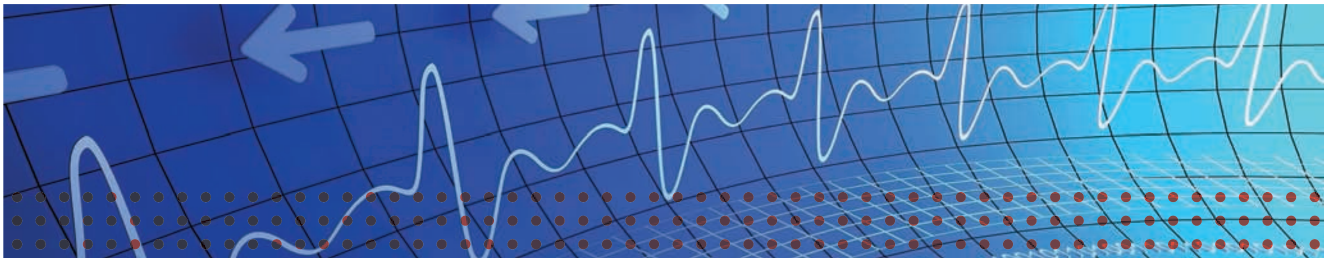

Toward an ElderCare Living Lab for Sensor-Based Health Assessment and Physical Therapy

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Cloud-based services can be designed for eldercare at residential homes with high-speed broadband access and privacy-preserving sensing technologies.

As they age, many older adults have significant challenges in managing chronic health conditions and maintaining physical functions. early detection of health problems can help elders maintain good health and function by allowing timely health interventions. Traditional approaches of healthcare take place in medical centers or clinics, which require availability of transportation from the home. This is, however, a disadvantage for rural and sometimes suburban areas where travel distances can be very long. With emerging digital technology and multisensor techniques, new approaches for ongoing health assessment are emerging to realize enhanced living environments (ELEs) for eldercare. While older adults stay in the home of their choice, in-home sensors can be used to monitor older adults' activity patterns; smart algorithms recognize changes in the patterns and send health alerts to care coordinators to flag potential health changes and administer targeted coaching. Our previous study has shown that in-home sensor data from bed, motion, and gait sensors, gathered using web services in an app form, can automatically provide ongoing health assessments without being obtrusive.[1] Although they can even alert caregivers when the system detects health changes, alert notifications capability as provided in our App-1 are not enough. In App-2,[2] we have shown how care coordinators can provide active corrective health coaching by real-time analysis of a large amount of data from patient's homes using a cloud platform. An example of the use of App-2 is illustrated in Figure 1, where an interface is shown that we developed for a physical therapist (PT) at a clinic. The app helps the PT interact with an older adult in a home to assess his/her mental and physical health status through guided physical exercises designed to overcome the risk of falling.

In order to deliver such cloud-based apps within ELEs for eldercare, the challenges that arise include 1) ensuring stable network performance and performance-tuned cloud platforms for large-scale sensor information analysis, 2) interactive interface and intuitive displays suitable for effective interactions between older adults and PTs, and 3) the integration of apps in their social context of use as secure, privacy-preserving, and socially embedded technologies.

Our pilot studies and conceptual work address these challenges in order to satisfy the needs of independent living, where older adults have the choice to remain in their private homes supported through a combination of ongoing health monitoring and alerts along with access to on-demand remote physical therapy. In this paper, we describe the design of ElderCare-as-a-SmartService (ECaaS) along with related technical and sociotechnical challenges[3] when moving from the sandbox settings in our prior works into a living lab environment and its ultimate transformation into a real-world ELE for eldercare. Toward realizing this vision, we seek to answer bold research questions such as:

1. What new kinds of web services and cloud platform issues, particularly in networking, need to be investigated to deliver an effective, efficient, secure, and privacy-preserving smart service system such as the ECaaS?
2. How can technology play a role in the future to improve remote accessibility of ECaaS apps? How to assess whether new ECaaS app delivery would be the same or different from either of the urban, suburban, and rural user perspectives?
3. What are the costs of the smart service system when implementing ECaaS? How should the implementation be planned with regard to usability, sociotechnical issues, and human-centered integration?
4. What new kinds of clinical studies can be enabled by the ECaaS apps to see a) how much longer older adults live, b) does it enable the family to be more aware of the health status of older adults while allowing autonomy during aging in place, and 3) to what extent does ECaaS save money and improve care as well as the quality of life?

