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Wireless as Enabler of Innovation in 21st Century Health and Social Care

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Abstract. This paper overviews new and emerging wireless technologies that could positively impact on the lives of the elderly or disabled, as Social Care users of Assistive Technology (AT) for 'independent living'. Novel Internet of Things (IoT) radio systems and wireless locating systems being researched at The University of Sheffield are discussed in the context of Social Care technology use-cases.

Keywords. High-reliability IoT, Alzheimer patient tracking, Wireless Social Care Systems.

1. Introduction

Existing technologies used for Social Care and healthcare applications can be seen by potential users as a 'badge of infirmity' and so are often met with reluctance in both adoption and use, regardless of need. Additionally, due to increasing financial constraints on Social Care budgets [1] the capability of such systems generally remains basic in scope, which further limits appeal to all but the desperate. There is a growing problem in caring for able-bodied people with degenerative disease, such as Alzheimer [2], with a strong desire for this care to be delivered in the home setting, but with some risk. Furthermore, the shift in demographics mean that such demands will continue to grow.

Technological innovation is vital to business by a) mitigating against product commodification; b) supporting competitor product differentiation and c) facilitating access to new markets. Contemporary commercial manufacturing organisations operate on rapid time-to-market, favouring application of low-risk and proven technologies - which can limit solution creativity. However, the insight gained from judicious engagement with end-user needs can inform longer-term R&D strategy; justifying conception of ambitious technology, with risk mitigated by appropriate feasibility studies.

Against this backdrop, this paper proposes that emerging wireless technologies can act as enablers for innovation - facilitating development of new, user-centric health and Social Care products. Acceptance of smart healthcare products is growing, due to devices such as wellness monitors and connected medical devices (e.g. smart inhalers [3]). Research at The University of Sheffield's Advanced Radio Technology Centre (ARTC) is addressing the need for future radio technology in Social Care and healthcare applications; focusing on high reliability IoT (Internet of Things) and location detection.

2. Emerging Commercial IoT Systems Relevant to Social Care Products

Niche, proprietary IoT connectivity (often aimed at the Smart City) is now commercially available. Inevitably, the relevance of individual technologies will evolve, particularly as open-standards (e.g. IEEE 802.15.4 and 6LowPAN) and new mobile cellular systems are deployed. Other emerging connectivity systems (notably Weightless-P and 802.11ah) have yet to show commercial viability. IoT radio systems in Social Care may encompass the following applications and use-cases:

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a) Ubiquitous, discreet emergency-call and reassurance devices for both domestic and assisted-living facilities (i.e. next generation telecare); **b)** body-worn health data telemetry (e.g. blood pressure, heart function) for remote clinicians; **c)** medical device data telemetry (e.g. blood glucose monitoring, inhaler monitoring) for remote clinicians; **d)** family wellbeing (e.g. medicine reminders, activity monitors, location monitors); **e)** medical interventions and remote device control (e.g. pacemakers).

Overall, there are presently 4 deployable, or near-term, IoT radio technologies applicable to the above example use-cases, which are now summarised below.

2.1. LoRa and LoRaWAN

LoRa is a radio physical-layer technology and LoRaWAN is the most common network implementation for city-wide areas [4]. Trial deployments have been conducted by potential network operators in the EU (including France, Sweden and Italy) but extensive national roll-outs are yet to occur. User data payload lengths can be up to 256 bytes. Bidirectional data is supported and peak power consumption is appropriate for primary cells from CR2 size. *LoRa is suitable for use-cases that can support a rechargeable / replaceable battery (i.e. 'b-d'). LoRa is often deployed by as a private, bespoke, network.*

2.2. Sigfox

Sigfox provides base station infrastructure and Cloud services for national Sigfox Network Operators (SNOs) to install and manage. It also provides embedded software to product manufacturers wishing to incorporate Sigfox connectivity into products. Sigfox has been primarily a unidirectional system, but limited bidirectional capability now exist. Globally, France and Spain enjoy the most comprehensive coverage; Arqiva cover 11 cities in the UK [5]. Sigfox packets are limited to 12 bytes of user data and peak current consumption dictates use of batteries from CR2 size. *Products using Sigfox include fall detectors, smoke detectors and goods tracking. Sigfox is suitable for applications of physical size supporting a rechargeable / replaceable battery (i.e. 'b-d').*

