Characterization of Iterative PLIM for Environmental Observations and Transmission Design

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***Abstract*—In LPWA(Low Power Wide Area), a low-power, long-distance communication method, throughput degradation is an issue due to transmission time limitations. PLIM (Packet Level Index Modulation), which transmits packet transmission timings and access channels as an index of information, can be added to packet data. However, as LPWA is in a competitive access environment, missing information due to packet collisions is a challenge. To minimize packet collisions, a method has been proposed to design the mapping, which is the allocation relationship between the index and sensor information, by mathematical optimization. This method cannot sufficiently suppress missing packets, which require information collection with non-optimal mappings, because the statistical trend of sensor information is estimated in advance. In this paper, an iterative statistical estimation of sensor information and mapping design method is proposed, where the statistical trend of sensor information is estimated sequentially and the mapping is redesigned. The effectiveness of the method is demonstrated by computer simulations.**

***Index Terms*—LPWA,PLIM**

I. Introduction

With the rapid shift to IoT in recent years, LPWA [1], a low-power, long-distance communication method, has attracted attention. LPWA has issues that throughput is reduced due to transmission time limitations in order to narrow the transmission bandwidth and reduce noise power. The PLIM [2] method is used to address this issue. This method uses the combination of the transmission time and transmission frequency channel of the transmitted packet as an index of the transmitted information, which enables additional information to be transmitted even under transmission time limits, thereby reducing throughput degradation.

However, if multiple sensors transmit packets to the same location in the index, which is the correspondence between transmission time and frequency, transmission information will be lost due to packet collisions, so Miyamoto et al. Miyamoto et al. established an optimal design based on a mathematical model that minimizes the packet collision probability using a trend analysis of prior sensor information. The problem with this optimal design is the assumption that the aggregation environment measurements have already been completed. Actual optimization with a view to large-scale aggregation takes a great deal of time.

TABLE I
Example of Mapping Table

Information	00	01	10	11
SensorA	2	3	4	1
SensorB	3	1	2	4

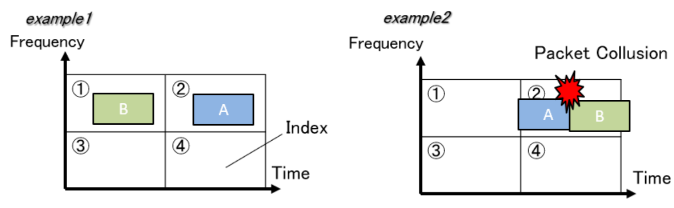

Fig. 1. Example of Mappings

Until the measurement of the aggregation environment is completed, packet transmission is carried out under a non-optimal design, which results in packet loss. This paper aims to reduce this packet loss as much as possible.

II. About Mapping

Mapping is the correspondence between transmitted information about a sensor and an index. Table 1 shows an example mapping table and Figure 1 shows an example mapping. For example, in example 1 in Figure 1, sensor A obtains information 00 and refers to index 2, and sensor B obtains information 01 and refers to index 1. In example 2, sensor A obtains information 00 and sensor B obtains information 10, both referring to index 2. If the same index is referenced as in example 2, packet collision will occur and both packets will not arrive.

III. The Conventional Method

A. About The Conventional Method

$$\min \sum_{k=1}^{K}\sum_{i_1=1}^{I}\sum_{i_2=i_1+1}^{I}\sum_{j_1=1}^{J}\sum_{j_2=1}^{J} P_{i_1,j_1}P_{i_2,j_2}x_{i_1,j_1,k}x_{i_2,j_2,k} \tag{1}$$

