IoT and WSN Based Health and Home Management

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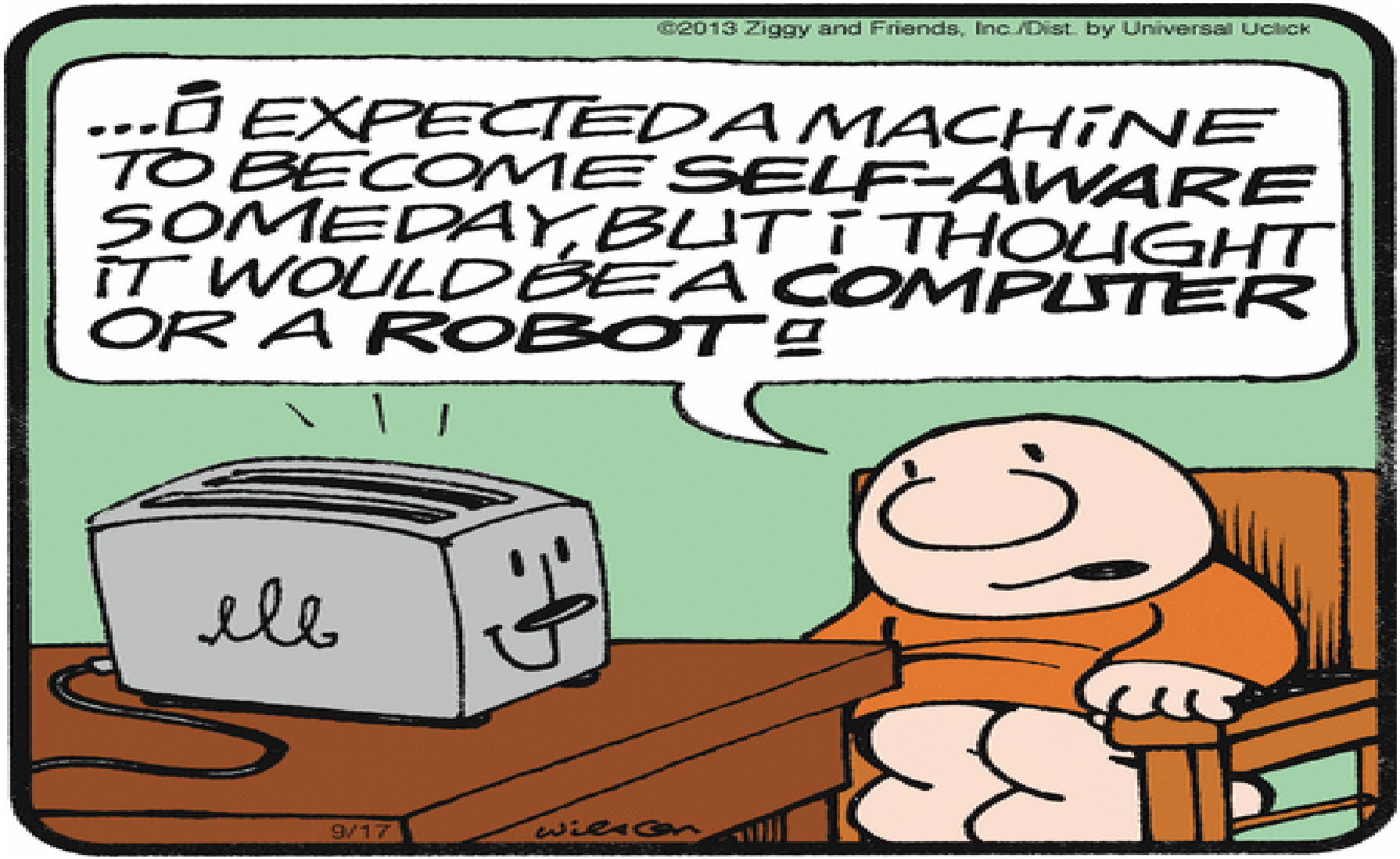
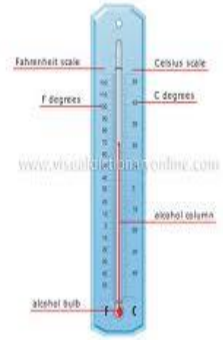
Outline of the Presentation

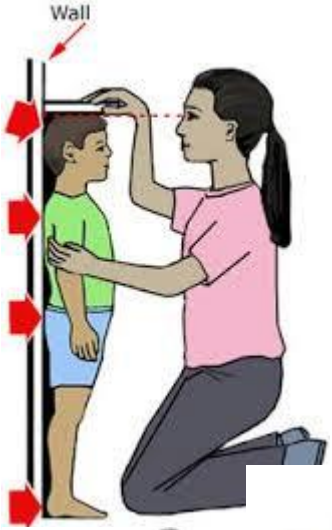
- Sensors, WSN and IoT
- Ambient Assisted Living: WSN and IoT Based Smart Home
- Wellness Determination
- Wellness Indices and Forecasting
- Challenges and Opportunities

Summary


©2013 Ziggy and Friends, Inc./Dist. by Universal Uclick
...I EXPECTED A MACHINE TO BECOME SELF-AWARE SOMEDAY, BUT I THOUGHT IT WOULD BE A COMPUTER OR A ROBOT.
9/17

Sensing devices around us

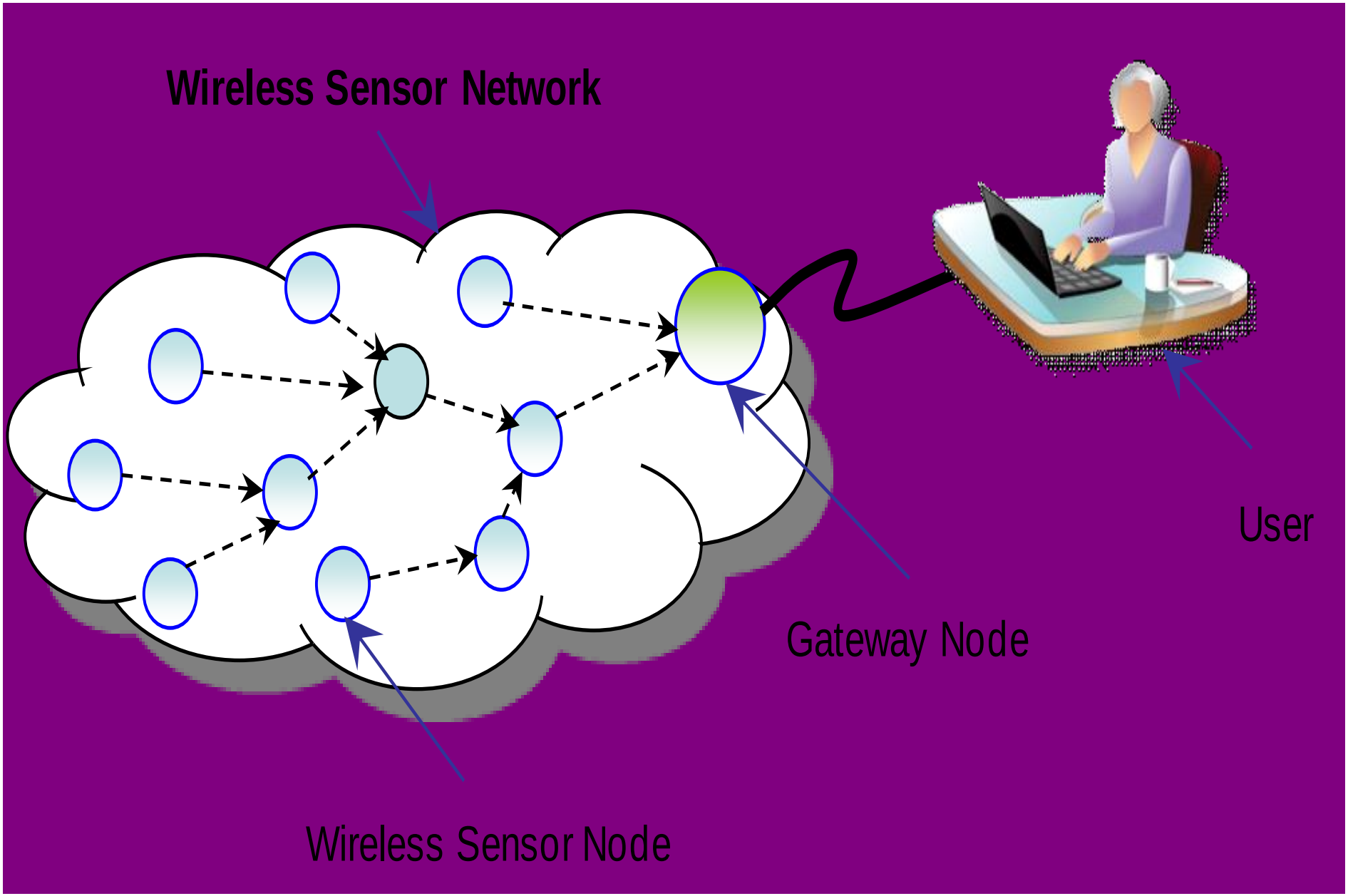




“If you cannot measure it, you cannot improve it.”

Lord Kelvin, 1824-1907

Wireless Sensor Network - WSN



Applications of WSN

- *Precision agriculture*
- *Environment comfort & efficiency*
- *Smart homes*
- *Alarms, security, surveillance.*
- *Disaster management*
- *Health Care*
- *Traffic Management*
- *Transportation safety*
- *Land mine Detection*

Sensor Augmented Fire Response

Earthquake Response

Manufacturing

Wind Response

Elder Care

Internet of Things (Internet Sensing)

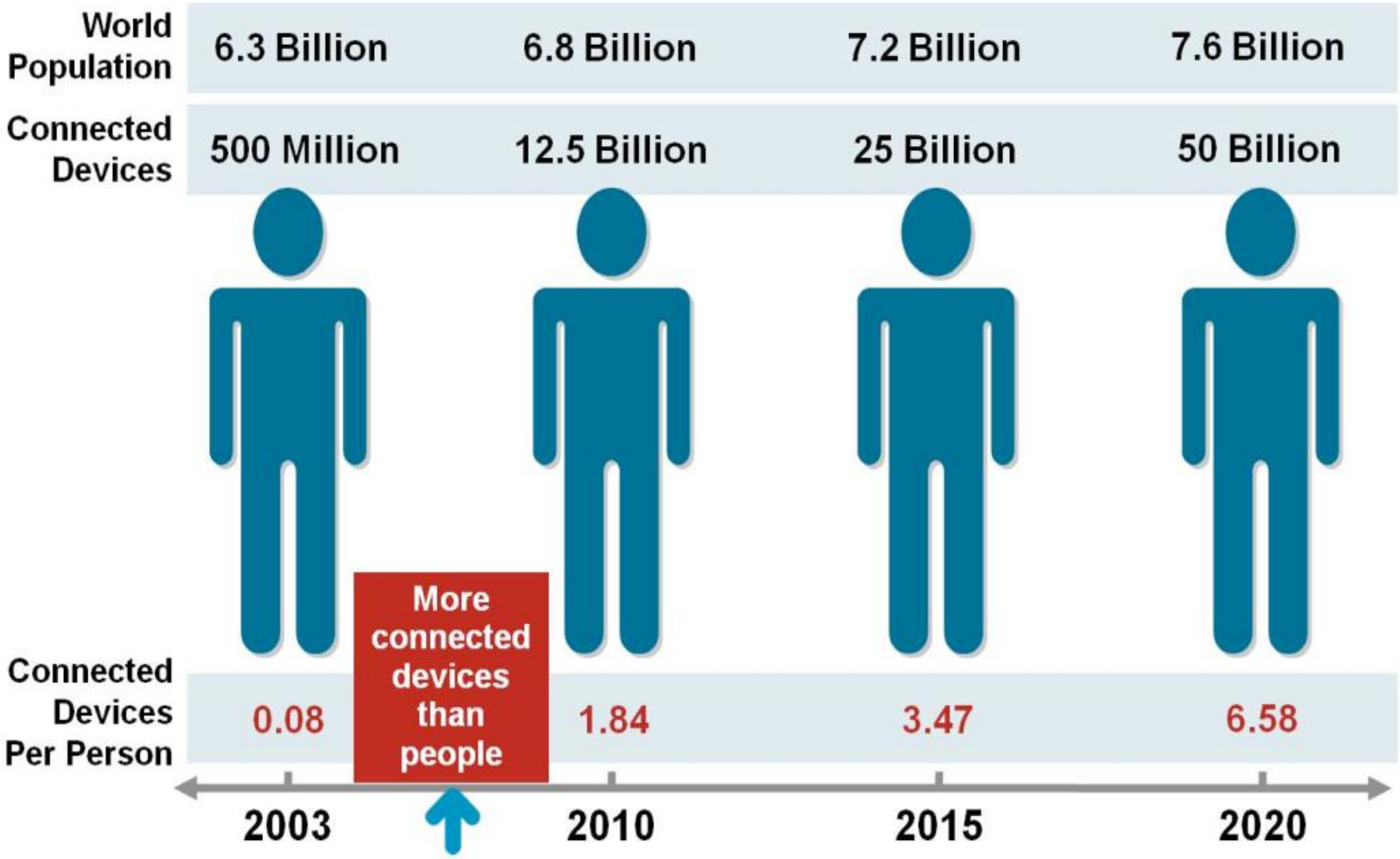
'**The Internet of Things'** is a network of items – each embedded with sensors – which are connected to the Internet.

