TECHNICAL SUPPORT TO DEFENCE SPECTRUM PROJECT

ISM LE Band Audit (Market Study of the LE 2400 MHz band)

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Executive Summary

(1) This report provides information on the applications currently deployed, or planned to be deployed, in the 2.4 GHz Industrial, Scientific and Medical (ISM) band excluding those that are already well established and known to be using the band (i.e. residential and enterprise WiFi, Bluetooth, smart metering and others).

(2) The applications contained in this study were found through web searches, articles and reports so there is the possibility that there other applications that have not been identified. It appears that there is significant growth potential in respect of the number of devices that may be installed for those applications contained in this report.

(3) It is already considered that the 2.4 GHz band is very saturated – most applications are licence exempt and the use of technologies such as Bluetooth, ZigBee and WiFi has enabled a number of wireless devices to share this band with each other as well as with other devices such as microwave ovens.

(4) The specific applications that were explored in more detail as part of the Study were:

- Wireless accessories for hearing aids,
- Medical applications in hospitals and telehealth / telecare in the home,
- Street lighting,
- Industrial automation,
- Road traffic management,

(5) as well as the availability of sensor devices that can be used by systems integrators to implement wireless sensor networks for a wide range of applications (e.g. agriculture, smart cities, traffic control etc.).

(6) A number of the applications are ones that support Government (local and national) objectives such as reducing the costs of local councils and reducing the carbon footprint by remote controlling street lighting or enabling the elderly to remain in their own homes through the provision of remote telecare.

(7) The 2.4 GHz band is available on a no protection from interference basis. A number of the applications allow for the potential for interference by being able to save data and re-transmit the information once a wireless connection is re-established but it would be expected that any long term interference would be an issue. In others, such as industrial control and automation, it may be necessary to interrupt the process to ensure safety and this could impact on the efficiency of a plant. Where mesh networks are deployed, such as street lighting, interference into a limited number of nodes is not likely to be a problem as the networks are self-healing. However in the case of wireless accessories for hearing aids latency is a key consideration and interruptions due to interference would negate any advantages such devices would provide to the user. Similarly there are specific medical

applications, such as the one provided by St Jude Medical, where the loss of data could be a significant issue but in such cases proprietary FHSS (Frequency hopping) and redundancy protocols are deployed to ensure the wireless links are extremely resistant to interference from other devices operating in the band.

(8) It was also noted that an increase in the noise floor may impact on the ability of sensors to transmit data over planned distances and the specific example was provided of where the use of an iPad, as a generic piece of electrical equipment, impacted on the sensitivity of the sensors. This could have an impact and require an increase in the number of sensors and central points which could influence the viability of any solutions which are cost sensitive (e.g. telecare).

(9) The following provides a brief overview of the different categories of applications that were identified against a number of criteria.

Table 1: Overview of applications

Application	Technology	Susceptibility (Note 1)	Projected Volume (Note 2)
Consumer applications and devices (domestic / personal use) e.g. wireless cameras, model aircraft control, wireless keyboards, mice, wireless toys and game controllers.	Bluetooth, ZigBee, analogue FM (CCTV)	Low for model aircraft controls as many use frequency hopping and likely to be sufficient distance from potential interferers to minimise risk.	Low (high end product and alternative bands available)
		Medium – high for analogue video cameras as have limited interference protection.	Low to medium
		Low for wireless keyboards, mice as physical separation is usually very small.	High
		Low – possibly medium for wireless toys and game controllers. PS3 uses Bluetooth so large number of channels and frequency hopping. Xbox 360 controller uses MS	High

Application	Technology	Susceptibility (Note 1)	Projected Volume (Note 2)
		proprietary technology and no specific information re interference resilience.	
Control / Automation (domestic e.g. smart lighting)	Bluetooth, ZigBee, IP based 802.15.4	Low. Used within the home and both technologies have a number of channels available in the band. Some devices have in-built time diversity so can re-send in instances of interference.	High
Control / Automation (industrial)	Bluetooth	Low. Large number of channels, frequency hopping and use in closed / controlled environment should limit susceptibility. Can design overall automated system to take account of potential interference from other deployed 2.4 GHz devices	Unknown Our expectations are that could be deployed in high volumes in new industrial plants or on new production lines in preference to wired alternatives. Bluetooth will be used for low data rates and where need robust and / or ad-hoc connections.
	ZigBee	Low. 16 channels available and can deploy mesh networks. Will generally be deployed in closed / controlled environment but might be an issue if used outdoors such as for monitoring pipelines.	Unknown
	802.11 based devices	Low - Medium. Limited number of channels but	Unknown

Application	Technology	Susceptibility (Note 1)	Projected Volume (Note 2)
		deployed in closed / controlled environment.	
Hearing aids (wireless accessories)	Bluetooth based.	Low – Medium. When used within the home the environment can be controlled to minimise potential for interference but outside the home increased risk of interference. Number of channels available and uses frequency hopping.	Medium - High
Medical applications (patient monitoring in hospitals)	WiFi	Low - Medium. The hospital and ambulance is generally a controlled environment. Potential to store and re-send data.	Low - Medium
Medical applications (disposable sensors / permanently installed pressure transmitters)	Proprietary FHSS + redundancy protocol	Low. Cannot accept data loss but specifically designed to operate within 2.4 GHz band.	Medium
Medical applications (in home telecare / telehealth)	Bluetooth, ZigBee	Low – Medium. Both technologies have a number of channels available. Data can be stored and re-sent and generally only requires transmission of small amounts of data (a few hundred bytes).	High
Street lighting	ZigBee	Low – Medium. Uncontrolled outside environment. Use	High

Application	Technology	Susceptibility (Note 1)	Projected Volume (Note 2)
		mesh network that will allow failure of 2 – 3 lamp post nodes without impacting on overall network	
Transport (traffic lights)	ZigBee	Low – Medium. Uncontrolled outside environment. Receivers mounted on poles.	Unknown
Transport (real time tracking)	RFID + WiFi	Low – Medium. Uncontrolled outside environment.	Unknown. Possibly low as more suitable bands exist for RFID (868 MHz)

Note 1: The measure of susceptibility to interference is based on number of available channels and also the environment in which they are likely to be deployed.

Note 2: The projected volume is based on the potential number of devices in operation in approximately 5 years in the UK. Low is 0 – 999, Medium is 1,000 – 10,000 and High is >10,000. It should be noted that these figures are very approximate and are based on the information provided in Section3 or best estimates by the Study team.

Contents

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1 INTRODUCTION

1.1 Background

(10) The reason for the Study was to obtain information on the use of the ISM band to inform how the anticipated future release by the MOD of the adjacent 2.3 GHz band might affect existing users.

1.2 Scope

(11) The scope of this short Study was to identify those applications currently deployed, or planned to be deployed, in the 2.4 GHz licence exempt band (2400 – 2483.5 MHz) in the UK excluding those applications that are currently well known. The following were specifically excluded:

- Residential and enterprise WiFi
- Bluetooth
- London Underground
- Smart metering

(12) A sub-set of the applications identified was then further investigated to understand the technologies used to avoid the potential for interference, measures adopted to overcome any instances of lost data and the implications of such occurrences, and the current and potential market size for such devices.

1.3 Approach

(13) The information obtained is based on secondary research (articles in magazines, reports and web-searching) and in the case of the sub-set of the applications through direct contact with organisations offering the identified wireless products and applications in the 2.4 GHz band. We would like to express our thanks to all those companies that responded to our requests for information.

1.4 Report Structure

(14) This report is structured as follows:

- **Section 2** provides a brief overview of the ISM band and the different technologies that may be deployed. It includes, for completeness, some information from an earlier Logica report that addressed the different users of the band;
- **Section 3** provides information on the findings of this Study; overview of the market and the specific applications that were further investigated;
- **Section 4** details the conclusions from this Study.

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2 OVERVIEW OF THE ISM BAND

2.1 ISM Band Use / Users

(15) The ISM (Industrial Scientific and Medical) band is generally used by licence-exempt communications devices, although there is a limited amount of registered licensed usage for Programme Making and Special Events (PMSE) to provide analogue and digital video links.

(16) In the licence-exempt sector there are many device categories, which are generally devices that communicate over a few tens of metres and these cover every conceivable application. In many cases applications that use the 2.4GHz band may also operate in other frequency bands (e.g. Wi-Fi can operate in the 5GHz band). The main uses of the band are for:

- Scientific, medical and industrial: Users of the band include many hospitals, which use the frequency for medical diathermy machines, industrial heating devices, and microwave ovens, which should be screened but will have low levels of radiation outside of the enclosure.
- WiFi or WLAN: Used in homes and offices to provide WLAN routers and in addition to this indoor use there are WiFi hotspots that offer both indoor and outdoor coverage in major cities. There is also the potential for use for rural community broadband schemes.
- Bluetooth: Used to provide wireless ad-hoc personal networks.
- ZigBee: Specifically designed for low-cost, low-power wireless sensor and control networks and a technology candidate for smart metering communications.
- Short Range Devices: There are already many short range devices operating in the 2.4GHz band and these are covered by Ofcom Interface Requirement 2030. These could be railway devices[1], Radio Frequency Identification Devices (RFID), intruder detection, short range video links, radio determination, industrial / commercial telemetry and telecommand, etc. and must comply with EN300 328 or EN 300 440, Directive 1999/5/EC or the RTTE Regulations. There is also a good ecosystem of radio data modems using the 2.4 GHz ISM band, using spread spectrum or OFDM, either proprietary or IEEE 802.11g compliant.
- Medical Body Area Networks: Users wear medical sensors which transmit the data to a central point.

