The future of technology-enabled care

Everything everywhere all at once

r-cubed

Contents

Introduction

The UK is transitioning to an all-digital (IP-based) telephone network with significant operational and strategic implications for alarm-based telecare services. However, this transition also presents a unique opportunity for the technology-enabled care (TEC) sector to be reimagined through digital transformation. By embracing a shift to data-rich applications, the sector can improve how it supports individuals to live their best lives, delivering improved outcomes for all, whilst reducing the demands on carers, allowing them to use their time more effectively,

> **If I had asked my customers what they wanted, they would have said a faster horse.**
>
> Henry Ford

"*If I had asked my customers what they wanted, they would have said a faster horse*." This quote is often attributed to Henry Ford, who developed the motor car at the beginning of the 20th century. It highlights the distinction between identifying a problem or need and choosing a solution – with an assumed bias favouring familiar and established approaches. Although there is no evidence that Ford ever said this, it is still used to emphasise that sometimes a leap of faith is required – a shift to an entirely new way of thinking… a solution that does not simply replicate or improve the existing way of doing things but completely reimagines a way of solving the problem, Figure 1.

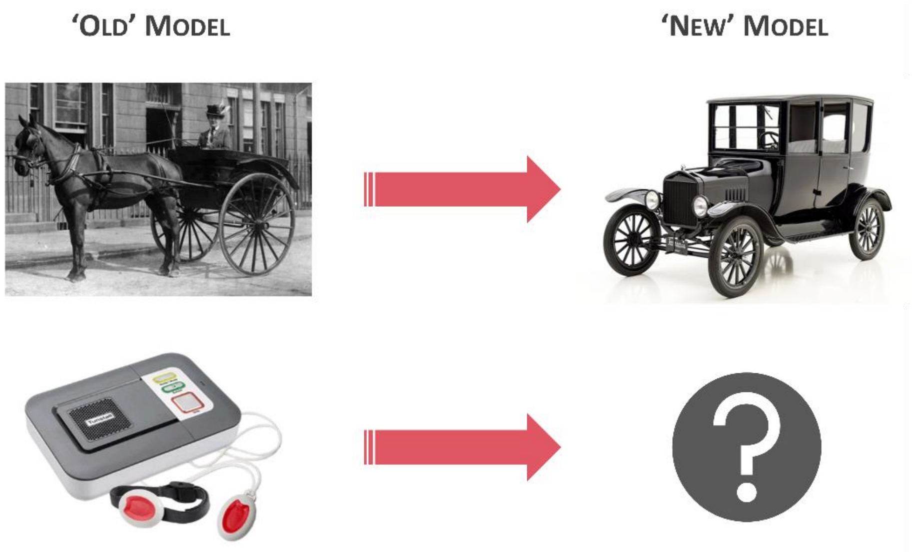

Figure 1: Sometimes a paradigm shift changes our expectations.

The care and support sector is currently faced with a choice between two competing approaches: legacy reactive services that respond (after the event) to alarms and new proactive services (and potentially preventive interventions) informed by data. Telecare services, the most common form of TEC employed in the UK, are transitioning from older analogue infrastructure to new digital IP-enabled hubs and monitoring platforms. This provides technical futureproofing while addressing reliability issues associated with the switch from analogue to digital technologies. However, most digital alarm hubs merely replicate the functionality of their analogue counterparts. Therefore, they fail to take up the opportunity to develop new proactive support models that exploit modern intelligent and digitally connected technologies and devices, many of which are mainstream consumer products.

At present, data-driven applications are in the early stages of development and adoption, but their capabilities and use will likely progress rapidly. They use data to assist people in their daily routines and offer proactive interventions before situations escalate to requiring an emergency response, thus supporting the preventative agenda. They are more likely to be used every day and are, therefore, perceived as beneficial to the people using them compared with previous alarm-based technologies that are infrequently used and viewed as ‘insurance’ against worst-case scenarios.

Service commissioners and providers' commitment to migrate to these newer monitoring platforms relies on a leap of faith until their success is apparent. However, change can be difficult for risk-averse organisations that favour established service models and technologies over newer, less proven approaches. But there is also a risk in not changing. Focusing solely on replicating analogue TEC services is backwards-looking and wasteful and would represent a missed opportunity. As people become used to smartphones and other digitally connected consumer technologies in their everyday lives, the perceived value of a traditional alarm service may decline mainly as it is rarely used and is constrained to use in the home. This could lead to a reduction in the number of service users in the UK, currently estimated at 1.8 million, when it should be growing to meet the needs of a broader range of people, using new technologies, and supporting the needs of an increasingly elderly population.

The successful adoption of such systems will require redesigning how services are configured and deployed. This will involve shifting from a model centred on an alarm monitoring centre towards a more distributed approach, centred around people. This new model will be supported by intelligent care technologies and the direct involvement of family members, friends, and many other care, support, and responder agencies. Significantly, the role of technology-enabled care must evolve from a uniform ‘just-in-case’ approach to one that is more versatile, personalised, and offers ‘just enough support' at the right time.

This report discusses the evolution of technology-enabled care products and platforms and considers how services can evolve to take advantage of these developments. It argues that the key to enabling the next generation of technology-enabled care requires a unified data model enabled via a ‘meta’ platform giving access to ‘everything everywhere all at once’.

The Evolution of Technology-Enabled Care

Technology-enabled care services (TECs) use technology to help people live independently in their homes, in supported living environments, or while out in the community. To date, there have been several generations of TEC, which were initially defined in 1996[1], and which we have now expanded to include fourth, fifth and next-generation (NG) approaches, Figure 2.

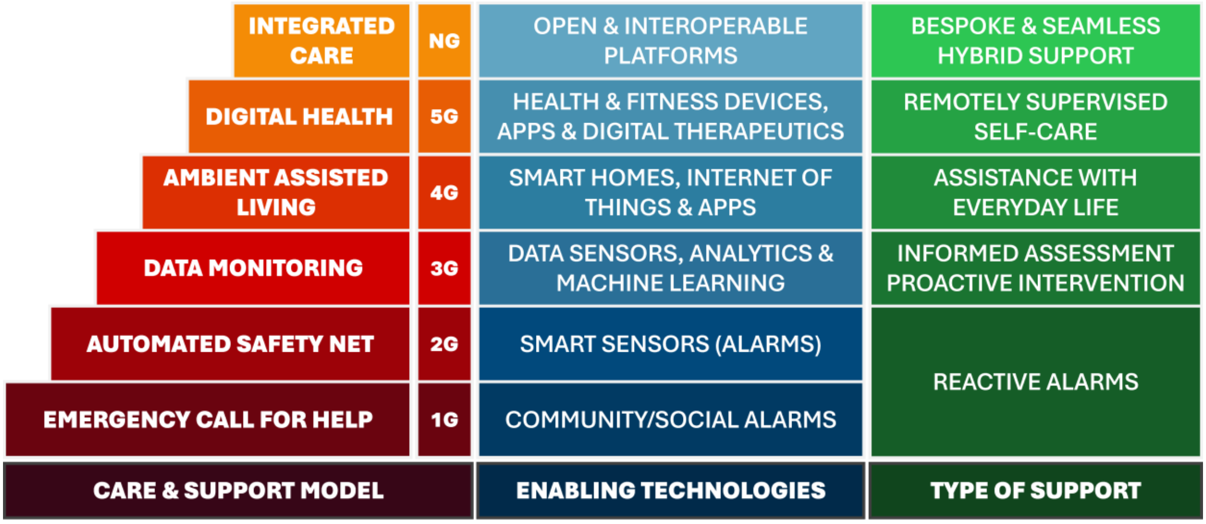

Figure 2: The evolution of technology-enabled care support models.

1 and 2G systems

First-generation (1G) technology-enabled care services are community or social alarm systems designed to support older people living, generally but not exclusively alone, in sheltered housing. They were extended to people who lived in dispersed housing using their landline telephone connection and a 24-hour monitoring centre that could summon support in an emergency. This allowed individuals to seek help by manually activating an alarm using a pull cord or a wireless pendant. Over time, these systems were enhanced with additional alarms, such as smoke detectors.

Second-generation (2G) services introduced *passive* monitoring using smart sensors to address the issue of users being unable or unwilling to raise alarms themselves. Smart sensors could automatically raise alarms for various environmental conditions, such as localised flooding, high or low ambient temperatures, excessive heat, and for life events or activities such as falls, bed/chair occupancy status, nocturnal enuresis and epilepsy, external doors being left open, and if individuals exited their property at inappropriate times.

Over time, alarm hubs with built-in mobile connectivity were introduced to support individuals who didn't have access to a landline telephone service. Mobile telecare alarms were also developed to assist people when they were away from their homes.

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[1] *Doughty, K et al. "Three generations of telecare of the elderly." Journal of telemedicine and telecare vol. 2,2 (1996): 71-80. doi:10.1177/1357633X9600200202*

These performed the role of a mobile alarm pendant that allowed users to speak with a call handler at the press of a button. They often included GPS location tracking and fall detection features so that an appropriate response could be quickly arranged for the individual (these can be considered 2.5G services).

2G services rely on alarm-based responses to manage risk. They remain the predominant type of technology-enabled care in the UK today. Figure 3 provides an overview of 1G and 2G TEC systems.

