digitalaccessprovisionforum

Lifetime Digital Homes – New Homes

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Contents

1. Purpose and aims

This discussion document aims to support commissioners and designers identify infrastructure options that will deliver integrated assisted living (telecare, telehealth and environmental control) services in new domestic buildings. While any assisted living function or service may be provided by a stand-alone system, the benefit of an integrated system is that devices and systems can synchronise their operation, deliver greater overall functionality than the sum of the parts, provide greater robustness, and offer potential 'plug and play' flexibility, at lower cost and greater efficiency.

This is one of several documents based on the RIBA Assisted Living Design Guide[1].

See also 'Lifetime Digital Homes - retrofit homes' and 'Lifetime Digital Homes – residential and high density homes'. This guide is supplemented by a BRE Lifetime Digital Homes Decision-Support tool for commissioners and designers of new homes available at www.bre.co.uk.

The aim of the document is to support decision making:

- by commissioners and designers of new homes within the social rented sector, though it is also relevant to homes designed for purchase
- that results in cost-effective, flexible and robust systems that respond to the changing needs of an individual, to the variety of needs within a family unit and between one resident and the next on a local population basis
- that is relevant at a population level, therefore this must be relevant equally to clients with any physical, sensory or cognitive impairment, who may be experiencing the impacts of disability, ageing or managing a long-term health condition from the point of low requirement for services, characterised by self care, to high requirement for services, characterised by dependence on statutory support
- that results in an integrated digital, power and communication infrastructure able to support the broadest range of current and near market assisted living devices
- that accommodates foreseeable infrastructure implementation developments over the next 10 years including smart grid development, and in-home energy and climate management
- that is pragmatic and acknowledges the budgetary restraints relating to the funding of social housing
- that can be understood by an informed but non-expert audience, providing links to industry guidance on implementation for a more expert audience
- that is informed by a vision for assisted living services as illustrated by the DAP Forum demonstrator tool available at www.dapforum.org.uk

1.1. Relationship to existing regulation and good practice

This discussion document does not constitute guidance as each specification for new build housing will call for expert assessment and design. However it does aim to inform commissioners of new homes of some currently available options and to support decision making.

There are currently no minimum UK legal requirements for the provision of data communication into and around the home.

This document assumes that implementation will be carried out by the relevant professionals who have knowledge of and, where required, can comply with existing regulation and documented good practice in electro-technical, gas, and water installation. A note of current documents to be considered is included in Appendix 1.

This document is set in the context of the following reference papers:

- Standards, Interoperability and Broadband, Technology Strategy Board, Assistive Living Innovation Platform (ALIP), 2010
- The Interoperability Framework Requirement Specification (IFRS), TAHI, CENELEC June 2010[2]

This discussion document sets out the main points that commissioners need to consider but should to be read in conjunction with these reference papers.

2. Scope

This section sets out the scope of the discussion so that the subsequent review of current infrastructure options and the report's analysis can be assessed for relevance by commissioners and designers faced with their own specific situation.

2.1. Location of infrastructure

This document considers data, telecommunication and power[a] infrastructure provision within the home as this element within an integrated end-to-end system has not yet been looked at in detail. The majority of telecare installations have not so far required integrated systems and have been put in place at point of need, at relatively high cost.

With increased recognition of the potential benefits of assisted living systems to meet emerging and preventative health and social care requirements at scale across broad population groups, alongside an increased complexity in terms of infrastructure requirements for internet protocol (IP) enabled devices, there is now a requirement to document the options for installing an integrated home infrastructure. Many of us live with a legacy of inadequate provision of power around the home with one or two sockets per room and we are in danger of replicating that failure to design our homes adequately in terms of access to data and automated control of homes and home services.

While the focus of this document is on optimising the in-home element of the assisted living system, consideration has to be given to issues relating to the whole system. This means that devices are outside the direct focus of this document, but will be discussed, as will external communications networks.

2.2. Boundary of communication infrastructure

Establishing a home communication infrastructure, whether hard wired or wireless, usually requires a communications port (a hub, router, or server) to gather the data from within the home and then enable it to be sent out of the home either through a hard-wired solution (e.g. broadband ADSL or "cable") or a wireless solution (mobile communication, e.g. GSM). Coming from the hub and around the house there are a range of home data network options to achieve internal connectivity. Data transfer between the home and the outside world has been considered, but is outside the direct scope of this document.

2.3. Capacity of communication infrastructure

A reliable power supply and average speed broadband supply is assumed to be available. Where a broadband service is not available to, or affordable by an individual or family, then it is assumed that in the future they may be introduced or afforded and that, in the mean time, there is benefit to having communication between devices within the home.

Historically telecare equipment has not required broadband as it consists of small 'packets' of information that can be sent reliably over standard analogue phone lines. However next

[a] 230-volt mains power circuits, for example; those supplying 13 amp socket outlets or spurs for fixed equipment and lighting circuits including overhead and wall mounted lights

generation assisted living technologies will increasingly use IP communication as they integrate with consumer electronics devices and communicate using next generation digital telecommunication networks. The move to IP-enabled devices is also prompted by business and technology developments that are prompting solutions that can shift the focus of services from reactive alarm services to interactive support services.

To do this it is anticipated that there will be a requirement to communicate in 'richer' formats, such as video, and to manage and represent complex information. The potential of presenting a breadth of information to clients, linked to health or activity monitoring information, is widely considered to provide significant potential to support health education, personalisation of services and preventative self care. Such presentation of a breadth of information, advice and resources to the client can most economically be delivered over the internet.

2.4. Related in-home data infrastructure

The provision of network support for assisted living services has to be implemented in the context of the roll-out of energy management services (smart metering), home entertainment and security networks. Each area has developed proprietary implementation in silos and trying to interoperate between them at this time may not be feasible as they have different operational requirements, e.g. the frequency with which data is gathered and also transmitted out of the home. The ALIP Standards Paper[3] (p7) notes 'such devices are not required to interoperate at the physical layer but should take mutual advantage of shared systems and interwork'.

2.5. Functionality of infrastructure

People with emerging or complex needs, require two key functions to support assisted living:

- **The flow of data in, out and around the home**. Data in this sense can be information about the whereabouts, well-being and activities of the resident but can also be information brought into the home to support independent living, such as a phone call from a call centre or informal care network or information on healthy living delivered on IPTV.

- **Building control.** Residents may also rely on assisted living infrastructure to control a range of services and devices within the home. Interface between the data network and the home mains power, gas and water networks enables control of devices and services in the following ways:

    a) to control devices which are normally connected to mains power, such as lights, thermostats and electrical appliances,

    b) to control objects that are not normally connected to mains power, such as doors, windows and curtains;

    c) to control devices that use services such as gas and water, such as ovens, radiators and baths.

  This control may be direct, using a remote control to open a curtain, window or door; it may be pre-programmed (to respond at a specific time) or in response to data received from in-home sensors (triggered by temperature, light conditions, etc) or it may be in response to an external signal sent from outside the home. Such control may be required to enable a graduated response to a potential risk, such as a dangerously overheating oven, or doors or windows that have been left open when the resident has gone to bed.

The current infrastructure options set out in Section 5 below are discussed in relation to their capacity to easily and cost-effectively deliver these range(s) of functionality (a-c above). A level of functionality to control devices and appliances in the home is likely to be as relevant for people with emerging levels of need as for those with significant levels of need. How much control should be enabled by installing an integrated infrastructure in new build homes is the subject of this paper.

Providing a range of ways to control the home and home services from manual through to external control and to do so at a level of specificity that can identify how a particular device impacts on the design of the infrastructure required.

