# IoT in Agriculture – FarmBeats

Lecture 13 (10/09/2024)

Davis Zhang

**Motivations**

- Agriculture output needs to increase by 70% by 2050 to meet rising demand, according to the United Nations
- Data-driven agriculture improves yield, reduces cost, and ensures sustainability
- However, according to USDA, the high cost of manual data collection prevents farmers from using data-driven agriculture

**Challenge 1: No Internet Connectivity**

- Over half of farmers do not have adequate internet access
- Even if connectivity exists, weather-related outages can disable the networks for weeks
- Sensors can be a few miles away from the farmer's home/office (range)
- Sensors can also be obstructed by crops and canopies, which further reduces range and data bandwidth

**Challenge 2: No Power**

- Farms do not have direct power sources
- Solar power, while easily available, is also heavily dependent on weather (solar-powered batteries saw up to 30% downtime in cloudy months)

**Challenge 3: Limited Resources**

Farmers have to work with sparse sensor deployments

- Physical constraints due to farming practices
- Too expensive to deploy and maintain

How do we get coverage with a sparse sensor deployment?

FarmBeats is an end-to-end system that enables agricultural sensing at two orders of magnitude lower cost.

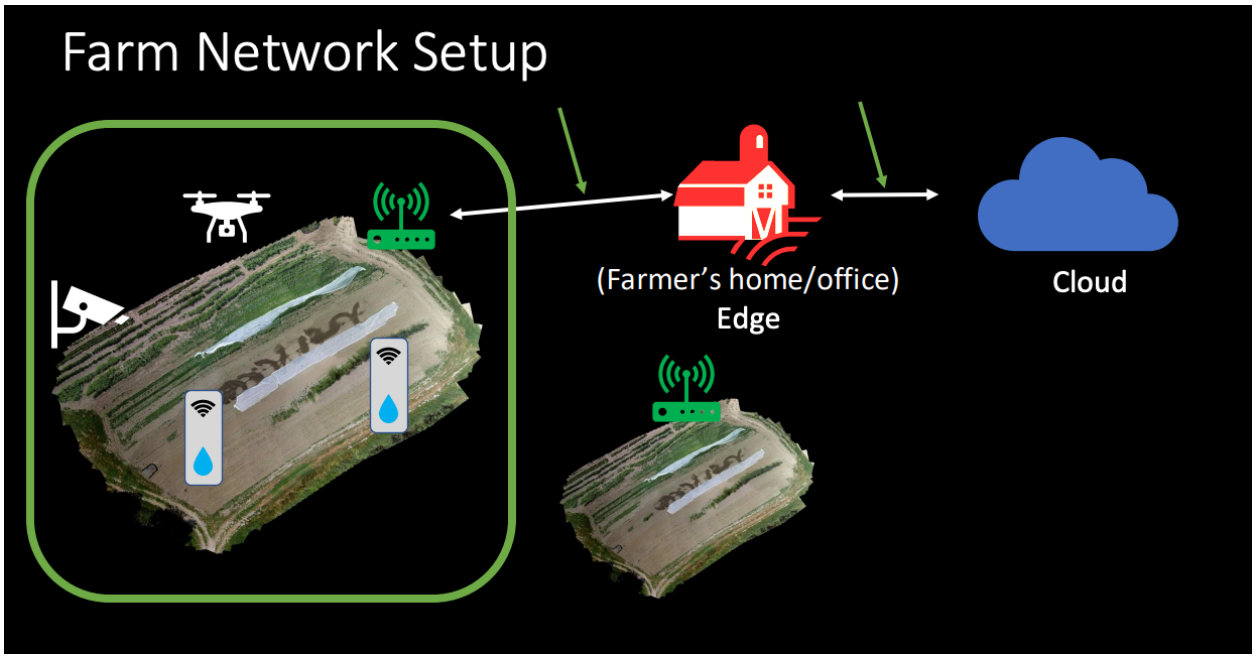
**Addressing Challenge 1 (No Internet Connectivity)**

Use TV White Spaces (TVWS) on the farm

- TVWS are unused TV channels

Benefits of TV White Spaces over Wi-Fi, Zigbee

- High throughput at long distances
- More than 100 MHz of the TV spectrum is available
- A TVWS base station can cover the entire farm




Newer connectivity solutions use Citizens Broadband Radio Service (CBRS)

