Chapter 12
Home Technologies, Smart Systems and eHealth

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12.1 Introduction

The concept of a Smart Home, Digital Home or Domotics is based around the deployment a range of technologies to provide features and functions related to the management of the domestic environment [1]. Key components of such systems are:

Sensors	Provide information on the environment and its users
Actuators	Provide and perform actions based on the interpretation of the sensor data
Controller	Analyses and interprets the sensor data in order to generate the appropriate actions in response
Smart devices	Individual devices integrated within the network providing a range of smart functions
Internal communications	Integrates devices within the home network and provides link to external communications as required
User interface	Enables the user to interact with the system to define operating parameters and set context as appropriate

Referring to Fig. 12.1, the general functionality of the home system can then be considered in relation to:

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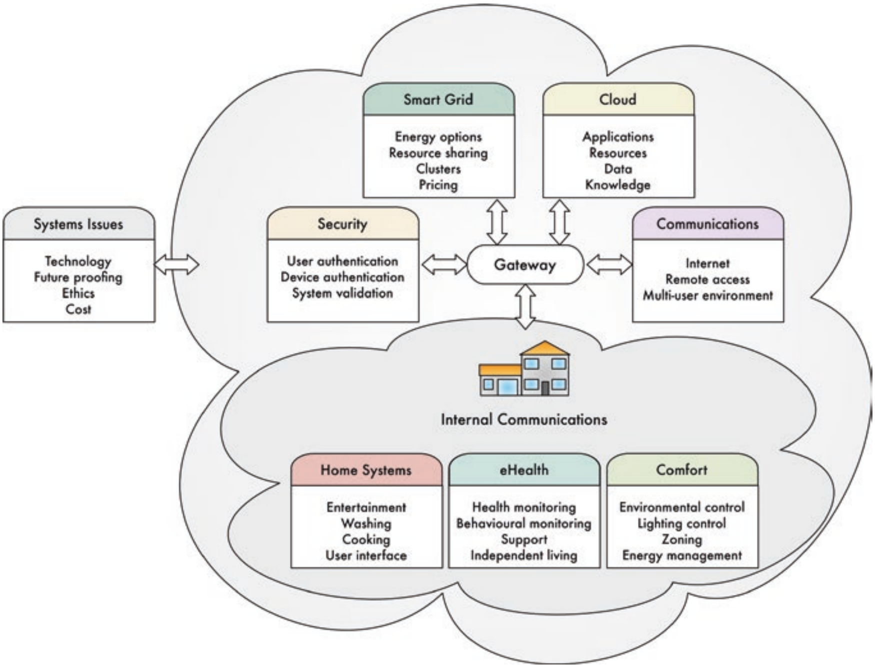


Fig. 12.1 Functionality of a smart or digital home

Cloud	Interaction with Cloud-based systems to provide a range of facilities and services
Comfort	This implies the operation of the environmental control systems to provide optimum comfort range for individuals within the home, including zoning to meet variations in individual user criteria and remote access as required
External communications	Supports the ability of individual systems within the home environment to access relevant, and context-based, information relative to their operation
eHealth and mHealth	Of increasing significance in the face of an ageing population and implies the introduction of a range of monitoring and response systems tailored to individual need
Home systems	Smart homes will inevitable and increasingly contain a range of smart, networked systems covering activities from entertainment to domestic functions such as washing, cleaning and cooking
Security	Implies both physical and cyber security under the general management of the home systems
Smart grid	Integrates individual homes within a group of homes and hence with the energy supply grids to provide efficient energy management and resource utilisation

The implementation of smart home and related technologies involves a number of systems issues for the short, medium and long terms such as the choice and future proofing of technologies, ethics and costs. The chapter begins by looking at the background to, and structure of, smart home technologies and systems before progressing to look at one particular area of application, that of eHealth and mHealth, in more detail.

12.2 From Domotics to Ambient Intelligence

Building automation services were initially provided by a set of non-integrated subsystems (heating, light control, fire alarm systems, escalators, etc.) within large buildings [2–5]. By the late twentieth century, this was starting to include home automation.

The introduction of the Internet then supported new concepts such as the *Digital Home*, *eHome* or *iHome* [6–8] and saw the evolution of the traditional automation services to include entertainment and communication supported by home networks and residential gateways [9, 10].

The twenty-first century also brought new paradigms such as “*ubiquitous computing*” [11] and “*ambient intelligence*” [12, 13], whose intent is to bring “*intelligence*” to the environment. In the case of ambient intelligence, this defines a context in which people will be surrounded by intelligent and intuitive interfaces embedded in everyday objects in an environment which will recognise and respond to their presence in a way which is sensitive and context dependent and which autonomously and intelligently adapts and responds to their needs [14]. As well as houses, this consideration encompasses spaces such as “*Smart Cities*” [15–17], strengthening concepts such as the Internet of Things (IoT) as is illustrated by the development of the associated terminology shown in Fig. 12.2.

