5G in Healthcare
Extending the Scope of Connected Care

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Introduction – Anticipating 5G

Many users across all industry sectors are anticipating the arrival of 5G in the hope that this will transform the industry they are working in. 5G infrastructure is expected to serve a wide range of applications and sectors like automated mobility, e-health and energy management.

" **telehealth use in the USA has increased 38 times from the pre-COVID-19 baseline**

Such vertical markets address specialised needs with a diverse range of networking and computing requirements. Further, 5G is seen as a critical element in advancing the digital economy and society. This is due to its ability to provide real-time data collection and analysis with virtually ubiquitous, ultra-high bandwidth and ultra-low latency connectivity.

At the same time, we are moving into a new era of healthcare. There has been a surge in telehealth resulting from two main causes: an ageing population, and the Coronavirus pandemic of 2020-21.

The Case for telemedicine
As people age, they accumulate more health conditions, particularly chronic conditions. Chronic diseases are associated with increased unplanned acute hospital use. Remote patient monitoring or telemedicine can detect disease exacerbations and facilitate proactive management, reducing costly acute hospital stays.

In parallel, the Covid-19 pandemic forced speedier moves towards telemedicine. The impact of the pandemic has exposed cracks in the way systems deliver healthcare, as the response to the crisis has unleashed continuous innovation which has had an impact on the way care is delivered across front-line services. This has led to healthcare teams and providers rethinking how to get the best evidence to clinicians, as well as guiding

them through decision-making care pathways. That said, it has also catalysed forces for new ways of thinking about healthcare and for positive change that is needed in a post pandemic world.

80 percent of older adults have at least one chronic disease, and 77 percent have at least two. Two-thirds of adults aged over 65 are expected to be living with multiple health conditions by 2035. The most common of these are arthritis, high blood pressure, respiratory disease, cancer and diabetes.

Concomitantly we are seeing a shortage of full time clinical staff: for example in UK hospitals, mental health services, and community providers are now reporting a shortage of nearly 84,000 full-time emergency staff. 36 million nurses and midwives will be needed worldwide by 2030. (Source: Kings Fund 2021)

This begs the question – will there be a 'return to normality' post Covid? Many analysts believe this is unlikely, since the case for telemedicine has been proven. For example, telehealth use in the USA has increased 38 times from the pre-COVID-19 baseline.

Additionally, some regulatory changes that facilitated expanded use of telehealth have been made permanent. Investment in virtual healthcare companies has reportedly grown, along with the growing elderly population

McKinsey July 2021 Telehealth: A quarter-trillion-dollar post-COVID-19 reality?

and increasing life expectancy. Analysts also report a rising demand for wearables and connected devices, and a rising expenditure for ventilators due to Covid-19.

Various agencies are responding to these changes. For example the UK's Connected Places Catapult agency is delivering a multi-year programme in support of the government's goal of helping older people to live independently at home. All this stimulates demand for remote patient monitoring and the equipment needed for it.

The data transmitted are disease-specific and commonly include measurements like blood pressure, weight, heart rate, respiration rate, pulse oximetry, spirometry, temperature, blood glucose levels or specific symptoms. Data can be collected automatically (through implanted or wearable devices) or manually collected by the patient using peripheral devices and a transmission hub.

5G Possibilities Across the Entire Continuum of Healthcare Settings

In this section we identify six care settings unified by continuity of care for a particular patient (**Figure 1**). Each features the activities involved in the patient's treatment. There is a case for 5G communications making each of these functions more efficient, as shown in the table (**Figure 2**).

Figure 1. *Continuum of care across six healthcare settings*

- Ambulance
- Emergency Room
- Field Hospitals

- Biomedical Research
- Drug Development
- New Therapies
- Clinical Trials

Connected Infrastructure & Readiness

- In-Hospital Stay
- Operating Theatre
- X-ray/Scanners

- GP Surgeries
- Dental Surgeries
- Opticians

- At Home
- Rehab
- Assisted Living

- Care Home
- Nursing Home
- Rehab
- Assisted Living

For more details on Figure 1, see previous report in this series at
https://www.sierrawireless.com/resources/white-paper/connected-medical-devices/

Figure 2. *5G attributes that can enhance different care settings within healthcare*