3. Services enabled by optimal infrastructure provision

Although addressing the requirements for those residents with health and/or social care needs, an optimal infrastructure in a home would also provide services for those with no requirement for assisted living.

3.1. Universal provision

For those with low health or social care needs, an optimal infrastructure would support services and functions that fall broadly within the Digital Economy and similar initiatives:

- Digital access (entertainment, education, employment, e-gov services, etc)
- Well-being monitoring (fitness, weight, smoking, etc)
- Social networking and rich media entertainment.
- Building management:
  - (a) of devices normally connected to mains power (including energy management, heating, appliances such as washing machines and security management, intercom)
  - (b) of objects not normally connected to mains power (door lock control for security, windows and curtains, for ventilation and energy management)

3.2. Assisted Living provision

Internet access from assisted living devices allows a range of services to be provided by statutory and private bodies, such as monitoring, control, communications. The exact nature of these services will evolve over time, but already there are clear signs of the value to disabled and long-term condition patients of having social connectivity tailored to their needs, activity monitoring to verify their general wellbeing, and smart control over their utilities and environment.

For those requiring assisted living an optimal infrastructure would also support:

- Personal health monitoring (vital signs monitoring for health conditions and well-being, presentation of health education information and advice)
- Activity monitoring (movement, daily living trends, entry and exit, etc,). Moving up to social alarms where appropriate.
- Social support and communication (videoconferencing, social inclusion, remote consultation)
- Mobility equipment (through-floor lifts, stair lifts, hoists)
- Building management:
  - (a) of devices normally connected to mains power (including intercom, lights, kitchen appliances)
  - (b) of objects not normally connected to mains power (door lock control, windows and curtains, mobility equipment, prompting devices such as medication reminders)

(c) of devices that use services such as gas and water (such as ovens, radiators and baths).

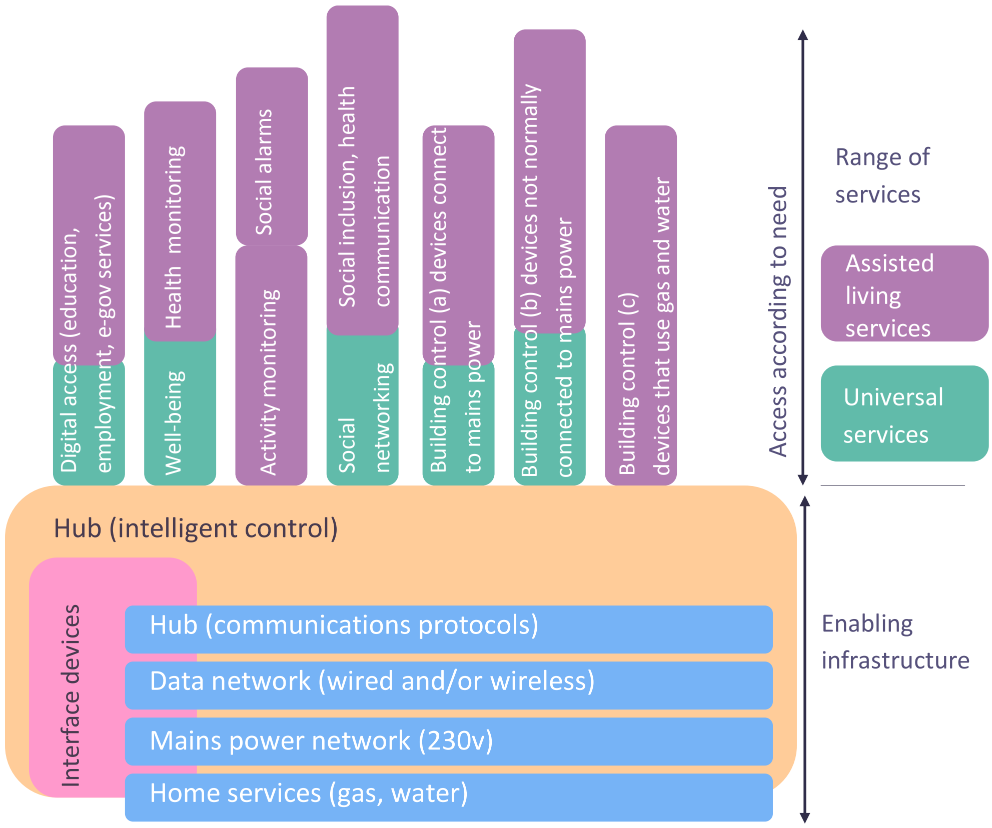

Figure 1 Enabling infrastructure and range of universal and assisted living services

New homes require an enabling infrastructure to ensure a range of services can be accessed during the lifetime of the home, according to the occupants' needs.

3.3. Infrastructure considerations

Infrastructure options have to be considered in relation to the communication protocols they enable, hub requirements to enable control of the home and home services and interface requirements between services, power, data and communications networks.

3.3.1. Diagrams of home / hub/ data connections around a home.

The following diagrams are intended as illustrations of typical scenarios in providing data infrastructure in the home. It is expected that, in practice, a mix of different types of devices may be required (wired, wireless) and that a mix of different data connection topologies and protocols may be employed.

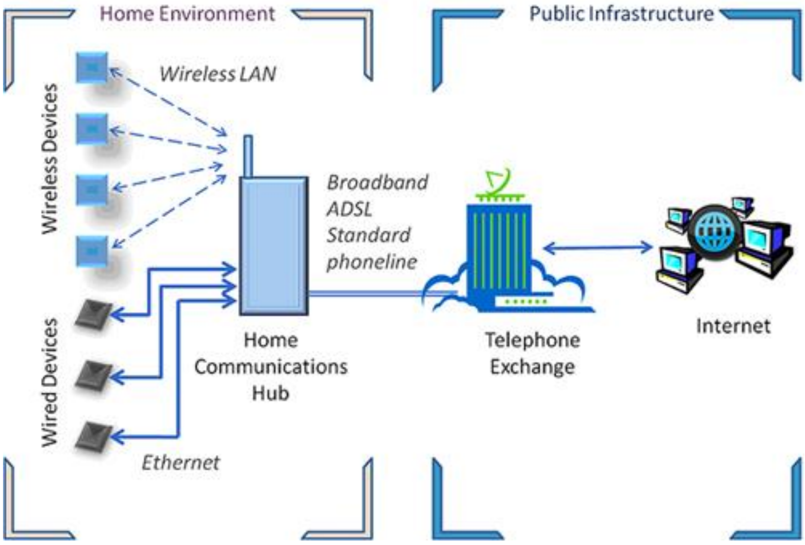

Figure 2 Classic Domestic communications set-up.

