International Conference on Fourth Industrial Revolution Technologies for Sustainable Development

UNITED NATIONS ESCAP
Economic and Social Commission for Asia and the Pacific
Asian and Pacific Centre for Transfer of Technology (APCTT)

Ministry of Science and Technology
Department of Scientific and Industrial Research

Disruptive 4IR applications in medical/healthcare services to combat COVID-19 in Asia-Pacific

Seminar on 4IR, UN, Nov 30, 2021

Harnessing power of IoT for Healthcare System

Subhas Mukhopadhyay, FIEEE, FIEE, FIETE

Professor of Mechanical/Electronics Engineering

School of Engineering

Macquarie University, NSW 2109, Australia

Seminar on 4IR, UN, Nov 30, 2021

Macquarie University

Based in Sydney

State-funded University

Established in 1964

Ranked #12 in Australia
#195 in the world (*Times Higher Education World University Rankings, 2021*)

Over 40,000 students

- including over 8,500 international students (from 120 countries)
- Over 2000 postgraduate research students

- WiFi 802.11a

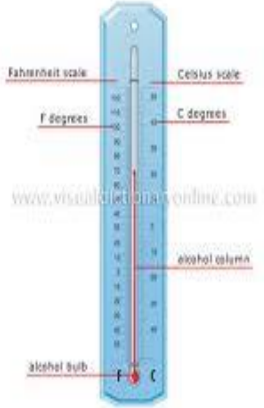
CSIRO

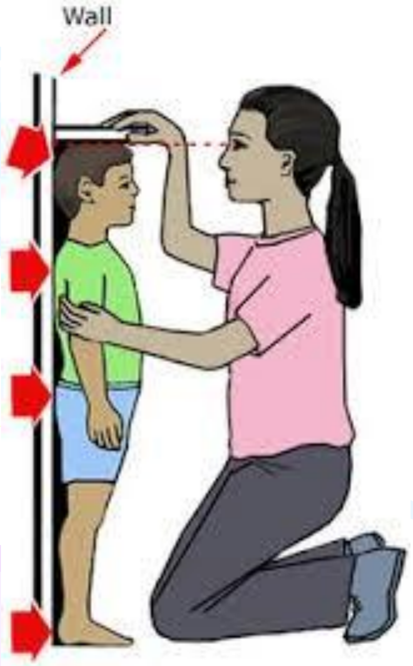
Prof David Skellern and Prof Neil Weste

https://www.mq.edu.au/study/international-students/why-study-here/our-reputation/university-rankings

https://www.mq.edu.au/research/research-expertise/Research-innovation/where-wi-fi-began

Sensing devices around us

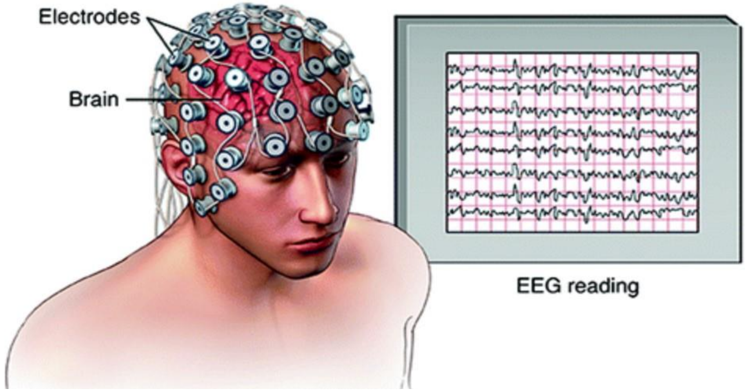


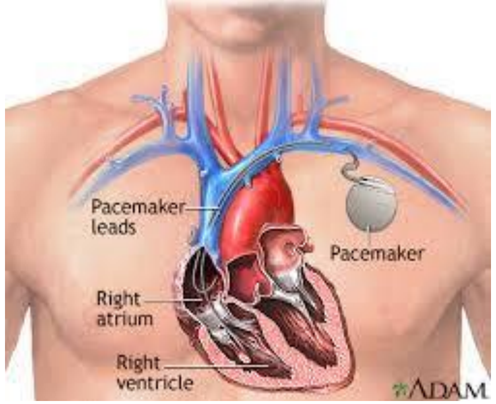


"If you cannot measure it, you cannot improve it."

Lord Kelvin, 1824-1907

Medical devices for keeping us safe

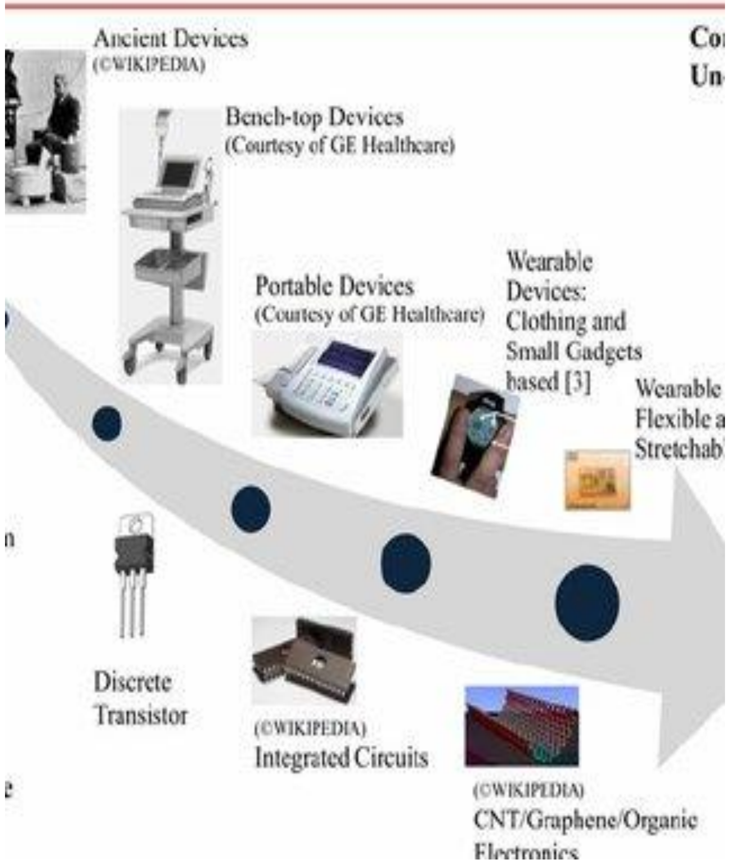


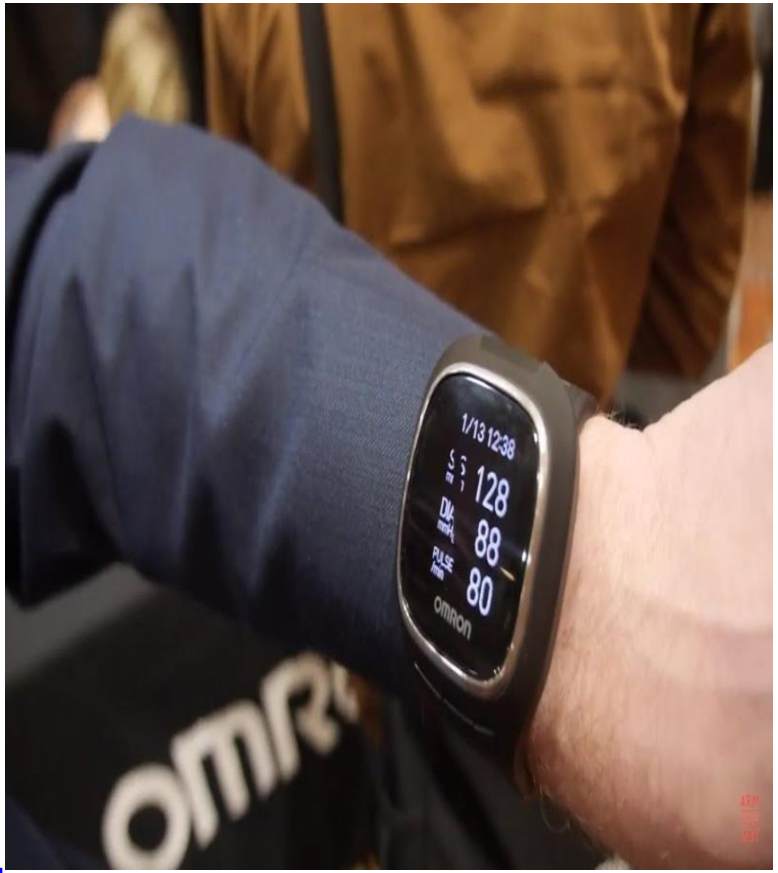


Wearable Device

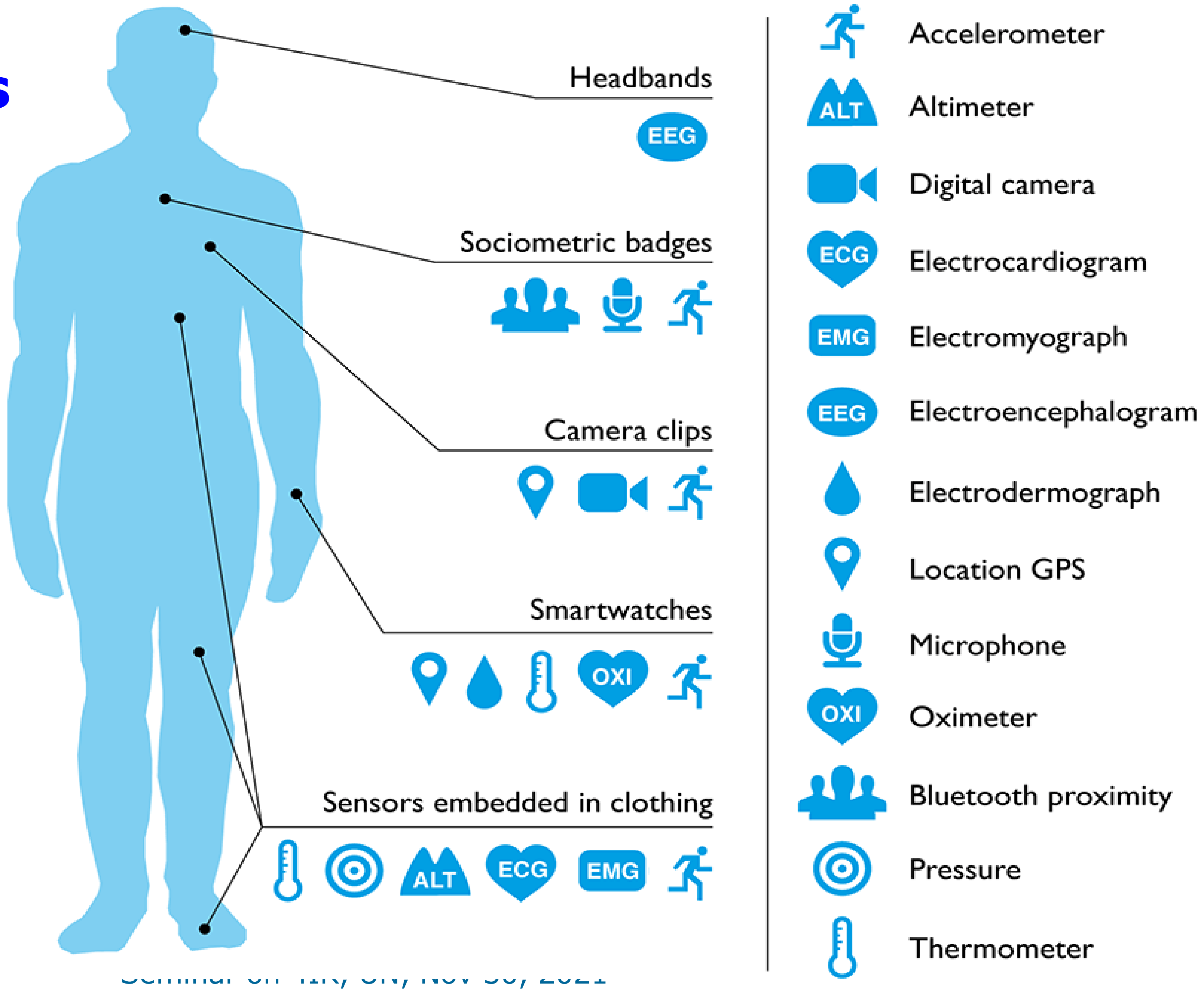
A wearable device is a technology that is worn on the human body. This type of device is small enough to wear and includes powerful sensor technologies that can collect and deliver information about their surroundings.