Care Setting	Activity / Facility	5G Attributes
1. Ambulance / Emergency Room / Field Hospitals, pop-up centres for acute care, vaccinations etc. *Use Case No.1*	Critical data for first responders including X-Ray, picture data Connected ambulance Emergency room readiness	Immediacy: Rapid, reliable and secure transfer of large amounts of complex data (picture data) – real time streaming
2. In Hospital: Operating theatre, X Ray, Scanners, heavy equipment, Beds as Equipment *Use Case No.2 & No.3*	Bed occupancy, Asset tracking (RFID), Connected machines – ventilators, infusion pumps, Vital signs monitoring with Handheld terminals, Staff and patient safety with wearables Environmental sensing (air quality, fire detection), HVAC, Robotic surgery, Laparoscopy (keyhole surgery)	Reliable and secure data transfer for vital signs monitoring Immediacy – ultralow latency for robotic surgery, handheld terminals, staff and patient safety Location accuracy (beds and patients move) VR-based surgical training
3. Care home / Nursing Home / Rehab / Telemedicine	Asset tracking (RFID), Patient tracking, geofencing Fall detection, Assistive Living e.g. smart beds, smart mattress, Chronic disease monitoring e.g. diabetes via continuous glucose monitoring, Environmental sensing (air quality, fire detection), HD virtual consultations via video	Immediacy – ultralow latency Enhanced video Hazard sensing Reliable and secure data transfer
4. At home / Rehab / Telemedicine	Assistive living, Fall detection Chronic disease monitoring, Geofencing	Immediacy – ultralow latency eg allergy attack Reliable and secure data transfer
5. GP Surgery / Dental Surgeries / Opticians	Test results notification Connected tools	Reliable and secure transfer of large data packets (video) Immediacy
6. Drug Development / New Therapies / Biomedical Research / Clinical Trials *Use Case No.4*	Data collection and transfer Analytics Planning	Reliable and secure transfer of large amounts of data Enhanced video (clinical trials)
Connected Infrastructure & Readiness *Use Case No.5*	Test results notification Connected tools	Reliable and secure transfer of large data packets (video) Immediacy

Care Setting 1 Comprises intensive care and emergency infrastructure, including field hospitals and pop up hospitals of the type that were set up to deal with the Covid-19 rush of patients. The requirements are around the needs of the patient and the staff, in this case, to ensure that:

- The facilities, equipment, staff are in the right place and ready for the patient intervention

- The emergency room is ready to receive the patient while in transit in the ambulance

- These needs depend on access to up-to-date electronic health records for anyone involved in the care of the patient.

- 5G will allow very large files to be transmitted very quickly (imaging files, scans) with up to 1GB of information per patient.

- Large amounts of data can be shared in seconds for example between the ambulance and the remote specialist

- Ambulances communicate back to the hospital with high resolution images/videos in a timely manner (ultra sound) to make an early diagnosis with a remote expert

- 5G allows a lot of data sharing across various departments involved in the patient's continuum of care table.

> **5G will allow very large files to be transmitted very quickly with up to 1GB of information per patient**

Use Case No.1
5G in emergency cases
The EU-funded 5G-TRANSFORMER project has demonstrated a new system for 5G-based health emergency plans. This personalised 5G automatic system reduces the time of intervention and minimises errors in emergency cases. The project utilises the concept of network slicing, which paves the way to leveraging the potential of 5G.
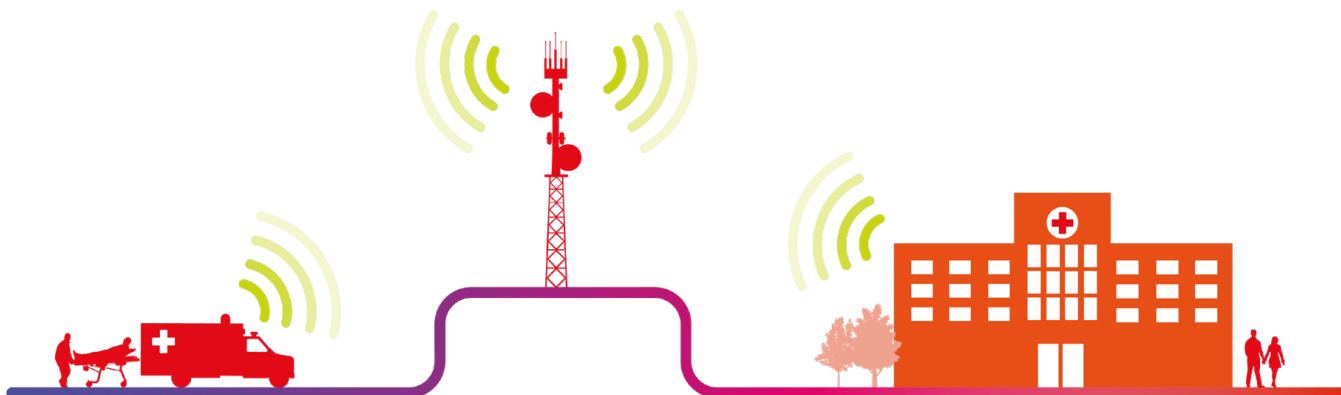
Care Setting 2 There are many ways that 5G will provide tangible new value to hospital care systems. It enables more pervasive and smart data collection, greater capacity and speed, with real time access to hospital support systems with many different types of devices connected. Allowing real time clinical support information being entered into the system at the point of care will allow clinicians to suggest better courses of treatment at an earlier stage.