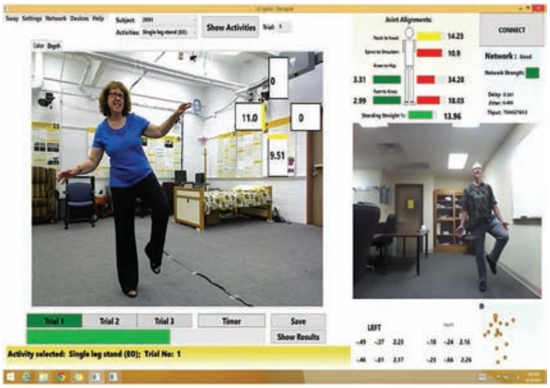

FIGURE 1. Screenshot of the physical therapist (PT) view of the interactive interface (left side shows the patient, right side shows the PT, right side top alignment parameters are informed by depth sensor data and exercise activities are administered using voice commands).

The goal of our design of ECaaS and associated apps is to ultimately develop and install ongoing health assessment, making it accessible for a broader group of older adults and physical therapy clinics. Toward this goal, we integrate living lab approaches and user experience principles. This helps us to prepare data-driven reflections for revisiting old and new design decisions and fosters future development of cloud-based services that can be delivered in ELEs for eldercare.

Related Work

Monitoring patients in the home for ongoing health assessment has typically been done using telehealth methods.[4] Particularly for monitoring known chronic health conditions, prior works use network-connected devices placed in the home, such as a weighing scale and a blood pressure cuff. The patient is expected to use these devices on a regular schedule such as once or twice a day. The data from the networked devices can be automatically transferred to a remote server for storage in the patient's health record. Several studies have shown that adherence with telehealth programs decreases over time.[4] Moreover, such approaches collect only a small number of data points per day and do not have the capability of monitoring and detecting changes in walking gait, sleep patterns, or daily activity patterns.

Our App-1 overcomes the above limitation by monitoring walking gait that is particularly useful for tracking health changes.[1] This is because, gait decline can be correlated with a variety of changes in physical, mental, or cognitive health.[5] Existing methods for measuring gait are typically infrequent

FIGURE 2. A walk captured in a private home using a depth sensor.

and provide coarse measurements, e.g., observation by a clinician who might use a stop watch for assessment during clinic visits that occur once every 6 or 12 mos. Those methods often lead to few or no objective assessments, which limit their results, and therefore do not catch a person's functional decline in a timely manner.[6] Our App-1 also builds upon new methods that use sensor technology to measure gait parameters on a continuous basis during normal daily activities. Using in-home sensor technology mounted in the patient environment, tangible information can be obtained for a variety of purposes, including automated fall risk assessments, early detection of illness, change in health status, and better assessment of progress during rehabilitation or change in medication.

Vision sensors have also been proposed for home use.[6] Video cameras offer the potential to track more detailed gait information as well as other activities. However, they require calibration and more computational resources and are sensitive to lighting variations. In addition, many consumers consider video cameras in the home to be a privacy invasion, although privacy protection methods can be applied to address this problem, such as the use of silhouettes.[7] Our App-1 uses the approach of depth sensing using a depth camera in a Microsoft Kinect that captures a distance measure for each pixel. The potential of the sensor is that it offers a single, low-cost sensor device and captures a three-dimensional representation of the environment as shown in Figure 2. Because it captures a depth image with only shape data instead of more recognizable video images, it is deemed to be privacy preserving. The Kinect depth sensor images are also used in App-2 in cases where much less computational resources are necessary compared to processing long periods of video camera streams.

Our adoption context for Kinect depth sensors in monitoring of gait in App-1 and other physical activities in App-2 is novel. There is prior work[8] where the authors propose a method for extracting joint locations from a side view, which the Microsoft SDK (software developer's kit) does not support. However, this has not been adapted for use in a naturalistic, unstructured home setting. In addition, there is prior work on tracking gait in the home using Microsoft SDK.[9] However, this is restricted to a limited viewing area, corresponding to the constrained gaming region. Our work addresses many of these limitations.[10] We track gait parameters of walking speed, stride length, and stride time over observation time windows in multiple residential homes. Gait change and risk of falling is automatically detected, which result in health alerts being sent to clinical staff. We have also validated the gait measurements in the lab using gold standard marker-based motion capture to ensure that the gait parameters extracted in the home are accurate.

