# eHealth and the Internet of Things

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Abstract: To respond to an ageing population, eHealth strategies offer significant opportunities in achieving a balanced and sustainable healthcare infrastructure. Advances in technology both at the sensor and device levels and in respect of information technology have opened up other possibilities and options. Of significance among these is what is increasingly referred to as the *Internet of Things*, the interconnection of physical devices to an information infrastructure. The paper therefore sets out to position the *Internet of Things* at the core of future developments in eHealth.

## 1 INTRODUCTION

In 2012 Dr Margaret Chan of the World Health Organization wrote that:

> "*Population ageing is a global phenomenon that is both inevitable and predictable. It will change society at many levels and in complex ways, creating both challenges and opportunities …*"

A globally ageing population in which the growth in the numbers of older people is increasingly ever more rapidly (Kinsella and Wan, 2009), places additional demands on resources. This in turn poses societal challenges in ensuring access and mobility while preventing trends such as increasing urbanisation and the depopulation of rural areas. The underlying vision is thus one of an eHealth environment where needs are met through the sustainable organisation and the structuring of the physical and information environments to meet the changing needs of an ageing population.

Thus mobility must be considered not just as an ability to move within the physical environment, with all that that implies, but also mobility within the information environment. It is argued that enhanced mobility within the information environment then acts to support physical mobility, for instance through developments in mobile healthcare (mHealth).

This overarching vision of an eHealth infrastructure which integrates the physical and the information environments implies the need for sustainable solutions which maximise benefits whilst optimising the use of resources in each of the short-, medium- and long-terms. Such solutions must address and support issues such as:

- The level of provision between urban and rural communities.
- Housing and the balance between new build and refit or refurbishment.
- The ability to effectively assess need, specifically within the home environment.
- Means of capturing new and novel forms of data such as observational data.
- Design strategies to be adopted in relation to each and all of these issues.
- Tools to support the effective assessment of the impact of change.

It must be recognised that many current systems have over time been the subject of evaluation, review, and indeed change. This has resulted in an interest, and indeed in some cases an investment, in maintaining the status quo, resulting in a degree of compartmentalisation and technological lock-in which acts to inhibit the introduction of new concepts, methods and ideas. For instance, physiological sensors might be considered as an element of telehealth and not of telecare, implying also a shift from societal to health related issues. Similarly, home based and mobile eHealth systems often tend to be separated rather than viewed as a continuum such as that of Figure 1.

In presenting the discussion, it is recognised that many of the individual components are themselves the subject of study, but what is generally lacking is

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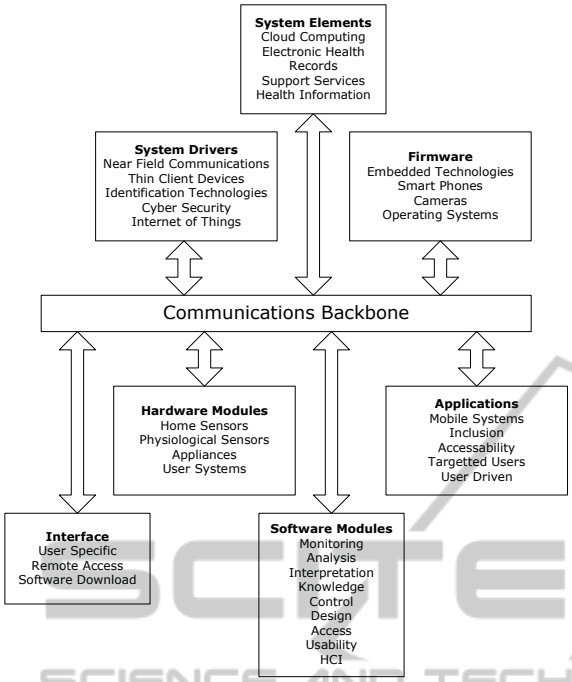


Figure 1: eHealth modules configured around a communications backbone.

their integration into a cohesive system. Key issues are:

1. Detection and identification of behavioural changes indicative of a change in status.
2. The detection and reporting of emergency conditions.
3. Incorporation of physiological monitoring.
4. An ability to extend functions into the mobile environment.
5. Integration within health informatics.
6. Establishment of user needs and requirements.
7. Identification of resources and their interactions.
8. Infrastructure and sustainability issues.
9. Design strategies and methods.
10. Decision support tools to inform on options and outcomes.

The key focus here is therefore that of the information infrastructure, and in particular, the role of the *Internet of Things* as a means of integrating a range of *smart* objects within that infrastructure (Kortuem et al., 2010); (Mattern and Floerkemeier, 2010).

## 2 THE *Internet of Things*

The underlying concept of the *Internet of Things* is the interconnection of discrete smart objects to provide information about both location and activity. Working from this base, consideration can be given to the potential range of actions and applications. Falling within the action group are:

- Information & Analysis – Monitoring the behaviour of objects in both space and time.
- Situational Awareness – Real-time monitoring of and interaction with the environment.
- Data & Information Driven – Distributed and networked sensors contributing to a rich information environment driven by advanced data analysis and visualisation.

While in relation to applications:

- Logistics – Materials handling, location and transfer.
- Health – Real-time monitoring of conditions and detection of change.
- Smart Environments – Direct management of the environment in response to the individual.
- Personal – Social networking and interaction, virtual communities and security.

