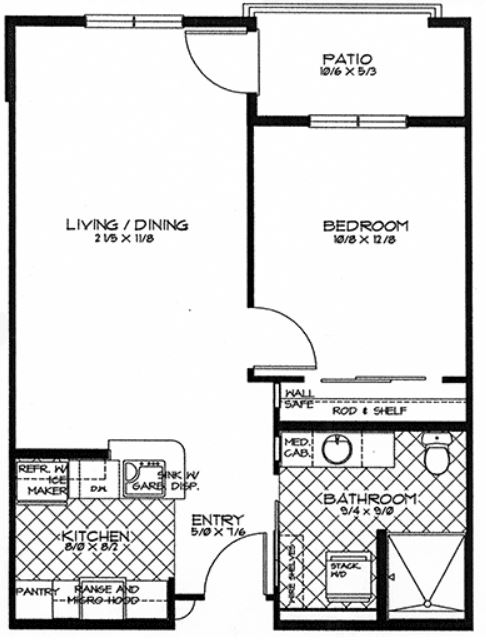
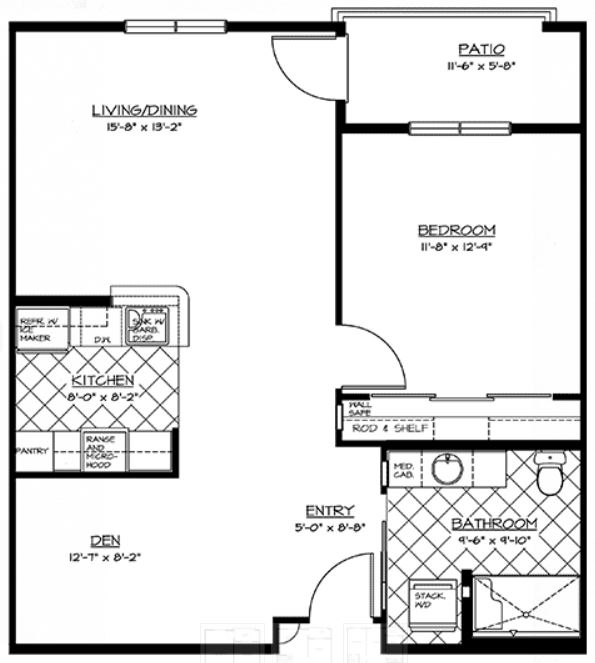
**Sensor Selection**

The aim of this document is to serve as a point of aggregation for our initial research on sensor selection. The goal of these sensors:

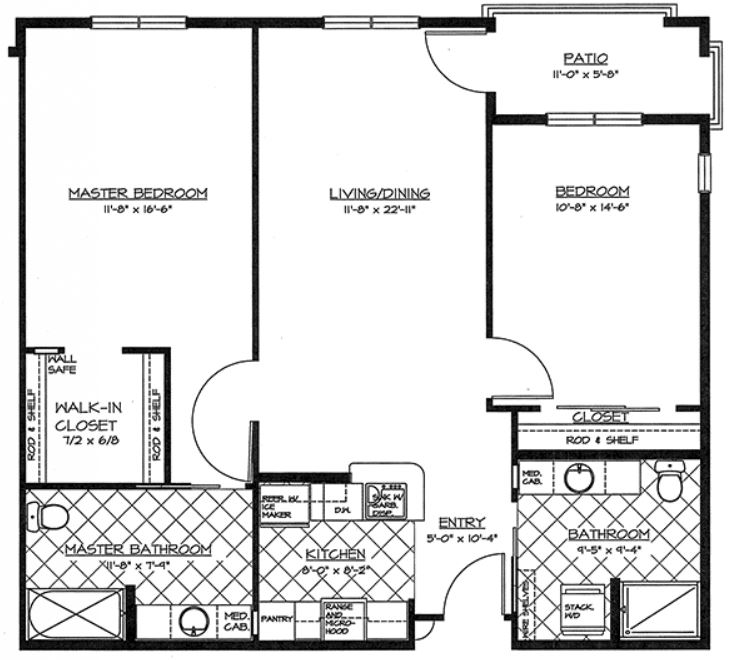
* Activity monitoring (who, where, when why)
* Cognitive change monitoring
* Function change
* Internal state of the person (depression, sick, dehydration etc)

The rooms that will be instrumented look like the following (example floor plans from Paradise Valley):

**1 Bedroom, no den 1 Bedroom with den**

**2 Bedroom**



**Sensor Documentation**

A major aspect of this project will be integrating different sensor technologies. We need to ensure that the backend can get access to the raw data, receive all measurements, and process the data. As such, for each sensor and sensor technology, we should consider:

1. Communication method (wired, Bluetooth, WiFi, etc.)
2. Data format (encrypted, JSON, proprietary binary message, etc)
3. Timing Requirements

**Events to capture**

**Fine Motor Control**

IBM feedback:

* Notepad with pen
* Android phone w 3d touch
* Accelerometers on items
* Hiro’s algorithms

Signs of cognitive decline include significant drop off in ability to [tap fingers](http://www.medicaldaily.com/finger-tapping-test-shows-no-motor-skill-decline-until-after-middle-age-244927) after age of 65 because the brain takes a long time to process planning a tap; and shaking/tremors

TV Remote Sensors:

1. **App on Andriod phone with 3D touch**
2. Apple TV remote
   1. Minimalistic, touch screen, voice processing
3. Amazon fire remote (need to look up more background)
   1. Bosch Sensortec BMA150 chip, 3-axis accelerometer (Currently not accessible via API)
   2. Voice processing

Both the Apple and Amazon remotes are likely too new and different from existing remote technologies for easy adoption

1. Could instrument a remote with accelerometer and small micro to communicate data to back end
   1. <http://ieeexplore.ieee.org/document/6906075/>
   2. Can use remote to also differentiate between people (http://bid.berkeley.edu/files/papers/chang2009inferring.pdf)
2. Skcript new design for elder-sensitive remotes: <https://www.skcript.com/svr/skcript-research-project-a-tv-remote-for-senior-citizens/>
3. iPhone 6S: measures the pressure of a finger touch: <https://www.forbes.com/sites/jvchamary/2015/09/12/3d-touch-iphone-6s/#2e4e9c704cee>
4. Touchscreen tablet use for measuring fine motor skills in children: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5078468/>
5. Android touch screen force:
   1. <https://developer.android.com/training/gestures/detector.html>
   2. How to detect it: <https://stackoverflow.com/questions/18538513/how-to-detect-screen-pressure-on-android>

Another avenue besides TV monitoring could include monitoring use of landline phones (From PI meeting)

1. Accelerometer?
2. Audio?

Another avenue could include monitoring usage of microwave, speed of taps based on sounds of button pressing?

