# Connected Independence

A Technical Paper prepared for SCTE•ISBE by

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# Introduction

This paper discusses how connectivity, IoT devices, and AI can address a growing worldwide problem: caring for our elders. By connecting the latest IoT technology and remote caregivers, aging in place or aging in place longer becomes a viable option for any older adult or loved one that has access to a broadband network.

While this paper recognizes that the world's older population is booming and the number of caregivers for that population is declining, creating a "care crisis", it does focus on aging, healthcare and insurance in the United States. Figure 1 below, along with the bullets above it emphasizes the scale of this problem. The burden on the healthcare industry to provide better care and better health at a lower cost is mounting. Technology in the form of Passive Remote Patient Monitoring (PRPM), Remote Patient Monitoring (RPM) and Telehealth is emerging as the go-to-resource multiplier to improve the way providers and caregivers take care of these individuals.

- By 2020 about 45 million Americans will be caring for 117 million seniors, taking responsibility for food delivery and health monitoring.
- Three out of four caregivers want to use technology to make their duties easier, but only 7% have done so, according to a 2016 study sponsored by AARP.
- By 2030, 20% of the US population will be aged 65 years or older
- As of Q4 2016, 79.5% of householders age 65 and older owned their homes
- Assisted living facilities cost an average of $43,200 per year
- A Home Health Aide costs an average of $20 per hour
- The average length of stay in a skilled nursing facility is 835 days (2.28 years)

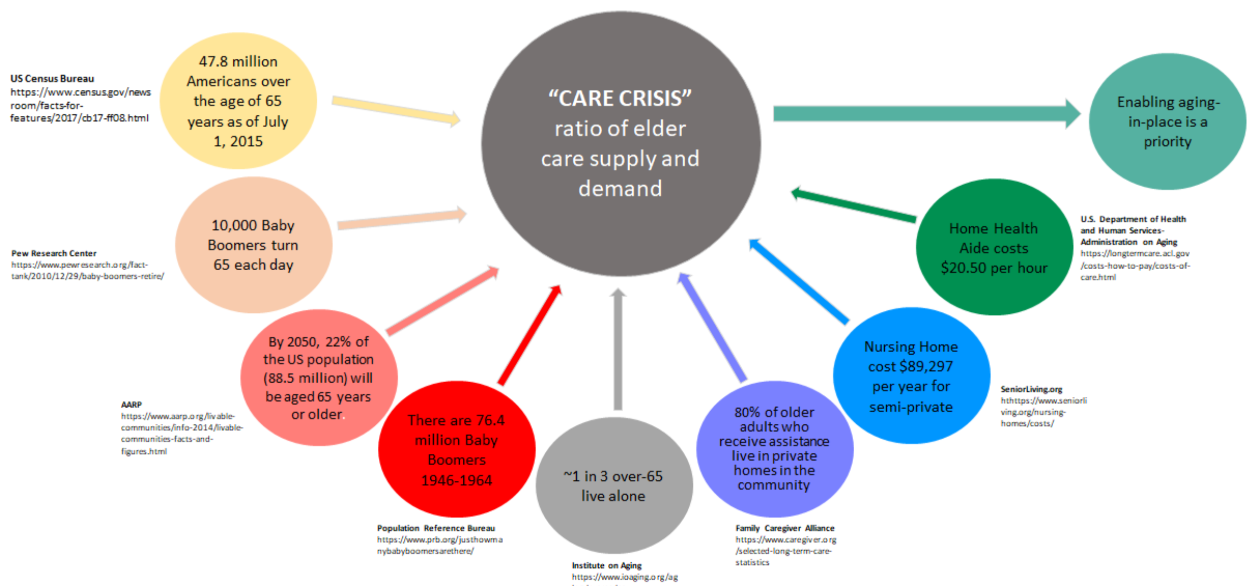


**Figure 1: Care Crisis Evidence**

"As the number of people over the age of 80 increases in the next 20 years, the number of people in the primary caregiving years will remain flat," states AARP's 2013 report. Meanwhile, in 2050, there will be three times as many people age 80 and older as there are today. As a result, by 2050, the caregiver support ratio which was 7.2 in 2010 when Boomers were in their peak caregiving years, is projected to drop to 2.9

 

percent when the boomers will have reached their eighties. According to AARP's report, "In just 13 years, as the Baby Boomers age into their 80's, the decline in the caregiver support ratio will shift from a slow decline to a free fall."

In summary, it is not uncommon for someone to receive care at home for several months or longer, followed by a two and a half year stay in an assisted living facility, with almost 60% then requiring a nursing home stay of somewhere between nine months and a little over two years. All combined, this is a total of approximately 4-5 years of long-term care. In this scenario, the total cost of care could easily exceed $300,000. This is daunting considering that it would be in addition to the approximately $245,000 that Fidelity Investments estimates the average retired couple will spend on healthcare- other than assisted living or nursing care expenses– during the span of their retirement years.

This reality is being recognized by many, including the Centers for Medicare & Medicaid Services (CMS). CMS' latest transformation initiative is called the Meaningful Measures framework which identifies the highest priorities for quality measurement and improvement and looks to drive change in those areas.