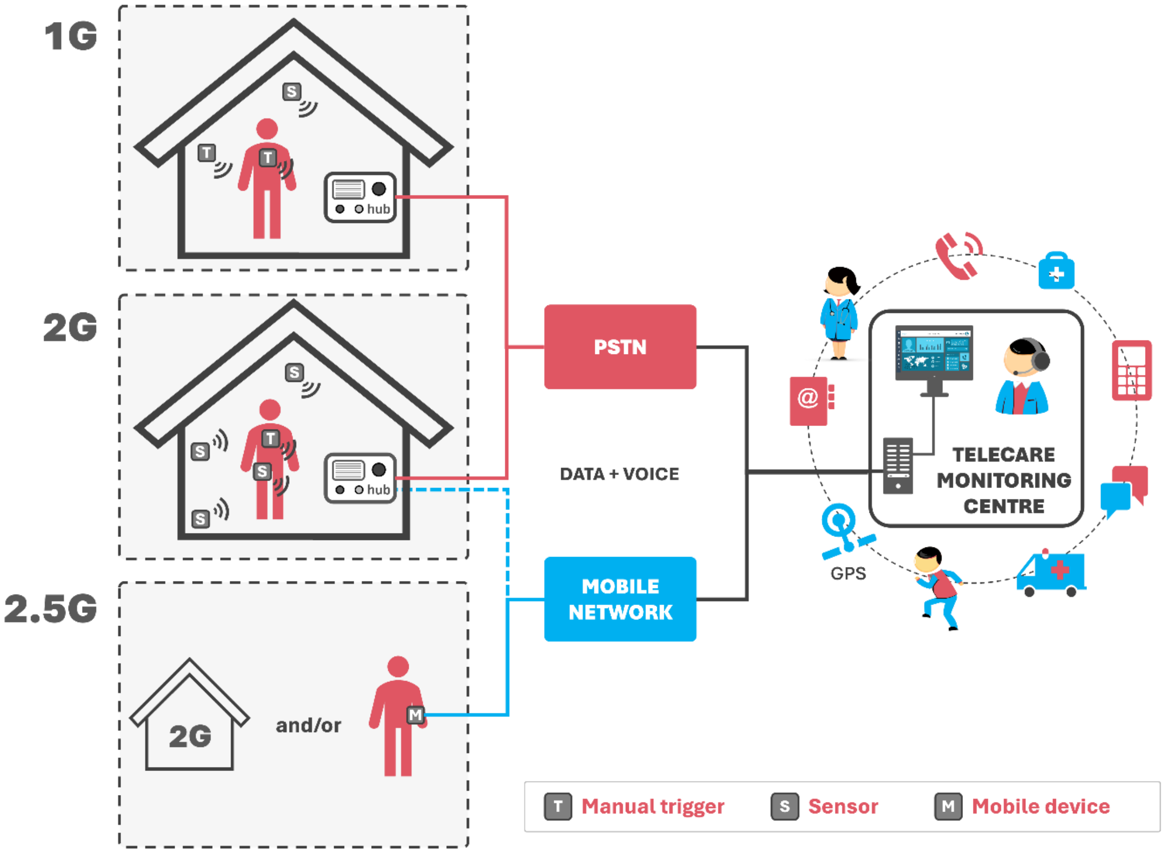

Figure 3: System overview of dispersed 1G and 2G TEC systems.

3G systems

Third-generation (3G) technologies shifted from alarm-based monitoring and response towards data-led, alert-based systems. These provide continuous monitoring of the home and track the activities and interactions of the individual within it. The data collected can reveal behavioural, social, and environmental trends, which can assist in identifying significant changes that may predict current or future problems. Consequently, 3G systems support the implementation of an intervention-based approach that could potentially lead to the development of prevention-based services.

A system overview of data-led (3G+) TEC systems is shown in Figure 4. Sensors installed in the home send data wirelessly to a bespoke hub, which uses either the home's broadband connection or, more commonly, an integrated mobile data connection to upload the data to a cloud-based server. Users can access this data using a dashboard, and rule-based alerts can be sent to a smartphone if an issue requires attention. Alert thresholds are often optimised for the user over time, using the data to learn standard behaviour patterns, improve performance and reduce false alerts. Alert conditions can, if required, be forwarded to a monitoring centre so that a call handler can respond and organise an appropriate response. These systems often provide different methods and levels of access for health and care professionals and family members. This allows family members to coordinate support for a loved one among themselves without involving professional care services if they prefer to handle it independently.

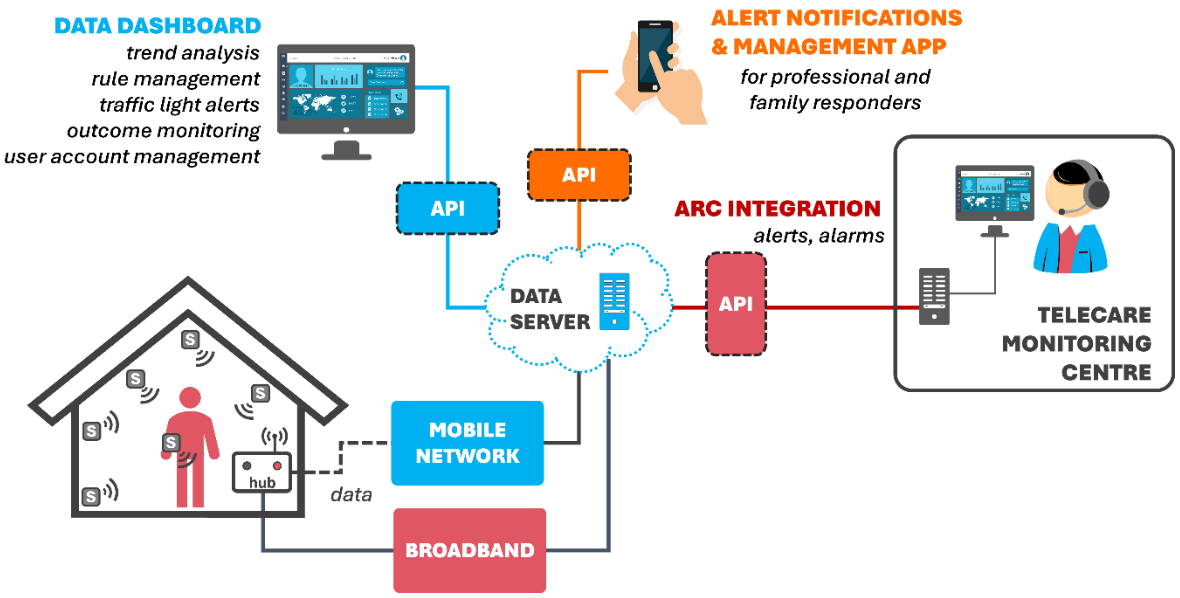

Figure 4: System overview of 3G+ data monitoring systems.

Third-generation systems are typically used in one of two ways:

- **Behavioural assessment** establishes an individual's behaviour over a period ranging from a few days to several weeks. This helps in understanding their daily routines and capabilities, allowing for the design of a tailored care plan that best meets their needs. It can also be used to justify the level of support they currently receive; or
- **Safety reassurance** involves continuously monitoring an individual's behaviour to assess how well they manage their daily tasks. In case of any issues, such as a sudden decline or change in their activities, the system can notify a responder.

3G approaches can also include basic health monitoring, sometimes called telehealth (these can be considered 3.5G services). This enables people to monitor health conditions such as chronic obstructive pulmonary disease, heart failure, and type 2 diabetes. Measurements are performed periodically and monitored by a health professional with interventions triggered by significant changes.

4G systems

3G systems focus on activity and environmental monitoring using 'closed' platforms, whereas **Fourth-Generation (4G)** systems make use of wireless connectivity standards to support connectivity with consumer products and enable smart home capabilities. They also extend support outside the home with wearables and apps. This allows them to offer additional features such as home automation, voice-based user interfaces, intelligent agents, location-based and context-aware support, and 2-way video calling. The latter enables video communication with family, friends, service providers, and/or monitoring centres. It also enables remote consultations with healthcare providers, such as GPs or other allied healthcare professionals.

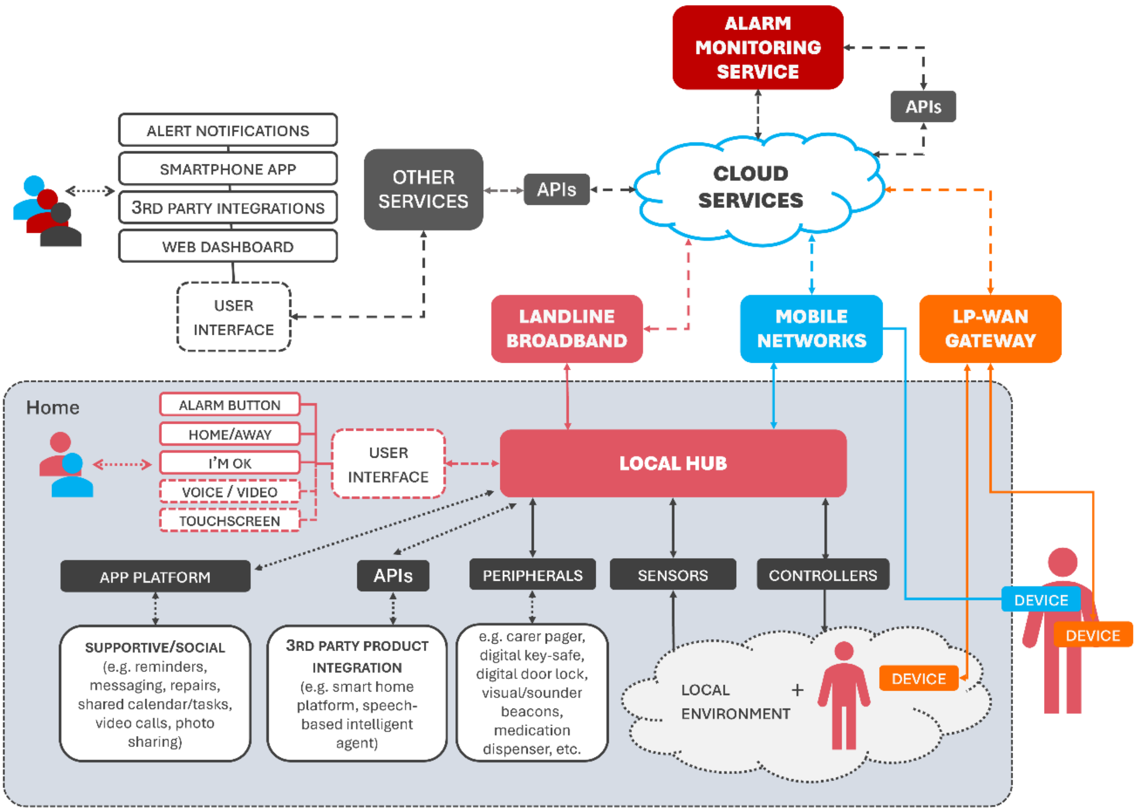

Figure 5: System overview of 4G systems.

4G systems, therefore, provide a flexible smart home platform that can effectively enable Ambient Assisted Living (AAL). AAL uses intelligent technology to assist individuals in maintaining an active lifestyle, staying socially engaged, managing their health, and living independently in their own homes and communities. AAL transforms the relationship between individuals and how they are supported by restoring their control and decision-making power. Individuals can (and should if possible) actively participate in the care process, using technology tailored to their needs and strengths. They also play a role in managing their care and support, becoming active users of the technology rather than passive recipients using it solely to manage safety or provide reassurance to others.

5G systems

Fifth-generation (5G) systems extend 4G capabilities by incorporating continuous health monitoring applications. These use a combination of consumer health and fitness trackers, smartwatches, and specialist medical-grade devices such as continuous glucose or blood pressure monitors for more complex health needs. Such devices can be the basis of virtual wards that allow 'hospital at home' services for people with chronic lung and circulatory issues and enable early but safe discharge of older people from hospitals with reablement support. When introduced appropriately, these systems have the potential to enhance users' quality of life and yield substantial cost savings for the NHS.

Next-generation systems

Next-generation (NG) approaches will extend these applications by providing improvements in machine learning (ML) and other Artificial Intelligence (AI) technologies. This will allow support to be better matched to the changing needs and circumstances of the individual.

These systems will also benefit from increased 'interoperability at scale' based on technical, semantic, and organisational cooperation across multiple products and agencies. This will lead to services built around and responding to the needs of individuals and care providers. They will enable the co-production of tailored support and care packages that use, by design, an optimised mix of people-based services and technology working in harmony to meet individuals' desired outcomes.