1. Simple audio sensor

**Sleep Trackers**

Capture restlessness, sleep habits, REM, nightmares, and accidents

A more comprehensive list of sleep trackers: <https://sleeptrackers.io/>

Sensors:

1. **EarlySense Bed/Sleep Sensor (IBM says “Good”)**
   1. IBM:
      1. had more features than withings aura; good relationship
      2. Susann will send me documentation; goes up to their cloud, can grab and pull down; have APIs where we can grab it
   2. Heart rate, heart rate variability, breathing rate
   3. <https://www.earlysense.com/medical-services/products/technology-platform/>
      1. Unsure how to integrate at this time. Limited information online.
   4. Correct product is EarlySense Live!! (<https://www.earlysense.com/digital-health/product/sleep-tracker/>)
      1. Allows download of up to 14 days of raw data through their app
2. Withings Aura Bed/Sleep Sensor (IBM says ??)
   1. $158.99 on Amazon <https://www.amazon.com/Withings-Aura-Smart-Sleep-System/dp/B00LC2VWJI>
   2. Review from sleeptrackers.io (<https://sleeptrackers.io/withings-aura/>)
   3. Provides light and sound to help you fall asleep
   4. Monitors heart rate, breathing rate, ambient light and temperature
3. BeautyRest Sleeptracker Monitor
   1. $129.25 on Amazon
   2. Amazon Echo/Alexa integration
   3. Tracks movement, respiration, and heart rate
   4. Plugs into wall, comms via WiFi
   5. Comes with two sensors so couples can independently track their sleep
   6. Place sensor under pillow end of bed
   7. Installation video (<https://www.youtube.com/watch?v=aeQy1Rzr6fM>)
   8. **Unable to access raw data**
4. Beddit 3 Sleep Tracker
   1. $149 on Amazon (currently unavailable)
   2. Acquired by Apple in May 2017
   3. Uses capacitive touch sensor to determine if person is in bed
   4. Monitors “sleep quality”, heart rate, breathing, snoring, room temp, and humidity
   5. Sleep Quality metrics:
      1. Sleep time and efficiency
      2. Sleep onset (time it takes to fall asleep)
      3. Light and deep sleep cycles
      4. Time way from bed
      5. Time awake
   6. USB power adapter, 3 m cable
   7. Detects snoring using a phone’s microphone
5. SevenHugs HugOne
   1. Consists of a base station that communicates over WiFi to up to 8 sensors
   2. Mini sensors are powered by CR2032 battery, lasts 6 months
   3. Sensors store data over night and transmit in burst upon wake up
   4. Base station has VOC sensor, humidity, and temperature sensor and can integrate with Nest. Can also communicate with Phillips Hue smart lights to change lighting hue to red shift at night and blue shift in morning in coordination with your sleep patterns
   5. Android/Apple application
   6. No info on website… Maybe not available any longer?
6. ResMed S+
   1. <https://sleep.mysplus.com/>
   2. Non-contact, sits on bedside table.
   3. Detects upper body movement, both respiration and overall postural changes. No HR!
   4. Also tracks light, noise, and temperature conditions of environment
   5. Operates by reflection of 10.5 GHz RF
   6. Has an S+ mobile app and sleep analysis performed on cloud-based system
7. Eight
   1. $299
   2. <https://eightsleep.com/>
   3. Someone developed an API by packet sniffing: <https://community.smartthings.com/t/release-eight-sleep-connect-v1-0-eight-sleep-mattress-and-cover/73106/26>
   4. Mattress cover
   5. Measures room temp, humidity, noise, ambient light, heart rate, breathing rate, movement, and bed temperature (maybe can control bed temperature on each half?)
   6. Connects to WiFi/BLE/IFTTT
8. Hello Sense
   1. (potentially shutting down company)
   2. $60-$100
   3. <https://hello.is/>
   4. Consists of a futuristic looking base station that sits next to bed, connects over BLE to a “Sleep Pill”. Base station monitors noise levels, temperature, humidity, and air quality (AQI)
   5. Sleep Pill has 6-axis acceleration. When placed on pillow, detects body movement during sleep. Battery lasts 1 year.
9. Emfit QS
   1. <https://www.amazon.com/Emfit-QS/dp/B0158W3E2A>
   2. Ballistiocardiography based sensor
   3. From <https://sleeptrackers.io/emfit-qs-hrv/>
      1. Data can be exported to a CSV
      2. Data includes HRV throughout the night, average heart rate, respiratory rate
10. Nokia Sleep
    1. <https://sleeptrackers.io/nokia-sleep/>
    2. IFTTT integration
    3. Ballistocardiography-based sensor
    4. Powered by USB
    5. Not yet available, released in Q2 2018
11. <http://delivery.acm.org/10.1145/3000000/2994562/p230-nguyen.pdf?ip=137.110.74.100&id=2994562&acc=ACTIVE%20SERVICE&key=CA367851C7E3CE77%2E30F2CC1B2E6C2B37%2E4D4702B0C3E38B35%2E4D4702B0C3E38B35&CFID=1004636877&CFTOKEN=12642948&__acm__=1510790939_2fa870bcf5bb9353523af9b6ffc6e04a>

**Wearable Watch**

From IBM: On-body watch was only used for physical therapy, people didn’t like it much for daily living

There are a large number of smart watches/fitness trackers on the market. They all have accelerometers (low power, easy to integrate), some have heart rate monitors (more power, lower lifetime), and a few have GPS (very energy intensive).

For smart watches with accelerometers only, several options exist that can last up to 8 months on a standard watch battery and have BLE connectivity. For those with heart rate monitoring, the battery lasts about a week before requiring a recharge.