### 2.1 Lifestyle Monitoring, eHealth and the *Internet of Things*

Lifestyle monitoring (Brownsell (1) et al., 2011); (Majeed, 2006) is here taken to encompass:

(i) Responding to changes in behaviour indicative of a change in need structured around the use of a range of sensors distributed throughout an individual's home environment. The sensor data is then interpreted to attempt to identify behavioural and other changes indicative of a change in need. However, there remains a sparsity of data with all current installations essentially being experimental in nature. The proposed approach is intended to support data integration and the use of techniques and methods such as knowledge and discovery as part of a learning system to support data analysis.

(ii) Support for emergency conditions such as falls.

Referring to the above, strategies such as:

- The recording of movement in and about the environment.
- Monitoring the utilisation of space (rooms).
- Observing the pattern of use of appliances.
- Monitoring the use of cupboards, refrigerators and wardrobes.

have all been considered and potentially could be linked through the joint concepts of *smart objects*

and the *Internet of Things*.

Developments in sensor technology are likely to lead in the near future to the availability of a range of initially wearable, and ultimately implantable, sensors capable of monitoring and recording a range of physiological parameters (Al-Jobouri, 2011); (Espina et al., 2006); (Luprano et al., 2006). The data from these sensors can then be linked through mobile communications and hence back to the home and to medical support.

However, the use of home-based, wearable and implantable devices brings with it ethical, both human and machine related, considerations which will need to be addressed. In particular, there are the concerns of allocating the responsibility for the well-being of an individual to an autonomous computer based system which makes decisions on their behalf (Bowes et al., 2012); (Perry et al., 2010); (Torrance, 2008).

# 3 EXEMPLARS

## 3.1 Emotive Computing and Ehealth

The authors have proposed that emotive computing may have a role to play in eHealth by providing information on a user's state of well being through the interpretation of everyday actions (Ball et al., 2011); (Bradley et al., 2011). The translation of this speculative approach into the wider concept of home-based and mobile lifestyle monitoring will require developments both in technology and the means of analysing and interpreting the resulting data. This implies developments in mobile applications to manage the data transfer as well as transitions from the home environment to the mobile environment. This will in turn require the creation of accessible applications and the education of developers in support of the wider concepts of e-Inclusion to maximise the potential benefit through the integration of diverse and disparate data streams.

Developments in this area are therefore likely to include:

- New forms of non-intrusive sensors capable of gathering emotion related data in a range of environments.
- Novel forms of application to maximise the levels of user interaction in relation to the gathering of such emotion related data.
- New and novel means of analysing and interpreting the data generated.

## 3.2 Collection and Management of Observed Data

It is argued that observation has the potential to be a significant additional data source to compliment data derived from sensors. Such observational data has the ability to provide information on a range of factors such as general levels of 'untidiness' or 'cleanliness' and can also report on issues such as odours which may not be detectable by other means (Brownsell (2) et al., 2011); (Brownsell (3) et al., 2011).

Observers range from care professionals such as the warden of sheltered or monitored accommodation, a carer or a health visitor to individuals such as family and friends who are not trained in observation, but whose relationship may enable them to identify issues in ways which might not otherwise be possible. Issues impacting on implementation include:

- Data capture and interpretation skills of the observer.
- Data checking and validation.
- Data security.

While means could include:

- Interpretation of freeform text.
- Structured questionnaire in which the answer to each question establishes the next question.

Placing this into the context of the *Internet of Things*, this implies the use of devices such as tablets and mobile phones integrated with a series of accessible smart applications to direct the user in relation to the data capture processes.

## 3.3 Impact Areas and User Groups

To develop the arguments in the paper and prove the potential for utilising both observational and emotive data in improving the health and wellbeing of an ageing population in particular, it is necessary to identify target users. Work undertaken in the area of telecare to establish such groups (Brownsell (1) et al., 2011), plus the preliminary results of an as yet incomplete literature review suggest the following potential impact areas and user groups.

- The *Well Elderly*, these are older individuals currently requiring no or low levels of support where the aim is the detection of change to ensure the earliest appropriate intervention.
- Progressive neurological diseases such as Alzheimer's or dementia to identify change in order to adjust provision accordingly.

The aim is thus to establish a case study to evaluate

both the technology and the user responses in order to properly establish and identify those areas where the resulting interventions are most likely to be effective.

# 4 CONCLUSIONS

Faced with an ageing population there is a need to undertake a radical review of the way in which eHealth systems, and sub-systems such as telecare and lifestyle monitoring are designed, developed and implemented. This is not to suggest that work in these areas to date is of no value, but rather that it is regarded as having established the foundation on which new concepts such as the *Internet of Things* can be introduced.

It is in this context therefore that the paper sets out in Section 1 its position regarding the underlying issues and concerns that need to be addressed in moving forward, and follows this in Section 2 with an argument for adopting an approach based on the *Internet of Things* as un overarching strategy. Then in Section 3, two exemplars as to how this approach may influence the approach to eHealth are presented, in each case based on research concepts which are currently under evaluation and development by the authors.

The overarching conclusion is therefore that there is a need for a new and novel approach to the design, development and operation of all forms of eHealth systems, and that the *Internet of Things* provides one possible means of achieving the necessary shift in both thinking and approach.

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