Use Case No.2

The Connected Hospital - Twenty first century hospital – Zuyderland Medical Centre Netherlands

This hospital, termed the hospital of the 21st century, has been designed to feature the latest technology with full connectivity for optimising patient well-being and the quality of care.

The staff workload in hospitals is enormous, and much time is wasted searching for assets and wandering patients. Smart, connected hospitals such as this feature the integration of bedside terminals, RFID to locate equipment, workstations, IP networks, fire safety and security systems, and a building automation system for clean air to provide a comfortable environment for patients. Electronic medical records no longer need to be transferred from one department to another – a task that used to take valuable time. Here the 'smart infrastructure' has been provided to optimise space efficiency and support the healing process.

Use Case No.3

Robotic Surgery

5G and AI with precision robotics are leading edge now but will become mainstream. Routine surgeries like cholecystectomies as well as more complex procedures could benefit from the precision and accuracy that robotic surgery brings. In the future surgeons operating remotely might be able to manually 'feel' the organ they are operating on. According to Ericsson, 1 millisecond latency would be needed for haptic feedback; high throughput will support HD imagery streaming; high network availability and minimal packet loss will allow an uninterrupted procedure; and mission-critical security given potentially life-threatening implications of a breach.
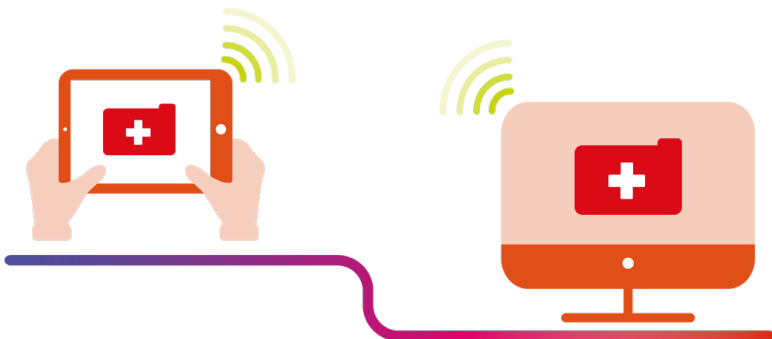
Care Settings 3 & 4 Programmes have been ongoing for years across Europe and elsewhere to develop ways of helping people with chronic conditions to manage their conditions away from the hospital. Assistive living applications are based around telemedicine and wireless connectivity, and focus on the development of an open, standardised, integrated platform to deliver connected ICT-based solutions in a variety of areas.

For those applications that would benefit from faster, near real time transmission of data from the patient to the IT system, 5G could provide performance improvements, additional capacity, higher data speed, lower latency, and lower cost per bit; these will enable some healthcare applications on wireless cellular networks which were not possible with 4G.

Care Settings 6 The activities supporting the development of new drugs and new therapies, designing clinical trials generate huge amounts of data. 5G supports the secure and reliable transmission of the wealth of new clinical data needed for planning and designing new and improved therapies.

The design of biomedical research and clinical trials programmes will be fed with huge amounts of data from new sources afforded by telemedicine.

> ## 5G supports the secure and reliable transmission of the wealth of new clinical data needed

Use Case No.4

Electronic Health Records
Electronic Health Record for Clinical Research (EHR4CR) is a European project designed to improve the efficiency of conducting clinical trials.