Wearable devices are also known as wearable gadgets, wearable technology or simply wearables.





Wearable devices



Role of wearable sensor to tackle COVID-19 or similar

IoT Based continuous monitoring of physiological parameters

Computation can be done in the cloud

Warning signals can be detected and send to GPs/caregivers

Most common symptoms:
- Fever
- dry cough
- Tiredness

Serious symptoms:
- difficulty breathing
- shortness of breath
- chest pain or pressure
- loss of speech or movement

A wearable system consists of
- Body temperature
- Breathing rate
- Heart rate
- Body conductance
- ECG
- Accelerometer

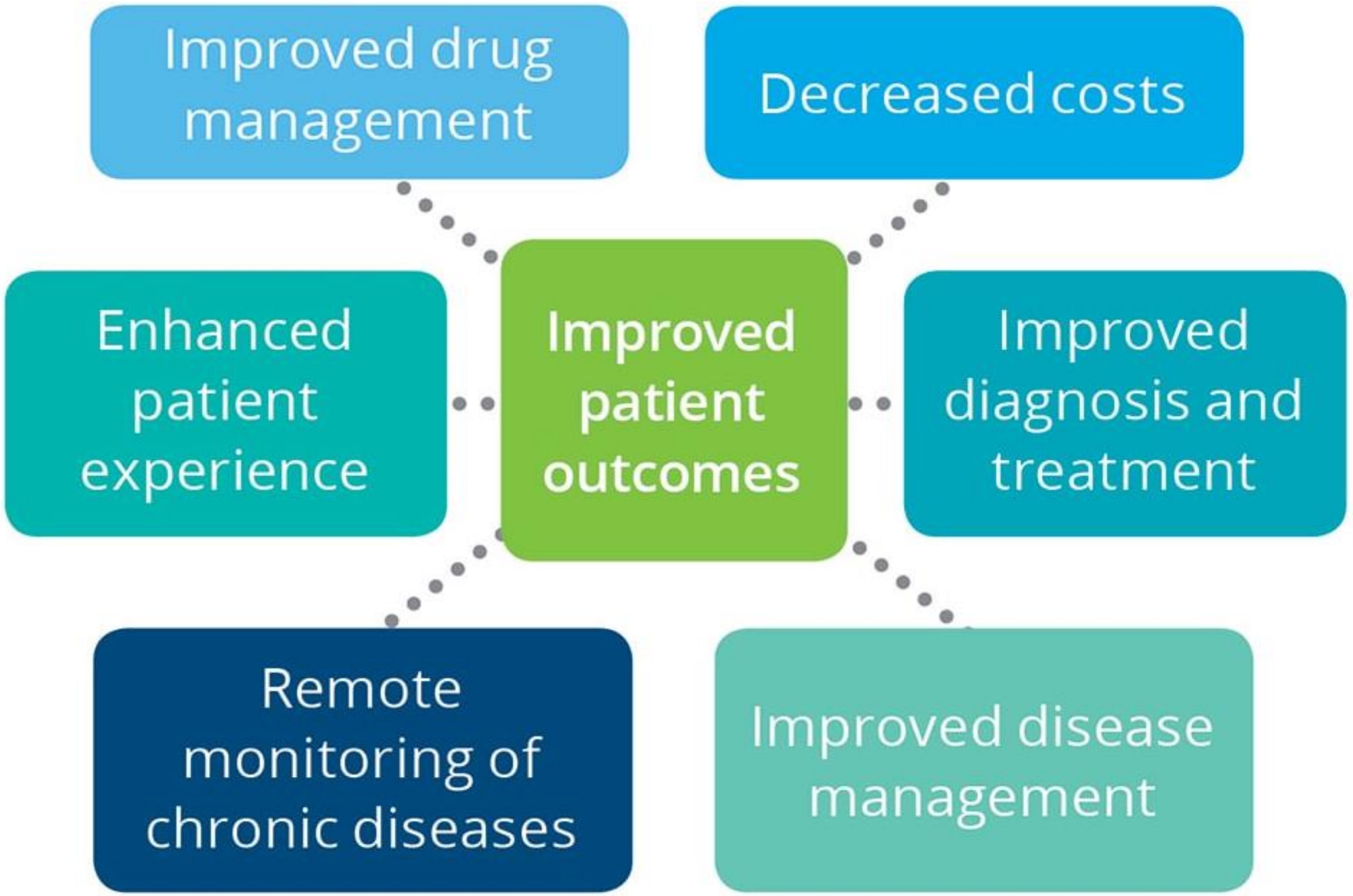
Less common symptoms:
- aches and pains
- sore throat
- diarrhoea
- conjunctivitis
- headache
- loss of taste or smell
- a rash on skin, or
- discolouration of fingers or toes

IoT for healthcare?

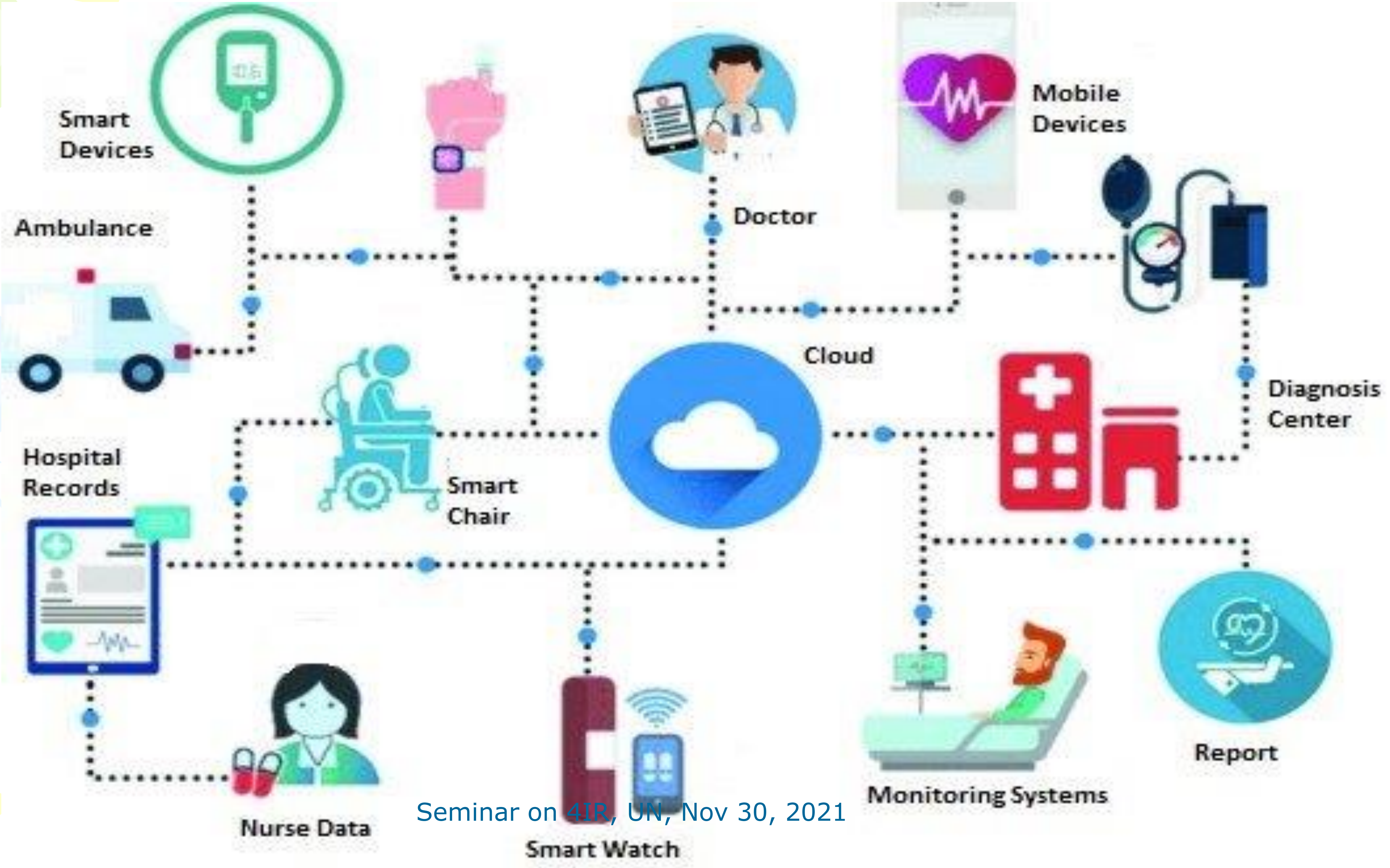
From diabetic testing kits to surgical instruments, artificial joints and MRI scanners, the medical technology (medtech) industry designs and manufactures a wide range of products. Technology is allowing these devices to generate, collect, analyse and transmit data, creating the Internet of Medical Things (IoMT) – a connected infrastructure of health systems and services.

The IoMT and its relationship to medtech is instrumental in helping health care organisations achieve better patient outcomes, lower climbing health care costs, improve efficiency and activate new ways of engaging and empowering patients. The pace and scale of health care transformation will be exponential if Medtech can harness the IoMT.