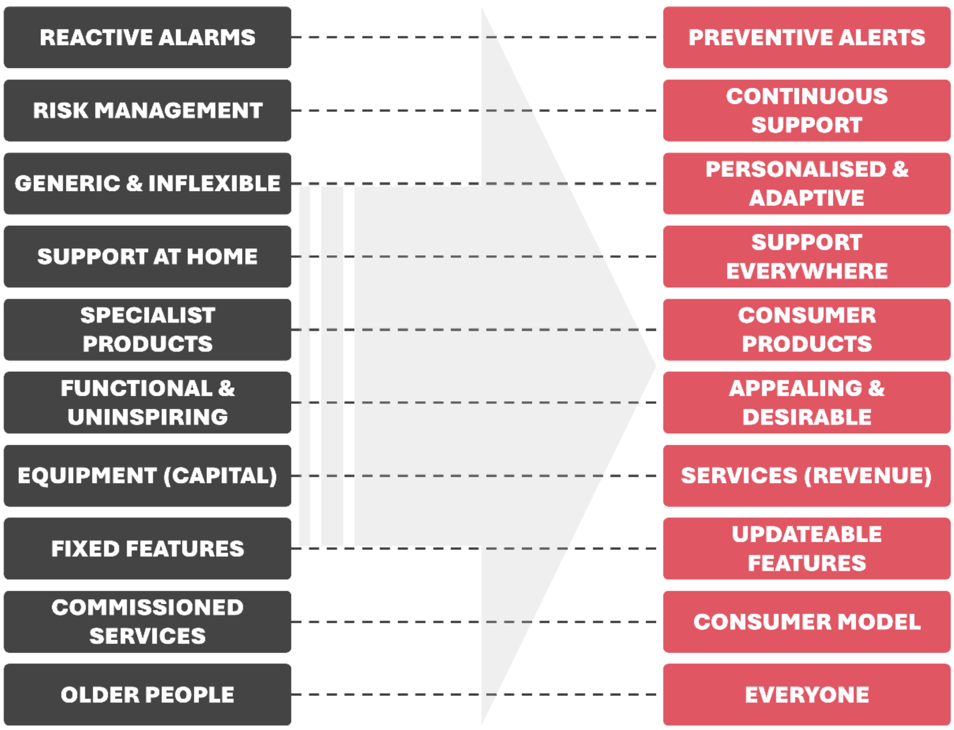

Figure 6: Market trends in the care technology sector.

Figure 6 summarises the key market trends in the technology-enabled care sector as it moves from a reactive analogue model to a proactive digital one. Some of these changes are already taking place, while others are still in the early stages of development.

UK TEC Technology Landscape

The first four generations of technology-enabled care are the pre-dominant models in use today, with most people benefitting from first- and second-generation systems. Third-generation activity monitoring systems have been available for many years, and 4G systems have recently become available. Still, they struggle to dislodge the alarm-based model currently dominant in the UK. Figure 7 This shows the UK's current supplier landscape for 1G and 2G TEC services, although it constantly changes due to consolidation and takeovers, as witnessed by Legrand's recent acquisition of Enovation, the developer of the UMO platform.

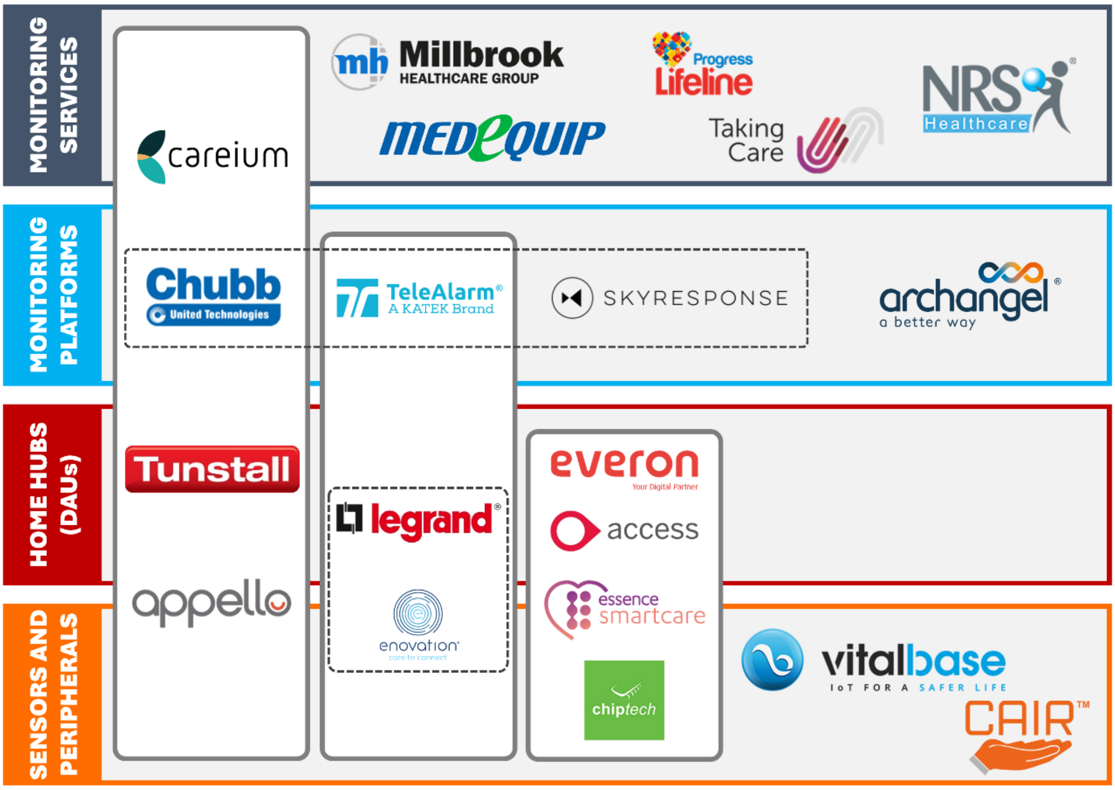

Figure 7: Traditional 1/2G telecare supplier landscape (not exhaustive).

This landscape comprises established telecare equipment suppliers heavily invested in the alarm-based model. Their primary focus is transitioning customers to digital alarm hubs to provide compatibility with the new digital IP-based telecommunications network, ensuring a smooth transition from legacy analogue platforms. Their alarm-based offer is essentially unchanged – at least with the first iterations of their digital alarm hubs, which replicate the functionality of their analogue counterparts, with a few additional features that primarily benefit the service providers.

Some suppliers operate at more than one level. They offer vertical integration of supply, which might present conflicts of interest if, for example, a supplier sells an alarm hub and a monitoring platform. They may also be less likely or slower to adopt or support open standards, providing a level playing field for all suppliers. Some suppliers also potentially compete with their customers if they operate a monitoring service.

Alongside them, some well-established suppliers focus on 3G activity monitoring-based systems. Figure 8 shows the equivalent landscape for 3G+ applications, none of which are exhaustive. Many new entrants want to disrupt the market by developing 4G+ systems using customised 'white label' IoT platforms to produce 'mix and match' smart home solutions tailored to the care technology market.

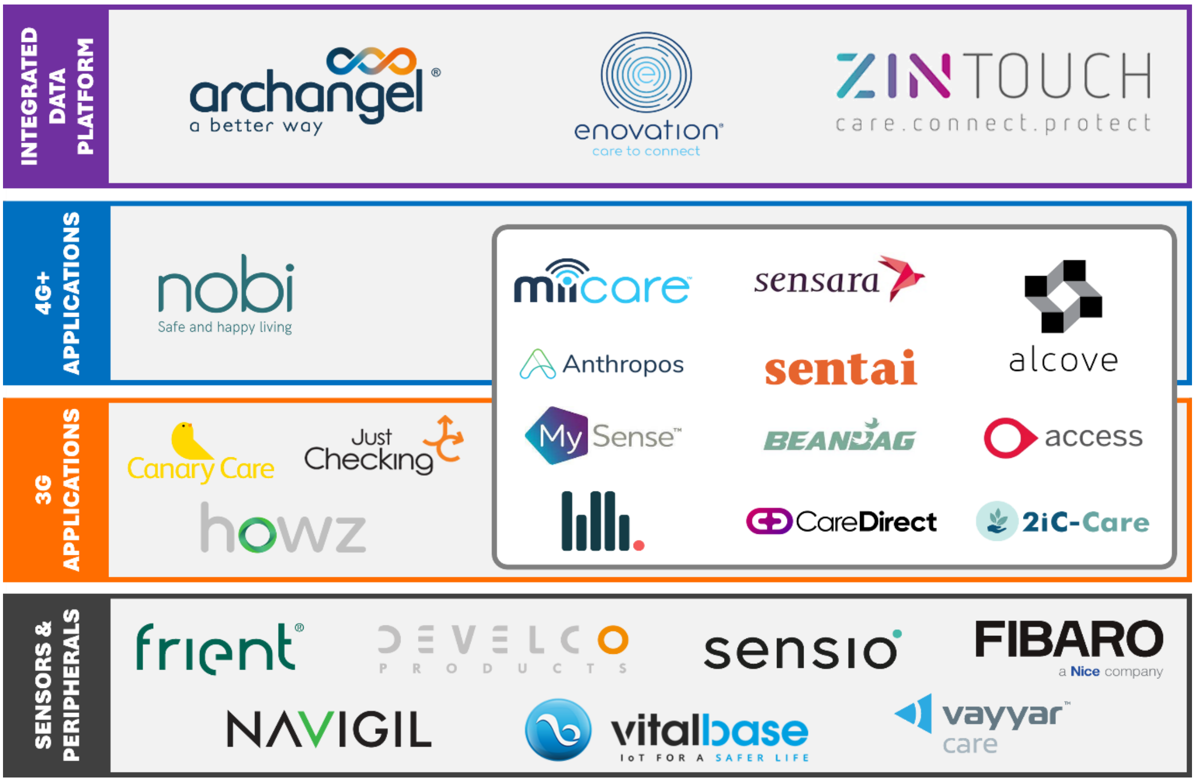

Figure 8: 3G+ data-monitoring supplier landscape (not exhaustive).

Devices installed in the home are increasingly seen as commodity products, with little differentiation between suppliers. Their focus is on improving the data analytics capabilities of their platforms using algorithms and machine intelligence to interpret meaningful events from data and to create actionable insights. This is necessary to:

- manage uncertainty,
- monitor long-term trends,
- provide context-aware support,
- identify possible alert conditions and
- present all this information to users simply and meaningfully.