Both wireless LAN (IEEE 802.11b/g/n) devices (blue) and wired (Ethernet – IEEE 802.3) devices (black) co-exist on the same network. Each device may access the internet independently using this topology, sharing the external connections. See section 5.2

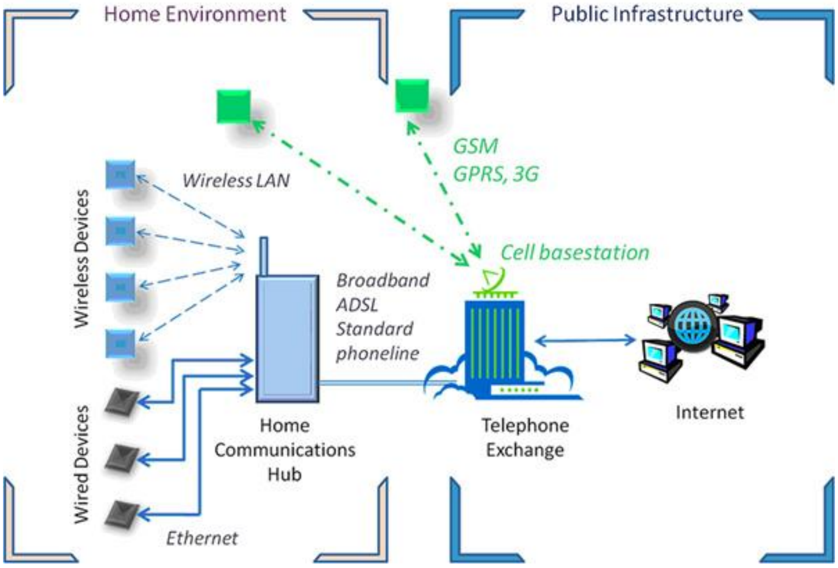

Figure 3 Network with 'mobile' devices using GSM (GPRS or 3G)

In areas where coverage allows, "mobile" devices (green) may be incorporated into the system. These bypass the hub, communicating directly with the mobile base station and out onto the internet. See section 5.3

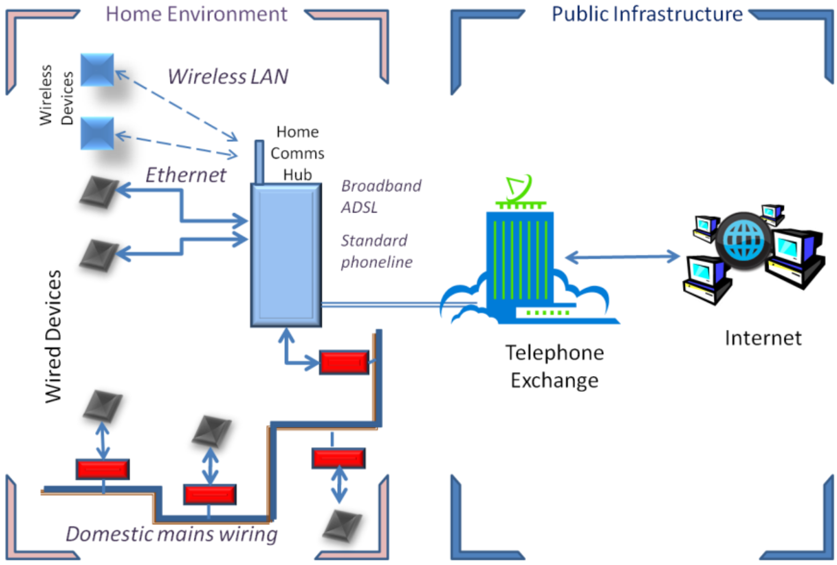

Figure 4 As an alternative to wired Ethernet cable, power line communications may be used

Options to be considered for hard wired home infrastructure include Ethernet cabling and the use of power line with adapters (red) which allow Ethernet devices to be networked back to the hub using the existing mains cabling. See section 5.4

3.3.2. Communication protocols

As described in the ALIP standards paper[3], communication transport standards fall into three geographies: body or personal area networks, networks in the home, and wide area networks, although they overlap significantly. These networks can be wired or wireless, broadband or narrowband, analogue or digital. There will be no single “Next Generation” network and related infrastructure; we can expect multiple standards, multiple wireless frequencies, and a world of digital heterogeneous IP networks.

An additional complication at this stage of standards development is that telecare (social alarms) equipment must conform to BS 8521 which specifies requirements for the transfer of information and controls within the social alarm system. The system consists of site control of local equipment and then extends to the alarm receiving centre via the telephone network. It allows for analogue equipment to perform over broadband, but is not an IP based protocol itself. It provides for interoperability of different telecare devices from different suppliers by ensuring alarms receiving centres can correctly interpret codes from compliant sensors and distributed alarm units.[b]

What this means is that there is a wireless communication protocol for telecare alarms that is different from and non-interoperable with, other emerging PAN and WLAN systems. Therefore in the immediate future, for most emerging telecare alarm systems there will be a proprietary hub for telecare services, additional to mainstream communication and entertainment hubs, though it is likely that at some point in the next 3-5 years these will be integrated.

3.3.3. The hub or gateway element of infrastructure

There are two aspects of the “hub” that need to be considered in any home data network solution for assisted living: the communications hub, and the intelligent hub. The intelligent hub may double as the communications hub.

- **Communications hub:** The most basic function for a hub is connectivity to the external world. This requires the hub to act as an interface between external and internal communications protocols.

- **Intelligent hub:** In order to function as an intelligent system, a home data network solution may need an intelligent hub which could be a set-top box, proprietary server, PC, internet gateway (see 3.3.7.), or even a mobile device. The intelligent hub may be required to carry out the following functions:

  - device management (alerts when devices are not working) and remote device and system fault diagnosis;
  - intelligent analysis of data;
  - data storage;
  - data transmission management;
  - integration with mainstream devices such as intercom, phone, TV, etc.;
  - reception and display of information from outside the home;
  - enable remote control and programming of devices and services within the home.

[b] Synopsis of information from ALIP standards paper [3]

3.3.4. The potential of Smart Meters as assisted living hubs

There is a growing availability of Smart Meters which are intended for the management of power usage around the home. Smart meters are due to be deployed throughout the UK by 2020. These range from passive information gathering to intelligent control of devices to minimise usage and cost. Though Smart Meters present a future opportunity for use for Assisted Living purposes, this is unlikely to happen until Utility companies adopt a broad vision for allowing wider services within their product offering.

3.3.5. Distributed intelligence

An alternative to an intelligent hub is a distributed intelligence approach. Each device (switch, control, actuator, sensor etc.) is connected in a network and each device has its own address on this network, and may be addressed by any other device. Such systems include Zigbee and KNX. Setting up such a system requires the act of associating devices together to perform the required function. A distributed intelligence approach may be combined with a central intelligent hub in a hybrid system. A fuller discussion of this approach is in Section 5.6.

Zigbee is a particularly well-known example of a protocol that supports mesh networking. A mesh is simply a collection of wireless access points ("nodes") that can relay messages between each other, thereby extending the network beyond the range of a single access point. Typically one or more nodes will then have external internet access to serve the rest of the nodes. A mesh may be fixed (in the sense that the relay paths are pre-determined by the installer) or it may be dynamic: the mesh nodes automatically find paths to relay the messages to the destination, providing each node is in contact with at least one other. Such a dynamic mesh aims to be "self-healing": it will adapt when nodes become non-operational, or when nodes leave the vicinity.