Connected Infrastructure and Readiness

The six care settings in Figure 1 are underlain by an infrastructure that provides all the connectivity needed for telemonitoring readiness, hardware software, connectivity and people involvement. Training of staff but also patients themselves and their carers.

Remote monitoring has been proven in other industries like manufacturing. With healthcare there is additionally an issue with patient privacy and ethics. In some cases it may be felt necessary to sacrifice some privacy in order to ensure wellbeing.

Devices are now able to collect a very wide range of data; however, they are very specific as to what data they collect in pursuit of a diagnosis. Data sets emanating from these are not necessarily compatible or interoperable. The greatest challenge is therefore to establish consistency of data between multiple data collection systems.

Healthcare systems are extremely complex in terms establishing secure communication between various data sources. An individual patient's healthcare record needs to be read in its entirety from anywhere including treatments from the hospital, clinic, care home, general practice and various clinics. If a patient is being treated in multiplicity of ways, a single unified record should be accessible from anywhere.

As healthcare strives towards making care data interoperable, this necessitates a common representation of diagnostic data across all conditions. This would put patients at the heart of their treatment rather than the care agency, ideally across national boundaries.

The development of ISO standards on EHR interoperability, personal health records, EHR requirements, security and data protection is ongoing, however creating such as system is hampered by the need to work across different jurisdictions and national interests.

In August 2021, the National Health Service (UK) launched a survey to better understand the usability of Electronic Patient Records (EPRs). Through gaining a better understanding of where EPRs are performing well and where they can be improved, the service hopes to develop their usability and adoption throughout the service.

> ## 🔍 *Use Case No.5*
> **Connecting Hospital with Home**
> One UK hospital trust is trialling 'The Virtual Ward' which connects patients being remotely monitored around the clock with hospital ward services. Subjects are provided with all the equipment needed (including hardware and software license costs) and full training. As of the time of writing, most patients and staff have welcomed the successes so far.
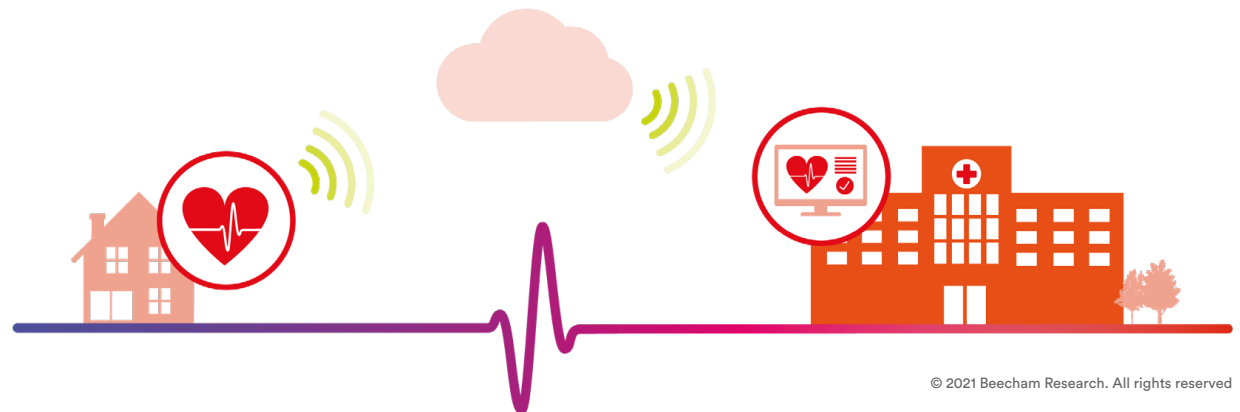
Research Findings

Beecham Research has conducted one-on-one interviews with healthcare professionals. The following are some of their views on use of 5G in Healthcare.

Drivers for 5G in healthcare

There are many drivers for 5G to be adopted in healthcare. Our interviewees gave a range of reasons, from demand for connected healthcare through to the possibilities offered by 5G.

With COVID there is shift towards remote monitoring, remote diagnosis

There is a move now towards prevention of diseases in large groups of people; a few years ago it was mainly diagnosis and treatment.

