The Potential of Internet of Things (IOT) for Assisted Living Applications

Robert S. H. Istepanian

Professor of Data Communications, Kingston University, London
Mobile Information and Network Technologies Research Centre
Faculty of Computing, Information Systems and Mathematics

Kingston University, London, UK
E-mail: r.istepanian@kingston.ac.uk

The Institution of Engineering and Technology
Assisted Living 2011
Wednesday, 6 April 2011 IET London: Savoy Place

Summary

- Mega Trends in Healthcare and IT
- Evolution of m-health and '**4G – Health**'
- IOT
- New **m-IOT** Concept
- Exemplars of m-IOT in assisted living
- Future trends

Collective inspiration

The Institution of Engineering and Technology
Assisted Living 2011
Wednesday, 6 April 2011 IET London: Savoy Place

MINT Research Centre

Mega Trends in Healthcare IT

Medicine

1.Telemonitoring of patients
2.Personalised Medicine
3.Customising clinical research with EHR

Politics and Society

1.Aging population in the West
2.Rising costs: The value of embedding value
3.Medical Tourism, innovation and globalisation

Technology

1.Cloud Computing
2.Medicine 2.0
3.Mobility in healthcare service provision
4.Robotics and Nanotechnology

REF: Healthcare IT Management ; 5;5, 2010

Today, there are roughly 1.5 billion Internet-enabled PCs and over 1 billion Internet-enabled cell phones. The present "Internet of PCs" will move towards an "Internet of Things" in which 50 to 100 billion devices will be connected to the Internet by 2020.

REF: **Vision and Challenges for Realising the Internet of Things, H.** Sundmaeker, et al (Eds.) 2010

KINGSTON UNIVERSITY

MINT Research Centre

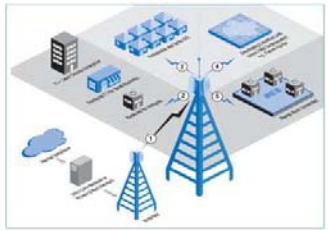
Mobile HealthCare (M-Health)

Wearable and Sensors
(BAN, PANs etc.)

Computing and Internet
Technologies

M-health

Information and
Communication Systems



Istepanian et al. IEEE 2004

M-health Evolution: 1997-2003

194 IEEE TRANSACTIONS ON INFORMATION TECHNOLOGY IN BIOMEDICINE, VOL. 4, NO. 3, SEPTEMBER 2000

Guest Editorial
Special Issue on Mobile Telemedicine and Telehealth Systems

Design of a Telemedicine System Using a Mobile Telephone

B. Woodward, *Member, IEEE*, R. S. H. Istepanian, and C. I. Richards

Abstract—**This paper describes the design of a prototype integrated mobile telemedicine system that is compatible with existing mobile telecommunications networks and upgradable for use with third-generation networks. The system, when fully developed, will enable a doctor to monitor remotely a patient who is free to move around for sports medicine and for emergency situations.**

Proceedings of the 25th Annual International Conference of the IEEE EMBS
Cancun, Mexico • September 17-21, 2003

Emerging Mobile Communication Technologies for Health: Some Imperative notes on m-health

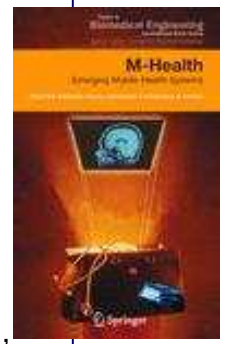
Robert S. H. Istepanian[1] and Jose C. Lacal[2]
[1]Mobile Information & Network Technologies Research Center; Kingston University (UK)
[2]Tele-Health Solutions; Motorola / iDEN Subscriber Group (USA)

KINGSTON UNIVERSITY

MINT Research Centre

m-Health Defined

Mobile Health Care (m-Health)



'Emerging Mobile Communications ,Network and Sensor Technologies For Healthcare Systems and Applications'

REF: Istepanian (*etal*.), 'm-health: Beyond Seamless Mobility for Global Wireless Healthcare Connectivity ', *IEEE Trans. Information Technology in Biomedicine*, Vol. 8, 4, pp. 405-412, 2004.

Guest Editorial
Introduction to the Special Section on
M-Health: Beyond Seamless Mobility and Global
Wireless Health-Care Connectivity

Long Term m-health Evolution

Some Interesting ‘ Google’ Statistics:

Google Search - March 2011

- ‘m-health’ > 102,000,000 Hits
- Internet of Things > 43,100,000 Hits
- Internet of Things for healthcare > 4,340,000

Mobile Healthcare Industry Summit 2010
21-22 September 2010
Radisson Blu, London

Opportunities in the global mobile healthcare market are estimated to be worth between $50bn and $60bn in 2010

Source: McKinsey & Company-2010

KINGSTON UNIVERSITY

MINT Research Centre

4G Health- The Long Term Evolution of m-health

Interim Definition:

'The evolution of m-health towards targeted personalised medical systems with adaptable functionalities and compatibility with the future 4G networks'

CALL FOR PAPERS: Special Issue on

4G Health

The Long Term Evolution of m-Health

KINGSTON UNIVERSITY

MINT Research Centre

m-health as a global Industry

O2 debuts mHealth division

O2 looks to develop opportunities in healthcare sector with new mHealth unit

Source: mobile news — The UK's leading mobile industry news source

2010

Qualcomm, AT&T Move in on 'M-Health'

The smartphone boom has tech giants and health-care companies eyeing demand for wireless gadgets and software that can deliver health services

Source: Bloomberg Businessweek

2010

MOBILE CLINICAL ASSISTANT

What is it?

Nurses and physicians need better access to patient information at the point of decision to provide quality care more efficiently. The Intel® Mobile Clinical Assistant (MCA) reference architecture was designed in collaboration with healthcare professionals to better access up-to-date patient care records at the point of care and to enable documentation of a patient's condition in real time. The MCA is built for the rigors of the clinical environment and with appropriate software the MCA helps to reduce transcription and medication administration errors, enhance clinician workflows, and enable more informed decisions at the point of care.

Source: Intel

Who is Who in m-Health!

IOT – Background and Definitions

In general there is no single accepted definition of the Internet of Things (IoT).

However, The term IoT, first used by Kevin Ashton from MIT- Auto- ID Centre during a presentation in 1998 and with David L. Brock in 2001 that describes an emerging global, Internet-based information service architecture.

REF: Rolf H. Weber, 2009, "Internet of Things - Need for a New Legal Environment?" Computer Law & Security Review, pp. 522-527.

The ITU in 2005 definedThe Internet of Things is a technological revolution that represents the future of computing and communications, and its development depends on dynamic technical innovation in a number of important fields, from wireless sensors to nanotechnology.

ITU, 2005, "Internet Reports 2005: The Internet of Things", ITU Internet Report.

IOT – Definitions-2

The Internet of Things (IoT) is an integrated part of the Future Internet and could be defined as a dynamic global network infrastructure with self configuring capabilities based on standard and interoperable communication protocols where physical and virtual “things” have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network.