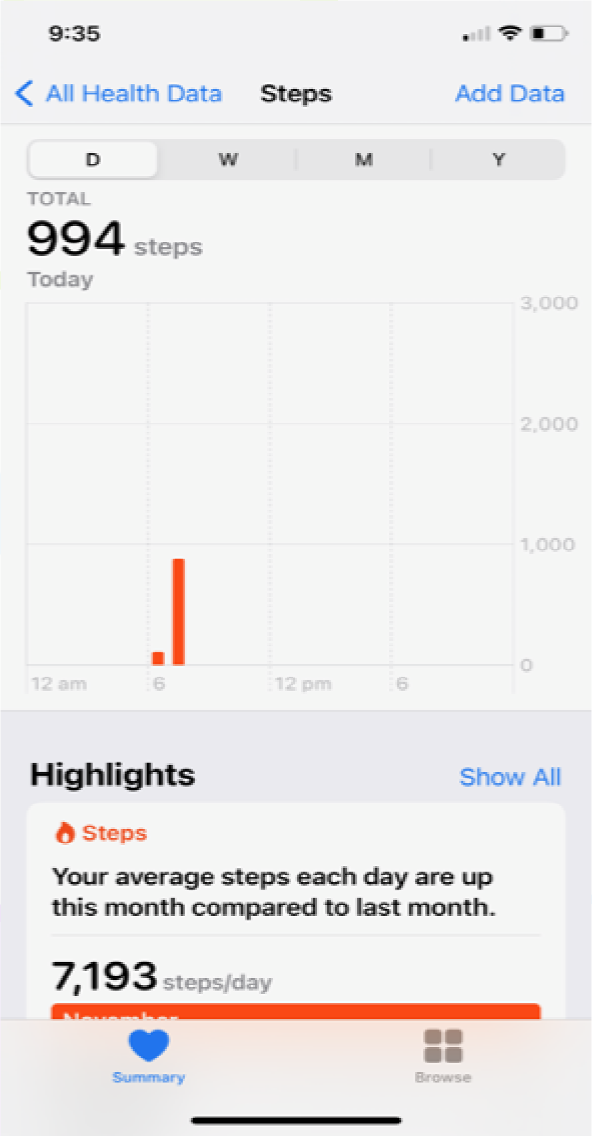
Benefits of IoT Enabled healthcare

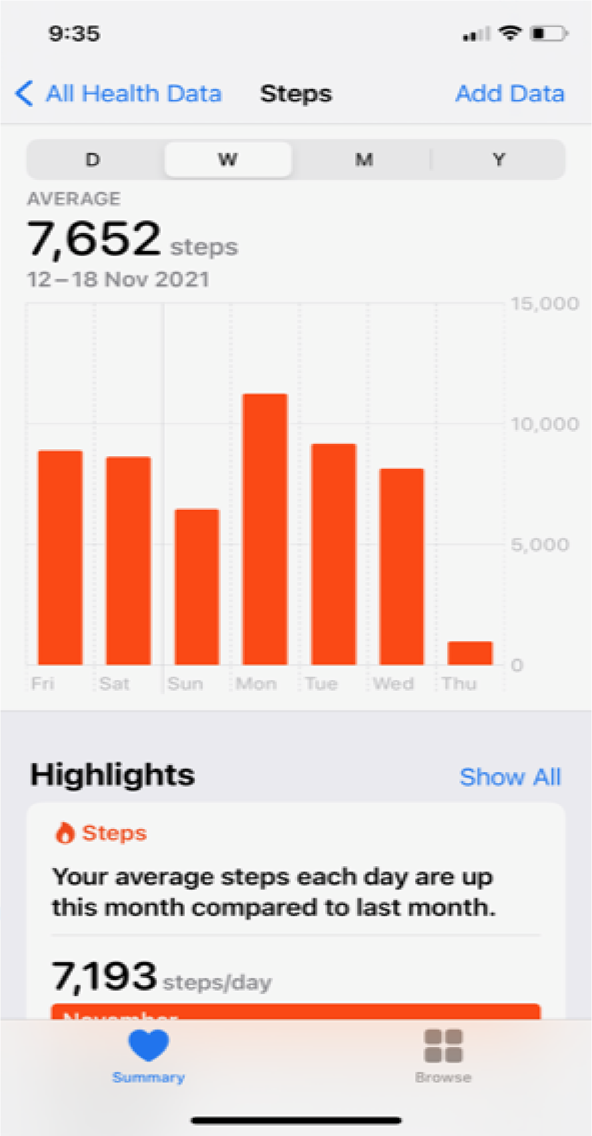


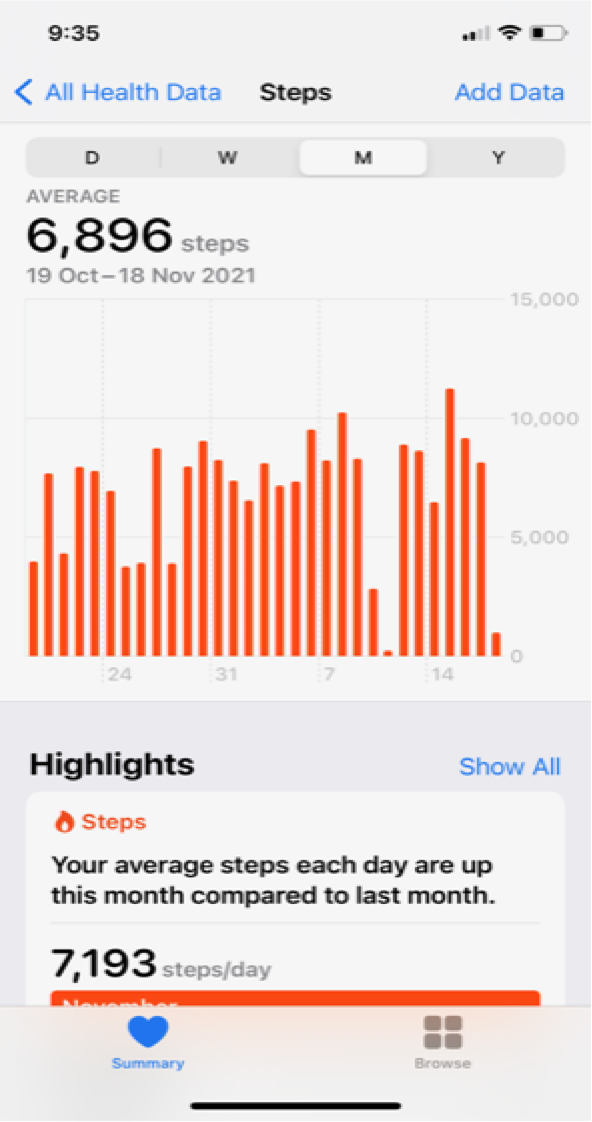
Architecture of IoT Enabled healthcare



Monitoring our activities by smartphone







Wearables and IoT: the building block

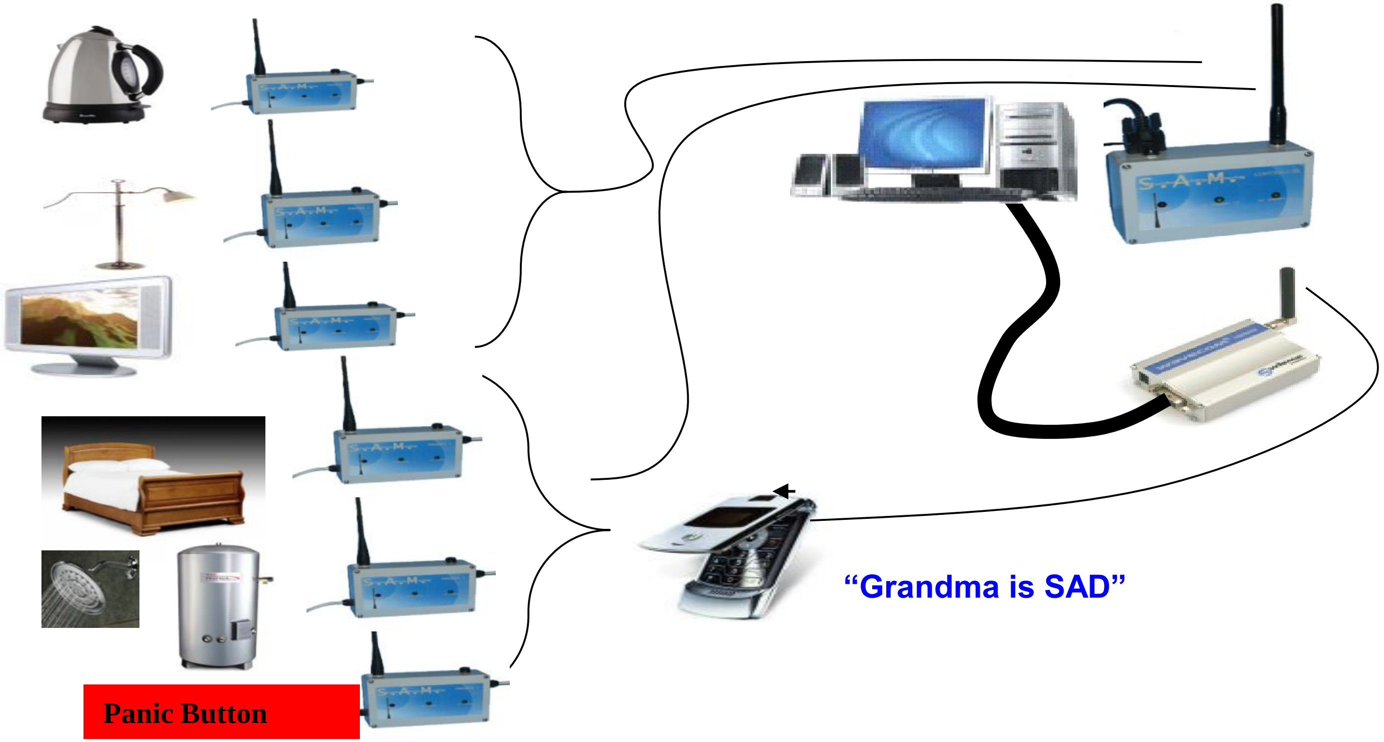
- ❑Embedded processing device
- ❑One or more sensors
- ❑Connectivity
- ❑Security

Summary of Wireless Protocols

Standard	ZigBee (IEEE 802.15.4)	BlueTooth (IEEE 802.15.1 WPAN)	WiFi (IEEE 802.11 WLAN)	WiMax (IEEE 802.11 WWAN)	LoRAWAN
Range	100 m	10 m	100-150 m	15 km	10 km+
Data rate	250-500 kbps	1 Mbps-3 Mbps	1Mbps-450 Mbps	75 Mbps	25 kbps
Band-width	2.4 GHz	2.4 GHz	2.4, 3.7, and 5 GHz	2.3, 2.5 and 3.5 GHz	868MHz, 915 MHz
Network Topology	Star, Mesh, Cluster Tress	Star	Star, Tree, P2P	Star, Tree, P2P	Star
Applications	Wireless Sensors (Monitoring and Control)	Wireless Sensors (Monitoring and Control)	PC based Data acquisition, Mobile Internet	Mobile internet	Environmental monitoring Smart city