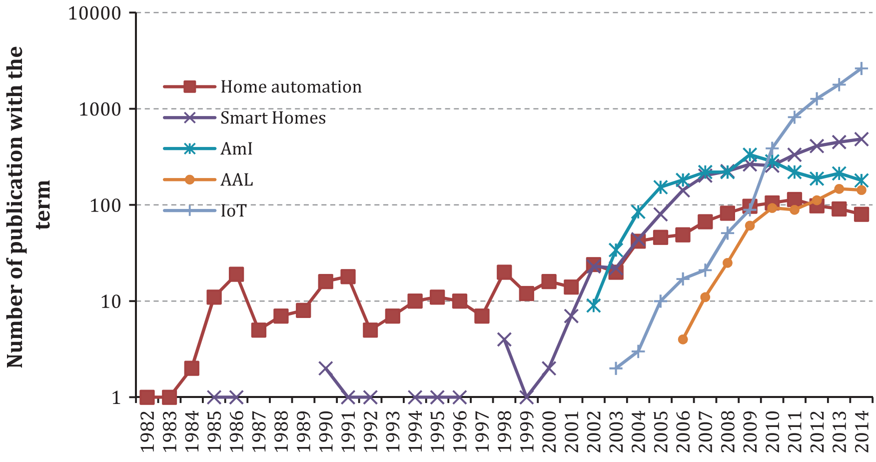


Fig. 12.2 Graphical representation of the evolution of terminology

12.2.1 New Services at Home

We are continually evolving our way of life, of work, of personal relationships and so on. For example, it is now common to communicate (i.e. talk, share information and so forth) almost every day with a wide community of individuals, some of whom we may never have met. From a technological point of view, more and more people seek an environment in which access to digital services from anywhere and at anytime is crucial. In this context, Information and Communications Technologies (ICTs) need to be continuously upgraded to adapt to the individual from two perspectives; services and technological infrastructure. For the former, people demand new electronic services to service their need while the technological infrastructure must support those services.

Traditionally, building automation and home automation have been associated with safety, energy saving and comfort through the automation of services such as lighting, environmental control and electrical appliances. In this context, it is common to distinguish "*personal security systems*", providing security services directly to a user, from "*central monitoring systems*" connected to remote sites. The progressive introduction of broadband to homes from the late 1990s then produced a change in the philosophy of service provision through the concept of the *Digital Home*, *eHome* or *iHome*.

In recent years, the Ambient Intelligence paradigm has supported the development of new smart devices integrated throughout networks to provide a service, for instance to distribute and display multimedia. Moreover, the trend of adding intelligence into devices is moving to wider environments as exemplified by the Internet of Things and Smart Cities. The resulting *Web of Everything* will integrate Smart Cyber-Physical Systems with the IoT to provide new forms of integrated service [18, 19].

12.2.2 Designing the Smart Home

Consider the following scenario. A user in the study uses a PC on a Virtual Personal Network, another user is in the living room, downloading and listening in real time to music on the home stereo, yet another user is reading online newspapers on a tablet and in the kitchen someone is doing the weekly shopping using the electronic whiteboard on the refrigerator.

In this scenario, several electronic services are being used. However, the technology remains visible to the users and people have to learn to use the individual technologies in order to access the required services. The longer the learning curve, the more visible the technology to the user and the more hidden the service. Further, communication and control networks are often unconnected and use proprietary systems.

Thus, in a current smart home the services and technology that provide support can lack integration due to their spontaneous emergence in response to a perceived need. As a consequence, services have tended to be specialised and the associated technology is quite visible. However, the trend towards more intelligent systems and components should enable environments to adapt to the user while hiding the complexity of the underlying technology.

The resulting solutions have to consider two key perspectives, integration and use. The former supports the provision of services irrespective of the technology used and allows for the interconnection of a wide range of devices. The latter, the user perspective, aims to support intelligent and transparent interaction by the user with the technology.

12.2.2.1 Integration of Services and Technology

Systems integration is an important consideration for the future of home technologies. ICTs develop from a continually evolving technological base and it is important that individual devices and systems are able to communicate with each other to provide more complex services involving both co-operation and competition for resources. In future, a distributed intelligence is likely to emerge from this interaction to support both system configuration and operation.

In this context, it is possible to distinguish three different networks within a smart home environment; namely control, multimedia and data, according to the functions managed by the network:

- The control network provides the infrastructure for those services identified with system automation and the management of simple commands and the regulation of specific levels. Requirements include low cost, ease of installation and reconfiguration, ease of expansion and fault tolerance. Devices connected to this network are primarily sensors, actuators and controllers.
- The multimedia network provides support for the distribution of audio and video. Requirements are related to the volume of data and the quality of service provision associated with the distributed audio and video data. Devices connected to this network are televisions, HiFi equipment and other media-based items.
- Data networks were initially associated with the sharing of computing resources such as files, programs and printers. With increased access to the Internet, the data network must provide access to it from anywhere within the home environment. Requirements include high bandwidth and low cost. Connected devices still include computers, printers, drives and scanners but also a wide range of other data sharing devices such as tablets and smartphones as well as increasing numbers of smart appliances.