(http://www.internet-of-things.eu) IoT - Architecture (IoT-A*) – EU project*

Internet of things, also known as the **Internet of objects**, refers to the networked interconnection of everyday objects. It is described as a self-configuring wireless network of sensors whose purpose would be to interconnect all things.

REF: Wikipedia- Conner, Margery (2010-05-10). Sensors empower the "Internet of Things". pp. 32–38. ISSN 0012-7515

The notion of an “**Internet of Things**” refers to the possibility of endowing every day objects with the ability to identify themselves, communicate with other objects, and possibly compute.

REF: Rellermeyer, J., S. – ETH Zurich- C. Floerkemeier et al. (Eds.): IOT 2008, LNCS 4952, pp. 87–104, 2008

Technologies of IOT

Enabling Building Blocks *These technologies directly contribute to the development of the IoT*	Synergistic Technologies *These technologies may add value to the IoT*
Machine-to-machine interfaces and protocols of electronic communication Microcontrollers Wireless communication RFID technology Energy harvesting technologies Sensors Actuators Location technology Software	Geo-tagging/geo-caching Biometrics Machine vision Robotics Augmented reality Mirror worlds Tele-presence and adjustable autonomy Life recorders and personal black boxes Tangible user interfaces Clean technologies

SRI Consulting Business Intelligence-2005
http://www.dni.gov/nic/PDF_GIF_confreports/disruptivetech/appendix_F.pdf

Potential IOT Applications

Some of the key areas and application domains of IOT are :

- Aerospace and aviation,
- Automotive,
- Telecommunications,
- Intelligent Buildings,
- **Medical Technology, Healthcare,**
- **Independent Living**
- Pharmaceutical,
- Retail, Logistics, Supply Chain Management,
- Manufacturing, Product Lifecycle Management,
- Oil and Gas

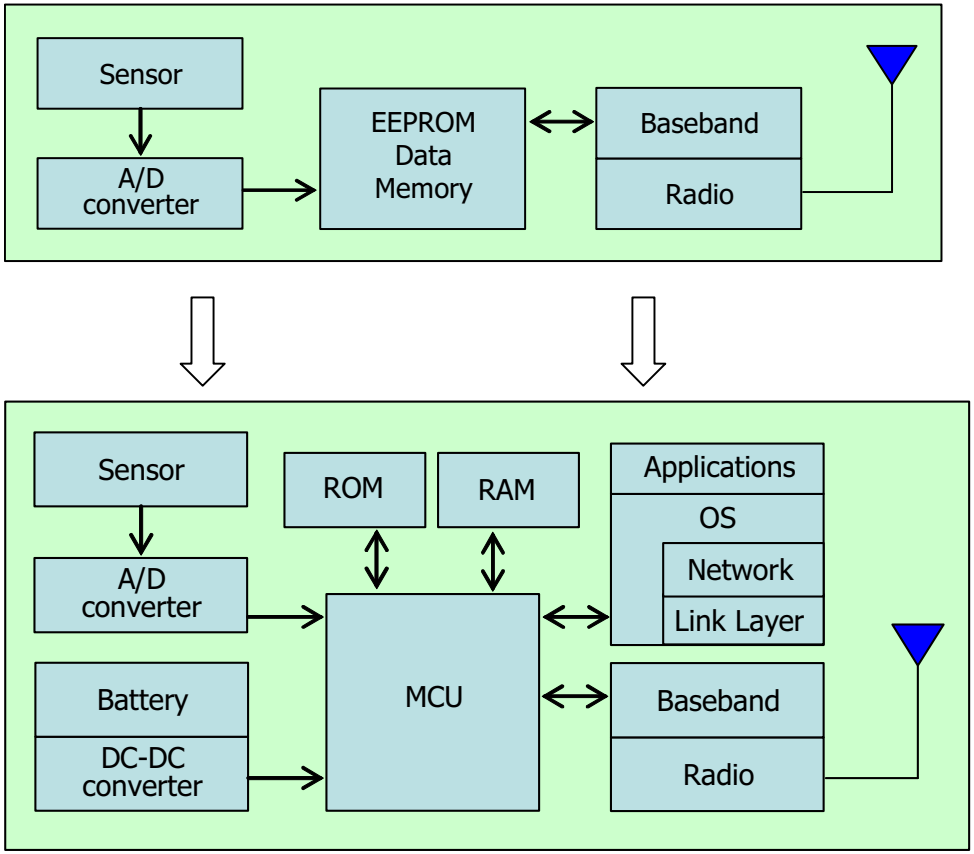
The 'Things' from the healthcare Perspective

Source: EU - Cluster of European Research Projects on the Internet of Things (CERP-IoT),- 2009

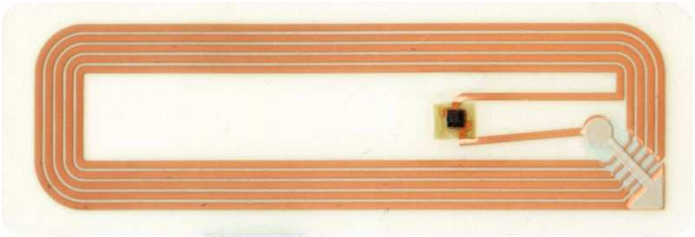
KINGSTON UNIVERSITY

MINT Research Centre

RFID and Internet of Things



Active RFID tags



Sensor nodes

(Sensor tag plus a microcontroller Communication links to other sensor nodes and readers)

- Enabling technology for the “Internet of Things”
- RFID connects the Internet to the real world
- RFID makes items “smart” and able to communicate with their environment

REF: CASAGRAS - www.feig.de-

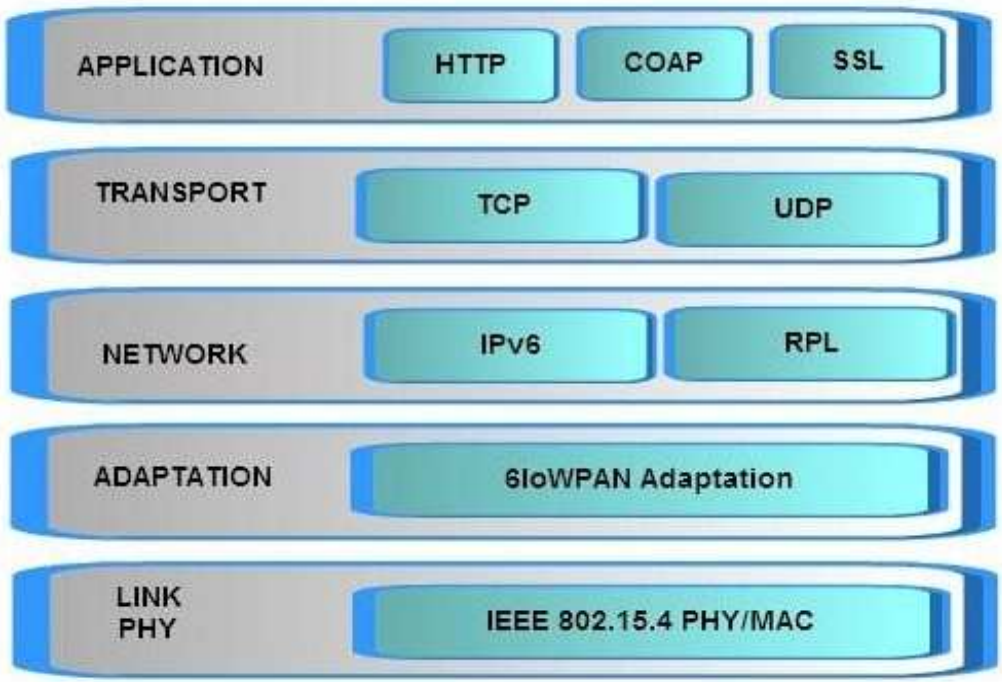
KINGSTON UNIVERSITY

MINT Research Centre

IOT Protocol and Layers

Link/PHY Layer:

IEEE 802.15.4-2006 is a standard that specifies the physical layer and media access control for low-rate wireless personal area networks (LR-WPANs). It is standardised by the IEEE 802.15 working group.



