An Intelligent Energy-driven System for Mobile Health Management

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Introduction

Possible Use	Agents like pets, animals, infants/toddlers, elderly, patients and those who encounter difficulty in communicating with caregivers or professionals about their health, wellness or other needs, e.g. when they get lost or in a dangerous situation. Such system and methods can extend to IoT scenarios such as machine-to-machine (M2M) communications as well when certain communication challenges exist among edge and cloud nodes.
Brief Description of Technical Innovation	Apply energy-driven sensor communication to make sure the agent is in a safe place and alert the caregivers and medical system when the agent has potential or predictive issues. An online social platform would facilitate the interaction and support from the whole community to help maintain agents' health and safety issue.

Background / Motivation

- People can communicate with our family, friends and the doctors when we are not feeling well and under pains. But agents like pets/animals/robots/infants/patients with dementia cannot tell people when they get lost or in a dangerous condition.
- We cannot stay together with the agent all day along if we have to work or travel to another place. But we want to make sure about the agent's safety when we are not around.
- When the agent get lost, we usually don't know how to find the agent back or whether the agent is in a safe place.
- Traditional sensors embedded in smartphone or smartwatch has limited computing power and battery could easily running out with large raw sensing data uploading in the wild(make it more difficult to find back the lost agent)

Prior Art

- **Limitation of Prior art:**
  - In mobile sensing field,“data transfer and battery consumption” are major issues for consistent data tracking and uploading[1], especially in the wild environment. That is why lots of mobile sensing-based health data tracking are mainly operated under experimental environment where human labor are intensively involved to manually control the sensor device[2]. The sensing data transmitted to the cloud or IoTs are usually raw data without filtering or classification, which could consume too much transmitting resource with low efficiency.
  - However, Not like human beings who can manually adjust the sensor device and watch out the battery usage[3][4], our agents are vulnerable groups who has communication difficulty and cannot help themselves to operate this devices, especially when they get lost in the wild.
  - As far as we known, there is no existing work focused on developing such an intelligent energy aware system to efficiently upload sensing data profile adaptively corresponding to the battery level and help save the lost agents in the wild.

- **Reference:**

- 1. Kim, Yunbin, et al. "Resource-efficient pet dog sound events classification using LSTM-FCN based on time-series data." *Sensors* 18.11 (2018): 4019.
- 2. Belda, B., et al. "Initial evaluation of PetPace activity monitor." *The Veterinary Journal* 237 (2018): 63-68.
- 3. Wang, Weichen, et al. "Social Sensing: Assessing Social Functioning of Patients Living with Schizophrenia using Mobile Phone Sensing." *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. 2020.
- 4. Wang, Weichen, et al. "." *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 2.3 (2018): 1-21.

Our innovations

System of energy-driven adaptive data analytics and upload, to improve battery life of mobile and sensor devices.

Method of behavior classification for predictive warning detection when agents at risk.

Method of decentralized agent relay, by connecting with other agents to find the lost agent.

Objective

This system helps find the agents when they get lost or stay in a dangerous place.

Give warning when the agents are having health problems or at risk.

An energy aware system facilitates efficient data profile and upload in the wild.

Cloud learning interacted with multi-modal edge data sensing to improve prediction

Who is our agent and what we can do with mobile sensing?