2.2 Technologies

(17) Whilst the study is not intended to consider the different technologies it is important to understand the potential susceptibility to interference so a short overview of the standards that have been used and general application information is provided here.

[1] For example on the London Underground Automatic Vehicle Identification (AVI) can be used to locate trains.

2.3 Bluetooth

(18) Bluetooth (IEEE 802.15[2] for Wireless Personal Networks (WPAN)) uses Frequency Hopping Spread Spectrum (FHSS), which has proven to provide good interference immunity, by splitting the 2.4 GHz ISM band into 79 x 1MHz channels. Bluetooth devices hop among these 79 channels typically 1600 times per second in a pseudo-random pattern (each channel is used for 625 microseconds). The system avoids interference by never staying on the same channel – if a channel is "bad" the system might not be able to use it and has to wait for the next "good" channel. At any one time only 1 MHz is occupied although it uses the full frequency band (2.402 – 2.483 GHz). It is recommended that a minimum of 15 MHz interference free (quiet) spectrum is required anywhere within the band at any point in time.

(19) Adaptive Frequency Hopping (AFH) was introduced in 2003 to enable co-existence with WLAN (in particular 802.11b) and it is expected it is now used in the majority of Bluetooth devices. AFH allows the frequency hopping to be limited to those channels which are not being used by other devices / protocols in the band and so only spread the frequency hops across the interference free channels.

(20) Bluetooth was developed to provide voice and data connections between small personal networks of battery powered devices. It is provided in many existing products and generally is used for ad hoc interoperability between cell phones, headsets, and PDAs – short range applications of between 0 and 10 metres. Bluetooth is ideally suited to applications that require relatively low power and moderate data bandwidth but devices do require regular recharging which may limit the applications.

(21) According to the Bluetooth Special Interest Group (SIG) there are Bluetooth products designed for a wide range of current applications / uses:

Figure 1: Bluetooth product types and number of supported devices [Source: Bluetooth SIG]

Product type	Number of supported devices
Audio and visual	1589
Automotive	1015
Gaming	84
Handheld (e.g. dongles, hands-free devices)	327
Headset	650
Home Environment (e.g. remote controls)	297

[2] IEEE 802.15.1 specifies the layers and 802.15.2 focuses on co-existence and proposes adaptive frequency hopping (used since version 1.2).

Product type	Number of supported devices
Input devices (e.g. Bluetooth mice, keyboards, etc.)	360
Medical	77
Phone	1153
Mobile phone accessory	598
Office equipment	72
Personal computer	518
Miscellaneous (e.g. hearing aids, remote controls)	585

(50) Whilst Bluetooth was excluded from the original scope of this Study it is important to understand how it co-exists with the other technologies using the same band. Also the use in hearing aids and medical applications was further investigated as described in Section 3.

2.4 WiFi

(51) WiFi is the "name" used for devices that are compliant to IEEE 802.11 standards and can be deployed in a Wireless Local Area Network (WLAN). Devices that meet the requirements of 802.11 b/g/n[3] operate in the 2.4 GHz band which is divided into 13 channels spaced 5 MHz apart. There is a difference between the standards:

- 802.11b is based on DSSS (Direct Sequence Spread Spectrum) with a total channel width of 22 MHz. To avoid overlapping channels such WiFi devices will typically operate on channels 1, 6 and 11 to provide 3 x 22 MHz wide non-overlapping channels. The maximum data rate is typically 11 Mbps and ranges are between 35 m (indoors) and 140 m (outdoors).
- 802.11g is based on OFDM (orthogonal frequency-division multiplex) but is also backward compatible with DSSS.The channel bandwidth is 20 MHz and there is scope to support four non-overlapping channels (1, 5, 9 and 13). The maximum data rate is 54 Mbps although typical average throughput speeds are more likely to be 22 Mbps and ranges are between 35 m (indoors) and 140 m (outdoors).
- 802.11n is newer and introduces MIMO techniques and has a channel bandwidth of 20 or 40 MHz and can support higher data rates (maximum of 72 or 150 Mbps),

(52) Wi-Fi uses a collision-avoidance protocol which allows multiple devices to use a single access point and networks using the same or over-lapping channels to co-exist although their capacity (throughput) may be reduced. A device will listen for a quiet channel before

[3] Also applicable to the 5 GHz band.

transmitting and if the channel is noisy it does a random back off in time before listening to the channel again. This process is repeated until a channel becomes available. In some circumstances a device may search for another access point if no channels become available.

(53) There is a need for at least one 22 MHz interference free channel and interference can be an issue due to the large bandwidth utilisation of WiFi and the impact of interference from other devices and technologies operating in the band.

2.5 ZigBee

(54) ZigBee defines a set of higher level protocols built on top of the IEEE 802.15.4 network standard. This operates on 16 channels across the 2.4 GHz band, each of 5 MHz bandwidth with the lowest centred at 2405 MHz and the highest at 2580 MHz.

(55) The ZigBee protocol features include:

- Support for multiple network technologies (point to point, point to multipoint and mesh)
- Low duty cycle (= long battery life)
- Low latency
- Direct Sequence Spread Spectrum (DSSS)
- Up to 65,000 nodes per network
- 128-bit AES encryption for secure data communications
- Collision avoidance, retries and acknowledgements.

(56) Mesh networks are less susceptible to interference as the topology allows the nodes to reconfigure the routing paths and this provides greater stability in changing environments or failure at single nodes.

(57) The ZigBee standard includes a channel selection protocol, whereby the band is scanned to identify the quietest channel during the setup phase.

(58) Applications include industrial process monitoring, home and building automation and control, consumer electronics, medical monitoring and similar areas. In an article “Creating value with ZigBee Networks”[4] there is specific mention of practical ZigBee applications – specifically:

(59) “Using the battery-powered capabilities of ZigBee networks can simplify dealing with explosive environments, such as the production of ethanol or other fuels. With a wireless connection between the sensor and its control logic, expensive and difficult-to-install explosive connectors, housing and bulkheads are eliminated”, and

[4] See http://industrial-embedded.com/pdfs/SoftwareTechGroup.Oct05.pdf

(60) "The ad-hoc capability of ZigBee can be used for cost-effective monitoring of a fleet of commercial vehicles. By supporting ZigBee devices integrated with a vehicle's on board diagnostic or sensing capabilities a plethora of information can be collected when a vehicle returns to a maintenance or rental facility".

(61) There have also been proposals to use ZigBee in gas sensors used for coal mining[5] rather than using the current fixed sensors. Whilst there is unlikely to be the potential for interference underground this demonstrates the wide scope of applications that are being proposed.

2.6 WirelessHART

(62) WirelessHART is an open wireless communication standard specifically designed for process measurement and control applications which is targeted at applications that have stricter timing requirements and higher security concerns than can be met by ZigBee or Bluetooth. It is a secure TDMA based wireless mesh networking technology (protocol uses a time synchronised, self-organising and self-healing mesh architecture) which operates in the 2.4 GHz band using IEEE 802.15.4 standard radios.

[5] See http://www.academypublisher.com/proc/iscsct10/papers/iscsct10p77.pdf

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3 FINDINGS

3.1 Summary of overall market

(63) A number of applications have been identified as part of this Study, including:

- Consumer applications and devices;
- Control and Automation;
- Medical;
- Public Safety;
- Street lighting;
- Transport.

(64) These of course will rely on the technologies mentioned in Section 2.2 and relate to a number of the uses / users in Section 2.1. Each of these categories is described briefly below. Examples of equipment manufacturers or vendors are also mentioned.

(65) In addition it was found that there were vendors providing devices (sensors and central control nodes / routers) that are suitable for a wide range of different applications depending on which sensors are deployed. One such company, Libelium, has developed a sensor (Waspmote) that works with protocols such as ZigBee and Bluetooth and also a router (Meshlium) that contains different wireless interfaces including ZigBee, Bluetooth and WiFi. They have reported that they have over 2,000 developers that have joined their sensor platform and use Libelium's Waspmote product to which they have added applications and new business models. The sensors can "interact with real objects and collect data everywhere from our environment, infrastructures, businesses and this huge amount of information is generating a new ecosystem of business opportunities around its storage, analysis and accessibility".

(66) Applications listed include smart cities, smart environment, smart water, smart metering, security and emergencies, retail, control, logistics, industrial, agriculture, smart animal farming, home automation and eHealth.

3.1.1 Consumer applications and devices

(67) Consumer applications include relatively mainstream devices like wireless keyboards, mice and CCTV cameras. More specialised applications include model control, where some suppliers are promoting 2.4 GHz as a higher performance alternative to traditional HF and VHF frequencies. A mix of technologies is deployed, including Bluetooth, ZigBee, analogue FM (in the case of CCTV) and in some cases proprietary technologies.

3.1.2 Control and Automation

(68) A wide range of control and automation applications are supported in the 2.4 GHz band for domestic and industrial applications. Domestic applications include lighting controls (dimming and switching on or off), heating controls and remote monitoring of homes for security (detection of windows and doors opening and the presence of intruders) or detection of water leakage.

(69) The use of Wireless LAN (802.11 and 802.15.4) and Bluetooth technology are reported, in a recent article[6], as being the dominant technologies for industrial applications. The main advantages quoted for using wireless include; increased mobility, replacement of expensive flexible wired options, fast and efficient implementation, increase personnel safety (e.g. can control devices from further away than with wired solutions) and can provide flexible Human Interface Devices (HID).

3.1.3 Hearing Aids

(70) One vendor, Resound, was identified that uses the 2.4 GHz band to wirelessly connect hearing aids to audio devices in the TV, computer, stereo and other devices without the need for the person to wear anything extra. Another accessory can provide wireless connection between a Bluetooth-enabled phone and the hearing aid making phone conversations reliable and clear.

