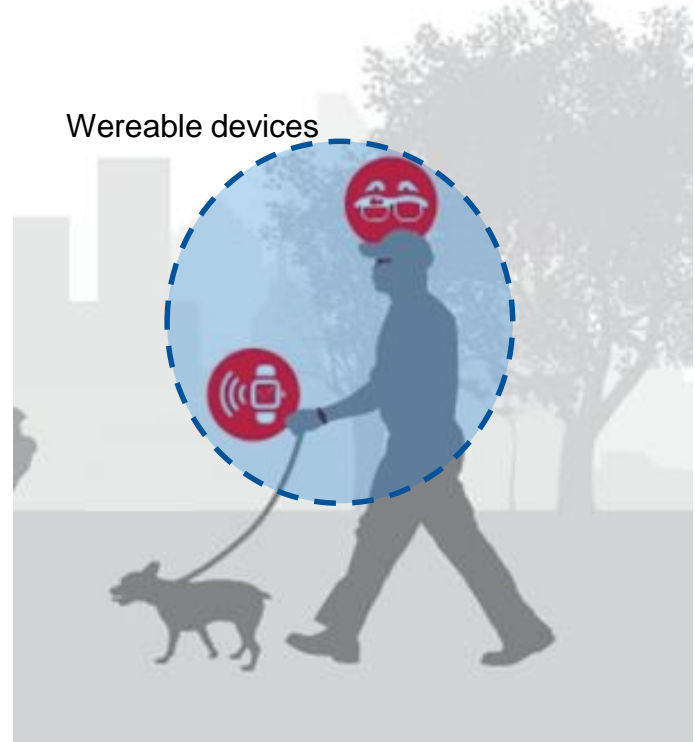
- Hospital health systems are expensive and have to attend a greater number of patients each day.
- Monitoring systems can reduce the cost of healthcare by taking monitoring outside the hospital environment.
- There are many diseases that require a continuous treatment (periodic visits in hospital) such as COPD.

# Traditional Monitoring System



## Online Monitoring system

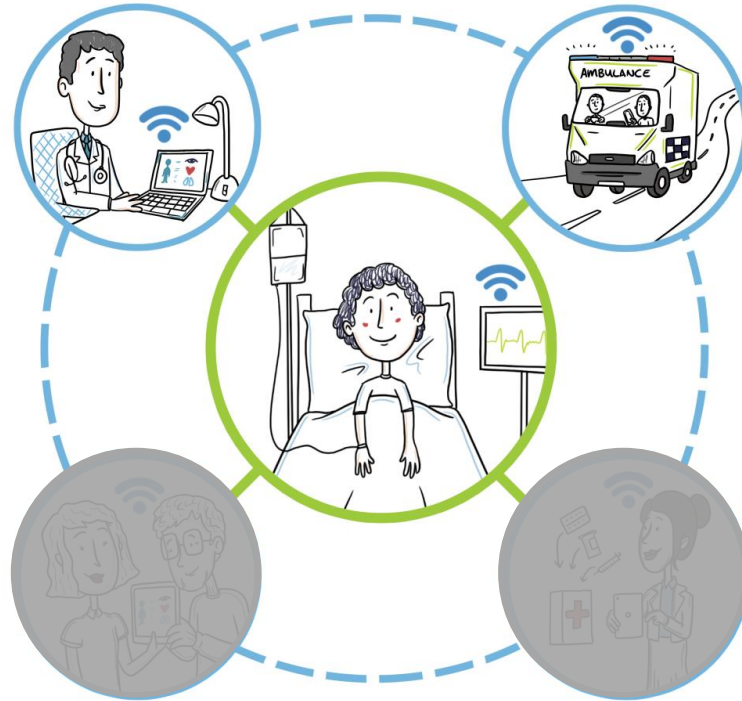
Wearable devices



# Evolution: E-Health, M-Health, U-Health

## E-Health System.

(Electronic)