The technology for each of these network types was initially proprietary or designed specifically to provide the services associated with them. Today, borders

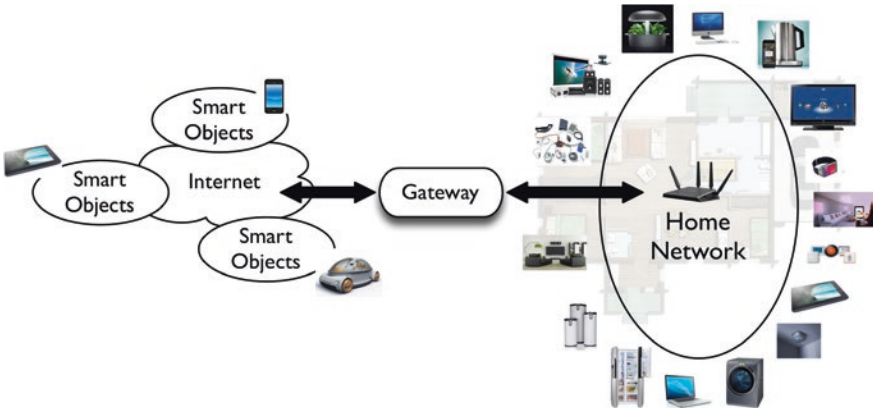


Fig. 12.3 Residential gateway

between multimedia and data networks are increasingly unclear as the bandwidth evolution of the data network[1] has resulted in the multimedia network becoming effectively a subset of the data network.

From the perspective of the control network, the majority of current technologies remain those designed specifically to provide home automation. However, convergence with data network technologies is increasing and control networks now contain devices able to connect to both networks. Hence, the trend is for a general convergence onto data network technologies.

Additionally, devices increasingly share information about themselves. For instance, lamps can provide a range of information including their status, energy consumption, hours of use and light levels, making them into a smart device. Other appliances such as refrigerators can become a smart devices notifying us (for example by email or SMS messaging) of shopping requirements, or even placing the order online themselves. The trend is thus towards intelligent devices which make use of network technologies to autonomously create larger, and more complex, integrated systems.

The result is a complex scenario of integration structured around services which are often specialised and strongly coupled to the technology that supports them. Moreover, services usually operate in isolation unless they have been explicitly designed to cooperate. The gateway as a concept then plays an important role in supporting communications between services and technologies through the concept of the *residential gateway* of Fig. 12.3 to provide a single, flexible and intelligent interface between external and internal networks.

Service and network levels were initially integrated with themselves and with each other in a centralised structure with the emergence of the gateway. However, the evolution of technology changes this centralised structure to a distributed structure

[1]Mainly technology structured around the IEEE 802 standard.

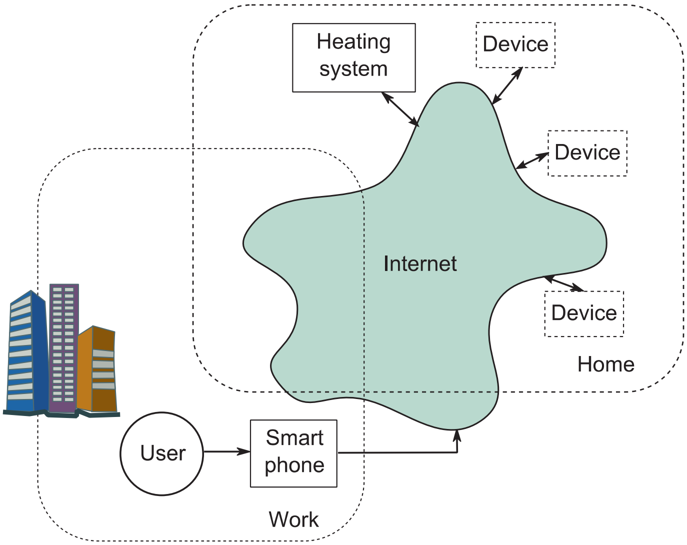


Fig. 12.4 A distributed system structure

in which the gateway supports any device with the necessary *intelligence* to enable it to interact with others [20, 21]. In the same way, individual services should have the ability to interact to provide a more elaborate service as suggested by Fig. 12.4.

There is therefore a technological challenge within ICT and the relationship with the IoT to provide a standardised architecture to support the development of new services. Horizon 2020 [22] commented that:

> The biggest challenge will be to overcome the fragmentation of vertically oriented closed systems, architectures and application areas and move towards open systems and platforms that support multiple applications. The challenge for Europe is to capture the benefits from developing consumer-oriented platforms that require a strong cooperation between the telecom, hardware, software and service industries, to create and master innovative Internet Ecosystems.

The above also implies the integration of smart components into cyber-physical systems. Here, Horizon 2020 commented that:

> Cyber-Physical Systems (CPS) refer to next generation embedded ICT systems that are interconnected and collaborating including through the Internet of things, and providing citizens and businesses with a wide range of innovative applications and services. These are the ICT systems increasingly embedded in all types of artefacts making "smarter", more intelligent, more energy-efficient and more comfortable our transport systems, cars, factories, hospitals, offices, homes, cities and personal devices.

Related to this new generation of components and systems, the challenge of technological integration is to:

> …. develop the next generations of smart systems technologies and solutions, based on systemic miniaturisation and integration, of heterogeneous technologies ….

This is associated with the evolution of the *Future Internet* [23] focusing on a redesign of the original client–server architecture to resolve issues of security, trust and mobility. This future implementation has to meet:

> the ever larger portfolio of business models, processes, applications/devices that have to be supported, coupled with a rapidly growing number of application and societal requirements.

12.2.2.2 Serving the Service

The user has to perceive the benefits of the service but not necessarily the technology that support it. Although the integration of services and devices is an important consideration, designing the user interface is potentially more challenging. Interfaces have to be friendly and easy to use regardless of age and technology skills. For example, a person has to interact with a home system to use the service, define preferences, adapt services and so on. In this situation the concept of Maes [24] that:

> Autonomous agents are computational systems that inhabit some complex dynamic environment, sense and act autonomously in this environment, and by doing so realize a set of goals or tasks for which they are designed.

remains important for user interfaces.