The technology 'stack' to achieve these key features, Figure 9, is typical of a complex digital data-rich platform and represents a significant change from the established alarm call-handling approach. Product differentiation and value are now provided by comparing data analytics capabilities, the simplicity of data visualisation and user dashboards and the range of applications supported. This is reflected in the shift of commercial models from ones based on capital expenditure to subscription-based approaches. This is driven partly by the need to charge a recurring fee to cover the costs of providing mobile connectivity, cloud services and upgrades, allowing new features and security updates to be applied to existing platforms.

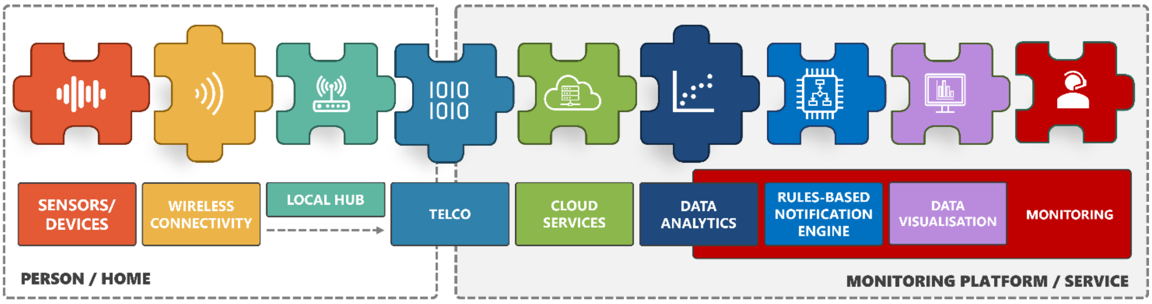

Figure 9: 4G+ TEC technology 'stack'.

This introduces issues around long-term product stability and support. However, some new features require improved hardware, leaving products outdated despite supporting legacy features. The key elements of a 4G+ technology 'stack' will be discussed in the remainder of this report.

The Internet of Care Things

The Internet of Things (IoT) is a network of devices that connect and exchange data over the Internet via cloud-based services, enabling the implementation of intelligent and interactive applications. We define The Internet of Care Things (IoCT) as a specific application of IoT within the care sector. It involves using IoT devices to implement care-based applications and services. Various devices and connectivity options are available and vary depending on the capabilities of each platform. This flexibility is a key strength of the Internet of Care Things and is a defining factor of 4G+ TEC services.

Devices

1G and 2G telecare sensors are glorified alarm triggers. They monitor a parameter (e.g. bed occupancy or room temperature) and process that information on board the device, usually concerning a predetermined or programmed alarm threshold and/or time period. For example, when a room temperature goes above or below a threshold or an individual fails to return to bed by a specific time, it will trigger an alarm. These devices do not share the underlying data with the monitoring system, so there is no scope to determine trends and intervene in response to meaningful changes.

3G systems use activity data to monitor behaviour and a few environmental parameters such as room temperature, whilst 4G+ systems also include integrated smart home capabilities. They do not generate alarms but monitor data, analyse trends, and act on them. This could be by raising an alert notification, communicating with the user, or performing some form of home automation in response to an event (e.g. lighting the way to the bathroom if the person gets out of bed in the middle of the night to go to the toilet).

Table 1: Example devices used in 4G+ monitoring systems.

Sensors – Home	Sensors – Wearables	Controllers / UI Devices
PIR motion sensor	Worn accelerometer (steps, falls)	Smart Socket
Magnetic contact sensor	Barometric altimeter (elevation)	Smart Lightbulb
Bed/chair occupancy sensor	Gyroscope	Smart Thermostat
Ambient light sensor	GPS	Water/Gas valve
Ambient temperature sensor	Compass	Door/window opener
Humidity sensor	Blood oxygen	Adjustable-height worktop
Air quality sensor	Heart rate / ECG	Smartphone app
Sound sensor	Galvanic skin response	Smart Speaker
Electrical appliance use sensor	Respiratory rate	Smart Display
Accelerometer interaction sensor	Wrist temperature	Smart TV
Current consumption sensor		Video Doorbell
(Water consumption sensor)		

Table 1 lists some of the devices used in 4G+ monitoring, and a selection is shown in Figure 10.

Figure 10: A selection of IoT sensors and devices.

Environmental sensors ensure the living environment is safe and comfortable for the home's occupants. They also support a landlord's responsibility for maintaining a healthy, energy-efficient home. Activity monitoring is used to determine changes in behaviour and to identify tasks performed in the home to keep track of activities of daily living and other events of interest. Some devices use novel imaging technologies with onboard processing to determine activities and identify adverse incidents such as falls. Wearables that provide continuous health and activity monitoring, like Google's Fitbit, the Apple Watch, and many other generic clones, provide simple activity tracking and health monitoring data. These can give irregular heart rate notifications, ECG monitoring, mobility and cardio fitness, sleep monitoring, fall detection, medication reminders, and stress measurement. Information from these devices will increasingly become available within technology-enabled care applications.

Once TEC systems are connected to a broader network of 'things', the scope for providing intelligent TEC applications increases, informed by data from numerous sources. This includes data from products in the home and their associated platforms (e.g., a voice assistant integrated into a smart speaker) and specialist devices (e.g., medication dispensers/'robots'). It can also include extended data sources such as local weather and environmental monitoring stations (for data on weather conditions, air pollution or localised flooding) and integration with smart city initiatives. The latter could include information on local traffic conditions and public transport, and wastewater monitoring (for epidemiological monitoring of viral infections such as COVID-19), Figure 11.

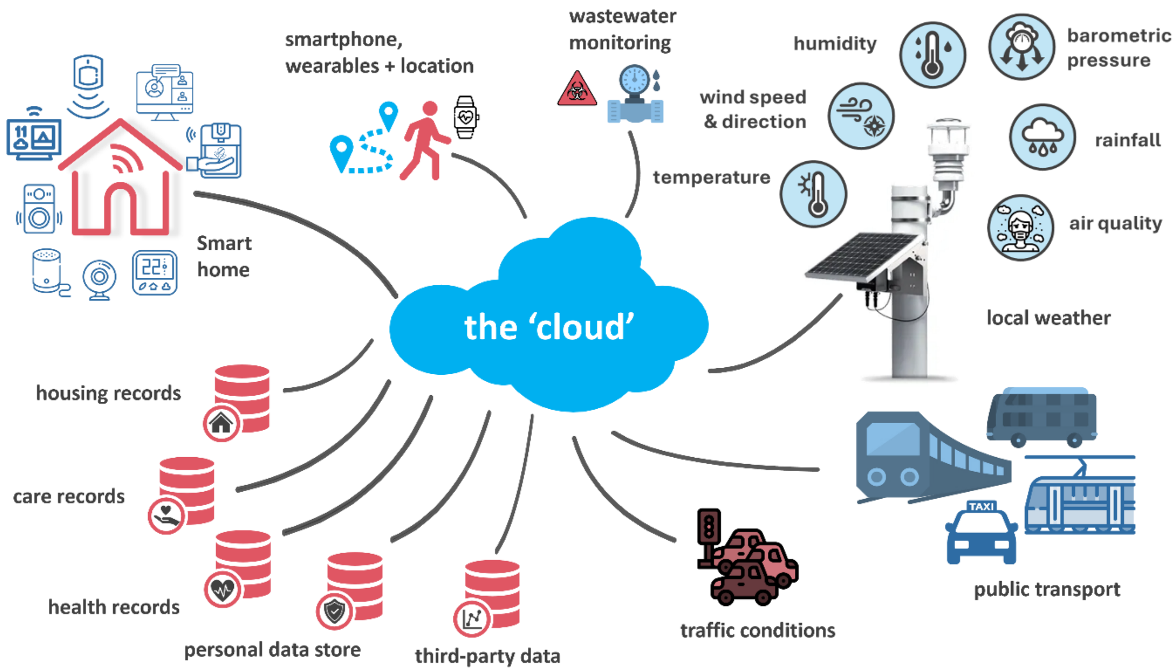

Figure 11: Extending the scope of connected data sources for use with technology-enabled care.

With improved interoperability, digital records can be seamlessly connected, making them a game-changer for service development. Using and sharing data with external organisations helps close the 'care loop' and inform strategic decisions. Policymakers will be able to make outcome-led data-driven decisions, leading to more effective and efficient service development.

Device connectivity

Traditional telecare devices use proprietary radio technology for alarm signalling so interoperability between products from different manufacturers is hard to achieve. It is also why they cannot transmit data, making them incompatible with 3G+ applications. 3G+ devices tend to use mainstream consumer wireless technologies as used in smart home applications, such as:

- **NFC** – Near-field communication is used for 'contactless' applications that securely transfer small amounts of data. It can be used to log caregivers' visits to a home or to provide access to a property.
- **Bluetooth/Bluetooth LE** – Bluetooth is commonly used for streaming audio over a relatively short distance. Bluetooth Low Energy (LE) transmits small data packets between devices, e.g., a fitness tracker and a smartphone app.
- **ZigBee/Z-Wave/Thread** are popular technologies that allow devices to communicate using mesh networking to help extend coverage across the home.
- **Wi-Fi** is ubiquitous in our homes and public spaces and allows devices to connect wirelessly to each other and to the Internet over a high-speed connection to access online services, browse the web and stream media.

These technologies have the potential to reduce reliance on a single supplier and open the possibility of in-home interoperability between products of different manufacturers, although other obstacles (such as coding standards, which can be overcome) exist.

Hub connectivity

In the home, devices typically connect wirelessly to a local hub that connects to the relevant platforms. This typically uses an integrated mobile data connection, a landline broadband connection, or both to provide redundant capacity if one channel should fail. The retirement of the analogue telephone landline connection to homes has impacted how legacy analogue telecare hubs can reliably transmit alarms to monitoring centres. This has been managed by replacing them with digital equivalents. This change does not affect 3G+ monitoring systems as they do not use the PSTN for their data connection.

Direct connectivity

An alternative and emerging connectivity technology that is increasingly being deployed, especially across housing, and other council services, is the Low Power Wide Area Network (LPWAN). Although some solutions may use a local hub, most link sensors *directly* to the Internet. This is achieved by a radio link with a local LPWAN gateway, with a typical range of a few kilometres in urban areas to over 10 km in rural settings. There are several competing technologies, including LoRaWAN and NBIoT/LTE-M. Both offer devices with a typical battery life of 10 years. LoRaWAN has been around for longer than NBIoT. Consequently, it is more mature and has a broader choice of devices, which generally have lower costs than NBIoT due to its wider adoption, although this may level out as NBIoT becomes more established. The range of LPWANs means that a single gateway or cell can monitor thousands of devices. The result is that these solutions are readily scalable, offering opportunities to provide services to entire communities. It also bypasses issues caused by changes to landline and mobile networks.

Cloud services

The digital transformation agenda has increased the use of cloud infrastructure for TEC applications, such as data storage for sensors and hosted monitoring platforms. The advantages of this approach include simplified IT requirements for monitoring providers, cost savings from switching to a subscription-based model, and flexible access to up-to-date monitoring platforms. This shift also allows for versatile remote and mobile working arrangements, shared access to data and applications, and reduced need for large premises and IT equipment and maintenance.