"… all about physical items talking to each other.."

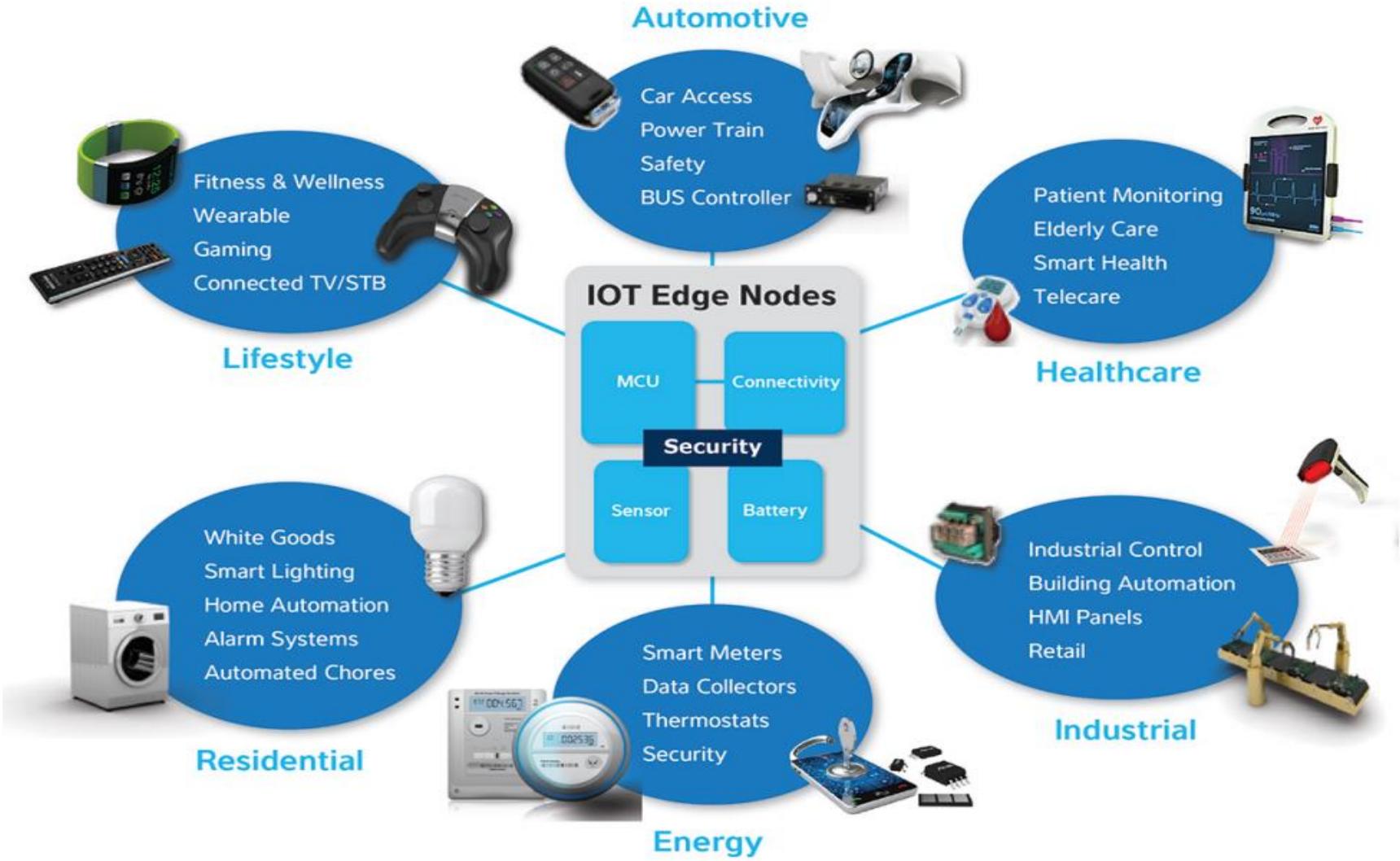
Machine-to-machine communications and person-to-computer communications will be extended to things.

Technologies that will drive the future Internet of Things: Sensor technologies including RFID, smart things, nanotechnology and miniaturization.

Population, connected devices, IoT

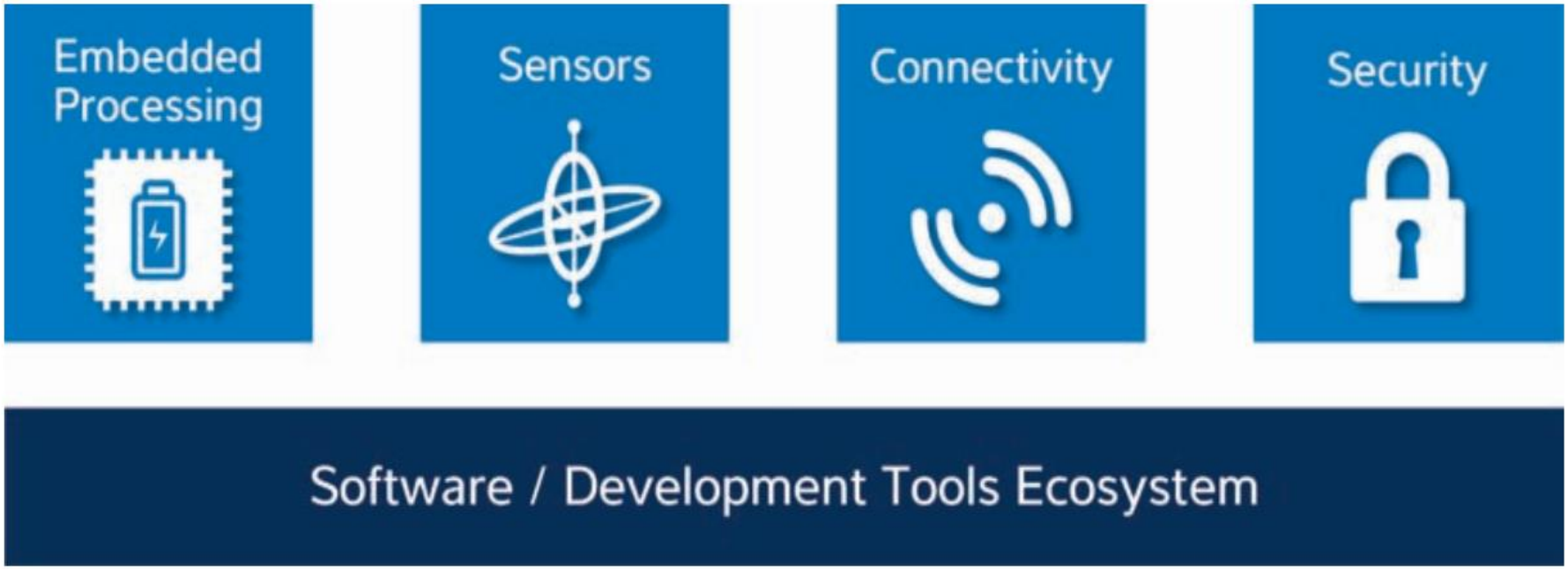


Impact of IoT



- **It provides more data to monitor, trend and analyze**
- **It allows manufacturers to take a completely different approach to the way they sell their products and services.**

Visualization of the building block of IoT



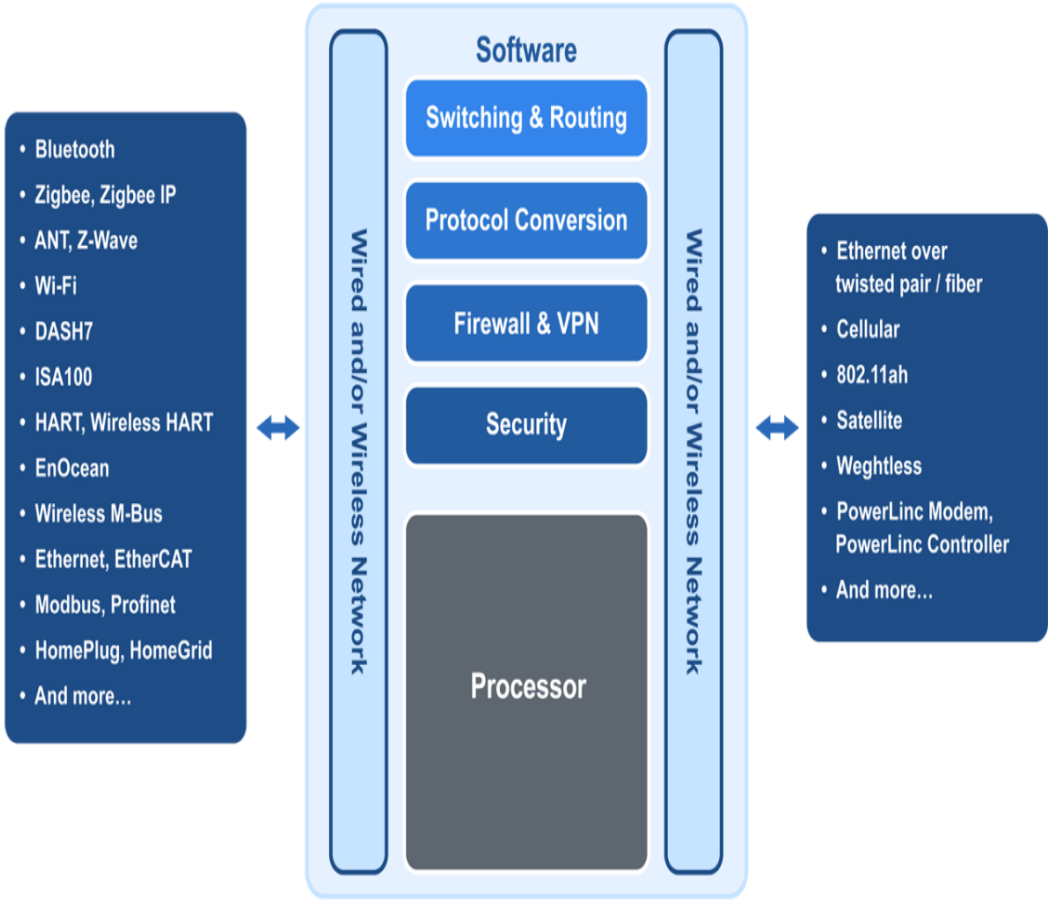
- ❑ Embedded processing device
- ❑ One or more sensors
- ❑ Connectivity
- ❑ Security

Gateway of IoT

Definition: A gateway connects two dissimilar networks so that data can flow between them. Usually this is a connection between a proprietary network and the Internet.

For example, in home automation, different utilities companies may install a wide variety of IoT devices in a house, each with their own gateway. These can include electricity or gas, water, phone, Internet, cable/satellite, alarm system, medical devices, and so on. Some of these gateways may require additional functions, such as local storage, or a user interface.