- If TVWS is Wi-Fi, CBRS is cellular

**Addressing Challenge 2 (No Power)**

Weather-aware IoT Base Station Design

- User weather forecasts to predict solar energy output
- Ration the demands to fit within power budget

Novel Inference Techniques for Compression of Aerial Imagery Data

- Performs local processing to compress data before sending it to the cloud, reducing bandwidth needs and enabling operation during internet outages

- Combines all the sensor data into summaries, which are 2-3 orders of magnitude smaller than raw data
- Cloud delivers long-term and cross-farm analytics

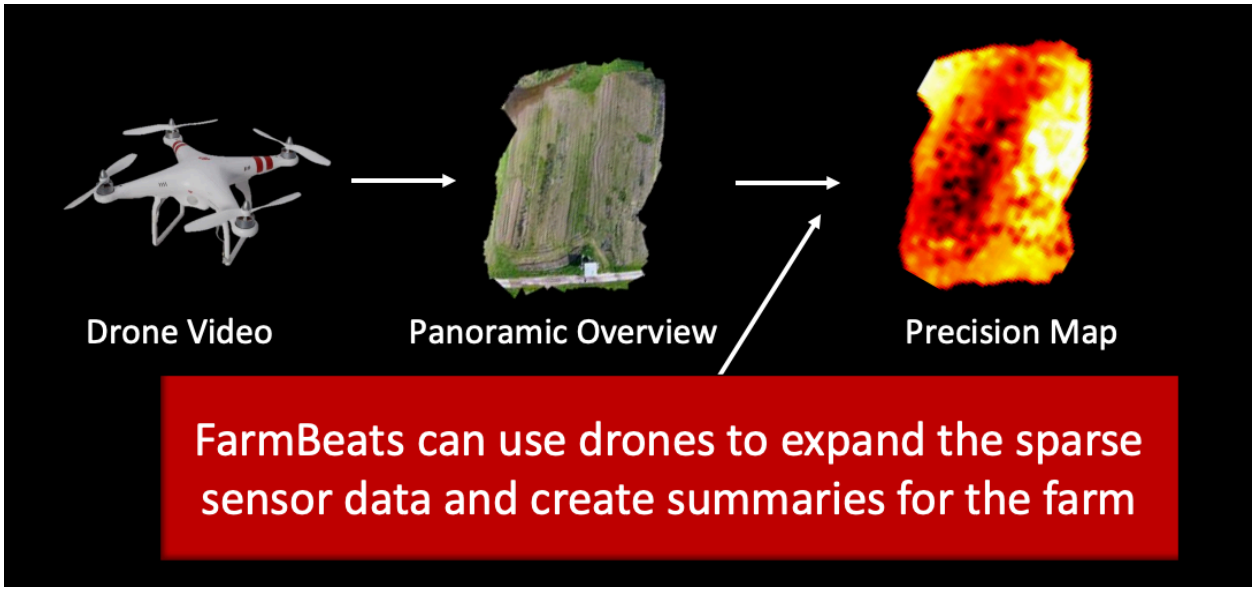
### Addressing Challenge 3 (Limited Resources)

Use UAVs to Enhance Spatial Coverage

- Drones can cover large areas of land quickly
- By combining sparse 3D reconstruction with image stitching, FarmBeats creates a panoramic overview of the farm with aerial footage from the drones

Wind-Assisted Drone Flight Planning Algorithm

- Leverages wind patterns to extend drone battery life and coverage area




However, UAVs have limitations in the developing world:

- Limited battery life
- Regulatory concerns
- Expensive

FarmBeats also experimented with Tethered Eye, a balloon with a camera attached, to enhance spatial coverage.

Nowadays farmers can leverage satellite imagery, which has become more readily available. However, drone footages provide more fine-grained resolution.

### Applications and Results

- Deployed in two farms over 6 months, collecting millions of sensor readings and images
- Reduced base station downtime to zero (from 30% previously)

- Improved drone flight coverage by 30%
- Generated more accurate precision maps compared to traditional interpolation methods

## Advantages

- Low-cost compared to existing farm sensor solutions
- Readily available even during power/internet outages
- Supports high-bandwidth sensors and drones
- Enables both real-time and long-term data analytics

## Future Implications

FarmBeats provides a promising platform for enabling data-driven agriculture techniques, which can help increase farm productivity to meet growing global food demand.