# Evolution: E-Health, M-Health, U-Health

## M-Health System. (Mobile)



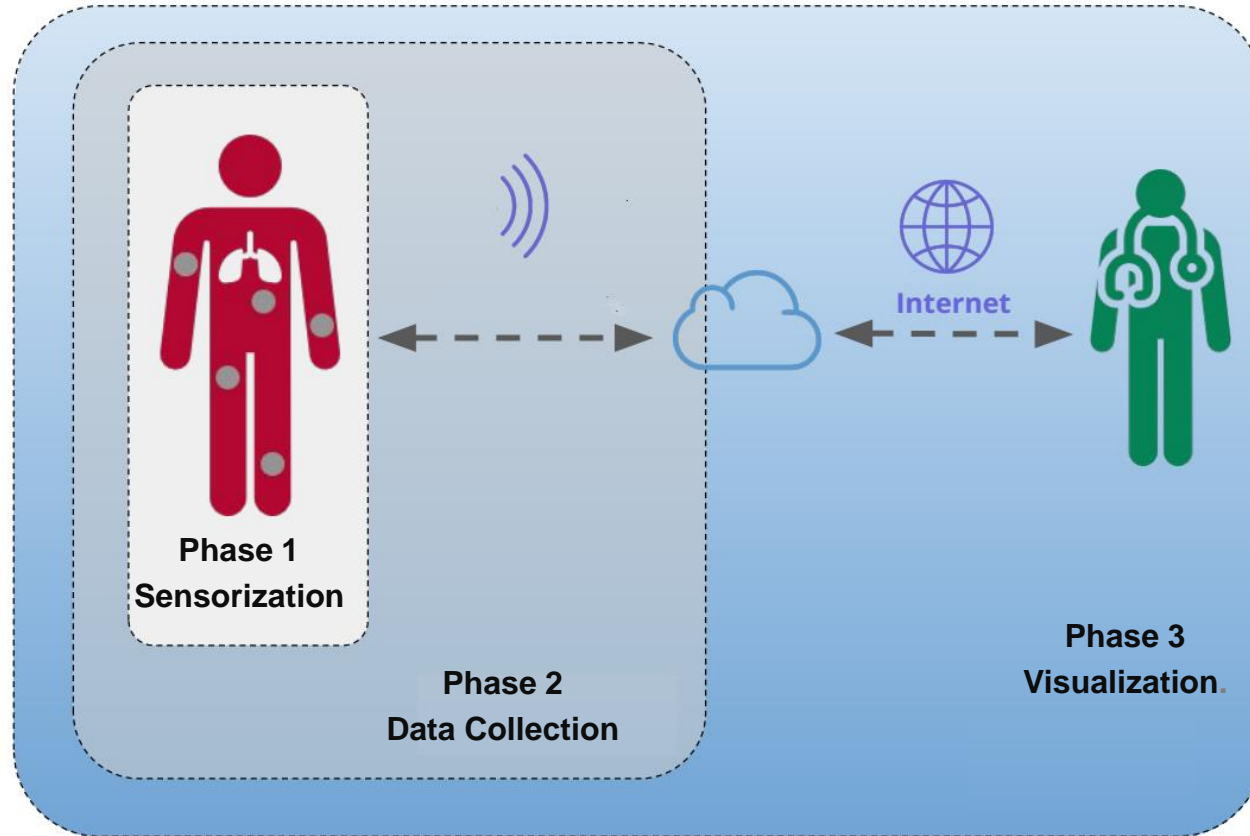


# Evolution: E-Health, M-Health, U-Health

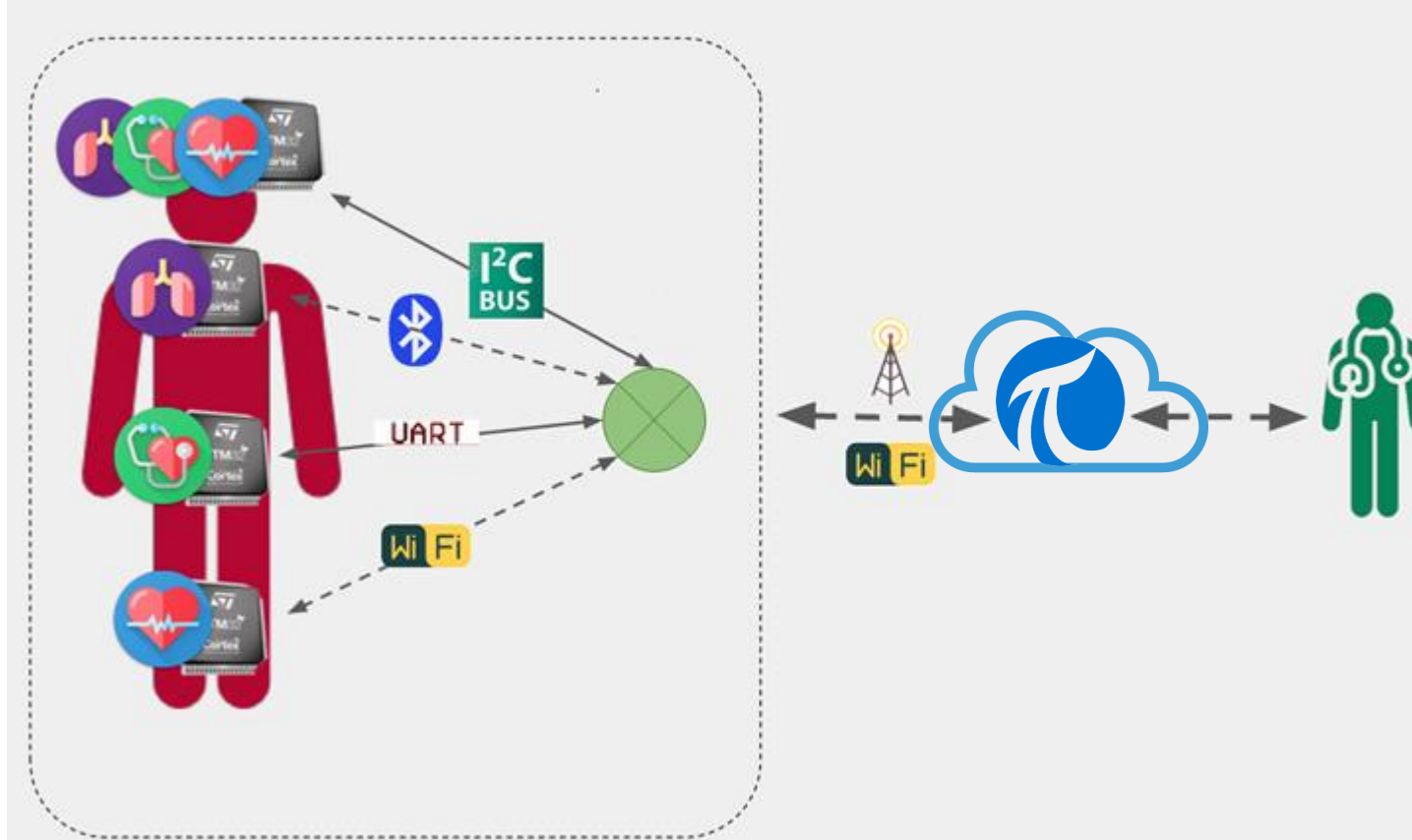
## U-Health System. (Ubiquitous)