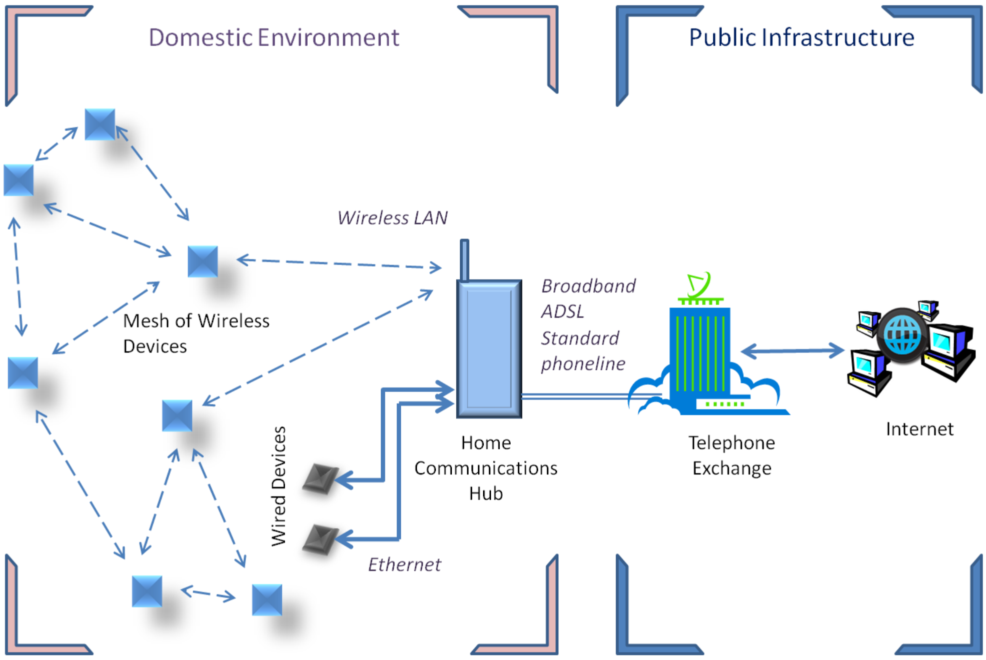

Figure 5 Example of a home wireless mesh

In larger houses a mesh network can help to extend the range and robustness of a wireless installation. The mesh may be fixed or dynamic and self-healing so that changes and faults are automatically accommodated.

3.3.6. Deploying a hub - general considerations

- Ventilation: the device needs adequate airflow for dissipation of heat.
- Ease of installation: the location needs to be accessible with provision of power.
- Security and safety: the location may need to be tamper-proof and possibly out of normal reach where it presents no obstacle to the occupant's normal lifestyle.

3.3.7. Hubs for differing infrastructure options

Hub functionality can be incorporated into a range of devices, depending on the needs of the installation and what devices are required.

- Wireless networks are generally supported by a wireless router supporting WLAN (WiFi); this function is not complex and could be incorporated into other equipment; one WLAN hub is required per network.
- To provide an intelligent hub on hard wired solutions such as Ethernet or for wireless networks, a PC acting as an IP server/gateway is suitable and may also provide a range of computing facilities to provide functionality according to occupant's needs, and storage facilities for data relevant to such functionality.
- If computing facilities are not required, then alternative hub options may be lower-cost, such as set-top boxes, or even advanced internet-enabled (IP)TVs.
- A mobile phone can provide hub functionality for nearby PAN connected devices such as Bluetooth. The phone gives access via WAN technology to the internet.
- External 'intelligence' options may be provided by cloud computing. The intelligent services are provided by a supplier and accessed over the internet: the "hub" becomes virtual. The advantage for the user is the flexibility of solutions according to changing needs. As this relies on an external link, a communications hub is still required locally, as is a local shadow intelligent hub if local functions are to be maintained should external connections fail.

3.4. Interface between data, power and services networks

In order to achieve building management at levels (a) to (c), control through the transmission of data messages to powered devices and infrastructure, including gas and water outlet devices, interface between these networks needs to be considered. There cannot be a direct interaction between mains powered devices and circuits and low voltage hard wired data infrastructure and devices.

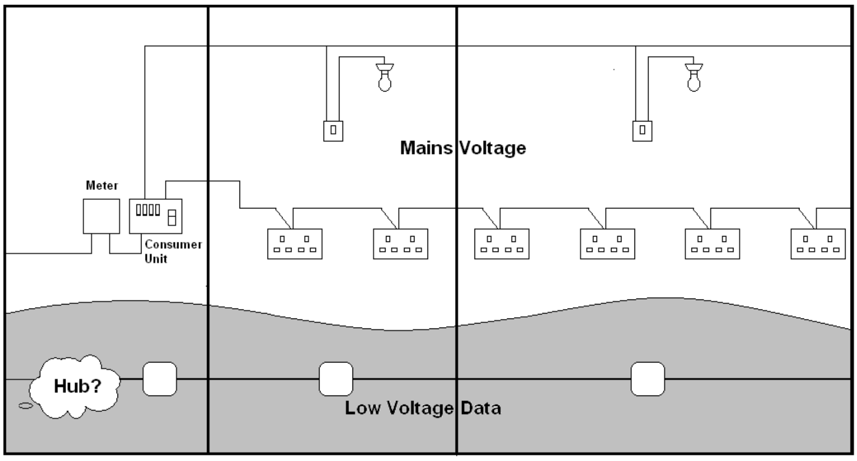

Figure 6 Configuration with separate power and data cabling

Therefore, an interface should be employed in order to enable communication with and control of mains powered equipment. This can be in the form of discrete items plugged or wired into the mains circuits.

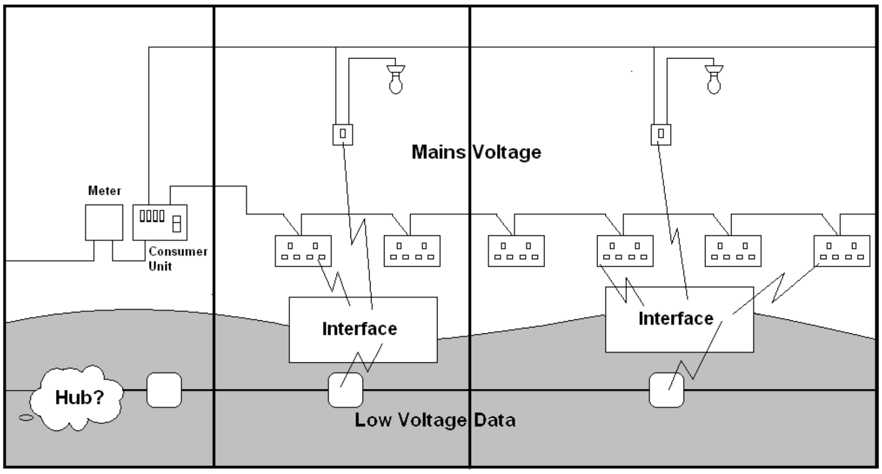

Figure 7 Control of powered lights and sockets from data system

Given the range of sensors, actuators for window and door control, gas and water outlet control, environmental control and mobility aids that may be required by some residents and the need to provide for in-home and external control and programming, this implies a potentially considerable data management requirement. It may be decided that a comprehensive data and power network is worth installing with these needs in mind.

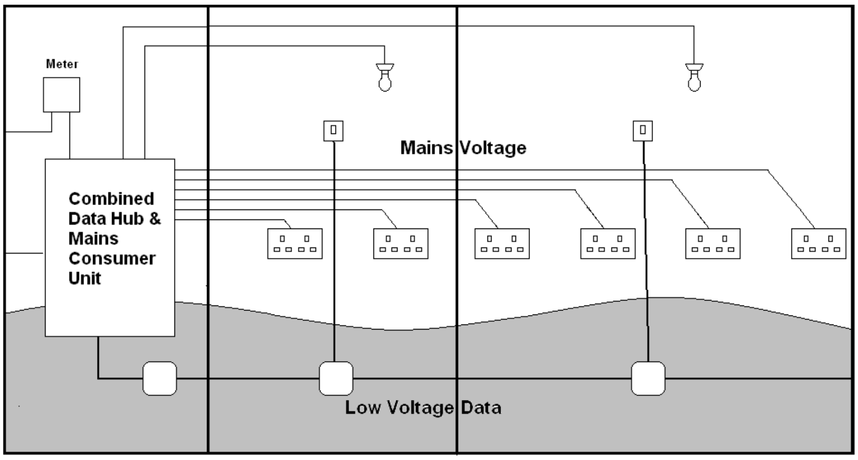

Figure 8 Fully integrated control system for lights and sockets

4. Overall Performance Criteria

These performance criteria inform the subsequent assessment of infrastructure options to deliver assisted living services.

