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To cite this article: S. Sheeba Rani *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **937** 012035

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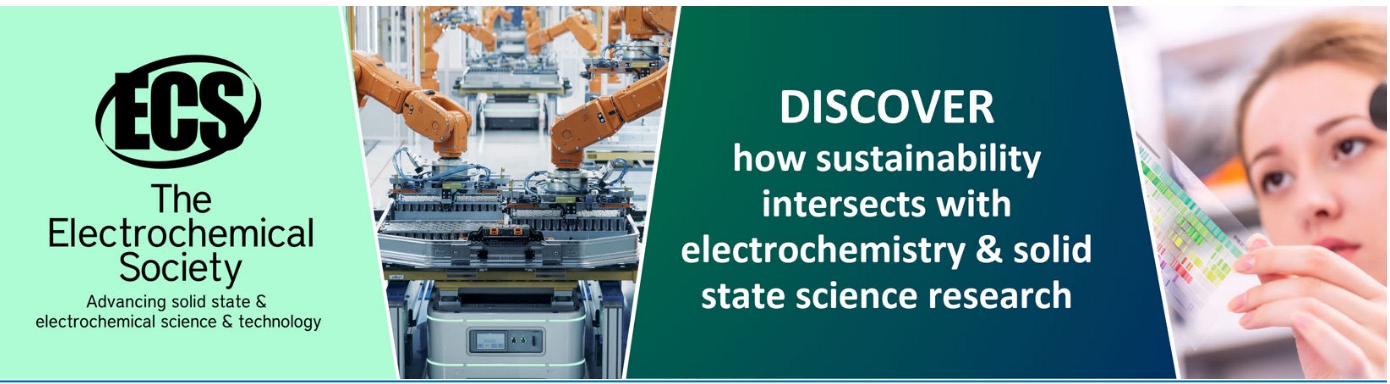

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IOP Conf. Series: Materials Science and Engineering **937** (2020) 012035 doi:10.1088/1757-899X/937/1/012035

UAV based Mapping System for Precision Agriculture

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Abstract. Agriculture the backbone of our nation as well many nations is essential to feed the people and smart farming is the much-needed disruptive technology to help the farmers increase their yield. Airborne vehicles and relays supplement the automation system to monitor the growth of the plants, individually and record the observations to estimate the level of pesticides and herbicides to be applied. However, there are no simulation platforms designed to help these farmers to collect and process the data gathered. The proposed work consists of a sensor fusion framework that will give the user a complete farming scenario which is focused on data gathering with airborne UAV or relay mechanism, line of sight deployment, coverage area, identify sensor placement, and usage of fog computing paradigm as a backend computing support. The paper focuses on providing an evaluation benchmark for energy consumption, system resource usage, packet delivery ratio and transmission delay.

1. Introduction

As technology advances, many digital ways for enhancing agriculture have been used over the past decades [1]. These inventions are generally focused on enhancing the productivity of crops by collecting and analyzing agricultural land. This process is accomplished with the use deployed sensors. Internet of Things is adopted for precision agriculture and gathering of information which is further used for decision-making based on the data. The presence of fog has paved way to many new challenges in smart agriculture.

It is therefore crucial that we device a system with sensor deployment to obtain the maximum yield in precision farming. But, the performance of the system will be affected due to many issues faced by the sensors. When the sensors are used to gather data, it is found that they consume more energy due to continuous periodic usage which reduces the network lifetime, overall [2]. Hence, it is essential to employ an informed deployment system that can survey the complete land for smart farming applications, in order to reach the desired goal.

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In today's development in smart farming, there are many works which make use of actual deployment that doesn't use prior knowledge leading to improper utilization of the resources. Based on surveys, it has also been observed that there are very limited toolkits developed which exists designed solely for the development of smart farming coupled with network configuration species. Some studies show that actual sensors [3] are used in emulated models for decision making with data obtained. However in these network properties, there are couple of things that are ignored such as energy consumption of underlying communication model, overlapping regions of deployed sensors leading to network congestion, and packet rate error.

Moreover, there are very limited framework which enables data processing in fog locations. To overcome these issues, there is need for developing a smart-farming simulation stack that also supports sharing and backend computing environments. Data driven modern sensor deployments are being employed in the recent years. This method is focused on not just monitoring the land, but also for intervention of the user depending on the situation analysis made through observation of the situation [5-15]. The development in high-speed networks and quick accessibility of the edges using cloud has increased the efficiency of the system, thereby increasing the productivity. The following are the important features of the toolkit:

- Use of different mobility models to support mobile and static sensor deployment. The sensors are specifically designed in terms of storage, data rate, transmission range and network parameters.
- Offers support for sensor energy models to give an overview of the realistic scenarios based on the simulation results.
- To support gathering of data using UAVs, a complete data of the UAV configuration has been inbuilt.
- Facility to use non-relay-based and relay based data communication mechanisms.
- Uses a broker who is used to collect UAV data which is further communicated with the other brokers to execute the scheduled policies based on analysis.
- The fog computing concept is used for delay-sensitive applications
- Using the fog computing model in the backend, it provides early warning system and data-driven monitoring [16-20].