The added novelty of our work is in our design to leverage the existing App-1 and App-2 over broadband networks and a cloud platform via new interactive interfaces for both clinicians and older adults as shown previously in an example in Figure 1. The study by Forkan et al.,[11] where a cloud-based solution is proposed for a context management system in ambient assisted living cases, is the closest to ours. The solution features a decision support middleware to process and visualize large amounts of medical and other ambience monitoring data in real time from a multitude of sensors and embedded devices. Two other studies[12,13] adopted similar cloud-based approaches for eldercare but instead focused on systems that support smart mobile companion robots that can be accessed via teleoperation. Pavon-Pulido et al. implemented a system that uses WebRTC, Google App Engine, and a fuzzy logic-based software for reactive navigation capabilities during teleoperation with safety considerations such as, e.g., avoiding obstacles.[12] Similarly, Bonaccorsi et al. developed a system that uses cloud computing for data computation tasks in support of robotic localization and monitoring services to empower a caregiver to simultaneously manage multiple elderly patients.[13]

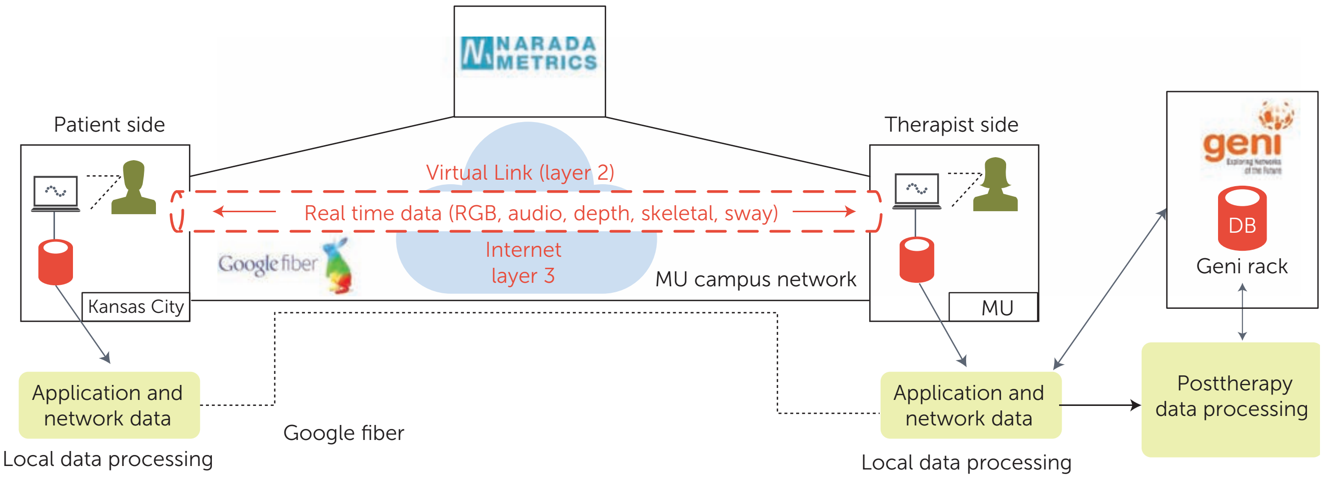

FIGURE 3. Remote physical therapy; immersive interactions between the physical therapist and the patient (older adult) using a network overlay setup.

ECaaS Design and Development Requirements

We envision the ECaaS design to mimic a smart service system that integrates the two primary apps we have previously developed using isolated sandbox approaches. In this section, we first provide our app details. Next, we outline requirements for their transformation into a secure, privacy-preserving, and embedded form within a real-world ELE for eldercare.