Table 1 Performance criteria used in this document

Key Criteria	Performance aspects
Effective anywhere	• Must work in any home • Work at any place in the home
Interference-proof	• Be immune from interference from other signals • Co-exist with other networks and devices, support interworking, ideally also support inter-operability[c]
Secure	• Be secure from unauthorised acquiring of information or control of home services functionality • Ensure the system does not create disproportionate barriers to installation and use • Based on standardised existing protocols
Resilient	• Provide and maintain an acceptable level of service in the face of various faults and challenges to normal operation (a fall-back approach). • Take account of foreseeable impacts from residents, contractors and other individuals (including common approaches to DIY, wear and tear impact, potential for unlawful removal of infrastructure elements, etc)
High capacity	• Enable the broadest range of services including those requiring high band-width communication
Adaptable	• Capable of easily altering functionality if an individual's needs change, in response to the differing needs within a household and between one tenant and the next. • Upgradeable so that additional features can be added without obsolescence of the installation and capable of adding functionality.
User-centred	• Support the status of the resident owner of the home, who is the first in the hierarchy of access and control management[2] • Minimise the need for users of the system to learn new behaviours or skills • Support non-specialist programming, set up and familiarisation
Cost-effective	• Minimise the cost of installation, maintenance, operation and altering functionality • Minimise power consumption requirements and the use of batteries. • Minimise the requirement for specialist practitioner support and the requirement for training of staff.

[c] TAHI [2] offer an introduction to the three phases of integrating electronic devices in the home:
- **Co-existence** - where different systems can operate in the same environment without hindering each others' operation;
- **Interworking** - where different technologies are connected together to transfer data end-to-end. It is primarily a technical solution encompassing connectors, protocols, bridges, etc.
- **Interoperability** - where different application functions are able use the shared information in a consistent way. This requires interworking as a building block as well as coexistence, and adds business rules, processes, and security provisions that enable applications to be joined together.

5. Current infrastructure options – September 2010

This section reviews some current options for establishing a home data network consisting of the hub and internal communications network.

- Analogue phone line and analogue-digital hybrid networks
- Wireless networks (PAN and WLAN)
- Wide Area Network (WAN) mobile communications
- Wired mains
- Wired data cabling – single and multiple point provision per room
- Building control and home automation protocols

Each option has benefits and disadvantages and these are discussed below:

5.1. Analogue phone line and analogue-digital hybrid networks

5.1.1. Analogue phone line

There is currently relatively wide provision of telecare services that use analogue telephone lines (sometimes known as Lifelines) where the distributed functionality of the system is facilitated by devices connected to the “base unit” which in turn is connected to the main incoming telephone point. Hard wired analogue end-to-end systems are a robust option for communication of traditional telecare alarm services but offer little flexibility in terms of the services offered and limited ‘band width’ support for videoconferencing or control of in-home appliances and services. It is becoming more difficult to specify a robust analogue end-to-end system as phone operators switch to IP based networks. The ALIP Standards paper[3] notes (p4) “Voice band analogue service is at the core of the traditional network, but this traditional network is gradually being replaced by a data solution with variable routing and increased end to end delays.” It is becoming clear that the next generation networks of some internet service providers are not as robust for telecare as previous analogue networks.

While external communications issues are outside the scope of this document, what is pertinent is the resilience of analogue telecoms networks is increasingly unavailable which means that there is reduced benefit to using analogue networks within the home as they support limited services.

5.1.2. Digital wireless telephony (DECT)

DECT (Digital European Cordless Technology) is an established wireless (digital) telephone handset standard that can extend the reach of an analogue telephone network around a standard dwelling (range up to 50m indoors). This is common approach to enabling multiple portable handsets around a home. A DECT base station is connected like a traditional phone to the external telephone line, and a power socket is required. This is only commonly used for telephony voice and messaging services, though some assisted living environmental (building) control manufacturers produce a small number of DECT-based intercom systems that can provide door entry functions; other devices such as baby alarms are also available.

Table 2 Review of DECT and other telephony-based systems

Performance Criteria	Pros	Cons
Anywhere	Medium [with DECT handsets]	DECT handsets require power point.
Interference-proof	DECT operates in a different band (1.9GHz), so not subject to interference from Bluetooth and WiFi	Risks to interference to wireless DECT systems are low but risks of interference to other systems from DECT devices have been documented.
Secure	Relatively high level of security.	
Resilient	High, well-established, proven technology - if using hard wired network.	Less resilient if using DECT wireless extension.
High capacity		Limited - will only deliver telephone based telecare services. In order to deliver broader range of services it would be necessary to provide additional network elements.
Adaptable		Limited – not many devices use this network infrastructure and these are predominantly telephony services.
User-centred	Familiar.	Low number of available functions can be restrictive in meeting users' needs over and above communication
Cost-effective	High if requiring telephony range of services	Low if requiring a broader range of services as an additional network would have to be established at time of need to deliver these.

Conclusion: these networks do not offer sufficient benefits in terms of resilience to outweigh the lack of capability (breadth of services that can be enabled) now that external communications networks are moving from analogue to IP based and the overall resilience of end-to-end communications is in any case compromised.

5.2. Wireless networks (PAN and WLAN)

Examples of relevant wireless data communications standards include: personal area networks (PAN) e.g. Bluetooth, zigbee, infrared, etc. and wireless local area networks (WLAN) e.g. "WiFi", IEEE 802.11; IEEE 802.11g and IEEE 802.11n.

A comprehensive review of relevant wireless standards is included in Annex C of the ALIP Standards paper[3]. Some relevant points for this discussion in relation to common wireless standards/ devices:

- **Bluetooth** is a commonly-used standard for telehealth peripherals. Bandwidth and range are more limited than for WiFi. Bluetooth provides wireless transmission of data over short ranges (typically less than 10 metres, although the standard supports up to 100 metres) and has been used for remote health monitoring, although the major expansion has been in hands free mobile phones, particularly when driving. Data rates of around 1Mbit/s will be sufficient for most applications. Typically, most connections are within a single room and between a computing device (e.g. home health station, mobile phone, telemedicine device, computer or PDA) and one or more Bluetooth enabled devices (e.g. medical, health and fitness sensors such as heart rate, blood pressure, glucose, weight, and oximeters etc).

- **ZigBee** (IEEE 802.15.4) is a low-cost, low-power, wireless mesh networking standard. The low cost allows the technology to be widely deployed in wireless control and monitoring applications, the low power-usage allows longer life with smaller batteries, and the mesh networking provides high reliability and larger range. ZigBee provides a redundant mesh network, allowing the range and number of participating devices to be scaled. .. The technology was intended to be simpler and cheaper than other WPANs such as Bluetooth. ZigBee protocols are intended for use in embedded applications requiring low data rates and low power consumption." Zigbee might be appropriate for sending simple data, such as presence monitoring, etc.

- Some devices relevant to this discussion use remote **InfraRed (IR)** control such as some mainstream window openers. This is not a widely used protocol and line of sight issues need to be addressed e.g. potential obstructions between the controlling and receiving devices, including furniture placement, etc and to some extent strong light source as this can interrupt the light signal. Signal repeaters that transform IR to RF signal and back to IR can accommodate a lack of line of sight though such problems could be avoided through the use of other solutions.

