# Overhearing-based Data Transmission Reduction Using Data Interpolation in Wireless Sensor Networks

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## ABSTRACT

In this paper, we propose a traffic reduction method using overhearing of wireless communications in wireless sensor networks, which is an extension of our previous method. In the extended method, each node autonomously determines the temporal redundancy of its reading by applying a lightweight interpolation based on the readings acquired by itself before determining the spatial redundancy according to our previous method. When the reading is determined as spatially or temporally redundant, the node stops transmitting it. This approach reduces the communication traffic since only the readings required for obtaining the data distribution of the entire area. Furthermore, we verify the effectiveness of our method by simulation experiments.

## 1 INTRODUCTION

In recent years, there has been a great deal of interest in Wireless Sensor Networks (WSNs), which consist of sensor nodes with radio communication modules. Since WSNs can be constructed only with many kinds of sensor nodes that can sense different types of data, WSNs can provide various applications associated with these sensors' types without constructing communication infrastructures in advance. However, sensor nodes have limited capabilities. Power supply, in particular, is one of the most critical constraints because sensor nodes are usually battery powered. Therefore, power saving of nodes is a significant issue for prolonging the service lifetime of a WSN. In WSNs, wireless communication (i.e., transmission and reception of packets) is the most energy consuming task. Thus, it would be effective to reduce the data traffic in the WSN. However, unplanned reduction of data traffic such as random discard of sensor readings may deteriorate the accuracy of WSN applications.

One of the typical applications of WSNs is monitoring the whole target area. In a monitoring application, sensor nodes sense the environment and send their readings (raw data) to the sink, which is connected to the WSN and manages the readings from the nodes.

Here, observations or sensor readings of monitoring applications, such as temperature, generally have the following two characteristics. First, readings are regarded as spatially and temporally discrete data corresponding to the sensed points and timings. Thus, it is necessary to estimate the data without actual readings. Second, readings tend to have spatial and temporal correlations. Thus, data without actual readings can be estimated using those correlations. This property is useful not only for estimating data at missing points but also for preventing the redundant data from being injected into the network. Several studies that exploit correlations among readings in order to reduce communication traffic in WSNs have been conducted [1], [3], [4], [7], [9]. These approaches can drastically reduce communication traffic in WSNs, however, require extra control traffic for generating or sharing information on the correlations.

To solve the problems of these conventional methods, we have proposed a novel data transmission reduction method, named ODAS (Overhearing based Data Aggregation method using Spatial interpolation), which reduces data traffic based on the spatial correlation of readings [5], [6]. ODAS exploits packet overhearing, which is a characteristic of wireless communication. Each node determines the spatial redundancy of its reading by comparing the reading (actual value) with the estimated value calculated by the overheard readings. Accordingly, only the readings required to grasp information on the whole area will be transmitted, and thus, traffic in WSNs can be reduced. In [5], we have verified that ODAS can reduce the data traffic and the energy consumption in WSNs compared with the conventional methods.

Here, readings in WSNs have not only spatial correlation but temporal correlation. In this paper, we extend our ODAS and propose ODAST (Overhearing based Data Aggregation method using Spatial and Temporal interpolations), that further reduces communication traffic by utilizing both spatial and temporal correlations of readings. In ODAST, before determining the spatial redundancy, each node determines the temporal redundancy of its reading by comparing the reading with the estimated value calculated by the past readings acquired by itself. Accordingly, further traffic reduction can be achieved by suppressing the transmission of temporally redundant readings.

The rest of this paper is organized as follows: In Section 2, we describe the assumptions in this paper. In Section 3, we briefly introduce related work. We introduce our previous method ODAS in Section 4. In Section 5, we explain the details of our method ODAST. In Section 6, we show the results of simulation experiments regarding the performance evaluation of our method. Finally, we conclude this paper and discuss some ideas for future work in Section 7.

## 2 ASSUMPTION

Figure 1 shows an overview of the system. We assume a multi-hop sensor network system, which consists of a sin-

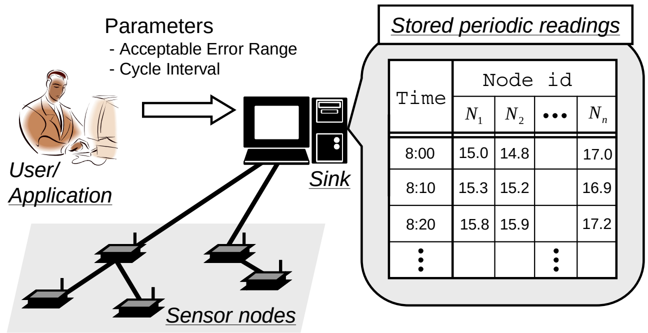



Figure 1: Assumed environment.