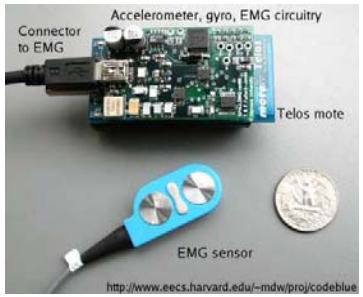
6LoWPAN is the enabling protocol of Internet of Things and providing IPv6 addressing and connectivity to the 802.15.4 based embedded devices. It works by compressing 60 bytes of headers down to just 7 bytes, and optimizing mechanisms for wireless embedded networking

M-health IOT (m-IOT)

The ‘Things’ from the m-health Perspective

The IoT technologies will have numerous applications in the healthcare sector, with the possibility of using the future mobile technologies and wearable sensor capabilities as a next generation platform for different m-health applications.

Future IoT applications will also impact on different independent/ assisted living applications. These include developing new enabling platforms for aging population, such as detecting the activities of daily living using wearable and ambient sensors, monitoring social interactions and chronic disease managements.



M-health IOT (m-IOT)- Definition

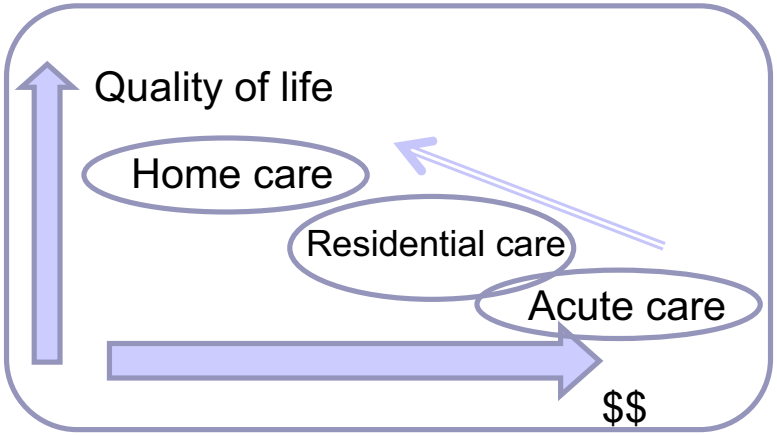
‘m-IOT is a new concept that matches the functionalities of the two paradigms of IoT and m-health for a new and innovative 4G- health applications’.

In principal (m-IOT) introduces a new healthcare connectivity paradigm that interconnects IP based communication technologies such as Near Field Communications (NFC), 6LOWPAN, Low power Bluetooth and emerging 4G networks for future Internet based healthcare services.

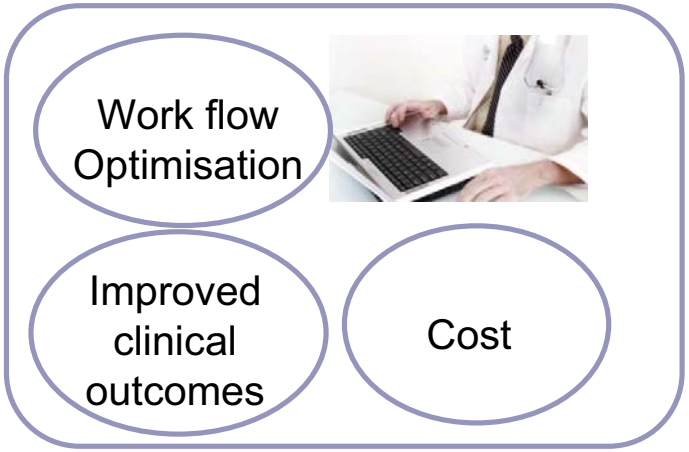
The Institution of Engineering and Technology
Assisted Living 2011
Wednesday, 6 April 2011 IET London: Savoy Place

The need for m-IOT applications in healthcare

Shift to home care demands



Mobility in Healthcare



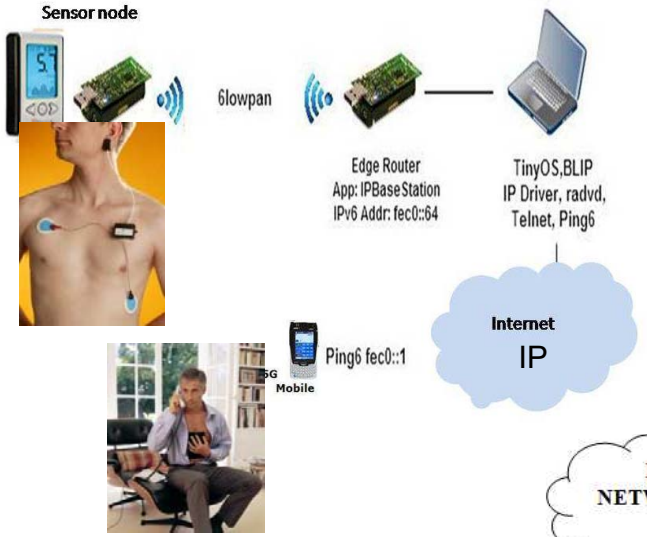
Network and IP based Infrastructure Growth