Healthcare transformation has existed since the beginning of medicine, driven by culture, beliefs, values and technology. The latest evolutionary phase began in the early 2000's driven by reimbursement and technology changes and is yet to reach a stable, functional model. Coordinated, evidence-based accountable care is now a key driver to healthcare transformation to deliver better care and better health at lower costs. Connectivity in the home and in the form of wearables is the platform to enable this. Technology becomes both a safety net to support independent living and a lever to multiply the amount of finite care available from a dwindling caregiver population. To accelerate this change, CMS is authorizing Medicare Advantage beneficiaries to be reimbursed for technology assistance starting in calendar year 2019.

A health and wellness platform offers MSOs a unique opportunity to participate in this latest healthcare transformation. With reimbursement change being driven by the Centers for Medicare and Medicaid and that change being fundamentally dependent upon health and wellness information, better coordinated care and teamwork among the caregivers, connectivity and technology providers will be an integral part of a successful and stable transformation. The connected home market is estimated to be about $28 billion, growing roughly 20% annually. Markets include broadband companies, home healthcare providers, assisted living, nursing homes & the consumer.

With HIPAA-compliant wireless IoT-based sensors and smart speakers placed in the home, connected to secure communication links between the home and cloud-based AI engines, the technology foundation for transformation is established. Proactive monitoring and measurement lead to improved risk management, the primary goal for CMS and insurance providers and an opportunity for MSOs.

# Technology and Process

Activities of Daily Living (ADLs) are standards that describe routine activities that people tend to do every day without needing assistance. There are six basic ADLs: eating, bathing, dressing, toileting, transferring (walking), continence, and several others that contribute to the ability for a person to live independently. Table 1 presents the full, standard list of ADLs and IADLs. The performance of these ADLs is important for determining what type of long-term care is required. The commonly accepted activities of daily living are listed in the Roper-Logan-Tierney Model of Nursing (RLT). There are also Instrumental Activities of Daily Living (IADL) defined by Lawton & Brody. The IADLs are a more complex measure of a person's ability to live independently.

 

**Table 1:ADLs and IADLs**

| ADL | Source | Type |
|---|---|---|
| Breathing | RLT | ADL |
| Communication | RLT | ADL |
| Continence | RLT | ADL |
| Controlling body temperature | RLT | ADL |
| Dressing | RLT | ADL |
| Drinking | RLT | ADL |
| Eating | RLT | ADL |
| Elimination (Toileting) | RLT | ADL |
| Maintaining a safe living environment | RLT | ADL |
| Mobilization - Body Movement | RLT | ADL |
| Sleeping | RLT | ADL |
| Bathing | RLT | ADL |
| Working and playing with a sense of purpose | RLT | ADL |
| Handling Transportation (driving or navigating public transit) | Lawton-Brody | IADL |
| Housework and Basic Home Maintenance | Lawton-Brody | IADL |
| Managing Finances | Lawton-Brody | IADL |
| Managing Medications | Lawton-Brody | IADL |
| Preparing Meals | Lawton-Brody | IADL |
| Shopping | Lawton-Brody | IADL |

Today's technology supports a platform solution that provides peace of mind to families by enhancing the "Aging at Home" experience with an economical and comprehensive, independent-living activity measuring and monitoring solution.  This technology-based solution uses unobtrusive (i.e.; no cameras) sensors to track, measure, and assess the ADLs and IADLs of a subscriber.  Connecting this monitoring and measuring with timely human acknowledgment, interaction, and resolution through a caregiver network, including a 24/7 customer care center will provide the guardrails to allow more people to age at home. In a majority of situations, adult children have assumed the burden of caring for their parents, but still have the responsibility of their own families and frequently live in a different local than their parents. This health and wellness system enables an older adult to stay in their home and maintain a level of independence, yet creates a safety net and means for caregivers to actively care for an aging adult without being physically tied to the older adult's home will revolutionize the well-being of older adults. With nearly 48 million seniors in America and 90% wanting to stay in their homes, technology is the enabler to make this happen.