2.3. NB-IoT

The cellular industry has created Narrow Band IoT (NB-IoT) as an update to LTE. NB-IoT benefits from a 20dB link budget enhancement over 4G LTE voice and data [6], which could translate into a combination of a 3-fold range increase outdoors or enhanced building penetration. If the commercial model for network access and the module costs are competitive (to Sigfox and Lora), NB-IoT is poised for wide scale adoption due to likely ubiquitous coverage and operator Quality of Service. Data rates up to circa 20kb/s, with variable packet lengths and bidirectional modes are supported. *NB-IoT modules are not yet commercially available. A high peak current consumption is expected to preclude NB-IoT from using Coin Cell batteries, hence limiting end-product minimum size and Social Care applications as similar to those of LoRa and Sigfox.*

2.4. Bluetooth Low Energy & Bluetooth 5

Bluetooth Low Energy (BLE, also known as *Bluetooth Smart*) is widely incorporated into smartphones. BLE has become a common short-range connectivity technology for 'wearable' devices powered by coin cell batteries, but can suffer range limits indoors of circa 10m. Coverage range is expected to increase 4 fold with the release of Bluetooth 5 (BT5) [7], allowing a BT5 body-worn product to connect to a host smartphone located anywhere within a typical dwelling. Given the popularity of current BLE enabled smartphones and the likely low-cost of BT5 LE chips, it is suspected that this technology will significantly disrupt the AT health and Social Care device market. *At present, BLE is the only IoT technology capable of being powered by coin cells (e.g. CR2032) for multiple years. BLE is applicable to use-cases 'a-d'. The major limitation of BLE5 remains the requirement for local access points (e.g. smartphone).*

3. Research at The University of Sheffield's Advanced Radio Technology Centre

The ARTC is researching new radio concepts highly relevant to Social Care and AT: 1) high reliability, city coverage for low power IoT devices and 2) low power techniques for identification of indoor and outdoor user position.

3.1. High Reliability Wide-Area IoT Wireless Connectivity for Social Care Devices

Body-worn AT IoT systems must be cost-effective, discreet in size and extremely reliable (*message* reliability comparable to domestic telephone availability of 99.999%), whilst also offering multi-year service life from a coin cell battery. None of the emerging IoT radio technologies are 'fit-for-purpose' in high reliability scenarios. The ARTC is researching 2 broad and interrelated themes to address the needs of all use-cases '**a-e**':-

1) **Distributed Massive MIMO** is proposed to be implemented in a geographically distributed form (rather than on a single mast as envisaged in 4G cellular systems), with low-complexity access points operating at VHF and UHF. The 'Massive' aspect of MIMO is therefore implemented by the geographic distribution of access points. This concept will provide enhanced link budget to an IoT mobile device- minimising battery requirements and supporting small, low efficiency antennas. Resulting wearable Social Care products could hence be very small and low-cost.

2) **Cognitive Radio (CR)** with multi-frequency band capability will allow the IoT device to assess its operational radio environment, identify and avoid sources of interference and select optimal frequency, power and modulation to use for a message transmission. International spectrum regulators have agendas to share and broaden access to spectrum. This will inevitably lead to increased interference and reduced reliability for links that do not employ CR- unacceptable for AT products.

3.2. Low-Power Location Detection & Tracking for Alzheimer Sufferers

Indoor localisation remains a challenge for research, often delivering unsatisfactory performance [8], [9]. High accuracy requires spatial diversity and bandwidth [10]. Today, much research addresses centimetre accuracy- using systems (e.g. UWB) requiring high powers and bandwidth, which are unsuitable for body-worn, discreet AT. Social Care products for location tracking conventionally use GPS and smartphone technology [11] which are expensive, require daily battery charging and suffer from poor indoor GPS coverage. Systems to cost-effectively and discreetly track Alzheimer sufferers living in the community are vital: identifying if they have wandered and subsequently locating them quickly, in an urban environment.