3.1.4 Medical Applications

(71) There appears to be growing interest in the use of 2.4 GHz band for medical telemetry applications, in part reflecting the absence of a dedicated European band for such use. The emerging IEEE standard for Wireless Body Area Networks (802.15.6) includes specific provision for the 2.4 GHz band and this is considered to be the most mature band for such applications currently. The standard covers “short range, wireless communication in the vicinity of, or inside, a human body”. One of the key considerations is to minimise power consumption, with a target of 1 – 5 mW compared to 10 – 50 mW for ZigBee / Bluetooth and 100 mW – 1W for WiFi. Hence communication is typically very short range (up to 3 m) and transmission power very low (typically 1 mW). It should be noted that other bands are also covered by the standard, including 2360 – 2400 MHz which has recently been allocated to medical telemetry in the USA.

(72) The 802.15.6 standard is still in draft form but a number of other technologies are already being deployed in the 2.4 GHz band for medical applications. These include Philips’ proprietary Intellivue telemetry system, which uses “smart hopping” technology to dynamically avoid interference in the band, and Draeger Medical System’s Infinity Care that "provides a fully networked solution that allows a single monitor to follow the patient during

[6] See “Wireless Technologies for Industrial Applications”, by Mats Andersson of connectBlue, March 2012.

the entire care pathway to minimise undetected events and provides patient information accessible throughout the hospital". Sensors are fitted to the patient and these are connected to the bedside or patient worn device and the data can be sent to a central location using, for example, the hospital's WiFi network.

(73) St Jude Medical offers two main products that use radio technology in the 2.4 GHz band to provide information on pressure / temperature inside the small arteries of a patient's heart and can be used in surgery. Whilst such devices are typically used in the controlled environment of a catheterisation laboratory, the wireless technology has also been specifically developed to ensure that it is highly resistant to disturbances from other devices operating in the band as it cannot accept data loss.

(74) Other applications apply to the telehealth / telecare applications where data from sensors can be provided wirelessly to a central node and then sent to the doctor or care service, for example, depending on the precise requirements. Personal sensors could be used to measure blood glucose or blood pressure and allow a more detailed record of the patents status to be obtained and analysed remotely. Other uses can be monitoring movement through sensors – for example bed and chair sensors, pressure mats or door contact sensors.

3.1.5 Public Safety

(75) Public safety use of 2.4 GHz is mainly limited to mainstream WiFi and Bluetooth applications, however Proxim's Orinoco mesh technology is targeted at public safety users who wish to set up ad-hoc wide area WiFi networks[7] to deal with major incidents or for use in conjunction with, for example, video cameras to monitor key locations in a town.

3.1.6 Street Lighting

(76) The increasing pressure on councils / local authorities to reduce costs and carbon footprint makes remote controlled lighting an attractive proposition. This provides the potential to dim or switch off lights in different areas depending on the time of the night and any specific circumstances. For example during an emergency it may be necessary to increase the illumination or switch the lights on again in a restricted geographic area. Also events, such as road works, may require illumination whereas normal practice might be to switch off or dim the lights between certain hours.

3.1.7 Transport

(77) Transport use of the band relates to established applications like railway AVI and in-car Bluetooth connections. Applications such as intelligent transport systems (ITS) and road traffic telemetry and telematics (RTTT) have specific allocations around 5.9 GHz but there

[7] Also available in the 4.9 GHz and 5 GHz bands

are some similar applications that currently do use 2.4 GHz. For example, the Italian company Reicom markets a range of wireless Ethernet bridges aimed at the transport sector (both private and public). These are based on the emerging 802.11p standard for wireless access in a vehicular environment which is primarily intended to operate in the 5.9 GHz ITS band, but Reicom's current products appear to operate in the 2.4 GHz band.

(78) Another transport application in the band is real time tracking, an example being Zebra Technology's WhereNet system, which combines 2.4 GHz RFID technology with WiFi backhaul in the same frequency band. Other potential transport related applications are likely to include distribution of departure information to bus stops and wireless feeds to mobile billboards or other advertising media. In practice, however, it is more likely that a wide area mobile network (either public or private) would be more appropriate for such use, except for the use of in-store displays which could be connected to existing WiFi networks.

(79) Siemens offer traffic management systems based on small battery operated sensors that can be installed in the road or pavement and connect, using ZigBee technology with pole mounted access points. One application is control of traffic lights based on the actual traffic movement and changing to red based on natural gaps in the traffic. Libelium has a product that can measure any Smartphone in an area by measuring WiFi and Bluetooth activity which allows pedestrian and traffic congestion to be determined in real time. Other applications use sensors that can be buried in parking spaces, and can be used to detect the arrival and departure of vehicles and so update the status of car parking in a town or city.

3.1.8 Summary

(80) The following provides a brief overview of the different categories of applications that were identified against a number of criteria.

Table 2: Overview of applications

Application	Technology	Susceptibility (Note 1)	Projected Volume (Note 2)
Consumer applications and devices (domestic / personal use) e.g. wireless cameras, model aircraft control, wireless keyboards, mice, wireless toys and game controllers.	Bluetooth, ZigBee, analogue FM (CCTV)	Low for model aircraft controls as many use frequency hopping and likely to be sufficient distance from potential interferers to minimise risk.	Low (high end product and alternative bands available)
		Medium – high for analogue video cameras as have limited interference protection.	Low to medium

Application	Technology	Susceptibility (Note 1)	Projected Volume (Note 2)
		Low for wireless keyboards, mice as physical separation is usually very small.	High
		Low – possibly medium for wireless toys and game controllers. PS3 uses Bluetooth so large number of channels and frequency hopping. Xbox 360 controller uses MS proprietary technology and no specific information re interference resilience.	High
Control / Automation (domestic e.g. smart lighting)	Bluetooth, ZigBee, IP based 802.15.4	Low. Used within the home and both technologies have a number of channels available in the band. Some devices have in-built time diversity so can re-send in instances of interference.	High
Control / Automation (industrial)	Bluetooth	Low. Large number of channels, frequency hopping and use in closed / controlled environment should limit susceptibility. Can design overall automated system to take account of potential interference from other deployed 2.4 GHz devices	Unknown Our expectations are that could be deployed in high volumes in new industrial plants or on new production lines in preference to wired alternatives. Bluetooth will be used for low data rates and where need robust and / or ad-hoc connections.

Application	Technology	Susceptibility (Note 1)	Projected Volume (Note 2)
	ZigBee	Low. 16 channels available and can deploy mesh networks. Will generally be deployed in closed / controlled environment but might be an issue if used outdoors such as for monitoring pipelines.	Unknown
	802.11 based devices	Low - Medium. Limited number of channels but deployed in closed / controlled environment.	Unknown
Hearing aids (wireless accessories)	Bluetooth based.	Low – Medium. When used within the home the environment can be controlled to minimise potential for interference but outside the home increased risk of interference. Number of channels available and uses frequency hopping.	Medium - High
Medical applications (patient monitoring in hospitals)	WiFi	Low - Medium. The hospital and ambulance is generally a controlled environment. Potential to store and re-send data.	Low - Medium
Medical applications (disposable sensors / permanently installed pressure transmitters)	Proprietary FHSS + redundancy protocol	Low. Cannot accept data loss but specifically designed to operate within 2.4 GHz band.	Medium

Application	Technology	Susceptibility (Note 1)	Projected Volume (Note 2)
Medical applications (in home telecare / telehealth)	Bluetooth, ZigBee	Low – Medium. Both technologies have a number of channels available. Data can be stored and re-sent and generally only requires transmission of small amounts of data (a few hundred bytes).	High
Street lighting	ZigBee	Low – Medium. Uncontrolled outside environment. Use mesh network that will allow failure of 2 – 3 lamp post nodes without impacting on overall network	High
Transport (traffic lights)	ZigBee	Low – Medium. Uncontrolled outside environment. Receivers mounted on poles.	Unknown
Transport (real time tracking)	RFID + WiFi	Low – Medium. Uncontrolled outside environment.	Unknown. Possibly low as more suitable bands exist for RFID (868 MHz)

Note 1: The measure of susceptibility to interference is based on number of available channels and also the environment in which they are likely to be deployed.

Note 2: The projected volume is based on the potential number of devices in operation in approximately 5 years in the UK. Low is 0 – 999, Medium is 1,000 – 10,000 and High is >10,000. It should be noted that these figures are very approximate and are based on the information provided in Section3 or best estimates by the Study team.

3.2 Grouping and prioritisation of applications

(81) A number of the applications were investigated in more detail as follows:

- Hearing aids

- Medical applications in hospitals and telehealth / telecare in the home
- Street lighting
- Industrial automation.

(82) These specific applications were chosen on the basis of:

- The possible large volume of devices
- The potential need to avoid interruptions in transmission
- The likelihood the devices use solutions to avoid the potential for interference
- Potential use of the complete ISM band.

(83) In addition the study team was asked to investigate an example vendor that was providing modules that could be deployed for a wide range of different applications and further information is provided on the products from Libelium.

(84) The following sections provide further information on the applications identified above.

3.2.1 Hearing Aids

3.2.1.1 Overview

(85) There is at least one vendor[8] that has developed wireless accessories that work with specific hearing aids and allow the user to hear things outside the range of their hearing aid. They provide, for example, clear stereo sound from TVs, computers and other sources directly to the hearing aid from up to 7 metres away whilst still allowing the user to hear other sounds around them. The advantage of this solution, unlike others, is there is no requirement to wear extra devices around the neck or for any cables or wires making the solution discrete and allowing the user non-restricted mobility thereby increasing user satisfaction.