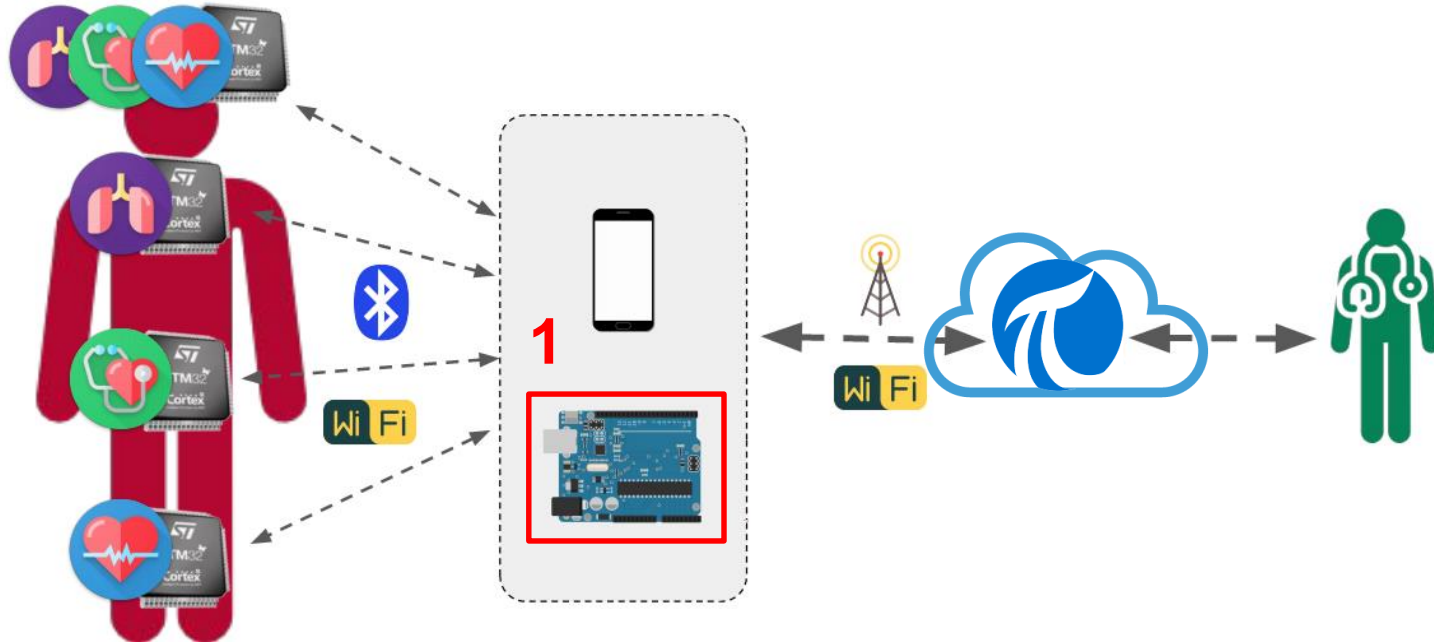
# uHealth Infrastructure



# uHealth Infrastructure: Monitoring



# uHealth Infrastructure: Monitoring



# uHealth Infrastructure: First approach

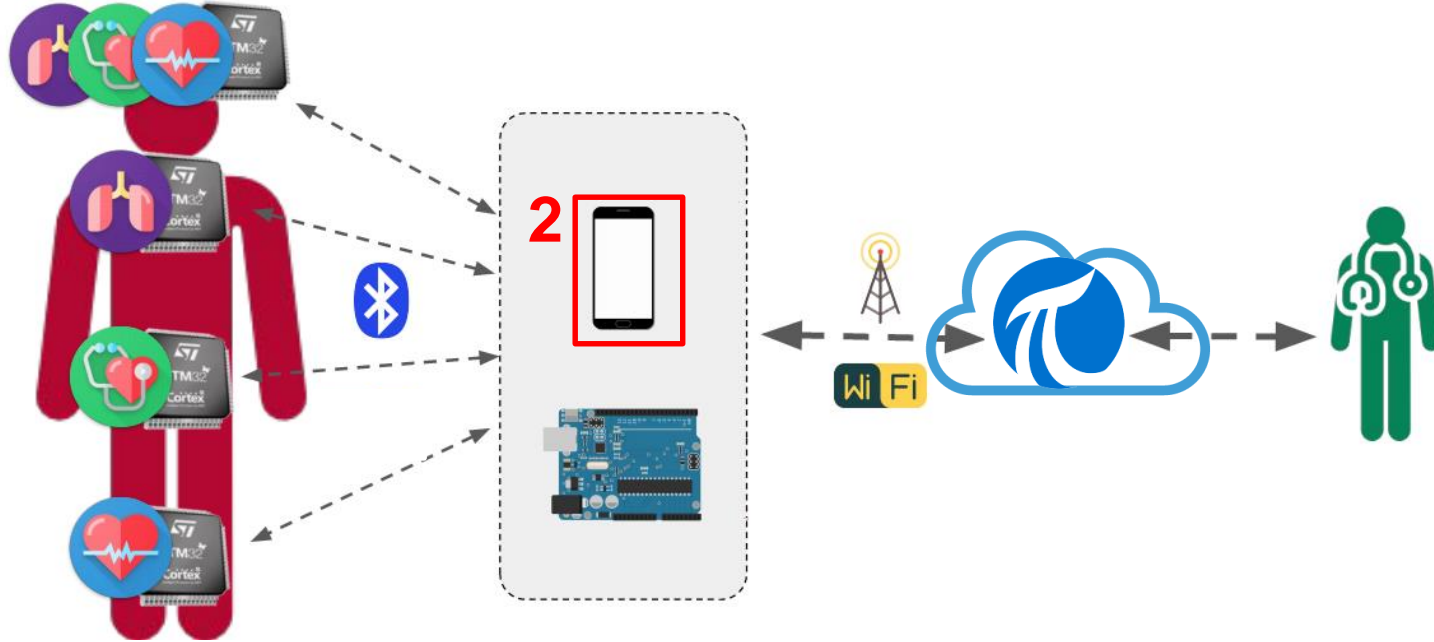
- **Features**

- ☐ Using special embedded devices (Arduino-based)
- ☐ All sensors are connected to these devices.
- ☐ The data are monitored and stored into a local PC.

- **Features that need improvements:**

- ☐ Complexity of the system.
- ☐ Use of standard devices such as smartphone.
- ☐ The storage of the data in remote systems.
- ☐ Organization of the patient data.