The user interface has to emphasise autonomy while learning to perform tasks for their users and providing proactive assistance as necessary. The user interface could observe and monitor the actions performed by the user in order to learn, suggest or perform an action. Additionally, the user interface should have the ability to adapt to the user.

Consider a person who wishes to set the house temperature to be 20 °C when they arrive home from work. The most conventional solution is to programme the time at which the heating system turns on, with obvious issues for early or late return. A more evolved scenario would be the interaction of the user with the heating system via a website or mobile app. Taking this concept a stage further, the heating system could independently communicate directly with (say) the user's car or relevant public transport system and autonomously turn on the heating based on an estimated time of arrival, taking into account factors such as traffic, external temperature and the (learned) heat transfer properties of the building.

The final solution requires a distributed intelligence within the system enabling devices to cooperate or compete for resources and services. This implies smarter devices incorporating predictive, reactive and cognitive capabilities.

Another important issue is the volume of information that home systems are increasingly required to manage. Here, the predictive analysis of human behaviour is an important issue to consider as is the predictive analysis of the home as entity composed of different devices communicating with others both inside and external to the home. According to the CONNECT forum [25]:

…. the integration of 'Things' as actors in the Internet via massive and innovative sensors, actuators, and real-time reactivity will cause another order-of-magnitude data explosion with challenges that we have yet to understand and deal with.

12.2.3 Home Systems Challenges

The most important goal is that of enabling individually intelligent devices to effectively communicate and interact with the other devices and actors in the environment. To provide intelligence at the device level, this could be seen as part of the service layer of the device where the decisions are taken regarding the service it provides. Alternatively, it could be seen as a layer which involves both services and technology as it both provide services and uses the technology in different ways depending on the requirements of the other devices in the environment.

At the technological level, advances are in two main directions, miniaturisation and performance improvement. Within the IoT, reducing the size of the devices to integrate them in essentially everything is an essential requirement, including implantable devices as part of an eHealth and mHealth environment.

12.3 eHealth and mHealth

In the introduction to the report '*Good health adds life to years: Global brief for World Health Day 2012*' Dr. Margaret Chan, the then Director-General of the World Health Organization,[2] wrote that [26]:

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 ….. This great demographic challenge of the first half of the 21st century therefore demands a public health response….

In another context, the World Economic Forum in their series of *Global Risks Reports* [27] has consistently identified mismanagement of population ageing as a high likelihood, high impact area lying on the societal axis of their analysis. This challenge of an ageing society is not only a global issue, as illustrated by Fig. 12.5a, b, but also one that is accelerating [28].

Globally, the effective delivery of all aspects of healthcare is an increasing priority, and the World Health Organisation commented that [29]:

…. as long as the acute care model dominates health care systems, health care expenditures will continue to escalate, but improvements in populations' health status will not.

[2]Appointed 2007 and re-appointed for a further 5-year term in 2012.