ECaaS Apps

App-1 is an in-home health alert system with remote care coordination capabilities that is based on ongoing analysis of sensor data obtained unobtrusively from older adult homes[1]. This app (voted best app in health at the 2013 US Ignite Summit, Chicago) was developed for generation of health alerts based on hydraulic bed sensors, motion sensors, Kinect depth sensing for in-home gait analysis, and data analysis algorithms from the University of Missouri. The project involved installation of sensor networks (each generates 23 Gbytes/person/week, even with compressed images) in 15 senior apartments in Iowa, having motion, bed and gait sensing for one year. Health alerts that are based on, e.g., changes in sleep patterns were sent to clinical staff in Missouri and Iowa. A major outcome was the development of bed sensor hardware and algorithms that capture pulse, respiration, and restlessness of elders, while positioned under a mattress.

App-2 is an in-home remote physical therapy application that is hosted within a Global Environment for Network Innovation (GENI) cloud infrastructure supported by the US National Science Foundation and utilizes high-speed last-mile network connections[2]. This app involved an interactive interface (see an example of a screenshot shown in Figure 1) that connects a PT located at a clinic to an older adult at home as illustrated in Figure 3. App-2 has been developed using Kinect-sensing technologies and has been tested with five participants in Kansas City connected through Google Fiber last-mile network connections. Major outcomes include the effectiveness of the PT interface through quantitative and qualitative assessments on gait and balance using depth images and results of network performance tests.

Figure 4 shows an example set of measurements we collected during the laboratory testing and baseline performance characterization of our App-2. Specifically, the figure shows the empirical cumulative distribution function plots of the bandwidth consumption of various stream types (audio, skeletal, color, depth) individually and in an aggregate as obtained from the Kinect API calls. We can see that a single PhysicalTherapy-as-a-Service (PTaaS) app session requires a peak of ≈ 200 megabits per second (Mbps) end-to-end available bandwidth between the therapist and patient to exchange the various data streams.

Moreover, given that the performance of the PTaaS app can be affected due to network health factors (e.g., delay, jitter, packet loss), we have tested the controlled network path between the patient and therapist. Thereby, we have confirmed the expected and degraded behavior under good and bad network scenarios, respectively. We also identified the need for integration of cloud-based services on GENI infrastructure for the large data handling/analysis from the homes. Further, we have identified the need to deal with a lack of public Internet Protocol (IP)

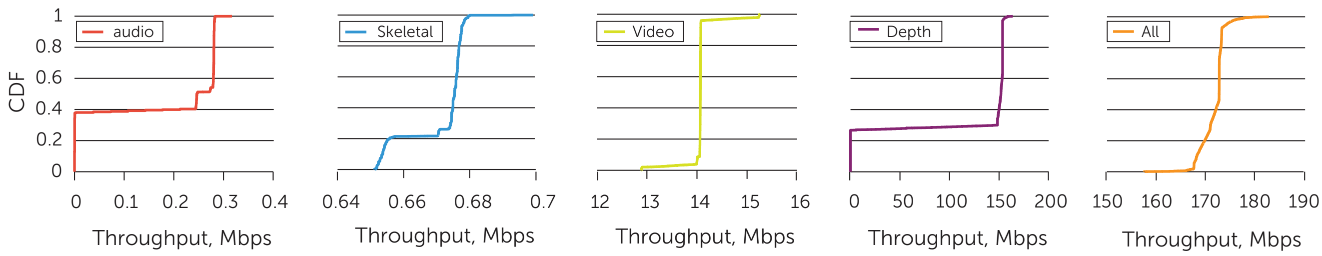

FIGURE 4. Bandwidth consumption of different PhysicalTherapy-as-a-Service data streams shown as empirical cumulative distribution function plots: (a) audio stream, (b) skeletal stream that has the lowest bandwidth consumption, (c) video stream with medium bandwidth consumption, (d) depth data stream that shows the highest bandwidth consumption, (e) all streams together nearly require ≈ 200 megabits per second end-to-end available bandwidth between the provider and home.

address support in private homes with Google Fiber. These have consequently led to our ongoing investigations on Layer 2 tunneling and related time synchronization for correlation analysis of Kinect sensor data, therapist/senior user experience, red, green, and blue (RGB) video, depth, as well as skeletal data[2].