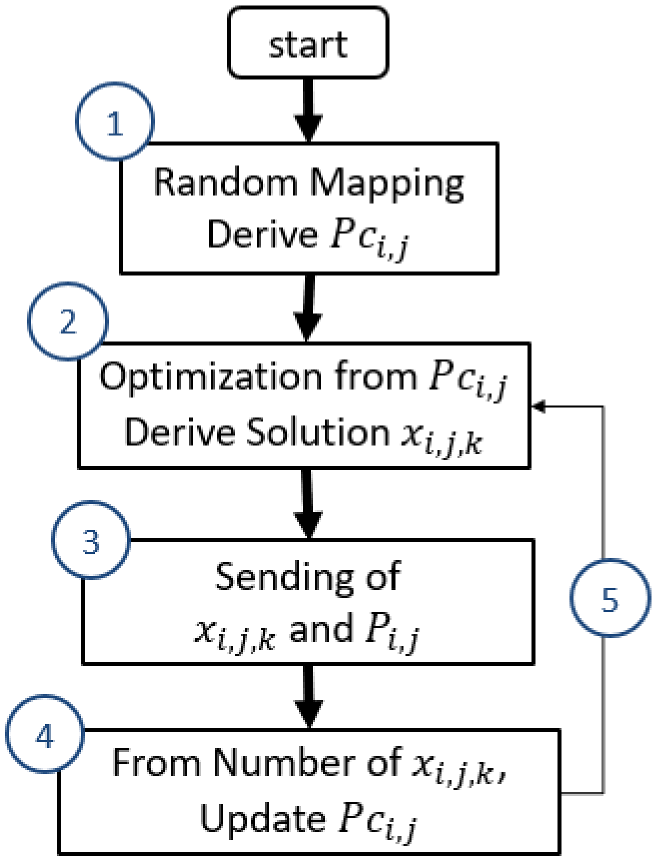

Fig. 2. Flow of The Proposed Method

TABLE II
THE SIMULATION SOURCES

Number of Sensor	8
Number of RSSI(Quantization Number)	8
Number of Index	10

In the conventional method, a second-order integer programming problem mathematical model (1) was made to minimise the packet non-arrival rate, which is the rate of packet loss, assuming that the trend analysis of sensor information is complete.

I is the total number of sensors, J is the total number of quantised information and K is the total number of indices, $P_{i,j}$ is the probability that when i sensor observes the jth information, $x_{i,j,k}$ is mapping of whether i sensors assign the jth information to the k index, and, It is a variable in the 0-1 integer programming problem, where $x_{i,j,k}$ is assigned when $x_{i,j,k}$ is 1 and not assigned when $x_{i,j,k}$ is 0.

B. Problems of Conventional Methods

The conventional method assumes that aggregate environmental measurements have already been completed, and until then, random mapping, which is a non-optimal mapping, is used. Random mapping is only assigned to an index by random numbers and has a high packet collision rate. And because aggregate environmental measurements are aggregated at the receiver side, the packet loss portion cannot be aggregated, resulting in aggregate measurement results with poor estimation accuracy due to the execution of non-optimal mappings.

IV. The Proposed Method

A. About the Proposed Method

The flow of the proposed method, ”The Iterative PLIM”, is shown in Figure 2. Here, the actual aggregation environment is $P_{i,j}$, which is a black box under simulation and cannot be used for optimisation. The $Pc_{i,j}$ is continuously updated based on trend analysis of sensor information.

1) Random mapping is performed and $Pc_{i,j}$ is derived based on the aggregated correspondences
2) Using $Pc_{i,j}$ to obtain $x_{i,j,k}$ from the mathematical model of the conventional method.
3) Constant transmission using $x_{i,j,k}$.
4) Mapping information arriving by transmission is aggregated at the receiver.
5) Update $Pc_{i,j}$ based on tally and return to 2.

B. Advantages of the proposed method

The conventional method has the problem of inaccurate aggregate measurement results and increased packet loss rate due to long time random mapping, but by using quasi-optimal values as the optimal design for intermediate estimates, the system of aggregate measurement results can be improved and the number of packet losses during measurement can be reduced by shortening the random mapping time.

V. Simulation

A. Simulation Description and Overview

A comparison between the random mapping of aggregate measurement results in the conventional method to the completion of the estimation of aggregate measurement results and the proposed method was carried out using simulation. Table 2 shows the simulation sources.

$P_{i,j}$ randomly determines the jRSSI number with the highest probability of reference for a given sensor i. The probability is set to 0.5 or more, and the probability of adjacency is a random number that is lower than the already determined adjacency probability, The distribution is such that it is close to a biased normal distribution, with the remainder being put in as it is for places where there is no adjacent undetermined probability.