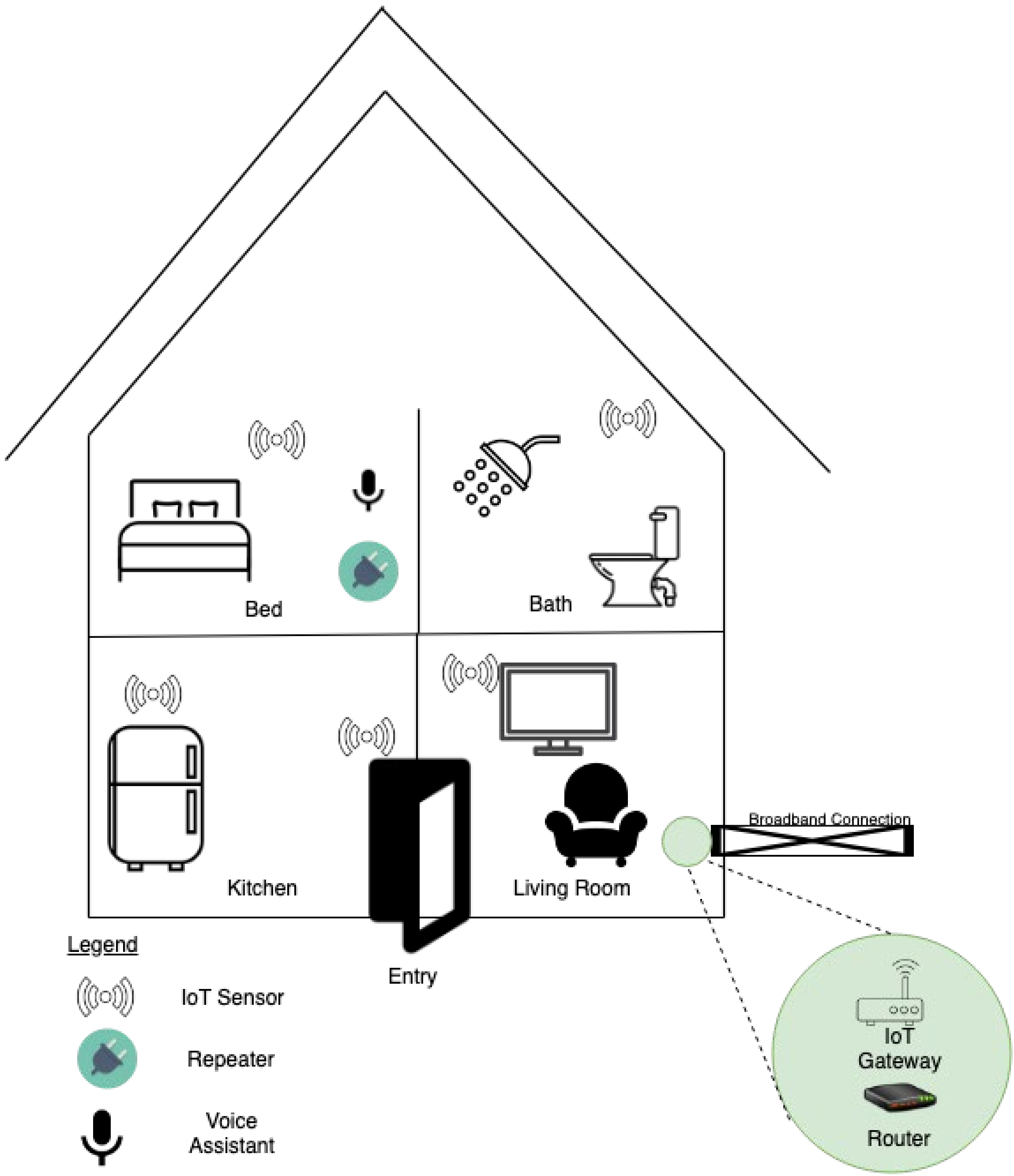


**Figure 2: Representative Health and Wellness System Deployment**

IoT devices, that when properly configured and deployed within a living space, along with pattern analysis can help identify the fulfillment or lack of fulfillment of an ADLs/IADLs. A minimum viable product would be comprised of on-premise IoT sensors and a custom voice assistant configured to identify ADL event occurrences, assess IADL and ADL competency, provide 2-way audio or physical communications and securely communicate event attributes to an IoT gateway. The IoT gateway provides local infrastructure management, event data caching and secured event data transport to a cloud-based operational support system (OSS). The secured OSS includes artificial intelligence and machine learning to automatically configure and optimize the ADL event monitoring algorithms, sensor configuration actions, and IADL assessment actions. Figure 2 presents a conceptual architecture of this platform.

It is extremely important that the system is tuned to avoid "alarm fatigue". A variety of modern communications methods, chosen by each individual caregiver to suit their own preferred communication method should be utilized to engage remote support assistance in a recursive model to assure an event response.

This entire communication path should be secured using a combination of FIPS 140-2 compliant modern cryptography methods such as TLS, RSA-1024 certificates, AES-128, AES-CCM, and ECDH key exchange to produce the highly secure and HIPAA-compliant health and wellness measurement and monitoring system.

The platform is built upon the tenet that technology can be leveraged to provide a safety net for those wishing to maintain their independent living lifestyle. The system's second key tenet is that humans will establish a normal and measurable pattern of physical and cognitive behavior, deviations from which indicating areas of concern for the caregivers of that individual. Care plans must be unique for every independent living person. The care plan establishes a normal pattern of behavior, defines the thresholds for specific monitorable actions and a set of users. The activity engine receives the raw events and applies a series of care plan rules with their custom thresholds via a machine learning model. This statistical data-to-decision process generates an alert when a deviation from normal is detected and also automatically adjusts the monitoring action thresholds to optimize the alerting to the independent living person's normal patterns.

# 1. Architecture

## 1.1. IoT Sensors

Critical to the assessment of the ADLs/IADLs are the sensors that pick up the activity of the person being monitored. The sensors pick up the physical and environmental cues of the individual's activity that defines a pattern of daily activity.