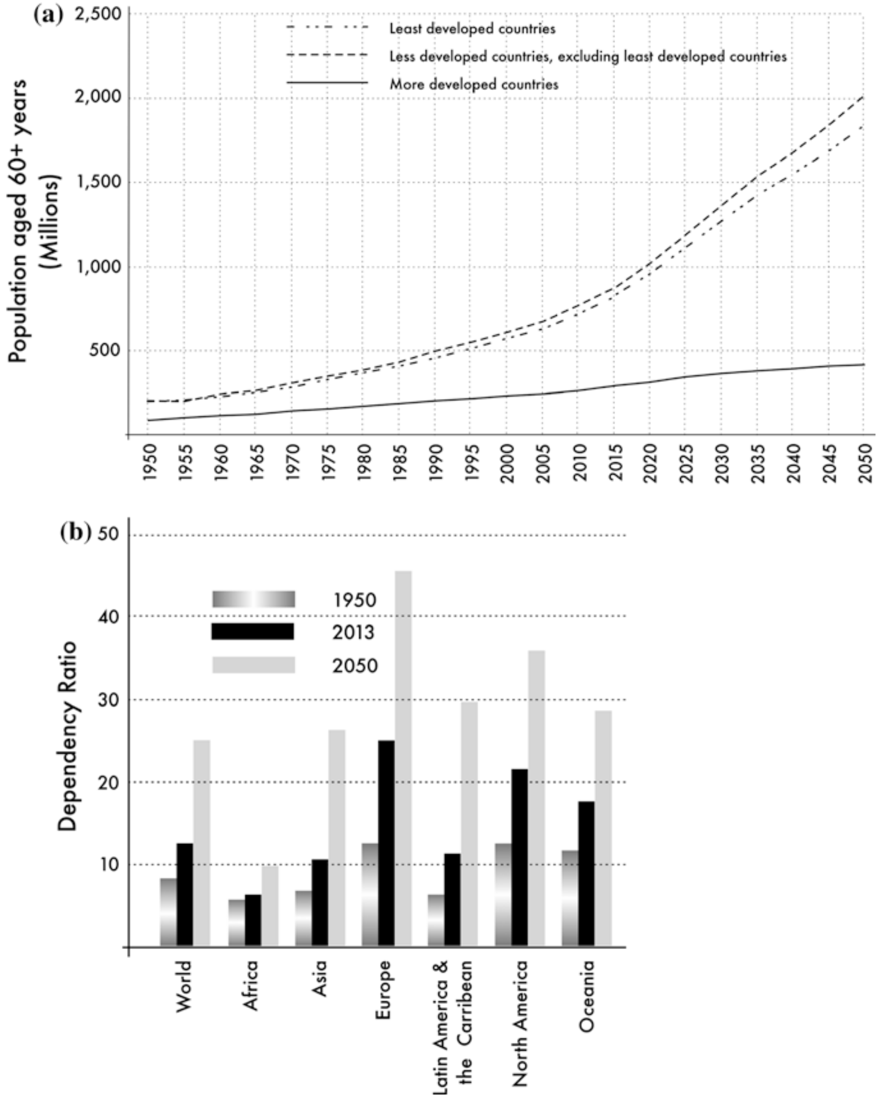


Fig. 12.5 The challenge of ageing. **a** Growth in population aged 60+ years. **b** Dependency ratios—defined as the number of people aged over 65 for every 100 people in the age range 15–64

Further, the EU Commission in 2009 noted that [30]:

> In order to limit the expected increase in public expenditure, policy measures which can either reduce disability, limit the need for formal care amongst elderly citizens with disabilities, favour formal care provision at home rather than in institutions or, more generally, improve the cost-effectiveness of long-term care provision, e.g. through introduction of eHealth and telecare must be developed.

These factors, together with the associated demands on physical, human and social resources, has led to a consideration of wide-ranging eHealth strategies deploying advanced ICTs as a means of providing the desired and required levels of support. However, the evidence base remains relatively weak and Demiris and Hensel in their 2008 systematic review of health related smart home applications [31] stated that:

> …. in spite of the growing number of initiatives in this area, the field is in relatively early stages and is currently lacking an extensive body of evidence.

and there has been little since to suggest a significant change in this position.

In practice, evaluation has to date tended to be based on relatively limited evidence, often structured around the extrapolation of relatively small data sets, which themselves are often concentrated around a focussed application or a selected group of participants. It is therefore suggested that such evaluation as does exist can perhaps best be categorised as trials aimed at establishing the performance of specific system components rather than establishing their functional and operational integration at the system level, for whom and in what circumstances [32, 33]. The effect has thus been that to date installations have essentially been experiments, and need to be considered and evaluated as such.

In the absence of a wider integration of such data as is available, access to which may well have commercial implications, this position of sparse data and lack of confirmation is likely to be the case for the immediate future.

There is also the concern that within the overall context of eHealth there has been an inevitable, and to a degree understandable, compartmentalisation of technologies and applications in order to integrate them within conventional healthcare structures and organisations. Thus for instance, physiological monitoring is often seen as a constituent component of telehealth, but not of telecare, whereas from both a technical perspective, and perhaps more importantly a user perspective, they form part of a continuum of applicable technologies.

It is also the case that there has been a significant shift in the nature of technology since telecare, telehealth and telemedicine systems began development in the late 1980s and early 1990s. Of these, perhaps the most significant has been the evolution of smart objects and their interconnection through the medium of the IoT. This level of connectivity is illustrated by Fig. 12.6 which shows the rise in the number of connected devices per person.

The result is a combination of technology push in the development of new and novel forms of sensing, cloud computing, near field communications, smart communications, adaptive and emotive computing, machine ethics, and user pull driving demands for increased service provision.

Developments such as the IoT and Cyber-Physical Systems imply the large-scale interconnection of a range of smart, and essentially mechatronic, objects to service information [34, 35]. This, however, represents a paradigm shift in systems development from an environment in which information is used to service artefacts to one in which (smart) artefacts are used to service information. This in

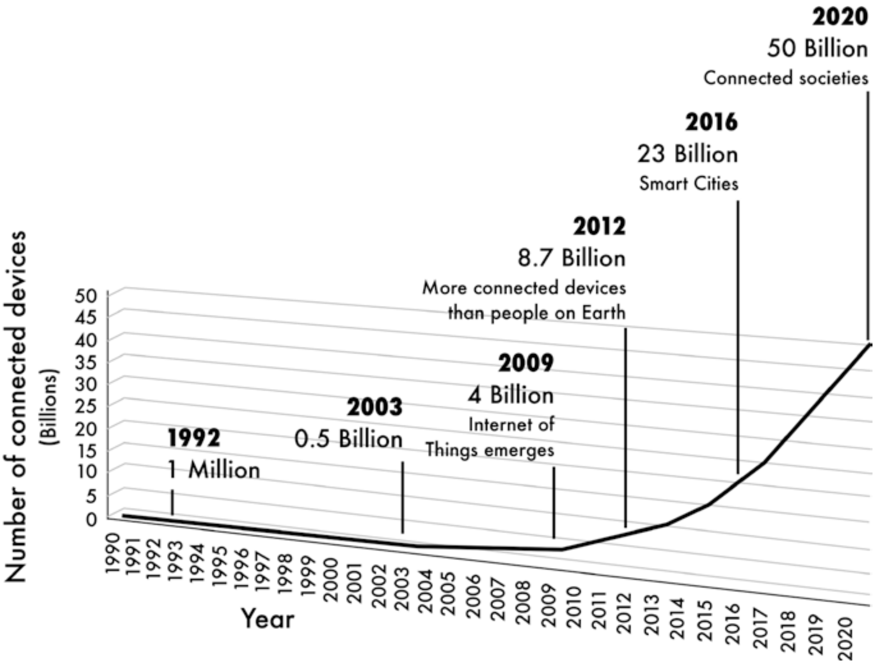


Fig. 12.6 Growth in connectivity

turn implies a change in the way in which systems are viewed as being relatively inflexible and task oriented to highly flexible goal-oriented entities whose role can easily be changed by reconfiguring the connected smart objects. In such an environment, connectivity, and the ability to configure user interfaces to suit individual requirement and need becomes paramount to system functionality.