In the proposed method, the number of packet transmissions by transmission simulation until the optimisation was performed was varied. It defined ”turm$n$” if n packets are sent, run optimisation.

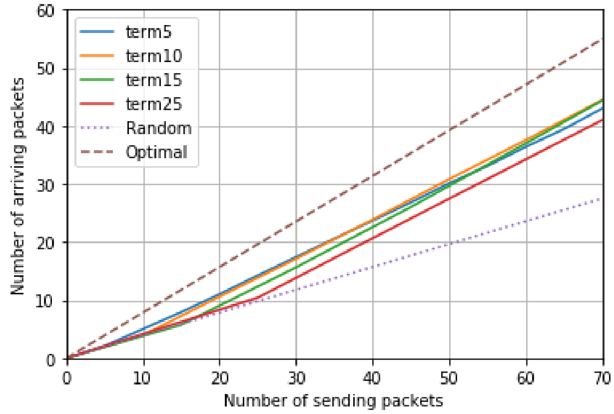

Fig. 3. Result1 of Simulation

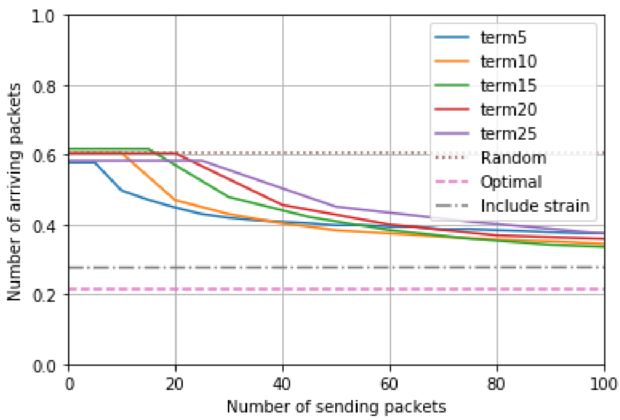

Fig. 4. Result2 of Simulation

It defined "Optimal" if optimisation based on information $P_{i,j}$ for which trend analysis has already been completed. And because the number of sensor numbers and RSSI numbers received at the receiver side when there is a packet collision, A and B are not equal. A trend analysis, taking into account packet collisions, has been carried out to fully the mapping result from the optimised solution based on $Pc_{i,j}$ is defined "include strain".

Annealing methods were used for optimisation.

B. Simulation Results

For each turm, for the random mapping scheme, Optimal, include strain, In figure 3, the number of arriving packets relative to the number of transmitted packets, In figure 4, the packet non-arrival rate against the number of packets sent is plotted based on The results are plotted and compared based on the values measured and averaged 10 times.

The proposed method arrives more packets than the conventional method of random mapping, it was found to be superior to the conventional method. The shorter the turn, the better it tends to be in turms of packet arrivals, Term 5 is superior between 5 and 20, but is then overtaken by turms 10 and 15, so it cannot be said to be superior in general.

VI. Summary

By repeating the optimisation process without waiting for the trend analysis to be completed, improvements in the number of packet arrivals were achieved. However, we are doing this on the basis of residual poor estimates of arrival rates obtained earlier in the trend analysis, and we believe that these can be improved by incorporating forgetting variables, etc. In addition, in this paper, the trend A of sensor information is time-invariant However, in the reality-intensive environment, the trend of sensor information has time degeneration due to the movement of the sensor itself, the appearance of obstacles, etc. We believe that the forgetting variable is even larger and more useful when it is time-denatured. There are also many prospects, such as deriving aggregate measurement results and mappings with a low non-arrival rate as quickly as possible by performing biased aggregate measurements through deliberate mapping, rather than performing aggregate measurements based on a compromise optimal solution for each stage, studying the trade-offs mentioned earlier, re-measuring aggregate measurements only for sensors with high packet loss, and demonstrating this using actual real-world data models. There are many prospects, for example, to actually demonstrate this using real data models.

Acknowledgements

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