Look at this article about validation of commercially available smart bands: <https://www.ncbi.nlm.nih.gov/pubmed/26969518>

Almost all connect to a smart phone (Android, iOS) and there’s a mixture of display types.

1. Apple Watch
   1. (IBM says: did not give adequate data for those analyzing it)
   2. $329
   3. GPS, heart rate sensor, cellular connectivity
   4. <https://www.apple.com/newsroom/2017/11/apple-heart-study-launches-to-identify-irregular-heart-rhythms/?utm_source=Benedict%27s+newsletter&utm_campaign=3558ad1e7e-Benedict%27s+Newsletter&utm_medium=email&utm_term=0_4999ca107f-3558ad1e7e-70535861>
2. **Withings Go (now called Nokia Go) - Tajana check SmartGrid watch**
   1. (IBM says: good)
   2. <https://health.nokia.com/hk/en/go>
   3. Battery lasts 8 months
   4. BLE connectivity
   5. Accelerometer
3. Fitbit Alta HR
   1. $149
   2. Heart rate tracking, OLED touch screen, can monitor sleep patterns
4. Nokia Steel
   1. <https://health.nokia.com/us/en/steel-limited-edition>
   2. Looks like good looking traditional watch
   3. Standard watch battery that lasts 8 months
   4. Accelerometer
   5. BLE connectivity
5. Midas Watch??

**Lifelogging Cameras**

A clip-on camera or device that can be worn that either takes pictures at preset intervals or when sensors indicate that a picture should be taken. Person can wear it when a significant event is about to happen. By reviewing images after the fact, the individual can better form memories of the event.

1. SenseCam (From PI meeting, not available for purchase)
   1. Classified as a “lifelogging camera”. Digital camera that takes photographs passively while being worn
   2. Electronic sensors that include light intensity, light color, passive infrared, temp sensor, and multiple-axis accelerometer
   3. Can capture about 30,000 images on flash memory, useful for supporting a person’s memory
2. FrontRow FR
   1. <https://www.frontrow.com/>
   2. Hangs around the neck
   3. Several hour battery life
   4. Records video, fast charge over USB, touchscreen on back and speaker to play back video
3. iON Lite SnapCam
   1. 1.5 in^2, < 1 oz
   2. Clips on with clip or magnet
   3. Tap on the camera to take a picture, double tap to shoot HD video
   4. Bright colors
   5. 7 day stand-by battery life
   6. 3000 photos/2 hr HD video on single charge
4. SereneLife Clip-On
   1. Clip on
   2. SD Card slot
   3. 1.8 in LCD screen to review pictures
5. GoPro Hero5
6. **Kinect - can get gait and body posture**
   1. Use as a stick figure

**Balance/Gait**

How they are walking: their gait, speed, stability, etc.  
How fast a patient walks could be a better predictor of health issues like cognitive decline, falls, cardiac diseases, etc.

Sensors: **Tajana: It might be interesting to put something on/in a shoe; check on connectivity; nothing too invasive; accelerometer on a shoe?; nike step counter?**

1. Gait up: <https://www.gaitup.com>
   1. Strap around shoes
2. Gait: <https://www.apdm.com/mobility/>
   1. System consists of a chest monitor, two wrist sensors, and two shoe sensors
   2. Can also get just a belt sensor
3. Fall Detection: <http://www.toptenreviews.com/health/senior-care/best-fall-detection-sensors/>
4. WiGait (MIT design): <http://news.mit.edu/2017/dina-katabi-csail-team-develop-wireless-system-to-detect-walking-speeds-0501>
5. **Moticon Insole**
   1. 13 capacitive pressure sensors and a 3-axis accelerometer in insole
   2. Battery life 6-48 hours (continuous monitoring) or > 59 hrs in smart mode (utilizes sleep/wake cycles, doesn’t record when user isn’t wearing shoes, etc)
   3. <http://www.moticon.de/science/>
   4. Datasheet/User Manual <http://www.moticon.de/wp-content/uploads/2017/05/Moticon-SCIENCE_booklet_en_print_01.01.01.pdf>
   5. 2.4 GHz ANT wireless
   6. Plug into USB for data comms or charging
   7. High cost (1000s of Euros per pair)
   8. **Balance and Gait:** *(Michael)* We will use a gait and balance monitoring system that is installed in a subject's shoes with a replaceable insole. Available systems, such as the Moticon Science insoles (<http://www.moticon.de/science/>), have pressure sensors embedded into the insole to detect weight distribution and accelerometers to detect foot motion and impact force. The sensors can operate for 14 days before requiring a recharge over microUSB. Data can be acquired from the insoles by either a wireless ANT+ connection to a local aggregator for real-time updating of data or through a download over a microUSB connection by researchers after the study period. All data will be associated with an anonymized subject ID and stored encrypted.
6. IBM Japan with Kinect
7. Lianne Chiakovsky’s sensors in shoes to detect balance changes
   1. From PI meeting, need more detail.
8. **Pressure Mats - can put them in front of a sink, how well balance on feet? By shower?**
   1. Tekscan MatScan (<https://www.tekscan.com/products-solutions/systems/matscan>)
      1. Tethered (usb) or wireless
      2. Detailed analysis of weight balance
   2. Cheaper binary pressure switches
      1. Could be used to activate local sensors to save on battery life or as an additional input
      2. <http://www.frightprops.com/pressure-sensing-mats-0425.html>
      3. <https://www.thomasnet.com/products/pressure-sensing-mats-50353101-1.html>
   3. SensingTex
      1. <http://sensingtex.com/pressure-sensor-tex>
      2. Provided SDK

**Audio Capture**

Pauses in speech and language and syntax usage can be used to infer cognitive decline.