# uHealth Infrastructure: Monitoring



# uHealth Infrastructure: Second approach

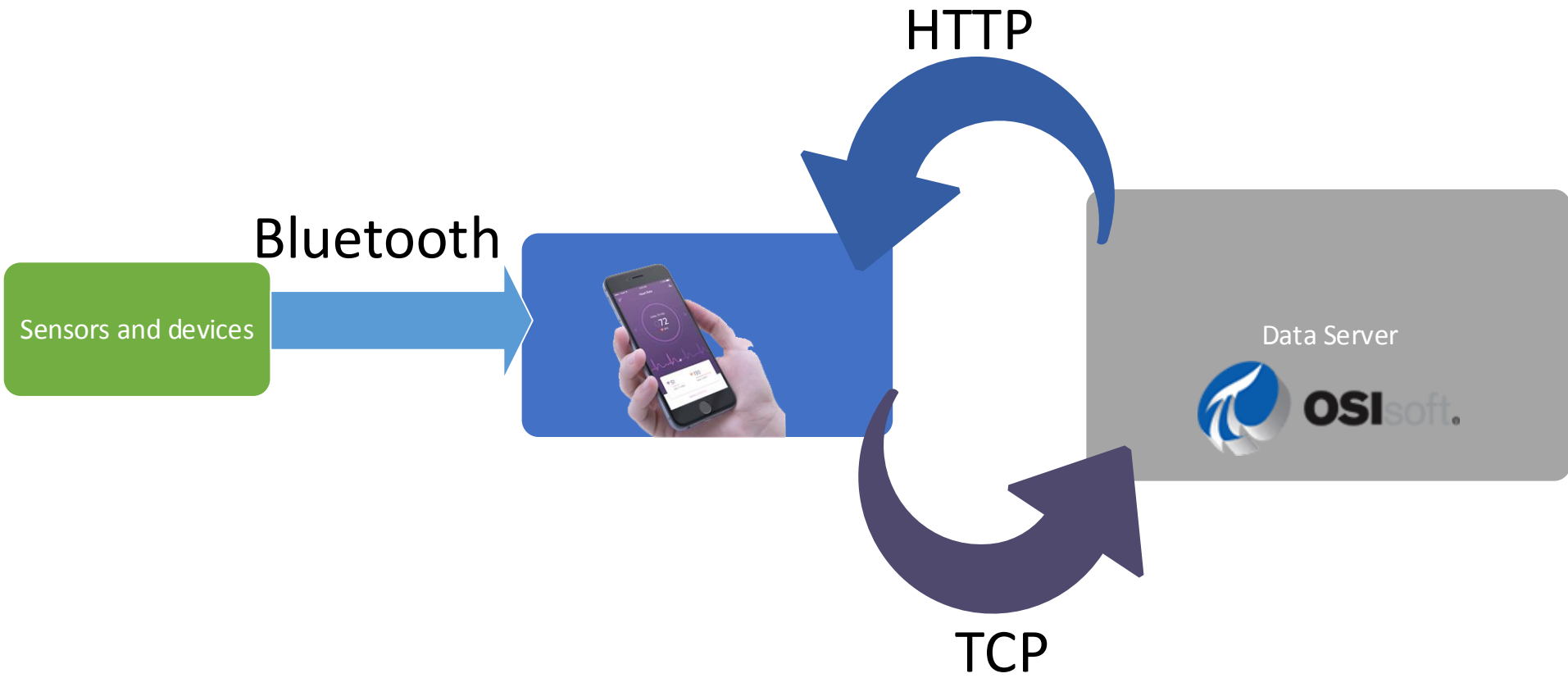
- **Features**

- ☐ Use of standard devices for monitoring and storing data.
- ☐ All sensors are connected to these devices (Bluetooth)
- ☐ The data are monitored and stored in a remote system.
- ☐ The system complexity is reduced.

- **Features that need improvements:**

- ☐ How the data is organized?
- ☐ How the information is exploited?