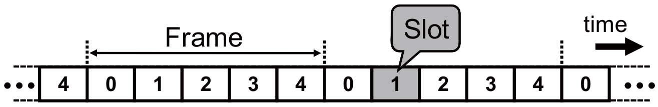



Figure 2: Overview of TDMA (Number of slots = 5).

gle sink and $n$ sensor nodes and is deployed in a flat target area. Each sensor node is assigned a unique identifier $N_i (1 \leq i \leq n)$. Every sensor node has the same capabilities of resources such as calculation capacity, cache size, and radio module. The radio propagation ranges of all nodes have a radius of $r$. Each sensor node knows the locations of itself and its *neighbors*. Here, neighbors of a node are defined as the set of nodes that exist within the range of $r$ from the corresponding node. The sink knows the location of every node.

Each node periodically senses physical phenomena, such as temperature and light intensity, and sends the reading to the sink via a communication route. Sensing is performed simultaneously on all nodes, and the sensing interval is set by the application in advance. We call this interval $cycle$. The sink stores and manages all gathered readings.

The application specifies the *acceptable error range* $E$ between the actual reading and the estimated value of a sensor node, i.e., the system collects the data of all nodes so that the errors from the corresponding actual readings are within the range of $E$. For this aim, the following condition should be satisfied for all sensor nodes in each cycle:

$$|v_i(t) - \hat{v}_i(t)| \leq E \quad (1 \leq i \leq n). \tag{1}$$

In the above expression, $v_i(t)$ and $\hat{v}_i(t)$ are the actual reading and the estimated reading of node $N_i$ respectively.

The wireless communication route from each node to the sink is constructed in advance. We assume a static tree-shaped network for data gathering. Specifically, each node has a parent node to which it simply transfers packets. Since our method is independent of the routing, any other routing protocols, such as a cluster based protocol, can be applied.

As the medium access control protocol, we assume time division multiple access (TDMA). In TDMA, the channel bandwidth is divided into time units, called *slots*, as shown in Figure 2. Each sensor node is assigned a slot, and it is allowed to transmit packets in its assigned slot. Moreover, multiple slots are grouped into a *frame*, which is the cycle of packet transmissions, i.e., a slot appears with a period of the frame. We assume that all nodes know the slots assigned to themselves and their neighbors. In addition, time is synchronized among all nodes by applying a conventional protocol such as [2].

## 3 RELATED WORK

There have been several studies for reducing data traffic in WSNs that exploit the correlations among readings of sensor nodes. Guestrin et al. proposed a distributed regression method [4] that divides the target area into multiple subregions and compresses the readings in each subregion into a specified number of coefficients by the regression approximation calculated in a distributed manner. This method can reduce the amount of data transferred to the sink by approximating the data by spatial, temporal, or other aspects. However, nodes have to exchange some messages for regression process, and it is difficult to limit the range of error within a specified value.

Kotidis proposed a method for snapshot queries [7] in which several representative nodes are elected based on the correlation of readings between nodes, and answer queries instead of the other nodes. This method reduces the traffic of both data and queries until the representative nodes die or the property of data distribution changes. However, this method assumes an environment where queries are transferred to nodes, which is different from our assumption. Moreover, this method also requires message exchanges between nodes to exploit the correlation of readings.

Some methods [1], [3] use statistical models to estimate the readings of nodes. These methods construct statistical models at the sink, or at several nodes that head disjoint subregions of the WSN. Statistical models can drastically reduce the amount of data sent by nodes since a statistical model basically requires few readings to respond to queries. However, there methods consume much time (specifically, days to weeks) and energy for constructing these models because they require huge amount of data. Also, since the answers from their systems are probabilistic, the performance may be deteriorated when applications require a specific acceptable error range.

## 4 ODAS: OUR PREVIOUS METHOD

This section presents ODAS which is our previous traffic reduction method. As shown in Figure 3, ODAS defines the following two phases:

- **Redundancy Determination Phase (RDP)**: In this phase, each node autonomously determines the spatial redundancy of its reading. If a node determines its reading as spatially redundant, it decides to stop transmitting its reading in the current cycle.