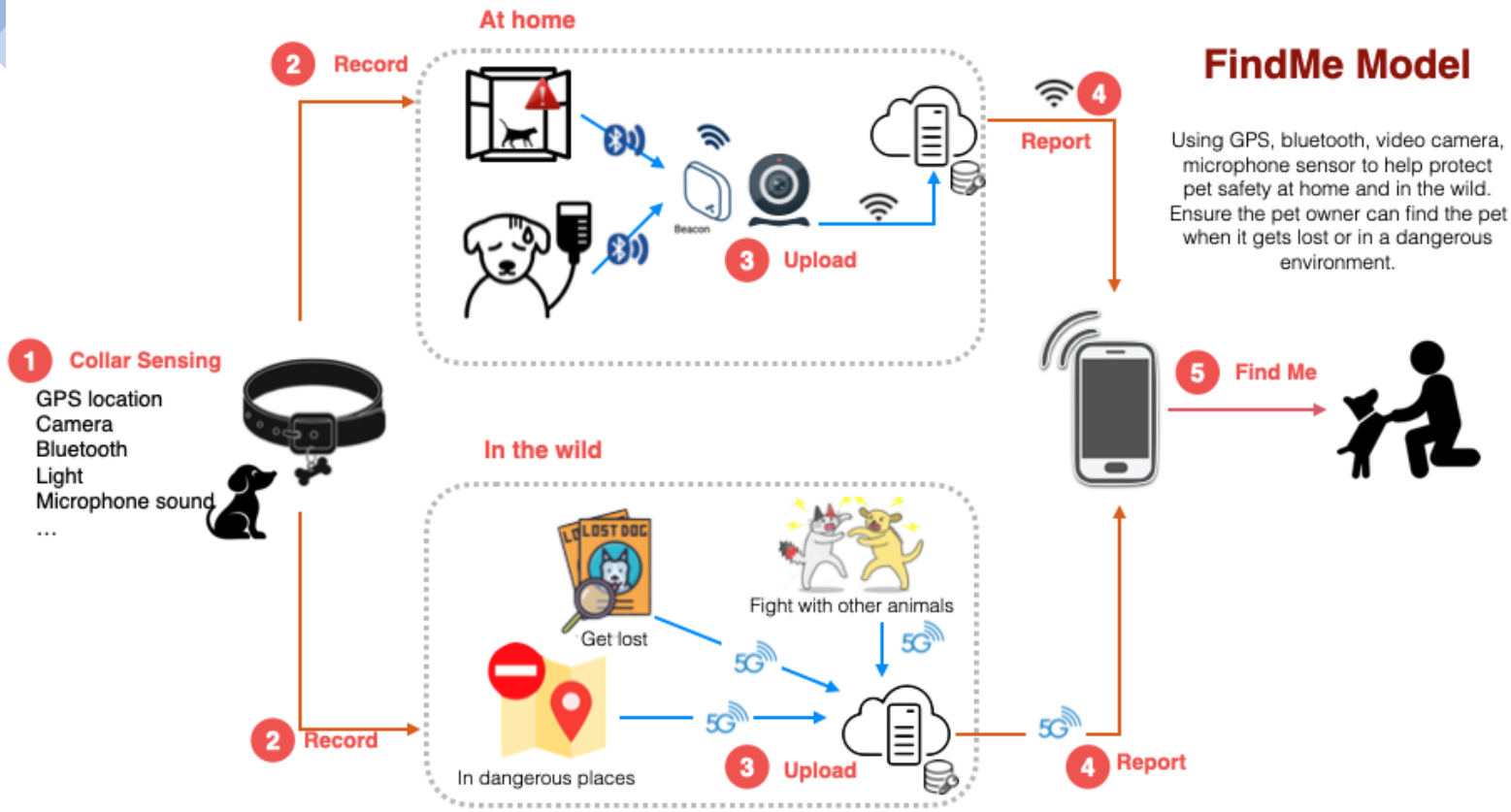
Our agent refers to……

What can we do for them using our sensors?

- Find Me
- Healthcare
- Community

FindMe Model

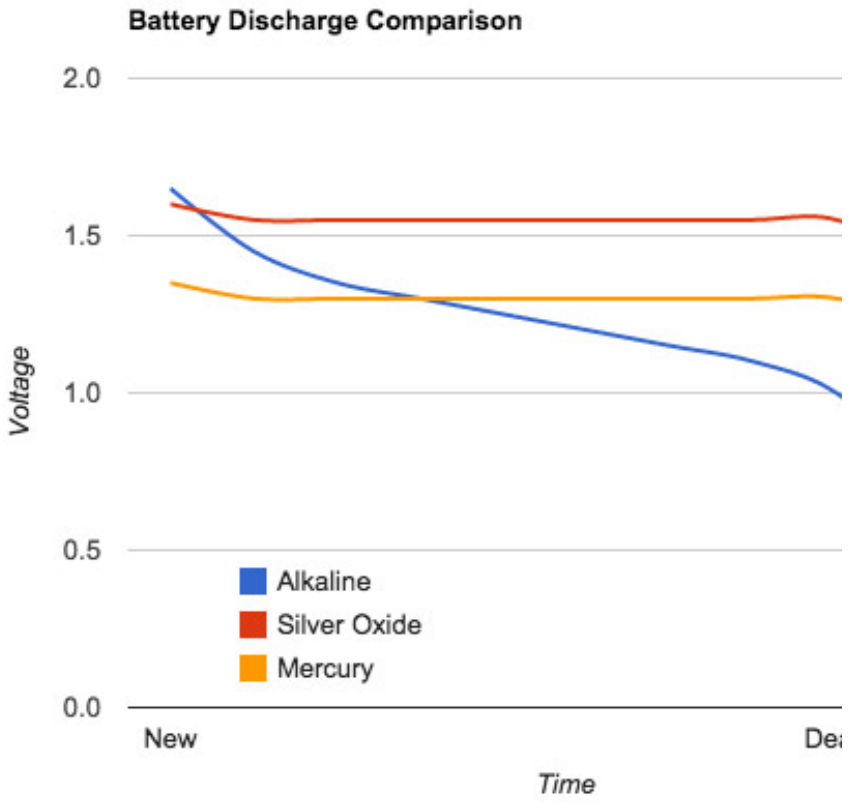
Using GPS, bluetooth, video camera, microphone sensor to help protect pet safety at home and in the wild. Ensure the pet owner can find the pet when it gets lost or in a dangerous environment.