Smart Home
for
safe, sound, secured and independent living

Wireless Sensor Network Based Smart Home




Digital Signal Processing Creative Design Contest

2009

Award

This is to certify that

Anuroop Gaddam

Massey University of New Zealand

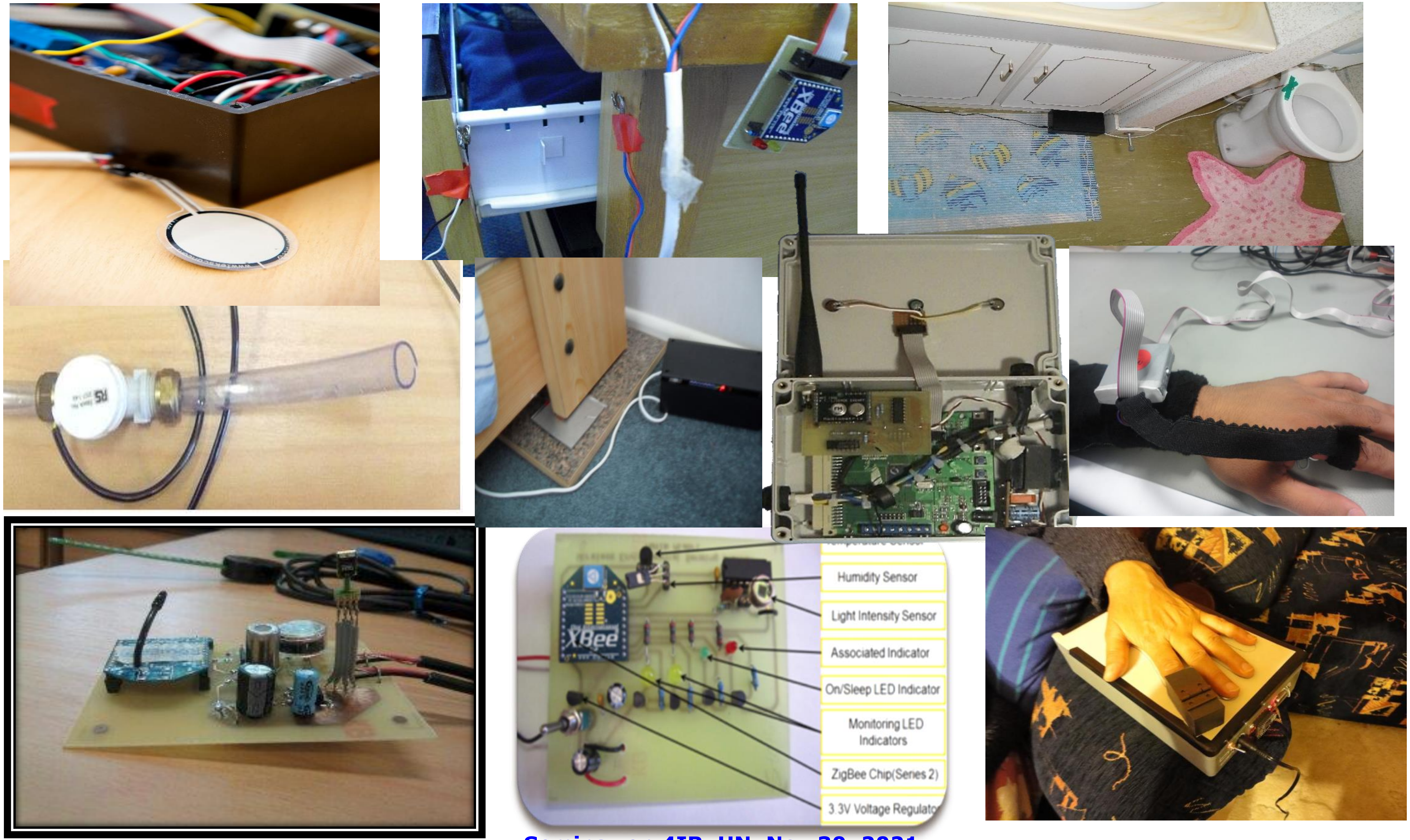
advised by Prof. Subhas Mukhopadhyay and Prof. G. Sen Gupta

have gotten THE SECOND PRIZE AWARD
in the 2009 Digital Signal Processing Creative Design Contest.

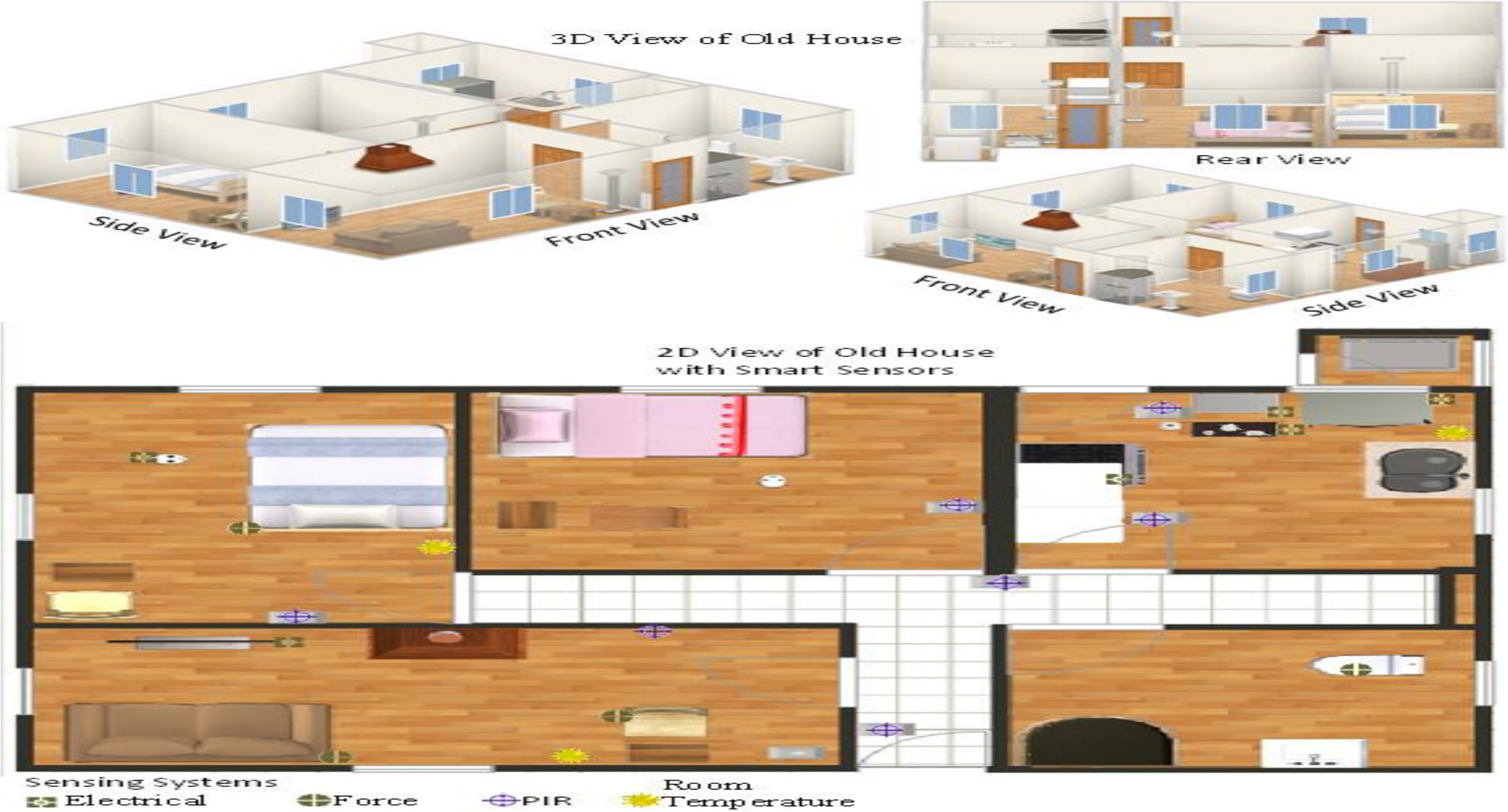
Minister
Ministry of Education, TAIWAN
November 19, 2009

A. Gaddam, et. al.,, "Elderly Care Based on Cognitive Sensor Network", IEEE Sensors Journal, Vol. 11, No. 3, March 2011, pp. 574-581.

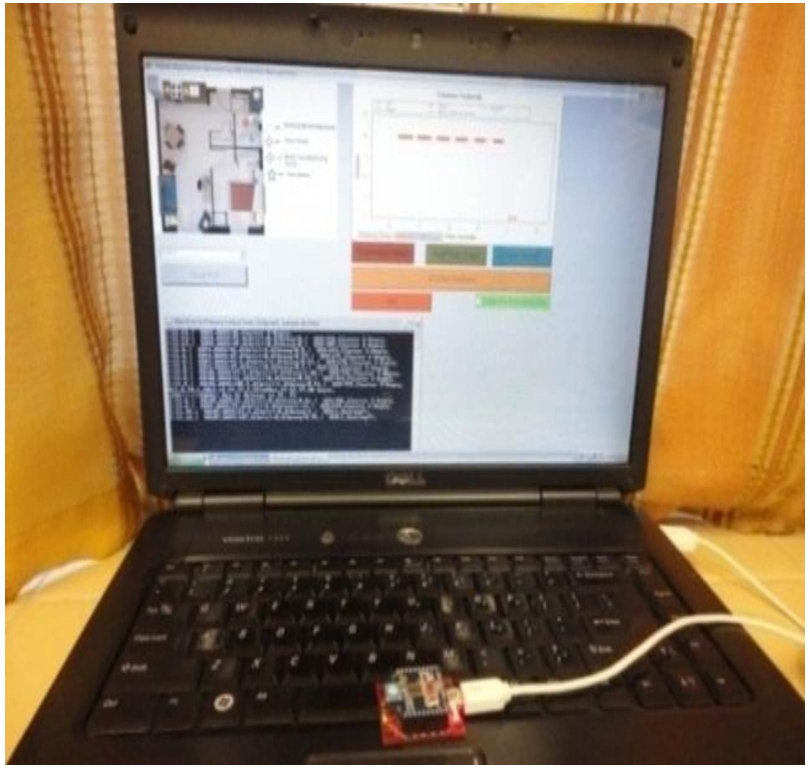
Heterogeneous Sensors for home monitoring