Data-Enabled Care

4G+ applications and services are enabled using data. Data acquisition was considered in the previous section but is barely half the story. The way in which data is processed and combined is fundamental in shaping modern TEC services, enabling new proactive support and preventative interventions. This is described below.

Data processing

Once collected, data is processed and combined to derive useful information about the behaviour, wellbeing and needs of the person being monitored. Complex algorithms, sometimes with machine intelligence, perform this processing. Long-term trends are also established to monitor how significant parameters change over time. This can help calculate critical thresholds for generating alerts using a rule-based 'notification engine' to help bring critical actionable insights or issues to the attention of an interested party, such as an observer or a responder.

Rules-based notification engine

The notification engine is responsible for raising alerts if monitored parameters move outside the normal range ('green') to a point where they are significant, warranting further investigation (an 'amber alert') or are so far outside agreed norms to warrant immediate concern (a 'red alert'). The level of sophistication provided by notification engines varies. Alerts can be set up using straightforward procedural ('If… then…') rules with pre-defined thresholds. More sophisticated approaches involve modifying initial baseline thresholds based on learning the individual's behaviour. Alert notifications may be generated using various approaches, including on-screen notifications, SMS or other instant messaging services, in-app notifications, e-mail, and other platforms via third-party APIs.

Data visualisation

Most leading TEC monitoring platforms provide a data dashboard for offering essential insights about the status of an individual or a group of individuals (e.g. all active monitored individuals or those limited to a geographical area/customer base). Key parameters are often colour-coded for instant review using a traffic light approach into three categories: normal (green), worthy of investigation (amber) or significant, and requiring intervention (red). Further investigation is possible by drilling down to view and consider the underlying data. An example dashboard UI is shown in Figure 12, which is an example from the Archangel platform.

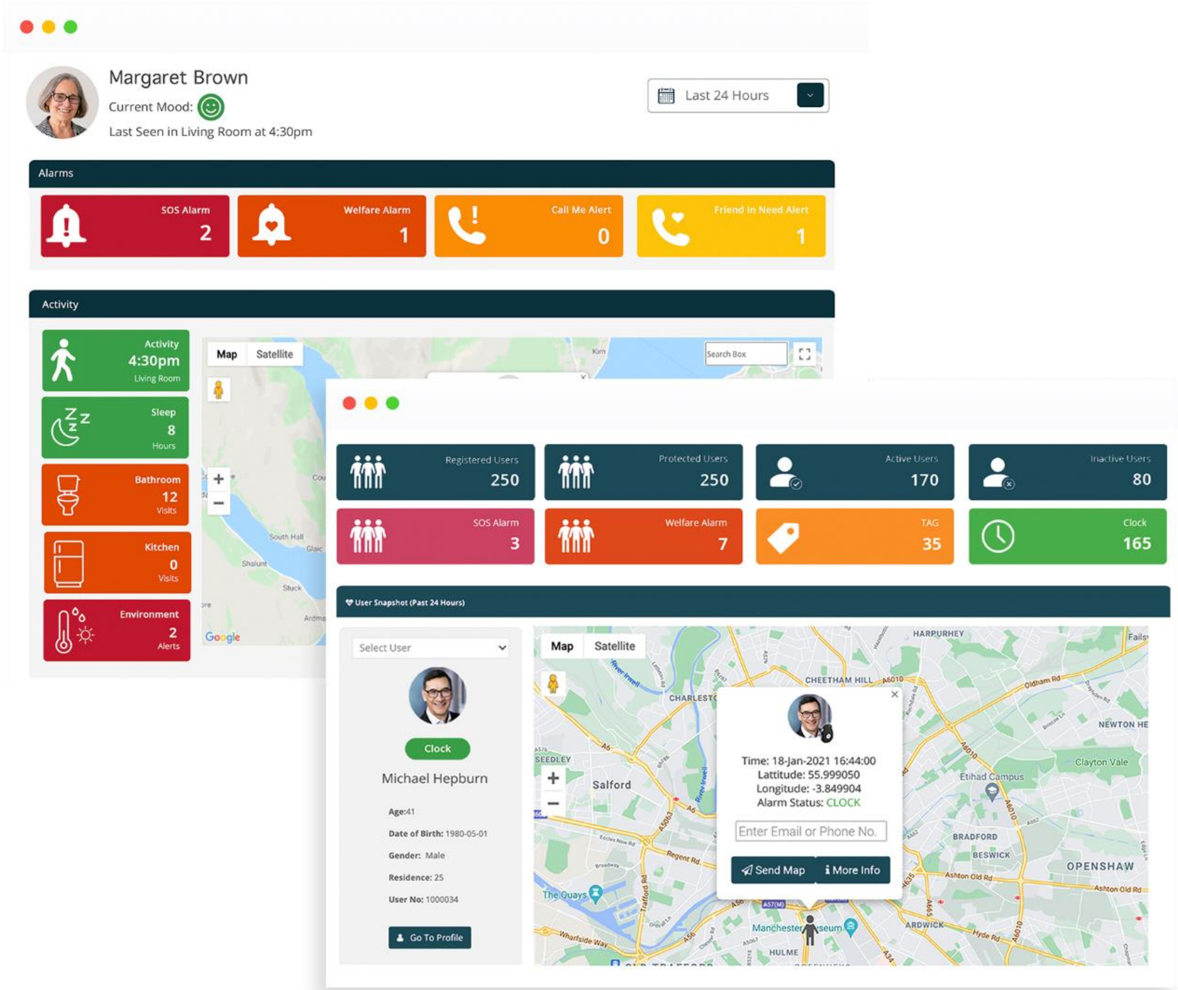

Figure 12: Example dashboards from a modern digital monitoring platform (Archangel).

These platforms also support other applications such as alarm call handling, location tracking, lone worker monitoring, device management, user account management, secure messaging and others.

Building a unified data model

In practice, a service commissioner or provider may depend on systems from multiple vendors, each using a separate technology platform, as indicated in the monitoring centre configuration on the right of Figure 13. This approach is impracticable because it requires switching between platforms and does not offer the benefits of a holistic approach. Far better to be able to use a single integrated platform capable of accessing a 'single source of truth' or unified data model, as shown in the monitoring centre on the left of Figure 13. The ability to achieve this level of integration depends on the willingness of the monitoring platform provider and each technology provider to collaborate and support interoperability between their systems.

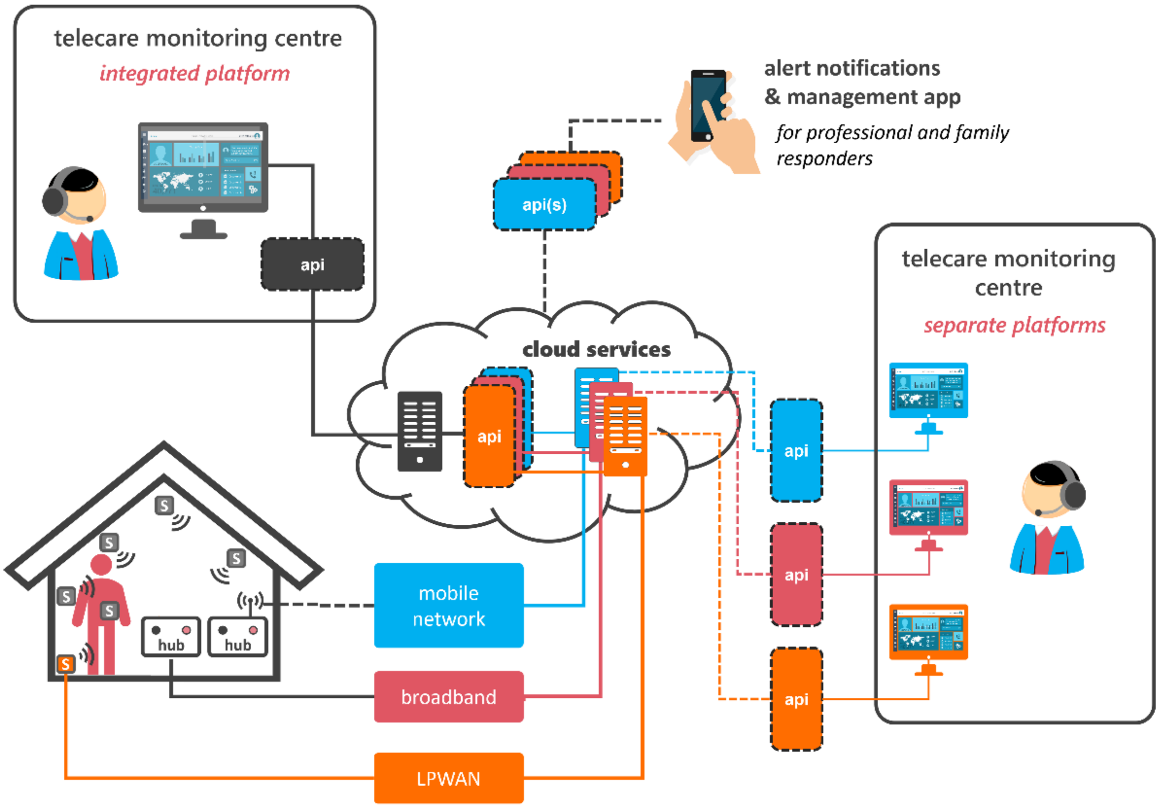

Figure 13: Multiple 4G+ applications each with their own technology stack and user interface.

We call such an arrangement a 'meta' platform – one that can combine data from the Internet of Things and static records, including the examples shown below:

Monitored/'real-time' data	Static records
• Home-based activity monitoring and environmental data • Health tracking data (from a wearable) • Additional wellbeing responses to a prompt/questionnaire (from a smart device or through proactive calling) • Location data from wearable/smartphone • Physiological data (from medical devices/telehealth) • Public IoT devices/applications for additional context & useful information e.g. public transport, local traffic conditions, weather, wastewater, etc.	• Telecare alarm service records • Electronic patient records • Social care records • Homecare agency records • Housing management records • Medication prescription/ administration records

It should be vendor- and technology-agnostic, allowing full 'whole-of-market' interoperability for all connected devices. It would also be interoperable with multiple other extended sources of data allowing information to be shared between key stakeholders as required and according to agreed permissions and consents, Figure 14.