Innovation 1: Energy-driven adaptive data profile and upload system

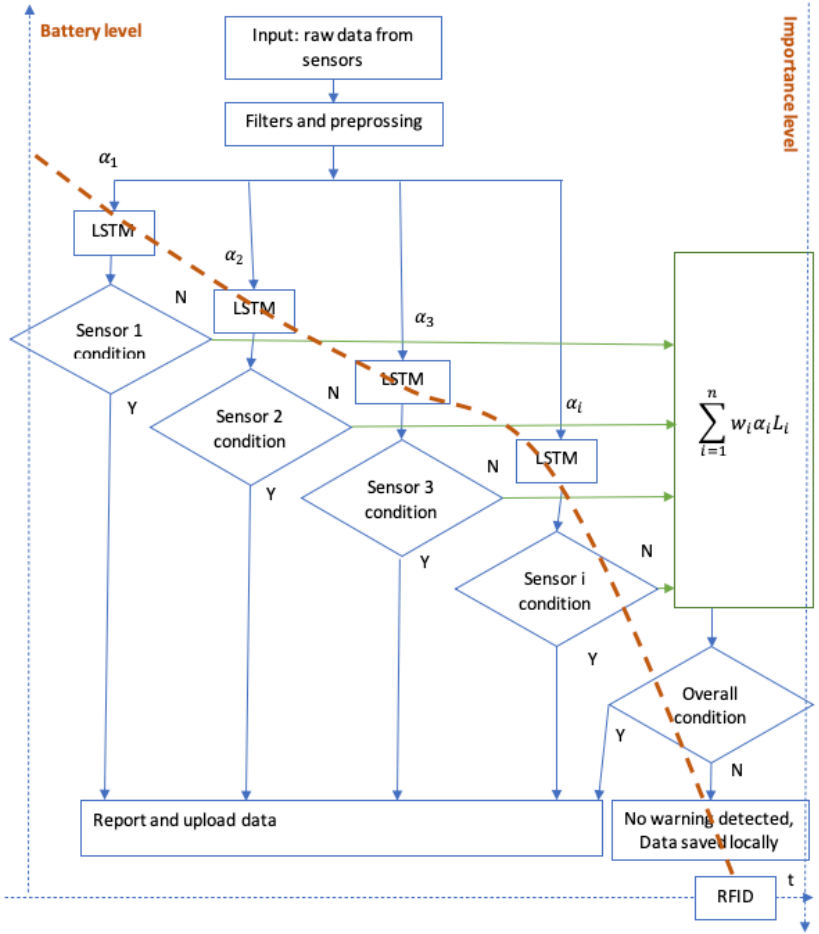
Q: How to prioritize battery life and data collection of mobile sensors in the wild?

- Energy-driven data profile and transfer only when conditions/criteria are met.
- Adaptive and customized to individual agent.
- Can be calibrated as lookup table in device ROM, etc.