- **Data Gathering Phase (DGP)**: In this phase, the nodes, that received readings from their children on the tree-

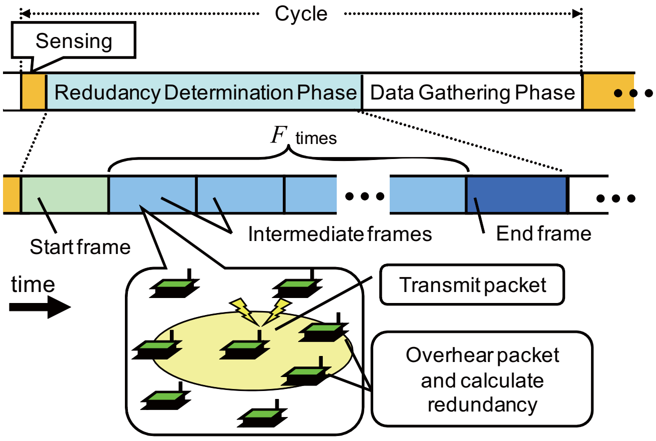



Figure 3: Overview of ODAS.

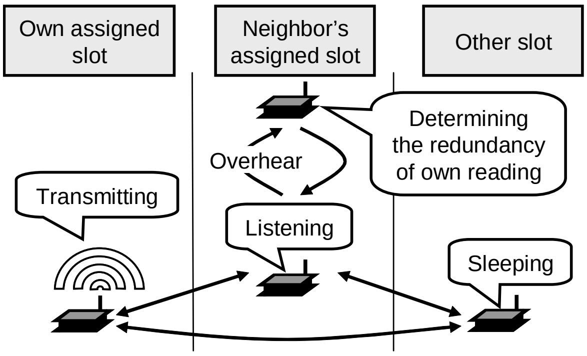



Figure 4: Operations of nodes.

shaped communication route in the RDP, transfer the readings to the sink according to the route.

In what follows, we describe the behaviors of nodes in the RDP, and that of the sink after gathering readings.

## 4.1 Operations of nodes

Figure 4 shows the operations of each node in a frame. Basically, each node is in the sleep mode in which its radio transceiver is turned off. In the slot assigned to each of its neighbors, the node turns the transceiver on and overhears a packet transmitted by the neighbor. Here, since each node transmits one packet at the maximum in a RDP, a node stays in the sleep mode in a slot assigned to the neighbor that has already transmitted a packet in a preceding frame. Each packet consists of an identifier, the raw reading of the node, and the information about whether the packet is sent in the end frame or not. The node determines the spatial redundancy of its reading every time it overhears a packet. Besides, in its assigned slot, the node transmits a packet if necessary.

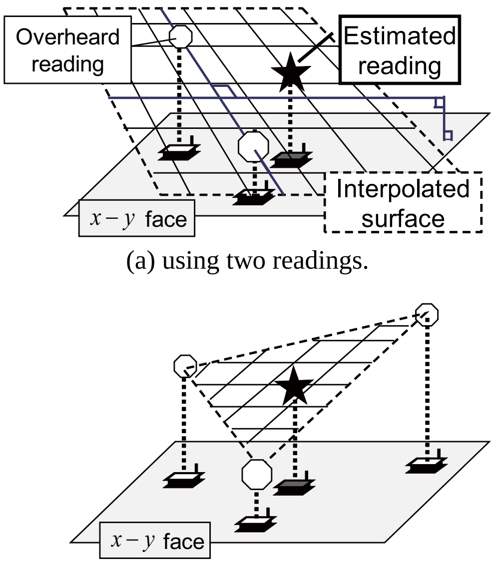
## 4.2 TDMA format in a RDP

A RDP consists of the *start frame*, $F$ frames of *intermediate frames*, and the *end frame* (see Figure 3).

In the start frame, the nodes that did not transmit packets in the previous cycle become *trigger nodes*, and transmit packets in their assigned slots. We call these packets *trigger packets*. When a trigger node overhears a trigger packet transmitted by its neighbor, the node stops transmitting the trigger packet. By doing so, trigger packets are transmitted uniformly according to the communication range $r$.

In an intermediate frame, each node transmits a packet or overhears the channel according to the result of the spatial interpolation described in Section 4.3.

The end frame terminates the RDP. In this frame, no node determines the spatial redundancy of its reading because there is no succeeding frame, i.e., all nodes that have not determined the spatial redundancy of their readings until the beginning of this frame transmit packets in this frame.




(a) using two readings.

(b) using three readings.

Figure 5: Spatial interpolations.

