A Field Experience on DTN-Based Sensor Data Gathering in Agricultural Scenarios

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***Abstract*—This paper describes our field experience on data collection from remote sensors. By letting tractors, farmers and sensors have short-range radio communication device with delay-disruption tolerant networking (DTN), we can collect data from those remote sensors to our central database. Although, several implementations have been made by using PHS devices or mesh network in the past, DTN-based systems for such applications are still under explored. The main contribution of this paper is to present our practical implementation and experiences on DTN-based data collection from remote sensors. The software, which we have developed for this research, is very small – only about 3000 lines in C, which is much smaller than any other DTN implementations. We carried out an experiment with 10 DTN nodes in the University of Tokyo. They achieved 100% collection with moderate delivery latency showing sufficient usefulness in data granularity.**

***Index Terms*—DTN, Application, Implementation, Sensor Networks**

I. INTRODUCTION

Agricultural researchers and farmers deploy sensors at their remote agricultural-fields to obtain the data of temperature, humidity, soil moisture and so on. Automatic collection of those data greatly helps their analytical works and schedule planning for their activity. Currently, they are relying on network providers, for example, personal handy-phone system (PHS) to achieve such automatic collection from their remote sites, which is not feasible for most of the farmers because of the operational cost reason.

We have explored a DTN-based system that collects sensor data from remote sites without relying on network providers. DTN, which stands for delay (or disruption) tolerant network, was originally proposed for inter-planetary communication[1]. It is now widely acknowledged that we can apply the concept to village-to-village communications[2], vehicular communications[5], [3] and sensor networks[4], [7]. Focusing on the application of DTN to sensor networks, we contribute to the research community by showing our implementation-based experiment.

Several approaches exist for collecting data from such remote sensors. However, we must keep in mind that sensors should cover the agricultural fields sparsely but the number would become large because the field itself is large. Thus, attaching a personal handy-phone system (PHS) device or satellite communication device to every sensor is not feasible for normal farmers because of the communication fee. Setting up wireless mesh network with ad-hoc technologies (e.g., OLSR) could be used but it requires a huge number of relay nodes in the large area so as to extend network connectivity to sensors. The DTN approach with using the mobility of tractors and farmers allows sparse deployment of sensors in large area and collects data along with the movement of daily works.

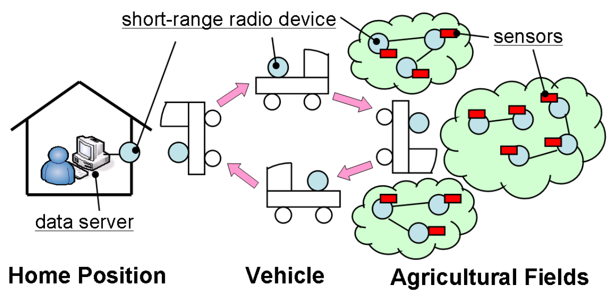

Fig. 1. By using the movement of vehicle, DTN allows data gathering from remote agricultural field sensors.

We assume that sensors, vehicles (e.g., tractors, farmers) and the homes of farmers have short-range radio communication device. Farmers and researchers use their tractor or their foot to visit their remote sites constantly (e.g., everyday or every week). The radio device on such vehicles contacts with sensors at the remote sites, and returns to their home position. By making use of the ad hoc communication chances, they collect remote sensor data to their data server.

This paper is organized as follows. Section 2 describes the system overview for DTN-based data collection from agricultural-fields. We show our experiments and the results in section 3. In section 4, we provide a discussion for future work. Section 5 provides the conclusion of this paper.