Innovation 1: Energy-driven adaptive data profile and upload system

- When the battery level decreases, the system should reduce data processing, i.e., the lower the battery, the more important the conditions should be processed. Let a_i be a parameter showing if data of sensor i can be processed, i.e., $a_i = 1$, depending on battery level. Assuming a device has m battery levels, the higher the level, the more power left. Let $b_i = \{1, \dots, m\}$ be the cutoff battery level of a sensor, which is predefined for each sensor. Note that the higher the cutoff level, the less chance a sensor will work when battery level is low, i.e., a sensor will only work when the battery level is higher than its cutoff level. Let b_t be the battery level at time t, H be the Heaviside function, and
- $a_i = H(m - b_i) = \begin{cases} 1, if\ b_i < b_t \\ 0, if\ b_i \geq b_t \end{cases}$.
- Note that a_i will be normalized based on the available sensors in the integration process, the green rectangle in the figure. The goal of using a_i is to only process the important conditions when battery level is low.



Innovation 2: Cloud learning guided multi-modal edge data sensing

- Innovation: Combination of Decision tree based method and DNN based learning methods for prediction, increase the accuracy and efficiency of edge computing, and increase interpretability of the prediction system.

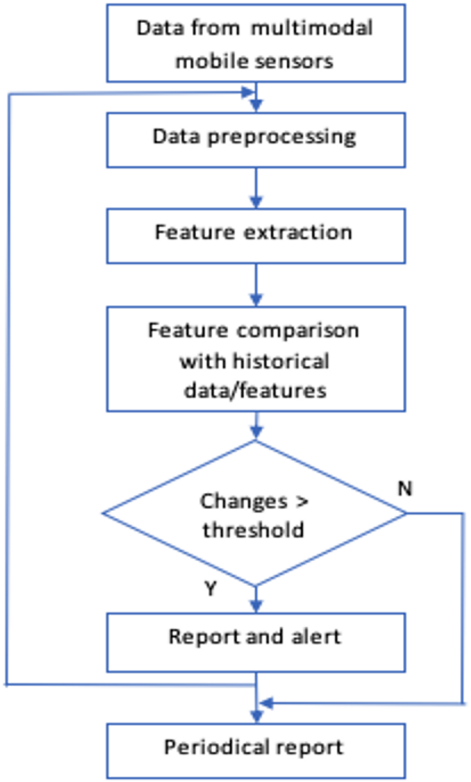
- Feature embeddings, and Decision thresholds (i.e. the separation planes for the decision tree) can be learned via data-driven machine learning.

- For example, using DNN to simultaneously learn the feature encoding parameters and the decision tree's separation planes' parameters, and learning is based on the training data with associated ground truth of decisions:

- e.g., LSTM as the teacher model, and the above framework as the student model and train the student model by supervision from the learned LSTM model. Then, the parameters of encoder and classifier from the student model are used to create the decision tree in the edge devices for efficient edge computing: the parameters of encoder are used for selecting subset of features and feature conversion, and the parameters of the classifier are used for deciding the thresholds.

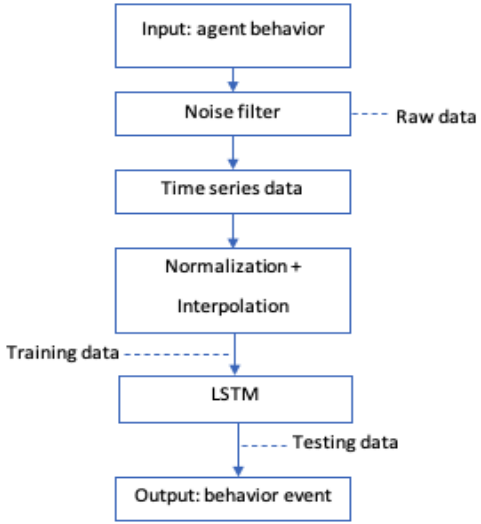
Innovation 2: Cloud learning guided multi-modal edge data sensing