(86) In a paper[9] from Resound it discusses the user requirements, determined from market research of both fitters and users, and how these determined the choice of wireless technology. The table below provides a brief overview of the limitations of some possible solutions:

Table 3: Overview of options for Hearing Aids and its limitations Source: ReSound

Option	Limitations
Near Field Magnetic Induction (NFMI) based	Limited range (few feet)

[8] See http://www.gnresound.co.uk/.

[9] "How user requirements affect technology choice for wireless hearing instruments", by Jennifer Groth and Brian Dam Pederson at http://www.google.co.uk/#hl=en&tbo=d&output=search&sclient=psy-ab&q=how+user+requirements+affect+technology+choice+for+wireless+hearing+instruments&oq=how+user+requirements+affect+technology+choice+for+wireless+hearing+instruments&gs_l=hp.3...4312.27828.1.28828.79.76.0.0.0.2.1109.28277.0j20j14j18j7j9j7j1.76.0.les%3B..0.0...1c.1.Ht_Xi-jhqTE&psj=1&bav=on.2,or.r_gc.r_pw.r_qf.&bvm=bv.41248874,d.d2k&fp=287e96e52b4ce49e&biw=1280&bih=571

Option	Limitations
technology	Device must be worn on the body
Bluetooth (to stream audio to body worn streamers of NFMI based wireless hearing instruments)	Power consumption high for hearing instruments (Bluetooth designed to support a wide range of products and so communications protocols have to be broad and flexible and require more power) Audio streaming introduces a delay that might be unacceptable for TV viewing (lip synch issues)

(87) As well as Resound there are other hearing aid manufacturers that offer similar wireless accessories: one company – Starkey Corporate in the US – has products Surflink Media and Surflink Mobile that can be used with specific versions of their hearing aids[10]. Information on the web-site of a supplier of hearing aids in the UK, Crystal Hearing[11], also indicates that there are a number of hearing aid manufacturers (e.g. Phonak) that also offer wireless accessories. It appears that the wireless accessory that is required varies by manufacturer / hearing aid.

(88) Whilst it appears that the main use is within the home to watch TV or listen to music it is also possible to use such accessories to provide the following connections wirelessly:

- Person to person (Remote microphone to hearing instrument)
- Teacher to student (Remote microphone to hearing instrument)
- Person to mobile phone bridge (Hearing impaired using a mobile phone)
- Remote control to hearing instrument (when used by person)
- PC / clinical fitting to hearing instrument (at person's ears)

(89) It is also envisioned that such devices could be used for meetings, lectures, banks and cinemas so is not restricted to use just in the home environment.

3.2.1.2 Technology

(90) ReSound has developed a solution, shown below, where the hearing instruments control the connections.

[10] See http://www.starkey.com/starkey-products/product-overview/browse-by-technology/wireless-hearing-aids for their brochures

[11] See http://www.crystalhearinguk.co.uk/

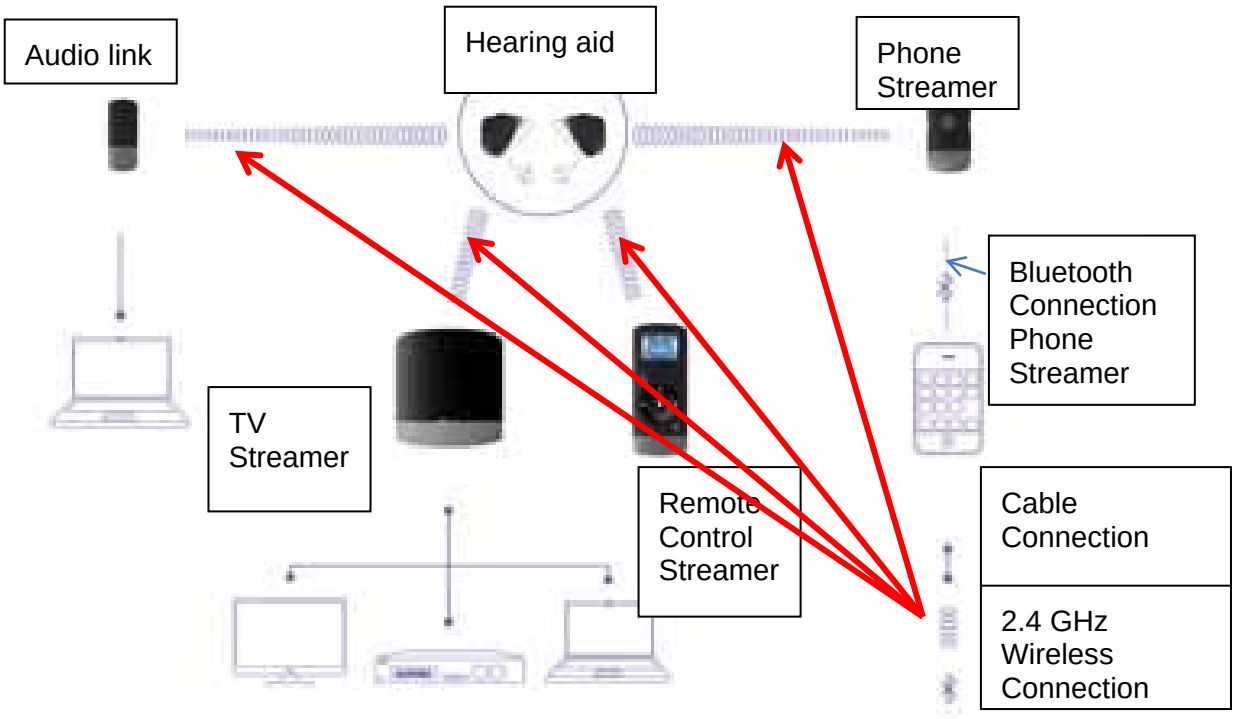

Figure 2: ReSound Wireless System Source: ReSound

(91) To ensure a stable wireless connection of up to 7m and avoid interference from other devices operating in the 2.4 GHz band the system divides the available spectrum into 35 channels and uses both time division and frequency hopping. No device will transmit on a channel for more than 0.4 seconds and there is a choice of 35 channels for the transmission (it is assumed this means each channel has a bandwidth of approximately 2.39 MHz). This means that each time a new piece of data is to be sent a new channel out of the 35 possible channels is picked for the transmission. "The hearing instrument mutually agrees with the wireless accessory on which channel to send the next data packet. As all the different devices (e.g. wireless mouse, wireless network, headsets) in the band use a different selection strategy they virtually always steer clear of each other". Also to ensure audio quality and avoid lip synch issues a protocol has been developed that minimises latency.

(92) It is essential that such systems are robust to ensure the best audio quality and also to avoid the loss of data (communication). It is understood, from the vendor, that such systems fall under the medical device category as they are considered vital for disabled / hearing impaired people.

(93) Information from other vendors indicate the use of Bluetooth for the wireless accessories but it is understood that this may be a proprietary standard based on Bluetooth to achieve the required distances.

3.2.1.3 Potential market

(94) ReSound indicated that deployment of such wireless accessories in the US is now substantial and of course US citizens will travel to Europe and want to continue to use their devices in Europe. The market is fast growing due to advantages of hands free calls and improved speech understanding and it is expected that more manufacturers and types of connectivity will be developed. We understand that two new wireless accessory products are due to be released in the UK market shortly in addition to those already available.

(95) In terms of the prospective market we have estimated the market size in the UK based on those hearing impaired that intend to replace or purchase their first hearing aids. According to the Euro Trak UK 2010[12] study undertaken by Anovum on behalf of BHAMA[13] and the European Hearing Instrument Manufacturers Association (EHIMA) in a sample size of 214,980 people:

- 1,335 were hearing impaired
- 822 with hearing loss did not own hearing aids
- 512 were hearing aid owners of which 74% received NHS hearing devices
- The average age of currently owned hearing aids was 2.6 years
- 9% of non-owners intended to buy a hearing aid within the next year and 13% of owners intended to re-buy.

(96) This, when considering the total population of 63 million[14] in the UK, equates to a total of 150,042 hearing aid owners and 240,888 hearing impaired that do not have hearing aids. The annual market, based on 9% of non-owners and 13% of owners, is around 41,180 hearing aids. A number of these may decide to purchase those hearing aids that can be used with associated wireless devices to connect to wireless phones, TVs etc. using the 2.4 GHz band. Even a 5% market share for such hearing systems means there is the potential for over 2,000 to be purchased each year. Over time, if the solution meets the identified market requirements for both users and fitters, the market penetration will increase with a total market potential of around 400,000 hearing impaired people in the UK. However it is anticipated that over the next 5 years around 15,000 (assumes already 5,000 in use now and 2,000 purchased each year) may be in use and this is mainly restricted to use within the home. However this might be pessimistic as it is expected that once these wireless accessories demonstrate their advantages over current solutions the market could grow very quickly.

[12] See http://www.bhama.org.uk/cgi-bin/download.cgi for a link to the report.

[13] The British Hearing Aid Manufacturers Association (BHAMA) is a forum for manufacturers in the UK and to qualify as a member of BHAMA, each manufacturing company must supply more than 1,000 hearing aids per annum within the U.K. market. BHAMA's members account for over 97% of the hearing aids professionally fitted by hearing aid audiologists in the UK. They include all the leading hearing aid manufacturing and distributor companies that supply both the NHS and independent sector Hearing Aid Dispensers (Hearing Aid Audiologists). ReSound is a member of BHAMA.

[14] Source: index mundi estimate of 63,047,162 in July 2011.