II. DTN-BASED DATA COLLECTION FROM REMOTE AGRICULTURAL-FIELDS

Fig. 1 shows the overview of the data collection mechanism from remote agricultural-fields. Here, we assume that this system is operated by a research laboratory or a farmer. There is a data server at their home position that archives the data collected from their remote sites. Their tractor moves between the home position and the remote sites. Each node (i.e., data server, vehicle and sensor) has a wifi interface, and the wifi interfaces are working in "ad hoc" mode. Thus, when they

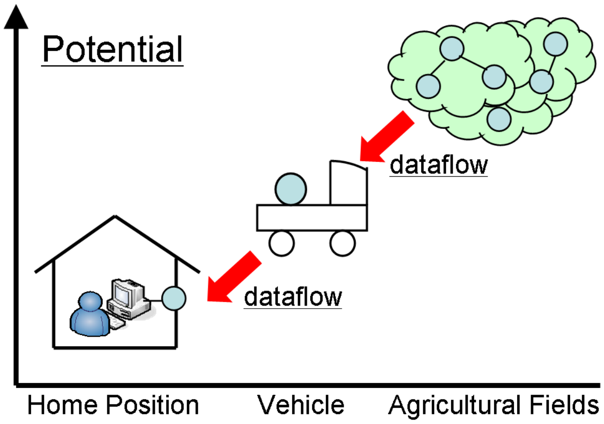

Fig. 2. By setting higher potential to remote sensors and lower potential to data server, sensor data autonomously gathers at lower potential node, just as water flows from higher places to lower places.

Fig. 3. DTN nodes for the experiment. People carry them by hand. They implement potential-based entropy adaptive routing.

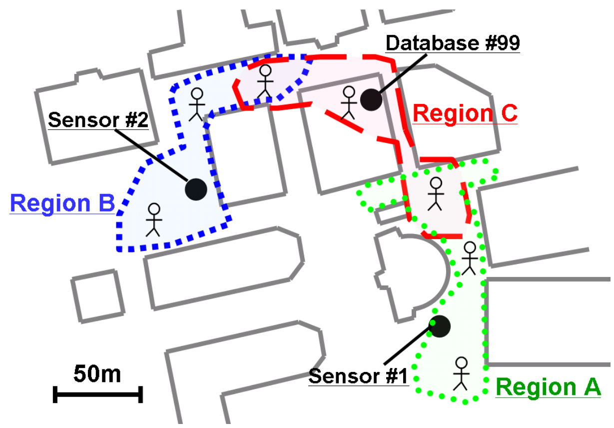

Fig. 4. An experiment scenario in the University of Tokyo. We deployed sensors, database and mobile nodes into three regions (A, B and C).

come into radio communication range, they find each other and can exchange data. For example, when the tractor arrives at the remote sites, it gets the history record of the sensor data and saves into its local storage. After returned, it transfers the stored data to the data server. Even though the delivery of data is not real-time (because it is physically bound to the movement of the vehicle), it is sufficient for data analysis purposes.

We apply potential-based routing (PBR) approach to enable autonomous data transfer. Fig. 2 shows how PBR allows autonomous data delivery from sensors to the data server by making use of the vehicle. In PBR, we introduce *potential* – a scalar value that represents a heuristic proximity from the destination. We define a rule that a node sends messages to the node that has the lowest potential among its neighbors. By setting higher potential for the sensors and lower potential for the server, the vehicle receives data from the sensors at the remote sites and provides data to the server when returned. In this way, sensor data gathers at the data server by making use of the movement of the vehicle.

Each sensor submits observed sensor readings in a message form periodically to the network with specifying the destination to be the data server. For example, the content of a message sent by a sensor could be as follows:

```
Destination: 99
Source: 1
TTL: 81250

Timestamp: 2010-11-02T12:34:00+09:00
Temperature: 25.5
Humidity: 56.9
RainFall: 0.3
```

This message is composed of header part and body part. In the header part, it specifies that the destination is 99 (their data server) and shows that it came from 1 (sensor #1). This message still has 81250 second for delivery lifetime. In the body part, the message has timestamp and sensor readings. Though this is not the real format we used in the experiment (we used binary format in a UDP message), this kind of information was contained in the message.

The sensor application program itself does not need to care the storage or transfer of the message. The network manages the delivery with taking care of storing and transferring by using the message header information.