- **Wireless LAN ("WiFi")**: The IEEE 802.11 series of WLAN standards provide for mostly in building coverage. Use in the UK is largely confined to 802.11b/g, but has been widely implemented. Roll out of WiFi was largely a result of the wide availability of the Intel chip set in lap tops. Typical coverage is 10s of metres, but in building hot spots can "leak" beyond the confines of the building or home. Security can be an issue. Hot spots have been set up in hotels, airports and restaurants (e.g. Starbucks), but it may be that WiFi is now passed its peak, because it does not generate an operator profit model, largely because of the problems of supporting differentiation and quality in unlicensed spectrum.

Wireless connectivity offers the resident advantages such as access to services around the home and, when working optimally, offers plug-and-play set up. However wireless connections can be tricky to set up and are subject to connectivity problems due to obstacles within the building structure. Instances where building fabric and structure interfere with radio frequency (RF) based communication networks are where metal within the fabric of the building interferes with wireless communication creating a Faraday Cage which result in wireless 'dead spots'. Common examples relate to reinforced metal in concrete structures, foil backed plaster board walls. Interference can also be caused by bodies of water (e.g. water tanks). Wireless communications may also be subject to interference from other devices including mobile phones and microwave ovens, as well as susceptible to unauthorised access.

Wireless devices use batteries rather than mains power which creates problems relating to replacement in terms of resilience of the system and the cost of servicing. Many residents would be able to replace batteries in control and data gathering devices, however some will not and many current devices are not designed for easy user-replacement of batteries. Issues to consider are whether the network will automatically recognise battery failure and the consequence of battery failure on the functionality required by the device in terms of safety and continued reliable use of the system. Rechargeable batteries obviously have some advantages here, and docking stations can be provided for some devices, and may also provide communications connections; this is already done for some Telehealth devices.

To overcome the challenges posed by larger buildings or dead-zones within buildings, wireless networks can be enhanced using "mesh networks". Mesh networks provide installation and maintenance advantages in that the network can accommodate failure of communication within individual devices or nodes. Although some products exist already, mesh networking is still evolving, and the general standard IEEE 802.11s is in the final stages of definition. Figure 5 depicts a possible mesh configuration with external broadband connections.

Due to the requirement for social alarm systems to conform to sector-specific communications standards, interfacing into wireless LAN networks in the home would be required for a fully integrated intelligent solution. Social alarms operating in the 869MHz band are available, which makes them less prone to interference from other wireless systems. Ranges of up to 1000m are available, allowing people to remain covered while in the neighbourhood.

Table 3 Wireless network review

Performance Criteria	Pros	Cons
Anywhere	Wireless solutions should be easy to install anywhere. Wireless LAN/PAN applications allow a more mobile monitoring system and less confinement of the resident to limited areas around the home.	Signal reliability depends on building topology and construction. In some circumstances, such as in larger homes or where the construction of the walls presents a barrier to radio-communications, wireless may not be accessible in all parts of the home. This may be overcome using signal repeaters, at the cost of additional installation and more detailed testing. **WiFi** performs better than the other standards in this respect.
Interference-proof		Medium – susceptible to interference from devices on same frequency or on adjacent band without good immunity, e.g. **WiFi** and **Bluetooth** share the same frequency (2.4GHz) and have to co-exist, though in practice few problems are reported. Safety critical systems warrant higher levels of shielding and need to be Class 1 devices[d]
Secure	Relatively high if security is enabled.	Security enablement of WiFi systems can reduce ease of installation. As for all IP interfaces connected to the internet, firewalls are required.
Resilient	Some wireless devices such as Zigbee devices can route data around the network to find a route for transmission if default or initial route is barred.	Battery failure is a risk to reliability.
High capacity	Wireless devices can provide high bandwidth information, such as videoconferencing when working optimally.	Not all wireless solutions offer this capacity, care when selecting devices needs to be taken if video based services are to be supported.

[d] Background to Class 1

The upgraded EN300 220-2 V2.1.2 safety standard, which came into effect on 1st January 2008, classifies radio receivers into three categories Class 1, 2 and 3. It states that Class 2 and 3 receivers should be used only for 'devices where failure to operate does not constitute a safety hazard'. Class 1 receivers are for use within 'Safety Critical devices servicing systems where failure may result in a physical risk to a person'.

It is for this reason that EN 300 220-2 mandates Class 1 for social/ telecare alarms. Class 1 receivers significantly enhance reassurance for users and are specifically designed to ensure radio transmissions from related devices are picked up reliably and are not interfered with by transmissions from other radio devices. This means that signals from personal radio triggers carried by service users and telecare sensors within their homes are picked up reliably by the telecare/ social alarm and are not blocked by other transmissions.

Performance Criteria	Pros	Cons
Adaptable	Ease of installation and mass-production of devices means that wireless devices/ systems can evolve. WiFi certified produces are guaranteed to be backwards compatible. Challenges to business models for some wireless networks such as WiFi may mean this is not a sustainable solution.	Can not necessarily integrate with existing telecare alarm devices. Non-WiFi certified devices are not necessarily backwards compatible.
User-centred	The transmission of data takes place quickly and seamlessly such that the user need not be involved. [ALIP paper]	Pairing Bluetooth devices can be difficult for some users.
Cost-effective	Organisational costs can be low, this approach may be the easiest to install: no additional wiring is required to reach equipment in other parts of the home, and therefore new equipment may be installed at minimal additional cost. Wireless access points simply need access to power (usually through batteries).	Batteries need replacing and it is often not feasible for the resident to carry out replacement. Wireless installation should be 'plug and play' but this is not always the case so some specialist installation may be required, increasing costs. Wireless activity monitoring sensors may need specialist installation to ensure desired data can be gathered.

Conclusion: wireless networks are needed in order to provide a solution that does not limit normal living, that can be low-cost to install, and flexible enough to easily adapt the system to changing circumstances. An in-home communication network that depended solely on a wireless network has a significant risk of connectivity failure that cannot always be foreseen or avoided through building design; once installed and tested however, the risk of problems arising later is reduced. It appears to be likely that a wired element within the network to create a hybrid system would make for a more resilient system.

5.3. Wide Area Network (WAN) mobile communications

The use of wireless devices using mobile communications offers residents benefits for movement outside the home and may also provide advantages for in-home communication. Mobile Wide Area Networking (WAN) devices will typically involve the use of mobile phones (using 2G (GSM, GPRS), 3G (UMTS, WCDMA) HSPA–Mobile etc).

The bandwidth requirement for transmission of medical information is not beyond the limitations of legacy 2G mobile networks. 3G Mobile gives greater potential capability but it is 3G+ HSPA (High Speed Packet Access) that offers maximum capacity. The current processing power of hand-held mobile platforms (such as iPhone, Android etc) is well above that required for quite sophisticated mobile medical monitoring, social support services and other assisted living applications. Any applications requiring reliable live streaming of video present a challenge to current and legacy systems.

A major constraint on the use of mobile networks for reliable and timely transmission of information has been patchy coverage. The UK has theoretical 99% coverage by mobile networks but coverage holes exist, although these will vary across networks. In-building coverage will be less than outdoor.

Table 4 Review of mobile communication (WAN)

Performance Criteria	Pros	Cons
Anywhere	Theoretical 99% coverage in UK	Some limitations to network coverage and to reception within buildings.
Interference-proof	Generally reliable, 3G spread-spectrum designed for interference-resilience	Interference to other devices can occur.
Secure	Web-technologies can be used to provide any current level of security.	
Resilient	Proven technology.	Battery-operated devices need re-charging / replacing regularly.
High capacity	Various levels of functionality available, ranging from SMS to video calls.	Many current video conferencing solutions are based around LAN interfacing, so this may imply not only 3G connection but also a WiFi connection at both ends of the call.
Adaptable	Flexible solutions offered through range of apps on smart phones, etc.	Few long-term limits to the adaptability of this technology: new generations of handheld processor technology continually evolving.
User-centred	Hand-held devices may theoretically easily be designed with appropriate user interfaces for many levels of ability. Mobile devices can provide real-time capture and transmission of data rather than limited fixed period transmission.	Issues with youth-centred design and familiarisation challenges for older people; mainly economic barriers to designing for older people or impaired abilities.
Cost-effective	Mass production results in low costs.	The cost of the device and contract may be high if a small number of applications or limited transmissions are required.