The IoT sensors may be connected to each other and/or other resources via wired or wireless connections. Today's industry standards for these connections may be implemented through the use of any known wired or wireless communication standard, including but not limited to Ethernet, 802.11a/b/g/n/x, universal serial bus (USB), Bluetooth, Bluetooth LE, cellular, near-field communications (NFC), Z-wave, ZigBee or even a proprietary standard.

Sensors can relay events to an IoT gateway in one of two ways. The sensor can be polled by the IoT gateway and the state of the sensor can be read, or the sensor can be set either by the manufacturer or via a configuration to transmit an event when a sensor threshold is met. For example, a temperature sensor can be polled every five minutes to generate a stream of events. Alternatively, the temperature sensor can be sent to transmit an event for every 0.1° of change. Both methods have benefits and drawbacks. Polling unchanged data risks reducing battery life. Using thresholds requires thresholds to be set at a sensitive enough level to collect the needed information for analysis.

When a threshold is met, or a sensor is polled, it creates an event that is transmitted to the IoT gateway. The IoT gateway converts the signals from the IoT network nodes into a communications protocol that is capable of transferring the events to a cloud-based computing infrastructure that supports complex algorithmic data analysis and event handling workflow.

 

### 1.1.1. Sensor Types

There many types of IoT sensors and many sensor packages are capable of collecting multiple types of data simultaneously.

- Motion Sensors are used to ensure that a person is active and moving around when they should be, and not active at times they should not be. They can be used to monitor waking and sleeping, trips to the bathroom, and movement around the house or rate of movement. Motion sensors can be infrared-based, radar-based, laser-based or ultrasonic.
- Temperature Sensors are used to ensure that the environment is safe for a person. It can be used to confirm that climate control is working properly and is being used. Localized temperature changes can also be an indicator of stove or oven use or a personal hygiene event (i.e.; taking a bath) and the duration of that event.
- Light and UV Sensors are used in conjunction with motion sensors to help establish activity, especially at night. Motion at night along with the presence of light can indicate that a person is awake and intend to stay awake for a period of time. UV sensors can help identify if the light source is natural (the sun) or man-made.
- Contact (aka; Door/Window) Sensors can be used to determine if a person is arriving or leaving the home, has left a door open or closed for too long or used a door at a time that they shouldn't be. These contact sensors can also be used to determine if food preparation is occurring by monitoring the opening and closing of refrigerators, microwaves, and ovens or be used to know when a particular cabinet or drawer has been accessed (i.e.; a medicine cabinet).
- Pressure sensors can be used to determine a more precise location of a person. They can identify is a person is standing at a specific location (i.e.; near a toilet), lying in bed, or sitting in a chair.
- Smoke and Gas Sensors can be used to identify if there is a safe environment for a person. It can be used to identify fire, or gas leaks, especially where stoves are involved.
- Moisture Sensors can be used to identify environmental issues (i.e.; water leaks or flooding) or personal hygiene incidents.
- Biomedical - There are many biomedical sensors on the market for measuring medically relevant parameters such as heart rate, respiration, oxygen levels, glucose levels, weight, temperature, and many others.

### 1.1.2. Sensor Selection

Sensor selection is critical for the accurate and reliable measurements of ADLs. There are many considerations in the selection of sensors. Poor sensor selection can have a very detrimental effect on the systems operations or the ability to support deployments. Below are some of the parameters of sensors that should be examined when making a selection.

- Ease of installation - The installation of sensors should be easy to do with common tools or no tools at all. The sensor should be designed so that the installation should be reliable; the sensor should be capable of being installed in a way so that it will stay in the location at which it is installed and stay orientated properly.

 

- Powering - Considerations must be made on how the device is to be powered. Batteries must be monitored and changed when low. Some devices may be difficult to access to change the batteries. And some sensors use an uncommon type of battery that is not readily available via normal retail outlets. If a device is powered via a wall outlet, the length of the power cable and location of outlets limit installation options.

- Sensitivity / Accuracy / Detection Zone- Sensors should be capable of monitoring the environment they are deployed in. They should have the appropriate sensitivity to measure indications of the presence of people, motion, temperature, and light. For example, a motion sensor should be able to detect motion at a reasonable distance in a room. It is not necessary for the sensor to detect motion across an entire room as sensors can be placed in choke points or areas people are forced to travel through as they move from room to room.

- Communication Range - Sensors need to communicate back to the IoT gateway. All wireless sensors have a rated range but in actual real-world deployments, that range tends to be much smaller than what is advertised. Sensors placed out of range for direct communication with the gateway can still be communicated with by placing repeaters throughout the home or using a mesh network technology. Repeaters do add cost, installation complications, and complexity to the deployment that could affect reliability.

- Tamper Detection - Even though the primary use is not as a security system, it is still important to know if a sensor is being tampered with. Knowing whether a sensor has been touched helps diagnose detection issues or other failures of the sensor and its event reporting.

- Communication Method - Whether it's wired ethernet, or a wireless standard, the communication method of the sensor has a large impact on other selection considerations. It affects powering options and battery life, installation options and the ease of installation, the distance at which the sensor can be placed from a gateway, security of the system, the cost of the sensor itself and the IoT gateway cost and functionality. Deployments with a mix of communication methods can complicate installations and drive up the cost of gateways.