## 4.3 Spatial redundancy determination

Each node calculates the estimated reading at its location by spatial interpolation every time it overhears packets transmitted by its neighbors. Here, we assume an $x$–$y$–$z$ space in which the $x$–$y$ face corresponds to the target flat space for sensing, i.e., the $x$ and $y$ coordinates represent the sensor node's location, and the $z$ coordinate corresponds to the sensor reading at the location. The algorithm of spatial interpolation is as follows:

- When a node stores only one overheard reading, the node just regards this reading as its estimated reading.
- When a node stores two overheard readings, as shown in Figure 5(a), the node first derives a flat surface including the line containing overheard readings, and its perpendicular that is parallel to the $x$–$y$ face. Next, the node chooses the value, whose $x$ and $y$ coordinates correspond to the ones of itself, from the derived surface as its estimated reading.
- When a node stores more than two overheard readings,

as shown in Figure 5(b), the node first chooses three nodes whose locations construct a triangle containing the location of itself. If there are multiple candidates, the node chooses one in which the total distance between the three nodes and itself is the smallest. On the other hand, if there is no set of nodes that construct a triangle containing the node, the node chooses three nodes in which the total distance between the three nodes and itself is the smallest. Next, the node derives a flat surface that contains the triangle constructed of the overheard readings of the chosen three nodes. Finally, it chooses the value, whose $x$ and $y$ coordinates correspond to the ones of itself, from the derived surface as its estimated reading.

After calculating the estimated reading, each node determines the spatial redundancy of its reading. In this procedure, the node evaluates the following condition:

$$\left|v_i(t) - \hat{v}_i^S(t)\right| \leq E. \quad (2)$$

Here, $v_i(t)$ is the actual reading of node $N_i$, $\hat{v}_i^S(t)$ is the estimated reading calculated by the spatial interpolation described above, and $E$ is the acceptable error range specified by the application. When the condition is not satisfied, the node determines that its reading is not spatially redundant, and transmits the packet in a succeeding frame.

### 4.4 Restoring missing readings

The readings determined as spatial redundant will not be transferred to the sink. The sink restores such 'missing' readings by reenacting the spatial interpolation process performed by each node that has not transmitted packet in the RDP. Note that the readings transmitted in the end frame are not used for data restoring because it is obvious that no node used them in the spatial interpolation process.

## 5 ODAST: OUR PROPOSED METHOD

In ODAS, each node determines the spatial redundancy of its reading based on the overheard readings. In this section, we propose ODAST, which extends ODAS in order to further reduce communication traffic by utilizing temporal correlation of readings.

Similar to ODAS, ODAST defines two phases, the redundancy determination phase (RDP) and the data gathering phase (DGP). In addition, each node determines the temporal redundancy of its reading at the beginning of a RDP as shown in Figure 6.

In what follows, we first explain the details of the temporal redundancy determination. After that, we describe the behaviors of nodes in the RDP, and that of the sink after gathering readings.

### 5.1 Temporal redundancy determination

After performing sensing, each node calculates the estimated reading of itself at the present cycle by temporal interpolation based on the past readings acquired by itself.

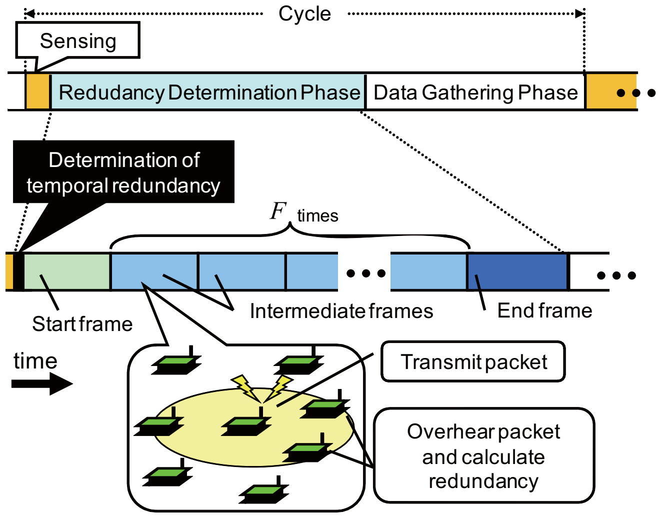



Figure 6: Redundancy determination phase in ODAST.

- When the node transmitted only one reading in the past, the node just regards this reading as its estimated reading as shown in Figure 7(a).

- When the node transmitted more than one readings in the past, as shown in Figure 7(b), the node first chooses two readings transmitted in the most recent cycles. Next, the node derives a line that contains these readings. Finally, it chooses the value, whose time corresponds the sensing time of the current cycle, from the derived line as its estimated reading.

After calculating the estimated reading, each node determines the temporal redundancy of its reading. In this procedure, the node evaluates the following condition:

$$\left|v_i(t) - \hat{v}_i^T(t)\right| \leq E. \quad (3)$$

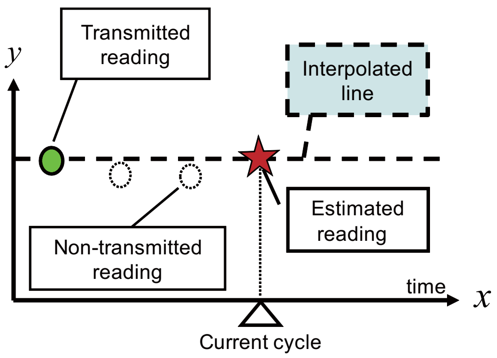
Here, $\hat{v}_i^T(t)$ is the estimated reading at cycle $t$ calculated by the temporal interpolation described above. When the condition is not satisfied, the node determines that its reading is not temporally redundant, and becomes a trigger node in the succeeding start frame.