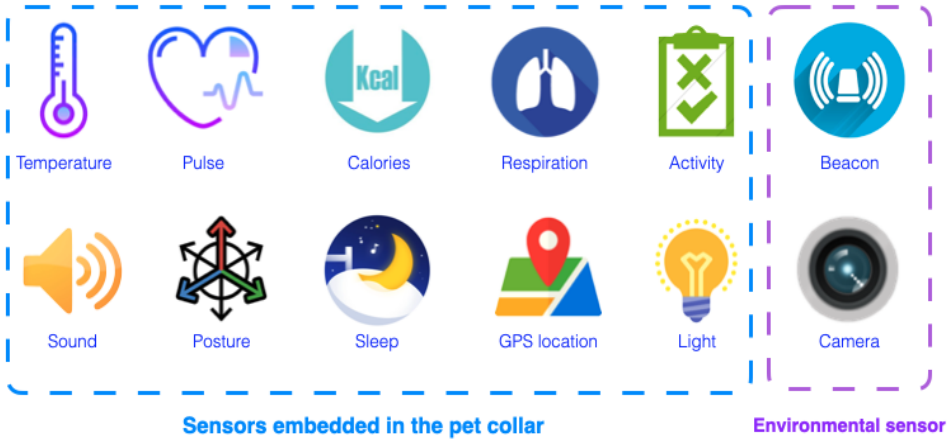
- Specifically, let $\boldsymbol{Y} = \{Y_1, Y_2, \dots Y_i, \dots, Y_n\}$ be the input data of sensors, where Y_i for sensor i.
- Let $\boldsymbol{F} = \{F_1, F_2, \dots F_i, \dots, F_n\}$ be the corresponding features from the data of sensors. In addition, let $\boldsymbol{T}r = \{T_1, T_2, \dots T_i, \dots, T_n\}$ be the threshold values for the changes of features.
- If $\nabla F_i > T_i$, the sensor system will activate the attention system to investigate why the changes in behaviors.



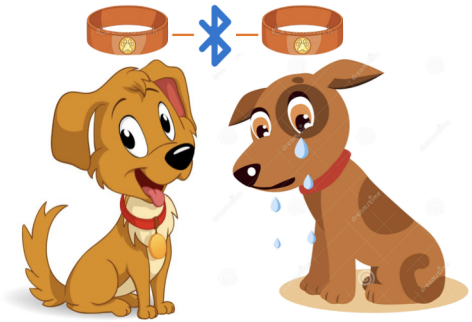
Innovation 2.1: Multi-modal behavior classification for early warning detection when agents at risk

- Use behaviors of dog as an example. As dogs can make 10 different barking sounds, and when they are having pains, “yelping” and “whimper” would be the main sound they are making. By labeling and learning especially their sound when they are sick or expressing pain can help us better pretrain a model and write this method into the sensor device chip. Combined with temperature and heart rate and other sensors features, the device can give timely warning to the owners and vets for medical intervention.



