ENERGY EFFICIENT LOCATION TRACKER FOR DEMENTIA PATIENTS

Continuous GPS tracking devices always suffer short battery life when used by caregivers to reduce the risk of wandering to dangerous areas by dementia patients. Currently the best existing tracker for dementia patients on the market only supports less than 10 hours battery life with a gigantic battery. It not only requires daily battery charging from patients/caregivers, but also becomes a very restrictive device. We are trying to propose a novel energy efficient, small wristband by integrating the latest LoRa communication and GPS duty cycling technologies. Our model and data show the GPS wristband is able to support up to 40 hours continuous GPS tracking with a frequent 60 seconds location update rate. Its range also spans 3km, effectively monitoring patient locations.

THE PROBLEM

Dementia is a group of mental disorders characterized by loss of memory and impairment to thinking and problem- solving capabilities, which has plagued all nations around the world and posed substantial challenges to health, aged care and social economics . It is a leading cause of death and disability in persons aged over 65 . By 2050 the amount of people with dementia will be tripled to 132 million, with societal economic costs accounting for 1% of global GDP .

Wandering is a common form of disruption for people with dementia for a number of reasons, such as memory problems, disorientation and boredom. According to the Alzheimer's association, 6 in 10 people with dementia will wander . *It can pose a great risk to the safety and well-being for the person and thus is a critical concern for caregivers.* Although there is still no effective cure for dementia related wandering, precautions and efforts can be taken to reduce the risk of wandering to dangerous ares and to help release the burden and depression of caregivers. The Alzheimer society has thus suggested a list of off-the-shelf location technologies specifically designed for dementia patients to address wandering and to help keep them safe and secure . In general, these devices utilize a GPS module to retrieve geolocation from satellites and a GSM module to transfer real time locations back to a central server. These locations are compared against a preset geofence or virtual boundary, i.e. safe zones, and will trigger timely interventions from caregivers when necessary.

To maximize convenience, these GPS trackers are de- signed to be battery powered and in order to minimize obtrusiveness, these trackers are of a small size, light weight and are flexible so that they can be easily carried around. Unfortunately this small size also limits the size of the battery.

Standby mode refers to the status when a device is powered on without being used. The longest battery life of devices under this mode is no more than 3 days. If devices are working in a real time GPS tracking mode such as in geofence monitoring to ensure safety, the longest battery life drops to 10 hours.

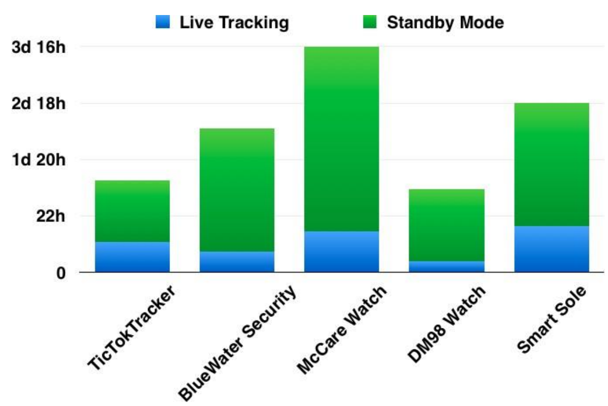

Fig. 1: Battery life comparison of existing solutions

For any generic GPS tracker with GSM communication module, we can get a rough estimation of the battery life by measuring the total power usages of its different modules against the device battery capacity. A typical GPS module will use 20mA of current during tracking and a GSM module will use 240mA. These are two significant energy consump- tion modules which overshadow the summation of the other components, which count for less than 5mA. Therefore, a tracker equipped with 250mAh battery can only last for 1 hour if GSM data and GPS connections are always kept alive, i.e. running at 100% duty cycle. Even if the users can tolerate a gigantic 2000mAh battery, which are normally used for large sized smart phones, the devices fail to last more than 8 hours. This poor battery life not only limits the GPS tracking duration, but adds extra burdens to patients/caregivers as they are required to charge the device daily. We believe this is the most critical issue that severely affects the acceptance rate of existing GPS trackers among dementia patients and careers.