- Cost - As there will be multiple sensors per deployment, the cost of sensors adds up very quickly. Every other consideration has an effect on cost. Sensors that are powered by batteries tend to be cheaper then sensors that include power supplies, but servicing batteries also has a cost. More reliable communication methods tend to drive up cost, but may simplify installation. Cost is always a balancing act and it's important to factor in the long-term operational costs of maintaining a sensor, and not just examining the per unit cost of acquiring a sensor.

## 1.2. IoT Gateway

The IoT Gateway provides connectivity to the mesh of sensors and the local area network. It's responsible for receiving events from the sensor, adding additional context and metadata to the event then passing that event on to the cloud infrastructure via the Broadband gateway.

If the IoT gateway does not have internet connectivity, it can cache the events so that when connectivity is restored, cached events can be transmitted.

There IoT gateway may support one of many communication standards like Ethernet, 802.11a/b/g/n/x (WiFi), universal serial bus (USB), Bluetooth, Bluetooth LE, cellular, near-field communications (NFC), Z-wave, ZigBee or other proprietary standards.

 

If WiFi or ethernet is used care must be taken to allow for the segmentation of data via routing of the sensor mesh network traffic from other broadband traffic in the home. Many IoT gateways include their own WiFi APs which can be used to establish a hidden, secure SSID for the sensor mesh network.

The IoT Gateway is also responsible for enabling the provisioning and configuration of the sensors, along with the monitoring of the sensors. The gateways have physical or API mechanisms to enable the pairing process of sensors that use NFC, Bluetooth, Z-Wave or ZigBee protocols. The pairing process needs to include a way to name and identify the location of the sensors during the pairing process. It must keep track of the sensor identification and serialization and include that data with the event messages it passes on to the cloud services. The Gateways should collect and report the battery level and online status of sensors and report this information up to the cloud monitoring services.

### 1.3. Broadband Gateway

The Broadband Gateway provides internet connectivity to the IoT Gateway. As communication from the IoT Gateway is secured with encryption the IoT Gateway can communicate on the customer's local area network. If quality of service (QoS) is desired, it may be necessary for the IoT Gateway to communicate to the Broadband gateway via and isolated network.

It is important that the availability of the Broadband Gateway is monitored closely. If the Broadband Gateway becomes unavailable, real-time monitoring the customer is not possible. Ideally if there is an outage that affects the Broadband Gateway, all stakeholders related to the monitoring of the customer should be notified.

### 1.4. Cloud Infrastructure

All the events created in a home are collected and analyzed in the cloud infrastructure. each event is correlated to a specific customer in a specific location to a specific sensor at a specific point in time. This event stream is collected and analyzed with machine learning to establish ADL patterns. Is important that A large sample set of normal behavior is collected so that baseline patterns can be established. Machine learning will continue to adjust the base line patterns but flag deviations that are out of the ordinary.

Not only can out-of-the-ordinary deviations be flagged, but hard rules can be set such as if somebody is not up and moving by 9 a.m., an alert condition is reached.

When an alert condition is reached, the infrastructure can automatically begin notification escalations based on a real set that's established for the customer. This escalation can start with notifying local Caregiver, move on to notify distant loved ones and if there is no response from the escalations ultimately result in a notification to Emergency Services to perform a wellness check.

It is imperative that the cloud infrastructure is highly reliable and continually monitored. Services should be deployed across multiple data centers and geographically diverse locations, with load balancing, fail over a disaster recovery.

## 2. User Experience

While the functionality of the aging in place platform depends upon cutting edge technology for sensing, artificial intelligence and machine learning, all of that innovation is wasted unless it can be translated into a compelling user experience. One that is intuitive and appropriate for the target user. One that is informative enough to become part of the user’s daily routine, or efficient enough to be used all day long or intuitive enough to be used weekly, monthly or even less frequently and yet, not so "noisy" as to drive the user to a point where the platform becomes a source of irritation for the user.

Above all, the user experience needs to be flexible. Plain old voice telephony must be covered, SMS messaging must be supported and mobile push notifications must be available. Smart speakers should be available to support voice-first interaction with the system where appropriate.

In the independent living ecosystem, there are a variety of aging in place system user types to be addressed:

## 2.1. Subscriber

For purposes of this paper, the term "subscriber" refers to the person for whom the aging in place platform is being used to establish a safe and healthy independent living situation. In the eyes of the cable operator this is a subscriber. In the eyes of a medical provider, this is a patient. In the eyes of the insurance company, this is a beneficiary. In the eyes of a home healthcare agency, this is a client. In the eyes of the senior community, assisted living facility, skilled nursing facility, or memory care facility, this is a resident.

The subscriber interacts with the system in both active and passive manners. Active interaction includes verbally communicating with the caregiver network and call center agents, responding to system-initiated queries, setting home/away status and engaging in cognitive analysis activities. Passive interaction happens by the subscriber going about their normal daily routine.

An important item to consider is the subscriber's technology aptitude and the technology that they have access to. They may or may not have a landline. They may or may not have a mobile phone and if they have a mobile phone, it may or may not be a smart phone. They may or may not have a tablet and they may or may not have a computer.