Advances in Wireless medical Devices

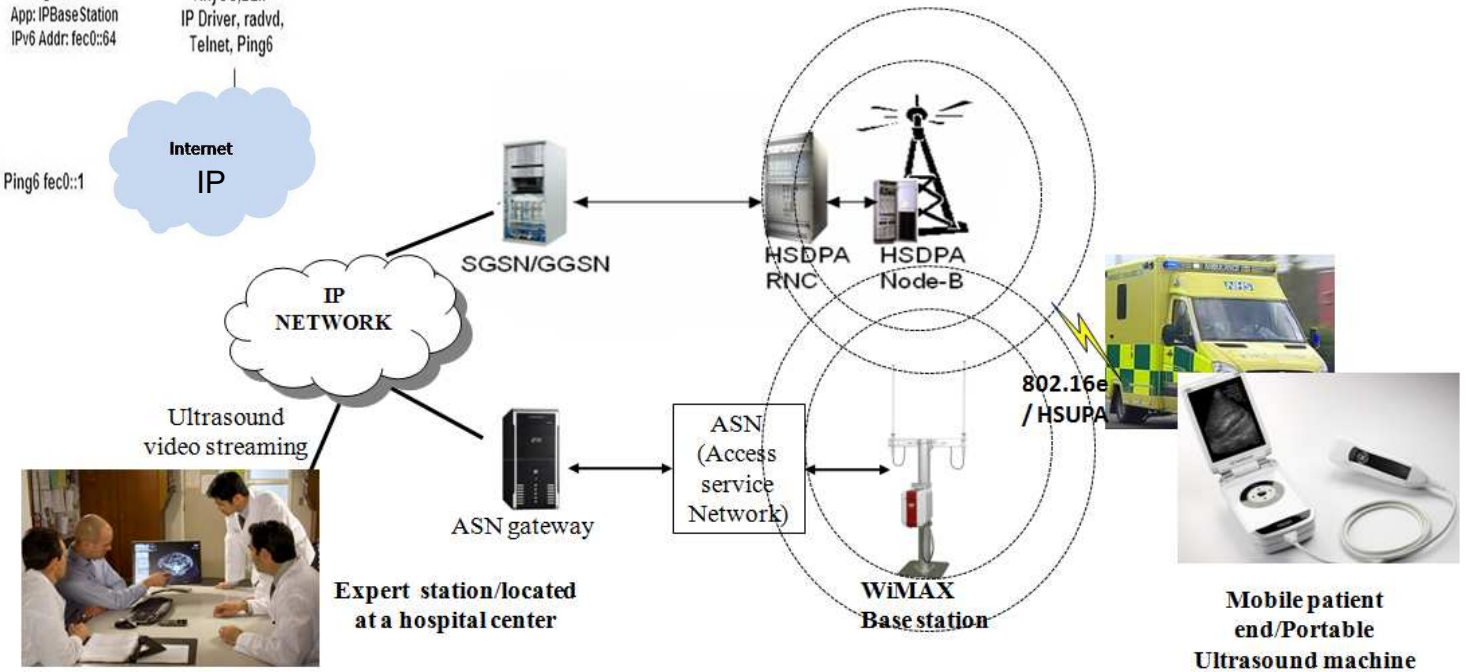
KINGSTON UNIVERSITY

MINT Research Centre

m-IOT Exemplars

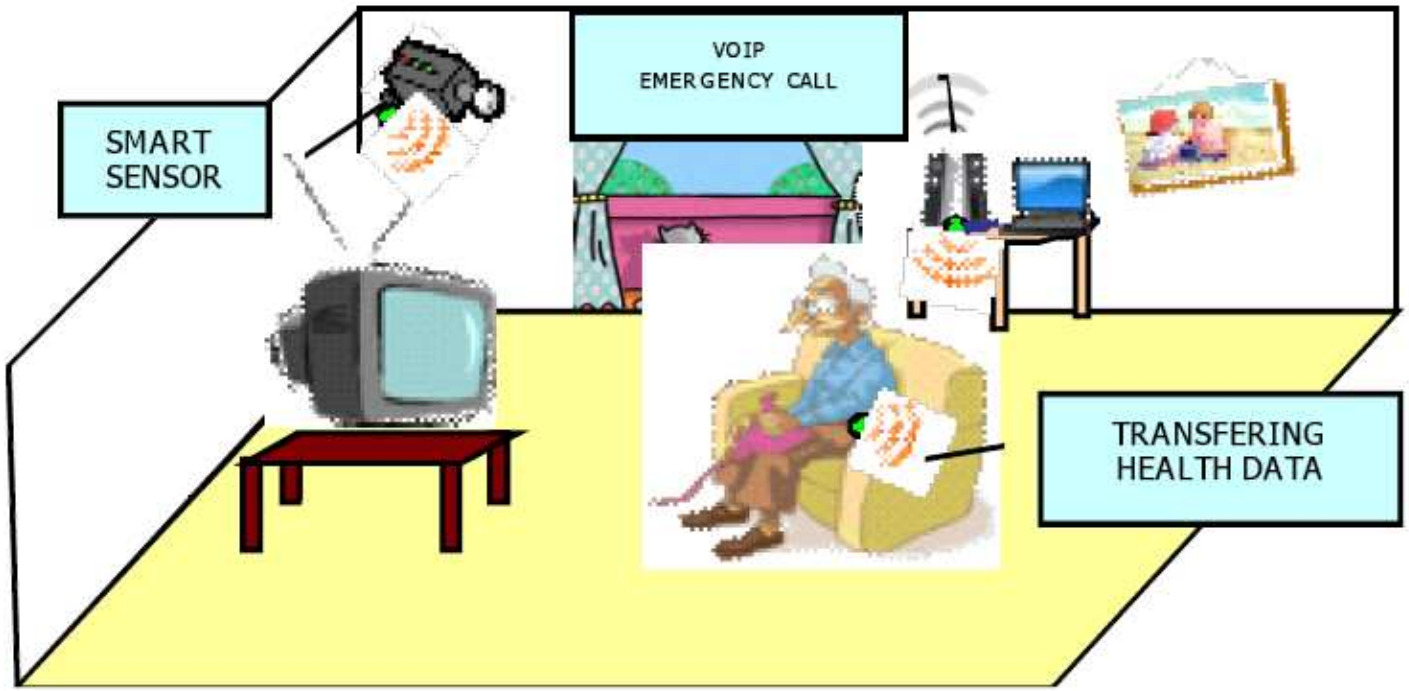


Next Generation of Wearable and personalised healthcare



Medical Video Streaming

Context Aware WSN and AAL Systems



Typical Elderly @ home monitoring scenario

KINGSTON UNIVERSITY

MINT Research Centre

AAL – Needs/ Support/ Challenges

To live independently I need :	electronic support can help a lot in the form of:	but there are challenges:
a secure environment, peace of mind	proactive environmental sensors and assistive technology	currently too expensive, reimbursement issues
food and drink I like	monitoring of meals, dietary help, Internet shopping	need for standards for smart labelling and packaging
contacts with friends and family, including giving reassurance	user-friendly communications	
physical, social and mental stimulation	local media, local activities, employment/occupation, voluntary work	little local and personalized content available
healthcare in my home, comfort, peace of mind	tele-health sensors, medication reminders, medication management	presently tele-care and health systems incompatible
certainty that my carers will come	electronic carer monitoring and communication	
appropriate response when things go wrong, peace of mind	appropriate response team, proactive calling	how?, can one team deliver?, cross-organizational issues with respect to business models and responsibilities