### 5.2 TDMA format in a RDP

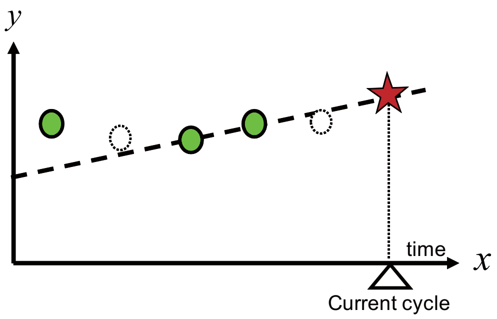
Similar to ODAS, a RDP consists of the start frame, $F$ frames of intermediate frames, and the end frame.

In the start frame, the nodes that determine their readings as temporally nonredundant become trigger nodes. When a trigger node overhears a trigger packet transmitted by its neighbor which exists within the range of $R_{TN}$ from itself, the node stops transmitting the trigger packet. By doing so, trigger packets are transmitted uniformly according to the range of $R_{TN}$.

In an intermediate frame, each node transmits a packet or overhears the channel according to the result of the temporal interpolation described in Section 5.3.




(a) using one reading.




(b) using two readings.

Figure 7: Temporal interpolations.

In the end frame, each node that has not transmitted packet in the preceding frames checks whether it satisfies the following conditions:

- It determines that its reading is neither temporally nor spatially redundant.
- It determines that its reading is not temporally redundant, and did not overhear $N_{IC}$ packets in the preceding frames.

When the node satisfies either of the above conditions, it transmits packet in the end frame.

### 5.3 Spatial redundancy determination

Similar to ODAS, each node performs transmitting/overhearing packets or transiting to the sleep mode according to slots. Here, each node does not determine the spatial redundancy of its reading until it overhears $N_{IC}$ packets from its neighbors. On the other hand, once a node overhears $N_{IC}$ packets, the node determines the spatial redundancy of its reading every time it overhears a packet from its neighbor. By doing so, the sink can uniquely reenact the redundancy determination process of each node that does not transmit packet.

### 5.4 Restoring missing readings

Similar to ODAS, the sink in ODAST restores missing readings by reenacting the interpolation process of each node that has not transmitted packet in the RDP. In what follows, we show the details of restoring a missing reading.

1. The sink checks the number of packets transmitted by neighbors of the corresponding node in the RDP.
2. When the number of transmitted packets is less than $N_{IC}$, the sink restores the reading by reenacting the temporal interpolation process of the node. This is because the node has not transmitted its reading according to the result of the temporal interpolation.
3. When the number of transmitted packets is equal to or more than $N_{IC}$, the sink restores the reading by reenacting the spatial interpolation of the node. This is because the node has not transmitted its reading according to the result of the spatial interpolation.

Here, the sink restores a missing reading by using the same readings that the corresponding node uses. Thus, the difference between the actual(missing) reading and the restored reading becomes less than the acceptable error range $E$.

### 5.5 False nonredundant nodes

In order for the sink to reenact the interpolation process of a node, ODAST introduces the parameter $N_{IC}$. As described in Section 5.3, when a node overhears $N_{IC}$ packets from its neighbors, the node determines the spatial redundancy of its reading regardless of the result of the temporal redundancy determination. In such a case, when the node determines its reading as spatially redundant, it transmits packet even if the reading is temporally redundant. We call such a node *false nonredundant node*.

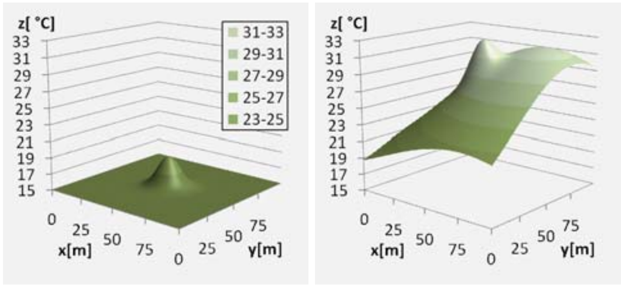
When a false nonredundant node transmits packet, its neighbors may also become false nonredundant nodes due to the increase of overheard packets. In order to suppress such an increase of false nonredundant nodes, it is effective to set the number of intermediate frames $F$ small. When $F$ is set small, each node may have less opportunities to overhear more than $N_{IC}$ packets transmitted by its neighbors.