The subscriber themselves may have hearing, seeing or speaking impairments which will also impact their relationship with the system. Both a mobile app and a web page user interface should be available to a subscriber to support their personal needs.

## 2.2. Family Caregiver

A family caregiver is someone who provides emotional, financial, nursing, social, homemaking, and other services on a daily or intermittent basis for a family member, a friend or a neighbor. Most family caregivers volunteer their time, without pay, to help with the care needs of a loved one.

The family caregiver user experience is always an active interaction and involves managing their preferred communication method, responding to alerts, managing the rule thresholds (for those with administrative privileges), requesting and reviewing activity reports, limited infrastructure management and managing caregiver priorities (for those with administrative privileges).

In most situations, it is expected that the family is involved in the aging in place care plan. In fact, patient and family involvement is one of CMS's Quality Strategy goals. A robust aging in place system will support event management and event escalation through a series of caregivers. After all, this is a volunteer position and Family Caregivers typically have their own immediate family responsibilities which may prevent them from always responding to an alert.

 

Both a mobile app and a web page user interface should be available to a Family Caregiver to support their personal needs.

## 2.3. Professional Caregiver

Professional caregivers are hired to provide care for the subscriber. These caregivers can provide medical or non-medical care in the home. Frequently, payment for services is the only difference between a Professional Caregiver and a Family Caregiver. Therefore, the user experience is the same between a Family Caregiver and Professional Caregiver.

Both a mobile app and a web page user interface should be available to a Professional Caregiver to support their personal needs.

## 2.4. Institutional Caregiver

The Institutional Caregiver is a Professional Caregiver working in a commercial care facility environment. Independent living, assisted living, skilled nursing and memory care are the typical commercial care facility types. In these environments, the user experience at the individual resident level is the same as for a Family Caregiver; however, there is also a dashboard to support a centralized monitoring and dispatch capability. In telecom terms, this dashboard looks much like a display you might see in a Network Operations Center (NOC). This dashboard allows the user to see a high-level status of each resident and comprehensive view of the active alerts.

Institutional Caregivers are typically equipped with tablets.

## 2.5. Call Center Agent

The Call Center Agent serves as the backstop to the aging in place care escalation model. In the event that none of the caregivers in the subscriber's call escalation tree are able to respond to an alert, it will be routed to a 24/7 staffed call center. This call center must be staffed with agents that are more health-oriented than what an MSO employs. Here the Call Center Agent will attempt to reach the subscriber one more time before engaging first responders. Because of the potential financial charges, the subscriber needs to opt-in for the type of response that the call center is to take with respect to first responders.

Call Center Agents would be considered super users which means they would have the same capability as a Family or Professional Caregiver and also to serve as a help desk for system users. Additionally, they would have responsibilities with respect to system administration to address equipment issues, billing issues and network outages.

Call Center Agents would be desktop users.

## 2.6. Healthcare Provider

One of the great benefits of this technology is the additional insight into patient physical and cognitive wellness that is available to a healthcare provider. The system provides a time-series of evidence for the healthcare provider to corroborate the observations from the patient assessment. With the additional insight afforded to them, Healthcare Providers are better able to catch symptoms early on before they develop into something more serious. Continued interaction with the patient also allows the Healthcare Provider a chance to evaluate how well treatments are progressing, and to change medication and visits as needed.

 

While it is not expected that a Healthcare Provider would be an active member of the patient's escalation call tree, that decision should be left up to the patient and their family. In this scenario, the user experience would be just like a Family or Professional Caregiver. Rather the expected Healthcare Provider interaction with the system will be through graphs and reports showing event occurrence and trends.

The subscriber or Family/Professional Caregiver would need to permit the Healthcare Provider to access the subscriber's information and this could be delivered in a push or pull model. Certain health plans reimburse healthcare providers for reviewing digitally collected data as part of a treatment plan. Scheduled reports could be delivered to the Healthcare Provider. Alternatively, the Healthcare Provider could pull up health and wellness reports on-demand during an office visit or as part of the burgeoning house call services for instance.

Aging in place data can also be fed into the patient's electronic health record for long-term trend analysis.

### 2.7. Case Manager

Insurance companies, hospitals, and home health providers may all assign a Case Manager to monitor a patient. Case management is designed to provide for a patient's needs while controlling costs. A Case Manager evaluates what services are considered medically necessary, and works with different service providers to ensure that the required services are being given in the proper setting.

Once the patient is discharged from the hospital, Case Managers often must navigate complex care needs in a remote setting, which may involve different services being offered at different times by different providers. Ensuring that procedures and services fall under insurance policy coverage and will be paid for is a critical function that requires evidence to make proper decisions. It also involves educating patients on lifestyle adjustments, how to take medication, and when to come in for follow up appointments.

Chronic illness management, post-acute care and readmittance reduction are all activities of a Case Manager that depend upon evidence-based ADL and IADL measurement. The aging in place health and wellness measuring and monitoring system is designed to provide that information. As with the Healthcare Provider, scheduled reports could be delivered to the Case Manager or they could request reports on-demand.