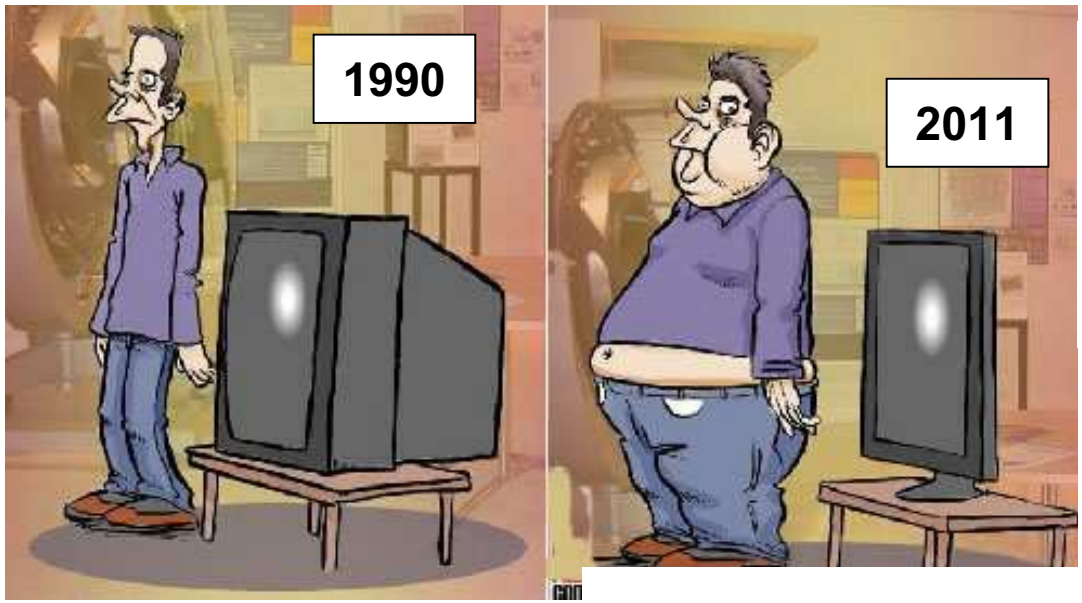
REF: Lowe, C. 2008, aNeAT Solution NHS Newham

Roadmap for AAL Innovative technologies

Innovative technology	Short term (2010)	Mid term (2015)	Long term (2020)
4G mobile technology	Mobile devices designed with older people in mind e.g. simplified layout, large keypad and screen, availability of alternative output modes		
Satellite technology	Improvements to accuracy of GPS GLONASS available	Galileo available. Seamless switch between satellite, mobile and wireless technologies	
Digital maps for pedestrians			Comprehensive coverage of urban areas with detailed, regularly updated digital maps Delivery to hand-held devices via range of suitable outputs
Web-services	More personalized services available	Distributed computing systems linking different content providers	
Near-field communication	Technology mature by 2010	Widespread deployment in transport applications	
Wireless networks	Technology mature and reliable	Deployment of systems, indoor and outdoor. Systems and people communicate via personal wearable devices (PWD), e.g. smart jewellery, or smart phone/hand-held devices	
Sensor networks		Deployment of systems. Systems and people communicate via personal wearable devices (PWD) or smart phone/hand-held devices	

REF: EU- ALLIANCE- Ambient Assisted Living Roadmap, 2010

Diabetes and Obesity in the elderly



Country	Prevalence	Number of people
England	5.4 per cent	2,338,813
Northern Ireland	3.7 per cent	68,980
Scotland	4.1 per cent	223,943
Wales	4.9 per cent	153,175

UK average = 4.26 per cent

Therefore the known diagnosed population is now 2.8 million people.

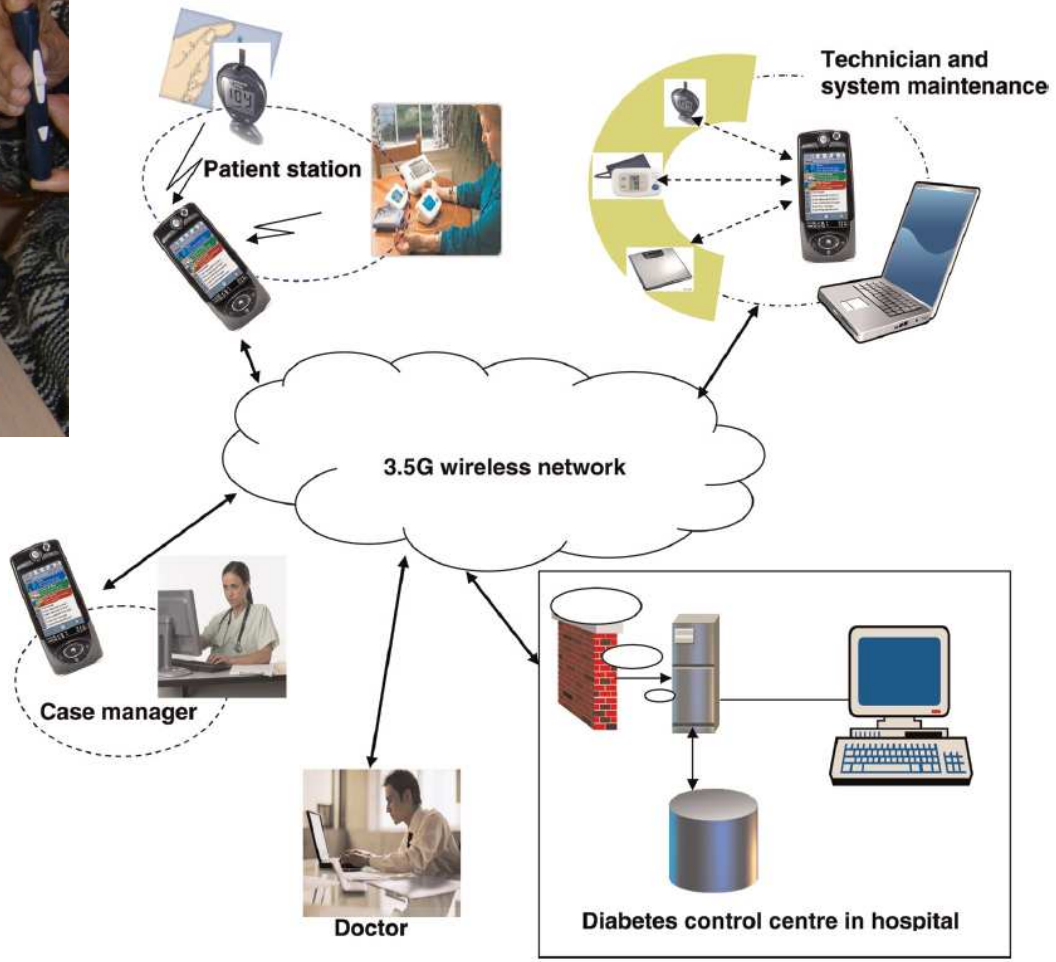
REF: Diabetes UK, 2011

Amongst the elderly population, type 2 diabetes is a growing problem, and a larger proportion of newly diagnosed diabetics are older.