Resources:

* GREAT RESOURCE to understand: <https://www.asha.org/PRPSpecificTopic.aspx?folderid=8589935289&section=Signs_and_Symptoms>
* pauses/filler words (Ex. “uhh”)
  + One minute speech [test](https://www.medscape.com/viewarticle/883159)
* Language, syntax, etc.
* How to implement [gap detection](https://www.audiologyonline.com/ask-the-experts/gap-detection-641) in speech
* Excellent microphone array implementatoin in robotics; recommended by Henrik C: <https://introlab.3it.usherbrooke.ca/mediawiki-introlab/index.php/8SoundsUSB>

Sensors:

1. **Microphone array - collect data ourselves with RPi - not the words said but pattern in speech, never send data but do analysis locally**
2. Google voice: https://www.cnet.com/how-to/how-to-delete-your-google-home-voice-recordings/

**Localization**

(short description)

Sensors:

1. **Bluetooth Localization - look into Dhanesh’s code re. WiFI/BT localization; go w BLE enabled watch**
   1. Use BLE beacons for localization. Deploy beacons throughout the house (as required) and use simple clustering algorithms over RSSI values. (Would require the user to carry device on person ). Batteries last around 1~2 years. Some of them even more. Requires per house/location training.
   2. Available commercially. Most major beacon manufacturers provide their own localization engine as well to minimize dev time.
   3. Can also be used in combination with WiFi localization
   4. [Estimote beacons](https://estimote.com/?gclid=EAIaIQobChMItZjUw5zN1wIVEdlkCh2gGwrFEAAYAiAAEgKnEvD_BwE)
      1. Open SDK
      2. Battery life of 2 years for larger location beacons, 6-12 mo for location stickers
   5. [Kontakt](https://store.kontakt.io)
      1. Implement iBeacon and Eddystone protocols
      2. Variety of form factors (Beacon, Beacon Pro, Card Beacon, USB Beacon)
      3. Beacon: 2 yr battery life, BLE
      4. Card Beacon: 18 mo battery life, on/off switch, BLE + RFID + NFC
      5. Beacon pro: 5 yr (seems long), BLE + NFC
2. WISP <https://sensor.cs.washington.edu/WISP.html> - evaluate further
3. WiFi/RF - MIT
   1. Not a good option - fails at multi-occupant tracking, multipath effects can vary due to movement of everyday objects. Requires extensive training.
   2. Monitor channel state, exploit multipath to localize occupants and monitor human movements
   3. If multiple routers are available localization could be done by relative estimation of phone wrt the routers. (Similar to BLE Beacon approach). Again requires the user to carry a device.
4. RFID - can tell who touched object that is tagged
   1. Intel WISP - tells you if object moved but not who touched it
      1. Similar to RFID but use a more high powered reader in the home (10 feet range) and use WISP tags on objects
      2. Battery free and wirelessly powered.
      3. <https://github.com/UCSD-SEELab/papers/blob/master/har/daily-rfid.pdf>
      4. Requires a RFID reader which are quite expensive.
   2. Tag every object and the reader is on a user’s wrist
   3. Passive sensing can be used as well. Deploy transmitters and receivers and observe changes in signal due to multipath effects as user moves around([paper](http://delivery.acm.org/10.1145/2080000/2070992/p365-xu.pdf?ip=169.228.154.217&id=2070992&acc=ACTIVE%20SERVICE&key=CA367851C7E3CE77%2E30F2CC1B2E6C2B37%2E4D4702B0C3E38B35%2E4D4702B0C3E38B35&CFID=1007911442&CFTOKEN=19808974&__acm__=1511184935_18fcb7081e9b535c0d224b78bab657e9))
   4. Same issues as that of WiFi. Requires extensive training. Requires re-training when things are moved around.
   5. Battery life: Usually not a concern as tags are generally passive and are powered wirelessly by the reader.
   6. A few different methods are available: eg. This one uses read rates ([paper](http://delivery.acm.org/10.1145/2400000/2396811/p375-yan.pdf?ip=169.228.154.217&id=2396811&acc=ACTIVE%20SERVICE&key=CA367851C7E3CE77%2E30F2CC1B2E6C2B37%2E4D4702B0C3E38B35%2E4D4702B0C3E38B35&CFID=1007911442&CFTOKEN=19808974&__acm__=1511185942_f2b3cabd8fd1d8d6e87a2a48fce8c473))
   7. Used in stores for monitoring sales statistics (eg. how long consumers spend time in front of a product etc.). No idea about localization usage in commercial / off the shelf settings.
5. Audio (Max) - see google home if we can tap into it
   1. Sample audio below Nyquist to preserve privacy
   2. In research only (just 1 paper). No sufficient literature to determine how effective this would be. Think this would be an effective idea though.
6. Static electric field (Not Optimal)
   1. Measure relative capacitance between sensor and human body to determine movement and proximity to objects (Research ). Not implemented / available commercially.
7. Chemical sensors for detecting occupancy, cooking, bathing, etc
   1. Ramon Huerta

**Motion Sensors**

Passive Infrared (PIR) **need battery powered version**

* Detects body heat (infrared energy) over wide area.
* Can be masked to enhance detection of specific areas

1. Adafruit PIR sensor
   1. Cheap, easy to deploy, require power, would have to connect to processor (RPi or other)
   2. <https://www.adafruit.com/product/189>
2. D-Link Wi-Fi Motion Sensor (DCH-S150)
   1. WiFi enabled motion sensor, has a plug on back and is meant for monitoring from a socket
   2. Sends push notification over iOS and Android
3. **Samsung Presence Sensor - pick one of the two that gives more info**
4. **Samsung PIR Motion Sensor - either PIR or presence**
5. SwiftSensors Wireles Motion Sensor (PIR) (302)
   1. <https://www.swiftsensors.com/shop/sensors/ss-sen-302/>
   2. BLE or WiFi, may have to use a SwiftSensors data bridge
6. Look up more sensors from https://www.smartthings.com/products/-/filter/categories/sensors

Microwave

* Sends out microwave pulses and measures the reflection off a moving object. They cover a larger area than infrared sensors, but they are vulnerable to electrical interference and are more expensive. Can be used to approximate size and velocity? (find citations)