## 3. Key Metrics

Because the platform is dealing with subscriber health and wellness, availability of the platform is critical. Making sure the sensors, IoT Gateway, Broadband Gateway are operating correctly, that systems have internet connectivity, and the cloud platform's services are fully functional is critical to providing a safe service.

MSOs are quite familiar with monitoring their infrastructure and outside plant to proactively address outages. However, when problems arise with customer premise equipment and services usually contact initiated by the customer drives service calls.

When providing a platform that deals with health and wellness a proactive approach needs to be taken to ensure that things are working correctly on premise. In fact, unlike other services MSO offer the subscriber is unlikely to know if part of the service is not operating correctly.

 

## 3.1. Sensors Metrics

As the majority of sensors are battery-powered, one of the most important metrics to track is battery level. It is important to understand what metrics reflects the imminent failure of a battery. Is also important to understand the average lifespan of a battery of a device based on the number of events generating so the projection can be made as to when the battery should be serviced. Servicing batteries infrequently can result in sensor failure. Servicing batteries too frequently is a waste of money and can be an annoyance of the subscribers.

### *3.1.1. Sensor Battery Levels*

Each sensor model and vendor may report battery levels differently. They may return voltages, a percentage of 'life' remaining, or sometimes values that are unclear or not well documented. Is important to characterize battery performance of a specific type and model of sensor to understand how to set thresholds for battery replacement. Below are graphs from two different sensors made by two different vendors showing battery life:

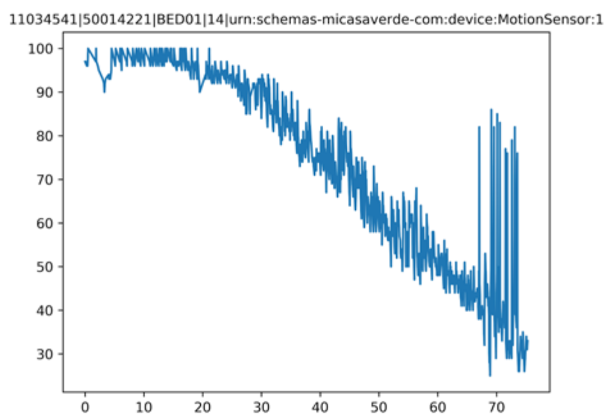


**Figure 3: Multi Sensor Battery Life**

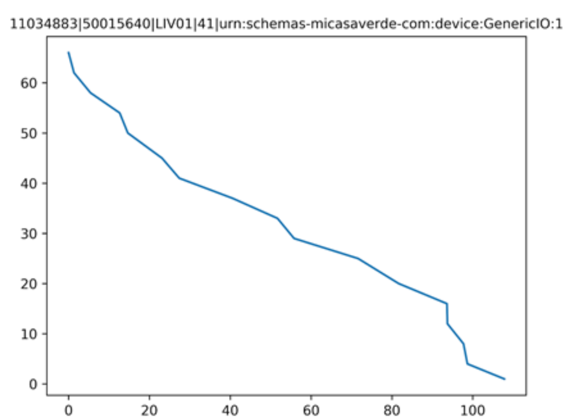


**Figure 4: Motion Sensor Battery Life**

 

In both graphs the x-axis represents time and the y-axis represents battery level. In the first graph you'll notice that when battery life reaches about 50% there are spikes showing an increase in battery level. This is because the sensor is shutting off due to low voltage. Once the cutoff voltage is reached, there is no current draw on the battery and its voltage level increases high enough over the cutoff threshold so that the sensor starts operating again. Soon after that, the sensor again reaches a low voltage cutoff and the sensor shuts off. This cycle continues until the battery does not have enough voltage to raise above the cutoff voltage and restart the sensor. When sensors behave this way it's important to track sensor battery level history, and not to use individual samples to determine when the battery should be replaced. It is possible that a single sample can be misleading as it can indicate a high battery level while the sensor is actually in a failure mode.

The graph on the right shows a sensor with a more predictable behavior. You can see that there's a relatively linear decrease of battery level overtime until the battery level reaches about 15% at which point there's a quick drop off.

In both cases battery levels will reach a point where the sensor is inoperative and battery levels cannot be collected. It's important to be able to identify if a sensor has become inoperative due to battery failure or due to some other reason. Not having battery history on a per sensor basis makes that determination impossible.

It is also important to be able to predict battery failure and ensure that batteries can be delivered and installed on premise either by a technician or by caregiver before the sensor fails.

#### *3.1.2. Other Sensor Failures*

Sensors may stop operating properly for reasons other than battery failure. They could have been moved from where they were installed, or even reoriented so that they are not monitoring the correct area. It is hard to know if events are not being received because of a sensor failure or because there is no activity the area the sensor is intended to detect.

Many sensors are not polled for events, but generate events when thresholds set at the sensor are met. The lack of events could be due to either sensor failure, or that there is nothing in the environment making events. If a motion sensor is pointed at the ceiling, it will still respond to queries from the IoT, report battery level and appear healthy, but it will not generate events. This is effectively a sensor failure.