Living Lab: Placement of sensors in an old house



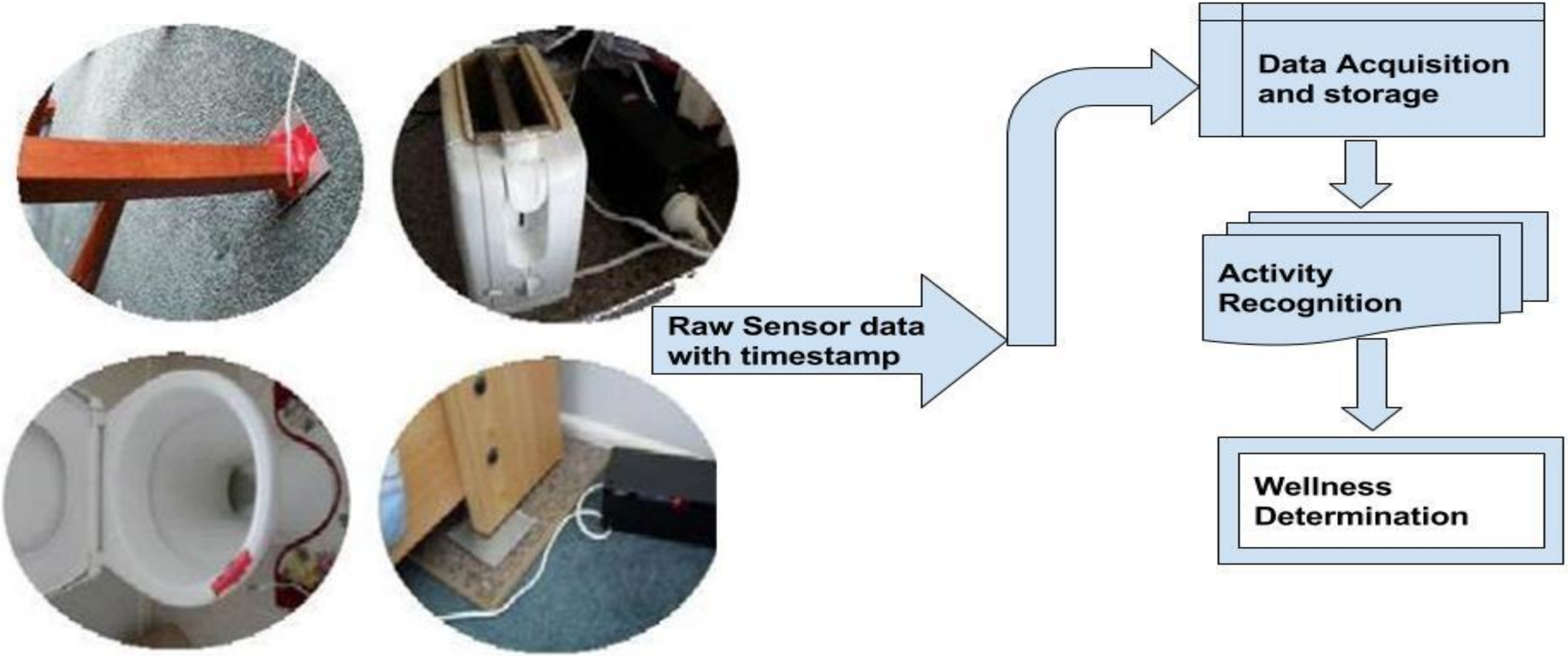
Sensors Integrated with Everyday Objects



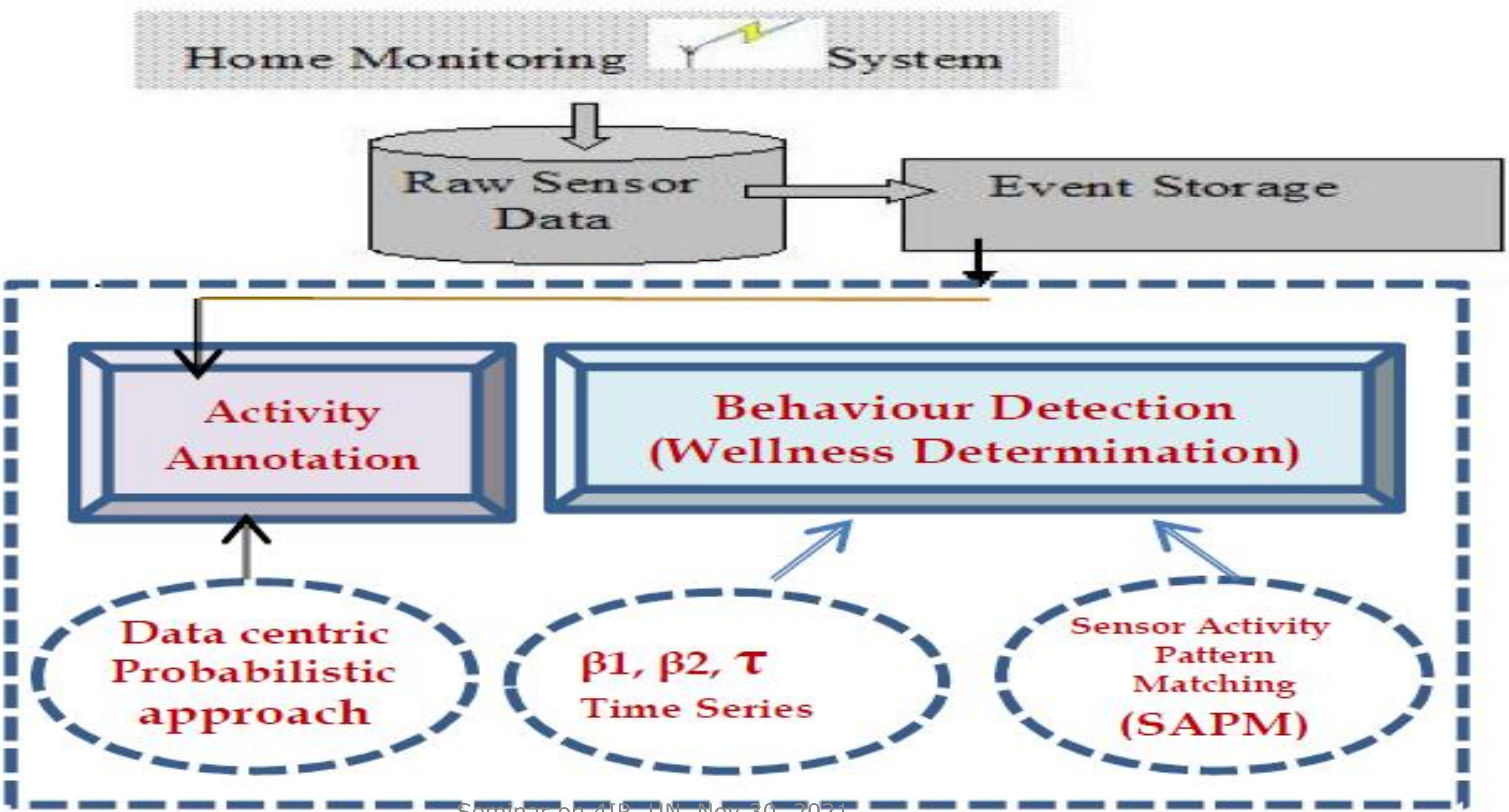
Sensors and associated instrumentation developed in-house

N. K. Suryadevara and S.C. Mukhopadhyay, "Determining Wellness Through An Ambient Assisted Living Environment", IEEE Intelligent Systems, May/June 2014, pp. 30-37.

Technology Assisted Home



Wellness Determination: Tools



Selection of Sensors and Using Minimum Number of Sensors for Monitoring Basic ADL's

Life Style of the Elderly

Sensors for basic ADL monitoring

Determination of minimum sensors

Frequency of Sensor usage

Room Type	Sensor Type	Connected to Device	η	
			Trail	Test
Living	Force, Electrical	Couch, Chair, TV, Heater	0.03, 0.05, 0.05,0.1	**0.03, 0.04, 0.03,.1**
Kitchen	Electrical	Microwave, Toaster, Kettle	0.05, 0.05, 0.02	**0.04, 0.06, 0.00**
Bed	Force	Bed	0.29	**0.37**
Bath	Force	Toilet	0.35	**0.33**
Storage	**Contact**	**Cupboard**	**0.01**	**0.00**

N.K.Suryadevara, S. C. Mukhopadhyay, R. Wang, R.K. Rayudu, Forecasting the behavior of an elderly using wireless sensors data in a smart home, *Elsevier: Engineering Applications of Artificial Intelligence,* Available online 12 September 2013, ISSN 0952-1976, http://dx.doi.org/10.1016/j.engappai.2013.08.004.

Activity Annotation

Sensor-id/ Status	Connected to Appliance	Type of Sensor	Time of Usage	Annotated Activity	Run Time Data
18(Active)	Bed	Pressure Sensor	09:00pmto 06:00am	Sleeping (SL)	2018-6-9 21:02:10 18 ON SL b 2018-6-10 05:50:10 18 OFF SL e
11/12/13 (active)	Microwave Oven/ Water Kettle/ Toaster	Electrical sensor	6:00amto 10:00am	Breakfast (BF)	2018-6-5 06:16:42 11 ON BF b 2018-6-5 06:21:35 11 OFF BF e
17(active)	Dining Chair	Pressure sensor	Anytime	Dine (DI)	2018-6-11 14:43:02 17 ON DI b 2018-6-11 14:43:05 17 OFF DI e
10(active)	Toilet	Pressure sensor	Anytime	Toileting (TO)	2018-6-7 02:15:30 10 ON TO b 2018-6-7 02:16:07 10 OFF TO e
19(active)	Couch	Pressure sensor	Anytime	Relax (RE)	2018-6-8 05:20:45 19 ON RE b 2018-6-8 05:35:30 19 OFF RE e
26(Active)	Grooming Cabinet	Contact	Anytime	Self Grooming (SG)	2018-6-8 09:20:10 26 ON SG b 2018-6-8 09:22:40 26 OFF SG e

Wellness Functions, β1 and β2

Wellness Function, β1 used to determine the wellness of elderly based on the Inactive usage of house-hold appliances.

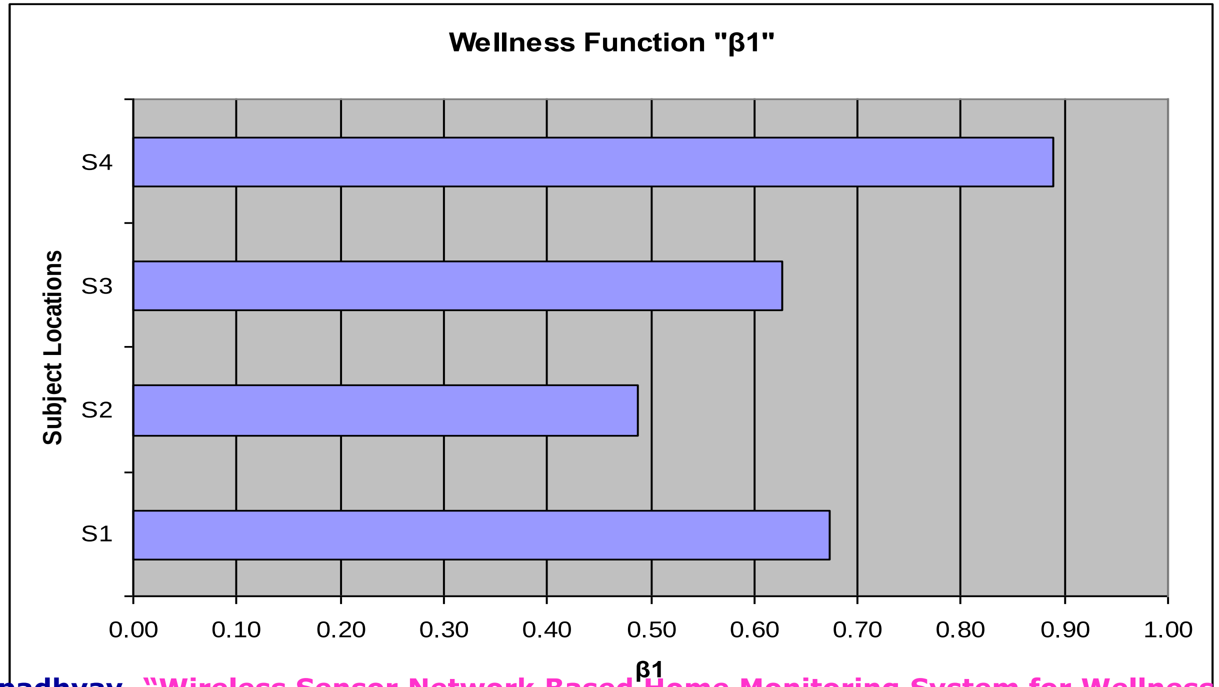
Wellness function β1 = $1 - \frac{t}{T}$

Where β1 =Wellness function of the inhabitant based on Inactive usage measurement of appliances

t = Time of Inactive duration of all appliances (i.e.) duration time no appliances are used.