Gateway Architecture



Currently available Hardware for IoT

Genuino 101

Annikken Andee

Blend Micro

Arduino YÚN

Bluetooth 4.0 Low Energy

WiFi Integrated

Intel Gallileo

- Off the shelf development board.
- Easy to use in different applications.
- Programmed easily in Arduino IDE.
- All the libraries are open source. Built-in example sketches included in IDE.
- There are some other IoT hardwares are available in the market which are- (http://postscapes.com/internet-of-things-cloud#flexible)

Top IoT applications

http://www.libelium.com/resources/top_50_iot_sensor_applications_ranking/

SMART CITIES

01: Smart Parking: Monitoring of parking spaces availability in the city.
02: Structural health: Monitoring of vibrations and material conditions in buildings, bridges and historical monuments.
03: Noise Urban Maps: Sound monitoring in bar areas and centric zones in real time.
04: Smartphone Detection: Detect iPhone and Android devices and in general any device which works with WiFi or Bluetooth interfaces.
05: Eletromagnetic Field Levels: Measurement of the energy radiated by cell stations and and WiFi routers.
06: Traffic Congestion: Monitoring of vehicles and pedestrian levels to optimize driving and walking routes.
07: Smart Lighting: Intelligent and weather adaptive lighting in street lights.
08: Waste Management: Detection of rubbish levels in containers to optimize the trash collection routes.
09: Smart Roads: Intelligent Highways with warning messages and diversions according to climate conditions and unexpected events like accidents or traffic jams.

SMART ENVIRONMENT

10 Forest Fire Detection: Monitoring of combustion gases and preemptive fire conditions to define alert zones.

11 Air Pollution: Control of CO2 emissions of factories, pollution emitted by cars and toxic gases generated in farms.

12 Snow Level Monitoring: Snow level measurement to know in real time the quality of ski tracks and allow security corps avalanche prevention.

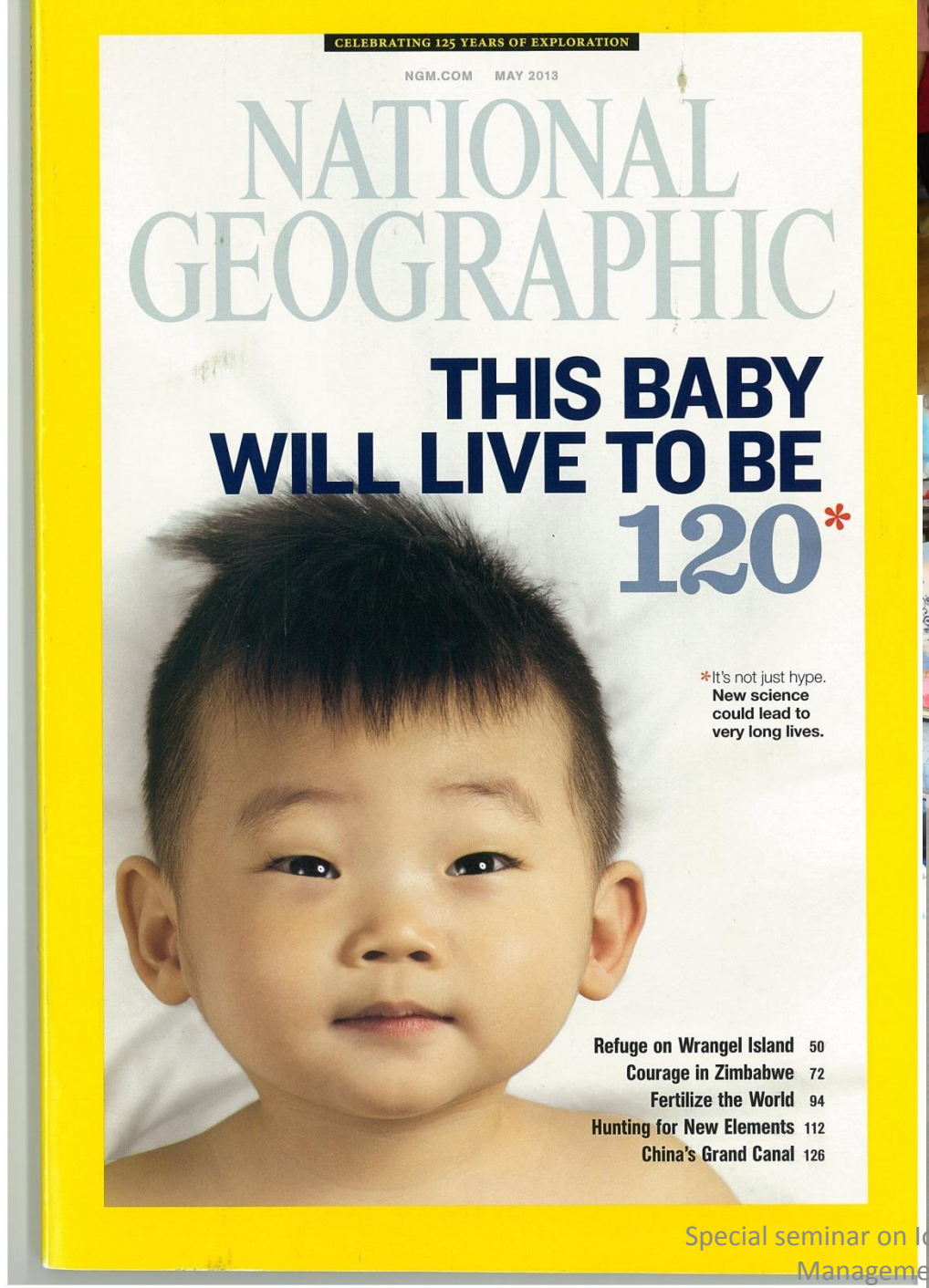
13 Landslide and Avalanche Prevention: Monitoring of soil moisture, vibrations and earth density to detect dangerous patterns in land conditions.

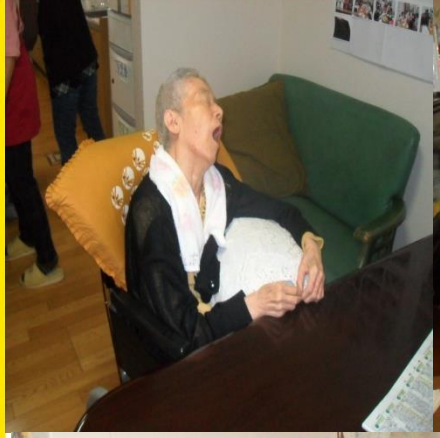
14: Earthquake Early Detection: Distributed control in specific places of tremors.

IOT+WSN Based Smart Home for Assisted Living

Special seminar on IoT+WSN
HH Management

Why Smart Home?



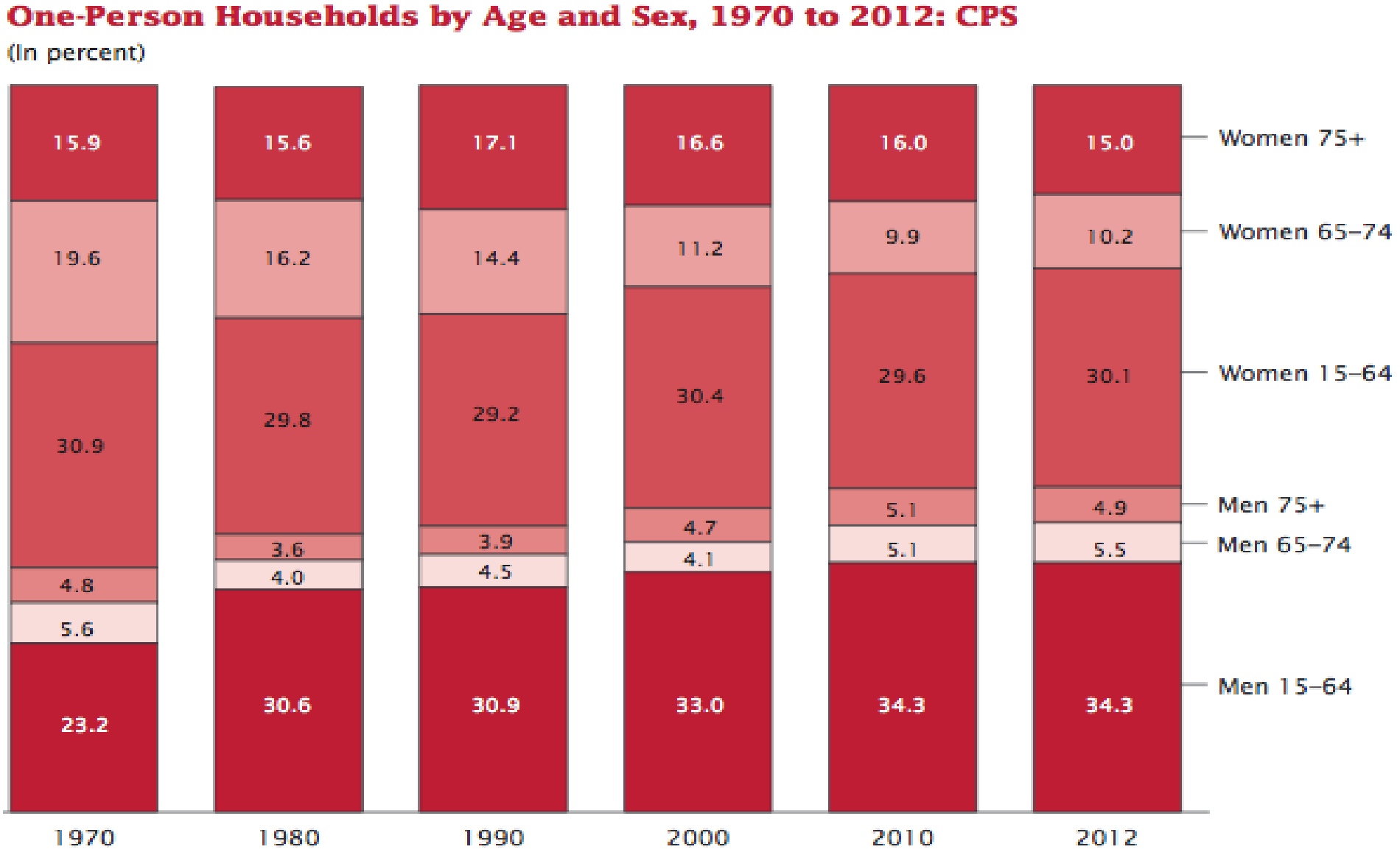


Life of learning: Lewis Clarkson discovered his passion for learning late in life but wasted no time in gaining qualifications through extramural study at Massey University.

Dinner discussions: Mr Clarkson at home in Christchurch. Photos: SUPPLIED

Resting place: The Crewe Cres house where Lewis Clarkson was found dead after a neighbour noticed flies gathering at a window. Photo: DAVID UNWIN/FAIRFAX NZ

Independent living; Different age groups

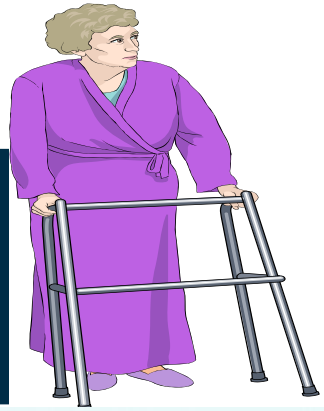


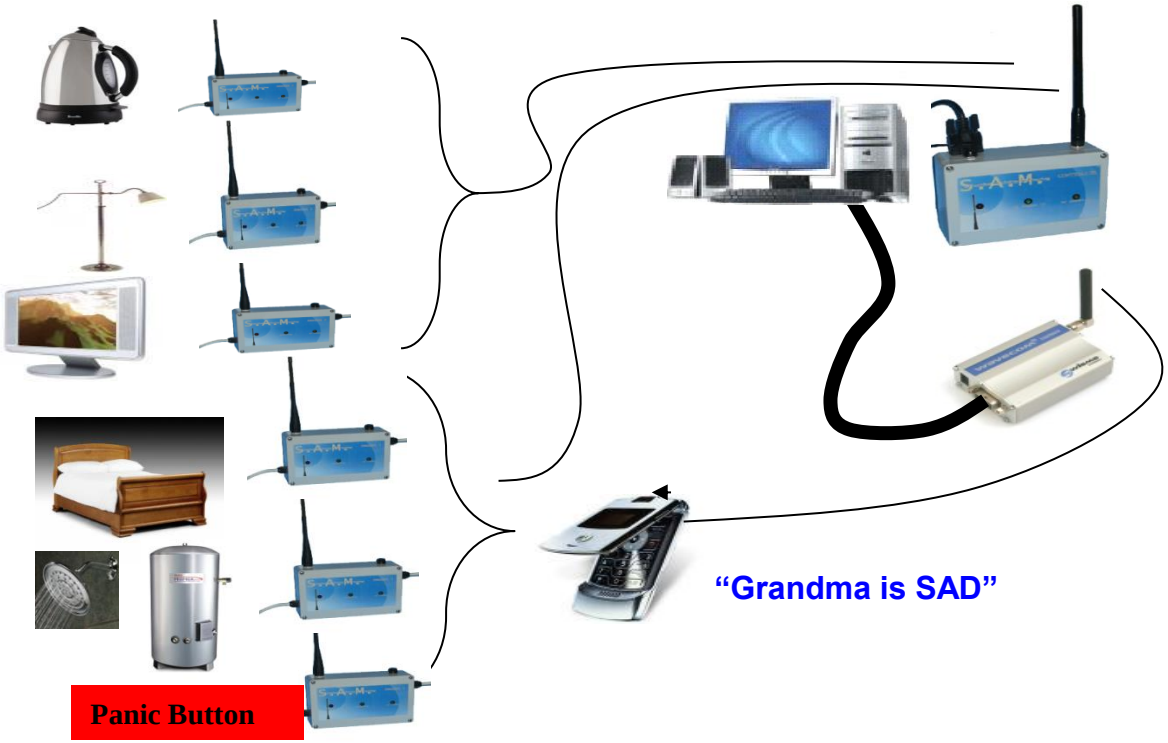
One person households by Age and Sex, 1970 to 2012 in US