SOLUTION: ARCHITECTURE OF THE LORAWAN PROTOCOL

The immediate approach of an energy efficient tracker will be reducing the consumptions of the two most energy hungry sections, the GSM and GPS. Furthermore, within our specific application of dementia patient location monitoring, there are two observations:

a) A GSM module is not a necessary requirement for real time tracking:

It is true that GSM provides a wide coverage area, however for dementia patients, 75% in an urban environment are found between 1-3km from their home . Therefore, for the majority of the time we only need to ensure that within a certain distance from their home the GPS information can be uploaded back to the server in real time. This motivates the use of LoRaWAN (Long Range Wide Area Network) communications protocol for transferring GPS data.

Similar to Zigbee , LoRaWAN is a LPWAN (Low Power Wide Area Network) protocol. Built on the Semtech LoRa modules, LoRaWAN is especially good at satisfying applications with long distance, low energy requirements at reduced data rate (0.3k to 50k bps). Typically LoraWAN supports up to 5km communication range in urban areas and 20km in rural areas, with extremely low energy consumption rate, usually an order of magnitude lower than the GSM protocol.

b) A frequent GPS location updates are not needed to ensure safety of dementia patients:

Since we only start worrying about dementia patients when they are approaching the boundary and showing symptoms of wandering away from the safety zone, we can thus choose to turn off GPS whenever we are comfortable with the current location of the dementia patients while still keeping vigilant to trigger the device to work on full throttle when necessary. This dynamic duty cycling strategy helps keep the GPS module working in sleep mode longer and consequently less time in active mode. However, on the other hand, we can not keep the GPS module in sleep mode too long, because this will affect the duration required, i.e. GPS lock time (tl), to get a geolocation from satellites when switched to active mode. This is because in order for the GPS Module to calculate its current location, it needs to know both the location of satellites (Locs) and the last location of itself (Locl). Specifically, the value of tl is affected by the knowledge of Locs and Locl and can be categorized into three types:

- **Hot start:** With a short period in sleep mode, both Locs and Locl are still valid and will lead to a smallest tl.
- **Warm start:** A longer period in sleep mode, usually forcing updates of Locl, thus results in a larger tl.
- **Cold start:** The long time in sleep mode make both Locs and Locl invalid. The GPS module needs to download all necessary information from satellites with an extremely small data rate (50 bps) , therefore tl will be the largest.

Motivated by the aforementioned two observations, we propose a novel LoRa GPS tracker that communicates GPS location data to a LoRaWAN server in real time. The tracker is designed in a compact and lightweight form to reduce obtrusiveness to dementia patients.

Compare the size of our tracker against Apple watch

We can select a micro-controller (MCU which is small enough to fit in the wristband and also has low power consumption. Our GPS is an all-in-one module with an internal Antenna and embedded amplifiers. This allows the antenna to be situated within the wristband tracker rather than relying on an external one. The LoRa module is from HopeRF§R , which can easily fit in the wristband.

However in order to work with the LoRaWAN base station, the LoRaWAN protocol had to be implemented for the MCU.

We also include low power Inertial Measurement Units in our wristband tracker, an Accelerometer and Magnometer that are to be used for location estimation and to assist with the dynamic GPS duty cycling strategy for longer battery life. These units consume only 30uA when sampling at 100Hz, the required rate for accurate location estimation. Finally to simplify battery charging, we can add a wireless charging module to the back of the board,

*An App will be provided to the care takers for live tracking of the patient and it will alarm the care taker if suspicious activity of the patient is detected****. Through Machine Learning, the tracker can be made intelligent so that, it will track the lifecycle of the patient and adapt accordingly.***

RANGE OF COMMUNICATION OF LORA

In a more communication friendly suburban environment and with a reasonably good outdoor antenna, the LoRa signal transmission has a high possibility of reaching around 3km. We believe this communication range should be enough to support our dementia patients tracking application.

Considering the 220mAh battery used in our wristband tracker, if we assume a GPS duty cycling strategy with a fixed sleep interval sn, then sn = 30sec leads to 30 hours battery life and sn = 240sec will **push the battery life to 70 hours.** Assuming a daily average of 4 hours outdoor activity of dementia patients, the wristband can thus support continuous GPS **tracking up to 18 days.**

Alternatively we can also choose an adaptive GPS duty cycling strategy which only activates GPS module if the estimated future locations will be outside a preset safety zone. This will usually ensure even longer battery life of continuous GPS tracking .