- ☐ Security of data.

# uHealth Infrastructure: Backend





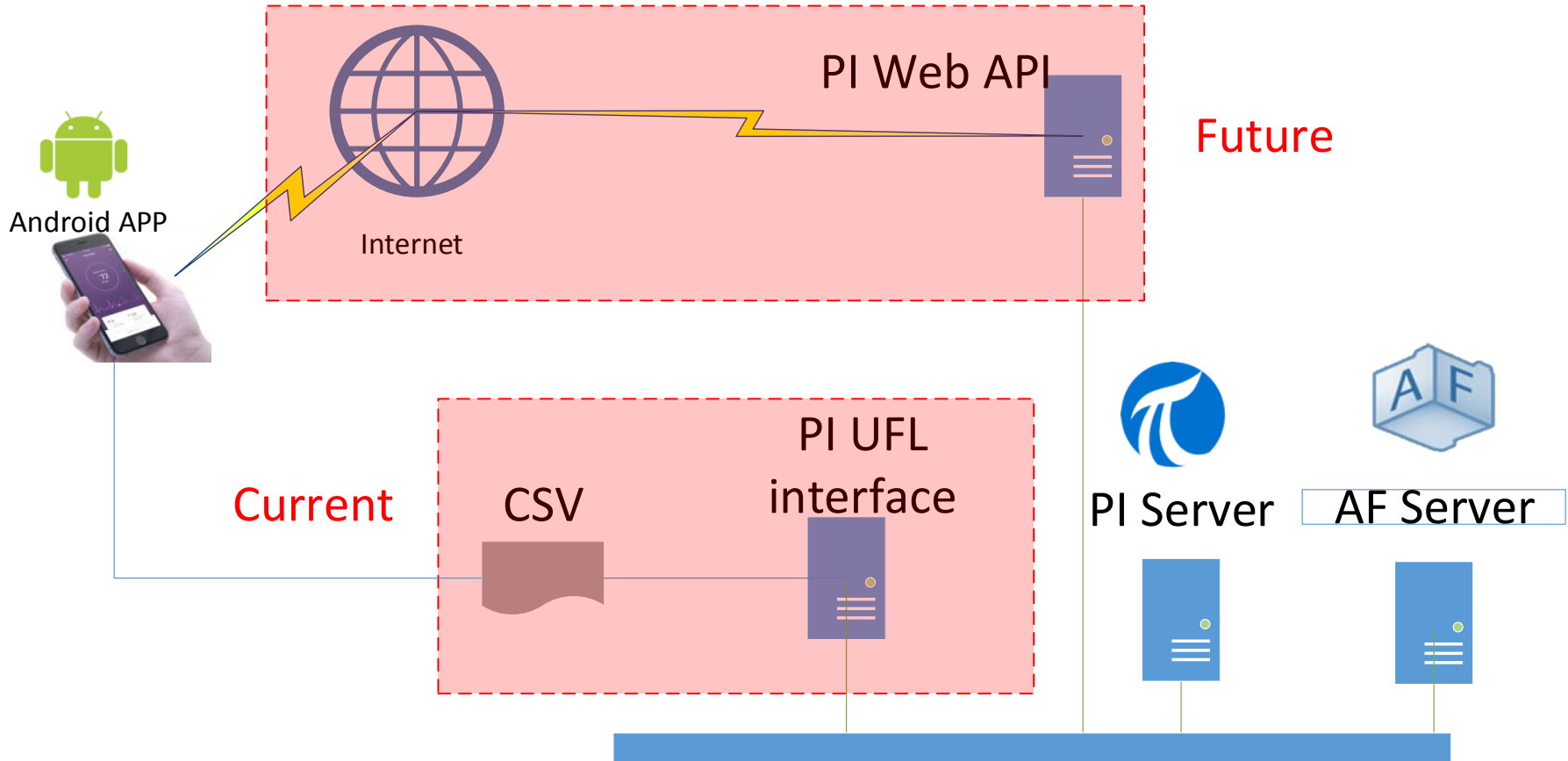
# PI system infrastructure

- It is necessary to build a robust and flexible platform to store the data of the uHealth infrastructure.
- Also this platform must provide tools for:
  - ✓ High availability and capacity to store any information type.
  - ✓ Organizing data in order to identify patients data easily
  - ✓ Providing mechanisms to exploit data and build analysis with them.