Robotics, telehealth and remote surgery will be most probably the ones that will use 5G

The global pandemic has led to a crucial need for new healthcare approaches, telemedicine, teleconsultation, real-time collaboration between doctors and primary care

Through medical devices information can be shared faster, 5G will enable early diagnosis in emergency situations by sending images and medical information in real-time from the ambulance to hospital

Demand for connected healthcare services was accelerated by COVID 19. Patients received care remotely which reduced exposure to the virus

There is a huge potential for really integrating the rolling emergency room with the resources of the local hospital

The main drivers come from a need to bring different health experts together for one patient

Typical high data rates applications that will benefit from 5G are motion videos, scanned x-ray, remote access to medical records with video.

Near term applications

Our respondents identified a number of near term applications in the offing.

For the near term I would say, medical devices are in use for remote health monitoring and transmission of vital signs such as blood sugar. The early warning of changes in vital signs makes for faster diagnostics and treatment

Telehealth applications will benefit from 5G in rural and underserved areas. There is a growing demand for higher bandwidth which improves the overall experience, such as video conferences with clinicians

Ambulances services communications back to hospital with high resolution images/videos in a timely manner help to make an early diagnosis with a remote expert

AR and VR for training purposes will be very popular, for physiotherapy as well; it is relatively low risk so it is ready to be used. In higher risk situations it will take longer to develop

Remote diagnosis consultation again that is picking up quickly, we have just seen that with COVID

Disinfections performed by autonomous robots in hospitals are looking promising

Ambulance and emergency communications are a natural next step to 5G, it will start to pick up quickly in the next 18 months

Applications involving the real time management of medical resources - staff, medical equipment – would be useful.

Longer term applications

Longer term applications would bring a wider reach to telehealth

Automating the reordering and organising parts of the care plan; this involves a high degree of asset tracking, background ordering, and in some cases IoT push buttons (bedding, sanitary products, elevators, exercise equipment...

Some telehealth solutions are being introduced in hospital and used for daily procedures. The patients then keep their devices when discharged to convalescent

homes or their daily lives. This allows wider adoption of telehealth and also provides good data for comparing care settings

There are projects to monitor and re-organise the interaction of visitors. Children can have their parents staying nearby and take part in physio and infection control training.

Enabling technologies

The newest advances are in artificial intelligence, machine learning, edge and cloud computing, digital twins, though security is more important than ever.

Many key healthcare functions are beginning to use AI to determine potential diagnoses and decide on the best treatment plan for a specific patient. You need data mining and AI to detect diseases early. AI helps predict which patients are more likely to have post-operative complications, allowing healthcare systems to provide early interventions when necessary

In surgery AI is in a very early stage, I think that it is much more advanced in radiology

A lot of activity is going on with AI and ML, in particular with imaging, recognition, diagnostic type tasks, visualisation type problems as well as what relates to the remote telehealth and sharing information between different doctors/specialist and making early diagnotics

Digital twins for clinical decision making, there are a lot of companies working on it today

Edge computing is a really interesting area. We are having more intelligence in wearables and in ambulances, where 5G enables low latency data transfer from ambulance equipment to hospitals

I think there is some reluctance from hospitals to put data in the cloud so they want it mostly on premises

In remote surgery also a very high level of security will be required. Cybersecurity is the highest priority in that area to protect patient data and vital sign monitoring systems during a surgery procedure

Emergency rooms, intensive care units are also very sensitive areas, where 5G should provide the highest level of data security.

With the high data rates and low latency applications such as remote robotic surgery, I think you will see a role for Private 5G Networks.

Business and economic issues

To provide high quality care in times of added pressure and reduced physical access as well as early detection of trends

Other priorities are around scarce resources such as the time and ability to make good decisions of experts, capacity of care settings in and out of hospital.