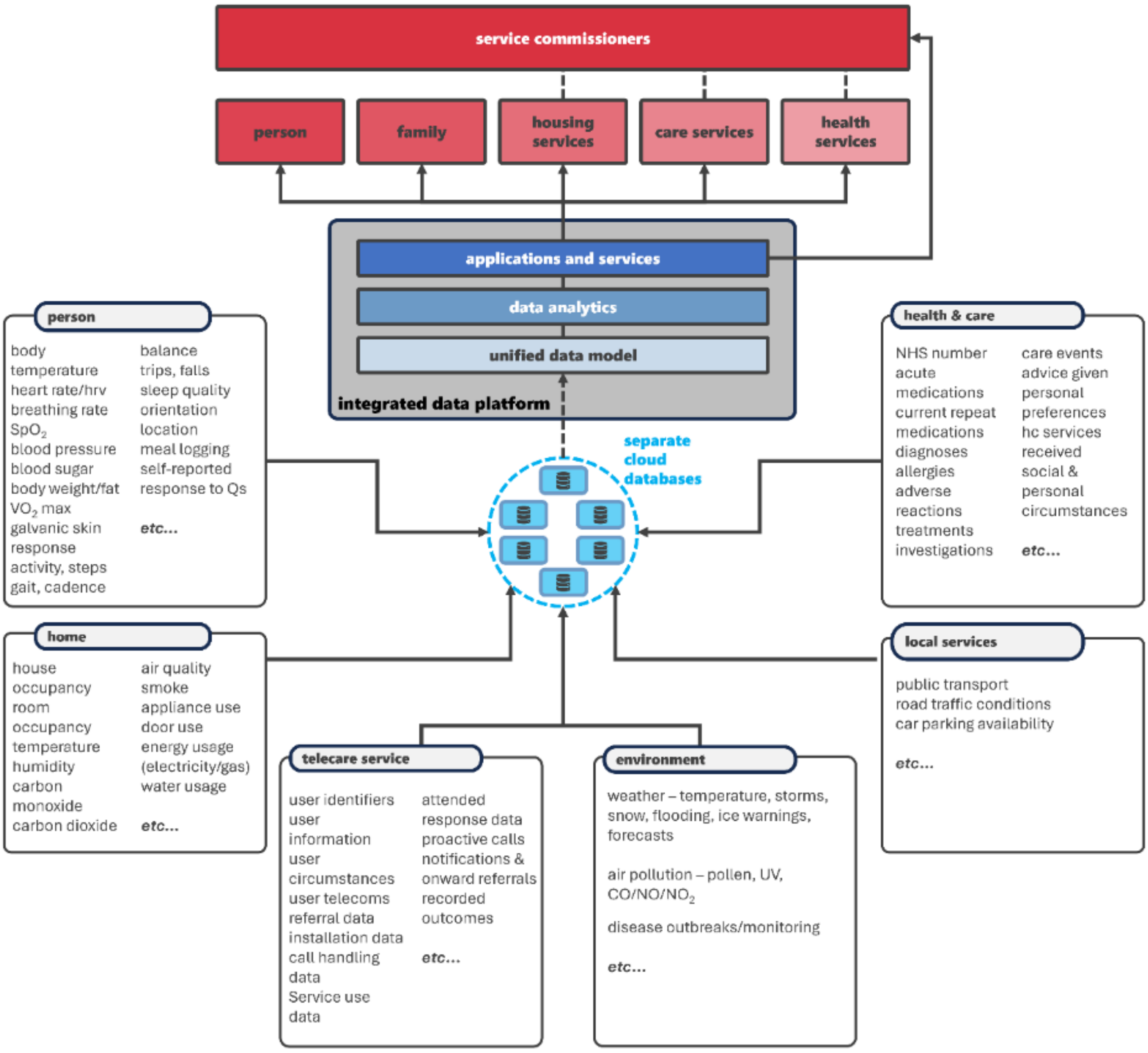

Figure 14: Combining data from different sources to create a unified data model.

The meta platform

Let us then review the requirements of such a unifying 'meta' platform, a high-level overview of which is shown in Figure 15. Starting at the bottom, it shows how sensors can be used to monitor people, places, and things – and how they interact. Smart home functionality is enabled by devices and controllers that can switch on a light, close a shutter or lock, or unlock a door. This also includes wearable and carried mobile devices that support use outside the home. Such systems may or may not have a significant user interface component; if they do, it might be through a touchscreen tablet device, voice assistant, smartwatch, or app.

A layered architecture is needed, starting with a...

- **Universal access layer** – for connecting to products/platforms in the home, on the person, and the Internet of Things. These may have a direct connection or link in using an API[2]. As discussed above, it also supports integration with other platforms and data records using API access and sector-wide/open protocols.

- **Data layer** – a data-aggregation platform that enables a unified data model incorporating relevant data from various sources to enable data-led proactive interventions, support and services.
- **Application layer** – key features that support the delivery of services such as data cleansing, analytics, machine learning and prediction/alerting algorithms.
- **Service layer** – high-level integrated services enabled by the layers below.

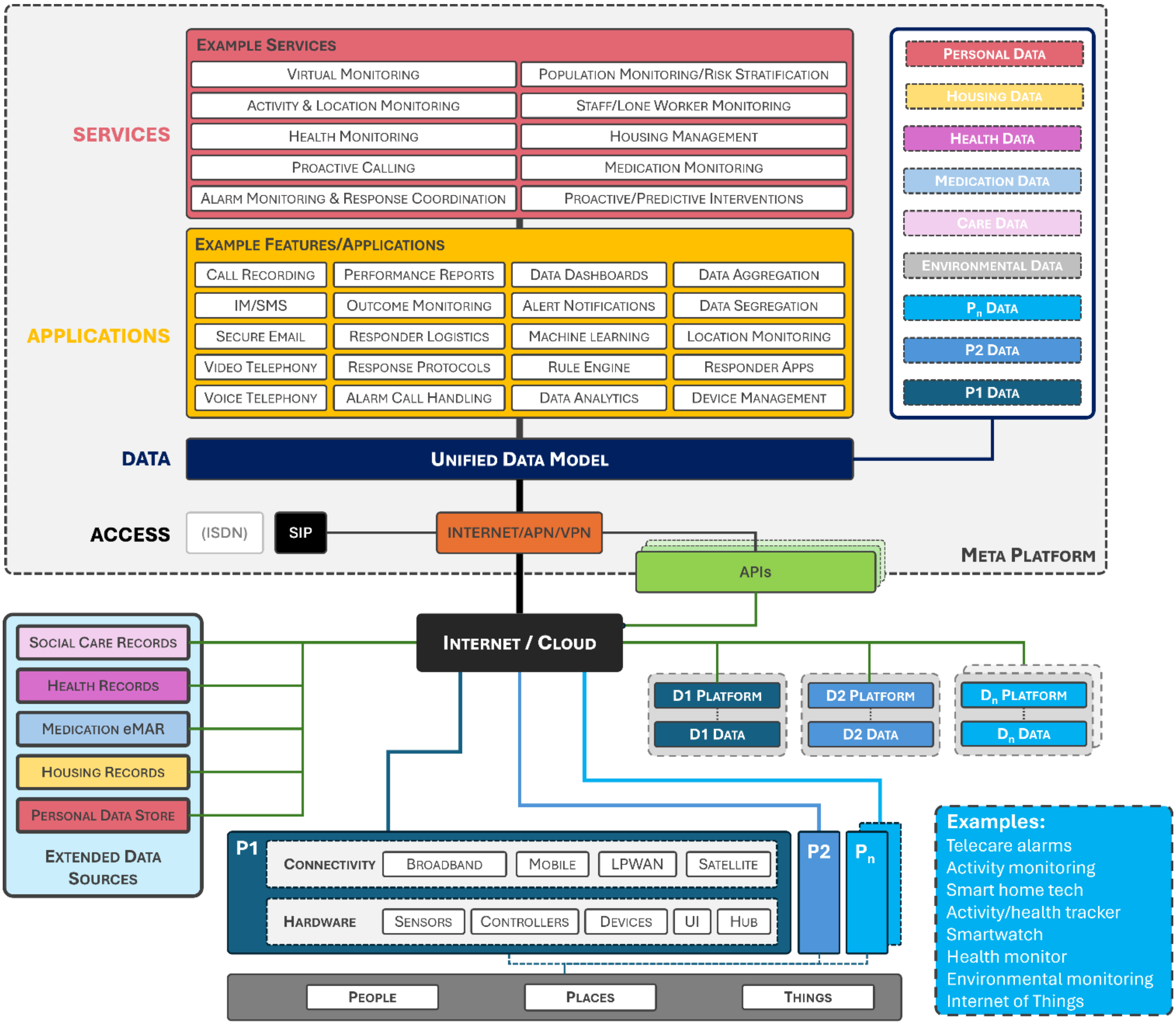

Figure 15: Modular overview of a 'meta' platform.

The goal of a 'meta' platform, therefore, would be to allow access to data from each of these platforms (P1, P2, P_n) using appropriate API access with each. Additional data can be pulled from extended data sources to help build the unified data model to build integrated applications and services. Digital telecare alarms can also be connected

[2] *An API, which stands for application programming interface, is a set of protocols that enable different software components or systems to communicate and transfer data.*

using IP alarm protocols. To achieve this, the platform needs to support secure connections over the Internet or through VPNs and SIP to support IP Voice services. The ability to export data to external records is also desirable.

The key features of such a platform include:

- Built on resilient and adaptable cloud-based infrastructure.
- Supports TEC sector/open standards and is 'whole of market'.
- Applications are built on a unified data model, supporting sector standard minimum data sets and beyond.
- Incorporates intelligent data analytics and risk models for predictive interventions.
- Provides a simple user interface with clear data dashboards.
- Supports an agile approach for a wide range of use cases.
- Includes skill/availability-based routing for optimal response.
- Offers comprehensive outcome and performance monitoring and reporting capabilities.

Towards a New Hybrid Dispersed Model of Care

As the adoption of 4G+ technologies increases, several factors will influence how TEC services evolve. As we move into the digital age, the ARC-based reactive model which has been in place for many decades, is ripe for disruption due to several factors:

- **Economies of scale:** Monitoring services are being consolidated due to financial challenges faced by district councils and local authorities. Alarm monitoring centres are costly to operate, requiring a minimum of 2 call handlers working 24/7, even though the volume of emergencies during nights and weekends may be low.
- **Shift to mobile:** Increasing use of smartphones, replacing the need for landline connections.
- **Digital transformation:** Adopting consumer technologies within homes to provide increasingly intelligent TEC applications and services, focusing on data.
- **Data-led preventive services:** Reframing the role of monitoring services based on long-term data trends for a preventive approach.
- **Self-support:** A growing trend towards self-care and support using smart technologies and apps.
- **Virtual support:** Remote support services provided to individuals as needed, e.g. using videophone or voice calls.
- **Family monitoring:** Family members can respond to alert notifications with monitoring services providing a backup service.

All the above means that the appeal of the 'linear' ARC service model is waning and is likely to be replaced sooner rather than later by a new distributed model, Figure 16, which offers both an emergency alarm approach (to the left of the user) and a preventive approach (to the right), where new and emerging services and agencies will offer interventions aimed at delaying or preventing future threats to the health and wellbeing of monitored individuals. This more agile model can be adapted to support most likely arrangements.