Consider an eHealth system structured around the following core functions:

- The monitoring and analysis of activity to detect and respond to anomalies or indicators of changed status, and hence a change in need.
- Physiological sensing and the recording of symptoms.
- The monitoring of emotion and its integration with other forms of behavioural data.
- The recording of specific observational data related to the monitored individual.
- The use of smart interfaces to provide the link between the individual and the system.
- The use of the Cloud as a data storage and transfer medium.

In the context of the IoT this functionality can then be associated with appropriate groups or clusters of smart objects to provide the connectivity.

Table 12.1 Characteristics of technological and other forms of lock-in

Characteristic
• Consumption of resources continues to increase even after changes which would seem to permit reductions
• The take-up of a new technology is a function of the 'inertia', as expressed for instance through market position, of the existing technologies and systems
• Technologies become embedded within political, social and economic systems such as markets, patterns of consumer demand, systems of regulation and infrastructure
• Institutional lock-in arising from existing interests and an adherence to convention
• Inferior designs become fixed in use by a process in which circumstance are often as important as the design itself
• Established technologies often show economies of scale, and replacement with new designs and processes can incur significant structural and resource costs at the introductory stage, even where the long term consumption of resources, functionality, environmental impact and costs are likely to be superior

12.3.1 System Design Issues in eHealth and mHealth

A substantial background of research has defined the current state of knowledge and provided an understanding of the issues involved. However, there has perhaps been a trend towards increasingly complex technological solutions [36], potentially resulting in a lack of focus on the user. Approaches which compartmentalise system elements are inevitably vulnerable to a form of 'lock-in', in which self-reinforcing barriers act to inhibit change or prevent the uptake of new technologies or the integration of such technologies within established systems [37]. The characteristics of such a lock-in are summarised in Table 12.1, and are often associated with the levels of research, time and investment that have gone into a system or technology, and the resulting, and entirely understandable, desire to make this work.

To take advantage of developments in technology, it is therefore argued that there needs to be a more open approach to system design and implementation along the lines of the *Open Innovation* strategy as outlined by Chesbrough [38].

12.3.1.1 Sensors

The increasing availability of new generations of initially wearable, but almost certainly ultimately implantable, sensors capable of providing information on a range of physiological signs such as pulse, respiration, body temperature and movement needs to be accommodated within the next generation of eHealth systems. While the data from these, as for instance relating to movement, could be correlated with activity data derived from PIRs, they could also act independently in establishing, on a clinical basis, the requirements for an emergency response.

Specifically, the introduction of wearable, and eventually implantable, sensors supports a separation of the functions of monitoring and emergency response in a way which is linked directly to the individual. It is therefore argued that this form of sensing has the potential to play a significant role within eHealth and mHealth in a number of different roles, including [39]:

- The direct monitoring of a range of physiological parameters.
- The separation of functions such as general behavioural monitoring and emergency response with physiological data being used to supplement data from the behaviour monitoring system.
- The ability to extend the support for an individual from the home environment to the wider environment through the linking of the body hub or implanted sensors to mobile communications networks which would provide a continuous monitoring of the appropriate data.

12.3.1.2 mHealth

The coming together of the technologies of worn or implantable sensors with mobile communications affords an opportunity to expand the coverage to the environment as a whole, enhancing the ability of an individual to move between the home and the wider environment. Thus, an individual with implanted physiological sensors has an application loaded onto a smart phone to enable it to serve as their personal information node. This then allows their data to be monitored in both the home and wider environments.

In normal use, this data will be integrated with home derived data such as the recording of the use of space as part of the general monitoring process. Should an abnormal condition arise then depending on the nature of the abnormality, a number of actions could result, including:

- Messages passed to the care team for appropriate follow-up.
- The user advised of any immediate actions to take.
- An emergency response initiated if appropriate.

Should this condition be such as to cause, say, the individual concerned to be unconscious when the emergency response team arrive, the fact that they are linked to their health record would enable the response team, with proper safeguards in place, to access information such as known medical conditions and medication to enable a more effective response than might otherwise be the case.

Mobile health or mHealth-related applications structured around the use of mobile communications as a specific element within eHealth thus offer great promise. Applications include the collection of data, dissemination of information, and patients, real-time monitoring and related issues [40, 41].

12.3.1.3 Standards

Standards and protocols are competing for the home networking market are largely based around the IEEE 802.11 standard and its range of amendments. Their use for telecare applications is then dependent on systems providers adopting appropriate standards to allow for the networking of a range of devices. However, and for understandable commercial reasons, systems suppliers are at times reluctant to adopt an open systems approach, which would allow devices from a range of suppliers and providers to be integrated onto a single home network and which put in place appropriate safeguards for the handling of the health-related data generated [42].