Acceleration Tags

1. **Samsung Multisensor Accelerometer** and Contact (IBM said old version of contact did not work well - evaluate)
2. **Netatmo Tag Accelerometer - IBM liked it**
   1. <https://www.netatmo.com/en-US/product/security/welcome/tags>
   2. From website “Netatmo Tags only work with the Netatmo Welcome”
   3. Netatmo Welcome is an indoor security camera with face recognition
   4. Applications on Apple and Android
   5. Communicates over WiFi or ethernet
3. SwiftSensors Wireless Waterproof Vibration Sensor
   1. <https://www.swiftsensors.com/shop/sensors/ss-sen-202/>
   2. Communicates over BLE
   3. (non waterproof version) <https://www.swiftsensors.com/shop/sensors/ss-sen-201/>
4. **Estimote Sticker** - long battery life, easy development environment, open 6-12mo
   1. <https://estimote.com/products/>
   2. <https://github.com/Estimote/Android-SDK>
5. Adtile sticker

Contact Sensors - open/close cupboards - find reliable version

1. BLE wireless contact sensor
   1. <https://www.amazon.com/Bluetooth-Smart-Wireless-Contact-Sensor/dp/B00WER6CU4>
   2. CR2032 coin battery, alerts on open/close
2. iSmartAlarm
   1. <https://www.ismartalarm.com/p/isa00004/contact-sensor?productId=3>
   2. WiFi, battery powered
   3. IFTTT compatible

mmWave technology

High frequency RF (77-81 GHz) wave are transmitted and reflections are measured. Based on phase shift of reflections, angular position can be determined. TI showcased this technology at CES for use with people tracking using a single eval board (IWR1642BOOST) (<https://www.youtube.com/watch?v=RT56YzqME6M>) and cascaded chips (<https://www.youtube.com/watch?v=C49lhsiIrso>). Resolution is limited by the FFT that is performed on the received chirp data. By having additional RX antenna, the resolution will increase. Alternatively, increasing the number of TX antenna and transmitting using orthogonal codes or TDMA will also scale. Using multiple RX and TX is termed MIMO radar. For N = N\_TX \* N\_RX, angular resolution theta = 2 / N . The test cases shown on the above YouTube videos shows the technology in operation out to 100+ m, which is more than sufficient for our use case. The arrangement of the antenna can potentially allow for up-down discrimination in addition to left-right discrimination, but data from orthogonal axes would require antenna that could no longer operate in the other direction, reducing angular resolution. (Antenna layout for different monitoring applications could be potentially interesting)

An overview of the technology can be found <http://www.ti.com/lit/an/swra554/swra554.pdf> .

The AWR series (AWR1443, AWR1642, AWR1243) has a higher operating temperature range. The IWR series (IWR1443, IWR1642) has a normal industrial temperature range (-40 to 105 deg C). All chips, except for AWR1243, have an integrated TI MCU. The 1443 series has a hardware accelerator with 4 RX and 3 TX antenna connections. The 1642 series uses a DSP and has 4 RX and 2 TX antenna. The TI micros can be programmed using Code Composer Studio, which used to be quite expensive, but now is free!

The eval module is the IWR1642BOOST (<http://www.ti.com/tool/iwr1642boost>) and can be purchased for $299 or $598 for the eval board + development kit. TI application engineers have developed applications for the eval board that should be easy to bring up, including a people counting demo (http://dev.ti.com/tirex/#/?link=Software%2FmmWave%20Sensors%2FIndustrial%20Toolbox%2FLabs%2FPeople%20Counting%20Demo)

**Toileting - let’s stick with motion sensor correctly masked**

1. Intelligent toilet seat (<http://scholarworks.rit.edu/cgi/viewcontent.cgi?article=10426&context=theses>)
   1. Monitors ECG, PPG, BCG, weight, balance
   2. Created in a lab at RIT, will have to contact for further access
2. Pressure sensing mat - on toilet bowl
   1. <http://www.telehealthsensors.com/products/toilet-sensor/>
   2. <https://www.tekscan.com/products-solutions/systems/matscan>

**Smart Scale - check with CogSci people**

1. Scale that measures BMI, bone index, and water volume index: <https://www.pcmag.com/roundup/343154/the-best-smart-bathroom-scales>
2. BIA-type scale: Tanita Duo Scale
3. <https://thewirecutter.com/reviews/best-smart-scales/>
4. Tanita ($50), QuardioBase ($110), Yunmai ($50),
   1. Upload data to cloud using wifi, bluetooth sync data from app
      1. <https://www.iyunmai.us/pages/faqs#general6>

**Video-Like Devices**

1. DVS camera
   1. (a few thousand $) - see how to use it in a home; merge data with kinect
   2. 1000 frames/sec (toby in germany offered to help)
   3. only sends out changes so lower storage; neuromorphic camera
   4. Give fidelity on tremors, gestures
2. **Kinect Sensor - IRB, min 2, one on each end of the main room**
   1. Advantage of Kinect is that it can only send depth map instead of full RGB, potentially making people more comfortable
   2. Unstructured Human Activity Detection from RGBD Images
   3. Link to mihir’s work: <https://drive.google.com/drive/folders/0B3YnzISnFfRfVzBjZ2xmUGlPZjg>
   4. <http://pr.cs.cornell.edu/humanactivities/>
3. Other stereo cameras?

**Power Measurement**

1. **Smart Plugs (Rishi via Dhanesh) TPlink worked well**
   1. WeMo Insight Switch
      1. $45
      2. <http://www.belkin.com/us/p/P-F7C029/>
      3. Works with Amazon Alexa and Google Voice, Wi-Fi (3G/4G)
   2. Elgato Eve
      1. $50
      2. https://www.elgato.com/en/eve/eve-energy
   3. D-Link Wi-Fi Smart Plug
      1. $50
      2. <http://us.dlink.com/products/connected-home/wi-fi-smart-plug/>
   4. Samsung plug
   5. Tp-link Wi-Fi Smart Plug (HS100) - got lots of them
      1. $30
      2. <http://www.tp-link.com/us/products/details/cat-5516_HS100.html>
2. **Smart Bulbs** (Rishi via Dhanesh)
   1. tells you about activity in a particular space
   2. TPlink from Dhanesh; got lots of bulbs
   3. Check if Samsung has them?