Smart Service System Challenges

Several open challenges need to be solved to go beyond our isolated sandbox approaches for the apps in order to scale them in a cloud-based smart service system of ECaaS that can be widely deployed in urban, suburban, and rural areas. Our ECaaS vision is to make it suitable for ongoing assessment of health changes based on an individual's behavior, activity patterns, and baseline health conditions. We also seek to foster remote access at older adult homes involving frequent health assessments, physical therapy sessions, and health interventions, especially for those with transportation challenges, e.g., frail older adults who do not drive or those living in rural communities with long distances to a PT clinic. In the following, we list the two salient design challenges that we believe should be critically overcome to transform the ECaaS apps to a living lab environment for ongoing development that will ultimately result in a real-world ELE for eldercare.

Technical Architecture Design

The first challenge refers to provisioning of a technical networking capacity that can support the ECaaS, both with and without network paths involving last-mile Gigabit fiber connections such as, e.g., Google Fiber. Given the general assumption that all end user sites will have very high-speed last-mile links is not practical, we need to ensure that the apps delivery works properly in cases where the end-to-end network performance is unstable or not adequately tuned for satisfactory user experience. For instance, the app configurations should handle bottleneck cases such as, e.g., where a PT might want to know if the data from an older adult home is based on the actual gait measurements of balance or if the lags in the patient responsiveness data are inaccurate because of network latency or end-to-end available bandwidth problems.

Usability Design of Apps

The second challenge pertains to the delivery of the apps for older adults and PTs through user-friendly and interactive/immersive interface displays. The displays would need to be designed differently for the older adults and PTs in terms of the feature sets and access controls to sensor data and eldercare technology functions. Usability and user experience studies are required to provide the user interface layout and system components design for delivering the best quality of experience to the care coordinators. This will involve iterative development with end users as codesigners right from the beginning until the apps are regularly used in practice, i.e., the end users will need to help with the integration of the technical and the social dimensions to make the apps be ultimately delivered as socially embedded technologies within ELEs for eldercare.

Cloud-Based ECaaS Architecture

In this section, we present our vision of the cloud-based ECaaS architecture in terms of the network and computation infrastructure components and cloud services. We also describe our solutions that we obtained through experimentation and prescribe web service development guidelines that can help realize the cloud-based ECaaS architecture in practice.

Network Infrastructure Solution

The cloud-based ECaaS architecture relies on high-speed broadband connections between the older adult's home, the app provider (i.e., the clinic) site, as well as the ECaaS apps hosted within a cloud infrastructure. In order to develop a reference implementation of our proposed ECaaS architecture, we have set up a novel peer-to-peer app deployment infrastructure that integrates related technology components as illustrated in Figure 5. Our solution approach facilitates app services intercommunication and is suitable for security purposes if sensitive information is being exchanged between the app provider and older adult sites. Further, to meet the large data movement tasks in cloud service interactions and to satisfy the real-time requirements in the sensor data analysis, we have experimented with a variety of network configurations for network overlay setup between the various sites based on virtual link (Layer 2) technologies. For the out-of-band communications to support data processing with app-related data logs, we utilize regular Internet (Layer 3) protocols.

Through extensive performance troubleshooting of software and hardware virtualization alternatives provided by the Brocade Vyatta vRouter, we have engineered the overlay paths to satisfy the fast data movement requirements of video, audio, RGB, depth, and skeletal data for real-time display of gait and other movement parameters at both ends. Given that private home access network connections in Google Fiberhoods as well as in other home network settings do not have public IP addresses, our overlay network solution was also helpful in cases where our PT interactive interface (an example screenshot shown previously in Figure 1) needed binding of ports between the app provider and older adult home ends to allow custom protocol communications.

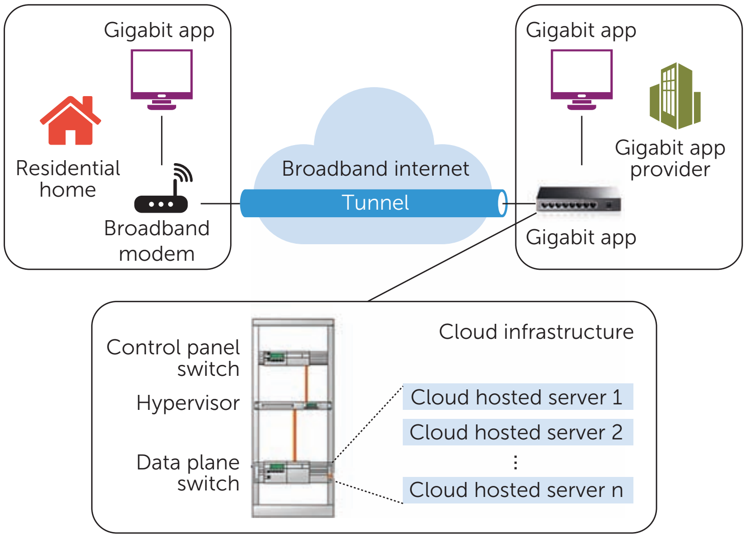

FIGURE 5. Peer-to-peer cloud-hosted gigabit app deployment infrastructure components between provider (physical therapist/clinic) and home user (patient).