In addition, the number of false nonredundant nodes can be suppressed by setting the parameter $N_{IC}$ large. However, when $N_{IC}$ is set large, many nodes do not perform the spatial redundancy determination process until the beginning of the end frame. This may result in the increase of packet transmissions in the end frame. Such a situation frequently occurs when the number of intermediate frames $F$ is set small. In order to avoid such a situation, it is effective to control the parameter $R_{TN}$. When $R_{TN}$ is set small, the number of trigger packets transmitted in the start frame increases. Thus, many nodes can perform the spatial redundancy determination process until the beginning of the end frame.

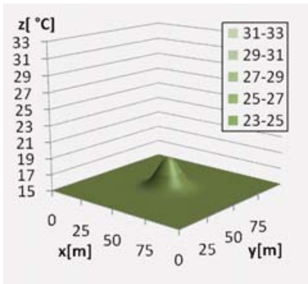
In summary, the number of false nonredundant nodes can be affected by three parameters $F$, $N_{IC}$, and $R_{TN}$. We evaluate the effects of these parameters to the performance of ODAST in Section 6.

## 6 PERFORMANCE EVALUATION

In this section, we show the results of the simulation experiments regarding the performance evaluation of ODAST.

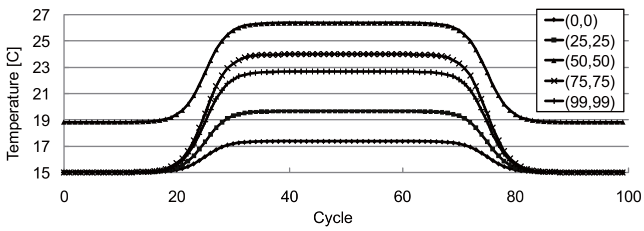


Cycle: 1 Cycle: 50



Cycle: 100

(a) Data distributions in particular cycles.




(b) Dynamic changes in data at particular points.

Figure 8: Data distribution.

In the simulation experiments, we assume a monitoring application which measures the temperature in a target area. First, we evaluate the effects of parameters in ODAST, i.e., $F$, $N_{IC}$, and $R_{TN}$. In addition, we compare the performance of ODAST with that in other data gathering methods.

## 6.1 Simulation environment

In the experiments, there are 600 sensor nodes $(N_1, ..., N_{600})$ and single sink in the 100[m]×100[m] flatland. Each node is located randomly and the sink is located at the corner of the area, i.e., $(x, y) = (0, 0)$. The communication range $r$ is set as 10[m]. Figure 8 is the data distribution applied to the experiments, which assumes the dynamic change of temperature in a room. Table 1 shows the energy consumption model of a node, which is set according to the specification of MICAz Mote[8].

In the above environment, we evaluate the following four criteria:

- **The number of trigger packets**: The total number of trigger packets transmitted in a RDP.
- **The number of transmitted packets**: The total number of transmitted packets in a RDP.

Table 1: Energy consumption model.

| Operation | Current $[mA]$ |
|---|---|
| Transmit packet | 22 |
| Receive (Overhear) packet | 22 |
| Listen | 2 |
| Sleep | 0.15 |

- **The number of false nonredundant(FN-) packets**: The total number of packets transmitted by the false nonredundant nodes in a RDP.
- **The energy consumption**: The total energy consumed by all nodes in a cycle.

## 6.2 Effects of the number of intermediate frames $F$

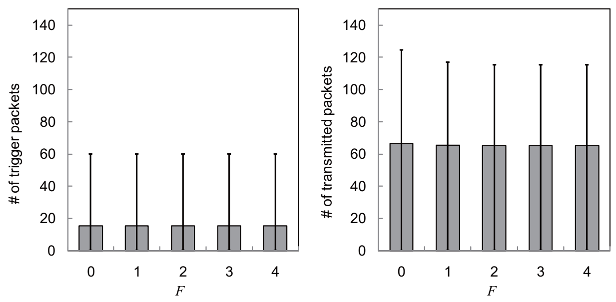
Figure 9 shows the simulation results changing the number of intermediate frames $F$. In this experiment, parameters $N_{IC}$ and $R_{TN}$ are respectively set as 1 and 10. The horizontal axis indicates $F$, the vertical axes respectively indicate the number of trigger packets in Figure 9(a), the number of transmitted packets in Figure 9(b), the number of false nonredundant packets in Figure 9(c), and the energy consumption in Figure 9(d).

From the result in Figure 9(a), we can see that the number of trigger packets does not change regardless of the change in $F$. This is obvious because the number of intermediate frames $F$ does not affect the number of trigger packets.