**Water Flow - check into this**

1. Use a small custom sensing node with just an accelerometer and WiFi and stick it to the top of the tap (the rotating or swiveling head)?  
   IDEA: Taps rotate / swivel in specific directions (clockwise - anti clockwise if it’s a screw type, up or down if it’s a lever like mechanism). We could just stick a small MCU platform with a microcontroller like ESP8266 or Arduino Lillypad to train/monitor it for these specific movements. Can easily figure out how long the tap was running, whether it was turned off or not, approximate flow, how often it was used etc. Cost effective as well.
2. Use **vibration sensors?** Sound?
3. Leak detector?
4. Ultrasonic flow meters
   1. FLUID <http://www.fluidwatermeter.com/>
      1. Kickstarter, not available until 2018
   2. Osiris (<https://www.myazapps.com/store>)
      1. Currently “Out of stock”, available Nov 2017
   3. Ultrasonic front end from TI
      1. <http://www.ti.com/lit/an/snia020/snia020.pdf>
   4. Flow Pulse (<https://www.pulsar-pm.com/product-types/flow/flow-pulse.aspx>)

**Indoor Air Quality/Environment**

1. Netatmo Indoor Weather - used by IBM
   1. Temperature, humidity, CO2 levels
   2. Interfaces with Amazon Alexa, individual can ask about the weather, potentially analyzing speech patterns
   3. $149 for indoor/outdoor pair
   4. https://www.netatmo.com/en-US/product/weather/weatherstation
2. **MetaSense Air Quality Sensor - point to published paper**

**Sentiment Detection**

Used by a Stanford group since depression is a large factor in dementia (<http://stanfordhealth.weebly.com>). Videos were labelled for moods identified using face detection, face, and content.

To work with privacy constrictions, could analyze face expressions in place and remove video. Video may be needed for initial training and validation of models.

1. 4k video for facial analysis (but too big storage)
   1. From PI meeting, need more detail.

**On-Body Sensing**

* Good resource for a number of wearable body sensors: <https://www.tractica.com/research/smart-clothing-and-body-sensors/>

1. Electrochemical glucose sensors from Joe Wang
   1. "Re-usable Electrochemical Glucose Sensors Integrated into a Smartphone Platform", A. J. Bandodkar, S. Imani, R. Nunez-Floresa, R. Kumar, C. Wang, A. M. V. Mohan, J. Wang, P. P. Mercier, Biosens. Bioelectron., 101 (2018) 181.
   2. "Wearable Non-invasive Epidermal Glucose Sensors: A Review", J. Kim, A. S. Campbell, J. Wang, Talanta, 177 (2018) 163.
2. Sensors to detect multivitamin mixtures from Joe Wang
   1. "Electrochemical Signatures of Multivitamin Mixtures", V. Mohan, B. Brunetti, A. Bulbarello, J. Wang, Analyst, 140 (2015) 7522.
3. ~~Myo armband - lets not use~~
   1. ~~Wearable (arm motion and gesture recognition) - EMG + 9-axis IMU~~
   2. [~~https://www.myo.com/~~](https://www.myo.com/)
4. Leg monitor (TSR: could you clarify please?)
5. ~~Hexoskin: wearable clothing that monitors cardiac, respiratory, sleep, and activity data. Uses bluetooth connectivity.~~ [~~https://www.hexoskin.com~~](https://www.hexoskin.com)
   1. $400
6. Vital Connect patch measures heart rate, activity posture, single-lead ECG, skin temp, fall detection: <https://vitalconnect.com/solutions/vitalpatch/>
   1. No specific platform?
   2. Has been used with PhysIQ--analytics designed platform designed to process multiple vital signs from wearable sensors and create a dynamic baseline for each individual
      1. <https://vitalconnect.com/physiq-and-vitalconnect-collaborate-to-deliver-home-hospital-pilot-initiative-for-patients-admitted-to-home/>
   3. Open, scalable and highly secure cloud connectivity is another important part of the VitalConnect platform. This enables the measurement data that VitalPatch secures from patients to be instantaneously delivered to servers, computers and mobile devices, available for real-time analysis by healthcare professionals
      1. <https://vitalconnect.com/solutions/>
7. Dehydration sensors - provide more info; smart scale might do it?
   1. Potential sensors:
      1. <http://nixbiosensors.com/biosensor/> - not on the market yet
      2. <https://www.bsxinsight.com/>
      3. <https://www.kenzen.com/> - wearable smart patch for sweat analysis
      4. WBAN:
      5. BiSensor that UC Berkeley built using Texas Instrument Circuts: <https://www.allaboutcircuits.com/technical-articles/exploring-uc-berkeley-wearable-sweat-sensor-monitoring-dehydration/> - small, wearable, but not on the market as a product yet; it can track hydration levels as well as the presence of ions that indicate pH, glucose levels, cystic fibrosis insights - <http://www.mobihealthnews.com/content/stanford-and-uc-berkeley-researchers-develop-wearable-sweat-sensor-diagnostic-tool> - more info - <https://www.nature.com/articles/nature16521#affil-auth>
      6. If we can looks at just the chemical makeup of the surface of the skin:
         1. <https://bio-medical.com/skin-conductance-sensor.html> - skin conductance
         2. <https://www.robotistan.com/galvanic-skin-response-gsr-measurement-sensor-lie-detector> - measures level of sweat secretion
         3. [https://www.mindfield.de/en/Biofeedback/Products/Mindfield®-eSense-Skin-Response.html](https://www.mindfield.de/en/Biofeedback/Products/Mindfield%C2%AE-eSense-Skin-Response.html) - moisure level and conductivity
      7. NanoEngineering department @UCSD?
8. Skin pH
   1. UC Berkeley BioSensor ( not on the market yet? )
9. Temperature
   1. Thromcon iSensor + Rock Tape (Recommended by Todd Coleman)
      1. <https://www.thermochron.com/product/ds1922l-thermochron/>
      2. <https://www.amazon.com/RockTape-Kinesiology-Athletes-2-Inch-16-4-Feet/dp/B002SF7AOO>
      3. Tapes sensors onto people? Tape sensors onto walls/objects?
      4. Indestructible temperature monitor
      5. Requires custom reader to download data. Reader connects over USB
   2. Gentag fever skin patch: <http://gentag.com/nfc-skin-patches/>
10. Saliva levels
11. Urine samples
12. Lab on a chip
13. **MC10**
    1. <https://www.mc10inc.com/>
    2. band-aid-like sensor that measures heart rate, respiration rate, specific body movements, ECG, sEMG
    3. Uses a gyroscope, accelerometer, and electrodes
    4. Each sensor captures data and transmits it via Bluetooth to their Investigator App that the researcher can use to control sensors and to stop recording. Once data recording has been halted, it is synced to the cloud (Investigator Portal) where the data can be downloaded as a CSV or JSON file. All data from past and present studies is available for visualization and download through the Investigator Portal.
       1. [example code](https://github.com/MC10Inc/biostamp_rc) for accessing/ processing data.
       2. User manual: <https://cdn2.hubspot.net/hubfs/2433253/BioStampRC%20UserManual%20(version%201-%20OLD).pdf>