Computation Infrastructure Solution

The MU (University of Missouri) hydraulic bed sensors as well sensors for motion and gait data collection are installed as part of the App-1 deployment. In the case of the App-2 deployment, the interactive interfaces on both the PT and older adult ends use a Kinect device along with a local computer (specifications: Windows 7 64 bits, RAM 4 Gbytes, storage 500 Gbytes, Gigabit NIC) that is mounted on a mobile cart that has a large display (specification: 1920 × 1080 pixels). The application, system and network performance data across the ECaaS-supporting infrastructure are processed locally for tasks such as preliminary sanitization and meta-data annotation (e.g., data folder naming), and are immediately sent to a cloud-hosted database for detailed data processing that help with later activity report discussions between the care coordinators and the older adults.

We utilize a GENI Rack, i.e., a community cloud infrastructure for the database hosting, to handle data management tasks. We also use the GENI Rack to host the peer-to-peer application orchestration signaling coordination module that is part of the overlay network setup described previously. For these purposes, the GENI Rack is configured with three virtual machines provisioned using the VMware ESXi hypervisor. The entire application, system, and network performance data collection, aggregation, and visualization are performed with our Narada Metrics software,[14] which was developed previously as an end-to-end network and application performance measurement framework[2].

Cloud Services Solution

For high-scale delivery of the ECaaS apps within a cloud-based infrastructure, we prescribe two layers of services with REST (representational state transfer) web services abstractions that are commonly used in cloud platforms, viz., 1) Secure Compute and Network Services and 2) Data Services. In Figure 6, we show our App-2, i.e., PTaaS, within the cloud-based ECaaS architecture. A challenge in the infrastructure configuration for secure services refers to compliance issues, i.e., pertaining to Federal Information Security Management Act Moderate or Heath Insurance Portability and Accountability Act (HIPAA), which are paramount in the healthcare-related technology infrastructures.

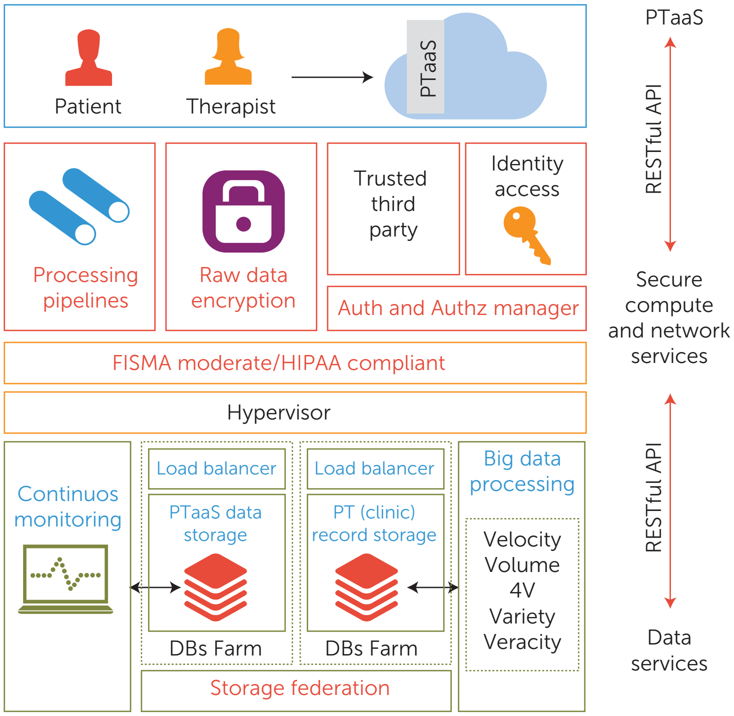

FIGURE 6. ElderCare-as-a-SmartSevice cloud-based services architecture for PhysicalTherapy-as-a-Service app delivery.