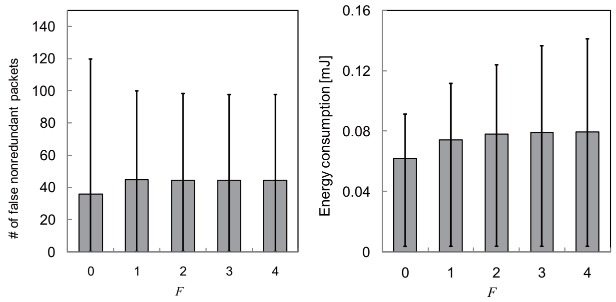
From the result in Figure 9(b), the number of transmitted packets shows little change even when $F$ changes. This is because the temporal changes in data show similar characteristics across the entire area as shown in Figure 8(b), and the data distribution at each cycle is spatially continuous as shown in Figure 8(a). In such an environment, when the data distribution temporally changes, almost all nodes become trigger nodes, and trigger packets are transmitted uniformly according to the range of $R_{TN}$. Since the data distribution is spatially continuous, most of nodes that overhear trigger packets determine their reading as spatially redundant. As a result, packets other than the trigger packets are rarely transmitted in a RDP. Here, when $F$ is set as 0, the number of transmitted packets becomes small. This decrease is due to the decrease of false nonredundant packets as shown in Figure 9(c). This indicates that the number of false nonredundant nodes can be suppressed by setting the number of intermediate frames $F$ small, as discussed in Section 5.5.

From the result in Figure 9(d), the energy consumption increases as the number of intermediate frames $F$ gets larger. From this result, we can confirm that the larger the number of intermediate frames, the larger the energy consumption becomes due to the energy consumed in the listen and sleep modes.

In summary, we can see that it is effective to set the number of intermediate frames $F$ small for suppressing the energy consumption.




(a) # of trigger packets. (b) # of transmitted packets.




(c) # of FN-packets. (d) The energy consumption.

Figure 9: Effects of the number of intermediate frames $F$.

## 6.3 Effects of parameters $N_{IC}, R_{TN}$

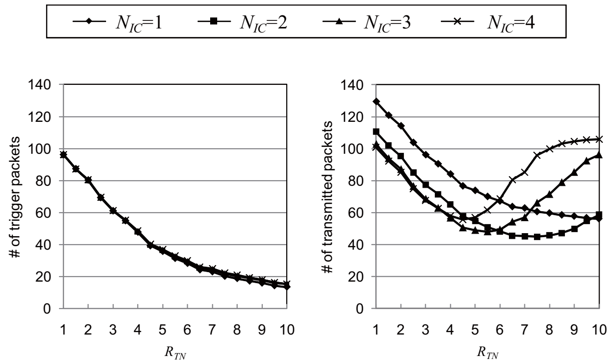
Figure 10 shows the simulation results changing parameters $N_{IC}$ and $R_{TN}$. Here, the number of intermediate frames $F$ is set as 0 considering the results described in the previous section. The horizontal axis indicates $R_{TN}$, the vertical axes respectively indicates the number of trigger packets in Figure 10(a), the number of transmitted packets in Figure 10(b), the number of false nonredundant packets in Figure 10(c), and the energy consumption in Figure 10(d).

From the result in Figure 10(a), we can see that the number of trigger packets decreases regardless of $N_{IC}$ as $R_{TN}$ gets larger. This is because the larger the parameter $R_{TN}$ is, the larger the number of trigger nodes that stop transmitting packets becomes as described in Section 5.2.

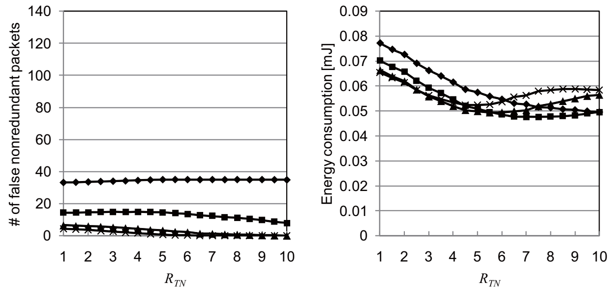
From the result in Figure 10(b), the number of transmitted packets decreases regardless of $N_{IC}$ as $R_{TN}$ gets larger. This is due to the decrease of trigger nodes. When $N_{IC}$ is larger than 1, the number of transmitted packets increases after $R_{TN}$ exceeds a certain value. This is because some nodes whose readings are not temporally redundant cannot determine the spatial redundancies of their readings due to the decrease of trigger packets. This results in the packets transmitted in the end frame.