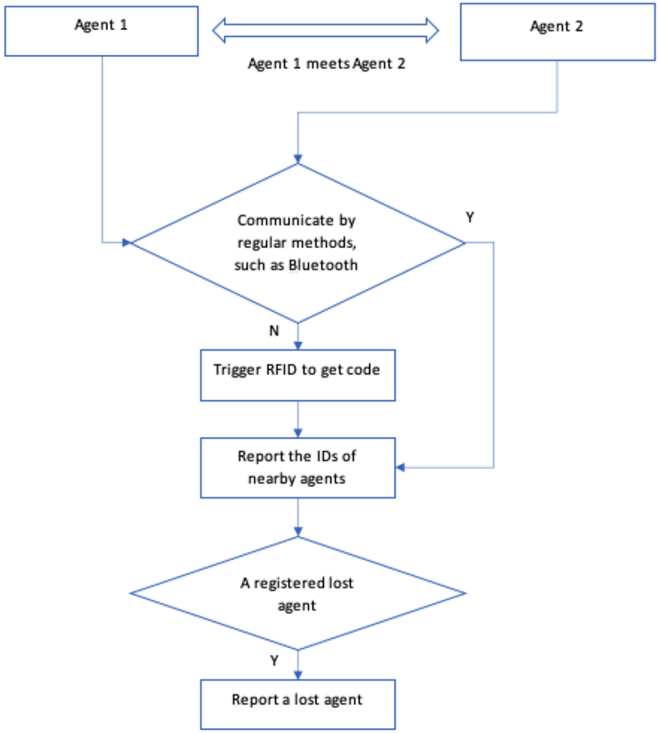


Innovation 3: Decentralized relay & connect to FindMe



“FindMe” from friend The lost pet

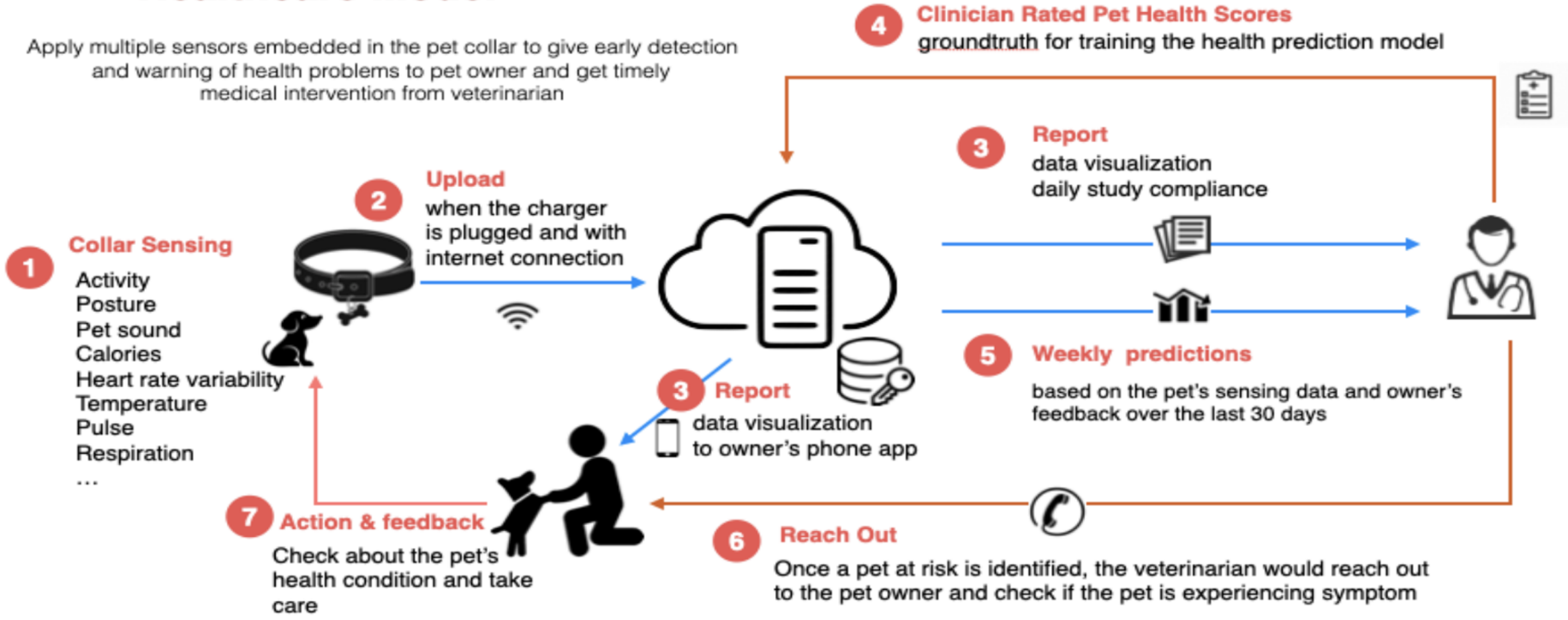
Remember: The collar sensor can automatically connect each other when they are geographically close



