THE IMPORTANCE OF SENSORS TO THE INTERNET OF THINGS

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Introduction

The excitement and hype surrounding the emerging technology market known as the Internet of Things (IoT) has attracted a great deal of attention from industry, business leaders, and governments alike. According to Cisco estimates[1], the IoT will create a $14 Trillion global opportunity, and Business Insider predict it will be the largest market for technology hardware ever [2]. If these are correct, the impact on traditional business models through the adoption of new technology within industry, the service sector and governments will be transformational. At an individual and societal level, important areas such as health care and aging population will particularly benefit from IoT. The changes on tomorrow's society can only be imagined but there is little doubt, whether individually, societally, economically, or industrially, these changes will be far reaching.

However, the promise of future riches can fool the unwary into overlooking the jewels that already exist which are delivering benefit to the UK economy today; whose presence will be pivotal to the UK's position in the IoT market of tomorrow. In the SILC white paper 'The IoT Tree of Life'[3], the 4 foundation roots from which the IoT will develop are: Low Power Processing, Miniature Sensors, Ubiquitous Wireless, and Power Efficiency. This briefing paper explores Sensor Systems, the 'eyes and ears' of the IoT, and elucidates how the existing UK strengths in this area can be leveraged to deliver competitive advantage to the UK economy in the emerging IoT market.

Sensor Systems.

In 2011, I wrote a short paper [4] as an 'aide memoir' identifying the different layers in a generic sensor system essential for the conversion of data into information. This 'Stack' model has now been widely adopted as a framework to understand Sensors Systems and what they do. Several important criteria in developing the hierarchical concept were defined in the creation of the Sensor Systems 'stack' model shown in figure 1 and a summary of these is worthwhile.

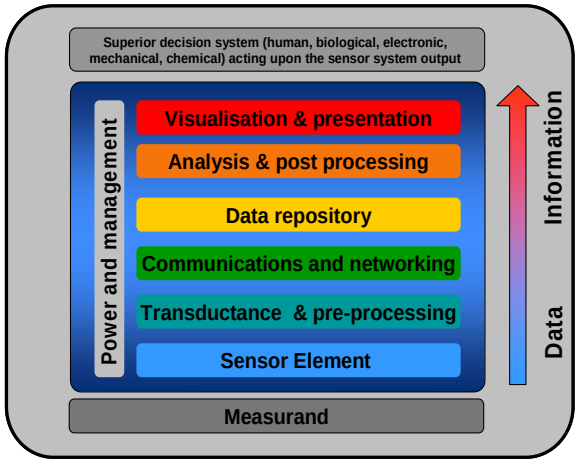

Figure 1: Sensor Systems Hierarchical 'Stack'

a. The model should be representative of all sensor systems, whether complex or simple, whether it represents a plurality of sensor elements, sensor data fusion, or a single point sensor.

b. The model should only address the conversion of data into information; it does not include any decision process on that information. This is important as it separates sensing, decision process, and

[1] http://www.cisco.com/web/about/ac79/docs/innov/IoE_Economy.pdf
[2] http://uk.businessinsider.com/how-the-internet-of-things-market-will-grow-2014-10
[3] http://www.gambica.org.uk/app/images/documents/publications/IoT%20Tree%20of%20Life%20White%20Paper%20130215.pdf
[4] http://sensorsystems.org.uk/wp-content/uploads/sensor-stack-overview.pdf

actuation. Although many applications may integrate all three into a single unit, they remain separate and distinct functions internally.

c. Common elements or attributes such as power, management, and control which affect performance across all layers of the stack are captured separately.

The Internet of Things

The IoT central tenets are ubiquity and connectivity; whether personal, industrial, or infrastructure. The long term vision is everyone and everything will be connected to the Internet. The benefits of this widespread connectivity is the ability to collect and fuse the data from many thousand (perhaps millions) of individual sensors to create a massive data set. This data can then be interrogated to derive information, hence providing services that will deliver economic benefit. In some instances and application, the IoT 'Thing' will integrate both sensing and actuation functions, the decision process being performed remotely [5].