REF: Diabetes.co.uk

KINGSTON UNIVERSITY

Current m-health Diabetes Management System



KINGSTON UNIVERSITY

REF: Istepanian etal, JTT, 15,3 2009

Examples of UK Clinical Studies on m-health Diabetes

Evaluation of a mobile phone telemonitoring system for glycaemic control in patients with diabetes

Robert SH Istepanian*, Karima Zitouni*, Diane Harry†,
Niva Moutosammy†, Ala Sungoor*, Bee Tang* and Kenneth A Earle†

*Mobile Information and Network Technologies Centre, Kingston University, London; †St George's Hospital NHS Trust, London, UK

Journal of Telemedicine and Telecare Volume 15 Number 3 2009

Mobile Telemonitoring for Achieving Tighter Targets of Blood Pressure Control in Patients with Complicated Diabetes: A Pilot Study

Kenneth A. Earle, M.D.,[1,2] Robert S.H. Istepanian, Ph.D.,[3] Karima Zitouni, Ph.D.,[1,2]
Ala Sungoor, Ph.D.,[3] and Bee Tang, M.B.A.[3]

DIABETES TECHNOLOGY & THERAPEUTICS
Volume 12, Number 7, 2010

KINGSTON UNIVERSITY

MINT Research Centre

Effectiveness of Diabetes Management using Cellular Phone Technologies

Author/ year	Study design	Sample age	Duration in months	Clinical area	Control	Intervention	Measures	Results C vs I or pre–post
Benharnou, *et al*., 2007	RCT, crossover	30, 41.3 years	12	Type 1 diabetes	No weekly SMS support	Weekly clinical support via SMS	HbA1c SMBG QOL score Satisfaction with life Hypoglycemic episodes No. of BG tests/day	+0.12 vs -0.14%, $P < 0.10$ +5 vs -6 mg/dl, $P = 0.06$ 0.0 vs +5.6, $P < 0.05$ -0.01 vs + 8.1, $P < 0.05$ 79.1 vs 69.1/patient, NS -0.16 vs -0.11/day, NS
Hurling, *et al*., 2007	RCT	77, 40.4 years	4	Healthy	Verbal advice, during clinic visit, no phone support	Cell phone support, i.e., exercise plan, PA charts, reminders, tailored advice	Change in: PA overall, MET min/week PA leisure time, MET min/week Hours sitting: overall Hours sitting: weekday Hours sitting: weekends Accelerometer epochs BMI Lost % body fat BP, diastolic BP, systolic Perceived control Intention to exercise Internal control External control	4.0 vs 12, NS -5.5 vs 4.1, $P < 0.05$ -0.17 vs -2.18, $P < 0.05$ 1.4 vs -5.9, $P < 0.05$ -0.2 vs -5.2, NS 208.7 vs 218.5, $P < 0.05$ 0.10 vs -0.24, NS -0.17% vs -2.18%, $P < 0.05$ 0.73 vs 0.69, NS 0.41 vs 0.13, NS -0.37 vs 0.57, $P < 0.01$ -0.01 vs 0.45, $P < 0.01$ 5.85 vs 7.24, $P < 0.001$ 5.33 vs 6.38, $P < 0.01$
Kim, 2007	RCT	51, 47 years	3	Type 2 diabetes	Standard care during clinic visit	Weekly BG-based optimal recommendations via SMS	Group 1: <7%, pre–post: HbA1c FPG levels mg/dl 2HPMG Group 2: ≥7%: HbA1c FPG levels mg/dl 2HPMG	 0.53 NS vs -0.21, $P < 0.05$ -5.8 NS vs -13.4, $P < 0.05$ -3.1 NS vs -56.0, $P < 0.05$ 0.22 NS vs -2.15, $P < 0.05$ 14.5 NS vs -3.3 NS 24.8, NS vs -115.2, NS

REF: Krishna etc. , J. Diabetes Science and Technology, 2,3, 2008

Summary of the cellular phone for Diabetes Management

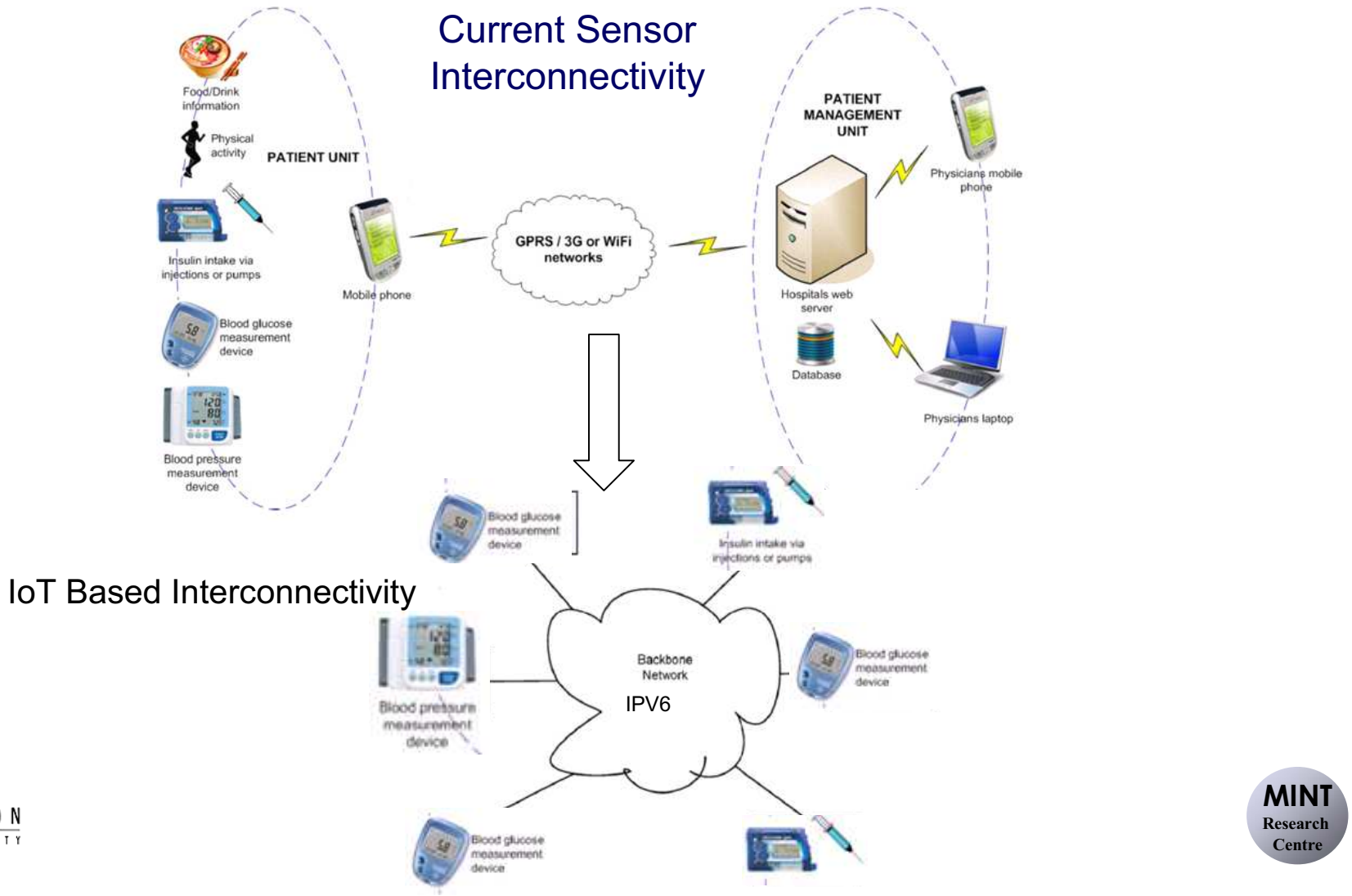
- 18 Studies of the use of cellular phone for Diabetes and Obesity Management.