2. System Modeling

Consider 'F' to be a farm with 'L' as length and 'W' as width. The dimensions of the farm is represented by L.W and 'S' represents sensors. The system developed is built such that there are N heterogeneous sensors with varying transmission times Ts and energies Es. At the location Sxy the sensors are either mobile deployed or are static [21-30]. They also used to communicate information, apart from sensing, to the central node. The UAVs are used to obtain data from the sensors and then use this data to be sent to the main server where it is analyzed and used in real-time. Every UAV used is configured with an energy Eu

and communication range Ru. These two sensors are designed in such a way that they operate in two modes: active mode and sleep mode [31-35].

Total Energy consumed Et is represented as

$$Et = Eactive + Esleep \quad (2.1)$$

where Eactive and Esleep are the energies consumed in active and sleep modes, respectively.

Here,

$$Eactive = Ewup + Emsr + Epcs + Etmt + Ercp \quad (2.2)$$

$$Esleep = Psleep \, . \, Tsleep \quad (2.3)$$

Where,

Tsleep= Time sleeping

Psleep=Power consumption

Ercp=Energy consumption for data reception

Etmt= Energy consumption for data transmission

Epcs= Energy consumption for data processing

IOP Conf. Series: Materials Science and Engineering **937** (2020) 012035 doi:10.1088/1757-899X/937/1/012035

Emsr= Energy consumption for sensing data measurements
Ewup= Energy consumption for wakeup

These energies are configured depending on the active duration and the frequency of the sensor processing unit. Data is gathered from M-UAVs and any interaction within the UAVs and the deployed sensors is done through uplink with OFDMA. 'K' simultaneous connections are supported by the UAVs for gathering information. Moreover, the system designed by us is programmed to share data between nearby fog/edge locations with UAVs [6]. There is possibility for high packet rate error occurrence as the deployed sensors are mobile. Hence Line of Sight (LoS) has to be fixed to enable effective communication.

The probability of Line of Sight is computed as follows:

$$pLoS = 1/(1+\rho * \exp(\sigma[\Phi-\mu])) \quad (2.4)$$

Where σ and ρ are the constants depending on the type of area and communication frequency, Φ is the elevation angle between the UAV Uxy and the sensors Sxy.

As the altitude of UAV increases, so does the probability which indicates that if and only if the LoS probability is close to 1 and the deployed sensors are assigned to UAV jth such that Φ is ≥ pLoS. Hence the this condition can be defined using the formula

$$dij \leq hj/(\sin(pLoS)) \quad (2.5)$$

Where,
hj is the altitude of the UAV
dij is the distance between jth UAV and ith sensor node

If it is assumed that there are m x n sensors deployed, then tc is the coverage time wherein UAVs is calculated as follows:

$$t_c = \sum_m \sum_n T_{mn} + \frac{2}{M} \sum_k \sum_j S_{kj} \quad (2.6)$$

Where,
Skj is the number of sensors
M is the count of UAVs utilized for gathering data
Tmn represents the time required to move the Unmanned Aerial Vehicle from one sensor to the other

B brokers are used to keep track of the fog locations and are used for proper use of the available fog information near the end users. The resources for the neighboring locations are allocated by the broker. This will aid in decreasing the communication delay, thereby enabling IoT based delay sensitive application. The distance between the nodes is represented as the network delay td such that

$$td = da + db \quad (2.7)$$

Where,
db represents the delay between the assigned fog location and the UAV
da is the network delay between UAV and the sensor

The network cost is represented as C which is a linear function represented as follows:

$$C = \varphi . (di,j + \sum_{(k \in B \ \& \ j \neq k)} d_{(j,k)}) \quad (2.8)$$

Where,

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di,j is the distance between the local broker j and the ith UAV
φ is a constant and j
d_(j,k) is the distance between the brokers leasing compute resources and the local broker j ∈ B

3. Proposed Methodology

The method proposed is based on INET5 and OMNet++4, which is the extention of FogNetSim++ [4]. An outline of the execution model is represented in the Figure X . The core modules are as described below:

3.1. Communication Module:

This module is made up of many devices and different features. The sensors used in this module are built to sustain short-range communication and hence their communication mechanism also differs. These sensors communicate with the nearby sensor nodes to exchange data which is in turn conveyed to the gateway node. This means of communication requires efficient planning. Surveys show many significant contributions in route planning for sensor nodes which employ overhead of data routing and leader election which will lead to the consumption of energy at a significant scale. To overcome this, we propose gathering of data using airborne vehicles. When the time to gather data comes, the UAV is triggered to alert the ground sensors and a connection is established between the two points. Data is shared by the sensors with the UAV and after sharing the data, the sensors discard the information [10]. Similarly, the data gathered using UAVs will impose new challenges. These conflicts are resolved using a callout mechanism deviced instead of the traditional approach of leader-based grouping model. However, the proposed method is not economical in terms of energy. In the proposed work, the callout mechanism used will assume that prior information is saved in the UAV regarding unique identification number and deployed sensors. When the sensors are called out, the UAV sends request to the sensors which responds. This method can be further used in real time collaboration of UAV to UAV to gather data.

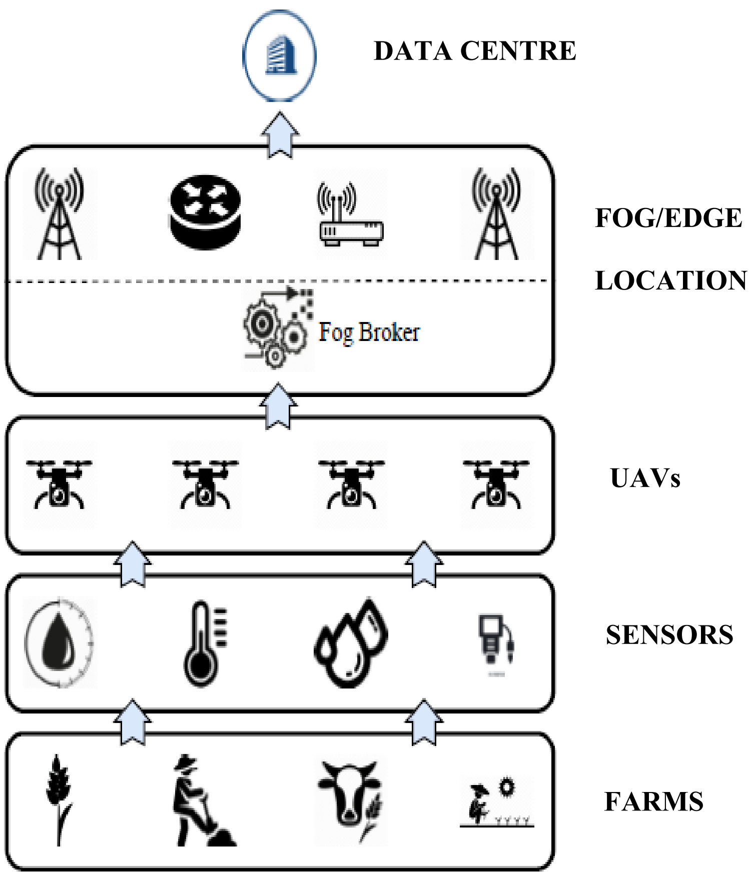

Figure 1. Layered Architecture of Toolkit for Smart Farming

3.2. Fog Nodes

These nodes are resources that are used to store, process and receive the information temporarily from the UAV streams. There are q ∈ 1, 2,….m fog resources at the fog location .Hence, depending on the real-time scenario, specification of every location can be configured accordingly [8].

3.3. Sensors

The proposed work makes use of mobile and static deployment to collect data real-time and increase farm productivity. The sensors are built with different battery life, storage and transmission ranges. These sensors are capable of forwarding the data to the neighbouring nodes using ad hoc ways. The figure X.2 gives an illustration of a sensor node. The UAVs are used too gather information from the mobile sensors and static sensors resulting in a mobile gateway node. In general, data is gathered by the sensors and forwarded to the gateway [7]. But, this will result in unnecessary wastage of energy during route finding and leader selection. To overcome this defect, a mobile gateway concept is employed by us which will increase the lifetime of the sensors and also optimize it for accurate data gathering. The limited storage availability and energy is also modeled accordingly. Figure X.2 represents the architecture of UAV.