III. Implementation and Deployment

A. Experiment Setting

We assembled 11 DTN nodes (as Fig. 3) and installed the software we developed for disruption tolerant networking[1]. The software implements potential-based entropy adaptive routing (PEAR)[6] with about 3000 lines in C source code. We carried out experiments in the campus of the University of Tokyo. As Fig. 4, we allocated three regions (A, B and C) with

[1] http://sourceforge.net/projects/pear/files/

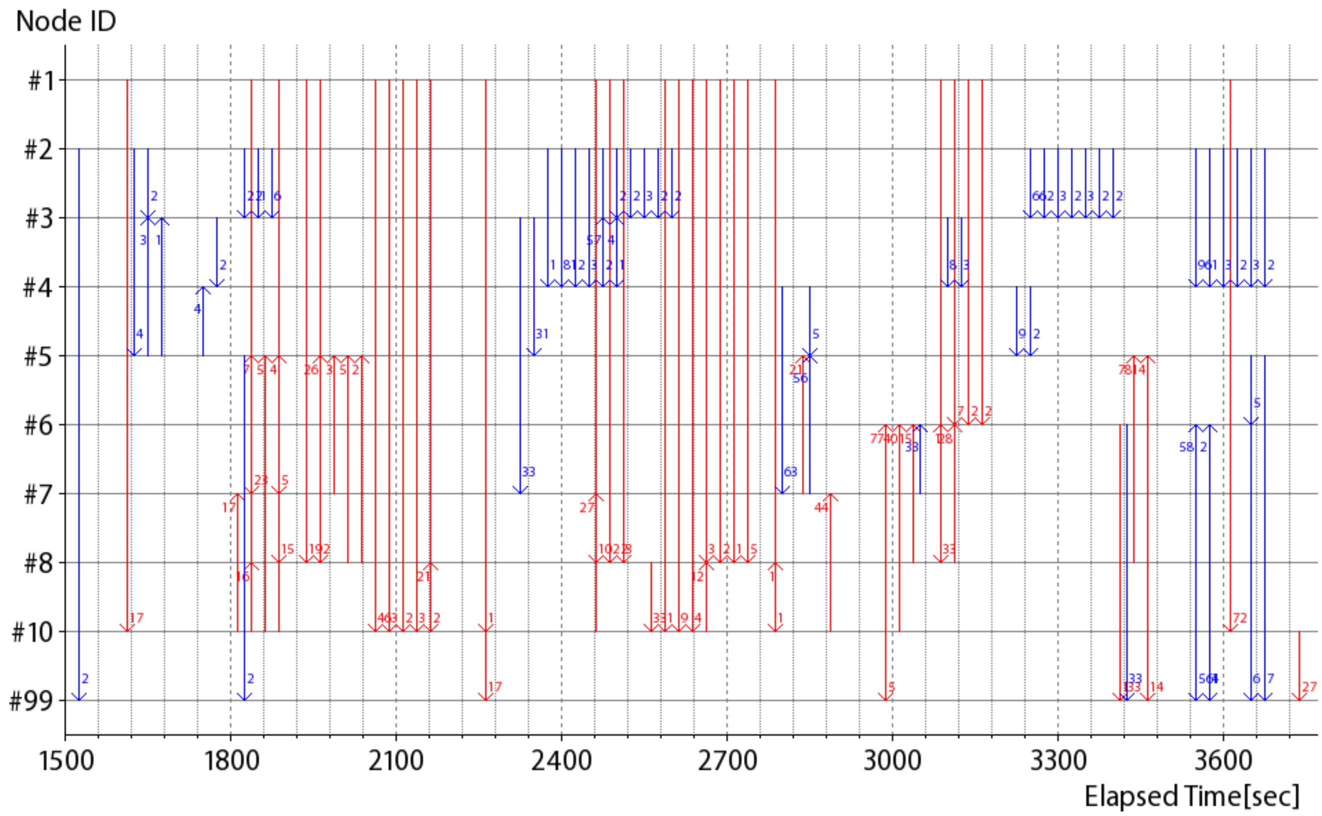

Fig. 5. Dataflow from the sensors (#1, #2) to the database (#99). Red arrows illustrate delivery of data from sensor #1, and blue arrows from sensor #2. The number shown along with an arrow indicates how many DTN messages were transmitted between the two edges.

small overlapped areas. The nodes were numbered as #1, #2, #3, ..., #10, #99. Both #1 and #2 had a weather sensor and sent 100-bytes message to #99 in every ten second. #99 was the gateway node for a data server that archives the history record of sensor readings. The nodes from #3 to #10 were assigned to workers (i.e., farmers) who moved in their working region. We deployed sensor #1 into region A and sensor #2 into region B. #99 was deployed into region C. #3 and #4 moved in B. #5, #6 and #7 moved in C. #8, #9 and #10 moved in A. We set 2400 second for message TTL. The experiment was conducted for 60 minutes, and we studied the delivery pattern, rate and latency and the collected sensor readings.