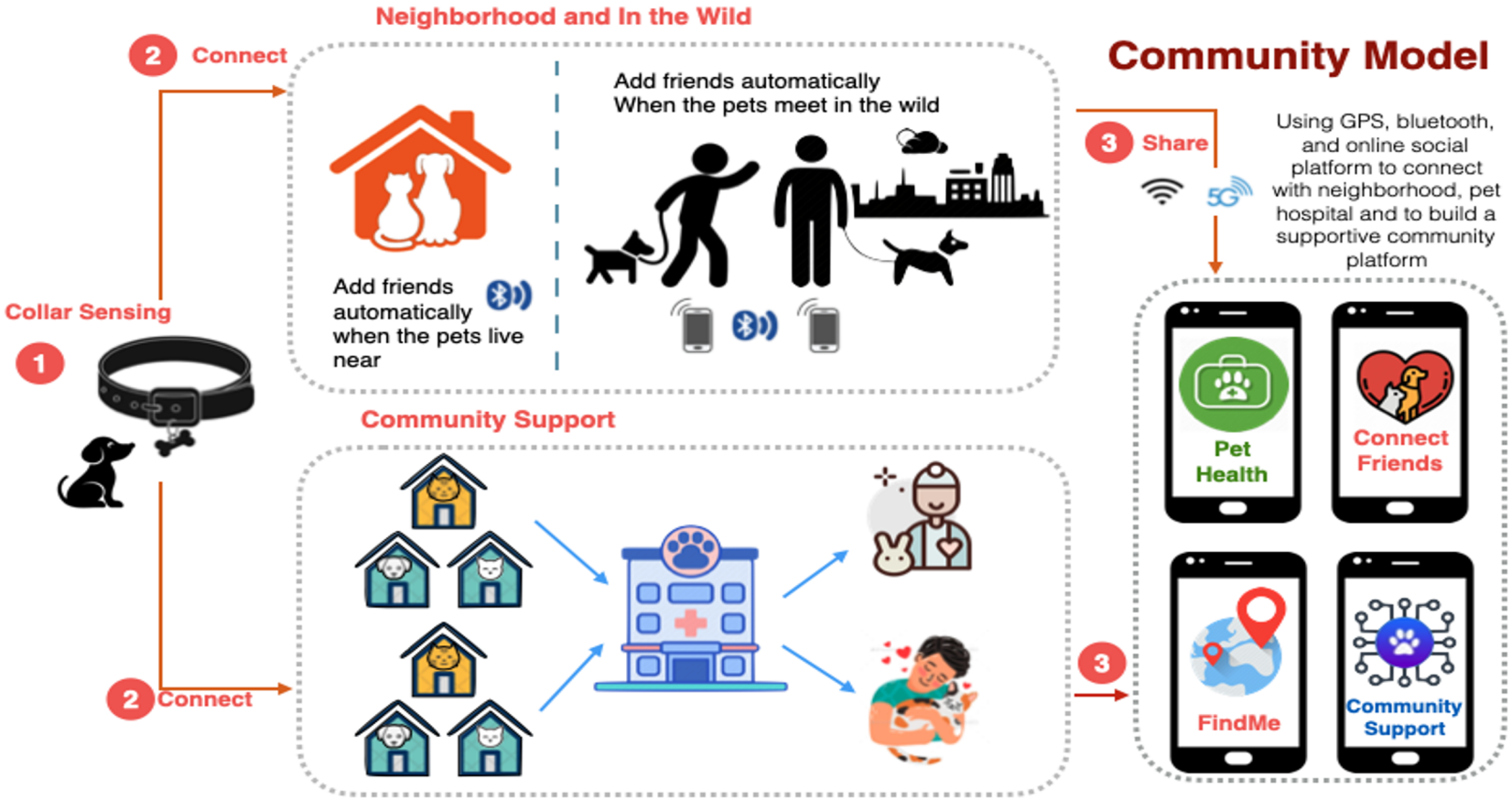
The figure above is for agent<->agent communication in lost and found. RFID doesn’t need battery and can be trigger by a simple charge by scan. Therefore, it can be use when the battery of major sensors is out.

Application to healthcare

Apply multiple sensors embedded in the pet collar to give early detection and warning of health problems to pet owner and get timely medical intervention from veterinarian



Application to community



Pet Care Market Size Worth $202.6 Billion By 2025 | CAGR: 4.9%

https://www.grandviewresearch.com/press-release/global-pet-care-market

Commercial Benefit

A sensing device and community platform equipped on the app and website to attract more industry attention, with commercial benefits from ads recommendation.

Avoidability

We developed an energy aware system which could help tracking agent's health data, behavior change during their lost time. It could not be avoided while we don't have timely battery charge to maintain mobile sensing.

Also, the cloud-edge computing can better predict multi-modal sensing data and detect early disease symptoms or hidden pain that might not be obviously observed from the agent's appearance. It can provide the caregiver and doctors with early warning and timely intervention to the agent. This cannot be avoided if we want to know what exactly happened to our agents while they can not speak or describe about their disease and pains in words.

Ease of detection

- We develop an energy-driven adaptive data profile and upload system to efficiently upload data and save battery in the wild. This system would automatically allocate resources according to battery level and make sure we can have enough time to search for our lost agent. It is very easy to detect if other manufacture is using our techniques in their work. We can check their user manual and product datasheet to find out if they are using our technique.
- We integrate the Find, Healthcare and Community function into a social networking platform and create a unique business model on this integrated platform, which can be displayed on the website and mobile app. It is easy to detect if other party is using our module by navigating through their contents in the website and app to see if they use the similar module.


Thank You

At Home & In The Wild

camera

At Home

* Use camera to detect pets posture and face expression
* Apply beacon to detect whether the pet is near some dangerous places

Beacon

In the wild

when the two pets come close to each other in the wild, the bluetooth would detect and add them as friends automatically.