Wireless Sensor Network Based Smart Home



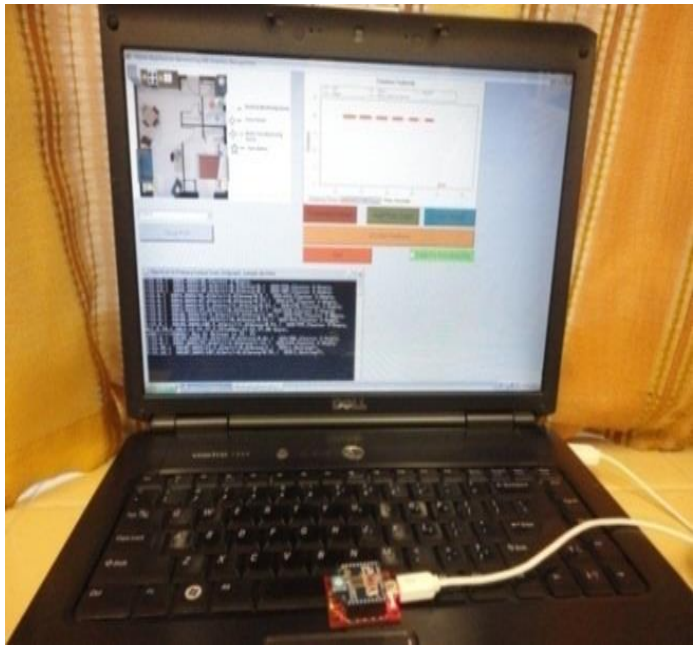






N.K. Suryadevara and S.C. Mukhopadhyay, "Wireless Sensor Network Based Home Monitoring System for Wellness Determination of Elderly", IEEE Sensors Journal, Vol. 12, No. 6, June 2012, pp. 1965-1972.

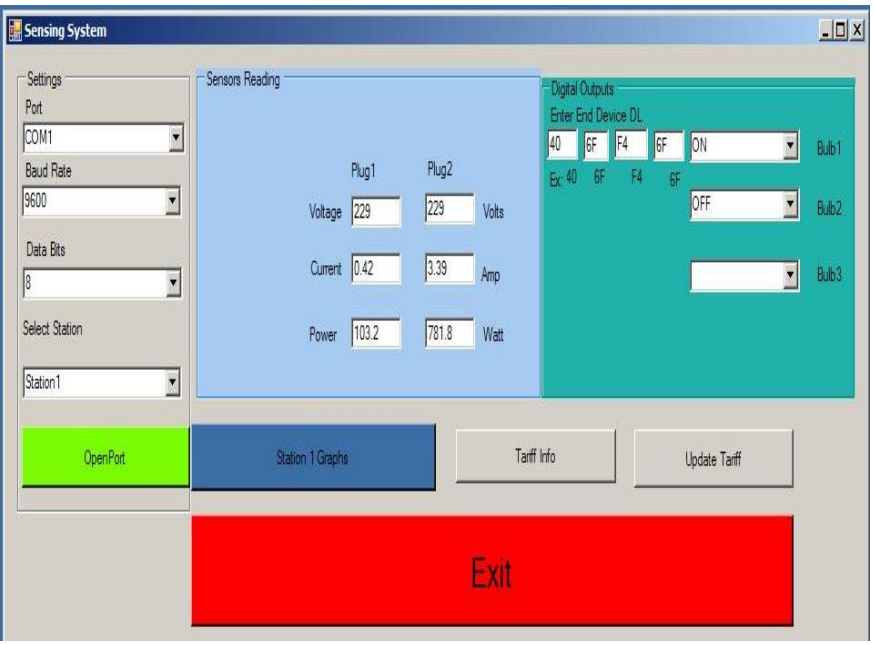
Sensors Integrated with Everyday Objects

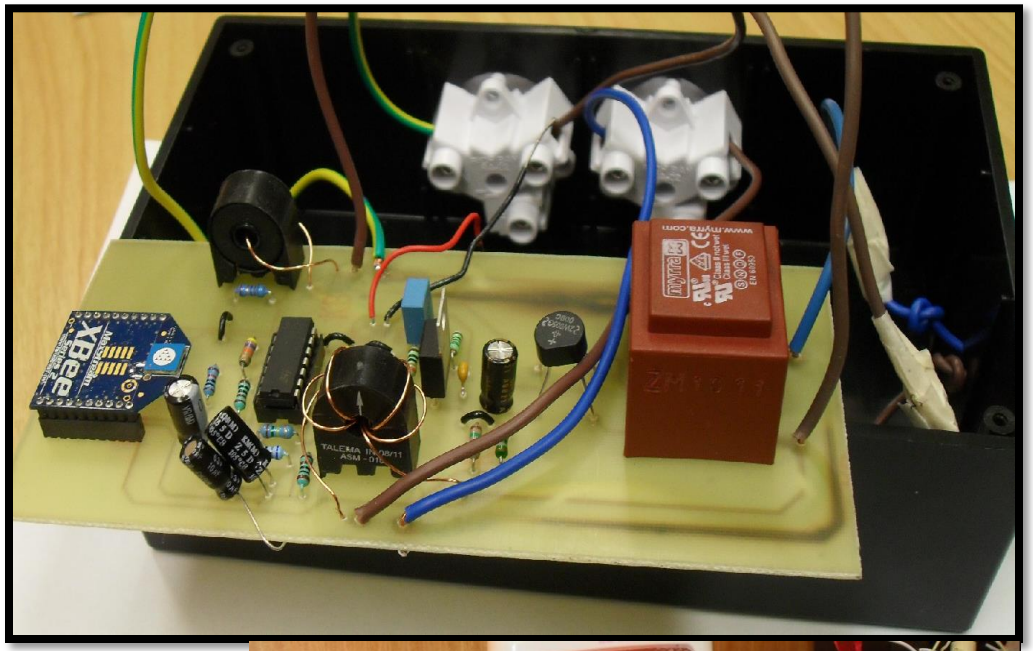


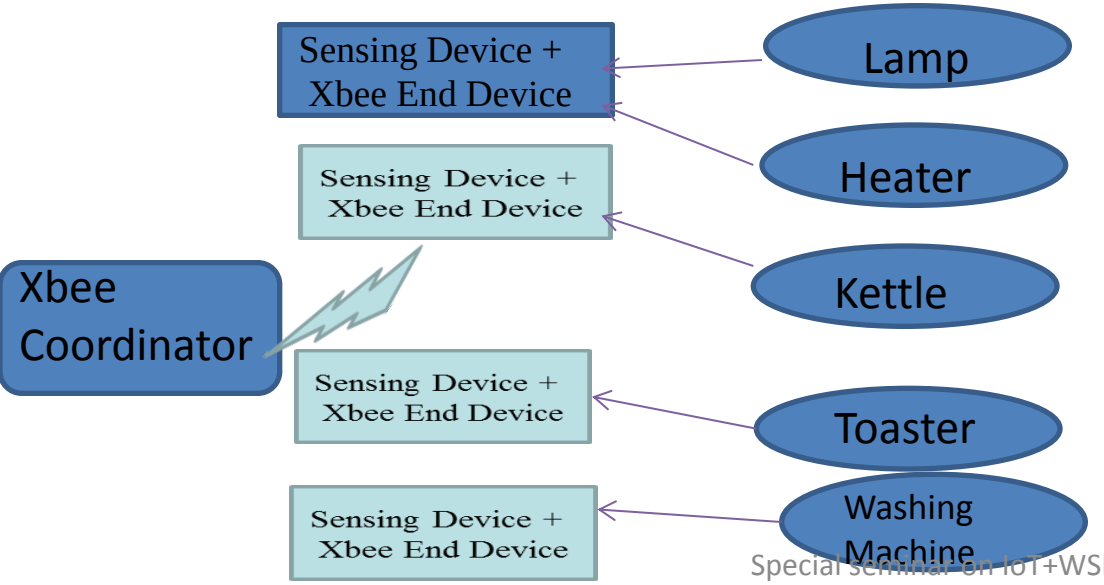
Sensors and associated instrumentation developed in-house