Conclusion: the benefits of mobile communications devices for real-time, anywhere transmission of data are considerable. This has to be balanced against the disadvantages in terms of some problems with reliability of transmission of data.

5.4. Wired mains power line

Given the limitations in terms of resilience of some wireless and mobile communications systems, an option to be considered is the use of hard-wired systems within the home. One hard wire option, that avoids the need to install supplementary data wiring, is to use power-line data communication (PLC)[e] on the mains power wiring (230v). Systems include HomePlug, Universal Power line Association, HD-PLC. IEEE 1901 is a draft standard.

A typical installation of PLC consists of small adapter units that plug into power outlet sockets and attach to the device to be connected. The adapter unit converts the data signalling (e.g. from Ethernet to the PLC carrier). A similar adapter unit elsewhere in the home receives the signals and converts them back to the data standard required by another device. Figure 4 shows a possible domestic scenario with power line installed. Control of appliances may only require a programmable controller or user operated remote handset.

At present PLC is in widespread use to connect computers to broadband routers, printers and other peripherals around a home and should be virtually plug-and-play with little installation work. It may therefore be considered to be particularly suitable for low-cost installations.

The advantage of PLC is that the range may be high within the context of the in-home environment, reaching anywhere on a mains ring circuit within the home. However any home with several floors will have to have separate ring circuits for each floor which creates an integration challenge.

The continued existence of non-interoperable standards presents a risk that equipment may not be supported in the future if standards become obsolete through competition, but equipment installed to an existing standard should remain fully functional within an installation once installed.

There are indications that this is not a robust system due to earthing faults caused by residents, unqualified contractors, etc. and due to vulnerability to signal interference from home appliances on the circuit, such as motors in washing machines, etc.

Table 5 Review of Power line communication (PLC)

Performance Criteria	Pros	Cons
Anywhere	Uses the mains power distribution that will anyway be installed around the home.	Limited to where power supply and sockets exist, e.g. may not be available in bathrooms. Different floors of a building will have separate ring circuits and so will not form a coherent network.
Interference-proof		Subject to interference from household equipment. May generate interference to other devices.
Secure	Hard wired system using	Wireless interfaces connected to

[e] A related technology, Broadband over PowerLine (BPL) delivers communications services to the home using the public electricity distribution cabling. However, this is controversial at present, as trials have demonstrated strong interference with Defence, Aeronautical, Maritime, Emergency, Scientific and Broadcast radio-spectrum licensed users.

Performance Criteria	Pros	Cons
	bespoke communication protocol so generally good.	network have security vulnerabilities identified above. As for all IP interfaces, firewalls are required.
Resilient	Physical infrastructure (copper mains wiring) is robust. In new buildings, performance limitations should be avoidable by adhering to current standards.	There is a question of continued reliability due to the prevalence of home DIY installations interference.
High capacity	Capacity to carry simple control data to multimedia devices.	Care need to be taken to ensure correct transmission capacity for specific tasks.
Adaptable	Range of devices available for related security and control functions.	Care need to be taken to ensure compatibility of devices.
User-centred		Health and safety implications of 230V opposed to low voltage hard wiring alternatives
Cost-effective	It requires no additional wiring around the home, so could be low cost.	Extensions to fixed wiring require electrician to carry out alterations to installation.

Conclusion: Transmitting data through the mains power line circuit within the home can provide a low cost data network. There are disadvantages in terms of integration between home ring circuits, with interference on the line, with vulnerability to DIY faults and potential health and safety risks related to working with high voltage power line.

5.5. Wired data cabling – single and multiple point provision per room

The use of wired data cable as an element within a home data infrastructure offers advantages for assisted living installations. Twisted pair copper cable (such as category (Cat) 5, 6 and 7) enables IP Ethernet data protocols. Ethernet is the most commonly used data protocol, providing the fastest and most reliable in-home data transmission medium. Fibre optic is also an option for hard wire data cabling.

A single cable is required for each device or each wireless access point (WAP) with separate WAPs for each wireless protocol (WiFi, Bluetooth, etc). Multiple cables may therefore be run from the patch panel to each room to enable a breadth of devices or WAPs. Each cable is usually connected to an RJ45 socket, normally mounted on a faceplate.

Cat 6 or 7 cabling can now be installed at modest cost when fitted as part of a new build programme. Costs associated with installation arising from lack of experienced installers and costs of training have largely been addressed, particularly in relation to skill requirements for new build housing. The costs for training relate to using the hard wire and wireless infrastructure to tailor it to the individual and to adapt the programme to changing need.

If the installation is to be flexible and low cost to maintain, then as much as possible of the cabling and equipment should be accessible in use. Ducting and equipment cabinets will facilitate this. Comprehensive guidance on ducting infrastructure for new homes is available from Communities and Local Government[i] (see section 2.3).

If it is contained within the same cable management solution (i.e. ducting/ trunking) data cable will need to be well segregated from mains power cables to reduce "cross talk" or other interference issues. Ideally, separate cable enclosures taking different routes within the building lower the risk of interference from power cables.

5.5.1. Single point data provision to each room

Multiple cable/ single point data provision to each room (i.e. several RJ45 outlets grouped together at one point in the room) minimises installation costs and addresses connectivity problems that may occur with hub-wireless network configurations. What this cabling configuration offers is the ability to either plug in devices directly to an RJ45 outlet or to plug in wireless access points (WAPs) that can then control around 30 battery operated wireless devices within the vicinity.

Some of these wireless devices can be used to interface with the mains power circuit to control powered objects such as lights. This facilitates building management level (a); control of devices normally connected to mains power (including lights and kitchen appliances) but not building management levels (b) or (c).

5.5.2. Multiple data and power point provision per room:

Additional data and power supply around rooms is required to achieve building management level (b); control of devices not normally connected to mains power and (c); to control devices that use services such as gas and water, such as ovens, radiators and baths.

What this cabling configuration offers is the ability to control devices in areas that are not normally connected to power; such doorways and window frames (for window and door openers which cannot feasibly operate on batteries); to objects that are not normally connected to power such as actuators (valves) on radiators and baths and to power devices to avoid the use of batteries (for intercoms and sensors).

Table 6 Review of fixed data-wire networking solutions

Performance Criteria	Pros	Cons
Anywhere	Single point provision when linked with wireless solutions and multiple point provision provides an 'anywhere available' solution.	
Interference-proof	As long as properly installed in a segregated environment there should be no interference.	
Secure	Data transmitted within the confines of a hard wired data network will be secure. Well established security protocols.	Supplementary wireless solutions will have the security issues identified above. If hub is IP enabled this will have related security issues.
Resilient	Provides a robust data management solution.	Wireless networks associated with single point provision per room will

Performance Criteria	Pros	Cons
		require battery management programmes to ensure resilience.
High capacity	Provides a high-bandwidth network solution able to provide high levels of building management.	
Adaptable	Backwards compatibility is provided within the Cat5/6/7 standards. Non-proprietary and device agnostic network so can provide plug and play interoperability of compliant devices. Outlet housings are compatible with other switches and power outlets allowing change of use.	
User-centred	Safe low voltage. In theory simple plug-in connections.	In reality some devices are not completely plug and play, some degree of technical knowledge is required to install new devices (limitation dependent on sophistication of devices).
Cost-effective	In new build situations a single point provision with wireless network can be achieved at relatively low cost, through running data lines like power lines, ideally through ducting. Little installer training is required. New switches can be fitted at low cost.	More specialist and therefore costly installation of the system may be required for multiple point data network. Devices and WAPs equipped to connect to hard wired networks may be more expensive than stand-alone solutions.