In the first layer, different processing pipelines should be developed that handle the workflow, security issues for the large amount of data-in-motion (e.g., SSL), and the access control as well as encryption for the high volume data-at-rest. The access control for security management needs to be implemented using Federated Identity and Access Management frameworks such as Shibboleth. We suggest that custom web interfaces be developed for the owners of the PTaaS system to be able to add, delete, or modify permissions of the different data query, analysis, and visualization tasks. In the second layer, components are related to data services that operate in virtualized storage environments and need to be federated across multiple private cloud (e.g., hospital data center) and public cloud (e.g., Amazon Web Services) platforms.

While making these decisions in the beginning and assessing their impact, our approach is to use the codesign and continuous monitoring approach with frameworks such as Narada Metrics. This approach allows us to query data from multiple sources and feed the results to tools that perform data analysis and visualization to indicate salient trends or bottleneck anomaly events. This procedure helps in decision making while using ECaaS with the goal of confirming, renewing, or revising them based on given data by App-1 and App-2 performance evaluations in a controlled environment.

Network Quality Estimator

We tested the health alert system of App-1 in senior housing with face-to-face clinical care coordination. However, as implemented currently, the approach does not scale well. Sensor data that was collected in the home is over 23 Gbytes/week/elder. To transfer that data in a timely manner to support health alerts has been hard to achieve consistently. Moreover, the relational database methods that have been applied have not allowed fast interactive access for huge databases. These technical issues involving local data processing at the network edge, i.e., at the elder homes, can be addressed through the emerging paradigm of fog computing to meet latency bottlenecks for interactive data analysis. For instance, the GENI Rack compute services can be coordinated with a local compute service that can intelligently perform preprocessing at the patient side, and postprocessing at the clinical care coordinator side based on the estimation of network quality constraints at the end sites. However, such a fog computing architecture in ECaaS will introduce security/privacy issues that need to be considered carefully in the data storage and data access configurations.[15]

In the case of App-2, ECaaS relies heavily on video conferencing for remote care coordination and thus requires high performance (≈ 200 Mbps) for accurately recognizing facial expressions, skin color, eye clarity, and speech patterns as well as inspection of depth data in real-time at the PT side. A robust network architecture with predictable end-to-end performance is essential for interactive monitoring and health interventions. We approach this design challenge by instrumenting the App-2 to obtain measurements for network quality estimation. Both active measurements (i.e., end-to-end TCP throughput, round-trip time delay, jitter, and packet loss) and passive measurements (i.e., transfer rate on uplink of the local interface, download rate at remote interface) are being collected using the Narada Metrics measurement framework.[14]

The technical challenges for integrating the ECaaS App-1 and App-2 point to several design options. We argue that a good start for ECaaS is the integration with remote deployment of sensing, big data analysis methods for storing and accessing consumer data, high-definition video-based communication, HIPAA-compliant security, and interactive interfaces, leveraging cloud computing and overlay network channels. For this integration, we are starting to use and test the newly deployed fiber networking infrastructures within urban, suburban, and rural communities in the state of Missouri. We have established ongoing partnerships with healthcare providers and gigabit fiber connection providers (e.g., Google Fiber, Co-Mo Connect, MOREnet) in these efforts in order to translate our research into real-world ELEs for eldercare.

A Living Lab Environment for ECAAS

We conceptualize the living lab for ECaaS as a combination of technology, network optimization, and cloud-based integration of our two apps as well as other future apps. We are working toward building a living lab environment that involves eight private homes of senior adults in urban, suburban, and rural areas as well as several local PT clinics in the Missouri region. We have access to a few of these homes and PT clinics from previous projects and through our project partners of Google Fiber and Co-Mo Connect. Our next step in the development of ECaaS as design-in-use within a living lab environment is guided by data-driven design-based research approaches such as usability testing, data analytics, and iterative design testing with end users.

We address three research approaches that we plan to pursue to deliver ECaaS to users in a performance-optimized manner for satisfactory user experience. The three research approaches and the corresponding research questions are described in the following subsections.