- 9 out of 10 studies reporting on the HbA1c reported significant improvement among patients receiving education and care support.

- Text messaging provided improved clinically outcomes and increase self management behaviour and self-efficacy.

REF: Krishna etc. , J. Diabetes Science and Technology, 2,3, 2008

Connectivity of Multiple Sensors in Typical mobile Diabetes Management



KINGSTON UNIVERSITY

MINT Research Centre

Current Challenges wireless medical sensors for assisted living

1. Reliability of the wireless Sensor networking and topologies
2. Processing issues ,co-existence and interferences mitigation
3. context aware with power control and battery management
4. Security and privacy issues

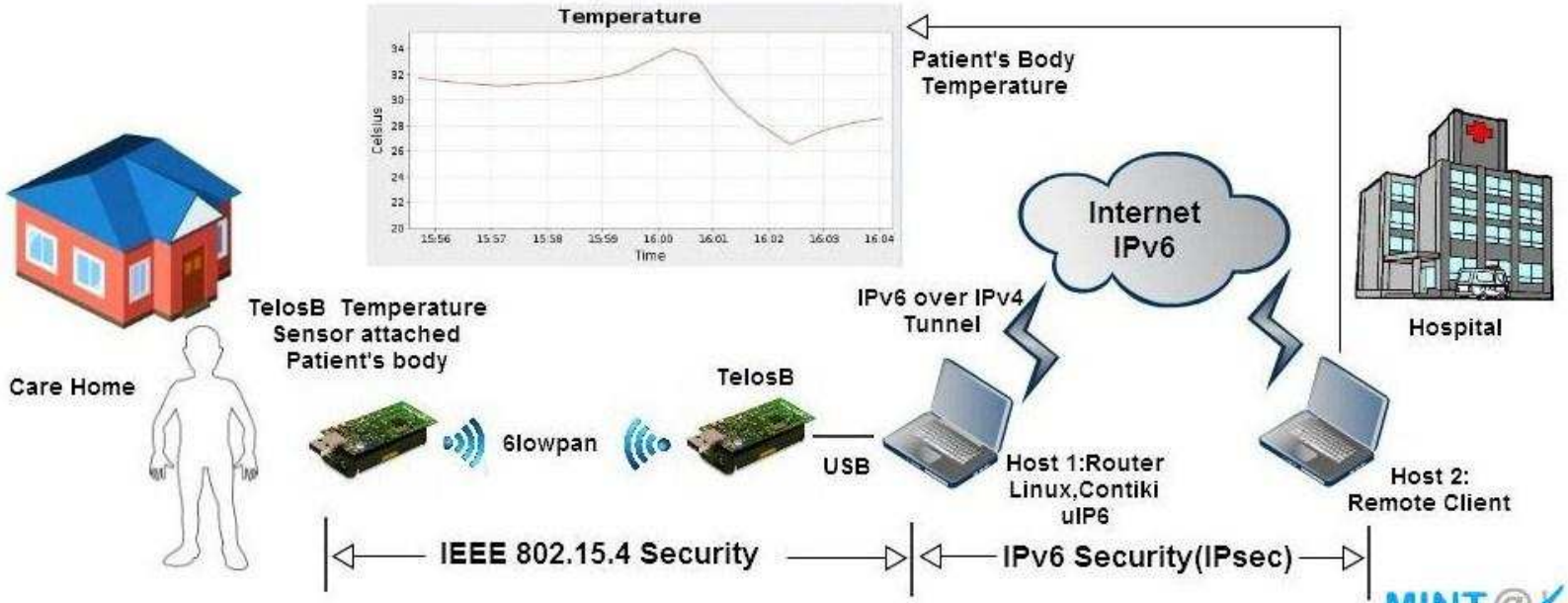
KINGSTON UNIVERSITY

MINT Research Centre

6LoWPAN based m-IOT platform

A 6LoWPAN (IPv6 over Low-Power Wireless Personal Area Networks) based test bed has been designed in the MINT lab in Kingston University, London.

6LoWPAN is a protocol that enables all the capabilities of IPv6 on WSN architectures that are compatible for m-IOT healthcare applications

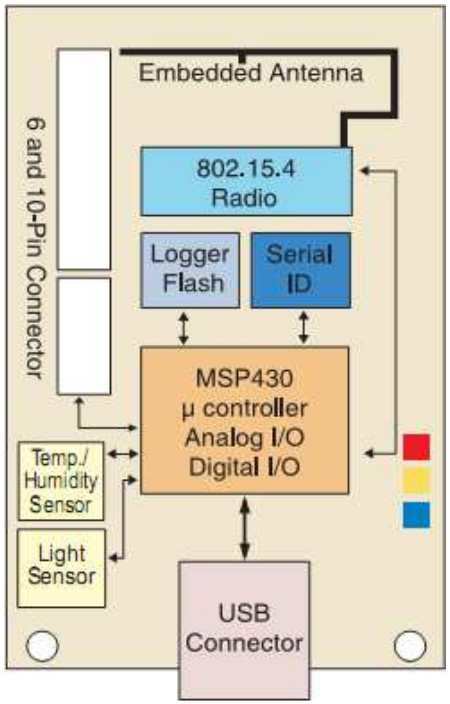


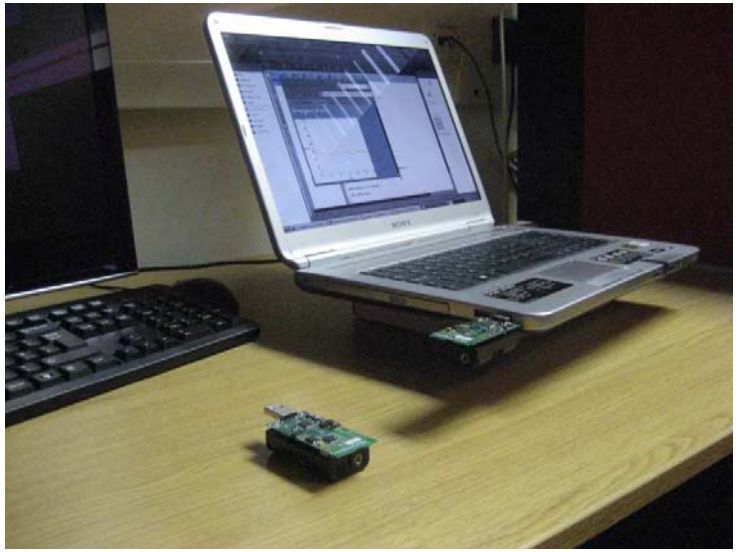
6LoWPAN Open Source Stacks and Functionalities

Concept	Matus	blip	ηstack	μIPv6
State	Unachiev	Compl.	Compl.	In dev.
Support OS	TinyOS AM	TinyOS	FreeRTOS	Contiki
License		LGPL	GPL	BSD
AM	X			
UDP	X	X	X	X
TCP				X
ICMP	X	X	X	X
Mesh-Rout.		X	X	
Frag.	X	X	X	X
Compress.	X	X	X	X
Broad. BC0	X	X	X	X
Neigh. Disc.		X		X
Radio chip	CC2420	CC2430	CC2430	CC2430
Unix tools	X	X	X	X
Monolithic	X	X	X	X

Platform Implementation

The system was developed using TelosB open source platform and the ContikiSec, OS . This OS it has added features of secure network layer important for m-IOT sensor applications under. The programming is in C language for MSB-430 platform by ScatterWeb.