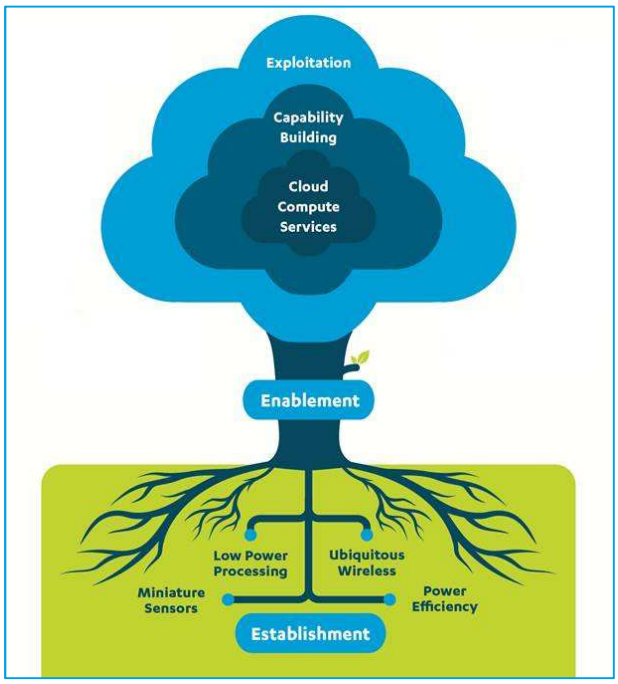

Figure 2: The IoT Tree of Life

The importance of Sensor Systems underpinning the successful exploitation of the IoT becomes obvious when the maturisation of the IoT market is considered. In a completely connected world, virtually every networked element will require a level of sensing, whether as a primary function of the device in applications such as environmental monitoring or mobile health, or in low level devices such as garage door or heating controllers. In the former examples, the precision, accuracy, and resilience of the information is critical to the application or service being provided, in the latter examples the sensors function provides a much simpler go, no-go indication of status.

The Tree of Life paper explains the 3 phases of IoT market development; **Establishment**, **Enablement**, and **Exploitation**. The IoT market is presently in the establishment phase where equipment and early service adopters are deploying rudimentary services to prove the underlying concept behind the IoT. The real benefits of the IoT will not manifest themselves until the first two phases are complete.

Traditionally, UK industry has been highly successful in the development , manufacture, and application of precision sensors, particularly for defence and aerospace applications. Global organisations such as Rolls Royce have been at the forefront of investing in the UK in extreme environment sensing. These technologies and capabilities have migrated into the automotive sector through the UK's leadership in Formula 1 racing developments. The demands on data quality made by high end applications generate technological strengths that continually improve the quality of sensor data, and hence the quality of decision and actuation which depend on it. These technologies will be key to the success of IoT where the

[5] The analysis and interpretation of this data will drive the push for 'Big Data' applications, a closely related (but distinctly separate) field to IoT. The IoT can be considered the physical interface between the real world and the virtual world of 'Big Data'.

consequence of decisions and actions is high. Fluency and familiarity with the sensing challenges will enable UK suppliers to expand the scope of their businesses. As the IoT market develops, it is imperative that the UK capitalise on existing skills and augment these through an aligned strategy, combining our newly found interest in software and 'Big Data', with our recognised global expertise in sensing and Sensor Systems.

Conclusion

This briefing paper is not intended to provide a full justification of the role that Sensor Systems play in supporting the development of the IoT, rather it is intended to provide sufficient information, supported by some key references[6] why the IoT relies on sensors. In a global context, the IoT has been extensively promoted but the applicability and relevance to the UK economy has had less attention. Given our historic interest and expertise in precision sensing and measurement, SILC is championing the need for a Sensor Systems Catapult Centre and its pivotal capability to drive improvements in the ultimate performance of the IoT. Through investment in the UK's expertise in sensing technologies, and combining this with the emergence of the IoT market, this Centre would establish the UK's leadership in shaping this opportunity.

Duncan Bremner works for the University of Glasgow within the School of Engineering as Business Development Manager, and is a member of the SILC committee. With over 25 years in the semiconductor industry, he has an in-depth understanding of new technology adoption. He has a particular interest in the development and exploitation of the emerging Internet of Things (IoT) market:

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[6] InnovateUK White Paper reference site http://bit.ly/IoT-Papers