Our approach uses PI system



# PI system infrastructure



# Data Model in PI: AF structure (ElementTemplate).

Library

- BIOMEDICAL
  - Templates
    - Element Templates
      - PatientTemplate**
      - Event Frame Templates
      - StressTest
    - Model Templates
    - Transfer Templates
  - Enumeration Sets
  - Reference Types
  - Tables
  - Table Connections
  - Categories
    - Analysis Categories
    - Attribute Categories
    - Element Categories
    - Notification Rule Categories
    - Reference Type Categories
    - Table Categories

PatientTemplate

General Attribute Templates Ports Analysis Templates Notification Rule Templates

Filter

	Name	Description	Default Value
Category: BiomedicalData			
	BO	Blood Oxygen	0
	BPD	Diastolic Blood Pressure	0
	BPS	Systolic Blood Pressure	0
	HR	Patien Heartbeats	0
Category: DataTest			
	Duration	Test Duration length	0 m
	FC	Heart rate(lpm)	0
	FCxTA	*100	0
	Incline	Treadmill Inclination	0 %
	METS	Work	0
	Speed	Treadmill Speed	0 km/h
	TAD	TA Diastolic (mmHg)	0
	TAS	TA Sitolic (mmHg)	0
	TestStart	Flag to Start the Test	False
Category: PersonalData			
	Age	Patient Age	0
	Gender	Patient Gender (Male Fe...	<gender>
	Height	Patient height	0 cm
	Identifier	Patient Identifier like so...	00001
	Name	Patient Nombre	<surname,name>
	Weight	Patient weight	0 kg

# Data Model in PI: AF structure (Analysis Template).

The screenshot displays the PI AF (Analysis Framework) interface. On the left is a tree view of the 'Library' structure, including categories like BIOMEDICAL, Templates, Element Templates, PatientTemplate, Event Frame Templates, StressTest, Model Templates, Transfer Templates, Enumeration Sets, Reference Types, Tables, Table Connections, Categories, Analysis Categories, Attribute Categories, Element Categories, Notification Rule Categories, Reference Type Categories, and Table Categories.

The main window is titled 'PatientTemplate' and has tabs for General, Attribute Templates, Ports, Analysis Templates, and Notification Rule Templates. The 'Analysis Templates' tab is active, showing the configuration for a 'StressTest' analysis template.

Configuration details for 'StressTest':

- Name: StressTest
- Description: (empty)
- Categories: (dropdown menu)
- Analysis Type: ☐ Expression ☐ Rollup ☒ Event Frame Generation ☐
- ☒ Start analyses when created from template
- [Create a new notification rule template for StressTest](#)

Example Element: [Spain\Andalucia\Granada\HP Inmaculada\Patient1](#)

Event Frame Template: StressTest

Below the configuration, there is a table for defining triggers:

Name	Expression	True for	Severity	Value at Evaluation	Value at Last Trig
<b>Start triggers</b>					
Start	'TestStart' = "true"	Set (optional)	None		
<b>End trigger</b>					
EndTrigger	'TestStart' = "false"				

# Data Model in PI: AF structure (EventFrame Template).

The screenshot displays the OSISoft software interface for configuring an EventFrame Template. On the left, a 'Library' pane shows a hierarchical tree of templates, with 'StressTest' selected under 'Event Frame Templates'. The main area is titled 'StressTest' and contains a 'General' tab and an 'Attribute Templates' tab. Below the tabs is a 'Filter' bar and a table listing attributes for the 'DataTest' category.

Name	Description	Default Value
Category: DataTest		
Duration	Test Duration length	0 m
FC	Heart rate(pm)	0
FCxTA	*100	0
Incline	Treadmill Inclination	0 %
METS	Work	0
Speed	Treadmill Speed	0 km/h
TAD	TA Diastolic (mmHg)	0
TAS	TA Sitolic (mmHg)	0
TestStart	Flag to Start the Test	False

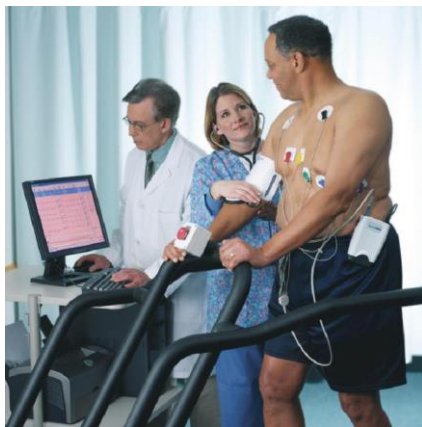
# Study case: COPD (*Chronic Obstructive Pulmonary Disease*)

- **COPD** : Obstruction of the airways in a progressive and non-reversible manner, with a decrease in respiratory capacity that can lead to death:
  - ❑ 65 million suffer from it in the world.
  - ❑ 3 million deaths a year.
  - ❑ 18 thousand deaths in Spain.
  - ❑ 90% of deaths in low-income countries.
  - ❑ Smoker disease: Appears in 20% to 25% of the total.