The ARTC is investigating non-GPS techniques based on multiple frequency Angle of Arrival (AoA). This novel AoA radio system can offer indoor and outdoor coverage, with acceptable location accuracy for Social Care use-cases. Simulations of the novel Multi-Frequency and Multi-Frequency with Virtual Array (VA) algorithms are seen to provide improvements in AoA accuracy and signal reflection suppression, compared to current popular single-frequency spectral based methods such as MUSIC (fig 1).

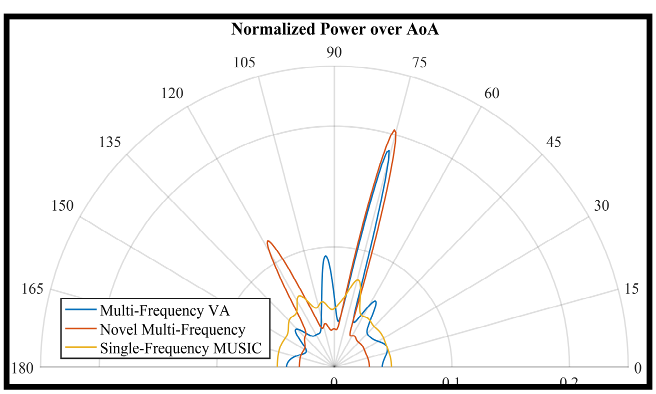

Figure 1. Polar Angle of Arrival of direct and reflected rays (source AoA bearing is at 75 degrees).

Additionally, the application of lower complexity signal decompositions, such as QR [12], reduces the energy requirements for calculating bearing. The current trial system is equipped with ten antennas and jointly uses three frequency bands (fig 2). Novel hardware will facilitate the identification of the primary signal amid multiple signal reflections, and hence rapidly provide a bearing of a source, whether indoors or outdoors. The Alzheimer sufferer would be required to wear a small, discreet 'tag' transmitting source, powered by a coin-cell lasting several years. The worn device could also be used as an emergency alarm, specifically supporting use-case '**a**'.

A set of detection systems could be used to cover a city, with the bearings resolved to identify a tag's location. Furthermore, the systems may use Cloud-hosted signal processing algorithms, reducing detection node hardware cost and power consumption.

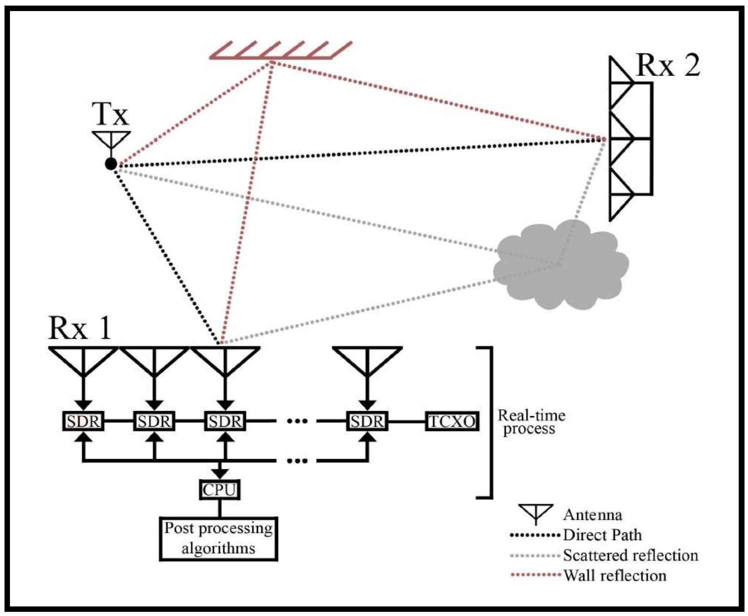

Figure 2. The Systems (RX1, RX2) resolves a bearing from tag (TX) in presence of reflections.

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