T= Maximum inactive duration during which no appliances are used.

If β1 is equal to 1.0 indicates the inhabitant is in healthy situation. If β1 is less than 1.0 and goes below 0.5 the situation indicates some unusual situation.



N.K. Suryadevara and S.C. Mukhopadhyay, "Wireless Sensor Network Based Home Monitoring System for Wellness Determination of Elderly", IEEE Sensors Journal, Vol. 12, No. 6, June 2012, pp. 1965-1972.

Wellness Functions, β2

Wellness function

$$\beta_2 = 1 + \left(1 - \frac{Ta}{Tn}\right)$$

Where β2 = Wellness function of the elderly based on excess usage measurement of appliance.

Ta= Actual usage duration of any appliance.

Tn = Maximum usage time of appliance.

Under normal condition, $T_a < T_n$ (i.e.) No Abnormality

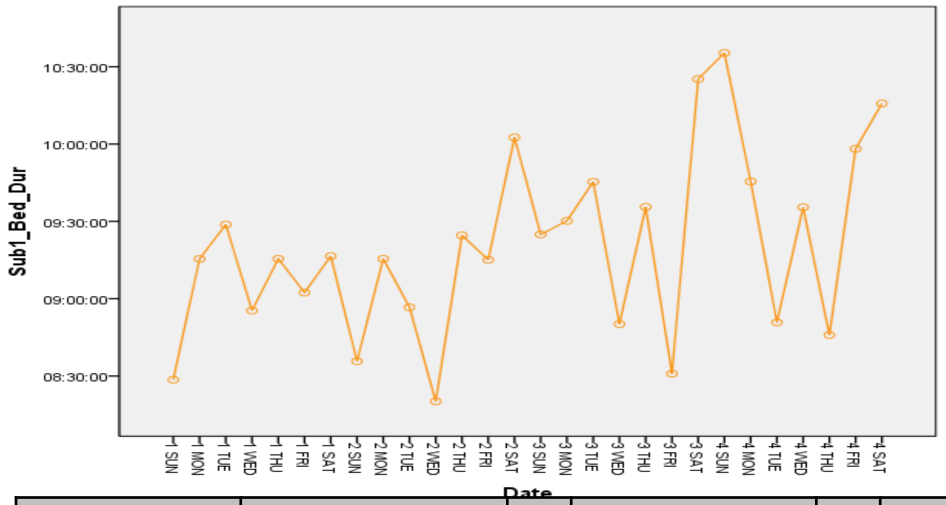
Only if Ta > Tn then β2 is calculated.

The value of β2 close to 0.8 and above may be considered as normal situation.

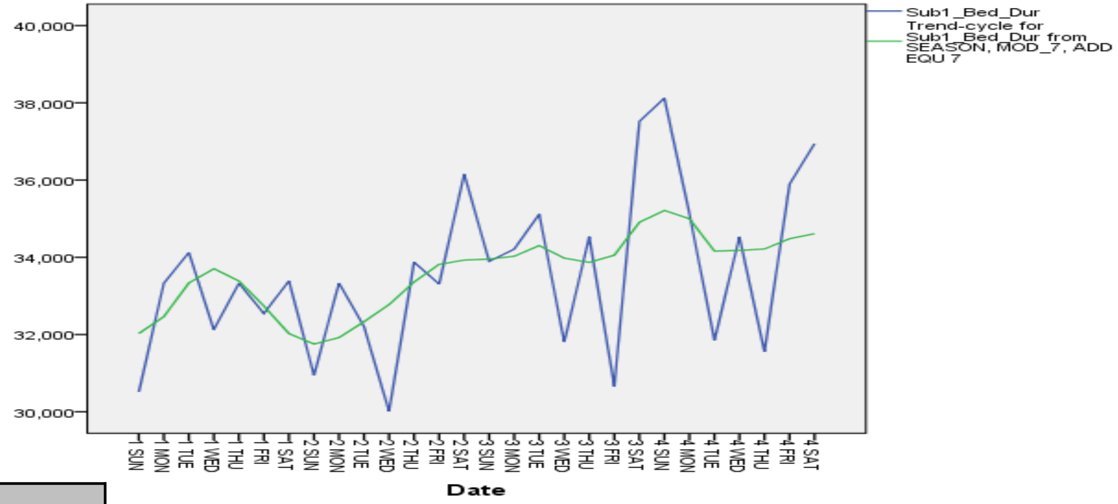
If β2 goes less than 0.5 indicates excess usage of the appliance and may lead to an abnormal condition.

Prediction of Future Behaviour (Trend Analysis)

Plot for four week Bed usage data



Sequence plot + Trend cycle(green) for four week Bed usage data



Additive model	Extended Trend value	+	Seasonal factor	=	Forecast value Week #5
	T		SAF		F
5 SUN	9:46:53	+	0:10:42	=	9:57:35
5 MON	9:43:19	+	0:10:30	=	9:53:49
5 TUE	9:29:21	+	-0:11:35	=	9:17:46
5 WED	9:29:38	+	-0:25:22	=	9:04:16
5 THU	9:30:16	+	0:05:27	=	9:35:43
5 FRI	9:34:41	+	-0:25:02	=	9:09:39
5 SAT	9:36:53	+	0:35:23	=	10:12:16

Error in the forecast is not likely to be more than twice the standard deviation of the residuals (95% confidence)

Maximum Likely Error is 2 x00:22:57≈ +/- 45Mins(Approx)

Prediction of Future Behaviour (Trend Analysis)

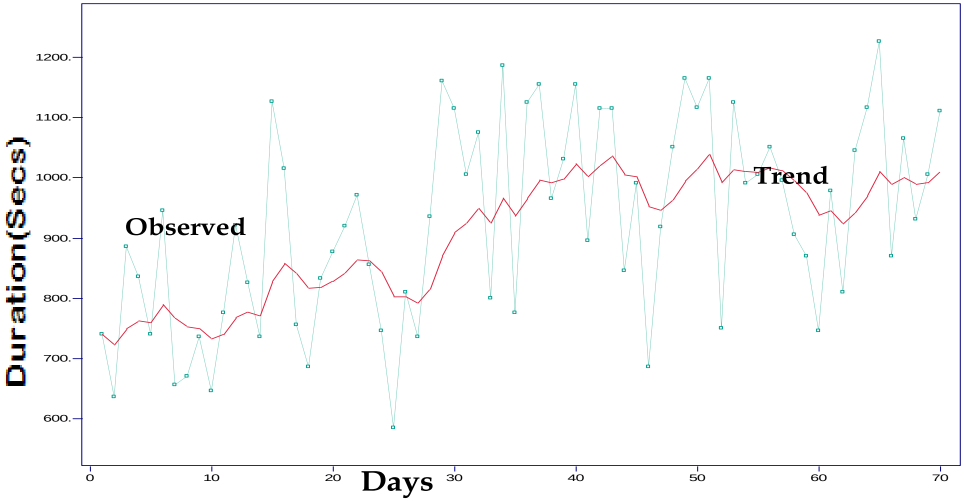


Fig 9(a) Toilet usage Trend for 70 days

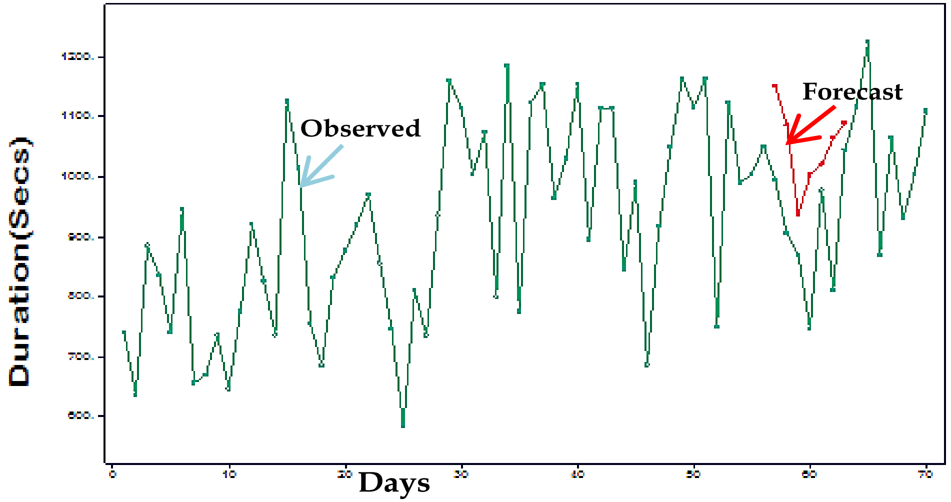


Fig 9(b) Toilet usage (Ninth week forecast pattern)

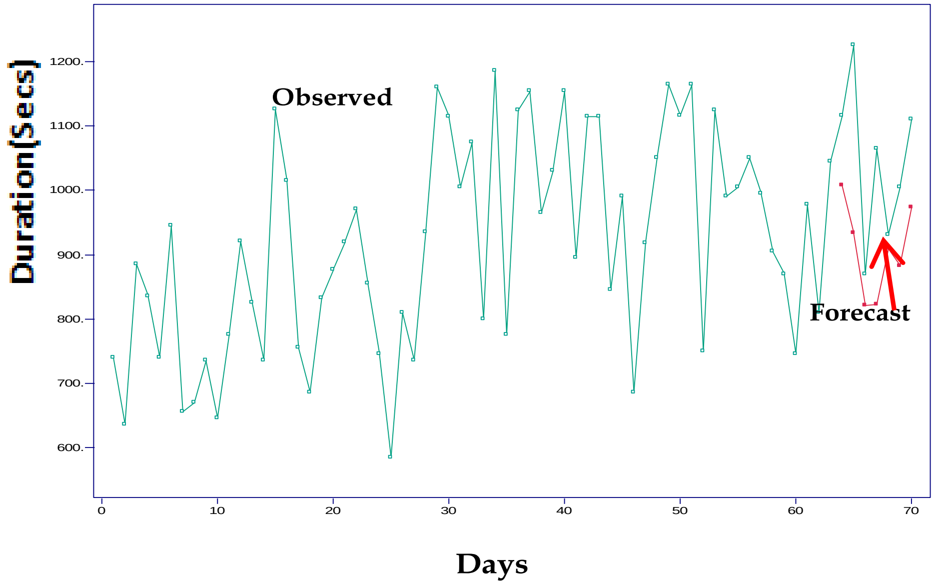


Fig 9 (c) Toilet usage (Tenth week forecast pattern)