3.2.2 Street Lighting

3.2.2.1 Overview

(97) The major market for street lighting solutions is the local authorities / councils. The main reasons for investing in lighting solutions that include Central Management Systems, which can control the switching on and off and dimming of lights, are to:

- reduce energy consumption,
- reduce billing costs, and
- reduce CO_2 emissions

(98) Whilst at the same time ensuring safer streets and reduced crime. Private sector funding and management of lighting systems became possible under the Private Finance Initiative (PFI) which was introduced in the mid-1990s. Contracts are let that not only include the replacement/ upgrading of street lamps but also the management systems and the ongoing maintenance.

(99) There are a number of different solutions / technologies that can be deployed – at least one that uses the 2.4 GHz band and others that use the 868 MHz band and others that use powerline or cellular networks.

3.2.2.2 Technology

(100) Mayflower, part of SSE, provides a solution that operates in the 2.4 GHz band. On each lantern (street lamp) an external or internal node can be installed to control the on/off function and the light level of the lamp. The internal nodes are generally used for practical and aesthetic reasons where it is not possible to use an external node. The nodes can monitor and record data and can send alerts re potential faults (e.g. change in lamp status including failure).

(101) The nodes are deployed in a mesh network that can be dynamically configured and is self-healing in the event of failure. The nodes can be spaced up to 200 metres apart, but typically aim for 120 metres, and the system uses the ZigBee 802.15.4 standard. It is possible for 2 or 3 adjacent street lamp nodes to fail, assuming a spacing between lamp posts of 40 metres, without impacting on the overall operation of the system. Up to 500 nodes can be connected to a sub-master which is then connected to the client central server. The Mayflower solution enables the remote management of the entire lighting system, both in real-time and to pre-set conditions and the central server can report on energy usage, failed units, and can control the light level element (brightening/dimming) of light clusters in defined areas. For example in the case of an emergency it is possible to increase the illumination or switch on the lights in the specific geographic area.

3.2.2.3 Potential market

(102) As noted above the major market is the local authorities / councils who are under pressure to reduce costs and emissions. According to information on the SSE / Mayflower web-site the first trials that they undertook of remote monitoring of public lighting installations was in 2003 in Plymouth, followed by Wales. By the end of 2005 15,000 nodes had been installed across the UK. However this volume is small compared with recent contracts that have been awarded.

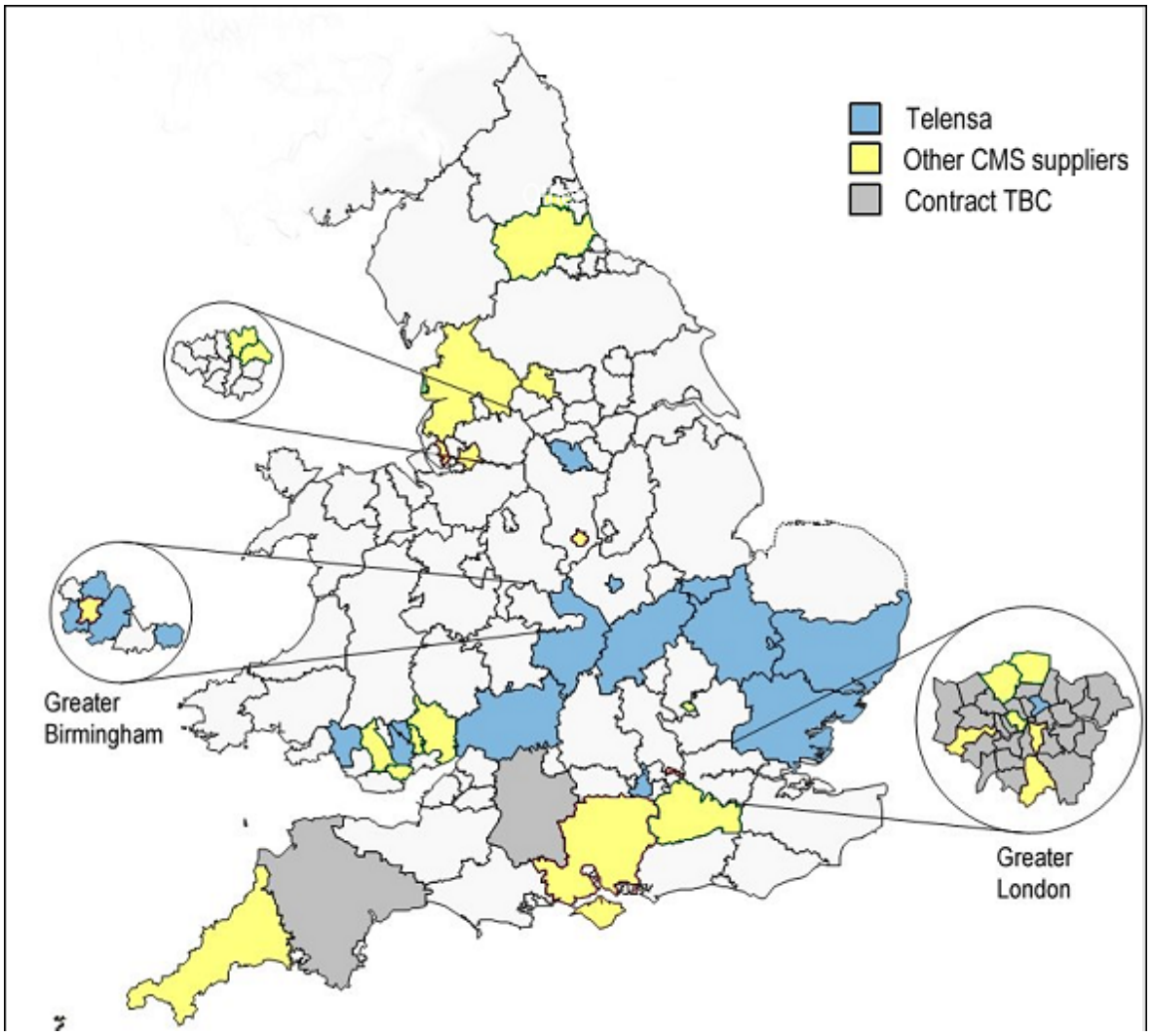

Figure 3: CMS Lighting Contracts with Local Government in the UK (England and Wales). Source: Telensa

(103) The map above provides information on contracts that have been awarded and those geographic areas where contracts are to be confirmed.

(104) For example in Hampshire the street lighting replacement and upgrading is taking place in the first five years between 2010 and 2015[15] and around 150,000 street lights and illuminated

[15]See http://www.lightsoninhampshire.co.uk/Public/Default.aspx

signs and bollards will be replaced or upgraded and at the same time a Central management System will be installed – this means around 150,000 nodes operating in the 2.4 GHz band may be installed. See http://www.lightsoninhampshire.co.uk/Public/Default.aspx.

(105) It was reported in August 2011[16] that the Knowsley street lighting contract took the "number of local authorities with which SSE has long-term street lighting replacement and maintenance PFI contracts to 12 and the number of lighting units covered by such contracts to over 600,000". This means there are potentially over 600,000 nodes that will operate in the 2.4 GHz band once these contracts have been implemented. Mayflower comment on their web-site that their "current installation programme is in excess of 250,000 units".

(106) Not all the contracts will use the 2.4 GHz band as there are vendors, such as Telensa, offering solutions in the 868 MHz band (shown in blue on the above map) and SELC[17] using powerline or the GPRS / mobile networks. Of course there may be other vendors offering solutions in the 2.4 GHz band.

(107) According to the Highways Agency[18] there are around 5.6 million street lights in England including motorways. In November 2010 it was reported[19] that up to 75% of councils were "planning to turn off street lamps or dim the lights in an attempt to save money and meet climate change targets". It was noted that many councils have at least 100,000 lights and that "Britain's 7.5 million street lamps cost an estimated £500 million a year to run".

(108) Assuming that there are 8 million street lamps in the UK (assumes a further 0.5 million for Northern Ireland) and three quarters of these will be turned off or dimmed using a centrally managed system and that a third of these centrally managed systems will use the 2.4 GHz band then potentially there could be a total of 2 million 2.4 GHz nodes installed on street lights. The timescales for such deployment is very dependent on the UK economy but based on information from Mayflower there will be at least 250,000 nodes installed within the next 3 years.

3.2.3 Medical Applications

3.2.3.1 Overview

(109) Medical devices can be used in both the hospital and the home. The potential advantages of using wireless technology are provided in the table below:

Table 4: Advantages of wireless solution for Medical Applications. Source: connectBlue

Advantages	Explanation
Improved	Allows patient to move around which can promote faster and

[16] See http://www.lightsoninhampshire.co.uk/Public/Community.aspx - the Knowsley Street Lighting news release.
[17] See http://www.selclighting.com/products-services/central-monitoring-system/
[18] See http://www.kgbanswers.co.uk/how-many-street-lights-are-there-in-england-including-motorways/21214483
[19] See http://www.dailymail.co.uk/news/article-1328243/Up-75-cent-councils-dimming-street-lights-save-money.html

Advantages	Explanation
outcomes	better outcomes from treatment
	Allows patient monitoring while mobile to provide more realistic results and diagnosis and better outcomes
Increased safety	Replaces cables which are safety hazards
	Easier to avoid infections compared with wires and cables
Improved efficiency	Results of patient monitoring can be viewed from central point in hospital, for example by consultants so can avoid, for example, unnecessary ward visits to obtain updates on monitoring
	Remote monitoring supports home care (earlier patient release or less patients required to stay in hospital)
	Allows diagnostic results to be sent by emergency teams to ensure right resources etc. are available on patient arrival
Cost savings	Potentially significant costs savings as maximise use of resources (beds, staff etc.)