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

Smart Power Management based on WSN

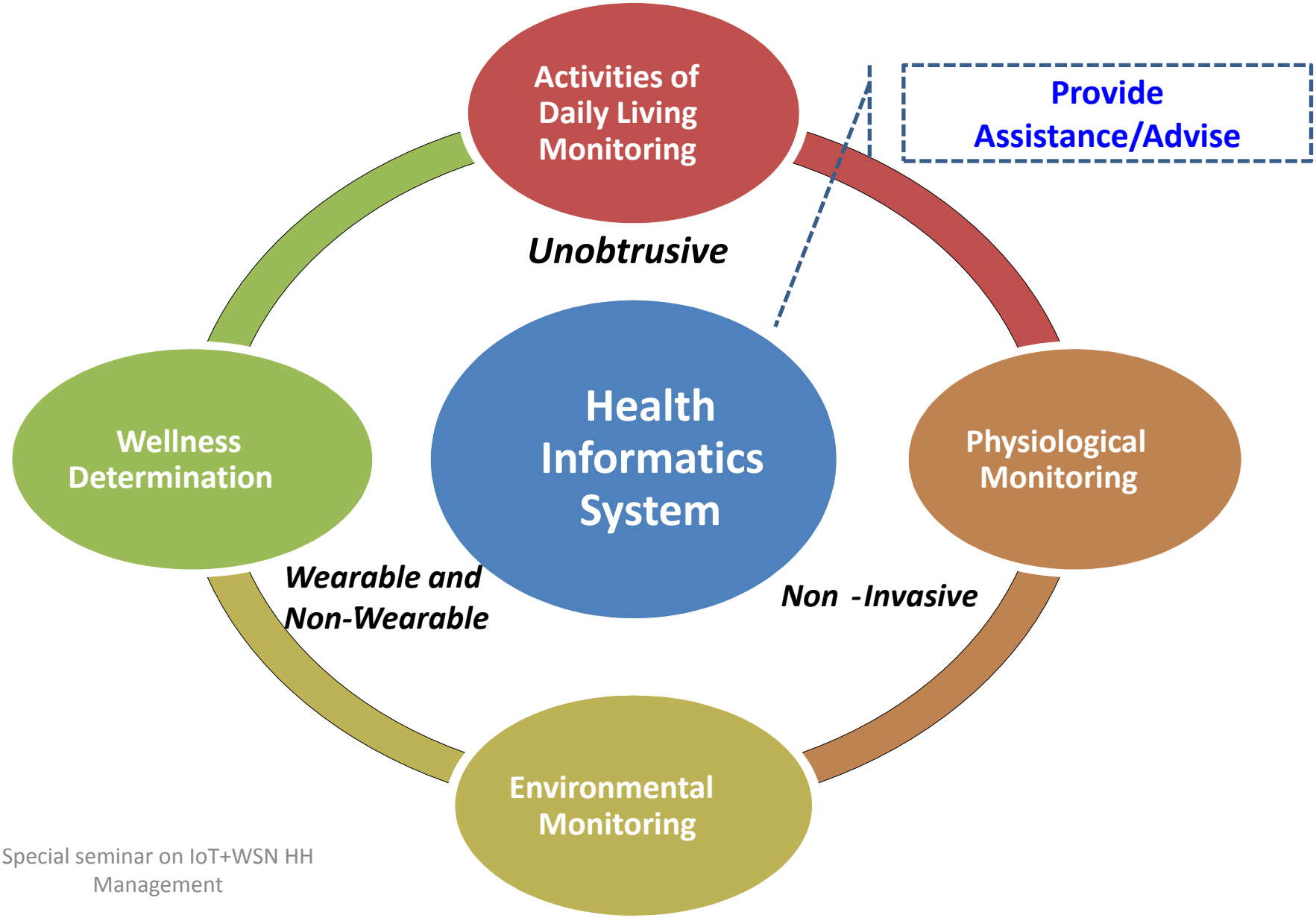




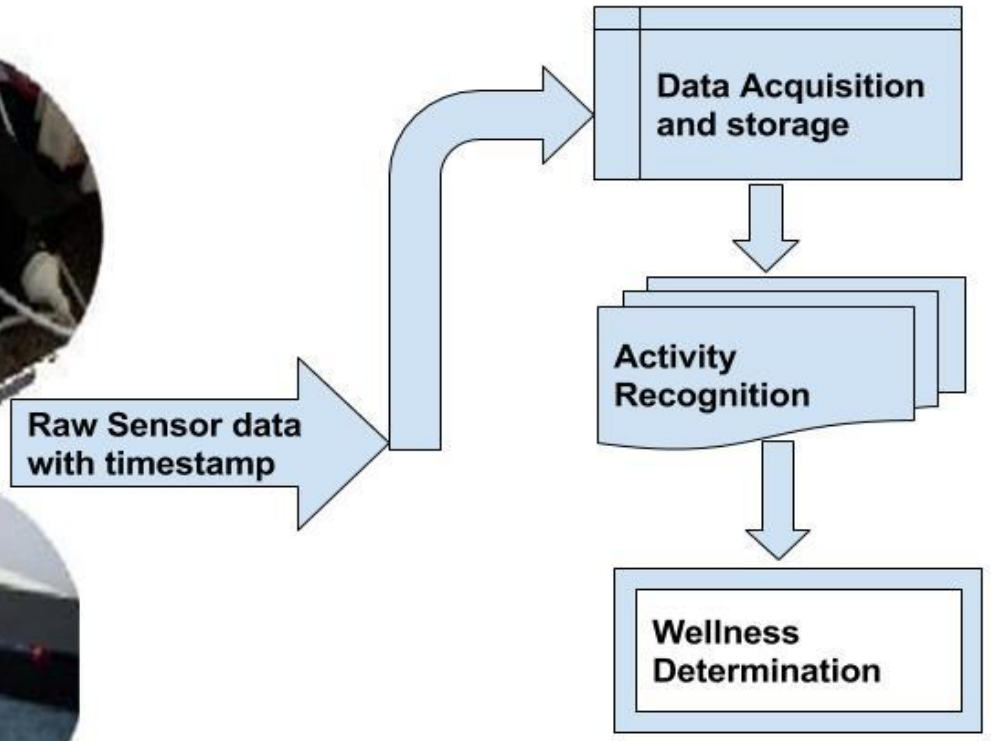


N.K. Suryadevara, S.C. Mukhopadhyay, S.D. T. Kelly and S. P. S. Gill, WSN-Based Smart Sensors and Actuator for Power Management in Intelligent Buildings, IEEE Transactions on Mechatronics, Vol. 20, No. 2, April 2015, pp. 564-571

Our Research



Technology Assisted Home



Key Components – Health Informatics System

- **Information and Communication Technology**
  - **Compatibility of Sub-Systems**
  - **Flexibility**
  - **Robust**
  - **Real-Time Processing of Data**

Wellness of an Independent Living Person

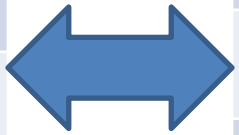
- *How "Well" a person living alone in their home is able to perform their essential daily activities in terms of using household appliances*?
- **Performance of Daily Activities**

Performance behavior

- Livelihood activities are Cyclic
- **Monitor usage of household objects for recognizing the habitual nature of the person.**

Monitoring Basic ADL

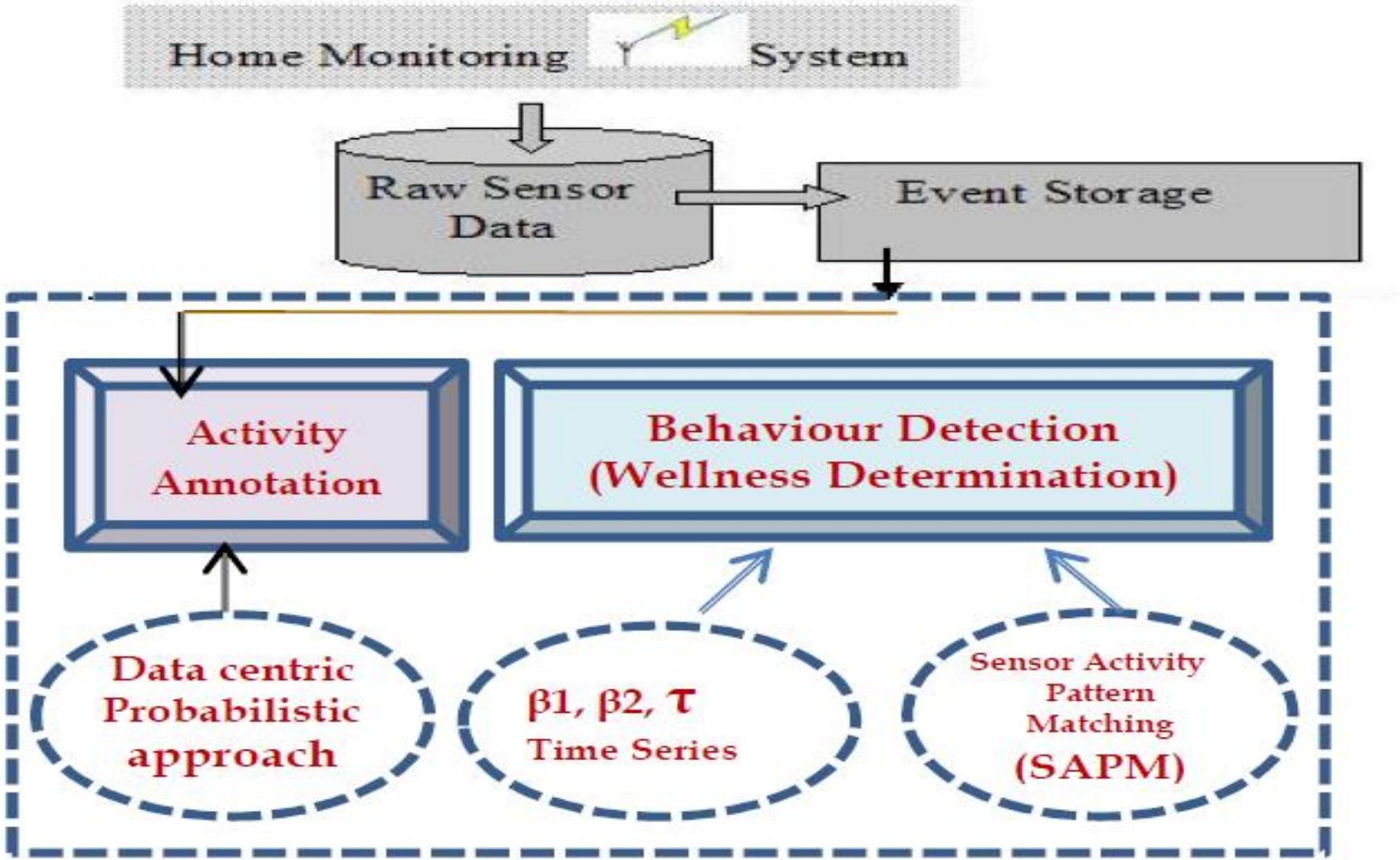
ADL	α	Household Appliance Usage
Preparation of Food (Breakfast,Lunch,Dinner)		Microwave, Water Kettle, Toaster or (any other item used regularly in Kitchen)
Sleeping		Room Heater
Toileting, Self Grooming		Television/Radio
Dinning		Bed, Couch, Chair, Toilet
Relax		Any other appliance used as habitual
Watching TV(while sitting on Couch)		



Passive Infra Red(PIR) Sensors: Mobility(Movements monitoring)

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.

Wellness Determination:Tools



Wellness Functions, β1 and β2

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

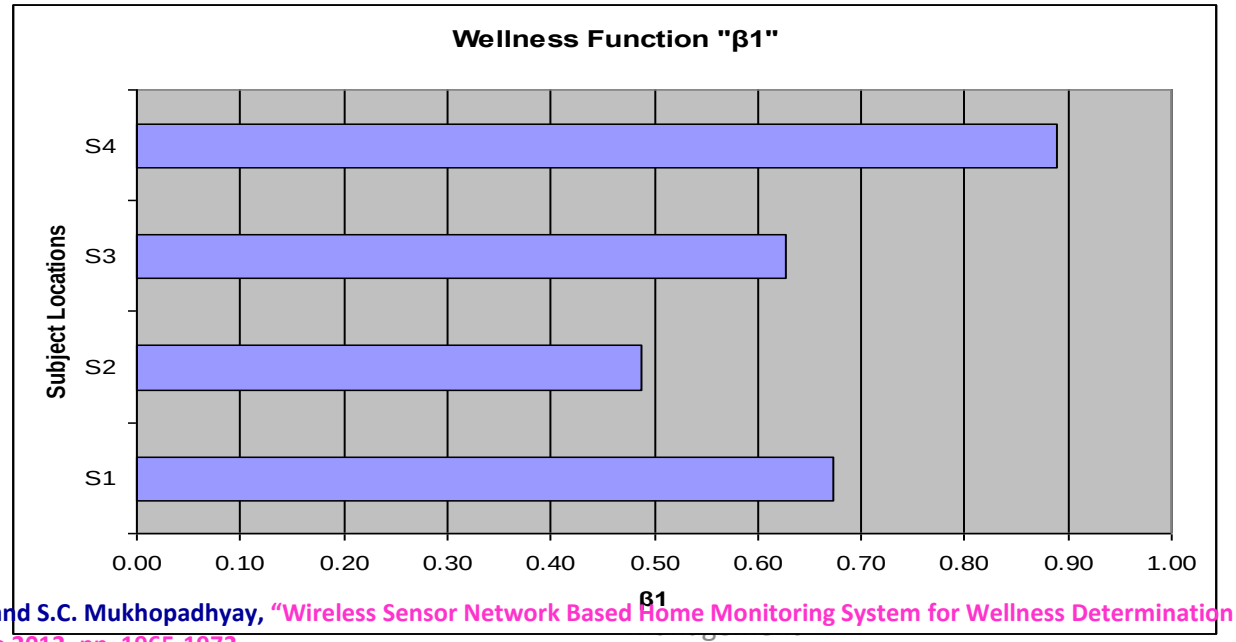
Wellness function **β1 =** $1 - \frac{t}{T}$

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.