**Meeting Notes from Call w MC10 on Jan 1, 2018**

* BioStamp:
  + Post-hoc analysis
  + The mobile app (Investigator App) is to be used in a clinical study to control the sensors and to stop recording which tells the system to sync the data to the cloud
  + The cloud system is intended for study PI (designing a study)
    - We cannot avoid the cloud, even if we wanted to use a local network, we would have to route it there after it passes through the cloud
    - We can view the data and access it through their API (from the cloud)
    - Not HIPAA compliant
  + Real-time component is only for signal verification check
    - It isn’t intended to be used for continuous streaming (data instead is sent in batches)
  + Clock sync: 1s/day by an NTP server
    - Each sensor has an independent clock and they can drift suddenly (though not by a serious amount)
    - For hyper-aligning, we can use a linear transformation on each stamp
  + Can we get a sample?
    - There is a loaner program that gives you a 3-sensor kit for 2 months but there is a waitlist so it could take a while to get a kit
    - Otherwise, there is an academic discount so we could buy our own kit for $1500
    - Also there some group at UCSD has worked with the BioStamp before so there could be one on campus but we don’t know who it is
* Next Generation System (BioStamp 2.0)
  + It will be available sometime between the end of March and April
  + It will have 2x the battery power and 2x the memory
  + This device is intended for a subject to take home and wear rather than in a clinical trial
    - They could wear it in the day then we would charge it overnight (this is more along the lines of what we intend to do)
  + Additionally it measures heart rate variability, respiration during sleep, posture…
  + This cloud would be HIPAA compliant
  + Data (like the old generation) cannot continuously stream high res data, instead it is sent to the memory then synced

1. Wireless headsets for EEG
   1. Ask them to wear at a particular time
   2. Quasar System
   3. Neurosky has BT connectivity
   4. Need ms alignment?
   5. Brain Products?
   6. Vandrico
      1. MindWave: measures brainwave signals and attention ($80)
         1. Has apps that well help to test brain activities
         2. Research tools: Neuroview & NeuroSkyLab ($500)
      2. InteraXon Muse: records brain activity which is then translated into actionable data and sent to a tablet/smartphone/computer and claims to help manage emotions, also has an accelerometer ($270)
         1. Many researchers use this
         2. App shows results
      3. Somaxis MyoLink [Not worn on the head!!]: focuses on muscle activity but does have and EEG, EMG, ECG, & EKG sensor ($100)
         1. Cricket: worn on the body, communicates with app (Chirp), exports raw data to computer, not interrupted by skin stretching, has gyroscope, accelerometer, and used with patches for EKG, EEG
      4. http://vandrico.com/wearables/device-categories/components/eeg-sensor

**Door Entrance Monitoring**

Does Paradise Valley use a keycard or a key based system?

1. For ID Card-based system
   1. Leverage swipe information every time someone enters the condo
2. For key based system
   1. Could use RFID tag/accelerometer on key to track fine motor movement and who is entering/exiting

**Car Monitoring**

Idea from PI meeting

1. **GPS transceiver**
   1. Wide range of GPS transceivers available, but fall into two main categories: passive and active
      1. Passive: record data and do not transmit in real time, cheaper
      2. Active: record data and broadcast over cellular network in real time, typically require a monthly subscription plan
   2. GPS Tracking Key 2
      1. <https://www.landairsea.com/gps-tracking-key-2/>
      2. Passive system, download over USB when needed
      3. Turns off after 2 minutes of inactivity
      4. Storage capacity: 100 hrs of driving time
      5. Battery life on 2xAAA batteries: 3 weeks at 1 hr/day
2. Eye tracking while driving

**Cell Phone Application**

(ideas for what this might look like, what it would monitor)

**Backend Technology for Deployment**

**Communication Network**

ARTIK (<https://www.artik.io/modules/artik-0-family/>)

Samsung technology that can create a small subnetwork?

**Storage**

**Time Synchronization**

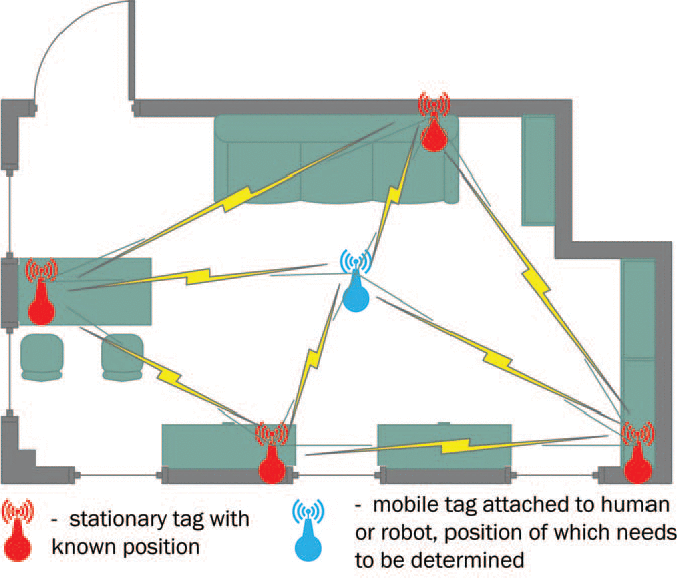
We desire time synchronization down to 1 ms. Prof. Dinesh Bharadia (from MIT) thinks he can do it using off-the-shelf components.