(110) The environment in which medical devices have to operate differs between the hospital and the home. In the hospital there maybe local area networks (WiFi) as well as mobile phones used by patients, visitors and staff as well as other devices that emit RF that may be used. In the home as well as local home networks, mobile phones, games consoles, Bluetooth connections there are likely to be other devices such as microwave ovens. This means that any devices must be robust enough to effectively operate in such environments.

3.2.3.2 Technologies

(111) In a paper by connectBlue[20] they compare the different available technologies and this is summarised in the table below:

Table 5: Comparison of technologies used in medical devices

Technology	Advantages	Disadvantages
WiFi (IEEE 802.11 a/b/g/n)	Can allow devices to directly connect into hospital's LAN network where one is available. 2.4 and 5 GHz bands available.	Interference from intentional radiators within the hospital environment can cause interference due to the bandwidth required (uses Direct Sequence Spread Spectrum). Requirements to ensure security to comply with standards required for medical

[20] See "Wireless technologies for medical devices: Choices and Trade –offs"

Technology	Advantages	Disadvantages
		data.
ZigBee (IEEE 802.15.4)	Low power and low cost – ideal for low cost, low data, battery powered medical devices. Standards address security. Ideal for home environment as matches needs for many home devices.	Only available band world-wide is 2.4 GHz. Any need for frequent re-transmission, due to other devices operating in the band, may lead to dramatically degraded battery life and increased data latency and data throughput.
Bluetooth (IEEE 802.15.1)	Large number of channels and FHSS provide higher immunity to interference. Ideal for small battery powered devices[21].	
UWB (ultra-wideband)	Wide range of frequency bands. Higher data rates. Low power.	

(112) WiFi, ZigBee and Bluetooth are all technologies used in the 2.4 GHz band for medical devices. In addition, in the home, sensors may be deployed to monitor the movement of home care patients and the elderly.

(113) In the following sections we provide some information on available devices.

Hospital devices

(114) There are a number of vendors that market devices suitable for use in hospitals. For example the Draeger Medical Systems Infinity Care System "provides a fully networked solution that allows a single monitor to follow the patient during the entire care pathway to minimise undetected events and provides patient information accessible throughout the hospital". Sensors are fitted to the patient and these are connected to the bedside or patient worn device and the latter allows the patient to move around a hospital[22]. Figure 4 below shows an example of the monitors.

[21] It was noted that Bluetooth Core Specification v4.0 (low energy) aimed at fitness and medical devices. Bluetooth low energy is ideal for lower data rates (approx. 100 kbps) and ranges up to 250 ms whereas classic Bluetooth for higher data rates (2 Mbps) and longer ranges (up to 1000m with line of sight).

[22] See for example http://www.draeger.com/AU/en/products/medical_monitoring/patient_worn_monitoring/mon_infinity_m300.jsp

Figure 4: Patient worn monitor. Source: Draeger

(115) **Technology:**All patient monitoring devices can be connected to the Infinity central station monitor via wireless technology (e.g. to the hospital WiFi network). Figure 5 provides an example configuration.

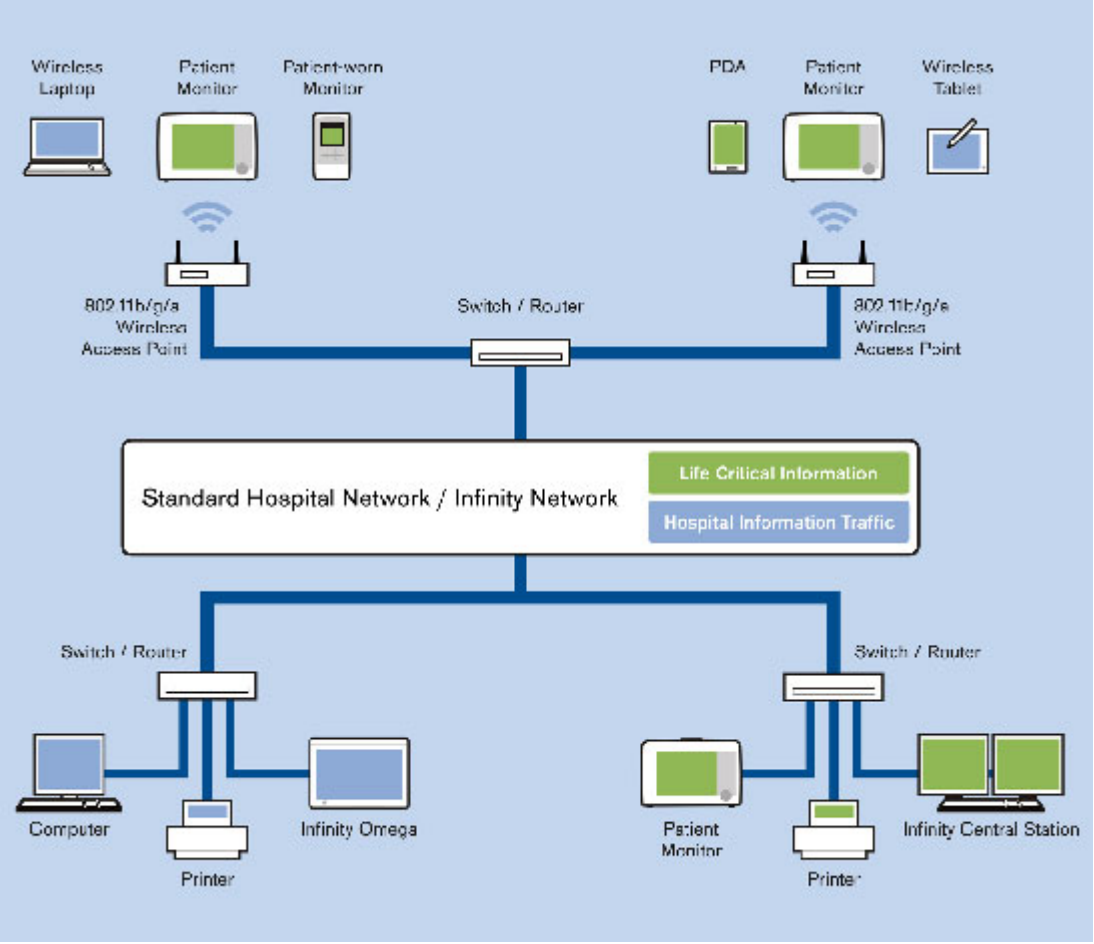

Figure 5: Typical system configuration. Source: Draeger

(116) Infinity OneNet is a network design that supports both wired and wireless real-time patient monitoring on an existing hospital's WiFi network. "It allows the use of 802.11 b/g access points and takes advantage of open industry standards which means that the Draeger access points can be shared between life critical patient monitoring and other hospital applications". If the patient device moves out of the hospital's wireless network coverage area it will provide continuous standalone monitoring.

(117) The system allows clinical staff to overview all bedside devices and patient worn devices centrally, collate alarm and event data and generally keep an eye on patients from that location. Alarms are triggered when measured clinical parameters go outside of a preconfigured limit. If wireless access was unavailable then the local device would still alarm and the alarm event would be stored and re-transmitted when wireless connection was re-established.

(118) St Jude Medical uses radio technology in two main products which are used in the area of coronary intervention[23]. One is a long thin sensor as shown in the figure below:

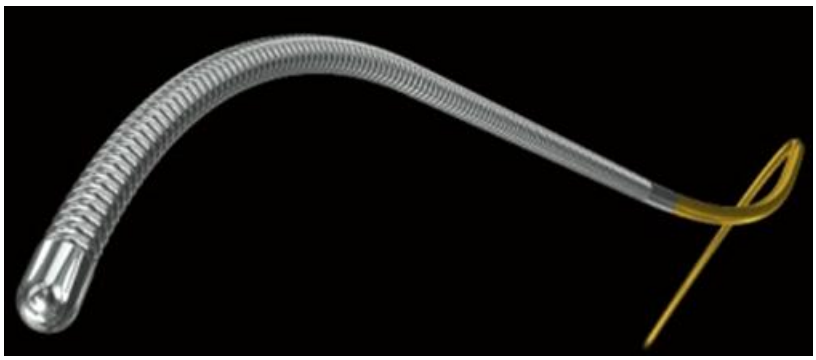

Figure 6: PressureWire Aeris photo. Source: St Jude Medical

(119) The device includes a wireless sensor which is used to measure pressure / temperature etc. inside small arteries in the patient's heart. It is a disposable single use, interventional guide wire with a battery powered transmitter which is used by the interventional cardiologist inside cathlabs to diagnose lesions in clogged arteries. The transmitter sends data to the receiver shown in the middle of the figure below and this can either act as a stand-alone interface to other equipment or to St Jude's own instrumentation.

Figure 7: Wireless System Components for PressureWire Aeris. Source: St Jude Medical

(120) St Jude Medical also markets another product which is a permanently installed pressure transmitter which is connected to 3rd party pressure transducers and broadcasts this signal to instrumentation. As noted earlier the advantage is the system allows a cable free environment, which is also sterile, and gives great flexibility when installing / moving instrumentation. Both may be used in surgical procedures (e.g. fitting of STENTS) and are currently exclusively used in the catheterisation laboratory but in theory they could be used on wards as there is no limit technology-wise.

[23] See http://www.reuters.com/article/2012/12/18/idUS120046+18-Dec-2012+BW20121218 for an article on use of the products in the assessment of the need for coronary intervention.

(121) **Technology:** The products use proprietary FHSS (hopping protocol) and in addition use a redundancy protocol which makes the link extremely resistant to any disturbances (interference). The devices are low power – it is understood the maximum power is 1mW peak and can typically wirelessly connect over a range of 2 m (no line of sight).