B. Experiment Result

Fig. 5 shows the message delivery pattern from sensor #1 and #2 to #99. Red arrows illustrate the transmission of messages came from sensor #1, and blue arrows from sensor #2. The number along with an arrow shows how many messages were transmitted at the same timeslot. Here, #9 is not shown because it was malfunctioning during the experiment and thus, we removed from the graph. Fig. 6 shows the spectrum of delivery latency. Data were collected with moderate latency about 10 minutes to 30 minutes, effectively using the movement of people (we admit that these

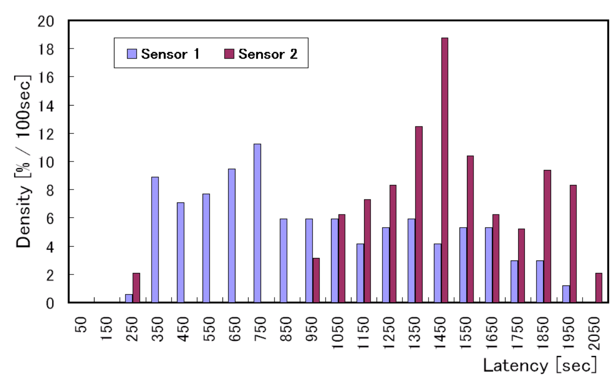

Fig. 6. Distribution of delivery latency from the sensors (#1, #2) to the database (#99).

distributions certainly depended on physical movement of the nodes). Finally, all the data were gathered at the database. Fig. 7 is the sequence of the collected temperature. We can read that it has collected data in sufficient granularity for agricultural application usages. Actually, there was no loss. All the messages have been delivered.

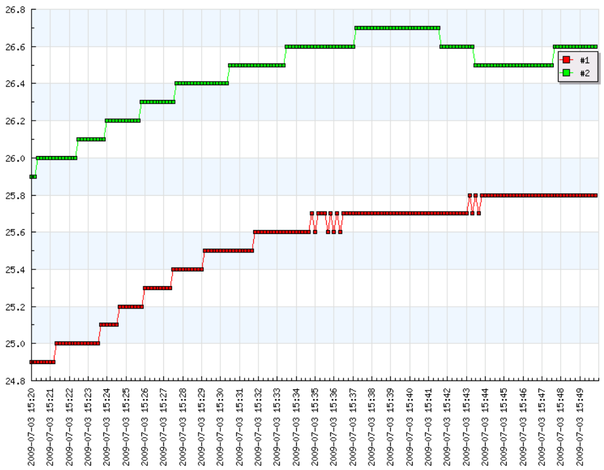

Fig. 7. Collected temperature from sensor #1 and #2. There was no loss during data delivery. It provided sufficient granularity.

IV. Discussion

Compared to PHS-based sensor data gathering, DTN-based system has much longer delay in delivering sensor data from remote sites. However, farmers can install their own DTN-based sensor data gathering system using the equipments they have: e.g., tractors. If the application allows the delay that the network has, the DTN approach would be practically useful for their applications.

We have used PEAR as an implementation of DTN in our experiment. The period of the experiment is shorter than the expected real deployment. We have also assumed that the powers of nodes are always turned on. However, in more realistic situation, the power of them may fail, but messages are still need to be delivered to the destination. In that, we still need to explore and develop the implementation that assumes such situations.

V. Conclusion

In this paper, we have presented our practical study on DTN-based sensor data gathering for agricultural-field sensors. To get sensor data automatically from remote sensors, PHS devices with network providers could be used. However, DTN-based approach also allows data gathering by making use of the movement of tractors or farmers.

We have carried out an experiment with PEAR, a DTN implementation, in the campus of the University of Tokyo. We confirmed that messages from sensors steadily transferred to the data server. In our experiment settings, all the messages were delivered in 10 minutes to 30 minutes delay.

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