# Clinical Study

## Stress Test :

- ☐ % Oxygen in blood.
- ☐ Heart Beats.
- ☐ Blood pressure.
- ☐ Speed
- ☐ Inclination
- ☐ Distance



- Hospital Inmaculada (Granada)
- Participants: 18 patients
- Medical Staff:
  - Pedro Romero (Pneumology).
  - Luis Arrebola Moreno (Cardiology)
- Technical: José Francisco Matas

# Study case: COPD

## Set of parameters to monitoring (continuously):

- ☐ % Oxygen in blood.
- ☐ Heart Beats.
- ☐ Blood pressure.



Elements

Elements

Spain

Andalucia

Granada

HP Inmaculada

Patient1

Patient2

Patient3

Patient4

Patient5

Patient6

Patient7

Patient8

HP Virgen de las Nives

Element Searches

Patient4

GeneralChild ElementsAttributesPortsAnalysesNotification RulesVersion

Filter

NameValue

Category: BiomedicalData

BO99

BPD160

BPS99

HR122

Category: DataTest

Duration15 m

FC111

FCxTA188

Incline0 %

METS1

Speed0 km/h

TAD80

TAS170

TestStartFalse

Category: PersonalData

Age66

GenderFemale

Height0 cm

Identifier00004

Namexxxxx,x

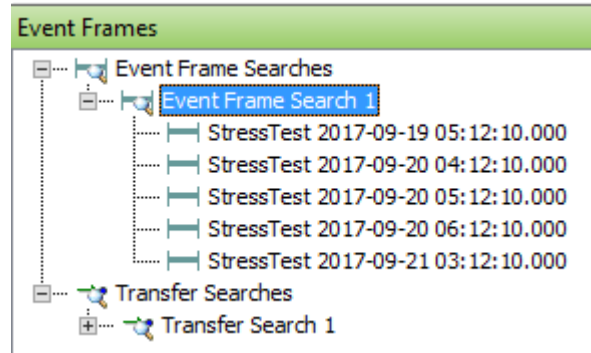
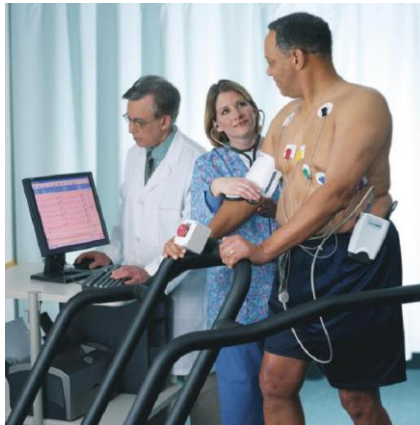
Weight0 kg



# Study case: COPD

## Stress Test :

- ☐ % Oxygen in blood.
- ☐ Heart Beats.
- ☐ Blood pressure.
- ☐ Speed
- ☐ Inclination
- ☐ Distance