Cloud Service Management Studies

Huge amounts of data in real time can cause irritations for the users due to technical network problems (e.g., delays in providing data). The care coordinator or PT needs to be able to confidently assess whether nonideal performance in the exercise forms of an older adult is being adversely affected by lags in network communications in data-intensive interactive sessions or in fact is adversely affected by the physical and cognitive limitations of the older adult. The research questions to be answered include: How to optimize networks and cloud systems for ECaaS using health assessment data in remote settings? How to perform troubleshooting in bottleneck cases?[2]

Data Analytics Studies

Gait information needs to be presented back to older adults in-home and in a clear, understandable format. Furthermore, the apps need to provide pertinent information that fosters feedback to patients, PTs, or care providers to take suitable actions in cases where proactive care is essential. An important research question here is: What sensor information for automated health alerts needs to be fused for real-time analysis and optimization when in remote use?

Usability and Human-Centered Development Studies

There needs to be an integration of the apps into their context of use through sociotechnical design configurations such that patients, care coordinators, and PTs will actually use the apps in a sustained manner, instead of avoiding them. Important research questions include: How to integrate the sensors and apps into private homes and PT clinics such that they will become part of a sociotechnical system that supports co-evolutionary growth? Which interface layouts work best for the older adults, care coordinators, and PTs in the context of being user friendly, effective, and efficient?[16]

The above sociotechnical studies and system development involve agile iterative design testing, usability studies with end-users as codesigners, as well as data collection; we will adopt the sociotechnical walkthrough (STWT) method[17] for this purpose. STWT is a qualitative codesign workshop method based on focus group interviews in which the PTs and patients become codesigners of ECaaS and model the ECaaS in practice. STWT is moderated by an experienced research team member in a series of workshops (typically up to six workshops per year) to explore the users' perspectives and measure the benefits of ECaaS. Each workshop lasts 2 to 3 h, and the obtained results are organized as case vignettes.[18] The case vignettes inform the iterative and agile software development of ECaaS to produce user-friendly solutions.

Data collection in urban and rural homes through usability methods can include tasks analysis with think aloud techniques and user surveys with 10-point standard usability score rankings administered during the ECaaS apps use. The data collection also encompasses quantitative data such as cloud system and network performance measurements. Collected datasets can allow us to measure whether the ECaaS solution is usable by the users and how fast the users achieve their tasks when they use ECaaS. User surveys also help us to evaluate interactive interfaces in the context of both remote PT and clinical care coordination, studying the technical quality of the video and audio streams as well as usability, user satisfaction, and effectiveness. Further, they can help us assess whether/how ECaaS increased the patient quality of life (e.g., avoiding many hours of travel to have access to a PT).

Conclusion and Outlook

In this article, we presented the design of an ECaaS system that can facilitate proactive health monitoring and targeted care coordination of older adults within their in-home settings. We detailed the challenges in the cloud transformation of sandbox approaches of ECaaS apps into a living lab environment with actual users. The purpose of the living lab is to facilitate ongoing app development to ultimately create real-world ELEs for eldercare. We not only focused on the technical design of the infrastructures and apps development, but argued how the social and organizational design needs to be considered within the context of ECaaS use in practice, i.e., within the organization of clinics, PTs, and their workflows as well as the environments and daily processes of patients' in-home settings.

We outlined how a codevelopment strategy that involves the stakeholders to assume relevant roles (i.e., healthcare providers serving as app owners as well as older adult end-users serving as app consumers) in order to work together to make ECaaS into a highly secure, privacy-preserving, and socially embedded smart service system. Our suggested approach was to apply different methods of usability and human-centered design concepts such as the STWT to help stakeholders to adopt the ECaaS and refine it during design-in-use within a living lab environment. Further research of ECaaS activities based on our design presented in this paper can enhance understanding at the level of sociotechnical configurations for ELEs targeted for elder care. In particular, our proposed efforts to obtain user surveys and conduct behavior modeling with end users will lead to useful interactive interfaces for the ECaaS apps that improve clinical care coordination. In addition, they enable studies of cloud-based services to effectively handle the video and audio streams through metrics of usability, user satisfaction, and app effectiveness for eldercare that can be seamlessly delivered across urban, suburban, and rural areas. Thus, our ECaaS design has the potential to improve quality of life for older adults and their care coordinators through pertinent social embedding of apps within ELEs for eldercare.

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