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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

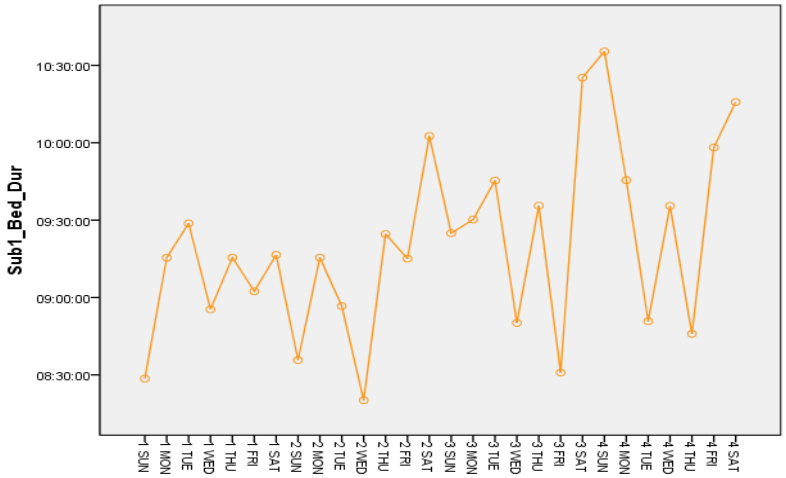
Only if Ta > Tn then β2 is calculated.

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

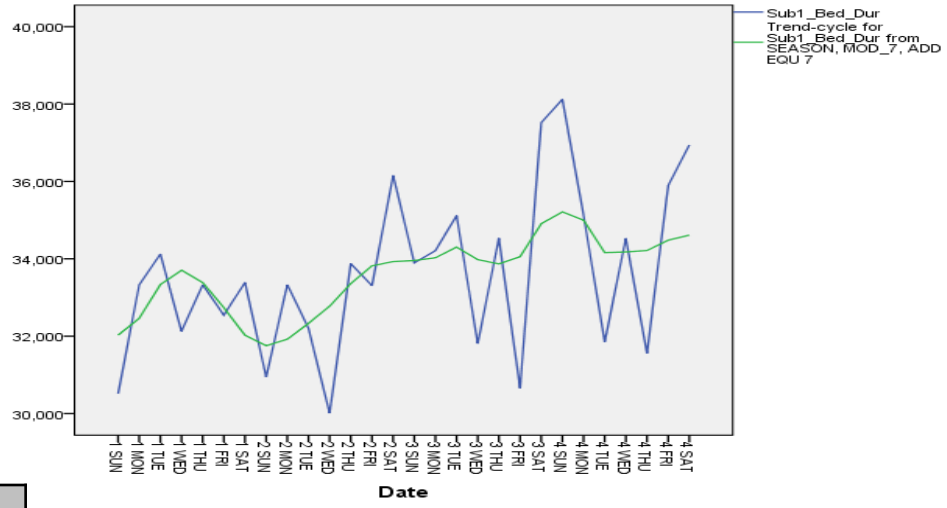
If β2 goes less than 0.5 indicates excess usage of the appliance and may lead to an abnormal condition.

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)

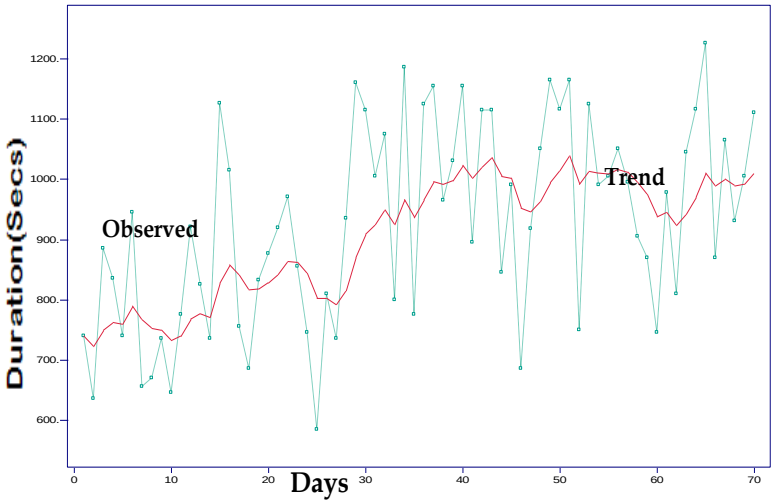


Fig 9(a) Toilet usage Trend for 70 days

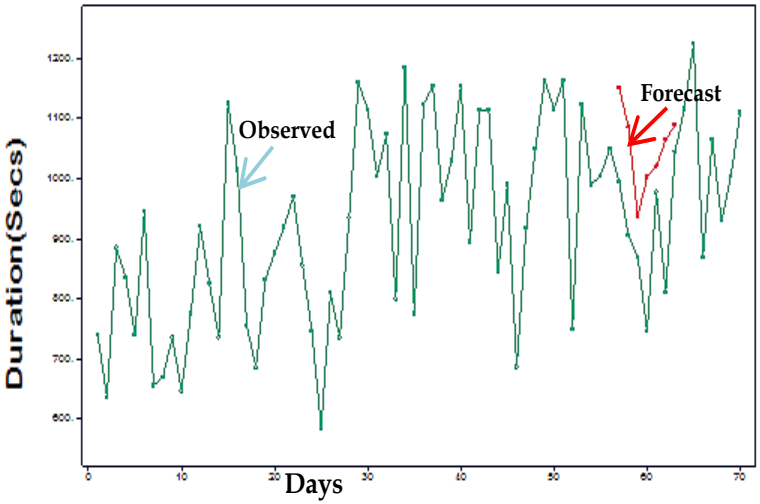


Fig 9(b) Toilet usage (Ninth week forecast pattern)

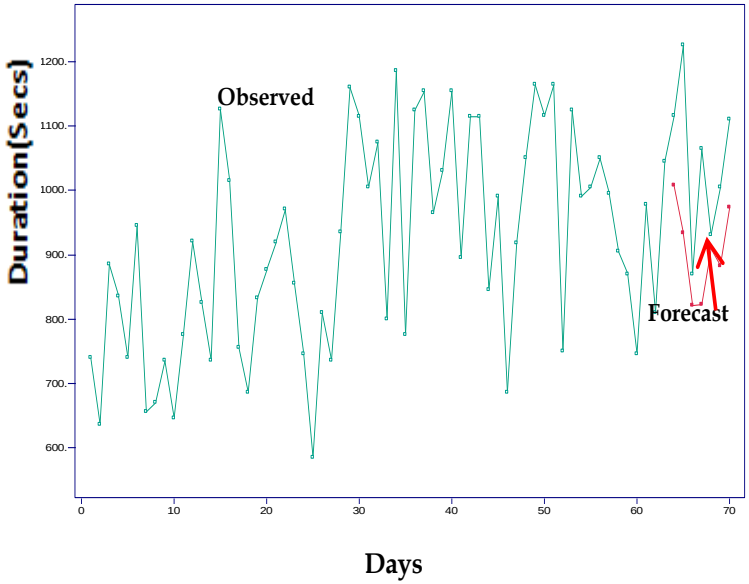


Fig 9 (c) Toilet usage (Tenth week forecast pattern)

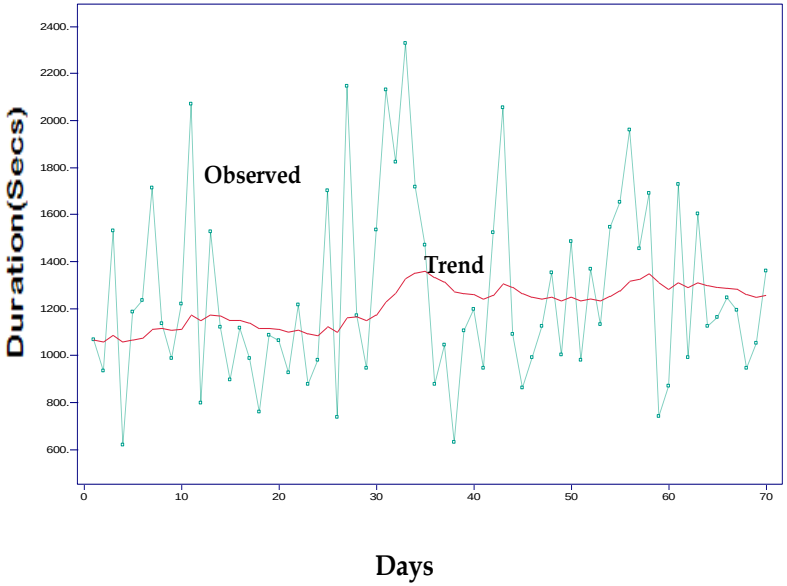


Fig 9(d) Chair Usage Trend for 70 days

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.

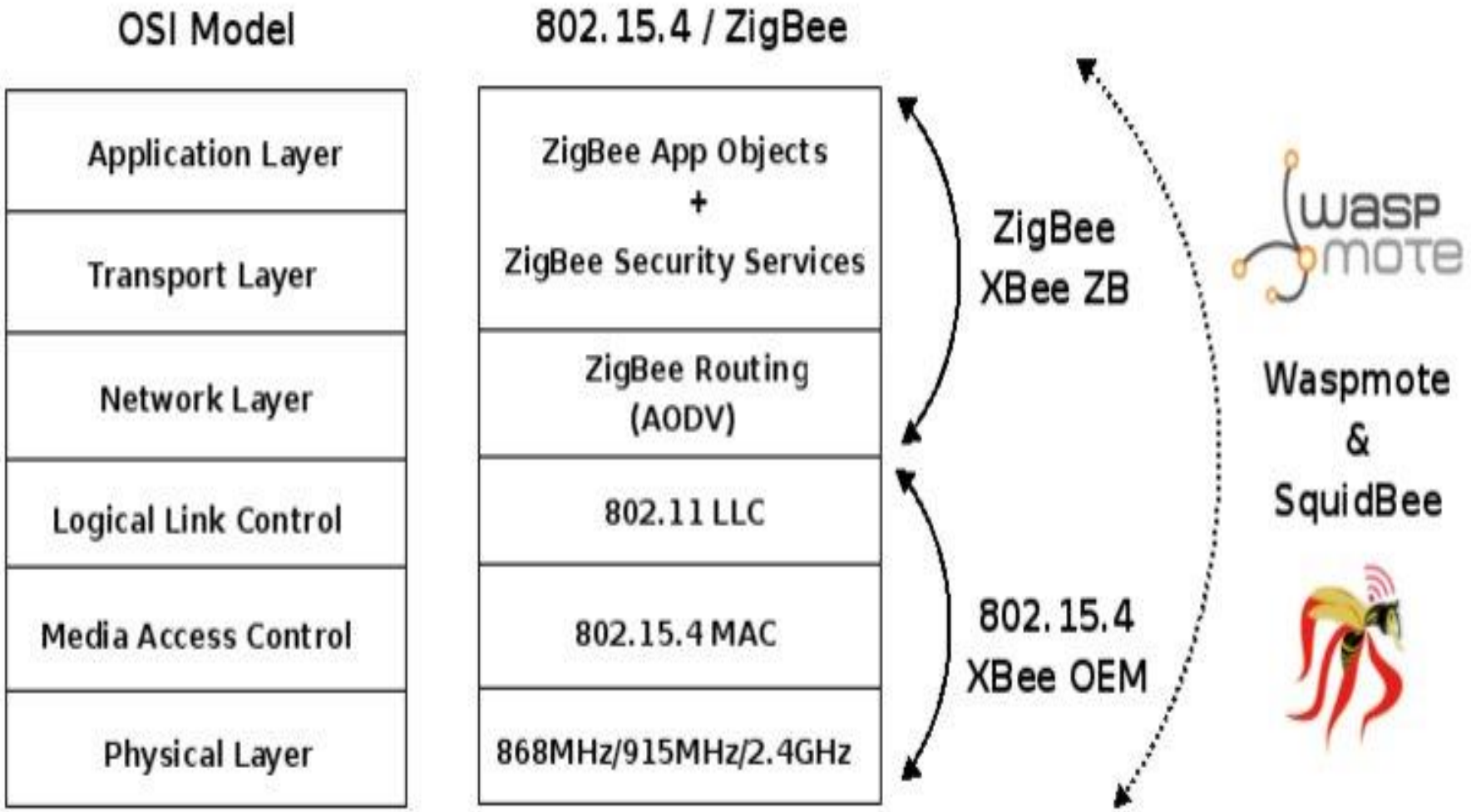
Development of New Protocol

Wellness Protocol: A Proposal and Implementation for Smart Home

Why a new protocol?

a. The protocol used was a generalized protocol
b. The protocol provides possibility of adding a huge number of nodes (65,535), forcing to use a lot of data for device identification
c. The routing protocol was designed by the manufacturer (proprietary protocol), not allowing to include anything of our own
d. The ZigBee is not able to process any data
e. The header data is too large
f. A huge amount of data are transmitted and creating a problem
g. The sampling was not adaptive
h. Storage of data was also a big issue.