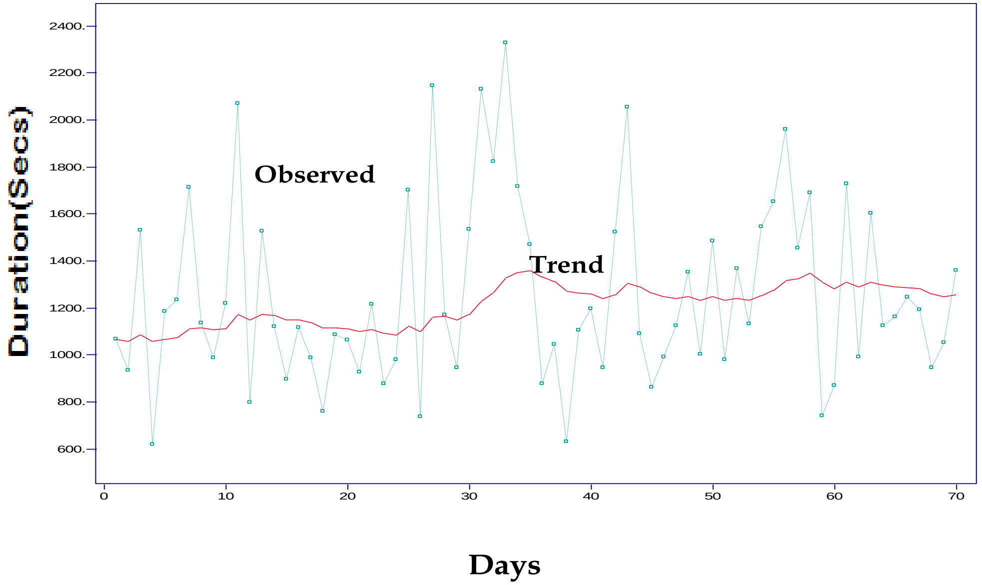


Fig 9(d) Chair Usage Trend for 70 days

N.K.Suryadevara, S. C. Mukhopadhyay, R. Wang, R.K. Rayudu, Forecasting the behavior of an elderly using wireless sensors data in a smart home, *Elsevier: Engineering Applications of Artificial Intelligence,* Available online 12 September 2013, ISSN 0952-1976, http://dx.doi.org/10.1016/j.engappai.2013.08.004.

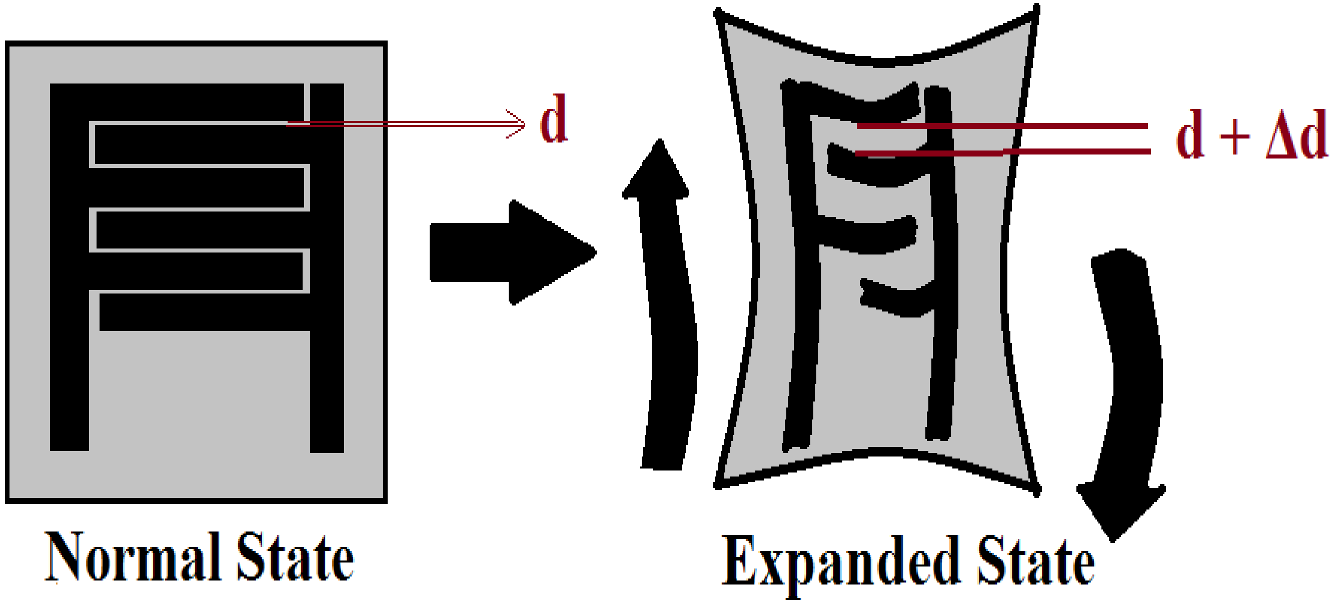
Fabrication of Flexible Wearable Sensors

MEMS Based sensors have a few issues:

- Difficult to attach sensors with rigid substrates.
- The cost of fabrication of sensors with rigid substrates is high.
- Difficulty in fabrication process.
- Electrode material comes off on attachment of the chips.
- Difficult to work with liquids due to hydrophilicity.

Working principle of Flexible sensors

The developed sensor patch is strain sensitive in nature where the capacitance changes as a function of the dimensions on the application of strain.

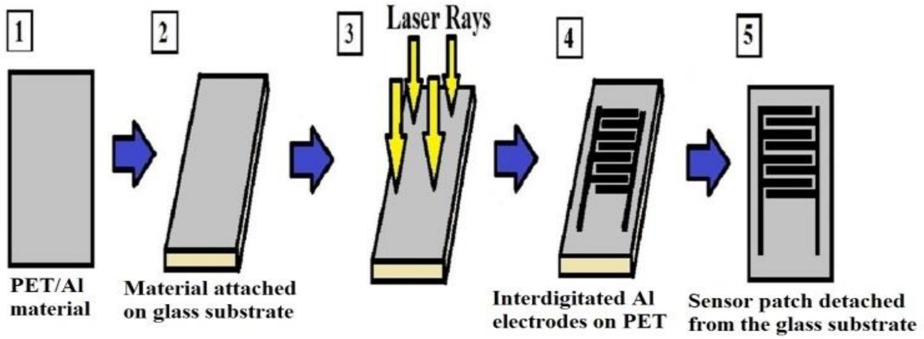


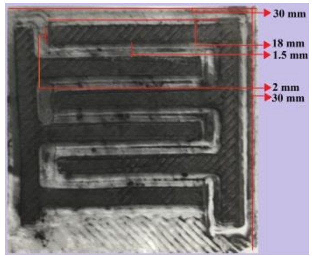
Reasons for using the Substrate Materials

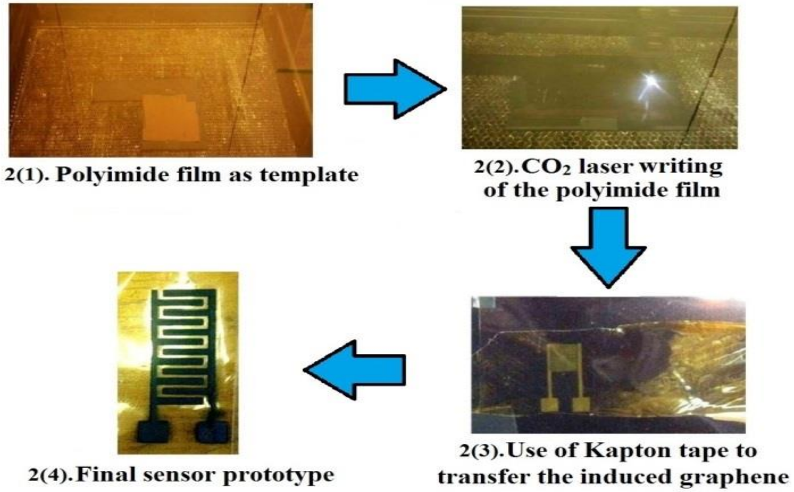
	PDMS (Polydimethylsiloxane)	PET (Polyethylene terephthalate)	Polyimide
• Advantages	• Inert • Non-toxic • Non-flammable • Hydrophobic in nature	• Cheap • Good chemical resistance • High resistance to temperature • High flexibility	• High flexibility • Good chemical and thermal resistance • High mechanical toughness
• Disadvantages	• Difficult to integrate electrodes • Carry out deposition directly on its surface	• Very susceptible to heat degradation • Poor impact strength	• Expensive • Poor resistance to alkalies • Low impact strength

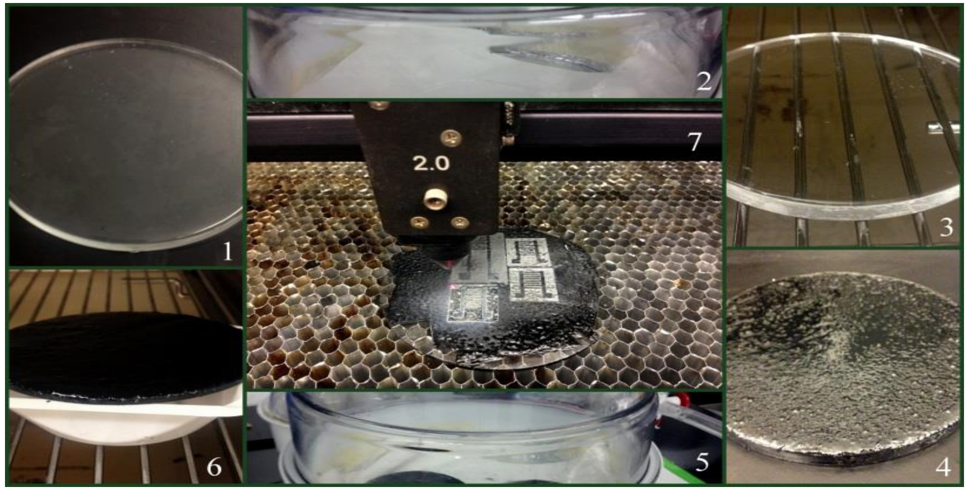
	CNTs	Graphene	Aluminum
• Advantages	• Better dispersion with the mixed polymer • Better compatibility • Higher flexibility	• High surface-to-volume ratio • Excellent electrical conductivity • High carrier mobility and density • High thermal conductivity	• Corrosion resistance • Strong at low temperatures
• Disadvantages	• Low purity • Low lifeline • Expensive growth process	• Does not have a band gap • High quality graphene is expensive and complex process • Graphene exhibits some toxic qualities	• Growth of oxide layer • More expensive than steel • Abrasive to tooling