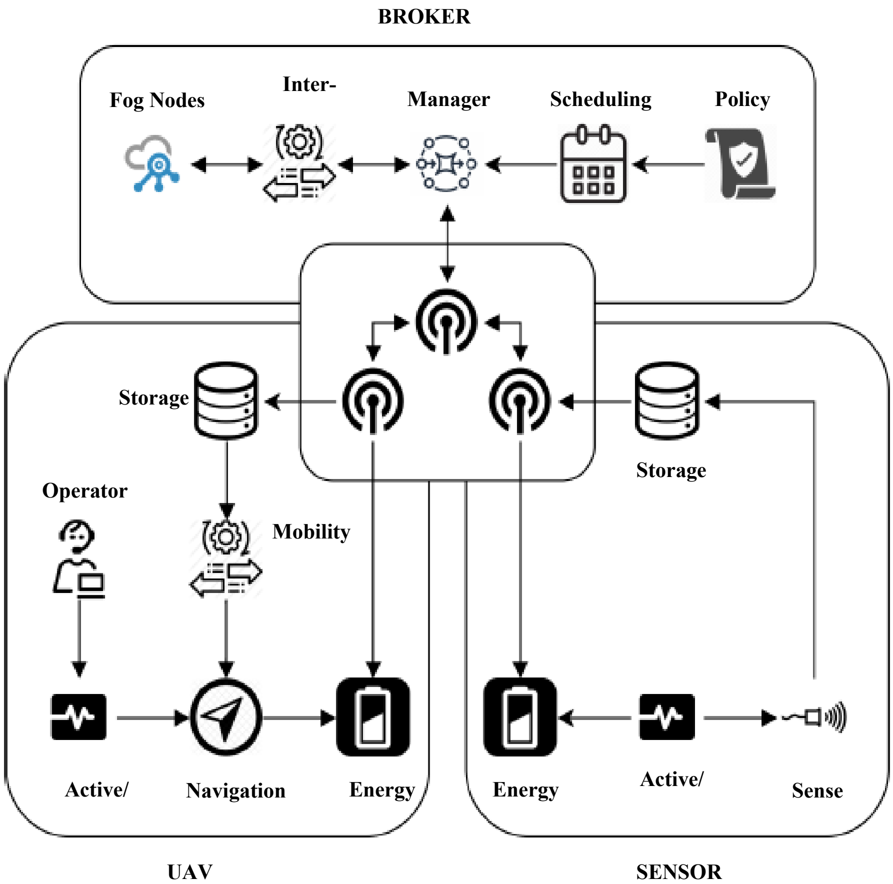

Figure 2. Internal Architecture

3.4. Broker
The fog resources are managed by the brokers and a broker is assigned for every fog location. There are M UAVs assigned to a fog location and broker nodes are used to administer these locations. These nodes further communicate with each other to find an apt resource for the UAV. At the fog location, the broker node is placed as a fixed entity as shown in the architecture, thereby managing scheduling and communicating with the fog nodes. Fault tolerance is enabled using a secondary which will kick in on failure of broker nodes do not reproduce well when printed out—your diagrams may lose vital information when downloaded and printed by other researchers. Try to ensure that lines are no thinner than 0.25 pt. Note that some illustrations may reduce line thickness when the graphic is imported and reduced in size (scaled down) inside Microsoft Word

3.5. Mobility Models
These modules enable movement of the mobile sensors in specific patterns. Though there are several static sensor deployed, the system is designed such that it supports the use of mobile sensors for various purposes. One such use is the utilization of UAVs to obtain information from the sensors on-ground. Vehicle mobility, linear mobility, circle mobility, mass mobility, nomadic community, column mobility, Gauss Markov and random way-points are some examples of mobility models that are support by the proposed framework [9]. There is also an option to extend the mobility models to suit the user requirements.

4. Results and Discussion
Evaluation of the proposed framed is carried out to analyse its performance in terms of UAVs and sensor energy consumption, transmission and processing delay, and system resource usage. UAVs are employed to gather information from the ground sensors. This data is then sent to the broker nodes which will allocate fog resources to perform the task completion. The tasks are generated as MIPs with the help of remote or local resources. Meanwhile, UAVs are also used to evaluate the transmission delay and packet delivery ratio which is important to measure the performance of the wireless sensors at a large-scale [11]. The proposed work also supports the use of fog nodes depending on the number needed by the user. Since the sensors are fixated to a particular location, it might fail due to loss of energy, which is the biggest drawback of the system. The track of fog devices that are available is maintained by the broker with the help of data gathered from the fog nodes.

5. Conclusion
It is observed that the simulation tools play a large part in supporting research in many fields. There are no such tools designed specifically for smart farming purpose and almost all the work is dependent on sensors. Moreover, users are also unaware of sensors congestion phenomena, transmission range and placement of the devices. Hence the proposed framework gives a complete farming ecosystem which is inclusive of fog location, UAVs and sensors. It will give the user access to gather data via sensor relays or UAVs, deploy sensors and also perform fog computation. The work carried out is also equipped with facility to measure transmission delay, energy of the sensor and packet delivery ratio. Future work can be carried out as an extension of this work by incorporating WCN using ANN for intelligent systems and big data analytics for smart farming.

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