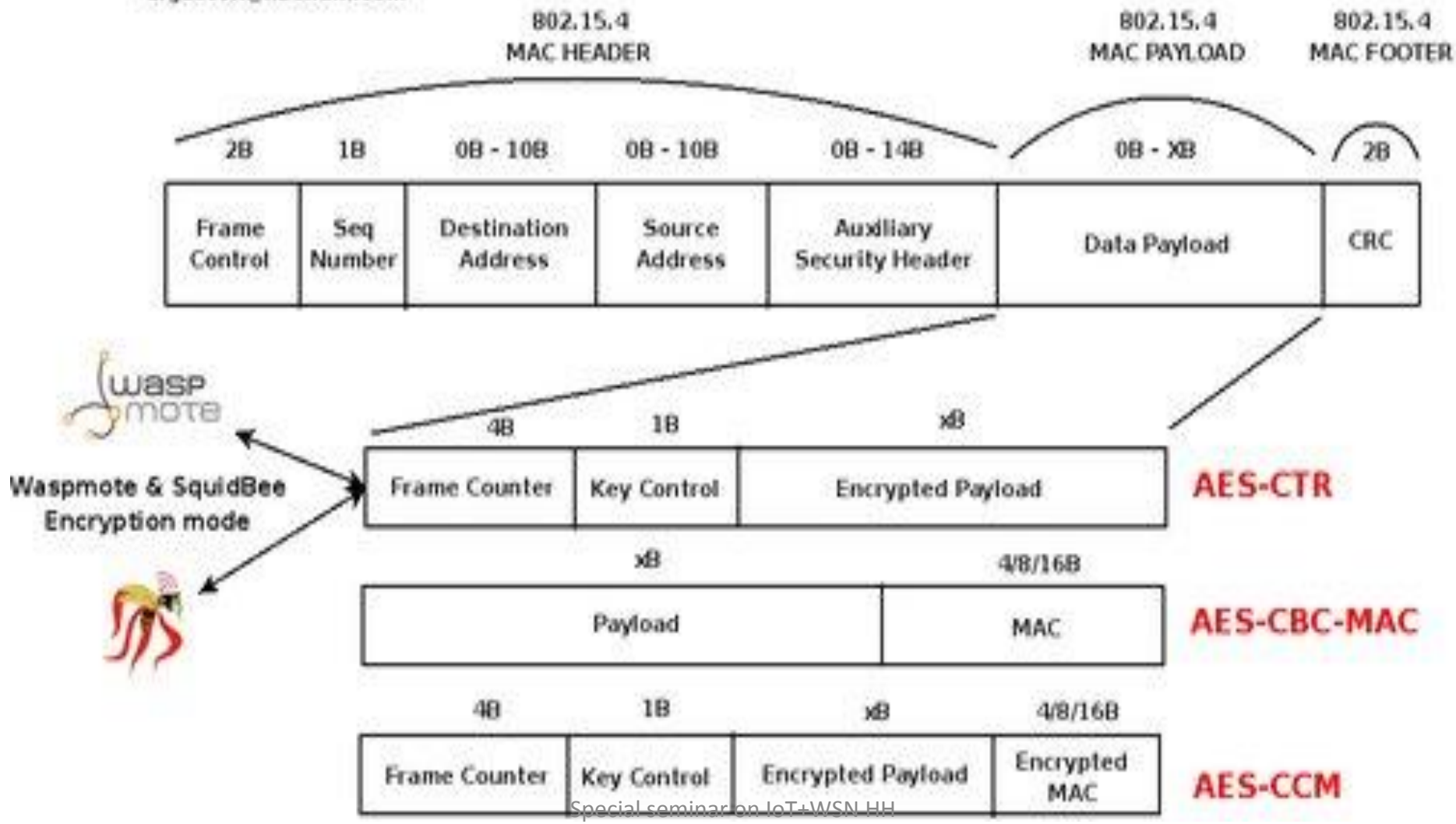
ZigBee Model



ZigBee protocol

Security in the IEEE 802.15.4 MAC FRAME
http://www.sensor-networks.org

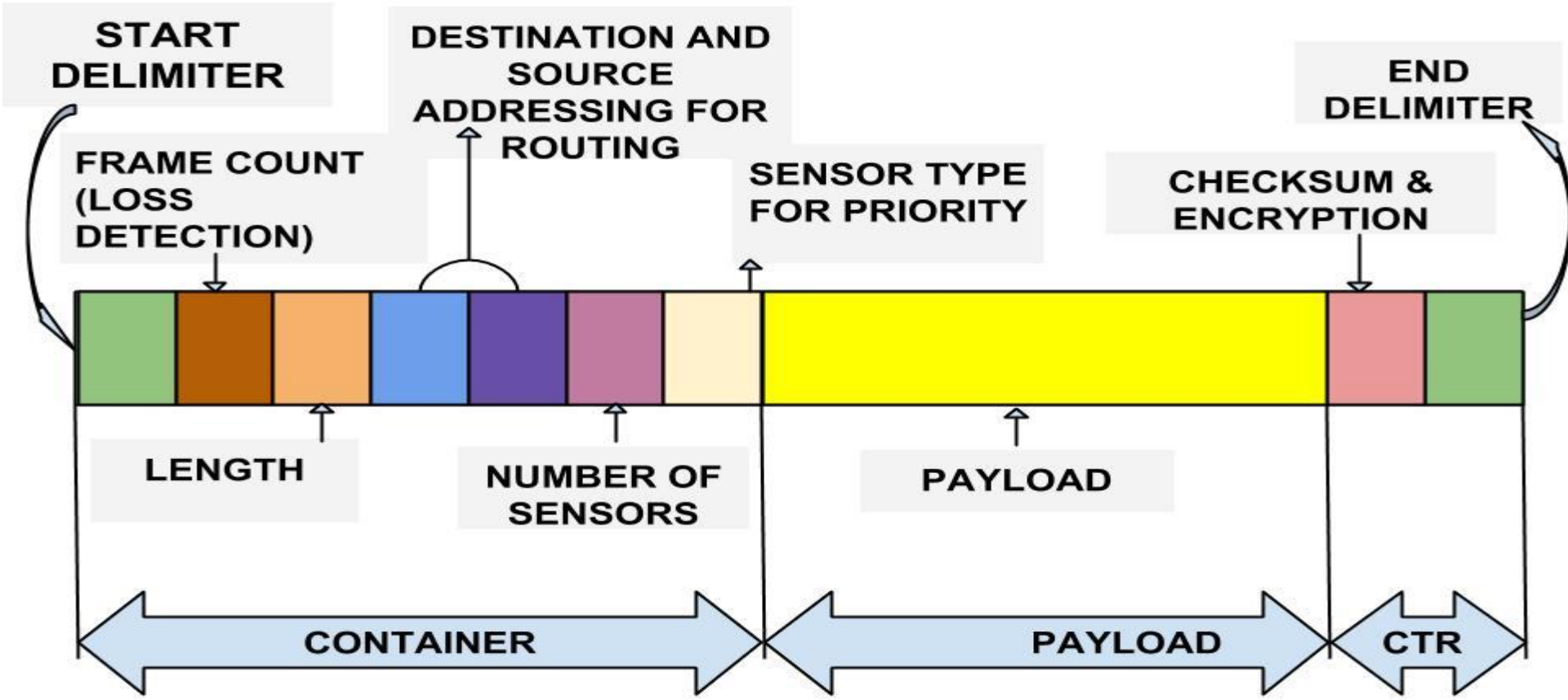
Author: David Gascón
d.gascon@libelium.com



Problem solution : Proposed protocol, Customized solution for smart home

Byte Order	Field Name	Field Value	Data Type	Description
1 and 2	Delimiter	B1	Fixed 2 bytes	Start Delimiter
3	Frame count	0000 to 1111 (Binary)	4 bit fix size	Cycle counting to check missing frame
	Length	0000 to 1111 (Binary)	4 bit fix size	Number of bytes between length and checksum
4	Destination Address	0000 to 1111 (Binary)	4 bit fix size	Destination 4-bit address
	Source address	0000 to 1111 (Binary)	4 bit fix size	Sender 4-bit address
5	Number of data	0000 to 1111 (Binary)	4 bit fix size	Indicated the number of sensors
	Sensor type or priority	0000 to 1111 (Binary)	4 bit fix size	Indicates the type of sensor, such as 0000= Highest priority panic button, 0001= fire sensor
7	Payload		8 bit to 16 bit	If the data is digital 8 bit and analog 16 bit
8	Checksum		8 bit fix size	0xFF minus 8-bit sum of bytes between the length and checksum fields
10	Delimiter	C1	2 bytes fix size	End Delimiter

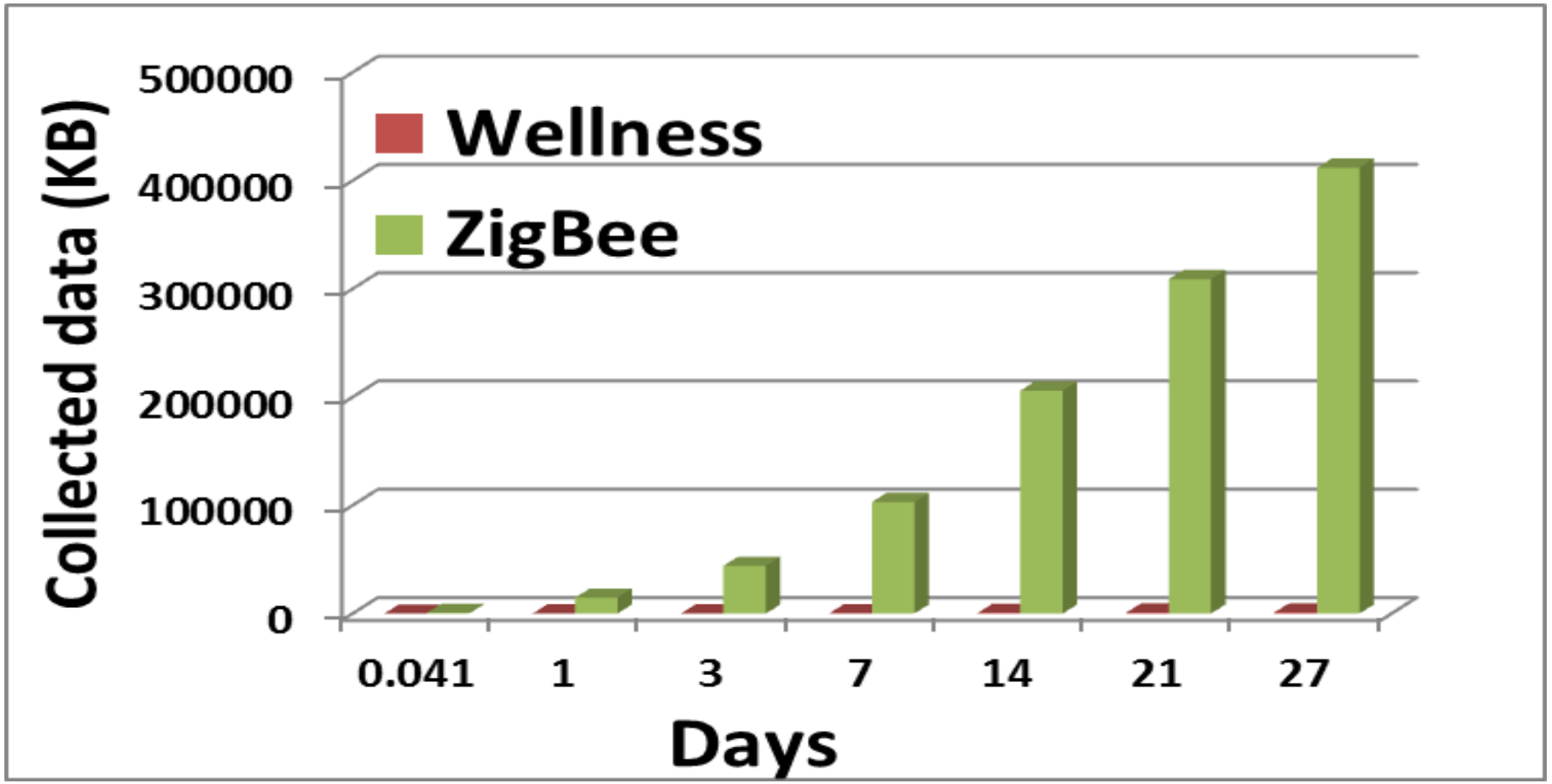
Packet Encapsulation structure



Experimental Results: IoT based Website

Time begin and end	Object type	Duration
21:50:30 to 7:00:42	Bed	09:10:12
07:15:38 to 07.26:21	Toilet	00:10:43
07:50:20 to 08:09:29	Dining table	00:19:09
08:23:32 to 09:54:21	Sofa-set	01:30:49
11:19:11 to 11:50:52	Dining table	00:37:41
12:10:27 to 13:33:54	Sofa-set	01:23:27
13:55:44 to 14:04:51	Toilet	00:08:07
15:21:31 to 15:33:42	Dining	00:12:11
17:01:29 to 17:08:44	Toilet	00:07:15
17:11:43 to 17:34:22	Sofa-set	00:22:39
18:10:24 to 18:40:55	Dining table	00:30:31
19:10:42 to 20:38:21	Sofa-set	01:27:39
21:38:32 to 21:42:22	Toilet	00:03:50