There are new funds available to make permanent changes prompted by the pandemic to the health care system that are directly linked to digitalisation. The efficiency of the healthcare provision asked for better and more trained staff and wider use mobile technology. This drives an eco-system of connectivity, IoT and in the end, Intelligence.
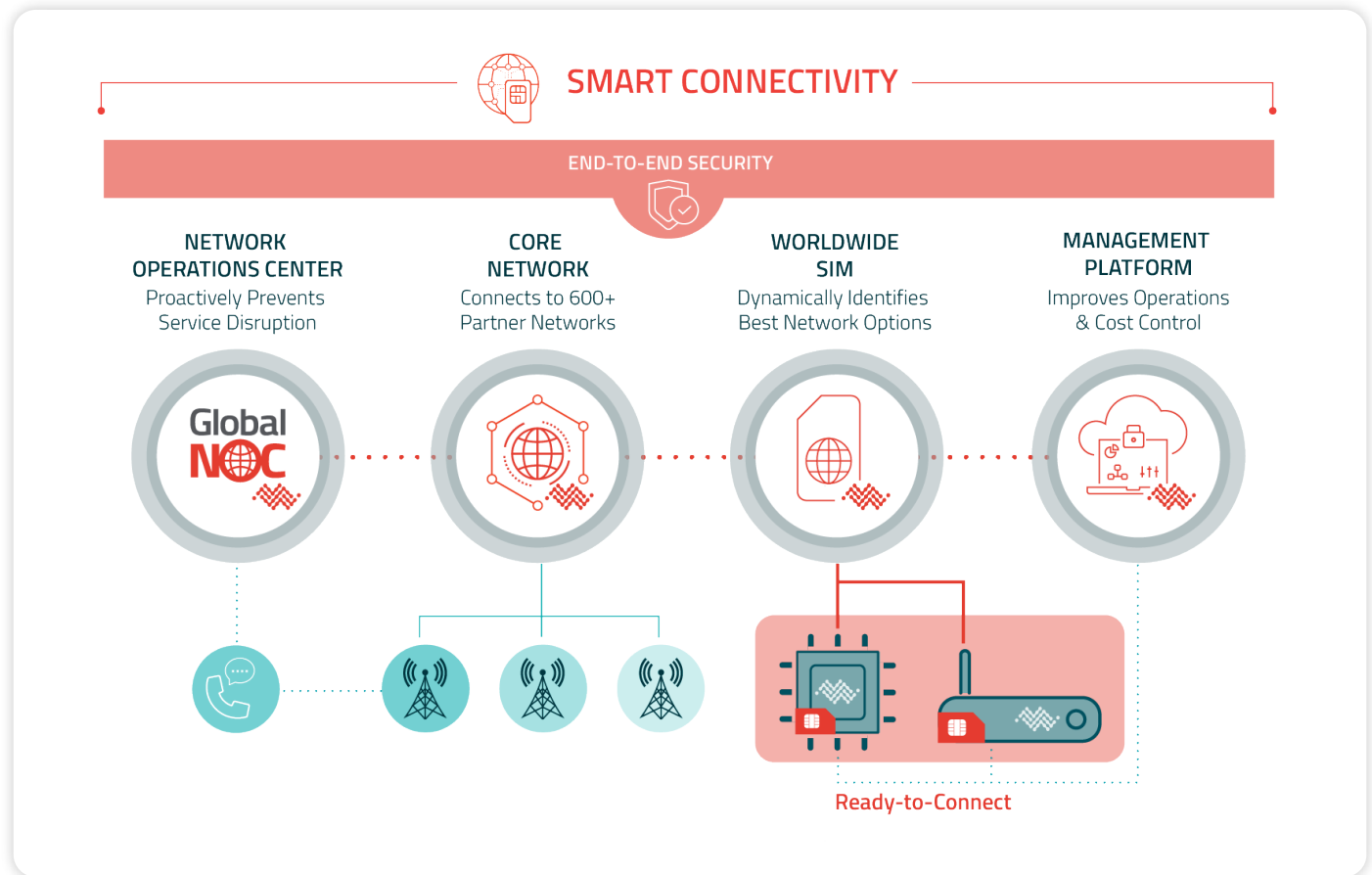
Sierra Wireless in Healthcare

Ready-to-Connect: Sierra Wireless offers connectivity solutions for healthcare inside and outside hospitals

The pandemic of Spring 2020 has drawn attention to the huge gaps that were present between collecting clinical data and its secure integration into patient electronic medical records. Taking into consideration the range of treatments available to patients through specialist devices utilised in different forms of treatments (see Figure 2 on page 3), the task of integrating all the aspects of a patient's care is challenging and complex.

Sierra Wireless' 'Ready-to-Connect' modules, gateways and routers simplify IoT development when utilised in conjunction with Ready to Connect. They enable a tightly integrated and secure data stream to the Cloud, while embedded SIMs (eSIMS) pre-integrated inside the Ready-to-Connect devices can be activated over-the-air anytime, anywhere. This reduces the need for individual device provisioning and reducing gaps where errors can arise. The secure and resilient global coverage is important for healthcare applications.

Sierra Wireless' resilient network infrastructure also includes private network options with round the clock monitoring, to provide an end-to-end secure data stream from the device to the cloud.