In relation to eHealth systems, the ISO/IEEE 11073 Personal Health Data (PHD) standards [43] aim to support:

- The provision of real-time plug-and-play interoperability for medical, healthcare and wellness devices.
- The facilitation of the efficient exchange of care device data, acquired at the point-of-care, in all care environments.

12.3.1.4 Informatics, Data Security, Ethics and a Knowledge Economy

The integration and management of healthcare-related data from all sources presents a major informatics challenge in ensuring the robust and secure control of an individual's data whilst allowing appropriate access to that data [44]. Indeed, resolving questions of data and information security is likely to be a major issue in developing personal health databases to achieve the necessary levels of user confidence while ensuring appropriate access.

Other issues of growing importance are the ability to use an integrated health informatics system, sometimes referred to as a '*Learning Health System*' [45], in which the ability to use the information residing in an integrated health informatics system, and particular patient data, can be used in support of the planning, organisation and management of a health system, for instance through the identification of trends and patterns to enable earlier interventions to take place.

Such systems envisage an infrastructure along the lines of that shown in Fig. 12.7 in which related information can move freely between the strategic groupings associated with the provision, development and management of healthcare while relating back to the individual. Again, however, there are significant issues of security and confidentiality. In particular, the ensuring of patient anonymity while enabling the relevant data to be accessed for strategic purposes. Studies of the potential of cloud computing in healthcare [46, 47] have served to highlight and identify problems associated with the maintenance of data security within a shared environment whilst also suggesting pointers to potential solutions.

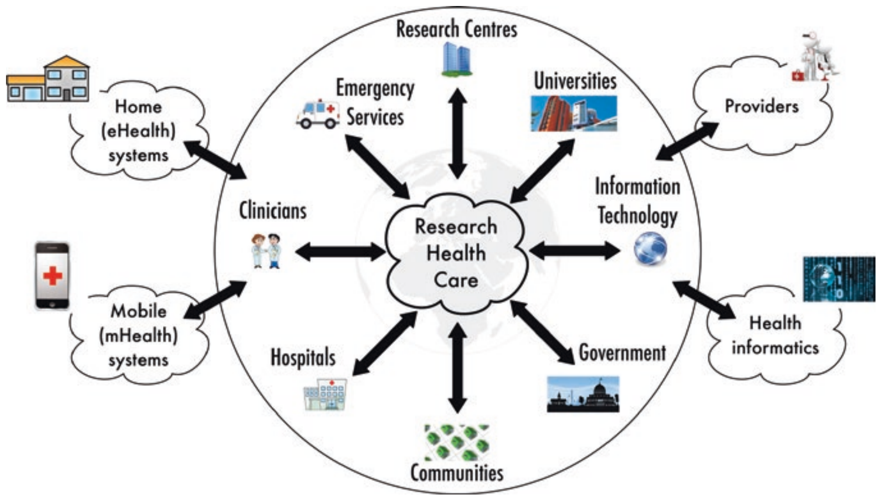
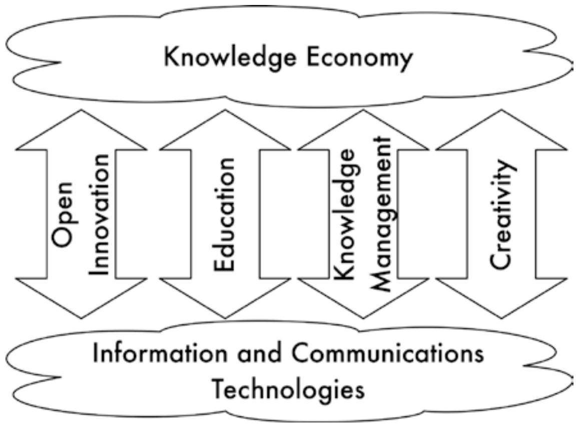


Fig. 12.7 eHealth/mHealth infrastructure

Fig. 12.8 Knowledge economy



Further, discussions regarding the general access to, and use of, anonymous data have confirmed the significant levels of concern associated with providing access to such data, even when it is recognised that the application is benign.

All of the above have ethical, both human- and machine-related, implications which will need to be addressed if the approach is to become adopted. 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 as to their state of health.

Further, such an infrastructure must be positioned within the context of an evolving knowledge economy as suggested by Fig. 12.8 within which the data and information relating to individuals may well be seen as having significant contextual, or indeed financial, value. Thus, concerns have been expressed that such data may be traded and used to prohibit access to certain levels of provision. The ethical issues associated with such information transactions, and their balancing to maximise the return to the individual while optimising the management of their healthcare provision will need to be resolved if eHealth and mHealth are to impact on such provision [48, 49].

12.3.2 eHealth and mHealth Challenges

In an environment seeing a rapid growth in the number of older people places significant additional demands on resources, including infrastructure resources such as housing, communications and transport. Further, many of these older individuals wish to live as independently as possible for as long as possible, posing societal challenges in ensuring access and mobility whilst preventing trends such as increasing urbanisation and the depopulation of rural areas, as for instance the Highlands and Islands' in the UK.

The underlying vision must therefore be one of an environment in which stakeholder needs are met through a sustainable organisation and the structuring of both the physical environment and the information environment to meet the changing needs of an ageing population.