TelosB TPR 2420

KINGSTON UNIVERSITY

MINT Research Centre

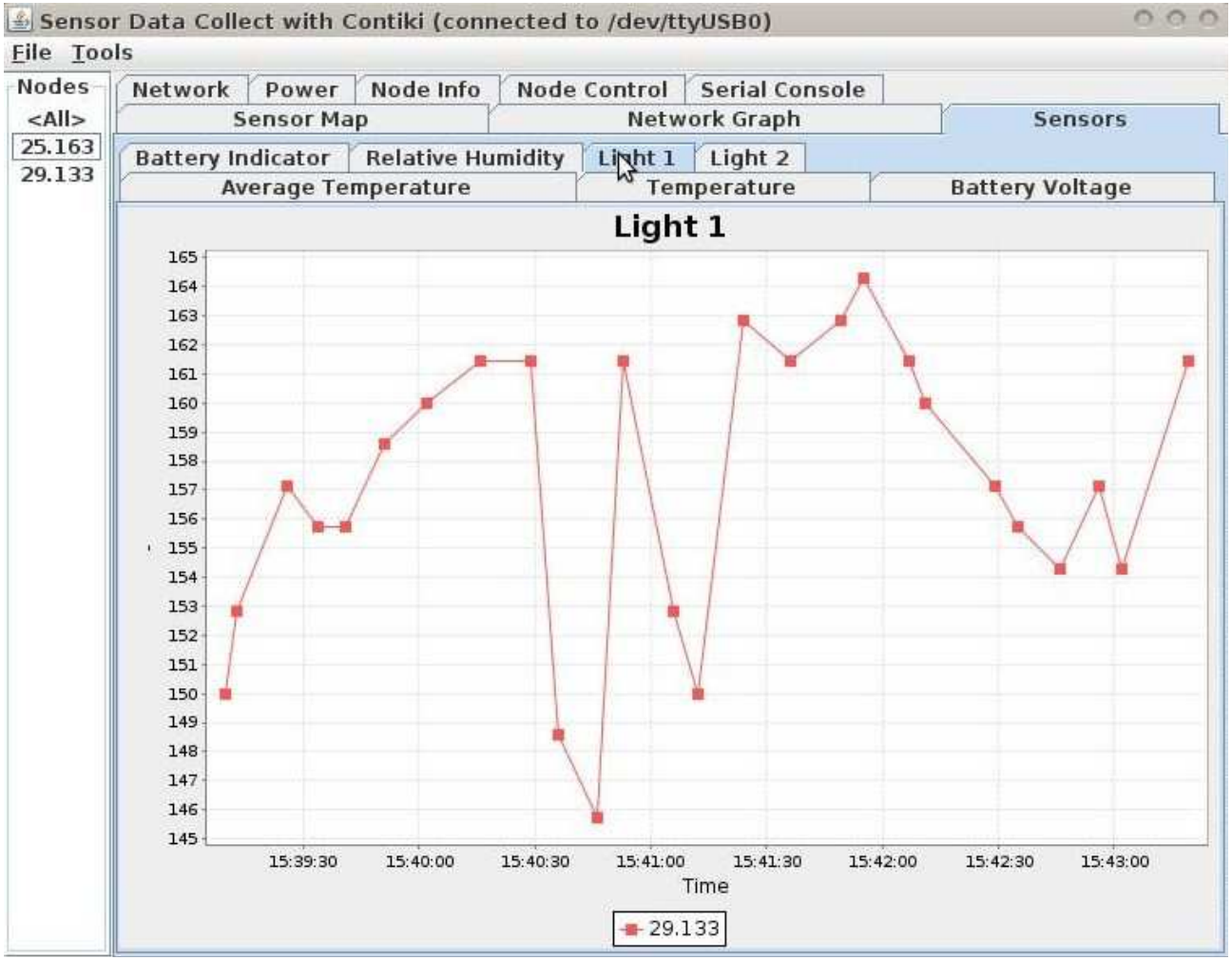
Implementation of the Contiki OS and uIPv6

- **Contiki** is a small, open source, highly portable, operating system developed for use on a number of memory-constrained networked embedded devices. It is built around an event-driven kernel.

- Features include Multitasking kernel, Optional per-application pre-emptive multithreading, Protothreads, TCP/IP networking including IPv6, Windowing system and GUI, Networked remote display using Virtual Network Computing, A web browser (claimed to be the world's smallest), Personal web server, Simple telnet client, Screensaver

- **uIPv6** is the world's smallest certified IPv6 stack for low-cost networked device such as sensors and actuators

Experimental Temperature Measurement Results



KINGSTON UNIVERSITY

MINT Research Centre

Potential m-IOT based Assisted Living applications

- **Medication adherence for elderly**
- Person centered home care monitoring
- **IOT robotic Assistive Technologies**
- Cognitive Fitness and Assessment for elderly
- Implantable and multiple wearable sensors

Challenges of m-IOT systems

- Security and Privacy challenges
- Standardisation of medical devices for IOT connectivity.
- Interoperability with other low power devices and 4G mobile networks.
- Context Aware issues of m-IoT within m-health applications
- Development of m-IOT ecosystem.

KINGSTON UNIVERSITY

MINT Research Centre

Top 11 Technologies of the Decade

1. Smart Phone
2. Social Networking
3. Voice over IP
4. LED Lighting
5. Multicore CPU
6. Cloud Computing
7. Drone Aircraft
8. Planetary Rovers
9. Flexible AC Transmission
10. Digital Photography
11. Class –D Audio

Source: IEEE Spectrum Jan. 2011

Finally!

“And men got dreaming. Shouldn't there be a network that made all my Devices collaborate at all times, converse spontaneously among themselves and with the rest of the world, and all together make up a kind of single virtual computer – the sum of their respective intelligence, knowledge and know how?"

Rafi Haladjian, 2005

The length of a film should be directly related to the endurance of the human bladder.

- Alfred Hitchcock

KINGSTON UNIVERSITY

MINT Research Centre

MOMED

THANK YOU

Robert S. H. Istepanian
r.istepanian@kingston.ac.uk
http://cism.kingston.ac.uk/mint

Acknowledgements:
•Dr. Ala Sungoor- MINT- Kingston University
•Dr. Nada Philip- MINT- Kingston University
•Mr. Faisal Ali – MINT- Kingston University
•Mr. Antonio Jara- University of Murcia-Spain

KINGSTON UNIVERSITY

MINT Research Centre