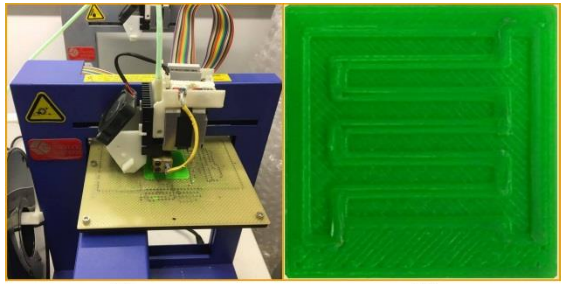
Printed flexible sensors at MQ



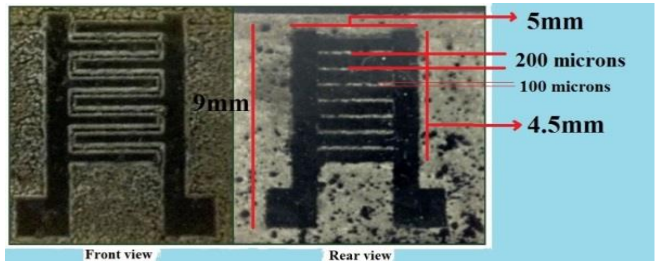


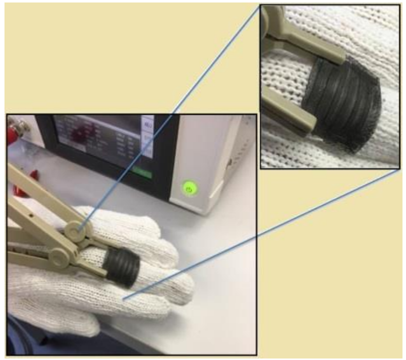


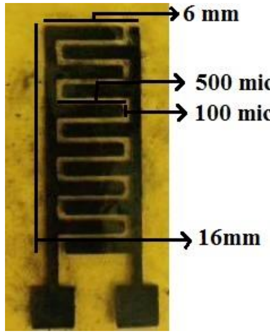


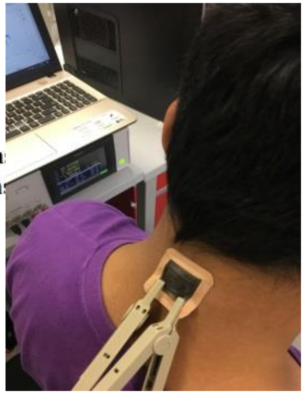


(a) (b)



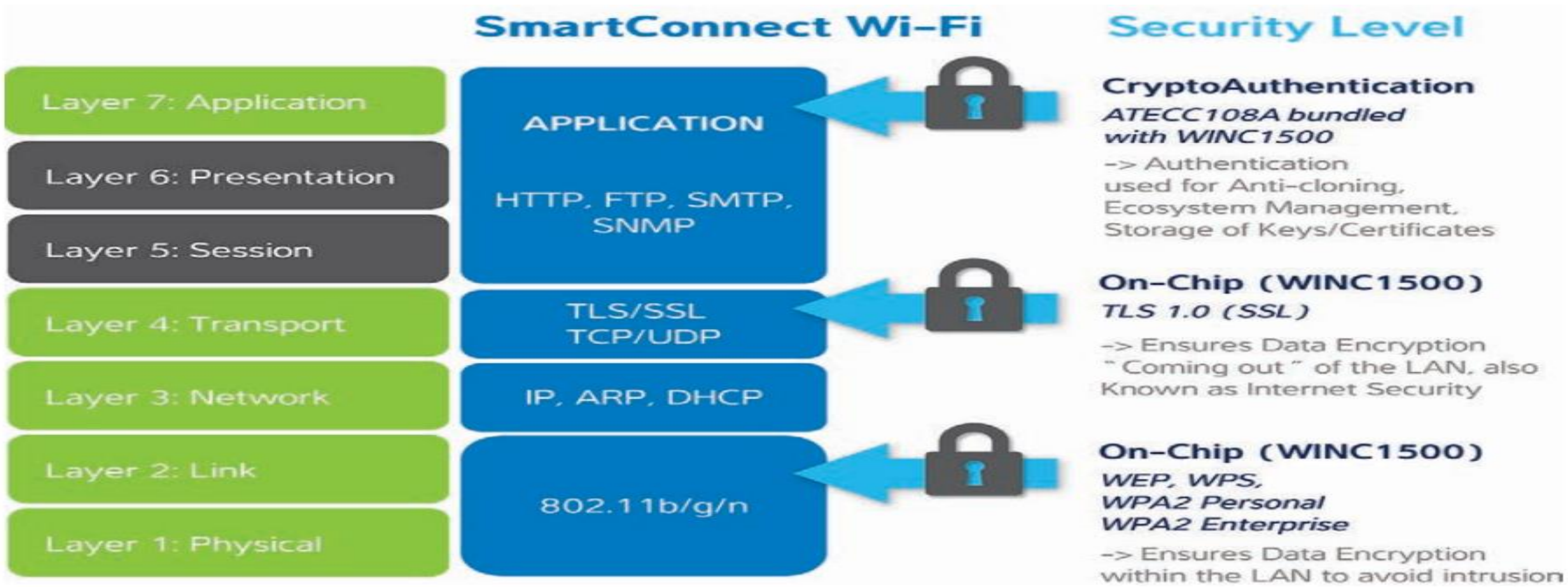






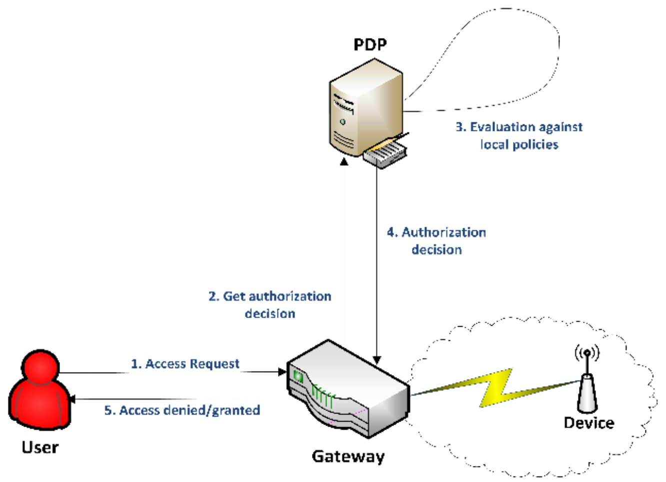
Security of IoT and Wearable/Medical Devices

- Any wearable/medical device cum IoMT product requires highest level of security.
- Wearable applications store personal information, identities and log– in details
- Some IoT application controls other application such as heating and air conditioning, need to provide security to avoid fatal consequences.

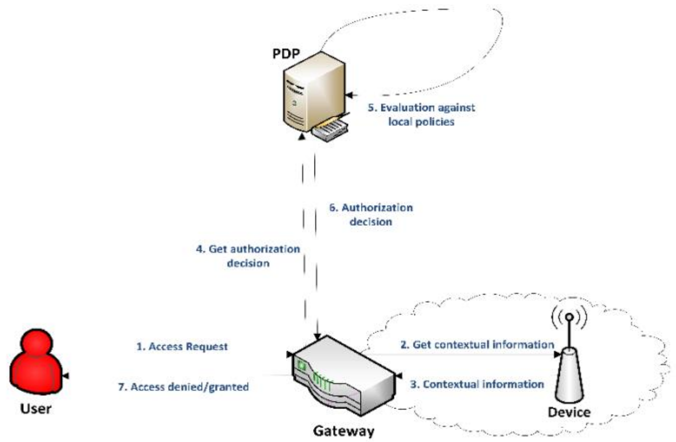


Access Control for IoT Enabled Healthcare: Architectures

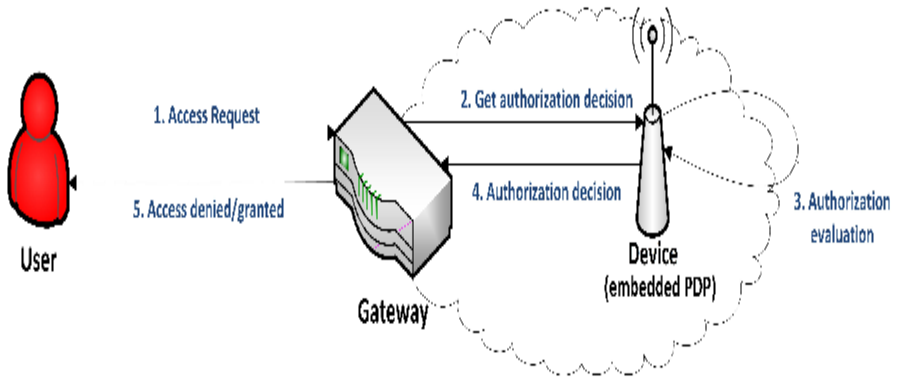
- Centralized



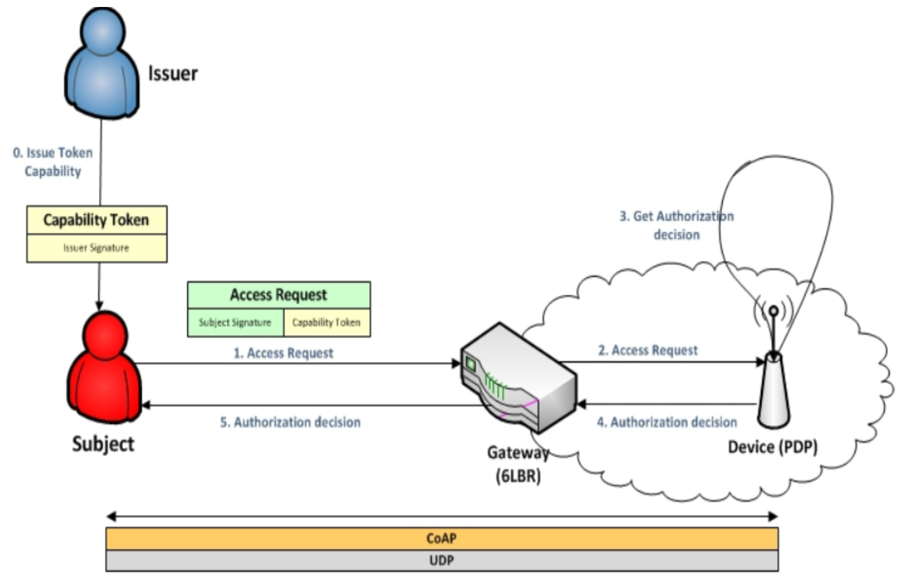
- Centralized and Contextual



- Distributed



- Distributed Capability-Based



Summary

- **Design and Fabrication of sensors for human wellness**
- **Wearable sensors finding more and more acceptability in society**
- **Flexible sensors are becoming very popular**
- **Fabrication of large size electronic skin is a challenge**
- **Resolution, sensitivity, interfacing electronics as well as energy harvesting are topics of research**
- **New applications are more and more investigated (implanted sensors).**
- **IoT will provide a connected healthcare system in future**