Max & Michael follow up with student of Mani Srivastava UCLA

**Sensor info from PI meeting (to be added and sorted to categories above)**

Security cameras - Paradise Village decided to not use them

* Video camera: minimum 2 per space; plus dedicated one for kitchen
* Tiny RFIDs on grocery items etc.



monitors in hospitals

* Ultrawideband (UWB) sensors - a few beacons per room
* IR - detect activities - joint motion
* RBG cameras to get joint information
* Counting people entering and leaving a home

**Constraints:**

No breaking skin

No video, except Kinect?

Audio (not outside, analyzed locally)?

From Suzanne’s presentation in IBM box “UCSD IBM AI for Eldercare” (slide 3)

* Motion sensing sensors was bad (it was ok for showering)
* Samsung contact sensor (magnetic sensor) was one of the worst → used accelerometer instead
* Used Samsung ARTIK devices (<https://www.artik.io/>) for connection architecture
* Nothing so far for dressing and eating

# WiFi Requirements for Sensors

Business level WiFi APs support more concurrent devices.

For example UniFi AP support 127 per radio (usually they have 1 2.4Ghz and 1 5Ghz (but the reported results on forums claims that it is better to shoot for 50 users per radio to avoid issues).

Many of these business level APs can be deployed in the same WiFi network so we could deploy a couple per house to support around 100 devices connecting to WiFi.

E.g.

**Ubiquiti Networks Unifi 802.11ac Dual-Radio PRO Access Point**

<https://www.amazon.com/Ubiquiti-Networks-802-11ac-Dual-Radio-UAP-AC-PRO-US/dp/B015PRO512/ref=sr_1_1?s=electronics&ie=UTF8&qid=1511205328&sr=1-1&keywords=unifi>

Also these UniGi devices can be managed easily form a cloud system using the Ubiquiti Unifi Cloud Key

**Ubiquiti Unifi Cloud Key - Remote Control Device (UC-CK)**

<https://www.amazon.com/gp/product/B017T2QB22/ref=s9_dcacsd_dcoop_bw_c_x_2_w>

# Smart Speakers (Echo etc.)

**Amazon Echo**

Echo records all the command (initiated by Alexa or other keywords) on the amazon cloud. It listen continuously but saves only what it understands as a command.

Amazon echo plus includes ZigBee hub.

It appears that there is no way to access and record what the microphone hears in Echo.

**Google Home**

It appears that the programming goes through the AssistantApp so you can't access the raw feed of the google home microphones

**Microsoft various speakers with Cortana**

Same issue here but there is support in new Windows 10 for far-field microphone technology

**DIY**

You could do a system yourself using a raspberry Pi and a microphone array.

Multiple arrays exists and you can rig them to work with the assistants.

<https://medium.com/snips-ai/benchmarking-microphone-arrays-respeaker-conexant-microsemi-acuedge-matrix-creator-minidsp-950de8876fda>

<https://www.minidsp.com/applications/usb-mic-array>

<https://www.minidsp.com/products/usb-audio-interface/uma-8-microphone-array>

<https://www.minidsp.com/applications/usb-mic-array/uma-8-rpi-diy-amazon-echo>

<https://www.minidsp.com/applications/usb-mic-array/uma-8-ibm-watson-chatbot>

<https://www.minidsp.com/applications/usb-mic-array/uma-8-cortana>

# Cameras

### Arlo Pro 2

FullHD, can keep local copy plus cloud recording

When connected to power continuous recording.

Uses wifi n protocol but has its base station without connecting to home wifi.

Base can be connected with ethernet (up to 6 cameras kits).

Motion detection with infrared.

Night vision.

3 camera system costs 520.99

<https://www.amazon.com/Arlo-NETGEAR-Security-System-Siren/dp/B01LWS96JV/ref=sr_1_8?s=photo&ie=UTF8&qid=1511239402&sr=1-8&keywords=arlo+pro+2>

MAY Require to save video on the vendor CLOUD!!!

## UniFi G3

Full HD WiFi camera offer the option of secure local storage.

The G3-Micro support wifi on 2.4 and 5 Ghz a/b/g/n

Dedicated Hardware NVR with 2TB HD ($400)

Cost 215 per camera

<https://www.amazon.com/Ubiquiti-Networks-UVC-G3-MICRO-1080p-Single/dp/B077H91CM7/ref=sr_1_2?ie=UTF8&qid=1511240719&sr=8-2&keywords=unifi+video+micro>

## Dlink Cameras

mydlink Network Video Recorder DNR-322L

With 2 bays for standard, inexpensive Hard Drives, The NVR also includes the option to protect data using a RAID 1 configuration

Camera

DCS-2630L 180 degree view field <<http://us.dlink.com/products/connect/full-hd-180-degree-wi-fi-camera/>>

Save locally or on the Network recorder.

## Samsung SmartCam

SNH-V6431BN

Full HD camera save on local SD card (max 128GB)

WiFi AC (dual band)

Stores stuff to the Samsung cloud

## Logitech BRIO

Suggested by Stephan Kaufhold, student of Federico's

<https://www.amazon.com/Logitech-BRIO-Conferencing-Recording-Streaming/dp/B01N5UOYC4>

2 microphones, adjustable field of view, 4k, 1080p, and 720p options. Connects to computer over USB 2 or 3

# Insteon/Z-Wave/ZigBee sensors

## Insteon

Now support both a wireless mesh network on 915MHz and Powerline connection

Has hub with some cloud and API

## Wink

Hub with video supports many sensors and have API

Wink Hub 2

* Bluetooth LE
* Kidde
* Clear Connect
* Z-Wave
* ZigBee

Wink Relay can communicate with Wi-Fi and Zigbee products.

Support sensors, switchs and plugs of multiple brands

## SmartThings

Samsung hub with support of SmartThings cloud (also hub + wifi AP) Supports

* Z-wave,
* ZigBee,
* Bluetooth

Lots of sensors (ZigBee)

* Arrival Sensor
* SmartThings Water leak sensor
* Samsung SmartThings Multipurpose Sensor (opened/closed sensor)
* Samsung SmartThings Motion Sensor
* Samsung SmartThings Outlet

Same hub supports Z-Wave of other producers