Thus for instance, 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, for instance through the deployment of new and novel approaches to interfaces and visualisation. It is argued that such enhanced mobility within the information environment then acts to support physical mobility, for instance through developments in mobile healthcare (mHealth) to allow aspects and elements of telecare to move with the individual rather than be fixed to their home environment.

This overarching vision of a healthcare infrastructure which integrates the physical and the information environments to support the user in turn implies the need for sustainable solutions which maximise benefits whilst optimising the use of resources in each of the short, medium and long terms. These solutions must address and support issues such as

- The balancing of the level of provision between urban and rural communities whilst recognising the needs of such communities.
- The nature of the housing stock and the balance between new build and refit or refurbishment.
- The ability to effectively assess need, specifically within the home environment rather than a laboratory.
- Means of capturing new and novel forms of data such as observational data.
- The design strategies to be adopted in relation to each and all of these issues.
- The nature of the tools to be used to support the effective assessment of the impact of change.

It must also be recognised that many current systems have over time been the subject of evaluation, review and indeed change. This has in turn often resulted in an interest, and indeed in some cases an investment in maintaining the status quo, resulting in a potential for a degree of technological lock-in which acts to inhibit the introduction of new concepts, methods and ideas. Meeting these and related challenges is fundamental to managing an ageing population.

Key issues for debate are therefore suggested as being:

- Establishment of user needs and requirements through interaction with the full range of stakeholder groups. This is an aspect of the process that is too often neglected and requires the development and implementation of conflict resolution strategies to ensure a balanced outcome.
- Identification of resources and of the interactions, both levels and forms, between different types of resource; i.e., human, financial, societal, infrastructure, etc.
- Infrastructure issues impacting upon both perceived and real issues of access and mobility.
- Sustainability issues impacting upon access to and availability of resources and including economic sustainability.
- Issues of user interaction and the incorporation of the necessary communications infrastructures within the built environment.
- Definition and evaluation of methods and techniques to carry out user evaluations in both the laboratory and the home environment.
- Design strategies and methods and the exporting of these to the relevant stakeholder groups.
- The development and implementation of decision support and related tools to inform decision-makers as to options and outcomes.
- The role of the IoT as a means of integrating a range of *smart* and *mechatronic* objects within that infrastructure.

The question must also be asked as to why, despite advances in technology that have taken place over the past 20 years, have there been no validated large-scale eHealth installations taking advantages of those technologies. It is suggested here that this is because the development of the systems required to make effective use of the technologies have lagged behind the development of the technologies. Requirements here are for:

- The deployment of the techniques of data mining and knowledge extraction as applied to large data sets and the dissemination of that knowledge to the individual.
- The restructuring of functional, organisational and operational systems and procedure within the overall context of healthcare provision to make effective use of new knowledge being generated.
- The future proofing, as far as is practical or possible, of such systems to take account of future developments.
- Ethical and security issues associated with the management of the growing volume of both generic and user-specific data.

12.4 Conclusions

A major focus of attention in the development of future Smart Homes is the ability to make the underlying technology as non-invasive as possible. Thus in relation to the user interface, computer vision and speech recognition offer many possibilities, but require improvements over current solutions. Included here is the need to achieve new and novel solutions that encompass machine intelligence to extract useful data from visual and audible information together with the communication protocols necessary to secure and fast communications. Developments up to the time of writing in these areas include Apple *Siri*,[3] Microsoft *Cortana*[4] for speech recognition and Microsoft *Kinect*,[5] *Leap Motion*[6] and *Sentry Eye Tracker*[7] for motion recognition based on computer vision.

While computer vision has the potential to simplify and improve the interaction of the users with a smart environment there still exist a number of challenges to be resolved, including:

- Facial expressions in adverse lighting conditions, for instance during the night when the light levels are low.
- The environment may host several people and the system may be required to extract both individual and global information, for instance to lead people to the safest exit in the event of fire.
- Provision of methods and means which ensure privacy, particularly where the system may be required to respond differently to the differing needs of different users.

Wearable devices also have the potential to support location independent services. These could include:

- Detecting and responding to dangerous situations such as a hole in the street or approaching traffic.
- Route guidance in unknown locations.
- Support in emergencies, for instance by informing users as to potential actions while autonomously communicating with emergency services.

In a wider system context, challenges include:

- The ability to analyse and respond to the level of activity in a street to autonomously regulate the lighting, traffic signals and other elements of the environment to optimise factors such as safety and energy consumption.

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[3] www.apple.com/ios/siri (accessed 8 October 2015).

[4] www.windowsphone.com/en-US/how-to/wp8/cortana/meet-cortana (accessed 8 October 2015).

[5] http://dev.windows.com/en-us/kinect (accessed 8 October 2015).

[6] www.leapmotion.com (accessed 8 October 2015).

[7] http://steelseries.com/gaming-controllers/sentry-gaming-eye-tracker (accessed 8 October 2015).

- Detect and report on damage to infrastructure to support pre-emptive maintenance.
- Detecting and responding to dangerous or hazardous situations and acting to mitigate these.
- The provision of design tools to support the design of integrated systems based around the presence of numbers of smart devices.
- Ensuring user privacy.

The chapter has set out to try, through the medium of the Smart House and eHealth technologies in particular, to suggest how the increasing availability of smart devices and systems will impact on the way in which individuals react to and interact with their environment, and to identify some key issues for which resolution is required in order that the user potential may be achieved.

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