From the result in Figure 10(c), the number of false nonredundant packets decreases as $N_{IC}$ gets larger. This is because the larger the parameter $N_{IC}$ is, the smaller the number of nodes that perform the spatial redundancy determination process becomes as described in Section 5.5.

From the result in Figure 10(d), the energy consumption shows similar tendency with the number of transmitted packets. This is because the number of intermediate frames is set as 0. In other words, the effects of energy consumed in the listen and sleep modes becomes small.




(a) # of trigger packets. (b) # of transmitted packets.




(c) # of FN-packets. (d) The energy consumption.

Figure 10: Effects of the parameters $N_{IC}$ and $R_{TN}$.

## 6.4 Comparison with other methods

In this section, we compare the number of transmitted packets and the energy consumption in ODAST with those in the following methods:

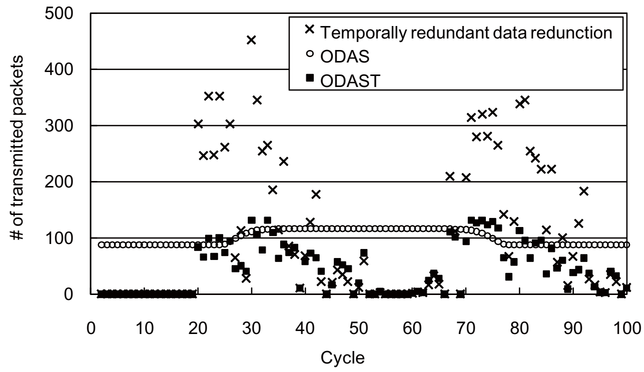
- **ODAS**[5], [6]: This method reduces transmissions of spatially redundant readings using spatial interpolation described in Section 4.3. Note that ODAS does not determine the temporal redundancies of readings.

- **Temporally redundant data reduction method**: In this method, each node only performs the temporal redundancy determination process in a RDP. Specifically, each node transmits packet in the start frame when it determines that its reading is not temporally redundant.

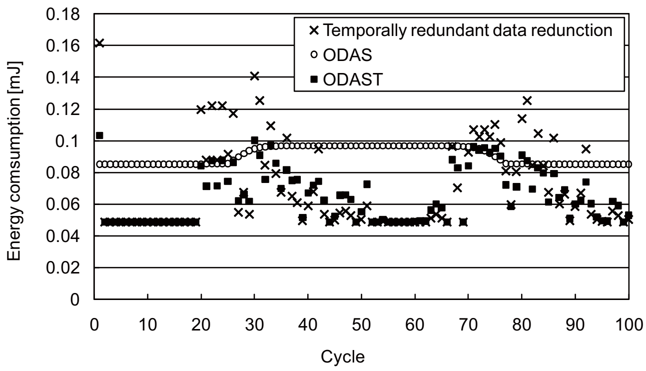
Here, we set the parameters $F, N_{IC}, R_{TN}$ as 0, 2, 7.5. In addition, we set the same tree-shaped network for data gathering in all methods.

Figure 11 shows the simulation results. The horizontal axis indicates cycles, the vertical axes respectively indicate the number of transmitted packets in Figure 11(a) and the energy consumption in Figure 11(b).

From the result in Figure 11(a), we can see that about 100 packets are transmitted at every cycle in ODAS. This is because ODAS needs to transmit trigger packets uniformly according to the communication range (10[m] in this experiment). In the temporally redundant data reduction method,




(a) # of transmitted packets.




(b) The energy consumption.

Figure 11: Comparison with other methods.

many packets are transmitted at some particular cycles (around 30th and 80th cycles). As shown in Figure 8(b), the characteristics of the data distribution changes around these cycles. In such a situation, almost all nodes determine that their readings are not temporally redundant.

On the other hand, ODAST reduces the number of transmitted packets even at the cycles when there are many nodes whose readings do not temporally redundant, e.g, around 30th cycle, while keeping small number of packet transmissions at other cycles. This indicates that ODAST can efficiently reduce the data traffic by using both temporal and spatial interpolations.

From Figure 11(b), we can see that the energy consumption in ODAST becomes smaller than those in other two methods. This is due to the decrease of transmitted packets. From this result, we can confirm that ODAST achieves the effective reduction in the energy consumption by using both of temporal and spatial redundancies.

## 7 CONCLUSION

In this paper, we have proposed ODAST, which reduces the data traffic using data interpolation and overhearing. In ODAST, each node in a WSN autonomously determines the redundancy of its own reading by using the temporal and spatial interpolations. The simulation results show that ODAST reduces the data transmissions and energy consumption compared with other methods.

As part of our future work, we plan to evaluate the effectiveness of ODAST in other data distributions. In addition, we plan to address several other interpolations in order to improve the accuracy of data interpolation.

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