Conclusion:

- Fixed wire data cabling (e.g.Cat 6/7) to single point per room, supplemented with wireless access points and devices, is likely to be a cost-effective solution providing resilience to system that is lacking from a network that would depend on wireless alone or one dependent on power line as data network. Additional costs at point of build are minimal. Running costs associated with wireless devices.
- Fixed wire data cabling (e.g.Cat 6/7) to multiple points per room, plus mains power wiring where required, is a more expensive installation option which provides greater building control and resilience within the system. Greater control and adaption of the building will incur some costs but these are low compared to retro-fitting integrated systems at a later stage.

5.6. Building control and home automation protocols

An option for achieving all required levels of building control (a to c)[f], as well as the full range of universal and assistive living services, is to use a Building Management System (BMS) These systems have been available for several decades in various stages of development and can be crudely divided into two control topographies. Control may be provided via a central hub or controller, or the “intelligence” of the control system can be achieved when the limited control functions of many components within the system form a collective intelligence (devices employ an open communication protocol). A well-known example of such a system would be KNX.

5.6.1. KNX building management system

KNX[g] is the current state-of-the-art of BMS systems. Initially intended for use in larger commercial buildings BMS manufacturers have more recently focussed on the domestic market. KNX can support control of lighting, security systems, heating, ventilation, air conditioning, monitoring, alarming, water control, energy management, metering as well as household appliances, and audio.

Data in a KNX control system is transmitted via system specific 4-core copper cable (commonly known as “green wire”). In both instances control between mains power and devices may be achieved centrally via components sited in a mains distribution board, or locally by discrete devices.

If Cat5/6/7 cabling with Ethernet is installed in a building, then KNX systems can be configured to use them, KNX is therefore one possible control protocol supported by the underlying infrastructure provision. KNX can also be configured to use Infrared, Power line (PLC), Twisted Pair (such as standard telephone cables), and hybrid combinations of these.

KNX is still not commonly deployed in homes and so there are costs relating to specialist installation as well as costs inherent in the cabling and devices. Additionally the benefits of such a system are available through the employment of installers and programmers with the necessary skills to customise the infrastructure and devices to the needs of the residents and their health care support network. As there is currently no training specifically designed to support the development of these skills, it is likely that maximum benefits from such as system are not widely available.

Table 7 Review of KNX

Performance Criteria	Pros	Cons
Anywhere	Low voltage nature of KNX means controls, switches triggers etc. can be located practically anywhere including bathrooms	
Interference-proof	KNX data cables are capable of being run alongside mains power cables	

[f] See section 3.2
[g] (EN 50090, ISO/IEC 14543, http://www.knx.org/)

Performance Criteria	Pros	Cons
Secure	Data transmitted within the confines of a hard wired data network will be secure. Well established security protocols.	Supplementary wireless solutions will have the security issues identified above. If system is connected to an IP enabled device this will have related security issues.
Resilient	KNX is specifically designed to differentiate between low priority standard signals and those high priority signals, specifically intruder alarm and fire alarm signals. Proven ability to provide a fail-safe solution on power failure with resumption of service in safe mode.	
High capacity	Infrastructure has capacity to deliver full range of data and building control assisted living services.	The capacity to deliver building control is limited by low availability of specialist technicians (with knowledge of assisted living). Green wire does not have the capacity to deliver video conferencing or live video streaming
Adaptable	Non-proprietary and device agnostic provides plug and play interoperability for range of devices. Because of the modular nature of either system adding new functionality to or indeed reprogramming an existing system should be relatively easy in terms of programming.	Changes in function and system infrastructure require knowledge of KNX programming protocol and access to programming software Change of installation and acquisition of programming skills required by installation personnel.
User-centred	KNX systems if pre installed in a domestic residence can provide an occupant with a high degree of remote control over the buildings electrically operated devices from heating and lighting to home security. With KNX it is possible to use existing switches, which is useful for making home as familiar and non-stigmatising as possible. Low voltage so safe.	Specialist programming skills required for changes in function.
Cost-effective	Existing power wiring is simplified (no mains to switch) with separate KNX loop through all switches.	Unfamiliarity for installation staff for KNX will have cost implication as will the requirement for specialised programming service. Requires interface between data and mains powered devices which has a cost implication.

Conclusion: Though KNX potentially offer many benefits to people needing the full range of assisted living services, the cost of installing the system and the likelihood of not gaining maximum benefit from the system due to lack of suitably skilled installers and programmers, may make this inappropriate for general-purpose low density social housing. If a building is already equipped with hard wired data cabling such as Cat 6/7 or fibre optic then the installation of a building management system such as KNX is likely to be far less costly than installing it in a home that does not have the necessary data wiring infrastructure.

6. Option Appraisal – decision support

To support decision-making between the various methods and systems discussed in this paper, this section summarises the Review Tables of the Performance Criteria for each of the technologies, classifying them according to the following scheme:

G	Green: Technology meets or exceeds the Performance Criterion
A	Amber: Technology partially meets the Performance Criterion, with some deficiencies, risks, or design sensitivities
R	Red: Technology fails to meet the Performance Criterion or meets on only a limited way

For a fuller understanding of the issues, this analysis should be read in conjunction with the narrative in the corresponding section(s) of the document.

This analysis aims to support the process of decision-making, rather than providing a definitive recommendation: each set of circumstances should be considered for how important each of the Performance Criteria is before using this table to support any implementation decision.

Table 8 Decision support summary

		Performance Criteria							
Technology	**See section**	**Anywhere**	**Interference-proof**	**Secure**	**Resilient**	**Capable**	**Adaptable**	**User-centred**	**Cost-effective**
Telephony/ analogue	5.1	A	G	G	G	R	R	G	G
Wireless networks	5.2	R	R	R	A	G	G	G	G
Mobile networks	5.3	A	A	A	A	A	G	A	G
Mains power line	5.4	A	A	A	A	A	G	G	G
Data cable, single point per room with wireless devices	4.5.1 3.3.7.	G	G	G	G	A	G	G	G
Data and power cable, multiple point per room	4.5.2	G	G	G	G	G	G	G	A
Data and power cable with BMS control system	5.6	G	G	G	G	G	G	A	R

7. Conclusions

Text to be drafted in light of consultation on draft document.

8. Appendix 1. – Regulation and guidance

Relevant current regulation and documented good practice in electro-technical installation including:

- IEE Wiring Regulations 17th Edition : (BS 7671: 2008)
- BS EN 50174 series. Information technology. Cabling installation
- BS 6701:2010: Telecommunications equipment and telecommunications cabling. Specification for installation, operation and maintenance
- BS EN 60601-1:2006: Medical electrical equipment. General requirements for basic safety and essential performance
- BS EN 62480:2009: Multimedia home network. Network interfaces for network adapter
- BS EN 50523-1:2009: Household appliances interworking. Functional specification
- BS EN 62457:2008: Multimedia home networks. Home network communication protocol over IP for multimedia household appliances
- BS EN 62379-2:2009: Common control interface for networked digital audio and video products. Audio

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