Home environment devices

(122) Acute technology market devices for the telecare / telehealth markets and so are used in the home environment. Sensors are body worn to provide data on specific body functions (blood pressure, glucose levels etc.) and the data is sent, ideally, to a single data collection point (central home hub) that connects the devices to the Internet. The monitoring data can then be assessed remotely by clinical experts who can assess the patient's conditions over time without the need for frequent home visits. Sensors can also be used to provide information on movement around the home – for example whether a person is sat or in bed, and for how long, or how many times they have passed a certain point in the home (e.g. access to the kitchen). This allows, for example, telecare providers, family members and organisations that visit the elderly to monitor the level of mobility and whether there is any unusual or lack of activity.

(123) The main standards are ZigBee (802.15.4 g/e) and Bluetooth and the applications do not support alarms. In the case of any interference the data can be stored and resent provided the interference is only transient.

3.2.3.3 Potential market

(124) As noted above there are two potential markets and these are considered below.

Hospital wireless devices market

(125) Data from the Department of Health[24] indicates that there are the following average daily number of available beds open overnight in England and also provides information on the average daily number of occupied beds and the percentage occupied, across all 230 Hospitals / NHS Foundation Trusts.

Table 6: Total beds available and occupied across all 230 Hospitals and NHS Foundation Trusts

	Average number of available beds		Average number of occupied beds		%age of beds occupied	
	April – June 2012	July – Sept 2012	April – June 2012	July – Sept 2012	April – June 2012	July – Sept 2012
Total	137,339	135,602	117,935	115,587	85.9	85.2

[24] See http://transparency.dh.gov.uk/?p=19745

	Average number of available beds		Average number of occupied beds		%age of beds occupied	
General & Acute	104,933	103,774	92,013	89,777	87.7	86.5
Learning Disabilities	1,962	1,739	1,457	1,414	74.3	81.3
Maternity	7,897	7,830	4,730	4,737	59.9	60.5
Mental Illness	22,548	22,258	19,736	19,659	87.5	88.3

(126) Then looking at specific consultants' specialities the average number of beds open overnight in England, for example, are:

Table 7: Total beds available and occupied across all 230 Hospitals and NHS Foundation Trusts for specific specialities

Speciality	April – June 2012	July – September 2012
Cardiothoracic Surgery	1,264	1,325
Cardiology	3,898	3,773
Paediatric Cardiology	556	531
Rehabilitation	2,512	2,554
Geriatric	15,274	14,503

(127) The Study has identified some specific medical applications, as described above, that use wireless. The disposable sensors used to diagnose lesions could have an annual market of thousands. For example if it is assumed such devices are used in relation to just 1% of patients occupying beds for cardiothoracic surgery, cardiology and paediatric cardiology and that the usual stay per patent is 3 days then the market could be around 6,900 per annum. Another way of estimating the market is based on there being approximately 45,000 coronary angioplasty and stenting operations undertaken each year[25] which could involve the use of such wireless sensors and even if only 10% use disposable wireless sensors the potential market is around 4,500 per annum.

(128) A number of companies provide solutions that allow a cable free patient environment and provide greater flexibility both to the patient and with installing / moving instrumentation. Based on information provided by vendors it appears that this market may only be in the hundreds each year currently but in the very long term, if wireless solutions are proved to be reliable, flexible and cost effective the total number of wireless solutions could match the number of beds in use (e.g. around 115,000 for Hospitals and NHS Foundation Trusts).

[25] See http://www.drfosterhealth.co.uk/medical-dictionary/surgical-procedures/coronary-angioplasty-stenting.aspx

Home environment

(129) It is expected that there will be increasing pressure to provide the health and social care needs of the population in the UK within their own homes due to the ageing population, increasing number of people with chronic conditions and constraints on the resources available for health and social care. According to a recent report[26] remote care is firmly on the government agenda and at least £160m of public funding was spent across the UK on initiatives to support the uptake over the period 2006-2012. The Department of Health (DH) believes that at least three million people with long term conditions and/or social care needs could benefit from the use of telehealth and telecare services[27]. However the challenge in respect of the development of the market is the fragmentation of the demand-side – "the silo-working in health and social care".

(130) The predictions for the size of the market vary considerably depending on the definition of "remote care":

- Estimates for the European telehealth market size vary between €165m and €429m[28].
- Compound annual growth rate (CAGR) for the global remote care market is around 15 – 20 per cent.

(131) The report on remote care, "Developing the capacity of the remote care industry to supply Britain's future needs", considers the potential market size on the basis of the demographic and health profile of the population that could benefit from remote care. They group the potential market into 3 categories:

Table 8: Three potential markets of remote care industry

Market	Requirements	Potential number of users
High risk healthcare users (poor symptom management)	Frequent monitoring needs	• 500 to 1000 people per PCT (average PCT has a population of 284,000). A maximum of around 150,000 in England at any one time. • About 150 patents per half a million population. Around 15,500 patients in England at any given time.
Preventative remote care (occasional health service	Remote care to allow those that want to remain	In the UK the population over 75 is expected to

[26] "Developing the capacity of the remote care industry to supply Britain's future needs", November 2012, which can be found at http://www.telecareaware.com/index.php/one-report-to-rule-them-all-uk.html#axzz2FiBx9R2D .

[27] See http://3millionlives.co.uk/

[28] Revised Frost and Sullivan figures provided in 2010

Market	Requirements	Potential number of users
users)	in their home to do so as long as possible.	grow from 4.9 m (2012) to 8.9m (2035) and surveys suggest around 85% would wish to remain at home. Assuming a third derives benefit from remote care then the potential market could grow from 1.4 m, now, to over 2.5 m over the next 25 years.
Elective telehealth (privately arranged and paid for by individuals for themselves or their relatives).	Remote care.	Unclear. Currently telehealthis a prescribed service so would need a new business model(s).

(132) The report indicates the following actual and proposed remote care market in the UK:

Table 9: Actual and proposed remote care market figures in the UK

Actual remote care market 2010	Potential remote care market 2010	Potential remote care market 2050
350,000	1,400,000	3,200,000

(133) Assuming that it is possible to provide adequate connectivity using a single data collection point there could be the potential for over 3 million systems each with at least one sensor. However it is unlikely that all the market will be addressed using wireless solutions and even if the current penetration is maintained then there could be around 800,000 systems and with further Government initiatives could be significantly more.

(134) Estimates for the total number of sensors that might be used in 2015, assuming at least one sensor for measuring a specific body function and four sensors to provide movement information could be in the millions.

3.2.4 Industrial automation

3.2.4.1 Overview

(135) Wireless communications have been used in industrial applications for a significant time[29] and in many cases proprietary solutions have been developed to meet the specific

[29] connectBlue have indicated for over 30 years.

requirements of an industry. One of the main requirements of automated applications is control and the ability to collect and process information and deliver it back to each actuator.

(136) There are some key considerations when deciding whether wireless technology would be suitable in manufacturing plants and these are outlined in the table below:

Table 10: Typical considerations that influence use of wireless technology[30]

Consideration		Advantages	Disadvantages
Costs	Savings (start up and maintenance)	Flexible cables, swivels etc. needed for wired solutions can be very expensive and require significant maintenance.	
Resilience and safety	Impact of link failure over system safety must be minimised.	Allows control possibility from further distances and so ensures personnel safety in hazardous environments.	Wireless vulnerable to interference / receiver jamming.
Priority	Safety requirements must use reliable protocols and provide real time guarantees.		Only way of guaranteeing safety is to interrupt process whenever messages get lost. Could impact on efficiency.
Mobility	Industrial applications may require nomadic solutions.	Easy to reconfigure assembly lines, provides fast and efficient installation and commissioning.	
Scalability	Ability to increase number of users connected to same device (point to multipoint)	Potentially allows greater option for interconnection compared with wired.	

(137) An automated industrial system, like an assembly line will normally have a well-defined hierarchy of control systems. At the top there is the operator who operates or monitors the system using a Human Machine Interface (HMI). Then there are the programmable logic controllers that use Ethernet connections and finally there is the fieldbus that links the controllers to the components that do the work (e.g. electric motors, sensors, actuators,

[30] See http://www.smerobot.org/08_scientific_papers/papers/Calcagno_et-al_ISR-Robotik06.pdf

switches, valves etc. The typical wireless communication and associated technologies that can be used instead of wired connections are shown in the table below:

Table 11: Alternative use of wireless communication instead of wired connections in industry applications

Use	Wireless technology	Additional information
Replace serial cables which connect to PCs / operator	Bluetooth or Wireless LAN	Bluetooth most suitable for ad-hoc connections. Used to connect to configuration or programming tools.
Replace Ethernet cables / infrastructure	Bluetooth or Wireless LAN	Ethernet cables commonly used where there are mobile, rotating and temporary installations. Wireless LAN is used for applications requiring high data rate and Bluetooth for robust data transfer and / or where a high system density is needed (many devices require connection)
Fieldbus Cable replacement	Bluetooth	There is a need for low latency (delays) at this level of the hierarchy

(138) In addition ZigBee and Wireless Hart are used in industrial applications where there is a need for battery operated devices.

3.2.4.2 Potential market

(139) The market could potentially be huge, much larger than other applications. In a report[31] from 2006 it was estimated that the worldwide market for wireless technology in manufacturing would grow at a compounded annual growth (CAGR) of 26% - from a market of $325.7 million in 2005 to more than $1 billion in 2010. The size of the market will depend on the potential for new greenfield projects (i.e. where new industrial plants are being installed) or where existing plants / production lines may be under expansion.