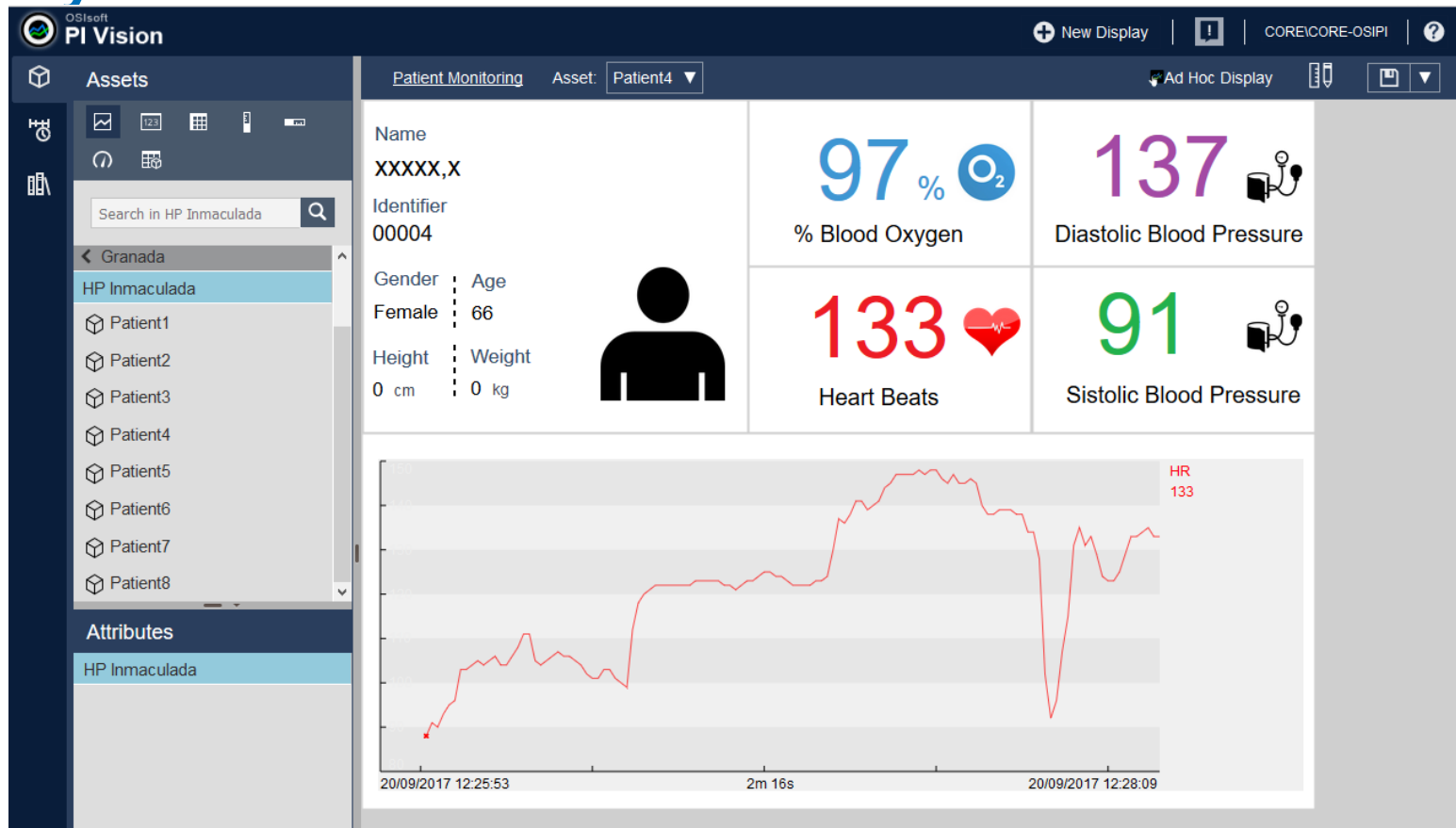


Event Frame Search 1

Filter

	Name	1 [1.22:10:02]	Duration	Start Time	End Time
	StressTes...		0:13:10	19/09/2017 14:12:10	19/09/2017 14:25:20
	StressTes...		0:14:40	20/09/2017 13:12:10	20/09/2017 13:26:50
	StressTes...		0:14:40	20/09/2017 14:12:10	20/09/2017 14:26:50
	StressTes...		0:14:40	20/09/2017 15:12:10	20/09/2017 15:26:50
	StressTes...		0:10:02	21/09/2017 12:12:10	21/09/2017 12:22:12

# Study case: COPD PI Vision Dashboard



# Summary

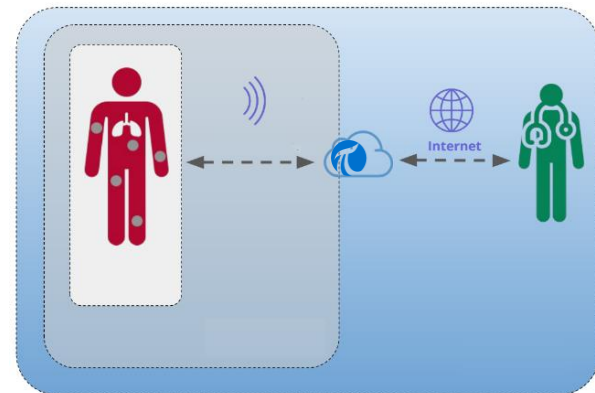
## COMPANY and GOAL

Company: Research group in real time and Industrial systems

Goal: To achieve an U-Health system using wearable devices with a robust platform to exploit the information.



Granada University



## CHALLENGE

1. Create a robust sensorization system.
2. Build flexible and simple data collection system
3. Plan the organization and persistence of data
4. Exploit the information to create predictive and visualization system

## SOLUTION

1. Development of uHealth Infrastructure based on wearables devices and smartphones.
2. Using PI system to store and organize the information
3. Develop a visualization and prediction system with PI tools and SDKs

## RESULTS

1. App in Android to collect the data coming from wearables devices through Bluetooth.
2. Continuous monitoring system for chronic diseases.
3. Use PI system to development of a U-Health system for COPD.

# Conclusion

- The PI system offers a powerful platform to:
  - ❑ Store and collect data.
  - ❑ Organize information coming from different sources.
  - ❑ Provide Robust and High availability platform.
  - ❑ Achieve flexibility to exploit de data, get several SDKs and connectors for developing and programming.
- We need to store huge amounts of data in a robust, accessible and manageable way in order to deal with this data (Timely data).
- The study will correlate the monitored data with the evolution of the disease; that is important for therapeutic treatment.

# Future Works

- Use PI analytic tools analytic tools to analyze the collected data (Predictive system).
- Use the same architecture to monitoring cardiovascular diseases.
- Study the application of the PI uHealth solution to other areas (e.g., sport monitoring).
- Collaborate with technology companies, universities and public health systems.

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University Professor

Granada University



## Questions

Please wait for the **microphone** before asking your questions

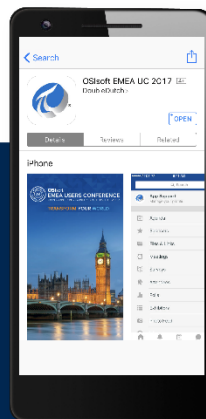


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감사합니다

Danke

谢谢

Merci

Gracias

**Thank You**

ありがとう

Спасибо

Obrigado