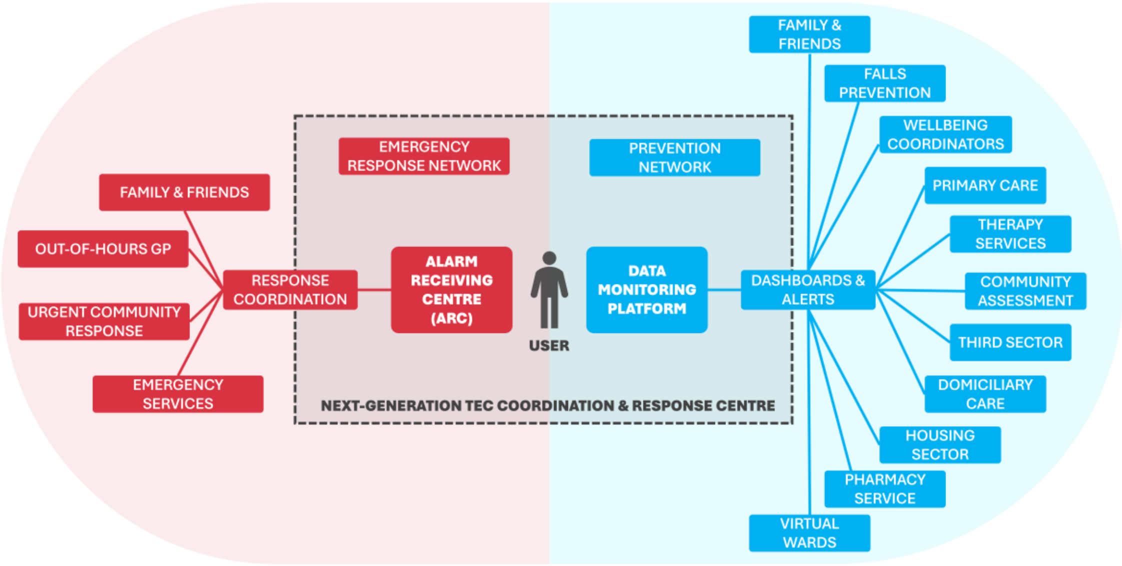

Figure 16: The shift from linear telecare to a more agile and distributed digital care service.

Figure 17 shows a hybrid model consisting of three main elements: people-based support, virtual support, and sources of information and advice available through the Internet. The role of a monitoring service, as well as the roles of different forms of support and physical response, is incorporated into this design.

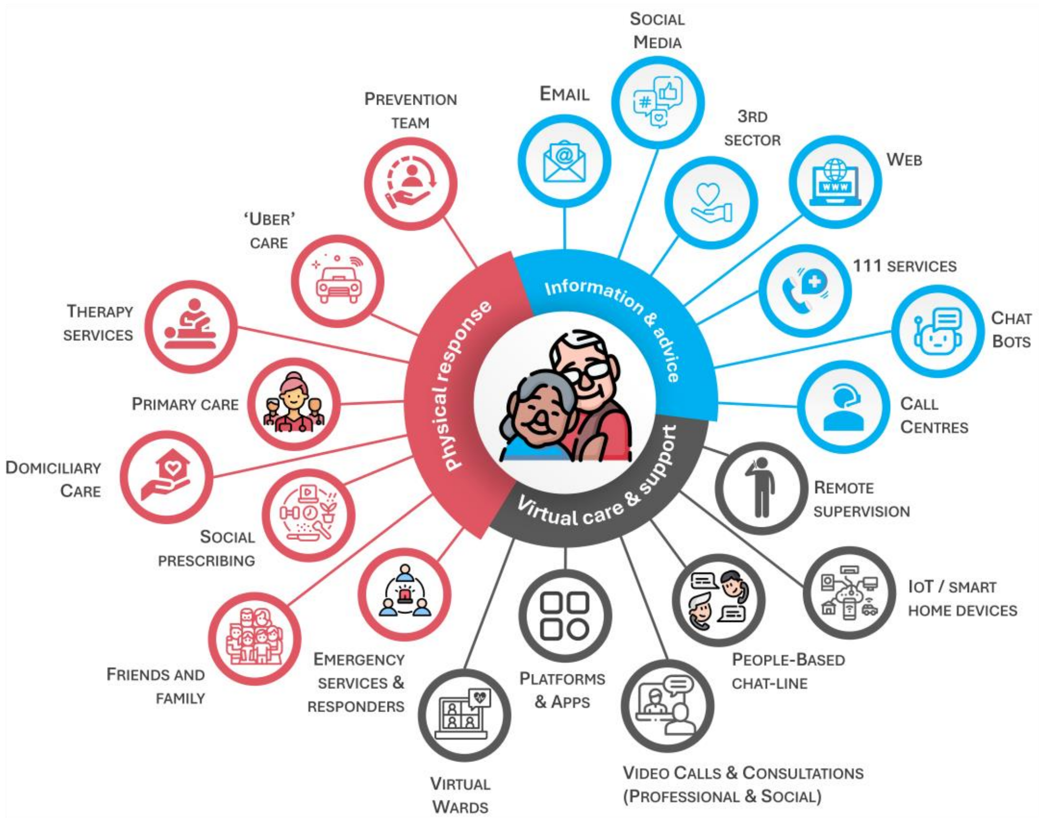

Figure 17: Components of a dispersed and integrated TEC model.

The model includes routine forms of support, such as domiciliary care, and social prescriptions. In this case, we extend the concept of social prescribing to include day centres and other forms of entertainment and occupation, such as Virtual Reality applications, that can be delivered at central locations or to individuals' homes using peripatetic support staff.

A Glimpse of the Future?

How might a unified data model for technology-enabled care enable intelligent applications to change how people are supported?

We consider the type of support that could be provided using two fictional vignettes that compare how an individual might be supported using current approaches to how they might be helped using linked-up next-generation technologies, considering the effect on outcomes.

Lorna

Lorna, 82, lives by herself after her husband of 53 years passed away a couple of years ago. She keeps busy and is reasonably independent but does not drive any more after she gave up her car when it was deemed unroadworthy. Lorna has a medical appointment with a specialist to discuss her mobility, as she has recently stumbled a couple of times and fell over when going down the step from her landing into her bathroom at home. She wasn't carrying her mobile telecare alarm, which might have automatically detected the fall. She did have her telecare alarm pendant around her neck, but on this occasion, she didn't feel she needed to bother anyone. Luckily, she hadn't badly hurt herself and managed to get up unaided, with only a few bruises and some hurt pride. This event led her to ask her GP about her mobility, and the GP arranged for her to be seen by a mobility specialist in her local healthcare clinic.

The morning of her appointment is cold and icy. The salt gritters had been out the night before, and some snow had stuck to the roads and pavements outside her home; they were slippery...

Now...

Lorna planned to catch a bus into town for her appointment. Unfortunately, she was running late – everything took longer these days – so she had to walk a little quicker than usual to get to the bus stop in time for her 9:43 bus, which took her right past the clinic. Lorna slipped on an icy patch and fell as she turned on the pavement. Thankfully, she didn't hit her head, but immediately knew something was wrong.

Luckily, she wore a mobile telecare alarm with GPS and automatic fall detection. It detected the fall and raised an alarm call through her monitoring service, where they spoke with Lorna and some other people who had come to assist. They called for an ambulance and notified a mobile responder – luckily there was one not far away, so she did not have to wait long for Anna to arrive; she comforted and assessed Lorna – who was in some pain – and established that she may have indeed broken a bone. Anna provided Lorna with a blanket and support for her head.

After a wait of about 45 minutes, an ambulance arrived and took Lorna to the local hospital's Accident and Emergency unit where the triage nurse suspected a fractured hip. The hip repair operation was performed the next day. It was a success, enabling her to be discharged to her daughter's home after a few days. She would stay there for a few weeks while recovering.

The telecare service was notified of her new living arrangements, and they informed her that her alarm pendant would not work until she returned home and to make sure her mobile alarm unit was always within reach when alone in the house. Lorna eventually returned to her own home, but after her fall, her confidence was not what it was, and she didn't go out as much as she used to.

What if?

Lorna's Intelligent Support and Lifestyle Assistant ('ISLA') – an intelligent voice assistant provided by her care technology monitoring service, knew that local weather conditions were terrible and that the local transport networks were struggling with the icy conditions. It also knew that Lorna was at an increased risk of falling – the activity sensors in her home and her wrist-worn health tracker showed that she had slowed down recently and stumbled a few weeks ago. Data from her health tracker also indicated her gait showed signs of imbalance. ISLA also knew she would attend a mobility assessment clinic this morning. Due to the increased risk of falling due to internal and external factors, ISLA decided to intervene and suggest some options to Lorna…

ISLA knew the local clinic where she was due to have her scheduled medical appointment supported remote video consultations. So, it explained the situation to Lorna and suggested whether it might be an idea to have her consultation remotely using her video care console. Lorna had tried this before, and although it was adequate, she decided she would rather see the specialist in person on this occasion and told ISLA of her preference. ISLA asked how Lorna was planning on getting to her appointment, and Lorna decided she would catch a bus – probably the 9:43 bus that took her right past the clinic. ISLA searched to see whether the bus was running on time and established that it was running 12 minutes late this morning. Lorna was pleased to hear this as she was running a little late and was wary of slipping on the icy pavement.

As it happened, just before Lorna was due to leave her house to catch her bus, ISLA caught her attention and let her know that a mobile telecare responder was due to pass her home in the next five minutes and could provide her with a lift to her appointment if she liked. This sounded like a much better option and would avoid walking down to the *bus stop, so she let ISLA know she would like this. A few minutes later, Lorna answered the door to Anna, a mobile telecare responder she had met before, who escorted her to her car and took her straight to her appointment. Lorna was very grateful, but Anna explained she was heading back to the office anyway and the clinic was on her route. Anna checked with Lorna about how she planned to get back home, and she decided to book a taxi – just in case!*

The specialist recommended some strength training to improve her balance and provided her with some details on a local Tai Chi exercise class, especially for older people, that could be offered as a social prescription. Lorna thought this sounded like a good idea and took up the offer…

Lorna now looks forward to her Tai Chi classes and has made a new friend, Sally, with whom she shares many interests, including a love of reading, various TV shows, and cake and coffee! They now see each other regularly, independent of the classes. She has also found that her strength has improved, and she now feels more confident about her mobility.

George

George, 77, lives independently in a sheltered housing scheme, having moved there shortly after his wife died last year. He is overweight, with type 2 diabetes and mild hypertension; both controlled using oral medication. He is prone to bouts of depression and sometimes misses meals and admits that he probably does not drink enough during the day. He used to be a heavy smoker and drinker until he gave up in his mid-50s due to health concerns, but he has taken up smoking the occasional cigar and enjoys a glass or two of red wine most evenings and the occasional beer at the weekends with his supper. He is prone to respiratory infections.