3.2.5 Traffic Management

3.2.5.1 Overview

Siemens offer Traffic management systems[32] (Sitraffic Wimag) that can be used to provide data on volume of traffic passing point X at second Y. This data can be used in traffic control systems and traffic management systems such as traffic lights. “The high detection rates of Sitraffic Wimag make it possible, for example, to record the time gaps between vehicles enabling the green times of lights to be adjusted to the actual traffic situation”. The

[31] ARC Advisory Group in 2006.

[32] See http://www.mobility.siemens.com/mobility/global/SiteCollectionDocuments/en/road-solutions/urban/infrastructure/Sitraffic-Wimag-Magnetic-Pull-en.pdf

advantage of such systems is the sensors can be installed in the road in a few minutes (only 7.5 x 7.5 x 5 cms) and they connect, using the 2.4 GHz band, to an access point which can be pole mounted, as shown in Figure 8 above the pedestrian crossing lights, and then sent via Ethernet to a controller. They can be used to replace inductive loop detectors as much cheaper, easier to install, will operate for 10 years with no maintenance and no cabling required. Sensors can be up to 500m from access point.

Figure 8: Sitraffic Wimag implementation. Source: Siemens

(140) Libelium has a platform that can sense the flow of Bluetooth devices on a specific road or pedestrian area and can differentiate between those installed in vehicles and those used by pedestrians. This data is sent using multi-hop ZigBee radio to a server via an internet gateway and can be analysed to address congestion problems.

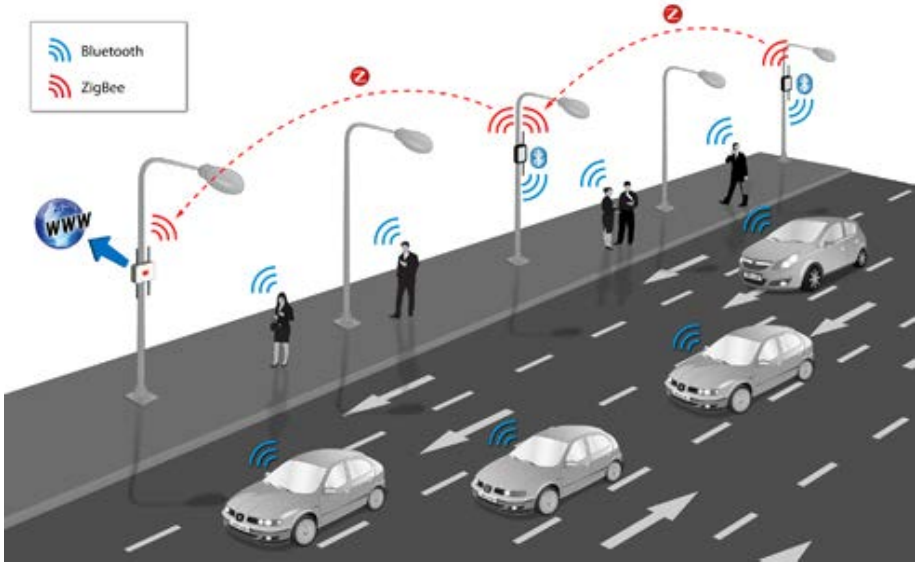

Figure 9: Traffic flow system. Source: Libelium

3.2.5.2 Technology

(141) In the case of Sitraffic Wimag communication is based on ZigBee (IEEE 802.15.4) and is modified for traffic detection. A special protocol reduces the number of transmissions to a minimum. Without traffic the detector is completely idle apart from a "sign" every minute.
The vehicle traffic monitoring platform uses a mixture of Bluetooth detection and ZigBee as the means of connecting to the internet as shown in

(142) ***Figure 9*** above.

3.2.5.3 Market Overview

(143) The Siemens product was released in 2010. No information has been found on take up of either of the devices.

3.2.6 Sensor Devices and Systems Integrators

3.2.6.1 Overview

(144) During the course of the Study it was identified that there are companies that market wireless sensor devices that can be used by system integrators to “implement scalable, modular wireless sensor networks”. In addition products (gateway routers) are available that allow the sensor networks to be connected to the Internet.

(145) Libelium is one such vendor that has developed 2 products – Waspmote plug and sense and Meshlium Gateway Router. The products are sold on a world-wide basis. The Waspmote plug and sense device, shown below, allows up to 6 sensors to be connected[33] depending on their function.

Figure 10: Installed Waspmote plug and sense. Source: Libelium

(146) Any Waspmote Plug & Sense model allows the radio, power option, sensors and optional accessories to be determined by the customer. There are eight basic sensor models available integrating more than 60 sensors and they have the following features:

[33] See http://www.libelium.com/xhjs76gd/waspmote_plug_and_sense_catalogue.pdf

- Robust waterproof IP65 enclosure
- Allow sensor probe to be added or changed in seconds
- Solar powered with internal and external panel options
- Radios available: ZigBee, 802.15.4, 868/900MHz, WiFi and 3G/GPRS
- Over the air programming (OTAP) of multiple nodes at once
- Special holders and brackets ready for installation in street lights and building fronts
- Graphical and intuitive programming interface

(147) The application will determine the relevant sensors which include; CO, CO_2, NO_2, SH_2, CH_4, O_3, NH_3, Isobutane, Ethanol, atmospheric pressure, soil moisture, soil temperature, leaf wetness, ultraviolet radiation, trunk diameter, fruit diameter, meteorological station data (wind speed etc.), liquid presence, liquid flow, liquid level, angle of tilt, motion. The web-site provides information on specific applications and available sensors.

3.2.6.2 Technology

(148) The Waspmote devices can support different radio interfaces depending on the application requirements. Those applicable to the 2.4 GHz band are shown in the table below:

(149)

Table 12: RF modules for Waspmote. Source: Libelium

Protocol	Transmitter Power	Sensitivity	Range (line of sight and 5 dBi dipole antenna)
802.15.4	1 mW	-92 dBm	500m
802.15.4	100 mW	-100 dBm	700m
ZigBee-Pro	2 mW	-96 dBm	500m
ZigBee-Pro	50 mW	-102 dBm	700m
802.11 b/g (WiFi)	1 – 15 mW	-83 dBm	Not specified
Bluetooth	1.7 mW	-86 dBm	30m NLOS indoors 250 m LOS outdoors

(150) Meshlium, the Gateway router is specially designed to connect Waspmote sensor networks to the Internet via Ethernet, WiFi and 3G interfaces.

3.2.6.3 Potential market

(151) The Waspmote plug and sense devices as noted above can support different radio interfaces. Currently the highest demand is for ZigBee which appears to suit the customers' applications many of which require battery operation. Agricultural use, for example, can be to automatically turn on watering systems depending on the humidity of the soil. This is followed by parking sensors and gas sensors. The data from the sensors is often required in real time (for example parking sensors typically send information once every 5 minutes so information on spaces in a car park can be updated and information on humidity of the soil is sent every minute at various depths) but the information can be stored in the sensor and resent so this overcomes any short term interference problems.

(152) In terms of numbers of sensors required this will often depend on the level of precision required. In the agriculture application between 500 to 600 sensors are required for each project. A typical car parking project will have 100 sensors as will a major city where the sensors are used to measure gas emissions for real time pollution data.

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4 CONCLUSIONS

(153) There is a considerable range of applications that have been identified as part of this Study that are currently using the ISM band. These have been mainly found through web searches, articles and reports so there is the possibility that there are other applications that have not been identified. It appears that there is also significant growth potential in respect of the number of devices that may be installed for those applications identified in this report.

(154) The availability of wireless sensor devices that can be used by systems integrators to implement networks for a wide range of applications demonstrates the possible growth into less expected applications associated with agriculture as well as for smart cities, traffic control etc.

(155) A number of the applications are ones that support Government (local and national) objectives such as reducing the costs of local councils and reducing the carbon footprint by remote controlling street lighting or enabling the elderly to remain in their own homes through the provision of remote telecare.

(156) The main technologies that are deployed in this band are WiFi (IEEE 802.11 b/g), Bluetooth (IEEE 802.14 for WPAN) and ZigBee (IEEE 802.14.4) as well as proprietary solutions, some based on these standards. It is possible for devices that use these technologies to effectively share the 2.4 GHz band on a no-interference, no protection basis and provide reliable communications based on inputs to this Study. However for such technologies to be effective there is a need for a minimum number of free channels to be available – for example for Bluetooth which uses Adaptive Frequency Hopping it is recommended that there should be a minimum of 15 MHz of unoccupied spectrum at any point in time. The choice of technology depends on a number of factors including the distance over which the data is to be transmitted, the actual amount of data that is to be sent and whether there is a need for battery operation because, for example, of the physical location of the device.

(157) A number of the applications allow for the potential for interference by being able to save data and re-transmit the information once a wireless connection is re-established but it would be expected that any long term interference would be an issue. In others, such as industrial control and automation, it may be necessary to interrupt the process to ensure safety and this could impact on the efficiency of a plant. Where mesh networks are deployed, such as street lighting, interference into a limited number of nodes is not likely to be a problem as the networks are self-healing. However in the case of wireless accessories for hearing aids latency is a key consideration and interruptions due to interference would negate any advantages such devices would provide to the user. Similarly there are specific medical applications, such as the one provided by St Jude Medical, where the loss of data could be a significant issue but in such cases proprietary FHSS (hopping) and redundancy protocols are deployed to ensure the wireless links are extremely resistant to interference from other devices operating in the band.

(158) It was also noted that an increase in the noise floor may impact on the ability of sensors to transmit data over planned distances and the specific example was provided of where the use of an iPAD impacted on the sensitivity of the sensors. This could have an impact and require an increase in the number of sensors and central points which could influence the viability of any solutions which are cost sensitive (e.g. telecare).