Experimental Results: Large data issues



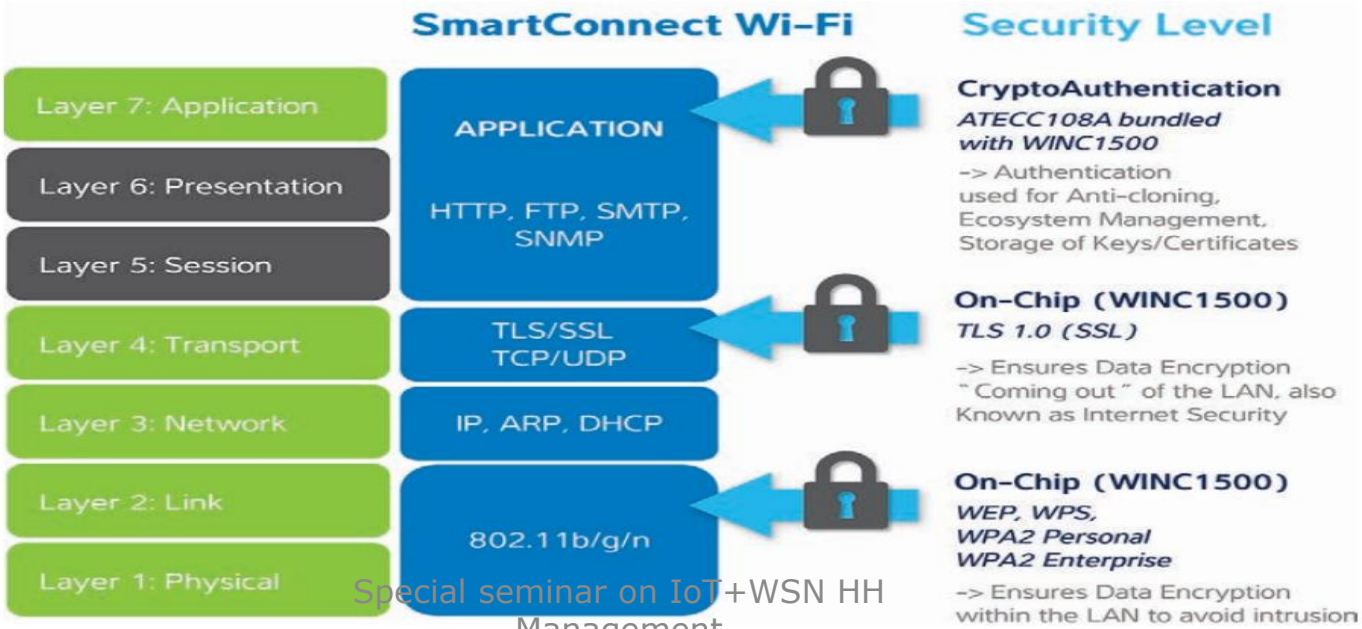
Comparative graph on data collection between ZigBee and Wellness protocol for Electrical & Electronic sensing unit when the ZigBee's sampling rate was 1s.

Challenges of IoT System

- Availability of internet at everywhere at all time
- Low-cost smart sensor node development
- Energy harvesting
- Computational ability
- Security issues,
- Scalability, Reliability
- Fault Tolerance
- Power Consumption of nodes and transceiver

Security of IoT Device

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



Power Supply for sensor nodes

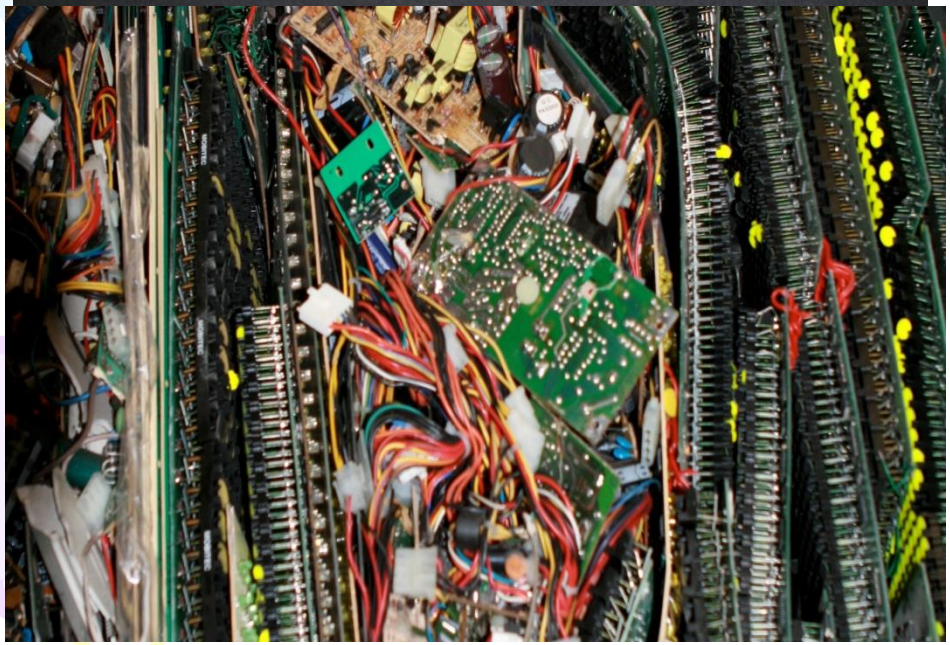
Battery selection:

- Type of battery (Alkaline, Lithium-Ion, NiCad, NiMH, Lead-Acid)
- Life-time (Ahr requirement)
- Environmental impact
- Cost
- Size
- Memory effect
- Safety issue
- Etc.

Opportunity: Development of Environmentally friendly new types of rechargeable batteries.

Research on Energy harvesting techniques.

Other Challenges: Emerging Environmental Issues, e-Waste



Dumping of computers, monitors, cell-phones??

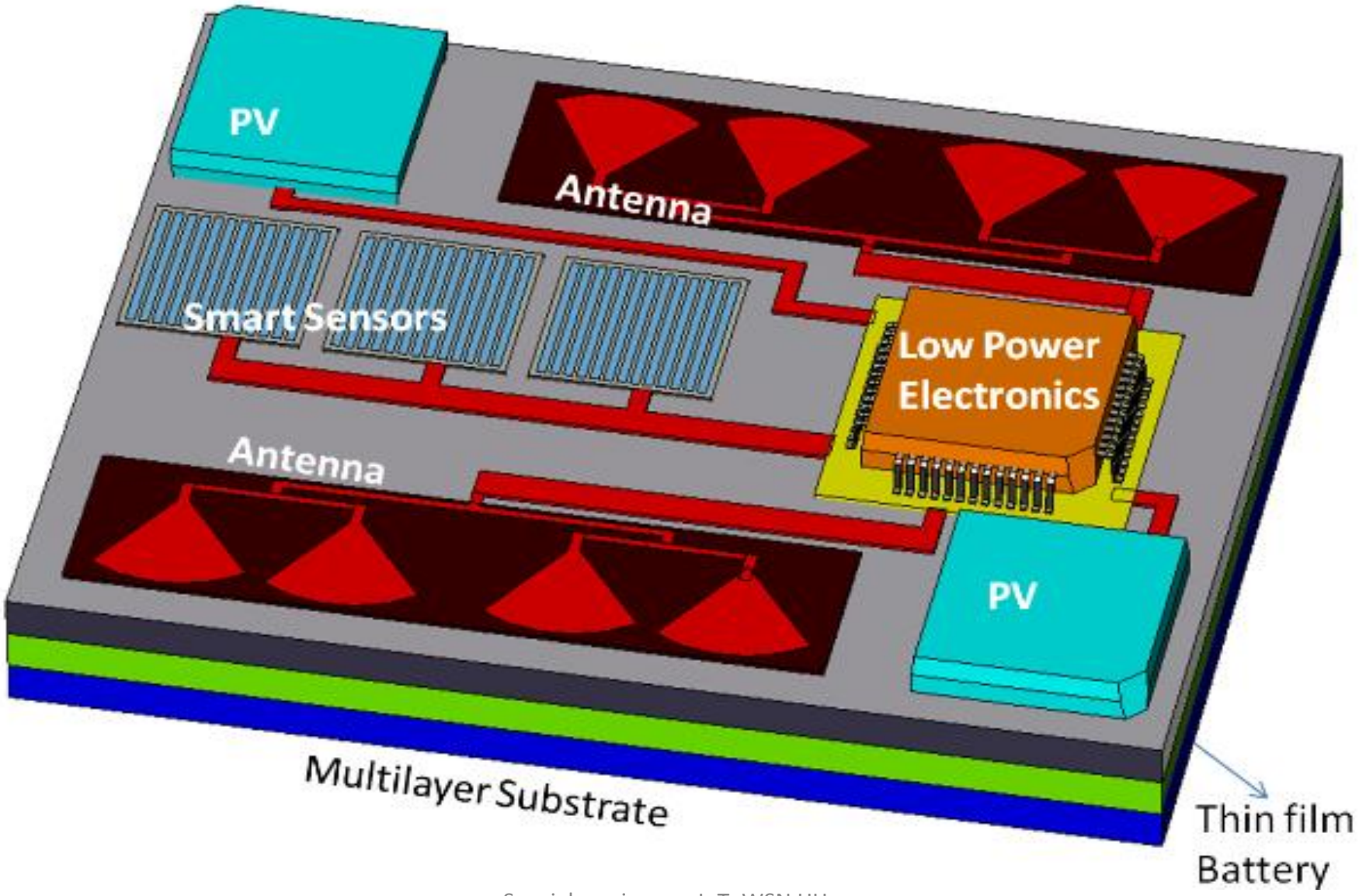
Donate those items to underdeveloped countries to be used at school or other educational organizations?

E-Waste: Opportunity

Design Bio-degradable WSN

Design Non-Hazardous WSN

Smart Sensor Node for IoT



Summary

- A WSN and IoT Assisted based smart home.

- The integrated system is able to support people who wish to live independently.

- A new protocol especially for smart home has been proposed, designed and developed.

- The developed system is robust and is possible to develop at a low cost due to indegenious development.

- The system will inform the wellness status of the inhabitant to the caregiver in advance.

Thank You

Questions & Comments

The Communication Protocols of IoT

-There are some protocols which are used to communicate to the internet for an IoT device. They are

HTTP (Hypertext Transfer Protocol): HTTP is the foundation of the client-server model used for the Web. The more secure method to implement HTTP is to include only a client in the IoT device, not a server to avoid outside access to the network.

WebSocket: WebSocket is a protocol that provides full-duplex communication over a single TCP connection between client and server. It is part of the HTML 5 specification

CoAP (Constrained Application Protocol): designed by the IETF for use with low-power and constrained networks. It is a RESTful protocol. CoAP is a good choice of protocol for devices operating on battery or energy harvesting.

MQTT (machine-to-machine (M2M)/"Internet of Things"): is an open source protocol for constrained devices and low-bandwidth, high-latency networks. It is a publish/subscribe messaging transport that is extremely lightweight and ideal for connecting small devices to constrained networks.