One week in March, George feels increasingly under the weather with what appears to be a lousy cold…

Now…

George hadn't been feeling great for a few days. He just couldn't shift a cough and felt a little shaky. Had he taken his medications last night? He wasn't sure… and couldn't remember if he was supposed to skip a missed dose or take extra… George was watching the morning news on the television, although he wasn't sure why… just endless bad news! Although, he couldn't concentrate… he was tired and felt a little drowsy. He'd not been sleeping well recently. He should make himself breakfast, but just couldn't be bothered. He didn't feel like eating … Maybe a nap would be a good idea…

George woke up startled by the sound of his phone ringing. He answered it and took a while to realise who he was speaking to. It was the telecare service! He realised he hadn't pressed the 'I'm OK' button on his telecare hub before 10 am! No matter, they were always very understanding. He told them he was fine and had just nodded off after a bad night's sleep (although he suspected he was coming down with something). They asked him how his blood sugar readings were, and he told them they were fine (although he'd not taken a reading for several weeks now). He apologised, but they seemed happy enough. He settled down to watch his favourite quiz show on the telly…

The following day, George felt much worse, and couldn't get out of bed. He reached over to find his wireless pendant to raise an alarm for help, but it wasn't there! He remembered that he had taken it off the other day when Emily, his daughter, had popped over to see him – he never liked admitting that he needed that awful button! He felt too poorly to get out of bed to press the button on the alarm hub downstairs for help; he'd also left his mobile phone in the kitchen to charge overnight. No matter, the telecare service would be in touch eventually after they realised that he hadn't pressed the button (he looked at his bedside clock – it was 6 am) … in 4 hours!

By the time the monitoring service reached out to him, and received no response, George's condition had worsened. An ambulance arrived to find him dehydrated and disoriented, and with a bad cough, requiring hospitalisation. He was in hospital for 10 days, waiting for social care to arrange a domiciliary care package when he was discharged. Thereafter, a carer would call twice daily to supervise George taking his medication and to prepare his meals. The result was that George could no longer go out for the day. He had lost his independence.

What if?

George was beginning to feel a little under the weather. He'd started coughing the day before yesterday and just wasn't feeling himself. He had a few aches and pains, which made it difficult for him to get out of bed and walk to the bathroom first thing. Luckily, it seemed to be alright after he'd moved around for a bit.

His ISLA care hub pinged when he entered the lounge – "Hi George, how are you feeling?" It offered him some options to respond, and he decided on "Not great!" – he wasn't sleeping so well and felt more tired than usual – and there was this cough. George relied on his ISLA voice assistant – it reminded him to take his medications, when he had appointments and even to make a cup of tea! That, and his health tracker, which he liked because it told him the time, allowed him to ask his voice assistant to play an Elvis song, and let him call for help if he ever needed to – much better than that old alarm pendant he used to have! ISLA suggested he make himself a drink, but George had just sat down and didn't fancy getting up immediately. The ISLA care hub was connected directly to various devices in his apartment – motion sensors, a kettle-use monitor, and a fridge door sensor. It also had access to information about the ambient conditions in his home, provided by the environmental sensors that the housing association had installed throughout the scheme (including room temperature, humidity and air quality).

ISLA was prompted to ask about George's wellbeing after receiving an update from his wearable health tracker. The update showed his agitation during the night, his low saturated blood oxygen levels, and his laboured breathing. This, together with a significant drop in his usual activity levels and reduced fluid intake, raised an alert that prompted ISLA to check in with George and notify the monitoring service.

After a while, ISLA pinged again, "George, would you like me to contact Emily and let her know you aren't feeling great?" George thought about it for a while, he would like to see his daughter, but she was a busy teacher, and he didn't want to cause her any undue worry – especially at this time of the day. He told ISLA it was fine. ISLA then reminded him to take his morning medication with his cup of tea. George heard but couldn't be bothered to get up to fetch his tablets from the drawer across the kitchen. ISLA pinged again and said, "George, shall I turn up the heating for a little bit? It's a little chilly don't you think?". It was chilly, but George was trying to reign in his spending, "No, thank you, ISLA", he replied. He turned on the telly for the news…

ISLA pinged again, "George, Anna from the responder service is going to pop round to see you later this morning at around 11 a.m. just to see if you are alright. Is that OK?" George was fond of Anna, and he was happy to know that he would have some company. He let ISLA know that it would be fine.

Anna was just collecting her coffee from the drive-thru in her mobile response vehicle when she received an amber alert on her car's smart display. She accepted the task, and asked for details… "George Williams, age 74, requires an urgent wellbeing visit. Activity levels reduced – Significant change in sleep score – Elevated body temperature – Elevated resting HR – Oximetry low – Hydration reminders increased – Acoustic analysis indicates a new and persistent cough – Medical records indicate he is prone to respiratory infections. The average self-reported wellbeing index is down 26% over the past 6 weeks. Ambient environment low-temperature alert – Action… Query: Reduced appetite? Query: Infection? Query: General wellbeing? Query: Environmental comfort?"

When Anna arrived at George's house, he answered the door very slowly, and she could instantly see that he didn't look well. She asked him how he was doing, and he told her about the cough, being off his food, and generally feeling under the weather. He also said he was a little down as the anniversary of his wife's death was approaching. Maybe he wasn't taking as much care of himself as usual. She suggested he make an appointment to see his GP as she thought he had a bad chesty cough. She said getting it sorted before it got worse would be better. He agreed.

Anna asked ISLA to arrange for an appointment with George's GP surgery. They were linked to the ISLA platform and supported an automated booking system if the data supplied to them indicated that an appointment was advised. George was booked in as a priority to see the GP the next day, where he was provided with antibiotics and advice on rest. His blood pressure was high, and the GP ordered some blood tests. A follow-up appointment was arranged, where the GP informed George that his blood sugar A1C level was significantly increased. The GP altered his medication to address his blood sugar and pressure issues. His medication concerns were noted and addressed using a smart *dispensing device to administer his medication with remote supervision by the pharmacy. He was also provided with a blood glucose monitor that automatically uploaded readings to the ISLA platform and referred to a specialist type 2 diabetes support group to assist with his diet and a local walking club to help with his overall health.*

Conclusions

Technology continues to advance, offering new ways of performing routine tasks and helping us to get on with our everyday lives. Inevitably, new applications will emerge that will help us to live more independently and, through the support of others, help us to compensate for losses of strength, cognition, sensing and other factors that decline with the years. Until recently, such applications were limited to raising an alarm to request help when an individual had a problem. Increasingly, services built using data are being deployed. These can identify important context and significant changes in an individual's lifestyle or wellbeing that can trigger a timely intervention before an emergency arises. This offers the hope of implementing prevention-based strategies that will offer early interventions to improve outcomes, rather than relying only on reactive responses to incidents such as a fall. New mechanisms of preserving data ownership and managing consent will be required to keep individuals in control of their data and avoid unrestricted sharing and use beyond the preference of the individual being supported.

This approach's success depends entirely on building a holistic model of an individual's wellbeing and life circumstances. This relies on a thorough needs assessment, coupled with using sensor data and incorporating other IoT-connected devices and static records to gather pertinent information. This requires interoperability between all relevant components of the system, allowing a unified data model to be established. It also needs a meta-platform approach capable of accepting data from multiple sources and sharing data with other key stakeholders. This provides service providers with a single point of access to all relevant data. When considering a new digital monitoring platform to enable hybrid and dispersed services, commissioners should consider these key features:

- **Communications:** Support for a wide range of communication channels.
- **Device connectivity & Interoperability:** Compatibility with a variety of devices and connection with other platforms using APIs and open protocols.
- **Real-time monitoring:** Ability to process data in real-time and trigger appropriate actions.
- **Accurate and insightful data:** Analysis of data trends and proactive interventions.
- **Data visualization:** User-friendly visual representation of important information with different dashboards/viewpoints for each stakeholder.
- **Care coordination:** Integration with other healthcare systems and data sharing.
- **Reliable and trustworthy:** Robust security features and ethical data handling.
- **Scalability:** Easily adaptable to changing demand.

- **Extensible features:** Ability to add modular functionality and link to third-party platforms.
- **Fair charging model:** A transparent and fair pricing structure that doesn't penalise individuals with multiple needs who require several different monitoring systems.
- **Well-evidenced:** Validated product features before deployment.

Although smart-technology-based and virtual interventions will help to support individuals in many instances, a physical response will still be necessary in many circumstances to avoid an adverse outcome. Automation and smart home technology may make an increasingly important contribution, as will robotic devices that help to keep an eye on older and more vulnerable people, but many responses will be from families, friends and professional carers and responders. They will be empowered by apps that guide them where to prioritise their support. New protocols will be needed that advise on the best interventions to achieve the optimum outcomes. They will need to learn how and when to attend when predictions indicate a potential catastrophe.

In all these cases, services should operate in a hybrid manner, combining technology's benefits with conventional support delivered by dedicated staff. A dispersed model that combines information, virtual support, and physical care will emerge but will depend on the collection, processing, and good use of the data available through a next-generation TEC system.

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About T-Cubed

T-Cubed Ltd. was founded in 2008 by Dr Gareth Williams and Dr Kevin Doughty. It is an independent consultancy specialising in digital care, assisted living technologies and technology-enabled care services. The company's immediate success was marked by its commission by the six councils of North Wales – Anglesey, Conwy, Denbighshire, Flintshire, Gwynedd and Wrexham – to revolutionise the sustainability and future of telecare monitoring services across the region. The analysis and recommendations led to the creation of a single monitoring body across two sites, a model many other local authorities adopted to enhance the quality and efficiency of their service offering.

T-Cubed then published a quality framework used as the basis of service evaluations across the UK, including leading providers in Northern Ireland, Scotland, and England. These led to service improvement plans that were adopted by many local authorities, who also subscribed to the Telecare EPG, an online resource for comparing telecare and other electronic assistive technology devices. Over 50 local authorities and NHS trusts were rolled into subscriptions during 2012.

T-Cubed was recruited into the Liverpool DALLAS (delivering assisted lifestyles at scale) project in 2013/14, for which they developed the Vivo Pro online resource that enabled professionals and members of the public to match the most appropriate items of technology to the needs of people in their care. The methodology was then adapted for use in an interactive team training workshop, which has been improved over several years to satisfy the changing technology and care agendas and to address issues such as cost and ethics. TEC training has been provided in West Sussex, the London Borough of Bromley, and North Wales, focusing on care technologies for people with a learning disability. This follows a successful 2-year project with the Alternative Futures Group on Merseyside.

Over the past 15 years, T-Cubed has provided consultancy and advisory services for over 40 organisations, including local authorities, housing associations, product manufacturers and national governments and agencies. More recently, T-Cubed has also provided service review and support services for Pobal regarding the Seniors Alert Scheme in Ireland and evaluated new product designs on behalf of major manufacturers.

Find out more about us at t-cubed.co.uk

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