It is possible to correlate multiple events across multiple sensors related to a common action in the environment. Machine learning can be used to pick up these patterns. But generally, if someone moves from the bedroom to the kitchen one would assume they would see events in both bedroom and kitchen. If events are being received in the kitchen but never being received in the bedroom it is possible that the bedroom sensor has failed. Is important to generate a set of metrics and to understand the general premise layout to correlate activities across multiple sensors to help determine sensor failure.

 

### 3.2. IoT and Broadband Gateway availability

Should an IoT Gateway or Broadband Gateway become unavailable. It is important to quickly assess whether the outage is due to a problem in premise or due to an event on the operator's network. Metrics on gateway availability must be continually tracked and when the gateways become unavailable the cause of the failure must be determined quickly. This so that the correct resources can be dispatched to re-establish communication. It is also imperative to notify caregivers when outages occur, to allow them to take actions to reduce risk to the subscriber.

### 3.3. Escalation and Incident Response

It's useful to track the number of escalations needed before a satisfactory response is achieved on a subscriber by subscriber basis and by population. The main point of escalations is to have someone check on the subscriber to ensure that they are safe and healthy. This may be a phone call or an in-person check. It could even be an escalation to emergency services. If over the course of several separate events, it takes multiple escalations before subscriber safety is determined, it may be an indication that the subscriber may not have the correct escalation order or the correct people involved in escalations. Metrics can help make recommendations to the subscribers to examine and adjust their escalation paths.

It is also important to understand how quickly people in the escalation chain take to respond. A balance must be struck between giving a person a chance to respond to an escalation versus how long is it safe to wait before the next person in the escalation path is contacted. Escalate too fast and there is a risk in repeatedly causing stress to the people responding to the escalation (i.e.; caregiver fatigue). Escalate too slow and there is risk that the subscriber is not getting the help they need. It's important to understand escalation and response timing for specific users and for populations to help set the correct thresholds.

# Conclusion

### "Necessity is the mother of invention"

With more aging adults needing care than there are caregivers to provide it for them, technology must be leveraged to provide that care. Broadband providers have long sought to be a part of this solution and the timing is finally right for that to happen with the maturation of IoT sensor technology and cloud computing. This paper has presented the concept of a cloud-based system of unobtrusive monitoring and measurement that is aligned with Medicare's value-based programs and quality strategy. These initiatives seek to financially reward those that deliver better care, better health and lower cost. Put more simply, Medicare is moving towards reimbursement of a service that utilizes MSOs' broadband service.

By starting with a simple wellness system, adoption by the subscriber will be easier to overcome, technical and logistical deployment challenges will be easier to overcome and reimbursement models will be easier to understand. Passive Remote Patient Monitoring is designed to advance to Remote Patient Monitoring and then to full Telehealth as needs require.

MSOs are an ideal delivery mechanism for health and wellness monitoring systems. Older adults, and their caregivers, are already comfortable and familiar with basic broadband technology. Additionally, those caring for older loved ones tend to embrace new technology and are increasingly open to using it in their personal health and wellness care.

The model PRPM platform is non-intrusive, protects patient privacy, provides caregiver peace of mind, is accessible, easy to use, interactive, facilitates better outcomes, optimizes patient/provider interaction, and reduces overall health and wellness costs. It does not require MSOs to turn themselves into telehealth providers.

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# Abbreviations

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| ADL | Activities of Daily Living |
| CMS | Center for Medicare and Medicaid Services |
| HIPAA | Health Insurance Portability and Accountability Act of 1996 |
| IADL | Instrumental Activities of Daily Living |
| IoT | Internet of Things |
| MSO | Multiple System Operator |
| NFC | Near-Field Communications |
| NOC | Network Operations Center |
| OSS | Operational Support System |
| PRPM | Passive Remote Patient Monitoring |
| RLT | Roper-Logan-Tierney Model of Nursing |
| RPM | Remote Patient Monitoring |

# Bibliography & References

*Roper-Logan-Tierney Model of Nursing*; Winifred W Logan, Alison J Tierney, Elsevier Health Sciences, 2000. ISBN 0702041076, 9780702041075

*Instrumental activities of daily living;* MP Lawton, EM Brody, U Médecin. The Gerontologist, 1969.

https://www.aarp.org/content/dam/aarp/home-and-family/personal-technology/2016-01/2016-Caregiving-Innovation-Frontiers-Infographics-AARP.pdf

http://westviewnursing.com/by-2030-u-s-demographic-milestone-begins-to-lower-caregiver-ratio

https://www.census.gov/newsroom/facts-for-features/2017/cb17-ff08.html

https://www.mylifesite.net/blog/post/so-ill-probably-need-long-term-care-but-for-how-long/

https://longtermcare.acl.gov/costs-how-to-pay/costs-of-care.html

http://www.aarp.org/home-family/caregiving/info-08-2013/the-aging-of-the-baby-boom-and-the-growing-care-gap-AARP-ppi-ltc.html

https://www.mylifesite.net/blog/post/so-ill-probably-need-long-term-care-but-for-how-long/

https://www.catman.global/how-best-buy-could-soon-dominate-a-28-billion-market