Figure 3. Sierra Wireless Smart Connectivity, with Ready-to-Connect

SMART CONNECTIVITY

END-TO-END SECURITY

NETWORK OPERATIONS CENTER
Proactively Prevents Service Disruption

CORE NETWORK
Connects to 600+ Partner Networks

WORLDWIDE SIM
Dynamically Identifies Best Network Options

MANAGEMENT PLATFORM
Improves Operations & Cost Control

Global NOC

Ready-to-Connect

Modules versus gateways

As shown in Figure 5, Sierra Wireless offers two types of Ready-to-Connect devices: one based on a gateway and the other on a module.

Wireless gateways are increasingly used in clinical settings. They consist of dedicated hardware appliances or software programs and serve as a connection point between the cloud server/application and the devices and/or sensors. The gateways pre-process the data package before sending it to the Cloud; in addition to collecting patient data, they collect data on device and machine status and location.

The module solution may best suit high quality wearables including in vivo like heart monitors where a life-threatening condition needs to be tracked. (Code 02 and 04 in Figure 2). By contrast, the gateway solution could be applicable to a hub solution for several pieces of equipment and data sources to connect, as for example, in the processing of heterogeneous clinical trial data (Code 14 in Figure 2).

Security in layers to protect deployment

The One point of Accountability feature provided lowers the time it takes to identify the root cause of any anomalies or outages in the connected device. As noted earlier, high levels of security are needed in order to ensure there is no interference with data transfer and possible ultimate harm to the patient. The Sierra Wireless Solution provides an intrinsic end to end view of security across the entire production chain. Ready-to Connect devices use a layered approach with different security mechanisms built into every component of the solution (device, network, cloud). This goes along with end-to-end schemes, thereby ensuring the appropriate level of security. It also provides a single point of responsibility for the overall security solution. These various security measures work together to protect the deployment, minimise the risk of any loss or theft, and significantly reduce the financial risk of running an IoT-enabled service.

Sierra Wireless owns all parts of the security layers and takes specific security measures at each level; these include secure boot in the device and probes in the network. To address device security inside and outside the hospital, the concealed eSIMS in the Ready-to-Connect modules prevent SIM tampering or theft, along with the latest encryption technologies in the device, network, and cloud to create layers of protection for the deployment.

In summary, Sierra Wireless Smart Connectivity makes it easy to maintain a secure and reliable connection to fixed and mobile assets anywhere in the world. This ensures the best connection available at any time, based on bandwidth, latency and signal strength. Smart Connectivity delivers:

- One Point of Accountability – with a single vendor for devices, connectivity and support, and a single management platform to optimize deployments

- Resilient and Secure Coverage – with redundant routes to multiple networks in every country to eliminate local coverage gaps

- Maximum Uptime – with our 24/7/365 global network operations centre proactively preventing service disruptions

- Seamless Expansion –into new markets with one worldwide Sierra Wireless SIM module accessing 600+ partner networks in 190+ countries, including at least 3 local carriers in each European country

- Reduced Operational Costs and Security – no manual SIM insertion, removal, or replacement - plus no SIM card programming

Conclusion

Healthcare is moving towards more personalised medicine – with much more data from telemedicine and 5G making it possible.

We are seeing new era in healthcare marked by seamless connectivity between patients, providers and other stakeholders. Data from health records combined with uploaded data from remote monitoring can form a rich dataset from which machine learning algorithms can be developed, for example, to predict outcomes and improve decision making as well as allow the development of new treatments.

Barriers remain, however, including appropriate security and safety concerns arising from the major possibilities afforded from 5G. The demand on healthcare systems, which was particularly increased throughout the pandemic will be further increased in the short term.

Staff who have been working with strained resources will be hard put to become familiar with the new ways of working demanded from telemedicine technologies; however in the long term, the improved management of healthcare from IoT and 5G will provide major savings and better outcomes for patients.

For the patients, though geographically remote, they must not feel forgotten or isolated, but empowered, connected and cared for and free to contact their care team at any time. Already various online fora have sprung up whereby these isolated patients can exchange ideas and experiences with others in similar situations, regarding their conditions and their treatments.

For more information, visit the Connected Medical Devices website
www.sierrawireless.com/applications/healthcare/connected-medical-devices/

and the Smart Connectivity website www.sierrawireless.com/smart-connectivity